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The youngest radio sources

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Abstract. GHz Peaked Spectrum (GPS) radio galaxies and their subclass of Compact Symmetric Objects (CSOs) represent the early stage of the life of a radio source Fanti et al. (1995). Their radio structure is a scaled down version of the powerful extended (hundreds of kpc or even larger) radio sources.
The integrated radio spectrum is convex, with the peak frequency around a few GHz. The projected linear size generally never exceeds 1 kpc, and there are sources a few tens of pc in size only. Their ages are of the order of 1000-10000 years and they will grow large to form the extended radio source population, whose age is typically between 10 and 100 million years. Owsianik et al. (1998) first discovered proper motion of the outer edges in CSOs, confirming the hypothesis that the young radio source is growing within its host at a typical speed of 0.2 c.

1. Properties of young radio sources

Young radio sources have a peaked radio spectrum, since their size is small enough to activate synchrotron self-absorption. Given that the smallest objects are located well within the Narrow Line Region, also free free absorption may play a role. Polarisation measurements across the spectral turnover would provide very useful insight on the dominant mechanism, but unfortunately, all the small radio galaxies are not polarised around or below the spectral peak, and often are unpolarised also at cm wavelengths.
The various source components, characterised by different flux densities and sizes, may peak at different frequencies. In case pc scale resolution images are available, it is possible to study the local spectrum, and the typical results are: the core (whose contribution to the total flux density is of the order of 1% at most, or even smaller) has a convex spectrum and its emission is optically thick even at cm wavelengths; in a number of cases the core is visible at cm wavelengths only. Hot-spots instead have power-law spectra. Backflow tails and lobes have steeper spectra, with indications of spectral breaks due to ageing at frequencies around 1 GHz or higher. Jets are generally quite weak in GPS galaxies and sometimes are not detected at all. The typical properties of a GPS galaxy is described in Murgia (2003) who presented results from spectral ageing applied to the CSO B1943+546. A detailed study of the synchrotron spectrum of the individual components in the source was carried out and the results are consistent with a

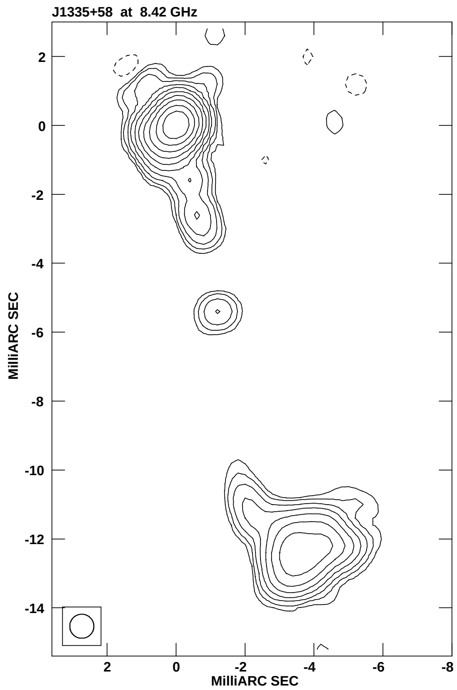

Fig. 1. VLBA image of the radio galaxy J1335+5844 at 8.42 GHz. The core is the unresolved component about at the center of this plot.

scenario in which the radio emitting electrons once they are accelerated at the hot-spots are left behind by the growing source and they age. Relativistic electrons at larger distances from the hot-spot are, then, older.

The local radio spectrum with the lowest break frequency led to a radiative age estimate of 1275 yr only (H_o= 100 km sec^{-1} Mpc^{-1}), very consistent with the idea that it is a young radio source. This radiative age and the radio source angular size (about 50 mas) lead to a velocity separation of the hot spots in excellent agreement with the value of 0.26c, obtained by Polatidis & Conway (2003) (see also Murgia (2003))

A key issue in the study of these sources is the identification of the core. In fact the definition of a CSO source requires the detection of the radio nucleus. This ensures that the morphological interpretation is correct, and beyond that, it allows to study in more detail the properties of the radio source in particular those associates with the observed asymmetries. Furthermore, the image registration to the core position allows the determination of the outward motion of individual hot-spots. In most cases high dynamic range VLBI images at cm wavelength are needed to reveal the source core like in the case of the source J1335+5844 shown in Fig. 1. It is located about midway from the two outer and much brighter components, from which two backflow tails rather than jets departs toward the source center. This galaxy source belongs to a sample of very small sources Dallacasa et al. (2000) in which it is possible to find the smallest CSOs known to date, given their very high peak frequency. Indeed J1335+5844 is about a factor of 3 smaller than B1943+546 and in case of a similar growth speed would be 3 times younger. The youngest radio galaxies can then be found among the sources with turnover frequencies at a few GHz or higher frequencies, known as High Frequency Peakers, HFPs Dallacasa (2003).

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