Observational Evidence for Extended Emission to GW170817

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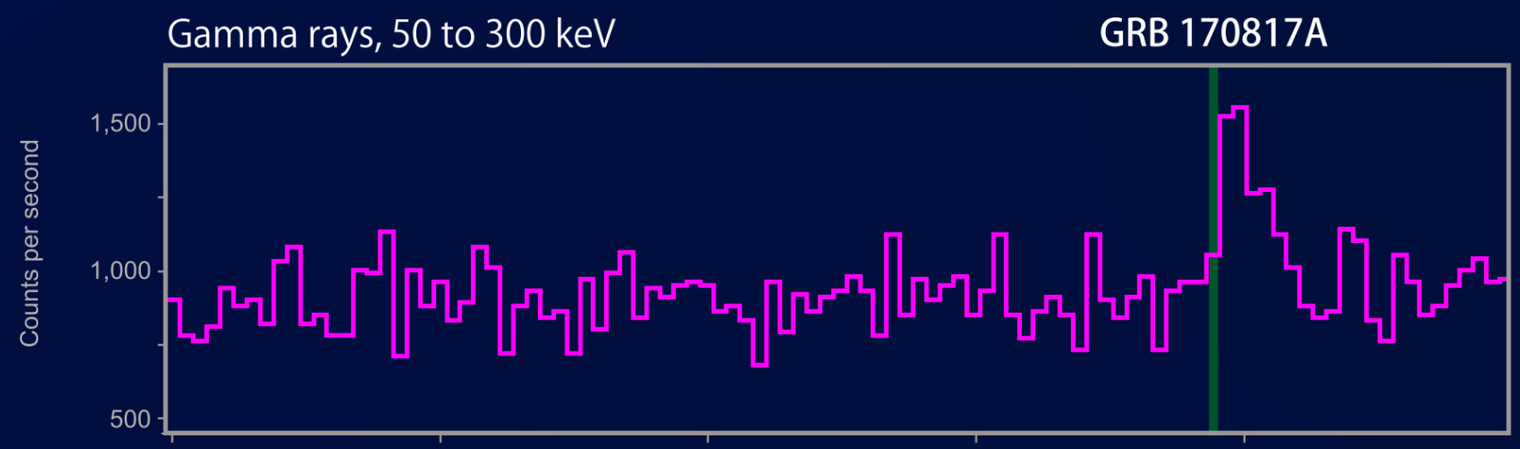
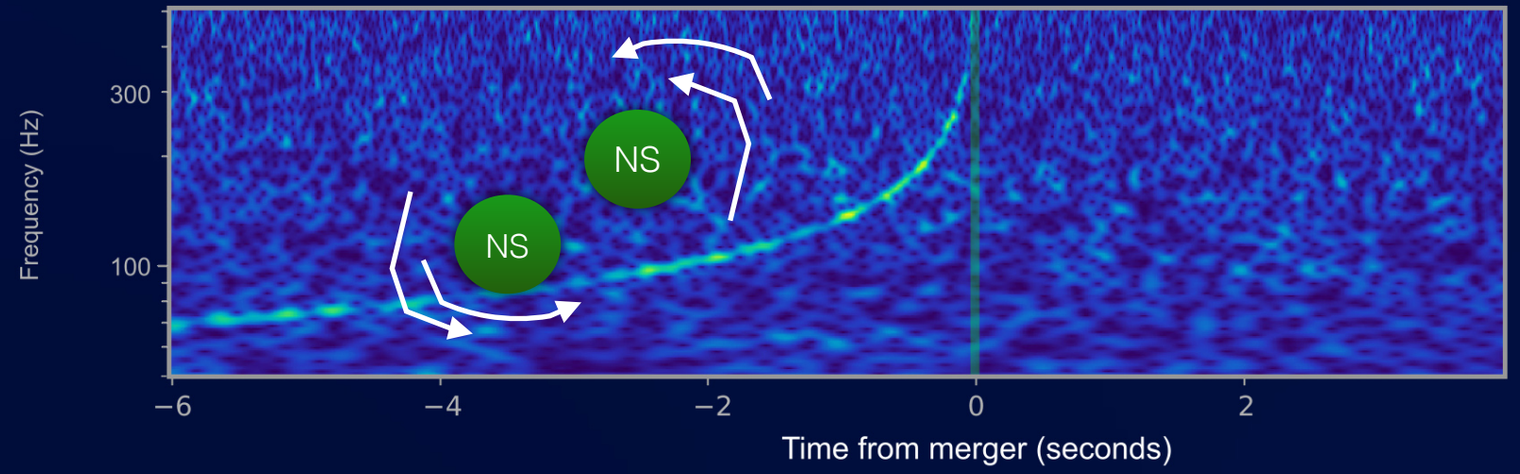
A multi-messenger window to the Universe

Fermi



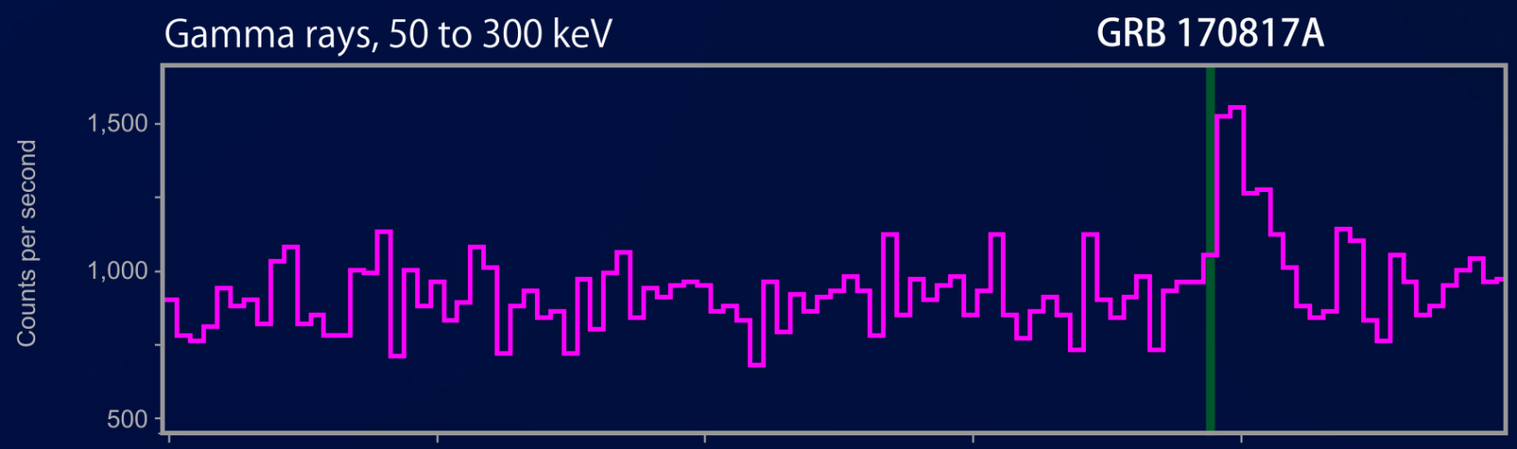
LIGO



https://fermi.gsfc.nasa.gov

GW170817: *what happened?*

Fermi



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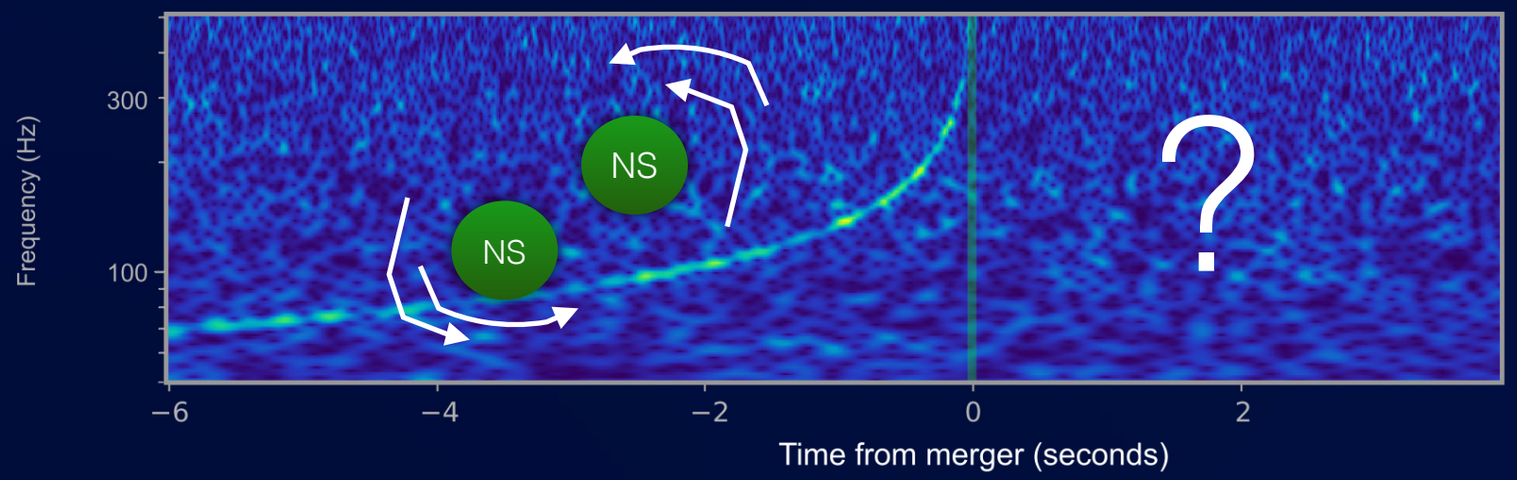
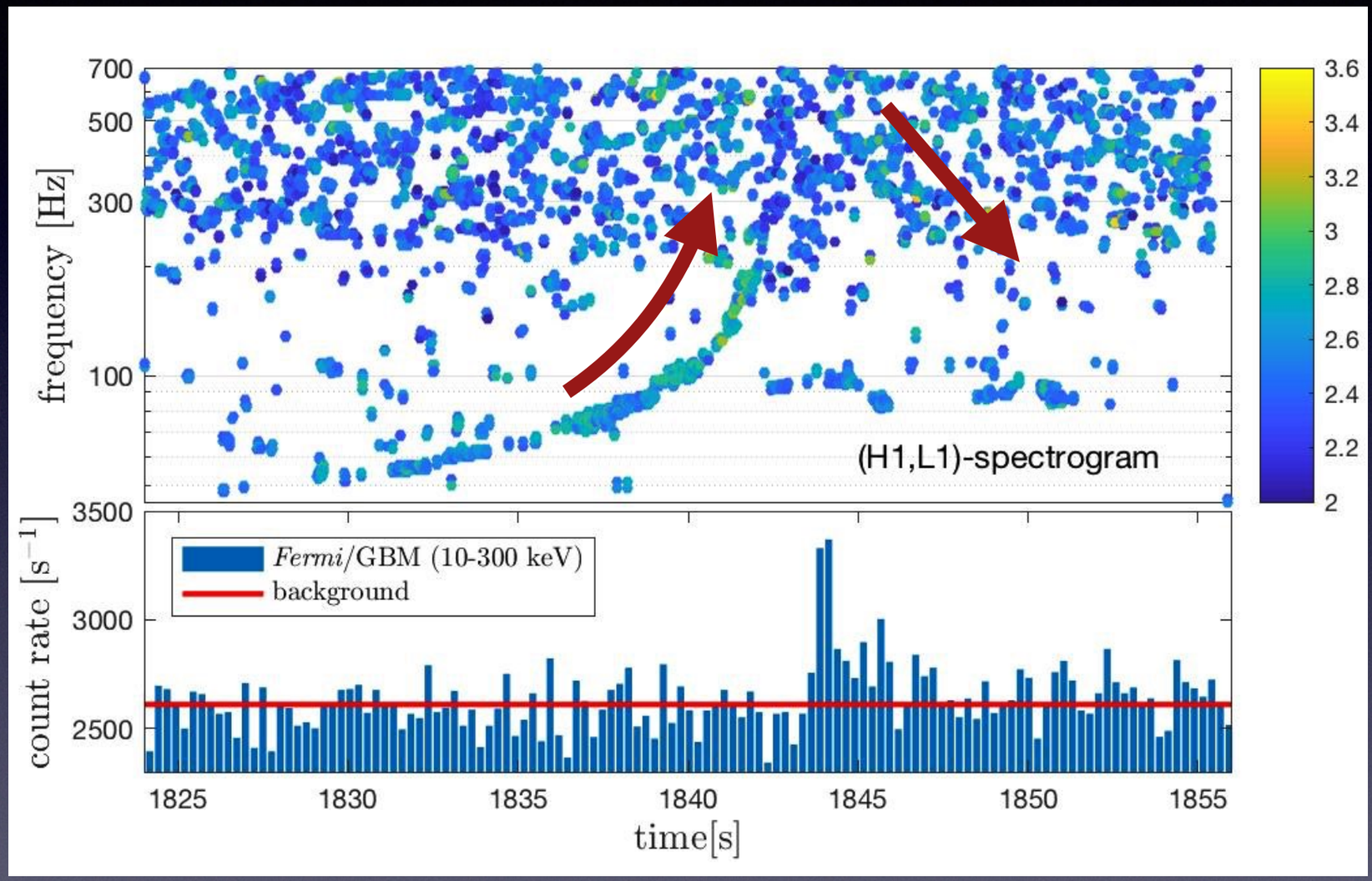


https://fermi.gsfc.nasa.gov

GW170817: ***Extended Emission***

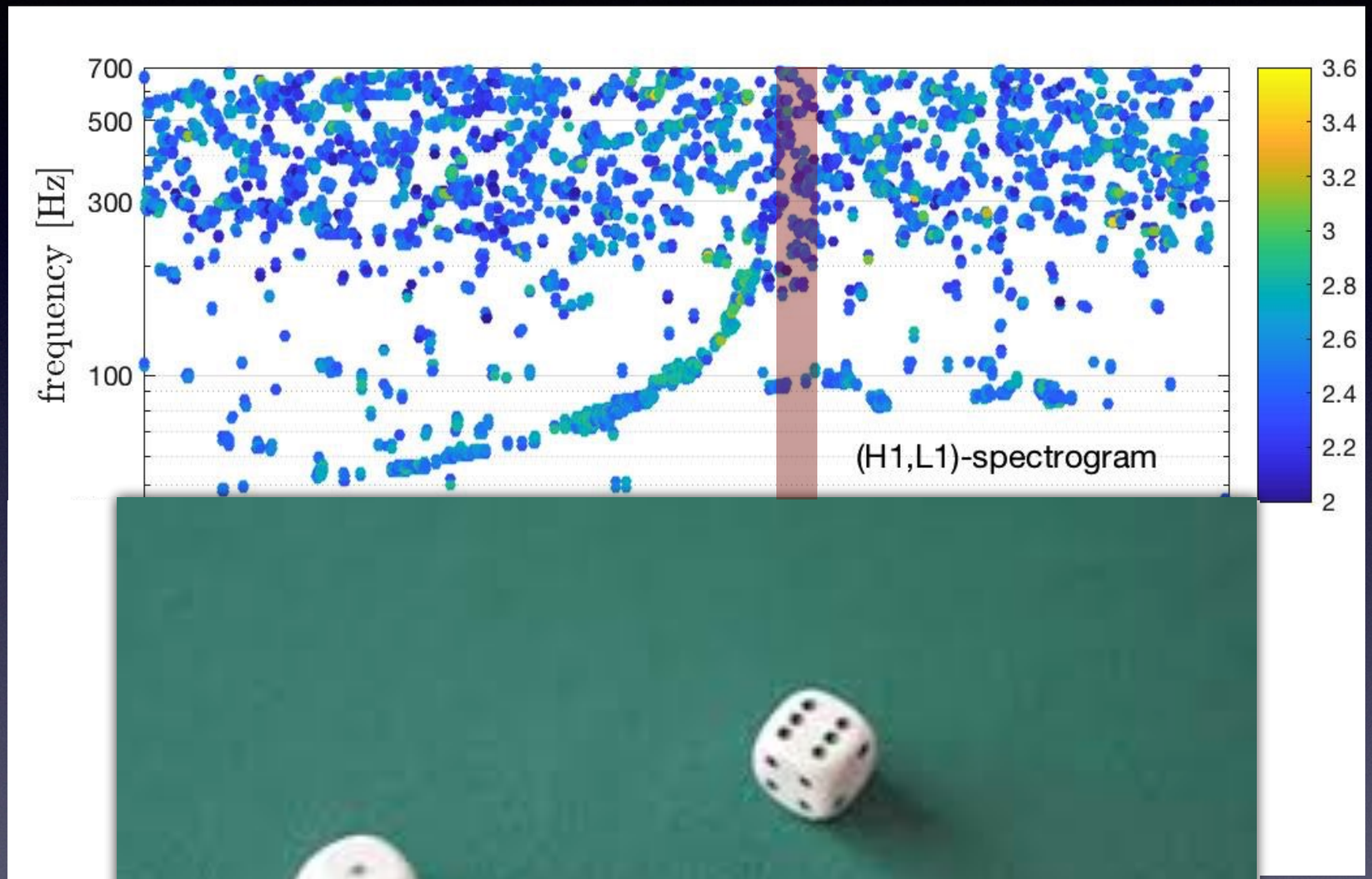


van Putten & Della Valle, 2018, MNRAS Letters, 482, L46

JGW-G1808513-v1 https://gwdoc.icrr.u-tokyo.ac.jp/

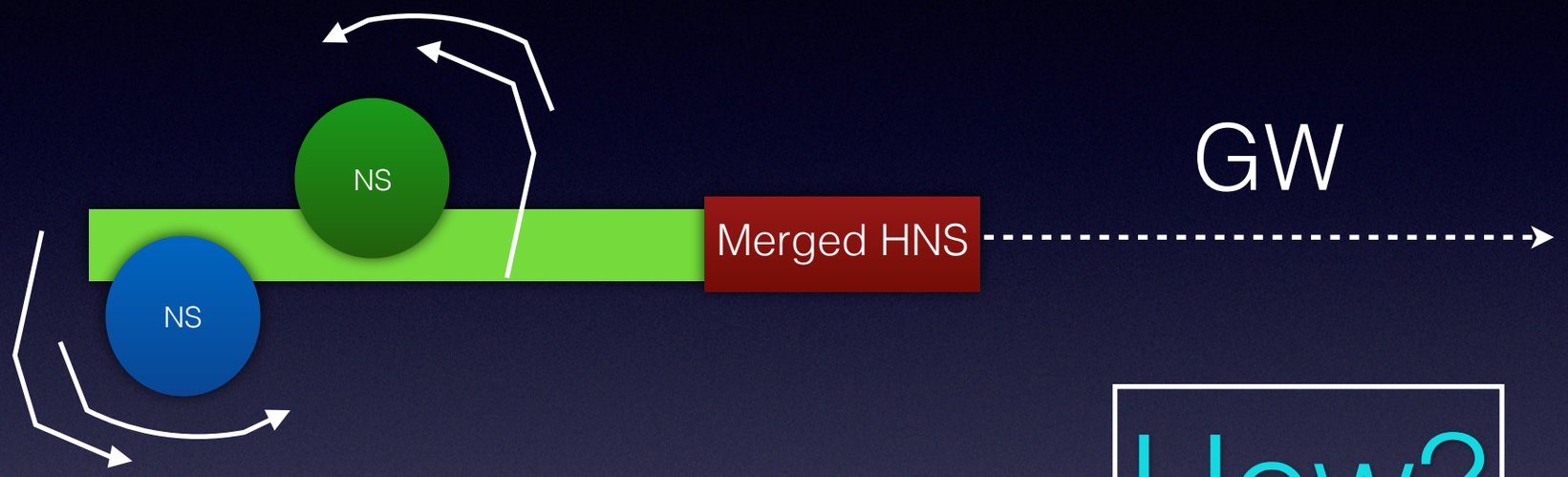
Observational significance 4.2σ (1:40.000) by timing and amplitude

(statistically independent attributes)



EE starts at 0.67s post-merger in1.7 s gap

EE - a descending chirp - radiates *J* HNS out to infinity.



How?

YAHOO! NEWS

https://news.yahoo.com/epic-crash-neutron-stars-creates-174436470.html

Epic Crash of Neutron Stars Creates 'Hypermassive Magnetar'

Mike Wall, Nov. 16 2018

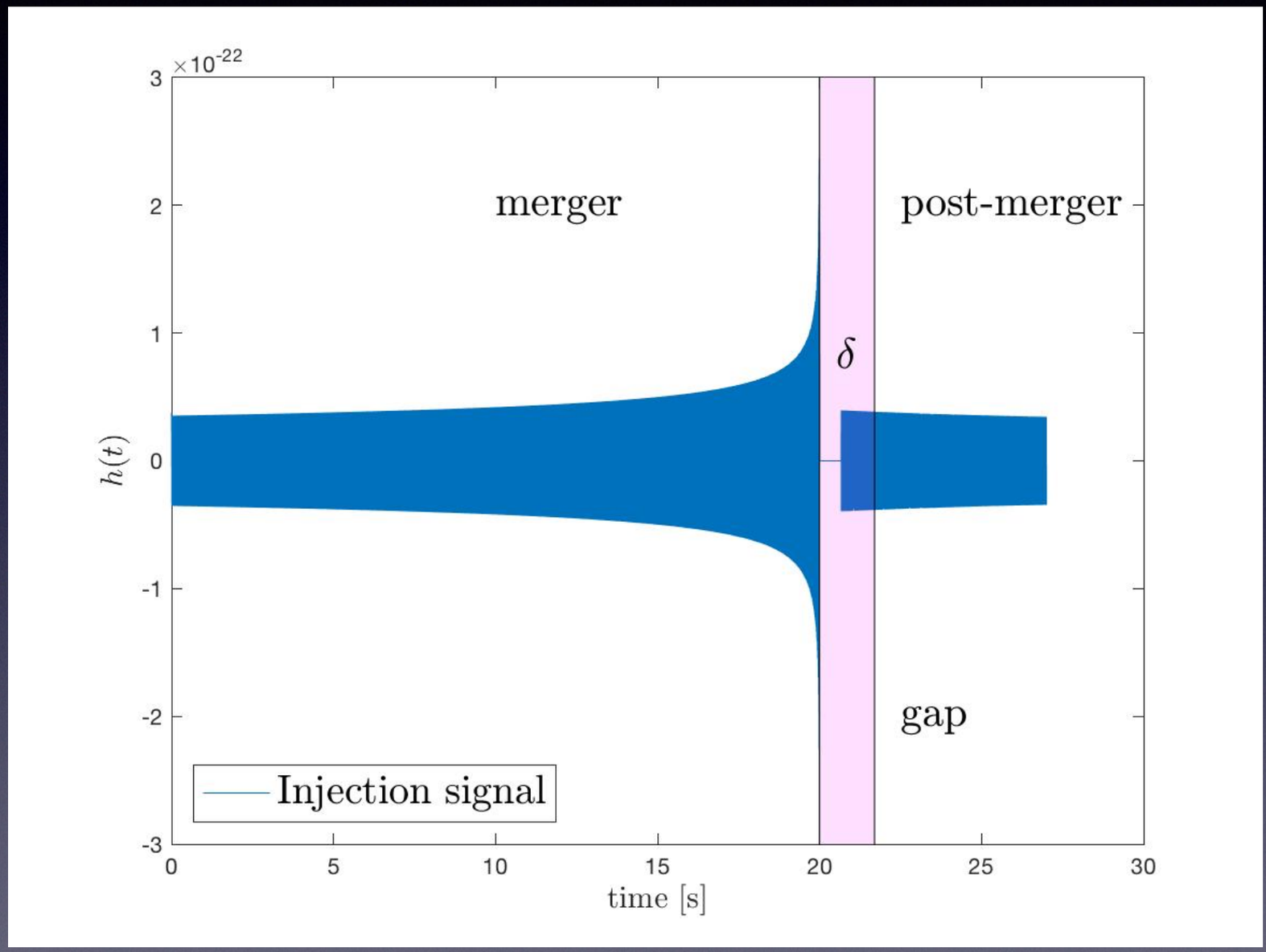
Calorimetry on Extended Emission

van Putten & Levinson, 2002, Science, 295, 1874; ibid. 2003 ApJ 584 937
van Putten Della Valle & Levinson, 2019, under review

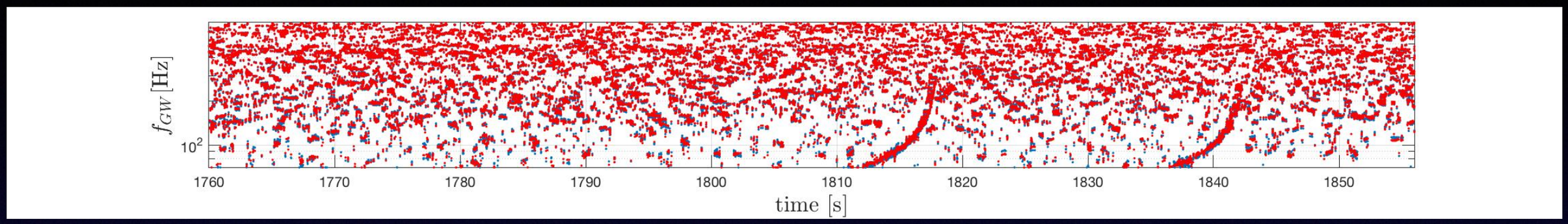
Calorimetry by Injection Experiment

(work at AEI, Hannover)

GW170817 $\mathscr{E} \simeq ?\,\% M_\odot c^2$



(H1,L1)-spectrogram merged by frequency coincidences



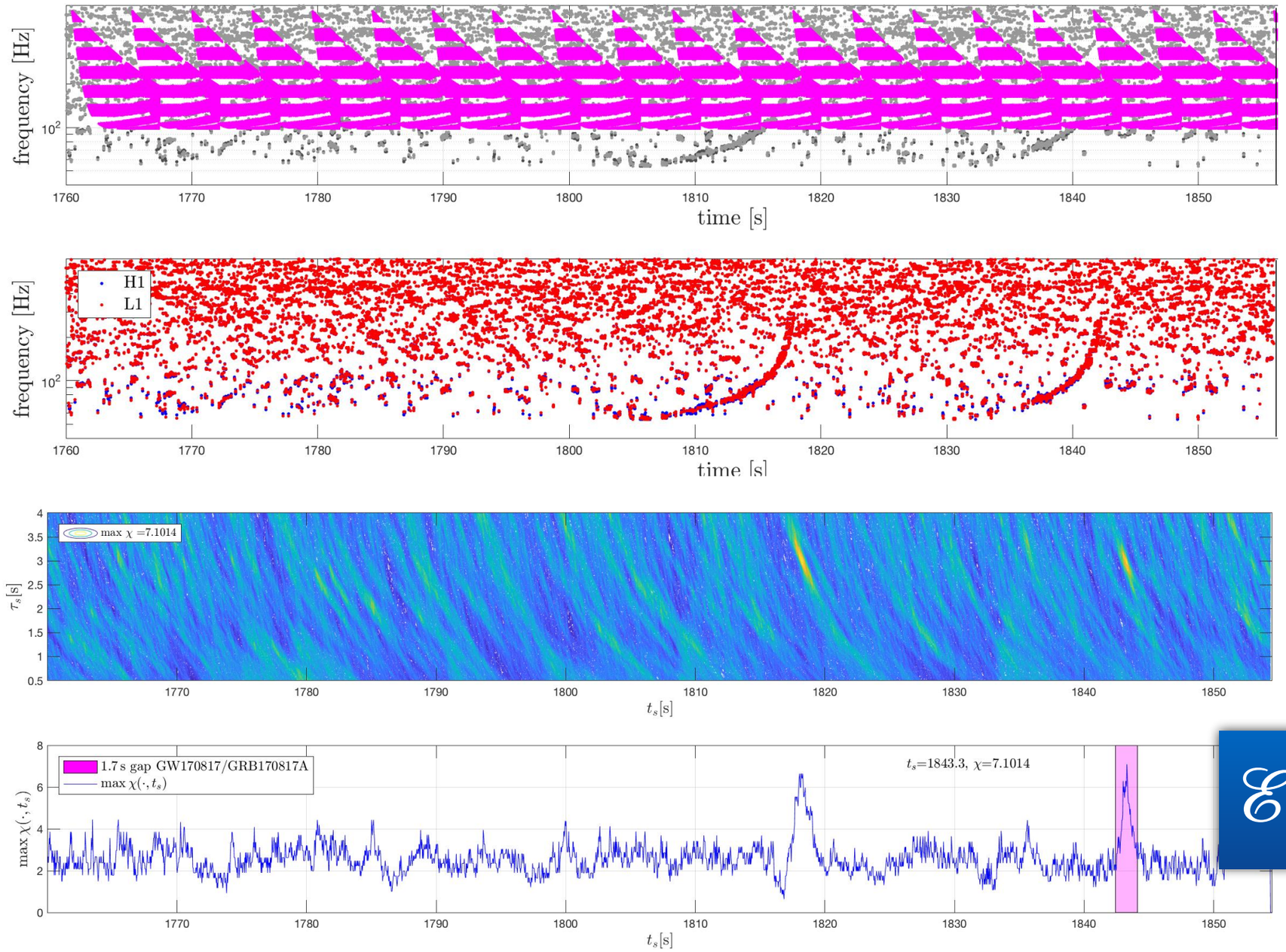
Injection GW170817EE

Matching ascending branches: true-to-observed strain ~ 0.7

Matching descending branches...

χ-image analysis: matching peaks

Scan over exponential features



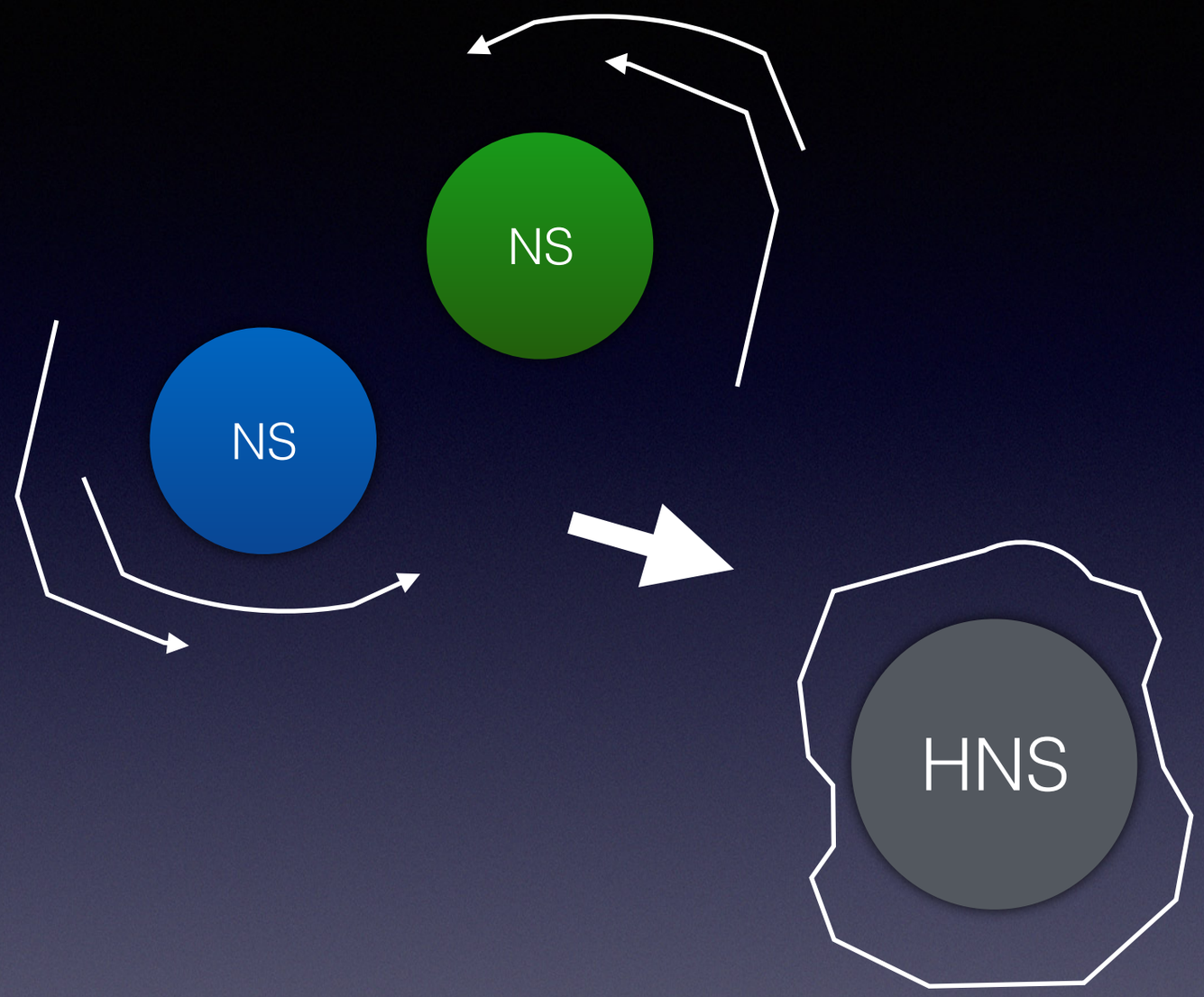
τ

$$\mathscr{E} \simeq 3\,\% M_\odot c^2$$

$$t_s \simeq 0.67 \text{ s}$$

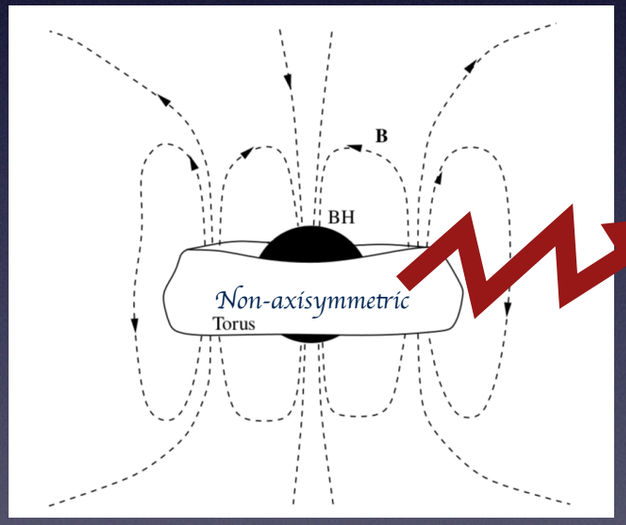
Core-collapse greatly enhances E_J

R.P. Kerr
(Crafood Prize 2016)



$$E_J \lesssim 1 M_\odot c^2$$

($\sim 3 M_\odot$Kerr BH)



van Putten, 2001, PRL 091101

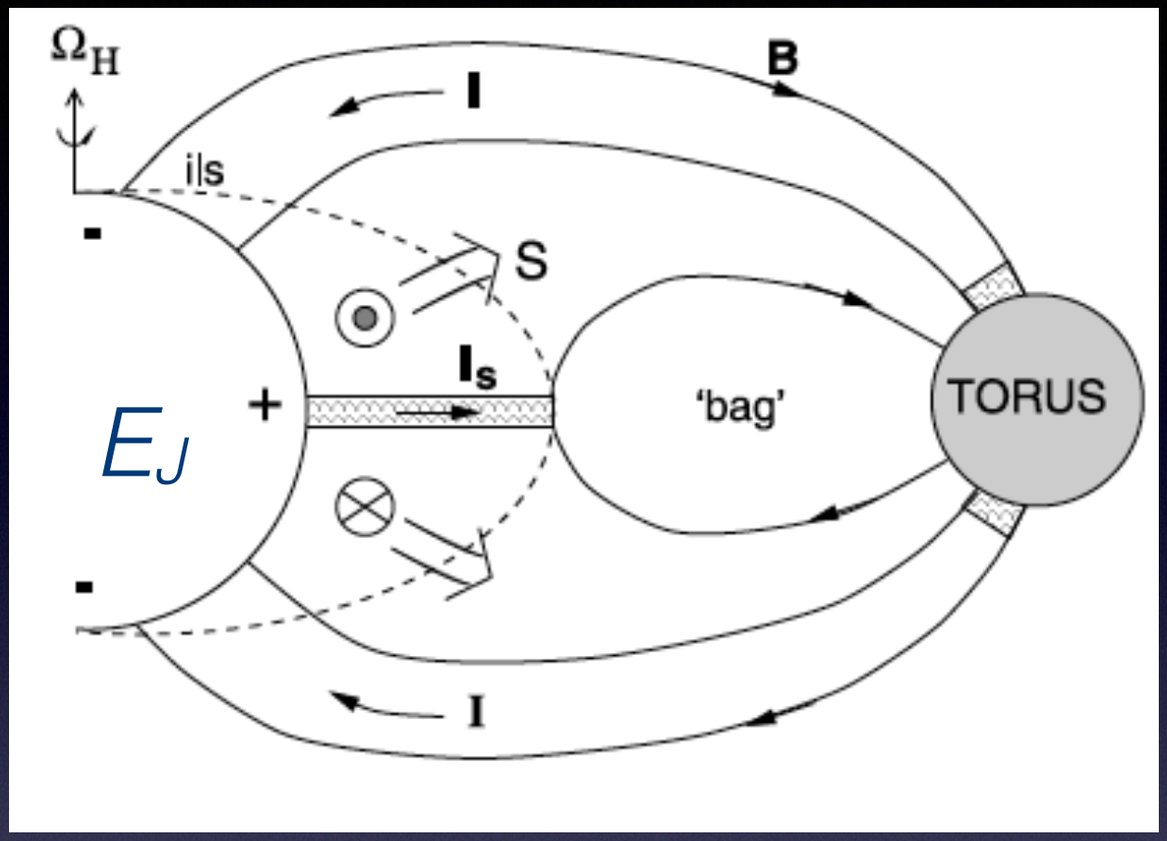
Lifetime $\lesssim 0.67$ s

Duration = T_s

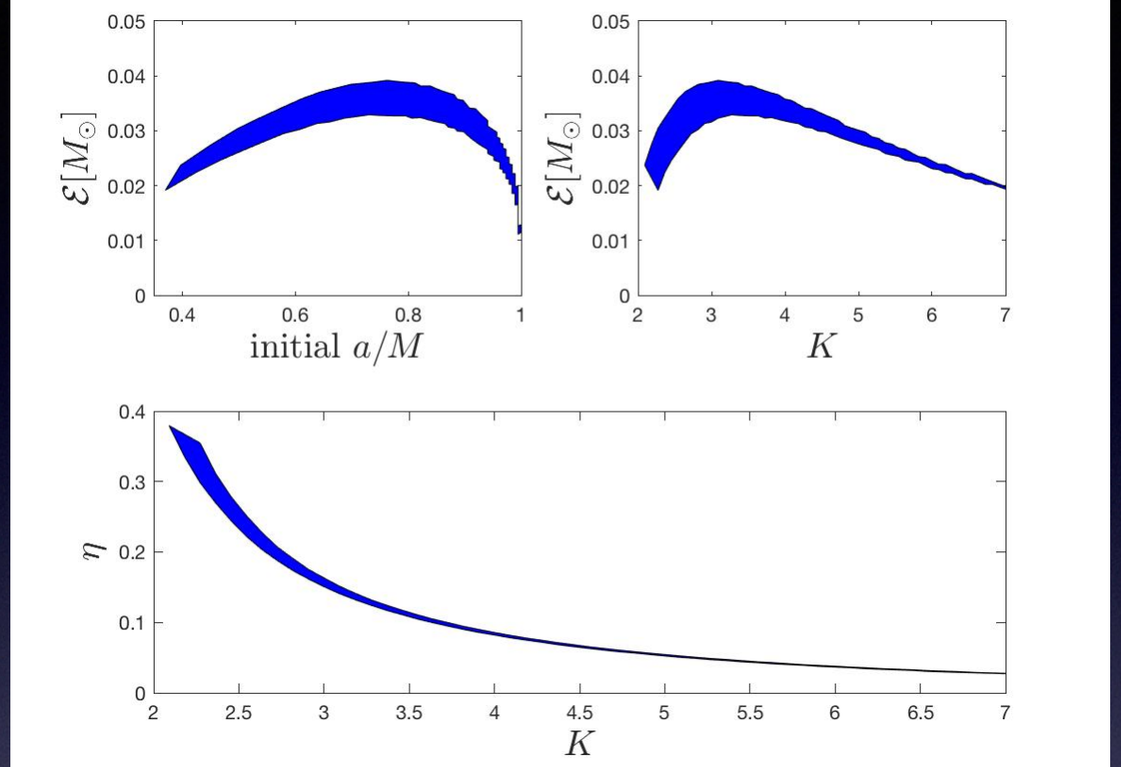
cf. $t_c \lesssim 0.9$ s, talk by A. Murguia-Berthier

Numerical solution equations of suspended accretion

van Putten, 1999, Science, 285, 115



van Putten, Della Valle & Levinson, 2019 (under review)



$$L_H = -\dot{M},\ T = -J_H$$

$$Kr_{ISCO}$$

$f_{GW,i}$ = 650Hz (observed):

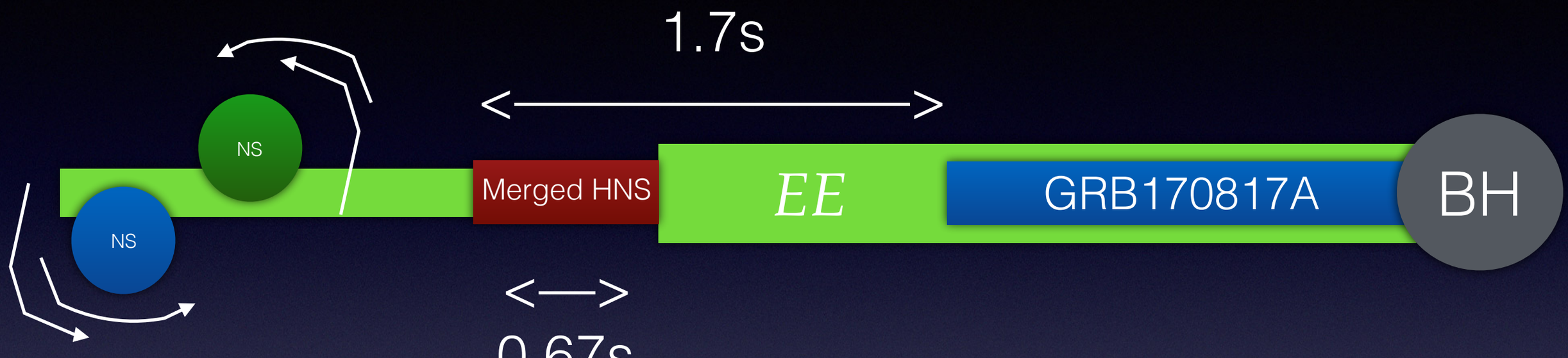
$$K \simeq 3,\ \eta \simeq 15\,\%$$

$$\mathscr{E} \simeq 3\,\% M_\odot c^2$$

by non-axisymmetric torus of ~3R_{ISCO} about a low mass non-extremal BH (a/M~0.75)

Theory and injection results agree.

GW170817EE: complex sequence in three Acts



$$E_J < 1\,\%\, M_\odot c^2 \rightarrow E_J \simeq 0.3 M_\odot c^2 \rightarrow \mathscr{E} \simeq 3\,\%\, M_\odot c^2$$

$J = J_{\rm HNS}$ conserved in CC

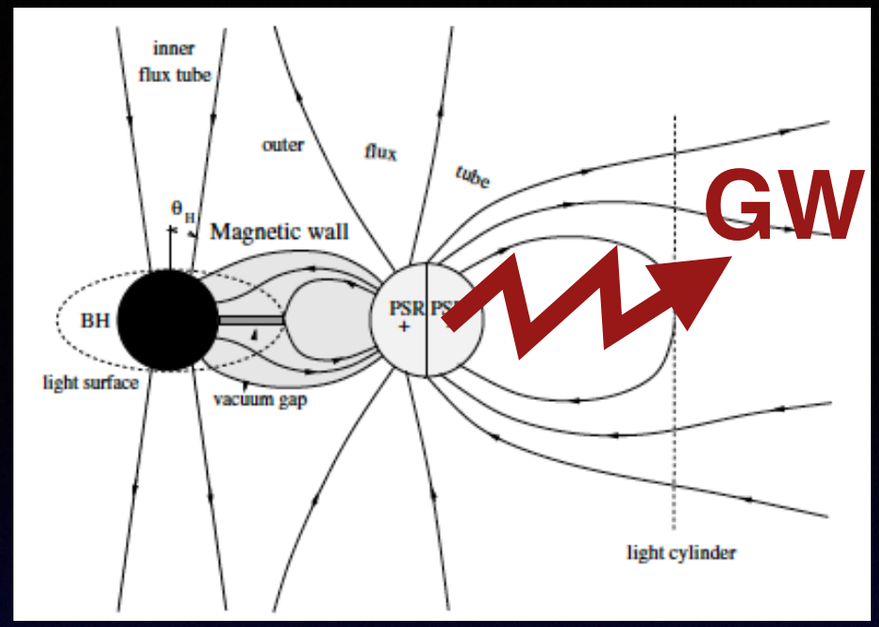
van Putten, Della Valle & Levinson, 2019 (under review)

Short burst of MMEE

Duration set by lifetime of spin:

$$T_s \simeq 1.5\text{s}\left(\frac{\sigma}{0.1}\right)^{-1}\left(\frac{z}{6}\right)^{4}\left(\frac{M}{M_\odot}\right)$$

$$z=\frac{r}{M},\quad \sigma=\frac{M_T}{M}$$



van Putten & Levinson, 2003, ApJ, 584, 937

GRB170817A - kilonova:

$$E_j \simeq \frac{1}{4z^4}E_J \simeq 10^{50}\text{erg}\quad E_w \simeq \eta^2 E_J \simeq 10^{52}\text{erg}$$

Agrees with observational constrains (Mooley et al. 2019):

$$E_j \simeq 10^{49-50}\text{erg}\quad E_k \simeq 4.5\times 10^{51}\text{erg}$$

kilonova

GRB170817A

van Putten, Della Valle & Levinson, 2019 (under review)

Multi-messenger Extended Emission

GW170817**EE**: $\mathscr{E} \simeq 3\,\% M_\odot c^2$

Kilonova: $0.2\,\% M_\odot c^2$

GRB170817A: $0.01\,\% M_\odot c^2$