Thermal Effects in Binary Neutron Star Mergers

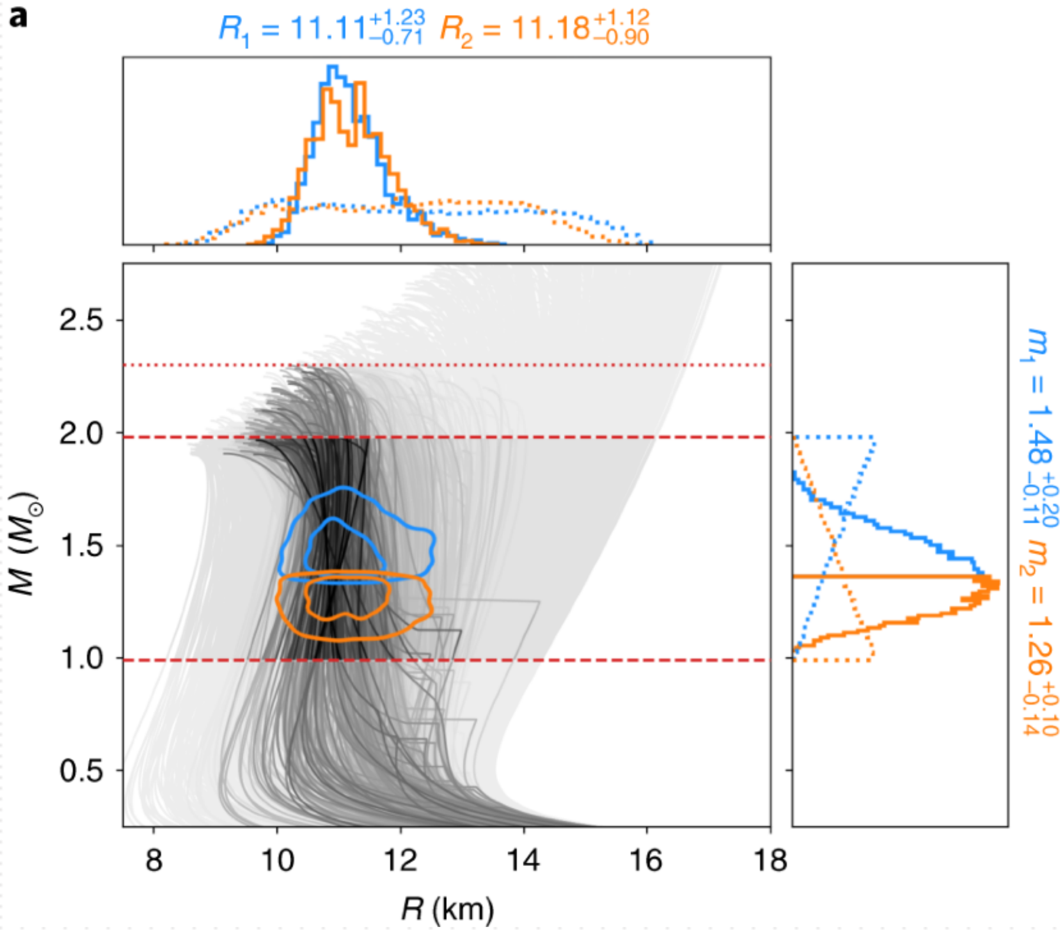
Jacob Fields

J. Fields, A. Prakash, M. Breschi, D. Radice, S. Bernuzzi, A. d. S. Schneider. (accepted for publication in *ApJL*),

arXiv:2302.11359 **[astro-ph.HE]**.

Status of the nuclear equation of state

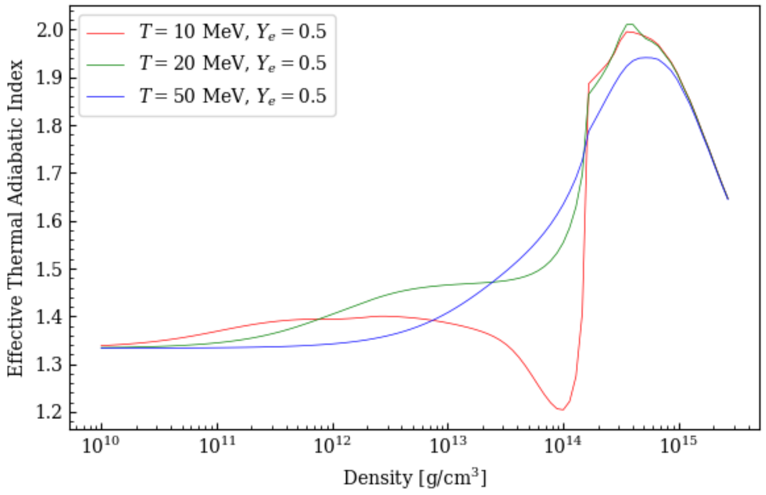
- Some major sources of constraints:
  - Heavy-ion collisions
  - X-ray and radio observations of pulsars
  - GW observations of BNS inspirals and EM counterparts
- Few constraints for hot matter at NS densities!

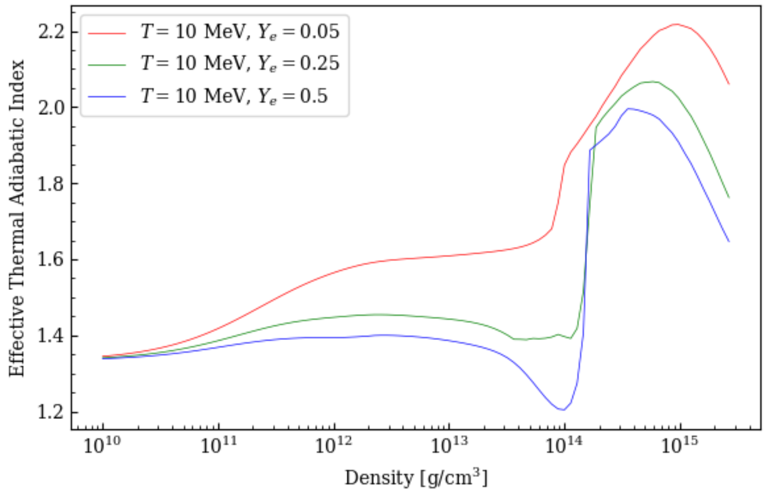


Capano *et al*, Nat. Astr. 4, 625-632 (2020).

Prior work in thermal effects

- Modifying *only* thermal component usually requires hybrid EOS
  - Effective thermal Γ strongly dependent on temperature and composition
- Neutrinos (if included) incorporated via leakage
  - Cannot account for trapped neutrinos in optically-thick regions





A parameterized EOS

- EOS w/ Skyrme-interaction of form

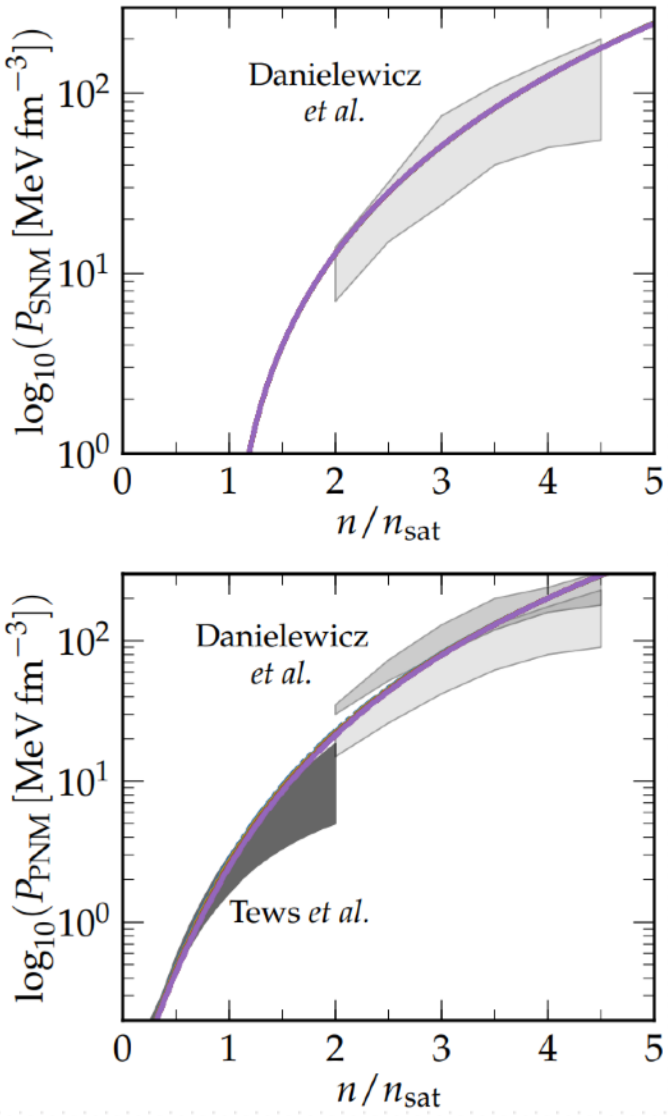
$$e_B(n, y, T) = e_{\mathrm{kin}}(n, y, T) + e_{\mathrm{pot}}(n, y)$$

- $e_{\mathrm{kin}}(n, y, T)$ depends on effective nucleon masses m_{n}^* and m_{p}^*

- Can be parameterized by defining

$$m^* \equiv m_n^*(n = n_{\mathrm{sat}}, y = 1/2)$$

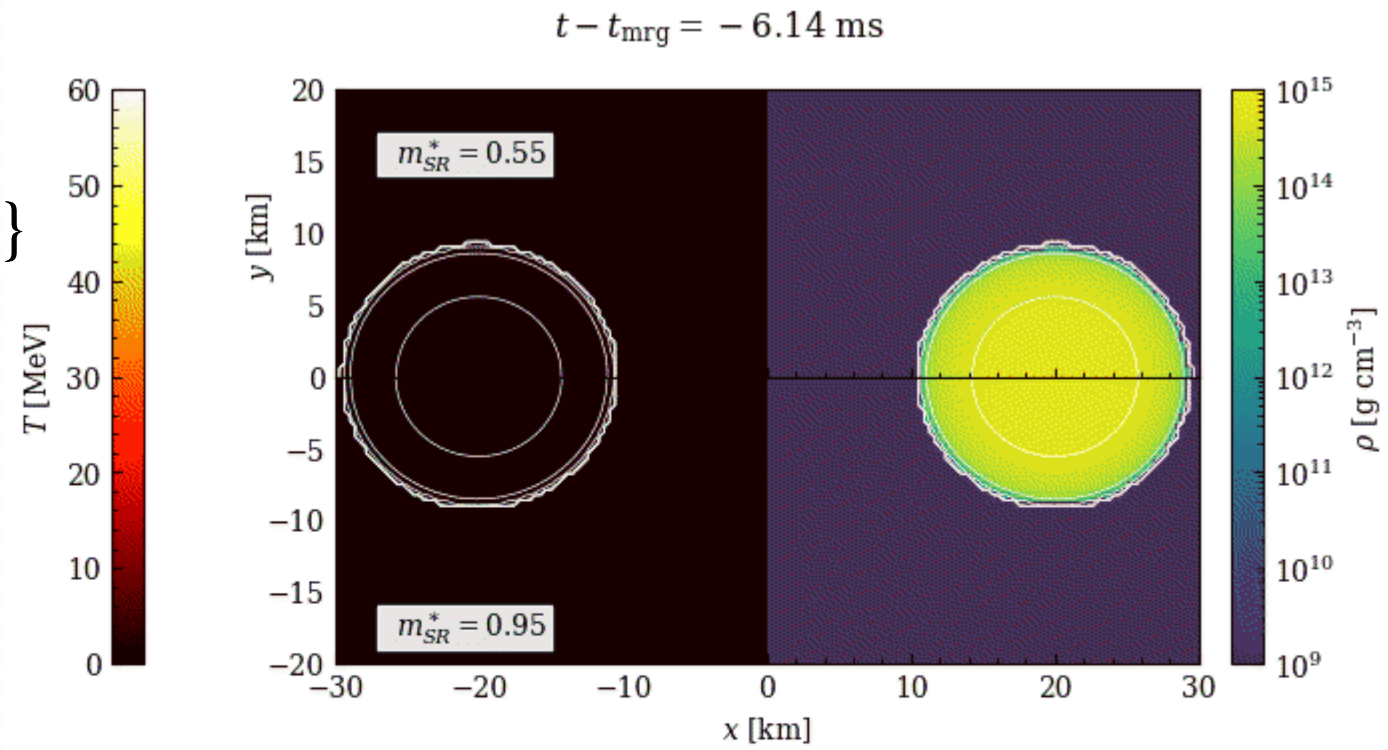
- **m^* effectively controls the specific heat capacity ➔ only affects thermal behavior**



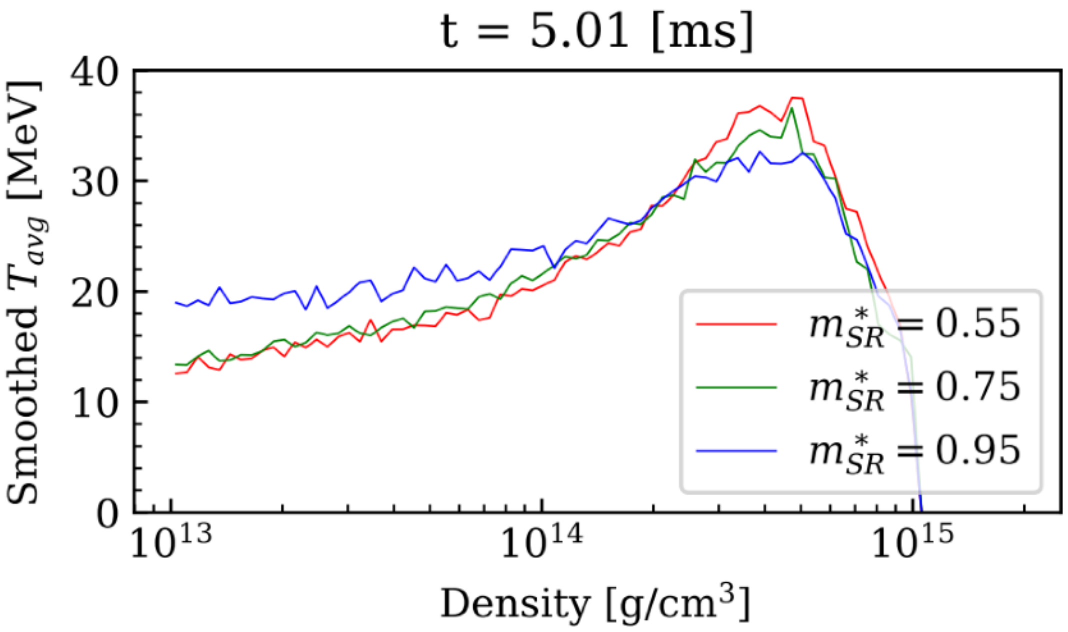
Schneider *et al*, PRC 100, 055802 (2019).

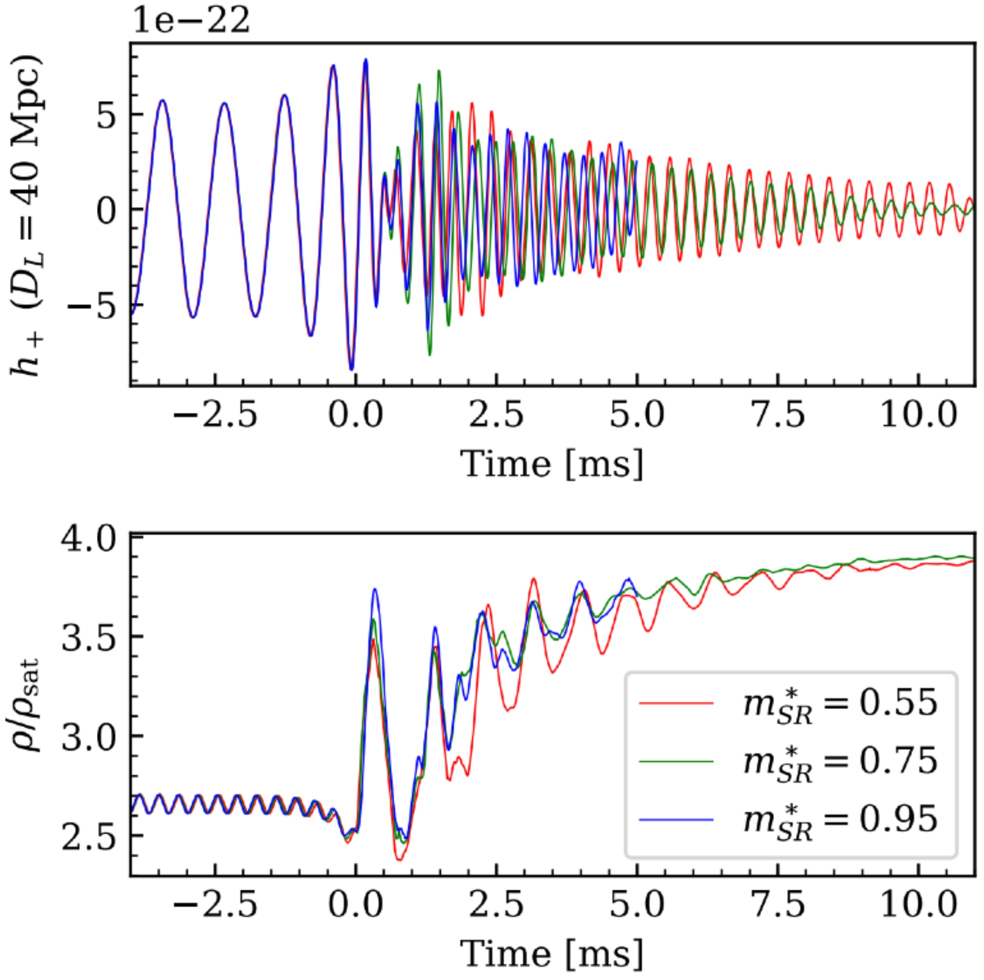
Simulations

- Equal mass binaries with $m^*/m_n \in \{0.55, 0.75, 0.95\}$
- THC_M1
  - No magnetic fields
  - M1 neutrino transport
  - GRLES subgrid model



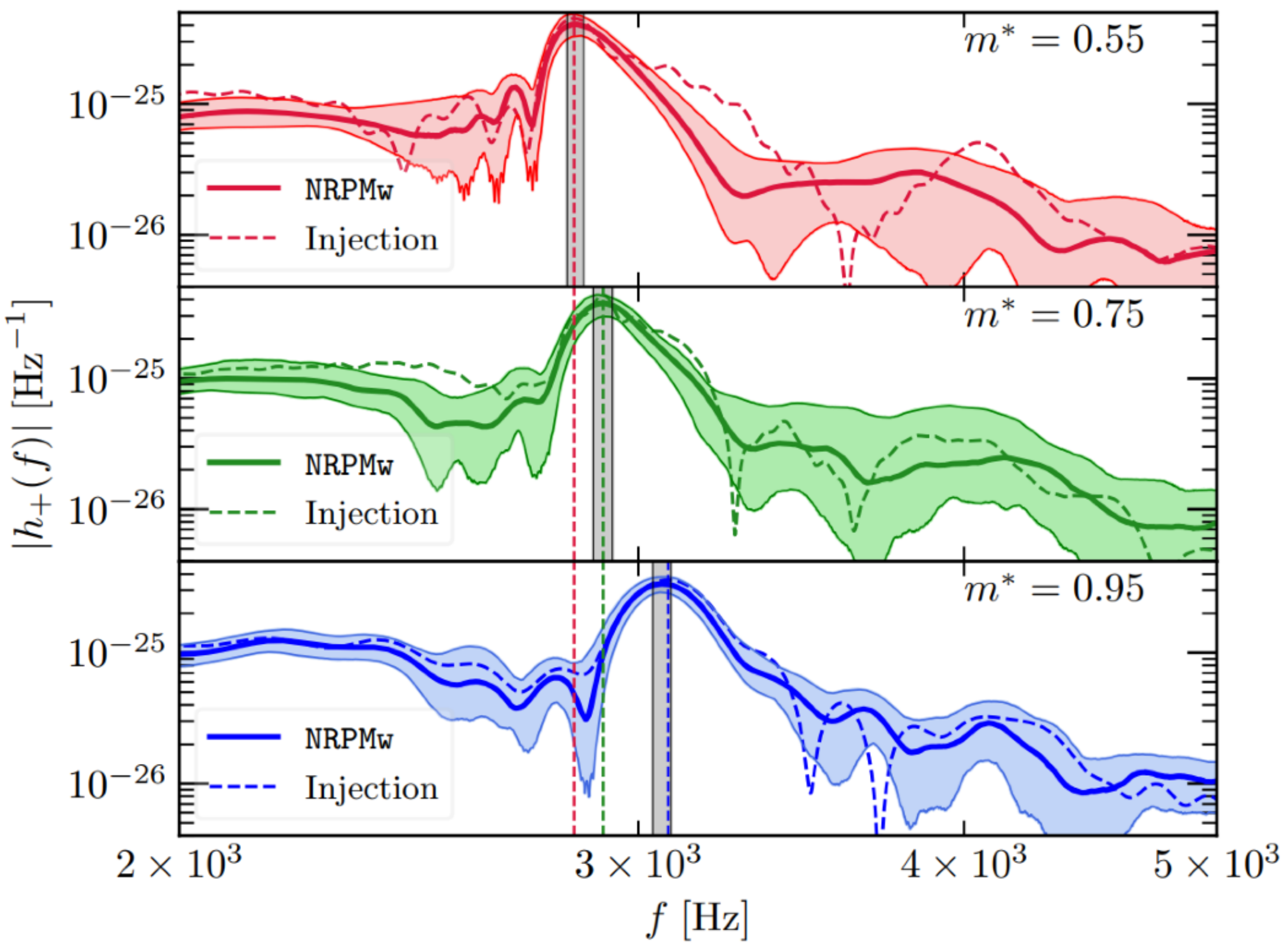
Results


t = 5.01 [ms]
Smoothed T_{avg} [MeV]
40
30
20
10
0
10^{13}
10^{14}
10^{15}
Density [g/cm^3]
$m^*_{SR} = 0.55$
$m^*_{SR} = 0.75$
$m^*_{SR} = 0.95$


1e−22
h_+ ($D_L = 40$ Mpc)
5
0
−5
−2.5
0.0
2.5
5.0
7.5
10.0
Time [ms]
ρ/ρ_{sat}
4.0
3.5
3.0
2.5
−2.5
0.0
2.5
5.0
7.5
10.0
Time [ms]
$m^*_{SR} = 0.55$
$m^*_{SR} = 0.75$
$m^*_{SR} = 0.95$

Observational signatures

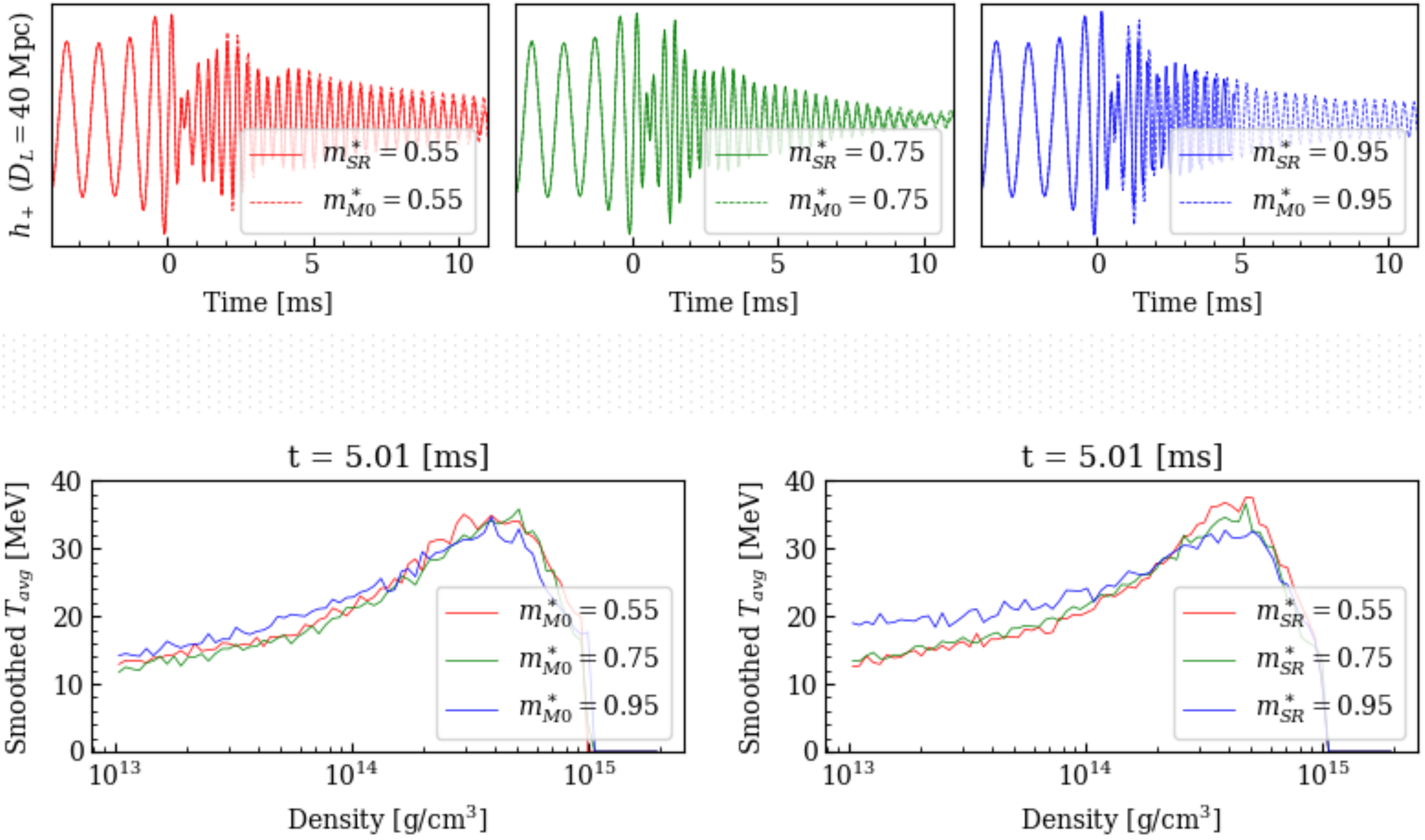
- Peak frequency positively correlated with m^*
- Differences discernible at SNR 15 or less in next-gen detectors



Summary

- Simulated BNS mergers with parameterized finite-temperature EOS and M1 neutrino transport
- Higher m^* results in denser, colder cores
- Effective mass m^* shows correlation with peak post-merger frequency
    - Models are distinguishable in future GW detectors at SNR 15

M1 vs. M0


h_+ ($D_L = 40$ Mpc)
$m^*_{SR} = 0.55$
$m^*_{M0} = 0.55$
$m^*_{SR} = 0.75$
$m^*_{M0} = 0.75$
$m^*_{SR} = 0.95$
$m^*_{M0} = 0.95$
Time [ms]
t = 5.01 [ms]
Smoothed T_{avg} [MeV]
$m^*_{M0} = 0.55$
$m^*_{M0} = 0.75$
$m^*_{M0} = 0.95$
$m^*_{SR} = 0.55$
$m^*_{SR} = 0.75$
$m^*_{SR} = 0.95$
Density [g/cm^3]

M1 vs. M0 (cont.)

M0

M1