THE OBSERVATIONAL SIGNATURES OF BINARY NEUTRON STAR MERGERS

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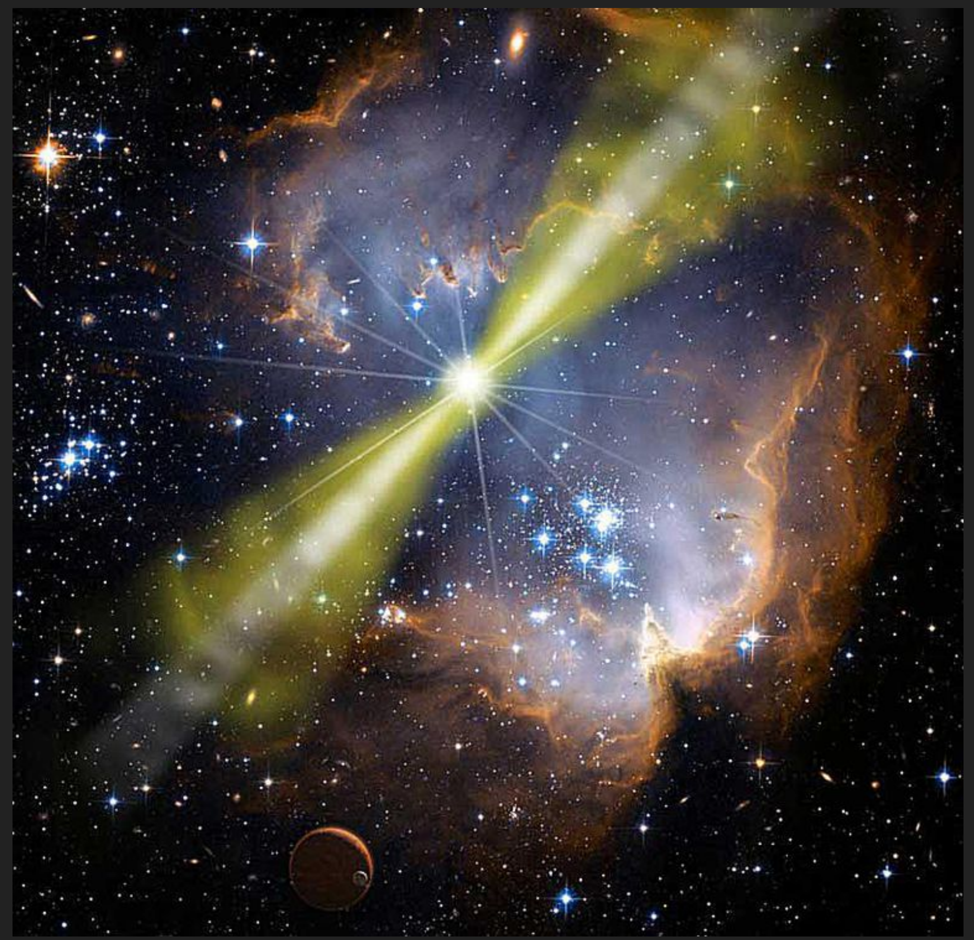
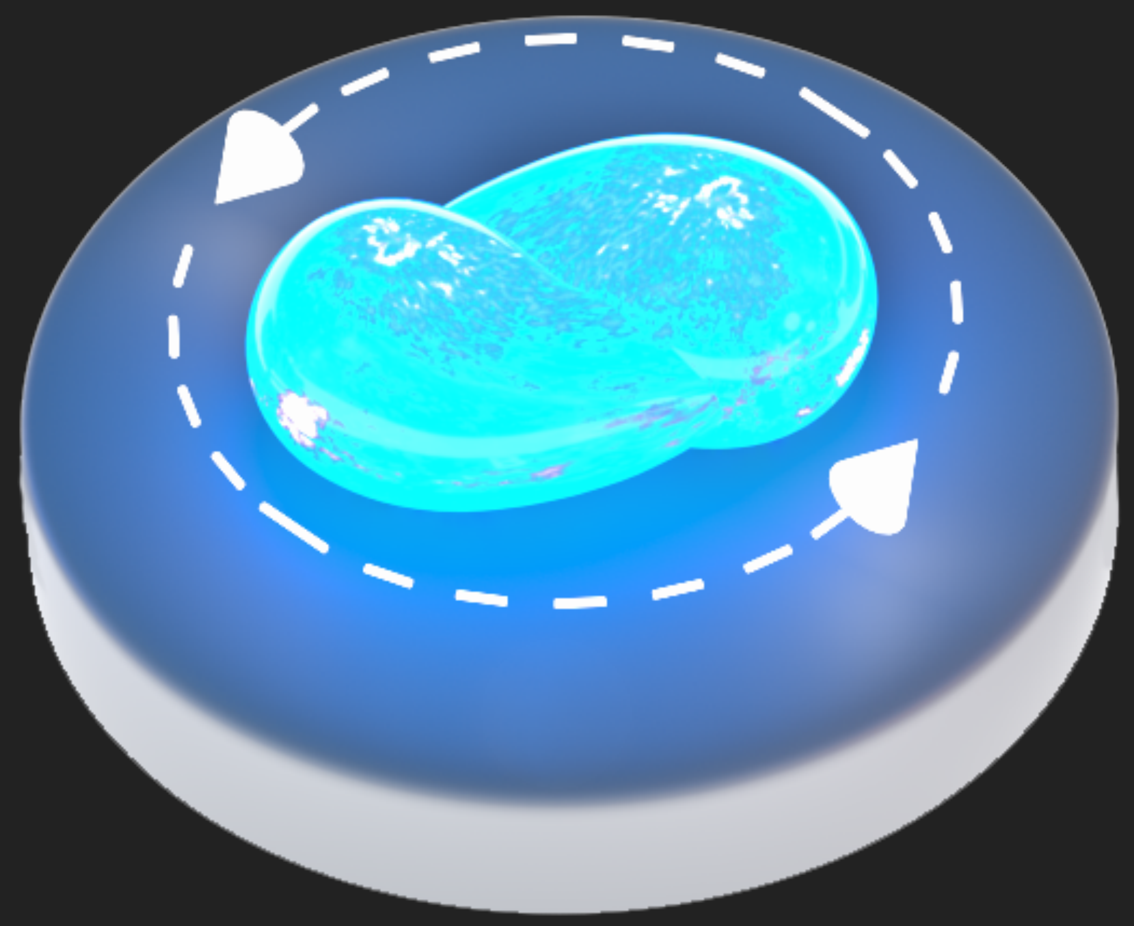
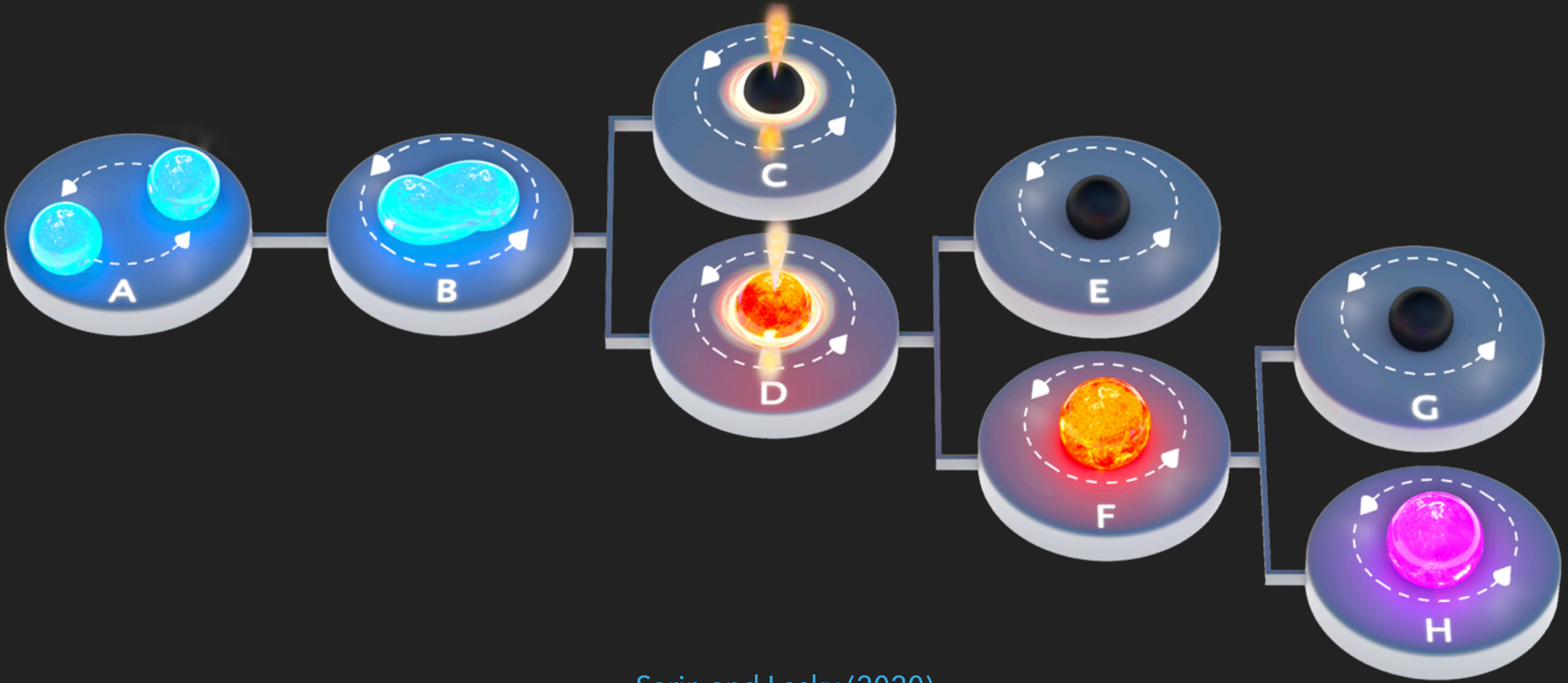




AN OVERVIEW OF A NEUTRON STAR MERGER



Sarin and Lasky (2020)
Review in General Relativity
and Gravitation.

Credit: Carl Knox

- What is the GRB central engine?
- What remains behind after the merger?
- To answer these questions. We raise more questions?
    - How does the merger outcome affect what we see?
    - The physics of jets and kilonovae.
- Theseus will allow us to probe all these questions.

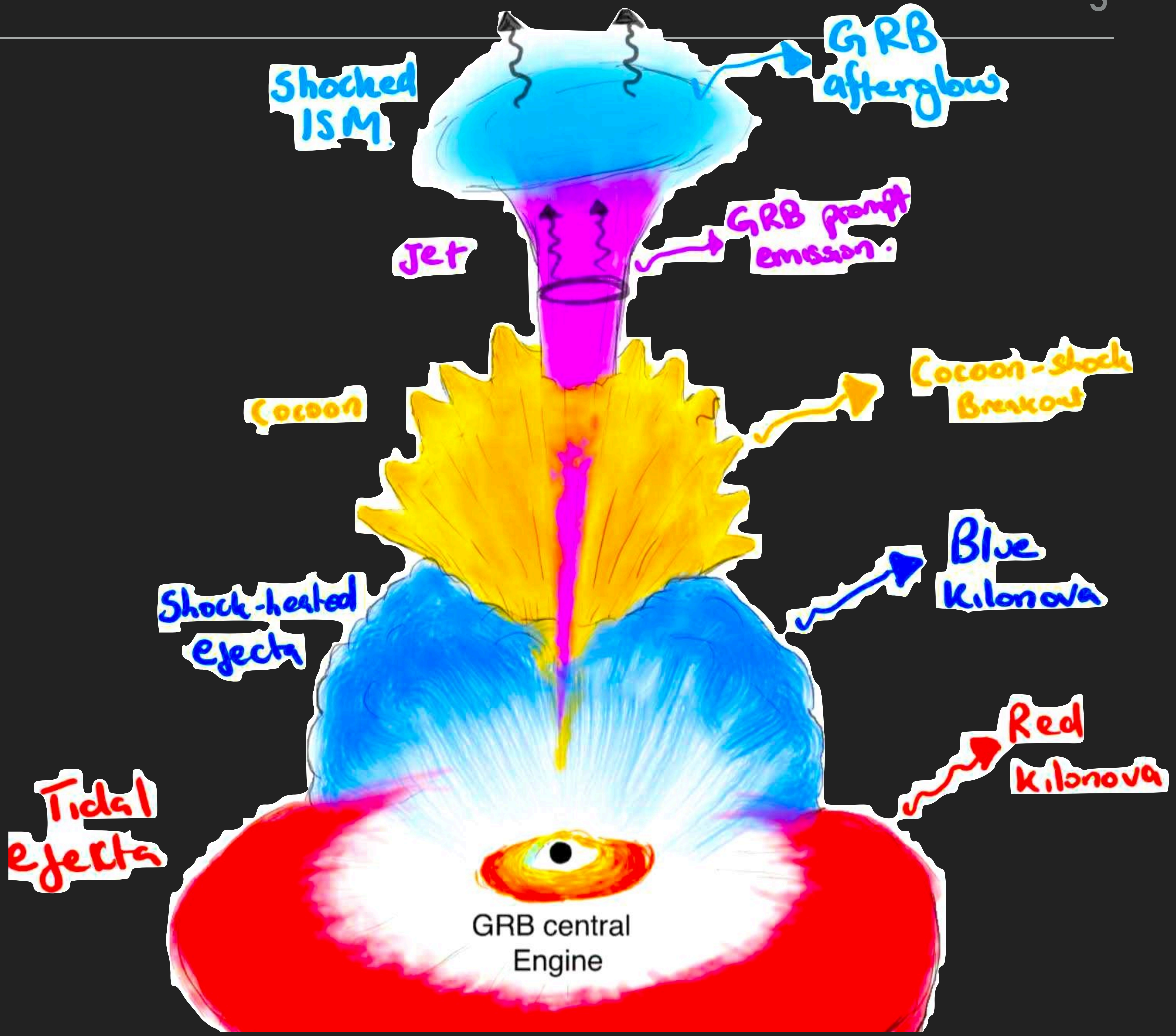
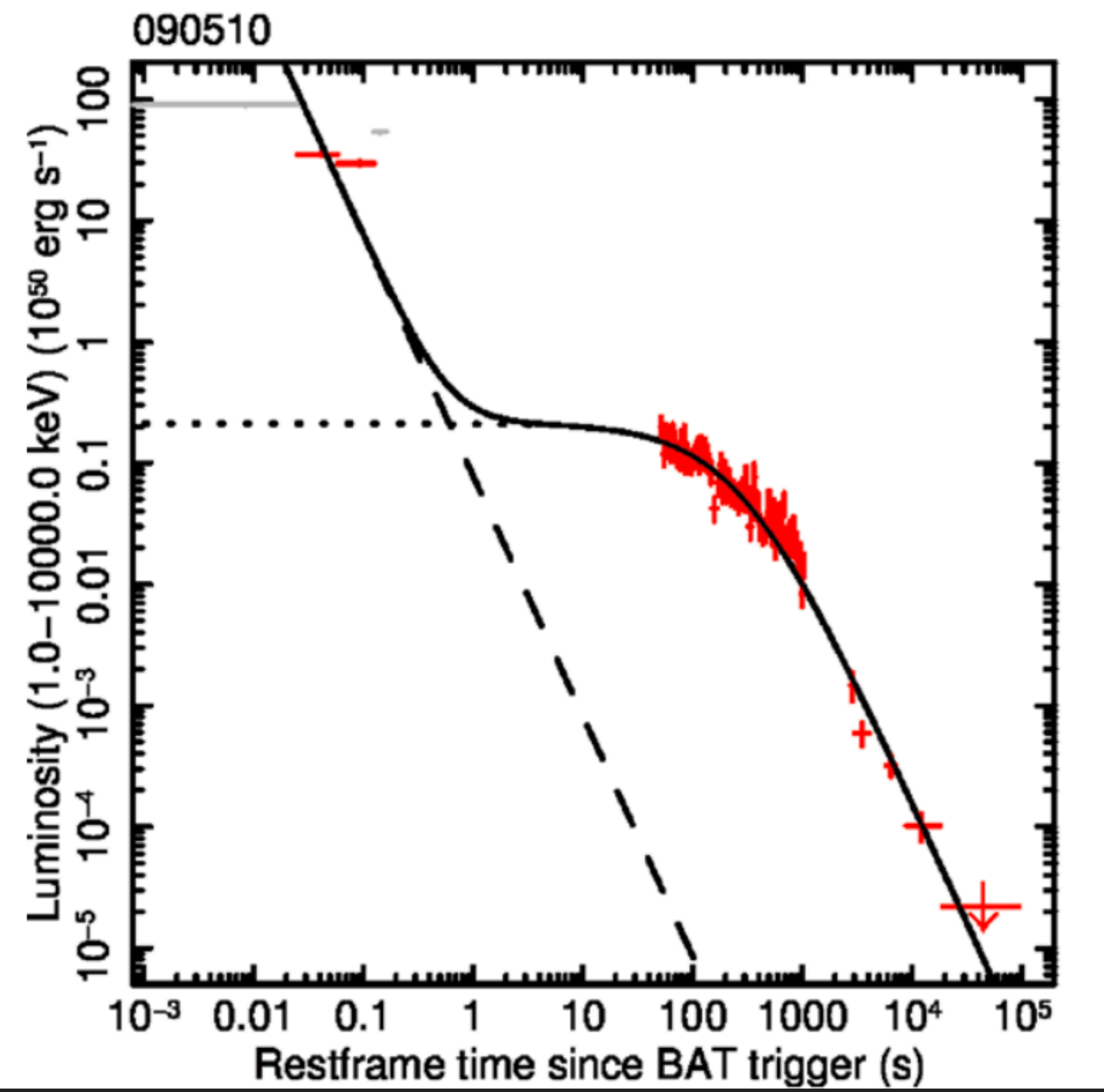
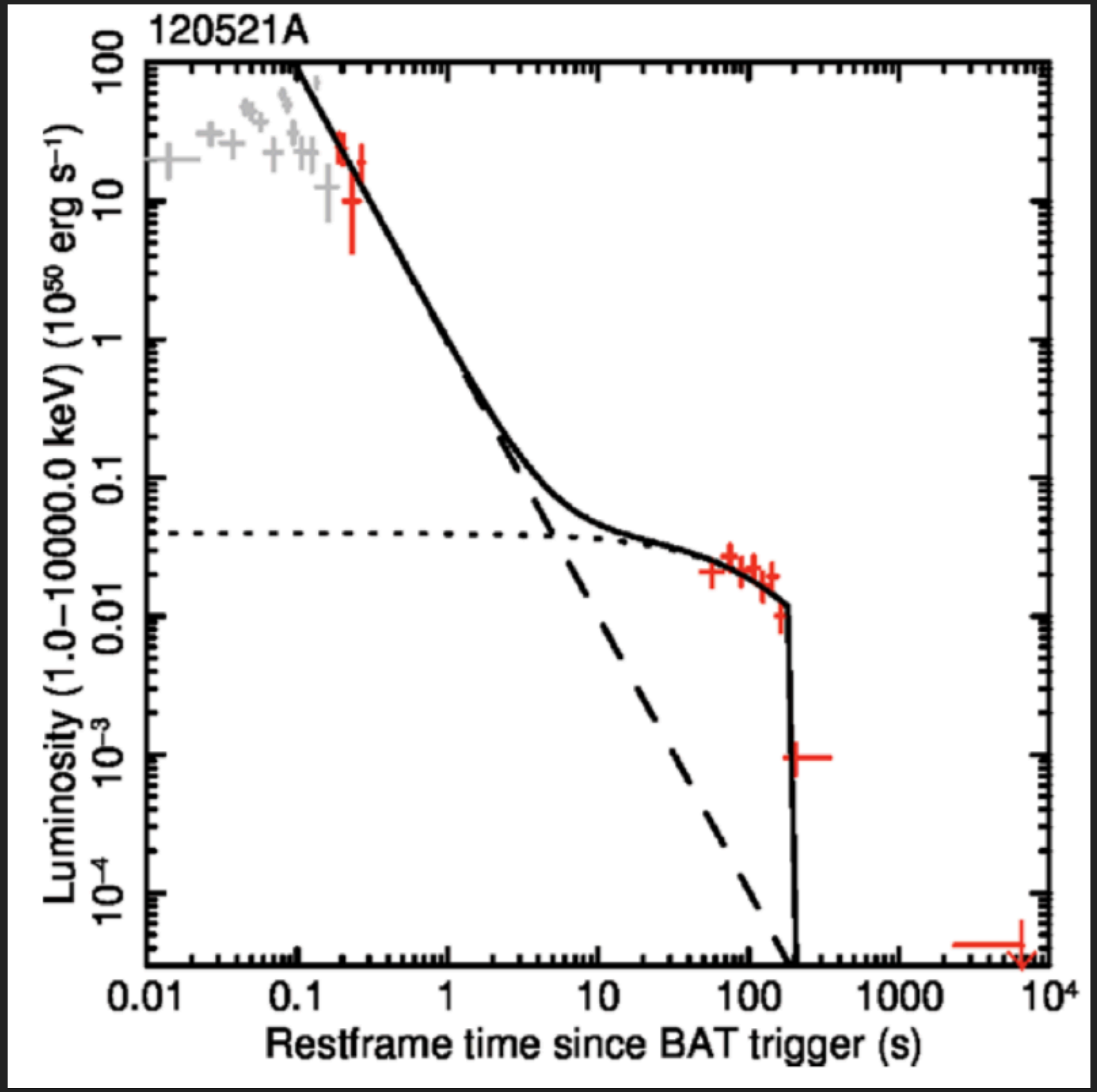


Figure adapted from Ascenzi+2020

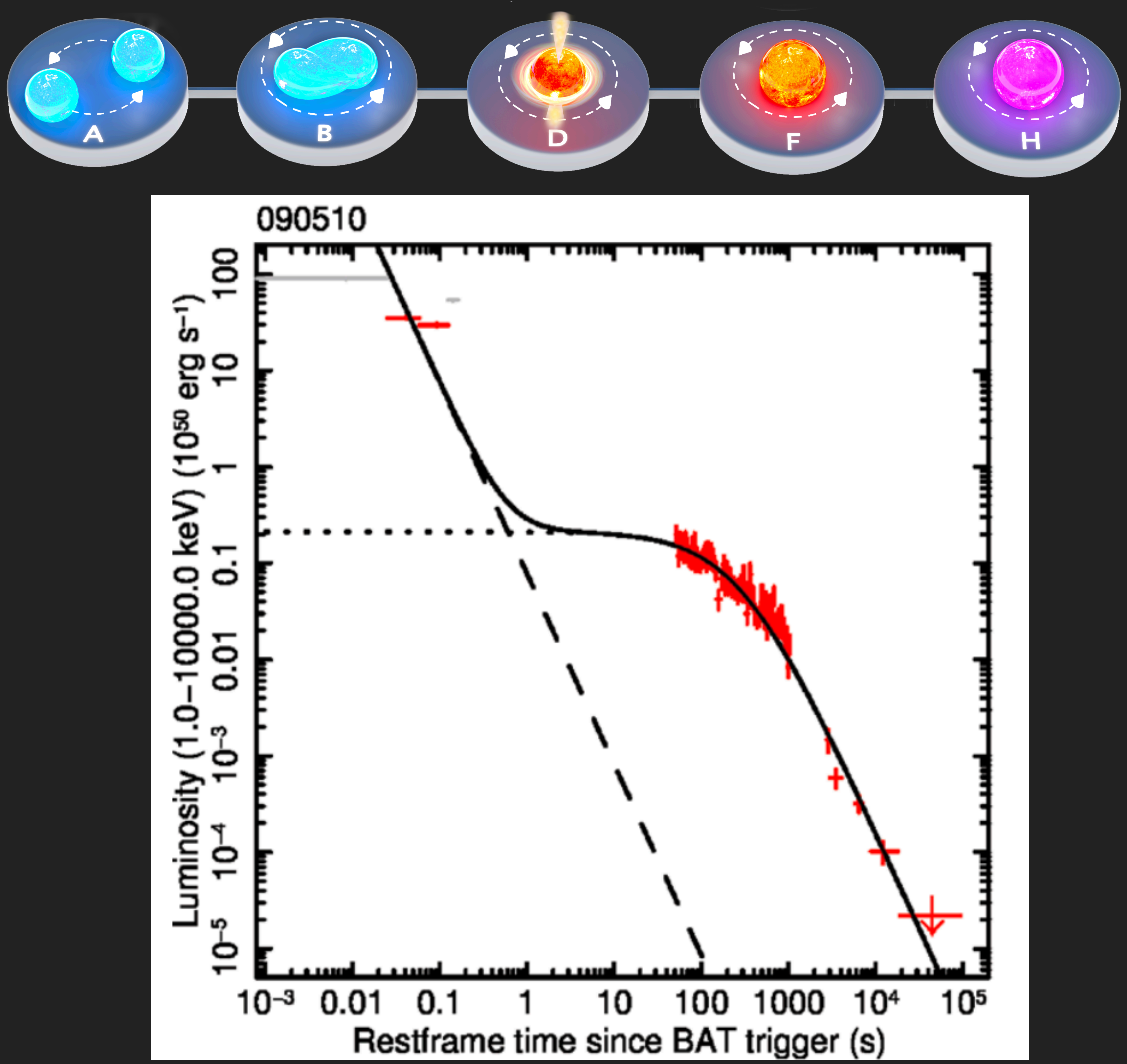
- The X-ray afterglows of a good fraction of GRBs have features that are incredibly difficult to explain with the interaction of a jet with the surrounding interstellar medium.

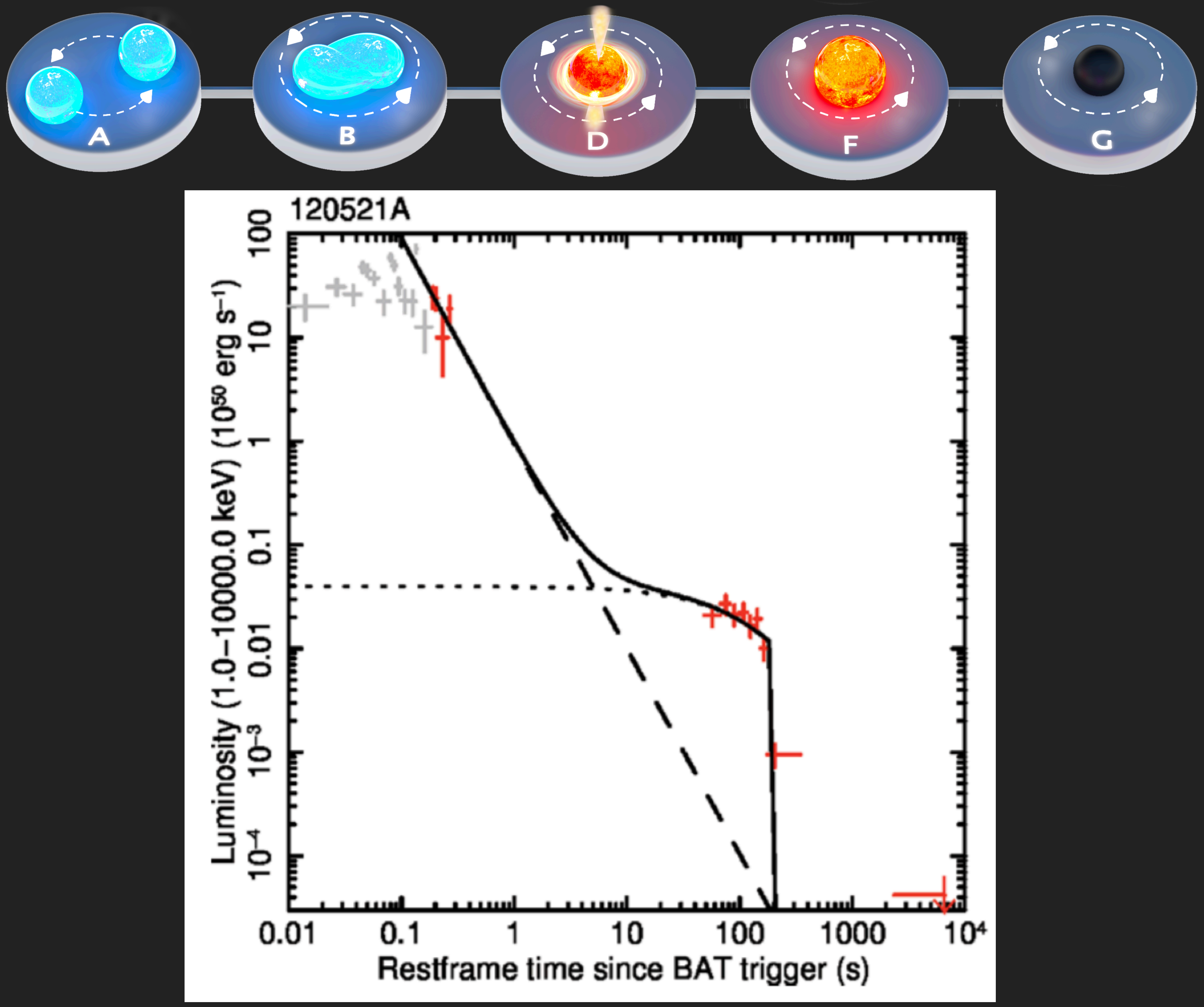




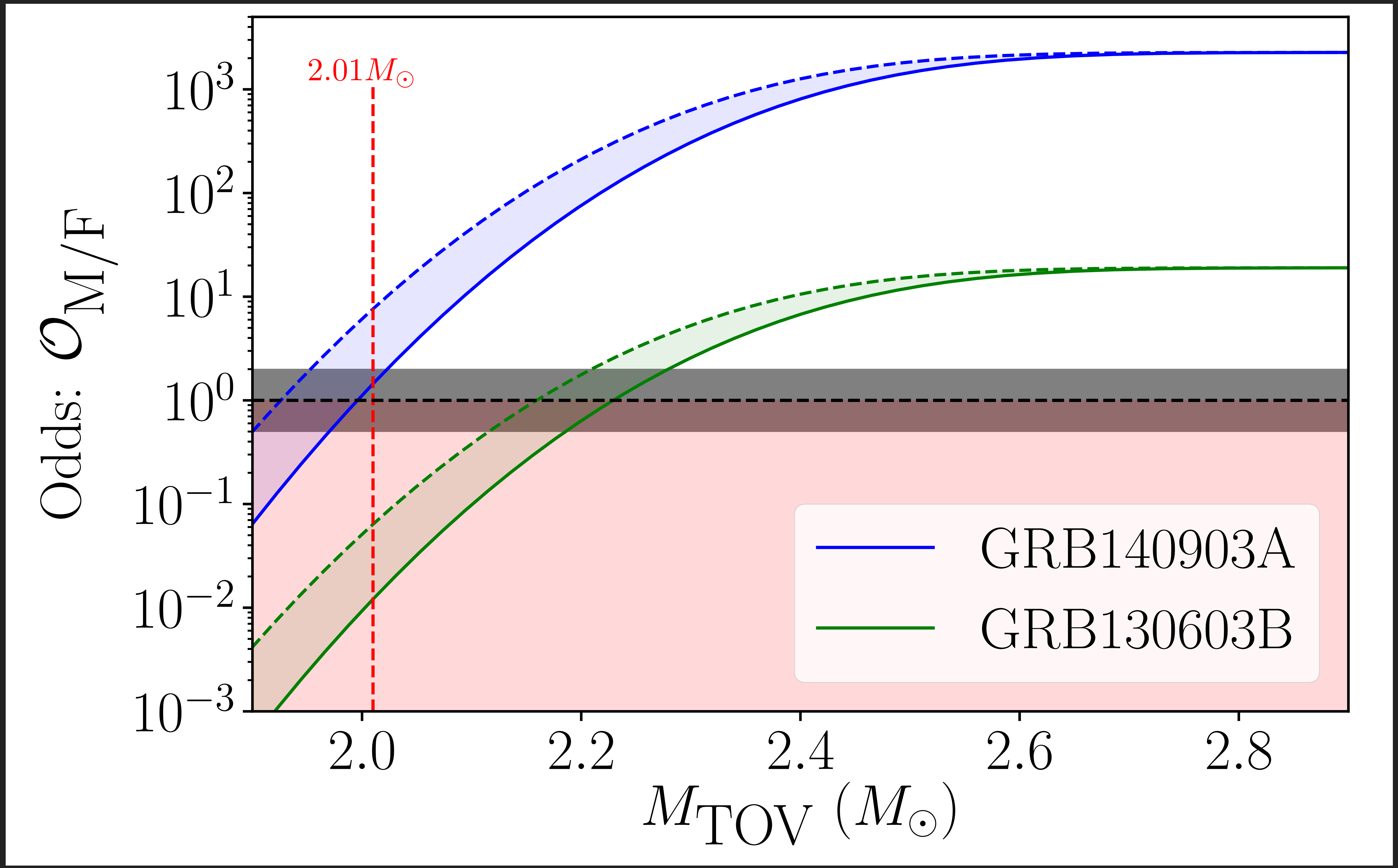
Rowlinson+2013

- These features are easily interpreted by adding an additional energy source. The spin-down energy of a highly magnetic, rapidly rotating neutron star!





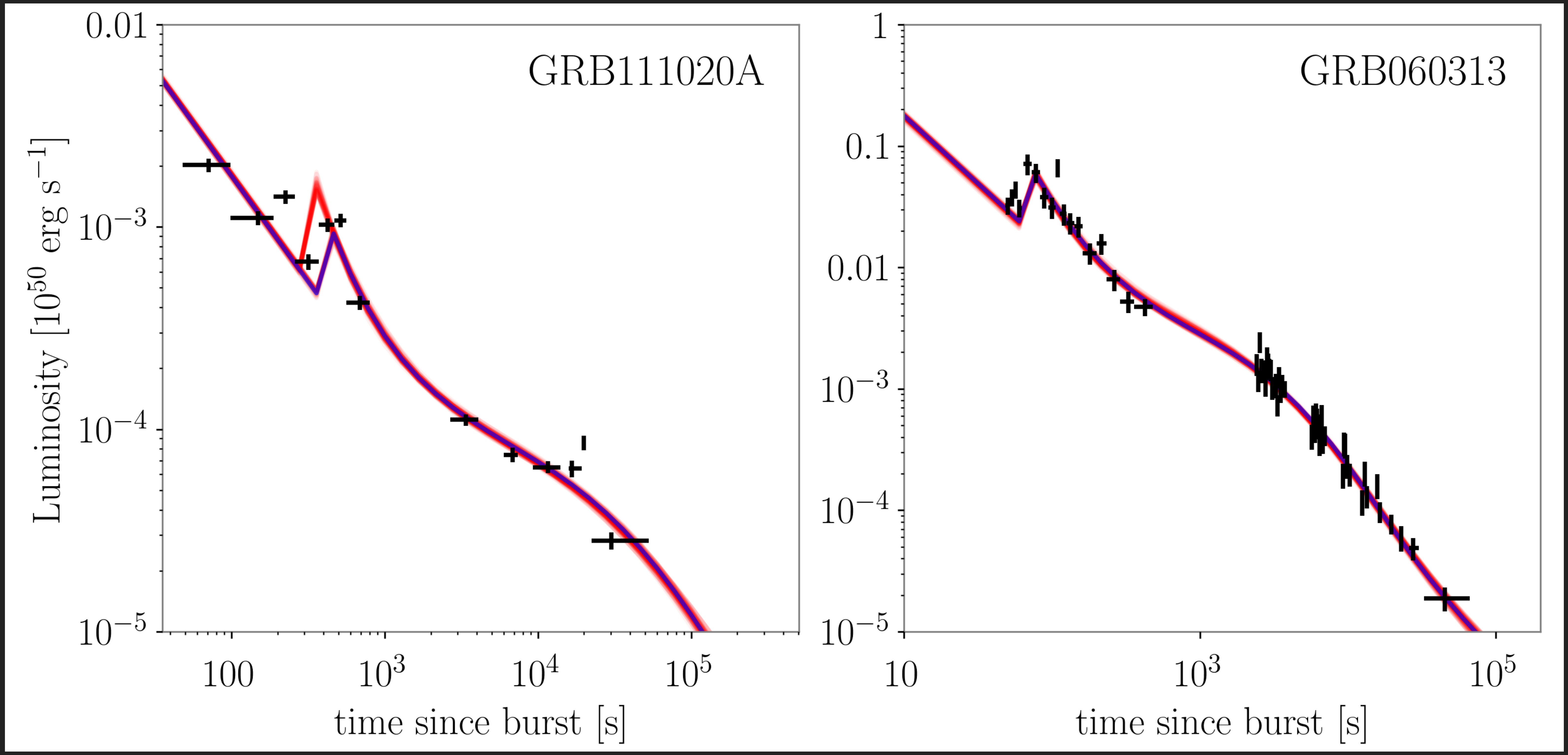
Rowlinson+2013



Sarin+2019

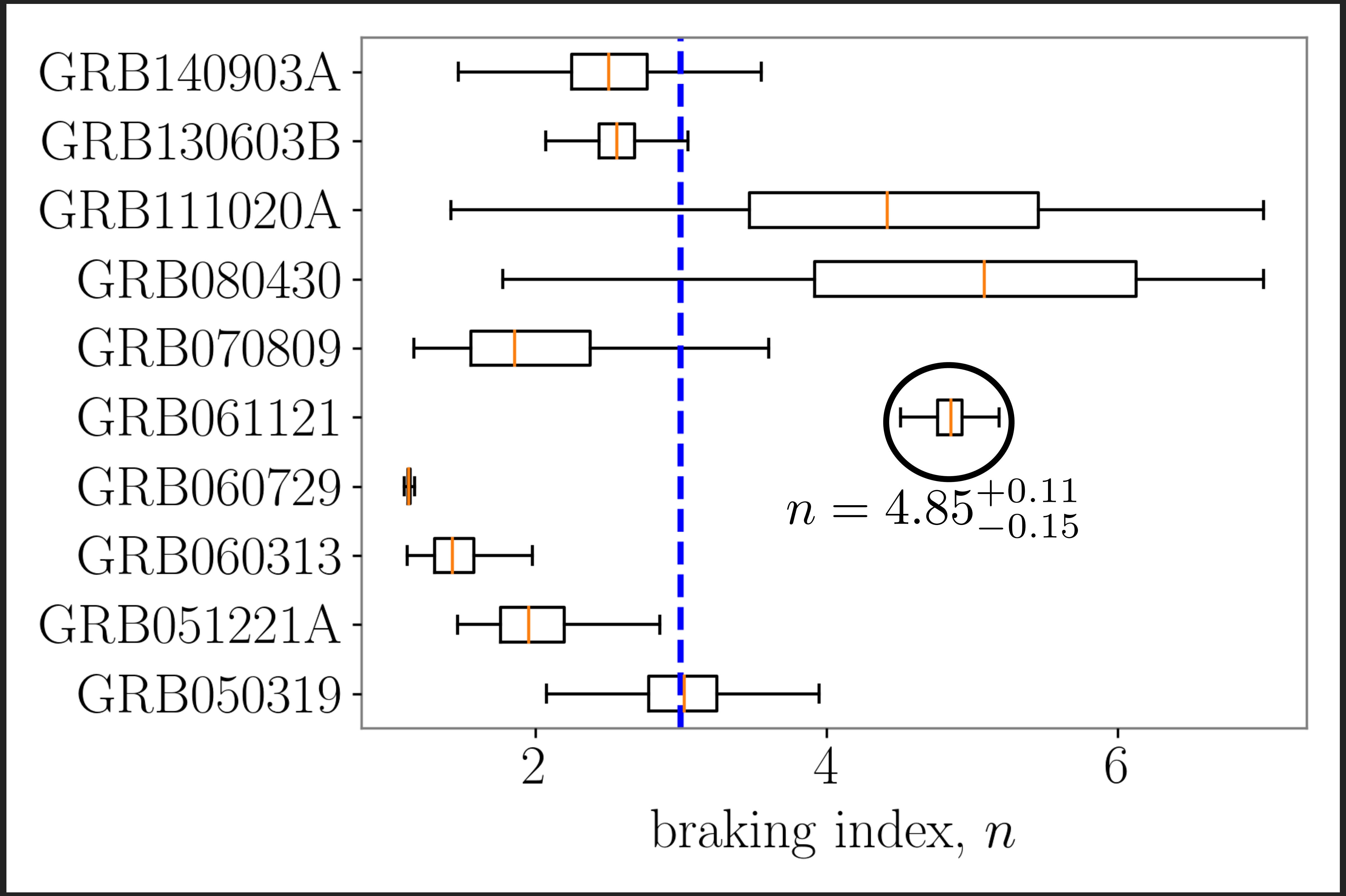
- Selecting between a jet or neutron star interpretation for an afterglow is dependent on the equation of state.
- GRB140903A data favours the existence of a nascent neutron star for all possible equation of states.

- In Sarin+2020b we developed a new model for gamma-ray burst afterglows with a nascent neutron star.
- We can now start to naturally explain X-ray flares!



Sarin et al. (2020b)

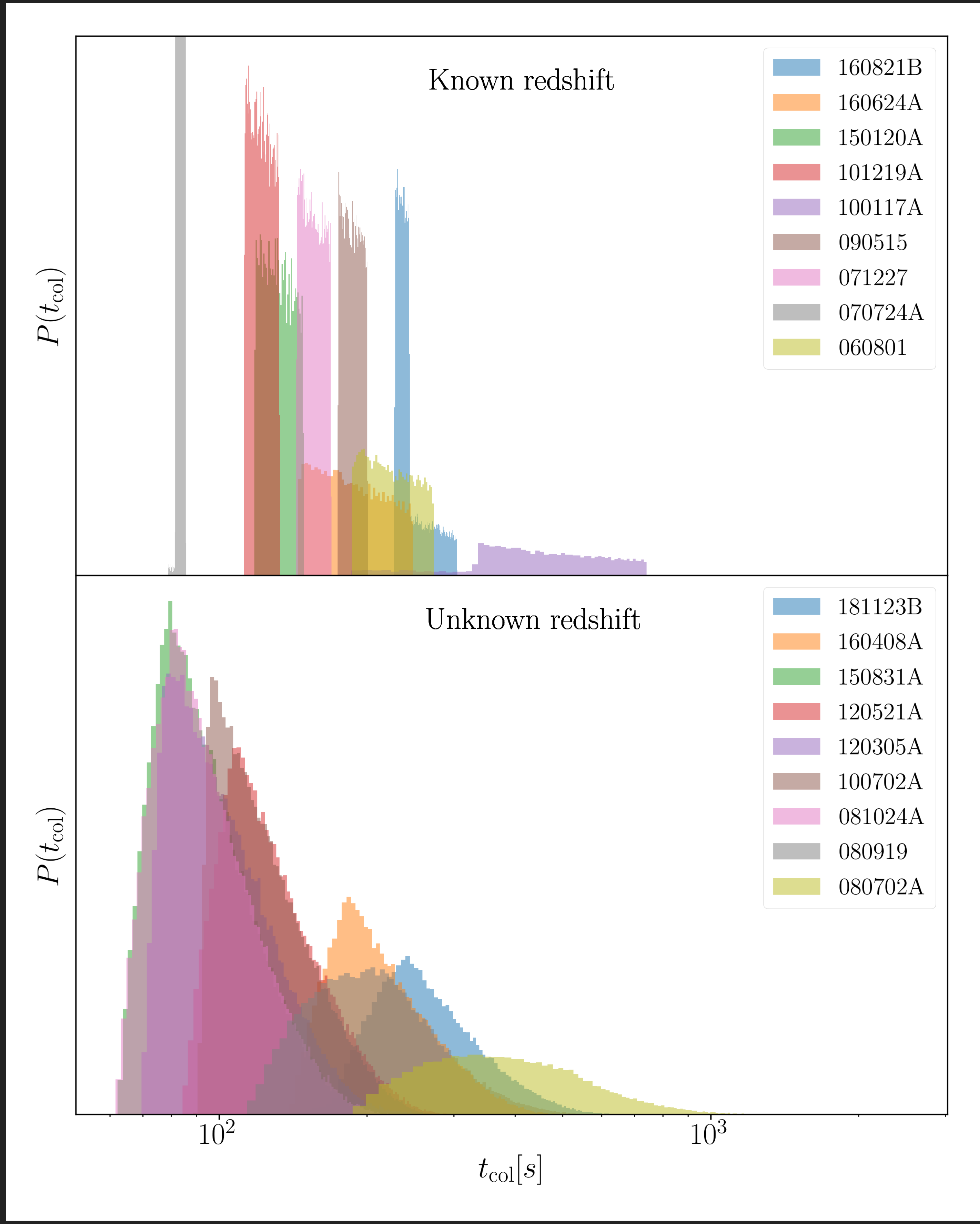
- Can measure the braking index of putative nascent neutron stars.



Sarin et al. (2020b)

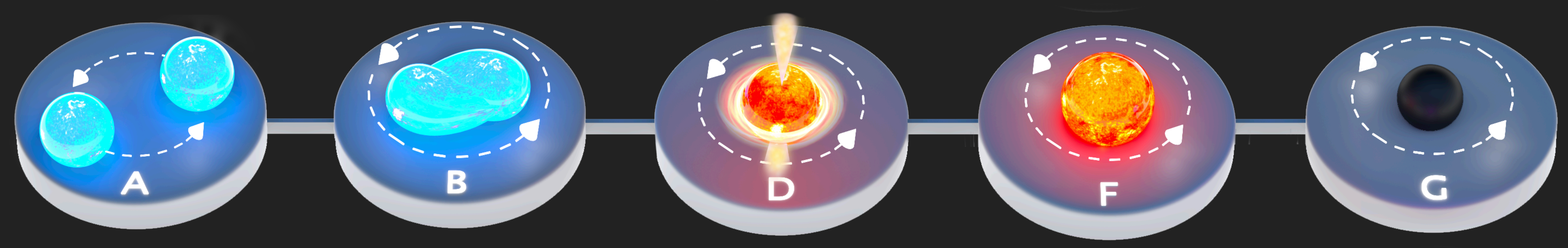
- GRB061121 potentially spins down predominantly through gravitational-wave emission.
- Do we expect to detect these gravitational waves in aLIGO? No. See e.g., Sarin+2018.

- We can look at the population as a whole.
- We measured the collapse-time of 18 putative long-lived neutron stars from the X-ray afterglow of 72 short gamma-ray bursts.



Sarin et al. (2020a)

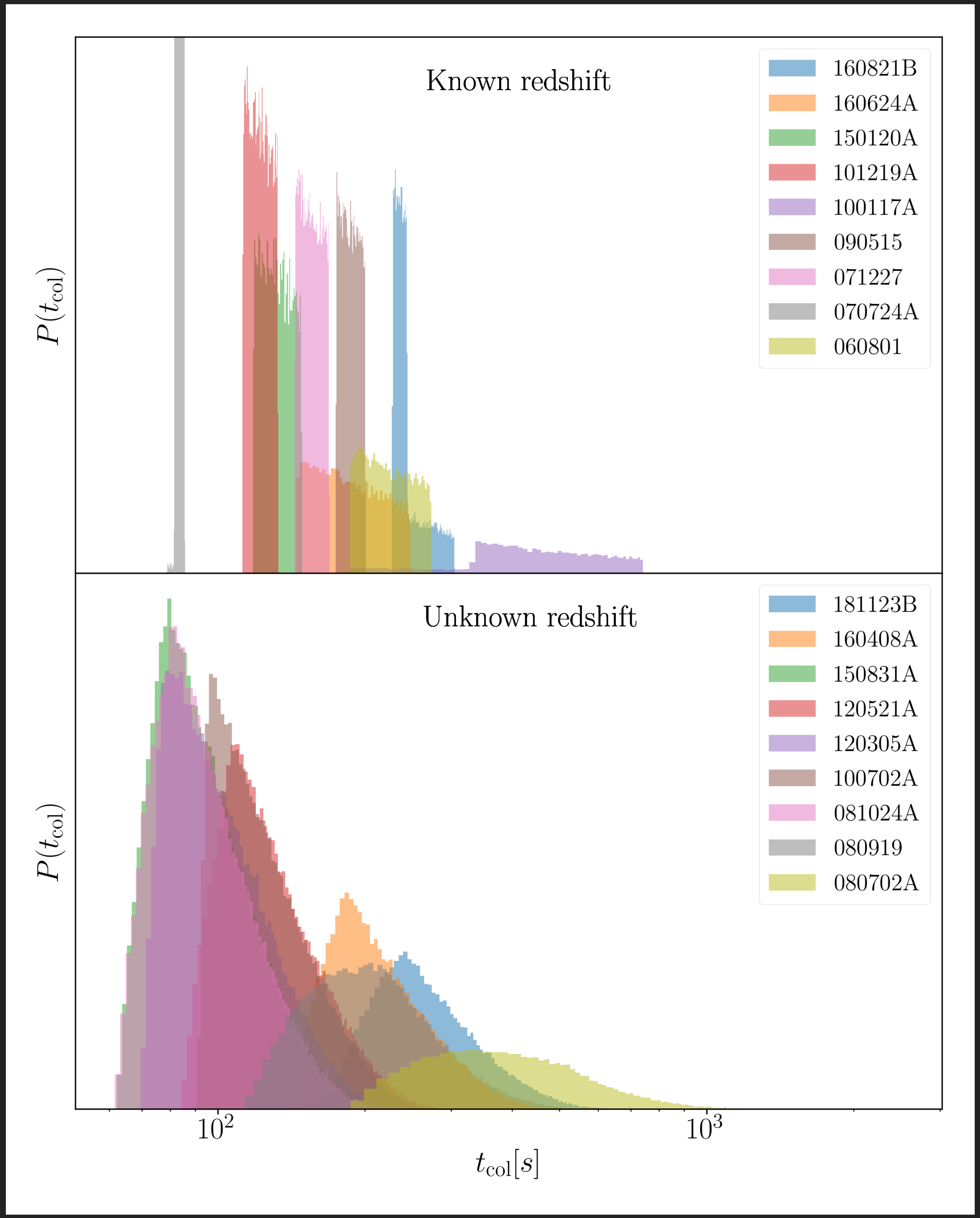
USING X-RAY AFTERGLOWS AS A POPULATION



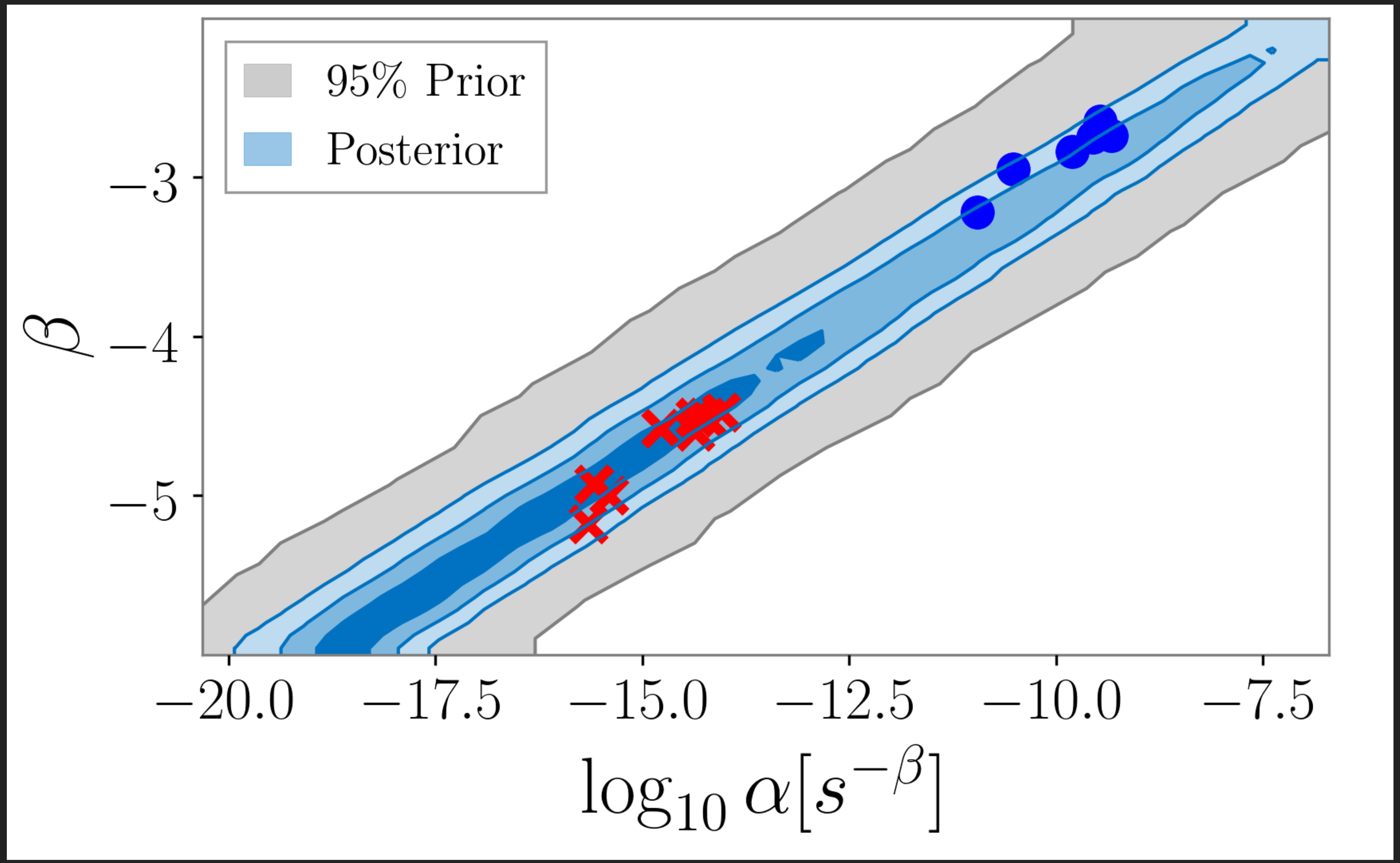
$$t_{col,i} \propto \tau_i, p_{0,i}, M_{p,i}, \gamma_i, \alpha, \beta, M_{\rm TOV}$$

$$\gamma_i = \frac{\langle n \rangle_i + 1}{\langle n \rangle_i - 1},$$

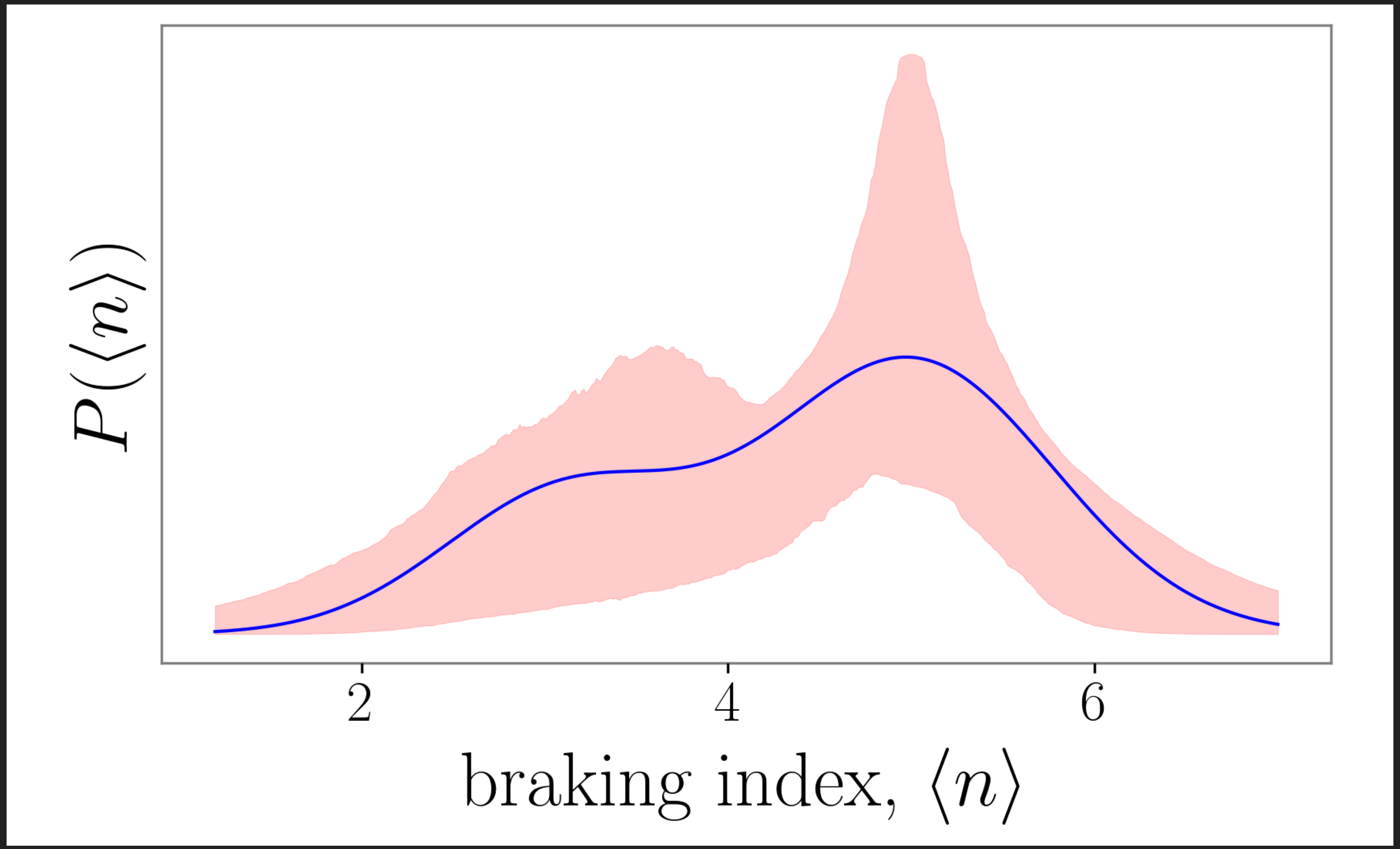
$$M_{\rm max} = M_{\rm TOV}\left(1 + \alpha p^{\beta}\right)$$



Sarin et al. (2020a)



- This method can be used to determine the equation of state in hot, massive neutron stars.
- Some indications that these post-merger remnants are quark stars, at the one-sigma level.
- This may point towards a temperature dependent phase transition from hadronic to deconfined quarks!



- A significant fraction of these objects spin-down predominantly through gravitational-wave emission. While the rest also indicate potentially some spin-down early in their lifetime through gravitational-wave emission.
- This suggests nascent neutron stars will contribute to the stochastic gravitational wave background, and their contribution may be detectable with third generation telescopes (Cheng et al. 2017).

- The merger outcome has significant implications for what we might see from a binary neutron star merger.
- Early X-ray afterglow observations are invaluable in determining the fate of binary neutron star mergers.
- We can learn a lot about the nuclear equation of state and neutron star dynamics from the X-ray afterglows of gamma-ray bursts.
- Theseus will enable many different independent probes into what is happening in the aftermath of neutron star mergers.