THE ‘GRAVITATIONAL LENSING’ BIBLIOGRAPHY

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Abstract: We present a non exhaustive bibliography on “Gravitational Lensing” (GL), totalizing nearly 2000 titles. It also includes recent abstracts of papers dealing with gravitational lensing and submitted to astro-ph@babbage.sissa.it.

The GL bibliography is accessible via WWW (take a look at URL http://vela.astro.ulg.ac.be/grav_lens/grav_lens.html).

We are aware that the present compilation is not complete, not always uniform and that there are still errors, typos, etc. We would appreciate very much if you could communicate to us (via E-mail: ‘asurdej@astro.ulg.ac.be’ or ‘surdej@astro.ulg.ac.be’) missing or new titles (published or accepted for publication), errors, changes and suggestions.

It would also be nice for us to receive in the future your preprints or reprints related to ‘Gravitational Lensing’ studies. Please send your material to: A. Surdej or J. Surdej, Institut d’Astrophysique, Avenue de Cointe, 5, B-4000 Liège, Belgique

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Abstracts of articles whose first author is marked with a $\star$ among submitted papers and articles in press

Paper: astro-ph/9609165 From: alard@iap.fr (Christophe Alard) Date: Tue, 24 Sep 96 19:42:11 +0200

Title: Lensing of unresolved stars towards the Galactic Bulge Author: C. Alard (DEMIRM and CAI, Obs. de Paris) Comments: 12 pages LaTeX with l-aa.sty and psfig.sty. Accepted for publication in Astronomy and Astrophysics Report-no: MAMA-9
Previous calculations of the rates and optical depths due to microlensing only considered resolved stars. However, if a faint unresolved star lens is close enough to a resolved star, the event will be seen by the microlensing experiments and attributed to the bighter star. The blending biases the duration, making the contribution of the unresolved stars very significant for short events. This contribution is confused with lensing by brown dwarfs. The exact rates of these blended events are extremly sensitive to the limiting magnitude achieved in the microlensing search. Appropriate calculations of the optical depth and rates are provided here, and illustrated in the case of the DUO and OGLE experiments. The additional contribution of unresolved stars is very significant and probably explains the high optical depth and rates observed towards the Galactic Bulge. The blended unresolved event can be identified using either the color shift or the light curve shape. However, neither of these two methods is apropriate to identify a large number of blended events towards the Bulge. In some cases of good photometry and small impact parameter, an identification is possible, as for the OGLE 5 event, which clearly appears as a case of lensing of an unresolved star. The recent results obtained by the PLANET collaboration indicate that a high resolution and dense sampling of the light curve is possible, and will probably provide a very interesting possibility to correct the blending bias, as demonstrated for OGLE 5. This possibility, is certainly better than a statistical estimation of the lensing rates, which are always prone to some uncertainty. But, at this time, the contribution of unresolved stars must be included in the analyses of microlensing experiments. (http://xxx.lanl.gov/abs/astro-ph/9609165 , 84kb)

Paper: astro-ph/9610128 From: Penny D. Sackett psackett@astro.rug.nl Date: Wed, 16 Oct 1996 11:24:53 MDT

Title: The Planet Collaboration: Probing Lensing Anomalies Authors: The PLANET Collaboration: M. Albrow, J.-P. Beaulieu, P. Birch, J.A.R. Caldwell, J. Greenhill, K. Hill, S. Kane, R. Martin, J. Menzies, R.M. Naber, J.-W. Pel, K. Pollard, P.D. Sackett, K.C. Sahu, P. Vreeswijk, R. Watson, A. Williams, M. Zwaan Comments: LaTex (using conf_iap.sty) 5 pages with 5 figures, the two large figures Fig. 3 and Fig. 5b are in .gif format. To appear in the Proceeedings of the 12th IAP Conference: Variable Stars and the Astrophysical Returns of Microlensing Surveys

The Probing Lensing Anomalies NETwork (PLANET) is a worldwide collaboration of astronomers using semi-dedicated European, South African, and Australian telescopes to perform continuous, rapid and precise multi-band CCD photometric monitoring of on-going Galactic microlensing events. As well as providing important additional information on the nature, distribution and kinematics of Galactic microlenses, PLANET photometry is optimized for the detection of Jovian-mass planets orbiting several AU from Galactic lenses. The final PLANET database is expected to contain hundreds of variable stars sampled at hourly time scales with 1-5(http://xxx.lanl.gov/abs/astro-ph/9610128 , 109kb)

Paper: astro-ph/9702199 From: Andrew Becker becker@lensing.astro.washington.edu Date: Sat, 22 Feb 1997 13:56:50 -0800 (281kb)

Title: MACHO Alert 95-30 : First Real-Time Observation of Extended Source Effects in Gravitational Microlensing Authors: C.Alcock, W.H.Allen, R.A.Allsman, D.Alves, T.S.Axelrod, T.S.Banks, S.F.Beaulieu, A.C.Becker, R.H.Becker, D.P.Bennett, I.A.Bond, B.S.Carter, K.H.Cook, R.J.Dodd, K.C.Freeman, M.Gregg, K.Griest, J.B.Hearnshaw, A.Heller, M.Honda, J.Jugaku, S.Kabe, S.Kaspi, P.M.Kilmartin, A.Kitamura, O.Kovo, M.J.Lehner, T.E.Love, D.Maoz, S.L.Marshall, Y.Matsubara, D.Minniti, M.Miyamoto, Y.Muraki, T.Nakamura, B.A.Peterson, M.R.Pratt, P.J.Quinn, I.N.Reid, M.Reid, D.Reiss, A.Retter, A.W.Rodgers, W.L.W.Sargent, H.Sato, M.Sekiguchi, P.B.Stetson, C.W.Stubbs, D.J.Sullivan, W.Sutherland, A.Tomaney, T.Vandehei, Y.Watase, D.L.Welch, T.Yanagisawa, M.Yoshizawa, P.C.M.Yock Comments: 32 pages including 6 tables, and 15 figures; Uses AASTeX 4.0; submitted to The Astrophysical Journal

We present analysis of MACHO Alert 95-30, a dramatic gravitational microlensing event towards the Galactic bulge whose peak magnification departs significantly from the standard point-source microlensing model. Alert 95-30 was observed in real-time by the Global Microlensing Alert Network (GMAN), which obtained densely sampled photometric and spectroscopic data throughout the event. We interpret the light-curve "fine structure" as indicating transit of the lens across the extended face of the source star. This signifies resolution of a star several kpc distant. We find a lens angular impact parameter$\theta_{min}/\theta_{source} = 0.715 \pm 0.003$. This information, along with the radius and distance of the source, provides an additional constraint on the lensing system. Spectroscopic and photometric data indicate the source is an M4 III star of radius 61 +/- 12 Rsun, located on the far side of the bulge at 9 kpc. We derive a lens angular velocity, relative to the source, of 21.5 +/- 4.9 km/s/kpc, where the error is dominated by uncertainty in the source radius. Likelihood analysis yields a median lens mass of 0.67+2.53-0.46 Msun, located with 80a distance of 6.93+1.56-2.25 kpc. If the lens is a main-sequence star, we can include constraints on the lens luminosity. This modifies our estimates to M_lens = 0.53+0.52-0.35 Msun and D_lens = 6.57+0.99-2.25 kpc. Spectra taken during the event show that the absorption line equivalent widths of H alpha and the TiO bands near 6700 A vary, as predicted for microlensing of an extended source. This is most likely due to center-to-limb variation in the stellar spectral lines. These data demonstrate the feasibility of using microlensing limb crossings as a tool to probe stellar atmospheres directly. (http://xxx.lanl.gov/abs/astro-ph/9702199 , 281kb)

Paper: astro-ph/9606165 From: Will Sutherland w.sutherland1@physics.oxford.ac.uk Date: Wed, 26 Jun 1996 18:59:14 +0100 (BST)

Title: THE MACHO PROJECT LMC MICROLENSING RESULTS FROM THE FIRST TWO YEARS AND THE NATURE OF THE GALACTIC DARK HALO Authors: C. Alcock, R.A. Allsman, D. Alves, T.S. Axelrod, A.C. Becker, D.P. Bennett, K.H. Cook, K.C. Freeman, K. Griest, J. Guern, M.J. Lehner, S.L. Marshall, B.A. Peterson, M.R. Pratt, P.J. Quinn, A.W. Rodgers, C.W. Stubbs, W. Sutherland, D.L. Welch (The MACHO Collaboration) Comments: Latex, 54 pages, uses aas2pp4.sty and astrobib.sty, with 24 out of 26 Postscript figures in gzipped tar file. 2 extra greyscale figures and/or full paper available from ftp://igpp.llnl.gov/pub/macho/LMC2/ Submitted to ApJ, June 1996

The MACHO Project is a search for dark matter in the form of massive compact halo objects (Machos). Photometric monitoring of millions of stars in the Large Magellanic Cloud (LMC), Small Magellanic Cloud (SMC), and Galactic bulge is used to search for gravitational microlensing events caused by these otherwise invisible objects. Analysis of the first 2.1 years of photometry of 8.5 million stars in the LMC reveals 8 candidate microlensing events. This is substantially more than the number expected (~ 1.1) from lensing by known stellar populations. The timescales Ts of the events range from 34 to 145 days. We estimate the total microlensing optical depth towards the LMC from events with $2 < Ts < 200$ days to be $\tau_2^{200} = 2.9^{+1.4}_{-0.9} 10 **-7$ based upon our 8 event sample. This exceeds the optical depth, $\tau_{\rm backgnd} = 0.510 **-7$, expected from known stars, and the difference is to be compared with the optical depth predicted for a "standard" halo composed entirely of Machos: $\tau_{halo} = 4.710**-7$. Likelihood analysis gives a fairly model independent estimate of the halo mass in Machos within 50 kpc of $2.0^{+1.2}_{-0.7} 10 **11 M_{odot}$, about half of the "standard halo" value. We also find a most probable Macho mass of $0.5^{+0.3}_{-0.2} M_{odot}$, although this value is strongly model dependent. Additionally, the absence of short duration events places stringent upper limits on the contribution of low-mass Machos: objects from $10^{-4} M_{odot}$ to $0.03 M_{odot}$ contribute $\simeq$ 20% of the "standard" dark halo. (http://xxx.lanl.gov/abs/astro-ph/9606165 , 793kb)

Paper: astro-ph/9502102 From: kaplan@lpthe.jussieu.fr (Jean KAPLAN) Date: Mon, 27 Feb 1995 18:19:31 +0100 (MET)

Title: AGAPE, AN EXPERIMENT TO DETECT MACHO's IN THE DIRECTION OF THE ANDROMEDA GALAXY Authors: R. Ansari, M. Auriére, P. Baillon, A. Bouquet, G. Coupinot, C. Coutures, C. Ghesquière, Y. Giraud-Héraud, P.

Gondolo, J. Hecquet, J. Kaplan, A.L. Melchior, M. Moniez, J.P. Picat and G. Soucail Comments: 4 pages, 1 figure in a separate compressed, tarred, uuencoded uufile. In case ofproblem contact kaplan@lpthe.jussieu.fr Report-no: PAR-LPTHE 95-07
The status of the Agape experiment to detect Machos in the direction of the andromeda galaxy is presented.

Paper: astro-ph/9602015 From: Jean Kaplan kaplan@cdf.in2p3.fr Date: Fri, 2 Feb 1996 19:46:45 +0100 (MET)

Title: AGAPE, A MICROLENSING SEARCH IN THE DIRECTION OF M31: STATUS REPORT Authors: R. Ansari, M. Auriere, P. Baillon, A. Bouquet, G. Coupinot, C. Coutures, C. Ghesquiere, Y. Giraud-Heraud, P. Gondolo, J. Hecquet, J. Kaplan, Y. Le Du, A.L. Melchior, M. Moniez, J.P. Picat, and G. Soucail Comments: 5 pages, Latex2e, includes 5 figures, uuencoded gziped tar file. Proceedings of the workshop "The dark side of the Universe : experimental efforts and theoretical framework" Roma 13-14 November 1995 Report-no: LPC 96-04/conf
A status report of the microlensing search by the pixel method in the direction of M31, on the 2 meter telescope at Pic du Midi is given. Pixels are stable to a level better than 0.5can clearly be detected.(http://xxx.lanl.gov/abs/astro-ph/9602015 , 122kb)

Paper: astro-ph/9607040 From: Jean Kaplan kaplan@cdfas2.in2p3.fr Date: Sat, 6 Jul 1996 12:55:46 MDT

Title: AGAPE: A SEARCH FOR DARK MATTER TOWARDS M31 BY MICROLENSING EFFECTS ON UNRESOLVED STARS Authors: R. Ansari, M. Aurière, P. Baillon, A. Bouquet, G. Coupinot, Ch. Coutures, C. Ghesquière,Y. Giraud-Héraud, P. Gondolo, J. Hecquet, J. Kaplan, Y. Le Du, A.L. Melchior, M. Moniez, J.P. Picat, G. Soucail Comments: 13 pages, 15 figures, tex source and figure in one uuencoded gziped tar archive. Text and figures with better definition will also be available at http://cdfinfo.in2p3.fr/Experiences/AGAPE/publis.html Report-no: LPC 96 33
M31 is a very tempting target for a microlensing search of compact objects in galactic haloes. It is the nearest large galaxy, it probably has its own dark halo, and its tilted position with respect to the line of sight provides an unmistakable signature of microlensing. However most stars of M31 are not resolved and one has to use the "pixel method": monitor the pixels of the image rather than the stars. AGAPE is the implementation of this idea. Data have been collected and treated during two autumns of observation at the 2 metre telescope of Pic du Midi. The process of geometric and photometric alignment, which must be performed before constructing pixel light curves, is described. Seeing variations are minimised by working with large super-pixels (2.1") compared with the average seeing. A high level of stability of pixel fluxes, crucial to the approach, is reached. Fluctuations of super-pixels do not exceed 1.7 times the photon noise which is 0.1% of the intensity for the brightest ones. With such stable data, 10 microlensing events are expected for a full "standard halo". With a larger

field, a regular and short time sampling and a long lever arm in time, the pixel method will be a very efficient tool to explore the halo of M31. (http://xxx.lanl.gov/abs/astro-ph/9607040 , 363kb) Paper: astro-ph/9607040 replaced with revised version Tue, 10 Dec 1996 10:23:35 MST

Title: AGAPE: a search for dark matter towards M31 by microlensing effects on unresolved stars Authors: R. Ansari, M. Aurière, P. Baillon, A. Bouquet, G. Coupinot, Ch. Coutures, C. Ghesquière,Y. Giraud-Héraud, P. Gondolo, J. Hecquet, J. Kaplan, Y. Le Du, A.L. Melchior, M. Moniez, J.P. Picat, G. Soucail Comments: 15 pages, 15 figures. Text and figures with better definition will also be available at http://cdfinfo.in2p3.fr/Experiences/AGAPE/publis.html Modified according to the requirement of the referee. To appear in A and A Report-no: LPC 96 33 (http://xxx.lanl.gov/abs/astro-ph/9607040 , 557kb)

Paper: astro-ph/9611110 From: asada@vega.ess.sci.osaka-u.ac.jp (Hideki Asada) Date: Thu, 14 Nov 96 11:44:33 JST

Title: Critical Lines in Gravitational Lenses and the Determination of Cosmological Parameters Authors: Hideki Asada (Osaka U.) Comments: 16 pages, LaTeX(aaspp4), 11 postscript figures included; submitted to The Astrophysical Journal Report-no: OU-TAP-49

We investigate the cosmological test recently proposed by B. Fort, Y. Mellier and M. Dantel-Fort (FMD), where the observed location of the critical line in gravitational lensing is used to determine the cosmological parameters, Ω and λ. Applying this method to the cluster of galaxies Cl0024+1654, FMD obtained a constraint on the cosmological constant, $\lambda > 0.6$, assuming the spatially flat universe. It plays a crucial role in this method that the angular diameter distance-redshift relation depends on the cosmological models through the cosmological parameters. First, using the angular diameter distance in the Friedmann-Lemaitre- Robertson-Walker universe, we show that one can hardly determine Ω by this method without the assumption of the spatially flat universe. We also investigate the effect of inhomogeneities of the universe by using the Dyer-Roeder angular diameter distance. It is shown that the effect of inhomogeneities can become too large to be ignored, particularly for a high density universe. As a result, this method cannot be taken as a clear cosmological test to determine Ω and λ, though it may provide a bound on Ω and λ. Moreover, we mention the uncertainty of the determination of the velocity dispersion, which is regarded as one of the most serious problems in this test. (http://xxx.lanl.gov/abs/astro-ph/9611110 , 105kb)

Paper: astro-ph/9608061 From: KATSUAKI ASANO
sph10001@bkc.ritsumei.ac.jp Date: Mon, 12 Aug 1996 17:18:20 +0900

Title: Elliptical lens model in PG1115+080 Authors: K.Asano and T.Fukuyama (Ritsumeikan Univ.) Comments: 12pages, Latex, 10 tables as Postscript file, 3 PostScript Figures Report-no: Ritsumei-pp-12

Using the new observational data, the elliptical lens model with softened power law behaviour has been applied to the multiple quasar PG1115+080. Our result shows that the lensing object is not compact contrary to the result by Narashimaha et al. Core radius ranges $3 \sim 5Kpc \cdot h^{-1}$ and total mass is roughly $10^{12} M_{\odot}$. Central density $\rho_0 \simeq 10^{-23} h^2 g/cm^3$, which is 10 times larger than the density of the standard galaxy. The numerical results and their discrepancies with the observations are discussed, especially, in comparison with the multipole expansion model. (http://xxx.lanl.gov/abs/astro-ph/9608061 , 85kb)

Paper: astro-ph/9508107 From: tsa@merlin.anu.edu.au (Tim Axelrod) Date: Thu, 24 Aug 1995 15:59:08 +1000

Title: THE MACHO DATA PIPELINE Author: T. S. Axelrod (MSSSO and LLNL), R. A. Allsman (ANUSF), P. J. Quinn (ESO), D. P. Bennett (CfPA), K. C. Freeman, B.A. Peterson, A. W. Rodgers (MSSSO), C. Alcock, K. H. Cook (LLNL), K. Griest (UCSD), S. L. Marshall, M. R. Pratt, C. W. Stubbs (UW), and W. Sutherland (Oxford) Comments: 36 pages, 6 Postscript figures, uuencoded compressed tar. Submitted to PASP

The MACHO experiment is searching for dark matter in the halo of the Galaxy by monitoring more than 20 million stars in the LMC and Galactic bulge for gravitational microlensing events. The hardware consists of a 50 inch telescope, a two-color 32 megapixel ccd camera, and a network of computers. On clear nights the system generates up to 8 GB of raw data and 1 GB of reduced data. The computer system is responsible for all realtime control tasks, for data reduction, and for storing all data associated with each observation in a data base. The subject of this paper is the software system that handles these functions. It is an integrated system controlled by Petri nets that consists of multiple processes communicating via mailboxes and a bulletin board. The system is highly automated, readily extensible, and incorporates flexible error recovery capabilities. It is implemented with C++ in a Unix environment.

Paper: astro-ph/9611080 From: library@astro.Princeton.EDU Date: Mon, 11 Nov 1996 11:40:44 -0500 (EST)

Title: Dark Matter Authors: Neta Bahcall (Princeton University Observatory) Comments: Figures can be obtained by e-mail to neta@astro.princeton.edu Report-no: Princeton Observatory Preprint 693

Observations in the optical, in X-rays, and gravitational lensing of galaxies, clusters of galaxies, and large-scale structure are beginning to provide clues to the dark matter problem. I review the impact of these observations on some of the main questions relating to dark matter: How much dark matter is there? Where is it located? What is the nature of the dark matter? and what is the amount of baryonic dark matter.

(http://xxx.lanl.gov/abs/astro-ph/9611080 , 9kb)

Paper: astro-ph/9606065 From: Rennan Bar-Kana barkana@arcturus.mit.edu Date: Mon, 10 Jun 1996 16:43:49 -0400

Title: LIMITS ON A STOCHASTIC BACKGROUND OF GRAVITATIONAL WAVES FROM GRAVITATIONAL LENSING Authors: Rennan Bar-Kana (MIT) Comments: 12 pages, LaTex + 1 PS Figure, submitted to Phys. Rev. D

We compute the effects of a stochastic background of gravitational waves on multiply imaged systems or on weak lensing. There are two possible observable effects, a static relative deflection of images or shear, and an induced time-dependent shift or proper motion. We evaluate the rms magnitude of these effects for a COBE normalized, scale-invariant spectrum, which is an upper limit on spectra produced by inflation. Previous work has shown that large-scale structure may cause a relative deflection large enough to affect observations, but we find that the corresponding effect of gravity waves is smaller by $\sim 10^4$ and so cannot be observed. This results from the oscillation in time as well as the redshifting of the amplitude of gravity waves. We estimate the magnitude of the proper motion induced by deflection of light due to large-scale structure, and find it to be $\sim 10^{-8}$ arcsec per year. This corresponds to ~ 50 km/s at cosmological distances, which is quite small compared to typical peculiar velocities. The COBE normalized gravity wave spectrum produces motions smaller still by $\sim 10^2$. We conclude that light deflection due to these cosmological perturbations cannot produce observable proper motions of lensed images. On the other hand, there are only a few known observational limits on a stochastic background of gravity waves at astrophysical wavelengths. High-resolution imaging of lens systems with VLBI can set limits on the relative motions of images. We show that a limit on gravity waves of $\Omega_\lambda \sim 10^{-5}$, valid for wavelengths λ greater than a few pc (up to ~ 100 Mpc), is feasible with a ten-year observation of a four-image system. (http://xxx.lanl.gov/abs/astro-ph/9606065 , 20kb) Paper: astro-ph/9606065 replaced with revised version Mon, 11 Nov 1996 17:30:27 -0500

Title: Limits on a Stochastic Background of Gravitational Waves from Gravitational Lensing Authors: Rennan Bar-Kana (MIT) Comments: 14 pages, LaTex + 1 PS Figure, accepted version to be published in Phys. Rev. D15, Dec. 1996. An incorrect assumption was removed, also various other minor changes

(http://xxx.lanl.gov/abs/astro-ph/9606065 , 21kb)

Paper: astro-ph/9701068 From: Rennan Bar-Kana barkana@arcturus.mit.edu Date: Mon, 13 Jan 1997 18:12:25 -0500

Title: Analysis of Time Delays in the Gravitational Lens PG1115+080 Authors: Rennan Bar-Kana (MIT Physics Dept.) Comments: 14 pages, Latex, submitted to ApJ

We present a new method for determining time delays among the light curves of various images in a gravitational lens. The method is based on constructing a simple model for the source variation and forming a χ^2 measure of the agreement of this same variation with all of the lightcurves. Our method provides a simpler and more assumption-free alternative to Press et al. (1992a, b), but it has similar advantages: it yields an approximate reconstruction of the source variation and it easily incorporates different assumptions about the relation between the light curves and about measurement errors. We apply this method to the light curves of the quadruple gravitational lens PG1115+080 measured by Schechter et al. (1996). Unlike Schechter et al. we include correlated measurement errors in the analysis, as well as the possibility that microlensing may cause different images to vary by different factors in flux. We find a value of $25.0^{+3.3}_{-3.8}$ days (95between components B and C (close to the 24 day value of Schechter et al., and so implying a similar H_0 for a given lens model). However, the ratio t_{AC}/t_{BA} of the two intermediate delays is poorly determined at $1.13^{+.18}_{-.17}$ (68models (~ 1.4) unlike the Schechter et al. value (~ 0.7). The variation ratios of C with respect to A and of A with respect to B are both different from 1, $1.39^{+.16}_{-.20}$ and $.79^{+.10}_{-.12}$ (95confidence), respectively. This is an indication of a microlensing gradient, and this type of microlensing may allow us to set both an upper and a lower limit on the size of the quasar optical emission region. (Shortened Abstract) (http://xxx.lanl.gov/abs/astro-ph/9701068 , 49kb)

Paper:astro-ph/9601125 From: A. Bartsch armin@MPA-Garching.MPG.DE Date: Tue, 23 Jan 1996 20:11:35 +0100 (MET) Title: REANALYSIS OF THE ASSOCIATION OF HIGH-REDSHIFT 1-JANSKY QUASARS WITH IRAS GALAXIES Author: Armin Bartsch, Peter Schneider and Matthias Bartelmann (Max-Planck-Institut f. Astrophysik)

Comments: 29 pages, LaTex, including 9 figures, submitted to Astronomy and Astrophysics Report-no: MPA 922

We develop a new statistical method to reanalyse angular correlations between background QSOs and foreground galaxies that are supposed to be a consequence of dark matter inhomogeneities acting as weak gravitational lenses. The method is based on a weighted average over the galaxy positions and is optimized to distinguish between a random distribution of galaxies around QSOs and a distribution which follows an assumed QSO-galaxy two-point correlation function, by choosing an appropriate weight function. With simulations we demonstrate that this weighted average is slightly more significant than Spearman's rank-order test which was used in previous investigations. In particular, the advantages of the weighted average show up if the two-point correlation function is weak. We then reanalyze the correlation between high-redshift 1-Jansky QSOs and IRAS galaxies, taken from the IRAS Faint Source Catalog; these samples were analyzed previously using Spearman's rank-order test. In agreement with the previous work, we find moderate to strong correlations between these two samples; considering the angular two-point correlation function of these samples, we find a typical scale of order $5'$ from which most of the correlation signal derives. However, the statistical significance of the correlation changes with the redshift slices of the QSO sample one considers. Comparing with simple theoretical estimates of the expected correlation, we find that the signal we derive is considerably stronger than expected. On the other hand, recent direct verifications of the overdensity of matter in the line-of-sight to high-redshift radio QSOs obtained from the shear field around these sources, indicates that the observed association can be attributed to a gravitational lens effect. (http://xxx.lanl.gov/abs/astro-ph/9601125 , 73kb)

Paper: astro-ph/9702118 From: richard_barvainis reb@dopey.haystack.edu Date: Thu, 13 Feb 1997 10:05:34 EST (75kb)

Title: Multiple CO Transitions, CI, and HCN from the Cloverleaf Quasar Authors: Richard Barvainis, Philip Maloney, Robert Antonucci, and Danielle Alloin Comments: 14 pages of text, plus two figures. Requires aaspp4.sty, included. To be published in the Astrophysical Journal
New millimeter-wavelength emission lines are reported for the Cloverleaf (H1413+117), a gravitationally lensed quasar at redshift 2.56. High signal-to-noise ratio spectra of four lines in CO (J=3-2, J=4-3, J=5-4, and J=7-6) have been obtained and are modeled using an escape probability formalism. The line brightness temperatures are flat or rising between CO(3-2) and CO(4-3) and then drop to the CO(5-4) and CO(7-6) lines; this falloff suggests that the optical depths in the CO lines are modest ($\tau_{4-3} < 3$), and that the gas is relatively warm (T 100 K) and dense ($n_{H2} > 3X10^3 cm^{-3}$). The neutral carbon fine structure line CI(3P1-3P0) was detected with moderate SNR on two separate occasions, and appears secure. The HCN(4-3) line is somewhat more tentative, as it was observed only once and detected with moderate SNR. However, its brightness ratio of 0.25 relative to the CO(4-3) line is very similar to the ratio seen in luminous infrared galaxies. The detectability of the Cloverleaf in molecular and neutral atomic transitions is largely due to high emissivity of the gas and magnification from gravitational lensing, rather than an extremely large mass of gas. (http://xxx.lanl.gov/abs/astro-ph/9702118 , 75kb)

Paper: astro-ph/9609183 From: benitezn@astsun2.ifca.unican.es (Narciso Benitez) Date: Thu, 26 Sep 96 17:09:20 +0200

Title: Large Scale QSO-galaxy correlations for radio loud and optically selected QSO samples Authors: N. Benitez and E. Martinez-Gonzalez, IFCA (CSIC-UC) Comments: 18 pages, 8 figures, AASTeX, accepted for publication in ApJ
We have studied the distribution of $B_J < 20.5$ galaxies from the ROE/NRL COSMOS/UKST catalogue around two samples of $z > 0.3$ QSOs with similar redshift distributions. The first sample is formed by 144 radio-loud QSOs from the Parkes Catalogue, and the other contains 167 optically selected QSOs extracted from the Large Bright Quasar Survey. It is found that there is a $\approx 99.0\%$ significance level excess of COSMOS/UKST galaxies around the PKS QSOs, whereas there is a marginal defect of galaxies around the LBQS QSOs. When the distribution of galaxies around both samples is compared, we found that there is an overdensity of galaxies around the PKS sample with respect to the LBQS sample anticorrelated with the distance from the QSOs at a 99.7% significance level. Although this result apparently agrees with the predictions of the double magnification bias, it is difficult to explain by gravita-

tional lensing effects alone; dust in the foreground galaxies and selection effects in the detection of LBQS QSOs should be taken into account. It has been established that the lines of sight to PKS flat-spectrum QSOs go through significatively higher foreground galaxy densities than the directions to LBQS quasars, what may be partially related with the reported reddening of PKS QSOs. (http://xxx.lanl.gov/abs/astro-ph/9609183 , 68kb)

Paper: astro-ph/9703071 From: benitezn@astsun1.ifca.unican.es (Narciso Benitez) Date: Tue, 11 Mar 97 16:53:17 +0100 (12kb)

Title: Statistical excess of foreground galaxies around high-z radiogalaxies Authors: N. Benitez, E. Martinez-Gonzalez and J.M. Martin-Mirones (IFCA, CSIC-UC) Comments: 4 pages, 1 figure, A&A Latex, accepted for publication as a letter to A&A
K-band imaging of a sample of 21 radiogalaxies with $z \sim 1.5$ reveals the existence of a statistical association of foreground galaxies with the positions of the radiosources. The excess is detected within a 1' radius at a high significance level (¿99.8mass, so this result indicates the existence of an association between foreground mass perturbations and background radiosources, as expected from the magnification bias effect, and confirms previous results obtained for other high-z radio-loud AGN. (http://xxx.lanl.gov/abs/astro-ph/9703071 , 12kb)

Paper: astro-ph/9510104 From: bennett@igpp.llnl.gov (Dave Bennett) Date: Thu, 19 Oct 1995 22:57:24 -0700

Title: THE MACHO PROJECT DARK MATTER SEARCH Authors: D.P. Bennett, C. Alcock, R.A. Allsman, T.S. Axelrod, K.H. Cook, K.C. Freeman, K. Griest, S.L. Marshall, B.A. Peterson, M.R. Pratt, P.J. Quinn, A.W. Rodgers, C.W. Stubbs, W. Sutherland (The MACHO Collaboration) Comments: 12 pages, uuencoded gzip compressed postscript (356 kb). Figures included. To appear in the Proceedings of the Astronomical Society of the Pacific Symposium on Clusters, Lensing, and the Future of the Universe
We provide a status report on our search for dark matter in our Galaxy in the form of massive compact halo objects (or Machos), using gravitational microlensing of background stars. This search uses a very large format CCD camera on the dedicated 1.27m telescope at Mt. Stromlo, Australia, and has been taking data for almost 3 years. At present, we are in the midst of analyzing our second year data for 8 million stars in the Large Magellanic Cloud. We find more microlensing events than expected from known stellar populations suggesting that Machos are indeed present in the Galactic halo, but the observed microlensing rate toward the LMC is too small to allow for a halo dominated by sub-stellar Machos. Our observations of the Galactic bulge have also yielded substantially more microlensing events than anticipated including a number of exotic “deviant” microlensing events. The implications of these results are discussed. (astro-ph/9510104 , 256kb)

Paper: astro-ph/9606012 From: bennett@igpp.llnl.gov (Dave Bennett) Date: Tue, 4 Jun 1996 02:47:28 -0700 (PDT)

Title: A BINARY LENSING EVENT TOWARD THE LMC: OBSERVATIONS AND DARK MATTER IMPLICATIONS Authors: D.P.Bennett, C.Alcock, R.A.Allsman, D.Alves, T.S.Axelrod, A.Becker, K.H.Cook, K.C.Freeman, K.Griest, J.Guern, M.J.Lehner, S.L.Marshall, D.Minniti, B.A.Peterson, M.R.Pratt, P.J.Quinn, S.H.Rhie, A.W.Rodgers, C.W.Stubbs, W.Sutherland, and D.Welch (The MACHO Collaboration) Comments: 5 pages, 3 postscript figures included; To appear in the Proceedings of the Dark Matter '96 Conference held in Santa Monica, CA, Feb., 1996

The MACHO collaboration has recently analyzed 2.1 years of photometric data for about 8.5 million stars in the Large Magellanic Cloud (LMC). This analysis has revealed 8 candidate microlensing events and a total microlensing optical depth of $\tau_{meas} = 2.9 + 1.4/ - 0.9 \times 10^{-7}$. This significantly exceeds the number of events (1.1) and the microlensing optical depth predicted from known stellar populations: $\tau_{back} = 5.4 \times 10^{-8}$, but it is consistent with models in which about half of the standard dark halo mass is composed of Machos of mass $\simeq 0.5 M_{\odot}$. One of these 8 events appears to be a binary lensing event with a caustic crossing that is partially resolved which allows us to estimate the distance to the lenses. If the source star is not a short period binary star, then we show that the lens system is very likely to reside in the LMC. However, if we assume that the optical depth for LMC-LMC lensing is large enough to account for our entire lensing signal, then the binary event does not appear to be consistent with lensing of a single LMC source star by a binary residing in the LMC. Thus, while the binary lens may indeed reside in the LMC, there is no indication that most of the lenses reside in the LMC. (http://xxx.lanl.gov/abs/astro-ph/9606012 , 77kb)

Paper: astro-ph/9612208 From: David Bennett bennett@bustard.phys.nd.edu Date: Sat, 21 Dec 1996 10:57:10 -0500

Title: Planetary Microlensing from the MACHO Project Authors: The MACHO Collaboration: D.P.Bennett, C.Alcock, R.A.Allsman, D.Alves, T.S.Axelrod, A.Becker, K.H.Cook, K.C.Freeman, K.Griest, M.J.Lehner, S.L.Marshall, D.Minniti, B.A.Peterson, M.R.Pratt, P.J.Quinn, S.H.Rhie, A.W.Rodgers, C.W.Stubbs, W.Sutherland, T.Vandehei and D.Welch Comments: 5 pages, Latex, 5 postscript figures included, To appear in the Proceedings of "Planets Beyond the Solar System and the Next Generation of Space Missions", held at STScI, October 16-18, 1996

We present the lightcurves of two microlensing events from the MACHO Project data that are likely to be due to lenses with masses similar to Jupiter's mass. Although the MACHO Project survey data are not sufficient to definitively establish the identification of planetary mass lenses in these cases, observations by microlensing follow-up networks such as GMAN and PLANET should be able to definitively determine the planetary nature of similar events which may occur in the near future.

(http://xxx.lanl.gov/abs/astro-ph/9612208 , 88kb)

Paper: astro-ph/9610060 From: "Giulio Mignola, ++ 41 22 767 3572" ¡MIGNOLA@vxcern.cern.ch¿ Date: Wed, 9 Oct 1996 17:51:33 +0200 (CET-DST)

Title: On neutralino stars as microlensing objects Author: V. Berezinsky, A. Bottino and G. Mignola Comments: 7 pages, LaTeX, no figures Report-no: CERN-TH 96-283, DFTT 53/96

The microlensing objects, Machos, recently observed in the halo of our Galaxy, can be interpreted as dense neutralino objects, neutralino stars, produced by the gravitational instability of neutralino gas. Taking the mass and radius of these objects from microlensing observations we calculated the diffuse gamma-ray flux produced in neutralino–neutralino annihilation inside the objects. The resulting flux is many orders of magnitude higher than the observed one. (http://xxx.lanl.gov/abs/astro-ph/9610060 , 8kb)

Paper: astro-ph/9611012 From: fbernard@wasa.saclay.cea.fr (Francis Bernardeau) Date: Sat, 2 Nov 1996 12:14:04 +0100

Title: Weak Lensing Detection in CMB Maps Authors: F. Bernardeau (SPhT Saclay) Comments: 13 pages; Submitted to Astronomy and Astrophysics Report-no: Saclay SPhT T96/122

The weak lensing effects are known to change only weakly the shape of the power spectrum of the Cosmic Microwave Background (CMB) temperature fluctuations. I show here that they nonetheless induce specific non-Gaussian effects that can be detectable with the four-point correlation function of the CMB anisotropies. The magnitude and geometrical dependences of this correlation function are investigated in detail. It is thus found to scale as the square of the derivative of the two-point correlation function and as the angular correlation function of the gravitational displacement field. It also contains specific dependences on the shape of the quadrangle formed by the four directions. When averaged at a given scale, the four-point function, that identifies with the connected part of the fourth moment of the probability distribution function of the local filtered temperature, scales as the square of logarithmic slope of its second moment, and as the variance of the gravitational magnification at the same angular scale. All these effects have been computed for specific cosmological models. I stress that, as the amplitude of the gravitational lens effects has a specific dependence on the cosmological parameters, the detection of the four-point correlation function can provide precious complementary constraints to those brought by the temperature power spectrum. (http://xxx.lanl.gov/abs/astro-ph/9611012 , 73kb)

Paper: astro-ph/9611012 replaced with revised version Wed, 5 Mar 1997 16:55:13 +0100

Title: Weak Lensing Detection in CMB Maps Authors: F. Bernardeau (SPhT Saclay) Comments: 13 pages; revised version, in press in Astronomy and Astrophysics Report-no: Saclay SPhT T96/122 (http://xxx.lanl.gov/abs/astro-ph/9611012

, 73kb)

Paper: astro-ph/9702140 From: Orfeu Bertolami orfeu@cosmos.ist.utl.pt Date: Mon, 17 Feb 1997 13:06:27 GMT (6kb)

Title: Weak Lensing, Shear and the Cosmic Virial Theorem in a Model with a Scale-Dependent Gravitational Coupling Authors: Orfeu Bertolami Comments: Latex file. To be published in Gen. Relativity and Gravitation Report-no: DF/IST-1.96

It is argued that, in models where the gravitational coupling is scale-dependent, predictions concerning weak gravitational lensing and shear are essentially similar to the ones derived from General Relativity. This is consistent with recent negative results of observations of the MS1224, CL2218 and A1689 systems aimimg to infer from those methods the presence of dark matter. It is shown, however, that the situation is quite different in what concerns an analysis based on the Cosmic Virial Theorem. (http://xxx.lanl.gov/abs/astro-ph/9702140 , 6kb)

Paper: astro-ph/9606064 From: bezecour@srvdec.obs-mip.fr (jocelyn bezecourt) Date: Mon, 10 Jun 1996 22:03:26 +0200

Title: REDSHIFT SURVEY OF GRAVITATIONAL ARCLETS IN ABELL 2390 Authors: J. Bezecourt and G. Soucail (Observatoire Midi-Pyrenees, Toulouse) Comments: 10 pages, Latex with 10 postscript figures, accepted by Astronomy and Astrophysics, postscript file also available by anonymous ftp at ftp://summer.obs-mip.fr/pub/OUTGOING/a2390.ps. or upon request at bezecour@obs-mip.fr

In this paper, we present new determinations of redshifts on a sample of gravitational arclets identified in the cluster of galaxies Abell 2390. The arclets candidates were selected from their elongated morphology as seen in recent deep HST images of the cluster. The spectra display various features, and the redshifts of the background objects range from 0.398 to 1.268, most of them being between 0.6 and 0.9 with [O II] λ=3727Å being the main emission line encountered. This distribution is mostly concentrated in two redshifts planes at $z = 0.64$ and $z = 0.90$. The existence of two pairs of background galaxies at different redshifts, almost superimposed on the same line of sight are used to infer some limits on the mass of galaxy-size deflectors. A detailed writing of the lensing distorsion by two lens planes at different redshifts is developped for this purpose. Finally, [O II] equivalent widths are used to compute approximate star formation rates which appear to be of the same order of magnitude as in nearby spiral galaxies. The implications on both the lensing properties of the cluster and the analysis of the field galaxy evolution are also discussed. (http://xxx.lanl.gov/abs/astro-ph/9606064 , 245kb)

Paper: astro-ph/9612026 From: Ortwin Gerhard gerhard@astro.unibas.ch Date: Tue, 3 Dec 1996 09:42:31 +0100 (MET)

Title: Microlensing Optical Depth of the COBE Bulge Authors: N.

Bissantz (1,2), P. Englmaier (1), J. Binney (3), O. Gerhard (1) ((1) Astron.Inst., Univ.Basel, CH, (2) Phys.Inst., Univ.Freiburg, D, (3) Dpt. Theoret. Phys., Oxford, UK) Comments: 9 pages, TeX. 7 figures (gif). Submitted to MNRAS. Also available with full resolution figures as ps-file at http://www.astro.unibas.ch/dynamics/papers.html Report-no: Basel Preprint No.97
We examine the left-right asymmetry in the cleaned COBE/DIRBE near-infrared data of the inner Galaxy and show (i) that the Galactic bar is probably not seen very nearly end-on, and (ii) that even if it is, it is not highly elongated. The assumption of constant mass-to-light ratio is used to derive simulated terminal-velocity plots for the ISM from our model luminosity distributions. By comparing these plots with observed terminal velocities we determine the mass-to-light ratio of the near-IR bulge and disk. Assuming that all this mass contributes to gravitational microlensing we compute optical depths τ for microlensing in Galactic-centre fields. For three models with bar major axis between 10 deg -25 deg from the Sun-Galactic Center line, the resulting optical depths in Baade's window lie in the range $0.83\times10^{-6} < \tau < 0.89\times10^{-6}$ for main-sequence stars and $1.2\times10^{-6} < \tau < 1.3\times10^{-6}$ for red-clump giants. We discuss a number of uncertainties including possible variations of the near-infrared mass-to-light ratio. We conclude that, although the values predicted from analyzing the COBE and gas velocity data are inconsistent at the $2-2.5\sigma$ level with recent observational determinations of τ, we believe they should be taken seriously. (http://xxx.lanl.gov/abs/astro-ph/9612026 , 108kb)

Paper: astro-ph/9608154 From: borra@phy.ulaval.ca (Ermanno Borra) Date: Fri, 23 Aug 1996 19:16:44 -0400

Title: Liquid Mirror Telescopes: A progress report Authors: Ermanno F. Borra, Marc Ferrari, Luc Girard, Gilberto Moretto, Gregoire Tremblay and Gerard Lemaitre Comments: To appear in the SPIE conference proceedings 'Optical Telescopes of Today and Tomorrow', May 29 - June1, Landskrona/Hven, Sweden, Additional info on LMs at: http://astrosun.phy.ulaval.ca/lmt/lmt-home.html
We review the present status of liquid mirror telescopes. Interferometric tests of liquid mirrors (the largest one having a diameter of 2.5 meters) show excellent optical qualities. The basic technology is now sufficiently reliable that it can be put to work. Indeed, a handful of liquid mirrors have now been built that are used for scientific work. A 3.7-m diameter LMT is presently being built in the new Laval upgraded testing facilities. Construction of the mirror can be followed on the Web site: http://astrosun.phy.ulaval.ca/lmt/lmt- home.html. Finally we address the issue of the field accessible to LMTs equipped with novel optical correctors. Optical design work, and some exploratory laboratory work, indicate that a single LMT should be able to access, with excellent images, small regions anywhere inside fields as large as 45 degrees. (http://xxx.lanl.gov/abs/astro-ph/9608154 , 308kb)

Paper: astro-ph/9612151 From: Ian Smail ¡ian.smail@durham.ac.uk¿

Date: Mon, 16 Dec 1996 07:15:55 MST

Title: A Weak Lensing Survey in the Fields of z 1 Luminous Radio Sources Authors: Richard G. Bower and Ian Smail Comments: 10 pages, Latex, 3 figures, uses mn.sty and psfig.sty. Submitted to MNRAS

In this paper we present weak lensing observations of the fields around 8 z 1 luminous radio sources. These data are searched for the lensing signatures of clusters that are either physically associated with the radio objects, or are foreground systems projected along the line of sight. The radio sources were all imaged with WFPC-2/HST providing high quality shape information on large numbers of faint galaxies around them. Statistical analysis of the coherent shear field visible in the shapes of the faint galaxies indicates that we have detected a weak lensing signal close to one of the targets, 3C336 at z=0.927, with a high level of confidence. A second, independent WFPC-2 observation of this target reinforces this detection. Our results support the earlier suggestion of weak lensing in this field by Fort et al (1996) using ground-based data. We also combined the shear distributions in the remaining 7 field to improve our sensitivity to weak shear signals from any structure typically associated with these sources. We find no detectable signal and estimate an upper limit on the maximum shear allowed by our observations. Using an N(z) estimated from lensing analyses we convert our observed lensing signal and limits into estimates of the masses of the various structures. We suggest that further lensing observations of distant radio sources and their host environments may allow the cluster L_X-mass relationship to be mapped at high-z. This is crucial for interpreting the results of the next generation of deep X-ray surveys, and thus constraining the redshift evolution of the cluster mass function out to z=1. (http://xxx.lanl.gov/abs/astro-ph/9612151 , 197kb)

Paper: astro-ph/9511150 From: tjb@wibble.berkeley.edu (tom broadhurst) Date: Thu, 30 Nov 1995 20:31:02 -0800 Date (revised): Thu, 30 Nov 1995 21:04:52 -0800

Title:GRAVITATIONAL 'CONVERGENCE' AND CLUSTER MASSES Authors: Tom Broadhurst Comments: 12 pages, compressed uuencoded, 3 figures Journal-ref: apjl, submitted

Two colour photometry of the cluster A1689 reveals a 'relative magnification-bias' between lensed blue and red background galaxies, arising from a dependence of the faint galaxy count-slope on colour. The colour distribution is skewed blueward of the far field, allowing us to measure the cluster magnification and to understand the notorious blueness of large arcs. We show that the magnification information can be combined with the usual image distortion measurements to isolate the local 'convergence' component of lensing and hence derive the projected mass. This is achieved through a simple local relation between the convergence and the observables, which can be applied generally over the surface a cluster. In the weak lensing limit, the convergence reduces to a dependence on the magnification alone, so that in the outskirts of clusters the surface-density of matter is obtained directly from the surface-density of background galaxies. Hence, useful lensing work requires colour information but not necessarily good seeing. Interestingly, convergence varies slowly at high redshift, saturating at a level depending on the Horizon distance, allowing a useful model-independent measurement of the Global Geometry. (astro-ph/9511150 , 86kb)

Paper: astro-ph/9604144 From: ari@parsifal.phys.columbia.edu (Ari Buchalter) Date: Wed, 24 Apr 96 18:37:16 EDT

Title: RATES FOR PARALAX-SHIFTED MICROLENSING EVENTS FROM GROUND-BASED OBSERVATIONS OF THE GALACTIC BULGE Authors: Ari Buchalter (Columbia University) and Marc Kamionkowski (Columbia University) Comments: 25 pages, 7 Postscript figures Report-no: CAL-603, CU-TP-744

The parallax effect in ground-based microlensing (ML) observations consists of a distortion to the standard ML light curve arising from the Earth's orbital motion. In most cases, the resolution in current ML surveys is not accurate enough to observe this effect, but parallax could conceivably be detected with frequent followup observations of ML events in progress. We calculate the expected fraction of events where parallax distortions will be detected by such observations, adopting Galactic models consistent with the observed ML timescale (t_0) distributions. We study the dependence of the rates for parallax-shifted events on the sampling frequency and on the photometric precision. For example, we find that for hourly observations with typical photometric errors of 0.01 mag, 6% of events where the lens is in the bulge, and 31% of events where the lens is in the disk, (or $\simeq$ 10% of events overall) will give rise to a measurable parallax shift at the 95% confidence level. These fractions may be increased by improved photometric accuracy and increased sampling frequency. Parallax measurements yield the reduced transverse speed, $\tilde{v}$, which gives both the relative transverse speed and lens mass as functions of distance. We give examples of the accuracies with which $\tilde{v}$ may be measured in typical parallax events. Using only the 3 standard ML parameters to fit ML light curves which may be shape-distorted by parallax or blending, can result in incorrect inferred values for these quantities. We find that the inferred timescales from such fits tend to shift the event duration distribution by $\simeq$ 10% towards shorter t_0 for events with disk lenses, but do not affect bulge lenses. In both cases, the impact-parameter distribution is depressed slightly at the low and high ends. (http://xxx.lanl.gov/abs/astro-ph/9604144 , 102kb)

Paper:astro-ph/9601031 From:P.Schneider peter@MPA-Garching.MPG.DE Date: Tue, 9 Jan 1996 11:26:06 +0100 (MET)

Title: VERY CLOSE PAIRS OF QUASI-STELLAR OBJECTS Authors: G. Burbidge, F. Hoyle and P. Schneider Comments: 8 pages, including 1 figure, submitted to Astronomy and Astrophysics Letters Report-no: MPA 916

It is pointed out that there are now known four very close pairs of QSOs with separations ¡ 5 arcsec and very different redshifts. Several estimates of the probability that they are accidental configurations range between 10^{-7} and 3.5 x 10^{-3}. We conclude either that this is further evidence that QSOs have significant non-cosmological redshift components, or that thave significant non-cosmological redshift components, or that the pairs must be explained by gravitational lensing. (astro-ph/9601031 , 17kb)

Paper: astro-ph/9610074 From: CAPOZZIELLO@astrna.na.astro.it Date: Thu, 10 Oct 1996 18:18:48 +0100 (CET)

Title: Luminosity variation in (de)focusing microlensing Authors: Salvatore Capozziello, Ruggiero de Ritis, Vladimir Mank'o, Alma Angela Marino, Giuseppe Marmo Comments: 9 pages, latex, submitted to Phys. Lett. A
The luminosity variation of a stellar source due to the gravitational microlensing effect can be considered also if the light rays are defocused (instead of focused) toward the observer. In this case, we should detect a gap instead of a peak in the light curve of the source. Actually, we describe how the phenomenon depends on the relative position of source and lens with respect to the observer: if the lens is between, we have focusing, if the lens is behind, we have defocusing. It is shown that the number of events with predicted gaps is equal to the number of events with peaks in the light curves. (http://xxx.lanl.gov/abs/astro-ph/9610074 , 11kb)

Paper: astro-ph/9610161 From: CAPOZZIELLO@napoli.infn.it Date: Mon, 21 Oct 1996 19:39:46 +0100 (CET)

Title: Defocusing gravitational microlensing Authors: Salvatore Capozziello, Ruggiero de Ritis, Vladimir Mank'o, Alma Angela Marino, Giuseppe Marmo Comments: 19 pages, latex, submitted to Physica Scripta
We introduce the notion of defocusing gravitational lens considering a MACHO located behind a light source with respect to an observer. The consequence of defocusing effect is a temporal variability of star luminosity which produces a gap instead of a peak as tell–tale signature in the light curve. General theory of (de)focusing rays (geodesics) in a gravitational field is presented. Furthermore, we give estimations of the mass of the lens and the optical depth connected to such a phenomenon. (http://xxx.lanl.gov/abs/astro-ph/9610161 , 18kb)

Paper: astro-ph/9610232 From: Fabio Governato
fabio@hermes.astro.washington.edu Date: Mon, 28 Oct 1996 19:07:52 MST

Title: Prospects for Cosmology with Cluster Mass Profiles Authors: Mary Crone, Fabio Governato, Joachim Stadel and Thomas Quinn Comments: 11 pages, 2 postscript figures included. Submitted to ApJL. .ps version also available at http://www-hpcc.astro.washington.edu/faculty/fabio/index.html
We test the precision with which weak lensing data can provide characteristic cluster mass profiles within Cold Dark Matter scenarios. Using a parallel treecode to simulate volumes as large as 500h-1 Mpc with good resolution, we generate samples of large clusters within a standard CDM model and an open CDM model with $Omega_0 = 0.3$.

We mock high-quality lensing data by including realistic errors, selecting cluster samples based on velocity dispersion, and fitting profiles within a realistic range in radius. We find that a sample of ten clusters can determine logarithmic profile slopes with 1 sigma errors of about 7than 5measures of cluster profiles obtained with weak lensing do place strong constraints for general CDM–like models of structure formation, and we discuss the optimal strategy for obtaining data samples to use for this purpose. (http://xxx.lanl.gov/abs/astro-ph/9610232 , 26kb)

Paper: astro-ph/9610067 From: arlin@astro.columbia.edu (Arlin Crotts) Date: Wed, 9 Oct 1996 21:01:09 -0400

Title: VATT/Columbia Microlensing Survey of M31 and the Galaxy Authors: Arlin P.S. Crotts (Columbia U.) Comments: presented at the International Conference on "Dark and Visible Matter in Galaxies" (Sesto Pusteria, Italy, 2-5 July 1996), 8 pages, Latex, 3 required .sty files (incl. paspconf.sty), 4 figs.

We describe the results and outline the methods used in a search for microlensing events affecting stars in the outer bulge and inner disk of M31, due both to masses in M31 and the Galaxy. These observations, from 1994 and 1995 on the Vatican Advanced Technology Telescope and KPNO 4m, rule out masses over much of the range from 10e-7 Msol to 0.08 Msol as the primary constituents of the mass of M31 and the Galaxy towards this field. Furthermore we find six candidate events consistent with microlensing due to masses of about 1 Msol, but we suspect that some of these may be cases where long-period red supergiant variables may be mistaken for microlensing events. Coverage from anticipated data should be helpful in determining if these sources maintain a constant baseline, and therefore are best described by microlensing events. We analyzed our data using the new technique of "difference image photometry" (also called "pixel lensing"). A brief overview of this technique is included in the Appendix I. This contribution summarizes two other recent papers (Tomaney and Crotts 1996, Crotts and Tomaney 1996). (http://xxx.lanl.gov/abs/astro-ph/9610067 , 128kb)

Paper: astro-ph/9702033 From: delaix@theory6.phys.cwru.edu (Andrew de Laix) Date: Mon, 3 Feb 1997 15:04:40 -0500 (44kb)

Title: Gravitational Lensing Signature of Long Cosmic Strings Authors: Andrew A. de Laix, Lawrence M. Krauss, and Tanmay Vachaspati Comments: 4 pages, revtex with 3 postscript figures included Report-no: CWRU-P1-97

The gravitational lensing by long, wiggly cosmic strings is shown to produce a large number of lensed images of a background source. In addition to pairs of images on either side of the string, a number of small images outline the string due to small-scale structure on the string. This image pattern could provide a highly distinctive signature of cosmic strings. Since the optical depth for multiple imaging of distant quasar sources by long strings may be comparable to that by galaxies, these image patterns should be clearly observable in the next generation of redshift surveys such as the Sloan Digital Sky Survey. (http://xxx.lanl.gov/abs/astro-ph/9702033 , 44kb)

Paper: astro-ph/9605171 From: delaix@theory6.phys.cwru.edu (Andrew de Laix) Date: Tue, 28 May 1996 13:11:10 -0400

Title: GRAVITATIONAL LENSING BY COSMIC STRING LOOPS Authors: Andrew A de Laix and Tanmay Vachaspati Comments: 17 pages, RevTex with 1 pict and 9 postscript figures. Postscript figures are 100dpi bitmaps (full resuolution figures are available at http://cwsing.phys.cwru.edu/preprints) Report-no: CWRU-P9-1996

We calculate the deflection of a light ray caused by the gravitational field of a cosmic string loop in the weak field limit and reduce the problem to a single quadrature over a time slice of the loop's world sheet. We then apply this formalism to the problem of gravitational lensing by cosmic string loops. In particular, we find an analytic solution for the special case of a circular loop perpendicular to the optical axis. As examples of more complicated loops, we consider two loops with higher frequency Fourier modes. The numerical analysis illustrates the general features of loop lenses. Our estimates, using typical parameters for GUT scale loops, show that the stringy nature of loop lenses can be observed for lensing systems involving high redshift galaxies ($z \sim 2$), and we suggest that gravitational lensing can confirm the existence of GUT scale strings if they are the seeds for large scale structure formation. (http://xxx.lanl.gov/abs/astro-ph/9605171 , 117kb)

Paper: astro-ph/9702088 From: rd@cfata5.harvard.edu (Rosanne Di Stefano) Date: Mon, 10 Feb 1997 19:04:31 -0500 (393kb)

Title: Identifying Microlensing by Binaries Authors: Rosanne Di Stefano, Rosalba Perna Comments: 22 pages, 5 figures; submitted to ApJL 11 December 96; resubmitted to ApJ 7 February 1997

The microlensing monitoring programs have studied large numbers of standard light curves which seem to be due to lensing by a dark point mass. Theory predicts that many microlensing events should display significant deviations from the standard form. Lens binarity in particular is expected to be common. So far, however, only a handful of light curves exhibit evidence that the lens is a binary; all of these display dramatic deviations from the standard light curve, exhibiting pronounced multiple peaks and/or caustic crossings. Binary-lens events in which the light curve is less dramatically perturbed should also exist in the data set. Why, then, have we not detected them? The answer may lie in the fact that the perturbations, though often significant, tend to be less distinctive than those associated with caustic crossings. We present a method to determine whether a light curve is due to lensing by a binary. The method works for both gently and dramatically perturbed binary-lens light curves. Our method identifies all degenerate solutions– i.e., all possible lensing events that might have given rise to the observed light curve. It also enables us to eliminate from consideration large ranges of possible false positive identifications associated with light curves that might mimic microlensing by a binary. This method, or a generalization of it, can also be applied to the analysis of light curves that deviate from the standard point-mass lens form because of astronomical effects other than lens binarity. (http://xxx.lanl.gov/abs/astro-ph/9702088 , 392kb)

Paper: astro-ph/9701035 From: Martin Dominik dominik@hal1.physik.uni-dortmund.de Date: Wed, 8 Jan 1997 09:54:47 MST

Title: Estimating physical quantities for an observed galactic microlensing event Authors: M. Dominik Comments: 23 pages in LaTex2e format including 6 PostScript figures Reort-no: DO-TH 96/28

For a given spatial distribution of the lenses and distribution of the transverse velocity of the lens relative to the line-of-sight, a probability distribution for the lens mass for a single observed event is derived. In addition, similar probability distributions are derived for the Einstein radius and the separation of the lens objects and their rotation period for a binary lens. These probability distributions are distinct from the distributions for the lens population, as investigated e.g. by the mass moment method of De Rujula, Jetzer, and Masso (1991). However, it is shown that the expectation value for the mass from the probability distribution coincides with the value from the mass moment method applied to a single observed event. The special cases of a Maxwellian velocity distribution and of a constant velocity are discussed in detail. For a rudimentary model of the Galactic halo, the probability distributions are shown and the relations between the expectation values of the physical quantities and the event timescale are given. For this model, it is shown that within a 95.4the mass varies by a factor of 800. (http://xxx.lanl.gov/abs/astro-ph/9701035 , 88kb)

Paper: astro-ph/9702039 From: Martin Dominik dominik@hal1.physik.uni-dortmund.de Date: Tue, 4 Feb 1997 07:35:37 MST (165kb)

Title: Galactic microlensing with rotating binaries Authors: M. Dominik Comments: 34 pages LaTeX2e format including 18 PostScript figures Report-no: DO-TH 97/05

The influence of rotating binary systems on the light curves of galactic microlensing events is studied. Three different rotating binary systems are discussed: a rotating binary lens, a rotating binary source, and the motion of the earth around the sun (parallax effect). The most dramatic effects arise from the motion of a binary lens because of the changes of the caustic structure with time. I discuss when the treatment of a microlensing event with a static binary model is appropriate. It is shown that additional constraints on the unknown physical quantities of the lens system arise from a fit with a rotating binary lens as well as from the earth-around-sun motion. For the DUO No2 event, a fit with a rotating binary lens is presented. (http://xxx.lanl.gov/abs/astro-ph/9702039 , 165kb)

Paper: astro-ph/9703003 From: Martin Dominik ¡dominik@hal1.physik.uni-dortmund.de¿ Date: Fri, 28 Feb 1997 06:25:44 MST (450kb)

Title: Ambiguities in fits of binary lens galactic microlensing events Authors: M. Dominik Comments: 35 pages in LaTeX2e format including 37 PostScript figures Report-no: DO-TH 97/06

For observed galactic microlensing events only one fit is usually presented, though, especially for a binary lens, several fits may be possible. This has been shown for the MACHO LMC No1 event (Dominik & Hirshfeld 1996). Here I discuss the strong binary lens events OGLE No7 and DUO No2. It is shown that several models with a large variety of parameters are possible. For most of the fits, 1-sigma-bounds on the fit parameters are given. The variation of the parameters within the bounds is in some cases considerable. (http://xxx.lanl.gov/abs/astro-ph/9703003 , 450kb)

Paper: astro-ph/9611004 From: Ian Smail ian.smail@durham.ac.uk Date: Fri, 1 Nov 1996 10:11:24 MST

Title: HST Observations of Distant Clusters: Implications for Galaxy Evolution Authors: Alan Dressler and Ian Smail Comments: 9 pages, Latex, 3 figures, hx37_latex.sty included. Invited review to appear in the proceedings of the 37th Herstmonceux conference "HST and the High Redshift Universe"

The "MORPHS" group has completed the cataloging, parameterization, and morphological classification of 2000 galaxies in 10 rich clusters from 0.36 ¡ z ¡ 0.56. From a weak lensing analysis using these data, which compares the X-ray properties (L_X) of the clusters with virial temperature estimates (T_v) from the lensing shear strength, we find little evidence for evolution in the $L_X - T_v$ relation from that observed for local clusters. We discuss how this observation constrains models for the X-ray evolution of clusters. The data have also been used to study the color dispersion of bona-fide ellipticals in high-z clusters: we find the spread to be very small, suggesting an early formation epoch for the stellar populations of cluster ellipticals. This is consistent with the evolution of the morphology-density relationship, in which we find ellipticals to be as abundant at z=0.5 as in clusters today, and already well ensconced in the dense regions. In contrast, S0's are less plentiful and less well-concentrated compared to the present epoch, and spiral galaxies everywhere more abundant. Combined with other spectroscopic and morphological data, these observations suggest that most of these rapidly evolving systems are not likely to become bright ellipticals, which were more likely formed at early epochs. Cluster S0 galaxies, on the other hand, are likely to have been produced in large numbers in the recent past. (http://xxx.lanl.gov/abs/astro-ph/9611004 , 27kb)

Paper: astro-ph/9703169 From: Timothy Ebbels tebbels@ast.cam.ac.uk Date: Wed, 26 Mar 1997 05:31:48 MST (214kb)

Title: Spectroscopic Confirmation of Redshifts Predicted by Gravitational Lensing Authors: Tim Ebbels, Richard Ellis, Jean-Paul Kneib, Jean-Francois Le Borgne, Roser Pello, Ian Smail and Blai Sanahuja Comments: 20 pages, LaTeX, 18 figures. Submitted to MNRAS. Figures 1,8,9,10 & 11 and whole paper available at ftp://ftp.ast.cam.ac.uk/pub/tebbels/a2218inv/

We present deep spectroscopic measurements of 18 distant field galaxies identified as gravitationally-lensed arcs in a Hubble Space Telescope image of the cluster Abell 2218. Redshifts of these objects were predicted by Kneib et al. (1996) using a lensing analysis constrained by the properties of two bright arcs of known redshift and other multiply-imaged sources. The new spectroscopic identifications were obtained using long exposures with the LDSS-2 spectrograph on the William Herschel Telescope and demonstrate the capability of that instrument to new limits, $R \simeq$24; the lensing magnification implies true source magnitudes as faint as $R \simeq$25. Statistically, our measured redshifts are in excellent agreement with those predicted from Kneib et al.'s lensing analysis which gives considerable support to the redshift distribution derived by the lensing inversion method for the more numerous and fainter arclets extending to $R \simeq 25.5$. We explore the remaining uncertainties arising from both the mass distribution in the central regions of Abell 2218 and the inversion method itself, and conclude that the mean redshift of the faint field population at $R \simeq$25.5 ($B \sim$ 26-27) is low, $< z >$=0.8-1. We discuss this result in the context of redshift distributions estimated from multi-colour photometry. Although such comparisons are not straightforward, we suggest that photometric techniques may achieve a reasonable level of agreement particularly when they include near-infrared photometry with discriminatory capabilities in the $1 < z <$2 range. (http://xxx.lanl.gov/abs/astro-ph/9703169 , 214kb)

Paper: astro-ph/9702152 From: Emilio E. Falco falco@aperea.harvard.edu Date: Tue, 18 Feb 1997 09:16:17 MST (283kb)

Title: An estimate of H_0 from Keck spectroscopy of the gravitational lens system 0957+561 Authors: Emilio E. Falco, Irwin I. Shapiro (CfA), Leonidas A. Moustakas, Marc Davis (Berkeley) Comments: 29 pages, 12 .eps figs, AAS Latex, ApJ, in press

We present long-slit LRIS/Keck spectroscopic observations of the gravitational lens system 0957+561. Averaged over all of our data, the rest-frame velocity dispersion $sigma_v$ of the central lens galaxy G1 is $sigma_v$ = 279 +- 12 km/s. However, there appears to be a significant decrease in $sigma_v$ as a function of distance from the center of G1 that is not typical of brightest cluster galaxies. Within 0.2" of the center of G1, we find the average $sigma_v$ = 316+- 14 km/s, whereas for positions ¿ 0.2" from the center of G1, we find the average $sigma_v$= 266+-12 km/s. A plausible explanation is that G1 contains a central massive dark object of mass M_MDO $4x10^9$ h_100^{-1} M_sun (h_100 = H_0/100km/s/Mpc), which contributes to the central velocity dispersion, and that the outer value of $sigma_v$ is the appropriate measure of the depth of the potential well of G1. The determination of a luminosity-weighted estimate of $sigma_v$ is essential for a determination of H_0 from 0957+561; our accurate measurements remove one of the chief uncertainties in the assumed form of the mass distribution of the lens. Thus, with the recent apparent reduction in the uncertainty in the measurement of the time delay for the images A and B of 0957+561, $\Delta\tau_B A = 417 + -3d$ (Kundic et al. 1996), we obtain an estimate for the Hubble constant: $H_0 = 62 + -7km/s/Mpc$. If for some reason the trend of $sigma_v$ with slit position is spurious and we should use the dispersion averaged along the slit, then the estimate of H_0 increases to 67+-8 km/s/Mpc. These standard errors do not, however, include any contribution from any errors in the assumed form of the mass distribution of the lens. In particular, we used the mass model described by Falco, Gorenstein & Shapiro (1991), as updated by Grogin & Narayan (1996a, b). The reduced χ^2 (http://xxx.lanl.gov/abs/astro-ph/9702152 , 161kb)

Paper: astro-ph/9610164 From: FARAONI@phastf.phys.UVic.CA Date: Mon, 21 Oct 1996 14:02:09 -0700 (PDT)

Title: The creation of multiple images by a gravitational wave Author: Valerio Faraoni (University of Victoria) Comments: latex, 7 pages, no figures, to appear in Proceedings of the Pacific Conference on Gravitation and Cosmology, Seoul, Korea 1996

We describe gravitational lensing by a gravitational wave, in the regime in which multiple images of a light source are created. We adapt the vector formalism employed for ordinary gravitational lenses to the case of a non-stationary spacetime, and we derive an approximate condition for multiple imaging. It is shown that certain astrophysical sources of gravitational waves satisfy this condition. (http://xxx.lanl.gov/abs/astro-ph/9610164 , 6kb)

Paper: astro-ph/9703189 From: "Phil Fischer" philf@astro.lsa.umich.edu Date: Thu, 27 Mar 1997 23:34:46 -0500 (114kb)

Title: The Mass distribution of the Most Luminous X-ray Cluster RXJ1347.5-1145 from Gravitational Lensing Authors: Philippe Fischer, J. Anthony Tyson Comments: 21 Pages LaTeX, AASTEX version 4 macros, Accepted for publication in the AJ. 8 of 12 figures included, full paper at

http://www.astro.lsa.umich.edu:80/users/philf/www/papers/list.html

Galaxy cluster mass distribution are potentially useful probes of Ω_0 and the nature of the dark matter. Large clusters will distort the observed shapes of background galaxies through gravitational lensing allowing the measurement of the cluster mass distributions. In this paper we describe weak statistical lensing measurements of the most luminous X-ray cluster known, RXJ1347.5-1145 at z=0.45. We detect a shear signal in the background galaxies at a signal-to-noise ratio of 7.5 in the radial range $120 \leq r \leq 1360h^{-1}$ kpc. A mass map of the cluster reveals an 11σ peak in the cluster mass distribution consistent with the position of the central dominant galaxy and 3 σ evidence for the presence of a subcluster at a projected radius of $1.3 - 1.7h^{-1}$ Mpc from the cluster center. In the range $120 \leq r \leq 1360h^{-1}$ kpc mass traces light, and the azimuthally averaged cluster mass and light profiles are consistent with singular isothermal spheres with M(r¡1 Mpc) = $1.7 \pm 0.4 \times 10^{15} M_\odot$. Assuming an isotropic velocity distribution function, the implied velocity dispersion is $\sigma = 1500 \pm 160 kms^{-1}$. The rest-frame mass-to-light ratio is $M/L_B = 200 \pm 50 h M_\odot / L_{B\odot}$. The lensing mass estimate is almost twice as high as a previously determined X-ray mass estimate. (http://xxx.lanl.gov/abs/astro-ph/9703189 , 114kb)

Paper: astro-ph/9606039 From: mellier@iap.fr (Yannick Mellier) Date: Thu, 6 Jun 96 15:12:48 +0200

Title: DISTRIBUTION OF GALAXIES AT LARGE REDSHIFT AND COSMOLOGICAL PARAMETERS FROM MAGNIFICATION BIAS IN Cl0024+1654 Authors: B. Fort (1) Y. Mellier (2,1,3) M. Dantel-Fort Fort (1) ((1) Observatoire de Paris DEMIRM , (2) Institut d'Astrophysique de Paris, (3) UMR 5572 Observatoire Midi Pyrenees.) Comments: Latex, 11 pages, l-aa.sty and psfig.sty, 10 figures. 187K gzipped tar file. Submitted to Astronomy and Astrophysics Main Journal

We analyse the surface density of very faint galaxies at the limit of the sky background noise in the field of the cluster of galaxies Cl0024+1654. The radial variation of their number density in the magnitude bins $B = 26 - 28$ and $I = 24 - 26.5$ displays an (anti)bias magnification effect for $I < 24$ which provides the redshift range of the populations seen in B and I. The depletion curve can be reproduced with two redshift populations with $60\% \pm 10\%$ of the B galaxies between $z = 0.9$ and $z = 1.1$ and the remaining at a redshift close to $z = 3$. The I selected population is similar but with a minimum extending from the B inner critical line to $R_I = 60$". Whatever the cosmological model, the I-selected galaxies spread up to a larger redshift with about 20% above $z > 4$. Using a model for the gravitational potential, the locations of the two extreme critical lines for the B and I galaxies favour Ω_Λ-dominated flat universes with a cosmological constant ranging from 0.6 to 0.9. The result is confirmed by a preliminary investigation of A370. We discuss the method to search the "last critical line" and the various biases. (http://xxx.lanl.gov/abs/astro-ph/9606039 , 178kb)

Paper: astro-ph/9608068 From: "Joshua Frieman" frieman@falstaff.fnal.gov Date: Mon, 12 Aug 1996 20:54:04 -0500

Title: Weak Lensing and the Measurement of q0 from Type Ia Supernovae Author: Joshua A. Frieman Comments: 14 pages LaTeX with 2 figures; earlier version (Mar. '96) accepted for publication in Comments on Astrophysics. Also available by WWW at http://www-astro-theory.fnal.gov/Publications/00Index.html Report-no: Fermilab-Pub-96/067-A

On-going projects to discover Type Ia supernovae at redshifts z = 0.3 - 1, coupled with improved techniques to narrow the dispersion in SN Ia peak magnitudes, have renewed the prospects for determining the cosmic deceleration parameter q_0. We estimate the expected uncertainty in the Hubble diagram determination of q_0 due to weak lensing by structure in the universe, which stochastically shifts the apparent brightness of distant standard candles. Although the results are sensitive to the density power spectrum on small scales, the induced flux dispersion $\sigma_m < 0.04\Omega_{m,0}^{1/2}$ mag for sources at $z \leq 0.5$, well below the "intrinsic" spread of nearby SN Ia magnitudes, $\sigma_M \simeq 0.2 mag$. Thus, density inhomogeneities do not significantly impact the current program to measure q_0, in contrast to a recent claim. If, however, light-curve shape and other calibrators can reduce the effective intrinsic spread to 0.1 mag at high z, then weak lensing could increase the observed spread by 301. (http://xxx.lanl.gov/abs/astro-ph/9608068 , 20kb)

Paper: astro-ph/9702061 From: "Takashi Okamura (Dep. of Phys.)" okamura@th.phys.titech.ac.jp Date: Thu, 06 Feb 1997 21:27:37 +0900 (25kb)

Title: On the General Theorems about the Gravitational Lensing Authors: Takeshi Fukuyama and Takashi Okamura Comments: 8 pages, aastex, 2 figures We study the general theorem about the gravitational lensing which says the relationship between the numbers of images with different parities. Our formulation allows an extension to the nontranparent and singular model. (http://xxx.lanl.gov/abs/astro-ph/9702061 , 25kb)

Paper: astro-ph/9508071 From: Geza Gyuk gyuk@oddjob.uchicago.edu Date: Wed, 16 Aug 1995 19:19:00 -0500 Date (revised): Wed, 16 Aug 1995 21:02:56 -0500

Title: GRAVITATIONAL MICROLENSING AND THE GALACTIC HALO Authors: Evalyn I. Gates, Geza Gyuk, and Michael S. Turner Comments: 19 pages, 13 multipart figures are available at

ftp://astro.uchicago.edu/ftp/pub/astro/gyuk/ Report-no: FERMILAB–Pub–95/267-A

By means of extensive galactic modeling we study the implications of the more than eighty microlensing events that have now been observed for the composition of the dark halo of the Galaxy, as well as for other properties of the Galaxy. We take the Galaxy to be comprised of luminous and dark disk components, a bulge, and a dark halo consisting of both MACHOs and cold dark matter with each component being described by several observationally motivated parameters. We pare down an initial model space of millions of galactic models to viable models, those which are consistent with the observational data, including rotation curve, local projected mass density, and microlensing rates toward the LMC and bulge. On the basis of a conservative, minimal set of observational constraints an all-MACHO halo cannot yet be excluded, although in most viable models of the Galaxy the halo MACHO fraction is between 0% and 30%, consistent with expectations for a universe whose primary component is cold dark matter. An all-MACHO halo is required to be light, and when data on the local escape velocity and satellite-galaxy proper motions, which probe the extent of the dark halo, are taken into account, models which have a high MACHO mass fraction are ruled out. We also explore the possibility that there are no MACHOs in the halo. Finally, we point out several important tests that could definitively exclude an all-MACHO e.g., optical depth for microlensing which is less than 1.5×10^{-7} toward the LMC or greater than 3×10^{-6} toward the bulge.

Paper: astro-ph/9606104 From: Bernard S. Gaudi gaudi@payne.mps.ohio-state.edu date: Mon, 17 Jun 96 14:26:18 EDT

Title: DETECTION RATES FOR CLOSE BINARIES VIA MICROLENSING Authors: B. Scott Gaudi, Andrew Gould Comments: 19 pages including 6 figures. Uses *phyyzx* format. Send requests for higher quality figures to gaudi@payne.mps.ohio-state.edu Report-no: OSU-TA-16/96

Microlensing is one of the most promising methods of reconstructing the stellar mass function down to masses even below the hydrogen-burning limit. The fundamental limit to this technique is the presence of unresolved binaries, which can in principle significantly alter the inferred mass function. Here we quantify the fraction of binaries that can be detected using microlensing, considering specifically the mass ratio and separation of the binary. We find that almost all binary systems with separations greater than $b \simeq 0.4$ of their combined Einstein ring radius are detectable assuming a detection threshold of 3%. For two M dwarfs, this corresponds to a limiting separation of $\geq 1AU$. Since very few observed M dwarfs have companions at separations $\leq 1AU$, we conclude that close binaries will probably not corrupt the measurements of the mass function. We find that the detectability depends only weakly on the mass ratio. For those events for which individual masses can be determined, we find that binaries can be detected down to $b \simeq 0.2$. (http://xxx.lanl.gov/abs/astro-ph/9606104 , 74kb)

Paper: astro-ph/9610123 From: B. Scott Gaudi gaudi@payne.mps.ohio-state.edu Date: Wed, 16 Oct 96 07:05:30 EDT

Title: Planet Parameters in Microlensing Events Authors: B. Scott Gaudi, Andrew Gould Comments: 38 pages, 11 figures, TeX, uses PHYZZX, higher quality figures available upon request Report-no: OSU-TA-26/96

A planetary microlensing event occurs when a planet perturbs one of the two images created in a point-mass microlensing event, causing a deviation from the standard Paczyński curve. Determination of the two physical parameters that can be extracted from a planetary microlensing event, the planet/star mass ratio q, and the planet/star separation in units of the stellar Einstein ring, y_p, is hampered by several types of degeneracies. There are two distinct and qualitatively different classes of planetary events: major and minor image perturbations. For major image perturbations, there is a potentially crippling continuous degeneracy in q which is of order δ_d^{-1}, where δ_d is the maximum fractional deviation of the planetary perturbation. Since the threshold of detection is expected to be $\delta_d \simeq 5\%$, this degeneracy in q can be a factor of $\simeq 20$. For minor image perturbations, the continuous degeneracy in q is considerably less severe, and is typically less than a factor 4. We show that these degeneracies can be resolved by observations from dedicated telescopes on several continents together with optical/infrared photometry from one of these sites. There also exists a class of discrete degeneracies. These are typically easy to resolve given good temporal coverage of the planetary event. Unambiguous interpretation of planetary microlensing events requires the resolution of both types of degeneracy. We describe the degeneracies in detail and specify the situations in which they are problematic. We also describe how individual planet masses and physical projected separations can be measured. (http://xxx.lanl.gov/abs/astro-ph/9610123 , 171kb)

Paper: astro-ph/9701070 From: Matthias Bartelmann msb@MPA-Garching.MPG.DE Date: Tue, 14 Jan 1997 14:13:20 +0100 (MET)

Title: Constraining the Mass Distribution of Cluster Galaxies by Weak Lensing Author: Bernhard Geiger (MPA) Comments: 10 pages, including 6 figures, Latex, uses lamuphys.sty, to appear in the proceedings of the ESO Workshop on Galaxy Scaling Relations: Origins, Evolution and Applications. Garching, 18-20 November 1996

Analysing the weak lensing distortions of the images of faint background galaxies provides a means to constrain the mass distribution of cluster galaxies and potentially to test the extent of their dark matter halos as a function of the density of the environment. Here I describe simulations of observational data and present a maximum likelihood method to infer the average properties of an ensemble of cluster galaxies. (http://xxx.lanl.gov/abs/astro-ph/9701070 , 224kb)

Paper: astro-ph/9509149 From:Ortwin Gerhard gerhard@astro.unibas.ch Date: Fri, 29 Sep 1995 09:36:43 +0100 (MET)

Title: BARYONIC DARK HALOS; MACHOS AND COLD GAS? Authors: Ortwin Gerhard (Astron.Inst., Univ.Basel, CH) and Joseph Silk (Dpt.Astron. and Phys., Univ.Calif., Berkeley, USA) Comments:13 pages, submitted to ApJ.Uuencoded, gzip-compressed ps-file including 2 figures.Also available at

http://www.astro.unibas.ch/ gerhard/papers/dmmn.ps.gz.uu Report-no: Astr.Inst.Basel Prep.Ser.84

We consider the possibility that the dark matter in the halos of galaxies may be in the form of clusters of machos within which are embedded cold, dense gas clouds. Microlensing experiments have found evidence that the Galactic halo contains up to half of its mass in the form of low-mass macho s. A number of observational and dynamical arguments point to the existence of hitherto unobserved cold gas around galaxies. We show that the cold gas can be stabilized by macho clusters. Within the framework of a simple two-component model, we derive constraints on the macho clusters and on the halo cold gas content. Typical cluster masses are $\sim 10 M_\odot$, typical macho masses are $\sim 0.01 M_\odot$, and the gas content could be up to of order 50 %. Various predictions are given for testing the hypothesis that such objects could constitute most of the mass in the dark halos of galaxies. If halos are indeed baryonic and contain significant amounts of cold gas, they are likely to play a much more active role in galaxy formation and evolution than is commonly supposed. (astro-ph/9509149 , 103kb)

Paper: astro-ph/9601108 From: gioia@abell.IFA.Hawaii.Edu (Isabella gioia) Date: Sat, 20 Jan 96 20:49:15 HST

Title: X-RAY SELECTED CLUSTERS OF GALAXIES Author: Isabella M. Gioia (Institute for Astronomy, University of Hawaii, Honolulu, HI and Istituto di Radioastronomia del CNR, Bologna, Italy) Comments: 5 pages Report-no: IfA-95/65

This paper given at the meeting on "Mapping, Measuring and Modelling the Universe" presents three topics: 1) the study of the clusters and groups of galaxies found serendipitously in the North Ecliptic Pole (NEP) region of the ROSAT all-sky survey; 2) the highest redshift clusters found in the EMSS (up to z=0.82) and the cosmological implications of their very existence; 3) the gravitational lensing in the EMSS X-ray selected clusters of galaxies observed by the Hubble Space Telescope. (http://xxx.lanl.gov/abs/astro-ph/9601108 , 447kb)

Paper: astro-ph/9610010 From: Paolo Gondolo gondolo@menuhin.berkeley.edu Date: Tue, 1 Oct 1996 17:15:06 MDT

Title: AGAPE: a Microlensing Search for Dark Matter by Monitoring Pixels Authors: P. Gondolo, R. Ansari, M. Auriere, P. Baillon, A. Bouquet, G. Coupinot, Ch. Coutures, C. Ghesquiere, Y. Giraud-Heraud, J. Hecquet, J. Kaplan, Y. Le Du, A.L. Melchior, M. Moniez, J.P. Picat, G. Soucail Comments: presented at the International Conference on "Dark and Visible Matter in Galaxies" (Sesto Pusteria, Italy, 2-5 July 1996), 8 pages, 7 figures, uses paspconf.sty, psfig.sty

AGAPE is an observational search of massive compact halo objects (MACHOs) in the direction of M31 by means of a novel method: the gravitational microlensing of unresolved stars. The search consists in examining CCD pixel light curves for microlensing features. The high level of temporal stability necessary to detect microlensing events has been achieved, with quiet pixels stable within a factor of two of the photon noise (the brightest ones down to a level of 0.001 mag). The data analysis is still in progress, but hundreds of variable objects (cepheids, novae, ...) have already been found. Among them there are several lightcurves that resemble microlensing events. (http://xxx.lanl.gov/abs/astro-ph/9610010 , 100kb)

Paper: astro-ph/9603148 From: Andrew P. Gould gould@payne.mps.ohio-state.edu Date: Wed, 27 Mar 96 17:58:48 EST

Title: EXTREME MICROLENSING Author: Andrew Gould Comments: 17 pages Report-no: OSU-TA-9/96

Extreme microlensing events, defined as events with maximum magnification $A_{\geq}200$ are a potentially powerful probe of the mass spectrum and spatial distribution of objects along lines of sight toward the Galactic bulge. About 75 yr^{-1} such events are expected for main-sequence sources with $I_0 < 19$. For many of these it is possible to measure both a "proper motion" and a "parallax" which together would yield individual mass, distance, and transverse-speed determinations of the lensing object.

The proper motion is determined from finite-source effects when the lens transits, or nearly transits the source. The parallax is determined by observing the difference in the light curve as seen from two Earth observatories separated by about 1 Earth radius, $R_\oplus$. The size of the parallax effect is $\sim A_{max} R_\oplus / = r_e$ where $= r_e$ is the projected Einstein radius. This can be of order 1%. Detection of candidate events requires a pixel-lensing search of the entire bulge once per day, preferably by at least two observatories on different continents. Follow-up observation must be carried using optical/infrared photometry, with short (e.g. 1 minute) exposures on small (≥ 1 m) telescopes. Extreme microlensing observations toward the Large Magellanic Cloud do not appear feasible at the present time. (http://xxx.lanl.gov/abs/astro-ph/9603148 , 50kb)

Paper: astro-ph/9605105 From: Andrew P. Gould gould@payne.mps.ohio-state.edu Date: Fri, 17 May 96 06:46:36 EDT

Title: LES MICROLENTILLES GRAVITATIONNELLES Author: Andrew Gould Comments: Four lectures given at College de France, Paris. 48 pages. Figures available separately Report-no: LPC-96-23

Je presente une revue des microlentilles gravitationnelles en quatre lecons. Dans un premier temps, je discute la theorie des microlentilles dans le contexte general des lentilles, en incluant les effets de la taille finie des sources, de la parallaxe, et du retard temporel entre les images. Dans la deuxieme lecon, j'analyse les experiences courantes. Je montre qu'il n'est pas possible d'expliquer les evenements observes avec les etoiles connues, que ce soit en direction du bulbe ou du Grand Nuage de Magellan. Je decris quelques nouvelles experiences qui pourraient nous reveler les caracteristiques des objets detectes. Le troisieme sujet porte sur la methode des pixels, inventee pour observer des evenements de microlentilles sur des sources non resolues. Je presente une analyse generale de la methode, en incluant des problemes d'alignement geometrique, photometrique, et de PSF, du rapport signal sur bruit, et de la nature des informations tirees des observations. Je presente un rapport sur le progres des experiences actuelles et je discute de deux idees pour rechercher des objets sombres dans l'amas de Virgo et des 'microlentilles extremes' dans le bulbe. Pour finir, je parle de l'avenir des microlentilles. J'explique comment on peut les utiliser pour rechercher des planetes, pour mesurer les vitesses transverses de galaxies et les vitesses de rotation d'etoiles geantes, et pour rechercher les objets de la masse d'une comete se trouvant de l'autre cote de l'univers. Ce texte est publie sous forme de rapport interne du Laboratoire de Physique Corpusculaire du College de France (LPC 96-23). Il inclue une copie des transparents de ces quatres lecons, copie disponible aupres de Daniele Levaillant: levaillant@cdf.in2p3.fr (http://xxx.lanl.gov/abs/astro-ph/9605105 , 35kb)

Paper: astro-ph/9608045 From: Andrew P. Gould gould@payne.mps.ohio-state.edu Date: Fri, 9 Aug 96 14:44:34 EDT

Title: The Hollywood Strategy for Microlensing Detection of Planets

Author: Andrew Gould Comments: 6 pages, no figures, Talk given at the 12th IAP Colloquium: Variable Stars and the Astrophysical Returns of Microlensing Surveys Report-no: OSU-TA-19/96

Follow the big stars! I review the theory of detection and parameter measurement of planetary systems by follow-up observations of ongoing microlensing events. Two parameters can generically be measured from the event itself: the planet/star mass ratio, q, and the planet/star separation in units of the Einstein ring. I emphasize the advantages of monitoring events with giant-star sources which are brighter (thus easier to monitor) and bigger (thus offering the prospect of measuring an additional parameter from finite-source effects: the proper motion μ). There is potentially a strong degeneracy between q and μ. I present a simple analytic representation of this degeneracy. I then describe how it can be broken using accurate single-band photometry from observatories around the world, or optical/infrared photometry from a single site, or preferably both. Both types of observations are underway or will be soon. Monitoring of giant-star events seen toward the bulge is also the best way to determine the content and structure of the inner Galaxy. (http://xxx.lanl.gov/abs/astro-ph/9608045 , 9kb)

Paper: astro-ph/9611057 From: Andrew P. Gould gould@payne.mps.ohio-state.edu Date: Thu, 7 Nov 96 10:02:03 EST

Title: Measuring the Rotation Speed of Giant Stars From Gravitational Microlensing Author: Andrew Gould Comments: 11 pages including 1 embedded figure Report-no: OSU-TA-29/95

During some gravitational lensing events, the lens transits the face of the star. This causes a shift in the apparent radial velocity of the star which is proportional to its rotation speed. It also changes the magnification relative to what would be expected for a point source. By measuring both effects, one can determine the rotation parameter $v \sin i$. The method is especially useful for K giant stars because these have turbulent velocities that are typically large compared with their rotation speed. By making a series of radial velocity measurements, one can typically determine $v \sin i$ to the same accuracy as the individual radial velocity measurements. There are approximately 10 microlensing transit events per year which would be suitable to make these measurements. (http://xxx.lanl.gov/abs/astro-ph/9611057 , 14kb)

Paper: astro-ph/9611136 From: "Andrew P. Gould" ¡gould@payne.mps.ohio-state.edu¿ Date: Mon, 18 Nov 96 10:07:35 EST

Title: Microlensing: Prospects for the Future Author: Andrew Gould Comments: from Sheffield workshop on Identification of Dark Matter, 12 p Report-no: OSU-TA-30/96

Four ongoing microlensing experiments have produced important new results but also big puzzles, the major one being that the expected classes of lenses cannot account for the observed distribution of time scales. I discuss future experiments that could resolve these puzzles. By far the most important would be to launch a parallax satellite into solar orbit. I also discuss a number of non-dark-matter applications of microlensing, including searching for planets, measuring the rotation speeds of giant stars, and imaging a black hole at the center of a quasar. (http://xxx.lanl.gov/abs/astro-ph/9611136 , 14kb)

Paper: astro-ph/9703050 From: "Andrew P. Gould" gould@payne.mps.ohio-state.edu Date: Sun, 9 Mar 97 10:51:14 EST (25kb)

Title: Microlensing: Current Results and Future Prospects Authors: Andrew Gould Comments: Talk given at 25th Anniversary of Wise Observatory. 11 pages Report-no: OSU-TA-5/97

The initial results of microlensing surveys toward the Galactic bulge and the LMC are puzzling. Toward the LMC, the total mass in MACHOs is of order half that required to explain the dark matter, but the estimated MACHO mass (0.4 Msun) is most consistent with stars that should have been seen. Toward the bulge, the total mass is consistent with that given by dynamical estimates of the bulge mass, but the observed timescales seem to require that a large fraction of the bulge is made of brown dwarfs. I discuss possible experiments to resolve these puzzles. I also discuss several applications of microlensing to non-dark-matter problems including searching for planets and imaging the black hole at the center of a quasar with 10^{-10} arcsec resolution. (http://xxx.lanl.gov/abs/astro-ph/9703050 , 25kb)

Paper: astro-ph/9611185 From: "Andrew P. Gould" gould@payne.mps.ohio-state.edu Date: Fri, 22 Nov 96 05:46:19 EST

Title: Star Counts From HST: Implications for Dark Matter Author: Andrew Gould Comments: from Sheffield workshop on Identification of Dark Matter, 4 p Report-no: OSU-TA-32/96

Star counts made with the Hubble Space Telescope (HST) probe four populations that are important for dark matter: disk, halo, bulge, and intergalactic. The disk mass function falls for masses M¡0.6 Msun in sharp contrast to the rising Salpeter function usually assumed. The amount of "observed" disk material is therefore lower than commonly believed which implies the need for disk dark matter. Halo stars contribute no more than a few percent of the dark matter. Disk and halo together contribute no more than 10microlensing optical depth toward the Large Magellanic Cloud. The bulge luminosity function is similar to that of the disk down to M_V 10. If this similarity continues to the bottom of the main sequence, the bulge microlensing events can only be explained by a large population of brown dwarfs. Intergalactic stars in the Local Group have a density lower than the local halo density by at least $10^{-3.5}$. (http://xxx.lanl.gov/abs/astro-ph/9611185 , 7kb)

Paper: astro-ph/9606003 From: Andrew P. Gould gould@payne.mps.ohio-state.edu Date: Mon, 3 Jun 96 10:59:44 EDT

Title: FEMTOLENS IMAGING OF A QUASAR CENTRAL ENGINE

USING A DWARF STAR Authors: Andrew Gould and B. Scott Gaudi Comments: 12 pages including 3 embedded figures Report-no: OSU-TA-13/96

We show that it is possible to image the structure of a distant quasar on scales of $\sim 1\,\mathrm{AU}$ by constructing a telescope which uses a nearby dwarf star as its "primary lens" together with a satellite-borne "secondary". The image produced by the primary is magnified by $\sim 10^5$ in one direction but is contracted by 0.5 in the other, and therefore contains highly degenerate one-dimensional information about the two-dimensional source. We discuss various methods for extracting information about the second dimension including "femtolens interferometry" where one measures the interference between different parts of the one-dimensional image with each other. Assuming that the satellite could be dispatched to a position along a star-quasar line of sight at a distance r from the Sun, the nearest available dwarf-star primary is likely to be at ~ 15¸$(r/40\,\mathrm{AU})^{-2}$. The secondary should consist of a one-dimensional array of mirrors extending $\sim 700\,\mathrm{m}$ to achieve 1 AU resolution, or $\sim 100\,\mathrm{m}$ to achieve 4 AU resolution. (http://xxx.lanl.gov/abs/astro-ph/9606003 , 49kb)

Paper: astro-ph/9612144 From: "Andrew P. Gould" gould@payne.mps.ohio-state.edu Date: Sat, 14 Dec 96 08:51:30 EST

Title: Signatures of Accretion Disks in Quasar Microlensing Authors: Andrew Gould and Jordi Miralda-Escude Comments: 11 pages plus 1 postscript figure Report-no: OSU-TA-33/96

We propose that relative variability on short time-scales of the multiple images of a lensed quasar, after removal of the time delay, may be caused by hot spots or other moving structures in the accretion disk crossing microlens caustics caused by stellar mass objects in the lensing galaxy. Such variability has been reported in the two images of 0957+561. The short durations would be due to the high rotation speed of the disk (v/c   0.1), rather than planetary mass objects in the slowly moving (v/c   0.001) lens. This interpretation could be confirmed by finding periodicity, or correlations of the spectral and flux variations due to the Doppler effect in the disk. We also propose another signature of stationary accretion disks (with no intrinsic variability): the gradient of the magnification over the accretion disk should cause a relative color change between the images whose sign and amplitude are correlated with the time derivative of the flux difference between the images. Other color terms induced by the radial variation of disk colors are of second order in the magnification gradient. The methods proposed here can be used first to verify that accretion disks near supermassive black holes are the source of the continuum radiation from quasars, and then to study them. (http://xxx.lanl.gov/abs/astro-ph/9612144 , 32kb)

Paper: astro-ph/9510089 From: griest@astrophys.ucsd.edu (Kim Griest) Date: Tue, 17 Oct 95 17:51:18 PDT Date (revised): Tue, 17 Oct 95 18:05:14 PDT

Title: THE NATURE OF DARK MATTER Author: Kim Griest Comments: 32 pages, uuencoded, compressed, tarred plain tex file, with 9 postscript figures

included. Lectures presented at the International School of Physics "Enrico Fermi" Course "Dark Matter in the Universe", Varenna, 25 July - 4 August, 1995. To appear in the proceedings
We review some recent determinations of the amount of dark matter on galactic and larger scales, with special attention to the dark matter in the Milky Way. We then briefly review the motivation for and basic physics of several dark matter candidates, and then go into more depth for two candidates, the neutralino from supersymmetry, and the baryonic Macho candidate. We give some motivation for supersymmetry and review neutralino detection strategies. For Machos we give a description of the discovery of Machos via gravitational microlensing and the interpretation of the results with respect to the dark matter problem. (astro-ph/9510089 , 129kb + 592kb)

Paper: astro-ph/9506016 From: griest@astrophys.ucsd.edu (Kim Griest) Date: Fri, 2 Jun 95 13:14:42 PDT

Title: MACHO COLLABORATION SEARCH FOR BARYONIC DARK MATTER VIA GRAVITATIONAL MICROLENSING Author: K. Griest, C. Alcock, R.A. Allsman, T.S. Axelrod, D.P. Bennett, K.H. Cook, K.C. Freeman, J. Guern, M. Lehner, S.L. Marshall, S. Perlmutter, B.A. Peterson, M.R. Pratt, P.J. Quinn, A.W. Rodgers, C.W. Stubbs, W. Sutherland, D. Welch (The MACHO Collaboration) Comments: 18 Pages, figures included. To appear in the proceeding of the Pascos/Hopkins Symposium, Baltimore, Maryland 1995. uuencoded, tarred, compressed postscript
Results are presented from the MACHO collaboration gravitational microlensing search. The experiment and the nearly 50 microlensing events that have been detected are described. Limits on the baryonic content of the halo are given, as are estimates of the Macho contribution to the dark halo. Optical depths toward the bulge, and several unusual events such as a binary lens and a parallax event are discussed. Possible interpretations of these results are also discussed.

Paper: astro-ph/9607134 From: Geza Gyuk gyuk@oddjob.uchicago.edu Date: Thu, 25 Jul 1996 15:32:33 -0500

Title: GRAVITATIONAL MICROLENSING AND THE STRUCTURE OF THE INNER MILKY WAY Authors: Geza Gyuk (Univ. Chicago) Comments: 32 pages, Sixteen figures available at ftp://astro.uchicago.edu/pub/astro/gyuk/micromap/
We analyze the first-year MACHO collaboration observations of microlensing towards the Galactic center using a new direct likelihood technique that is sensitive to the distribution of the events on the sky. We consider the full set of 41 events, and calculate the direct likelihood against a simply-parameterized Galactic model consisting of either a gaussian or exponential bar and a double exponential disk. Optical depth maps are calculated taking into account the contribution of both disk lenses and sources. We show that based on the presently available data, a slope in the optical depth has been clearly detected (3σ) in Galactic latitude and that there are indications of a small slope in Galactic longitude. We discuss limits that can be set on the mass, angle and

axis ratio of the Galactic bulge. We show that based on microlensing considerations alone, $M_{Bulge} > 1.5 \times 10^{10} M_{odot}$ at the 90% confidence level and that the bulge inclination angle is less than 30 deg also at the 90% confidence level. The mostly likely bar mass is $M_{Bulge} = 3.5 \times 10^{10} M_{odot}$. Such a high mass would imply a low MACHO fraction for the halo. We consider disk parameters and show that there are two degeneracies between the effects of a disk and those of a bar on the optical depths. Finally, we discuss how to break these degeneracies and consider various strategies for future microlensing observations. (http://xxx.lanl.gov/abs/astro-ph/9607134 , 23kb)

Paper: astro-ph/9607080 From: Deborah Becker Haarsma dhaarsma@maggie.mit.edu Date: Tue, 16 Jul 96 19:13:41 EDT

Title: THE 6cm LIGHT CURVES OF B0957+561, 1979-1994: NEW FEATURES AND IMPLICATIONS FOR THE TIME DELAY Authors: Deborah B. Haarsma (MIT), Jacqueline N. Hewitt (MIT), Joseph Lehár (CfA), and Bernard F. Burke (MIT) Comments: Submitted to Astrophysical Journal. 36 pages; aaspp LaTex plus 15 postscript figures. Hard copies available on request (dhaarsma@maggie.mit.edu), also available by anonymous ftp to ftp://zenobia.mit.edu/pub/dhaarsma
We report on 15 years of VLA monitoring of the gravitational lens B0957+561 at 6 cm. Since our last report in 1992, there have been 32 additional observations, in which both images have returned to their quiescent flux density levels and the A image has brightened again. We estimate the time delay from the light curves using three different techniques: the χ^2 analysis of Press, Rybicki, and Hewitt (1992a,b), the dispersion analysis of Pelt et al. (1994, 1996), and the locally normalized discrete correlation function of Lehár et al. (1992). Confidence intervals for these time delay estimates are found using Monte Carlo techniques. With the addition of the new observations, it has become obvious that some observations from Spring 1990 are not consistent with the statistical properties of the rest of the light curves, so we analyze the light curves with those points removed, as well as the complete light curves. The new features in the light curve show that the time delay is less than 500 days, in contrast with analysis of earlier versions of the radio light curves. The three statistical techniques applied to the two versions of the data set show that the time delay is in the range 375 to 485 days (or 1.03 to 1.33 years, A leading B), and the flux ratio is in the range 0.695 to 0.707 (B/A). (http://xxx.lanl.gov/abs/astro-ph/9607080 , 337kb) Paper: astro-ph/9607080 replaced with revised version Tue, 26 Nov 96 11:55:25 EST

Title: The 6 cm Light Curves of B0957+561, 1979-1994: New Features and Implications for the Time Delay Authors: Deborah B. Haarsma (MIT), Jacqueline N. Hewitt (MIT), Joseph Lehár (CfA), and Bernard F. Burke (MIT) Comments: To appear in The Astrophysical Journal, April 10, 1997. Changes in discussion section and Table 1. 37 pages, including 15 postscript figures. Also available at http://space.mit.edu/RADIO/papers.html
(http://xxx.lanl.gov/abs/astro-ph/9607080 , 324kb) For general information on the new physics archive (partitioned by keyword subject classification), see

http://xxx.lanl.gov/new/ For subscribe options to combined physics archives, e-mail To: physics@xxx.lanl.gov, Subject: subscribe

Paper: astro-ph/9703136 From: Takashi Hamana hamana@astroa.astr.tohoku.ac.jp Date: Fri, 21 Mar 1997 20:14:44 +0900 (634kb)

Title: Lensing Effects on the Protogalaxy Candidate cB58 and their Implications for the Cosmological Constant Authors: T. Hamana (1), M. Hattori (1), H. Ebeling (2), J. P. Henry (2), T. Futamase (1) and Y. Shioya (1) ((1) Astronomical Institute, Tohoku University, (2) Institute for Astronomy, University of Hawaii) Comments: LaTex, 9 pages, 9 figures, uses aas2pp4.sty, Accepted for publication in ApJ The amplification of the protogalaxy candidate cB58 due to gravitational lensing by the foreground cluster of galaxies MS1512.4+3647 is quantified based on recent ROSAT and ASCA X-ray observations. It is found that the amplification is at most 25 for any reasonable cosmological model with or without cosmological constant. It is also argued that the system may be used to place new constraints on the value of the cosmological constant. The gas mass fraction for this cluster is found to be about 0.2. (http://xxx.lanl.gov/abs/astro-ph/9703136 , 159kb)

Paper: astro-ph/9610207 From: Francois Hammer Francois.Hammer@gin.obspm.fr Date: Fri, 25 Oct 1996 19:43:12 +0100 (MET)

Title: Detailed lensing properties of the MS2137-2353 core and reconstruction of sources Authors: F. Hammer, P. Teyssandier, E. J. Shaya, I. M. Gioia, G. A. Luppino and O. Le Fèvre Comments: 12 pages,Latex, available at

ftp://gin.obspm.fr/depot/hammer , Submitted to ApJ Letter
A deep HST image of the MS 2137-2353 core has revealed detailed morphological structures in two arc systems, which are modelled and well reproduced after a complete analysis of the lensing properties of the dark matter component. Latter could have a simple elliptical mass distribution with ellipticity and angular orientation similar to those of the visible and X-ray light, which suggests that the MS 2137-2353 is a relaxed cluster at z=0.313. The predicted density profile ($\rho \sim r^{-1.56\pm0.1}$ with $r_c \leq 22.5 h_{50}^{-1}$ kpc) within $150 h_{50}^{-1}$ kpc implies increasing M/L ratio with the radius, and could be in agreement with predictions from standard CDM simulations. At least two faint sources (unlensed magnitude, R=23.9 and 26, respectively) are aligned with the cluster core and are responsible of the arc systems. They have been reconstructed with details as small as 0".02 (or $160 h_{50}^{-1}$ pc in the source assumed at z= 1), one could be a nearly edge-on barred spiral galaxy, and the other has a more complex morphology, which could be related to a close interacting pair and/or to dust. They show strong signs of star formation indicated by compact HII regions well off their center. The observation of giant luminous arcs by HST could even resolve the size of giant HII regions at z$\sim$ 1. (http://xxx.lanl.gov/abs/astro-ph/9610207 , 123kb)

Paper: astro-ph/9608008 From: Han Cheongho cheongho@payne.mps.ohio-state.edu Date: Thu, 1 Aug 96 14:39:43 EDT

Title: THE EFFECTS OF AMPLIFICATION BIAS IN GRAVITATIONAL MICROLENSING EXPERIMENT Author: Cheongho Han Comments: 16 pages including 4 figures, ApJ, submitted Report-no: OSU-TA-18/96

Although a source star is fainter than the detection limit imposed by crowding, it is still possible to detect an event if the star is located in the seeing disk of a bright star is and gravitationally amplified: amplification bias. Using a well-constrained luminosity function, I show that $\sim 40\%$ of events detected toward the Galactic bulge are affected by amplification bias and the optical depth might be overestimated by a factor ~ 1.7. In addition, I show that if one takes amplification bias into consideration, the observed time scale distribution matches significantly better, especially in the short time-scale region, with the distribution expected from a mass-spectrum model in which lenses are composed of the known stellar population plus an additional population of brown dwarfs than it is without the effect of the amplification bias (http://xxx.lanl.gov/abs/astro-ph/9608008 , 36kb)

Paper: astro-ph/9604031 From: Han Cheongho cheongho@payne.mps.ohio-state.edu Date: Fri, 5 Apr 96 15:07:09 EST

Title: DETERMINATION OF THE EINSTEIN RING RADIUS FROM A BINARY-SOURCE EVENT Author: Cheongho Han and Andrew Gould (The Ohio State University) Comments: 15 pages including 1 table and 3 figures Report-no: OSU-TA-11/96

We show that the Einstein ring radius and transverse speed of a lens projected on the source plane, $\hat{r}_{\rm e}$ and $\hat{v}$, can be determined from the light curve of a binary-source event, followed by the spectroscopic determination of the orbital elements of the source stars. The determination makes use of the same principle that allows one to measure the Einstein ring radii from finite-source effects. For the case when the orbital period of the source stars is much longer than the Einstein time scale, $P \gg t_{\rm e}$, there exists a single two-fold degeneracy in determining $\hat{r}_{\rm e}$. However, when $P \leq t_{\rm e}$ the degeneracy can often be broken by making use of the binary-source system's orbital motion. Once $\hat{r}_{\rm e}$, and thus $\hat{v}$ are determined, one can distinguish self-lensing events in the Large Magellanic Cloud from Galactic halo events. In addition, we propose to include eclipsing binaries as sources for gravitational lensing experiments. (http://xxx.lanl.gov/abs/astro-ph/9604031 , 55kb)

Paper: astro-ph/9702097 From: Avi Loeb loeb@cfata1.harvard.edu Date: Tue, 11 Feb 1997 14:32:33 -0500 (79kb)

Title: Microlensing of an Elliptical Source by a Point Mass Authors: David Heyrovsky and Abraham Loeb (Harvard University) Comments: 25 pages, 9 figures, submitted to ApJ

We present an efficient method for computing lightcurves of an elliptical source which is microlensed by a point mass. The amplification of an extended source involves a two-dimensional integral over its surface brightness distribution. We show that for a general surface brightness profile with an elliptical symmetry, this integral can be reduced to one dimension. We derive analytical results for the entire lightcurve in the limit of low (e.g. planetary) mass lenses, and for the wings of all microlensing lightcurves in general. In both cases, the lightcurve carries information about deviations of the source from elliptical symmetry, e.g. due to spots. The method is used to find the amplification of a circular red giant photosphere and an inclined accretion disk. We demonstrate that microlensing of an emission line from a disk can be used to infer the disk velocity structure and surface brightness profile. (http://xxx.lanl.gov/abs/astro-ph/9702097 , 79kb)

Paper: astro-ph/9611077 From: Bhuvnesh Jain bjain@MPA-Garching.MPG.DE Date: Mon, 11 Nov 1996 22:18:14 +0100

Title: Cosmological Model Predictions for Weak Lensing: Linear and Nonlinear Regimes Authors: Bhuvnesh Jain (MPA) and Uros Seljak (CfA) Comments: 35 pages, 10 figures included; submitted to ApJ Report-no: MPA Preprint, November 1996

Weak lensing by large scale structure induces correlated ellipticities in the images of distant galaxies. The two-point correlation is determined by the matter power spectrum along the line of sight. We use the fully nonlinear evolution of the power spectrum to compute the predicted ellipticity correlation. We present results for different measures of the second moment for angular scales $\theta \simeq$ 1'-3 degrees and for alternative normalizations of the power spectrum, in order to explore the best strategy for constraining the cosmological parameters. Normalizing to observed cluster abundance the rms amplitude of ellipticity within a 15' radius is $\simeq 0.01 z_s^{0.6}$, almost independent of the cosmological model, with z_s being the median redshift of background galaxies. Nonlinear effects in the evolution of the power spectrum significantly enhance the ellipticity for $\theta <$ 10' – on 1' the rms ellipticity is $\simeq 0.05$, which is nearly twice the linear prediction. This enhancement means that the signal to noise for the ellipticity is only weakly increasing with angle for 2'$< \theta <$2 degrees, unlike the expectation from linear theory that it is strongly peaked on degree scales. The scaling with cosmological parameters also changes due to nonlinear effects. By measuring the correlations on small (nonlinear) and large (linear) angular scales, different cosmological parameters can be independently constrained to obtain a model independent estimate of both power spectrum amplitude and matter density Ω_m. Nonlinear effects also modify the probability distribution of the ellipticity. Using second order perturbation theory we find that over most of the range of interest there are significant deviations from a normal distribution. (http://xxx.lanl.gov/abs/astro-ph/9611077 , 82kb)

Paper: astro-ph/9601122 From: MASSO@IFAE.ES Date: Tue, 23 Jan

1996 12:52:25 GMT+0100

Title: MICROLENSING IMPLICATIONS FOR HALO DARK MATTER Authors: Philippe Jetzer (PSI, Villigen, and Institute of Theoretical Physics, Univ. of Zurich) and Eduard Masso (IFAE and Dep. Fisica, Univ. Autonoma de Barcelona) Comments: Six pages. Two figures (they can be telefaxed by request to masso@ifae.es). Talk at the second workshop on "The dark side of the Universe: experimental efforts and theoretical frameworks" (Rome, 13-14 November 1995) Report-no: Zurich University ZU-TH 1/96

The most accurate way to get information on the mass of the MACHOs (Massive Astrophysical Compact Halo Objects) is to use the method of mass moments. For the microlensing events detected so far by the EROS and the MACHO collaborations in the Large Magellanic Cloud the average mass turns out to be $0.08 M_\odot$. Assuming a spherical standard halo model we find that MACHOs contribute about 20% to the halo dark matter. The eleven events recorded by OGLE, mainly during its first two years of operation, in the galactic bulge lead to an average mass of $0.29 M_\odot$, whereas forty events detected by MACHO during its first year give $0.16 M_\odot$, thus suggesting that the lens objects are faint disk stars. (http://xxx.lanl.gov/abs/astro-ph/9601122 , 6kb)

Paper: astro-ph/9611218 From: mike@mrao.cam.ac.uk Date: Tue, 26 Nov 96 17:50 GMT

Title: Detection of a CMB decrement towards the z = 3.8 quasar pair PC1643+4631A and B Authors: Michael E. Jones(1), Richard Saunders(1), Joanne C. Baker(1), Garret Cotter(1), Alastair Edge(2), Keith Grainge(1), Toby Haynes(1), Anthony Lasenby(1), Guy Pooley(1), Huub Rottgering(3)((1)MRAO Cambridge UK, (2)IoA Cambridge UK (3)Leiden Observatory) Comments: 8 pages, LaTeX, 2 PostScript figures. To appear in Astrophysical Journal Letters

In a 15-GHz Ryle-Telescope observation of PC1643+4631 A and B, a pair of quasars at redshifts z = 3.79 and 3.83 separated by 198 arcsec on the sky, we find a decrement in the cosmic microwave background (CMB) of -380 +/- 64 uJy in a 110 arcsec x 175 arcsec beam. Assuming this to be a Sunyaev-Zel'dovich effect due to an intervening cluster, the minimum magnitude of the central temperature decrement is 560 uK. A serendipitous ROSAT observation shows that there is no X-ray-luminous cluster in the direction of the decrement at z ¡ 1. The implied gas mass is $> 2x10^{14}$ solar masses (assuming a temperature of 5 keV), indicating a total mass of $> 10^{15}$ solar masses. This result demonstrates the existence of a massive system too distant to be detected by its emission, but which can be found via its imprint on the CMB. (http://xxx.lanl.gov/abs/astro-ph/9611218 , 28kb)

Paper: astro-ph/9507075 From: Takashi Okamura Dep. of Phys,Tokyo.Inst. of Tech. okamura@th.phys.titech.ac.jp Date: Thu, 20 Jul 1995 19:56:18 +0900 Date (revised): Thu, 20 Jul 1995 21:34:35 +0900

Title: GRAVITATIONAL LENSING AND CATASTROPHE THEORY

Authors: Y. Kakigi, T. Okamura and T. Fukuyama Comments: 24 pages, latex, 18 figures
Singularities of caustics appeared in gravitational lensing effect are discussed analytically. Multipole expansion model of lensing object is mainly studied since it is tractable and universal. Our analyses are confirmed by numerical calculations and applied to multiple quasar system of PG1115+080. Consistencies with elliptical lens models are also discussed.

Paper: astro-ph/9610120 From: Nick Kaiser kaiser@cita.utoronto.ca Date: Tue, 15 Oct 1996 20:22:18 -0400 (EDT)
Title: Weak Lensing and Cosmology Author: Nick Kaiser (CITA, U. Toronto) Comments: 15 pages, submitted to Astrophysical Journal http://www.cita.utoronto.ca/ kaiser for related papers/links Report-no: CITA-96-16
We explore the dependence of weak lensing phenomena on the background cosmology. We first generalise the relation between $P_\psi(\omega)$, the angular power spectrum of the distortion, and the power spectrum of density fluctuations to non-flat cosmologies. We then compute P_ψ for various illustrative models. A useful cosmological discriminator is the growth of P_ψ with source redshift which is much stronger in low matter density models, and especially in Λ-dominated models. With even crude redshift information (say from broad band colours) it should be possible to constrain the cosmological world model. The amplitude of $P_\psi(\omega)$ is also quite sensitive to the cosmology, but requires a reliable external normalisation for the mass fluctuations. If one normalises to galaxy clustering, with M/L fixed by small-scale galaxy dynamics, then low density models predict a much stronger distortion. If, however, one normalises to large-scale bulk-flows, the predicted distortion for sources at redshifts $Z_s \sim 1-3$ is rather insensitive to the background cosmology. The signals predicted here can be detected at a very high level of significance with a photometric survey covering say 10 square degrees, but sparse sampling is needed to avoid large sampling variance and we discuss the factors influencing the design of an optimum survey. Turning to weak lensing by clusters we find that for high lens redshifts ($Z_l \simeq 1$) the critical density is substantially reduced in Λ models, but that the ratio of the shear or convergence to the velocity dispersions or X-ray temperature of clusters is only very weakly dependent on the cosmology. (http://xxx.lanl.gov/abs/astro-ph/9610120 , 107kb)

Paper: astro-ph/9611216 From: C. R. Keeton ckeeton@mars.harvard.edu Date: Tue, 26 Nov 1996 10:34:30 MST
Title: Determining the Hubble Constant from the Gravitational Lens PG 1115+080 Authors: C. R. Keeton, C. S. Kochanek (Harvard-Smithsonian Center for Astrophysics) Comments: 28 pages, 7 Postscript figures, submitted to ApJ
The quadruple gravitational lens PG 1115+080 cannot be fit by a single ellipsoidal mass distribution, but it can be well fit by adding a perturbation from the nearby group of galaxies. With the existing constraints, there are degeneracies in the models

with respect to the radial profiles of the galaxy and the group and with respect to the position of the group, so that a wide range of models give fits with $\chi^2/N_{DOF} < 1$. We find $H_0 = 60 \pm 17 km/s/Mpc (1\sigma)$ for a reasonable range of models. Smaller uncertainties in H_0 can be achieved by reducing the standard errors in the lens galaxy position from 50 mas to 10 mas, by reducing the the uncertainties in the time delays from 3.4 days to 0.5 days, and by constraining the lens mass distribution using HST photometry and the fundamental plane. (http://xxx.lanl.gov/abs/astro-ph/9611216 , 274kb)

Paper: astro-ph/9610163 From: Uros Seljak uros@cfata1.harvard.edu Date: Mon, 21 Oct 1996 14:56:11 -0400

Title: Shear and Ellipticity in Gravitational Lenses Authors: C.R. Keeton, C.S. Kochanek and U. Seljak Comments: 38 pages, 9 figures, submitted to ApJ Galaxies modeled as singular isothermal ellipsoids with an axis ratio distribution similar to the observed axis ratio distribution of E and S0 galaxies are statistically consistent with both the observed numbers of two-image and four-image lenses and the inferred ellipticities of individual lenses. However, no four-image lens is well fit by the model (typical $\chi^2/N_{dof} \sim 20$), the axis ratio of the model can be significantly different from that of the observed lens galaxy, and the major axes of the model and the galaxy may be slightly misaligned. We found that models with a second, independent, external shear axis could fit the data well (typical $\chi^2/N_{dof} \sim 1$), while adding the same number of extra parameters to the radial mass distribution does not produce such a dramatic improvement in the fit. An independent shear axis can be produced by misalignments between the luminous galaxy and its dark matter halo, or by external shear perturbations due to galaxies and clusters correlated with the primary lens or along the line of sight. We estimate that the external shear perturbations have no significant effect on the expected numbers of two-image and four-image lenses, but that they can be important perturbations in individual lens models. However, the amplitudes of the external shears required to produce the good fits are larger than our estimates for typical external shear perturbations (10-15instead of 1-3structure must be intrinsic to the primary lens galaxy in most cases. (http://xxx.lanl.gov/abs/astro-ph/9610163 , 265kb)

Paper: astro-ph/9610070 From: Eamonn Kerins kerins@wirtz.u-strasbg.fr Date: Thu, 10 Oct 1996 07:17:45 MDT

Title: Zero-metallicity VLM stars as halo dark matter Authors: E. J. Kerins Comments: 11 pages incl. 4 figures. Submitted to A and A. Latex processing requires A and A style file (l-aa.sty) and epsf.sty for the figures (both macros can be obtained from http://xxx.lanl.gov/ftp/hep-th/papers/macros/). Postscript and dvi+figures versions can be obtained via anonymous ftp to

ftp://cdsxba.u-strasbg.fr/pub/incoming/kerins/vlm/

Hubble Space Telescope (HST) limits on the amount of halo dark matter (DM) in the form of very low-mass (VLM) stars close to the hydrogen-burning limit have been interpreted as excluding such stars as viable candidates. However, these limits assume that the stars are smoothly distributed and have at least the metallicity of Population II stars, whilst some baryonic DM formation theories predict that they may instead be clumped into globular-cluster configurations and have close to zero metallicity. I re-analyse the HST data employing the zero-metallicity VLM star models of Saumon et al. (1994), which predict V-I colours below the cuts of previous analyses. From the models I derive new limits on the allowed halo fraction comprising VLM stars for both the unclustered and clustered cases. In the unclustered regime I find a 95limit on the allowed halo fraction of 1.4comparable to limits derived by previous studies for non-zero metallicity populations. In the cluster scenario I show that clusters of mass M and radius R can satisfy both HST and the recent MACHO gravitational microlensing results, which indicate a lens halo fraction of $40R < 1.2(M/10^4 Mo)^0.74pc$. However, existing dynamical limits restrict the allowed range to a tiny region characterised by $M \sim 4x10^4$ Mo and R$\sim 3pc$. Furthermore, consistency between MACHO and HST demands a present-day clustering efficiency of 92implied by these limits is theoretically well motivated and the VLM star scenario may also help to provide an explanation for the faint red 'halo' light recently reported around another galaxy. (http://xxx.lanl.gov/abs/astro-ph/9610070 , 54kb)

Paper: astro-ph/9611217 From: C. R. Keeton ckeeton@mars.harvard.edu Date: Tue, 26 Nov 1996 10:47:59 MST

Title: Gravitational Lensing Limits on Early-Type Galaxies Authors: C.S. Kochanek and C.R. Keeton (Harvard-Smithsonian Center for Astrophysics) Comments: 10 pages, 6 figures Proc. of the Second Stromlo Symposium, The Nature of Elliptical Galaxies

Gravitational lenses are a unique new constraint on the structure of galaxies. We review the evidence that most lenses are early-type galaxies, the optical properties of the lens galaxies, the evidence against constant M/L models, recent work on the axis ratios of the mass distribution, and the role stellar dynamics plays in gravitational lensing. (http://xxx.lanl.gov/abs/astro-ph/9611217 , 206kb)

Paper: astro-ph/9608138 From: mhlee@lola.phy.queensu.ca (Man Hoi Lee) Date: Thu, 22 Aug 1996 01:17:57 -0400

Title: Statistics of Gravitational Microlensing Magnification. I. Two-Dimensional Lens Distribution Authors: Lev Kofman, Nick Kaiser, Man Hoi Lee, and Arif Babul Comments: 35 pages, including 6 figures; uses AASTeX v4.0 macros; submitted to ApJ Report-no: UH IfA-96-46

(Abridged) In this paper we refine the theory of microlensing for a planar distribution of point masses. We derive the macroimage magnification distribution P(A) at high magnification (A-1 ¿¿ tau^2) for a low optical depth (tau ¡¡ 1) lens distribution by modeling the illumination pattern as a superposition of the patterns due to individual "point mass plus weak shear" lenses. We show that a point mass plus weak shear lens produces an astroid- shaped caustic and that the magnification cross-section obeys a simple scaling property. By convolving this cross-section with the shear distribution, we obtain a caustic-induced feature in P(A) which also exhibits a simple scaling property. This feature results in a 20In the low magnification (A-1 ¡¡ 1) limit, the macroimage consists of a bright primary image and a large number of faint secondary images formed close to each of the point masses. Taking into account the correlations between the primary and secondary images, we derive P(A) for low A. The low-A distribution has a peak of amplitude $1/tau^2$ at A-1 tau^2 and matches smoothly to the high-A distribution. We combine the high- and low-A results and obtain a practical semi-analytic expression for P(A). This semi-analytic distribution is in qualitative agreement with previous numerical results, but the latter show stronger caustic-induced features at moderate A for tau as small as 0.1. We resolve this discrepancy by re-examining the criterion for low optical depth. A simple argument shows that the fraction of caustics of individual lenses that merge with those of their neighbors is approx 1-exp(-8 tau). For tau=0.1, the fraction is surprisingly high: approx 55the manner we did, low optical depth corresponds to tau ¡¡ 1/8. (http://xxx.lanl.gov/abs/astro-ph/9608138 , 131kb)

Paper: astro-ph/9610162 From: wes@astro.Princeton.EDU Date: Mon, 21 Oct 1996 14:05:56 -0400 (EDT)

Title: A Robust Determination of the Time Delay in 0957+561A,B and a Measurement of the Global Value of Hubble's Constant Authors: Tomislav Kundic (Th. Astroph., Caltech), Edwin L. Turner, Wesley N. Colley, J. Richard Gott, III, James E. Rhoads, Yun Wang (Princeton), Louis E. Bergeron, Karen A. Gloria, Daniel C. Long (Apache Point Observ.), Sangeeta Malhotra (IPAC), Joachim Wambsganss (Astroph. Inst., Potsdam) Comments: AASTeX 4.0 Report-no: Princeton Observatory Preprint 687

Photometric monitoring of the gravitational lens system 0957+561A,B in the g and r bands with the Apache Point Observatory (APO) 3.5 m telescope during 1996 shows a sharp g band event in the trailing (B) image light curve at the precise time predicted from the observation of an event during 1995 in the leading (A) image with a delay of 415 days. This success confirms the "short delay," and the lack of any feature at a delay near 540 days rejects the "long delay" for this system, resolving a long-standing controversy. A series of statistical analyses of our light curve data yield a best fit delay of 417 +/- 3 days (95confidence interval). Recent improvements in the modeling of the lens system (consisting of a galaxy and cluster) allow us to derive a value of the global (at z = 0.36) value of Hubble's constant H_0 using Refsdal's method, a simple and direct distance determination based on securely understood physics and geometry. The result is $H_0 = 63 + / - 12 km/s/Mpc$ (for Omega = 1) where this 95confidence interval is dominated by remaining lens model uncertainties. (http://xxx.lanl.gov/abs/astro-ph/9610162 , 172kb) Paper: astro-ph/9610162 replaced with revised version Wed, 8 Jan 1997 14:49:13 -0500 (EST)

Title: A Robust Determination of the Time Delay in 0957+561A,B and a Measurement of the Global Value of Hubble's Constant Authors: Tomislav Kundic (Th. Astroph., Caltech), Edwin L. Turner, Wesley N. Colley, J. Richard Gott, III, James E. Rhoads, Yun Wang (Princeton), Louis E. Bergeron, Karen A. Gloria, Daniel C. Long (Apache Point Observ.), Sangeeta Malhotra (IPAC), Joachim Wambsganss (Astroph. Inst., Potsdam) Comments: accepted by ApJ, AASTeX 4.0 preprint, 4 PostScript figures Report-no: Princeton Observatory Preprint 687
(http://xxx.lanl.gov/abs/astro-ph/9610162 , 173kb)

Paper: astro-ph/9608139 From: mhlee@lola.phy.queensu.ca (Man Hoi Lee) Date: Thu, 22 Aug 1996 01:19:57 -0400
Title: Statistics of Gravitational Microlensing Magnification. II. Three-Dimensional Lens Distribution Authors: Man Hoi Lee, Arif Babul, Lev Kofman, and Nick Kaiser Comments: 52 pages, including 15 figures (Figures 3, 6, and 10 have been bitmapped); uses AASTeX v4.0 macros; submitted to ApJ Report-no: UH IfA-96-47 In Paper I we studied the theory of gravitational microlensing for a planar distribution of point masses. In this second paper, we extend the analysis to a three-dimensional lens distribution. First we study the lensing properties of three-dimensional lens distributions by considering in detail the critical curves, the caustics, the illumination patterns, and the magnification cross-sections sigma(A) of multiplane configurations with two, three, and four point masses. For N_* point masses that are widely separated in Lagrangian space, we find that there are $2^{N_*} - 1$ critical curves in total, but that only N_* of these produce prominent caustic-induced features at the high magnification end of sigma(A). In the case of a low optical depth random distribution of point masses, we show that the multiplane lens equation near a point mass can be reduced to the single plane equation of a point mass perturbed by weak shear. This allows us to calculate the caustic-induced feature in the macroimage magnification distribution P(A) as a weighted sum of the semi-analytic feature derived in Paper I for a planar lens distribution. The resulting semi-analytic caustic-induced feature is similar to the feature in the planar case, but it does not have any simple scaling properties, and it is shifted to higher magnification. The semi-analytic distribution is compared to the results of previous numerical simulations for optical depth tau 0.1, and they are in better agreement than a similar comparison in the planar case. We explain this by estimating the fraction of caustics of individual lenses that merge with those of their neighbors. For tau=0.1, the fraction is approx 20than the approx 55(http://xxx.lanl.gov/abs/astro-ph/9608139 , 436kb)

Paper: astro-ph/9702191 From: jlehar@astrometry.harvard.edu (Joseph Lehar) Date: Fri, 21 Feb 1997 12:05:23 -0500 (83kb)
Title: The Gravitationally-Lensed Radio Source MG0751+2716 Authors: J. Lehar (1), B.F. Burke (2), S.R. Conner (2), E.E. Falco (1), A.B. Fletcher (2), M. Irwin (4), R.G. McMahon (5), T.W.B. Muxlow (3), P.L. Schechter (2) ((1)CfA, (2)MIT,

(3)NRAL, (4)RGO, (5)IoA) Comments: 1 Latex aaspp4 manuscript, 17 pages with 5 postscript figures. Submitted to AJ 1997.02.19
We report the discovery of a new gravitationally lensed radio source. Radio maps of MG0751+2716 show four lensed images, which, at higher resolution, are resolved into long arcs of emission. A group of galaxies is present in optical images, including the principal lensing galaxy, with a much brighter galaxy just a few arcseconds away. We have measured the redshift of this brighter galaxy. Lens models that can readily reproduce the lensed image positions all require a substantial shear component. However, neither the very elongated lens nor the bright nearby galaxy are correctly positioned to explain the shear. Lens models which associate the mass with the light of galaxies in the group can produce an acceptable fit, but only with an extreme mass-to-light ratio in one of the minor group members. (http://xxx.lanl.gov/abs/astro-ph/9702191 , 83kb)

Paper: astro-ph/9606141 From: e.linder@ic.ac.uk Date: Fri, 21 Jun 1996 16:01:54 +0100

Title: CORRELATED GRAVITATIONAL LENSING OF THE CMB Author: Eric V. Linder (Imperial College London) Comments: uuencoded gzipped tarred TeX and PostScript files, 13 pages, 1 figure Report-no: Imperial/Astro/96-8
Cosmological inhomogeneities gravitationally deflect radiation propagating from distant sources, transforming the spatial and angular correlation functions of intrinsic source properties. For a gaussian distribution of deflections (e.g. from a primordial gaussian density perturbation spectrum or from the central limit theorem) we calculate the probability distributions for geodesic deviations. If the intrinsic variable is also gaussian, e.g. the large scale velocity flow field or cosmic microwave background temperature anisotropies, then distributions and correlation functions of the observed image sky properties can be obtained. Specialising to CMB temperature fluctuations we rederive simply the influence of independent gravitational lensing on the anisotropy angular correlation function and calculate the new effect of lensing correlated with the anisotropies, e.g. arising from the same primordial gravitational perturbation field. Characteristic magnitudes and scales are given in terms of the density power spectrum. The correlated deflection-temperature effect is shown to be negligible. (http://xxx.lanl.gov/abs/astro-ph/9606141 , 15kb)

Paper: astro-ph/9702042 From: Charley Lineweaver charley@cdsxb6.u-strasbg.fr Date: Tue, 4 Feb 1997 22:26:48 +0100 (182kb)

Title: Gold in the Doppler Hills: Cosmological Parameters in the Microwave Background Authors: C. H. Lineweaver (Observatoire de Strasbourg) Comments: 21 pages, 11 figures, to appear in the Proceedings of the International School in Astrophysics: "From Quantum Fluctuations to Cosmological Structures" held in Casablanca, Morocco, December 1 - 10, 1996
Research on the cosmic microwave background (CMB) is progressing rapidly. New

experimental groups are popping up and two new satellites will be launched. The current enthusiasm to measure fluctuations in the CMB power spectrum at angular scales between 0.1 and 1 degree is largely motivated by the expectation that CMB determinations of cosmological parameters will be of unprecedented precision: cosmological gold. In this article I will try to answer the following questions: 1) What is the CMB? 2) What are cosmological parameters? 3) What is the CMB power spectrum? 4) What are all those bumps in the power spectrum? 5) What are the current CMB constraints on cosmological parameters? (http://xxx.lanl.gov/abs/astro-ph/9702042 , 182kb)

Paper: astro-ph/9701100 From: Avi Loeb loeb@cfata1.harvard.edu Date: Wed, 15 Jan 1997 17:15:09 -0500

Title: Gravitational Lensing of Quasars by Spiral Galaxies Author: Abraham Loeb (Harvard Univ) Comments: 4 pages, 2 figures, contribution to Texas symposium 1996

Gravitational lensing by a spiral galaxy occurs when the line-of-sight to a background quasar passes within a few kpc from the center of the galactic disk. Since galactic disks are rich in neutral hydrogen, the quasar spectrum will likely be marked by a damped Lyman-alpha absorption trough at the lens redshift. Therefore, the efficiency of searches for gravitational lensing with sub-arcsecond splitting can be enhanced by 1-2 orders of magnitude by focusing on a subset of all bright quasars which show low-redshift (z¡1) strong Lyman-alpha absorption ($N > 10^{21} cm^{-2}$). The double-image signature of lensing could, in principle, be identified spectroscopically and without the need for high-resolution imaging. The absorption spectrum of a spiral lens would show a generic double-step profile due to the superposition of the two absorption troughs of the different images. Finally, we note that searches for microlensing signatures of quasars with damped Lyman-alpha absorption could calibrate the fraction of MACHOs in galactic halos at high redshift. (http://xxx.lanl.gov/abs/astro-ph/9701100 , 25kb)

Paper: astro-ph/9610222 From: pyl@gag.observ-gr.fr (Pierre-Yves Longaretti) Date: Mon, 28 Oct 1996 12:36:13 +0100

Title: Lens reconstruction and source redshift distribution Author: Pierre-Yves Longaretti (Observatoire de Grenoble, France) Comments: 4 pages, LaTex, Springer-Verlag's LaTeX Astronomy and Astrophysics macro package, submitted to A and A Letters

The currently used linear and nonlinear lens inversion techniques are based on distortion estimators whose complicated source redshift dependence makes the influence of the redshift distribution of the sources difficult to take into account and to analyze. However, the lens equations can be explicitly averaged over the source redshift distribution by a suitable choice of the estimators. Lens reconstruction procedures are outlined, which make use of all the information and in which all the unknown quantities of the problem can be recovered simultaneously in both the linear and nonlinear regime, for either noncritical or critical lenses. These procedures require no prior knowledge of the redshift distribution of the sources, but are possibly dependent on the Cosmology in some instances. Possible methods of recovery of the source redshift distribution itself are briefly discussed at the same time. (http://xxx.lanl.gov/abs/astro-ph/9610222 , 8kb)

Paper: astro-ph/9610233 From: Sangeeta Malhotra san@ipac.caltech.edu Date: Mon, 28 Oct 1996 21:24:04 MST

Title: Through a Lens Darkly: Evidence for Dusty Gravitational Lenses Authors: Sangeeta Malhotra (IPAC), James E. Rhoads (KPNO), Edwin L. Turner (Princeton) Comments: Sumitted to MNRAS, 6 pages, 3 figures. Also available at http://www.astro.princeton.edu/ san/Abstracts/dusty.html

Foreground galaxies that amplify the light from background quasars may also dim that light if the galaxies contain enough dust. Extinction by dust in lenses could hide the large number of lensed systems predicted for a flat universe with a large value of the cosmological constant Λ. We look for one signature of dust, namely reddening, by examining optical-infrared colors of gravitationally lensed images of quasars. We find that the lensed systems identified in radio and infrared searches have redder optical-IR colors than optically selected ones. This could be due to a bias against selecting reddened (hence extincted) quasars in the optical surveys, or due to the differences in the intrinsic colors of optical and radio quasars. Comparison of the radio-selected lensed and unlensed quasars shows that the lensed ones have redder colors. We therefore conclude that at least part of the color difference between the two lens samples is due to dust. From the color difference between lensed and unlensed radio quasars (and assuming Galactic extinction law) we can reconcile a large cosmological constant ($\Lambda = 0.9$) with the number of lensed systems observed in flux limited optical surveys. These results substantially weaken the strongest constraint on cosmological scenarios that invoke a non-zero cosmological constant to explain age discrepancy problems, satisfy predictions of inflationary models of the early universe and play a role in large scale structure formation models. They also raise the prospect of using gravitational lenses to study the interstellar medium in high redshift galaxies. (http://xxx.lanl.gov/abs/astro-ph/9610233 , 23kb)

Paper: astro-ph/9701110 From: Ariyeh Maller ¡maller@maxwell.UCSC.EDU¿ Date: Thu, 16 Jan 1997 13:17:59 -0800

Title: Inclination Effects in Spiral Galaxy Gravitational Lensing Authors: Ariyeh Maller, Ricardo Flores, Joel Primack Comments: 10 pages, AAS LaTex, 5 postscript figures

Spheroidal components of spiral galaxies have been considered the only dynamically important component in gravitational lensing studies thus far. Here we point out that including the disk component can have a significant effect, depending on the disk inclination, on a variety of lensing properties that are relevant to present studies and future surveys. As an example, we look at the multiple image system B1600+434, recently identified as being lensed by a spiral galaxy. We find that including the disk component one can understand the fairly large image separation as being due to the inclination of a typical spiral, rather than the presence of a very massive halo. The fairly low magnification ratio can also be readily understood if the disk is included. We also discuss how such lensed systems might allow one to constrain parameters of spiral galaxies such as a disk-to-halo mass ratio, and disk mass scale length. Another example we consider is the quasar multiple-lensing cross section, which we find can increase many-fold at high inclination for a typical spiral. Finally, we discuss the changes in the gravitational lensing effects on damped Lyman alpha systems (DLAS) when disk lensing is included. (http://xxx.lanl.gov/abs/astro-ph/9701110 , 78kb)

Paper: astro-ph/9612159 From: Dan Maoz ¡dani@wise1.tau.ac.il¿ Date: Tue, 17 Dec 1996 12:43:51 +0200

Title: A survey for large image-separation lensed quasars Authors: Dan Maoz, Hans-Walter Rix, Avishay Gal-Yam, and Andrew Gould Comments: LaTex, ApJ, submitted

The statistics of gravitationally lensed quasars with multiple images in the 0.1"-7" range have been measured in various surveys. Little is known, however, about lensed-quasar statistics at larger image separations, which probe masses on the scale of galaxy clusters. We extend the results of the HST Snapshot Survey for Lensed Quasars to the 7"-50" range for a sub-sample of 76 quasars that is free of known selection effects. Using a combination of multicolor photometry and spectroscopy, we show that none of the point sources in the entire field of view of the HST observations of these quasars are lensed images. Large-separation quasar lensing is therefore not common. We carry out a detailed calculation of the expected statistics of large-separation lensing for this quasar sample, incorporating realistic input for the mass profiles and mass function of galaxy clusters. We find that the observational null results are consistent with the expected effect of galaxy clusters, even if these have existed in their present form and number since z of about 2. The rarity of large-separation lensed quasars can rule out some extreme scenarios, e.g. that the mass-function of clusters has been severely underestimated, or that large mass concentrations that are not associated with galaxies (i.e. "failed" clusters) are common. The rareness of wide lensing also sets limits on the cosmological constant that are independent of limits derived from galaxy lensing. The lensing statistics of larger quasar samples can probe the structure, number, and evolution of clusters, as well as the geometry of space. (http://xxx.lanl.gov/abs/astro-ph/9612159 , 75kb)

Paper: astro-ph/9609187 From: draza ¡draza@tac.dk¿ Date: Thu, 26 Sep 1996 15:27:27 MDT

Title: Microlensing, structure of the galactic halo and determination of dark objects' mass function Authors: D. Markovic and J. Sommer-Larsen (Theoretical Astrophysics Center, Copenhagen) Comments: MNRAS LaTeX style, 14 pages, 11 figures embedded

We study the accuracy of inference of the massive halo objects' (MHO or 'Macho') mass function from microlensing events observed toward LMC. Assuming the spatial distribution and kinematics of the objects are known, the slope and the range of the MHO mass function (modeled here by a simple power law) will be possible to determine from 100-1000 detected events if the slope α is in the range [-2.5, -0.5], with the statistical errors reaching their minima at $\alpha = -1.5$. Outside this range the errors grow rapidly making the inference difficult even at very large numbers of events ($N \simeq 10000$). On the other hand, the average mass of the MHOs will be determined to better than about 30accuracy from $N \simeq 100$ events for any slope. We find that the accuracy of inference at fixed N will not be strongly affected by the presently available detection efficiencies if the typical MHO masses are in the range indicated by the events detected so far. We also estimate the effects of uncertainty of the MHOs' spatial distribution and kinematics on the determination of their mass function. The halo models considered are all spherical but we allow for various density profiles and a radius-dependent, anisotropic velocity dispersion. We find that, while the mass function slope and range are weakly affected for $-2.5 < \alpha < 0$, the error in the average mass due to the halo uncertainties could be reduced to less than 50% only through the detection of 1000 or more events. Reliable estimates of the halo structure itself [density profile and velocity dispersion profile] can start only at very large numbers of detections, N ¿ 10000. (http://xxx.lanl.gov/abs/astro-ph/9609187 , 222kb)

Paper: astro-ph/9609187 replaced with revised version Thu, 12 Dec 1996 20:00:55 MST

Title: Microlensing, structure of the galactic halo and determination of dark objects' mass function Authors: D. Markovic and J. Sommer-Larsen (Theoretical Astrophysics Center, Copenhagen) Comments: MNRAS LaTeX style, 14 pages, 11 figures embedded; some changes in the estimates of the last section; a few references added. Also available from http://www.tac.dk/ draza/papers/macho1.ps.Z Report-no: 1996-024 (http://xxx.lanl.gov/abs/astro-ph/9609187 , 201kb)

Paper: astro-ph/9702231 From: martinez@astax1.ifca.unican.es Date: Wed, 26 Feb 1997 19:51:30 +0100 (60kb)

Title: The Effect of Weak Gravitational Lensing on the Cosmic Microwave Background Anisotropy: Flat versus Open Universes Author: Enrique Martinez-Gonzalez, Jose L. Sanz and Laura Cayon Comments: latex file in ApJ style, 17 pages, 3 ps figures Report-no: IFCA-26

We have studied the effect of gravitational lensing on the Cosmic Microwave Background (CMB) anisotropy in flat and open universes. We develop a formalism to calculate the changes on the radiation power spectrum induced by lensing in the Newtonian and synchronous-comoving gauges. The previously considered negligible contribution to the CMB radiation power spectrum of the anisotropic term of the lensing correlation is shown to be appreciable. However, considering the nonlinear evolution of the matter power spectrum produces only slight differences on the results based on linear evolution. The general conclusion for flat as well as open universes is that lensing slightly smoothes the radiation power spectrum. For a given range of multipoles the effect of lensing increases with Omega but for the same acoustic peak it decreases with Ω. The maximum contribution of lensing to the radiation power spectrum for $l \leq 2000$ is $\sim$ 5(http://xxx.lanl.gov/abs/astro-ph/9702231 , 60kb)

Paper: astro-ph/9601145 From: MASSO@IFAE.ES Date: Thu, 25 Jan 1996 14:05:05 GMT+0100

Title: BARYONIC DARK MATTER: THEORY AND EXPERIMENT. OVERVIEW Authors: Eduard Masso (IFAE and Dep. Fisica, Univ. Autonoma de Barcelona) Comments: Written version of a talk at IV Workshop on Theoretical and Phenomenological Aspects of Underground Physics, TAUP95, Toledo (Spain), Sept. 17-21 Report-no: UAB-FT-380

The general arguments for baryonic and galactic dark matter are presented. Limits coming from a variety of theoretical considerations and observations are discussed. The surviving candidates for galactic baryonic dark matter seem most likely to be in the form of compact objects and could be in one of two mass windows: either in the brown dwarf regime or in the mass range corresponding to supermassive black holes. Microlensing towards LMC is probing the first window. It is important to keep in mind that these experiments may detect compact heavy objects, independent of their constituency. (http://xxx.lanl.gov/abs/astro-ph/9601145 , 14kb)

Paper: astro-ph/9703015 From: Smita Mathur ¡smita@head-cfa.harvard.edu¿ Date: Mon, 03 Mar 1997 14:06:54 -0500 (16kb)

Title: X-ray Absorption Towards The Einstein Ring Source PKS1830-211 Authors: Smita Mathur (Harvard-Smithsonian Center for Astrophysics) and Sunita Nair (Univ. of Manchester) Comments: To appear in the ApJ Vol. 484, July 20, 1997. LaTex, 15 pages. Requires AAS macros

PKS1830-211 is an unusually radio-loud gravitationally lensed quasar. In the radio, the system appears as two compact, dominant features surrounded by relatively extended radio emission which forms an Einstein Ring. As the line of sight to it passes close to our Galactic center, PKS1830-211 has not been detected in wave-bands other than the radio and X-ray so far. Here we present X-ray data of PKS1830-211 observed with ROSAT PSPC. The X-ray spectrum shows that absorption in excess of the Galactic contribution is highly likely, which at the redshift of the lensing galaxy ($z_l = 0.886$) corresponds to $\mathrm{N}_H = 3.5^{+0.6}_{-0.5} \times 10^{22}$ atoms cm^{-2}. The effective optical extinction is large, A$_V$(observed)gax5.8. When corrected for this additional extinction, the two point optical to X-ray slope aox of PKS1830-211 lies just within the observed range of quasars. It is argued here that both compact images must be covered by the X-ray absorber(s) which we infer to be the lensing galaxy(galaxies). The dust to gas ratio along the line of sight within the lensing galaxy is likely to be somewhat larger than for our Galaxy. (http://xxx.lanl.gov/abs/astro-ph/9703015 , 16kb)

Paper: astro-ph/9608105 From: mellier@iap.fr (Yannick Mellier) Date: Fri, 16 Aug 96 08:15:31 +0200

Title: Weak lensing at the limit of the sky background noise Authors: Y. Mellier (1,2), B. Fort (2) ((1) Institut d'Astrophysique de Paris, (2) Observatoire de Paris DEMIRM) Comments: 12 pages, Contributed talks for the ESO Workshop on "The Early Universe with the VLT" 1-4 April 1996. Latex with lamuphys.sty and psfig.sty, Latex, 12 pages, 6 figures, also available on ftp.iap.fr/pub/incoming/mellier. Recent weak lensing observations have pushed the use of 4 meter-class telescopes to the limits of their capabilities with exposure times exceeding several hours. The leading idea is that the surface density of faint galaxies up to very faint magnitude ($B > 28 - 30$) raises continuously thus potentially offering a dense template of distant sources whose intensity contrast is at the sky noise level. In complement to the Peter Schneider's presentation on dark matter search from weak lensing (this conference), we review some of these recent advances in weak lensing analysis based on this extreme faint population of galaxies in order to explore: the dark matter distribution on large scales, the redshift ditribution of lensed sources at very large distance, and eventually the values of cosmological parameters. For each observational topic we will briefly discuss these new methods as compare to more classical lensing studies as well as the possible VLT scientific impact in the domain. (http://xxx.lanl.gov/abs/astro-ph/9608105 , 185kb)

Paper: astro-ph/9608158 From: mellier@iap.fr (Yannick Mellier) Date: Sun, 25 Aug 96 09:01:33 +0200

Title: Gravitational Lensing and the Redshift Distribution of $B > 25$ galaxies Authors: Y. Mellier (1,2) ((1) Institut d'Astrophysique de Paris, (2) Observatoire de Paris DEMIRM) Comments: 8 pages, Invited talks for the 37th Herstmonceux Conference on "HST and the High Redshift Universe" 1-5 july 1996. Latex with hx37_latex.sty and psfig.sty. 8 pages, 4 figures 191K gzipped tar file. Also available on ftp.iap.fr/pub/incoming/mellier
In addition to the determination of the mass distribution of lenses (see P. Schneider, this conference), strong and weak lensing can also be powerfull tools to analyse the redshift distribution of faint galaxies. In this review, I summarize the present status of redshifts of galaxies beyond $B = 25$ as they are inferred by spectroscopy of magnified galaxies, lensing inversion and magnification bias. (http://xxx.lanl.gov/abs/astro-ph/9608158 , 176kb)

Paper: astro-ph/9609197 From: fbernard@wasa.saclay.cea.fr (Francis

Bernardeau) Date: Mon, 30 Sep 1996 12:11:54 +0200

Title: Recent Advances in Gravitational Lensing Authors: Y. Mellier (Obs. Paris and IAP), L. van Waerbeke (Obs. Midi-Pyrenees), F. Bernardeau (SPhT Saclay) and B. Fort (Obs. Paris) Comments: Invited talk for the VIIIth Rencontres de Blois, "Neutrinos, Dark Matter and the Universe" 6-12 june 1996. Latex, 15 pages, 6 figures. Also available on ftp://ftp.iap.fr/pub/incoming/mellier Report-no: Saclay SPhT T96/109

The gravitational lensing effect is one of the most promising tools for cosmology. Indeed it probes directly the total mass distribution in large-scale structures and can as well provide valuable informations on the values of the density parameter Omega and the cosmological constant lambda. In this review we summarize the most spectacular observational and theoretical advances obtained in this field during the last five years. (http://xxx.lanl.gov/abs/astro-ph/9609197 , 607kb)

Paper: astro-ph/9505100 From: mohanty@prl.ernet.in (SUBHENDRA MOHANTY) Date: Mon, 22 May 1995 13:37:39 +0530

Title: NO BIREFRINGENCE IN EINSTEIN'S GRAVITY Authors: S. Mohanty and A.R. Prasanna Comments: latex file no figures

Einstein's theory predicts that, massive test particles with non-zero spin or angular momentum, in an external gravitation field, follow geodesics which depend upon the orientation of the spin-angular momentum . It has been claimed that such an effect also holds for photons i.e. photons with different helicities follow different geodesics in the gravitational field of a rotating body and would give rise to a polarisation dependent deflection of light passing in the vicinity of the sun or a polarisation dependent time delay of pulsar signals . We show here that contrary to earlier claims , in Einstein's gravity there is no birefringence and photons follow null geodesics irrespective of polarisation. Thus if gravitational birefringence is ever observed experimentally it would be a signal of new physics beyond Einstein's gravity

Paper: astro-ph/9612074 From: Nakamura Takahiro (UTAP) nakamura@utaphp1.phys.s.u-tokyo.ac.jp Date: Sat, 07 Dec 1996 20:00:34 +0900

Title: Strong Gravitational Lensing and Velocity Function as Tools to Probe Cosmological Parameters: Current Constraints and Future Predictions Authors: Takahiro T. Nakamura and Yasushi Suto (University of Tokyo) Comments: 27 pages, 8 figures, ptptex. Progress of Theoretical Physics, in press Report-no: UTAP-236/96, RESCEU-23/96

Constraints on cosmological models from strong gravitational lensing statistics are investigated. We pay particular attention to the role of the velocity function in the calculation of the lensing probability. The velocity function derived from the observed galaxy luminosity function, which is used in most previous work, is unable to predict the large separation lensing events. In this paper, we also use the Press-

Schechter theory to construct a velocity function theoretically. Model predictions are compared with the observed velocity function and the HST snapshot survey. Comparison with the latter observation shows that the predictions based on the theoretical velocity function are consistent with the observed large separation events in COBE normalized low-density models, especially with a non-vanishing cosmological constant. Adopting the COBE normalization, however, we could find no model which simultaneously satisfies both the observed velocity function and the HST snapshot survey. We systematically investigate various uncertainties in the gravitational lensing statistics including finite core radius, the distance formula, magnification bias, and dust obscuration. The results are very sensitive to these effects as well as theoretical models for the velocity function, implying that current limits on the cosmological parameters should be interpreted with caution. Predictions for future surveys are also presented. (http://xxx.lanl.gov/abs/astro-ph/9612074 , 180kb)

Paper: astro-ph/9606001 From: Matthias Bartelmann msb@MPA-Garching.MPG.DE Date: Mon, 3 Jun 1996 08:45:37 +0200 (MDT)

Title: LECTURES ON GRAVITATIONAL LENSING Authors: Ramesh Narayan (1) and Matthias Bartelmann (2) ((1) Harvard-Smithsonian Center for Astrophysics; (2) Max-Planck-Institut fuer Astrophysik) Comments: Lectures held at the 1995 Jerusalem Winter School; 51 pages without figures; postscript file including figures can be retrieved from

http://www.mpa-garching.mpg.de/Lenses/Preprints/JeruLect.ps.gz

The Lectures give an introduction to Gravitational Lensing. We discuss lensing by point masses, lensing by galaxies, and lensing by clusters and larger-scale structures in the Universe. The relevant theory is developed and applications to astrophysical problems are discussed. (http://xxx.lanl.gov/abs/astro-ph/9606001 , 61kb)

Paper: astro-ph/9509016 From: Preprint account preprint@ast.cam.ac.uk Date: Mon, 4 Sep 1995 17:51:00 +0100 (BST)

Title: STUDY OF THE DYNAMICS OF THE CORE OF A2218 Author: Priyamvada Natarajan Comments: uuencoded compressed postscript, without figure. The preprint is available in complete form at http://www.ast.cam.ac.uk/preprint/PrePrint.html Report-no: CAP-9509005

We report the results of an attempt to study the velocity structure of the core of the cluster A2218 in order to probe its dynamical state. The aim is to understand if the core is indeed virialized? relaxed? or in hydrodynamic equilibrium? We use cluster lensing data in conjunction with the optical galaxy data to solve in detail for the nature of galaxy orbits and the velocity anisotropy in the core. We present our preliminary results below.

Paper: astro-ph/9509029 From: Preprint account preprint@ast.cam.ac.uk

Date: Wed, 6 Sep 1995 15:18:31 +0100 (BST)

Title: EFFECT OF SUB-STRUCTURE IN CLUSTERS ON THE LOCAL WEAK-SHEAR FIELD Author: Priyamvada Natarajan and Jean-Paul Kneib Comments: uuencoded compressed postscript. The preprint is also available at http://www.ast.cam.ac.uk/preprint/PrePrint.html Report-no: CAP-9509007
Weak shear maps of the outer regions of clusters have been successfully used to map the distribution of mass at large radii. The effects of substructure in clusters on such reconstructions of the total mass have not been systematically studied. We propose a new method to study the effect of perturbers (bright cluster galaxies or sub-groups within the cluster) on the weak shear field. We present some analytic results below.

Paper: astro-ph/9604084 replaced with revised version Mon, 30 Sep 1996 09:18:13 +0100 (BST)

Title: An analytic approximation to the isothermal sphere Author: Priyamvada Natarajan (IoA, Cambridge) and Donald Lynden-Bell (IoA, Cambridge and University, Belfast) Comments: 6 pages, figures included, revised version, accepted for publication in MNRAS Report-no: CAP-9604002 (http://xxx.lanl.gov/abs/astro-ph/9604084 , 115kb)

Paper: astro-ph/9607063 From: Doris Neumann

don@rosat.mpe-garching.mpg.de Date: Fri, 12 Jul 1996 11:43:03 +0200 (MET DST)

Title: X-RAY PROPERTIES OF THE DISTANT CLUSTER Cl0016+16 Authors: Doris M. Neumann, Hans Boehringer (MPE) Comments: 11 pages, submitted to MNRAS Report-no: MPE Preprint 369
We present X-ray data on the distant cluster Cl0016+16 (z=0.5545) from ROSAT PSPC and HRI observations and use them to study the physics of the intracluster medium (ICM) and the dynamical state of the cluster. The surface brightness distribution is not only described by a spherically symmetric model but also by a two-dimensional β-model fit. Subtracting an elliptical model cluster as defined by the best fit parameters of the two-dimensional model we find significant residuals, indicating an additional, extended X-ray source within the cluster. This source, likely to be a merging subcomponent of the cluster, coincides with a peak in the weak lensing mass map of Smail et. al. (1995). In the course of this analysis we present a new approach to quantify the significance of substructure in cluster X-ray images dominated by Poisson noise and smoothed with a Gauss filter. We determine the radial mass profile integrated out to a radius of 3Mpc and find for the total mass of the cluster a value of $\sim 1.4 - 3.3 \times 10^{15} M_{odot}$ and $\sim 4.5 \times 10^{14} M_{odot}$ for the gas mass, yielding a gas-to-total mass ratio of 14-32%. There is no significant radial dependence of the gas-to-total mass ratio in the cluster. (http://xxx.lanl.gov/abs/astro-ph/9607063 , 135kb)

Paper: astro-ph/9701060 From: nikolaev@kestrel.phast.umass.edu (Sergei

Nikolaev) Date: Mon, 13 Jan 1997 11:38:03 -0500 (EST)

Title: A rigorous reanalysis of the IRAS variable population: scale lenghts, asymmetries, and microlensing Authors: Sergei Nikolaev and Martin D. Weinberg Comments: 22 pages, LaTeX, 12 figures

Previous work reported a bar signature in color-selected IRAS variable stars. Here, we estimate the source density of these variables while consistently accounting for spatial incompleteness in data using a likelihood approach. The existence of the bar is confirmed with shoulder of 4 kpc and position angle of 19 +/- 1 degrees. The ratio of non-axisymmetric to axisymmetric components gives similar estimate for the bar size 3.3 +/- 0.1 kpc and position angle 24 +/- 2 degrees. We estimate a scale length 4.00 +/- 0.55 kpc for the IRAS variable population, suggesting that these stars represent the old disk population. We use this density reconstruction to estimate the optical depth to microlensing for the large-scale bar in the Galactic disk. We find an enhancement over an equivalent axisymmetric disk by 30account for the MACHO result. In addition, we predict a significant asymmetry at positive and negative longitudes along lines of sight through the end of the bar with optical depths comparable to that in Baade's window. An infrared microlensing survey may be a sensitive tool for detecting or constraining structural asymmetries. More generally, this is a pilot study for Bayesian star count analyses. Bayesian approach allows the assessment of prior probabilities to the unknown parameters of the model; the resulting likelihood function is straightforwardly modified to incorporate all available data. (http://xxx.lanl.gov/abs/astro-ph/9701060 , 126kb)

Paper: astro-ph/9608006 From: richard mcmahon rgm@ast.cam.ac.uk Date: Thu, 1 Aug 1996 17:43:41 +0100 (BST)

Title: MOLECULAR GAS AND DUST AROUND A RADIO-QUIET QUASAR AT REDSHIFT 4.7 Authors: Alain Omont, Patrick Petitjean, Stephane Guilloteau, Richard G. McMahon, P. M. Solomon, Emmanuel Pecontal Comments: 14 pages, 1 table, 2 figures, LaTex (aas2pp4.sty, psfig.sty), also available at

http://www.ast.cam.ac.uk/ rgm Journal-ref: Nature, 382, 428-431, 1 August 1996

We report the detection of emission from dust and carbon monoxide in the radio-quiet quasar BR1202–0725 at redshift z=4.7. Maps of these emissions reveal two objects separated by a few arc seconds, which could indicate either the presence of a companion to the quasar or gravitational lensing of the quasar itself. Regardless of the precise interpretation of the maps, the detection of carbon monoxide confirms the presence of a large mass of molecular gas in one of the most distant galaxies known, and shows that conditions conducive to huge bursts of star formation existed in the early Universe. (http://xxx.lanl.gov/abs/astro-ph/9608006 , 163kb)

Paper: astro-ph/9604011 From: Bohdan Paczynski bp@astro.Princeton.EDU Date: Tue, 2 Apr 1996 10:57:45 -0500 (EST)

Title: GRAVITATIONAL MICROLENSING IN THE LOCAL GROUP Authors: Bohdan Paczynski (Princeton University Observatory) Comments: 41 pages, latex, 13 figures, postscript version with figures available at http://www.astro.princeton.edu/ library/prep.html Report-no: POPe-661

The status of searches for gravitational microlensing events of the stars in our galaxy and in other galaxies of the Local Group, the interpretation of the results, some theory, and prospects for the future are reviewed. The searches have already unveiled about 100 events, at least two of them caused by binaries, and have already proven to be useful for studies of the Galactic structure. The events detected so far are probably attributable to the effects of ordinary stars, and possibly to sub-stellar brown dwarfs; however a firm conclusion cannot be reached yet because the analysis published to date is based on a total of only 16 events. The current searches, soon to be upgraded, will probably allow determination of the mass function of stars and brown dwarfs in the next few years; these efforts will also provide good statistical information about binary systems, in particular their mass ratios. They may also reveal the nature of dark matter and allow us to detect planets and planetary mass objects. (http://xxx.lanl.gov/abs/astro-ph/9604011 , 276kb)

Paper: astro-ph/9606060 From: bp@astro.Princeton.EDU Date: Mon, 10 Jun 1996 11:55:18 -0400 (EDT)

Title: THE MASSES OF NEARBY DWARFS AND BROWN DWARFS WITH THE HST Authors: Bohdan Paczynski (Princeton University Observatory) Comments: submitted to Acta Astronomica, 7 pages, 2 figures uuencoded, gzipped, tarred Latex and postscript files

The known nearby stars, moving in front of the background of distant stars and galaxies, create 'weak gravitational lensing' variations in their positions. These variations may be measurable with the HST, and they may allow a direct mass determination for the nearby stars. The cross section for the HST measurable astrometric effect is much larger than the cross section for the photometric effect which is measurable from the ground. The mass determination will be easier for the fainter nearby lenses which will be discovered in future searches of faint high proper motion stars. (http://xxx.lanl.gov/abs/astro-ph/9606060 , 38kb)

Paper: astro-ph/9609204 From: mgp@astro.Princeton.EDU Date: Mon, 30 Sep 1996 18:04:12 -0400 (EDT)

Title: Gravitational Lensing Statistics in a Flat Universe Authors: Myeong-Gu Park (Kyungpook National University, KOREA) Comments: 14 pages, 3 Postscript figures, uses REVTEX. To appear in the Journal of Korean Physical Society

The probability distribution of lens image separations is calculated for the "standard" gravitational lensing statistics model in an arbitrary, flat Robertson-Walker universe, where lensing galaxies are singular isothermal spheres that follow the Schechter luminosity function. In a flat universe, the probability distribution is independent of the source distribution in space and in brightness. The distribution is compared with observed multiple-image lens cases through Monte-Carlo simulations and the Kolmogorov-Smirnov test. The predicted distribution depends on the shape of the angular selection bias used, which varies for different observations. The test result also depends on which lens systems are included in the samples. We mainly include the lens systems where a single galaxy is responsible for lensing. We find that the "standard" model predicts a distribution which is different from the observed one. However, the statistical significance of the discrepancy is not large enough to invalidate the "standard" model with high confidence. Only the radio data reject the model at the 95cases. Therefore, we cannot say that the observational data reject the "standard" model with enough statistical confidence. However, if we take the velocity dispersion of dark matter without the conversion factor$(3/2)^(1/2)$ from that of luminous matter, the discrepancy is quite severe, and even the ground-based optical survey data reject the "standard" model with ¿ 90confidence. (http://xxx.lanl.gov/abs/astro-ph/9609204 , 29kb)

Paper: astro-ph/9702173 From: Myeong-Gu Park mgp@kyungpook.ac.kr Date: Thu, 20 Feb 1997 05:07:35 MST (37kb)

Title: Curvature of the Universe and Observed Gravitational Lens Image Separations Versus Redshift Authors: Myeong-Gu Park, J. Richard Gott III Comments: 21 pages, 4 figures, AASTeX4 Report-no: KNU-DAAS-97-02
In a flat, k=0 cosmology with galaxies that approximate singular isothermal spheres, gravitational lens image separations should be uncorrelated with source redshift. But in an open k=-1 cosmology such gravitational lens image separations become smaller with increasing source redshift. The observed separations do become smaller with increasing source redshift but the effect is even stronger than that expected in an Omega=0 cosmology. The observations are thus not compatible with the "standard" gravitational lensing statistics model in a flat universe. We try various open and flat cosmologies, galaxy mass profiles, galaxy merging and evolution models, and lensing aided by clusters to explain the correlation. We find the data is not compatible with any of these possibilities within the 95regard the observed result as a statistical fluke, it is worth noting that we are about twice as likely to observe it in an open universe (with 0¡Omega¡0.4) as we are to observe it in a flat one. Finally, the existence of an observed multiple image lens system with a source at z=4.5 places a lower limit on the deceleration parameter: $q_0 > -2.0$. (http://xxx.lanl.gov/abs/astro-ph/9702173 , 37kb)

Paper: astro-ph/9612062 From: Stanton Peale peale@io.ucsb.edu Date: Thu, 5 Dec 96 21:47:35 PST

Title: Expectations from a Microlensing Search for Planets Author: S. J. Peale (University of California at Santa Barbara) Comments: 26 pages, LaTeX, uses aas2pp4.sty, 11 postscript figures, Submitted to Icarus

The statistical distribution of the masses of planets about stars between the Sun and the center of the galaxy is constrained to within a factor of three by an intensive search for planets during microlensing events. Projected separations in terms of the lens Einstein ring radius yield a rough estimate of the distribution of planetary semimajor axes with planetary mass. The search consists of following ongoing stellar microlensing events involving sources in the center of the galaxy lensed by intervening stars with high time resolution, 1planetary perturbations of the otherwise smooth light curve. It is assumed that 3000 events are followed over an 8 year period, but with half of the lenses, those that are members of binary systems, devoid of planets. The remaining 1500 lenses have solar-system-like distributions of 4 or 5 planets. The expectations from the microlensing search are extremely assumption dependent with 56, 138, and 81 planets being detected for three sets of assumptions involving how the planetary masses and separations vary with lens mass. The events can be covered from 54from a system of three or four dedicated two meter telescopes distributed in longitude, so 38perturbations of the light curve) will be missed. But perturbations comparable to a day in length means all of the detectable Jupiters and Saturns will in fact be detected as well as a large fraction of the Uranuses. Although meaningful statistics on planetary masses and separations can be inferred from such an intensive search, they, like the inferred data set, will be dependent on the assumed nature of the systems. (http://xxx.lanl.gov/abs/astro-ph/9612062 , 175kb)

Paper: astro-ph/9603146 From: roser@srvdec.obs-mip.fr (roser pello) Date: Wed, 27 Mar 1996 19:19:46 +0200

Title: IDENTIFICATION OF A HIGH REDSHIFT CLUSTER IN THE FIELD OF Q2345+007 THROUGH DEEP BRIJK' PHOTOMETRY Authors: R. Pello (1), J. M. Miralles (1), J.-F. Le Borgne (1), J.-P. Picat (2), G. Soucail (1), G. Bruzual (3) ((1) Observatoire Midi-Pyrenees LAT URA 285, (2) Observatoire Midi-Pyrenees URA 1281, (3) Centro de Investigaciones de Astronomia) Comments: 16 pages, A and A macros (l-aa.sty), 11 postcript fig. included with psfig, to appear in Astronomy and Astrophysics Main Journal Report-no: MS 4721

This paper describes new results on the identification of the complex gravita- tional lens responsible for the double quasar Q2345+007. A gravitational shear field was detected recently about 45" away from the QSO, centered on an excess of faint blue galaxies. We present deep photometric data in the near-IR (J and K'), which are used together with optical BRI photometry to build spectral ener- gy distributions for all the objects, and to derive a photometric redshift esti- mate by comparison with synthetic spectrophotometric data. We propose a statis- tical method to analyse the distribution in z. An excess of galaxies at z about 0.75 is detected in this field, with a 2D distribution showing a maximum located at the center of the weak-shear field. The z inferred for this overdensity (a distant cluster of galaxies) corresponds to an absorption system in the spectrum of the quasar B. Most cluster-member candidates at z=0.75 are undergoing a star- formation process or are burst systems 1 to 3 Gyr old. We also discuss the exis- tence of other possible excesses of galaxies at different z planes. (http://xxx.lanl.gov/abs/astro-ph/9603146 , 295kb)

Paper: astro-ph/9701226 From: Avi Loeb loeb@cfata1.harvard.edu Date: Wed, 29 Jan 1997 14:06:19 -0500 (183kb)

Title: Microlensing of Quasars By Stars In Their Damped Lyman-alpha Absorbers Authors: Rosalba Perna and Abraham Loeb (Harvard University) Comments: 25 pages, latex, 8 figures, submitted to ApJ

The Damped Lyman-Alpha absorbers (DLAs) in quasar spectra are believed to be the progenitors of present-day disk galaxies. We examine the probability for microlensing of background quasars by stars in their DLAs. Microlensing should magnify the continuum but not the broad emission lines of the quasars. We model a representative spiral galaxy as a closed system composed of a bulge, a disk, and a halo, and evolve the mass fraction of stars in the disk based on the observed metallicity of DLAs at high redshifts. The microlensing signatures are strongly enhanced if the halo of the galaxy is made of Massive Compact Halo Objects (MACHOs). In this case, the distortion imprinted by microlensing on the equivalent width distribution of quasar emission lines can be detected with high significance in a sample of ¡10 DLAs with HI column densities$N > 10^{21} cm^{-2}$ and absorption redshifts z¡1. About a tenth of all quasars with DLAs ($N > 10^{20} cm^{-2}$) might show excess variability on timescales shorter than five years. A search for these signals would complement microlensing searches in local galaxies and calibrate the MACHO mass fraction in galactic halos at high redshifts. (http://xxx.lanl.gov/abs/astro-ph/9701226 , 183kb)

Paper: astro-ph/9607082 From: Frank P. Pijpers fpp@obs.aau.dk Date: Wed, 17 Jul 1996 07:10:34 MDT

Title: THE DETERMINATION OF TIME LAGS USING SOLA Authors: Frank P. Pijpers (TAC, Aarhus, Denmark) Comments: 13 pages, including figures, uses epsf.tex and mn.tex submitted to MNRAS Report-no: TAC 1996-015

A common problem in astronomy is the determination of the time shift between two otherwise identical time series of measured flux from a variable source, in short the determination of a time lag. Two examples of where this problem occurs are in the determination of the Hubble constant from multiple images of gravitationally lensed variable quasars and also in the determination of distances to OH/IR stars. It is shown here that this problem can be seen as a restricted inversion problem. It therefore can be solved using the subtractive optimally localized averages (SOLA) method for inversion which has been described elsewhere (Pijpers and Thompson 1992, 1994 ; Pijpers and Wanders 1994). (http://xxx.lanl.gov/abs/astro-ph/9607082 , 144kb)

Paper: astro-ph/9606134 From: Mark Pratt

mrp@darkstar.astro.washington.edu Date: Thu, 20 Jun 1996 18:43:00 -0700

Title: THE MACHO PROJECT 2nd YEAR LMC MICROLENSING RESULTS AND DARK MATTER IMPLICATIONS Authors: M.R. Pratt, C. Alcock, R.A. Allsman, D. Alves, T.S. Axelrod, A.C. Becker, D.P. Bennett, K.H. Cook, K.C. Freeman, K. Griest, J. Guern, M.J. Lehner, S.L. Marshall, B.A. Peterson, P.J. Quinn, A.W. Rodgers, C.W. Stubbs, W. Sutherland and D.L. Welch Comments: 10 pages, 6 epsf figures and style file included, 451k, also at

http://wwwmacho.mcmaster.ca/Pubs/Pubs.html; To appear in the Proceedings of "Sources and Detection of Dark Matter in the Universe", Santa Monica, CA, Feb., 1996

The MACHO Project is searching for galactic dark matter in the form of massive compact halo objects (Machos). Millions of stars in the Large Magellanic Cloud (LMC), Small Magellanic Cloud (SMC), and Galactic bulge are photometrically monitored in an attempt to detect rare gravitational microlensing events caused by otherwise invisible Machos. Analysis of two years of photometry on 8.5 million stars in the LMC reveals 8 candidate microlensing events, far more than the ~ 1 event expected from lensing by low-mass stars in known galactic populations. From these eight events we estimate the optical depth towards the LMC from events with $2 < Ts < 200$ days to be $\tau_2^{200} \simeq 2.9^{+1.4}_{-0.9} 10**-7$. This exceeds the optical depth of $0.510**-7$ expected from known stars and is to be compared with an optical depth of $4.710**-7$ predicted for a "standard" halo composed entirely of Machos. The total mass in this lensing population is $\approx 2^{+1.2}_{-0.7} 10**11 M_{odot}$ (within 50 kpc from the Galactic center). Event timescales yield a most probable Macho mass of $0.5^{+0.3}_{-0.2} M_{odot}$, although this value is quite model dependent. (http://xxx.lanl.gov/abs/astro-ph/9606134 , 233kb)

Paper: astro-ph/9503020 From: joel@lick.UCSC.EDU Date: Sat, 4 Mar 1995 11:20:52 -0800 (PST) Date (revised): Sat, 4 Mar 1995 11:41:54 -0800 (PST)

Title: STATUS OF COSMOLOGICAL PARAMETERS: CAN $\Omega = 1$? Author: Joel R. Primack Comments: 14 pages, uuencoded compressed .ps file Report-no: SCIPP 95/10 (February 1995), Plenary talk at Snowmass 1994

I discuss the Hubble parameter H_0, the age of the universe t_0, the density Ω_0, and the cosmological constant Λ. To focus the discussion, I will concentrate on the issue of the value of the density Ω_0 in currently popular cosmological models in which most of the dark matter is cold, especially Cold + Hot Dark Matter (CHDM) and flat low- Ω CDM with a Cosmological Constant (ΛCDM). The evidence would favor a small $\Omega_0 \simeq 0.3$ if (1) the Hubble parameter actually has the high value $h \simeq 0.8$ favored by many observers, and the age of the universe $t_0 \geq 13$ Gy; or (2) the baryonic/total mass ratio in clusters is actually $\sim 20\%$, about 3-4 times larger than expected for standard Big Bang Nucleosynthesis in an $\Omega = 1$ universe, and standard BBN is actually right in predicting that the density of ordinary matter Ω_b lies in the range $0.009 \leq \Omega_b h^2 \leq 0.02$. The evidence would favor $\Omega = 1$ if (1) the POTENT analysis of galaxy peculiar velocity data is right, in particular regarding outflows from voids or the inability to obtain the present-epoch non-Gaussian density distribution from Gaussian initial fluctuations in a low-Ω universe; or (2) the preliminary report from LSND indicating a neutrino mass ≥ 2.4 eV is right, since that would be too much hot dark matter to allow significant structure formation in a low-Ω ΛCDM model. Statistics on gravitational lensing of quasars provide a strong upper limit on Λ. Reliable data on all of these issues is becoming available so rapidly today that a clear decision between these alternatives may be possible within the next few years.

Paper: astro-ph/9510041 From: carroll@marie.mit.edu (Sean Carroll) Date: Fri, 6 Oct 1995 13:14:31 -0400

Title: HIGHER-ORDER GRAVITATIONAL PERTURBATIONS OF THE COSMIC MICROWAVE BACKGROUND Authors: Ted Pyne and Sean M. Carroll Comments: 20 pages, one figure Report-no: MIT-CTP-2455

We study the behavior of light rays in perturbed Robertson-Walker cosmologies, calculating the redshift between an observer and the surface of last scattering to second order in the metric perturbation. At first order we recover the classic results of Sachs and Wolfe, and at second order we delineate the various new effects which appear; there is no *a priori* guarantee that these effects are significantly smaller than those at first order, since there are large length scales in the problem which could lead to sizable prefactors. We find that second order terms of potential observational interest may be interpreted as transverse and longitudinal lensing by foreground density perturbations, and a correction to the integrated Sachs-Wolfe effect. (astro-ph/9510041 , 46kb + 20kb)

Paper: astro-ph/9611118 From: Bo Qin ¡qin@class2.bao.ac.cn¿ Date: Fri, 15 Nov 1996 15:14:46 +0800 (CST)

Title: Self-Microlensing in Compact Binary Systems Authors: Bo Qin, Xiang-Ping Wu and Zhenlong Zou Comments: 5 pages Latex file, Chin. Phys. Lett., in press

The signature of the self-microlensing in compact binaries (white dwarfs, neutron stars and black holes) is a flare with the characteristic time of typically a few minutes. The probability of detecting these microlensing events can be as high as 1/50 for a flux sensitivity of $\Delta m = 0.01$ in magnitude. The discovery of the self-microlensing by binaries would furnish an additional way to find the masses of the lens and the companion and will be promising for the searches of black holes. (http://xxx.lanl.gov/abs/astro-ph/9611118 , 5kb)

Paper: astro-ph/9512039 From: Avi Loeb loeb@cfata1.harvard.edu Date: Thu, 7 Dec 1995 11:11:05 -0500

Title: PROBING CLUSTER POTENTIALS THROUGH GRAVITATIONAL LENSING OF BACKGROUND X-RAY SOURCES Authors: Alexandre Refregier and Abraham Loeb Comments: to appear in Proc. of "Rontgenstrahlung from the Universe" 1995, 2 pages, 2 figures included, uuencoded compressed Postscript

We examine the gravitational lensing effect of a foreground galaxy cluster on the number count statistics of background X-ray sources. The lensing produces a deficit in the number of resolved sources in a ring close to the critical radius of the cluster. This deficit could be detected at the $\sim 3\sigma$ level with the AXAF-ACIS camera. (astro-ph/9512039 , 46kb)

Paper: astro-ph/9612102 From: rcecile@hep.saclay.cea.fr Date: Tue, 10 Dec 1996 18:37:28 +0100

Title: Observational Limits on Machos in the Galactic Halo Authors: EROS collaboration: C. Renault, C. Afonso, E. Aubourg, P. Bareyre, F. Bauer, S. Brehin, C. Coutures, C. Gaucherel, J.F. Glicenstein, B. Goldman, M. Gros, D. Hardin, J. de Kat, M. Lachieze-Rey, B. Laurent, E. Lesquoy, C. Magneville, A. Milsztajn, L. Moscoso, N. Palanque-Delabrouille, F. Queinnec, J. Rich, M. Spiro, L. Vigroux, S. Zylberajch, R. Ansari, F. Cavalier, F. Couchot, B. Mansoux, M. Moniez, O. Perdereau, J.-Ph. Beaulieu, R. Ferlet, Ph. Grison, A. Vidal-Madjar, J. Guibert, O. Moreau, E. Maurice, L. Prevot, C. Gry, S. Char, J. Fernandez Comments: 4 pages, 3 Postscript figures, submitted to Astronomy and Astrophysics

We present final results from the first phase of the EROS search for gravitational microlensing of stars in the Magellanic Clouds by unseen deflectors (machos: MAssive Compact Halo Objects). The search is sensitive to events with time scales between 15 minutes and 200 days corresponding to deflector masses in the range 1.e-7 to a few solar masses. Two events were observed that are compatible with microlensing by objects of mass of about 0.1 solar mass. By comparing the results with the expected number of events for various models of the Galaxy, we conclude that machos in the mass range [1.e-7, 0.02] $M_{\odot}$ make up less than 20(http://xxx.lanl.gov/abs/astro-ph/9612102 , 29kb)

Paper: astro-ph/9612102 replaced with revised version Mon, 10 Mar 1997 12:53:13 +0100

Title: Observational Limits on Machos in the Galactic Halo Authors: EROS collaboration: C. Renault, C. Afonso, E. Aubourg, P. Bareyre, F. Bauer, S. Brehin, C. Coutures, C. Gaucherel, J.F. Glicenstein, B. Goldman, M. Gros, D. Hardin, J. de Kat, M. Lachieze-Rey, B. Laurent, E. Lesquoy, C. Magneville, A. Milsztajn, L. Moscoso, N. Palanque-Delabrouille, F. Queinnec, J. Rich, M. Spiro, L. Vigroux, S. Zylberajch, R. Ansari, F. Cavalier, F. Couchot, B. Mansoux, M. Moniez, O. Perdereau, J.-Ph. Beaulieu, R. Ferlet, Ph. Grison, A. Vidal-Madjar, J. Guibert, O. Moreau, E. Maurice, L. Prevot, C. Gry, S. Char, J. Fernandez Comments: 4 pages, 3 Postscript figures, to be published in Astronomy & Astrophysics (http://xxx.lanl.gov/abs/astro-ph/9612102 , 30kb)

Paper: astro-ph/9508123 From: sunhong@igpp.llnl.gov (Sun Hong Rhie) Date: Fri, 25 Aug 1995 18:22:55 -0700

Title: INFIMUM MICROLENSING AMPLIFICATION OF THE MAX-

IMUM NUMBER OF IMAGES OF n-POINT LENS SYSTEMS Authors: Sun Hong Rhie (IGPP, LLNL) Comments: 10 pages, 1 Figure, uuencoded tar compressed postscript
The total amplification of a source inside a caustic curve of a binary lens is no less than 3. Here we show that the infimum amplification 3 is satisfied by a family of binary lenses where the source position is at the mid-point between the lens positions independently of the mass ratio which parameterizes the family. We present a new proof of an underlying constraint that the total amplification of the two positive images is bigger than that of the three negative images by one inside a caustic. We show that a similar constraint holds for an arbitrary class of n-point lens systems for the sources in the 'maximal domains'. We introduce the notion that a source plane consists of *graded caustic domains* and the 'maximal domain' is the area of the source plane where a source star results in the maximum n^2+1 images. We also show that the infimum amplification of a three point lens is 7, and it is bigger than n^2+1-n for $n \geq 4$.

Paper: astro-ph/9607055 From: sunhong@igpp.llnl.gov (Sun Hong Rhie) Date: Thu, 11 Jul 1996 17:07:44 -0700 (PDT)
Title: SEARCH FOR EARTH-MASS PLANETS AND DARK MATTER, TOO Authors: S.H.Rhie, D.P.Bennett Comments: 5 pages, submitted to the Proceedings of the Second International Symposium on Sources and Detection of Dark Matter in the Universe
Gravitational microlensing is known for baryoninc dark matter searches. Here we show that microlensing also provides a unique tool for the detection of low mass planets (such as earths and neptunes) from the ground. A planetary system forms a binary lens (or, a multi-point lens), and we can determine the mass ratio of the planet with respect to the star and relative distance (= separation/Einstein ring radius) between the star and planet. Such a microlenisng planet search project requires a $\simeq 2$ m survey telescope, and a network of $1.5-2$ m follow-up telescopes capable of monitoring stars in the Bulge on a 24-hour basis. During the off-season of the Galactic bulge, this network can be used for dark matter search by monitoring the stars in the LMC and SMC. (http://xxx.lanl.gov/abs/astro-ph/9607055 , 81kb)

Paper: astro-ph/9603119 From: Esteban Roulet roulet@susy.he.sissa.it Date: Thu, 21 Mar 96 16:12:43 MET
Title: MICROLENSING Authors: E. Roulet and S. Mollerach (SISSA) Comments: postscript file, 59 p. + 13 figures included, review to appear in Physics Reports Report-no: SISSA-171/95/EP
Microlensing observations have now become a useful tool in searching for non–luminous astrophysical compact objects (brown dwarfs, faint stars, neutron stars, black holes and even planets). Originally conceived for establishing whether the halo of the Galaxy is composed of this type of objects, the ongoing searches are actually also sensitive to the dark constituents of other Galactic components (thin and thick disks, outer spheroid, bulge). We discuss here the present searches for microlensing of stars in the

Magellanic Clouds and in the Galactic bulge (EROS, MACHO, OGLE and DUO collaborations). We analyse the information which can be obtained regarding the spatial distribution and motion of the lensing objects as well as about their mass function and their overall contribution to the mass of the Galaxy. We also discuss the additional signals, such as the parallax due to the motion of the Earth, the effects due to the finite source size and the lensing events involving binary objects, which can further constrain the lens properties. We describe the future prospects for these searches and the further proposed observations which could help to elucidate these issues, such as microlensing of stars in the Andromeda galaxy, satellite parallax measurements and infrared observations. (http://xxx.lanl.gov/abs/astro-ph/9603119 , 328kb)

Paper: astro-ph/9702180 From: sasselov@cfassp36.harvard.edu (Dimitar Sasselov) Date: Thu, 20 Feb 1997 18:46:13 -0500 (20kb)

Title: The Chromaticity of Microlensing (Surface Imaging of Stars) Author: Dimitar D. Sasselov (Harvard-Smithsonian Center for Astrophysics) Comments: 5 pages, 2 figures, LaTex, invited talk 12th IAP Colloquium on "The Astrophysical Returns of Microlensing Surveys", eds. R.Ferlet and J.P.Maillard
Gravitational microlensing is not achromatic when the star being microlensed is resolved by the lens. We show how narrow-band photometry and moderate- to high-resolution spectroscopy can be used to reconstruct the stellar surface intensity distribution of a microlensed star. Such microlens imaging can provide a unique opportunity to study the surfaces of normal red giants where Doppler imaging is not applicable due to slow rotation. (http://xxx.lanl.gov/abs/astro-ph/9702180 , 20kb)

Paper: astro-ph/9611213 From: mike@mrao.cam.ac.uk Date: Tue, 26 Nov 96 15:50 GMT

Title: Sunyaev-Zel'dovich observations with the Ryle Telescope Authors: Richard Saunders (MRAO, Cambridge, UK) Comments: 5 pages, LaTex, uses 'cmb.sty' (included), 1 PostScript figure. To appear in proceedings of the XXXIst Rencontre de Moriond, 'Microwave Background Anisotropies'
The Ryle Telescope has been used to provide images at 15 GHz of the Sunyaev-Zel'dovich decrements towards a dozen clusters in an X-ray luminosity-limited sample. So far, X-ray data have allowed H_0 estimates towards two of these, both giving "low" values that are self-consistent, though it is essential to obtain many more estimates to reduce the effects of cluster projection. We have also discovered a decrement towards the z=3.8 quasar pair PC1643+4631A and B (198" separation); substantial X-ray, optical and infrared follow-up show that the cluster responsible is either at z¿1 or very underluminous and that very significant gravitational lensing must be occuring. (http://xxx.lanl.gov/abs/astro-ph/9611213 , 14kb)

Paper: astro-ph/9611219 From: mike@mrao.cam.ac.uk Date: Tue, 26 Nov 96 18:55 GMT

Title: Optical and infrared investigation towards the z=3.8 quasar pair PC1643+4631A and B Authors: Richard Saunders (1), Joanne C. Baker (1), Malcolm N. Bremer (2), Andrew J. Bunker (3), Garret Cotter (1), Steve Eales (4), Keith Grainge (1), Toby Haynes (1), Michael E. Jones (1), Mark Lacy (3), Guy Pooley (1), Steve Rawlings (3) ((1) MRAO Cambridge UK, (2) Leiden Observatory, (3) Oxford, (4) Cardiff) Comments: 9 pages, LaTeX, 2 PostScript figures. To appear in Astrophysical Journal Letters

In a companion paper (Paper I: Jones et al. 1996) we report the discovery of a cosmic microwave background decrement, indicative of a distant cluster with mass 10^{15} solar masses, towards the quasar pair PC1643+4631A and B (z=3.79,3.83, separation 198”). To search for the cluster responsible, we have obtained R-, J- and K-band images of the field and have also carried out optical spectroscopy of selected objects in it. No such cluster is evident in these images. Assuming the cluster causing the decrement is similar to massive clusters already known, our magnitude limits imply that it must lie about or beyond z=1. This provides independent support for the X-ray-based distance argument of Paper I. The cluster must gravitationally lens objects behind it; for a cluster z around 1-2, the Einstein-ring radius for sources at z = 3.8 is 100”. Simple modelling, producing simultaneously the S-Z effect and the lensing, shows that the source positions of quasars A and B lie within 10” of each other and may indeed be coincident. The two quasar spectra are found to be remarkably similar apart from their one-percent redshift difference. Assuming A and B are images of a single quasar, we present a possible explanation of this difference. (http://xxx.lanl.gov/abs/astro-ph/9611219 , 130kb)

Paper: astro-ph/9606101 From: saust@astro.Princeton.EDU Date: Mon, 17 Jun 1996 13:29:25 -0400 (EDT)

Title: A STATISTICAL INVESTIGATION OF THE CONTAMINATION OF BINARY GRAVITATIONAL LENS CANDIDATES BY CATACLYSMIC VARIABLE Author: Ann B. Saust (Princeton University Observatory) Comments: 11 pages, LaTex, 10 PostScript files, uses aaspp.sty and psfig. Submitted to Astropysical Journal

A common remark at conferences and meetings has been: ”One can fit any light curve with binary lens models because of the large number of parameters!” It is especially tempting to claim that some of the possible binary events in the Galactic microlensing searches could be caused by cataclysmic variables since both phenomena exhibits asymmetric light curves. This paper presents a statistical analysis comparing the light curves of cataclysmic variable stars to the light curves generated from binary lens models. It is shown that the light curves of high amplitude cataclysmic variables are one example of light curves that can not be explained with binary lens models. It is, therefore, not only unlikely, but also impossible that cataclysmic variables can contaminate the binary microlens candidates. (http://xxx.lanl.gov/abs/astro-ph/9606101 , 55kb)

Paper: astro-ph/9607064 From: Sabine Schindler sas@MPA-Garching.MPG.DE Date: Fri, 12 Jul 1996 13:40:28 +0200 (MDT)

Title: ROSAT/HRI STUDY OF THE OPTICALLY RICH, LENSING CLUSTER CL0500-24 Authors: Sabine Schindler, Joachim Wambsganss Comments: 7 pages, including 5 figures, submitted to A and A Report-no: MPE Preprint 370
An analysis of a ROSAT/HRI observation of the optically rich, gravitationally lensing galaxy cluster CL0500-24 (or Abell S0506) is presented. We show that the X-ray luminosity of this supposedly rich cluster is relatively low at $1.1^{+0.2}_{-0.1} \times 10^{44}$ erg/s in the ROSAT band, the bolometric X-ray luminosity is $2.0^{+1.5}_{-0.7} \times 10^{44}$ erg/s. The X-ray emission is strongly correlated with the northern subconcentration of the cluster galaxies at redshift $z = 0.327$. The derived total mass of the (sub-)cluster within 1 Mpc is $(1.5 \pm 0.8) \times 10^{14} \mathrm{M}_{\odot}$, with an upper limit to the gas mass of about $0.5 \times 10^{14} \mathrm{M}_{\odot}$, corresponding to a gas mass fraction of $\leq 30^{+30}_{-10}\%$. The X-ray luminosity and the morphology of the extended X-ray emission supports the view that CL0500-24 consists of two clusters at a velocity difference of $\Delta v \simeq 3200$ km/s that happen to lie along the line of sight. (http://xxx.lanl.gov/abs/astro-ph/9607064 , 217kb)

Paper: astro-ph/9512047 P. Schneider peter@MPA-Garching.MPG.DE Date: Fri, 8 Dec 1995 13:16:00 +0100 (MET)

Title: COSMOLOGICAL APPLICATIONS OF GRAVITATIONAL LENSING Author: Peter Schneider, Max-Planck-Institut für Astrophysik, Garching, Germany Comments: 26 pages, including 2 figures (a third figure can be obtained from the author by request) gziped and uuencoded postscript file; to be published in Proceedings of the Laredo Advanced Summer School, Sept. 95 Report-no: MPA 901
The last decade has seen an enormous increase of activity in the field of gravitational lensing, mainly driven by improvements of observational capabilities. I will review the basics of gravitational lens theory, just enough to understand the rest of this contribution, and will then concentrate on several of the main applications in cosmology. Cluster lensing, and weak lensing, will constitute the main part of this review. (astro-ph/9512047 , 198kb)

Paper: astro-ph/9601039 Peter Schneider peter@MPA-Garching.MPG.DE Date: Wed, 10 Jan 1996 10:03:20 +0100 (MET)

Title: DETECTION OF (DARK) MATTER CONCENTRATIONS VIA WEAK GRAVITATIONAL LENSING Author: Peter Schneider (Max-Planck-Institut f. Astrophysik, Garching, Germany) Comments: 24 pages, Plain-Tex, no macros needed, including 10 figures, submitted to Monthly Notices of the Royal Astronomical Society Report-no: MPA 917
The distortion of images of faint background galaxies by (weak) gravitational lensing can be used to measure the mass distribution of the deflector. The image distortions can be used to define a weighted mean of the mass inside a circular aperture, as was

first suggested by Kaiser. The aperture mass can be used to *detect* dark matter concentrations. Keeping in mind that wide-field cameras will become increasingly available, this method can be used to search for mass concentrations on wide-field images. To do this, the aperture mass measure is generalized to account for different weighting functions. For each such weighting function, a signal-to-noise ratio can be calculated. For an assumed mass profile of the density concentrations, the weighting function can be chosen such as to maximize the resulting signal-to-noise ratio. Numerical simulations which adopt parameters characteristic of 4-m class telescopes are then used to show that dark halos with a velocity dispersion in excess of ~ 600 km/s can be reliably detected as significant peaks in the signal-to-noise map. The effects of seeing and an anisotropic PSF are then investigated and shown to be less important than might be feared. It is thus suggested that the method of aperture mass measures developed here can be used to obtain a mass-selected sample of dark halos, in contrast to flux-selected samples. Shear fields around high-redshift bright QSOs as detected by Fort et al. provide a first successful application of this strategy. The simplicity of the method allows its routine application to wide-field images of sufficient depth and image quality. (astro-ph/9601039 , 157kb)

Paper: astro-ph/9607095 From: Matthias Bartelmann msb@MPA-Garching.MPG.DE Date: Thu, 18 Jul 1996 17:13:22 +0200 (MDT)

Title: APERTURE MULTIPOLE MOMENTS FROM WEAK GRAVITATIONAL LENSING Authors: Peter Schneider and Matthias Bartelmann (Max-Planck-Institut fuer Astrophysik, Garching, Germany) Comments: 14 pages including 3 figures, submitted to MNRAS

The projected mass of a gravitational lens inside (circular) apertures can be derived from the measured shear inside an annulus which is caused by the tidal field of the deflecting mass distribution. Here we show that also the multipoles of the two-dimensional mass distribution can be derived from the shear in annuli. We derive several expressions for these mass multipole moments in terms of the shear, which allow large flexibility in the choice of a radial weight function. In contrast to determining multipole moments from weak-lensing mass reconstructions, this approach allows to quantify the signal-to-noise ratio of the multipole moments directly from the observed galaxy ellipticities, and thus to estimate the significance of the multipole detection. Radial weight functions can therefore be chosen such as to optimize the significance of the detection given an assumed radial mass profile. Application of our formulae to numerically simulated clusters demonstrates that the quadrupole moment of realistic cluster models can be detected with high signal-to-noise ratio S/N; in 85 per cent of the simulated cluster fields S/N ¿ 3. We also show that the shear inside a circular annulus determines multipole moments inside and outside the annulus. This is relevant for clusters whose central region is too bright to allow the observation of the shear of background galaxies, or which extend beyond the CCD.

We also generalize the aperture mass equation to the case of 'radial' weight functions which are constant on arbitrarily-shaped curves which are not necessarily self-similar. (http://xxx.lanl.gov/abs/astro-ph/9607095 , 64kb)

Paper:astro-ph/9507093 From:T. Schramm Schramm@tu-harburg.d400.de
Date: Mon, 24 Jul 1995 12:59:14 MESZ

Title: BELTRAMI EQUATION AND CLUSTER LENSING: CHARACTERISTIC EQUATIONS AND APPLICATIONS Author: Schramm, T Comments: 4 pages latex, 2 figures, uuencoded, compressed tar-file Report-no: RZ-TUHH-240795

Arclets in clusters of galaxies can be used to determine the lens mapping and not only to constrain the mass density of the cluster. Multiply imaged arclets are therefore easily identified without further modelling.

Paper:astro-ph/9601079 From:Carolin Seitz caro@MPA-Garching.MPG.DE
Date: Mon, 15 Jan 1996 08:58:58 +0100 (MET)

STEPS TOWARDS NONLINEAR CLUSTER INVERSION THROUGH GRAVITATIONAL DISTORTIONS: III. INCLUDING A REDSHIFT DISTRIBUTION OF THE SOURCES Authors: Carolin Seitz and Peter Schneider (Max-Planck-Institut f. Astrophysik Garching) Comments: 25 pages, Plain-Tex, no macros needed, including 9 figures, submitted to Astronomy and Astrophysics Report-no: MPA 920

In a series of previous papers we have considered the reconstruction of the surface mass density of a cluster of galaxies from images of lensed faint background galaxies. We showed that the reconstructed surface mass density is not uniquely determined, but that there exists a global invariance transformation that leaves the shape of the images of the lensed galaxies unchanged. Because of this, only lower limits on the total mass of a cluster can be derived if no further informations besides image ellipticities are used. Throughout these papers we used the simplifying assumption that all sources are at the same redshift. In this paper we account for a redshift distribution of the faint galaxies, and in particular, some of these galaxies can lie in front of the cluster or can be cluster members. We show how the mass distribution of a cluster of galaxies can be obtained from images of these faint galaxies, if the redshift distribution of these galaxies is known. We demonstrate that for the reconstruction of non-critical clusters we need less information on the redshift distribution of the galaxies, i.e., we only need to know two or three moments of the distribution. We show that the mean mass density across the data field is still a free variable, i.e., there remains a global invariance transformation of the resulting mass density field. For non-critical clusters we can derive the transformation explicitly and it is similar to that derived previously for the case of a single redshift of the sources. We discuss several theoretical ideas to break the mass degeneracy; of those considered, we find that only the magnification effect on the number density of galaxy images can be used successfully in practice. (astro-ph/9601079 , 181kb)

Paper: astro-ph/9602105 From: squires@magicbean.berkeley.edu (Gordon Squires) Date: Tue, 20 Feb 1996 14:18:04 -0800

Title: A WEAK GRAVITATIONAL LENSING ANALYSIS OF ABELL 2390 Authors: G.Squires, N. Kaiser, G. Fahlman, A. Babul, D. Woods Comments: 14 pages, latex file. Postscript file also available at
ftp://magicbean.berkeley.edu/pub/squires/a2390/massanlight.ps.gz Report-no: CfPA 96-th-07

We report on the detection of dark matter in the cluster Abell 2390 using the weak gravitational distortion of background galaxies. We find that the cluster light and total mass distributions are quite similar over an angular scale of $\simeq 7'$ ($1 Mpc$). The cluster galaxy and mass distributions are centered on the cluster cD galaxy and exhibit elliptical isocontours in the central $\simeq 2'$ ($280 kpc$). The major axis of the ellipticity is aligned with the direction defined by the cluster cD and a "straight arc" located $\simeq 38''$ to the northwest. We determined the radial mass-to-light profile for this cluster and found a constant value of $(320 \pm 90)h \ M_{\odot}/L_{\odot V}$, which is consistent with other published determinations. We also compared our weak lensing azimuthally averaged radial mass profile with a spherical mass model proposed by the CNOC group on the basis of their detailed dynamical study of the cluster. We find good agreement between the two profiles, although there are weak indications that the CNOC density profile may be falling more steeply for $\theta \geq 3'$ ($420 kpc$). (http://xxx.lanl.gov/abs/astro-ph/9602105 , 41kb)

Paper: astro-ph/9603050 From: squires@magicbean.berkeley.edu (Gordon Squires) Date: Tue, 12 Mar 1996 10:14:35 -0800

Title: A WEAK GRAVITATIONAL LENSING AND X-RAY ANALYSIS OF ABELL 2163 Authors: G. Squires, D. M. Neumann, N. Kaiser, M. Arnaud, A. Babul, H. Böhringer, G. Fahlman, and D. Woods Comments: 30 pages, latex file. Postscript file also available at
ftp://magicbean.berkeley.edu/pub/squires/a2163/a2163_paper.ps.gz Report-no: CfPA 96-th-09

We report on the detection of dark matter in the cluster of galaxies Abell 2163 using the weak gravitational distortion of background galaxies, and an analysis of the cluster X-ray emission. We find that while the qualitative distributions of the cluster light and the dark matter are similar – shallow and extended, with significant substructure – the X-ray morphology shows a more regular overall appearance. We interpret the joint lensing and X-ray observations as a signature of a merger event in the cluster. We present new ROSAT/HRI data and reanalyze ROSAT/PSPC data, accounting for the effect of a varying background to determine the best fit parameters in the β-model formalism. We combine the surface brightness fits with two determinations of the radial temperature profile to determine the total mass. Although there are slight variations in the total mass determinations introduced by the uncertainties in the β-fit, the main contributor to the error arises from the uncertainties in the temperature determinations. Even though the morphologies of the dark matter/light and X-ray gas are quite different, we find that the total mass determined from the X-ray and weak lensing estimates are consistent with each other within the 2σ error bars, with the X-ray inferred mass a factor of $\simeq 2$ larger. However, as the lensing mass estimates are differential (the surface density at any point is determined relative to the mean in a control annulus), the shallow, extended nature of the mass profile biases the lensing inferred mass downwards. We estimate the correction for this effect and find very good agreement between the corrected lensing and X-ray results. We determine the gas mass fraction and find $f_g \simeq 0.07h^{-3/2}$ at all radii and a constant mass-to-light ratio of M/L_V (http://xxx.lanl.gov/abs/astro-ph/9603050 , 372kb)

Paper: astro-ph/9609149 From: Albert Stebbins stebbins@perseus.fnal.gov Date: Sun, 22 Sep 1996 17:14:56 -0500

Title: Weak Lensing On the Celestial Sphere Authors: Albert Stebbins Comments: 27 pages, plain TeX, 7 figures, submitted to The Astrophysical Journal, PostScript version with embedded figures available from http://www-astro-theory.fnal.gov/Publications/Pub-96-328-A/ Report-no: FERMILAB-Pub-96/328-A
This paper details a description of the pattern of galaxy image distortion over the entire sky caused by the gravitational lensing which is the result of large scale inhomogeneities in our universe. We present a tensor spherical harmonic formalism to describe this pattern, giving many useful formulae. This is applied to density inhomogeneities, where we compute the angular power spectrum of the shear pattern, as well as the noise properties due to finite galaxy sampling and cosmic variance. We show that a detectable level of shear is present for very nearby galaxies, $z \simeq 0.2$. For such a shallow sample much of the largest signal-to-noise comes from very large angular scales, $\theta > 10°$, although it is in the form of very small shear at a level $\simeq 10^{-3}$. (http://xxx.lanl.gov/abs/astro-ph/9609149 , 257kb)

Paper: astro-ph/9703103 From: Marcus Straessle marcus@physik.unizh.ch Date: Mon, 17 Mar 97 14:12:23 MET (22kb)

Title: Complex Formulation of Lensing Theory and Applications Author: Norbert Straumann (University of Zurich) Comments: 12 pages, REVTeX, two postscript figures included Report-no: ZU-TH 7/97
The elegance and usefulness of a complex formulation of the basic lensing equations is demonstrated with a number of applications. Using standard tools of complex function theory, we present, for instance, a new proof of the fact that the number of images produced by a regular lens is always odd, provided that the source is not located on a caustic. Several differential and integral relations between the mean curvature and the (reduced) shear are also derived. These emerge almost automatically from complex differentiations of the differential of the lens map, together with Stokes' theorem for complex valued 1-forms. (http://xxx.lanl.gov/abs/astro-ph/9703103 , 22kb)

Paper: astro-ph/9611059 From: Will Sutherland w.sutherland1@physics.oxford.ac.uk Date: Thu, 7 Nov 1996 19:47:28 +0000 (GMT)

Title: Gravitational Microlensing Results from MACHO Authors: The MACHO Collaboration: W. Sutherland, C. Alcock, R.A. Allsman, D. Alves, T.S. Axelrod, A.C. Becker, D.P. Bennett, K.H. Cook, K.C. Freeman, K. Griest, J. Guern, M.J. Lehner, S.L. Marshall, B.A. Peterson, M.R. Pratt, P.J. Quinn, A.W. Rodgers, C.W. Stubbs, D.L. Welch Comments: Latex, 12 pages, uses sprocl.sty (included), with 5 Postscript figures. To appear in proceedings of workshop on "Identification of Dark Matter", Sheffield, Sep. 1996

The MACHO project is searching for dark matter in the form of massive compact halo objects (Machos), by monitoring the brightness of millions of stars in the Magellanic Clouds to search for gravitational microlensing events. Analysis of our first 2.3 years of data for 8.5 million stars in the LMC yields 8 candidate microlensing events, well in excess of the $\simeq 1$ event expected from lensing by known low-mass stars. The event timescales range from 34 to 145 days, and the estimated optical depth is $\sim 2x10^{-7}$, about half of that expected from a 'standard' halo. Likelihood analysis indicates the typical lens mass is $0.5^{+0.3}_{-0.2} Msun$, suggesting they may be old white dwarfs. (http://xxx.lanl.gov/abs/astro-ph/9611059 , 150kb)

Paper: astro-ph/9608173 From: Max Tegmark max@mppmu.mpg.de Date: Tue, 27 Aug 1996 12:56:37 +0200

Title: Is lensing of point sources a problem for future CMB experiments? Authors: Max Tegmark and Jens Villumsen Comments: 13 pages, with 3 figures included. Latest version and color figures at

http://www.sns.ias.edu/ max/lensing.html (faster from the US), from http://www.mpa-garching.mpg.de/ max/lensing.html (faster from Europe) or from max@ias.edu

No. Weak gravitational lensing from large-scale structure enhances and reduces the fluxes from extragalactic point sources with an rms amplitude of order 15exceeding some flux threshold are removed, which means that lensing will modulate the brightness map of the remaining unresolved sources. Since this mean brightness is of order 100 micro-Kelvin at 30 GHz for a reasonable flux cut, one might be concerned that this modulation could cause substantial problems for future CMB experiments. We present a detailed calculation of this effect and, fortunately, find that its power spectrum is always smaller than the normal point source power spectrum. Thus although this effect should be taken into account in a detailed CMB analysis, it will not substantially reduce the accuracy with which cosmological parameters can be measured. (http://xxx.lanl.gov/abs/astro-ph/9608173 , 55kb)

Paper: astro-ph/9608173 replaced with revised version Wed, 26 Mar 1997 17:41:02 +0100

Title: Is lensing of point sources a problem for future CMB experiments? Authors: Max Tegmark, Jens Villumsen Comments: Expanded to match published version. 14 pages, with 3 figures included. Color figures at http://www.sns.ias.edu/ max/lensing.html (faster from the US), from http://www.mpa-garching.mpg.de/ max/lensing.html (faster from Europe) or from max@ias.edu (http://xxx.lanl.gov/abs/astro-ph/9608173 , 58kb)

Paper: astro-ph/9702084 From: Philippe Jetzer jetzer@sonne.physik.unizh.ch Date: Mon, 10 Feb 1997 14:13:47 +0100 (7kb)

Title: Achromatic variability in the BL Lac object PKS 2155-304. A case for microlensing? Authors: A. Treves, F. Rovetti, Ph. Jetzer and C.M. Urry Comments: 11 pages, no figures, Latex

PKS 2155-304 is the only BL Lac object for which well-sampled multiwavelength light curves resolve the intraday variability at UV and X-ray wavelengths. In particular we focus on the multifrequency campaign of November 1991, which showed a rather exceptional behaviour of the source exhibiting substantial achromatic variability from optical to X-ray wavelengths. We suggest a scenario for this unique event, where the variability is due to microlensing. The relativistic motion of the source relative to the lens is taken into account. The lenses are proposed to be solar-mass stars in an intervening dwarf galaxy. The a priori probability of detecting a microlensing event, however, was only few percent, small but not negligible. (http://xxx.lanl.gov/abs/astro-ph/9702084 , 7kb)

Paper: astro-ph/9601168 From: Geza Gyuk gyuk@oddjob.uchicago.edu Date: Mon, 29 Jan 1996 17:09:39 -0600

Title: MACHOs: THE PLOT THICKENS Authors: Michael S. Turner, Evalyn I. Gates and Geza Gyuk Comments: 6 pages, two figures, postscript Report-no: FERMILAB–Pub–96/022-A

We discuss the implications of the recent upward revision of the LMC microlensing rate by the MACHO Collaboration. We conclude: (i) A good case for the existence of baryonic dark matter in the halo has been made; (ii) The case for the existence of cold dark matter is unaffected and still compelling; and (iii) The Galactic halo is still an excellent place to search for cold dark matter particles (e.g., axions or neutralinos). (http://xxx.lanl.gov/abs/astro-ph/9601168 , 31kb)

Paper: astro-ph/9601113 From: E.Kampen@roe.ac.uk Date: Mon, 22 Jan 96 15:25:22 GMT

Title: THE AMPLITUDE OF THE INITAIL DENSITY FLUCTUATION SPECTRUM FROM LRNSING STATISTICA" Authors: Eelco van Kampen (Royal Observatory Edinburgh, U.K.) Comments: 6 pages including 3 figures, gzip'ed and uuencoded Postscript, To appear in proceedings "Mapping, Measuring and Modelling the Universe", Valencia 1995, eds. P. Coles and V. Martinez

A complete catalogue of galaxy cluster models can be used to constrain cosmological parameters like σ_8, the amplitude of the initial density fluctuation spectrum. We focus here on two strong lensing statistics for clusters of galaxies: the fraction of rich Abell clusters that are critical to lensing, and the abundance of arcs in such clusters, especially the X-ray luminous ones. The specific aim of this paper is to constrain σ_8 for the standard Cold Dark Matter scenario within an Einstein-de Sitter universe. (http://xxx.lanl.gov/abs/astro-ph/9601113 , 109kb)

Paper: astro-ph/9606100 From: waerbeke@srvdec.obs-mip.fr (p'ti lu) Date: Mon, 17 Jun 1996 16:53:06 +0200

Title: WEAK LENSING AS A PROBE OF DARK MATTER Authors: L. Van Waerbeke (OMP, Toulouse, France) and Y. Mellier (IAP, Paris, France) Comments: 8 pages, Latex with 2 included postscript figures, 1 55kB JPEG figure (also available as (1.1MB) compressed ps file from anonymous ftp at ftp://summer.obs-mip.fr/pub/OUTGOING/ludo/simul.ps.Z), to be published in the proceedings of the XXXIst Rencontres de Moriond, Les Arcs, France, January 20-27 1996

Weak gravitational lensing of distant galaxies can probe the total projected mass distribution of foreground gravitational structures on all scales and has been used successfully to map the projected mass distribution of rich intermediate redshift clusters. This paper reviews the general concepts of the lensing analysis. We focus on the relation between the observable (shapes and fluxes) and physical (mass, redshift) quantities and discuss some observational issues and recent developments on data analysis which appear promising for a better measurement of the lensing signatures (distortion and magnification) at very large scales. (http://xxx.lanl.gov/abs/astro-ph/9606100 , 74kb)

Paper: astro-ph/9604137 From: waerbeke@srvdec.obs-mip.fr (p'ti lu) Date: Tue, 23 Apr 1996 17:05:32 +0200 (MET DST)

Title: THE AUTO-CORRELATION FUNCTION OF THE EXTRAGALACTIC BACKGROUND LIGHT: I. MEASURING GRAVITATIONAL SHEAR Authors: L. Van Waerbeke (1) Y. Mellier (1,2,3) P. Schneider (4) B. Fort (3) G. Mathez (1) ((1) Observatoire Midi-Pyrenees LAT URA 285, (2) Institut d'Astrophysique de Paris, (3) DEMIRM, Observatoire de Paris, (4) Max-Planck-Institut für Astrophysik.) Comments: 14 pages, A and A macros (l-aa.sty), postscript figs available from anonymous ftp at ftp://summer.obs-mip.fr/pub/OUTGOING/ACFfigs, Submitted to Astronomy and Astrophysics Main Journal

A new method for measuring the shear induced by gravitational light deflection is proposed. It is based on analyzing the anisotropy induced in the auto-correlation function (ACF) of the extragalactic background light which is produced by very faint distant galaxies. The ACF can be measured 'locally', and its anisotropy is caused by the tidal gravitational field of the deflecting mass distribution in the foreground of these faint background galaxies. Since the method does not require individual galaxy detection, it can be used to measure the shear of extremely faint galaxies which are not detectable individually, but are present in the noise. The shear estimated from the

ACF of the noise provides an independent measurement which can be compared to the shear obtained from the distortion of individual galaxy images. Combining these two independent estimates clearly increases the sensitivity of shear measurements. In addition, our method may allow to determine the local magnification caused by the deflector if the auto-correlation function is caused by a large number density of faint galaxies; in this case, the intrinsic ACF may provide a 'standard source' with respect to which shear and magnification can be obtained. Applications to real and synthetic data are shown and the feasibility of our new method is demonstrated. In particular, we present the shear maps obtained with our method for the double QSO 2345+007 and the cluster Cl0024+16 and compare them to published shear maps. (http://xxx.lanl.gov/abs/astro-ph/9604137 , 36kb)

Paper: astro-ph/9605113 From: jmq@gamma.uchicago.edu (Jean M. Quashnock) Date: Fri, 17 May 96 16:59:18 CDT

Title: AN EXCESS OF CIV ABSORBERS IN LUMINOUS QSOS: EVIDENCE FOR GRAVITATIONAL LENSING? Authors: Daniel E. Vanden Berk, Jean M. Quashnock, Donald G. York, (Dept. of Astronomy and Astrophysics, U. Chicago), and Brian Yanny (Fermilab) Comments: 21 LaTeX pages with 5 encapsulated Postscript figures included, uses AASTeX (v. 4.0) available at ftp://ftp.aas.org/pubs/ , to appear in The Astrophysical Journal, Sept. 20, 1996

We have compiled a new and extensive catalog of heavy-element QSO absorption line systems and analyzed the distribution of absorbers in bright and faint QSOs, to search for gravitational lensing of background QSOs by the matter associated with the absorbers. There is a highly significant excess of C IV absorbers in bright QSOs in the redshift range $z = 1.2 - 3.2$, and this excess increases strongly as a function of QSO absolute magnitude. No significant excess is found for Mg II absorbers in the redshift range $z = 0.30 - 1.55$. We rule out several possible reasons for this effect and argue that the C IV excess could be due to gravitational lensing. If so, then the lensing masses must be at $z \geq 1.5$ and within several hundred comoving Mpc of the QSOs, where the C IV absorbers are mainly found. The absence of an excess in the available Mg II sample would then arise because the Mg II data does not sample this region of space. (http://xxx.lanl.gov/abs/astro-ph/9605113 , 202kb)

Paper: astro-ph/9606084 From: Jens Villumsen jens@MPA-Garching.MPG.DE Date: Thu, 13 Jun 1996 18:07:41 +0200

Title: CLUSTERING OF GALAXIES IN THE HUBBLE DEEP FIELD Authors: Jens V. Villumsen (Max-Planck-Institut für Astrophysik), Wolfram Freudling (Space Telescope–European Coordinating Facility and European Southern Observatory), Luiz N. da Costa(European Southern Observatory and Observatorio Nacional, Rio de Janeiro, Brazil) Comments: 9 pages, Latex, [aas2pp4], 5 Postscript figures. Figures obtainable via anonymous FTP from ftp://ecf.hq.eso.org/pub/preprints/hdf Submitted to Astrophysical Journal. jens@mpa-garching.mpg.de

We compute the two-point angular correlation function w for a sample of ~ 1700 galaxies to a magnitude-limit equivalent of $R \sim 29.5$ using a catalog derived from the Hubble Deep Field images. A non zero value of w is measured down to $R = 29.0$. The amplitude of w at the bright magnitude limit, ($R \sim 26$), is consistent with previous ground-based observations. At fainter magnitudes the clustering amplitude continues to decrease but at a slower rate than that predicted by the power law $w(1'') \propto 10^{-0.27R}$ observed for shallower samples. The observed w over the magnitude range $20 < R < 29$ is consistent with linear evolution of the clustering of a galaxy population which at present has a correlation length r_0 of about 4 h1 Mpc, close to that of local *IRAS* galaxies. We also investigate the impact that magnification bias induced by weak gravitational lensing may have on our results. Although the observed amplitude of w can differ from the true amplitude by up to 30%, this effect is not large enough to affect our conclusions. Finally, by using a color-selected sample we examine whether the expected effects of magnification bias can be used for an independent determination of cosmological parameters in deep images. We conclude that the amplitude of the effect can be large and in some cases even produce an upturn of the amplitude of the correlation with limiting magnitude. However, we conclude that from the observed w, it is not possible to unequivocably detect the effects of magnification bias. We suggest that with redshift information, it is possible to measure the effects of magnification bias directly and thus have an alternative way of constraining Ω_0/b, where Ω_0 is the density parameter and b is the biasing factor. (http://xxx.lanl.gov/abs/astro-ph/9606084 , 14kb)

Paper:astro-ph/9512001 From:J. Villumsen jens@MPA-Garching.MPG.DE Date: Fri, 1 Dec 1995 16:08:42 +0100 (MET)

Title: CLUSTERING OF FAINT GALAXIES: ?? INDUCED BY WEAK GRAVITATIONAL LENSING Author: Jens Verner Villumsen (Max Planck Institute fur Astrophysik, Garching, Germany) Comments: 11 pages, 2 figures, Submitted to: Monthly Notices of the Royal Astronomical Society

Weak gravitational lensing by large scale structure affects the number counts of faint galaxies through the "magnification bias" and thus affects the measurement of the angular two-point correlation function ??. At faint magnitudes the clustering amplitude will decrease differently with limiting magnitude than expected from Limber's equation. The amplitude will hit a minimum and then rise with limiting magnitude. This behavior occurs because ?? due to clustering decreases with distance, while the "magnification bias" due to weak lensing increases with distance. The apparent magnitude m_{min} at which the magnification bias starts to dominate the observed clustering is model and color dependent. It is given by $\omega(m = m_{min}, \theta = 5') \simeq (1 - 2) \times 10^{-3}(5s-2)^2\Omega_0^2\sigma_8^2$, where s is the logarithmic slope of the number counts. Already published measurements of ?? at $R = 25$ may be strongly influenced by the "magnification bias". An experiment using the ratio of blue and red number counts across the sky can be designed such that the effects of the "true" clustering is minimized. The magnification bias is a measurement of the clustering of the mass. This weak lensing experiment does not require measuring shapes and position angles of galaxies. I derive a revised Limber's Equation including the effects of magnification bias. (astro-ph/9512001 , 47kb + 38kb)

Paper:astro-ph/9511137 From:Chris Kochanek kochanek@cfa.harvard.edu Date: Tue, 28 Nov 1995 09:03:05 -0500

Title: LensMEM: A GRAVITATIONAL LENS INVERSION ALGORITHM USING THE MAXIMUM ENTROPY METHOD Author: S. Wallington, C.S. Kochanek and R. Narayan (Harvard-Smithsonian Center For Astrophysics) Comments: 27 pages, uuencoded, gzip compressed postscript

We present a new algorithm for inverting poorly resolved gravitational lens systems using the maximum entropy method (MEM). We test the method with simulations and then apply it to an 8 GHz VLA map of the radio ring lens MG1654+134. We model the lens as a singular isothermal sphere embedded in an external shear field and find the critical radius of the lens is $b = 0 parcs$, the dimensionless shear is $\gamma = 0.0771$, and the position angle of the shear is $\theta = 100 deg$. These results are consistent with the results obtained by Kochanek (1995) using a complementary inversion algorithm based on Clean. (astro-ph/9511137 , 211kb)

Paper: astro-ph/9610096 From: Joachim Wambsganss jwambsganss@aip.de Date: Mon, 14 Oct 1996 15:39:54 +0100

Title: Testing Cosmological Models by Gravitational Lensing: I. Method and First Applications Authors: Joachim Wambsganss(1,2), Renyue Cen(2) and Jeremiah P. Ostriker (2) (1-Astrophysikalisches Institut Potsdam, 2-Princeton University Observatory) Comments: submitted to ApJ; 25 pages plus 11 Figures (partly in JPEG/GIF format due to size constraints). Postscript files of all figures can be downloaded at http://astro.princeton.edu/ cen/LENS_METHOD/lens_method.html (USA) or

http://www.aip.de:8080/ jkw/method_figures.html (Germany). Hardcopies of the (color) figures can be obtained on request by J.W

Gravitational lensing directly measures mass density fluctuations along the lines of sight to very distant objects. No assumptions need to be made concerning bias, the ratio of fluctuations in galaxy density to mass density. Hence, lensing is a very useful tool to study the universe at low to moderate redshifts. We describe in detail a new method to trace light rays from redshift zero through a three dimensional mass distribution to high redshift. As an example, this method is applied here to a standard cold dark matter universe. We obtain a variety of results, some of them statistical in nature, others from rather detailed case studies of individual "lines of sight". Among the former are the frequency of multiply imaged quasars, the distribution of separation of the multiple quasars, and the redshift distribution of lenses: all that as a function of quasar redshift. We find effects from very weak lensing to highly magnified multiple images of high redshift objects, which, for extended background sources, (i.e.

galaxies), range from slight deformations of the shapes through tangentially aligned arclets up to giant luminous arcs. Different cosmological models differ, increasingly with redshift, in their predictions for the mass (thus gravitational potential) distributions. Our ultimate goal is to apply this method to a number of cosmogonic models and to eliminate some models whose gravitational lensing properties are inconsistent with those observed. (http://xxx.lanl.gov/abs/astro-ph/9610096 , 459kb)

Paper: astro-ph/9605140 From: Yun Wang ywang@fnas07.fnal.gov Date: Wed, 22 May 1996 17:41:15 -0500

Title: GRAVITATIONAL LENSING OF GRAVITATIONAL WAVES FROM MERGING NEUTRON STAR BINARIES Authors: Yun Wang, Albert Stebbins, and Edwin L. Turner Comments: REVTeX, 13 pages including 3 figures. Submitted to Phys. Rev. Lett Report-no: Fermilab-Pub-96/091-A

We discuss the gravitational lensing of gravitational waves from merging neutron star binaries, in the context of advanced LIGO type gravitational wave detectors. We consider properties of the expected observational data with cut on the signal-to-noise ratio ρ, i.e., $\rho > \rho_0$. An advanced LIGO should see unlensed inspiral events with a redshift distribution with cut-off at a redshift $z_{\rm max} < 1$ for $h \leq 0.8$. Any inspiral events detected at $z > z_{\rm max}$ should be lensed. We compute the expected total number of events which are present due to gravitational lensing and their redshift distribution for an advanced LIGO in a flat Universe. If the matter fraction in compact lenses is close to 10%, an advanced LIGO should see a few strongly lensed events per year with $\rho > 5$. (http://xxx.lanl.gov/abs/astro-ph/9605140 , 36kb)

Paper: astro-ph/9607076 From: Yun Wang ywang@fnas07.fnal.gov Date: Mon, 15 Jul 96 19:38:10 -0500

Title: STATISTICS OF EXTREME GRAVITATIONAL LENSING EVENTS. II.THE SMALL SHEAR CASE Authors: Yun Wang (Fermilab) and Edwin L. Turner (Princeton) Comments: 17 pages including 3 figures, using AAS LATEX macros v4.0. Submitted to ApJ Report-no: FERMILAB-Pub-96/060-A

We consider an astrophysical system with a population of sources and a population of lenses. For each pair of source and lens, there is a thin on-axis tube-like volume behind the lens in which the radiation flux from the source is greatly increased due to gravitational lensing. Any objects (such as dust grains) which pass through such a thin tube will experience strong bursts of radiation, i.e., Extreme Gravitational Lensing Events (EGLE). We study the physics and statistics of EGLE for the case in which the shear is larger or comparable to the finite source size. We find that the presence of shear has only a small effect on the EGLE statistics. (http://xxx.lanl.gov/abs/astro-ph/9607076 , 50kb)

Paper: astro-ph/9701230 From: ywang@astro.Princeton.EDU Date: Wed, 29 Jan 1997 19:27:26 -0500 (EST) (7kb)

Title: Astrophysical Effects of Extreme Gravitational Lensing Events Authors: Yun Wang and Edwin L. Turner (Princeton) Comments: 3 pages including 1 figure, LaTeX. To appear in the Proceedings of the 18th Texas Symposium, World Scientific Press (editors A. Olinto, J. Frieman, and D. Schramm)
Every astrophysical object (dark or not) is a gravitational lens, as well as a receiver/observer of the light from sources lensed by other objects in its neighborhood. For a given pair of source and lens, there is a thin on-axis tubelike volume behind the lens in which the radiation flux from the source is greatly increased due to gravitational lensing. Any objects which pass through such a thin tube or beam will experience strong bursts of radiation, i.e., Extreme Gravitational Lensing Events (EGLEs). We have studied the physics and statistics of EGLEs. EGLEs may have interesting astrophysical effects, such as the destruction of dust grains, ignition of masers, etc. Here we illustrate the possible astrophysical effects of EGLEs with one specific example, the destruction of dust grains in globular clusters. (http://xxx.lanl.gov/abs/astro-ph/9701230 , 7kb)

Paper: astro-ph/9702078 From: ywang@astro.Princeton.EDU Date: Sun, 9 Feb 1997 19:33:31 -0500 (EST) (105kb)
Title: Caustics, Critical Curves and Cross Sections for Gravitational Lensing by Disk Galaxies Authors: Yun Wang and Edwin L. Turner (Princeton) Comments: 31 pages including 15 figure, LaTeX
We study strong gravitational lensing by spiral galaxies, modeling them as infinitely thin uniform disks embedded in singular isothermal spheres. We derive general properties of the critical curves and caustics analytically. The multiple-image cross section is a sensitive function of the inclination angle of the disk relative to the observer. We compute the inclination averaged cross section for several sets of lensing parameters. For realistic disk mass and size parameters, we find that the cross section for multiple imaging is increased by only a modest factor and *no* dramatic increase in the optical depth for strong lensing of QSOs would be expected. However, the cross section for high magnifications is significantly increased due to the inclusion of a disk, especially for nearly edge-on configurations; due to the strong observational selection effects favoring high magnifications, there might be significant consequences for lensing statistics. (http://xxx.lanl.gov/abs/astro-ph/9702078 , 105kb)

Paper: astro-ph/9608044 From: swhite@iris-6.MPA-Garching.MPG.DE (Simon White) Date: Fri, 9 Aug 1996 19:07:16 +0200
Title: Large-scale structure at high redshift Author: Simon D.M. White (MPA, Garching) Comments: 12 pages. Invited review for the ESO Workshop on "The Early Universe with the VLT" 1-4 April 1996. The three colour figures are available at high resolution from http://www.mpa-garching.mpg.de/ swhite
I discuss and illustrate the development of large-scale structure in the Universe, emphasising in particular the physical processes and cosmological parameters that most

influence the observationally accessible aspects of structure at large redshift. Statistical properties of this structure can be measured from the apparent positions of faint galaxies and quasars; the structure can be mapped in three dimensions by obtaining redshifts for large samples of such objects; it can be studied using foreground absorption in the spectra of quasars; finally the mass distribution can be constrained by measuring the gravitationally induced distortion of background galaxy images. The first and last of these techniques require deep imaging of large areas of the sky with the best possible image quality. The second and third will require 8m-class telescopes with efficient multiobject spectrographs. For QSO absorption line spectroscopy high spectral resolution is also important. (http://xxx.lanl.gov/abs/astro-ph/9608044 , 22kb)

Paper: astro-ph/9701246 From: llrw@ast.cam.ac.uk (Liliya L.R. Williams) Date: Thu, 30 Jan 1997 21:55:09 GMT (74kb)

Title: Distortion of gamma-ray burst light curves by gravitational microlensing Authors: L. L. R. Williams and R. A. M. J. Wijers (Institute of Astronomy, Cambridge, UK) Comments: 6 pages when LaTex'ed, with 5 figures included Accepted to MNRAS

If at cosmological distances, a small fraction of gamma-ray bursts should be multiply imaged by intervening galaxies or clusters, resulting in the appearance of two very similar bursts from the same location with a relative time delay of hours to a year. We show that microlensing by individual stars in the lensing galaxy can smear out the light curves of the multiply imaged bursts on millisecond time scales. Therefore, in deciding whether two bursts are similar enough to qualify as multiple images, one must look at time scales longer than a few tens of milliseconds, since shorter time scales are possibly rendered dissimilar by microlensing. (http://xxx.lanl.gov/abs/astro-ph/9701246 , 74kb) Paper: astro-ph/9701246 replaced with revised version Mon, 3 Feb 1997 22:31:32 GMT

Title: Distortion of gamma-ray burst light curves by gravitational microlensing Authors: L. L. R. Williams and R. A. M. J. Wijers (Institute of Astronomy, Cambridge, UK) Comments: 6 pages when LaTex'ed, with 5 figures included Accepted to MNRAS; replaced version contains psfigure.tex file, since psfig.tex was causing problems (no changes in the text or figures of the paper) (http://xxx.lanl.gov/abs/astro-ph/9701246 , 84kb)

Paper: astro-ph/9702021 From: Hans Joerg Witt hwitt@aip.de Date: Mon, 3 Feb 97 13:45:01 +0100 (44kb)

Title: Probing the Structure of Lensing Galaxies with Quadruple Lenses: The Effect of the "External" Shear Author: Hans J. Witt (Astrophysical Institute Potsdam) and Shude Mao (MPA, Garching) Comments: 16 pages including 3 Postscript figures, uses MN-Latex, submitted to MNRAS

We study a general elliptical potential of the form $\psi(x^2 + y^2/q^2)$ $(0 < q \leq 1)$ plus an additional shear (with an arbitrary direction) as models for the observed quadruple lenses. It is shown that a minimum additional shear is needed even just to reproduce the observed positions alone. We also obtain the dependence of the axial ratio, q, on the orientation of the major axis of potential. A general relation also exists between the shear, the position angle and axial ratio of the lensing galaxy. The relation shows a generic degeneracy in modelling quadruple lenses. In particular, it shows that only the ratio of the ellipticity, $\epsilon \equiv (1-q^2)/(1+q^2)$, to the magnitude of shear, γ can be determined. All these results are valid regardless of the radial profile of the potential. Our formalism applies when the galaxy position is observed, which is the case for seven of the eight known quadruple lenses. Application to these seven cases reveals two quadruple lenses CLASS 1608+656 and HST 12531-2914, requiring highly significant shear with magnitude ≈ 0.2. For HST 12531-2914, there must be a misalignment between the major axis of light and the major axis of potential (mass). We conclude that detailed modelling of quadruple lenses can yield valuable quantitative information about the shape of lensing galaxies and their dark matter halos. (http://xxx.lanl.gov/abs/astro-ph/9702021 , 44kb)

Paper: astro-ph/9702194 From: wozniak@astro.Princeton.EDU Date: Fri, 21 Feb 1997 15:32:14 -0500 (EST) (191kb)

Title: Microlensing of Blended Stellar Images Author: Przemyslaw Wozniak, Bohdan Paczynski (Princeton University Observatory, USA) Comments: 16 pages, 6 figures, Latex, aaspp4 Report-no: POP710

The current modelling of single microlensing light curves neglects the possibility that only a fraction of the light is due to the lensed star, the remaining being due to a close, unresolved blend, which may be related or unrelated to the lens. Unfortunately, the effects of blending are significant as all microlensing experiments choose very crowded fields as their targets. In this paper we point out a strong degeneracy of the fitting procedure which makes it practically impossible to detect the presence of a blend by purely photometric means, except in a small part of the parameter space. Some blends may be detected by astrometric means, but the majority have to be corrected for statistically. The luminosity function reaching well below the ground based detection limit (with the HST) would be very also important and this could be determined with the repeating microlensing events. If no correction is made then the event time scales, the lens masses, and the optical depth are all systematically underestimated. (http://xxx.lanl.gov/abs/astro-ph/9702194 , 191kb)

Paper: astro-ph/9512110 Xiang-Ping Wu wu@time.physics.arizona.edu Date: Sun, 17 Dec 1995 14:42:45 -0700 (MST)

Title: GRAVITATIONAL LENSING IN THE UNIVERSE Author: Xiang-Ping Wu Comments: Latex file, 55 pages, 32 figures (not included). Fundamentals of Cosmic Physics, in press

This work reviews the basic theoretical aspects, the main observational evidences and the recent applications of gravitational lensing in the Universe. The article is aimed particularly at providing the readers who don't work on gravitational lensing a relatively easy introduction to this active research field in today's astrophysics. (astro-ph/9512110 , 208kb)

Paper: astro-ph/9701196 From: wxp@bao01.bao.ac.cn Date: Sat, 25 Jan 1997 17:30:13 +0800

Title: A Statistical Comparison of Cluster Mass Estimates from Optical/X-ray Observations and Gravitational Lensing Authors: Xiang-Ping Wu and Li-Zhi Fang Comments: 18 pages plus 4 figures, using aastex. To appear in ApJ
We present a statistical comparison of three different estimates of cluster mass, namely, the dynamical masses obtained from the velocity dispersion of optical galaxies, the X-ray masses measured from the temperature of X-ray emitting gas under the assumption of isothermal hydrostatic equilibrium, and the gravitational lensing masses derived from the strong/weak distortions of background galaxy images. Using a sample of 29 lensing clusters available in literature, we have shown that the dynamical masses are in agreement with the gravitational lensing masses, while the X-ray method has systematically underestimated cluster masses by a factor 2-3 as compared with the others. These results imply that galaxies indeed trace the gravitational potential of their clusters, and there is no bias between the velocities of the dark matter particles and the galaxies in clusters. The X-ray cluster mass discrepancy is probably from the simplification in the models for the X-ray gas distribution and dynamical evolution. (http://xxx.lanl.gov/abs/astro-ph/9701196 , 22kb)

Paper: astro-ph/9508146 HongSheng Zhao hsz@MPA-Garching.MPG.DE Date: Wed, 30 Aug 1995 21:35:14 +0200

Title: A SELF-CONSISTENT DYNAMICAL MODEL FOR THE COBE OBSERVED GALACTIC BAR AND ITS APPLICATION TO MICROLENSING Author: HongSheng Zhao Comments: 6 pages, 2 figures, compressed and uuencoded. Contributed talk at IAU symposium 157, "Barred Galaxies"
A self-consistent stellar dynamical model for the Galactic bar is constructed from about 500 numerically computed orbits with an extension of the Schwarzschild technique. The model fits the *COBE* found asymmetric boxy light distribution and the observed stellar kinematics of the bulge. The model potential is also consistent with the non-circular motions of the HI and CO velocity maps of the inner Galaxy. We also use the stellar bar model to construct a N-body model to study stability and a microlensing map towards the bulge, which can account for the observed optical depth and the event duration by the MACHO and OGLE collaborations. The technique used here can be applied to interpret light and velocity data of external bulges/bars and galactic nuclei.

Paper: astro-ph/9606166 From: HongSheng Zhao hsz@strw.LeidenUniv.nl Date: Thu, 27 Jun 1996 12:39:52 +0200

Title: POSSIBLE IMPLICATIONS OF SAGITTARIUS TYPE DWARF GALAXY ON MICROLENSING TOWARDS THE LARGE MAGELLANIC CLOUDS Towards the Large Magellanic Cloud Authors: HongSheng Zhao (Sterrewacht Leiden and MPA-Garching) Comments: 3 pages in Latex, compressed uuencoded, no figure. Submitted to MNRAS

The discovery of the Sgr dwarf galaxy shows that the Galactic halo contains large clumps which are not full viralized. This may change implications of observed microlensing events towards the LMC. If more than one such systems are hidden in the Galactic halo, then given their enormous angular size, there is a significant chance for *any* line of sight, say the LMC direction, to intersect one of them. I use parameters of the Sgr dwarf galaxy to demonstrate that a foreground dwarf galaxy can provide much more micro-lenses than an isothermal dark halo of massive compact objects (MACHOs). As an alternative to the half-MACHO dark halo model, I discuss a model with lenses of the observed events being faint stars in a hidden Sgr-like disintegrated dwarf galaxy in the line-of-sight path to the LMC. (http://xxx.lanl.gov/abs/astro-ph/9606166 , 7kb)

Paper: astro-ph/9703097 From: HongSheng Zhao hsz@strw.LeidenUniv.nl Date: Fri, 14 Mar 1997 19:14:35 +0100 (17kb)

Title: Microlensing of tidal debris on the Magellanic great circle Authors: HongSheng Zhao (Leiden) Comments: 18 pages no figure

Increasing evidences suggest that the Galactic halo is lumpy on kpc scales due to the accretion of at least a dozen small galaxies (LMC/SMC, Sgr, Fornax etc.). Faint stars in such lumpy structures can significant microlense a background star with an optical depth $10^{-7} - 10^{-6}$, which is comparable to the observed value to the LMC (Alcock et al. 1996c). The observed several microlensing events towards the LMC can be explained by a tidal debris tail lying in the Magellanic plane if the progenitor of the Magellanic Clouds and Stream and other satellite galaxies in the Magellanic plane has a mass about twice that of the disc of the LMC. Two classes of models are studied: the LMC stars can either lense stars in the debris tail behind the LMC, or be lensed by stars in the part of debris tail in front of the LMC. The models are consistent with an elementary particle dominated Galactic halo without massive compact halo objects (MACHOs). They also differ from Sahu's (1994) LMC-self-lensing model by predicting a higher optical depth and event rate and less concentration of events to the LMC center. (http://xxx.lanl.gov/abs/astro-ph/9703097 , 17kb)

Paper: astro-ph/9605030 From: HongSheng Zhao hsz@MPA-Garching.MPG.DE Date: Wed, 8 May 1996 00:26:58 +0200

Title: ON THE MICROLENSING OPTICAL DEPTH OF THE GALACTIC BAR Authors: HongSheng Zhao and Shude Mao (MPA-Garching) Comments: 28 pages including 6 postscript figures in uuencoded compressed tar file. Submitted to MNRAS Report-no: MPAxxx

The microlensing probability (optical depth τ) toward the Galactic center carries information about the mass distribution of the Galactic bulge/bar, so can be used to constrain the very uncertain shape parameters of the bar. We find tau depends on the bar mass, radial profile, angle, axis scale lengths and boxyness by a few simple analytical formulae, which shows: (1) τ is proportional to the mass of the bar, M. (2) τ falls along the minor axis with a strong gradient. (3) An oblate bulge can have more optical depth than a triaxial bar if the bar angle $\alpha > 45$ degress. (4) τ is the largest if the angle α and the axis ratio y_0/x_0 conspires so that $y_0/x_0 = \tan\alpha$. (5) At a fixed field on the minor axis but away from the center, boxy bars with a flat density profile tend to give a larger optical depth than ellipsoidal bars with a steep profile. (6) Main sequence sources should have a significantly lower (20-50% lower) optical depth than red clump giants if main sequence stars are not observed as deep as the bright clump giants. An application to four COBE-constrained models (Dwek et al. 1994) shows most models produce optical depth 2σ lower than MACHO and OGLE observed values even with both a massive bar $2.8 \times 10^{10} M_\odot$ and a full disk. The high τ argues for a massive ($> 2 \times 10^{10} M_\odot$) boxy bar with $y_0/x0 \simeq \tan\alpha$ and $\alpha < 20$ deg and with a flat radial profile up to corotation. (http://xxx.lanl.gov/abs/astro-ph/9605030 , 97kb)

Paper: astro-ph/9702159 From: Zong-Hong Zhu zzh@class2.bao.ac.cn Date: Wed, 19 Feb 1997 12:35:32 +0800 (CST) (4kb)

Title: A remark on the inversion of the magnification bias in the quasar-galaxy associations Authors: Zong-Hong Zhu and Xiang-Ping Wu Comments: 3 pages, no figure, A&A in press

We present an alternative but intuitive method of obtaining the true or intrinsic quasar luminosity function through the observed one in the framework of gravitational lensing. Such a so-called inversion of the magnification bias can be straightforwardly performed by means of the Mellin transformation instead of other complex methods. Application of our approach to the well-known form of the observed quasar luminosity function identifies the previous results in literature. (http://xxx.lanl.gov/abs/astro-ph/9702159 , 4kb)