Interpreting Inferred Parameters from Analytic Modeling of Kilonova Light Curves

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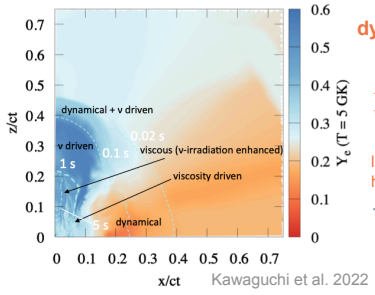
The light curve of kilonova

- The neutron star (NS) merger is considered as a promising site where rapid neutron capture process (r-process) takes place
- In the NS merger, electromagnetic emission powered by the radioactive decay of r-process elements can be observed → **"kilonova"**
- To study nucleosynthesis in NS mergers, it is important to understand the characteristics of mass ejection.
- The light curve of kilonova is characterized by ejecta mass M, velocity v and opacity κ.

Central Problem : Discrepancies between simulations and analytic modeling

Mass ejection after the merger



Kawaguchi et al. 2022

dynamical ejecta ($\lesssim 100$ ms)

$M_{\rm ej}^{\rm dyn} : 0.001 - 0.01\ M_\odot$

$v_{\rm ej}^{\rm dyn} : 0.1 - 0.3\ c$

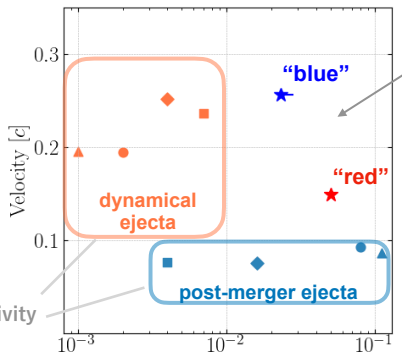
low-Y_e , lanthanide-rich
high opacity
→ **"red" (mainly NIR)**

post-merger ejecta ($\lesssim 1$ s)

$M_{\rm ej}^{\rm pm} : 0.01 - 0.1\ M_\odot$

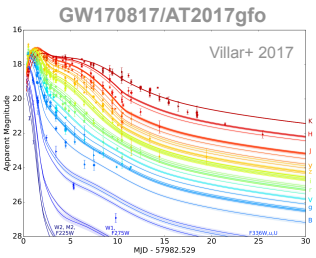
$v_{\rm ej}^{\rm pm} : \lesssim 0.1\ c$

high-Y_e , lanthanide-poor
low opacity
→ **"blue" (optical)**



Numerical relativity simulations
Fujibayashi et al. 2020c, 2023

Analytic modeling (two-component)



Simulations	$\Rightarrow M_{\rm ej}^{\rm dyn} < M_{\rm ej}^{\rm pm}$ and $v_{\rm ej}^{\rm pm} < v_{\rm ej}^{\rm dyn}$
GW170817/AT2017gfo	$\Rightarrow M^{\rm blue} < M^{\rm red}$ and $v^{\rm red} < v^{\rm blue}$

This study : Analytic modeling of simulated light curves

Data Fujibayashi et al. 2020c, Kawaguchi et al. 2022

Merger model : DD2-135

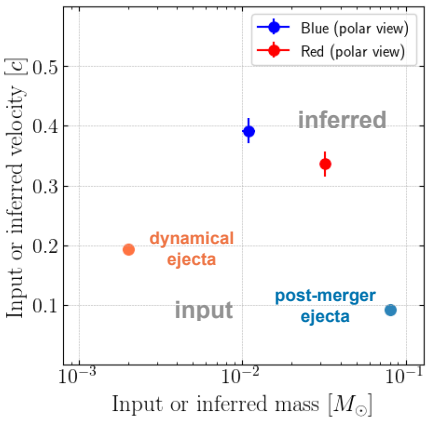
- Numerical Relativity + Hydrodynamical simulation
- Radiative transfer simulations (best match with GW170817)

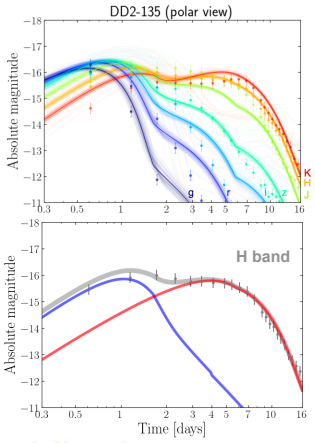
Fitting Model

Analytical model Metzger (2017) (similar to Villar et al. 2017)

Parameter estimation

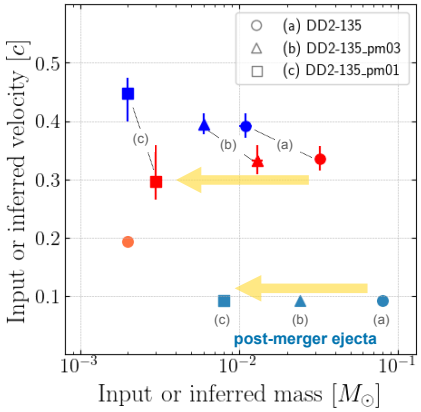
- Markov chain Monte Carlo (MCMC) methods
  emcee (Goodman & Weare 2010)
- 2 component : **blue** ($\kappa^{\rm blue} = 0.5\ {\rm cm^2 g^{-1}}$) + **red**
- 8 parameters : M, v, T_c for each component + $\kappa^{\rm red}$ + σ

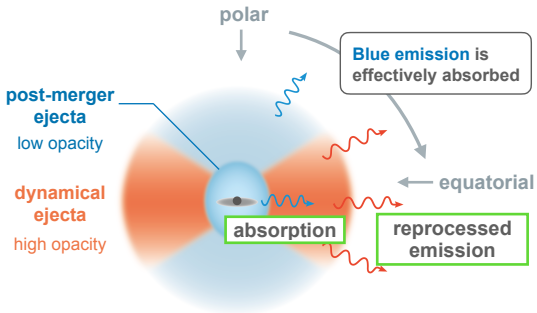




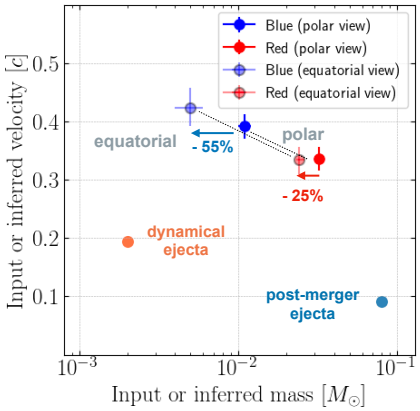
Inferred parameters from analytic modeling do not represent the actual configuration of the kilonova ejecta

For simulation data with different post-merger ejecta masses





Dependence on viewing angle



- The **post-merger ejecta** contribute to both **blue** and **red** emission components
- More emission escapes toward polar direction
- **Blue** emission is effectively absorbed in the equatorial direction