A SPIRAL-LIKE DISK OF IONIZED GAS IN IC 1459: SIGNATURE OF A MERGING COLLISION?

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Abstract. We report the discovery of a large (15 kpc diameter) Hα+[NII] emission-line disk in the elliptical galaxy IC 1459, showing weak spiral structure. The line flux peaks strongly at the nucleus and is more concentrated than the stellar continuum. The major axis of the disk of ionized gas coincides with that of the stellar body of the galaxy. The mass of the ionized gas is estimated to be $\sim 1\ 10^5$ M$_\odot$, less than 1% of the total mass of gas present in IC 1459. The total gas mass of 4 10^7 M$_\odot$ has been estimated from the dust mass derived from a broad-band colour index image and the IRAS data. We speculate that the presence of dust and gas in IC 1459 is a signature of a merger event.

1. Introduction

Contrary to the traditional view of elliptical galaxies as being essentially free of interstellar matter, advances in instrumental sensitivity have caused a recent renaissance of interest in dust and gas in elliptical galaxies. Many elliptical galaxies are now known to contain dust (*e.g.*, Véron-Cetty and Véron [1988] and references therein), HI gas (Knapp *et al.*, 1985), hot ($\sim 10^7$ K) X-ray gas (Canizares *et al.*, 1987) and ionized gas (Phillips *et al.*, 1986). Moreover, Jura *et al.* (1987) have shown that the *Infrared Astronomical Satellite* (IRAS) detected more than 50% of the elliptical galaxies with $B_T^0 < 11$ mag. in the *Revised Shapley-Ames Catalog* (RSA, Sandage and Tammann, 1981), indicating the presence of $10^7 - 10^8$ M$_\odot$ of cold interstellar matter. Thus dust and gas in ellipticals seems to be quite common.

The origin and evolution of the dust and gas are still not fully understood. To study the origin and evolution of interstellar matter in elliptical galaxies systematically we are currently undertaking a survey of all ellipticals with $B_T^0 < 12$ mag. in the RSA catalog. This survey aims at obtaining deep CCD colour index images and narrow-band (Hα+[NII]) images as well as spectroscopic data.

The CCD images of IC 1459, one of the galaxies in our sample, turned out to be so striking and unusual that we decided to present the results here.

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The giant elliptical IC 1459 is a member of a group of galaxies (group no. 15 of Huchra and Geller (1982)), containing 10 galaxies. As already noticed by Sparks *et al.* (1985), there is some dust absorption near its centre. The colour index image presented here confirms this result. It is one of the few ellipticals which are detected by IRAS in all four passbands (Jura *et al.*, 1987). It is also a compact, powerful radio source with a brightness of 1.0 Jy at 6 cm (Sadler *et al.*, 1989). Finally, it has been detected by the EINSTEIN satellite (Forman *et al.*, 1985). Franx and Illingworth (1988) discovered a fast (170±20 km s^{-1}) counter-rotating core, which is suggestive of a recent merging collision.

2. Observations and Results

Deep CCD imaging of IC 1459 has been performed using the ESO/MPI 2.2m and Danish 1.5m telescopes on La Silla, Chile. The galaxy was observed through Johnson B and V filters as well as through two narrow-band filters: one centered on the redshifted Hα line and one on the nearby continuum.

The final B−V colour index image of IC 1459 was obtained by dividing the (processed) V image by the B image. With the present high-quality data this technique reliably reveals features redder than about 0.005 in B−V over their surroundings.

To produce the final emission-line maps, we scaled the continuum image to the on-line image by comparing the counts in the two frames not too close to the dusty features as determined from the colour index image. After scaling the continuum image it was subtracted from the on-line image, yielding an image containing emission only.

A detailed account of the reduction and analysis method is given elsewhere (Goudfrooij *et al.*, 1990). Here we only present results on the dust and ionized gas in IC 1459.

2.1. Mass of neutral gas

In the B−V image (Fig. 1a) a red, diffuse nuclear region shows up. The mean colour excess of the dusty feature equals $E_{B-V} = 0.03$ over an area of 1083 $('')^2$. Assuming $H_0 = 50$ km s^{-1} Mpc^{-1} and $N_H/E_{B-V} = 5.8\ 10^{21}$ cm^{-2} mag^{-1} (Bohlin *et al.*, 1978) we find $M_{gas,B-V} = 3.6\ 10^7 M_\odot$. This mass estimate may be compared with an estimate based on the *IRAS* 60 and 100 μm data, using $M_{dust} = F_\lambda R^2 / [\kappa_\lambda B_\lambda(T)]$ where F_λ is the observed fluxdensity at distance R, κ_λ is the dust opacity and $B_\lambda(T)$ is the Planck function. Adopting $\kappa_\lambda \propto \lambda^{-1}$, a uniform temperature of 35 K as derived from the *IRAS* S_{100}/S_{60} ratio (Jura *et al.*, 1987) and $M_{gas}/M_{dust} = 100$, we find $M_{gas,IRAS} = 3.9\ 10^7 M_\odot$. This agrees very well with $M_{gas,B-V}$. The gas masses mentioned above are in agreement with the upper limit $M_{HI} < 2\ 10^8$ $M_\odot$ as derived by Welsh *et al.* (1990) from radio observations.

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2.2. *Mass of ionized gas*

In Fig. 1b the Hα+[NII] emission-line map is shown. The ionized gas is distributed in an extended disk, showing weak spiral structure.

Using the emission-line ratio [NII]λ6583/Hα = 1.44 as determined by Phillips *et al.* (1986) from a long-slit spectrum of IC 1459 taken in P.A. 144°, *i.e.* refering to the nuclear region only, we derive L(Hα) = 5.3 10^{40} erg s^{-1} from our Hα+[NII] map. Adopting an electron density of $\sim 10^3$ cm^{-3} as implied by the [SII]$\lambda\lambda$6717,6731 doublet ratio in the spectrum of Phillips *et al.* and standard (case B) recombination theory we derive a mass of ionized gas $M_{HII} = 1.2\ 10^5 M_{\odot}$.

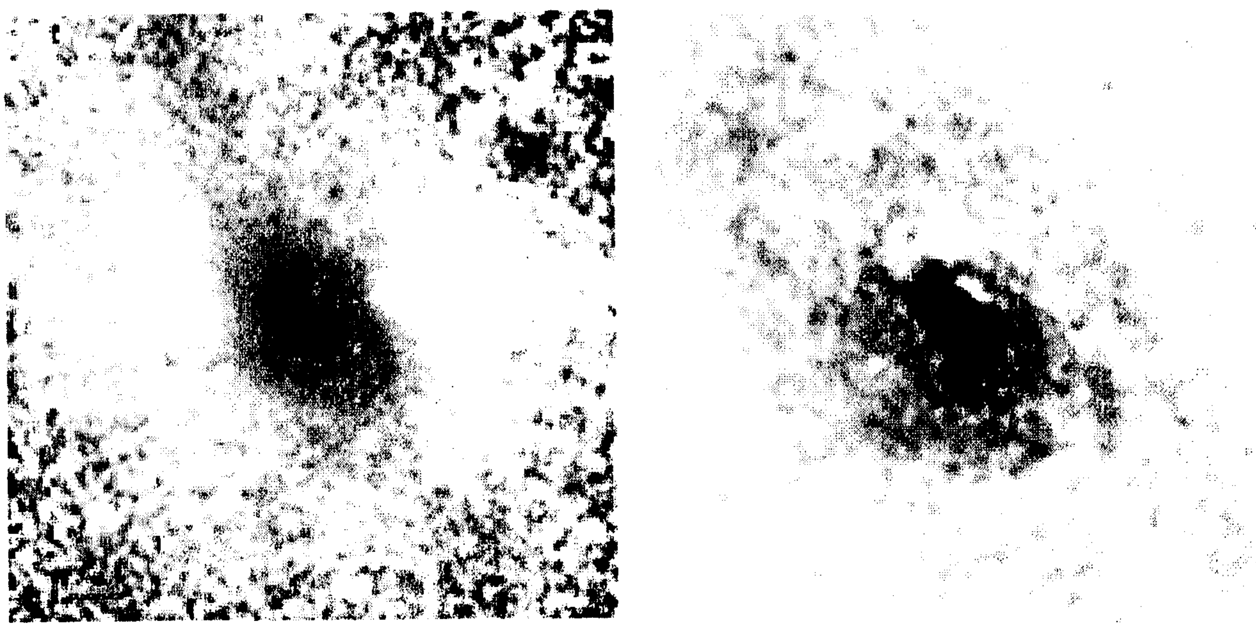

Figure 1. (a) *Grey-scale plot of the B−V index in the central 1!34 × 1!34 of IC 1459. North is up and east is left. Red features show as black. The very nucleus is reddened by E_{B-V} = 0.07.* **(b)** *Grey-scale plot of the Hα+[NII] emission in the central 1!34 × 1!34 of IC 1459. Emission shows as black. A spiral-like disk structure can be distinguished. Total Hα+[NII] luminosity is 1.5 10^{41} erg s^{-1}.*

3. Discussion

3.1. *On the morphology of the ISM in IC 1459*

The colour index map and the Hα+[NII] map show some interesting differences. First, the colour index map shows a smooth, diffuse colour gradient in the central region, whereas the Hα+[NII] intensity peaks very strongly at the centre. Secondly, the diffuse "dust patches" as seen in Fig. 1a extend into the outer parts of the galaxy along a position angle which deviates

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from that of the major axis of the disk of ionized gas. Thus the neutral and ionized gas in IC 1459 are probably distributed in a different way.

The morphology of the interstellar medium in IC 1459 suggests that the presence of dust and gas in this galaxy is due to a merger event. Since the disk of ionized gas coincides with the photometric major axis throughout its measurable size of 15 kpc, the study by Tohline *et al.* (1982) suggests that the merging collision has taken place ~3 10^9 yrs ago. This estimate depends on the original alignment of the smaller galaxy with the giant elliptical. The innermost part of the emission-line region is not ellipsoidal but rather irregular, indicating a young phenomenon. As to the weak spiral structure of the extended disk, this is probably not a remnant of the intrinsic shape of the smaller gas-rich galaxy. Tidal forces during the merging collision will have removed any pre-existing structure. The spiral-like structure might reflect the response of the gas in the gravitational potential of the elliptical galaxy.

3.2. Possible ionization mechanisms for the gas

Heat conduction from hot X-ray gas: This possibility has recently been put forward by Sparks *et al.* (1989) and de Jong *et al.* (1990) for the dominant cluster elliptical NGC 4696 in which the dust and ionized gas are distributed similarly. However, this mechanism does not seem to be able to account for the Hα emission of IC 1459. Although IC 1459 has been detected by the EINSTEIN satellite, the data by Canizares *et al.* (1987) show that its X-ray luminosity is probably dominated by the contribution of discrete sources (*e.g.*, binary X-ray sources and globular clusters). Thus the amount of hot gas in IC 1459 is presumably small.

Ionization by shock-heating in cloud-cloud collisions: This is to be expected while the gas captured by the giant elliptical is settling down to a rotating disk.

Photoionization by a central non-thermal source: Many features in the nucleus point at this possibility. The spectrum of the nucleus of IC 1459 by Phillips *et al.* (1986) is typical of a LINER and broad [NII]λ6583 line (426 km s^{-1} FWHM). Moreover, IC 1459 is identified with the radio source PKS 2254−367 which is a compact active radio galaxy with a spectral index ~0.0 (Disney and Wall, 1977) and it has a large far-infrared S_{25}/S_{60} ratio, characteristic of an active nucleus (de Grijp *et al.*, 1985; de Grijp and Goudfrooij, 1990).

Burst(s) of star formation, triggered by the merging collision: It seems that we may not discard this possibility, at least for the outer parts of the disk. From the observed Hα flux we derive a total Hydrogen recombination rate which can be maintained by ~3 10^4 B0 stars. Adopting M_V = −4.0 and B−V = −0.29 for a B0 star (Kurucz, 1979) we obtain B ~ 16.6 due to early-type stars. The observed B magnitude in the corresponding area equals B = 12.7 so that the observed amount of Hα emission could be due to recently formed early-type stars, which are unobservable in the broad-band photometry.

More severe constraints on the source of ionization and the kinematics of the extended emission-line regions in IC 1459 cannot be put until high signal-to-noise spectroscopic data are available.

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