Non-LTE Ionization Modeling for Helium and Strontium in Neutron Star Merger Ejecta

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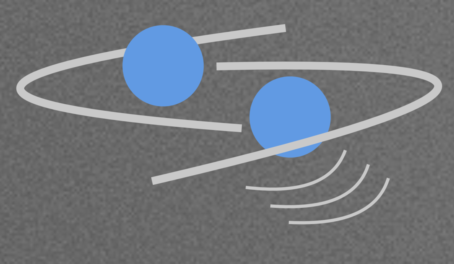
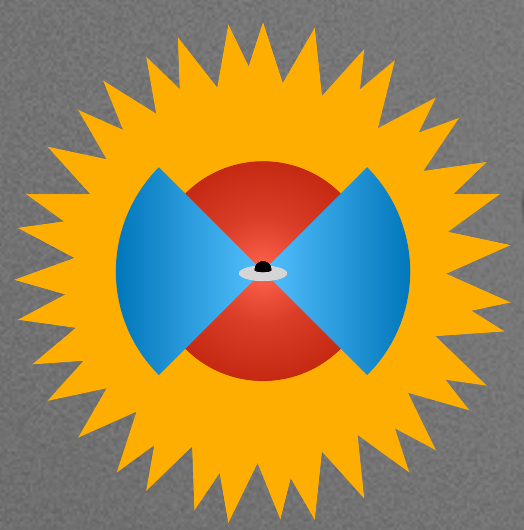
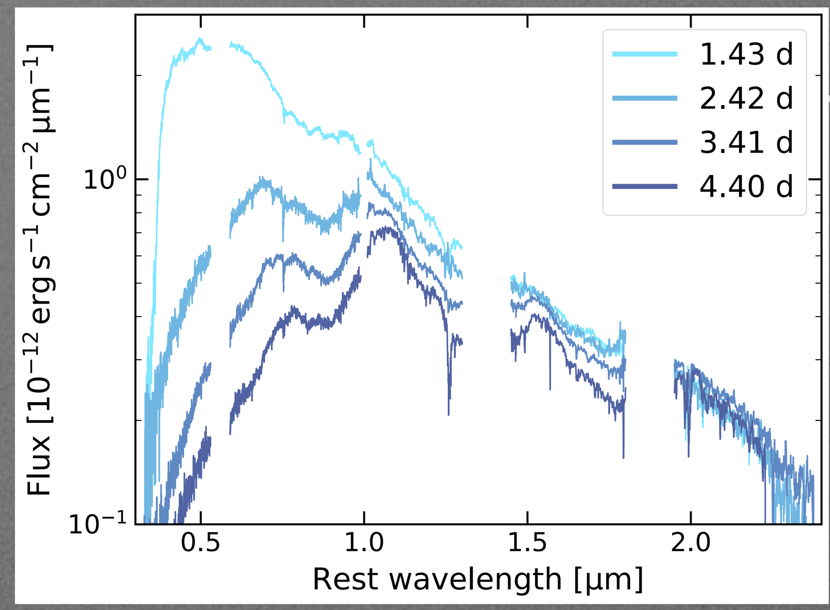
Introduction





Neutron Star (NS) merger : the origin of heavy elements

The early-phase spectra of AT2017gfo



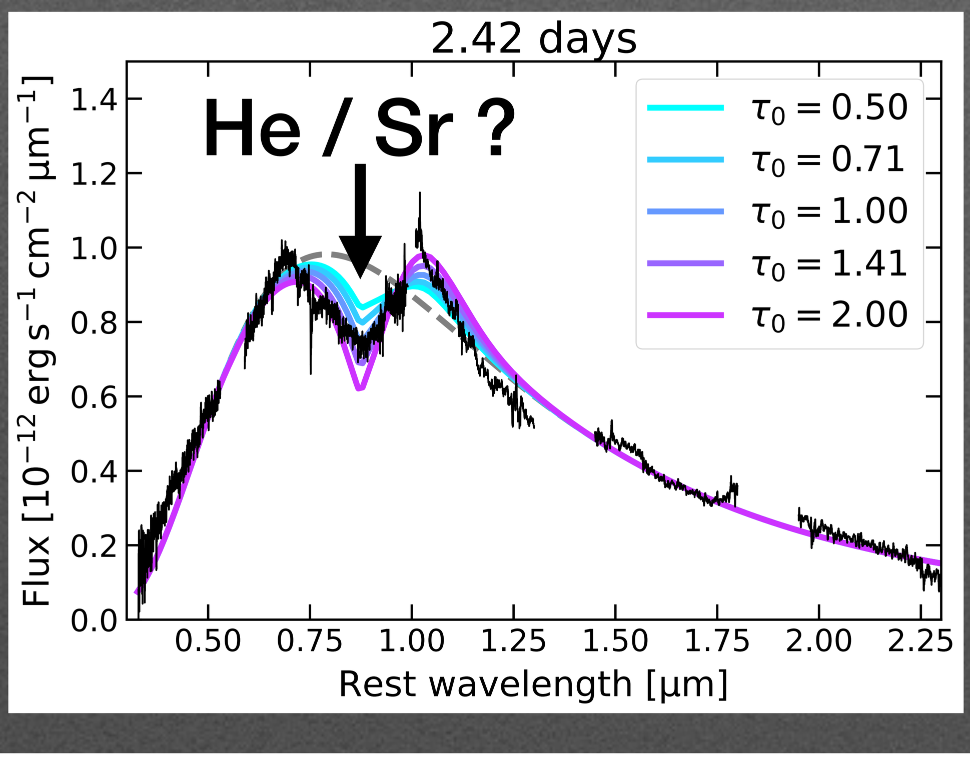
Non-LTE ionization modeling

Better estimate elemental abundances

- Nucleosynthesis condition ?
- Mass ejection mechanism ?

Methods

Sobolev optical depth : $\tau = \dfrac{\pi e^2}{m_e c}\lambda_l f_l t n_l$



Ionization balance

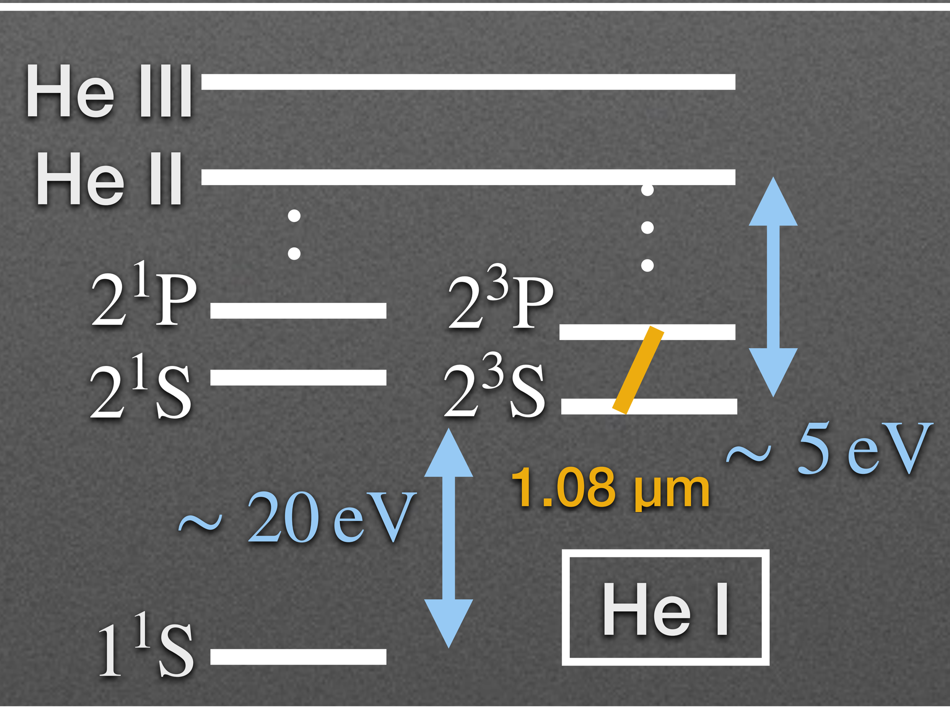
$$\frac{n^{(i+1)}}{n^{(i)}} = \frac{R_{\rm ph} + R_{\rm nt}}{n_e \alpha_{i+1}} \approx W\left(\frac{n^{(i+1)}}{n^{(i)}}\right)^* + \frac{1}{n_e \alpha_{i+1}}\frac{\dot{q}}{w_i}$$

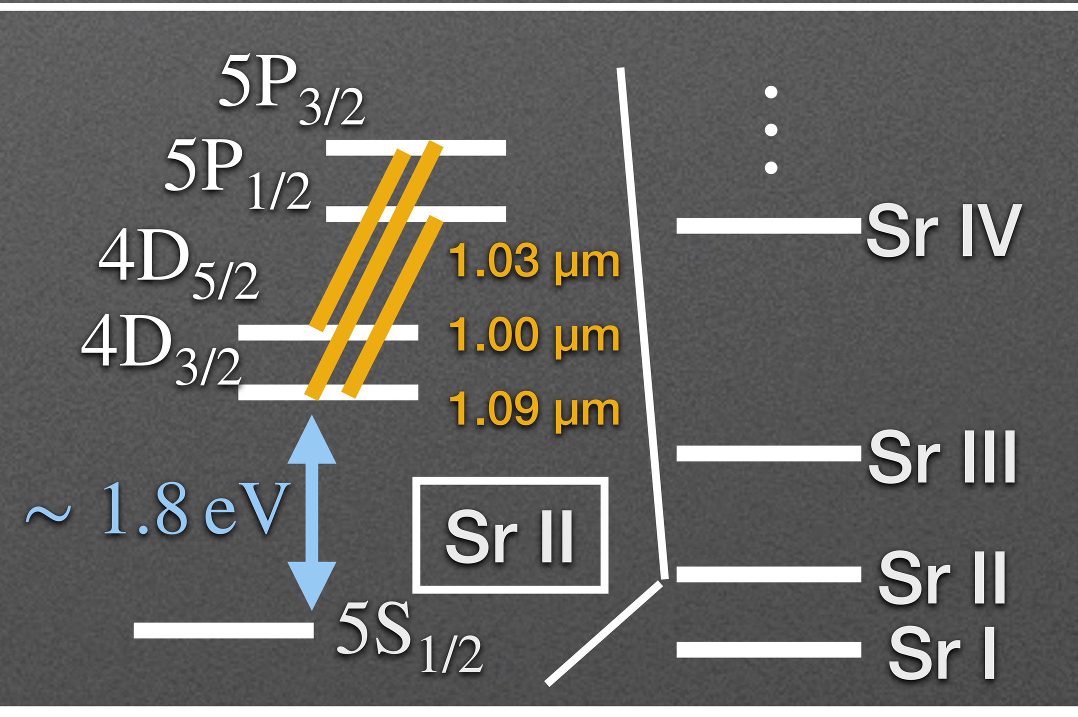
Thermal — Non-thermal (β-electrons)

Excitation balance

He : Solve rate equation

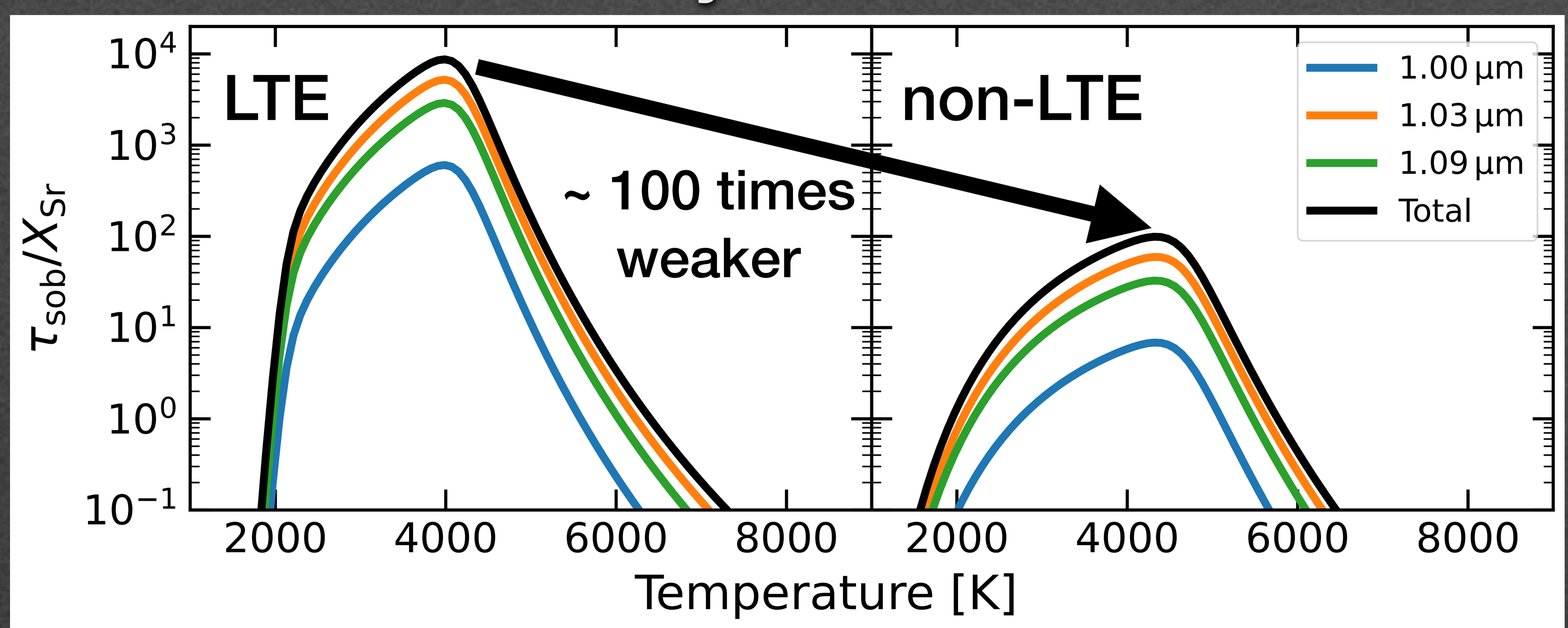
Sr : Assume the Boltzmann dist.





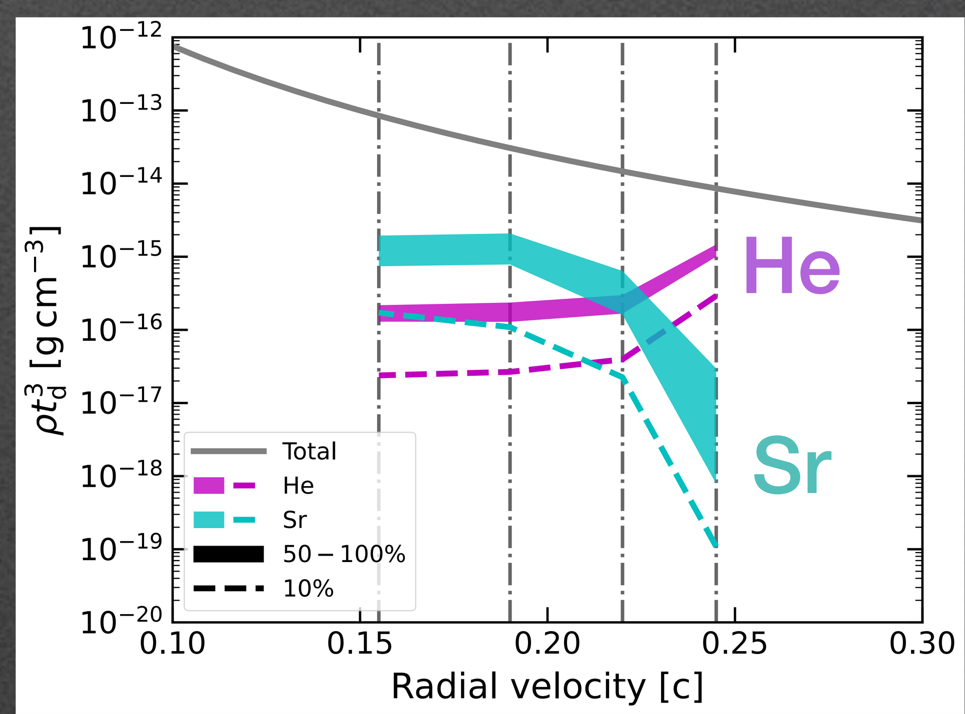
Results

Sobolev optical depth normalized by Sr mass fraction



Ionization by high-energy electrons is significant !

Required mass density of each element

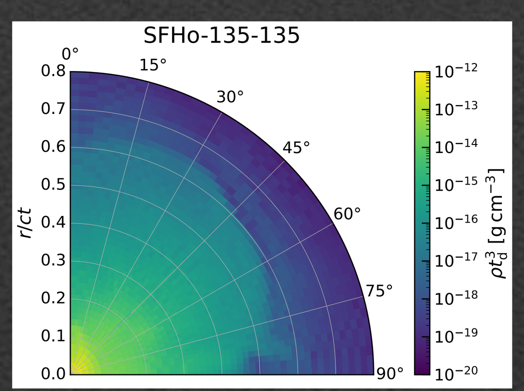


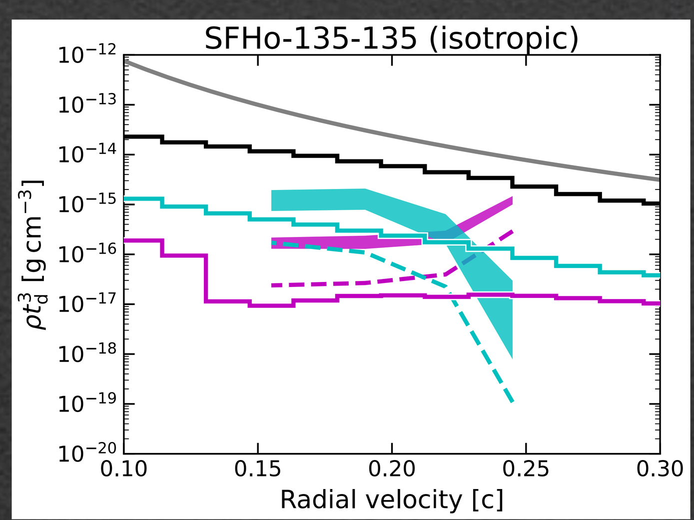
Tomography of elemental abundances

Discussion

Comparison with numerical simulations

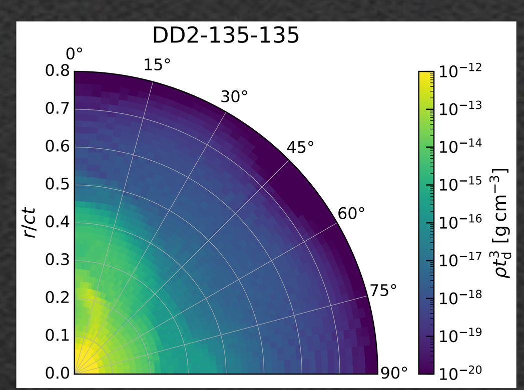
Short-lived NS remnant case

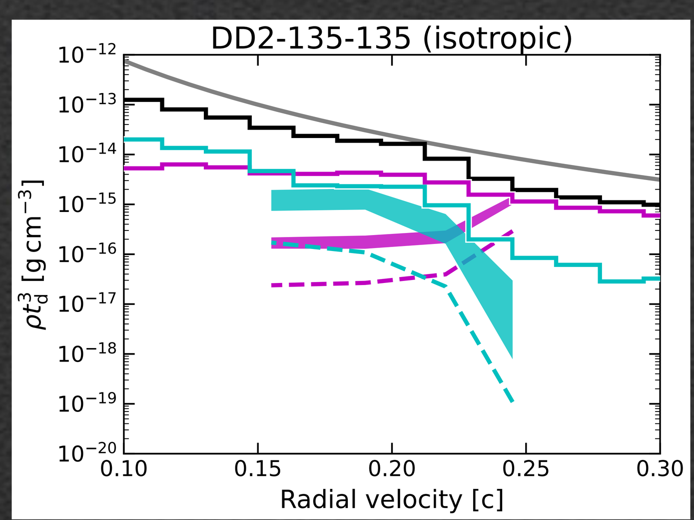




Fujibayashi+ 2023; Kawaguchi+ 2023

Long-lived NS remnant case





Fujibayashi+ 2020; Kawaguchi+ 2022

	Spectral feature (This work)	Light curve (Kawaguchi+)
Short-lived NS remnant case	Can be roughly reproduced by Sr alone	Fainter than the observed level due to insufficient mass
Long-lived NS remnant case	He is too much	Consistent

In GW170817, a sufficient post-merger mass ejection with small He abundance seems to occur