Spectral ageing analysis of a Giant Radio Quasar: PKS 1127-130

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Giant radio galaxies (GRGs) have been well known for decades (e.g., Willis et al., 1974). These spectacular objects have recently grown in a significant number thanks to the dedicated search using large-area sky surveys. Although the statistical study of the population of GRGs is currently advanced, careful examination of individual objects is still not very propagated and covers the small number of access. Therefore we decided to examine carefully one of the largest, the brightest, and distant GRG, PKS 1127−130. Using multiwavelength dedicated and archival observations, we determined the average synchrotron age of the lobe and several other important physical parameters of this object.

1 Introduction:

Giant radio galaxies (GRGs) are radio-loud Active Galactic Nuclei (AGN) (Antonucci, 1993; Netzer, 2013) whose projected linear size on the sky is larger than 0.7 Mpc[1]. A GRG with a quasar host refers as a Giant Radio Quasar (GRQ). In the local and intermediate Universe (z $\lesssim$ 0.6) the GRG density is $\sim$ 0.4 GRGs per deg^2 sky area whereas the density for GRGs larger than 2 Mpc is $\sim$ 0.009 GRGs per deg^2 sky area (estimated using data from Dabhade et al., 2020). The reason for which GRGs can achieve such large sizes is not yet clear. The possible physical explanations for the exceptional sizes of GRGs are: (1) they could be very old radio galaxies (RGs), giving their lobes enough time to expand in the intergalactic medium, (2) GRGs could have incredibly efficient and collimated relativistic jets, or (3) there is a sufficiently low-density environment around the GRG that allows the jets and lobes to propagate and expand almost freely.

2 Spectral age of radio galaxies:

The spectral age, i.e. the time which has elapsed since the particles were last accelerated in the hotspot region, can be derived from the steepening in the radio spectrum due to energy losses caused by synchrotron and inverse Compton processes (e.g. Jamrozy et al., 2008). The initial energy supply to the hotspot corresponds to the injection spectral index, $\alpha_{\rm inj}$. The spectrum becomes steep with an inflection at some break frequency, $\nu_{\rm br}$. The observed spectra of radio sources can be fitted using the continuum injection - CI, Kardashev-Pacholczyk - KP, and Jaffe-Perola - JP (for a review of these models refer: Myers & Spangler, 1985; Jamrozy et al., 2005) models with the help of the `SYNAGE` (Murgia, 1996) and/or `BRATS` (Harwood et al., 2013) packages.

[1]assuming the flat ΛCDM cosmological model: $H_0 = 67.8$ [km s^{-1} Mpc^{-1}], $\Omega_{\rm m} = 0.308$, Planck Collaboration et al. 2016

Under assumptions that (i) the magnetic field strength in a given lobe is constant throughout the energy-loss process, (ii) the particles injected into the lobe have a constant power-law energy spectrum with an index γ and (iii) the time-scale of isotropization of the pitch angles of the particles is short compared with their radiative lifetime, the spectral age, $\tau_{\rm spec}$, is given by equation:

$$\tau_{\rm spec}[{\rm Myr}] = 50.3 \times \frac{B_{\rm eq}[nT]^{0.5}}{B_{\rm eq}[nT]^2 + B_{\rm iC}[nT]^2} \{\nu_{\rm br}[GHz](1+z)\}^{0.5}, \tag{1}$$

where $\rm B_{iC} = 0.318(1+z)^2$ is the magnetic field strength equivalent to the cosmic microwave background radiation. Here $\rm B_{eq}$ is the equipartition magnetic field strength of lobes.

3 GRQ PKS 1127−130

The GRQ PKS 1127-130 (RA:$11^{\rm h}30^{\rm m}19.9^{\rm s}$ Dec:-13°20’50.0”, J2000) was first discovered by Bhatnagar et al. (1998). The r-band magnitude of the host galaxy is 15.98. Having a total radio flux density of 1.13 [Jy] and radio power 1.74×10^{27} [$\rm W\,Hz^{-1}$] (1.4 [GHz]) at a redshift of 0.63 with an overall projected linear size of 2.07 [Mpc] makes it the largest, the brightest, and distant GRQ known to date. The National Radio Astronomy Observatory (NRAO) Very Large Array (VLA) Sky Survey (NVSS: Condon et al., 1998) map of this source shows a classical Fanaroff–Riley type II (FR-II: Fanaroff & Riley, 1974) structure with two lobes extending in north-east and south-west direction. The core is not resolved properly due to the large beam size of this survey (refer Fig.1, left panel). In 3 GHz VLA Sky Survey (VLASS: Lacy et al., 2020) observation the core and hotspots look very prominent (Fig.1, left panel). Using dedicated and archival observations, we prepared the spectral age analysis of this GRQ.

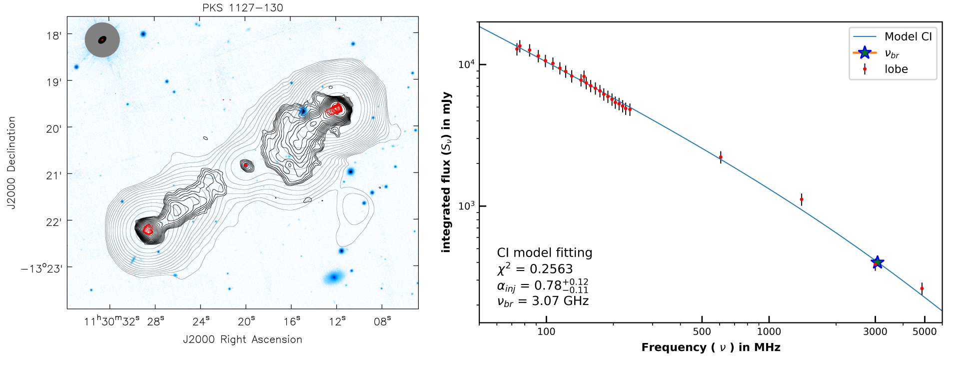

Fig. 1: *Left*: PKS 1127−130 1.4 GHz NVSS total intensity contour (gray), 3 GHz VLASS total intensity contours (red), tappered GMRT 0.6 GHz total intensity contours (black) overlaid on the Pan-STARRS r-band optical image (blue). The beam sizes are marked by either filled ellipse or circle in the top left corner of the image and the respective colors represent the respective contours. *Right*: Radio spectrum of the target source fitted with the continuum injection (CI) model. The continuous data points between 70 and 230 MHz are taken from the GLEAM catalog (Wayth et al., 2015).

4 Preliminary Result

We have done the spectral analysis for this source using `SYNAGE` (Murgia, 1996) algorithm. We obtained the best fit to the flux densities of the total lobes with the CI model. The obtained break frequency, $\nu_{\rm br}$ is 3.07 [GHz], alpha injection, $\alpha_{\rm inj}$ is $0.78^{+0.12}_{-0.11}$ (Fig.1, right panel). The value of the equipartition magnetic field, $B_{\rm eq}$, is calculated using the revised formalism proposed by Beck & Krause (2005) similar as used in Konar et al. (2008). We obtained the equipartition magnetic field, $B_{\rm eq}$ is 1.45 [μG] and the resultant average spectral age is 12 [Myr] of the source. This is a preliminary result, a further detailed and careful analysis is required.

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References

Antonucci, R., *ARA&A* **31**, 473 (1993)

Beck, R., Krause, M., *Astronomische Nachrichten* **326**, 6, 414 (2005)

Bhatnagar, S., Gopal-Krishna, Wisotzki, L., *MNRAS* **299**, 2, L25 (1998)

Condon, J. J., et al., *AJ* **115**, 5, 1693 (1998)

Dabhade, P., et al., *A&A* **635**, A5 (2020)

Fanaroff, B. L., Riley, J. M., *MNRAS* **167**, 31P (1974)

Harwood, J. J., Hardcastle, M. J., Croston, J. H., Goodger, J. L., *MNRAS* **435**, 4, 3353 (2013)

Jamrozy, M., Konar, C., Machalski, J., Saikia, D. J., *MNRAS* **385**, 3, 1286 (2008)

Jamrozy, M., Machalski, J., Mack, K. H., Klein, U., *A&A* **433**, 2, 467 (2005)

Konar, C., Jamrozy, M., Saikia, D. J., Machalski, J., *MNRAS* **383**, 2, 525 (2008)

Lacy, M., et al., *PASP* **132**, 1009, 035001 (2020)

Murgia, M., Laurea thesis, Univ. of Bologna (1996)

Myers, S. T., Spangler, S. R., *ApJ* **291**, 52 (1985)

Netzer, H., The Physics and Evolution of Active Galactic Nuclei, Cambridge University Press (2013)

Planck Collaboration, et al., *A&A* **594**, A13 (2016)

Wayth, R. B., et al., *PASA* **32**, e025 (2015)

Willis, A. G., Strom, R. G., Wilson, A. S., *Nature* **250**, 5468, 625 (1974)