Monash University

OzGrav

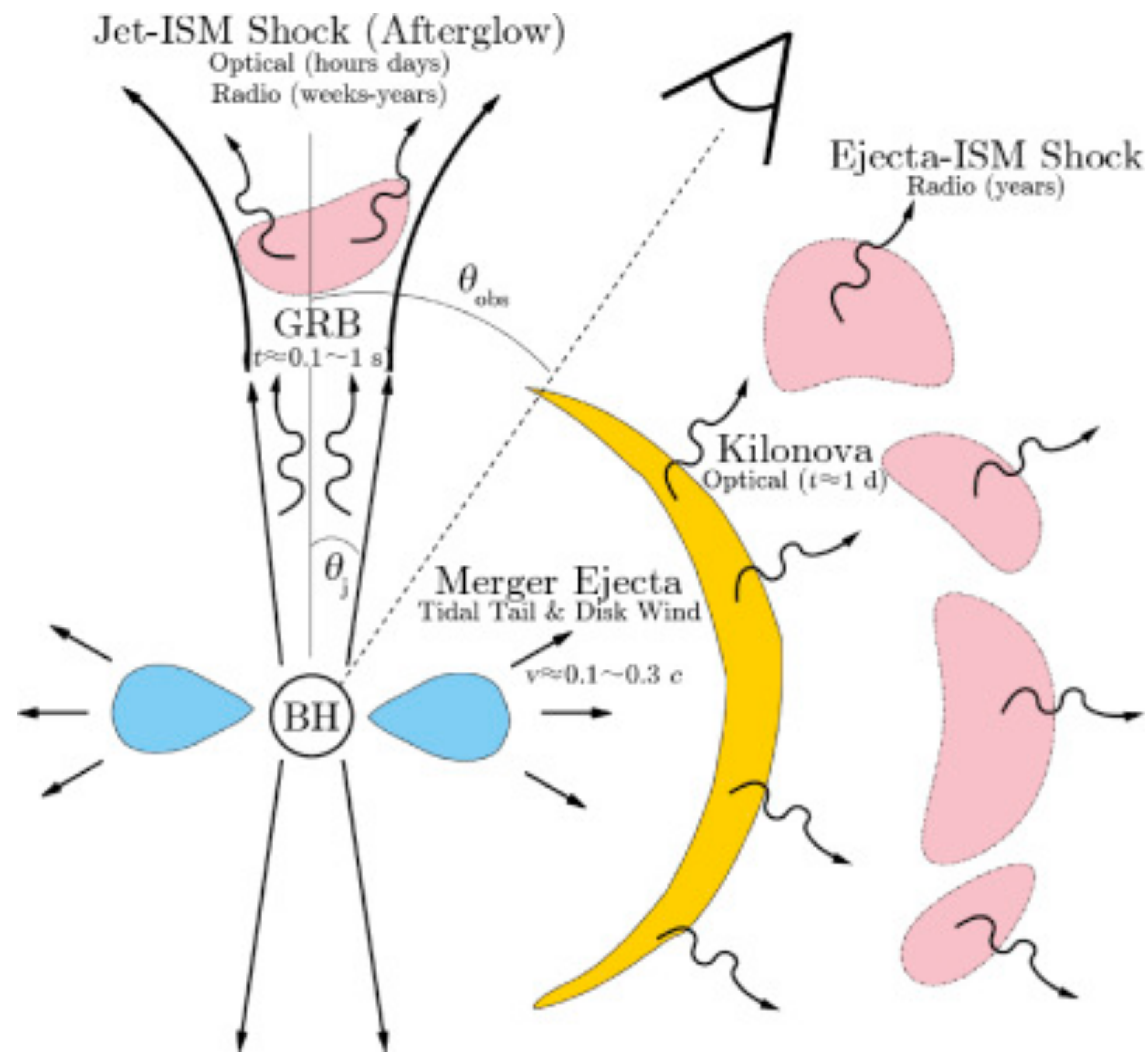
ARC Centre of Excellence for Gravitational Wave Discovery

SHORT GAMMA-RAY BURST AFTERGLOWS AND GRAVITATIONAL WAVES

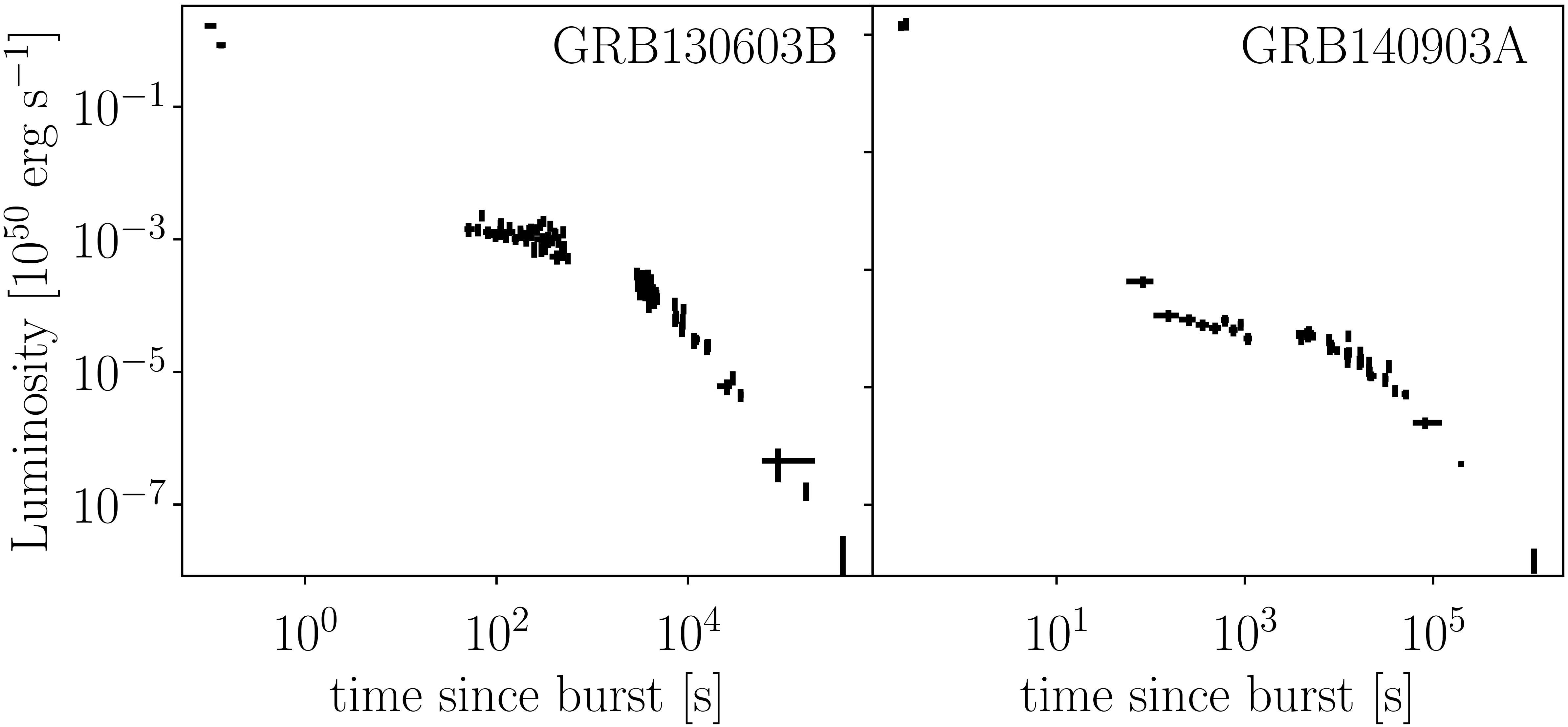
NIKHIL SARIN

PAUL LASKY GREG ASHTON

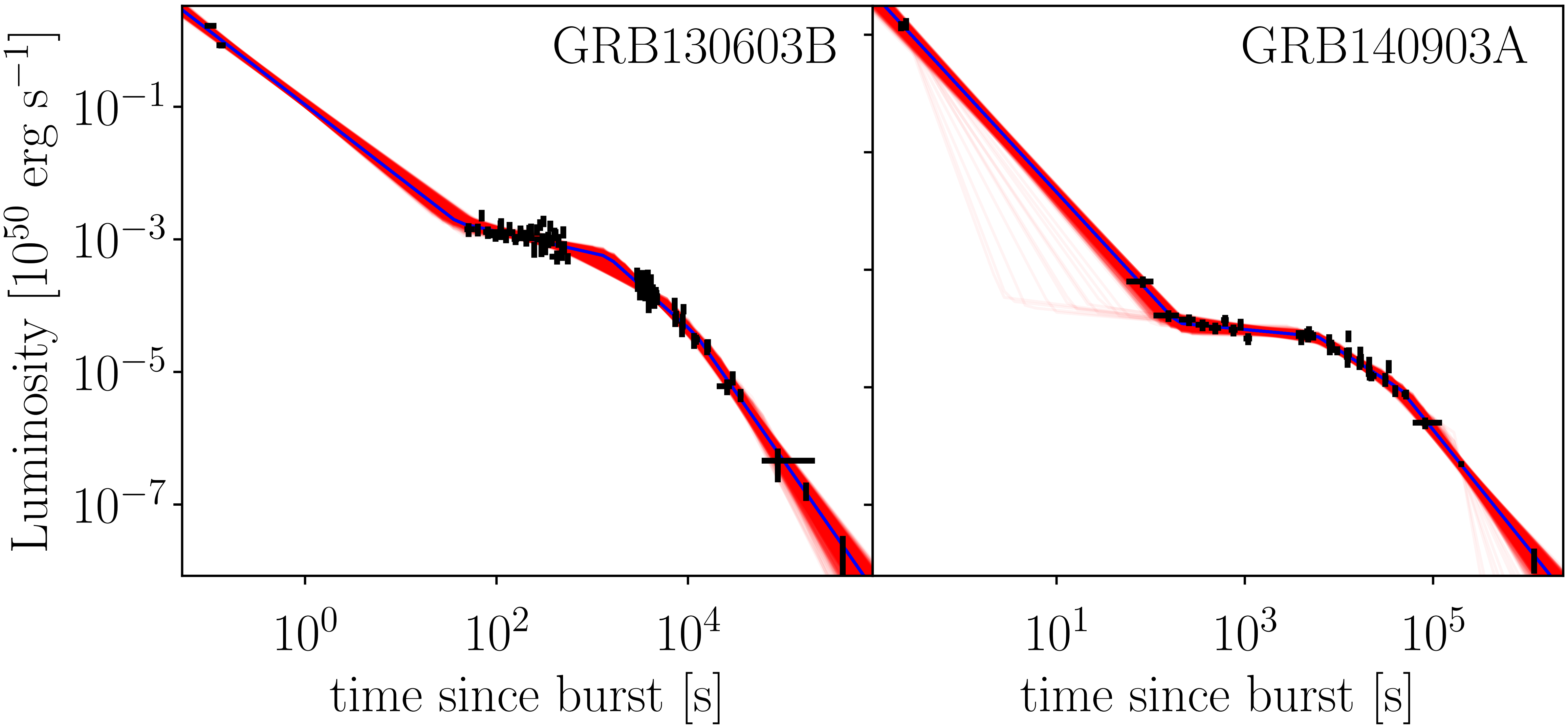
- Gamma-ray bursts often have an extended x-ray, optical, radio emission.
- Origin of this afterglow is unclear
  - External shock from a relativistic fireball.
  - Millisecond magnetar.
  - Both.



Schematic from Metzger and Berger (2012)

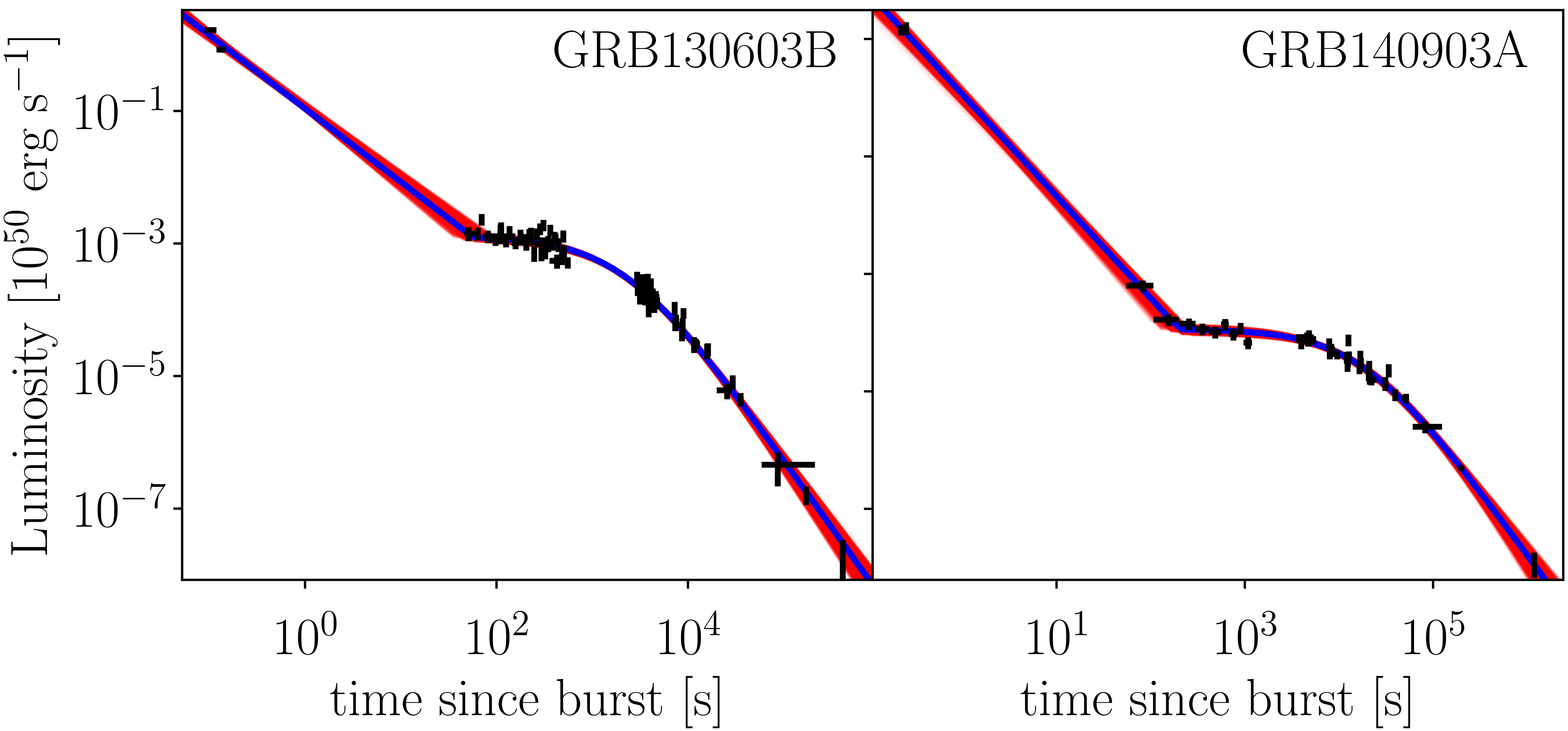

GRB130603B
GRB140903A
Luminosity [10^{50} erg s^{-1}]
10^{-1}
10^{-3}
10^{-5}
10^{-7}
10^{0}
10^{2}
10^{4}
10^{1}
10^{3}
10^{5}
time since burst [s]
time since burst [s]

Fireball



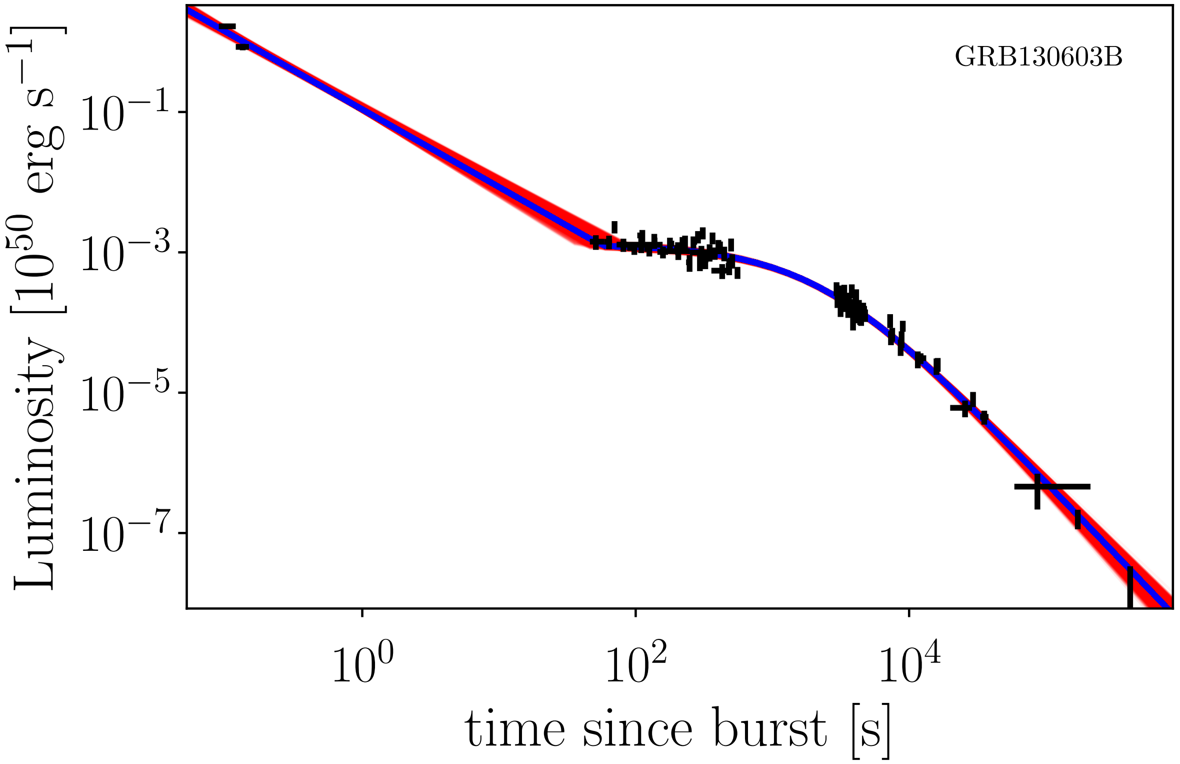
$$L = A_1 t^{\alpha_1} + A_2 t^{\alpha_2} + ... + A_n t^{\alpha_n}$$

Magnetar

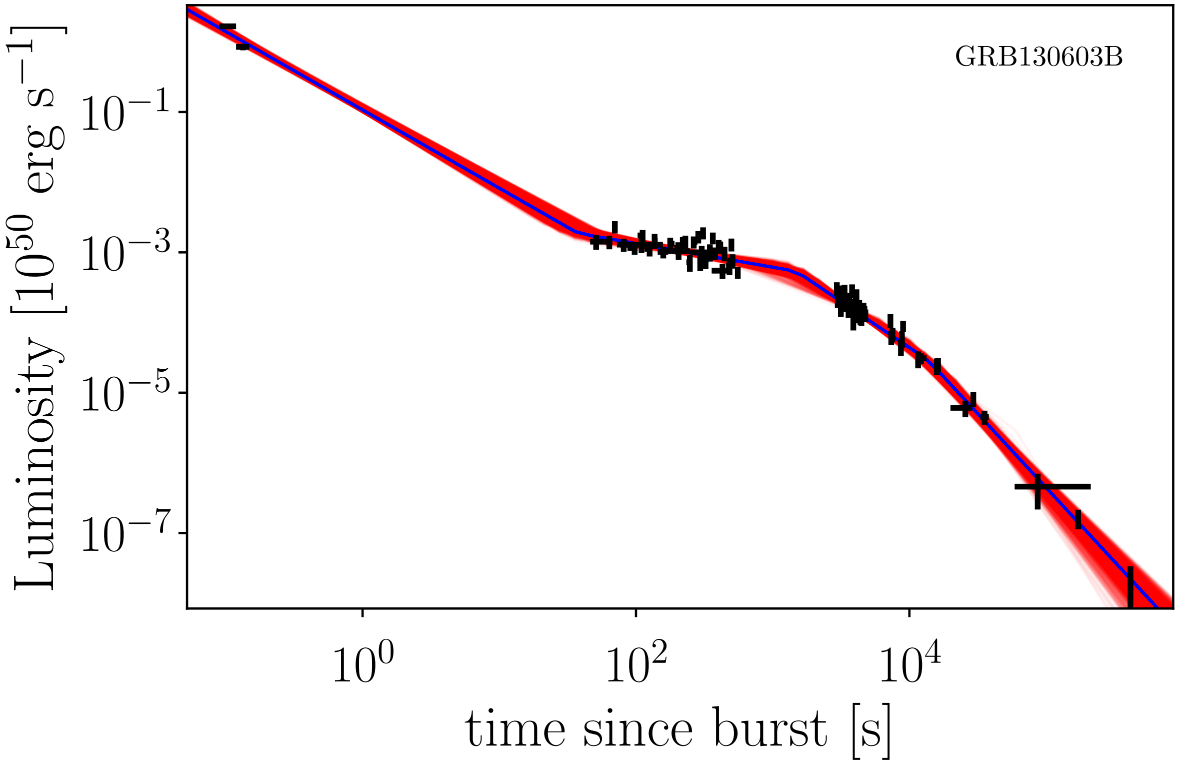


$$L = A_1 t^{\alpha_1} + A_2 \left(1 + \frac{t}{\tau}\right)^{\frac{1+n}{1-n}}$$

SO WHAT WINS?



Magnetar Model

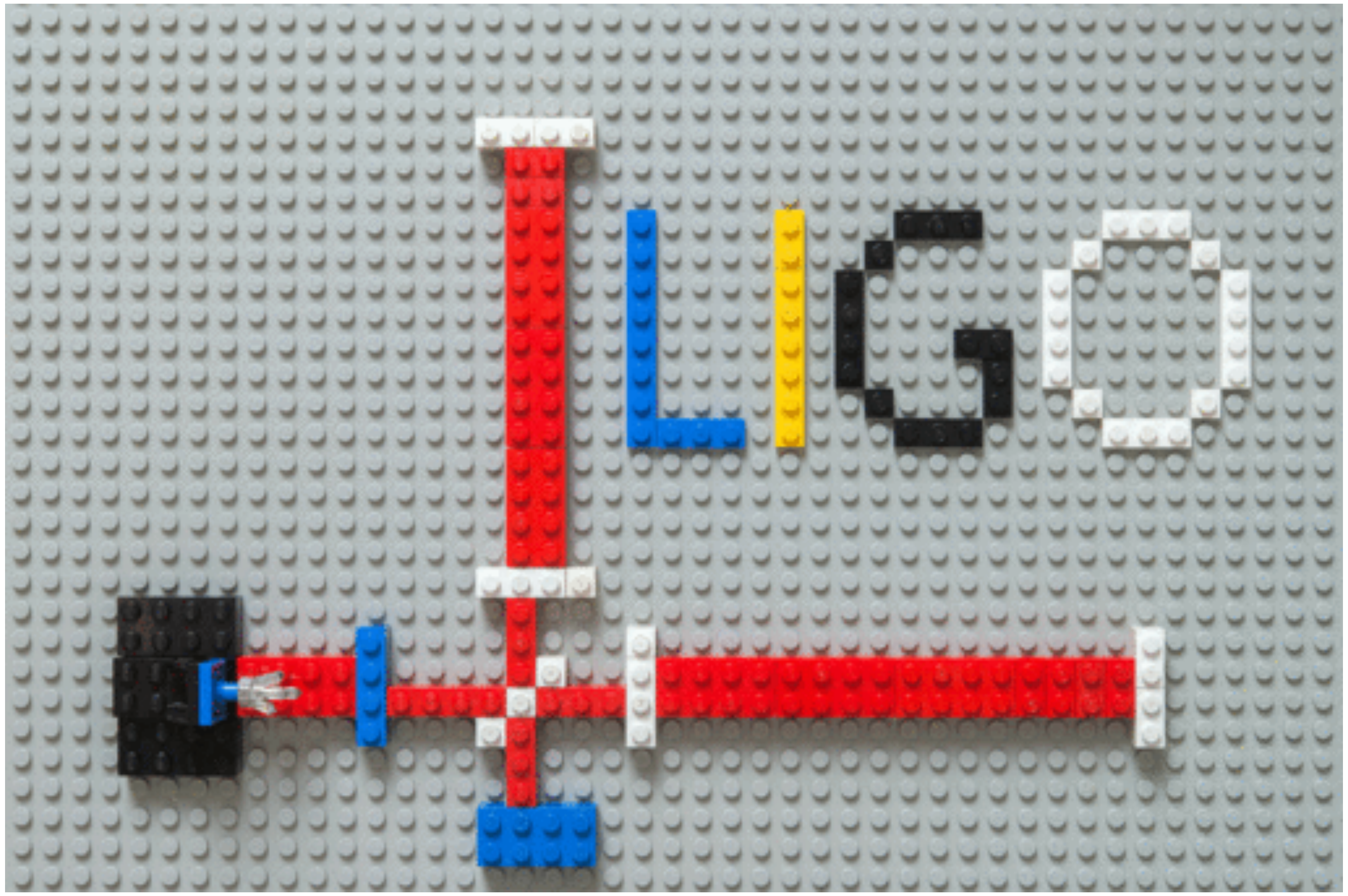


4 Component fireball model

	Bayes Factor
GRB130603B	30.12
GRB140903A	1712.9

- GRB140903A: magnetar model is ~1700 times more likely than a 4 component fireball.

- Magnetar model wins!
- This magnetar will spin down and emit gravitational waves
- How do we find them?



Credit: Paul Lasky

- A waveform model for the gravitational-wave frequency evolution:

$$f_{gw}(t) = f_{gw,0}\left(1 + \frac{t}{\tau}\right)^{\frac{1}{1-n}}$$

n is the braking index.

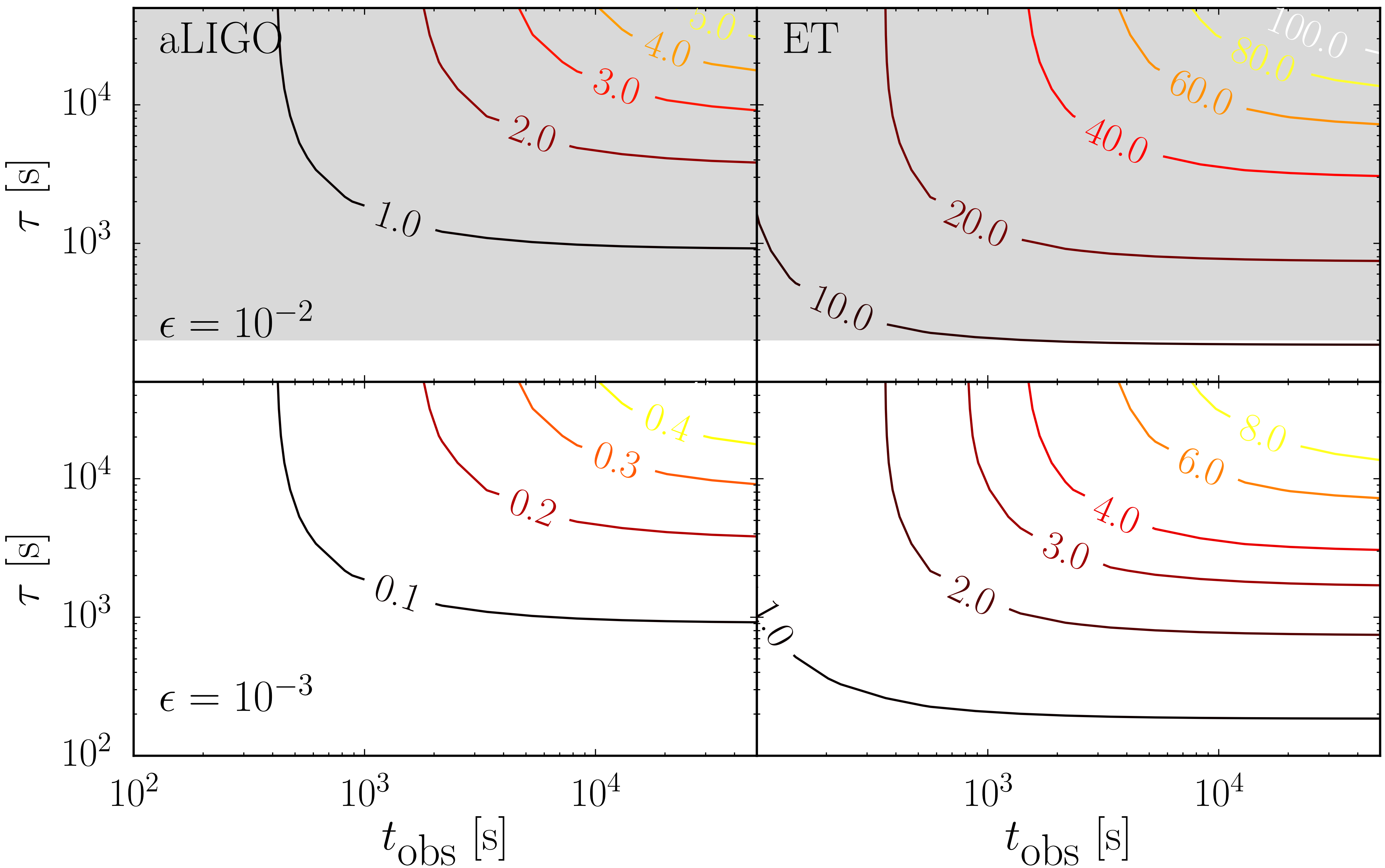
$f_{gw,0}$ is the initial gravitational-wave frequency

τ is the spin-down damping timescale

Lasky, Sarin & Sammut
(LIGO Document T1700408)
Abbott et al. (2017)
Search for post-merger gravitational waves from the remnant of the binary neutron star merger GW170817
Sarin et al. (2018)

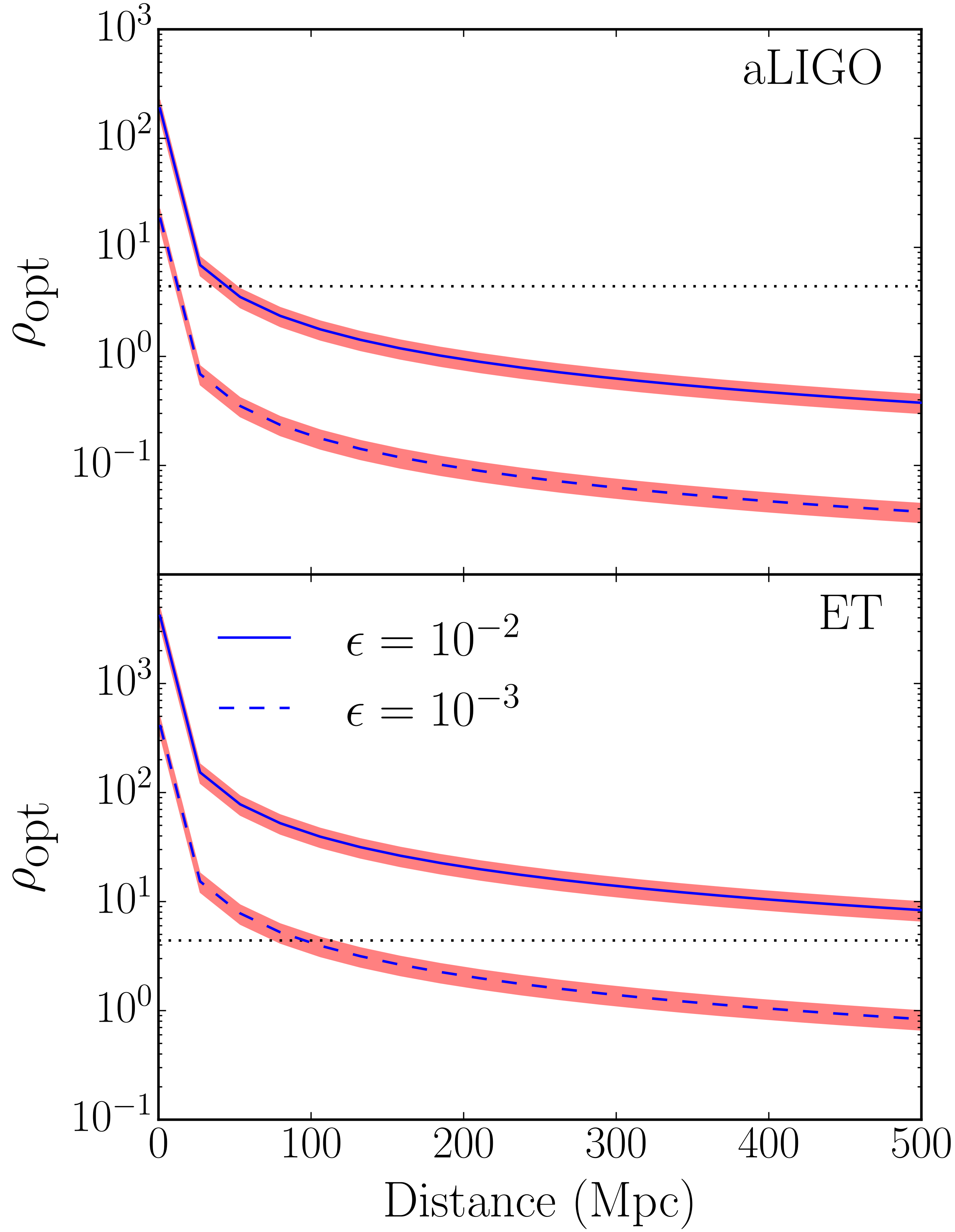
- Can use this as a template in a matched-filter search

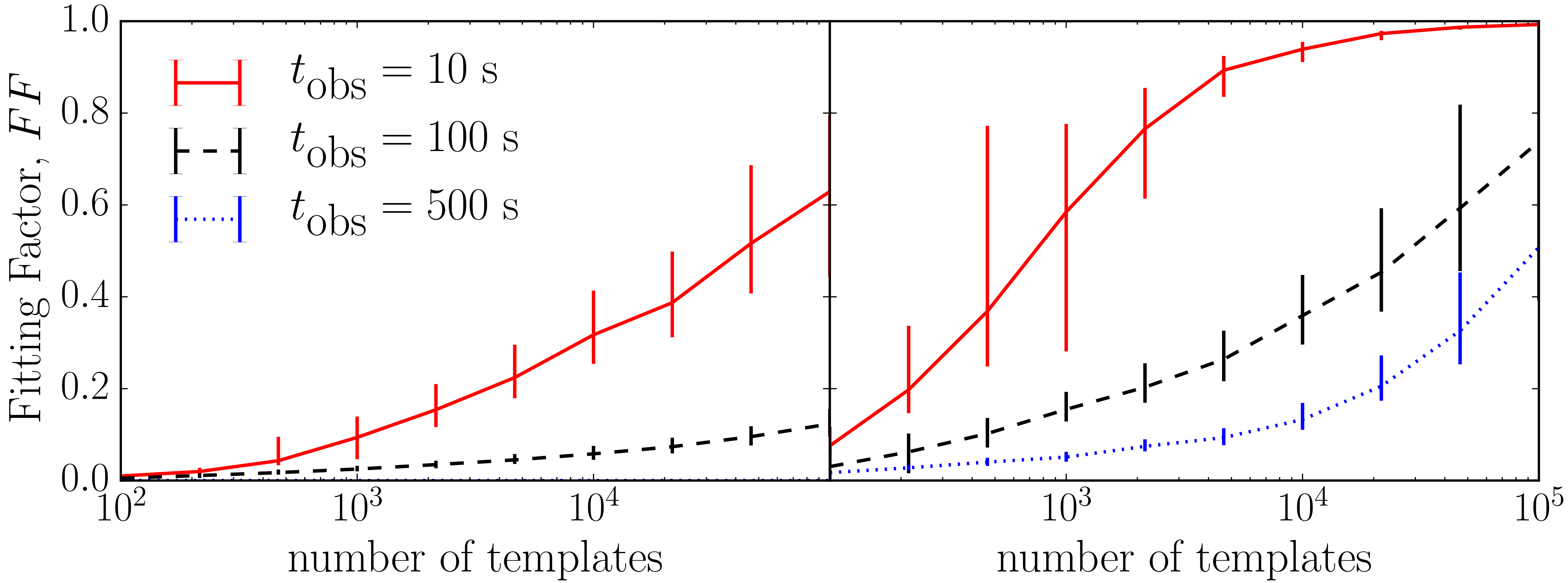
OPTIMAL MATCHED-FILTER SNR



- Parameter space for a post-merger remnant at the same distance as GW170817.

- Can also use the optimal signal-to-noise ratio to determine distances where we could detect signals out to.





- Fitting Factor (FF) is the penalty in signal-to-noise ratio due to mismatch between template and signal

$$FF = \frac{\rho}{\rho_{\mathrm{opt}}}$$

SUMMARY

- We find the millisecond magnetar model more favourable than the fireball model.
- Magnetar model implies a central engine that will spin down and emit gravitational waves.
- We develop a method to search for these gravitational waves.
- Gravitational-wave signals from these objects could be detected out to $\sim$2 and $\sim$45 Mpc with aLIGO and ET, respectively.