Multi-messenger Astrophysics: Neutron star merger ejecta estimation with kilonova light curve surrogates

DR. ATUL KEDIA

CCRG @ RIT

ATULKEDIA93@GMAIL.COM, ASKSMA@RIT.EDU

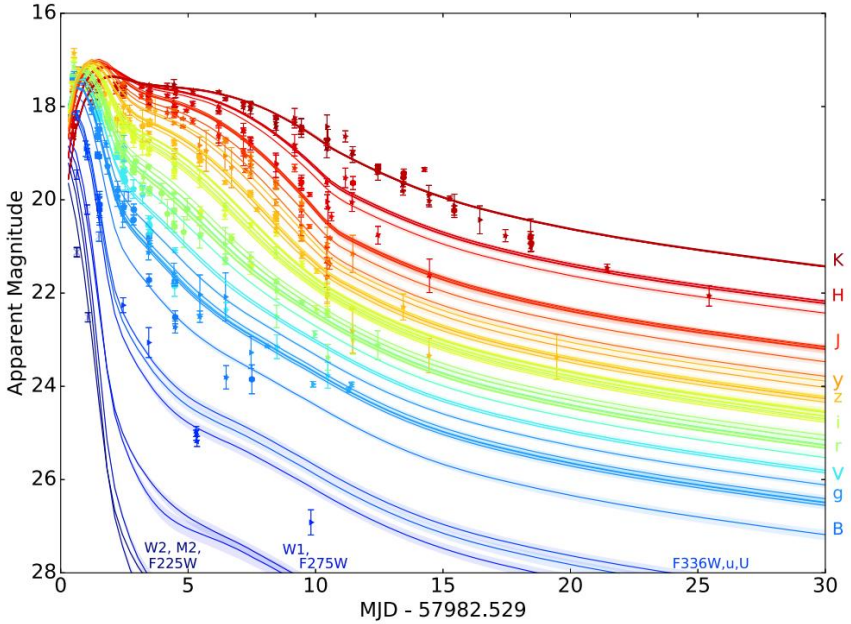
APS April meeting Multimessenger Astronomy II C13.5 **| 4/15/2023**

Collaborators: Marko Ristic, Richard O'Shaughnessy, Anjali Yelikar (RIT), Ryan Wollaeger, Chris Fontes, Eve Chase, Chris Fryer, Oleg Korobkin (LANL) Phys. Rev. Res. 5, 013168 (2023) or arXiv:2211.04363

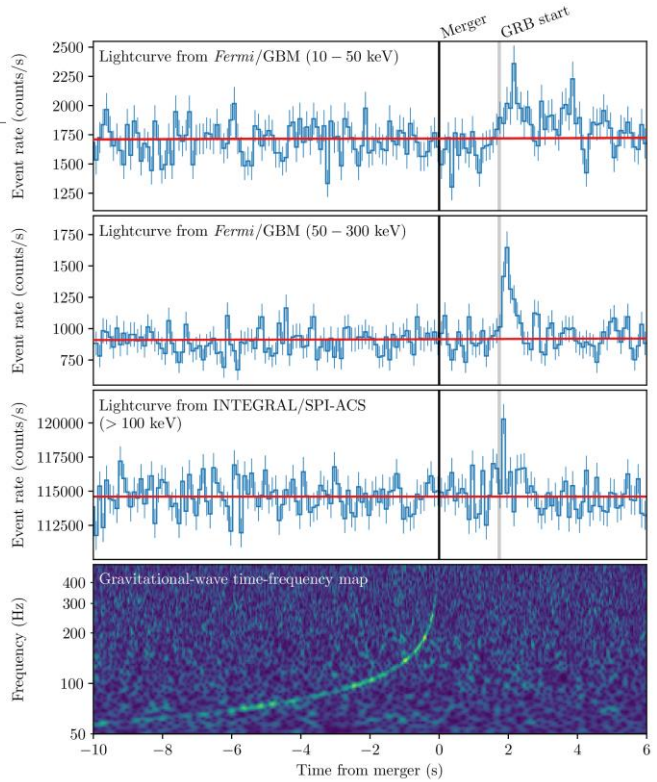
Runtime ~ 10mins

AT2017gfo / GW170817

sGRB ~ 2s



Villar et al ApJL 2017



Abbott et al PRL 2017

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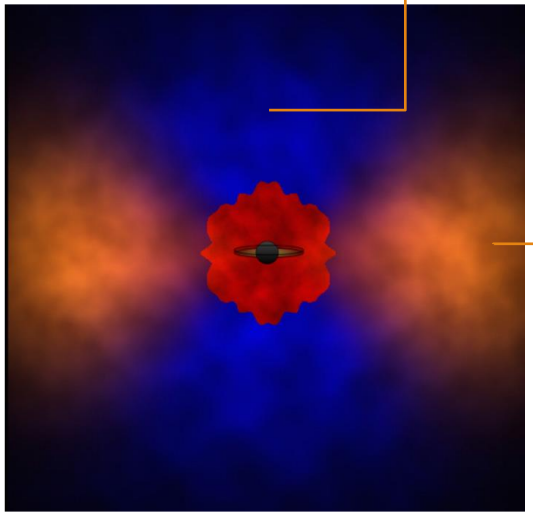
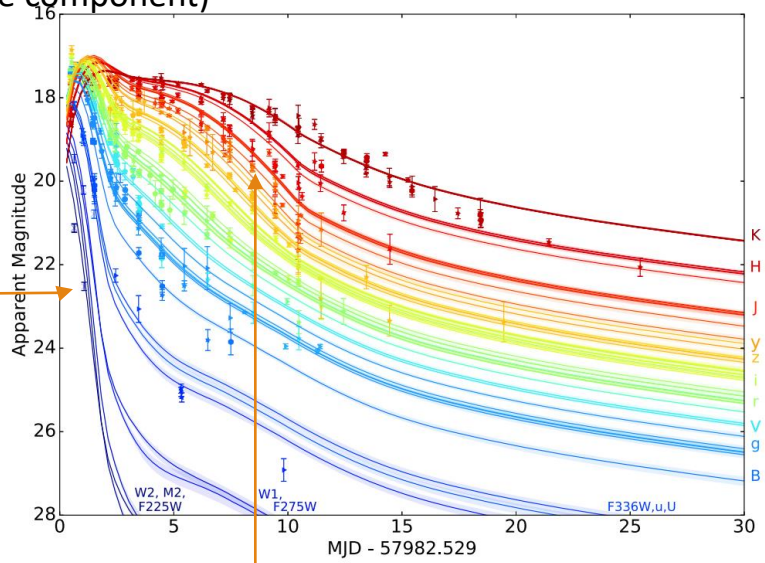
2. Ejecta models
3. Surrogates
4. Parameter Estimation

Ejecta components corresponding to kilonova spectrum



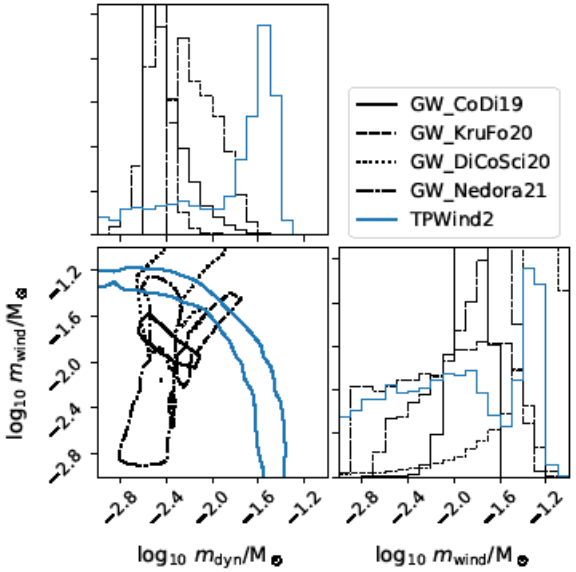
Wind ejecta (blue component)

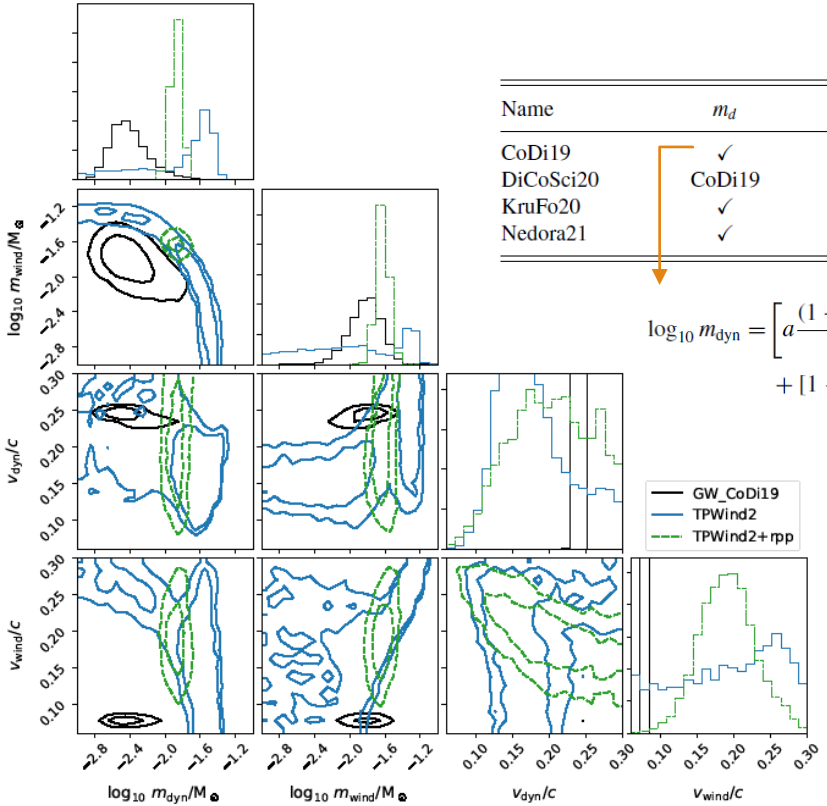


Dynamical ejecta (red component)

Kasen et al [Nature 2017]

EM v GW ejecta parameter tension

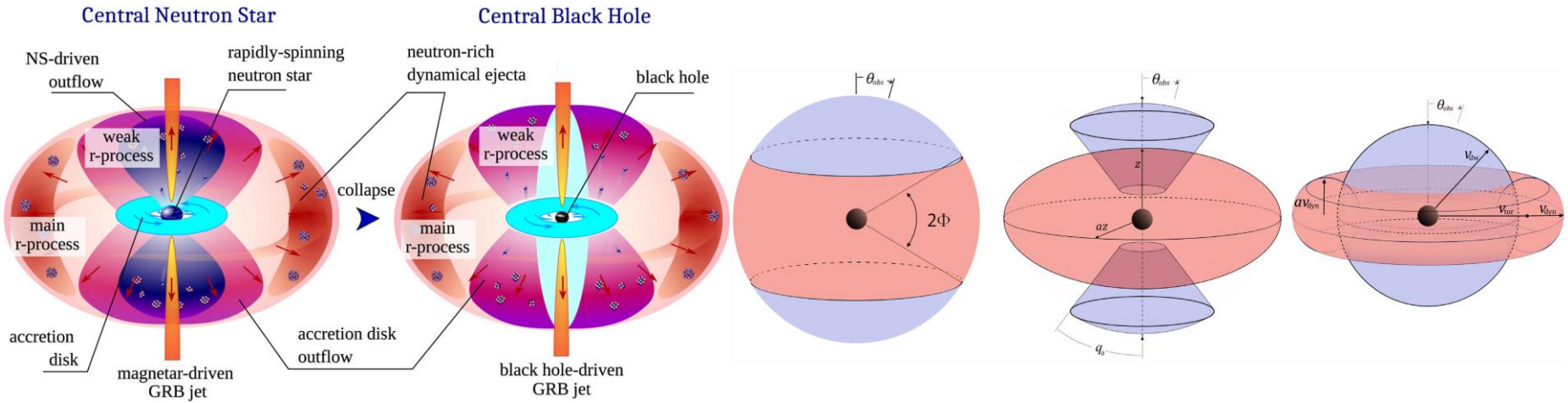




Name	m_d	m_w
CoDi19	✓	✓
DiCoSci20	CoDi19	✓
KruFo20	✓	✓
Nedora21	✓	CoDi19

$$\log_{10} m_{\rm dyn} = \left[a \frac{(1-2C_1)m_1}{C_1} + b\, m_2 \left(\frac{m_1}{m_2}\right)^n + \frac{d}{2} \right] + [1 \leftrightarrow 2],$$

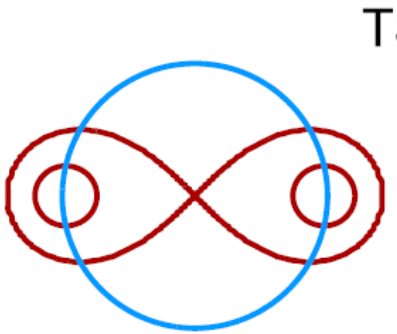
Kilonova ejecta morphologies



Rosswog, Korobkin, Ann. der Phys. 2022

Heinzel et al, MNRAS 2021

Ejecta profiles



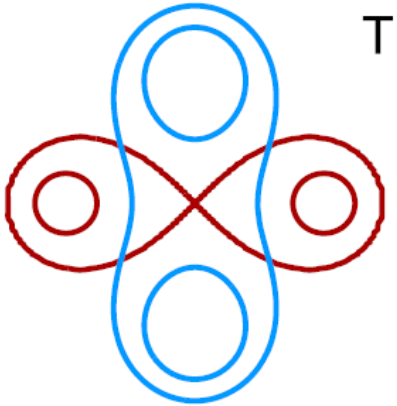


TABLE I. Ejecta morphologies and compositions studied in this paper. The composition of the dynamical component is fixed at $Y_e = 0.04$. In terms of this notation, the previous investigation studied a TPwind2 outflow [32].

	Wind		
Name	Morphology	Y_e	Dynamical
TPwind1	Peanut	0.37	Torus
TSwind1	Spherical	0.37	Torus
TSwind2	Spherical	0.27	Torus

Mass [Mo]	Velocity [c]
0.001, 0.003, 0.01, 0.03, 0.1	0.05, 0.15, 0.3

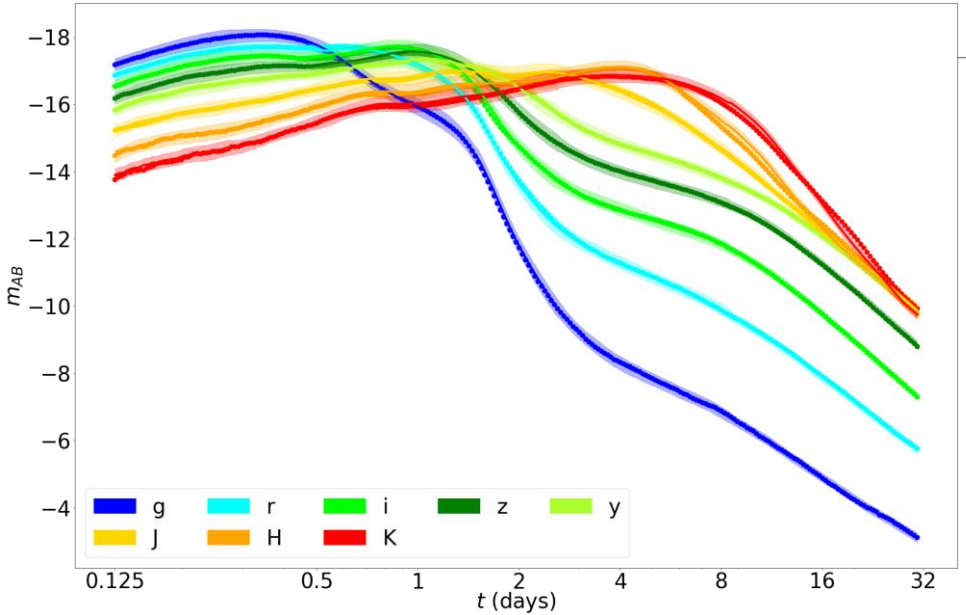
225 + 225 (active learning sims) = 450 /${Name}

Simulation setup

- Radiative transfer software using tabulated binned opacities on **SuperNu**. (Wollaeger et al 2013, 2014)
- Composition and radioactive heating from r-process elements, nucleosynthetic results from **WinNet.** (Winteler et al. 2012)
- Nuclear model
  - Heating rates (Korobkin et al.)
  - Thermalization model of (Barnes et al. (2016))
  - Atomic opacities (Fontes et at. 2020)
- Reprocessing of light from one component to another.
- Active learning to choose next set of models to reduce χ^2 error.

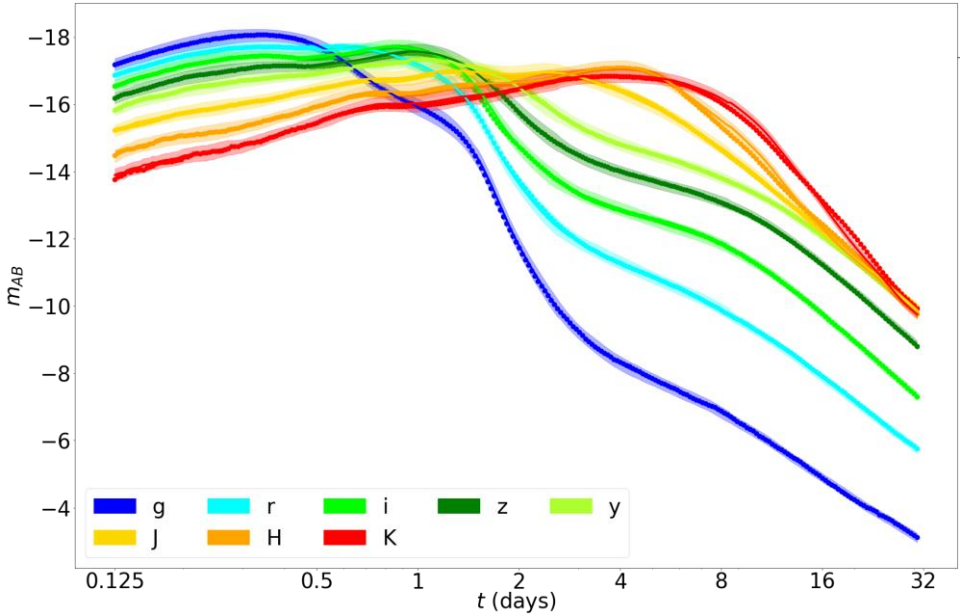
(Wollaeger et al 2013, 2014, 2018, 2021; Ristic et al, PhysRevResearch (2022))

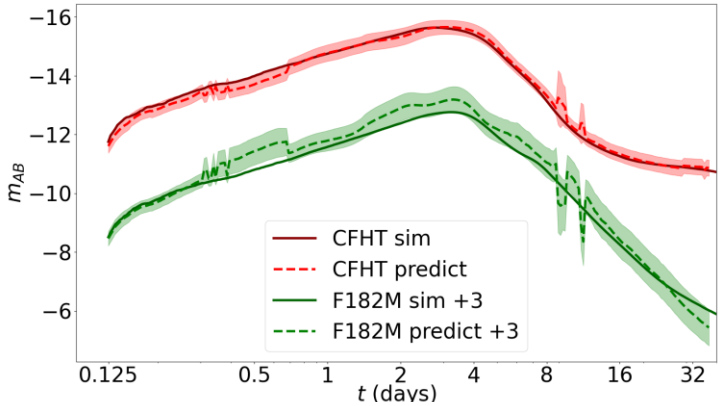
Gaussian Process regression Surrogate models

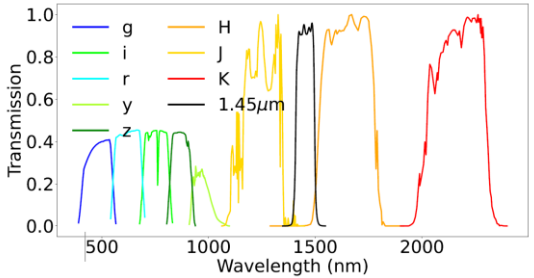


(*mdyn*, *vdyn*, *mwind*, *vwind*) = (0.097, 0.198, 0.084, 0.298)
TSwind2

Gaussian Process regression Surrogate models





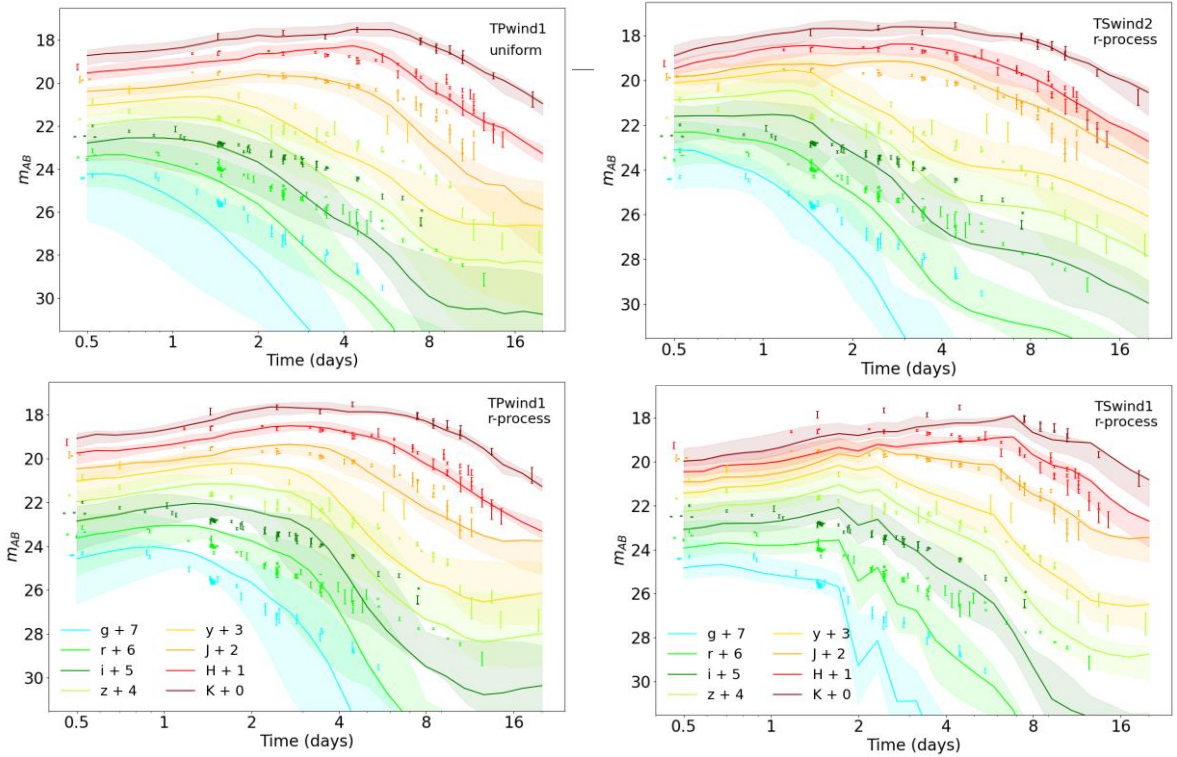


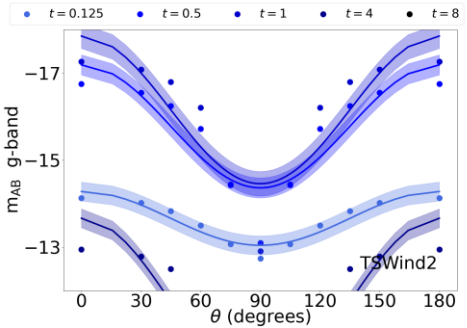
(*mdyn*, *vdyn*, *mwind*, *vwind*) = (0.097, 0.198, 0.084, 0.298)
TSwind2

Simulation data : https://zenodo.org/record/7335961#.ZAE4iXbMKslvı

GP Surrogate models : https://github.com/markoris/surrogate_kne

Fit Light curves (to AT2017gfo)

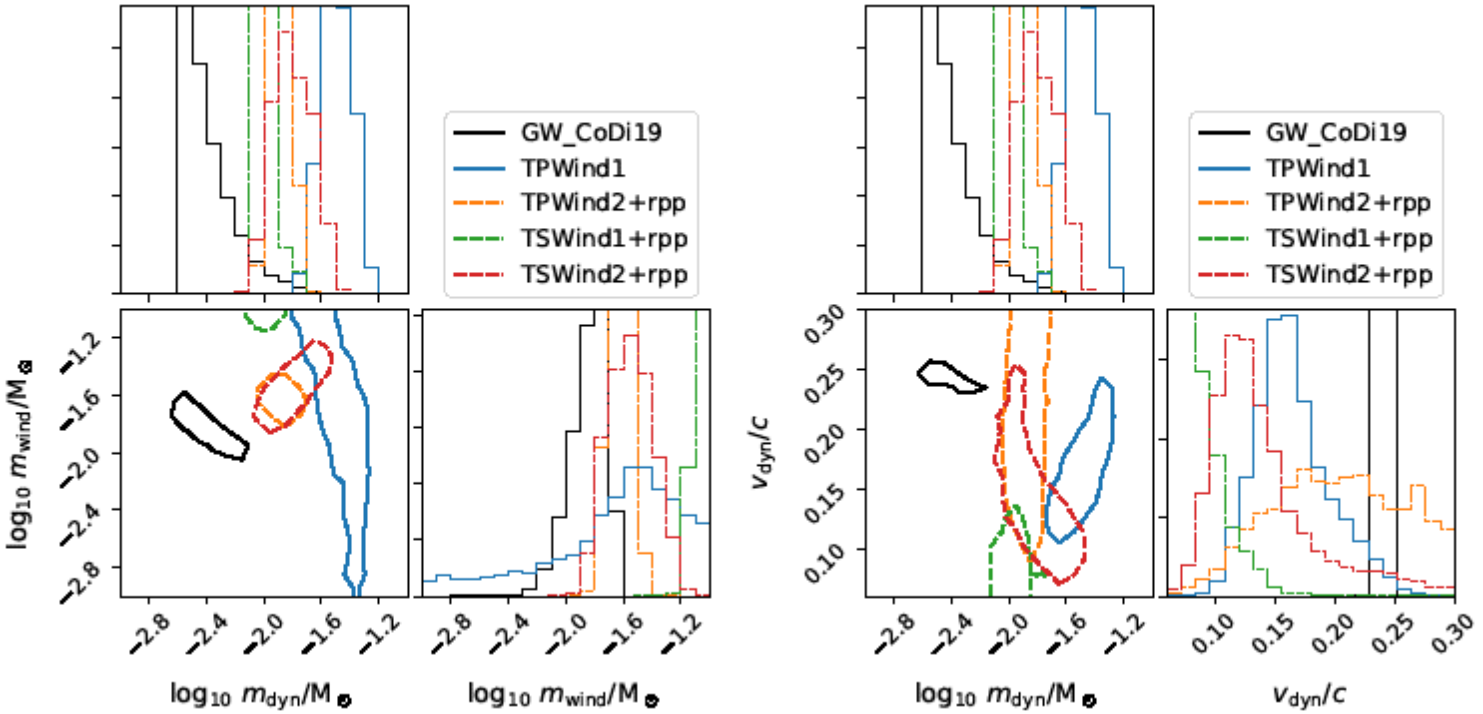




Lanthanide curtaining

AK et al
Phys. Rev. Research 5, 013168 (2023)

GW v EM ejecta parameter estimate tension



[Phys. Rev. Research 5, 013168 (2023)]

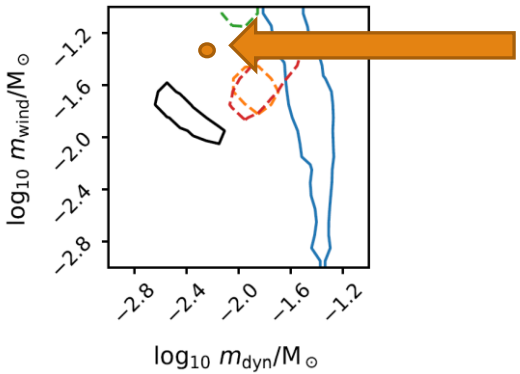
Potential relief : More observations!

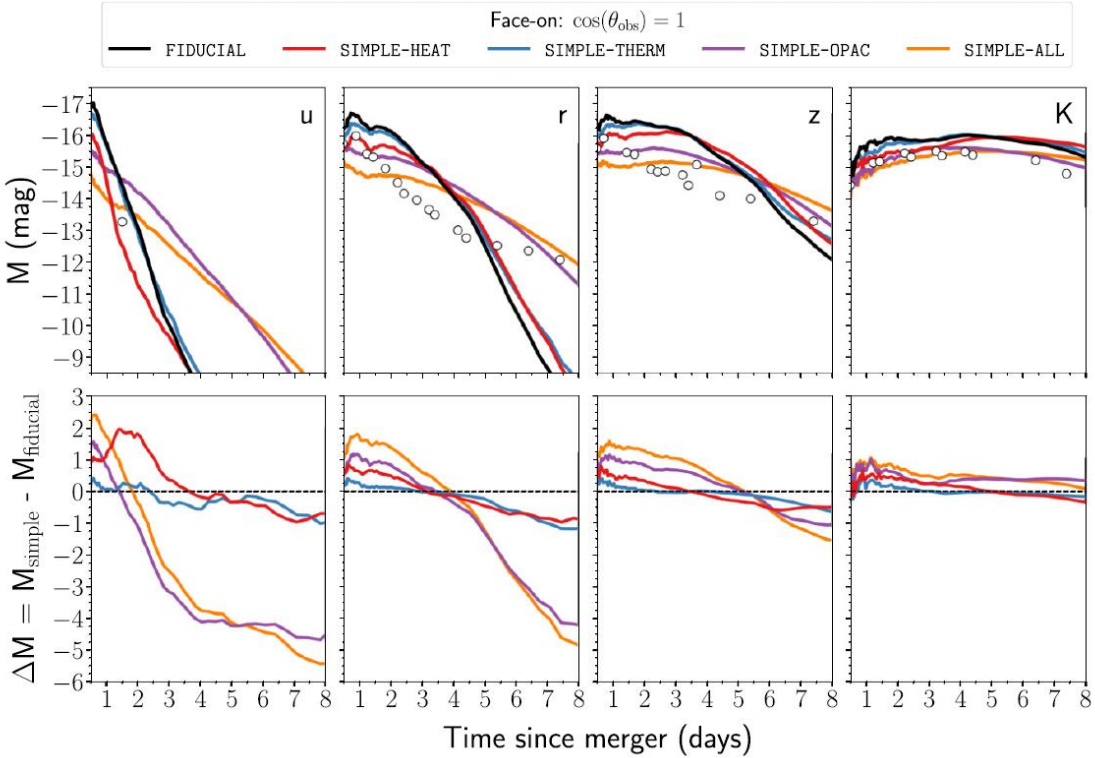
(also Updated Heating rates)

Fiducial (Black curve) : All updated

Simple-Heat (Red curve): heating rate formula non-local

(*mdyn*, *vdyn*, *mwind*, *vwind*) = (0.005, 0.2, 0.05, 0.05)

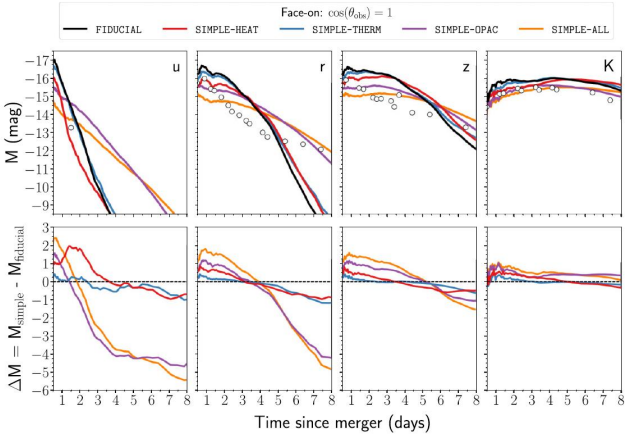




Bulla, MNRAS (2023) – POSSIS update

Ongoing work

- Upgrades to the binned Opacity (Fontes et al 2022)
- Heating rates new formulation (Rosswog and Korobkin 2022)
- Variable Ye along ejecta profiles.
- Third component to power the missing Blue peak cocoon shock cooling, or magnetar-like central engine activity. (motivated by the recent GRB211211A)
- Disk Wind simulations with vbhlight (Miller et al.)



Simulation data : https://zenodo.org/record/7335961#.ZAE4iXbMKsM
GP Surrogate models : https://github.com/markoris/surrogate_kne
Talk by Marko Ristic: F13.00006 Sunday 9:30 AM

Extra slides