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Compact Steep Spectrum Radio Sources

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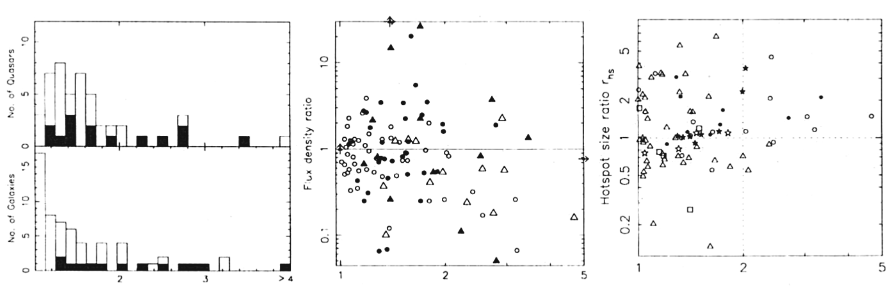
Abstract. We suggest that most compact radio sources are young objects advancing outwards through a dense environment which is asymmetric on opposite sides of the nucleus. This gas might be intimately related to the supply of fuel for the young radio source.

A compact steep-spectrum (CSS) source is defined to be less than about 20 kpc in size ($H_o = 100$ km s^{-1} Mpc^{-1}; $q_0 = 0$), and having a steep high-frequency radio spectrum ($\alpha \geq 0.5$; S$\propto$ $\nu^{-\alpha}$). The highly compact Gigahertz Peaked Spectrum (GPS) sources are also included. High-resolution observations of CSS and GPS sources have made it possible to probe the environment of these scales, and test their consistency with the unified scheme for radio galaxies and quasars. For the present study, we concentrate on the high-luminosity ($P_{178MHz} > 10^{26}$ W Hz^{-1} sr^{-1}) CSS sources with detected radio cores from the 3CR, 3C, Peacock & Wall and S4 samples, and the 3CR sample for the larger sources.

Lobe Separation Ratios

The distributions of the separation ratio, r_D, defined as the ratio of the distance to the further lobe to that of the closer one, show that the CSS objects, shown shaded in the figure, are more asymmetric and have a flatter distribution of r_D. This is likely to be due to environmental asymmetries. The dearth of symmetric quasars in the entire sample is consistent with the unified scheme for radio galaxies and quasars.



Lobe flux density ratios and source asymmetry

The flux density ratio, r_L, defined to be the ratio of the flux density of the further lobe to that of the closer one has been plotted in Fig. 1 against the lobe separation ratio for all the sources in the samples. 40 of the 61 galaxies and 24 of the 48 quasars have the brighter component closer to the nucleus suggesting environmental asymmetries. This trend is also seen in the CSS galaxies and quasars shown by open and filled triangles. Larger galaxies and quasars are shown by open and filled circles.

Hotspot size ratios and asymmetry

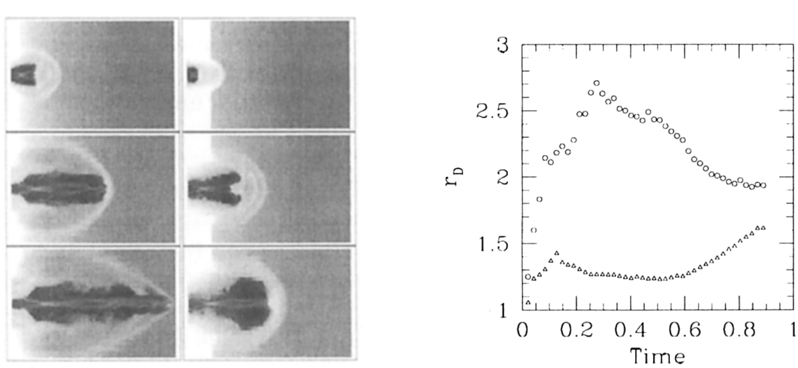
The ratio, r_{hs}, of the size of the hotspot further from the radio core to that of the oppositely-directed one closer to the core, is plotted against the separation ratio, r_d, for the sources with known hotspot sizes. In this sample of 33 high-luminosity sources with $P_{5GHz} \geq 10^{26}$ W Hz^{-1} sr^{-1}, the further hotspot is larger in 24 of them ($r_{hs} > 1$). This could be due to light travel time as well as environmental asymmetries. However, of the 12 sources with $r_D > 2$, almost all of which are CSSs, 9 have $r_{hs} > 1$. Current estimates of hotspot advance speeds suggest that this is due to an asymmetric environment.

Polarization studies

Evidence of such asymmetries in the distribution of gas, is also sometimes provided through huge differential rotation measures on opposite sides of the nucleus. This is seen clearly in the CSS quasar 3C147 (Junor et al. 1999, MN 299, 300).

Jet propagation in an asymmetric environment

Jet propagation in different asymmetric ambient media could explain the above asymmetries. We have made analytical estimates and numerical simulations of jets propagating outwards through different ambient media on opposite sides using the ZEUS-2D and 3D codes. We have modelled the different densities on opposite sides in terms of different power-law indices for the density distributions. The results of one-such 3D run is shown in Fig. 2 which depicts the natural logarithm of the density at three different times, and the separation ratio estimated from the Mach disk.



The arm-length ratio r_D (see figure) initially increases and then decreases. A similar trend is seen in the analytical estimates as well as in the 2D simulations. The luminosity ratio, estimated analytically, initially decreases and then becomes more symmetric at later times. The age of a source when it is in the CSS phase is $< 10^6$ years, suggesting that most sources may have passed through such a phase in its youth (Jeyakumar, Wiita, Saikia & Hooda, in preparation).

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