Proceedings of the 6th European VLBI Network Symposium
Ros, E., Porcas, R.W., Lobanov, A.P., & Zensus, J.A. (eds.)
June 25th-28th 2002, Bonn, Germany

SCP- α diagram analysis of CSS sources

B.W. Sohn[1⋆], K.-H. Mack[2,3,1⋆⋆], and U. Klein[1]

[1] Radioastronomisches Institut der Universität Bonn, Auf dem Hügel 71, D-53121 Bonn, Germany
[2] ASTRON/NFRA, Postbus 2, NL-7990 AA Dwingeloo, The Netherlands
[3] Istituto di Radioastronomia del CNR, Via P. Gobetti 101, I-40129 Bologna, Italy

Abstract. We present Spectral Curvature Parameter (SCP)–spectral index (α) diagrams of 44 Compact Steep Spectrum (CSS) sources. SCP quantifies any variations of the initial power law typical of synchrotron spectra. Murgia et al. (1999) who have analyzed the integrated flux densities of a sample of CSS sources in a profound synchrotron ageing study show that these sources have moderate spectral steepening, i.e. a difference of $\Delta\alpha \sim 0.5$ between low- and high-frequency spectral indices, which is predicted by the continuous injection model (CI). We have used this sample to test the SCP procedures which provide an alternative method for a quick analysis of synchrotron spectra. The most important results are:
- All sources are best fit with the CI model. This confirms the results of Murgia et al. (1999).
- A clear difference between sources with strong $B_{eq} > 10^3 \mu G$ and weak $B_{eq} < 5 \cdot 10^2 \mu G$ magnetic field is seen.
- A similar correlation is found for the dependence of the projected linear sizes. More compact sources have higher SCP values, i.e. show low-frequency flattening.
- There is a marginal difference between lobe- and core-dominated sources. The SCP values of the latter tend to be higher.
- There is no correlation with the redshifts of the sources. This implies that the intrinsic magnetic fields dominate by far over the magnetic field equivalent of the cosmic microwave background.
The results demonstrate that the SCP provides crucial parameters on the continuum spectrum of synchrotron radiation without the more complex modeling.

1. Spectral Curvature Parameter

This method is based on the so-called spectral curvature parameter (SCP), defined as

$$SCP \equiv \frac{\alpha_{high} - \alpha_{low}}{\alpha_{high} + \alpha_{low}}.$$

When displayed as a function of the spectral index α with $I_\nu \propto \nu^{-\alpha}$, the SCP indicates how the spectrum evolves, starting from its pure power-law. As α_{high} is more sensitive to both spectral steepening and spectral flattening than α_{low} (Pacholczyk 1970; Eilek & Hughes 1991; Carilli et al. 1991), we employ α_{high} as the counter axis of SCP. A more detailed explanation of the SCP-α diagram will be given by Sohn et al. (2002). As an example we present the application of our method to a sample of 44 Compact Steep Spectrum (CSS) sources.

2. Compact Steep Spectrum sources

O'Dea (1998) has reviewed the properties of CSS sources. There are two scenarios for CSS sources. In the '*youth scenario*', CSS sources are younger versions of the classical extended radio galaxies. The '*frustration scenario*' suggests that the growth of CSS sources is hindered by their environments.

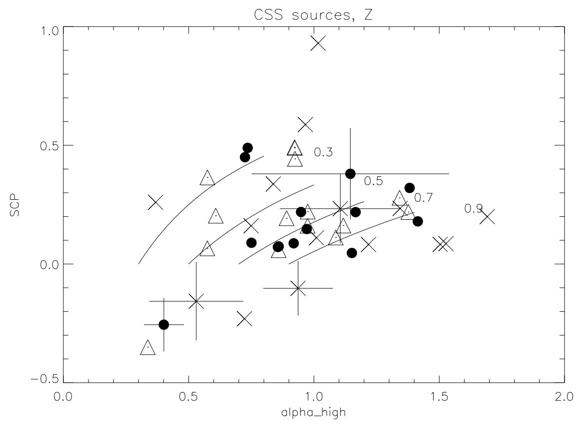

Fig. 1. Filled Circles are CSS sources with $z < 0.5$. Open triangles are CSS sources with $0.5 \leq z < 1.0$. Crosses are CSS sources with $z \geq 1.0$. The solid lines represent equal indices lines with the CI model. The numbers next to the solid lines indicate the corresponding α_{inj}.

For the integrated SCP and α_{high}, the four frequencies 408 (327) MHz, 1.4 GHz, 4.9 (5.0) GHz and 10.7 (10.6, 8.1) GHz, are used. When no data are found at these frequencies, the total intensity at the frequencies in the brackets are taken. In general, CSS sources are found in the region where α_{high} does not exceed $\alpha_{inj} + 0.5$. The range of α_{inj} values obtained is wide (0.2 .. 1.0). This confirms the results of Murgia et al. (1999).

⋆ The authors acknowledges partial support from the EC ICN RadioNET (Contract No. HPRI-CT-1999-40003).
⋆⋆ The author was supported by a Marie-Curie Fellowship from the European Union.

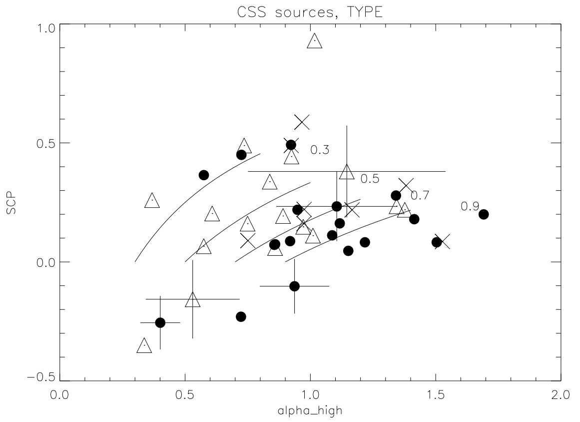

Fig. 2. Filled Circles are *lobe-dominated* CSS sources. Open triangles are *core-dominated* CSS sources. Crosses are CSS sources of undetermined type.

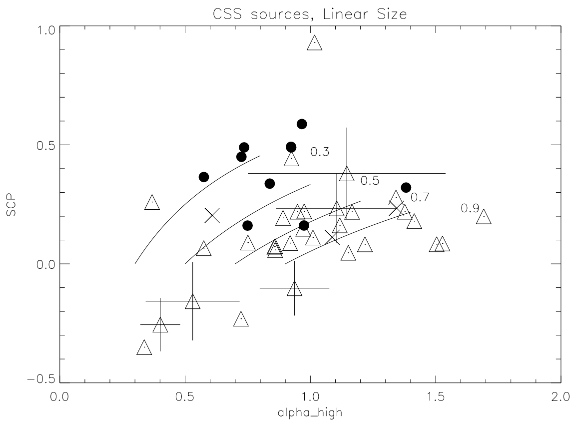

Fig. 3. Filled Circles are $d < 1$ kpc sources. Open triangles are $1 \leq d < 10$ kpc sources. Crosses are $d \geq 10$ kpc sources.

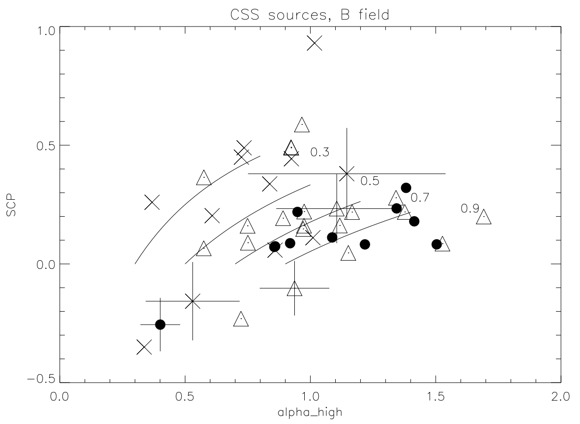

Fig. 4. Filled Circles are CSS sources with $B_{eq} < 5 \cdot 10^2 \mu G$. Open triangles are CSS sources with $5 \cdot 10^2 \mu G \leq B_{eq} < 10^3 \mu G$. Crosses are CSS sources with $B_{eq} \geq 10^3 \mu G$.

2.1. The result

Our results are displayed in four different figures. The aims are:

1. to test the reliability of the SCP-α diagram,
2. to find and explain the common properties from the SCP-α diagram.

In Fig. 1, six sources (0223+34, 0316+16, 0404+76, 1159+39, 1323+32 and 1358+62) with very flat $\alpha_{inj} < 0.3$, are Gigahertz Peaked Spectrum (GPS) sources. The α_{inj} values of these sources are strongly influenced by synchrotron self-absorption. GPS and CSS sources are found in all redshift ranges. In comparing Fig. 1 with Fig. 2, three *lobe-dominated* sources (0404+76, 1323+32 and 2342+82) are found to have $\alpha_{inj} < 0.3$. All these three have projected lengths less than 1 kpc[1].

The ambiguity shown in Fig. 2 can be partly due to the fact that CSS and GPS sources themselves are not defined by source morphology, but by their spectra and dimensions. Relatively nearby GPS sources can be resolved and defined as *lobe-dominated* and distant CSS sources can be unresolved and defined as *core-dominated.* A definite classification would only be possible with improved imaging in future VLBI observations.

In Fig. 3, all three sources with $l > 1$ kpc and $\alpha_{inj} < 0.5$ (0223+34, 1328+30 and 1829+29) are known to be *core-dominated.* All three are classified as CSS (O'Dea 1998). However, their integrated spectra have GPS properties in the SCP-α diagram as well as in the spectral ageing study (Murgia et al. 1999). This indicates that the three sources are not *lobe-dominated* CSS sources.

The existence of compact lobe dominated GPS sources with strong B_{eq} supports the '*youth scenario*' (see Fig. 4). The B_{eq} values by far exceed the B_{CMB}. The SCP-α diagrams for different magnetic field turn out to be the best for the classification of CSS and GPS sources.

It is proved that the SCP-α diagram is an efficient alternative method to derive important properties of synchrotron spectra which otherwise can be determined only with the much more complex synchrotron ageing analysis. The SCP-α diagram and SCP map are especially useful to analyze a large number of sources or a large number of spectral points in a source.

References

Carilli, C., Perley, R., Dreher, J., & Leahy, J. 1991, ApJ, 383, 554

Eilek, J. A. & Hughes, P. 1991, *Beams and Jets in Astrophysics* (Cambridge Univ. Press)

Murgia, M., Fanti, C., Fanti, R., Gregorini, L., Klein, U., & Mack, K.-H. 1999, A&A, 345, 769

O'Dea, C. P. 1998, PASP, 110, 493

Pacholczyk, A. 1970, Radio Astrophysics (Freeman, San Francisco)

Sohn, B., Klein, U., & Mack, K.-H. 2002, A&A, in preparation

[1] $H_0 = 100\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$ and $q_0 = 0.5$ are assumed.