Astron. Astrophys. 172, L14–L16 (1987)

ASTRONOMY AND ASTROPHYSICS

Letter to the Editor

A blue ring-like structure in the center of the A 370 cluster of galaxies

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Received April 24, accepted August 15, 1986

Summary

We report on a serendipitous observation from our first multispectroscopic run on the distant X-ray emitter Abell cluster A370 (z=0.373). We discovered a very particular ring-like structure of galaxies with a diffuse component lying near one of the very luminous galaxies of the cluster core. A very first analysis suggests that it may be the result of galaxy/galaxy interactions in the dense region or of star formation occuring from a cooling flow of the Intra-Cluster-Medium (hereafter I.C.M.).

Key words : Clusters : of galaxies

I-Introduction :

In September 1985 we conducted a first multiaperture spectroscopic observation of high redshift clusters of galaxies (z=0.4) on the Cassegrain focal reducer of the 3.60m C.F.H. Telescope. From CCD images in the R-band color the on-line fabrication of the multiaperture mask has been performed by the PUMA1 system (Fort et al 86). Our main purpose was to study the spectral energy distribution and the radial velocity of a large number of cluster galaxies with the maximum of samples in the CCD field. For this first run we chose to observe the A370 cluster as it was mentioned as an intense X-ray emitter (Henry et al 82) and one of the bluest Butcher-Oemler distant clusters (Butcher and Oemler, 1983). The procedure was fully automatized and we did not examine in great detail the CCD images during the nights of observation.

The data reduction showed a strange ring-like condensation on the R-image very close to a bright elliptical galaxy near the cluster center (fig. 1). The comparison of several images made during the run proved that it was not an artefact. This was confirmed from the blue plate of the field obtained by Butcher and Oemler (Butcher and Oemler 83) who had not noticed its existence.

From the measurement of 28 radial velocities of cluster galaxies we noticed that the bright elliptical galaxy (n° 35), in the rest frame of the cluster was at zero velocity (20 km/s, +/- 200 km/s) as was one of the galaxies embedded in the condensation (n° 37 : -50, +/- 200 km/s). This suggests that this system could be physically linked to the n° 35 massive galaxy located in the deep potential well of the cluster.

In this letter we describe our very first photometric and spectroscopic results about this structure.

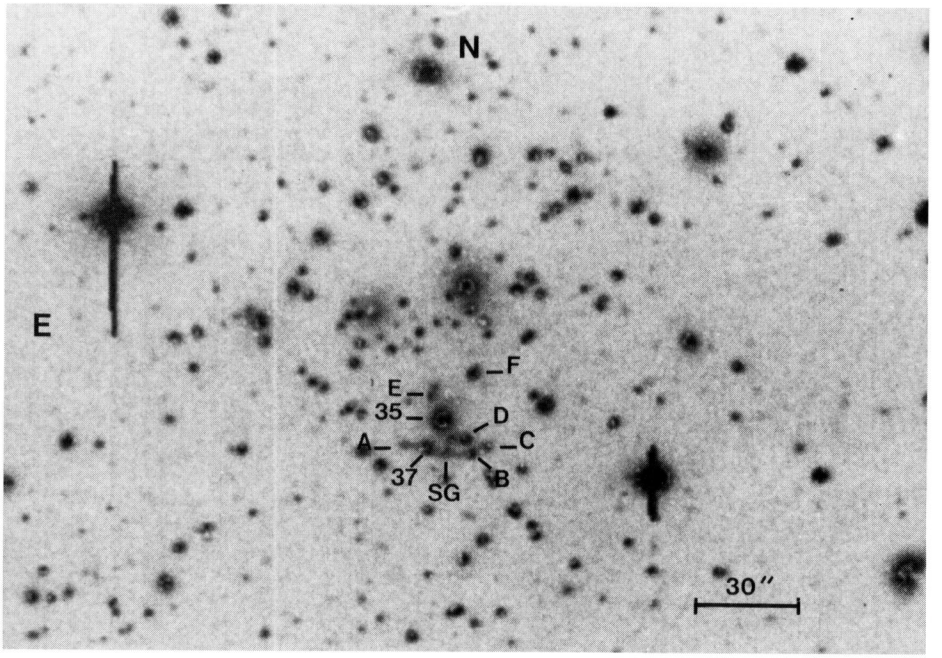

Fig. 1 : CCD image of the A370 center with a R filter at the F/2 C.F.H.T. focal reducer (exposure time 10 mn)

II-Photometry of the A370 cluster core

II-1 Observations and data reduction

The observations were conducted on the (F/8-F/2) focal reducer CIGALE of the 3.60m C.F.H. Telescope at Mauna Kea (4200m). We used the RCA CCD/CEA INAG detector which has a scale of 0.83 arcsec per pixel.
Four R-frames with an exposure time of 600 sec and one V-frame with an exposure time of 900 sec were obtained in very good seeing conditions (1 arcsec). The R filter, centered at 6980 A, matches the Johnson R band quite well, but our V filter is a little bluer than the standard one : λ=5320 A and $\delta\lambda$=200 A instead of λ=5500 A and $\delta\lambda$=400 A. As the redshift of A370 is 0.374, the 4000 A discontinuity is shifted to 5500 A, and we chose a filter avoiding this feature. This resulted in our V magnitudes (hereafter called V1) being larger than the V Johnson ones. For calibration purposes, we used a spectroscopic standard star (Hiltner 102 ; V=10.42) and 5 photometric standards chosen in the M31 Baade's field IV (V magnitudes between 16.26 and 18.48). For both photometric and spectroscopic observations, the sky level was sufficiently high for the CCD response to remain linear. The equivalent CCD counts outside the atmosphere obtained for each calibration star were compared to those previously published by Humphrey (Humphrey 79). From this comparison we can estimate the r.m.s. accuracy of the calibration : 0.05 magnitude for the R-band and 0.03 for the V1-band.

II-2 Spectroscopy

During multiaperture spectroscopic observations on A370 we obtained 28 spectra with a good signal-to-noise ratio using a GRISM whose dispersion is 9.8 A/pixel, giving a velocity accuracy better than 300 km/s (Fort et al. 86, Mellier et al. 86). For the structure in question we only have spectra for galaxy n° 35 (exposure time : 5h, fig. 2a) and for object n° 37 (exposure time : 1h, fig. 2b). The former is a typical E-galaxy whereas the latter has a spectral energy

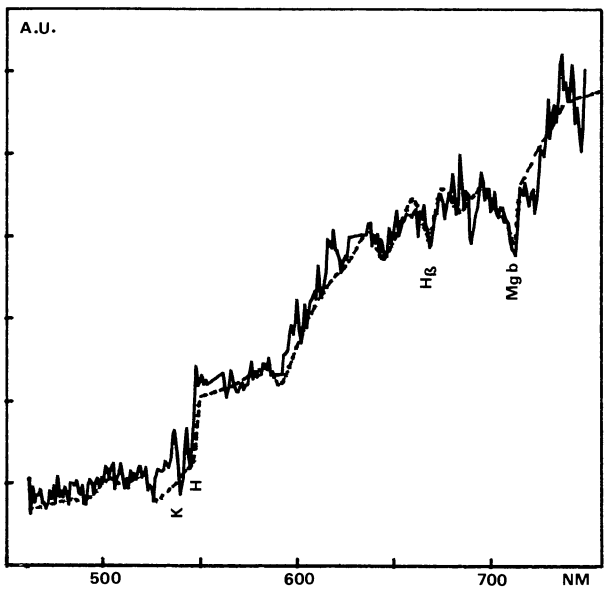

Fig. 2a : Spectrum of the elliptical galaxy n° 35 of the field (z = 0.374 ; exposure time : 3.5h). For comparison a typical spectrum of an elliptical galaxy at this redshift has been superimposed.

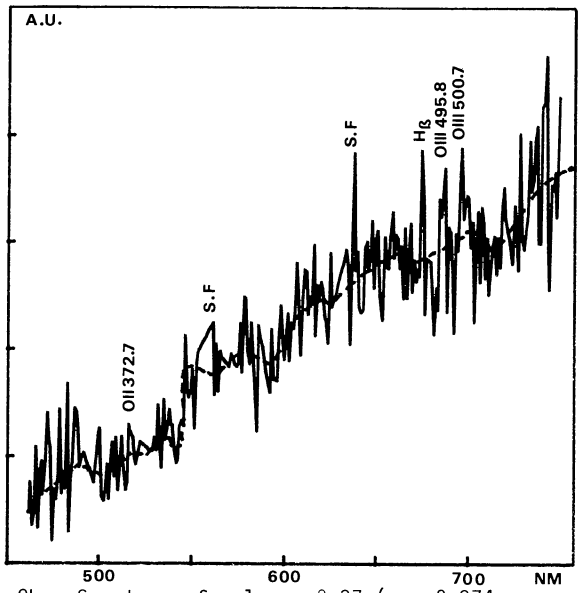

Fig. 2b : Spectrum of galaxy n° 37 (z = 0.374 ; exposure time : 1h). The solid smooth curve is an early type spiral energy distribution. The emission lines correspond to a redshift of 0.385 (δv = 3000 km/s). (SF = sky Features).

distribution like an early-type spiral galaxy (Dressler and Gunn 83) (fig. 2b). Its redshift measured by cross-correlation techniques is z=0.374 (+/- 0.001), just like the central galaxy, but the spectrum also displays typical emission lines (OII λ3727, Hβ λ4861 and OIII $\lambda\lambda$4959, 5007) corresponding to a redshift of z=0.385 (+/- 0.001).

II-3 Photometry

The deep photometry of objects which are not strongly blended was performed with an automatic software package (Le Fevre 86) giving V1 and R magnitudes of the isolated objects scattered in the center of the A370 cluster (Table I), corrected for atmospheric absorption but not for galactic absorption. The K-correction has not been applied.

Table I

Object	V1	R	V1-R
A	21.53	20.85	0.68
n° 37	21.18	19.23	1.95
B	22.18	20.06	2.12
C	22.03	20.58	1.45
D	19.30	17.86	1.44
n° 35	19.21	17.15	2.06
E	20.62	19.39	1.23
F	21.27	19.26	2.01
SG	21.90	20.60	1.30

Table I : VI and R magnitudes and color index of the main galaxies observed near the structure. The letters and numbers correspond to those mentioned on figure 1. The galaxies n° 35 and n° 37 are those for which a spectrum has been obtained during our September multispectroscopic run with PUMA1.

For the ring structure which is a typical alignment of blended features, we favoured a manual reduction using the Toulouse Observatory image processing system. From a region supposed to be free of any contamination from the surrounding bright galaxies (SG area on the fig. 3), we estimated the magnitudes of this small zone to be R=20.6, V1=21.9 and V1-R=1.3. An extrapolation to the overall condensation where galaxies were substracted lead to integrated magnitudes R_{tot}=18 and a $V1_{tot}$=19.3.
Finally, using the V1 and R CCD frame we drew the V1-R map of the cluster center (fig. 3), which shows a very blue ring-like structure connected to the external enveloppe aroung the bright elliptical galaxy n° 35. These features are quite blue (V1-R < 1.2) considering the color index of elliptical galaxies given by Bruzual's models (V-R = 1.6, Bruzual 81) at this redshift, or our color index of galaxy n° 35 : V1-R=2.

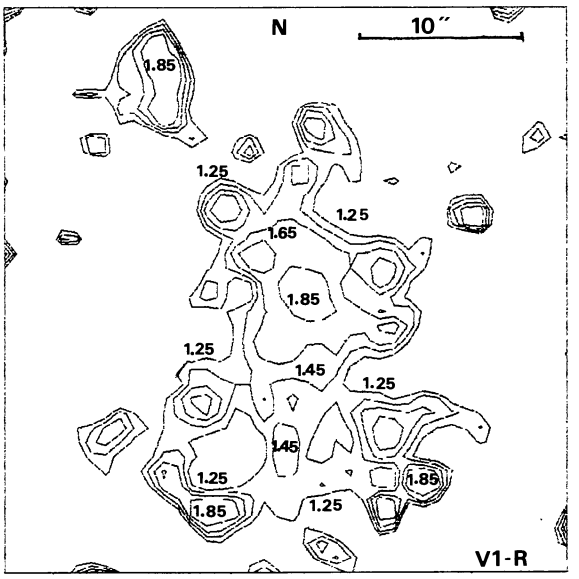

Fig. 3 : (V1-R) isodensitometry map showing a blue ring-like structure

III-Conclusions

From our photometric and spectroscopic data we detected a very peculiar structure in the Abell 370 cluster. Our first analysis can be summarized as follows :

1°) It is a rather blue contrasting condensation located in a dense central clump of the cluster.

2°) Assuming it really belongs to the cluster (not a projection effect), we estimate its size to 150 Kpc long and 20 Kpc wide (H_0=50 Km/s/Mpc). It seems to be embedded in a chain of galaxies surrounding a very bright (massive) one at a distance of 50 Kpc.

3°) From the spectroscopic observations we have shown that one of these surrounding galaxies (n° 37) really belongs to the cluster (z=0.374) and has a spectral energy distribution similar to an early type spiral system. Moreover, we detected typical emission lines superimposed on this spectrum but with a redshift corresponding to a velocity difference of about 3000 km/s.

4°) Finally this structure might be linked to the far diffuse extension of the central galaxy.
Although a clear half ring-like structure has definitely been detected in this cluster, at the moment we do not have enough information available to seriously discuss its origin (no B photometry, only 2 spectra available). For example we cannot completely exclude that it is an off-chance superimposition of faint cluster galaxies even if a diffuse component seems quite clear from the R CCD field. A gravitational lens effect on a background quasar is a possibility owing to the curvature of the structure but in fact it is too small (Hammer 86) and no blue object opposite the central galaxy has been detected. It is more likely that we are dealing with a star formation region located in the very rich core where galaxy/galaxy interactions can occur efficiently (Larson and Tinsley 1978, Sulentic 1976). But the very high richness of this cluster ($N_{0.5}$=31, Mellier et al 86) and its high X-ray luminosity ($9.7\ 10^{44}$ erg/s, Henry et al 81) give us reason to believe that this structure is the result of an intense cooling flow of gas falling towards the massive galaxy which could result in a star burst formation (Sarazin and O'Connel 83, Fabian et al 84 and references therein). This suggestion is partially supported by the emission lines detected on the spectrum of the galaxy n° 37 which may be the evidence of optical lines coming from filaments formed during the cooling flow (Fabian et al 84).
The spectroscopy of each galaxy as well as of the diffuse component of this condensation is necessary to discuss the origin of this singular central feature in any detail.

Acknowledgements : We wish to thank G. Mathez and D. Gerbal for their very pertinent remarks during the composition of this letter and especially Mireille Cailloux for her help during data reductions.

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