Formulating bulk viscosity for Neutron Star simulations

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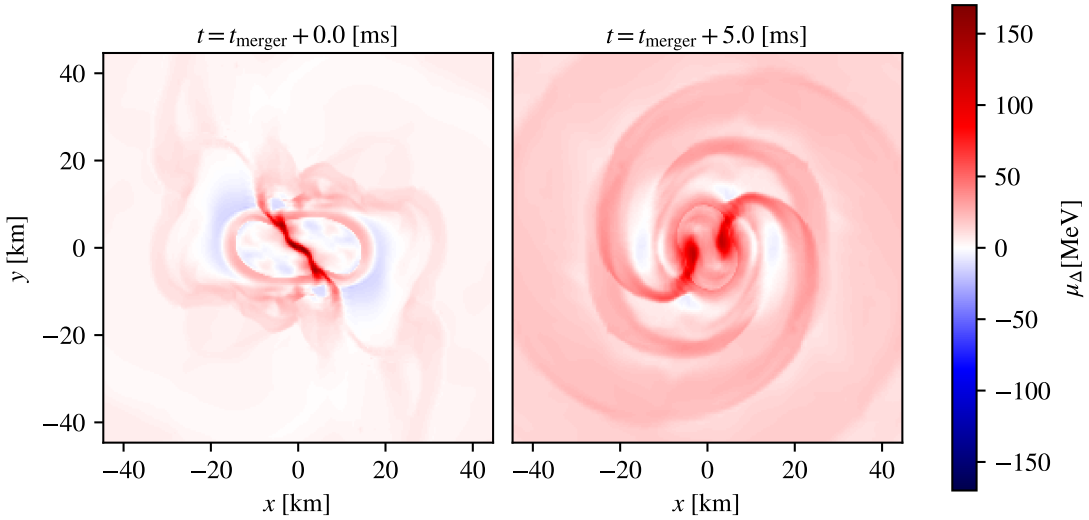
Collaborators: Hawke, I.; Hammond, P.; Andersson, N. and Comer, G.L.

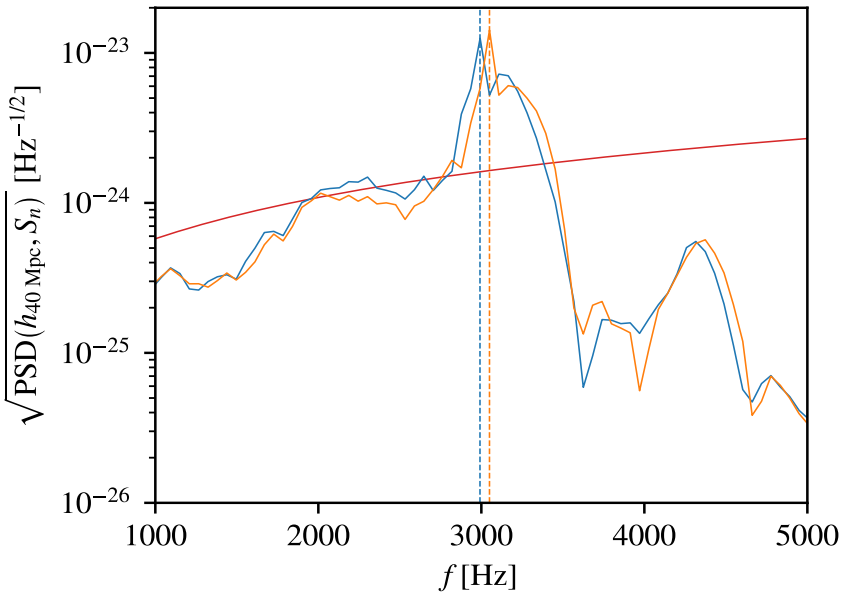
Deviations from chemical equilibrium



[Hammond+ (2021)]

We see large deviations from chemical equilibrium in binary neutron star merger simulations.

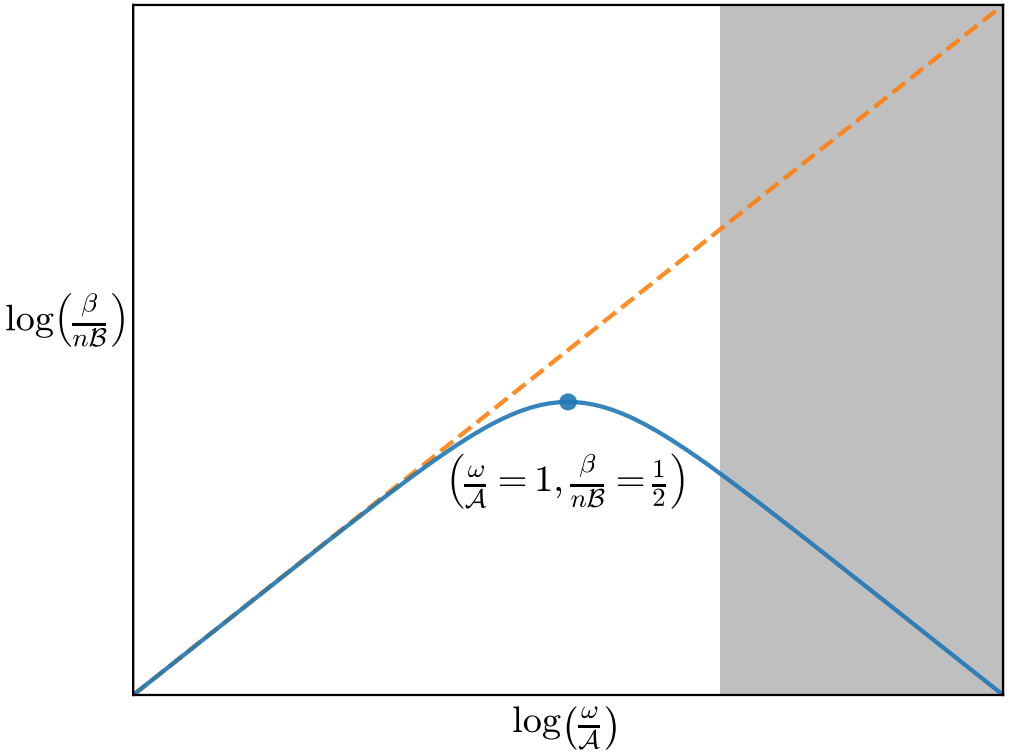
Third generation gravitational-wave detectors will be sensible to the difference it makes.



[Hammond+ (2022)]

Multi-scale methods

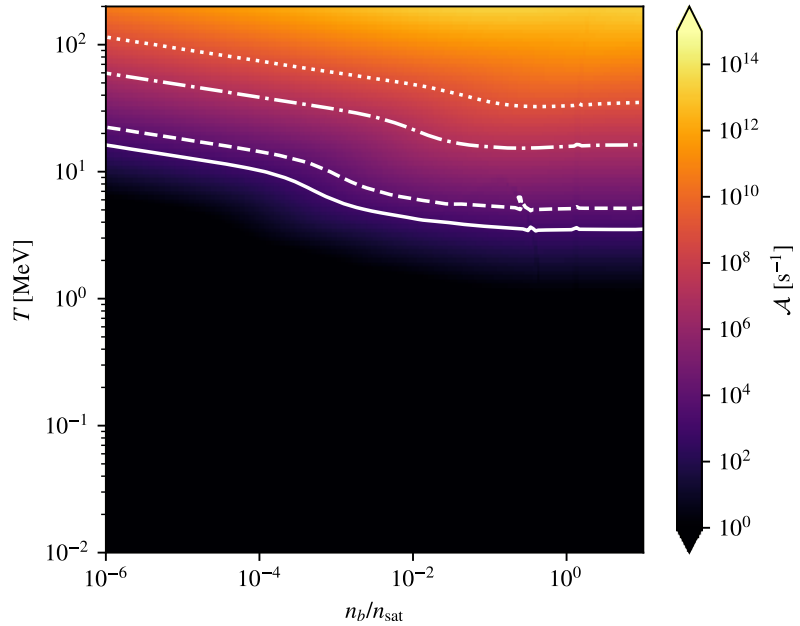
- Formulating a reactive system is easy, but...
- β-reaction timescales can be **shorter** than numerical time-step
- Rates are temperature dependent



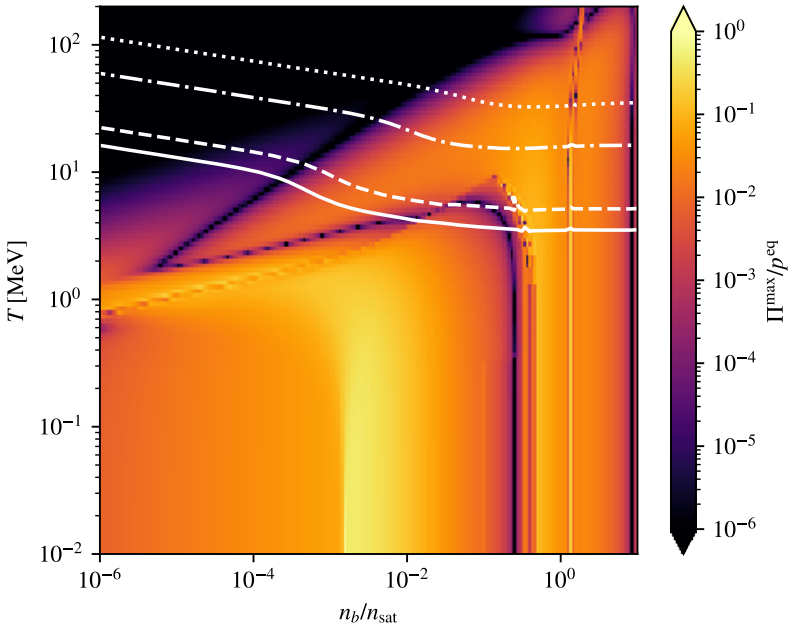
- The electron fraction evolution timescale "decouples"
- When faster, we can rely on **multi-scale** methods.
- Result: single fluid with NS-type bulk-viscous pressure.

Resolving vs not-resolving the UV limit.

Where and how high is the peak?



Reaction timescale with contours representative of relevant numerical timesteps.



Maximum relative importance of reactions, same contours overlaid.

This analysis suggests that we can make progress by implementing an adaptive model, and transition between the two descriptions on the fly.

"Conclusions"

- Reactions are hard to implement as the reaction timescale varies over many orders of magnitude in different regions of the parameter space explored in a merger.
- A way forward is to have a code that can transition between the electron-fraction and affinity description on the fly – implementing only the infra-red Navier-Stokes bulk viscosity.
- Flags:
  - The possible conflict / interaction with LES.
  - It is not entirely clear how difficult it is to implement this.
  - The double-counting issue.

THANK YOU!