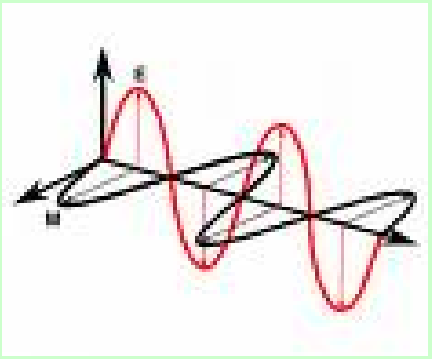


Polarimetry: a new window to the X-ray Universe

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*

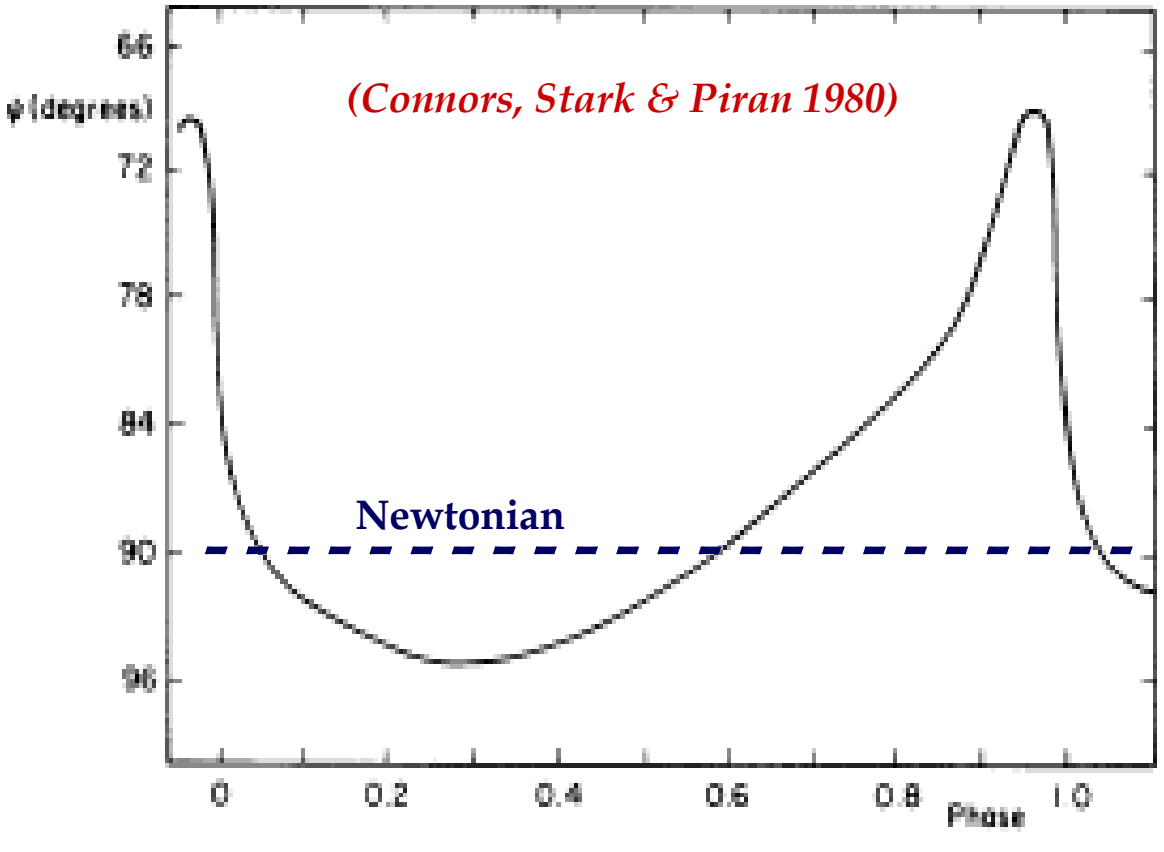
Many X-ray sources are likely to be strongly polarized

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

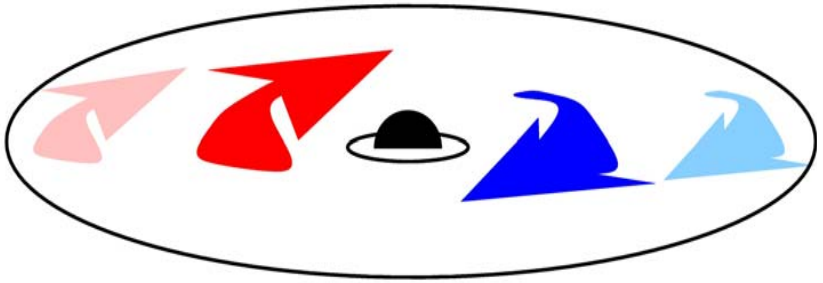
Strong gravity effects on polarization

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 inclination angles



(Connors, Stark & Piran 1980)

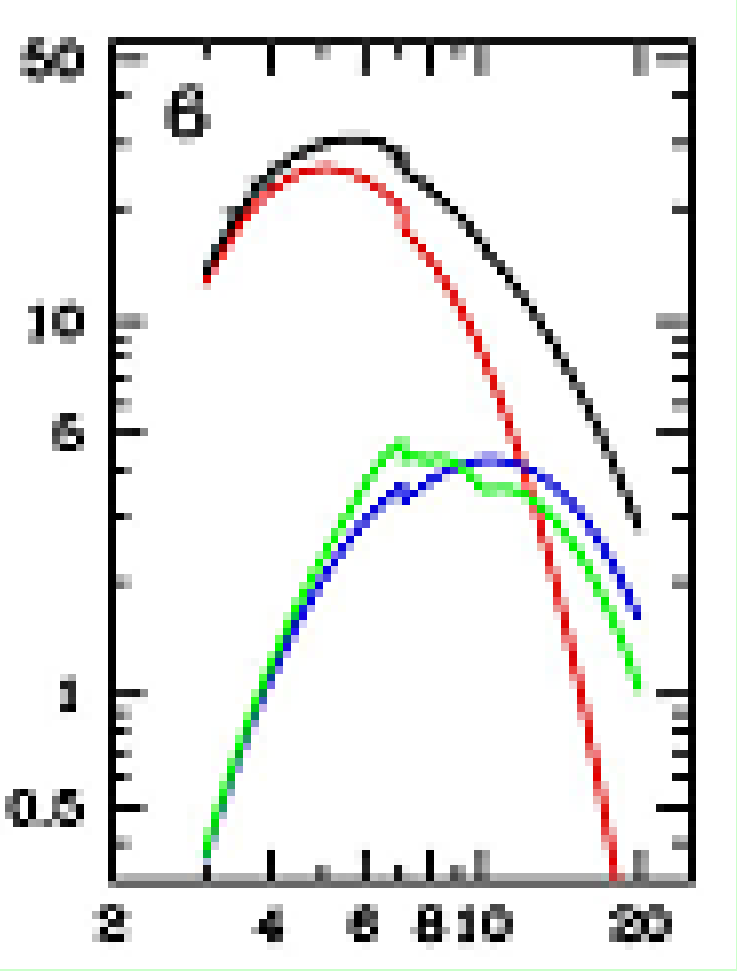


Orbiting spot with:
a=0.998; R=11.1 Rg
i=75.5 deg

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

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

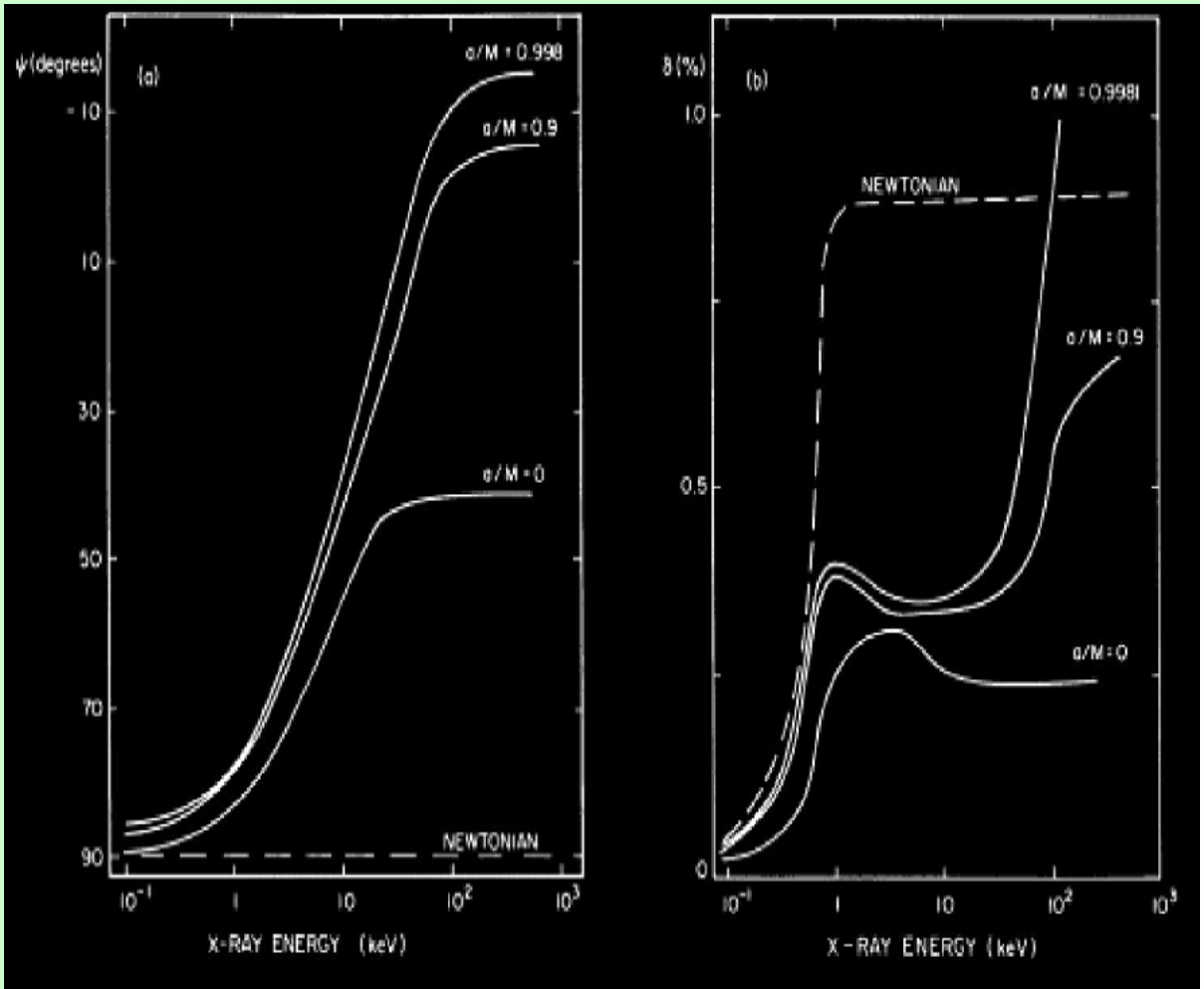
Galactic BH binaries in high state



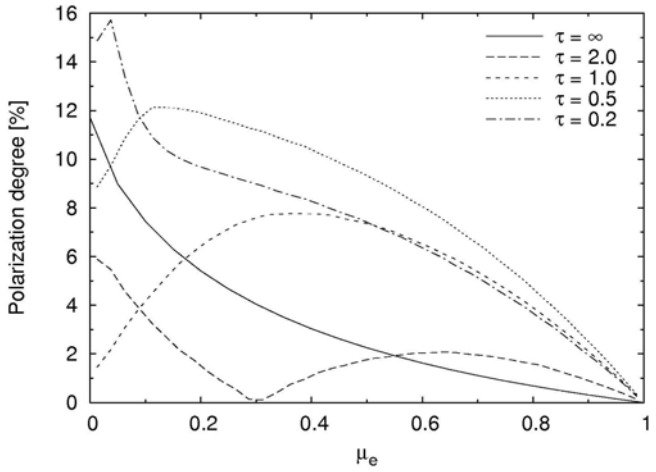
GRS 1915+105
(Done & Gierlinski 2004)

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

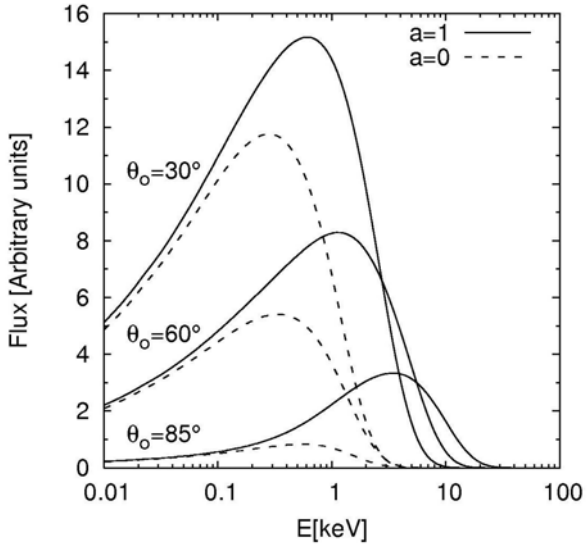
A rotation of the polarization angle with energy is therefore expected.



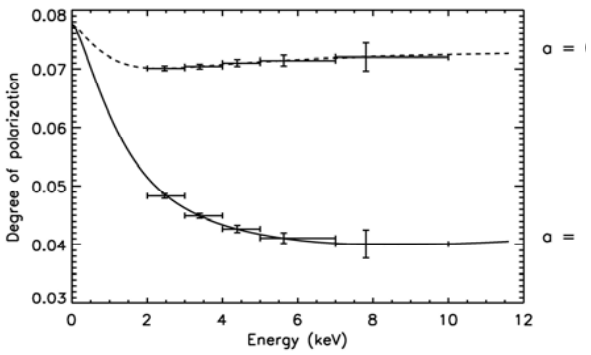
Connors & Stark (1977)

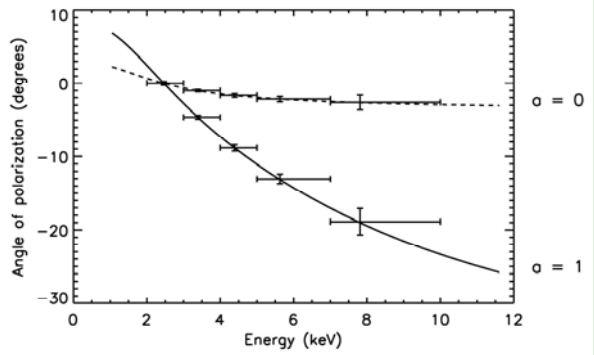


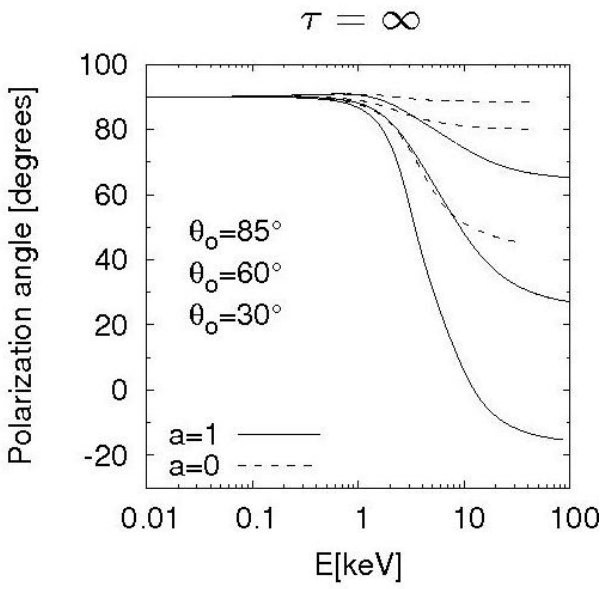
We (Dovciak et al. 2008) revisited and refined these calculations (see also Li et al. 2008, Schnittman & Krolik 2009).



Strongly dependent on the spin of the BH !!





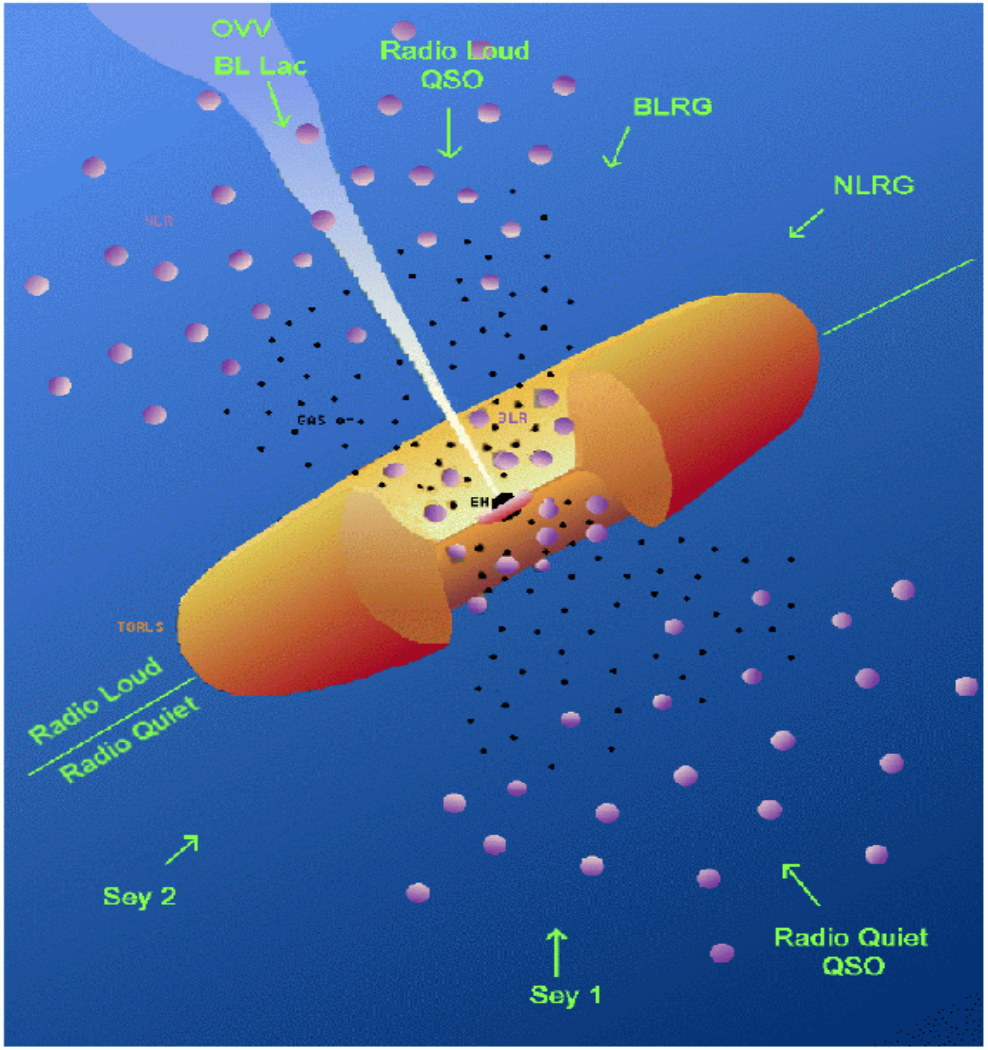


Detectability of the effect with IXO: GRS1915+105, 200ks (courtesy F. Muleri)

Active Galactic Nuclei

Active Galactic Nuclei (both radio-loud and radio-quiet) are definitely *aspherical systems*

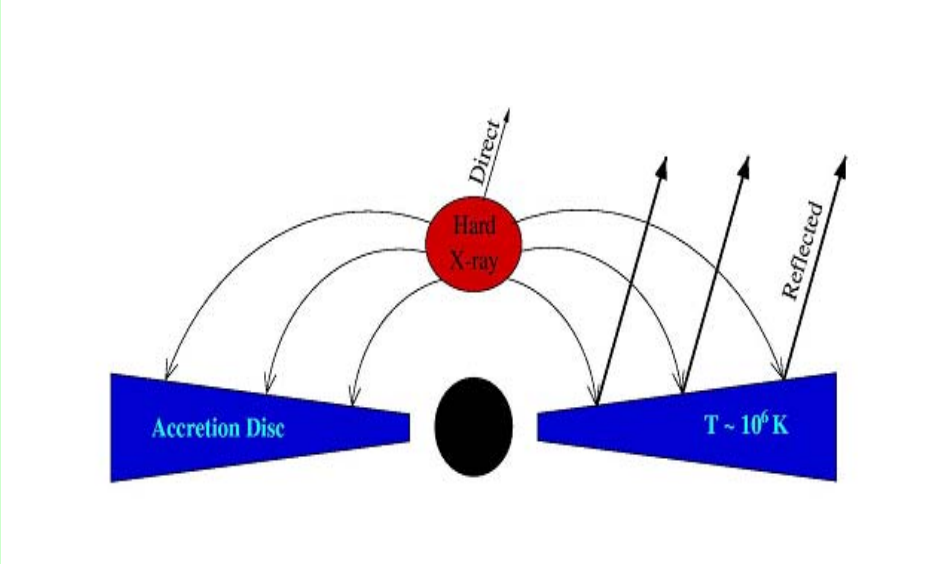
The X-ray emission (both primary and reprocessed) it is likely to be highly polarized.



Urry & Padovani (1995)

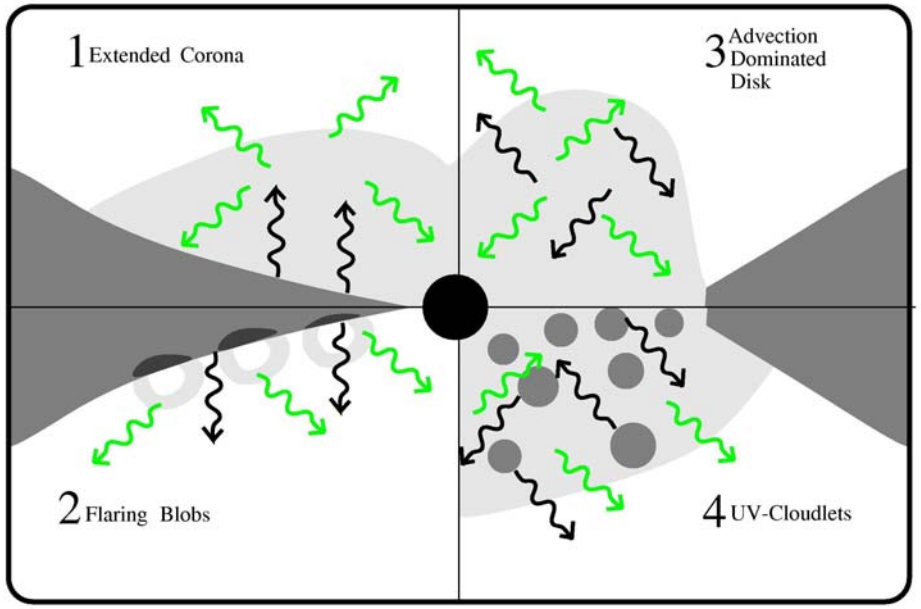
Primary emission from the hot corona

The geometry of the hot corona is unknown. Emission is expected to be polarized if the corona OR the radiation field are not spherical



Polarimetry will help understanding the geometry of the emitting region

NB: in ADAF models, no significant polarization is expected (LLAGN should be unpolarized)

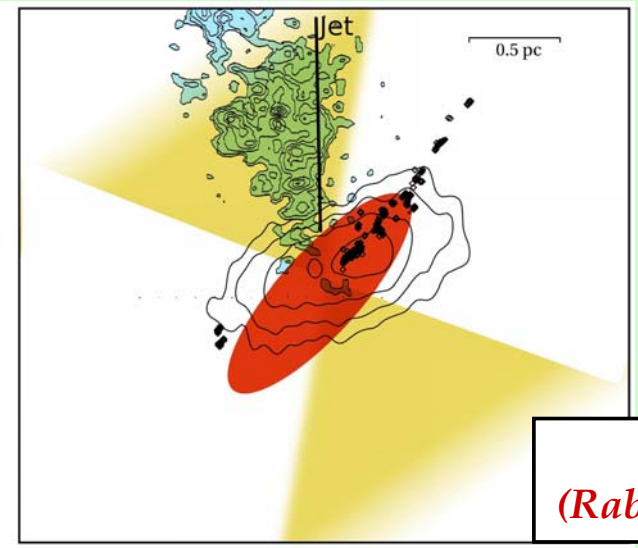


Haardt (1997)

Polarization of reflected flux

The primary X-ray emission may be reflected, and polarized, by:

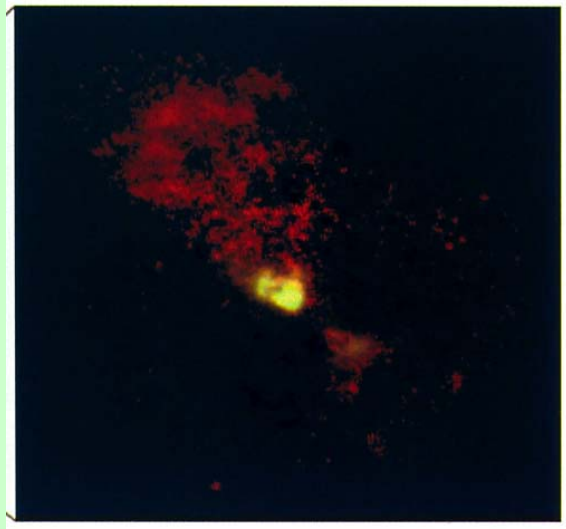
- **The accretion disc: the polarization properties are then modified by GR and SR, and *strong gravity can be probed***



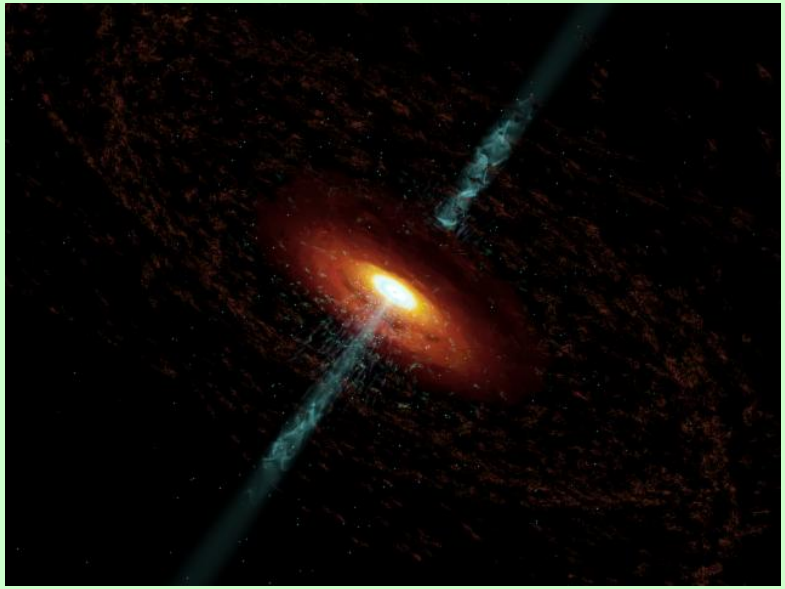
NGC 1068
(Raban et al. 2009)

- **The torus: the polarization angle will give us *the orientation of the torus*, to be compared with IR results, and with the ionization cones**

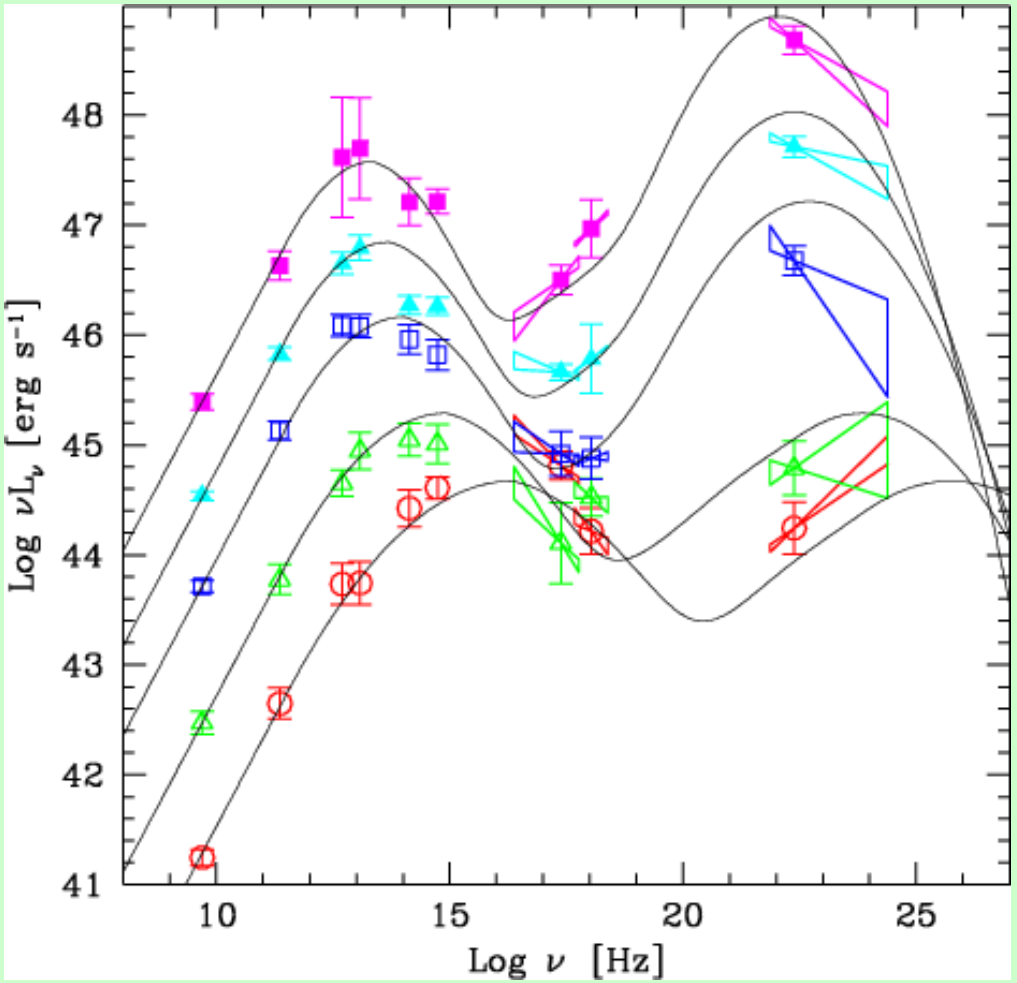
- **Ionized matter: will provide the orientation of the scattering region, to be compared with the ionization cones, and confirm *the photoionization model for the soft excess in Sey2***



The emission mechanism of Blazars



Donato et al. (2001)

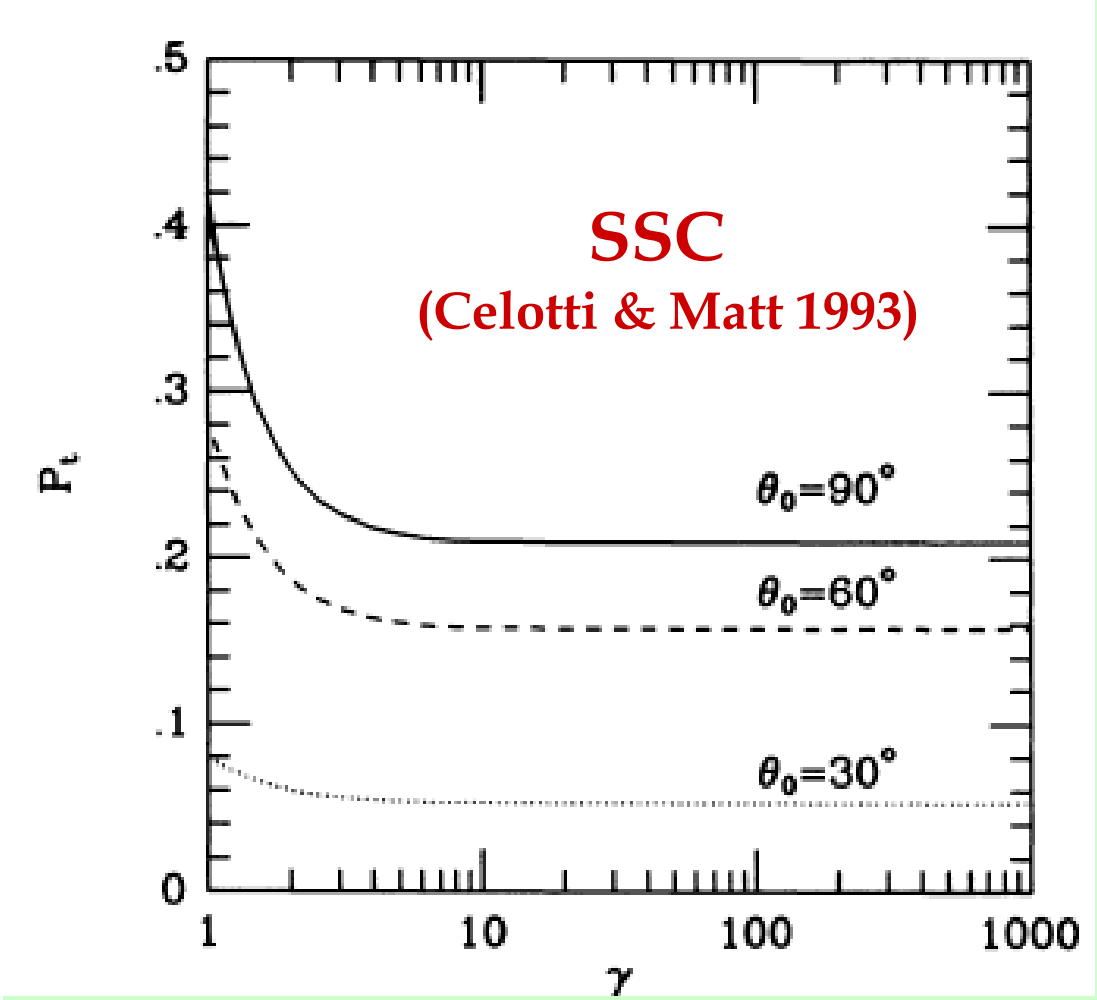


X-ray emission in Blazars is due to either synchrotron or Inverse Compton radiation.

In both cases it is expected to be highly polarized.

If due to synchrotron, multi-v polarimetric observations will tell us about the site of origin in the jet of the different spectral components

The emission mechanism of Blazars

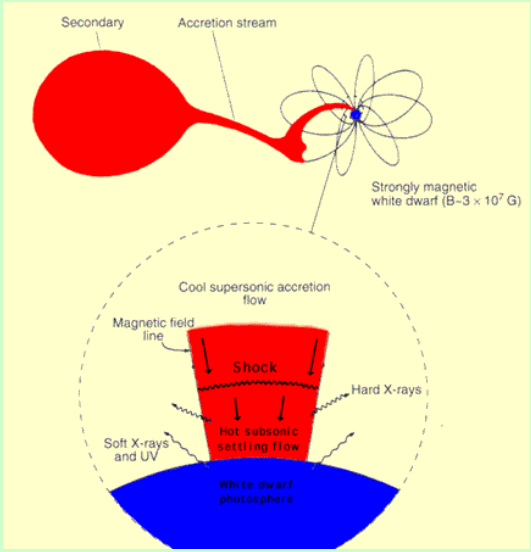


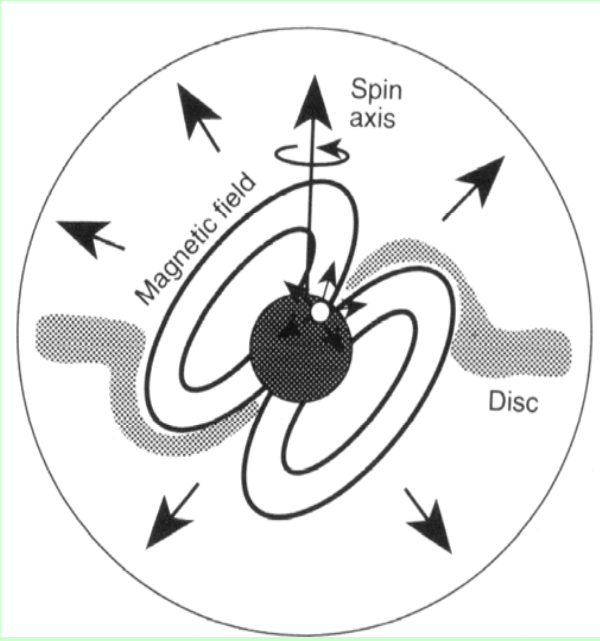
If due to IC, the radiation field may be either the synchrotron emission (SSC) or the thermal emission from the accretion disc (external IC).

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 longer directly related.

Strong magnetic fields

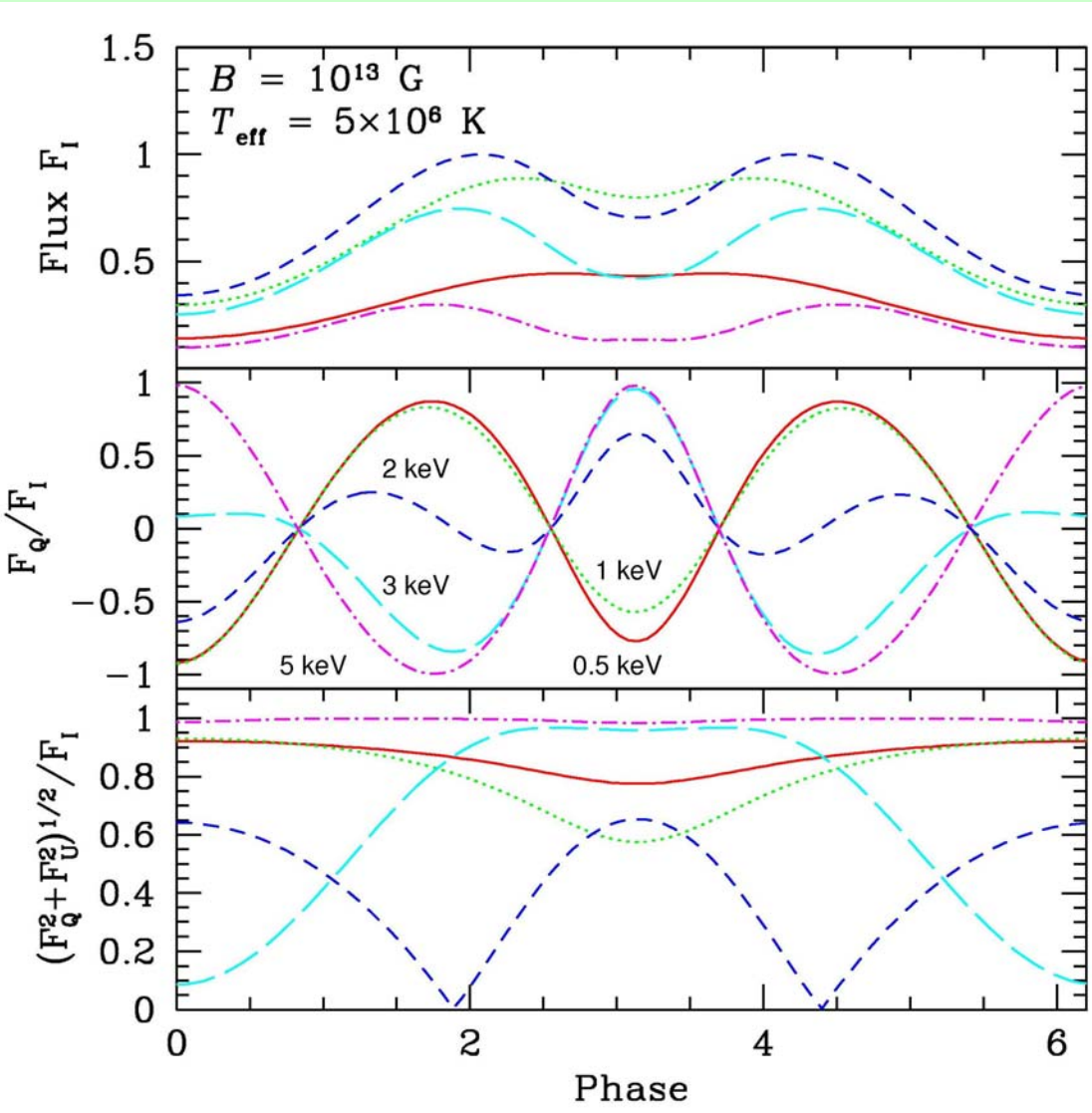
Accretion in Magnetic CVs (Polars) occurs via an accretion column; X-rays are produced by opt. thin thermal plasma emission in the post-shock region. The column may be moderately thick to Compton scattering, and the emission polarized (Matt 2004, McNamara et al. 2008). Reflection from the WE surface is also polarized





In X-ray pulsars, the phase–dependent polarization properties give the geometry of the system and may distinguish between fan and pencil beams models (Meszaros et al. 1988)

Extreme Magnetic Fields: magnetars



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 $B \geq 7\times10^{13}$ 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 probe of strong-field QED

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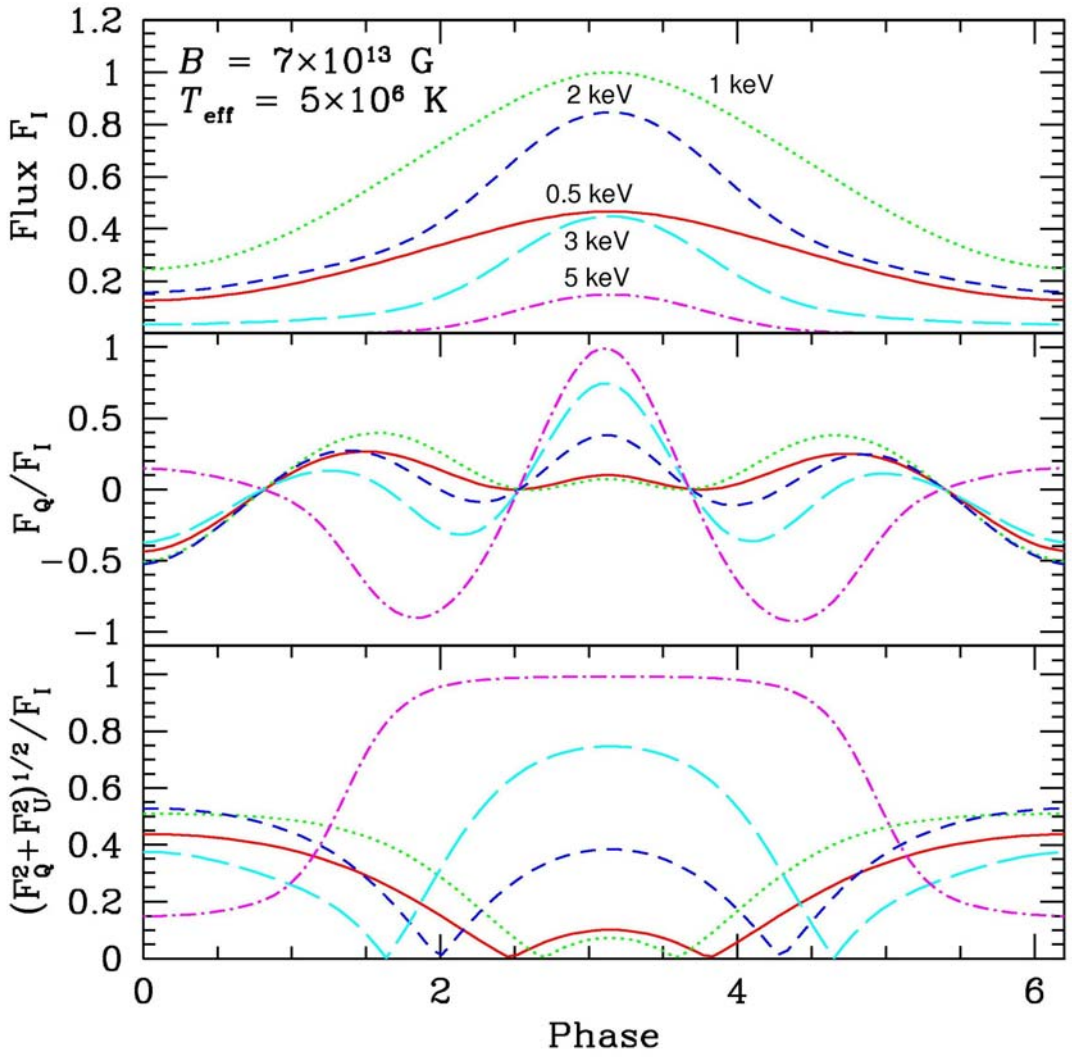

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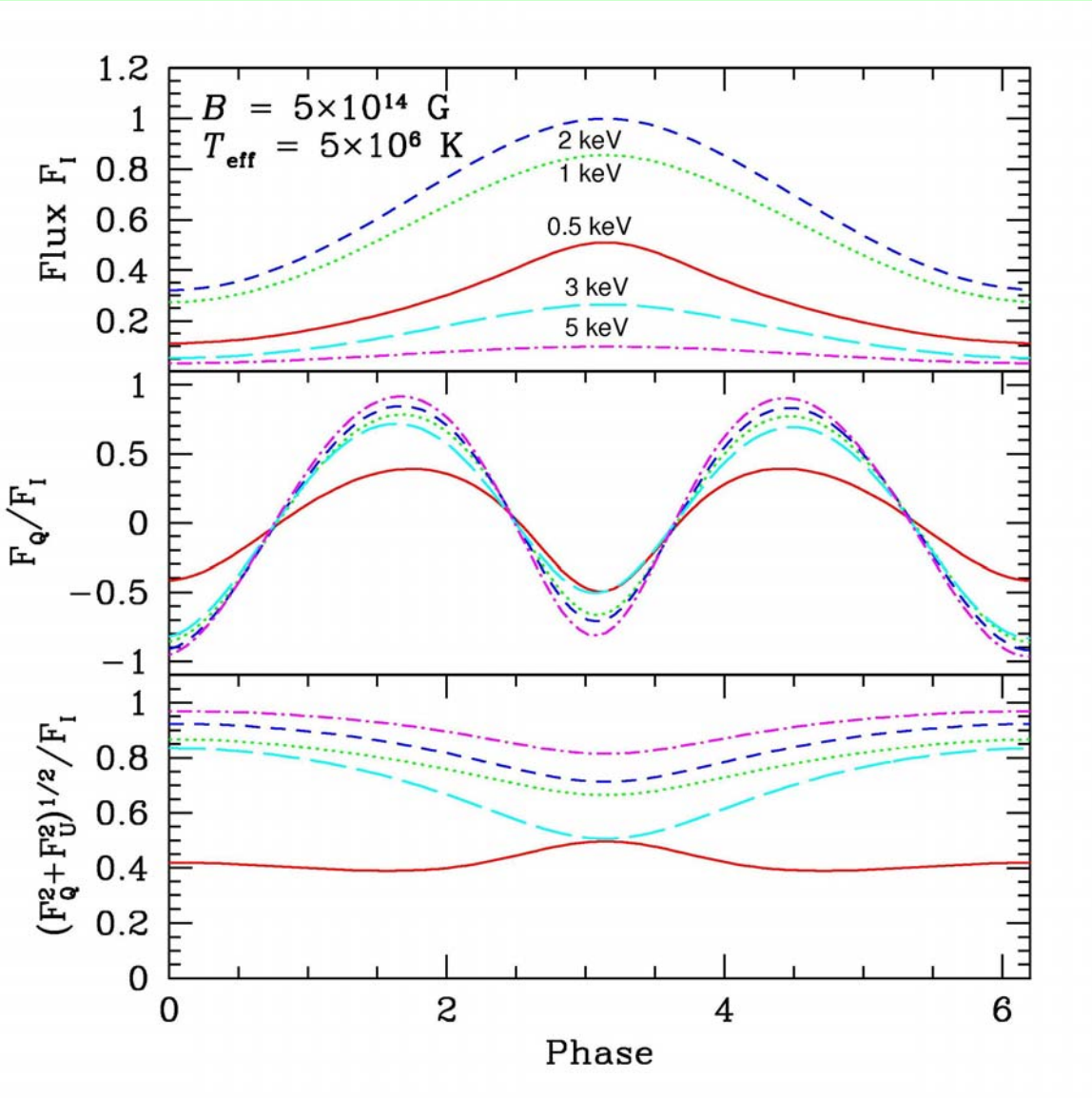

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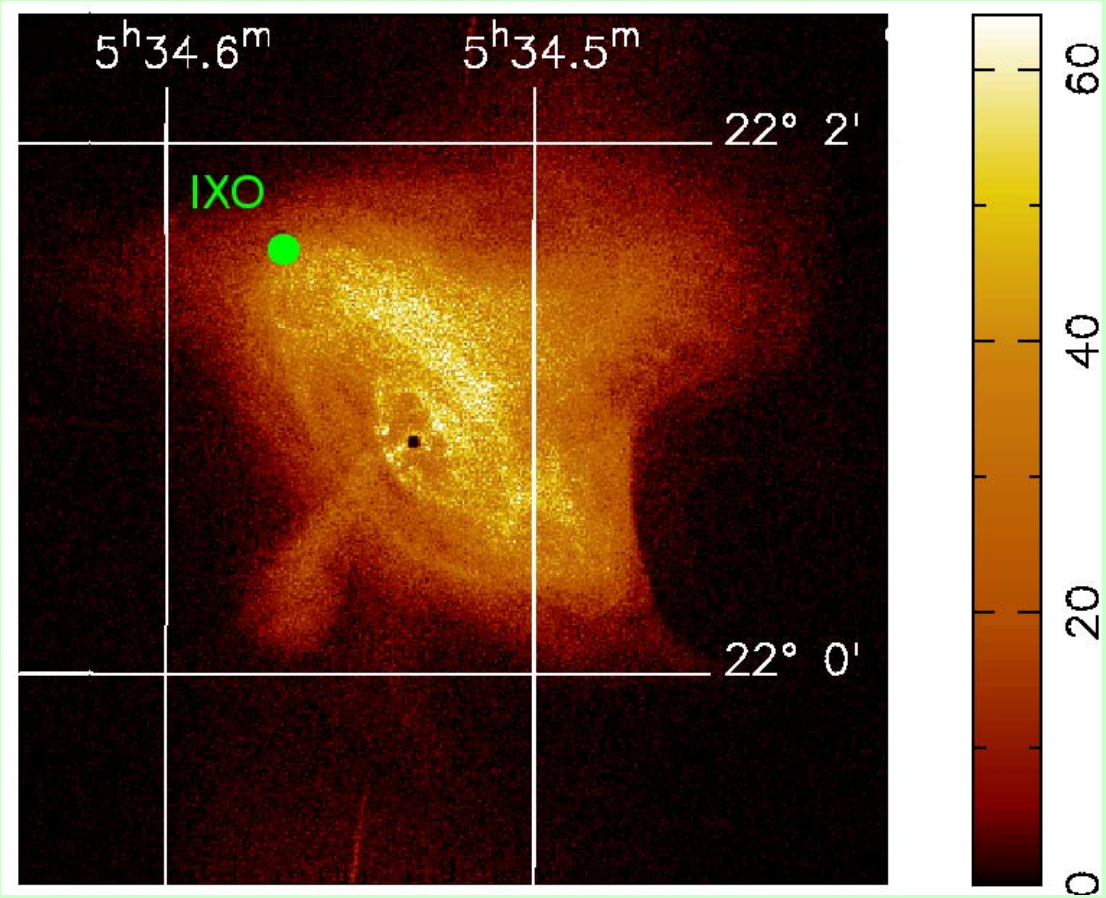
PWN: the Crab

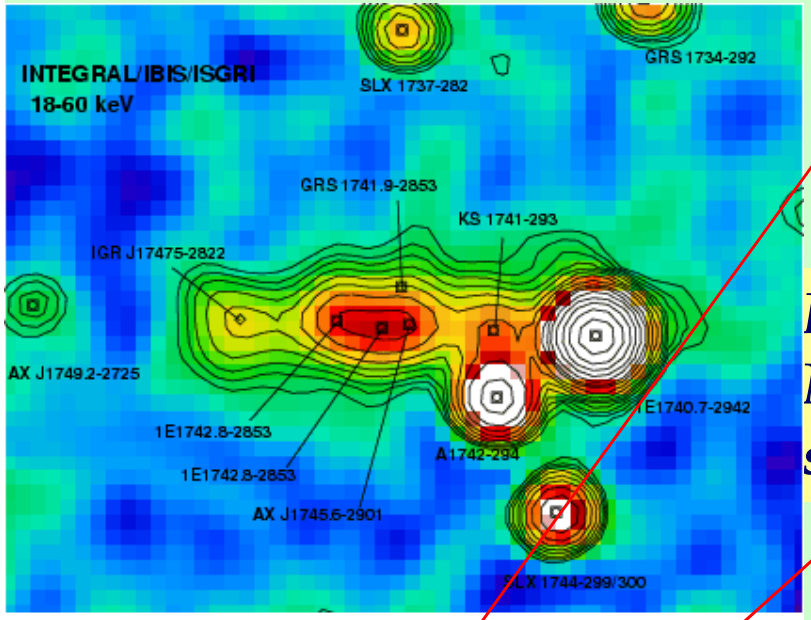


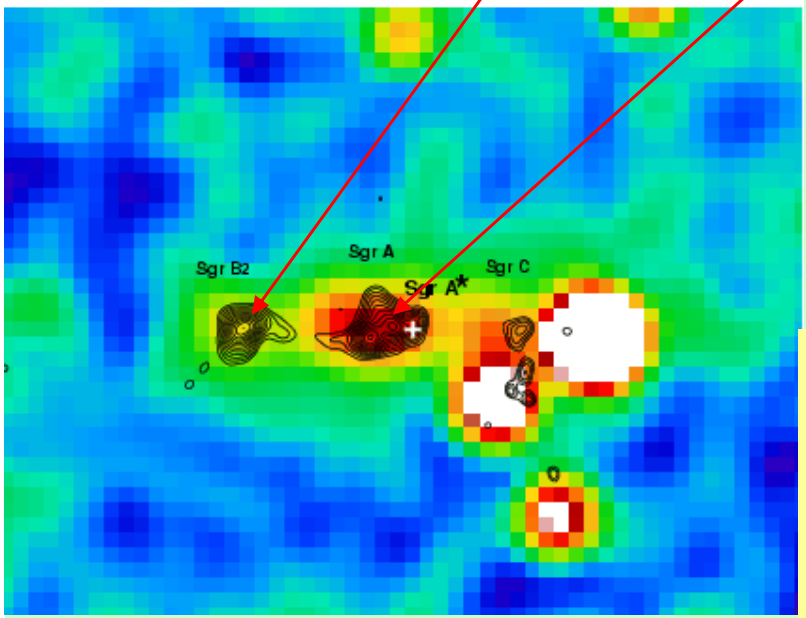
From Weisskopf et al. (2000)

The Crab Nebula is the only source in which the polarization degree has been measured so far (Weisskopf et al. 1978), P=19%.

The nebula is highly structured, as shown by Chandra observations, with a jet and a torus. Imaging polarimetry would be extremely important to map the magnetic field, to understand the acceleration and emission mechanisms in the Nebula.

The strange case of Sgr B2



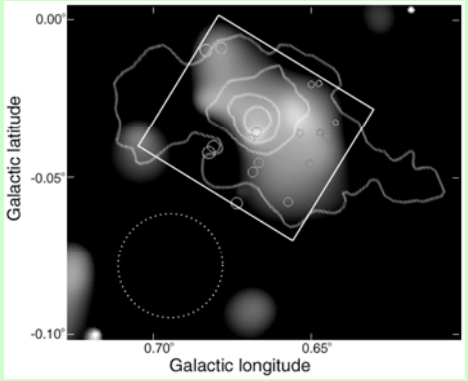


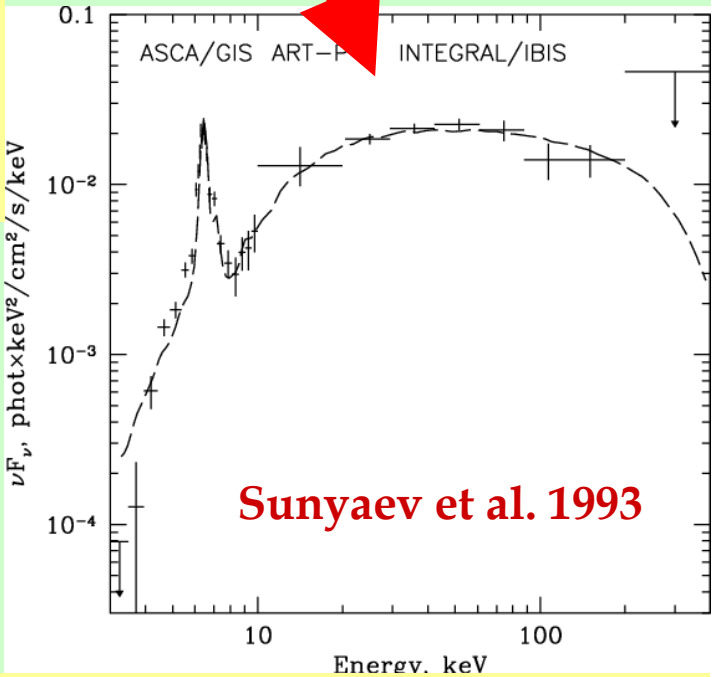
INTEGRAL Image of GC (Revnivtsev 2004)

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

The spectrum of SgrB2 is a pure reflection spectrum

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





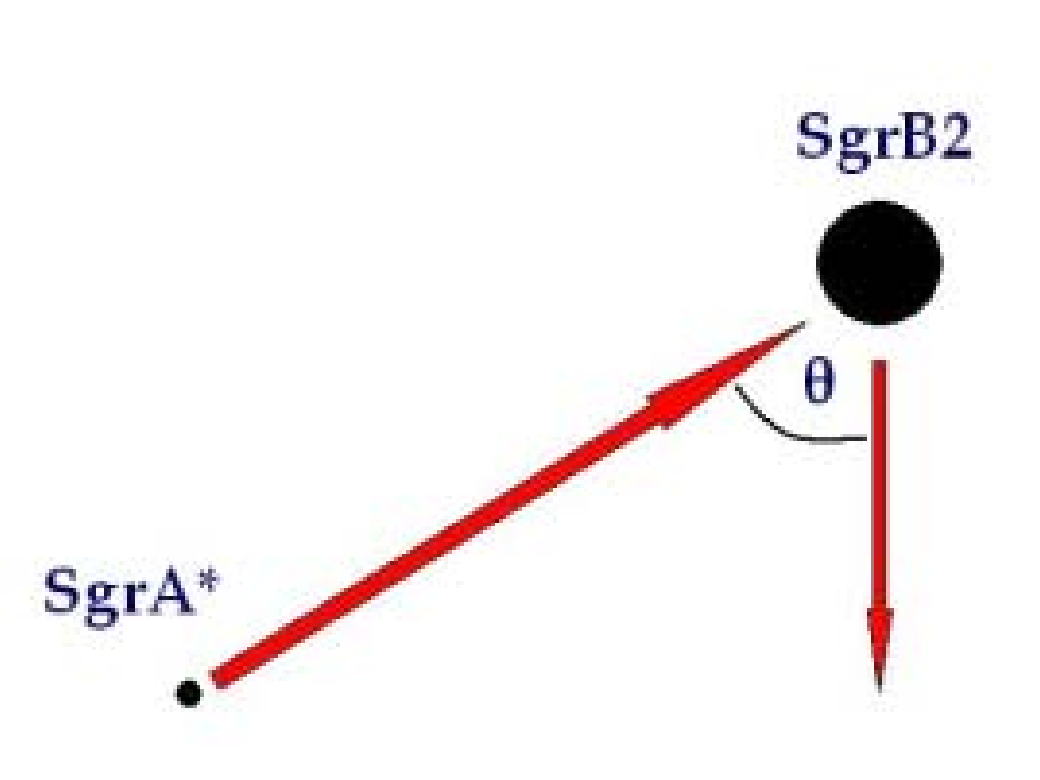
The emission from SgrB2 is extended and brighter in the direction of the BH (Murakami 2001).

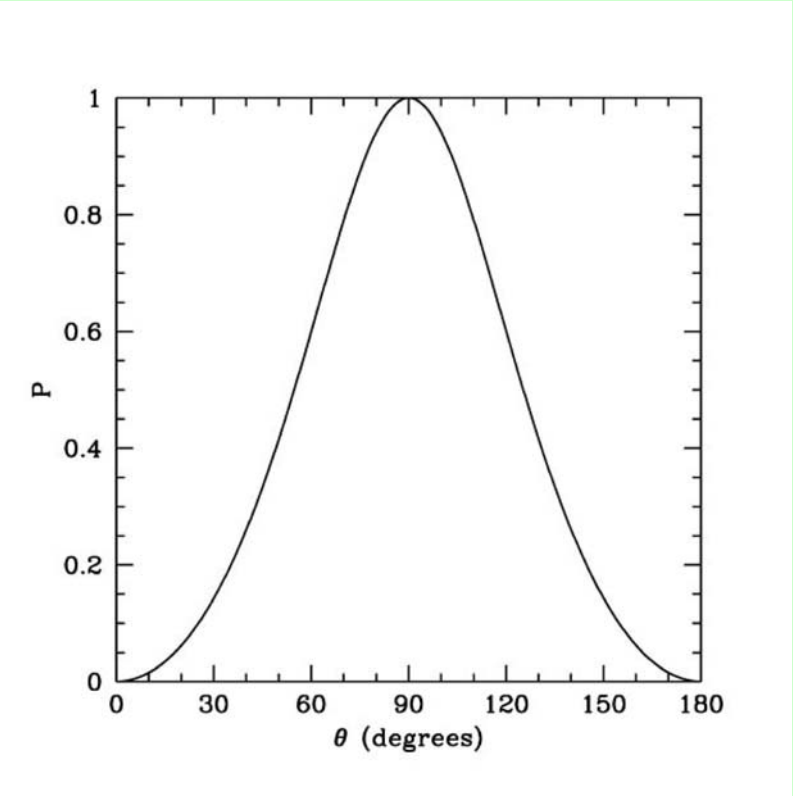
Is SgrB2 echoing past emission from the BH, which was then active in the past (e.g. Koyama et al. 1996) ???

Was the GC an AGN a few hundreds years ago?

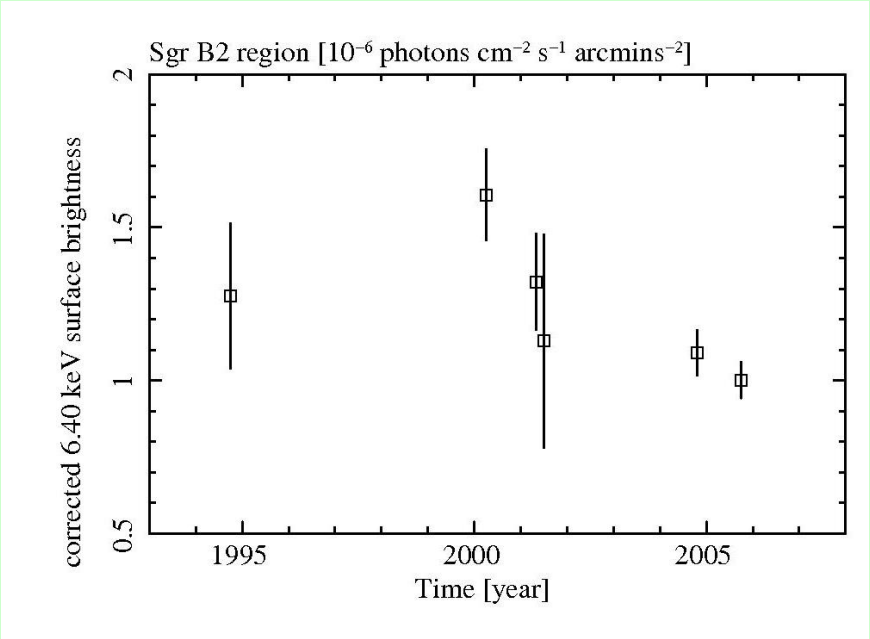
X-ray polarimetry can definitively proof or reject this hypothesis.

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





The degree of polarization would measure the angle and provide a full 3-d representation of the clouds (Churazov et al. 2002)



Unfortunately, the flux of SgrB2 is decreasing with time *(Inui et al. 2009)*

From Chandra web site

But there are many other time-varying molecular clouds, so we can hope that at the time of the first polarimetry mission (soon, hopefully!) there will be at least one bright enough to test the AGN scenario for the GC.

IXO/XPol vs. GEMS

- **XPol is imaging**

- **XPol sensitivity will be much better**

(XPol: MDP=1% for 1mCrab in 100 ks; GEMS=5%. This means that the same MDP is reached with a 25x fainter source or or with a 25x shorter exposure time). Therefore Xpol will be able to study many more sources, expecially extragalactic

GEMS results will be extremely useful to optimize XPol observing program

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 opportunity to perform imaging X-ray polarimetry with a sensitivity high enough to provide significant measurements on at least the brightest specimens of each class of interest.