Young radio sources: the duty-cycle of the radio emission and prospects for gamma-ray emission

M. Orienti[1,2], D. Dallacasa[1,2], M. Giroletti[2], F. D'Ammando[3,4], G. Giovannini[1,2]

1. Astronomy Department, Bologna University, Italy; 2. INAF-IRA Bologna, Italy; 3. INAF-IASF Palermo, Italy; 4. CIFS Torino, Italy

INTRODUCTION: It is nowaday clear that powerful radio sources are a small fraction of the Active Galactic Nuclei (AGN) generally associated with elliptical galaxies, implying that the radio activity is a transient phase in the life of these systems, as also suggested by the detection of relics. The onset of radio emission is currently thought to be related to merger/accretion events which provide fuel to the central AGN of the host galaxy. The evolutionary stage of an extragalactic powerful ($L_{1.4\,GHz} > 10^{25}$ W/Hz) radio source is related to its linear size. In this context, Compact Symmetric Objects (CSO) which are intrinsically small radio sources with linear sizes up to a few kpc, and a synchrotron spectrum that turns over from a few hundred MHz up to the GHz regime, represent the population of young radio sources. Their radio activity originated at most a few thousand years ago, as derived from kinematic (Polatidis & Conway 2003, PASA, 20, 69) and radiative studies (Murgia 2003, PASA, 20, 19). Their radio morphology is dominated by mini-lobes/hotspots resembling a scaled-down version of the edge-brightened FRII galaxies, suggesting CSOs as the progenitors of the large-scale radio galaxies. Several evolutionary models (e.g. Fanti et al. 1995, A&A,302,31) have been developed to describe the source growth, but the too high number of CSOs in flux-limited samples strongly suggests that additional ingredients, like the recurrence of the radio emission (Czerny et al. 2009, ApJ,698,840) or the interplay between the source and the environment, must be considered. Given their compact size, young radio sources entirely reside within the innermost region of the host galaxy, enshrouded by the dense and inhomogeneous ambient medium left by the merger/accretion episodes that triggered the radio emission. The interaction between the radio jet and the environment may play a major role in the source evolution, likely slowing down or even disrupting its expansion if a jet-cloud interaction takes place (Bicknell & Sutherland 2006, AN,327,235; Alexander 2000, MNRAS,319,8). However, such a rich environment may also be the reservoir of the thermal seed photons that scattered by the lobes' relativistic electrons may be detected in gamma-rays by the Large Area Telescope on board *Fermi* as the satellite continues to collect data and its sensitivity threshold improves.

The duty-cycle of the radio emission

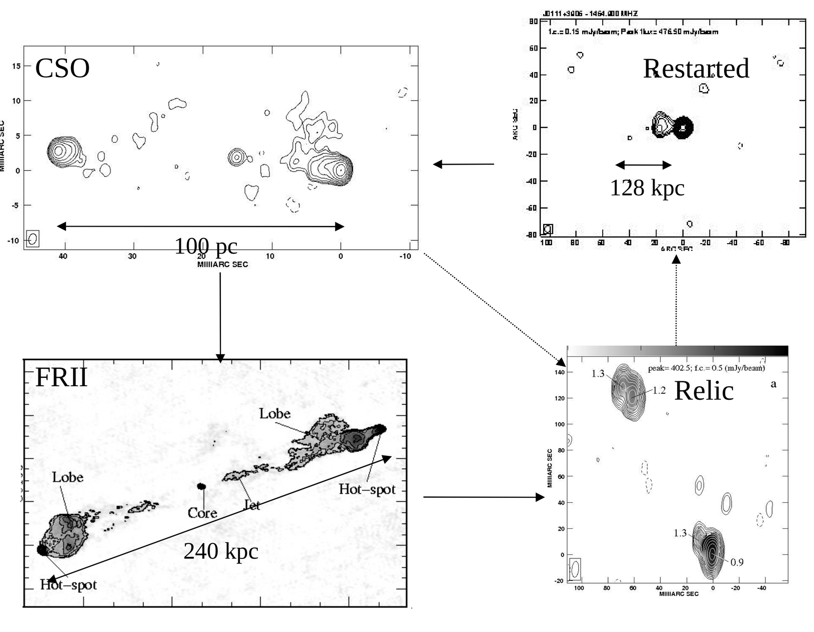

Fig. 1: The evolutionary track. Young CSO (*top left*) may become either a classical large FRII (*bottom left*) or a relic in the case the activity phase switches off soon after its onset (*bottom right*). If the central engine goes through another active phase, a newly-born, bright and compact object can be observed close to the relic of the previous activity (*top right*).

The discovery of the population of intrinsically compact and powerful radio sources yielded to an improvement of the models proposed to link the various stages of the radio emission. Following the evolutionary models, CSOs should be the progenitors of the "old" ($10^7 - 10^8$ yr) edge-brightened FRII. However, the excess of young objects in flux-limited samples suggests the existence of short-lived objects unable to become FRII. The CSO J1518+047 is a clear example of a young (10^3 yr), but already fading object (Orienti et al. 2010, A&A,402,1892). In this source only electrons with γ<600 are still contributing to the emission, while those at higher energies have faded away.

The radio luminosity

In terms of radio luminosity, CSOs are comparable with powerful FRII galaxies. This is clearly visible in Fig. 2, where CSOs (*x symbols*) seem to extend the correlation $L_{tot} - L_{core}$ found for FRI (*+ signs*) and FRII (*asterisks*) radio galaxies (Giovannini et al. 2001, ApJ,552,508) at high luminosity. Such luminosities are expected since CSOs are mainly found at z=0.4 – 2, with only a few objects with z~0.1.
An interesting aspect shown by Fig. 2 is the presence of 3 CSOs found in the region occupied by LBAS sources (*diamonds*; Abdo et al. 2009, ApJ,700,597), making these sources good candidate for high energy emission. It is worth noting that another misaligned object, the FRI 3C120, is in the same region and it has eventually detected by Fermi in 15-month observations (Abdo et al. 2010,ApJ,720,912).

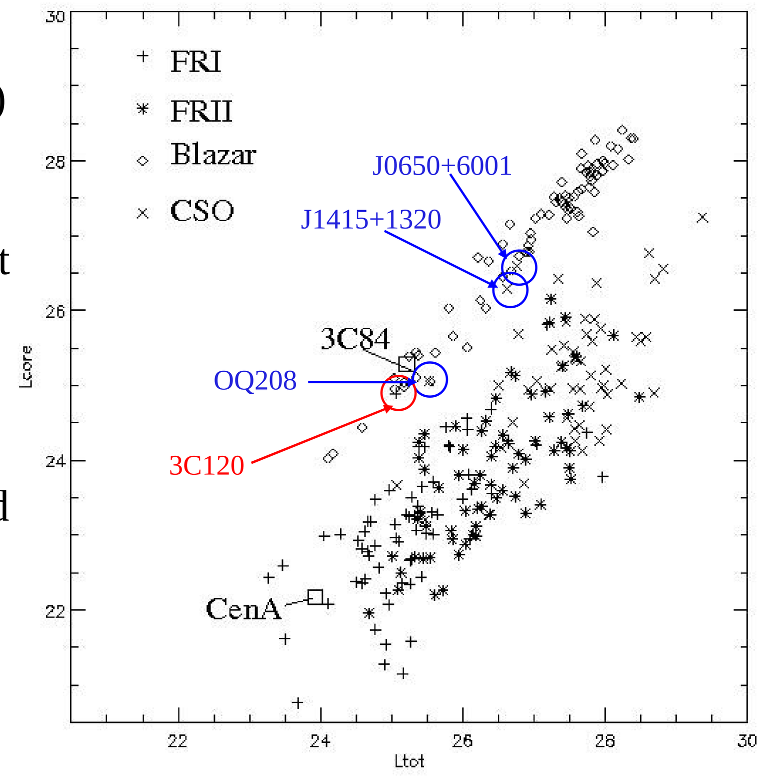

Fig. 2: Total luminosity (*x-axis*) vs core luminosity (*y-axis*). LBAS blazars are from Giroletti et al. 2010 (ASPC, 427, 283).

Two laboratory sources

The radio galaxy OQ208

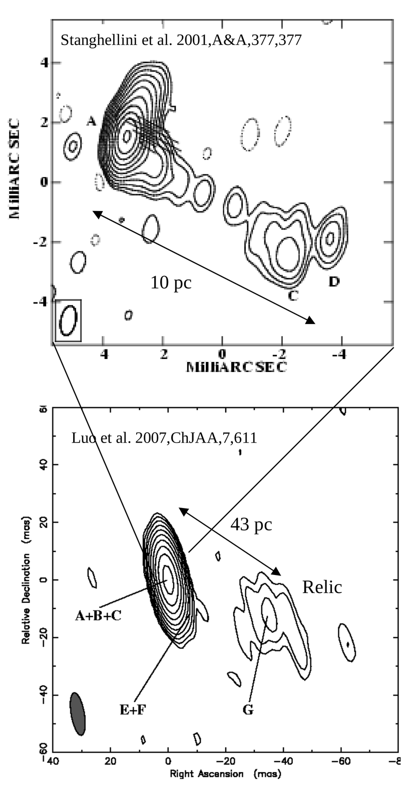

Fig. 3: VLBA images at 15 (*top*) and 1.7 GHz (*bottom*) of OQ208.

- Galaxy at z = 0.076
- $L_{syn} = 2\times10^{44}$ erg/s
- LS = 10 pc
- $v_{sep} = (0.2\pm0.1)c$
- $t_{kin} = 160\pm60$ years

Asymmetric radio structure (Fig. 3) dominated by the western component. Low-surface brightness feature is detected at low frequencies, and it marks the fossil of a previous radio activity that took place only a few thousand years before the new episode (Orienti & Dallacasa 2008, A&A, 487,885). No significant flux density variability is present (Fig. 4).

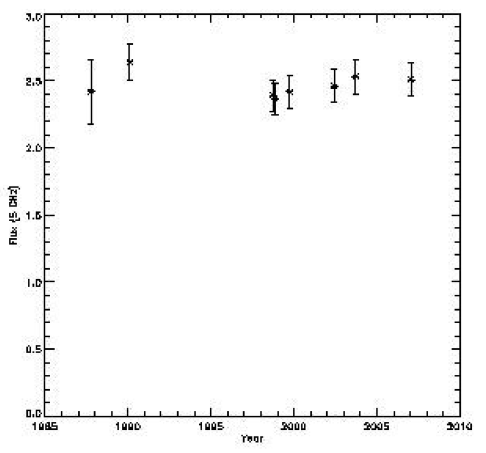

Fig. 4: the 5-GHz lightcurve of OQ208.

The radio quasar J0650+6001

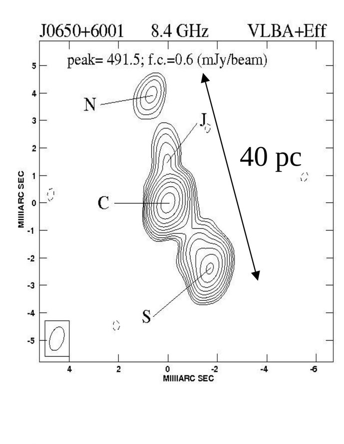

Fig. 5: VLBI image at 8.4 GHz of J0650+6001.

- Quasar at z = 0.455
- $L_{syn} = 10^{46}$ erg/s
- LS = 40 pc
- $v_{sep} = (0.39\pm0.19)c$
- $t_{kin} = 360\pm170$ years

Asymmetric radio structure (Fig. 5) dominated by the central component with a flat spectrum.
The variability of the central component (Fig. 6) and the apparent contraction between component C and S is interpreted as the presence of a mildly relativistic knot that is moving toward the southern lobe (Orienti & Dallacasa MNRAS,406,529).

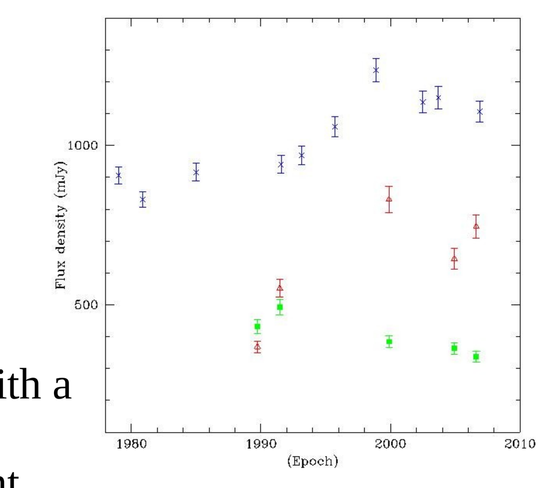

Fig. 6: the 5-GHz lightcurve of J0650+6001. Crosses indicate VLA total flux density. Triangles and squares refer to component C and S respectively.

Prospects for high energy emission from young radio sources

Since CSOs completely reside within the host galaxy, a possible mechanism may be the inverse Compton (IC) of thermal UV/IR photons by the lobes' relativistic electrons (Stawarz et al. 2008,ApJ,680,911). Using the formula from Stawarz et al (2008), we compute the expected luminosity at 1GeV for OQ 208 and J0650+6001.

Assumed parameters:

- $L_{jet} = 10\times L_{tot}$;
- $L_{UV} = 10^{46}$ erg/s;
- Equipartition

OQ 208 → $L = 2.8\times10^{44}$ erg s^{-1}; $S = 3.8\times10^{-11}$ erg cm^{-2} s^{-1}

J0650+6001 → $L = 5\times10^{44}$ erg s^{-1}; $S = 1.2\times10^{-12}$ erg cm^{-2} s^{-1}

Assuming standard parameters OQ208, that is one of the closest CSOs, should have been detected with the sensitivity obtained in one-year observations by *Fermi*, i.e. $5\sigma \sim 7\times10^{-12}$ erg cm^{-2} s^{-1} computed assuming Γ=2.5. The non-detection of the source indicates that the parameters used in the model are too extreme, setting upper limits to the jet power and the amount of UV photons.
The high redshift (z>0.4) typical of the majority of young radio sources makes these objects even more difficult to detect.
However, in the case of CSO associated with steep-spectrum quasars, like J0650+6001, where also moderate boosting effects should be present, we can consider an additional contribution of IC made by relativistic electrons from the jet (e.g. Ghisellini et al. 2005,A&A,432,401).

As *Fermi*-LAT continues to collect data and its sensitivity threshold improves, some young radio sources may be detected, giving us important information on the physical properties of these objects and the main mechanism responsible for their high energy emission.