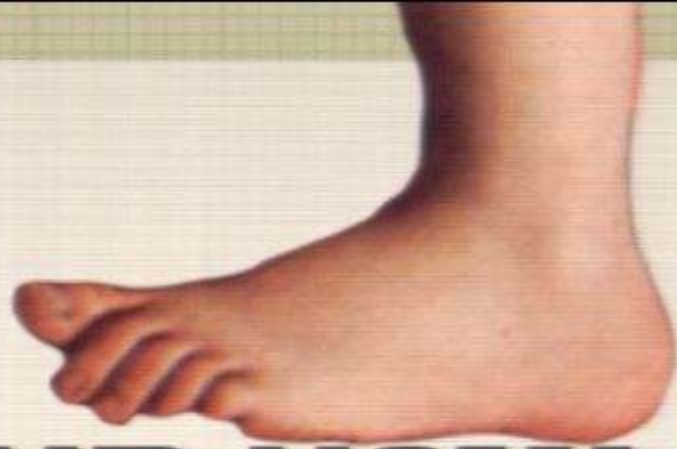


Title: Excitation of Neutron Star Modes During Binary

Date: Jun 20, 2011 04:50 PM

URL: <http://pirsa.org/11060018>

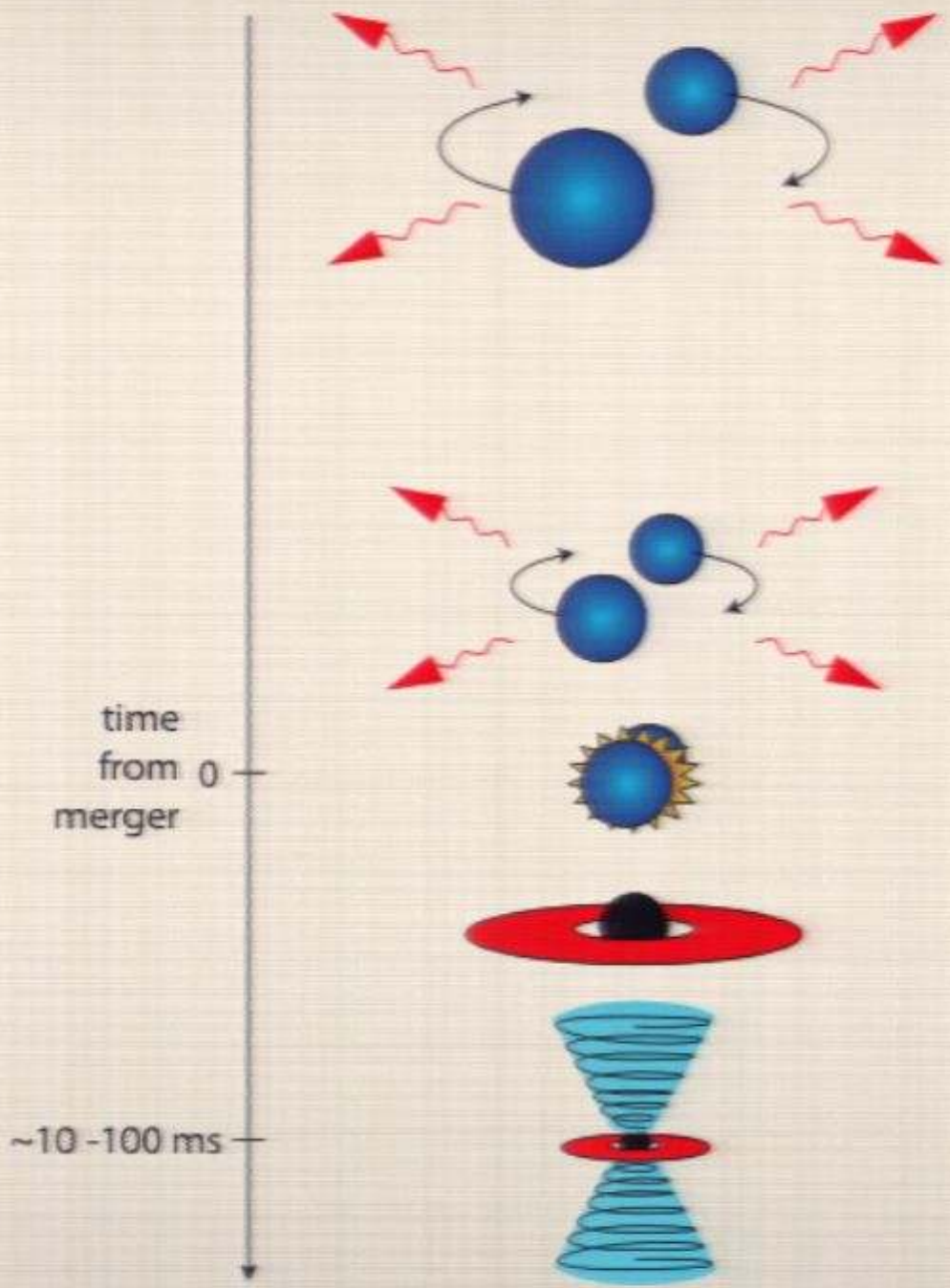
Abstract:



**AND NOW FOR
SOMETHING
COMPLETELY
~~DIFFERENT~~
ASTROPHYSICS**

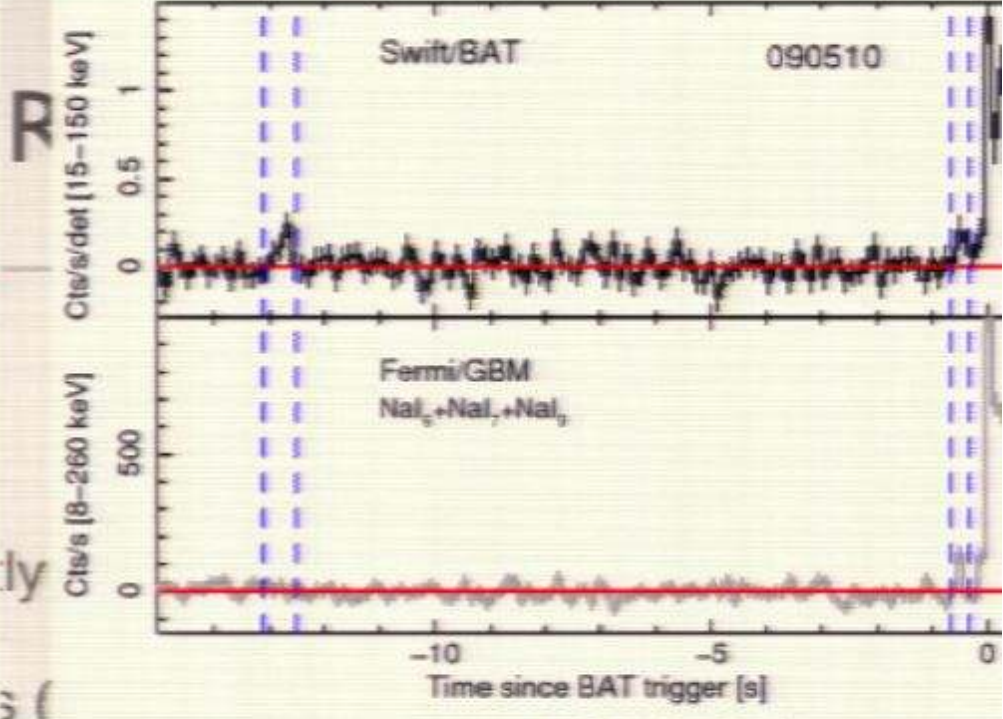
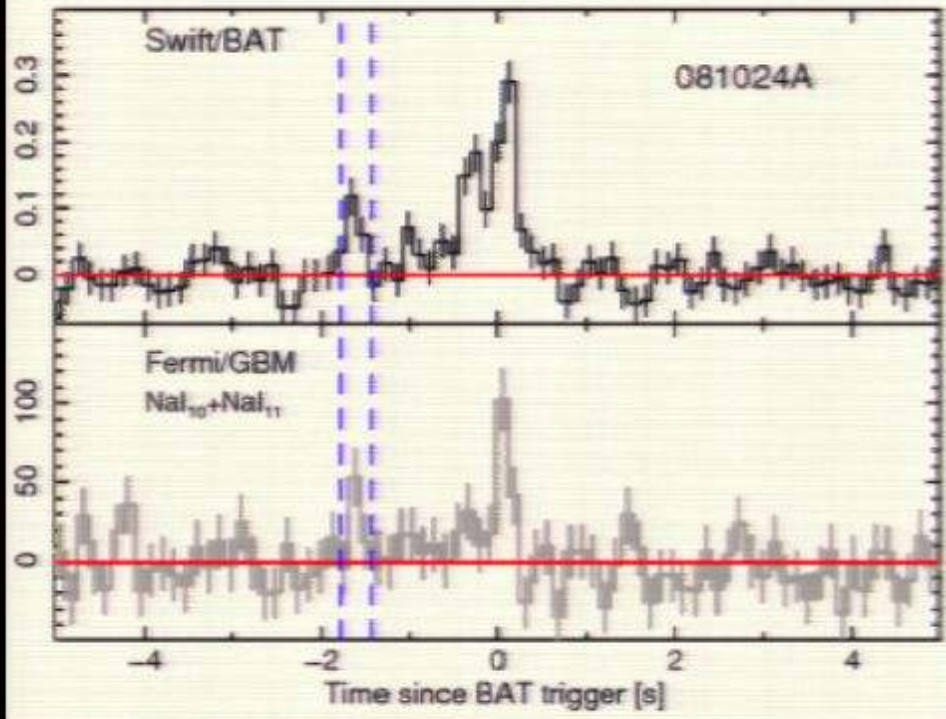
GAMMA RAY BURSTS

- GRBs - Most luminous Gamma Ray Sources
 - Long GRBs: $L \sim 10^{54}$ ergs, $T_{90} > 2s$
 - Collapse of Massive Star (?)
 - Short GRBs: $L \sim 10^{50}$ ergs, $T_{90} < 2s$
 - NS-NS or NS-BH merger (?)
- Swift/BAT, Fermi/GBM, Suzaku



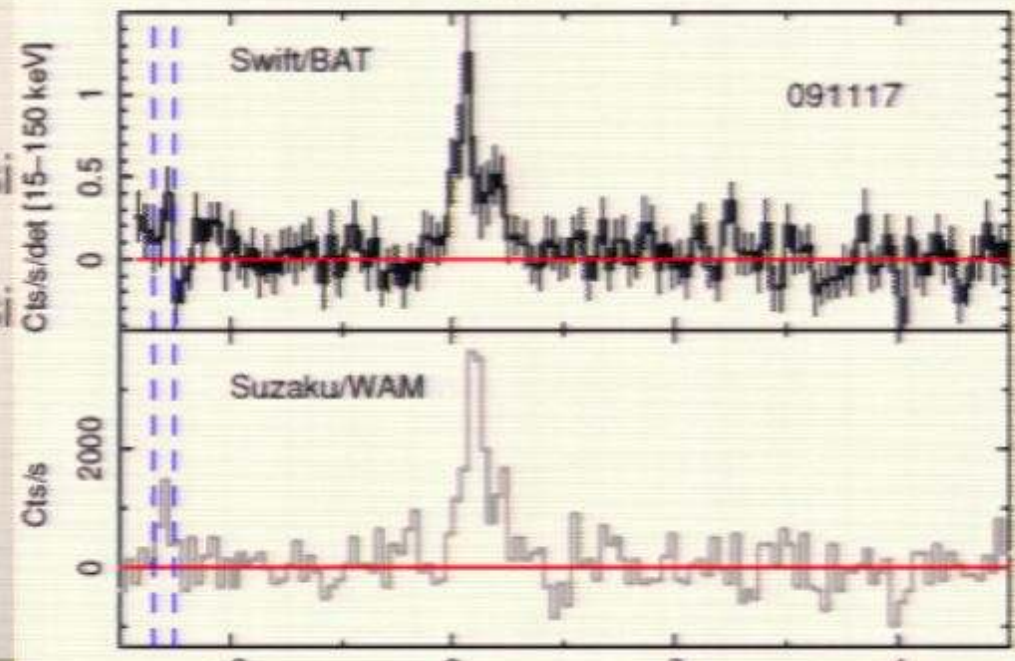
GAMMA RAY BURST PRECURSORS

- Precursors observed mostly for long GRBs
- A few examples for sGRBs (Abdo et al, 2009; Troja et al., 2010)
 - 5σ significant precursors $\sim 1-10$ s before main burst
 - 2σ significant precursors ~ 100 s before main burst



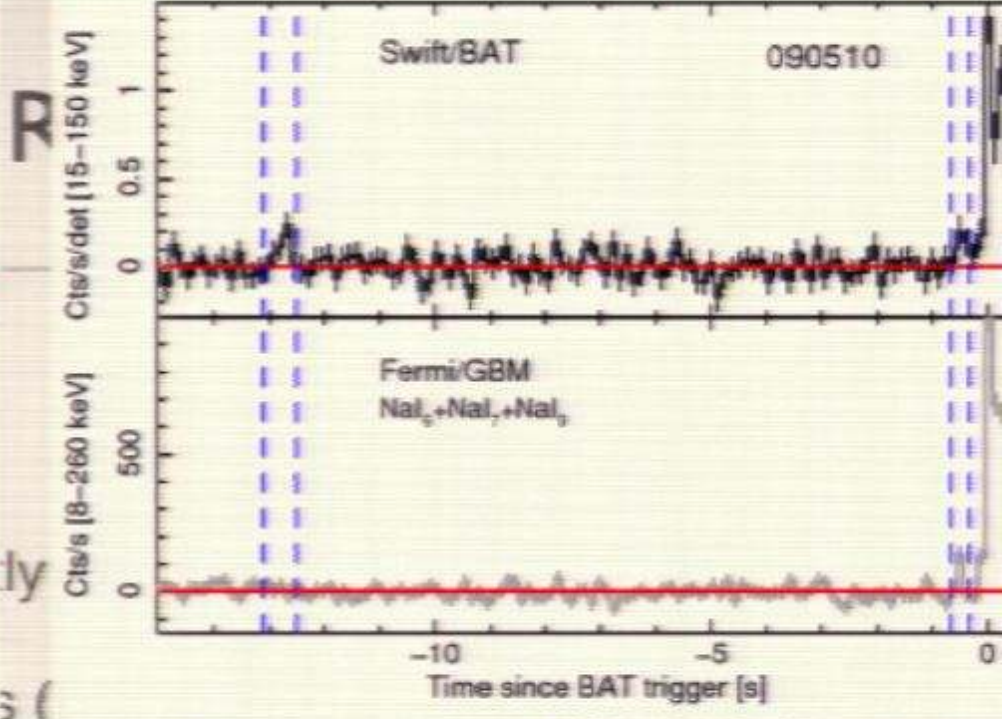
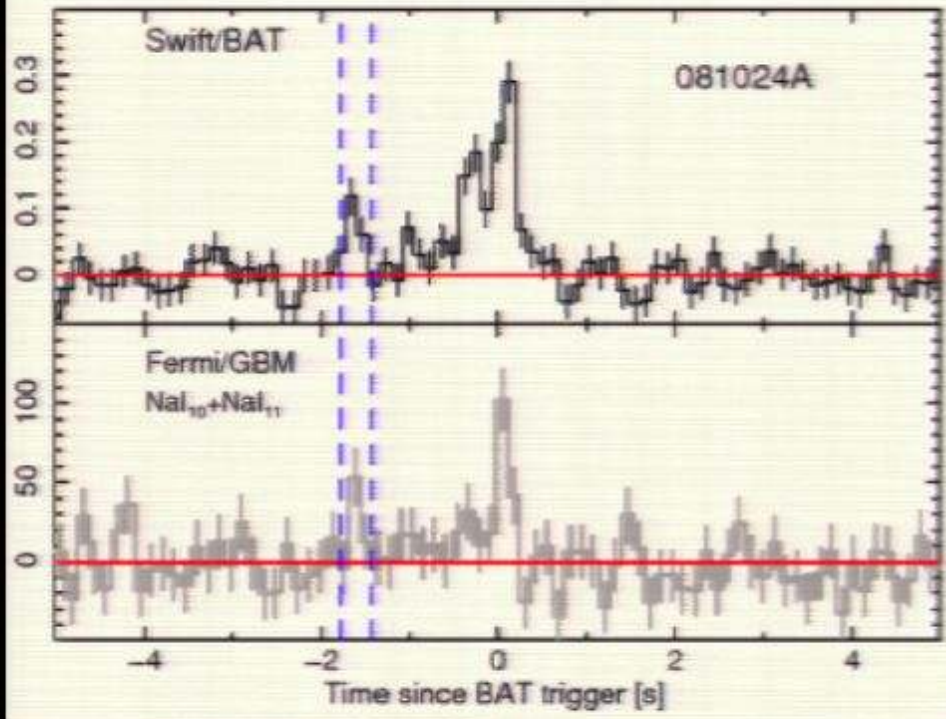
2010)

- 5 σ Si
- 2 σ Si



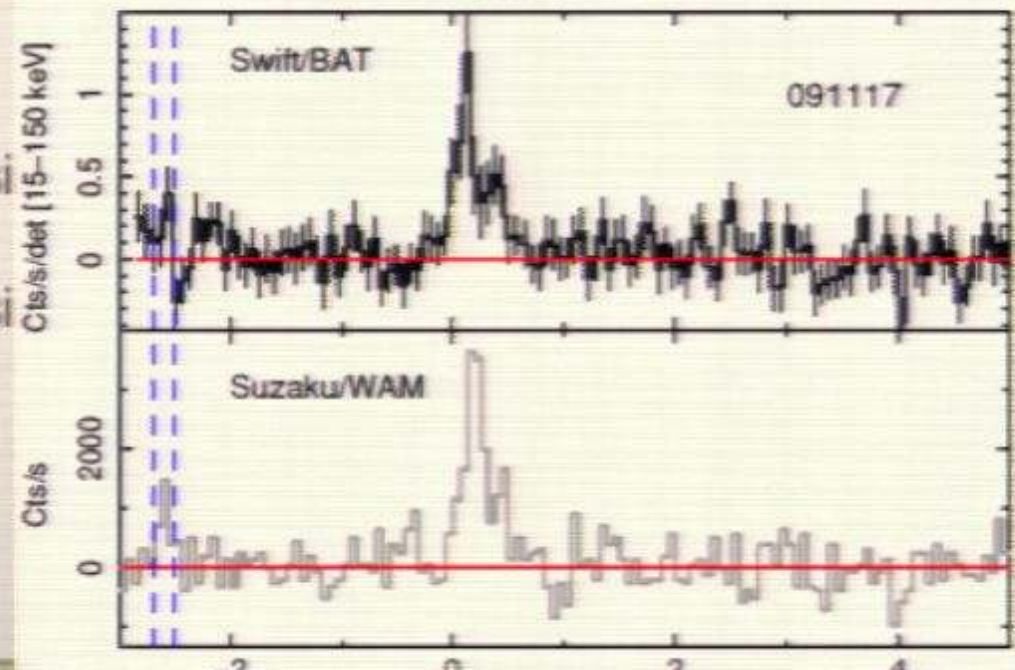
n burst

1 burst



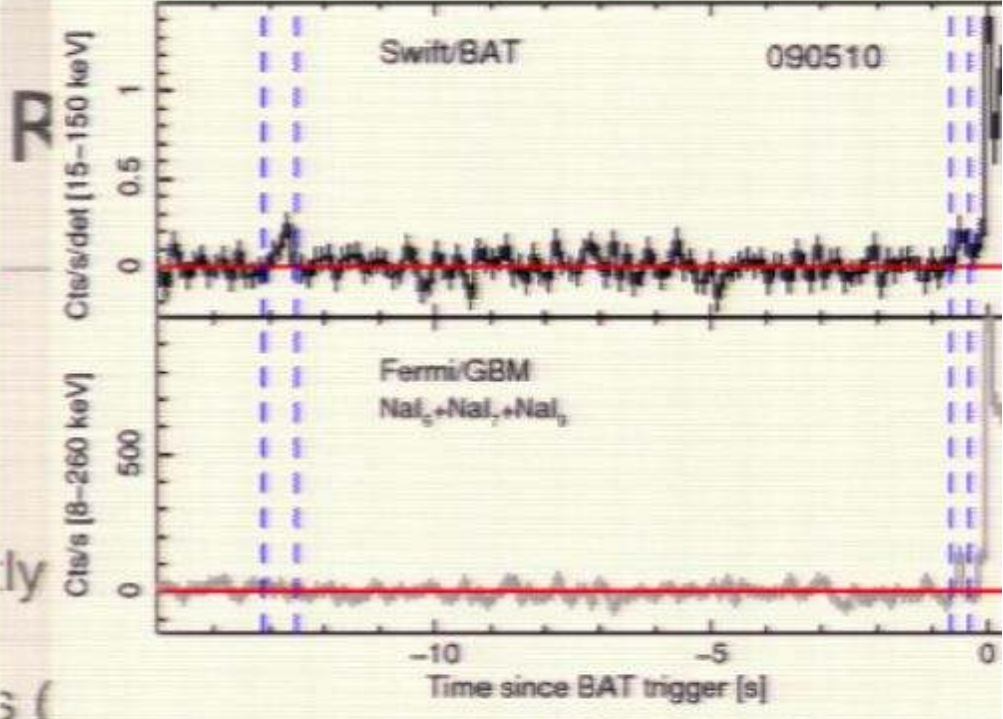
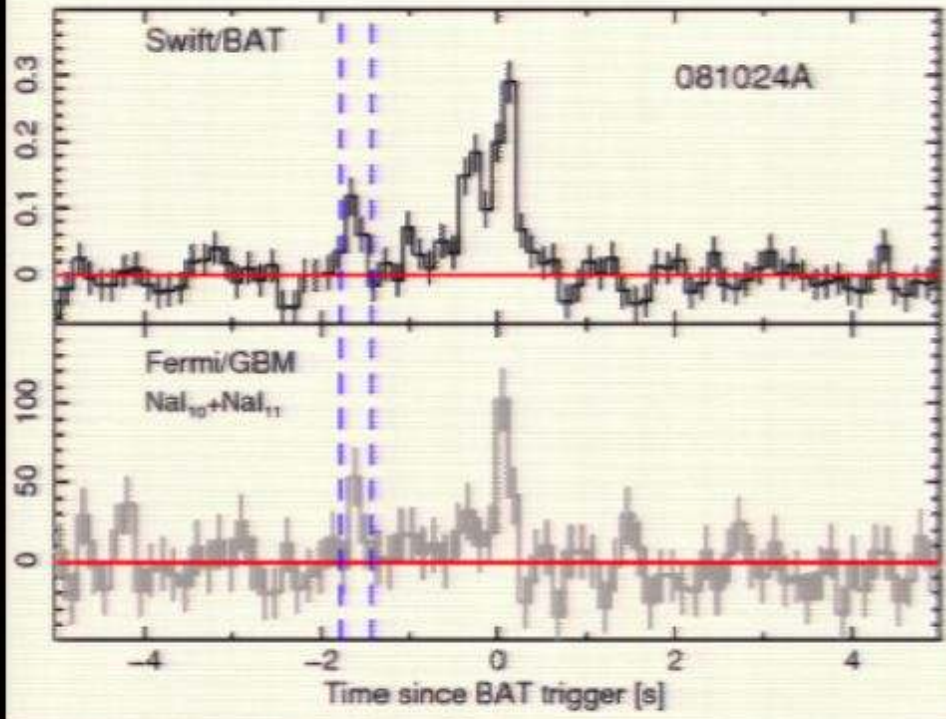
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n burst

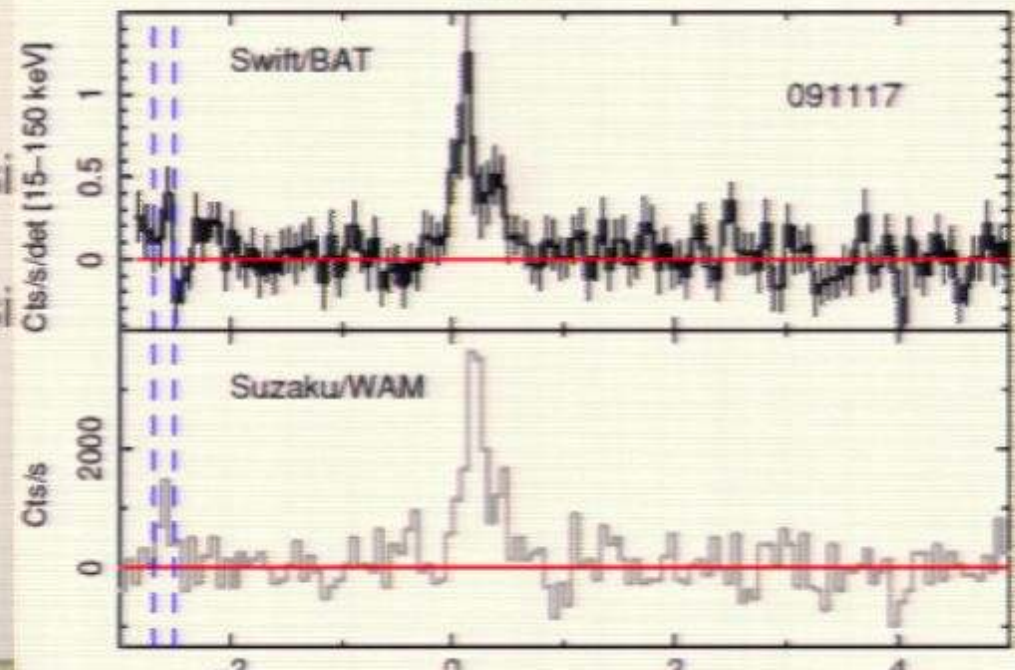
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2010)

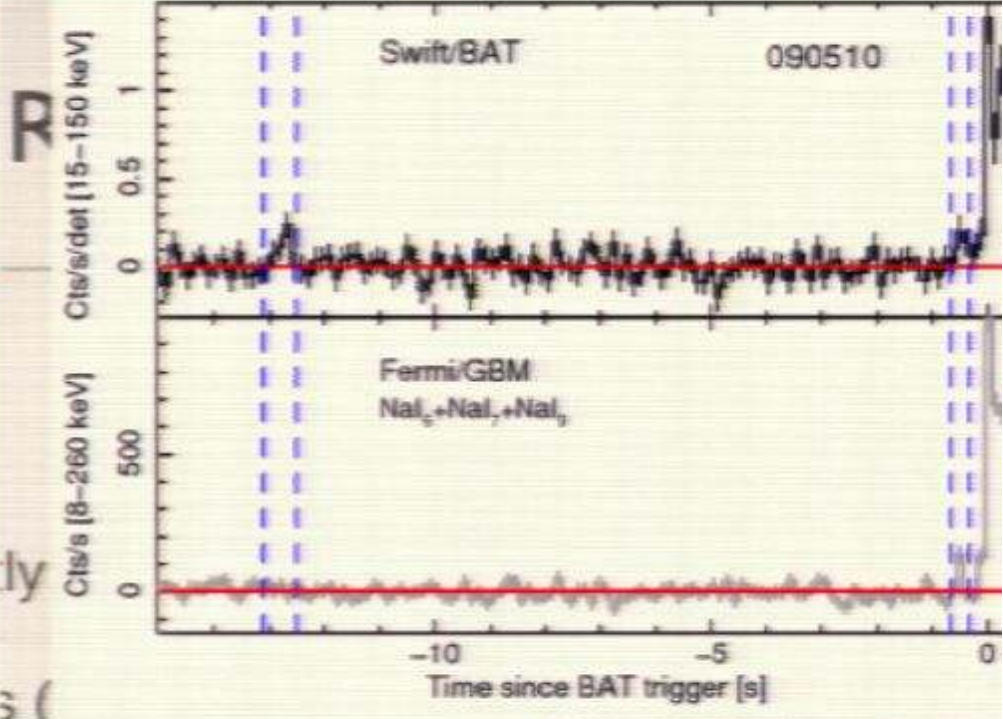
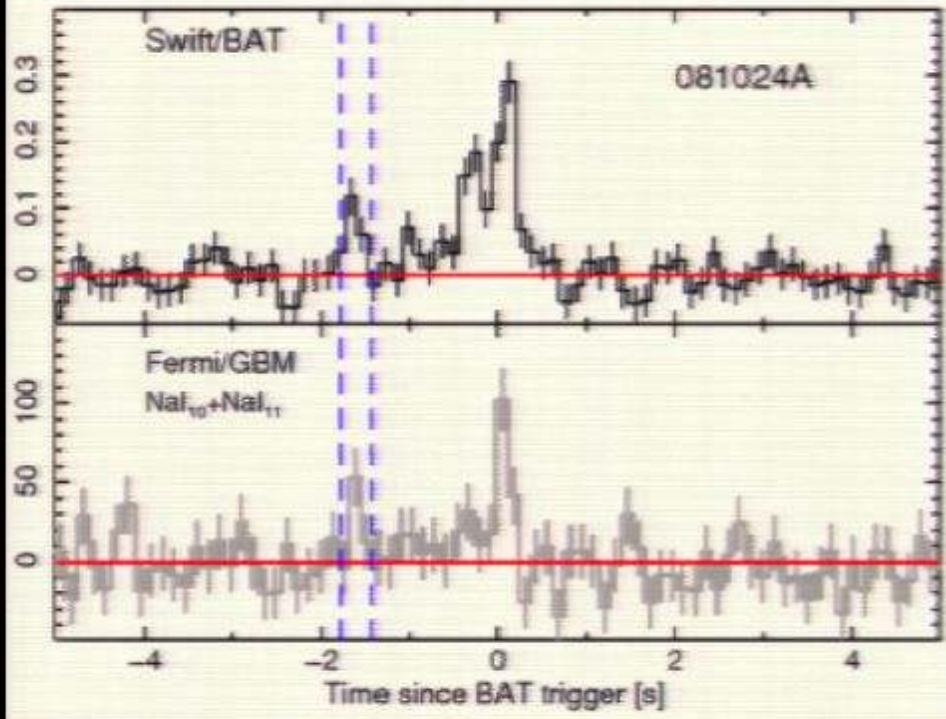
□ 5 σ Si

□ 2 σ Si



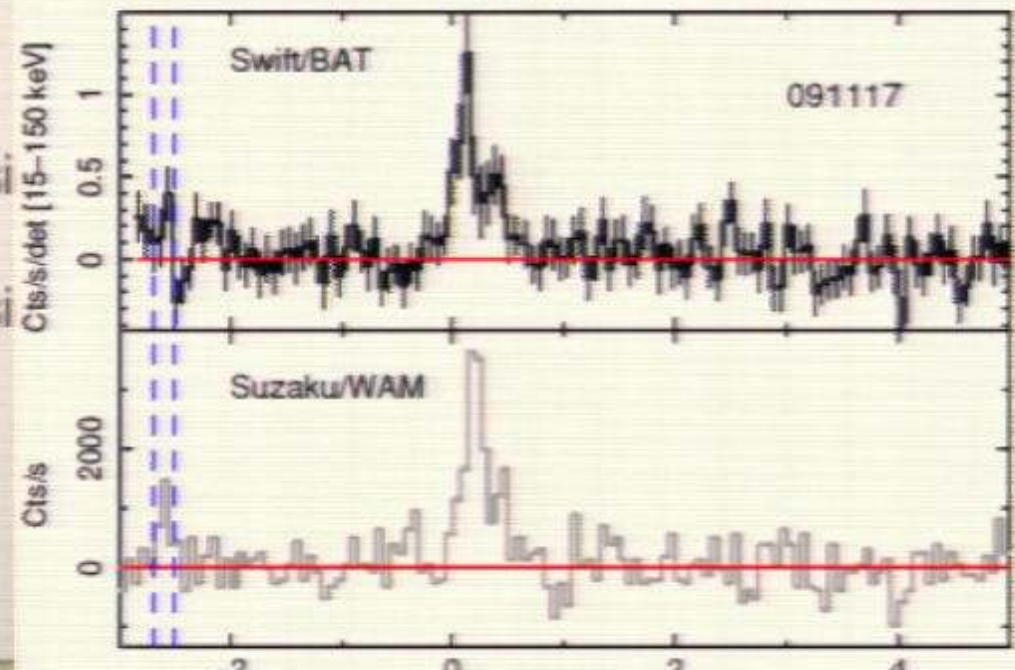
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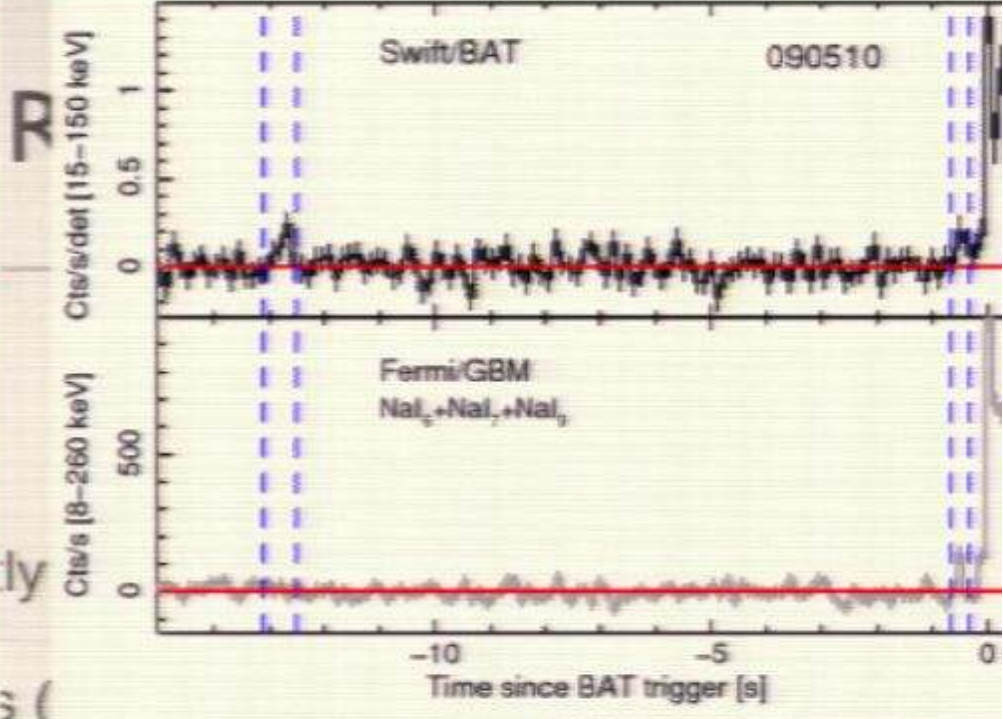
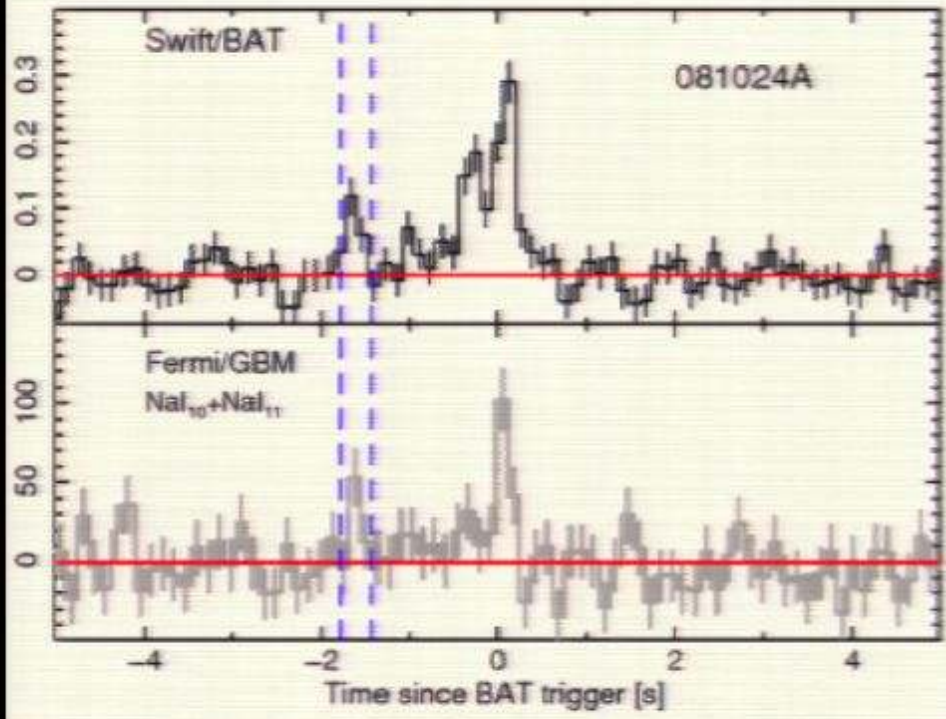
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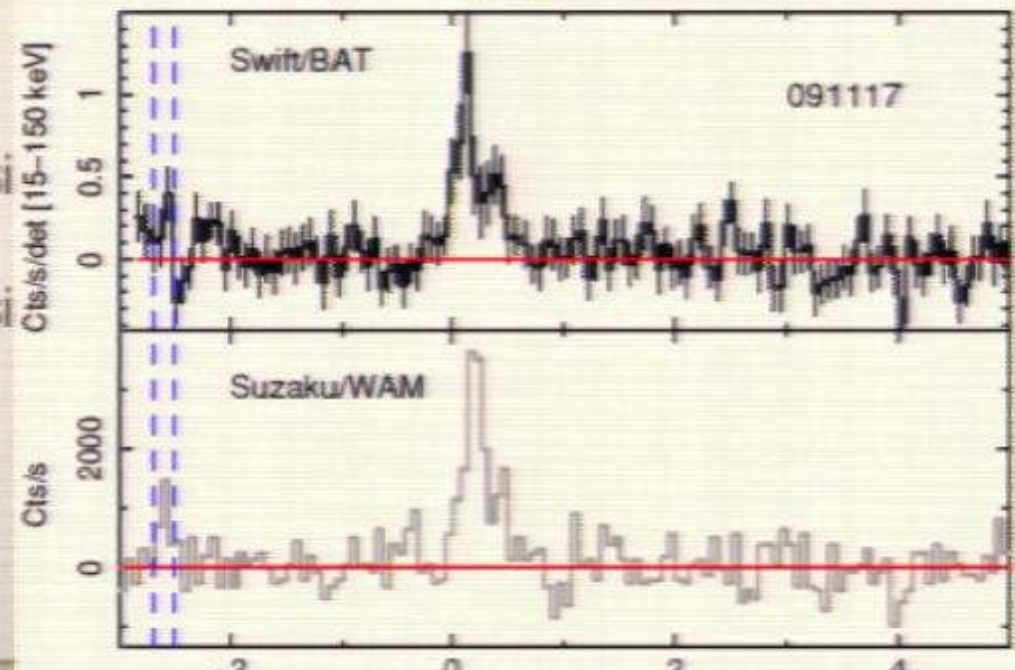
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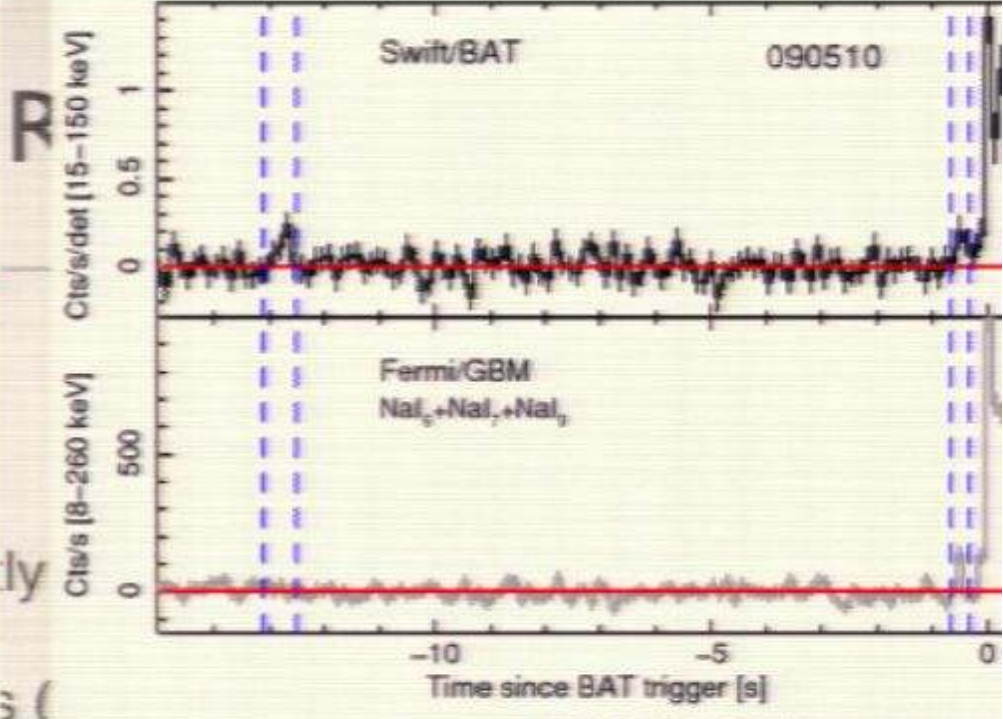
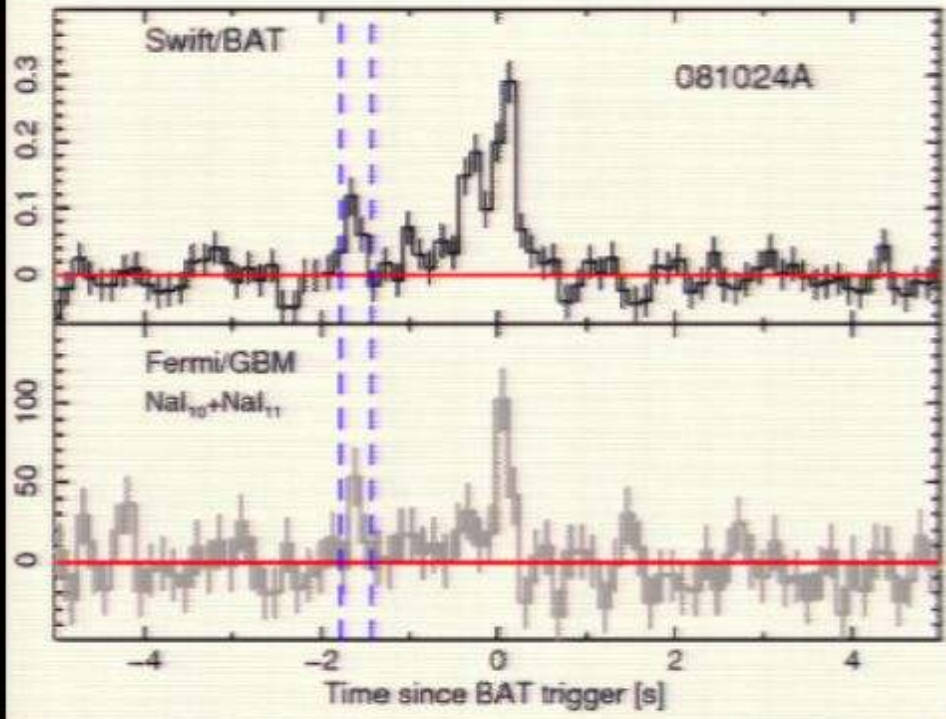
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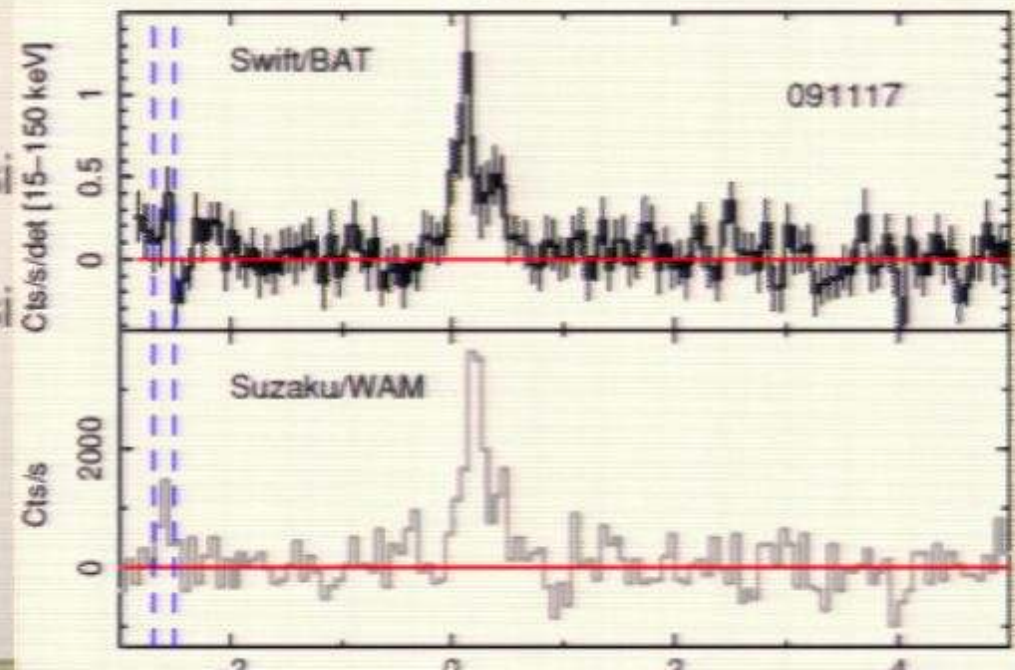
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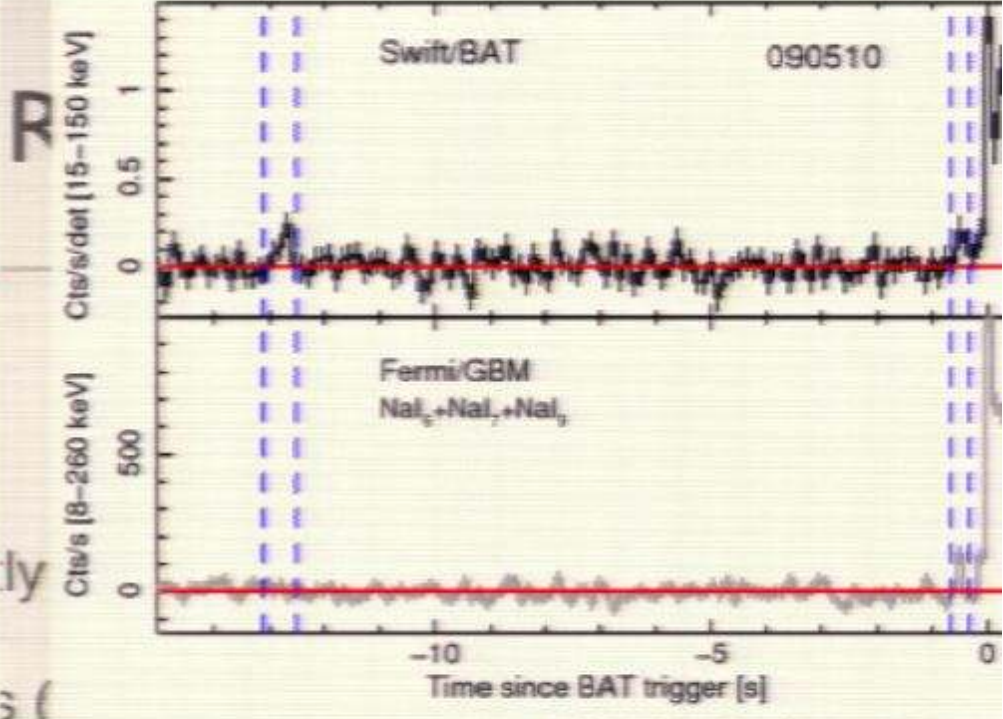
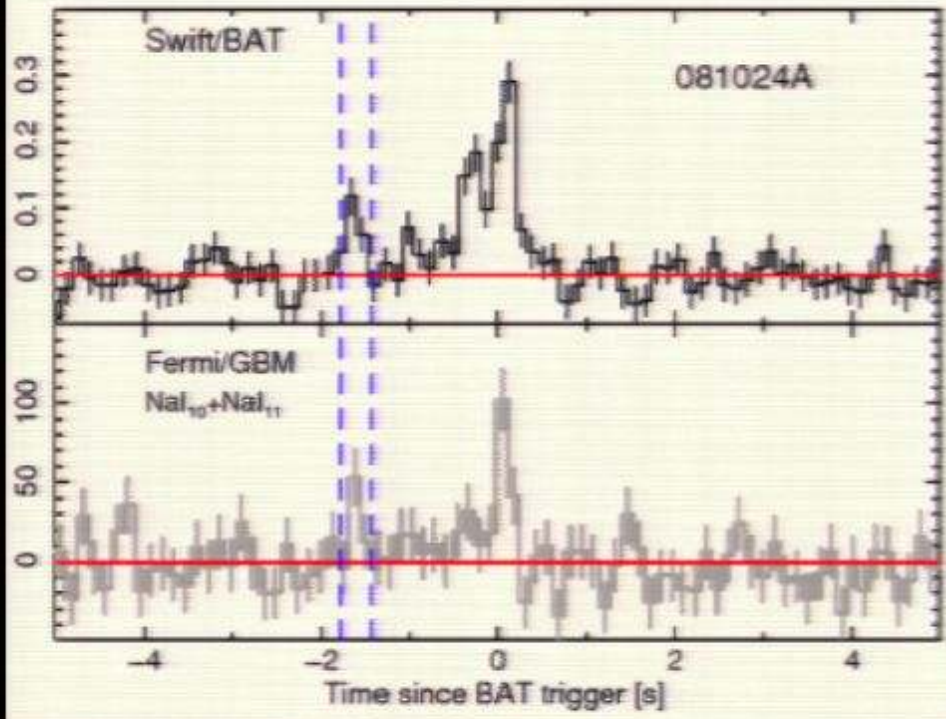
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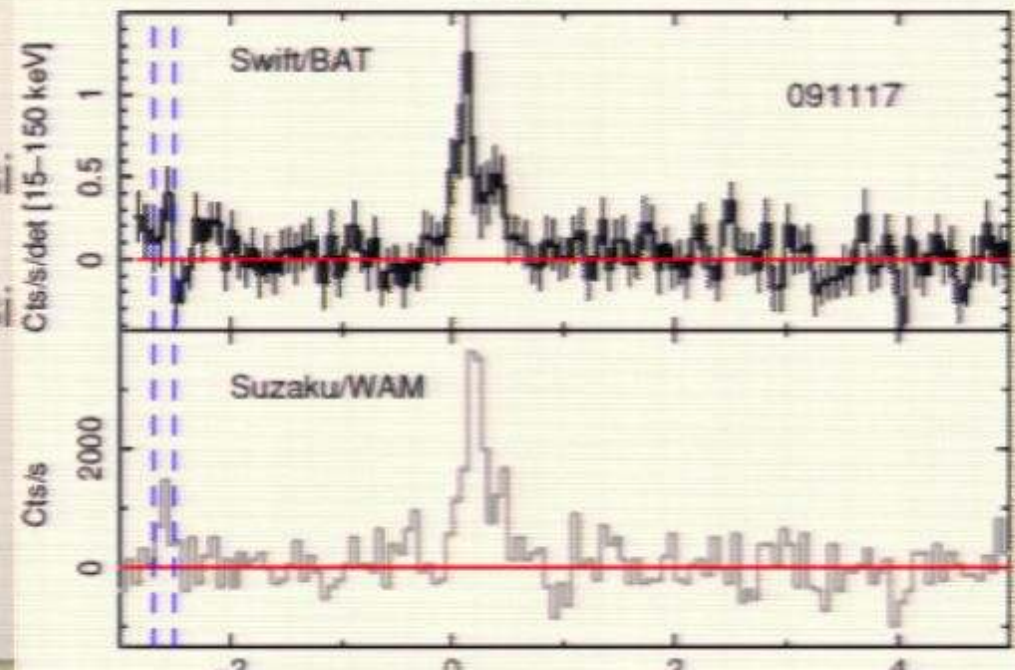
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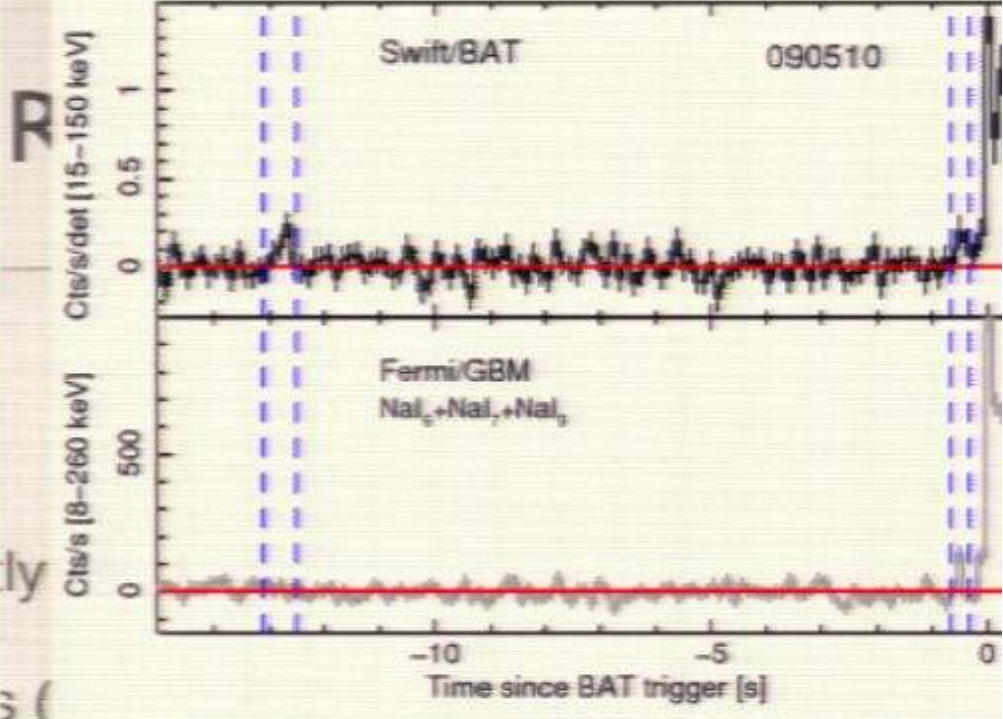
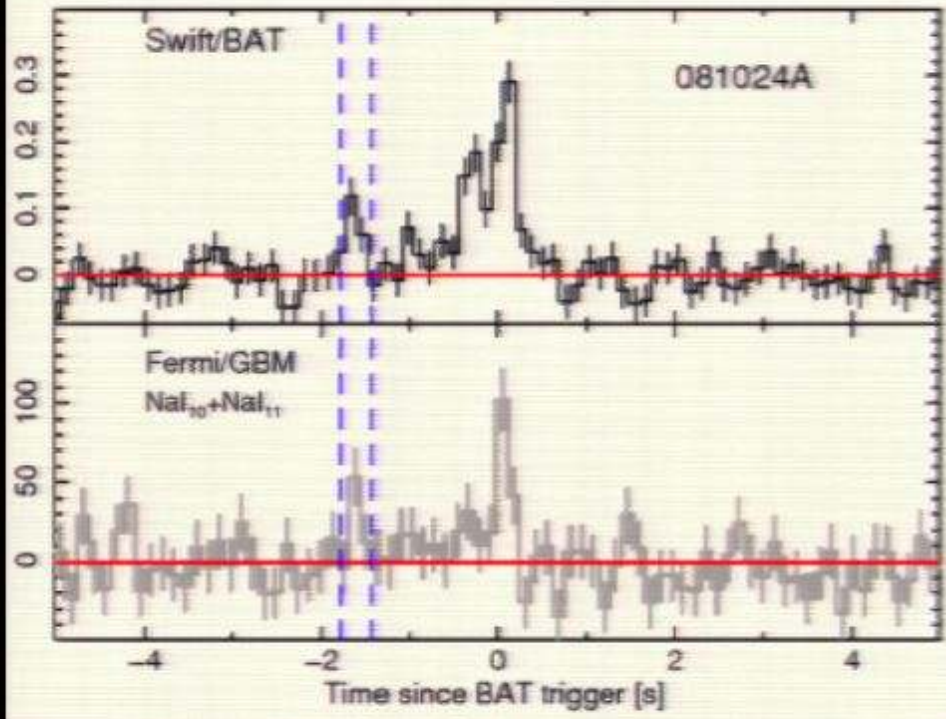
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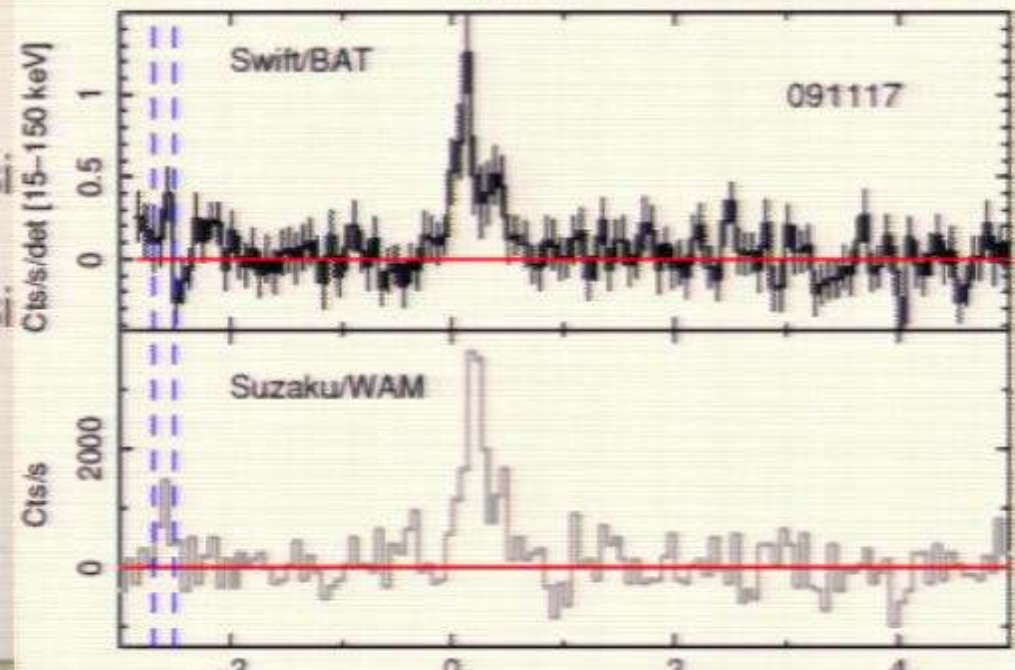
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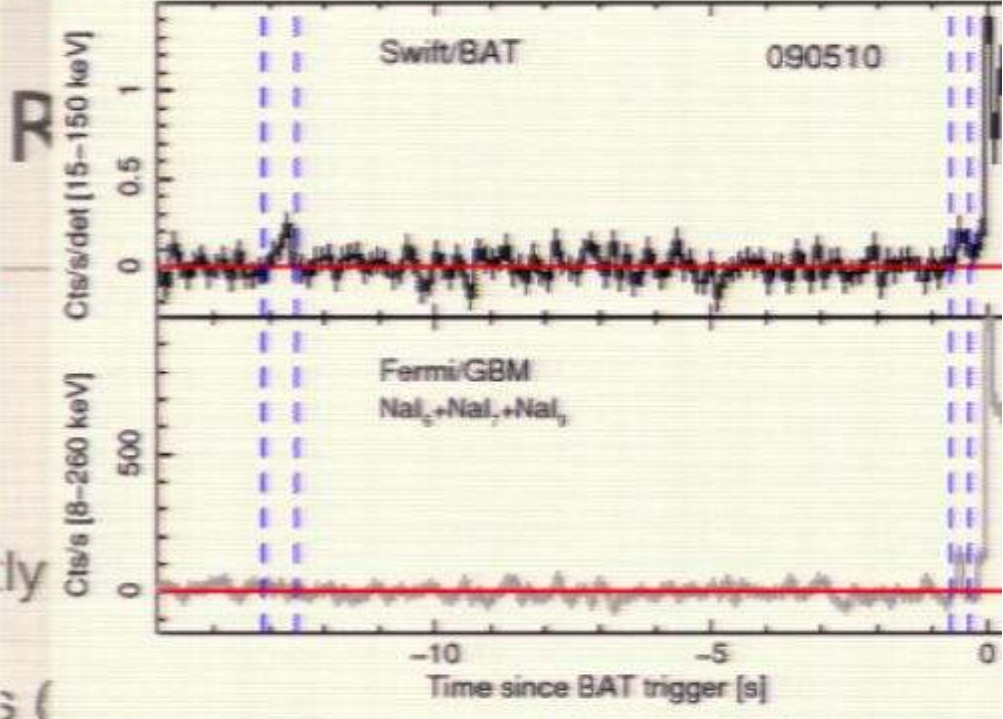
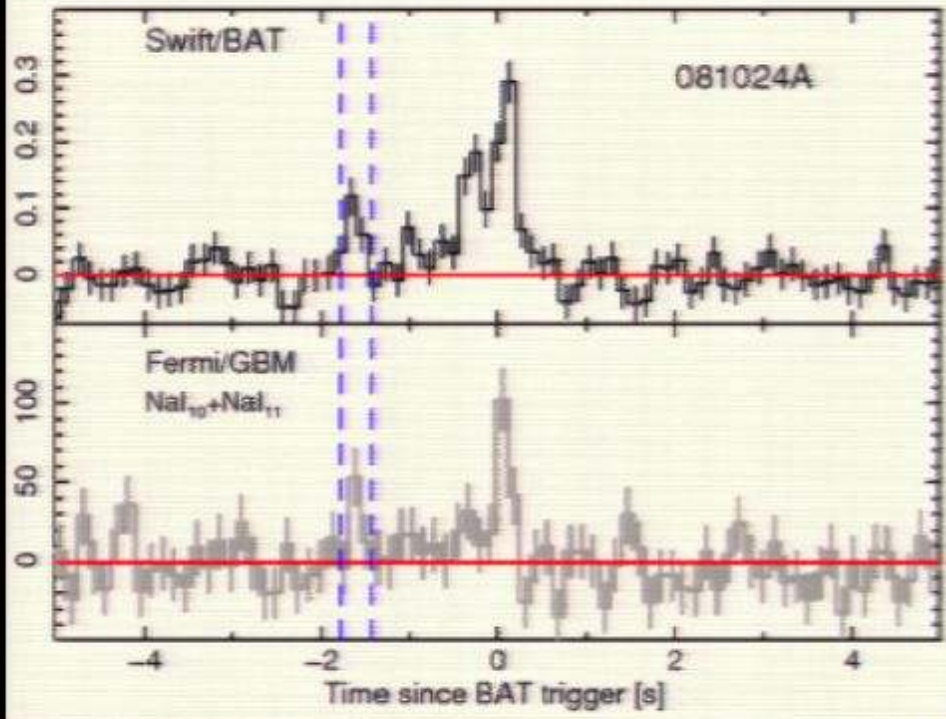
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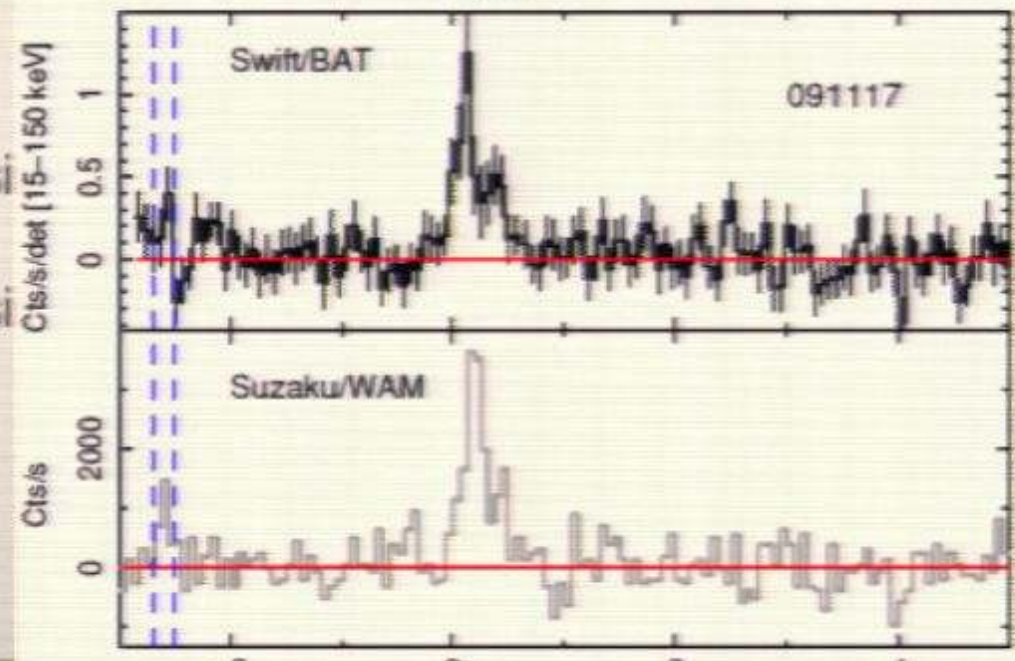
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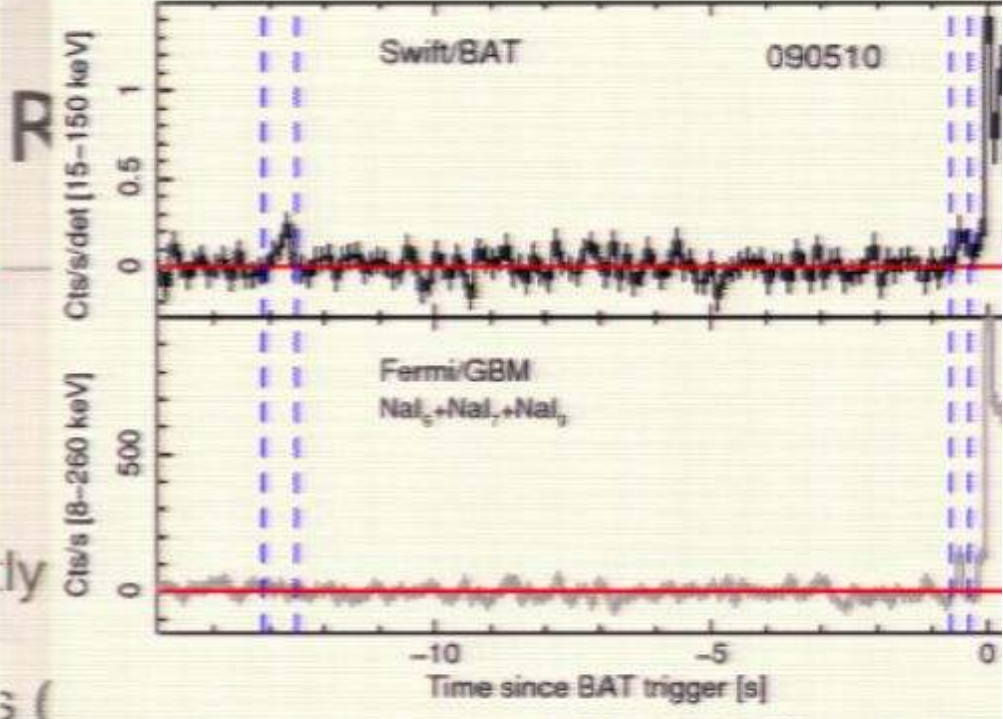
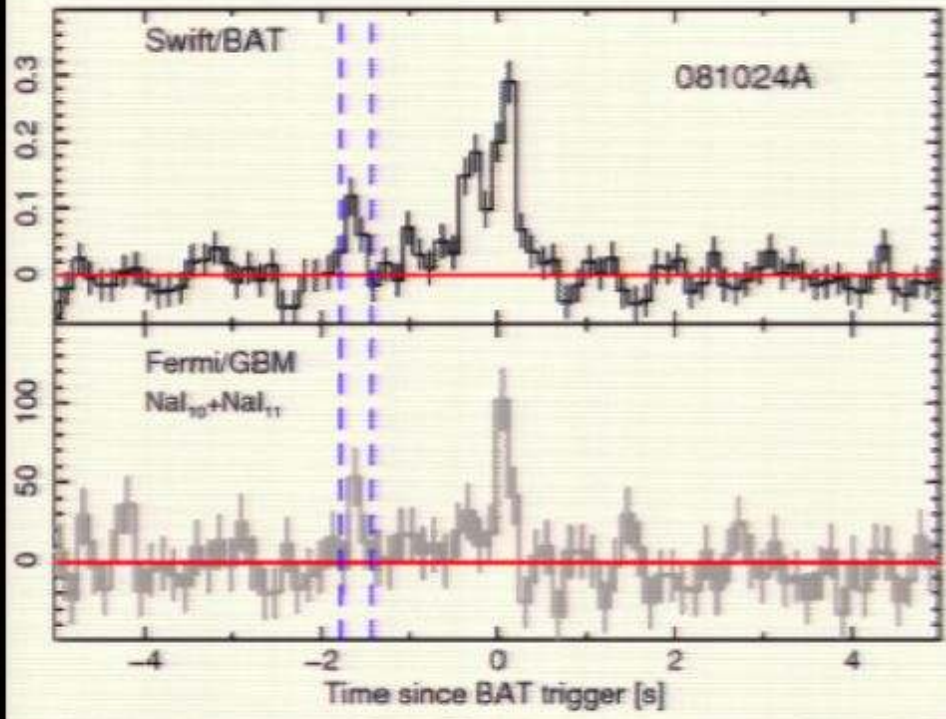
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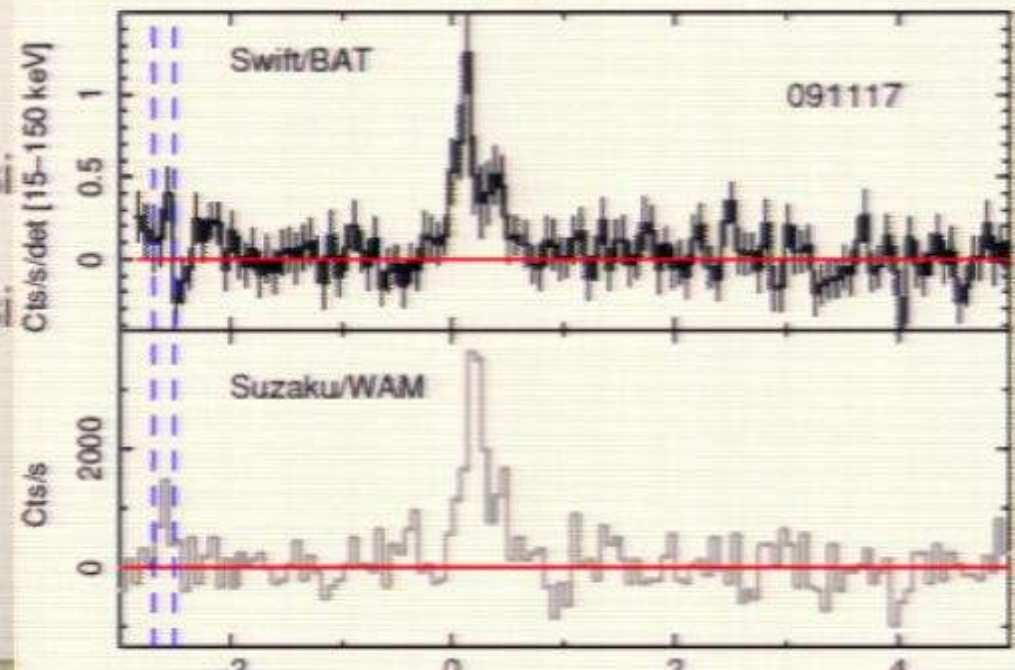
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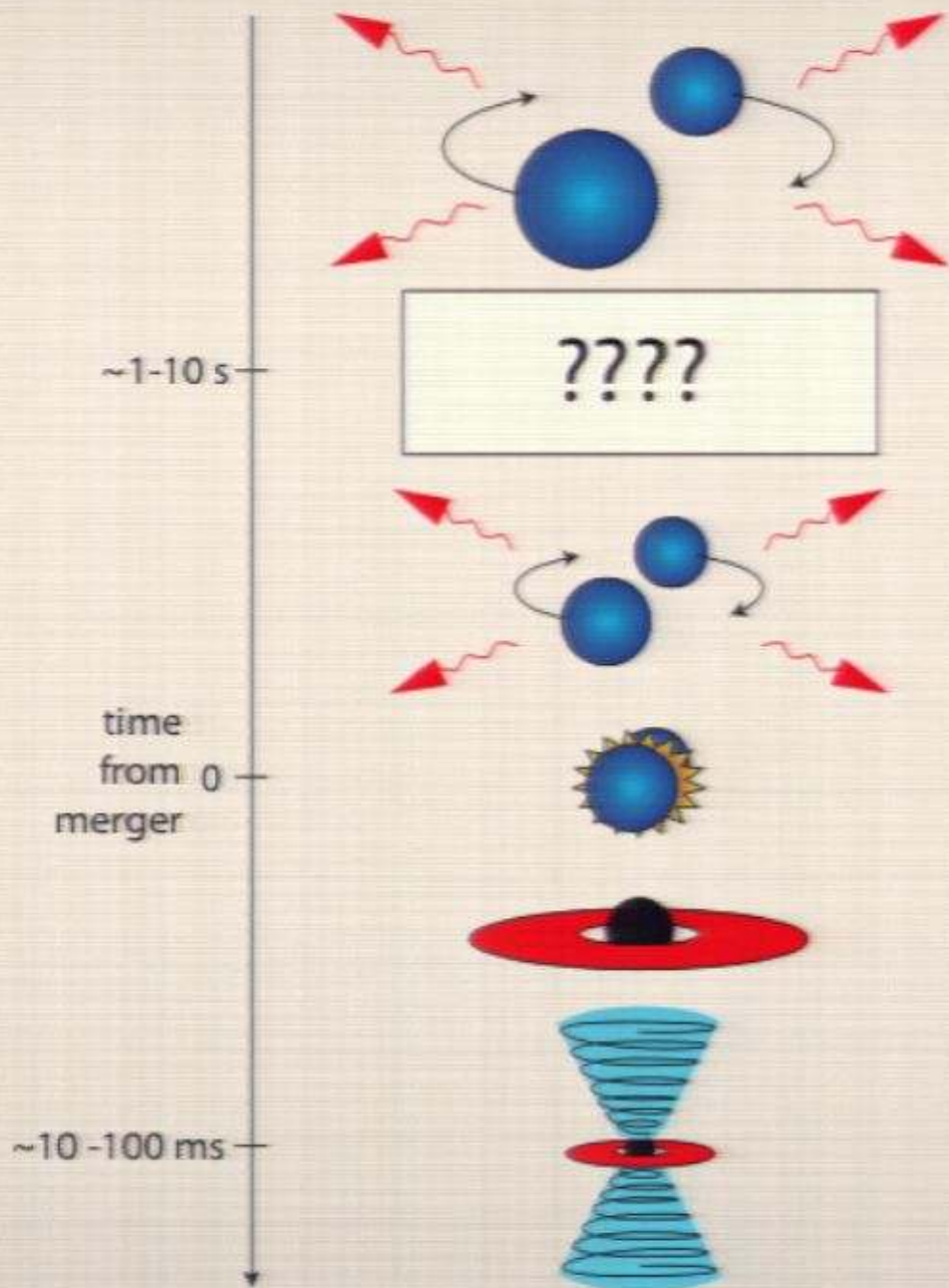
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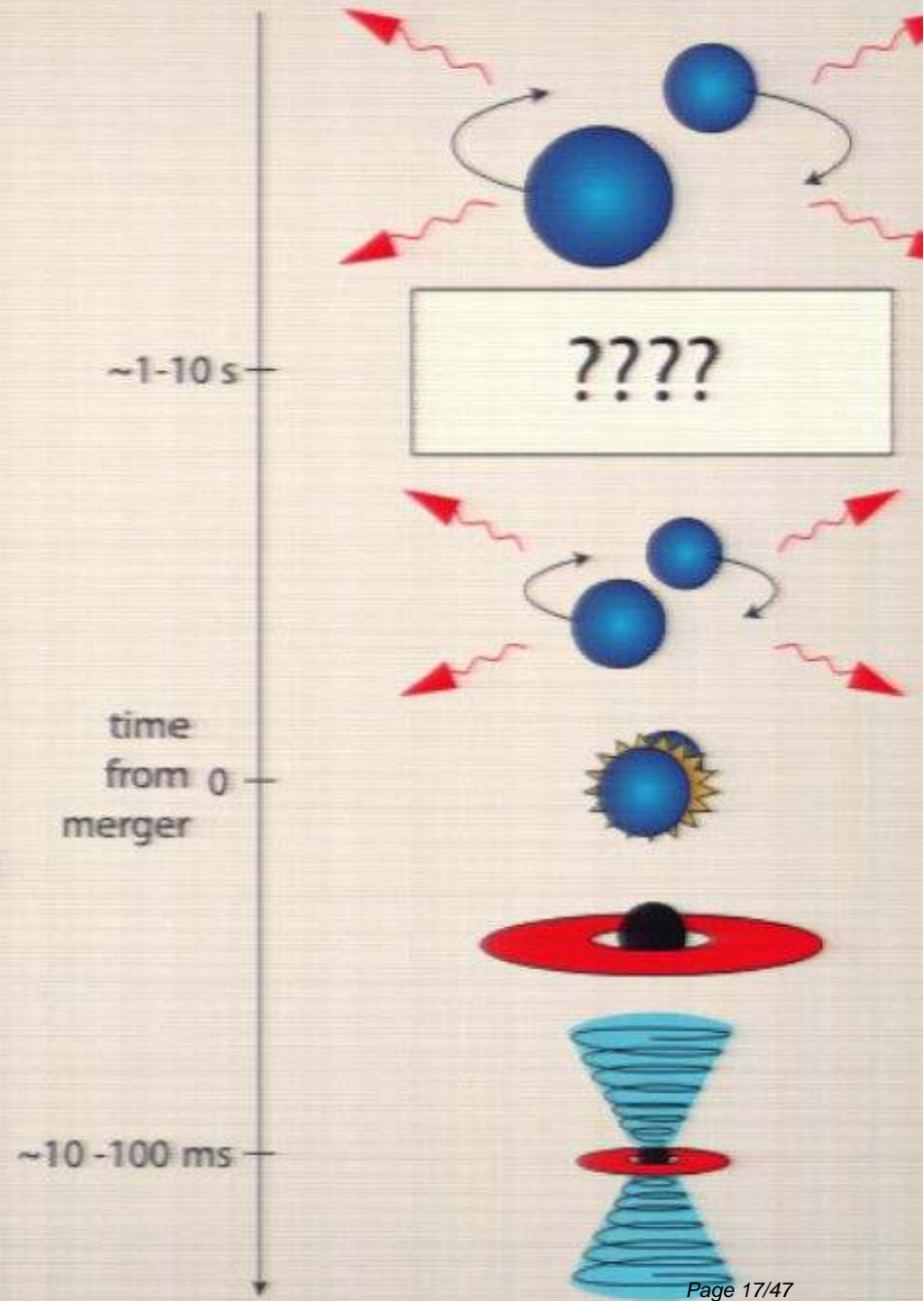


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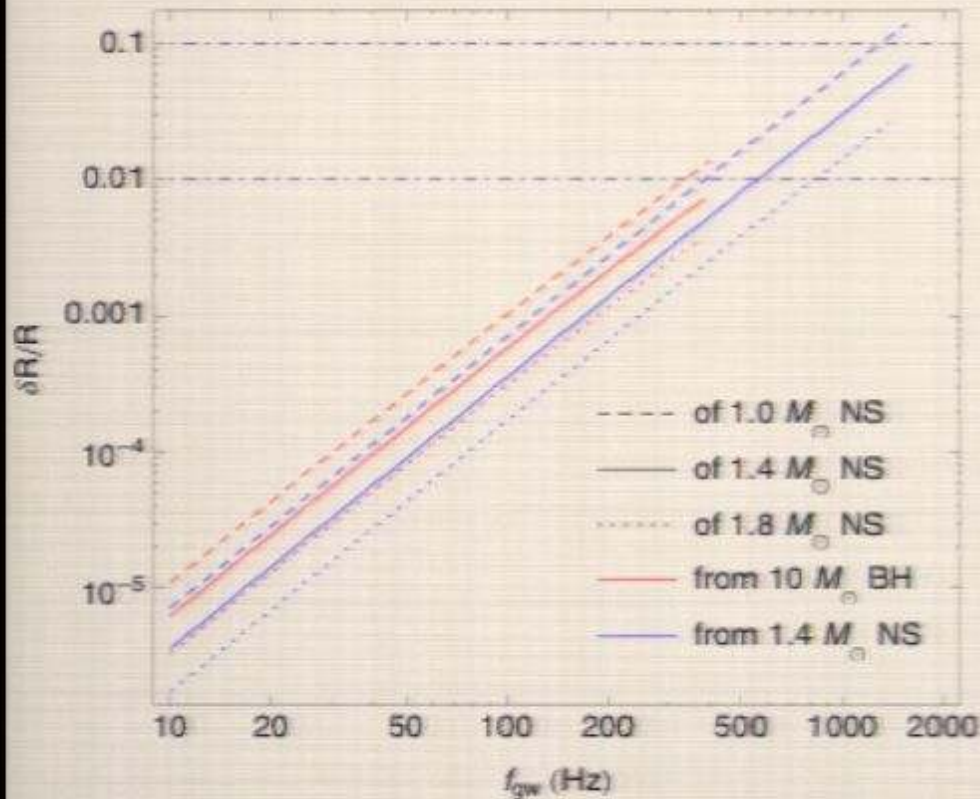


- Precursor Mechanism ????
- Magnetospheric Interaction
 - $B > 10^{15}$ G required
- Early Jet activity
 - Unlikely based on the timing
- What about Crust Cracking?

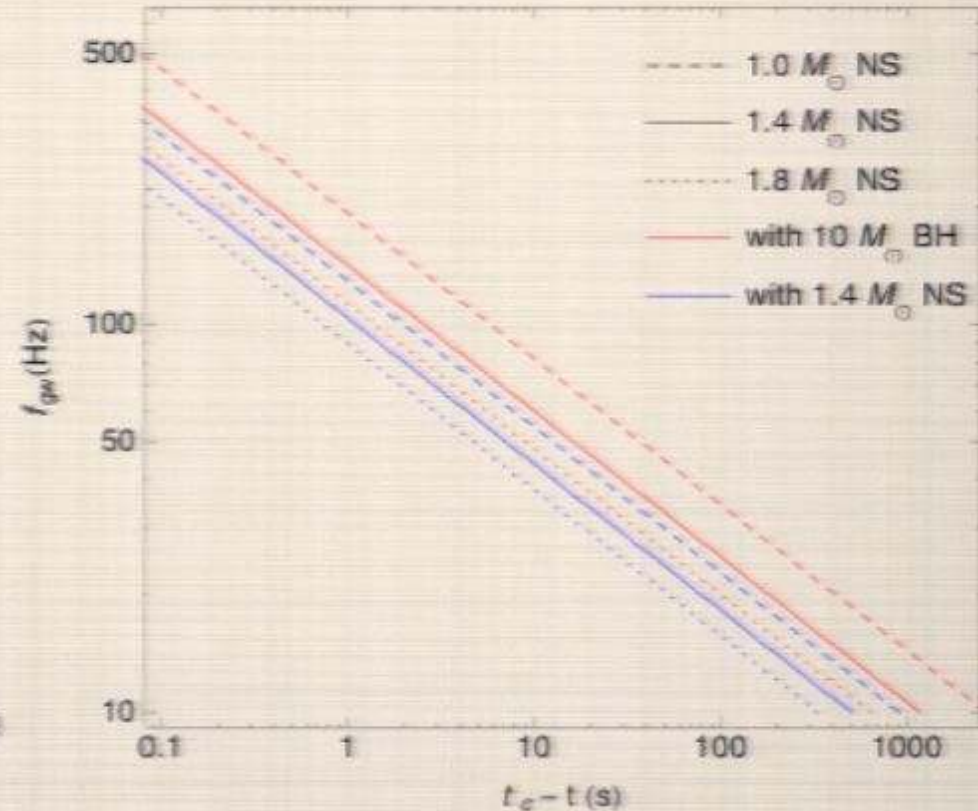


Tidal Crust Cracking

Surface deformation in inspiral



Frequency at time before merger

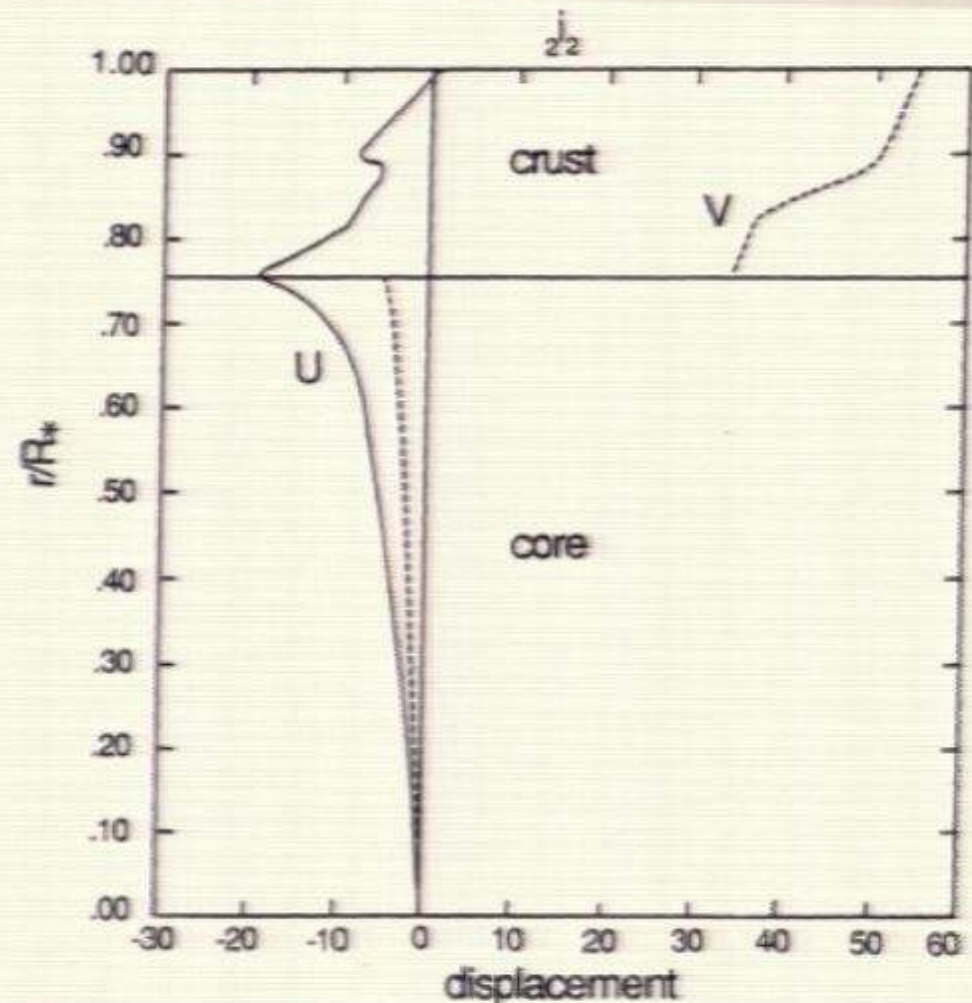


For tidal crust cracking we need $\delta R/R \simeq \epsilon_{\text{break}} \sim 0.1$

Direct crust cracking doesn't happen until just before merger.

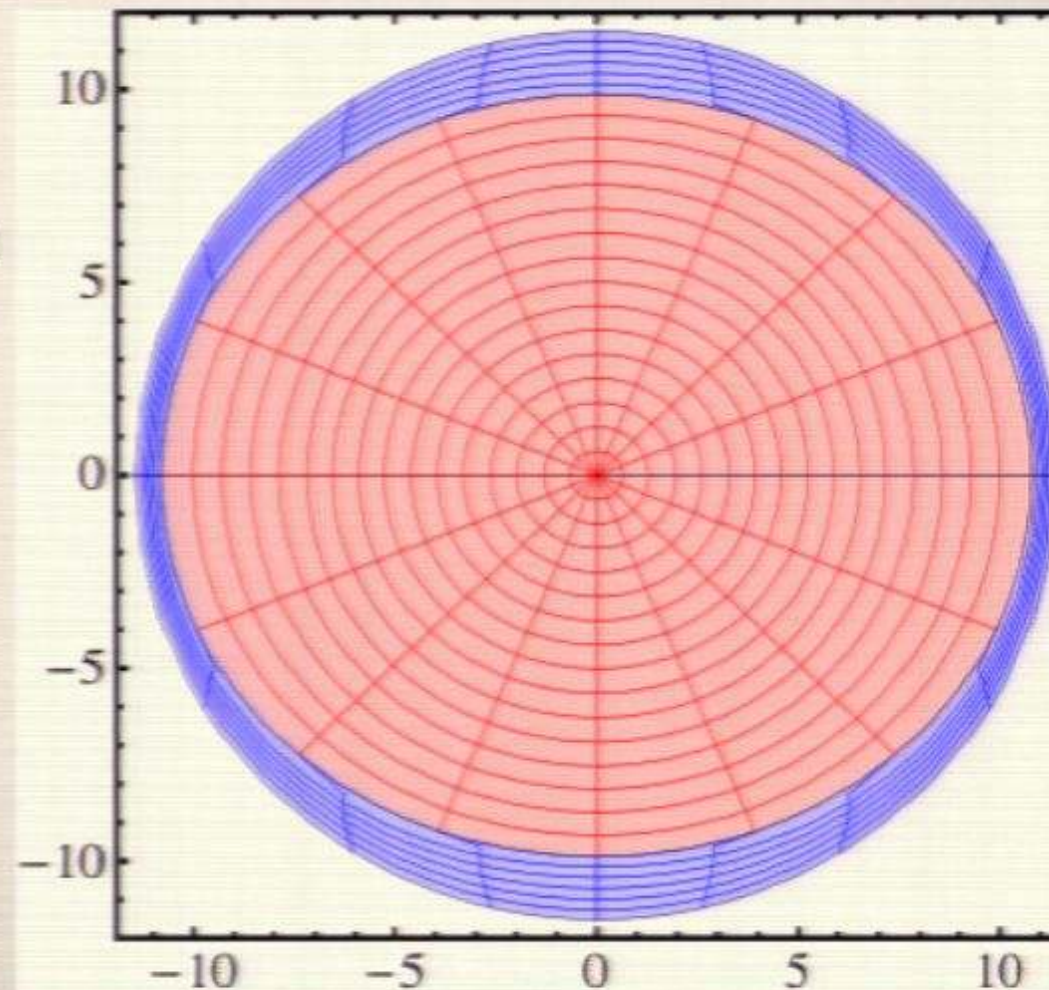
Resonant Tidal Interaction

- Neutron Stars have Normal Modes
- Tidal Resonance has been explored for g-modes and f-modes
- Including crust changes modes
- i-mode ~ 100 Hz
 - $l = 2$, crust/core interface mode
- Peaks at base of crust



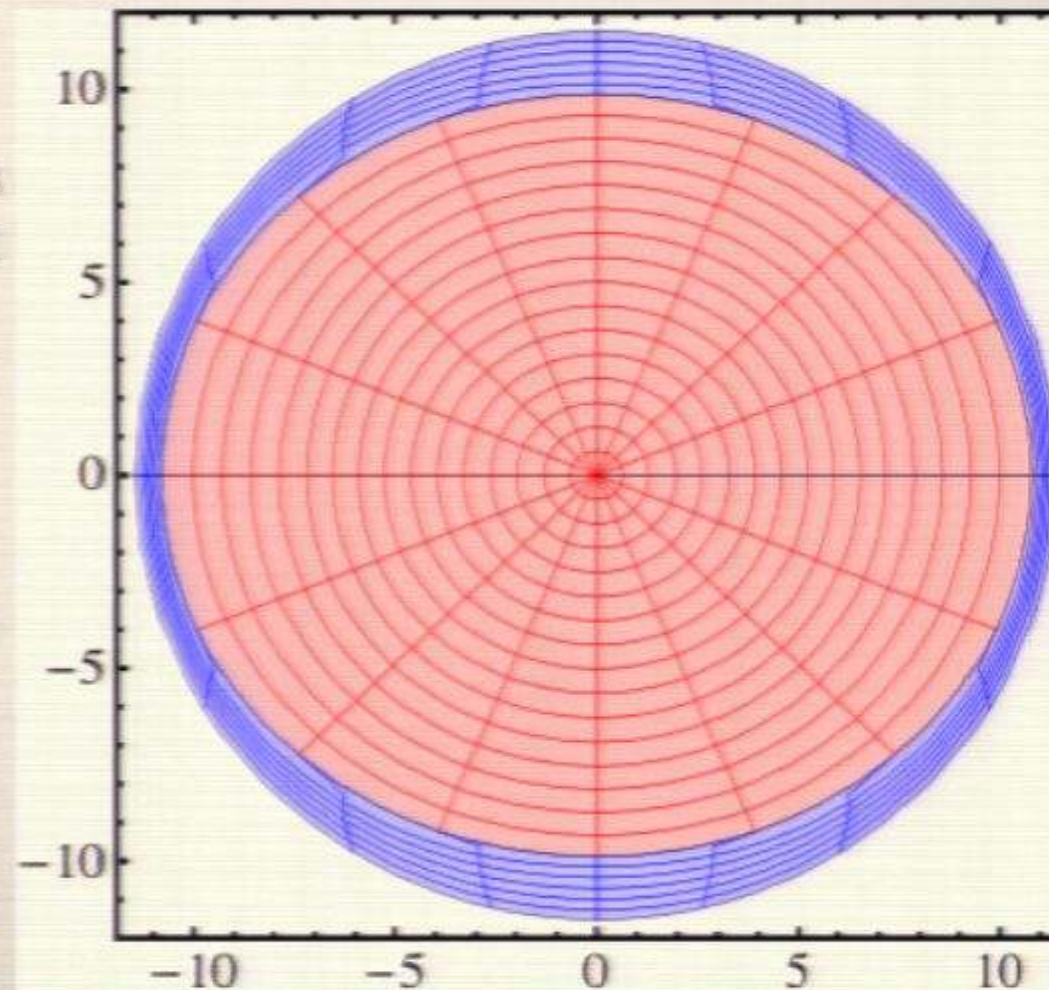
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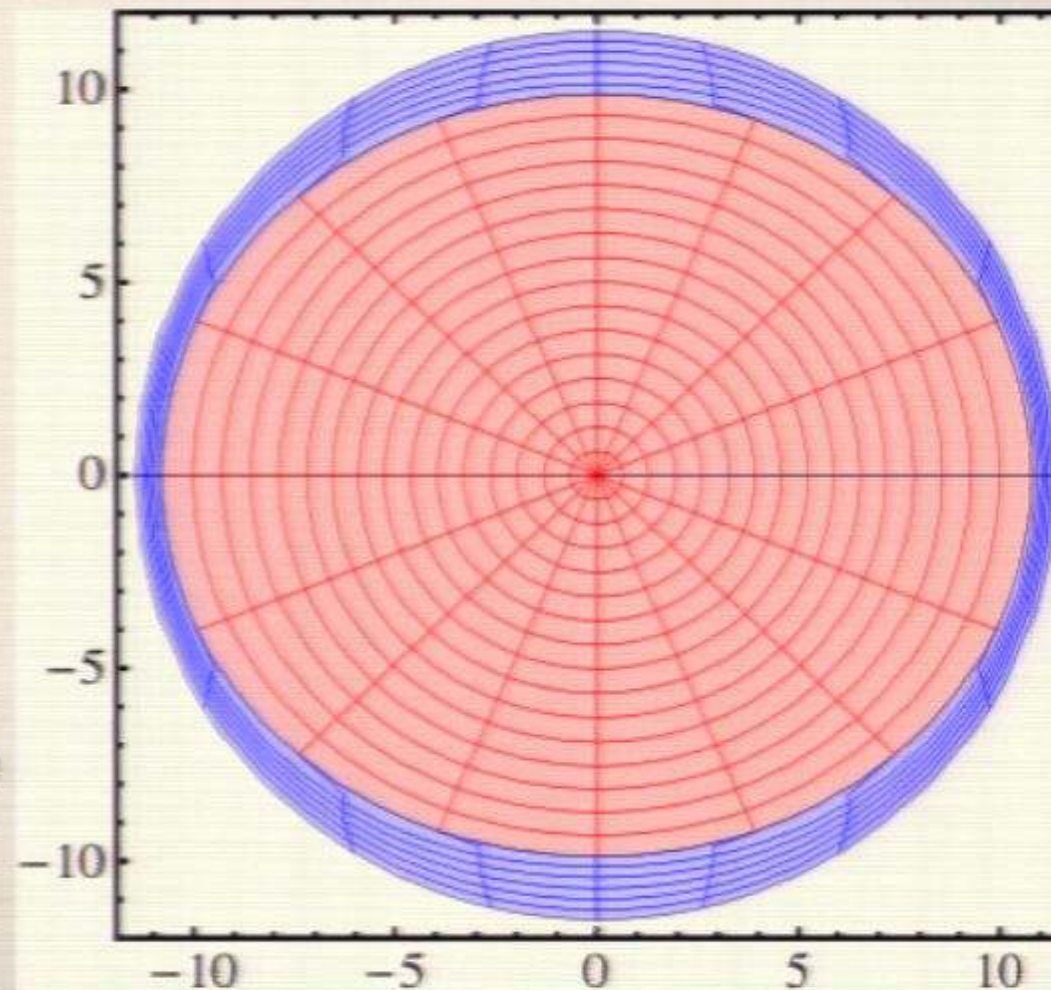
Resonant Tidal Interaction

- i-mode frequency probes NS structure and EOS at the base of the crust.
- Depends on:
 - physics near crust/core interface: shear modulus, composition/EOS, transition density, crust thickness
 - bulk properties: M and R



Resonant Tidal Interaction

- Tidal resonance:
 - $f_{\text{mode}} = 2f_{\text{orbit}} = f_{\text{gw}}$
 - Energy transferred from orbit to mode
 - $t_{\text{res}} \propto \sqrt{t_{\text{rr}} t_{\text{orbit}}}$
 - Mode can be excited to very large amplitude
 - NS isn't tidally locked



- How does the i-mode couple to the tidal field?

$$Q_{nl} \equiv \frac{1}{M_* R_*^l} \int d^3 x \rho \boldsymbol{\xi}_{nlm}^* \cdot \nabla [r^l Y_{lm}(\theta, \phi)] \simeq 0.002$$

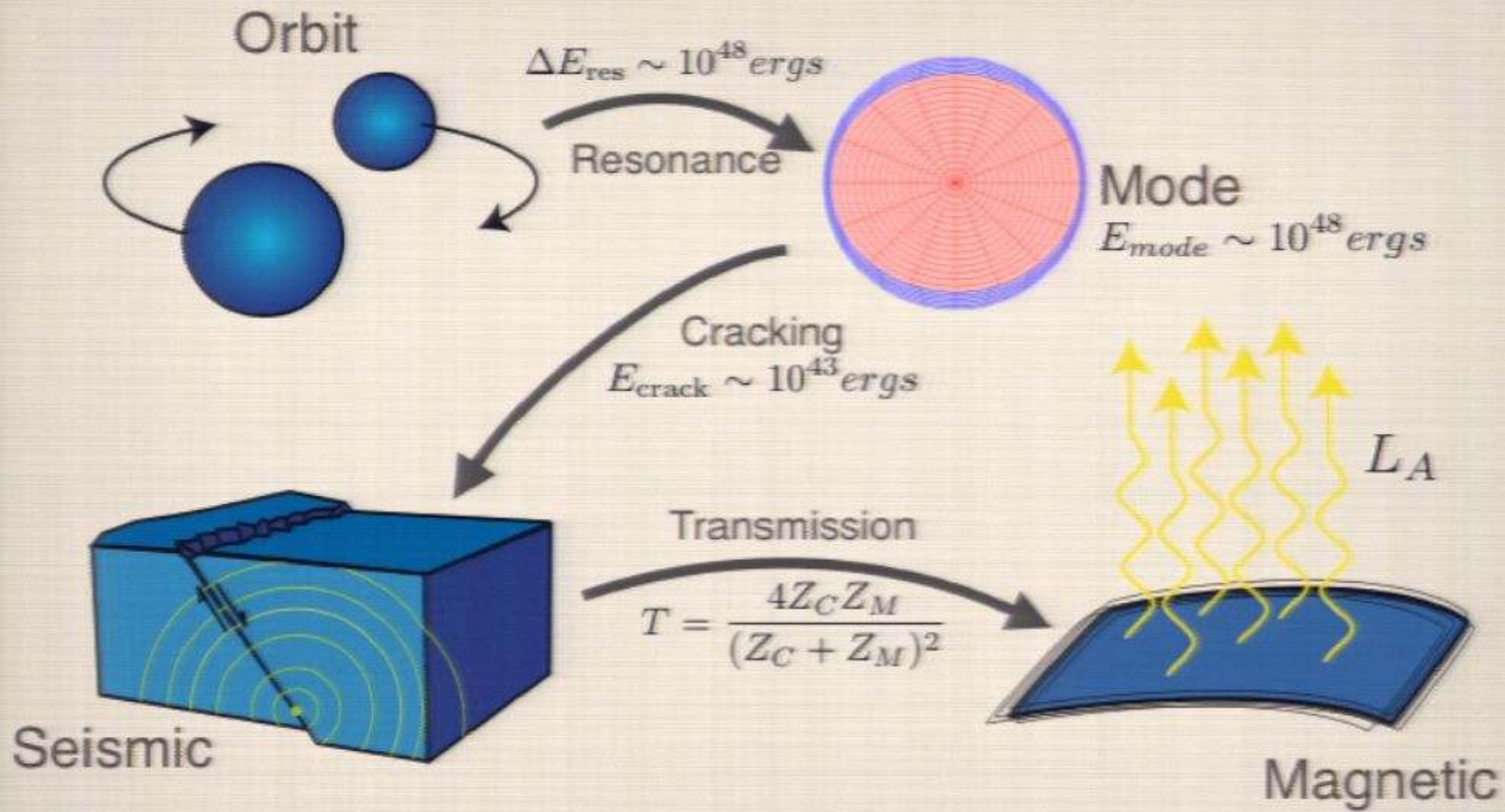
- How much energy can be transferred tidally?

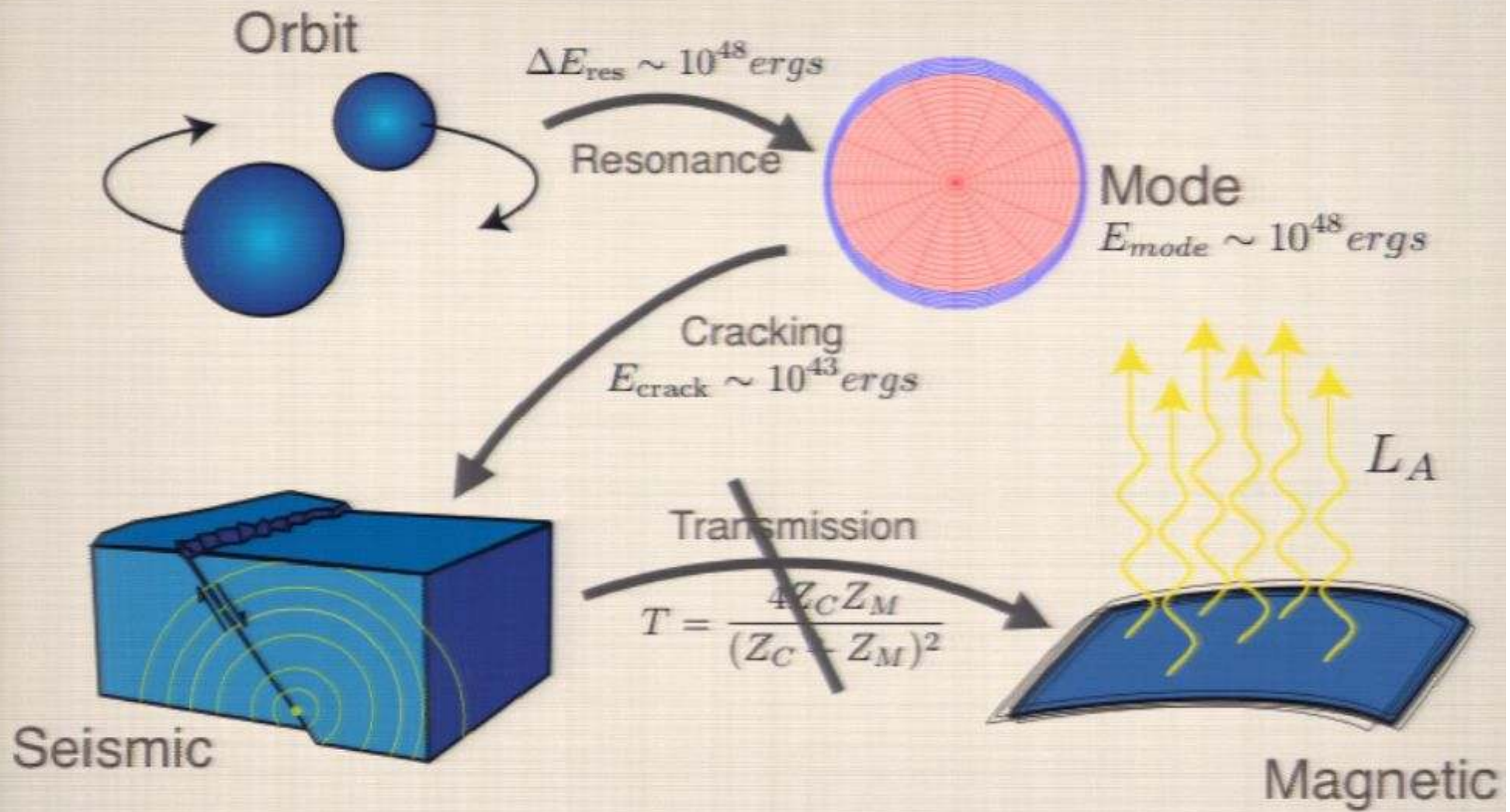
$$\Delta E_{\max} \sim 10^{48} \text{ ergs} \left(\frac{f_{nl}}{100 \text{ Hz}} \right)^{1/3} \left(\frac{Q_{nl}}{0.002} \right)^2 \left(\frac{M_*}{1.4 M_\odot} \right)^{2/3} \left(\frac{R_*}{11 \text{ km}} \right)^2$$

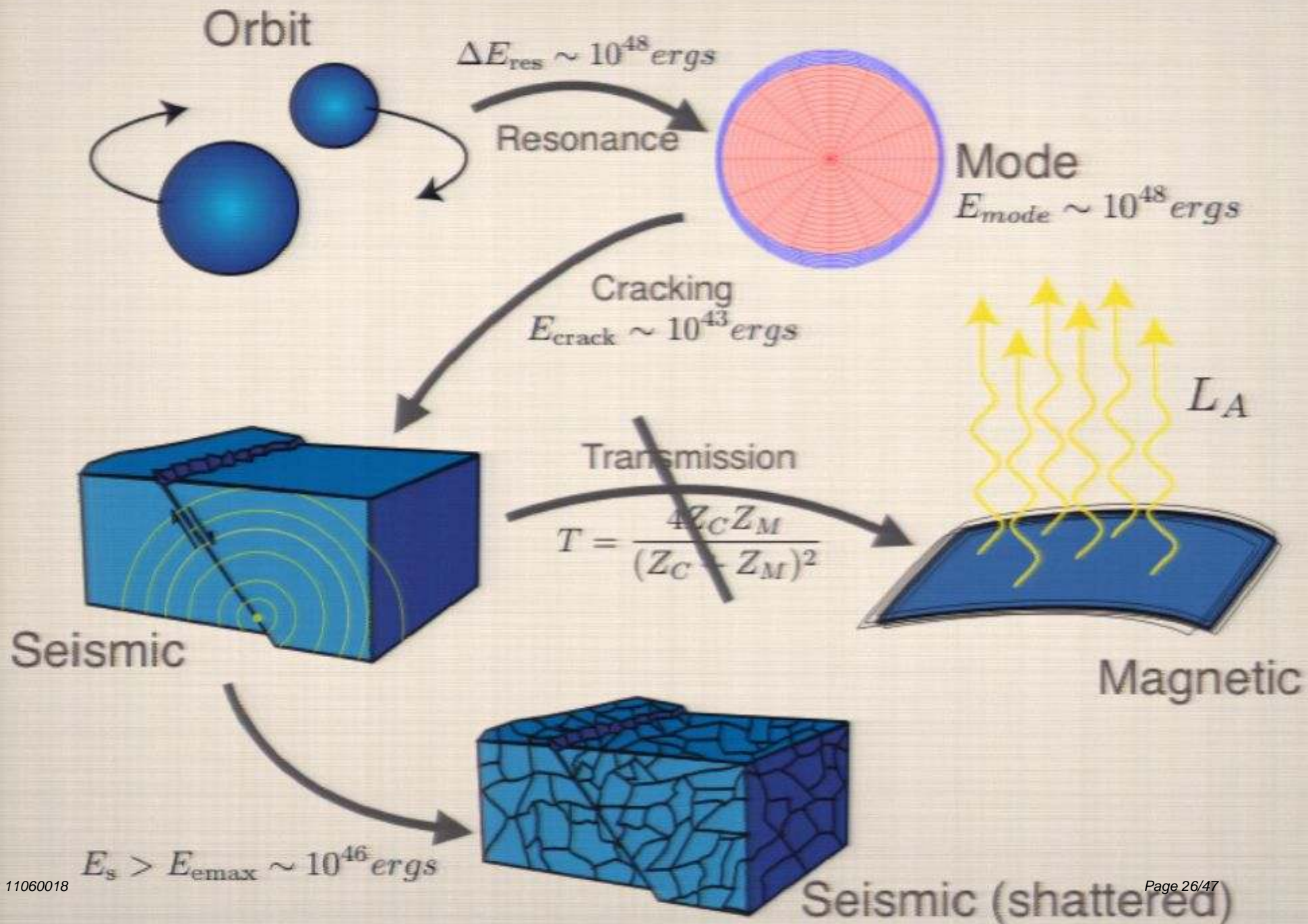
- How much energy does it take to break the crust?

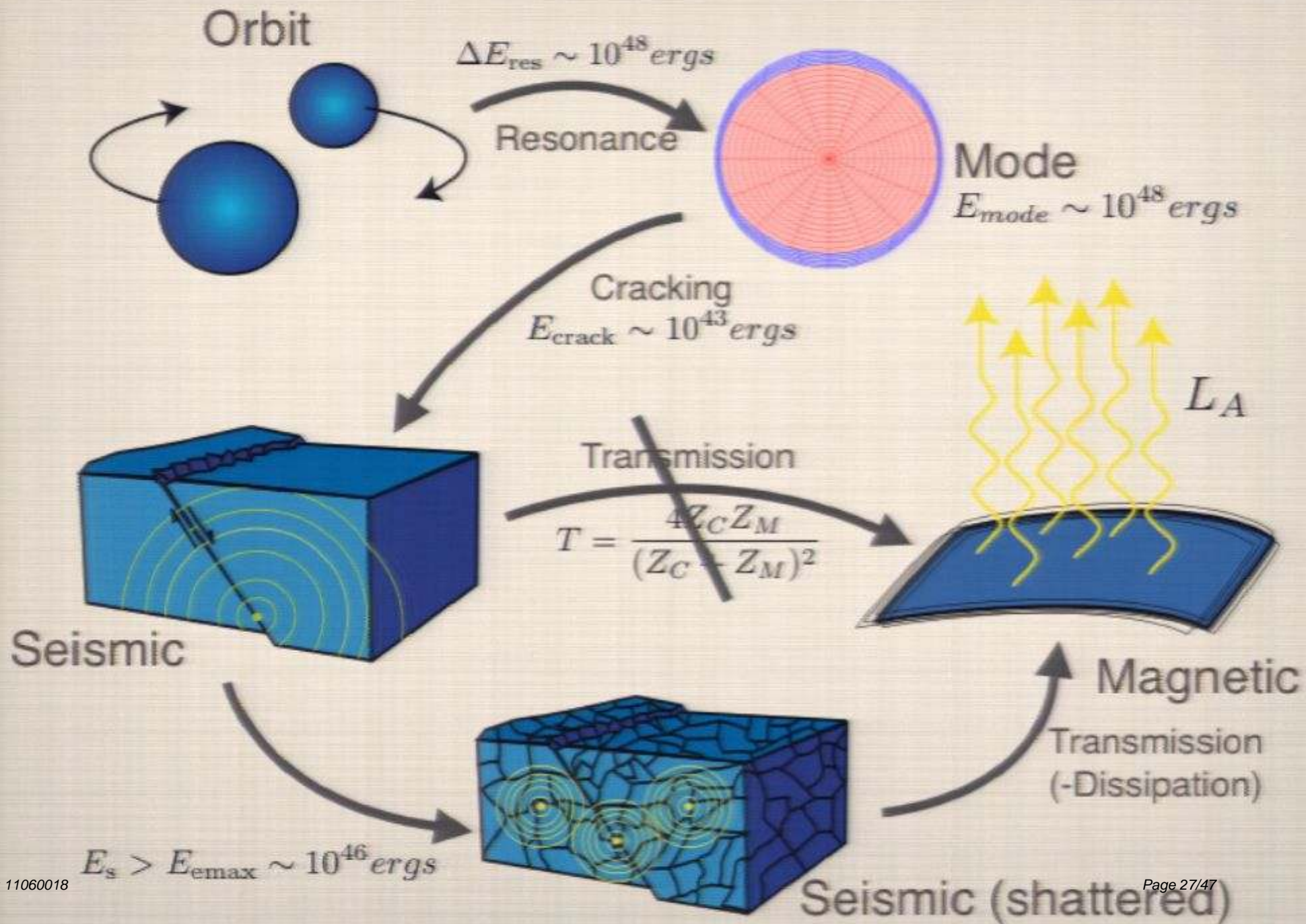
$$E_{\text{break}} \simeq 10^{48} \text{ ergs} \left(\frac{f_{nl}}{100 \text{ Hz}} \right)^2 \left(\frac{\epsilon_b}{10^{-1}} \right)^2 \frac{M_*}{1.4 M_\odot} \left(\frac{R_*}{11 \text{ km}} \right)^2$$

- What happens next?

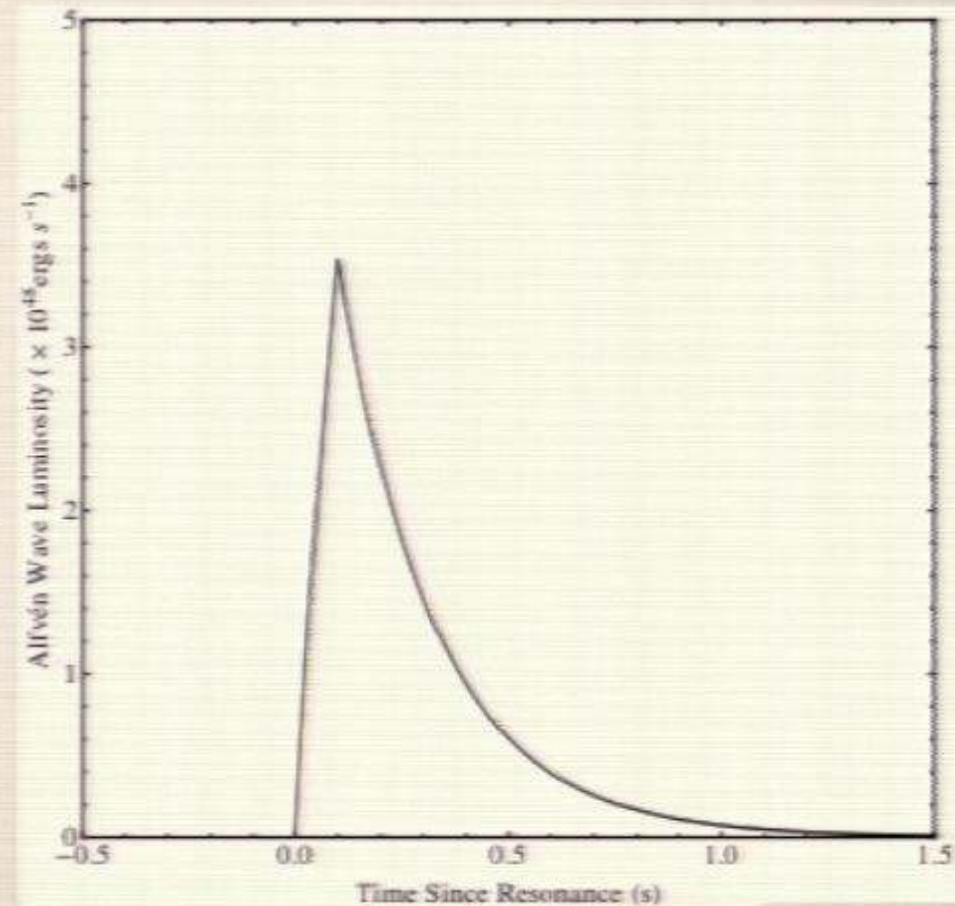




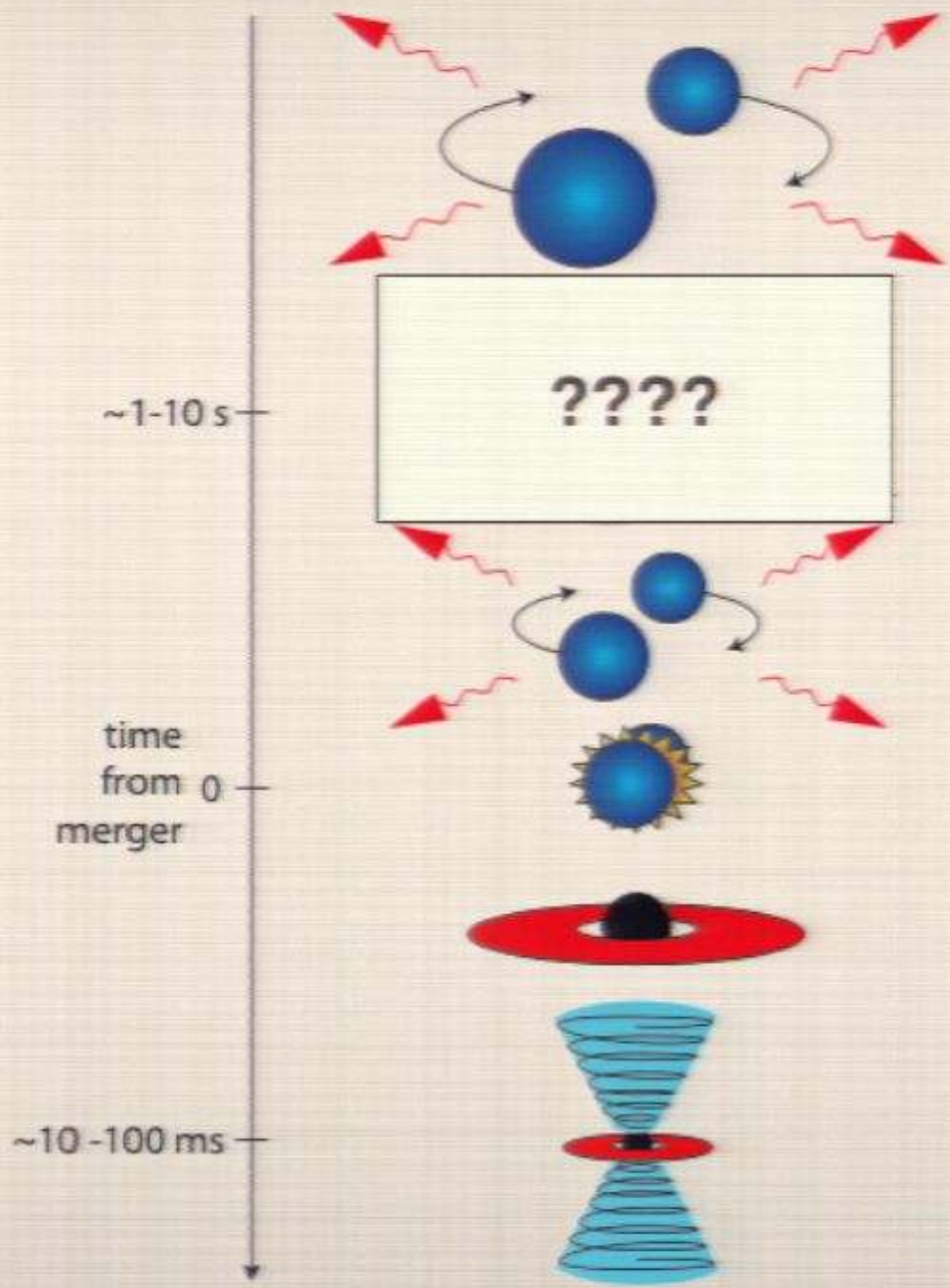


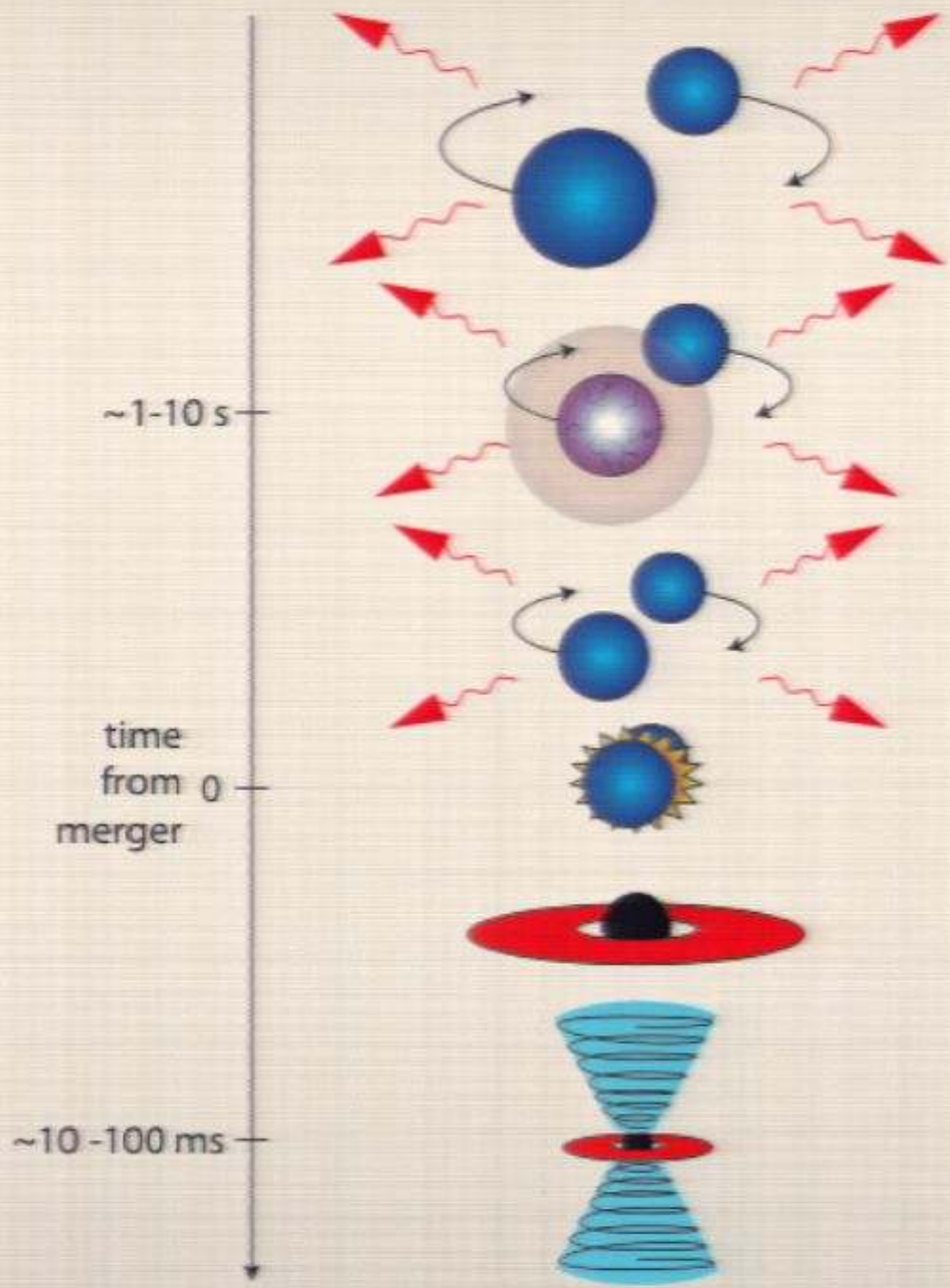


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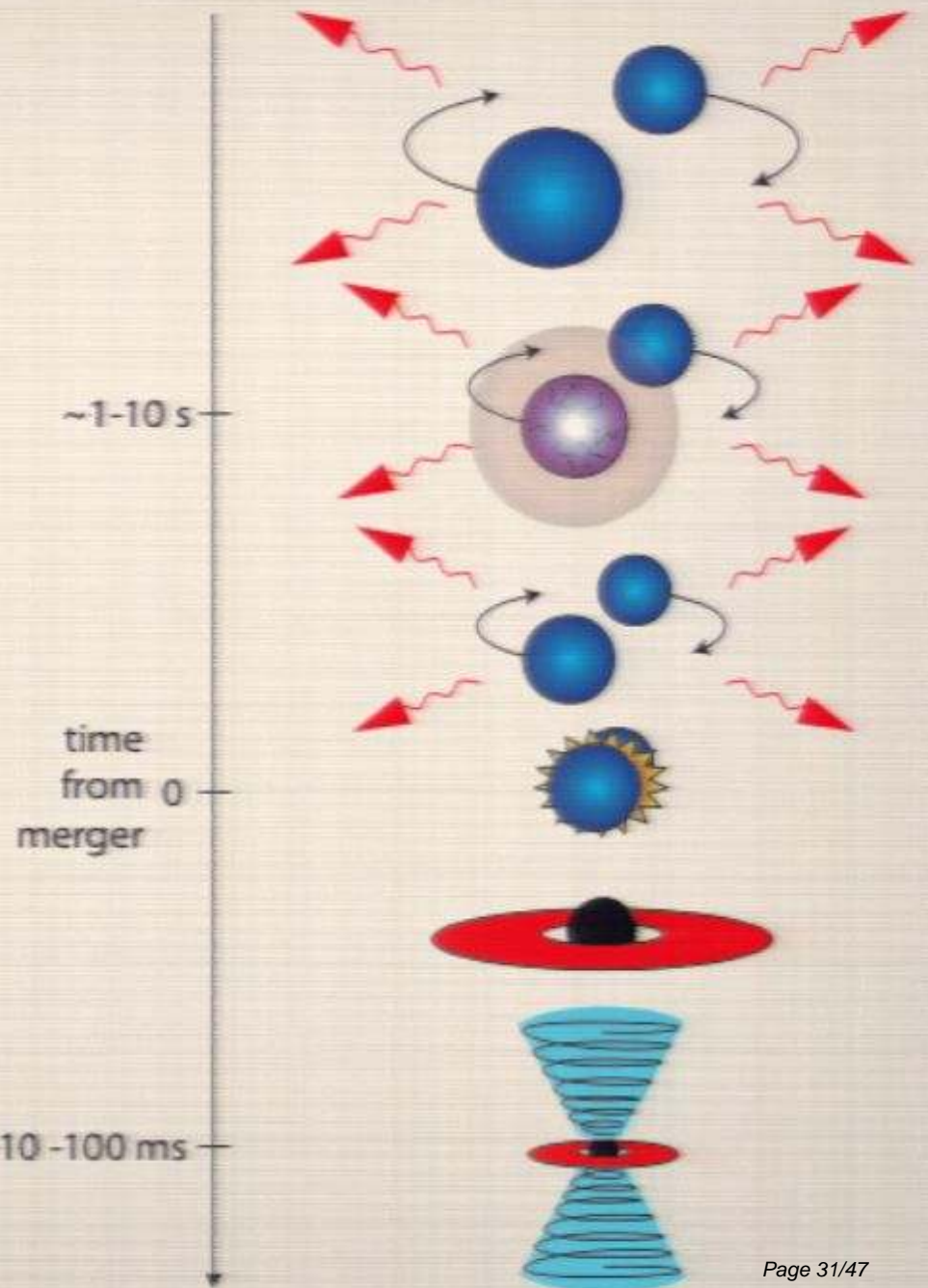


$$B = 10^{11} \text{ G}$$

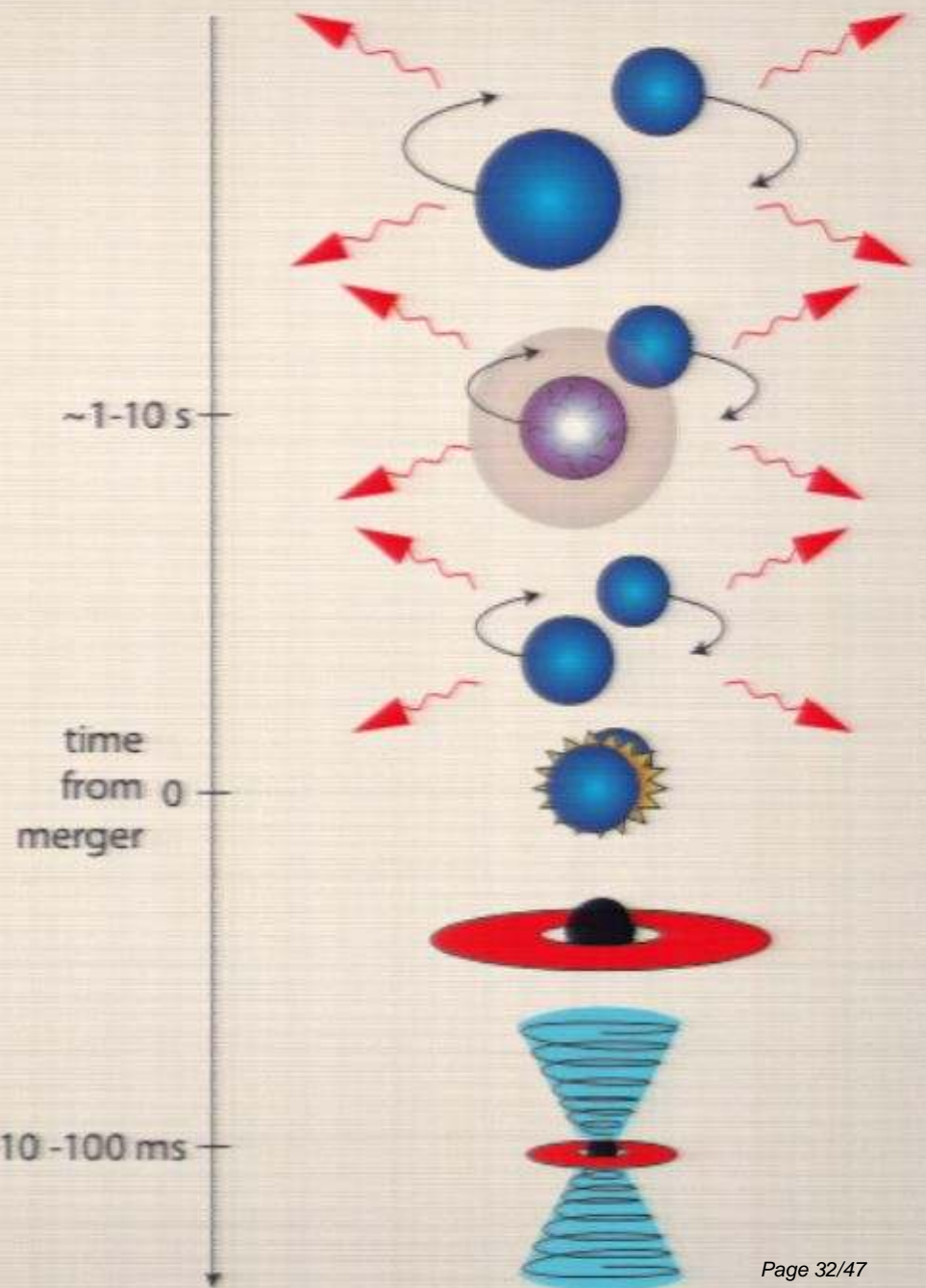




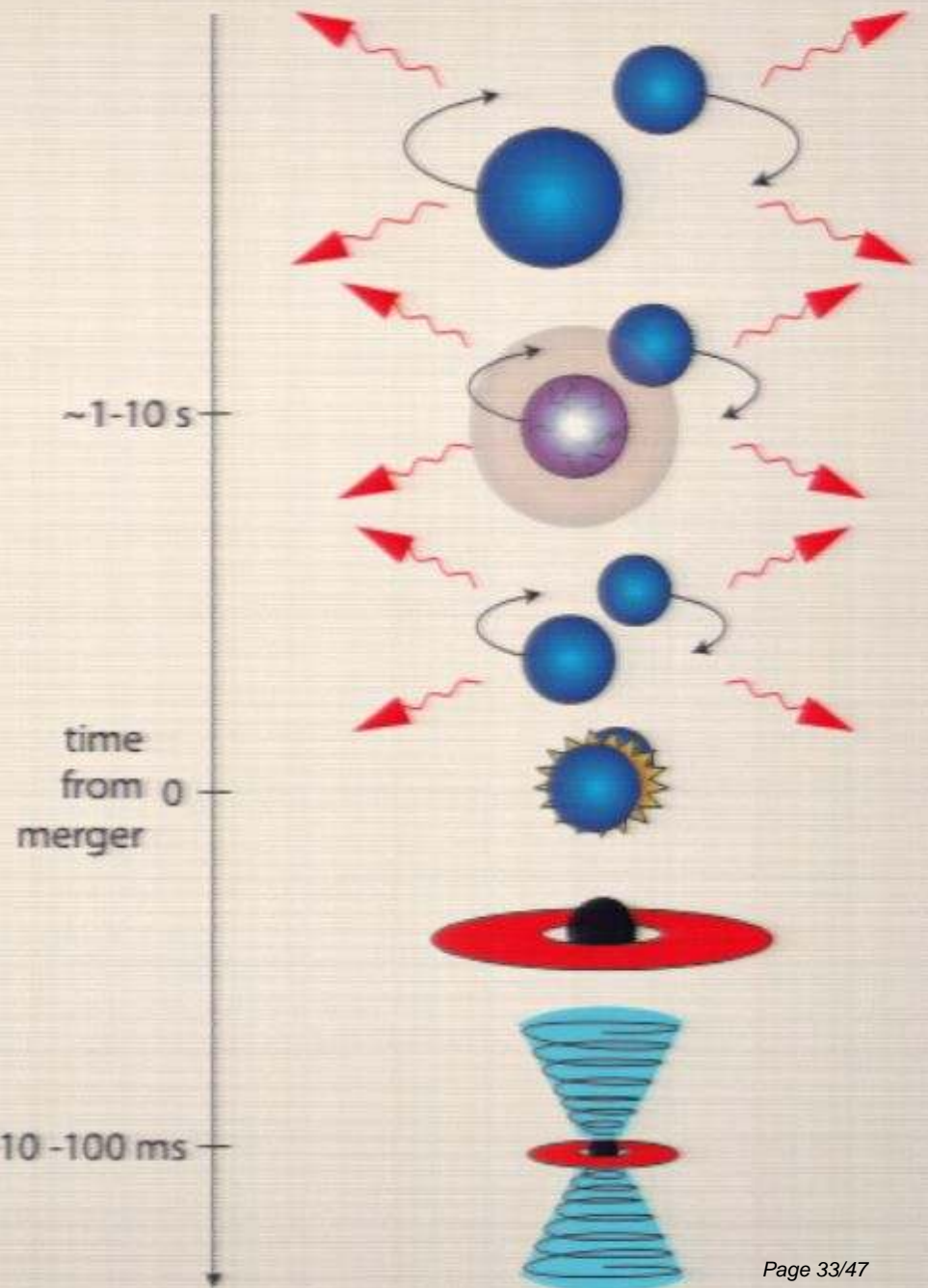
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- NS Asteroseismology
- Constrain NS EOS (near crust/core transition)
- Need AdvLIGO freq. measurement and coincident detection
- Multiple Precursors
- Different NS structure
- Isotropic Precursors may be ~ 10 - 100 ms confused with sGRBs



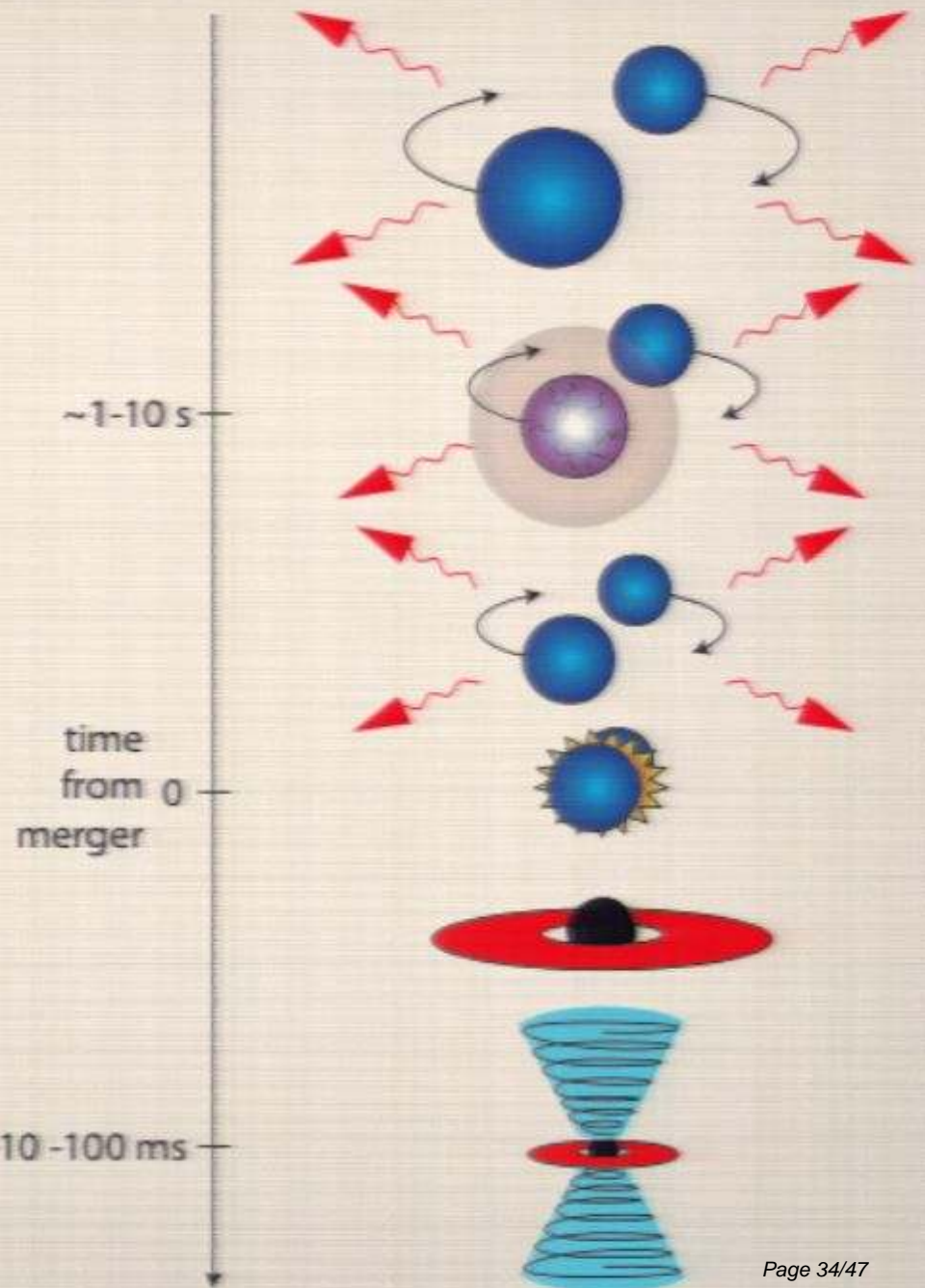
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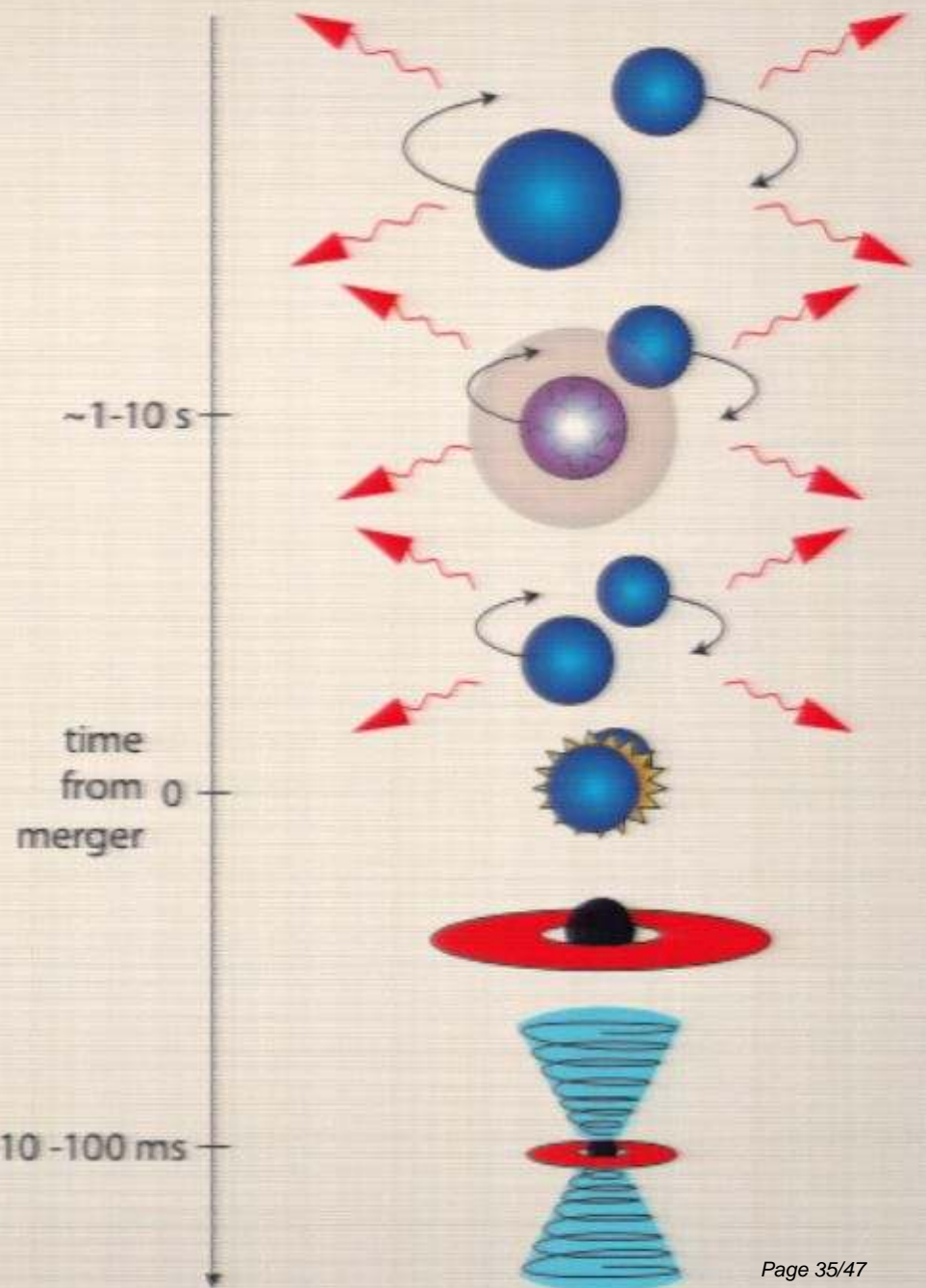
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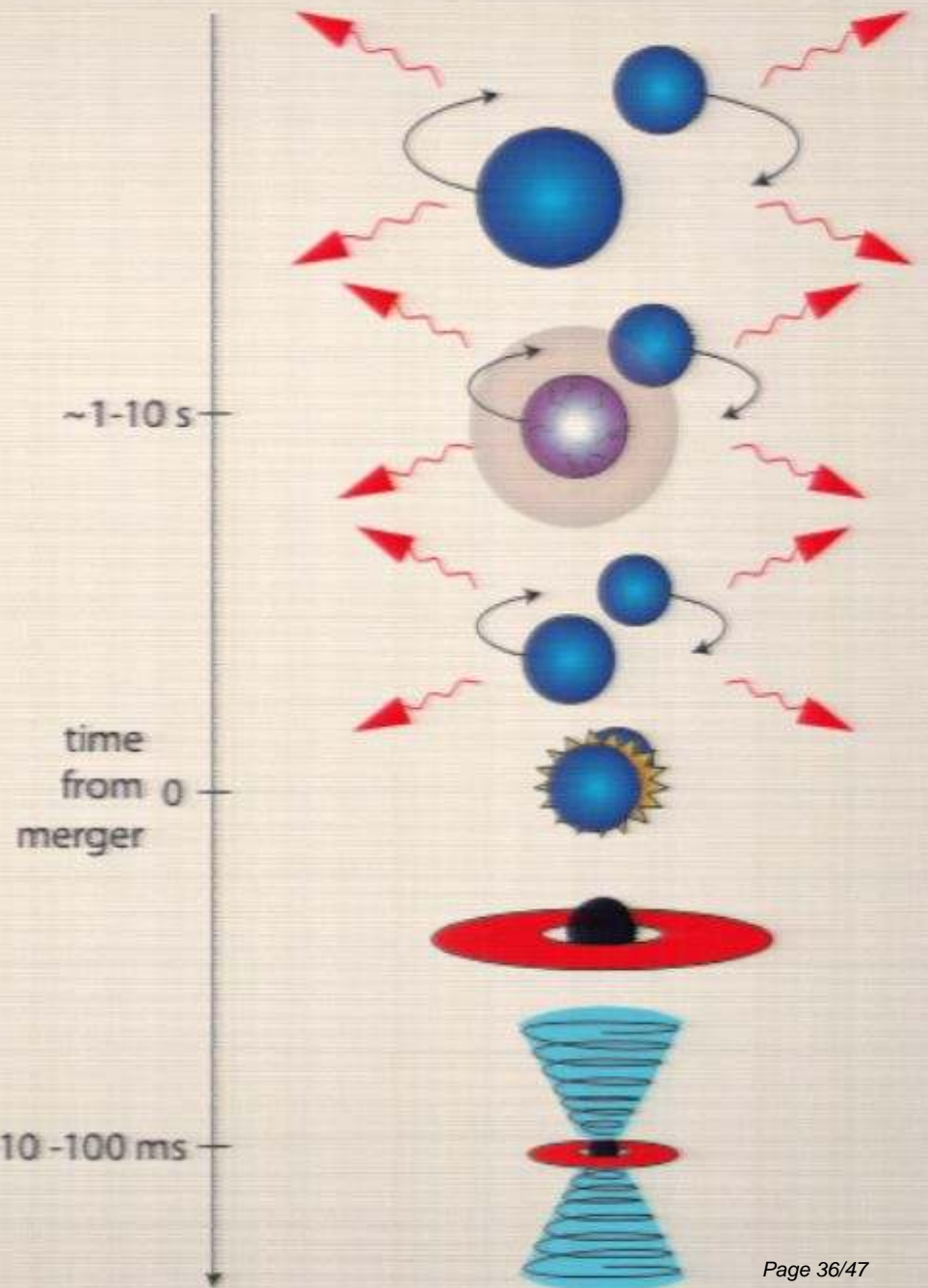
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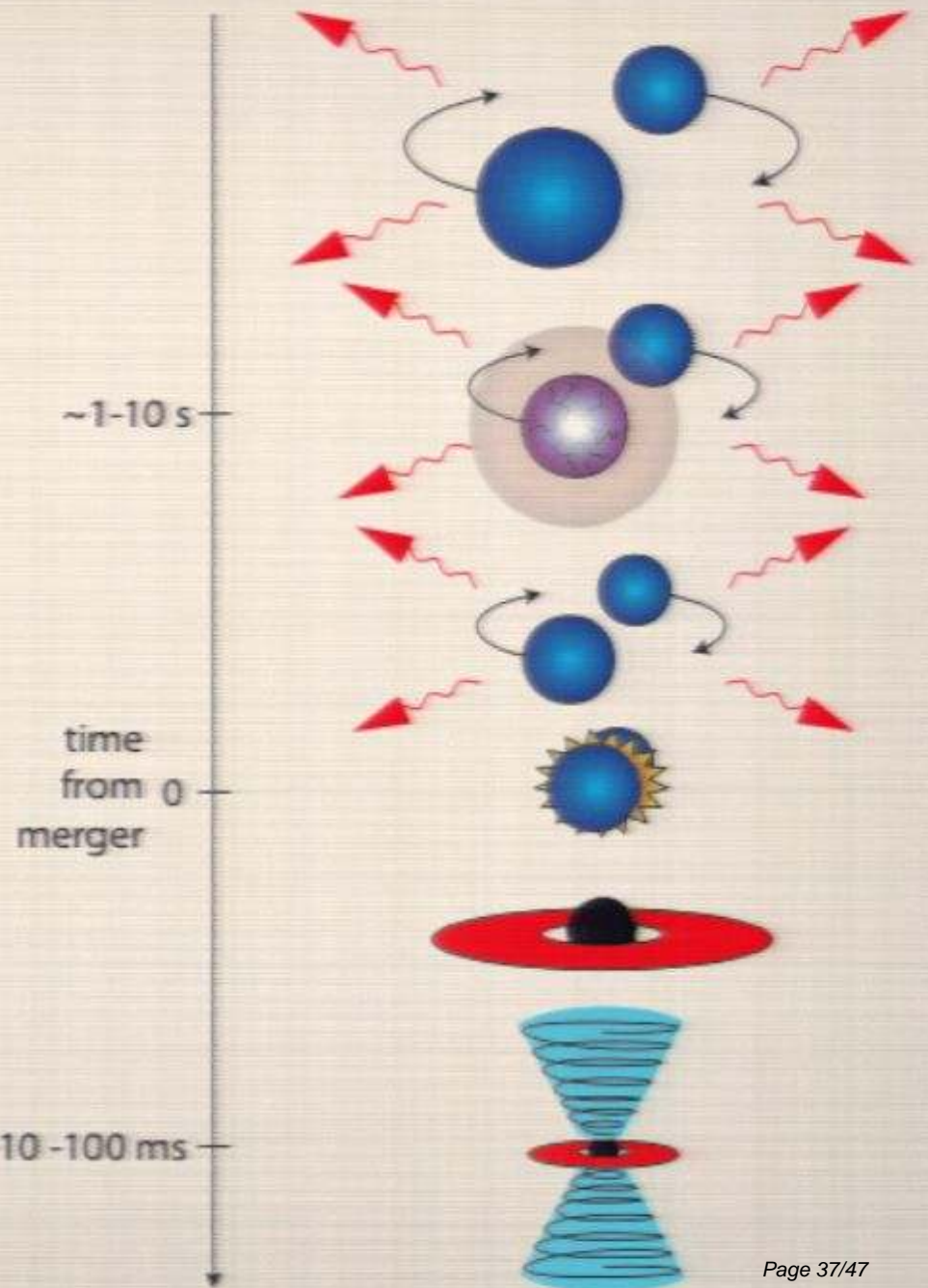
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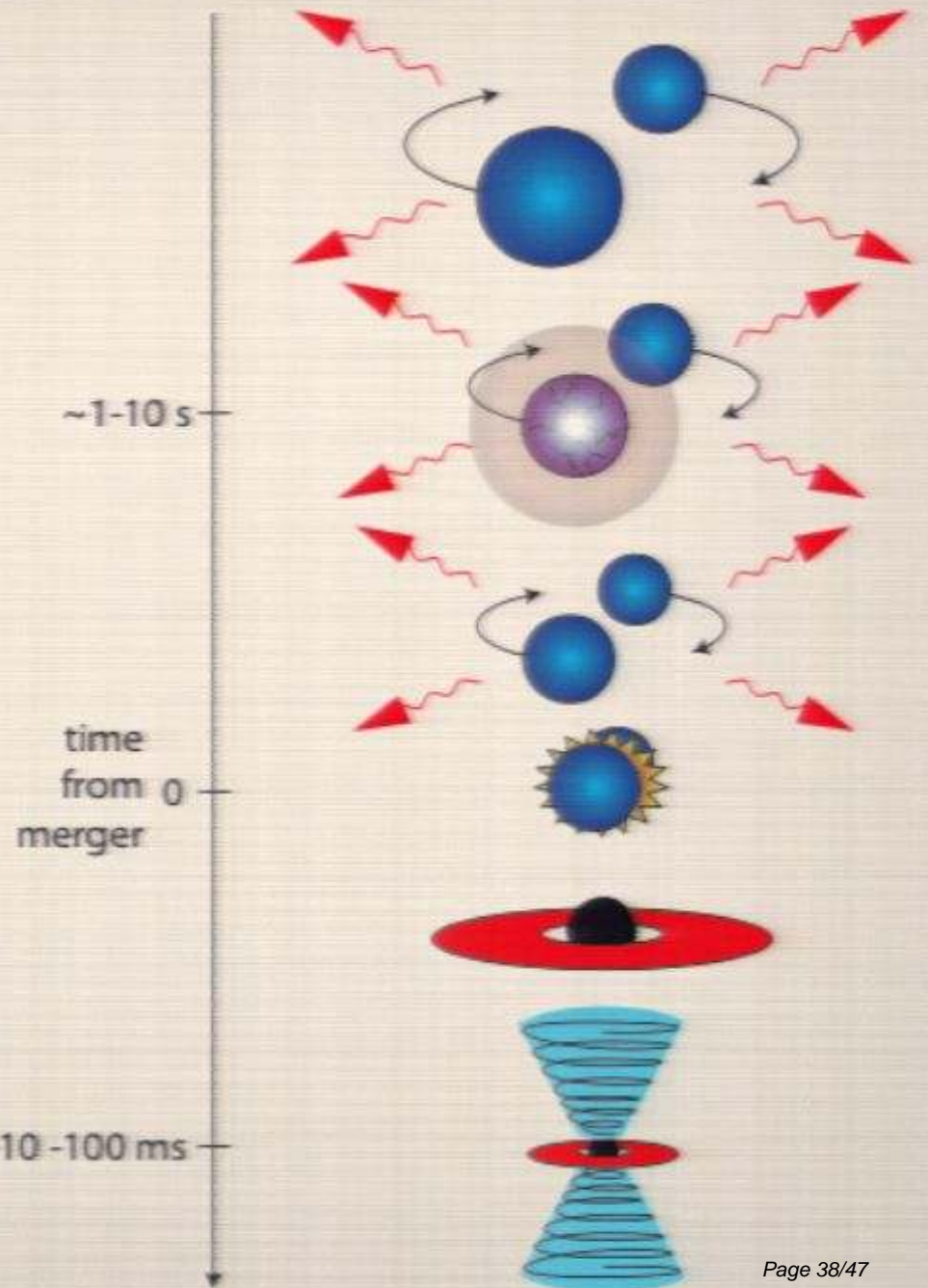
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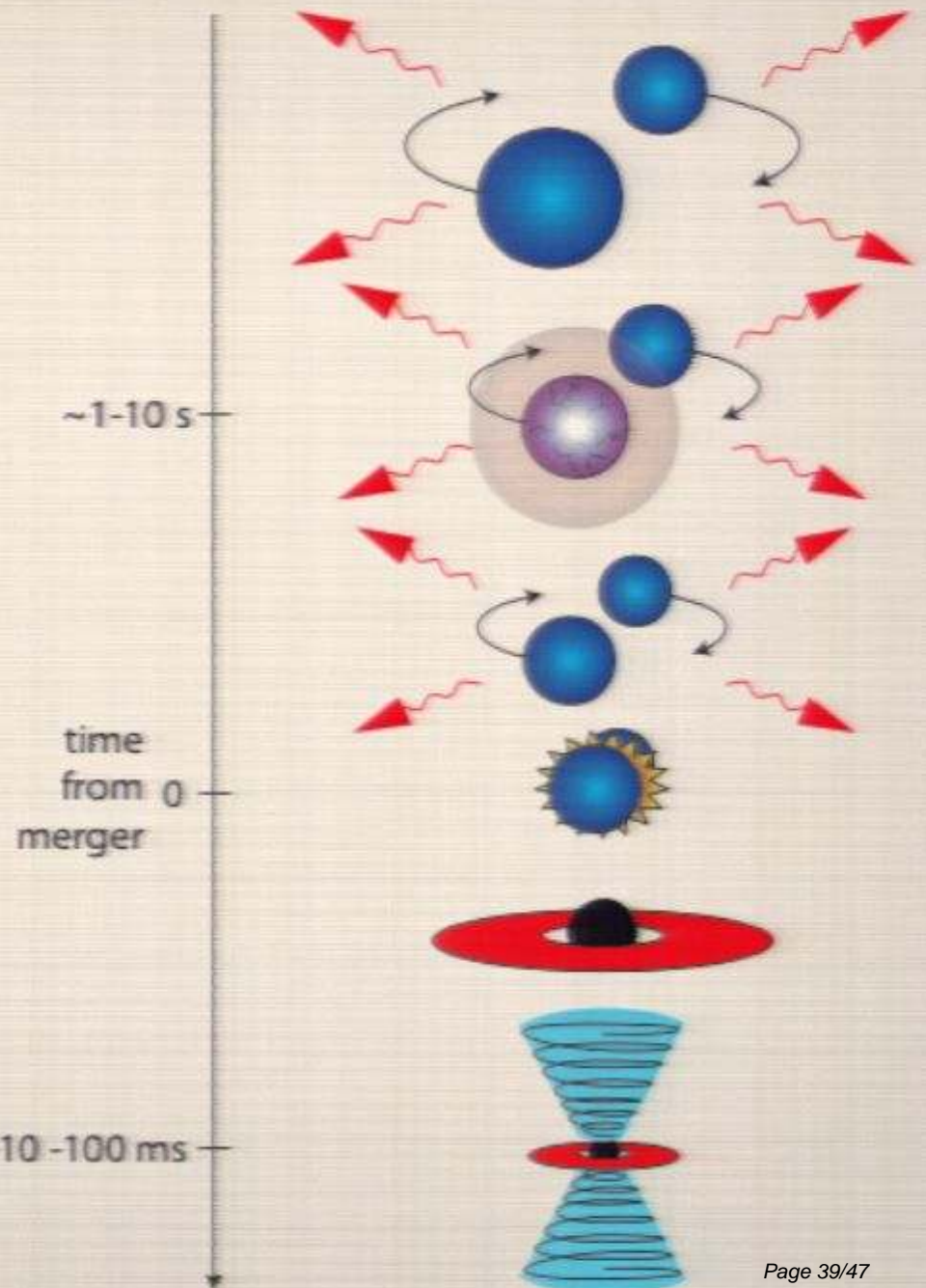
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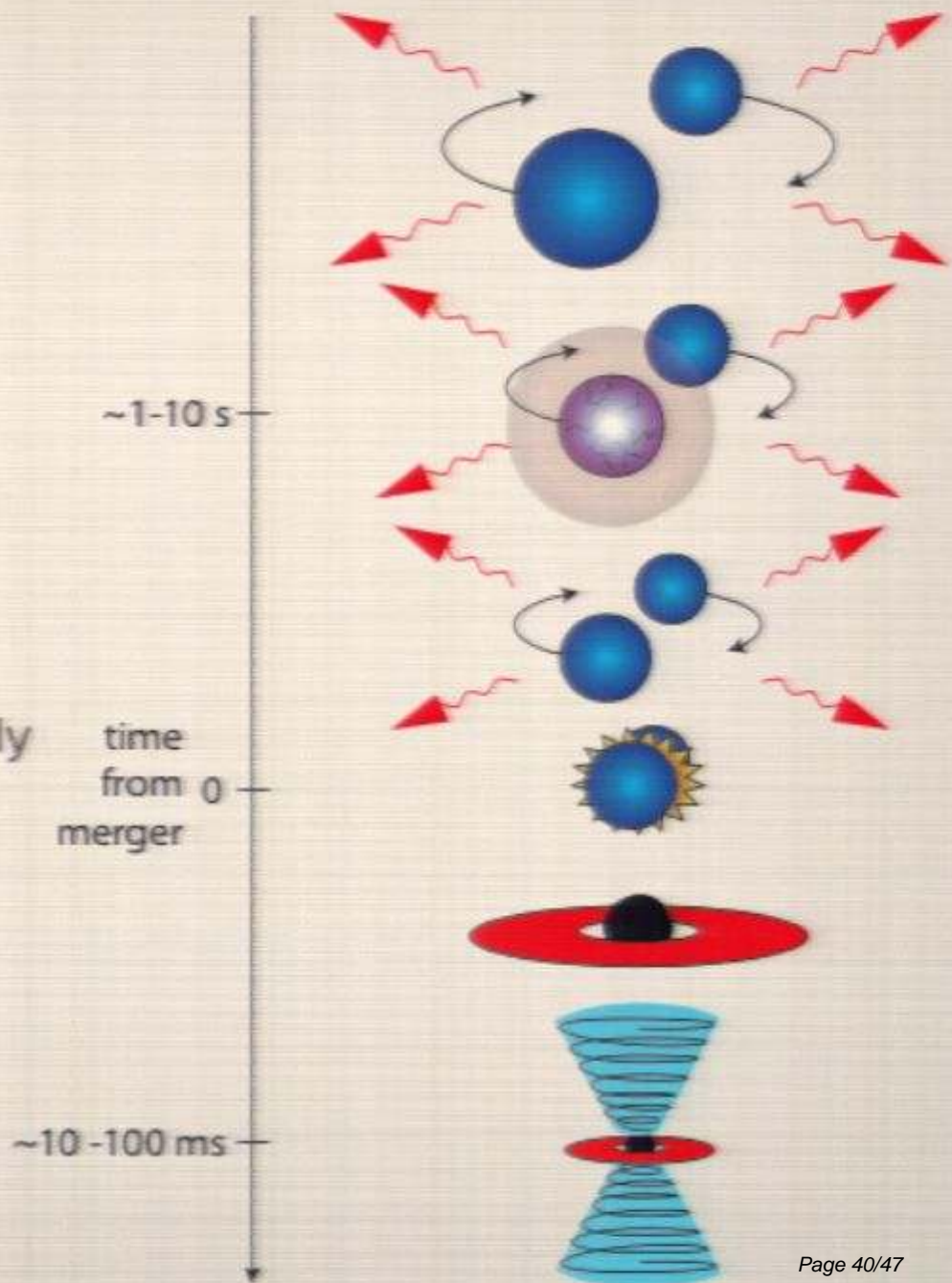
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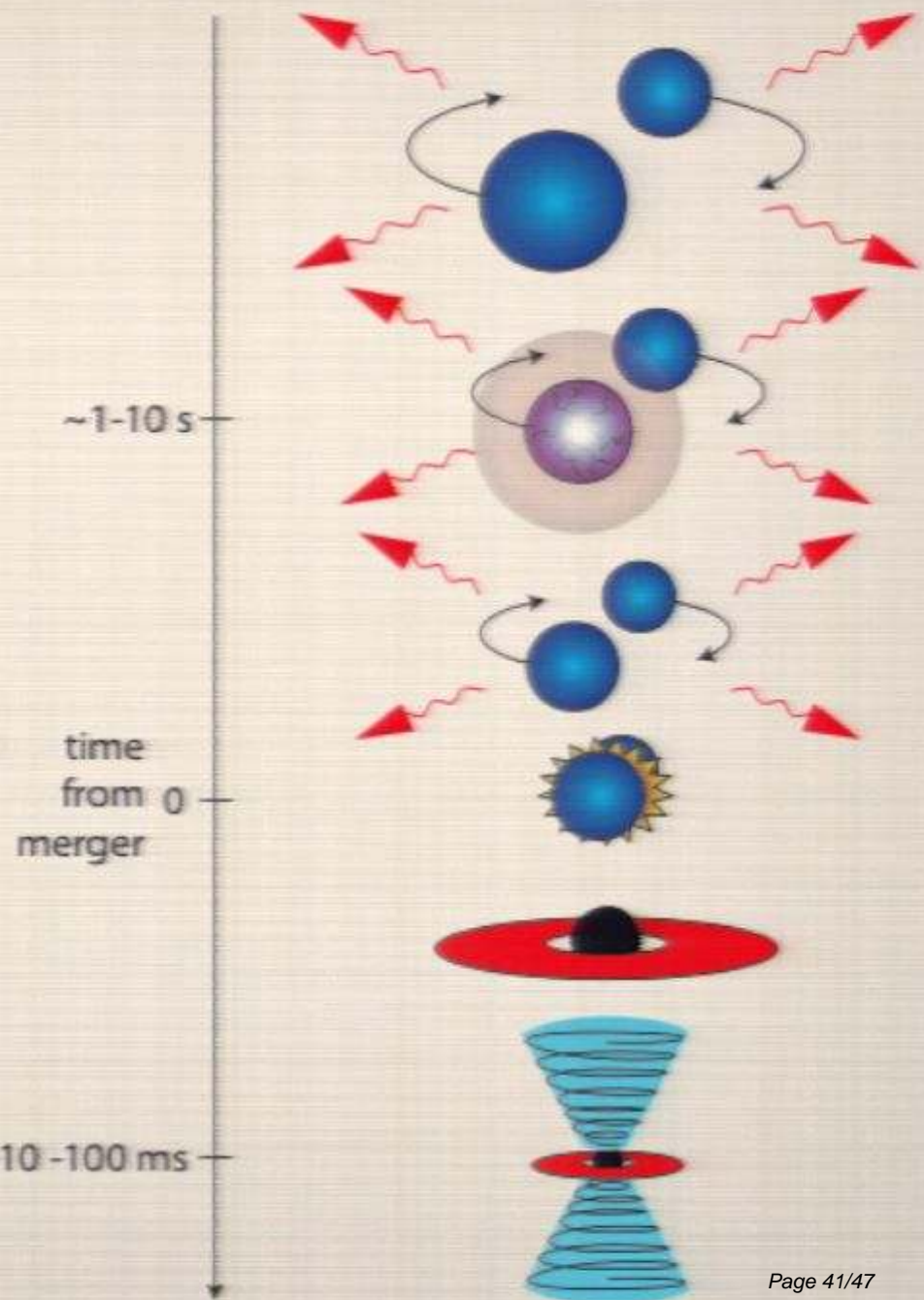
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- NS Asteroseismology from Magnetar flare QPOs
- Primarily toroidal crust modes, (upper) crustal constraints
- Gravitational waves of inspiral alone
- Mass, Radius, and love number constraints, primarily depends on core EOS.
- NS Asteroseismology from Multi-messenger timing of precursors
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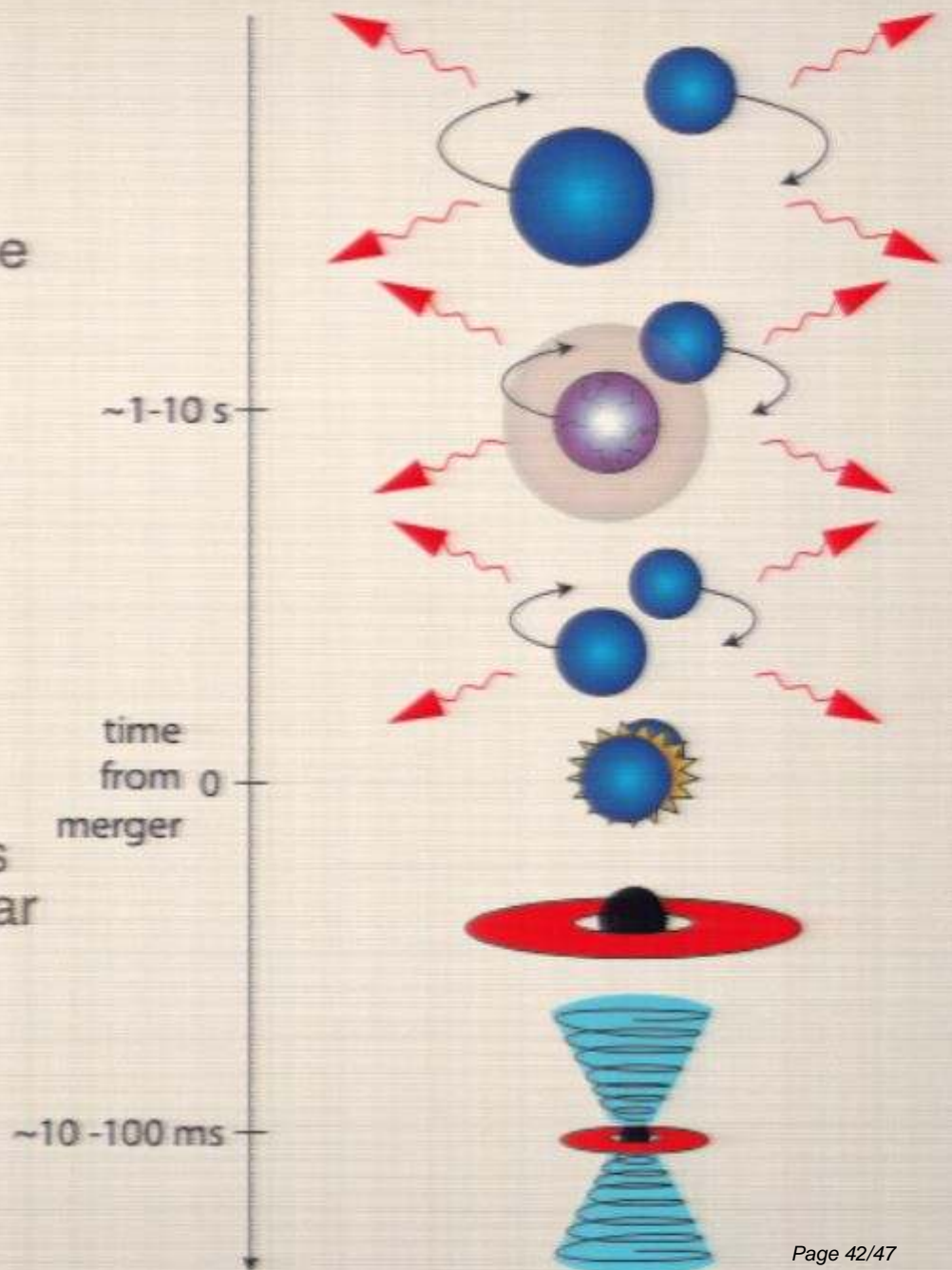


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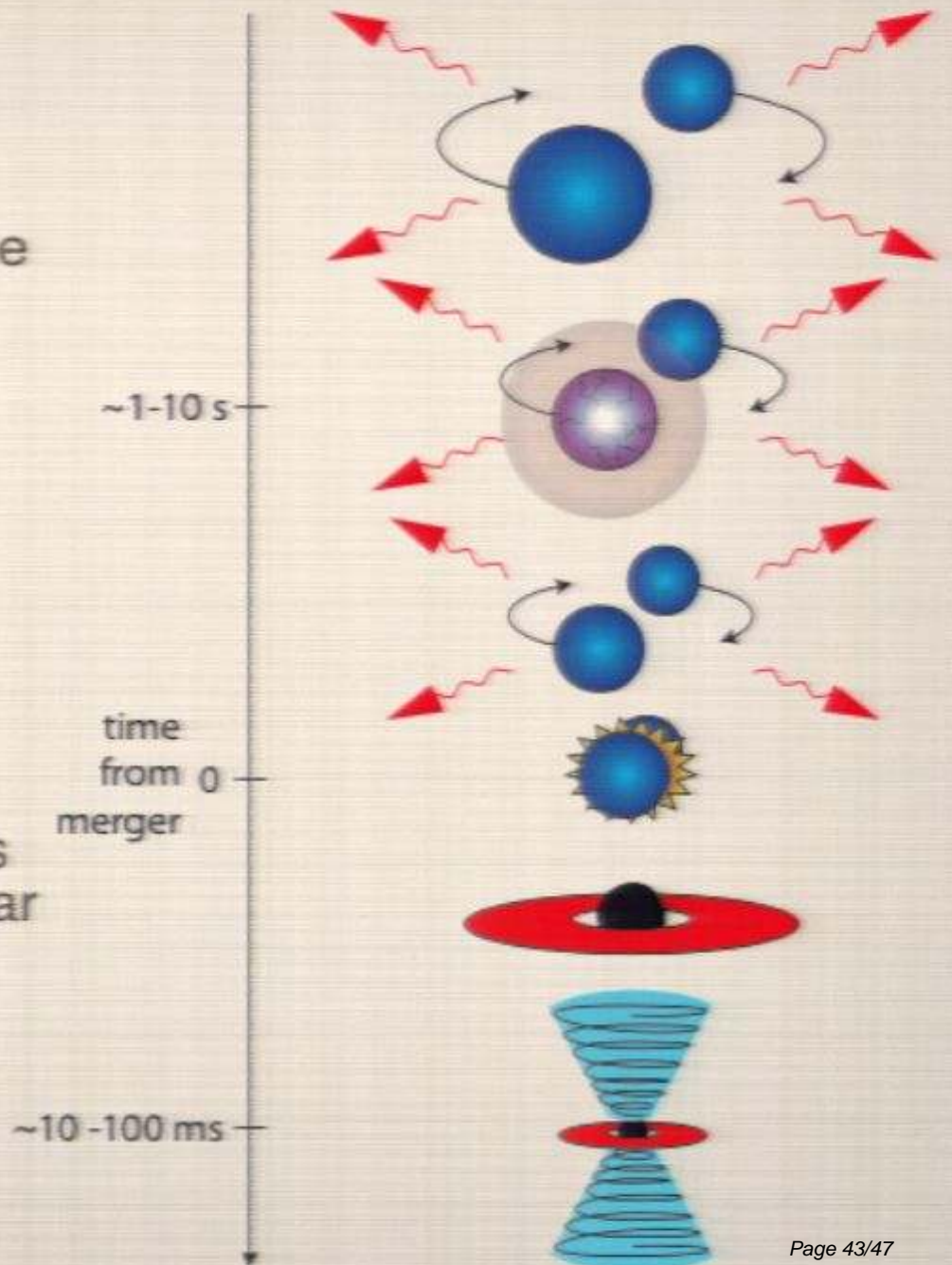
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- sGRB precursors (and some sGRBs) may be due to resonant crust cracking
- $E \sim 10^{48}$ ergs
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- With coincident signal and timing from AdvLIGO allows us to constrain NS EOS near crust/core
- Multiple precursors are possible for different NS structure



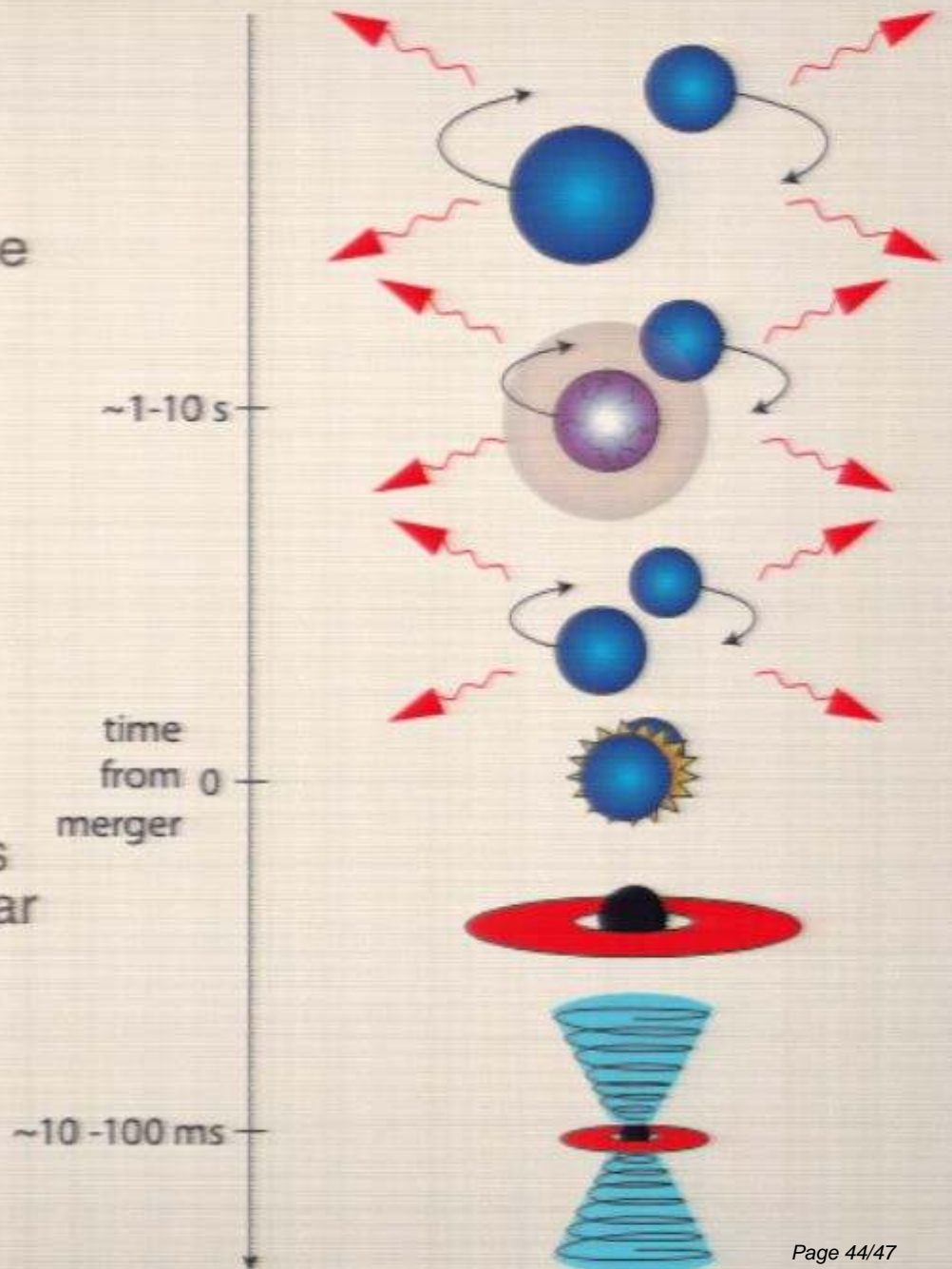
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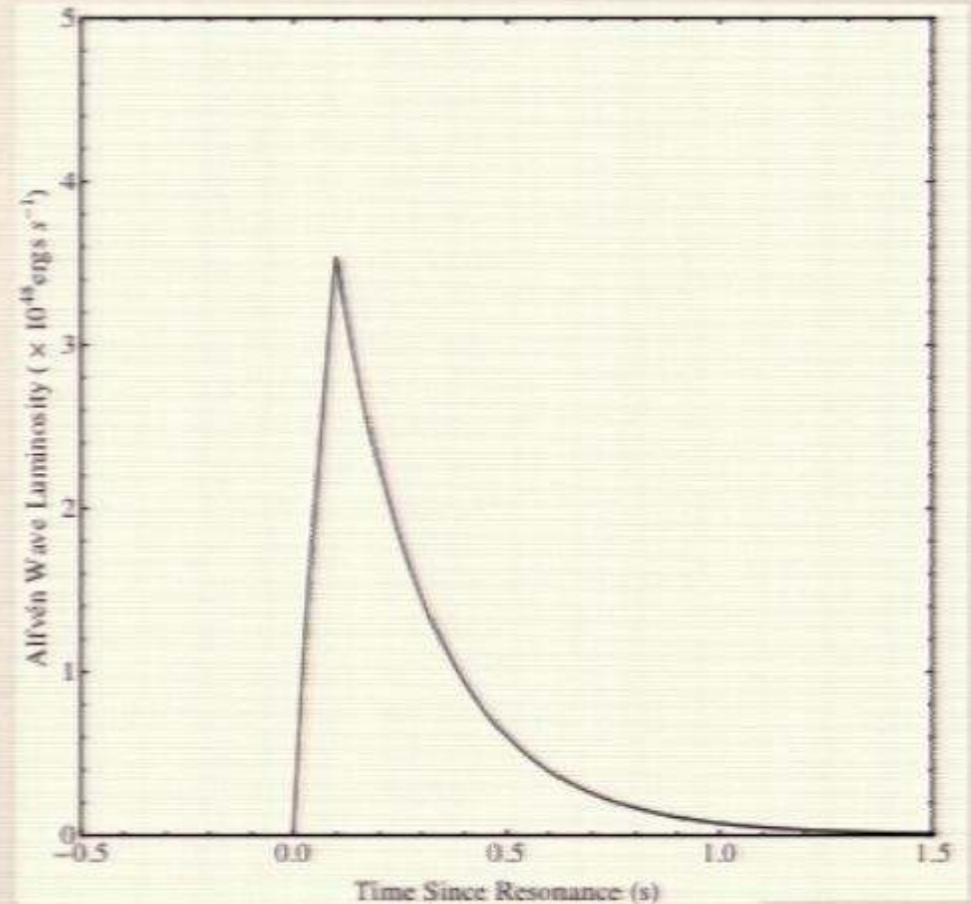


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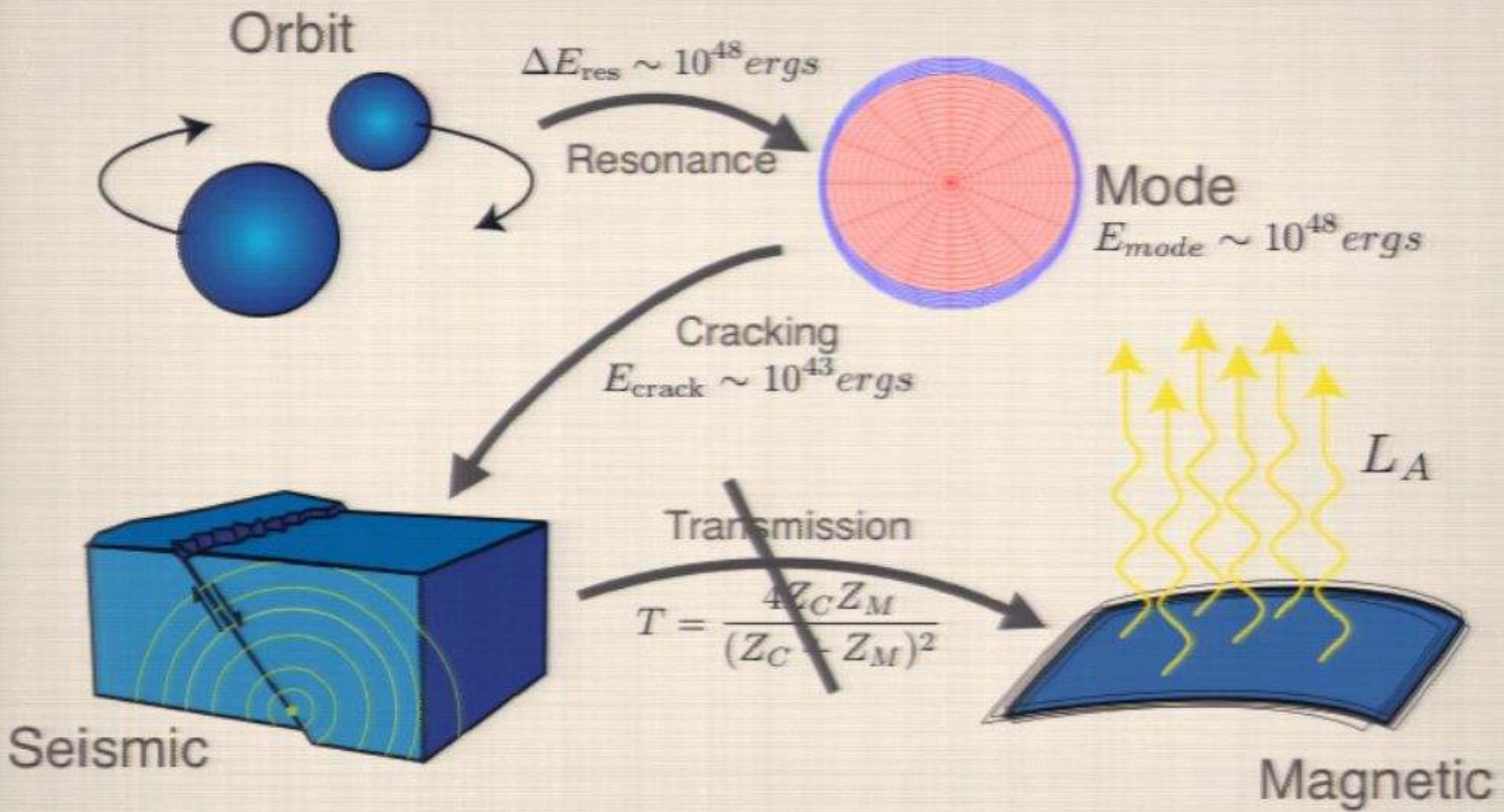
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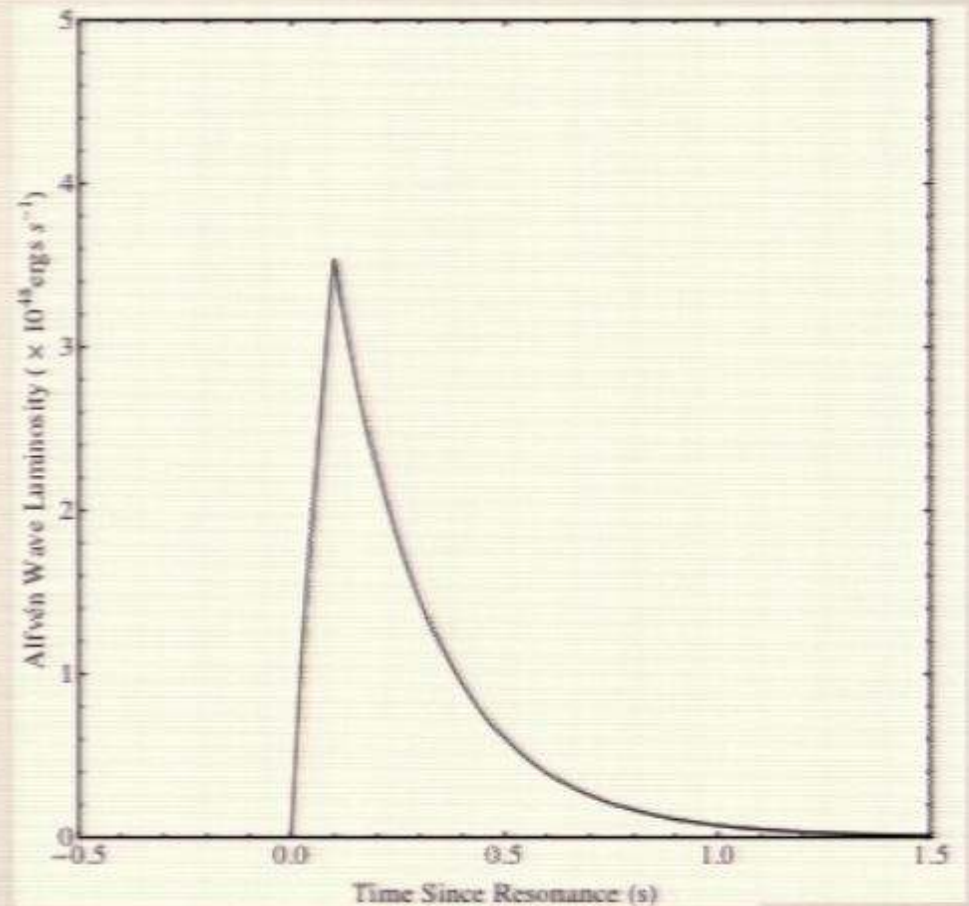
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