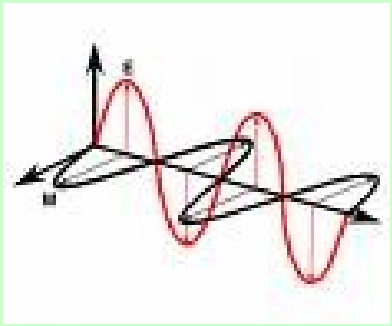


Polarimetry science with IXO

Giorgio Matt

(Dip. Fisica, Università Roma Tre)

Radiation is polarized when it is originated in anisotropic physical situations, as e.g. in *aspherical matter/radiation field distributions* or in *ordered magnetic fields*.

Polarization properties are strongly modified by *GR curvature of space-time*

Many X-ray sources are likely to be strongly polarized

Polarimetry will provide important and often unique informations (see the recent INTEGRAL results on the γ-ray polarization of the Crab)

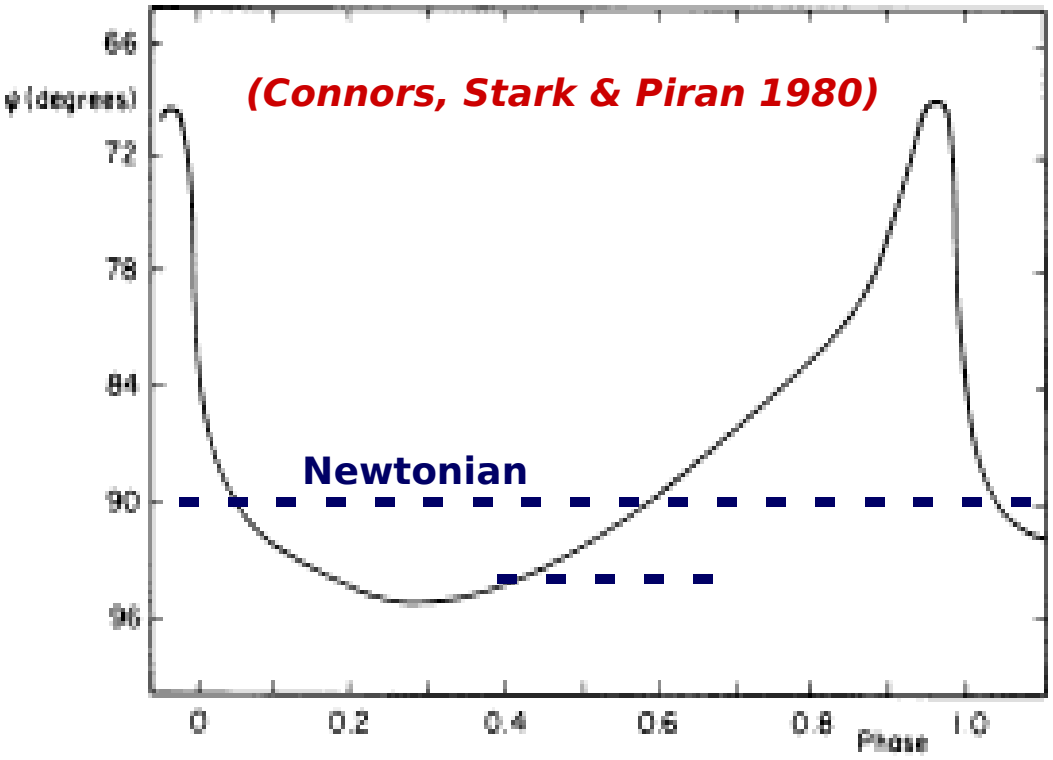
X-ray polarimetry may:

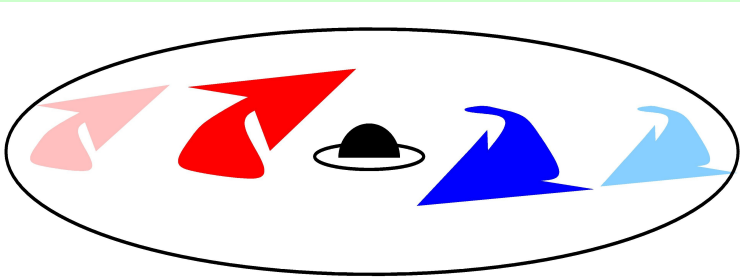
- **Probe strong gravity effects around BHs**
- **Determine the emission mechanism in Blazars**
- **Study strong and extreme magnetic fields in compact sources**
- **Disclose the past activity of the Black Hole in the Galaxy**

Strong gravity effects on polarization

General and Special Relativity effects around a compact object (here-in-after collectively indicated as "strong gravity effects") significantly modifies the polarization properties of the radiation.

In particular, the Polarization Angle (PA) as seen at infinity is rotated due to aberration (SR) and light bending (GR) effects (e.g. Connors & Stark 1977; Pineault 1977). The rotation is larger for smaller radii and higher inc





Orbiting spot with: a=0.998; R=11.1 Rg i=75.5 deg

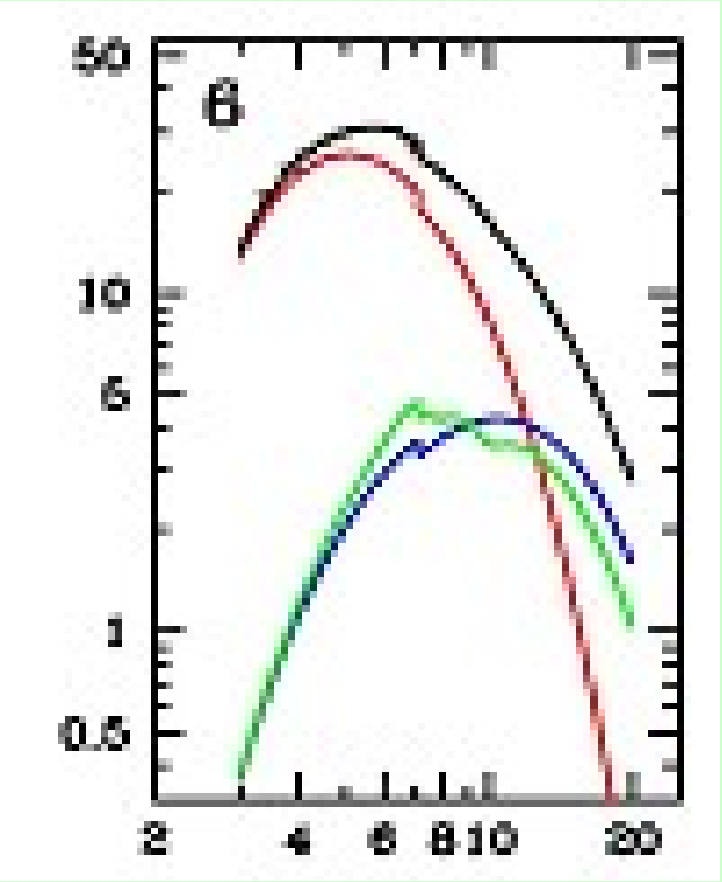
(Phase=0 when the spot is behind the BH).

The PA of the net (i.e. phase-averaged) radiation is also

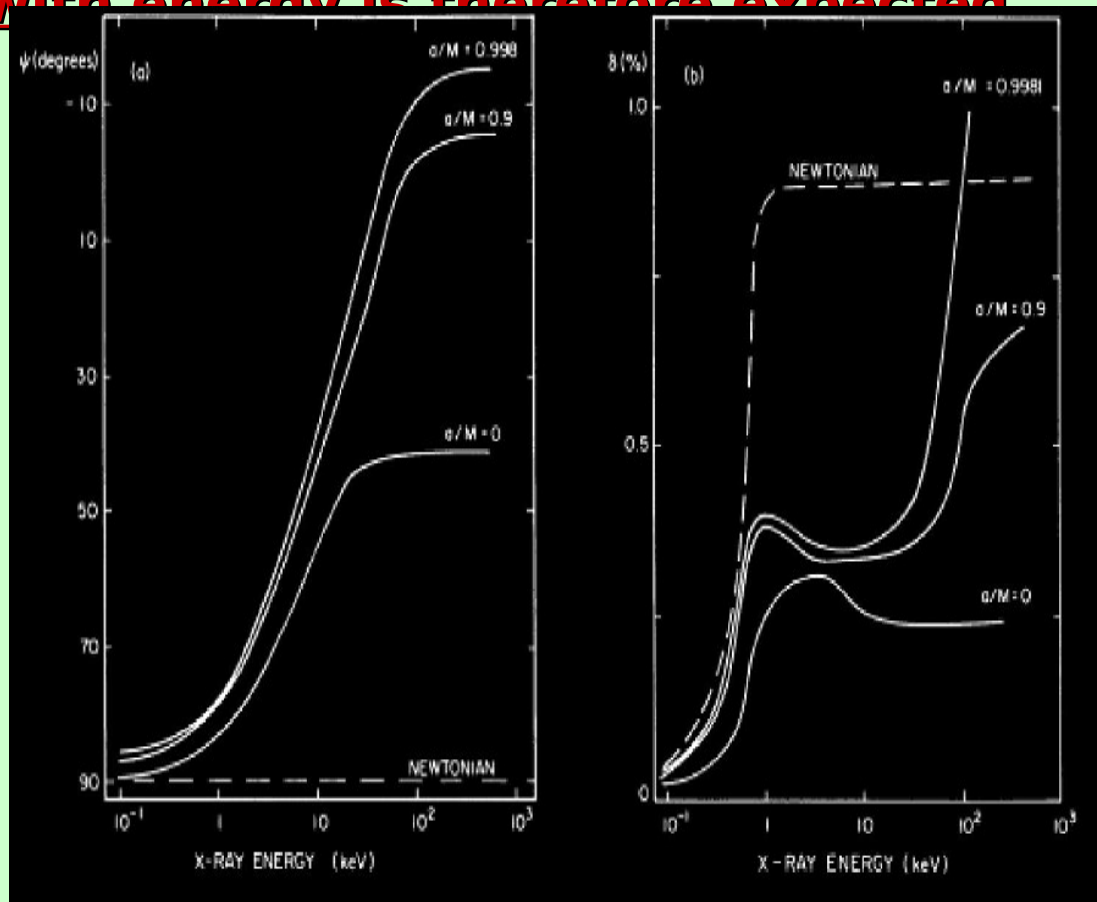
Galactic BH binaries in high state

X-ray emission in Galactic BH binaries in soft states is dominated by disc thermal emission, with *T decreasing with radius.*

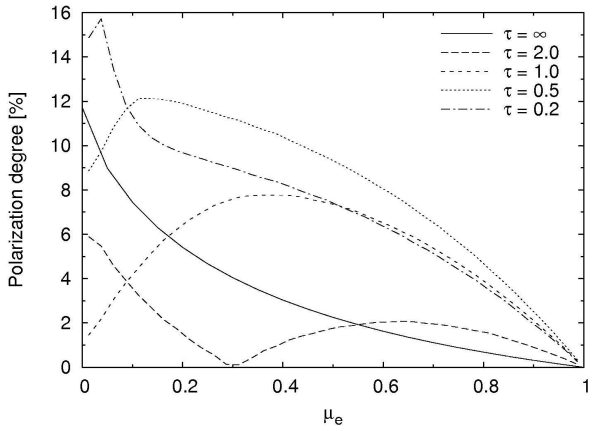
A rotation of the polarization angle with energy is therefore expected



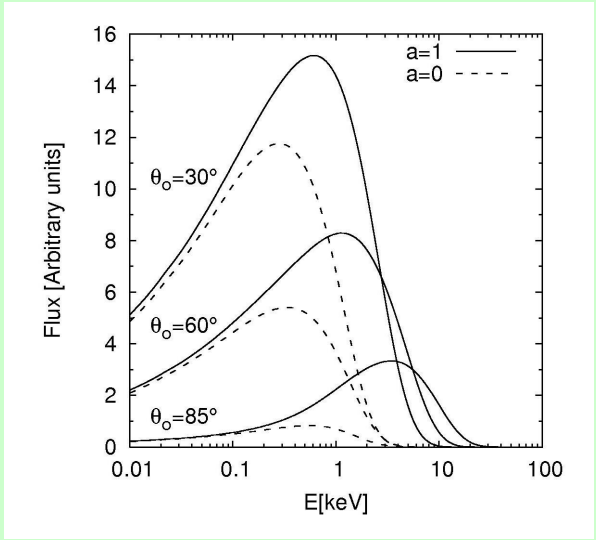
GRS 1915+105 (Done & Gierlinski 2004)



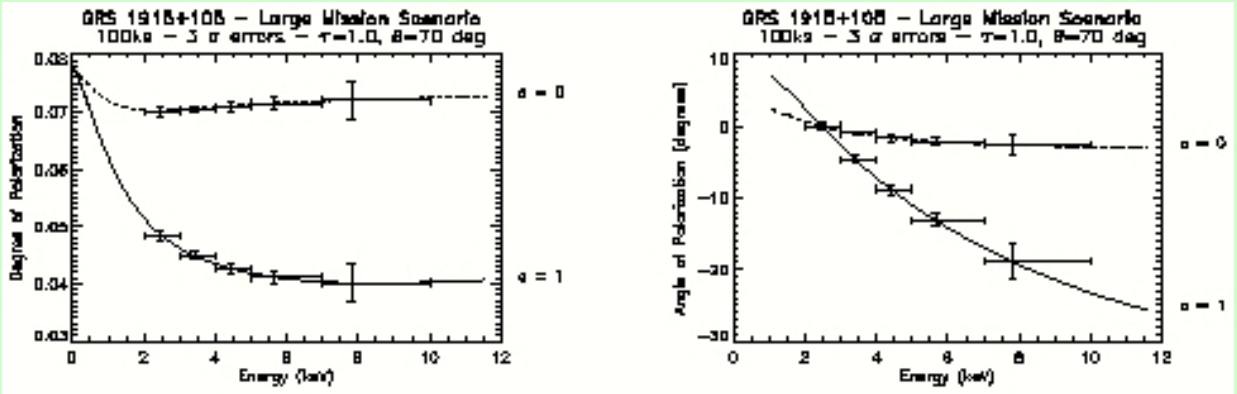
Connors & Stark (1977)

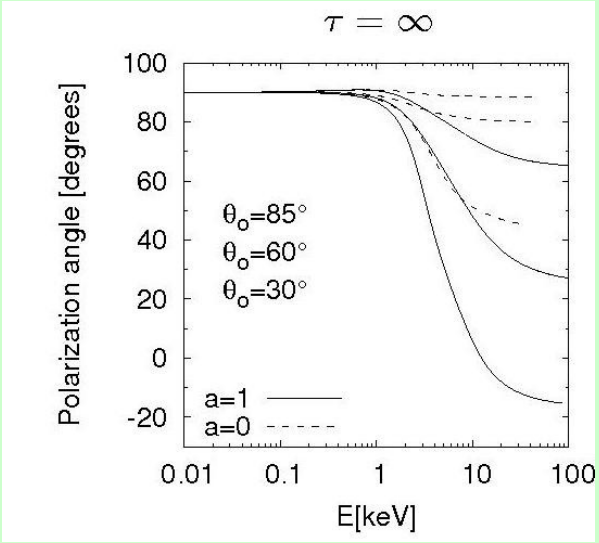


We (Dovciak et al. 2008; see also the poster upstairs) revisited and refined these calculations (see also Li et al. 2008).



Strongly dependent on the spin of the BH !!

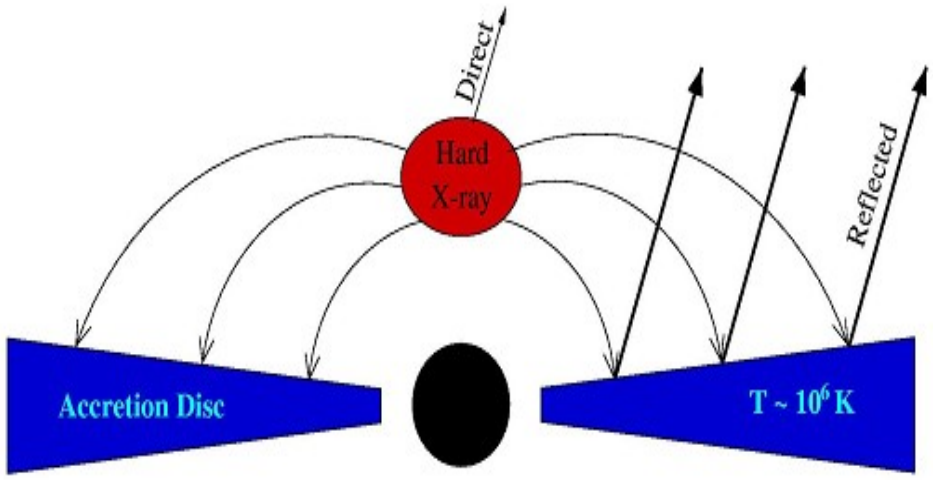




Detectability of the effect with IXO (actually XEUS, proposal to CV…)

Active Galactic Nuclei (radio-quiet)

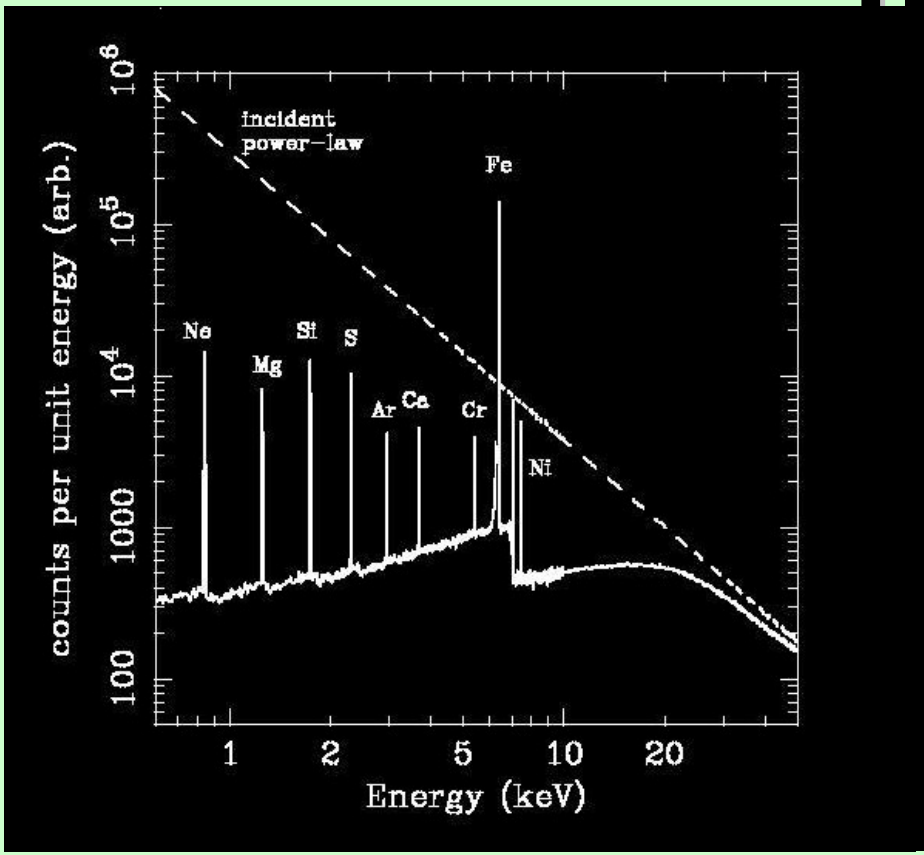
In Active Galactic Nuclei the primary X-ray emission is due to Inverse Compton by electrons in a hot Corona of the UV/Soft X-ray disc photons. It is likely to be significantly polarized (e.g. Haardt & Matt 1993,

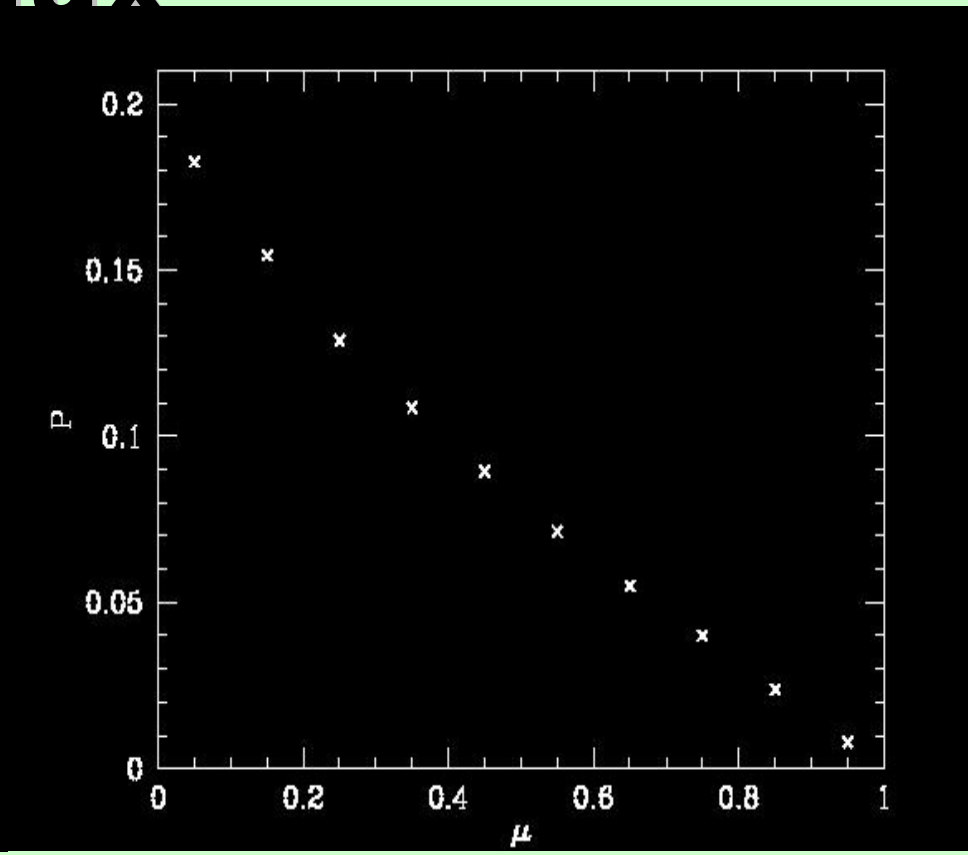


to have a

Part of the primary emission illuminates the disc and is reflected (and polarized) via Compton

Polarization of reflected flux

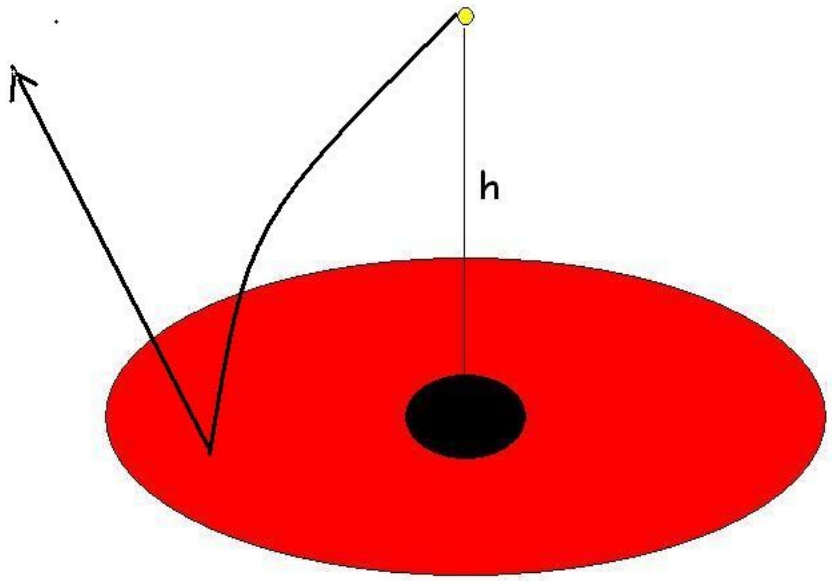


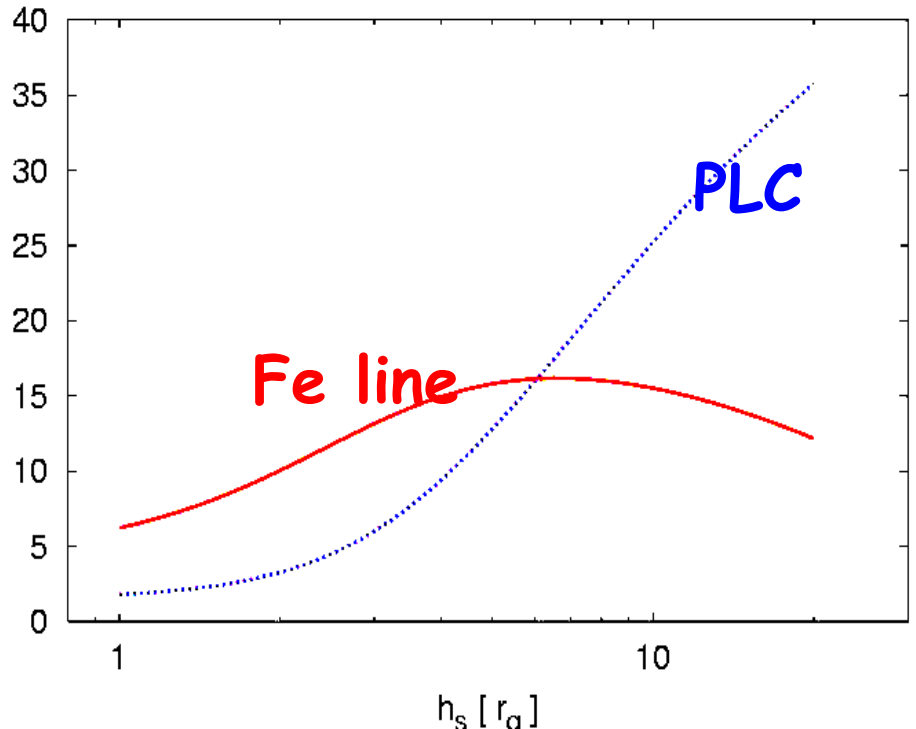


Polarization of reflected (continuum) radiation is large. For instance, it is up to 20% (Matt et al. 1989) assuming isotropic illumination, a plane-parallel reflecting slab and unpolarized illuminating radiation.

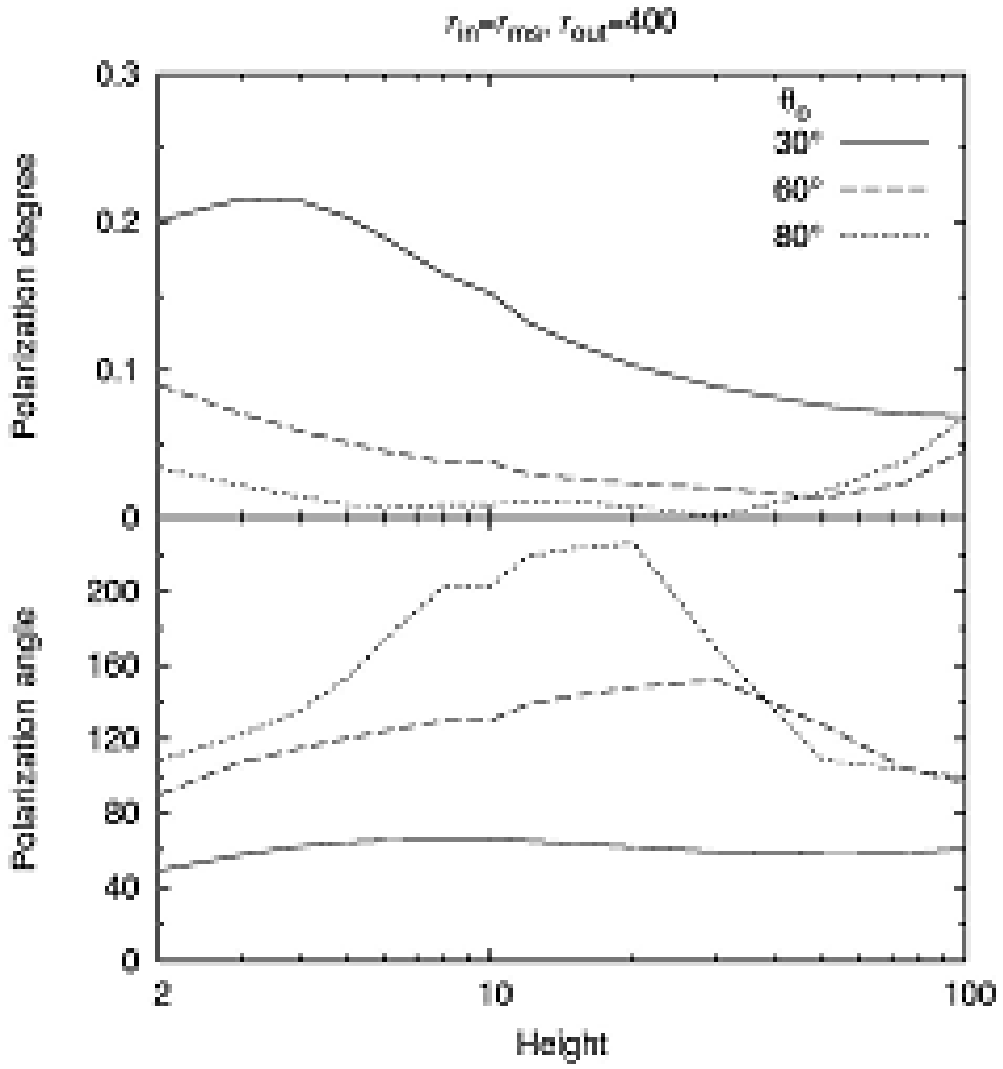
GR effects: MCG-6-30-15

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), where the line flux varies much less than the primary power law flux. This situation is what expected in the aborted jet model for the corona





Polarization of reflected radiation

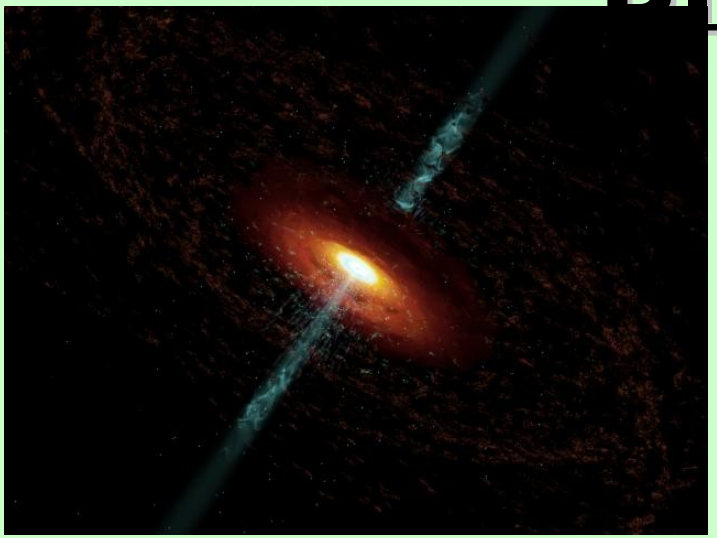


ovciak, Karas & Matt 2004)

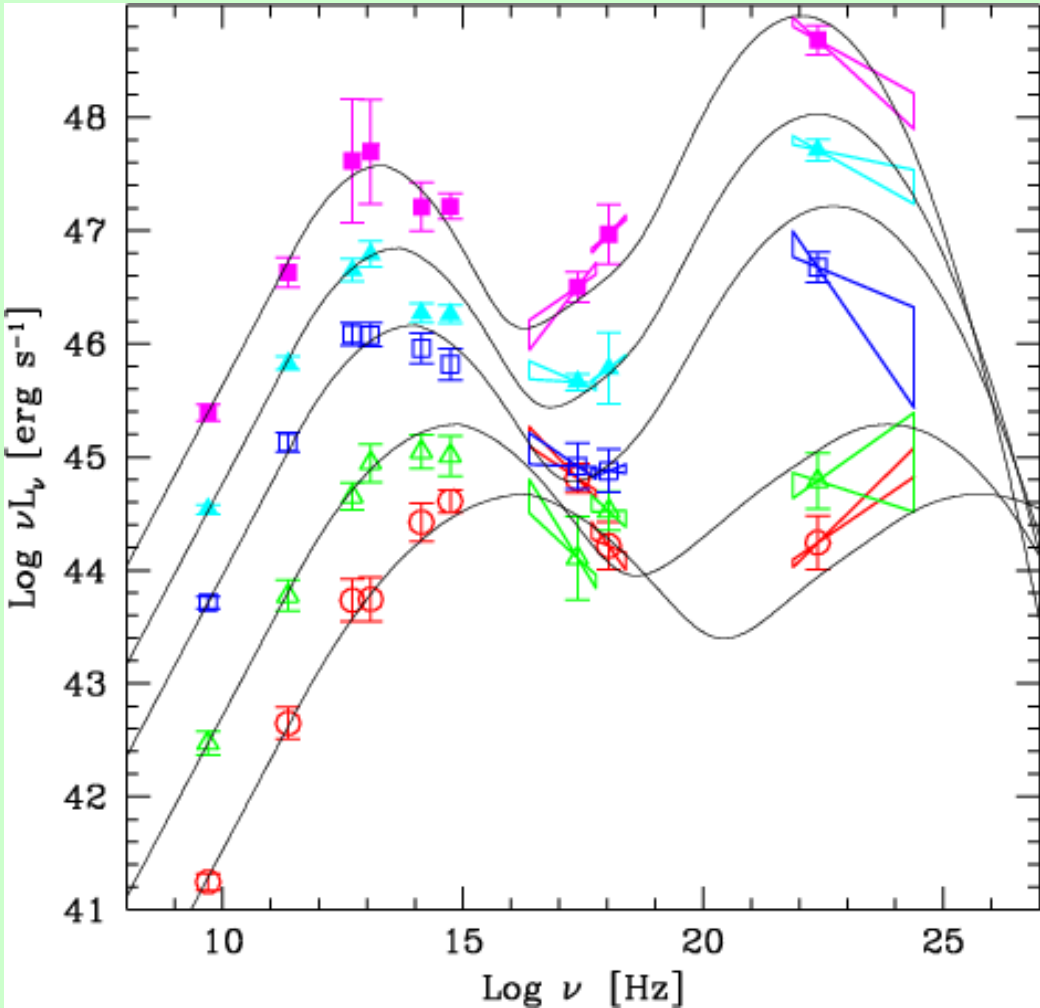
The polarization degree and angle depend on both *h* and the incl. angle (the latter may be estimated from the line profile; for MCG-6-30-15 is about 30 degrees, Tanaka et al. 1995)

Variation of h with time implies a time variation of the

The emission mechanism of Blazars



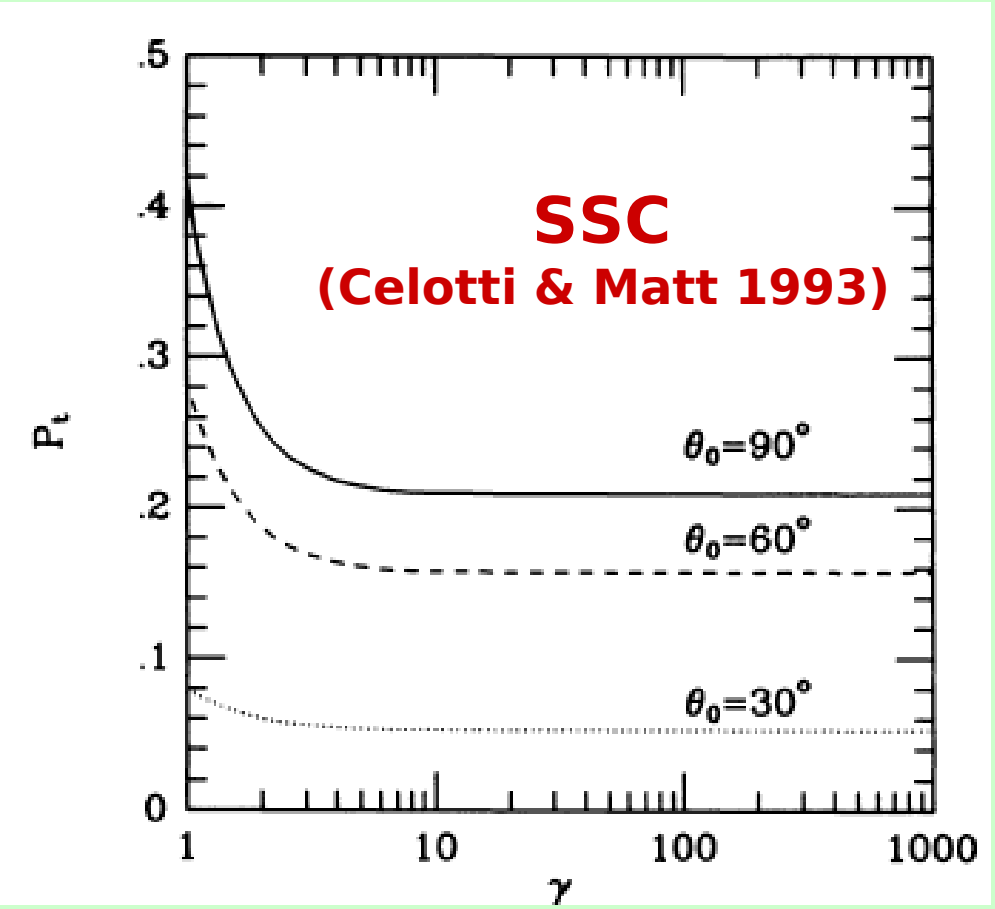
Donato et al. (2001)



X-ray emission in Blazars is due to either synchrotron or Inverse Compton radiation.

In both cases it is expected to be highly

The emission mechanism of Blazars

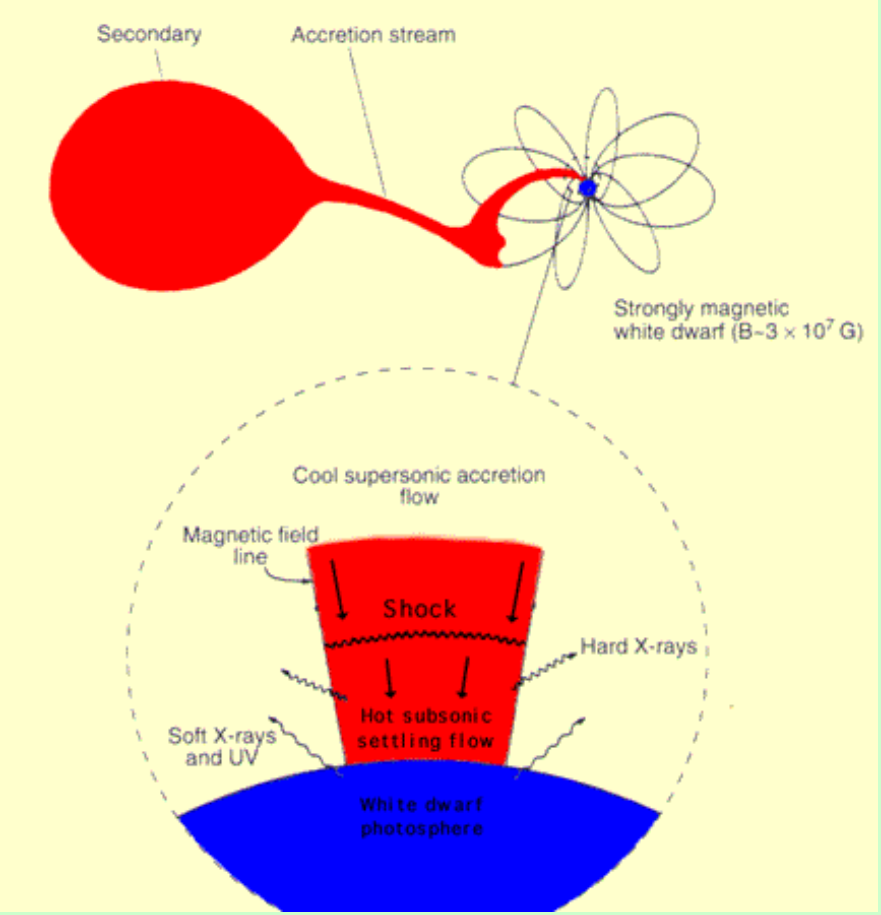


If due to IC, the radiation field may be either the synchrotron emission (SSC) or the thermal emission from the accretion disc (external IC).

The polarization properties are different in the two cases: e.g. while in the SSC the pol. angle of IC and S are the same, in the external IC the two are no

Strong magnetic fields: Polars

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



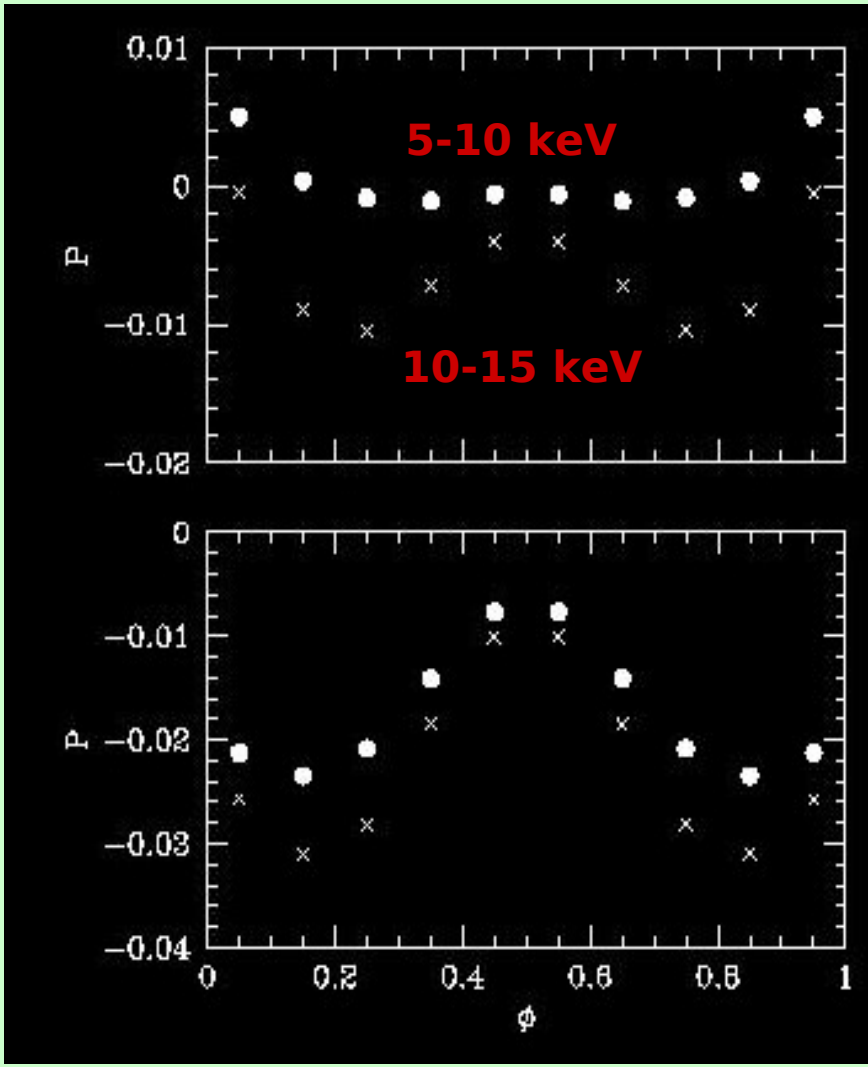
Half of the hard X-rays illuminate the WD

Example: AM Herculis

The emission from the accretion column itself may be polarized. In fact, the Thomson depth may be not negligible (τ_{Th}=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 τ_{Th} (Matt 2004; see also McNamara et al. 2008), which in turn depends on the accretion rate.

Using the geometrical parameters of AM Herculis (Cropper 1988), the expected degree of polarization as a function of the orbital phase can

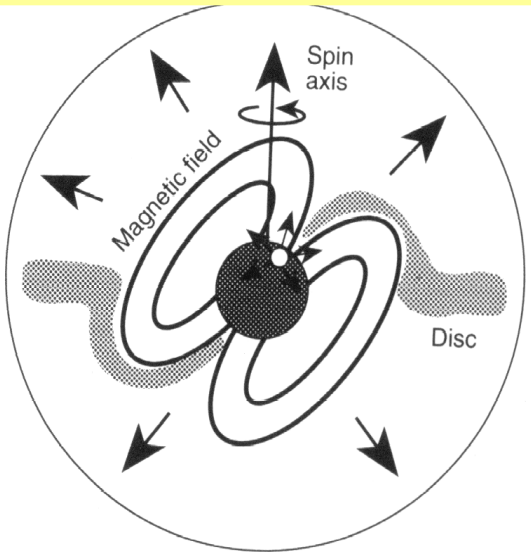


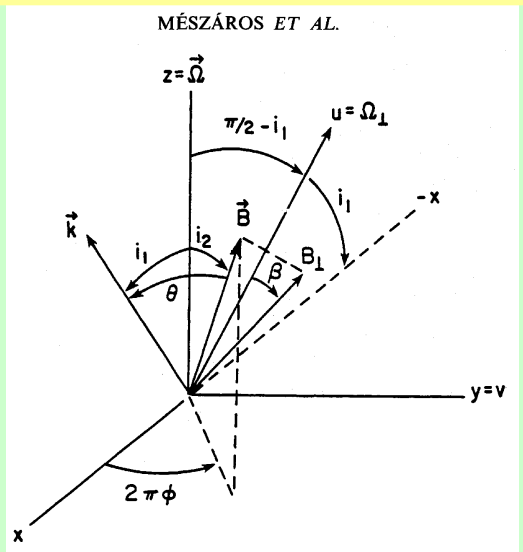
Very Strong Magnetic Fields: X-ray Pulsars

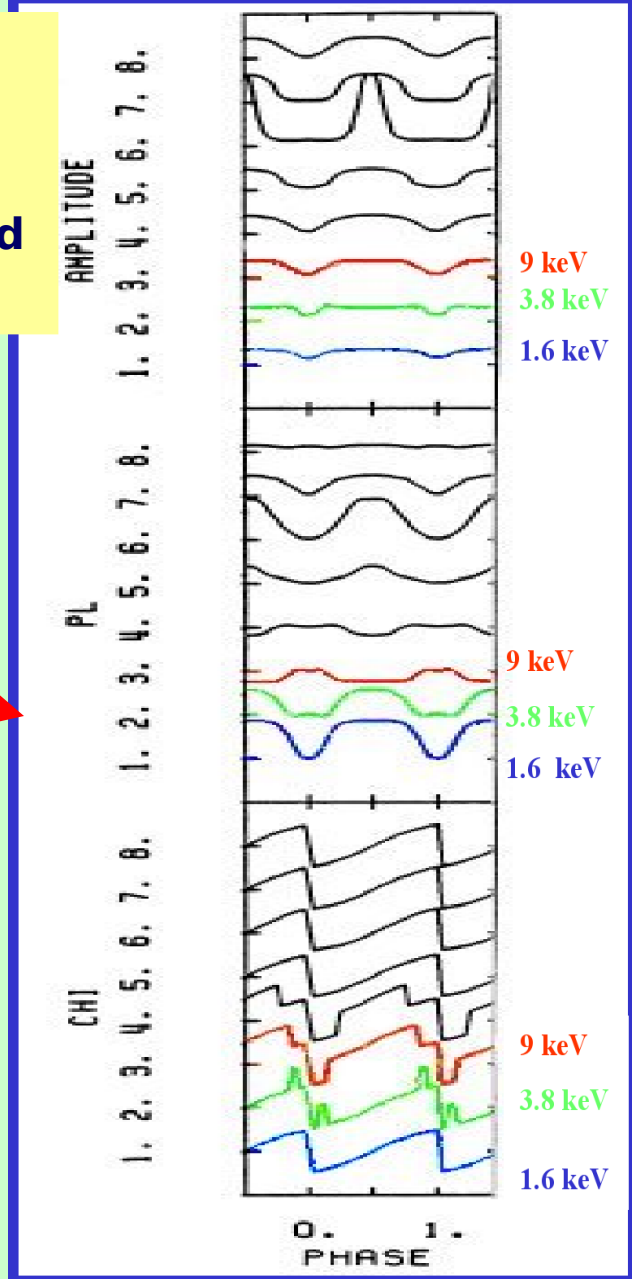
Polarized by:

- **Emission process: cyclotron**
- **Scattering on highly magnetized plasma: $\sigma_{\parallel} \neq \sigma_{\perp}$**

Polarization is modulated and the swing of the polarization angle with phase directly measures the orientation of the rotation axis on the sky and the inclination of the magnetic field: in the figure the 45° case is illustrated (from Meszaros et al. 1988)

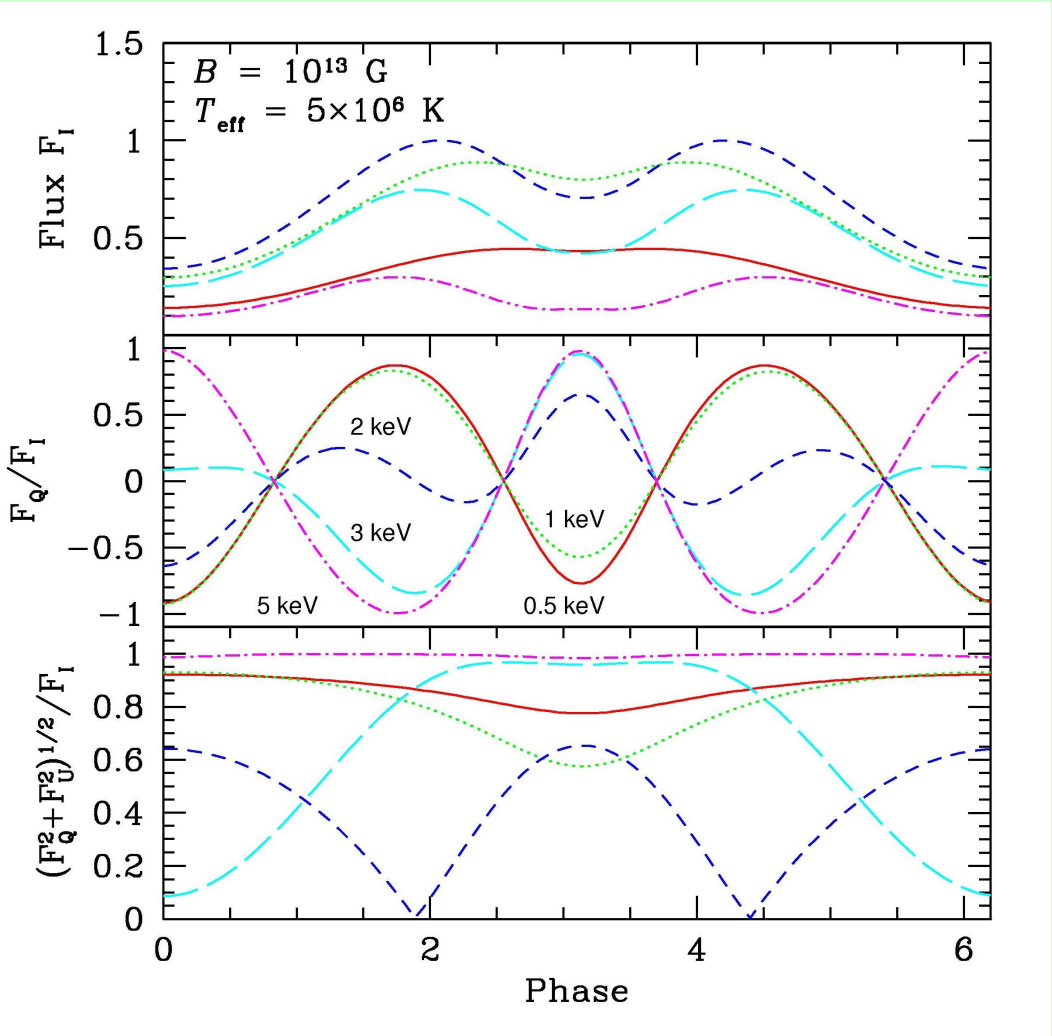






Extreme Magnetic Fields: magnetars

ee also poster by Zane et al.

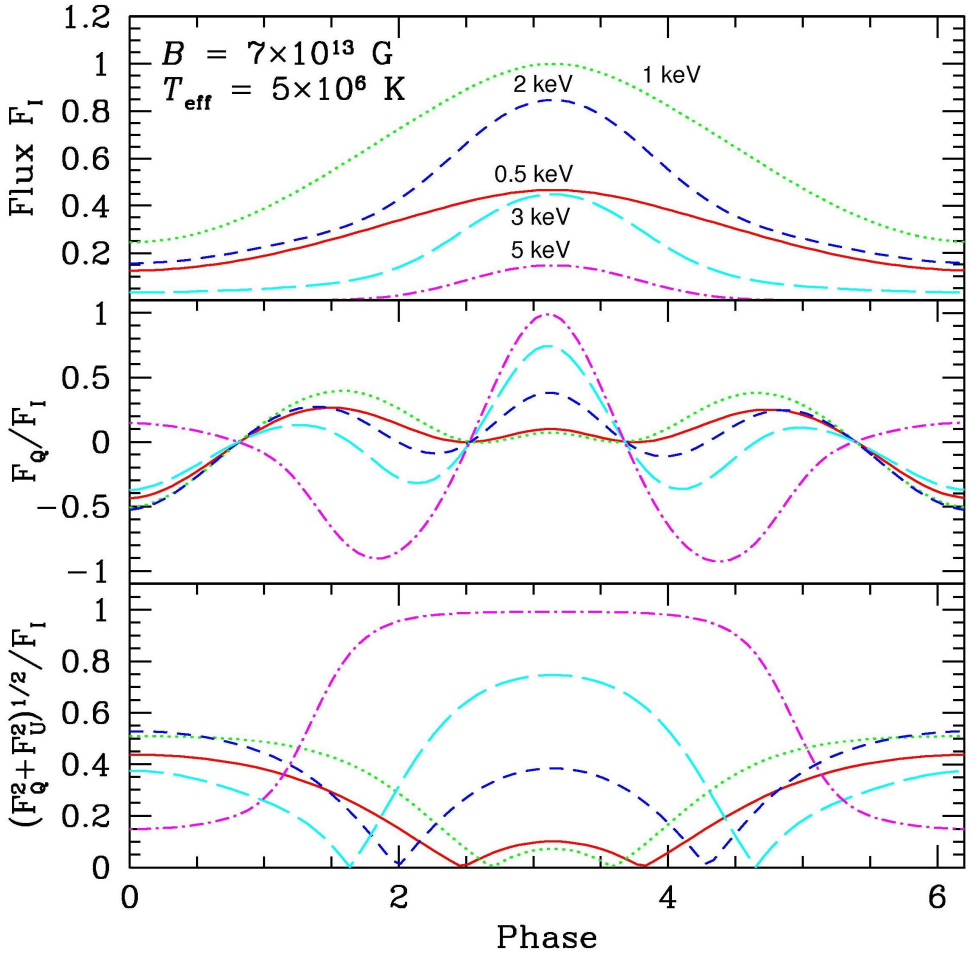


van Adelsberg & Lai 2006

Soft Gamma Repeaters and Anomalous X-ray Pulsars are interpreted in the frame of the Magnetar Theory (Thompson & Duncan 1993): neutron stars with extreme magnetic fields.

For B ≥ 7x10¹³ G strong-field QED (vacuum polarization) becomes important, significantly changing the dependence on the phase *and the energy* of the polarization, providing a measurement of B, a test of the magnetar paradigm and a

Extreme Magnetic Fields: magnetars



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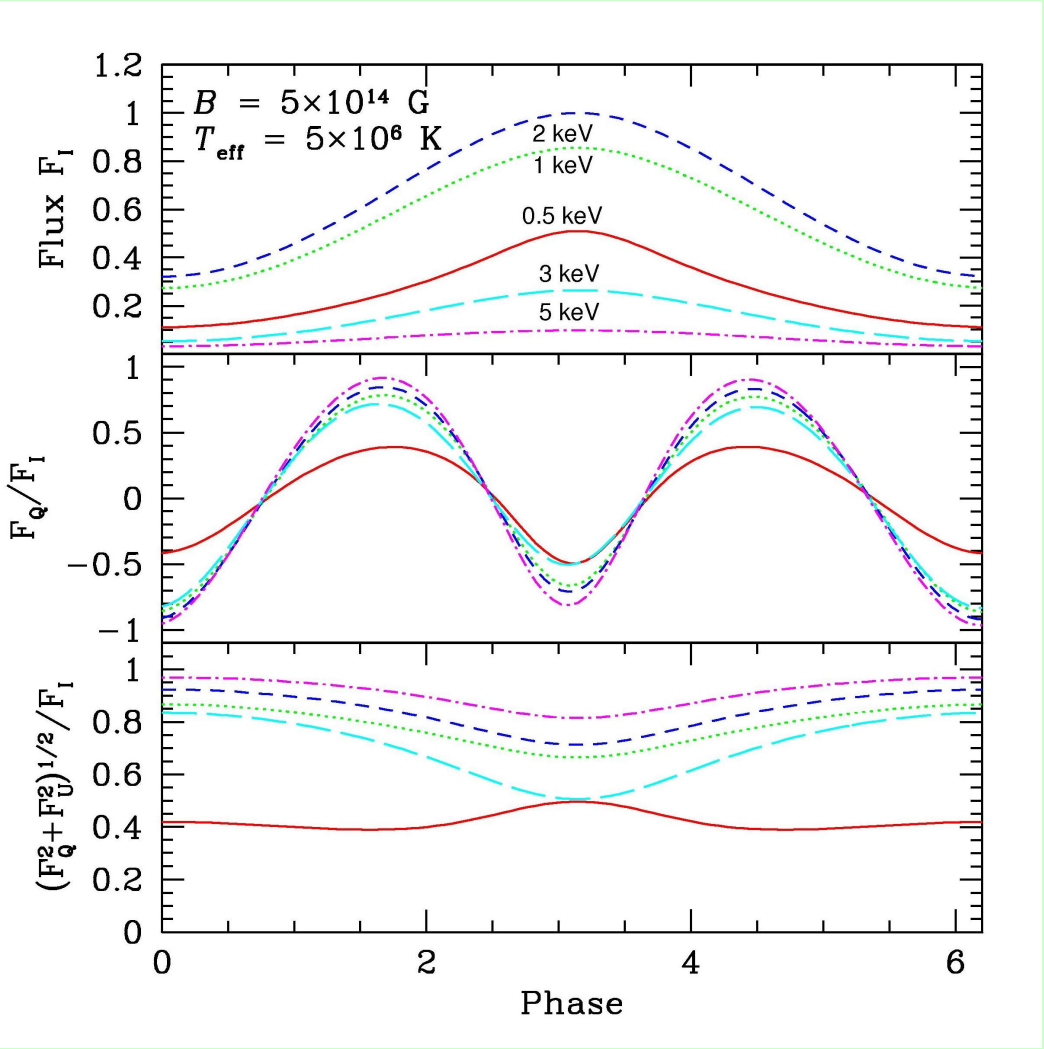

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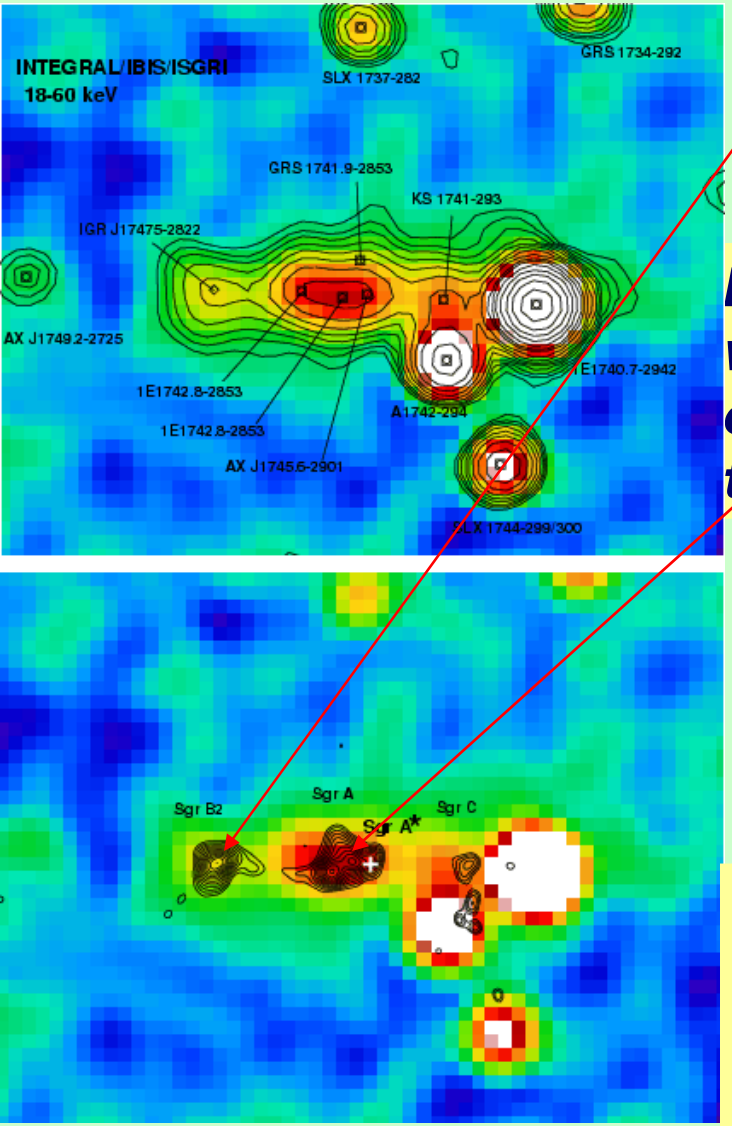
The strange case of Sgr B2

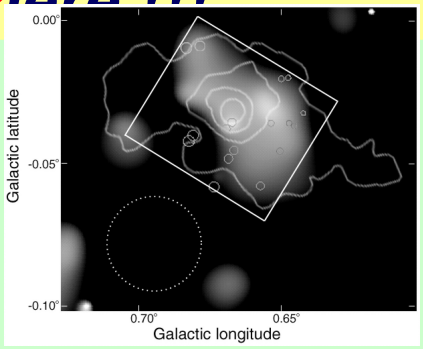


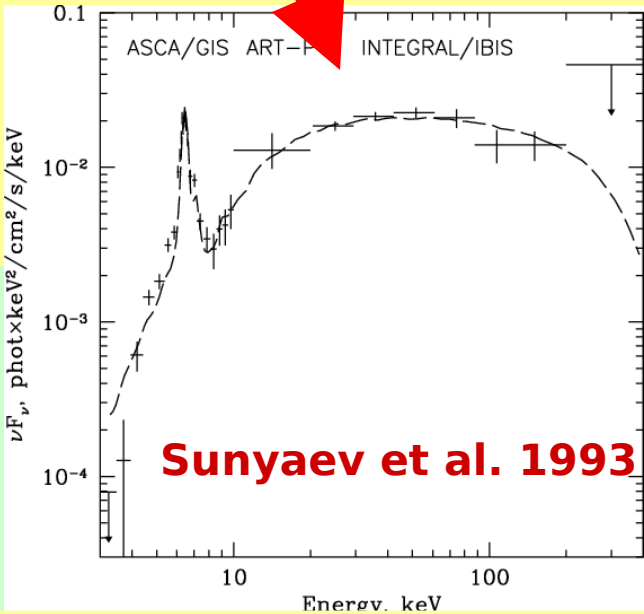
INTEGRAL Image of GC (Revnivtsev 2004)

SgrB2 is a giant molecular cloud at ~100pc projected distance from the Black

The spectrum of SgrB2 is a pure reflection spectrum

Reflection of what? No bright enough source is there !!!





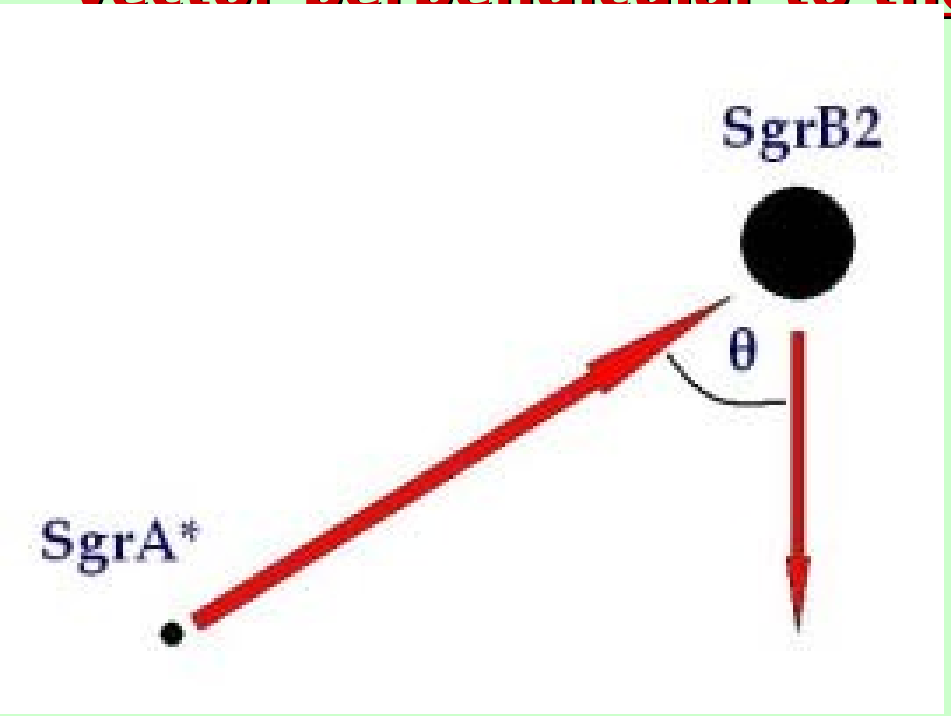
The emission from SgrB2 is extended and brighter in the direction of the BH (Murakami 2001).

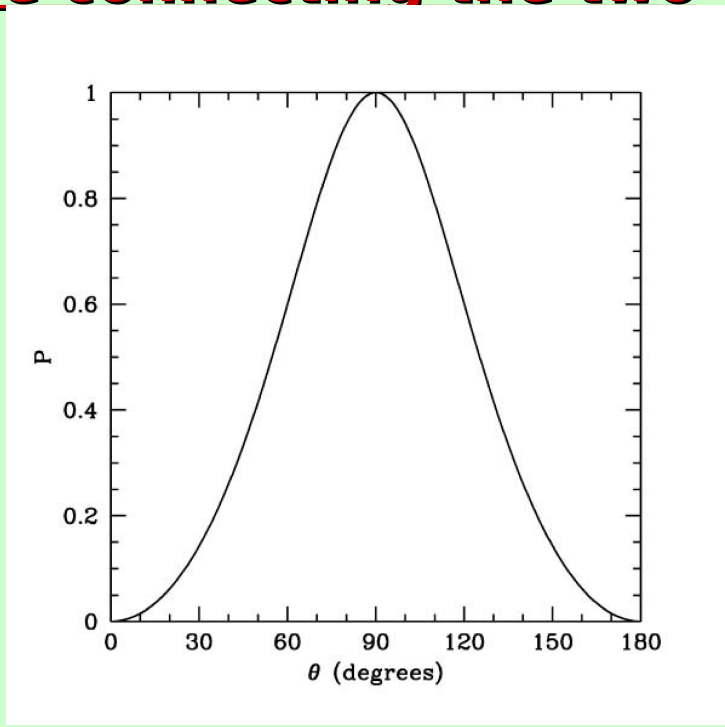
Is SgrB2 echoing past emission from the BH, which was then active in the past (e.g. Koyama et al. 1996) ???

Was the GC an AGN a few hundreds years ago?

X-ray polarimetry can definitively proof or reject this hypothesis.

SgrB2 should be highly polarized with the electric vector perpendicular to the line connecting the two





The degree of polarization would measure the angle and provide a full 3-d representation of the clouds

Summary

X-ray polarimetry can provide important, when not unique, information on several classes of astrophysical objects, as well as providing tests of fundamental physics.

IXO

will offer the best opportunity to perform X-ray polarimetry with a sensitivity high enough to provide

significant measurements on at least the

The coming of age of X-ray polarimetry

Roma, April 27th - 30th, 2009

Centro Studi Americani
Via Michelangelo Caetani 32
00186 Roma

http://projects.iasf-roma.inaf.it/xraypol/