

Polarization signatures of X-ray reflection

Giorgio Matt (Dip. Fisica, Università Roma Tre)



Plan of the talk

 Reflection from opt. thick matter

 Accretion discs (GR effects) in AGN and GBH
 WD surface in magnetic CVs
 The X-ray history of the Galactic Centre

Reflection from opt. thin matter - Seyfert 2 galaxies



Reflection from cold matter

Reflection from cold matter produces a continuum peaking around 20 keV (due to the combined effects of photoelectric absorption and Compton scattering) plus several fluorescent lines, most prominent of them the Fe K_ line at 6.4 keV (e.g. George & Fabian 1991, Matt et al. 1991.)



Reynolds et al. (1995)



Reflection from cold matter



Matt et al. (2003)

The reflection component depends on the optical depth of the reflector. Once the matter becomes Compton-thick, the reflection spectrum saturates.

In the following, we will assume Compton-thick matter, as appropriate for e.g. Accretion Discs, Molecular Tori or WD surfaces.



Polarization of reflected flux



Polarization of reflected (continuum) radiation is polarized up to 20% (Matt et al. 1989), assuming isotropic illumination, a plane-parallel reflecting slab and unpolarized Illuminating radiation

P does not depends much on energy (slightly decreases at high energies because of multiple scatterings and K-N).

(Polarization of disc emission)



Sunyaev & Titarchuk (1985)

Thermal emission, even in a pure scattering atmosphere, is at most polarized at about 12% (Chandrasekhar 1960), unless optically thin (Sunyaev & Titarchuk 1985; Phillips & Meszaros 1986).

P decreases if there is significant absorption (e.g. Loskutov & Sobolev 1981; Laor et al. 1990)



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Matt et al. (1993)

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GR effects in accretion discs

The polarization angle, _, depends on the photon's path (e.g. Connors & Stark 1977; Pineault 1977; Laor et al. 1990, Chen & Eardley 1971).

This implies a rotation of _ with energy, for disc thermal emission, due to the radial dependence of T (Connors et al. 1980). Relevant for GBH, T too low in AGN



Connors et al. (1980)



Breaking of the symmetry due to SR (Doppler boosting) and GR effects cause the polarization angle to rotate with respect to the Newtonian case. Changes in the illumination properties (e.g. height in a simple lamp-post geometry) will cause changes in the pol. angle, which is therefore likely to be time dependent (relevant for AGN, timescales too short for GBH).

Reflection in Relativistic discs <u>**1. Schwarzschild</u></u></u>**



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Reflection in Relativistic discs <u>1. Schwarzschild</u>

Reflection in ionized discs may be relevant also in soft X-rays (Ross & Fabian 1993, Matt et al. 1993).

The ionization state depends on the accretion rate and the BH mass



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Reflection in Relativistic discs <u>2. Kerr</u>

GR effects are of course even more dramatic for spinning BHs, when the disc may extend down to 1 Rg. Assuming a lamp-post geometry, *P* and _ can be calculated as a function of the height, *h*, of the source (Dovciak, Karas & Matt in prep.).

Variations of *h* have been suggested to be the cause of the puzzling temporal behaviour of the iron line in MCG-6-30-15 (Miniutti et al. 2003)



Reflection in Relativistic discs <u>**2. Kerr</u>**</u>



P and _ depend on both *h* and the incl. angle (the latter may be estimated from the line profile; for MCG-6-30-15, _~0.85, Tanaka et al. 1995)



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If the primary emission (supposed unpolarized) is included, the net polarization degree of course decreases, but it is still significant especially for low heigths, where light bending enhances the relative amount of reflection.





X-ray Polarization in magnetic <u>CVs</u>

Accretion in Magnetic CVs occurs via an accretion column; X-rays are produced by opt. thin thermal plasma emission in the post-shock region.

Half of the hard X-rays illuminate the WD surface → Compton reflection



(Polarization of the accretion

<u>column)</u>

The emission from the accretion column itself may be polarized. In fact, the Thomson depth may be not negligible (______=0.1-1), and a fraction of photons may be scattered (and polarized) before leaving the column.

The degree of polarization of course increases with ______ (Matt 2004), which in turn depends on the acc. rate.



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Polarization in magnetic CVs Example: AM Herculis

Using the geometrical parameters of AM Herculis (Cropper 1988), the expected degree of polarization as a function of the orbital phase can be calculated for this bright source.

Polarization measurements will yield the parameters of the column, providing a check of accretion models.





Reflection from Sgr B2 and the history of the Galactic Centre

The molecular cloud SgrB2, at the projected distance from SgrA* of about 100 pc, has a pure X-ray reflection spectrum. No illuminating X-ray source is however visible in the neighbourhood. It has therefore been suggested (Koyama et al. 1996) that SgrB2 is echoing the emission from the GC, which was supposed to be active a few hundreds years ago.



Koyama et al. 1996



Reflection from Sgr B2 and the history of the Galactic Centre

If this is true, the X-ray emission from Sgr B2 must be polarized (Churazov et al. 2002). The polarization degree depends on the true distance of Sgr B2 from the Galactic Centre





Churazov et al. 2002



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Churazov et al. 2002

Obscured Seyfert galaxies

Soft X-ray emission in X-ray obscured AGN can be due to either reflection from warm matter or Starburst emission. Polarization measurements may provide the answer



NGC 4507

Matt et al. (2004)

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Urry & Padovani (1995)

Obscured Seyfert galaxies

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Weaver (2002)

Reflection from opt. thin matter

Obscured Seyfert galaxies

Reflecting regions are clearly observed in the optical (polarized broad lines, ionization cones). They will reflect soft X-rays too.

Polarization degree may be quite high.

NGC 5738 - HST

Obscured Seyfert galaxies

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X-ray reflection is important in many different astrophysical contexts. Polarization measurements will help to:

Probe (strong-field) GR effects in AGN and GBH
 Test models of the accretion column in Mag. CVs
 Confirm that the Galactic Centre was active a few hundreds years ago
 Establish the nature of the soft X – ray emission in obscured Seyfert galaxies