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INVESTIGATION OF THE CANCER CLUSTER OF GALAXIES

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ABSTRACT

Redshifts for nine galaxies in the center of the Cancer cluster are reported. Four show emission lines and one of these galaxies is a high excitation peculiar object showing a distorted dust lane and "jet" or edge-on disc structure. A conventional virial theorem analysis of the cluster indicates a total cluster mass near $10^{14} M_{\odot}$ and suggests that the usual instability problem found in galaxy clusters is present.

INTRODUCTION

The Cancer cluster of galaxies has been described by Zwicky (1957) as a spherically symmetric, small to medium size aggregation of apparent diameter 7° with 300 members in the magnitude range $13.8 \leq m_p < 18.2$. This paper contains the results of a spectroscopic investigation of nine galaxies in the central region of the cluster and a discussion of other data available in the region. Figure 1 is a drawing of the central region which identifies the faint galaxies observed.

OBSERVATIONS

Unwidened low dispersion spectra ($231\text{\AA mm}^{-1}$) were taken with the Steward Observatory 90-inch (225 cm) telescope using the Cassegrain image tube spectrograph. The slit was oriented north-south for all galaxies except T4 for which special orientations, described later, were used. Most of the spectra were measured on both the two-screw Mann measuring engine and the Grant measuring engine at Steward Observatory. The two methods of measurement gave equivalent results within the errors in either set of measurements. A mean error of ± 100 km/sec is representative of the internal errors.

Table I lists our new redshifts and summarizes published data for other galaxies falling within the boundaries defined by Zwicky and Herzog (1963). Column 1 gives the NGC or IC number or the identification number given to the object by us. Column 2 gives a six digit number formed by the number of the Palomar Sky Survey field (number 119) in the Catalogue of Galaxies and Clusters of Galaxies (Zwicky and Herzog, 1963, hereafter referred to as CGCG) and a three digit running number giving the galaxy's position in the list of individual galaxies for that field. Columns 3 and 4 give the 1950 equatorial coordinates taken from the CGCG, or interpolated from the Palomar Sky Survey print. Column 5 gives a rough Hubble classification determined by examination of the Sky Survey prints, except where more accurate classifications are available from other sources. Column 6 gives the redshift, corrected for Earth orbital motion and galactic rotation using 300 km sec^{-1} as the speed of galactic rotation. Column 7 gives the apparent photographic magnitude taken from CGCG or estimated from the Palomar Sky Survey blue print. Column 8 references notes which give descriptions of the objects from the Palomar Sky Survey print, remarks concerning

FIGURE 1

An identification drawing of the core region of the Cancer cluster. The cluster center assumed is shown with a large cross. BD stars in the field are indicated.

the spectra, and other information. "Narrow" and "diffuse" refer to spectra with a rapid or gradual change respectively in plate density between nuclear and outer regions.

Eight of the nine galaxies for which spectra were taken show similar redshifts, with a mean of 4526 km sec^{-1} . Four of these galaxies show emission, and in three of them (T2, T4, T5) the emission is strong. The spectra show no differences in widths between hydrogen and forbidden lines, both of which are narrow within the limits of resolution of the spectrograph. One galaxy, T3, shows a very high redshift and is assumed to be a background galaxy.

Unlike rich clusters such as the Coma cluster, the much smaller Cancer cluster appears to have a high percentage of spiral and emission line galaxies in its core region.

THE PECULIAR GALAXY, T4

Plate 1 is an image tube direct blue photograph of T4 taken with the Steward Observatory 90-inch (225 cm) telescope. The scale is indicated, along with marks indicating the three spectrograph slit orientations at which spectra were obtained. The optical image of T4 shows some similarities to that of NGC 5128 as described by Burbidge and Burbidge (1959). There is an elliptical-shaped amorphous component crossed diagonally by a dust lane. In addition, there is a narrow band of luminous material which looks like a "jet" on the Sky Survey print and runs diagonally to both the amorphous component and dust lane. The appearance suggests a distorted edge-on disc structure with violent nuclear region activity superimposed. Table I gives a summary of the spectroscopic observations on T4. Strong emission is limited to the amorphous component; no emission was detected along the "jet". The E-W spectrum reveals emission in the N2 line west of the amorphous region, at a lower redshift than the central region, which may indicate rotation or ejection.

The level of excitation of T4 as indicated by the emission line ratios is higher than that of compact and Markarian galaxies surveyed by Sargent (1970a, 1970b). The N2 line is the strongest in the spectrum, [O II] 3727 dominates H β , and Ne III is clearly present. No object in the UHURU Catalog of X-Ray Sources (Giacconi, et. al., 1972) or the General Catalogue of Discrete Radio Sources (Howard and Maran, 1965)

PLATE I

Blue image tube direct photograph of the peculiar galaxy T4 in the Cancer cluster. Strong emission appears in the E-W amorphous component but not along the distorted disc or jet in position angle 54° .

DYNAMICS

There is considerable doubt that the redshift can be interpreted simply as a velocity (Tifft, 1972, 1973); however, since no previous conventional dynamical analysis of the Cancer cluster has been carried out we include such an analysis here. The CGCG chart covering the region of the Cancer cluster shows that the galaxies form a fairly concentrated core about $40' \times 90'$ surrounded by an uneven scattering of galaxies over a region 3 or 4 degrees across. The sample of 20 objects for which redshift data was available has 14 objects in the core (NGC 2557, 2560, 2563, IC 2338/39, 2341, Anon, T1, T2, T4, T5, T6, T7, and T8) and 6 in the outer regions (NGC 2545, 2554, 2565, 2582, 2595, and 2995). A dynamical investigation was done once for the 20 point sample and again for the 14 inner members, this segregation being made entirely on the basis of radial distance from the center of the core (taken as $8^h 17^m.5, +21^\circ 14'$).

A Hubble constant of 75 km/sec/mpc was assumed which for the mean redshift of 4658 ± 423 (me of mean) of the inner members implies a distance of 62 Mpc. Assuming $M/L=3$ for spirals and $M/L=55$ for ellipticals, estimates of the masses of individual members were obtained using magnitudes in Table 1 and the usual virial theorem treatment was applied to these data. The 20 point sample gave $2T/\Omega=18$ while the 14 point sample yielded $2T/\Omega=9.5$. The calculation was performed once again using the approximate relation

$$M_T \langle V^2 \rangle - GM_T^2 \langle \frac{1}{r} \rangle = 2T + \Omega = 0. \quad (1)$$

thus, inferring a total cluster mass of $2.6 \times 10^{14} M_\odot$ for the 20 point sample and $8 \times 10^{13} M_\odot$ for the core galaxies. The root mean square redshift residual for the two cases was 560 km/sec and 420 km/sec respectively. Using Zwicky's estimate of 300 members for this cluster, these total masses imply a mean mass per galaxy of $2 \times 10^{11} M_\odot$.

It may be argued that some or all of the six outer galaxies are not physical members of the cluster. These six objects are among the eight brightest galaxies in the 20 point sample and they tend to have lower redshifts. Five of the six outer galaxies are among those with

the seven lowest redshifts, NGC 2545 and 2565, having redshifts more than 1000 km/sec below the cluster mean are especially discordant. It should also be pointed out that NGC 2563 is seen to strongly dominate in the calculations due to its high apparent luminosity. However, if one supposes it to be a foreground galaxy and deletes it from the two data sets, then values of $2T/\Omega=208$ and 27 are found for the large and small samples respectively. Of course, the results are also rather sensitive to the M/L value chosen for ellipticals, since with M/L=55 the four ellipticals represent 90% of the mass in the 14 point sample. If we were to increase M/L to 100 for ellipticals and take $H=55 \text{ km sec}^{-1} \text{ Mpc}^{-1}$, the ratio $2T/\Omega$ quoted above would improve by more than a factor or two. It is clear, then, that the results of these calculations depend very sensitively on how one chooses to treat the data. Bearing these dependences in mind, it is concluded that the Cancer cluster is virially unstable.

The redshift and positional data were also investigated to see if any rotation of the cluster as a whole could be detected. No indication of rotation could be found.

ACKNOWLEDGMENTS

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TABLE I

Redshifts in the Cancer Cluster

Identity	Zwicky	α (1950)	δ	Type	Vo	mp	Notes
New Redshifts							
		h m	o ' "				
T5	119053	8 16.4	+21 13.0	S	4619	15.5	4, 5
T6		8 16.5	+21 09.7	S	3627	16.2	3, 4, 6
T4(0°)	119055	8 16.7	+21 16.3	Pec	5405	15.5	4, 7
T4(54°)					5415		
T4(90°)					5379		
T3		8 16.8	+21 11.7	S	28176	16.5	3, 4, 8
NGC 2565	119057	8 16.9	+22 11.	S	3503	13.8	9
T2	119059	8 17.1	+21 13.5	S	4173	15.7	4, 10
T1	119061	8 17.3	+21 13.7	S	5080	15.5	4, 11
NGC 2563	119065	8 17.7	+21 13.6	SO	4291	13.7	4, 12
T7		8 17.7	+21 14.3	E	4573	16.2	3, 4, 13
T8		8 17.9	+21 12.8	E	4441	16.0	3, 4, 14
Other Objects							
NGC 2545	119016	8 11.4	+21 31.	S	3086	13.2	1, 15, 26
NGC 2554	119033	8 15.0	+23 38.	S	4067	13.5	1, 16
Anon	119041	8 15.6	+20 55.1	S	2688	15.3	2, 4, 17
NGC 2557	119048	8 16.3	+21 35.6	S	4835	14.6	2, 4, 18
NGC 2560	119058	8 17.0	+21 08.6	S	4791	14.9	2, 4, 19
NGC 2562	119063	8 17.5	+21 17.4	Sa	4853	14.0	4, 20
IC 2338	119080	8 20.7	+21 30.	Pec	5119	14.7	2, 21
IC 2339	119080	8 20.7	+21 30.	Pec	5083		2, 21
IC 2341	119081	8 20.8	+21 35.8	E	4739	14.9	1, 4, 22
NGC 2582	119091	8 22.4	+20 30.	S	4270	14.3	1, 23
NGC 2595	119109	8 24.8	+21 38.	SB	4260	13.9	1, 24, 26
NGC 2599	119122	8 29.2	+22 44.	S	4587	13.4	1, 25, 26

NOTES TO TABLE I

- 1 Redshift from Chincarini and Rood (1972).
- 2 Redshift from Kintner (1971).
- 3 Magnitude estimated from Palomar Sky Survey print.
- 4 Coordinates measured from Palomar Sky Survey print.
- 5 Bright irregular blue nuclear region. Diffuse irregular halo.
Type S. 3727 and H β emission, H and K absorption.
- 6 Lenticular object with faint extension NE-SW. Type S. Narrow.
No emission.
- 7 See text for detailed description. Spectra show [O II] 3727,
[Ne III], [O III] N1 and N2, H β and H δ emission (H γ masked
by the night sky). K, G and weaker features measured in
absorption. The 5007 N2 line is detectable at two points
west of the nuclear region on the 90° position angle spectrum,
one of them showing a redshift of about 300 km sec⁻¹ less
than the redshift of the nucleus.
- 8 Compact semi-stellar redobject. Narrow. No emission.
- 9 Large bright elliptical nuclear region surrounded by faint disc
bounded by a very well developed blue ring showing an irreg-
ular structure. No emission. Chincarini and Rood (1972)
give a redshift of 3318.
- 10 Lenticular image, somewhat irregular. Very blue S-type. 3727,
H β , and [O III] N2 emission, H and K absorption.
- 11 Small S or SB. Nucleus quite red. Narrow. 3727 emission, H and
K absorption.
- 12 Type from Humason, Mayall and Sandage (1956) who give a redshift
of 4664. No emission.
- 13 Compact, nearly stellar red object. Narrow. No emission.
- 14 Compact, semi-stellar. Type E.
- 15 Similar to NGC 2565 but nuclear region larger and outer ring less
regular.
- 16 Large elliptical shaped nucleus with weak blue outer structure.
- 17 Moderately inclined spiral.
- 18 Lenticular nuclear region. Incipient spiral structure. Well
developed halo.
- 19 Large bright edge-on Sa-Sb spiral.

- 20 Redshift from Humason, Mayall and Sandage (1956) who classify this
object as Sa.
- 21 Bright blue irregular or distorted spiral.
- 22 Bright elliptical galaxy with well developed halo.
- 23 Well developed small spiral.
- 24 SBb with structure disrupted on SW.
- 25 Elliptical-like nucleus surrounded by faint, sharp outer ring,
which on the blue print appears to become somewhat irregular
suggesting incipient spiral structure.
- 26 Emission line object according to Chincarini and Rood (1972).