r-process and neutron star merger

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Where are the heavy elements from

- R-process nucleosynthesis

Rapid neutron capture process

- A succession of rapid neutron captures by heavy seed nuclei

- $\lambda_n > \lambda_\beta$

β −decay rate

- From the quantum perturbative theory:

$$\text{I(p)dp}=I(p)dp = \frac{2\pi}{\hbar}\left\|\int \varphi^*{}_f \; H\varphi_i\right\|^2 \frac{dn}{dE}$$

$$\varphi_i = u_i \qquad\qquad \varphi_f = u_f \phi_\beta \phi_{\overline{\upsilon}}$$

- In Fermi's theory, H is assumed to be a constant

Neutron capture

- $\lambda_n = n_n v \sigma_n$

- The neutron capture cross section:

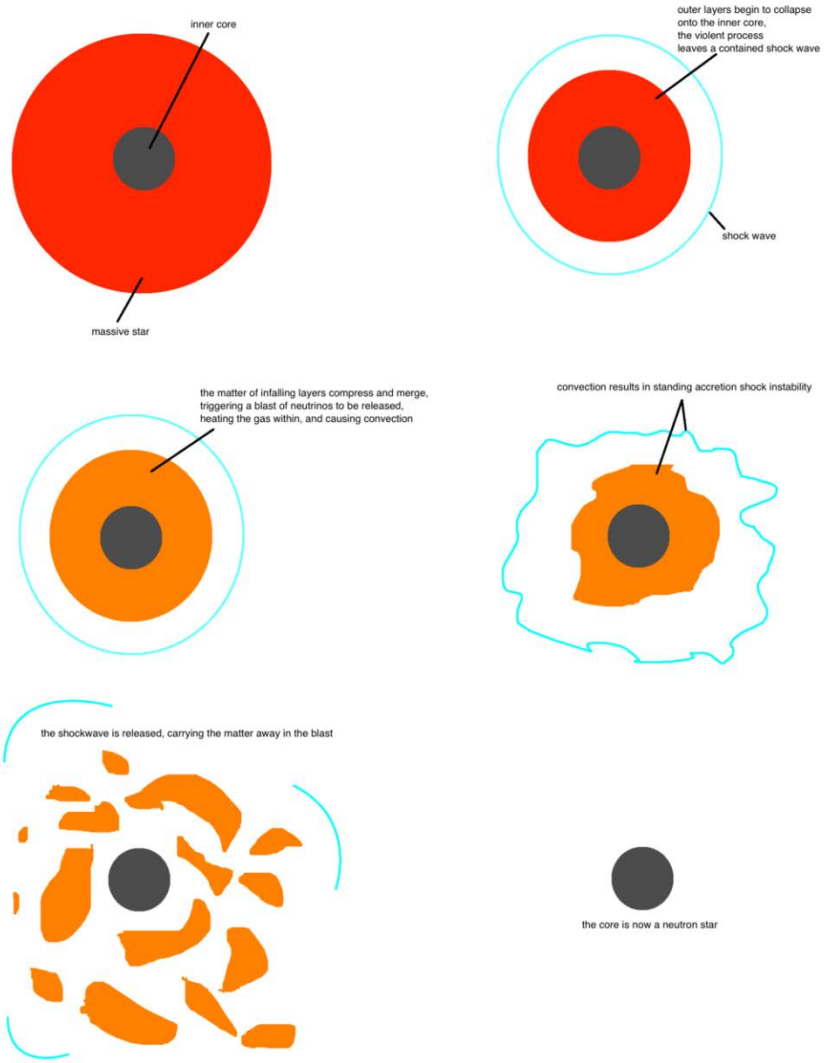
(1)The target type

(2)The incident particle energy(through the potential barrier)

(3)Nuclear reaction (scattering, fission…)

R-process in neutron star merger

- The neutron stars
  $p + e^- \rightarrow n + \nu_e$
- The ejecta
- provide the neutron-rich environment needed for the capture reactions

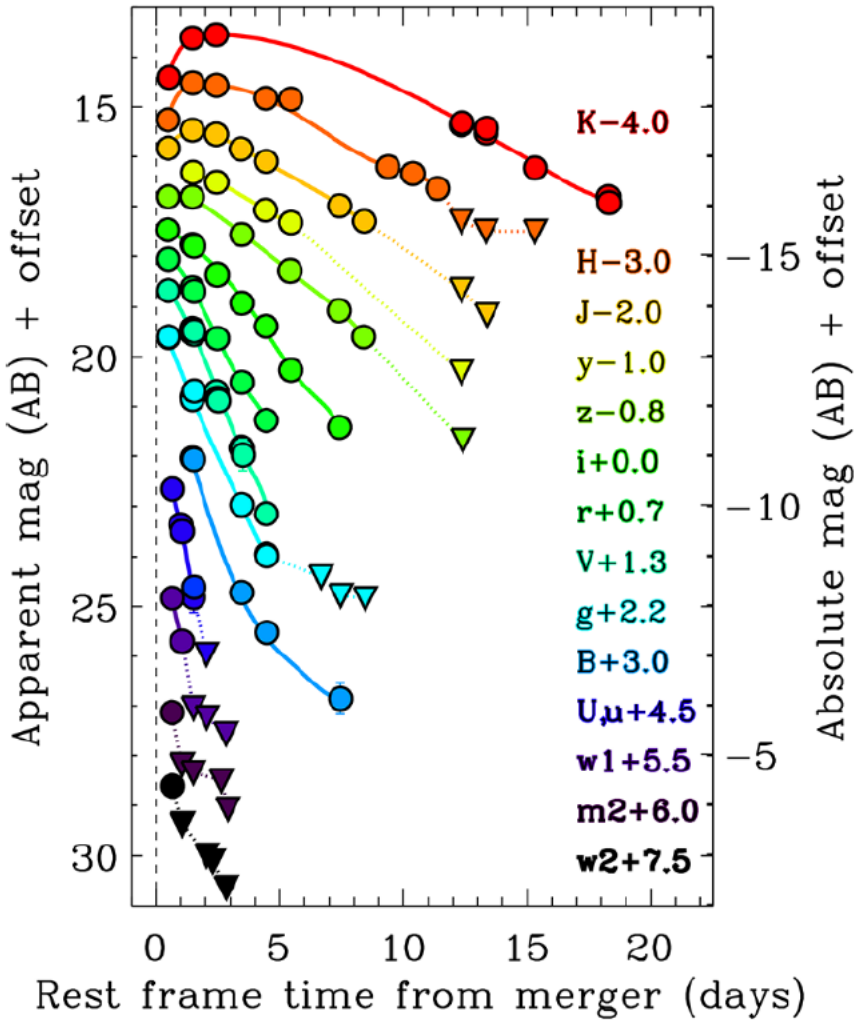


Observable signals ——light curve transition

- The neutron-rich matter from the r-process will decay and power a distinctive thermal glow, a transient in light curve similar to the Type 1a supernova

GW17817/GRB170817A/SSS17a

- An evidence of r-process in the neutron star merger



Other process?

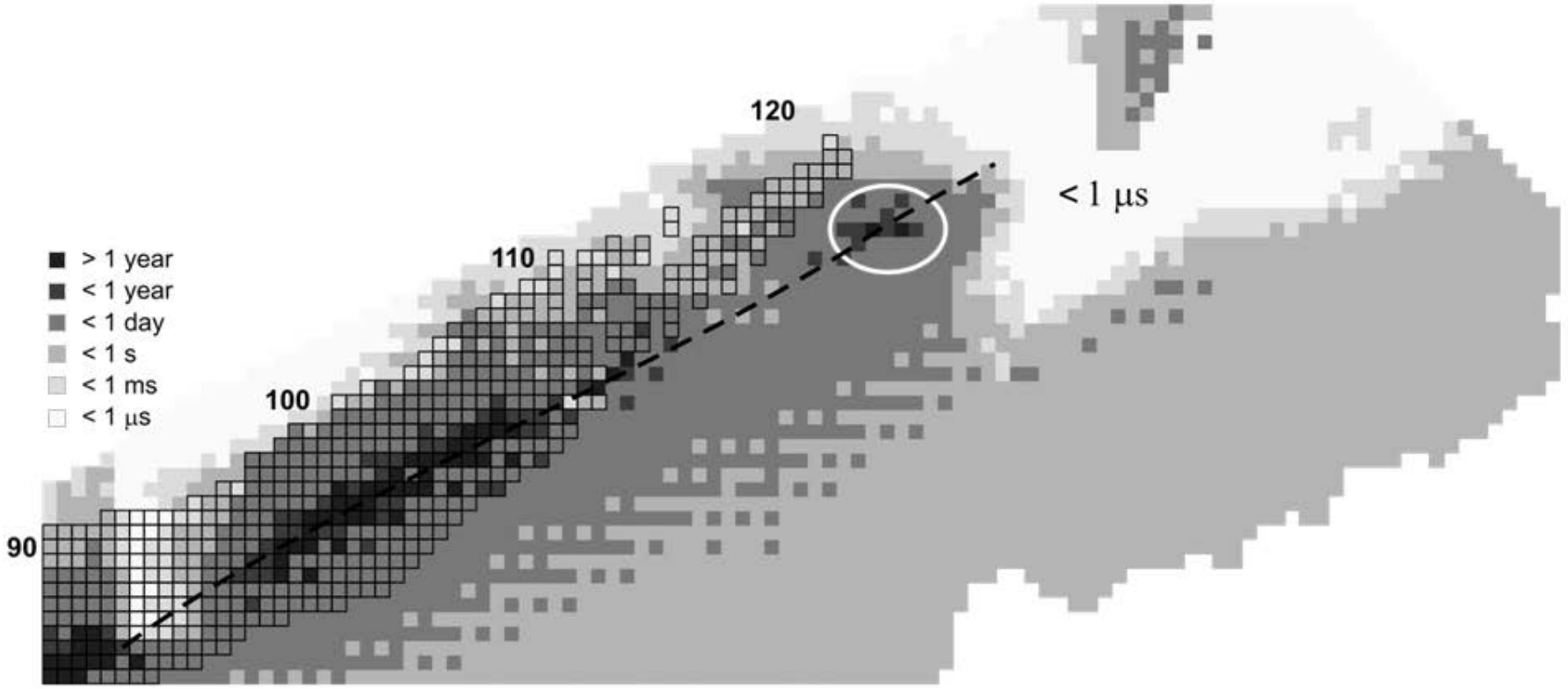
- Magnetic dipole spin down

$$L \propto t^{-2}$$

- Heating from radioactive nickel

My personal naïve opinion

- Super-heavy island of stability?



Magic number

- In quantum mechanics, we have learnt that the electrons of an atom form a shell-like structure. In a nucleus, we have similar structure when a nucleon type is at magic number.

- In nuclei the closed nucleon shells result in an enhanced binding of the atomic nucleus—that opposes Coulomb repulsion of protons.

Flerovium

- Flerovium is a super-heavy artificial element with sumbol Fl and atomic number 114. It is an extremely radioactive synthetic element.

- Flerovium is predicted to be near the centre of the island of stability, and it is expected that heavier flerovium isotopes, especially the possibly doubly magic flerovium-298, may have even longer half-lives.

Z=120 and the second island

- Element 120 (Unbinilium) has not been synthesized

- A second island is predict by Yuri Oganessian in 2008 and it would be centered on element 164 (Unhexquadium), especially the isotope 482Uhq, with a stability similar to that of flerovium.

I think it is possible

- The neutron capture process is an alternative method for the production of new heavy elements. Strong neutron fluxes might be provided by nuclear reactors and nuclear explosions under lab conditions and by supernova explosions in nature (Valeriy et. al. 2013)

Two questions

- Can we predict the half-life and the radiation energy of the unknown super-heavy elements?

- How can we distinguish the radiation of super-heavy elements from that of normal heavy elements based on the observation of the light curve?

Thanks