

# Neutrino Transport in Binary Neutron Star Mergers

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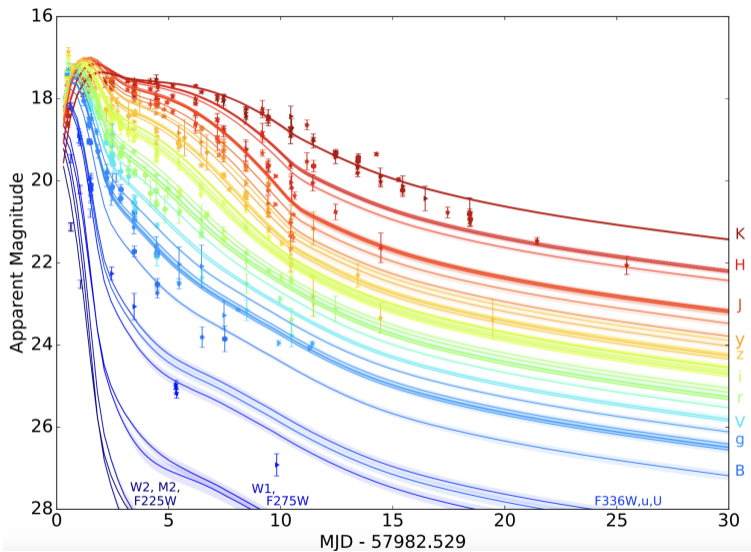
FAIRness  
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- 1 Motivation
- 2 Neutrino Transport Problem
- 3 Truncated Moments: M1 scheme
- 4 The M1 scheme in AREPO

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From Virall et al. 2017

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Neutrinos are crucial in the evolution of Binary Neutron Star mergers:

- The collision creates **hot** regions → **neutrino emission**
- Main source of **cooling** post-merger remnant (*if any*)
- Drive **neutrino-driven winds**
- Change the **composition** of matter
- Deposit energy in **polar regions**

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- Evolve the **Boltzmann equation**

$$p^\alpha \left[ \frac{\partial f_\nu}{\partial x^\alpha} - \Gamma_{\alpha\gamma}^\beta p^\gamma \frac{\partial f_\nu}{\partial p^\beta} \right] = \left[ \frac{df_\nu}{d\tau} \right]_{\text{coll}}$$

- **7-dimensional** problem
- Computationally **expensive**
- Coupling to hydro properties is **stiff**
- Coupling between different momenta, species
- Approximate methods to solve this: leakage schemes, Monte Carlo schemes, **truncated moment** schemes...

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- Moment formalism by Thorne (1981)
- Remove angular dependence → expand distribution function as series of **moments**

$$0^{\text{th}} \text{ order: } E = \int \epsilon^3 d\epsilon d\Omega f_{(\nu)}(x^i, t, p^\alpha)$$

$$1^{\text{st}} \text{ order: } F^i = \int \epsilon^3 d\epsilon d\Omega f_{(\nu)}(x^i, t, p^\alpha) l^i$$

...

- Can be cast in **conservative form** similar to the Hydro equations

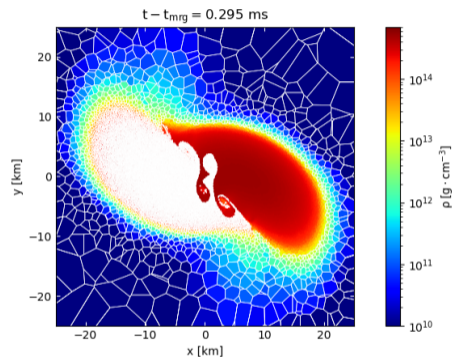
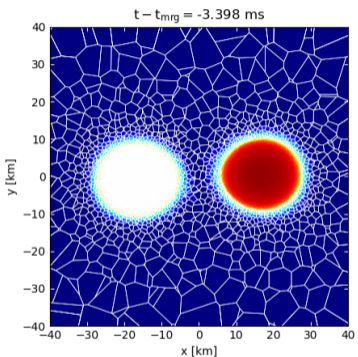
$$\frac{dE}{dt} + \nabla_i F^i = S_E$$

$$\frac{dF^i}{dt} + \nabla_j P^{ij} = S_F^i$$

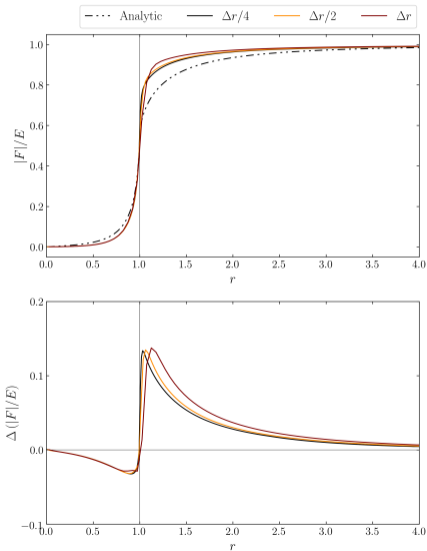
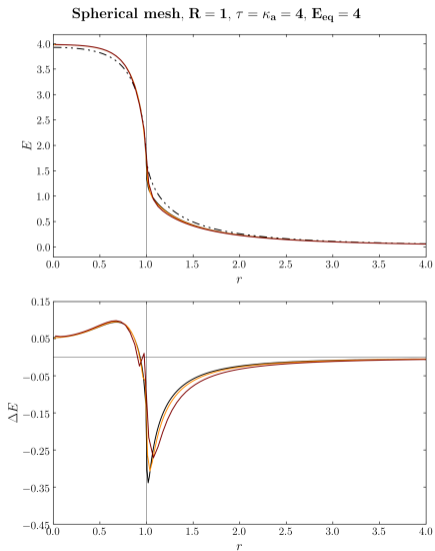
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- Each moment's evolution equation depends on the next order moment → **closure relation** needed (M1, Minerbo, ...)

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Plots from George Lioutas  
Lioutas + 2024



# Thank You!