COST — European Cooperation in Science and Technology
Polarisation as a tool to study the Solar System and beyond
Action MP1104

X-ray polarization in the lamp-post model of non-smooth black-hole accretion discs

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X-ray polarisation in astrophysics: a window about to open?
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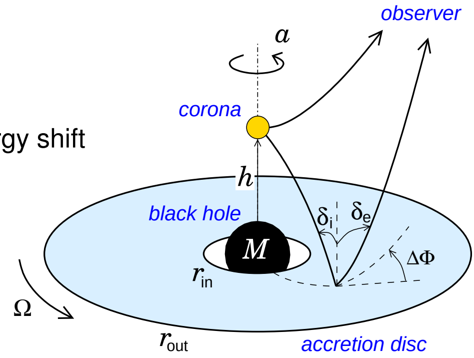
Scheme of the lamp-post geometry

- central black hole → mass, spin
- accretion disc
  → Keplerian, geometrically thin,
  optically thick and neutral
- compact corona
  → isotropic and unpolarised power-law emission
  → static (or slow motion)
  → height, photon index
- relativistic effects:
  → Doppler and gravitational energy shift
  → light bending (lensing)
  → aberration (beaming)
- references:
  → Matt (1993)
  → Dovčiak, Muleri, Goosmann, Karas & Matt (2011)



Motivation

- observational evidence of a rather compact X-ray source: variability, micro-lensing $\rightarrow$ corona size of ten(s) of $R_{\mathrm{g}} = GM/c^2$
- many effects should be qualitatively similar with a simple lamp-post geometry
- base of an aborted jet?
- light bending scenario to explain variability in continuum versus line flux (e.g. Miniutti & Fabian, 2004)
- polarization in reflection in non-axisymmetric geometry should be significant
- reflection versus absorption scenarios for origin of the AGN X-ray spectral shape in 2–10 keV range (Marin et al, 2012, 2013)
- new polarimetric detectors for next generation X-ray missions have been developed and proposed (XEUS, IXO, NHXM, GEMS, XIPE)

Stokes parameters at infinity

$$\Delta I(E) = \int_\Sigma \mathrm{d}S \, G \, I_{\mathrm{loc}}(E/g)$$

$$G = g^3 \, \ell \, \mu_{\mathrm{e}}$$

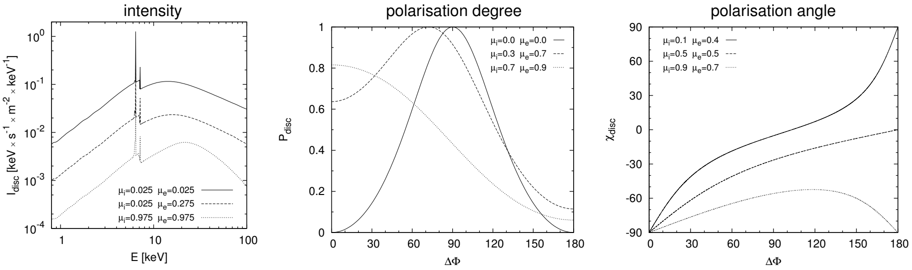
$$\Delta Q(E) = \int_\Sigma \mathrm{d}S \, G \, P_{\mathrm{loc}}(E/g) \, I_{\mathrm{loc}}(E/g) \, \cos 2[\chi_{\mathrm{loc}}(E/g) + \psi]$$

$$\Delta U(E) = \int_\Sigma \mathrm{d}S \, G \, P_{\mathrm{loc}}(E/g) \, I_{\mathrm{loc}}(E/g) \, \sin 2[\chi_{\mathrm{loc}}(E/g) + \psi]$$

$$P = \frac{\sqrt{(\Delta Q)^2 + (\Delta U)^2}}{\Delta I} \qquad \tan 2\chi = \frac{\Delta U}{\Delta Q}$$

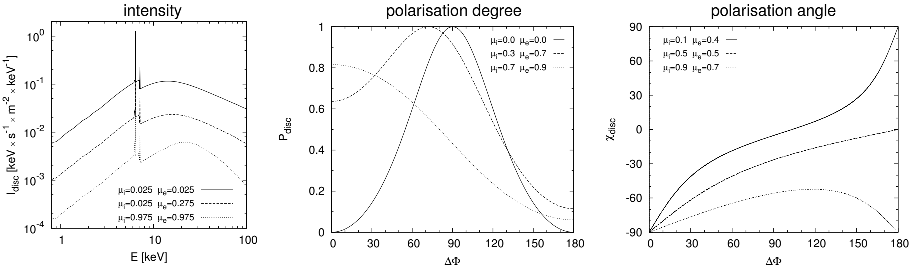
$\rightarrow$ I_{loc}, P_{loc} and χ_{loc} depend on local geometry of scattering

Local emission



- flux $\rightarrow$ multiple Compton scattering and Kα, Kβ fluorescence – `NOAR`
- polarization $\rightarrow$ single scattering approximation – Chandrasekhar (1960)
- irregular surface
  - to relax the assumption on such a well defined scattering geometry
  - on much smaller scale than the changes in relativistic effects
  - on much larger scale than the scale characterizing the radiative transfer
  - averaging of the local polarisation properties

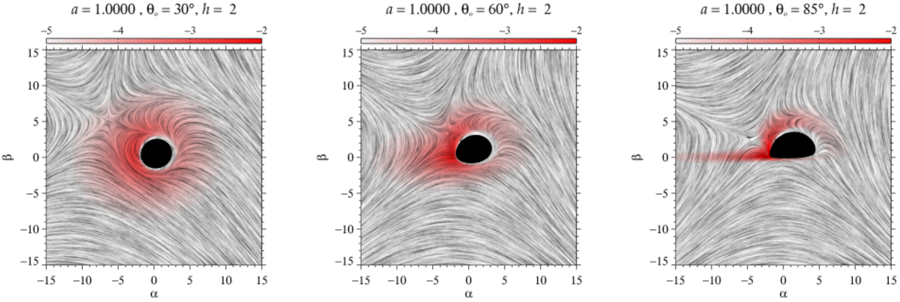
Local emission



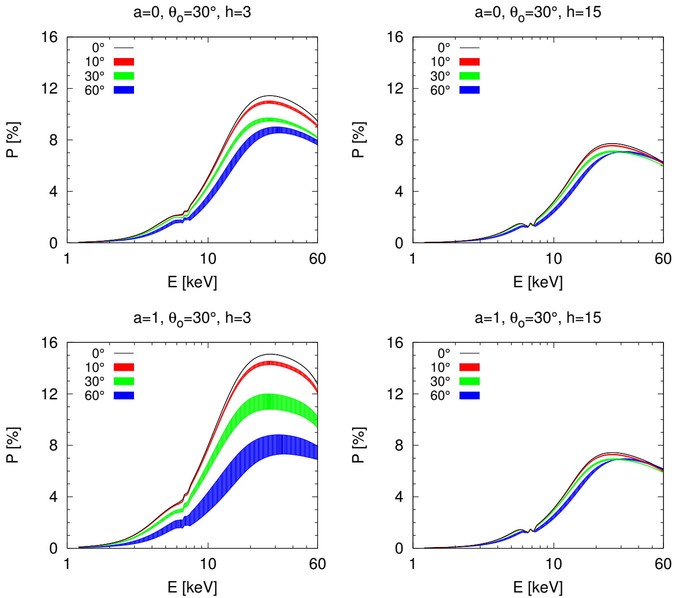
- flux $\rightarrow$ multiple Compton scattering and Kα, Kβ fluorescence – NOAR
- polarization $\rightarrow$ single scattering approximation – Chandrasekhar (1960)
- irregular surface
  - defined by the angle of the surface with respect to the equatorial plane, $\delta < \delta_{\text{max}} = 10^\circ, 30^\circ$ and 60°
  - locally symmetric in azimuthal angle
  - shading is not taken into account
  - two probability distributions are explored, $\mathscr{P}(\delta)$:
    $\rightarrow$ linearly decreases to zero for δ_{max}
    $\rightarrow$ linearly increases to be doubled for δ_{max}

Smooth disc

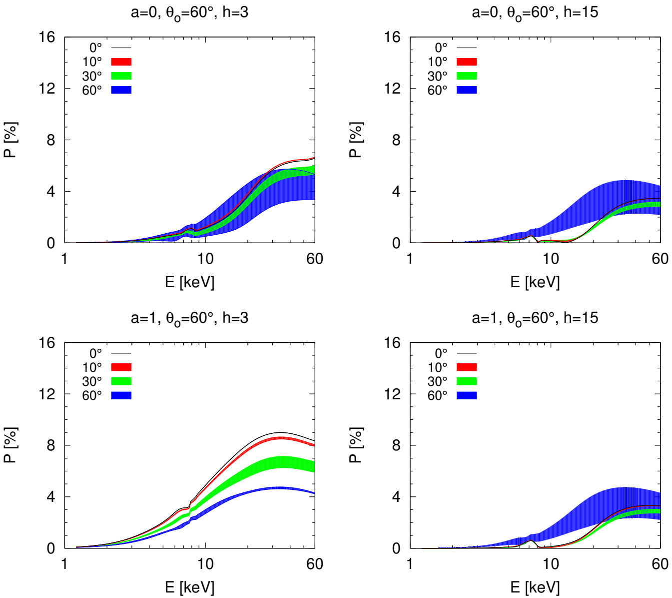
- → importance of the local polarization properties
- → geometry of scattering (incident, emission and relative azimuthal angles)
- → source height, observer inclination and black hole spin
- → formation of additional depolarizing critical points
- → illumination pattern depends on height of the source



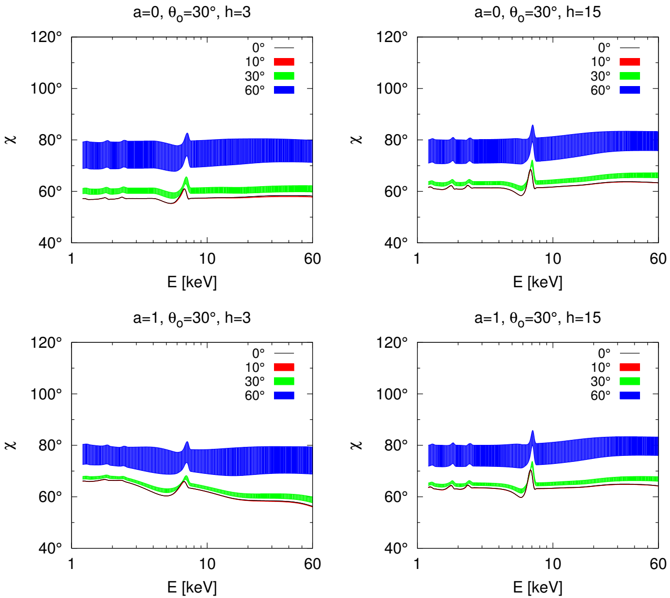
Irregular disc surface – polarisation degree



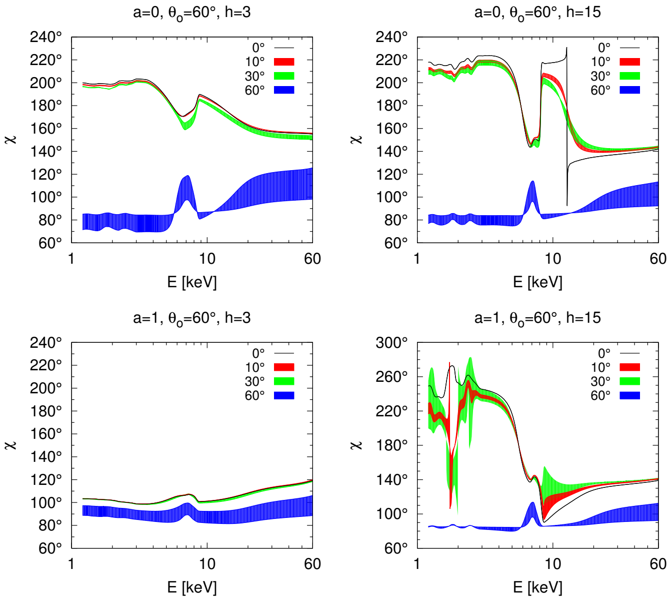
Irregular disc surface – polarisation degree



Irregular disc surface – polarisation angle



Irregular disc surface – polarisation angle



Conclusions

- relativistic effects change considerably the polarization of the emitted radiation
- importance of the system geometry and physical properties of the system
- effects of “large-scale” corona (in XRBs) $\rightarrow$ Schnittman & Krolik (2010)
- the differences between results for various heights get smaller for polarisation degree
- the irregularities in the disc lower the polarisation degree and change the angle more with higher δ_{max}
- the polarisation properties for $\delta_{max} \approx 60^{\circ}$ are similar for different heights and BH spins
- polarimetric observations could help to discriminate between competing scenarios and to determine the properties of the system
  $\rightarrow$ inclination, BH spin, corona geometry