MNRAS 000, 1–2 (2021) Preprint 5 April 2021 Compiled using MNRAS LATEX style file v3.0

Radiation hydrodynamics modeling of kilonovae with SNEC

Zhenyu Wu,[1★] Full author list TBD
[1] *Nanjing University*

Accepted XXX. Received YYY; in original form ZZZ

ABSTRACT
Draft version, not for distribution

Key words: keyword1 – keyword2 – keyword3

(i) Use bibtex keys from INSPIRE. I have a script to generate the bibtex automatically from those
(ii) The section titles are just suggestions and will be finalized later
(iii) Let's start with assembling the relevant plots and some text for the methods section

1 INTRODUCTION

2 METHODS

- Brief overview of SNEC
- Opacities
- Heating rates

At the times relevant for kilonovae, the ejecta has already lost all of its initial thermal energy at expansion, and the dominant source of heating is constituted by the decays of heavy elements produced in the r-process. This heating can be described by a specific heating rate which can be derived by evolving the system of the numerous characteristic nuclides in time while accounting for their mutual interactions.
Here, time-dependent heating rates obtained using the nuclear reaction network SkyNet with a FRDM nuclear mass model are employed. A single SkyNet run is determined by the set of thermodynamic variables initial electron fraction Y_e, initial specific entropy s and expansion timescale τ. The rates are thus computed on a comprehensive grid with $0.02 \leq Y_e \leq 0.48$ linearly spaced, $1.82\ \mathrm{k_B}/\mathrm{baryon} \leq s \leq 100\ \mathrm{k_B}/\mathrm{baryon}$ and $1.36\ \mathrm{ms} \leq \tau \leq 100\ \mathrm{ms}$ log-spaced, the results on a representative subgrid being reported in Figure 1.
In order to derive the heating rate for arbitrary initial conditions, the above trajectories are reduced to a parametrized functional form by means of a fit procedure intended to cover the time interval from 0.1 s to 50 days post-merger, and, in particular, a distinction between time regimes is introduced. For early times $t \lesssim 0.1$ days, the analytic fitting formula, derived from detailed nucleosynthesis calculations (Korobkin et al. (2012)), is employed:

$$\dot{\epsilon}_{\mathrm{r}}(t) = \epsilon_0 \epsilon_{\mathrm{th}} \left(\frac{1}{2} - \frac{1}{\pi} \arctan \left[\frac{t - t_0}{\sigma} \right] \right)^{\alpha}, \tag{1}$$

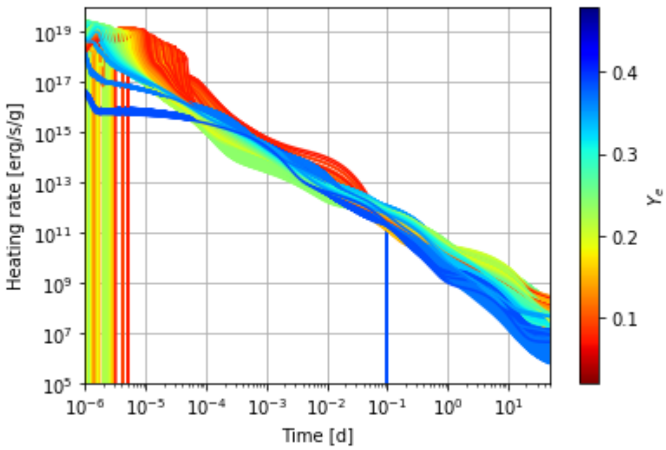

Figure 1. Heating rate trajectories as obtained by SkyNet on a subgrid of thermodynamic variables $0.05 \leq Y_e \leq 0.4$, $3\ \mathrm{k_B}/\mathrm{baryon} \leq s \leq 50\ \mathrm{k_B}/\mathrm{baryon}$ and $1\ \mathrm{ms} \leq \tau \leq 30\ \mathrm{ms}$ for visual clarity. Trajectories are color-coded to indicate different initial electron fractions. Vertical lines correspond to SkyNet noise which is averaged out in the fit procedure.

where ϵ_0, α, t_0 and σ are considered fit parameters, while $\epsilon_{\mathrm{th}} < 1$ is the thermalization efficiency. At late times $t \gtrsim 0.1$ days instead, we expect a power-law fit to be a sufficiently good approximation of the heating rates, and thus the fitting formula becomes:

$$\dot{\epsilon}_{\mathrm{r}}(t) = \epsilon_0' \epsilon_{\mathrm{th}} t^{-\alpha'}, \tag{2}$$

with ϵ_0' and α' additional fit parameters.
The heating rate fits, as obtained by using equations 1 and 2, are then joint together with a log-scaled smoothing procedure applied on the time interval $1 \times 10^3\ \mathrm{s} \leq t \leq 4 \times 10^4\ \mathrm{s}$, centered on $t \sim 0.1$ days in log-scale.
Figure 2 shows the fitted version of the heating rate trajectories presented in Figure 1.

- Initial and boundary conditions

★ E-mail: 171840687smail.nju.edu.cn

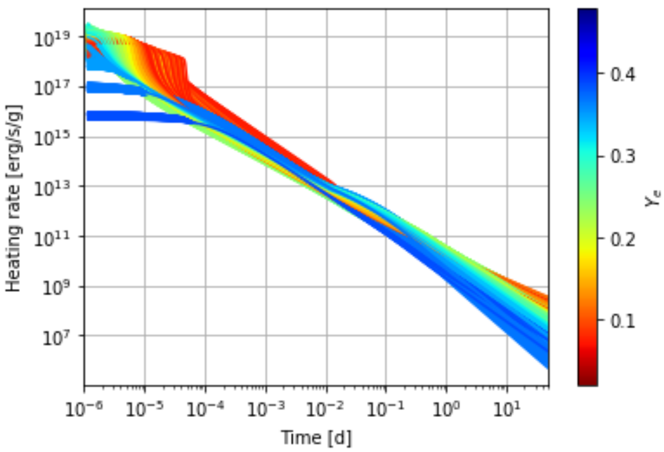

Figure 2. Heating rate fitted trajectories as obtained by performing the fit procedure on a subgrid of thermodynamic variables $0.05 \leq Y_e \leq 0.4$, 3 $\mathrm{k_B}$/baryon $\leq s \leq$ 50 $\mathrm{k_B}$/baryon and 1 ms $\leq \tau \leq$ 30 ms for visual clarity. Trajectories are color-coded to indicate different initial electron fractions.

3 CODE VALIDATION

3.1 Hydrodynamics

3.2 Energy conservation

3.3 Comparison with analytic models

4 AB-INITIO SIMULATIONS: FROM MERGERS TO KILONOVAE

4.1 General features

4.2 Impact of uncertainties in the heating rates

5 A FIRST APPLICATION TO AT2017GFO

5.1 Best fitting analytical models

5.2 Comparison between NR informed models and observations

5.3 Impact of shock cooling

6 CONCLUSIONS

REFERENCES

Korobkin O., Rosswog S., Arcones A., Winteler C., 2012, Mon. Not. Roy. Astron. Soc., 426, 1940

This paper has been typeset from a TEX/LATEX file prepared by the author.