Young Sources: X-ray & γ-ray properties

Giulia Migliori (Lab. AIM, France)

Outline

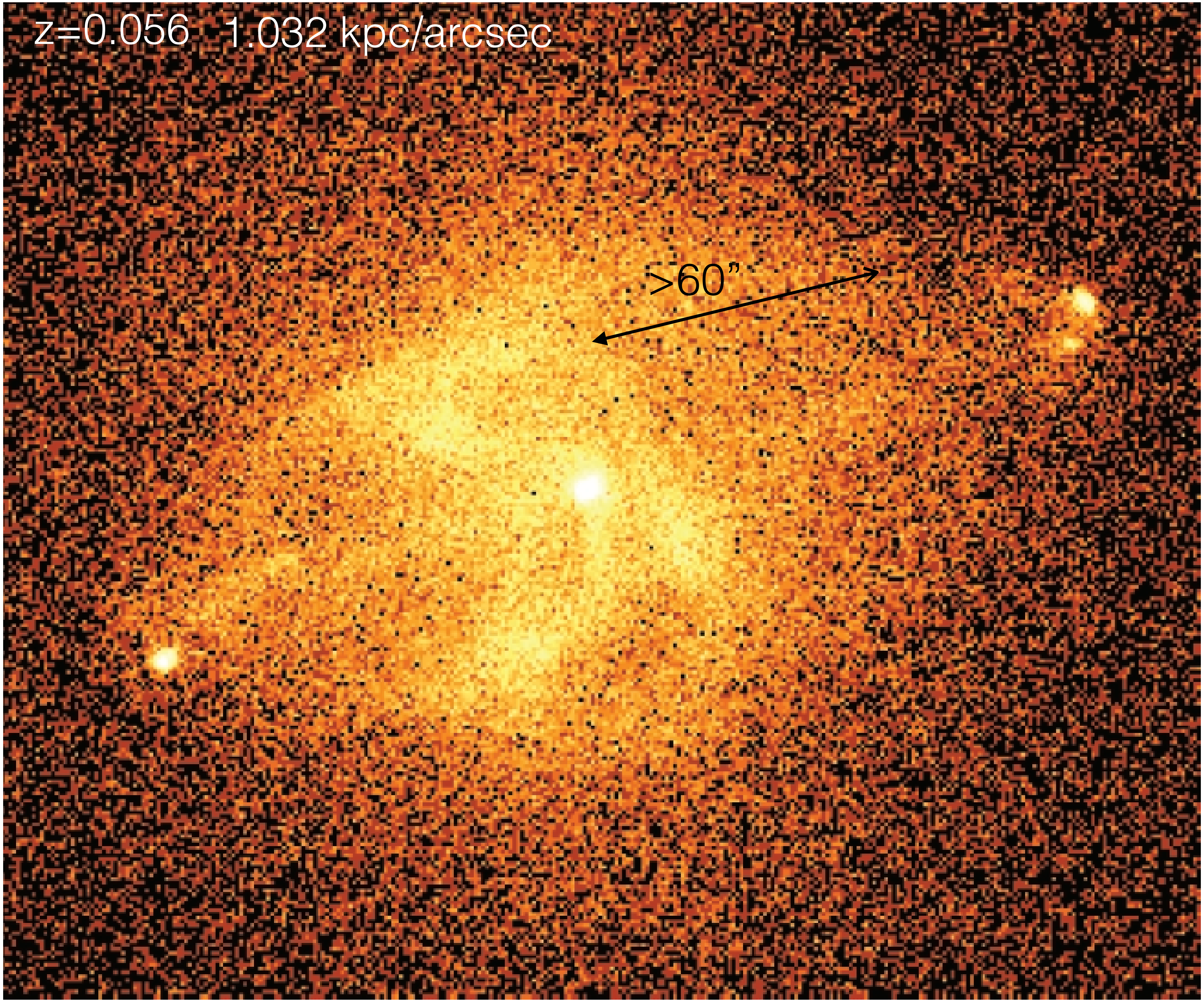
X-rays:

- X-ray properties: observations of GPS, CSS, CSO samples
- origin of the X-ray emission: samples and dedicated studies
- radio source evolution: X-ray perspective
- probing the young radio sources environment

Gamma-rays:

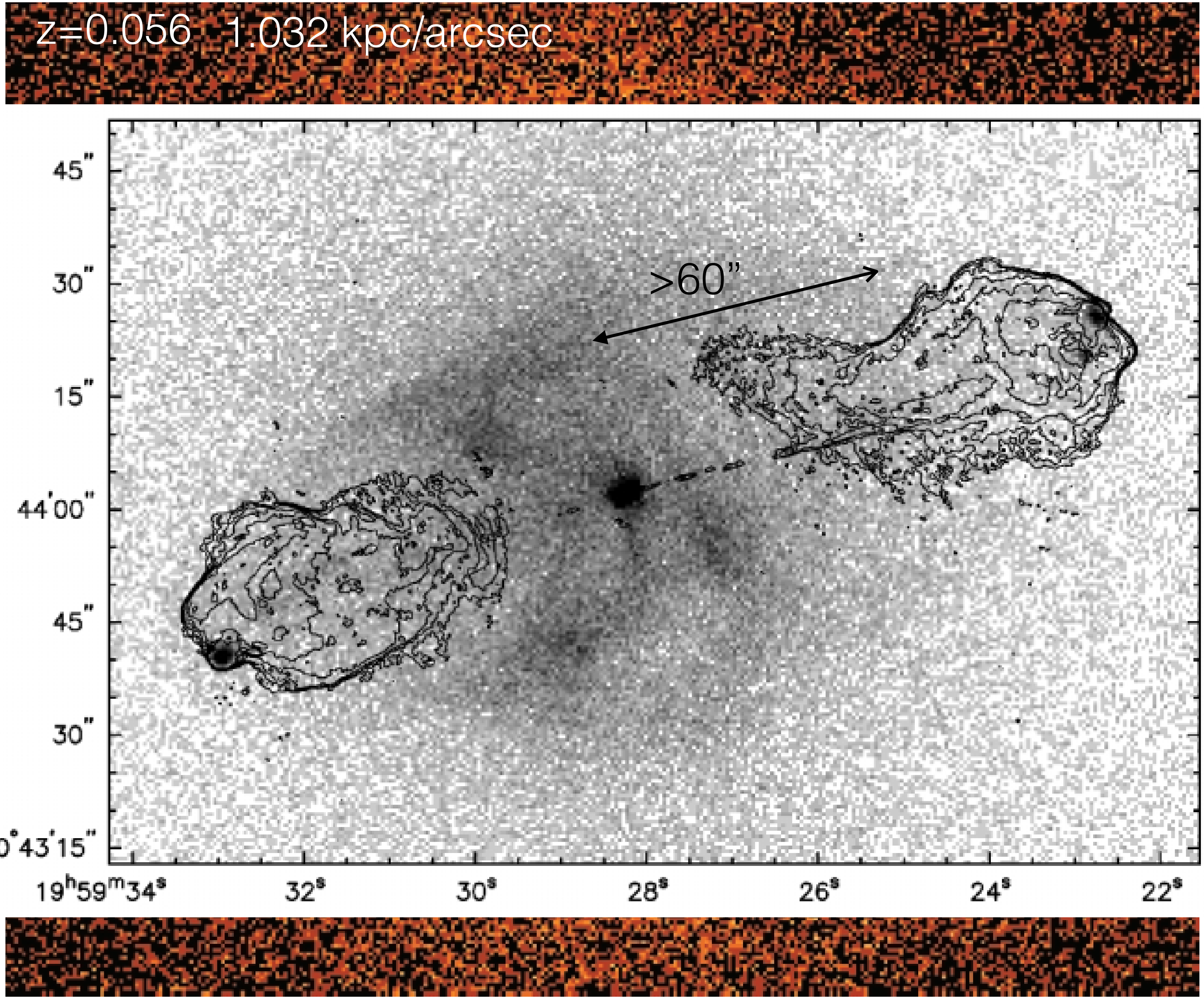
- Are young radio sources gamma-ray emitters?
- Theory
- Observations

From Cygnus A…



Wilson et al. (2006)

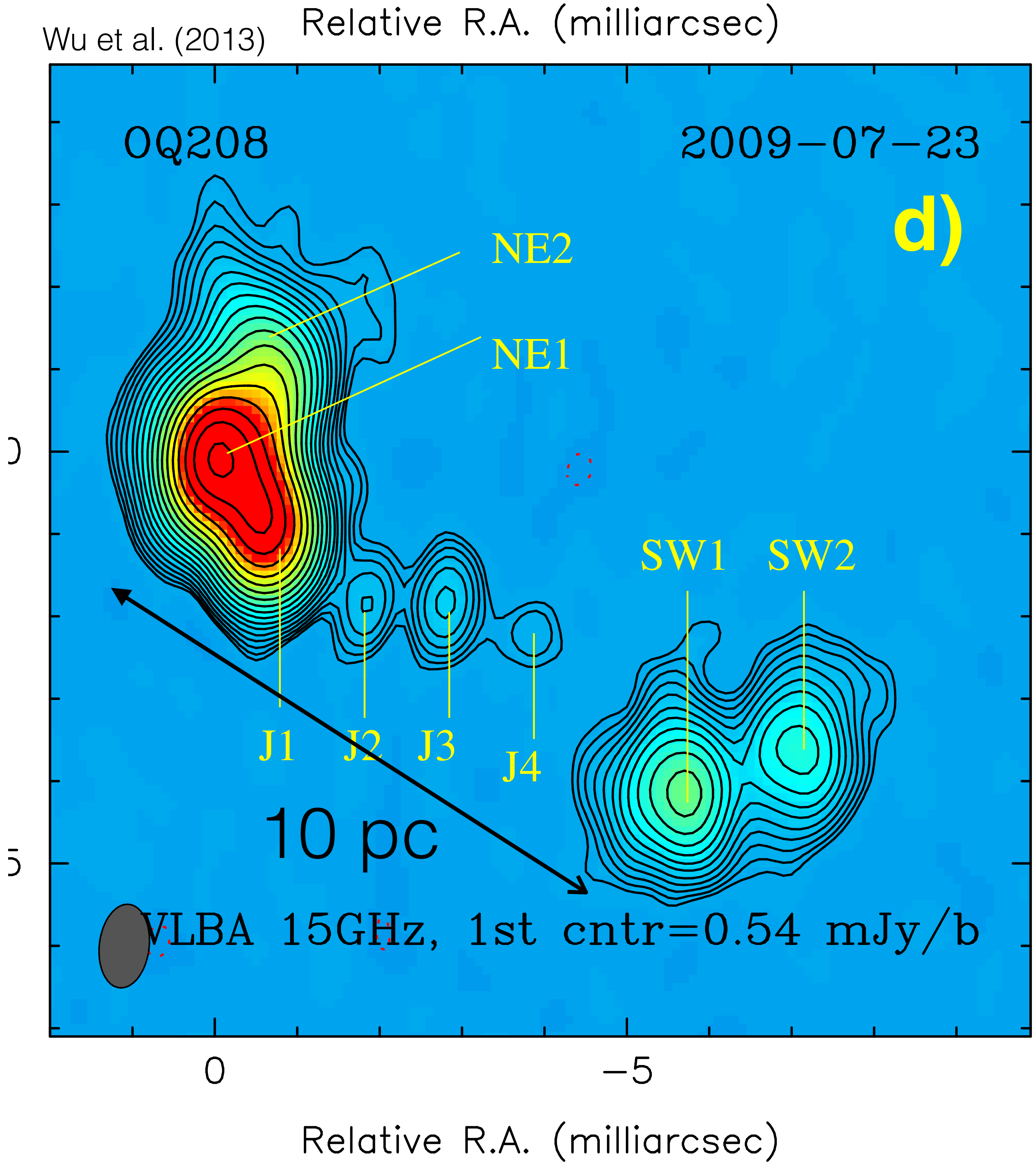
From Cygnus A…



Wilson et al. (2006)

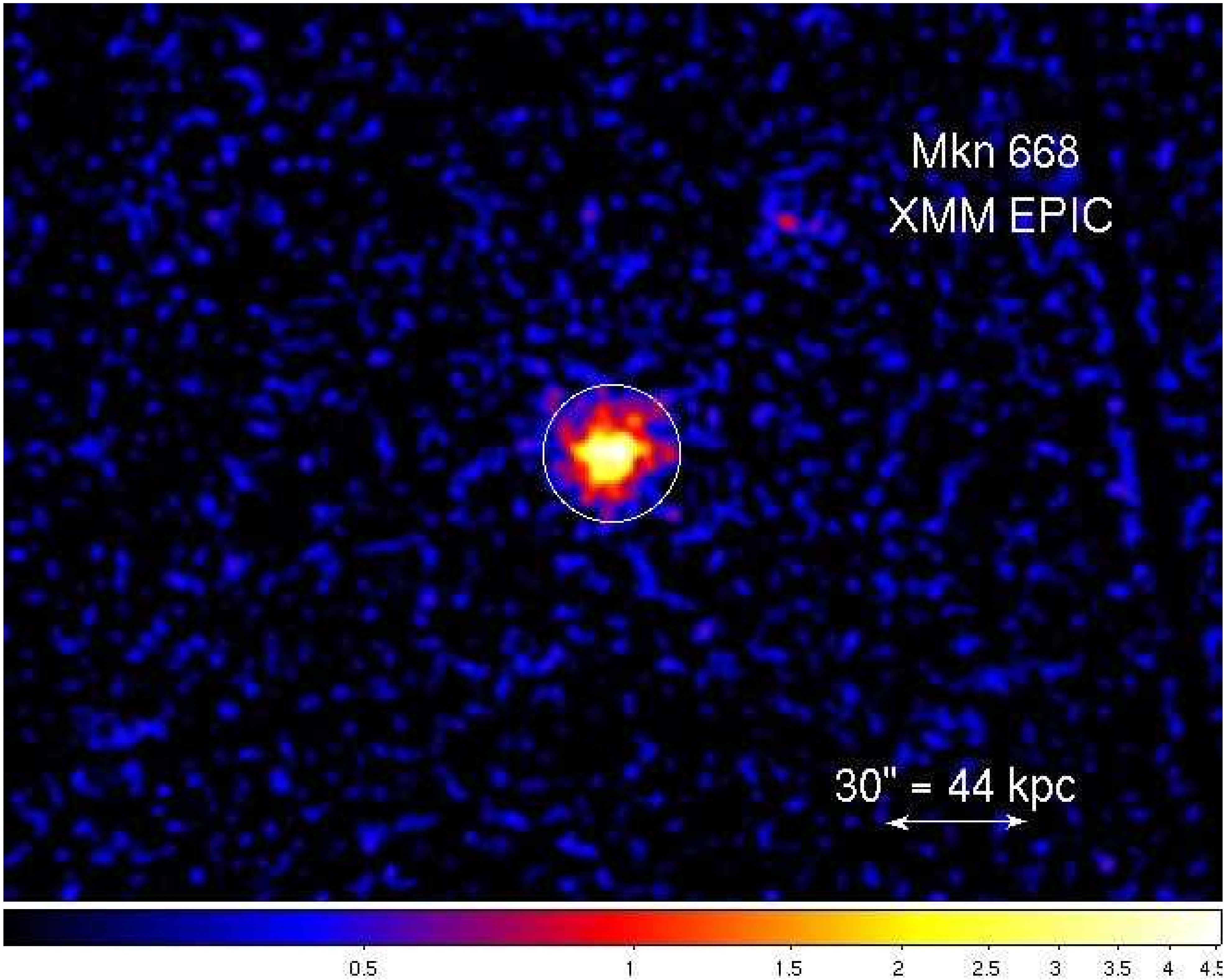
to baby Cygnus As…

Wu et al. (2013)



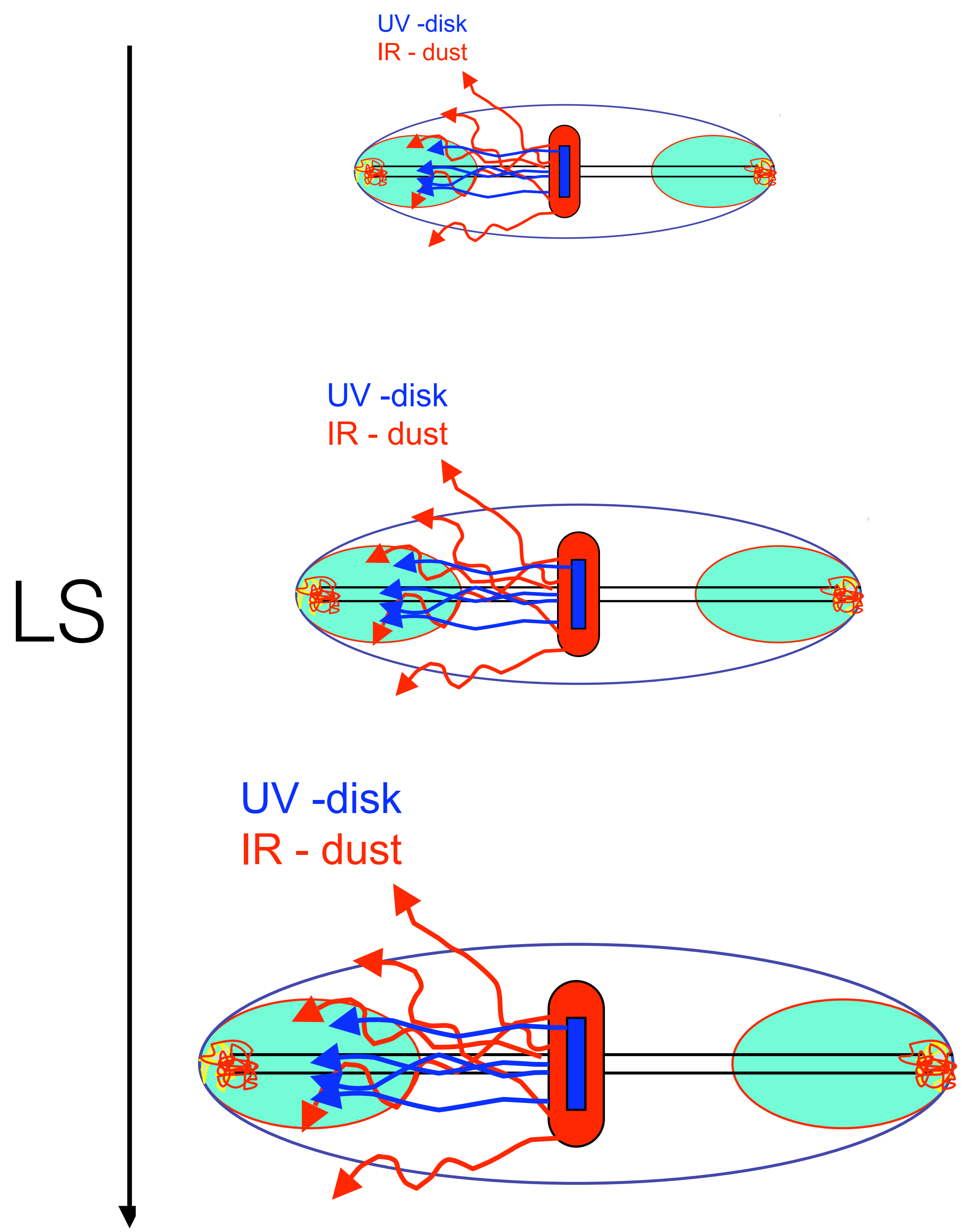
z=0.0765
1.406 kpc/“

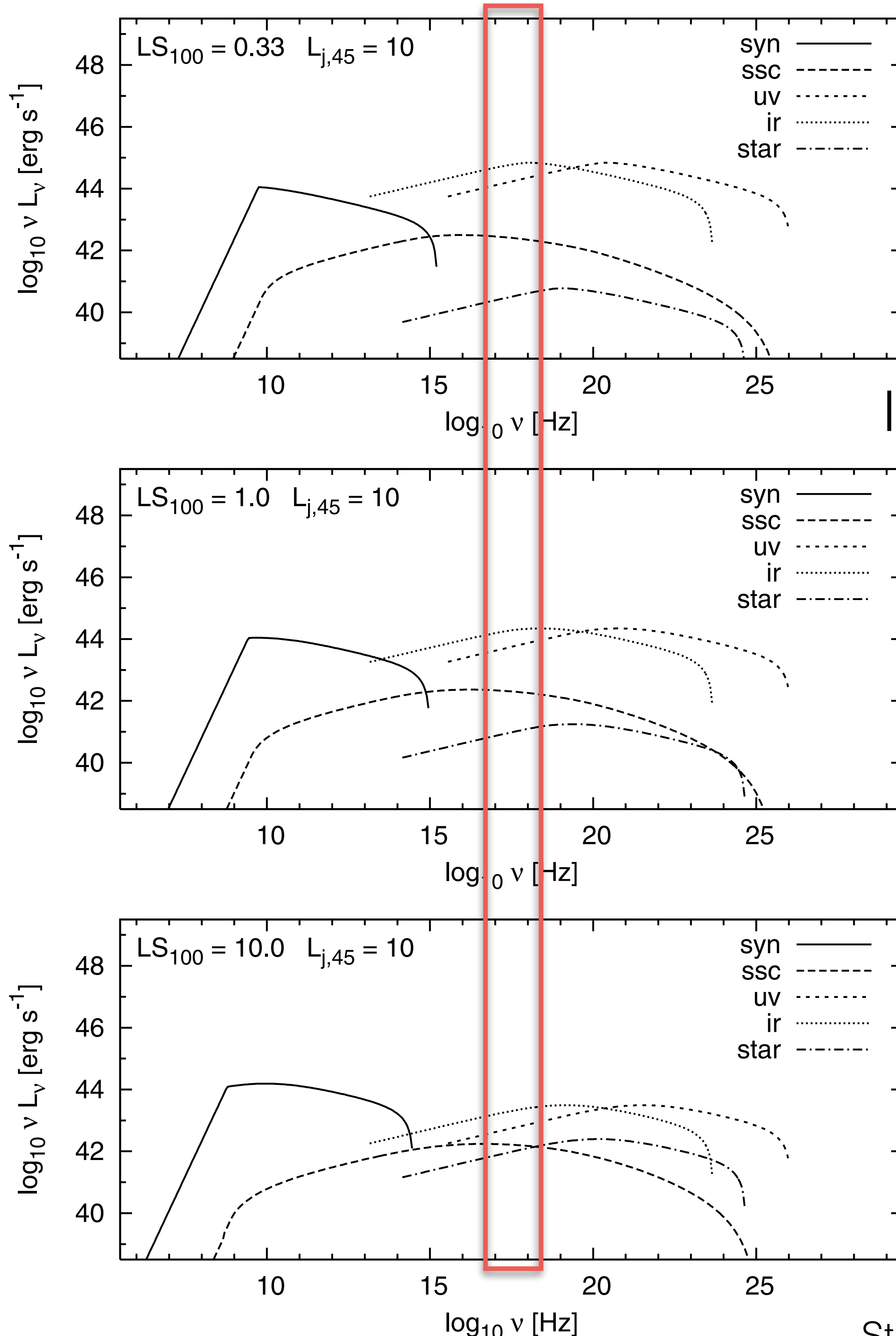
to baby Cygnus As…



to baby Cygnus As…

A smaller radio structure might not be a X-ray fainter one: mini-lobes





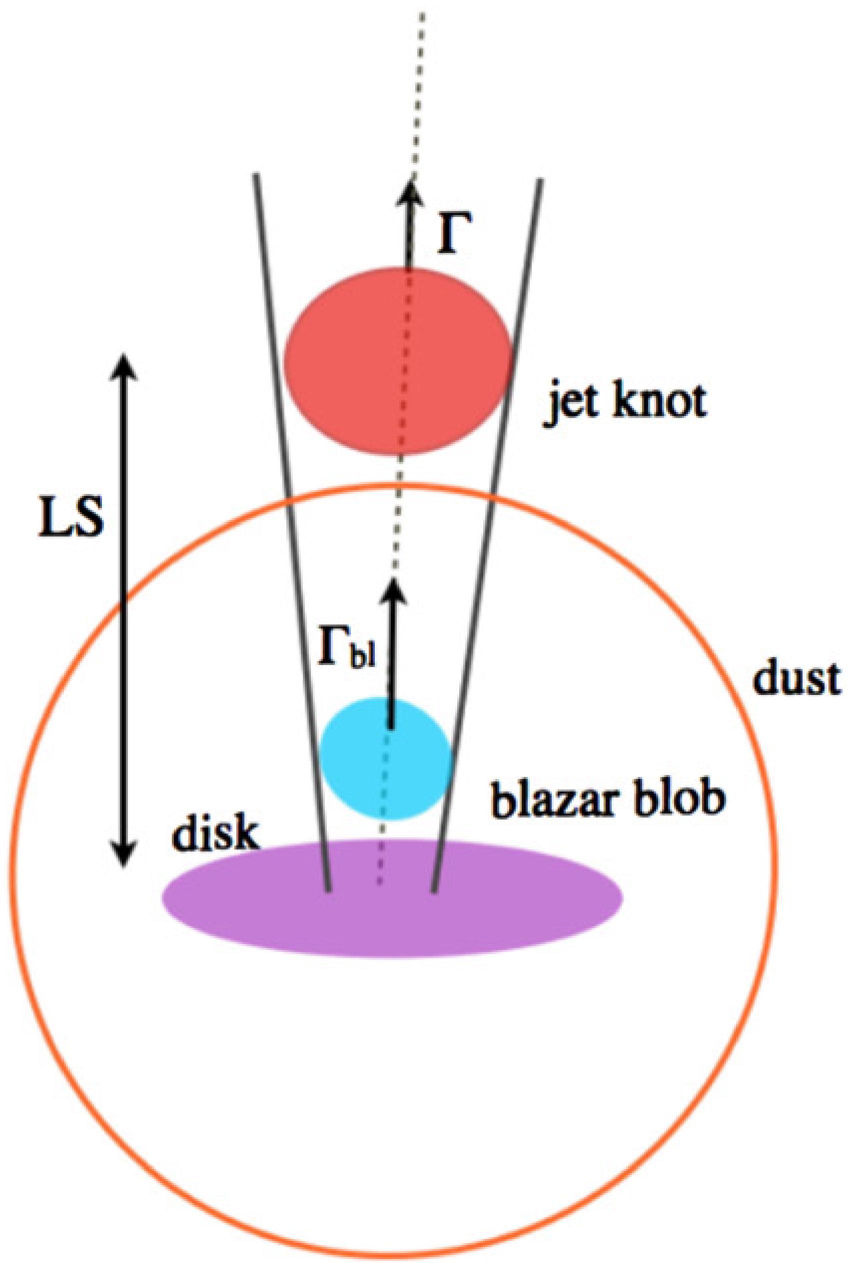
X-rays from IC off IR photons

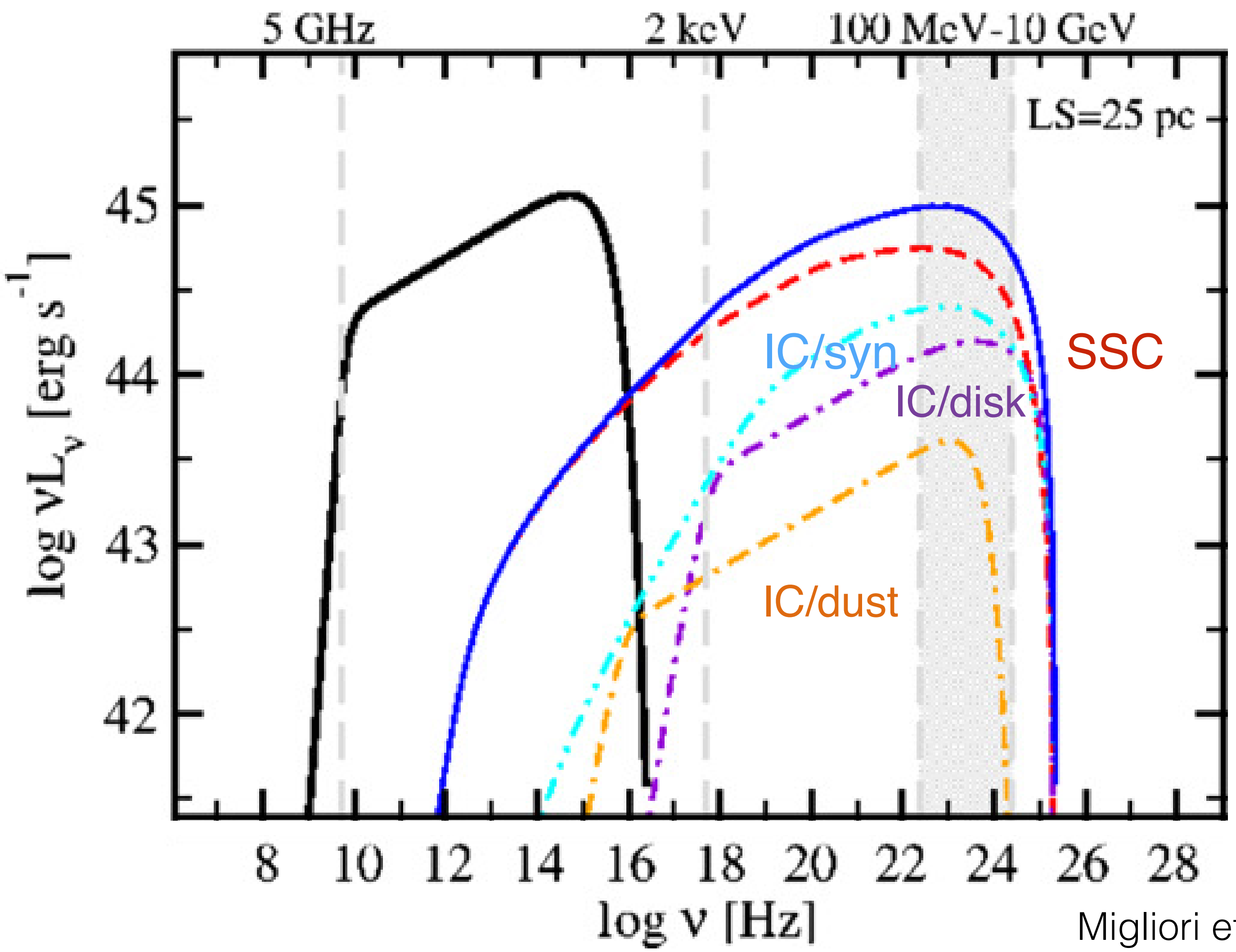
Stawarz et al.(2008)

Lobes expanding in a photon-rich medium

to baby Cygnus As…

A smaller radio structure might not be a X-ray fainter one: beamed jet emission





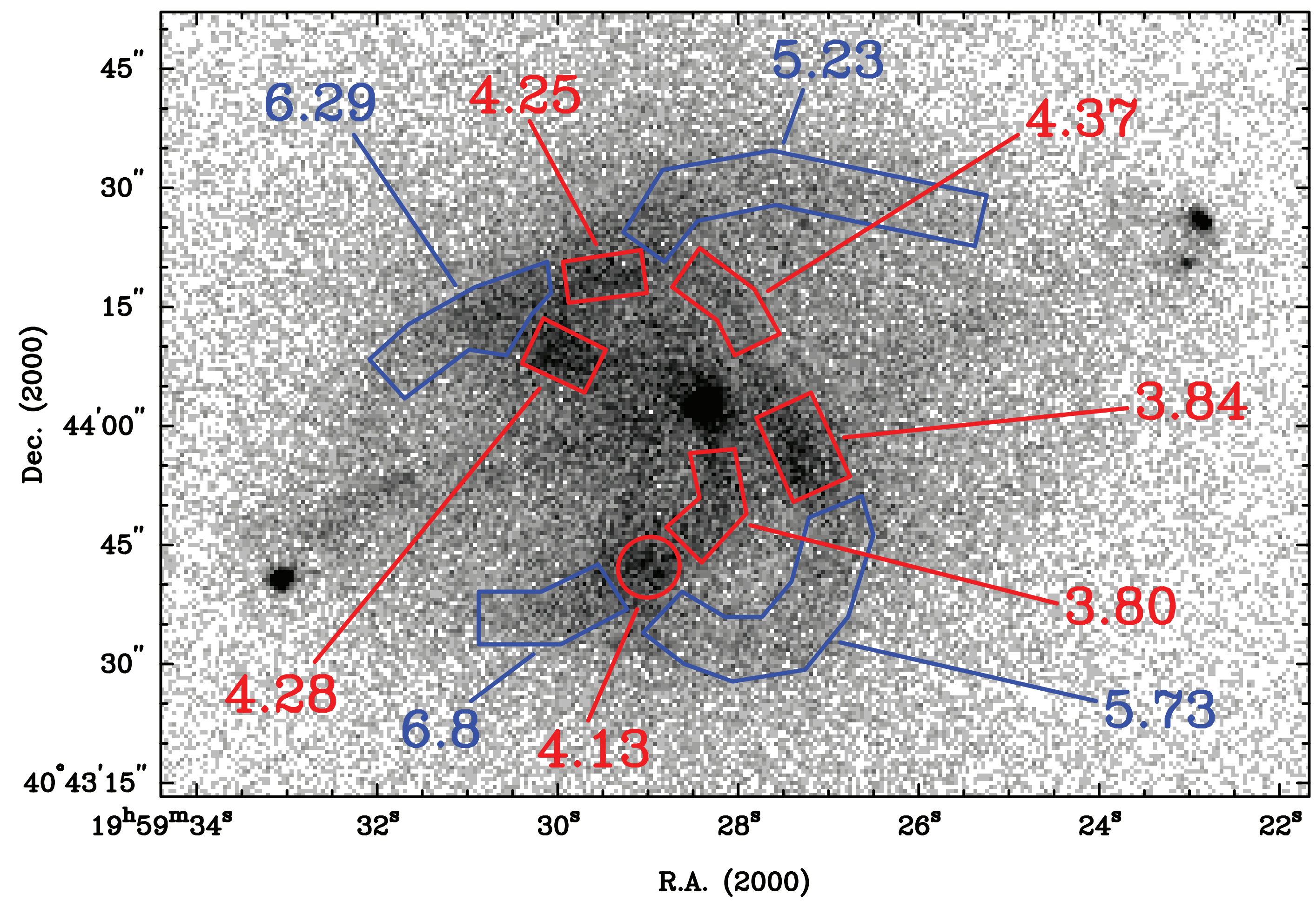
Migliori et al. (2014)

leptonic radiative model - parameters: jet power & disk luminosity, jet speed & inclination, linear size, electron energy distribution.

to baby Cygnus As…

Expanding source - ISM interactions

Wilson et al.(2006)

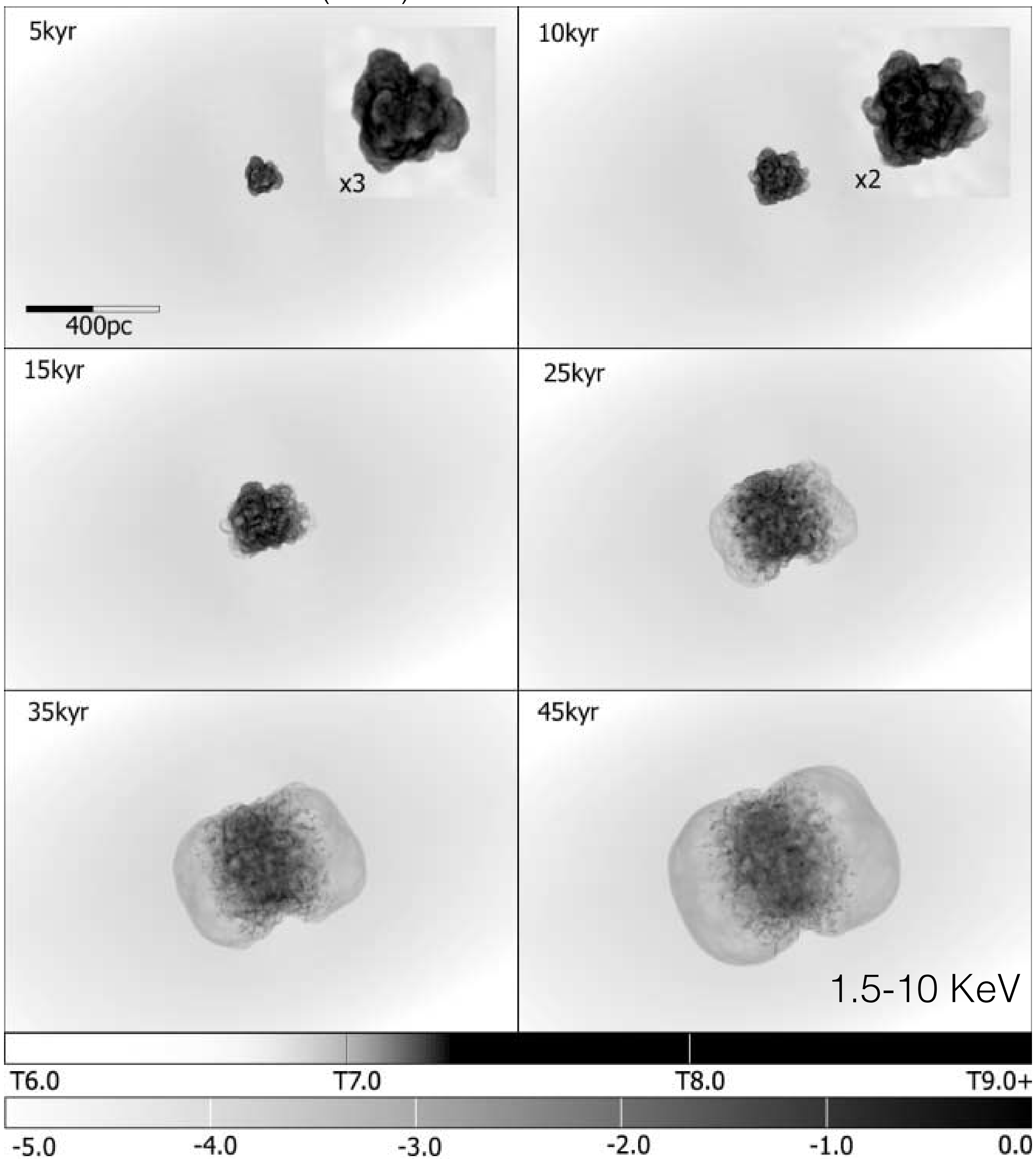


X-ray thermal emission from shocked heated ISM

to baby Cygnus As…

Expanding source - ISM interactions

Sutherland & Bicknell (2007)



Cocoons of hot (few 10^7 K) X-ray gas formed by the jet expansion

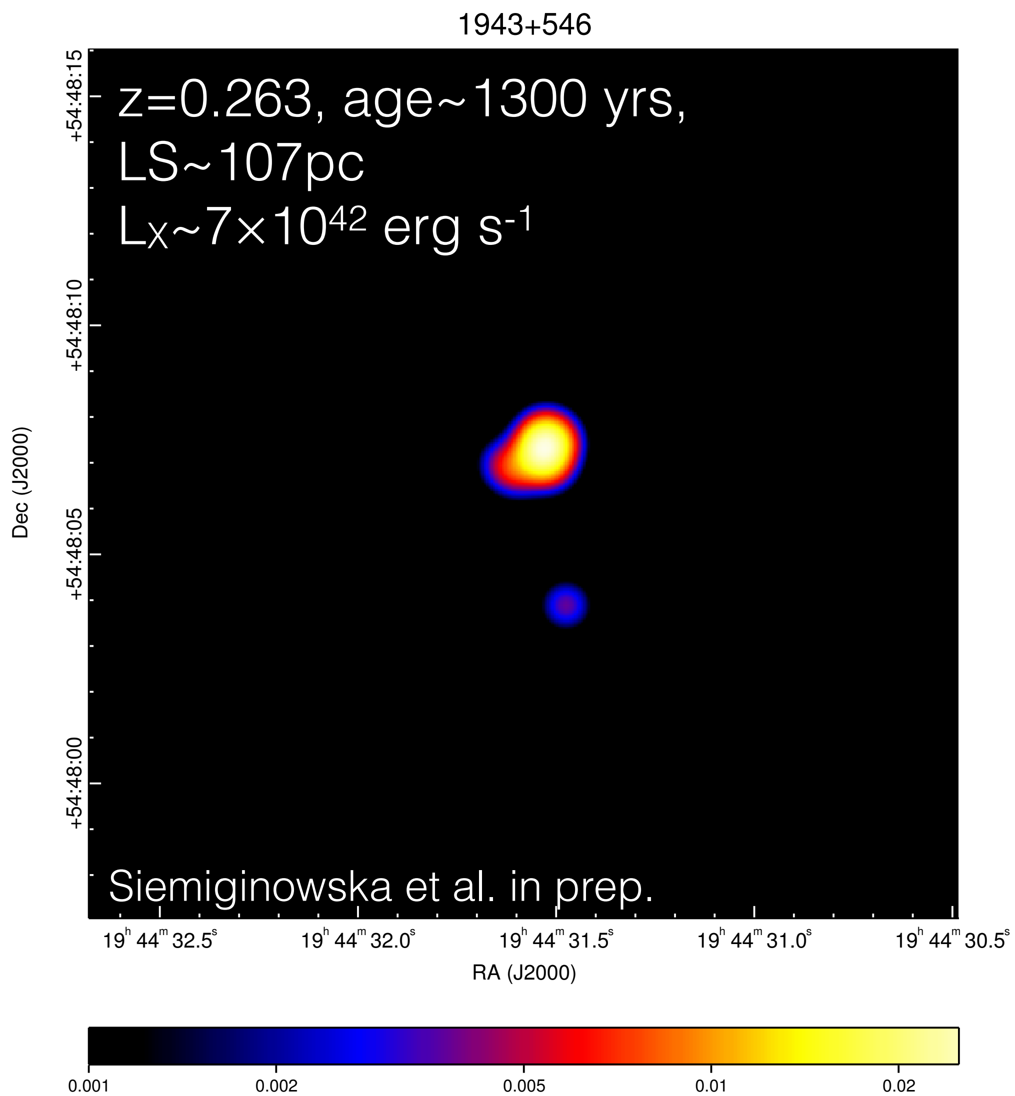
X-ray Observations of Young Radio Sources

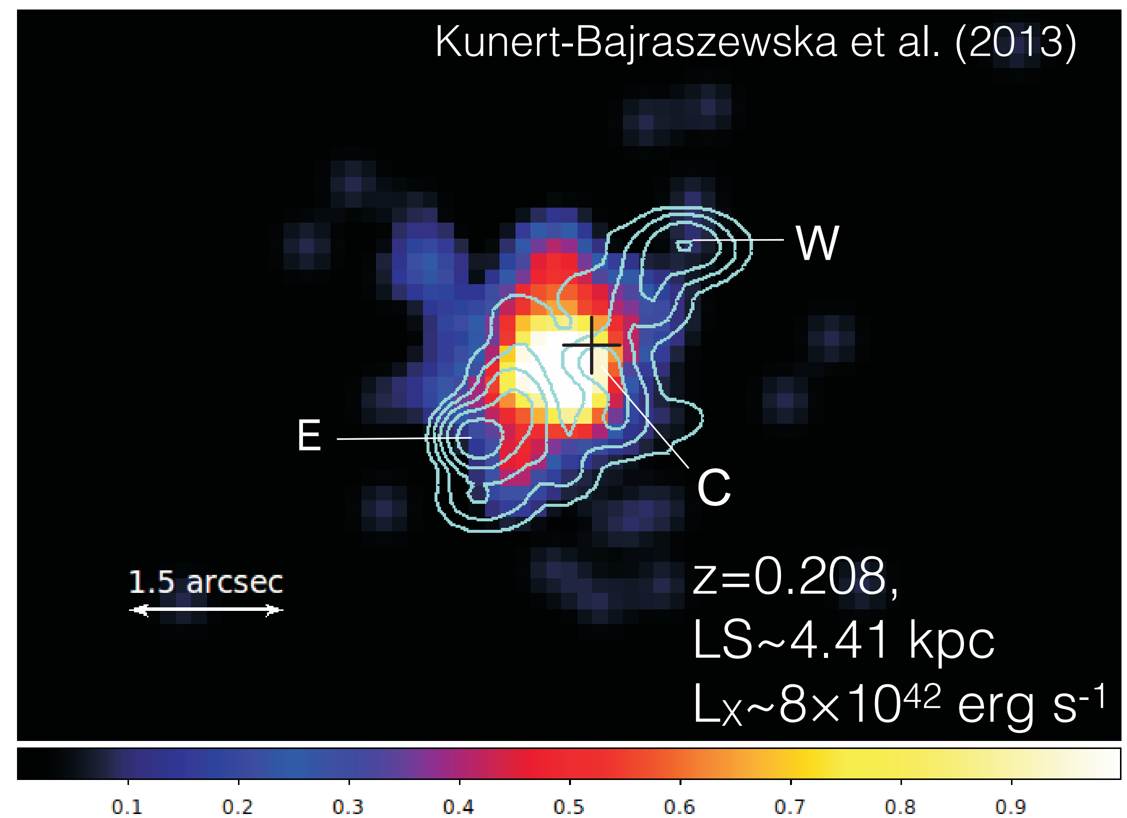
- 48 GPS & CSS observed in X-rays with Chandra and/or XMM-Newton;
- 13 quasars and 35 radio galaxies;
- 16 CSO: most compact (LS<200 pc) and youngest;
- 4 Low Luminosity Compact Sources (LLCs, $L_{5GHz}<5\times10^{42}$ erg s^{-1}, LS~2-17 kpc);
- 0.014<z<1.95

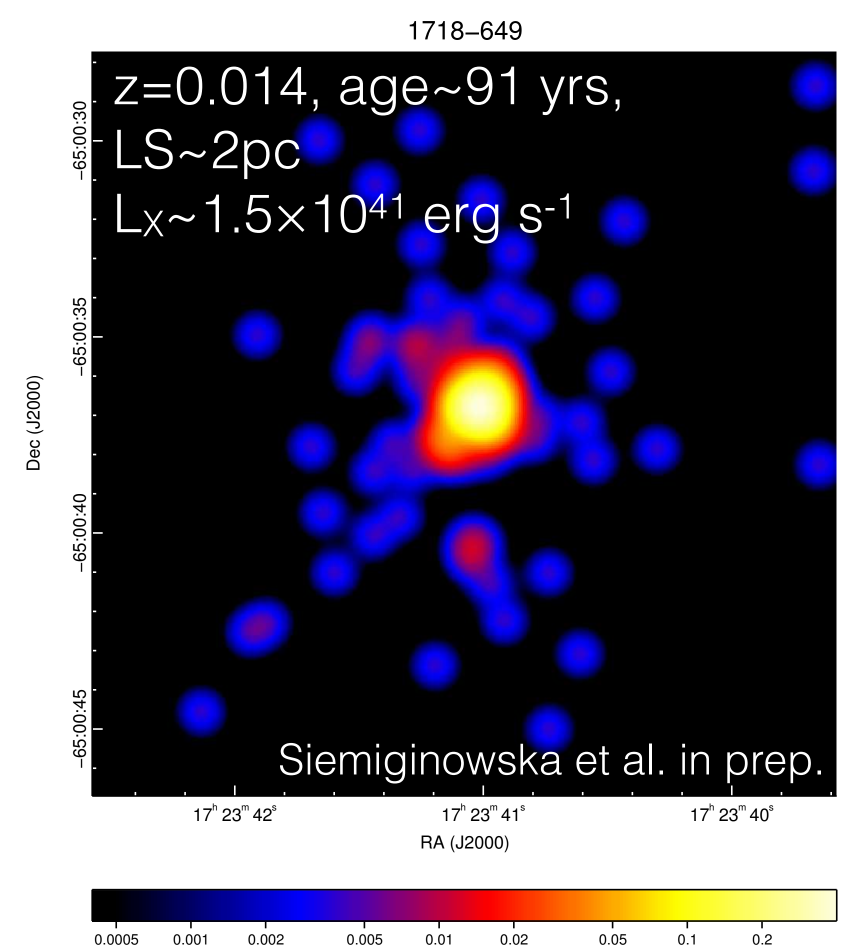
Young Radio Sources are X-ray emitters!

most of the X-ray detections from
snapshot (<10ksec) or short (~20ksec) observations

X-ray Observations: morphology





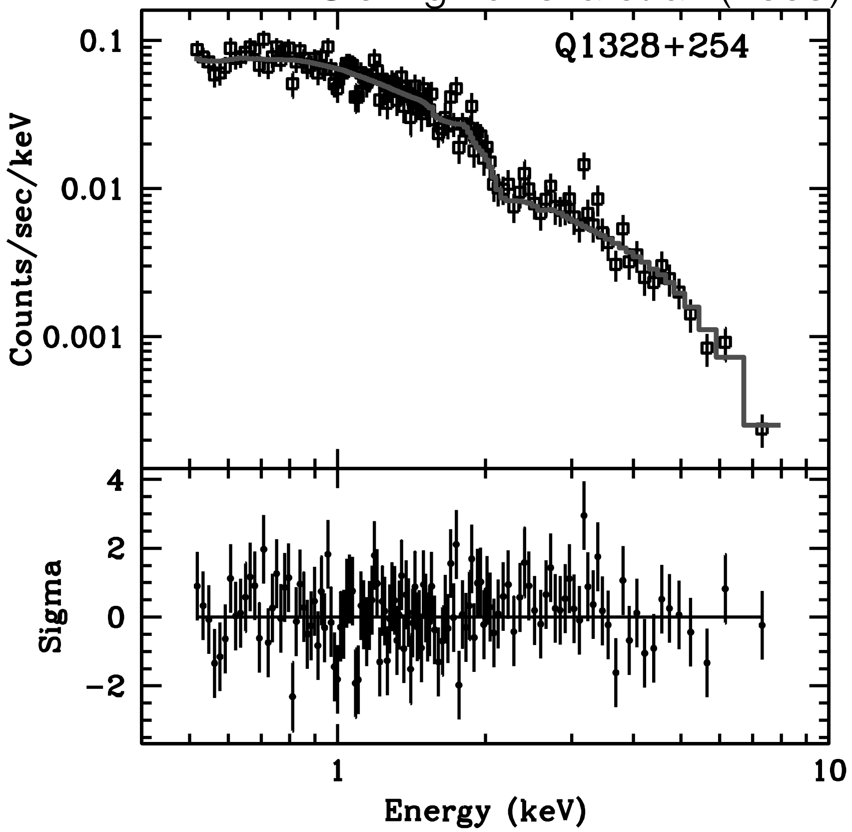


The X-ray emission is typically compact,
a diffuse component is present only in few cases

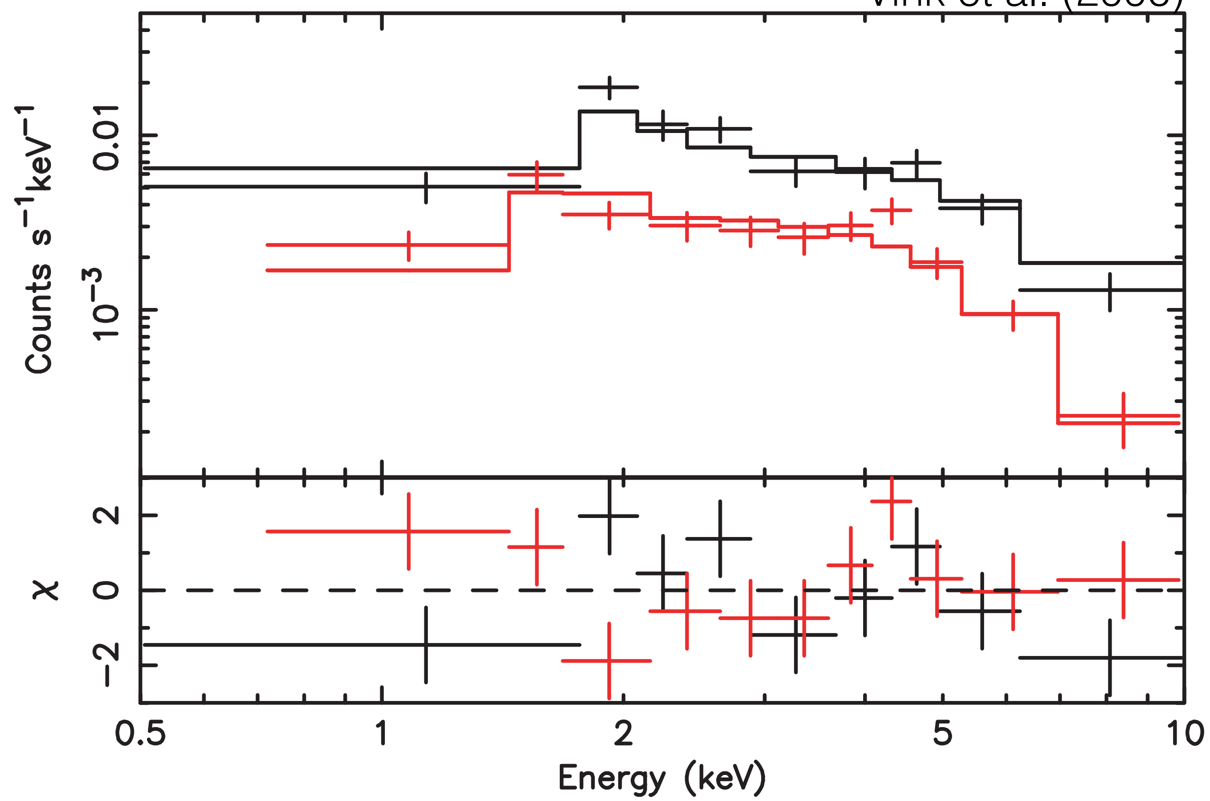
X-ray Observations: spectra

A (Power law + absorption) model is usually a good spectral fit:

Siemiginowska et al. (2008)

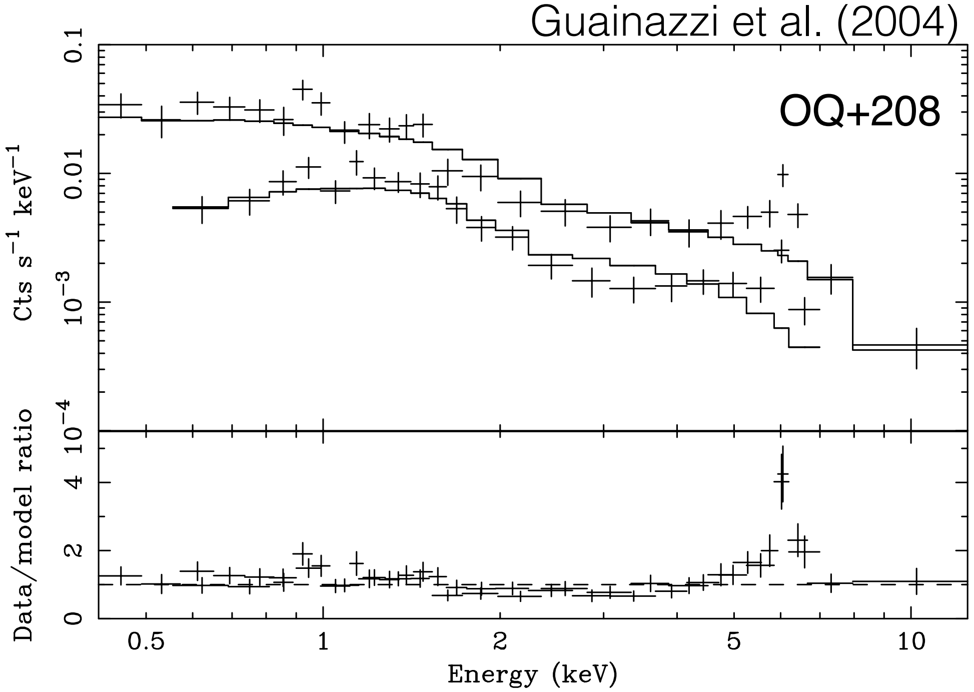


Vink et al. (2006)

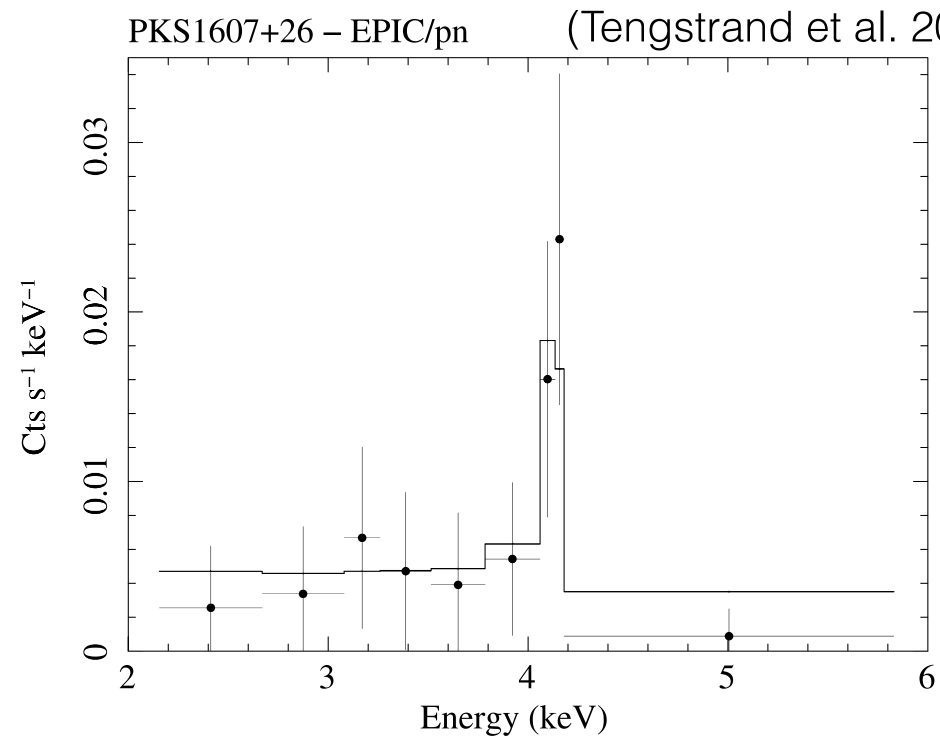


an additional component is need:

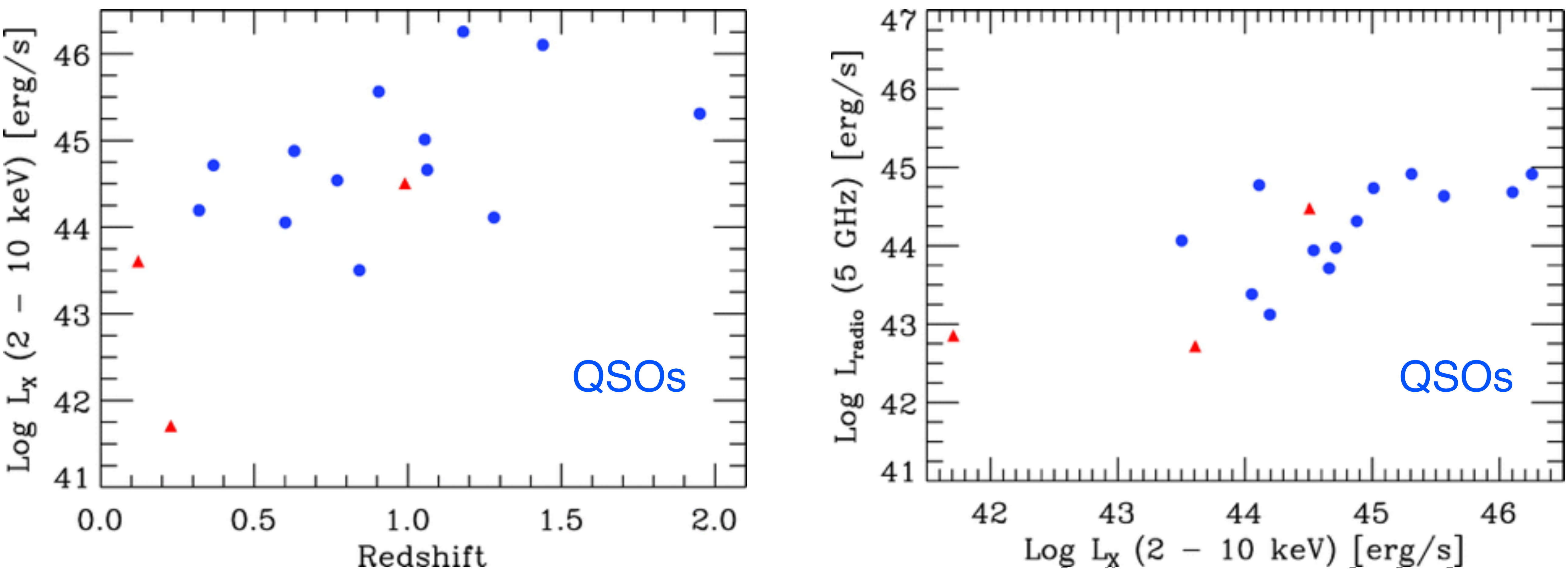
Guainazzi et al. (2004)



(Tengstrand et al. 2009)



X-ray samples: GPS & CSS Quasars

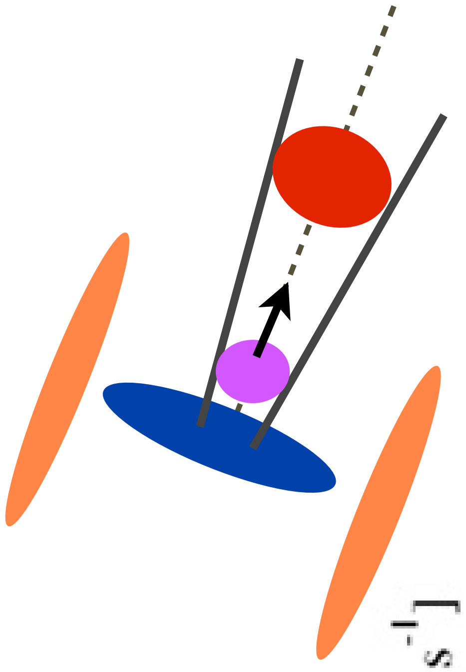


Siemiginowska et al. (2008)

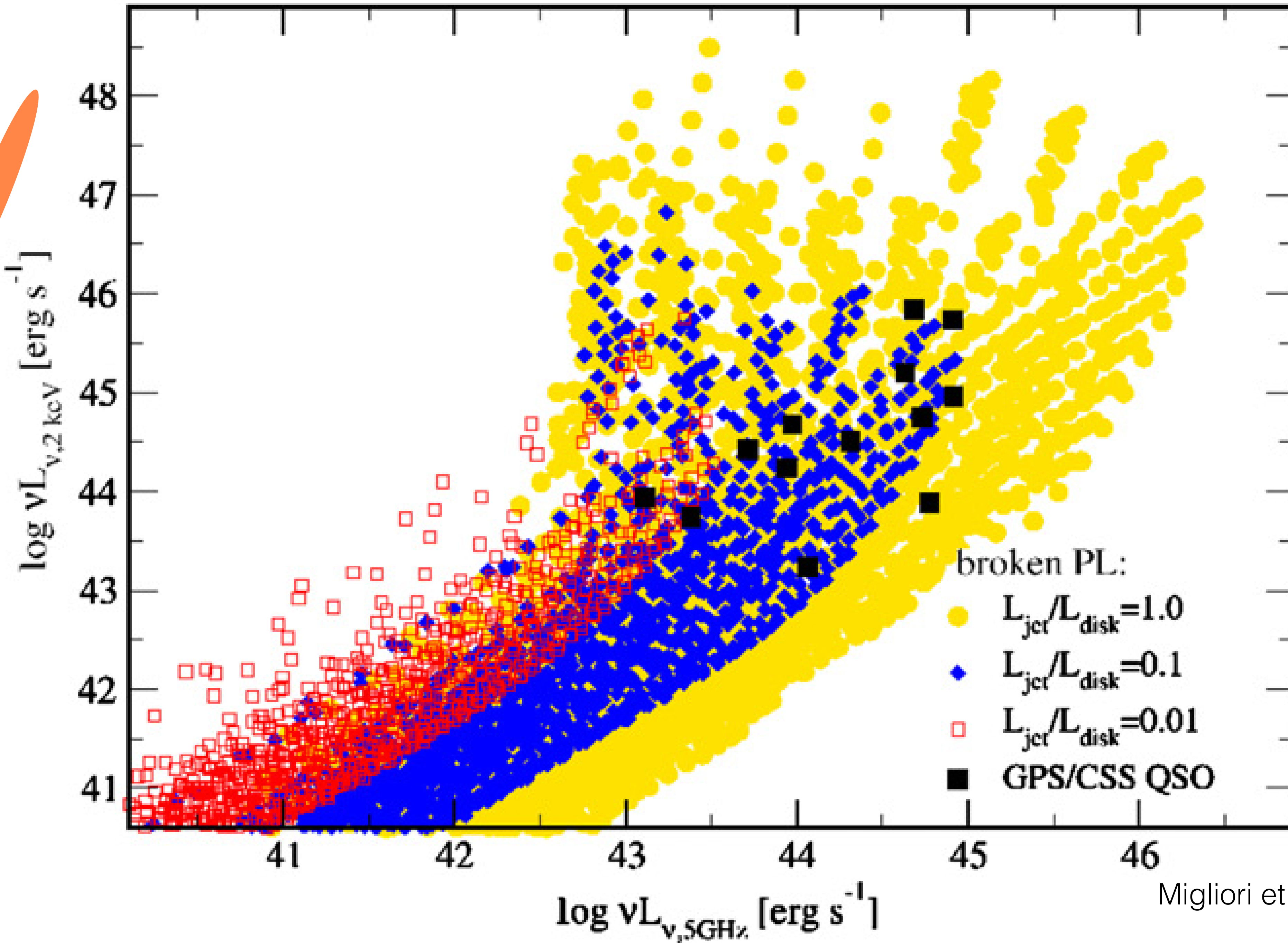
- X-ray luminosities similar to giant quasars;
- no intrinsic absorption ($N_H<10^{21}$ cm^{-2});
- median X-ray photon index ($\langle\Gamma\rangle=1.8\pm0.2$) and optical to X-ray spectral index ($\langle\alpha_{oX}\rangle=1.5\pm0.2$) similar to values found in radio quiet quasar samples ($\langle\Gamma\rangle=2.0\pm0.3$, $\langle\alpha_{oX}\rangle=1.5\pm0.2$);
- no significant L_X-L_{radio} correlation.

X-rays produced in the disk-corona?

X-ray samples: GPS & CSS Quasars



Simulated jet X-ray emission:

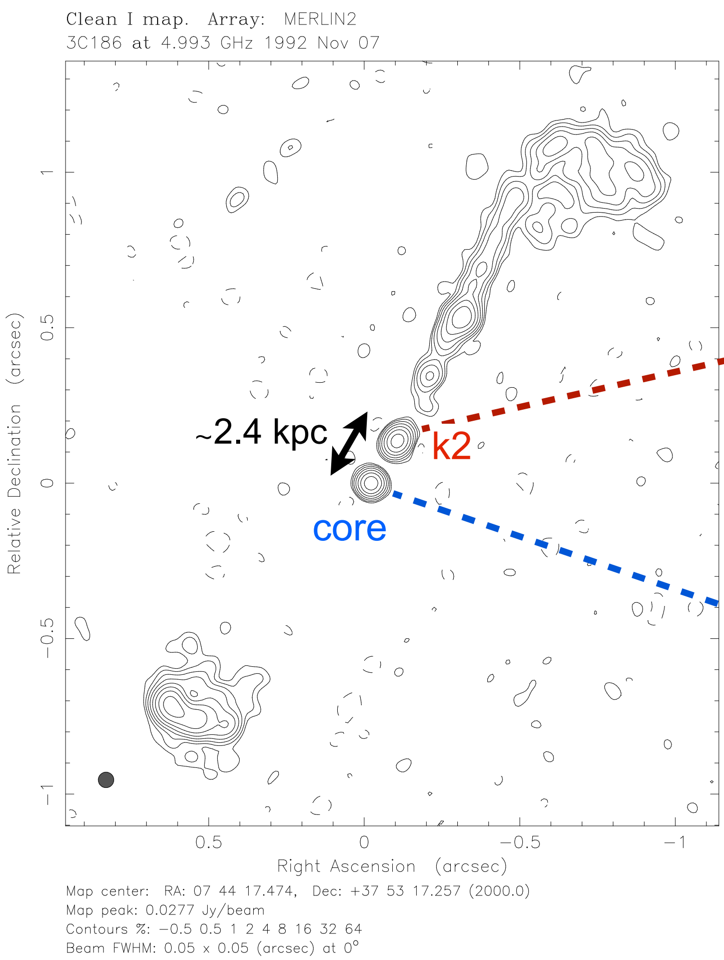


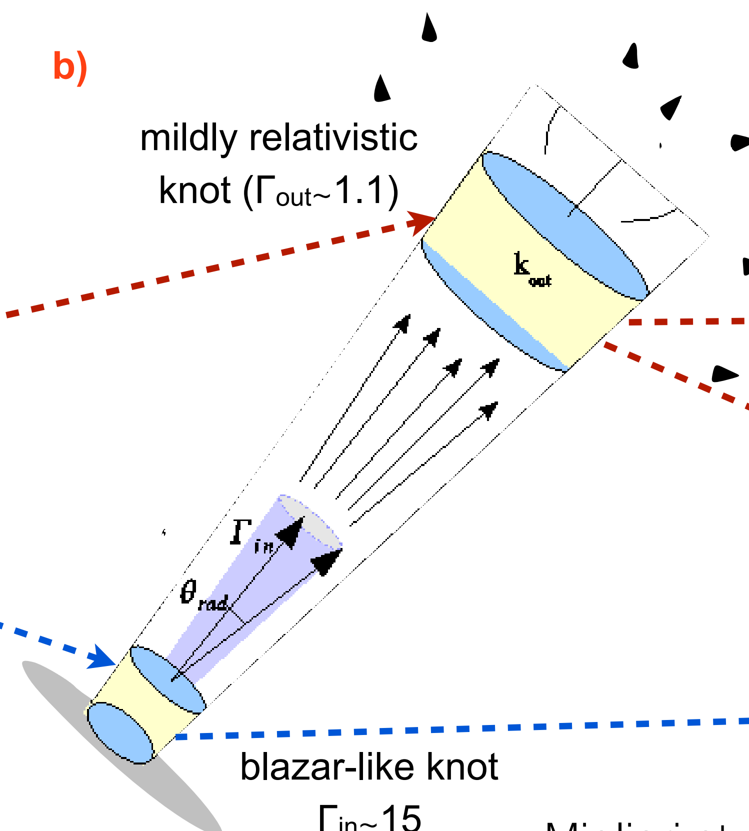
Migliori et al. (2014)

A radio-X-ray correlation should not be expected even if the X-ray emission comes from the jet

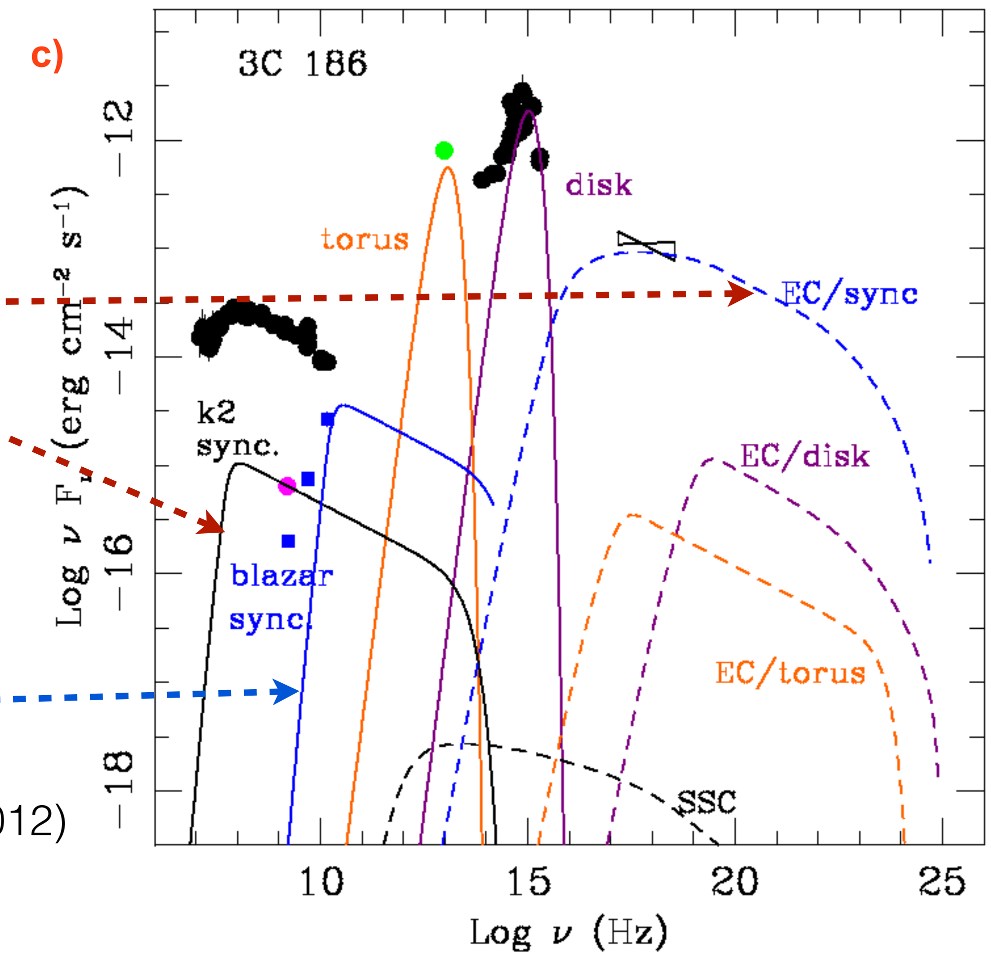
Origin of the X-ray Emission: SED modelling

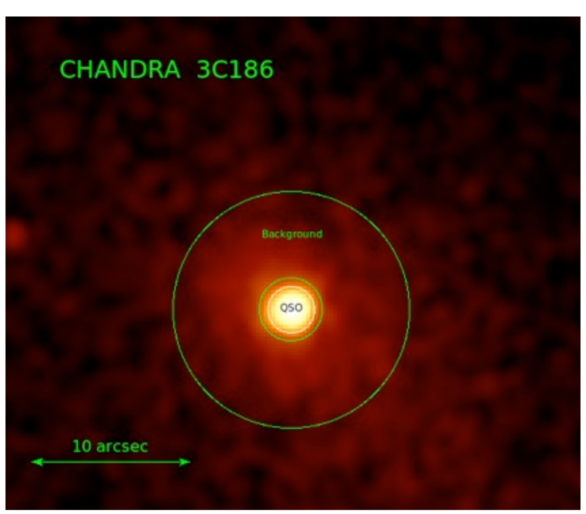
GPS/CSS quasars: jet component





Migliori et al. (2012)





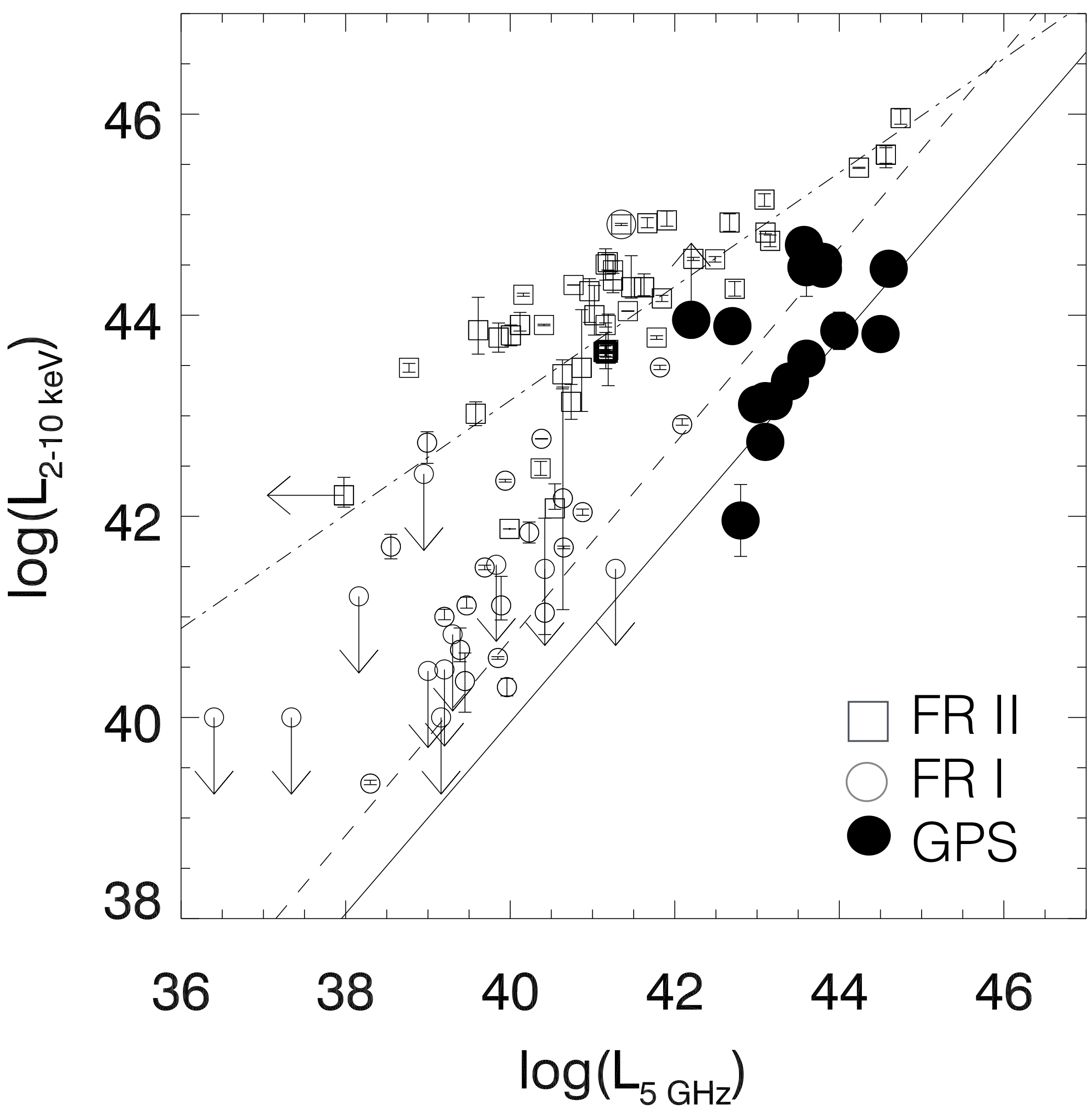
A decelerating jet can produce the observed X-ray emission but implies large jet powers and severe radiative dissipation (factor of ~100) on <kpc scales.

	core / blazar-like knot	k2 / mildly rel. knot
L_e (erg s^{-1})	3.2×10^{46}	2.0×10^{45}
L_p (erg s^{-1})	1.1×10^{48}	3.5×10^{46}
L_B (erg s^{-1})	2.1×10^{47}	7.8×10^{44}
L_{kin} (erg s^{-1})	1.4×10^{48}	3.7×10^{46}
L_r (erg s^{-1})	1.1×10^{47}	1.8×10^{45}

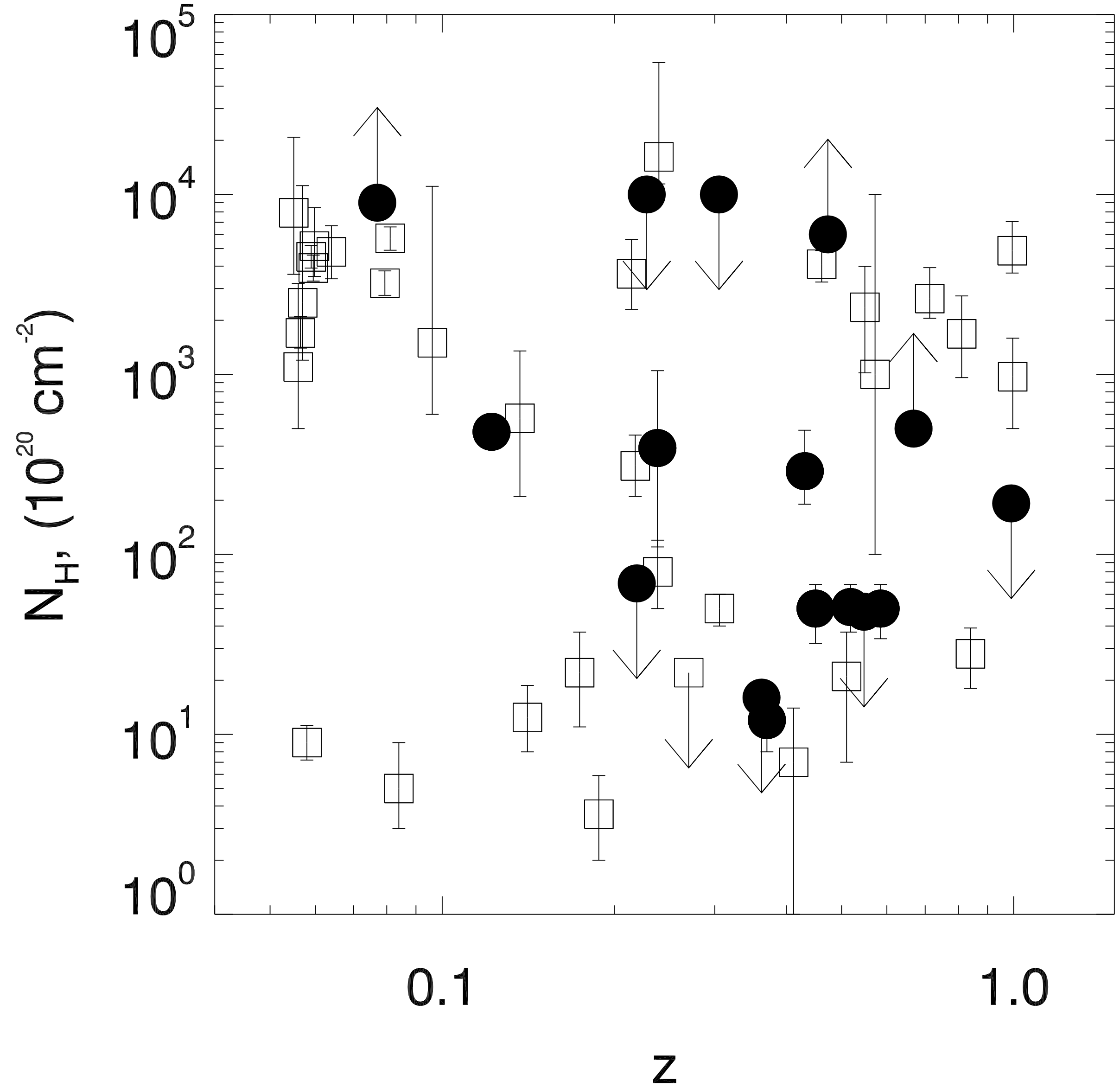
X-ray samples: GPS radio galaxies

Radio bright (>1Jy @5GHz) GPS galaxies (Tengstrand et al. 2009):

- $L_X = 0.09\text{-}50 \times 10^{43}$ erg s^{-1};
- $\langle \Gamma \rangle = 1.7 \pm 0.4$;
- $\langle N_H \rangle = 3 \times 10^{22}$ cm^{-2}.



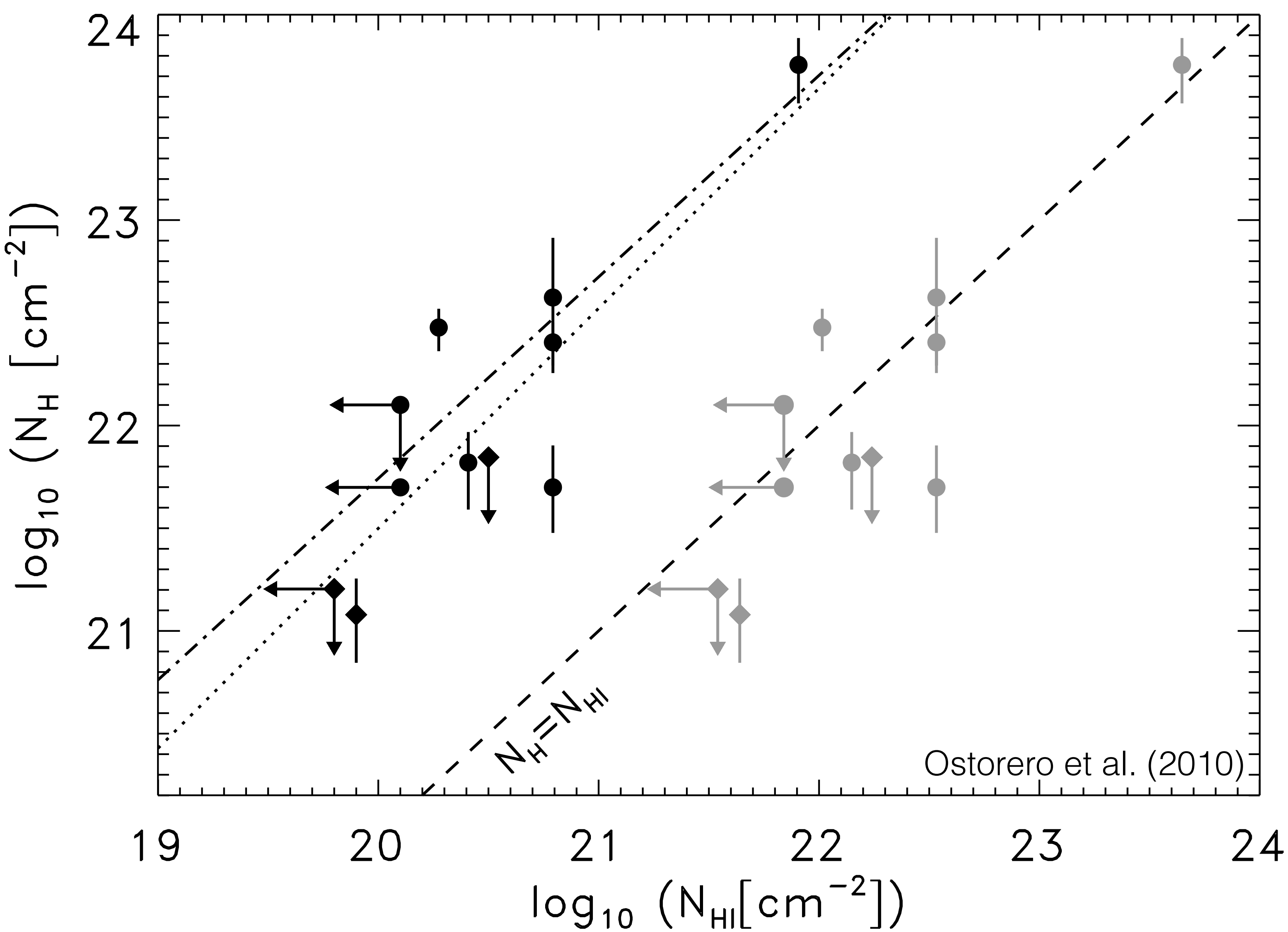
L_X similar to FR IIs but L_X/L_{radio} as for FR Is



caveat: N_H measurable only in few sources

X-ray samples: GPS radio galaxies

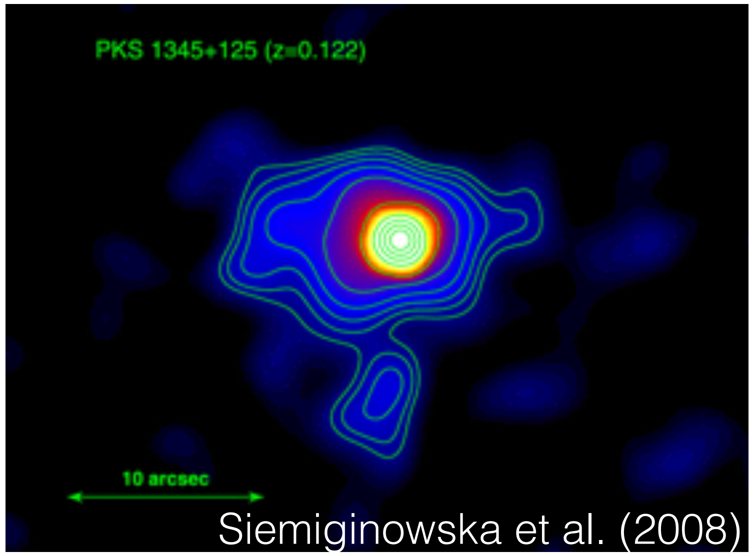
Clues on the origin of the X-rays from the X-ray (N_H) and radio (N_{HI}) column densities:



A positive correlation points to a common absorber

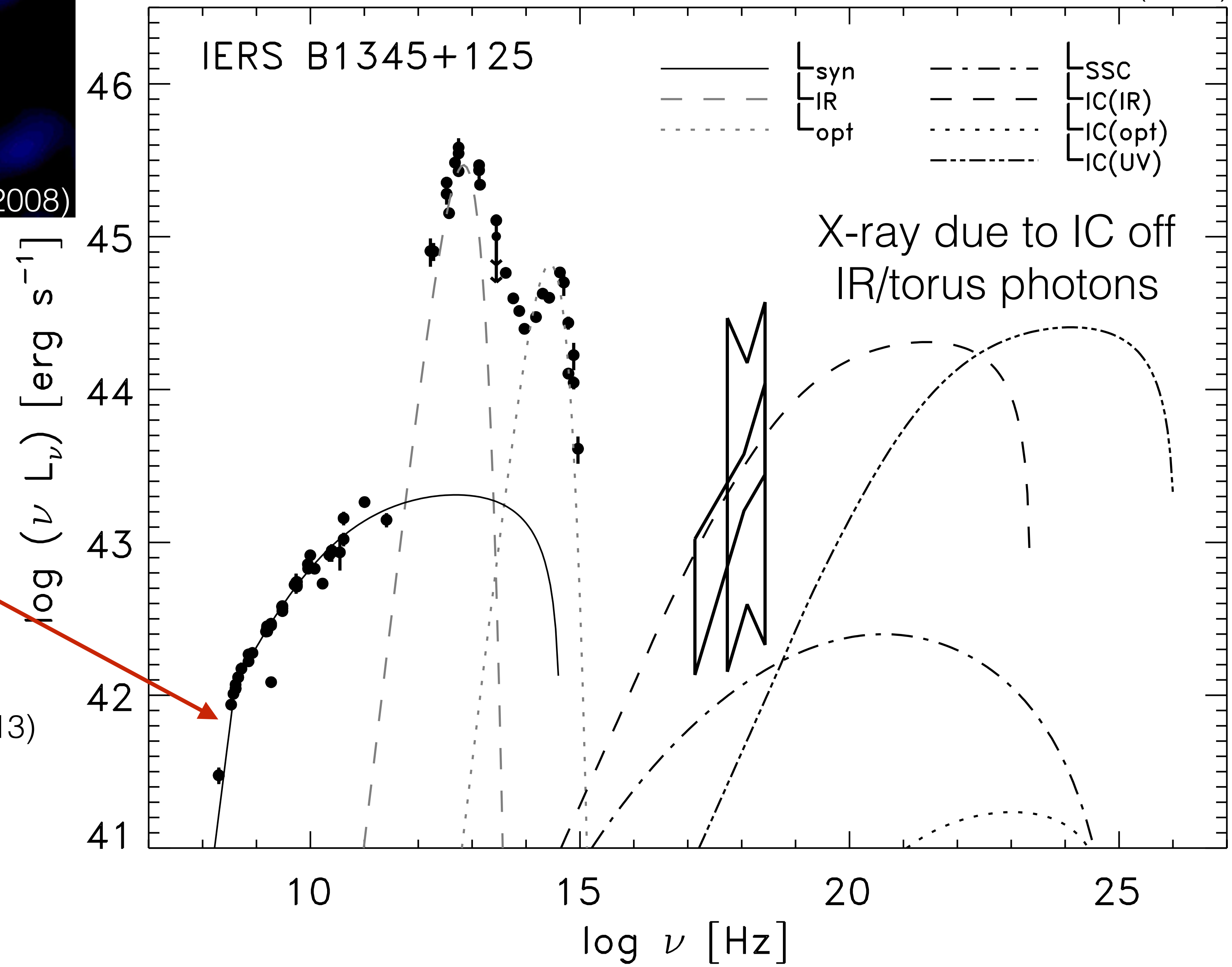
Caveat: N_{HI} measurements depend on assumptions on gas spin temperature & covering factor (Ostorero's talk)

Origin of the X-ray Emission: SED modelling



GPS/CSO lobe X-ray emission:

Ostorero et al. (2010)



break in the synchrotron spectrum due to FFA?

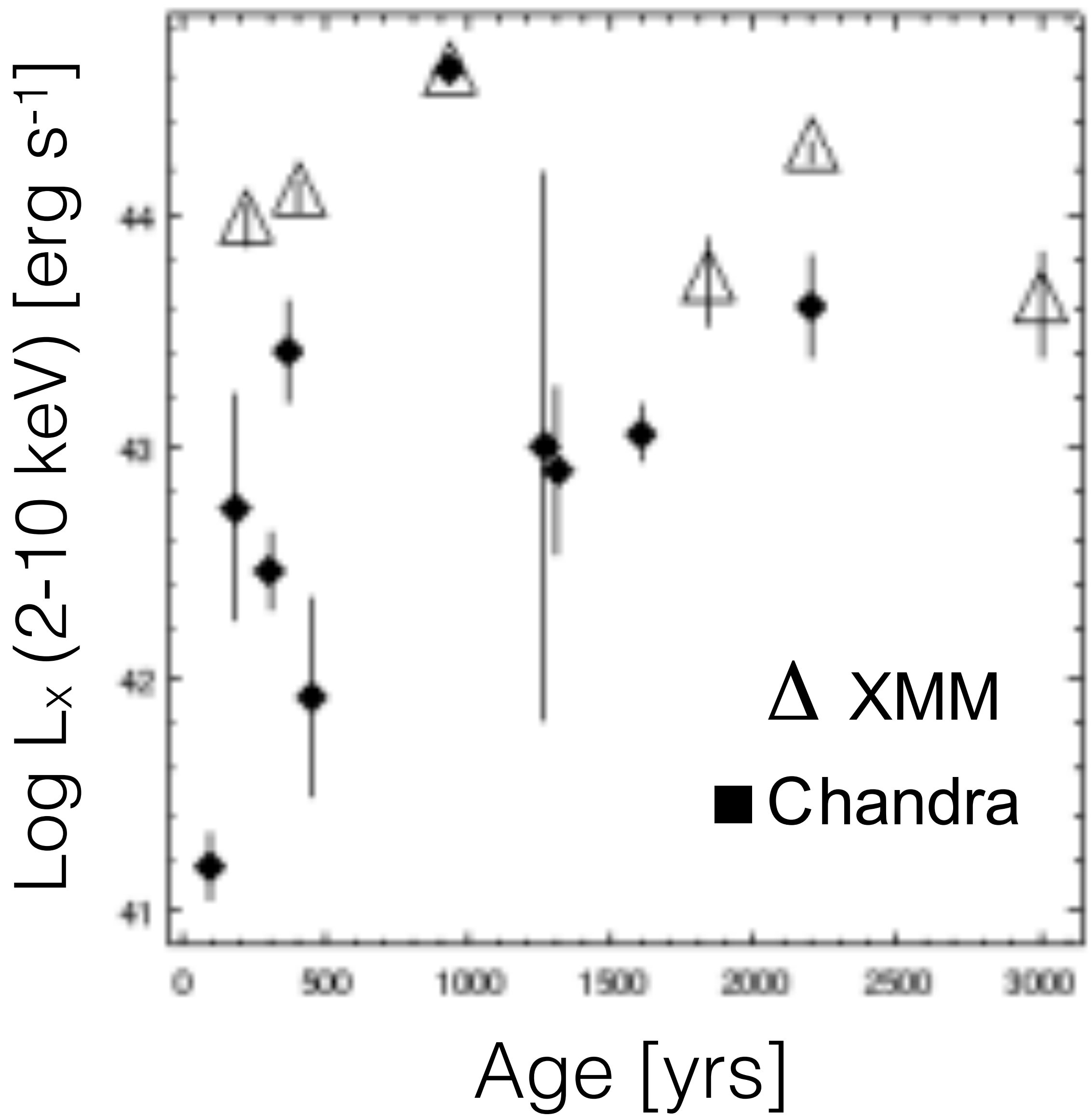
detection of jet-ISM interaction (Morganti et al. 2013)

The X-ray emission of GPS radio galaxies can be modelled as IC emission from the compact lobes

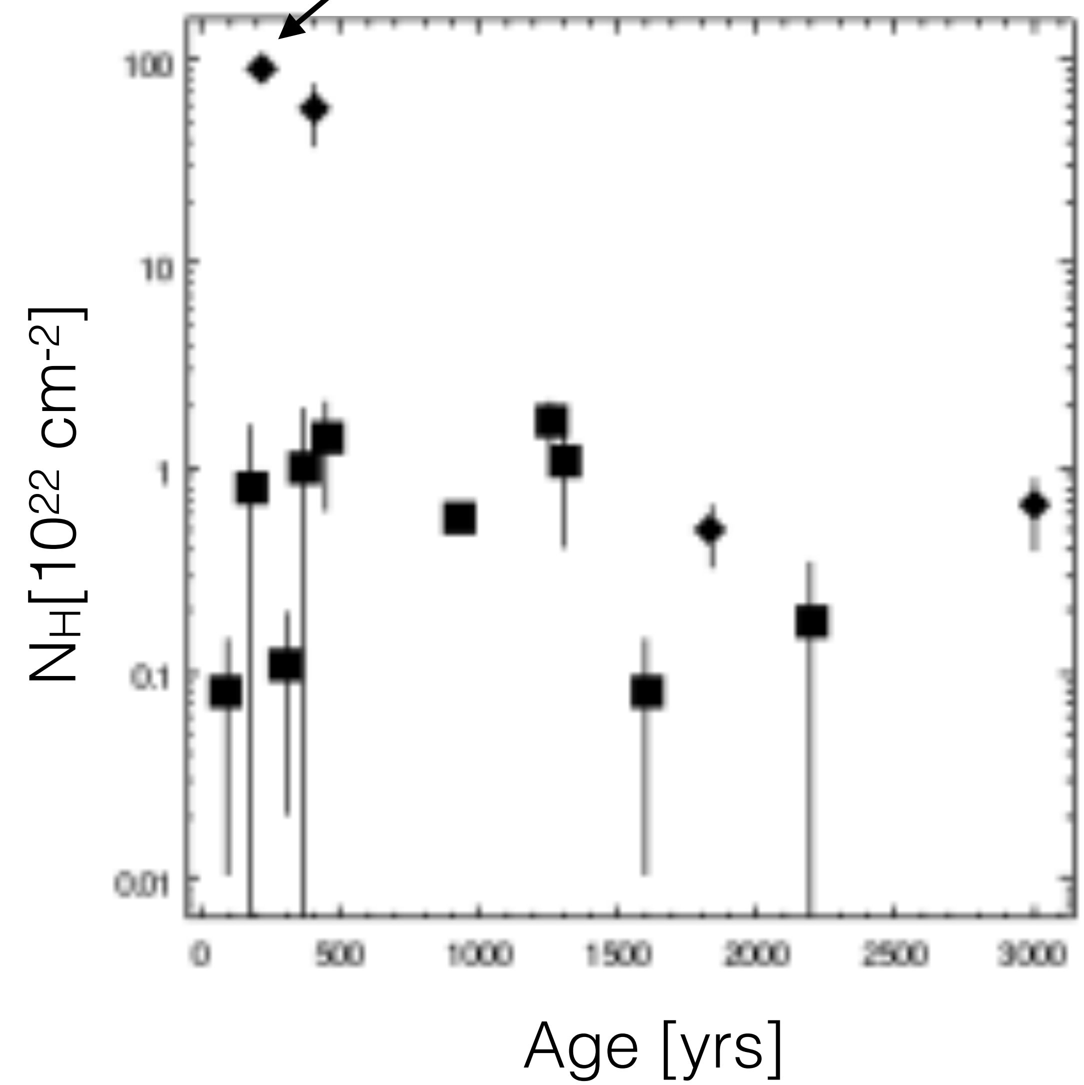
X-ray samples: CSOs

kinematic age measured from the radio hot spot expansion

Siemiginowska et al. in prep.

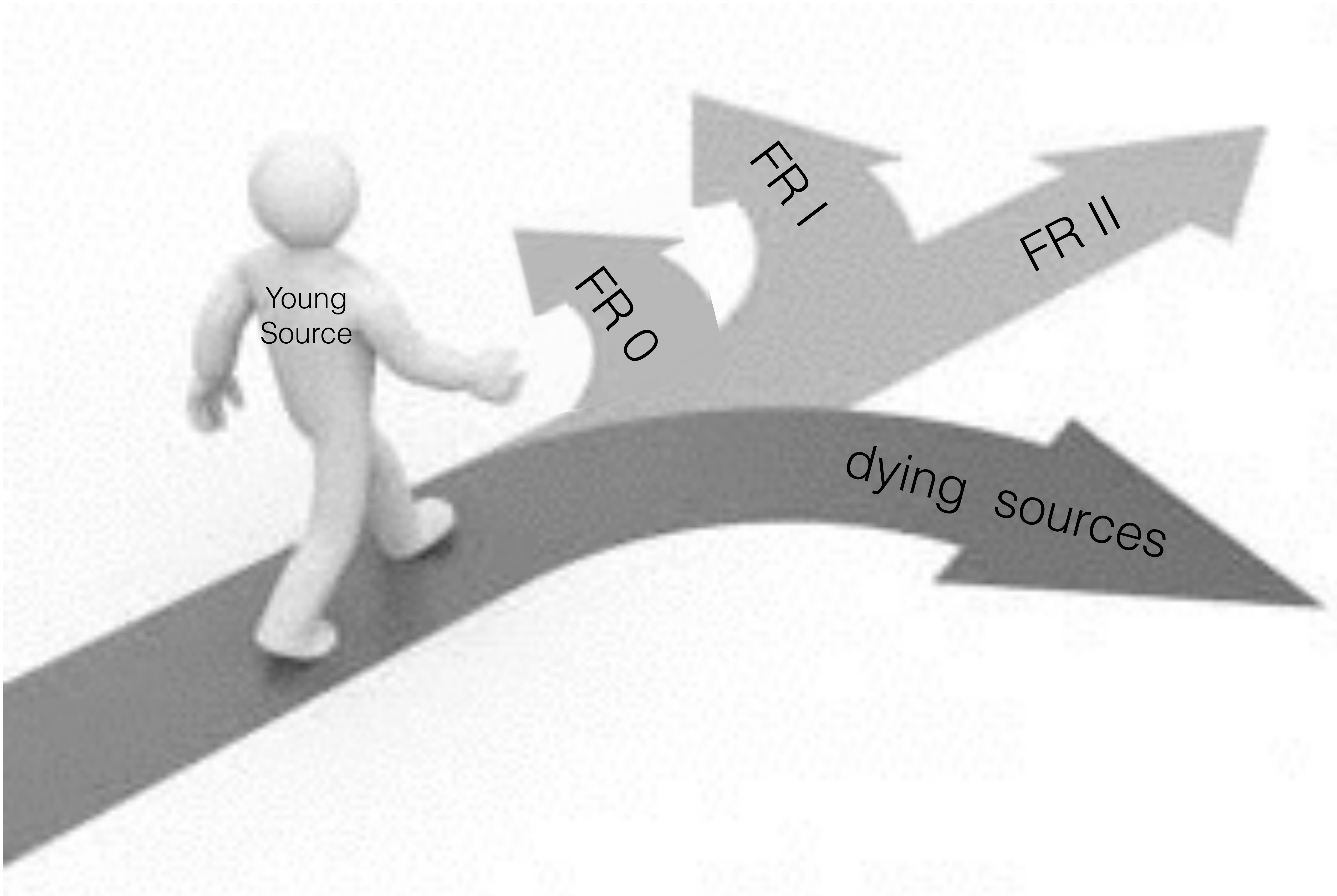


OQ208 (z=0.77) Compton thick
(Guainazzi et al. 2004)



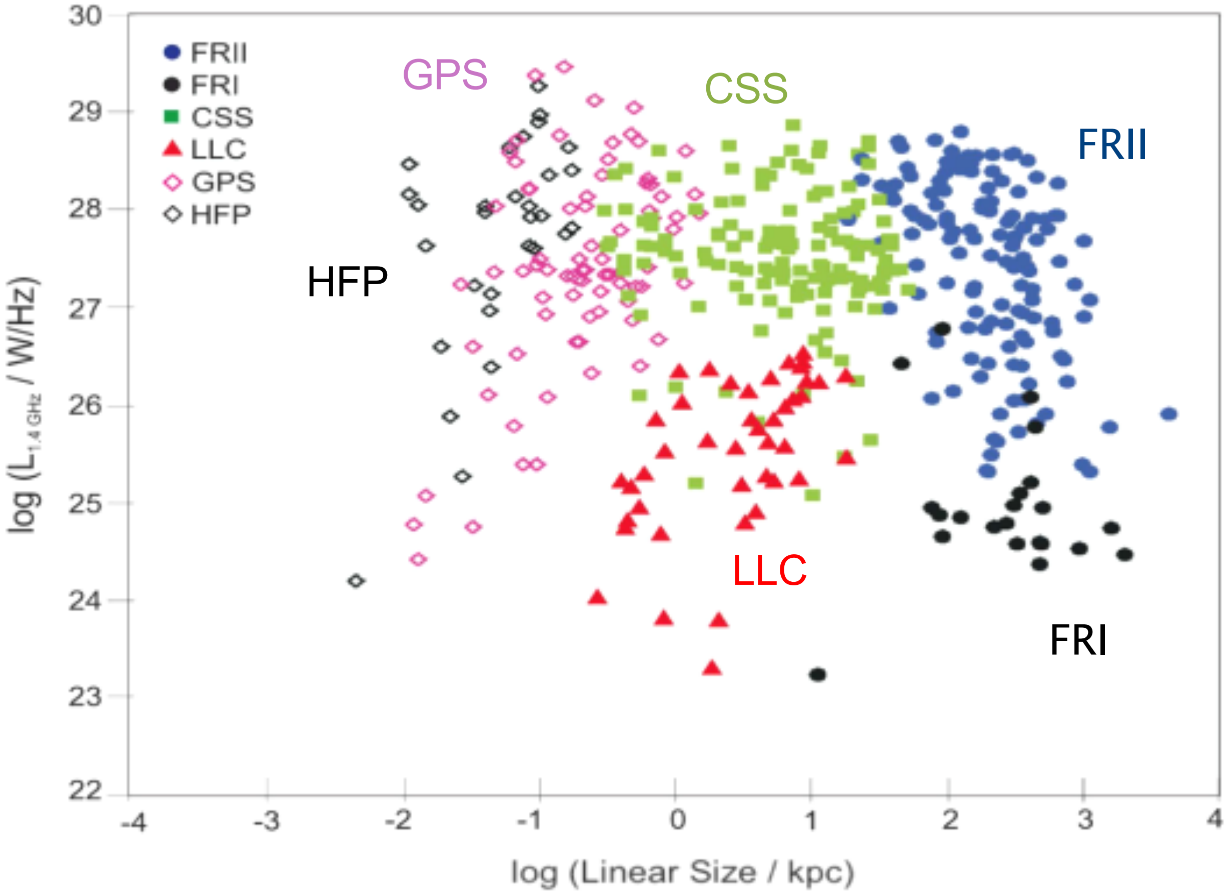
- Large spread in X-ray luminosity;
- no clear N_H vs age/size trend.

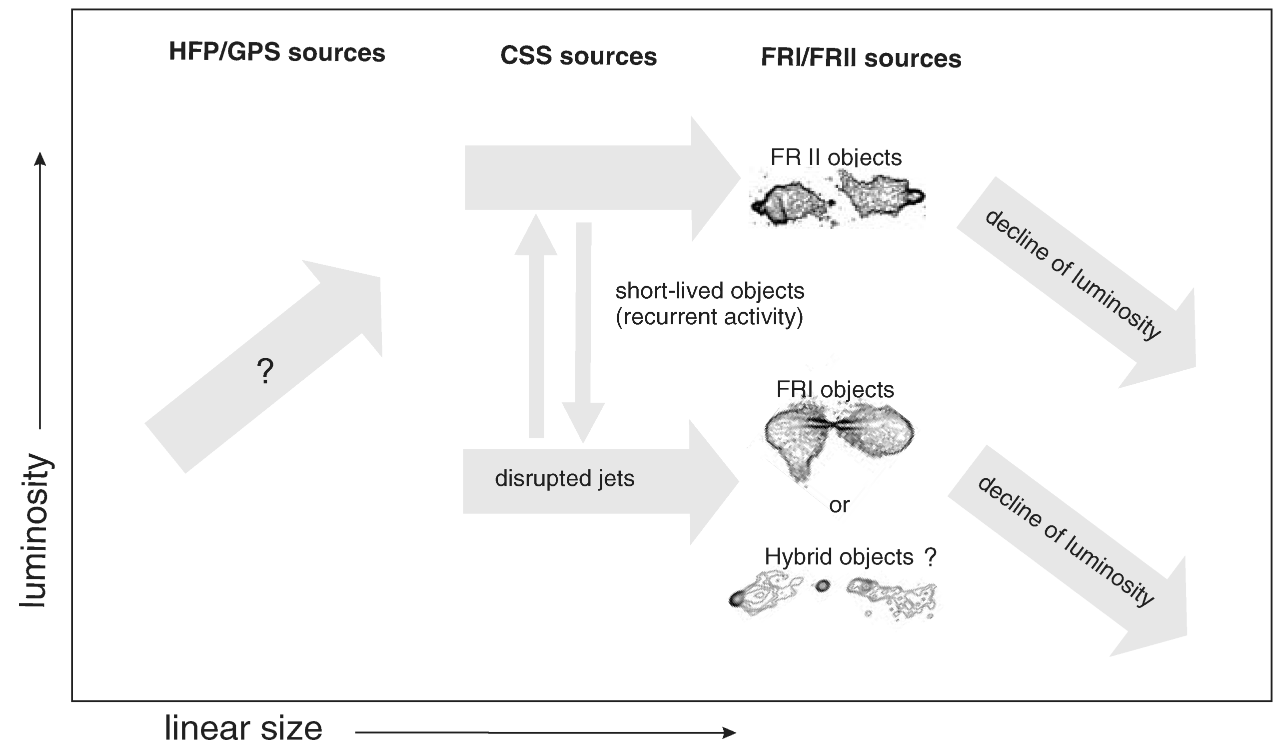
from baby Cygnus As to Cygnus A



Radio Source Evolution

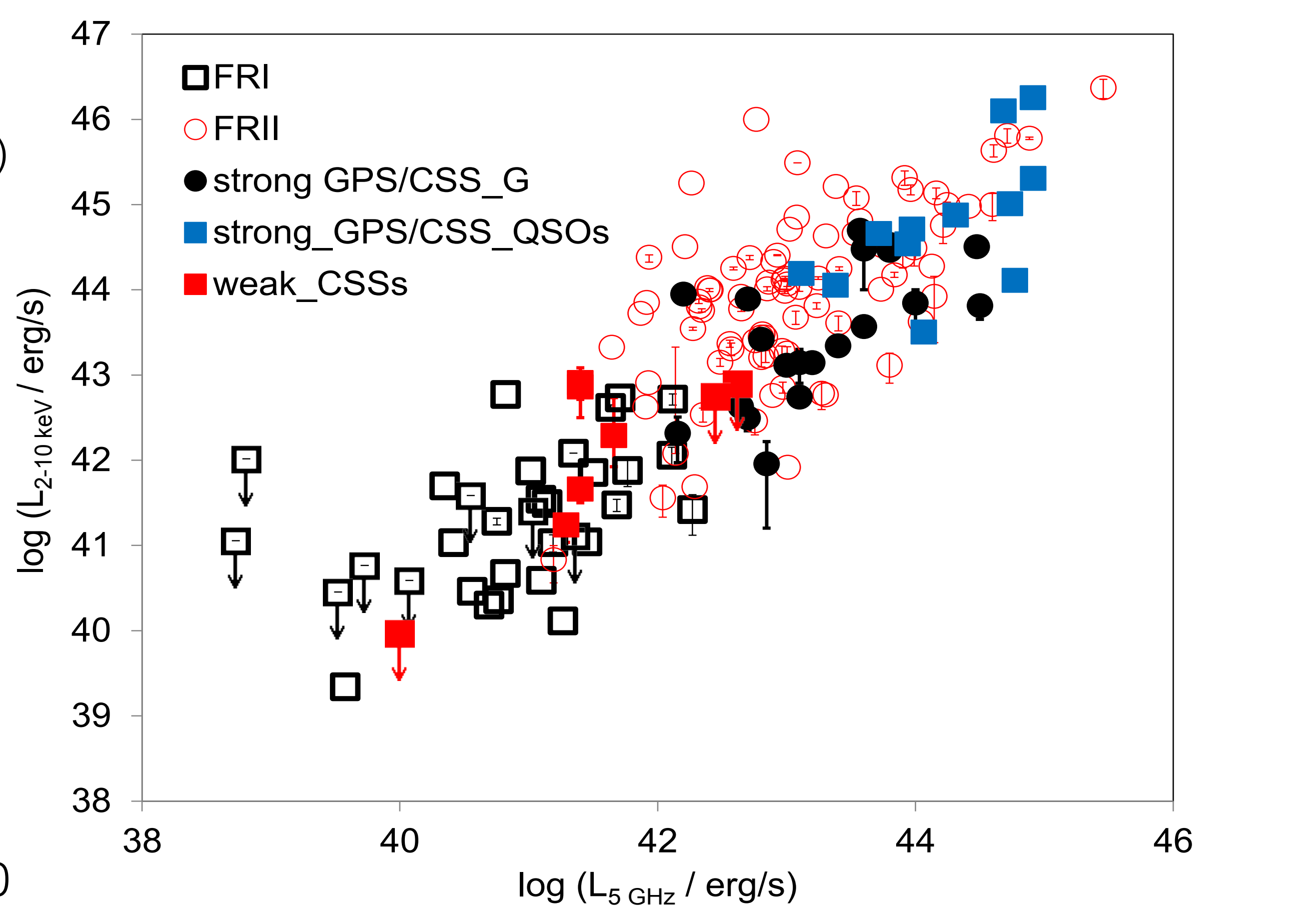
Low Luminosity Compact Sources:





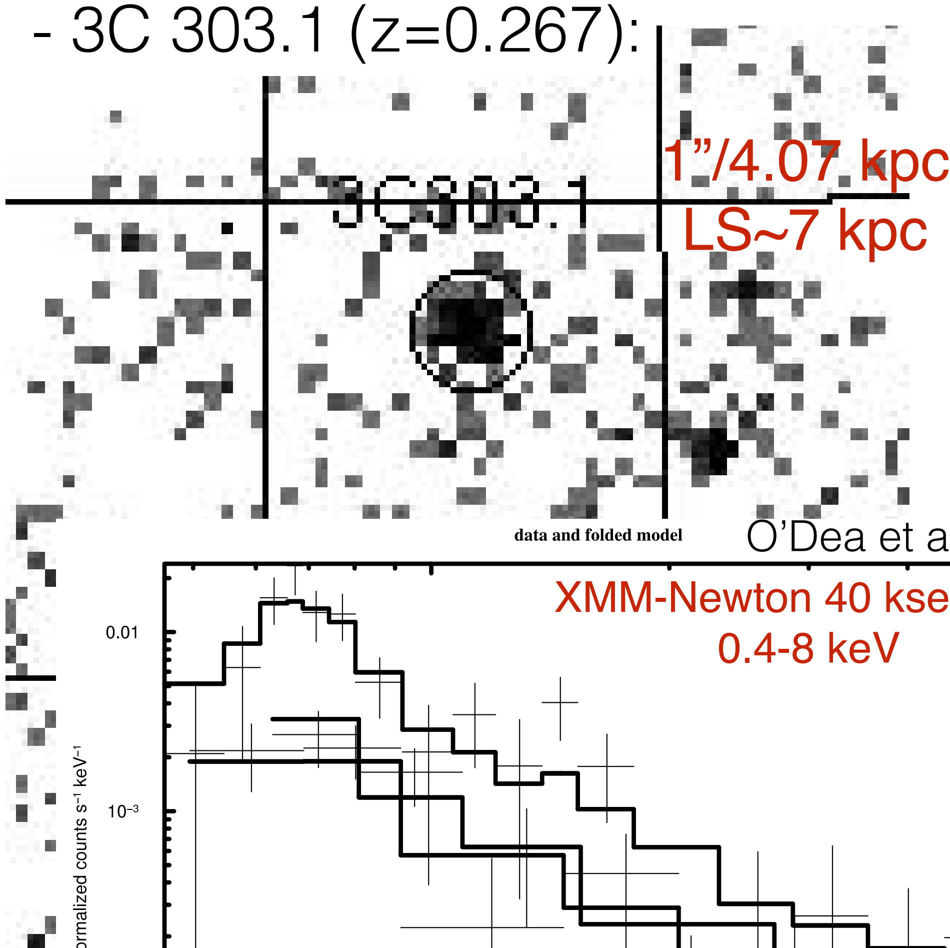
Kunert-Bajraszewska et al. (2010,2013)

- GPS/CSS radio galaxies & quasars occupy the same region of FR II radio sources;
- LCC have the same location of FR I sources

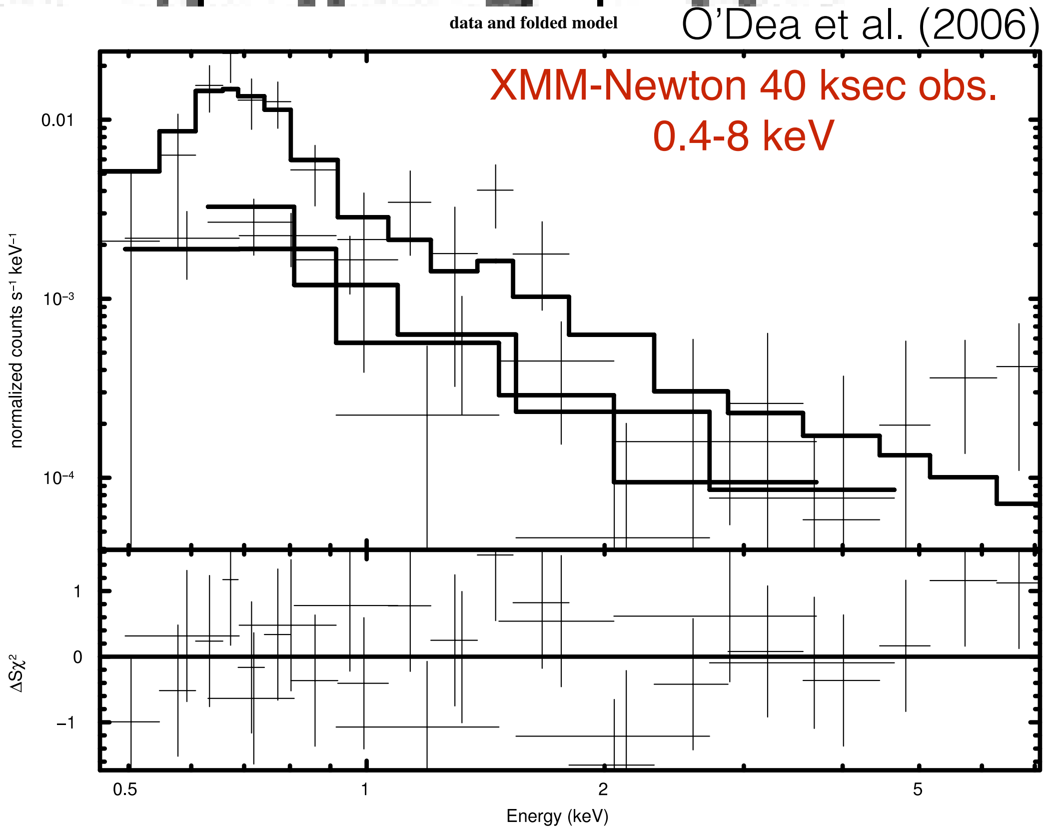


Radio Source - ISM interactions

- 3C 303.1 (z=0.267):

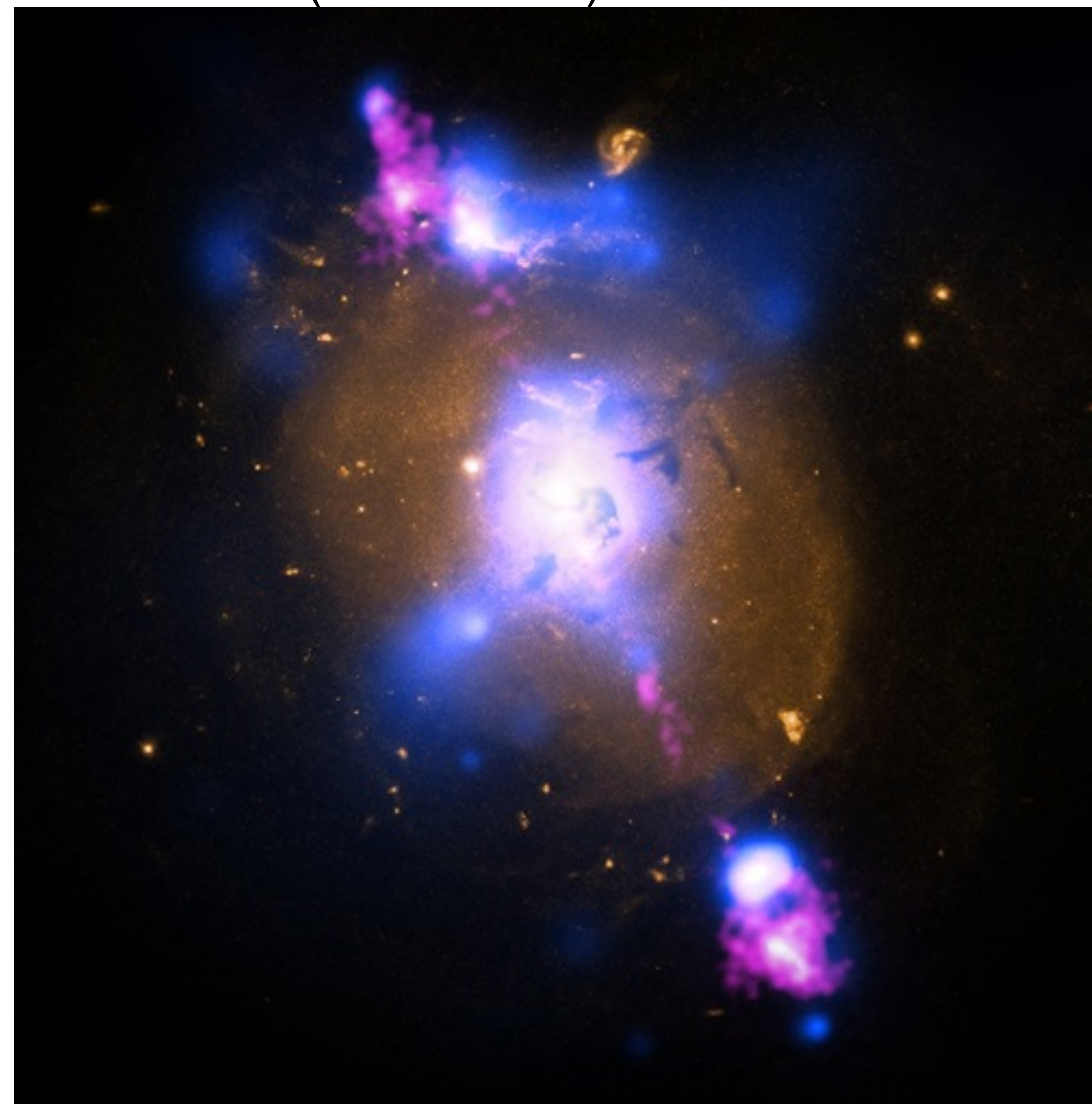


O'Dea et al. (2006)



Thermal emission (0.8 keV) from the host galaxy and signature of shocked hot gas emission?

- 4C29.30 (z=0.0647)



Siemiginowska et al. (2012)

Deep observations are needed to perform spectral and morphological X-ray studies

Radio Source - ISM interactions

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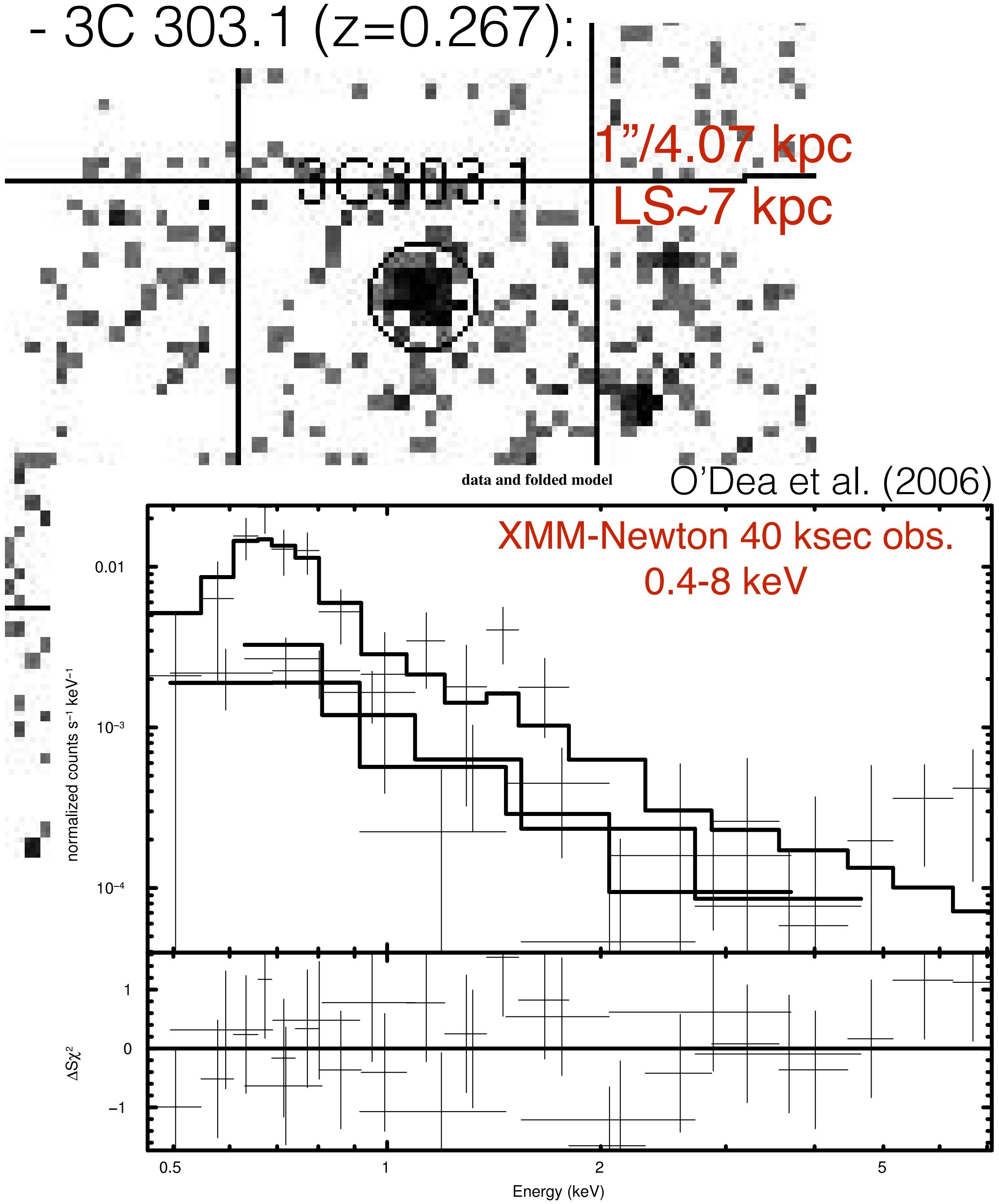

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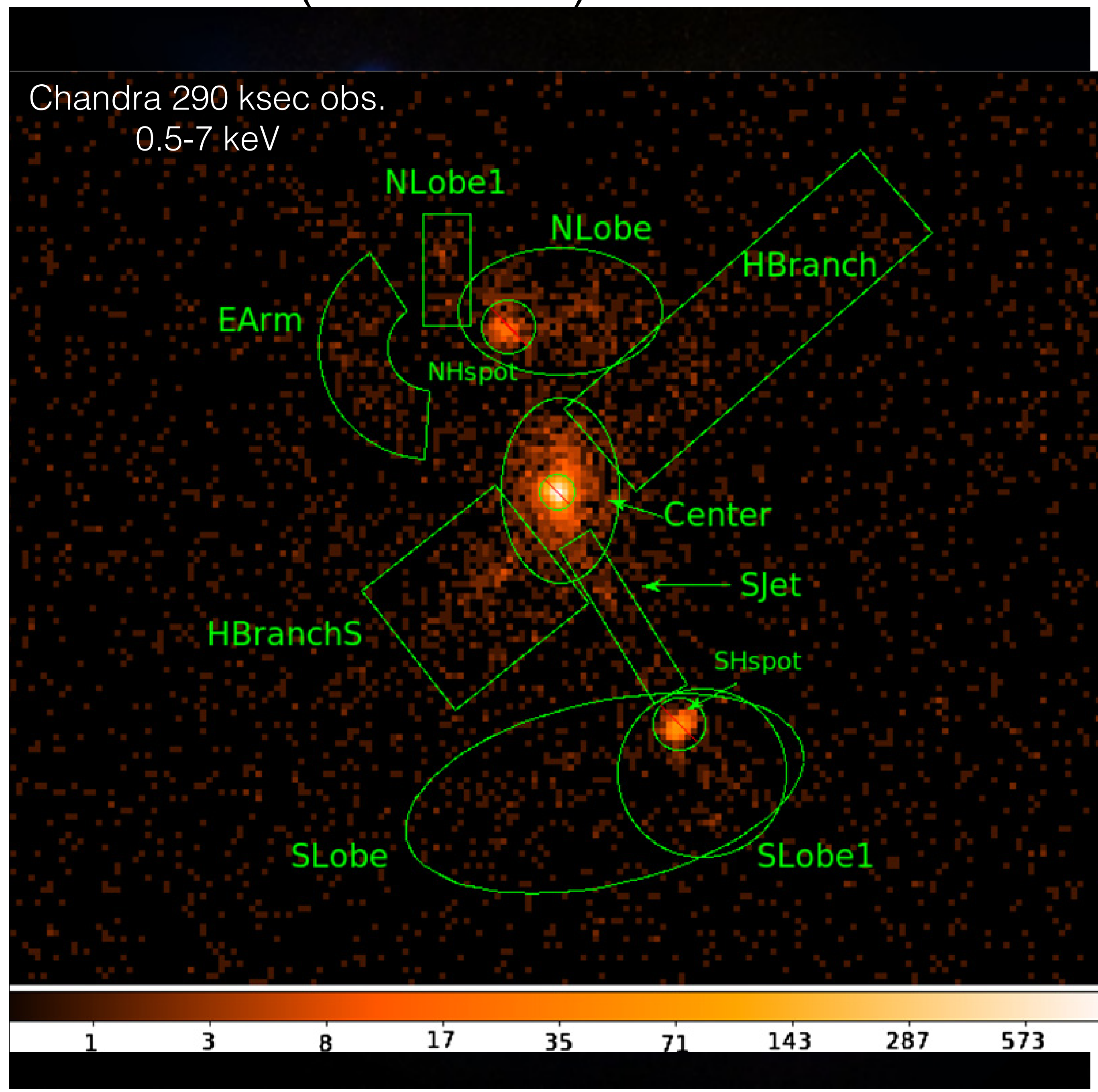
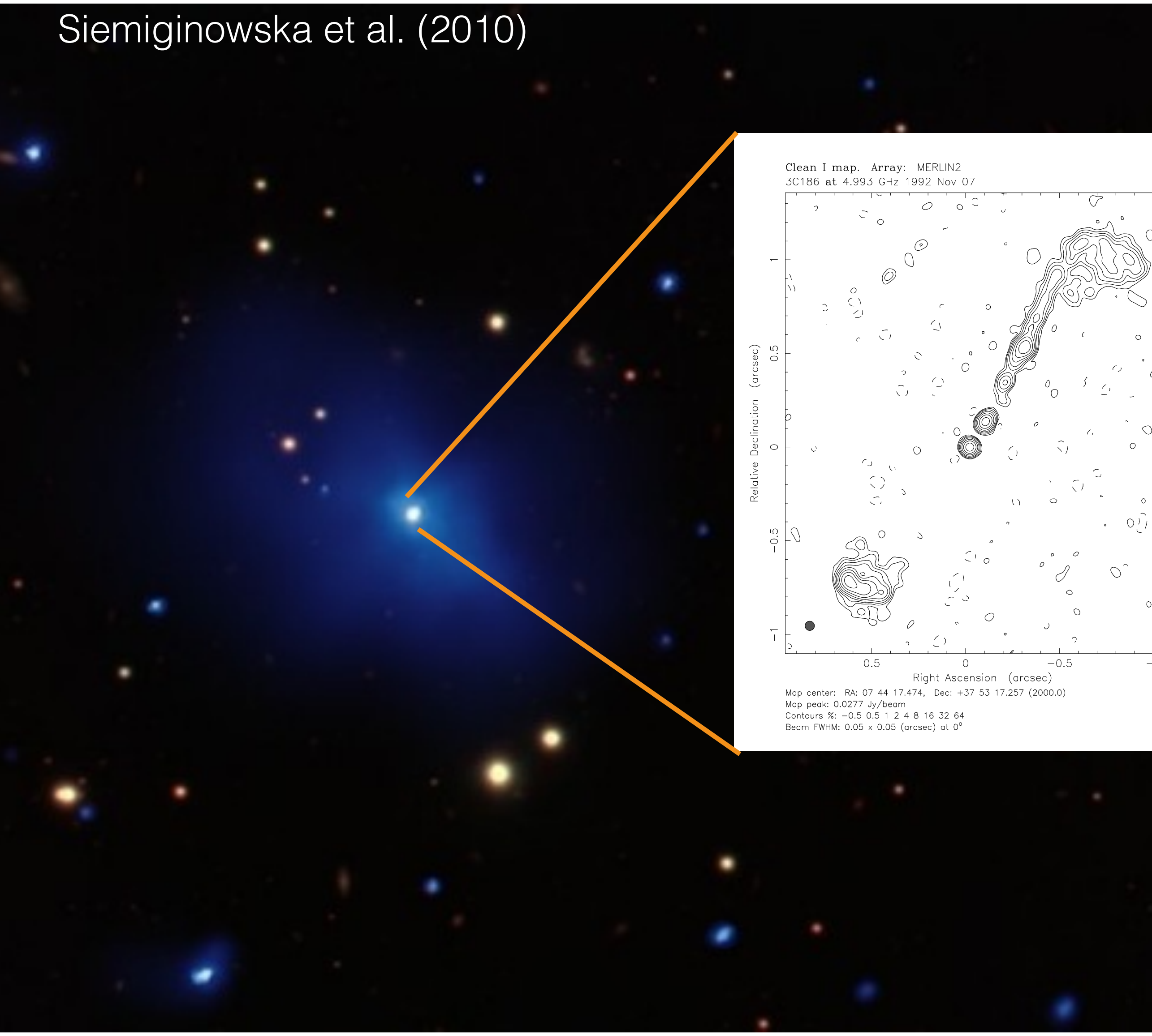


Siemiginowska et al. (2012)

Deep observations are needed to perform spectral and morphological X-ray studies

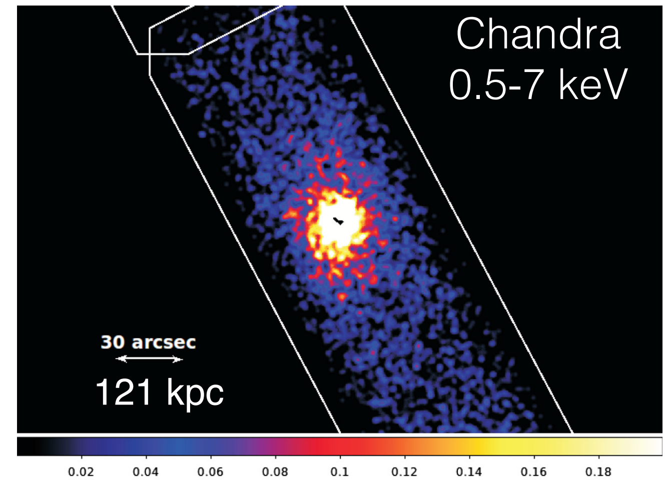
Young Sources in cool-core X-ray Clusters

- 3C 186 (z=1.06):

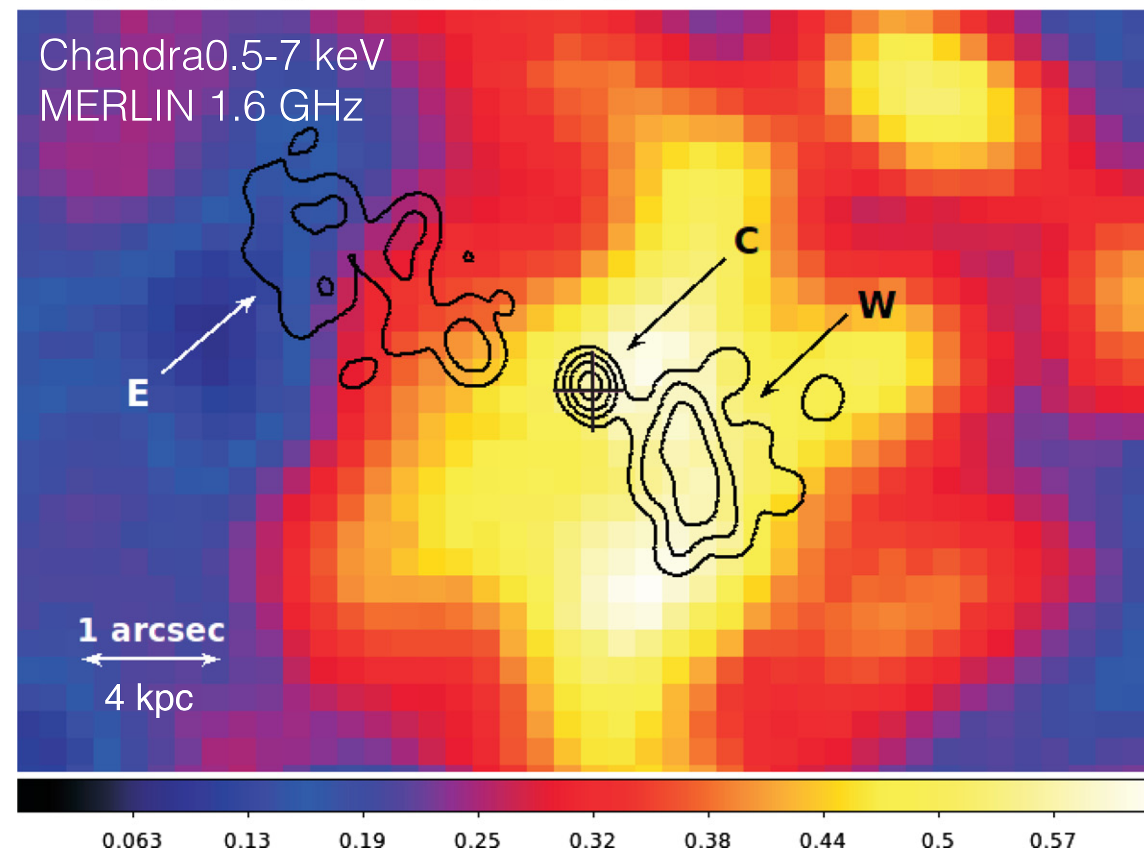


Luminous CSS with FRII like morphology in a high-z X-ray cluster: $L_{QSO,bol} > L_{jet}$, is radiative heating enough to prevent cooling in the cluster core?

- 1321+034 (z=263):



$L_{x,cl}=3\times10^{44}$ erg s^{-1}
<kT>=4.4 keV
$L_{5GHz,CSS}\sim10^{25}$ W Hz^{-1}
$L_{x,CSS}=3\times10^{42}$ erg s^{-1}



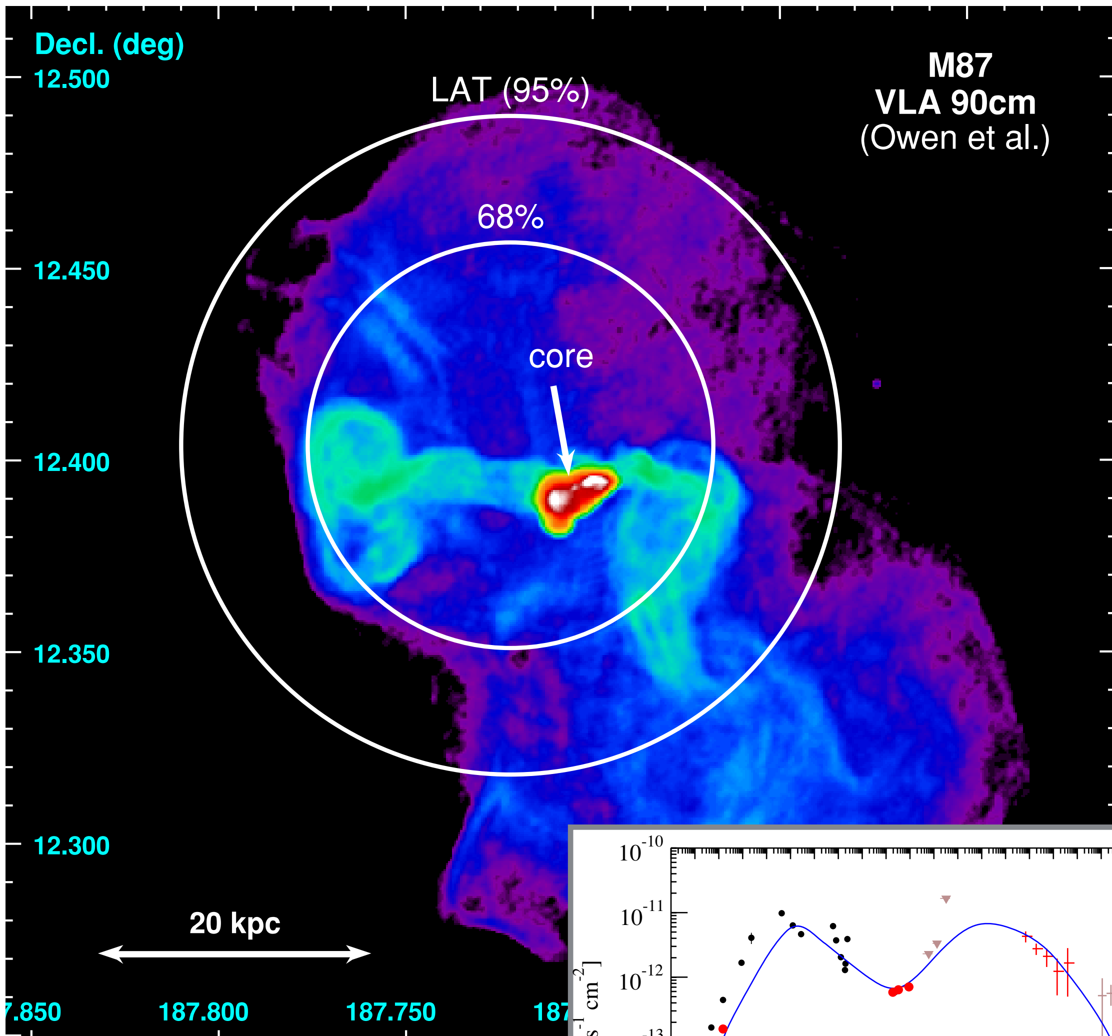
Kunert-Bajraszewska et al. (2013)

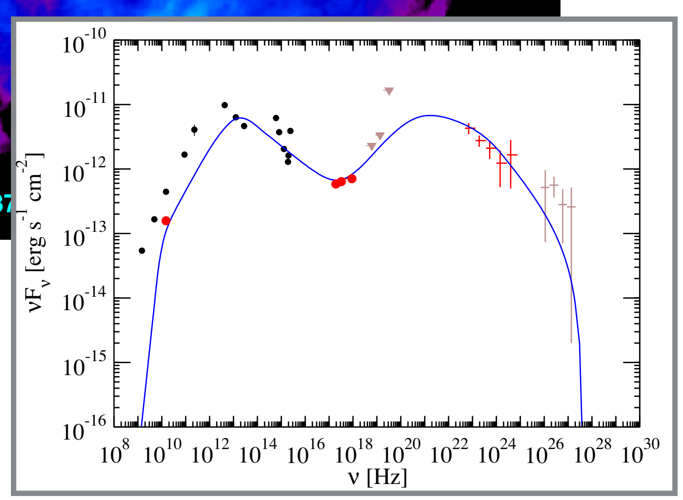
low power CSS LEG with FRI like morphology: no signatures of past radio activity in the cluster medium (cavities, shocks)

Gamma-rays

Misaligned AGN in γ-rays with Fermi-LAT:

γ-rays from the jet:

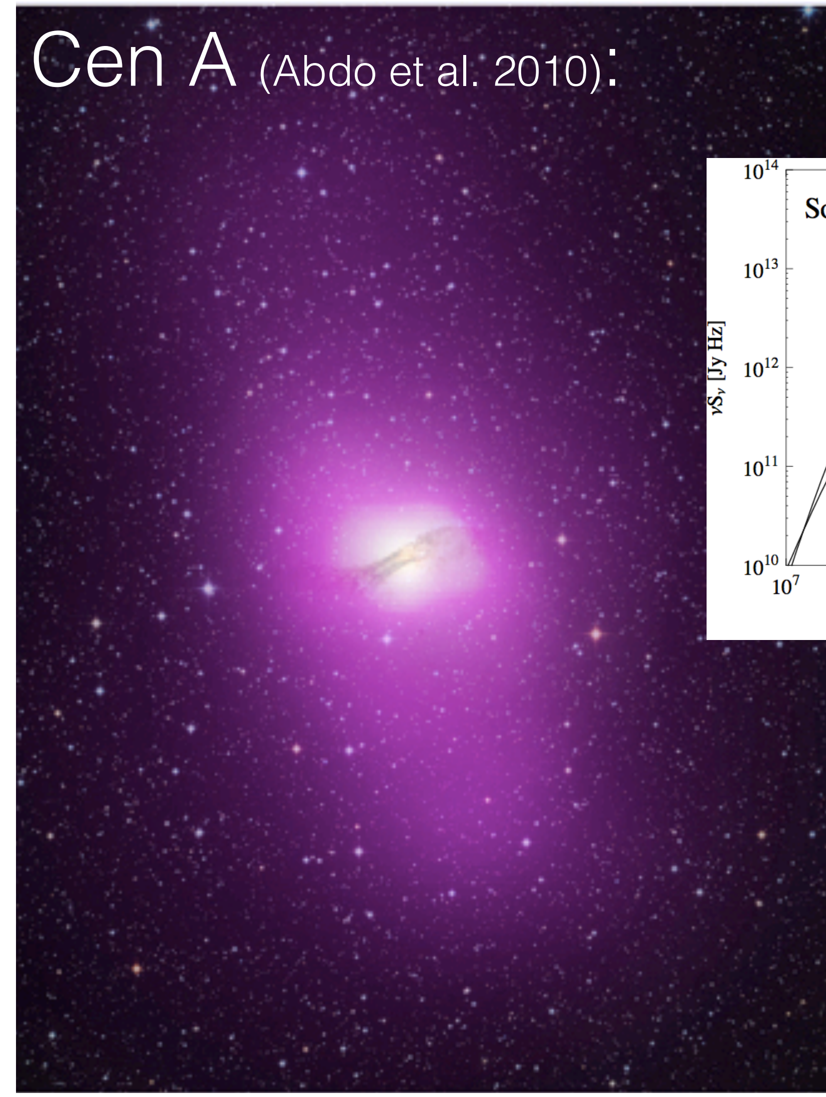


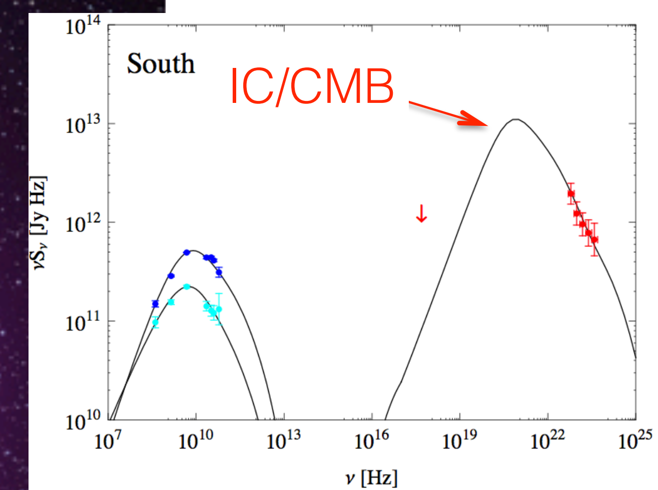


M87 (Abdo et al. 2009):

γ-rays from the radio lobes:

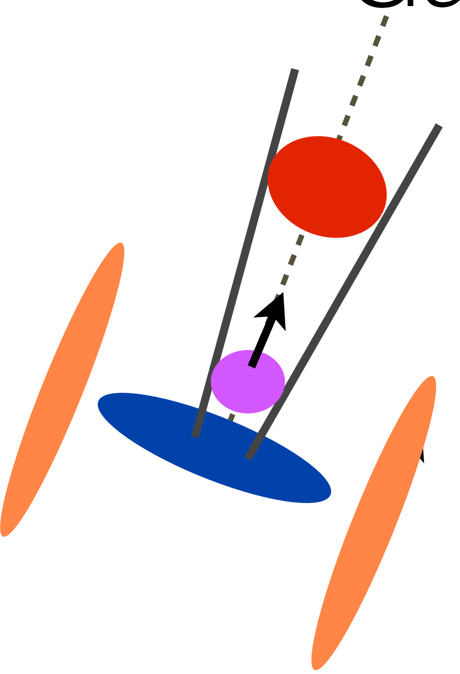
Cen A (Abdo et al. 2010):

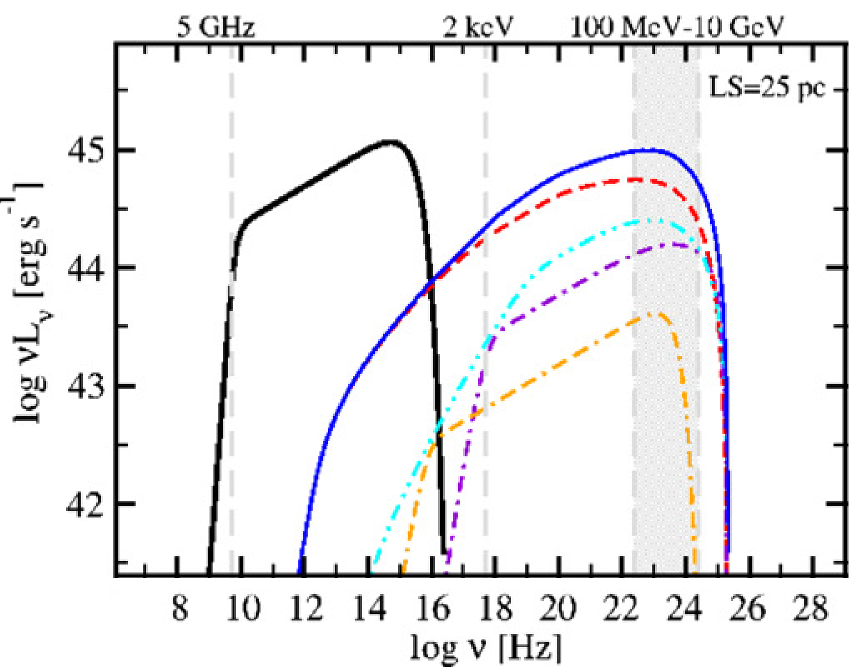


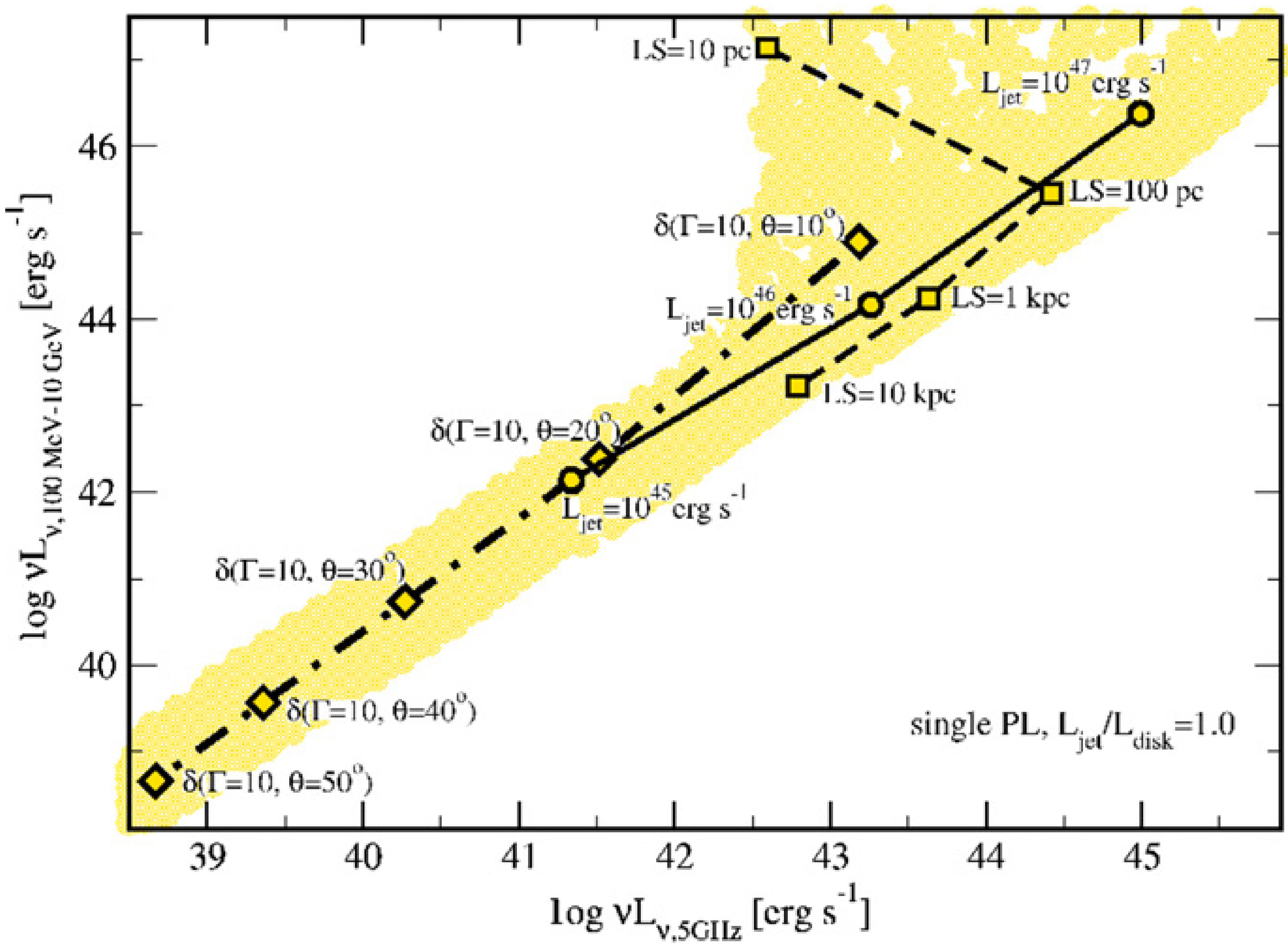


other candidates: Fornax A, Circinus galaxy

Gamma-ray emission in GPS and CSS quasars:

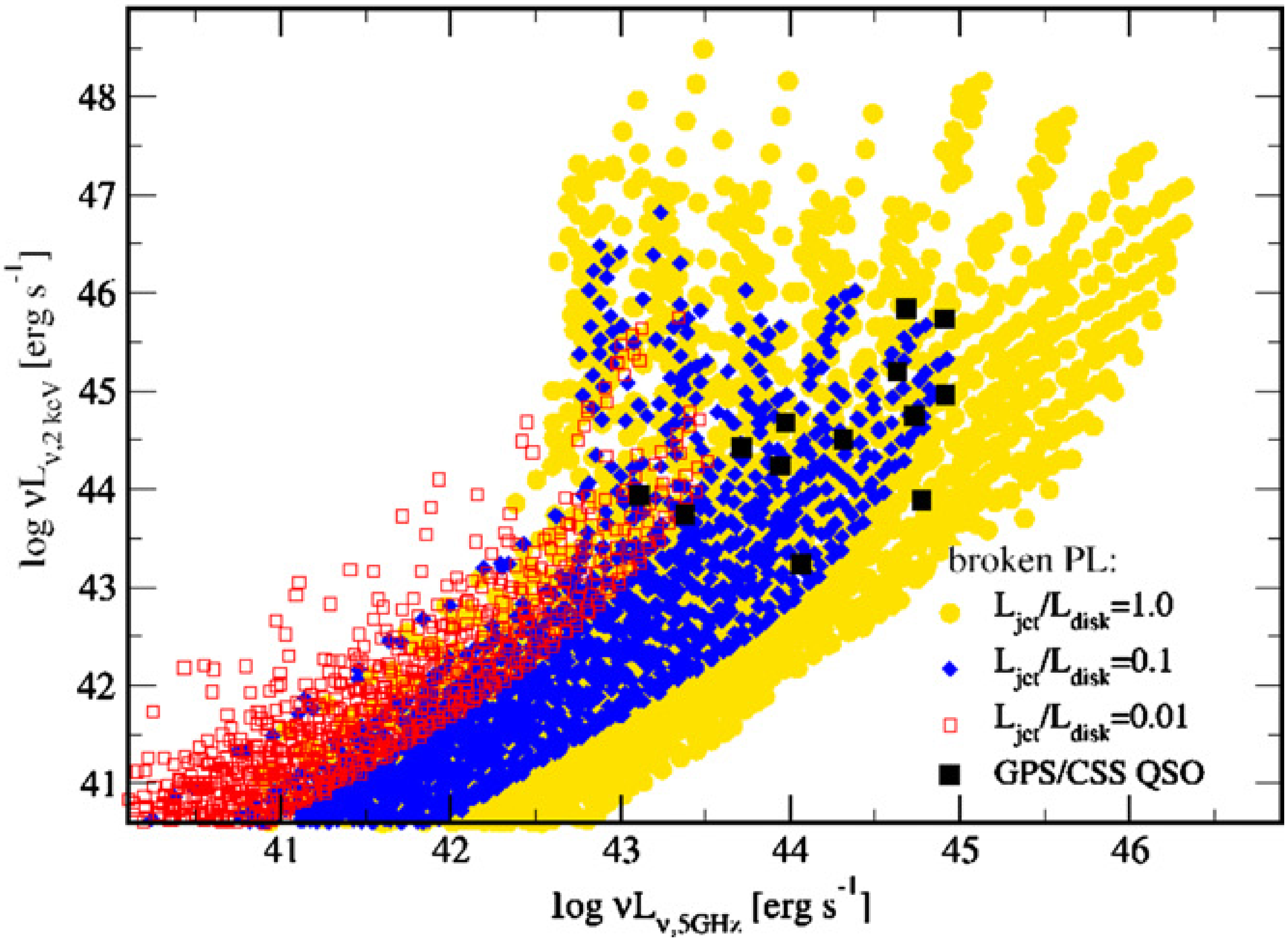






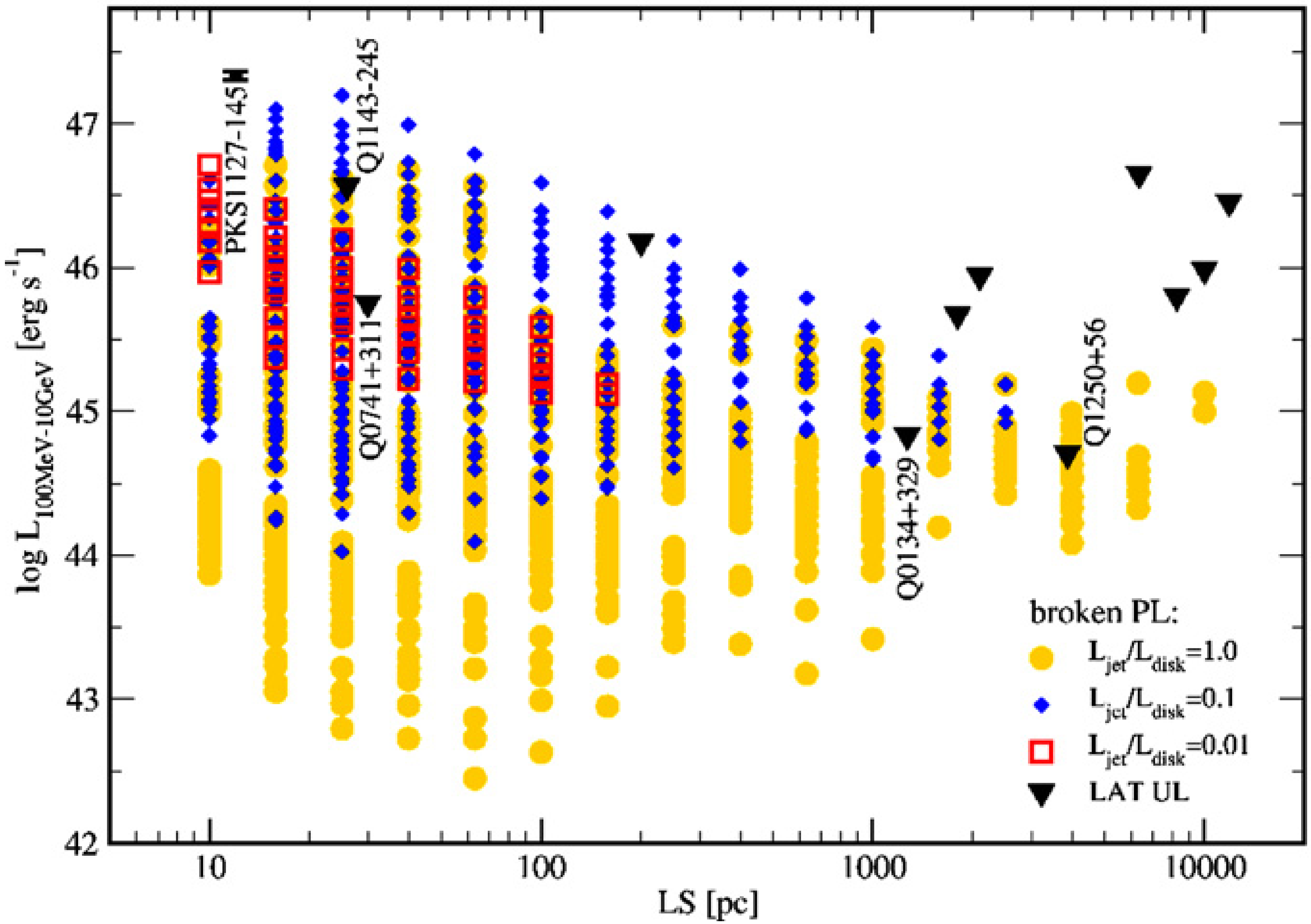
Jet SED are simulated for a distribution of linear sizes (LS), jet powers (L_{jet}), bulk motions (Γ_{bulk}) and jet inclinations (θ)

Gamma-ray emission in GPS and CSS quasars: predictions vs. observations



Simulated jets selected in the same luminosity range of the X-ray observed GPS/CSS sample ($L_{5GHz}=10^{43}\div10^{45}$ erg s^{-1}, $L_{2keV}=10^{43}\div10^{46}$ erg s^{-1}, $L_{Disk}=10^{45}\div10^{47}$ erg s^{-1})

Gamma-ray emission in GPS and CSS quasars: predictions vs. observations



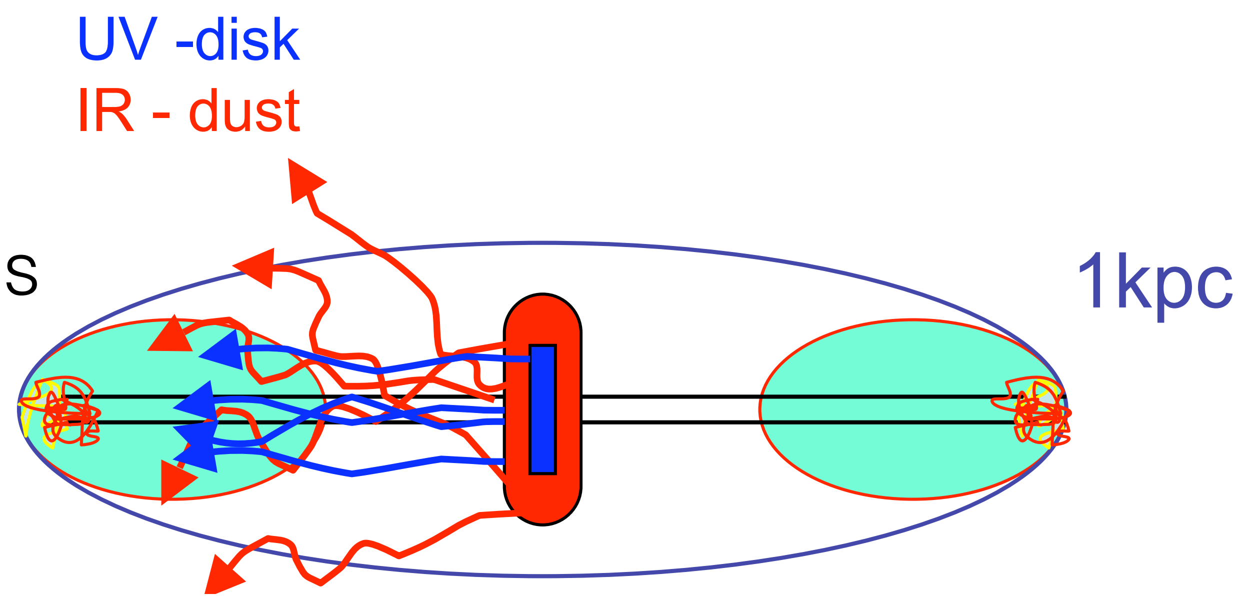
the model predicted γ-ray fluxes are still compatible with the Fermi-LAT upper limits (~4yrs data)

Are Young Radio Sources γ-ray emitters?

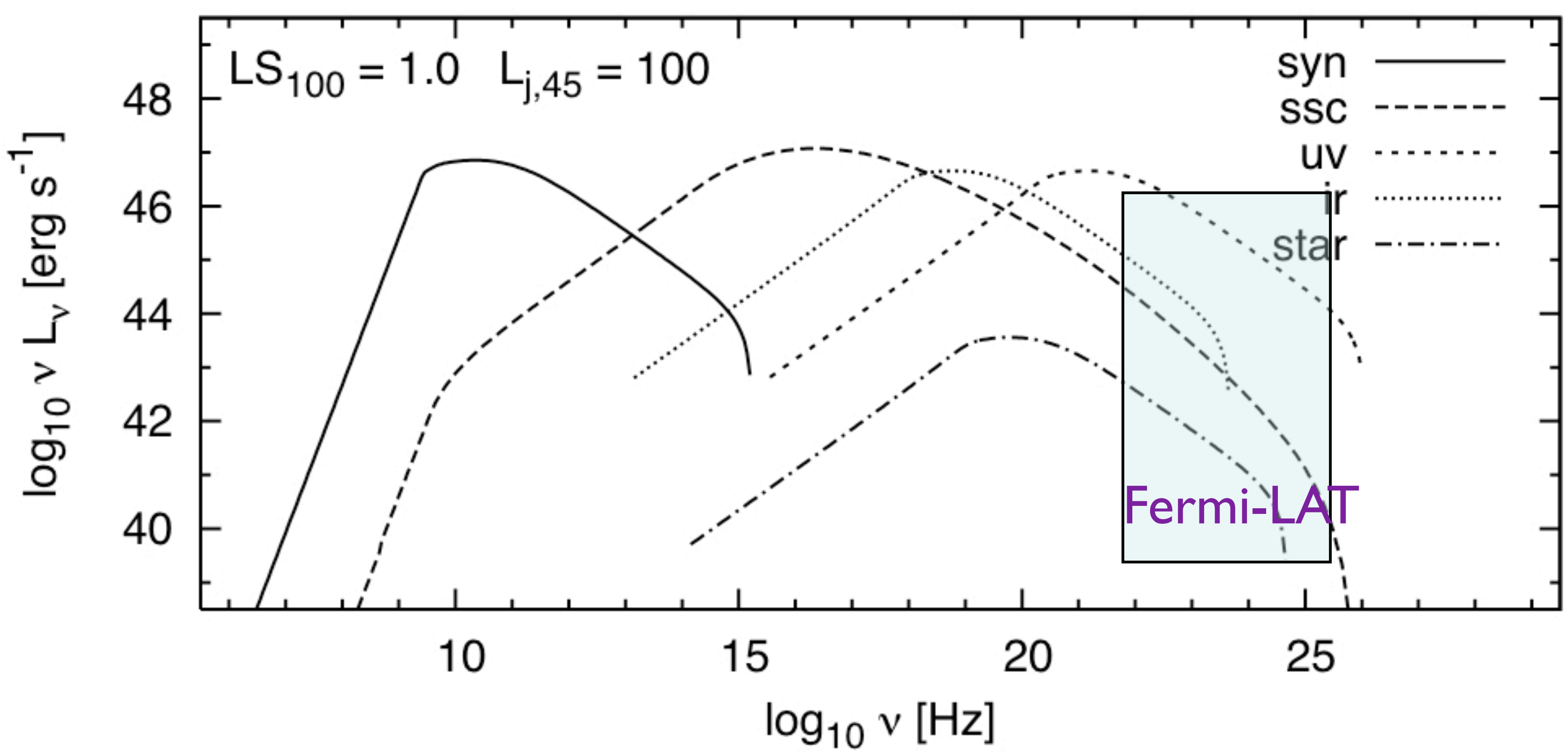
GPS radio galaxies and CSOs:

Theory:

non-thermal emission from the radio lobes in GPS/CSOs with linear sizes <1kpc



Stawarz+2008



alternative models: γ-ray from hadronic component in the lobes (Kino&Asano 2011) and GeV luminosities via bremsstrahlung from the cocoons (Kino et al.2009)

Are Young Radio Sources γ-ray emitters?

Observations:

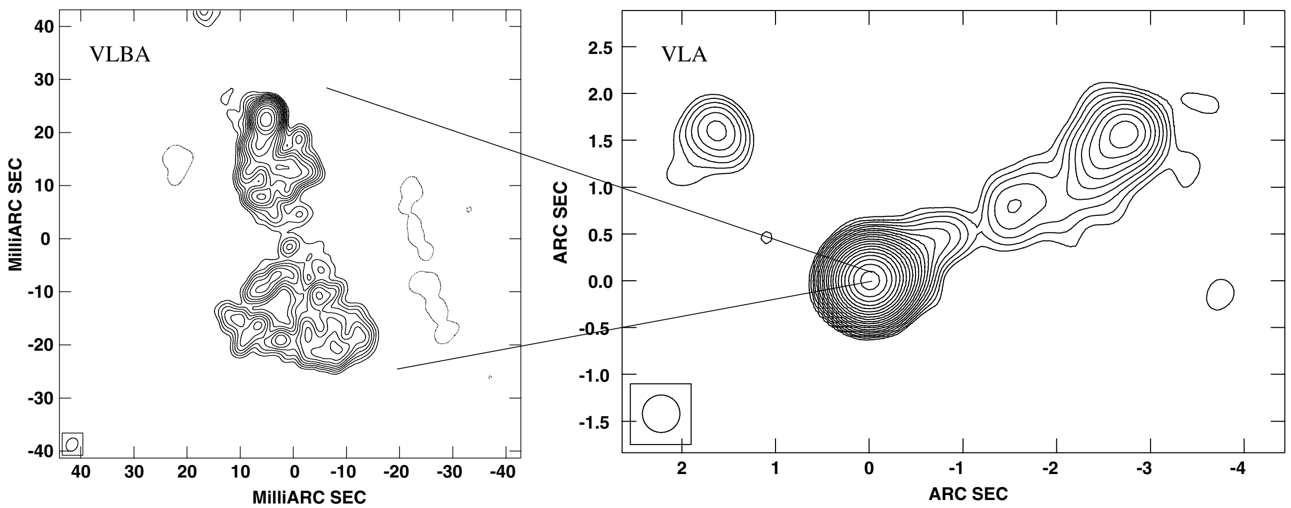
- 3rd Fermi-LAT AGN catalog: 2 γ-ray sources associated with CSS sources: 3C 286, 4C+39.23B (multiple associations), and a low power compact source (TXS 0331+39)

- 16 CSOs of the X-ray sample: no clear detection in 5 yrs of Fermi-LAT data except for the case of PKS 1718-64 (Siemiginowska et al. in prep.)

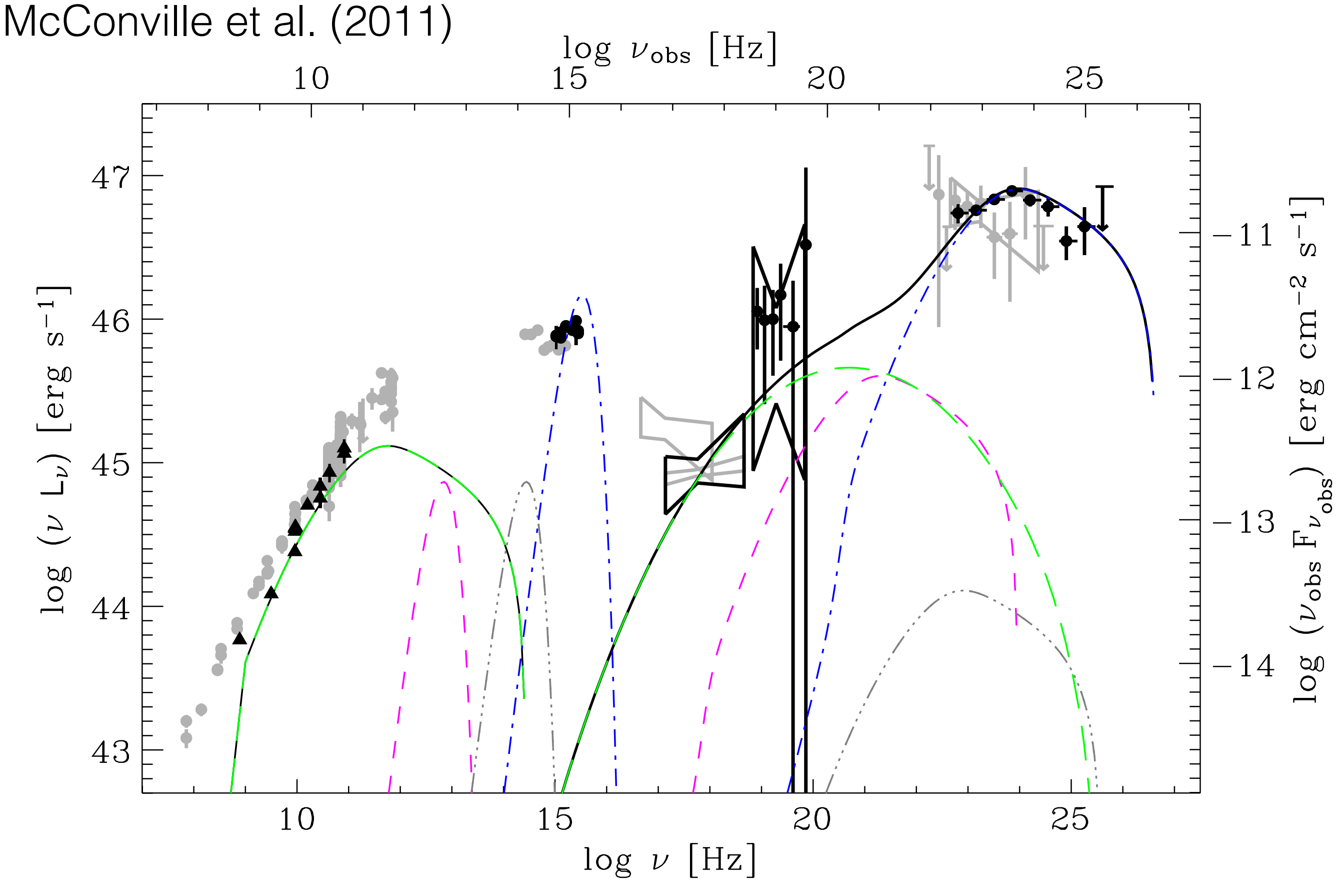
- PKS 1718-64 preliminary LAT analysis: TS~14, variable over year timescales.

LAT sources with a CSO small-scale structure

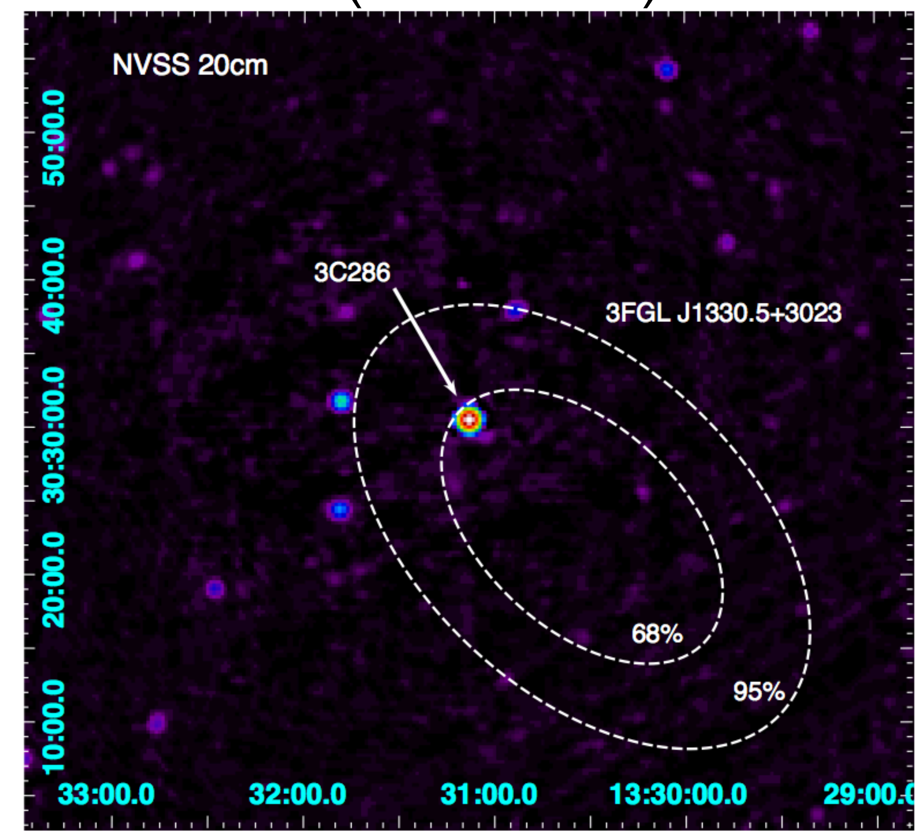
- 4C +55.17 (z=0.896):

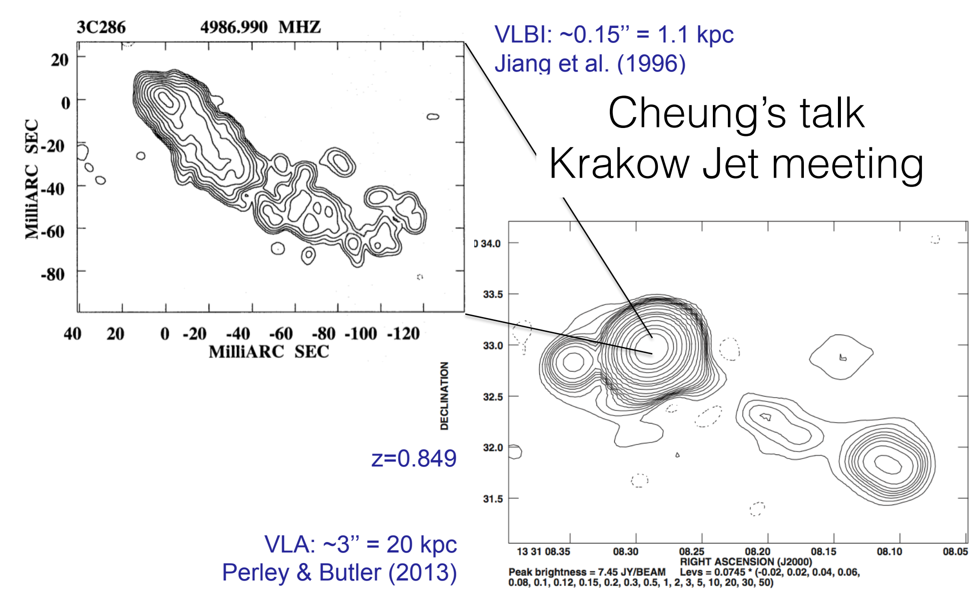


McConville et al. (2011)



- 3C 286 (z=0.849):





VLBI: ~0.15" = 1.1 kpc
Jiang et al. (1996)

Cheung's talk
Krakow Jet meeting

z=0.849

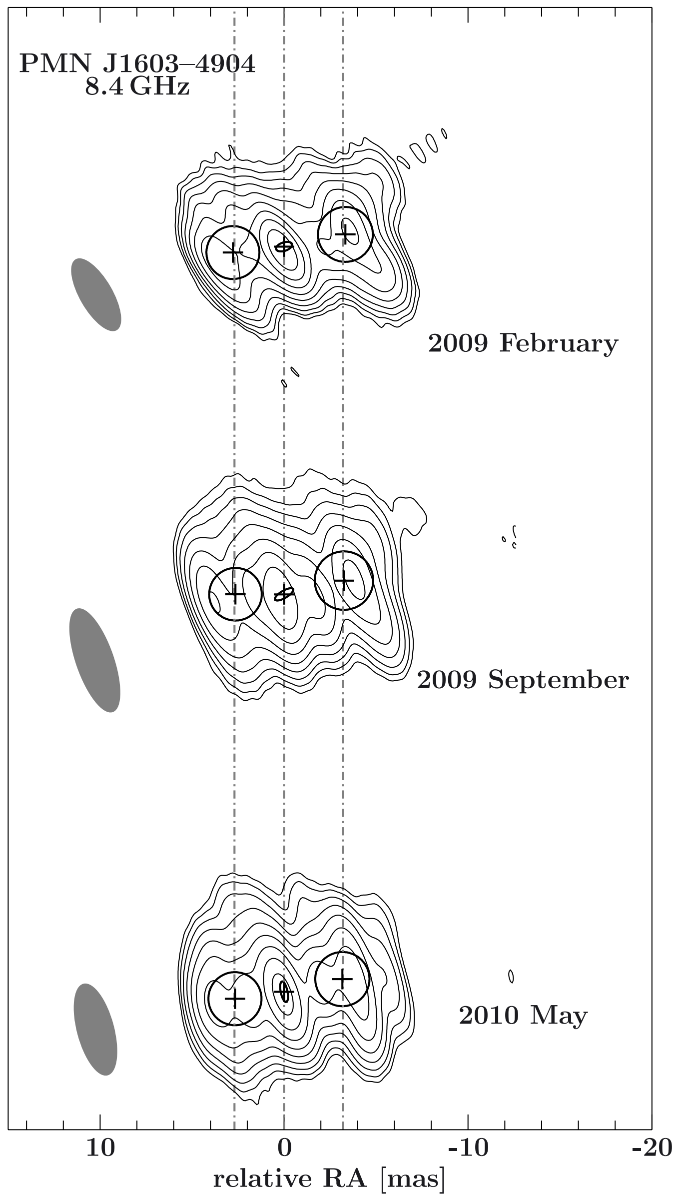
VLA: ~3" = 20 kpc
Perley & Butler (2013)

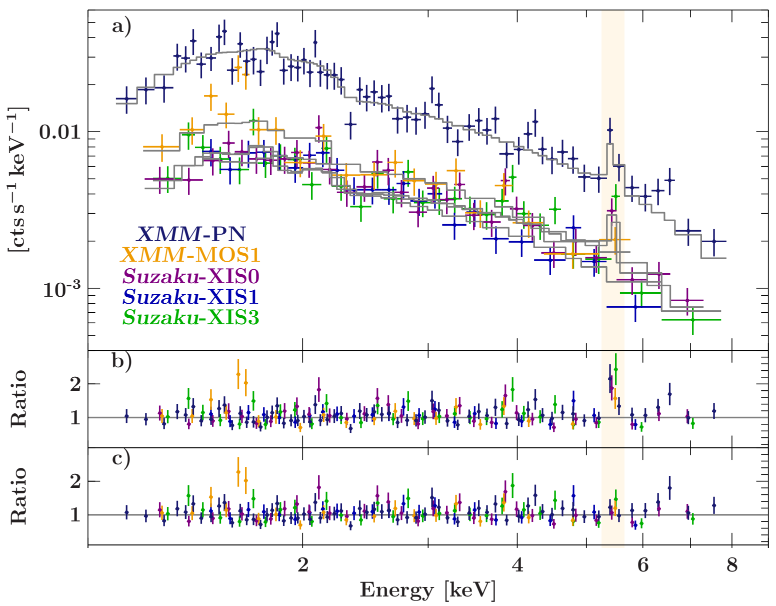
Is the γ-ray emission produced in the mini-lobes?

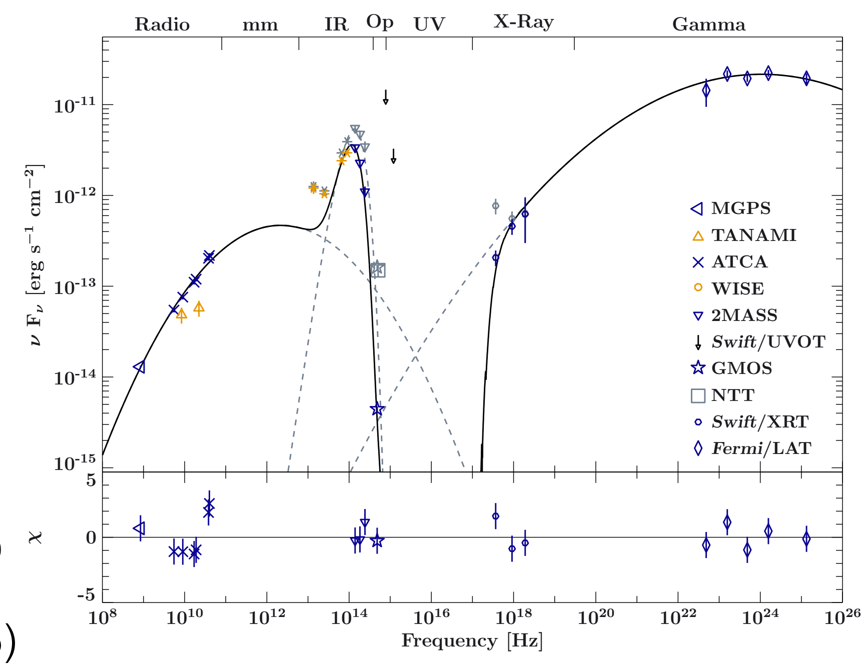
LAT sources with a CSO small-scale structure

- PMN J1603-4904 (z=0.18):

- γ-ray bright and hard spectrum;
- no short term/flaring variability;
- mas symmetric radio structure;
- Fe Kα line detection.







Müller et al. (2014,2015)

Why do we detect γ-ray emission only from CSO-like sources but not from CSOs?

γ-ray emission from small/restarted jets: see Nagai's talk on 3C 84

Summary & Future Perspectives

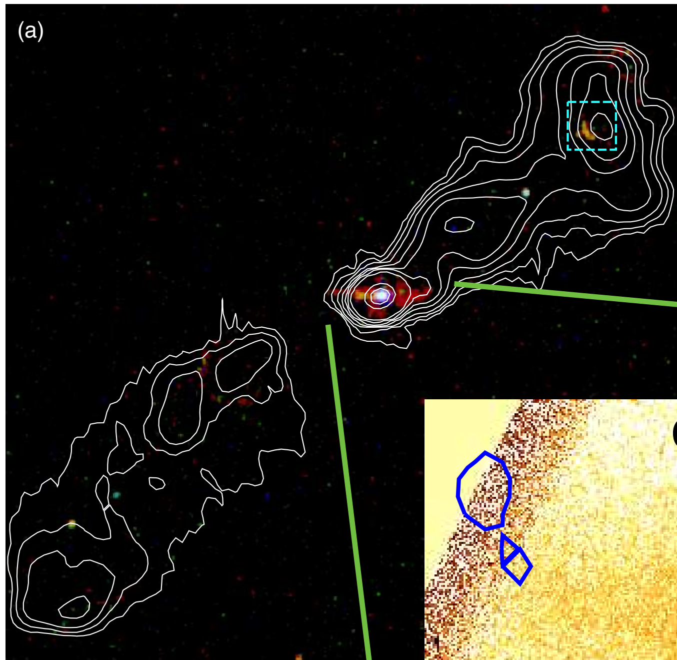
X-rays:

- Drastic increase of X-ray detections of young sources;
- Snapshots & short observations are good to define the basic X-ray properties of young radio sources as a class;
- Deep observations are needed in particular to investigate the source-environment interactions;
- X-ray observations of CSOs and LLC sources are necessary to understand the evolutionary path of extragalactic radio sources;

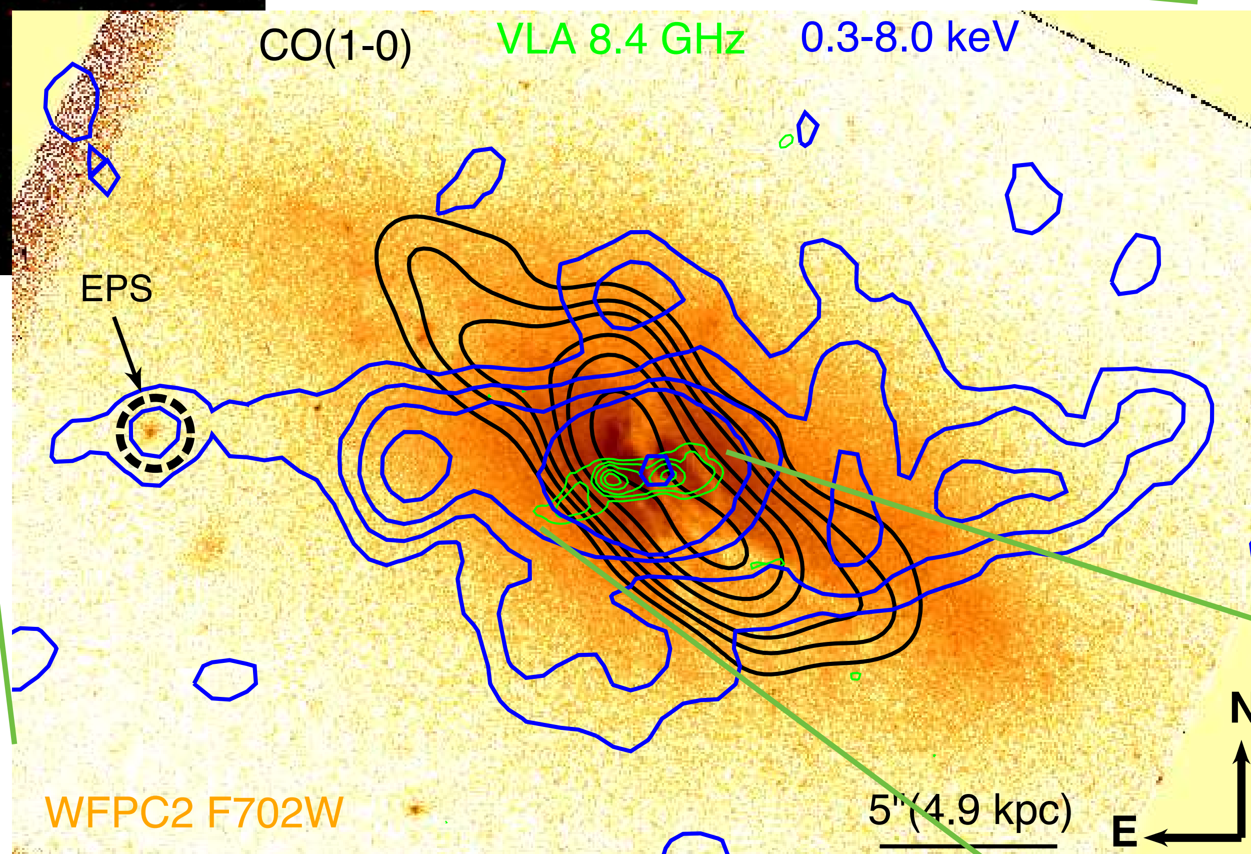
Gamma-rays:

- Still no detection of a young source but I’m looking forward to hear news from the next talks!
- waiting for CTA ?

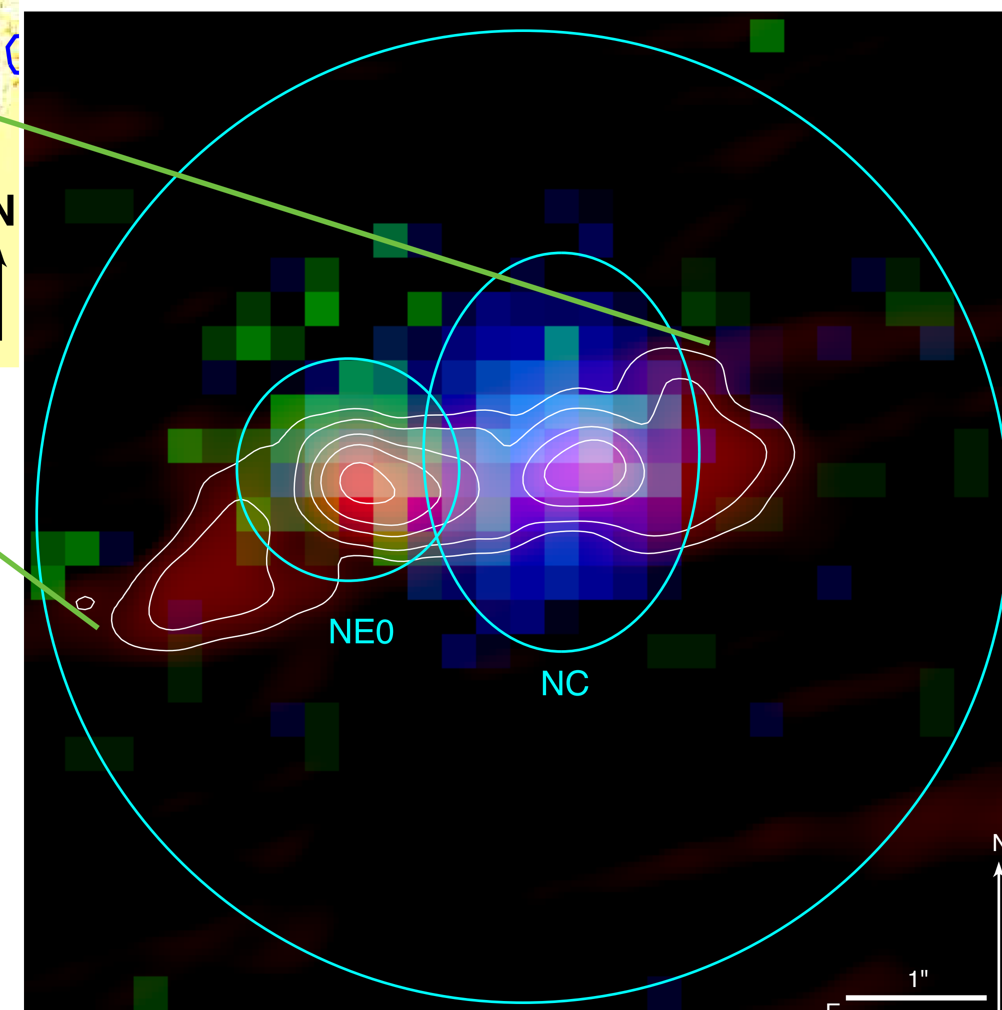
Radio Source - ISM interactions



3C 293 (z=0.045): thermal X-ray emission from jet-shocked ISM

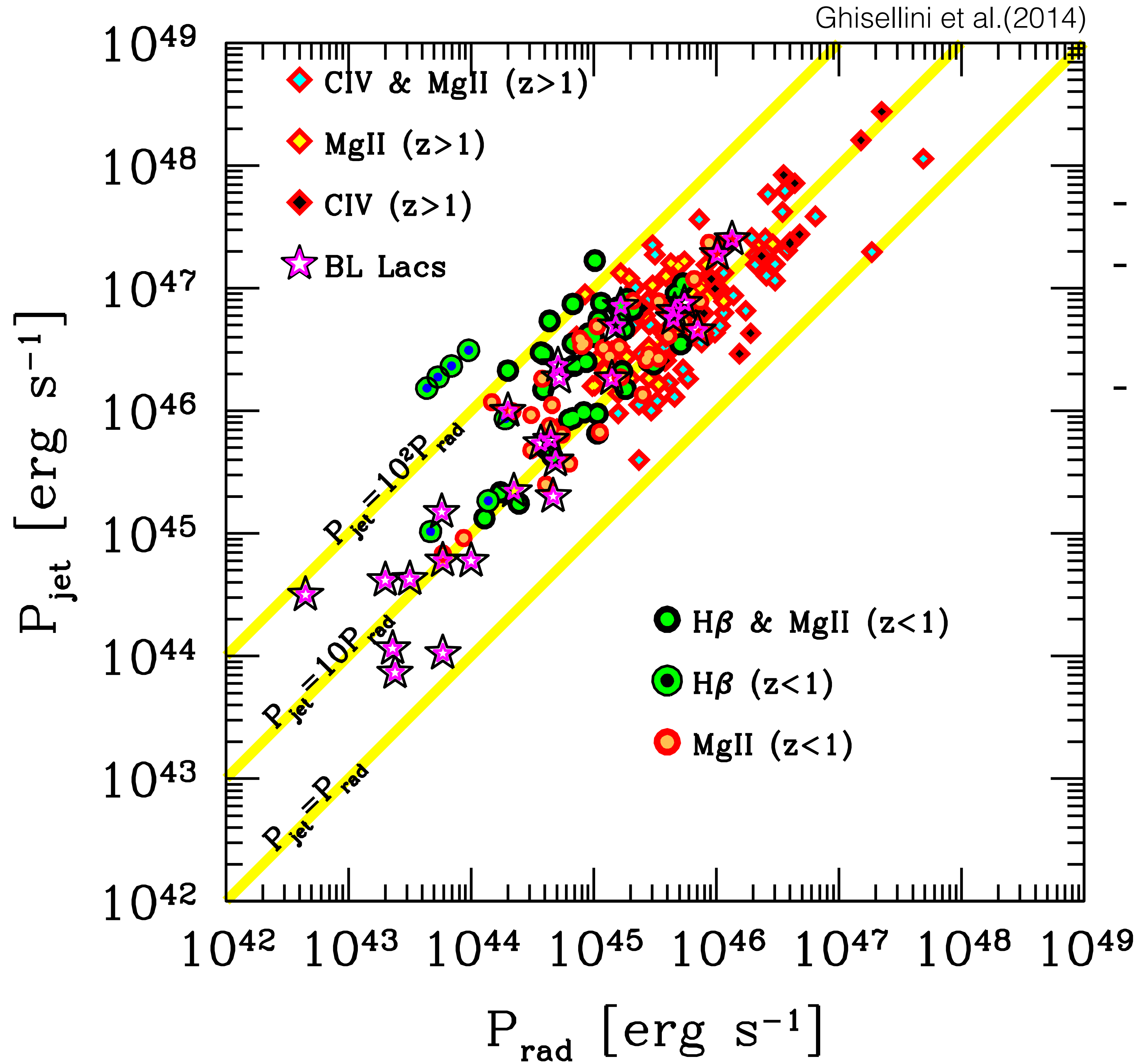


Lanz et al. (2015)



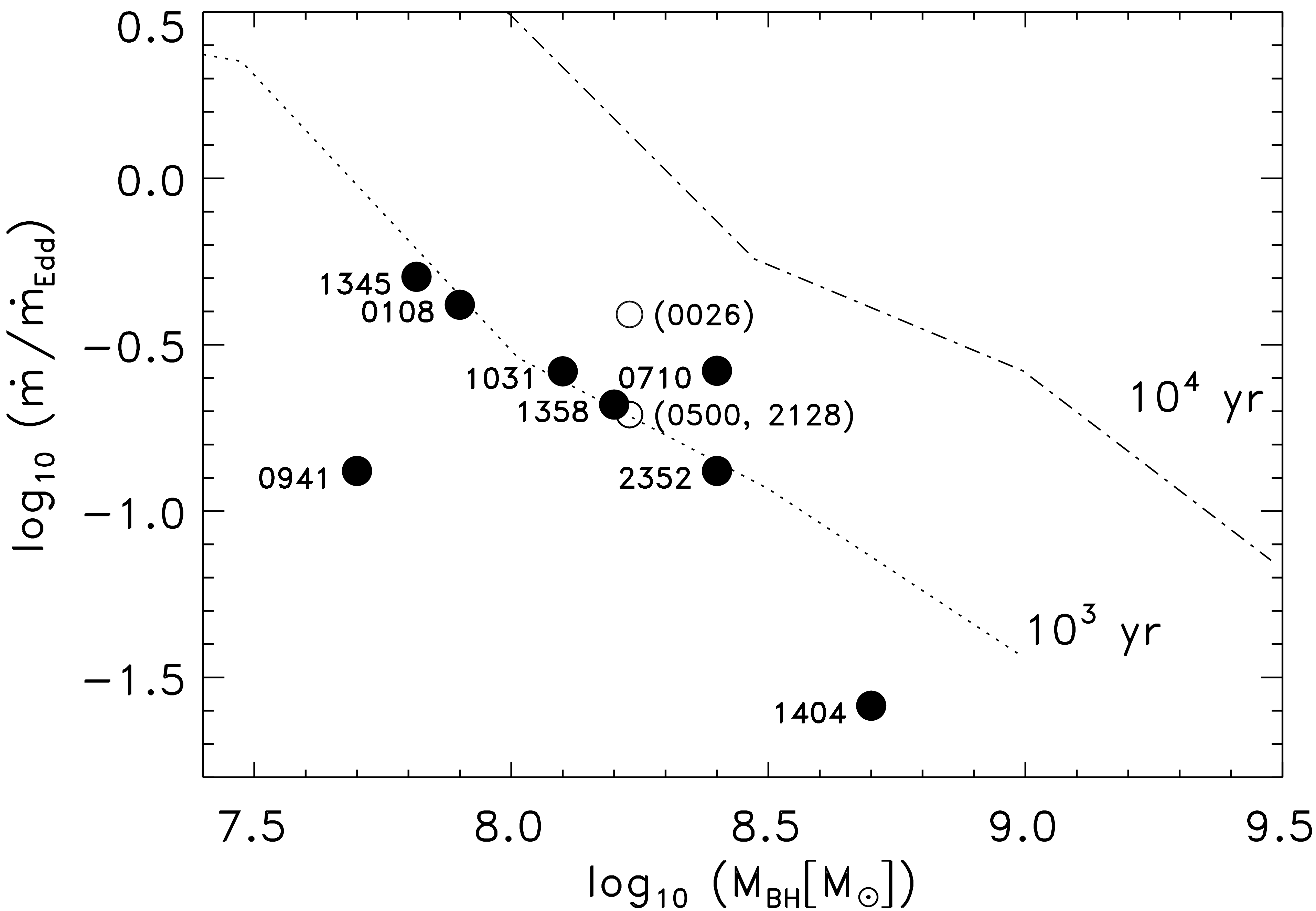
The jet powers both the hot X-ray gas (10^7 K) and warm molecular medium (H_2), which have similar masses and luminosities (L_X/L_{H2}~1)

Jet vs. Disk Power



- In γ-ray blazar L_{jet}/L_{disk}~10;
- in GPS/CSS galaxies, lobe model: L_{jet}/L_{disk}~0.01-0.1;
- in GPS/CSS quasars, jet model: L_{jet}/L_{disk}>0.01

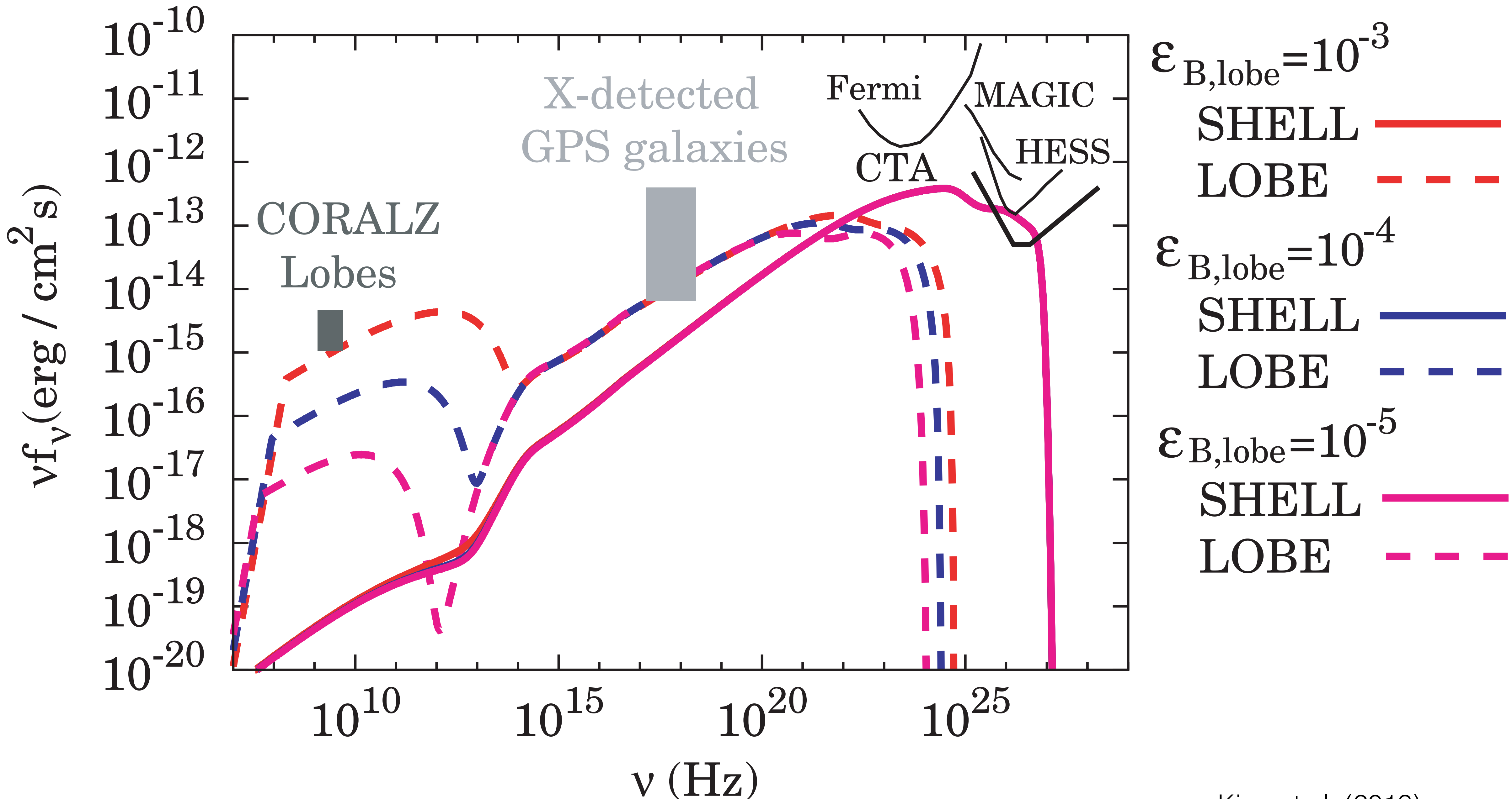
GPS/CSOs Eddington ratios:



Values are above the threshold for pressure instabilities being active in accretion disk: intermittent disk outburst

Young Radio Sources with CTA

Predictions for γ-ray IC emission from mini-shells around the lobes:

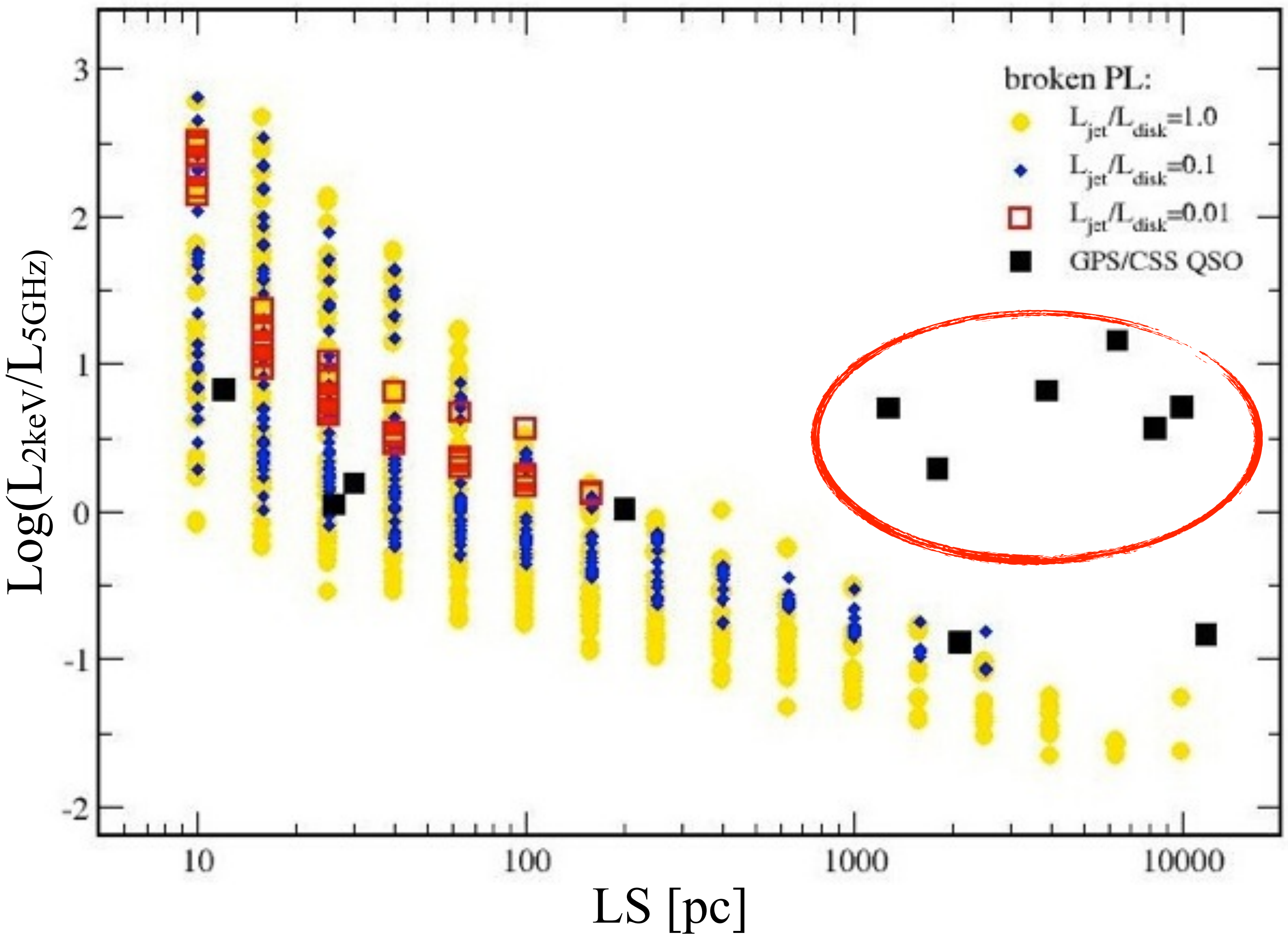


Kino et al. (2013)

Observations vs Simulations: X-ray

Simulated jets in the same luminosity range of the observed sample

($L_{5GHz}=10^{43}\div10^{45}$ erg s^{-1}, $L_{2keV}=10^{43}\div10^{46}$ erg s^{-1}, $L_{Disk}=10^{45}\div10^{47}$ erg s^{-1}):



LS vs L_{2keV}/L_{5GHz}: above LS~1 kpc, the modeled jet emission cannot account for the observed X-ray luminosity

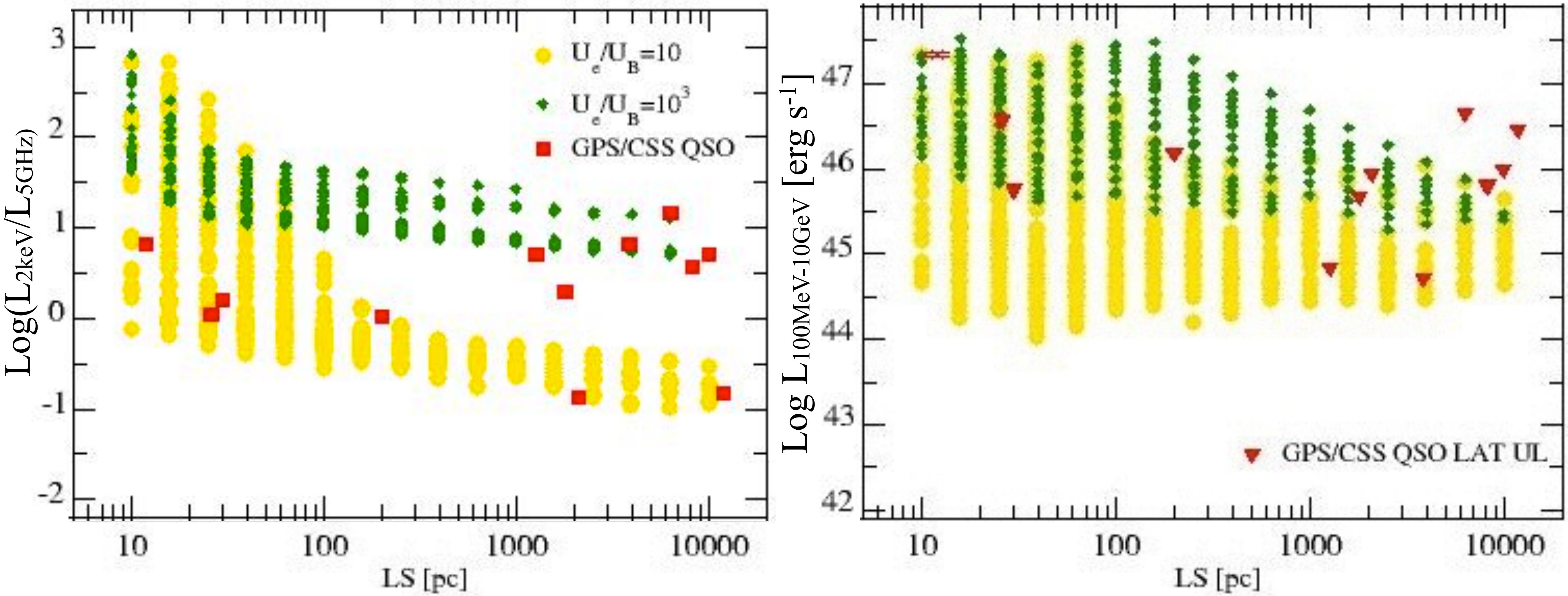
possible explanations:

- the bulk of the X-ray emission is always produced at jet small scales;
- there is an additional X-ray component (e.g. disk-corona emission)

U_e to U_B ratio

Data vs. simulations discrepancy holds true for different parameter values and model assumptions:

large departure from particle to B field energy equipartition:



Assuming $U_e/U_B \geq 1000$:
- the jet X-ray emission increases to the observed intensities;
- γ-ray luminosities above the LAT sensitivity limit would make a detection likely.