X-ray polarization as a tool to understand coronae in accreting sources

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Abstract

Up-scattering of low-energy photons by Inverse Compton on a hot gas of electrons (i.e. Comptonization) is an important mechanism in Astrophysics. In particular, in accreting sources such as X-Ray Binaries (XRBs) and Active Galactic Nuclei (AGN) this mechanism is believed to be responsible for their hard X-ray emission: soft photons produced by the accretion disc are Comptonized by a corona of hot electrons whose physical parameters and especially the geometry are not well known. Spectroscopical analysis alone is not able to discriminate between different geometries and parameters of the corona.
In the context of this scenario we used our code MoCA: a Monte Carlo code for Comptonization in Astrophysics to show how X-ray polarimetry can be the tool to understand coronae in accreting sources.

1. Introduction

In the last years several AGNs and XRBs have been observed by NuStar NASA mission. High quality spectra extending up to 78 keV show a high energy exponential cut-off suggesting that the coronae should be composed by hot electrons with thermal energies typically in the range kT_e = 50 - 100 keV. However the spectra can be fitted by traditional Comptonization model with different geometries and corona parameters and the spectral analysis alone could not discriminate between geometries while the expected X-ray polarization signal induced by Comptonization has the potential to solve this problem.

2. The code

To our knowledge MoCA is the first code using a single photon approach in a full special relativity scenario and including both polarization and quantum corrections (in the form Klein-Nishina cross-section and scattering angle distribution). MoCA is written in Fortran 2003 and it is modular, allowing for an application to different systems of astrophysical interest with minor changes (Tamborra et al., in preparation).

3. The results

We applied MoCA to the case of the nearby Seyfert galaxy IC4392A which has been observed by NuStar and the spectroscopical analysis alone could not discriminate between a SLAB corona with tau=1.25 and kT=33 keV or a SPHERICAL corona with tau=3.42 and kT=37 keV [1]. We simulate both scenarios and in Fig.1 we show the spectra seen by an observer at infinity looking at the system at 75 degrees with respect to the spin-axis (almost edge-on). We notice a difference in the spectra, especially at higher energies. However one can imagine that these differences might be smaller than the errors associated with real data and therefore indistinguishable.

On the other hand the X-ray polarization signal expected by the two geometries is quite different. In Fig.2 and Fig.3 we show, respectively, the polarization degree and the polarization angle as a function of μ in the energy band 2-8 keV where μ is the cosine of the inclination measured from the spin-axis.
For both geometries of the corona we expect a linear polarization parallel to the spin-axis (polarization angle = 90 degrees) however for the SLAB corona the polarization degree can be as high as ~15% if the system is observed almost edge-on ($\mu \sim 0$) while for the SPHERICAL corona the polarization degree is never higher than ~4%.

We choose the energy band 2-8 keV corresponding to the energy range of the X-ray polarimeter onboard of the approved NASA SMEX mission IXPE [2] as well as onboard of the ESA M4 candidate mission XIPE [3].
X-ray polarization represents a new window for high-energy astrophysics furnishing two more observables: the polarization degree and the polarization angle. In the context of accreting sources such as XRBs and AGN it can be an invaluable tool to understand coronae.

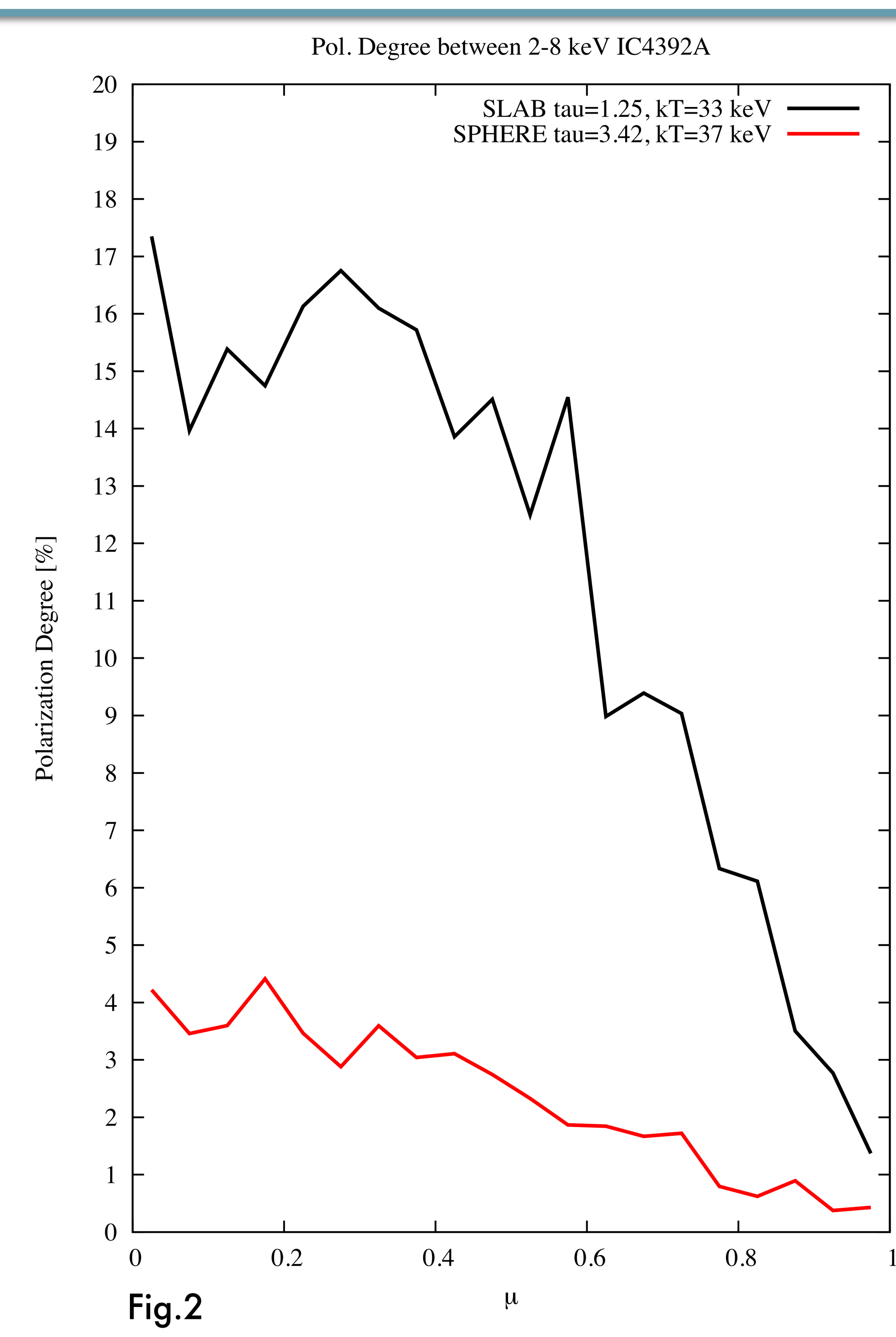

Fig.2

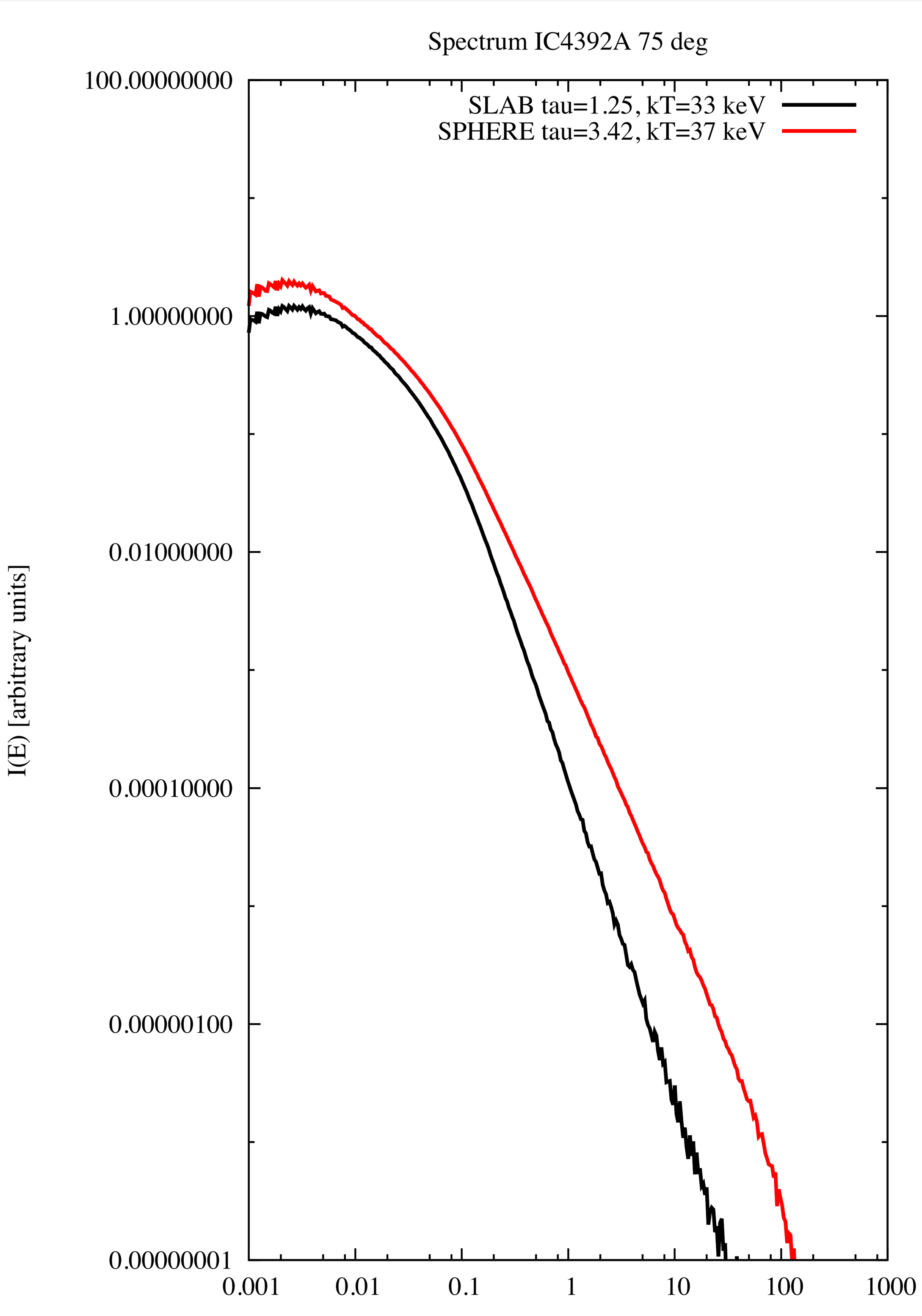

Fig.1

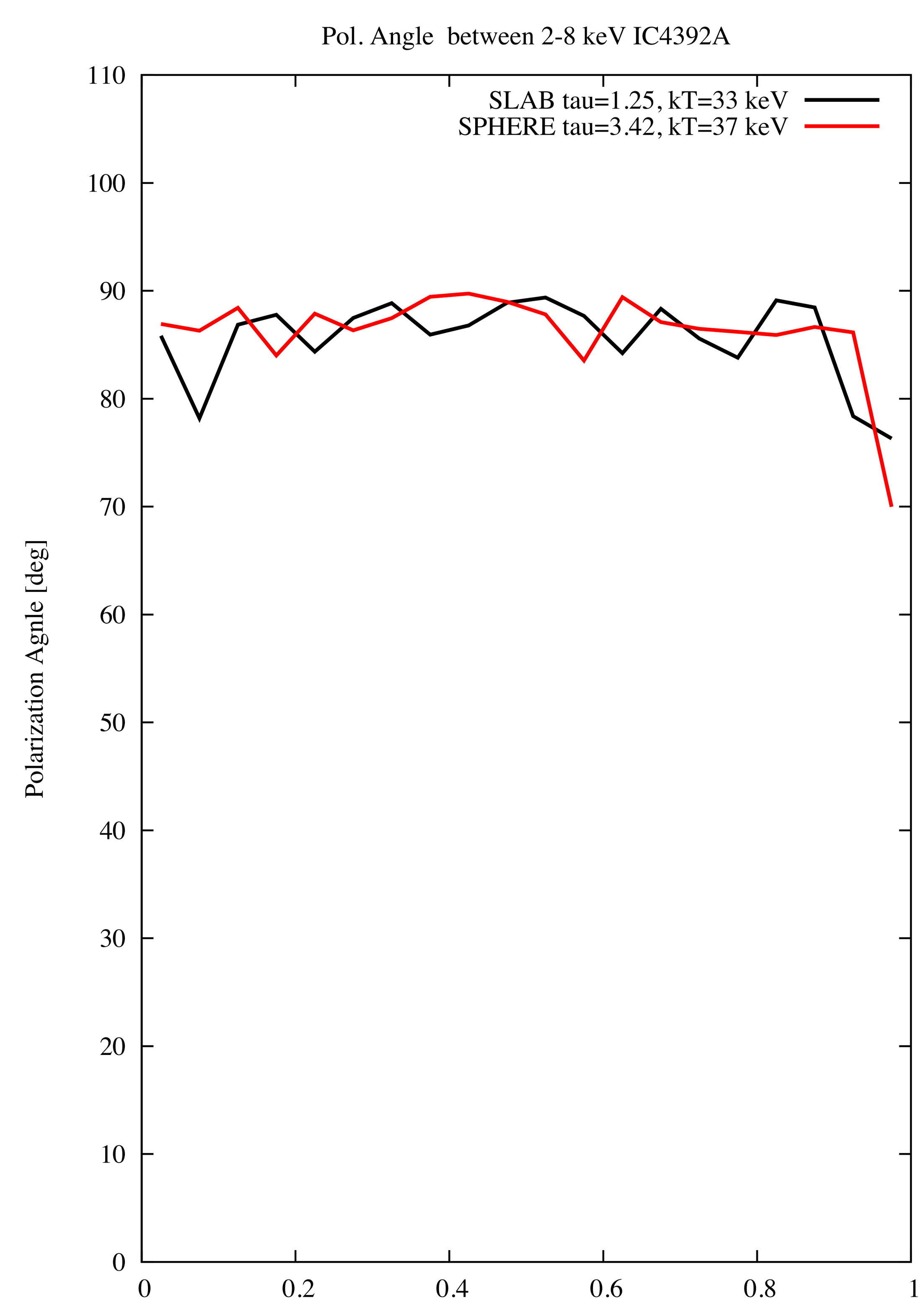

Fig.3

1. Brennemann et al., 2014, ApJ 781
2. Weisskopf et al., 2016, in Proc. SPIE, Vol. 9905
3. Soffitta et al., 2016, in Proc. SPIE, Vol. 9905

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