Constraints on the gamma-ray emitting region in blazars from multi-frequency VLBI measurements

K.V. Sokolovsky* (MPIfR/ASC Lebedev),

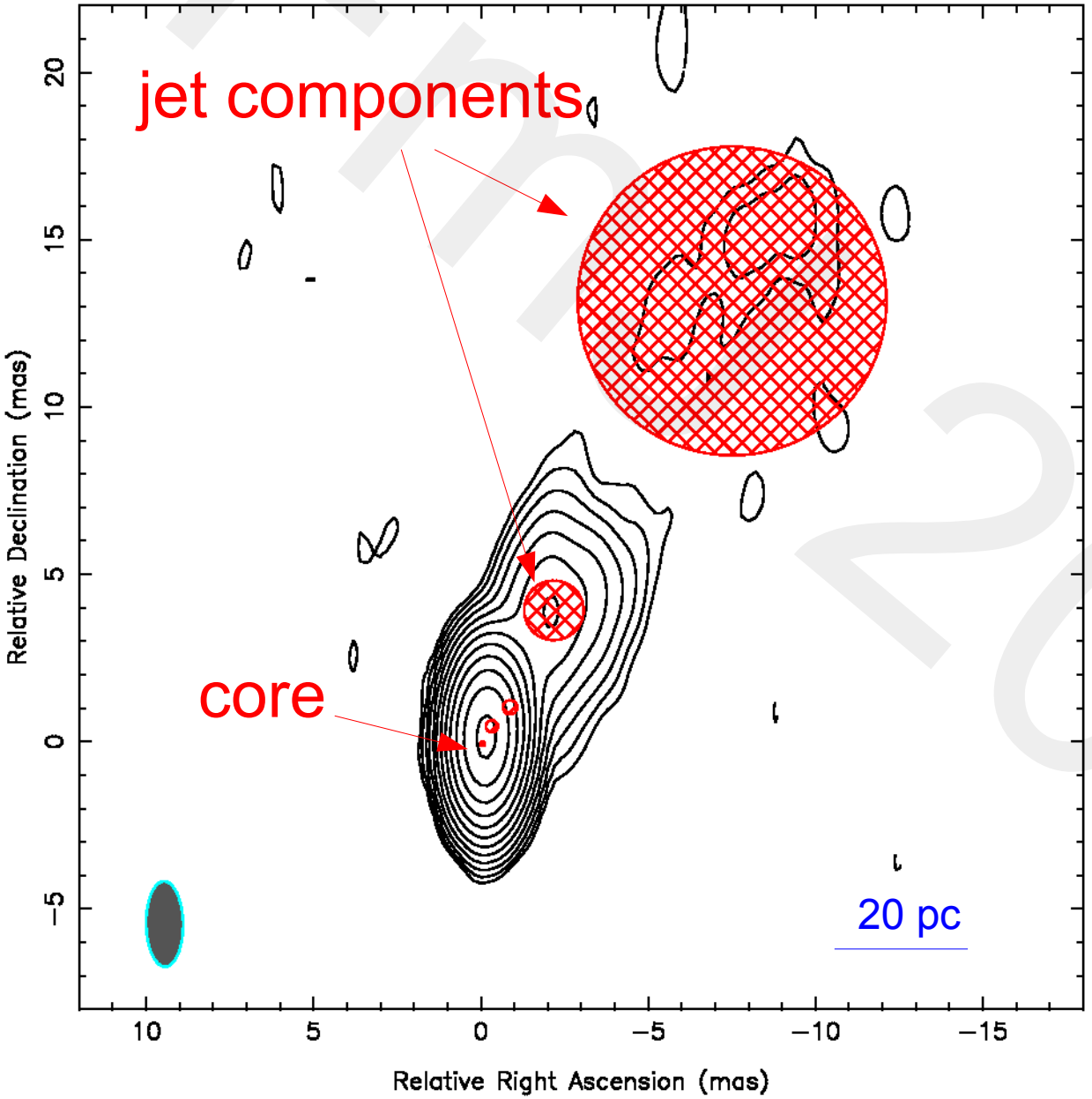
Y.Y. Kovalev (ASC Lebedev/MPIfR), A.P. Lobanov (MPIfR), J.D. Finke (NRL/NRC), T. Savolainen (MPIfR) A.B. Pushkarev (MPIfR, Pulkovo obs., CrAO), M. Kadler (Bamberg, Erlangen, CRESST/NASA GSFC, USRA), F.K. Schinzel* (MPIfR), V.H. Chavushyan (INAOE), L. Carrasco (INAOE), A. Carraminana (INAOE), M.A. Gurwell (CfA)

* IMPRS for Astronomy & Astrophysics

Outline of the talk

- Short introduction: features in parsec-scale jets and their radio spectra, physical parameter (B, N, p, R) estimation from radio spectra.
- Multifrequency VLBA observations of gamma-ray bright blazars: comparison of the results with published SED models.
- Quasi-simultaneous SED of PKS 1510-089.
- Summary and future plans.

A parsec-scale blazar jet as seen by VLBI



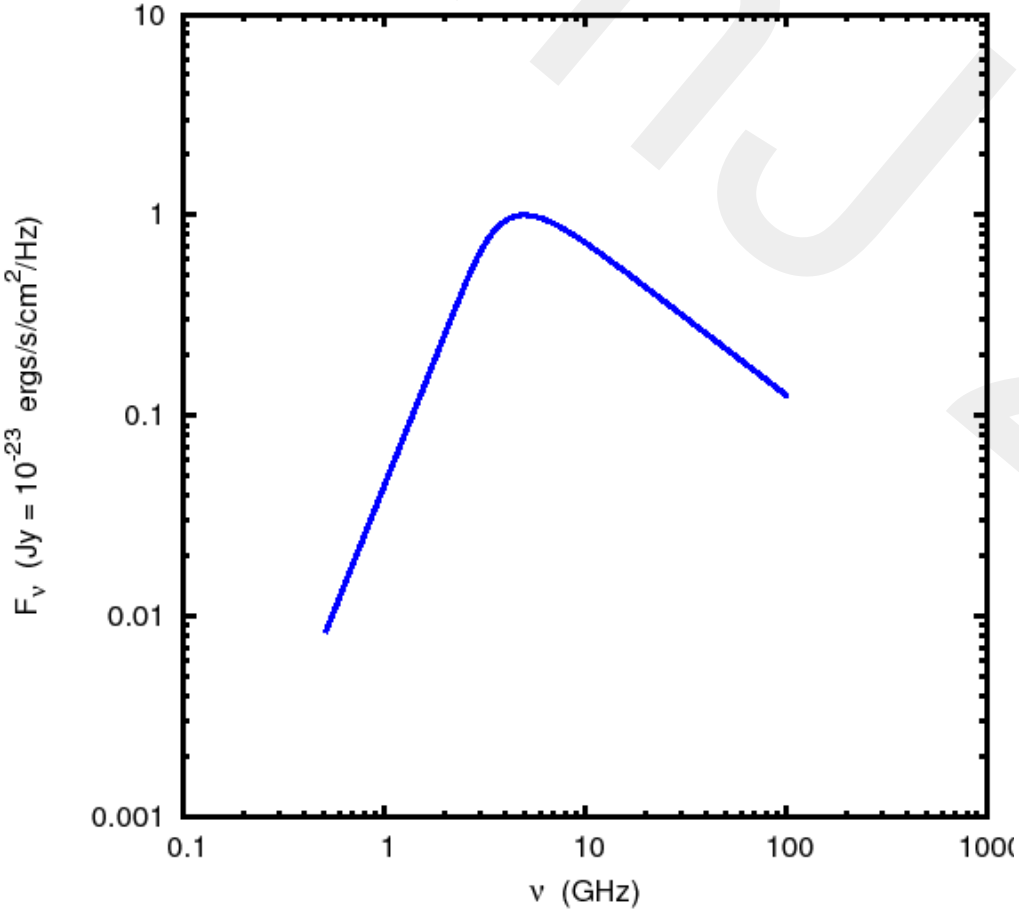
- Pc-scale jets often show a number of distinct bright components.

- Compact, bright region near the apparent base of the jet is called the core.

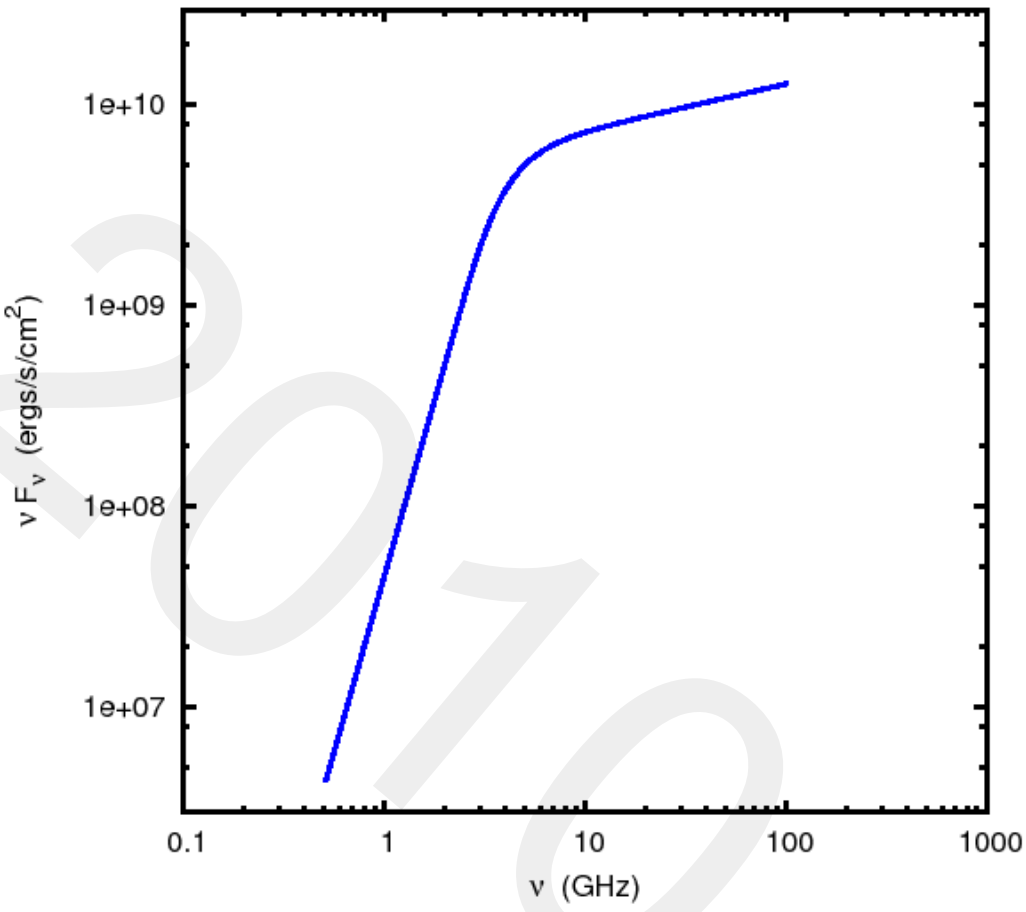
VLBA image of PKS 1510-089 at 8.4 GHz 2009-04-09, beam size: 2.55x1.10 (mas) at PA=0.8°

Theoretical radio spectrum of a uniform component

- Individual components may be approximated by a uniform source model
- Self-absorption break parameters are directly related to model parameters (B, N, p, R)
- Self-absorption break is usually detectable only in the core region



Spectral coordinates (ergs/s/cm^2/Hz)



SED coordinates (ergs/s/cm^2)

Multi-frequency VLBA observations

Twenty LAT early data release blazars have been observed with the VLBA at seven frequencies between 4.6 and 43 GHz quasi-simultaneously with Swift (typical time lag < 2d) between September 2008 and June 2009.

Multifrequency VLBA data provide:
- *spectrum* of the radio emitting region
- region *size*

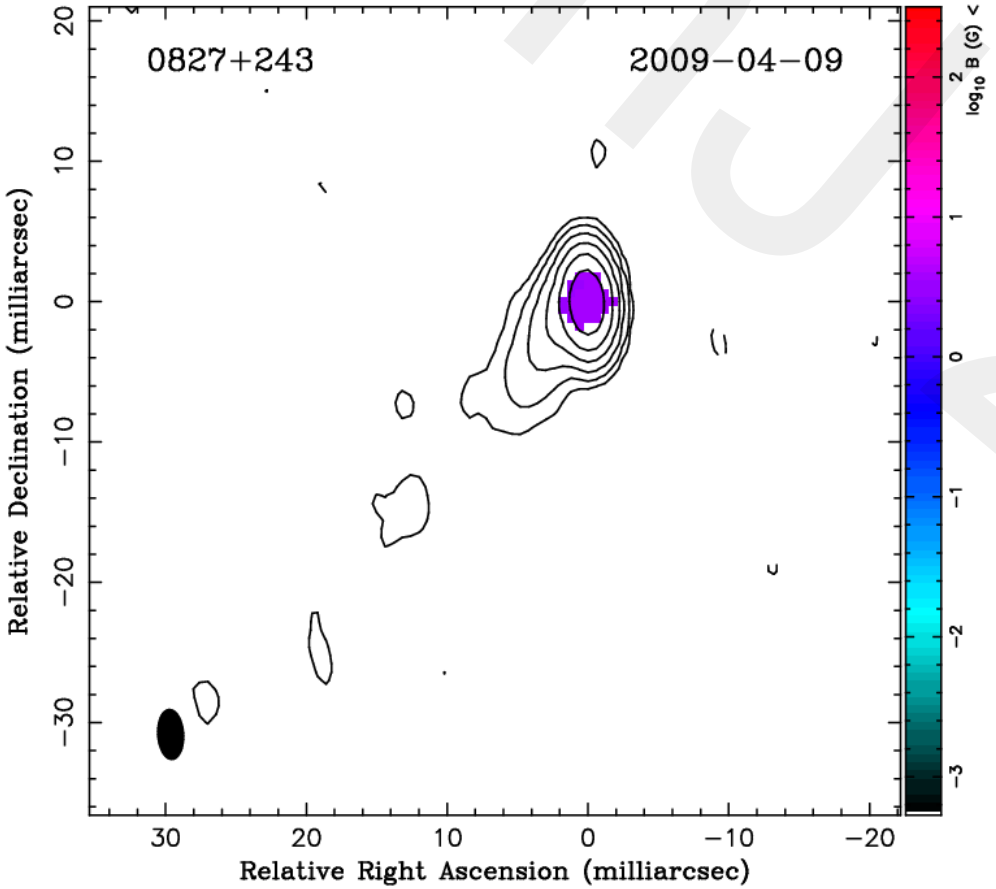
which in turn allow us to determine the magnetic field strength and electron energy spectrum (or at least put constrains on these parameters).

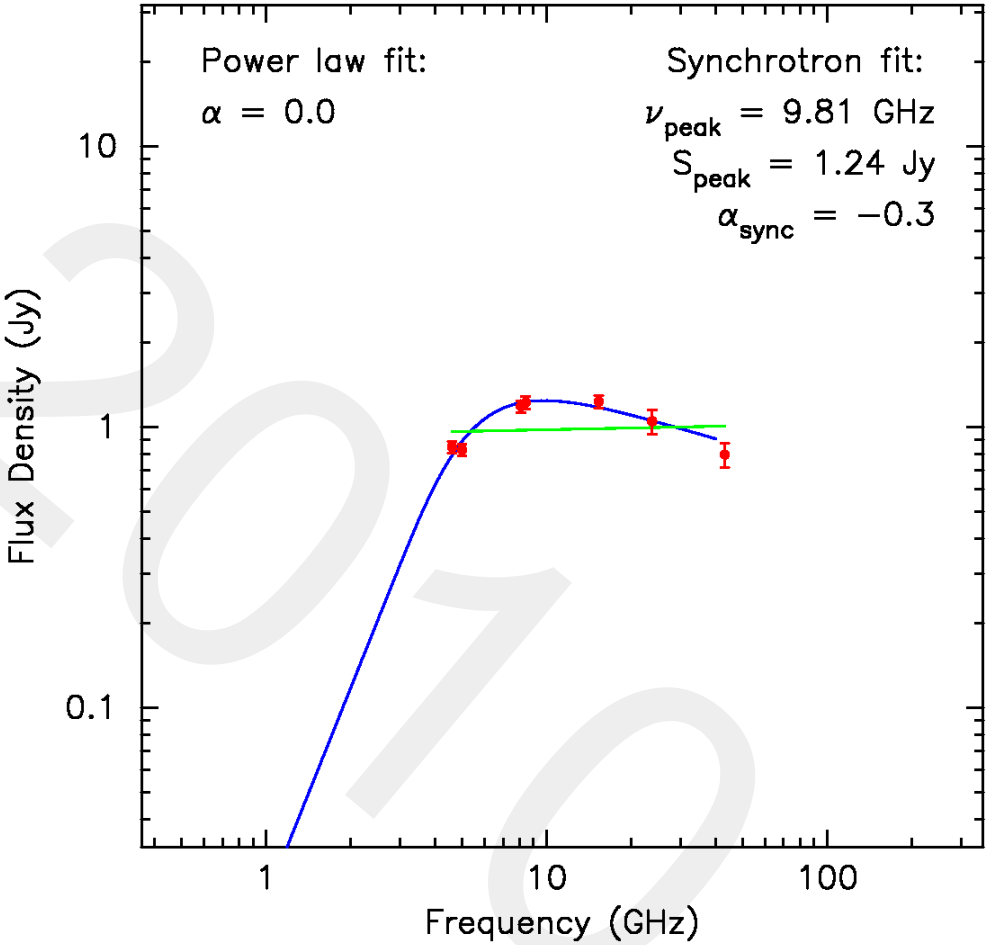
Parameters derived from VLBA data may be compared to those derived from SED modeling.

Goal: determine relation between radio and IR-to-gamma-ray emitting regions.

Pixel-based radio spectrum reconstruction

Spectrum in each pixel is reconstructed from CLEAN components around it which eliminates convolution artifacts.





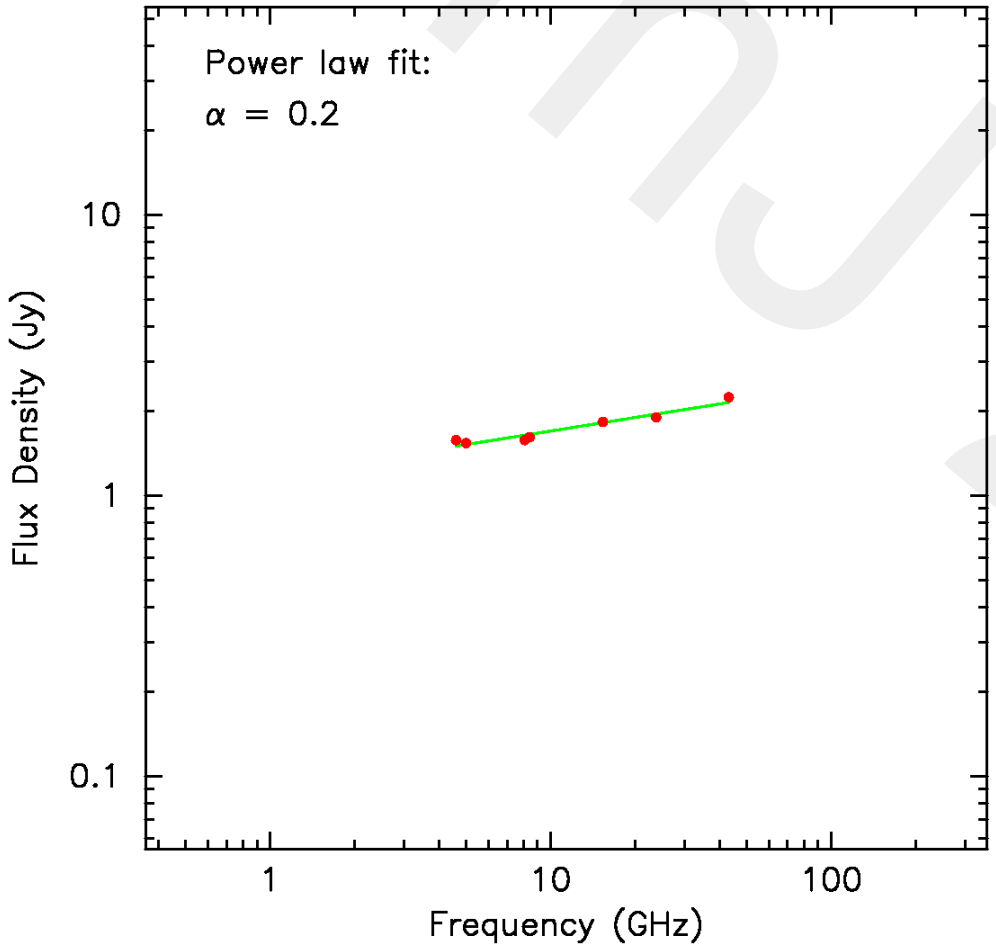
First VLBA results compared to SED models

Multi-frequency VLBA results (this work)				Published SED model parameters			
Name	$R_{43\ \mathrm{GHz}}$ [10^{15} cm]	p^{a}_{VLBA}	B_{VLBA} [G]	R_{SED} [10^{15} cm]	p^{a}_{SED}	B_{SED} [G]	Ref.
AO 0235+16	1050	0.8	< 11				
B0528+134	1564	1.4	< 1.2				
S5 0716+714	293	$\alpha = 0.4^{c}$		40	2.0	1	Chen et al. (2008)
OJ 248	4882	1.6	< 23				
OJ 287	719	$\alpha = 0.7^{c}$					
W Com	468	0.8	< 118	3	2.55	0.35	Acciari et al. (2009)
3C 273	850	2.0	≤ 0.2	20	2	12	Pacciani et al. (2009)
3C 279	1168	1.4	< 14	25	2.0	1.8	Giuliani et al. (2009)
PKS B1510−089	864	$\alpha = 0.2^{c}$		18	1.9	0.09	this work
4C 38.41	1291	1.0	< 1.8				
Mrk 501	279	1.6	< 67	1.03	2	0.3	Anderhub et al. (2009)
NRAO 530	3692	1.6	< 20				
B1959+650	270	1.4	< 300	7.3	2	0.25	Tagliaferri et al. (2008)
B2155−304	< 356	1.0	< 745	150	1.3	0.018	Aharonian et al. (2009)
BL Lac	494	1.0	< 3				
3C 454.3	1497	$\alpha = 0.8^{c}$		15	1.1	5.4	Bonnoli et al. (2010)
B2344+514	< 87	1.2	$< 57^{b}$				

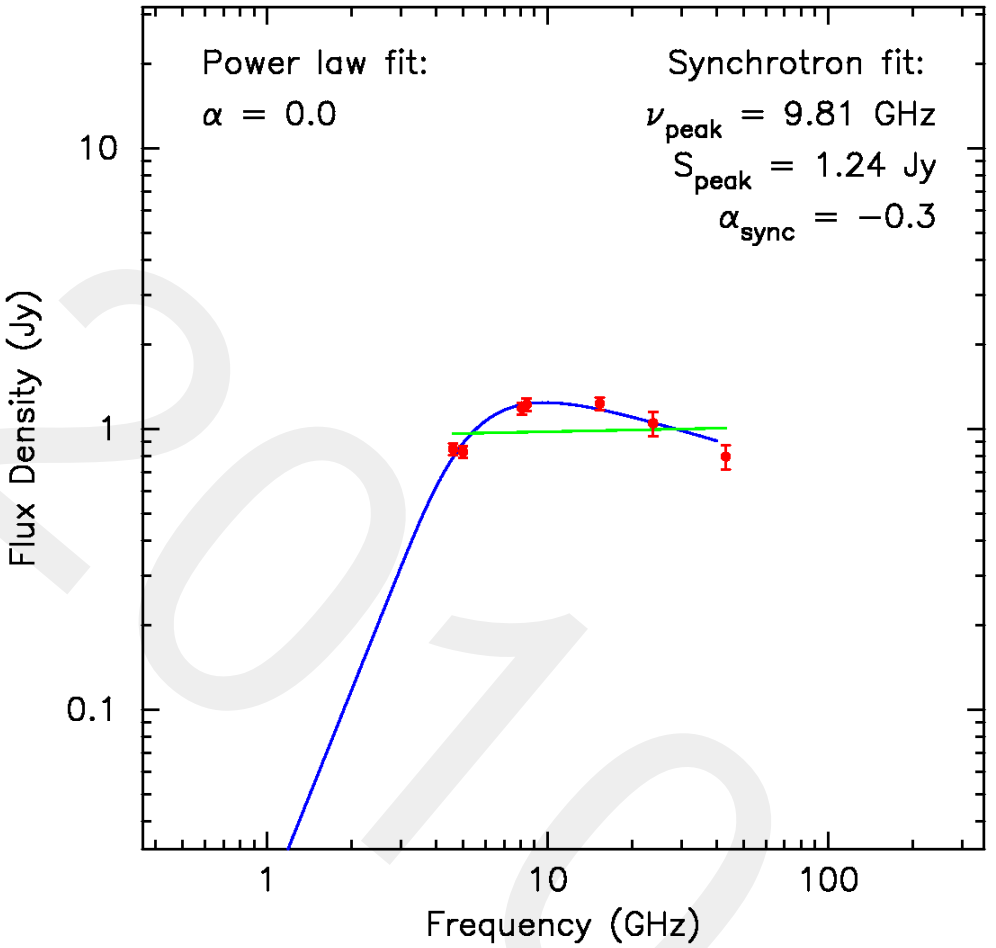
[a] p is the power law index in the electron energy distribution $N(E) = N_0 E^{-p}$.
[b] The value is in the observer's frame. [c] The homogeneous synchrotron source model is not applicable for such spectrum.

Radio spectra of 1510-089 and OJ248 compared

In some sources the core spectrum cannot be described by the uniform source model.

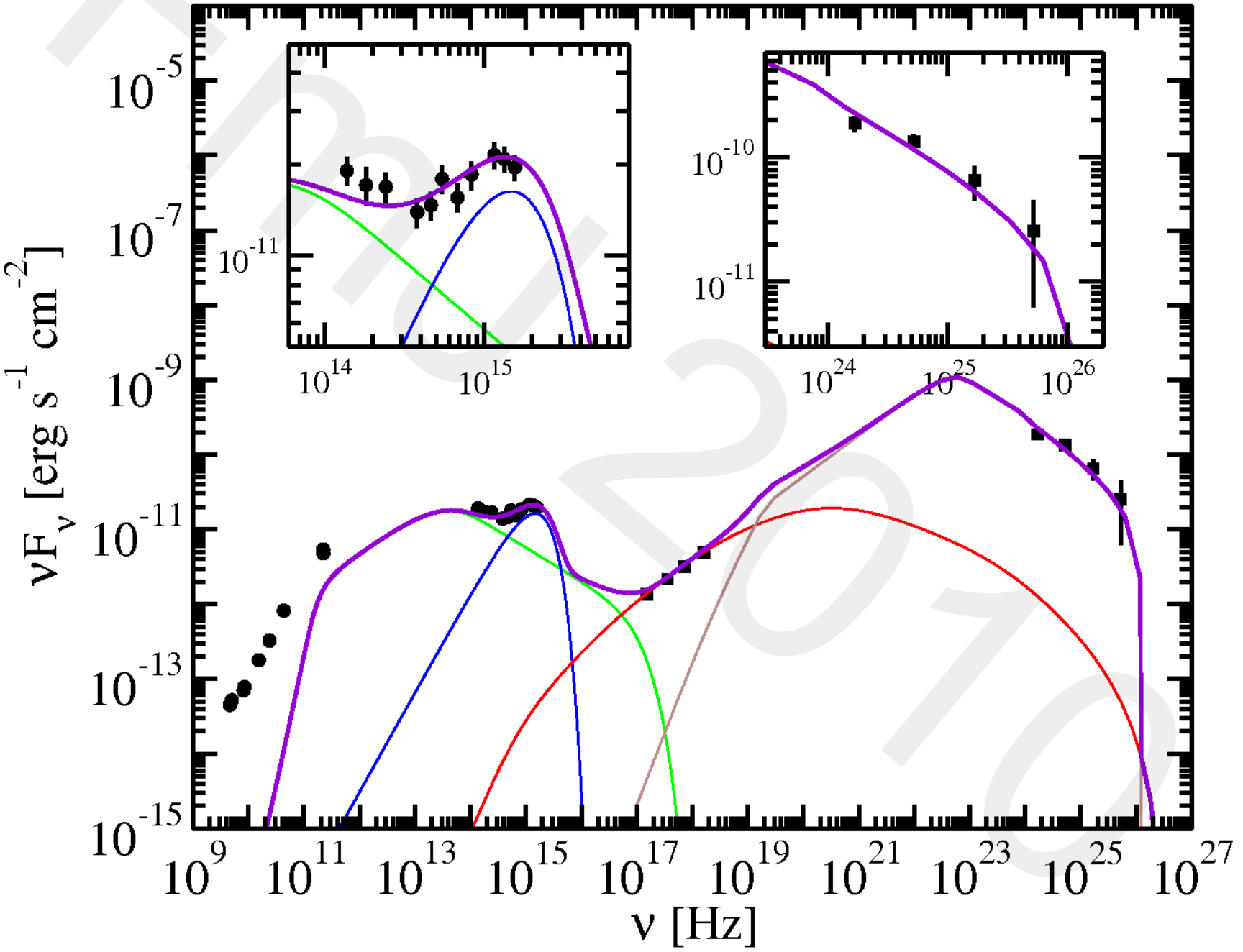


PKS 1510-089



OJ 248

SED of 1510-089 compared to one-zone ERC model



Summary

• Self-absorption turnover observations with the VLBA may provide useful constrains on SED models.
• Parsec-scale core regions of most of the observed sources may be described by the homogeneous source model. However, we found four notable exceptions.
• In PKS 1510-089 one-zone SED model fails to describe radio emission from the parsec-scale core. The reported correlation of activity in its pc-scale core region and activity at higher-energies challenges one-zone SED models.
• Detailed modeling of simultaneous SEDs which include multifrequency VLBI data is planned. Such modeling seems critical to obtain an accurate picture of broad-band emission of parsec-scale blazar jets.