The X-ray spectral and timing behaviour of the accreting pulsar V0332+53

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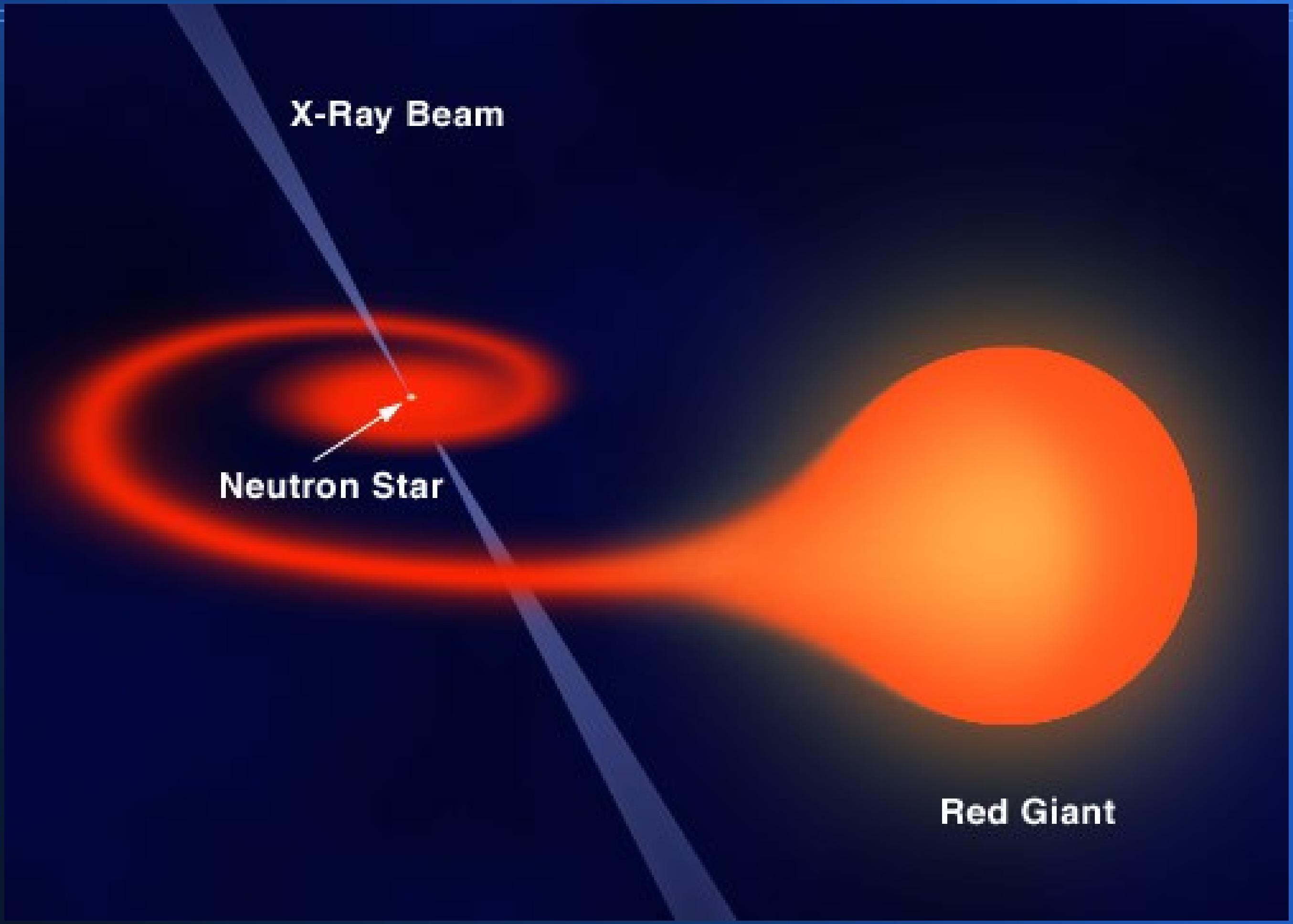
X-ray pulsars

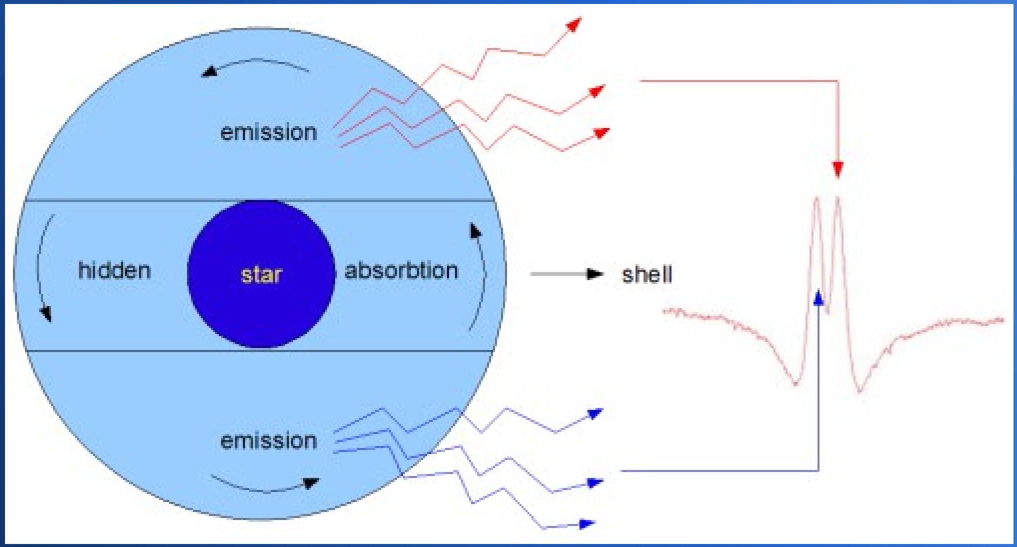


In a HMXB, the companion of the neutron star is a giant and the material is transferred from the giant to the neutron star. X-rays are emitted and a X-ray pulsar is formed.

Be X-ray pulsars

The companion star is a *Be* star that rotates very rapidly and apparently sheds a disk of gas around its equator (Porter & Rivinius, 2003).

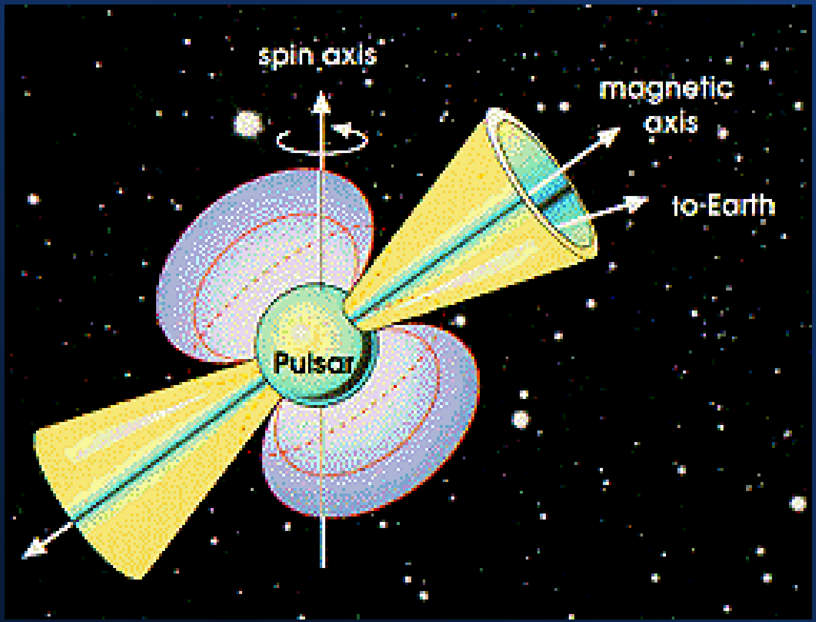
- The orbits of the neutron star with these companions are usually large and very elliptical in shape.
- When the neutron star passes nearby or through the *Be* circumstellar disk, it will capture material and temporarily becomes an X-ray pulsar.
- The circumstellar disk around the Be star expands and contracts, so these are transient X-ray pulsars.



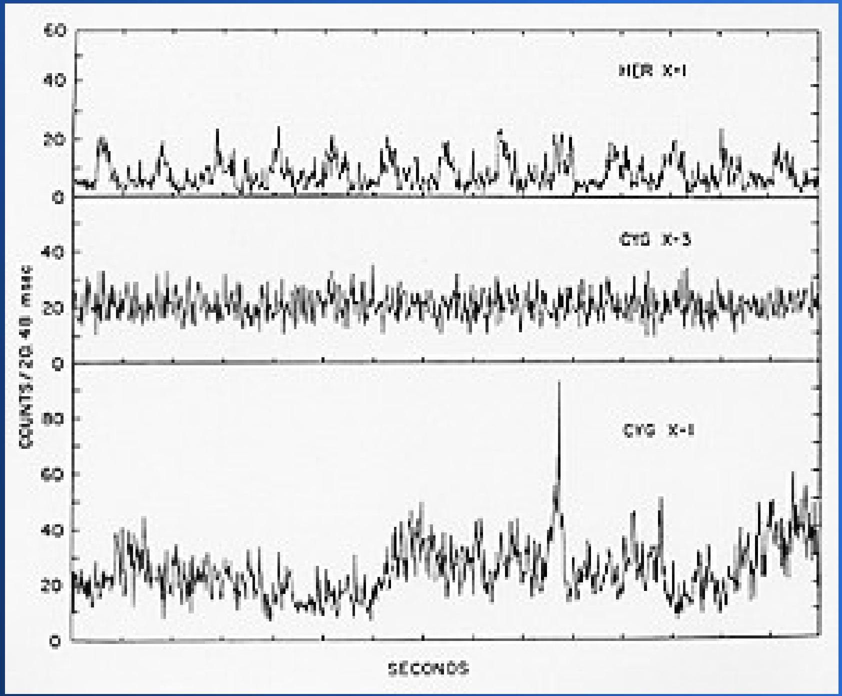
Model of a typical Be star (Kogure & Hirata. 1982)

X-ray pulses

- Due to the misalignment of the rotation and the magnetic field axes of the NS.
- They have as the period P_{spin}



A diagram of a pulsar, showing its rotation and magnetic axes.



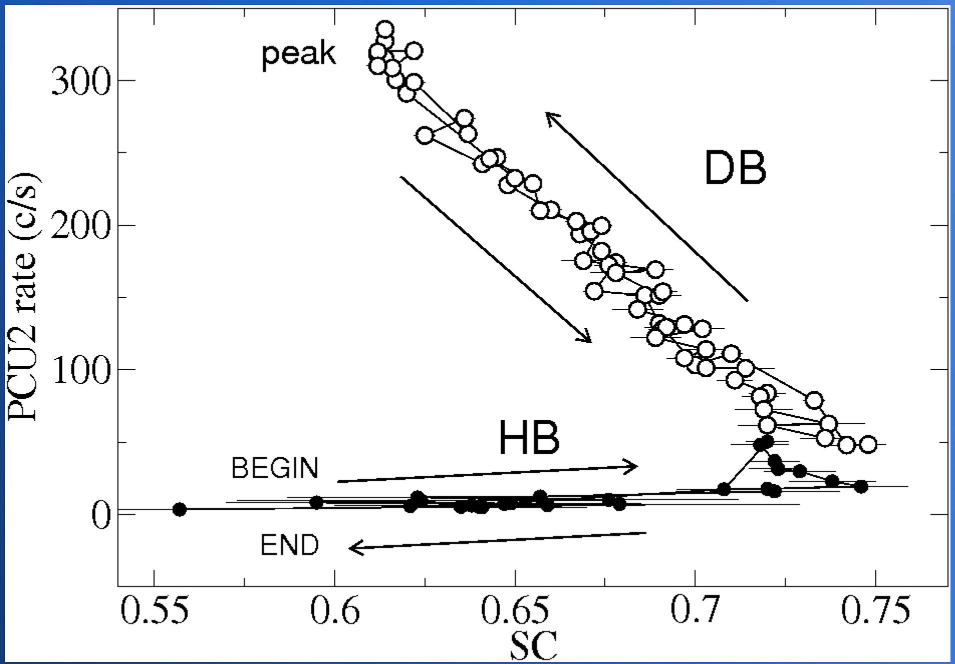
15-second X-ray samples. The 1.24 s pulsar period associated with Her X-1 is immediately evident from the data

V0332+53

- Be X-ray HMXB most of the time in the quiescent state. Interrupted by sudden increase of X-ray flux episodes (reaching the Eddington luminosity in type II outbursts).
- Discovered by the *Vela 5B* satellite (Terrell & Priedhorsky, 1984; Whitlock, 1989).
- Optical counterpart is a O8-9Ve star at D = 7 kpc (Negueruela+1999)
- Discovery of *pulsations* with X-ray period of P_{spin} = 4.4 s
- Orbital parameters: P_{orb} = 34.2 d ; e = 0.31 (Stella+1985)
- X-ray spectra show *QPOs* (0.05 Hz, 0.22 Hz) and *cyclotron lines* (25 keV, 50 keV, 70 keV,...; Kreykenbohm+05, Tsygankov+06).

X-ray (accretion) states

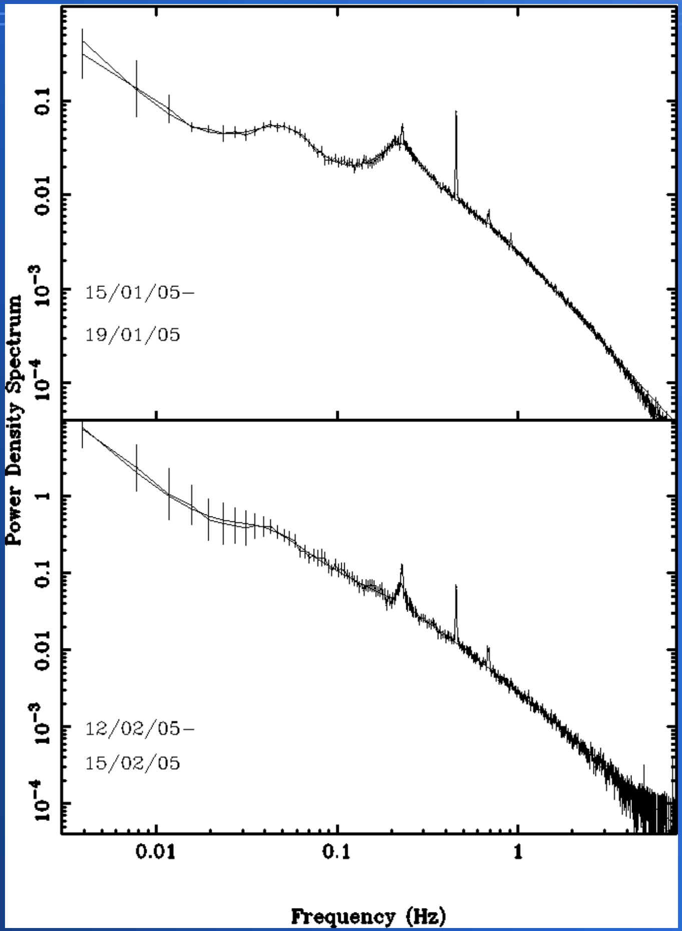
- Contrary to the case of BHs, timing-spectral studies of the accretion state in Be HMXBs have been barely performed.
- Only the **bright type II and giant outbursts** have been “widely” studied (Reig+06, Reig+12). $L_X > 10^{37}$ erg/s
- There are two branches (i.e. accretion states) in the hardness-intensity diagram: **<u>horizontal branch</u>** (low-intensity state, with high variability) and **<u>diagonal branch</u>** (high-intensity state).
- BUT: what is the situation for outbursts with $L_X < 10^{37}$ erg/s, i.e **<u>type I outbursts</u>** ???



Hardness-intensity diagram of KS 1947+300 showing two spectral branches: a low-intensity (horizontal) branch and high-intensity (diagonal) branch.

Quasi-Periodic Oscillations (QPOs)

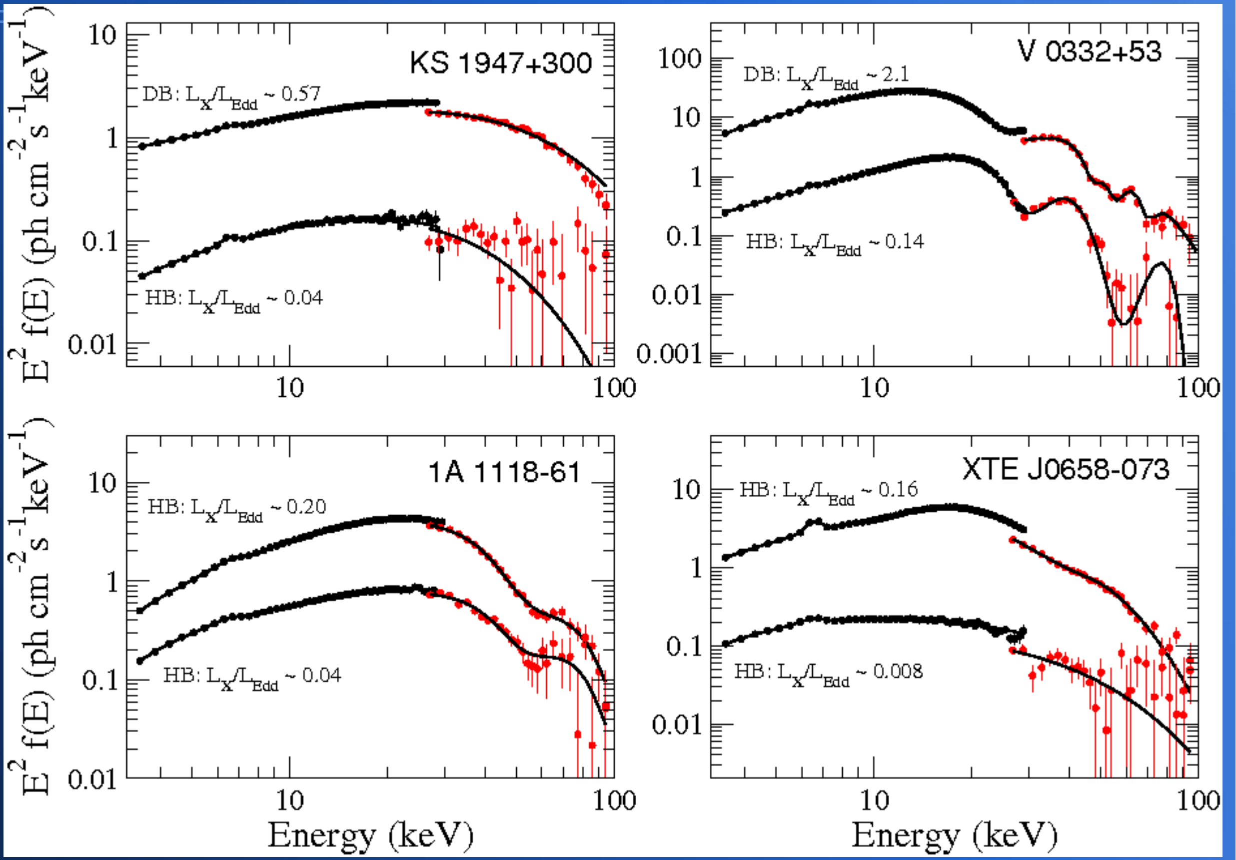
- They indicate the presence of an inner accretion disc.
- Sometimes present in the X-ray emission.
- Originated from the inner parts of the accretion disc around the NS (not necessary from the innermost regions).
- Frequencies commensurate with the spin of the NS (4.4 s).



Power spectra of V0332+53 obtained from two different datasets (Qu+2005).

Spectral analysis

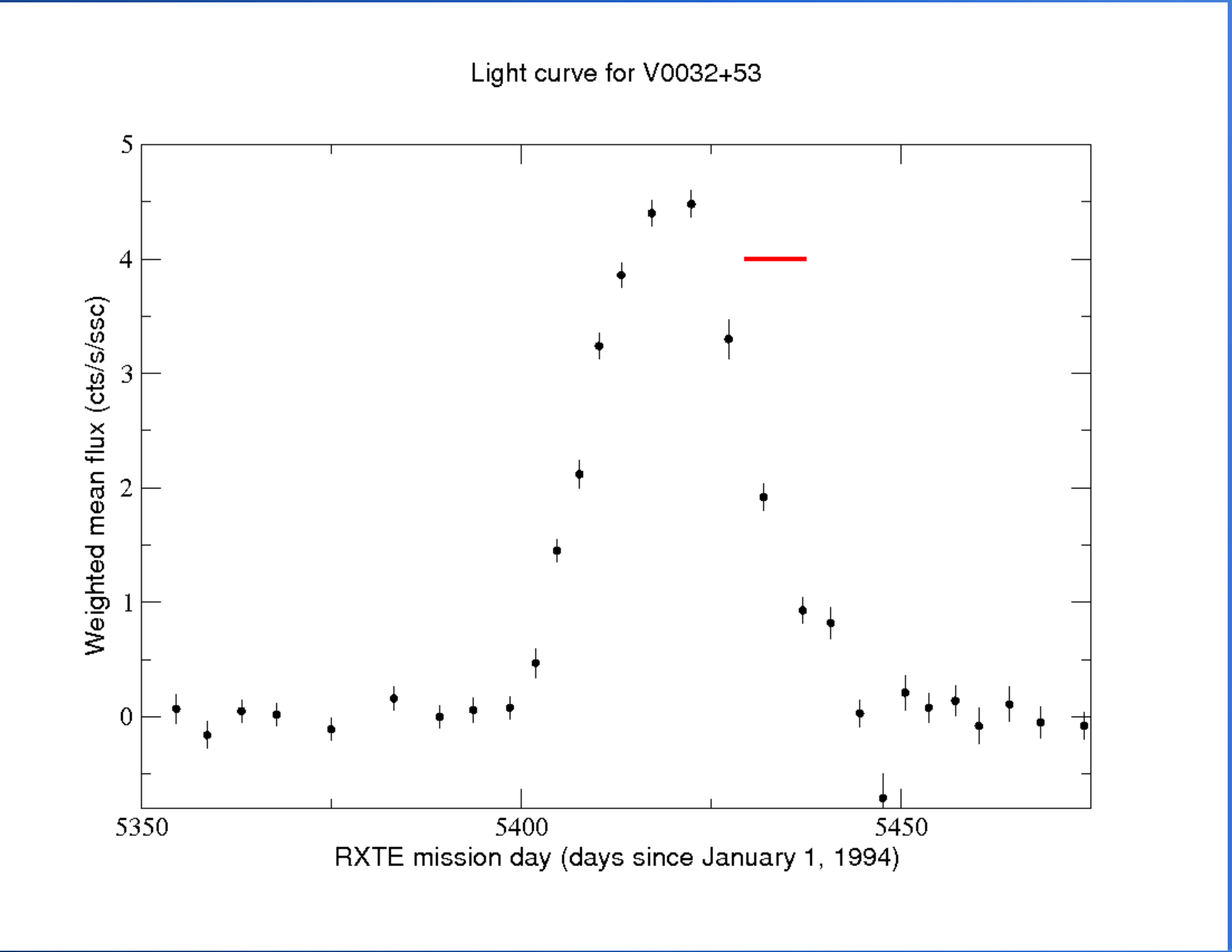
- *RXTE* spectra fitted well with a model consisting of a power-law with a high-energy exponential cut-off (@ 10-20 keV).
- Spectra distorted by the presence of cyclotron resonant scattering features → strong B
- Unknown physical components.
- Disc (diskbb) and Comptonization (compTT) components are present (Becker & Wolf, 2007; Ferrigno+09)



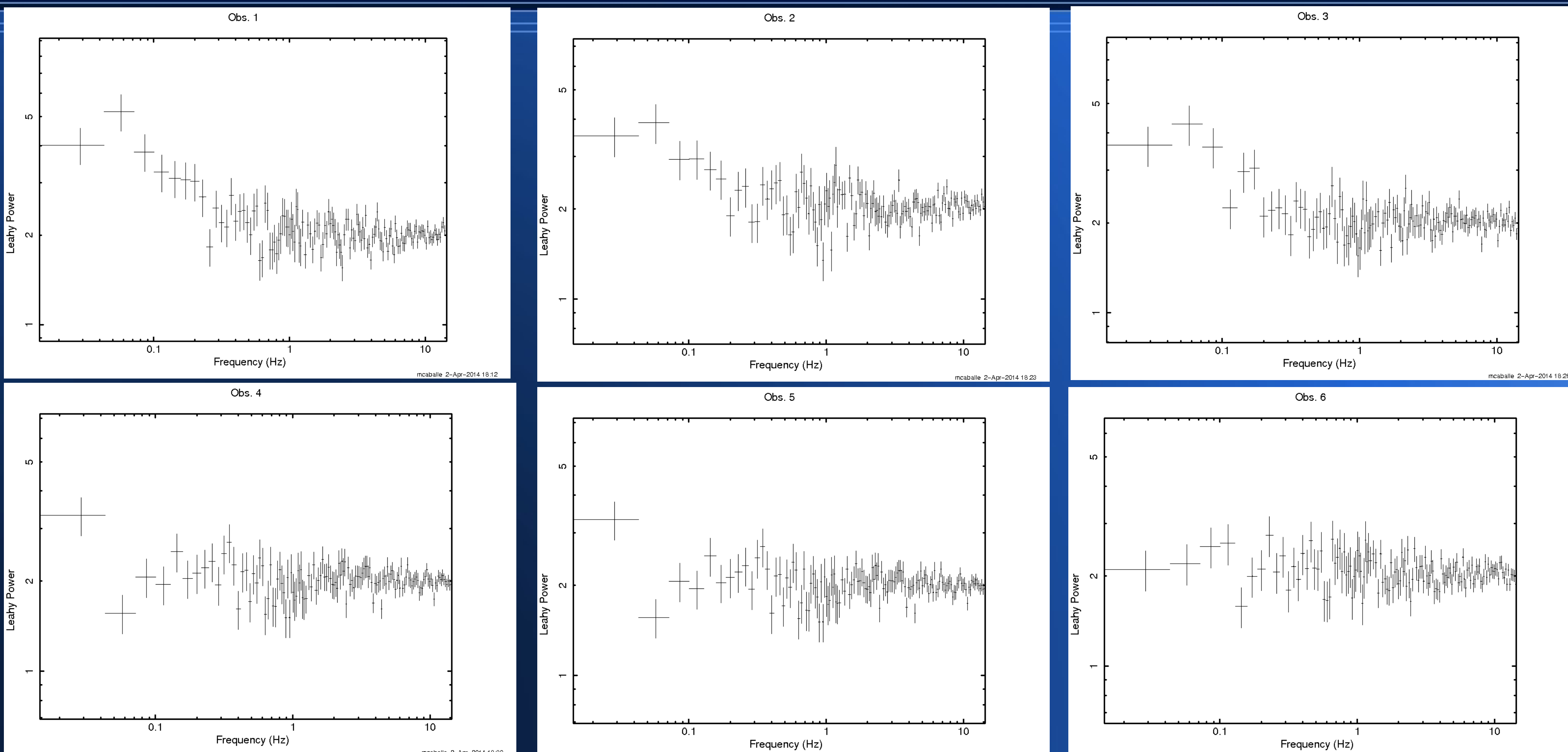
Average 2-100 keV energy spectra in the low and high intensity states (from Reig+12).

X-ray observations

RXTE/ASM light curve of the recent outburst during 2008 from V0332+53. The ***outburst in 2008*** *was covered with SWIFT, but the source was* ***not very bright****.*



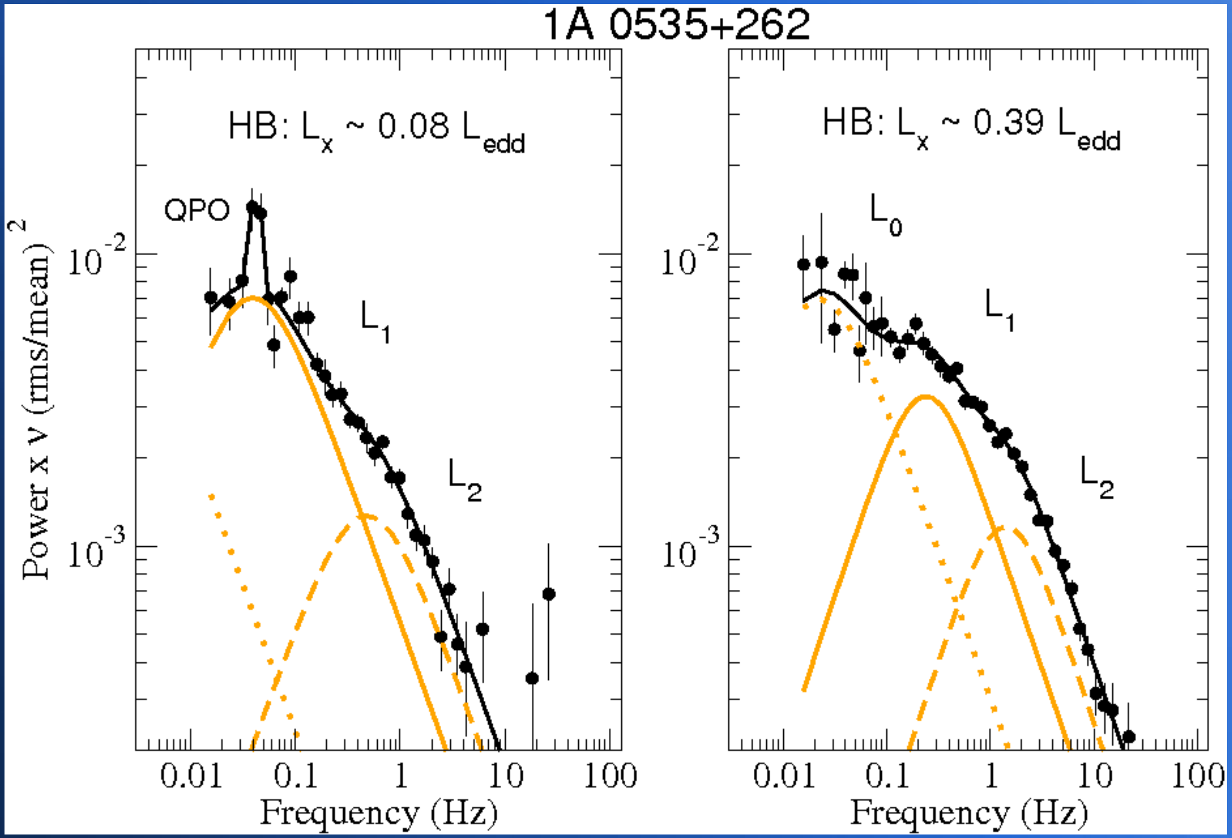
Timing analysis



(1-10) keV Power Density Spectra from the SWIFT/XRT light curves.

Timing analysis

- Fast time variability (low frequency red noise) at scales of ~ 10 s is seen, intrinsic to the source (typical time-scales of the fast variability in HMXB systems).
- *The higher the intensity → the variable region approaches the NS*

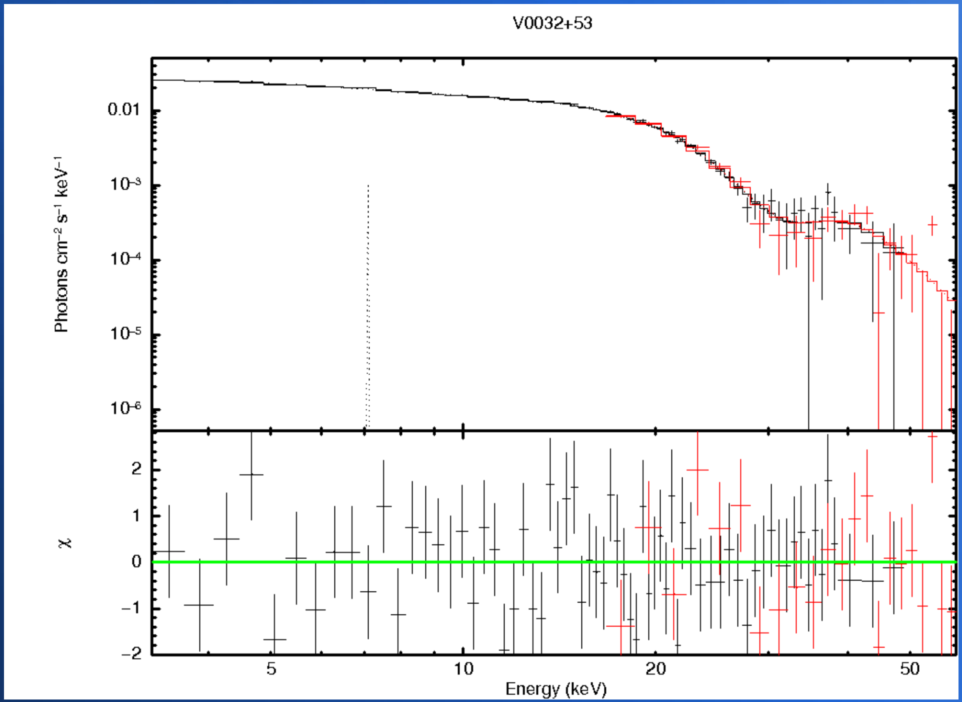


Power spectra for two levels of emitted (2-100 keV) luminosity (from Reig+12).

Spectral analysis

- Spectra well fitted with a model composed by a *powerlaw* with a *high-energy cut-off* plus a *Fe K line*@6.4 keV and a *cyclotron line*@30 keV.
- Low intensity state

  (L_X (0.3-10 keV) ≈ 10^{36} erg/s ≤ 0.02 L_{EDD}) → type I outburst → barely studied
- **<u>New accretion state? How is it characterised?</u>**



*(3-60 keV) RXTE spectra fitted with (gabs*gabs(gaussian+cutoffpl)) model.*

Conclusions

- Spectral-timing studies have been very useful to understand the physics of accretion for Black Hole binaries. Not performed yet for HMXBs with NS.
- We seek to use the same tools for HMXBs with NS.
- Previous works (Reig+) have shown *interesting* results for very bright accretion states.
- We have presented here an introduction of our work (*to be submitted very soon*) on the spectral-timing variability of the Be HMXB V0332+53 during its 2008 outburst (*SWIFT, RXTE* and *Suzaku* data).
- Our observations cover an unexplored low-intensity state. The goal is: **to give further insights into the accretion mechanisms around these (still enigmatic) compact objects !!!**