POST-MERGER GW EMISSION IN BNS MERGERS AND EMPIRICAL RELATIONS FOR GW ASTEROSEISMOLOGY

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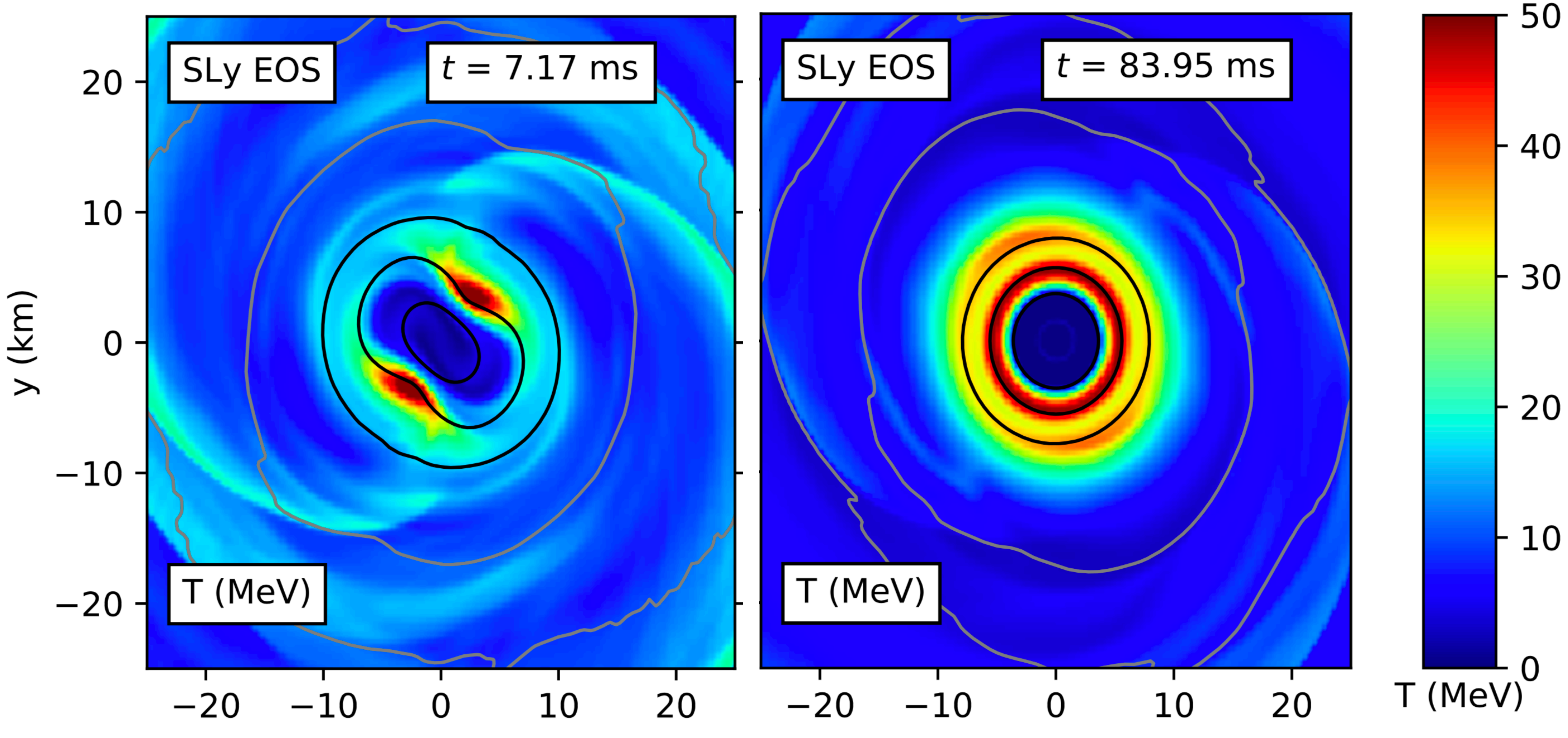
STRUCTURE OF POST–MERGER REMNANTS

Parts of the remnant reach temperatures of several tens MeV.



De Pietri et al. (2019)

Need to construct quasi-equilibrium models.

EQUILIBRIUM MODELS OF POST-MERGER REMNANTS

Sequences of (cold) equilibrium models of post-merger remnants:

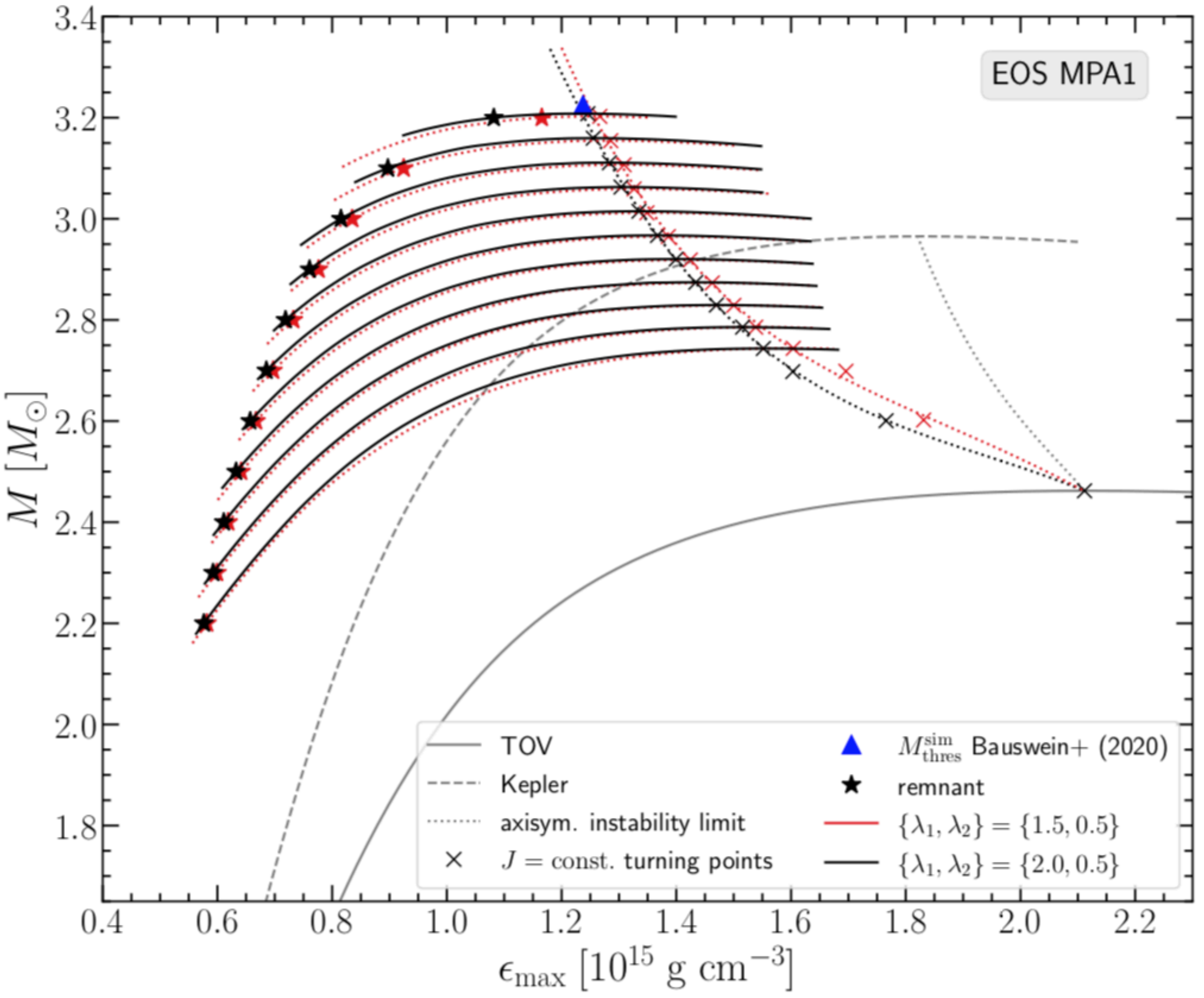
- 4-parameter rotation law by Uryu et al. (2017), with p=1, q=3.

$$\Omega = \Omega_c \frac{1 + \left(\frac{F}{B^2 \Omega_c}\right)^p}{1 + \left(\frac{F}{A^2 \Omega_c}\right)^{q+p}}$$

$$F \equiv u^t u_\phi$$

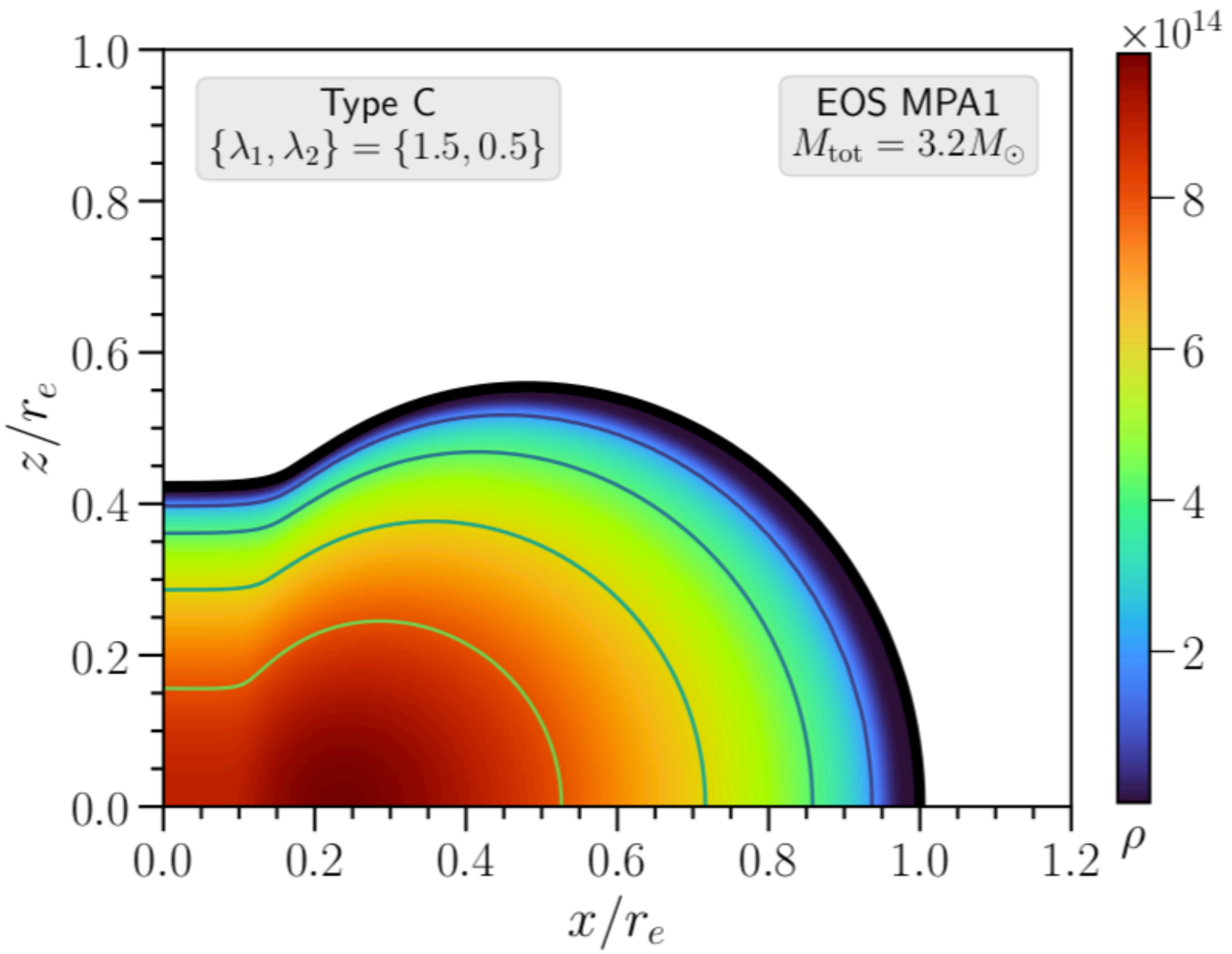
- The remaining two parameters A, B are redefined as

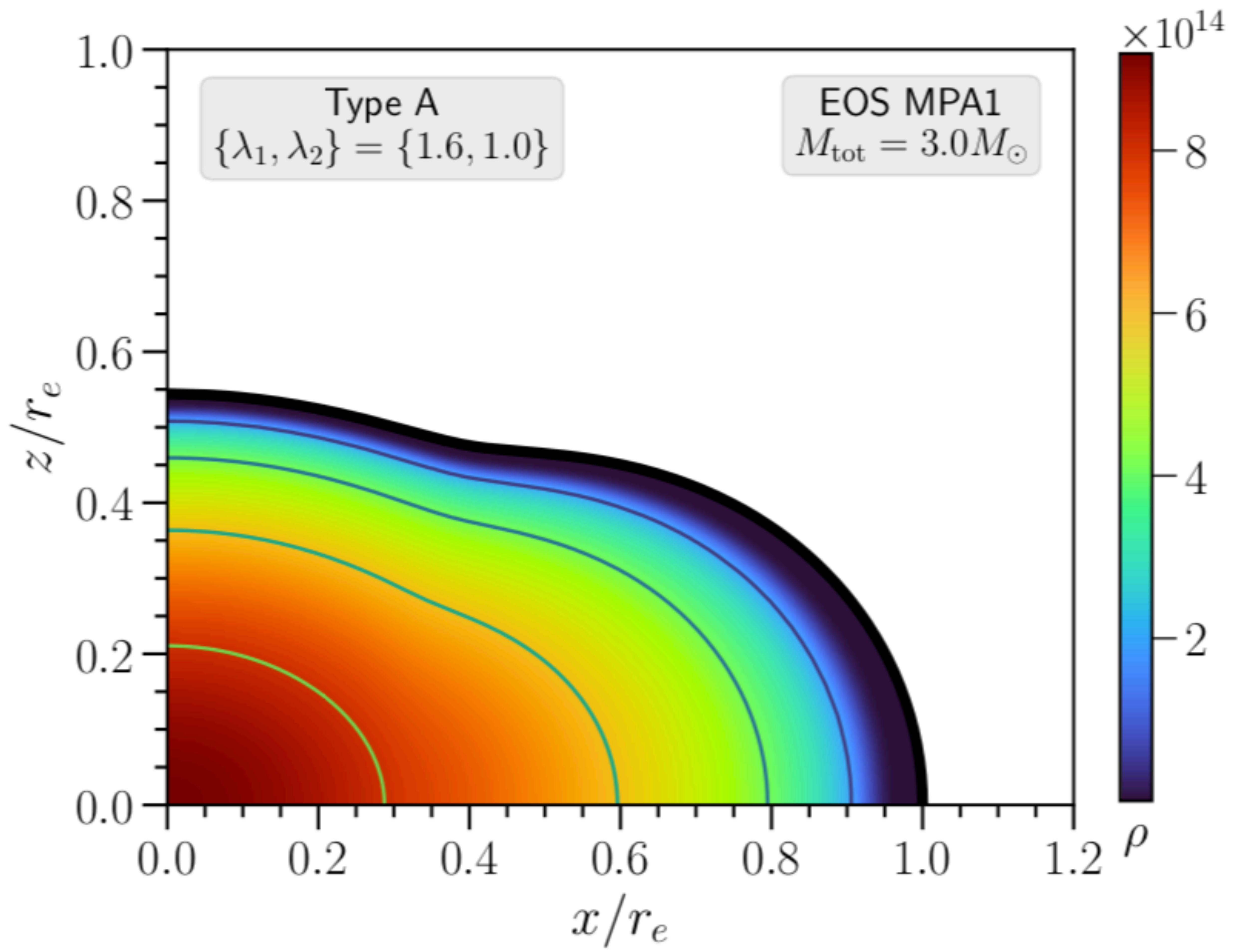
$$\lambda_1 \equiv \frac{\Omega_{\max}}{\Omega_c} \qquad \lambda_2 \equiv \frac{\Omega_e}{\Omega_c}$$



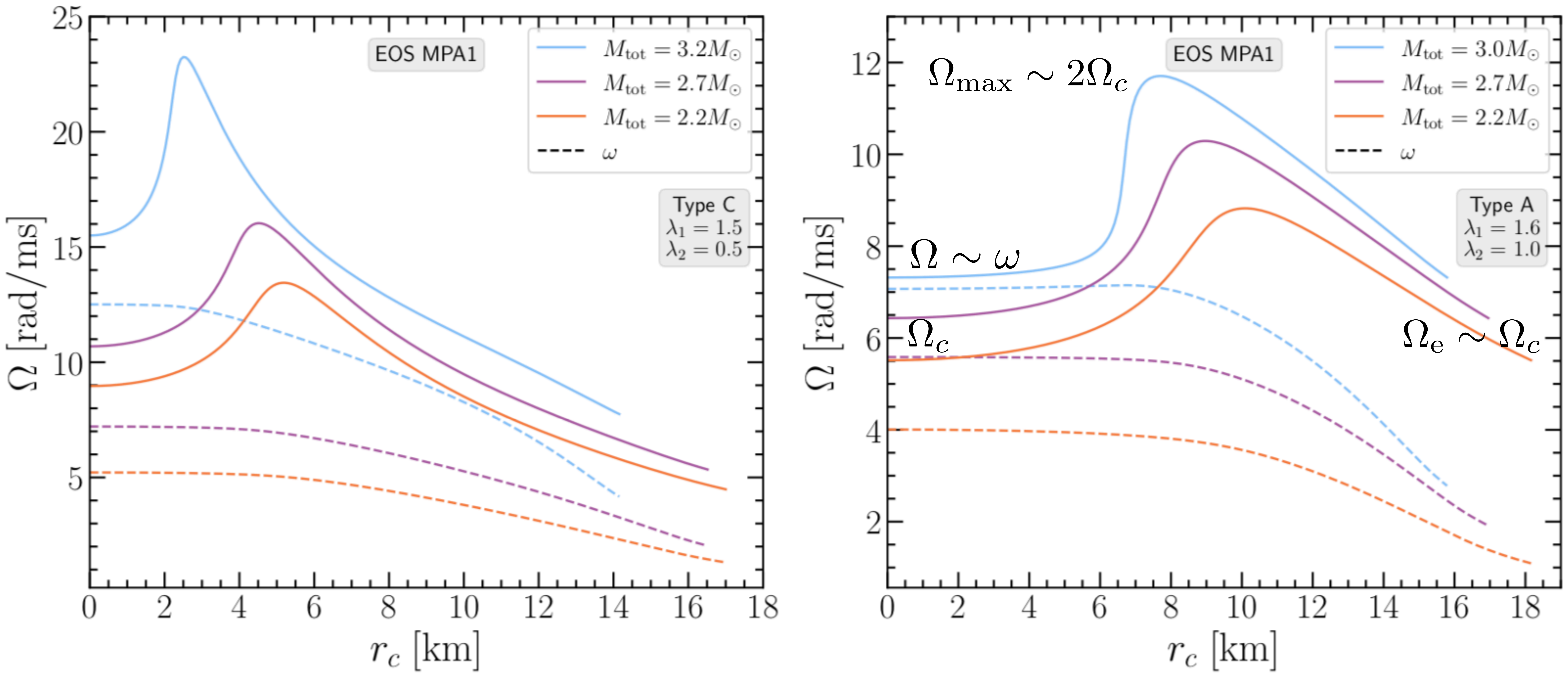
DENSITY DISTRIBUTION OF REMNANT MODELS

We find both quasi-toroidal (Type C) and quasi-spherical (Type A) models.



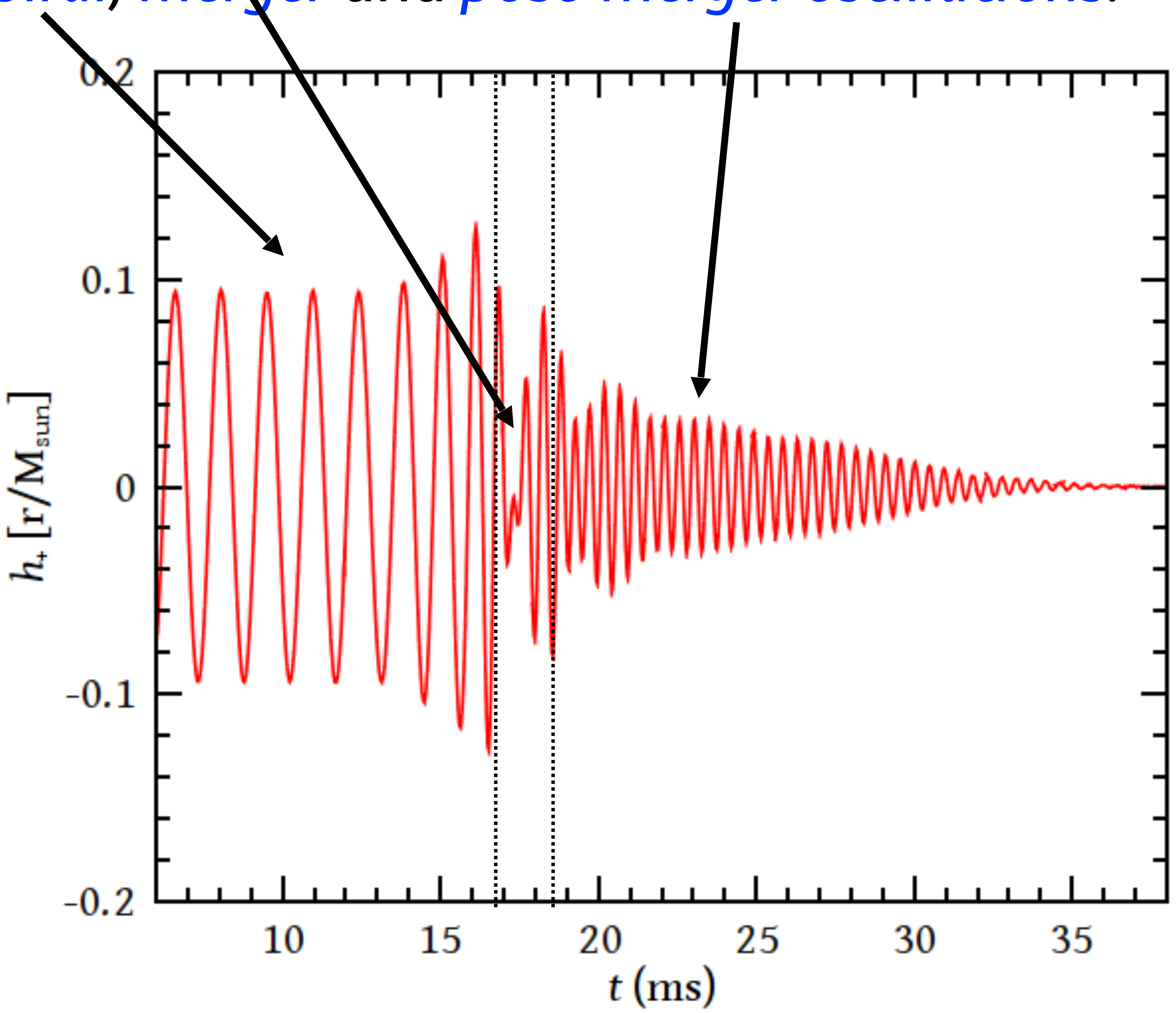


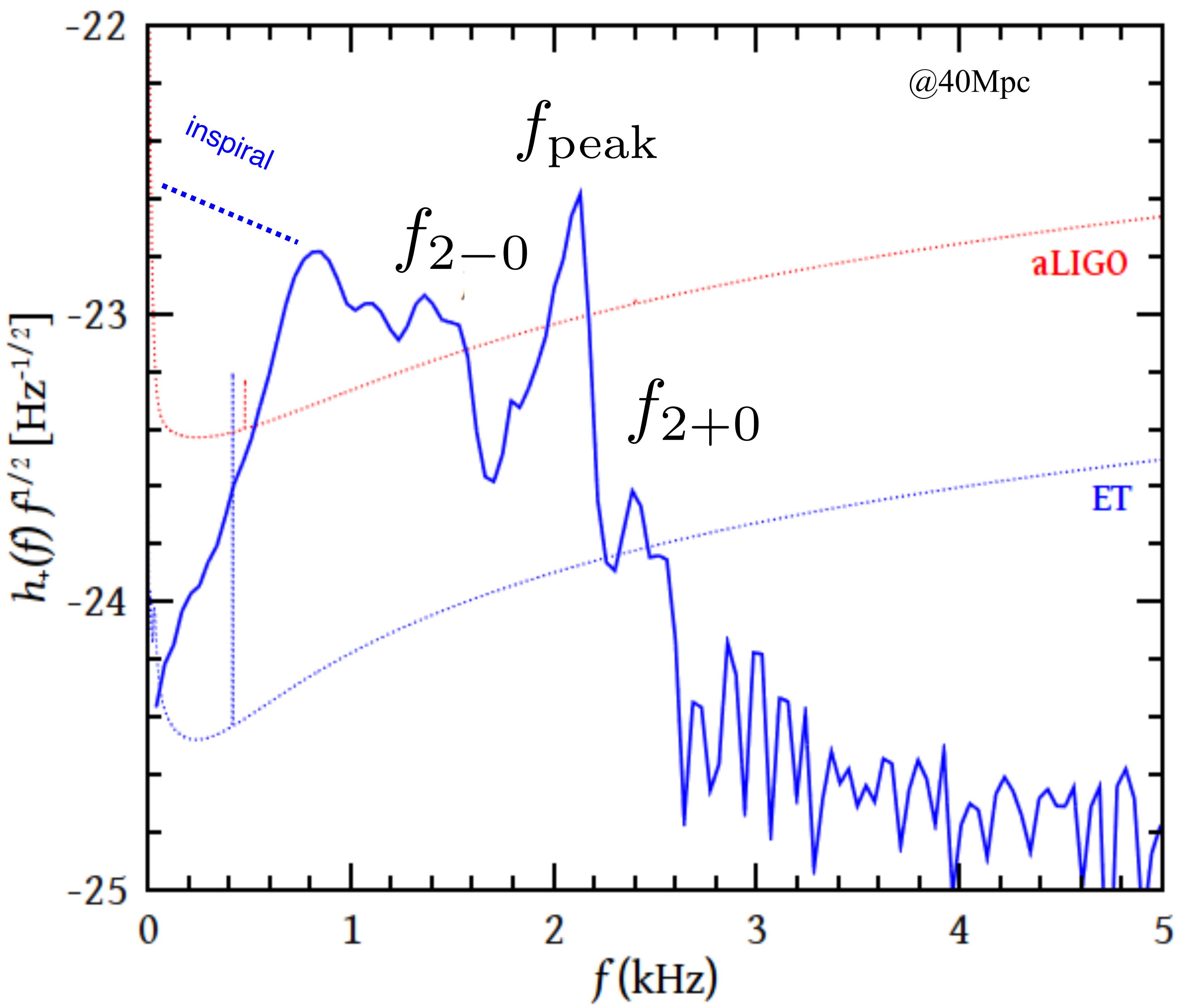
The rotation profiles show a qualitative agreement with those extracted from simulations.



Currently: time evolution of perturbed quasi-equilibrium models + hot EOS

The GW signal can be divided into three distinct phases:
inspiral, *merger* and *post-merger oscillations*.



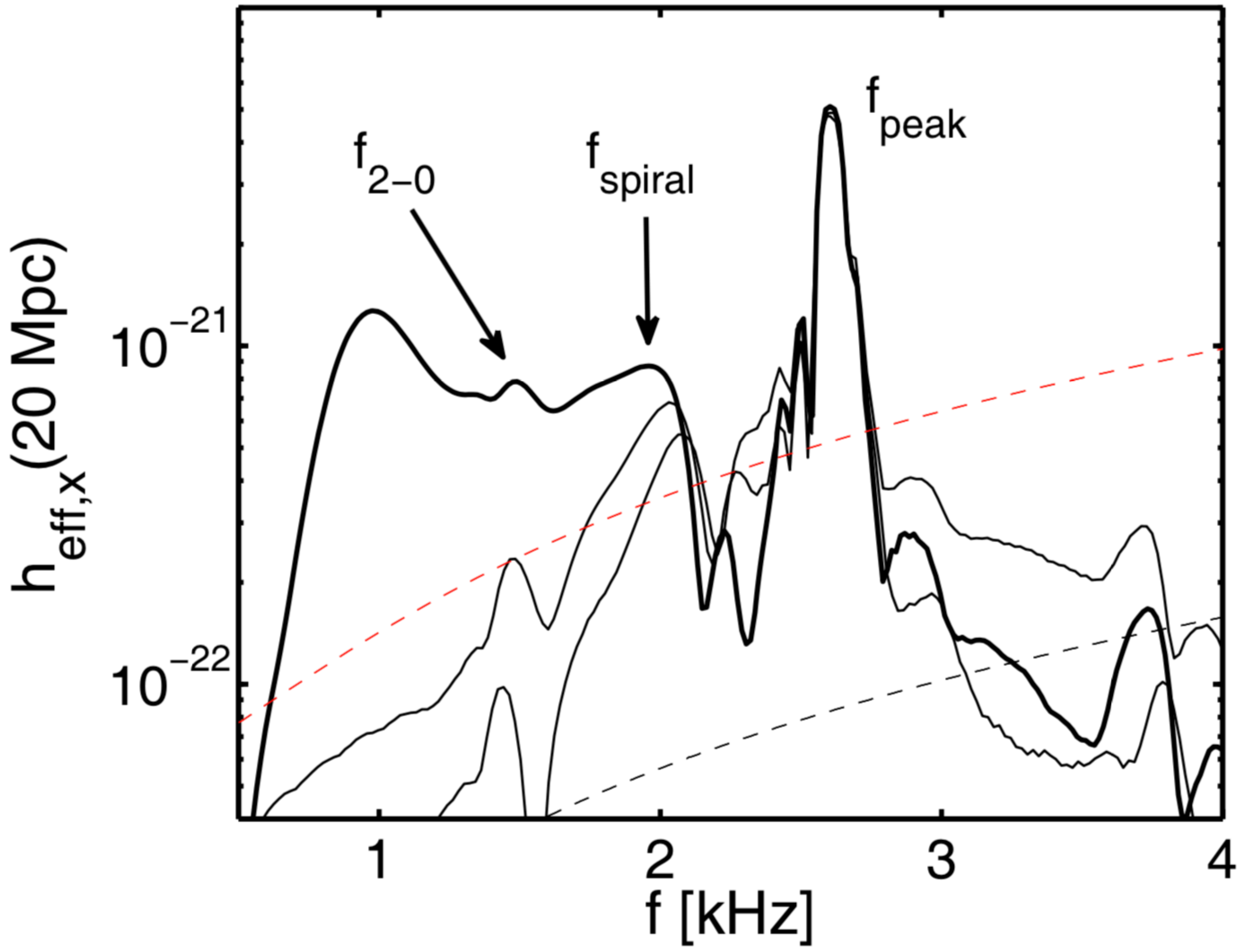


Stergioulas et al. (2011)

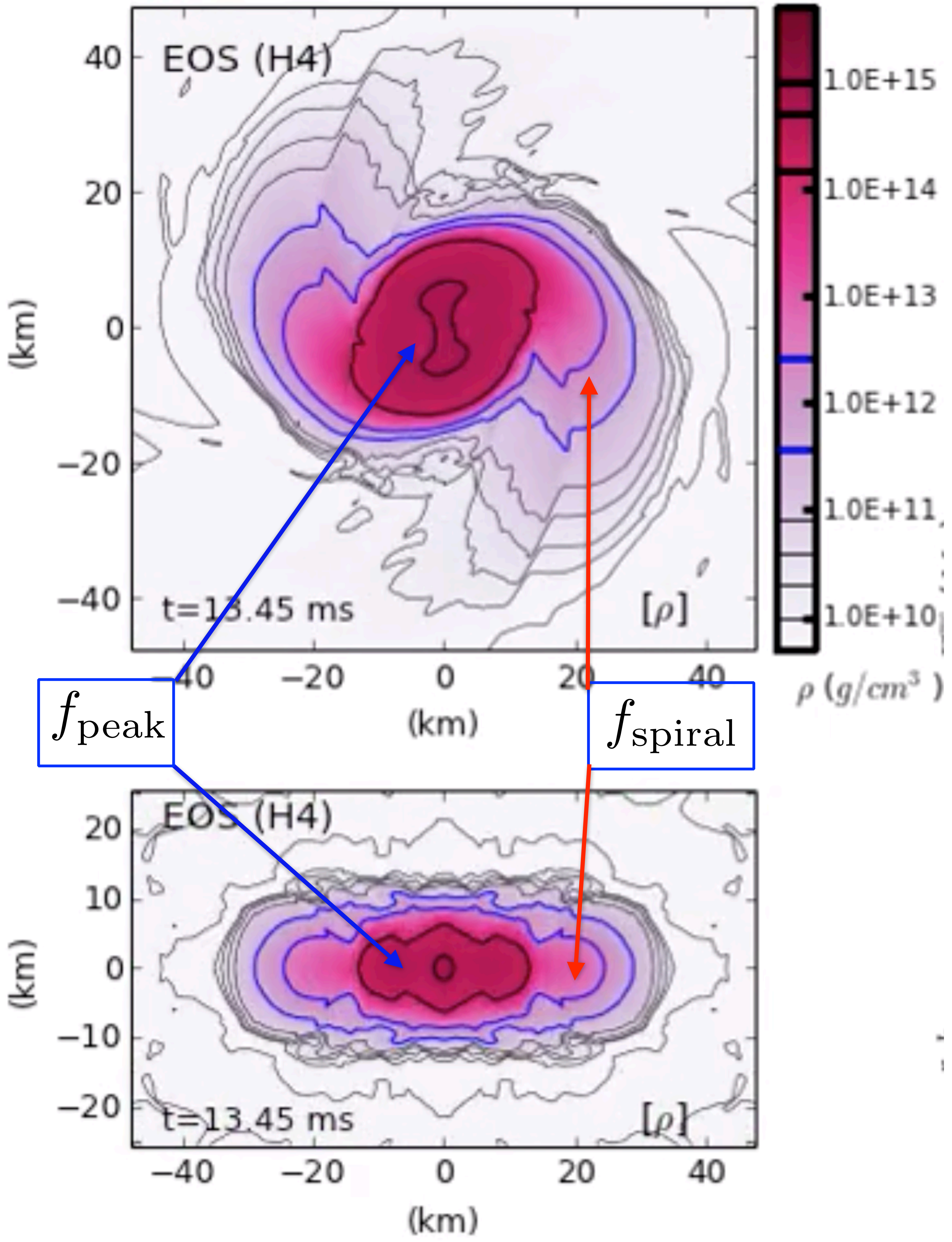
$f_{\text{peak}} = f_2$ is due to the fundamental *l*=*m*=2 *f*-mode oscillation

$f_{2-0} = f_2 - f_0$
$f_{2+0} = f_2 + f_0$ are quasi-linear combination tones

Orbiting spiral arms also lead to a distinct frequency $f_{\rm spiral}$

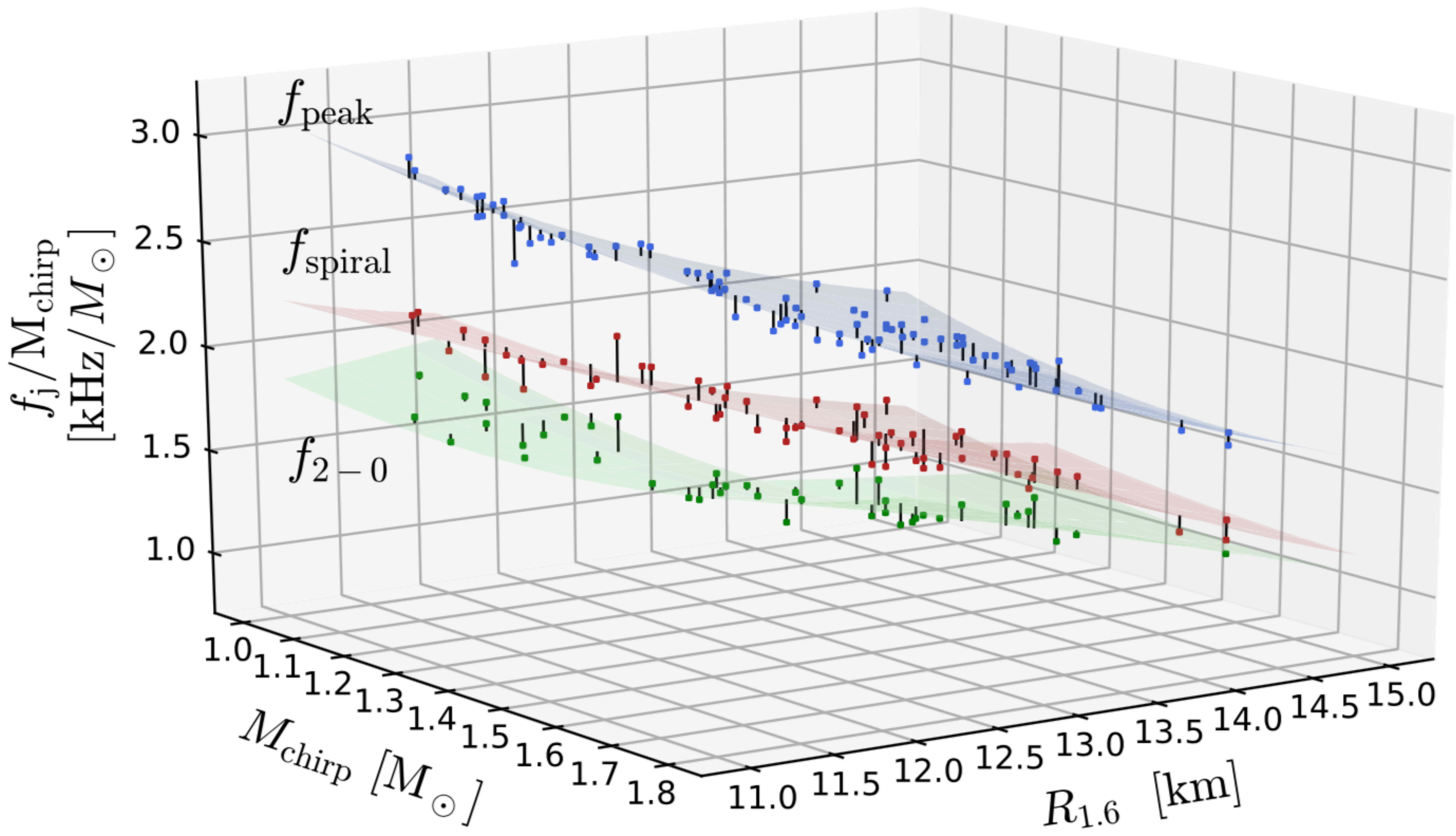


Bauswein & Stergioulas (2015)

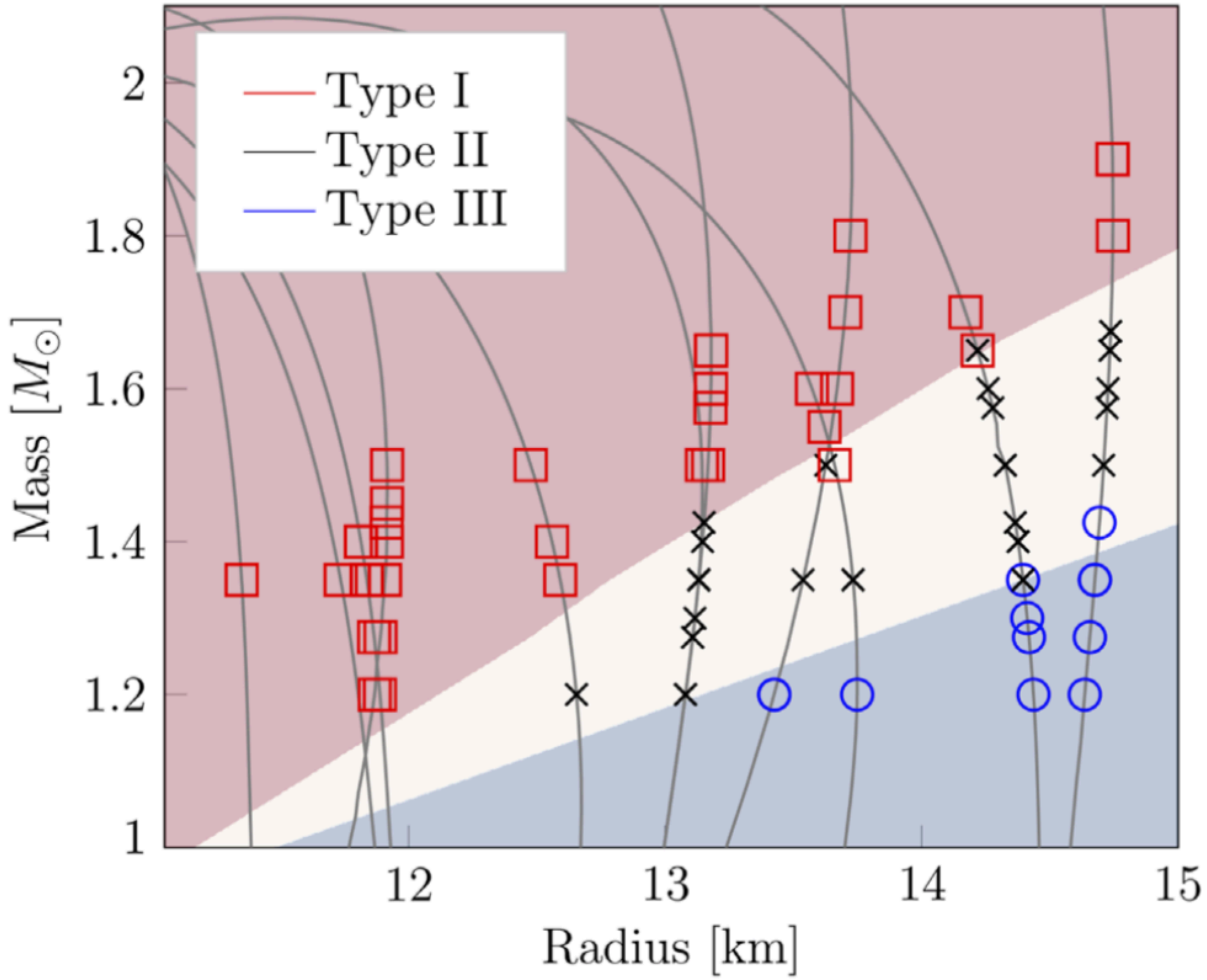


EMPIRICAL RELATIONS FOR GW ASTEROSEISMOLOGY OF BNS MERGERS

Distinct frequencies in the whole parameter space



Classification of post-merger GW emission

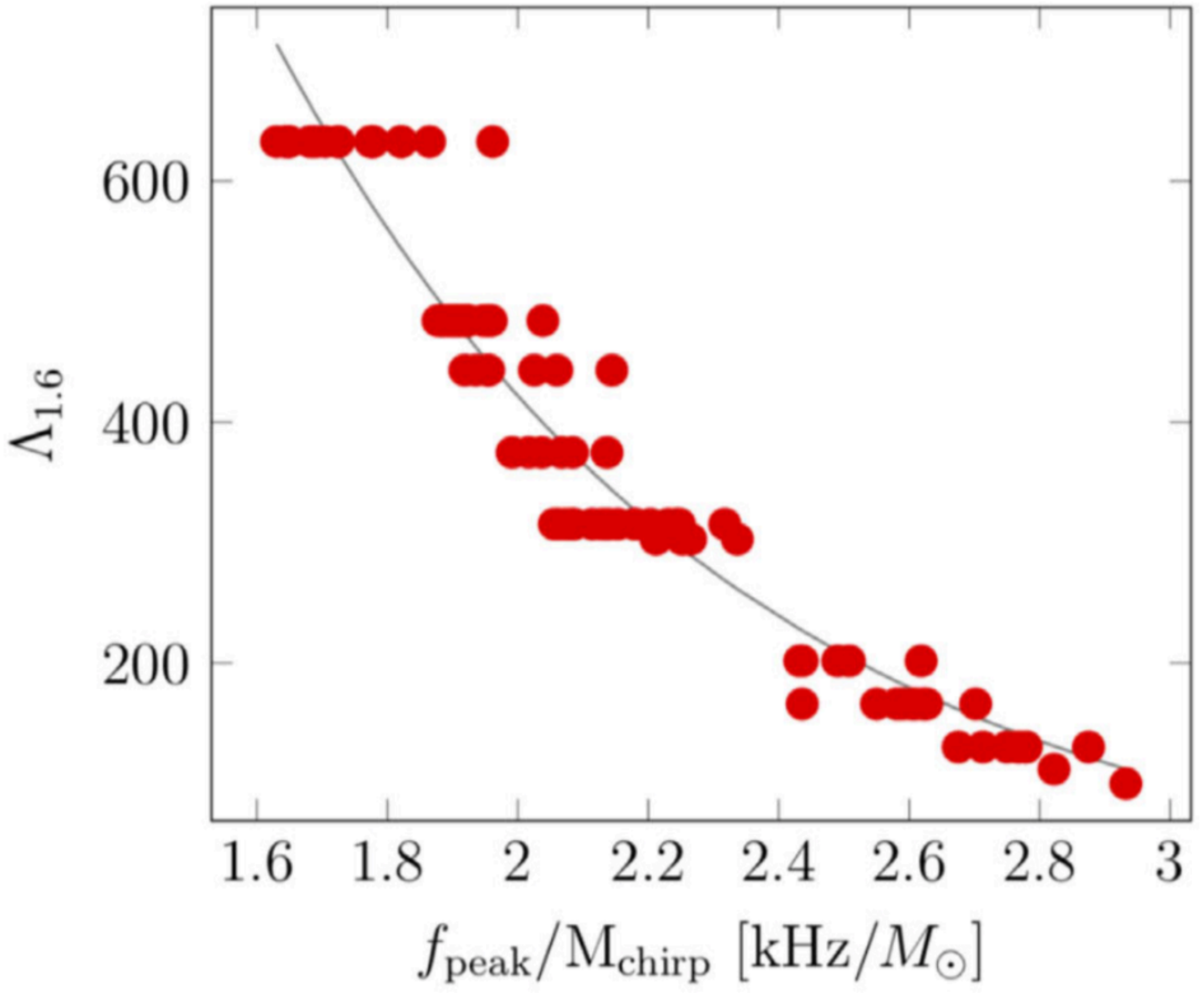


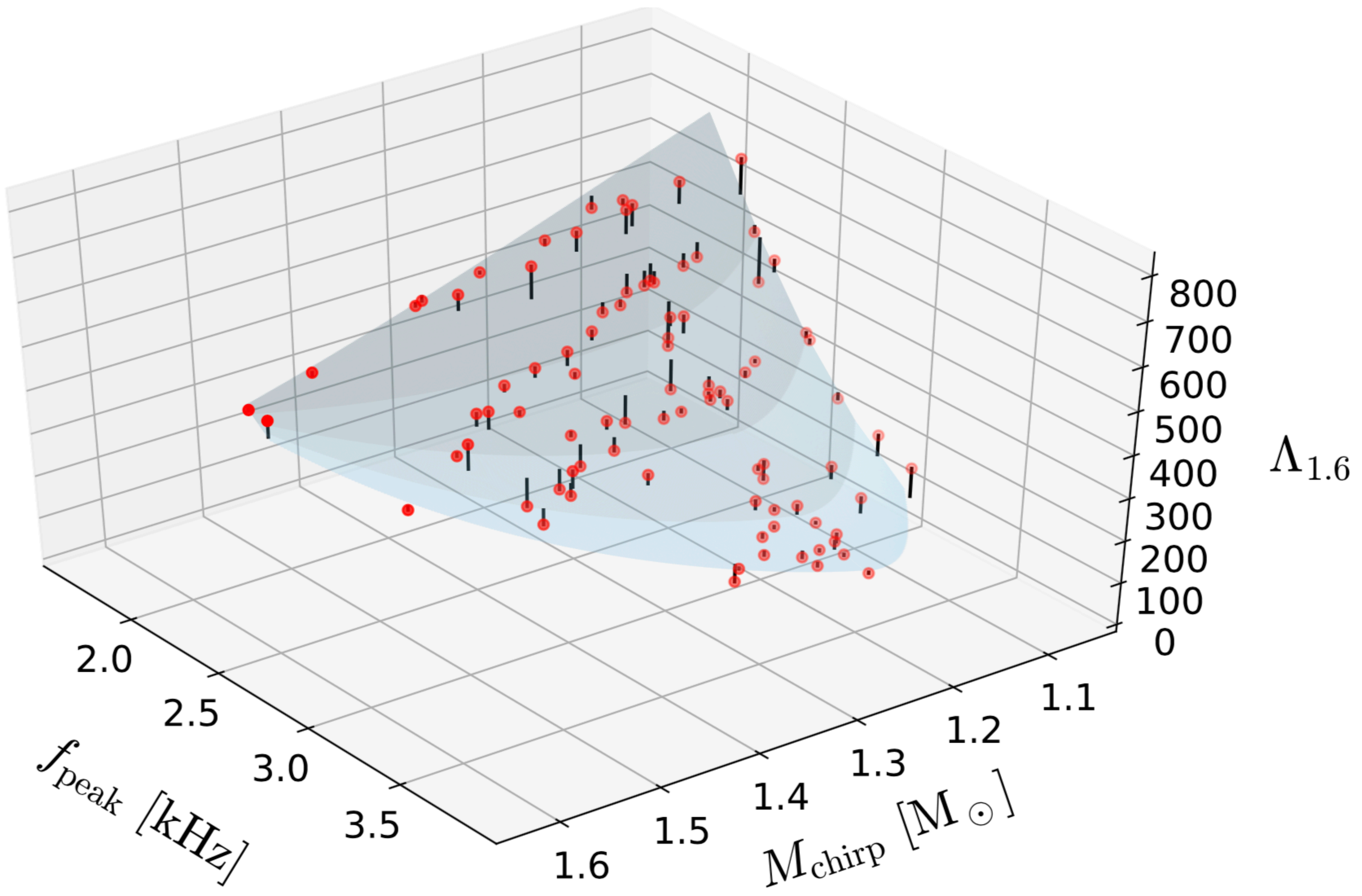
Vretinaris, Stergioulas & Bauswein (2020)

BIVARIATE vs. MULTIVARIATE EMPIRICAL RELATIONS

$$\Lambda_{1.6} = 7251 e^{-u/0.703} \qquad u = f_{\rm peak}/M_{\rm chirp}$$

$$\Lambda_{1.6} = 2417 + 770.2 M_{\rm chirp} - 1841 f_{\rm peak} + 262.9 f_{\rm peak}^2$$





$R^2 = 0.931$

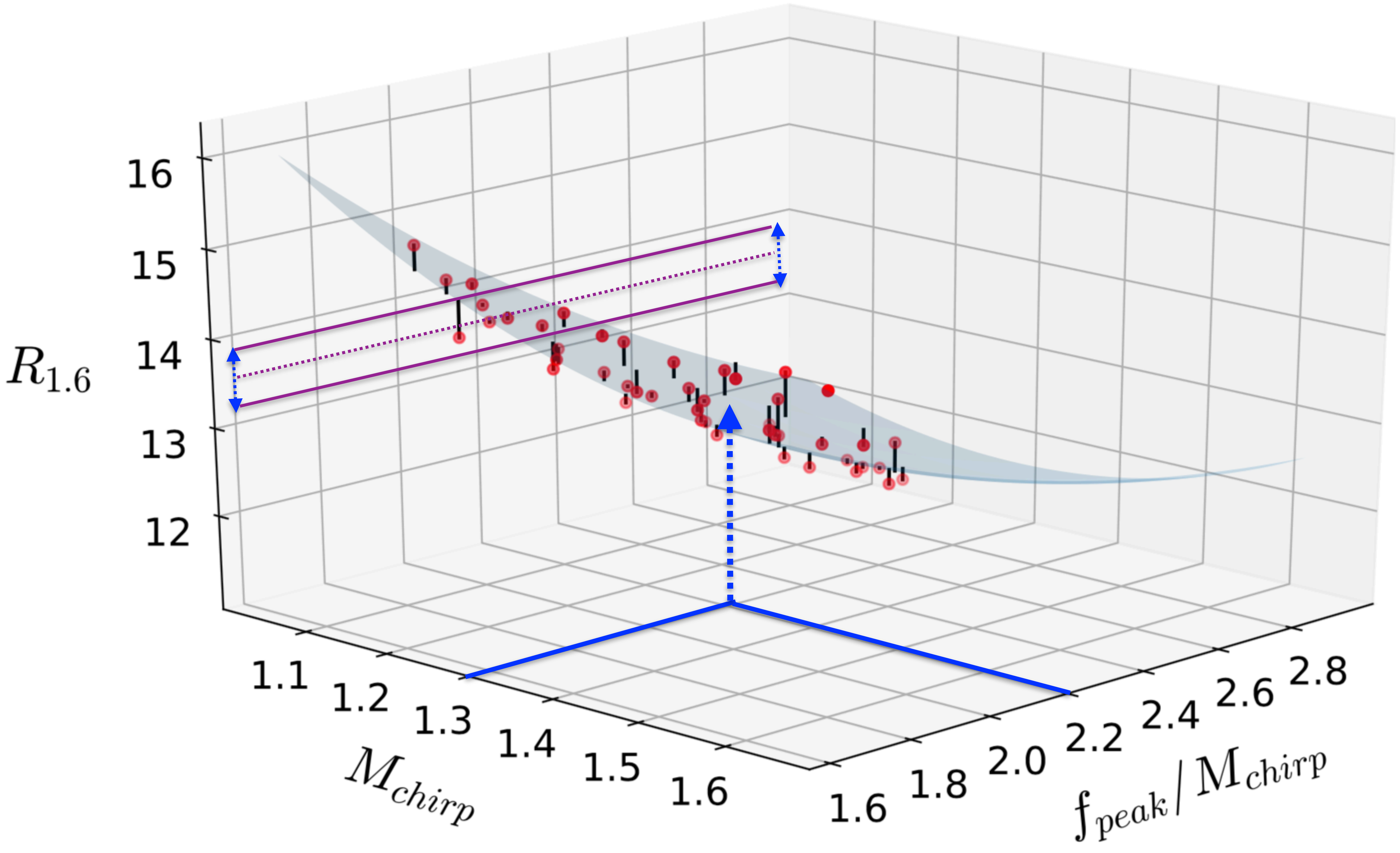
$R^2 = 0.964$

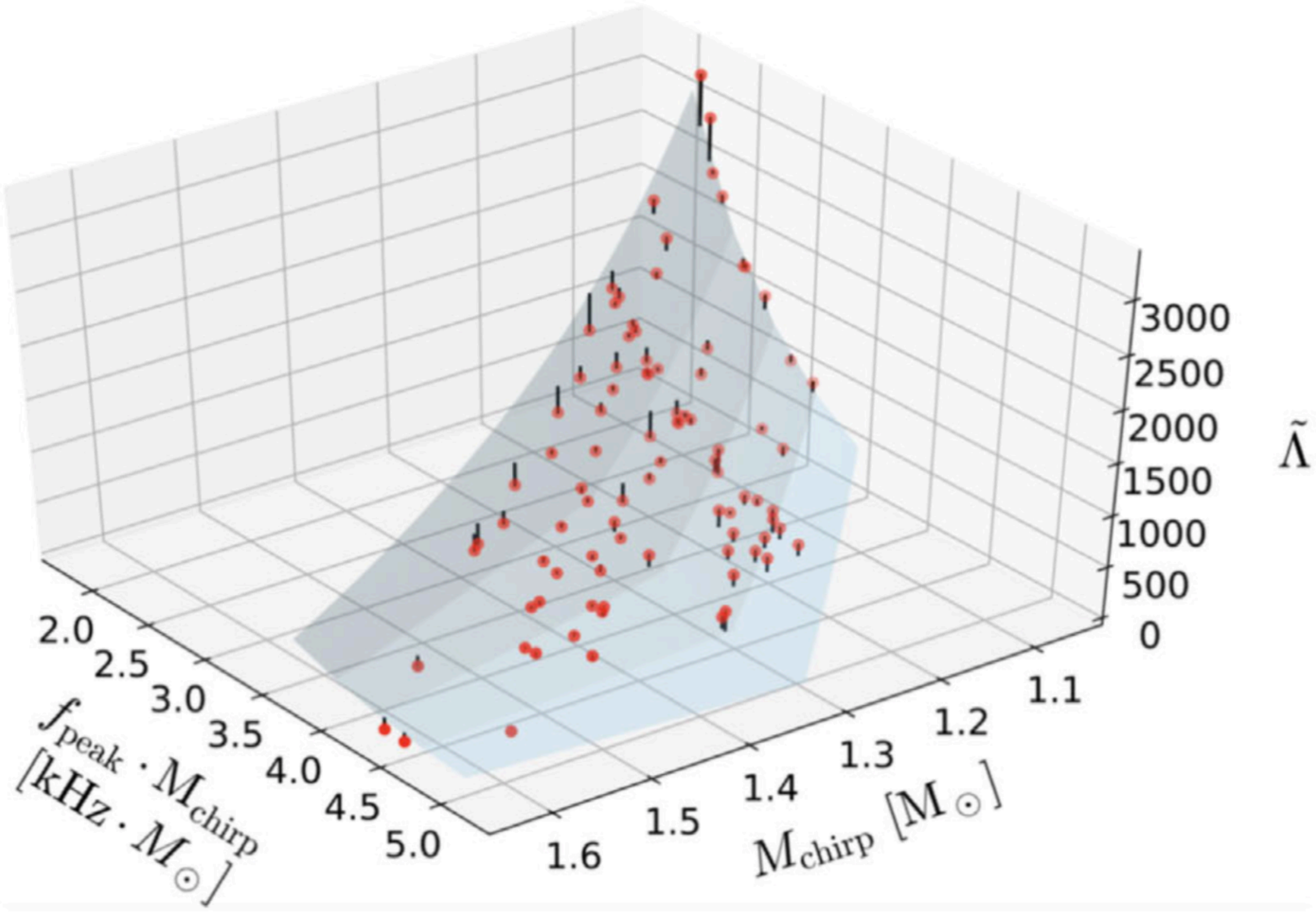
Vretinaris, Stergioulas & Bauswein (2020)

EMPIRICAL RELATIONS FOR GW ASTEROSEISMOLOGY OF BNS MERGERS

$$R_{1.6} = 43.796 - 19.984 M_{\rm chirp} - 12.921 f_{\rm peak}/M_{\rm chirp} + 4.674 M_{\rm chirp}^2 + 3.371 f_{\rm peak} + 1.26 (f_{\rm peak}/M_{\rm chirp})^2$$

$$\tilde{\Lambda} = -1344 + 108.9 M_{\rm chirp} f_{\rm peak} + 17208 f_{\rm peak}^{-2}$$

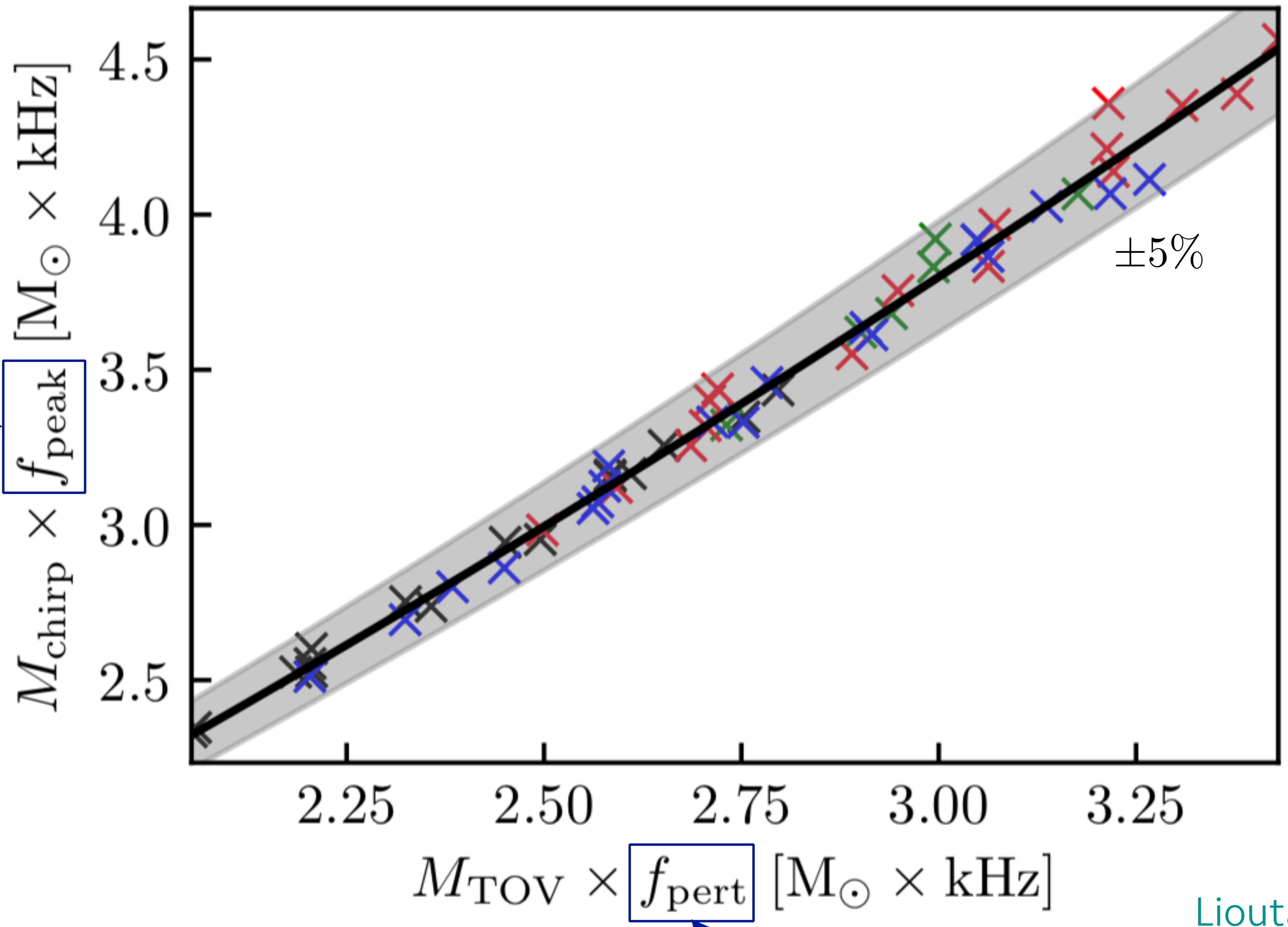




Vretinaris, Stergioulas & Bauswein (2020)

NEW UNIVERSAL RELATIONS BETWEEN REMNANTS AND NONROTATING STARS

m=2 mode of post–merger remnant



m=2 mode of nonrotating star

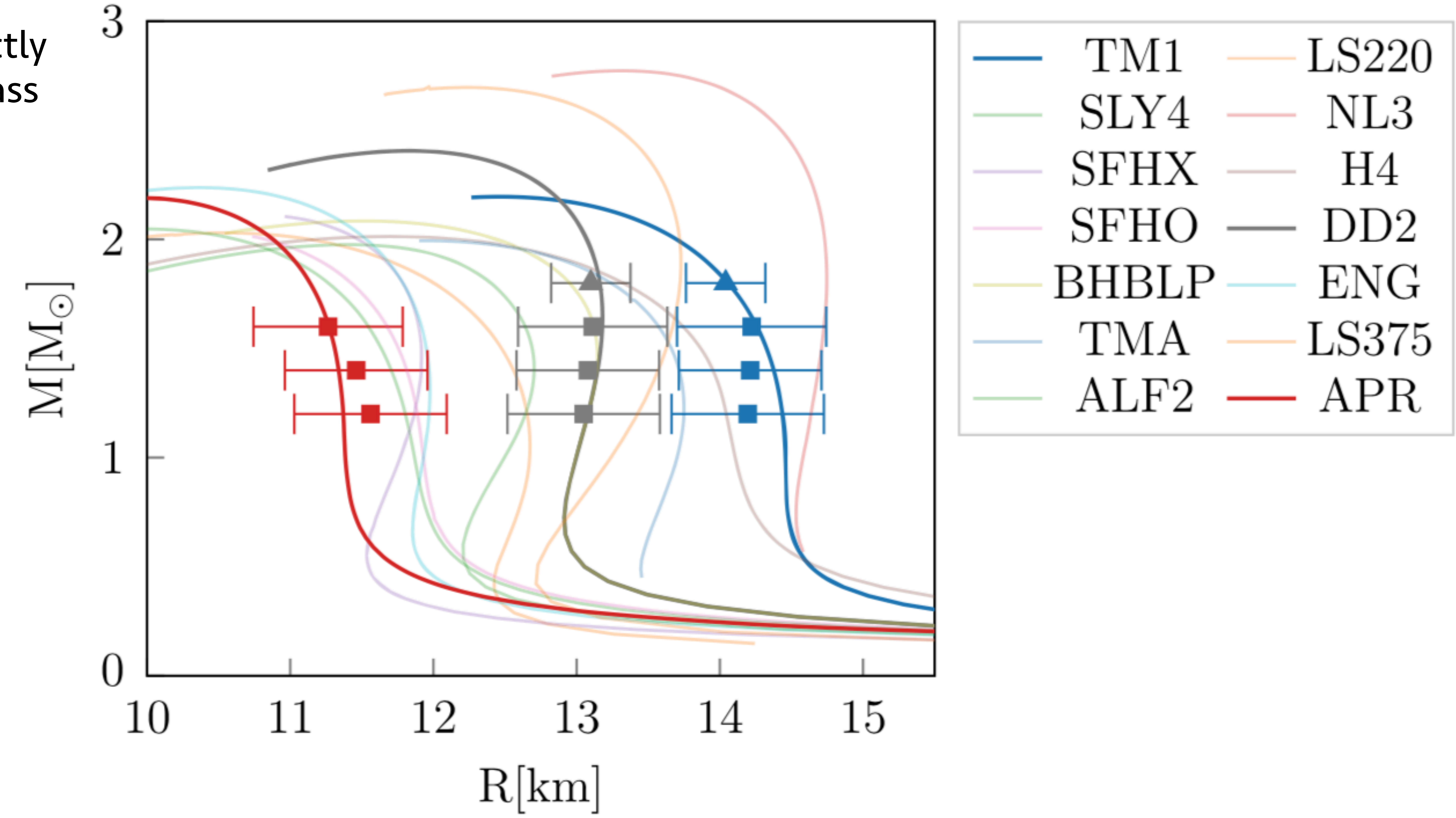
- Using the correspondence

$$M_{\rm TOV} = \sqrt[5]{2} \times M_{\rm tot}/2$$

Lioutas, Bauswein, Stergioulas (2021)

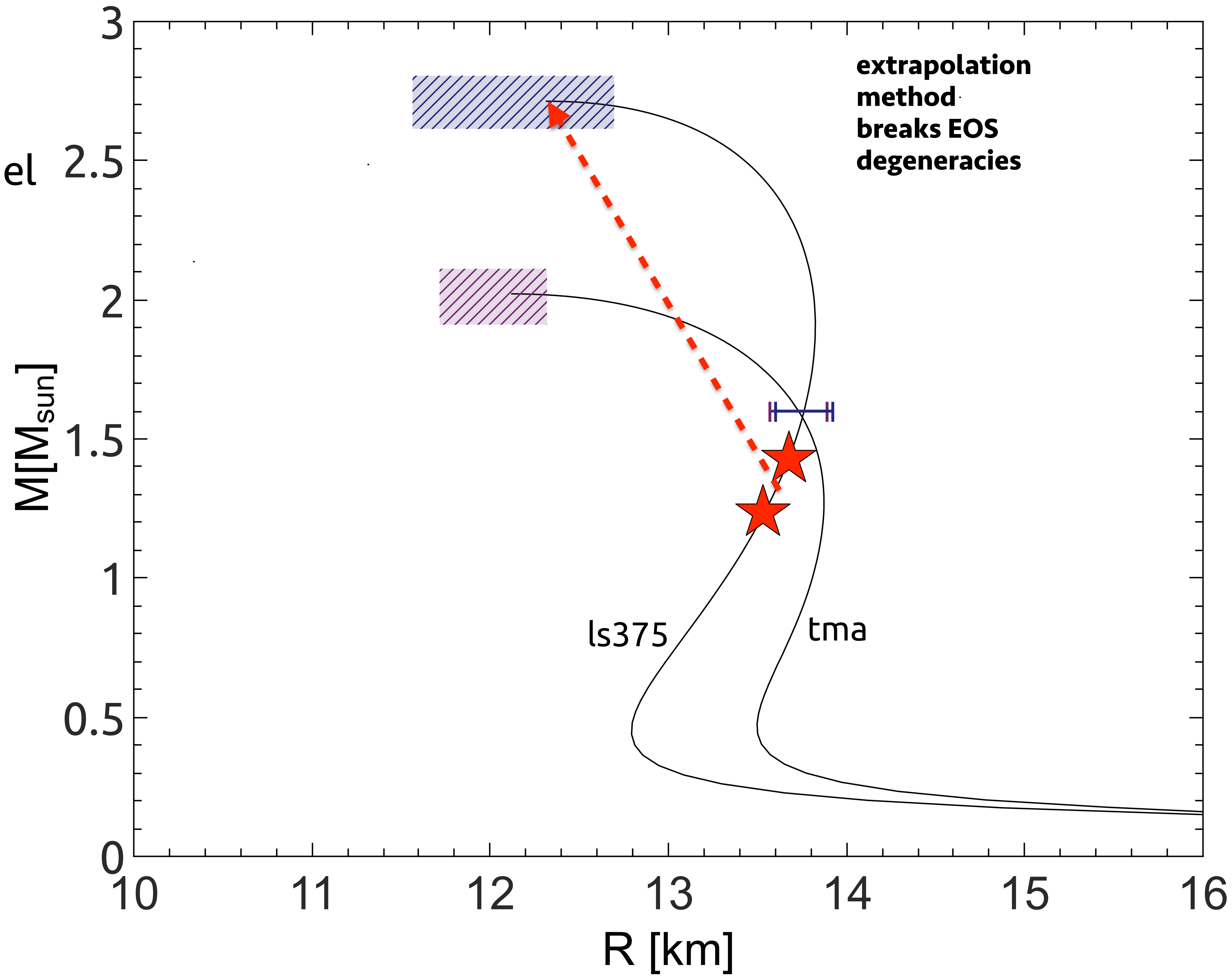
EOS CONSTRAINTS THROUGH POST-MERGER REMNANTS

It will be possible to directly extract the radius in a mass range $1.2 - 1.8 M_\odot$



Vretinaris, Stergioulas & Bauswein (2020)

Extrapolation method allows for constraints on maximum mass model using only low-mass detections.

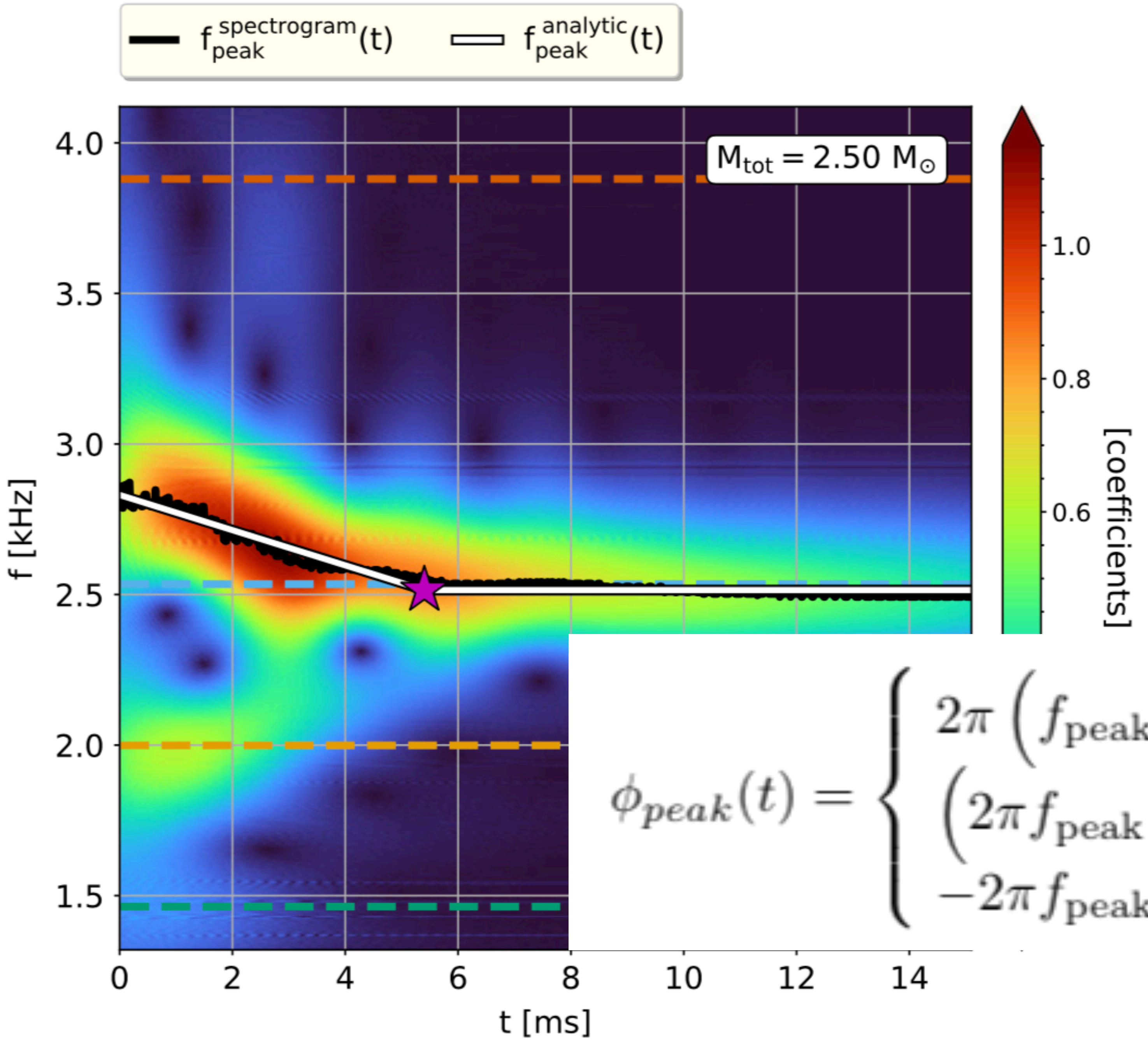


Bauswein, Stergioulas (2015)

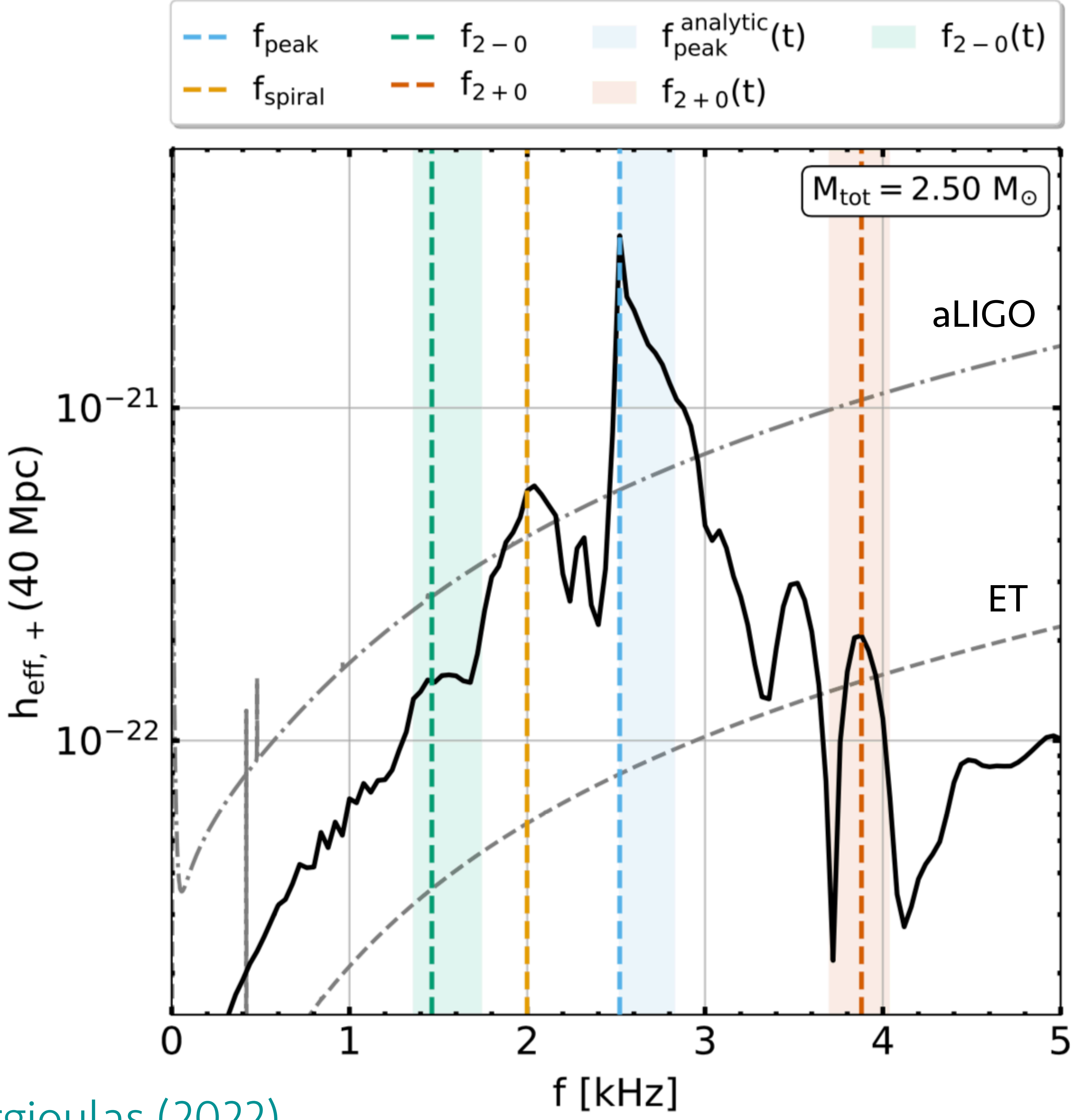
NEW ANALYTIC WAVEFORM TEMPLATE

Relies only on physical parameters

$$
\begin{aligned}
h_+(t) = {} & A_{peak}\, e^{(-t/\tau_{peak})} \cdot \sin(\phi_{peak}(t)) \\
& + A_{spiral}\, e^{(-t/\tau_{spiral})} \cdot \sin(2\pi f_{spiral} \cdot t + \phi_{spiral}) \\
& + A_{2-0}\, e^{(-t/\tau_{2-0})} \cdot \sin(2\pi f_{2-0} \cdot t + \phi_{2-0}) \\
& + A_{2+0}\, e^{(-t/\tau_{2+0})} \cdot \sin(2\pi f_{2+0} \cdot t + \phi_{2+0})
\end{aligned}
$$

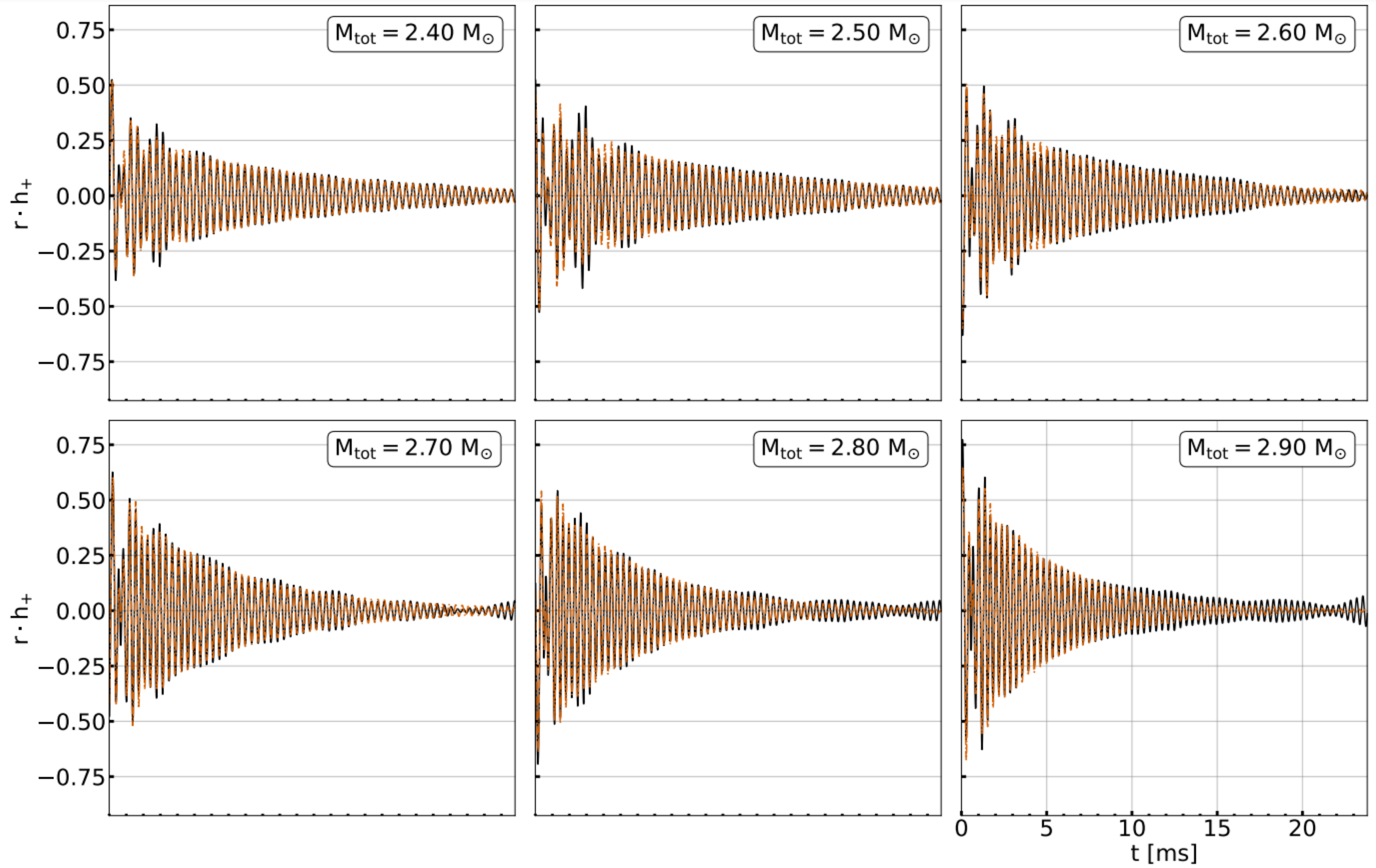


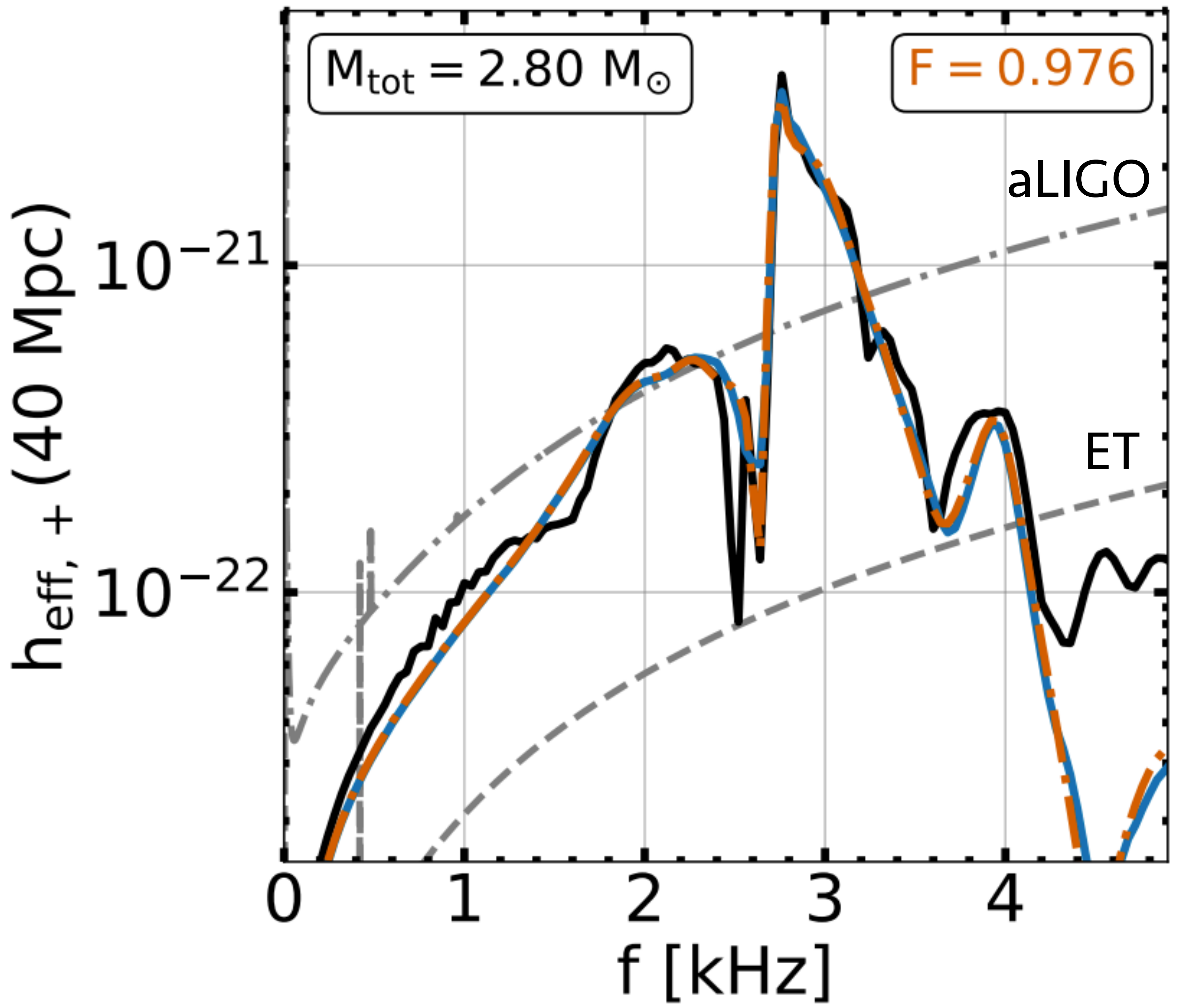
$$
\phi_{peak}(t) = \begin{cases} 2\pi \left(f_{peak,0} + \frac{\zeta_{drift}}{2} t \right) t + \phi_{peak} & \text{for } t \leq t_* \\ \left(2\pi f_{peak}(t_*) t \right) + \phi_{peak}(t_*) & \text{for } t > t_* \\ -2\pi f_{peak}(t_*) t_* & \end{cases}
$$



Soultanis, Bauswein, Stergioulas (2022)

Relies only on physical parameters

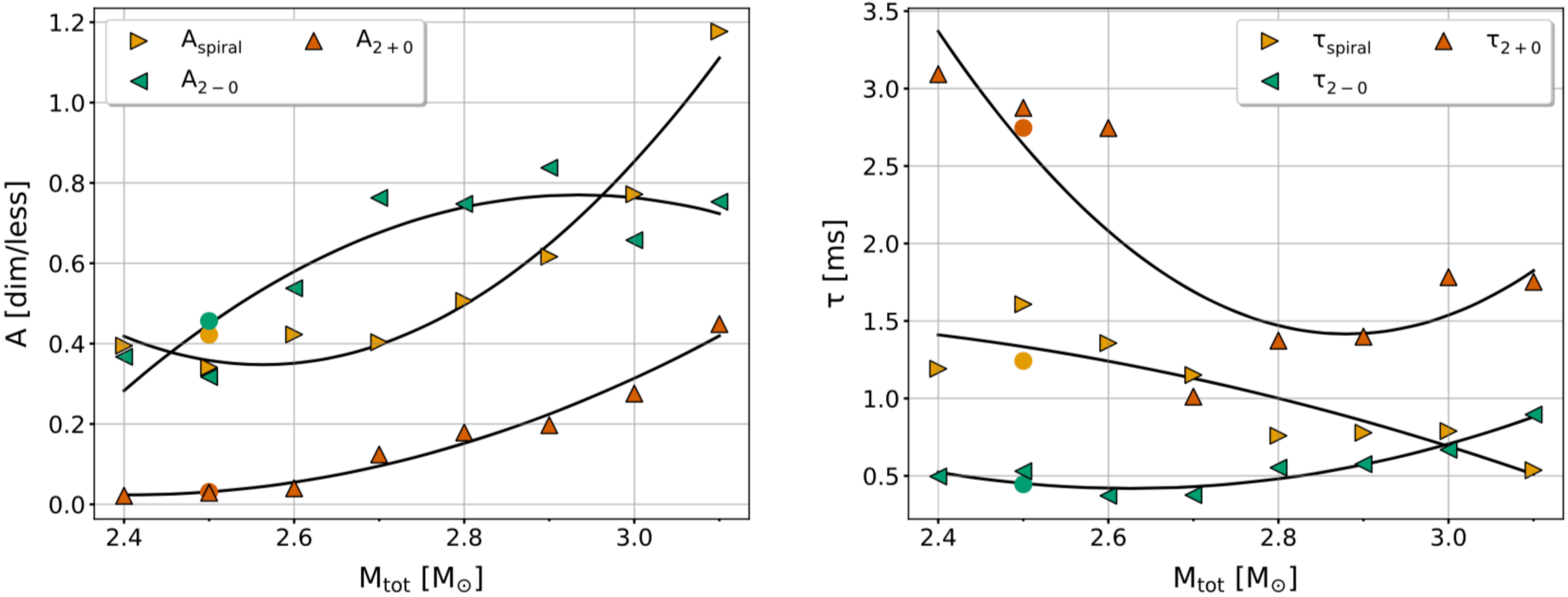




Soultanis, Bauswein, Stergioulas (2022)

NEW ANALYTIC WAVEFORM TEMPLATE

Physical parameters of analytic model depend mainly on total mass along a single EOS.



Soultanis, Bauswein, Stergioulas (2022)

Expect new, multi-variate empirical relations when extended to large EOS sample.

THANK YOU FOR YOUR ATTENTION