Electromagnetic Counterparts To Binary Mergers In the Gravitational Wave Era

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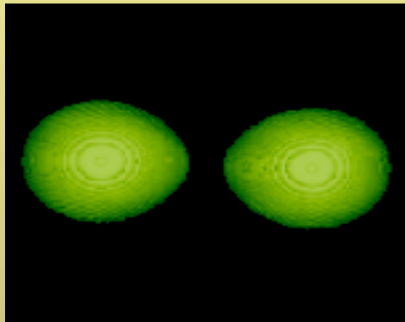
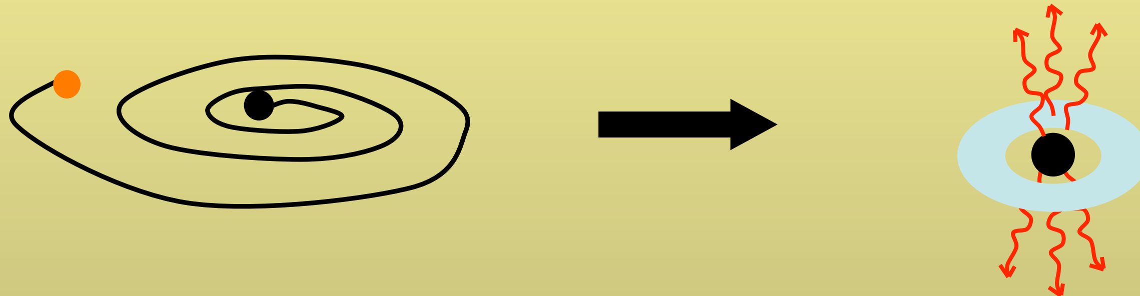
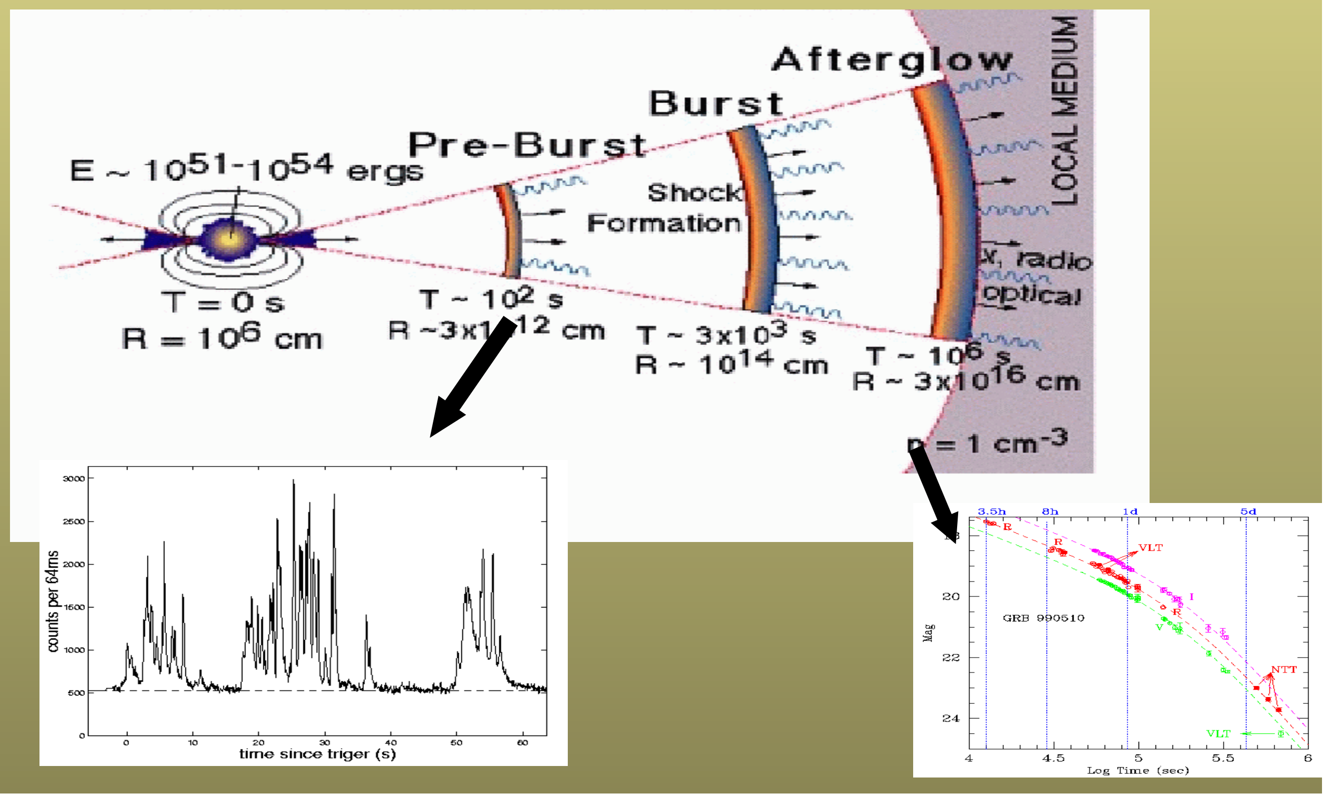
Binary (NS-NS and NS-BH) Mergers are naturally expected to be accompanied by Electromagnetic Counterparts



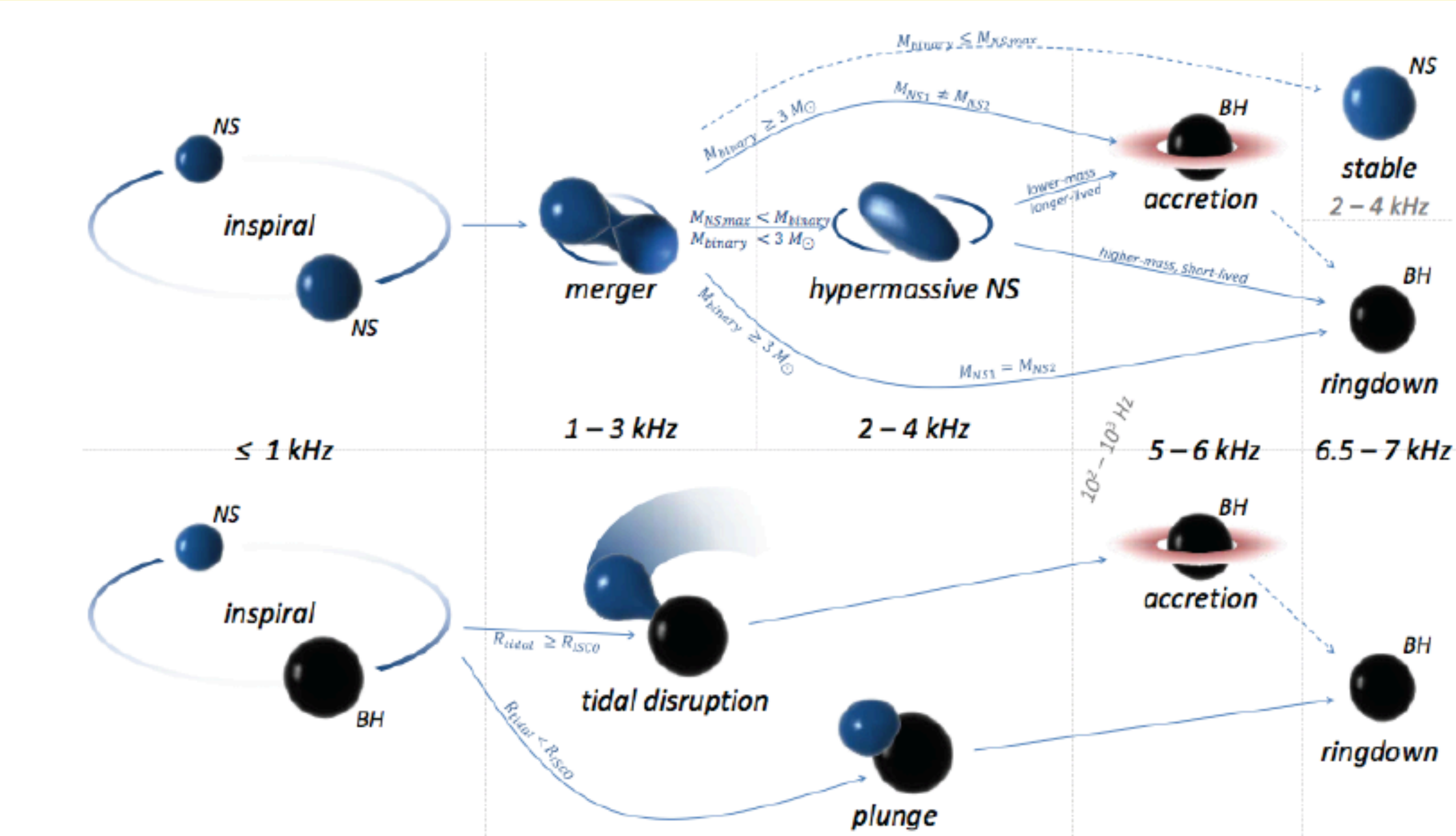


Likely already observed as Short GRBs



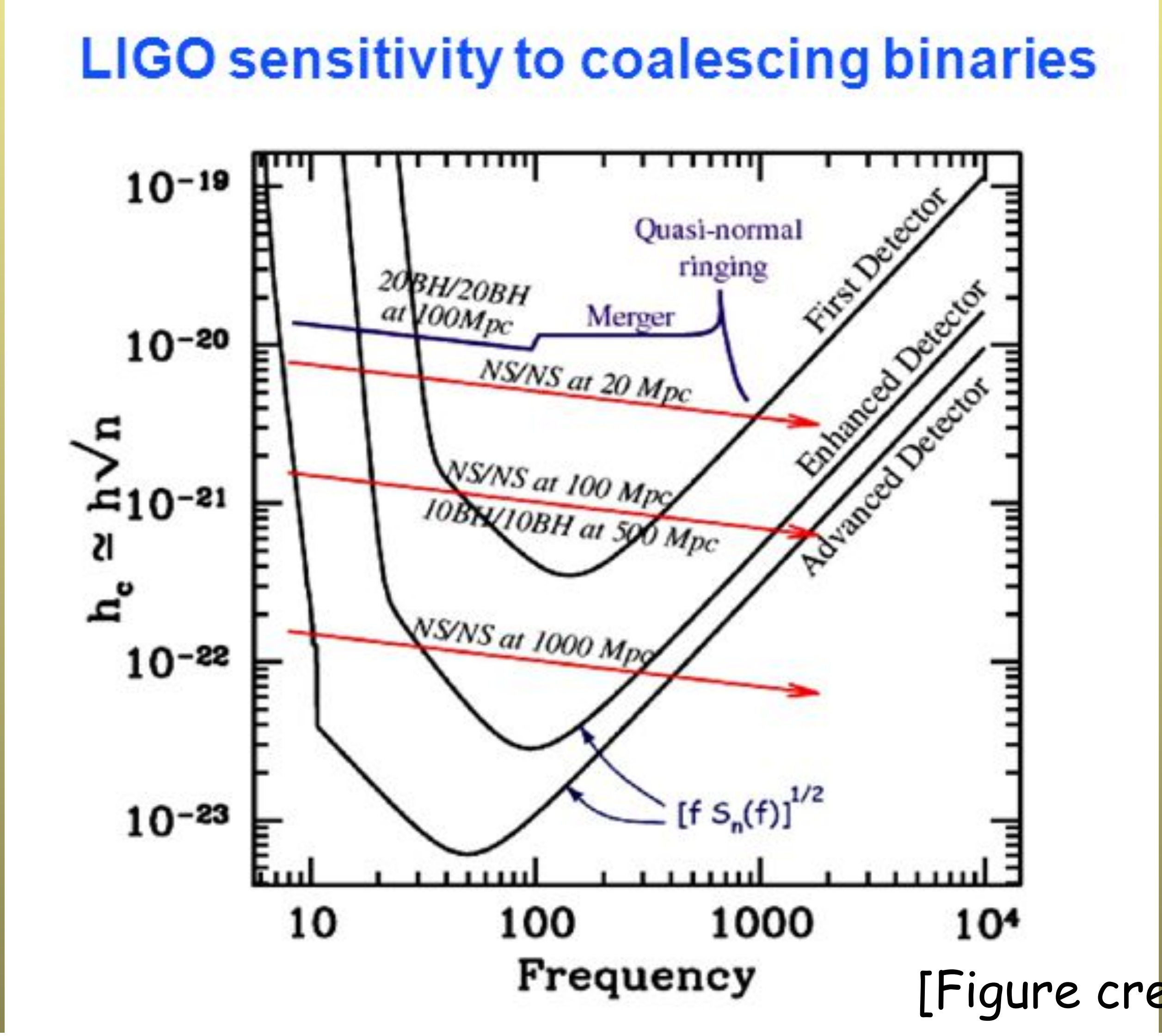
GWs from Binary Mergers

[Bartos et al. 2013]



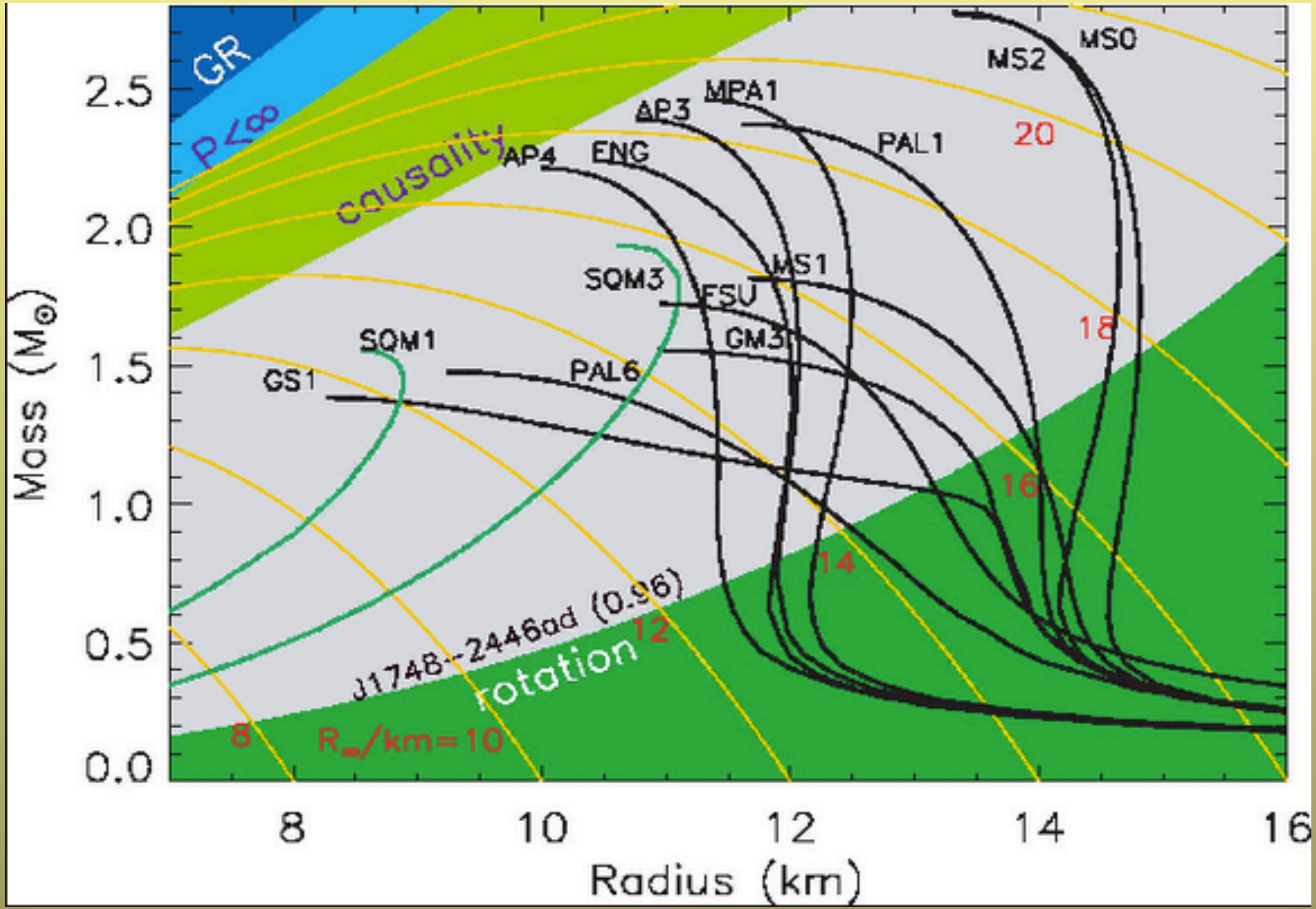
GW emission associated to various phases of the merger

Signal for NS-NS (and NS-BH) smaller than for BH-BH, but potentially *very informative*



[Figure credit: B. Barrish]

The Holy Grail of the *Equation of State (EOS) of Neutron Stars*

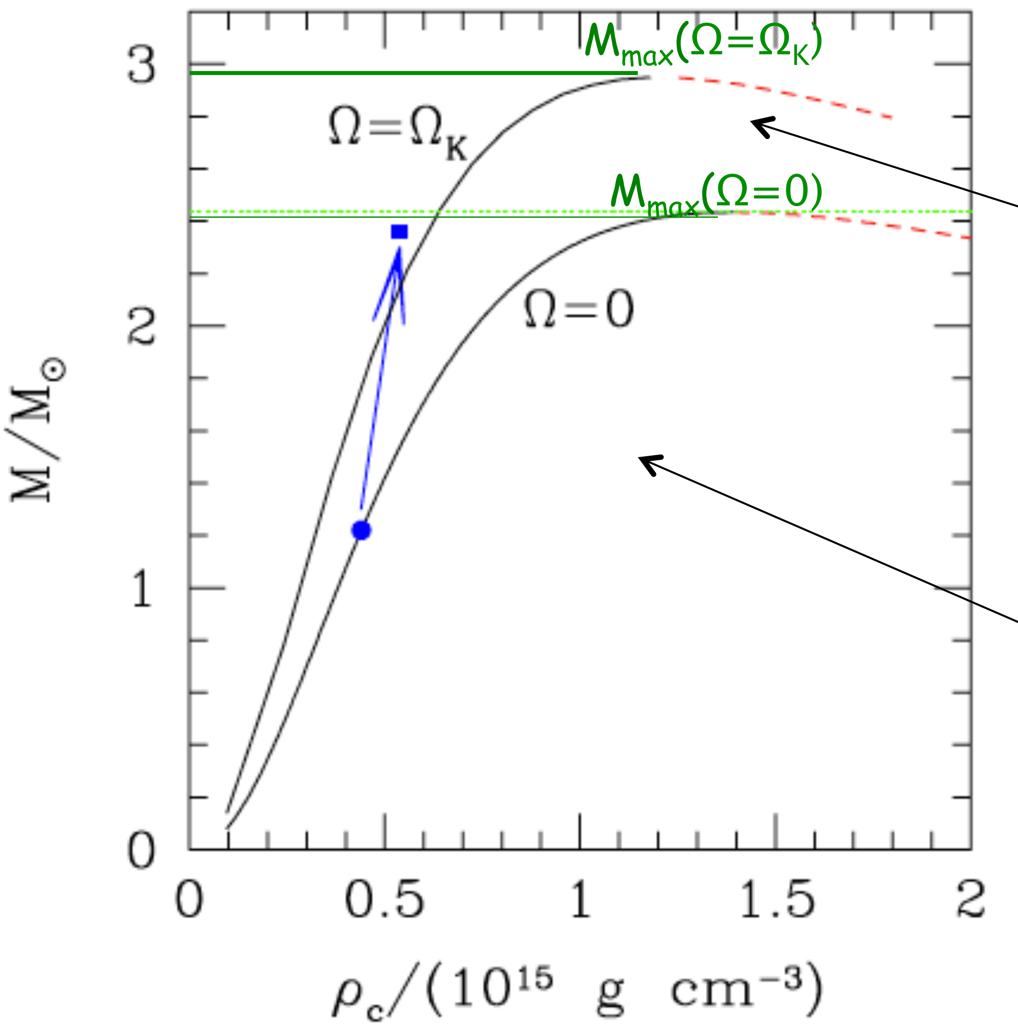


[Lattimer & Prakash 2007, 2015]

'Traditional' methods aim at direct measurements of Mass (Keplerian motion) and Radius (size of emitting region, PFs)

Gravitational waves open a new 'window' to the problem

What happens when two neutron stars merge?



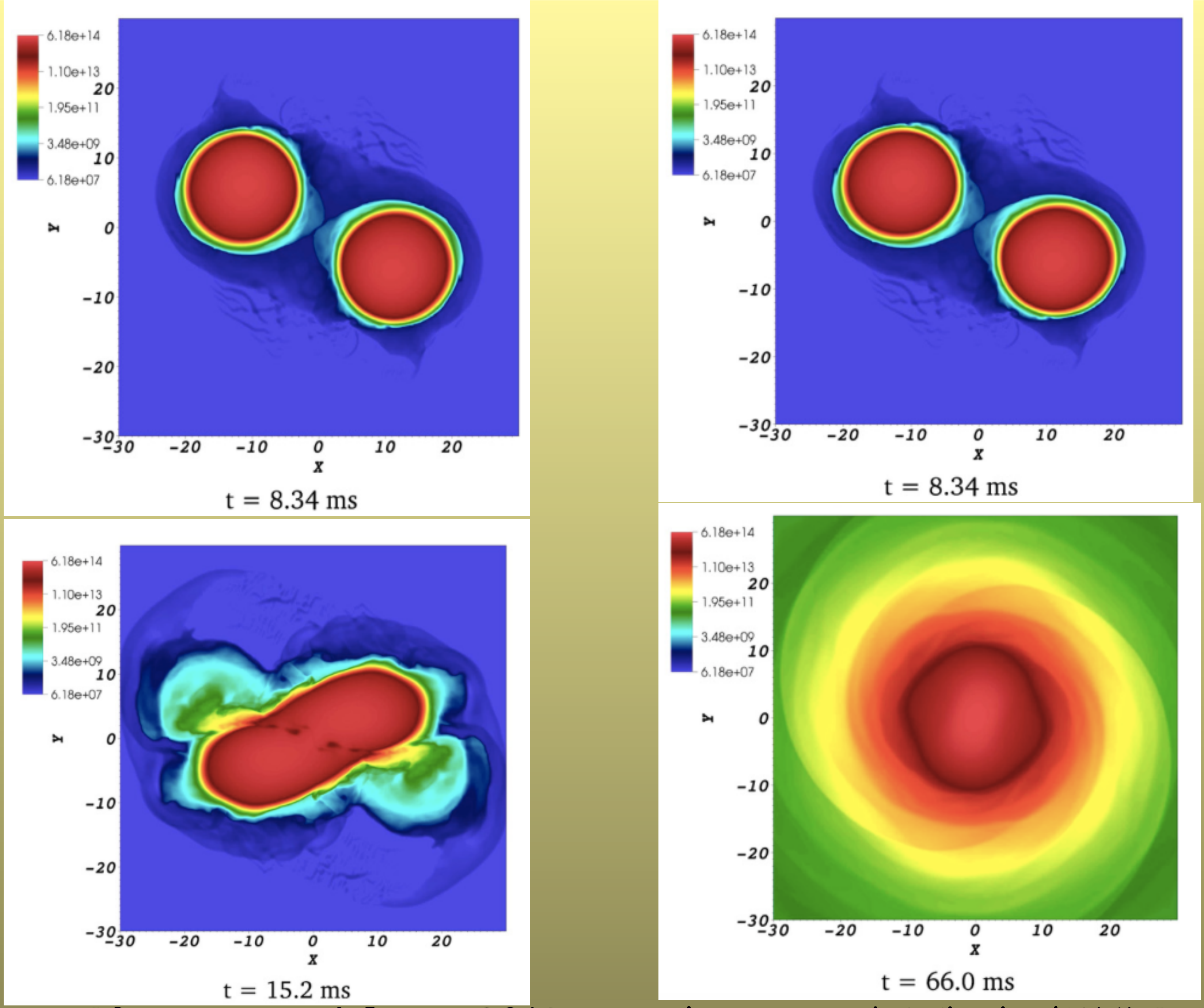
It depends.... but in a way which is sensitive to the NS EOS

Supramassive NS:
collapsing to a Black Hole after slowing down, at the point at which $M_{NS} = M_{max}(\Omega)$

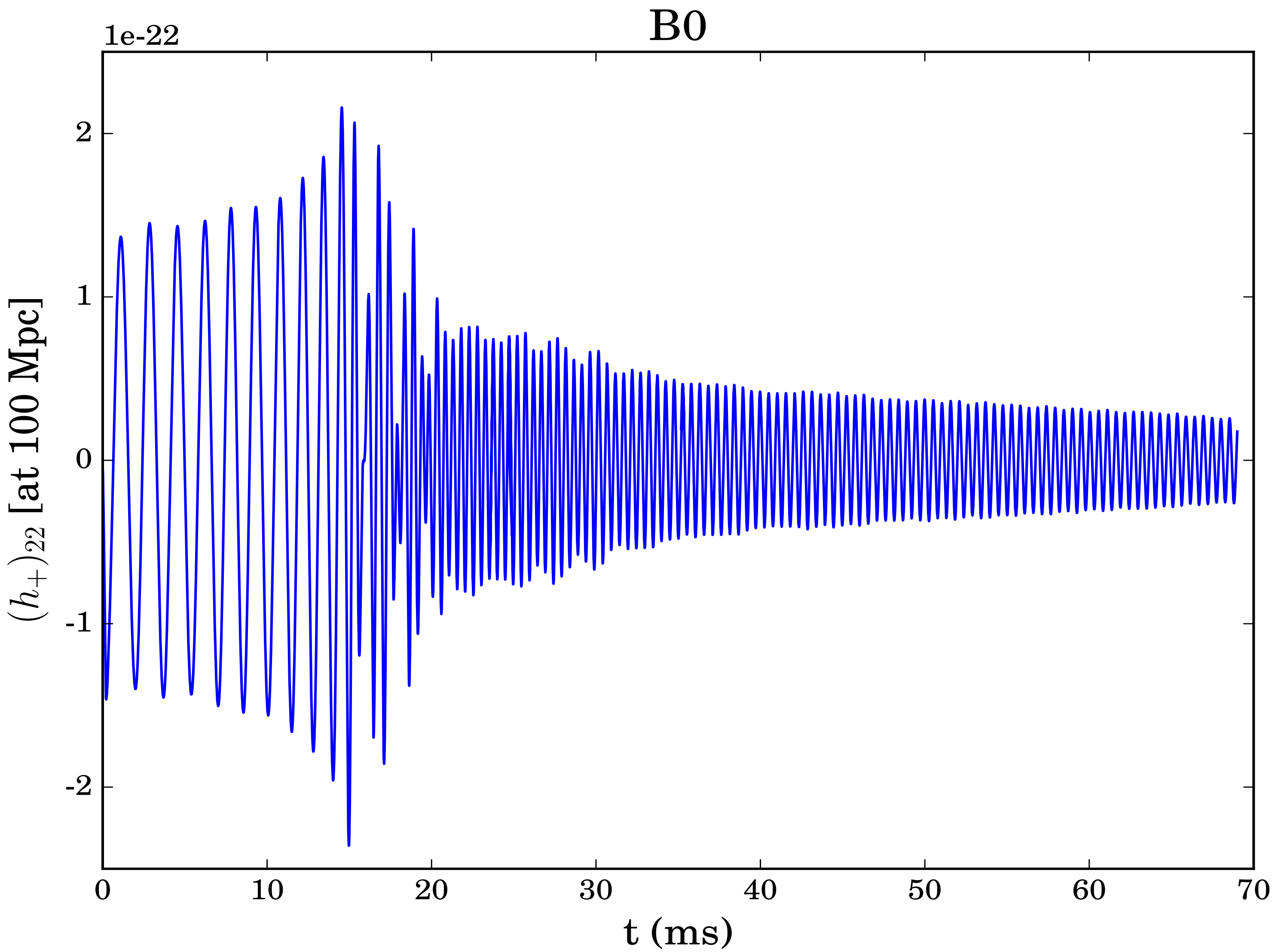
Stable NS

GWs bear imprint of NS EOS – compute with GRMHD simulations

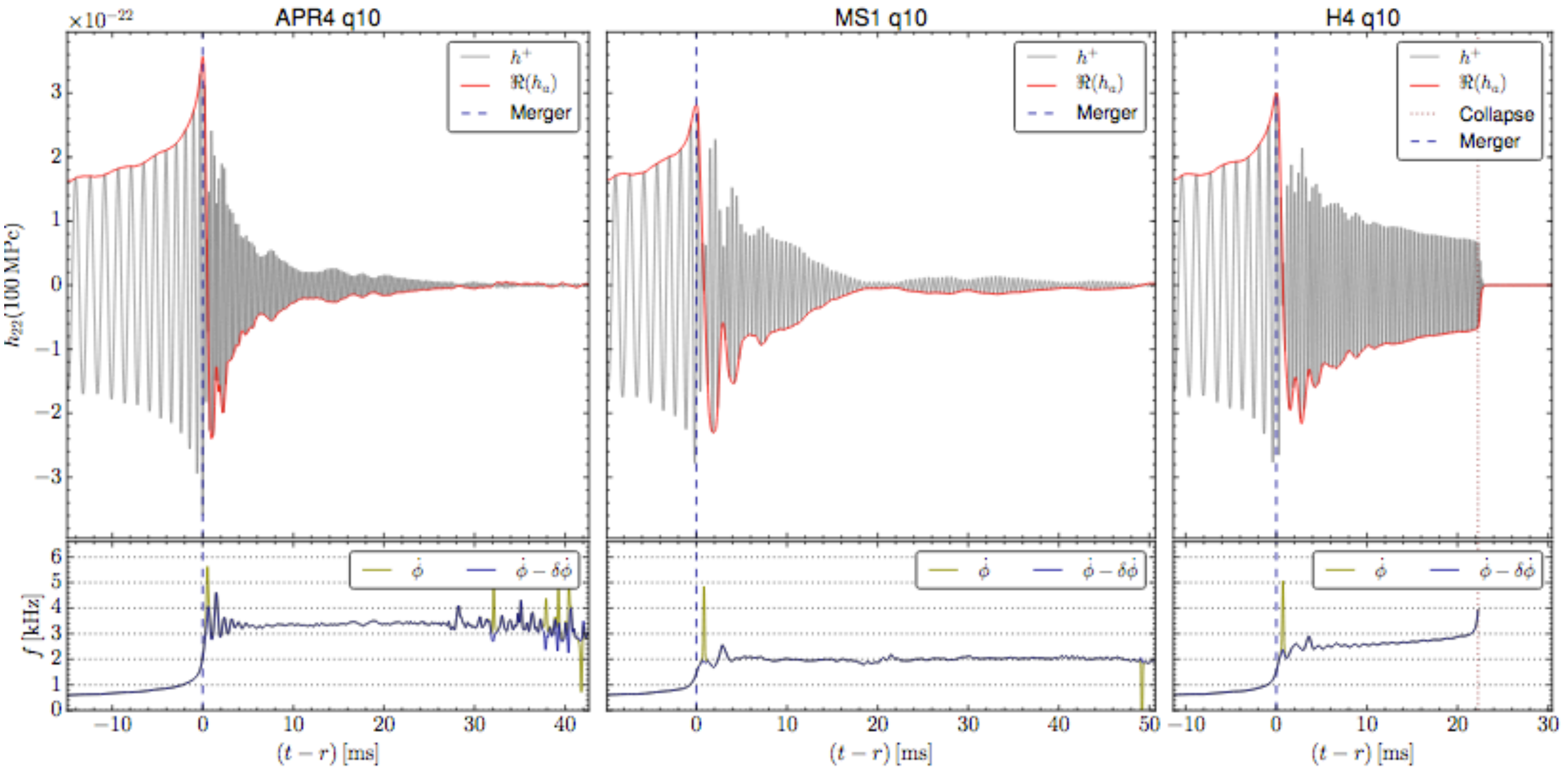
[Giacomazzo & Perna 2013]



[Giacomazzo & Perna 2013 - simulations with Whisky/MHD]



[Giacomazzo & Perna 2013
simulations with Whisky/MHD]



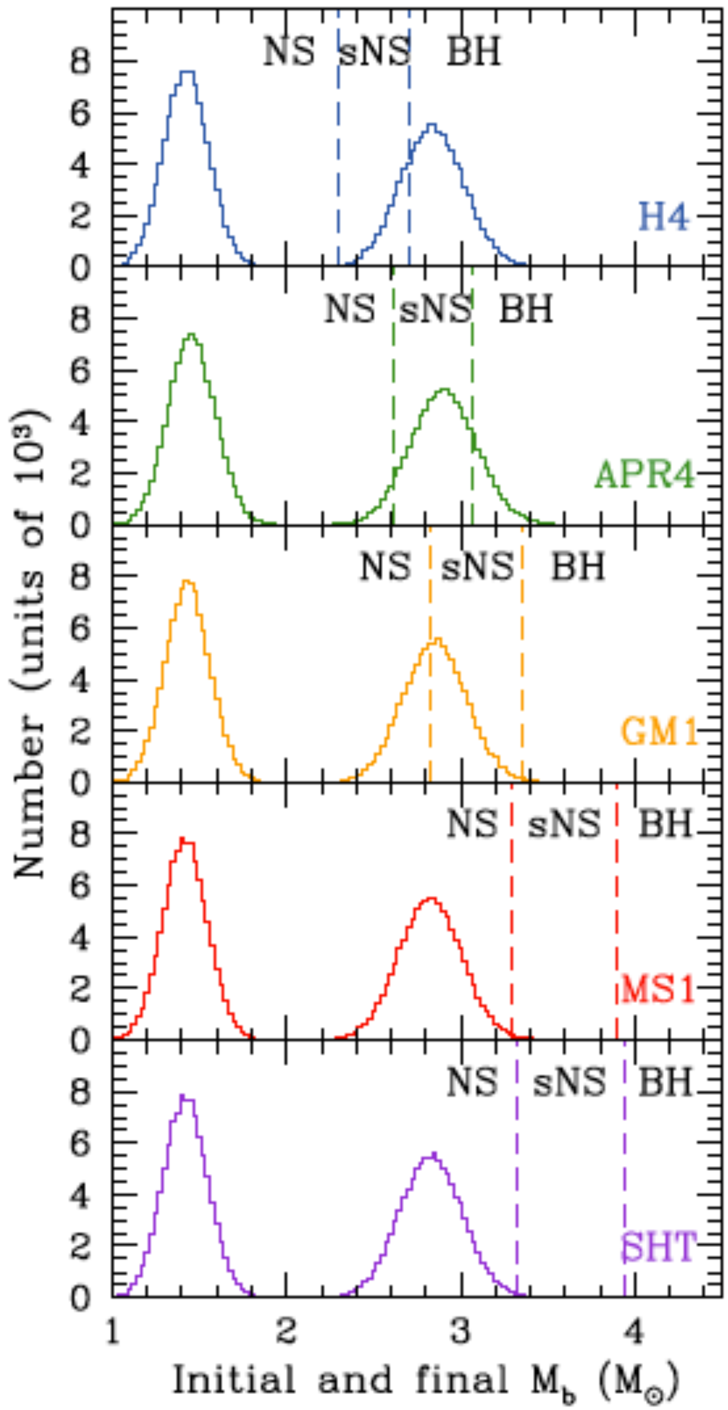
[Ciolfi et al 2017]

GW signal sensitive to equation of state of neutron stars

→ Merger of NSs probe physics of dense matter

Can we still learn something
from SGRBs + GWs
on the NS EOS without
measuring the detailed signal?

Dominant post-merger oscillation
frequency can be measured only for
merger events within about 20 Mpc
[Clark et al. 2014; Bauswein 2015]



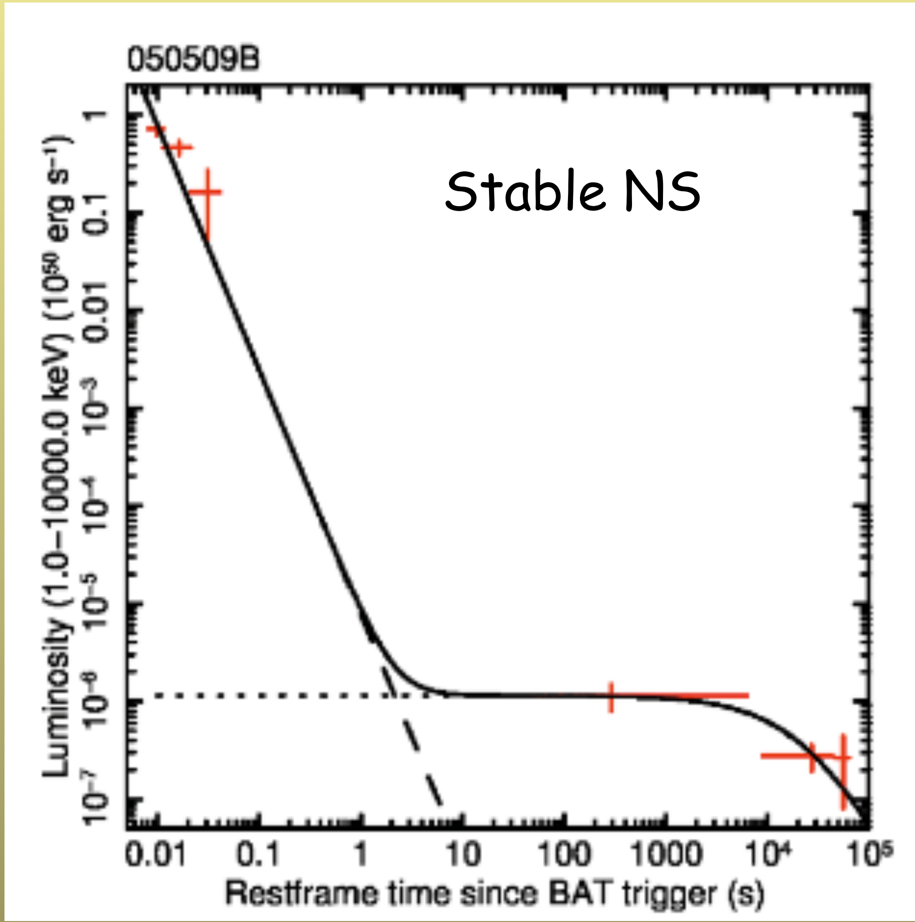
Predictions for distributions of remnants based on the observed distribution of NS in binaries

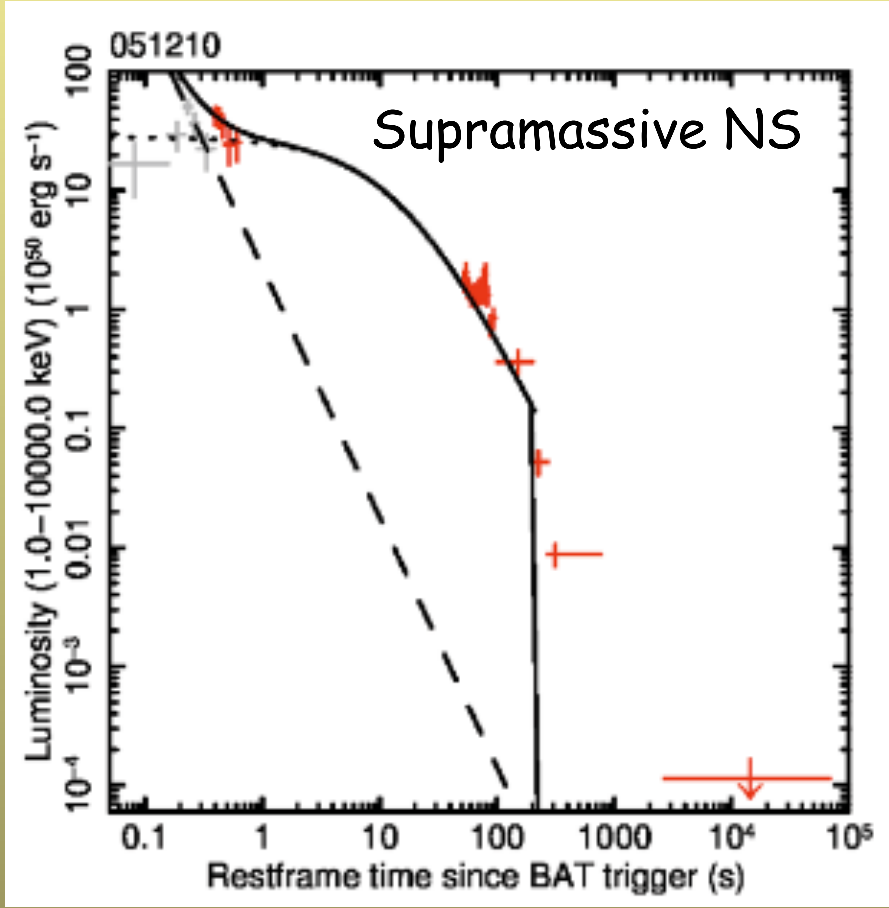
Fraction of outcome products (stable NS, supramassive NS, BH) highly dependent on the EOS of the NS

Simply identifying the remnant product in a fraction of merger events can constrain the NS EOS: both GWs and EM counterparts helpful for that.

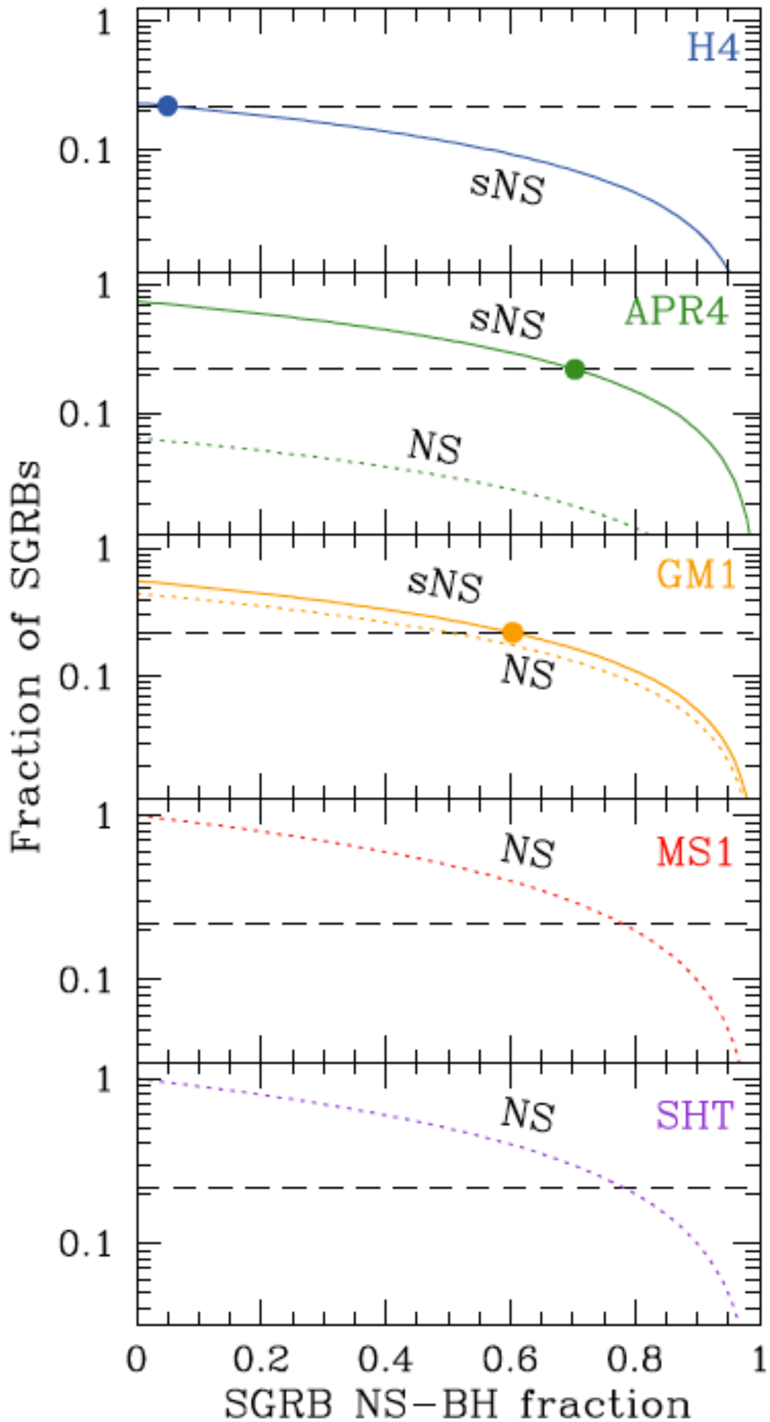
[Piro, Giacomazzo & Perna 2017]

EM counterparts may help reveal the nature of the compact object left behind after the merger





[Rowlinson et al. 2013]



Analysis of 96 SGRBs by Gao et al. (2016) argues for 22% of merger products to be sNS.

Any EOS which predicts a fraction of sNS larger than 22% requires that a fraction of SGRBs is due to NS-BH mergers instead of NS-NS mergers.

Dots indicate the required fraction for H4, APR4, GM1, while MS1 and SHT are incompatible with the data, since they predict a negligible fraction of sNS.

[Piro, Giacomazzo & Perna 2017]

Electromagnetic Counterparts to Binary ***Black Hole*** Mergers?

- Not *expected* on theoretical grounds (unlike the NS-NS & NS-BH cases)

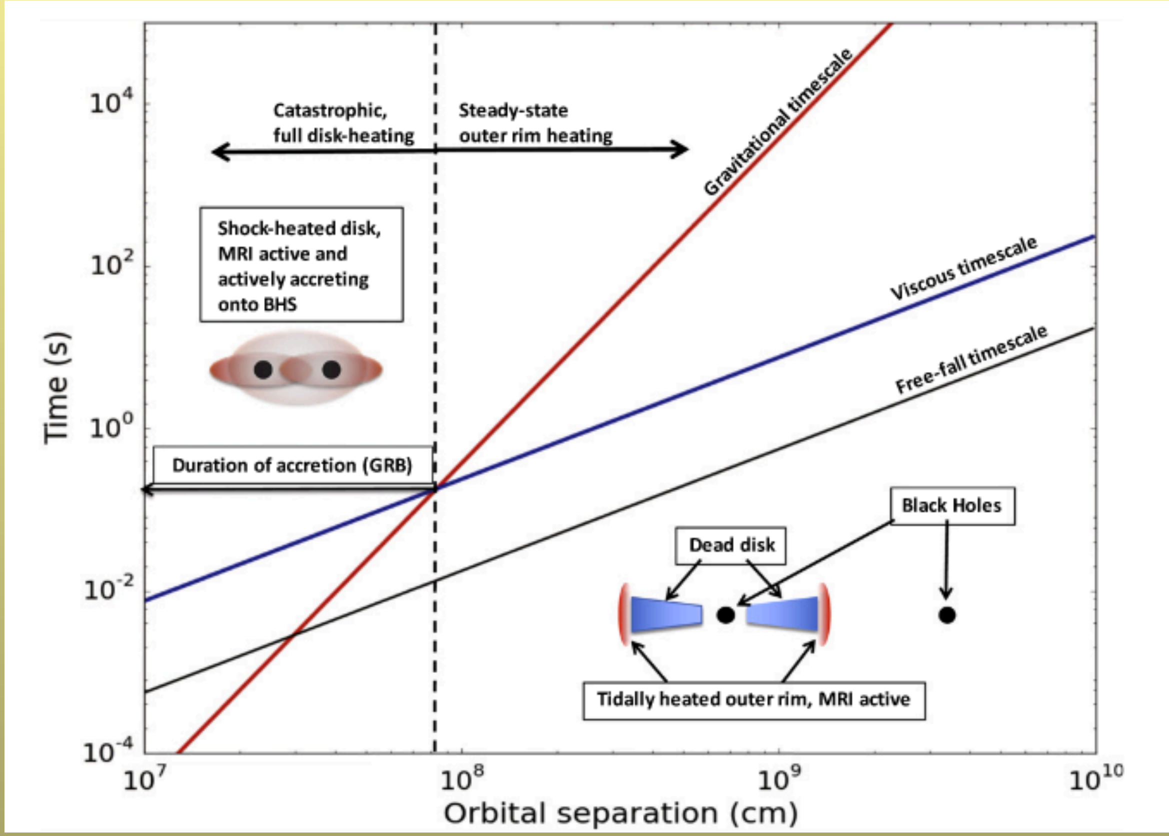
- Observationally: tentative detection of gamma-ray counterpart by Fermi (Connaughton et al. 2016) and by Agile (Stalder et al. 2017)

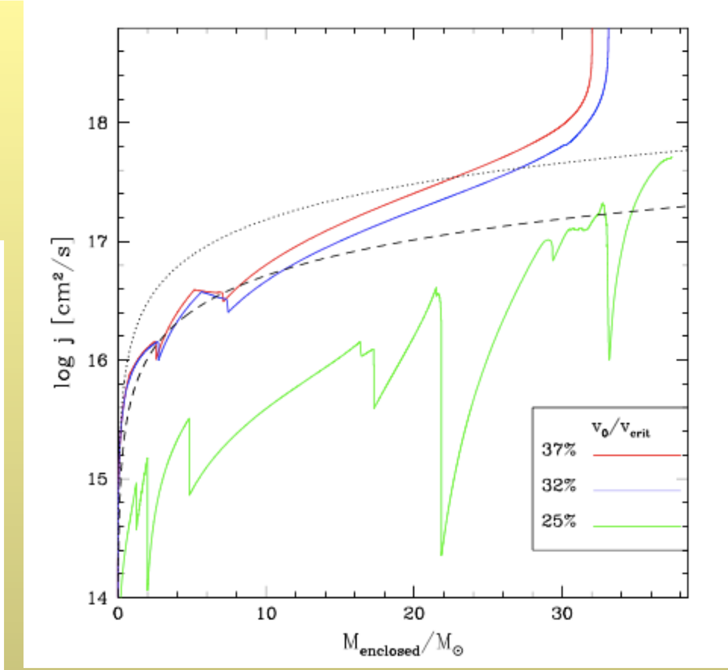
- Theoretically (after the facts): some ideas have been proposed

An (incomplete) list of some of the proposed ideas:

- Formation of a binary BH inside a massive star [Loeb 2016, but ruled implausible by Dai et al. 2016 & Woosley 2016]
- BH-BH merger with at least one charged BH generating evolving magnetic dipole and driving Pointing flux [Zhang 2017; see also Fraschetti 2016]
- Binary system of massive star+ BH ; star collapses forming a second BH; BH-BH merger (with mass accretion from the star envelope; [Janiuk et al. 2017]
- Heating of a circumbinary disk by shocks [De Mink & King 2017]
- Remnant disk from evolution of low-metallicity, high mass stars [Perna et al. 2016]

- Fallback Disk formed after SN explosion





[Perna, Lazzati & Giacomazzo 2016]

- Disk cools and eventually MRI shuts down → 'dead disk' can then survive for very long time

- During the final phases of merger the disk is reheated, the MRI operates again, and accretion operates on the usual dynamical scale – timescales just work out…

SUMMARY

- NS-NS and NS-BH mergers:
  EM radiation has been detected –
  now awaiting for GW counterparts

- BH-BH mergers:
  GW radiation has been detected –
  now awaiting for EM counterparts

LOTS to learn with both together…