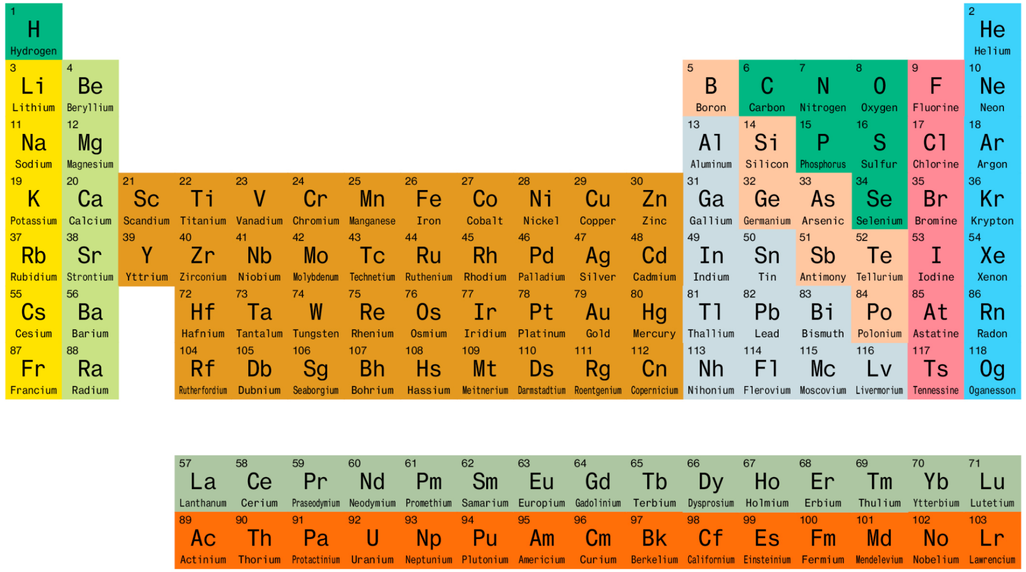
Kilonovae and Charged Particle Thermalization

Ben Shenhar, Phd Advisor: Eli Waxman
Weizmann Institute of Science, Rehovot, Israel

Transient Universe 2023, Cargese

Origin of Elements & Nucleosynthesis



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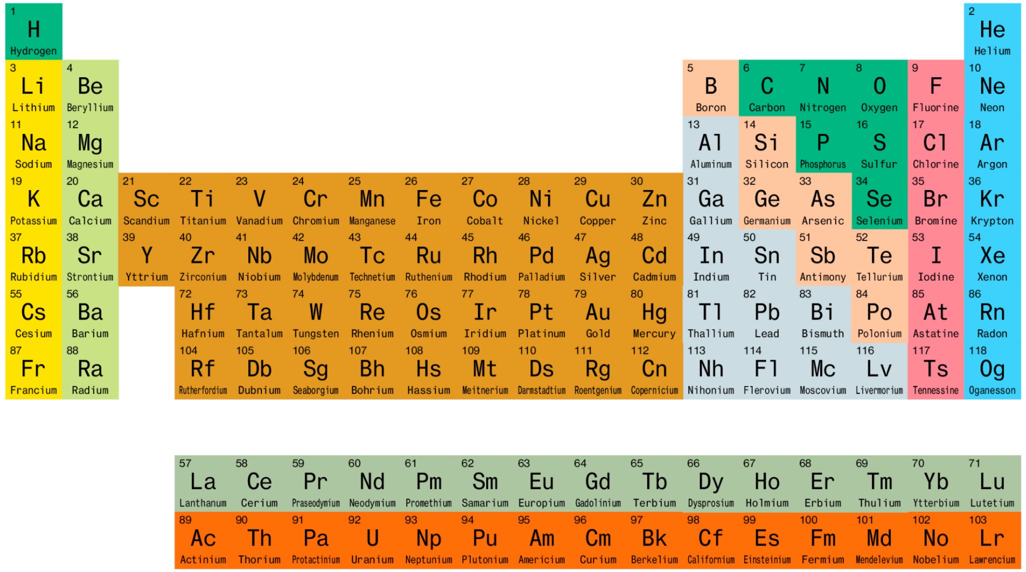

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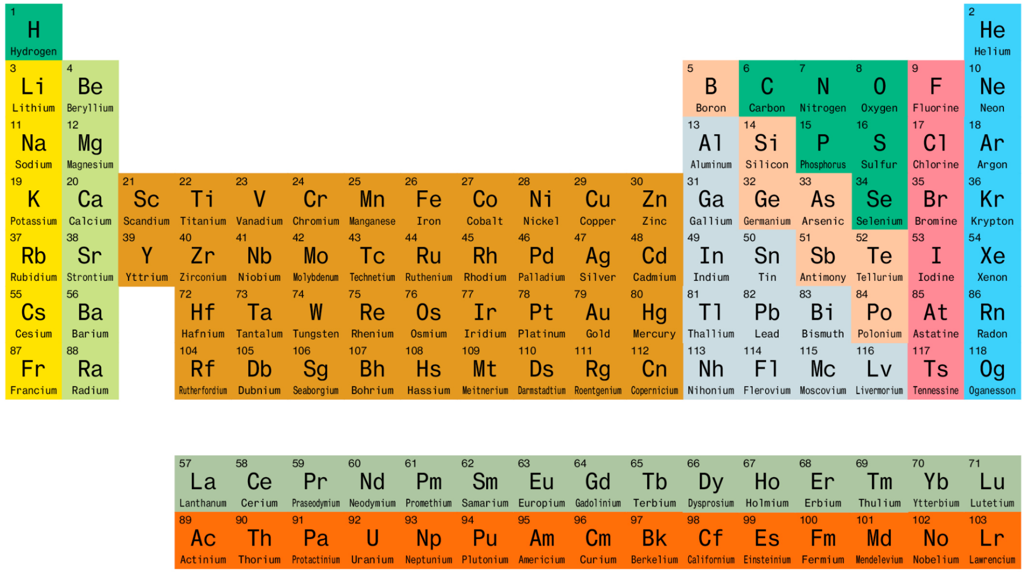

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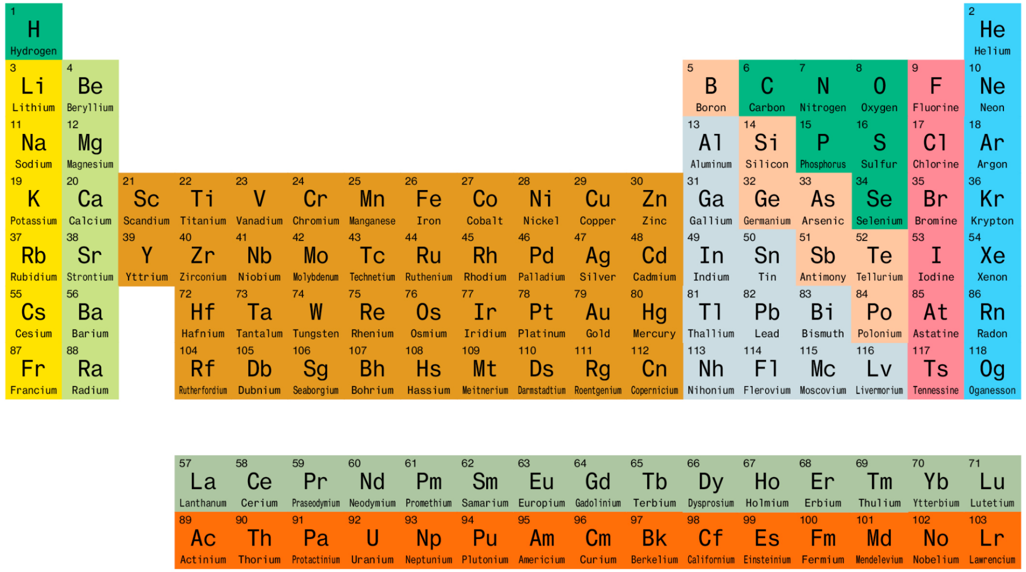

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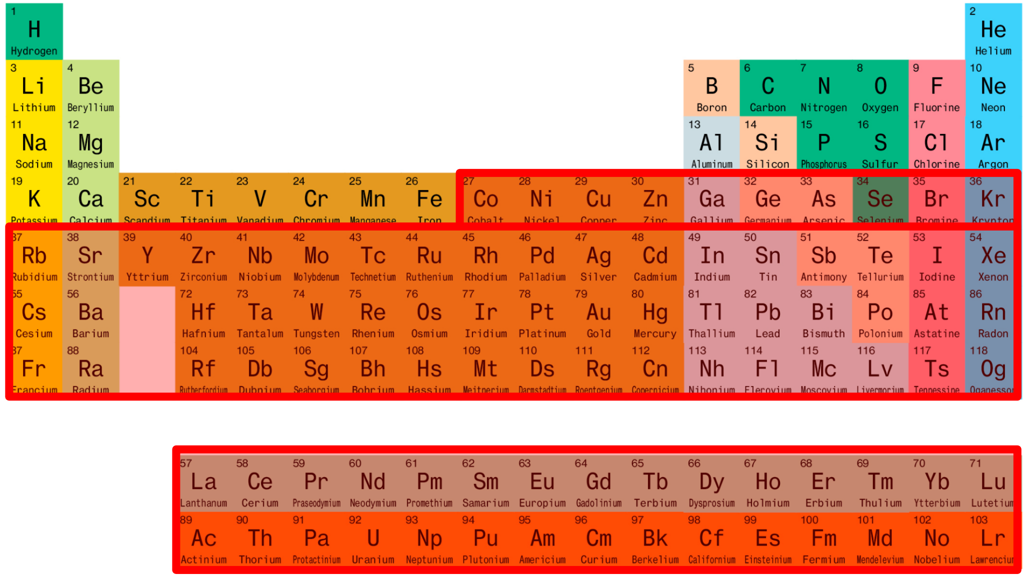
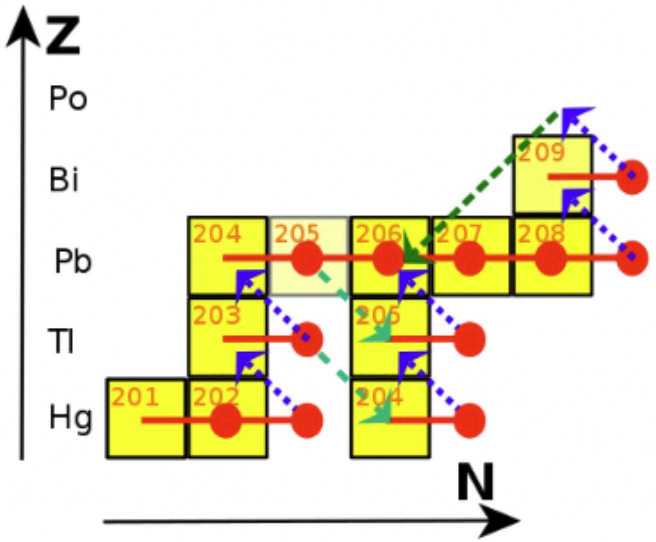


Neutron Capture: s-process



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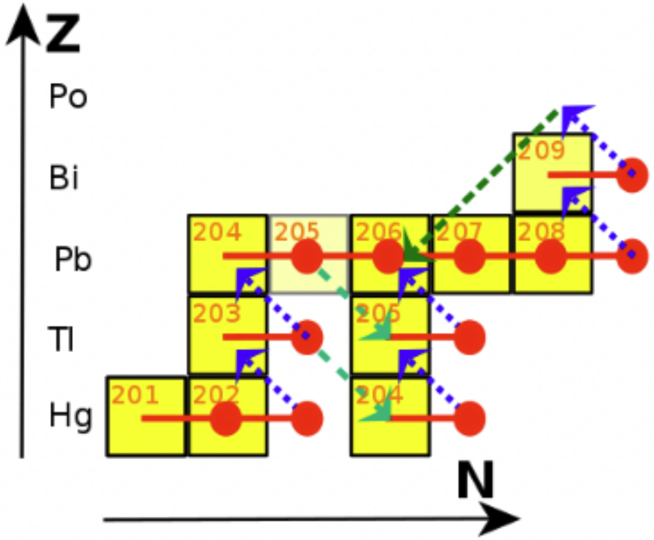

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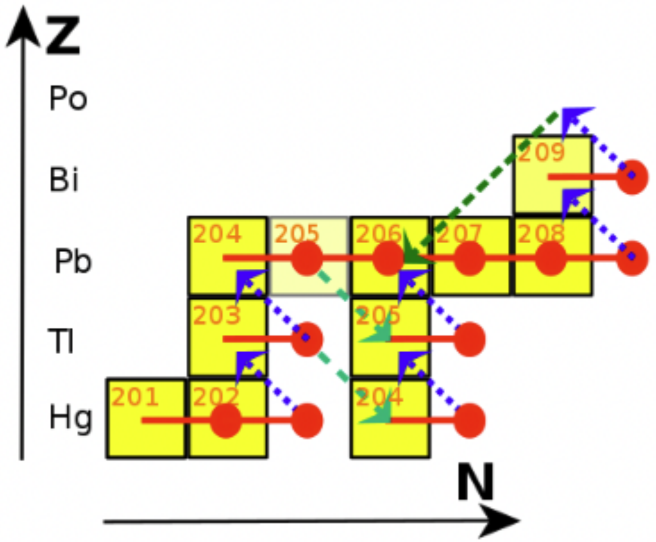

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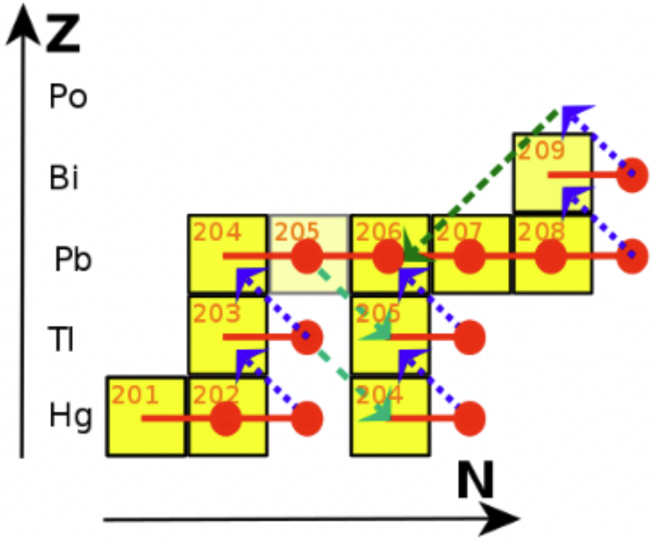

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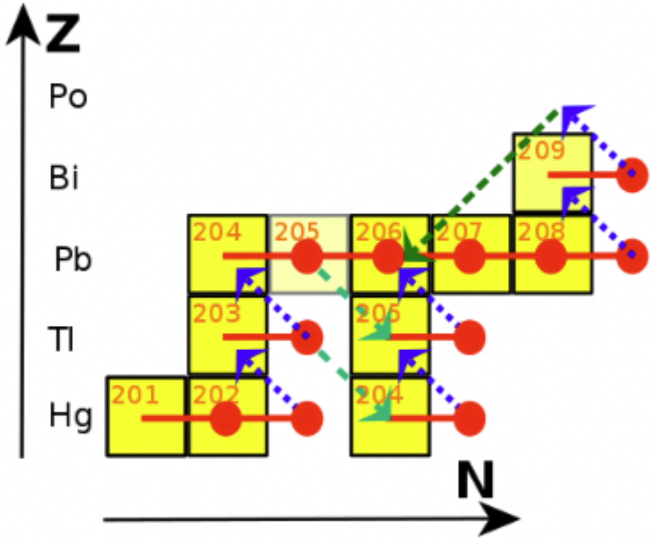
4. Slow, inefficient, can't reach all elements.
    1. Stops at lead, can't reach Uranium, thorium, etc.



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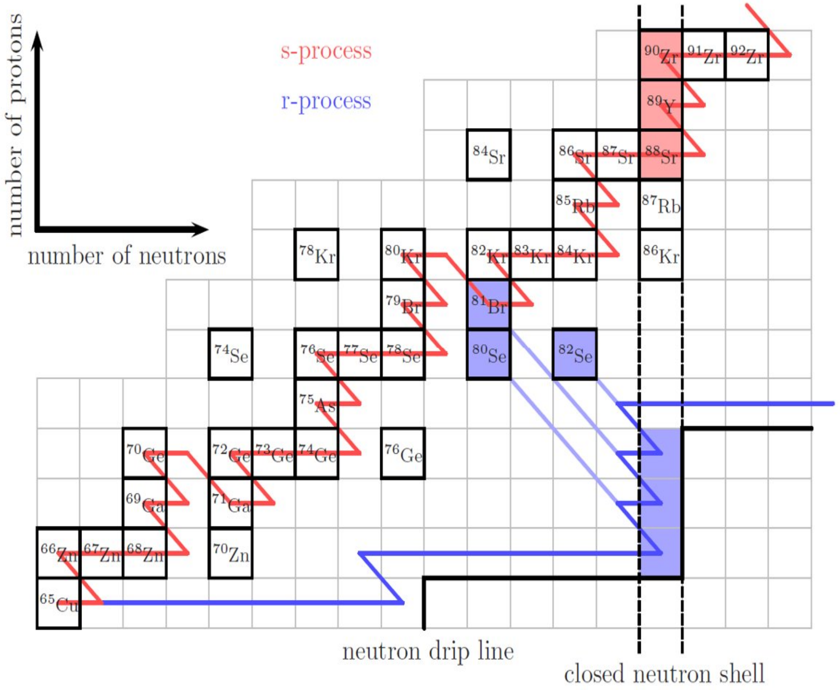

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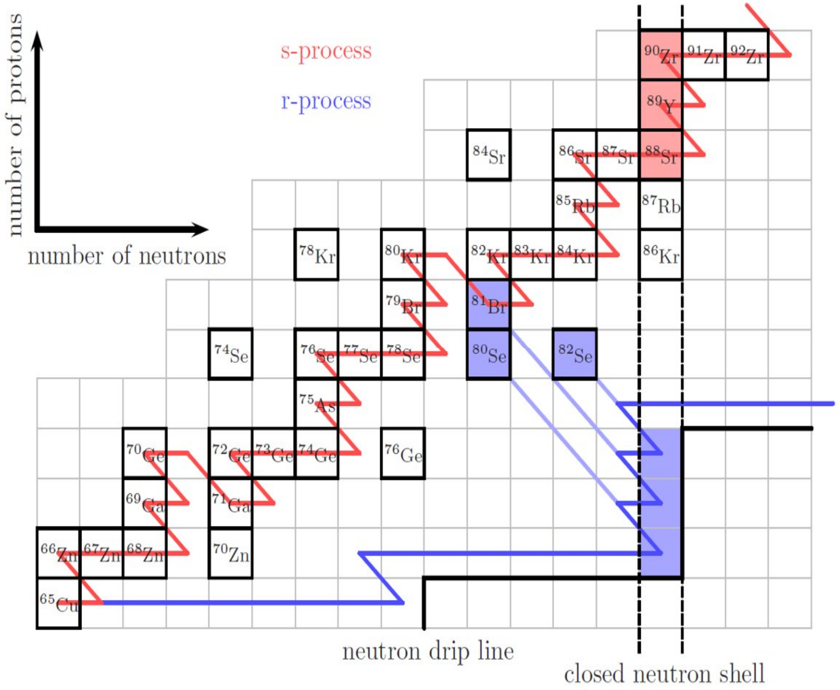
5. We need neutron-rich environment
    1. Neutron Star Mergers



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=> **Can we tell which heavy elements, and what amount, were synthesized by analyzing kilonova's thermal emission?**

* additional EM emission such as synchrotron, gamma-ray burst, etc.

Kilonovae Modeling Challenge

Merger	**Ejecta**	**R-process**	**Radioactive Plasma**	**Radiative Transfer**
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Weak Interactions (neutrinos)	Electron Fraction		Cloud Dynamics	Radiation Approx.
Magnetic Fields				non-LTE effects

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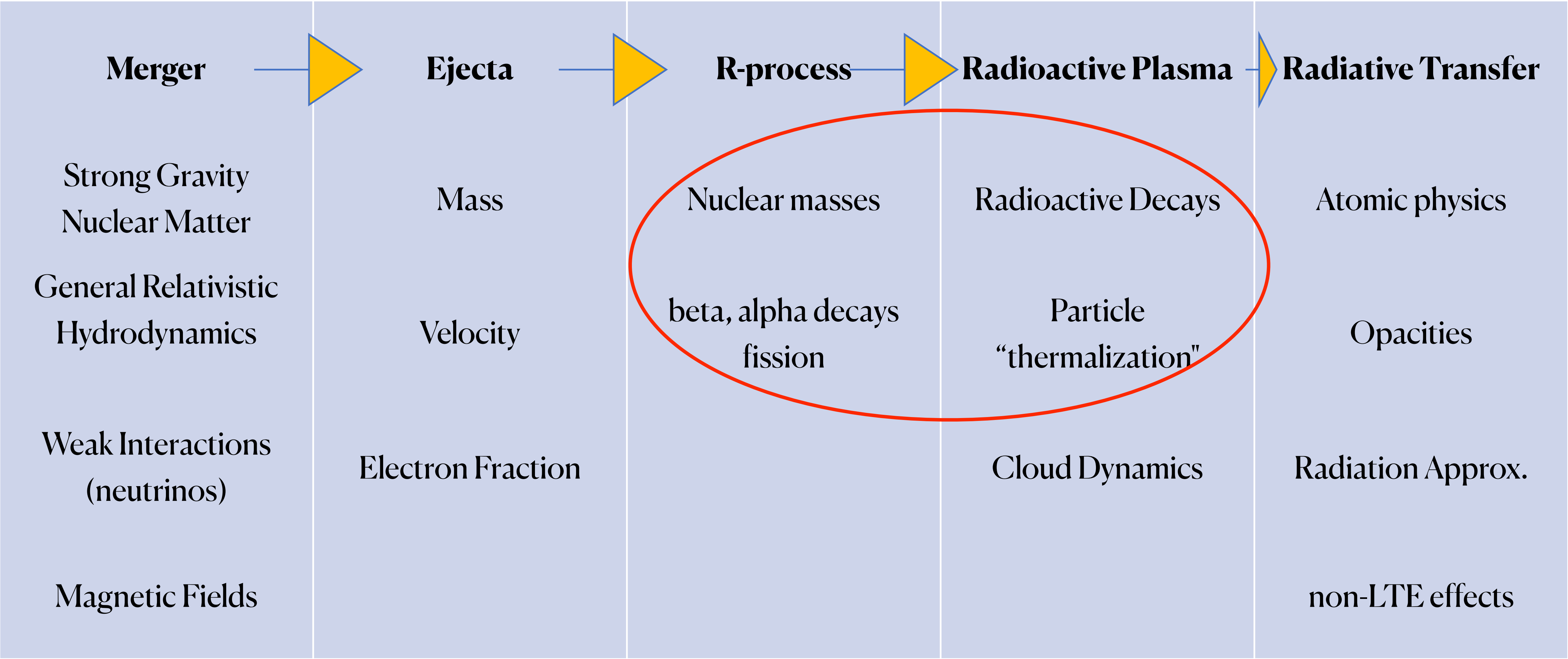

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GW170817 and Simulations

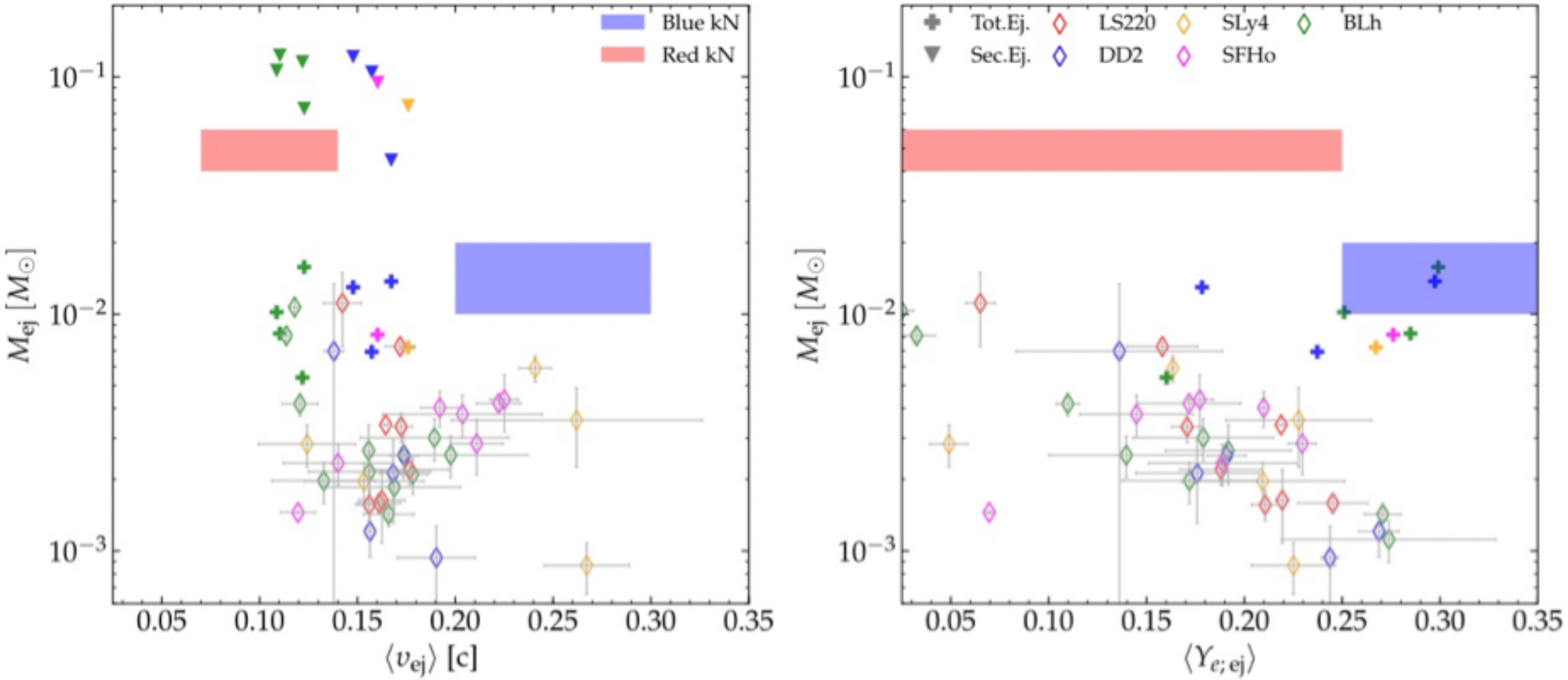

Figure 6. Summary of the ejecta properties of our models. Diamonds mark the dynamical ejecta, crosses include the contribution of the spiral-wave wind for the long-lived models, and triangles are an estimate of the total ejecta mass on a secular timescale, assuming 40% of the disk mass is unbound on secular timescales. The ejecta mass is shown is terms of the mass-averaged velocity (left) and of the averaged electron fraction (right). The filled blue and red patches are the expected values of ejecta mass and velocity for blue and red components of AT2017gfo compiled by Siegel (2019), based on Villar et al. (2017).

Nedora et al., 2021

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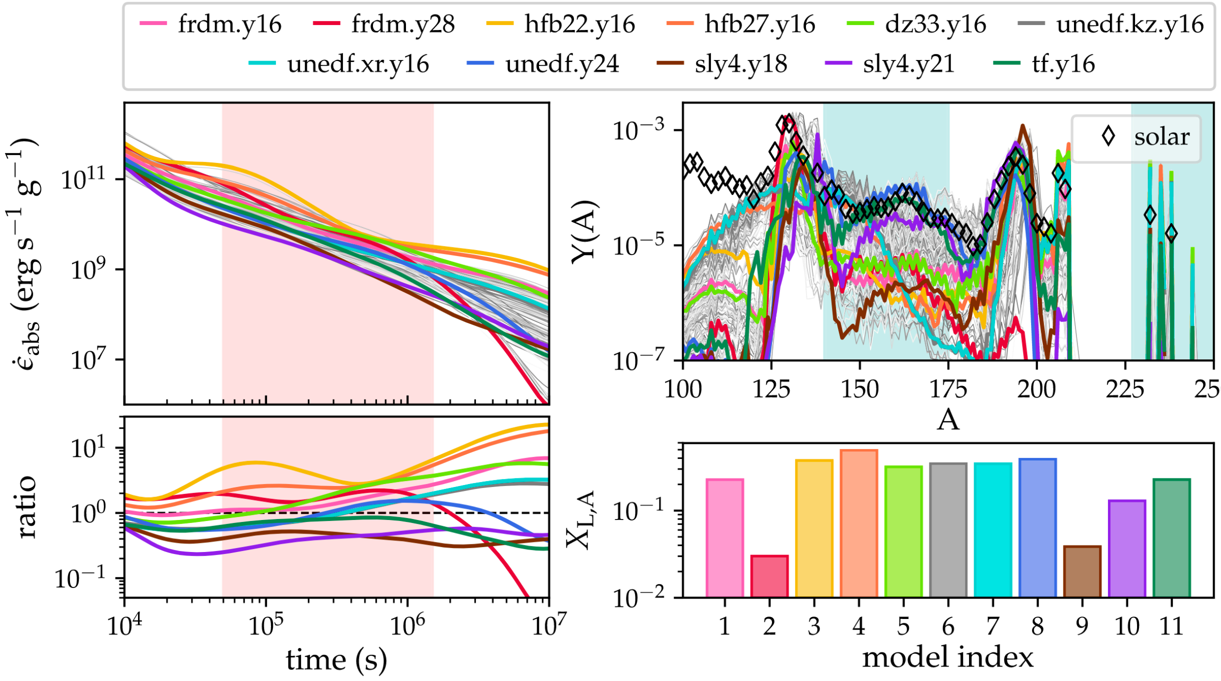
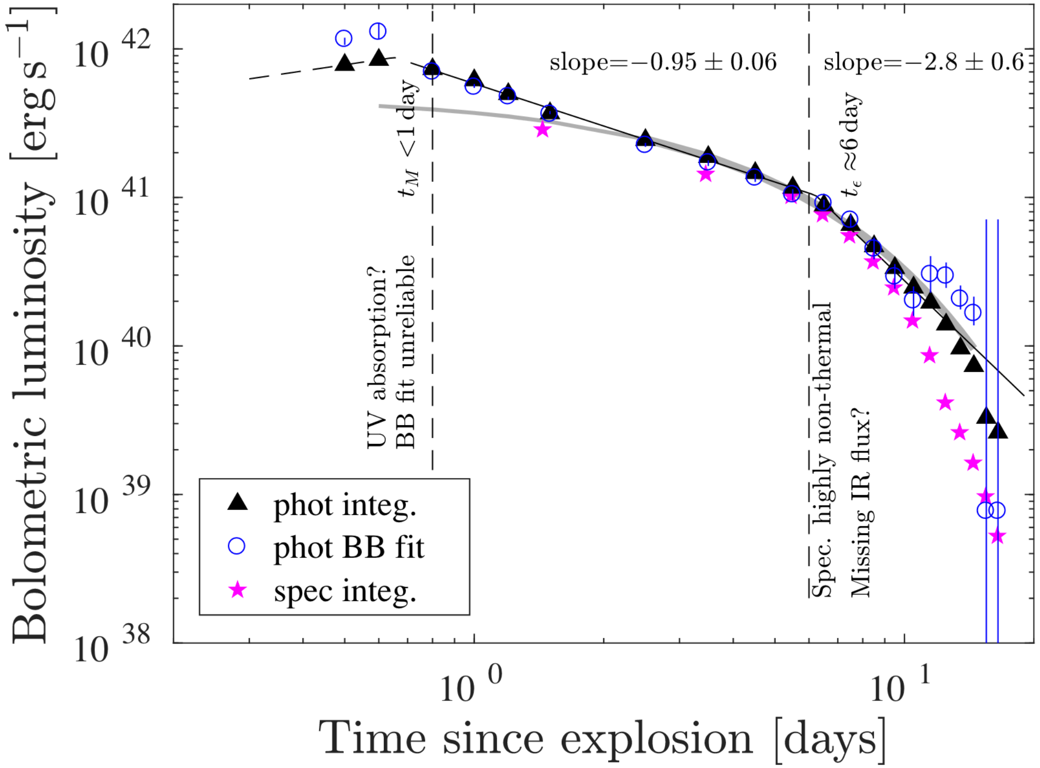


Barnes et al., 2020

GW170817



Waxman et al., 2018

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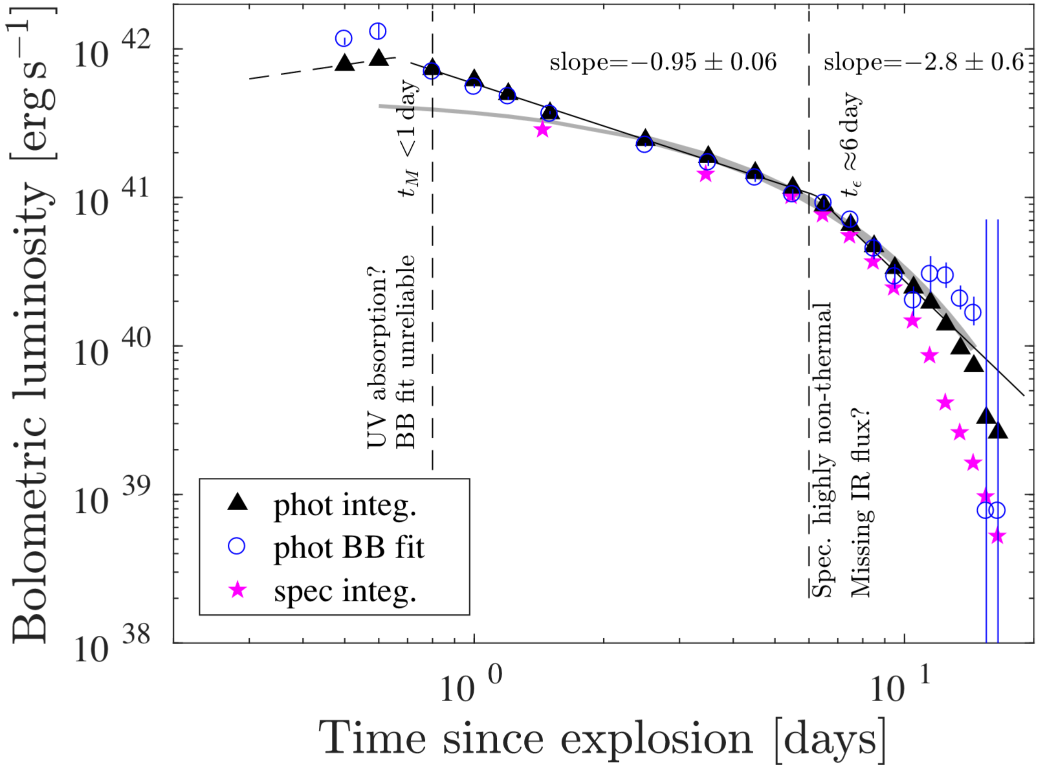

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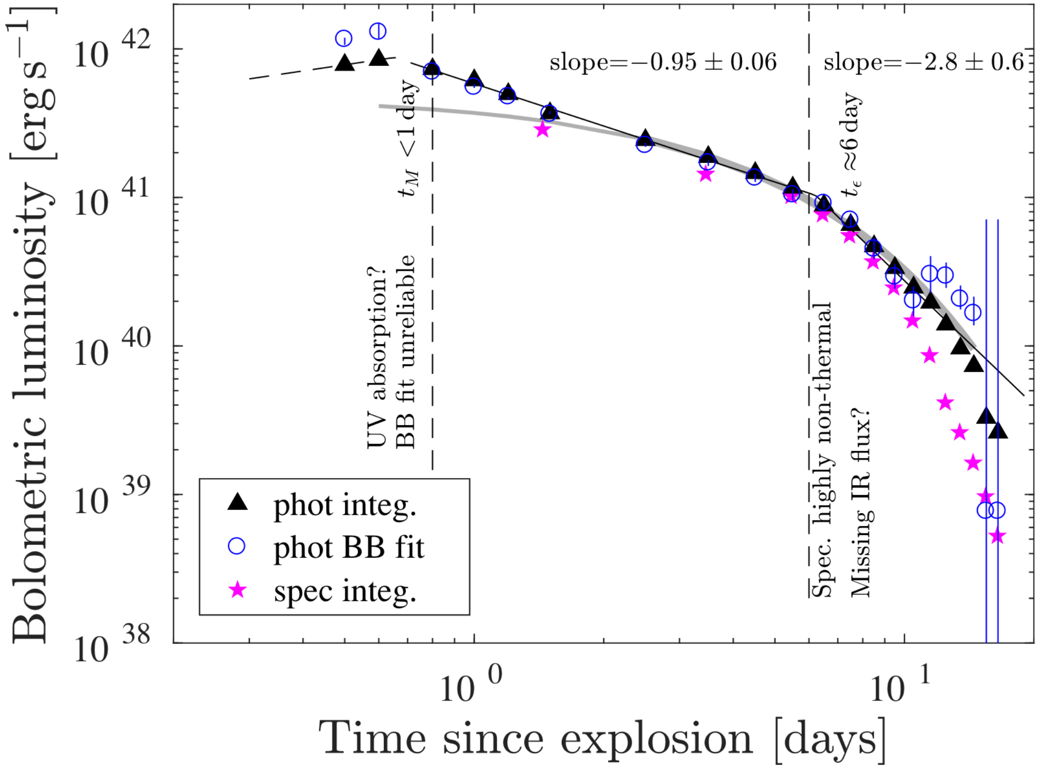

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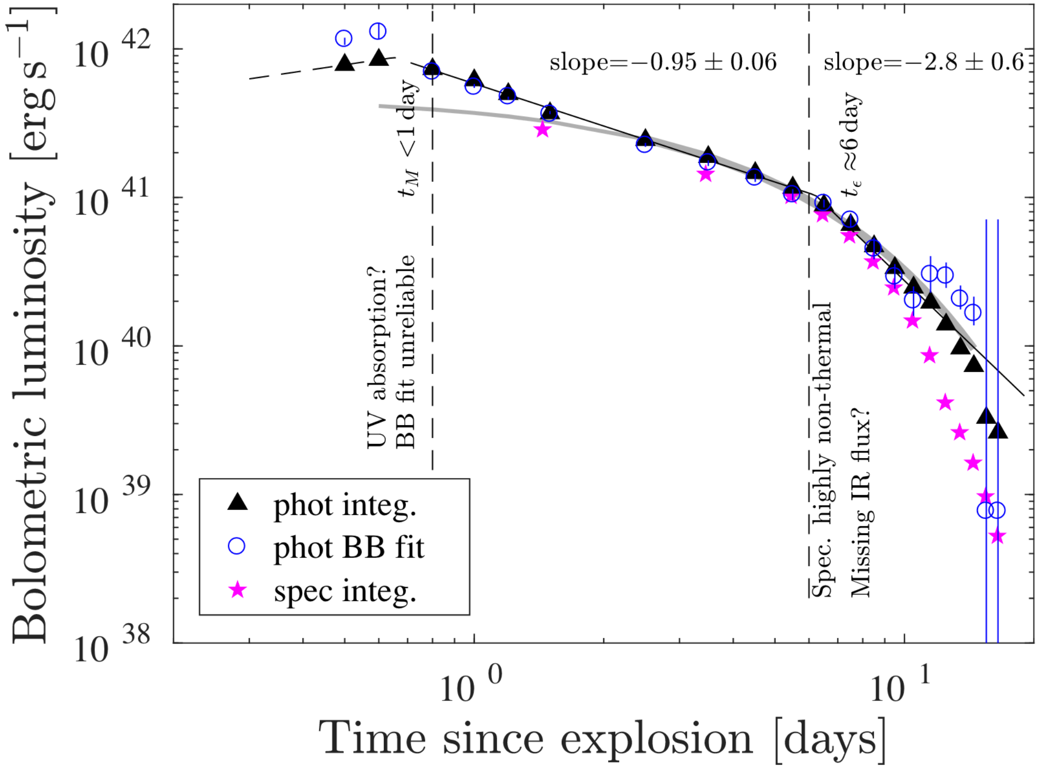
- Can we reconstruct nucleosynthesis from $\dot{Q}_{dep}$?



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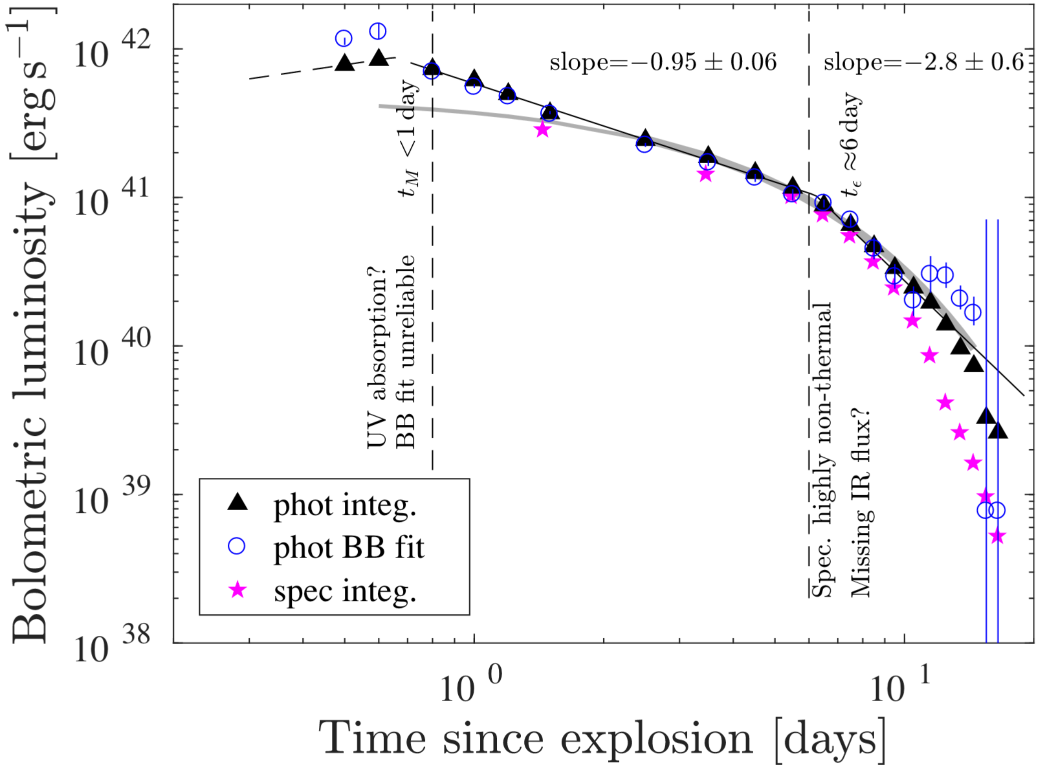

Waxman et al., 2018

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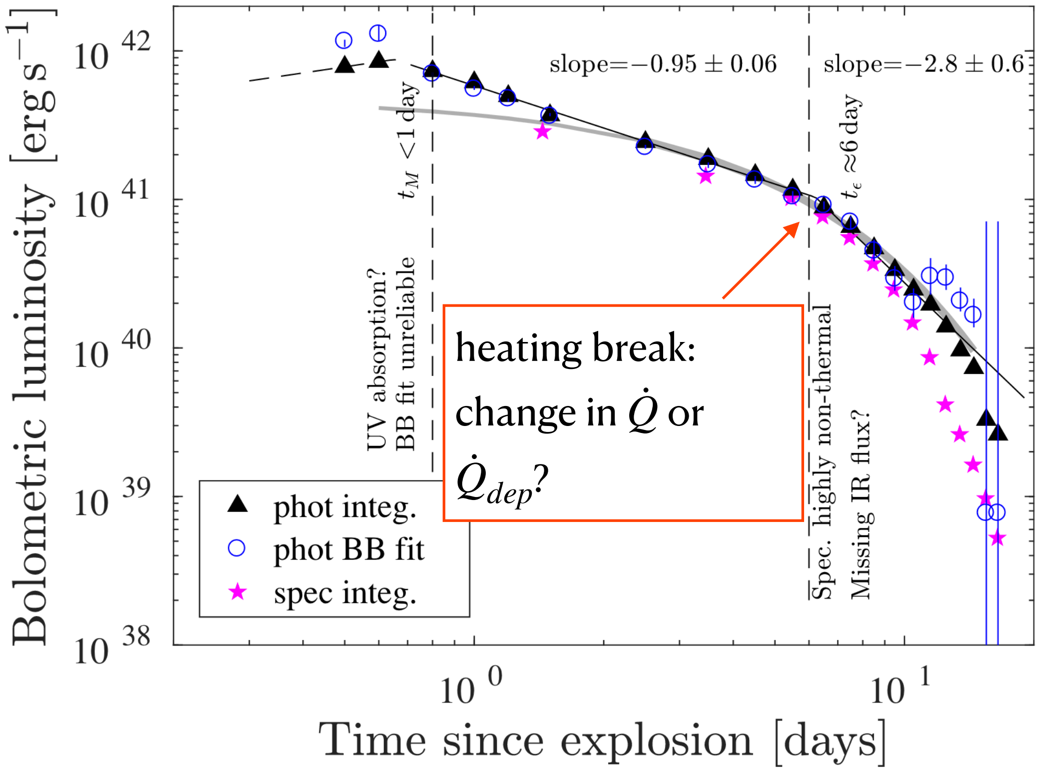

heating break: change in $\dot{Q}$ or $\dot{Q}_{dep}$?

Waxman et al., 2018

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- **I examine** decay particle thermalization for charged decay products (e, α-particles) based on extensive nucleosynthesis simulations.

How do Electrons Lose Energy?

Electron Losses

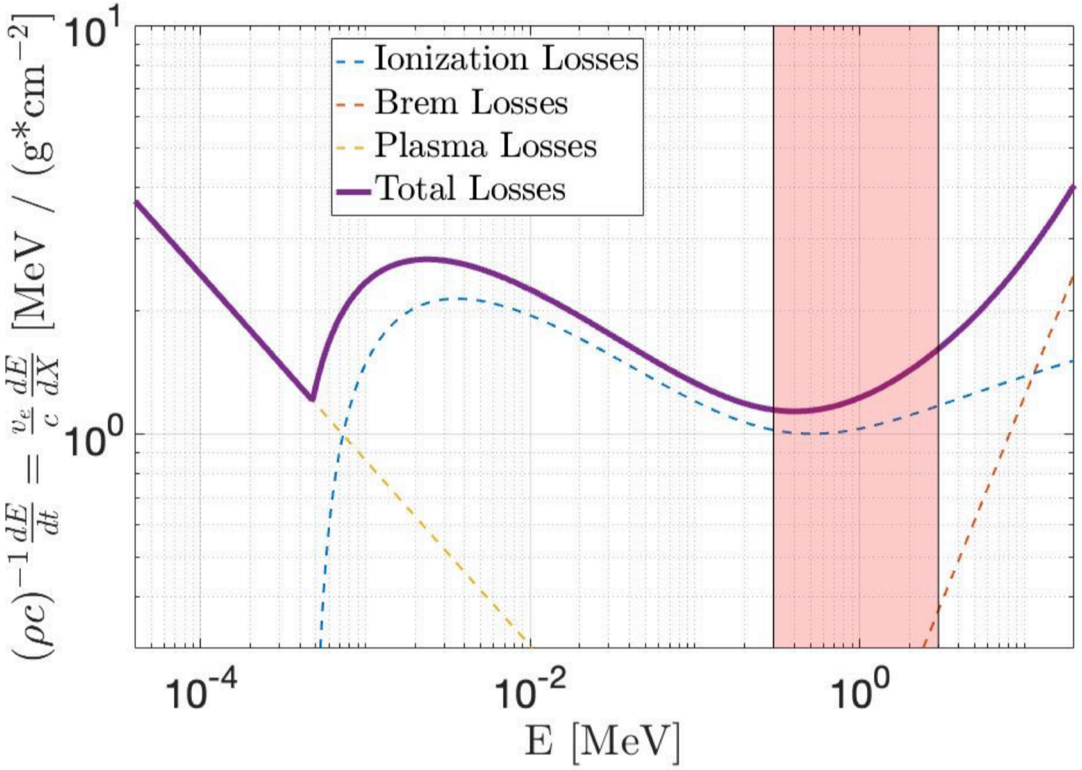

Figure 1: Energy loss rate of electrons propagating in a singly ionized $\chi_e = 1$ Xe plasma ($Z = 54$, $A = 131$). We take $\hbar\omega_p = 10^{-7} eV$. Shaded area shows typical average initial energies of β-decay electrons. For most relevant energies, ionization losses dominate.

Shenhar et al., in prep.

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- Three primary loss mechanisms:
  - plasma losses
  - **ionization losses**
  - Bremmstrahlung

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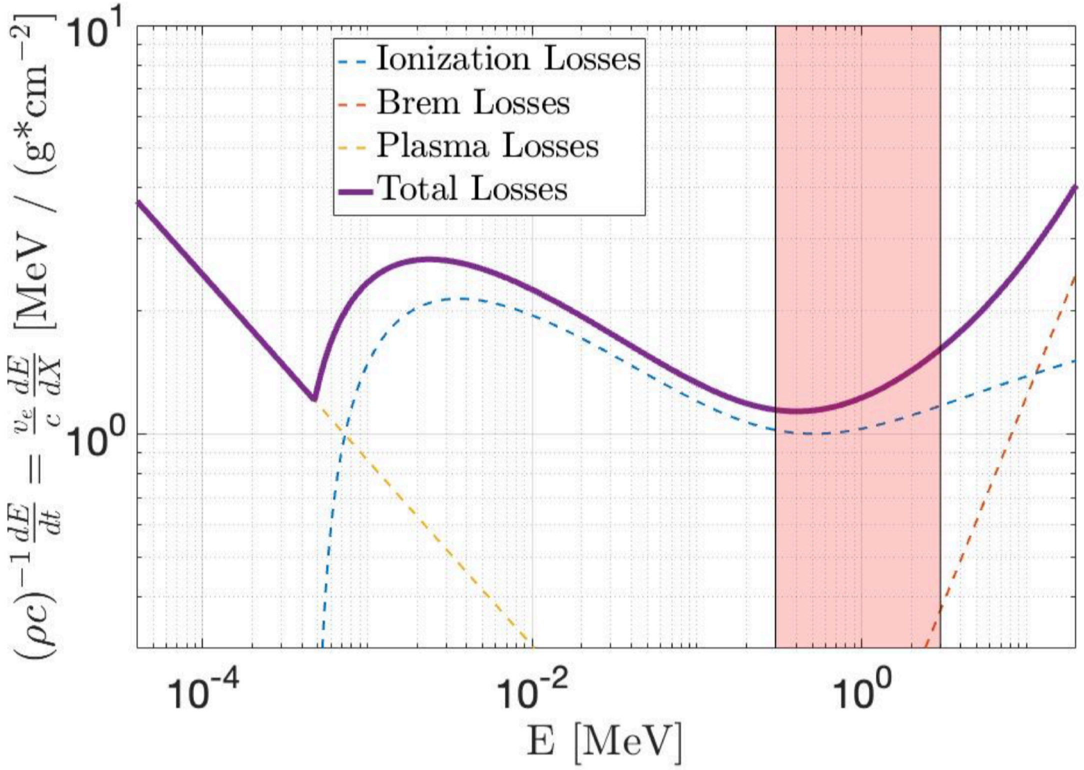

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- We have some preliminary results… to be continued