NEW GROUND-BASED STUDIES OF TWO ACTIVE IRAS GALAXIES

Institute for Astronomy, University of Hawaii
2680 Woodlawn Drive
Honolulu, Hawaii 96822, USA

C. A. Beichman
Jet Propulsion Laboratory
California Institute of Technology
4800 Oak Grove Drive
Pasadena, California 91109, USA

ABSTRACT. New data are presented for IRAS 0421+040P06 and NGC 6240. These two galaxies have properties that differ from both Seyfert and starburst galaxies.

1. INTRODUCTION

Although the majority of IRAS galaxies are explicable in terms of bursts of star formation, a small number have been found to show unusual types of behaviour not previously seen in active galaxies. This paper presents a progress report on our studies of two particular sources.

2. IRAS 0421+040P06

Some of the unusual properties of this galaxy have already been described in an earlier paper (Beichman et al. 1985). It is the only IRAS source in the "mini-survey" (Soifer et al. 1984) that has a double-lobe radio structure. Its nucleus has a spectrum similar to that of a Seyfert 2 or narrow-line radio galaxy, but it has the unusual property that ridges of luminous emission are seen connecting the galaxy to the radio lobes that lie well beyond the visible confines of the galaxy. In the earlier paper we speculated that these ridges were spiral arms. Subsequent long-slit spectroscopy and narrow-band imaging with the UH 2.2 m telescope at Mauna Kea (Figure 1) indicate that the light from these ridges has an essentially pure high-excitation emission-line spectrum. We therefore now believe that the ridges are more likely to be luminous curved jets produced as part of the radio-
galaxy phenomenon rather than regions of high stellar density in the galaxy disk. More details of the radio lobes can be seen in Figure 2, which is a new A-array VLA map of 0421+040P06. The radio lobes are now seen to have the classic Fanaroff and Riley (1974) class I structure characteristic of low-luminosity radio galaxies. No radio emission is seen from the visible jets, which extend approximately as far as the bright inner edges of the radio lobes, about 7° (7 kpc) from the nucleus.

Figure 1. Narrow-band images of 0421+040P06 at the wavelength of the [OIII] lines (left) and in an emission-line-free region of the continuum near 6000 Å (right). The diffuse object to the northeast of the main galaxy is a companion at a similar redshift. The images cover exactly the same region of sky as shown in Figure 2.

3. NGC 6240

NGC 6240 (IRAS 1650+023P04), with a bolometric luminosity of $4 \times 10^{11} L_\odot$, is one of the most powerful infrared galaxies known. Its nuclear region appears as a 1.6° (800 pc) double object at both radio and visible wavelengths. It is one of the few galaxies from which molecular hydrogen emission has been detected (Becklin et al. 1985; Rieke et al. 1985; Joseph et al. 1984). We have now obtained spectra of the galaxy with the 3.8 m UKIRT that span most of the 2.0 to 2.5 μm atmospheric window (Figure 3), plus the regions around Paschen-α at 1.9 μm and Bracket-α at 4.05 μm.

Four molecular hydrogen lines have now been detected. The line ratios are similar to those in Orion and NGC 1068, and correspond to the values predicted for shock excitation. The S(1) line has a width of 600 km/sec, similar to those of the optical lines, but is broader than the $H_2$ lines seen in any other source. The power emitted in the $H_2$ lines exceeds that from any other observed object, and comprises 0.02% of the total bolometric luminosity of NGC 6240.
Figure 2. VLA map of 0421+040P06 at 6 cm. The beamsize is 1.5". The central source coincides with the infrared galaxy and, in higher resolution maps, appears as a 0.8" double radio source.

The only hydrogen recombination line that has been detected from NGC 6240 at infrared wavelengths is the Paschen-α line; it has a flux of $0.60 \pm 0.13 \times 10^{-16} \text{ W m}^{-2}$. The reddening deduced from a comparison of the Paschen-α to Hβ line ($A_\gamma \approx 2.9 \text{ mag}$) is very similar to that deduced from the ratio of the Hα and Hβ lines; we find no evidence for the large amounts of extinction proposed by Rieke et al. (1985). The weakness of the recombination lines is surprising; normalized to the bolometric luminosity, the ionization rate in NGC 6240 is some thirty times less than in M82 and in most other 'starburst' galaxies. We conclude that the infrared luminosity in NGC 6240 is probably not caused by a starburst unless, for some reason, the starburst is devoid of any significant number of O stars.
Figure 3. Spectrum of NGC 6240 obtained with a 5.5" diaphragm using the Cooled Grating Spectrometer on UKIRT.

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