A new observational Window in Hard X-rays: The polarimetry

POLARIMETRY =

- Two additional parameters
- + their evolution with photon energy, time, and space

Unique information on
emission mechanism
magnetic field configuration
particle distribution

- Recent Polarisation measurements in hard X-rays (E > 100 keV)
- INTEGRAL mission, with both SPI and IBIS instruments
- Essentially 2 sources
  Crab Pulsar and Cyg X-1
- With tentative measurements in 2 GRBs but less significant

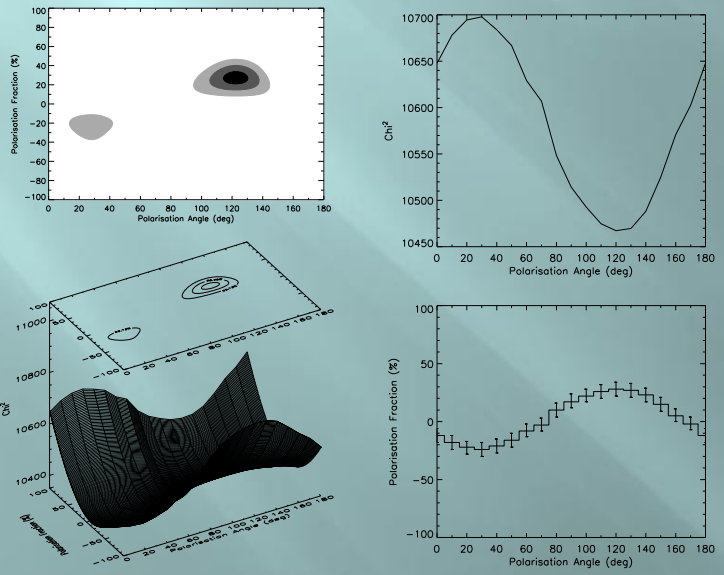
Crab Pulsar

Emission mechanism = synchrotron radiation

Polarisation seen at all wavelengths even in X-rays

→ wind geometry and B,
Acceleration processes

INTEGRAL results : highest energy particles



For the total emission (Psr + nebula)
~ 400 ks

Angle = 122° ±7°
aligned with rotation axis

Fraction = 28% ±6%

Crab Pulsar

Evolution along the phase:
(Dean et al. , Forot et al., 2008)

- Nothing in the pulsed emission
  (cf radio and optical : PF<10%)

- Off-pulse emission
  46 +/-10 % for SPI
  PF > 72% for IBIS

Polarisation vector aligned with rotation axis
Cf optical polarisation *from inner few arcsec*

Model dependent predictions

Optical

Kanbach et al. 2005

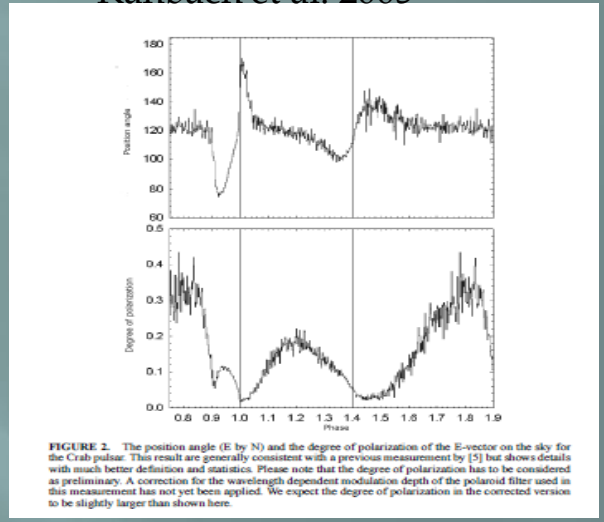


FIGURE 2. The position angle (E by N) and the degree of polarization of the E-vector on the sky for the Crab pulsar. This result are generally consistent with a previous measurement by [5] but shows details with much better definition and statistics. Please note that the degree of polarization has to be considered as preliminary. A correction for the wavelength dependent modulation depth of the polaroid filter used in this measurement has not yet been applied. We expect the degree of polarization in the corrected version to be slightly larger than shown here.

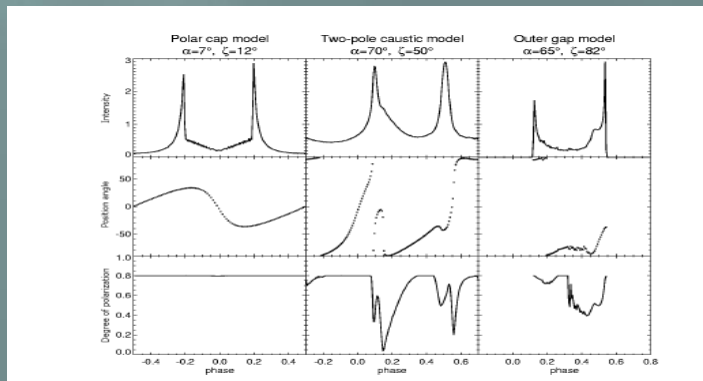


FIGURE 4. The optical light curve, the position angle and the degree of polarization calculated with the following models of high energy radiation from pulsars, from left to right: the polar cap model, the two-pole caustic model, and the outher gap model ([9]).

Prospects for Crab and other Pulsar

Currently, INTEGRAL polarimetry studies start at E > 100 keV
With a MDP ~50 mCrab (for 0.5 Ms)

With a polarimeter :

- Working down to 40-50 keV
- With a MDP of ~1 % in 100 ks (10 x better than INTEGRAL)

→ Detailed evolution of the polarisation along the phase (Crab)
→ Polarisation measurements for other pulsars
→ Information from PF and PA
→ Comparison with model predictions

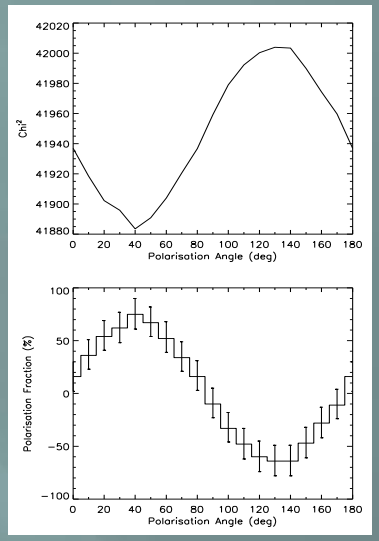
- a spatial resolution ~20''

→ Determination of parameters evolution inside the nebula
localisation of the acceleration site

CYG X-1

- ***Detection of a polarised emission quite unexpected***

- INTEGRAL results
  - Emission strongly polarised



42° +/- 3°
76 % +/- 15 %

  - PF increases with energy

250-400 keV **400-2000 keV**

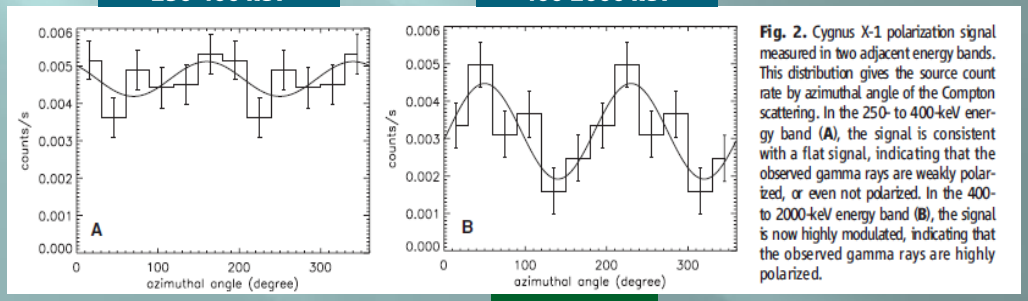


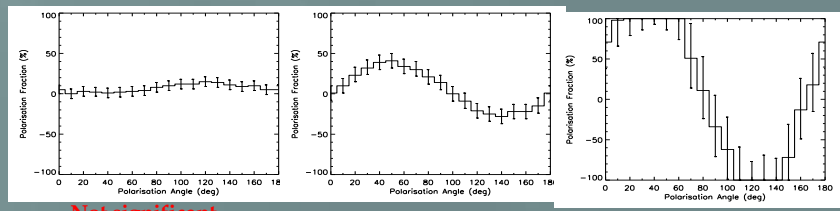
Fig. 2. Cygnus X-1 polarization signal measured in two adjacent energy bands. This distribution gives the source count rate by azimuthal angle of the Compton scattering. In the 250- to 400-keV energy band (**A**), the signal is consistent with a flat signal, indicating that the observed gamma rays are weakly polarized, or even not polarized. In the 400- to 2000-keV energy band (**B**), the signal is now highly modulated, indicating that the observed gamma rays are highly polarized.

Not significant

67%

Laurent et al., 2011

100-230 keV **230-370 keV** **370-850 keV**



Not significant

15 % +/- 6 % 122° +/- 6°

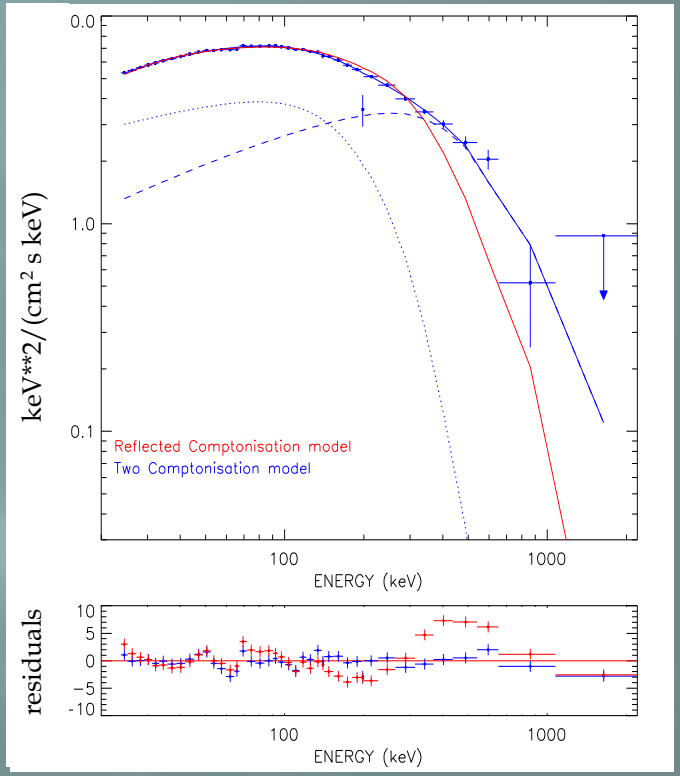
47° +/- 4°
41 % +/- 10 %

39° +/- 3°
100 % ; > 75 % (2 σ)

CYG X-1

Link with the spectral results

High Energy spectral shape more complex than a single Comptonisation emission: Requires at least 2 components



CYG X-1

Link with the spectral results

High Energy spectral shape more complex than a single Comptonisation emission: Requires at least 2 components

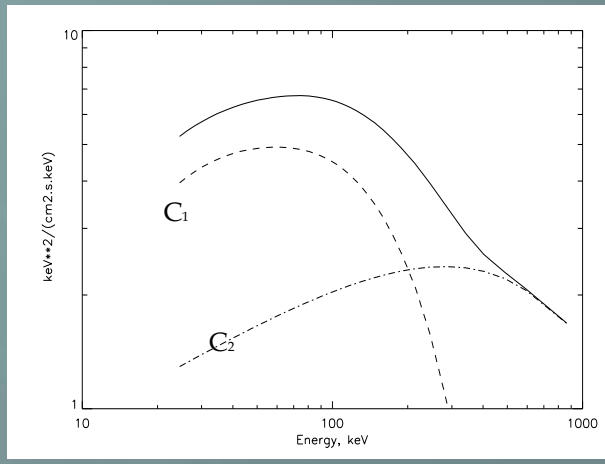
- Identification of the second component with the polarised signal

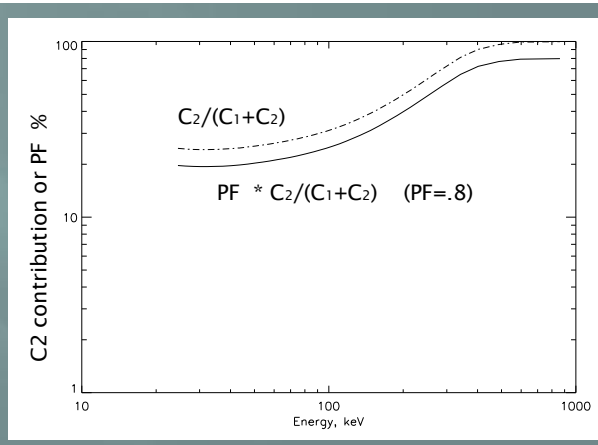
→ The evolution of the polarisation fraction with E can be explained by **two emission components**, one non polarised at low energy and the second strongly polarised and harder

$$PF_T = PF_2 * C_2/(C_1+C_2)$$

→ Synchrotron radiation in a **very ordered magnetic field**

→ Reciprocally: PF(E) determination allows to separate the two contributions to the hard X-ray emission : access to the corona and jet components parameters





CYG X-1 and other XRB

Polarisation measurements in the hard X-ray domain crucial for

- Identification of the mechanism at work for the second component observed in several objects (role of the jet)
  GX 339-4, GRS1915, H1743-322, Sco X-1, 1E, GRS 1758, GS 1826….
- Determination of its relative contribution
  → more precise knowledge of the Comptonisation part
- Potential studies of the reflection component
  (PF ~10 % predicted in some models)

SUMMARY

With a gain by a factor 10
and an extended energy band

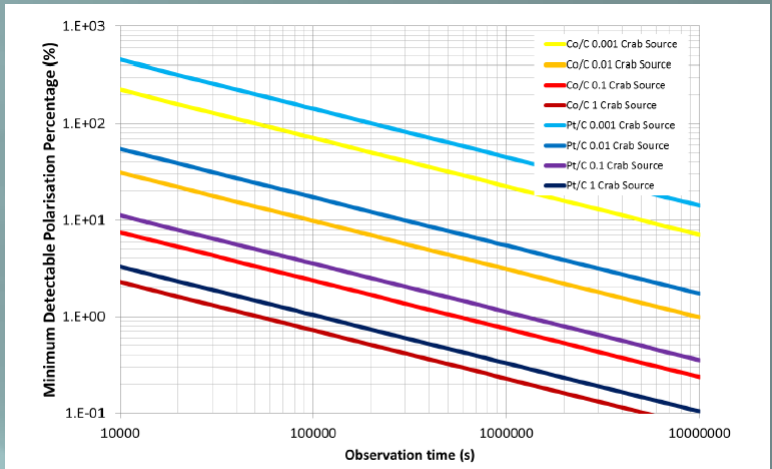


Figure 5: The minimum detectable polarisation (50-200 keV) for PheniX vs observation duration for different source strengths and mirror coatings.

Crab and other PSRs

- Detailed evolution
  of PF and PA versus the phase
- A sample of sources accessible

Cyg X-1/XRB

- Precise determination of the respective contributions of the Comptonisation and synchrotron emission (Hyp: PF(E) = Ct)
- Identification for a number of XRB of this second component

AGNs

- Study of the HE emission in brightest AGNs

Reflection Components

- XRB, AGNs, Sgr A*

THE END