# Dynamical Ejecta from Binary Neutron Star Mergers

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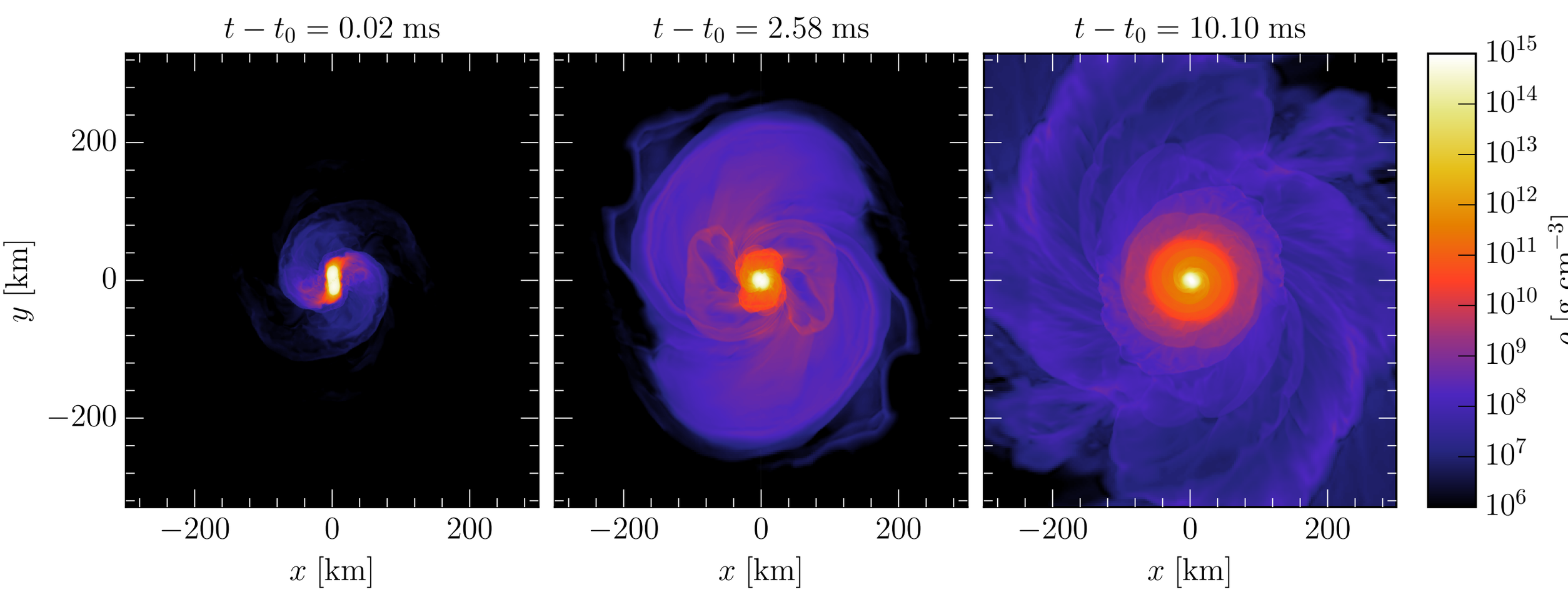
# Background



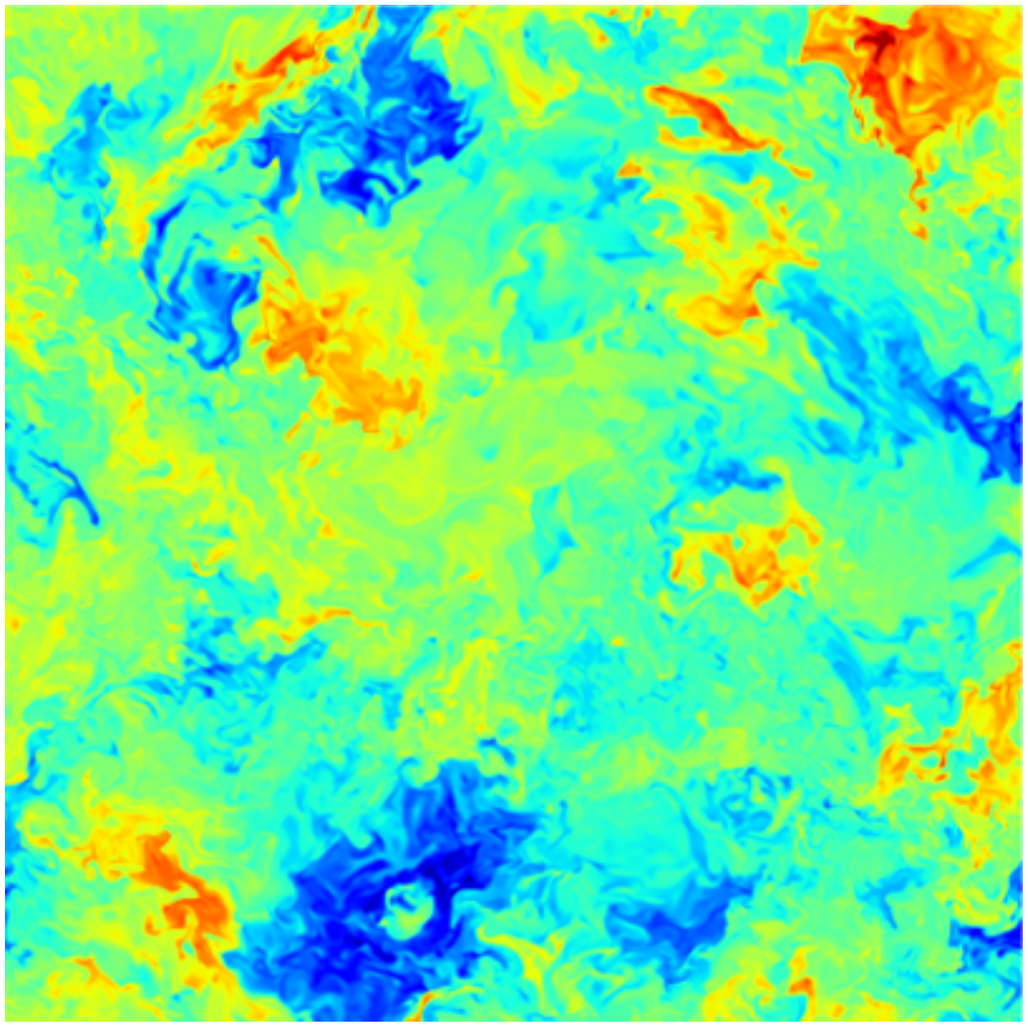

- Dynamical ejecta: outflow during merger
- Consequences: nucleosynthesis? EM counterparts?

See also talks by Dietrich, Branchesi, Metzger

# Open Questions

- Ejection: tides or shocks?
- Composition, morphology?
- Impact of weak reactions? EOS?
- NSNS mergers: the origin of r-process elements?

# Methods: WhiskyTHC

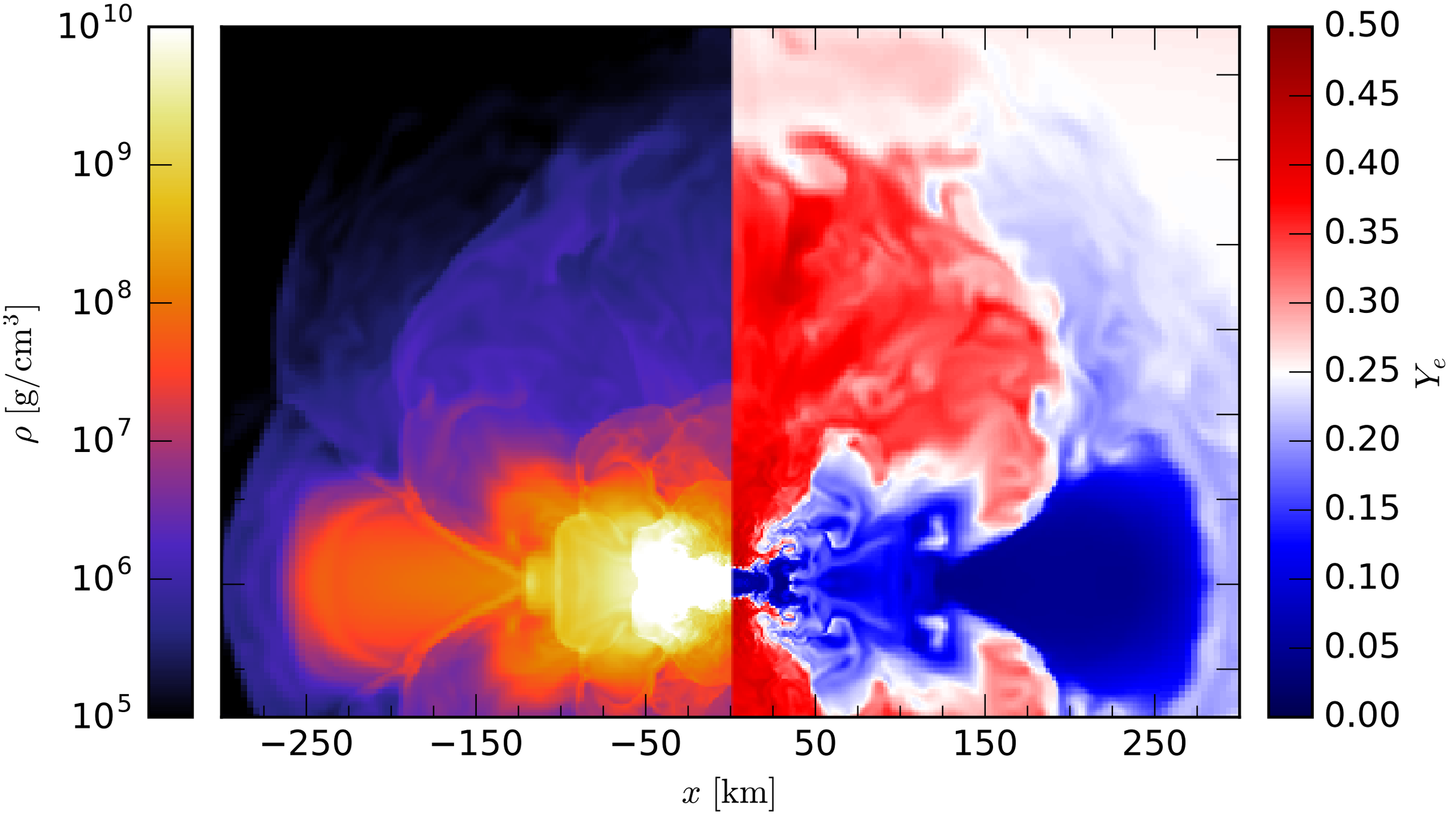


- GRHD: MP5+HLLE
- Gravity: BSSN or Z4c
- Tabulated nuclear EOS
- Neutrino cooling and heating

THC = Templated Hydrodynamics Code

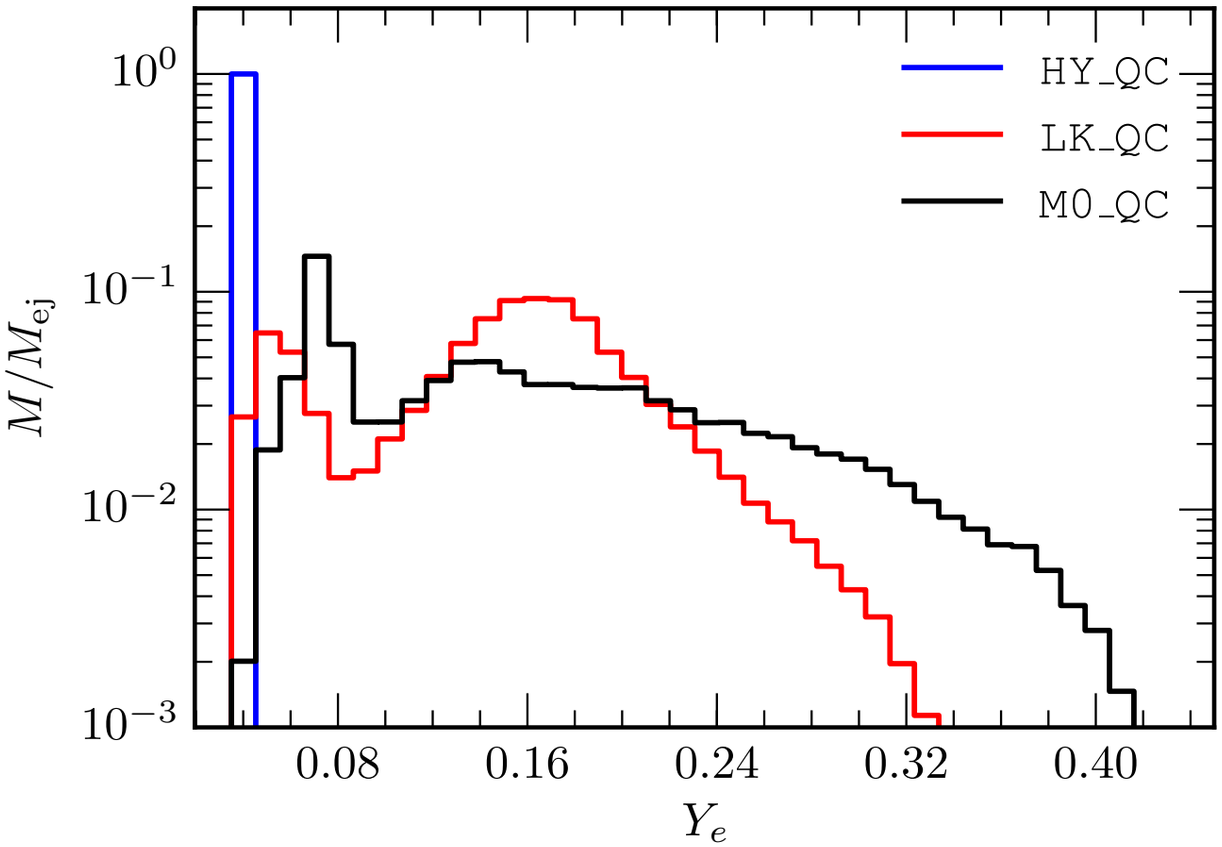
# Ejection Mechanisms

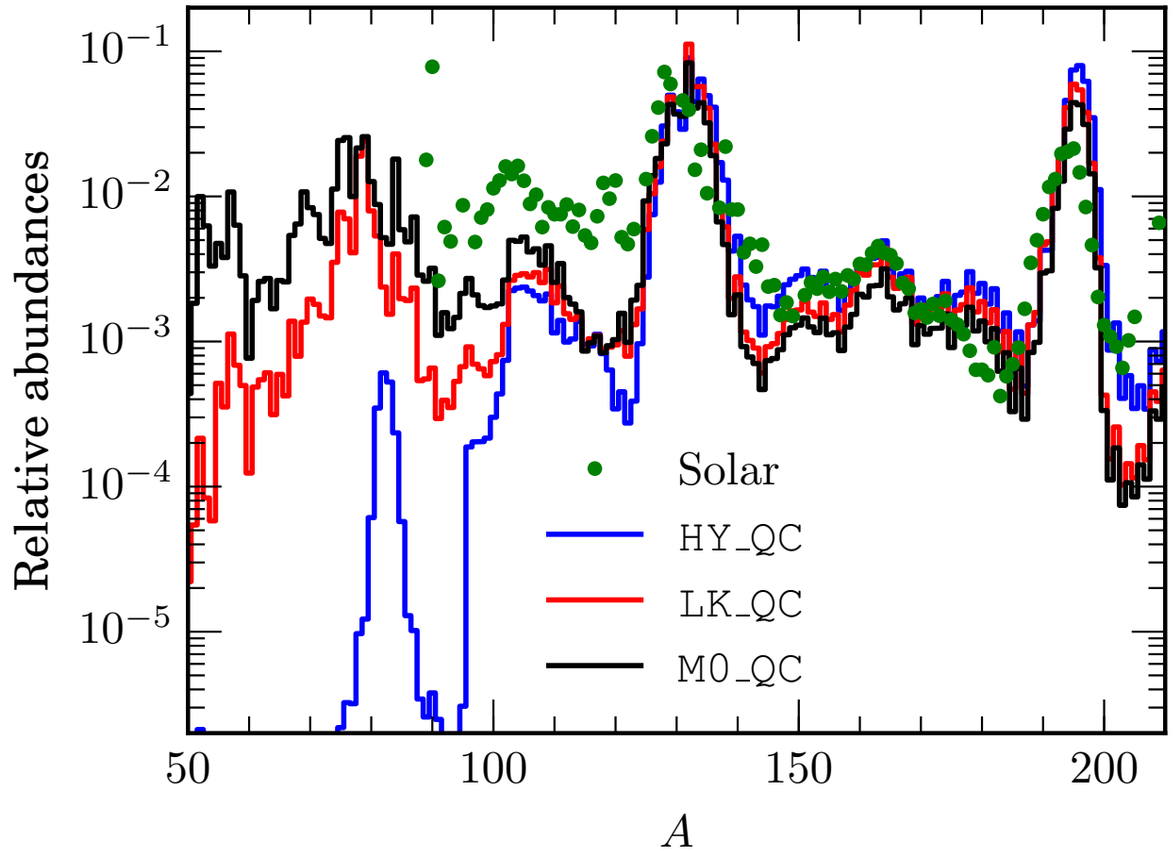
$\mathrm{EOS:\,LS220} \quad M = 1.38\,M_\odot$



# Impact of Weak Interactions

$$\mathrm{EOS:\,LS220} \quad M = 1.38\,M_\odot$$

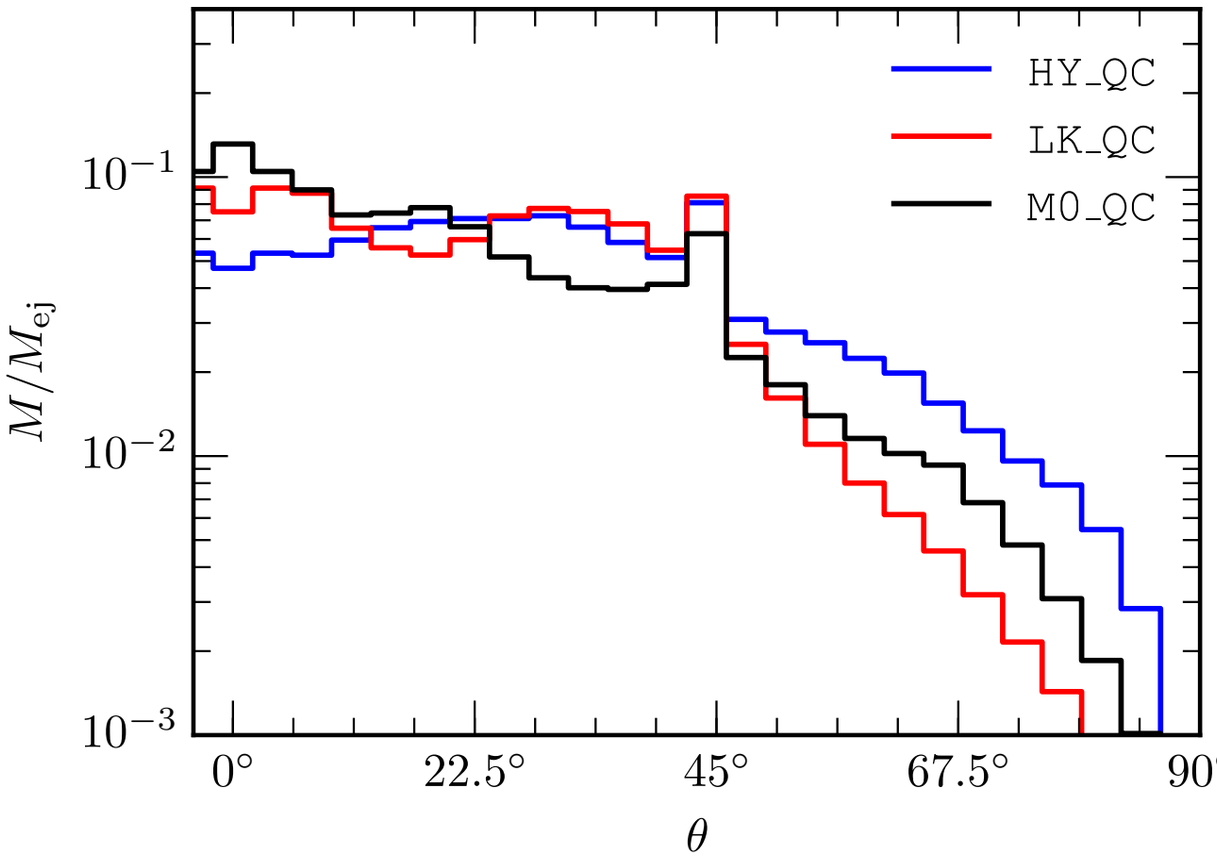


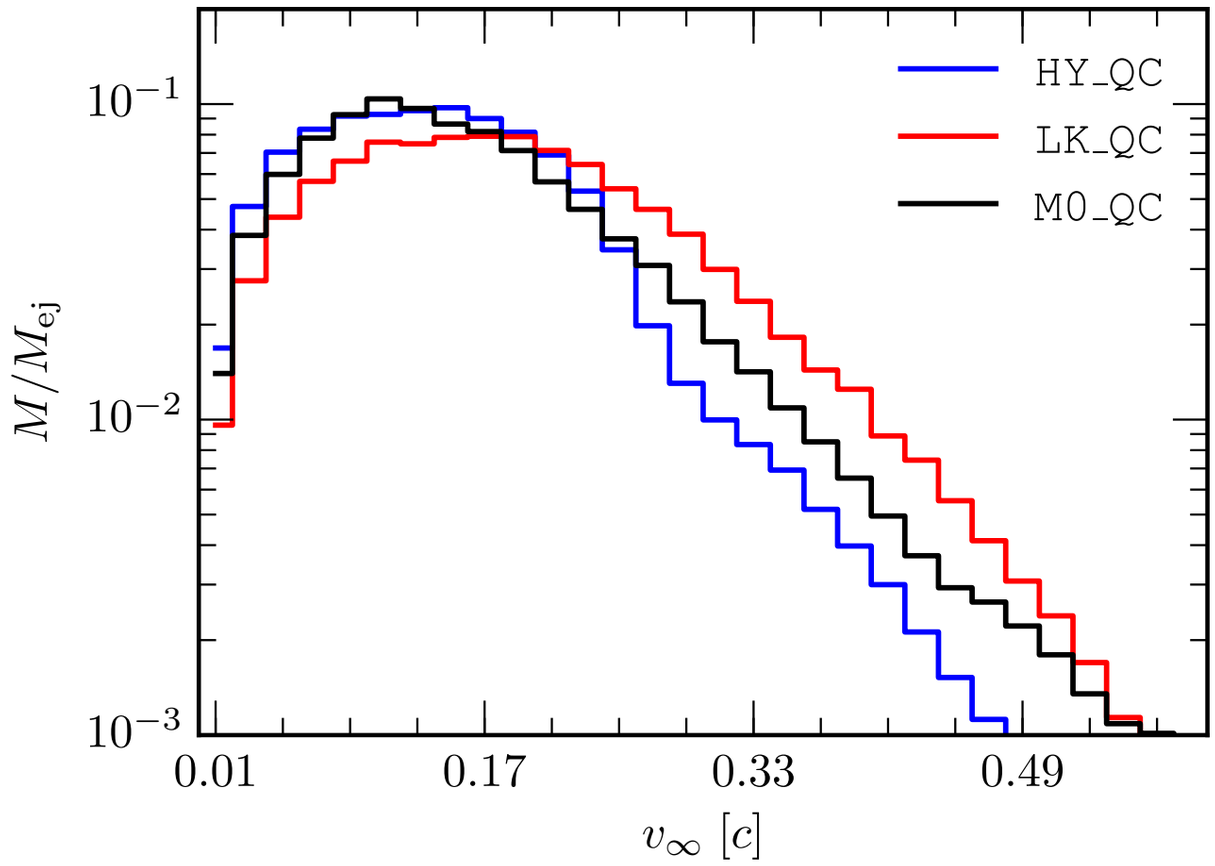




- The yields are robust for A > 120
- A < 120: needs Ye > 0.25, critical role of neutrinos

# Outflow Morphology

$$\mathrm{EOS}: \mathrm{LS220} \quad M = 1.38\, M_\odot$$

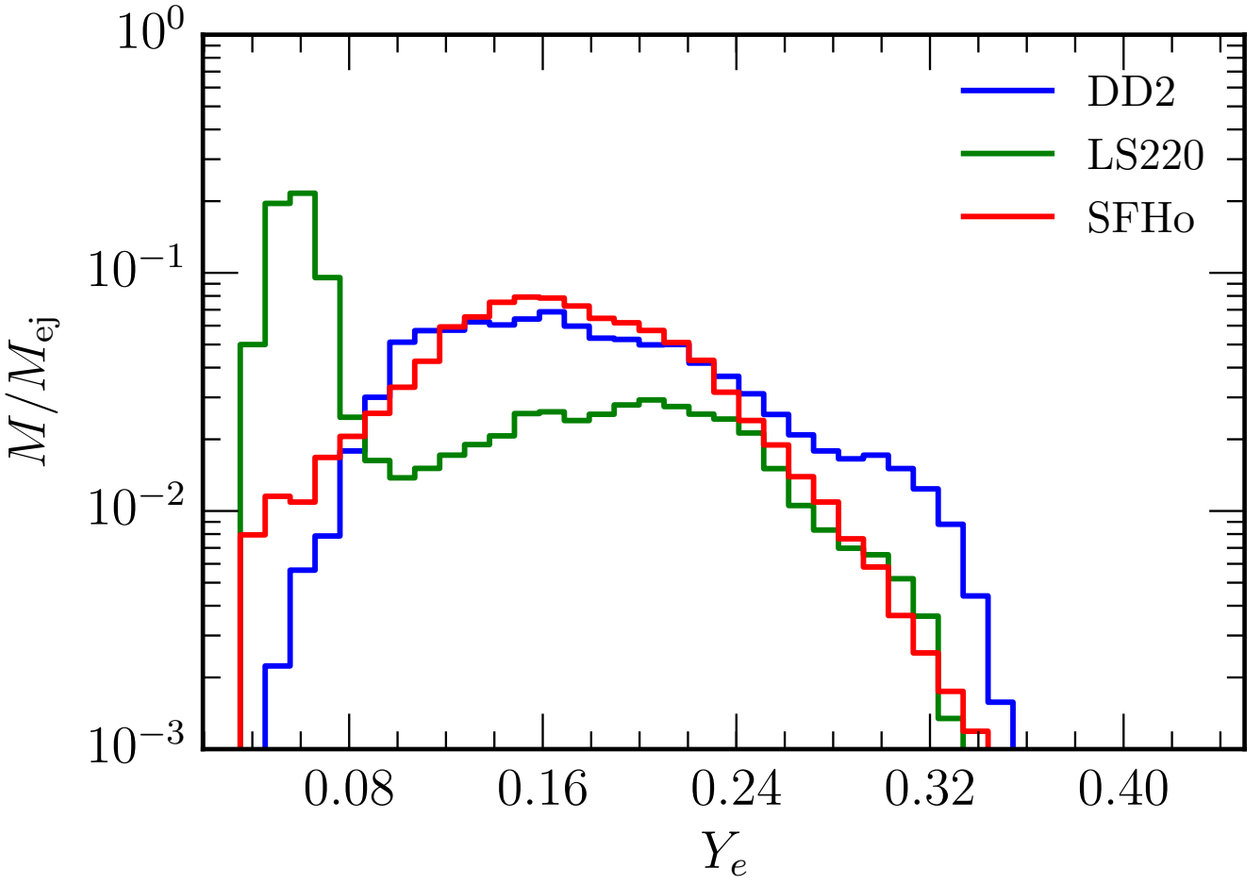


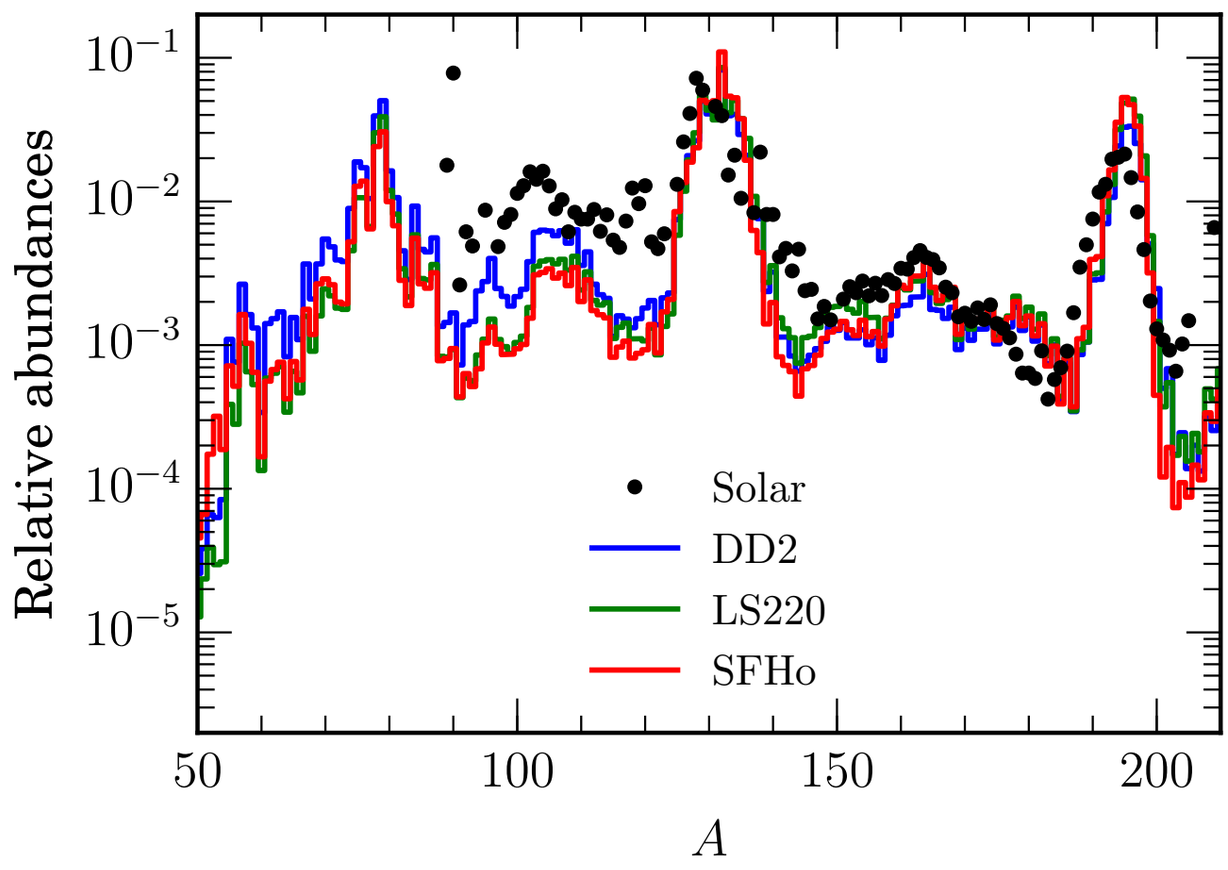




- Ejecta mostly contained within $60^0$ of orbital plane
- Mildly relativistic velocities

# Impact of Equation of State

$$\mathrm{EOS:\,DD2, LS220, SFHo} \quad M = 1.35\,M_\odot$$




- EOS impacts composition and mass
- The yields for A > 120 are robust;1st peak underproduced

# Total Ejected Mass

$$\mathrm{EOS:\,SFHo} \quad M = 1.35\,M_\odot$$

| Simulation | Cooling | Heating | Ejecta Mass [Msun] |
|---|---|---|---|
| WhiskyTHC | x | - | 3.5 x $10^{-3}$ |
| Palenzuela+ 2015 | x | - | 3.2 x $10^{-3}$ |
| Bauswein+ 2013 | - | - | 4.8 x $10^{-3}$ |
| Sekiguchi+ 2015 | x | - | 10.0 x $10^{-3}$ |
| Sekiguchi+ 2015 | x | x | 11.0 x $10^{-3}$ |

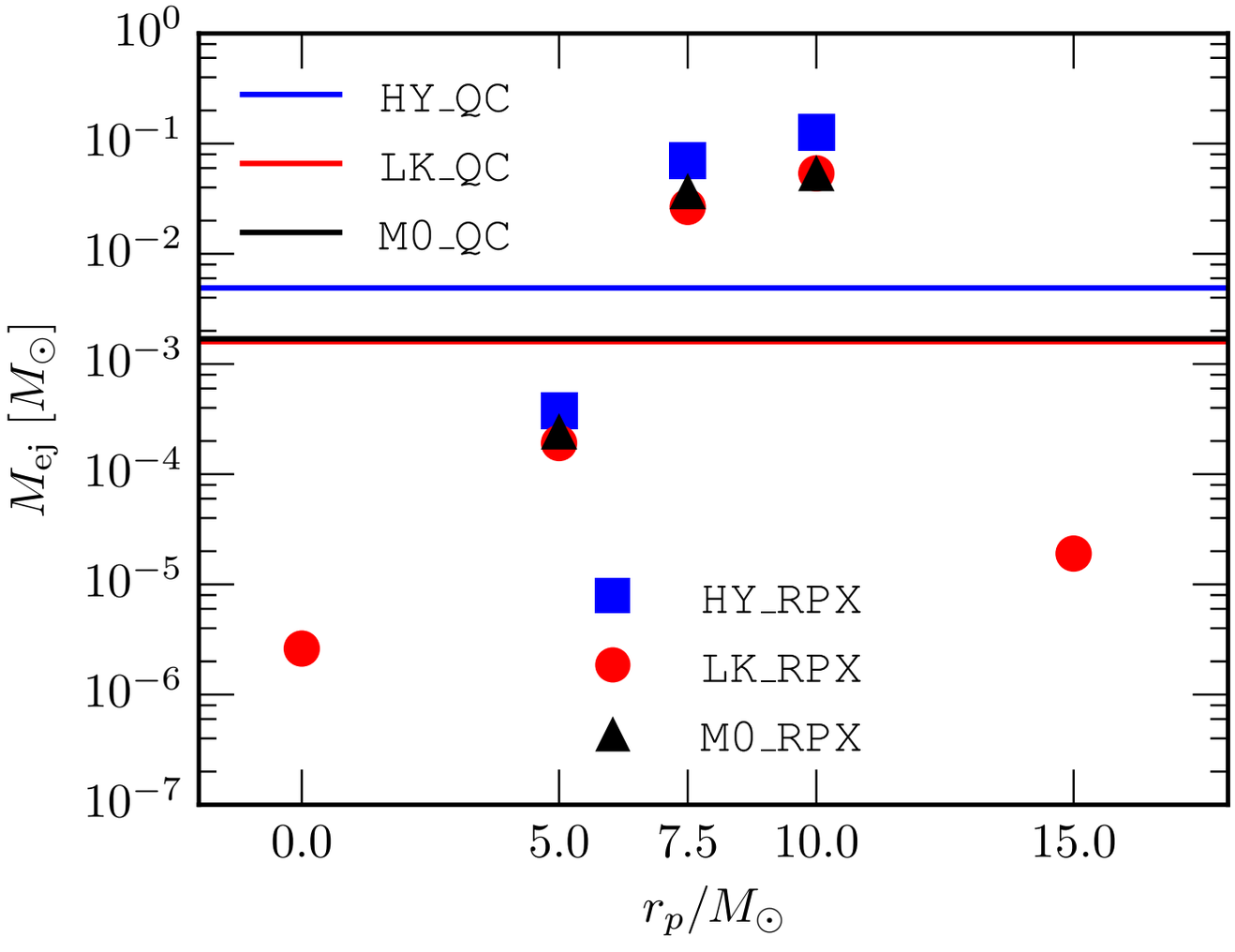
Large uncertainty in the ejecta mass!

# Conclusions

- Outflows driven by tidal torques, shocks, and neutrino radiation
- Robustly produce 2nd and 3rd peak r-process elements; 1st peak still unclear
- Still some work do to (better HD, radiation, MHD, disk winds, …)

# Impact of Orbital Dynamics

$$\mathrm{EOS:\,LS220} \quad M = 1.38\,M_\odot$$




- Neutrino cooling decreases ejecta mass by ~1/2
- Eccentric mergers can eject significantly more mass