Extragalactic

Near-infrared Imaging and Spectroscopy of Centaurus A

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Abstract: We present near-infrared images and spectra of the peculiar radio galaxy Centaurus A. The images reveal extended emission regions at the longer wavelengths and show colours characteristic of reddened starlight. We believe we are seeing stars within the warped disc of Cen A, which are obscured in the optical by dust. Both images and spectra indicate the presence of a compact core, whose colours are much redder than those of the surrounding stars. In the spectrum of the core, detections have been made of $[\text{Fe II}]$ 1.644 μm, $H_2$ 2.122 μm and Br $\gamma$. These lines appear to peak on the nucleus and their presence and width suggest starburst activity.

1. Introduction

In optical photographs the peculiar galaxy NGC 5128 resembles an E0 galaxy, but is bisected by a distinctive obscuring dust lane. It is the host galaxy of the strong radio source Cen A and exhibits a compact radio core (Meier et al. 1989) and a radio jet (Schreier et al. 1981). The jet has also been detected in the X-ray (Schreier et al. 1979) and the infrared (Giles 1986; Joy et al. 1991). Recent submillimetre work by Israel et al. (1990) shows evidence for a dense molecular cloud in the form of a circumnuclear disc of radius ~ 160 pc. Optical information on the core of Cen A has been difficult to obtain because of the large extinction. However, this extinction is greatly reduced in the infrared and has allowed access to the core and the discovery of the infrared jet. Infrared spectral information is particularly important as it provides species ratios and line widths which may reveal the nature of the active nucleus. We present here images and spectra of Cen A taken with the Anglo-Australian Observatory’s new infrared camera, IRIS (Allen 1992, these proceedings).

2. Observations

The data presented in this paper were obtained at the Anglo-Australian Telescope. The images were taken at f/36 with 0.79 arcsec/pixel resolution using a 128 square array. We obtained five overlapping images, centred on the nucleus and running parallel to the dust lane, at each of the three infrared wavelengths J (1.25 μm), H (1.6 μm) and K' (2.11 μm). Offset sky frames were used for the median sky subtraction. Uniform illumination of the dome was used to flat field and the frames were mosaiced using software developed by Jason Spyromilio. The final images extend ~ 300 arcsec along the dust lane.

Spectra of the nucleus were taken on 1991, April 26 and 27 and June 25 and 26, using the HK echelle grism. The slit width was 1.36 arcsec and the effective wavelength range was 1.5 to 2.5 μm at a spectral resolution of 400. Spectra were taken at either end of the slit and then differenced to subtract the sky. We combined the spectra to provide a total integration time of 7400 seconds.

3. Discussion

(a) Images

The shorter wavelength infrared images reveal that the dust lane has a rich and complicated structure (Figure 1a). In a manner similar to the optical, the dust lane appears to have two thick bands of obscuration. Optical images show the northern lane to be the darker, having either the greater density of obscuring dust, or being in the “foreground” of the galaxy and therefore having less galactic emission along the line of sight. In marked contrast, the infrared images show the southern dust lane to be the darker. This discovery supports the warped disc models of Nicholson et al. (1992) which
Figure 2 — This image was produced by dividing the J by the K' image. It is the same orientation and scale as Figure 1. The darker areas on this image show the regions of higher reddening. The characteristic warp is clearly evident in the dust lane, and there also appears to be a radial structure. The nucleus of the galaxy is visible here as a dark spot close to the southern dust lane. It is surrounded by a region of high obscuration, possibly a circumnuclear disc.

portrays this region as an inner disc whose foreground edge is folded over to the south, providing the increased optical depth which we see.

Perhaps the most striking feature of these images is the obvious emission seen within the dust lane at the longer wavelengths (Figure 1b). The structure from obscuring gas and dust seen in the J images is significantly reduced in the K' images, revealing emission which extends along the dust lane. The emission has an H-K' colour of ~ 0.4 corresponding to a blackbody temperature of ~ 2500 K and therefore too hot to be thermal emission from dust. We therefore conclude that the emission is probably due to stars. The observed emission is in excess of the emission from a relatively unobscured region of the galaxy at a similar radius, and this difference is even more apparent on dereddening the dust lane emission. This indicates that the emission is not the background galaxy seen through a gap in the obscuration, but rather emission from stars within the dust lane itself. Clumping can be seen in the NW emission region: this suggests large-scale clustering, probably associated with star forming regions within the dust lane.

Because of the significant reduction in dust extinction at K', it was possible to divide the J by the K' image and remove emission from the underlying galaxy. Figure 2 shows the resulting image of the dust lane where dark regions indicate higher reddening. The warp is clearly visible, as is the highly reddened core. Around the core there is a region of extreme extinction elongated parallel to the dust lane. This feature extends for ~ 16 arcsec or 380 pc (we assume the distance to NGC 5128 is 5 Mpc [Burbidge and Burbidge 1959]). Although it appears about the core, it may well be the circumnuclear disc proposed by Israel et al. (1990). The presence of this dense molecular cloud was inferred from submillimetre measurements of CO (J = 1—0) and was proposed to explain strong far-infrared emission in a region < 400 pc diameter about the nucleus (Joy et al. 1988) and the visible extinction to the nucleus ( ~ 25-30 mags; Giles 1986). Israel et al. also derive a spatial extent of ~ 400 pc diameter with an inner cavity 90 pc in diameter. This inner cavity should be emitting H excited by radiation and winds from the nucleus.

As well as showing the dust lane, these images also reveal the compact infrared core and the jet. The core is unresolved in the K' image and highly reddened. This implies a diameter of less than 18 pc. We confirm the presence of an infrared jet as reported by other researchers (Giles 1986; Joy et al. 1991). The jet is much bluer than the surrounding stars, appearing as an elongated structure extending to the north east of the nucleus in the J image (Figure 3), and is aligned at the same position angle as the radio and X-ray jets (Joy et al. 1991).

(b) Spectra

The combined spectra are shown in Figure 4. Spectra were extracted for both the core and the adjacent galaxy (Figure 4a). The galaxy spectrum shows CO absorption characteristic of late-type stars. An attempt has been made to subtract the galaxy from the nucleus, by scaling the galaxy spectrum to lie just below the nuclear spectrum in the H window where we know from broad-band imaging that the nucleus is not a strong component. The resulting spectrum of the subtracted nucleus (Figure 4b) shows no sign of CO absorption. Therefore, late type stars do not account for the infrared core. If we assume the core to be non-thermal, and approximated by a power law spectrum such that $F_{\nu} \propto \nu^{-1.3}$, we reproduce Giles' (1986) value of 25-30 mag for $A_{\gamma}$.

The spectrum contains emission from [Fe II] 1.644 μm, Hγ 2.122 μm and Brackett γ 2.166 μm. Moorwood and Oliva (1988) suggest that these lines are not detected in Seyfert 1 broad line regions. If we were seeing through to a Seyfert 1 core in Cen A we might expect a broad component underneath the Brγ emission. None is detected in our spec-
Figure 4 — Spectra of the core of Cen A: (upper panel) From top to bottom, the nucleus and the galaxy 2" away; (lower panel) the difference. Note that the galaxy shows strong CO absorption which is not present in the nucleus. Conversely, the galaxy does not show the strong emission lines present in the nucleus.

Seyfert nuclei (Moorwood and Oliva 1988), although our measurement and interpretation of this ratio will be affected if the regions emitting Br γ and H2 are spatially distinct. It is possible that the observed emission arises from an extended region of starburst around an active nucleus. However, comparison with the spatial profile of the core at 2.2 μm reveals that the emission line regions, especially the [Fe II], are not spatially resolved. This implies that the emission is coincident with the core. If the emission lines are not produced in the core itself, then they originate from a compact region of diameter less than 1.5 arcsec (or 36 pc) around the core. This is smaller than the diameter of the inner cavity of the disc proposed by Israel et al. Possible sources of excitation in this compact region include UV radiation from the active core, or hot stars forming within the dense molecular cloud.

4. Conclusions
Preliminary analysis of IRIS images and spectra have revealed important new properties of the dust lane and nucleus of Cen A (NGC 5128) at infrared wavelengths. The images reveal emission in the dust lane around 2 μm. The colour and location of this emission suggest that it is due to star formation within the dust lane.

In the spectra, we find no evidence for a broad line Seyfert component in Cen A. The spectrum of the nucleus shows emission lines characteristic of starburst activity, and a featureless continuum. The emission line regions are not spatially resolved. We suggest that the inner portions of a dense circumnuclear cloud are ionised to emit the lines we see. This excitation may be in the form of UV radiation from the active core or from hot stars forming within the molecular cloud.