1A 0535+262
in outburst

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Overview

- 1A 0535+262
- INTEGRAL observations
- Timing properties
- Spectral properties
- Summary

1 A 0535+262: Be/X Ray binary system

Neutron star

P~103,4 s

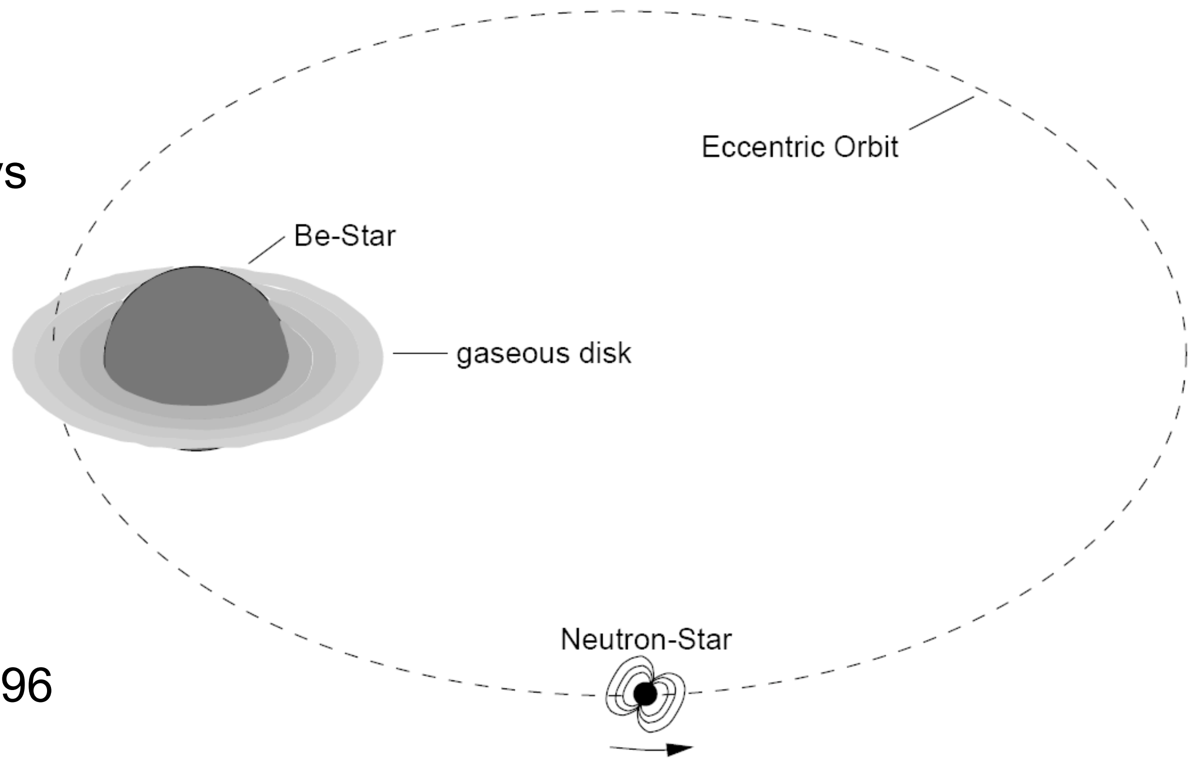
B ~4.10^{12}G

Companion HDE 245770

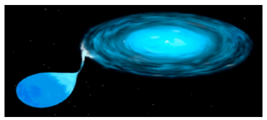
09.7-B0, IIIe

14Msun, 14Rsun, 1.4105Lsun,Teff =26000K

Porb=110 days



Kretschmar 1996



Outburst history of the source

It has shown 5 giant outbursts since its discovery (Rosenberg 1975)

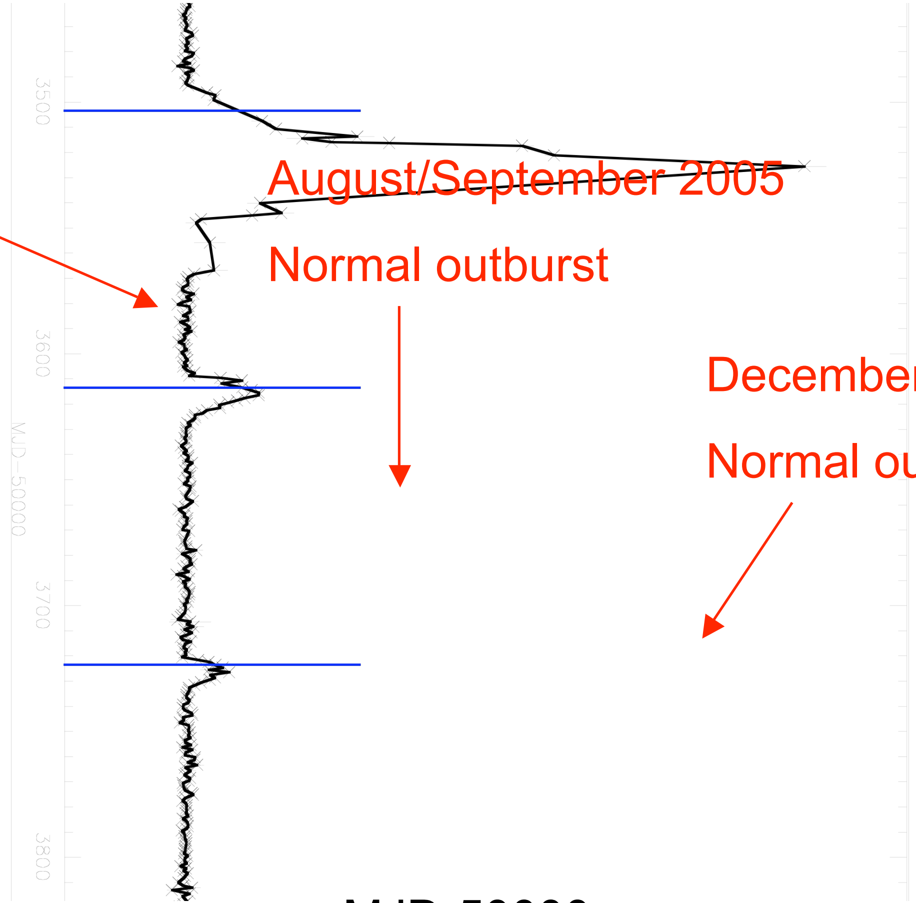
- April/May 1975
- October 1980
- March/April 1989
- February 1994

•May/June 2005=> too close to the sun!!!

But…after the last giant outburst it showed a normal outburst observed by INTEGRAL

May/June 2005

Giant outburst



August/September 2005

Normal outburst

December 2005

Normal outburst

ASM cps

MJD-50000

Periastron passage

RXTE/ASM light curve

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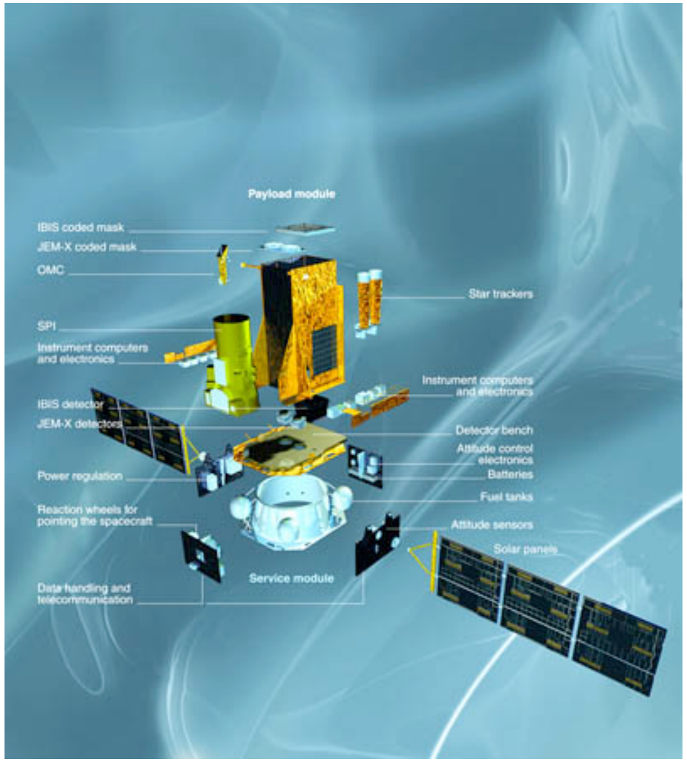
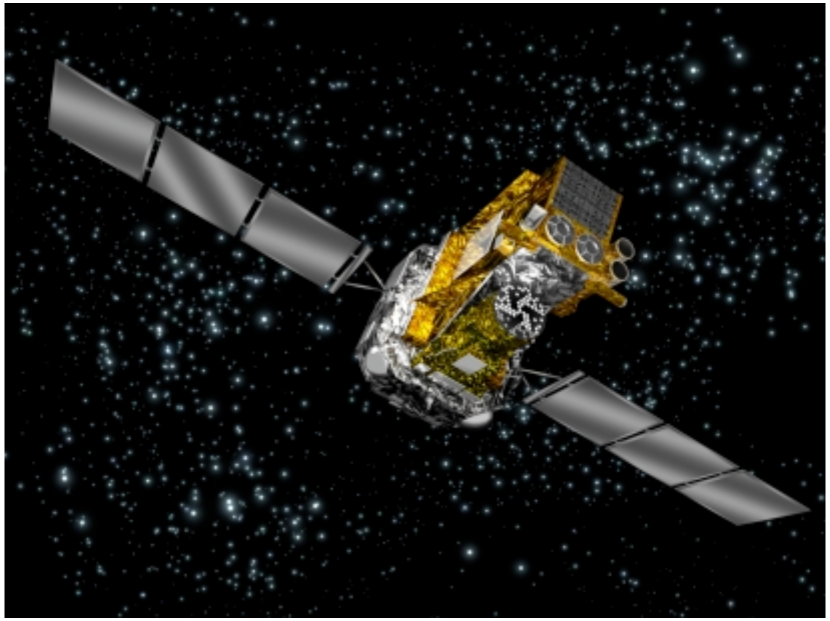
INTEGRAL



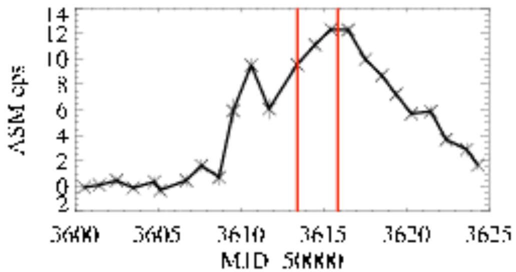
Launched in 2002
15 keV - 10 MeV gamma-ray observatory mission
Excentric orbit
72 hours



- IBIS, SPI: coded mask instruments
- JEM X, OMC: X ray and optical monitoring

IBIS
15 keV - 10 MeV

Our INTEGRAL observation

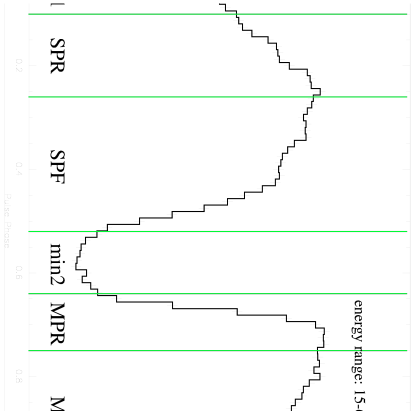


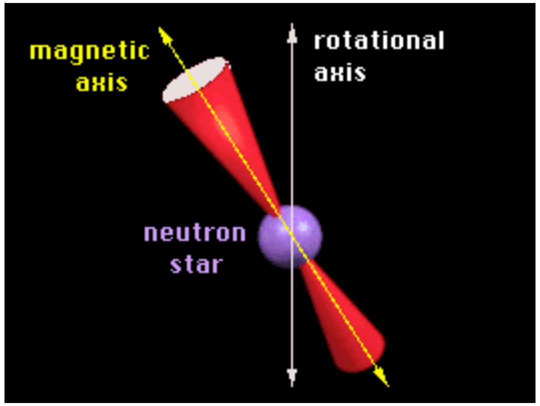
- DATA ANALYSIS
- OSA v5.1 (Offline Scientific Analysis)
- Additional software from INAF Palermo to perform phase resolved spectroscopy

Pulsed emission

- What do we observe from emission of a neutron star in a binary system?

lighthouse effect





Asymmetric pulsed emission is observed

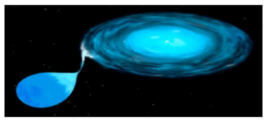
Pulse period of the source

Epoch folding technique

- Barycentered and binary corrected data
- fold the light curve versus a range of trial periods
- χ^2 maximization test

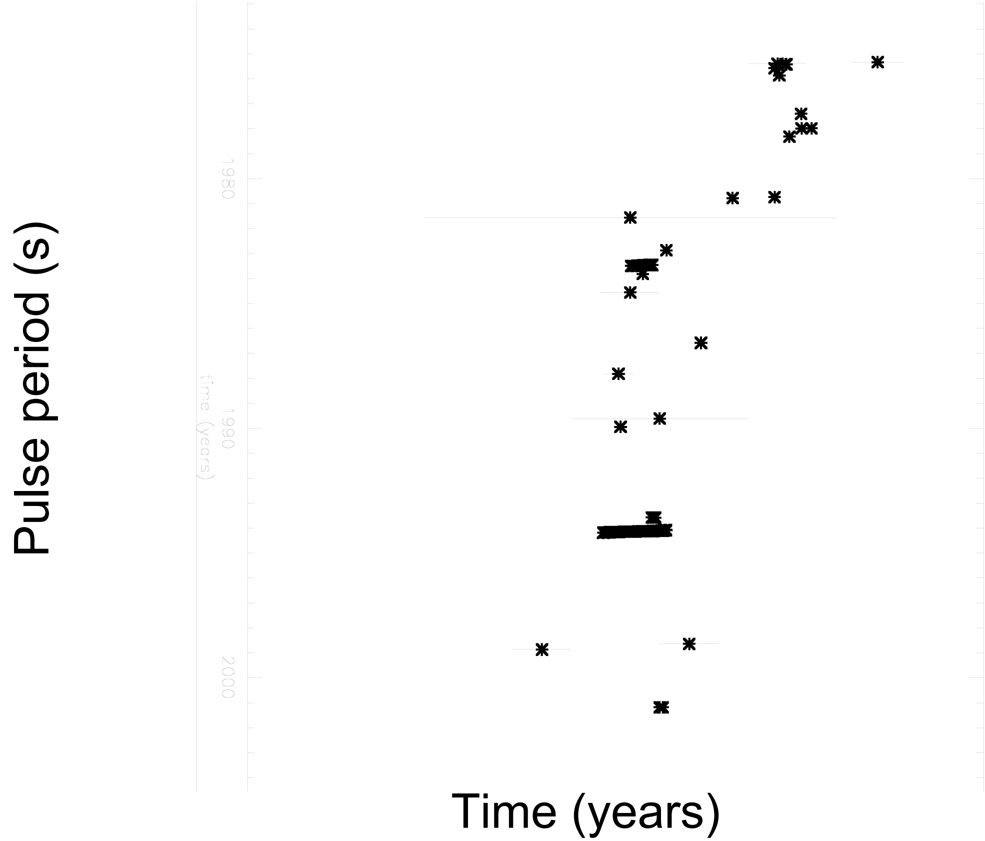
Best period obtained $$P = 103.392 \pm 0.004 s$$

For MJD 53613.460475



Pulse period history of 1 A 0535+262

Evolution of the pulse period since its first determination in 1975



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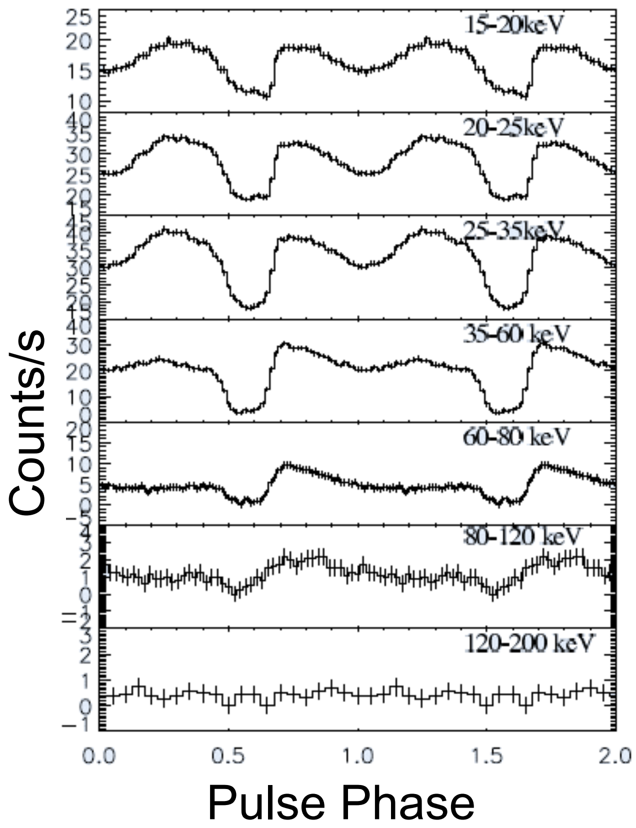
Pulse profiles



Double peak pattern at low energies

At higher energies one peak appears to be reduced

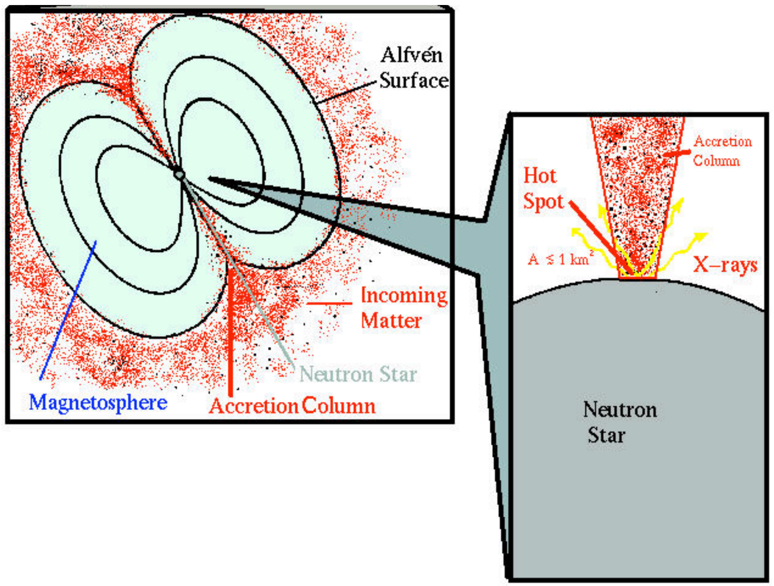
No modulation above 120 keV

Zoom on the emission region

The accreting plasma couples to the magnetic field at Alfvén radius

For typical NS parameters

[redacted] ≈ [redacted] × [redacted]



The Plasma can not penetrate the magnetosphere and the only way it can be accreted onto the surface of the neutron star is along the magnetic field lines onto the magnetic poles

Formation of accretion columns at polar caps

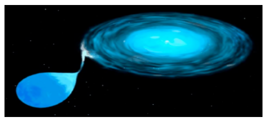
Accretion column

- When the accreted matter passes the boundary layer it is forced to follow the B filed lines. Free fall flow. The gas stream is concentrated in an accretion funnel onto both magnetic poles of the NS

- Small region ~ $1 km^2$ => main origin of X-ray emission

- Extreme physical conditions in the accretion funnel:

  $B \sim 10^{12} G$, relativistic plasma $v \sim 0.6c$, $L \sim L_{Edd}$



Accretion column

Hydrodynamical simulations (Basko & Sunyaev 1976) assuming $L \sim L_{Edd}$ reveal that infalling plasma passes a free-fall zone until it reaches almost the NS surface

Close to the surface the plasma is decelerated by Coulomb interactions with electrons of the NS atmosphere and due to inelastic scattering with photons

High accretion rates $\dot{M}$ =>"fan beam":

Radiation pressure dominates, plasma dissipates its kinetic energy by Inverse Compton scatering in a radiative shock. Below the shock subsonic v. Large optical depth within the shock => photons emitted in horizontal direction

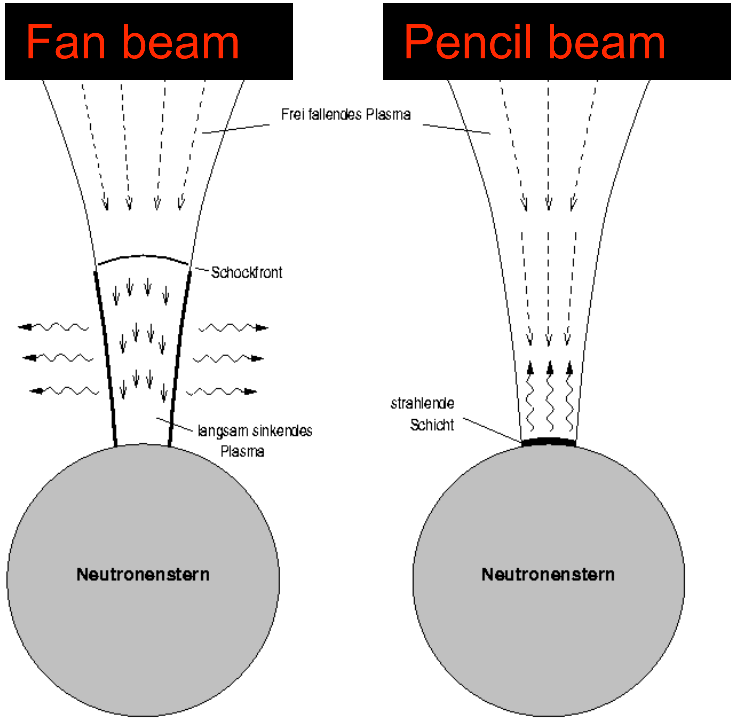


Fig. from Kretschmar (1996) after Harding (1994)

Low accretion rates $\dot{M}$ =>"pencil beam":

Emergent radiation pressure acting on the infalling plasma i neglible and optical depth of the accretin plasma is low=> photons escape in vertical direction

Spectral properties of Be/X ray binaries

CONTINUUM

- No convincing theoretical model for the continuum (Recent model Becker et al. 2005)
- Phenomenological models are used: generally power law times an exponential above a characteristic cutoff energy

Example:

$$f(E) = AE^{-\Gamma}\begin{cases} 1, E \leq E_{cut} \\ e^{-(E-E_{cut})/E_{fold}}, E \geq E_{cut} \end{cases}$$

CYCLOTRON LINES

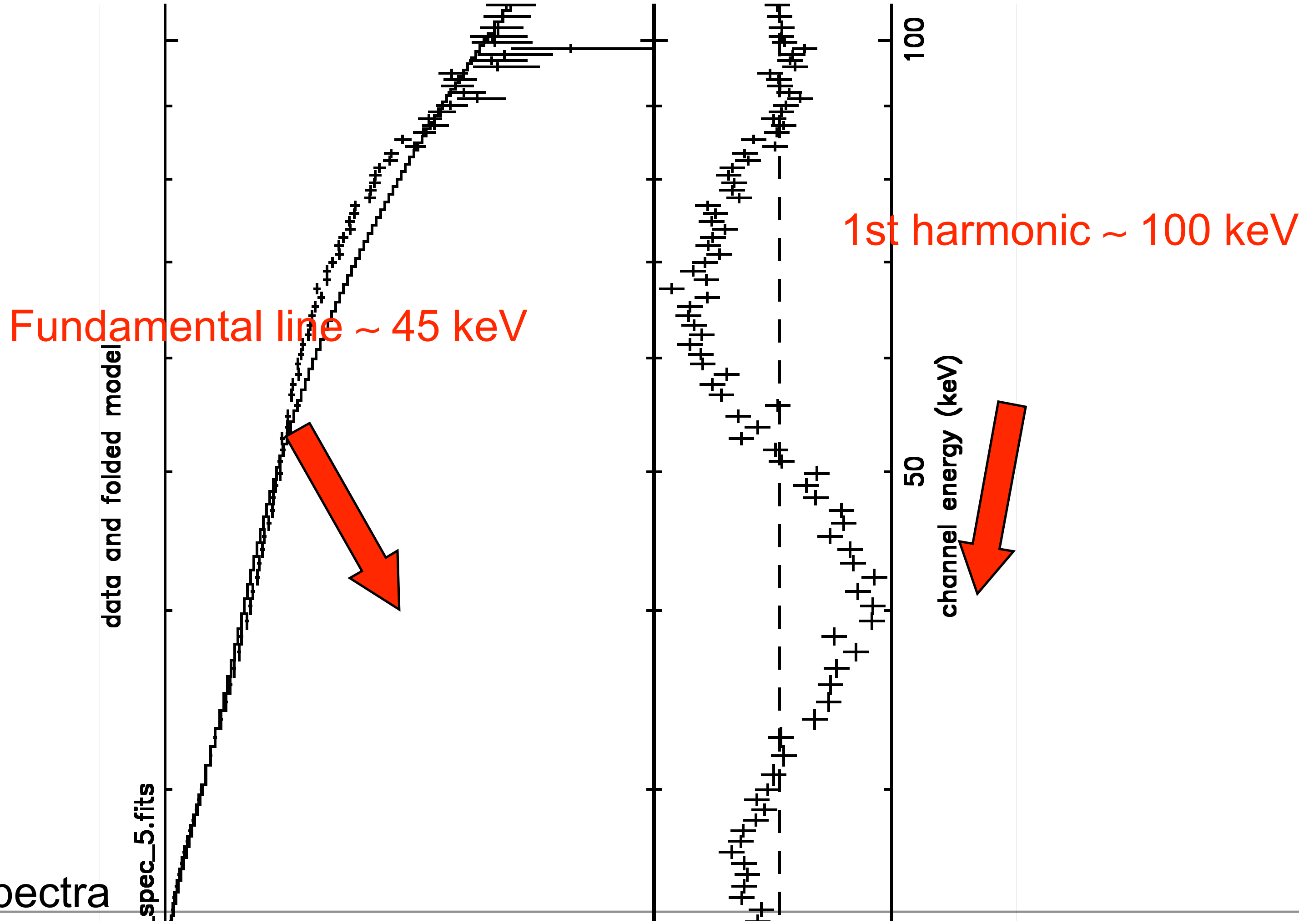
- electrons in a magnetic field move helicodally along the B field lines with gyromagnetic Larmor frequency
- The energy of the e perpendicular to the B field is quantized into the Landau levels

$$E_{cyc}^{obs} \approx \frac{11{,}6B_{12}}{(1+z)} keV$$

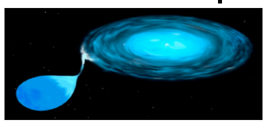
Importance of cyclotron lines: only method to directly measure B-field of an accreting neutron star!!!

Phase average spectra

Model for continuum: power law times exponential above a characteristic cutoff energy



ISGRI (IBIS) spectra



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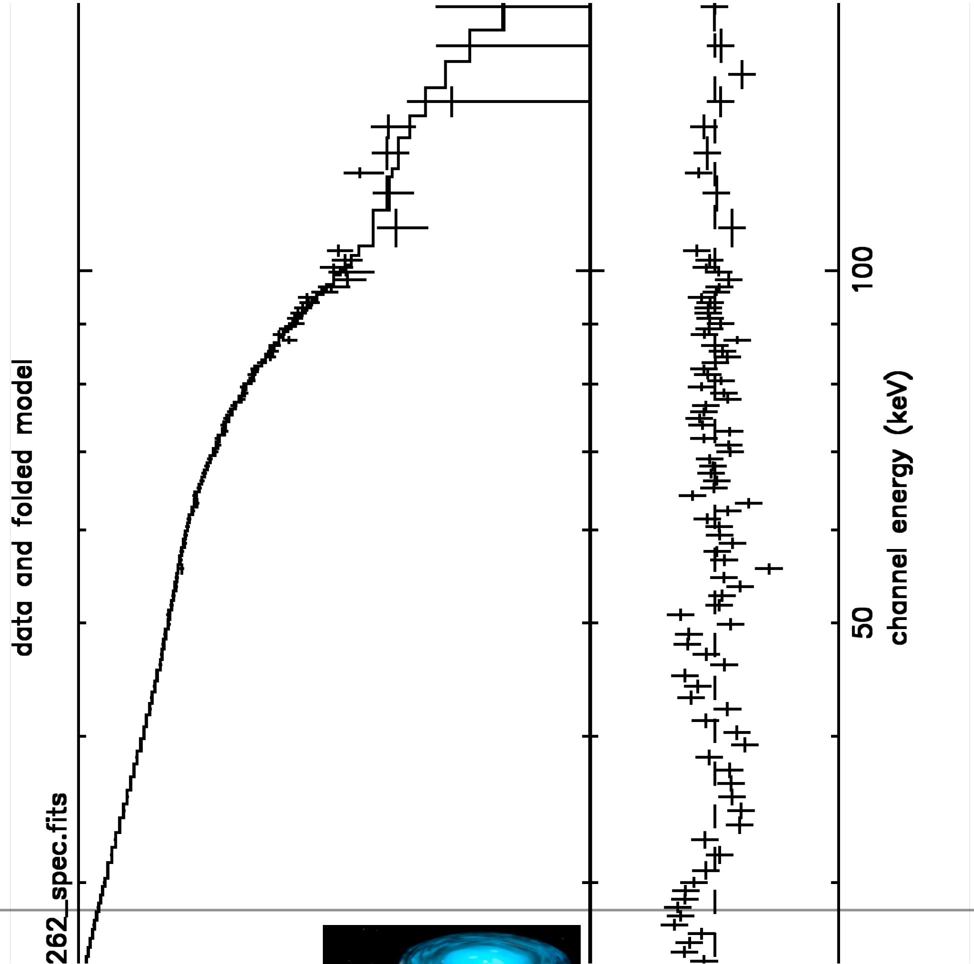
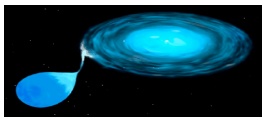
Phase average spectra

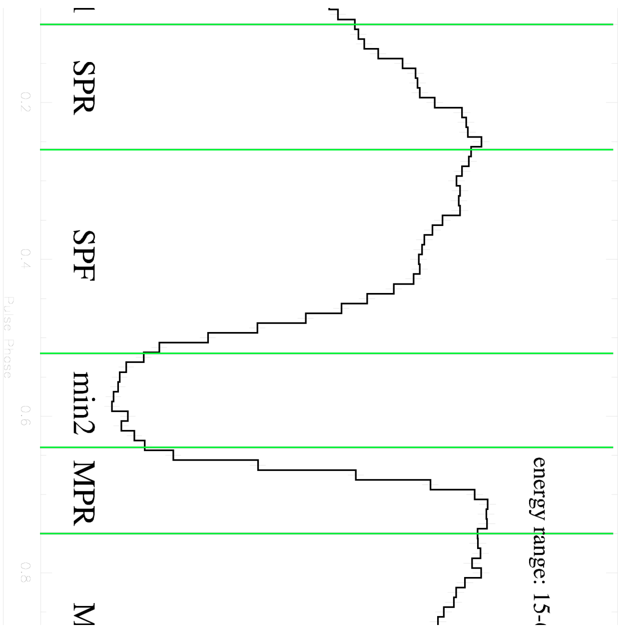
Model: power law times exponential above a characteristic cutoff energy

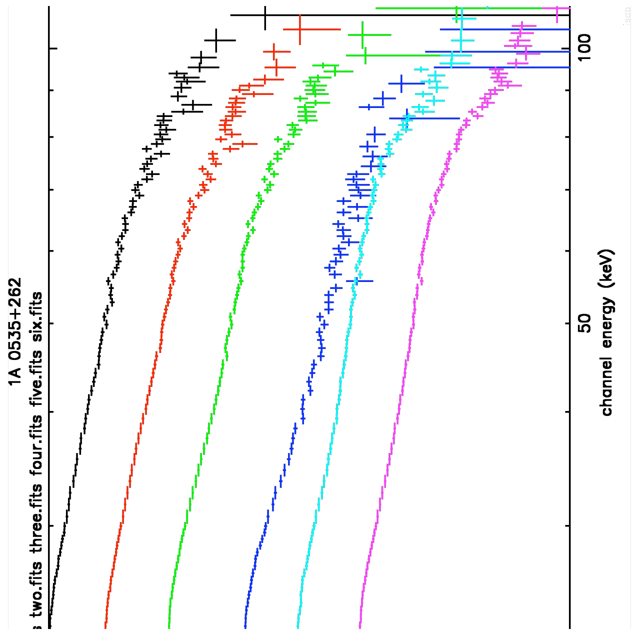
+ 2 gaussian lines in absorption





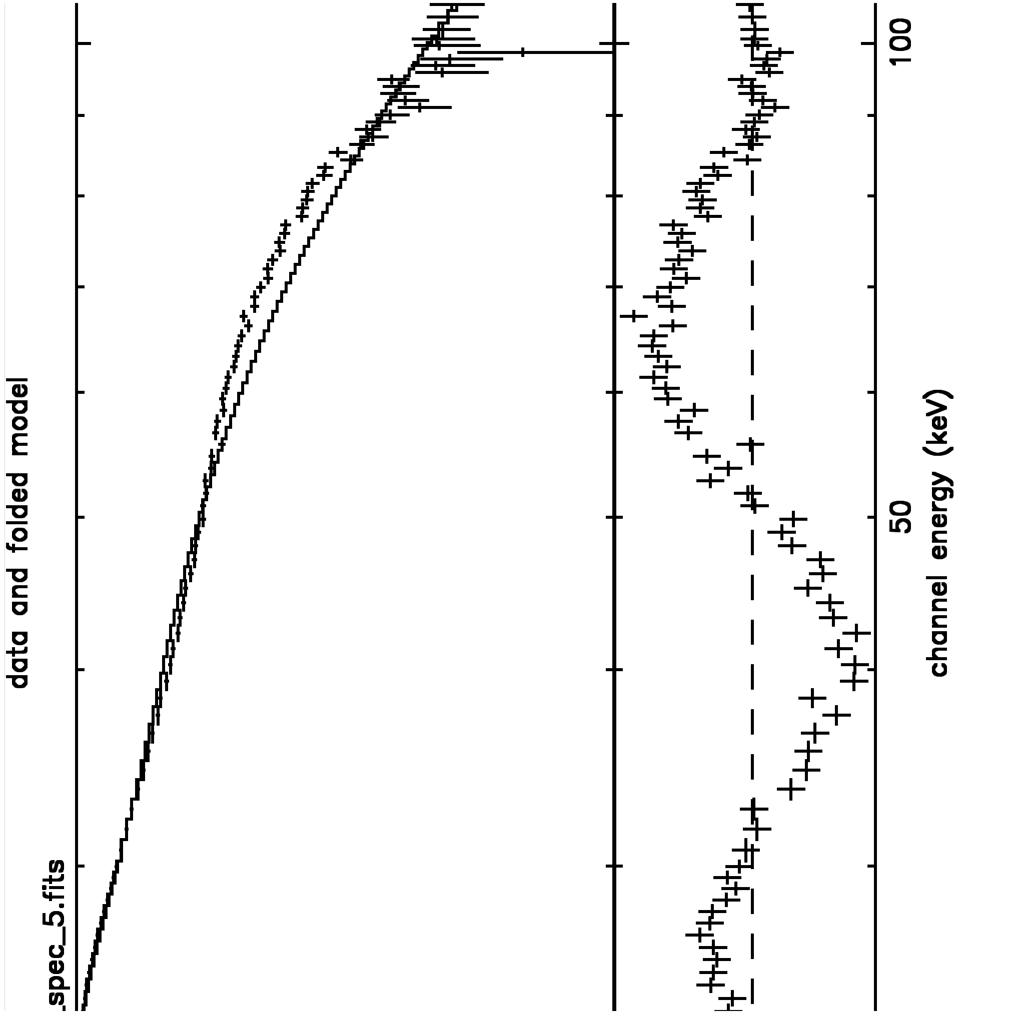
Phase resolved spectra





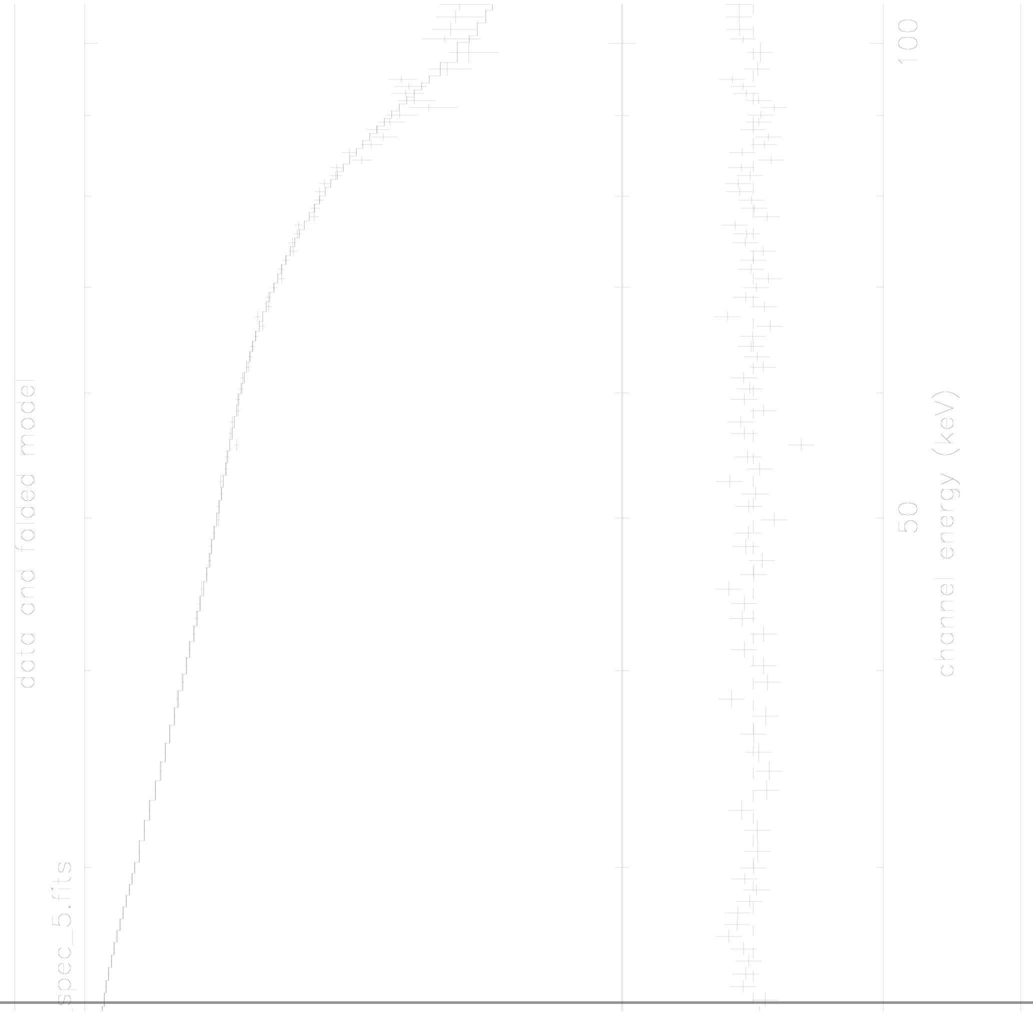
Clear variation of spectra within the phase

Phase resolved spectra



Main peak fall

Phase resolved spectra



Main peak fall

Summary

- Overview of Be/X ray binary systems –

  1 A 0535+262
- Period determination
- Detection of 2 cyclotron lines
- Next step:

Obtain the broad band spectra