Evolution of Giant Radio Sources

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Abstract

We present radio images of two giant quasars from the Molonglo/1Jy sample, and make a comparative study of giant radio sources selected from the literature with 3CR radio sources of smaller sizes to investigate the evolution of giant sources, and test their consistency with the unified scheme. The luminosity-size diagram shows that the giant sources are less luminous than smaller-sized sources, consistent with evolutionary scenarios where the giants have evolved from the smaller sources, losing energy as they expand. For the giant sources the equipartition magnetic fields are smaller, and inverse-Compton losses with the microwave background radiation dominates over synchrotron losses, while the reverse is true for the smaller sources. The giant radio sources have core strengths similar to those of smaller sources of similar total luminosity; hence their large sizes are unlikely to be due to stronger nuclear activity. The radio properties of the giant radio galaxies and quasars are consistent with the unified scheme.

Key words: galaxies: active - quasars: general - radio continuum: galaxies

1 Introduction

Giant radio sources (GRSs), defined to be those with a projected linear size \( \geq 1 \text{ Mpc} \) \((H_0=50 \text{ km s}^{-1} \text{ Mpc}^{-1} \text{ and } q_0=0.5)\), are the largest single objects in the Universe, and are extremely useful for studying a number of astrophysical problems. These range from understanding the evolution of radio sources and constraining orientation-dependent unified schemes to probing the intergalactic medium at different redshifts (Subrahmanyan & Saripalli 1993, Ishwara-Chandra & Saikia 1999 for more detailed discussion). In this paper we present

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radio images of two giant quasars from the Molonglo/1Jy sample, 0437–244 and 1025–229, and examine the evolution of GRSs and their consistency with the orientation-based unified schemes for radio galaxies and quasars.

2 Giant quasars from the Molonglo/1Jy sample

0437–244: This giant radio quasar (Fig. 1, left) is at a redshift of 0.84 and is at present the highest redshift giant quasar known and has a well defined FR II morphology. Its projected linear size is 1.06 Mpc, and has a core contributing about 10% of the total flux density at an emitted frequency of 8 GHz. The age estimates due to synchrotron radiative losses in the Kardashev-Pacholczyk model are $5.8 \times 10^7$ and $2.7 \times 10^7$ yr for the northern and southern lobes respectively. The rotation measure between 1.4 and 5 GHz are about $13.6 \pm 1.3$ and $4.2 \pm 3.4$ rad m$^{-2}$ for northern and southern lobes respectively. The quasar shows no significant depolarization till about 1.4 GHz.

1025–229: This is also a well-defined FR II radio source with two hotspots in the southern lobe, a core contributing about 12% of the total flux density of the source, and a possible jet-like structure close to the north of the radio core (Fig. 1, right). The redshift for this quasar is 0.309 and has a projected linear size of 1.11 Mpc. The spectral age estimates due to synchrotron radiative losses are $7.8 \times 10^7$ and $1.2 \times 10^8$ yr for the northern and southern lobes respectively. The rotation measures are $-21.3 \pm 2.3$, $-15.3 \pm 0.9$ and $-21.5 \pm 3.6$ rad m$^{-2}$ for the northern and southern lobes and the steep-spectrum jet-like feature close to the radio core respectively. Both the lobes do not show significant
Fig. 2. The luminosity - linear size or P-D diagram for all 3CR sources with 50 kpc < D < 1 Mpc and our sample of GRSs. The giant quasars and galaxies are shown by filled and open circles respectively; while the 3CR quasars and galaxies are shown by filled and open triangles respectively. FR I sources have been marked with an asterisk. The evolutionary scenarios for sources with jet powers of $1.3 \times 10^{40}$, $1.3 \times 10^{39}$ and $1.3 \times 10^{38}$ W from Kaiser et al. (1997) are shown superimposed on the diagram.

depolarization between 1.4 and 5 GHz.

3 Evolution of giant radio sources

We investigate the evolution of the GRSs by plotting all known GRSs from the literature in a luminosity-linear size or P-D diagram along with the complete sample of 3CR radio sources (Laing, Riley & Longair 1983) with sizes between 50 kpc and 1 Mpc (Fig. 2). There is a clear deficit of GRSs with high radio luminosity, suggesting that the luminosity of radio sources decrease as they evolve. We superimpose the evolutionary tracks suggested by Kaiser et al. (1997) for three different jet powers in the P-D diagram and find that our sample of GRSs is roughly consistent with their self-similar models where the lobes lose energy due to expansion and radiative losses due to both inverse-Compton and synchrotron processes. In the models developed by Blundell et al. (1999) the luminosity declines more rapidly than the Kaiser et al. tracks, providing somewhat better fit to the upper envelope for large linear sizes. There is also a sharp cutoff in the sizes of the GRSs at about 3 Mpc, with only one exception, namely 3C236, which has a size of 5.7 Mpc. To investigate whether there are larger sources which may have been missed, one requires low-frequency surveys with higher sensitivity to diffuse, low-brightness emission. Systematic searches for GRSs > 3 Mpc using telescopes such as the GMRT would help clarify the late stages of their evolution.
We study the relative importance of synchrotron and inverse-Compton losses in the evolution of GRSs using the plot of linear size against the ratio $B_{eq}^2/(B_{ic}^2 + B_{eq}^2)$, which represents the ratio of the energy loss due to synchrotron radiation to the total energy loss due to both inverse-Compton and synchrotron processes (Fig. 3). It is clearly seen that synchrotron losses dominate over inverse-Compton losses for almost all sources below about a Mpc while the reverse is true for the GRSs. This also illustrates that inverse-Compton losses are likely to severely constrain the number of GRSs at high redshifts since the microwave background energy density increases as $(1 + z)^4$.

4 Constraints on Orientation and environment

We have examined the suggestion that GRSs have powerful radio cores than smaller sources (Gopal-Krishna, Wiita & Saripalli 1989), which may be responsible for their large linear sizes. In Fig. 4, the fraction of the emission from the core at an emitted frequency of 8 GHz is plotted against the total radio luminosity at 1.4 GHz for GRSs as well as for smaller sources. There is an inverse correlation between the degree of core prominence and the total radio luminosity. However, GRSs have core strengths similar to the smaller sources when matched in redshift or luminosity, implying that GRSs are similar objects to the normal radio sources except for being larger and perhaps older.

In order to check the consistency of the GRSs with the unified scheme for radio galaxies and quasars, we have compared some of the orientation-dependent features such as core strength and core variability of giant radio galaxies and giant quasars. Although the available data are limited, these properties are
consistent with the unified scheme. We have also examined the environments around GRSs using their arm-length ratio and the misalignment angle. The arm-length ratio for GRSs are similar to those for the smaller sources, indicating that the environment might be asymmetric on Mpc scales. The misalignment angle for the GRSs is also similar to the smaller sources, suggesting that their large sizes are unlikely to be due to a steadier ejection axis.

References

Blundell K. M., Rawlings S., Willott C. J., 1999, AJ, 117, 677
Gopal-Krishna, Wiita P.J., Saripalli L., 1989, MNRAS, 239, 173
Ishwara-Chandra C. H., Saikia D. J., 1999, MNRAS, in press (astro-ph/9902252)
Kaiser C. R., Dennett-Thorpe J., Alexander P., 1997, MNRAS, 292, 723
Laing R., Riley J. M., Longair M., 1983, MNRAS, 204, 151
Subrahmanyan R., Saripalli L., 1993, MNRAS, 260, 908