COMPACT RADIO SOURCES IN THE NUCLEI OF ELLIPTICAL GALAXIES

R. D. EKERS*

California Institute of Technology, Pasadena, Calif., U.S.A.

Abstract. Ten percent of the intrinsically bright elliptical galaxies contain compact radio sources (angular size < 3 arc sec) with radio luminosity $\sim 10^{40}$ erg s^{-1}. The presence of a compact source is correlated with the presence of extended radio emission and with the presence of optical emission lines.

In order to investigate whether only giant elliptical galaxies have strong radio sources Rogstad and Ekers (1969) surveyed a sample of elliptical galaxies for radio emission at 10 cm. In addition to showing that being brighter than -20^m is a necessary condition for having a strong radio source, $L_R \geqslant 10^{41}$ erg s^{-1}, we found a number of elliptical galaxies which had weaker radio sources. At the same time Heeschen (1968) showed that NGC 1052 and NGC 4278 contained very small diameter radio sources with spectra of the type usually associated with the compact optically thick radio sources often found in quasi-stellar objects and Seyfert-type galaxies. These two galaxies were also included in our elliptical galaxies with weaker radio sources.

In order to investigate this class of object further I made a new survey at the Owens Valley Radio Observatory at 6 cm with an rms noise level of 0.03×10^{-26} W m^{-2} Hz^{-1} per observation. Twenty percent of the *bright* elliptical galaxies observed were detected. For these I obtained observations with the interferometer at a spacing of 16000 wavelengths, which permitted division of the sources into two angular size groups. Eight galaxies were found to have radio sources with most of the emission coming from a region <3 arc sec and 12 were found to be >3 arc sec (Table I).

All the more extended sources have power law spectra while the small diameter sources have various spectral forms of the type already mentioned for NGC 1052 and NGC 4278. Heeschen (1970) in an independent survey has obtained similar results.

The radio component in M87 with diameter $<0\farcs002$ (Cohen *et al.*, 1969) and the optically thick component in Centaurus A, reported at this symposium by Dr K. I. Kellermann, are of similar radio luminosity and are most probably also objects of this type.

More than 4/11 and probably at least 8/12 of the elliptical galaxies containing compact radio sources have extended components, i.e. they are like M87 although the extended components are intrinsically weaker for the other objects. From this it necessarily follows that the total life of the compact source must be comparable with that of the extended source which must be at least 10^6 yr (the light travel time) in some cases. Also it is most likely that there is a continuing causal relationship between the two types of radio emission.

Optical emission lines of Hα, [N II] λ 6583 and others, as well as [O II] λ 3727 (e.g.

* Present address: Kapteyn Laboratorium, Groningen, Netherlands.

D. S. Evans (ed.), External Galaxies and Quasi Stellar Objects, 222–223.

TABLE I

Elliptical galaxies detected at 6 cm

Extended (> 3 arc sec)			Compact (< 3 arc sec)		
NGC	Flux density 10^{-26} W m^{-2} Hz^{-1}	Other names	NGC	Flux density 10^{-26} W m^{-2} Hz^{-1}	Other names
383	2.1	3C 31	1052[a]	0.72[b]	
741[a]	0.22	PKS 0153 + 05	1587[d]	0.09	
1399	(0.9)	PKS 0336 − 35	2911[a]	0.16	
4261	9.0	3C 270	3078	0.14	
4374[a]	2.7	3C 272.1, M84	3998	0.13	
4472[a]	0.10		4278[a]	0.39	
4486[a]	68	Virgo A, M87	4472	0.06[b]	
5128	126	Cent A	4486	0.8[b,c]	Virgo A, M87
6047	⩾ 0.3		4552[a]	0.30	
7385	⩾ 0.14	PKS 2247 + 11	5077[a]	0.20	
7503	0.52	PKS 2308 + 07	7385	0.13[b]	
7626[a]	0.24	PKS 2318 + 07			

[a] Also found by Heeschen (1970).
[b] Both compact and extended components, flux density of compact component given.
[c] 13 cm flux of component < 0.002″ (Cohen *et al.*, 1969).
[d] Or its companion 1′*E*.

Burbidge and Burbidge, 1965) are seen in 5/8 (62%) of the galaxies with compact radio sources, compared with 37/180 (20%) with any emission lines at all for the other elliptical galaxies.

References

Burbidge, E. M. and Burbidge, G. R.: 1965, *Astrophys. J.* **142**, 634.
Cohen, M. H., Moffet, A. T., Shaffer, D., Clark, B. G., Kellermann, K. I., Jauncey, D. L., and Gulkis, S.: 1969, *Astrophys. J. Letters* **158**, L83.
Heeschen, D. S.: 1968, *Astrophys. J. Letters* **151**, L135.
Heeschen, D. S.: 1970, *Astron. J.* **75**, 523.
Rogstad, D. H. and Ekers, R. D.: 1969, *Astrophys. J.* **157**, 481.

Discussion

Miley: As Dr Ekers says, because M87 is close we can examine the structure of the compact component in very great detail, I would like to report some results which tend to throw doubt on the assumption of circular symmetry which is usually made in the expanding shell model. The compact source in M87 (< 0.05 arc sec) was in fact discovered by the Jodrell-Malvern group and was reported over 3 years ago. A detailed analysis of these results which is about to be published shows that this component is in fact elongated along the optical jet of M87 by ~ 0.3 arc sec, evidence for the injection of electrons from the nucleus of M87 into the radio halo. The recent results of the American VLBI group shows that the compact component probably has the hierarchical structure described by Dr Kellermann, with a sub-component of size ⩽ 0.001 arc sec. The synthesis map of M87 by Hogg *et al.* shows a second small component associated with the optical jet of M87 and the picture that emerges of the micro-structure of the galaxy M87 resembles closely the large scale structure of the quasar 3C 273.