High Energy Processes and Phenomena in Astrophysics
IAU Symposium, Vol. 214, 2003
X. D. Li, V. Trimble, and Z. R. Wang, eds.

Gravitational Lensing by Globular Clusters and Arp Objects

Alexander Yushchenko

Odessa Astronomical observatory, Odessa National University, park Shevchenko, Odessa, 65014, Ukraine

Department of Earth Science Education, Chonbuk National University, Chonju, 561-756, (South) Korea

Chulhee Kim

Department of Earth Science Education, Chonbuk National University, Chonju, 561-756, (South) Korea,

Alexander Sergeev

The International Centre for Astronomical, Medical and Ecological Research of the Russian Academy of Sciences and the National Academy of Sciences of Ukraine, Golosiiv, Kiev, 03680, Ukraine

Panos Niarchos, and Vasilis Manimanis

Department of Astrophysics, Astronomy and Mechanics, Faculty of Physics, University of Athens, 157 84 Zografos, Athens, Greece

Abstract. We try to explain quasar-galaxy associations by gravitational lensing by globular clusters, located in the halos of foreground galaxies. We propose observational test for verification of this hypothesis. We processed SUPERCOSMOS sky survey and found overdensities of star-like sources with zero proper motions in the vicinities of foreground galaxies from CfA3 catalog. We show mean effect for galaxies with different redshifts. Two effects can explain observational data - these are lensing by globular clusters and lensing by dwarf galaxies. We made CCD 3-color photometry with 2.0-1.2 meter telescopes to select extremely lensed objects around several galaxies for spectroscopic observations.

1. Introduction

35 years ago Arp (1968) discovered quasar-galaxy associations. Among the explanations of these phenomena was gravitational lensing, but for a long time the objects which can act as gravitational lenses were unknown. Baryshev, Raikov, & Yushchenko (1993) and Yushchenko, Baryshev, & Raikov (1998) pointed, that stellar globular clusters (GC) and dwarf galaxies in the vicinities of foreground galaxies (FG) can be these gravitational lenses. The cores of Seyfert and other active galaxies can be the background sources (BS). Yushchenko et al. (1998)

https://doi.org/10.1017/S0074180900194227 Published online by Cambridge University Press

developed the software for calculations the amplifications of extended sources by King objects. The amplification can reach 5-10 magnitudes in typical cases. Baryshev & Ezova (1997) showed, that in the case of fractal Universe, gravitational lensing can explaine observational data. Bukhmastova (2001, 2002) made new catalog of QSO-galaxy associations, proposed several new tests and estimated the influence of gravitational lensing on the luminosity function of BS.

Yushchenko (1999) proposed simple observational test for validation of this hypothesis. If Seyfert galaxies after amplifications look like QSO, than we must observe ordinary galaxies amplificated by GC. The number of ordinary background galaxies is two orders higher than that of active galaxies. And the mean number of GC in the halos of FGs is near 100. Yushchenko (1999, 2000) pointed that the surface density of star-like sources around FGs can be used as a test and found that this effect is detectable. Yushchenko et al. (2001) published the first results of processing the SUPERCOSMOS survey (Hambly et al., 2001). The nature appears more beautiful than we can predict - we found overdensity and underdensity of possible extremely lensed objects (ELO) around FGs with different redshifts.

2. Results from SUPERCOSMOS survey

SUPERCOSMOS is a digitization of photographic survey of the southern hemisphere observed with Schmidt telescopes at two different epochs. The limiting magnitude is near 21. We selected from the survey only star-like images with zero proper motions as a background images. We found the number densities of these objects around 19413 FGs from CfA3 catalog (Huchra et al., 1995) and around the dummy centers without galaxies in concentric rings (the widths of the rings were 30 arcseconds). Random centers showed zero effect. We expected to find overdensities around FGs. But the results were different for different groups of galaxies. On Fig. 1a, b one can see the typical results for groups of FGs with different redshifts.

The expected overdensity is well detected for FGs with higher redshifts. For FGs with smaller redshifts we can see underdensity.

The integration of the square between the line of number densities for dummy centers and the line for galaxies give us the number of objects which produce the overdensity or underdensity. On the Fig. 1c we show the plot of the number of objects responsible for underdensity or overdensity for different groups of FGs against the redshifts.

On the Fig. 1d we show the projected linear radii in the halo of FG where underdensity or overdensity reachs 2/3 of it's final value for different groups of galaxies. We omitted the groups with the lowest and highest redshifts - the results for these groups are very uncertain.

3. Conclusion

We found the number densities of point-like objects with zero proper motions in the vicinities of FGs. The overdensity is observed around FGs with Z=0.08-0.5. The FGs with Z< 0.08 show the underdensity. The projected linear radii where the effect reachs 2/3 of it's final value is different for groups were we can observe

https://doi.org/10.1017/S0074180900194227 Published online by Cambridge University Press

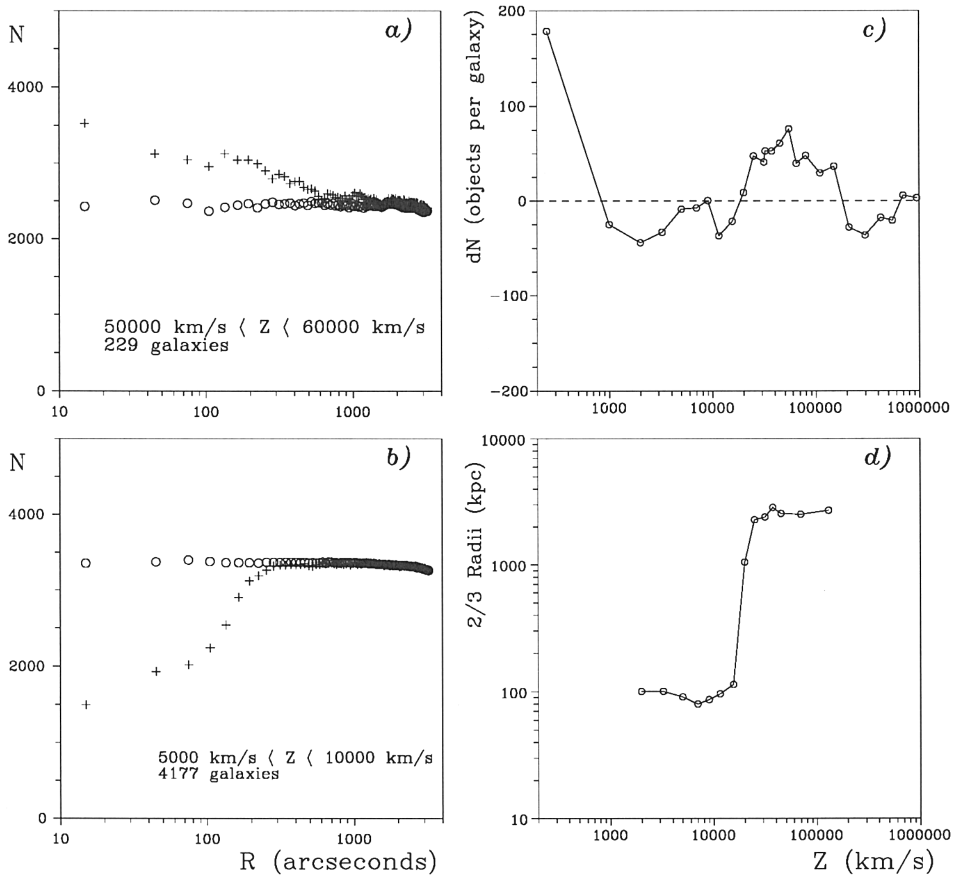

Figure 1. Results of processing the SUPERCOSMOS survey. *a*) The mean surface density of star-like sources with zero proper motions in the vicinities of 229 galaxies with redshifts from 50000 to 60000 km/s. The axes are the distance from the galaxy center in arcseconds and the number density of investigated objects per square degree. Circles and crosses - mean results for dummy centers without galaxies, and for centers with galaxies respectively. *b*) The same as *a*) but for 4177 galaxies with redshifts from 5000 to 10000 km/s. *c*) The mean number of objects, which produce overdensity or underdensity for groups of galaxies with different redshifts. The axes are the redshift in km/s and the number of objects, responsible for overdensity or underdensity. *d*) The value of linear radii, were overdensity or underdensity of objects reachs 2/3 of its final value (if integrate from the zero radii) for groups of galaxies with different redshifts. The axes are the redshift in km/s and the linear radii in kiloparsecs.

https://doi.org/10.1017/S0074180900194227 Published online by Cambridge University Press

underdensity or overdensity of investigated objects. The projected linear radii is near 100 kpc in the groups with underdensity and near 2500 kpc in the groups with overdensity.

Yushchenko et al. (2001) pointed, that it is necessary to take into account the microlensing. We have the software which permit us to simulate the propagation of the light beams through the GC. The results of calculations show that we can explain the underdensity for the nearest groups of FGs. The GC in this case must contain a big population of planets in the outer zones of GC. The radii near 100 kps is the radii of the halo of mean galaxy with GC in this halo.

The value of radii for more distant FGs - 2500 kpc, can be explained by lensing effect produced by dwarf spheroidal galaxies. The number of dSph galaxies in the Local Group is comparable with the value of overdensity around the galaxies with Z=0.08-0.5. dSph galaxies and GC in the small groups of galaxies, like Local Group, can explain the observational effect.

For final verification of our hypothesis it is necessary to point ELOs and to measure their redshifts. We made 3-color photometry in the vicinities of several galaxies with 2 m telescope located at peak Terskol (Ukraine-Russia), 1.8 m telescope of Bohyunsan observatory (South Korea) and 1.2 m telescope of Kryonerium observatory (Greece). The list of objects for spectroscopic observations is in preparation now. The used methodics were described by Yushchenko, Niarchos, & Manimanis (2001)

Acknowledgements

This work was supported by the grant of Post-Doc Program, Chonbuk National University (2002)

References

Arp, H. 1968, ApJ, 153, L33

Baryshev, Yu.V., Raikov, A.A., Yushchenko, A.V., 1993, Proc. of 31 Liege Astrophys. Coll. Gravitational lenses in the Universe, ed. J. Surdej (Liege, Belgium), 307

Baryshev, Yu.V., Ezova, Yu.L. 1997, Astronomy Reports, 41, 436

Bukhmastova, Yu.V., 2001, Astronomy Reports, 45, 581

Bukhmastova, Yu.V., 2002, Astrophysics, 45, 231

Hambly, N.C., MacGulliver, H.T., Read, M.A. et al. 2001, MNRAS, 326, 1279

Huchra, J.P., Geller, M.J., Clemens, C.M., Tokarz, S.P., Michel, A. 1995, ADC CD ROM, Vol. 3

Yushchenko, A.V., Baryshev, Yu.V., Raikov, A.A. 1998, Astron. Astrophys. Transactions, 17, 9

Yushchenko, A.V., 1999, Odessa Astron. Publ., 1999, 12, 85
reference Yushchenko, A.V. 2000, Kinematics and Physics of Selectial Bodies Suppl. Ser., 3, 174

Yushchenko, A.V., Niarchos, P.G., Terpan, S., Manimanis, V. 2001, Odessa Astron. Publ., 14, 211

Yushchenko, A.V., Niarchos, P.G., Manimanis, V. 2001, Proceedings of 5th Gellenic Astronomical Conference, Crete, Greece, September, 20-22, http://astrophysics.physics.uoc.gr/conf/fpap.htm