THE ENVIRONMENT OF X-RAY SELECTED BL LACS: HOST GALAXIES AND GALAXY CLUSTERING

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ABSTRACT

Using the Canada-France-Hawaii Telescope, we have imaged a complete, flux-limited sample of Einstein Medium Sensitivity Survey (EMSS; Gioia, *et al.* 1990, Stocke, *et al.* 1991) BL Lacertae objects in order to study the properties of BL Lac host galaxies and to use quantitative methods to determine the richness of their galaxy cluster environments.

INTRODUCTION

The extreme characteristics of BL Lacs have been suggested to be due either to Doppler-boosted beaming from a relativistically moving jet aimed almost exactly in our direction (*e.g.* Blandford and Rees, 1978; Browne, 1989) or gravitational lensing of a background QSO (Ostriker and Vietri, 1985). In this case the apparent host galaxy is actually the foreground lensing galaxy.

These two theories for BL Lacs make very different predictions about the host galaxy morphologies that we have begun to test with our imaging surveys:

1. Host galaxy morphology: the jet hypothesis requires all BL Lacs to have giant elliptical hosts since these are the hosts of the FR1 radio galaxies which are the proposed parent population for BL Lacs (*e.g.* Padovani and Urry, 1991). The lensing hypothesis prefers giant ellipticals since they have the deepest potential wells, but spirals and lower luminosity galaxies of any type can also be the lensing galaxies.

2. Point-source position: the jet hypothesis requires the point sources to be well-center in the host galaxy like they are for radio galaxies. The lensing hypothesis often requires off-centered point sources if most BL Lacs are lensed.

3. Clustering: the jet hypothesis suggests that many BL Lacs should be found in rich clusters since many FR1s are in rich clusters (*e.g.* Prestage and Peacock, 1988). The lensing hypothesis makes no specific clustering predictions.

CLUSTERING PROPERTIES AND HOST GALAXIES OF MS1207+39 AND MS1407+59

By measuring the amplitude of the galaxy-BL Lac spatial covariance function, B_{gb} (Yee and Green 1987), we have discovered rich clusters around two EMSS BL Lacs (see table below). For comparison, B_{gb} for clusters of Abell richness class 1 $\sim$ 650 and B_{gb} for Abell richness class 2 $\sim$ 945.

Both these objects are in well-resolved host galaxies consistent with FR1 hosts. A three-parameter fit of the isophotal profiles to a de-Vaucouleurs model elliptical galaxy plus point source gives an absolute Gunn-r magnitude for the host galaxies of -22.9 for MS1207+39 and -23.2 for MS1402+59 ($H_0 = 50, q_0 = \frac{1}{2}$). These absolute magnitudes are consistent with $\langle M_r \rangle = -23.3$ for brightest cluster galaxies (BCGs) (Hoessel *et al.* 1980).

This evidence leads us to the conclusion that these two BL Lac objects are in the nuclei of cD galaxies in rich clusters.

SPATIAL COVARIANCE AMPLITUDES B_{gb}

name	z	B_{gb}
1207+39	0.615	1092±228
1407+59	0.495	845±173

THE REMAINING EMSS BL LAC HOST GALAXIES

Of the remaining host galaxies, nearly all are resolved and their fitted profiles are consistent with BGCs as well (Figures 1 and 2). However, a small subsample demonstrates properties that may be inconsistent with the beamed FR1 hypothesis. In one case, MS 0205+35, the resolved host is clearly decentered (Figure 3), and the absolute Gunn r-magnitude of the galaxy at the measured redshift of 0.318 is <-21, too small for a BCG and also an unlikely FR1 host. In two other cases, MS0950+49 and MS1402+04 (z =0.200:), we were unable to resolve an underlying host. Consequently as many as 3 of 22 EMSS BL Lacs may be due to gravitational lensing, the remainder are consistent with being beamed FR1s.

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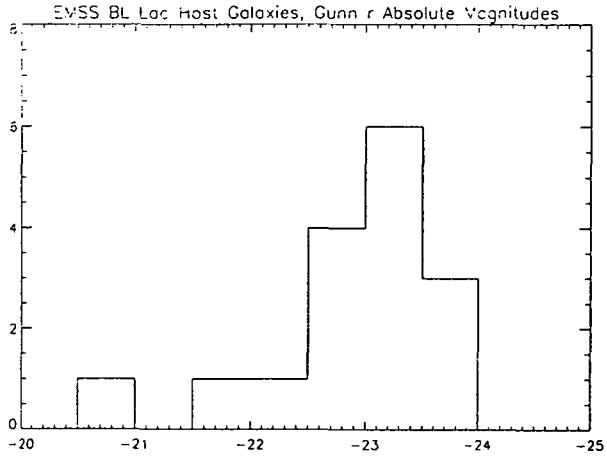

Figure 1. Absolute magnitude of host galaxies, determined from total magnitude of the profile fit. Where the fit was unsuccessful, we have plotted the lower limit on M_r given by subtracting a point spread function (PSF) fit to the central source and determining the magnitude of the remainder. $\langle M_r \rangle$ is -23.3 for brightest cluster galaxies (Hoessel *et al.* 1980).

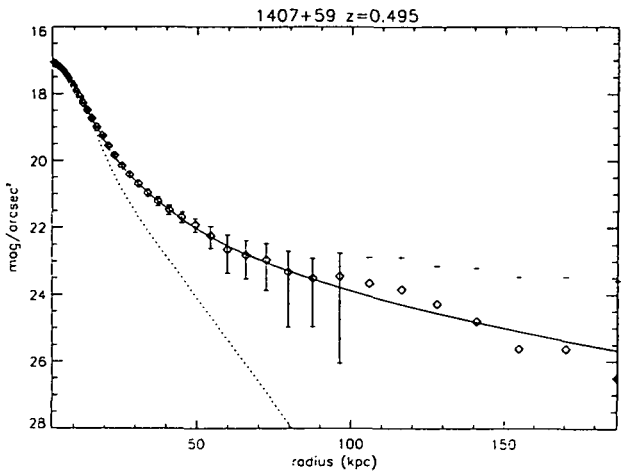

Figure 2. An example of a profile fit. The solid line is the fit to a point source + deVaucouleurs profile for 1407+59. The dotted line is the best fit PSF.

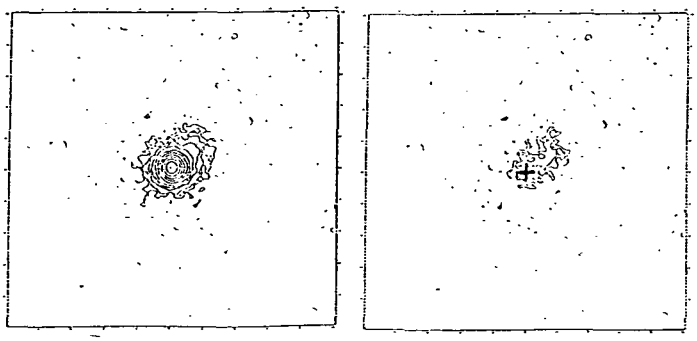

Figure 3. The image on the left is MS0205+35 before PSF subtraction. The image on the right is the same frame after subtracting a point source centered on the position of the cross. Each frame is 25 arcsec on a side.