Blazars and radio-quiet AGN from the new window of X-ray polarimetry: first year of IXPE observations

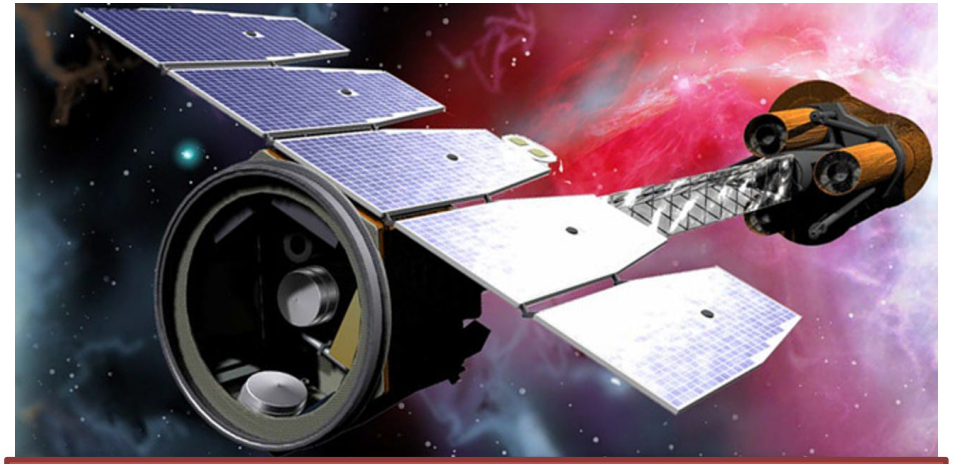
Laura Di Gesu

and

the IXPE SCIENCE TEAM

(https://ixpe.msfc.nasa.gov/partners_sci_team.html)

A NEW DIAGNOSTIC: X-RAY POLARIMETRY



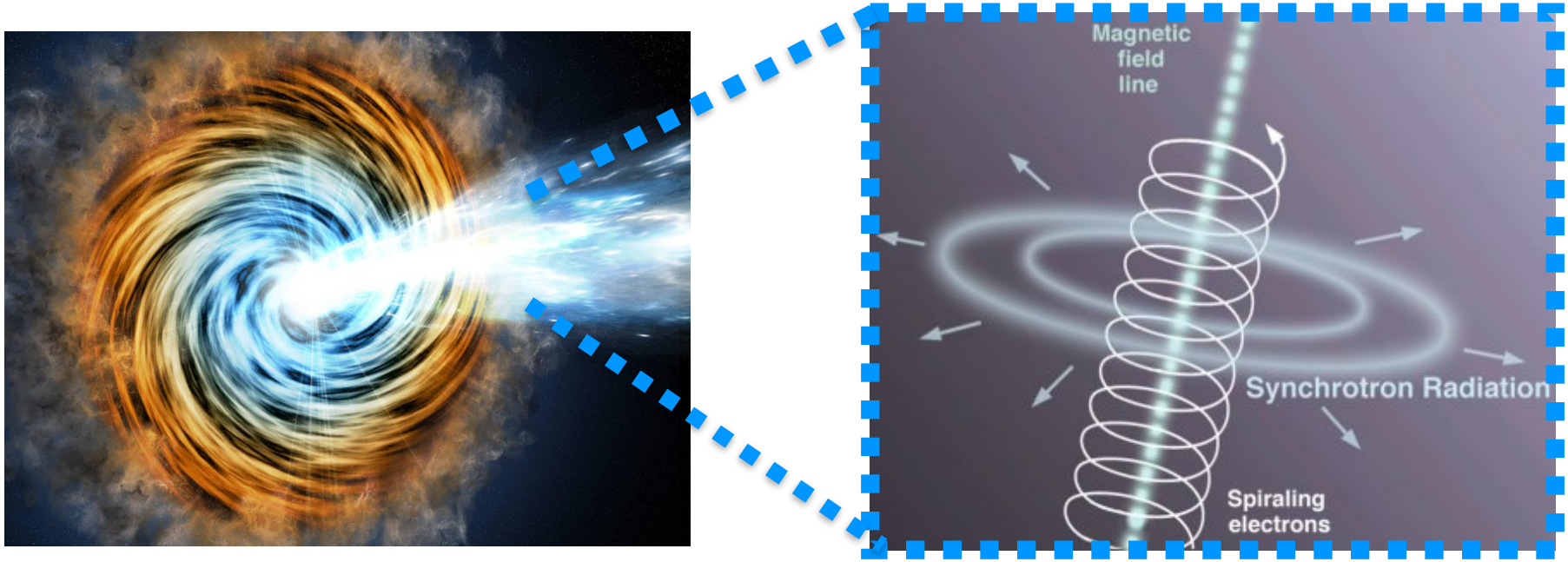
IXPE successfully launched on 9/12/2021!

- ***IXPE***:Imaging X-ray Polarimetry Explorer
- Bilateral NASA/ASI collaboration
- Three gas pixel detectors (***GPD***) with imaging capability (angular resolution of 25”) in the ***2.0-8.0 keV band.***
- Will increase the sensitivity of previous polarimeter (OSO-8, 1975) by 100.

… ***is allowing for the first time X-ray polarimetric observations of a variety of astrophysical sources including radio-quiet AGN and blazars.***

IXPE
Imaging X-Ray Polarimetry Explorer

BLAZARS: A LAB TO STUDY SMBH JETS



- Jetted AGN pointing to the observer
- SED dominated by jet emission: direct and reprocessed *synchrotron* radiation

…..Allow to address open critical questions about jet magnetic field structure, particles composition and acceleration mechanism.

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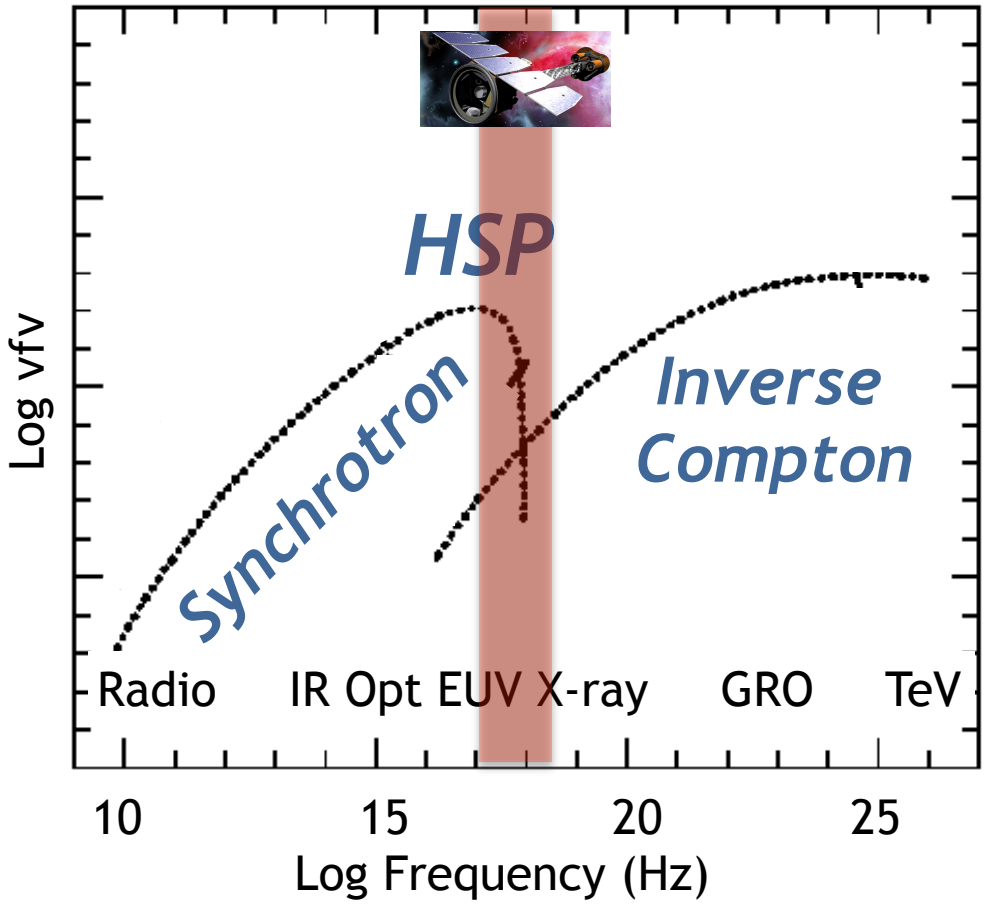
HIGH SYNCHROTRON PEAKED BLAZARS WITH IXPE:



For synchrotron, X-ray polarization is sensitive to the magnetic field conditions (ordered vs disorderd) and to the mechanism that accelerated the particles.

….predicted multiwavelength polarization variability can be now compared with data, including X-ray.

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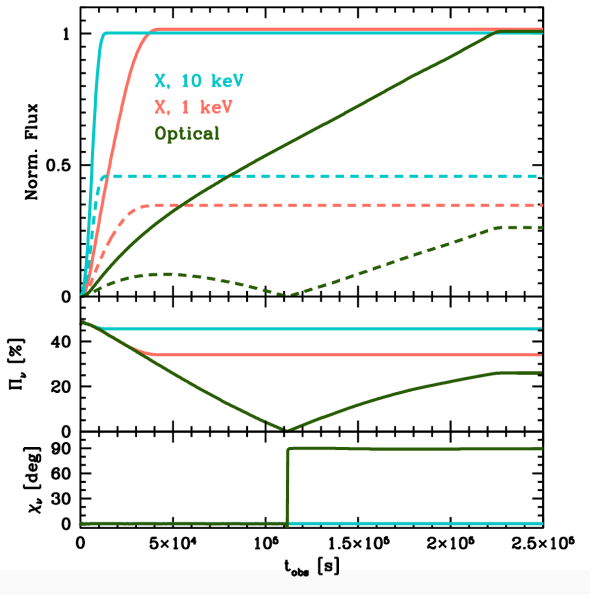
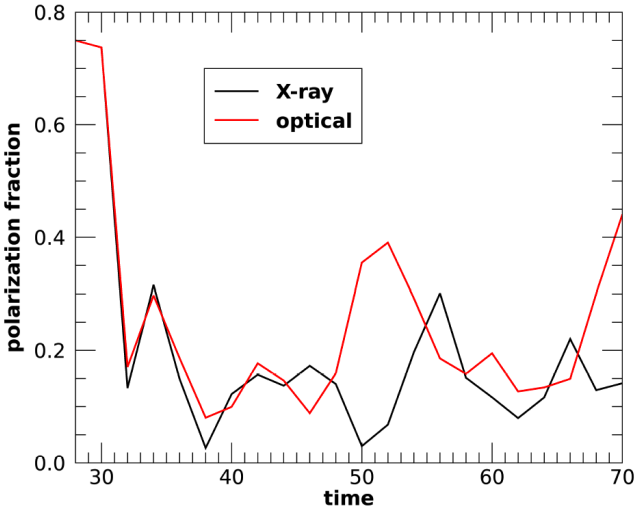
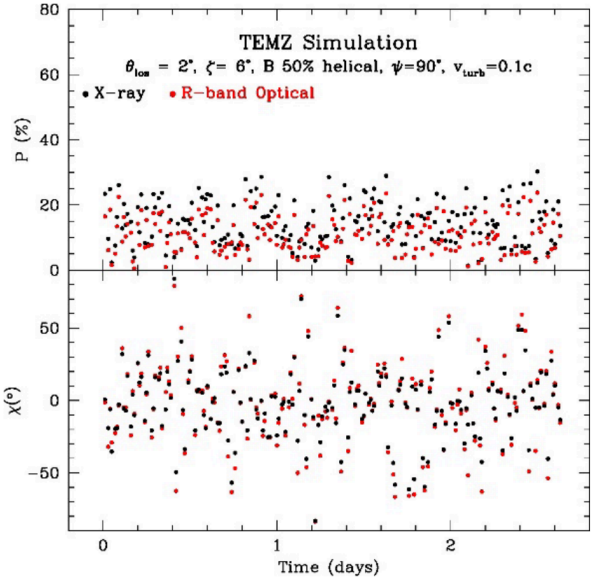
THEORETICAL MODELS:

E.G., TAVECCHIO+20, BODO+21, MARSCHER&JORSTAD+21







Shock:

- P_x higher than $P_{optical}$
- Time constant θ, while P_x mildly variable

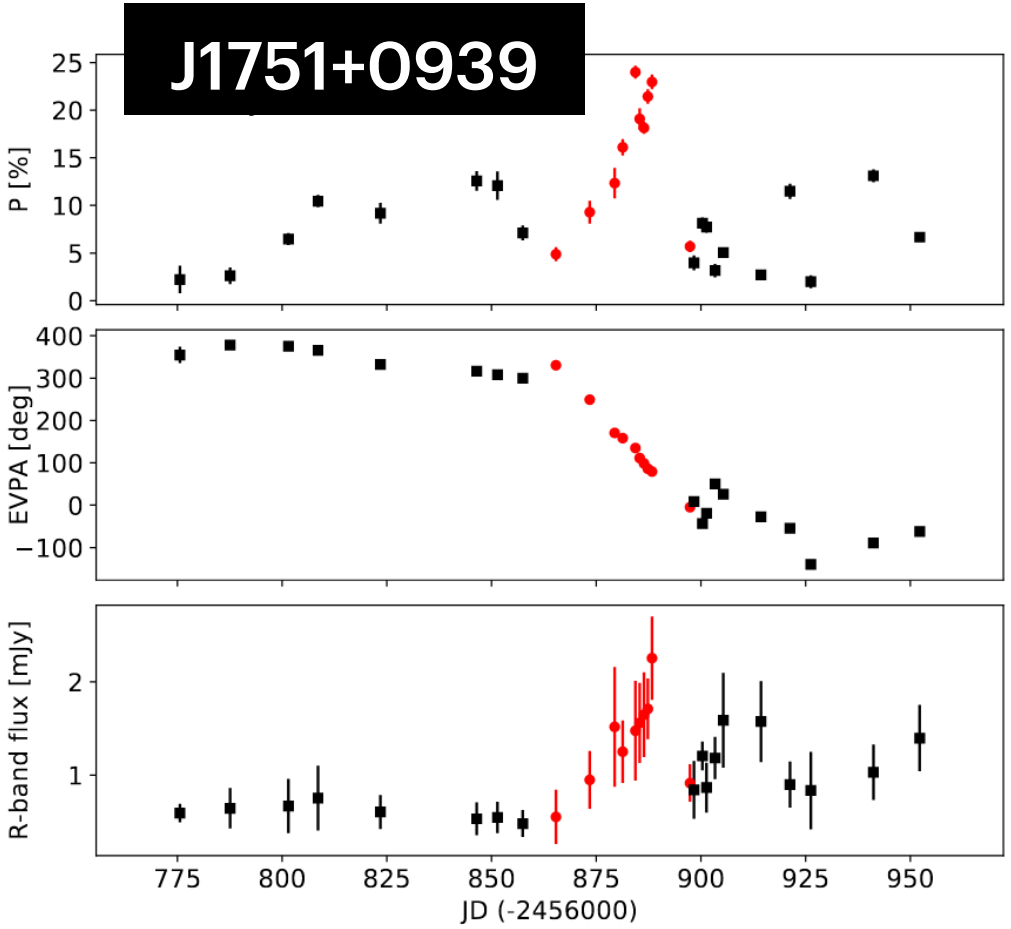
Magnetic Reconnection:

- Time modulation of both P_x and θ
- P_x often same order as $P_{optical}$

Turbulence:

- Erratic rapid variability of both P_x and θ

Optical Polarization angle rotation



- ΔT: 19-518 days,

  Δψ=74°-427°

- Some cases are produced by random walk of the polarization angle induced by turbulence, while others have been interpreted as evidence of motion of emitting plasma through a helical magnetic field

…is a common and well studied features in blazars

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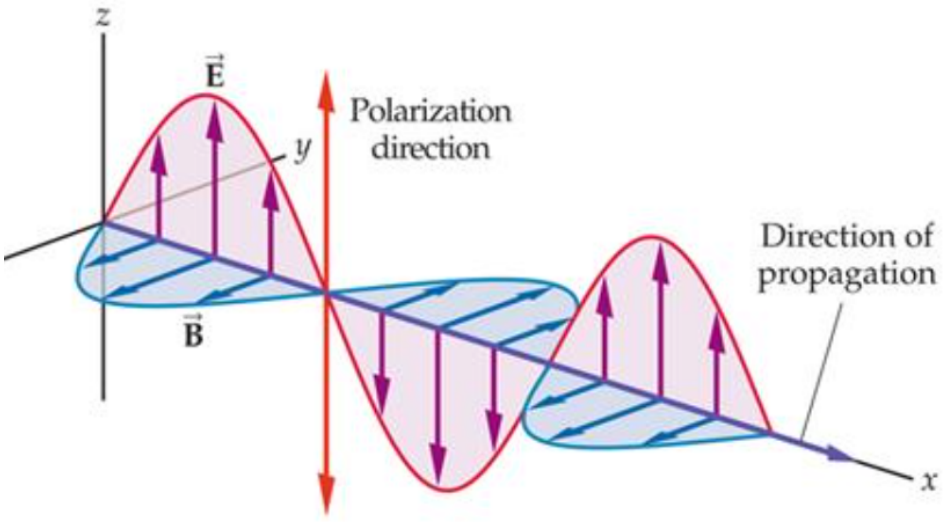
X-Ray
Polarimetry
Explorer

POLARIMETRY IN A NUTSHELL: FUNDAMENTALS



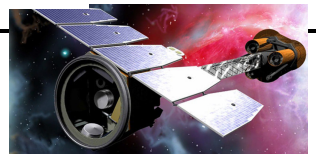
- P(%): fraction of polarised intensity
- θ: electric vector position angle
- I: total intensity
- Q: intensity linearly polarised at 90°
- U: intensity linearly polarised at +/- 45°

$$\theta = \frac{1}{2}\arctan\left(\frac{U}{Q}\right)$$

$$P = \frac{\sqrt{Q^2 + U^2}}{I} = \frac{polarized\ intensity}{total\ intensity}$$

POLARIMETRY IN A NUTSHELL:
THE DATA PRODUCTS

IXPE Imaging X-Ray Polarimetry Explorer



PHOTON LIST

Classic columns (t,x,y,ene…)

i, q, u, for each photon

Kislat+15 (ixpeobssim)

P, θ, I, Q, U, MDP

Energy bins

Spectra

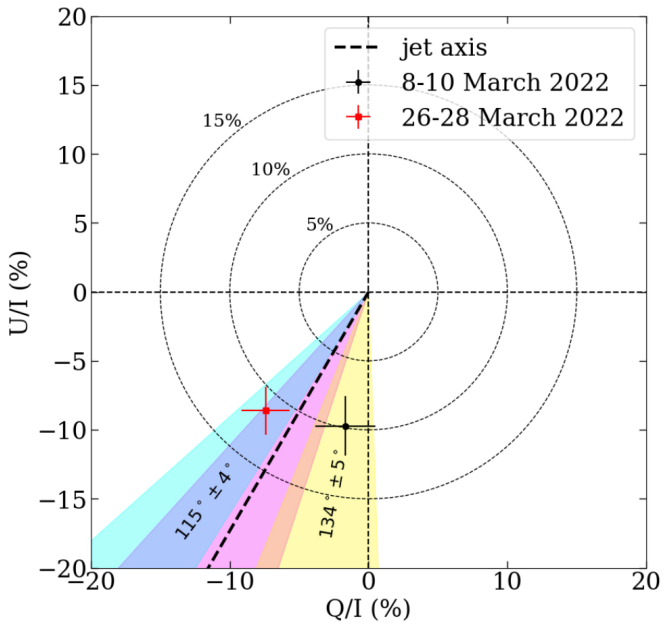
I,Q,or U

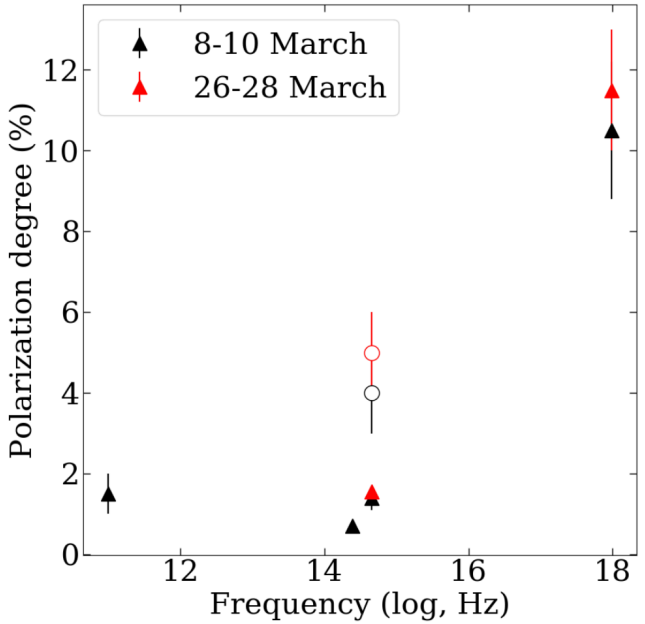
Energy

Spectro-polarimetric fit

FIRST IXPE OBSERVATION OF A BLAZAR: MRK 501 (MARCH 2022)

- HIGHLY SIGNIFICANT DETECTION.



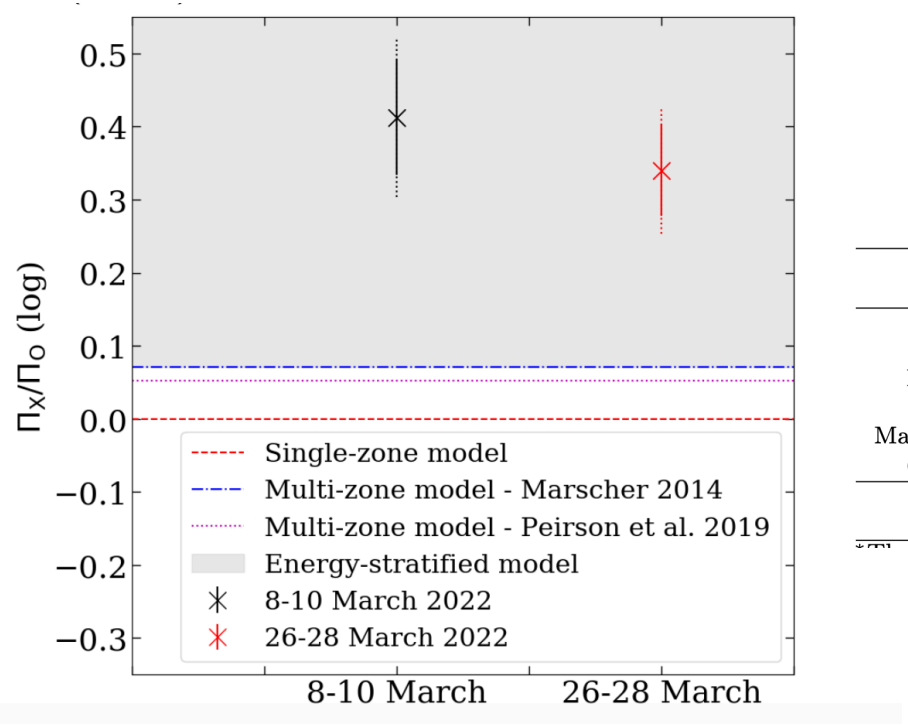


Liodakis 2022, Nature

- θ_x=134±5°
- ALIGNED JET DIRECTION.

- P_x=10±2% HIGHER than P_{opt}=1.5±2%

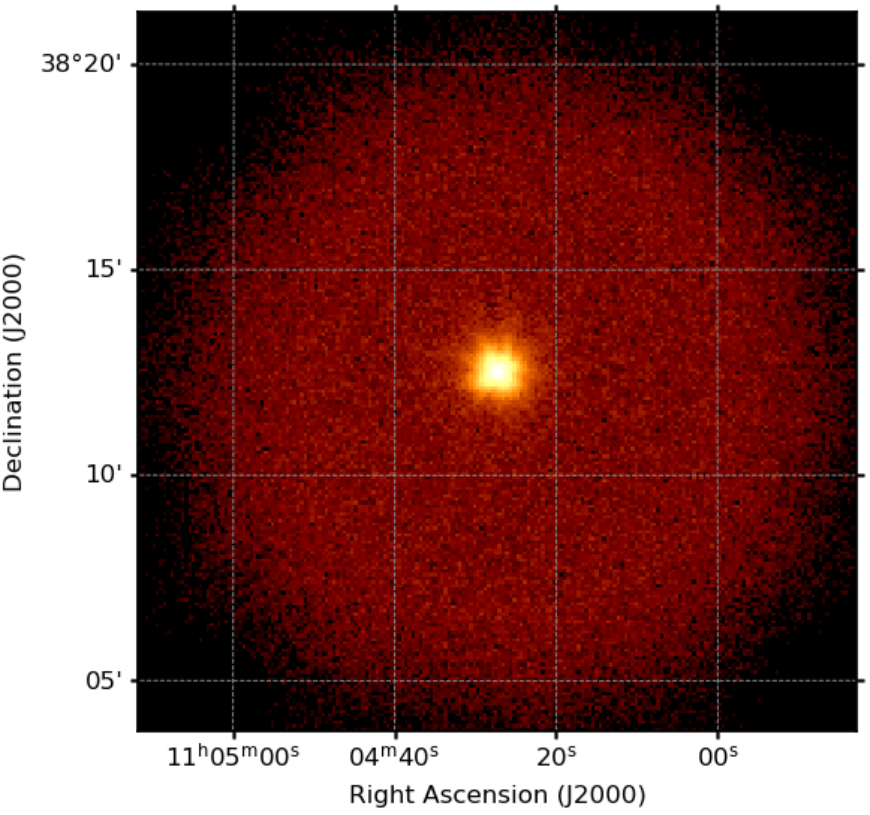
FIRST IXPE OBSERVATION OF A BLAZAR: MRK 501 (INTERPRETATION)

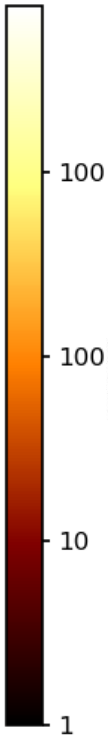


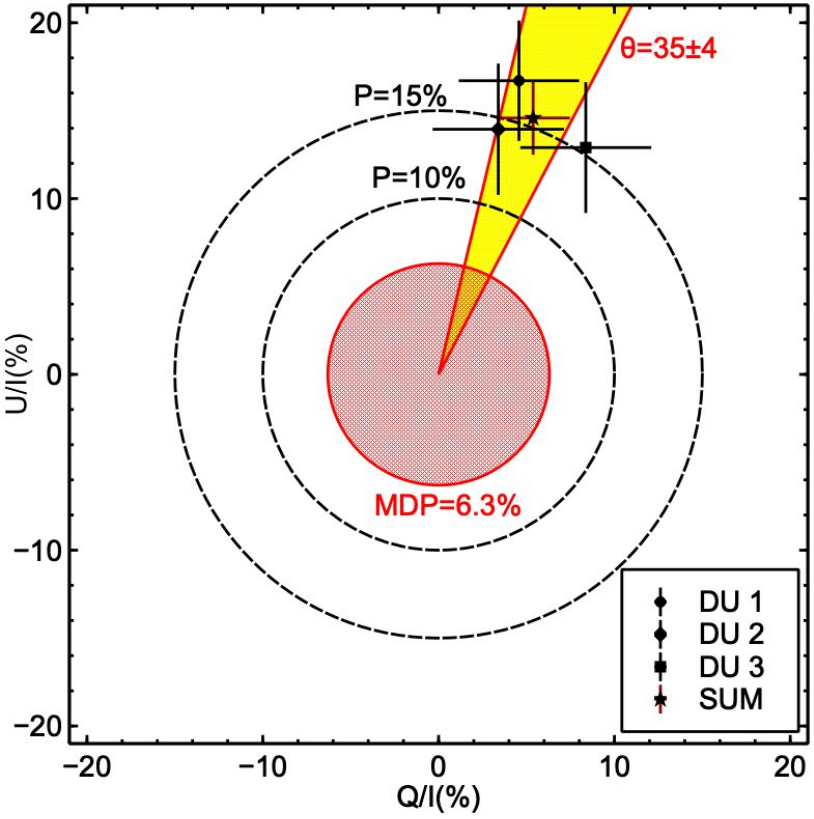
Model	Multiwavelength polarization	X-ray polarization variability†	X-ray polarization angle
Single-zone	constant*	slow	any
Multi-zone	mildly chromatic	high	any
Energy stratified (shock)	strongly chromatic	slow	along the jet axis
Magnetic reconnection (kink instability)	constant	moderate	perpendicular to jet axis
Observed	strongly chromatic	slow	along the jet axis

Shock acceleration in a energy stratified jet is favoured

FIRST IXPE OBSERVATION OF MRK 421: (KISLAT+15 APPROACH)



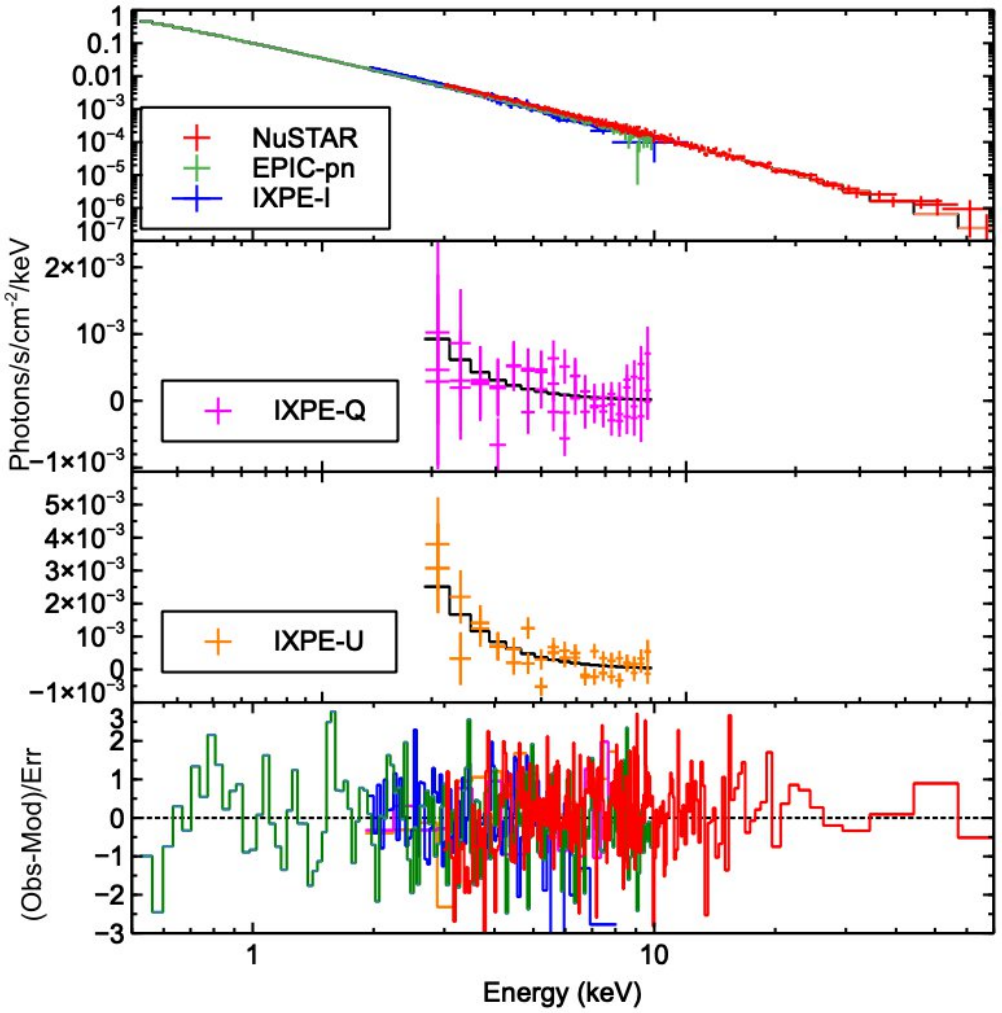




Di Gesu,2022, ApjL

Another highly significant (7σ,>99.99%) detection.

FIRST IXPE OBSERVATION OF MRK 421: (SPECTROPOLARIMETRIC FIT)

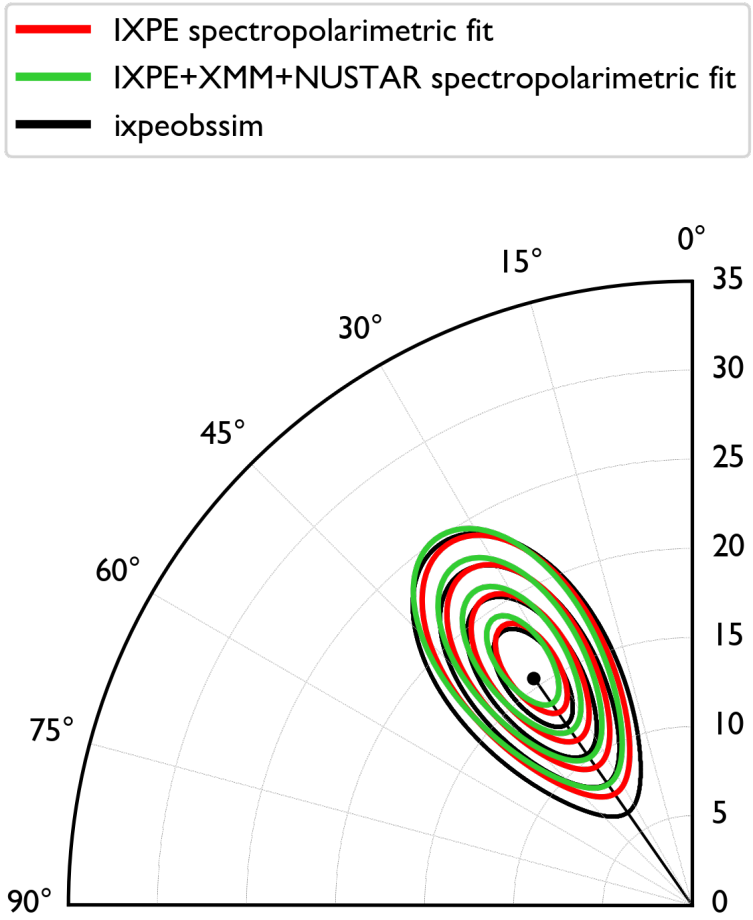


$$N(E) = K(E/E_{\rm p})^{(\alpha - \beta \log (E/E_p))}$$

$$P_{\rm x} = (16 \pm 2)\,\%\;\theta_{\rm x} = (34 \pm 2)$$

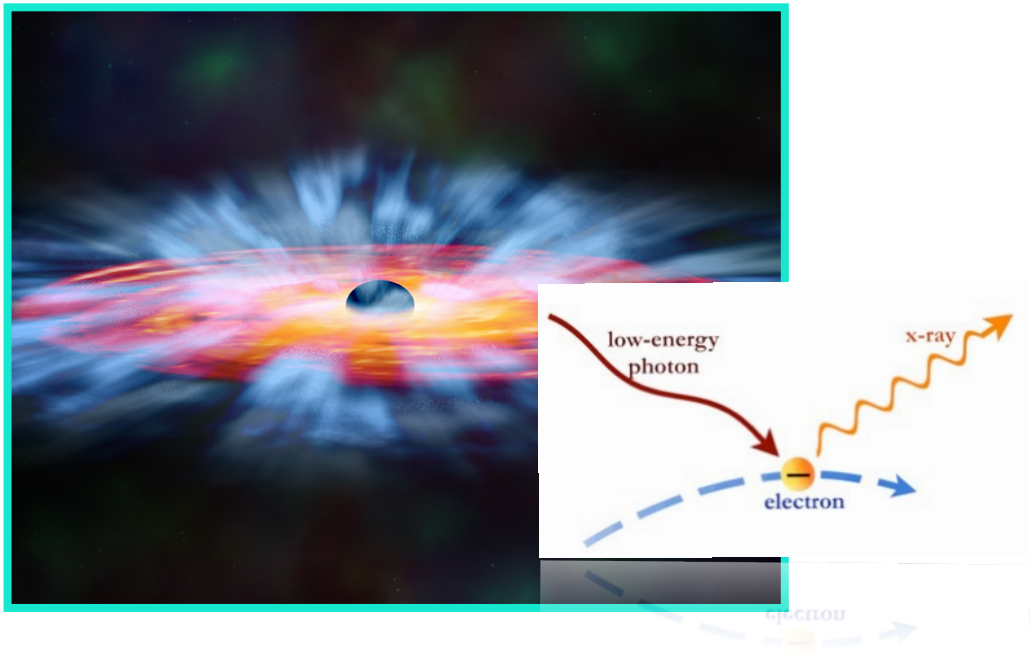
A log-parabola best fits the broadband spectral shape, while polarization parameters are consistent with the previous method.

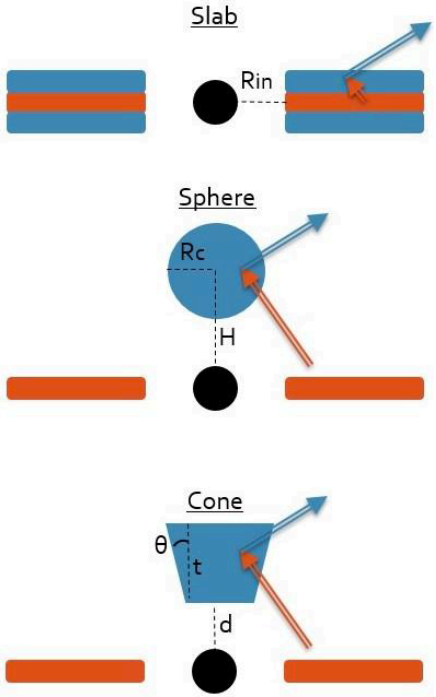
FIRST IXPE OBSERVATION OF MRK 421: (CONTOUR PLOTS FOR DIFFERENT METHODS)



Polarization parameters determination is robust against differences in the methodology used and in the modelling of the spectral shape.

CORONAL GEOMETRY IN TYPE 1 SEYFERT

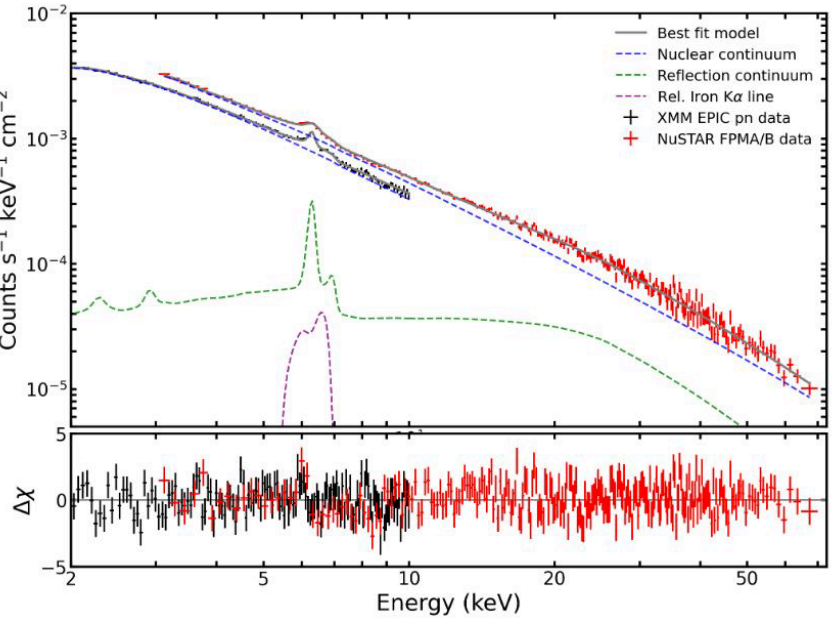


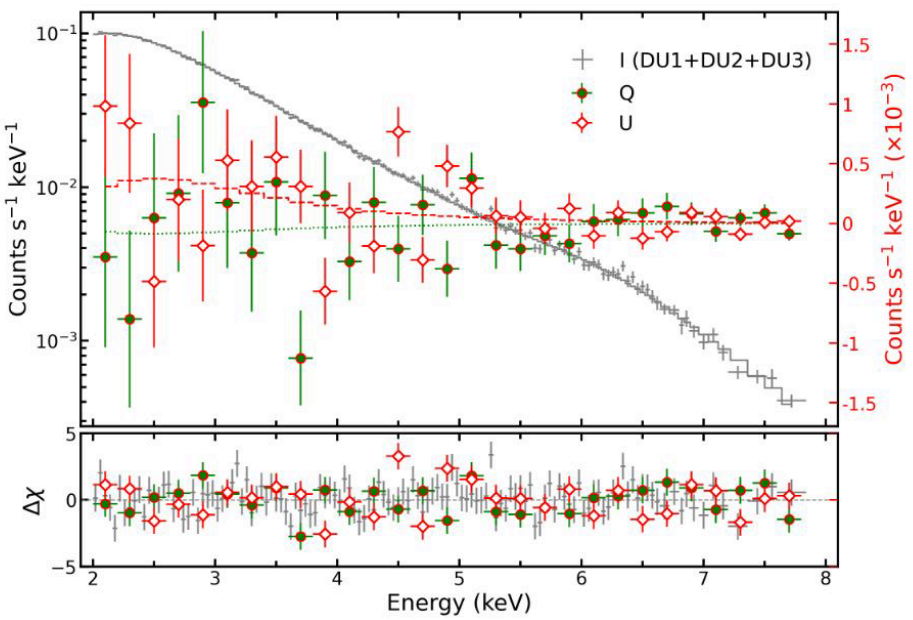


- The geometry of the hot corona is unknown.
- X-ray (brodband) spetroscopy ➠physical parameters (kT, τ)
- ***X-ray polarimetry ➠geometry ➠physical origin***
- by comparison with Monte Carlo radiative transfer code (e.g. MONK) see Zhang+19, Ursini+22,Tagliacozzo in prep.

IXPE Imaging X-Ray Polarimetry Explorer

MCG-5-23-16



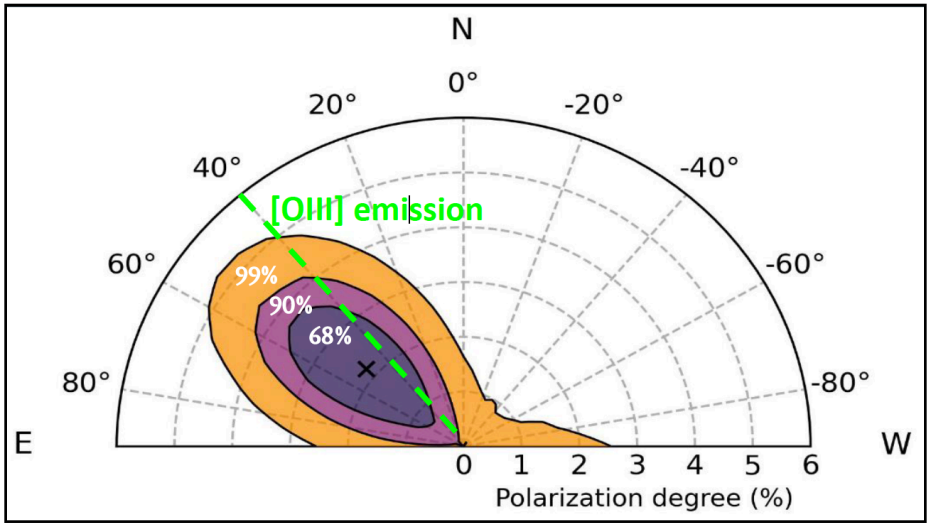


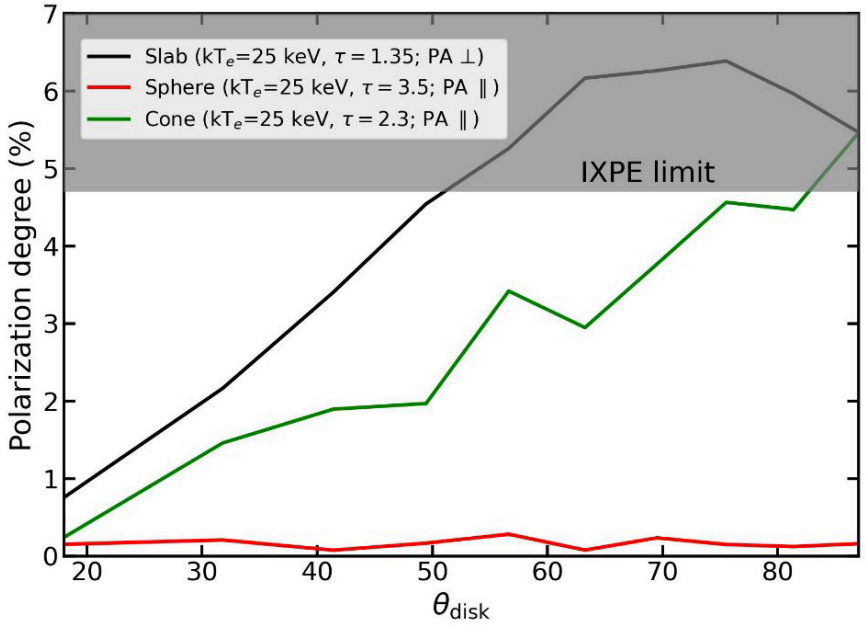
Marinucci+22

- Challenges: long exposure time needed. Complexities of the spectral model require synergy with other X-ray facilities.
- MGC-5-23-16➠Flux(2.0-8.0 keV):7.5E-11 erg/s/cm², observed for 500 ks by IXPE, simultaneously with XMM-Newton and Nustar.
- ***Px<4.7% at 99% confidence level***

IXPE Imaging X-Ray Polarimetry Explorer

MCG-5-23-16





- Preferred direction parallel to the AGN optical ionisation cone, as by the the [O III emission]
- Only a slab corona predicts a polarization angle perpendicular to the disk.
- A conical and a spherical corona are allowed at almost any disk inclination, while a slab is permitted only at inclination lower than 50°

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CONCLUSIONS :

- A new observational window for AGN is open.

- Shock acceleration in a energy stratified jet favoured in blazars.
- Slab geometry favoured in Seyfert 1.

- Stay tuned for upcoming papers for AGN and future monitoring of blazavariability!