Radio Continuum and Emission Line Morphologies of Southern Seyfert Galaxies

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1 Background

Modern active galactic nuclei (AGN) research is greatly concerned with geometry. The radiation and absorption anisotropies, and the orientation to the line of sight, are fundamentally important for both the object classification and for understanding the physical nature of the copious energy release.

There are two types of observed anisotropies – highly collimated radio emission, i.e., beams, jets (opening angle $\theta \sim 10^\circ$), and ionization cones ($\theta \sim 100^\circ$). The axial symmetry is determined on a subparsec scale but the two types of collimated radiation are traced out to kiloparsec scales. It is particularly important to understand the connection between the AGN axis and any global symmetry properties of the host galaxy. With no exception, the radio and ionization cone axis are aligned to within the measurement errors (e.g., Wilson & Tsvetanov 1994), but there is little relation to other galaxian scale axes.

To address the important questions of the AGN – host galaxy relationship we have collected extensive optical emission line and radio continuum imaging data for a volume limited sample of southern Seyfert galaxies. Our sample consists of 50 well classified galaxies with $cz \leq 3600$ km s$^{-1}$ and $\delta \leq 0^\circ$.

2 Observations

Optical [O III] $\lambda 5007$ and H$\alpha$+[N II] emission line and their adjacent continua images of all the galaxies in the sample were obtained at ESO using the 2.2 m, NTT and 3.6 m telescopes. The typical resolution of the emission line maps is $1''$, with a noise level of $\sim 1 \times 10^{-16}$ ergs cm$^{-2}$ s$^{-1}$ arcsec$^{-2}$. In addition to the emission line maps, for each galaxy in the sample we have formed an excitation/reddening map, the ratio [O III] $\lambda 5007$ / (H$\alpha$+[N II]), and a continuum color map. The later is affected by a combination of extinction and color effects.

New radio continuum observations were obtained for 29 of the galaxies in the sample. Objects with $-30^\circ < \delta < 0^\circ$, 8 in total, were observed with the Very Large Array (VLA) at 4.9 GHz (6 cm) and objects with $\delta < -30^\circ$ were observed with the Australia Telescope Compact Array (ATCA) at 8.4 GHz (3
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Both the VLA and ATCA radio maps have a resolution of $\sim 1''$ matching that of the optical images. All, but one of the observed sources were detected above the noise limit of $\sim 0.15$ mJy. Our radio observations were combined with data available from the literature to achieve almost 85% coverage of the sample.

3 Highlights of Results

In the radio, 30% of the sources show linear structure, 25% are only slightly resolved or diffused, and 45% remain unresolved at the $\sim 1''$ resolution. As in previous work, a correlation is found between the size of the radio structure and the radio power. The radio sources in Seyfert 2 galaxies have, on average, larger linear size than their type 1 counterparts (see Fig. 1), but there is no significant difference in radio power between types 1 and 2, although all the most powerful objects appear to be Seyfert 2’s. No significant difference is found in the spectral indices of the two Seyfert types.

Extended emission is common in Seyfert galaxies – essentially all objects observed show extended H$\alpha$ + [N II] and nearly 50% show extended [O III] emission. At least 40% (18 out of 50) of the galaxies show high excitation extended emission well outlined in the excitation map. The morphology of the high excitation extended emission line region vary from linear to conical to S-shaped and even X-shaped. Almost exclusively all elongated EELR are in Seyfert 2 galaxies. The orientation of the EELR appears to be random relative to either the major (or minor) axis or relative to the non-axisymmetric structures, such as bars or ovals, when present, and there is a hint of relation to the morphological type (Fig. 2).

![Fig.1](image1.png)  ![Fig.2](image2.png)

**Fig.1.** Radio power versus linear size of the radio structure. Open triangles are Seyfert 1’s, filled symbols are Seyfert 2’s. The K-S test suggests that the two distributions are significantly different. The median size of the radio structure is 0.32 kpc in Seyfert 1’s and 0.66 kpc in Seyfert 2’s (56% and 44% of measurements being upper limits, respectively).

**Fig.2.** Orientation of the galactic axis with respect to the ionization cone axis plotted as a function of the morphological type of the host galaxy. Objects are indicated by their NGC or Markarian number. Vertical lines connect the values on opposite sides of the nucleus. There seems to exist a clear tendency, but selection effects may play significant role.
References
Wilson, A.S., & Tsvetanov, Z.I. 1994, AJ, 107, 1227