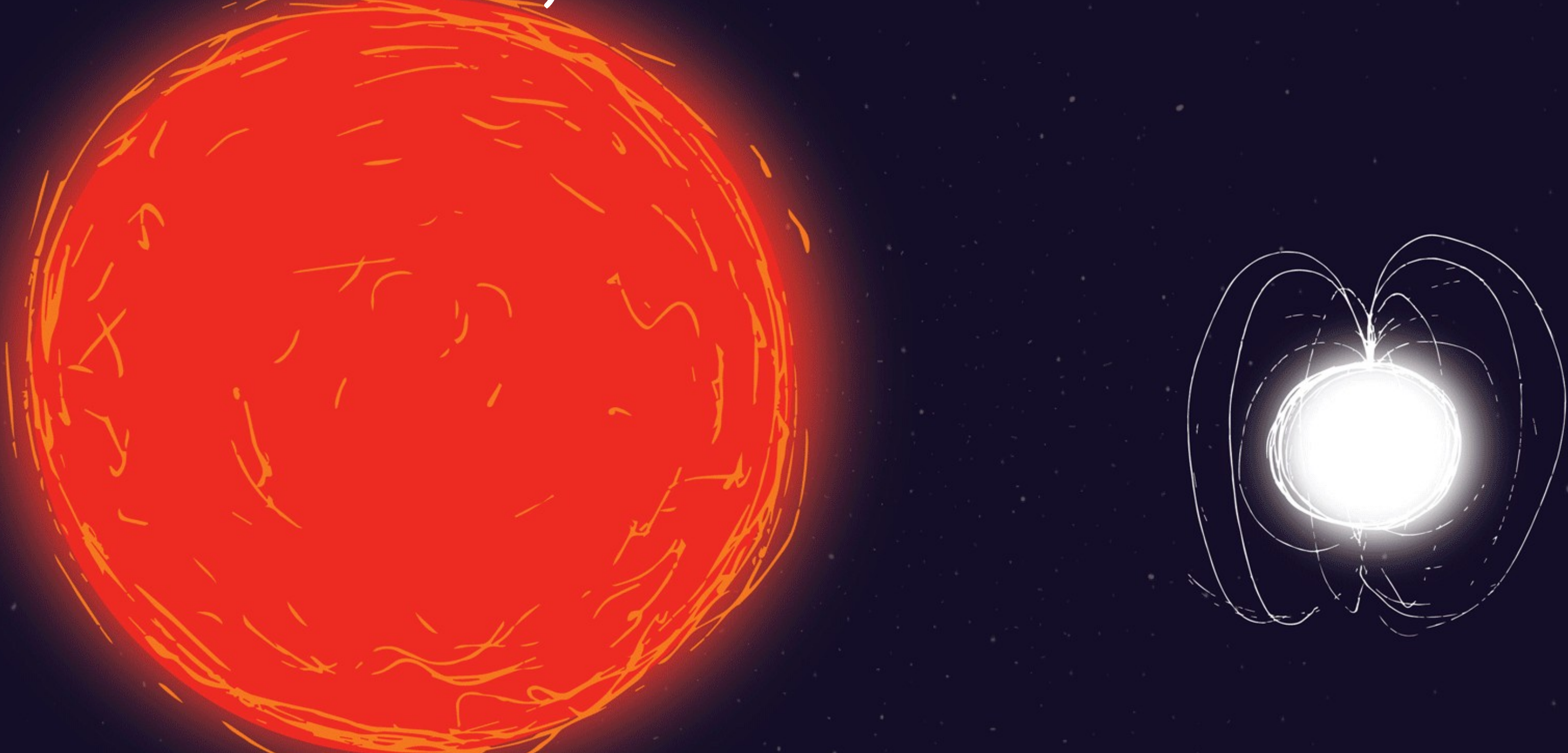
The symbiotic X-ray binaries Sct X-1, 4U 1700+24, and IGR J17329-2731



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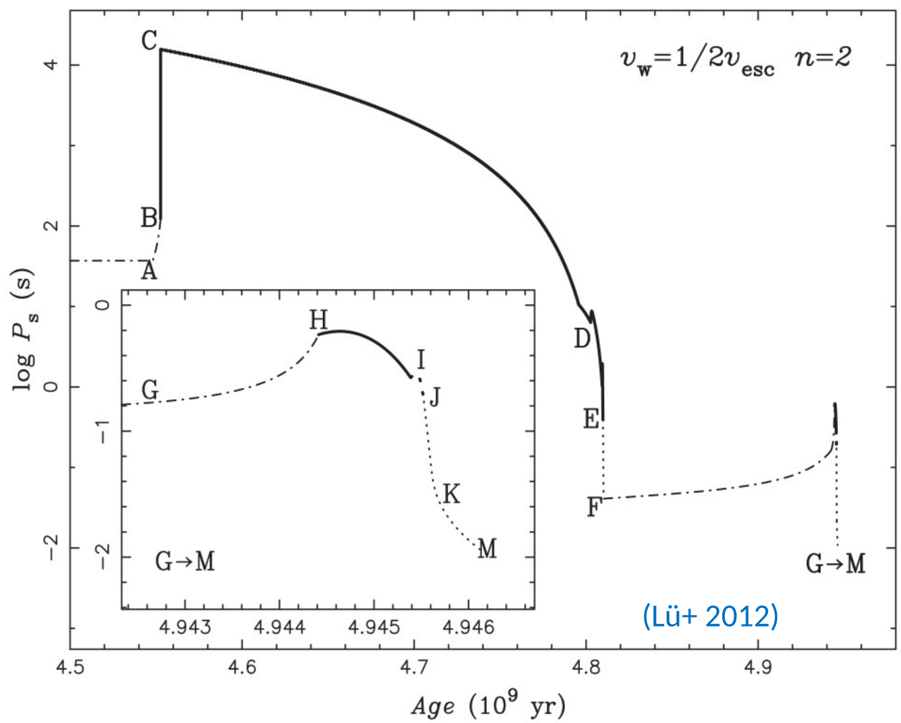
- **Peculiar class of Low Mass X-ray Binaries** (LMXBs):
  - Low mass companions
  - relatively low X-ray luminosity, L x $\sim 10^{34}$-10^{36} erg s^{-1}
  - flaring activity typical of wind-fed NS binaries
  - spin periods from several hundred to several thousand seconds
  - orbital periods of the order of months to several years
  - strong pulsations and pulsed fractions suggest highly magnetized NS (>10^{12} G)
  - X-ray spectra also typical of young pulsars
- **Evolution**:



Strongly depends on the details of:
- Progenitor mass distribution
- Mass accretion onto the NS and ejection due to propeller effect in disk- and wind-fed NS binaries
- Magnetic field decay law

(Kuranov+ 2015, Yungelson+ 2019)

The symbiotic X-ray binaries (SyXBs)

- Only 12 SyXBs known so far
- Rare systems and difficult to be identified
- Easily confused with wind-fed HMXBs
- First SyXB to be identified: GX 1+4 (1977)

SyXB	$P*$ (s)	P_b (day)	L_X (erg s^{-1})	d (kpc)
GX 1+4	≃140[1]	1161[2, 3] 295 ± 70[5] 304[6, 7]	10^{35}–10^{36} [4]	4.3[2]
~~4U 1954+319~~	~~∼18300 [8]~~	~~≳400?[9]~~	~~4×10^{32} [9]~~	~~1.7[9]~~
4U 1700+24	?	404 ± 20[6] 4391[23]	$2 \times 10^{32} - 10^{34}$ [10]	0.42 ± 0.4 [10]
Sct X−1	113[11]	?	2×10^{34} [11]	≥4[11]
IGR J16194–2810	?	?	$\leq 7 \times 10^{34}$ [12]	≲3.7[12]
IGR J16358–4726	5850[13]	?	$3 \times 10^{32} - 2 \times 10^{36}$ [14]	5–6; 12–13[15]
CGCS 5926	?	∼151[16]	$\lesssim 3 \times 10^{32}$[16]	5.2[16]
CXOGBS J173620.2–293338	?	?	$\sim 9 \times 10^{32}$ [17]	?
XTE J1743–363	?	?	?	∼5[18]
XMMU J174445.5–295044	?	?	$\gtrsim 4 \times 10^{34}$ [19]	$3.1^{+1.8}_{-1.1}$ [19]
3XMM J181923.7–170616IGR	407.9 [20]	?	$2.78 \times 10^{34} d_{10}^2$ [20]	?
IGR J17329–2731	6680 ± 3 [21]	?	?	$2.7^{+3.4}_{-1.2}$ [21]
IGR J17197–3010			$\lesssim 1.6 \times 10^{35}$ [22]	6.3–16.6[22]

(Yungelson+ 2019)

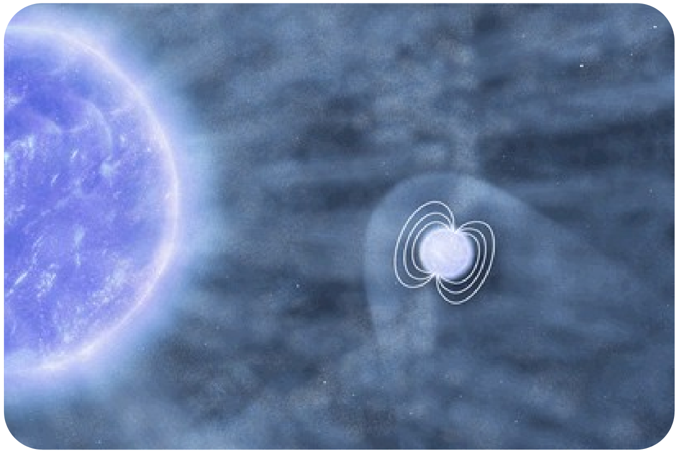
Why SyXBs are so interesting?

- **(could be used to) Probe NS channel formation via accretion induced collapse of a white dwarf**

    - A strongly magnetized NS (if demonstrated) cannot be Gyr-old (magnetic field decay). Thus the NS must be formed later on during the latest stages of the binary system evolution (Tauris+ 2013)

- **(most) SyXBs are wind accretors with NSs**

    - NS can be used as an «in situ» probe of the red giant wind
    - These are dust-driven winds, yet poorly known (as well as «deviations» from better explored accretion scenarios in the case of line-driven winds).



Probing stellar winds with accreting NSs

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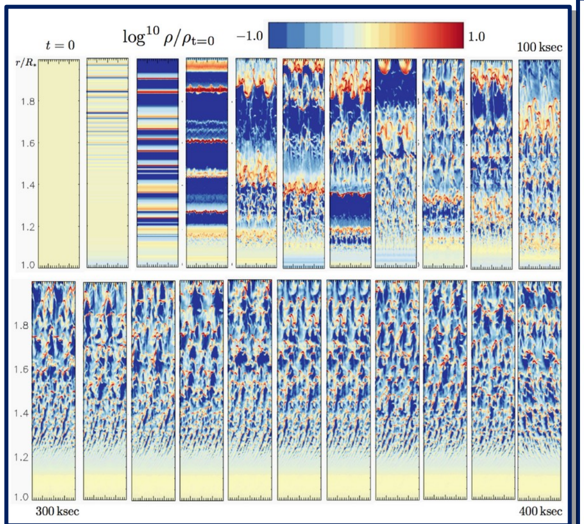
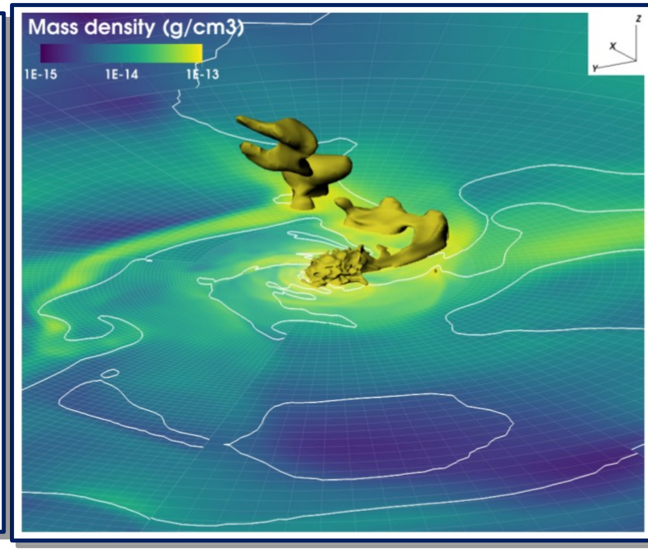
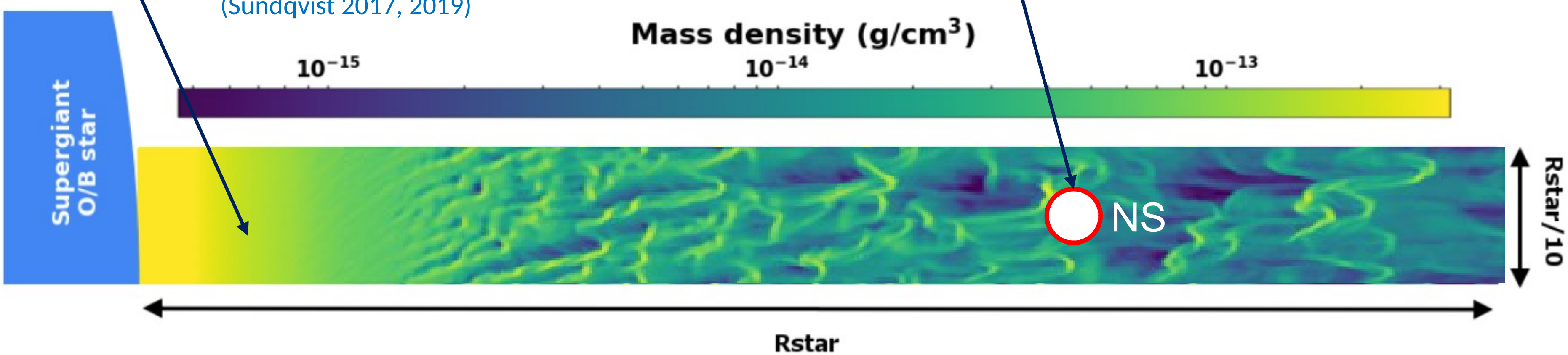


(Sundqvist 2017, 2019)

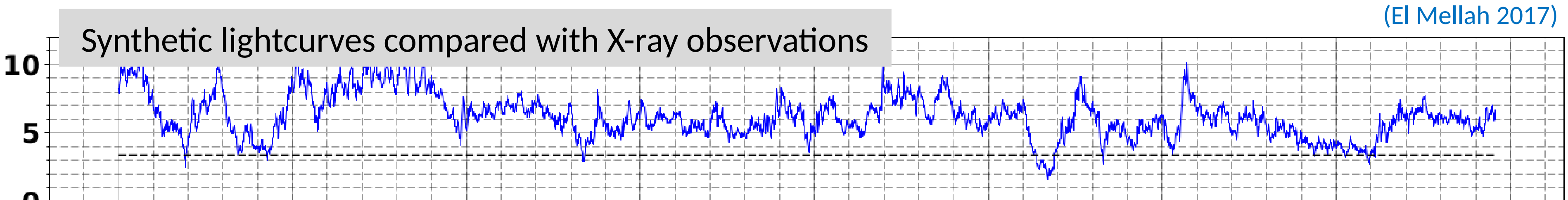


Merging knowledge of stellar winds from isolated stars with accretion physics in wind-fed systems

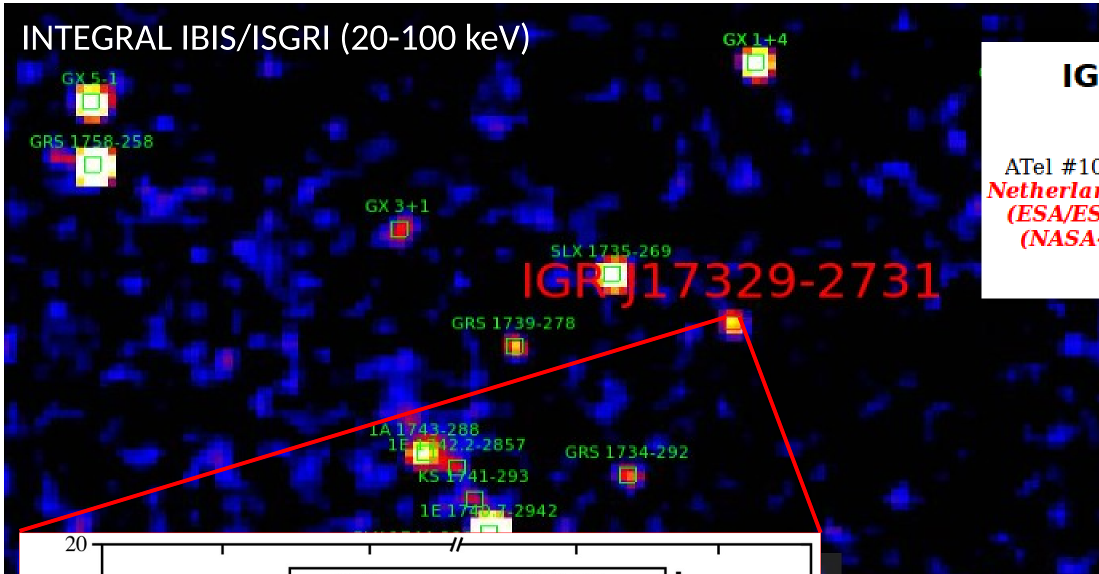
- Attempting to constrain stellar wind physical properties through X-ray observations of wind-fed X-ray binaries
(Martinez-Nunez+ 2017)



(El Mellah 2017)



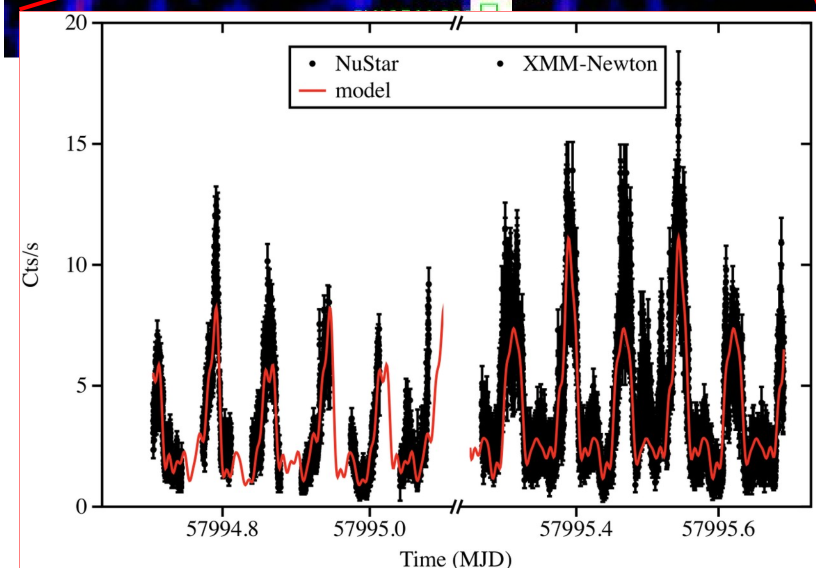
IGR J17329-2731: the newest SyXB

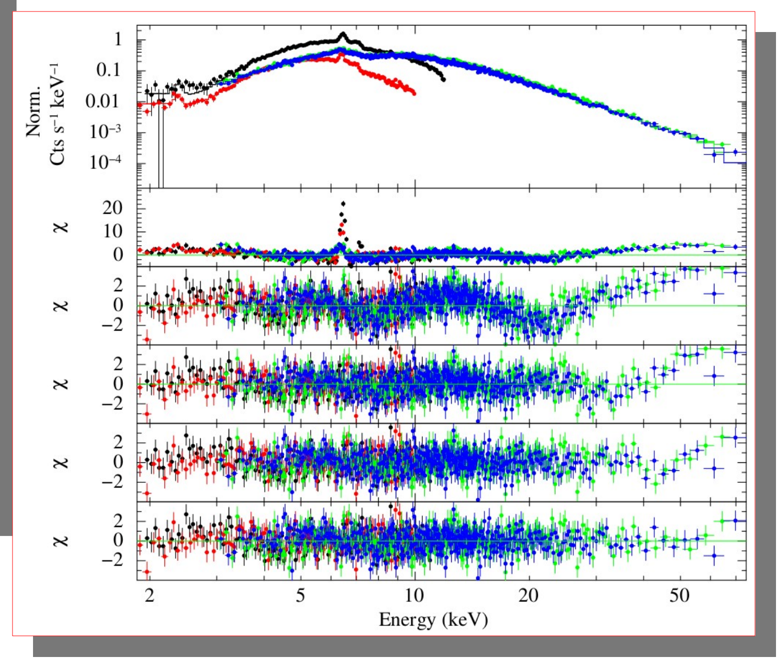


IGR J17329-2731: a new X-ray transient discovered by INTEGRAL

ATel #10644; *A. Postel (ISDC, Switzerland), E. Kuulkers (ESA/ESTEC, Netherlands), V. Savchenko (ISDC, Switzerland), C. Sanchez-Fernandez (ESA/ESAC, Spain), R. Wijnands (UVA, Netherlands), K. Pottschmidt (NASA-GSFC/UMBC, USA), V. Beckmann (CNRS/IN2P3, France), E. Bozzo (ISDC, Switzerland)*
on **15 Aug 2017; 21:27 UT**

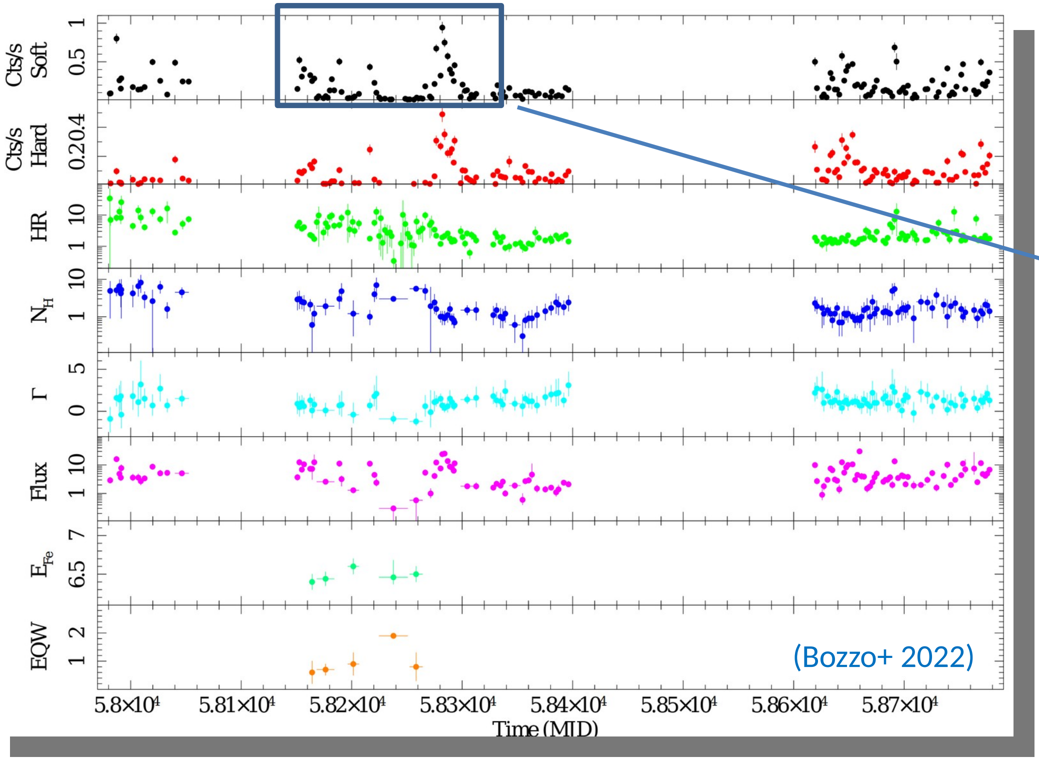
Pulse period **6680 s**
Cyclotron line in NuSTAR: **B~10^{12} G**
Companion M giant at **2.7 kpc**
Birth of a SyXB (no X-rays seen before)

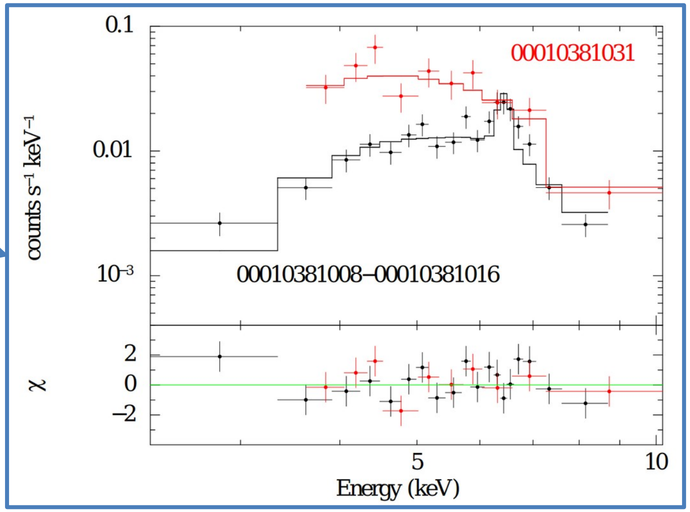




(Bozzo+ 2018)

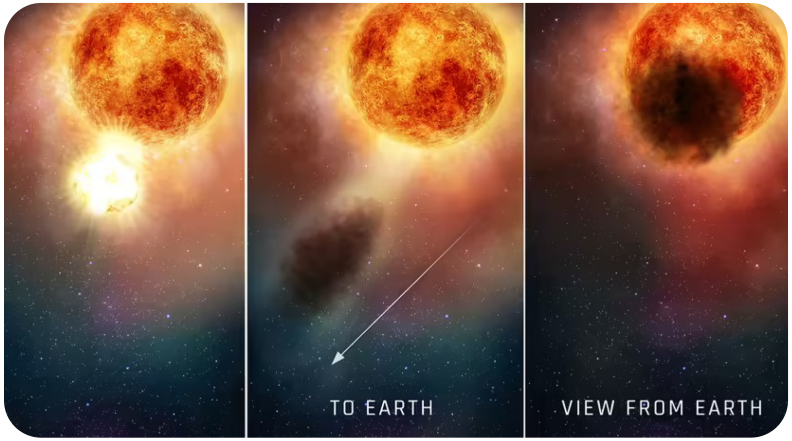
IGR J17329-2731: the newest SyXB





Strong spectral variability. Emerging iron line and flattening power-law: **obscuration** events

- **9 months daily** follow-up with Swift/XRT
- Strongly variable source
- Strongest flaring period ~2 months after discovery



Obscuration events due to:

- episodes of M giant **mass shell ejections**?
- NS encounters with **massive stellar wind clumps**?
- Direct probe of such structures! More data!

IGR J17329-2731: a milestone SyXB

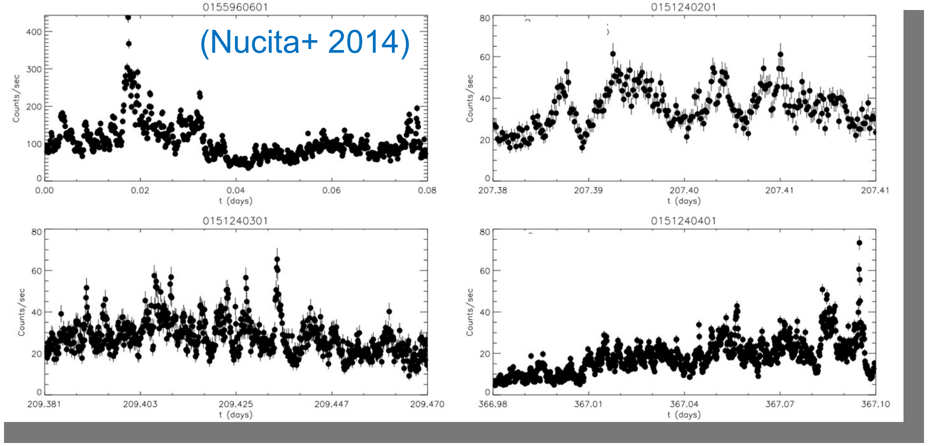
- **First direct measure of a strongly magnetized NS in a SyXB**
  - ➢ We find a direct proof that NS can be formed through the accretion-induced collapse of a white dwarf and that such collapses could give rise to magnetic fields as strong as $>10^{12}$ G

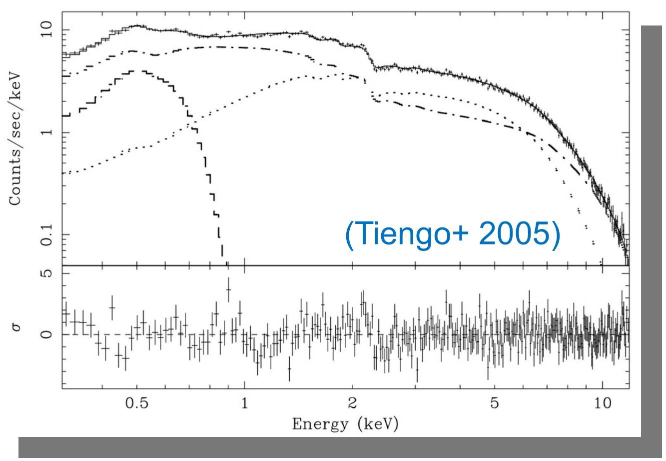
- **SyXBs are usually persistent while IGR J17329-2731 detected for the first time in X-rays**
  - Did we catch the «birth of a SyXB»?
    - ➢ Could be the beginnig of a substantial wind accretion phase but difficult to reconcile with the 4 mag brightening since 1991 (too much for a FGB)
  - Could be due to a «Thermal Pulse»?
    - ➢ Would explain the brightening since 1991 but these are expected for a giant on the AGB while evolutionary scenarios predict long spin periods more likely for the FGB phase

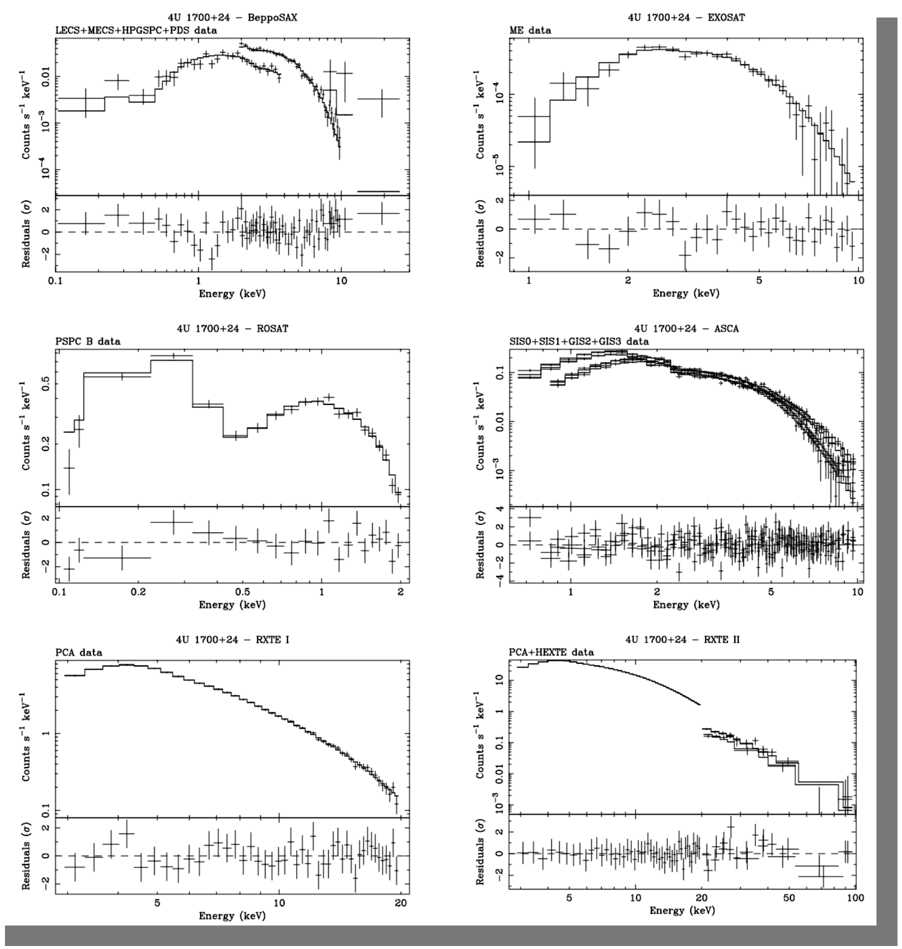
- **Follow-up observations revealed persistent and highly variable emission**
  - IGR J17329-2731 behaving as expected for a SyXB
    - ➢ After the «birth of a SyXB» the source become a variable but persistent object, as expected for a SyXB
  - Obscuration events associated to poorly knonw/understood dust-driven wind structures
    - ➢ IGR J17329-2731 deserves further attention and follow-up observations as it could be the gate toward a better understanding and direct probing of dust-driven stellar winds

- Discovered in the 70's
- Highly variable, outbursts detected by MAXI and Swift (dynamic range ⇒ L_X~200)
- Orbital period recently determined at 12 years (Hinkle+ 2019)
- Revised distance at 0.5 kpc (Arnason+ 2021)

(Masetti+ 2006)

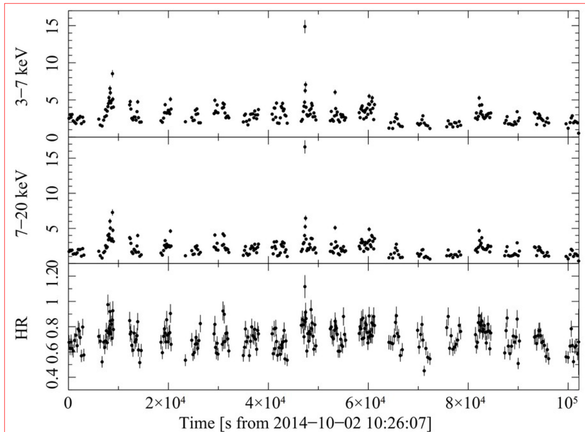






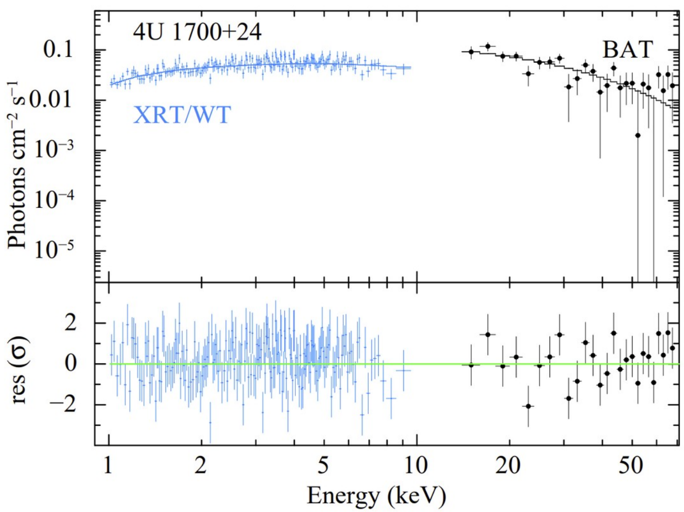
4U 1700+24: among the longest known SyXBs

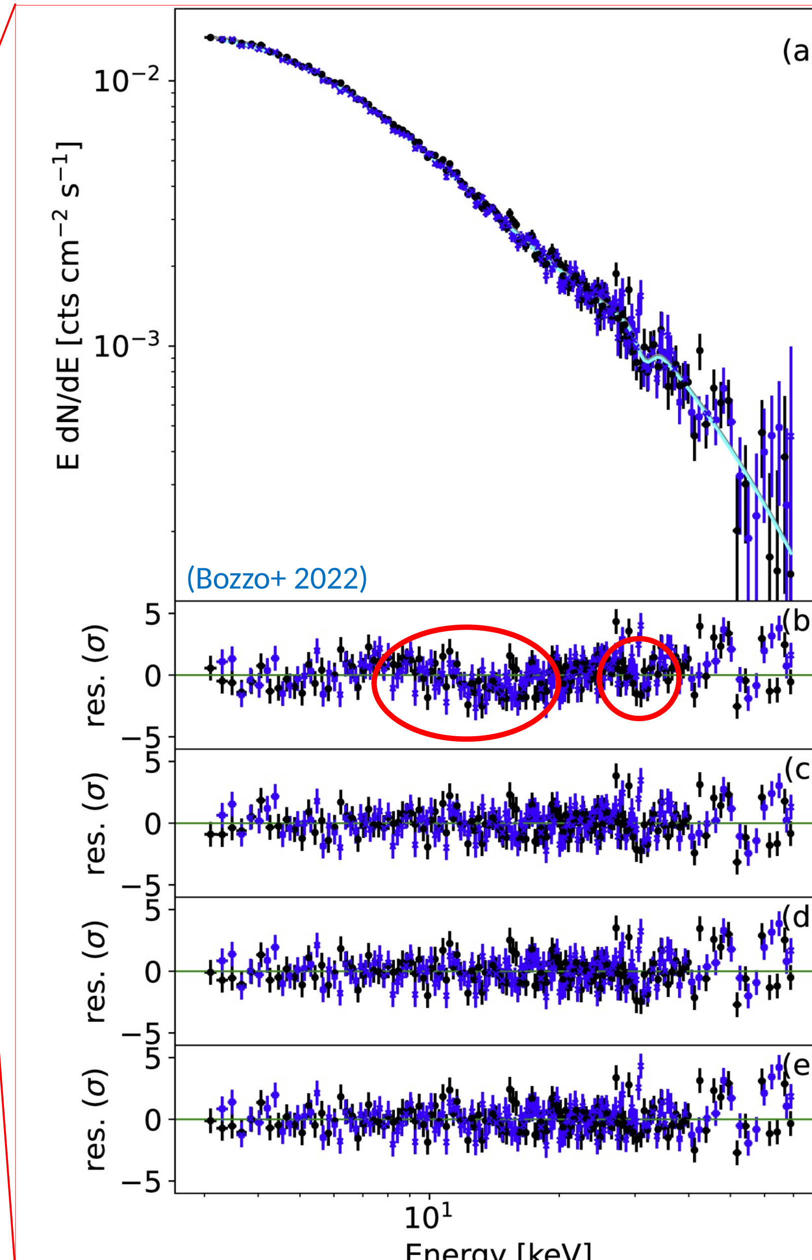
Lightcurve highly variable as expected



Residuals from a powerlaw fit show a «drop» at 15 keV:

- **cyclotron lines**
- high temperature **blackbody** (not compatible with XRT+BAT data)

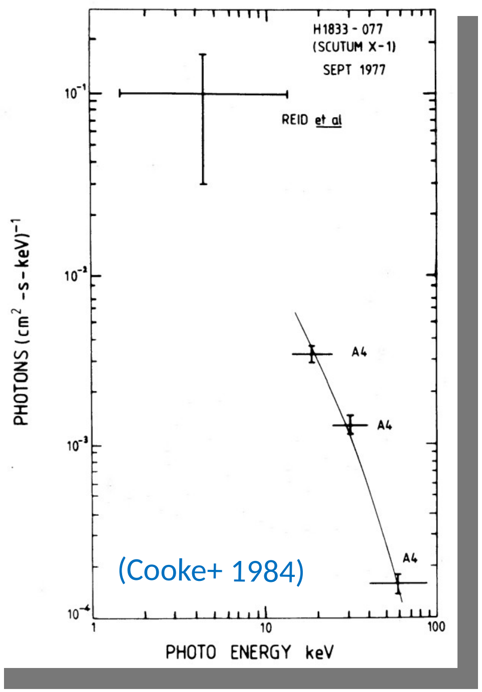


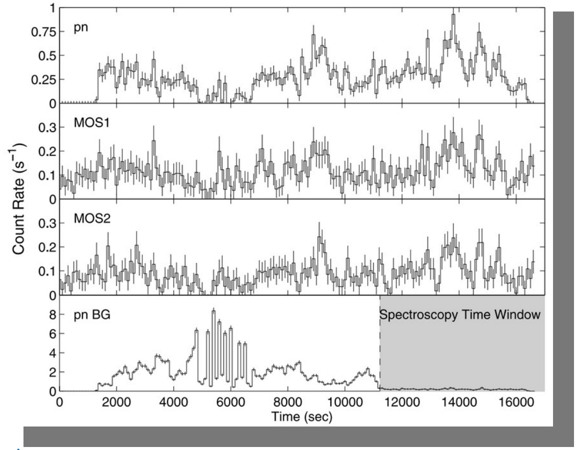


4U 1700+24: the second SyXB showing cyclotron lines?

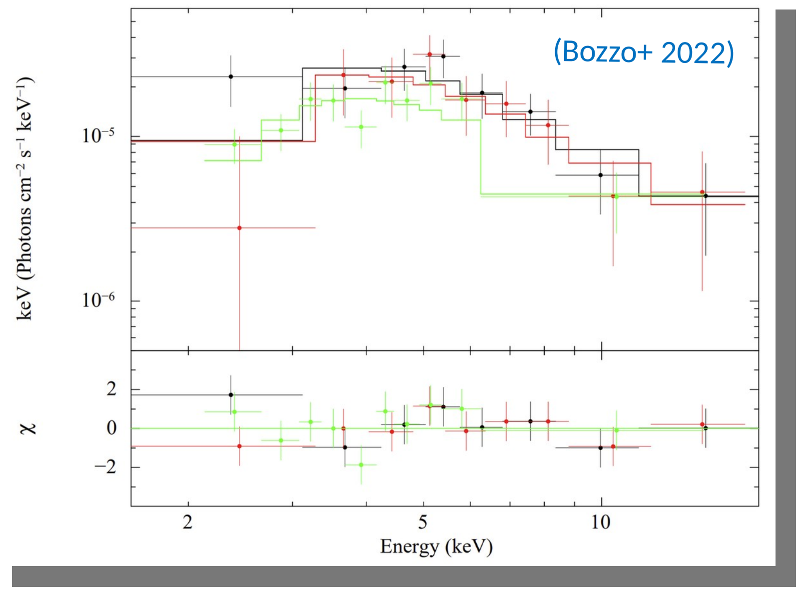
Sct X-1: a secular fainting SyXB

- Discovered in the 70's
- Highly variable (dynamic range ⩦ L_X~100)
- Relatively few dedicated observations, distance rough estimate ~4 kpc
- Pulse period of 113 s (Koyama 1991) last time confirmed by XMM-Newton (Kaplan+ 2007)





(Kaplan+ 2007)



- Our campaign: Chandra+NuSTAR (simultaneous)
- No cyclotron line detected (simple absorbed power-law)
- **Secularly fainted** from 3x10^{-10} (80's) to 2x10^{-13} erg/cm^2/s (2020)
- This is the second secularly fainting SyXB known (as XTE J1743-363)
- **The reason for such fainting remain to be understood**

Thank you!

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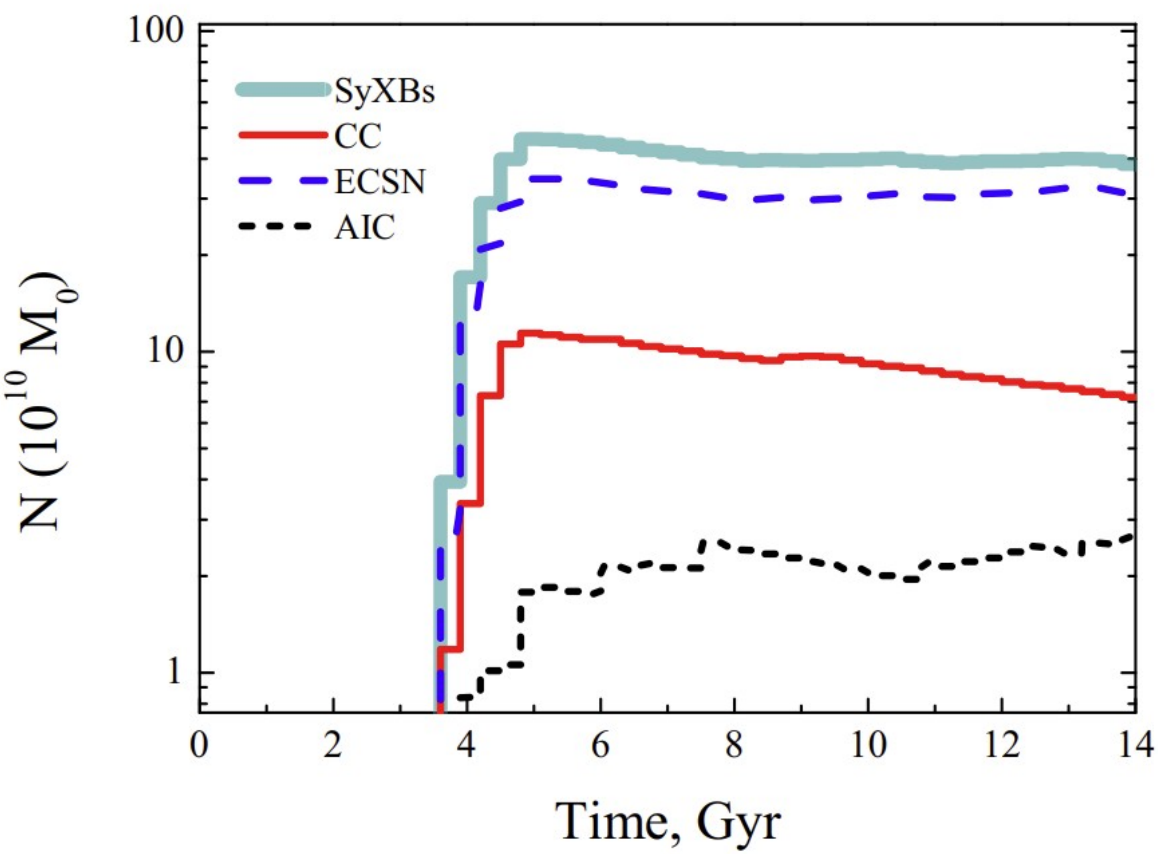
Accretion induced collapse of a white dwarf

Evolutionary calculations to form SyXBs exist, but they are strongly dependent on the accretion physics (poorly known)

The figure below shows that most of the NSs in SyXBs originate from ECSNe. The reason for this is clear: In their precursors, companions of the NS progenitors are (1–2) M stars. In such a case, a natal kick of only ∼100 km/s is sufficient to disrupt the binary in the SN event.



(Yungelson+ 2019)

Accretion induced collapse of a white dwarf

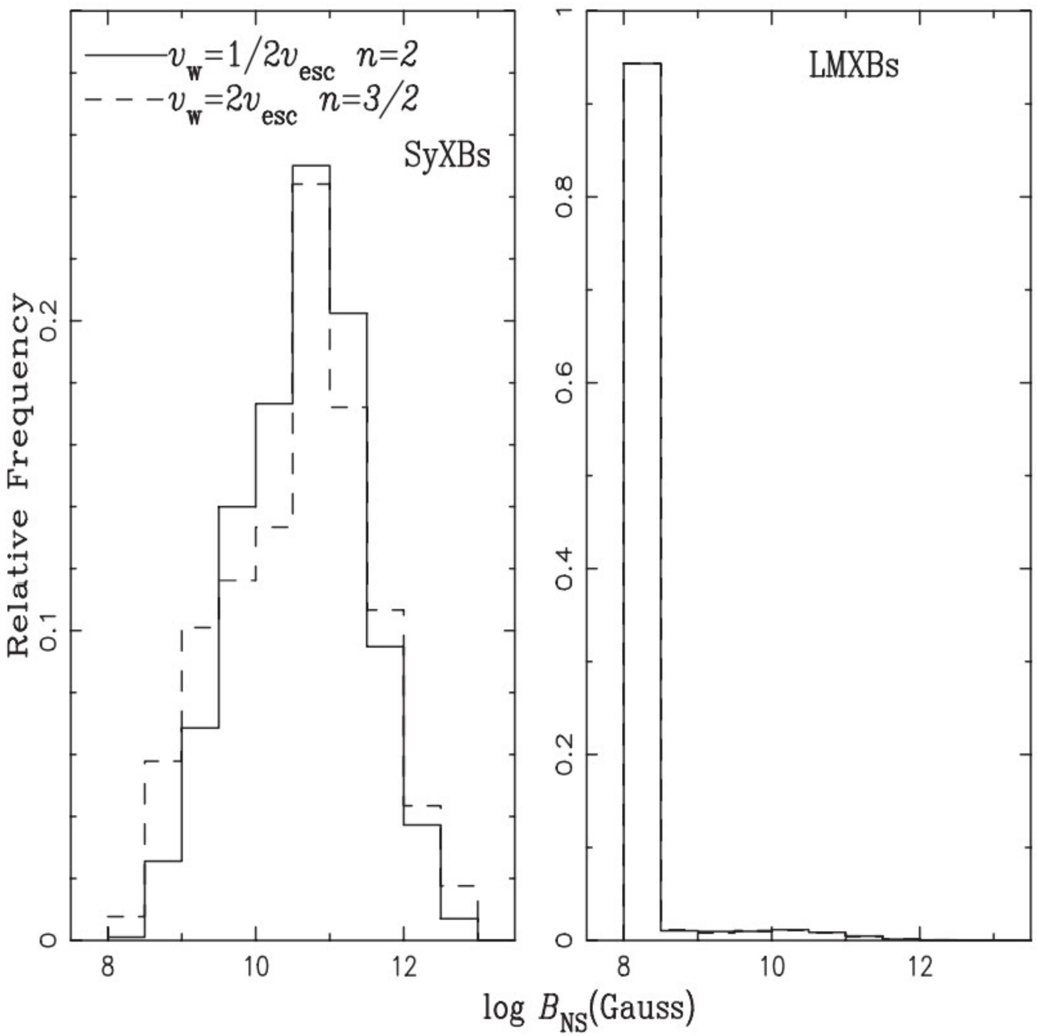


Figure 5. Similar to Fig. 4, but for magnetic fields of NSs in SyXBs and LMXBs.

Finally, we note that most of the model systems with NSs resulting from AICs have orbital periods too short to be identified with symbiotic stars.

This is in qualitative agreement with Hurley et al. (2010), who have shown that wide systems harbouring post-AIC NSs are exceptionally rare.

Below we will omit post-AIC NSs from consideration because the modelling of their magnetic fields and initial spins requires the study of the evolution of their WD progenitors, which is beyond the scope of this paper, and their vanishingly small number.

(Lu+ 2012; Yegelson+ 2019)

Accretion induced collapse of a white dwarf

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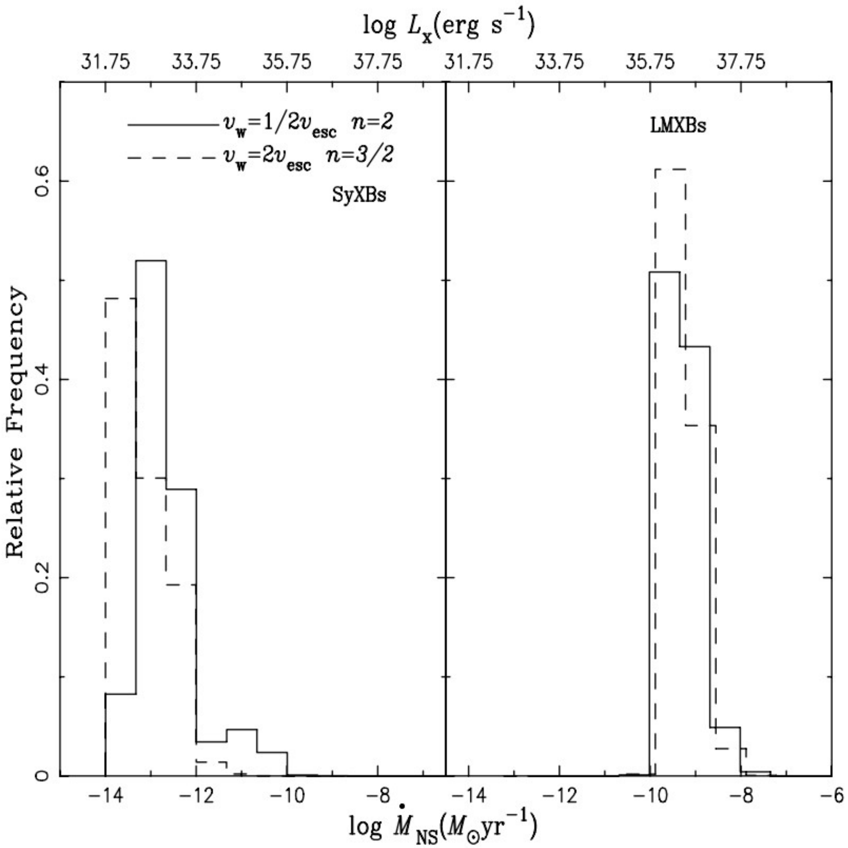

Figure 3. Distribution of accretion rates (X-ray luminosities) by NSs in SyXBs and LMXBs.

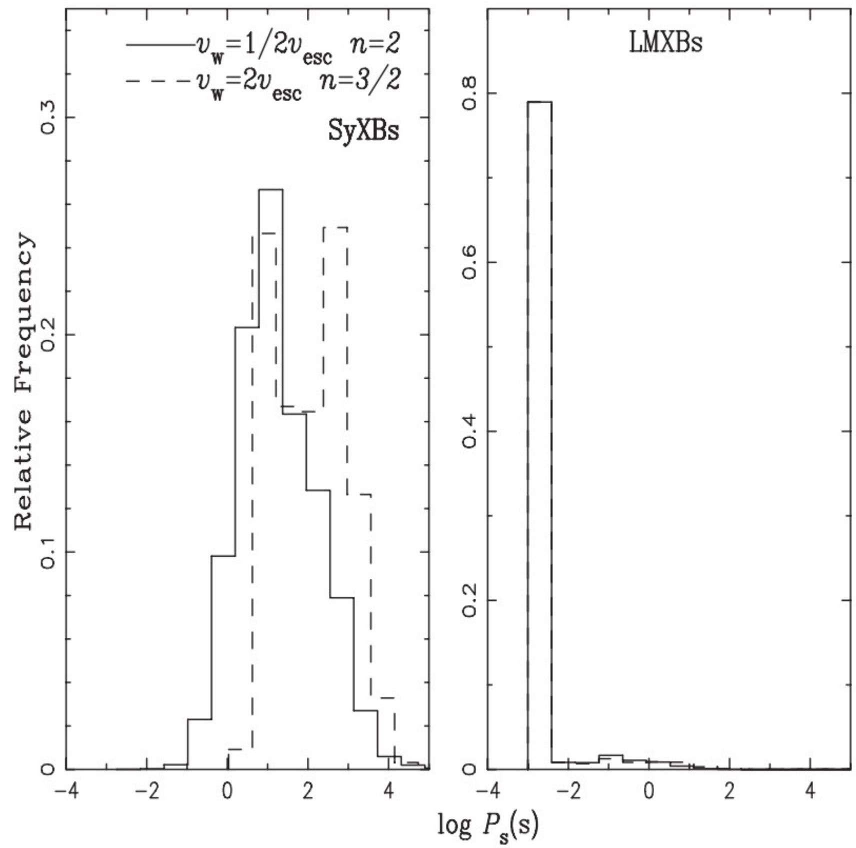

Figure 4. Number distribution of the spin periods of NSs in SyXBs and LMXBs. The left-hand panel is for the population of SyXBs and the right-hand panel is for LMXBs. The numbers are normalized to 1.

(Lu+ 2012)

Large international effort on-going since several years…

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