GLOBULAR CLUSTERS AS GRAVITATIONAL LENSES. OBSERVATIONAL TEST

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ABSTRACT. Let us suppose that globular clusters in the halos of distant galaxies can act as a gravitational lenses. The observational test for this hypothesis is the overdensity of star-like images near foreground galaxies. We analyzed USNO A2.0 catalog in the vicinity of 35862 galaxies with redshifts 0.01-0.33 and found that mean overdensity of objects brighter than 21^m is near 100 objects per galaxy.

Key words: quasi-stellar objects; galaxies: redshifts - gravitational lensing

1. Introduction

The first who proposed gravitational lensing for explanation of quasars was Barnotti (1965). But it was shown that neither galaxies, nor stars in the halos of galaxies cannot explain all properties of Arp's objects. Burbidge et al. (1990) found near 500 associations of quasars with foreground galaxies.

In a series of papers - Baryshev, Raikov, Yushchenko (1993), Baryshev & Ezova (1997), Yushchenko, Baryshev, Raikov (1998) - it was shown that quasar-galaxy associations can be explained by gravitational lensing by cores of globular clusters and dwarf galaxies. These globular clusters in the halos of foreground galaxies and dwarf galaxies can explain all associations. The properties of globular clusters as gravitational lenses were investigated by Yakovlev et al. (1983). In the above mentioned papers we extend the Yakovlev's results for sources with non-zero sizes. It was shown that amplification of small background sources by cores of globular clusters can reach 5-10 magnitudes. The angular sizes of amplified image is equal to the angular size of the core of globular cluster in the halo of foreground galaxy - this is star-like image for our optical telescopes.

Yushchenko & Raikov (1998) proposed, that significant part or all quasi-stellar objects can be explained by this effect. This hypothesis can work if the cores of globular clusters are transparent. The necessary condition are also the existence of distant Seyfert nuclei with spectral properties similar to that of quasars. Typically only one globular cluster per foreground galaxy can act as a gravitational lens - the number of background Seyfert nuclei is too small.

2. Hypothesis

Let us suppose that there are not only Seyfert nuclei at high redshifts, but galaxies of all types. It is known that the number of Seyfert galaxies is of order of 1% of all galaxies. If all types of galaxies will be gravitationally amplified by cores of globular clusters and dwarf galaxies by 5-10 magnitudes we can expect the excess of number density of star-like images near foreground galaxies. We know that the usual number of globular clusters per galaxy is near 10^2 or more.

That is why the expected number density of high redshift galaxies, gravitationally amplificated by globular clusters, must be two orders higher than the number density of quasi-stellar objects. The last catalogs of quasars contain near 10^4 objects. We can expect near 10^6 high redshifts star-like objects situated near foreground galaxies. The expected spectral properties of these objects will be similar to spectral properties of usual galaxies (with correction for redshift and evolution). In any case their colors will be more redder than quasars.

2. Observed number densities

For checking the validity of this hypothesis we used digitized Palomar survey with extension to south sky - USNO A2.0 catalog (Monet et al., 1998) - as a catalog of star-like images. This catalog contain more than 500 millions of objects brighter than 21^m. We used CfA catalog (Huchra et al, 1995) as a catalog of foreground galaxies. We selected 35862 galaxies with redshifts more than 3000 km/s from CfA catalog. We calculated the number density of all objects in the concentric rings around each galaxy up to 1.5 degree in diameter. The similar calculations were made for four

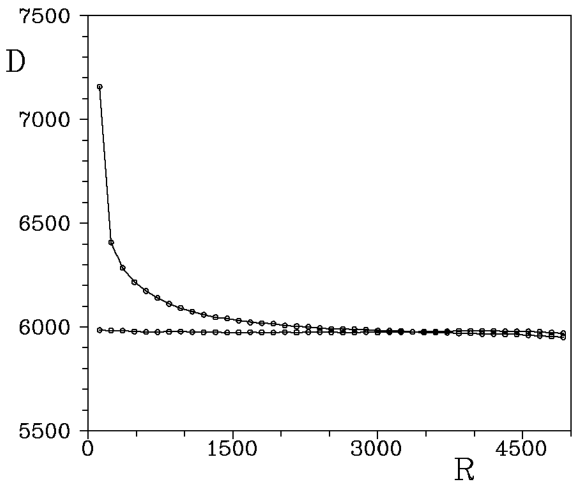

Figure 1: The mean density of objects in concentric rings around 35862 galaxies (the upper line), and around random centers. The axes are the radii of concentric rings in arc seconds and mean density of objects per square degree.

random centers around each galaxy.

The mean results are shown on fig. 1. We can see a well detected over-density of objects around galaxies in comparing with random centers. The overdensity is near 100 objects per galaxy. It should be noted that the mean density of objects in the investigated regions is near 6000 objects per square degree. 100 objects is near 1.5% over-density. Only mean results for 35862 galaxies permit us to claim that this overdensity exist. This means that near 35862∗100 or more than 3 millions objects in USNO A2.0 are star-like images of distant galaxies amplified by cores of globular clusters or dwarf galaxies by 5-10 magnitude.

The statistics is sufficient and we were able to plot the overdensity as a function of galaxies types and redshifts, the plots of the numbers of lensed images as a functions of their magnitudes and colors. The overdensity is insignificant for objects brighter than 15^m, and became more pronounced for fainter objects. The maximum of the distribution of B-R colors of discovered objects is located near B-R=1.5-2. These data confirm our hypothesis.

2. Conclusion

We predicted and found the overdensity of star-like images around galaxies. These star-like images are the images of high redshift galaxies, amplificated by cores of globular clusters (or dwarf galaxies).

The overdensity of objects near galaxies is an observational fact and it is necessary to investigate this problem. Part of this overdensity can be explained by usual images of galaxies - USNO A2.0 catalog do not resolve stellar and galaxy images.

It should be noted that there were surveys for detecting galaxies about quasars, for detecting quasars, but there were no surveys for detecting star-like images (with spectral properties different than spectral properties of quasars) around galaxies.

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