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## **Motivation**

**Polarization information** is important in research of astrophisic compact sources: **polarization direction** and **polarization degree** are 2 additional parameters, which allow relevant information about the cosmic source.

It is mandatory to have **space observatories** devoted to the

observation of celestial sources of X-rays.











XIPE, https://www.isdc.unige.ch/xipe/





### IXPE – Goals

IXPE will explore, for the first time, the hidden details of some of the most extreme and exotic astronomical objects, by means of X-rays polarimetry in the range 2-8 keV.

NASA, NASA Release 17-002, January 3, 2017

#### IXPE addresses two specific science objectives:

- "Determine the radiation processes and detailed properties of specific cosmic X-ray sources or categories of sources".
- "Explore general relativistic and quantum effects in extreme environments" - where gravitational, electric and magnetic fields are at their limits.

W.D. Deininger, *Proceedings of the 32nd Annual AIAA/USU* Conference on Small Satellites, Logan UT, USA, Aug. 4-9, 2018



NASA/IXPE, <u>https://wwwastro.msfc.nasa.gov/</u> ixpe/about/index.html



4

#### IXPE addresses key questions in High Energy Astrophysics:

- What is the spin of a black hole?
- What are the geometry and magnetic-field strength in magnetars?
- Was our Galactic Center an Active Galactic Nucleus in the recent past?
- What is the magnetic field structure in synchrotron X-ray sources?
- What are the geometries and origins of X-rays from pulsars?

W.D. Deininger, 2017 IEEE Aerospace Conference, Yellowstone Conference Center, Big Sky, MT, USA, March 4-11, 2017.





# **XIPE/IXPE polarimeter**

The **polarimeter** is based on the preferential alignment of the photoelectron emission with the polarization direction of the absorbed X-rays. Its **main element is a GPD** (Gas Pixel Detector).



- Absorption/drift region
- Amplification region (GEM)
- Multipixel anode (readout)





# **Polarimetric sensitivity**

The preferential alignment of the photoelectron emission (from incident X-ray) with **one direction**.

 $A_1 +$ 0.06 2 1.8 0.05  $\mathbf{A}_2$ Normalized # electrons / bin **Normalized # electrons / bin** 1.4 0.6 0.0 1 0.6 0.4 0.04 0.03 0.02 0.01 А, 0.2 0 90 180 225 270 315 360 0 45 135 45 90 180 225 0 135 270 315 360 Azimutal angle  $\phi$  (°) Azimutal angle  $\phi$  (°)

Polarization

direction.

Polarization degree = Q measured / Q intrinsic



7

**Modulation Factor** 

Q

 $A_2 = A_1$ 

#### <u>Our goal</u>

Determine the sensitivity of some gaseous media to the X-rays polarization direction in the energy range 2-12 keV.

#### <u>Method</u>

Custom-made Monte Carlo simulation model

determines the modulation factor Q of the electron clouds generated in the noble gases Xe, Ar, Ne and He and their mixtures with  $CH_4$  – assessing the electron position when it reaches subionizing energy.





## Monte Carlo (MC) simulation model





# Angular differential cross-sections for photoelec. emission

#### - Non polarized X-rays:

$$\frac{d\sigma_{nl}}{d\Omega}(E,\theta) = \frac{\sigma_{nl}(Z,E)}{4\pi} \left[ \left( 1 - \frac{\beta}{2} \right) + \delta \cos \theta + \left( \frac{3\beta}{4} + \frac{\gamma}{2} \cos \theta \right) \sin^2 \theta \right]$$

- Linearly polarized X-rays:

$$\frac{d\sigma_{nl}}{d\Omega}(E,\theta,\phi) = \frac{\sigma_{nl}(Z,E)}{4\pi} \left[ \left( 1 - \frac{\beta}{2} \right) + \delta \cos \theta + \left( \frac{3\beta}{2} + \gamma \cos \theta \right) \sin^2 \theta \cos^2 \phi \right]$$

 $\beta$ ,  $\delta$  and  $\gamma$ -correction parameters, energy (E) dependent  $\sigma_{nl}$  - total cross-section for the subshell *nl* 

Photoelectrol  $\boldsymbol{\theta}$ Field → v PhotonElectrict **X-Ray Photon** 

Photoelectric effect is very sensitive to polarization: photoelectric emission preferencially aligned with the direction of polarization (X) - modulation in  $\cos^2\phi$ 







## MC 2-D distributions of electron clouds in Xe



### **MC 2-D distributions of electron clouds in Ne**



## **MC** azimuthal angle $\phi$ histograms in Xe, Ar, Ne and He



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## **Electron transverse diffusion**

**Problem**: The electron transverse diffusion in noble gases is very high, with an deterioration of the collected electron track. **Solution**: Adding molecular gases.



# **MC** azimuthal angle $\phi$ histograms in NobleGas-10%CH<sub>4</sub>



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## MC Modulation factor Q vs X-ray energy









### **Photoionization cross-sections**

**Problem:** pure He and He-CH<sub>4</sub> mixtures are not good options relatively to **detection efficiency**.







#### New results with more realistic conditions

- Determine the modulation factor *Q* through the reconstrution of photoelectron emission direction (instead of the intire electron cloud)
- Consider also the effect in Q of electron transversal diffusion towards the anode (instead of only to subionization energies)

#### Further studies

- Binary mixtures of noble gas (Xe, Ar, Ne and He) with other molecular aditive (CF<sub>4</sub>, CO<sub>2</sub>, iso-C<sub>4</sub>H<sub>10</sub> and DME), to decrease electron diffusion.
- Complementar experimental study.





## Gas mixture study for GPD in IXPE/NASA mission





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