# X-ray polarimetry as a new and independent tool to discriminate reflection from absorption scenarios

*Predictions for MCG 6-30-15*

**Frédéric Marin**
René W. Goosmann, Michal Dovčiak,
Fabio Muleri, Delphine Porquet,
Nicolas Grosso, Vladimir Karas
and Giorgio Matt

AGENCE NATIONALE DE LA RECHERCHE ANR
Observatoire astronomique de Strasbourg
UNIVERSITÉ DE STRASBOURG

# The broad Fe Kα fluorescent line

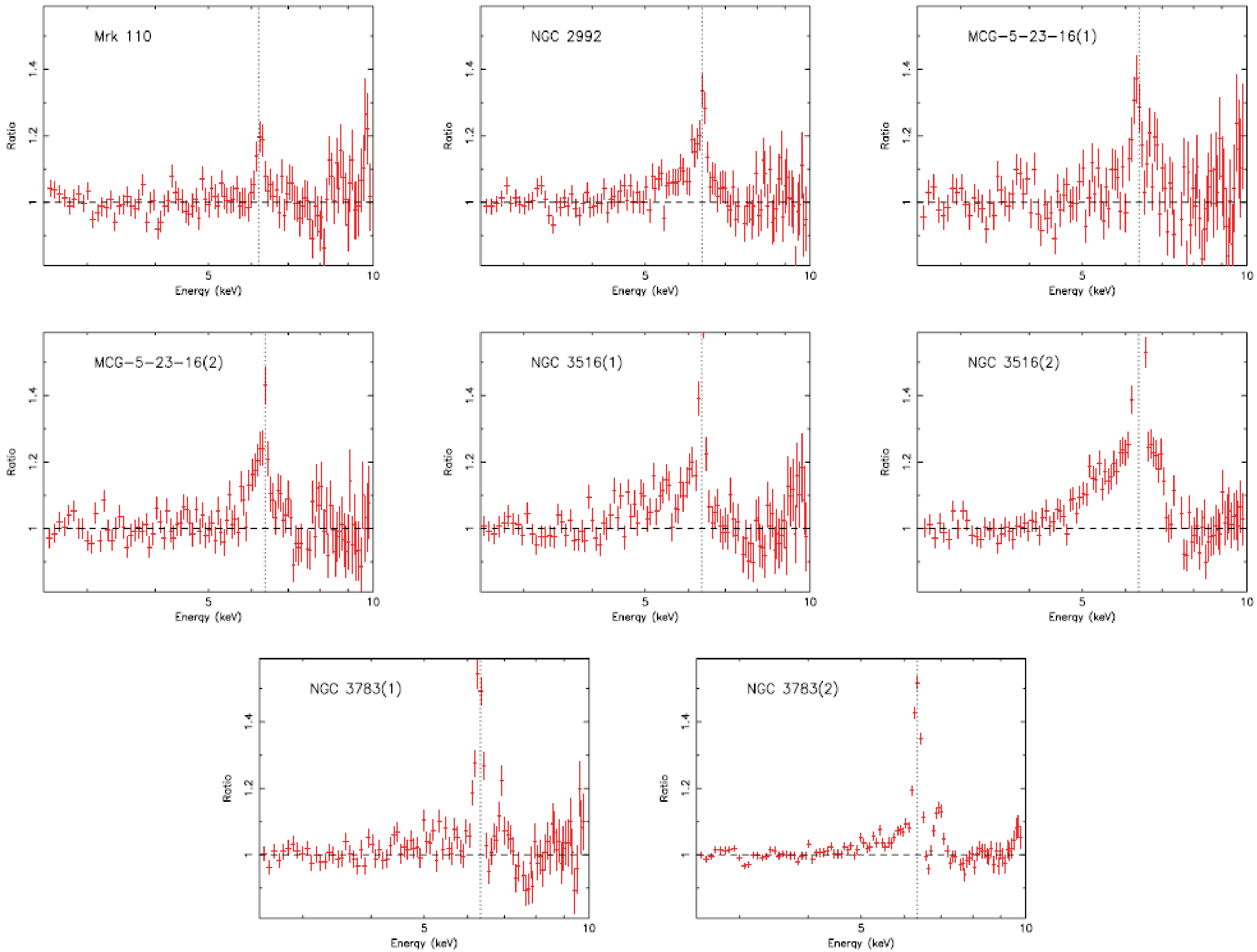



**Figure 3.** Data/model ratios, derived excluding the 4.5–7.5 keV region. The fitted continuum is either a simple power law with Galactic absorption or, in cases where it significantly improves the fit, additional absorption by photoionized gas. The vertical dotted lines show a rest-frame energy of 6.4 keV, which is expected for fluorescence from neutral iron.

**Nandra (2007) - XMM-Newton survey**

# MCG 6-30-15 : an archetypal AGN

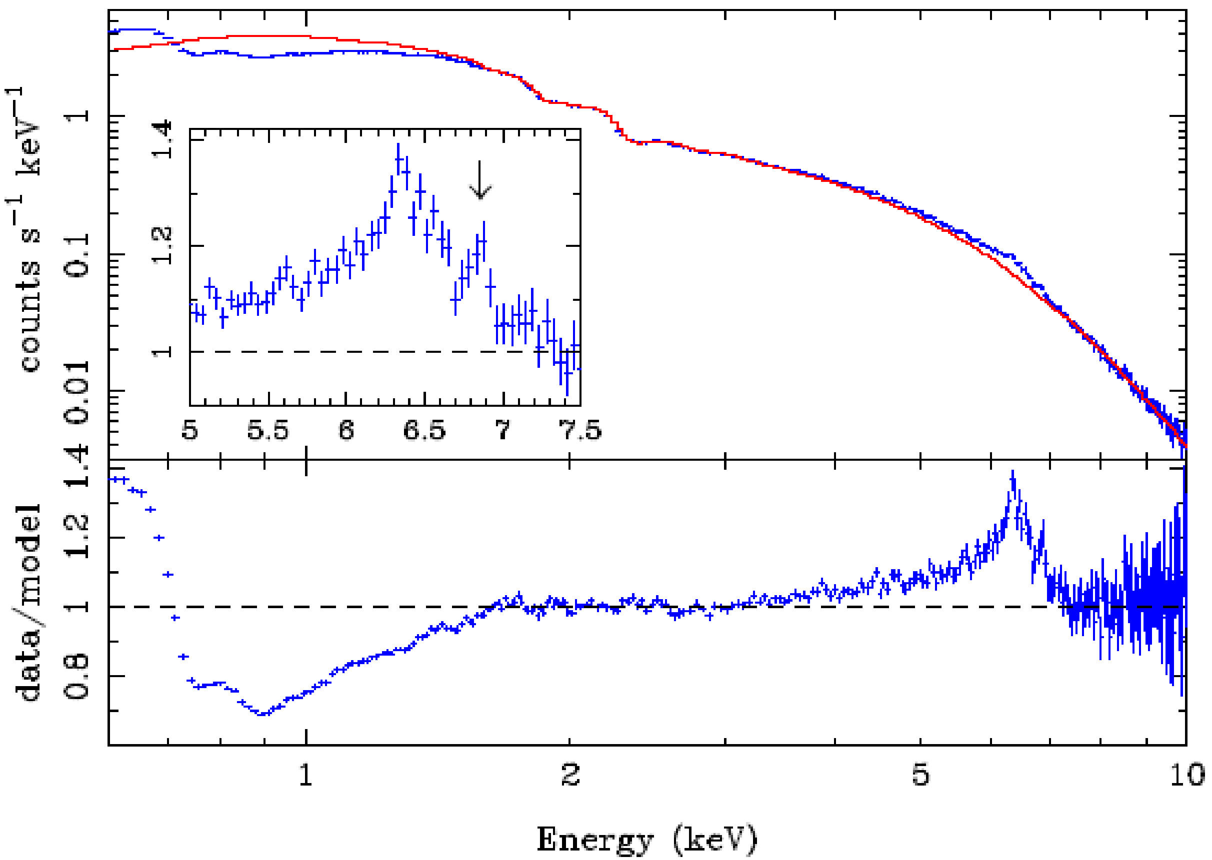



**Figure 1.** Combined MOS spectrum (the data were combined for plotting purposes only) and ratio of data to a power-law model joining the 2–3 keV data and 7.5–10 keV data. As this is not a realistic model for the continuum the residuals should be considered merely as representative of the spectral complexity. The inset panel shows a close-up of the iron line region with the 6.9 keV feature marked.

**Fabian (2002)**
**Combined MOS spectrum + power-law model**

Seyfert-1 galaxy
Z ~ 0.008

How can we interpret the broad Fe Kα line ?

# Relativistic reflection

Reflected and reprocessed X-ray emission from the accretion disc reaching down to the ISCO

GR + Doppler effects blurring the line centroid

If disc and irradiation truncated at the ISCO → BH spin constraints

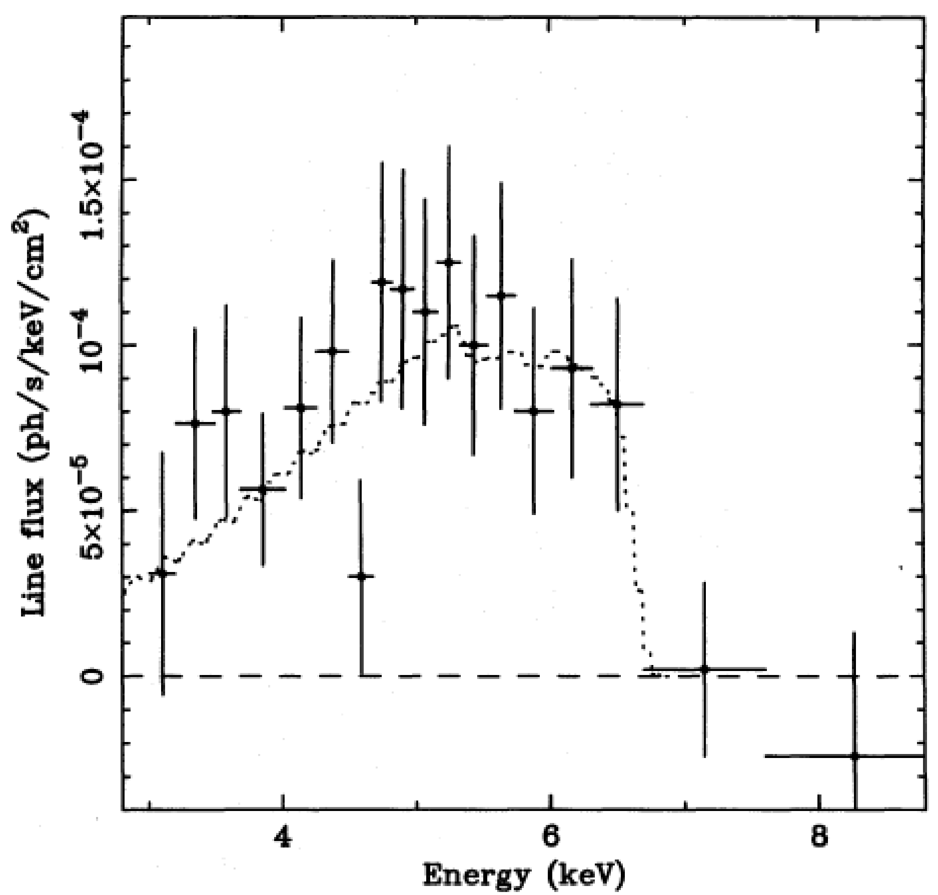
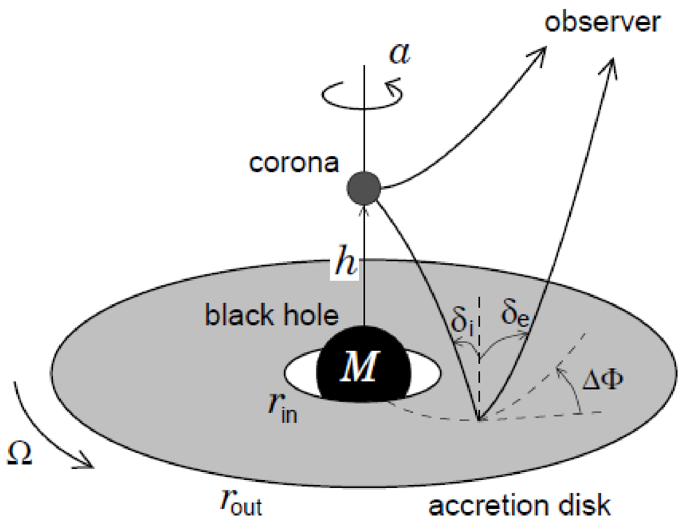



**Figure 12.** The line profile obtained from the deep minimum (*i-7*). Data from both S0 and S1 detectors have been summed. The profile has been corrected for absorption by the warm absorber and the detector response. The dotted line indicates a computed disc-line model for a Kerr metric (Laor 1991), assuming inner and outer radii of $R_{\rm in} \sim 1.24 r_{\rm g}$ and $R_{\rm out} \sim 20 r_{\rm g}$ of the disc inclined by $i = 30°$, and a radial emissivity index of $\alpha \sim 3$.

Iwasawa et al. (1996)



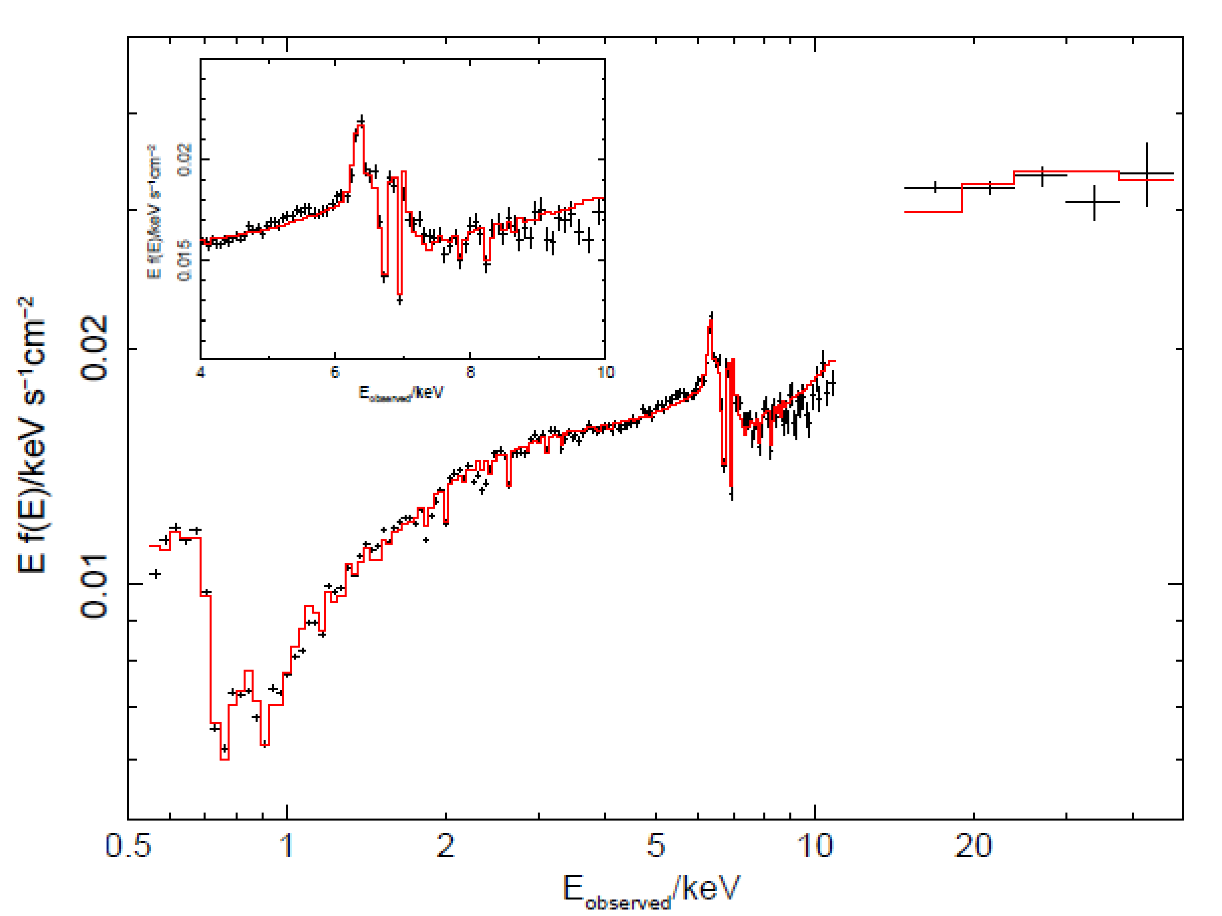

Dovciak et al. (2002)

# Complex absorption

Complex absorption situated along the line-of-sight partially covering the primary X-ray source

The extended red-wing is « carved out » by absorption

→ the line shape is then much less related to the SMBH spin

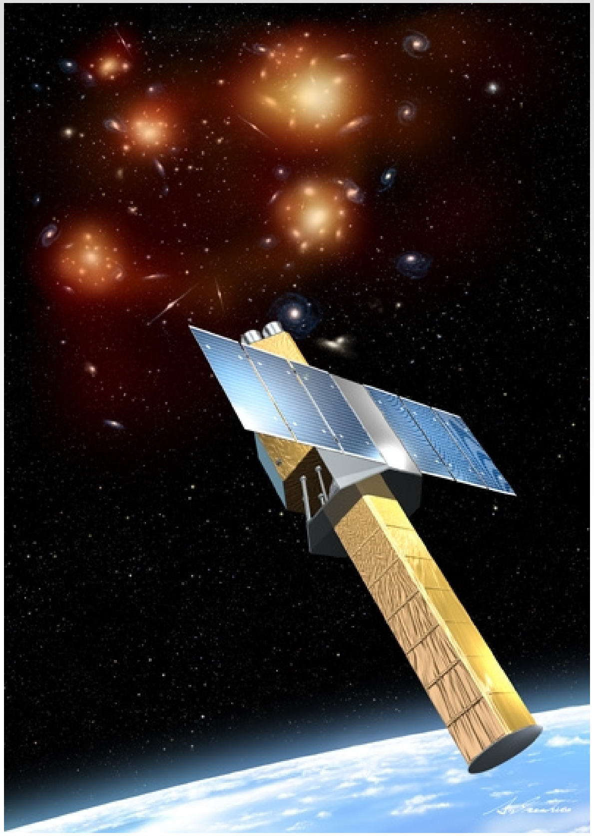



| zone | N $/10^{22}$ cm$^{-2}$ | log($\xi$/erg cm s$^{-1}$) | $\overline{C_f}$ |
|---|---|---|---|
| 1 | 1.18±.05 | 2.39 ± .01 | (1.0) |
| 2 | 0.027±.003 | 0.88 ± .16 | (1.0) |
| 3 | (8.0) | (3.95) | (1.0) |
| 4 | 191.±30 | - | 0.62 |
| 5 | 2.9±.1 | 1.38 ± .03 | 0.17 |

**Inoue & Matsumoto (2003)**
**Miller et al. (2009)**

# Exploring a different path

More advanced spectral and timing analyses (Astro-H, NuStar) + XMM-Newton may shed more light on the origin on the broadening of the Fe line

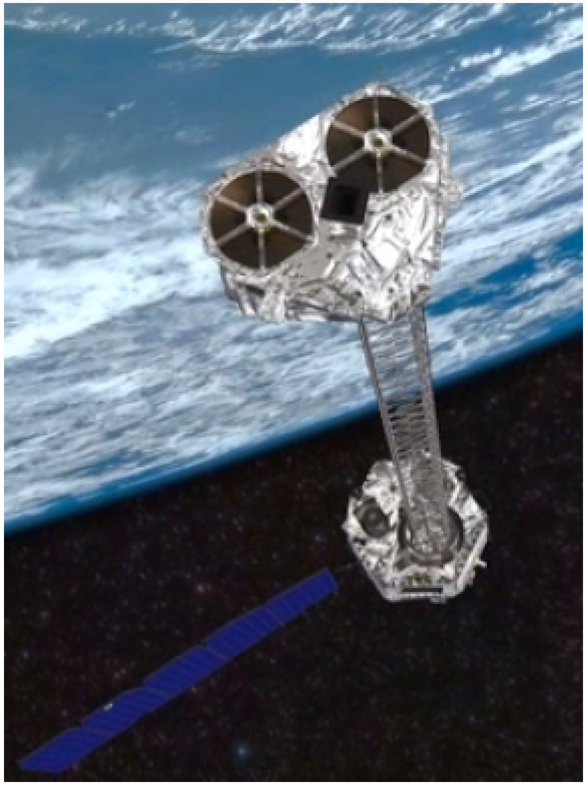


Astro-H (JAXA)

Goal of this presentation :

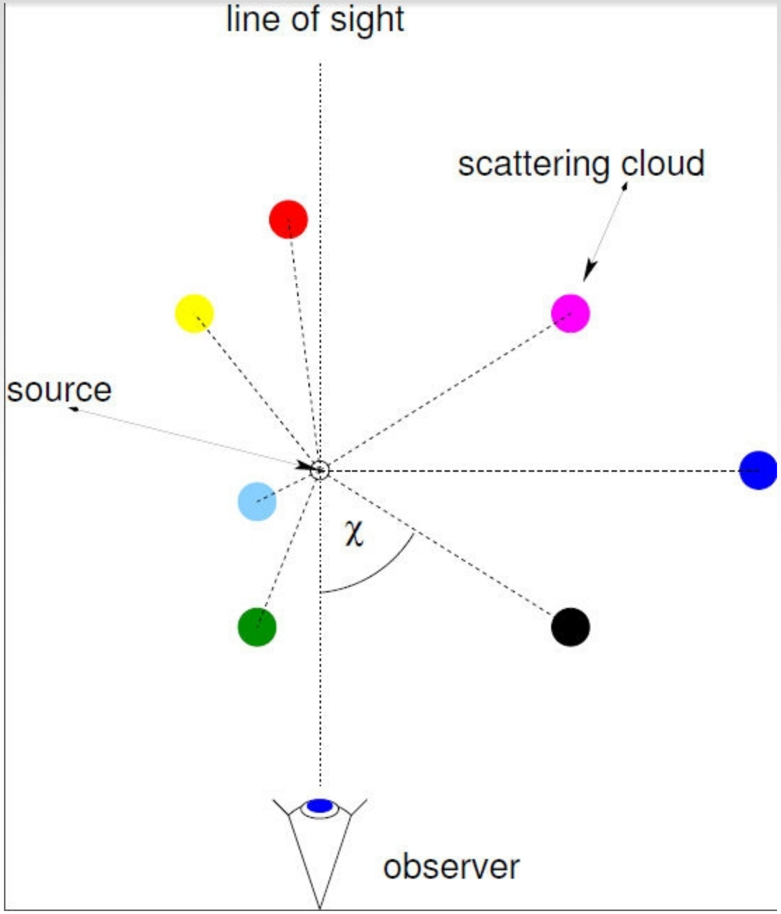
**Exploring still a different, independent path**

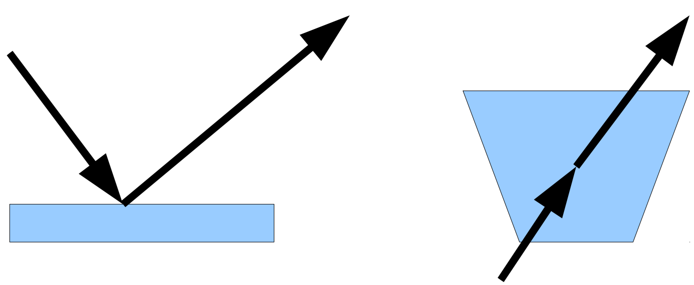
How X-ray polarimetry can help to independently discriminate between the two models ?



NuStar (NASA)

# Polarization by scattering

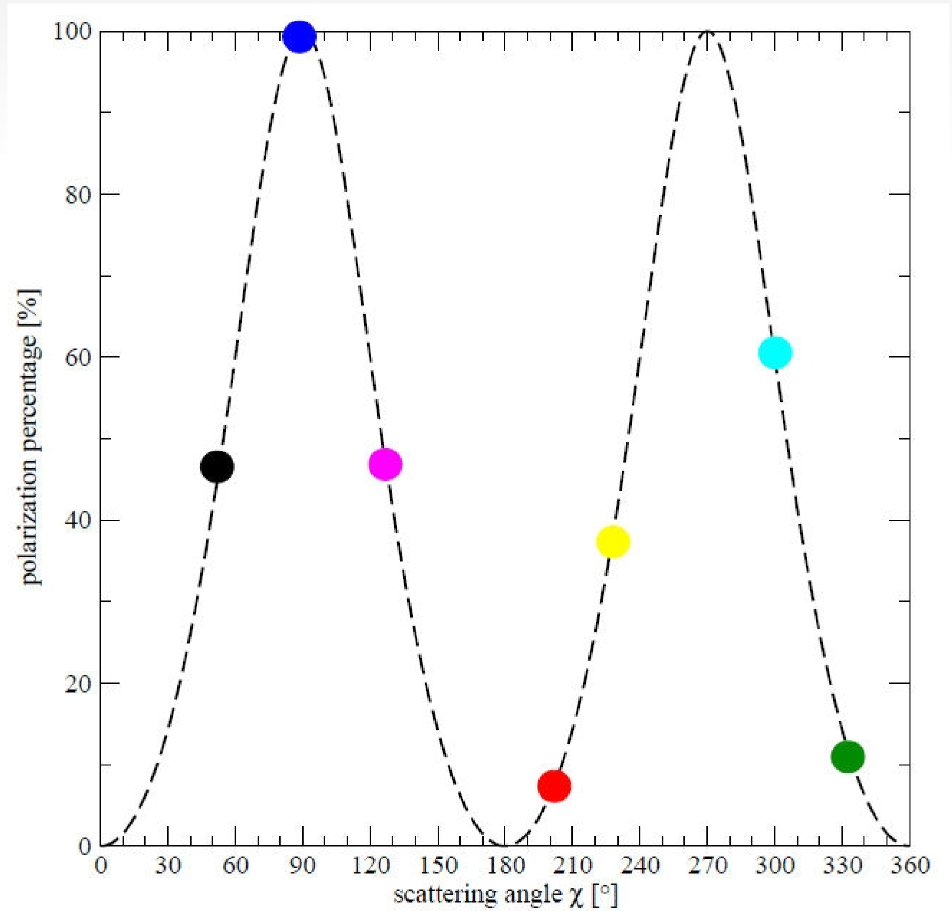


**Reflection** **Transmission**

Brings 2 additional informations
- Percentage of polarization
- Polarization angle

**Scattering phase function**



# Comparison of the two scenarios

## Relativistic reflection

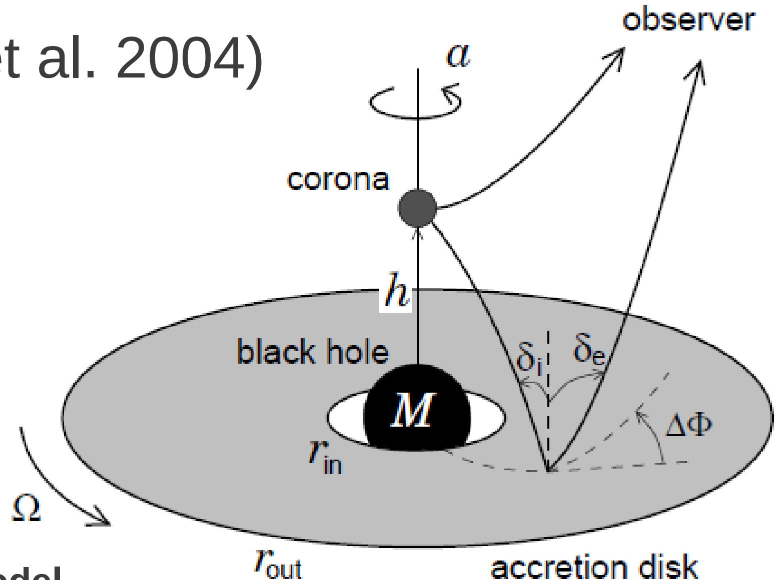
Relativistic reflection from a cold accretion disc illuminated by an elevated lamp-post on the disc axis

- re-emitted radiation from a rotating accretion disc using NOAR (Dumont et al. 2000)

- single scattering approximation (Chandrasekhar 1960)

- relativistic ray-tracing using KY (Dovciak et al. 2004)

$h = 2.5\ GM/c^2$
a = 1 (Kerr)
(Miniutti & Fabian 2004)




**Reflection model**

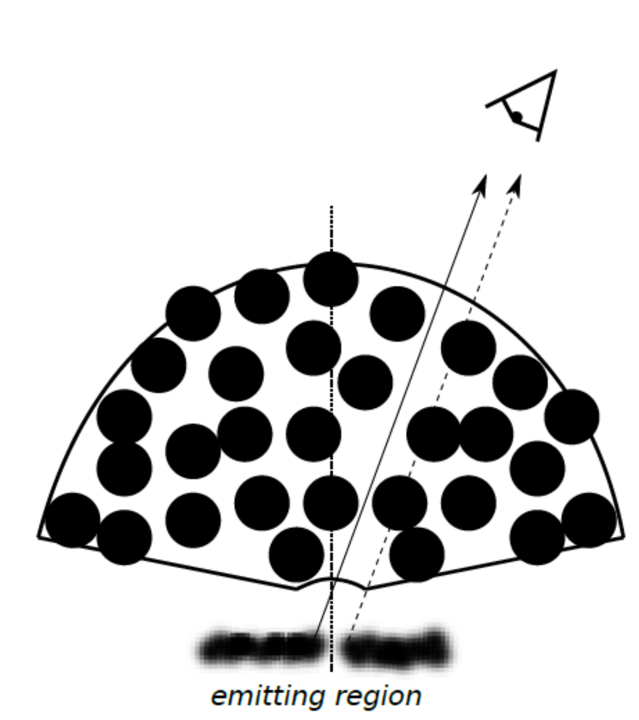
# Comparison of the two scenarios

## Complex absorption

Pure absorption by high-column density, low ionization medium partially covering the emission region

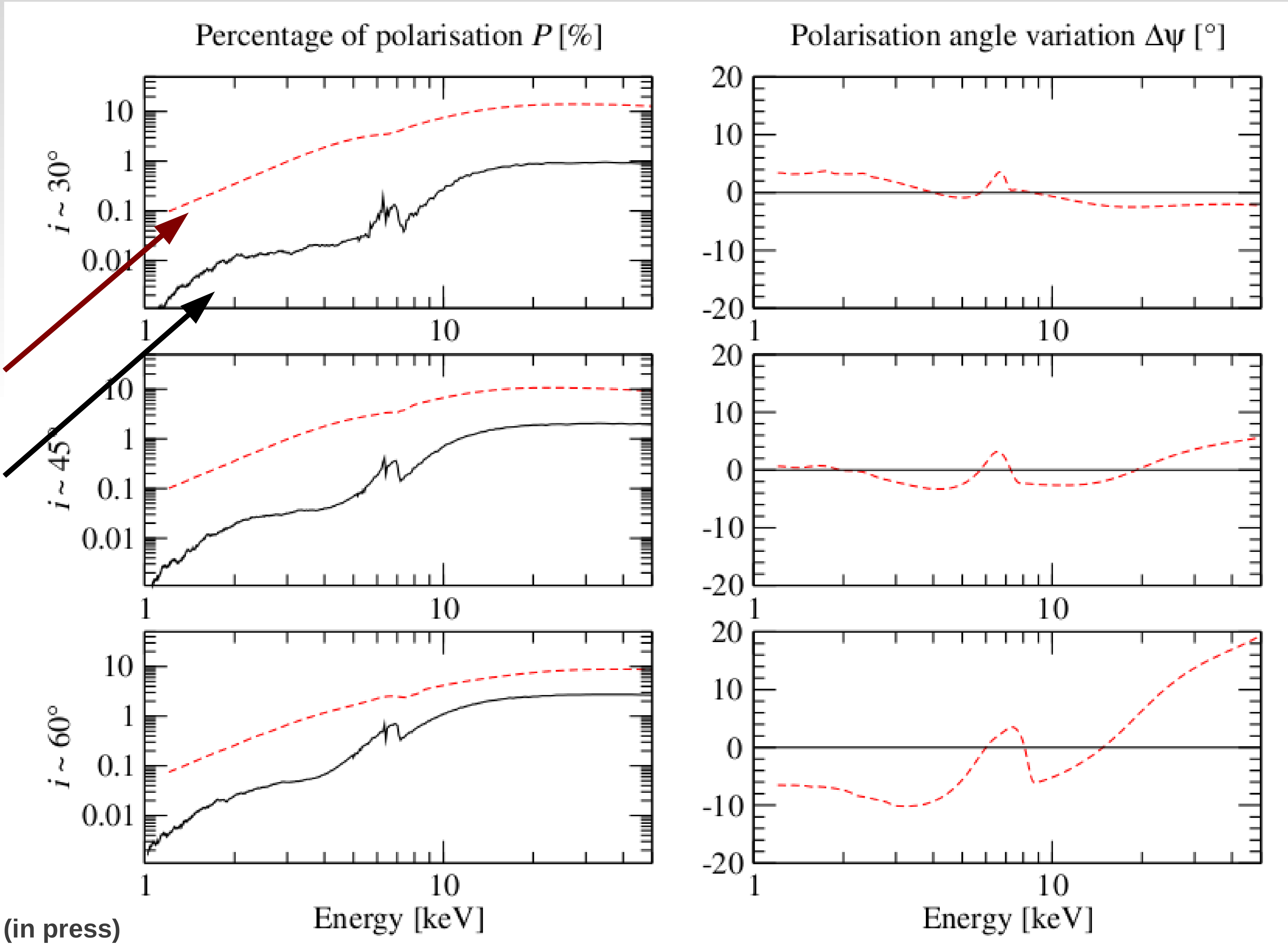
- in Miller et al. model, 5 zones are required to reproduce the Chandra and XMM-Newton grating data
  - → but only 2 absorbing zones cause the spectral curvature in the 1-10 keV band

- radiative transfer and polarization using STOKES (Goosmann & Gaskell 2007, Marin et al. submitted)




**Absorption model**

# Resulting polarization signatures



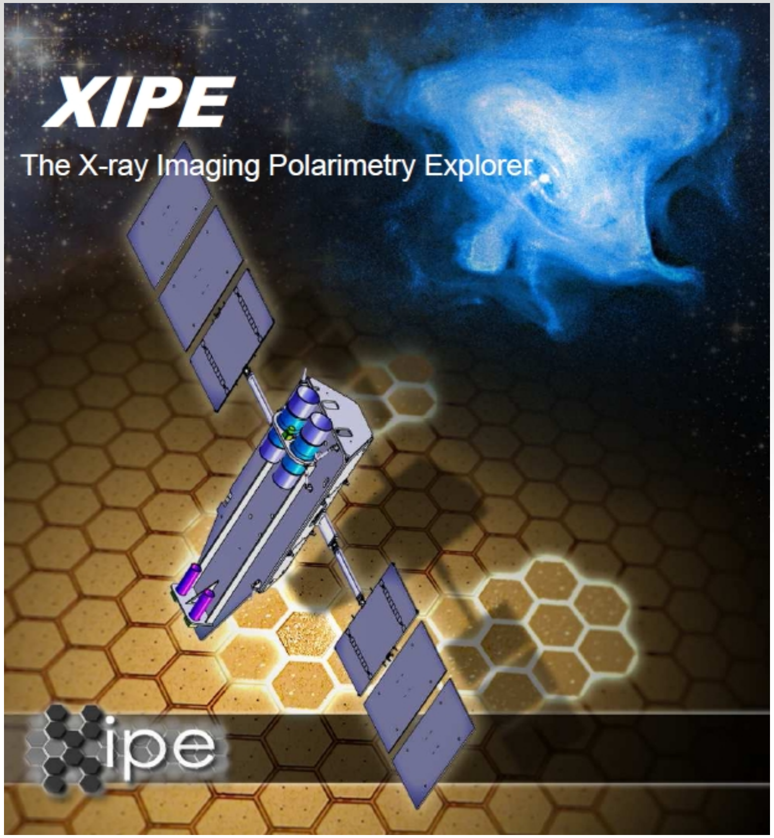

**Reflection**

**Absorption**

**Marin et al. (in press)**

# Observational prospects

## XIPE satellite

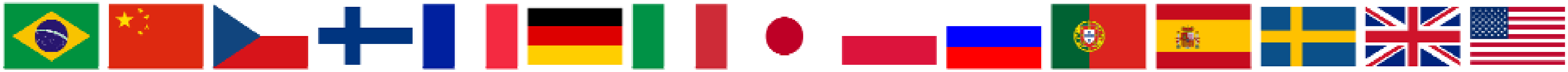



ESA S-mission call

- X-ray Imaging Polarimetry Explorer (XIPE)
- PI : Enrico Costa
- targeting pulsars, NS, BH, SNR and jets
- soft X-ray detector [2-10 keV]
- decision in September

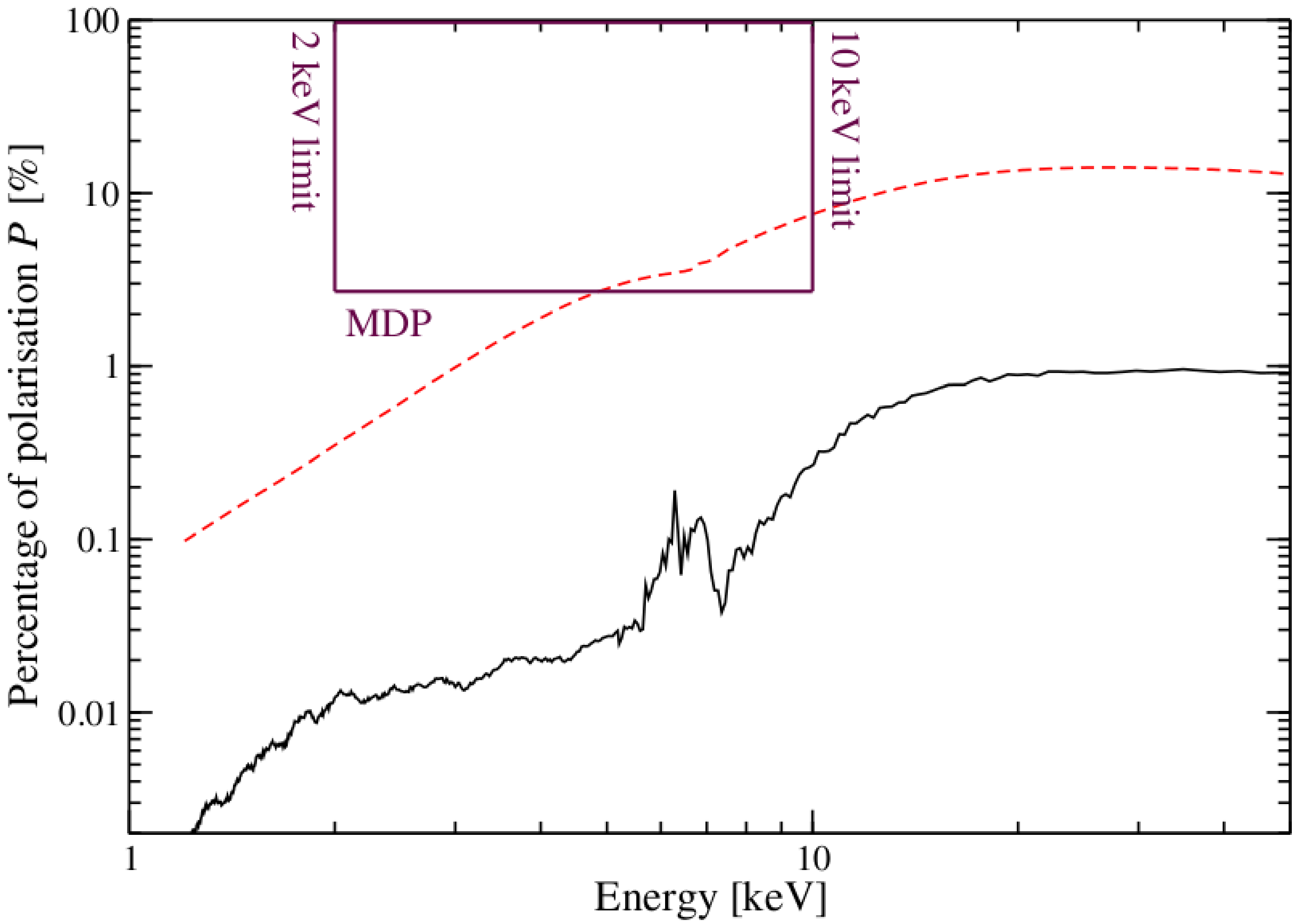
| | **2x EXP units** |
|---|---|
| *Polarization sensitivity* | MDP = 14% in 100ks for 1 mCrab |
| *Imaging capability* | 20'', 15x15 $arcmin^2$ FoV |
| *Spectral resolution* | 20% @ 5.9 keV |
| *Timing* | Resolution 8 μs, 10 μs dead time, negligible for all observations |
| *Mixture* | 20%He-80%DME 1 atm 1 cm |
| *Energy range* | 2-10 keV |
| *Background* | 1.3 $10^{-7}$ c/s or 1 μCrab |

**Detector performances from XIPE proposal**



# Observational prospects

XIPE predictions




Marin et al. (in press)

1 Ms observation, 3mCrab source, 1 µCrab background

# Conclusions and future work

Main result :

With current observational technology the relativistic scenario should produce measurable soft X-ray polarization while in the absorption case *P* should be globally undetectable

In addition :

If $\Delta\psi$ can be determined to vary across the iron line, a second, independent indicator for the reflection case is found

Other geometries must be explored :

- Grazing angles
- Pure clumpy model
- Different wind shapes (Elvis 2000, Sim et al. 2008,2010 …)

Different realizations of the reflection case :

- (Radial) Ionization of the accretion disc (Svoboda et al. 2012)
- Polarized primary source