Do Markarian ‘double nucleus’ galaxies have two nuclei? The case of Mkn 788

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Summary. Mkn 788 is a classic example of a ‘double nucleus’ Markarian galaxy. Previous studies have failed to distinguish between the two ‘nuclei’ in any physically significant way. We present an infrared image at 2.2μm taken with IRCAM on UKIRT, which shows source A to be the galaxy nucleus, whereas source B is probably an extra-nuclear H II region. This example suggests that it is premature to discuss ‘double nucleus’ Markarian galaxies as such until further studies can demonstrate the reality of the multiple nuclei.

1 Introduction

The sample of galaxies with strong ultraviolet continua identified by Markarian has been a rich source of material for investigation of nuclear activity in galaxies. One interesting aspect of this galaxy sample is the rather large fraction of them, about 10 per cent, which apparently exhibit double nuclei (Petrosyan, Saakyan & Khachikyan 1978). The origin of this nuclear structure, and its relation to the nuclear activity which many of these galaxies exhibit, is an intriguing problem. Two nuclei are, of course, suggestive of a recent merger between galaxies. Interest in these ‘double nucleus’ Markarian galaxies has therefore been highlighted recently by the discovery of the relation between ultraluminous infrared galaxies and interactions and mergers (Joseph & Wright 1985; Joseph 1986). Moreover there is growing appreciation of a connection between interactions and non-thermal nuclear activity in galactic nuclei (cf. Lilly & Longair 1984; Smith et al. 1986; Heckman et al. 1986). If it were established that Markarian ‘double nucleus’ galaxies really are the products of mergers, these two considerations would make them a particularly seminal class of galaxies with which to investigate the origin of nuclear activity in galaxies and its relation to interactions.

One such ‘double nucleus’ Markarian galaxy which has received considerable attention is Mkn 788. Kollatschny, Netzer & Fricke (1986, hereafter KNF) obtained CCD images in Hα and [O III], optical spectroscopy, a 21-cm spectrum and a VLA map at 20 cm for this galaxy. They find that both sources have the characteristics of high-excitation star-formation regions, and they suggest that both are starburst nuclei. They found no way to decide from these data which of the two
sources is the dynamical centre of Mkn 788. An intensity cut through the optical continuum image showing the profiles for both nuclei was presented by KNF and is reproduced in Fig. 1. While source A is stronger in Hα, [NII], and [SII], source B is stronger in Hβ and [OIII] and, as Fig. 1 shows, both sources seem identical in their optical continuum profiles.

Infrared imaging provides a powerful approach to the identification of galactic nuclei (cf. Telesco et al. 1985). Since the nuclear regions in many galaxies, and especially starburst galaxies, are often heavily enshrouded by dust, infrared observations can provide information on structure and physical conditions much deeper into a galaxy than can optical observations. In addition, the stars which constitute most of the mass of a normal galaxy have peaks in their continuum spectra in the near-infrared. For these reasons we obtained images in the $K$-band, 2.2 μm, of Mkn 788.

2 Observations

The observations were obtained at UKIRT on 1987 April 30 using the UKIRT infrared camera, IRCAM (McLean et al. 1986; McLean 1987). The detector array installed in the camera at this time was an engineering grade array of 62 x 58 InSb detectors, manufactured by Santa Barbara Research Centre. The camera was used in its high-resolution format, 0.62 arcsec pixel$^{-1}$, with a standard $K$ (2.2 μm) filter. An exposure time of 120 s, in a staring mode (i.e. no chopping) was used for each image. Four images of the galaxy were interleaved with four images of a nearby blank sky field, and the blank sky frames were used to flat-field the galaxy images. Dark current frames were subtracted from object and flat-field images before division by the flat field. The mean sky level was then subtracted from each frame. The final $K$-band image was made by coadding the four galaxy images. Since each galaxy exposure was shifted a few arcsec from the previous one, the effects of bad pixels were eliminated in the coadded image.

3 Results

A contour plot of the infrared image of Mkn 788 is shown in Fig. 2. This figure shows that the western source (nucleus A in the notation of KNF) is much more sharply peaked than in source B. The integrated luminosity of Source A at 2.2 μm is about twice that of B, whereas the FWHM of A, 2 arcsec, is about one-third that of B. This is in sharp contrast to the optical CCD image of this
galaxy – cf. fig. 1 in KNF, in which the two nuclei are virtually indistinguishable. This point is made more forcefully in Fig. 3(a), which shows a cut taken through the two infrared peaks. For comparison we have shown in Fig. 3(b) a similar cut taken through the nucleus in NGC 3690. This profile is taken from similar IRCAM K-band images of NGC 3690 obtained at UKIRT one night earlier. While source A has a profile characteristic of a galactic nucleus, source B does not. Thus

**Figure 2.** A contour plot of Mkn 788 at $K(2.2\mu m)$. The mean sky level has been subtracted after flat-fielding, and the image has been smoothed with a running block of $3 \times 3$ pixels ($1.8 \times 1.8$ arcsec$^2$). The contour scale is linear in surface brightness.

**Figure 3.** (a) A slice through the two peaks in the $2.2\mu m$ image of Mkn 788. (b) A cut through a similar $2.2\mu m$ image of the nucleus of NGC 3690A. The intensity scales are linear.
we suggest from the infrared images of Mkn 788 that source A is actually the nucleus of this galaxy.

The broader, lower-intensity profile of source B does not seem to be that of a galactic nucleus. A plausible interpretation is that source B is a giant extra-nuclear H II region, similar in character to such objects as 30 Doradus in the Large Magellanic Cloud (Werner et al. 1978), source C in NGC 3690 (Gerz, Sramek & Weedman 1983), or the 'jumbo' H II region in NGC 3310 (Telesco & Gatley 1984).

From the relative star-formation activity estimated by KNF for sources A and B, about 3 to 1, we can estimate how the total infrared luminosity which KNF infer from IRAS data is apportioned between the two sources. This gives source B an infrared luminosity of \(\sim 10^9 L_\odot\). This luminosity is about one-ninth that found for the 'jumbo' H II region NGC 3310 (Telesco & Gatley 1984), twice that found for the giant H II region NGC 5461 in M101 (Telesco & Gatley 1984) and 25 times that of 30 Dor (Werner et al. 1978). Thus the infrared luminosity of source B in Mkn 788 is consistent with our interpretation as a giant extra-nuclear H II region.

These interpretations are corroborated by the VLA map presented by KNF. The radio continuum of source A was detected at 20 cm, whereas source B was undetected to a limit about six times less than the flux density found for source A. This also suggests that source A is the true galactic nucleus.

4 Discussion

The optical features of both sources in Mkn 788 are so similar it is not surprising that they have been interpreted previously in terms of a double nucleus structure. It has taken infrared imaging to demonstrate which of the two sources has the light profile characteristic of a genuine galactic nucleus. It is tempting to speculate that many more of the 'double nuclei' in Markarian galaxies may also be shown by infrared imaging to be composed of a single nucleus and one or more giant extra-nuclear H II regions. In any case it is clear that caution is necessary in using these galaxies in discussions of interactions and mergers among galaxies.

This interpretation of the two sources in Mkn 788 is also consistent with the suggestion that 'double nuclei' turn up more frequently among Markarian galaxies than among the general galaxy population. Since the selection criterion, a strong ultraviolet excess, will tend to include galaxies with recent bursts of star formation, as well as galaxies with non-thermal nuclear activity, it would not be surprising if this selection criterion were to produce an unusually large number of galaxies with massive extra-nuclear star-formation regions, and hence apparent 'double nuclei'.

5 Conclusions

(i) An infrared image of Mkn 788 at 2\(\mu\)m shows that it is not a double nucleus galaxy; one source is a typical starburst nucleus and the other is probably a giant extra-nuclear H II region.

(ii) There is a strong possibility that a similar conclusion would be reached for many other 'double nucleus' Markarian galaxies if infrared images were obtained for a larger sample. In any case it is clearly premature to pursue discussions of the Markarian multiple nucleus phenomenon, its relations to interactions between galaxies, and connections between these events and various forms of nuclear activity in galaxies, until further observations, perhaps of the type described here, have conclusively demonstrated the reality of the 'double nuclei' in Markarian galaxies.

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