GRAVITATIONAL LENSING OBSERVATIONS OF QUASARS WITH THE 4-m ILMT

Talat Akhunov[1,2], Bhavya Ailawadhi[3,4], Ermanno Borra[5], Monalisa Dubey[1,6], Naveen Dukiya[1,6], Jiuyang Fu[7], Baldeep Grewal[7], Paul Hickson[7], Brajesh Kumar[1], Kuntal Misra[1], Vibhore Negi[1,2], Kumar Pranshu[3,8], Ethen Sun[7], Jean Surdej[9]

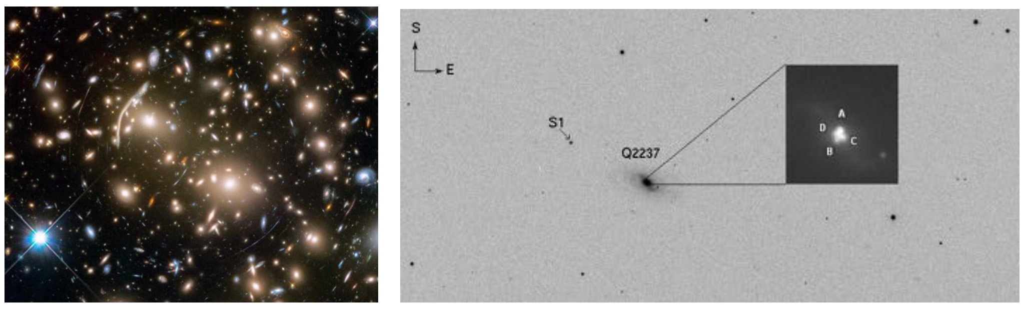
[1]National University of Uzbekistan, Tashkent, Uzbekistan
[2]Ulugh Beg Astronomical Institute, Tashkent, Uzbekistan
[3]Aryabhatta Research Institute of Observational sciencES, Nainital, India
[4]Deen Dayal Upadhyay Gorakhpur University, Gorakhpur, India
[5]Laval University, Quebec, Canada
[6]Mahatma Jyotiba Phule Rohilkhand University, Bareilly, India
[7]University of British Columbia, Vancouver, Canada
[8]University of Calcutta, Kolkata, India
[9]Institute of Astrophysics and Geophysics, Liège University, Belgium

Abstract

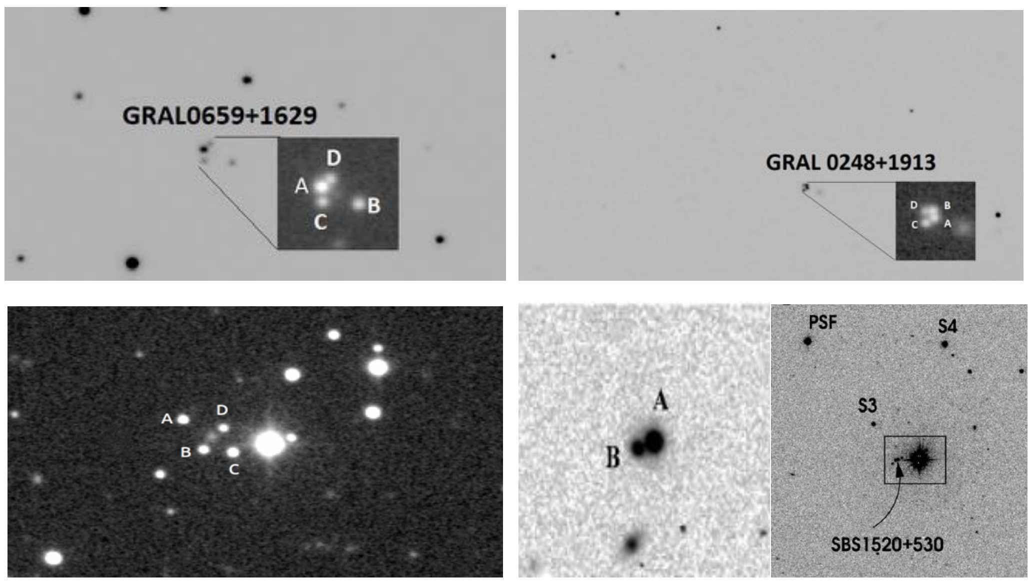
Gravitational lensing may enrich our view of the distant Universe and affect our physical understanding of various classes of extragalactic objects. The great interest in gravitational lensing comes from the fact that this phenomenon can be used as an astrophysical and cosmological tool to solve a number of scientific problems. Quasars and gravitationally lensed quasars (GLQs) are of particular interest since they sufficiently probe the deep Universe and can be bright enough to be detected and investigated. But to do this successfully we need to know how many multiply imaged quasars we will be able to detect in the ILMT field of view, how to analyze the observational data, their sensitivity, what problems and challenges await us. In this poster, we try to briefly highlight these points: why GLQs are interesting to us, what objects should we observe, how many of them, etc? According to our last estimations, the number of quasars which may be detected with the ILMT is ~ 6700. So, at least 15 of them should consist of multiply imaged quasars.

Introduction

The phenomenon of gravitational lensing is based upon the deflection of light rays in gravitational fields and had been predicted as a consequence of General Relativity. According to this theory, the gravitational potential associated with a massive object distort the spacetime in its vicinity and the gradient of this field is responsible for the angular deflection of the light trajectories. As a result we can see perturbed, distorted, multiply imaged distant sources.



Well known gravitational lensing around the Abell 370 galaxy cluster (Photo: NASA, ESA/Hubble) and the Einstein Cross [1].



A few more examples of multiply imaged quasars obtained with the ground-based telescope ATZ-22 at MAO. Top: GRAL0659+1629, GRAL0248+1913. Bottom: GRAL1651-0417, UM673, SBS1520+530. The angular separation between the lensed images ranges between 2" and 10".

Why Gravitational Lensing Is Interesting?

The great interest in gravitational lensing comes from the fact that this phenomenon can be used as an astrophysical and cosmological tool. Indeed, gravitational lensing may help astronomers to solve a number problems [2]:

- an independent determination of the Hubble constant H_0 will result in a better estimate of the distance scale of the Universe and possibly also the values of other cosmological parameters (the cosmological density Ω_0 and the cosmological constant λ_0)
- to constrain the mass distribution $M(r)$ of the lens
- to derive the extinction law in the deflector, usually located at high redshift
- to probe the nature and distribution of luminous and dark matter in the Universe
- to investigate the size and structure of quasars, e.g. microlensing-induced variations allow to investigate the structure of the accretion flow around their central supermassive black holes
- to measure the size of absorbing intergalactic gas clouds
- to set upper limits on the density of the cosmological population of massive compact objects

Acknowledgements

The 4m International Liquid Mirror Telescope (ILMT) project results from a collaboration between Aryabhatta Research Institute of Observational Sciences (ARIES, India), the Institute of Astrophysics and Geophysics (University of Liège, Belgium), the Universities of British Columbia, Laval, Montreal, Toronto, Victoria and York University. The authors also thank Hitesh Kumar, Himanshu Rawat and Khushal Singh for their assistance at the 4m ILMT.

Probable number of GLQs

Probable number of quasars and GLQs which can be detected in the field of view of the 4-m ILMT was first derived by Surdej & Claeskens [3,4]. The optical depth τ_q for the formation of multiple lensed images of a quasar at redshift z_q by galaxies distributed along their line-of-sight is given by the relation:

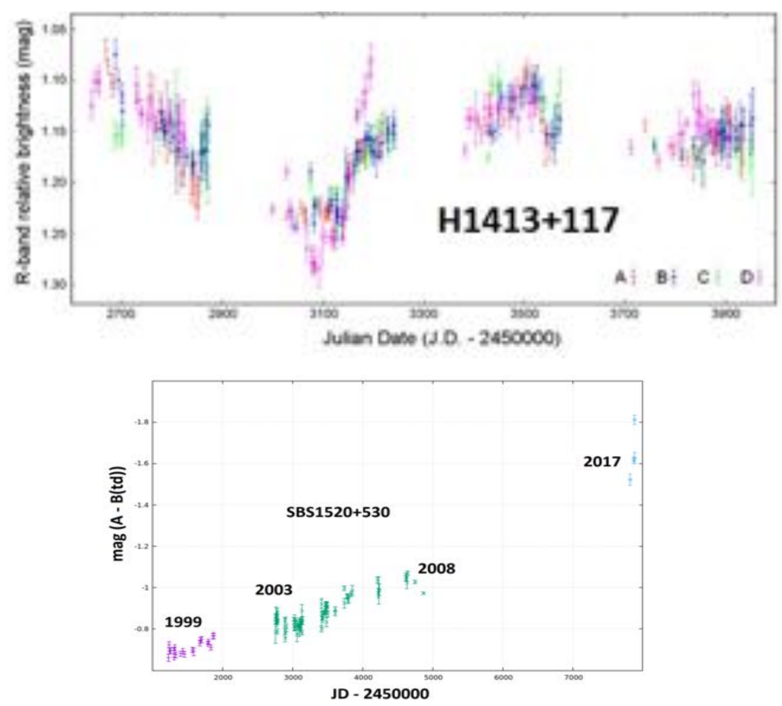
$$\tau_q = \frac{4}{15} F \left(1 - \left(1 + z_q\right)^{-0.5}\right)^3$$

where the parameter F is the effectiveness of the galaxies to produce multiply imaged quasars. So, adopting $F \cong 0.047$, we find $\tau_q = 9.46 \cdot 10^{-4}$ for $z_q = 2$. At that time, it was assumed that the 4-m ILMT would be able to detect about 20,000 quasars and that about 50 of them could be composed of multiple lensed images. Later these values were re-estimated by Finet [5]. The probable number of quasars was estimated as 9072 and about 22 of them are GLQs. However, more recently, by comparing and cross-correlating various catalogues (Milliquas, Gaia-DR2, etc.), a new estimation of the number of quasars that will fall into the FOV of the 4-m ILMT telescope has been obtained by Mandal et al. [6]. The final quasar catalogue for the ILMT contains 6738 objects, and accordingly the probable number of lensed quasars is about 15. The redshifts of the majority of the lensed quasars should be in the range $z_q = [0.5 \div 2.5]$, and their apparent magnitude $G = [18 \div 22.5]^m$ by an estimate using the Sloan magnitudes (g, r or i).

Light Curves: Time Delay and Microlensing

Homogeneous and continuous observational data through the three SDSS filters g, r and i allow us to provide photometric measurements and plot light curves. All available methods of digital photometry will be used to measure the apparent magnitudes of the multiple lensed QSO images: direct fitting of the PSF, adaptive fitting of the PSF, image deconvolution and restoration, etc. Photometric light curves will allow to detect variable sources among them. Correlated variations of brightness of the quasar images located close to each other will reveal GLQ candidates. Next we will get precise positions of the sources and lensed images, time delay values, microlensing events.

Two examples of lightcurves observed for the multiply imaged quasars H1413+117 and SBS1520+530



References and resources

1. V. Vakulik, R. Schild, et al. A&A 447, 905–913 (2006)
2. J.Surdej and J.-F. Claeskens. A&A Rev, 10: 263–311 (2002)
3. J.Surdej and J.-F. Claeskens. The Century of Space Science, 441-469 (2001)
4. Surdej and J.-F. Claeskens. Science with Liquid Mirror Telescopes, Marseille, France, April 14-15 (1997)
5. F. Finet. The International Liquid Mirror Telescope project: optical quality tests and prospective detection of multiply imaged quasars. PhD thesis, 2013
6. A.K. Mandal, B. Pradhan, et al. JAA, 41, 22 (2020)