



X-ray polarimetry in space with gaseous detectors

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12th Astroparticle Physics Science Fair 2025/2026: Low Energy

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12 / 02 / 2026

X-ray polarimetry

- **Light** from extra-galactic sources:

- spatial distribution

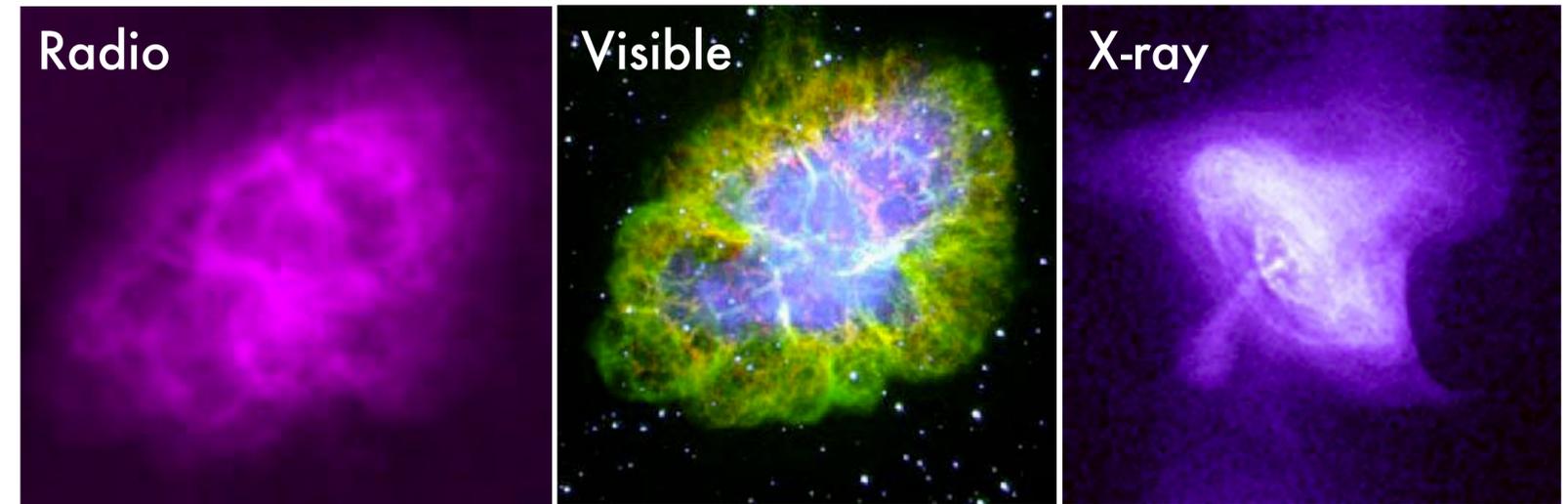
- energy spectrum

- time of arrival

- **polarization**

⇒ information on the extra-galactic sources

Crab Nebula



→ It depends on the **geometry** of the emitting object, magnetic fields, gravitational fields, etc.:

- ◎ polarization degree (**PD**) depends on the degree of symmetry of the emitting system

- ◎ polarization angle (**PA**) depends on the orientation

X-ray polarimetry

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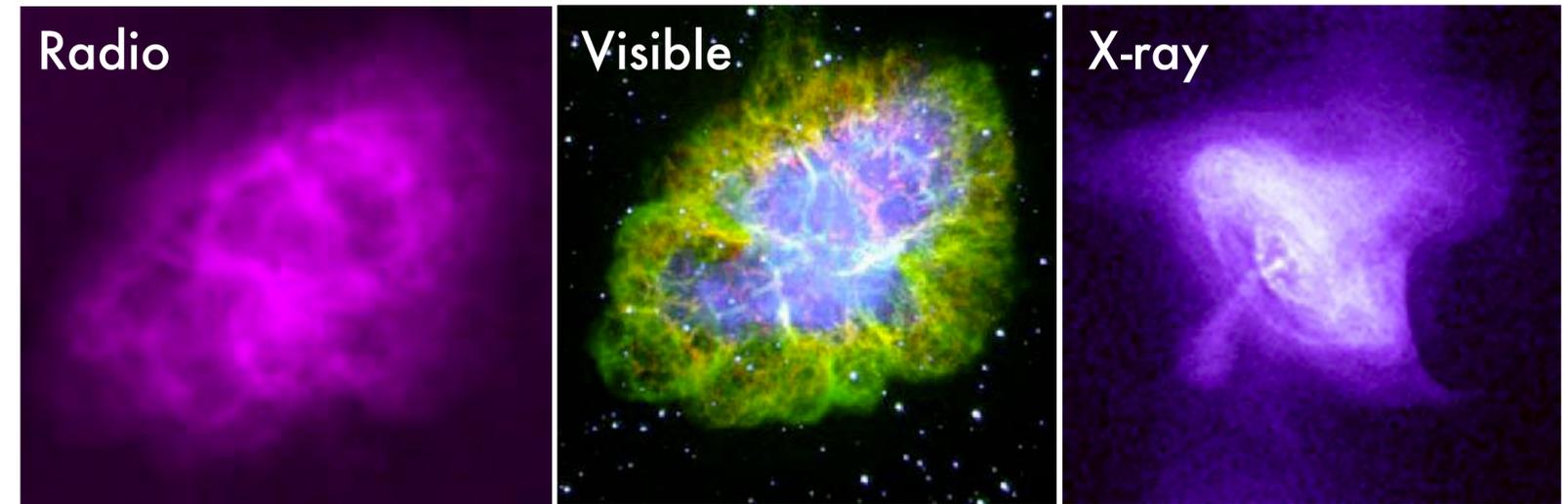
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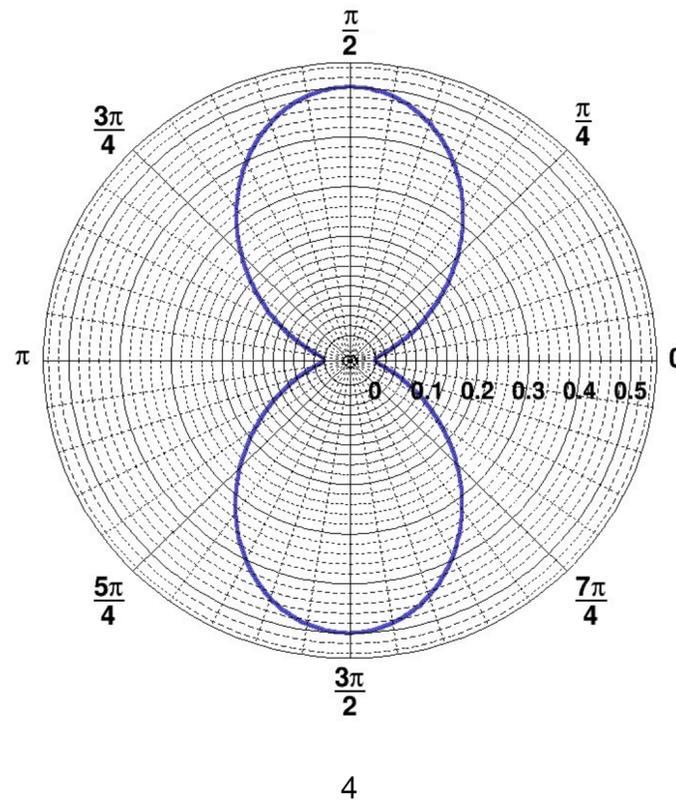
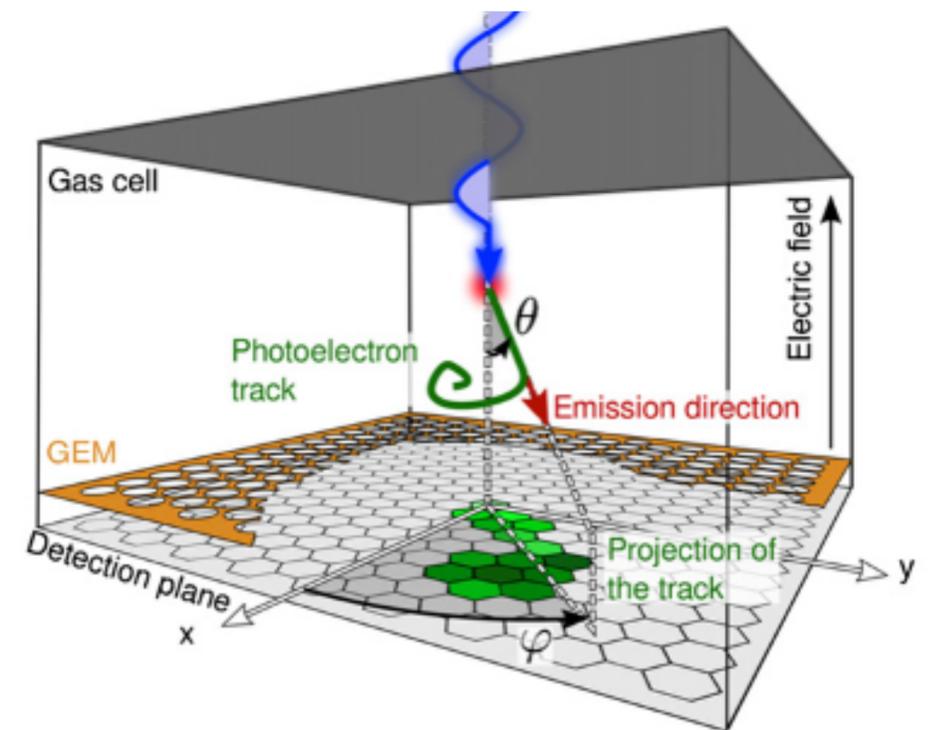
Crab Nebula



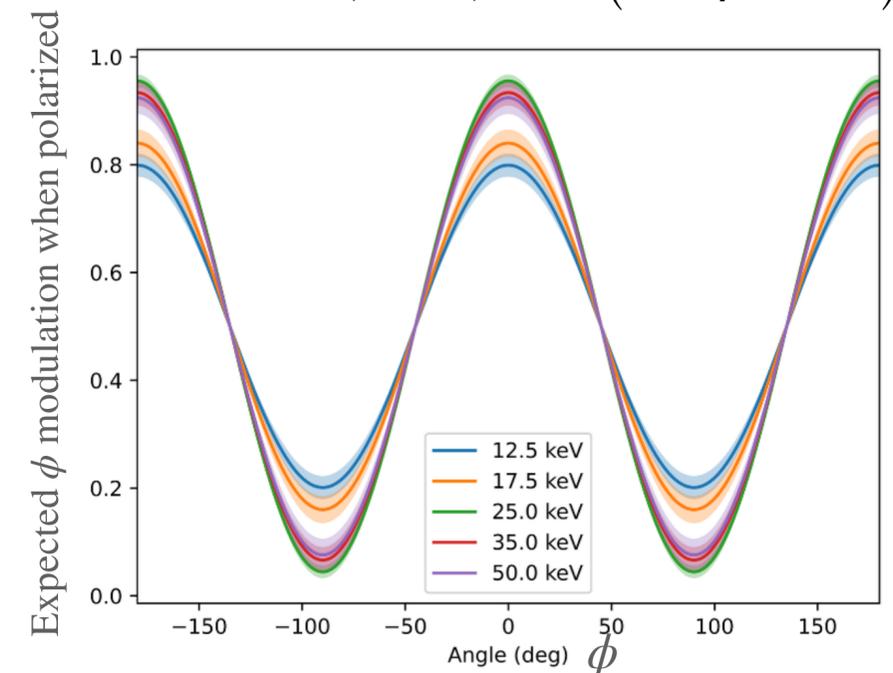
→ It depends on the orientation of the emitting source. In the case of pulsars, the observation of light from an emitting source is **complete only with polarization** on the entire energy spectrum

X-ray polarimetry with photoelectric effect

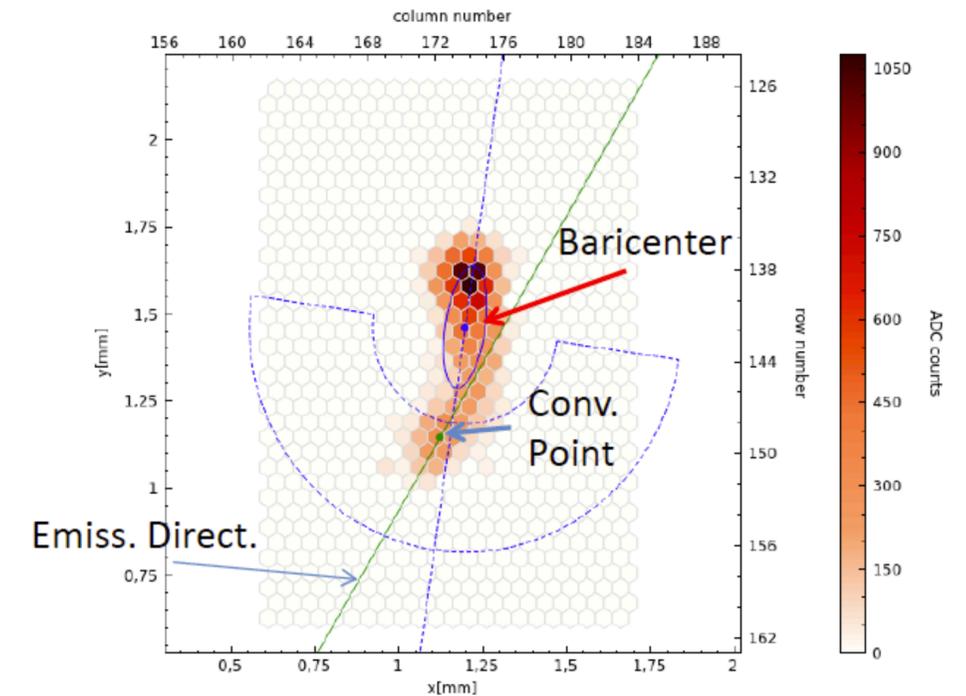
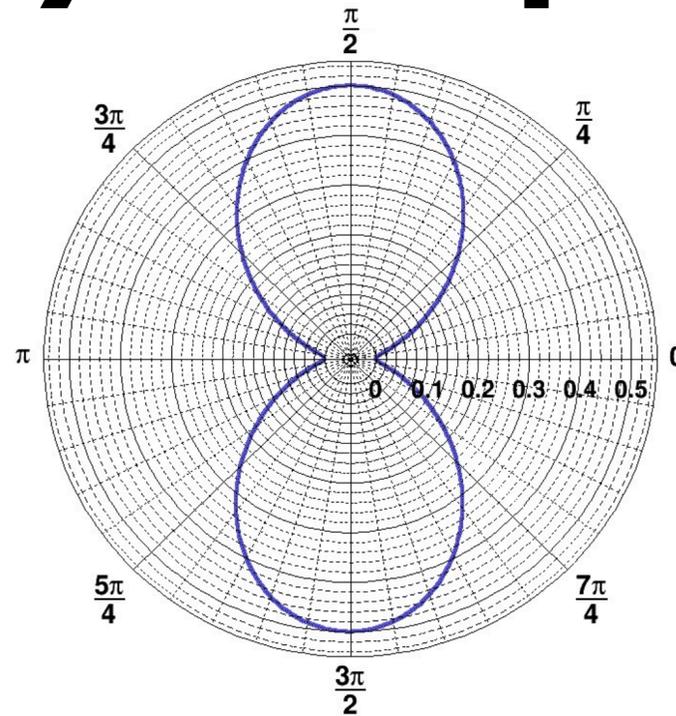
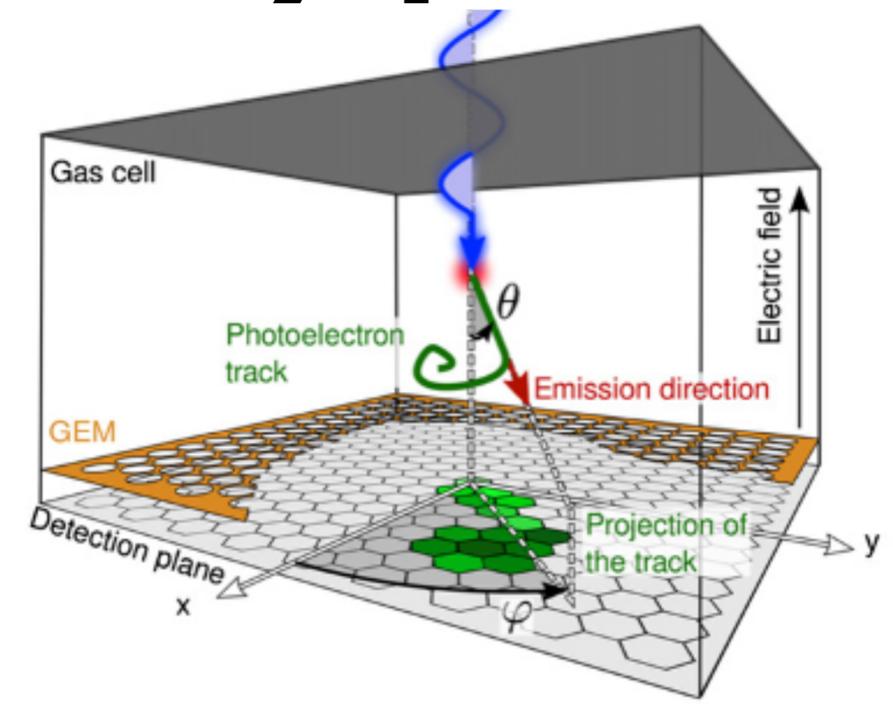
- Experimentally **difficult** to measure the polarization of X-ray photons at high energy, as they have a strong penetration power
- Measurement of polarization of several X-rays sources was recently made by the **IXPE** experiment in space, **based on gaseous detectors (GPD)**
- Possible by exploiting the **directionality** of the X-ray **photoelectric absorption**



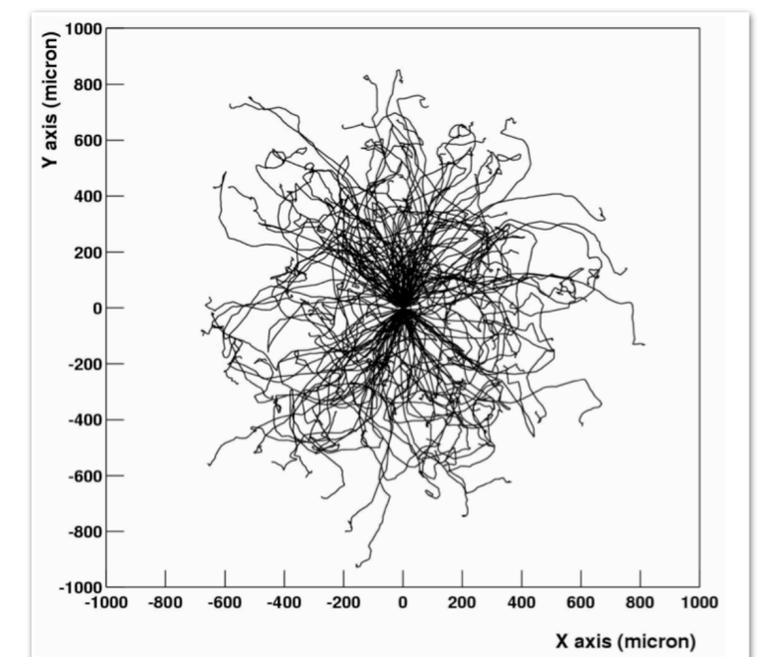
$$\frac{d\sigma}{d\Omega} = r_0^2 \frac{Z^5}{137^4} \left(\frac{mc^2}{h\nu} \right)^{\frac{7}{2}} \frac{4\sqrt{2} \sin^2 \theta \cos^2 \phi}{(1 - \beta \cos \theta)^4}$$



X-ray polarimetry with photoelectric effect



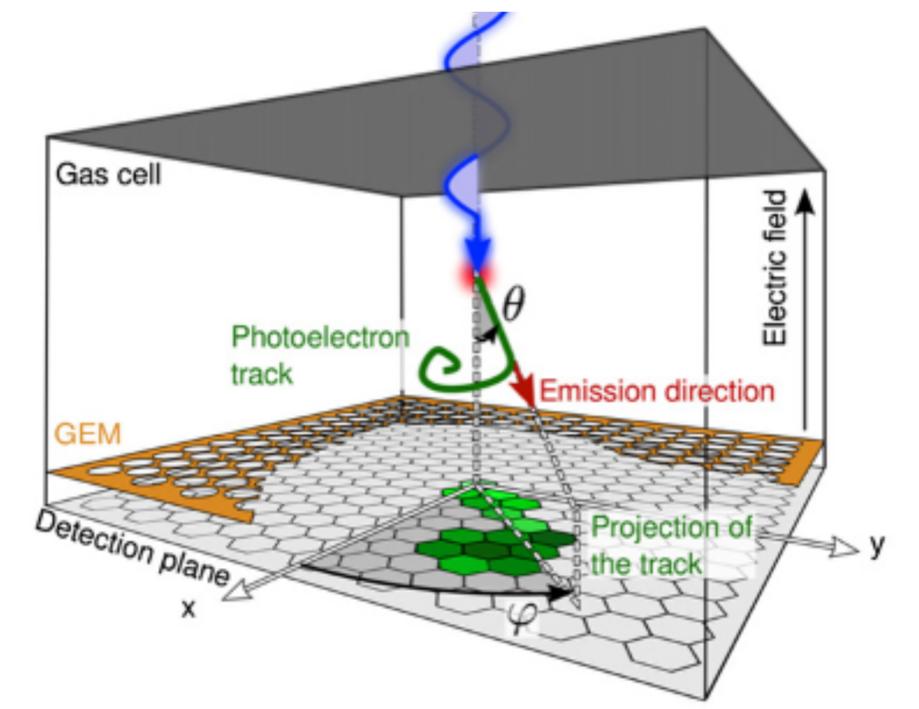
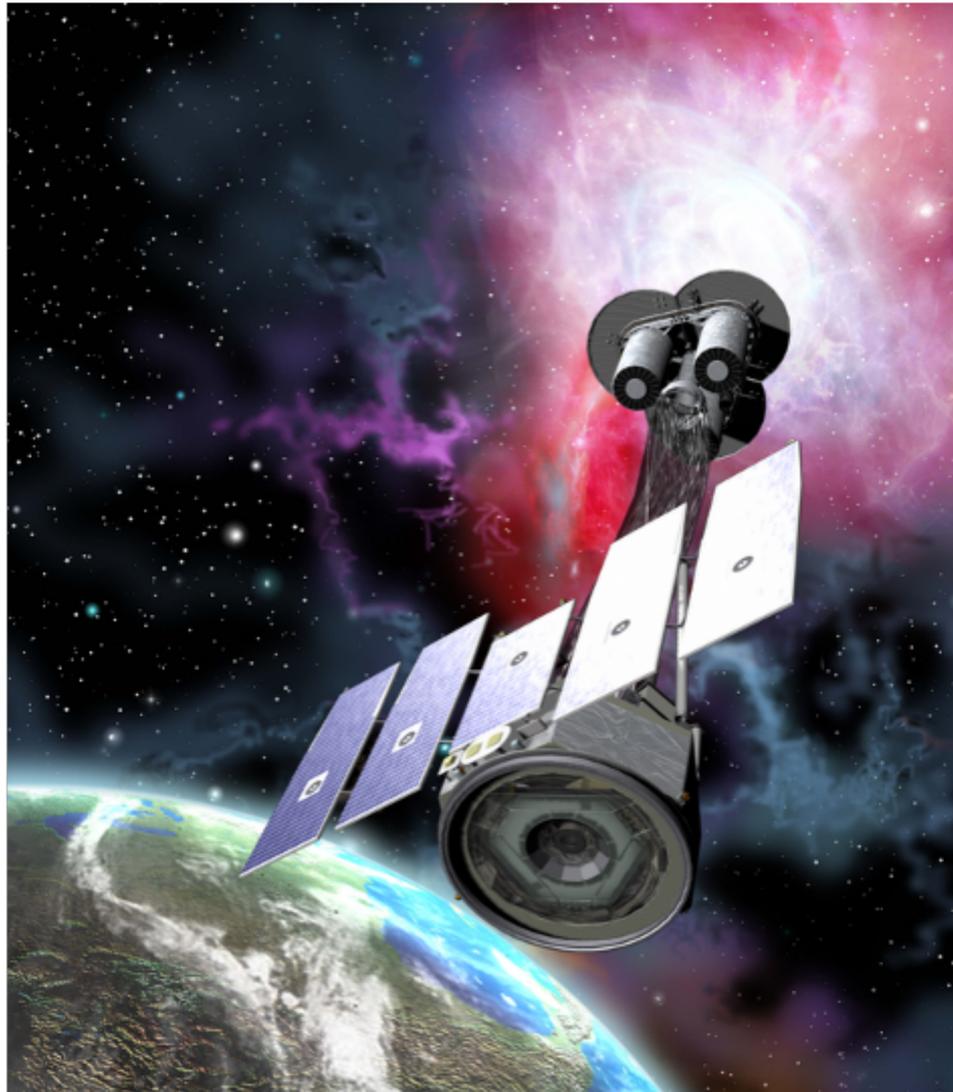
- The information on the direction of the photo-electron is contained only on the **first part of the track**
- At low energy $\sim 1-10$ keV, the track of the emitted photo-electron is $O(200-300 \mu\text{m})$ long \Rightarrow polarimetry with photoelectric effect is only possible using a **gaseous detector**



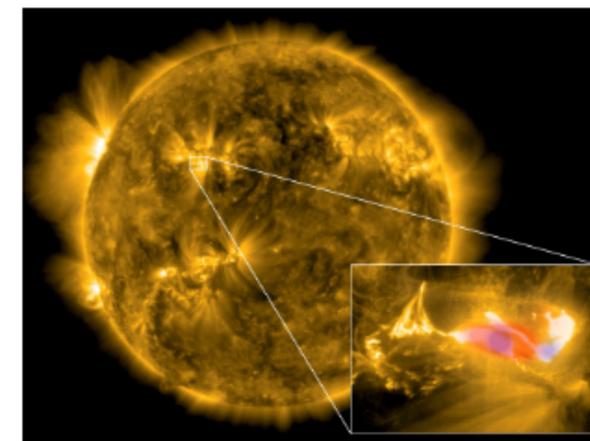
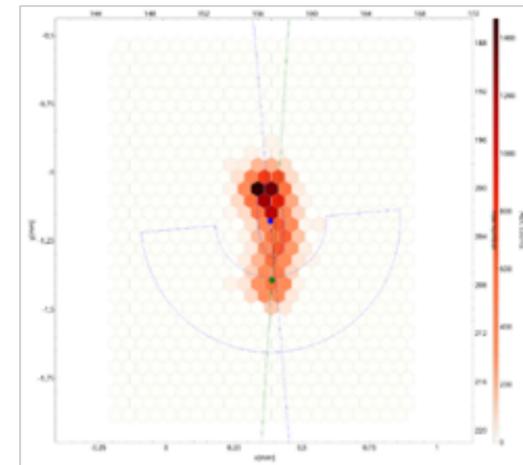
Limitations of IXPE

“IXPE was a great success but as experimentalists we can do better”

Paolo Soffitta



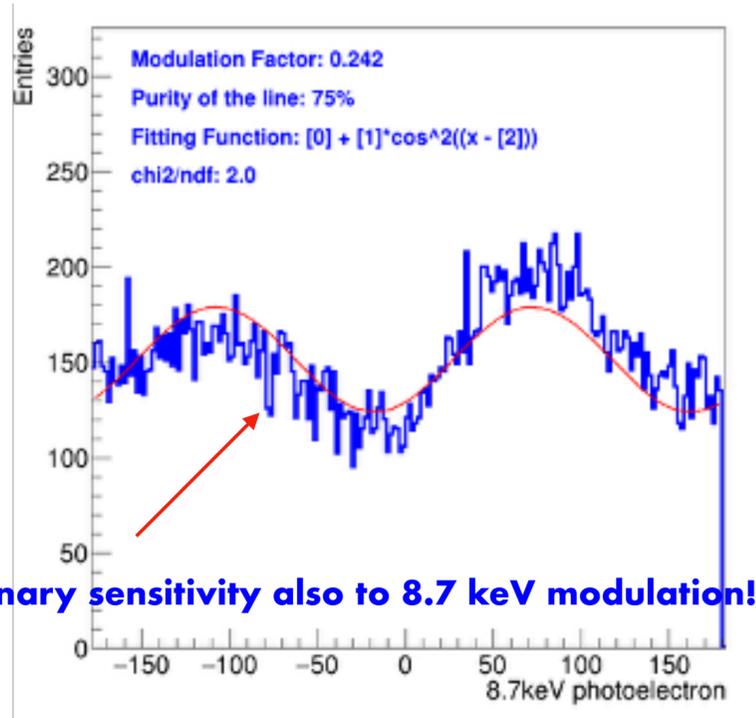
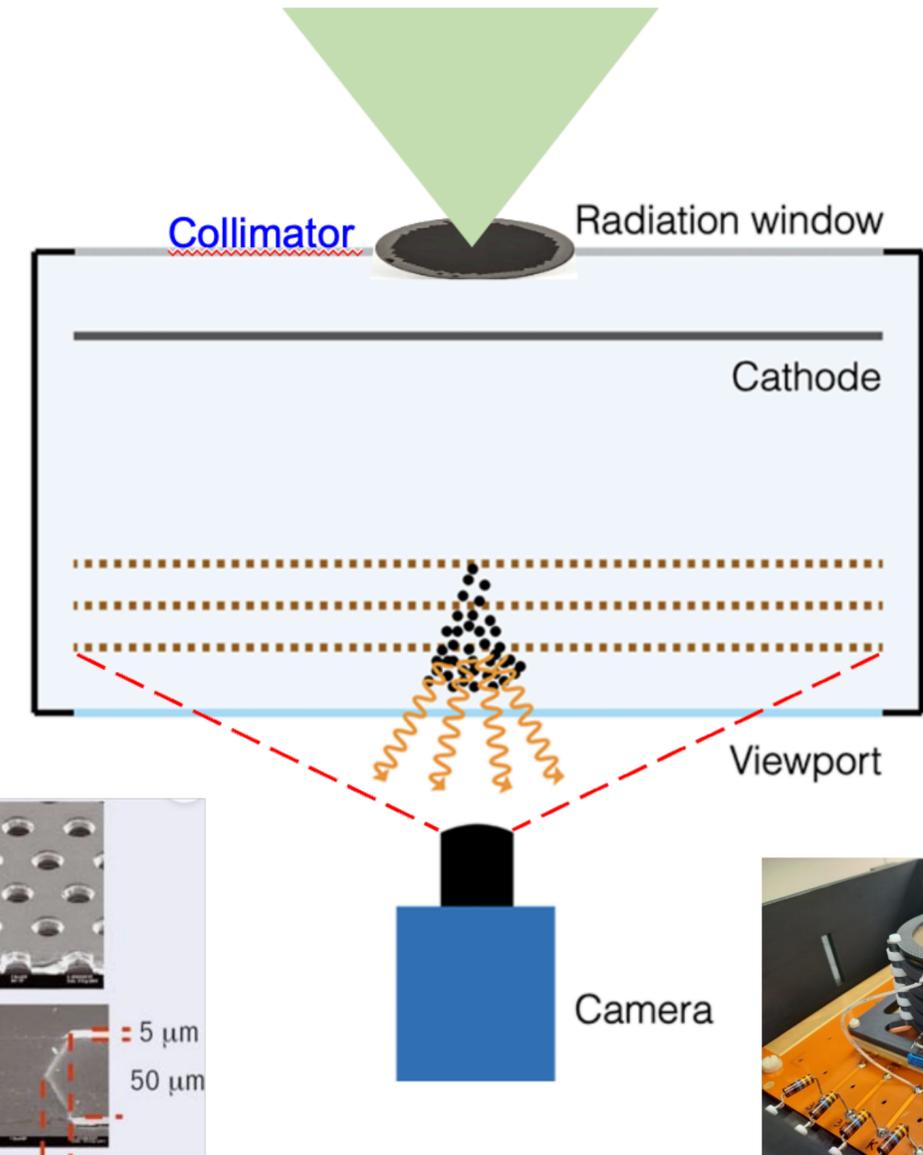
- **Deadtime of 1 ms per event**
 - Need to evaluate pedestal after every event
- **Continuous calibrations**
 - Caused by GEM and ASIC and glue absorption of gas
- **2D readout**
 - Lower discrimination power to tracks oriented toward the sensor plane
 - (more background)
- **Limited to focal plane of X-ray optics**
 - Limited field of view
 - Loss to sensitivity to transients (helpful for multimessenger physics)
- **Energy range < 9 keV**
 - Higher energies can increase information on different astrophysical phenomena



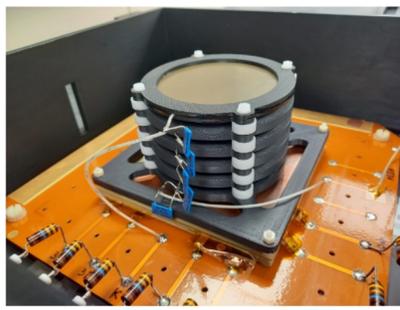
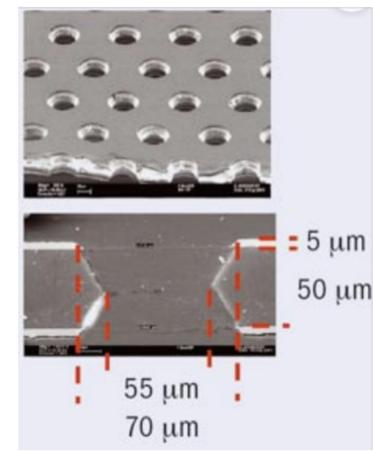
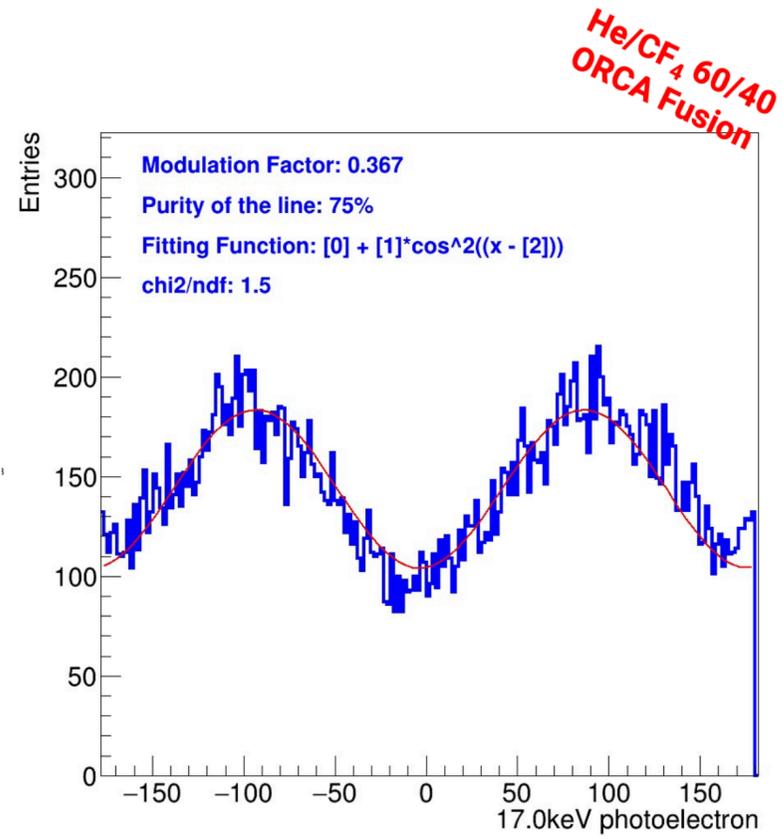
P.S. IXPE budget + launch = 200 M€

HypeX: High Yield Polarimetry Experiment in X-rays

- **R&D** activities carries out at LNGS, LNF and INAF facility
- **CYGN0 technology** (gaseous TPC + optical readout) applied to polarimetry, He:CF4 or Ar:CF4 mixtures
- **Promising results** from calibration with polarized source

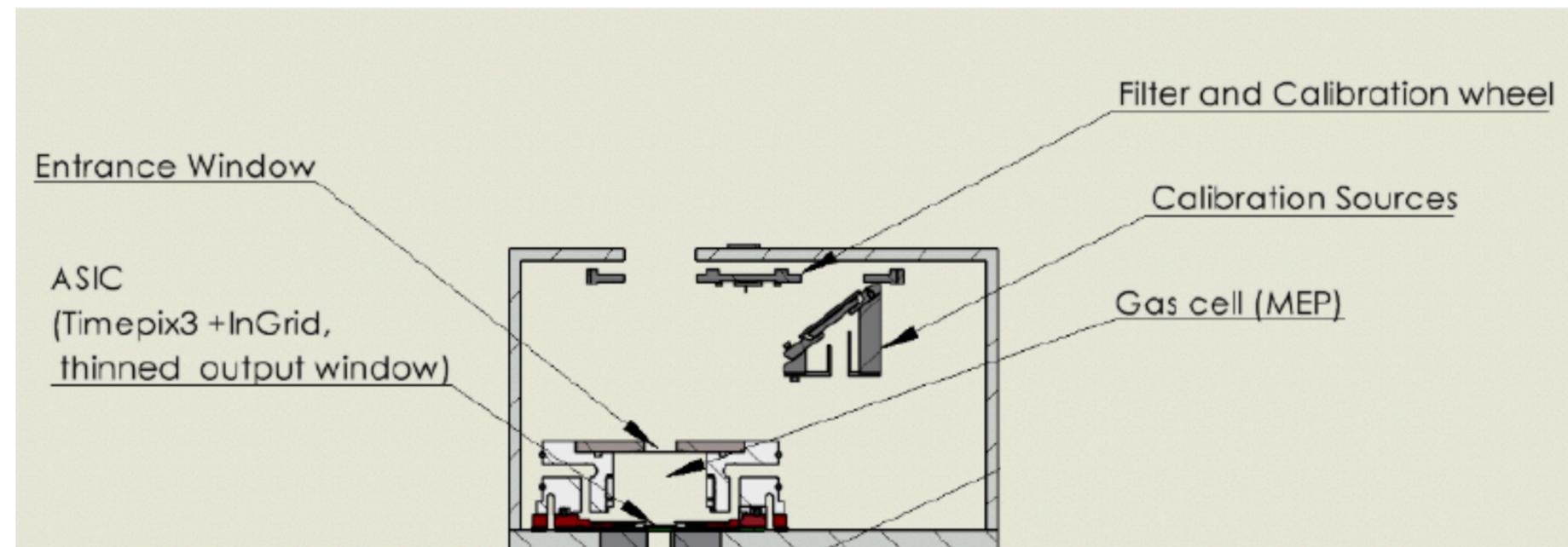
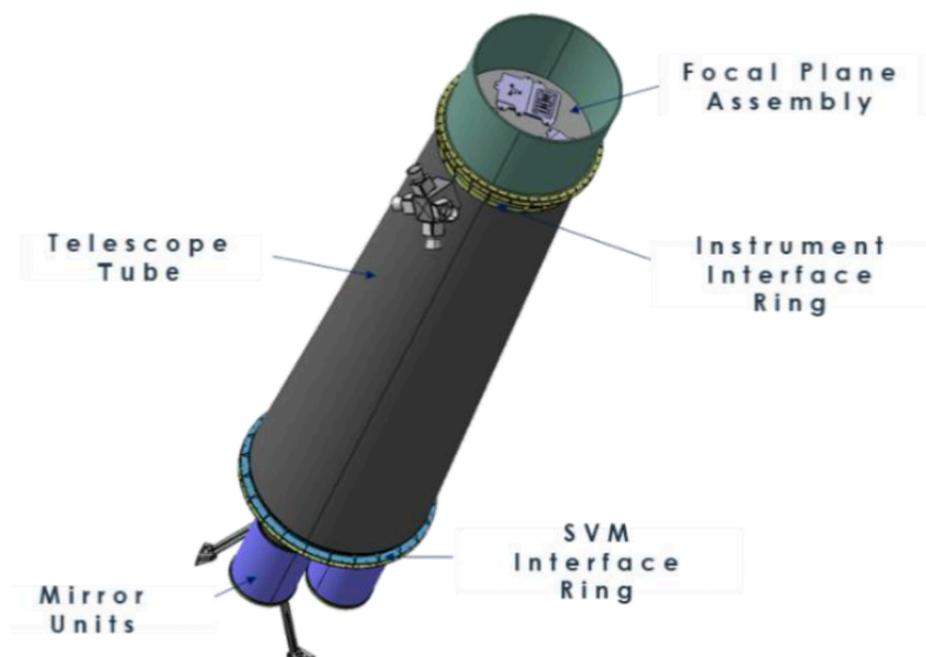
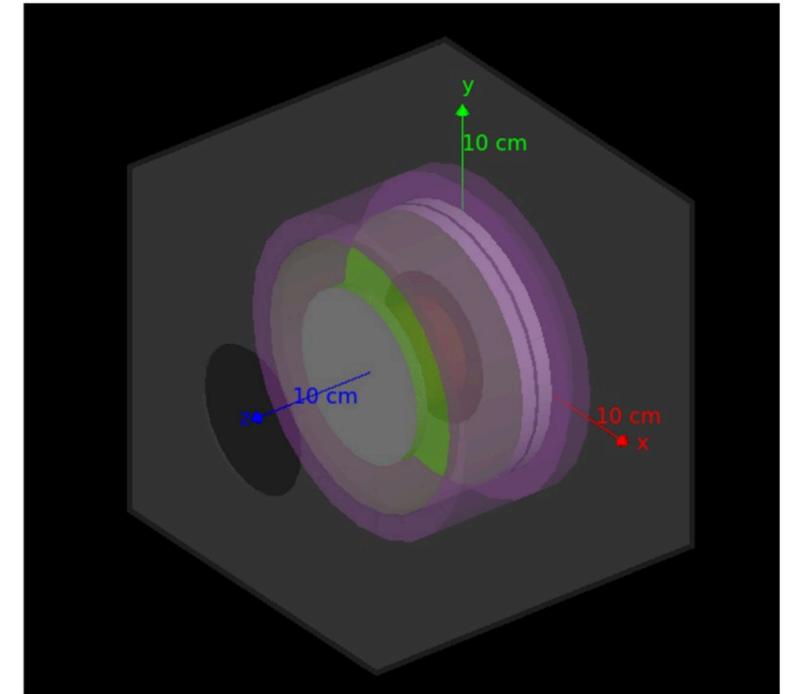


Preliminary sensitivity also to 8.7 keV modulation!



EXPO: Enhanced X-ray Polarimetry Observatory

- Polarimeter in the **6-30 keV range**
 - Timepix3 + InGrid, DME or Ne-DME
- **ESA M-8 proposal**: launch foreseen (if approved) in 2041
- Inherited **expertise from IXPE**
- **Status**:
 - **Step 1 selection passed**
 - **Step 2 submission on March 2026**



People at GSSI

Prof. Elisabetta Baracchini



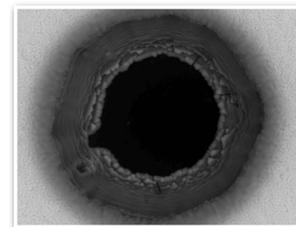
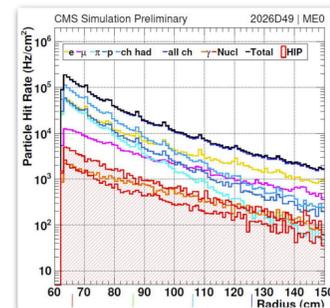
- BaBar
- MEG
- ERC: INITIUM (NID)
- DM, TPCs, MPGDs, Polarimetry, ...



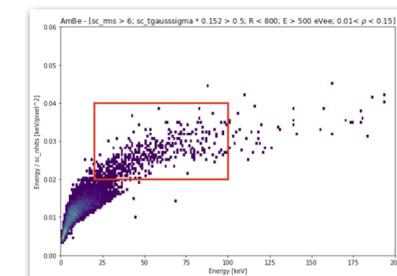
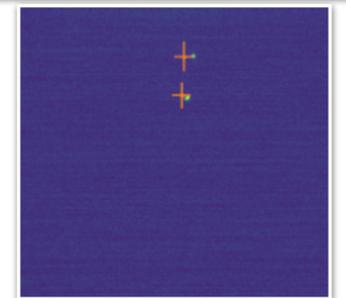
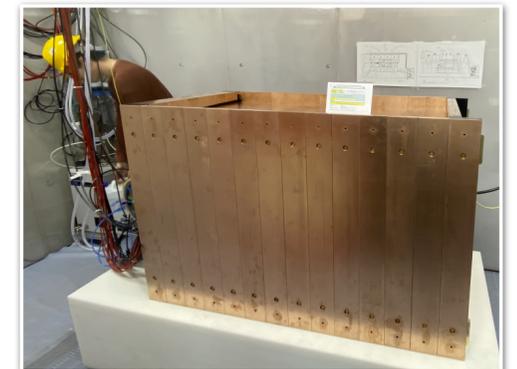
Davide Fiorina

Stefano Piacentini

- CMS
- GEMs
- Picosec (timing)
- CYGNO-04 design
- Polarimetry



- LIME operations and analysis (PMT and camera)
- CYGNO-04 DAQ
- DarkSide
- Sensitivity projections and limit setting
- Simulation
- Polarimetry





Backup

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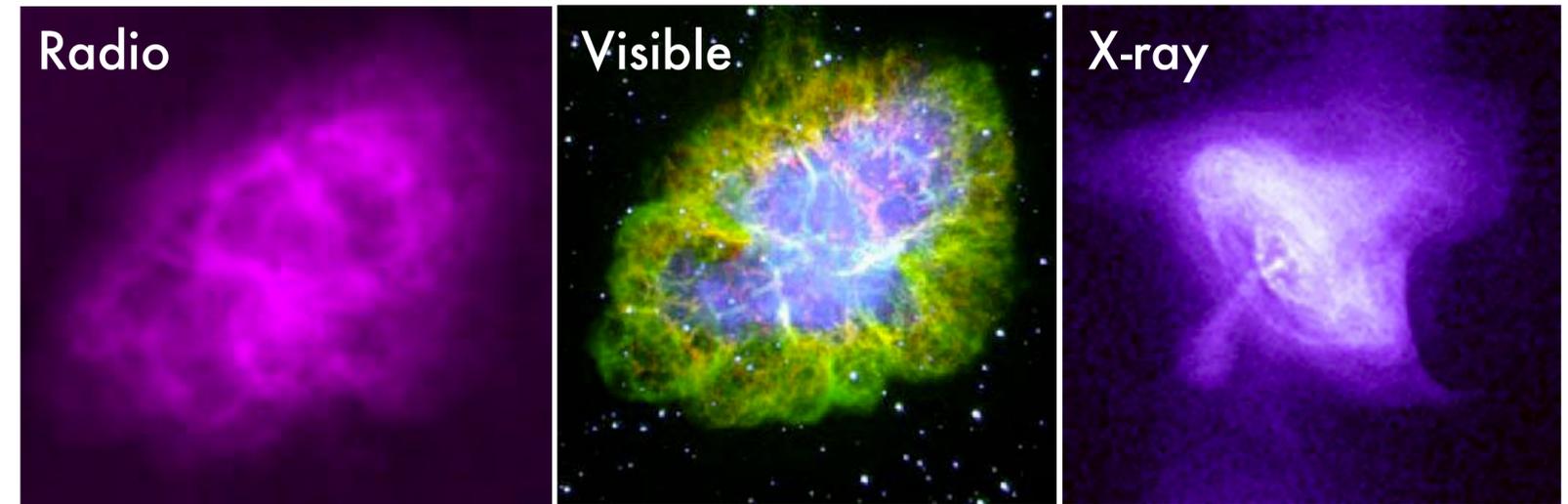
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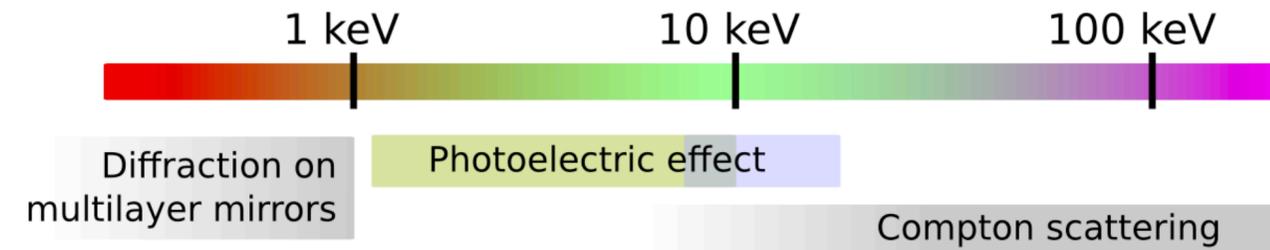
- Polarization from celestial objects may derive from:

- ▶ **Emission** processes themselves (cyclotron, synchrotron, bremsstrahlung)
[Westfold, 1959](#) [Gnedin & Sunyaev, 1974](#) [Rees, 1975](#)
- ▶ **Scattering** on non-spherical accreting plasmas (disks, blobs, columns)
[Sunyaev & Titarchuk, 1985](#) [Mészáros, P. et al. 1988](#)
- ▶ **Vacuum** polarization and bi-rifrangence through extreme magnetic fields
[Gnedin et al., 1978](#) [Mészáros & Ventura, 1979](#)

- The observation of light from an emitting source is **complete only with polarization** on the entire energy spectrum

Physics cases for X-ray polarimetry

- Physics cases that can be tested measuring the polarization at different X-ray energies:



Scientific goal	Sources	<1keV	1-10	>10 keV
Acceleration phenomena	PWN	yes (but absorption)	yes	yes
	SNR	no	yes	yes
	Jet (Microquasars)	yes (but absorption)	yes	yes
	Jet (Blazars)	yes	yes	yes
Emission in strong magnetic fields	WD	yes (but absorption)	yes	difficult
	AMS	no	yes	yes
	X-ray pulsator	difficult	yes (no cyclotron?)	yes
	Magnetar	yes (better)	yes	no
Scattering in aspherical geometries	Corona in XRB & AGNs	difficult	yes	yes (difficult)
	X-ray reflection nebulae	no	yes (long exposure)	yes
Fundamental Physics	QED (magnetar)	yes (better)	yes	no
	GR (BH)	no	yes	no
	QG (Blazars)	difficult	yes	yes
	Axions (Blazars, Clusters)	yes?	yes	difficult