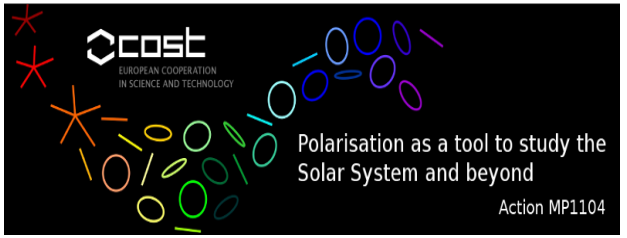
The perspectives of X-ray polarimetry on accreting sources

(with MoCA: a Monte Carlo code for Comptonization in Astrophysics)

FP7
Strong Gravity Project
WP4 "Comptonization models: spectra and polarization"



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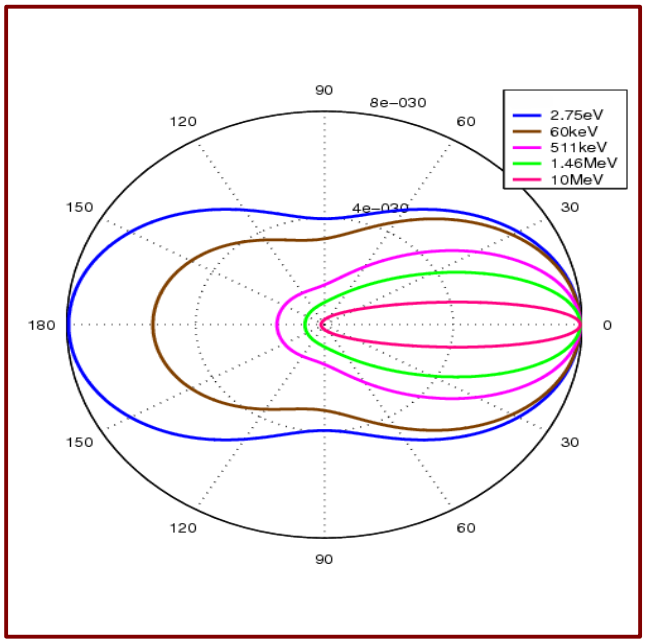
X-ray polarisation in Astrophysics – August 25th -28th Stockholm 2014

Outline

- Scientific Motivation
- The model
- The continuum emission in AGN
- The Iron line broadening in NS
- Conclusions & observational perspectives

Scientific Motivation



Why another code?

Except for a few cases

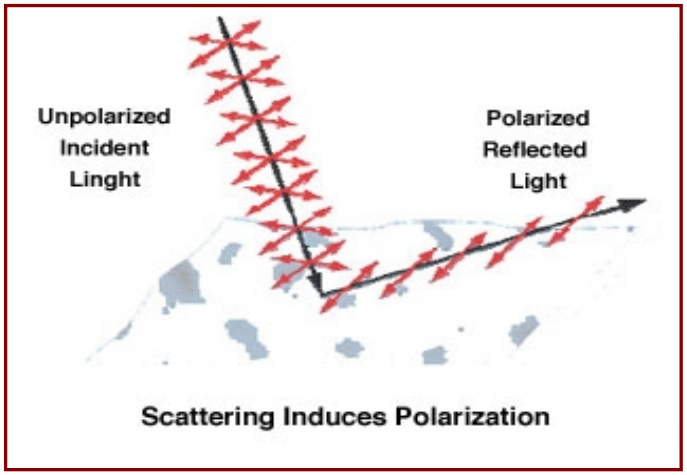
- no Klein-Nishina cross-section
- no polarization

MoCA includes both

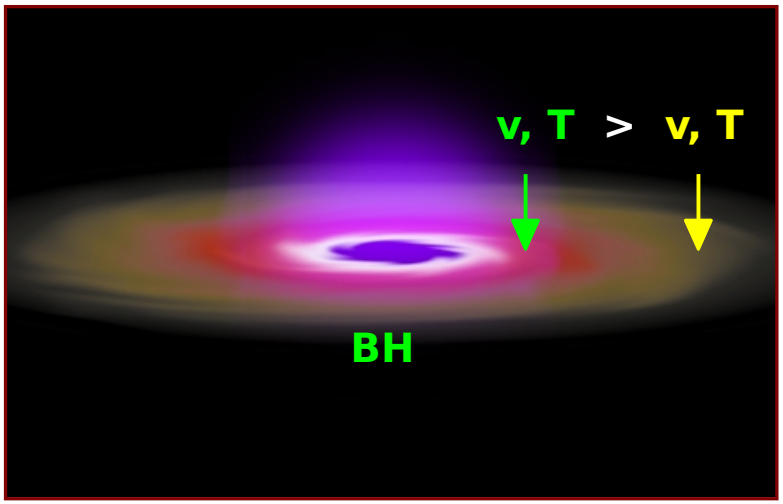
Why polarimetry?

Observational astronomy is manly made through EM radiation using 3 observables: wavelength, time and space
(i.e. spectroscopy, timing and imaging)

polarimetry adds 2 more indipendent observables which are very sensitive to geometry and inclination

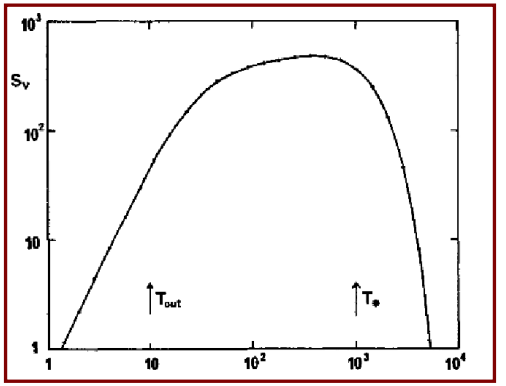


Comptonization



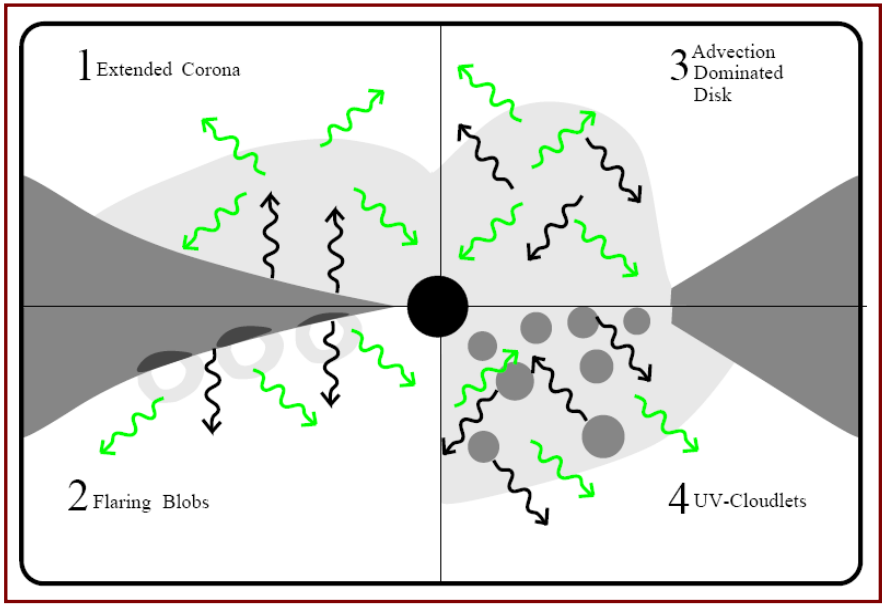
Steady, geometrically thin & optically thick disc (Shakura-Sunyaev 1973)

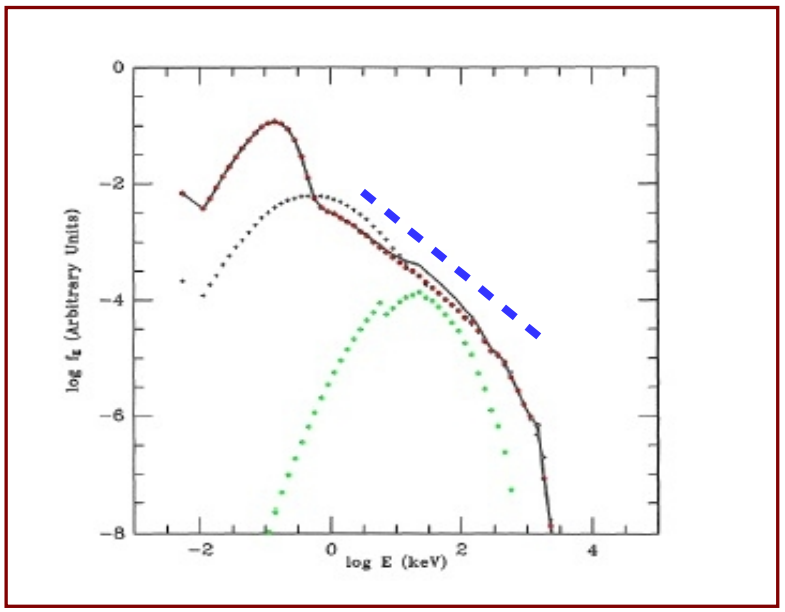
Multi-temperature BB emission



Galactic BHs (10 $M_\odot$) → soft X-rays
SMBHs (10^8 $M_\odot$) → UV

Comptonization by relativistic (thermal) electrons



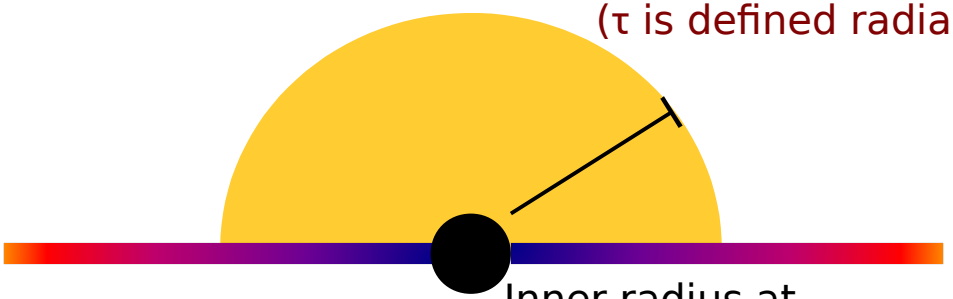


Two-phase disc (Haardt-Maraschi 1991)

The parameters of the corona are **basically unknown !**

The Model

HEMISPHERICAL corona

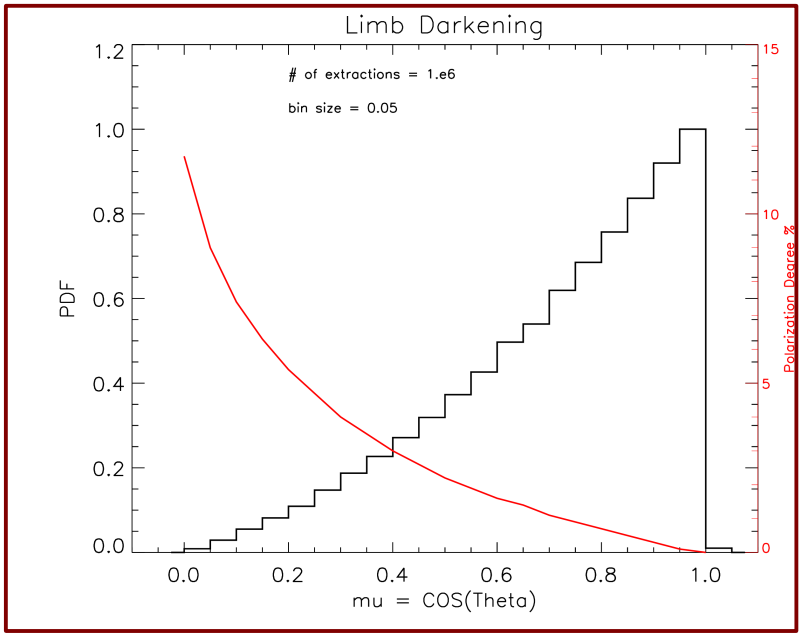


Schwarzschild SMBH
(10^8 M_{sun})

SLABBY corona

Seed photons:

- limb darkening
- **horizontal (i.e. 0°) polarization**



(Chandrasekhar 1960)

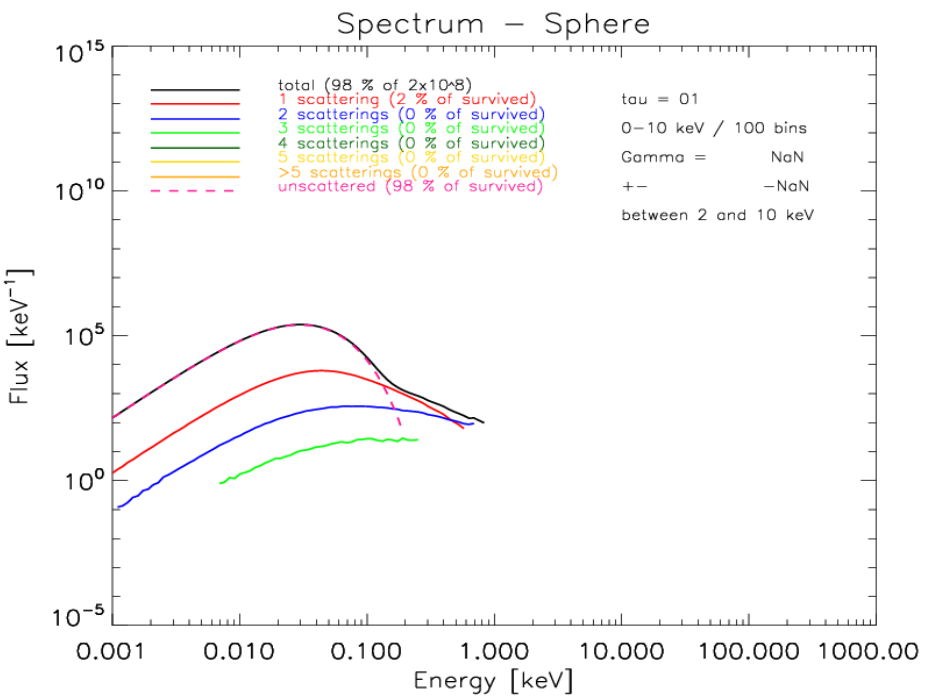
Corona parameters:

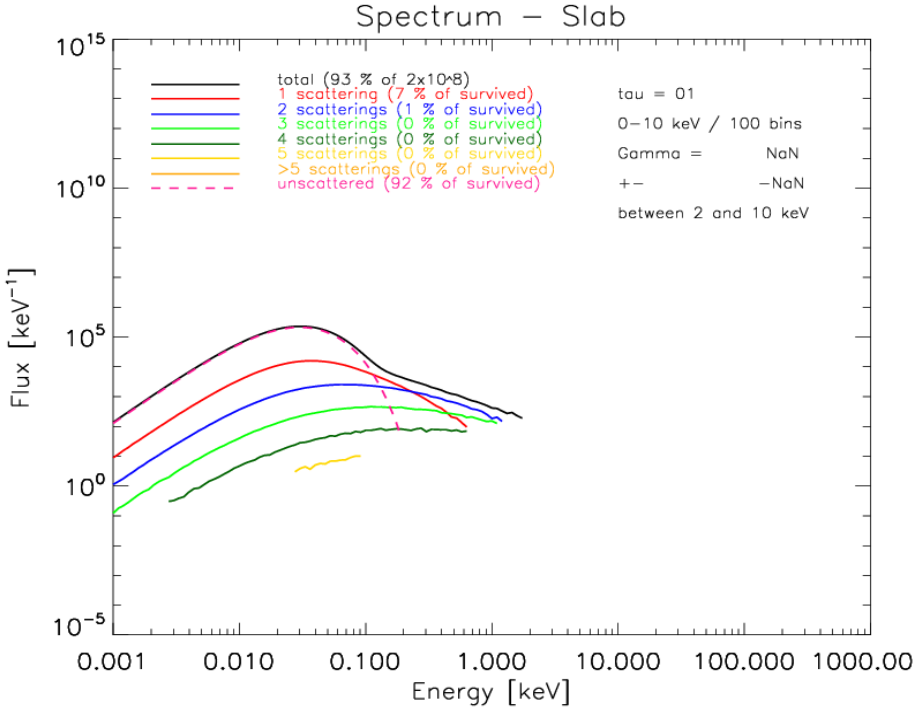
- thermal energy (kT = 100 keV)
- optical depth (τ = **0.1**, **1**)

AGN Spectra

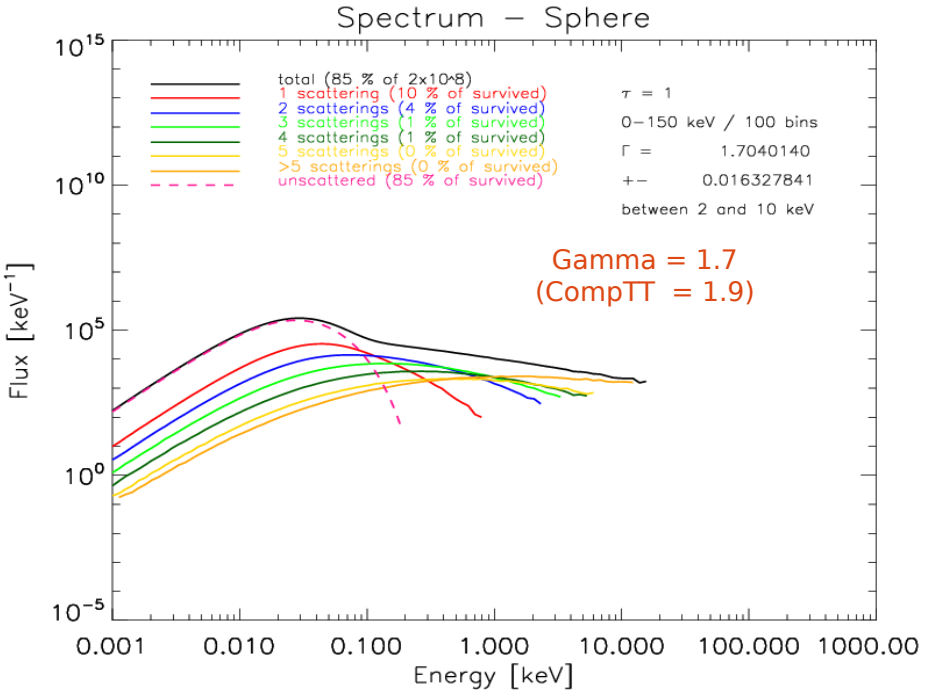
SPHERE **SLAB**

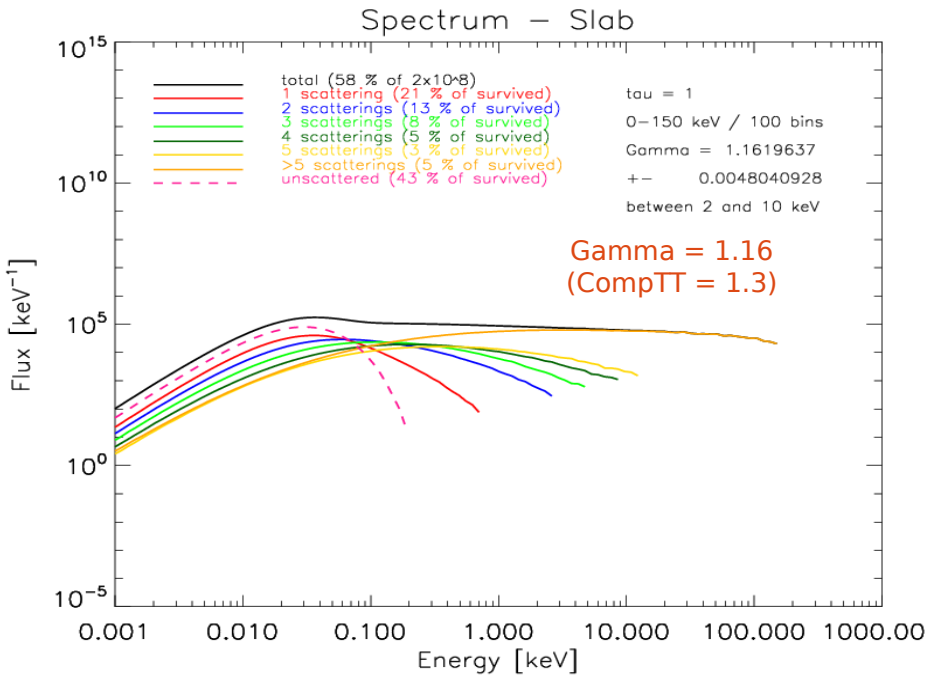
τ = 0.1





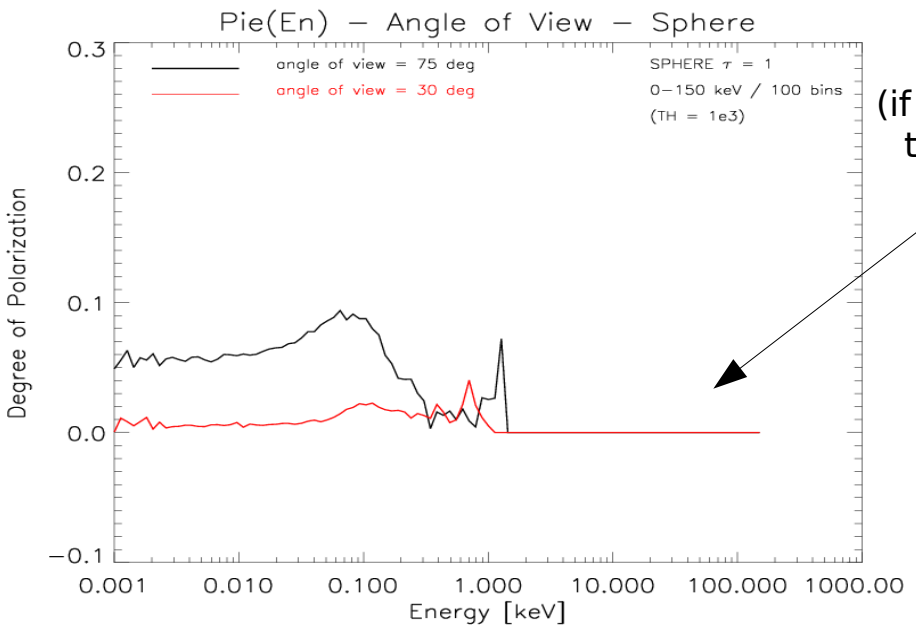
τ = 1





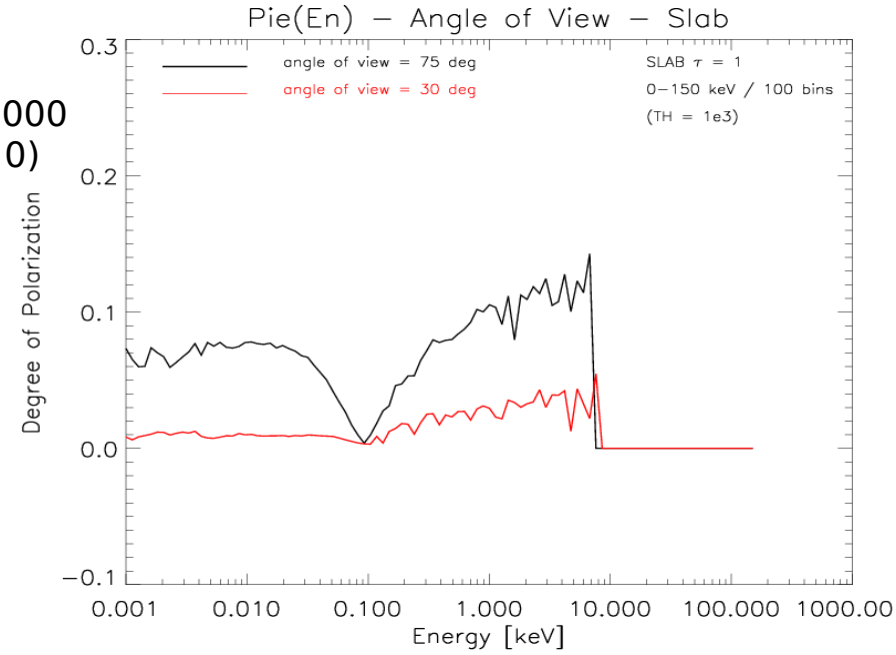
AGN Polarization

SPHERE
τ = 1



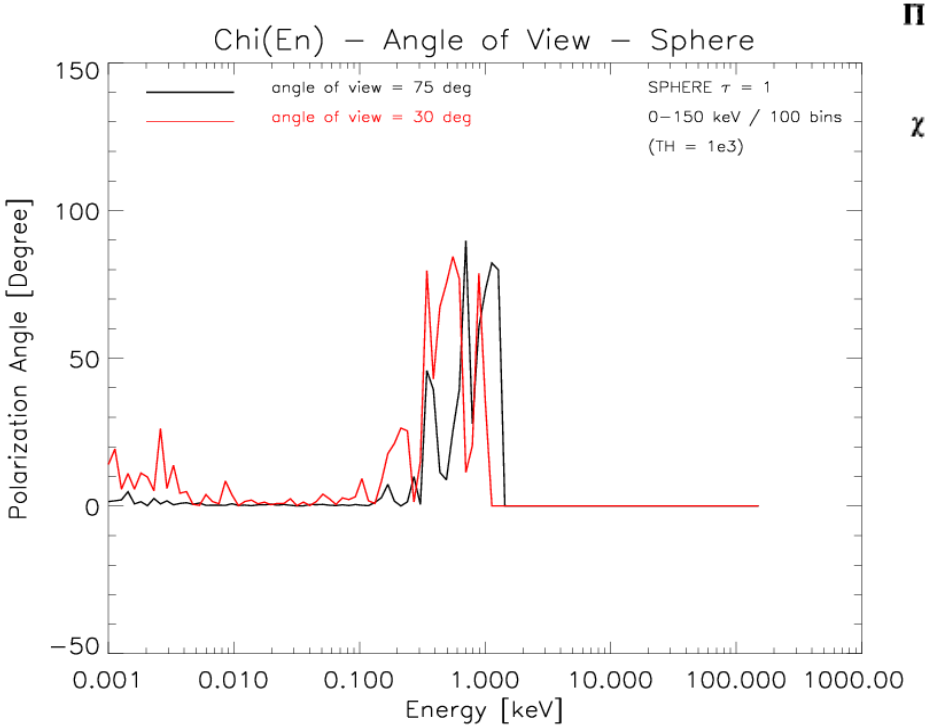
Treshold
(if counts <1000
then set to 0)

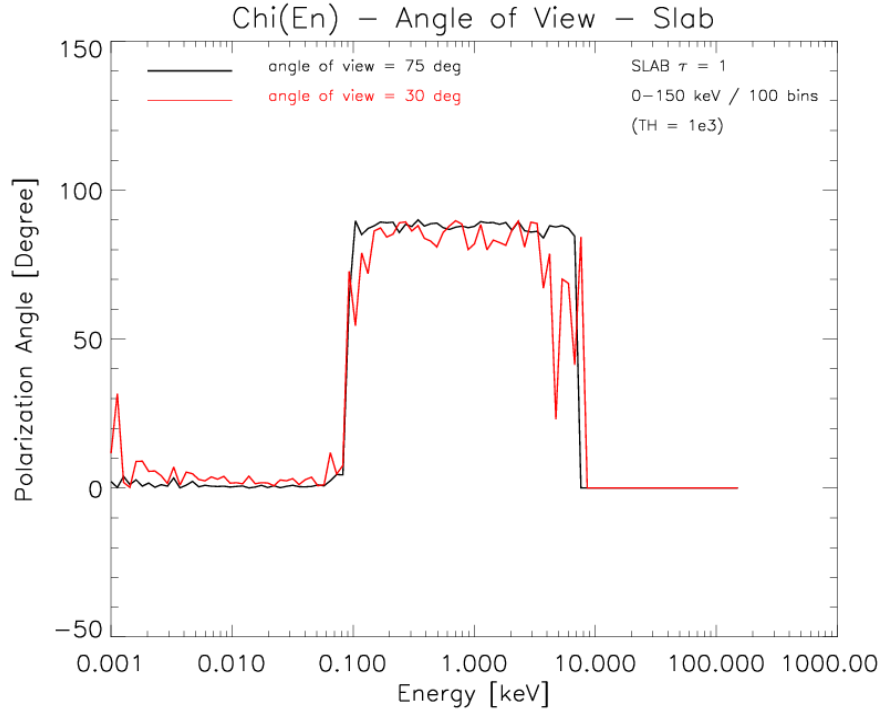
SLAB
τ = 1



$$\Pi = \frac{\sqrt{Q^2 + U^2}}{I},$$

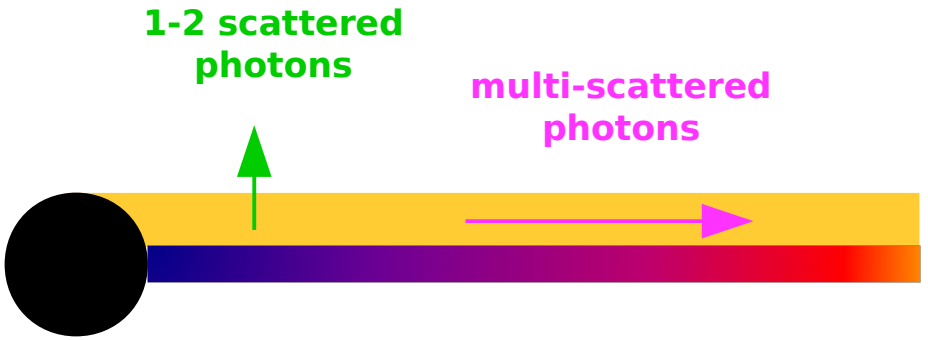
$$\chi = \tfrac{1}{2}\arctan\frac{U}{Q}.$$

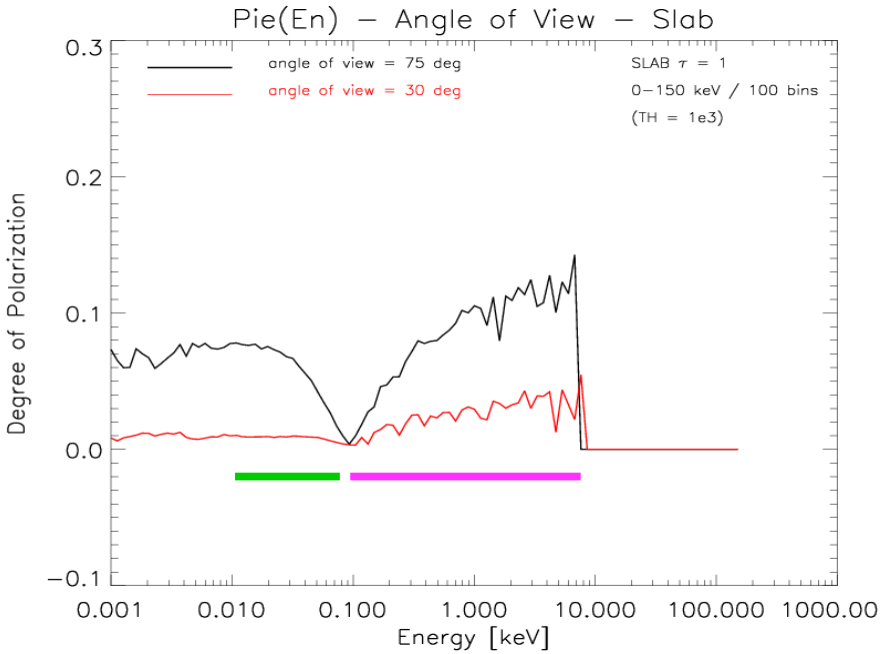


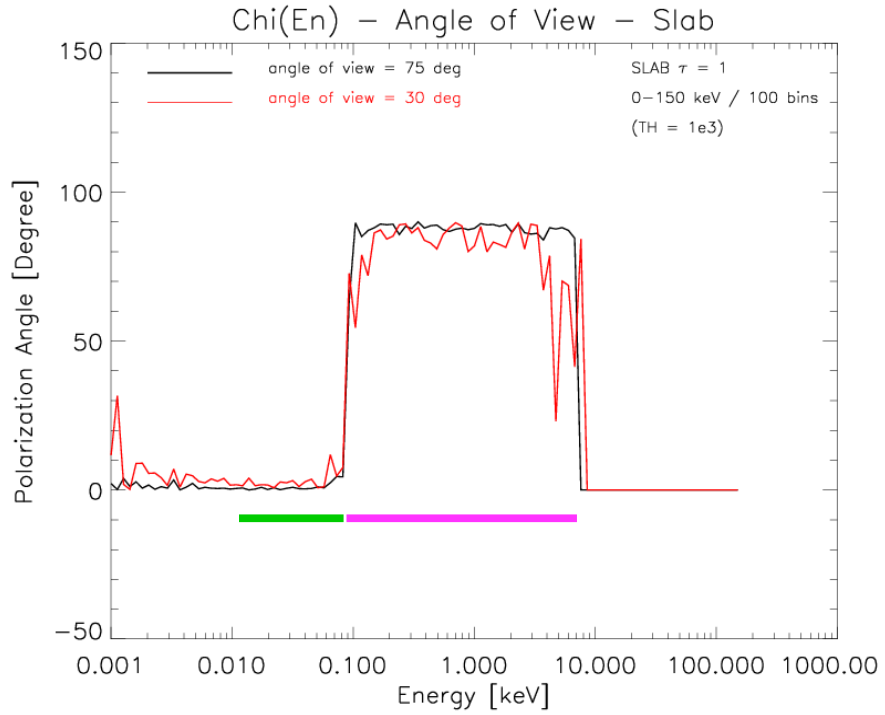


AGN Polarization

SLAB
τ = 1

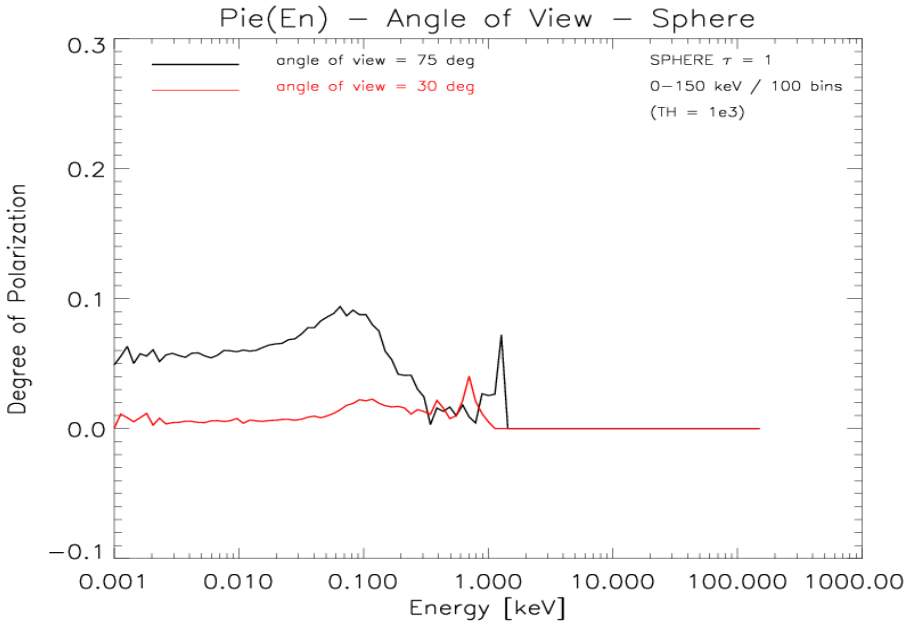


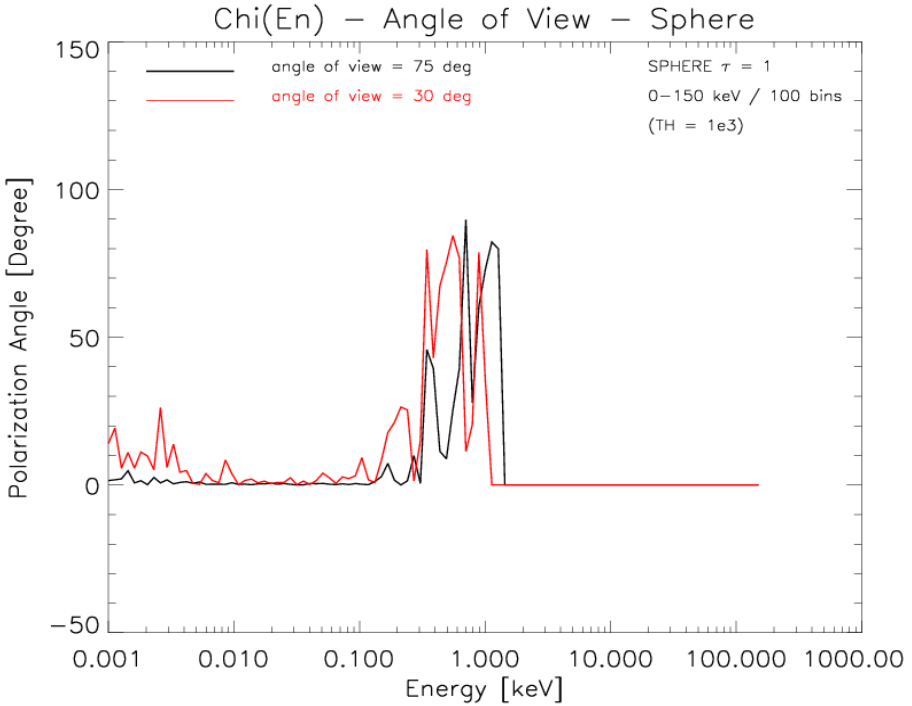


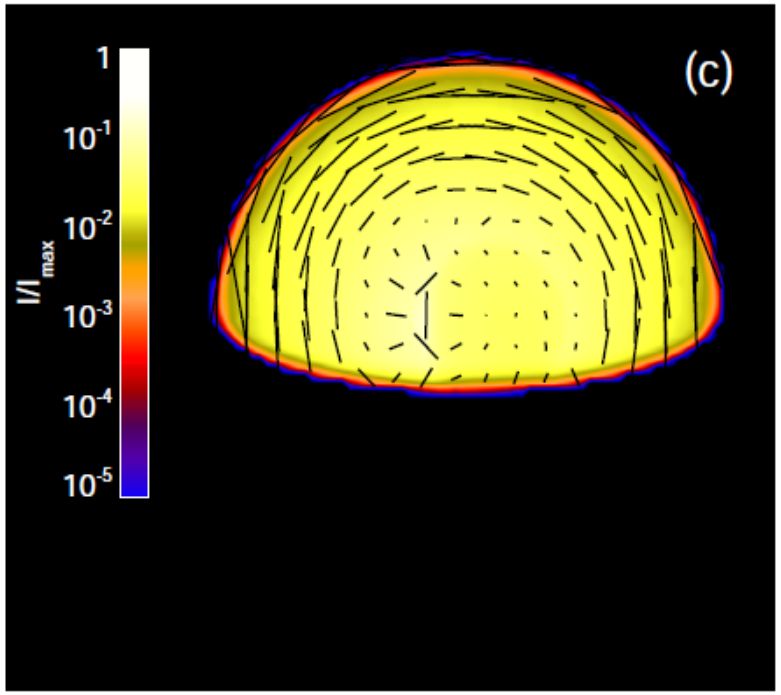


AGN Polarization

SPHERE
τ = 1







(picture from Schnittman+ 2009)

Iron line broadening in XRBs with NS

Relativistic Broadening or just Compton (down-)scattering?

Seed photons:

- monocromatic @ 6.4 keV
- unpolarized

Corona parameters:

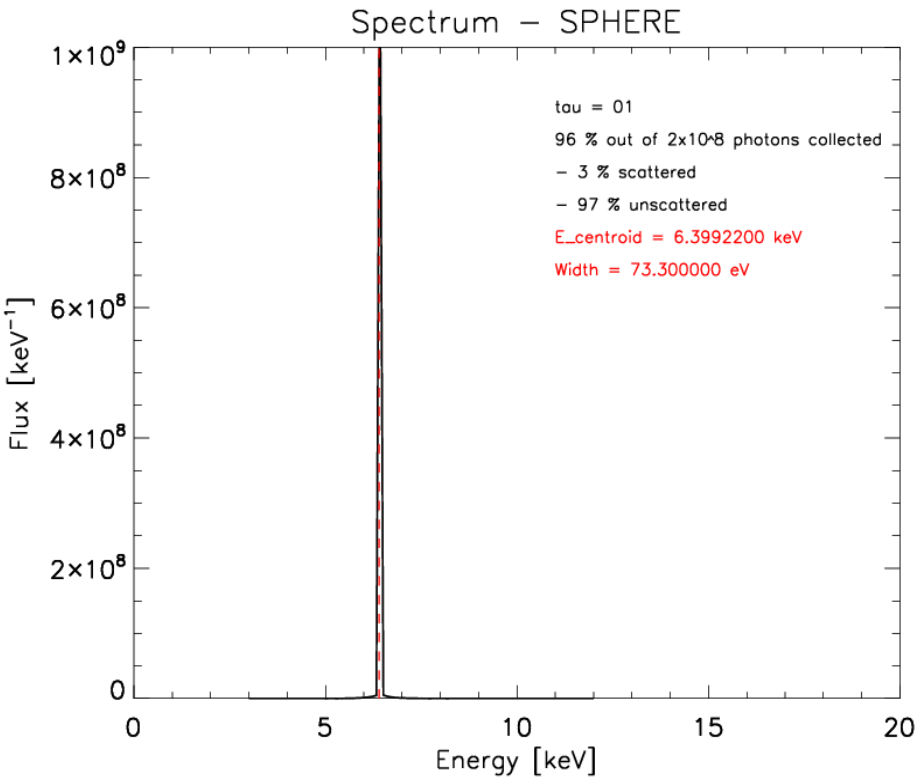
- thermal energy (kT = 2 keV)
- optical depth (τ = **0.1**, **1**, **3**)

di Salvo+ 2009
D'Ai+ 2009
Cackett+ 2010
Egron+ 2011-13

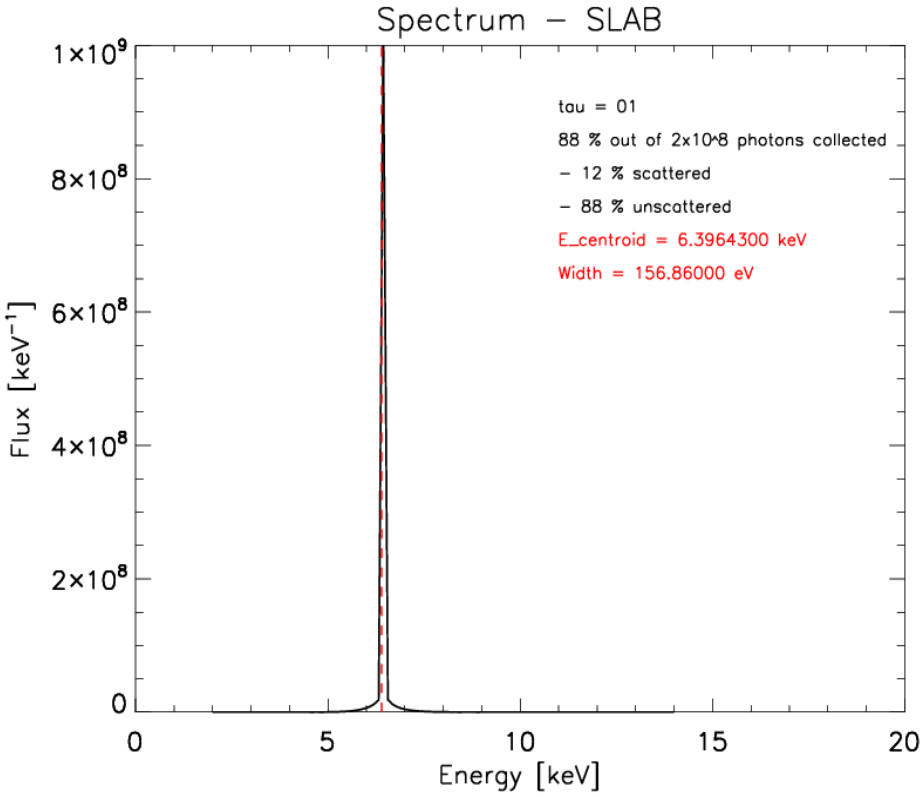
?

Ng+ 2010

SPHERE
τ = 0.1

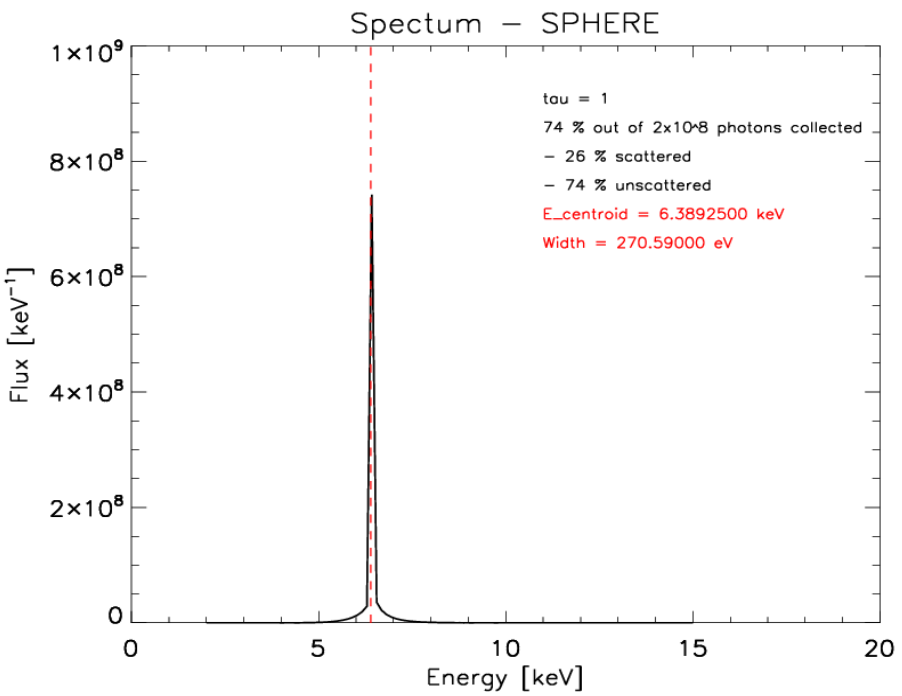


SLAB
τ = 0.1



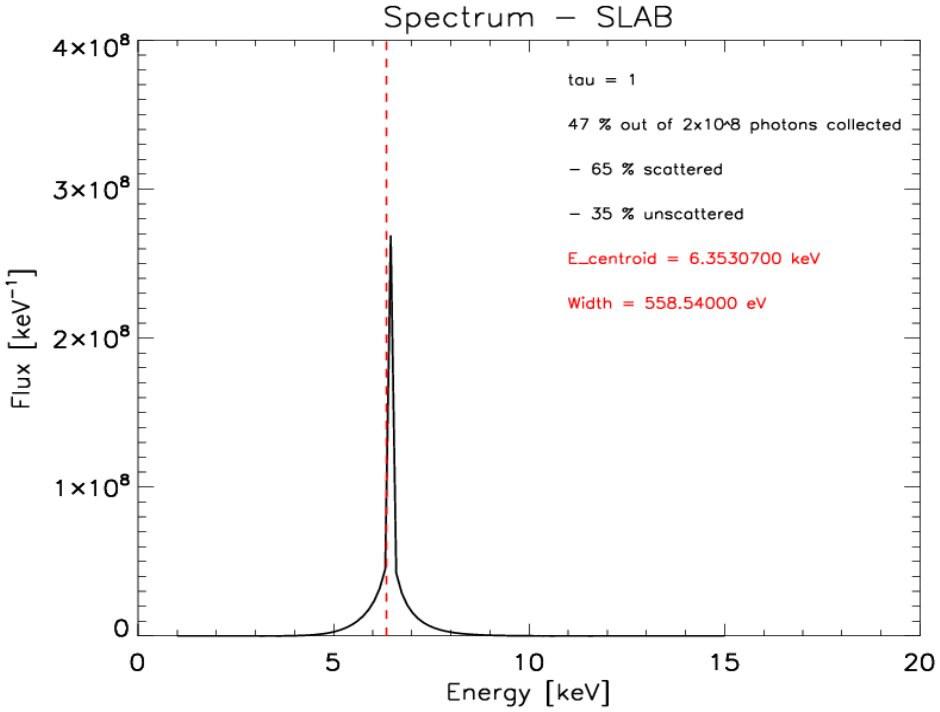
Line profile

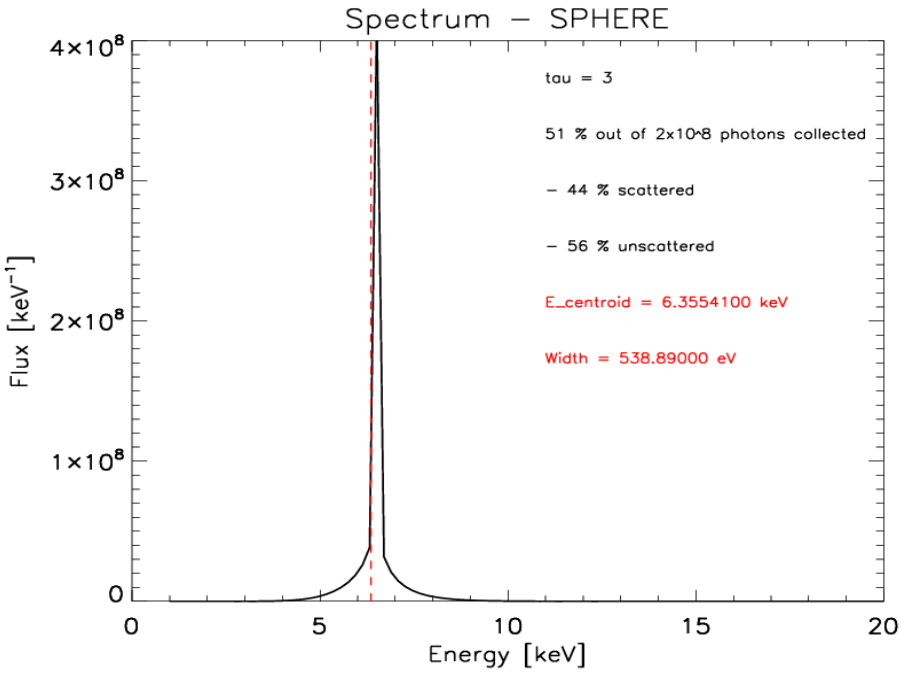
SPHERE



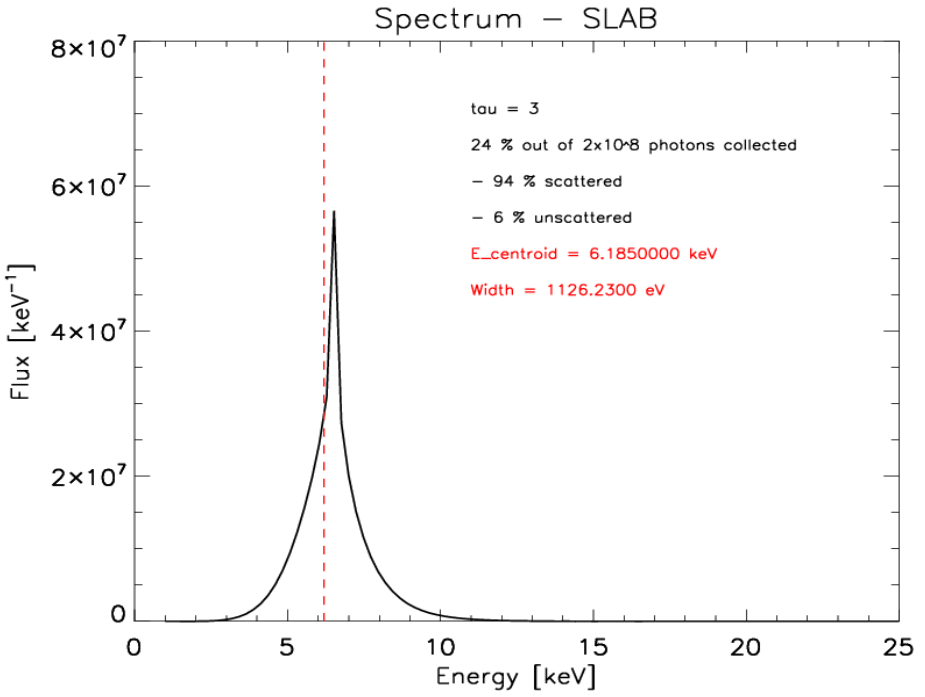
τ = 1

SLAB



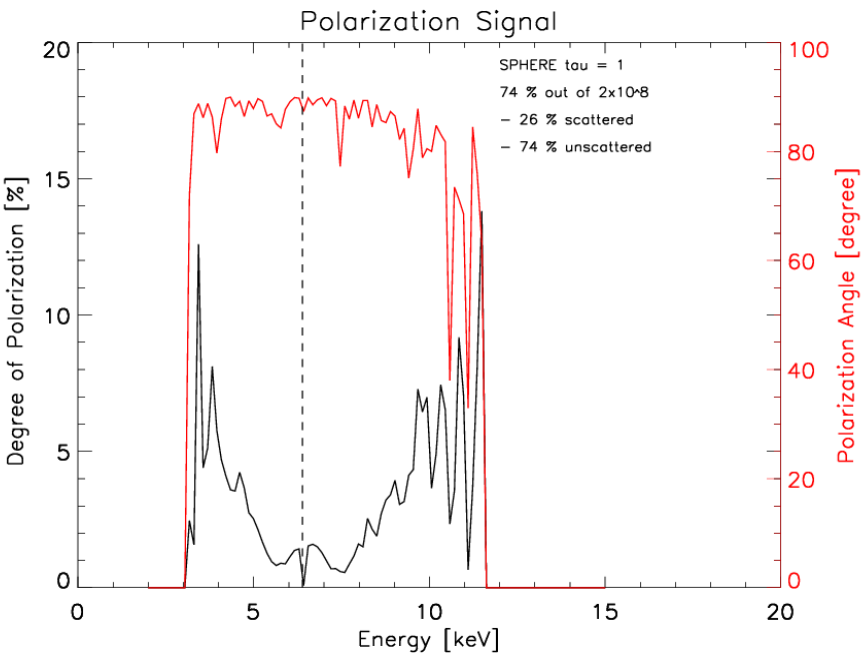


τ = 3



Line polarization

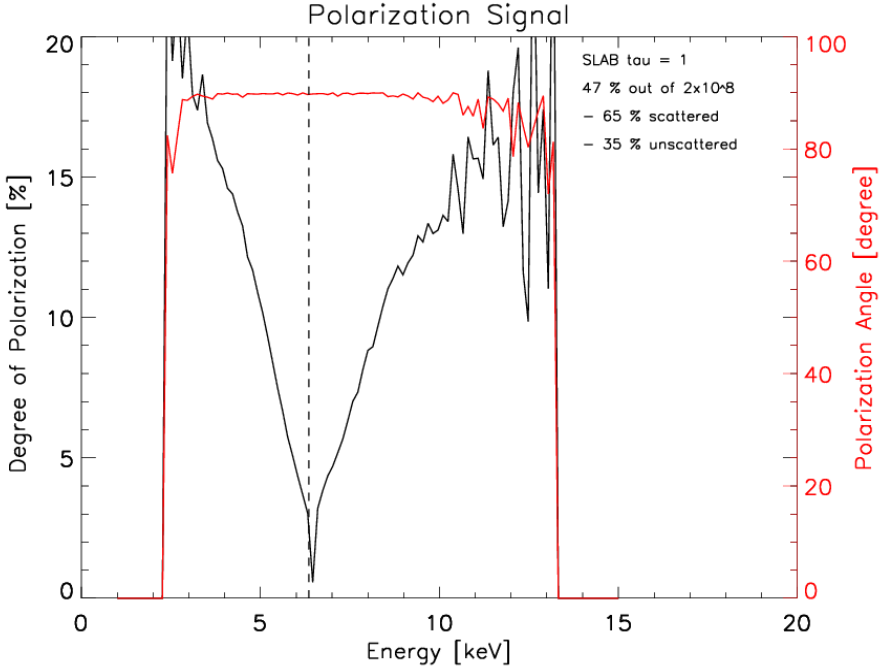
SPHERE

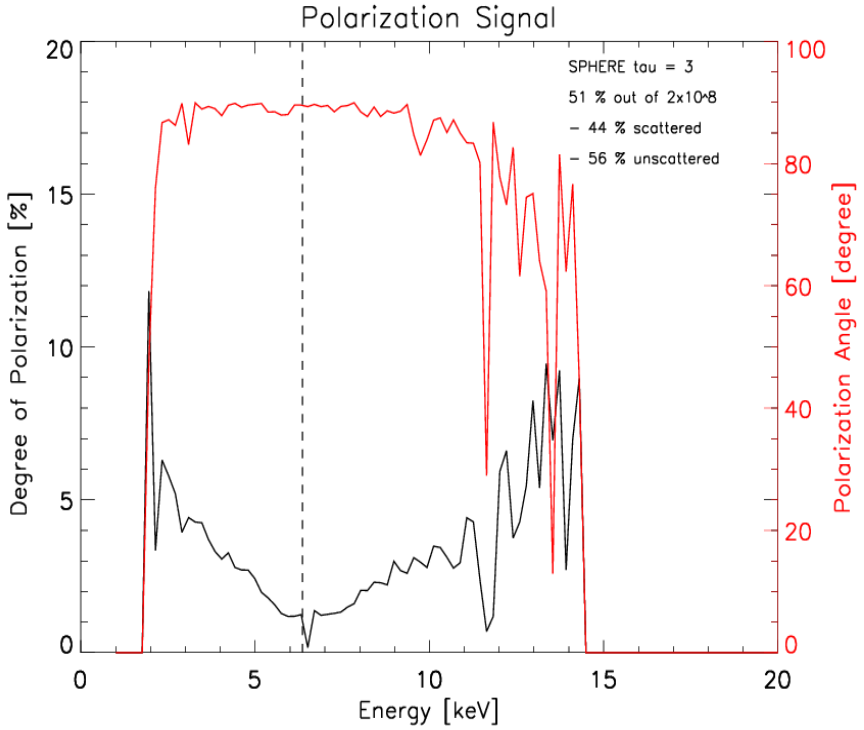


τ = 1

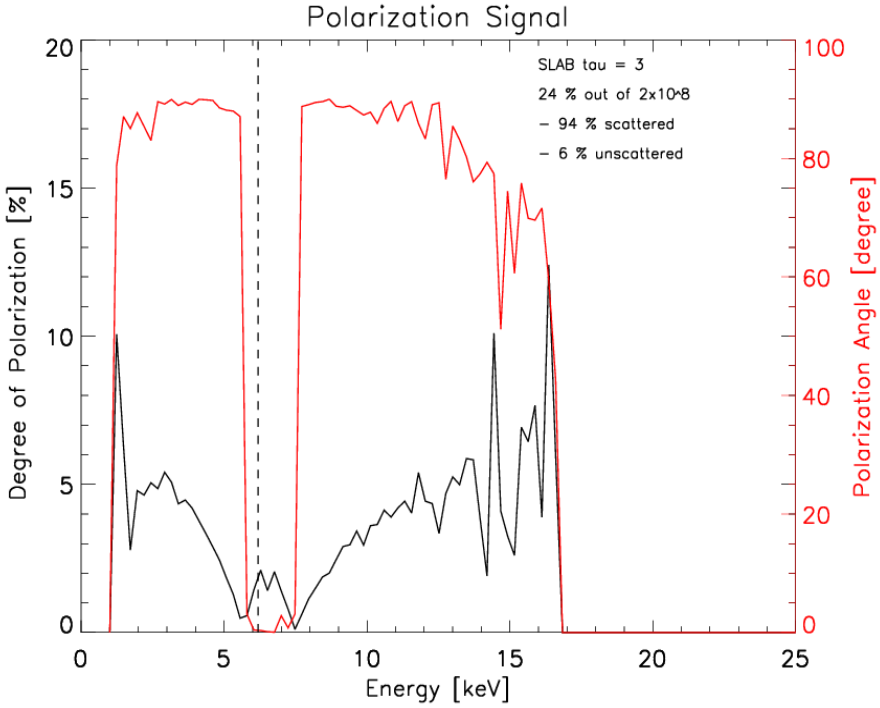
Treshold
100 counts

SLAB





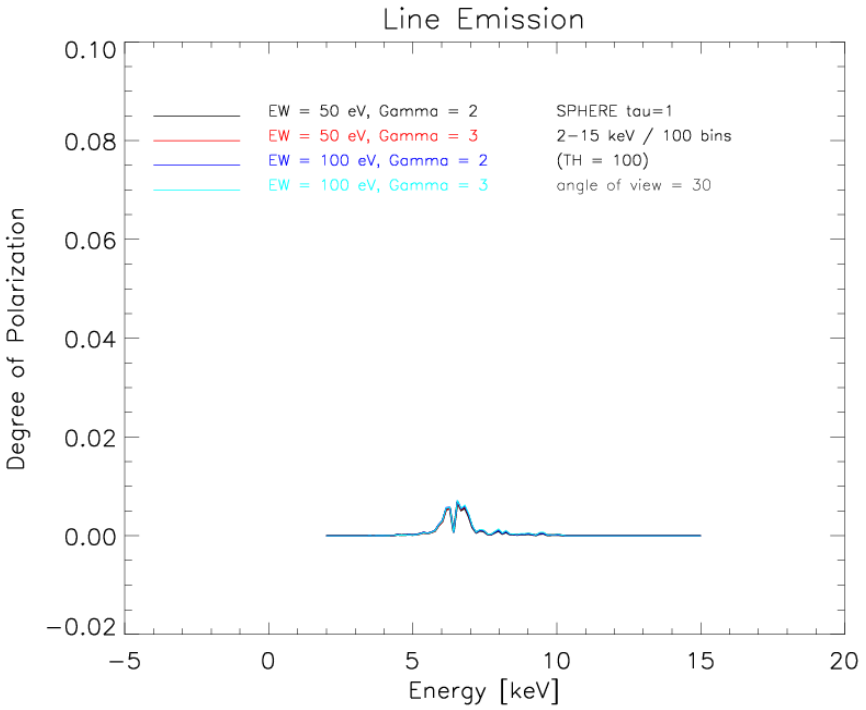
τ = 3

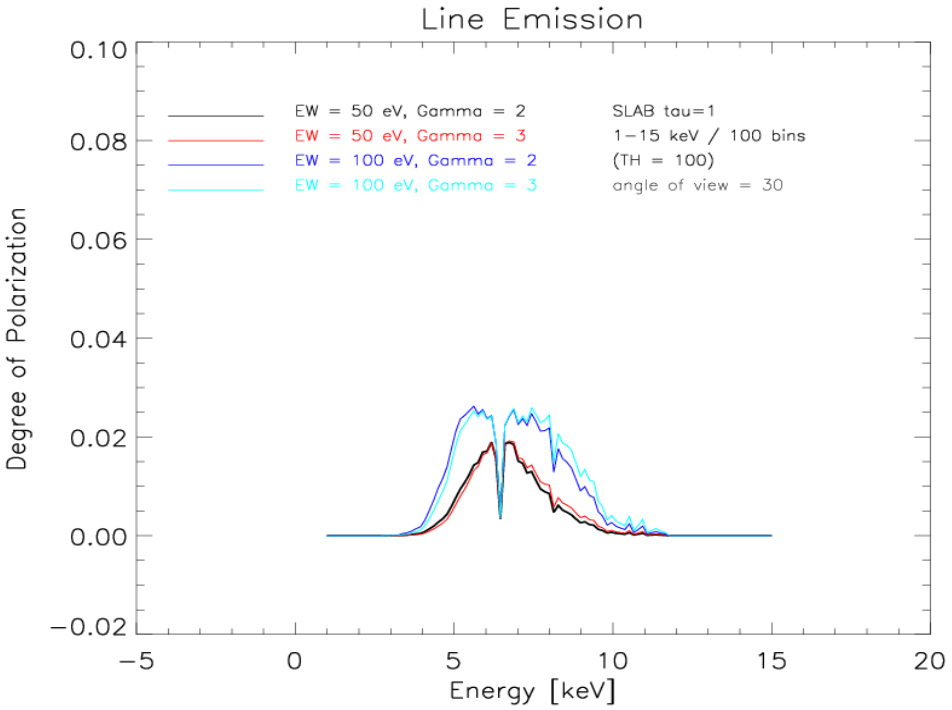


Net Polarization Degree – 30°

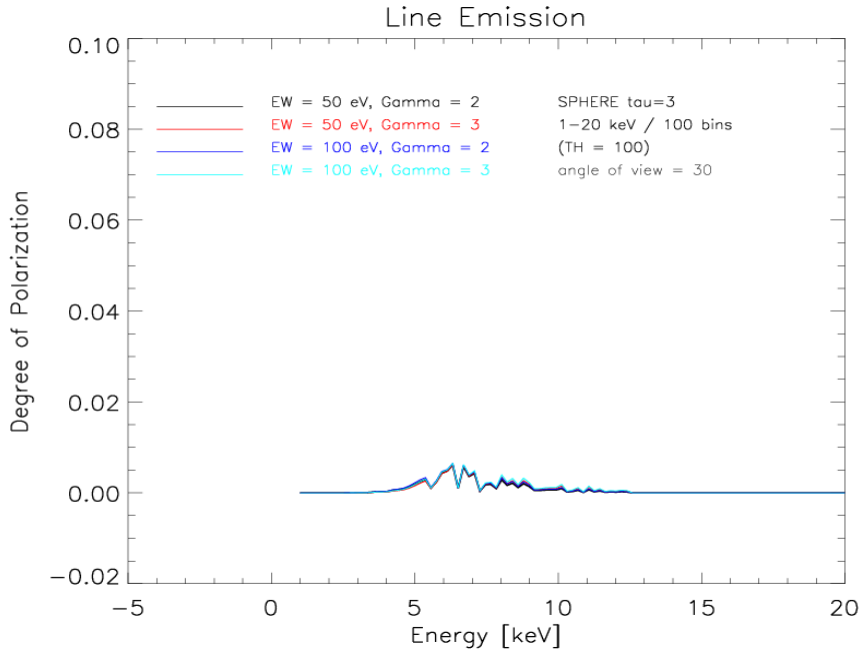
SPHERE **SLAB**

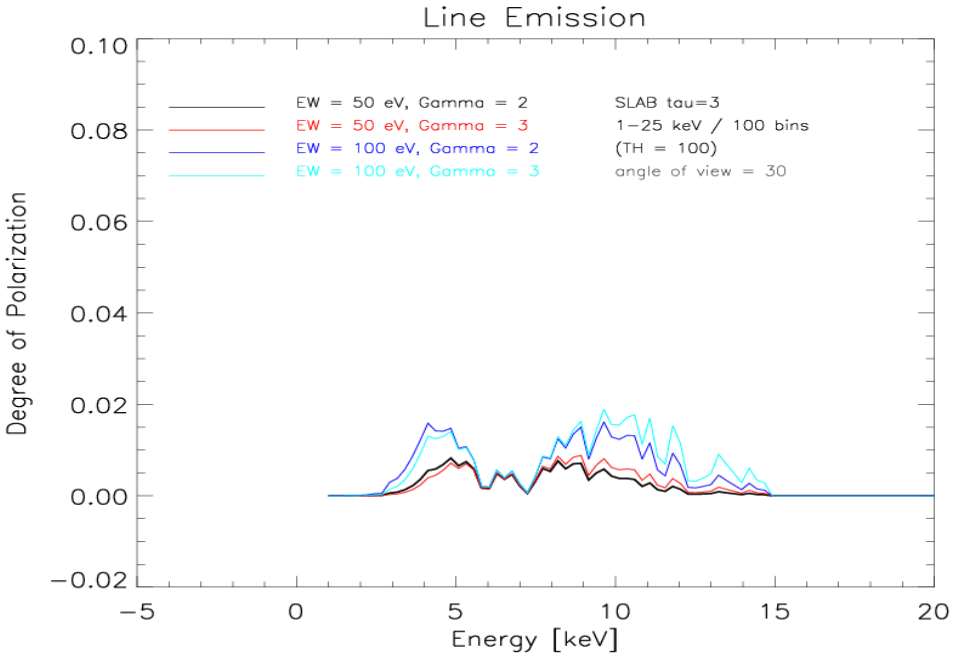
τ = 1





τ = 3

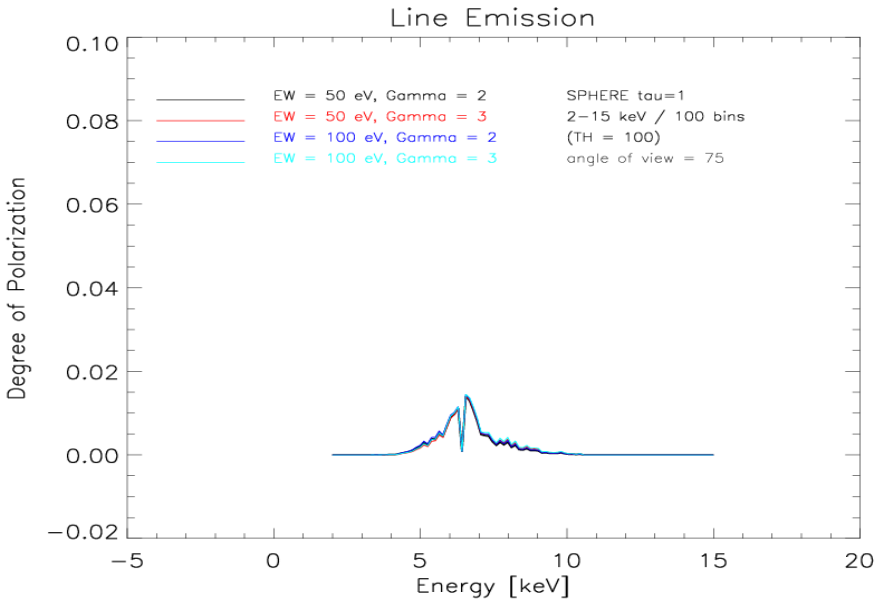


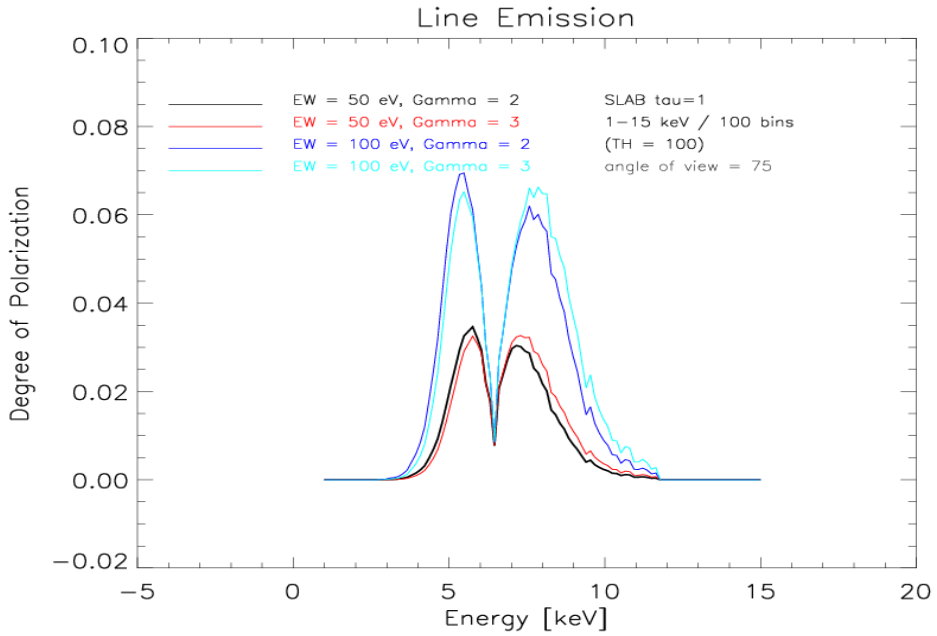


Net Polarization Degree - 75°

SPHERE **SLAB**

τ = 1





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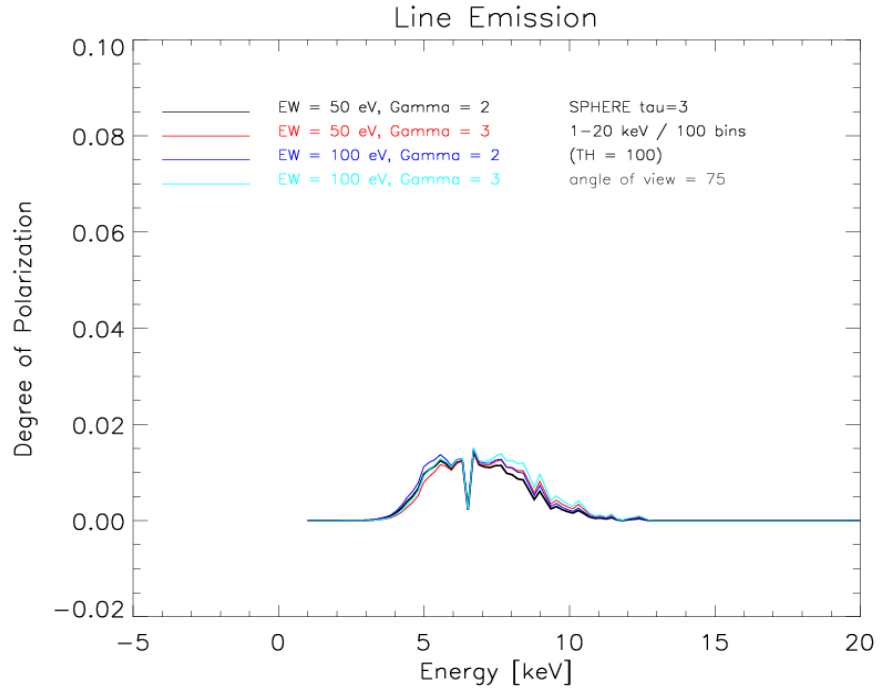
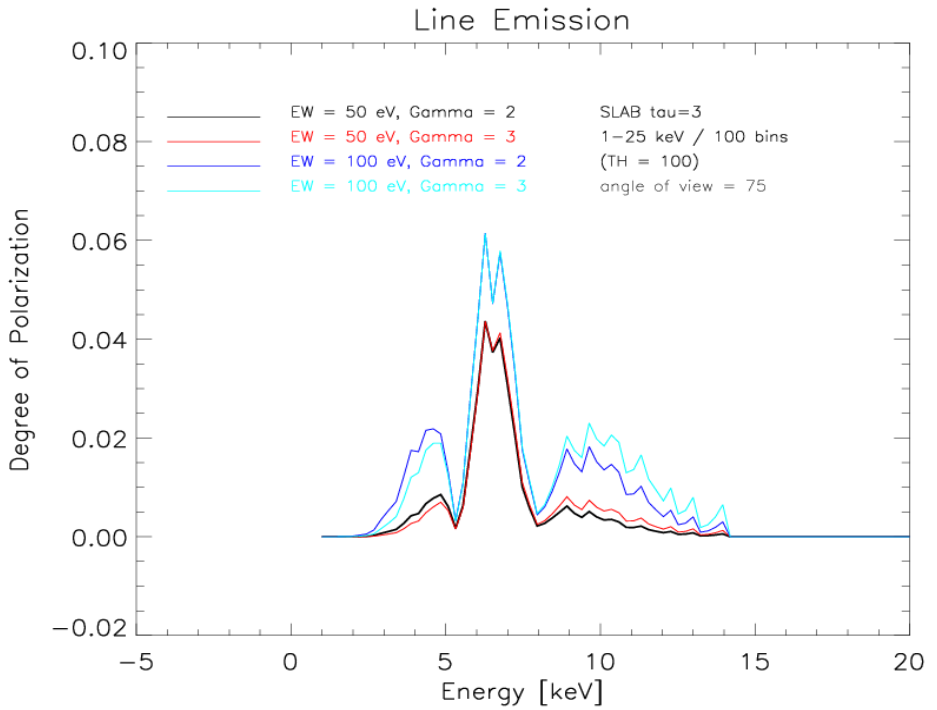




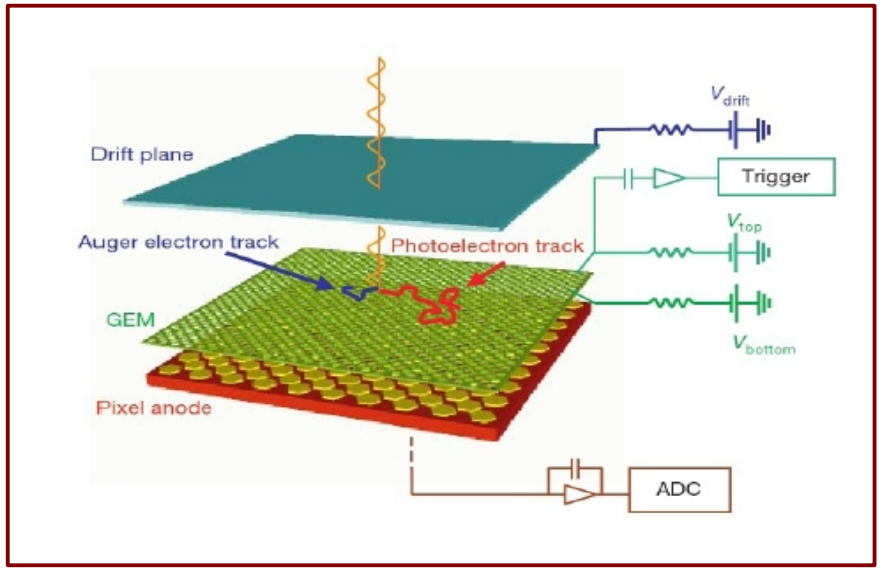
Conclusions

• Polarized radiation is expected in many sources being produced by scatterings, magnetic fields and general relativity

• Polarimetry offers 2 new independent observables (which is the opposite of adding more parameters!)

• These observables are extremely sensitive to geometry & angle of view if polarization is produced via scattering

Observational perspectives...none, yet!



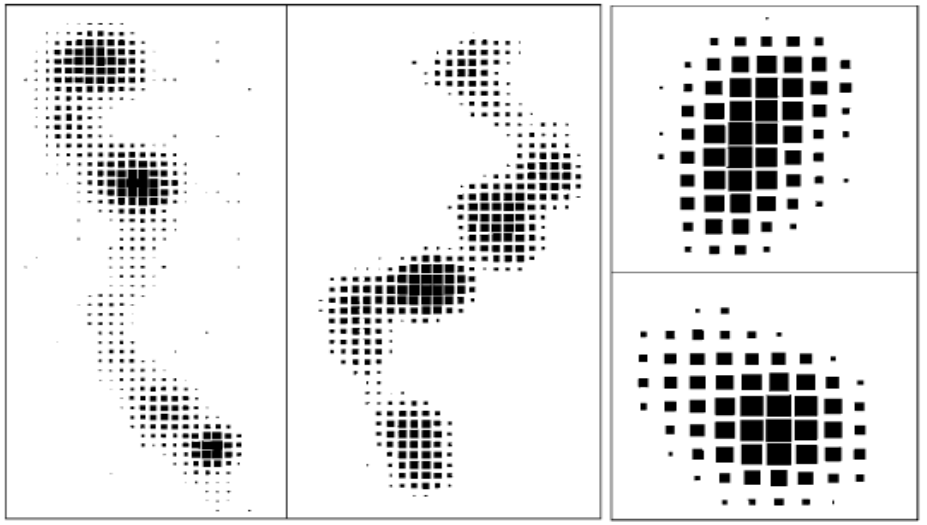
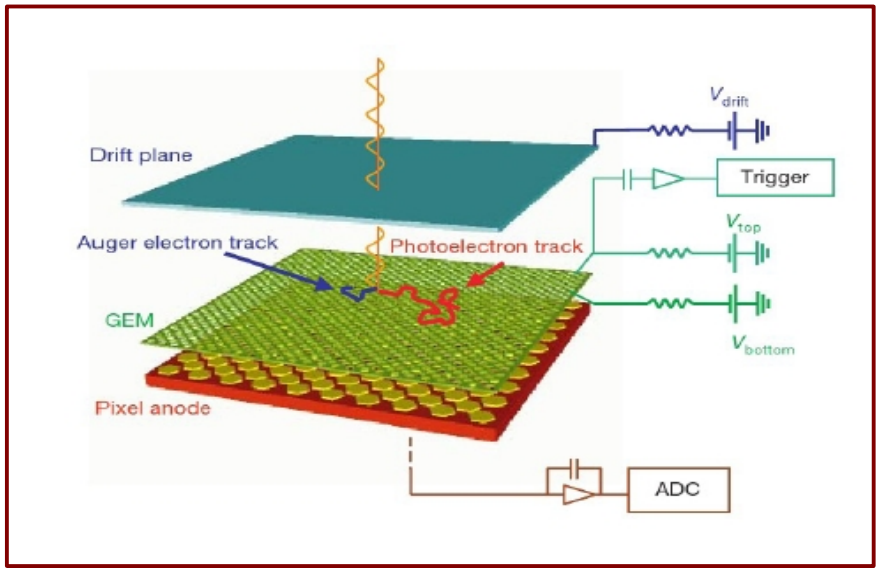


Fig. 3. Track images from 20 keV X-rays (left) and 4.5 keV X-rays (right).

Costa et al. (2001), Bellazzini et al.(2009), Muleri et al. (2009)

...but the technology is ready, well tested and perfectly fits a small mission (as we will see tomorrow afternoon).

Observational perspectives...none, yet!



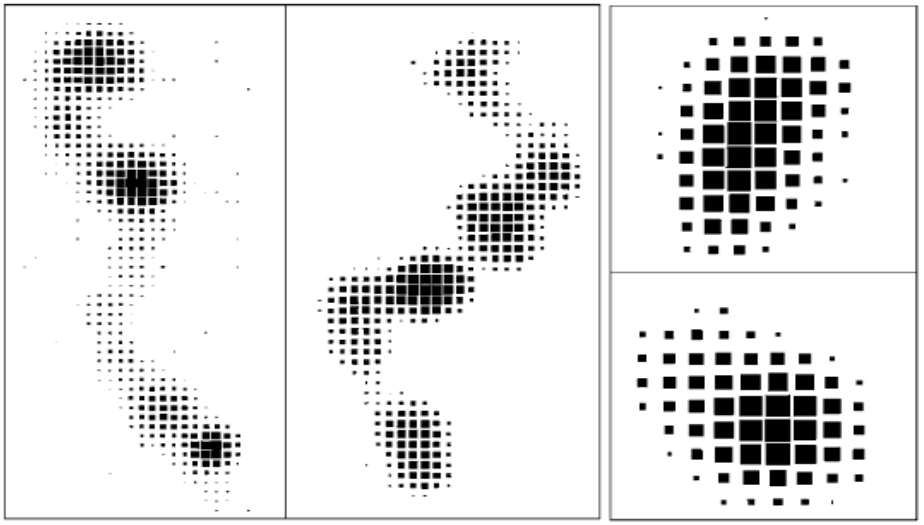


Fig. 3. Track images from 20 keV X-rays (left) and 4.5 keV X-rays (right).

Costa et al. (2001), Bellazzini et al.(2009), Muleri et al. (2009)

...but the technology is ready, well tested and perfectly fits a small mission.(as we will see tomorrow afternoon).

So let's open this window because:

"Even if the open windows of science at first make us shiver after the cozy indoor warmth of traditional humanizing myths, in the end the fresh air brings vigor, and the great spaces have a splendor of their own."

[Bertrand Russell]