HCG 16: A HIGH CONCENTRATION OF ACTIVE GALAXIES IN THE NEARBY UNIVERSE

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ABSTRACT

In the course of an extensive campaign to measure radial velocities of galaxies in a selected sample of compact groups photometrically studied by de Carvalho et al. (1994), we report the discovery of a system very rich in starburst galaxies and AGNs. This is the system HCG 16 of Hickson's (1982) catalog of CGs. The 7 brightest galaxies form a kinematical group with bi-weighted estimate mean velocity of $V_{BI} = 3959 \pm 66$ km s$^{-1}$, dispersion $\sigma_{BI} = 86 \pm 55$ km s$^{-1}$, a median radius $\langle R \rangle = 0.197$ Mpc, a mean density of $\langle D \rangle = 217$ gal Mpc$^{-3}$ and a total absolute magnitude of $M_B = -22.1$. From their spectral characteristics, we have identified one Seyfert 2 galaxy, two LINERs and three starburst galaxies. Thus, HCG 16 appears to be a dense concentration of active galaxies. In our sample of 17 Hickson groups, HCG 16 is unique in this regard, suggesting that it is an uncommon structure in the nearby universe.

Subject headings: galaxies: Compact groups – galaxies: interactions – galaxies: Seyfert – galaxies: starburst
1. Introduction

Compact groups (CGs) of galaxies may represent some of the densest concentrations of galaxies known in the Universe and so may provide ideal laboratories for studying the effects of strong interactions on the morphology and stellar content of galaxies. This concept has motivated several recent observational programs aimed at establishing the dynamical reality of these structures and signs of galaxy interactions. Whereas most of these works (Rubin et al. 1991, Pildis et al. 1995) have mainly considered objects in which clear morphological signs of interactions are evident, studies made with larger samples have surprisingly shown that the frequency of mergers in CGs is significantly less than that predicted by simple dynamical arguments (Zepf 1993). Confirming this result, in a search for tidal-tail induced dwarf galaxies in 42 Hickson’s (1982) CGs, Hunsberger et al. (1995) have shown that only 7 of them exhibit clear signs of such objects.

Another question that may be addressed by studying CGs refers to the environmental origin of the nuclear activity of galaxies (AGNs) represented by the presence of nuclear emission lines that cannot be explained in terms of normal stellar population. This longstanding question has been debated in the literature with no clear answer. For instance, whereas the studies of Kennicut & Keel (1984) and Keel et al. (1985) have shown that the AGN phenomenon occurs more often in binary or interacting systems, other studies found no relevant correlations between nuclear activity and interaction parameters (Dahari & de Robertis 1988; Laurikanen & Salo 1995). However, it seems clear from studies of optically selected samples that nearby AGNs avoid systems which are strongly interacting. Activity, if present, seems rather due to intense starburst formation induced by the interaction itself (Bushouse 1986). This may not be true for the ultraluminous infrared galaxies which are mostly interacting galaxies and show an increasing probability of being Seyferts with increasing infrared luminosity (Veilleux et al., 1995). One may speculate that if AGNs
do really prefer interacting systems but avoid those that are strongly interacting, then an ideal place to find them would be the CGs, or at least a subclass of them which, although apparently very dense as deduced from their radial velocities, show no signs of violent interactions.

In this Letter we spectroscopically revisit one compact group which has been previously noticed as presenting morphological signs of interaction among its galaxies. This is the system HCG 16 of Hickson’s (1982) catalog of CGs. We have found this group to be very rich in starburst galaxies and AGNs, being possibly a very rare case of such a high concentration of active galaxies in such a dense environment.

2. Data and Kinematic Properties

HCG 16 and its neighbouring galaxies were spectroscopically observed in the course of an extensive campaign aimed to measure radial velocities of galaxies of a selected sample of CGs photometrically studied by de Carvalho et al. (1994, hereafter dCAZ94). The spectra were taken at the 4m CTIO telescope, using the ARGUS fiber feed spectrograph. The details of the instrumental setup and data reduction are discussed by de Carvalho et al. (1996). Table 1 lists the galaxy number as given by dCAZ94 (column 1), positions R.A. and Dec. (columns 2 and 3), magnitudes in B (dCAZ94, column 3), and heliocentric velocities and errors (columns 4 and 5). We list here only the seven galaxies defining the group. A complete list of all the galaxies measured in the field is presented by de Carvalho et al. (1996).

We have used the ROSTAT statistical package (Beers et al. 1990) in order to analyse the velocity distribution of our sample of galaxies around HCG16 (0.5°×0.5° around the center), which is complete down to B = 18.6m. The analysis revealed the presence of a
kinematical group consisting of the 7 brightest galaxies in the field, with mean velocity (as given by the bi-weighted estimate) of \( V_{BI} = 3959 \pm 66 \, \text{km s}^{-1} \) and dispersion \( \sigma_{BI} = 86 \pm 55 \, \text{km s}^{-1} \) (90% confidence errors). A more detailed study is presented in Ribeiro et al. (1996a).

The compact group HCG 16 is a larger group than originally noted by Hickson, being composed of 7 galaxies. In Figure 1, we present the distribution of galaxies in HCG 16. The original group described by Hickson is composed of 4 galaxies: 1, 2, 4 and 5. To these galaxies, we added 3 others, 3, 6 and 10. Galaxies 3 and 6 are quite luminous, which suggests that this new addition is of great importance for the dynamical structure of the group. The median of the projected separations of the galaxies in the group is \( \langle R \rangle = 0.197 \, \text{Mpc} \left( H_0 = 75 \, \text{km s}^{-1} \, \text{Mpc}^{-1} \right) \), and the mean density is \( \langle D \rangle = 217 \, \text{gal Mpc}^{-3} \). The density is therefore smaller than the density \( \langle D \rangle = 10^4 \, \text{gal Mpc}^{-3} \) originally determined by Hickson. While this density is lower than that in the central part of rich clusters of galaxies, HCG 16 has a density roughly 30 times higher than those found for loose groups of galaxies, as determined by Maia et al. (1989). The total absolute magnitude of the system is \( M_B = -22.1 \) (as compared to \( M_B = -21.5 \) determined by Hickson).

3. Spectral Properties

In Figure 2, we present the spectra for the 6 emission-line galaxies out of the 7 which constitute HCG 16. The seventh member of the group, galaxy 10, does not show any emission lines. Because the spectra are not flux calibrated, we divided the number counts by their mean values, to compare the relative intensity of the emission lines in the different galaxies. The galaxy 4 shows the most intense emission lines. Except for the unusually high ratio of [NII]/\( \text{H}\alpha \) and the presence of a faint [OI]\( \lambda 6300 \) line, this spectrum is very similar to those of disk spiral HII regions. This galaxy is clearly experiencing an intense starburst phase in or near its nucleus. Based on the similarity of the spectra, the galaxies 3, 5 and 6
are also starburst galaxies, although at relatively lower intensities than 4. Galaxies 1 and 2 show a different type of spectrum, both with the high [NII]/Hα ratio typical of AGNs.

The classification of the kind of activity encountered in the galaxies of HCG 16 is based on the different line ratios shown by galaxies of different activity classes. The criteria that we have used for our spectral characterization are explained in detail in Ribeiro et al. (1996b). The presence or absence of a wide Balmer emission line component allows us to distinguish between a Seyfert 1 and a Seyfert 2. We distinguished between Seyfert 2 and LINERs based on the ratio [OIII]λ5007/Hβ > 2.5 (Coziol 1996). We adopted this definition because in many cases the [OII]λ3727 line, used by Heckman (1980) to characterize the LINER type, was not available. For the starburst galaxies, we distinguished also between HII galaxies and Starburst Nucleus Galaxies (SBNGs). This distinction is based on a correlation between spectroscopic characteristics and morphologies (Coziol et al. 1994). In general, the HII galaxies are high-excitation ([OIII]λ5007/Hβ > 2.5) small metal poor galaxies, while the SBNGs are low-excitation massive and metal rich galaxies. Usually, the spectra of SBNGs indicate a mean excess of 0.2 dex in the [NII]/Hα ratio as compared to normal HII regions (Coziol et al. 1996).

In Figure 3, we present the diagnostic diagram of [OIII]λ5007/Hβ vs. [NII]/Hα for all the emission-line galaxies in HCG 16. In this diagram, the dotted line represents our criterion to distinguish between high and low-excitation galaxies. The solid line is the empirical separation established by Veilleux & Osterbrock (1987) between galaxies ionized by an AGN and galaxies ionized by stars. The uncertainties on the line ratios are determined based on Poisson statistics. The high uncertainties in [OIII]λ5007/Hβ for galaxies 1 and 2 reflect the weakness of the emission lines. In those galaxies for Hβ the stellar absorption dominates over the nebular emission. Following our classification, HCG 16 contains 3 AGNs (2 LINERs and 1 Seyfert 2) and 3 starbursts. Based on the unusually
high intensity of the lines [SII]\(\lambda\lambda6716,6734\) (see Fig. 2), galaxy 2 looks more like a LINER than a Seyfert 2 (Rubin et al. 1991). The starburst nature of galaxy 4 was already suggested by its high emission in infrared (Sparks et al. 1986). The equivalent widths \(\text{EW}(\text{H}\alpha+\text{[NII]})\) for the galaxies 3, 4, 5 and 6 are 44, 146, 50 and 10 Å respectively. Except for galaxy 6, those values are comparable to those found in typical starburst galaxies (Kennicutt 1992).

4. X-Ray Characteristics

X-ray emission from HCG 16 was first detected by Bahcall et al. (1984). An analysis of ROSAT observations by Saracco & Ciliegi (1995) suggests that in general the emission is point-like and centered on the galaxies, although Ponman et al. (1996) have recently presented evidence for diffuse intragroup X-ray emission from this group. The two dominant galaxies, 1 and 2, appear to be in a common X-ray envelope, for which Saracco & Ciliegi give a total luminosity of \(L_{\text{x}}(0.5 - 2.3 \text{ kev}) = 4.3 \times 10^{40} \text{ erg s}^{-1}\). The fainter galaxies, 4 and 5 have resolved emission with luminosities \(4.6 \times 10^{40} \text{ ergs}^{-1}\) and \(1.9 \times 10^{40} \text{ ergs}^{-1}\), respectively. In the X-ray contour map presented by Saracco & Ciliegi (1995) we found a point-like emission at southeast which exactly coincides with galaxy 3. A crude estimate of the X-ray luminosity of this source gives \(\sim 0.5 \times 10^{40} \text{ ergs}^{-1}\).

For comparison, mean values found by Green et al. (1992) give \(L_{\text{x}}(0.5 - 4.5 \text{ kev}) = 1.8 \times 10^{41} \text{ ergs}^{-1}\) for Seyfert 2, \(2.2 \times 10^{40} \text{ ergs}^{-1}\) for LINERs and \(7.0 \times 10^{39} \text{ ergs}^{-1}\) for starburst galaxies. In general therefore, the X-ray luminosities of the galaxies in HCG 16 are comparable to those found in LINERs, and their X-ray emission intensities decrease with the decreasing intensity of the starburst activity.
5. Discussion

HCG 16 is a clear example of recent and multiple interacting galaxies. As suggested by the spectroscopy, these interactions have triggered a new phase of star formation in the galaxies 3, 4 and 5, while in the galaxies 1 and 2, it is likely that only the nuclei were activated. The fact that 1 and 2 do not exhibit a starburst seems to be in contradiction with the description of their morphologies by Rubin et al. (1991) who reported signs of interactions in the forms of weak antennas (in galaxy 1), tidal tails (galaxy 2), and a faint bridge between 1 and 2. Indeed, following models of interacting galaxies, the development of such structures, especially the very long tails, requires a few $10^8$ yrs (Barnes 1990), which is also comparable to the fading time scale of an induced starburst due to gas depletion (Mihos et al. 1993).

Based on the absence of tidal features in the galaxies 3, 4 and 5 we could suppose that those galaxies are examples of a more recent interaction (starbursts much younger than $10^8$ yrs) than the galaxies 1 and 2 which are at a more advanced stage of interaction. In favor of this scenario, we note that galaxies 1 and 2 may have a common X-ray envelope. The hot diffuse component could have been formed from gas that was stripped from the individual galaxies following their close encounter (Sulentic et al. 1995). As judged from the remnant traces of interaction in the morphologies of these two AGNs, the galaxies 1 and 2 could have experienced a very strong starburst in their recent past (but surely older than few $10^8$ yrs). Since then, the burst has faded and only low activity in the nuclei remains. More observations are needed to look for possible traces of post-starburst activity near the nuclei of galaxies 1 and 2. It is not clear however, if there exists any direct relation between the starburst event and the AGNs. In particular, galaxies 1 and 2 could already have possessed a well-formed Black Hole in their nucleus which was rejuvenated by a new infall of matter provided by the interaction.
A fundamental point we want to stress in this Letter is that our spectroscopic data support the identification of the HCG 16 as a real compact group. Both the kinematical parameters and the spectral classification of the six brightest galaxies as active are easily understood if HCG 16 is a bound, dense system. In contrast, our observations are difficult to understand if the enhanced activity and density in HCGs is explained by projections along filaments incorporating a true pair (e.g. Hernquist, Katz, & Weinberg 1995, Mamon 1995). At the same time, HCG 16 is unique among our sample of 17 groups as a clear case of compact structure, and groups like it may be very rare, at least in the nearby universe (Ribeiro et al. 1996a). The other structures have a wide variety of projections and dynamical configurations. This variety demonstrates how difficult it is to define small groups of galaxies, and how useful spectroscopy is for detecting groups both by picking out structures in velocity space and by testing for nuclear activity.

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Table 1. Velocity distribution analysis of HCG 16

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Fig. 1.— Position on the sky of the galaxies in HCG 16. Each circle represents a galaxy, with the diameter being proportional to its magnitude (the greater the brighter). The nearest 4 galaxies to the center form the original group, as defined by Hickson. The 3 new galaxies are within a projected distance of 900 arcsec. Symbols are as follow: ●, galaxies without measured radial velocity; ○, background galaxies; ⅄, galaxy at $V = 3167$ km s$^{-1}$, which has been excluded from the group based on the consistency of the observed distribution being drawn from a single gaussian parent population.

Fig. 2.— Optical spectra for the 6 emission-line galaxies of HCG 16. For each spectrum, the counts were divided by the mean value to facilitate the comparison between the galaxies. Each galaxy is identified by a running number (see Table 1). The letter in parenthesis refers to the original notation by Hickson (1982).

Fig. 3.— Diagnostic diagram of emission line ratio and classification of the different activity of the galaxies of HCG 16. The dotted line at log([O III]/Hβ) = 0.4 establishes a distinction between high–excitation and low–excitation galaxies (Coziol 1996). The solid line indicates the empirical separation between starburst galaxies and AGNs as determined by Veilleux and Osterbrock (1987).