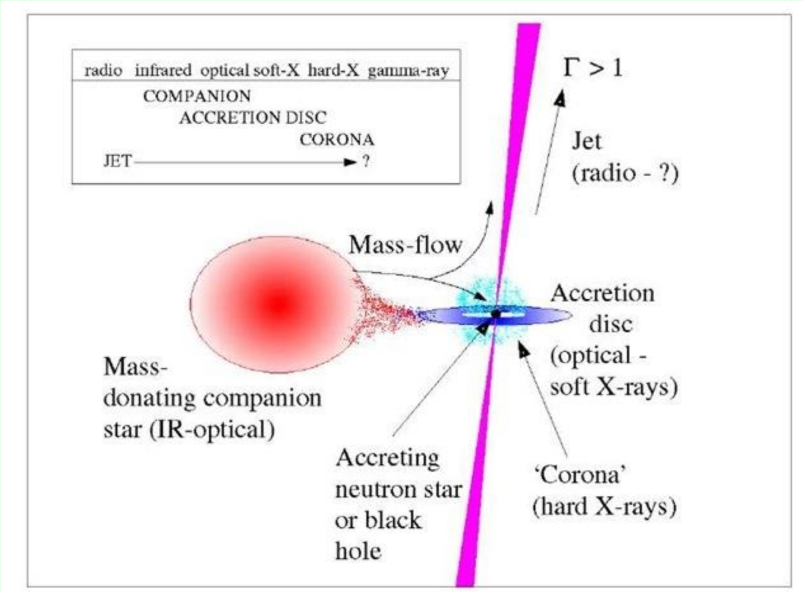
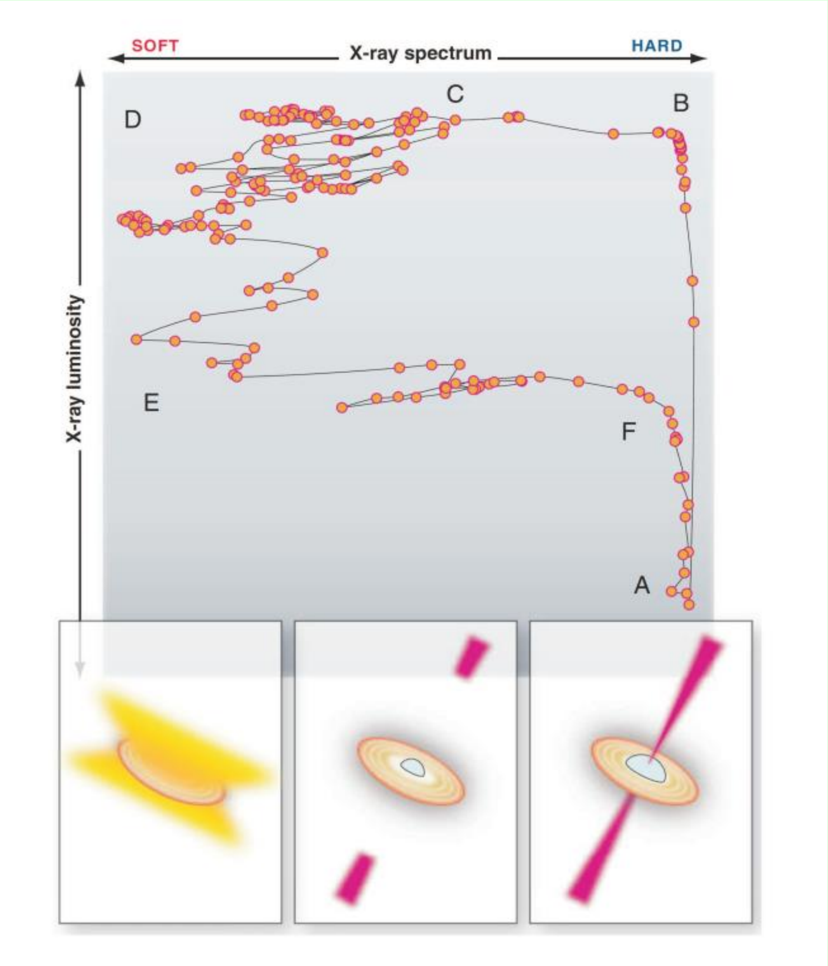
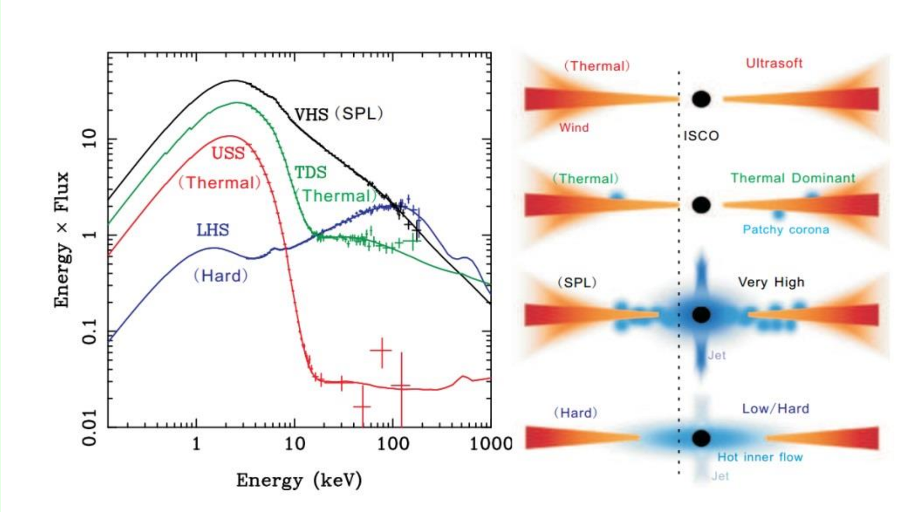
Studying microquasars with X-ray polarimetry

Giorgio Matt
(Università Roma Tre, Italy)

Accreting black hole systems



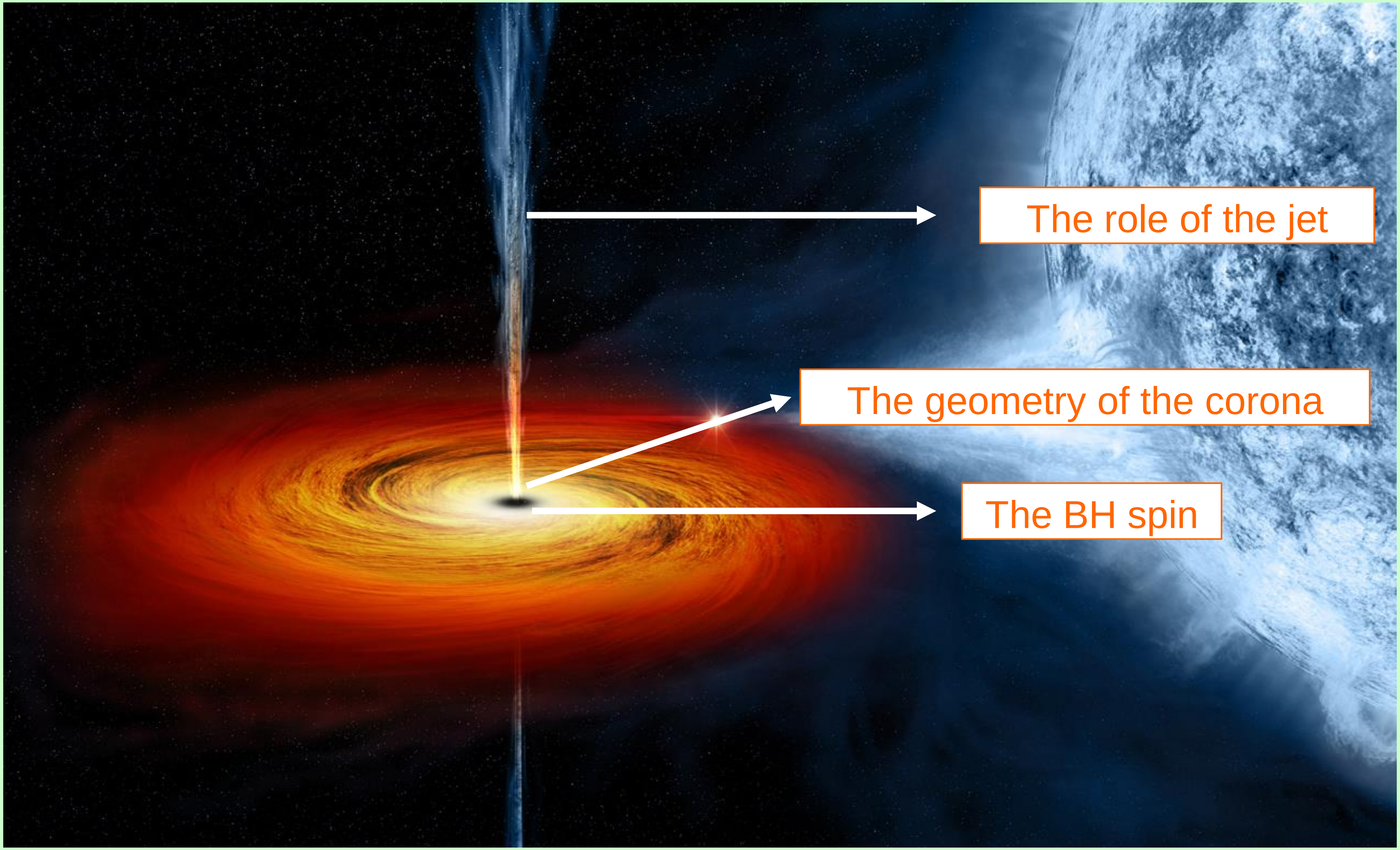




Done et al. 07

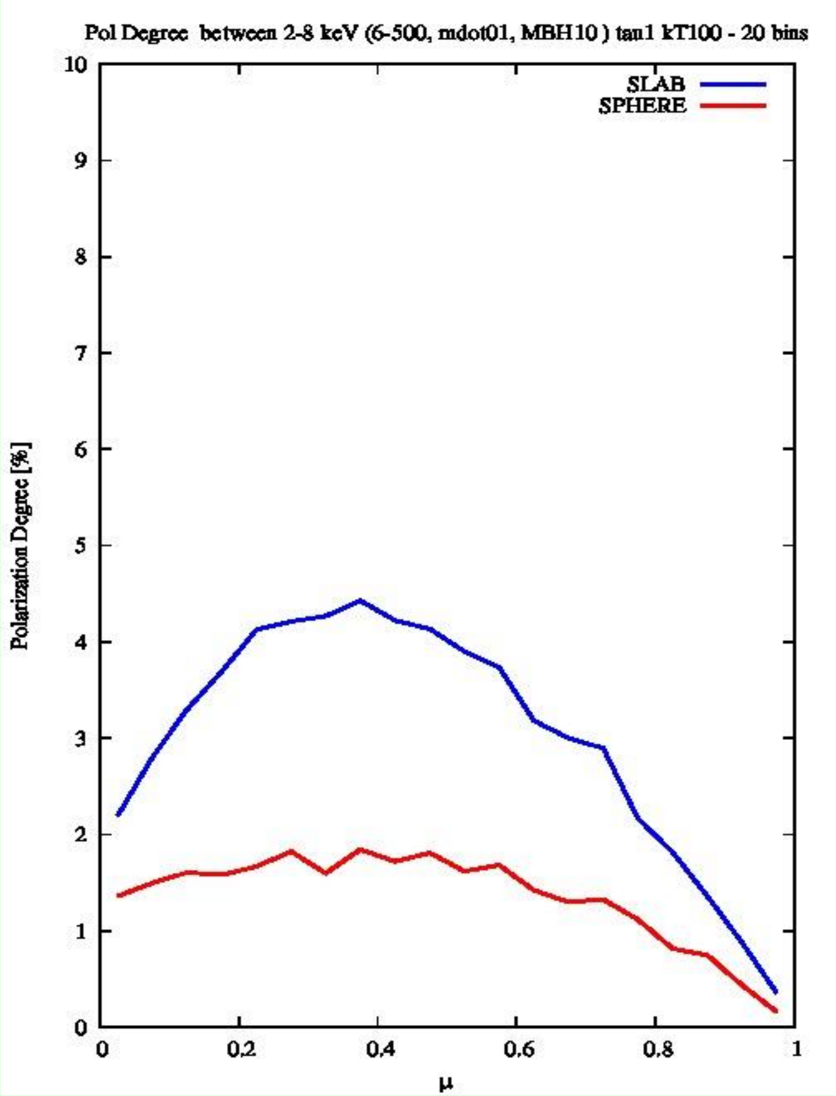
Fender &Belloni 12

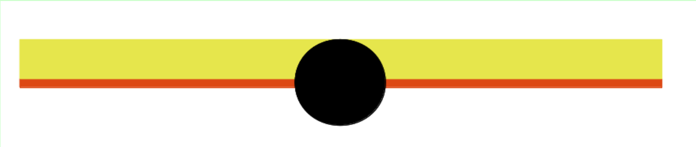
Accreting black hole systems

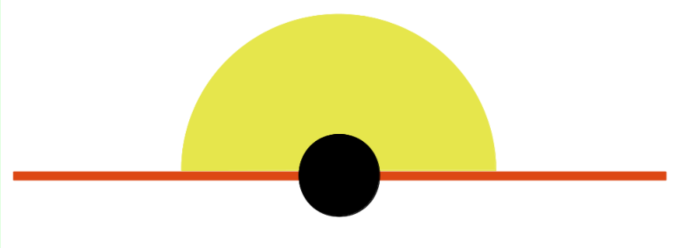


X-ray polarimetry can provide answers to several key problems:
The role of the jet - The geometry of the corona – The spin of the BH

The geometry of the corona (hard state)



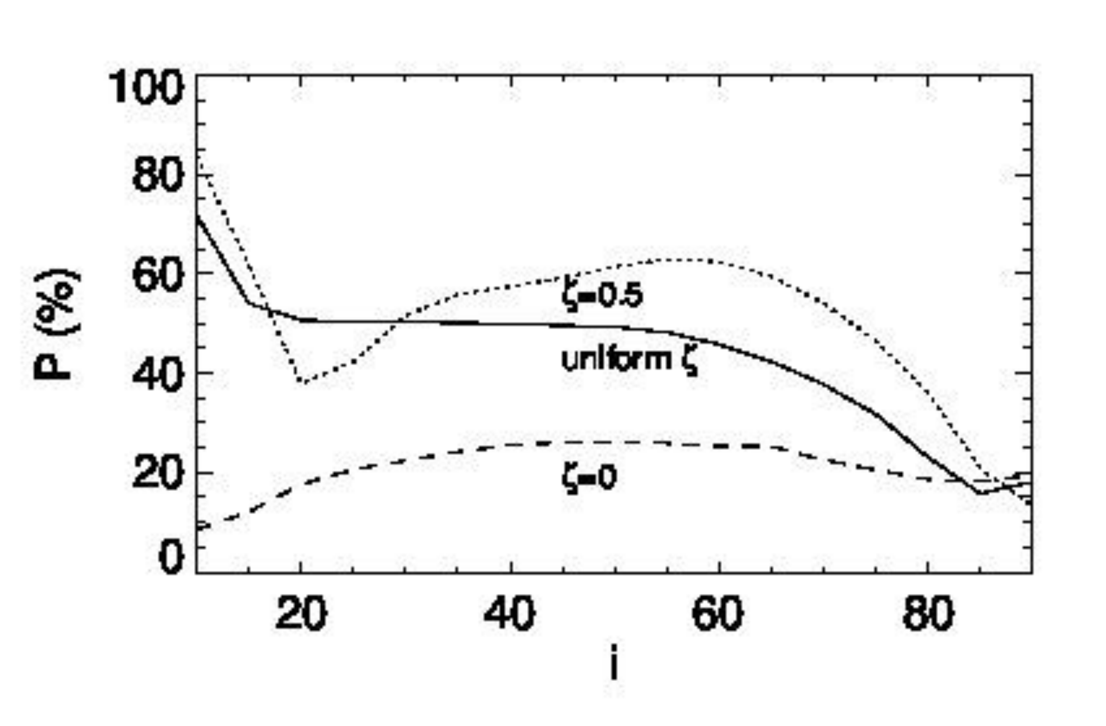


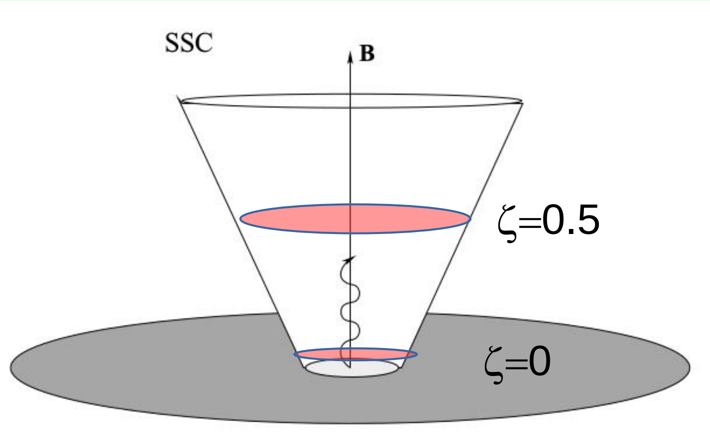


If the emission is due to Comptonization of the disc thermal photons in a hot corona, polarimetry can constrain the geometry of the corona

Courtesy: Francesco Tamborra

The role of the jet (hard state)



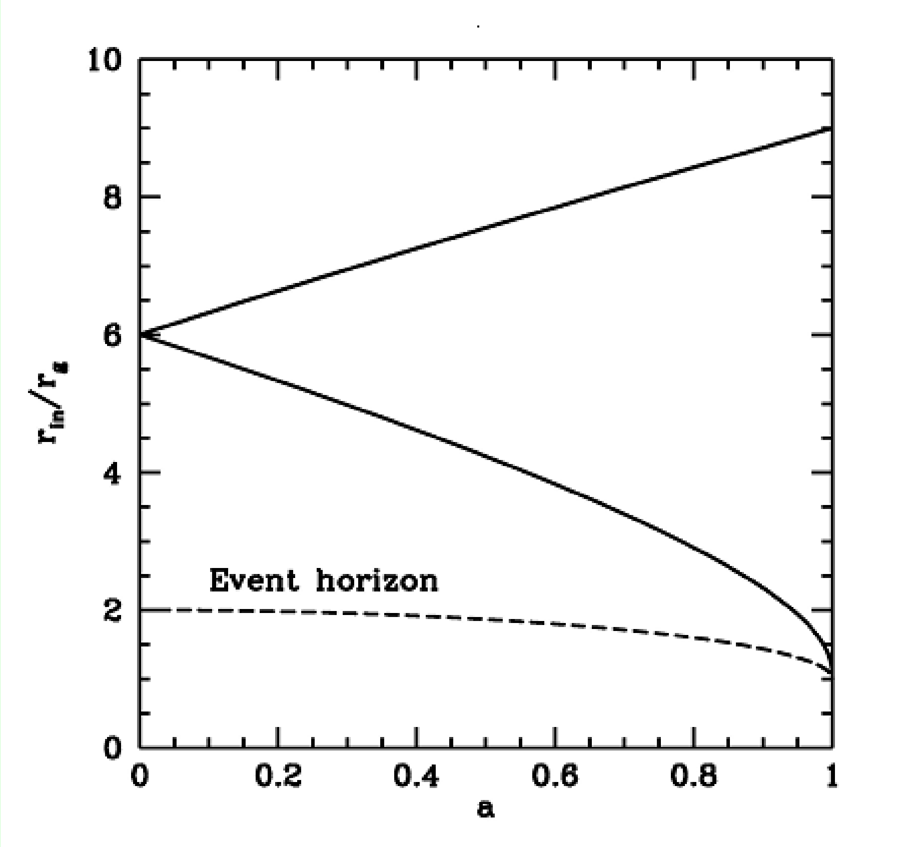


McNamara et al. 2009

Corona emission is predicted to be less than 10%.

Much larger polarization degrees are expected for jet emission

The spin of the black hole (soft state)



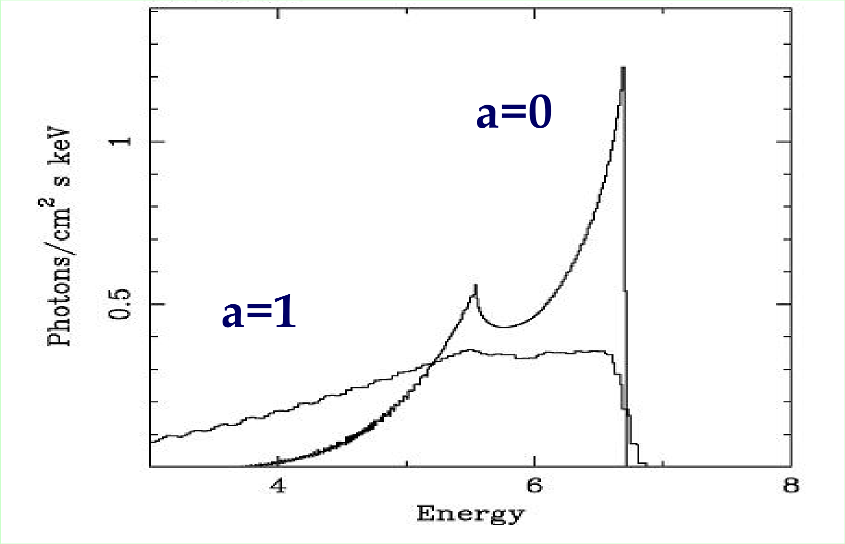
General Relativity modifies the polarization properties of the radiation emitted close to the black hole. In particular, the polarization angle rotates with respect to the Newtonian value.

The effect increases with decreasing radii, i.e. with increasing temperature, i.e. with increasing photon energy

→ rotation of the polarization angle with energy

The spin of the black hole (soft state)

In accreting Galactic black hole systems, X-ray polarimetry can provide a technique to measure the spin of the black hole, in addition to the three methods employed so far



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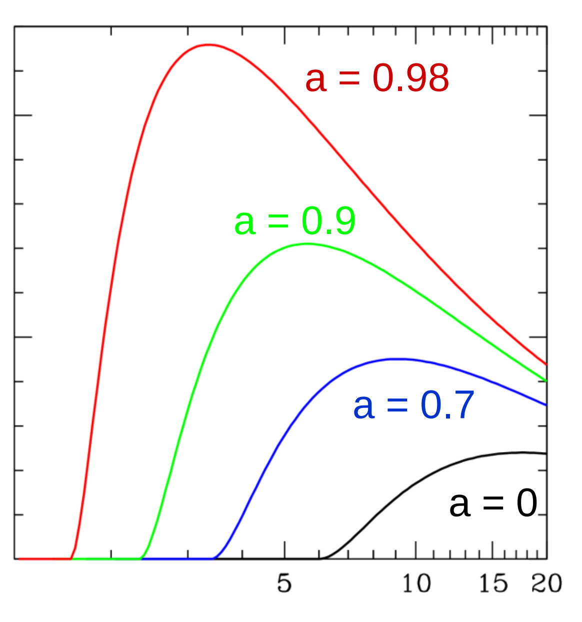

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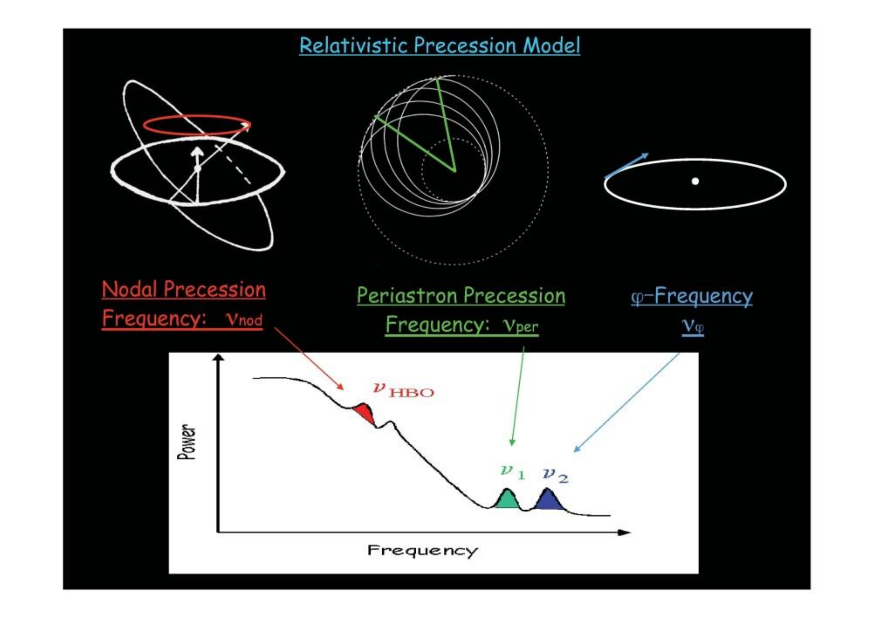

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J1655-40:

QPO: a = J/Jmax= 0.290±0.003

Continuum: a = J/Jmax= 0.7±0.1

Iron line a = J/Jmax > 0.95

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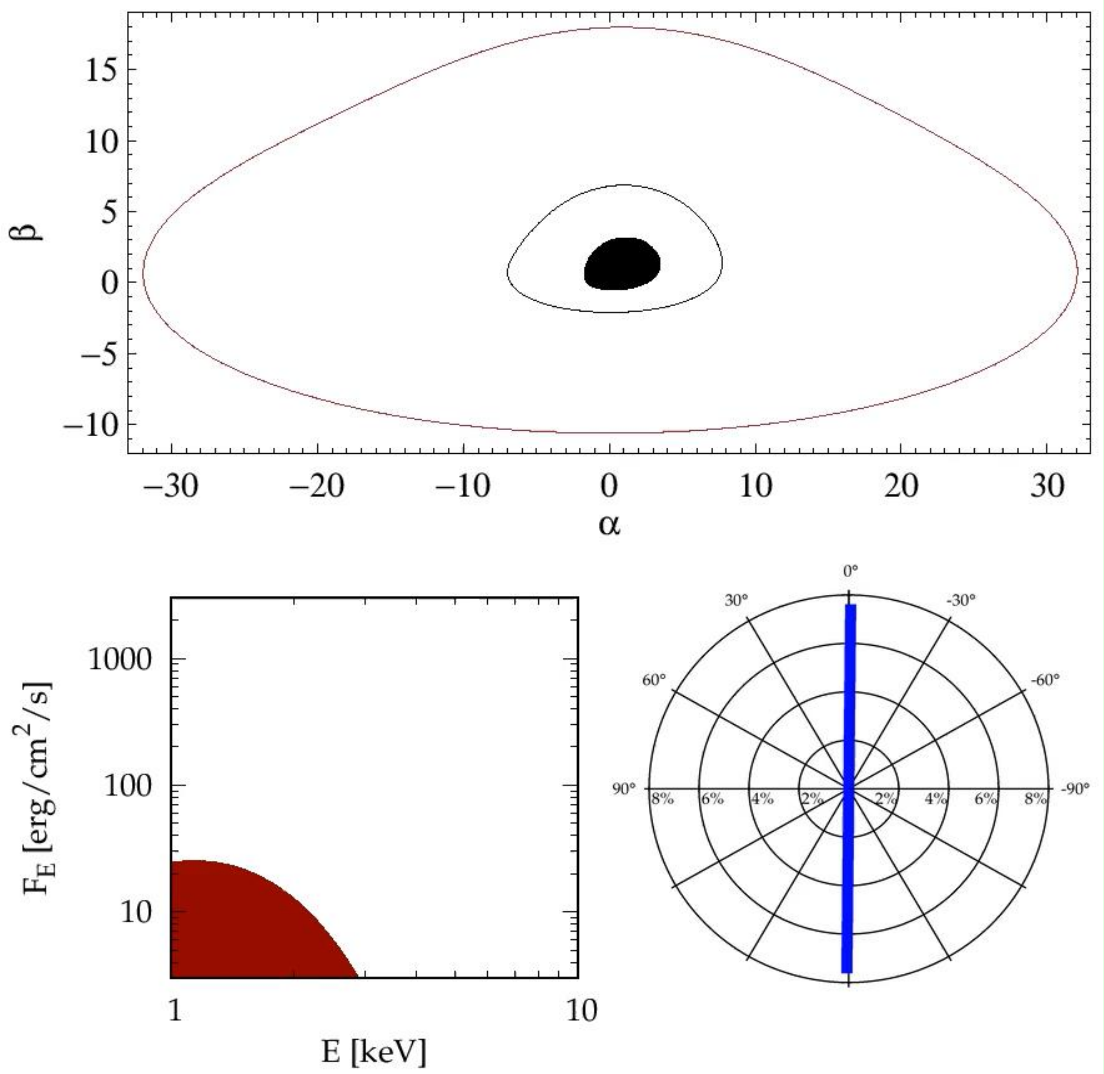

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Courtesy: Michal Dovciak

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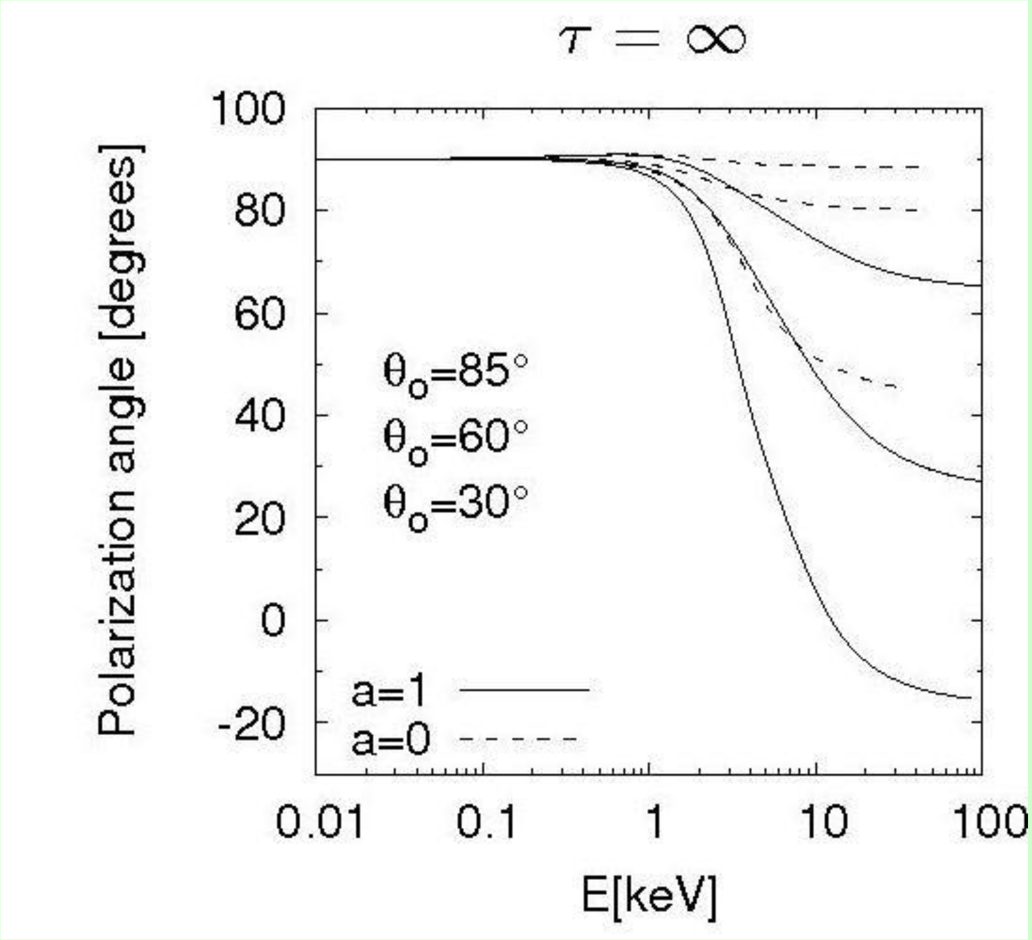

Dovciak et al. 2008

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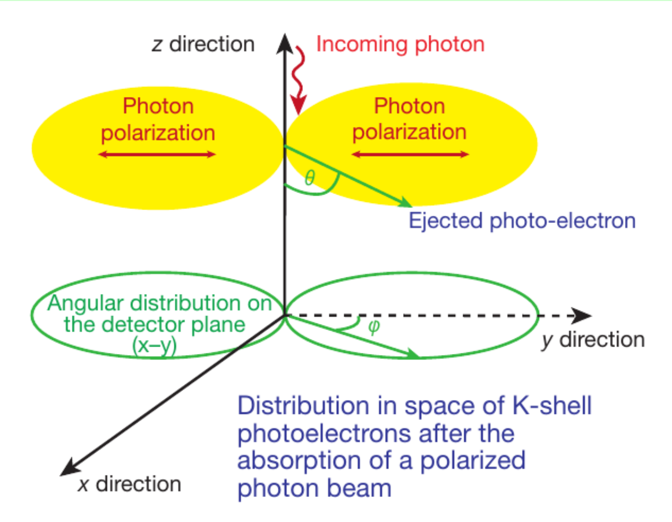
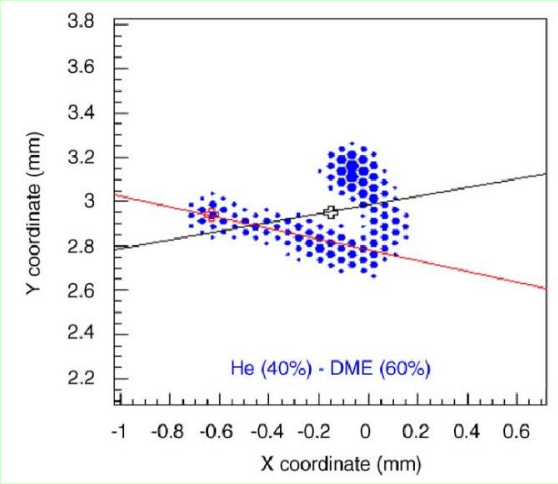
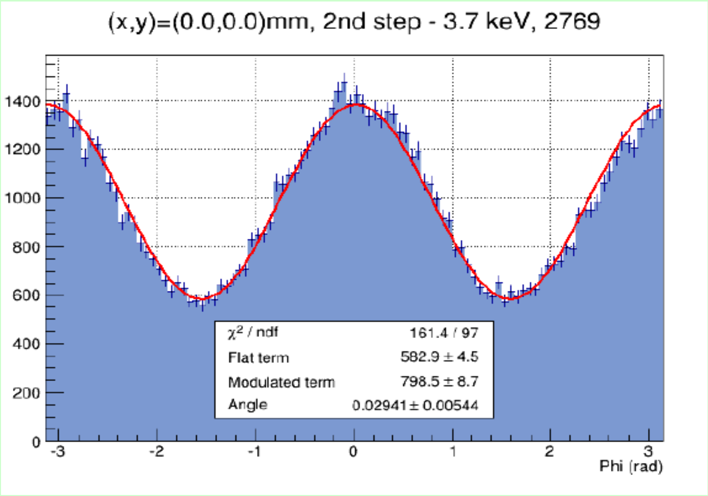
The photoelectric polarimeter

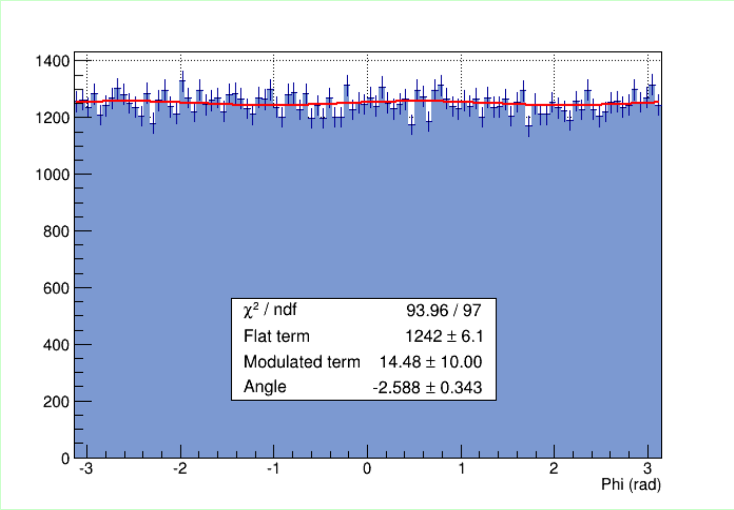


$$\frac{\partial\sigma}{\partial\Omega} = r_0^2 \frac{Z^5}{137^4} \left(\frac{mc^2}{h\nu}\right)^{7/2} \frac{4\sqrt{2}\sin^2(\theta)\cos^2(\varphi)}{(1-\beta\cos(\theta))^4}$$



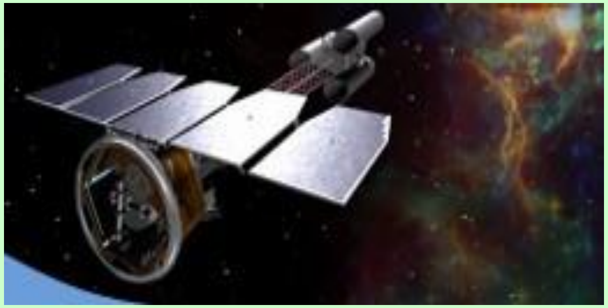


Real modulation curve derived from the measurement of the emission direction of the photoelectron.



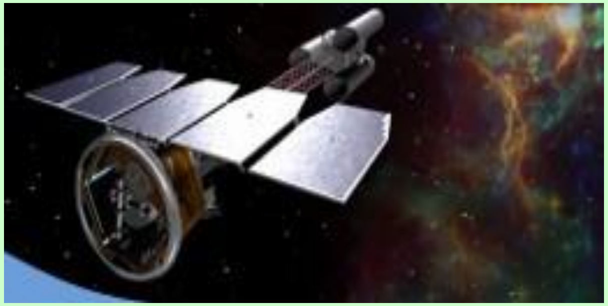
Residual modulation for unpolarized photons.

IXPE (Imaging X-ray Polarimetry Explorer)



- Proposed to NASA as a SMall EXplorer (SMEX) mission in December 2014
- One of the three proposals selected for an Assessment Study in August 2015
- Final down-selection in January 2017
- Launch on early 2021
- Baseline duration: 2 years

IXPE (Imaging X-ray Polarimetry Explorer)



Principal Investigator: **M. C. Weisskopf** (MSFC)

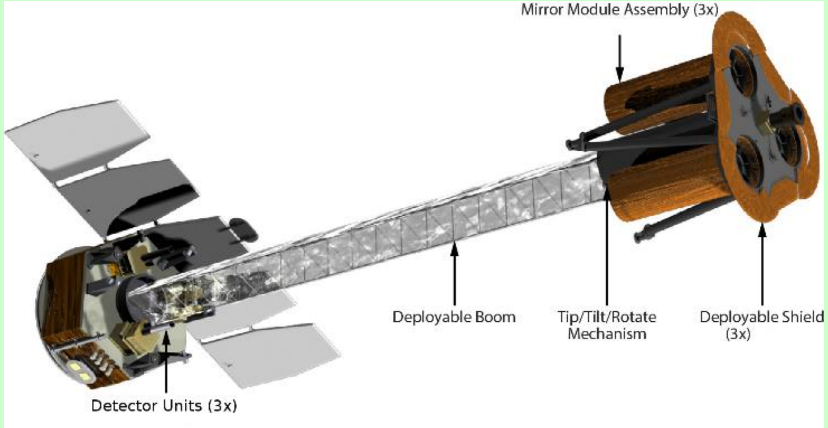
Co-Investigators: *Brian D. Ramsey, Paolo Soffitta, Ronaldo Bellazzini, Enrico Costa, Stephen L. O'Dell, Allyn Tennant, Herman Marshall, Fabio Muleri, Jeffery Kolodziejczak, Roger W. Romani, Giorgio Matt, Victoria Kaspi, Ronald Elsner, L. Baldini, L. Latronico*

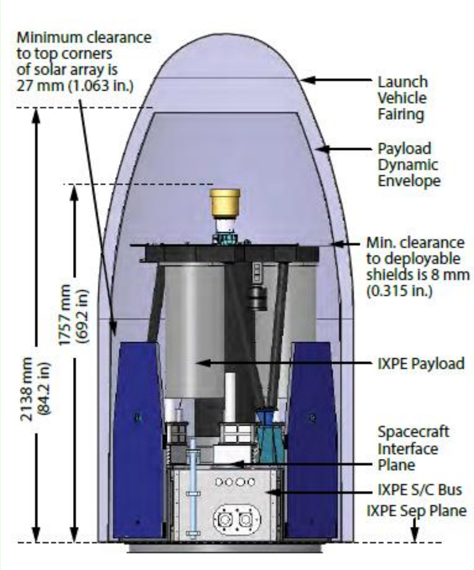
Marshall Space Flight Center: PI team, project management, SE and S&MA oversight, mirror module fabrication, X-ray calibration, science operations, and data analysis and archiving	iaps, INAF (Istituto Nazionale di Astrofisica / National Institute for Astrophysics), INFN: Polarization-sensitive imaging detector systems
	LASP: Mission operations
asi (agenzia spaziale italiana): Detector system funding, ground station	Roma Tre Università degli Studi, Stanford University: Scientific theory
	McGill: Science Working Group Co-Chair
Ball: Spacecraft, payload structure, payload, observatory I&T	Massachusetts Institute of Technology: Student collaboration

- **Pegasus XL launch from Kwajalein**
- **540-km circular orbit at 0° inclination**
- **2 year baseline mission, 1 year SEO**
- **Point-and-stare at known targets**
- **Science Operations Center at MSFC**
- **Mission Operations Center at CU/LASP**
- **Malindi ground station (Singapore Backup)**

IXPE (Imaging X-ray Polarimetry Explorer)

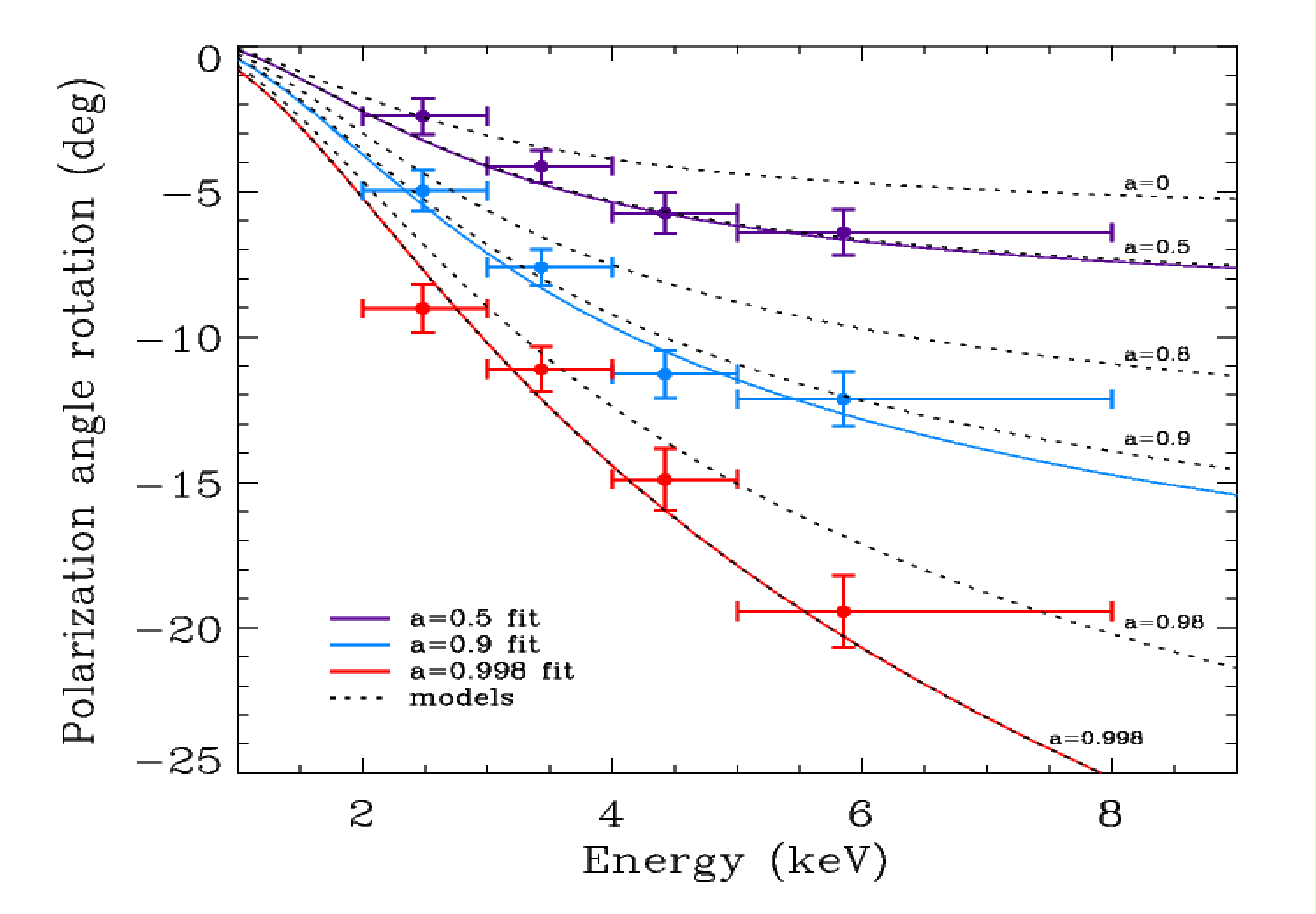
- **3x Telescopes**
  - 3x Mirror Units (MUs) + 3x Detector Units (Gas Pixel Detectors)
  - A Detectors Service Unit (DSU) with built-in redundancy
  - 4 m focal length, deployable boom and X-ray shield
- **Performance**
  - Polarization sensitivity: $MDP_{99\%}$<5.5% in 1 day for flux of 10^{-10} ergs/cm^2/sec
  - Energy range: 2-8 keV
  - Limit polarization: 0.5% (degree), 1 degree (angle)
  - Angular resolution: better than 30 arcsec, field of view larger than 9 arcmin
  - UTC synchronization: better than 250 μs
  - Energy resolution: better than 25%





IXPE (Imaging X-ray Polarimetry Explorer)

200 ks IXPE observation of GRS1915+105



Adapted from Dovciak et al. 2009

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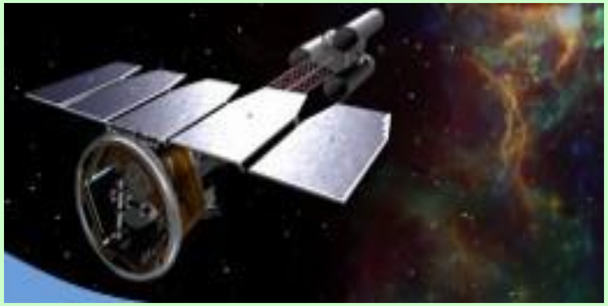
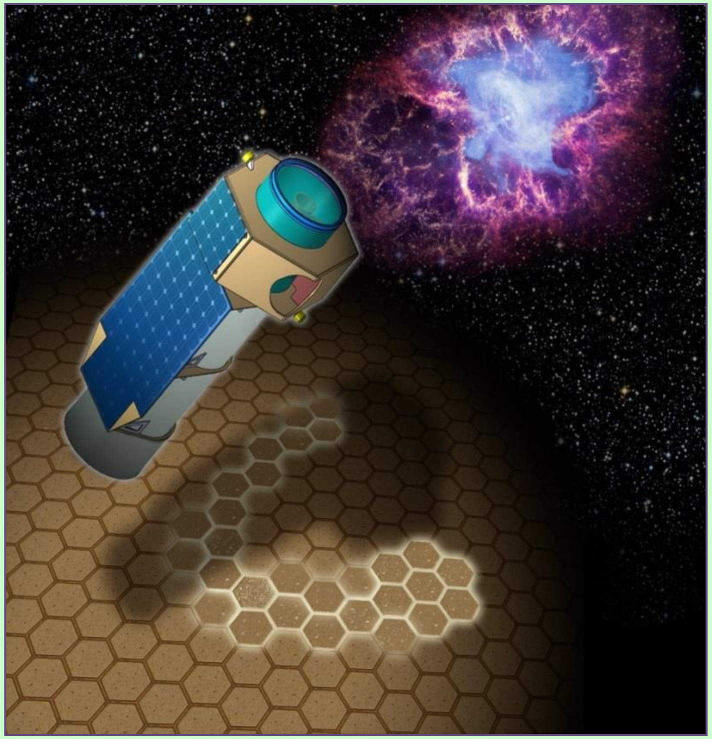


Detailed observing plan still to be defined, but certainly microquasars will figure prominently

XIPE

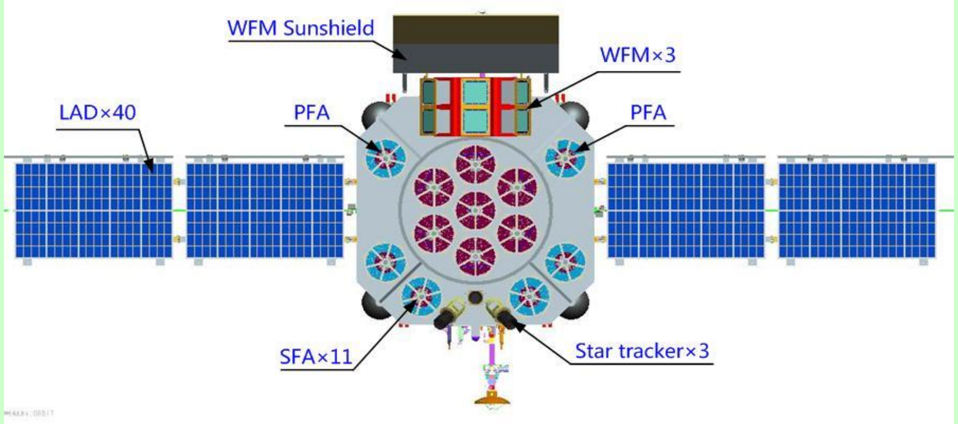
XIPE (X-ray Imaging Polarimetry Explorer)
Selected by ESA (M4) for phase A study
Final down-selection: by SPC on 21-22 November 2017
Lead Scientist: Paolo Soffitta (IAPS/INAF, Italy)



eXTP

eXTP (enhanced X-ray Timing and Polarimetry Mission). ***Proposed to CAS; selected in 2011 as one of 8 "background missions". Phase A study in 2011-14. P.I: Shuang-Nan Zhang (Tsinghua Univ.). An international consortium (China + many european countries). Launch: 2025+***

Simultaneous spectroscopic, timing and polarimetric observations



- Focal plane imaging polarimeter: 4 optics with 5.25m FL
- Imaging, PSF 20 arcsec HPD
- Gas Pixel Detector: single photon, <100μs
- Energy band: 2-10 keV
- Energy resolution: 20% FWHM @6 keV
- Total effective area: 900 cm^2 @2 keV (includes QE)

X-ray polarimetry promises to provide a great leap forward in our understanding of microquasars

IXPE will observe several such sources in different states to provide answers to a number of key questions