Investigation on γ-ray Emission in Young Radio Sources

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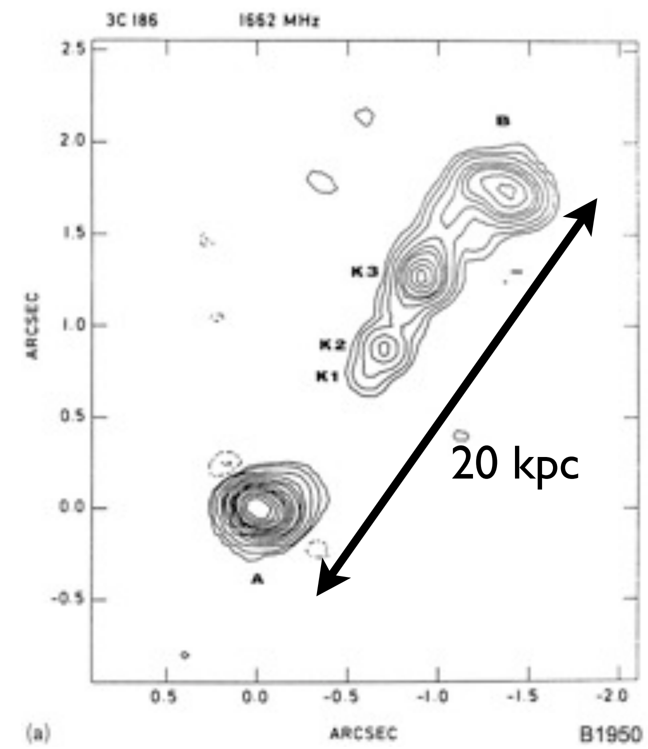
Outline

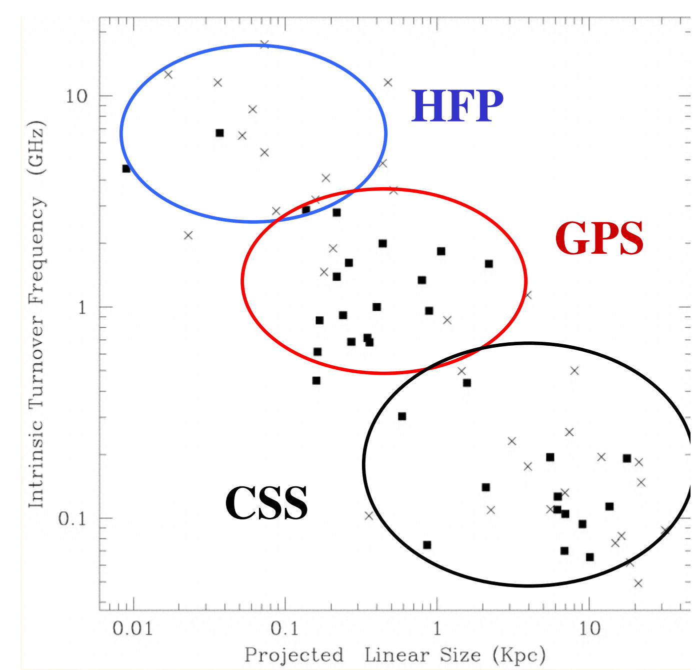
- Young Radio sources:
  - High-energy emission: X-rays and γ-rays
  - Modeling the jet broadband emission
  - preliminary results: predicted fluxes and Fermi

Young Radio Sources

- Small (≤20 kpc) but radio-powerful ($P_{1.4GHz}>10^{25}$ W Hz^{-1} O'Dea 1998 for a review), young counterparts of giant radio sources;
- Convex radio spectrum most likely due to synchrotron-self-absorption (ν_{peak} related to LS)
- Key to investigate the first stage of extragalactic radio sources' evolution

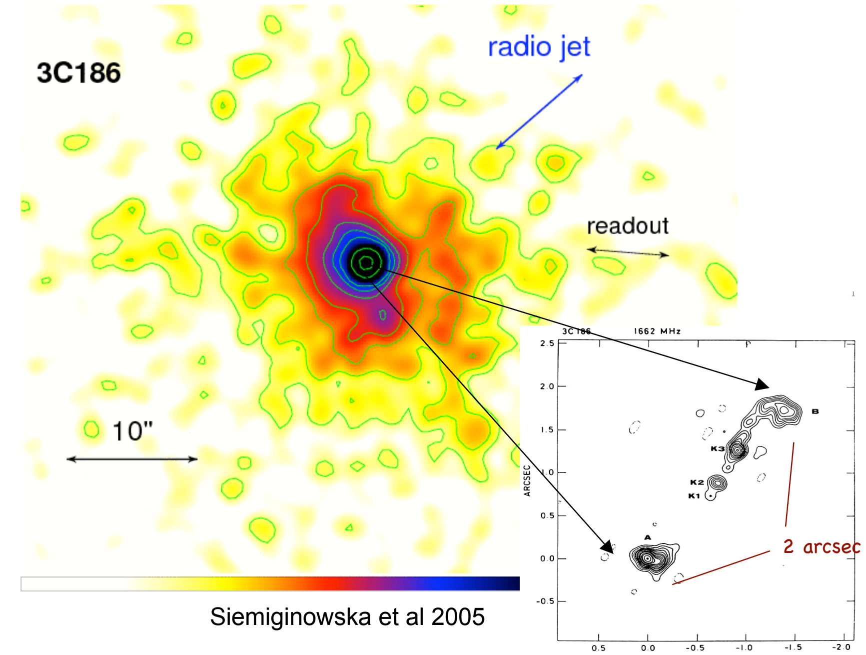


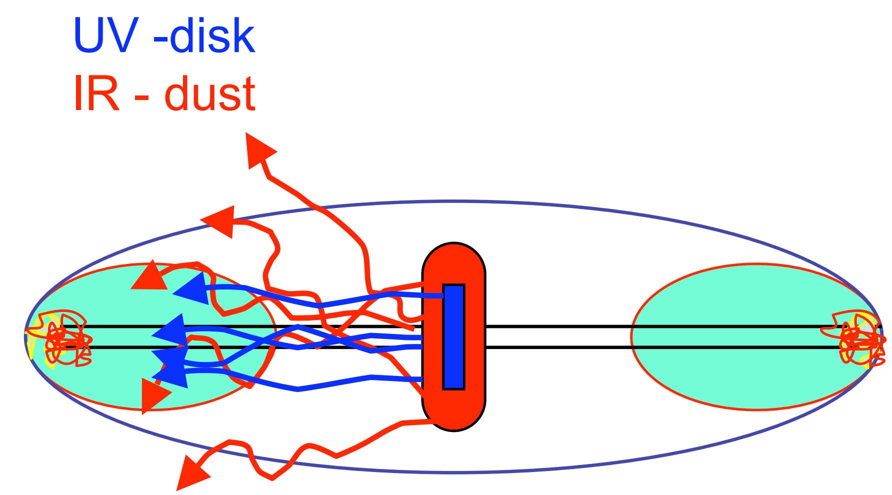
3C186 (Spencer et al.1991)

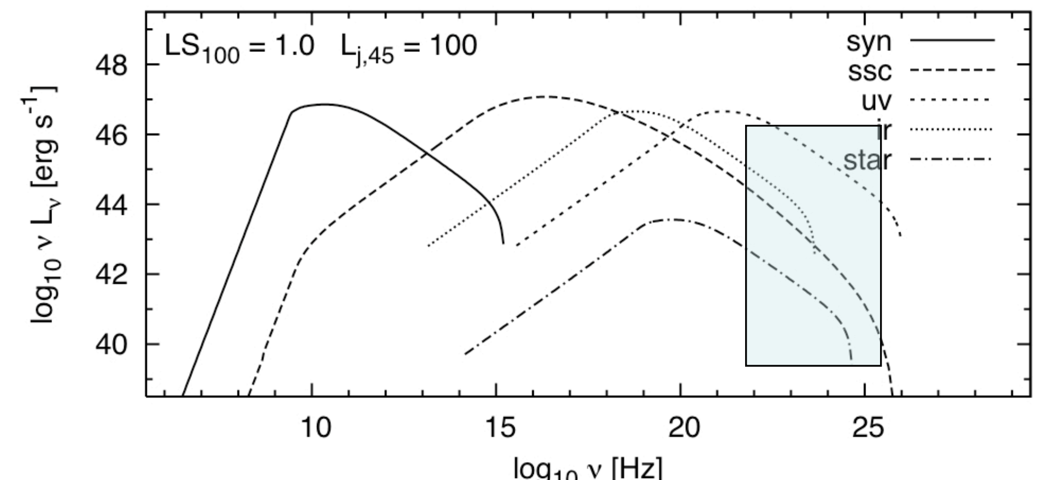


Young Sources in the high-energy band

- **X-rays:**
  - X-ray loud (Chandra and XMM-Netwon observations, Siemiginowska et al. 2008, Tengstrand et al. 2009)
  - Origin of the X-rays?
    - thermal (disk-corona, Tengstrand et al. 2009) vs. non-thermal (IC from lobes and jets, Worrall et al. 2004, Stawarz et al. 2008, Ostorero et al. 2010, Migliori et al. 2012)
- **Gamma-rays:**
  - predicted in non-thermal scenario
  - a young radio source (CSO) candidate detected with Fermi-LAT? (McConville et al. 2011)







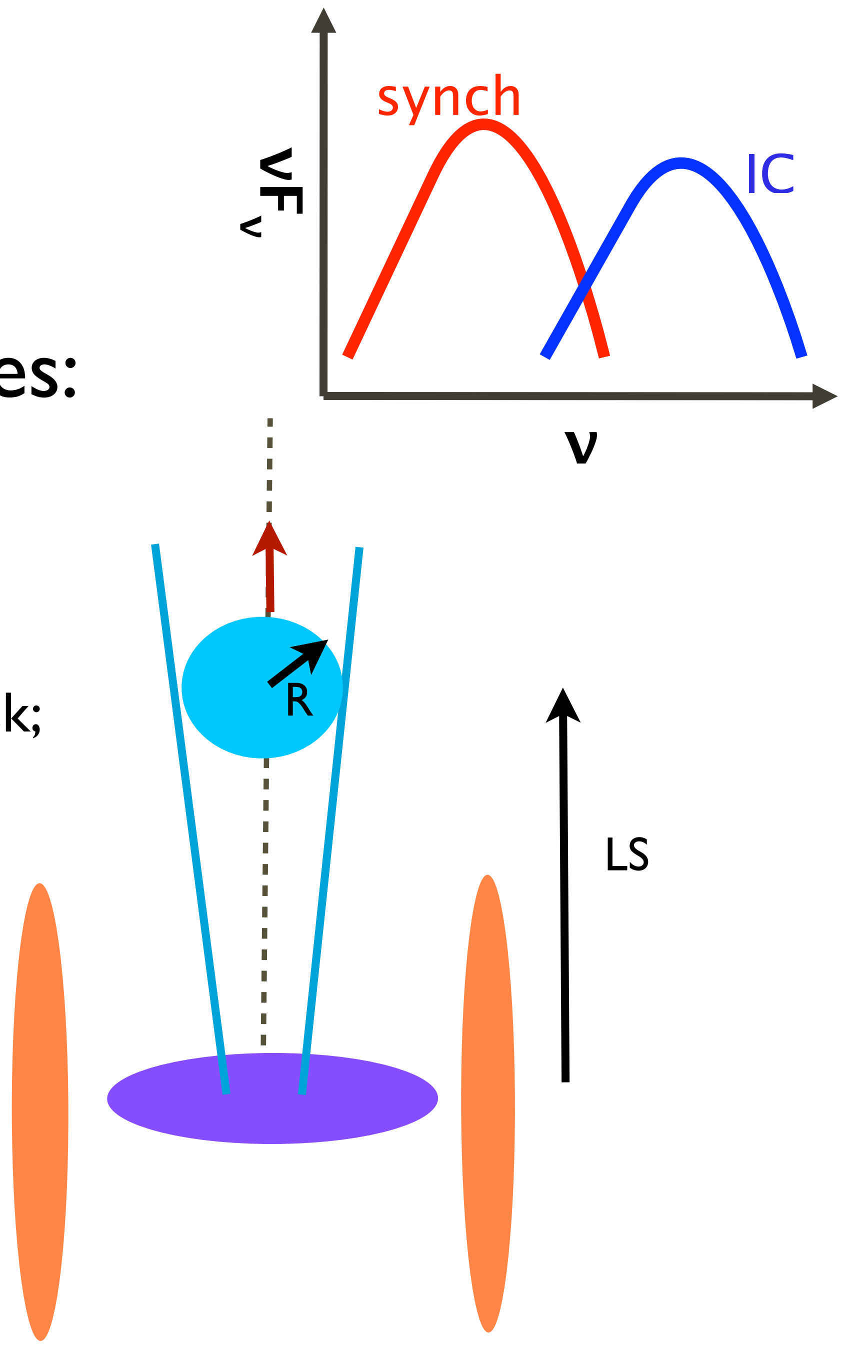
Stawarz et al.2008

Young Radio Sources in the gamma-ray band

- Goals of the study:
  - investigate the γ-ray properties of young radio sources;
    - constrain the energetics of young radio sources;
      - understand which is the preferential channel for the source-IGM feedback
- Approach:
  - we construct a simple model to predict the γ-ray emission from jets and lobes for sources of different power and size;
  - the simulated γ-ray intensities are used as a prior for the entire sample and used to estimate the expected distribution of γ-ray fluxes;
  - predicted fluxes are compared with Fermi-LAT observations

A simple jet model-I

- The jet SED is modeled using a synchrotron and IC model
- relevant photon fields at the young sources' scales:
  - local (SSC);
  - external (disk and torus photons);
- assumptions on geometry and luminosities:
  - $R \propto 0.1 LS$;
  - $L_{rad}=0.1L_{jet}$, $L_{disk} \sim L_{jet}$, $L_{dust/torus}=0.1L_{disk}$;
  - equipartition.



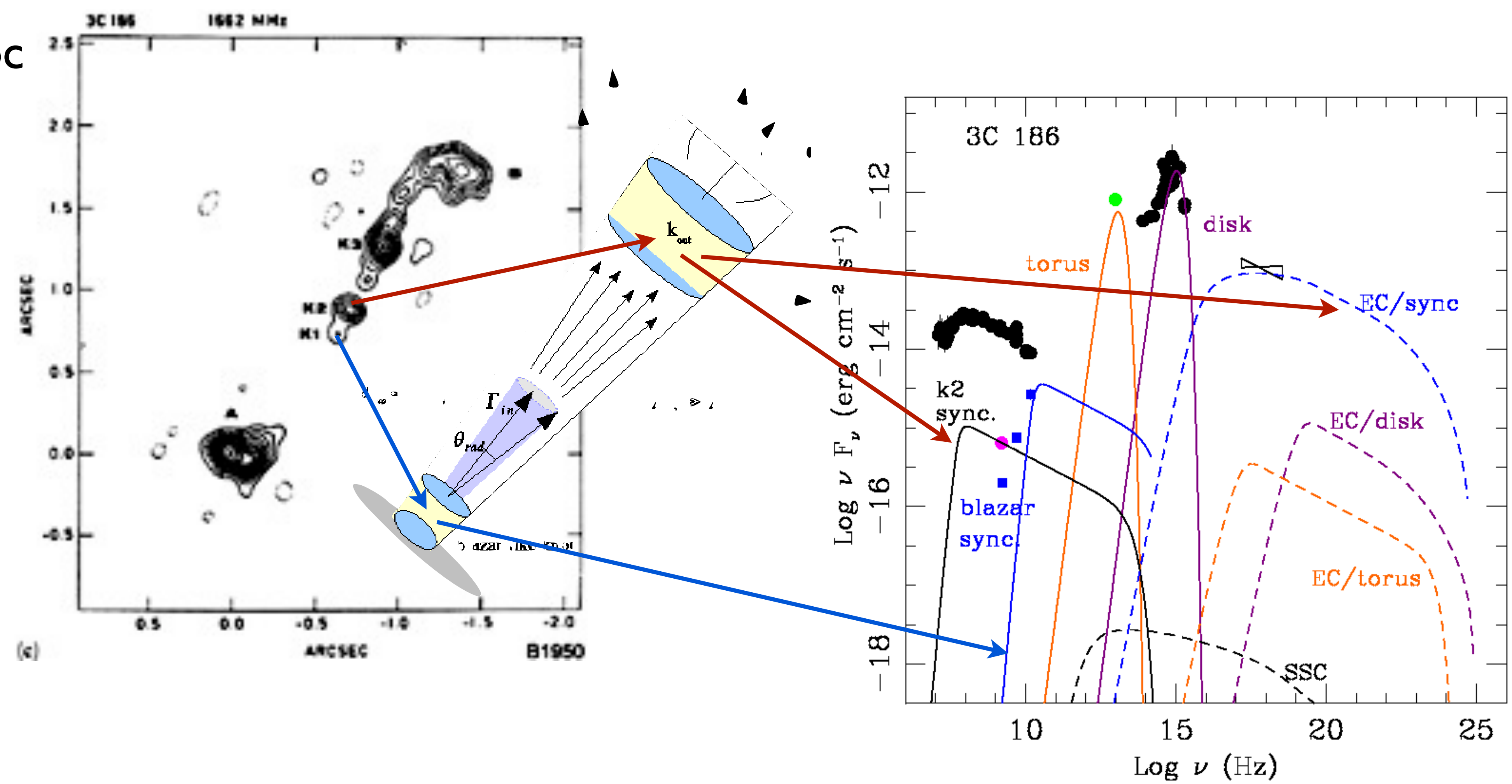
A simple jet model-II

- Clues for a complex structure in extragalactic relativistic jets in AGNs (radio observations, see also Hardcastle et al.2009, Miller et al. 2011)
- We include the case of a jet with an axial velocity structure (Celotti et al. 2001, see also Georganopoulos & Kazanas 2003, Ghisellini et al. 2005):

I. the jet decelerates on kpc scales within the host galaxy;

II. there are at least two emitting blobs, radiatively interacting;

III. synchrotron photons from a blazar-like blob can be Compton scattered by the electrons in the external, slower knot



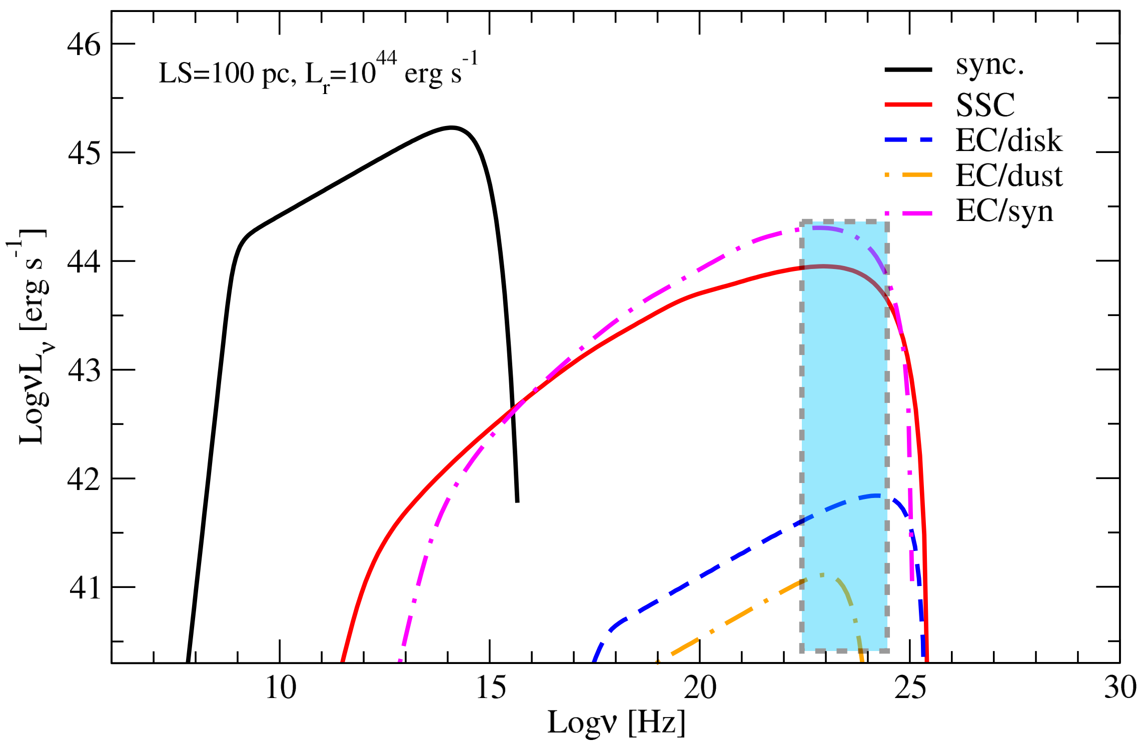
In 3C186 the jet contribution in the X-ray band depends on its dynamical structure

Simulated SEDs

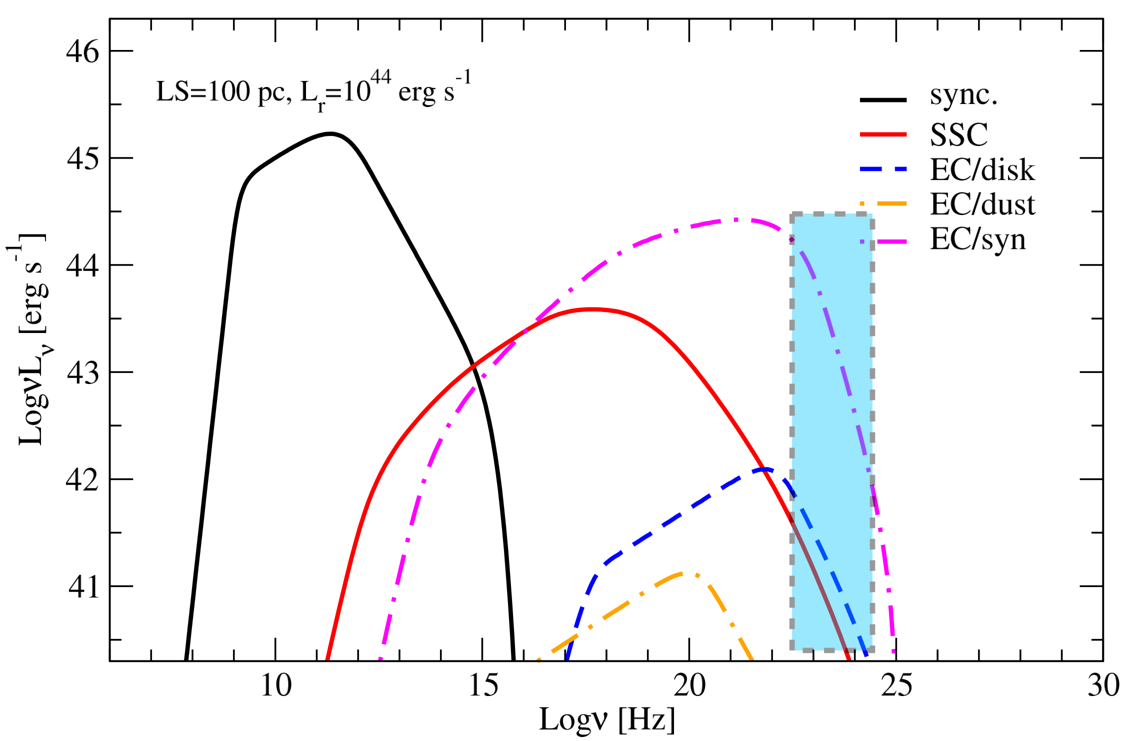
- 100pc jet SED:

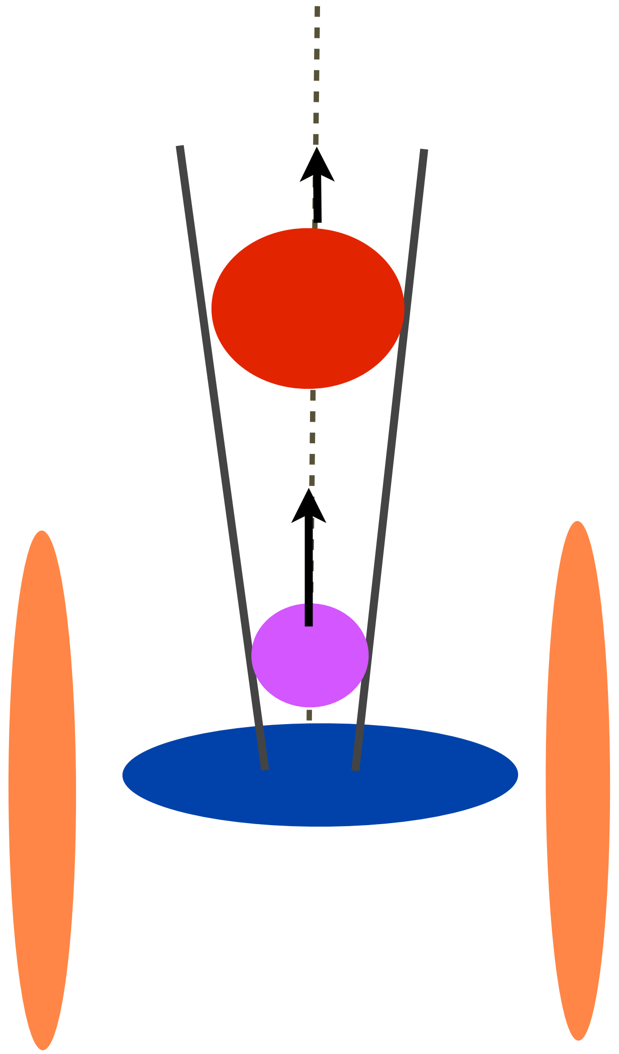
  Γ_{bulk}=5 θ=20°

  simple power-law:
  Γ=2.6



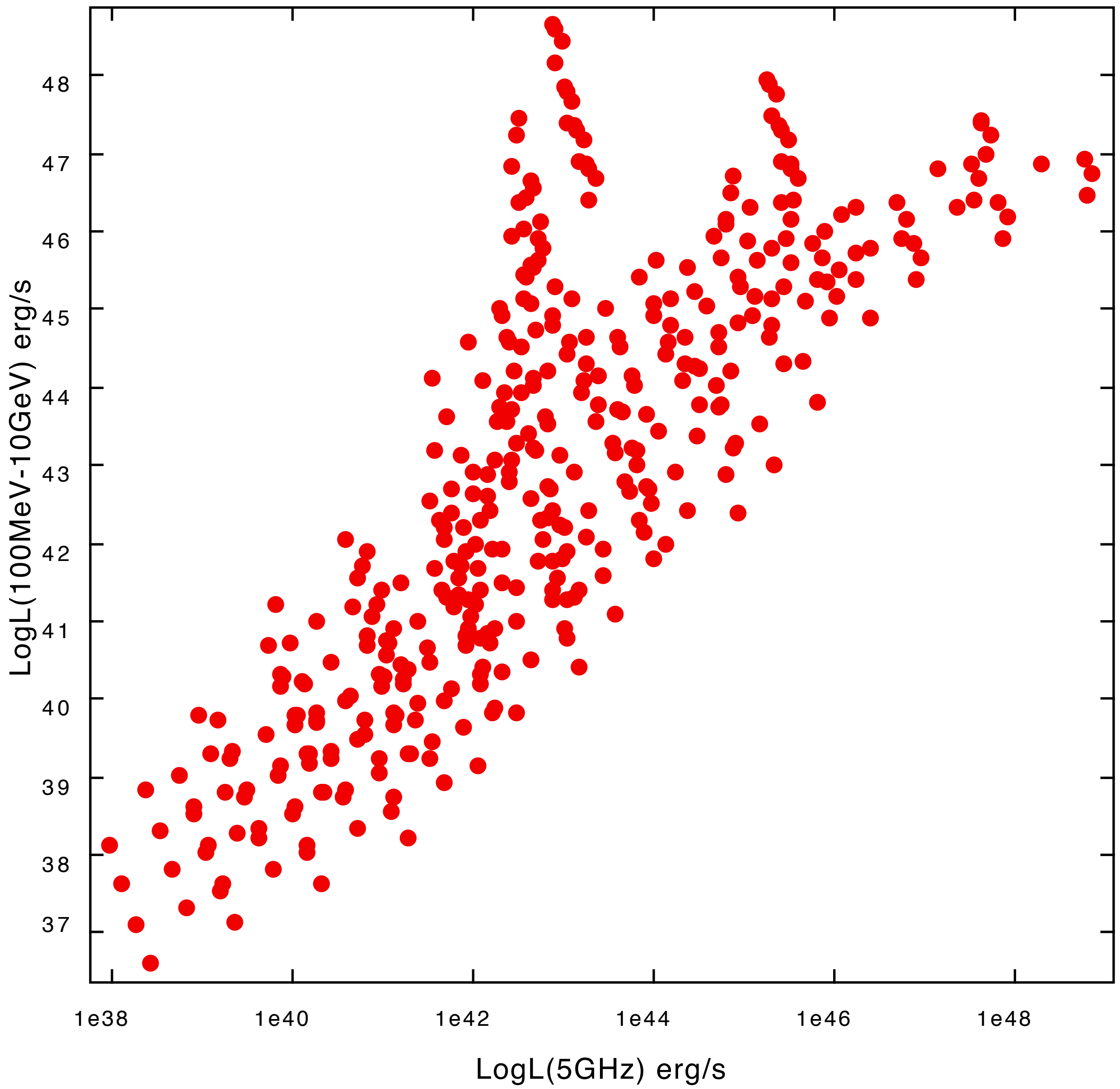
  broken power-law:
  Γ_1=2.3, Γ_2=4.4





Simulated SEDs: L_{5GHz} vs L_γ

- Model predictions for range of radio power and source linear sizes - preliminary results:



- Electron energy distribution is a simple power law (s=2.6);
- radio power $L_{radio}=10^{43}$-10^{46} erg s^{-1};
- linear size: LS=10 pc - 10 kpc;
- bulk motion: Γ_{bulk}=1.4-15;
- jet inclination: θ=5°-60°.

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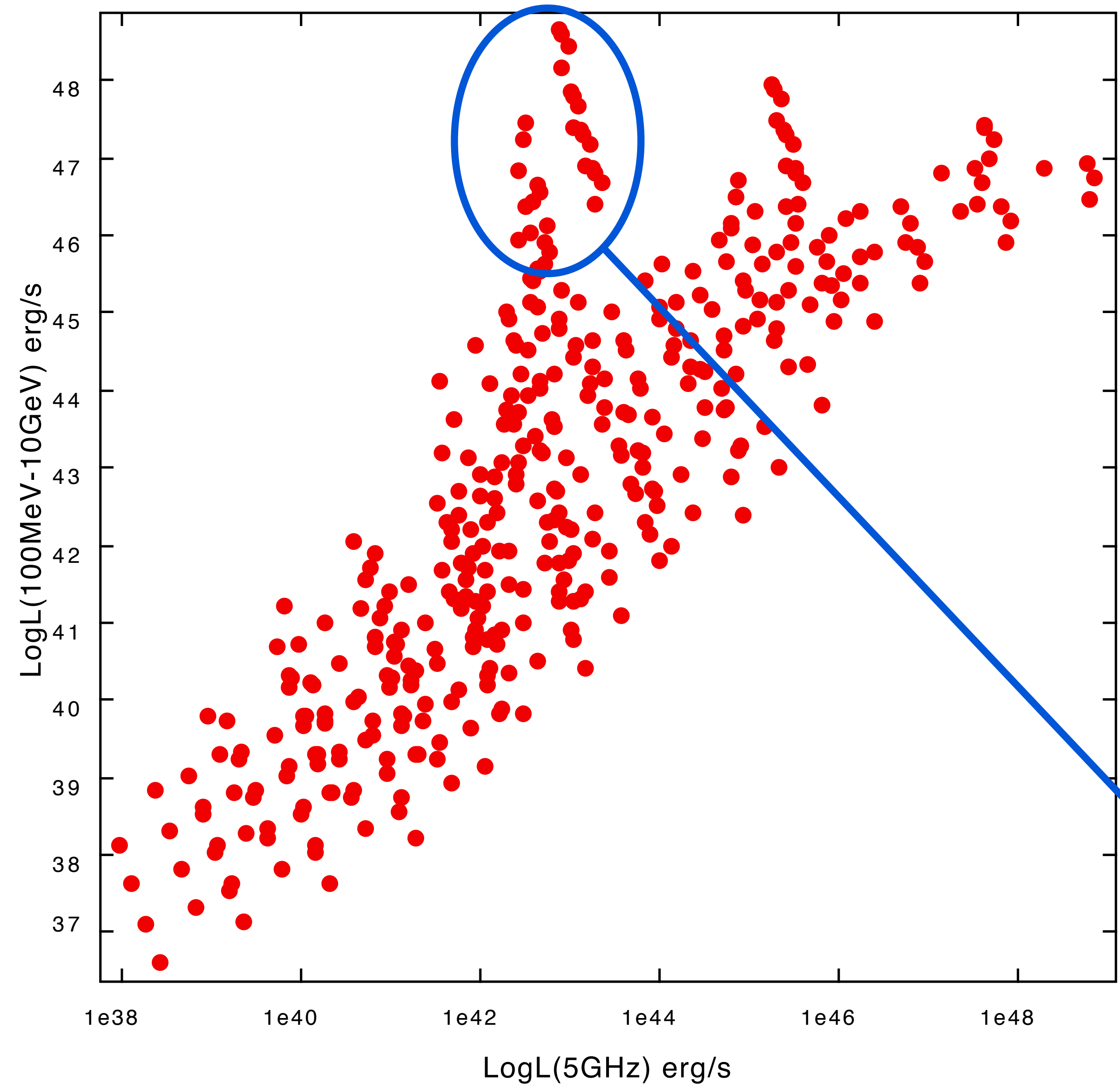

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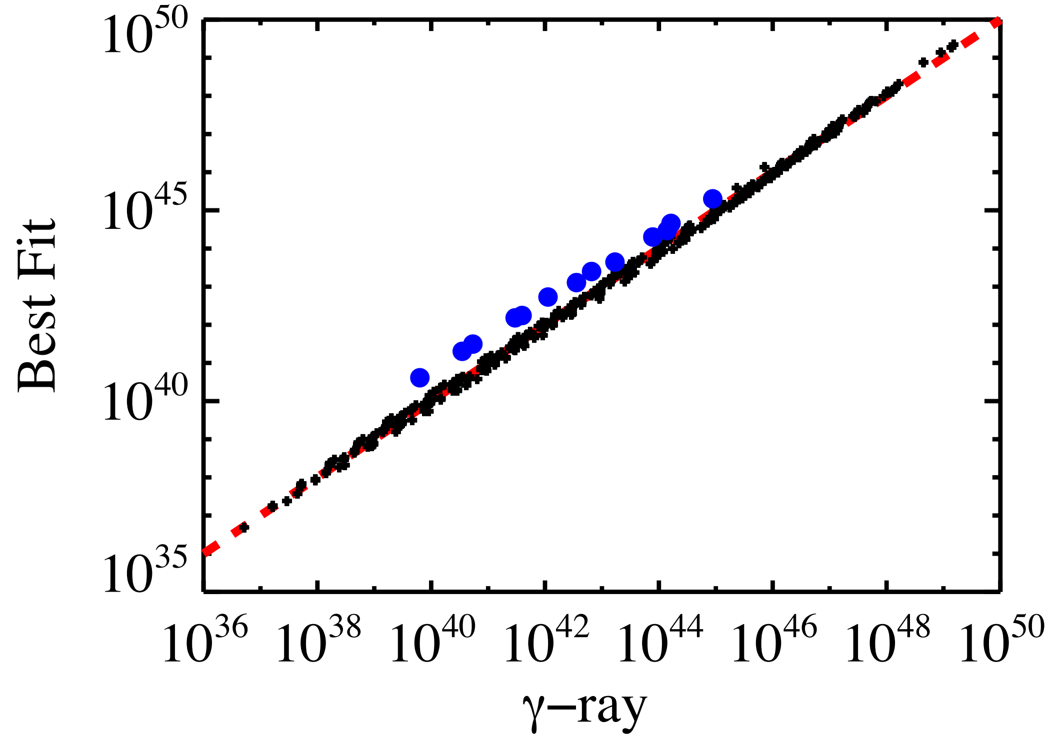
young (10-100pc) and powerful ($Lrad \sim 10^{45-46}$ erg s^{-1}) with $\Gamma_{bulk}=1.4-5$: EC/dust and EC/syn dominated

Fit of the simulated SEDs

- Fit of the simulated data (Kelly 2007):

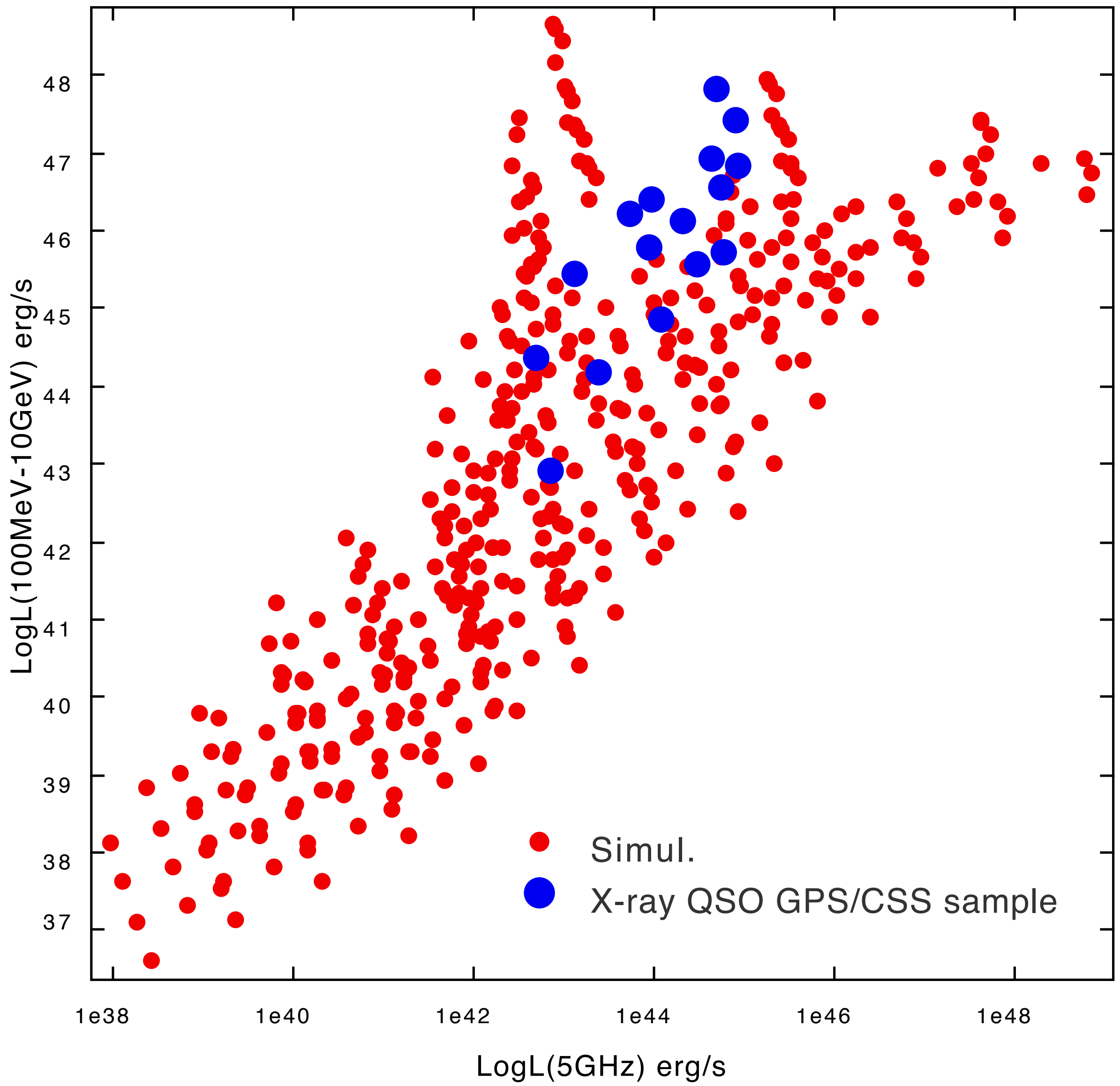
$$\text{Log } L_\gamma = 43.2 + 0.029\times(\log L_{5GHz} - 43.0) + 1.088\times(\log L_{X\text{-}ray} - 42.0)$$



- provides a simple relation to estimate gamma-ray luminosity from radio and X-ray luminosities.

Predicted fluxes for X-ray GPS/CSS quasars

- The relation is applied to the sample of X-ray observed GPS/CSS quasars (Siemiginowska et al. 2008):



Assumptions:

- X-ray emission is non-thermal
- The 5GHz flux is ascribed to the jet

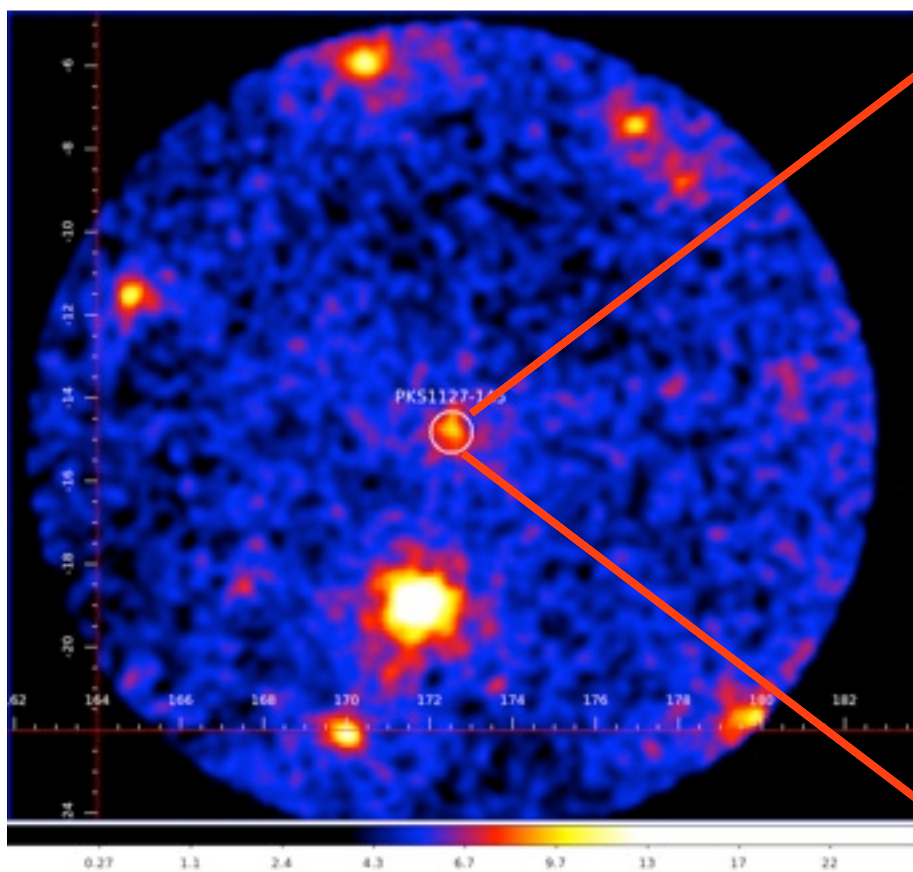
- z=0.32-1.95
- $L_{5GHz}=10^{42.7}-10^{44.9}$ erg s^{-1};
- $L_{2keV}=10^{41.7}-10^{46.2}$ erg s^{-1};
- predicted $F_{100\ MeV-10\ GeV}=(51-0.05)\times10^{-12}$ erg cm^{-2} s^{-1}

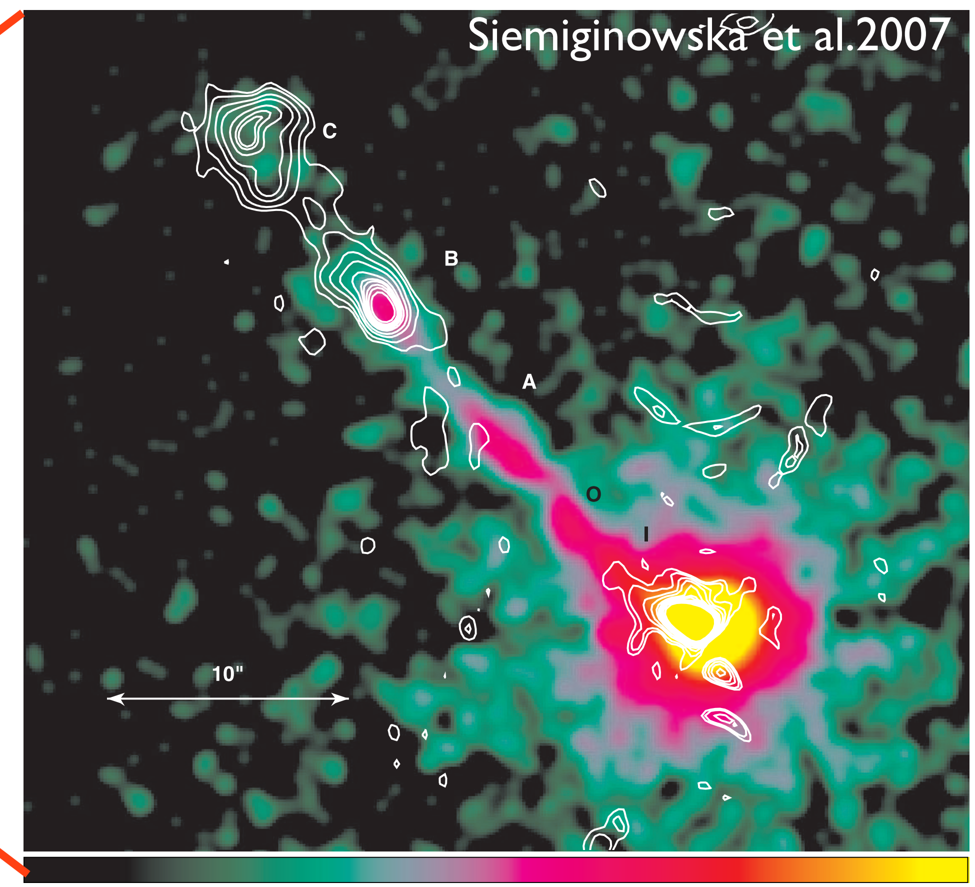
Gamma-ray brightest candidates: looking at the data

- No-associations with sources in the 2FGL except for one case (but 5σ detection limit);
- Fermi-LAT 4 yrs data - preliminary results for the 3 brightest candidates: upper limits for 2 sources (UL~(2.79-2.99)×10^{-7} phot. cm^{-2} s^{-1}) and 1 detected source.

PKS 1127-145:

- z=1.18
- 2FGL association with 2FGL1130.3-1448 (TS~25)
- gamma-ray variability
- Γ=2.75±0.5



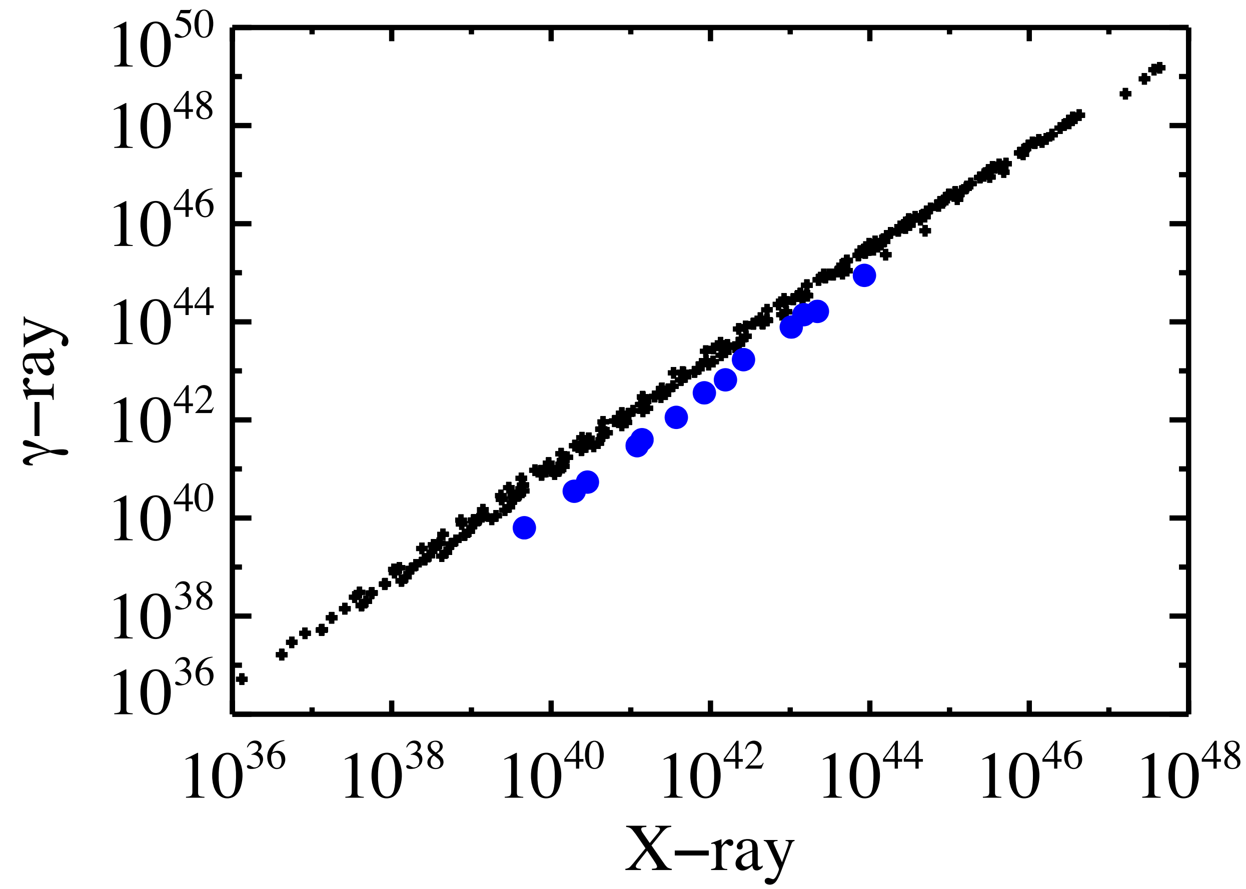


not a standard GPS;
radio and X-ray 300-kpc jet

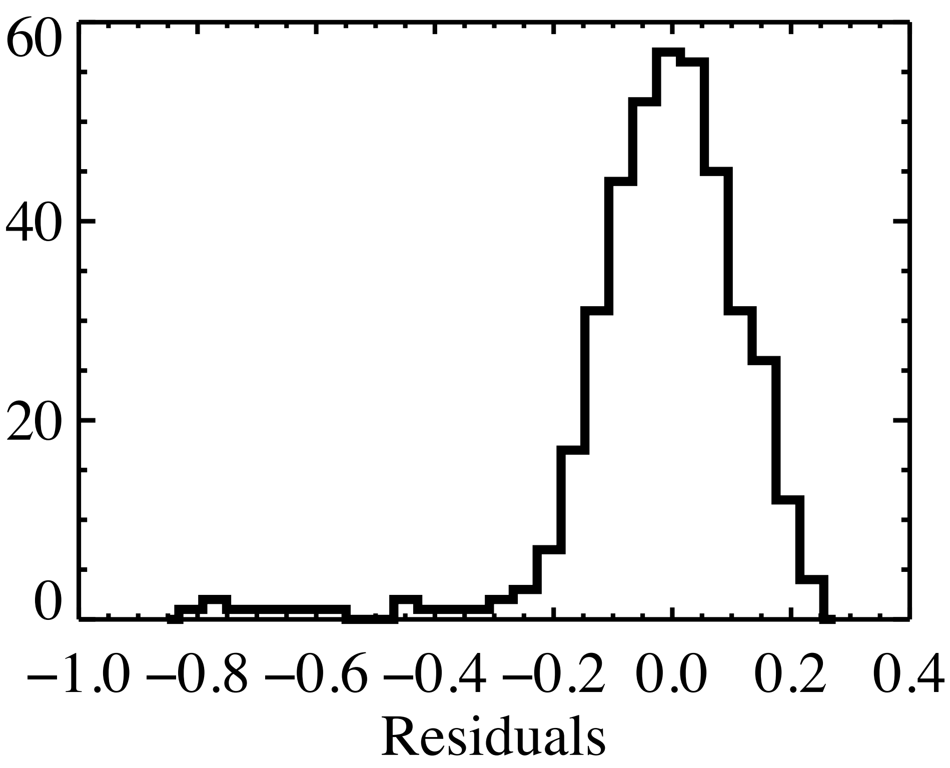
Future work

- Complete the gamma-ray analysis of the X-ray sample (quasars and radio galaxies) and use the results to better constrain the model parameters;
- More SED simulations with different parameters (EED shape, particle/magnetic field energy-ratio, nuclear luminosities)
- Include the case of gamma-ray emission from the lobes of radio galaxies

Outliers



10^{50}
10^{48}
10^{46}
10^{44}
10^{42}
10^{40}
10^{38}
10^{36}
γ–ray
10^{36} 10^{38} 10^{40} 10^{42} 10^{44} 10^{46} 10^{48}
X–ray

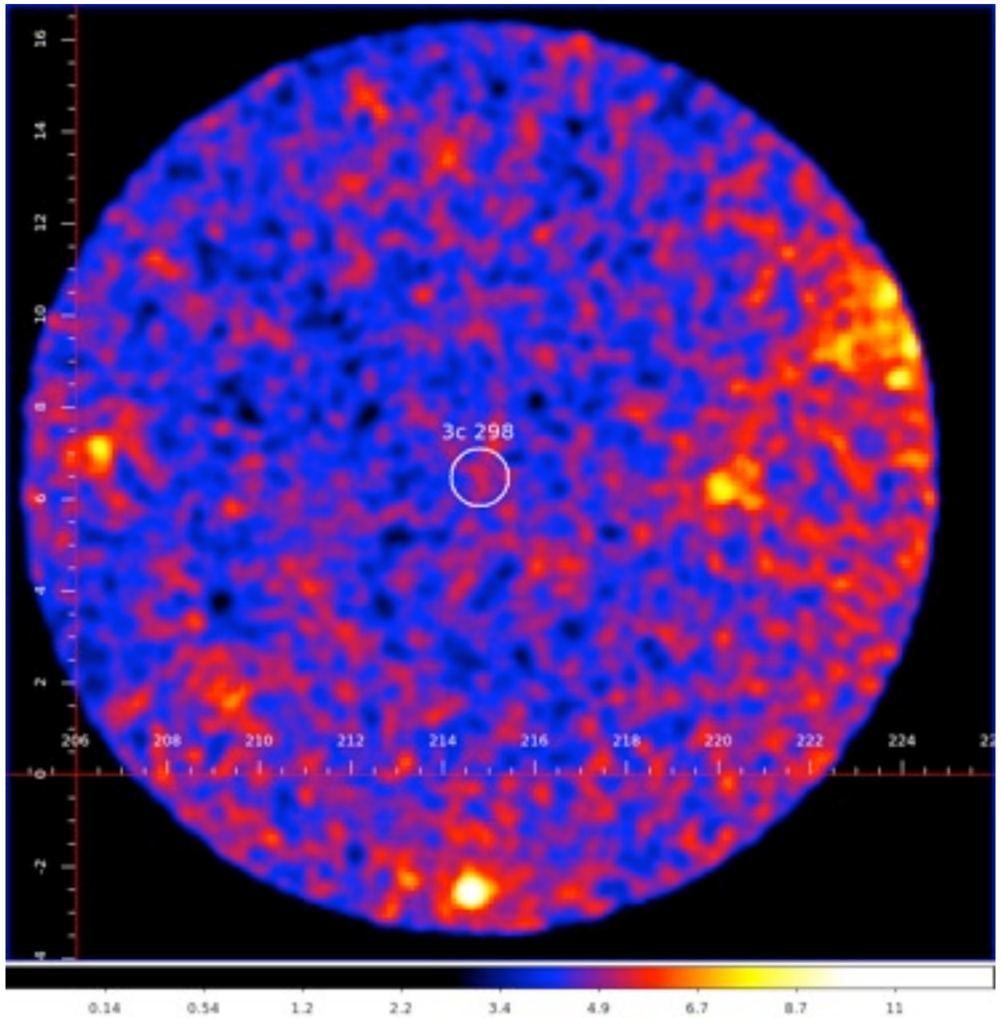


60
40
20
0
−1.0 −0.8 −0.6 −0.4 −0.2 0.0 0.2 0.4
Residuals

Gamma-ray brightest candidates: looking at the data

- 3C 48 & 3C 298

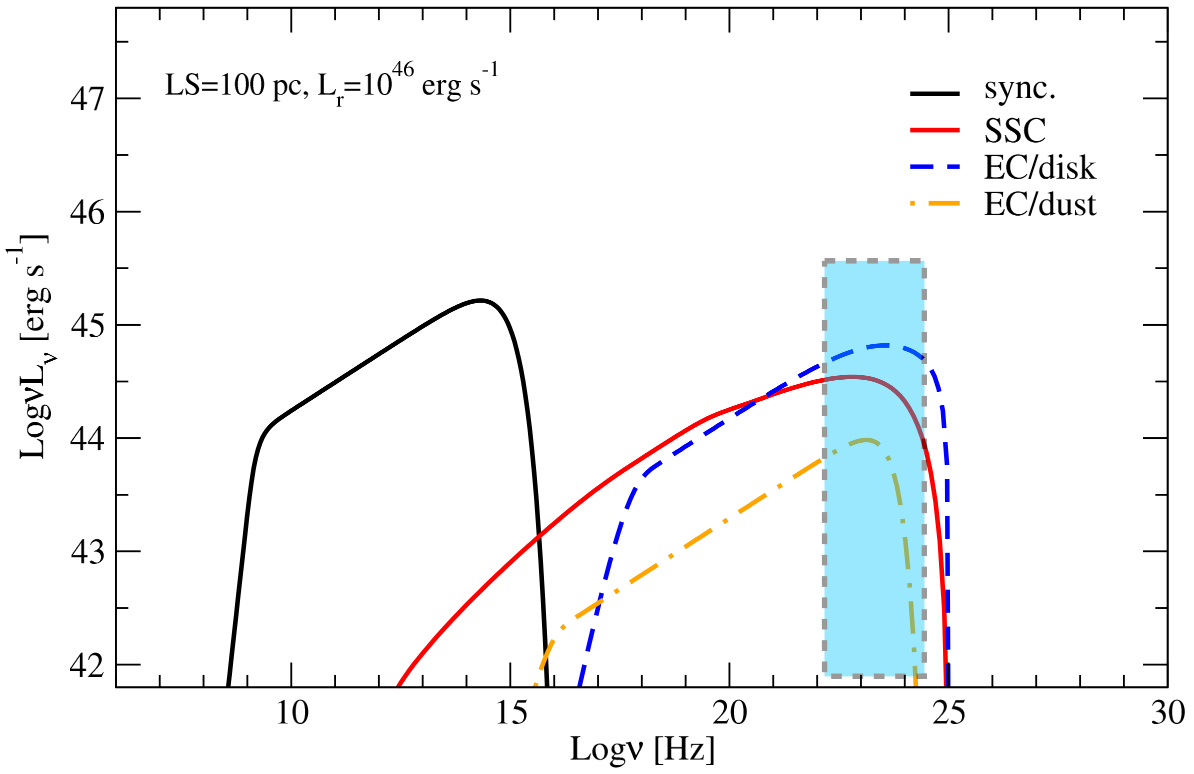
UL_{3C48}=2.99×10^{-7} phot. cm^{-2} s^{-1}
UL_{3C298}=2.79×10^{-7} phot. cm^{-2} s^{-1}



Simulated SEDs

- GPS lobes:

- simple power law:



- broken power law: