Radbound University

Where are the magnetar binaries?

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Magnetars – common or rare?

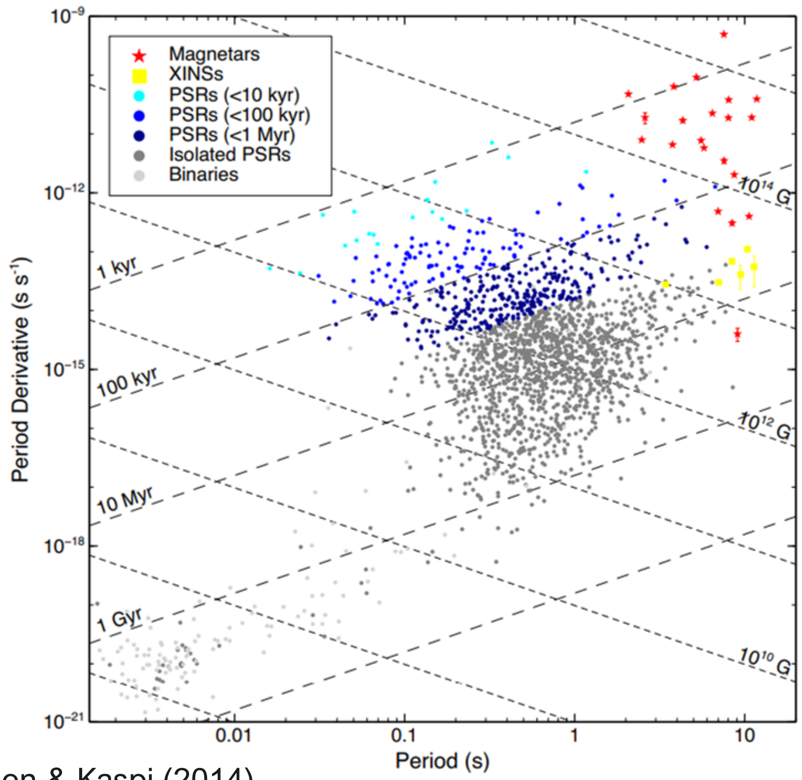
- Very young - 10^3-10^5 yr ($P/\dot{P}$, SNR/clusters/HII region associations)
- Galactic population might be representative of FRBs, which appear to be common extragalactic transients (Bochenek et al. 2020, Mannings et al. 2021, Chrimes et al. 2021, Bhandari et al. 2021)
- Common or rare (e.g. Muno et al. 2008, Beniamini et al. 2019)

Most NS start as magnetars but rapidly decay?

Specific conditions needed (e.g. MS merger, Schneider et al. 2020)?

AIC or MIC (Narayan & Popham 1989, Levan et al. 2006)? See FRB20200120E in M81 (Bhardwaj et al. 2021, Kirsten et al. 2021)

BNS mergers? (probably short lived, e.g. Lu et al. 2015)



Olausen & Kaspi (2014)

Outline

If magnetars are a common outcome from regular core-collapse supernovae: **some fraction should have a bound companion**

1. Population synthesis – how many expected to have bound companions?
2. Search in deep NIR HST imaging (+literature search and archival observations)
3. Can we identify any companion candidates? Consistent with pop synth and pulsars?
4. Any new non-stellar NIR counterparts or variability in known ones?
5. Further possible constraints: proper motions, progenitor mass estimates and unbound companions

How 'normal' are magnetars, compared to the broader neutron star population?

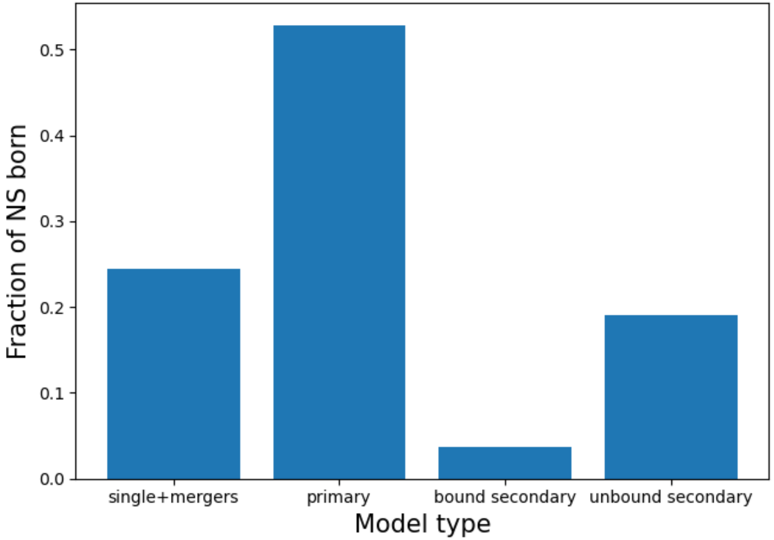
Chrimes et al. (in prep)

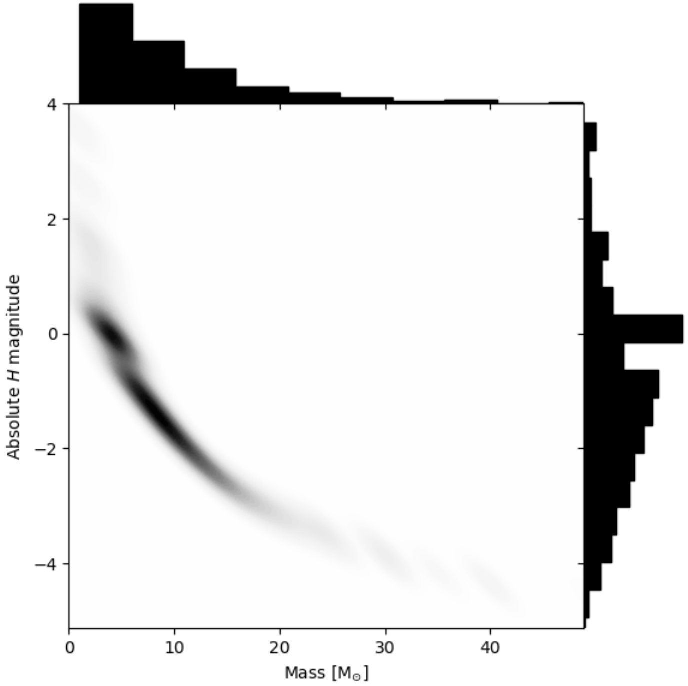
Population Synthesis

BPASS v2.2.1 (Eldridge et al. 2017, Stanway & Eldridge 2018)

~50% of NS are born from primary stars, and ~10% of these systems remain bound

~5% of newborn neutron stars to have a bound companion (f_{bound})





Pop Synth uncertainty

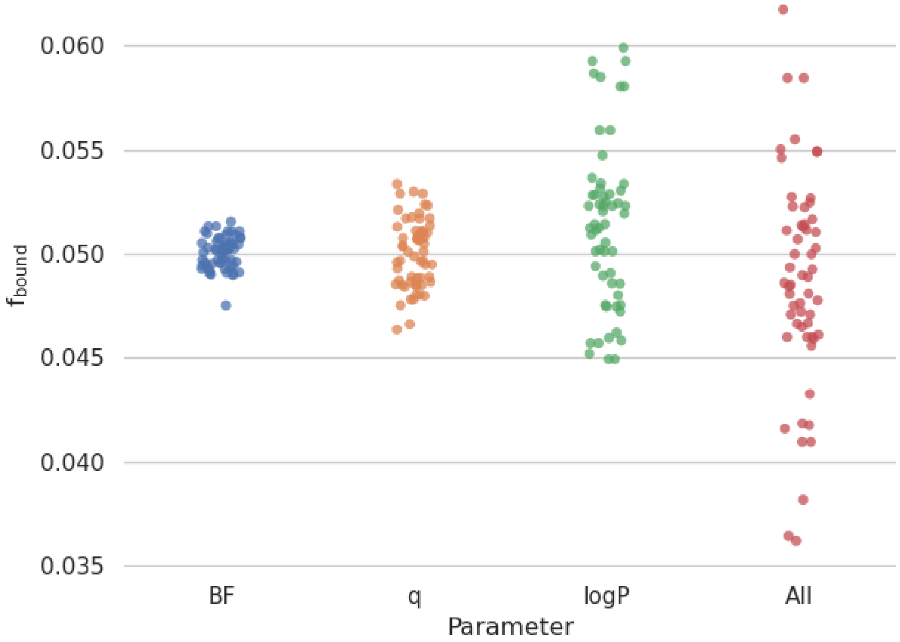
Varying input parameter distributions (see Stanway et al. 2020)

- Binary fraction (BF)
- Mass ratios (q)
- Initial orbital periods (logP)

$$f_{bound} = 0.049 \pm 0.005$$

* Solar metallicity (Z=0.020 by mass fraction) assumed

* other uncertainties: binary physics (e.g. common envelope), kicks…



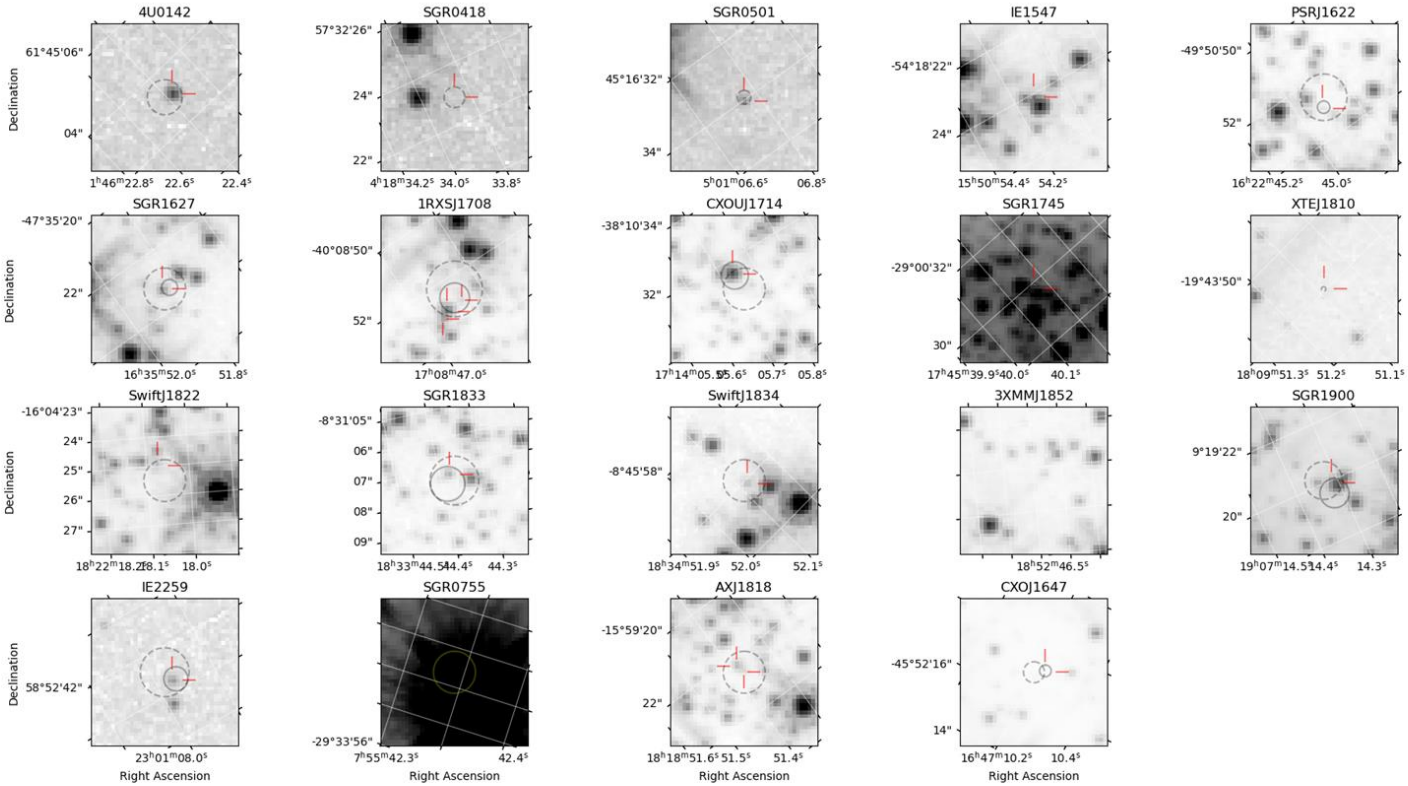
NIR counterpart localisation

HST imaging of 18 magnetars in F160W (~H) and F125W (~J)

PI: Levan

Most have Chandra X-ray localisations, enabling a precise localisation

5 new counterpart candidates:
Swift1822
Swift1833
Swift1834
AXJ1818
(COUXJ1714)



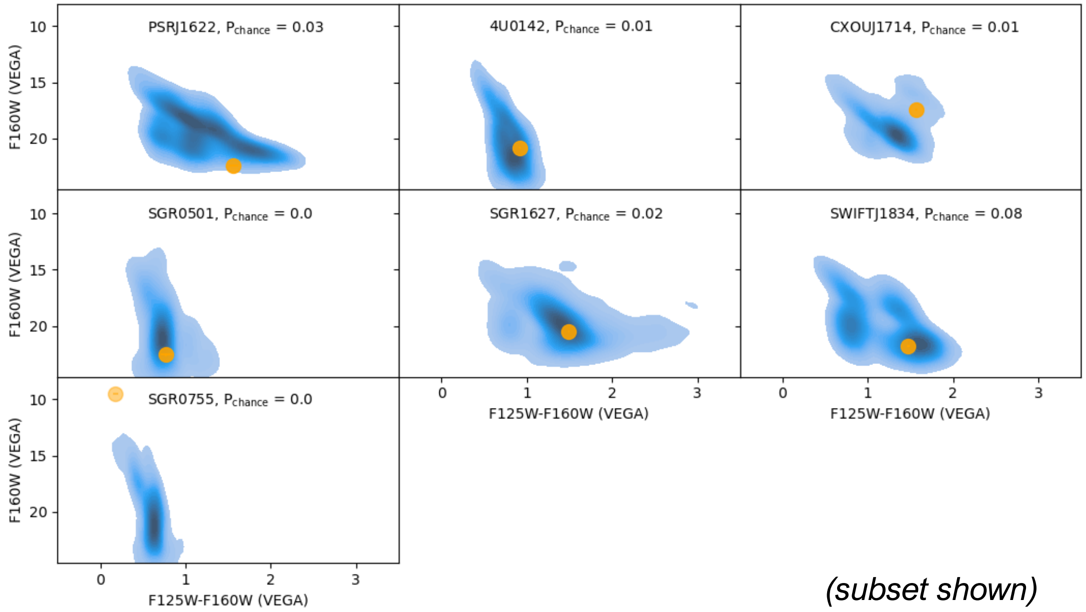
Observed colours

Do any sources stand out in a colour-magnitude diagram?

DOLPHOT for automated photometry on the HST images (Dolphin et al. 2002).

Unusually red – SN fallback debris disc? Magnetospheric emission? (e.g. Wang et al. 2006, Tam et al. 2008)

$$P_{chance} = 1 - e^{-\sigma \pi r^2}$$



(subset shown)

Apparent H-band magnitude comparison

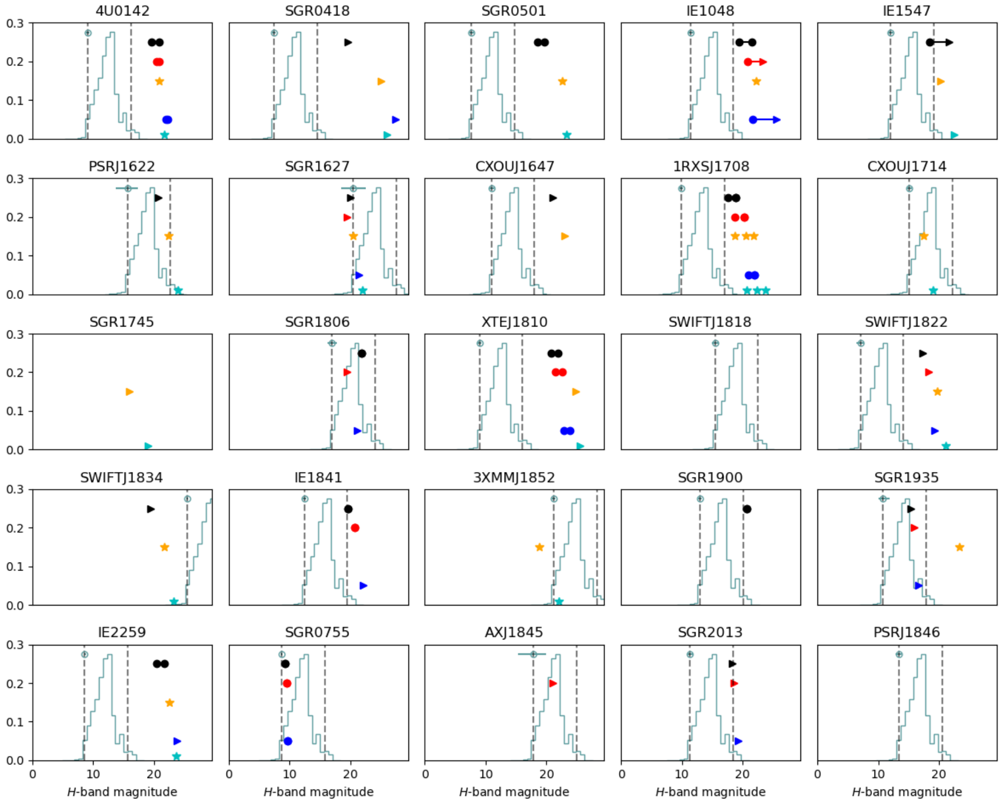
Using pop synth H-band absolute magnitudes for companions:

$m_H = M_H - \mu - A_H$

Extinction from:

- 3D dust map (Green et al. 2019)
- A_v-N_H relation (Predehl et al. 1995)
- 2D total extinction (Schlafly & Finkbeiner, 2011)

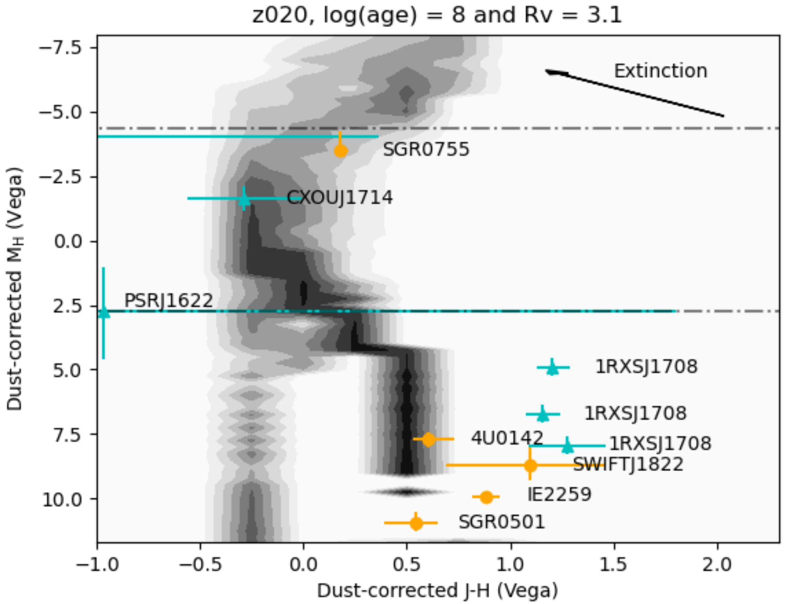
3D used if total LOS value ≈ 2D extinction, otherwise N_H used if available



Absolute magnitudes and colours

Made with HOKI (Stevance et al. 2020)

- A_V-N_H extinction
- 3D dust map extinction



95% of bound companions to NS (at t=0) according to pop synth

SGR0755 – a magnetar in an X-ray binary?

SGR 0755–2933: a new High Mass X-ray binary with the wrong name

V. Doroshenko[1,2], A. Santangelo[1], S. S. Tsygankov[3,2], and L. Ji[1]

Xu et al. 2021

(see also other talks in this session!)

Doreshenko et al. 2021a,b

- Chance alignment?
- Burst from the XRB itself?
- Magnetar accretor?

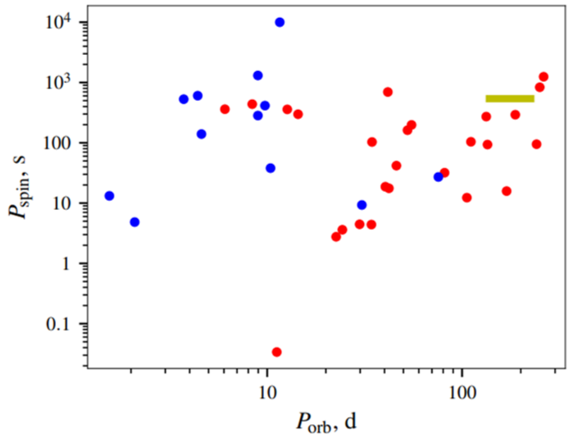
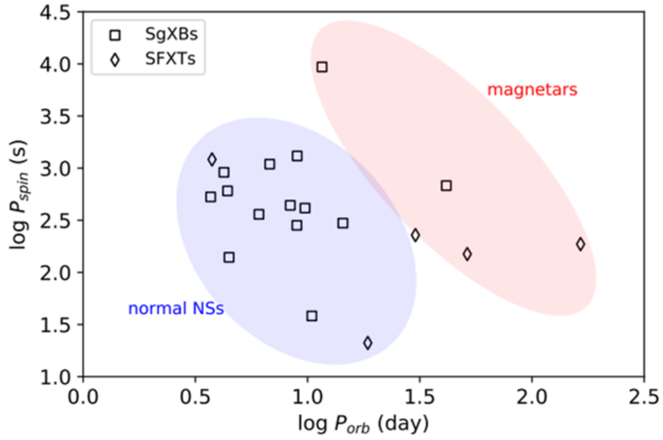


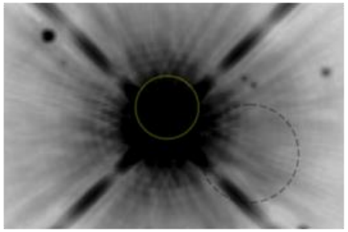
Fig. 8. Orbital period - spin period (Corbet 1986) diagram for wind accreting (blue) and Be (red) high-mass X-ray binaries. The position of SRGA J124404.1−632232/SRGU J124403.8−632231 is indicated with the yellow line assuming the orbital period from 138 to 225 d.



Overview of bound companion search

- Of those with the necessary constraints, at most 5/19 could plausibly have a bound companion (<26%, based on H-band only)
- Two secure candidates (10%) - CXOUJ1714 and SGR0755…
- …of which one could be a chance alignment: $0.05 < f_{bound} < 0.26$

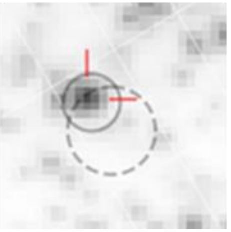
SGR0755 / HMXB



Pulsars

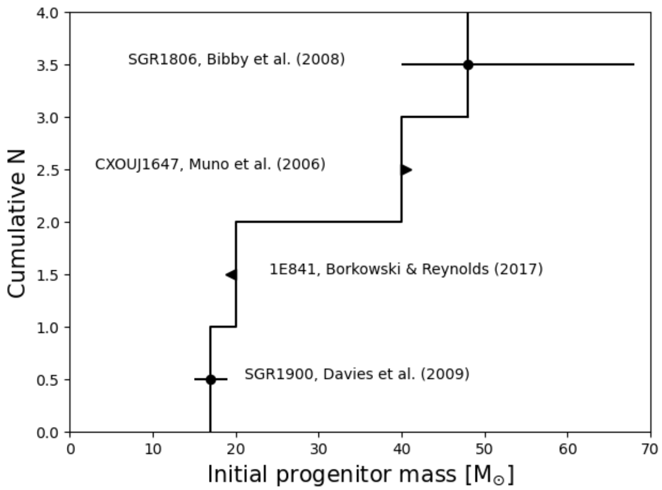
- Independent of pop synth assumptions…
- …but still subject to observational biases
- Pulsar f_{bound} based on ANTF (Manchester et al. 2005) = 0.07

CXOUJ1714

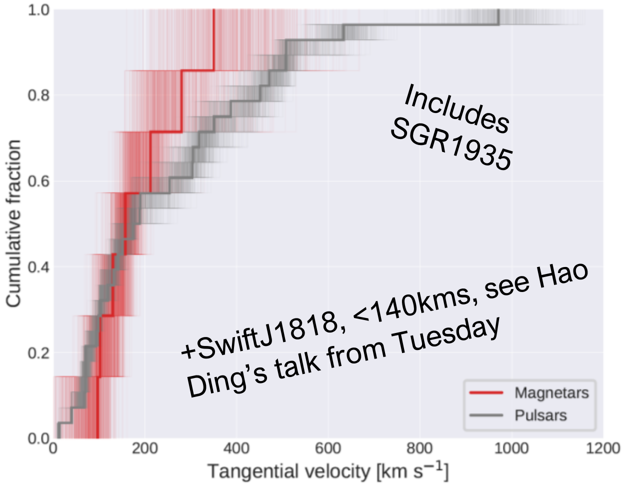


Other constraints

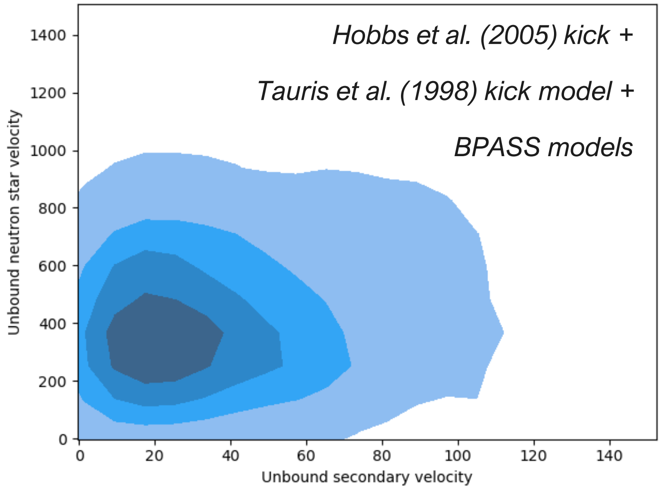
Progenitor masses



Proper motions (Lyman et al., submitted)



Unbound companions?



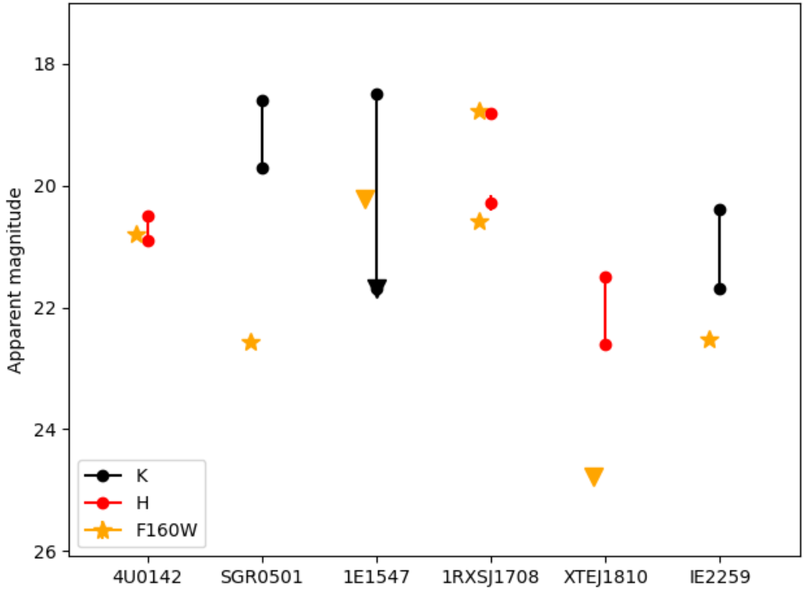
$F_{unbound} = 0.47$

1 candidate in Westerlund 1 (Clark et al. 2014)

Consistent with 'regular' neutron stars and their progenitors?

Variability of non-stellar counterparts

Later epochs (2018-2020) of known counterparts, previous observations from references in the McGill Catalogue (Olausen & Kaspi 2014):



Summary

- $0.05 < f_{bound} < 0.26$, consistent with pop synth expectation of 0.05 and pulsars (~0.07)
- Two strong bound companion candidates, one in an XRB?
- 5 new NIR counterparts identified

<u>Other ways to constrain the origin:</u>

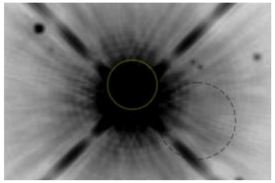
Proper motions

Progenitor masses

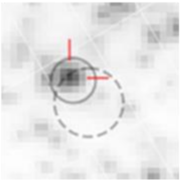
Search for unbound companions

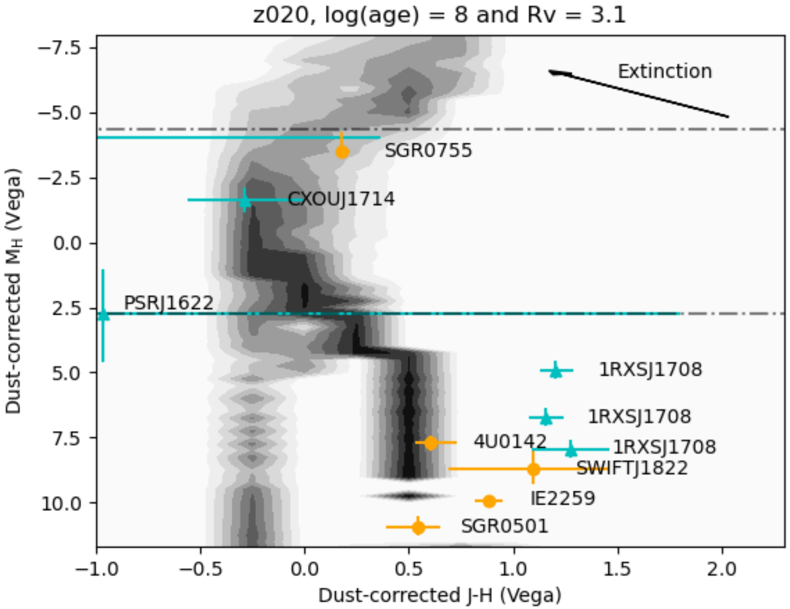
Optical/NIR SEDs (or spectra!) needed – JWST

SGR0755 / HMXB



CXOUJ1714





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