GRAVITATIONAL WAVES from SGR BURSTS

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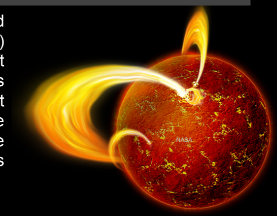
SGRs & AXPs: Magnetars

Soft gamma repeaters (SGRs) and anomalous X-ray pulsars (AXPs) sporadically emit short bursts of soft gamma rays with peak luminosities commonly up to 10^{42} erg/s [1]. Rare giant flare events, 10^3–10^4 times brighter, are among the most luminous events in the Universe [1]. 3 of 5 known galactic SGRs have each produced a giant flare.



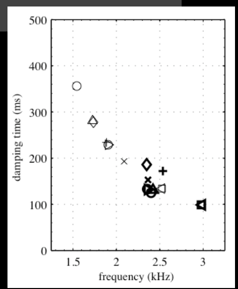
SGRs are promising gravitational wave (GW) sources. In the "magnetar" model SGRs are neutron stars (NS) with exceptionally strong magnetic fields, 10^{15} G [2]. SGR bursts may result from the interaction of the field with the solid NS crust, leading to crustal deformations and catastrophic cracking [3] with potential excitation of the star's nonradial GW-damped f-modes [4].

The Searches

Analysis is performed with the Flare pipeline [5,6] in ±2 s GW data signal regions around burst trigger times provided by IPN satellites. We assume GW bursts occur within ±0.5 s of EM burst. Loudest signal region events are compared to the background to estimate detection significance.

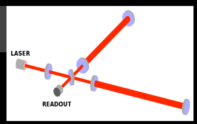
We target three frequency bands in GW data:
- 1 to 3 kHz where f-modes live
- 100 to 200 Hz max detector sensitivity
- 100 to 1000 Hz for full coverage.

We set loudest event upper limits on (isotropic) GW energy at 90% detection efficiency using 1) circularly and linearly polarized ringdowns (RDC, RDL) in the 1 to 3 kHz region; and 2) white noise burst (WNB) waveforms at low frequencies.



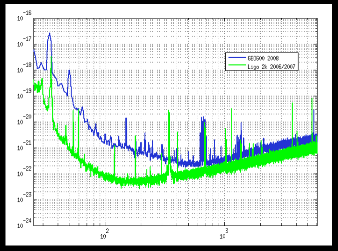
Predicted f-mode time constants and frequencies, for a variety of NS masses and equations of state, from [7]. (Figure from [8].)

The GW Interferometers



LEFT: Magnetar searches have been performed with data from two GW detectors in Washington (one with 4 km arms and one with 2 km arms) and one 4 km detector in Louisiana. In addition, ongoing searches use the Virgo detector in Italy (3 km arms) and the GEO detector in Germay (600 m arms).

BELOW: **GEO** and **LIGO 2 km** noise curves.

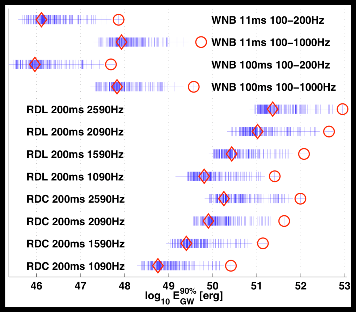


First Search: Giant Flare + 214 common bursts

Abbott et al. PRL 101, 211102 (2008)
No detection.
Search included the 2004 **SGR 1806-20 giant flare** (red circles), "GRB" 060806 from SGR 1806-20 (diamonds), common bursts from SGRs 1900+14 and 1806-20, and the SGR 1900+14 storm (see lightcurve below) .

E_{GW} upper limits for twelve waveforms in the three search bands are shown at right (10 kpc nominal distance, isotropic emission).

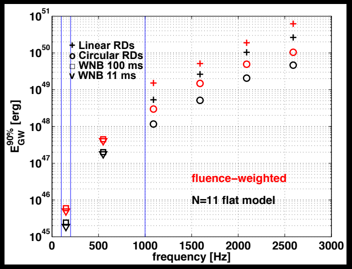
Best f-mode upper limit was **2×10^{48} erg.**
Best f-mode upper limit on **$\gamma \equiv E_{GW} / E_{EM}$** was **$2\times10^4$** (due to large E_{EM} from giant flare).



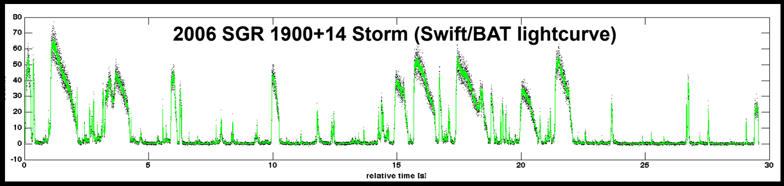
Stacked Search: SGR 1900+14 Storm

Abbott et al. ApJ 701, L68-L74 (2009)
No detection.
GW data near individual EM bursts were stacked (time-aligned) according to rising edges of EM bursts. Two stacking models were used: 1) the 11 most EM-energetic bursts; 2) all bursts weighted according to EM fluence ("fluence-weighted").

We assumed variation in delay between GW and EM emission is small compared to GW burst signal duration.



Stacking gave **12x sensitivity gain** (N=11 flat model). Best f-mode upper limit of **10^{48} erg.**



GW Emission Models

Little has been said about GW emission from magnetars. In Ioka's model [10] which may be the most detailed:

$\gamma \equiv E_{GW} / E_{EM} = 10^4$ not unreasonable
$E_{GW} = 10^{49}$ erg not unreasonable

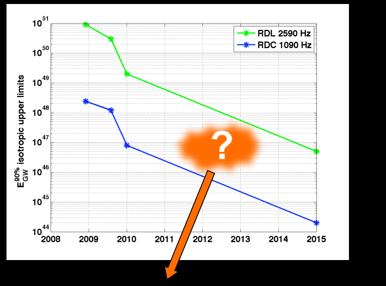
Our upper limits begin to enter this region.

We expect new predictions on GW amplitudes in 2010. Two of us (P. Kalmus and C. Ott) are using numerical GR models to do so. Ultimately we'd like to understand the relationships between the NS event and EM and GW emission (below).

Future Searches

Advanced LIGO is expected to give an addition 100x in energy sensitivity beginning in 2015.

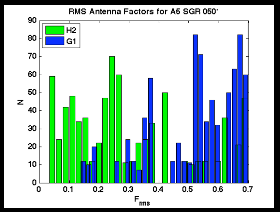
f-mode upper limits from 800 pc could then be as low as **10^{44} erg**. Will it be enough for detection?



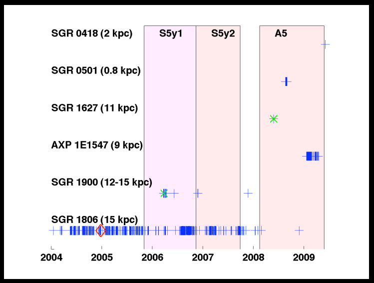
Additional orders of mag might come from:
- SGR @ 250 pc or less
- stacking SGR 0501 bursts
- clever new methods.

Ongoing: Recent bursts including nearby SGR 0501+4516

Bursts from 6 magnetars during the 2nd year of LIGO's 5th science run (S5y2) and Astrowatch (A5) commissioning period (A5 involved the LIGO 2 km and GEO detectors only). **SGR 0501+4516** (discovered 2009) is likely **800 pc from Earth** [9]. We thus expect **E_{GW} limits at least 10x lower** than before.



ABOVE: Antenna geometry during SGR 0501 bursts was more favorable for **GEO** than for **LIGO 2 km.**



LEFT: Magnetar bursts 2004 thru 2009. Red diamond is giant flare; green stars are storms.

References

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