Dust and Ionized Gas in Elliptical Galaxies: Signatures of merging Collisions?

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Traditionally elliptical galaxies were thought to be essentially devoid of interstellar matter. However, recent advances in instrumental sensitivity have caused a renaissance of interest in dust and gas in – or associated with – elliptical galaxies. In particular, the technique of co-adding IRAS survey scans has led to the detection of more than half of all ellipticals with $B_T^0 < 11$ mag. in the Revised Shapley-Ames catalog, indicating the presence of $10^7 - 10^8$ $M_\odot$ of cold interstellar matter (Jura *et al.* 1987). In addition, CCD multi-colour surface photometry shows dust patches in about 30% of the cases studied to date (*e.g.*, Véron-Cetty & Véron 1988). Thorough study of the gas and dust in ellipticals is important to **(1)** determine its origin (mass-loss from late-type stars, merging collisions with other galaxies or accretion inflows from cooling X-ray gas), and **(2)** investigate the 3-D shape of ellipticals, as can be derived from the orientation of the dust lanes and the 2-D velocity field of the gas.

A major difficulty in studies of ISM in ellipticals has been the lack of a reliable, unbiased sample. For instance, our knowledge on X-ray emission of ellipticals is mainly-based upon serendipitous observations by the EINSTEIN satellite, and recent systematic searches for dust, CO and Hα emission have been performed mainly for galaxies with high IRAS flux densities (*e.g.*, Kim 1989, Lees *et al.* 1991, Huchtmeier & Tammann 1992). This obviously makes it difficult to give conclusive statements on the origin, global occurrence, and fate of ISM in elliptical galaxies *in general.* With this in mind, we have performed a systematic optical CCD survey of a complete, magnitude-limited sample of nearby giant elliptical galaxies. This survey comprises both multi-colour broad-band and narrow-band CCD imaging as well as long-slit spectroscopy. A more thorough description of the survey is given by Goudfrooij (1991).

An important result of our comprehensive CCD imaging program is that a relevant fraction (~ 40%) of the sample objects exhibits dust patches within *extended* Hα+[NII] line-emitting filaments. This common occurrence can be easily accounted for if the dust and gas have an external origin, *i.e.*, mergers or interactions with gas-rich galaxies. Evidence supporting this suggestion: **(a)** the ionized gas is usually dynamically decoupled from the stellar velocity field (see, *e.g.*, Sharples *et al.* 1983, Bertola & Bettoni 1988); **(b)** it is shown in a companion paper (Goudfrooij *et al.* 1992) that internal stellar mass loss alone can not account for the dust content of elliptical galaxies.

The extended line emission often has a peculiar distribution and is more sharply peaked at the nucleus than is the stellar continuum. Furthermore, these ellipticals exhibit a compact flat-spectrum radio source in their nucleus, suggesting that this nuclear activity also has an external origin. In this respect it would be interesting to know the excitation mechanism of the gas.

Studies of the excitation mechanism of gas in ellipticals are difficult due to the fact that the emission-line spectrum is superposed on a strong-lined stellar continuum, making the detection of *e.g.*, weak Balmer line emission a hard task. However, elliptical galaxies as a class have a very similar stellar population (see, *e.g.*, Bica 1988). A suitable template absorption spectrum has thus been built from ellipticals which do not show any evidence for ionized gas from our CCD images. Subtraction of this template effectively reveals the pure emission spectrum of the gas in ellipticals. Results of this method are examplified by the emission line spectrum of the merger candidate NGC 5044 in Fig. 1, together with the B−I and Hα+[NII] images of that galaxy. The size of the images is 1.′34 × 1.′34.

The nuclear spectra of *all* ellipticals with ionized gas in our sample are found to show emission-line ratios typical of the LINER class, which are well fitted by models of photoionization by a nonthermal power law spectrum with a low ionization parameter (see, *e.g.*, Ferland & Netzer 1983). This mechanism is also thought to be responsible for the nonthermal radio emission. We just might be witnessing the picture brought forward by Gunn (1979) where the central monster is being fueled by gas which has been brought in during a merger or interaction with a gas-rich galaxy.

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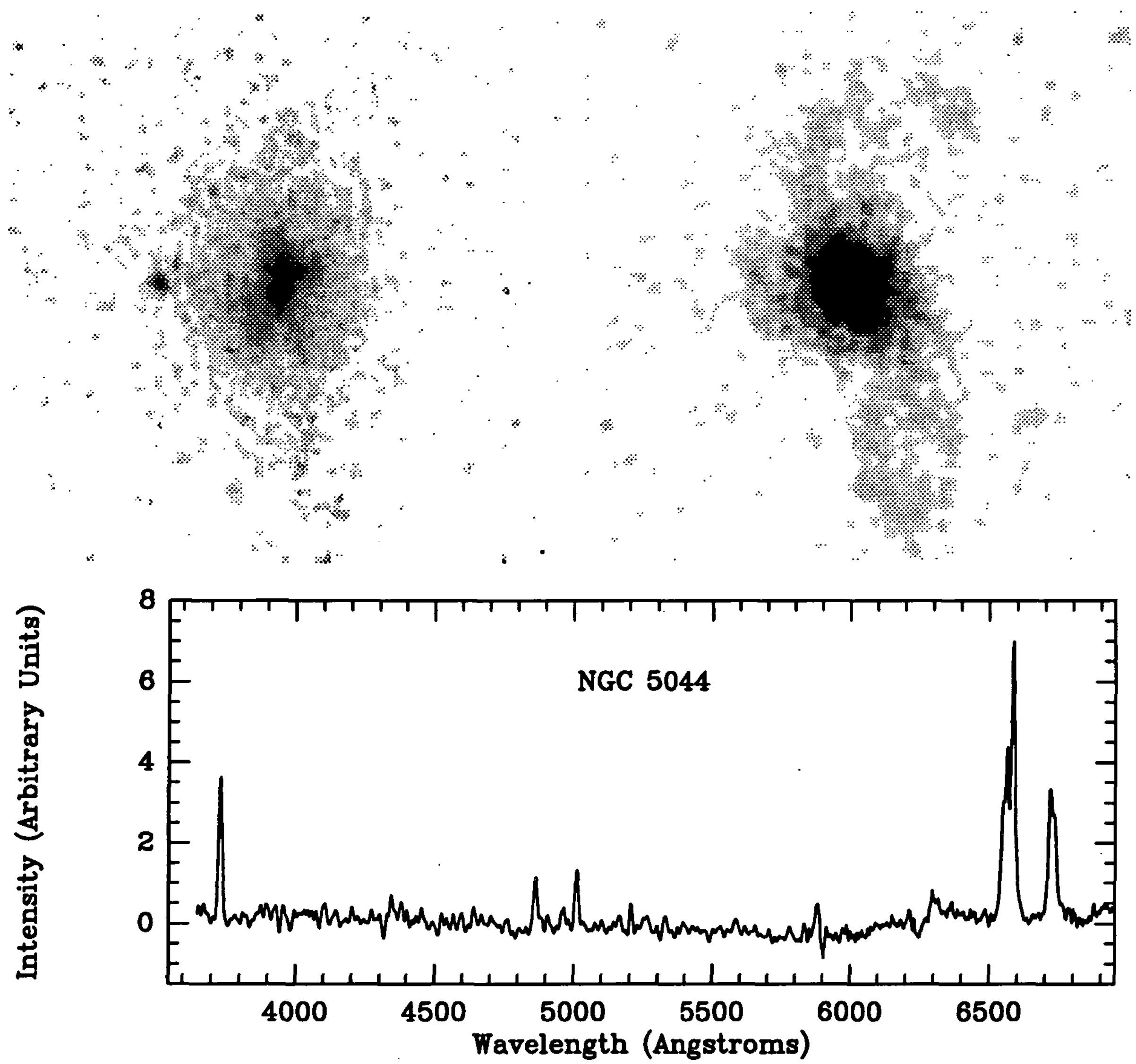

Figure 1. (Top) *The B–I colour index image (left) and the Hα+[NII] image (right) of NGC 5044. Note the spiral-like structure of the ionized gas which is associated with reddening by dust.* (Bottom) *Pure optical emission-line spectrum of the nucleus of NGC 5044, i.e., after subtraction of a suitable template absorption-line spectrum. Line ratios are typical of the LINER class.*

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