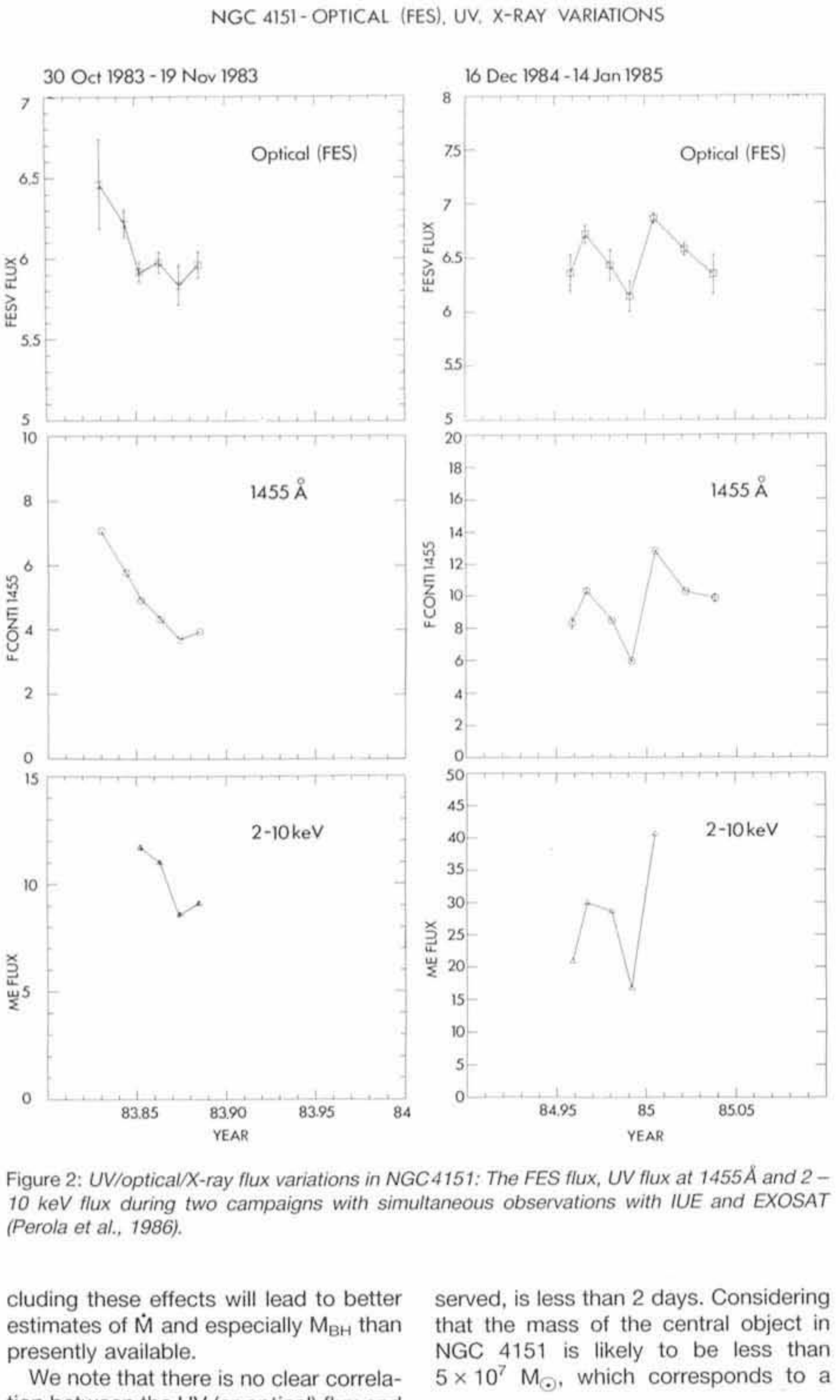

Figure 2: *UV/optical/X-ray flux variations in NGC 4151: The FES flux, UV flux at 1455 Å and 2 – 10 keV flux during two campaigns with simultaneous observations with IUE and EXOSAT (Perola et al., 1986).*

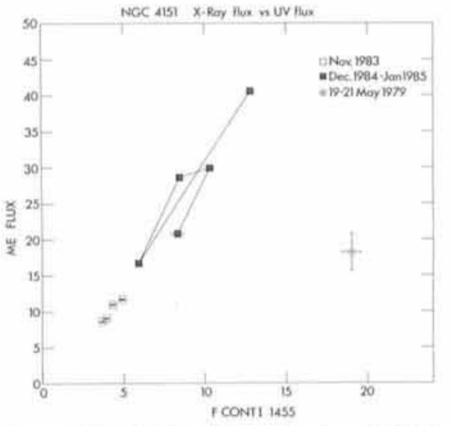

Figure 3: *The 2 – 10 keV flux vs the flux at 1455 Å for the dates of Figure 2, plus the point representing the X-ray and UV flux on May 19 – 21, 1979. The optical/X-ray data taken at isolated dates do not follow the correlation X-ray vs UV flux or X-ray vs optical flux defined by the November 1983 and December 1984 – January 1985 data. Altogether the data suggest that irradiation by the X-ray source produces the quasi simultaneous optical/UV flux variations at some epochs. But in general, it is the instabilities in the inner disk which modulate simultaneously the optical and UV fluxes.*

cluding these effects will lead to better estimates of $\dot{M}$ and especially M_{BH} than presently available.

We note that there is no clear correlation between the UV (or optical) flux and the X-ray flux in other AGN/quasars which have been adequately observed in different energy bands (NGC 4051: Done et al., 1990; 3C 273: Courvoisier et al., 1990). The good UV/X-ray correlation observed in NGC 4151 in November 1983 and December 1984 – January 1985 is exceptional for NGC 4151 as well as among the other AGN/quasars.

Evidently, a good estimate of the time delay between UV and X-ray variations provides constraints on the relative location of the different emission regions. This time delay in NGC 4151, at the epochs when the correlation was observed, is less than 2 days. Considering that the mass of the central object in NGC 4151 is likely to be less than 5×10^7 $M_\odot$, which corresponds to a Schwarzschild radius $r_s \leq 2 \times 10^{13}$ cm, the upper limit on the time delay available now is not very constraining.

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A New Jet in M 87?

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The giant elliptical galaxy M 87 (NGC 4486) has been the subject of intense study over the past two decades for a number of reasons. Firstly, it is large and bright, centrally placed in the Virgo cluster and also because of its bright optical synchrotron and radio jet emanating from the nucleus. The jet has been studied at all wavelengths from X-ray to radio. An understanding of these jets is important for probing the physical processes in active nuclei and their interac-

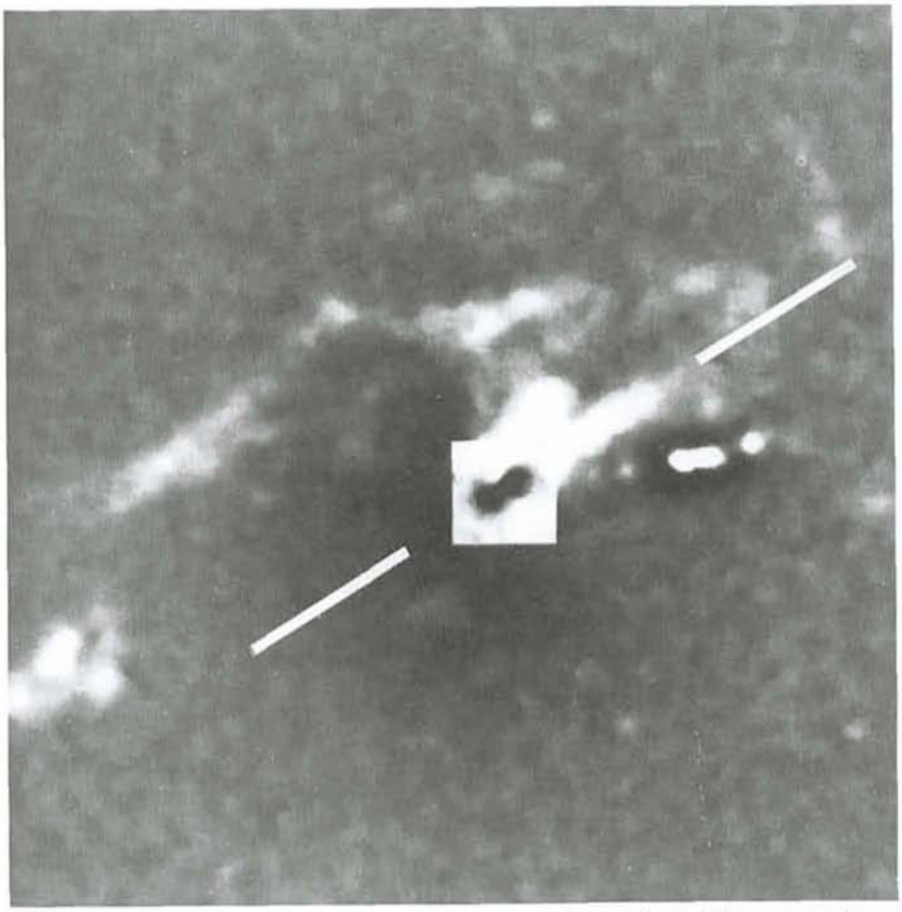

Figure 1: *Narrow-band continuum subtracted image (slightly smoothed) of the central region of M87 through a redshifted (70Å FWHM) Hα filter. The insert at the centre shows the [OIII] emission concentrated in the core region. The Hα + [NII] jet (PA = 317°.5) extends towards the upper right-hand corner, inclined about 25° from the radio synchrotron jet. Note the alignment of the Hα + [NII] jet with the [OIII] feature. The dimensions of the image are 4.8 × 4.8 kpc for an assumed distance of 15 Mpc.*

tions with the surrounding matter.

The nucleus of M87 is also interesting for other reasons since it is believed to contain a supermassive object, possibly a black hole, first proposed by Sargent et al. (1978) and Young et al. (1978). Very recent observations of the Calcium triplet absorption lines in the core of M87 by Jarvis and Melnick (1990) indicate a mass of about $5 \times 10^9 M_\odot$ within a radius of r = 3″. Surrounding the nucleus is a complex system of Hα + [NII] gas, loosely concentrated on the nucleus. This is clearly seen in narrow-band imaging by Ford and Butcher (1979) and more recently by van den Bergh (1987) and Jarvis (1989). We report here the kinematic observations of a "jet-like" Hα + [NII] feature, shown between the white lines in Figure 1, emanating from the nucleus at an angle of 25° northward of the optical synchrotron jet.

Narrow-band Hα + [NII] imaging observations, shown in Figure 1 were made on La Silla in August 1989 with the New Technology Telescope during its commissioning phase. Kinematic observations of the elongated emission feature aligned with the nucleus were made in March 1990 with the ESO 3.6-m telescope and Boller and Chivens spectrograph. The RCA CCD detector had pixels of dimension 1″.1 × 1.68Å with a spectral range of 5776 Å–7510Å. Four 60-minute exposures were co-added together with the slit aligned along the elongated emission feature and passing through the nucleus. Figure 2 shows an image of the reduced long-slit spectra in the region of the Hα + [NII] and [SII] emission lines. Gaussian profiles were least-squares fitted to the lines to determine their radial velocities. The results are plotted in Figure 3.

All five emission lines in Figure 2 show identical kinematic behaviour indicating that the emission-line regions are mov-

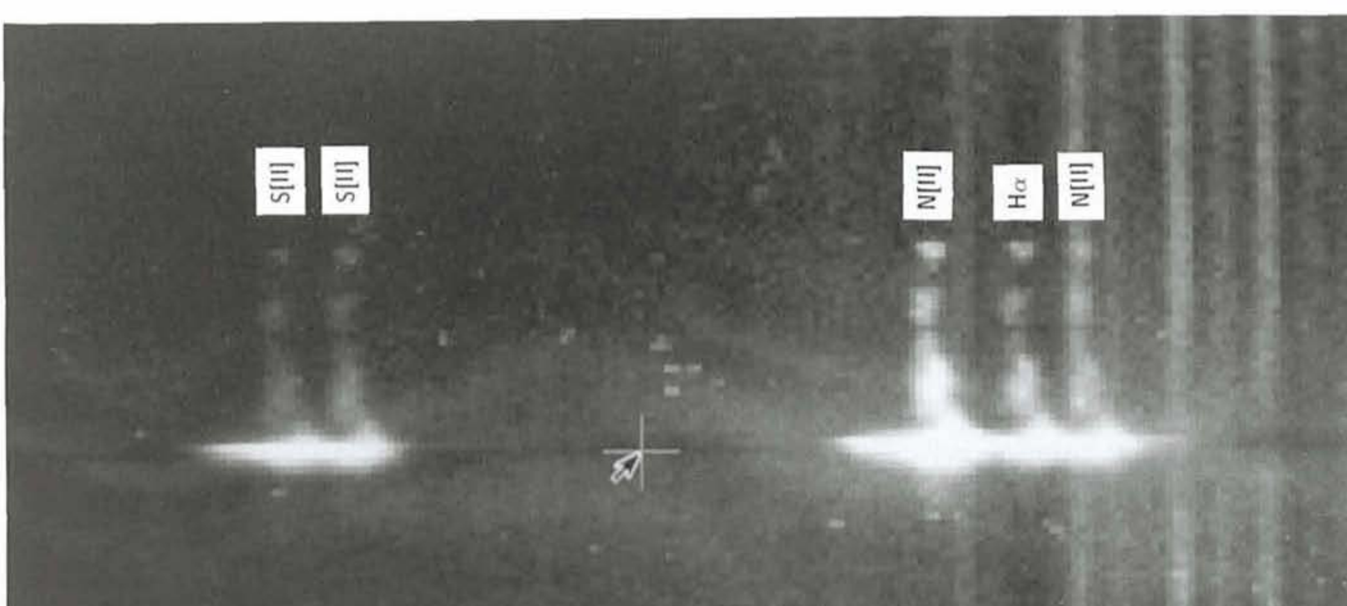

Figure 2: *Long-slit spectra of the Hα + [N II] jet feature in Figure 1. The vertical lines extending to the edges are night-sky emission lines and were included to show how the galactic emission lines are clearly inclined. All five galactic emission lines show the same rotation curve. The cursor marks the centre of the galaxy and the image is 94″ in height.*

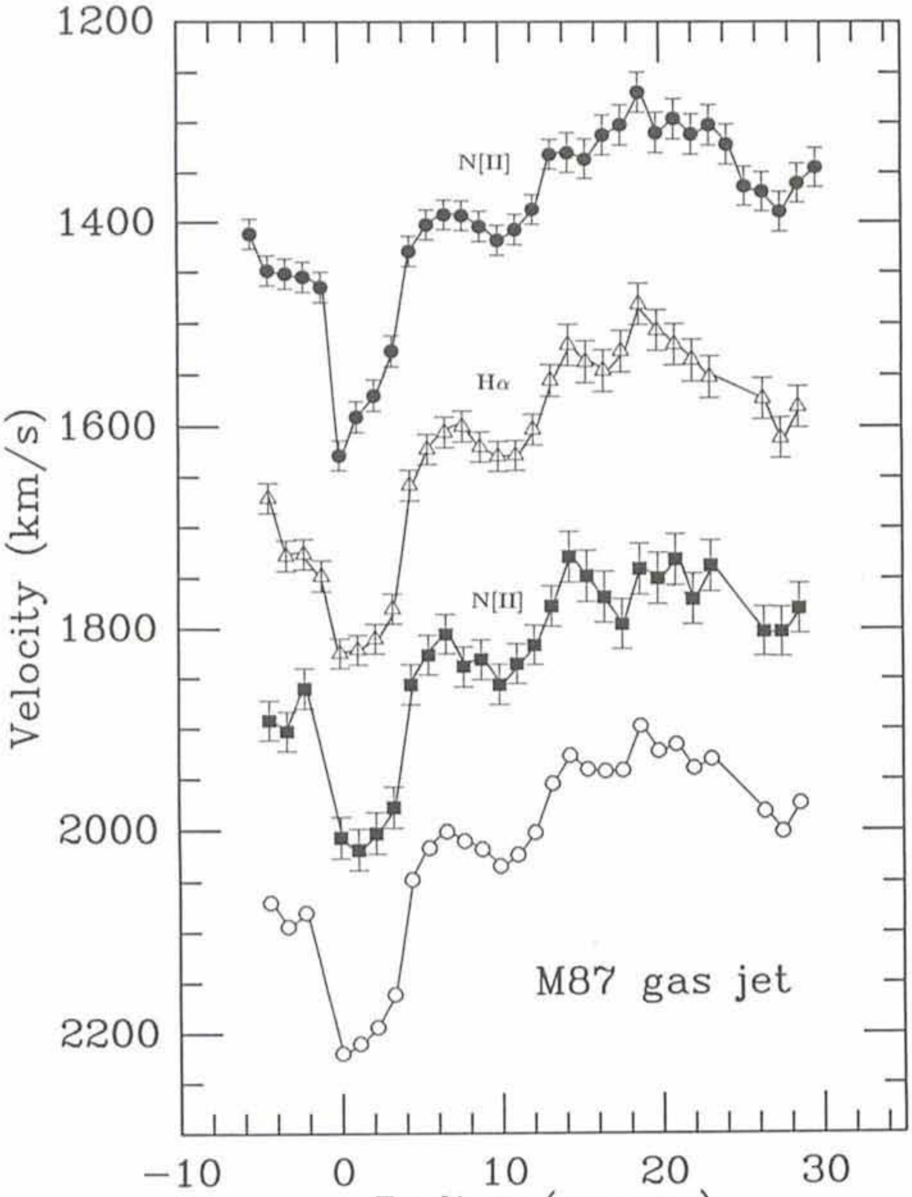

Figure 3: *Observed radial velocities, from long-slit spectra, of the Hα and two [NII] lines shown in Figure 2. The bottom curve shows their mean. The velocity scale is arbitrary.*

ing together. Their behaviour is characterized by a rapid increase in velocity of more than 200 km s^{-1} within the first 6″ from the nucleus. Between six and ten arcseconds, a small decrease is observed followed by another rapid increase to a maximum velocity of about 320 kms^{-1} relative to the core at 20″. Beyond 20″ there is a slow but smooth decrease for as long as there is measurable gas. It is interesting to compare the morphological characteristics of this "jet-like" feature with Keel's (1985) criteria for optical jets. Keel proposed four criteria for a jet, i.e. it must contain less than 10% of the host galaxy's luminosity, be one sided (with respect to the nucleus), have an aspect ratio greater than 10, and be straight to within the limits of its width. The optical feature studied here clearly satisfied all these conditions. With also a clearly defined velocity gradient we believe that this is a true jet, albeit gaseous and not stellar.

Could we be looking at a rotating, nearly edge-on disk of gas instead of a real jet of material? This possibility can be immediately rejected by the velocities measured on the opposite side of the nucleus from the jet. Figure 3 shows that this gas also shows a rapid rise in velocity away from the nucleus *in the opposite sense that would be expected if it were a disk of gas seen nearly edge-on*. Unfortunately, however, it is not possible to conclude from the velocities alone if this material is falling into the core or being expelled from it.

Morphologically, the jet is not continuous along its length since the outer emission-line regions are closely linked kinematically to the main body of the jet because those regions which lie on the slit also have velocities consistent with those of the inner continuous part. This suggests that the Hα + [NII] gas may share a common origin or fate depending upon whether it is being expelled from or falling into the nucleus. For an assumed distance of 15 Mpc, the continuous part of the jet is approximately 1 kpc in length.

Heckman et al. (1989) also observed the kinematics of the Hα + [NII] gas in M87 although not along the jet. However, their PA = 0° velocities are in close agreement with those here. Even though the Heckman et al. data extend to only about 10″ from the core, both data sets show the same amplitude of about 320 km s^{-1} and the sharp decrease approaching the core from both sides. They concluded that this gas is *infalling* at about the free-fall velocity. These observations suggest that *all* of the gas in the immediate vicinity of the nucleus is kinematically similar. Walker (1968) observed a fan-shaped distribution of [OII] emission (3726-29Å) between position angles 310°–65° to which he also reported an increasing velocity with radius. However, very little [OII] emission was observed at the position angle of the Hα + [NII] jet reported here. The velocity amplitude and maximum radial extent of the [OII] emission is very similar to that observed for the Hα + [NII] jet, i.e. about 1 kpc. The distributions, however, of the Hα + [NII] and [OII] emission-line regions are quite different. Contrary to Heckman's conclusions, he believed that this material was being *ejected* from the nucleus in which case an increasing velocity with radius means that the outflow is being ejected away from us. It would be worthwhile to repeat these observations with CCD's to obtain better S/N ratios than Walker obtained photographically.

Of particular interest is the very close alignment of the nuclear [OIII] emission with the optical Hα + [NII] emission-line jet. This is indeed curious in view of recent work by Haniff, Wilson and Ward (1988) and also Wilson and Baldwin (1989). Haniff et al. found that in a sample of 10 galaxies with "linear" radio sources, all showed alignment (within measurement errors) of the [OIII] emission-line region and the radio structures. Wilson and Baldwin's observations of another Seyfert galaxy, 0714-2914 showed the same effect. Moreover, Whittle et al., showed from a sample of 11 Seyfert galaxies that several also had clear evidence for double-lobe substructure in the [OIII] emission. This is also clearly seen in M87, except that the circumnuclear [OIII] is aligned with the

Hα + [N II[jet and *not* the well-known radio jet as in all other cases.

The nuclear spectra also show a complex structure: the Hα and two [N II] emission lines are multiple with at least three observable components. This is probably due to flows of gas in other directions, e.g. towards the north where other emission can be seen in Figure 1. The [O III] (5007 Å) emission line is double peaked in the core. This can be clearly seen in Figure 4. The emission lines then merge at about r = ± 2", reminiscent of an expanding shell of gas. The velocity of expansion is measured to be about 300 $km s^{-1}$.

In summary, the jet nature of the Hα + [N II] emission-line feature seems well established. The origin of the entire Hα + [N II] gas is not. Moreover, of particular interest is the alignment of the [O III] core emission with this jet since it is not seen in any other radio galaxy with emission-line activity. This gas and other species will merit more detailed study in the future.

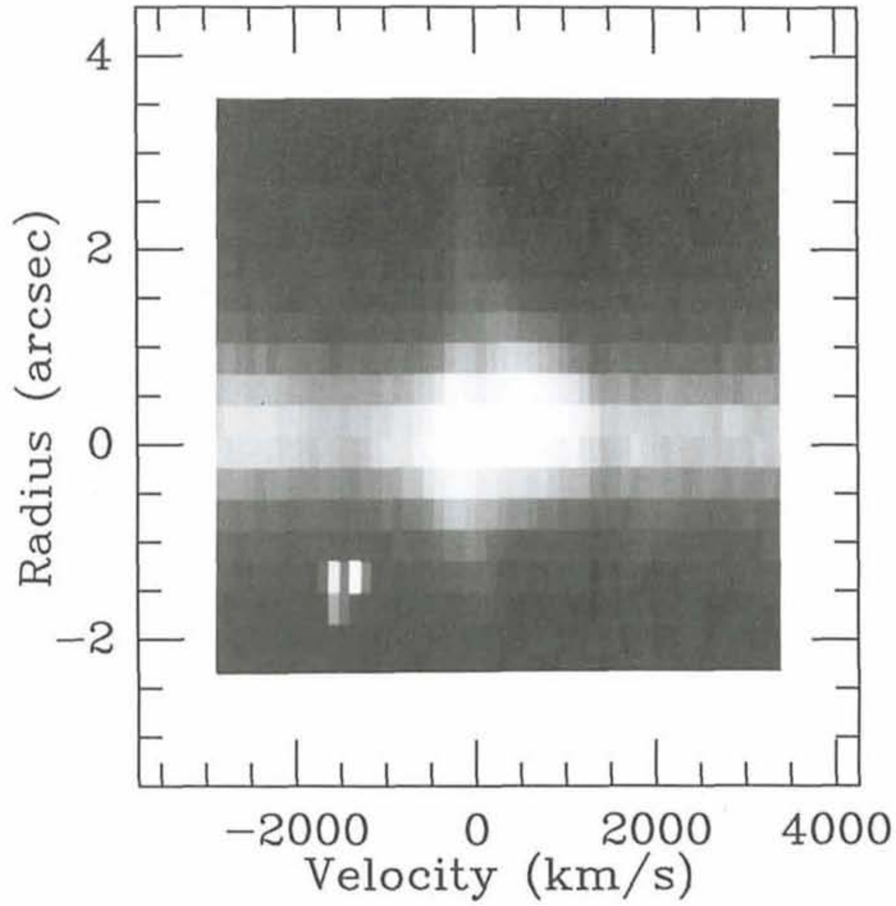

Figure 4: *The [O III] (5007 Å) emission line in the core of M87. Note the double peak at the centre.*

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Infrared Coronal Lines in Active Galaxies

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1. Introduction

Coronal lines are forbidden fine-structure emission lines from highly ionized heavy metals. Although the best known are probably those of [Fe VII]–[Fe XIV], which fall in the visible, many more coronal lines from a large number of elements fall in the infrared spectral range but have received little attention so far. These include transitions of [Ca VIII], [Al V], [Al VI], [Si VI], [Si VII], [Mg VIII], [Al IX], and [Si IX] at wavelengths between 1.96 and 3.92 μm which, although mostly falling in regions of poor atmospheric transmission, have now been observed from the ground in several novae. Discovery of these lines in novae was completey unexpected and their identification was controversial for some time until confirmed by subsequent work.

The [Si VI] ($^2P_{1/2}-^2P_{3/2}$) 1.96 μm and [Si VII] ($^3P_1-^3P_2$) 2.48 μm lines are also present in spectra of the extremely high excitation planetary nebula NGC 6302 and represent the highest ionization stages (ionization potentials of 167 eV and 205 eV respectively) observed in PN.

2. Infrared Lines

As further evidence that infrared spectroscopy is still in its exploratory phase, the first reported measurement of an infrared coronal line in an extragalactic object was our somewhat serendipitous detection of the [Si VI] 1.962 μm line in the Seyfert galaxy NGC 1068 while using IRSPEC at the ESO 3.6-m telescope to explore bright galaxies in previously unobserved portions of their infrared spectra lying outside the high transmission 'window' regions (Oliva and Moorwood 1990).