RADIO STRUCTURE OF SEYFERT GALAXIES

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We have recently mapped about a dozen Seyfert galaxies with the Very Large Array at 5 GHz and obtained less complete structural information on about a dozen more. Most sources are heavily resolved at resolutions near or below 1 arc sec, with linear scales in the range several hundred parsecs to a few kiloparsecs. For 3 galaxies (Mark 3, NGC 1068 and NGC 5548) the structure is double with two components more or less symmetrically placed on opposite sides of the optical nucleus. A third component, when present, coincides with the optical nucleus. This result provides strong evidence that "double radio source machines" also reside in the nuclei of active spiral galaxies as well as ellipticals. Other sources show a more diffuse morphology, but usually also possess a compact radio source associated with the optical continuum nucleus. A close relation between the extended radio emission and the thermal gas in the forbidden line region is indicated since (a) they have similar extents, (b) the radio and forbidden line powers are correlated, (c) the relativistic plus magnetic ($B_{eq}^2/4\pi$) and thermal pressures ($n_e kT_e$) are similar and (d) the kinetic energy of the thermal gas and the minimum energy for synchrotron radiation are comparable. For the double sources, the radio emitting plasma is probably ejected from the compact nucleus and slowed by the large quantities of thermal gas in the forbidden line region. Alternatively, radio sources with more diffuse morphology may derive their luminosity from cosmic rays accelerated "in situ" by shock waves associated with the high velocity thermal gas and a magnetic field from a compressed (accreted?) interstellar medium.

G.O. Abell and P. J. E. Peebles (eds.), Objects of High Redshift, 161–163.
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https://doi.org/10.1017/S0074180900068492 Published online by Cambridge University Press

DISCUSSION

Wolfe: Many radio galaxies studied by Osterbrock have extended forbidden-line regions and broad permitted lines resembling Seyfert nuclei. Yet the radio structures are compact, rather than being extended doubles. Since the emission-line characteristics of these ellipticals are so similar to those of the Seyferts, one would expect, on the basis of your model, that the radio structure would be extended. Could you explain this apparent contradiction?

A.S. Wilson: Yes, a small fraction of galaxies with Seyfert-type spectra have radio structures dominated by a very powerful compact core. In some cases (e.g., NGC 1275), extended radio emission is also seen. Since the cores are so much more powerful and compact than for typical Seyferts, one feels something different is going on. Alternatively, the radio emission from the core may be so strong in these cases because we view the galaxy almost along the direction of a relativistic beam (see Readhead's paper, to follow). This would also account for their lack of double radio sources. Note also, however, that even the radio-weak Seyferts I have described have, in general, weak, unresolved radio core coincident with their optical nuclei as well as the extended emission. Probably an isotropic radio component from the core is also present.

J. Roberts: Is it correct that all of your Class 1 sources are elliptical galaxies? What is the percentage of spirals in your Classes 2 and 3?

A.S. Wilson: Although many of the galaxies in Class 1 are classified merely as N, the answer to the first question is almost certainly yes, since almost all powerful double radio sources are associated with ellipticals, and never with spirals. The number of galaxies known in Class 2 is rather small and their classification is sometimes controversial (e.g., 3C 120), so no firm statements on their morphological types can be made. Since almost all optically-selected Seyferts lie in Class 3, their morphological breakdown follows that for Seyferts as a whole, for which the great majority are spirals (see Adams, T.F.: Ap. J. Suppl. 33, 19, 1977).

Gaskell: An interesting result has been obtained by Bill Keel of Lick Observatory (which has been submitted to the Publications, Astronomical Society of the Pacific). He measured the orientations of all known nearby Seyfert I and Seyfert II galaxies on the sky survey plates (by measuring the axial ratios of the discs). He also measured a control sample of disc galaxies. He found that orientation of the Seyfert II galaxies was the same as that of the control galaxies, but that the Seyfert I galaxies were preferentially face on! This could be either because there is some beaming along the pole of the galaxy, or because obscuration in the discs of Seyfert I galaxies is hiding their nuclei from us when they are near edge on.

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A.S. Wilson: This sounds interesting and I look forward to learning more. However, I find it hard to see how the line emission can be beamed! Also, Type 1 Seyferts can now be discovered via their X-radiation, which should not be affected by absorption above a few keV. Thus, there are severe constraints on such interpretations.

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