Nuclear matter properties effects on nucleosynthesis and Kilonova in BNS mergers

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Abstract ID: #45

The elemental yields and the Kilonova (KN) transient from a binary neutron star (BNS) merger are intimately related to the astrophysical conditions of the merger ejecta, which in turn indirectly depend on the equation of state (EOS) describing the nuclear matter inside the neutron star...

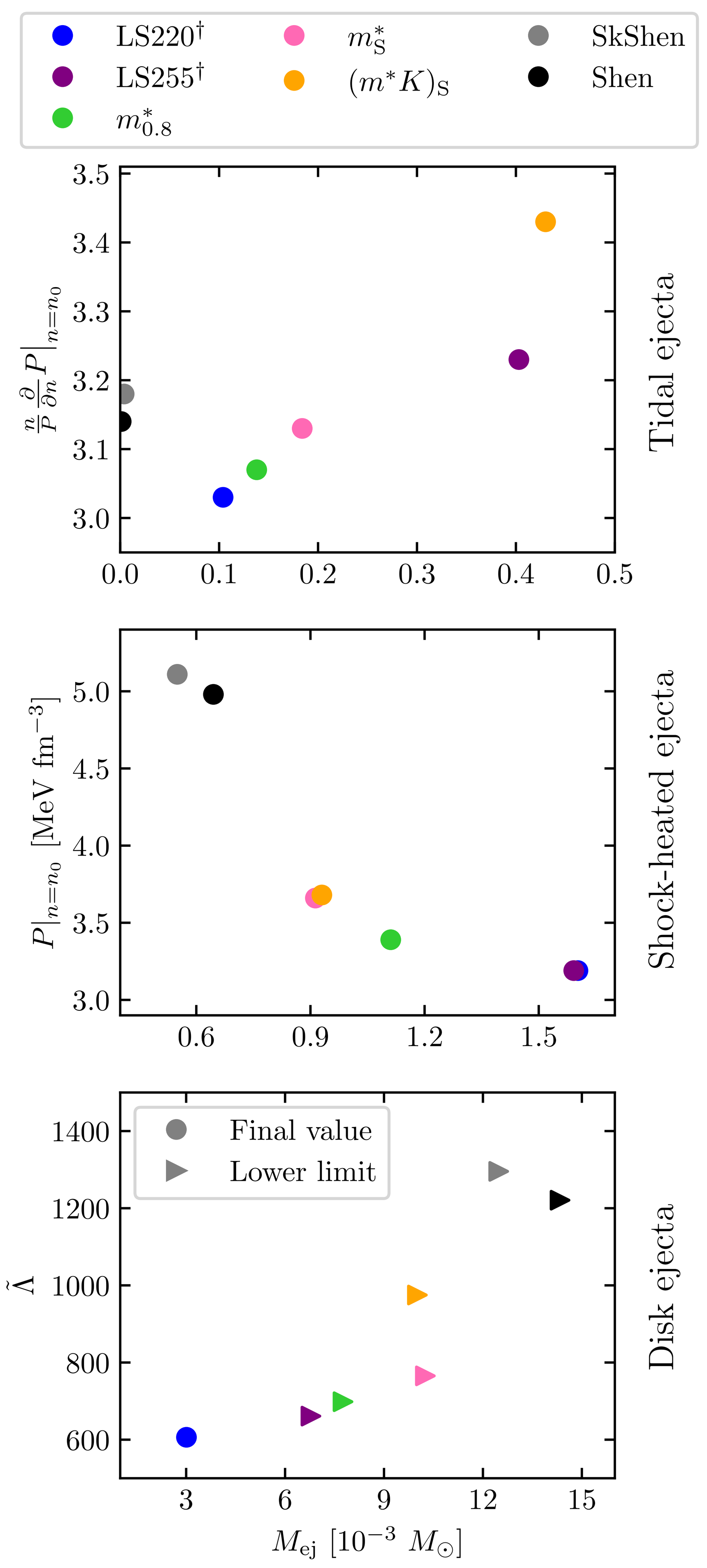
EOS models

Finite-temperature, composition-dependent nuclear EOSs based on Skyrme functional, computed with SROEOS [1; 2]:

Model	m^* $[m_n]$	K [MeV]	L [MeV]	$\tilde{\Lambda}$	$R_{\rm NS}$ [km]
LS175†	1.0	175	73.7	358.9	12.1
LS220†	1.0	220	73.7	606.2	12.7
LS255†	1.0	255	73.7	661.1	13.0
$m^*_{0.8}$	0.8	220	79.3	698.4	12.9
$m^*_{\rm S}$	0.634	220	86.5	765.4	13.2
$(m^*K)_{\rm S}$	0.634	281	86.5	975.0	13.5
SkShen	0.634	281	109.4	1295.5	14.5
Shen	0.634	281	110.8	1220.8	14.5

We vary systematically the value of incompressibility K and effective nucleon mass m^* at saturation density.
The EOS stiffness varies accordingly, as visible from the NS tidal deformability $\tilde{\Lambda}$ and radius R_{NS}.

Ejecta masses dependences

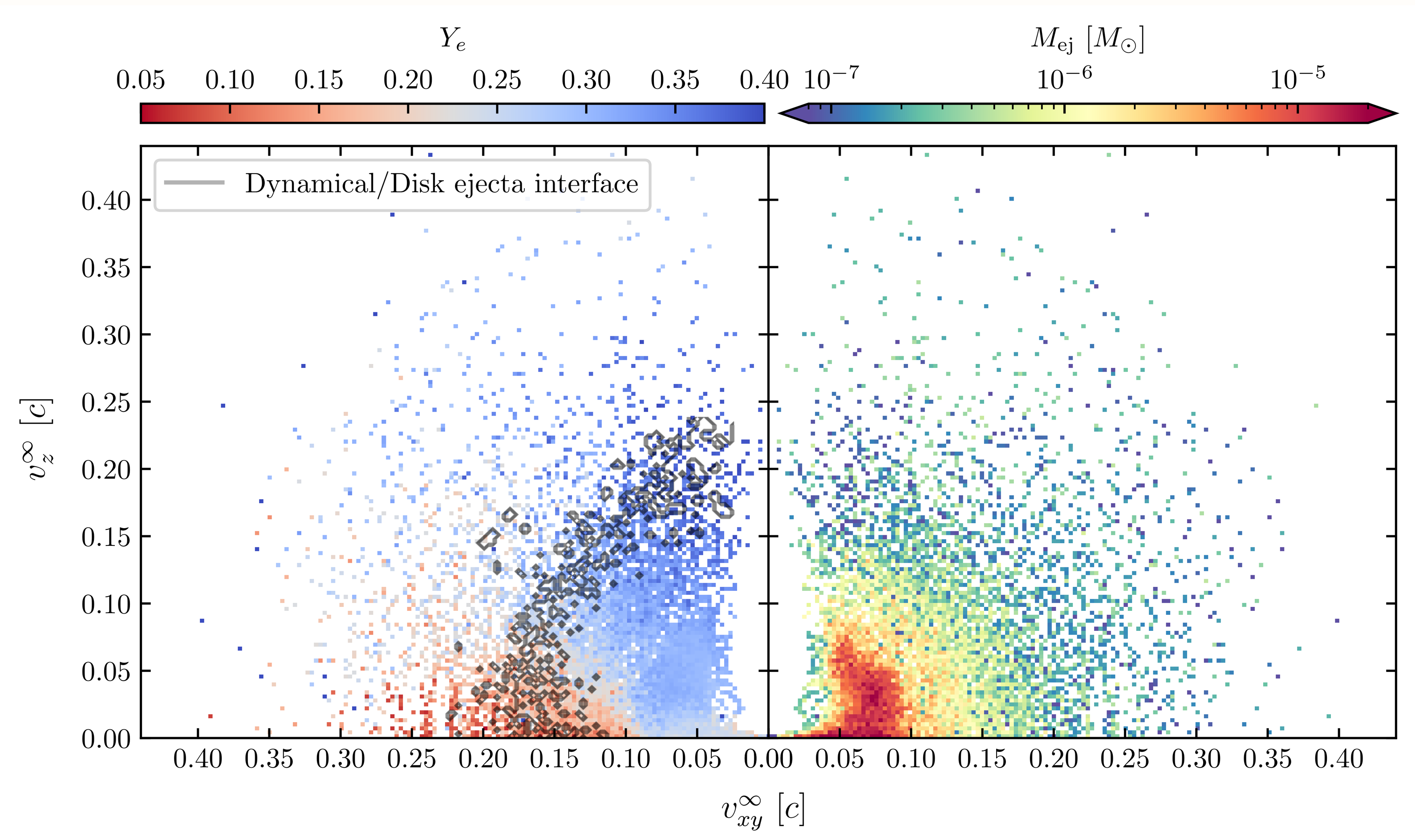


Shock-heated and tidal ejecta masses are affected by the value of the pressure at saturation density and its slope as a function of density, respectively.
These quantities are almost fairly independently accessed using K and m^*.

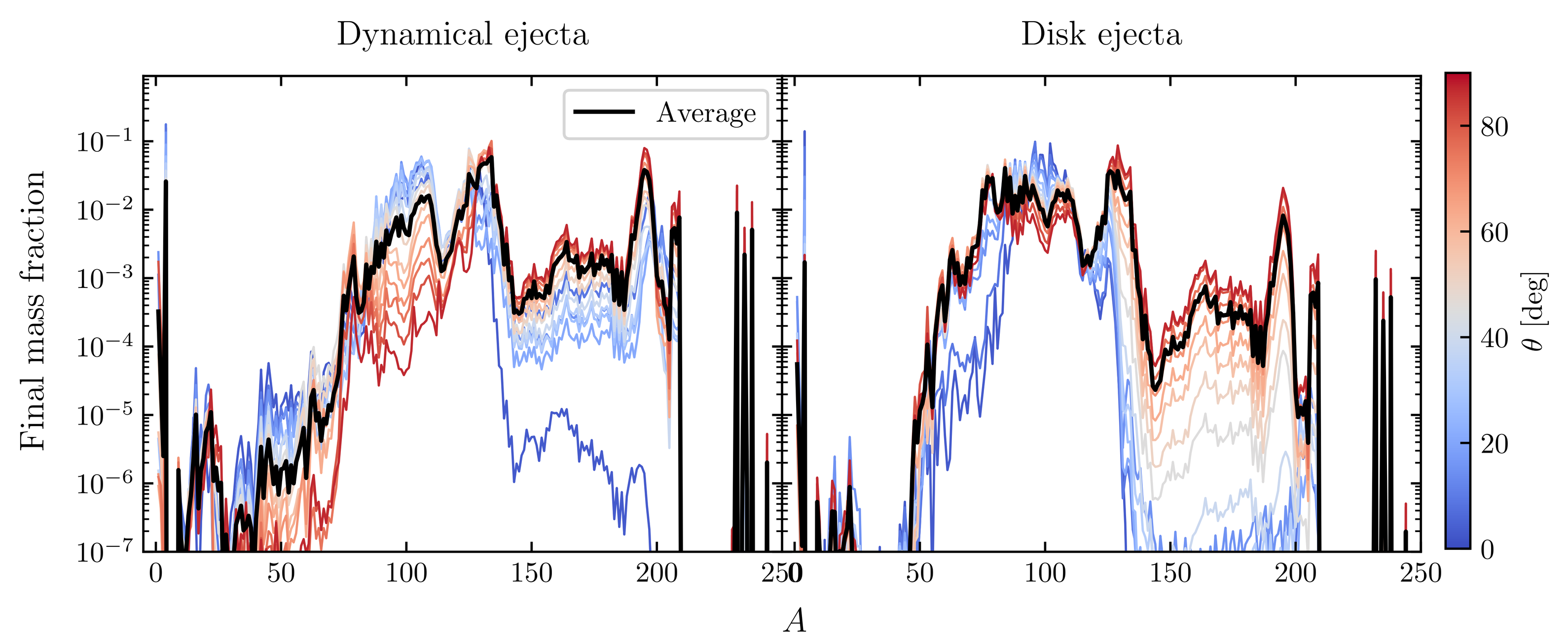
Methods

- Symmetric BNS merger simulations ($M_{NS} = 1.365\ M_\odot$) in 3D GRHD and M0 ν transport [2] with Whisky THC [3]
- Nucleosynthesis calculations with the nuclear reaction network Winnet [4]
- Decay data from ENDF/B-VIII [5] and transport simulations fits for the thermalization of decay products [6]
- Synthetic KN light curves with ray-by-ray [7] semi-analytic diffusion model [8]

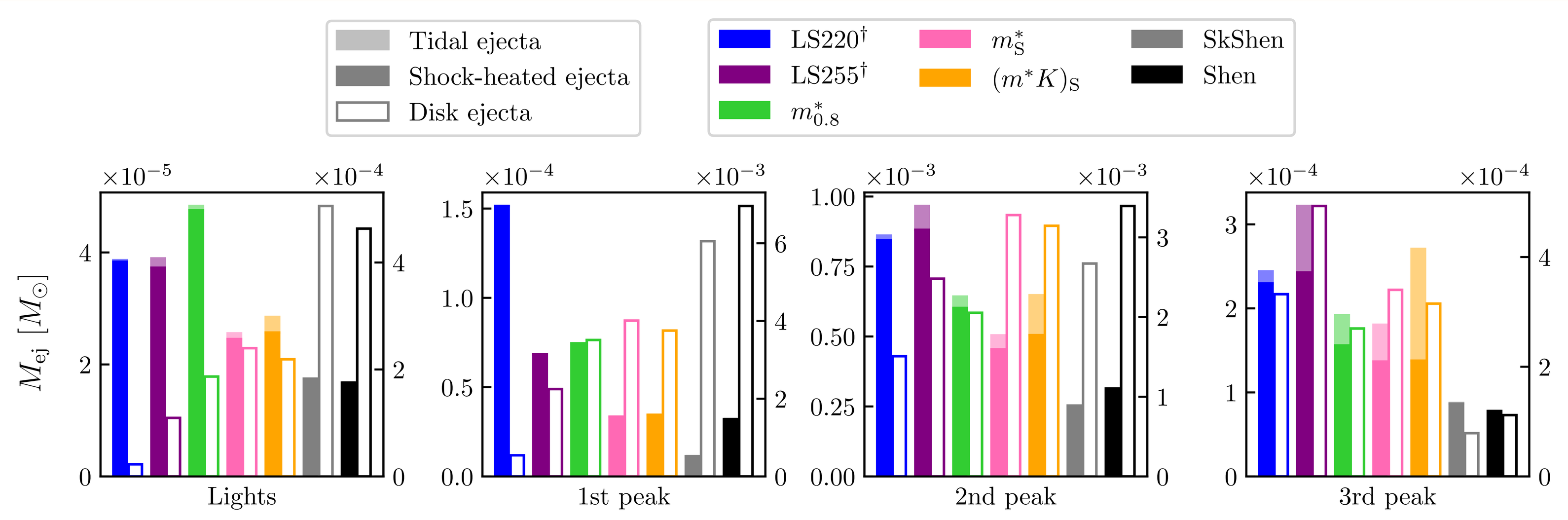
General ejecta features



The ejected material has a wide range of electron fractions (Y_e), both in the dynamical and in the subsequent phases, with the peak of the distribution around $Y_e = 0.25$. In the dynamical phase, heavy elements are produced both in the tidal and in the shock-heated ejecta component, in similar amounts. But, ultimately, the disk outflows driven by spiral density waves dominate the ejection and contribute relevantly to all three r-process peaks.

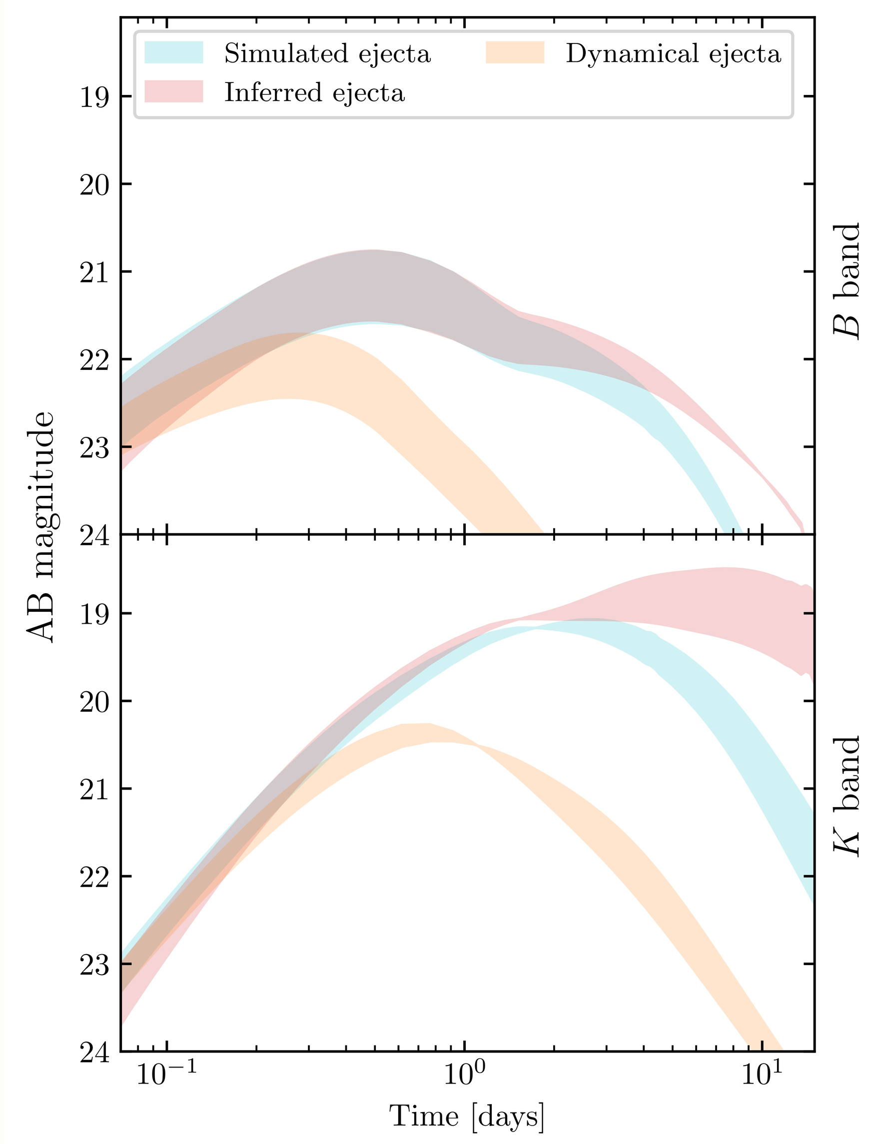


Yields variations



Models with more tidal ejecta have a slight boost in the production of 2nd and 3rd r-process elements. On the other hand, due to the greatly diverse conditions in the shock-heated ejecta, roughly all elements are boosted with the overall amount of such component. Notably, the yields of 3rd peak elements roughly scale inversely with the amount of disk ejecta. Both the latter and the shock-heated component are very sensitive to the details of the distribution of Y_e, precluding the emergence of solid trends linkable to K or m^*.

Kilonova light curves



Light curves are mostly impacted by the overall amount of ejecta, and we expect the red emission peak to be delayed once the full disk ejection is considered.
However, the disk ejecta can affect the emission already in its early blue stage, making it difficult to isolate KN features related to the sole dynamical ejecta.

References

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NPAXI Nuclear Physics in Astrophysics XI, September 15-20 2024, TU Dresden, Dresden, Germany