Synergic *Swift*-IXPE study of Blazars

Alessandro Paggi[1,2]

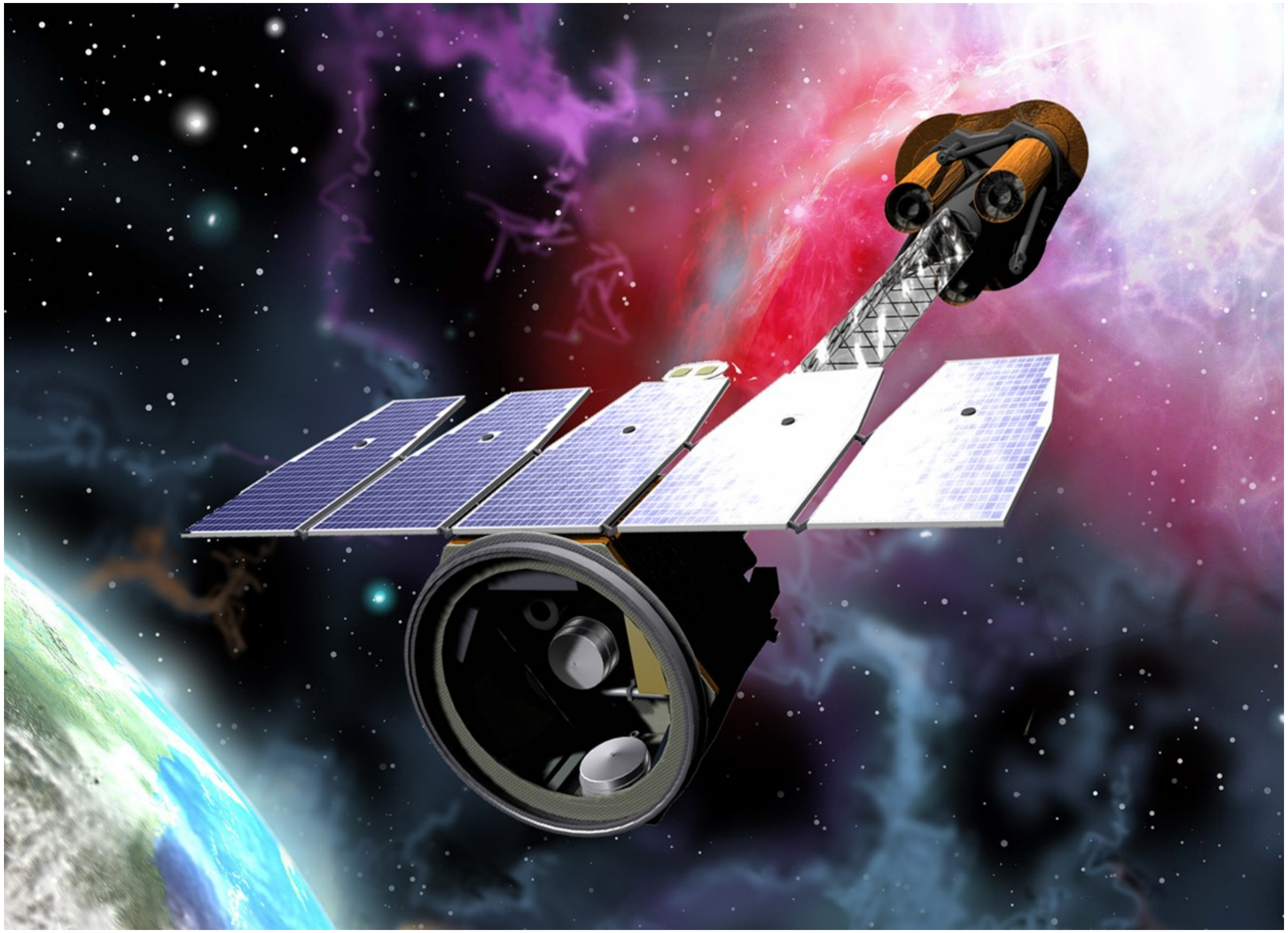
C. Raiteri[1], F. Massaro[1,2,3,4], IXPE Collaboration

[1]INAF-Osservatorio Astrofisico di Torino
[2]Istituto Nazionale di Fisica Nucleare - Sezione di Torino
[3]Dipartimento di fisica - Università di Torino
[4]Consorzio Interuniversitario per la Fisica Spaziale (CIFS)

AstroFit 2 3rd Annual Meeting - 15-16/10/2019

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 664931.

IXPE



Imaging **X**-Ray **P**olarimetry **E**xplorer (PI: M. C. Weisskopf)

- Launch data: April 2021
- Baseline duration: 2 years
- Galactic BHs, NS, AGN…

- ASI, INAF, INFN:
  - Detector Unit
  - Track reconstruction algorithm
  - Malindi Ground Station

Blazars

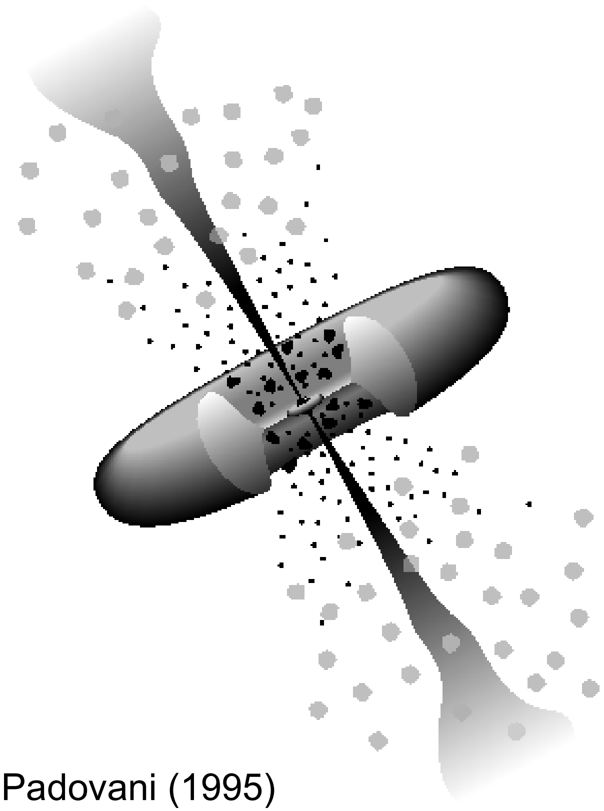
Radio-loud sources, high and variable (stochastic) polarization, superluminal motion, high luminosities, intense / rapid variability → jet aligned with l.o.s. within a few degrees (e.g., Blandford & Rees 1978; Begelman et al. 1984; Königl 1986),

FSRQs:

- $L_{iso} \leq 10^{48}$ erg/s
- flat R
- broad lines, BBB
- # / L peaks at z ~ 2.5

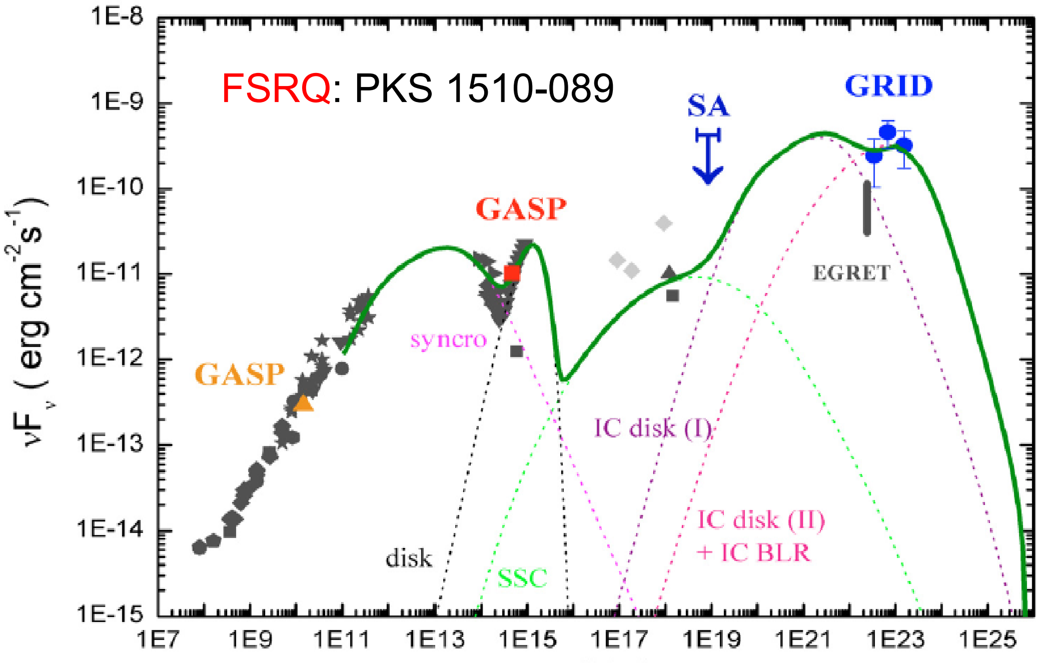
BL Lacs:

- $L_{iso} \leq 10^{46}$ erg/s
- continuum + no / weak em. Lines
- pure non-thermal radiation
- $z \leq 1$

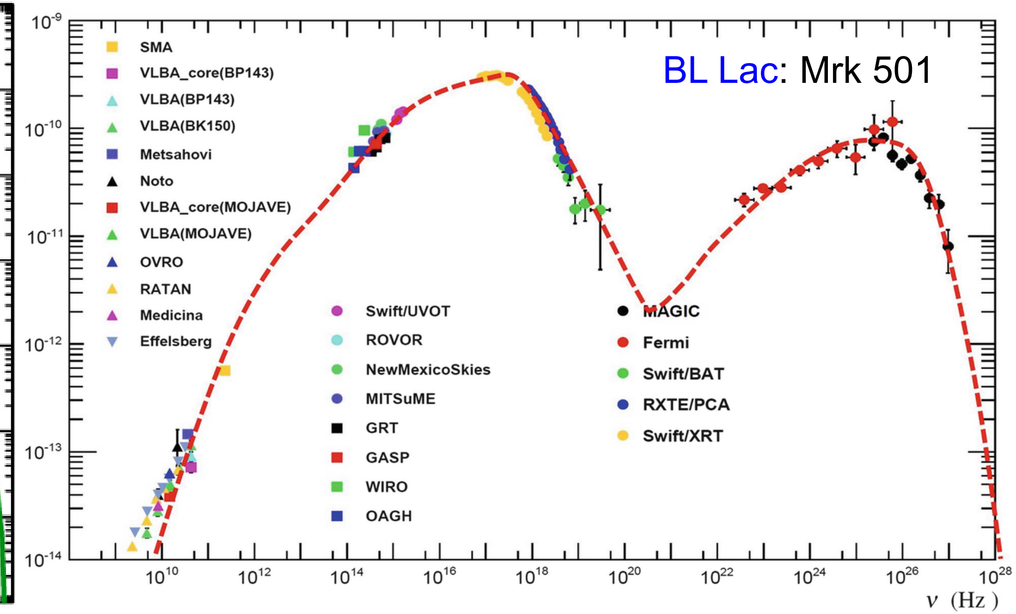


Urry & Padovani (1995)

FSRQs vs. BL Lacs



(Pucella et al. 2008)



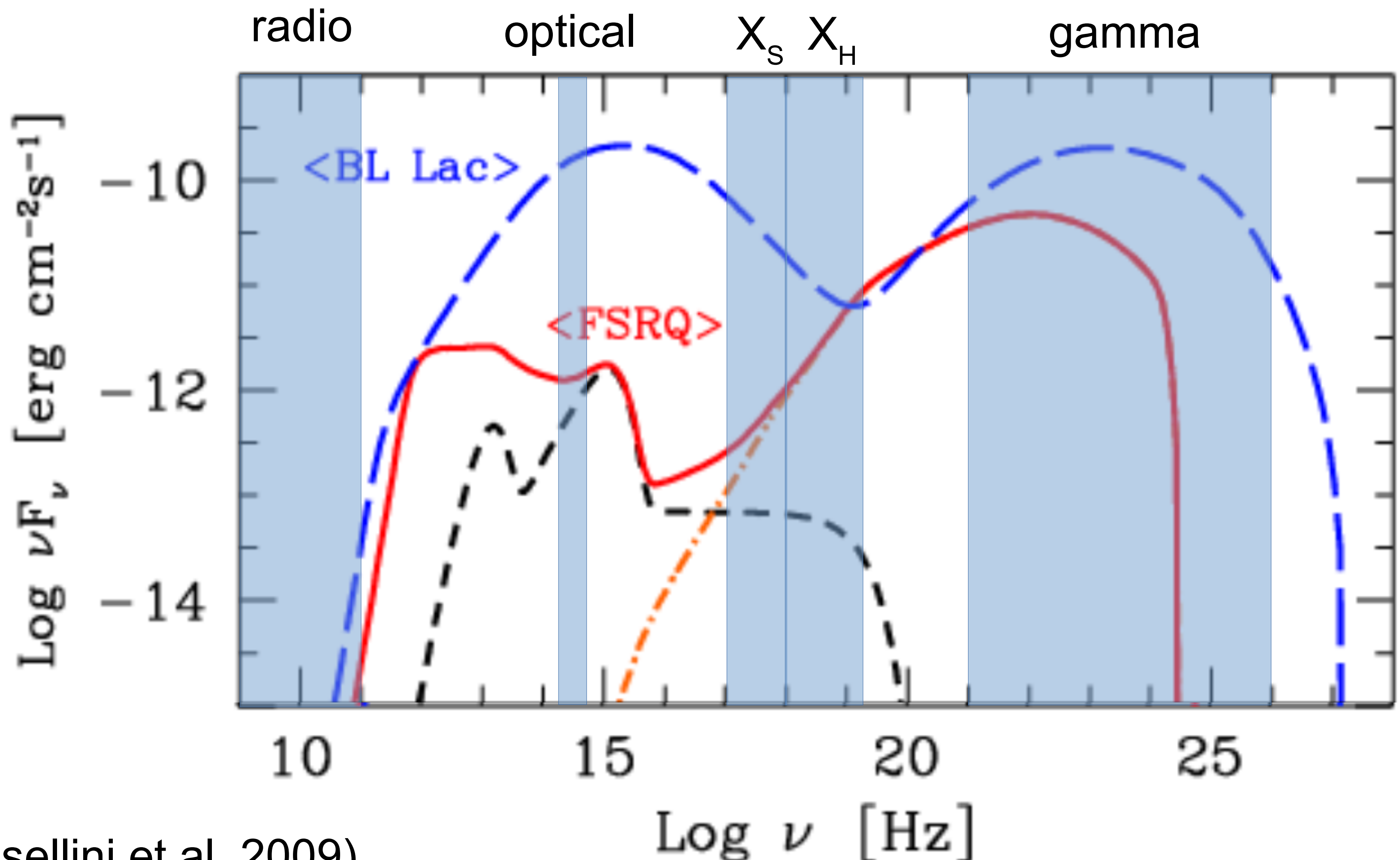
(Spurio et al. 2018)

Evidence of developed accretion disk (BBB + lines), γ-ray dominance (EC)

Pure non thermal continuum (SSC)

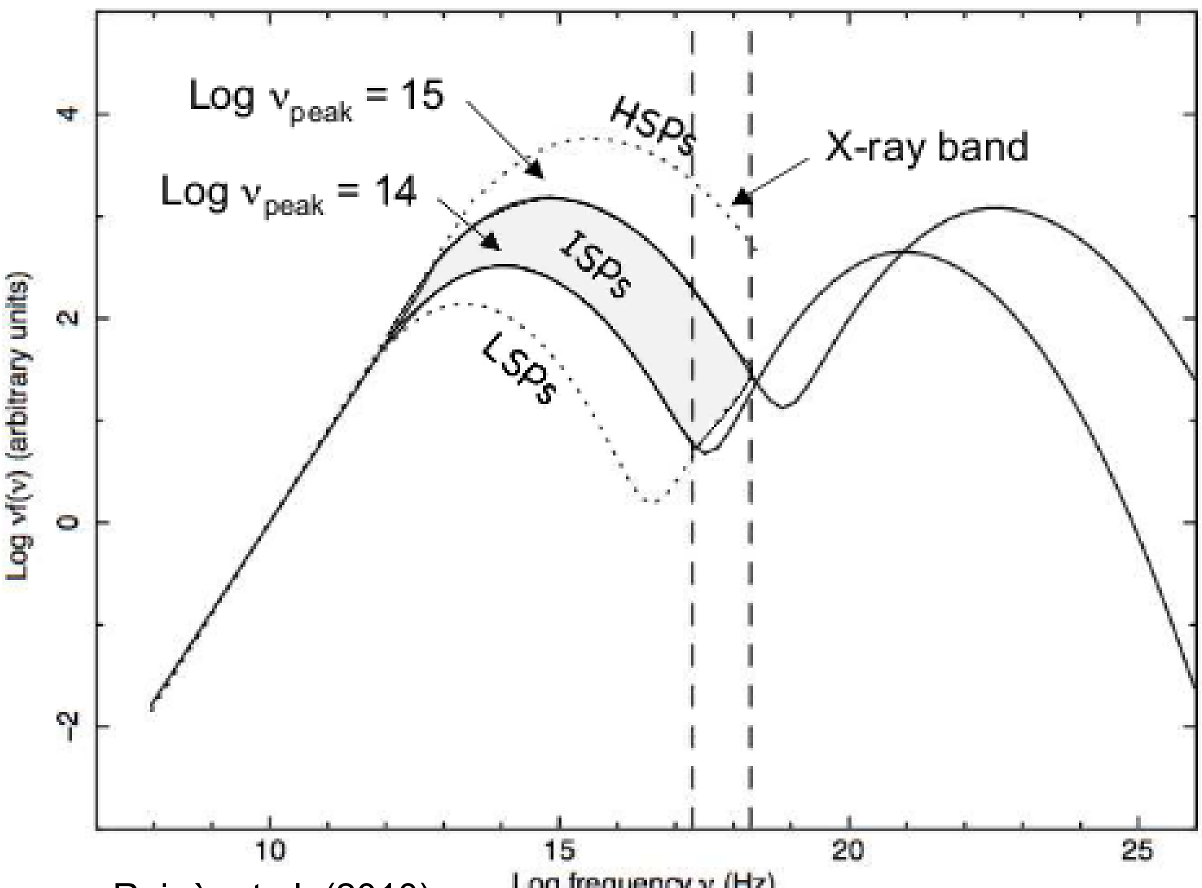
EC (seed photons from disk, BLR; Dermer & Schlickeiser 1993; Maraschi et al. 2001)
SSC (synch. by electrons in jets + IC by same electrons on synch. photons Jones et al. 1974; Marscher et al. 2010)

Blazar SED



(Ghisellini et al. 2009)

LSPs vs. HSPs



Rainò et al. (2010)

Ratio between X-ray and radio flux: LBLs vs HBLs (Padovani & Giommi 1995)

- LSP: $\nu_s < 10^{14}$ Hz
- ISP: 10^{14} Hz $< \nu_s < 10^{15}$ Hz
- HSP: $\nu_s > 10^{15}$ Hz

(Abdo et al. 2009)

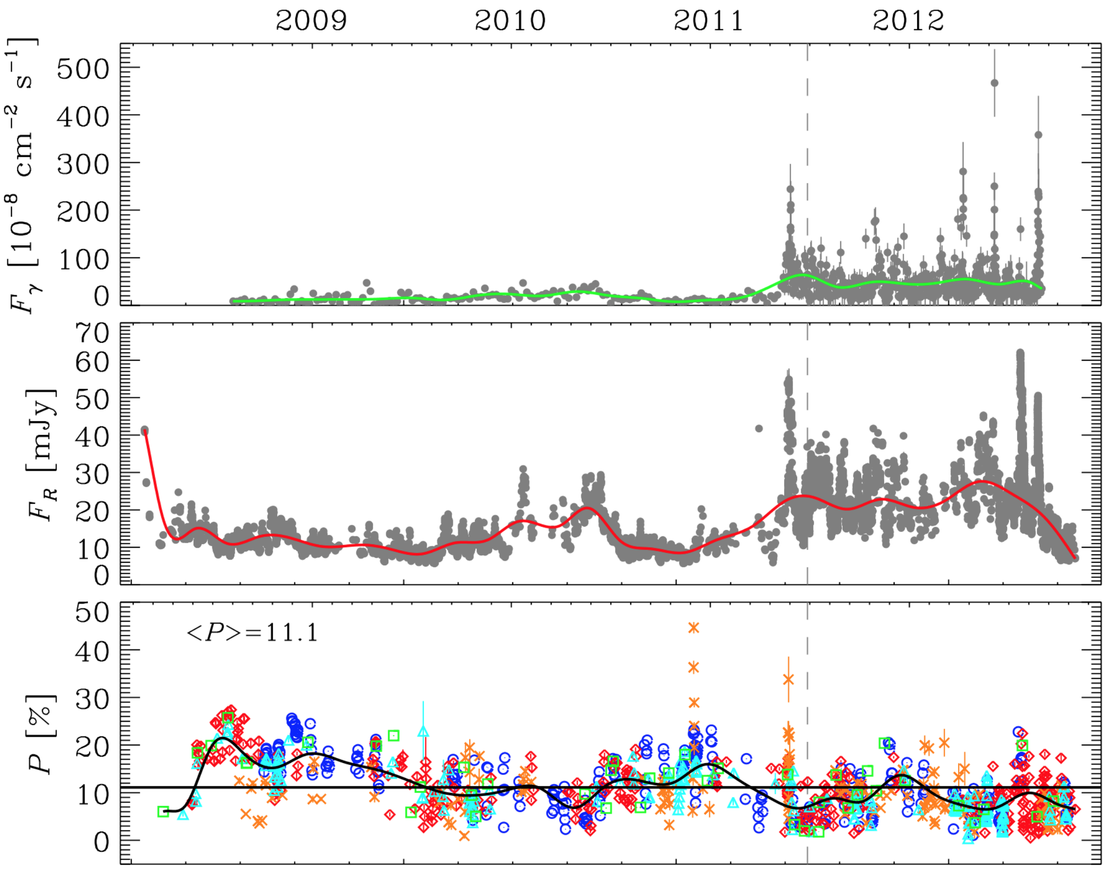
Dominant non-thermal radiation.

Polarization in Blazars

Radio and optical emission from blazars are known to be polarized few percents → synchrotron origin in a partially ordered magnetic field (D'Arcangelo et al. 2007, Lyutikov et al. 2005; Pushkarev et al. 2005).

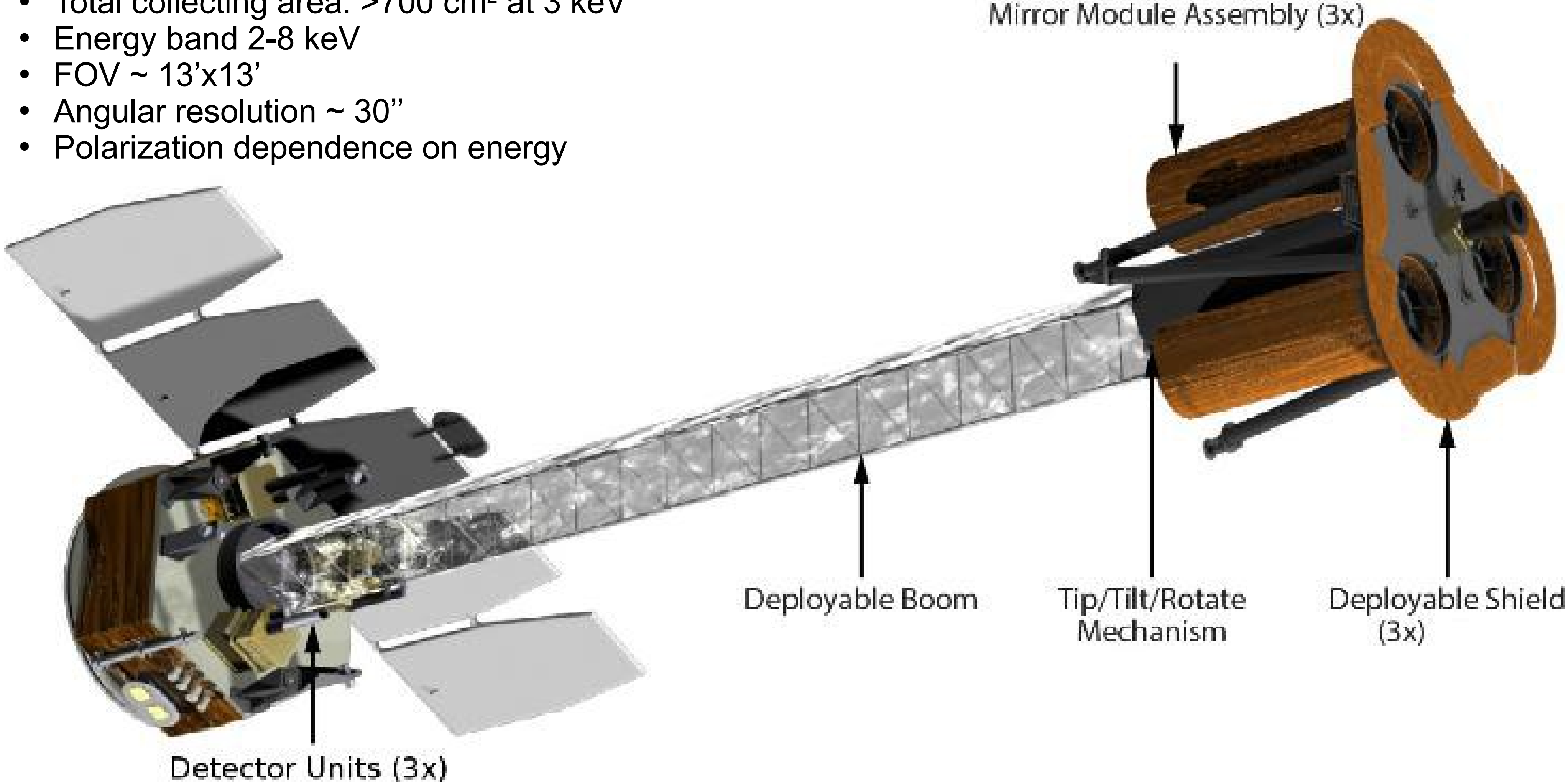
The expected X-ray polarization has also been evaluated (Zhang & Bottcher 2013).

Raiteri et al. (2013)



IXPE

- 3x Mirror Units + 3x Detector Units
- 4 m focal length, deployable boom and X-ray shield
- Total collecting area: >700 cm^2 at 3 keV
- Energy band 2-8 keV
- FOV ~ 13’x13’
- Angular resolution ~ 30’’
- Polarization dependence on energy

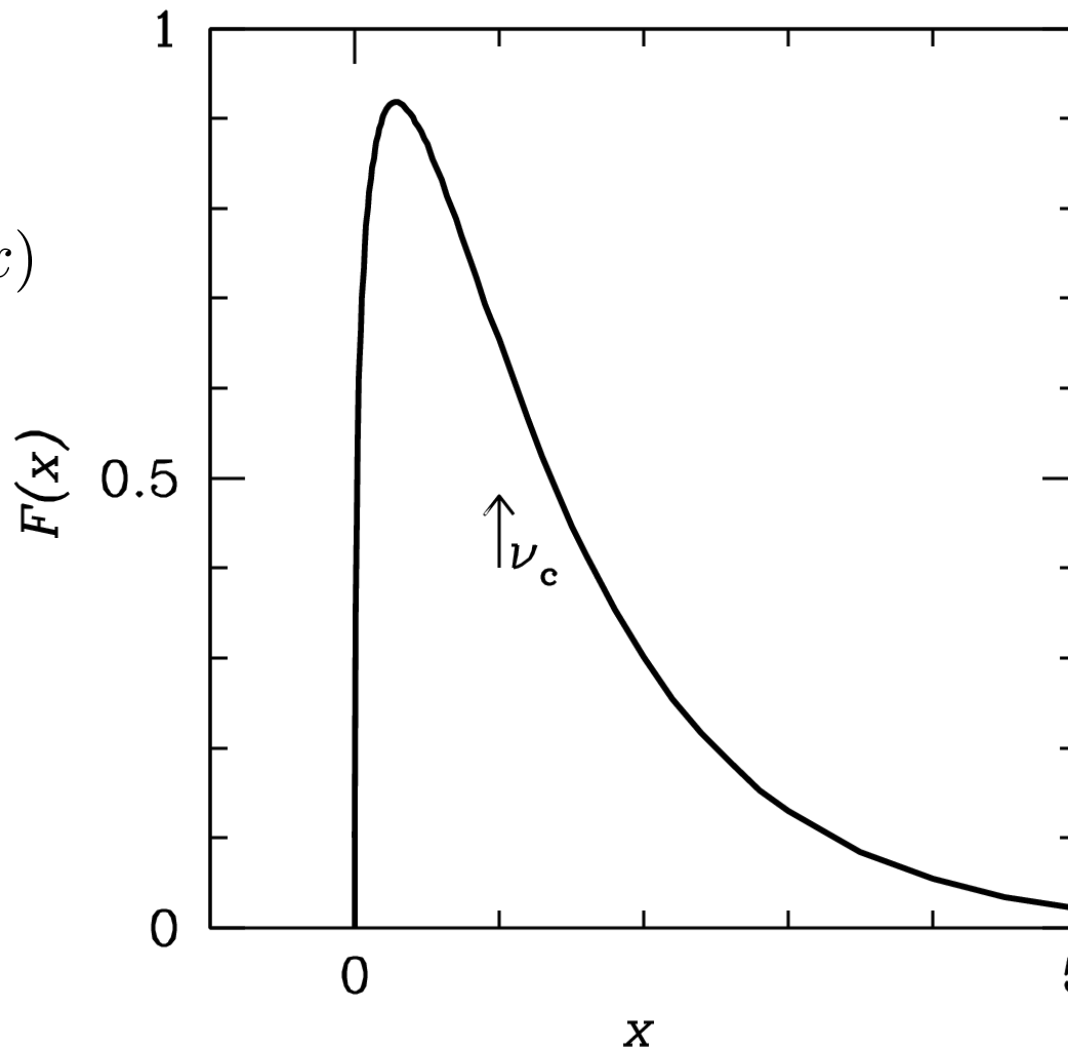


Synchrotron: Single Particle

$$P(\nu;\gamma,B,\alpha) = \frac{\sqrt{3}\,q^3 B\sin\alpha}{mc^2}F(x)$$

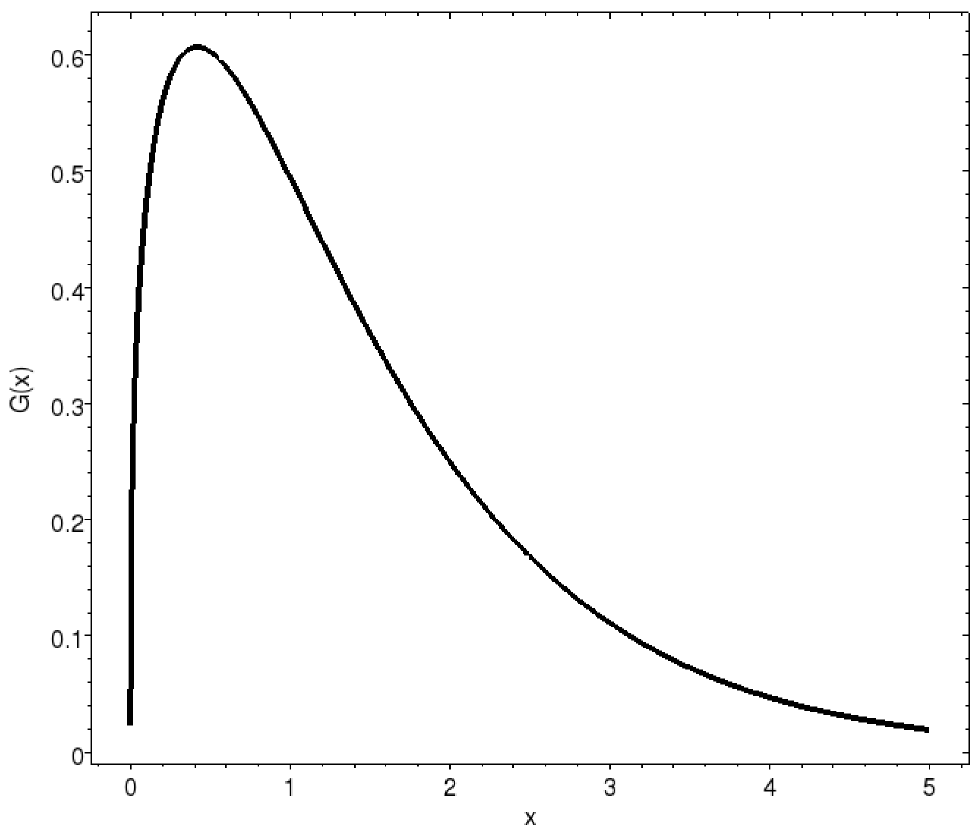
$$x = \frac{\nu}{\nu_c} \qquad \nu_c = \frac{3\gamma^2 qB\sin\alpha}{4\pi mc}$$

$$F(x) = x\int_x^\infty K_{\frac{5}{3}}(\xi)d\xi$$



Synchrotron: Polarization Degree

$$\Pi(\nu;\gamma,B,\alpha)=\frac{P_{\perp}(\nu;\gamma,B,\alpha)-P_{\parallel}(\nu;\gamma,B,\alpha)}{P_{\perp}(\nu;\gamma,B,\alpha)+P_{\parallel}(\nu;\gamma,B,\alpha)}=\frac{G(x)}{F(x)}$$



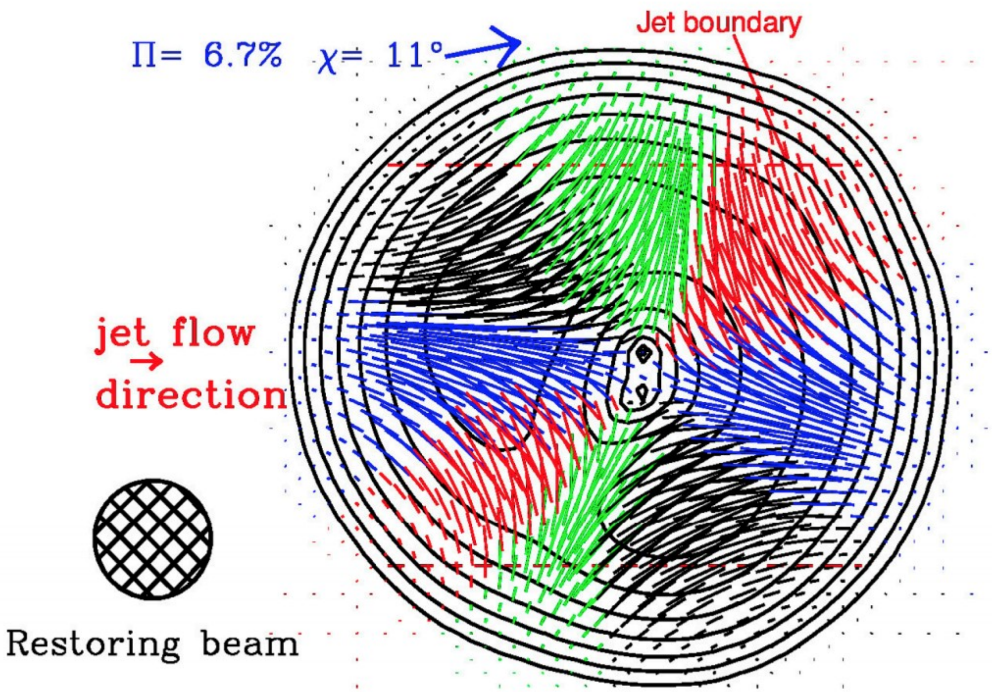
$$G(x)=xK_{\frac{2}{3}}(x)$$

$$\Pi(\nu;B,\alpha)=\frac{\int_{\gamma_{min}}^{\gamma_{max}}N(\gamma)G(x)d\gamma}{\int_{\gamma_{min}}^{\gamma_{max}}N(\gamma)F(x)d\gamma}$$

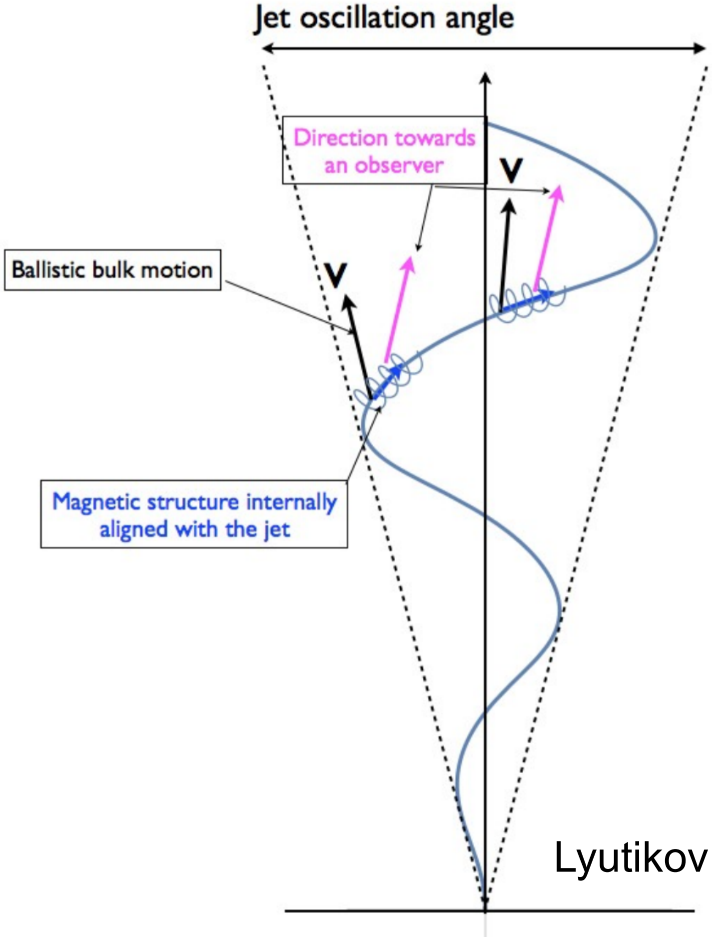
$$N(\gamma)=N_0\,\gamma^{-s}\Rightarrow\Pi(\nu;B,\alpha)=\frac{s+1}{s+\frac{7}{3}}$$

Jet Structure

Although homogeneous, single population electrons yield ~ 70% polarization, non homogeneous (Marscher et al. 2014, 2017, Peirson & Roger 2018) or varying source geometry and magnetic field (Villata & Raiteri 1999; Lyutikov et al. 2018) concur to lower the polarization degree to the observed values



Marscher et al. (2017)



Lyutikov et al. (2018)

Refined Electron Distributions

Test different acceleration and cooling process at work in blazar jets:

Broken power-law:

$$N(\gamma) = \begin{cases} N_0\,\gamma^{-s_1} & \gamma \leq \gamma_b \\ N_0\,\gamma^{-s_2}{\gamma_b}^{s_2 - s_1} & \gamma > \gamma_b \end{cases}$$

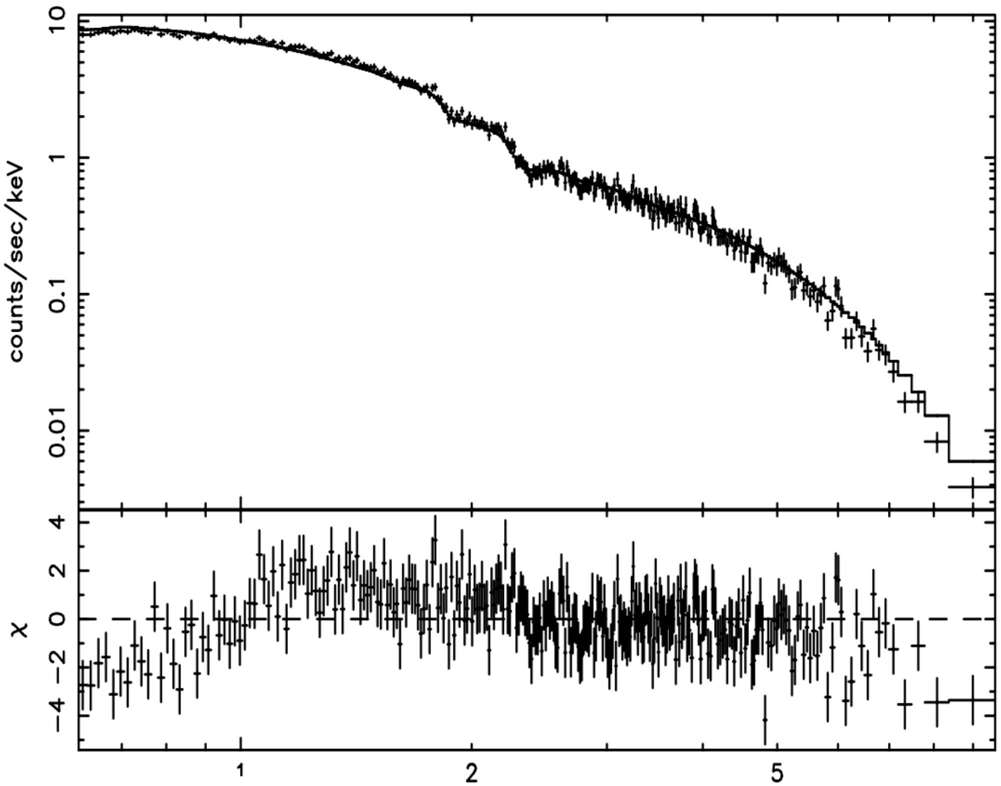
Power-law with exponential cut-off:

$$N(\gamma) = N_0 \gamma^{-s}\, e^{-\frac{\gamma}{\gamma_c}}$$

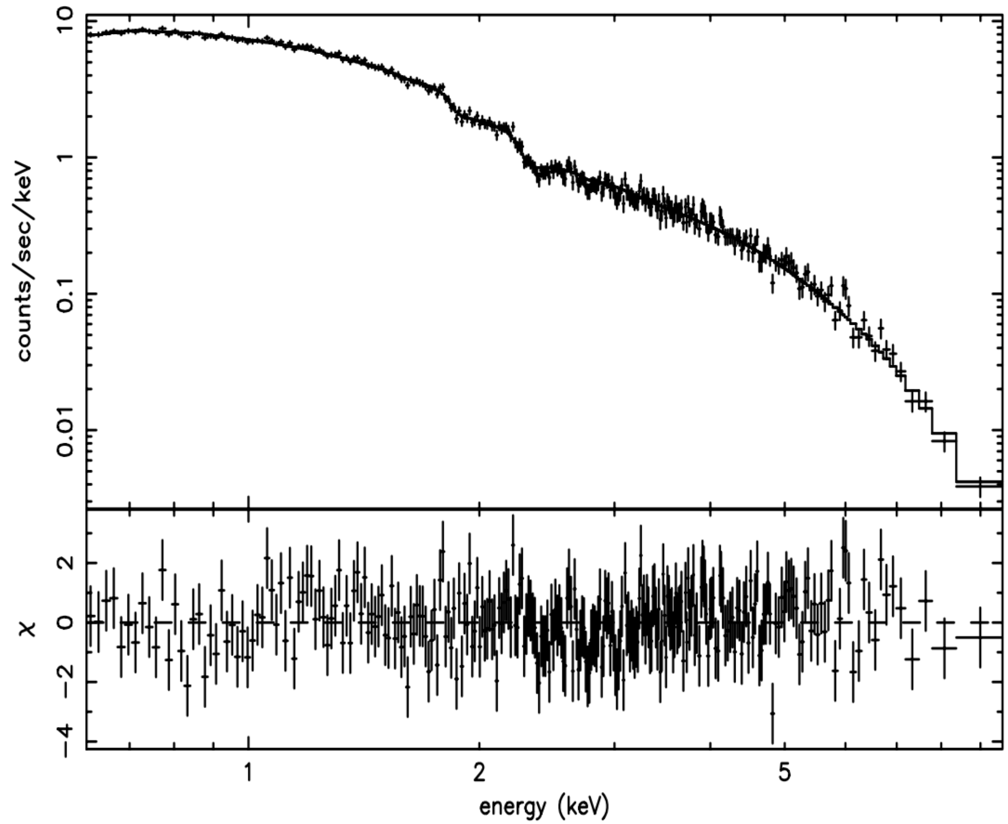
Log parabolic:

$$N(\gamma) = N_0 \left(\frac{\gamma}{\gamma_0}\right)^{-s - r\log\left(\frac{\gamma}{\gamma_0}\right)}$$

Curved spectra



Tramacere et al. (2007)



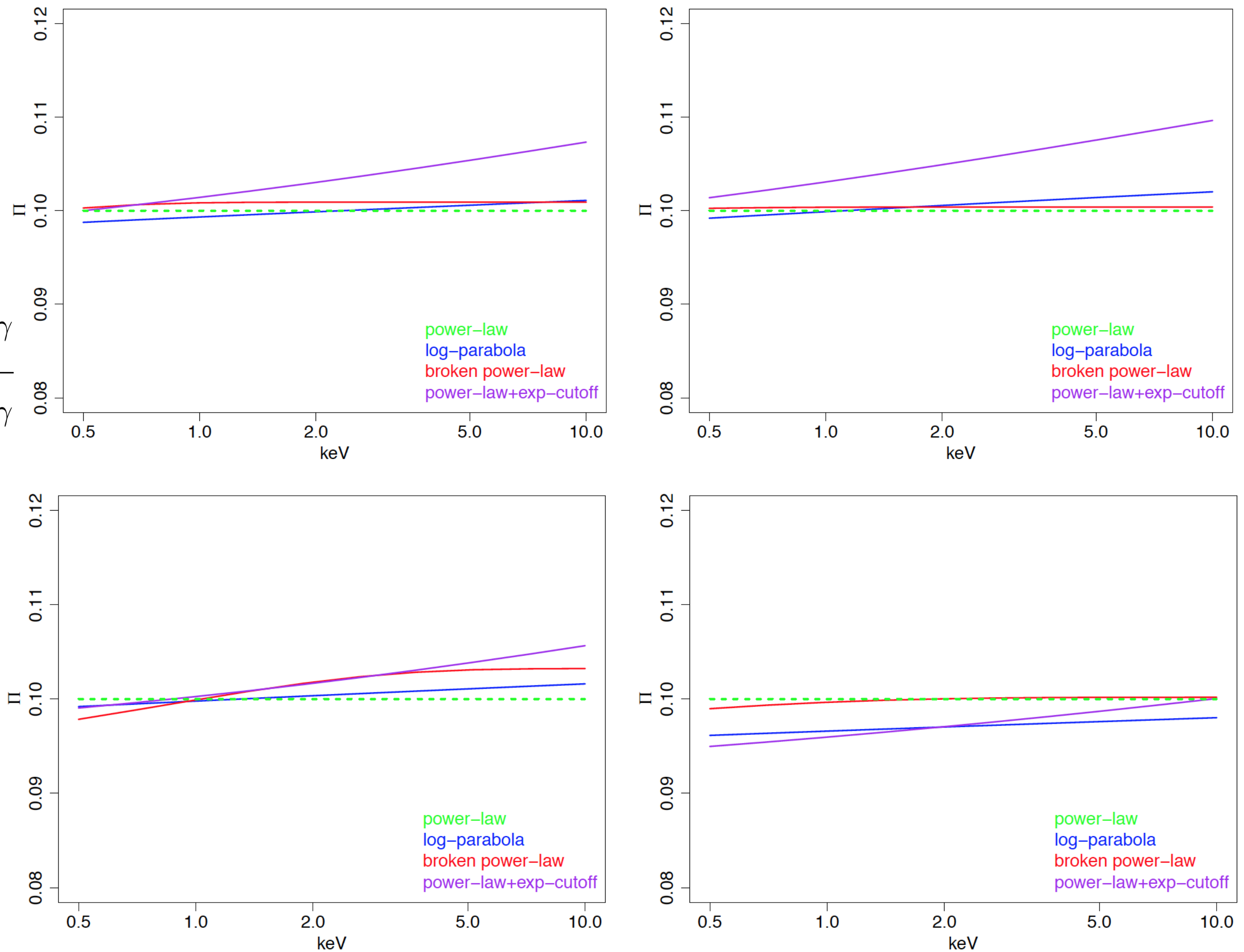
Synchrotron spectrum: $S(E) = K\,E^{-a-b\log(E)}$ $\quad b \approx \frac{r}{5}$

System. + stochast. acc
(Kardashev 1962)
Statistical acc.
(Massaro et al. 2004, 2006)

Polarization predictions

$$\Pi(\nu; B, \alpha) = \frac{\int_{\gamma_{min}}^{\gamma_{max}} N(\gamma) G(x) d\gamma}{\int_{\gamma_{min}}^{\gamma_{max}} N(\gamma) F(x) d\gamma}$$

$$\boxed{N \to \Pi}$$



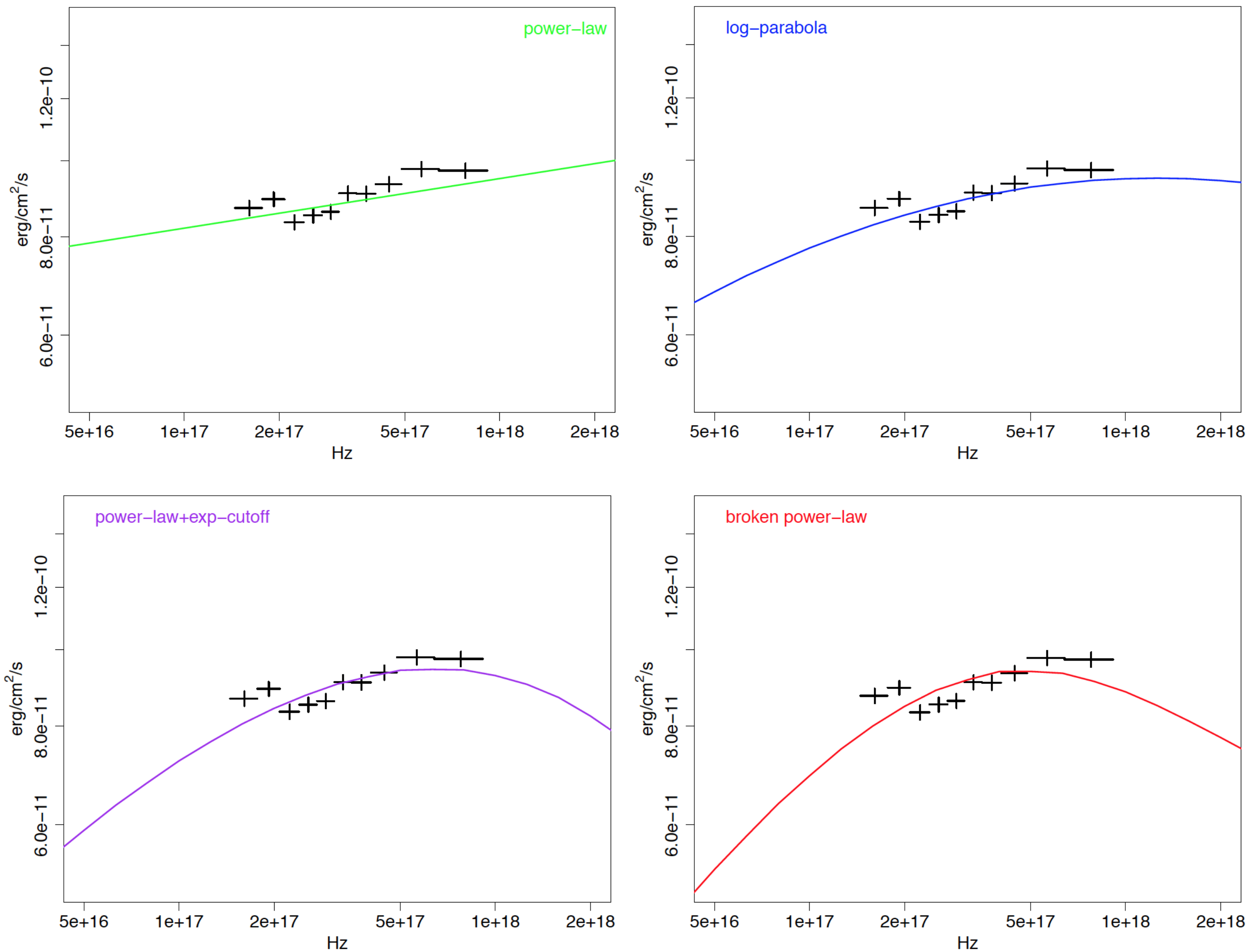
Swift observations of HSPs

Use Swift-XRT data to predict X-ray polarization observed by IXPE and its energy dependence.

IXPE Blazar Program for Year 1:

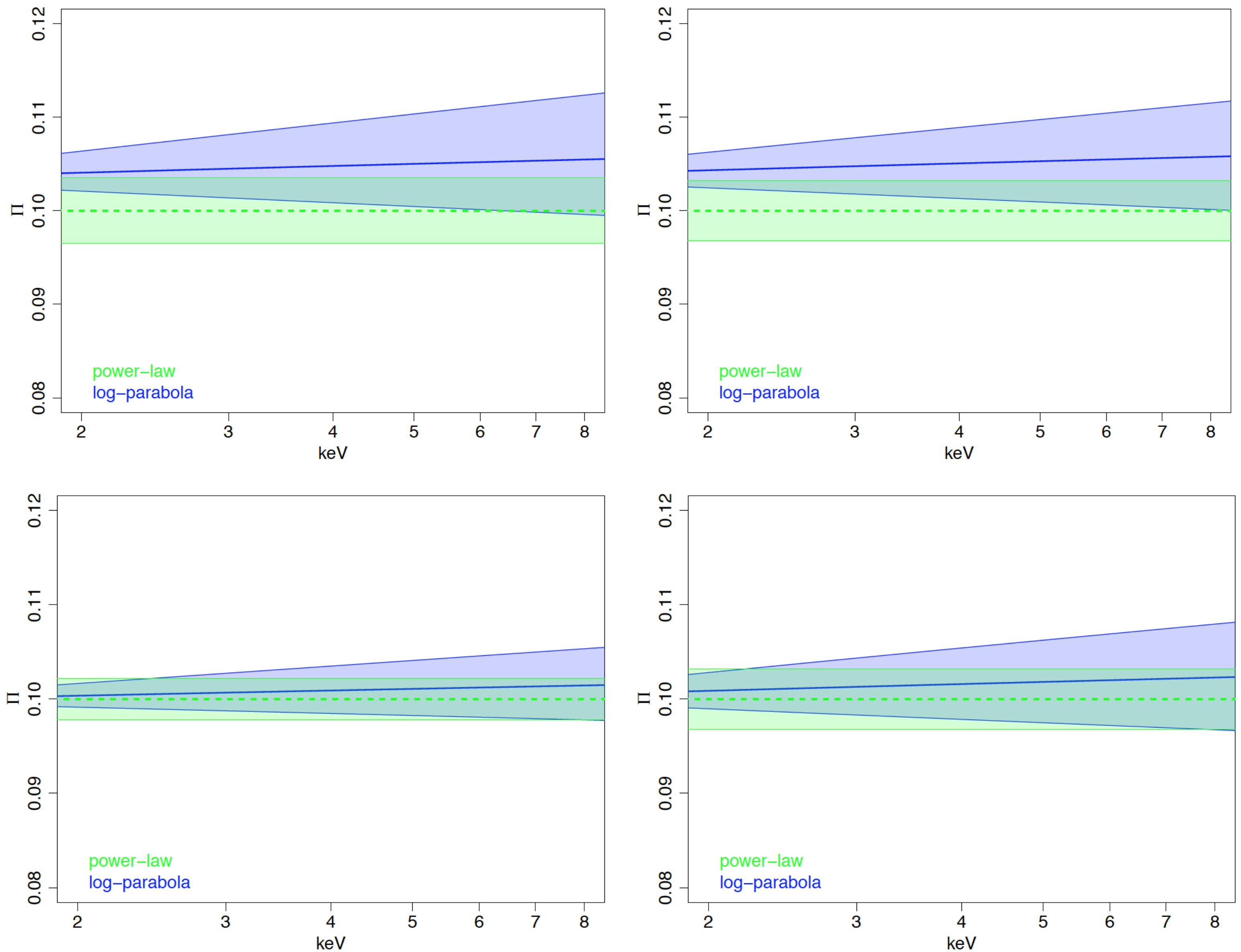
- ➔ **Mkn 501**
- ➔ **Mkn 421**
- • PKS 2155-304
- ➔ 1ES 1959+650

Swift-XRT SED fits

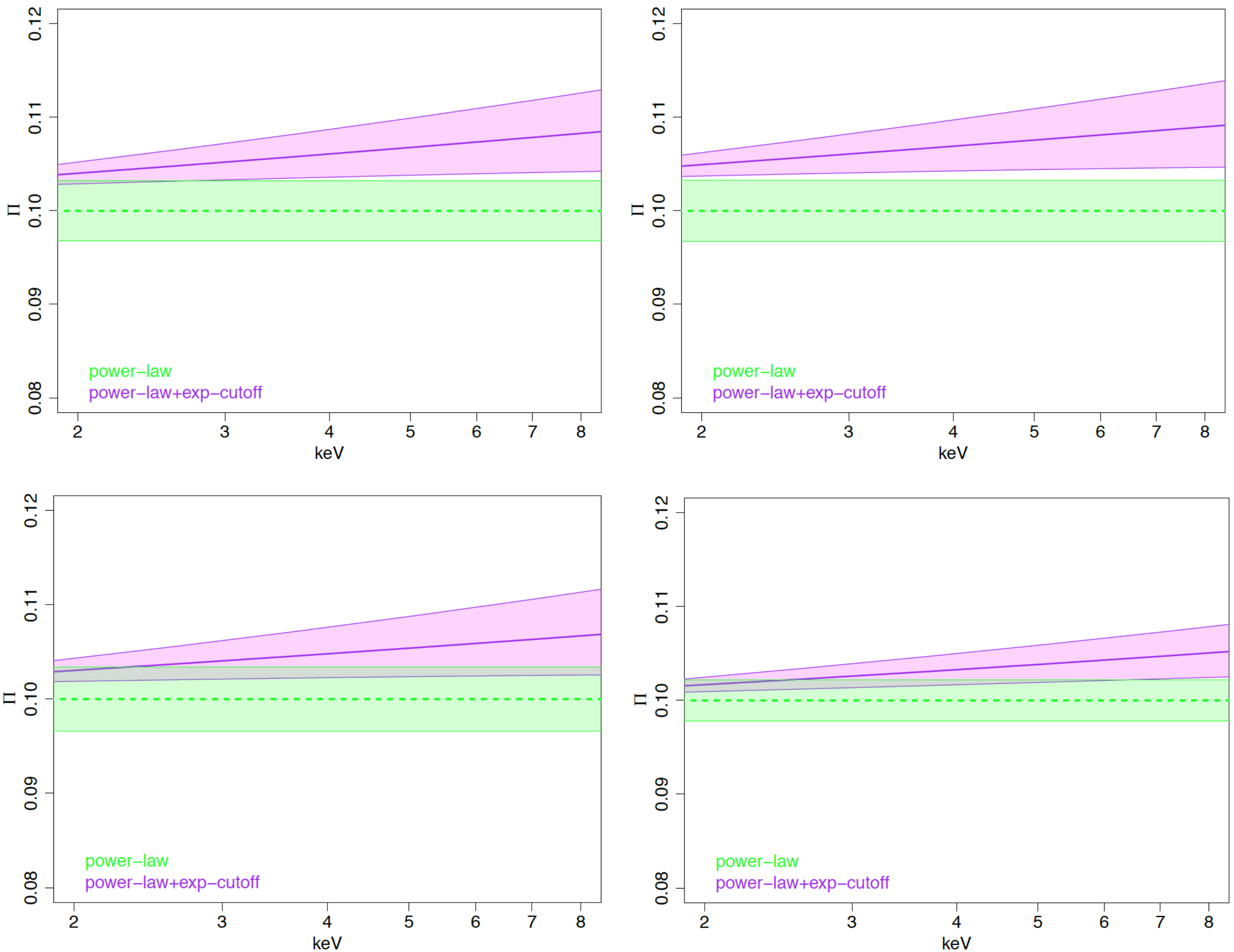


Jets SED modeler and fitting Tool (Tramacere et al. 2009, 2011) https://jetset.readthedocs.io/en/latest/
Electron distributions → source parameters (s, r, B, γ_b, etc.)

IXPE simulations

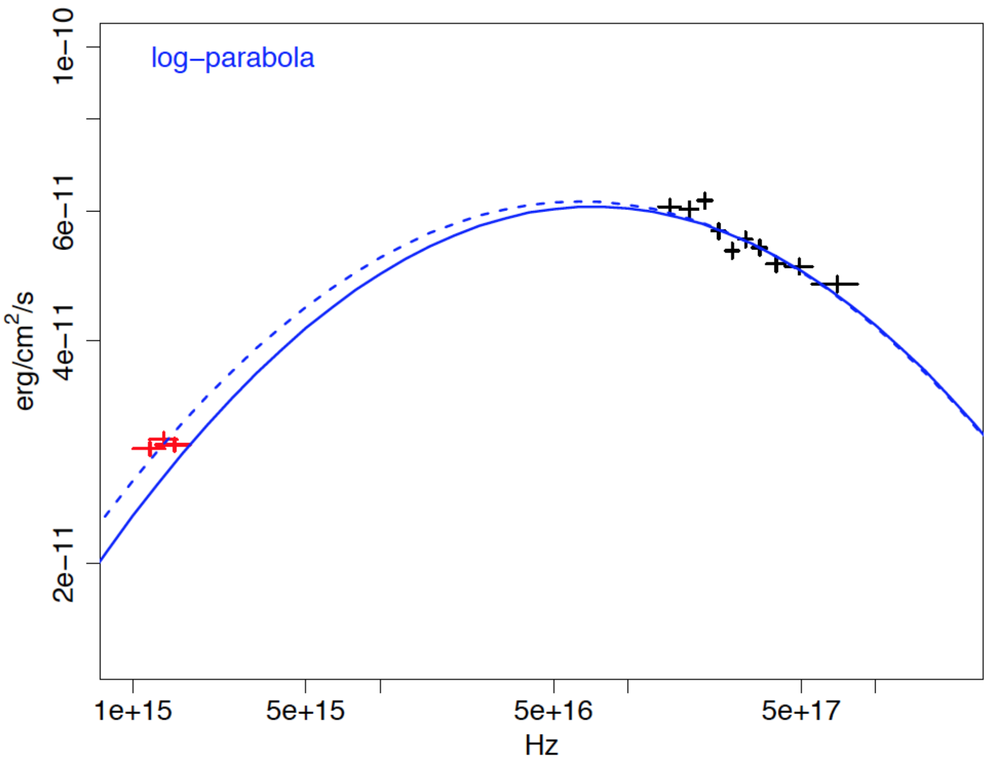


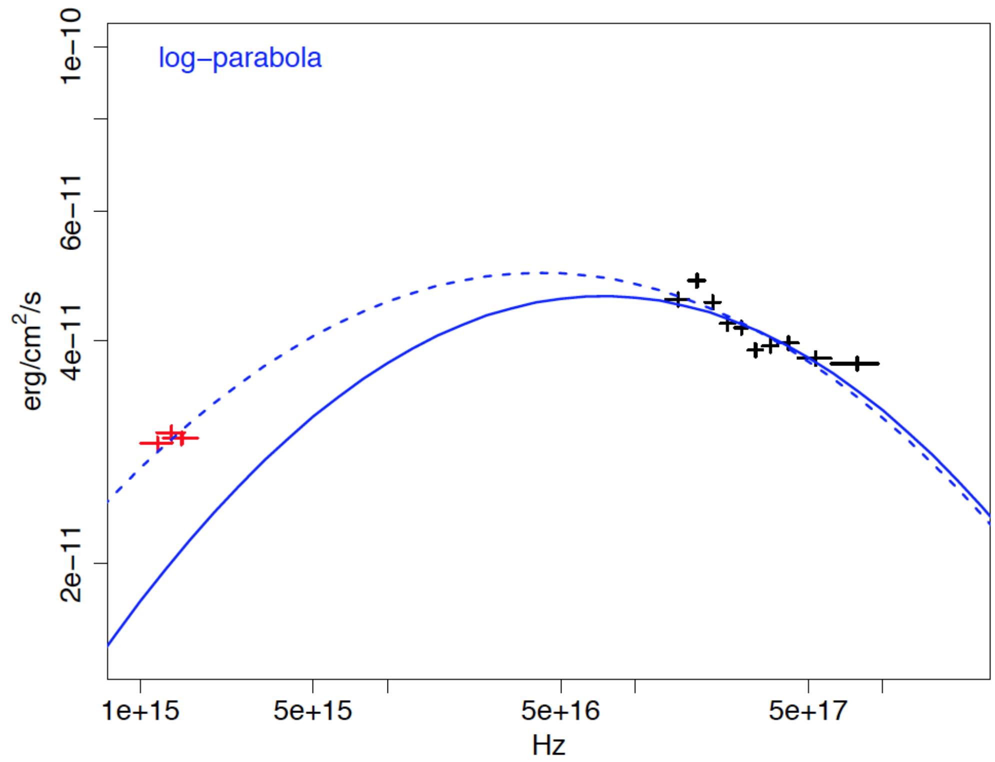
IXPE simulations



WIP: *Swift*-UVOT

Include UV-O observations in SED modeling.





Multiple electron populations (Massaro et al. 2004), host contribution?

Conclusions

- Simultaneous spectral-polarimetry measurements in HSPs can provide interesting insights in blazar emitting mechanisms
- Use *Swift*-XRT spectra to constrain the electron distribution and the X-ray polarization degree to make predictions for IXPE observations
- Log-parabolic models may be indistinguishable from power-law distributions, exponential cut-off cooling may be detected
- Comparison with simultaneous optical polarization measurements (e. g. WEBT)
- Test leptonic vs hadronic models for FSRQs and LPSs (Böttcher et al. 2013)

W. I. P.

To do:

- ➔ All 1st year IXPE HSPs
- ➔ Include *Swift*-UVOT data → evaluate optical dilution by host galaxy
- ➔ Extend electron distributions (broken power-law, power-law with log parabolic cut-off, etc.)
- ➔ Use *XMM-Newton* EPIC+OM data

ALMA Blazar Candidates

M. Bonato (IRA-INAF Bologna), C. Raiteri, M. Carnerero Martin, M. Villata (INAF-OATo)

- ~ 1600 blazar candidates (350 at low galactic latitude)
- Multi-wavelength characterization (SDSS, Gaia, WISE, LAMOST)
- 111 *Swift* XRT, 69 *Chandra* ACIS, 71 *XMM-Newton* EPIC