The binaries of GW events

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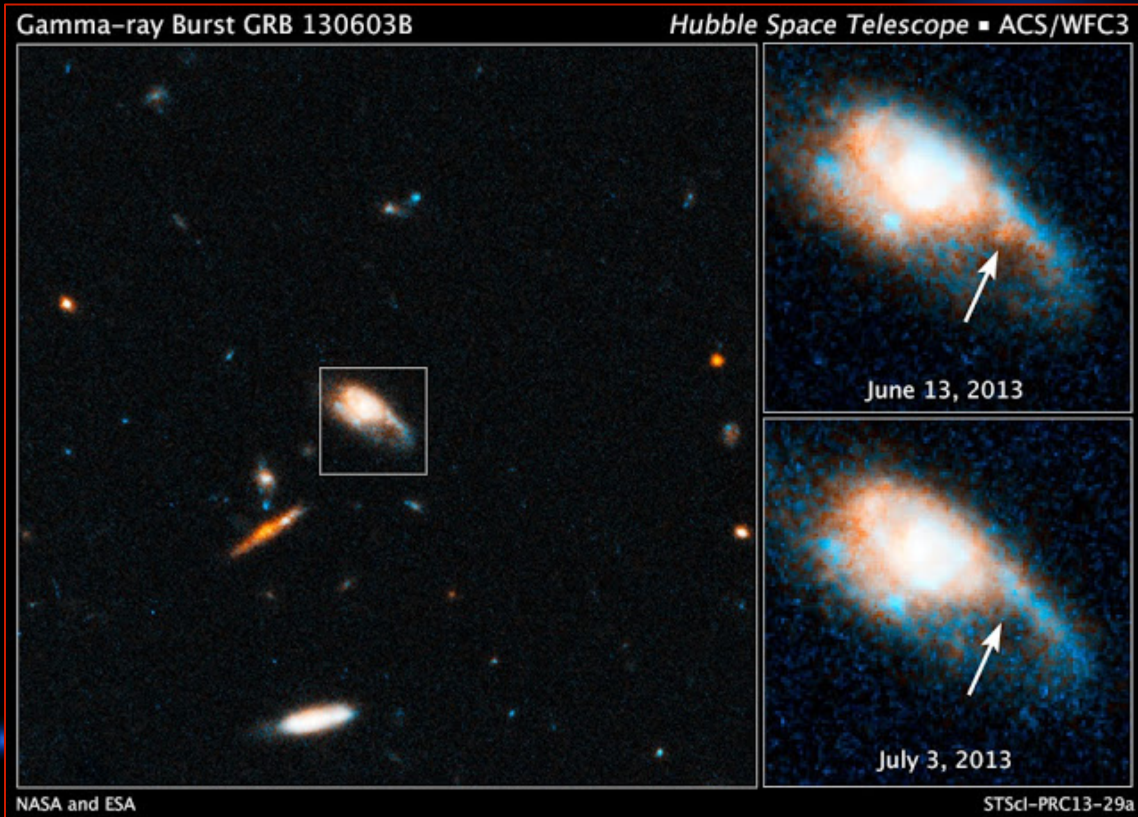
Perdón, Urânia !

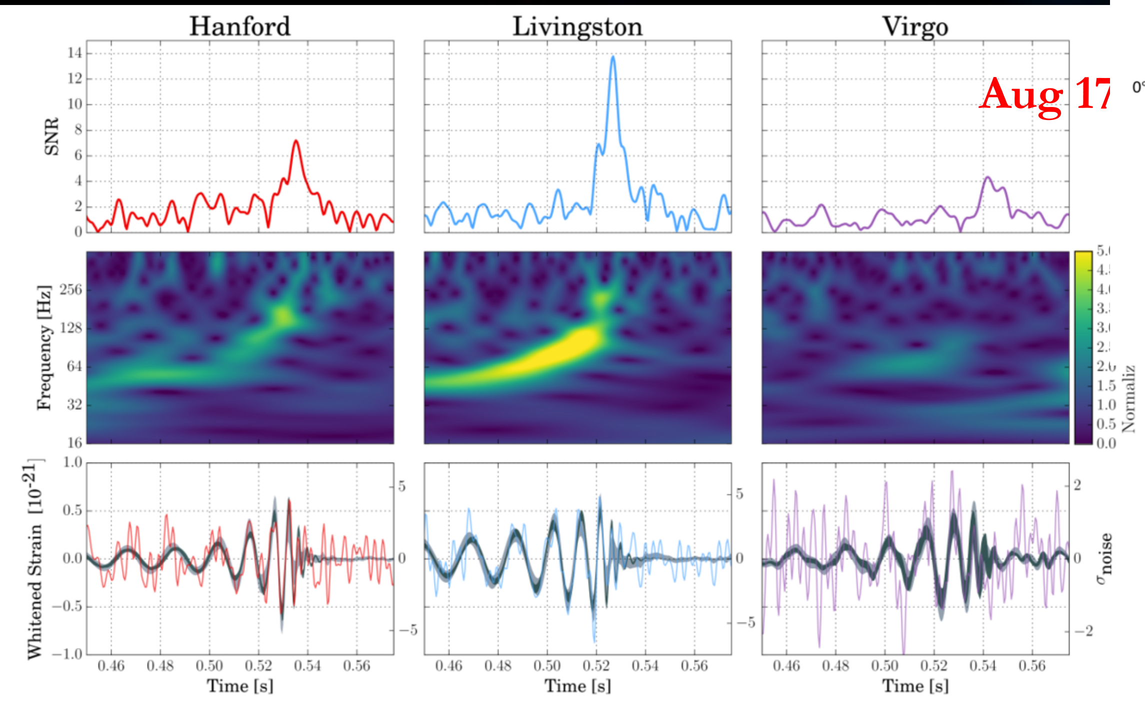


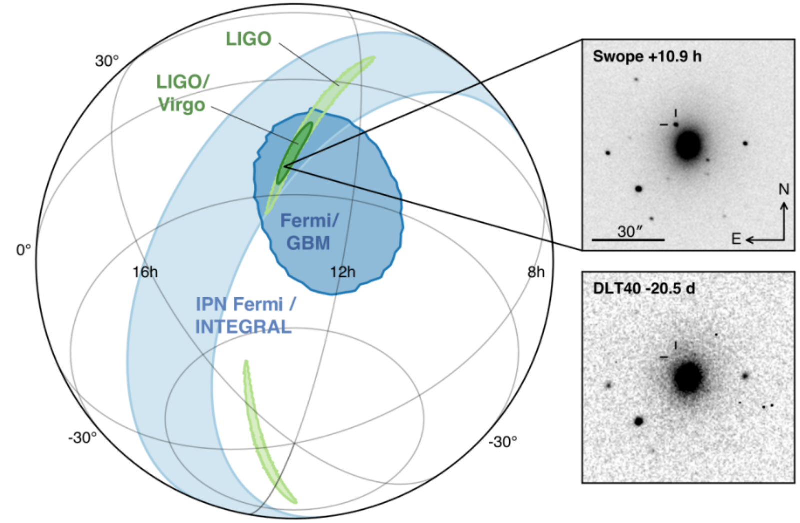
Kilonovae

NIR excess after a Gamma-ray burst GRB 130603B

20 $M_{\oplus}$ of gold and 140 $M_{\oplus}$ platinum !!!

GW 170817 @ 12:41:04.4 UTC

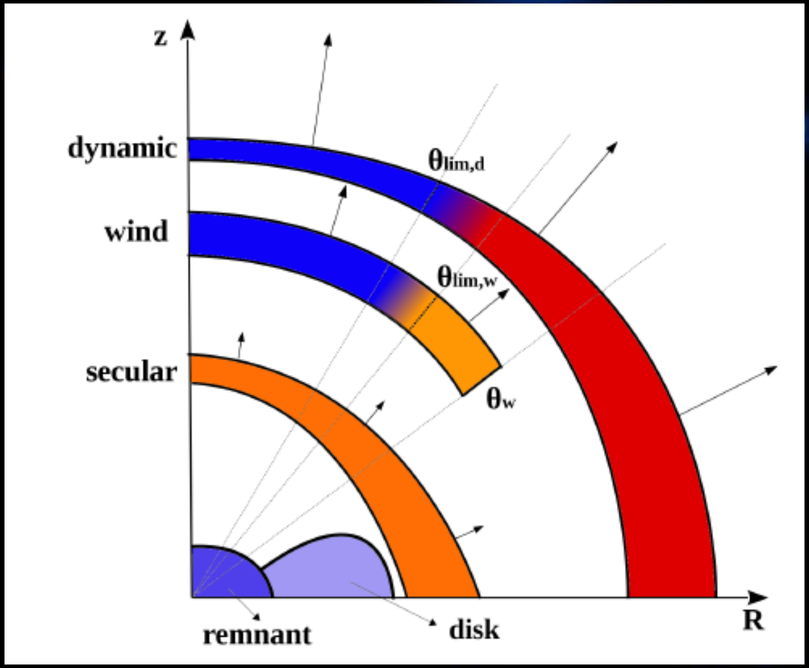




V_{dyn} ~ 0.3 c inferred

$>10^{-3}$ Mo ejected

Radice 2018



Ejection in cones (high velocity) and transient accretion disc (lower velocity)

"squeezed polar or dynamical"
less neutron rich

"secular or tidal tail "
more neutron rich

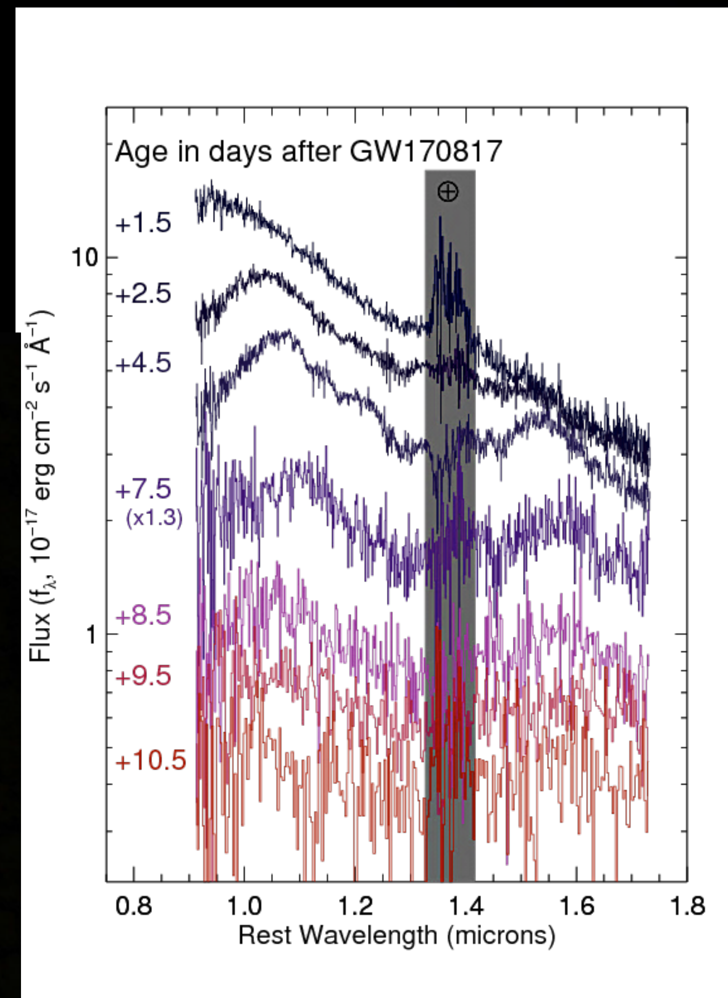
Because of different n/p ratios (or Y_e) and relativistic degree, they are usually referred as the "blue" and "red" components

Warning: the wind disk may eject 10 times more matter with a range of Y_e

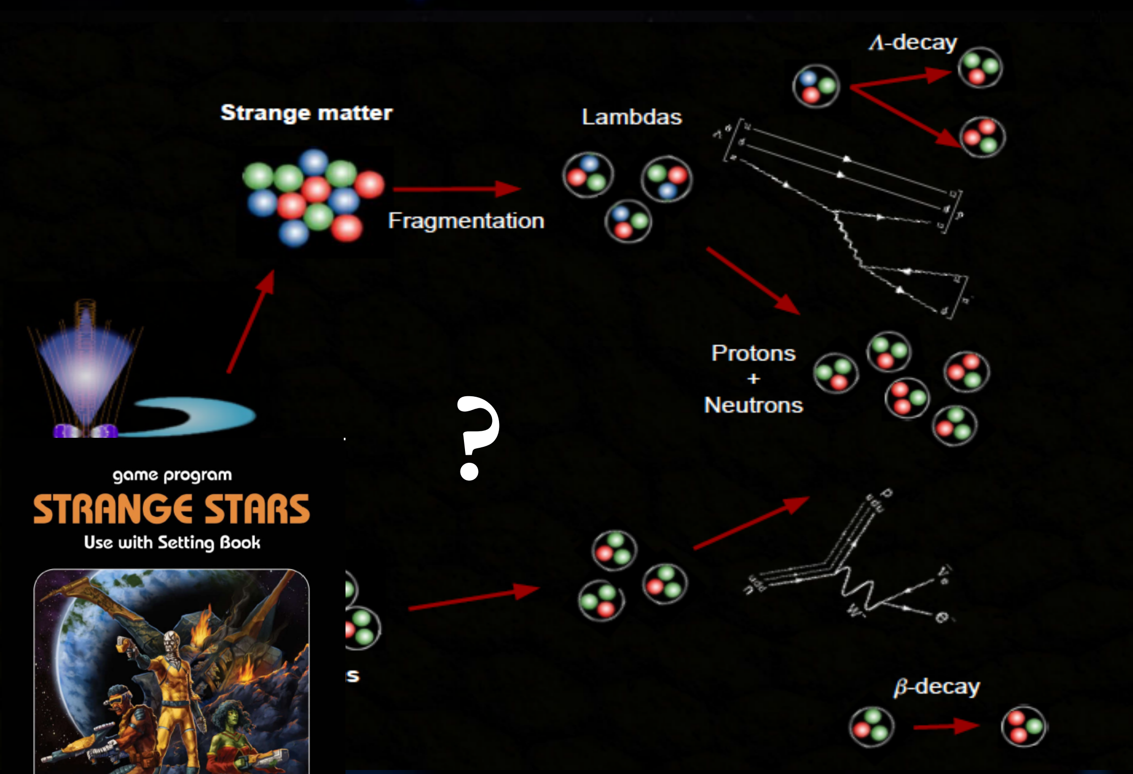
The spectral and lightcurve evidences

Two groups of r-process elements A< 140 and A> 140 give a "best fit" for the lightcurve, tentatively associated with the "dynamical" and "tidal tail" Ejecta

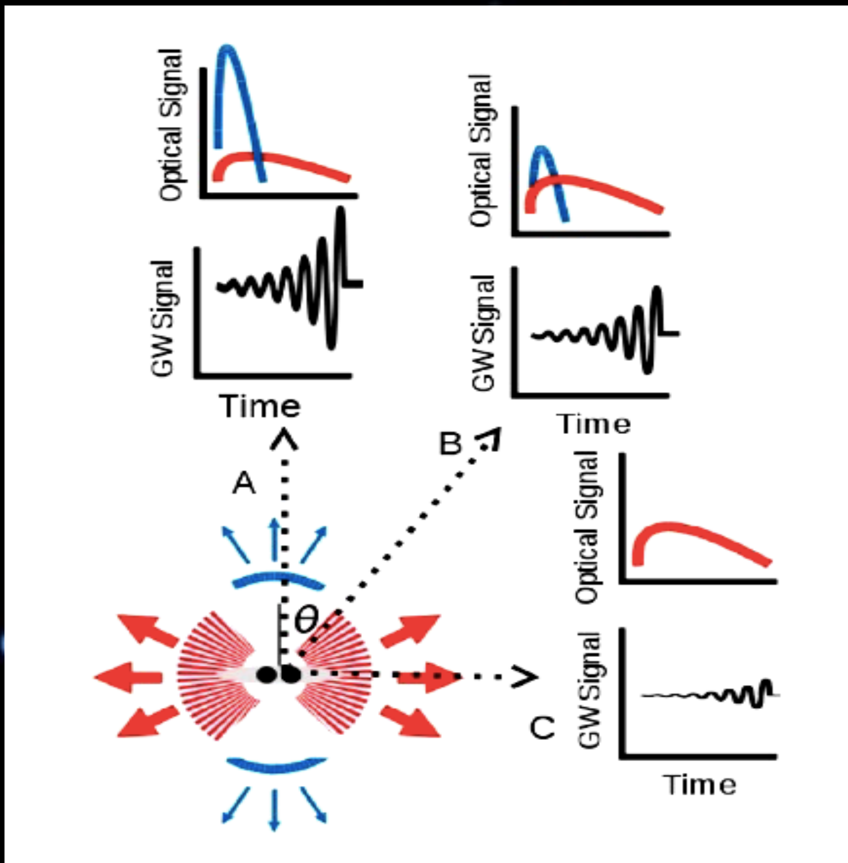
Peaks in the IR spectra associated to lanthanides (but not really identified…)



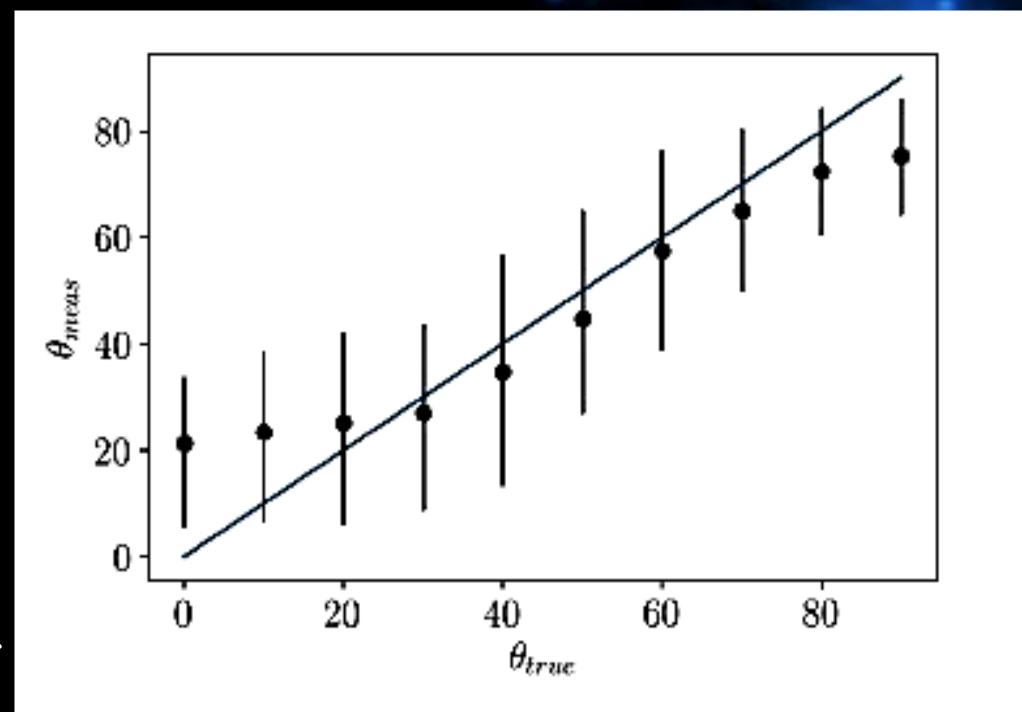
Is all this compatible with a SS-SS merger?



Disentangling the "red" and "blue" components from the viewing angle

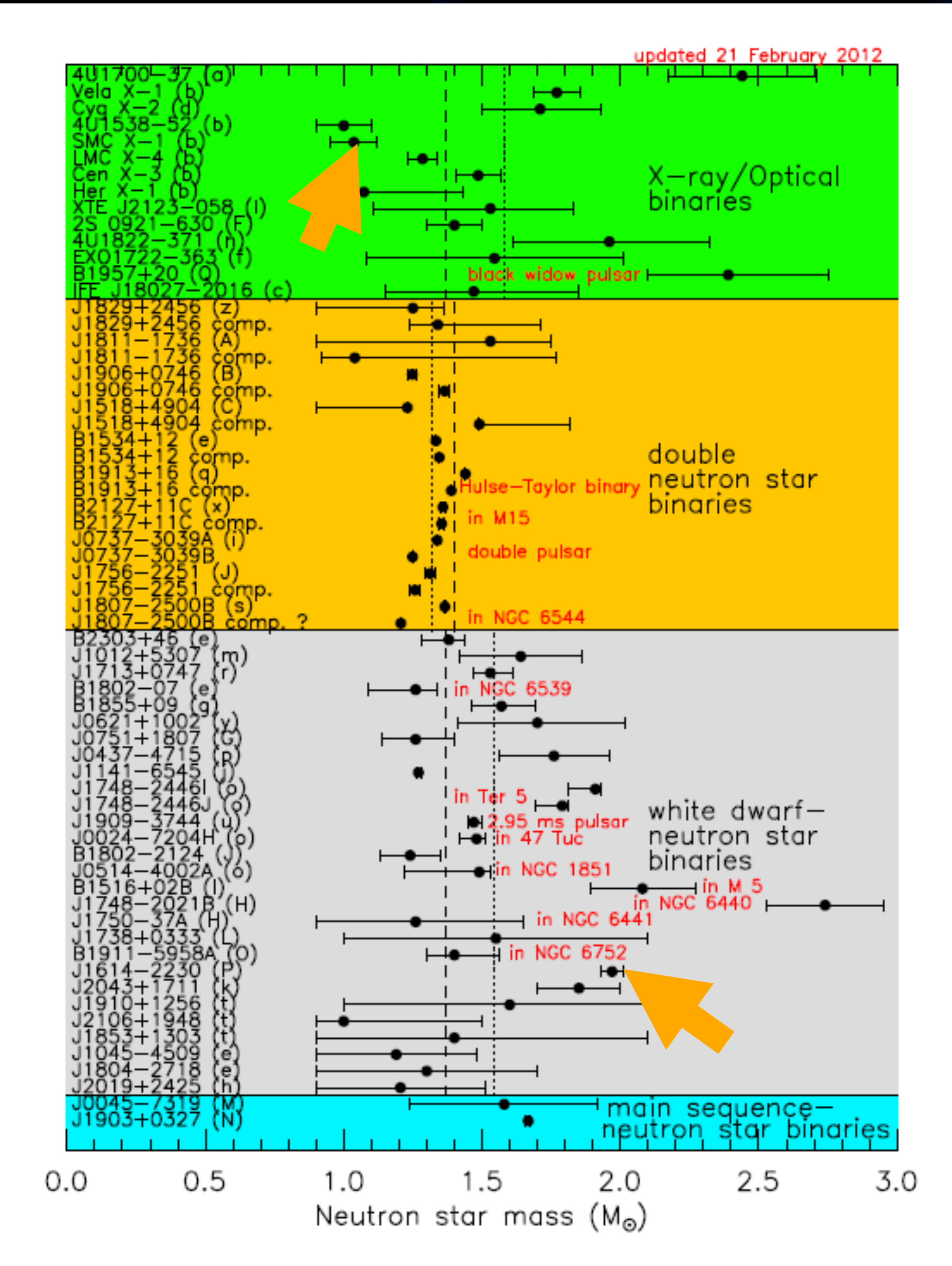


There is hope to measure the viewing angle for values greater than the opening angle of the polar emission TO time in large optical telescopes conceded
(M. Soares-Santos, personal comm.)



Preliminar simulation using

MOSFiT: Modular Open-Source Fitter for Transients (Guillochon et al. 2017)



Which kind of binary m_1, m_2?

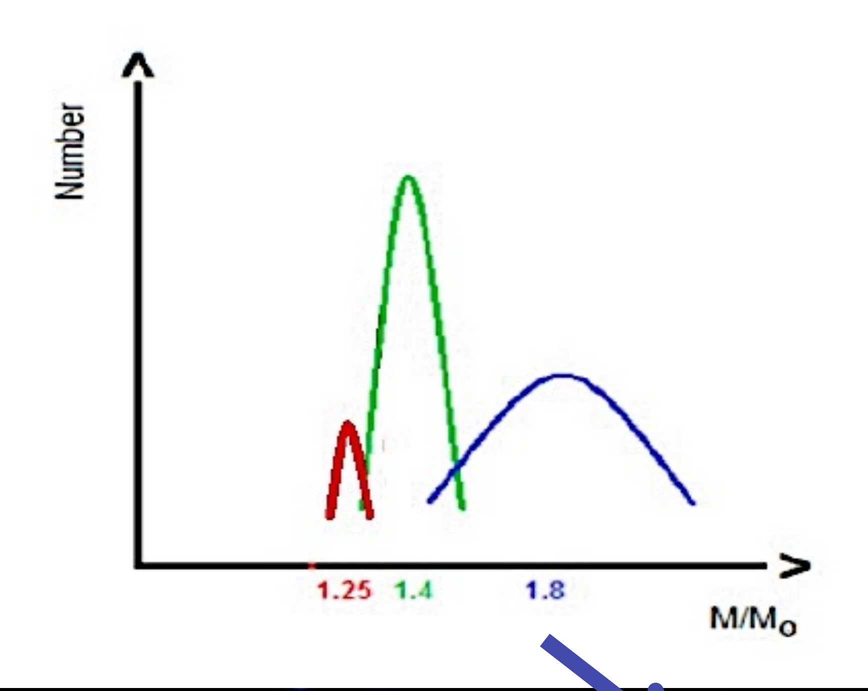
NS mass range is much wider than it used to be

Lattimer et al 2015, available at

http://www.stellarcollapse.org/nsmasses

(see also Valentim & Horvath, in *Handbook of Supernovae* astro-ph/1607.06981)

The observed NS distribution (Valentim, Rangel & Horvath 2011
C.M. Zhang et al. 2011
Ozel et al. 2012
Kiziltan, Kottas, Yoreo & Thorsett 2013



Reconstructed mass distribution from the observed data

Bayesian analysis gives the position of the peaks, the amplitudes and the widths within a Gaussian parametrization (R. Valentim, priv. comm.

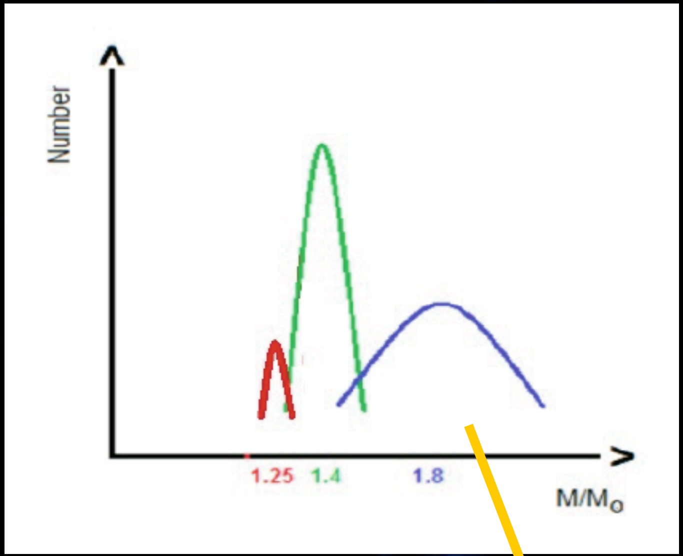
$$P(m) = \frac{0.14}{\sqrt{2\pi}\,\sigma_0} e^{-\frac{(m-1.25\,M_\odot)^2}{2\sigma_0^2}} + \frac{0.5}{\sqrt{2\pi}\,\sigma_1} e^{-\frac{(m-1.4\,M_\odot)^2}{2\sigma_1^2}} + \frac{0.36}{\sqrt{2\pi}\,\sigma_2} e^{-\frac{(m-1.8\,M_\odot)^2}{2\sigma_2^2}}$$

Mainly from electron capture SN (Schwab, Podsiadwolski & Rappaport 2010)

$$\sigma_0 = 0.07\,M_\odot$$
$$\sigma_1 = 0.08\,M_\odot$$
$$\sigma_2 = 0.28\,M_\odot$$

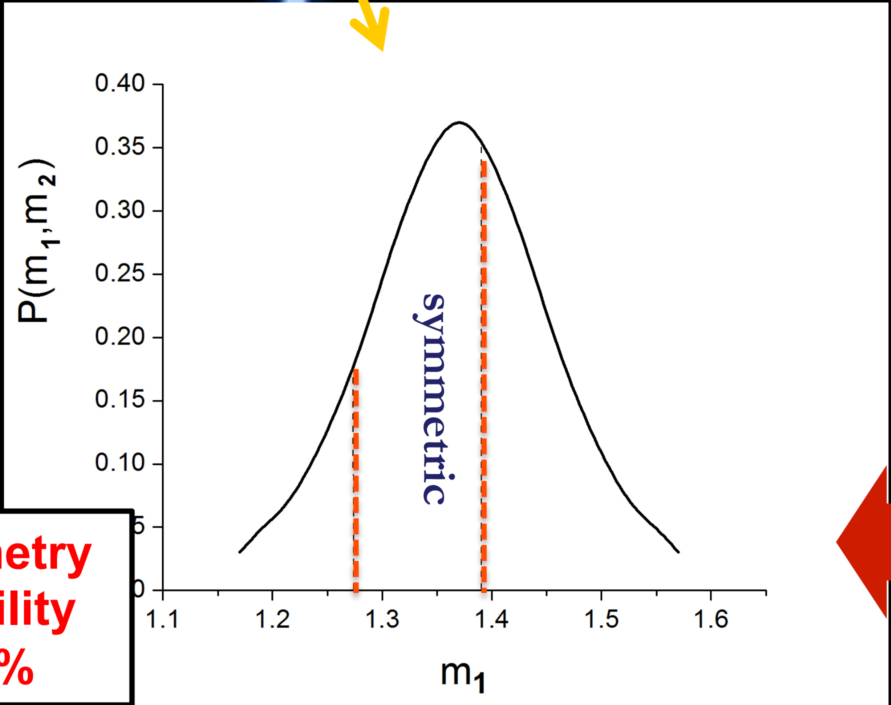
The asymmetry of the binary in GW170817 and observed NS

(see also Pankow 2018)



We can now calculate $P(m_1, m_2)$ subject to the observed constraints $m_1 + m_2 = 2.74 \pm^{0.04}_{0.01} M_\odot$

and $[1.17, 1.60]\, M_\odot$ is constructed



A "symmetric" system is defined to be the one in which m_1 lies within [1.33 − 0.06 Mo, 1.33+0.06 Mo], the observed distribution of double NS

Asymmetry probability is > 50%

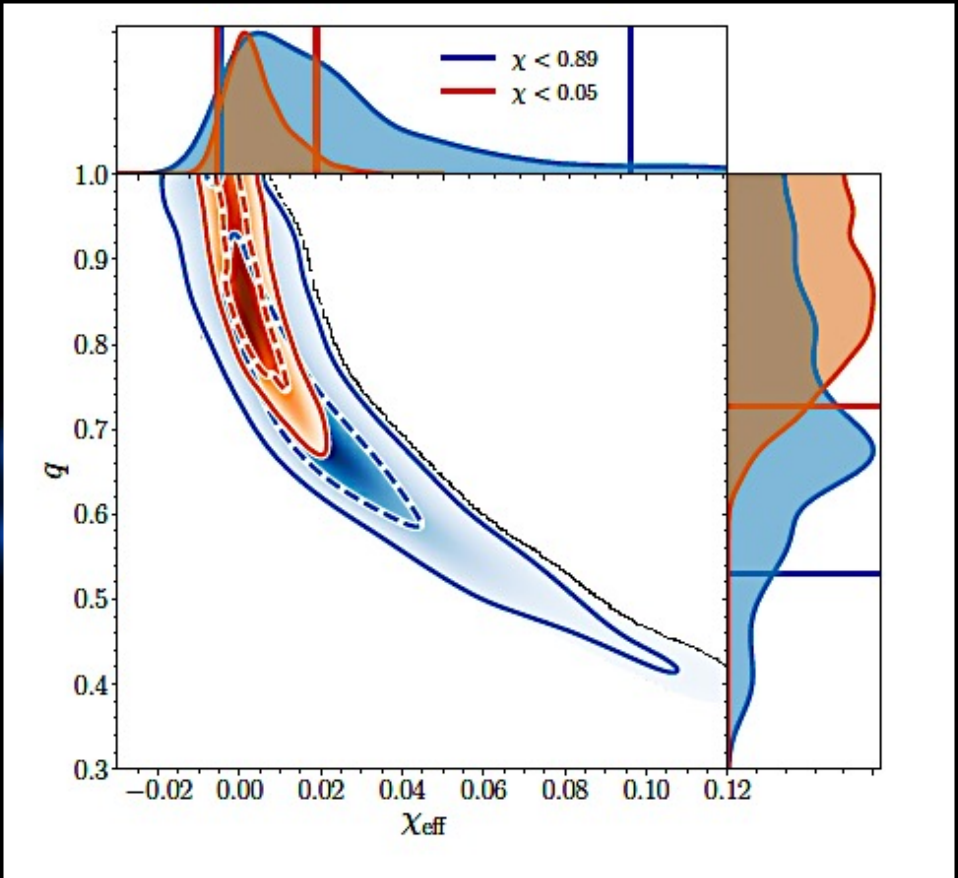
PSR J0453+1559 : an asymmetric double NS system (Martinez et al. 2016) measured with the Shapiro delay

$$M_p = 1.559 \pm 0.005\, M_\odot$$

$$M_c = 1.174 \pm 0.004\, M_\odot$$

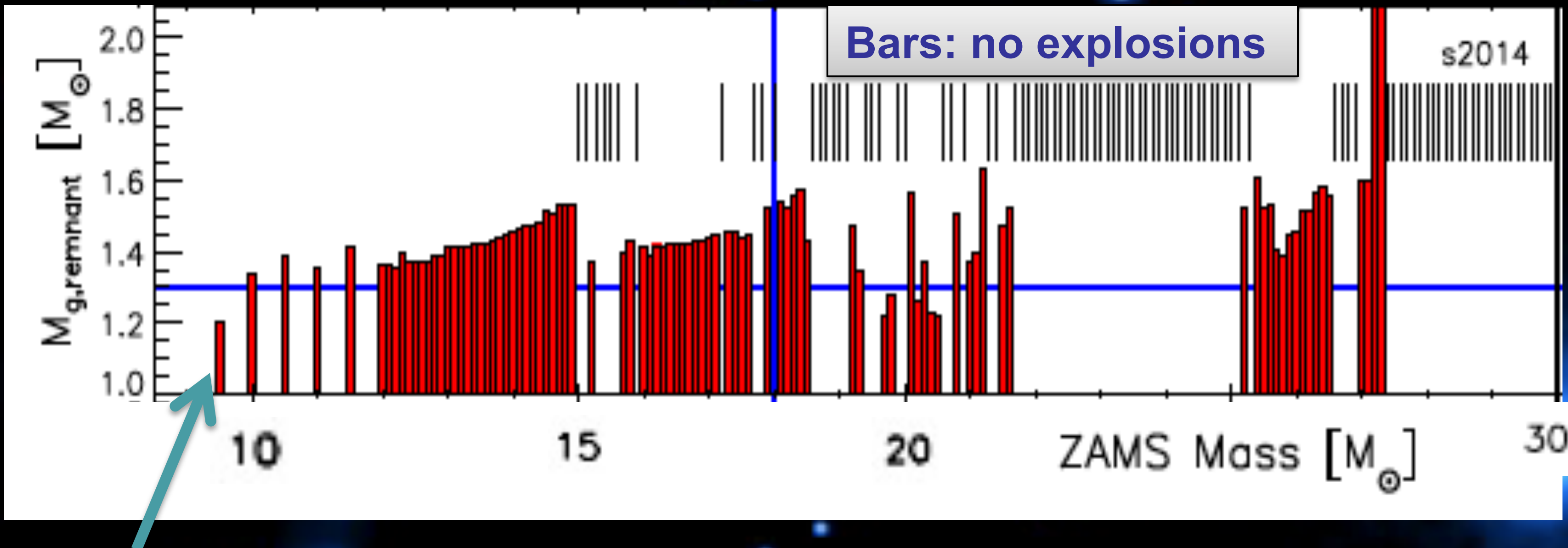
Why is this important?

LIGO Scientific Collaboration arXiv:1805.11579v2



$q = m_2/m_1 \sim 0.7\text{-}08$ is favored by data, either in the "low-spin" or "high-spin" priors

Recent works : the production of NS and BH is not monotonic : it depends on many things that vary with pre-SN and core physics



Lowest iron core NS mass, electron capture not included

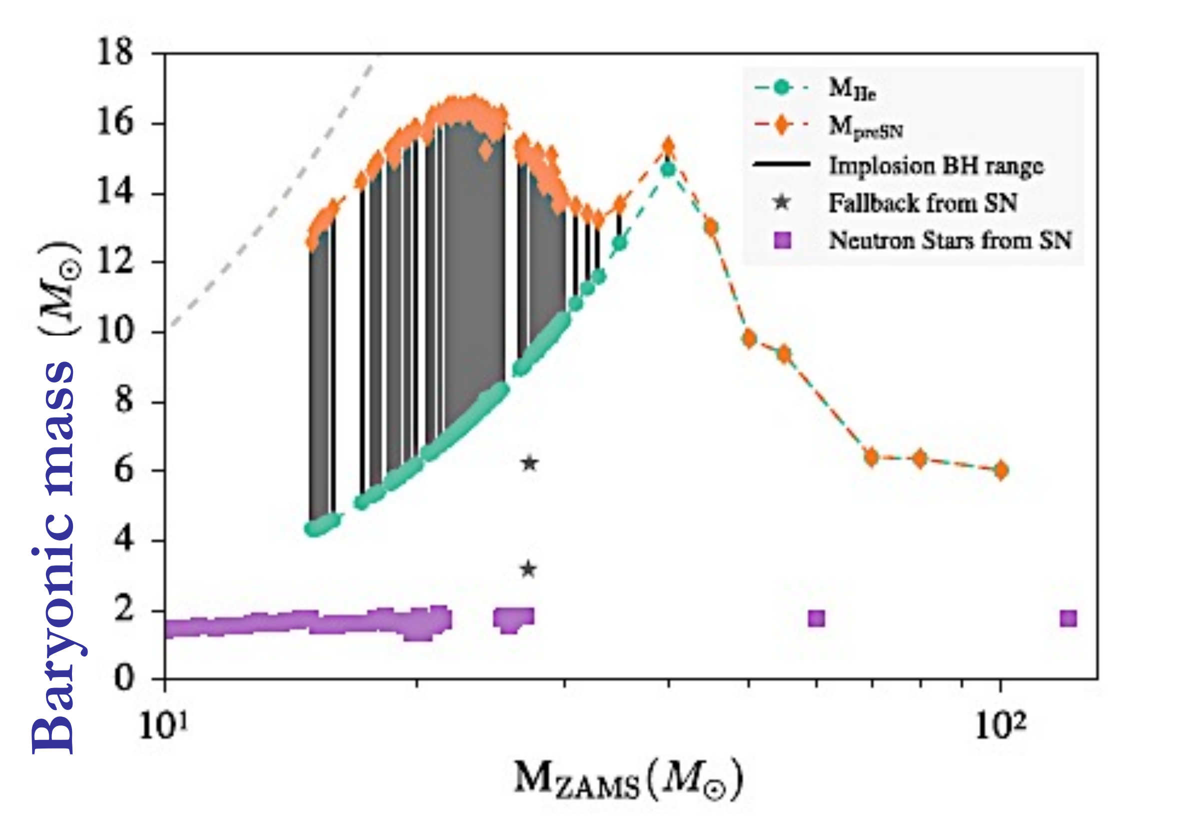
The "peak" at ~ 1.8 Mo does not appear, (at least in these calculations…)

T. Ertl[1,2], H.-Th. Janka[1], S. E. Woosley[3], T. Sukhbold[3], and M. Ugliano[4]

(submitted)

Same pattern in

Raithel, Sukhbold & Ozel, arXiv:1712.00021v2



Again the "peak" at ~ 1.8 Mo is **absent**, and the range 15-21 Mo and 25-28 Mo alternate BHs and NSs …

How to form a compact NS-NS binary merging in less than the Hubble time?

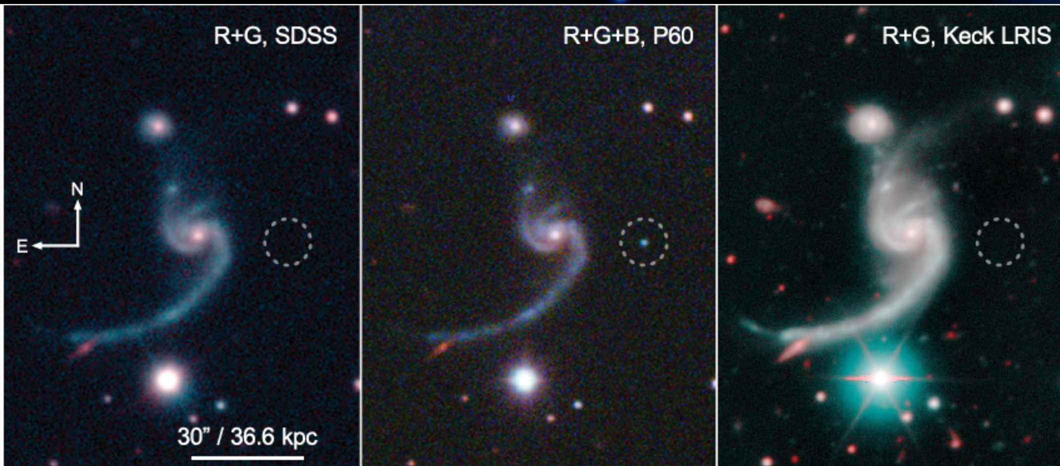
$$\tau_C = \frac{5}{256}\frac{c^5}{G^3}\frac{a_0^4}{\mu M^4}$$

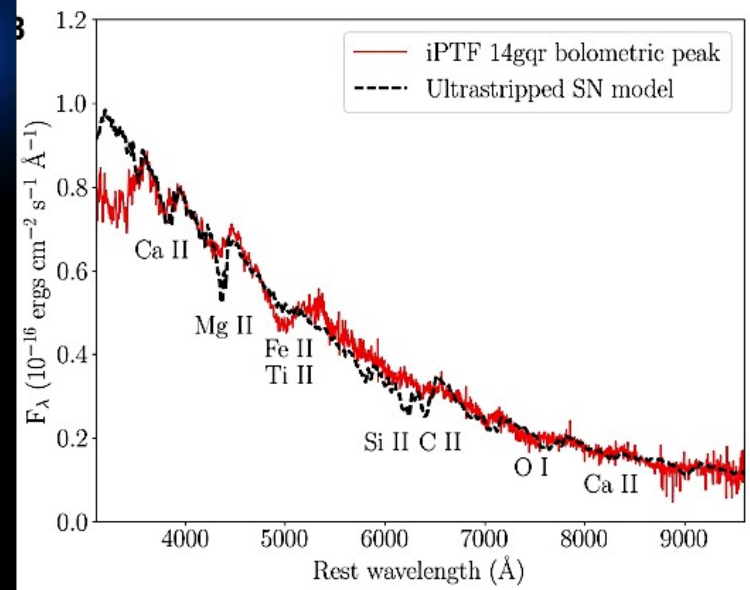
Unless the initial semi-axis is < few A.U.s the merger will take far too long and will not occur now…

"Independent" supernovae in binary progenitor systems will not be close enough (i.e. PSR J0453+1559) in general, thus, a different channel must exist… (the radius of a supergiant is typically > 1 A.U.s)

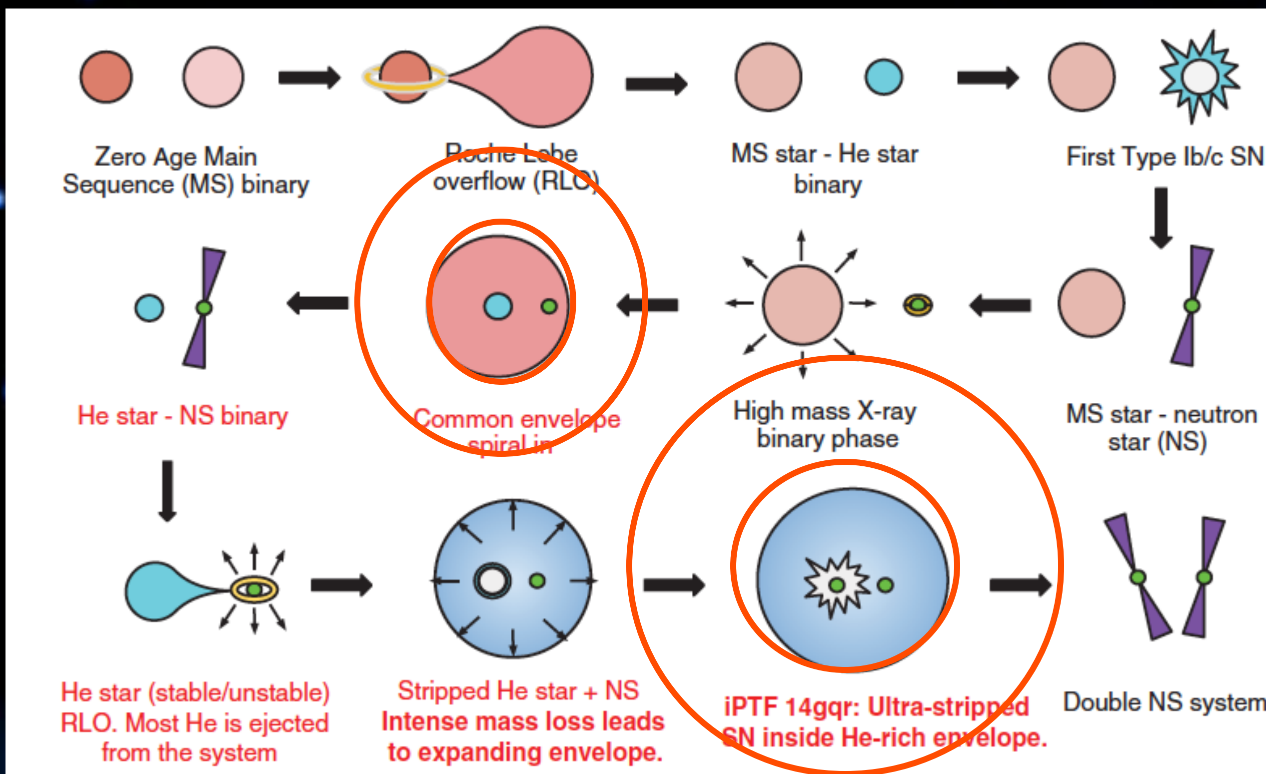
Moreover, if one of the SNe produces a light NS, we must consider electron-capture events for at least one of the pair (i.e. PSR J1756-2251) The so-called "symmetric" scenario (Ferdman et al. 2014) in which two near-equal massive stars explode almost simultaneously, ejecting little mass could have an electron-capture second explosion or an ultra-stripped Type Ic one…

iPTF 14gqr ultra-stripped supernova





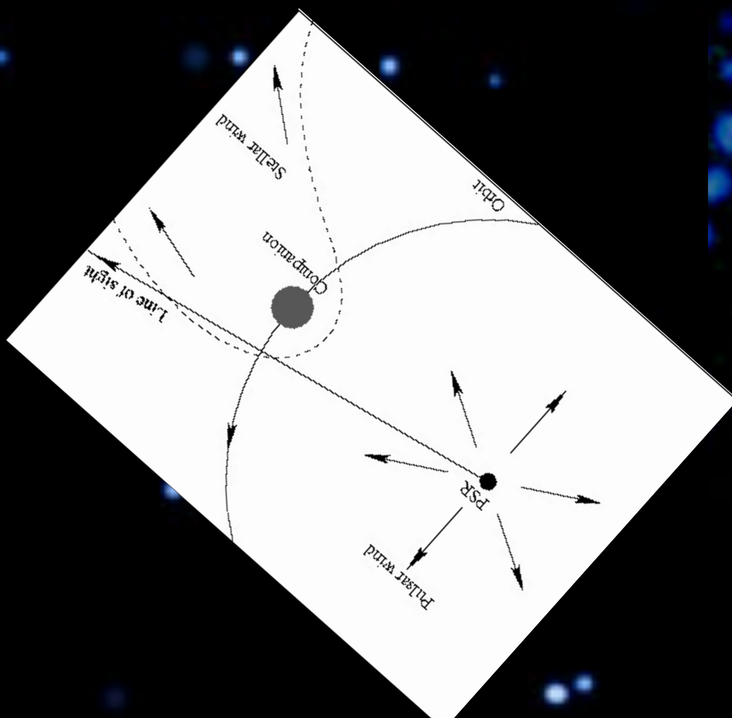
De et al. Science Oct 2018



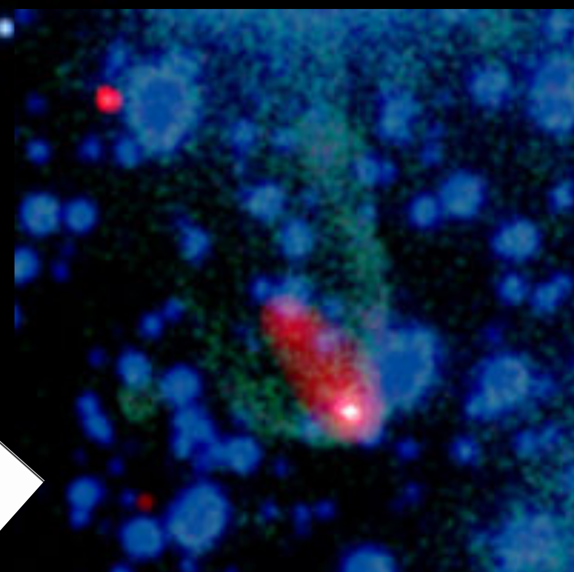
strong claim:

maybe the only way to produce very compact NS binaries

1988: Fruchter, Stinebring & Taylor (Nature 333, 237, 1988) found an eclipsing pulsar with a very low mass companion being ablated by the wind

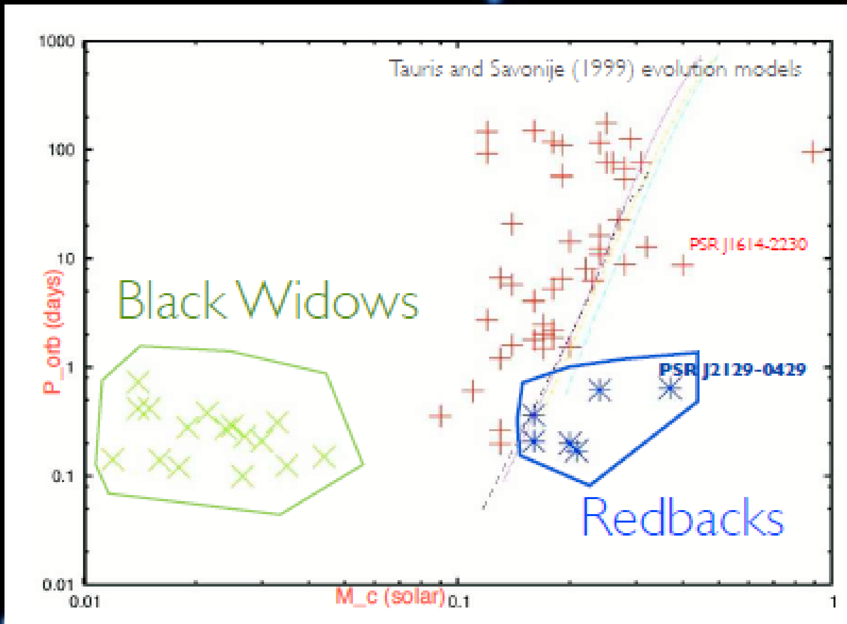


Original sketch of the PSR 1957+20 system

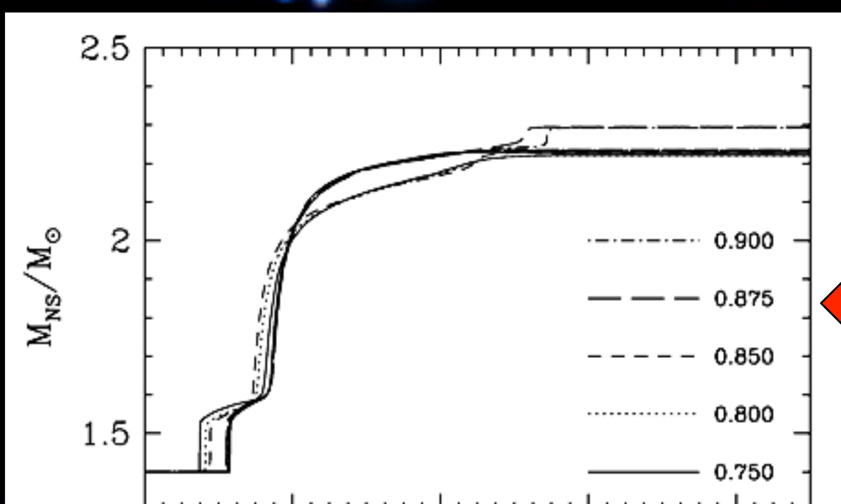


Composite Image from *Chandra* (2012)

A class of relativistic binary systems with a (massive) NS

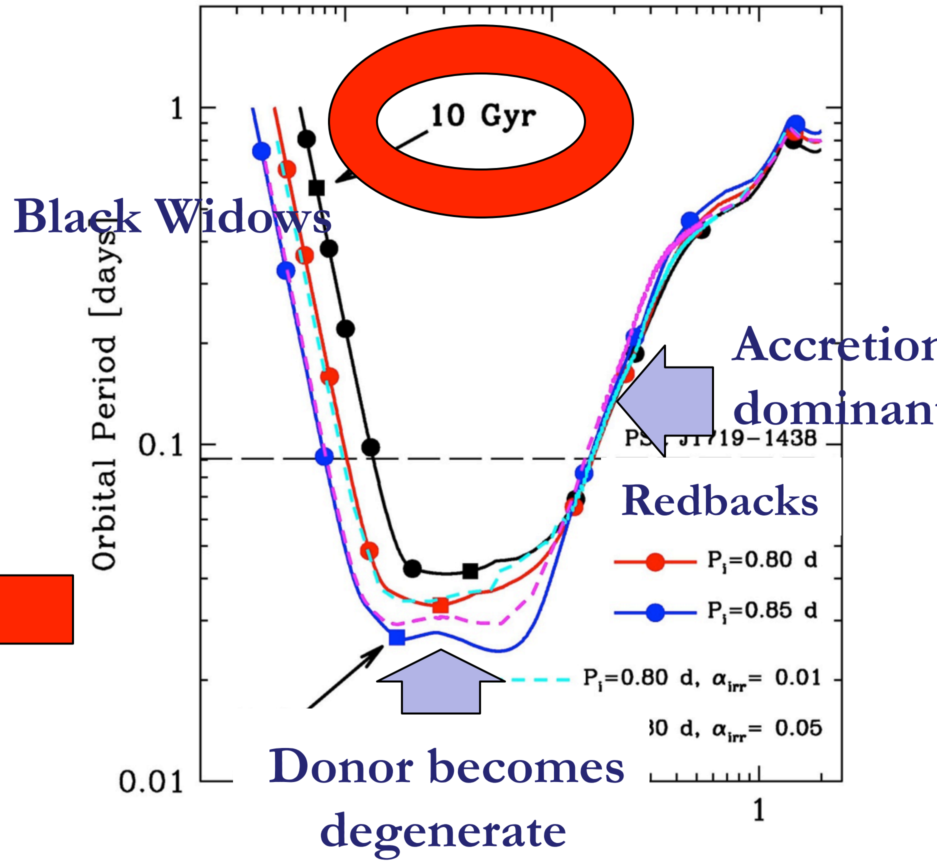


M. Roberts, arXiv:1210.6903



High masses are a natural yield

(Benvenuto, De Vito & Horvath 2012, 2014, 2015)



- The original "black widow" PSR 1957+20: results by van Kerkwijk, Breton & Kulkarni, ApJ 728, 95 (2011)

$$M_{psr} = 2.4 \pm 0.12\ M_\odot$$

($M_{psr} > 1.66\ M_\odot$ very firm)

* Romani et al. (ApJ 760, L36, 2012) found three high values for PSR J1311-3430, depending on the interpretation

$$M_{psr} > 2.1\ M_\odot \text{ up to } \sim 3\ M_\odot$$

* Linares, Shahbaz & Casares (2018) redback PSR J2215+ 5135

$$M_{psr} = 2.27 + 0.17 - 0.15\ M_\odot$$

There is a (still potential) tension with the $M_{max} < 2.17\ M_{\odot}$ determined from GW170817 (Margolit, Ang Li). If a massive NS was formed instead (Dai), this bound will not apply and massive Black Widow – Redback systems could find room.

In any case, Redbacks- Black Widows may be the most massive NS in Nature, independently of their exact value, because their extremely large accretion history/life

It is a good policy to keep an eye on them, because the issue of the maximum mass could be hidden there

Conclusions

- "Kilonovae" follow a (short) GRB, now proved to be associated to mergers of "neutron" stars and sources of GWs (although the GRB from GW170817 was ~ 1000 times fainter than average in spite of very nearby…)
- Most analysis assume a symmetric system, but this is not supported by LIGO/Virgo data
- The *a priori* probability of the system being asymmetric (in the sense defined above) is >50%. Thus we conclude that the merging system was most likely asymmetric, probably similar to PSR J0453+1559
- Compact asymmetric systems are difficult to produce, ultra-stripped supernovae can do this, but it is not clear (to me) how, and alternative formation channels should be investigated (and electron-capture supernova within them, for future events…)