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Pentachromatic VSOP and VLBA Survey of GPS Sources

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Abstract

We report an early results of the GPS survey project using the VSOP and the VLBA at 5 frequencies. All 9 objects observed with the VLBA at 3 frequencies show a convex spectrum, which can be fit by the free-free absorption model. We find a significant difference in the FFA opacities between QSO- and RG-type samples. This result is consistent with Barthel's unified scheme between quasars and radio galaxies.

1 Introduction

GHz-Peaked Spectrum (GPS) sources are powerful radio sources, which have a compact overall size (< 1 kpc) and a convex radio spectrum peaked at a GHz frequency (O'Dea et al. 1991). Their morphology and steep spectrum above the peak indicate that most of radio emission comes from double lobes. Since their lobes are extremely small, they are considered to be at a young stage ($10^3 - 10^5$ yrs) of the evolution (O'Dea 1998). There are two explanations for the spectral cut-off at low frequencies; synchrotron self-absorption (SSA) (Snellen 1997) and free-free absorption (FFA) (Bicknell et al. 1997). Our VSOP observation (Kameno et al. 2000) showed that FFA is preferable rather than SSA for the GPS source OQ 208. To confirm how common is FFA in GPS sources, we are conducting a pentachromatic (1.6, 2.3, 4.8, 8.4, and 15.4 GHz) GPS survey for 18 objects using the VSOP and the VLBA. Here we report early results for 9 sources at 3 frequencies with the VLBA.

2 The Sample, Observations, and Data Analysis

We selected 18 sample objects, based on the GPS catalog by de Vries et al. (1997), under the criteria: (1) the peak frequency $\nu_{\max}$ stands within our observing range, i.e., 1.6 GHz $< \nu_{\max} <$ 15 GHz, (2) since all sources must be bright enough to be detected with the VSOP and the VLBA, we put the criteria $S_{1.6\mathrm{GHz}} > 0.1$ Jy, $S_{5\mathrm{GHz}} > 0.5$ Jy, and $S_{15\mathrm{GHz}} > 0.2$ Jy. We observed 9 of 18 objects with the VLBA in 24 hours on 1998 December 15. Every object was observed at 3 frequencies with 2–6 scans. After the correlation process with the NRAO VLBA correlator, we took fringe fitting with AIPS and imaging with Difmap.

Table 1: Flux densities and FFA parameters of each component

Object & Optical ID	Comp-onent	Flux density 2.3 GHz (mJy)	8.4 GHz (mJy)	15.4 GHz (mJy)	S_0 (Jy)	τ_0
0108+388 (Sy2)	A	591± 3	574± 3	262± 2	16.1±1.5	11.6±0.75
	B	429± 3	286± 4	152± 2	8.2±1.5	9.7±1.25
NGC1052 (Sy2)	A	969± 6	1796± 6	1311± 2	70.0±1.9	17.4±0.47
	B	<5.6	77± 1	489± 1		
	C	13± 2	247± 2	189± 2	12.6±2.6	57.9±18.3
0248+430 (QSO)	A	173± 2	92± 2	65± 1	3.0±1.2	9.2±2.82
	B	5± 1	8± 2	7± 1	0.3±1.4	16.5±50.1
	C	63± 2	549± 3	354± 1	21.0±1.6	28.0±4.20
0646+600 (QSO)	A	360± 1	882± 2	866± 2	37.3±1.4	19.4±0.51
	B	402± 1	280± 1	120± 1	7.6±1.0	9.6±0.82
0738+313 (QSO)	A	2635±15	2627± 4	2156± 5	88.8±1.8	13.0±0.30
	B	187±16	981± 4	912± 5	43.4±2.6	36.2±3.77
1333+459 (QSO)	A	168± 6	319± 1	252± 1	10.9±0.8	17.8±2.76
	B	372± 9	204± 1	91± 1	5.5±0.7	8.2±1.66
1843+356 (QSO)	A	828± 2	225± 1	98± 2	5.8±0.9	4.0±0.94
	B	143± 2	221± 1	119± 2	6.6±1.1	14.6±1.96
2050+364 (RG)	A	1892±10	876± 3	247± 2	22.1±1.4	6.9±0.47
	B	553± 9	136±13	65± 2	3.8±2.1	3.9±3.31
	C	800±11	229±23	77± 3	5.2±2.5	3.6±2.82
	D	752± 4	250± 8	48± 3	5.8±2.1	4.5±2.08
2149+056 (RG)	A	771±20	572± 8	393± 6	18.8±0.8	12.5±0.49
	B	111± 4	47± 1	28± 1	1.3±0.9	1.9±4.01

3 Results and Discussion

We show all images by uniform weighting in Figure 1. Based on the images, we estimated a flux density of each lobe component using IMFIT in AIPS. We try model fitting based on the model: an optically thin synchrotron emission from the lobe is absorbed by external FFA plasma, $S_\nu = S_0 \nu^\alpha \exp(-\tau_0 \nu^{-2.1})$. Here, S_ν is the observed flux density, S_0 is the intrinsic flux density at 1 GHz, ν is the frequency, α is the intrinsic spectral index of the synchrotron emission, and τ_0 is the FFA coefficient. The flux densities and fitting results are shown in Table 1 and Figure 2.

From the FFA fit, we find a significant difference between QSO-type and RG- or Sy2-type GPS samples. QSO-type sources show asymmetric

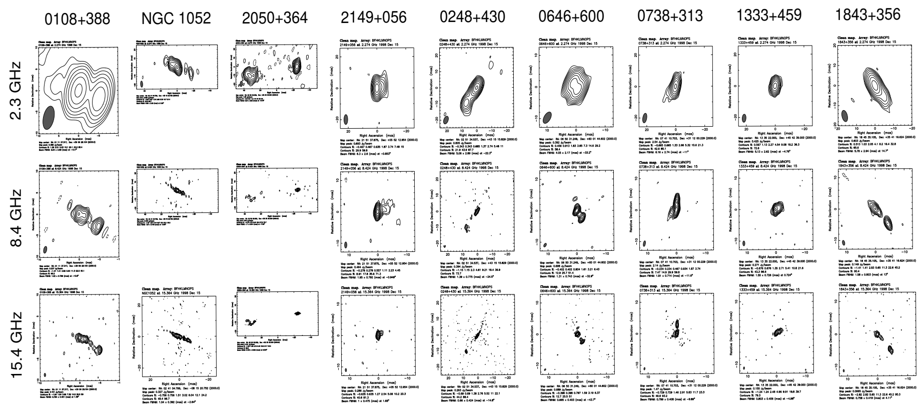

Figure 1: Trichromatic images of the GPS sources at 2.3, 8.4, and 15.4 GHz. Contours start at $\pm 3\sigma$ level, increasing by factors of 2.

FFA opacities towards double lobe, while RG- or Sy2-type sources have symmetric opacities. The histogram of the FFA opacity ratio R, defined as $R = \tau_{0\mathrm{A}}/\tau_{0\mathrm{B}}$ ($\tau_{0\mathrm{A}} > \tau_{0\mathrm{B}}$), clearly exhibits the difference (see Figure 3). We think that this result is related with Barthel's unified scheme between RGs and QSOs (Barthel 1989). If the line of sight is close to the jet axis, as thought to be QSO-type, a large difference of the path length in external plasma towards lobes causes an asymmetric FFA. In case of RG- or Sy2-type sample, the line of sight is nearly perpendicular to the jet axis, so that small difference in the path length results in a relatively symmetric FFA (see Figure 4).

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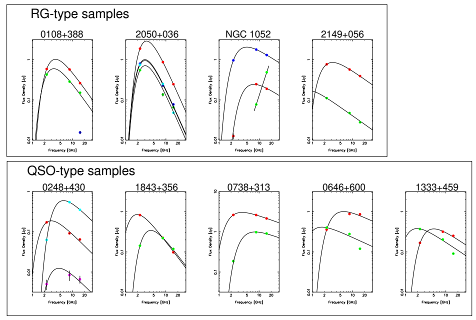

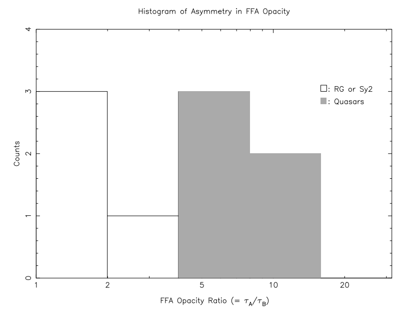

Figure 2: (left) Flux densities of each component at three frequencies (dots with an error bar) and the best-fit FFA model (solid lines).

Figure 3: (right) A histogram of the FFA asymmetry $R = \tau_{0\mathrm{A}}/\tau_{0\mathrm{B}}$. Open and filled areas indicate RG- and QSO-type sources, respectively.

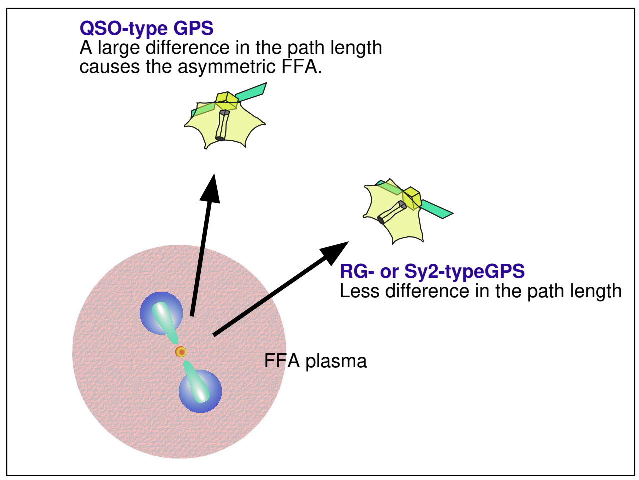

Figure 4: A schematic diagram of a GPS source. If the line of sight is close to the jet axis (QSO-type), a large difference in the path length causes asymmetric FFA. An RG-type source, on the contrary, has small difference in the path length, since the line of sight is nearly perpendicular to the jet axis.