sGRB Precursor Flares and Gravitational Waves

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sGRB Precursor Flares

- Three short Gamma-Ray Bursts (out of 41) have been preceded by a lower intensity signal known as a "Precursor"
  - < 3 seconds before main Burst
  - same source position as main Burst
  - also seen by Fermi or Suzaku

- One model suggests Precursors due to Resonant Shattering of NS Crusts during BNS inspiral
  - Resonant excitation by tidal deformation during NS binary inspiral
  - f_{res} depends on crust EOS
  - Tsang et al (PRL 108, 2012)

Looking for Precursor and GW

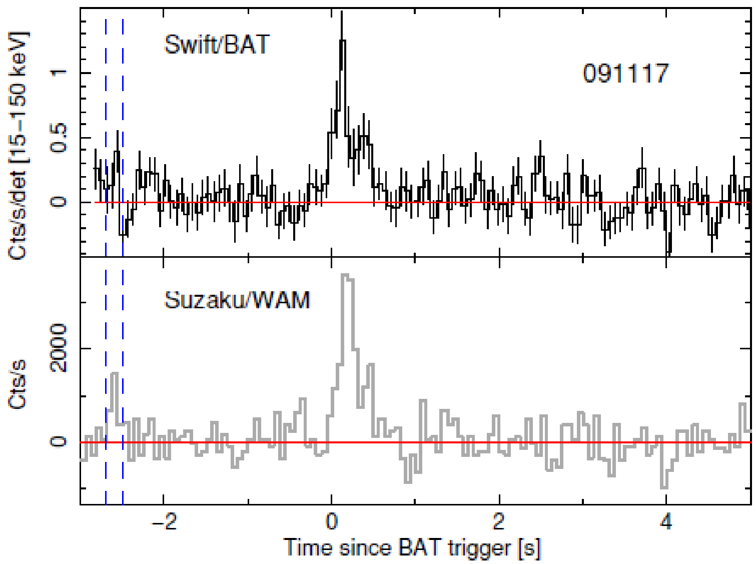
- Effect of Resonant Crust Shattering on GW is too small to be directly observed
  - $\Delta\phi \sim 10^{-3}$ rad

- However NS Crust Cracking flares will be isotropic
  - $10^{46\text{-}47}$ erg (vs. $10^{48\text{-}49}$ erg for main beamed Burst)
  - Observable to ~ 100-200 Mpc
  - Could possibly be observed in coincidence with GW

- Sub-threshold GBM search will help detections
  - Fits in with proposed O1 Fermi-LIGO sub-threshold search (discussed Sunday)

sGRB Precursors

Troja et al, Ap J 723 (2010)



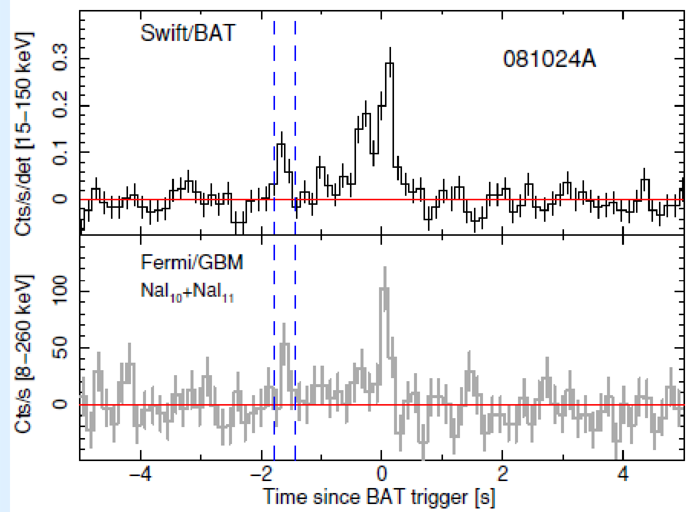
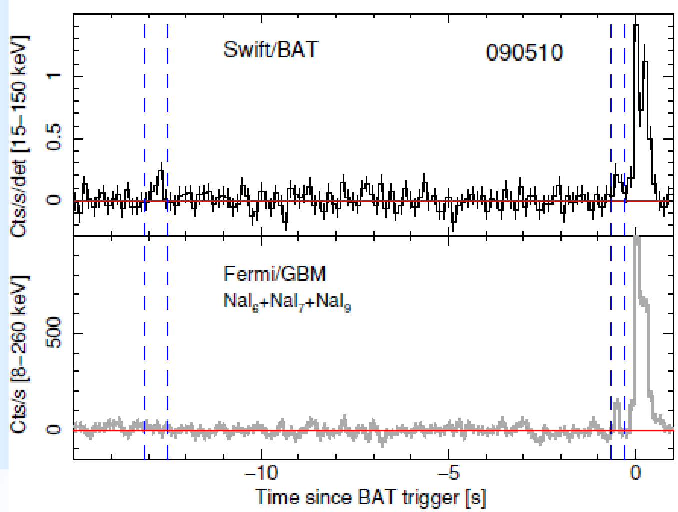


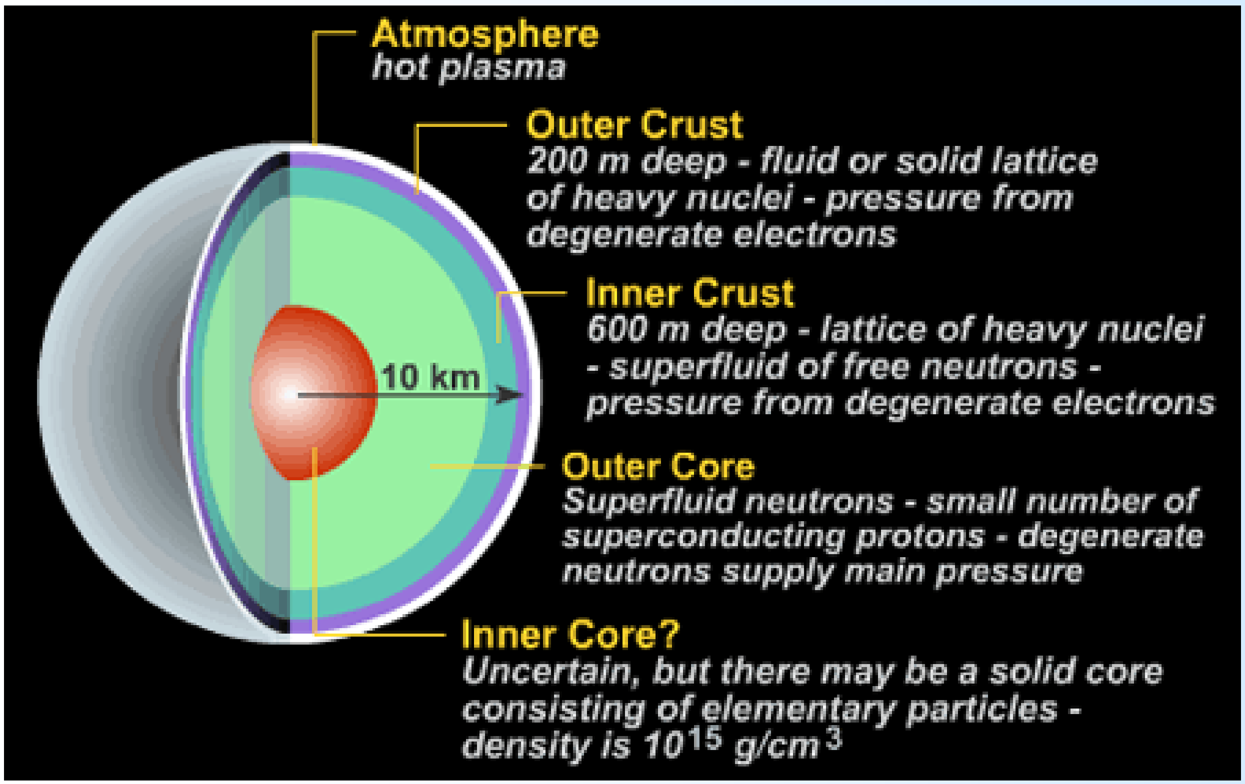
Table 1

Image Significance of the Candidate Precursors

GRB	T_i (s)	T_f (s)	Significance (σ)	Probability[a]	Others
050724 (EE)...	−108.5	−107.5	3.7	5×10^{-4}	...
080702A...	−140.6	−139.5	3.2	3×10^{-3}	...
081024A...	−1.70	−1.45	5.5	$<10^{-5}$	*Fermi*
090510 ...	−13.0	−12.6	5.2	$<10^{-5}$	...
	−0.55	−0.5	4.6	10^{-5}	*Fermi*
091117...	−2.75	−2.65	1.8	6×10^{-2}	*Suzaku*



Neutron Star Structure



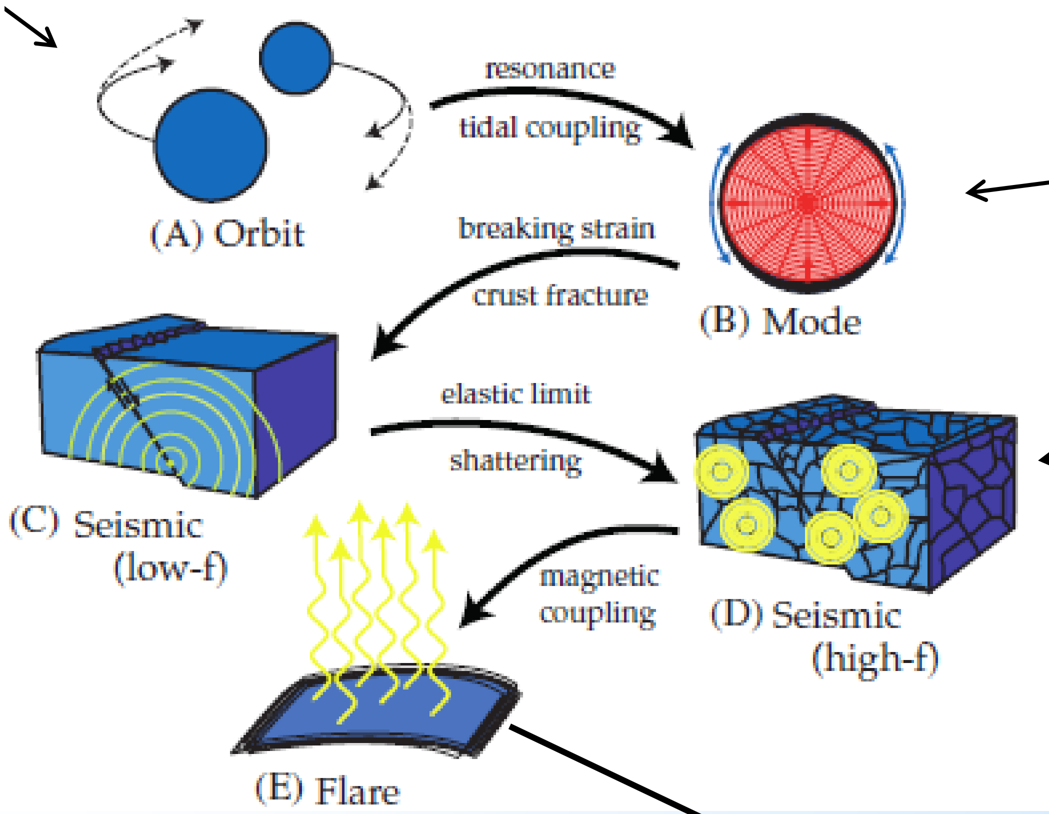
Cracking:
Inner and Outer Crust

Damping:
Core and Crust

Resonant Shattering Process (Tsang)

Available Tidal Energy

~ 10^{50} erg

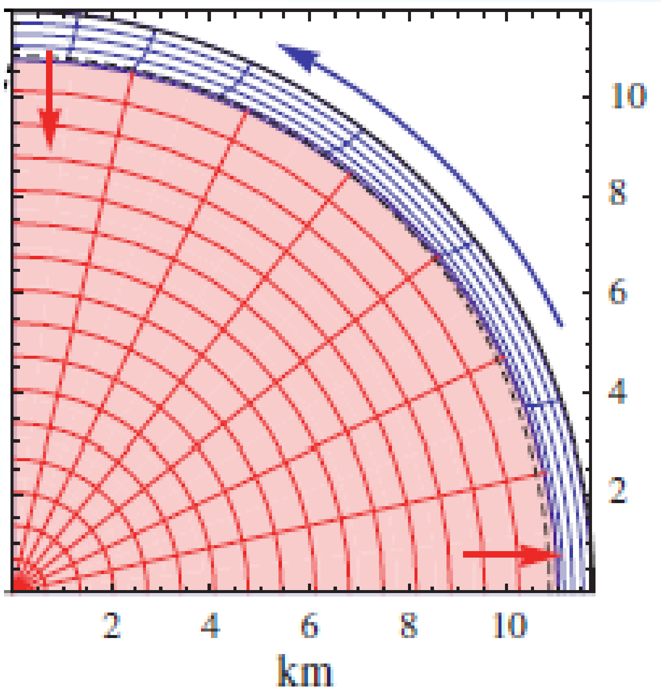


Mode Energy
~ 10^{47} erg
→ Fracture

Seismic Energy
~ 10^{46} erg
→ Shattering

Luminosity ~ $10^{46\text{-}47}$ erg 0.1 sec
(can see 10^{47} erg at ~ 150 Mpc)

Resonant Excitation of NS crust
Tsang et al, PRL 108 (2012)



Crust-Core Interface Mode

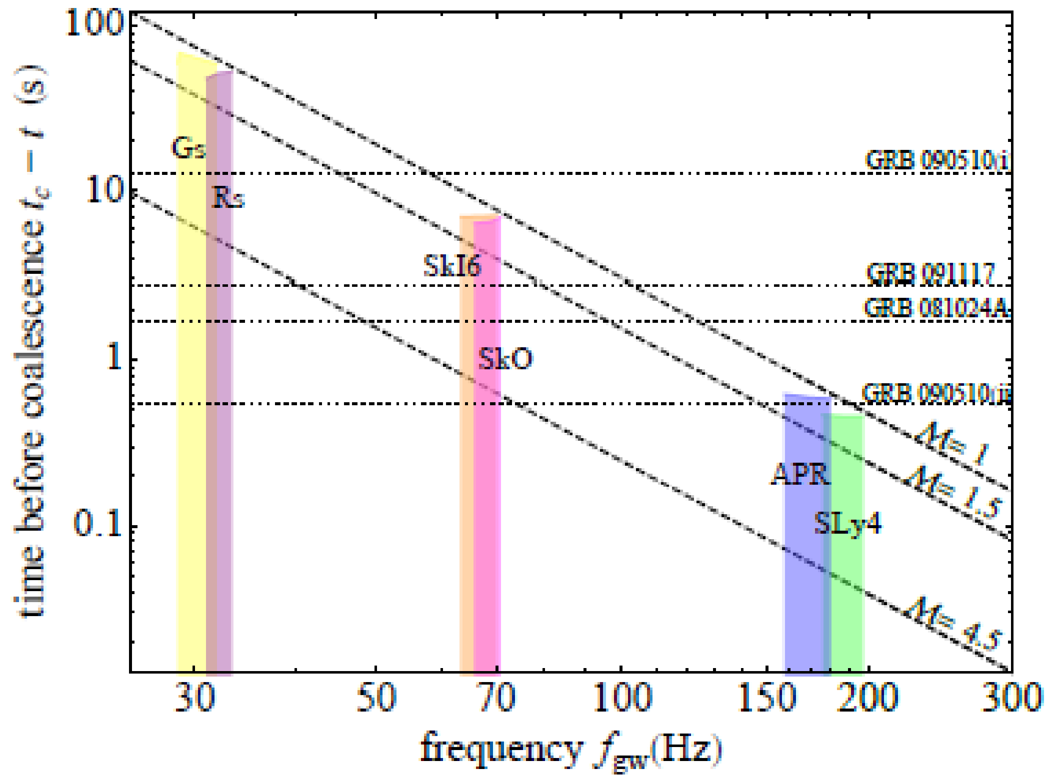
EOS	$f_{\rm mode}$ [Hz]	Q	$\Delta E_{\rm max}$ [erg]	E_b [erg]	$E_{\rm tidal}$ [erg/s]
SLy4	188	0.041	5×10^{50}	5×10^{46}	1×10^{50}
APR	170	0.061	1×10^{51}	2×10^{46}	9×10^{49}
SkI6	67.3	0.017	8×10^{49}	3×10^{45}	1×10^{48}
SkO	69.1	0.053	7×10^{50}	1×10^{46}	1×10^{49}
Rs	32.0	0.059	7×10^{50}	1×10^{46}	3×10^{48}
Gs	28.8	0.060	8×10^{50}	1×10^{46}	3×10^{48}

TABLE I: Resonant mode properties for the $l = 2$ i-mode. The background star is taken to be a 1.4 $M_\odot$ NS, with various equations of state given in [15]. The crust/core transition baryon density is fixed to be $n_t = 0.065\,{\rm fm}^{-3}$ for each model.

$t_{res} \sim 0.1$ sec $\rightarrow$ $\Delta E_{tidal} >> E_{fracture}$

Resonant frequency depends on EOS

Investigating NS Crust Equation of State



NS mass, f_{res} (from GW) and Precursor timing → NS EoS

Coherent Analysis of GBM Detectors
(L. Blackburn)

data

signal

$$\Lambda(d) = \frac{P(d|H_1)}{P(d|H_0)}$$

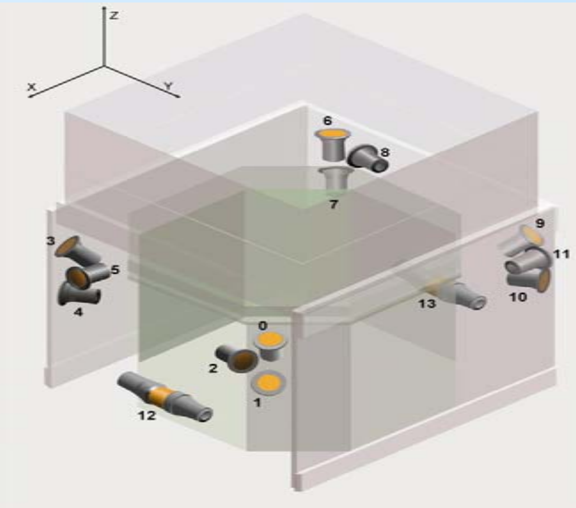
noise

Instrument response

source

$$P(d_i|H_1) = \prod_i \frac{1}{\sqrt{2\pi}\sigma_{d_i}} \exp\left(-\frac{(\tilde{d}_i - r_i s)^2}{2\sigma_{d_i}^2}\right)$$

$$P(d_i|H_0) = \prod_i \frac{1}{\sqrt{2\pi}\sigma_{n_i}} \exp\left(-\frac{\tilde{d}_i^{\,2}}{2\sigma_{n_i}^2}\right)$$



Evaluate Λ by marginalizing over source amplitude, position

r_i provided by GBM detector model (Connaughton, UAH)

Future work

- NS Resonant Excitation Model
  - Inclusion of damping
    - Core (bulk and shear viscosity)
    - Crust (shear viscosity)

- Tests of GBM coherent analysis
  - Does it raise SNR of precursors and marginal sGRBs

- Other potential Precursor mechanisms
  - NS Magnetosphere Interaction
  - Pre-ejected Neutrino-Driven Wind