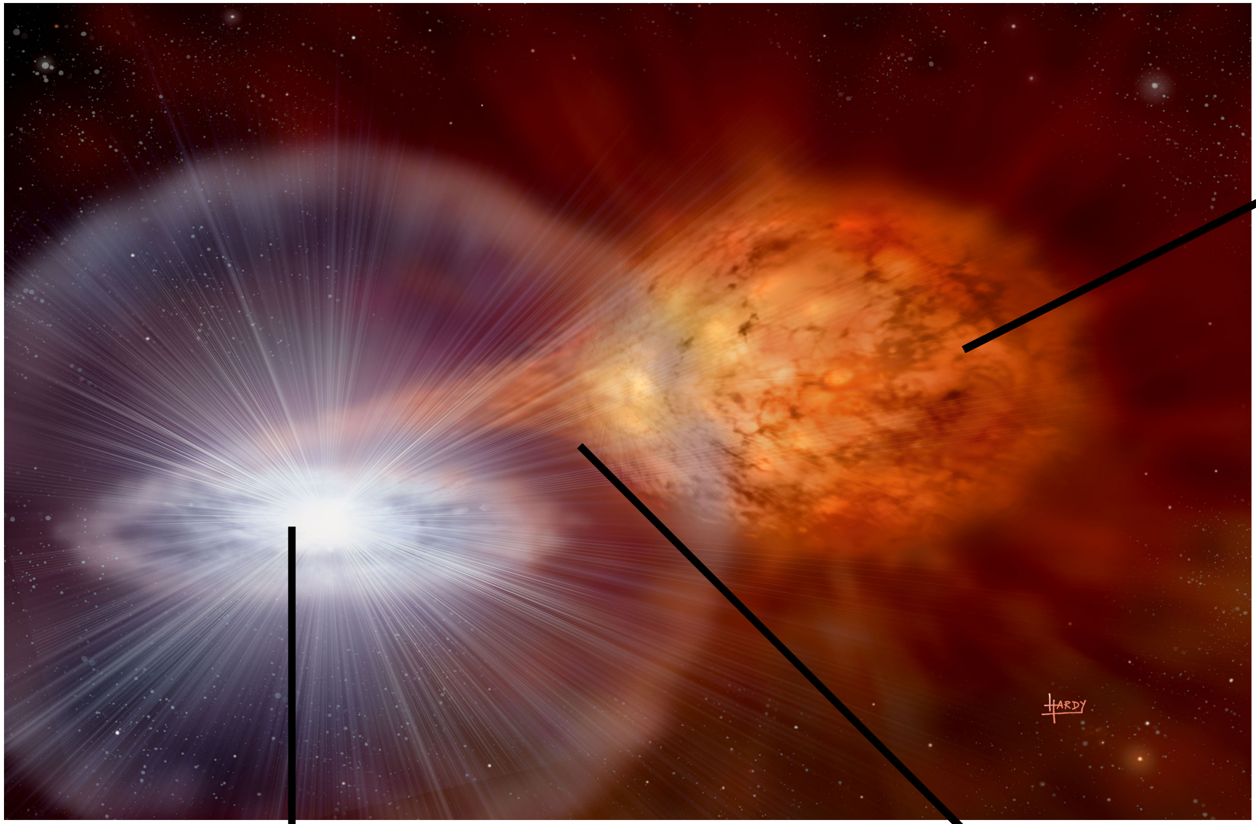
The INTEGRAL view of HIGH MASS X-RAY BINARIES

- *What is a X-ray binary?*
- *The ZOO of the X-ray binaries: LMXBs, HMXBs, SgXBs, BeXBs*
- *Accretion in SgXBs and the origin of the X-ray emission*
- *The INTEGRAL view of the Classical SgXBs*
- *The SgXB Vela X-1: INTEGRAL observation*
- *Beyond the classical SgXBs: INTEGRAL discovers the Supergiant Fast X-ray Transients*
- Very high energy emission from HMXBs

What is a X-ray binary?



Companion Star

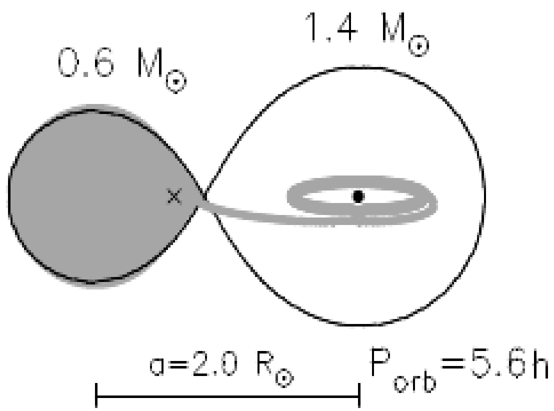
Neutron Star (NS)
we do not consider black hole binaries (see Claudio talk)

Matter is "somehow" transferred from the the companion star to the neutron star → "ACCRETION"

The ZOO of the X-ray binaries

Depending mainly on the nature of the compact object:

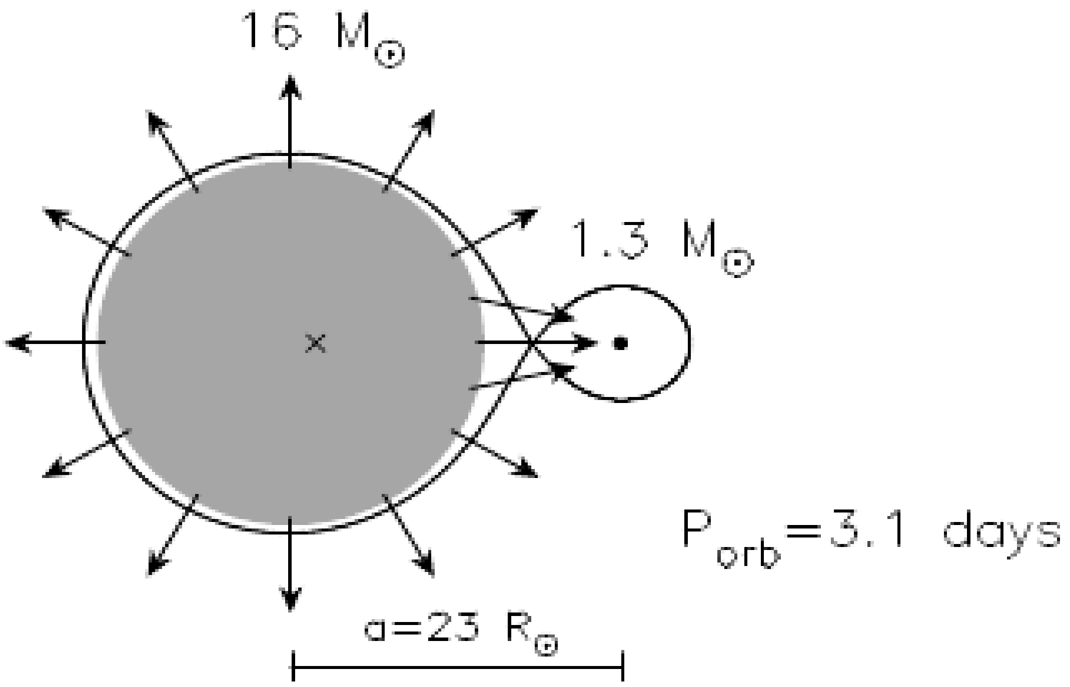
Low mass X-ray binaries



- Low mass companion star (<< 1 M_{SUN})
- Orbital periods few hours (compact)
- Old ages (10^8 - 10^9 yrs)
- Accretion through a disk

(see Carlo's talk)

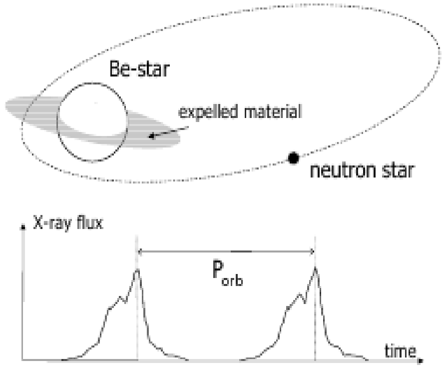
High mass X-ray binaries



- **High mass companion star (>> 1 M_{SUN})**
- **Orbital periods days**
- **Relatively young (10^6 - 10^7 yrs)**
- **Accretion through the companion wind**

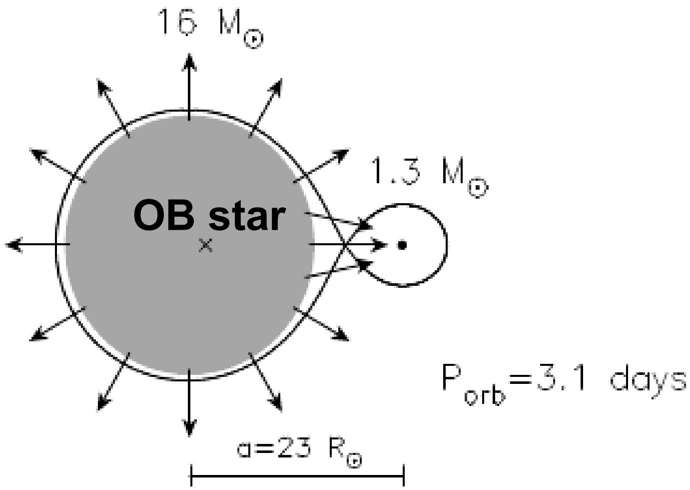
High mass X-ray binaries

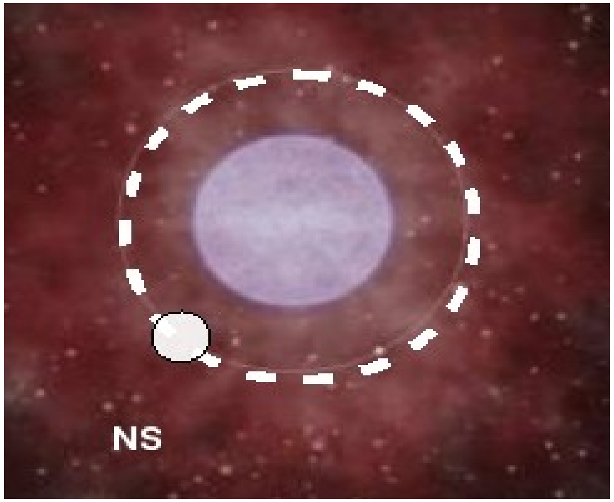
Be X-ray binaries



(see Carlo's talk)

"Classical" Super-giant Binaries (SgXBs)





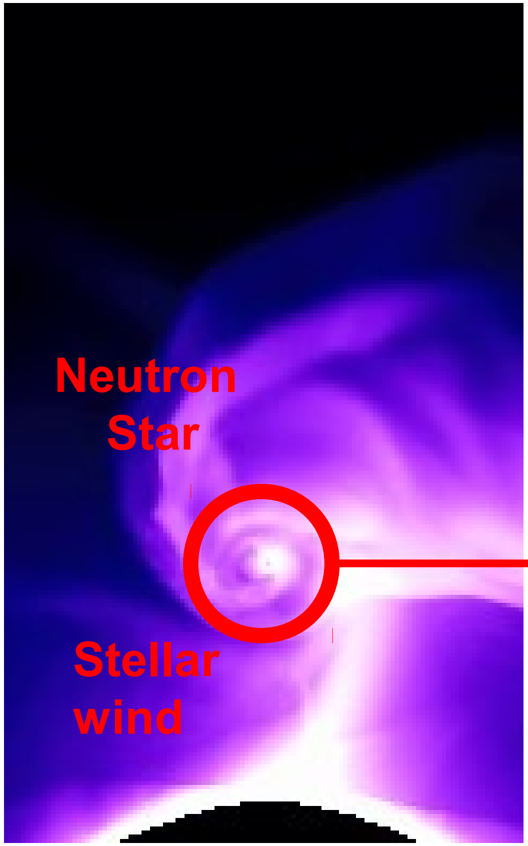
NS accretes matter from the supergiant OB companion star:

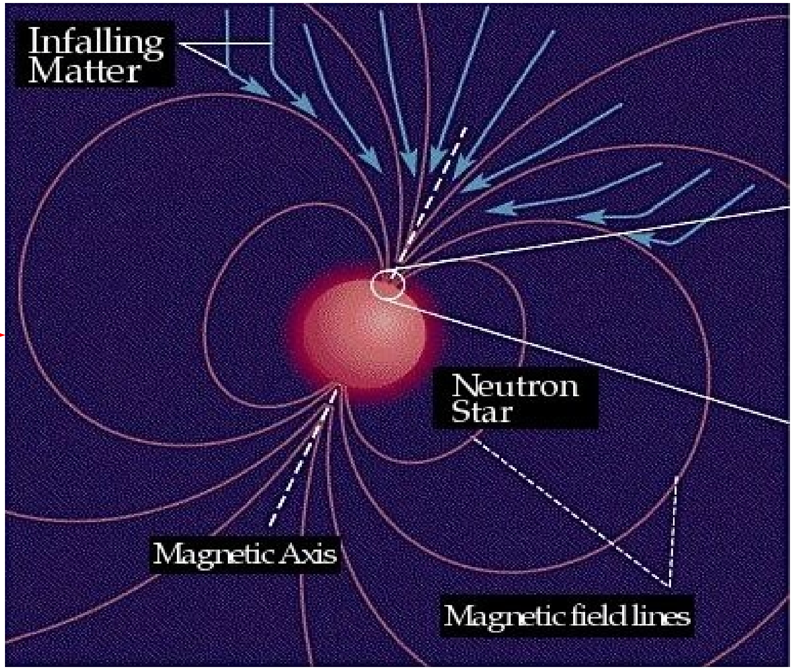
$L_X \sim 10^{35-37}$ erg/s

The origin of X-ray emission in HMXB

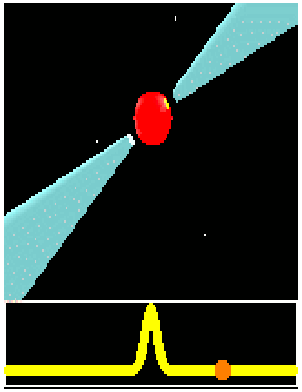
Magnetic field $\sim 10^{12}$ G

Young objects $\sim 10^{6}$ yr





Light-house effect

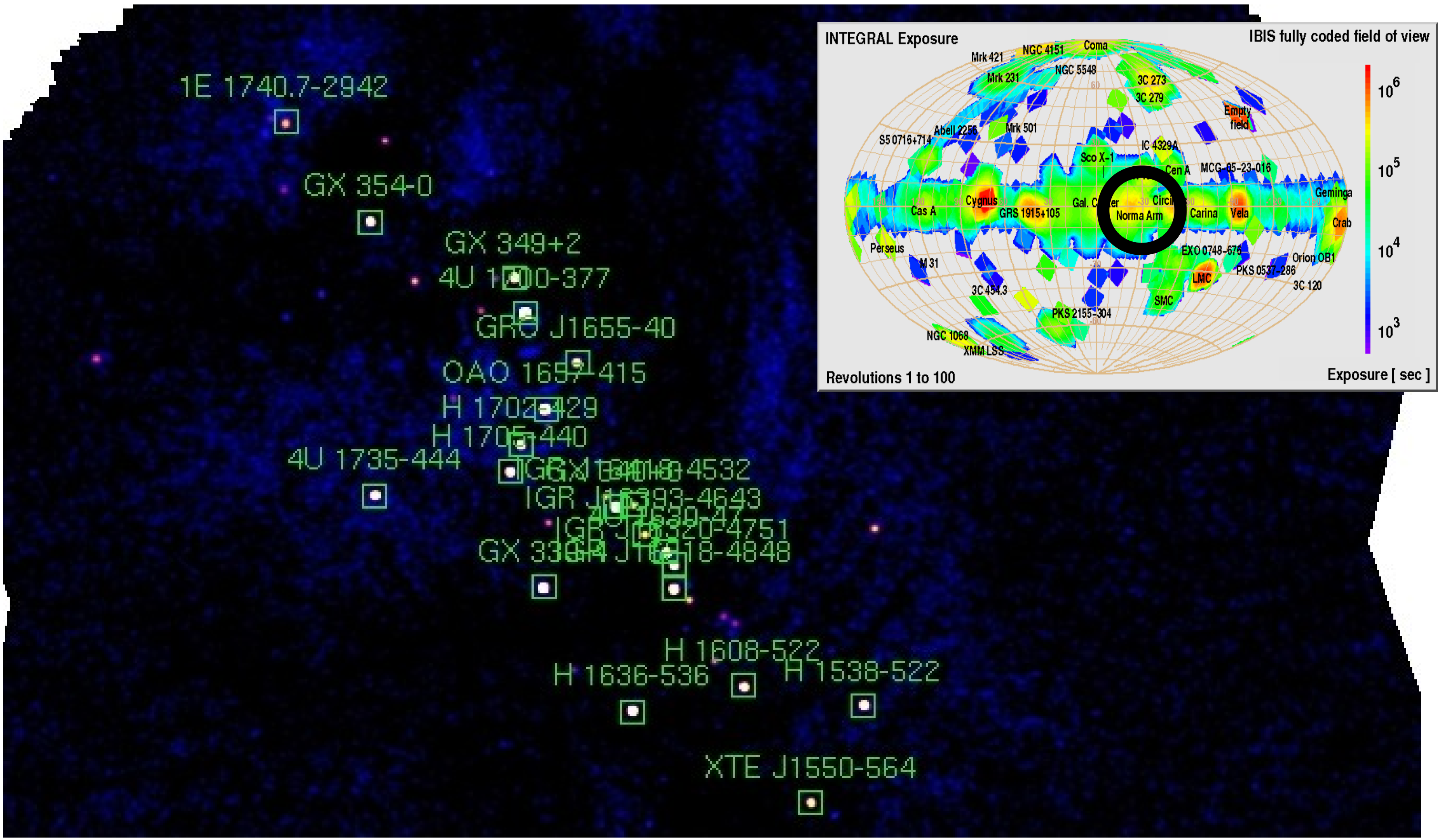


The **gravitational energy** of the inflowing matter is released onto the NS → T$\sim 10^{8}$ K → bulk of the **emission is in X-rays:**

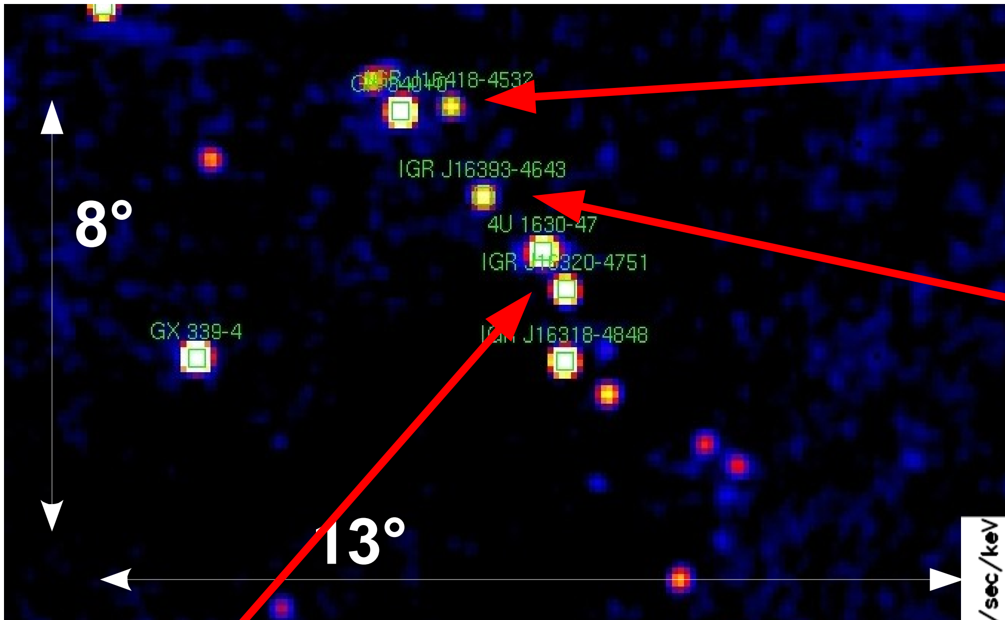
$$L_X = \frac{G M_{NS} \dot{M}}{R_{NS}} \simeq 10^{35} - 10^{37}\, erg\, s^{-1}$$

(~0.5-100 keV)

A quick look toward the Norma Region with IBIS/ISGRI (20-40 keV)



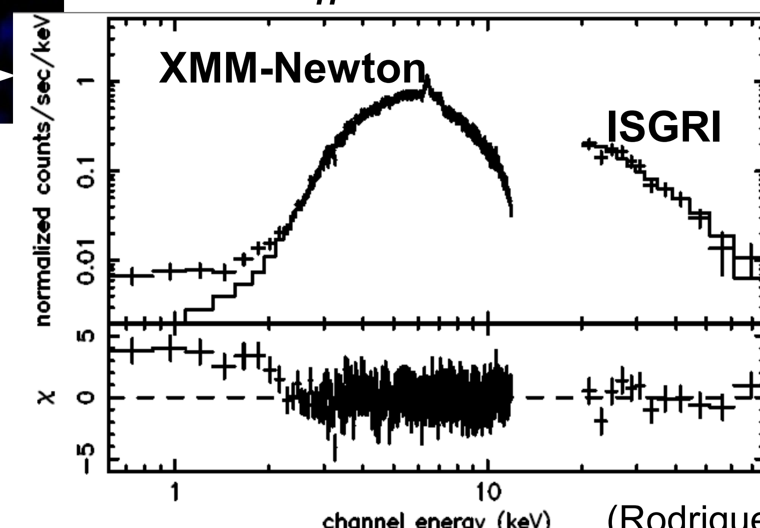
A quick look toward the Norma Region



IGRJ16418-4532
Pspin = 1200 s
Porb = 3.7 d
$N_H = 10^{23}$ cm^{-2}

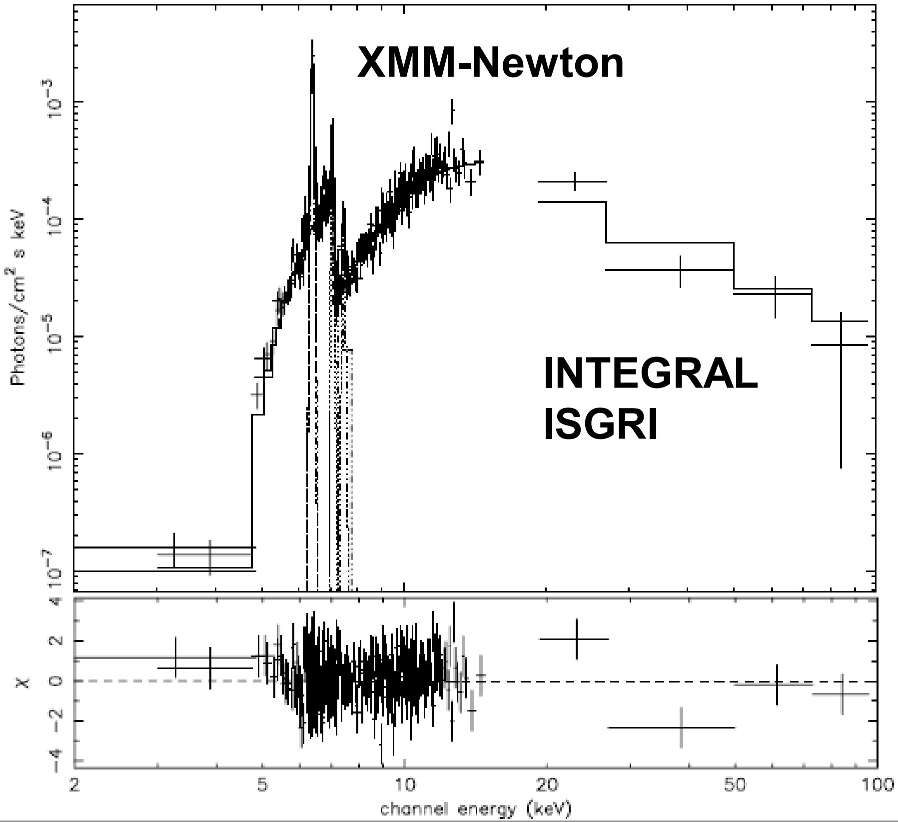
IGRJ16393-4643
Pspin = 912 s
Porb = 3.7 d
$N_H = 6 \times 10^{23}$ cm^{-2}

IGRJ16320-4751
Pspin = 1300 s
Porb = 9 d
$NH = 2 \times 10^{23}$ cm^{-2}



(Rodriguez 2008)

IGR J16318-4848: an extremely highly absorbed HMXB



(Walter 2003)

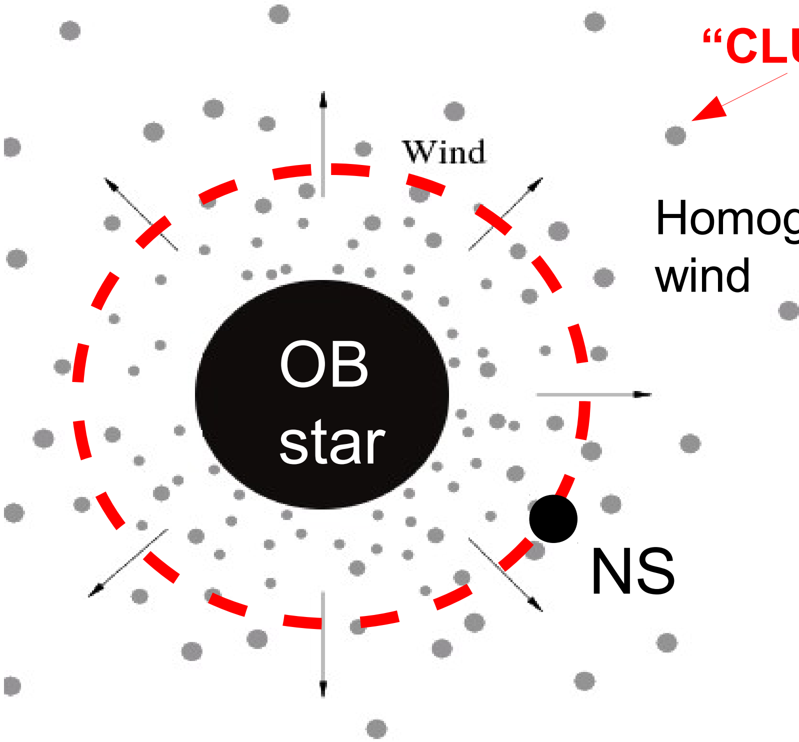
- Supergiant HMXB
- Most likely hosts a NS (Orbital and spin period not known)
- Extremely absorbed ($N_H \sim 10^{24}$ cm^{-2})
- Strong fluorescence Iron emission lines

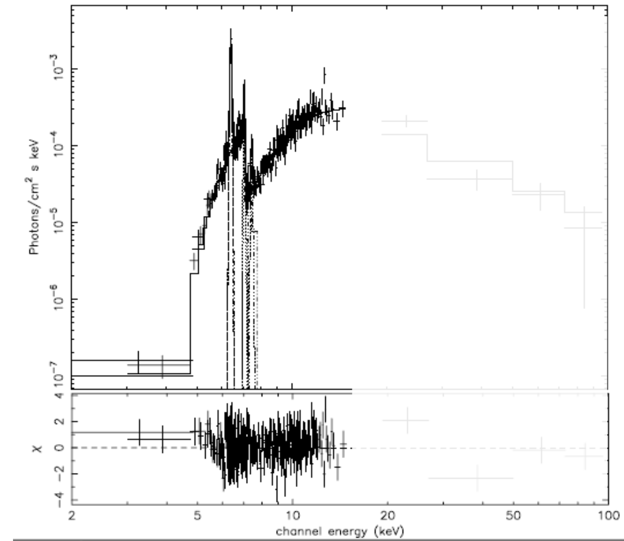
L (2-10 keV) ~ 2 x 10^{34} erg/s

L (20-100 keV) ~ 5 x 10^{34} erg/s

Highly absorbed SgXBs are very bright in 20-100 keV!!

1) Lower energies 0.5-10 keV



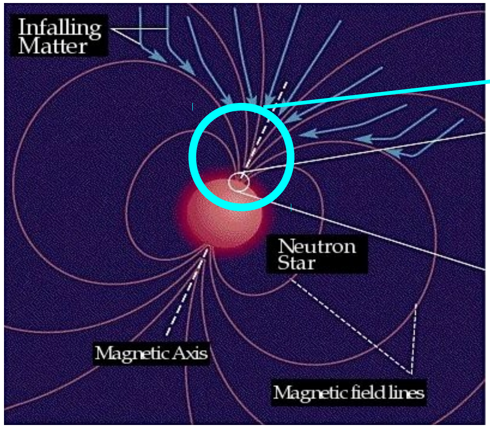


Instabilities in the supergiant wind
→ **non-homogeneous wind**:
diffuse low density component
+ clumps

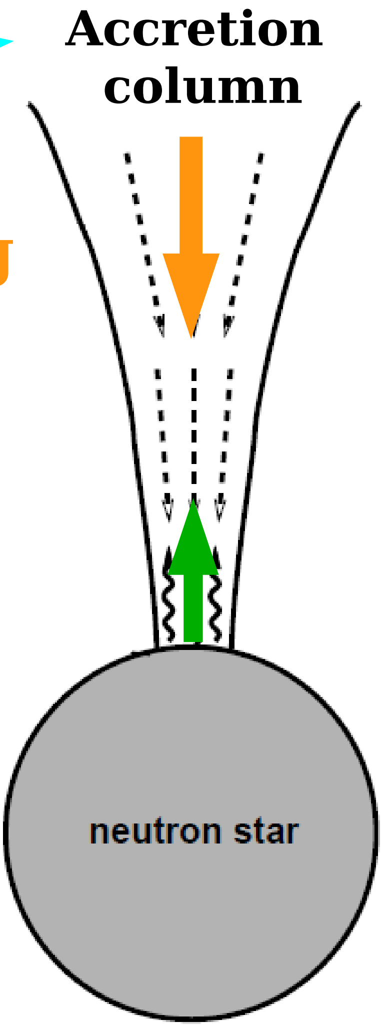
→ **ABSORPTION of soft X-rays coming from the accretion process by COLD MATERIAL around the NS (photoelectric effect)**

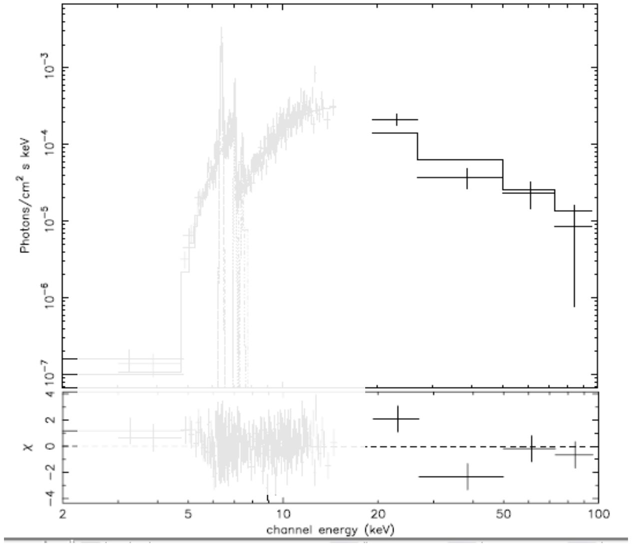
→ **Prominent iron lines due to REFLECTION of X-rays from accretion onto cold material**

2) Higher energies 10-100 keV



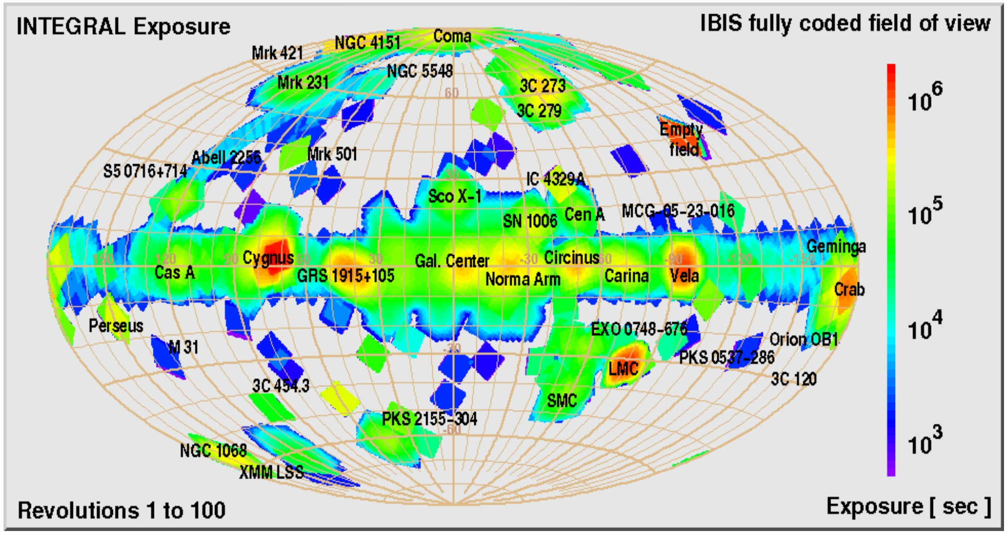
Hot accreting and infalling material





Soft thermal photons (<2 keV) from the NS are up-scattered to energies >> 10 keV

"Comptonization" of soft photons produces the high energy emission (~ 100 keV)

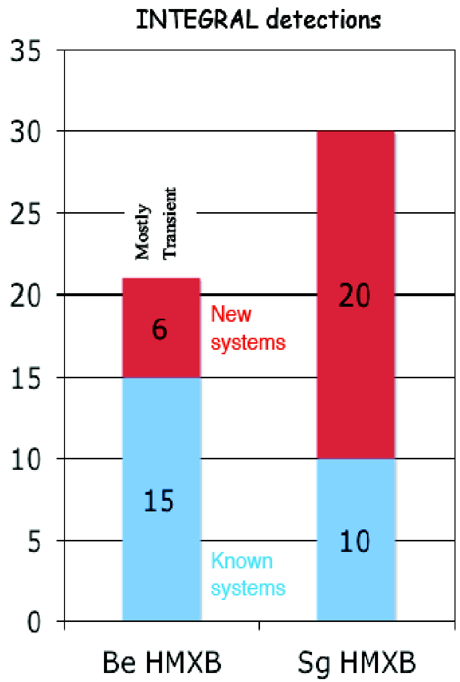


(Walter 2007)

Highly absorbed SgXBs are very bright in 20-100 keV →

They were designed to be studied with INTEGRAL!!!

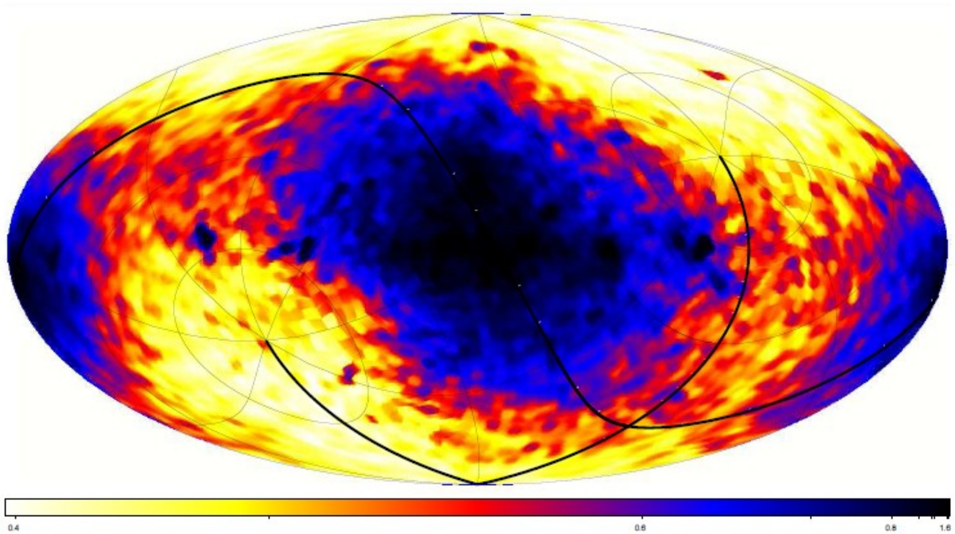
→ Unprecedented sensitivity in **20-100 keV**
→ Large field of view (**20° x 20°**)
→ **Deep exposures** in the direction of the Galactic plane and bulge



(Walter 2007)

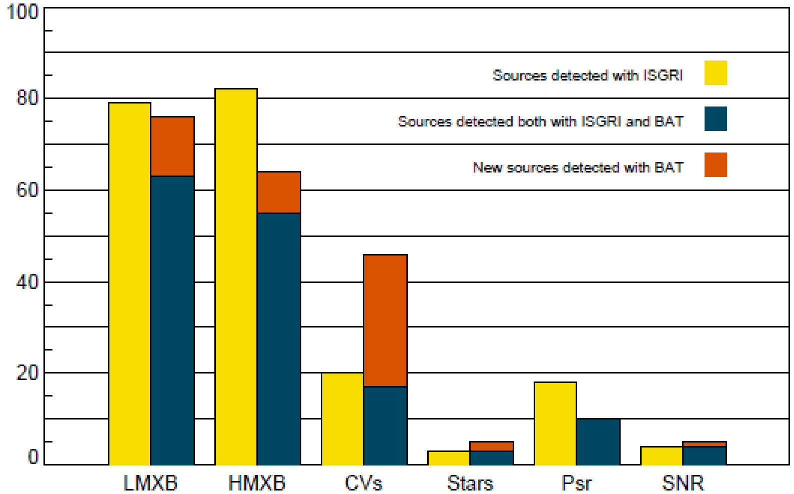
→ INTEGRAL tripled the number of HMXBs

A comparison with Swift/BAT (15-350 keV)

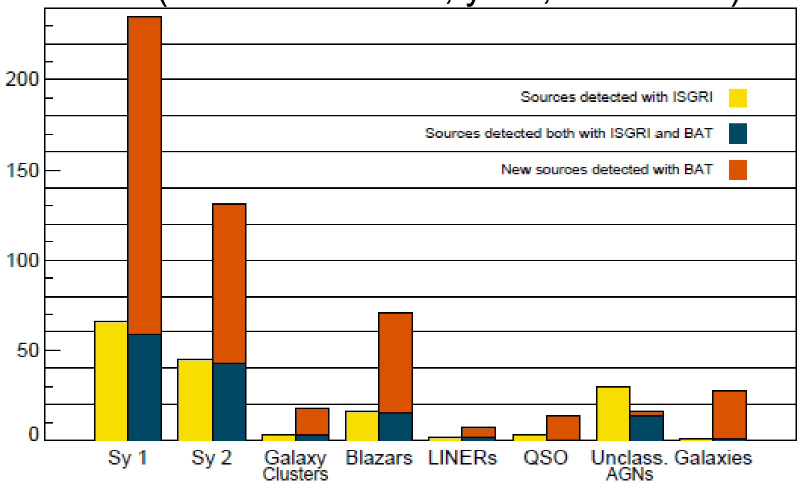


0.4 mCrab **1.6 mCrab**

(limiting flux)



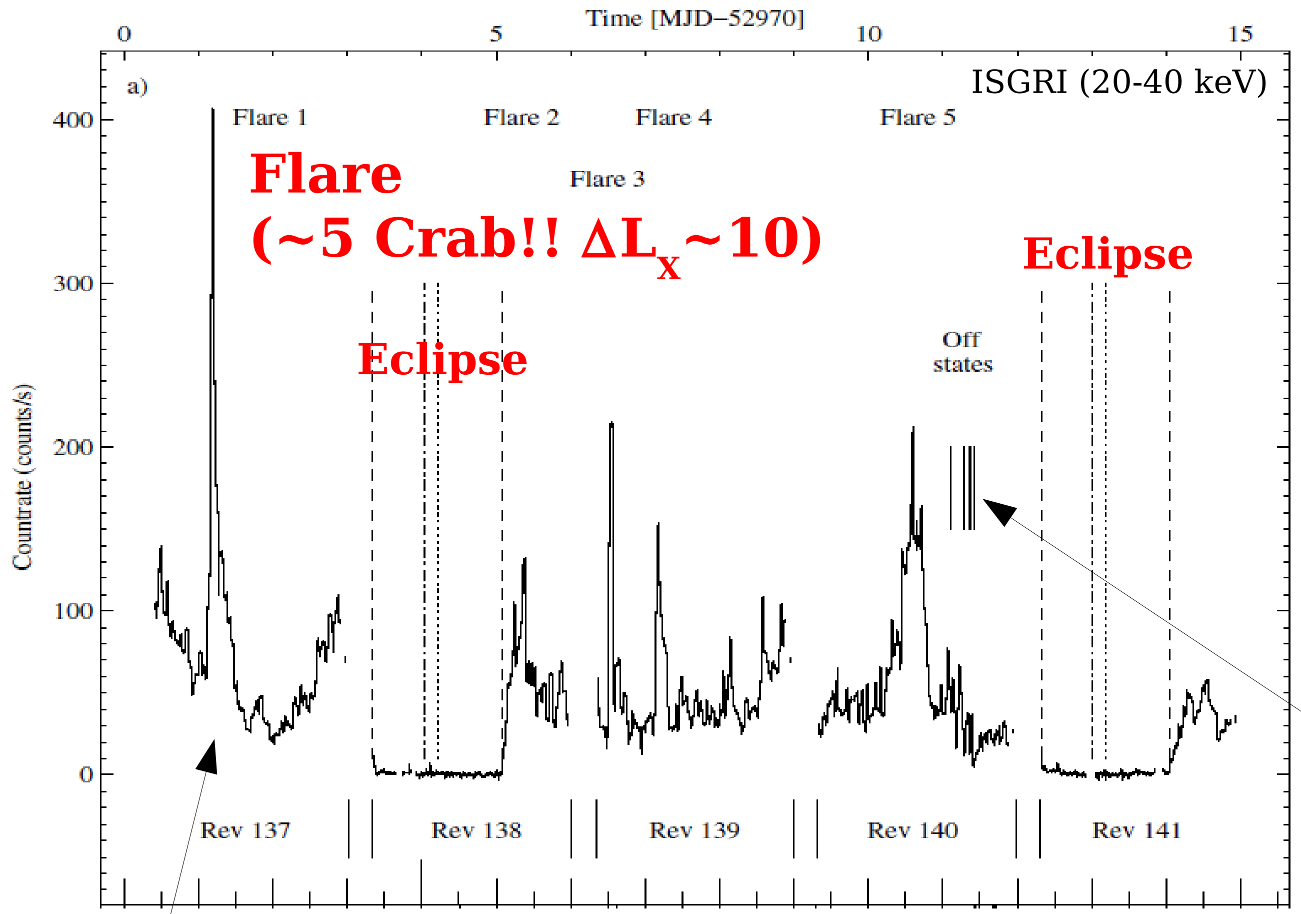
(Cosumano 2009, yCat, 35109048)



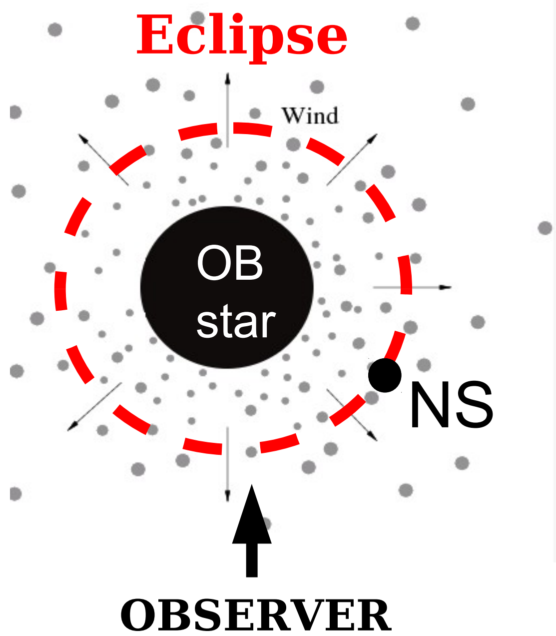
More dedicated to extra-Galactic objects

The SgXB Vela X-1: INTEGRAL observations

SgXB: NS + Supergiant star (23 M_{SUN}); Porb= 9 d; Pspin = 283 s



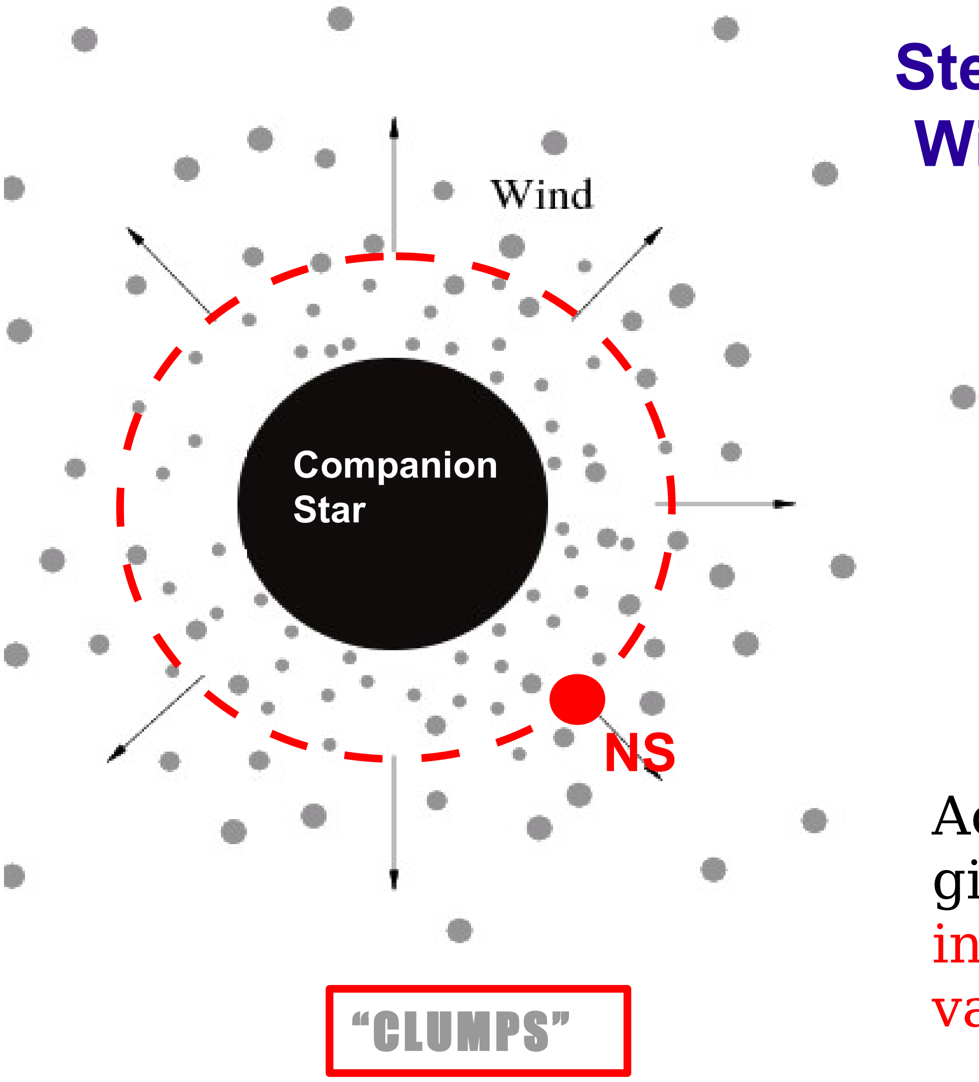
(Kreykenbohm 2008)



Flares = **<u>accretion of clumps</u>**

Off-States
(< 1000 s) =
<u>no clumps to accrete?</u>

The origin of the X-ray emission



Stellar Wind
- Homogeneous wind ρ_w
- Denser Clumps $\rho_c >> \rho_w$

$$L_X = \frac{G M_{NS} \dot{M}}{R_{NS}}$$

$$\dot{M} \propto \rho\, v_w$$

Accretion of denser material gives a higher X-ray luminosity

inhomogeneities in the wind ↔ variability in X-ray

SFXTs: a new subclass of SgXBs discovered by INTEGRAL

→ ~15 sources

→ OB supergiant companion stars (like in SgXBs)

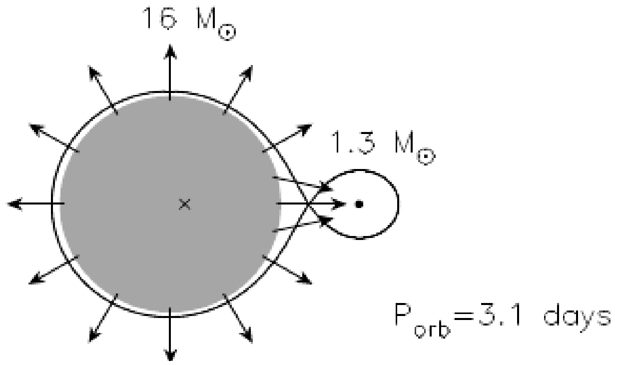
→ Sporadic hours-long outbursts (sometimes at the periastron)

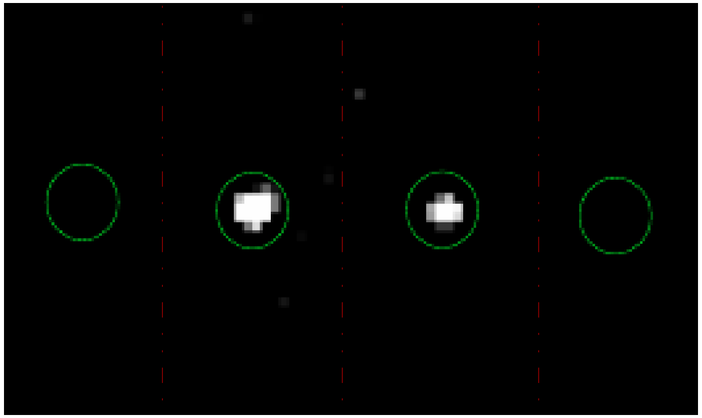
→ OUTBURST: ~10^{36} -10^{37} erg s^{-1}
→ QUIESCENCE: ~10^{32} -10^{34} erg s^{-1}

→ ΔL~10^4 - 10^5 >> Flares in SgXBs

→ Poorly known spin periods (from 4 s to 300 s)

→ Poorly known orbital periods (from 3.3 days to 30 days)

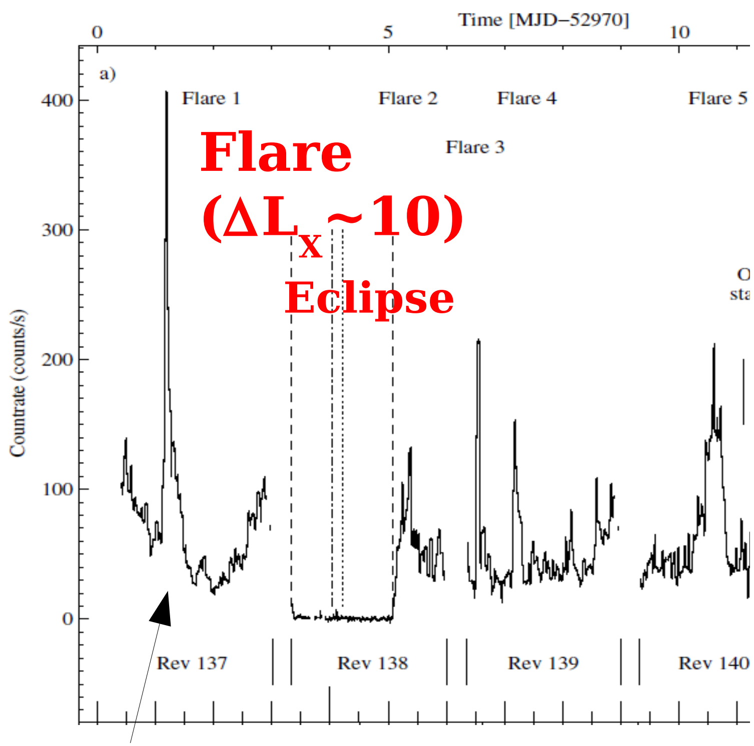


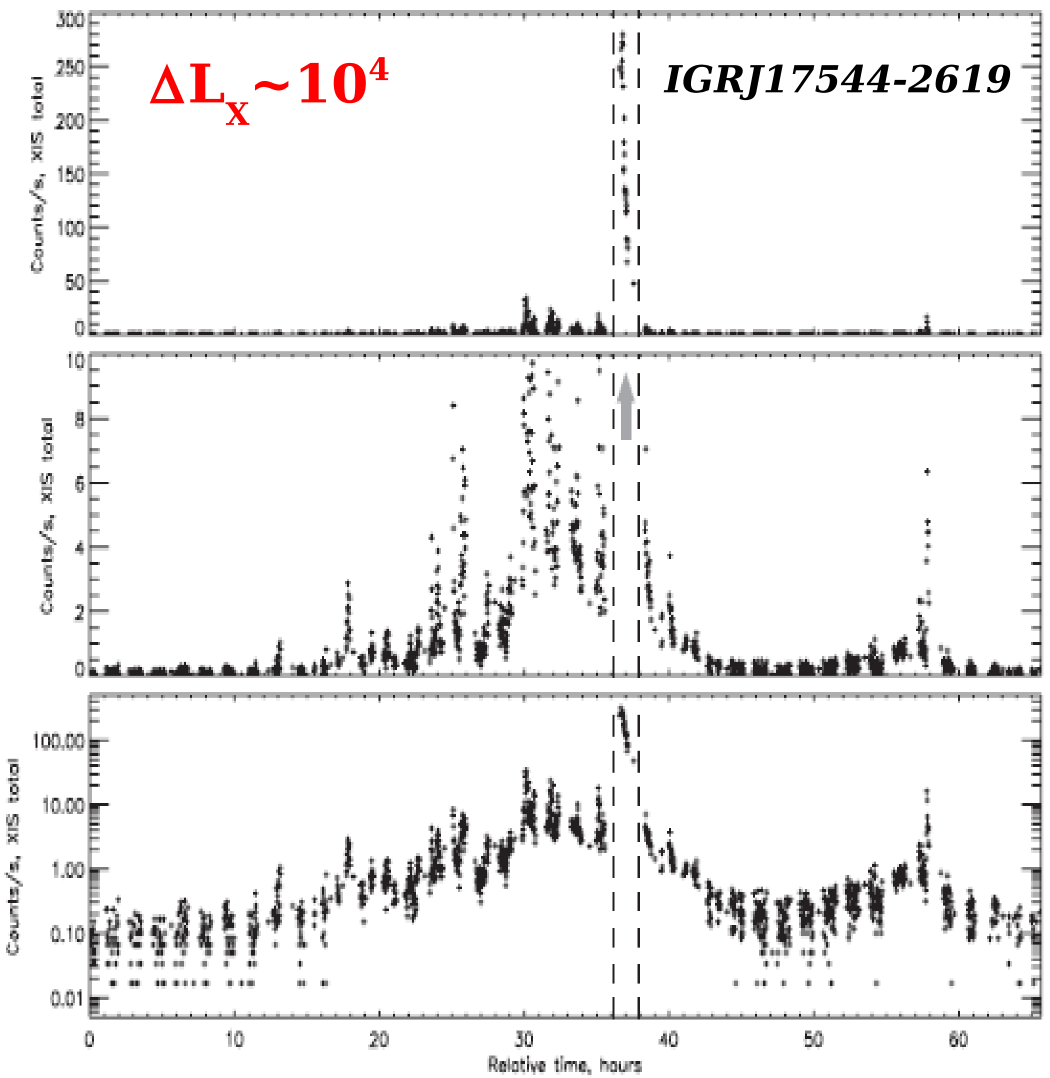


ISGRI image sequence (8 ks)
(Sguera et al. 2005)

LONG EXPOSURES AND WIDE FOVS NEEDED TO DISCOVER THESE SOURCES!!

The Supergiant Fast X-ray Transients (SFXT)





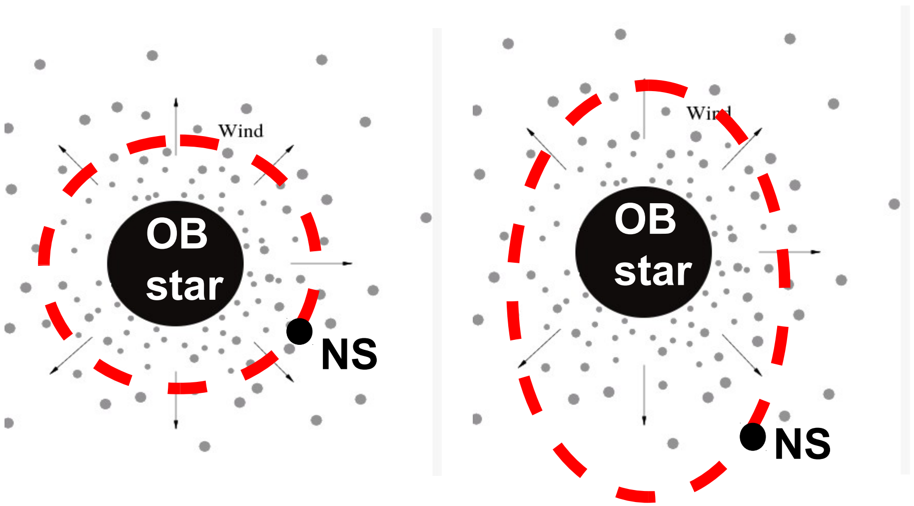
The first eclipse discovered in a SFXT is in *IGRJ16479-4514* (Bozzo 2009)

(Rampy 2009)

The Supergiant Fast X-ray Transients (SFXT)

Models for SFXTs → From the INTEGRAL monitoring of these sources different scenarios were proposed

1. The extremely clumpy wind model



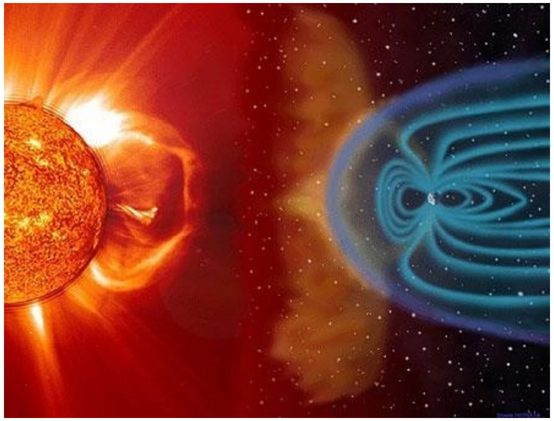
Clumps in the SFXTs might have extreme densities → produce larger flares.

Eccentricity helps extending quiescent periods

(Walter 2007; Negueruela 2008)

2. The extremely magnetized NS model

The NS might have an extremely high magnetic field (10^{15} G) that blocks accretion for most of the time (quiescence) and only sporadically permit it (outburst)

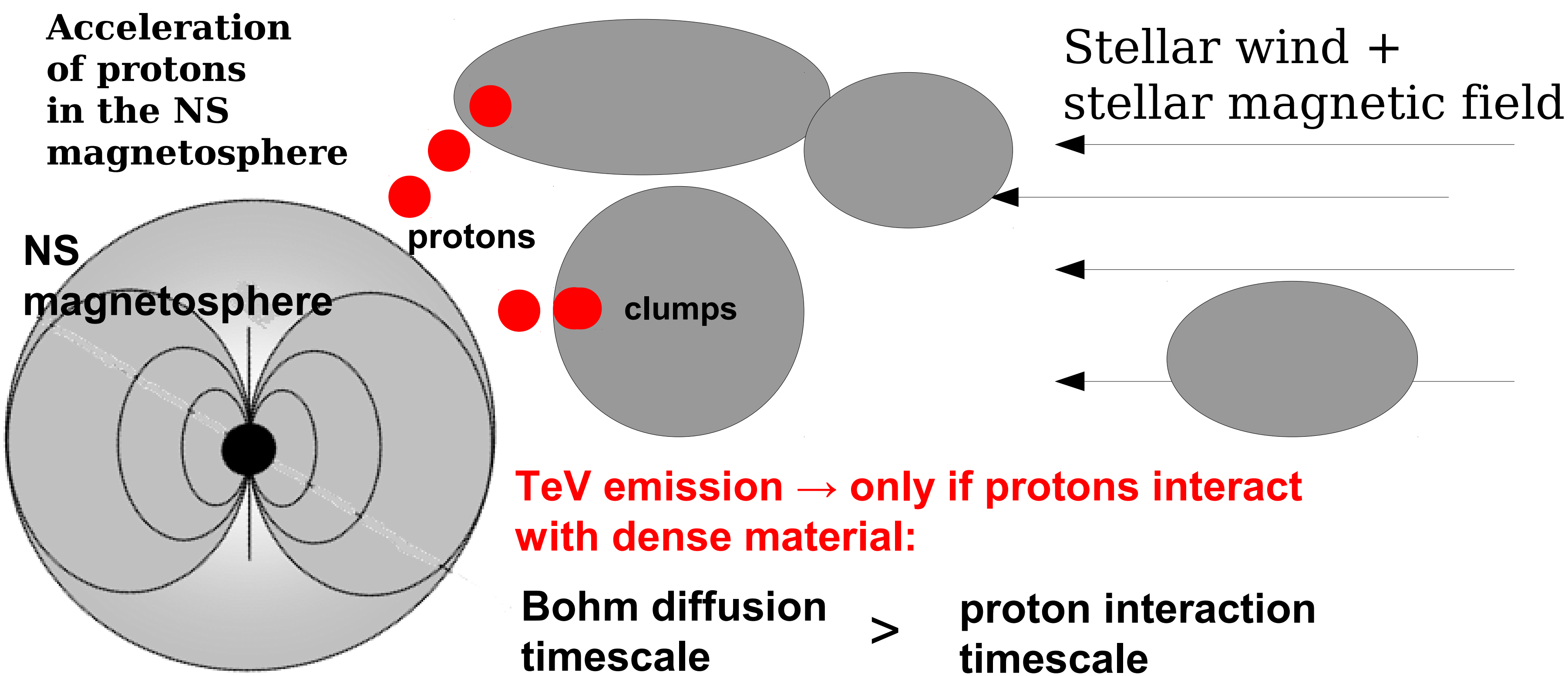


(Bozzo 2008)

Very high energy emission from HMXBs

HMXBs at TeV?

Beside the two famous TeV LOUD binaries
LS I +61303 and ***LS 5039***



(Walter 2007)

TeV emission → only if protons interact with dense material:

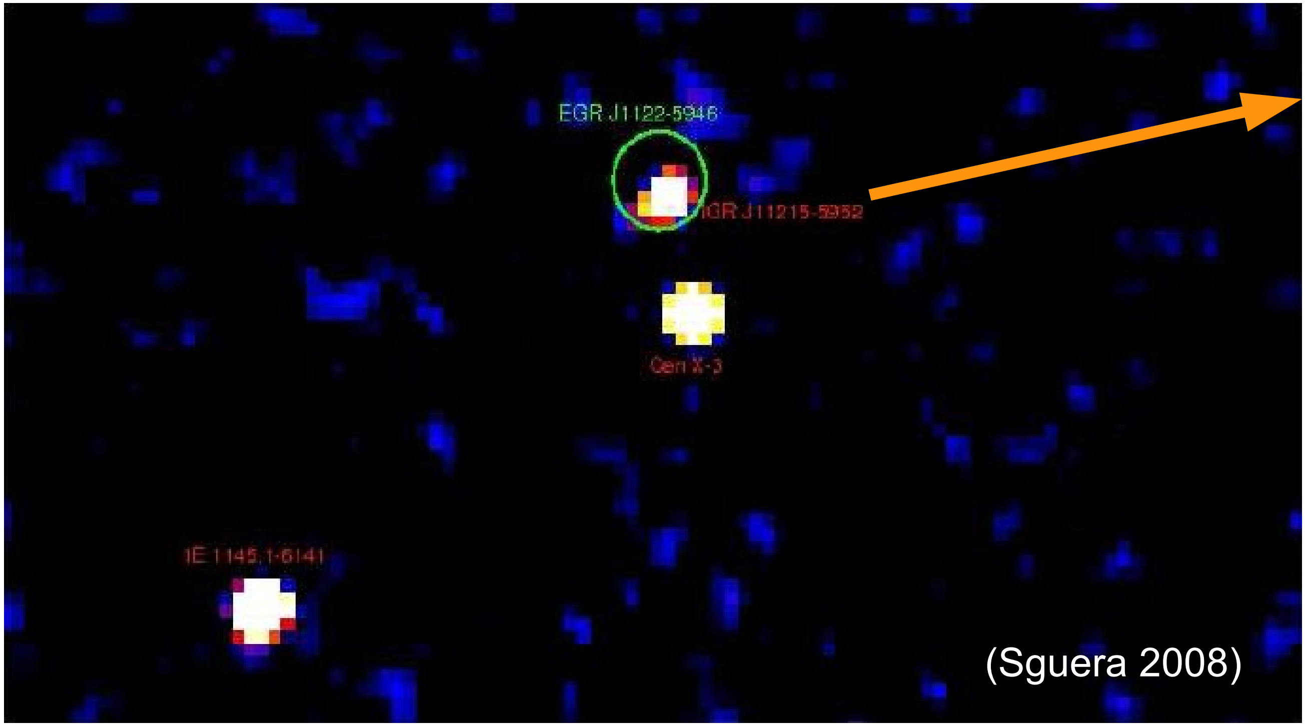
Bohm diffusion timescale > proton interaction timescale

$$N_H > 5\ 10^{23}\ cm^{-2}$$

X-ray burst → accretion of a clump … TeV short burst as well??

Very high energy emission from HMXBs

Hard fast X-ray transients as possible counterparts of unidentified MeV/TeV sources



The SFXT

IGR J11215-5952

Promising association between a SFXT and an EGRET source

...in progress...

References:

X-ray binaries:

Bhattacharya 1991, PhR, 203,
White 1983, ApJ, 270, 711

HMXBs with INTEGRAL:

Kreykenbohm 2008, A&A, 492, 511
Walter 2006, A&A, 453, 133
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Rodriguez, 2006, MNRAS, 366, 274

HMXBs at the VHE:

Bednarek 2007, MNRAS, 397, 1420
Dubus 2008, New Astronomy Reviews, 51, 778
Sguera 2008, astro-ph/0902.0245
Walter 2007, Astrophys. Space Sci, 309, 5

Main papers on SFTXs:

Bozzo 2008, ApJ, 683, 1031
Bozzo 2009, MNRAS, 391, 108
Negueruela 2008, AIPC, 1010, 252
Sguera 2005, A&A, 444, 221
Sidoli 2007, 476, 1307
Rampy 2009, ApJ, 707, 243
Walter 2007, A&A, 476, 335