Young radio sources in the γ-ray band

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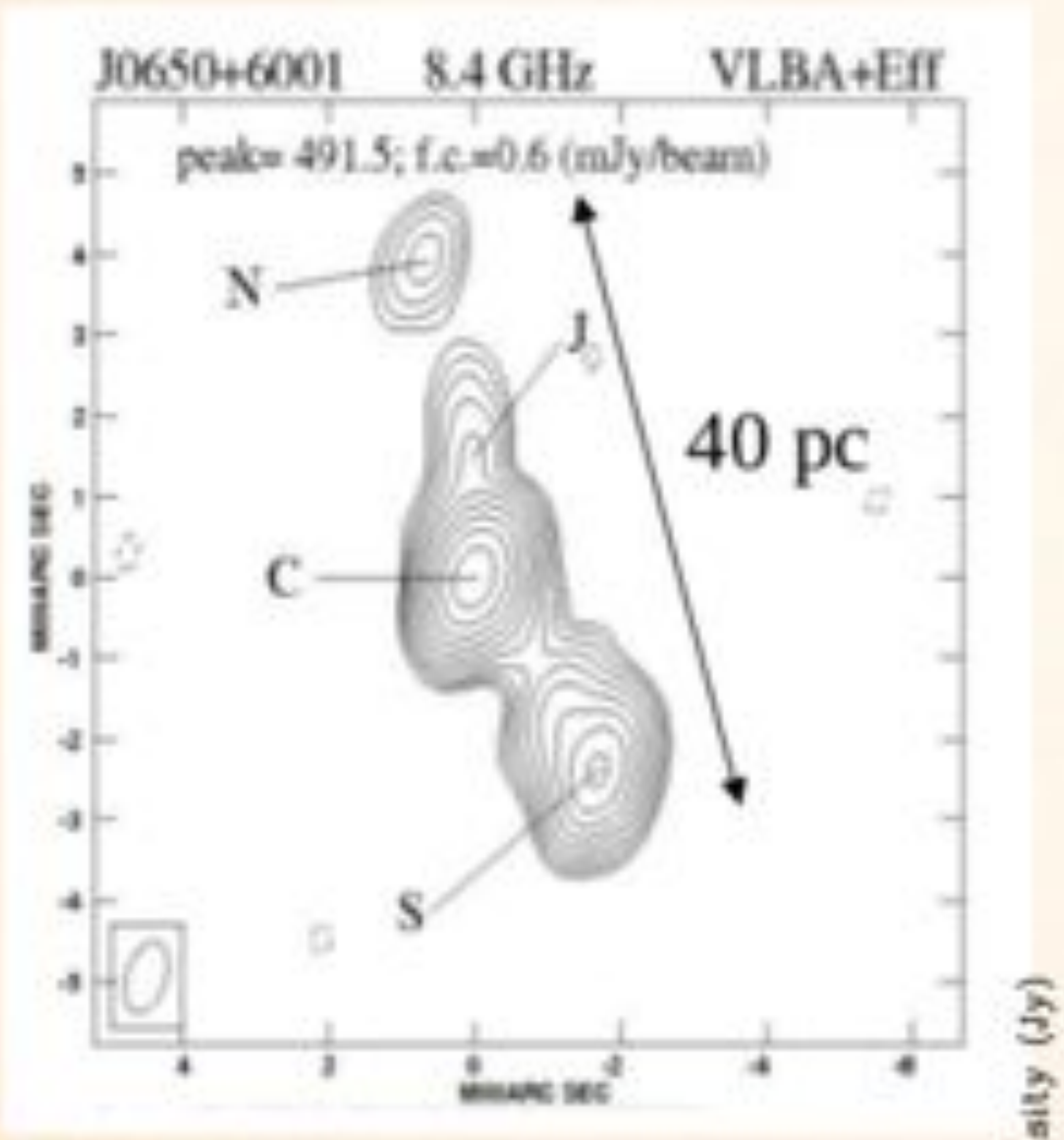
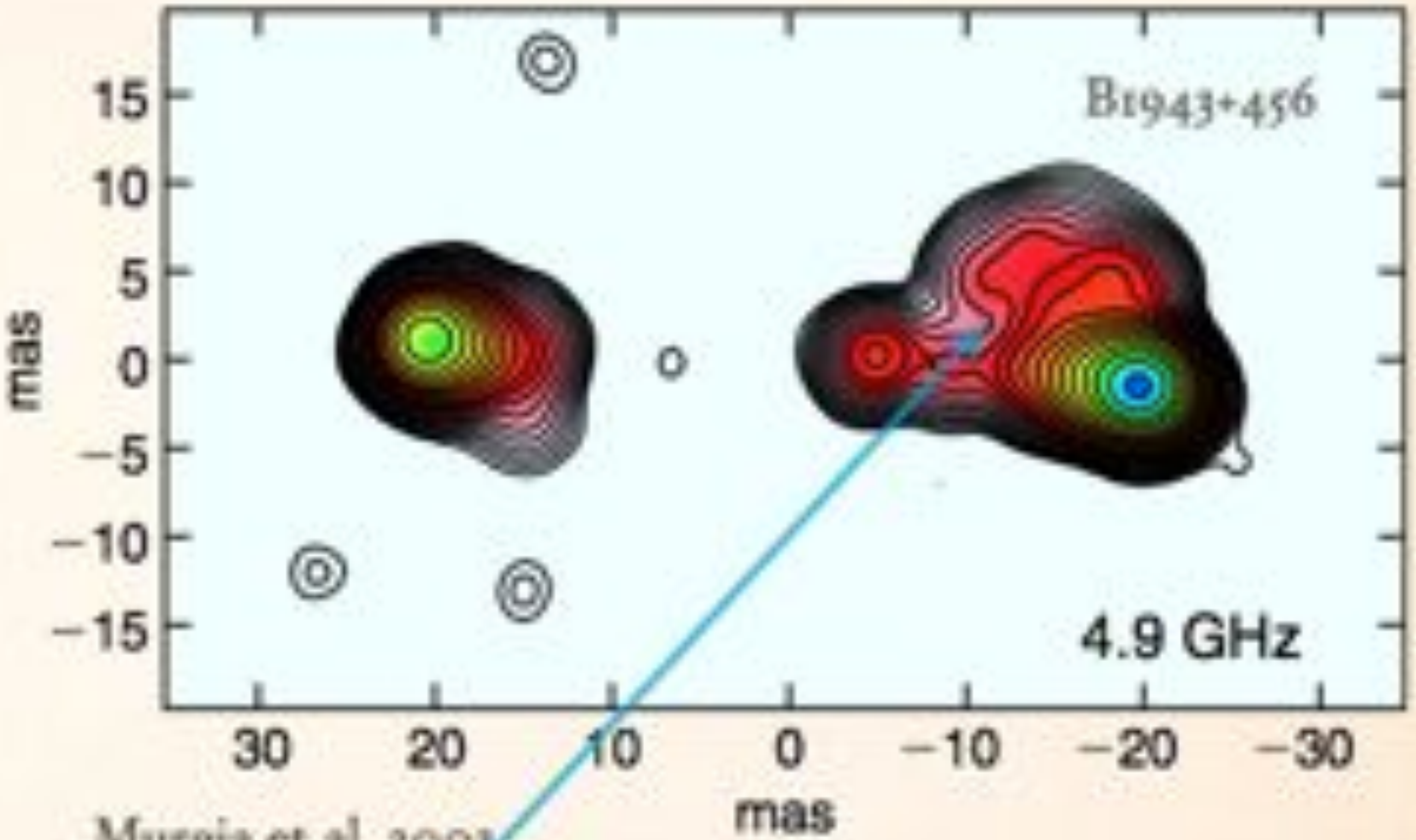
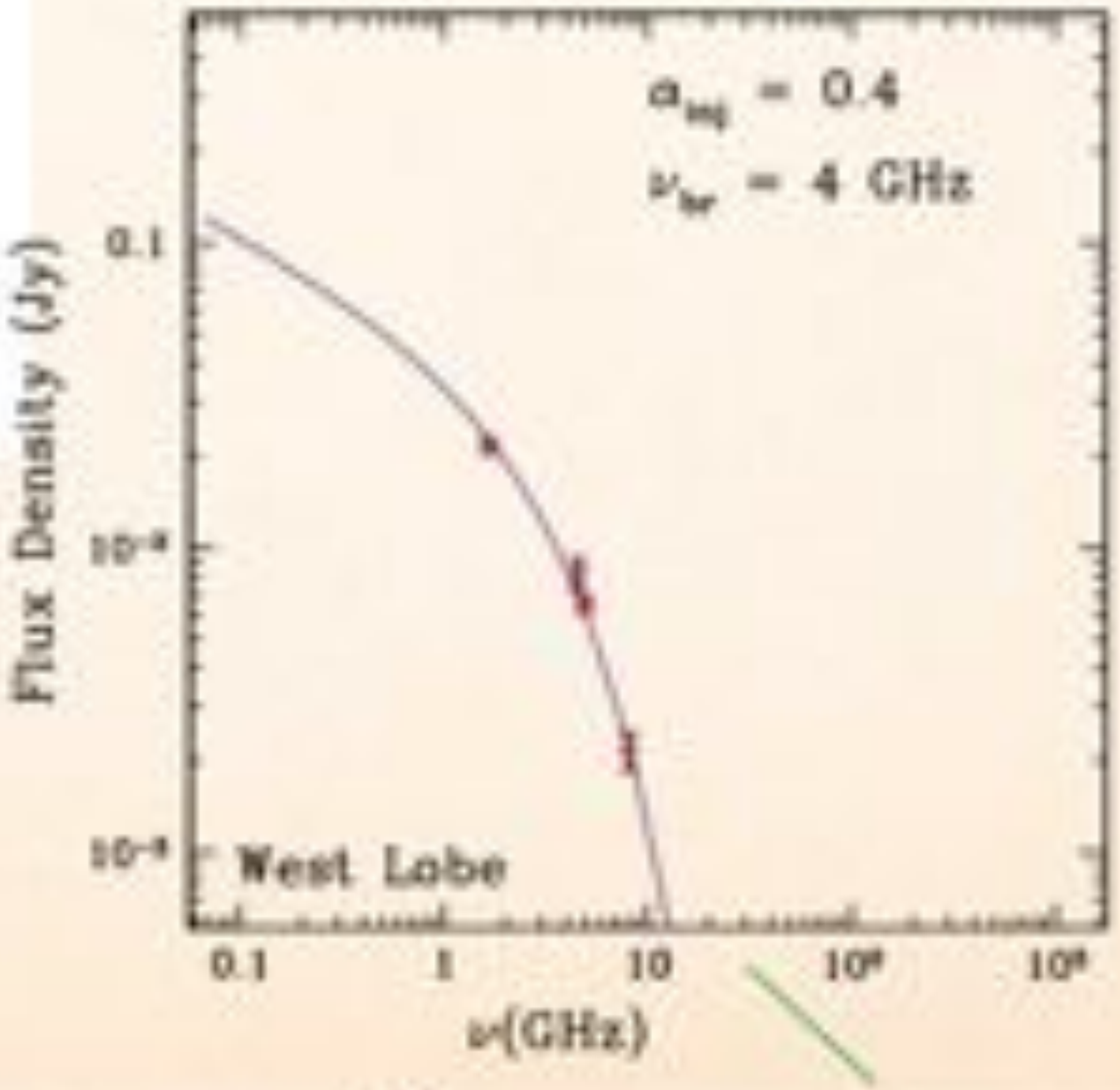
Young Radio Sources



Orienti et al. 2011



Murgia et al. 2003



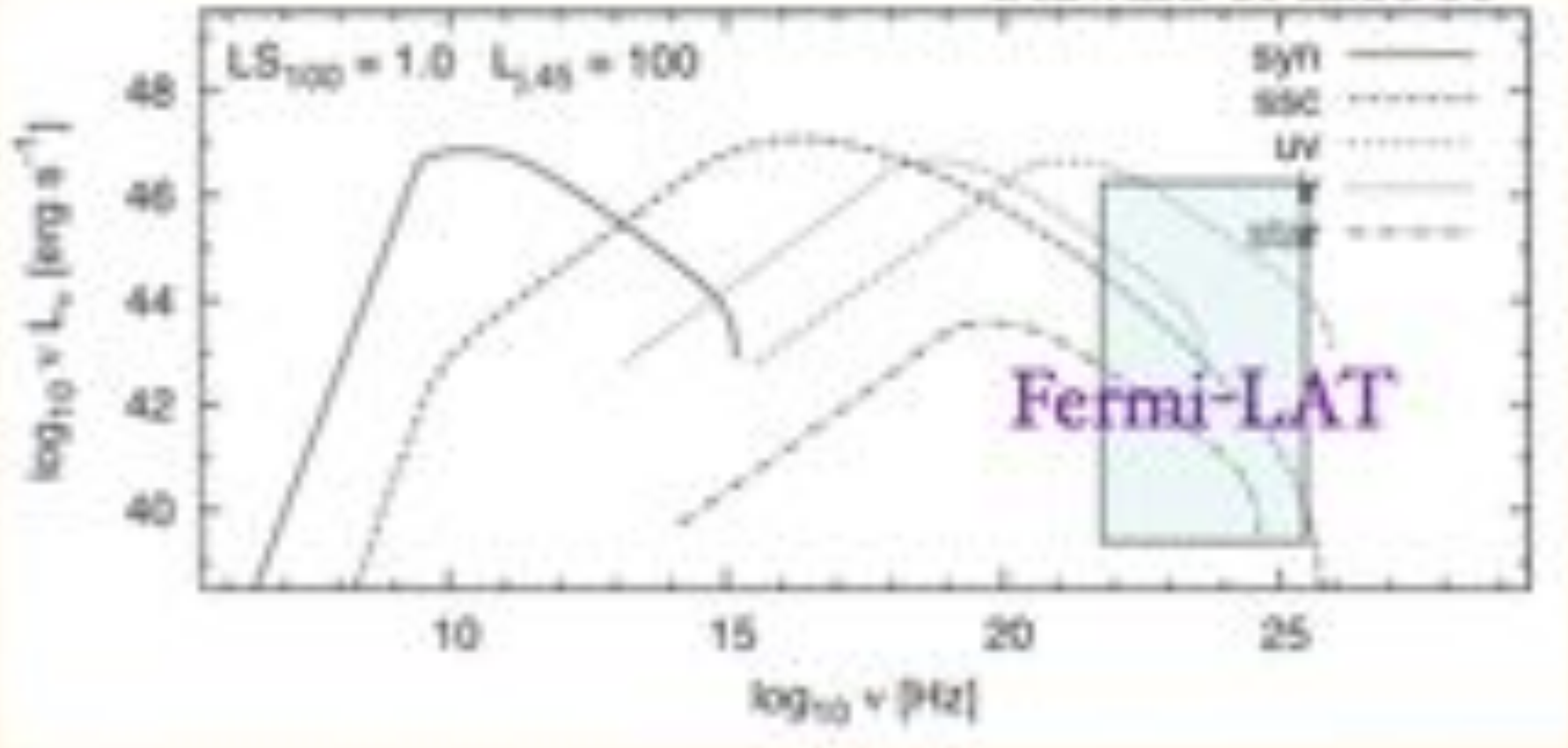
synchrotron age 1275 $h^{-3/7}$ yr in agreement with estimated dynamical age (Polatidis & Conway 2003)

Young radio sources at high energies

- **X-rays** (Siemiginowska et al. 2008, Tengstrand et al. 2009, Ostorero et al. 2010, Migliori et al. 2012):
  - -X-ray loud ($L_{2\text{-}10keV}=10^{42}$-$10^{46}$ erg s^{-1});
  - -origin of the X-ray? Disk/corona or non-thermal emission from lobes and jets;

- **γ-rays:**
  - -non thermal emission still possible while the disk/corona emission drops;
  - -Fermi-LAT: one γ-ray candidate (McConville et al.2011) but no associations in 2FGL (Abdo et al.2011, see also Orienti et al.2011)

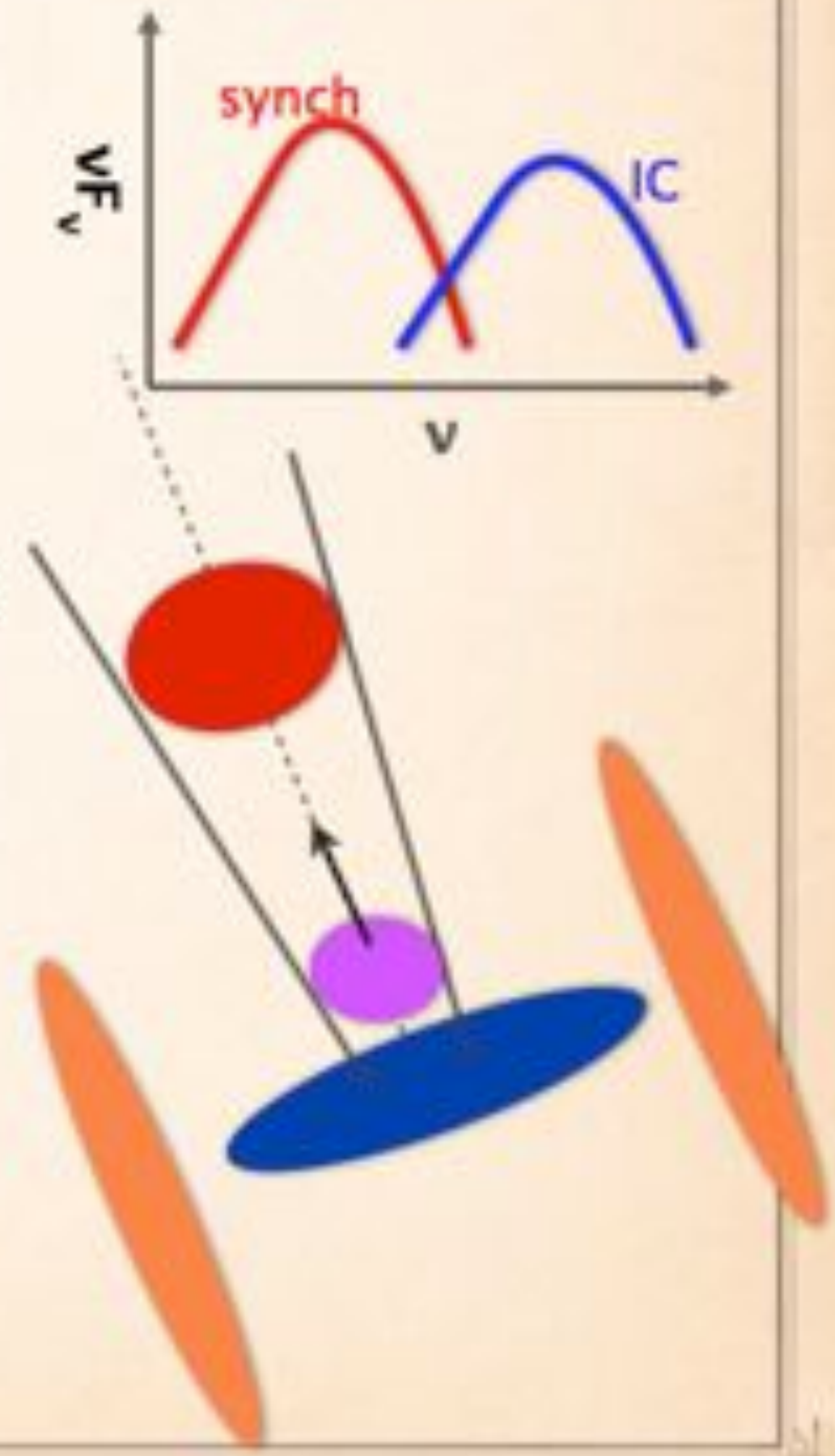
Stawarz et al.2008



Purpose of our study: investigate the young radio sources in the γ-rays and constrain the non-thermal (beamed/jet and unbeamed/lobe) component in the whole high energy band.

Jet component - radiative model

The jet SED is modeled using a leptonic synchrotron and IC model:



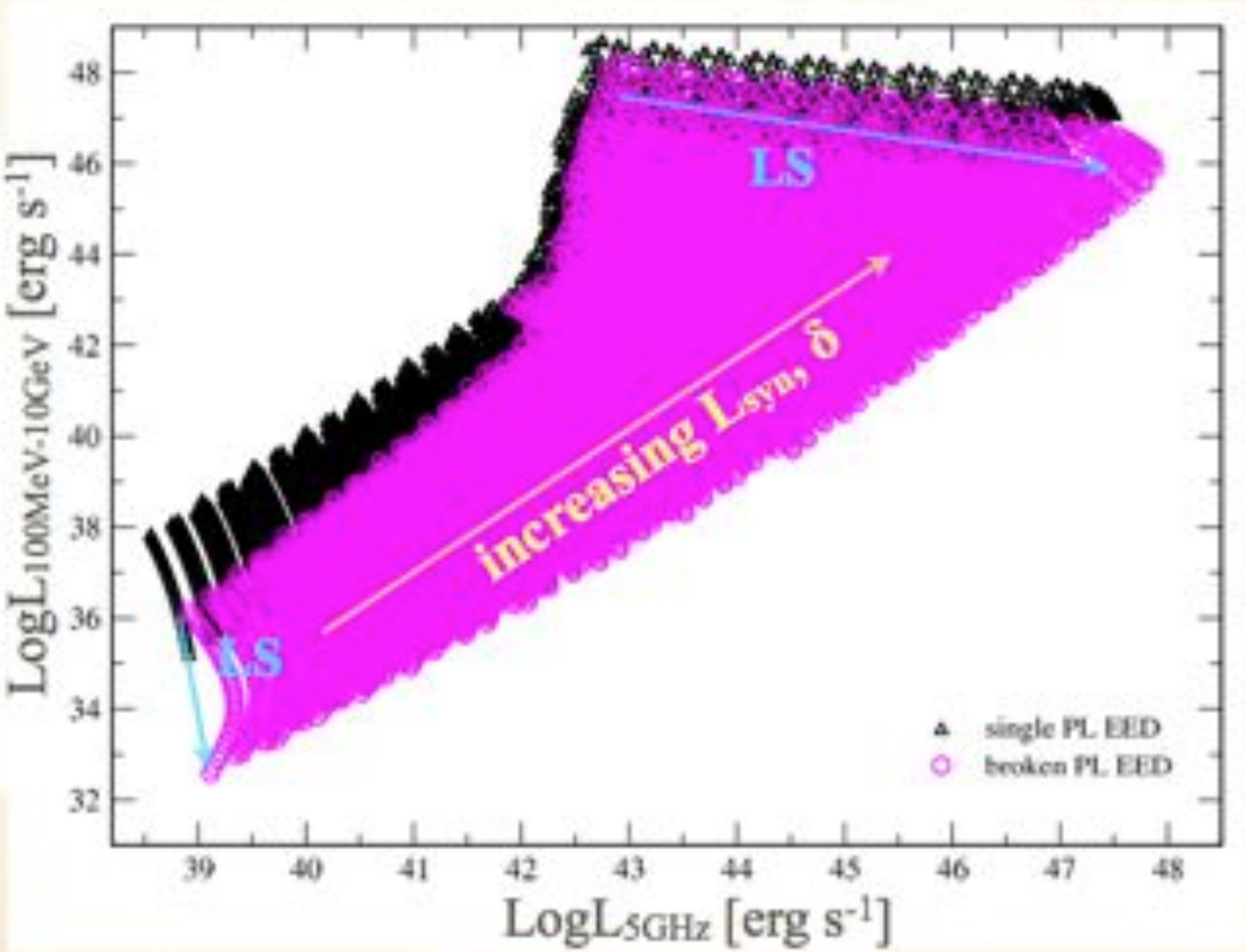
- relevant photon fields at young sources' scales:
  - local synchrotron photons (SSC);
  - external photons:
    - disk/UV and dust/IR;
    - structured jet (Celotti et al.2001, Georganopoulos & Kazanas 2003, Ghisellini et al.2005): synchrotron photons from a blazar-like blob
- assumptions on geometry and luminosities:
  - $R=0.1\times LS$;
  - $L_{rad}=0.1\times L_{jet}$, $L_{disk}\sim L_{jet}$, $L_{dust/torus}=0.1\times L_{disk}$;
  - equipartition.

Simulated Jet SED - L_{5GHz} vs. $L_{100MeV-10GeV}$

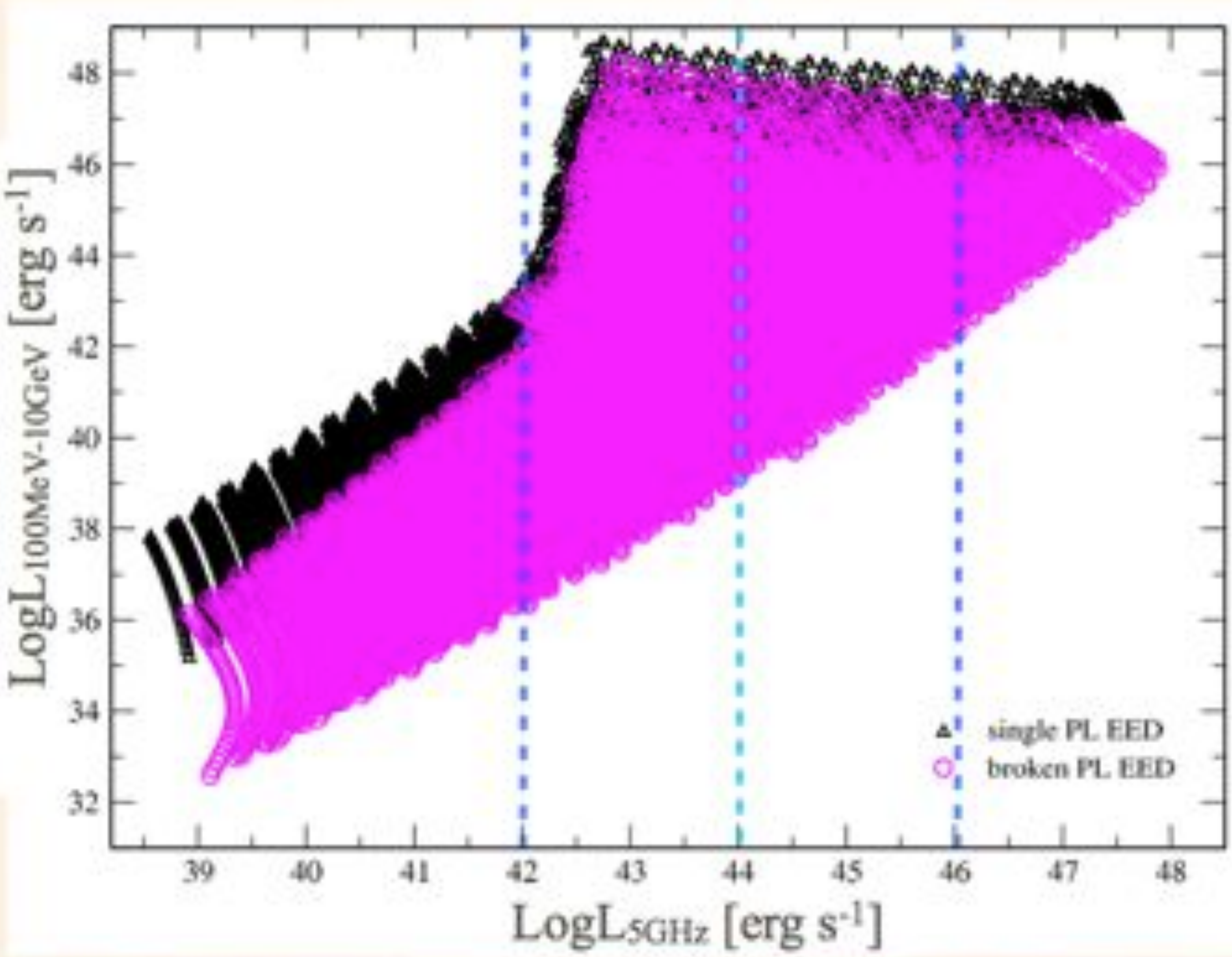
Jet SED are simulated for a distribution of linear sizes (LS), radio powers (L_{radio}), bulk motions (Γ_{bulk}) and jet inclinations (θ)

- Electron energy distribution is a single ($p=2.7$) or a broken power law ($p_{low}=2.5$, $p_{high}=4.0$ $\gamma_{break}=2\times10^3$);
- radio power $L_{radio}=10^{43}$-10^{46} erg s^{-1};
- linear size: LS=10 pc-10 kpc;
- bulk motion: $\Gamma_{bulk}=1.4$-15;
- jet inclination: $\theta=10^o$- 50^o.

L_{5GHz} vs. $L_{100MeV-10GeV}$:



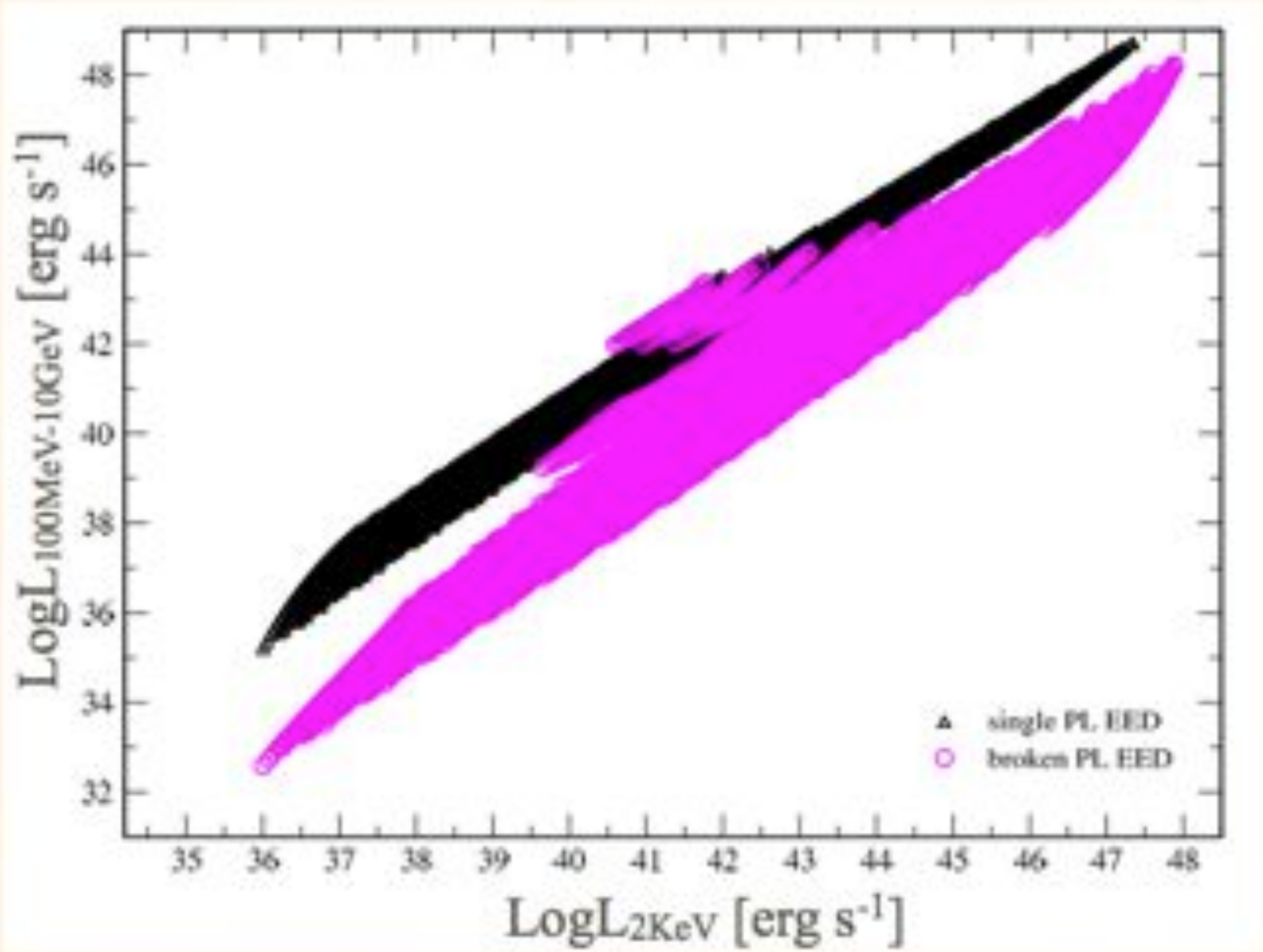
Simulated Jet SED - L_{5GHz} vs. $L_{100MeV-10GeV}$



L_{5GHz} is not an optimal indicator of good γ-ray candidates in beamed-component dominated sources

Simulated Jet SED - L_{2keV} vs. $L_{100MeV-10GeV}$

- Model predictions: L_{2keV} vs. $L_{100MeV-10GeV}$



- rather linear relation intrinsic to the assumed model;

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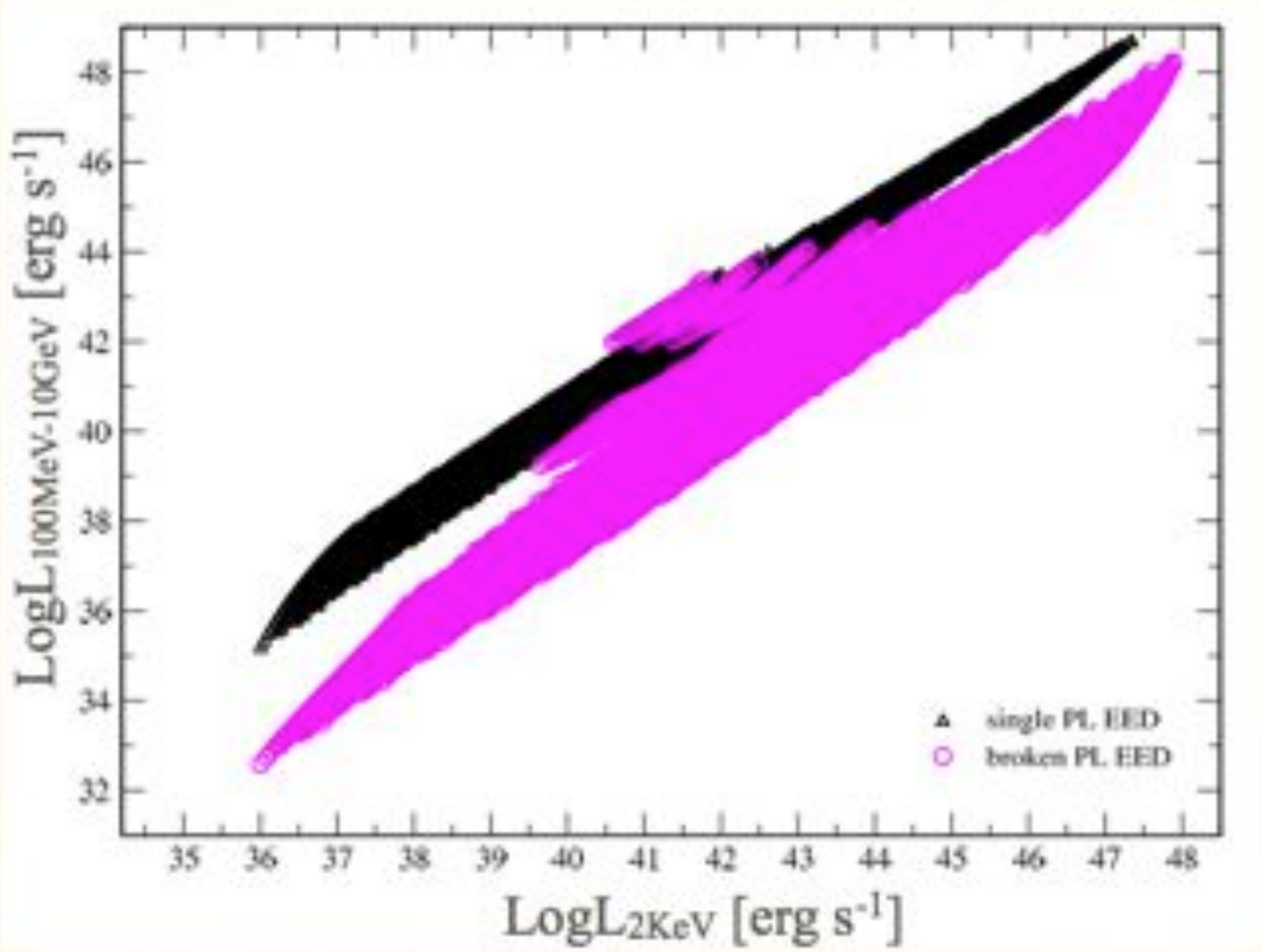

- rather linear relation intrinsic to the assumed model;
- larger spread for the broken power-law case: different kind of IC can mainly contribute to X- and γ-rays

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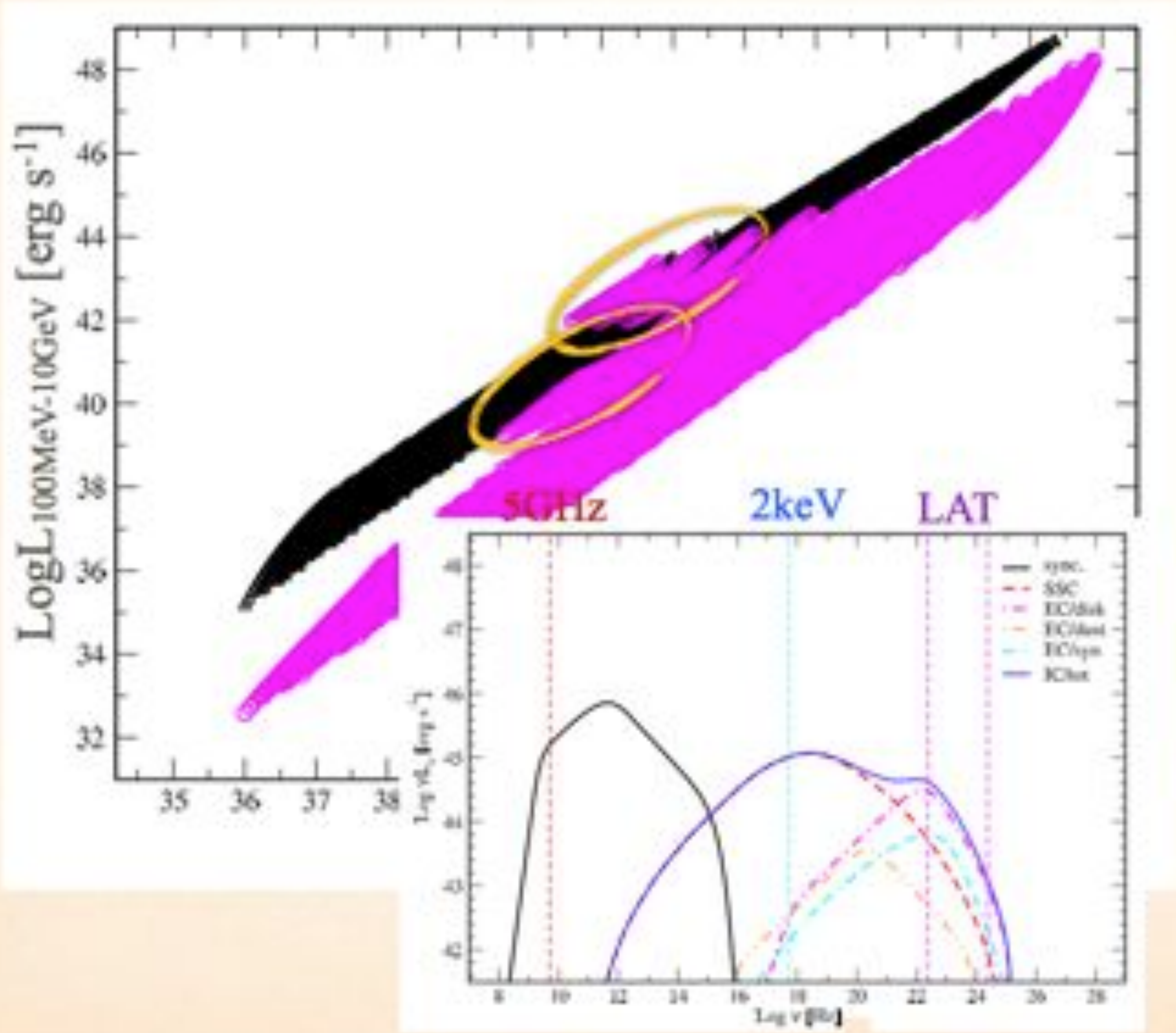


- rather linear relation intrinsic to the assumed model;
- larger spread for the broken power-law case: different kind of IC can mainly contribute to X- and γ-rays
- γ-ray overluminous sources: LS≤100 pc and $\Gamma_{bulk} \leq 3 \Rightarrow$ relevant EC/disk and EC/sync. contributions

Simulated Jet SED - L_{5GHz} L_{2keV} $L_{100MeV-10GeV}$ relation

The simulated SED are used to derive a relation among the radio, X- and gamma-ray luminosities (regression method in Kelly 2007):

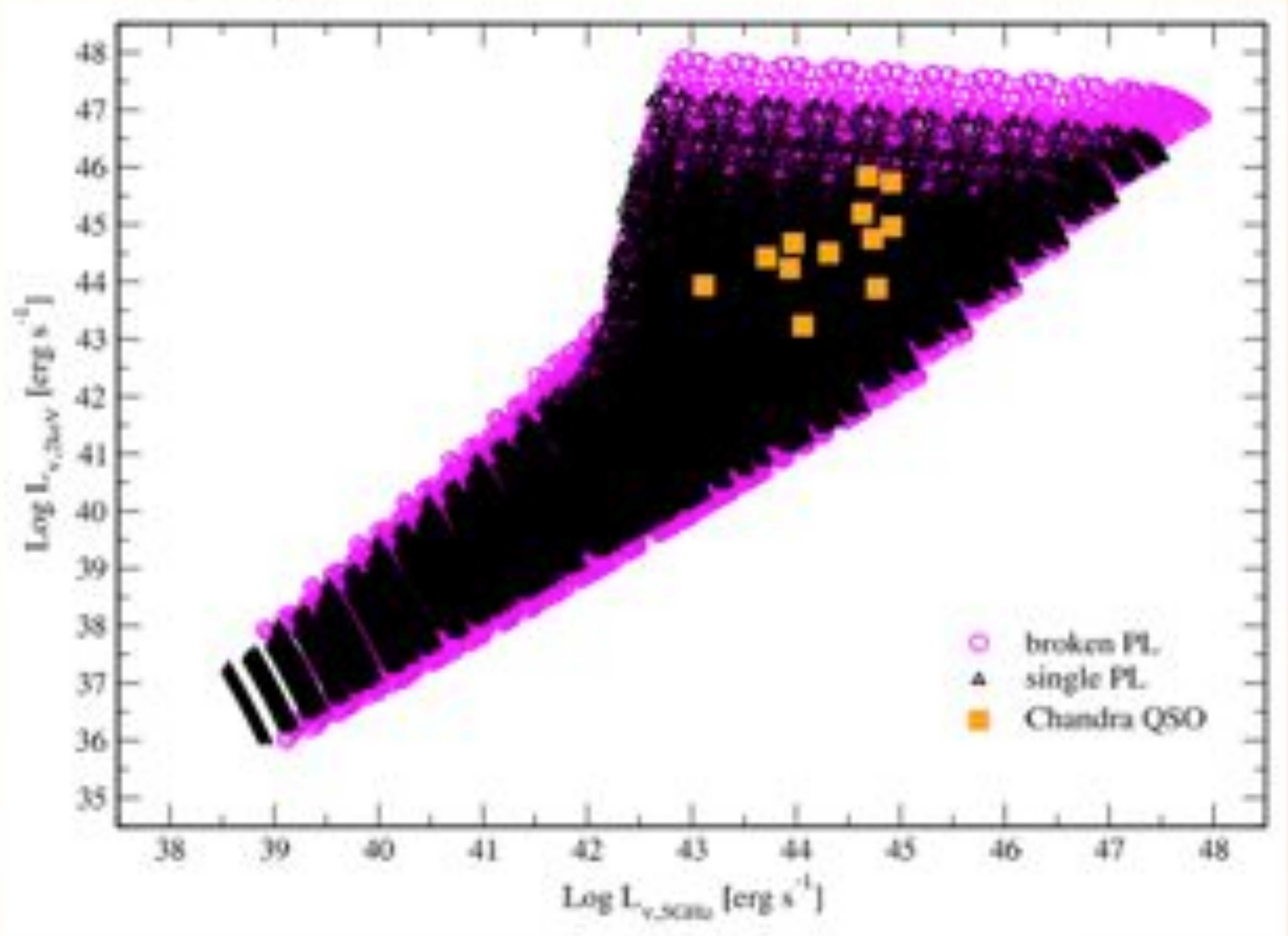
$LogL_{100MeV-10GeV}=43.2+0.029\times(LogL_{5GHz}-43.0)+1.088\times(LogL_{2keV}-42.0)$ (single PL)

$LogL_{100MeV-10GeV}=42.46-0.083\times(LogL_{5GHz}-44.0)+1.214\times(LogL_{2keV}-44.0)$ (broken PL)

These relations among observable quantities can be used to predict the expected γ-ray fluxes, from the jet, in a sample of young radio sources with X-ray and radio luminosities.

Simulated Jet SED and observed QSO - γ-ray predictions

- Young radio quasars with Chandra observations (X-ray sample presented in Siemiginowska et al. 2008 - 12 QSO):
  - z=0.32-1.95
  - LS=10 pc ÷12 kpc
  - $L_{5GHz}=10^{43}\div10^{45}$ erg s^{-1};
  - $L_{2keV}=10^{43}\div10^{46}$ erg s^{-1};
  - $L_{Bol}=10^{44.8}\div10^{47.2}$ erg s^{-1};



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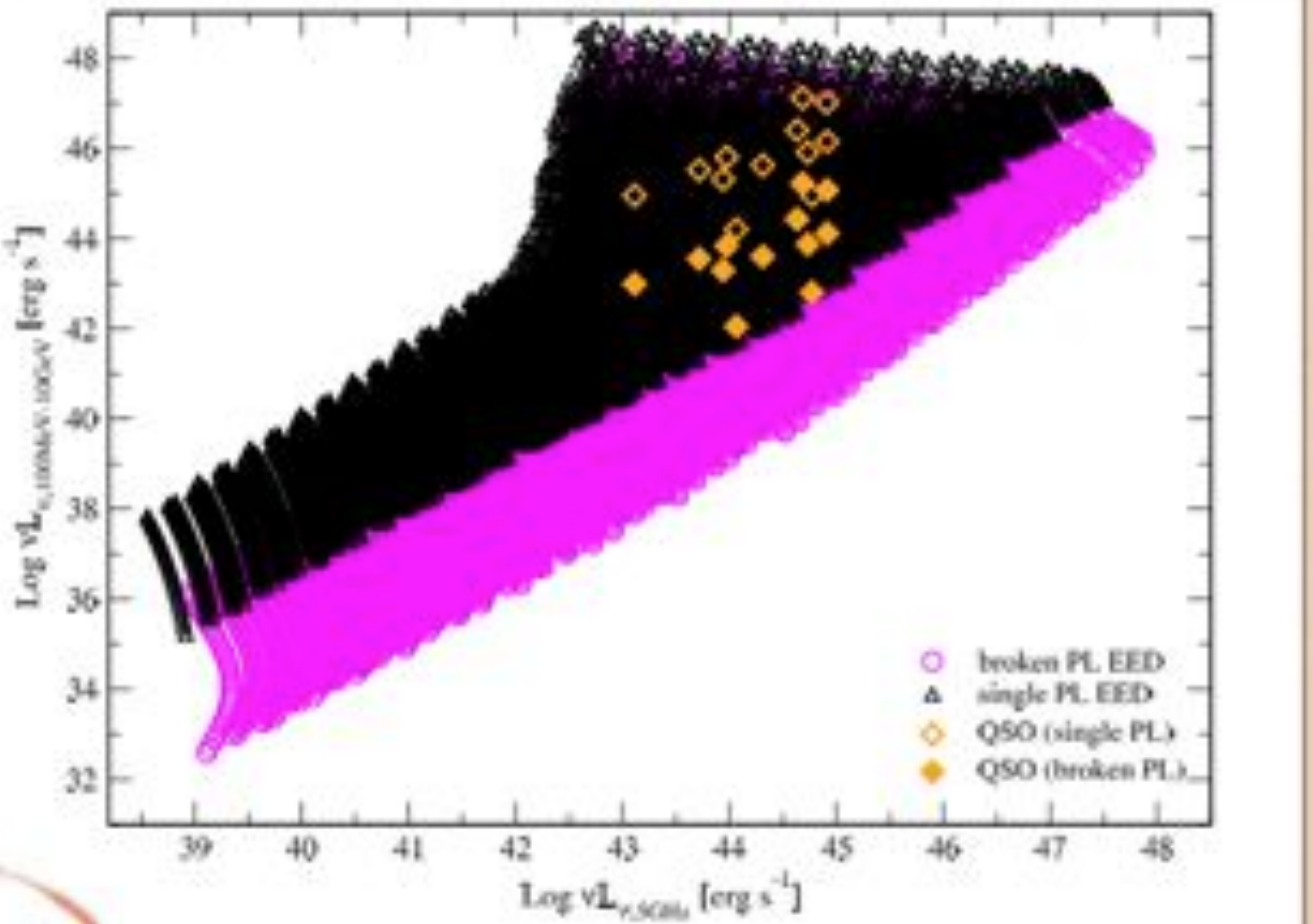
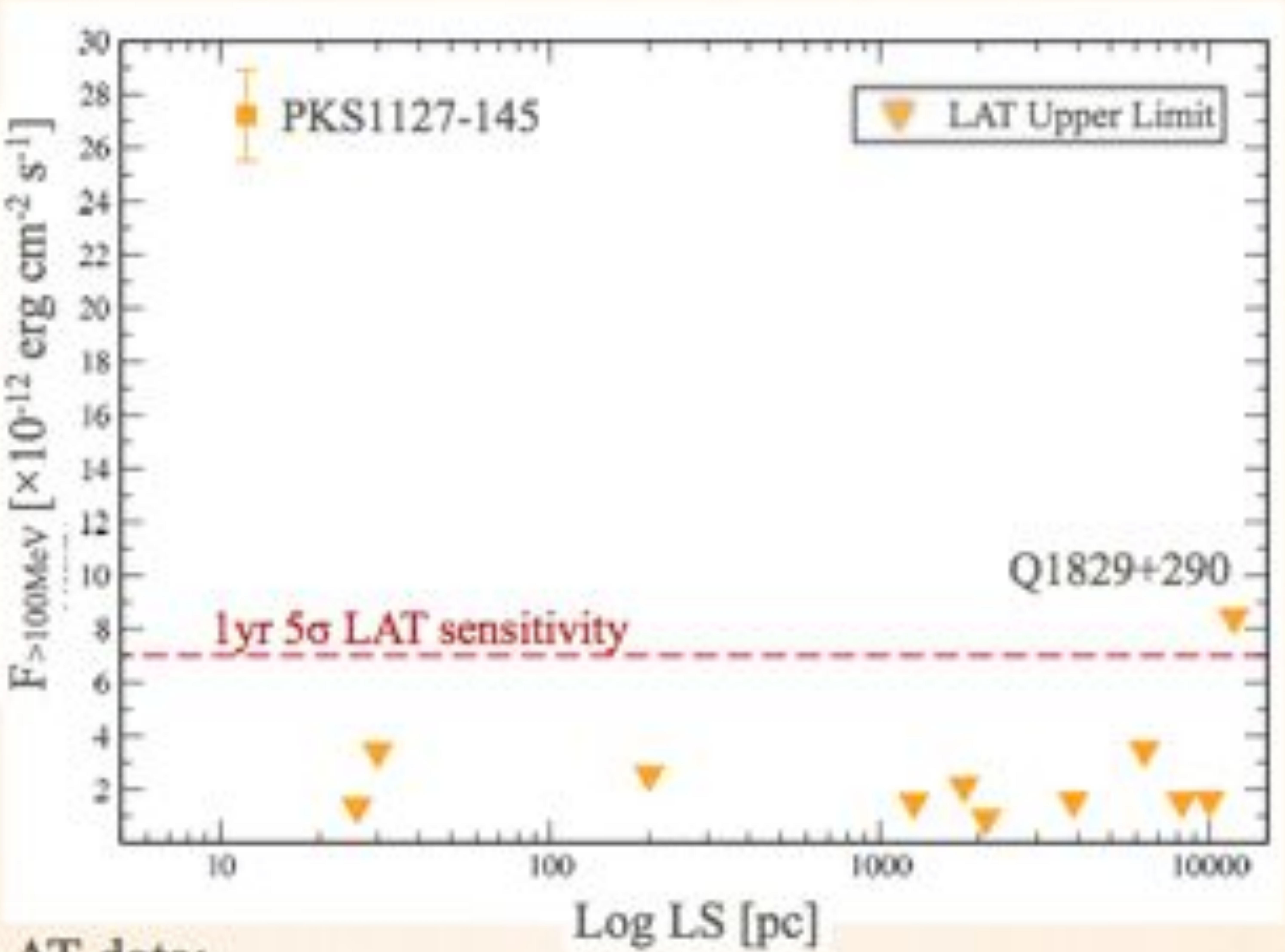
predicted γ-ray luminosities:

$L_{100MeV-10GeV}\sim10^{42}\div10^{47.1}$ erg s^{-1};

$F_{100MeV-10GeV}\sim$
$3\times10^{-16}\div1.4\times10^{-11}$ erg cm^{-2} s^{-1}



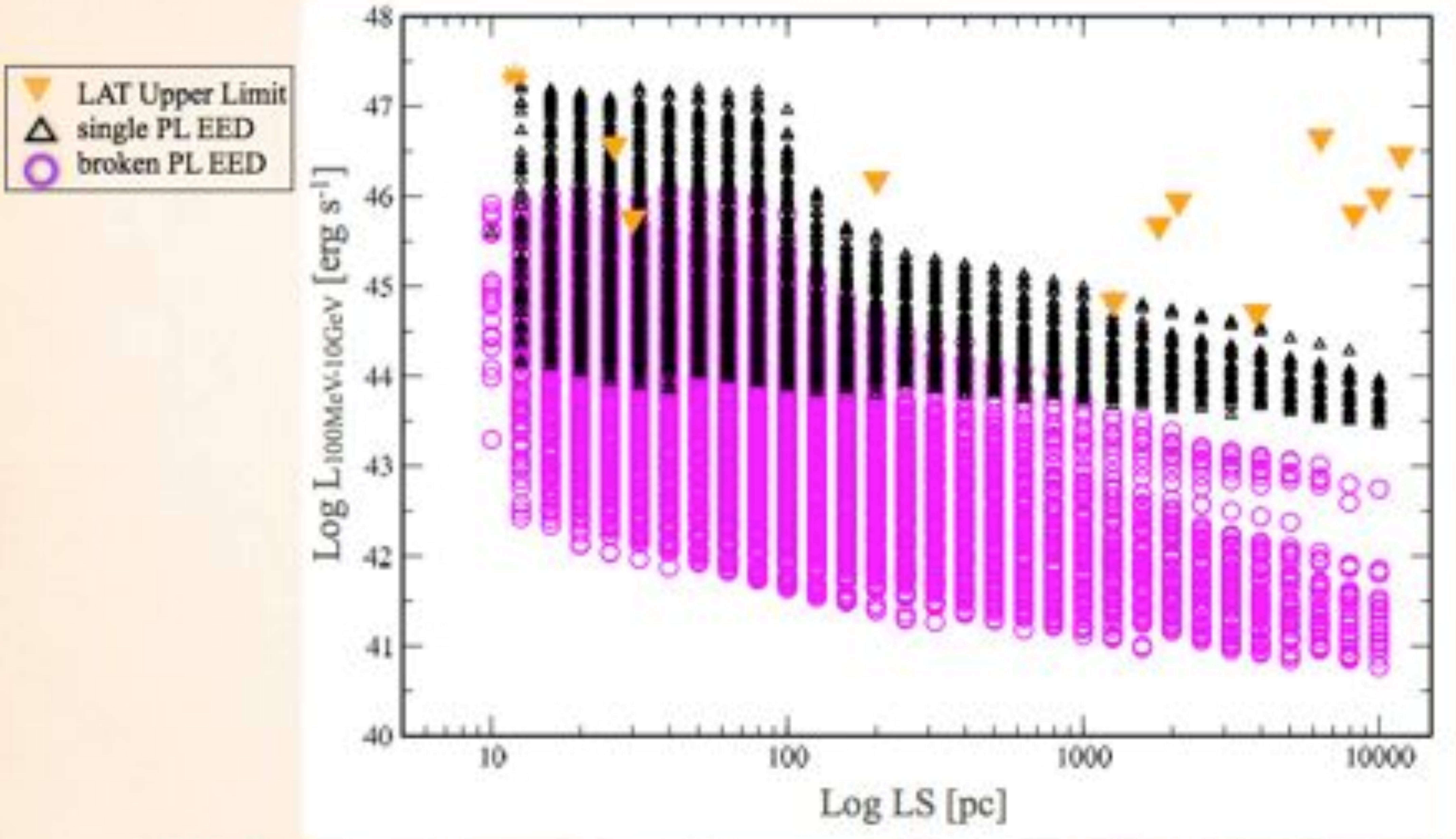
Simulated Jet SED and observed QSO - Fermi-LAT results



3.5 yrs Fermi-LAT data:

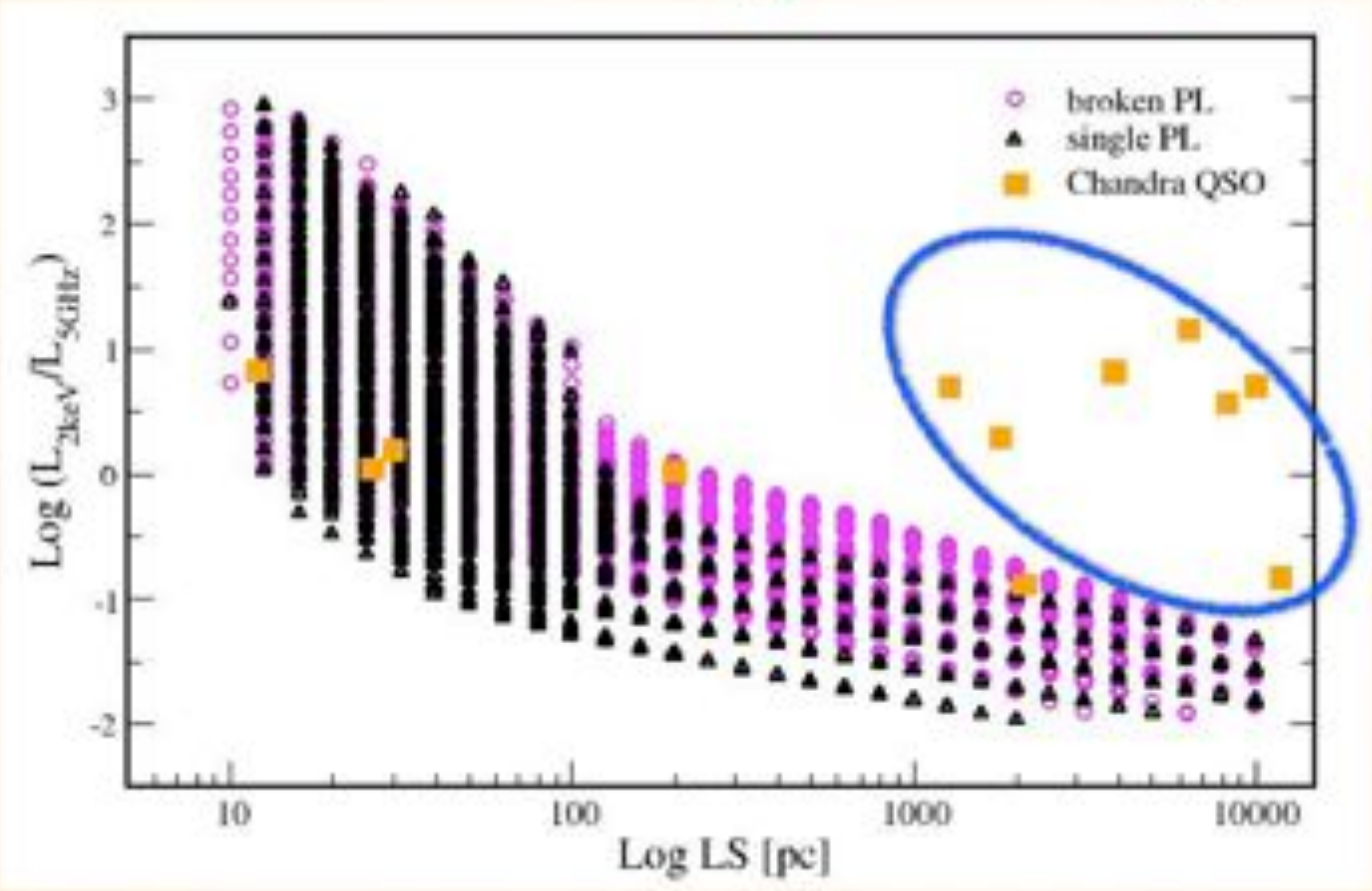
- no detections with TS≥25 (≥5σ) except for PKS1127-145 (already in 2FGL, Fermi-LAT coll.2011);
- TS<9 for 10 over 12 sources;
- 1 source (Q1829+290) with TS=20 (but contamination from near sources is likely)

Simulated Jet SED and observed QSO



Comparison with simulated jets:
predicted γ-ray luminosities are compatible with LAT upper limits

Simulated Jet SED and observed QSO - radio and X-ray luminosity comparison



LS vs L_{2keV}/L_{5GHz}: for increasing LS, the modeled jet emission cannot account for the whole 2 keV luminosity

possible explanations:

- the bulk of the X-ray emission is always produced at small scales;
- assumptions: equipartition could not hold in jets;
- there is an additional X-ray component (e.g. lobes, the disk-corona)

Conclusions

We tested the jet scenario for the high energy emission comparing predicted fluxes in the gamma- and X-rays for an assumed and general model with observations:

- L_{5GHz} is not an optimal tracer for high energy emission in beamed sources;

- no clear γ-ray detection of the young radio quasars in the X-ray selected sample with Fermi-LAT (>3yrs data);

- γ-ray upper limits do not rule out the jet model but γ-ray predicted fluxes are at the threshold of LAT sensitivity;

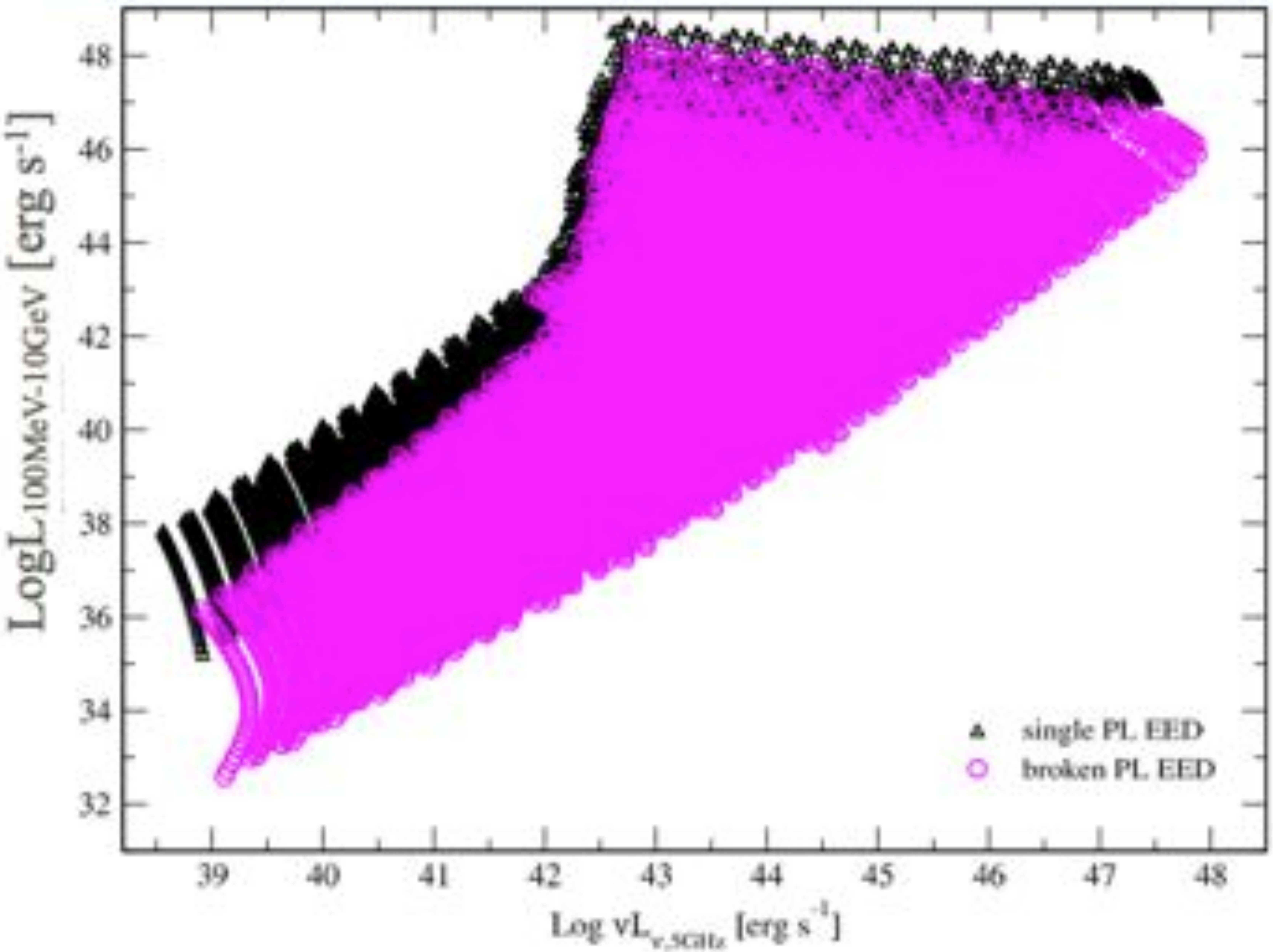
- X-rays: for sources with LS>1 kpc, the modeled jet emission cannot explain the whole observed X-ray flux, unless:
  - -making different assumptions (e.g. out of equipartition jets);
  - -the bulk of the X-rays is produced always at small scales (<1kpc).

Future Work

- observations in the optically thin part of the synchrotron spectrum can provide tighter constraints to the model (SMA observations of the quasar sample);

- unbeamed/lobe component estimates for radio galaxies and comparison with LAT data.

Simulated Jet SED - L_{5GHz} vs. $L_{100MeV-10GeV}$



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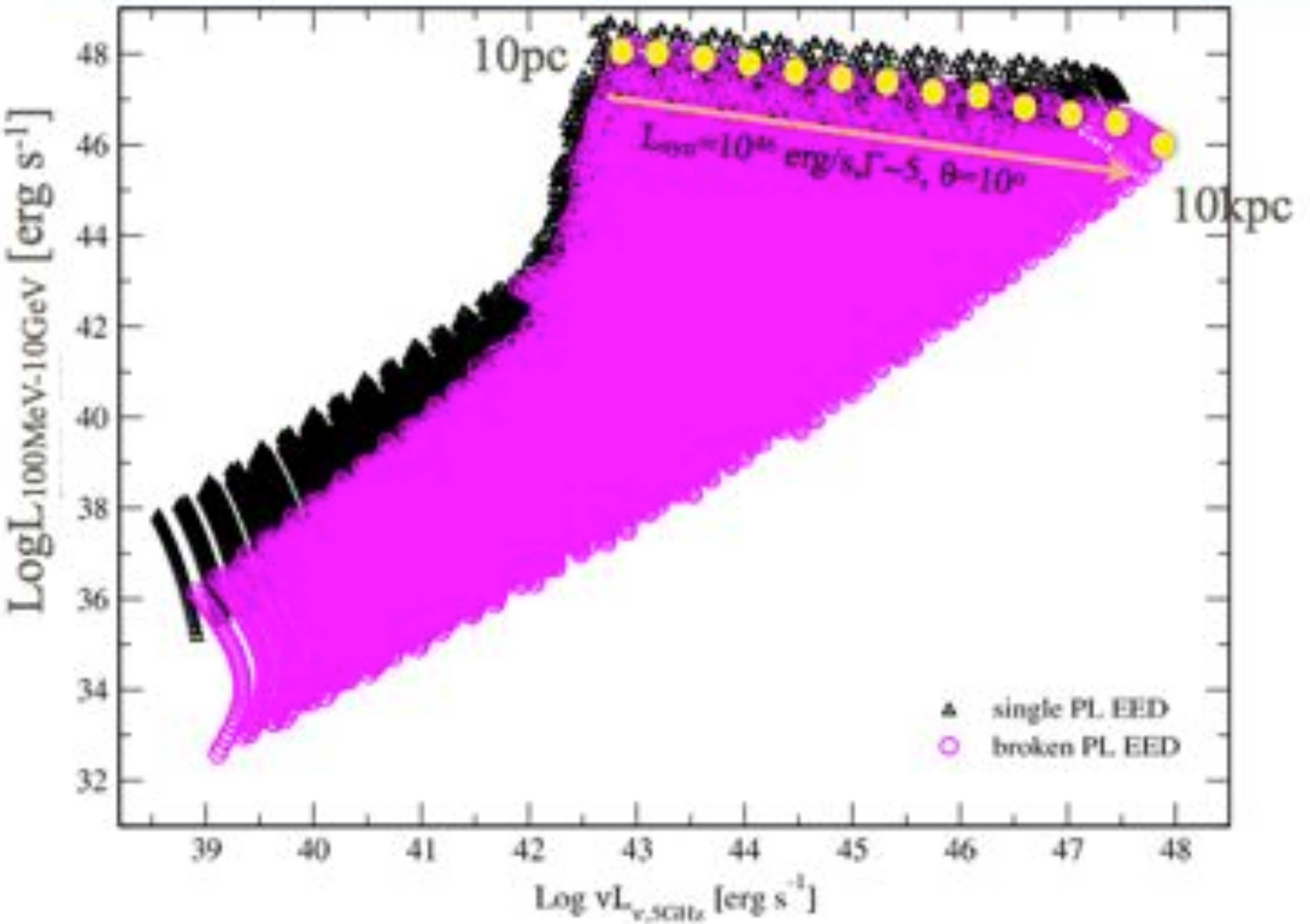
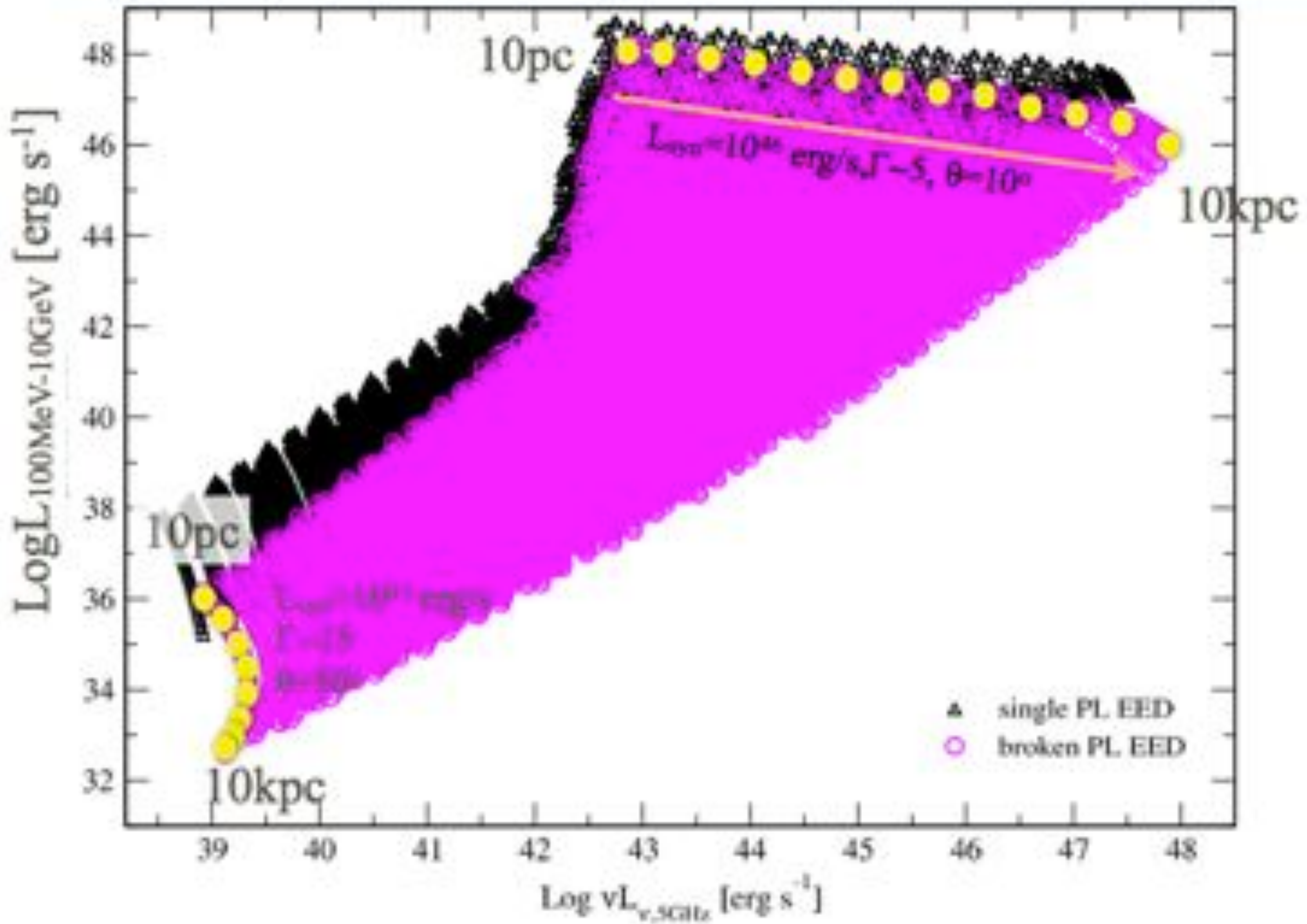


Simulated Jet SED - L5GHz vs. L100MeV-10GeV



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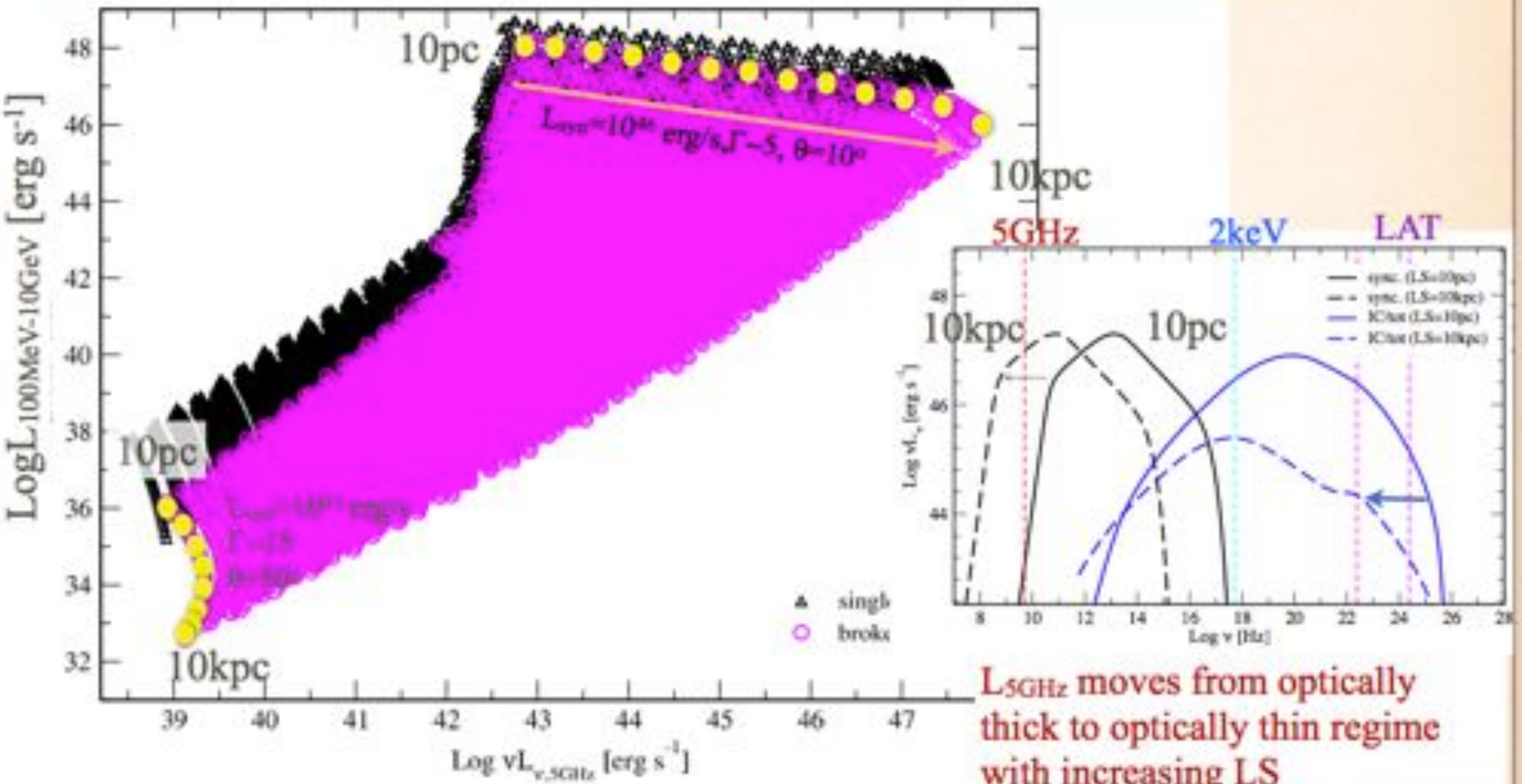

L_{5GHz} moves from optically thick to optically thin regime with increasing LS

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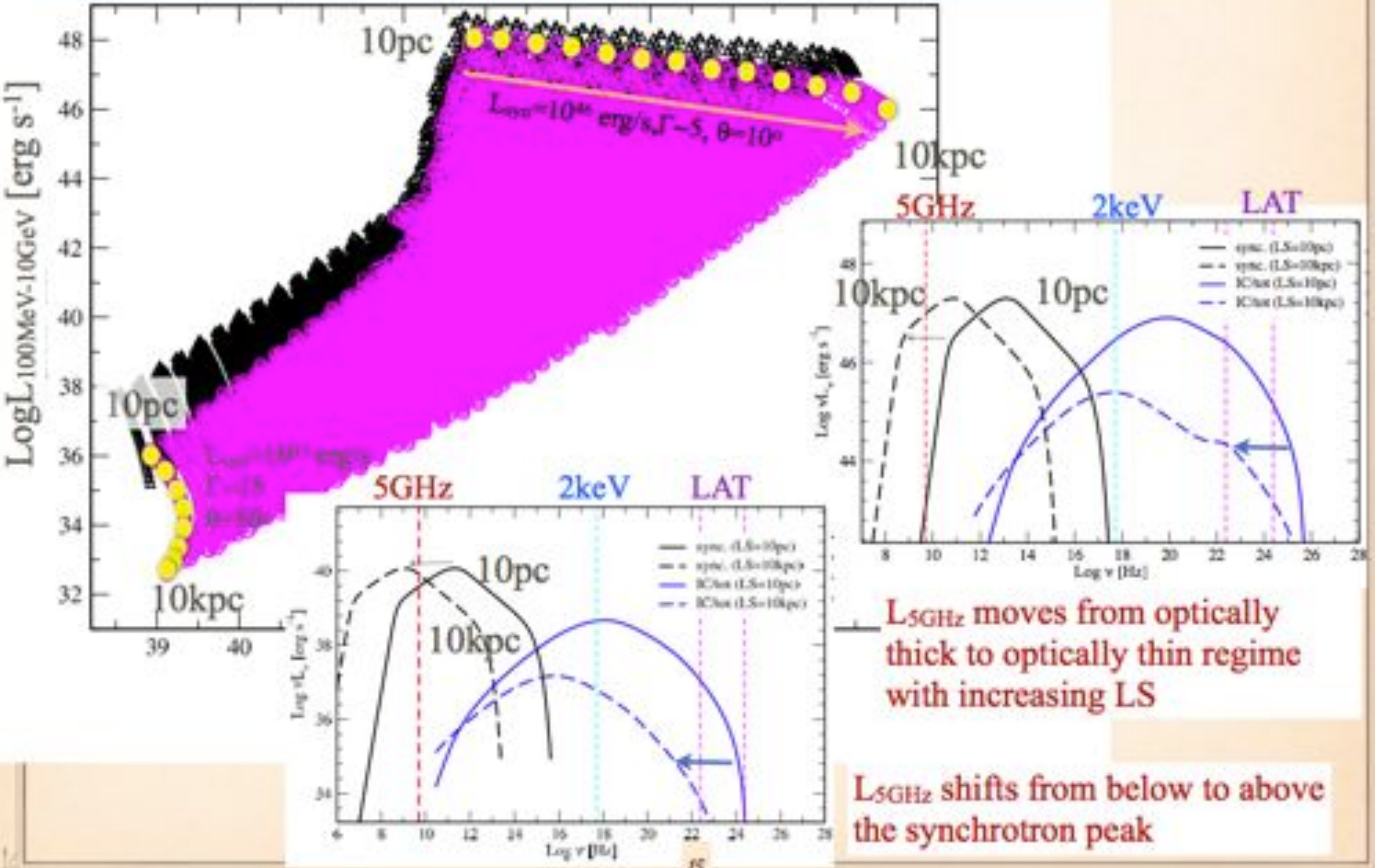
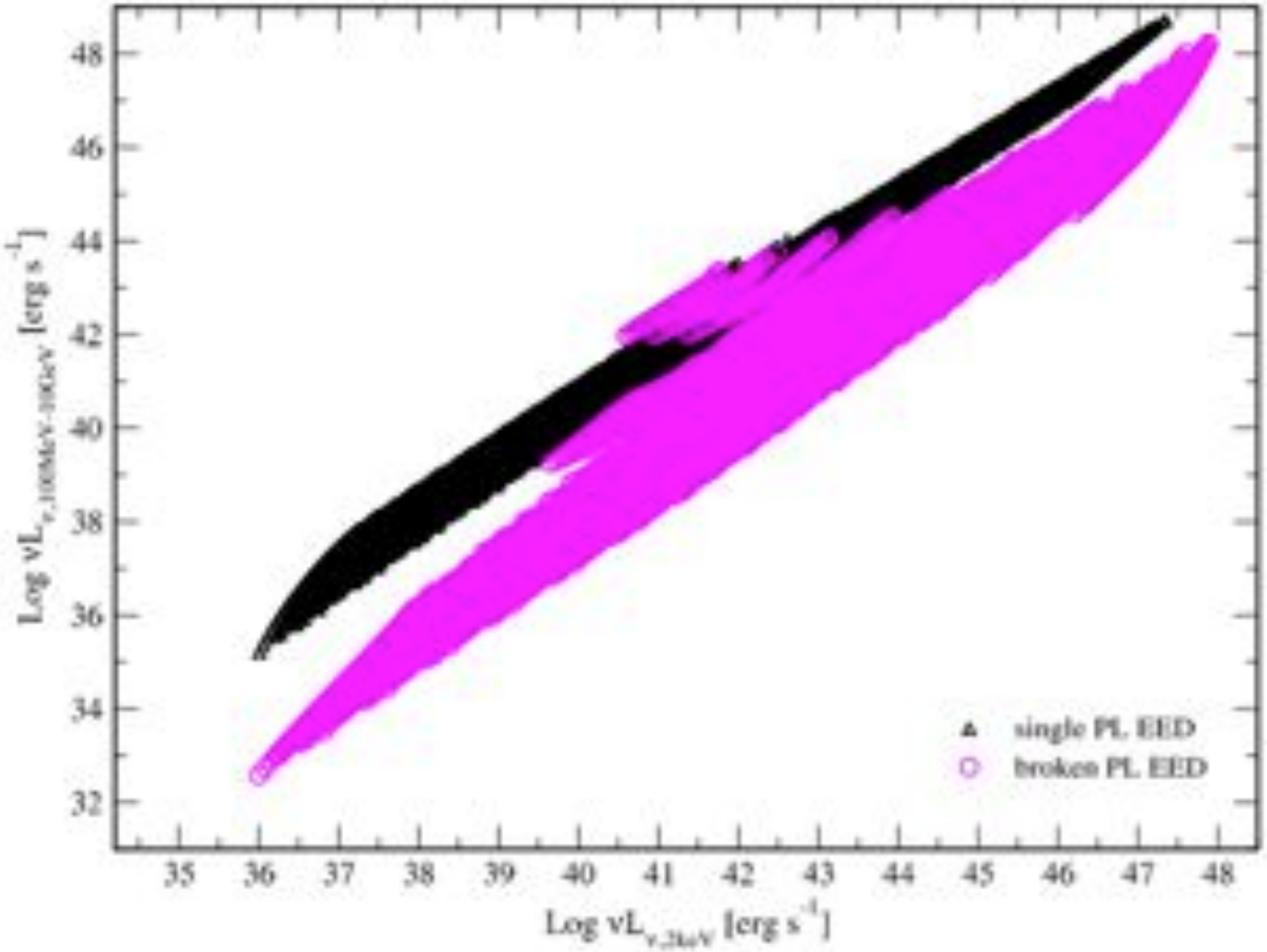


L_{5GHz} moves from optically thick to optically thin regime with increasing LS

L_{5GHz} shifts from below to above the synchrotron peak

Simulated Jet SED - L_{2keV} vs. $L_{100MeV-10GeV}$

- Model predictions: L_{2keV} vs. $L_{100MeV-10GeV}$



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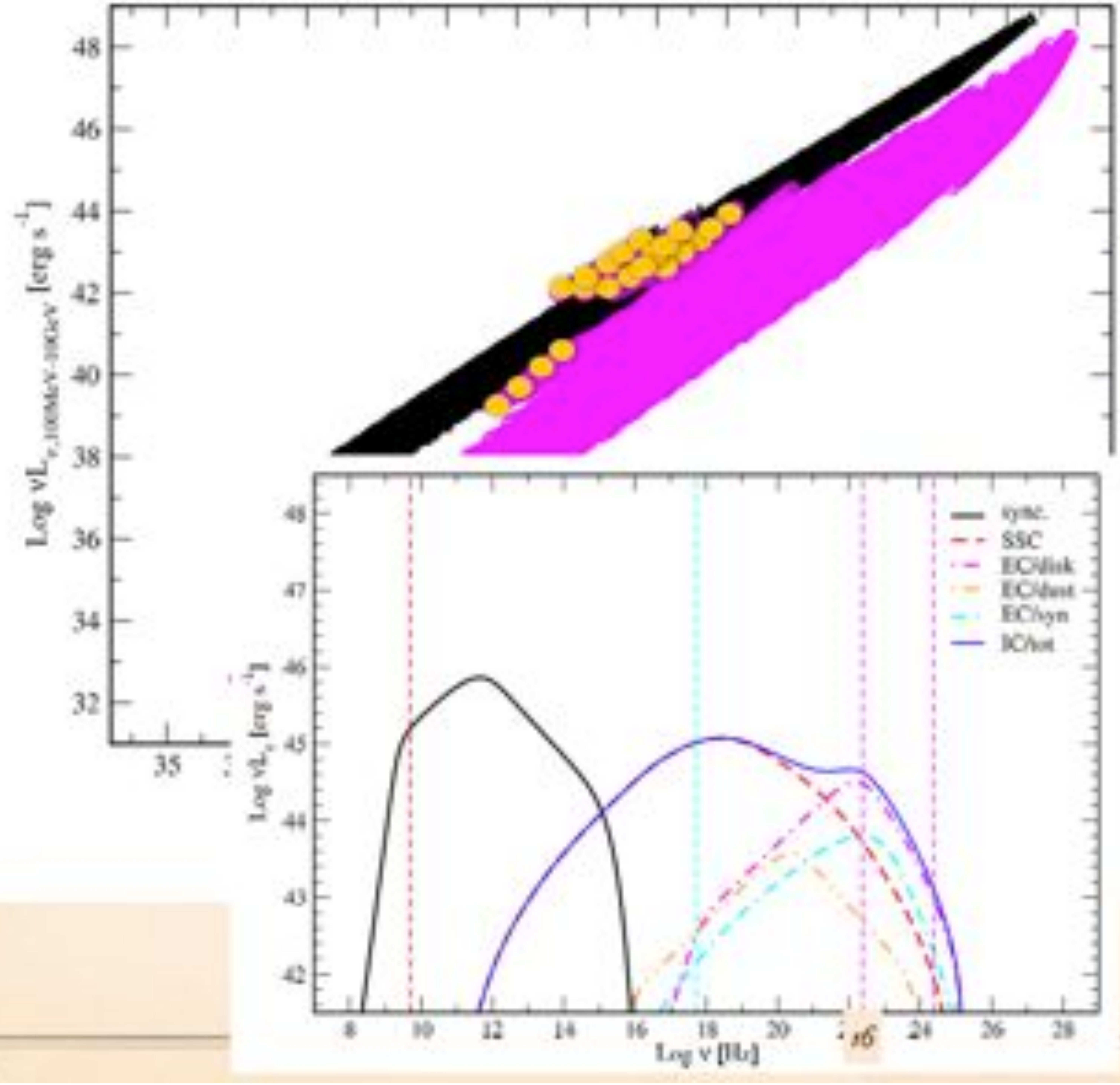

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- larger spread for the broken power-law case
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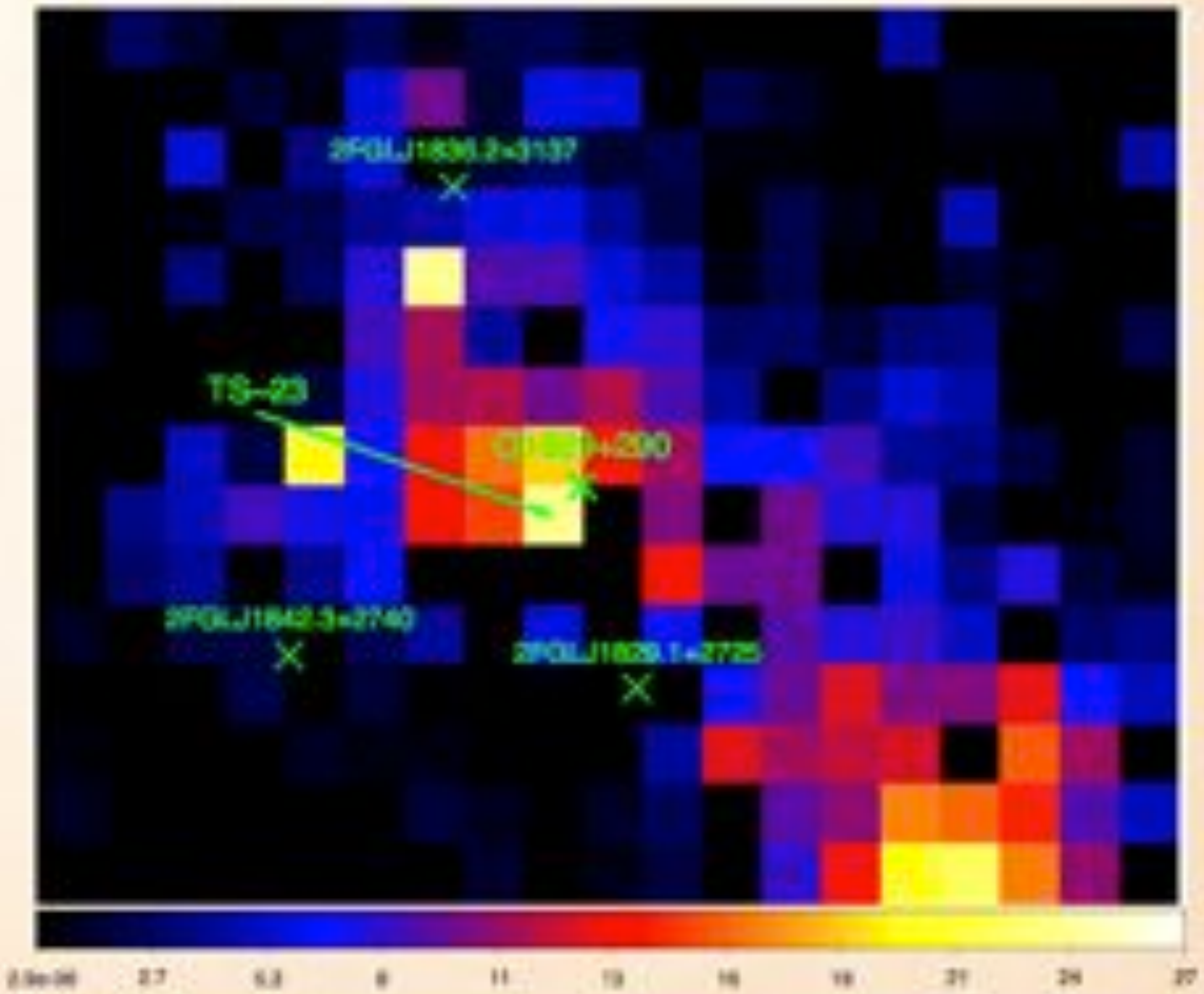
Simulated Jet SED and observed QSO - Fermi-LAT results

<u>PKS1127-14 (z=1.18):</u>

- 2FGL association with 2FGL1130.3-1448
- $\Gamma=2.75\pm0.5$
- γ-ray variable:

<u>Q1829+290 (z=0.842):</u>

- TS=20,
- $F_{>200MeV}=(3.7\pm1.4)\times10^{-8}$ phot cm^{-2} s^{-1},
- $\Gamma=3.5\pm0.4$;
- 3 sources within 3 deg, TS map (1px/ 0.5deg):



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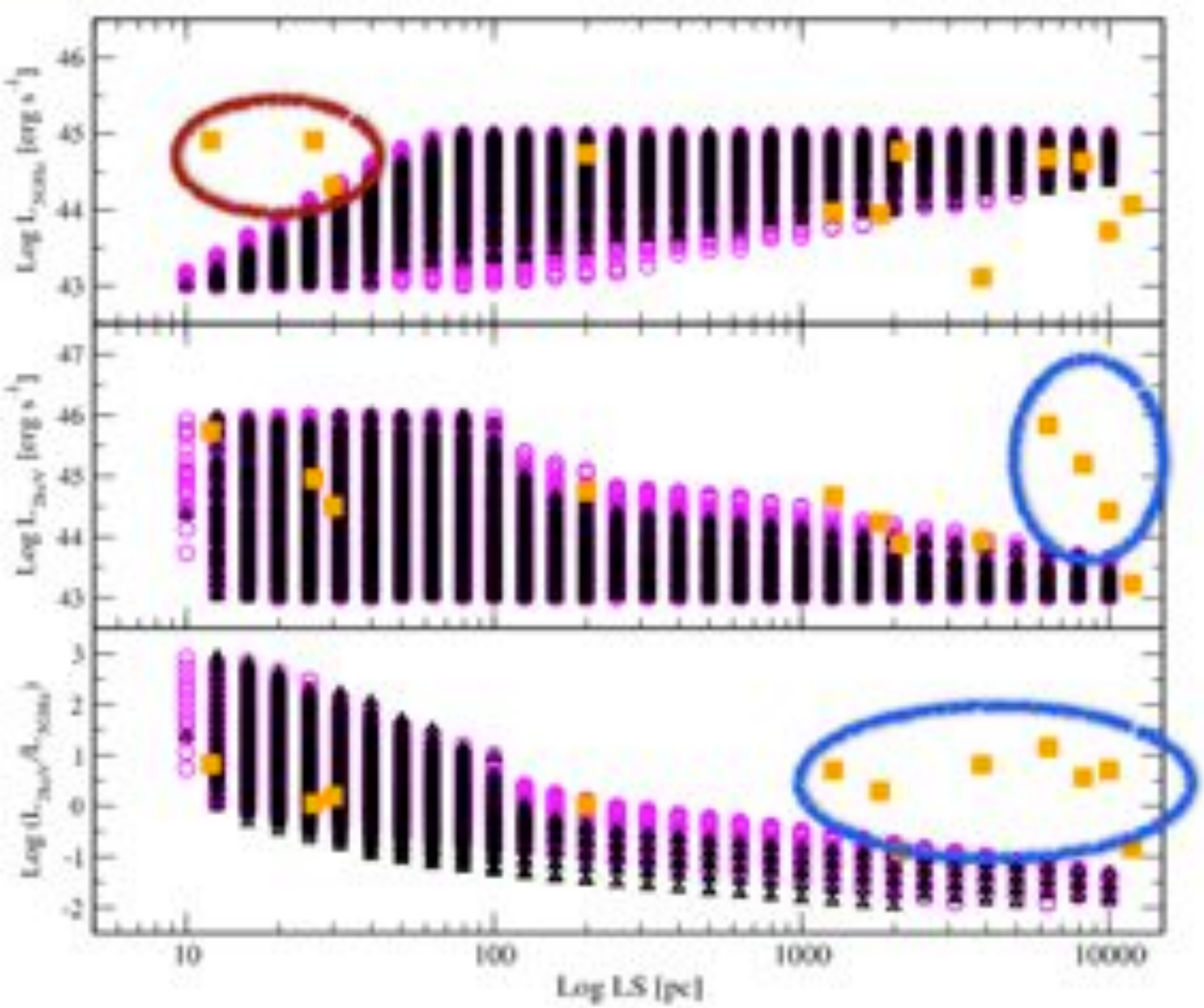

LS vs L_{5GHz}: in small, radio powerful, beamed jets, at 5 GHz we are still in synchrotron self absorbed regime

LS vs L_{2keV}: for increasing LS, the modeled jet emission cannot account for the whole 2 keV luminosity

2 possible explanations:
- equipartition could not hold in jets
- there is an additional X-ray component (e.g. the disk-corona)