kiloHertz gravitational-waveforms from neutron star merger remnants

arXiv:1908.11418 [gr-qc]

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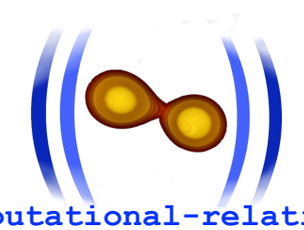
LVC Meeting – Warsaw
Sept 2019

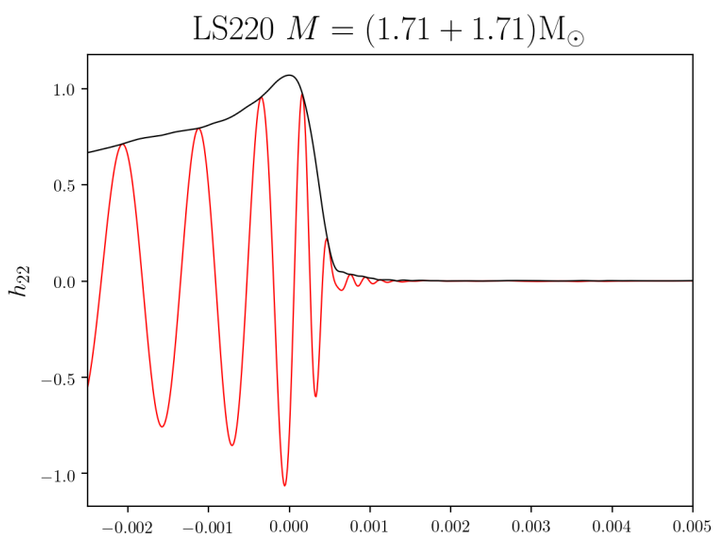
FRIEDRICH-SCHILLER-
UNIVERSITÄT
JENA



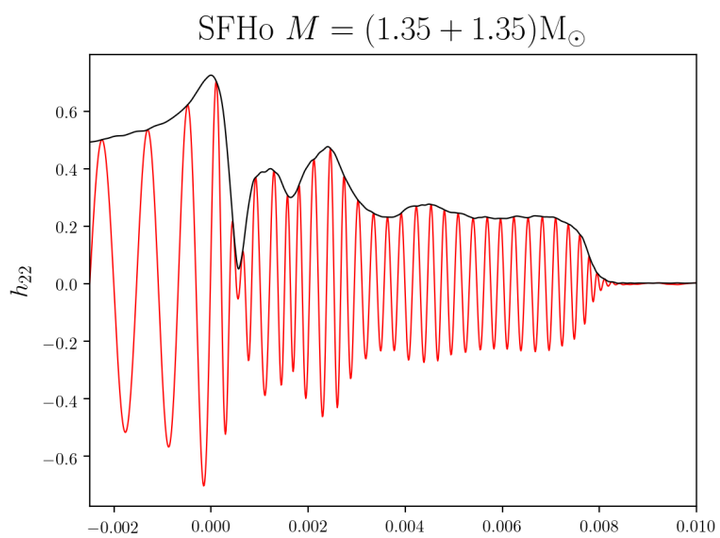
www.computational-relativity.org

BNS Remnant Scenario

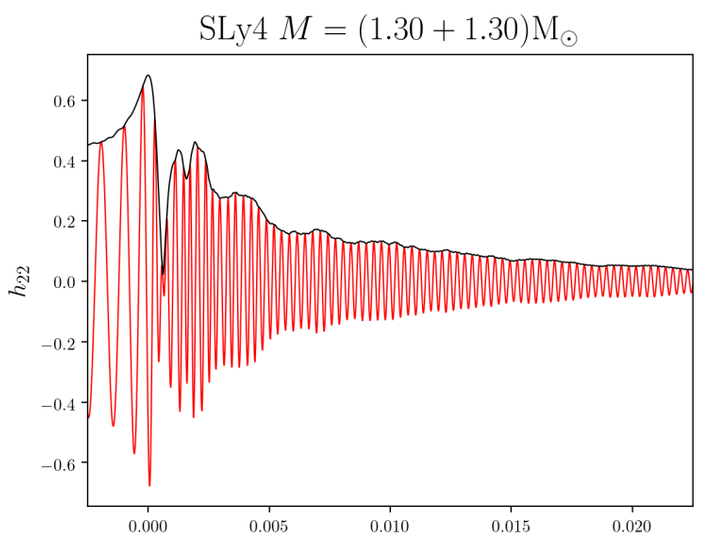
- **Prompt-Collapse**

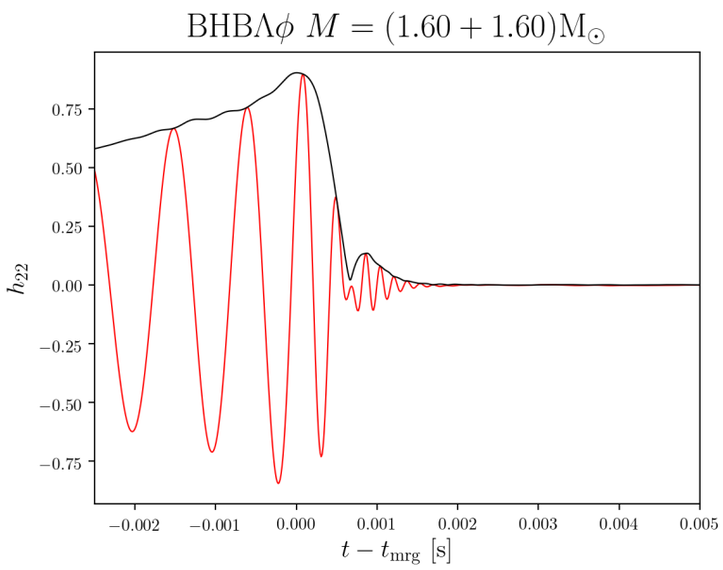


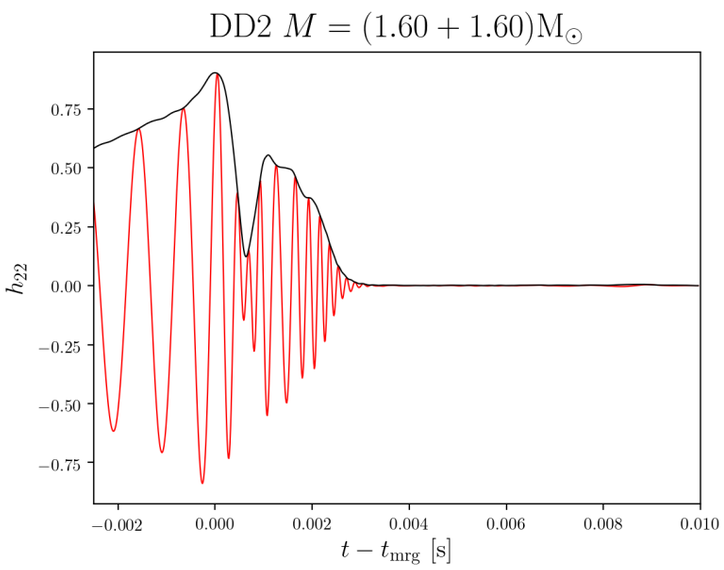
- **Short-Lived**

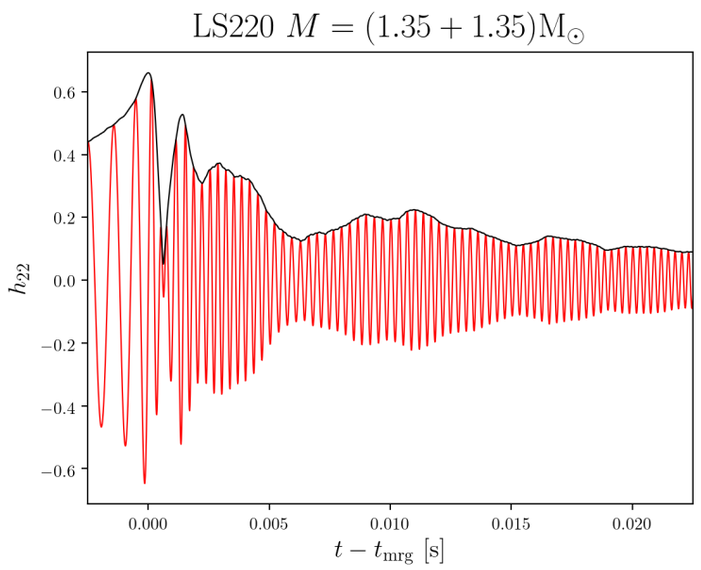


- **Long-lived**



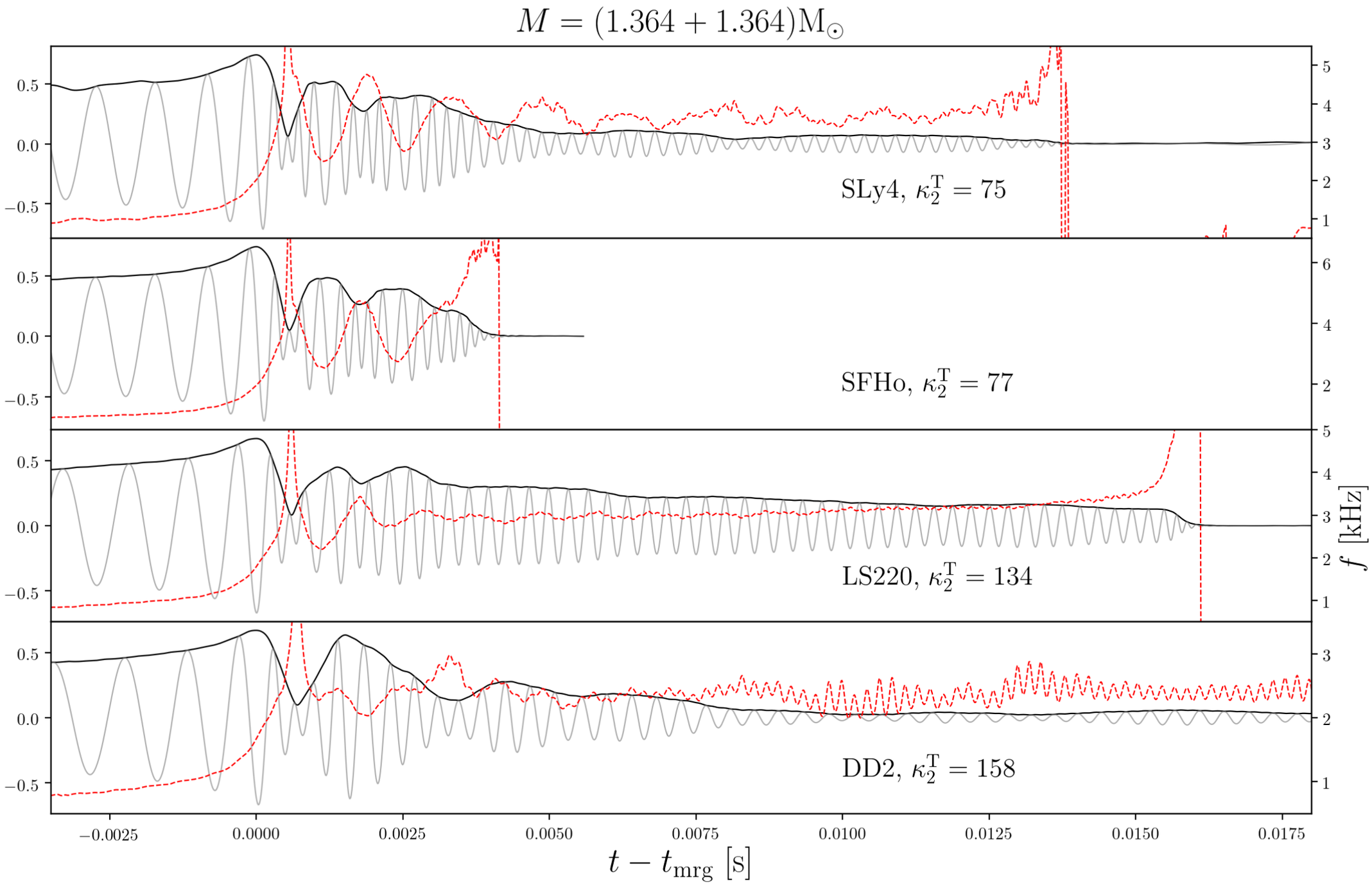






[1] T. Dietrich *et al.*, Class. Quant. Grav. 35 (2018)

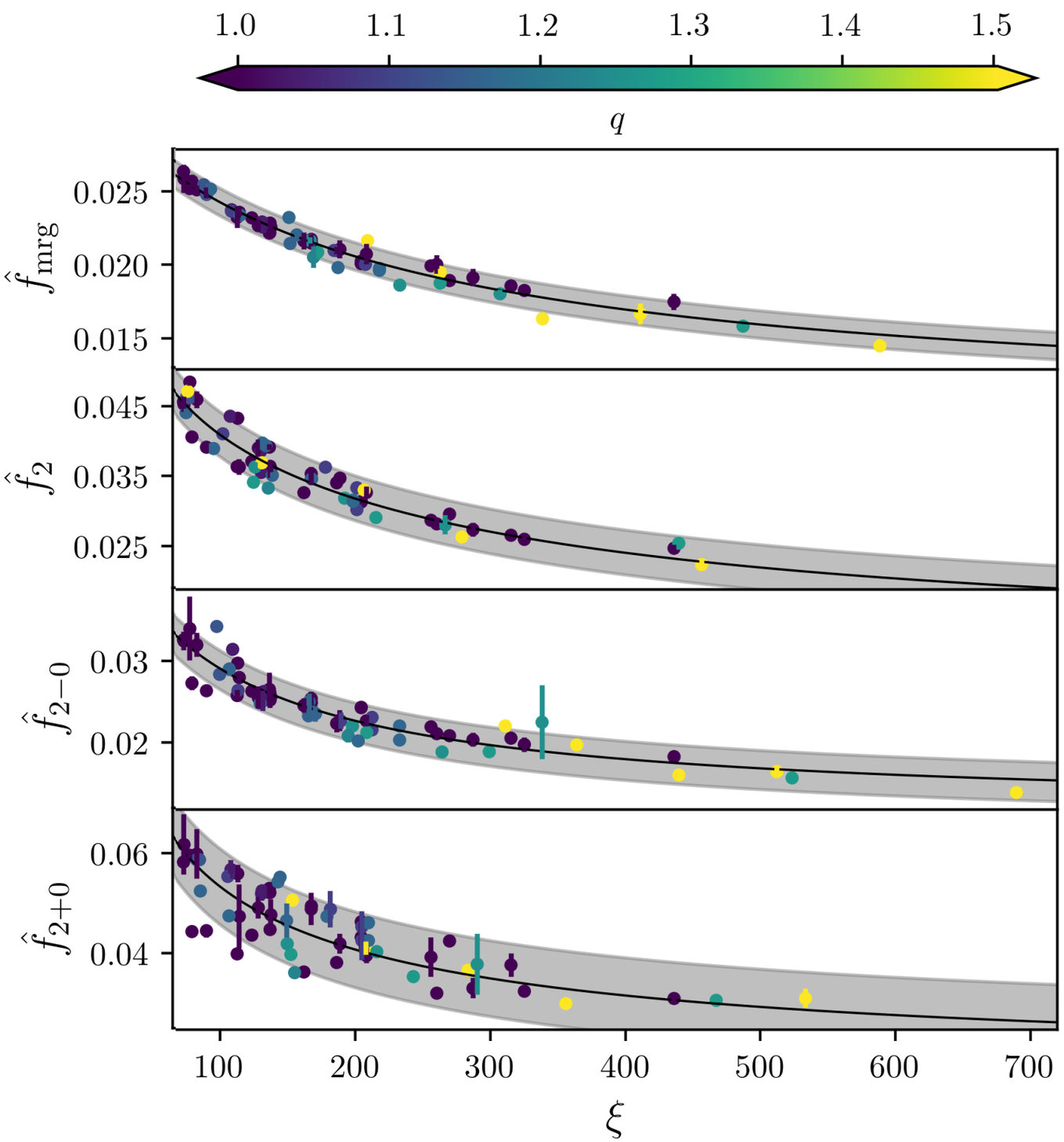
Postmerger Properties



[2] S. Bernuzzi *et al.*, Phys. Rev. D94 (2016)

[3] F. Zappa *et al.*, Phys. Rev. Lett. 120 (2018)

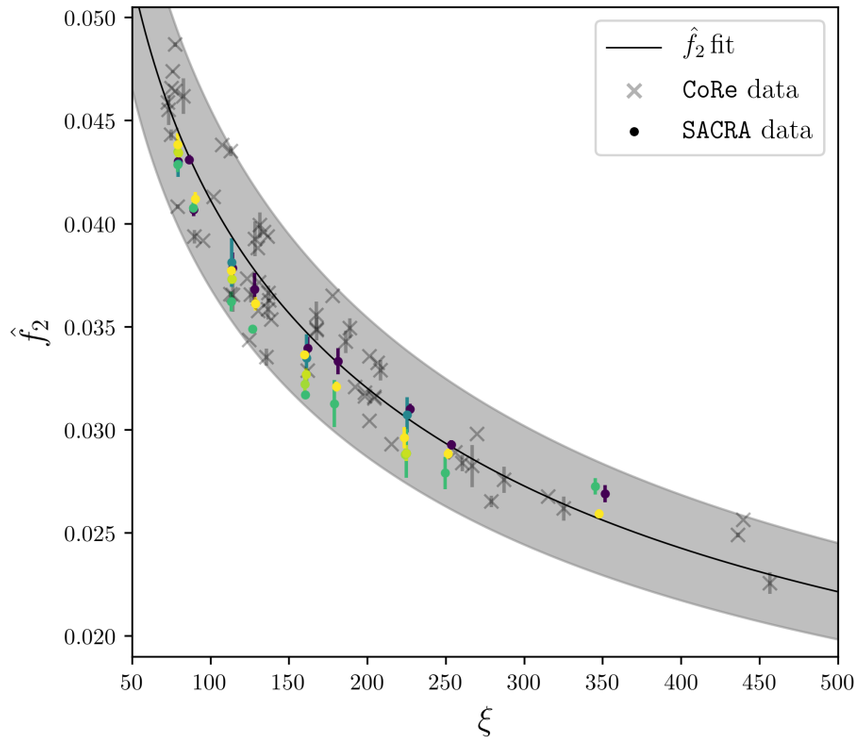
Quasi-Universal Relations



- Extended relations in [4,5] using **172 simulations** from `CoRe` database

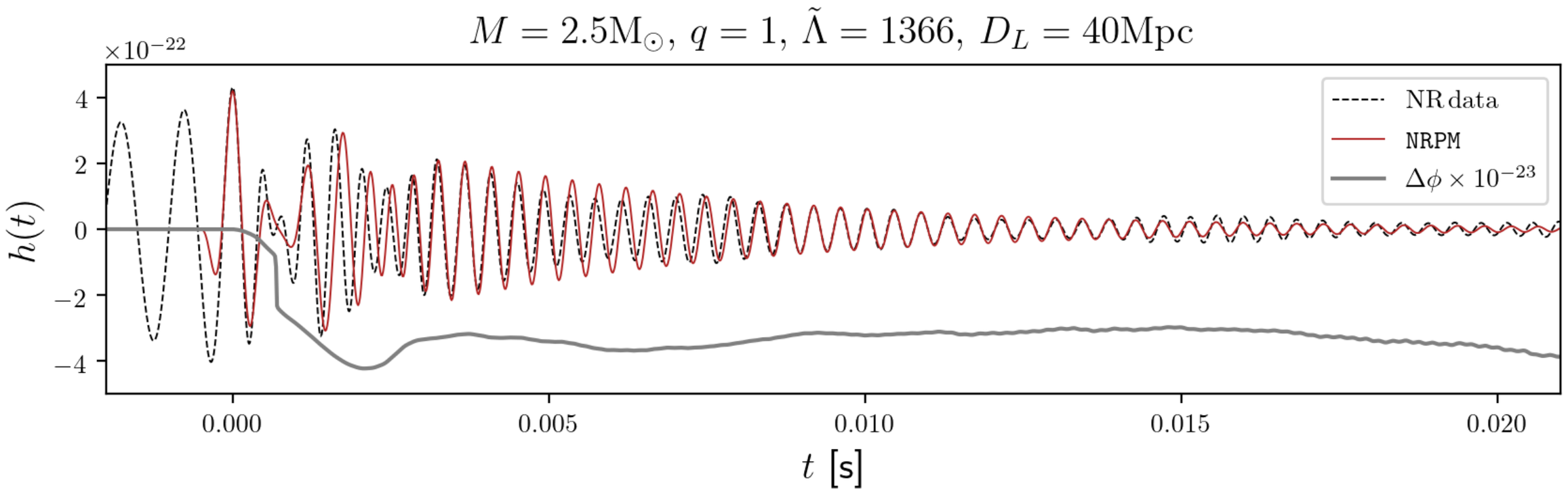
$$\xi = \kappa_2^{\rm T} + c\,(1 - 4\nu)$$

- Consistency with BNS properties extracted from independent code [6]



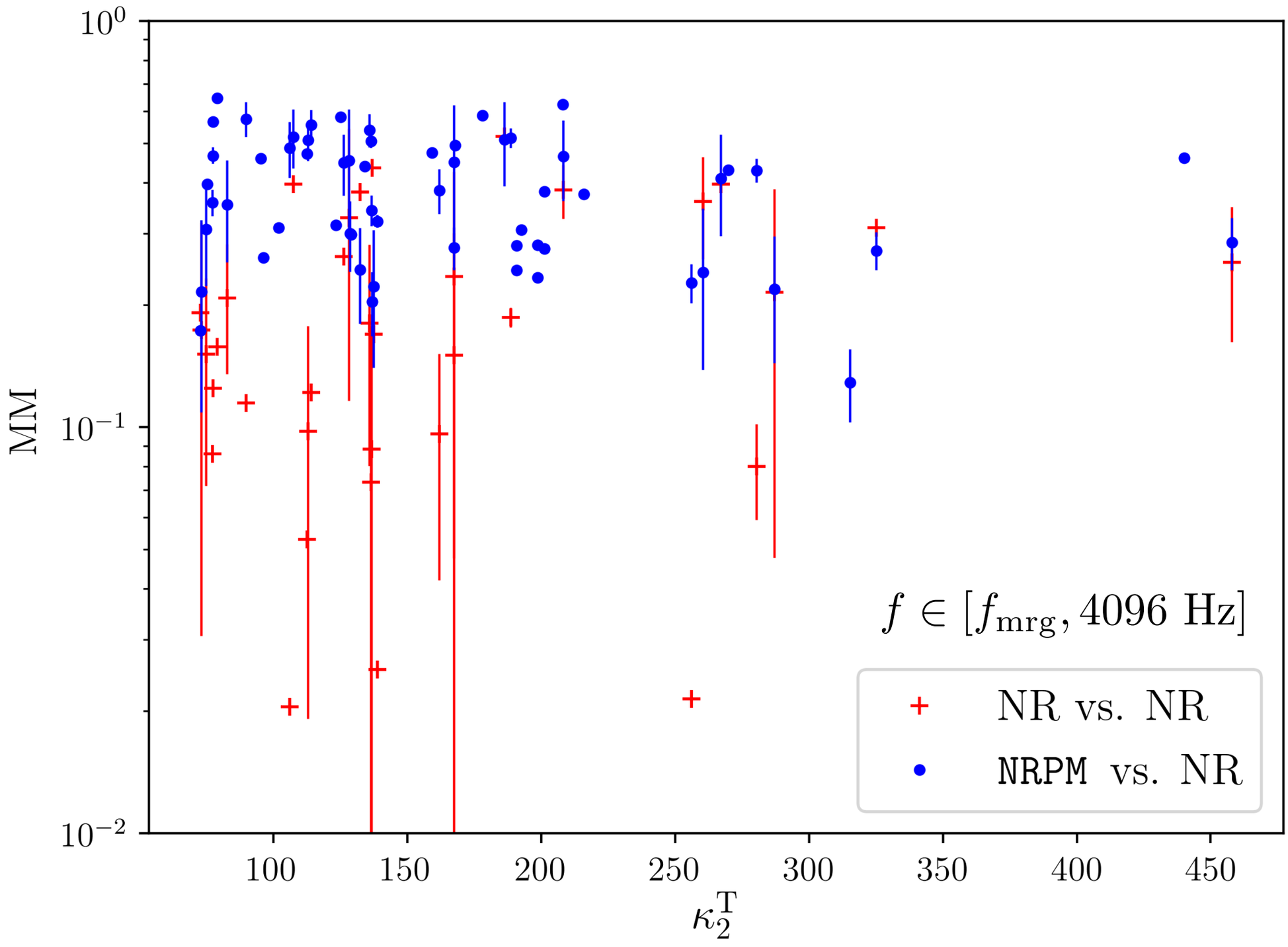
[4] S. Bernuzzi *et al.*, Phys. Rev. Lett. 112 (2014) [5] S. Bernuzzi *et al.*, Phys. Rev. Lett. 115 (2015) [6] K. Kiuchi *et al.*, Phys. Rev. D96 (2017)

NRPM

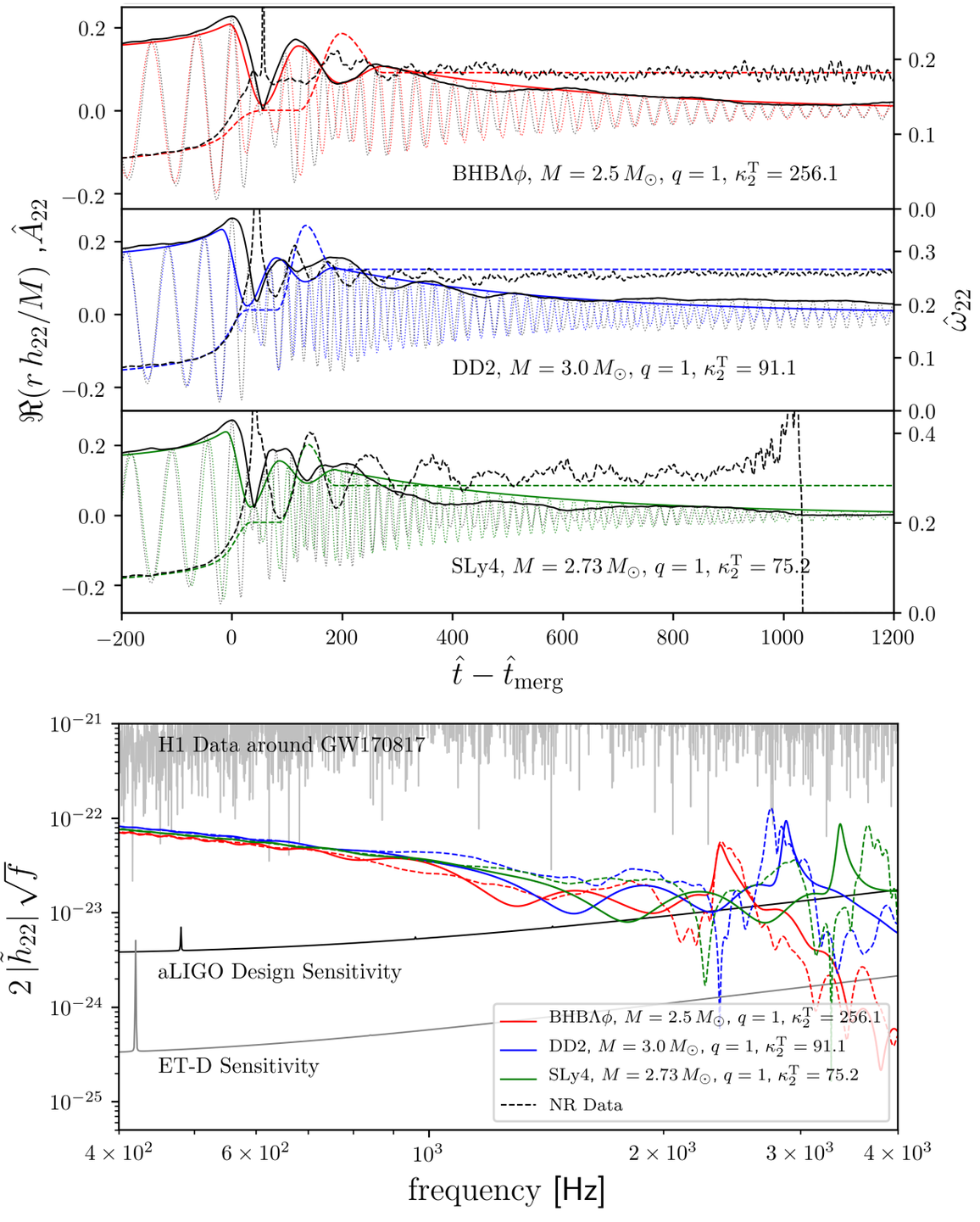


- NR-informed time-domain non-spinning model for BNS remnant
  - Three main characteristic frequencies
  - Amplitude decays as a damped exponential
  - Complete EOB model in the kHz regime

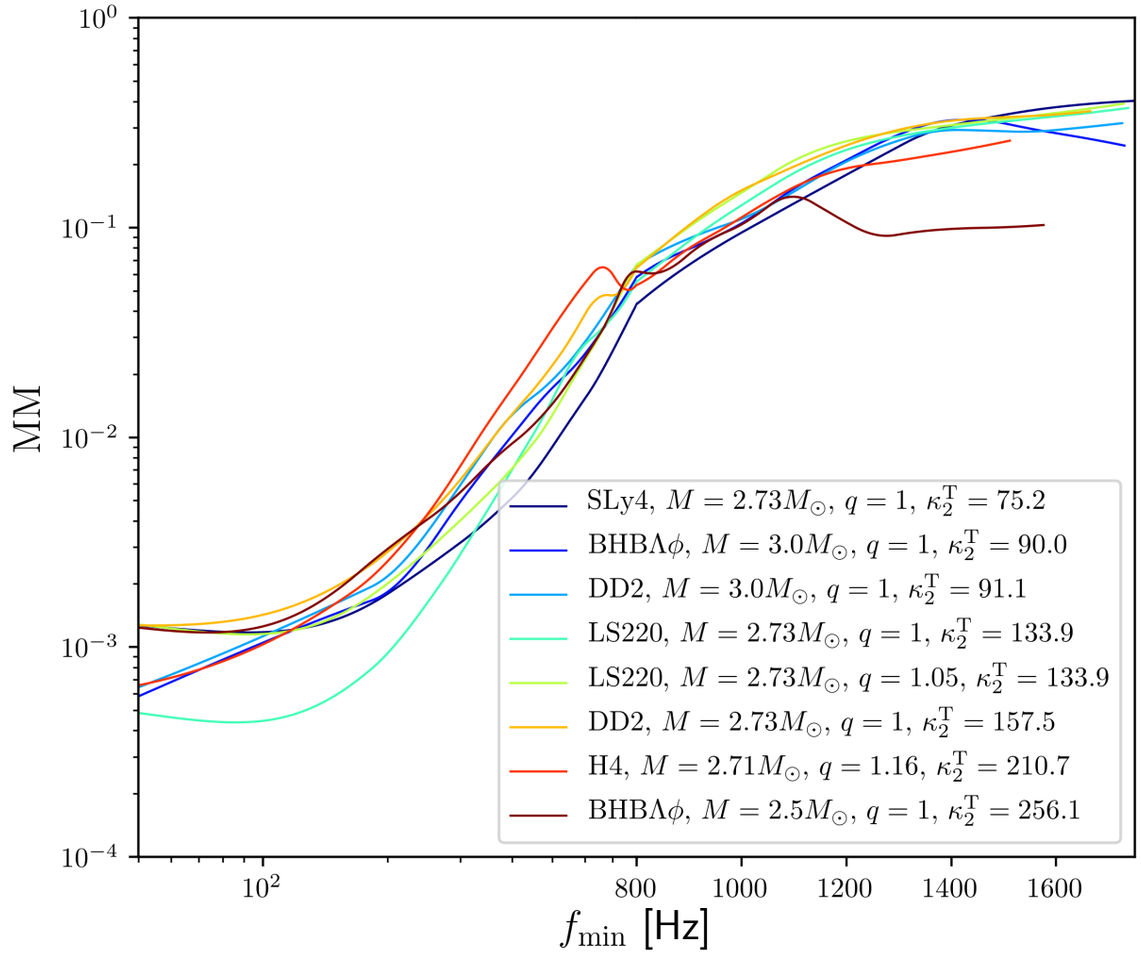
Validation


10^0
10^{-1}
10^{-2}
MM
100
150
200
250
300
350
400
450
κ_2^{T}
$f \in [f_{\mathrm{mrg}}, 4096\ \mathrm{Hz}]$
NR vs. NR
NRPM vs. NR

EOB Completion: `TEOBResumS_NRPM`



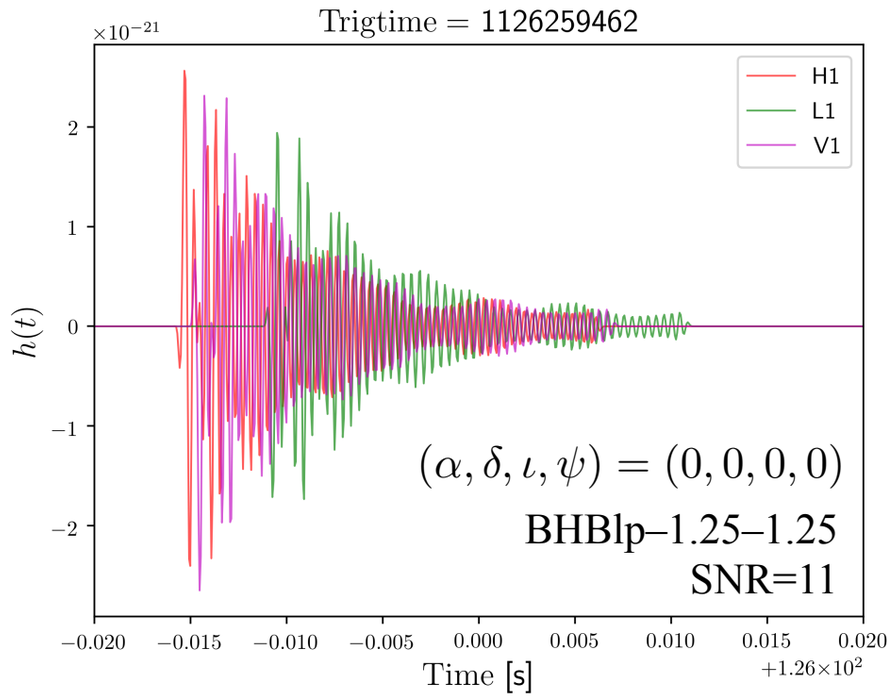
- Complete inspiral-merger-postmerger model for BNS coalescences, based on `TEOBResumS` [7]



[7] A. Nagar *et al.*, Phys. Rev. D98 (2018)

Injection Studies

- At which SNR can `NRPM` detect a PM signal?
- Which constraints can we impose?
- Is it possible to infer the EOS stiffness at the extreme densities reached in the NS remnant?

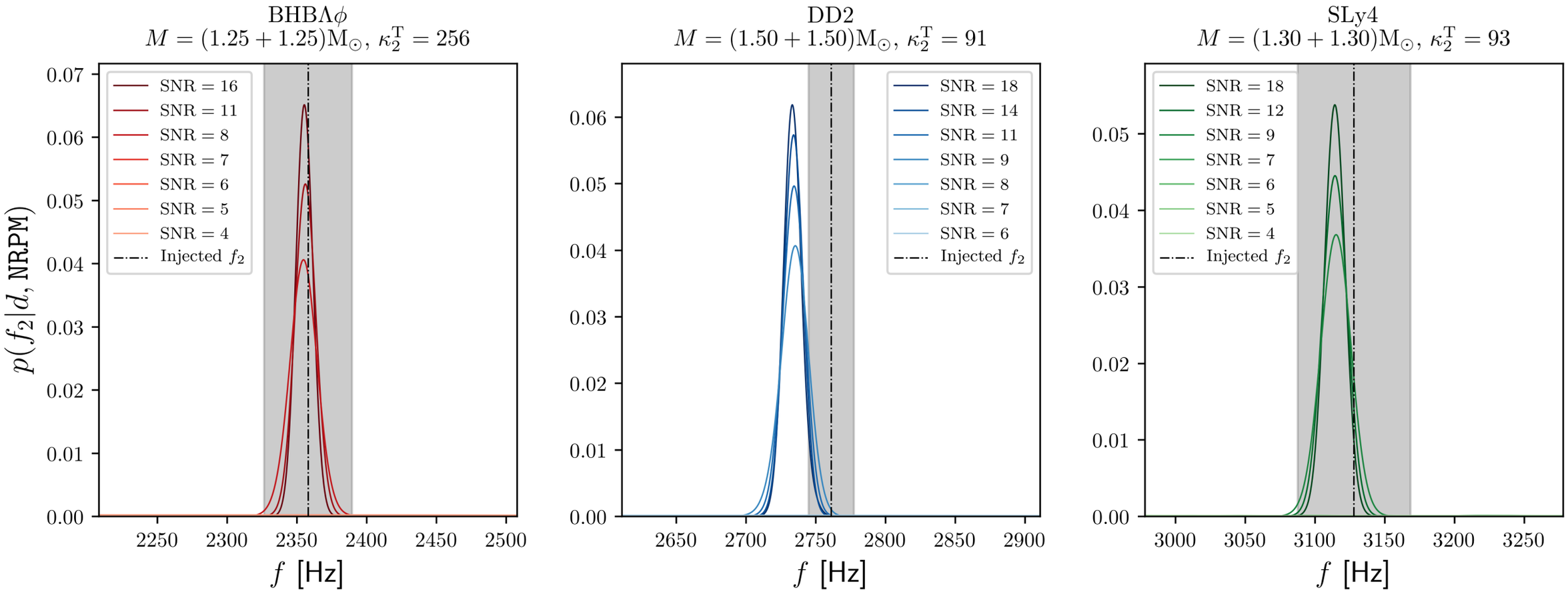


Parameters: $\Theta = \{M_A, M_B, \Lambda_A, \Lambda_B, D_L, \psi, t_0, \phi_0\}$

Priors : $\mathcal{M}_c \in [0.5, 2.2]\,, \quad q \in [1, 1.5]\,, \quad \Lambda_i \in [50, 5000]$

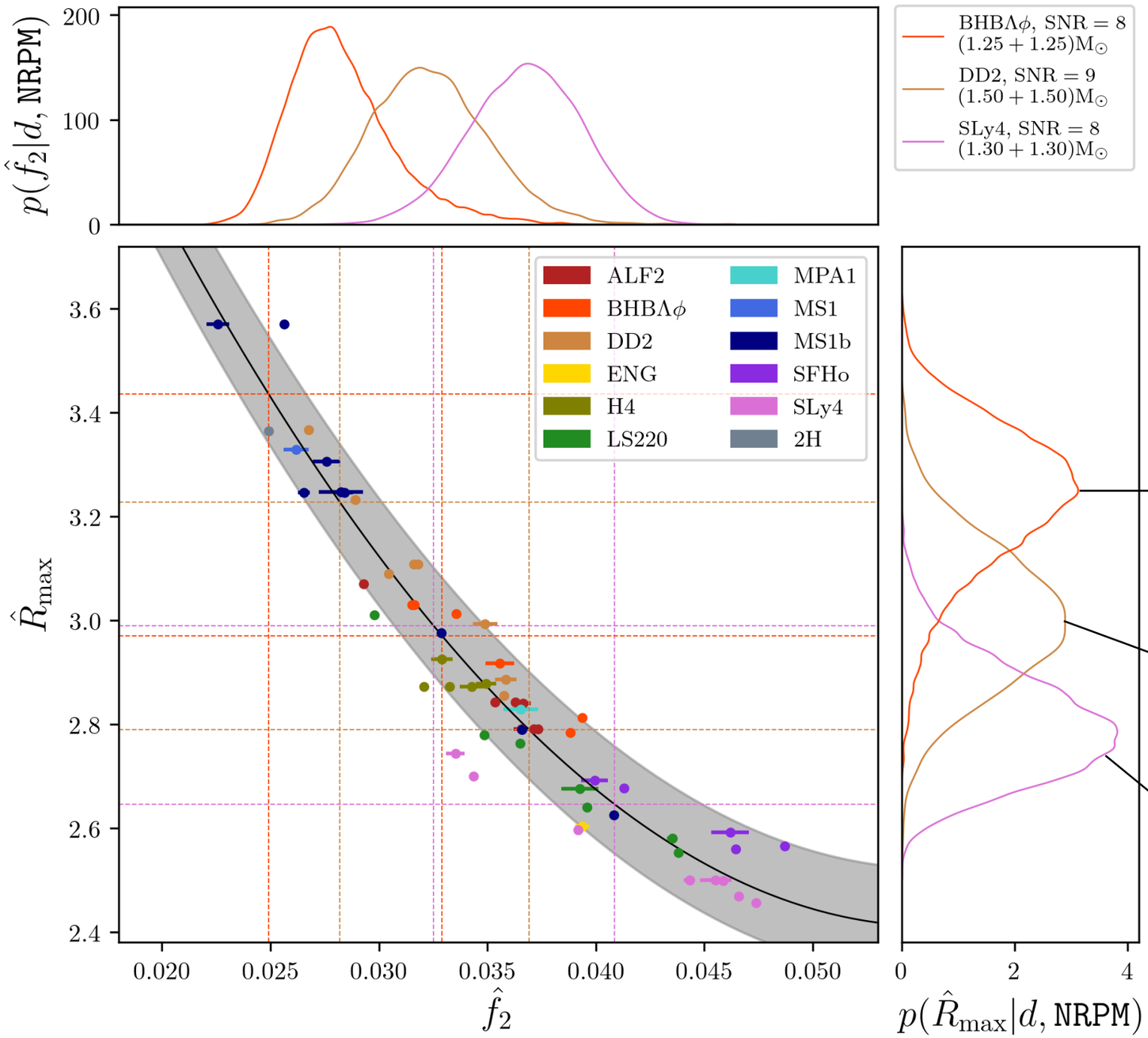
Nested Samp.: $f \in [1024\ \mathrm{Hz}, 4096\ \mathrm{Hz}]\,, \quad \mathrm{sampling\,rate} = 8192\ \mathrm{Hz}\,, \quad \mathrm{live\,points} = 2000$

Detectability



- `NRPM` gives evidence of detection from SNR 8–9
- Most of the recovered peak frequencies agree with the injected properties

EOS Contraints



$$\hat{R}_{\rm max} = p_0 + p_1 \hat{f}_2 + p_2 \hat{f}_2{}^2$$

$$\hat{R}_{\rm max} = R_{\rm max}/M$$

$$\hat{f}_2 = M f_2$$

$$R_{\rm max} = 11.5^{+0.9}_{-0.5}\ \text{km}$$

$$\left(R_{\rm max}^{\rm BHB\Lambda\phi} = 11.63\ \text{km}\right)$$

$$R_{\rm max} = 10.6^{+0.7}_{-0.7}\ \text{km}$$

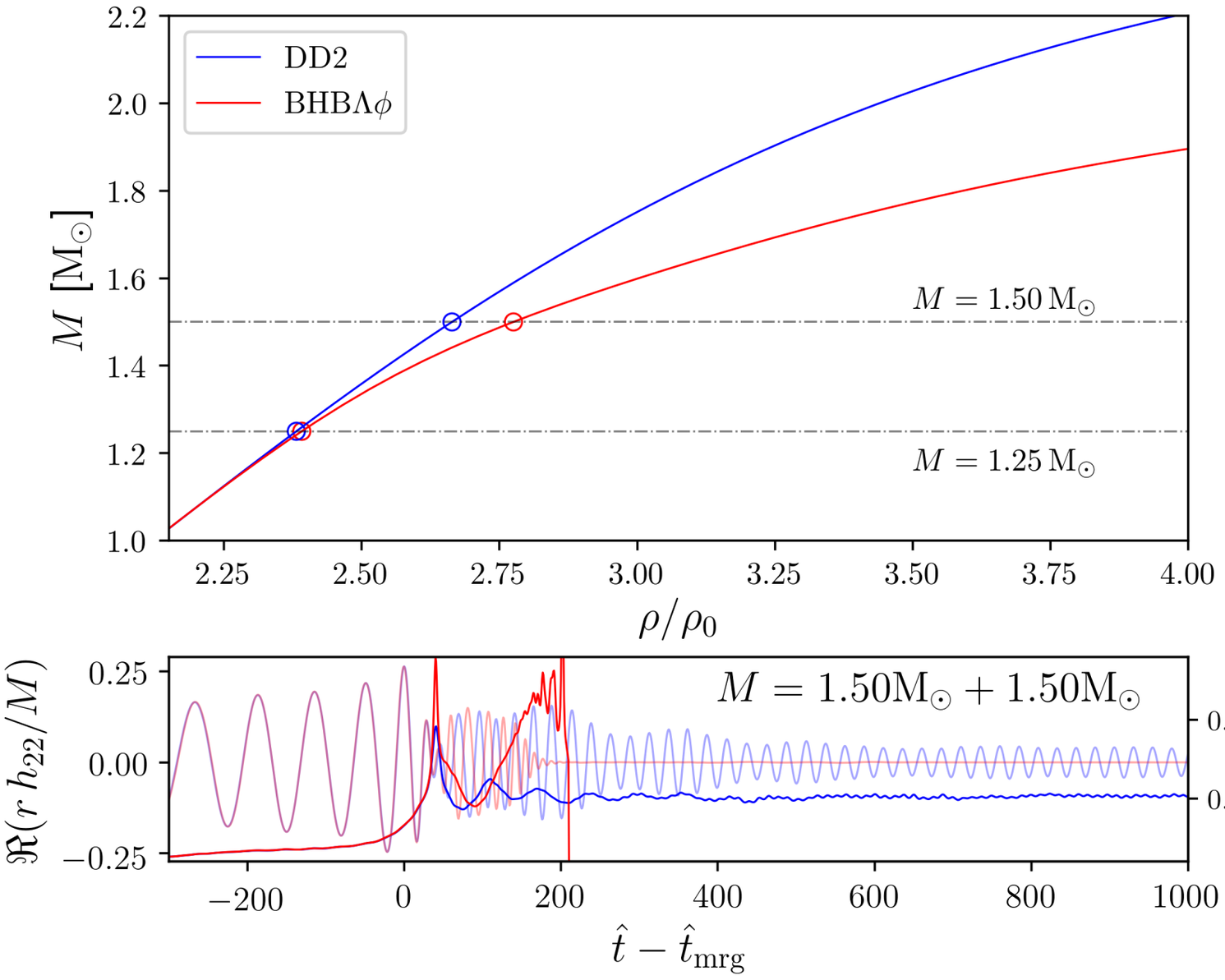
$$\left(R_{\rm max}^{\rm DD2} = 11.93\ \text{km}\right)$$

$$R_{\rm max} = 9.9^{+0.5}_{-0.6}\ \text{km}$$

$$\left(R_{\rm max}^{\rm SLy4} = 9.97\ \text{km}\right)$$

[8] A. Bauswein and N. Stergioulas, arXiv:1901.06969 [gr-qc] (2019)

Softness Test



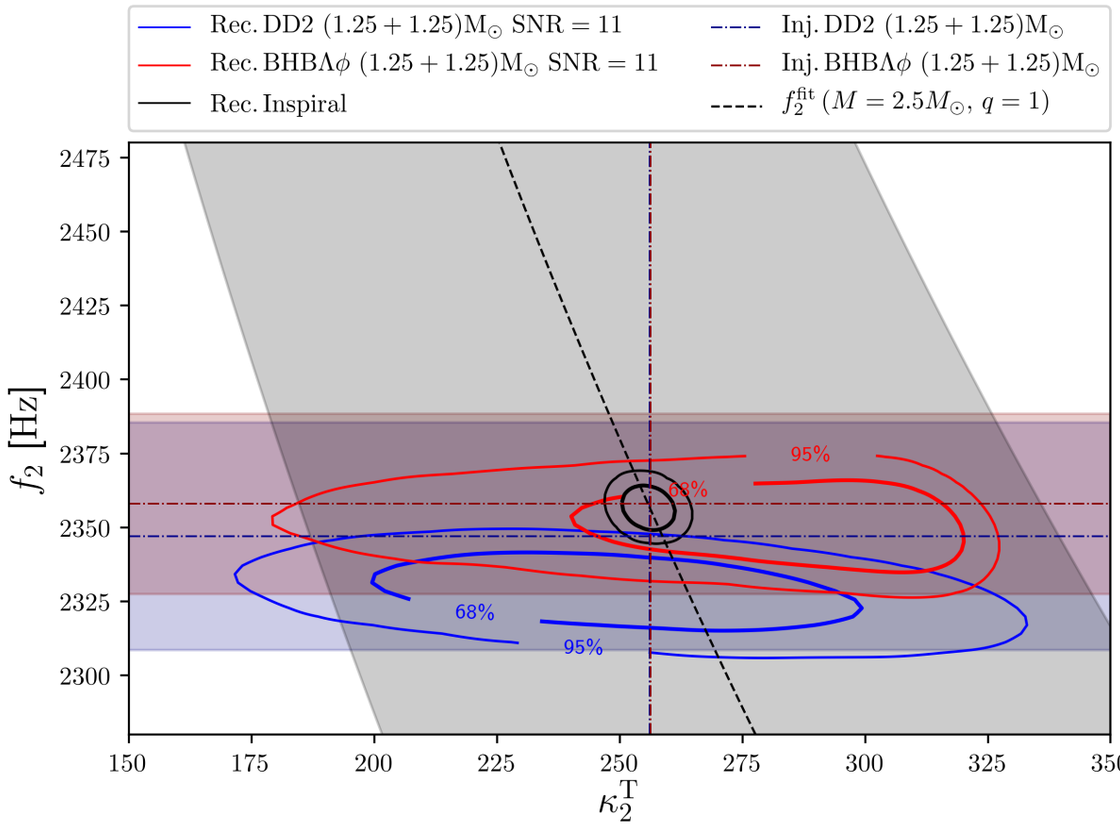
- Test the behavior of the EOS at **high densities** [9]
  - DD2 : stiff hadronic EOS
  - BHBlp : DD2 + hyperon, the EOS is softer at high densities due to the phase transition

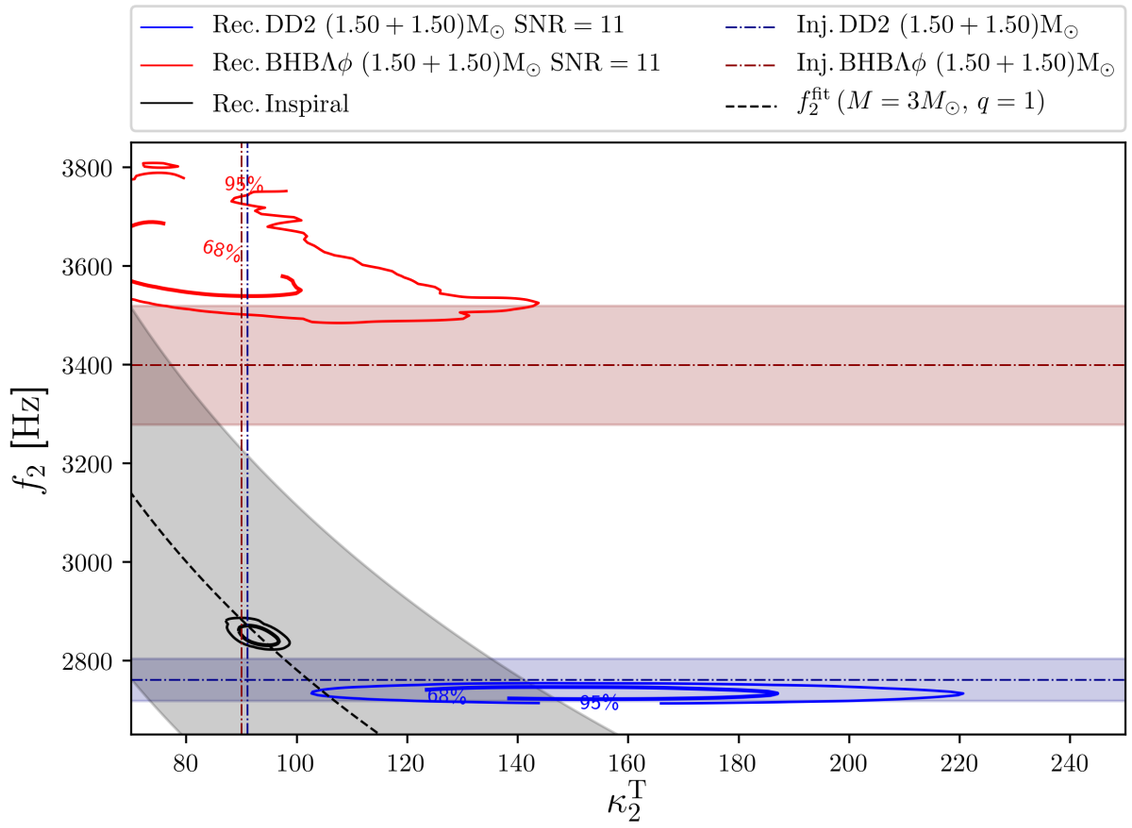
⇒ For low densities, these EOS describe the same physics

⇒ For high densities, these signals strongly differ

[9] D. Radice *et al.*, Ap. J. L., 842:L10 (2017)

Softness Test





- Low-mass case:
  - Consistency between inspiral and postmerger signals

- High-mass case:
  - Inconsistency between inspiral and postmerger signals

Outlook

- `NRPM` is a NR-informed time-domain model for BNS remnants
  - Designed to complete EOB model (`TEOBResumS`)
  - Gives evidence of detection from SNR ~ 8
  - Implemented in `LAL`
- If a PM signal is detected with sufficient SNR, it is possible to:
  - Set constraint on the minimum radius supported by the EOS
  - Test softening effects of the EOS at high densities
  - Apply model selection to infer prompt-collapse (see arXiv:1908.11418 [gr-qc])

Future Improvements

- Deep studies of statistical error
- Increase the number of free parameters for more agnostic analyzes
- Parametrize the residuals between `NRPM` and NR simulations
- Characterization of prompt-collapse
- Explore new methods for construction of reliable models

Thanks