Discovery of mm emission from a neutron star High Mass X-ray Binary

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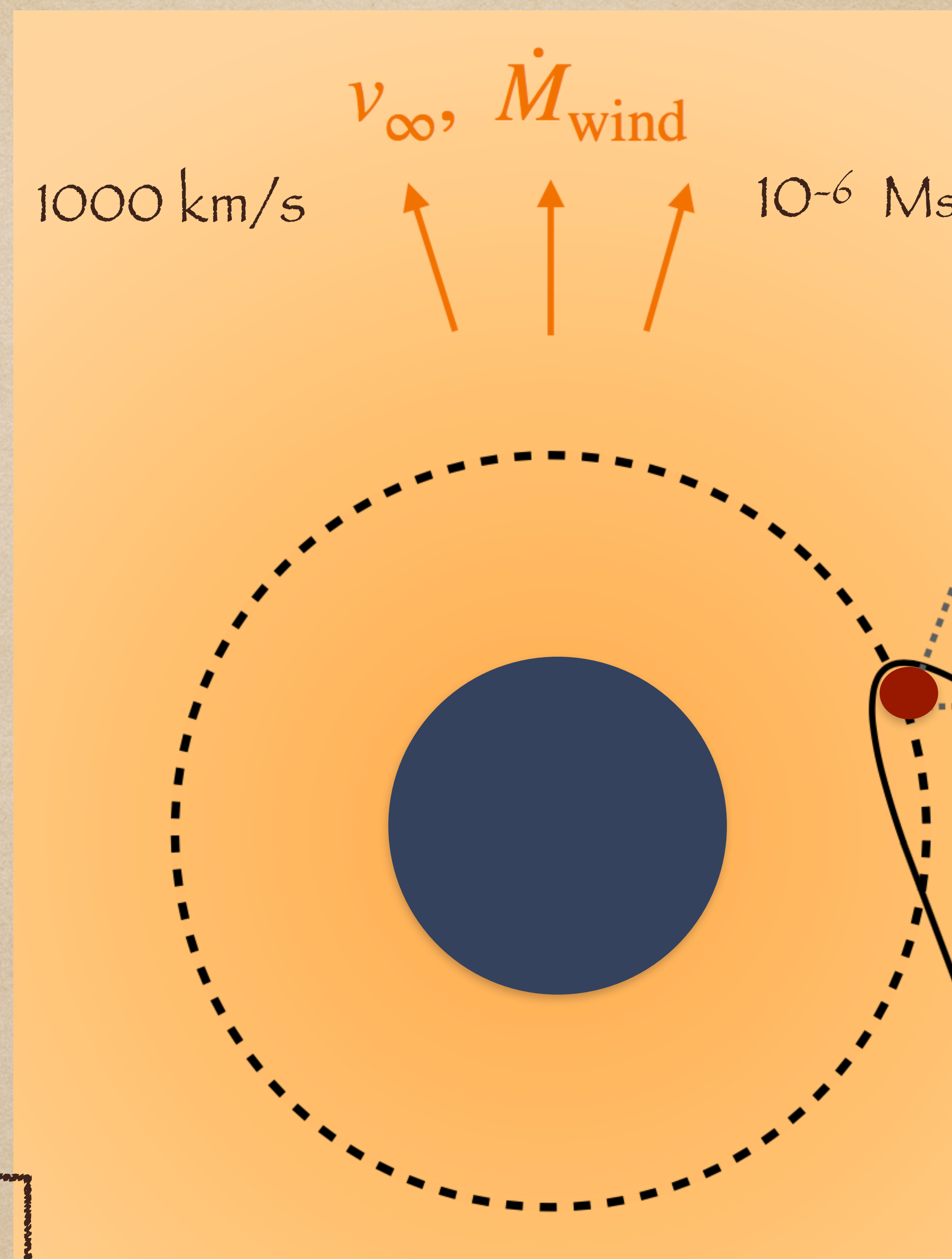
HMXBs host neutron stars accreting from the supergiant wind

O-type or B-type Supergiant Donor



Neutron Star

Line-driven strong winds

$$v(r) = v_\infty \left(1 - \frac{R_*}{r}\right)^\beta$$

Wind velocity

Wind accretion

$$L_X \propto \frac{\dot{M}_{\rm wind}}{a^2 v_{\rm rel}^4}$$

$$v_{\rm rel} \approx \sqrt{v_\infty^2 + v_{\rm orbit}^2}$$

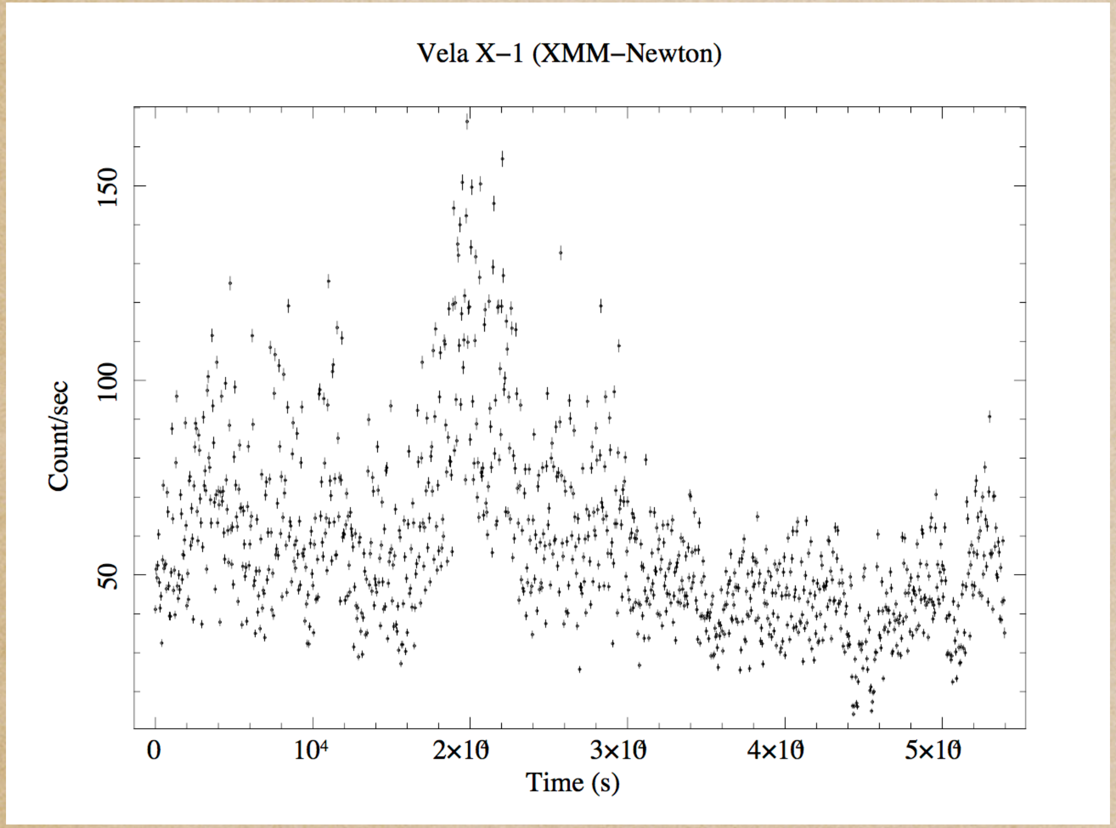
No RLO

No accretion disk

HMXBs with early-type supergiant donors: **two types** of X-ray light curves

Persistent SgHMXB

$L_X \approx 10^{36}$ erg/s

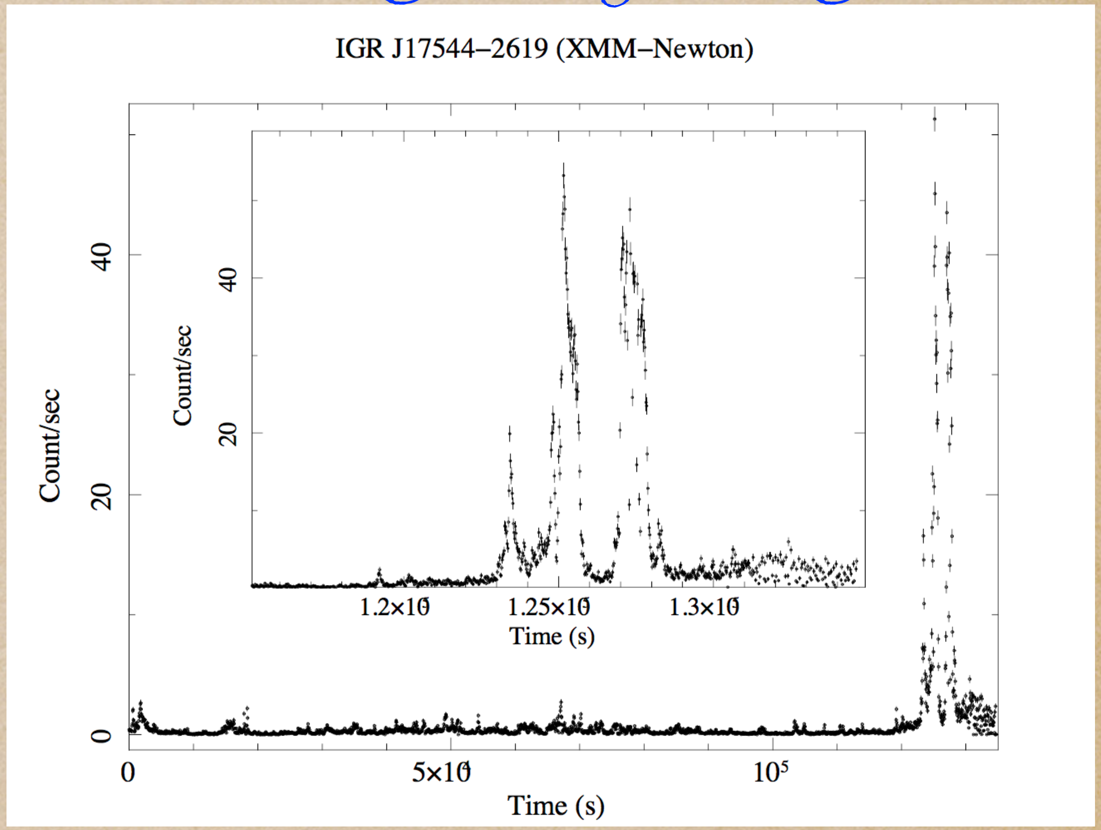


Martinez-Nunez et al. 2014

SFXT

Supergiant fast X-ray transient

$L_X \approx 10^{36}$ erg/s only during flares



Bozzo et al. 2016

HMXBs with early-type supergiant donors:

Which regime ?

Persistent SgHMXB

Direct wind accretion regime (Bondi-Hoyle)

$$L_X \propto \frac{\dot{M}_{\rm wind}}{a^2 v_{\rm rel}^4}$$

SFXT

Supergiant fast X-ray transient

Scenarios **to inhibit accretion** most of the time: quasi-spherical settling accretion, Propeller, magnetic barrier, helped by clumpy winds

But **no conclusive answer**, in absence of Pspin & B field measured in the same source

Pspin in pers and SFXTs are similar (100-1000 s),

B field in SFXTs is elusive (measured only in one source, B= 10^{12} G)

Porb values overlap (but with a few SFXTs with long Porb, 50-165 days)

HMXBs with early-type supergiant donors:

What if we look at the **optical counterpart** ?

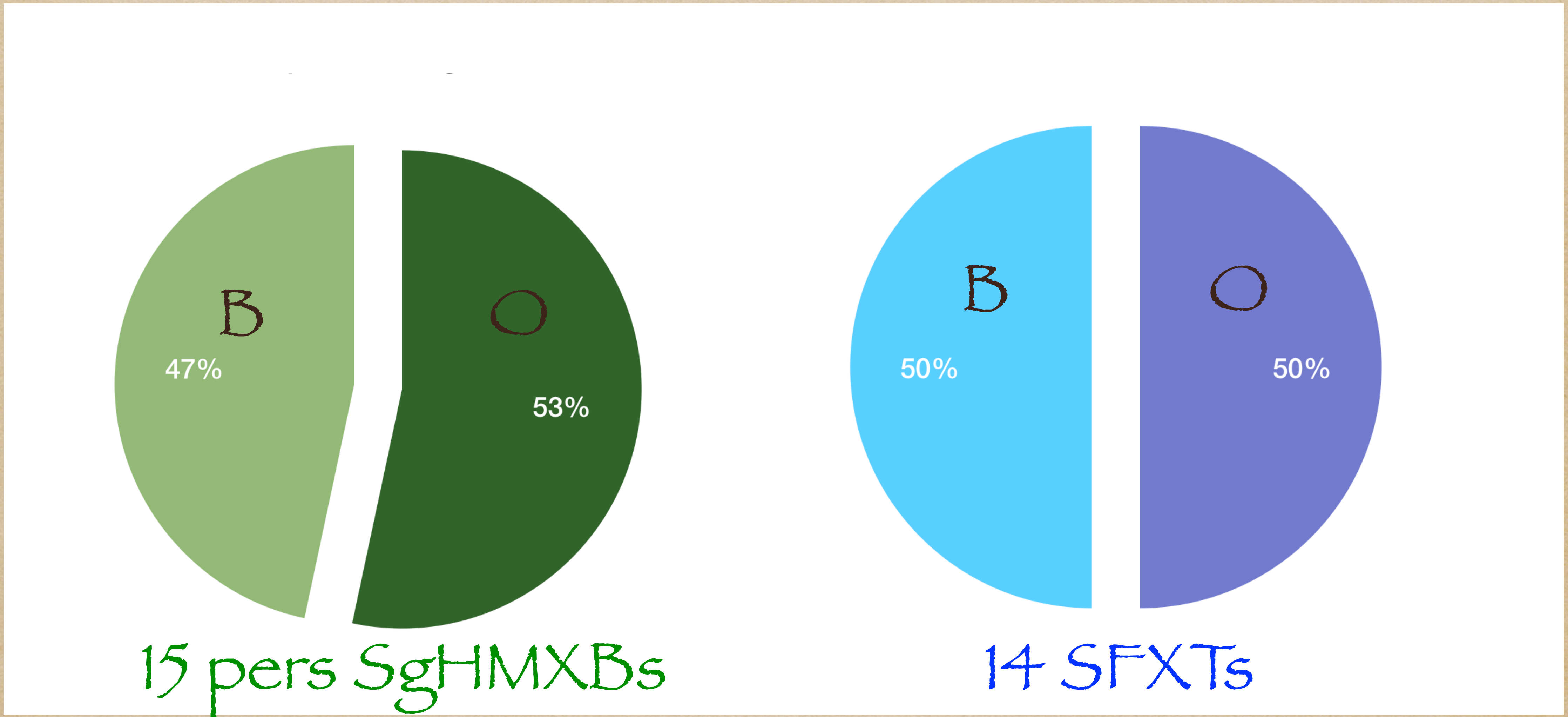
Is there any **difference in the wind properties**

(mass loss rate and wind velocity)

Able **to explain the dichotomy** in the **two types of wind-fed HMXBs ?**

Such comparisons of the supergiant wind properties are rare

Spectral types in optical counterparts of persistent HMXBs vs SFXTs



Data taken from the HMXBs cat by Neumann et al. 2023 (only Galactic sources)

Optical/UV spectroscopy of persistent HMXBs vs SFXTs

comparing the wind properties are **inconclusive**

Gimenez-Garcia et al. (2015) reported
On significant differences in the wind velocity
In a persistent source (700 km/s) vs a SFXT (1500 km/s)

Hainich et al. (2020) reported
No evidence for a dichotomy in the wind properties in a larger sample of HMXBs

Thermal stellar wind emission

Radio continuum observations are a well established tool for **estimating mass-loss rates** for massive stars

$$S_\nu \propto \nu^{0.6} \left(\frac{\dot{M}_{\rm wind}}{v_\infty} \right)^{\frac{4}{3}} d^{-2}$$

Wright & Barlow 1975
Olnon 1975
Panagia & Felli 1975

Radio continuum is due to **free-free emission** in the stellar wind and it is a more straightforward method to measure mass-loss rate

Our pilot study using NOEMA @ 100 GHz

SFXT

IGR J18410-0535 (aka AX J1841.0-0536) B I

Porb= 6.45 d (TBC)

Pspin= unknown; distances reported in the literature: 3.2 kpc, 6.9 kpc or 13.8 kpc (Gaia eDR3)

Persistent SgHMXB

X 1908+075 (aka 4U 1909+07) B0-B3 I

Porb=4.4 d ecc=0.021+/-0.036

Pspin=604 s; distance = 4.85 kpc

(van den Eijnden, LS, Diaz-Trigo et al. 2023)

Results of our **pilot study**

First detection of an SFXT @ 100 GHz

(van den Eijnden, LS, Diaz-Trigo et al. 2023)

SFXT (detected)

IGR J18410-0535 $S_\nu = 63.4 \pm 9.6$ μJy (100 GHz)

-> $L_\nu = 7.8 \times 10^{28}$ erg/s (at 3.2 kpc)

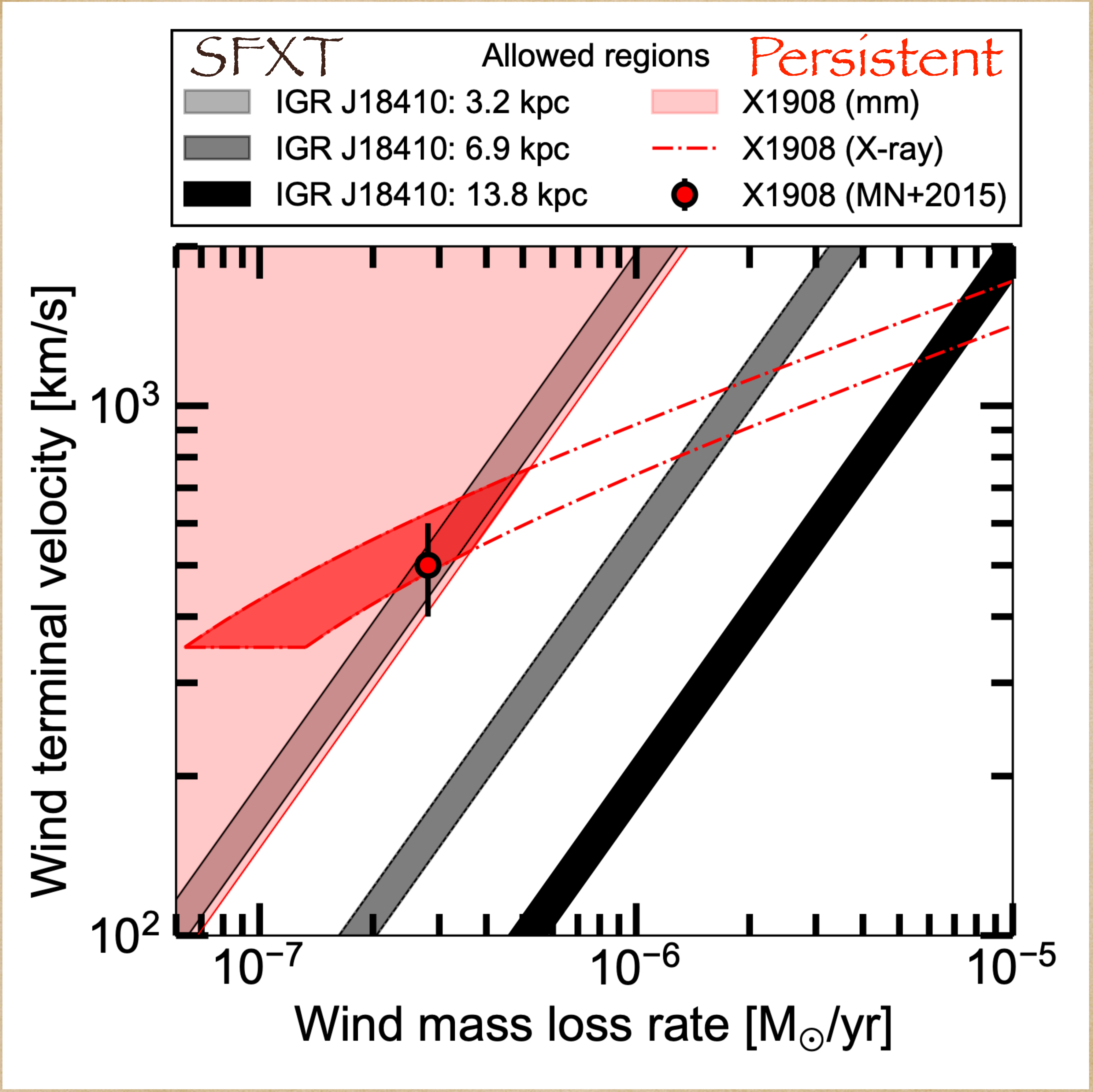
Complemented by ATCA (DDT) at 5.5 and 9 GHz two days after NOEMA, with no detection (< 48 μJ)

ATCA and NOEMA measurements imply a 3-σ lower limit on α (where $S_\nu \propto \nu^\alpha$) of $\alpha > -0.1$

Persistent SgHMXB **(undetected)**

X 1908+075 $S_\nu < 34.4$ μJy (100 GHz)

No ATCA time -> $L_\nu < 9.7 \times 10^{28}$ erg/s (at 4.85 kpc)


SFXT
Allowed regions
Persistent
IGR J18410: 3.2 kpc
IGR J18410: 6.9 kpc
IGR J18410: 13.8 kpc
X1908 (mm)
X1908 (X-ray)
X1908 (MN+2015)
Wind terminal velocity [km/s]
10^3
10^2
10^{-7}
10^{-6}
10^{-5}
Wind mass loss rate [$M_\odot$/yr]

The near future: our accepted ALMA proposal

The first deep ALMA + VLA survey of HMXBs

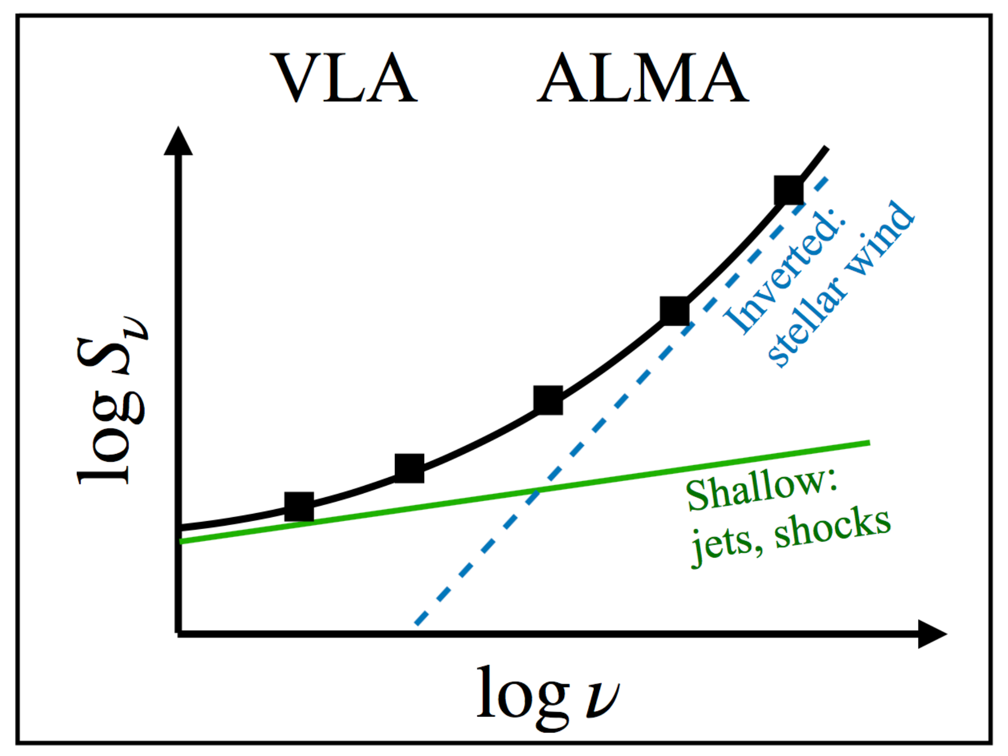
PI: J. van den Eijnden

VLA

(6 GHz, 10 GHz)

ALMA

(40, 150, 300 GHz)



To characterize the low frequency (6-300 GHz) SED of Six HMXBs (3 persistent & 3 SFXTs) and compare supergiant wind properties in these two sub-classes

Targets: Vela X-1, 4U1700-37, 4U1907+09 (pers) + IGRJ18410, IGRJ17544-2619, SAXJ1818.6-1703 (SFXTs)