*Perseus in Sicily: From Black Hole to Cluster Outskirts*
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# Jet production efficiency in the sample of the youngest radio galaxies

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**Abstract.** We investigate the sample of 16 the youngest radio galaxies with measured kinematic ages and available X-ray data from high-resolution Chandra or XMM-Newton observations. We characterize the accretion properties and derive the jet kinetic luminosities for our sources. We found high accretion rates ($> 1\%$ Eddington) and very high jet production efficiency for all the sources from our sample.This, along with the fact that the analyzed objects seem over-luminous in radio on the fundamental plane for the black hole activity, implies also that the radiative efficiency of the compact lobes is much higher than in the case of the evolved radio galaxies.

**Keywords.** techniques: spectroscopic, methods: data analysis, galaxies: jets, galaxies: active

## 1. Introduction

Compact radio galaxies, classified as Gigahertz-Peaked Spectrum (GPS) sources based on their radio spectra, are believed to represent the earliest phase in the evolution of radio-loud active galactic nuclei (AGN). As such they provide an excellent opportunity to study the jet formation in the very moment of triggering.

## 2. Method

In order to characterize the central engines for the objects in our sample, first we searched the SDSS database, and found spectra with sufficient quality for only four sources. We modeled these data with the STARLIGHT spectral synthesis code Cid Fernandes *et al.* (2005) and calculated (via velocity dispersion) the corresponding black hole masses. We also measured the $H\beta$ fluxes and derived the accretion disks bolometric luminosity using the scaling relation of Netzer (2009). For the remaining sources, we searched the literature for the measured $H\beta$ fluxes; if unavailable, we adopted the bolometric luminosity estimates following from different methods. We also adopted the remaining values for the black hole masses from Wu (2009), Willett (2010), Son (2012), and Trichas (2013).

We collected the 1.4 GHz fluxes for all the objects in our sample. With these, we estimated the jet total kinetic powers by means of the scaling relation introduced by Willott *et al.* (1999). We note that in some cases only the lower limit for the jet power could be derived due to pronounced absorption of the radio continua around GHz frequencies. However, since the scaling relation of Willott *et al.* (1999) has been established for the evolved sources, it may not be the most reliable one when applied to the youngest radio galaxies, for example due to the expected increased radiative efficiency of compact jets and lobes (see in this context Tadhunter (2016), Stawarz *et al.* (2008)). Therefore, we have also derived the *minimum* jet powers for all our sources by utilizing their measured kinematic ages, and assuming pressure equipartition within radio-emitting lobes. The jet kinetic luminosities derived in this way are about one order of magnitude lower than those following from the Willott *et al.* (1999) relation.

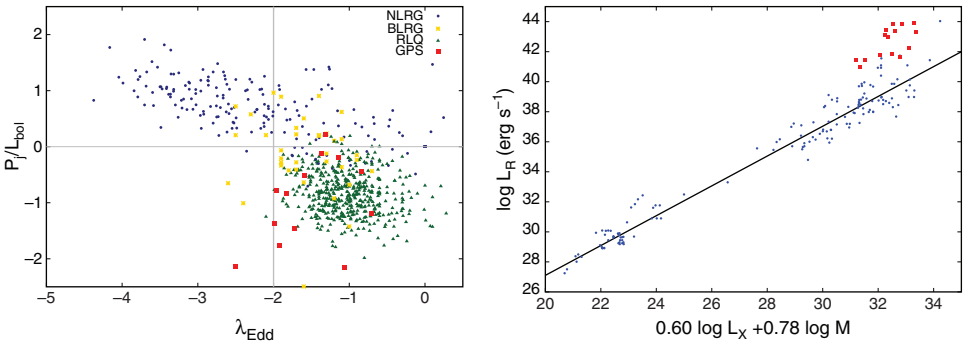


**Figure 1.** Left panel: Jet production efficiency vs. Eddington ratio estimated for our GPS/CSO sample, compared with evolved radio sources; jet powers estimated from measured kinematic ages, assuming pressure equipartition within the radio-emitting lobes. Right panel: fundamental Plane of the Black Hole Activity for Siemiginowska *et al.* (2016) sample of GPS compared with Merloni *et al.* (2003) sample. GPS are marked with red squares.

With such derived accretion rates, black hole masses, and jet kinetic powers, we were able to compare the jet production efficiencies in the youngest radio galaxies with those found in the evolved sources, including narrow-line radio galaxies (NLRGs), broad-line radio galaxies (BLRGs), and radio-loud quasars (RLQS), as listed in Rusinek *et al.* (2017) – see left panel of figure 1. With the addition of absorption-corrected (i.e., intrinsic) X-ray luminosities and 5 GHz radio luminosities available for our GPS/CSO sample, we also investigate the location of the youngest radio galaxies on the Fundamental Plane of the black hole activity (Merloni *et al.* (2003)) – see right panel figure 1.

## 3. Results & Conclusion

We found out that all but one (1718-649) the youngest radio galaxies studied in this work, accrete at high accretion rates (Eddington ratios $> 1\%$), and produce the jets with high efficiencies ($P_{\rm j}/L_{\rm bol} \sim 1\% - 100\%$), consistent with the prediction of the Blandford-Znajek model involving magnetically arrested disk (MADs). As such, they resemble more radio quasars and broad-line radio galaxies, rather than other types of radio-loud AGN. This, along with the fact that the objects from our sample seem over-luminous in radio on the fundamental plane for the black hole activity, implies also that the radiative efficiency of the compact lobes, i.e. a fraction of the jet kinetic luminosity converted to radio fluxes, is much higher than in the case of the evolved radio galaxies.

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