Kilonova Lightcurves & Fitting Formula

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History

- On 17th August 2017, LIGO detected a GW signal from the NS-NS merger 40 Mpc away.
- The discovery of EM counterpart AT2017gfo followed the event.

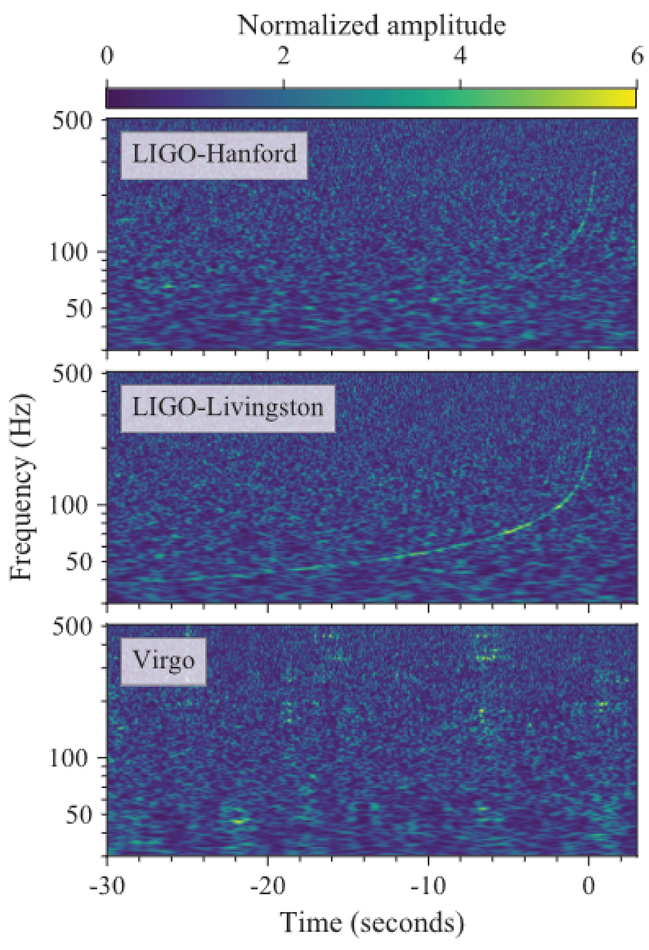

Figure 1. GW170817 Signal (Credit: Abbott 2017)

Questions we set to Answer

- Modelling of the observed Kilonova lightcurve using r-process.
- Understanding of the BNS merger .
- Expression for ejecta-mass and velocity given the masses of merging NS.

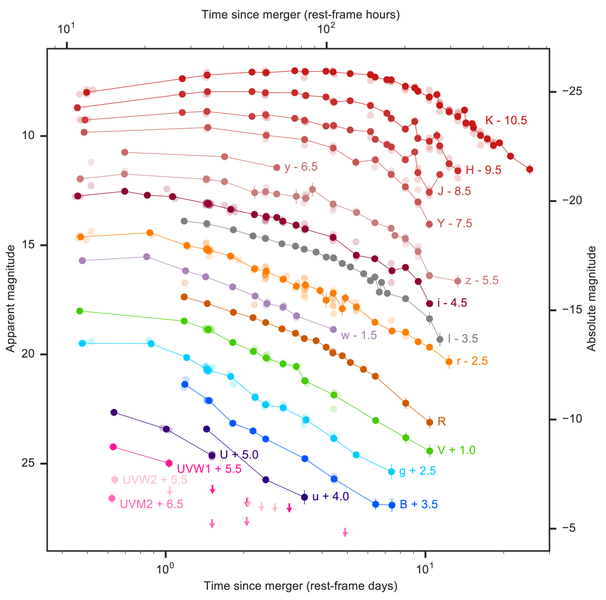

Figure 2. Observed Lightcurve of Kilonova AT2017gfo (Credit: Arcavi 2018)

Conclusion

- Given a fitting relation of ejecta mass and velocity for equal mass BNS merger.
- Obtain lightcurves of BNS merger with different remnants

General Kilonova Structure

- **Dynamical Ejecta :** Ejecta Components that arise in ms timescale mostly from polar regions with velocities $\geq 0.4c$.
- **Disk Wind Ejeta :** These arise from the equatorial region and mainly come from the accretion disk and velocities $\leq 0.2c$.

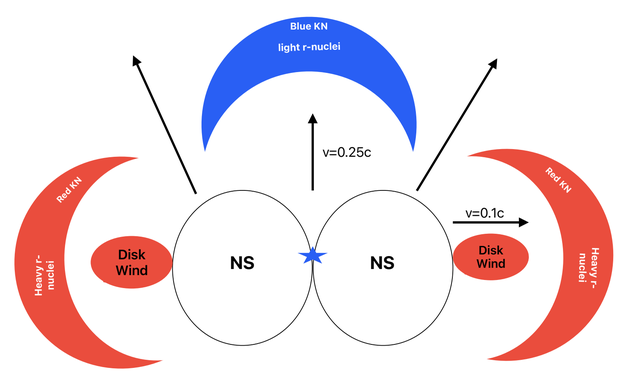

Figure 3. Schematic Diagram of Kilonovae Event

Kilonova Model

- Most of the energy of Kilonova is derived from the radioactive decay of neutron-rich elements.
- The energy is lost in the form of light we receive and in expansion
- Radioactive particles transfer energy by collisional excitation

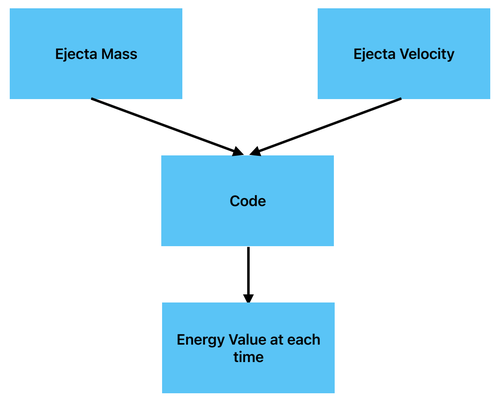

Figure 4. Input and Output of Code

Main Governing Equations

$$\frac{dE_i}{dt} = -\frac{E_i}{t} + \dot{Q}_i(t) - L_{rad,i}(t)$$

$$\dot{q}_i(t) = \sum_i \int_{t_{0,i}}^{t} dt' c\beta K_{st}(E_i; t', t)\rho_m(t)\frac{N_i(t')}{t}$$

$$L_{rad,i}(t) = \frac{f_{esc,i}E_i}{t_{esc}}$$

Results

Fitting Formula

$$\frac{M_{ej}}{M_\odot} = a * \left(\frac{M_1}{C_1}\right)^3 + b * \left(\frac{M_1}{C_1}\right)^2 + c * sin\left(\frac{M_1}{C_1}\right)$$

$$\left(\frac{v_{ej}}{c}\right) = a * C_1^3 + b * sin^2(C_1) + c * C_1$$

	a	b	c
M_{ej}	0.003	-0.038	-0.8977
v_{ej}	27788.340	-5680.583	289.371

Table 1. Fitting Values

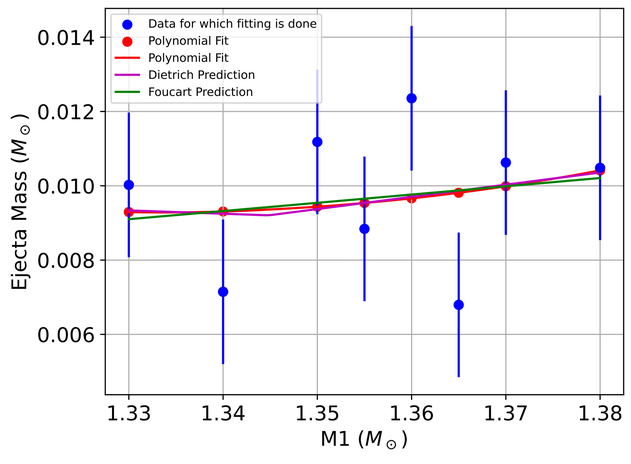

Figure 5. Ejecta Mass Fitting

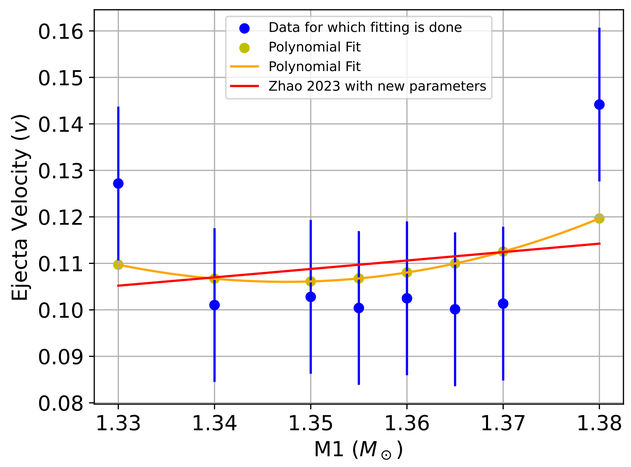

Figure 6. Ejecta Velocity Fitting

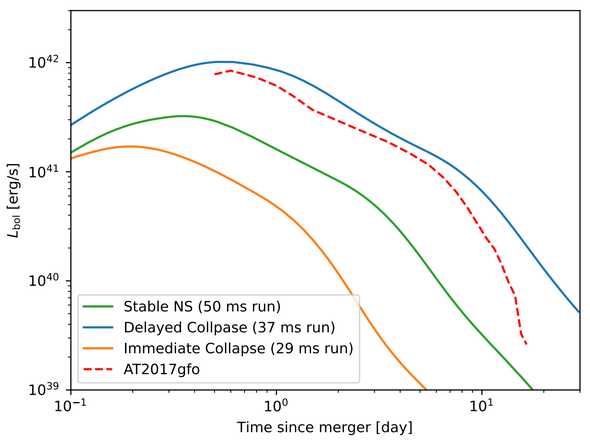

Figure 7. Lightcurve for Different BNS Remenants

References

[1] Kenta Hotokezaka and Ehud Nakar. Radioactive heating rate of r-process elements and macronova light curve. *The Astrophysical Journal*, 891(2):152, March 2020.

[2] Ehud Nakar. The electromagnetic counterparts of compact binary mergers. *Physics Reports*, 886:1–84, 2020. The electromagnetic counterparts of compact binary mergers.

[3] Brian D. Metzger. Kilonovae. *Living Reviews in Relativity*, 23(1), December 2019.

Future Directions

- Improve the fitting results to include unequal mass merger and cases of Kilonovae from NS-BH merger.
- Do a full GRMHD study of the merger phenomenon.
- Probe BNS merger as a central engine of GRBs