Identifying Potential Newly Formed Magnetars from Gamma-ray Bursts

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Gamma-ray Bursts
- Soft gamma ray flashes (~ 0.01 - 1 MeV) that can be observed through space telescopes like Swift.
- By looking at the emission of the gamma rays, we can classify the GRB in short or long duration based on certain time parameters (T90, time it takes to reach 95% brightness).
- Short Duration GRBs
  - T90 < 2 seconds.
  - These GRBs are associated with core-collapse supernovae.
  - Emission Mechanism
    - The dominant model on the emission of GRBs is the so-called Fireball model.
- Long Duration GRBs
  - T90 > 2 seconds.
  - These are associated with BH mergers.

Gravitational Waves
- Gravitational Waves (GWs) are ripples in the curvature of spacetime that propagate as a wave. These ripples are caused by the acceleration of high mass objects.
- The collapse of high mass stars should not only produce observable outbursts in the electromagnetic spectrum, but also produce gravitational waves.
- The advantage of the gravitational waves is that they allow us to directly study the collapsed star core, whereas the electromagnetic spectrum can be obscured by factors such as dust and ejected material.
- For short GRBs, that are caused by coalescing systems, three phases within the merger process will produce different types of GW signals: an inspiral phase, the merger, and a ring-down phase of the newly formed black hole.
- With our present GW observatories, we can only detect gravitational waves from sources within a 150 Mpc radius, so our GRB sample size is only a small volume of all GRBs that occur.

Light Curves
- A light curve is a time series record of electromagnetic emission.
- Looking at the X-ray light curve data, we see that several GRBs, instead of a standard curve, show a plateau phase where the luminosity is constant (Evans et al. (2007)).
  - GRB 170710A is an example of a standard light curve, whereas the rest have plateau phases.
  - This plateau phase can be explained by a central engine that is rejuvenating the shocks (Kobayashi & Meszaros (2003)).
- If LIGO showed a GW signal during the time of the plateau, we can model it for future GRB triggers, and strengthen our case for conducting a radio follow-up magnetar search of these sources.

Gravitational Waves

- Identifying Potential Newly Formed Magnetars from Gamma-ray Bursts
- The detection of GW170817 (Abbott et al., 2017), gravitational waves coming from the merger of two NS, and the associated short GRB is reinforcing this model, despite some existing uncertainties.
- The collapse of high mass stars should not only produce observable outbursts in the electromagnetic spectrum, but also produce gravitational waves.

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Results and Future Steps

A. Results
- 51 GRBs occurred between November 30th, 2016 to August 25th, 2017 and 9 of these have plateaus, as shown in Table 1. Out of these, 7 have coincident GW data for at least 50% of the plateau duration. However, 3 of them can be placed at distances beyond the sensitivity of LIGO.

B. Future steps
- Our next step will be to apply an algorithm (that is currently in development) to see if we can detect any signals from the LIGO data during the GRB candidates.
- We can model the signal and create a waveform that can be applied to future signal GRB searches.
- Publication in process

References:
- Swift Gamma Ray Burst Team. The cross patterns are flares that were observed. The solid black line is the fit provided by the best waveform. The cross patterns are flares that were excluded from the data list.

Table 1: All GRBs that have an X-ray plateau. The coincident time denotes the overlap of time that both LIGO detectors were on with the duration of the Plateau. The GRBs selected in light gray are our candidates.

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<th>Name</th>
<th>Redshift</th>
<th>Approx. Duration (s)</th>
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<td>3</td>
<td>1.91</td>
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