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Dark Matter in CL0017 (z = 0.272)

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1. Introduction

The motion of galaxies has been used to study the gravitational field around cluster cores and, thus, estimate their masses. An independent way to obtain the total mass in clusters is now available using gravitational lensing. In fact, gravitational arcs have become an additional test to probe not only the existence and amount of dark matter in clusters but also how this matter is distributed. (For a review see Tyson 1992).

Using recent results from observations of a medium-redshift rich cluster of galaxies, namely CL0017, we here make the case for one of the best candidates where to look for gravitational arcs. From spectroscopic data from 5 clusters at $z \sim 0.3$, we find that CL0017 meets all the necessary characteristics for a gravitational arc search: high mass, high M/L, medium redshift and extreme compactness.

2. Discussion

CL0017, a rich cluster at a redshift of 0.272, has turned out to be quite an interesting case. It was first discovered on deep CFHT prime focus plates by Infante et al. (1986). It is located near the South Galactic Pole and contains a giant galaxy at its centre, probably a cD galaxy. This galaxy is surrounded by several smaller galaxies in a disk-like configuration, all embedded in what seems to be a common, extremely compact, halo of diameter $\sim 77h^{-1}$ kpc ($q_0 = 0$) and total absolute magnitude in V of −24.

The brightest members of this cluster are clearly very red (i.e. (B−V) = 0.9) as would be expected for a cluster dominated by E/S0 galaxies. However, a significant blue population of galaxies (with (B−V) < 0.7, which would correspond to later than Sab spirals) is also found, consistent with the findings of Butcher and Oemler (1984) of a higher fraction of blue to red galaxies in medium redshift clusters as compared to low z clusters.

The above results motivated more detailed photometric and spectroscopic observations of this cluster. In 1987 Quintana and Infante observed the central nucleus of this cluster with the 2.5-m Las Campanas Observatory 2DF spectrograph and obtained a velocity of 81435 ± 68 km/sec (z = 0.272). Later in 1991, Giraud acquired short B,V and R CCD exposures with EMMI on the NTT. As reported in Infante, Giraud and Triay (1991), an arc-like feature on all these deep images was confirmed. Although during the NTT observations the seeing was 0.9″, poor for NTT standards, the arc-like feature is quite conspicuous in all the frames. The arc is significantly bluer than the red cluster galaxies. Furthermore, images of the cluster have been obtained in a variety of bandpasses (V,R,I,g,r) on a number of telescopes (CTIO 4-m, ESO 2.2-m, LCO 1-m). A paper reporting the results is in preparation (Infante et al. 1992).

Here we report the results from our spectroscopic observations with EFOSC1 on the ESO 3.6-m telescope. The observations were carried out on three non photometric nights in December 1990. Two multiobject plates were used to obtain spectra of about 25 selected red galaxies. The aim was to determine a dynamical mass of the cluster, particularly of its core, and its mass-to-light ratio. The spectra were reduced twice; a preliminary reduction with IHAP software and then a final reduction using IRAF 2D spectral package (details in Infante et al. 1992). Both reductions gave consistent results.

In Figure 1 we show the distribution of velocities. After clipping out 3 sigma

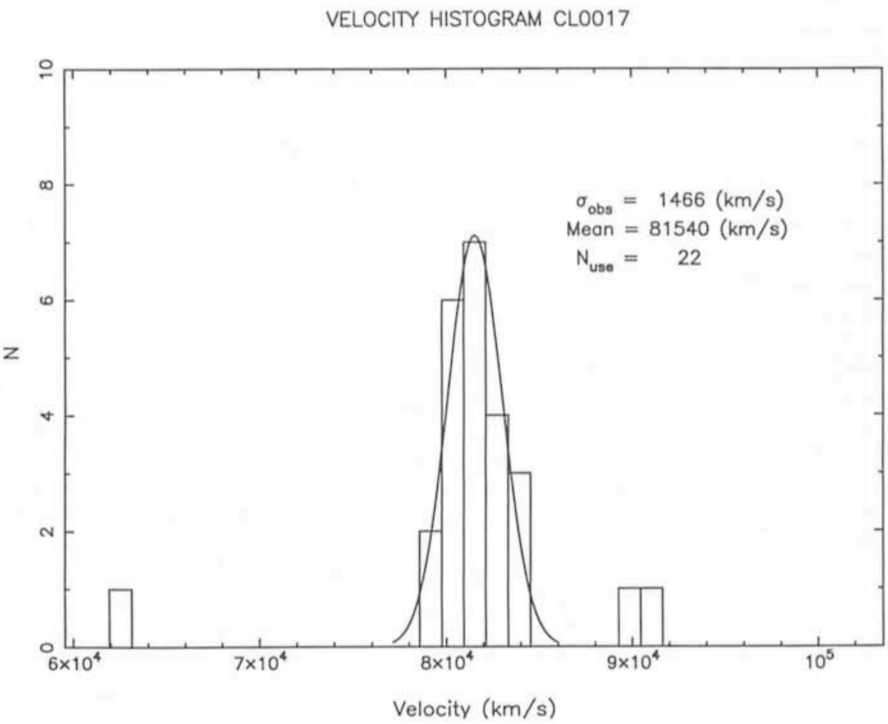

Figure 1: *Histogram of velocities in CL0017. Galaxies with velocities larger than 3σ* have been removed. 22 out of 26 galaxies remained. We also plot the best gaussian distribution to the points.

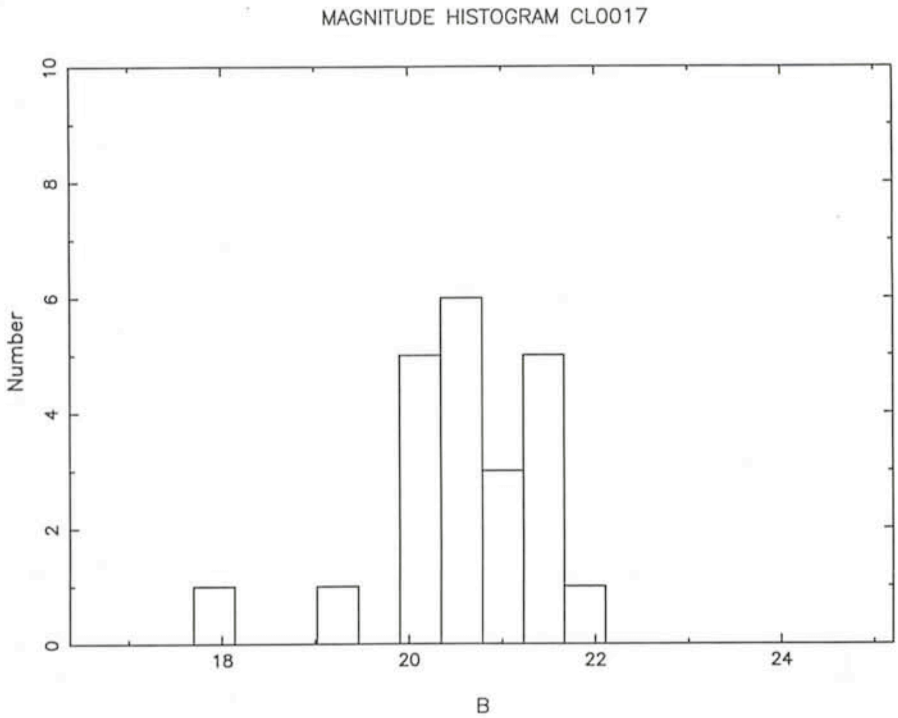

Figure 2: *Histogram of corrected B magnitudes.*

outliers 22 out of 26 galaxies remained. A Kolmogorov-Smirnov test which compares our distribution of velocities to a gaussian distribution returned a significance level larger than 95%. The uncorrected line-of-sight velocity dispersion and mean recession velocity are σ = 1466 kms^{-1} and υ = 81,540 kms^{-1} respectively.

We then applied the method described in Gourgoulhon et al. (1992) to determine the virial mass and mass-to-light ratio of the cluster. As the collapse time of the cluster (2 Gyr) is small compared to the Hubble time, the cluster is virialized, and its virial mass is a good estimator of its total mass.

We first correct our raw data for various effects: K-corrections are adopted from Pence (1976), and amount to −1.27 and −0.66 in the B and V-bands, respectively; evolutionary corrections are taken from Arimoto and Yoshii (1987) for a 10^{11} $M_{\odot}$ E/S0 galaxy, and amount to +0.34 and +0.08 for V-magnitudes and (B-V) colours, respectively; relativistic corrections to mass and mass-to-light ratio multiply uncorrected values by 0.42 and 0.35, respectively. The dependence of these corrections upon adopted values of H_o, q_o and z_f (redshift of formation) is small at the cluster redshift (0.272). Due to the location of the cluster (South Galactic Pole), galactic absorption is neglected; internal absorption is neglected as well, because most of our sample galaxies are early-type.

We obtain a corrected mass of 7.0×10^{14} $M_{\odot}$. For each galaxy, the uncorrected magnitude in the B-band is evaluated from Gunn g and r magnitudes, using Kent's (1985) relations. The corrected B-magnitude is then calculated adding −1.27+(0.34+0.08) = −0.85. The mean observed colour is g−r = 0.90, corresponding to B−V = 1.46. Applying the K-and evolutionary corrections to this value gives a corrected B−V at redshift 0 of 0.93 (typical of E/S0 galaxies), confirming the order of magnitude of these corrections. The total luminosity of the cluster in the B-band is obtained after correction for the contribution of faint members not measured. To make this correction, we integrate a Schechter luminosity function from the limiting magnitude of a complete sub-sample down to infinity. Figure 2 shows that our sample of 22 galaxies is complete down to a corrected B-magnitude of 20.8. Adopting a luminosity distance of 1200 Mpc, the correcting factor for incompleteness is 2.18. As the total luminosity of the galaxies brighter then 20.8 is 3.9×10^{11} $L_{\odot}$, we adopt a total luminosity of the cluster of $8.5 \times 10^{11} L_{\odot}$, corrected for relativistic effects and incompleteness. 20% of this luminosity is concentrated in the nucleus.

Finally, we derive a mass-to-light ratio in the B-band of 820 $M_{\odot}/L_{\odot}$.

3. Conclusions

Rich, compact and massive galaxy clusters at redshifts between 0.2 and 0.5 with line of sight velocity dispersions exceeding 700 km/s are good gravitational lens candidates. They distort background galaxies which are as far as twice the cluster distance. The magnification and distortion of these galaxies provide an independent method to detemine cluster masses and to study objects at high redshifts.

CL0017 is one of the best lens candidates available. It possesses a mass of 7.0×10^{14} $M_{\odot}$ and a luminosity of 8.5×10^{11} $L_{\odot}$ (M/L = 820 $M_{\odot}/L_{\odot}$), much of it in a very compact nucleus of size 77h^{-1} Mpc. Because of its high mass and high M/L ratio, CL0017 becomes an excellent candidate to search for multiple arcs and, therefore, probe the dark matter independently.

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New Features of IRSPEC

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In January 1991, IRSPEC at the NTT was equipped with a 58×62 pixel InSb array from Santa Barbara Research Center (SBRC). The chip replaced a 1D array and brought new observing features such as long-slit capability. The new system is discussed in the March 1991 issue of *The Messenger* **63,** p. 77. IRSPEC has been further improved in the meanwhile. Recent instrumental modifications have resulted in a higher sensitivity in the 1 – 2.5-μm region. Operational enhancements such as the implementation of automatic beam-switching and continuous mode have increased the efficiency of observations with IRSPEC. The modifications were carried out by Peter Biereichel, Gert