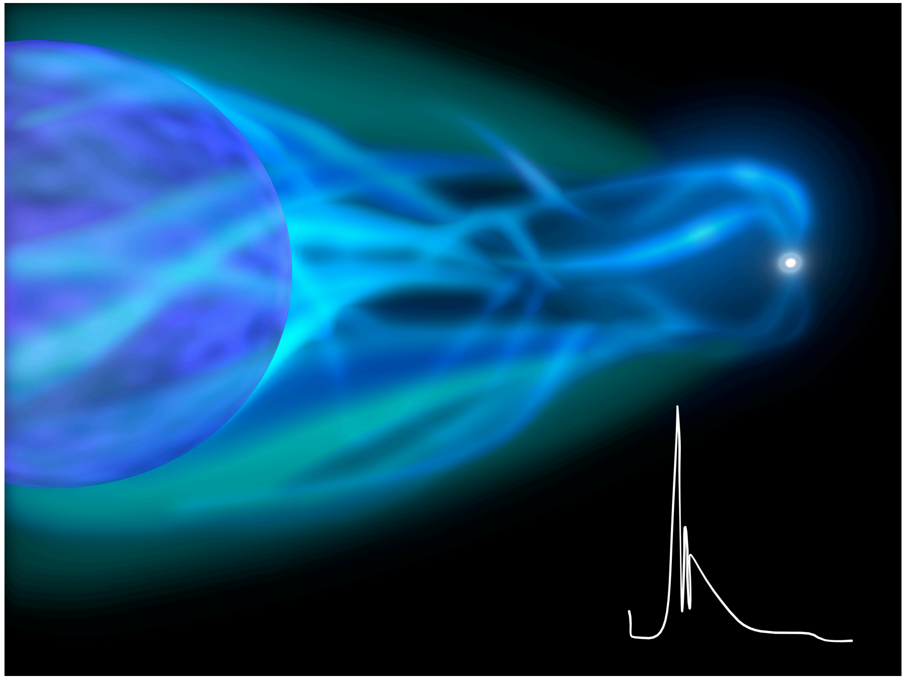
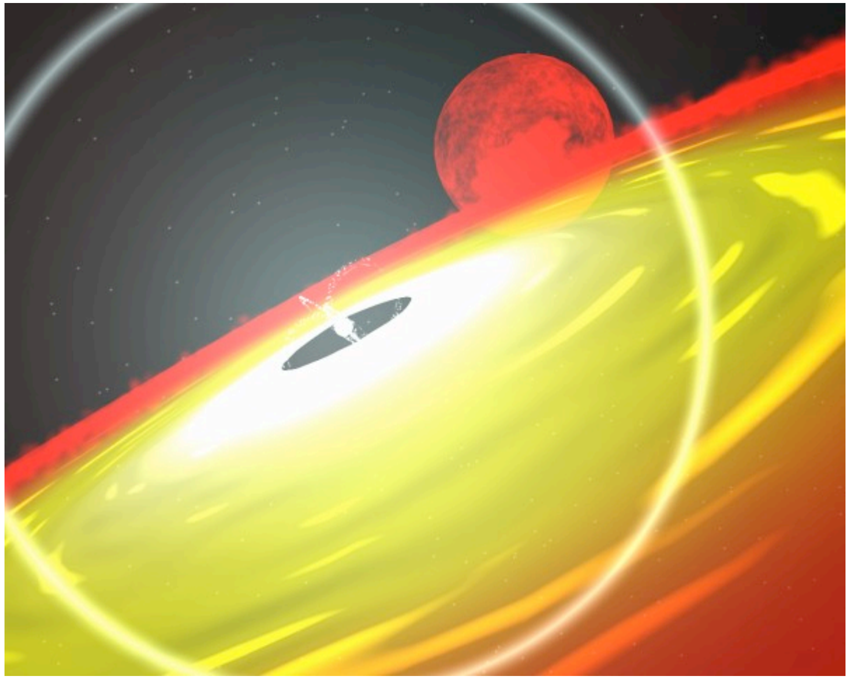
Mapping the magnetosphere of bright accreting pulsars.

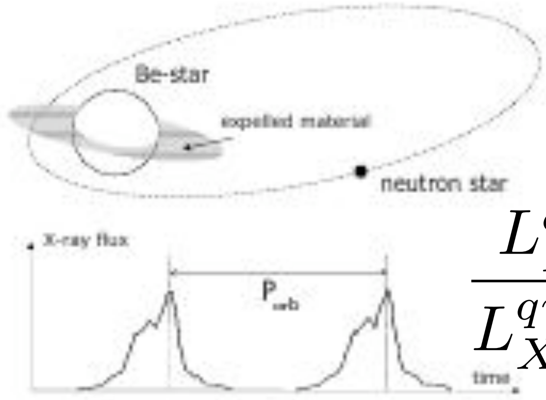
Carlo Ferrigno – ISDC INTEGRAL tutorial

Summary

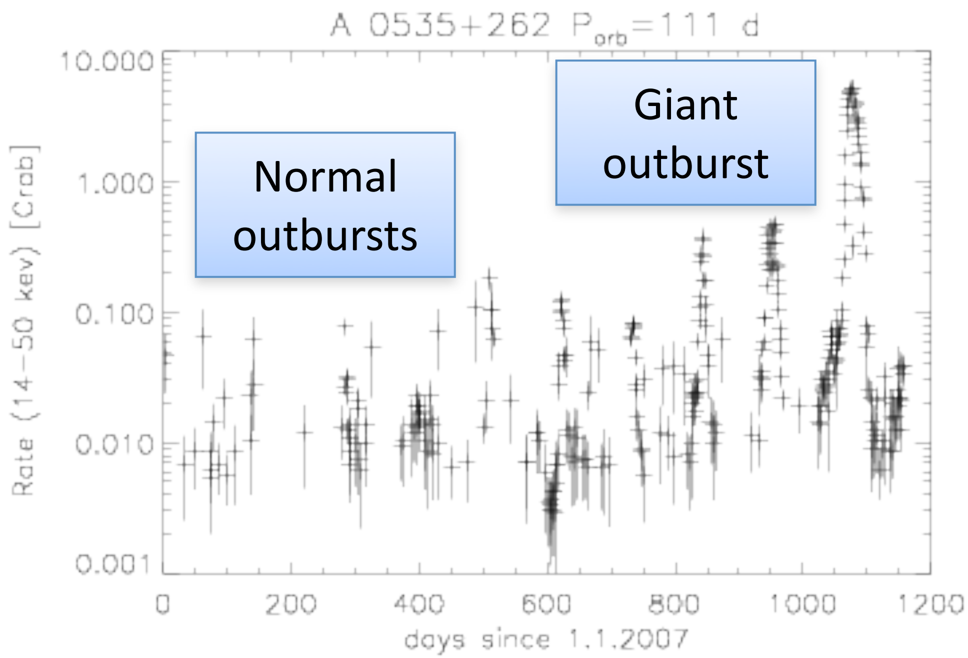
- Highly magnetized neutron stars, the Be binaries:
  - INTEGRAL achievements on V 0332+63.
- Low mass X-ray binaries:
  - the peculiar case of Her X-1;
  - accreting millisecond pulsars.
- X-ray emission in low a magnetic field:
  - average spectrum of the neutron star low mass X-ray binaries.
- Conclusions and future prospective.

The Be binaries

- Some giants posses an equatorial quasi-Keplerian disc driven by radiation instability.
- If a neutron star has an eccentric orbit around it, at each perigee there is Type I (or normal) outburst which lasts for a few days.
- On irregular basis, there are giant outbursts, which last about one month and can reach $L_x \sim 10^{38}$ erg/s
- A neutron star is generally characterized by a high magnetic field ($B \sim 10^{12}$G).
- The sources can be studied with great detail during these events.

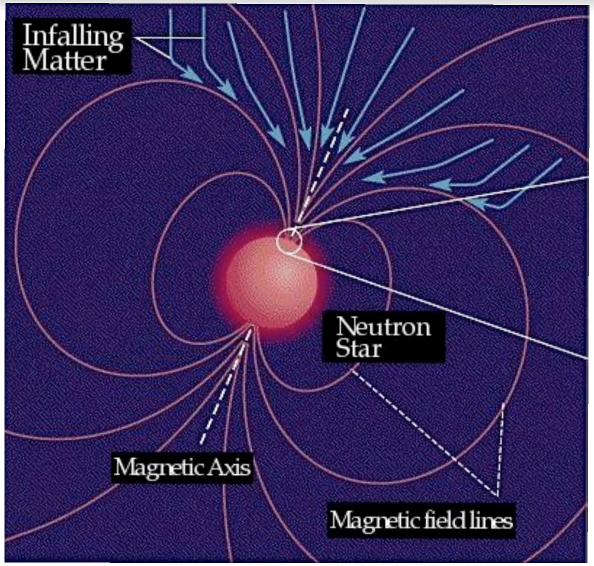


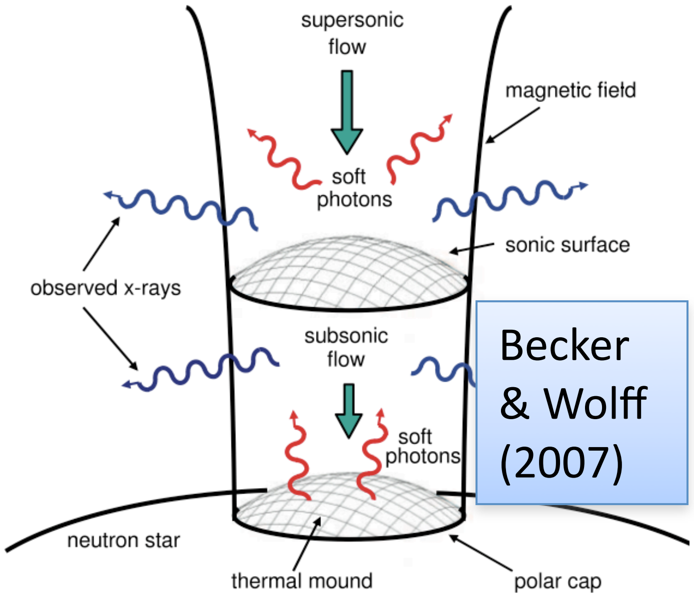
$$\frac{L_X^{outburst}}{L_X^{quiescence}} \sim 10^3$$



Emission mechanisms in high magnetic field

- The accreting matter acquires a high kinetic energy v~c/2 which is partially dissipated close to the compact object surface and emitted in the form of X and Gamma-rays.
- If the neutron star has a high magnetic field, the accreting matter is channeled at the magnetic poles along the field lines and accretes in columns.
- Seed photons coming from thermal mound and electron breemstrahlung, in the high B-field, are Compton scattered.
- Formation of absorption lines due to cyclotron scattering -> measure of B-field.



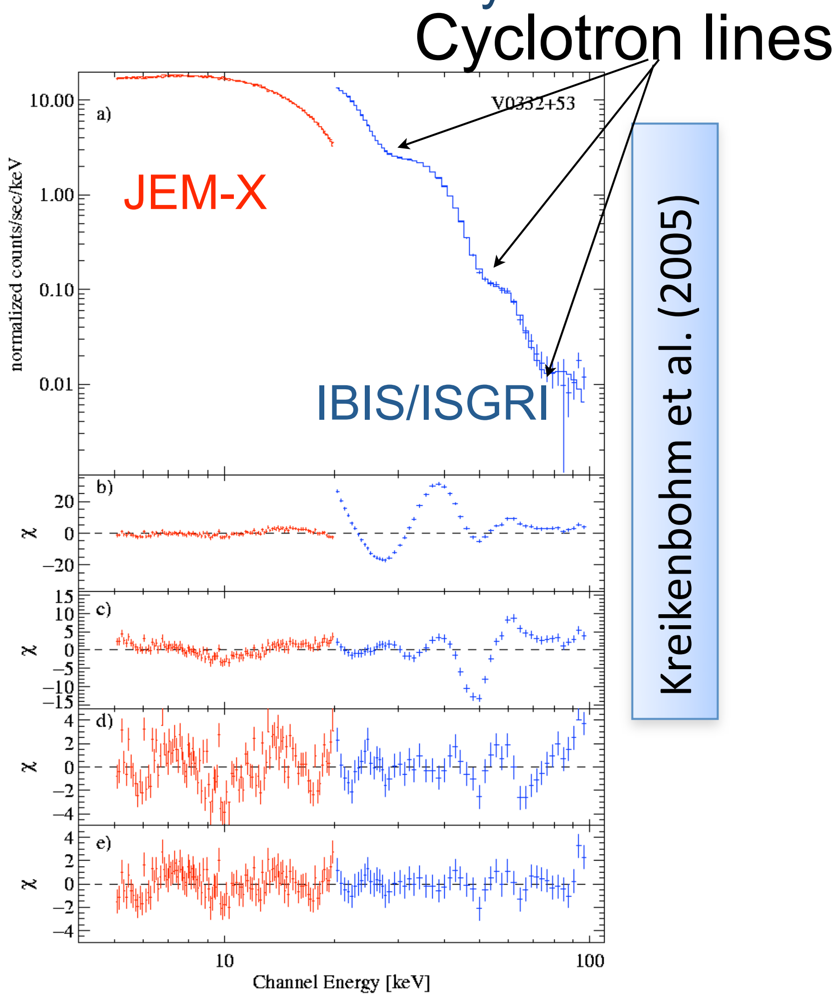


Becker & Wolff (2007)

V 0332+53

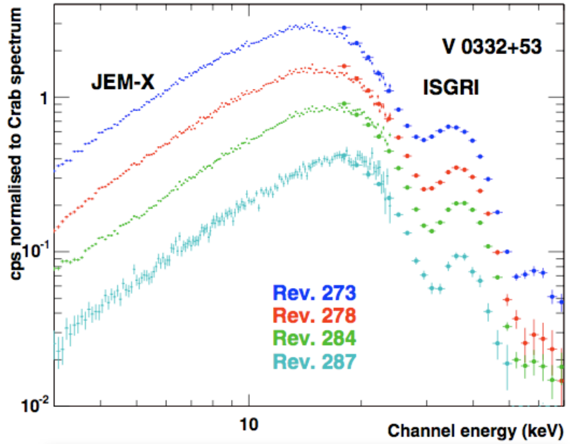
- Recurrent transient, consisting of a neutron star orbiting around a O8-9Ve star in 34.25d with e=0.34. Spin period ~3 s.
- Discovered in 1973, during a major outburst when it reached 1.6 Crab fluxes, it was outbursting other 3 times in 1983 (0.2 Crab), 1989 (0.4 Crab), and 2004-2005 (1 Crab). Distance is 7 kpc -> L_X~10^{38} erg/s at most.
- In 1989, a cyclotron scattering feature was observed. In December 2004, two harmonics have been observed using RXTE data.
- INTEGRAL discovered also the third harmonic.

- TOO INTEGRAL observation was scheduled as soon as possible on 6 January 2005.

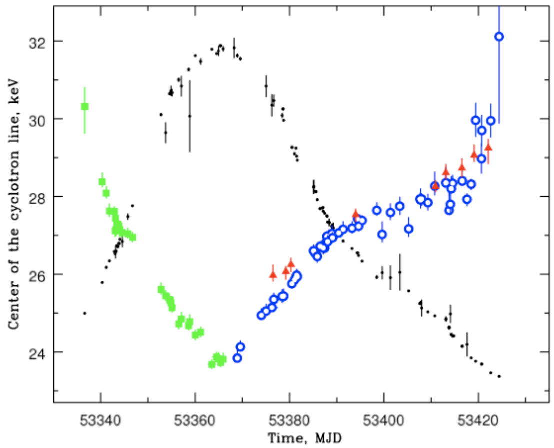


V 0332+53

- Complex shape of fundamental line at the outburst peak.
- Non regular spacing of fundamental line and higher harmonics.
- Monitoring campaign using INTEGRAL and RXTE revealed a peculiar luminosity dependency of the continuum, pulse shape and cyclotron line energy due to the different height of the accretion column.



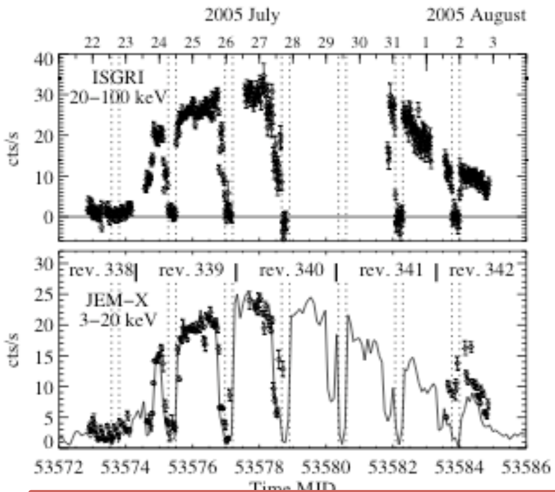
Mowlavi et al. (2006)

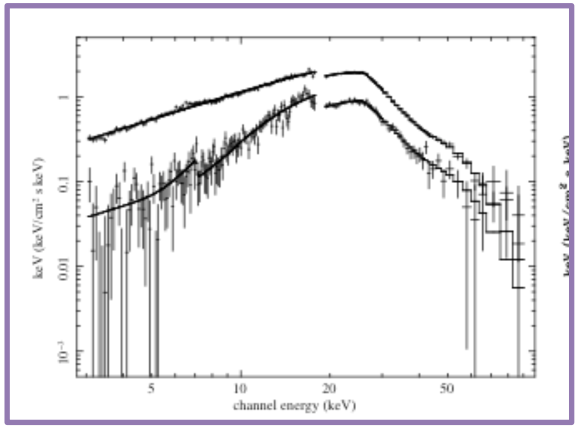


Tsygankov et al. (2010)

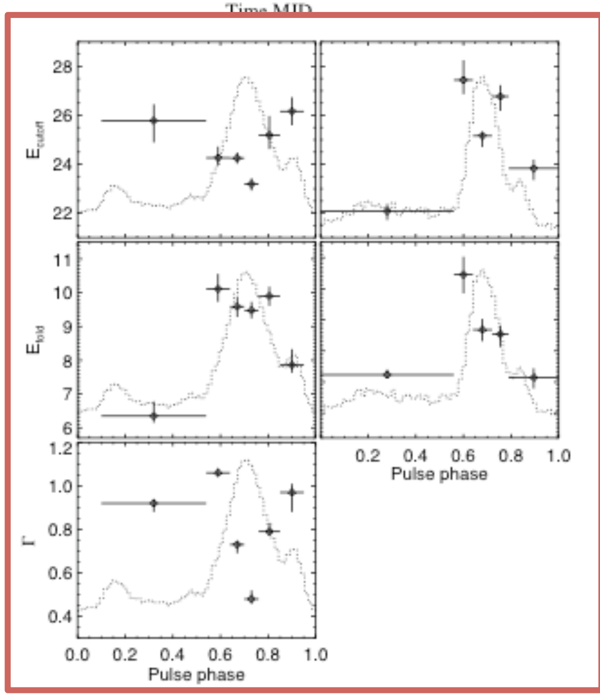
Her X-1 – LMXB with high B

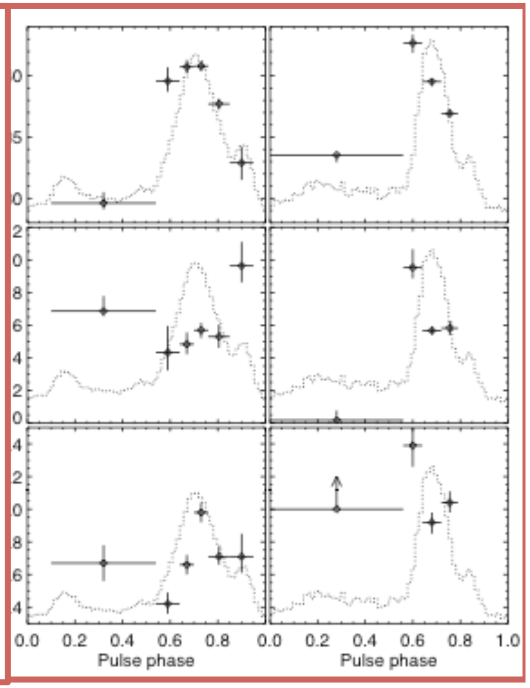
- Discovered in 1972, well studied.
- P_{orb}=1.7d P_{spin}=1.24s warped disc produces a cycle of 35d regular eclipses. Cyclotron line at ~40 keV.
- First measure of torque during the main on.
- Modeling of X-ray dips as due to a partial covering.
- Phase dependent variations of continuum and cyclotron line parameters.





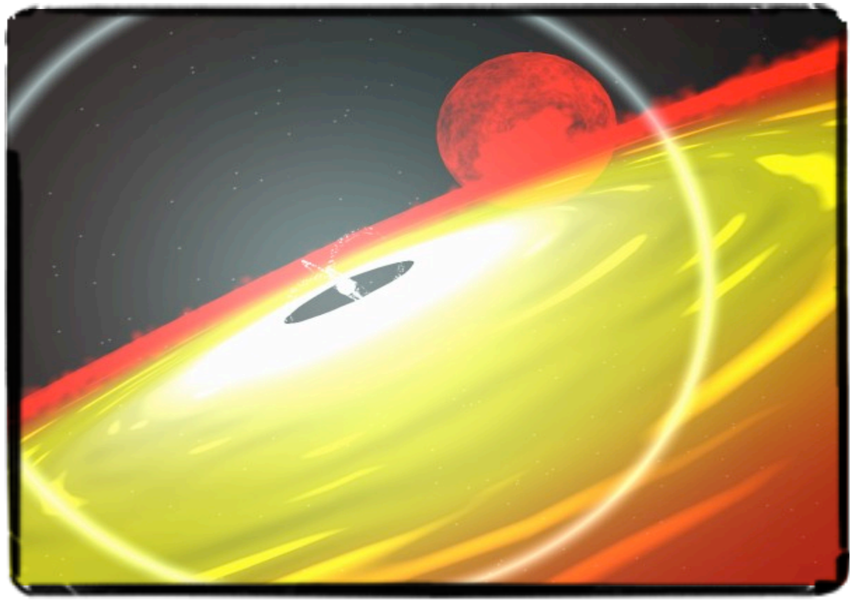
Klochkov et al. (2008)

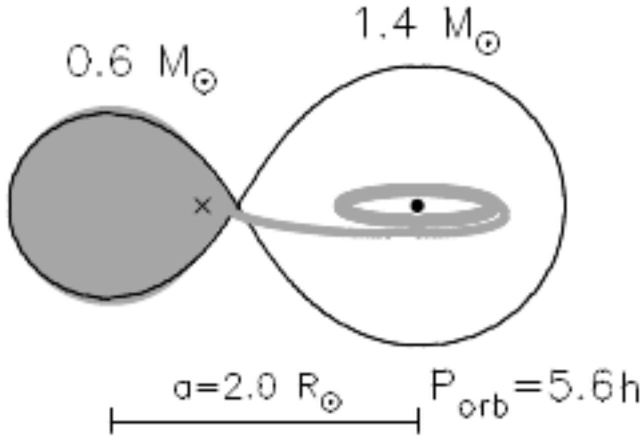




The accreting neutron star low mass X-ray binaries

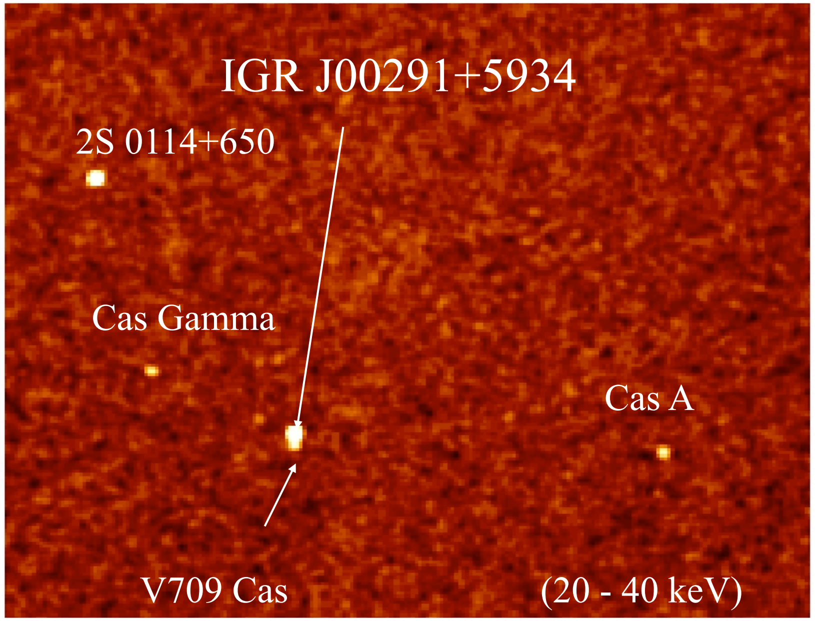
- In Low Mass X-ray Binaries. a solar type companion accompanies a compact object.
- Accretion is normally channeled via Roche Lobe overflow.
- The neutron star has generally a low magnetic field ($B<\sim10^{10}G$) or null in case of black holes.
- LMXB are divided into bright persistent Z sources and fainter flaring Atoll sources.
- The interesting subclass of millisecond accreting pulsars is the confirmation of the "recycling scenario", in which old pulsars are spun up by the accretion torque in binary systems.

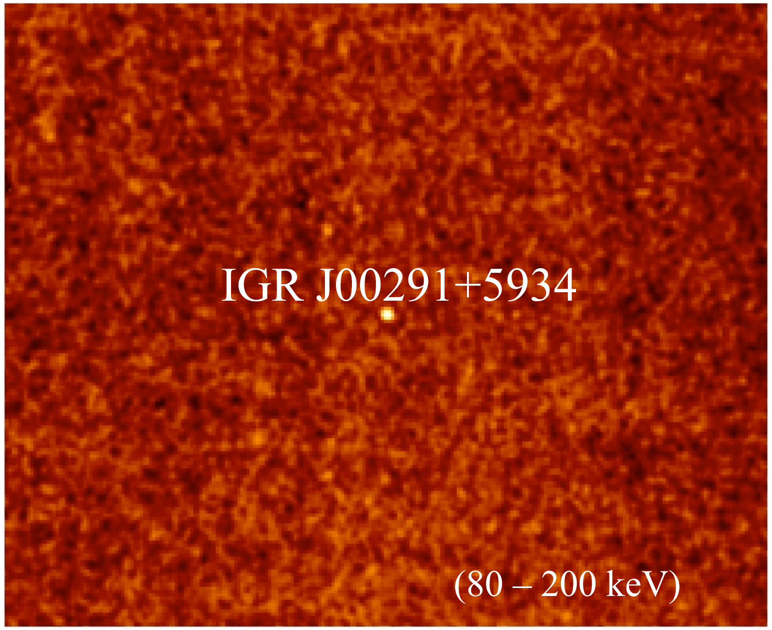




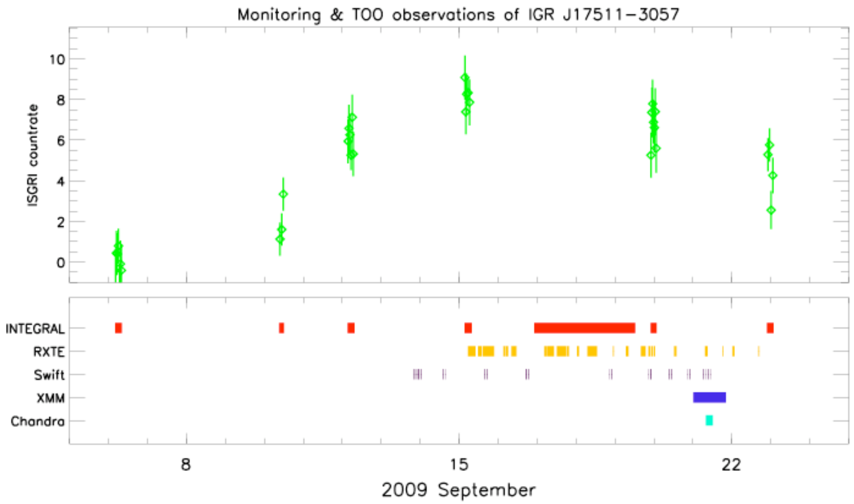
Discovery of new objects: millisecond pulsars

Falanga (2007)





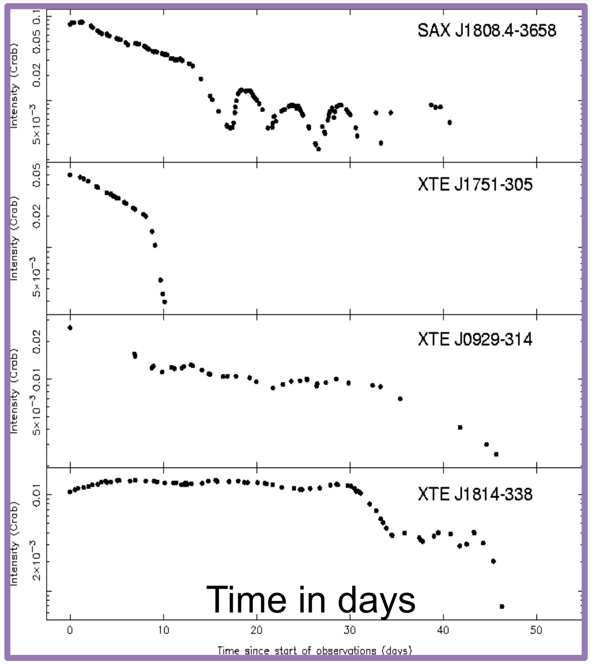
- The imaging capabilities and large FOV of IBIS/ISGRI led to the the discovery of two accreting millisecond pulsars (12 are known): IGR J00291+5934, the fastest with a spin period of 1.7 ms, and IGR J17511-3057, the latest discovered.
- Subsequent monitoring with many satellites demonstrates the interest.

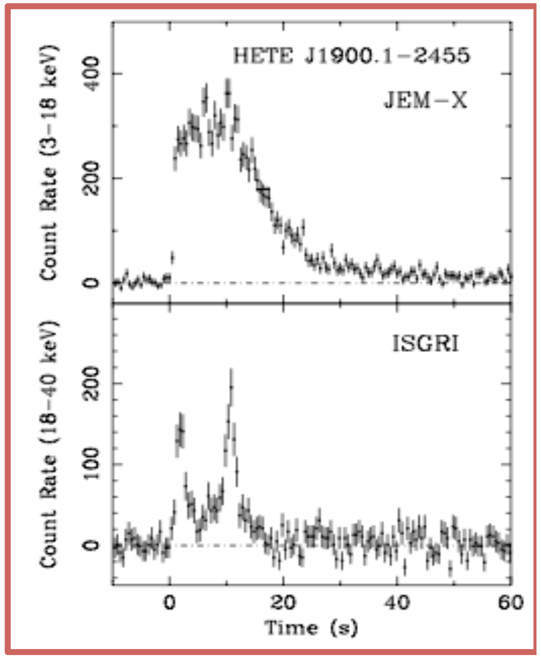


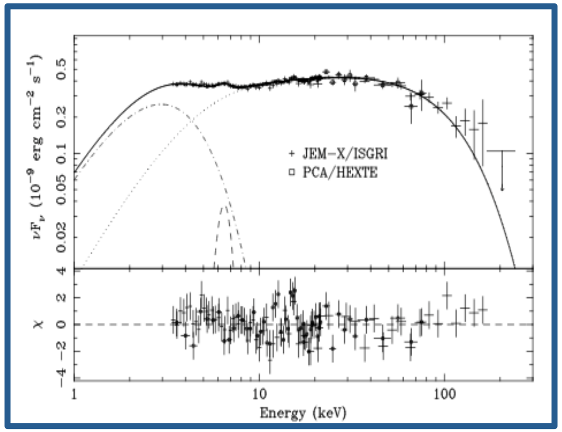
http://www.sciops.esa.int/

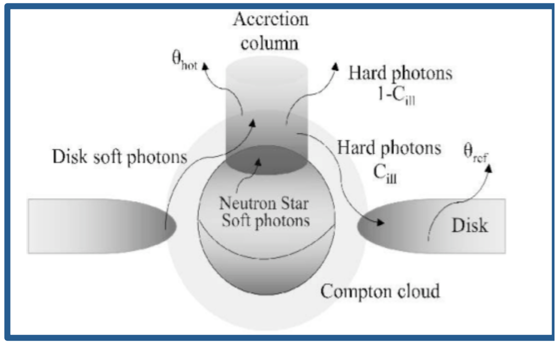
Accreting millisecond pulsars

- Observation of several objects thanks to the good timing capability of INTEGRAL.
- Peculiar light curve of the outbursts followed by INTEGRAL and RXTE.
- Determination of the distance using the Photospheric radius expansion during thermonuclear bursts.
- Self consistent Comptonization model for spectrum, pulsed fraction and time lags.



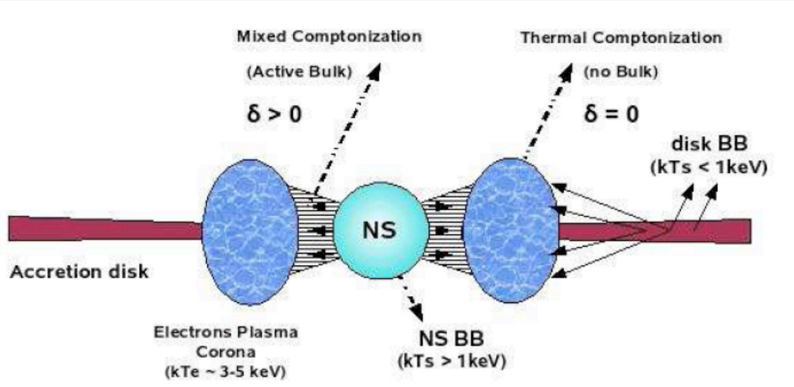






Falanga (2007)

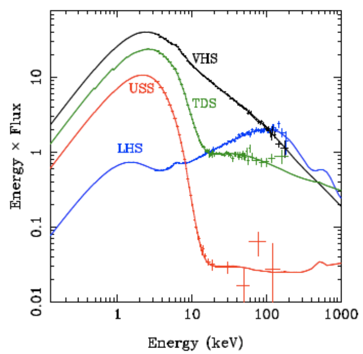
Emission mechanism of NS LMXB in low magnetic field

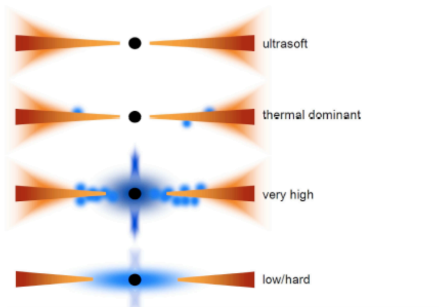


Paizis et al. (2010)

- The accretion disc extend almost to the central object. A characteristic boundary layer is formed near the NS surface.
- Emission is generated by Compton scattering of thermal seed photons of the NS or inner disc surfaces, plus thermal emission from the outer disc.
- Pulsations are sometimes present due to the funneling on magnetic poles, but often hidden by the accretion flow.

- They present different states ranging from soft bright state to hard low states (analog to the black-hole candidates.)
- The peculiar phenomenon of hard tails has been explained either by the bulk motion of plasma or by the onset of a jet and Comptonization corona.

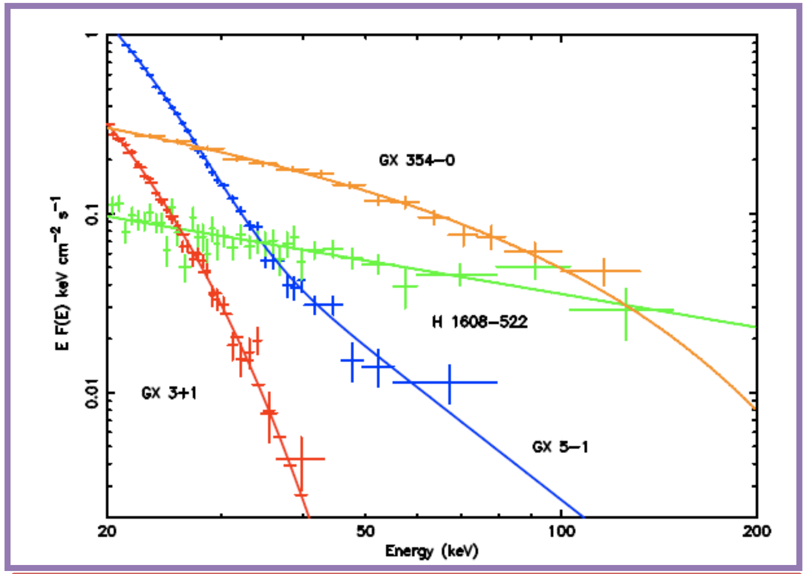


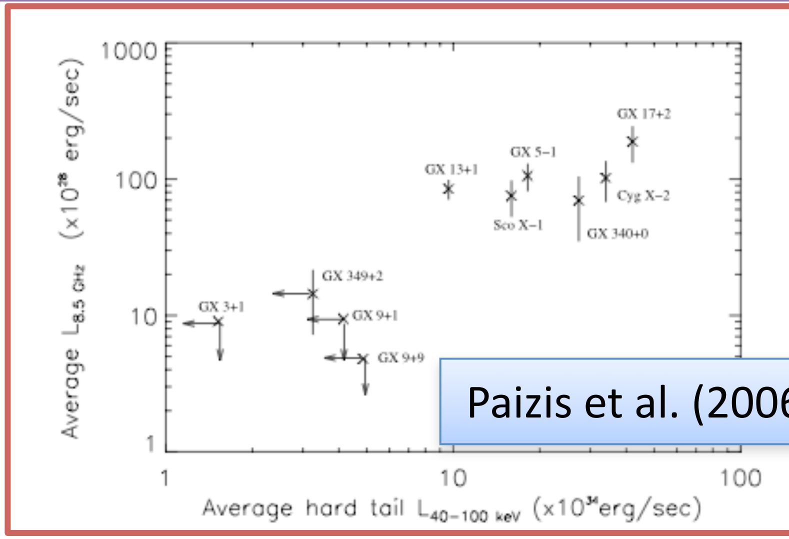


Done et al. (2007)

Spectral states of LMXB

- They show different spectral states from very soft to very hard.
- Using INTEGRAL it has been possible to study the average emission over years to characterize the sources in terms of soft, intermediate and hard states.
- Emission is explained in terms of a thermal and bulk Comptonization model.
- A correlation of the hard tail with radio emission suggests a common origin, probably in the Compton cloud close to the NS surface.





Paizis et al. (2006)

Conclusions

- INTEGRAL contributed in understanding the emission mechanisms in accreting pulsars, but many issues remain still open.
- The increased exposure time on several objects has not been exploited yet.
- New transient phenomena are continuously discovered also thanks to the ISDC quick look analysis.
- For forthcoming proposals, a great effort should be put in inter-playing the INTEGRAL observations with other instruments for multi-wavelength campaigns, e.g. with FERMI, Swift, XMM-Newton, radio telescopes.

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- Completing the puzzle of the 2004-2005 outburst in V0332+53: the brightening phase included **Tsygankov Sergey et al.** Monthly Notices of the Royal Astronomical Society, Volume 401, Issue 3, 2010, pp. 1628-1635