Astrophysical Letters, 1973, Vol. 15, pp. 21–25

Galactic Rotation and the Origin of Double Radio Sources

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Comparison of optical and radio position angles of double radio sources associated with elliptical galaxies usefully reduces the range of double-source models that is compatible with observation. Results from a preliminary investigation readily agree with the predictions of the gravitational-slingshot source model, and with the synchro-Compton model for prolate galaxies. The synchro-Compton model for oblate galaxies, and rotating-magnetoid models, can be supported only if it is assumed that their source-collimating regions carry small fractions of their galaxies' angular momenta.

INTRODUCTION

Twenty years have elapsed since the discovery (Jennison and Das Gupta 1953) of essentially double radio structures associated with elliptical galaxies, yet there have been few theories of the formation, as opposed to the confinement and evolution, of such structures. If the origin of the double structures could be elucidated, important insight might be gained into the particle-accelerating mechanisms and the ultimate energy reservoirs of the extragalactic radio sources. Studies of such properties of the double sources as their spectra, luminosities, and polarizations have not yet, however, led to a generally accepted model of their origin.

We report preliminary results of a study of the orientations of elliptical galaxies relative to their associated radio sources. Even though only a small sample of sources can presently be studied in this way, the results usefully narrow the range of acceptable models of the origin of double radio sources.

MEASUREMENTS

We have determined the position angles of the major axes of the light distributions of a sample of elliptical radio galaxies whose radio structures have been well resolved by the interferometers at Cambridge (Macdonald *et al.* 1968, Mackay 1969, Branson *et al.* 1972) or Caltech (Fomalont 1971). Our measurements were made on enlargements of prints from the Palomar Sky Survey using a technique that will be described elsewhere.

An initial sample of 37 galaxies with estimated photovisual magnitudes less than 17.5 mag was reduced to 18 after inspection of the Sky Survey prints. The magnitude cutoff was arbitrarily imposed for this preliminary study because of the increasing difficulty of measuring the orientations of fainter galaxies. For reasons of convenience, only galaxies north of $-10°$ were included. Nineteen galaxies from the initial sample were rejected because their images on the Sky Survey were circular or confused, or because their identification with the radio sources appeared to us to be uncertain or ambiguous. We also rejected sources where more than one conspicuous galaxy might be associated with the radio components.

The position angles of the major axes of the remaining 18 galaxies were measured. Where both a bright central region and an outer envelope of the galaxy could be distinguished, the position angles of both features were determined; in four cases, these 'central' and 'envelope' position angles differed by more than 20°. In two cases, only one of these position angles could be measured. The images of the 18 galaxies were also inspected on a plate copy of the Sky Survey to ensure that no ambiguities or spurious features on the lower-resolution print copy unduly influenced our measurements. The accuracy of our position-angle measurements is estimated to be generally of order $\pm 5°$, and is in all cases better than $\pm 10°$. The radio position angles given by the radio observers have been used; the accuracy of these position angles is thought to be generally better than $\pm 10°$. The optical and radio position angles of the galaxies in the final sample are given in Table 1.

Figure 1a shows a histogram of the 17 differences

TABLE 1

Optical and radio position angles of 18 galaxies

Source designation	3C number	Position angle		
		Radio	'Envelope'	'Central'
0053+26	28	146°	171°	85°
0106+13	33	20	162	133
0300+16	76.1	109	160	133
0325+02	88	65	157	157
0356+10	98	25	64	64
0819+06	198	38	92	80
0938+39	223.1	13	41	41
1216+06	270	90	158	158
1251+27	277.3	165	Circular	30
1319+42	285	79	129	Asymmetric
1559+02	327	100	137	137
1615+32	332	17	35	35
1626+39	338	82	34	56
1726+31	357	110	77	77
1833+32	382	53	80	80
1842+45	388	68	51	33
1957+40	405	109	152	152
2117+60	430	36	112	112

in position angle between the 'envelope' major axes and the radio structures. Figure 1b shows the histogram obtained using the 'central' position angles. The significant features of both histograms are the frequent occurrence of position-angle differences between 15° and 45°, and the absence of position-angle differences less than 15°. The latter feature contrasts with the high proportion of alignments noted by Mackay (1971). Comparison of Table 1 with Mackay's data shows that this discrepancy does not arise entirely from differences in our estimates of the position angles, but mainly from differences in the selection of our samples. Our sample appears to be more stringently selected (Table 2): many of Mackay's alignments involve identifications that we consider ambiguous, complex radio structures, or faint galaxies whose optical orientations are difficult to determine. Because the numbers of galaxies in both his sample and ours are small, further work is necessary to establish whether or not the discrepancy is merely a chance fluctuation.

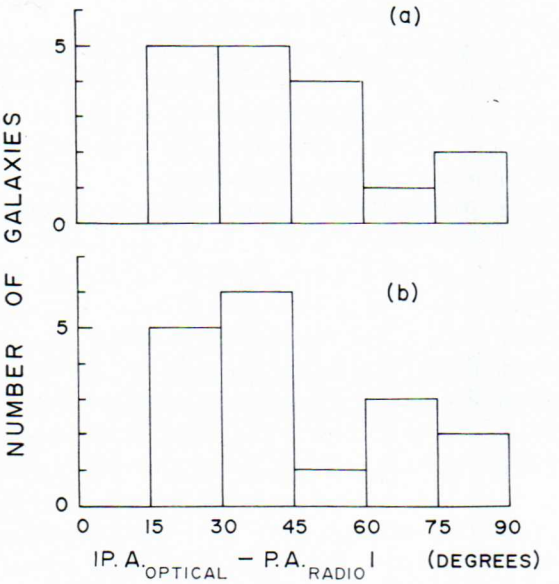

FIG. 1. Observed differences in position angle between optical major axes and radio component separations for 17 elliptical galaxies brighter than 17.5 mag; optical axes defined by (a) outer envelopes, (b) bright central regions.

TABLE 2

Galaxy-radio source alignments noted by Mackay

Source designation	3C number	Comments
0651+54	171	19.5 mag galaxy; too faint for our sample.
0951+69	231	M82; not a double radio source and not an elliptical galaxy; not in our sample.
1251+27	277.3	Our 'central' position angle of 30° is estimated from Sky Survey *plates*; there is an appearance of structure in the envelope which could be the image of another galaxy.
1420+19	300	18 mag galaxy; too faint for our sample.
1615+32	332	Our optical position angle differs from Mackay's by 4°; the source now contributes to the 15°–30° bins in Figure 1.
1825+74	379.1	We judge the optical image to be circular.
1940+50	402	Ambiguous identification; there are two VV galaxy systems within the radio structure.
2229+39	449	Ambiguous identification and radio position angle; galaxy VV6–49–29 has major axis near the position angle of the *inner* radio components (see Mackay 1969).
2356+43	470	19.5 mag galaxy; too faint for our sample.

DISCUSSION

Many models of the origin of double radio sources have associated their collimation with the dynamical symmetries of the parent objects. We have considered three classes of model.