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A dust lane in NGC 6251

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Summary. A dust lane cutting the central region of the radio galaxy NGC 6251 along its minor axis has been observed. This dust lane is roughly parallel to the radio jet. The implications of this observation are discussed:

(i) NGC 6251 resembles a prolate object, morphologically at least.

(ii) Since the jet is remarkably linear, the configuration of the dust lane–stellar potential–nucleus system is probably quite stable. The dust lane may be responsible for the bending of the jet outwards.

(iii) Time-scale arguments relative to a possible merging suggest a rather slow non-relativistic motion.

(iv) The orientation of the dust lane does not support the suggestion by Kotanyi & Ekers of a correlation between the axis of rotation of the gaseous disc and the jet axis in a radio galaxy, or of a correlation between the alignment of both rotation and jet axes with the power of the source.

1 Introduction

In many respects, the radio galaxy NGC 6251 has become in recent years a very attractive object since the discovery by Waggett, Warner & Baldwin (1977) of a remarkable radio jet. This jet is straight for nearly 200 kpc (assuming after the authors a distance of 142 Mpc) but extends over 3 Mpc. VLBI observations (Readhead, Cohen & Blandford 1978; Cohen & Readhead 1979) have shown that the nuclear source is made of a core and an inner jet approximately aligned with the outer jet.

At optical wavelengths, the only study was made by Young *et al.* (1979) who derived

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profile, colour, ellipticity and orientation from CCD photometry in the central region ($r < 17$ arcsec) and inferred from the photometry the existence of a supermassive black hole, very similar to that suggested in M87.

In this note, we present optical observations of NGC 6251 which have resulted in the detection of a dust lane in the cental region of the galaxy. We discuss the consequences of such observations.

2 The observations

The first observations were made at the prime focus of the Canada–France–Hawaii telescope through a B filter with the wide field corrector on 1981 March 8. The exposure times were of 55 min (plate CFH 996) and of 20 min (plate CFH 997). Because of the very high declination of the galaxy relative to the latitude of the site of the CFH telescope, the resulting resolution of the plate was 1.4–1.5 arcsec (full width at half maximum, FWHM, of a composite stellar profile), whereas plates taken at the zenith during the same night had FWHM of about 0.7–1.0 arcsec. On both plates, a dust lane is visible, but because of the grain of the IIa-O emulsion used, it was very difficult to confidently determine its shape and its orientation.

The same observations were consequently repeated on 1982 March 20 with IIIa-J emulsions and short exposure times through a B filter: 5 min (plate CFH 1929) and 2 min (plate CFH 1930). The resolution of the plates reached only 1.6–1.7 arcsec (FWHM), while that of plates taken at the zenith during the same night was of about 0.5–1.0 arcsec. This was sufficient to locate with enough accuracy the dust lane and determine its orientation. Because the dust lane is a relatively weak feature superimposed on a rapidly varying background, it has proved impossible to make prints which show all of its structure sufficiently clearly for reproduction. Fig. 1 shows the complex structure of the dust lane as seen from the different plates. In the very centre, the dust lane is narrow (< 1 arcsec) and would not

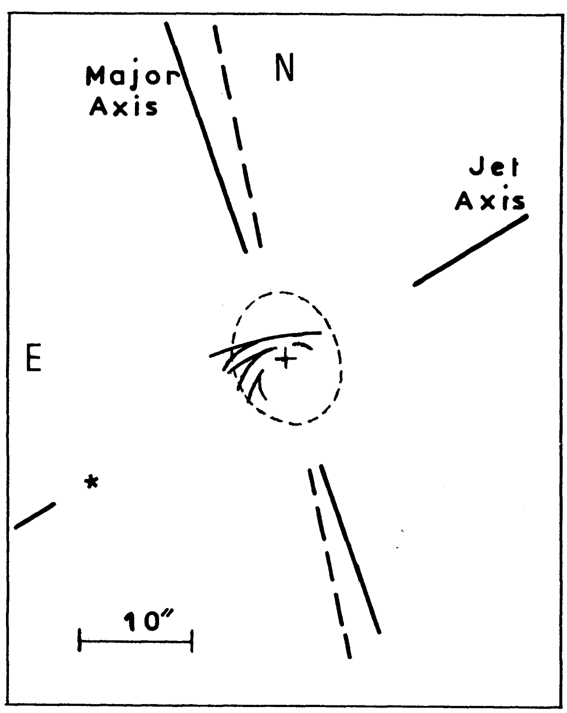

Figure 1. Sketch of the dust lane structure as seen from our photographic material. The broken line is perpendicular to the dust lane.

be detected at slightly poorer resolution. Other examples of weak dust lanes are those of NGC 3665 (Kotanyi 1979) or of NGC 4374 (Capaccioli & Nieto, in preparation) which would have been very difficult to detect at the distance of NGC 6251.

3 The optical morphology of NGC 6251

To determine the relative orientation of the dust lane with respect to the axes of the galaxy, we checked on our plates, from a procedure giving best-fit ellipses from the iosphotes up to about 30 arcsec, that the geometry of the galaxy presented no major isophote twists nor any ellipticity changes (see also Young *et al.* 1979).

Although the orientation of the dust lane is difficult to determine accurately, Fig. 1 shows that the dust lane is roughly oriented along the jet axis. Therefore it is also distributed along the minor axis, but not quite, since there seems to be a tilt angle of about 10°. This tilt is probably a common phenomenon; it clearly shows up in NGC 5128 (see Bertola & Galletta 1978) and in NGC 4374 (Capaccioli & Nieto, in preparation). In its outer parts, the structure of the dust lane presents some other patches similar to those in NGC 5128, 4374 and IC 5063 (Danziger, Goss & Wellington 1981).

4 Discussion

(1) The preferential alignment of radio structures along the apparent minor axis of galaxies (Guthrie 1979; Palimaka *et al.* 1979) suggests that radio sources are predominantly aligned with the angular momentum of the galaxy, if the latter rotates as an oblate system. The orientation of the dust lane in NGC 6251 suggests instead a prolate system, as discussed by Bertola & Galletta (1978). This would be the case if NGC 6251 is an intrinsically prolate system in a stationary state where gas and dust are in equilibrium (Tohline, Simonson & Caldwell 1982) but not if the prolate system is tumbling, in which case the dust lane is very likely to present warps such as in NGC 5128 or 4374 (van Albada, Kotanyi & Schwarzschild 1982). NGC 2685 might be another instance of a tumbling system but the gas may equally well be out of equilibrium (Shane 1980; Tohline & Durisen 1982).

With the resolution of our data, it is impossible to determine whether or not NGC 6251 presents a warped dust structure, although the slight tilt observed must be a hint for such a feature. Nevertheless, assuming that the gas in its inner part is a tracer of the potential, we shall define NGC 6251 as a figure close to a prolate system, morphologically at least.

(2) This dust lane or any interstellar matter related to it might be an obstacle responsible for the bending of the jet outwards.

(3) Since the structure of the dust lane is very reminiscent of that of NGC 5128 which is often suggested to be a merger [although recent observations (Marcelin *et al.* 1982) do not support such hypotheses], it is tempting to assume (see Rees 1978) that the merger hypothesis could account for the fuelling of the active nucleus emitting the jet and that the dust lane is a remnant of the merging. The remarkable linearity of the jet on a scale $1:10^5$ suggests that the dust lane may be in a very stable configuration in the equatorial plane defined by the stellar potential, which it should have reached in two or three rotation periods (see Rees 1978). Then the merging must have happened a few times 10^8 yr ago, which, along with the $10^6\,(v/c)^{-1}$ years since the birth of the flow, suggests a rather slow non-relativistic motion for the jet, except if the jet axis is close to the line-of-sight.

(4) Kotanyi & Ekers (1979) have reported that in seven clear cases amongst the eight radio galaxies showing a dust lane, the dust lane is nearly perpendicular to the axis of the radio source (see also Penston & Fosbury 1978). This point is quite consistent with a picture

in which the nucleus is accreting material from a disc and then ejecting beams along the rotation axis of the disc (see also Simkin 1977, 1979). Later, Kotanyi (1981) found a distribution of the angles separating these two axes more spread out, but suggested a correlation between the power of the source (at 1400 MHz) and the alignment of both axes, which implies that this alignment favours the development of giant radio sources. NGC 6251, which is quite a powerful radio source at 1400 MHz, has a dust lane parallel to the radio axis and, except if the dust is out of equilibrium, can be a case showing a different behaviour.

(5) Kotanyi & Ekers' results, with the assumption that jets are formed by polar ejection from the nucleus, suggested a nucleus oriented perpendicularly to the rotation axis of the dust and gas. Using also observations of 3C 31 (Butcher, van Breugel & Miley 1980) and of IC 5063 (Danziger *et al.* 1981), we are tempted to assume that there are counter-instances to a preferred orientation of the nucleus relative to the rotation axis of the gas and the dust.

Observations of nearby galaxies also suggest that nuclei have their own morphological and/or dynamical properties independent of the rest of the galaxy, in our Galaxy (Lacy *et al.* 1979), in M31 (Lallemand, Duchesne & Walker 1960; Light, Danielson & Schwarzschild 1974; Peterson 1978), in M32 (Walker 1962) and in M33 (Nieto & Aurière 1982). But these 'nuclei' might represent entities completely different and independent of those accreting material from a disc and powering radio sources. Are there some privileged orientations of the nucleus with respect to the main body of the galaxy? Among those, are there some configurations of the dust lane–stellar potential–nucleus system which are quite stable? With the assumption of a polar ejection the joint observations of dust lanes and radio jets could answer this question if a large enough statistical sample can be obtained.

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