Influence of initial spin in binary neutron star mergers

Wolfgang Kastaun[1], Filippo Galeazzi[2]

[1]Trento University

[2]Frankfurt University

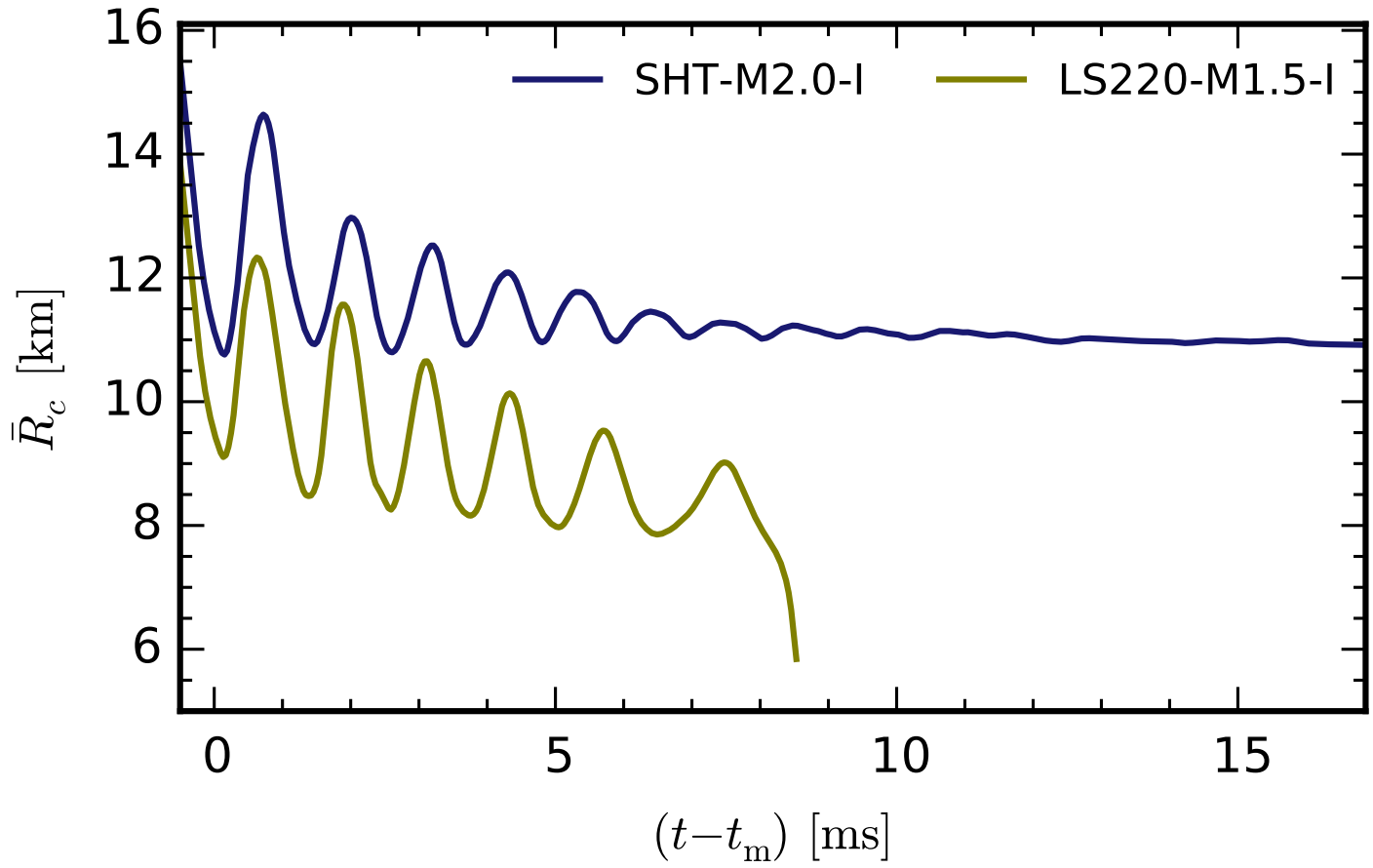
Thessaloniki, May 2015

Binary Neutron Star Models

Lattimer-Swesty ($K = 220\ \mathrm{MeV}$) EOS Equal mass, $M_{\mathrm{B}} = 3.12\ M_{\odot} = 1.10\ M_{\mathrm{Kepler}}$	
Irrotational	Aligned rotation $\Delta J_{\mathrm{ADM}} = 0.092\ M_{\infty}^2$ $\Delta F_{\mathrm{R}} \approx 160\ \mathrm{Hz}$
G. Shen, Horowitz, Teige (NL3) EOS Equal mass, $M_{\mathrm{B}} = 4.01\ M_{\odot} = 1.01\ M_{\mathrm{Kepler}}$	
Irrotational	Aligned rotation $\Delta J_{\mathrm{ADM}} = 0.101\ M_{\infty}^2$ $\Delta F_{\mathrm{R}} \approx 155\ \mathrm{Hz}$

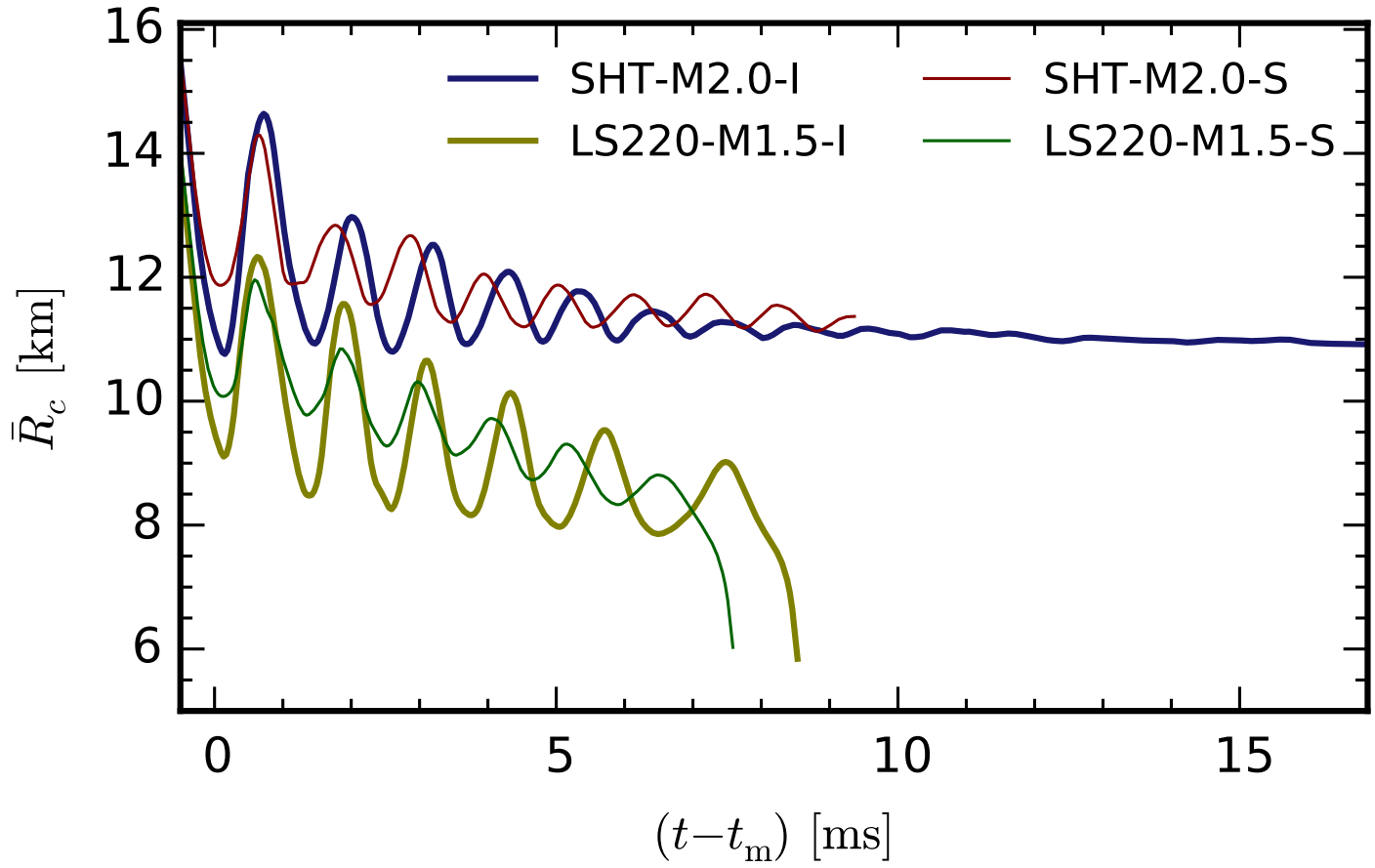
Merger Remnant – Radial Oscillations

- Strong quasi-radial oscilation.
- Low frequency of quasi-radial mode near critical mass.



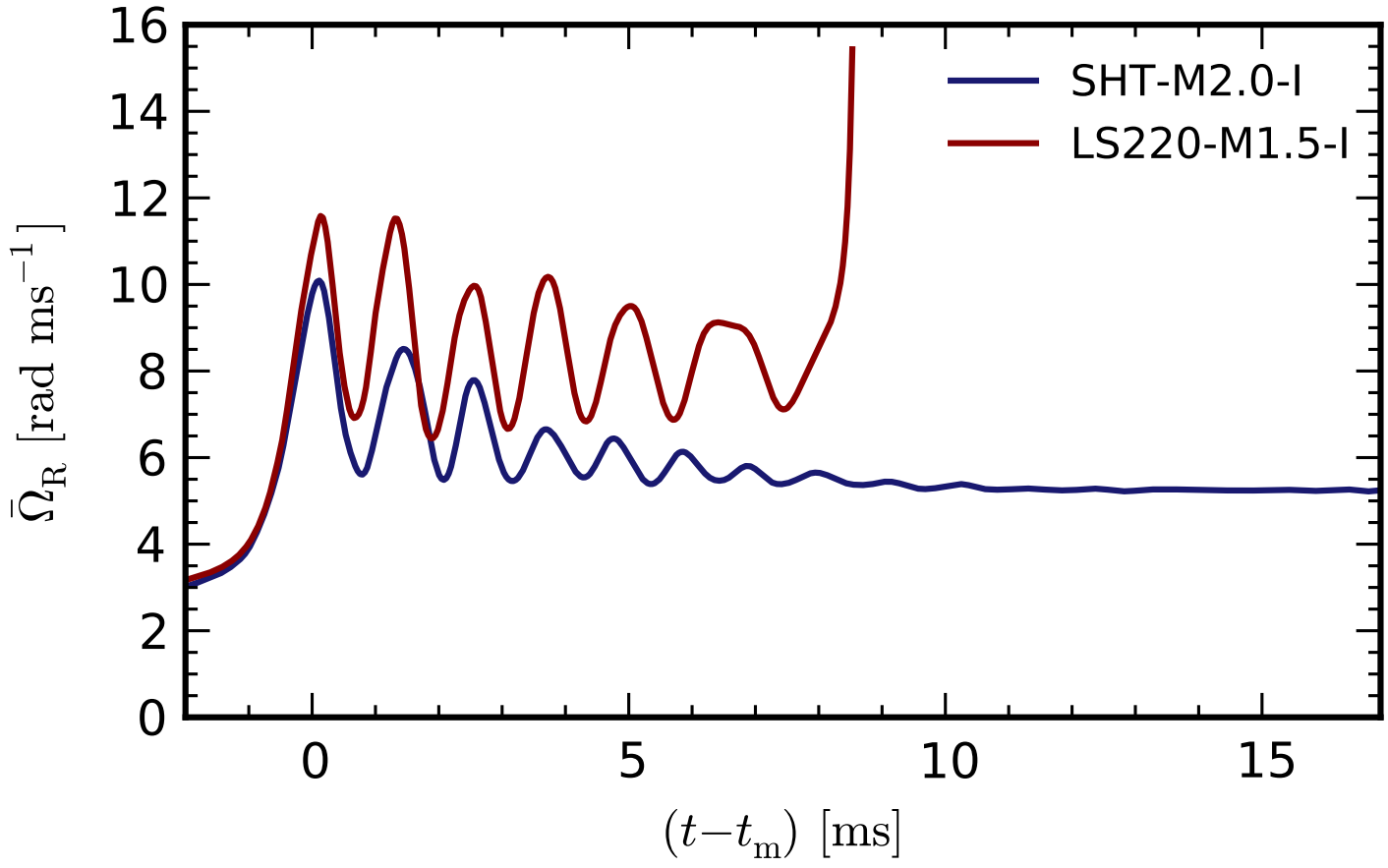
Merger Remnant – Radial Oscillations

- Strong quasi-radial oscilation.
- Low frequency of quasi-radial mode near critical mass.
- Oscillation amplitude smaller for spinning NSs.



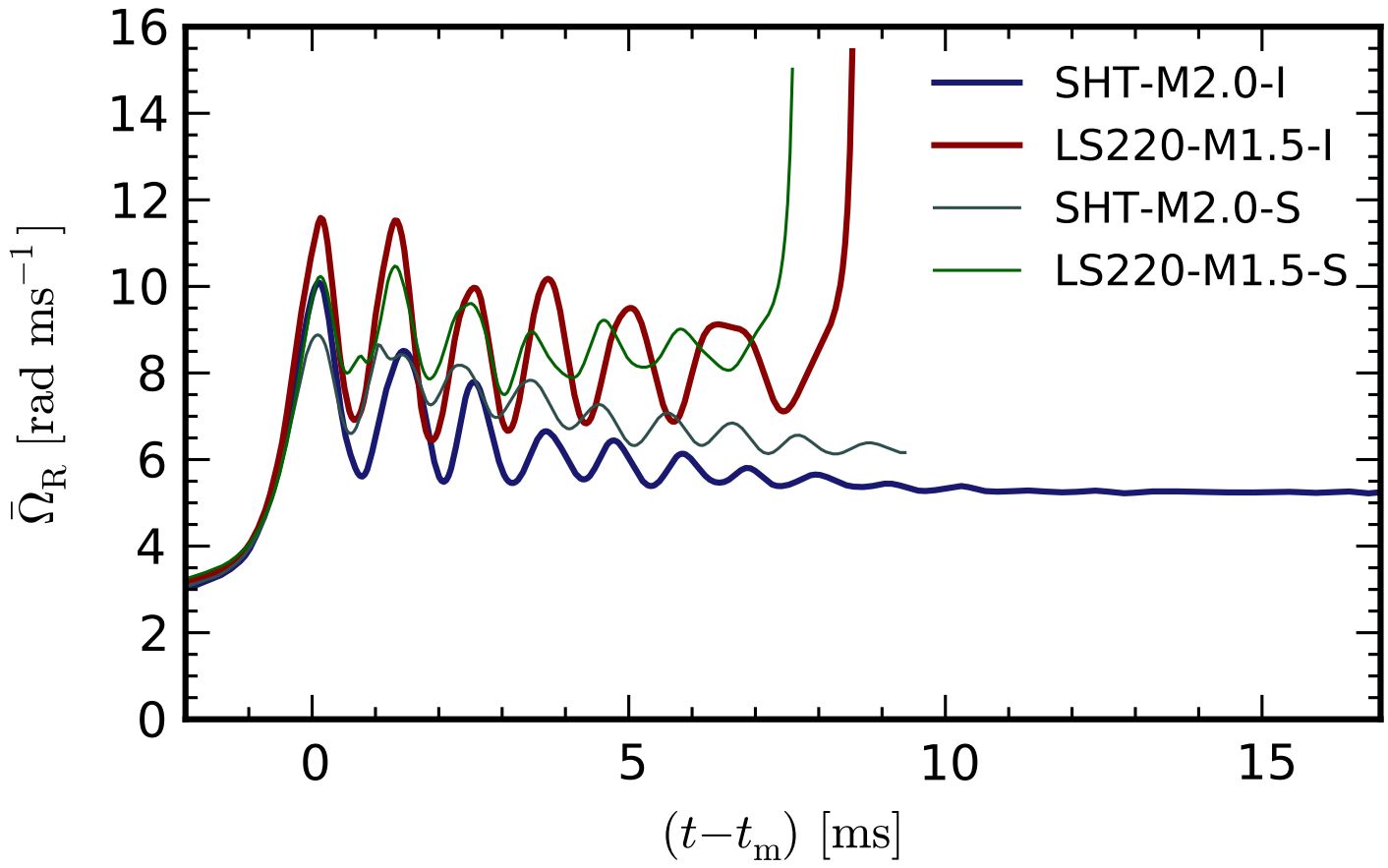
Merger Remnant – Rotation

- Rotation strongly modulated due to radial oscillation.



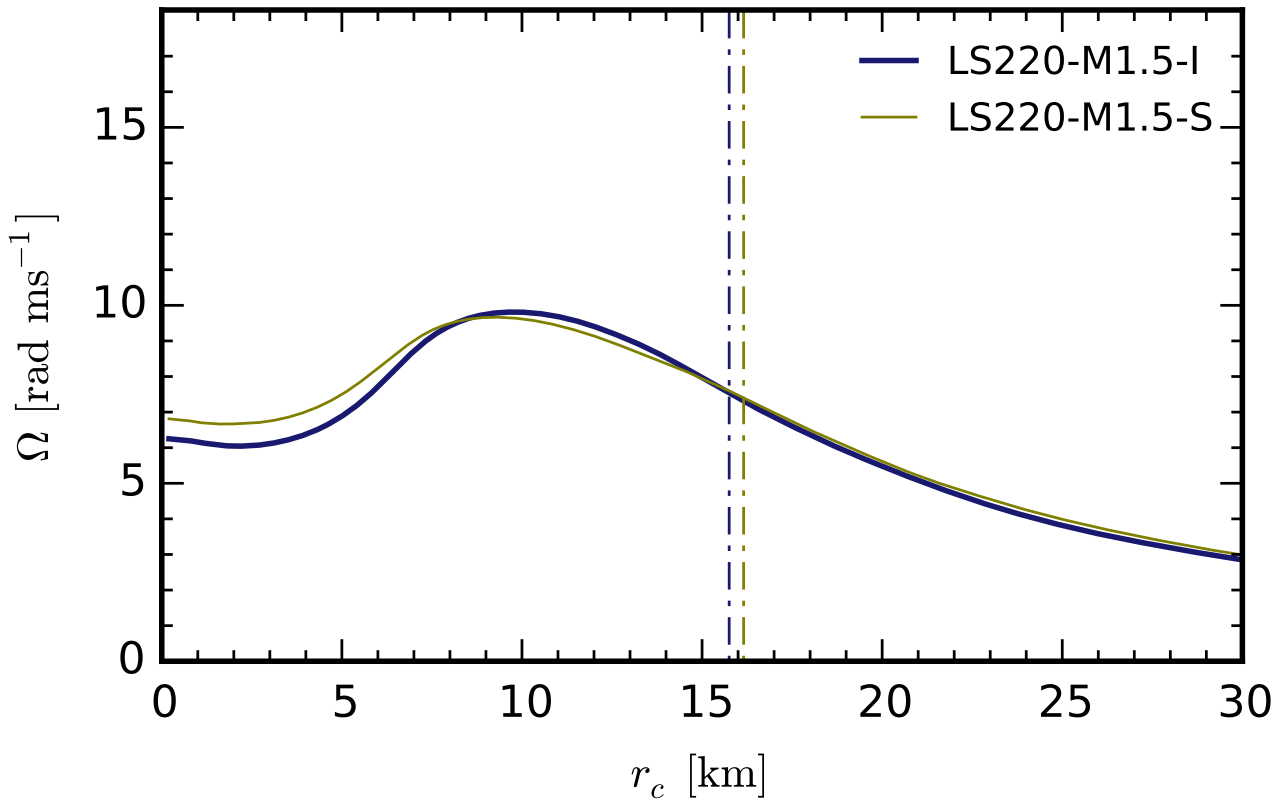
Merger Remnant – Rotation

- Rotation strongly modulated due to radial oscillation.
- Less modulation with initial spin.



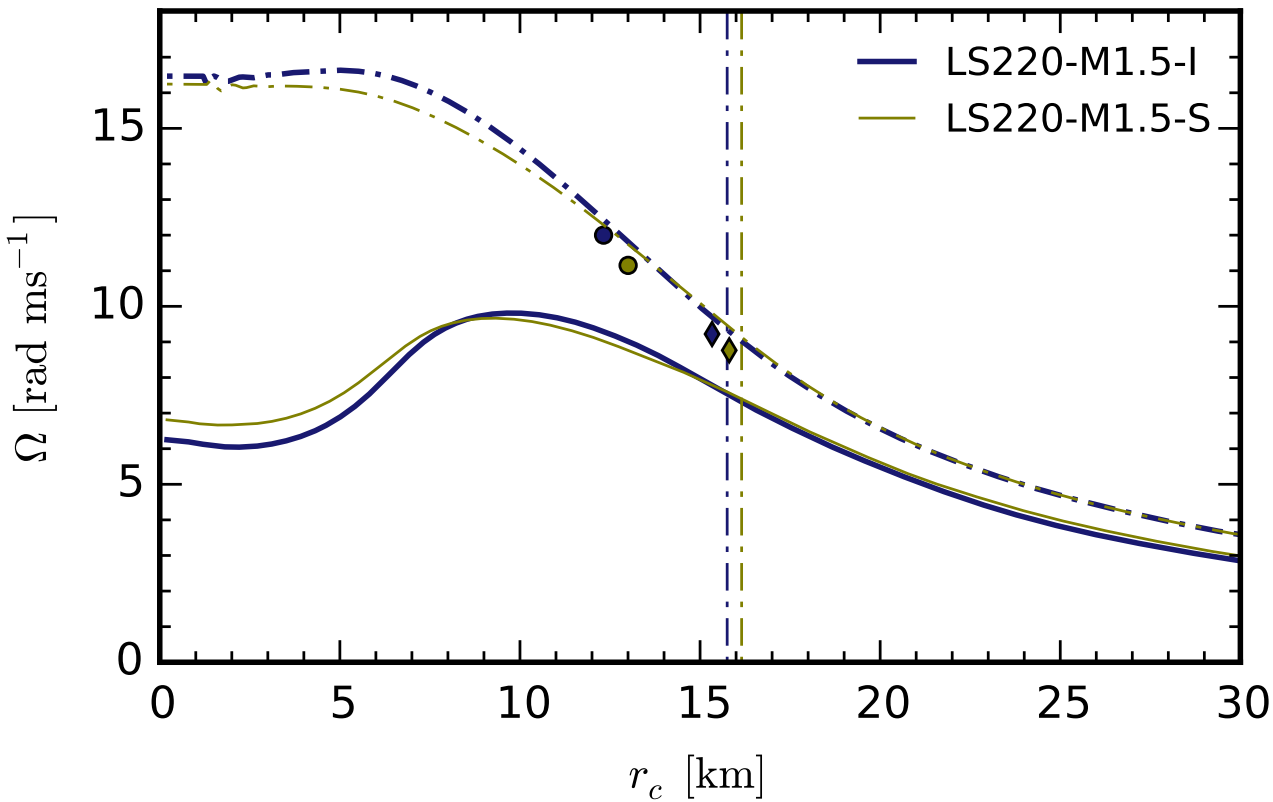
Merger Remnant – Rotation Profile

- Average rotation rate has central dip.



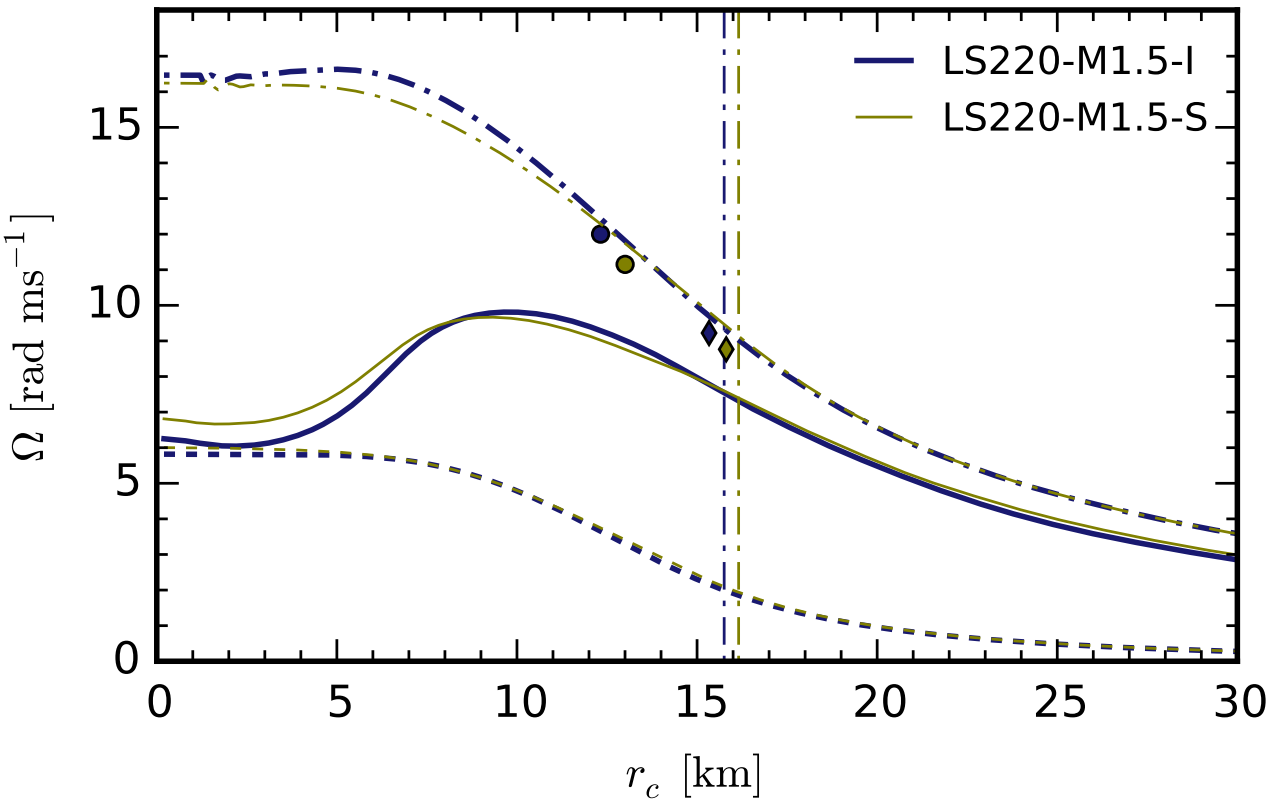
Merger Remnant – Rotation Profile

- Average rotation rate has central dip.
- Outer layers approach Kepler velocity.



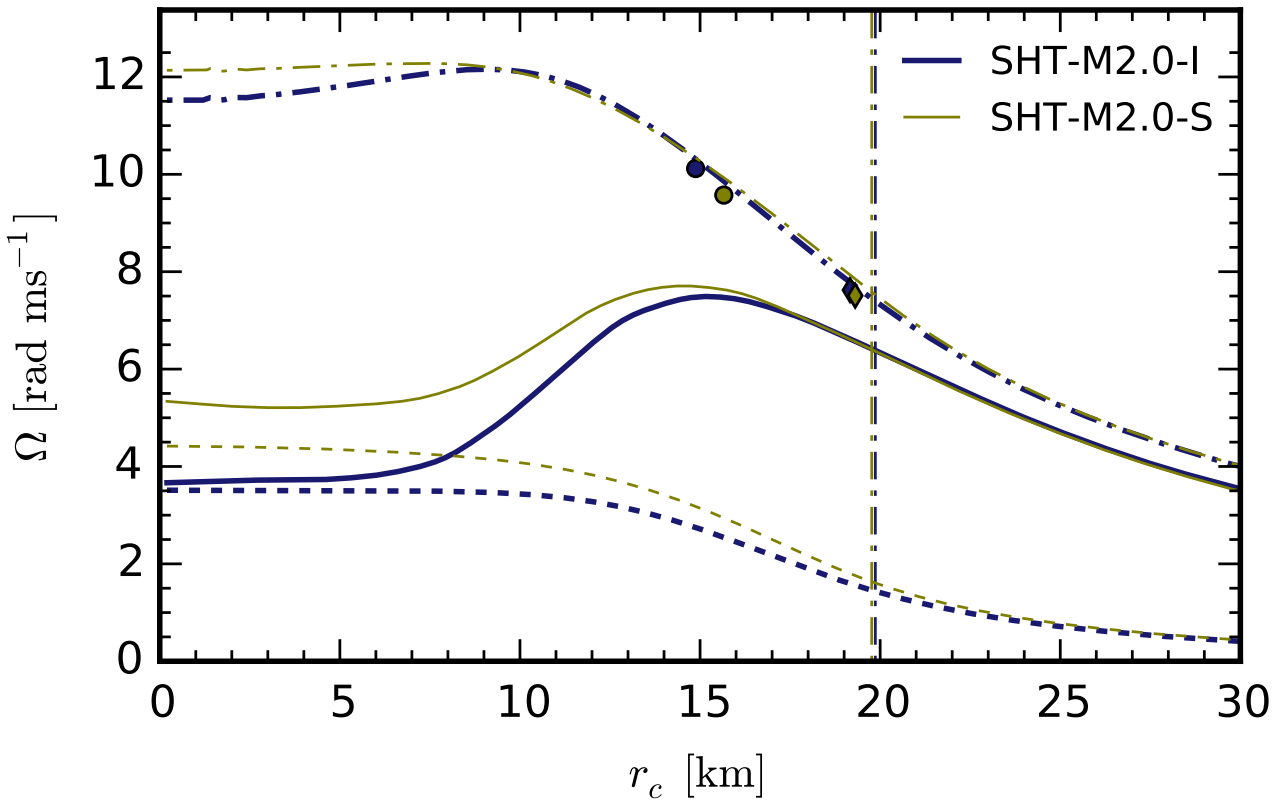
Merger Remnant – Rotation Profile

- Average rotation rate has central dip.
- Outer layers approach Kepler velocity.
- Core rotates very slowly in local inertial frame.



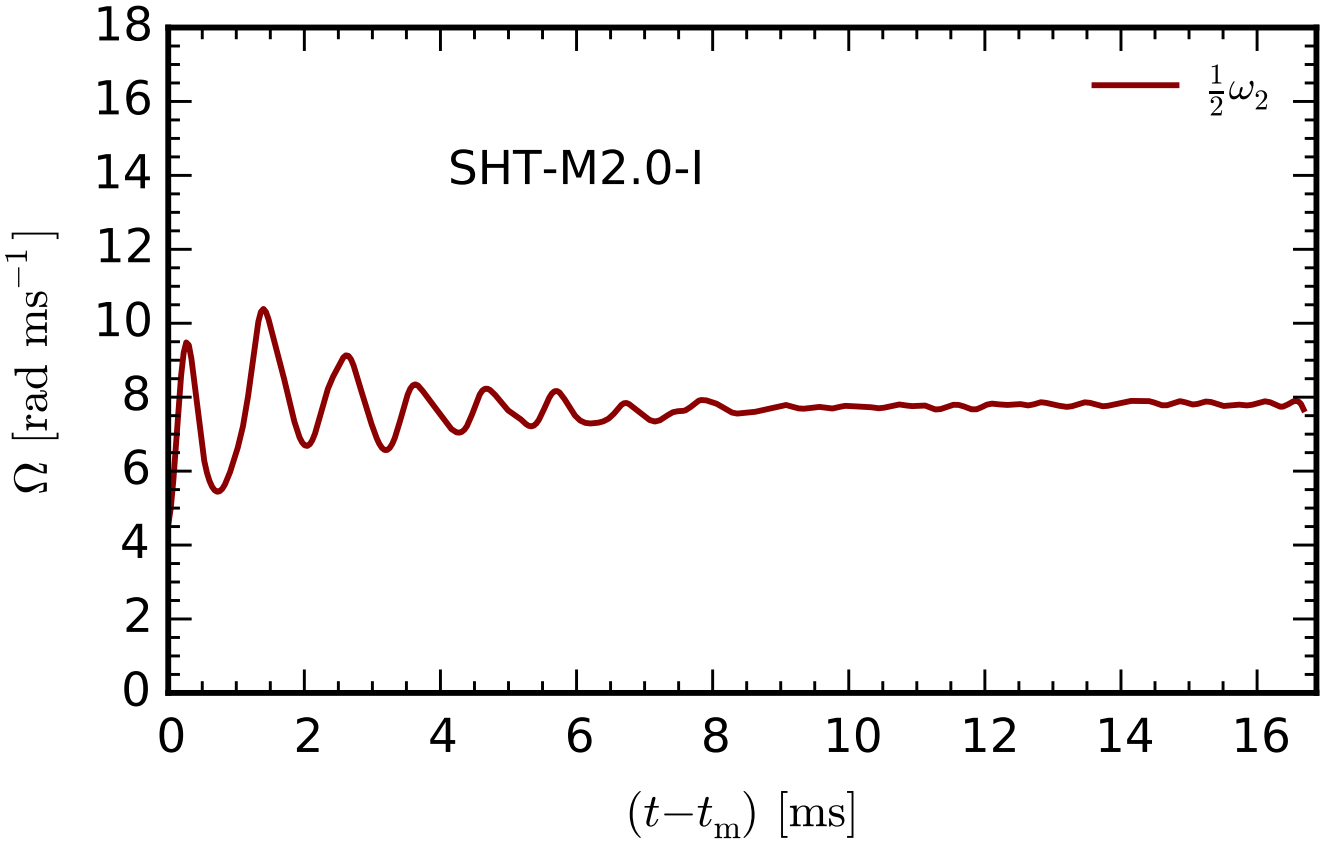
Merger Remnant – Rotation Profile

- Average rotation rate has central dip.
- Outer layers approach Kepler velocity.
- Core rotates very slowly in local inertial frame.



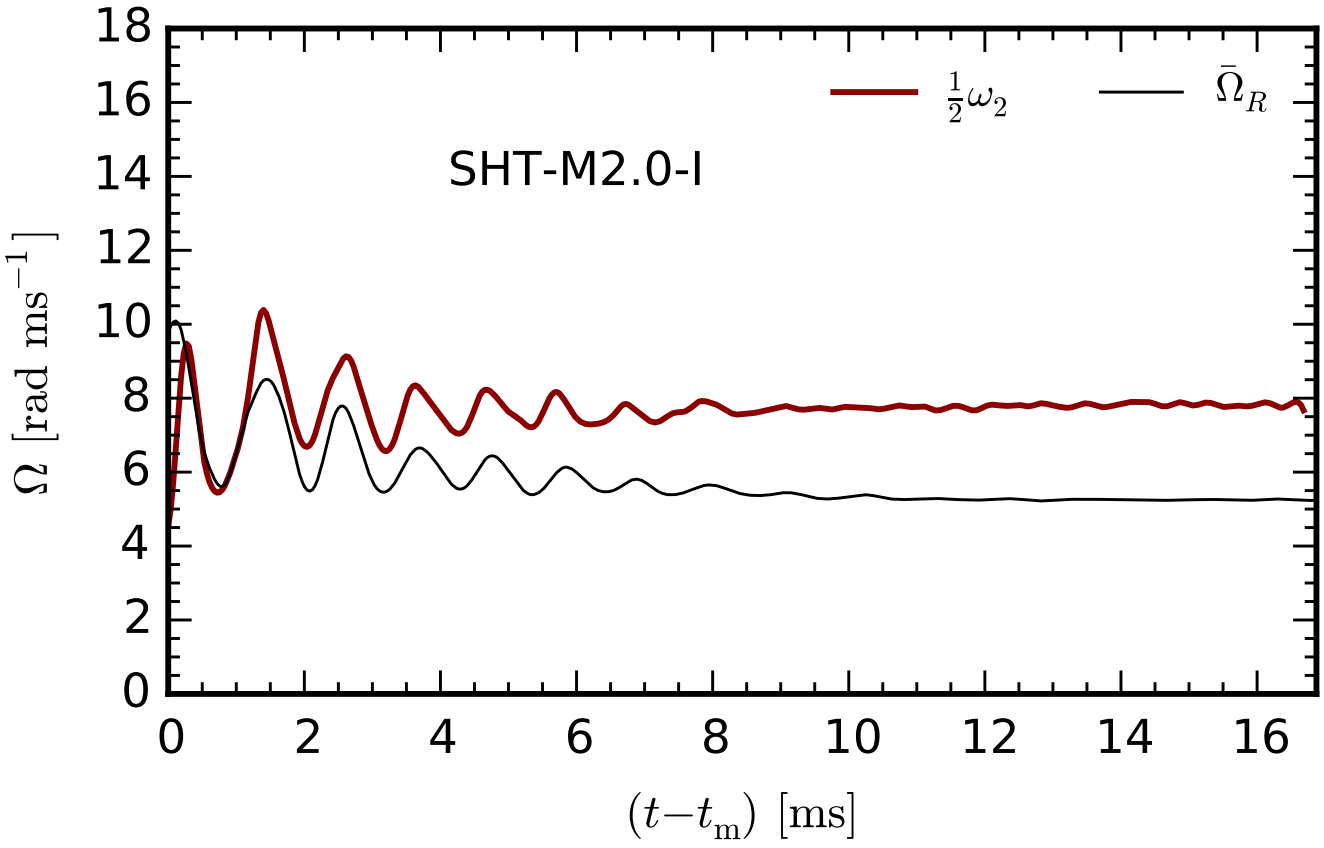
Merger Remnant – Nonaxisymmetric Oscillations

- Frequency of $m = 2$ mode strongly modulated.



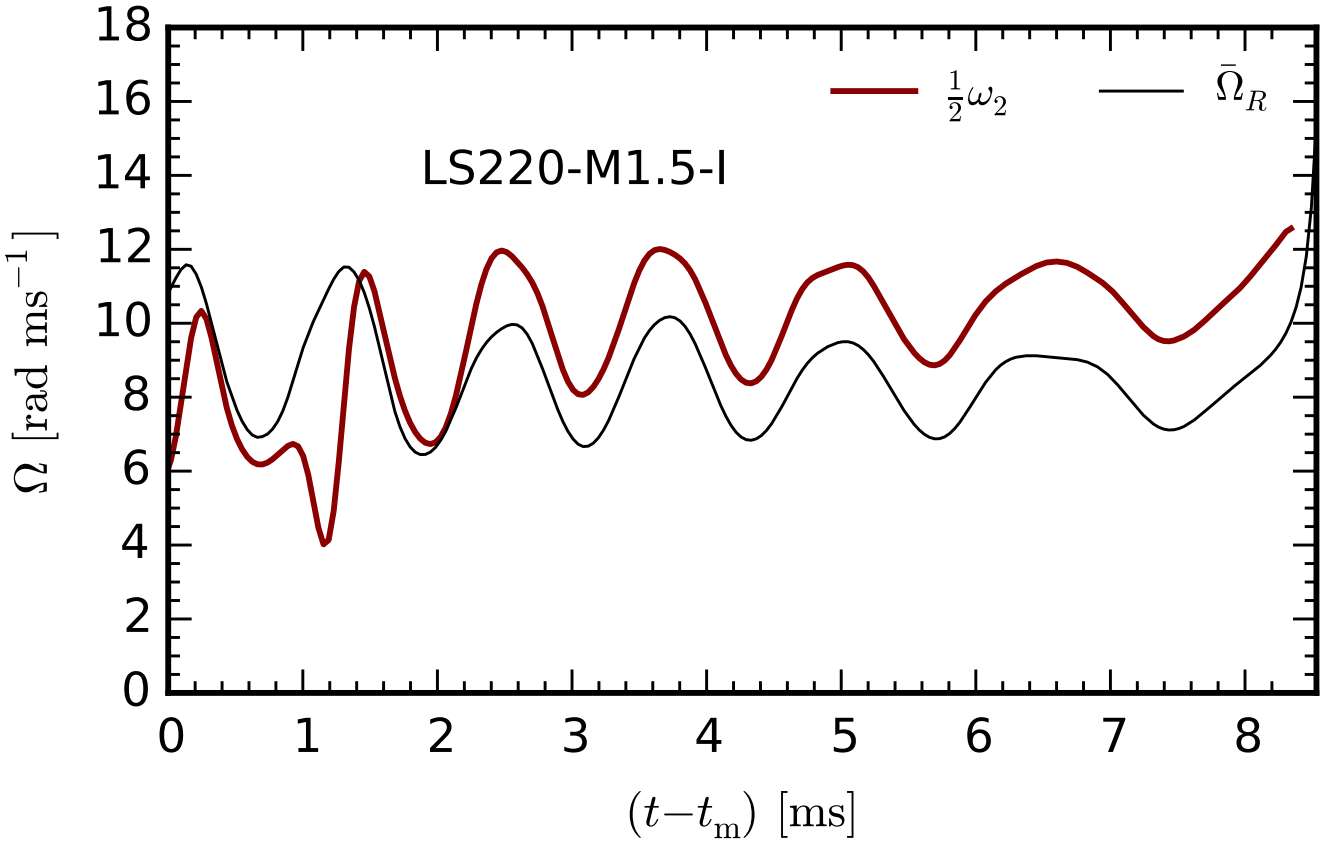
Merger Remnant – Nonaxisymmetric Oscillations

- Frequency of $m = 2$ mode strongly modulated.
- Correlated with rotation rate.



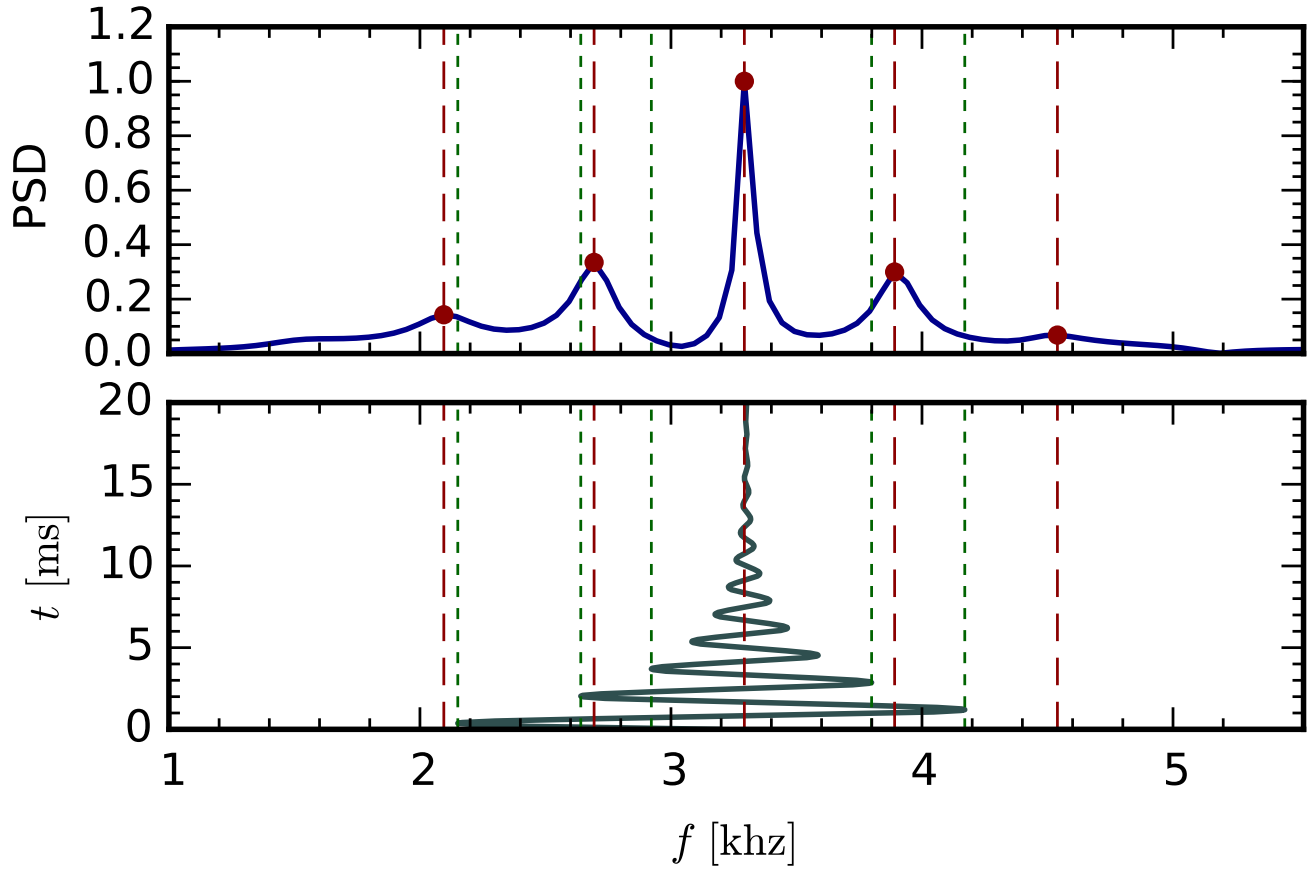
Merger Remnant – Nonaxisymmetric Oscillations

- Frequency of $m = 2$ mode strongly modulated.
- Correlated with rotation rate.
- Same situation for all four models.

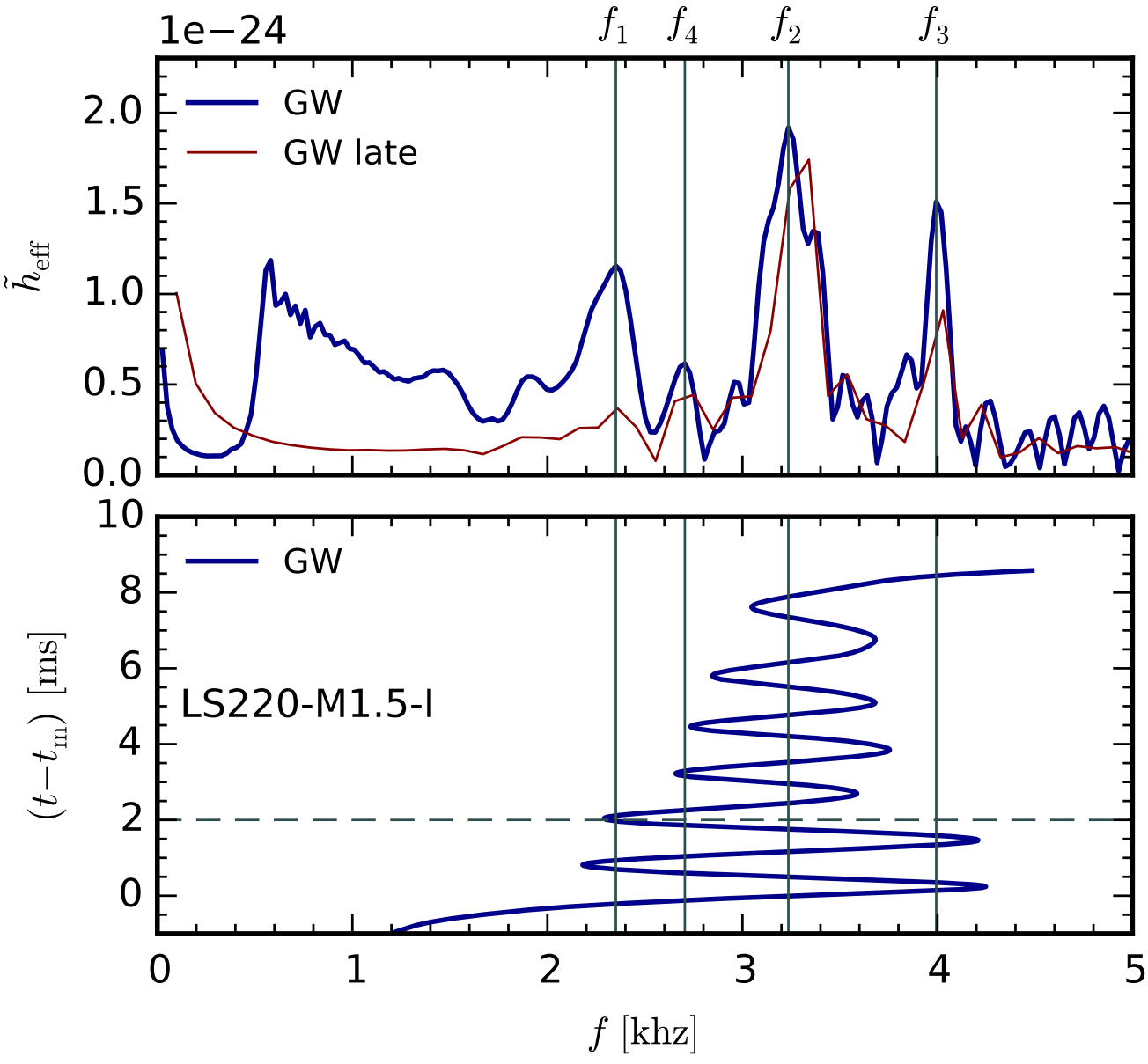


Frequency Modulation and Fourier Analysis

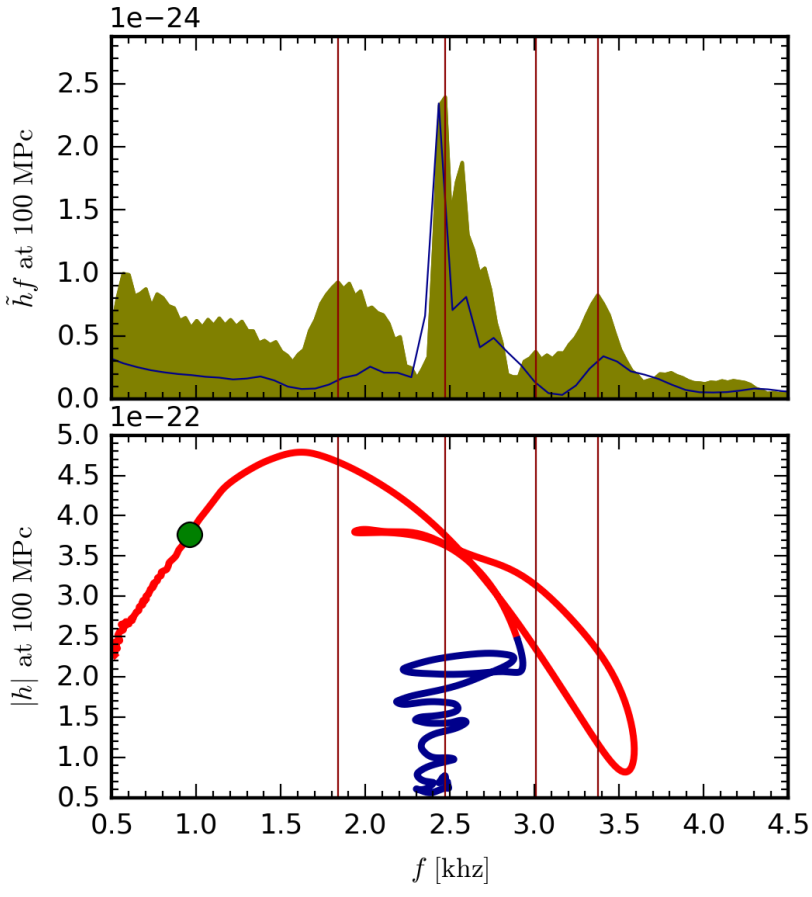
- Frequency-modulated toy signal.
- Spectrum shows additional peaks.
- Loosely related to local extrema of frequency.

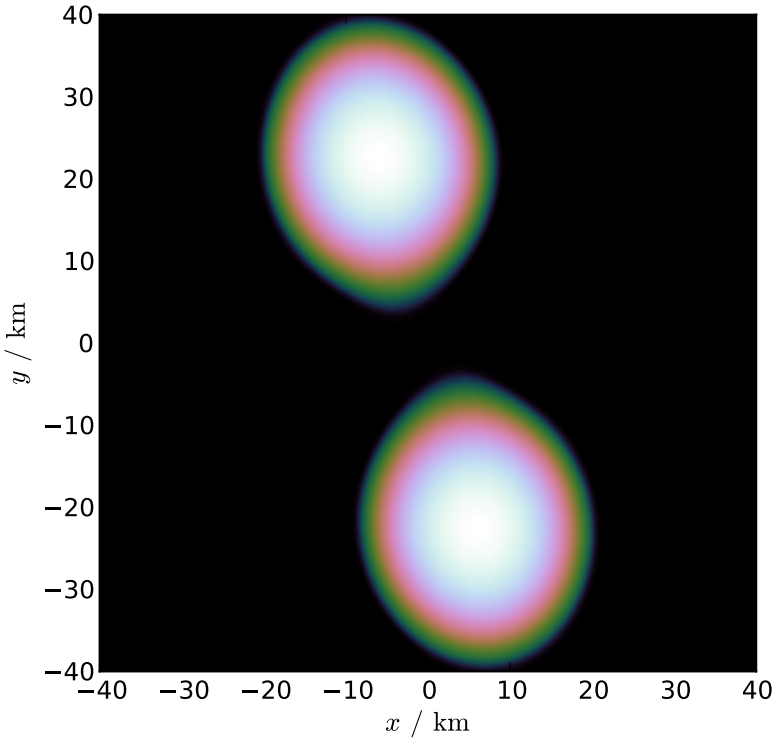


GW Spectrum

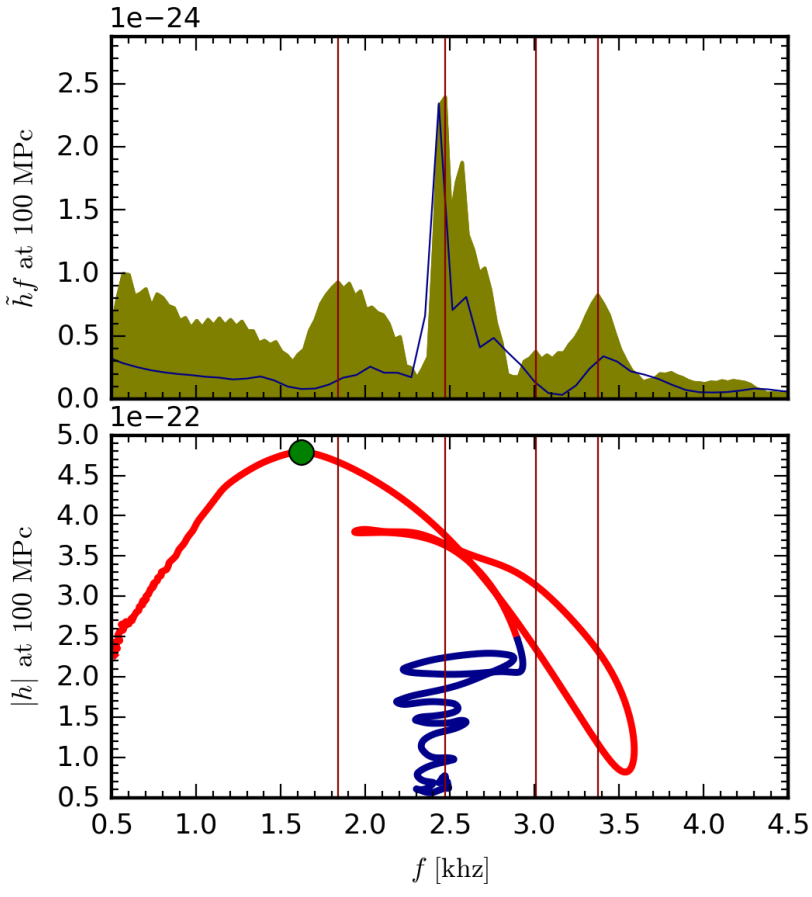

1e−24
f_1
f_4
f_2
f_3
GW
GW late
$\tilde{h}_{\rm eff}$
2.0
1.5
1.0
0.5
0.0
GW
LS220-M1.5-I
$(t-t_{\rm m})$ [ms]
10
8
6
4
2
0
0
1
2
3
4
5
f [khz]

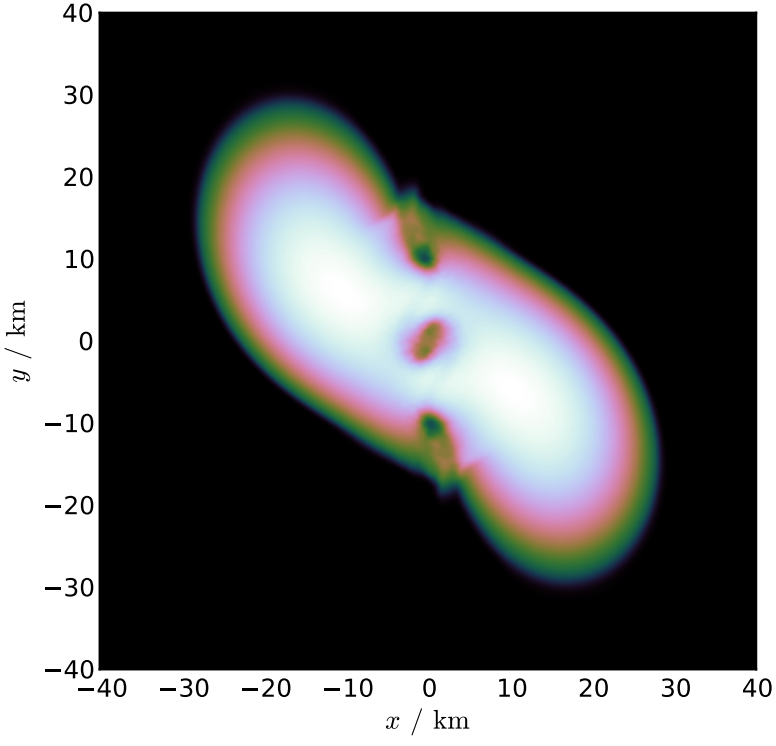
GW Spectrum



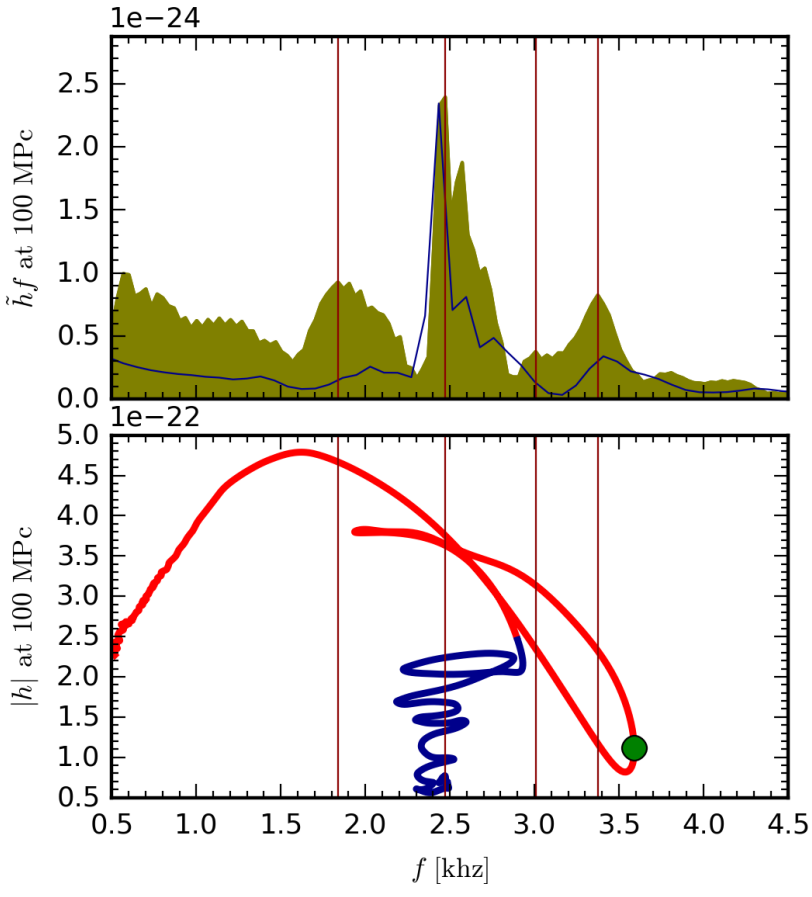


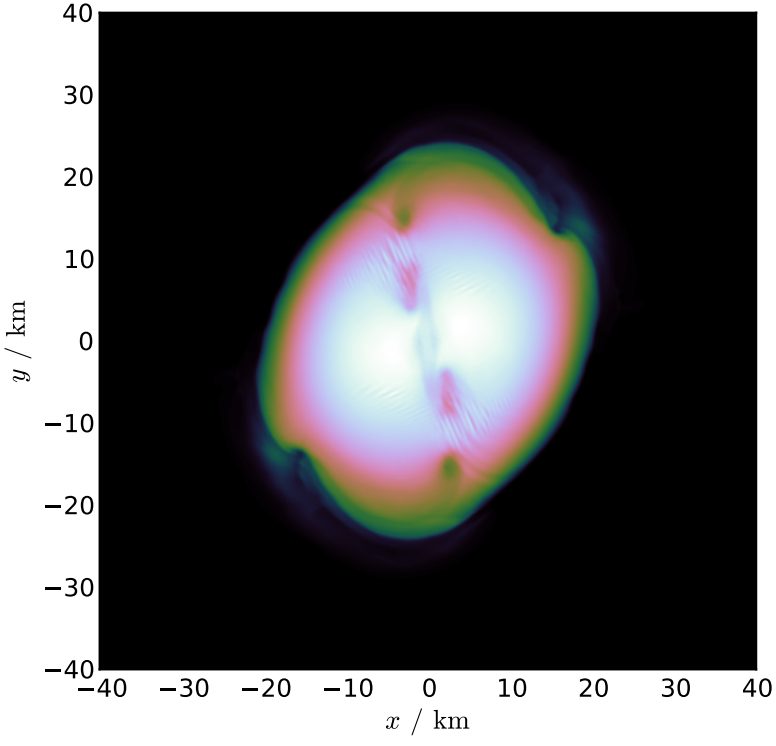
GW Spectrum



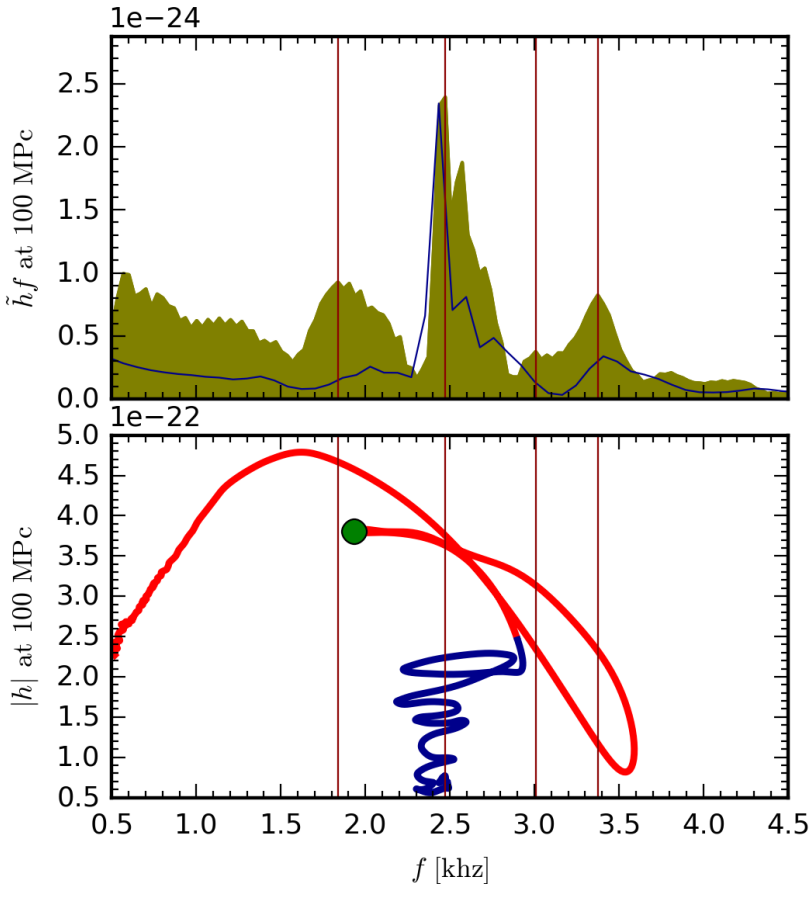


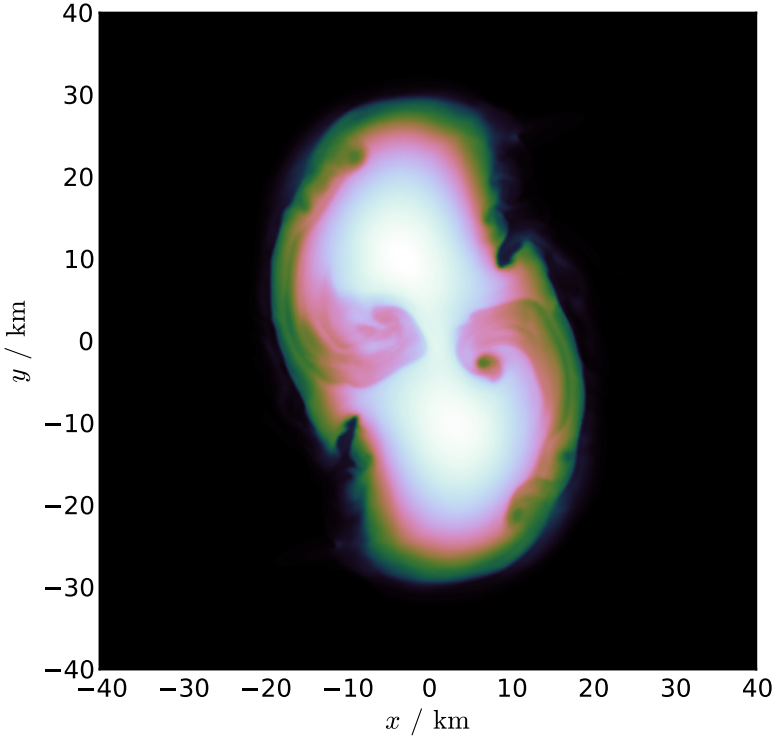
GW Spectrum



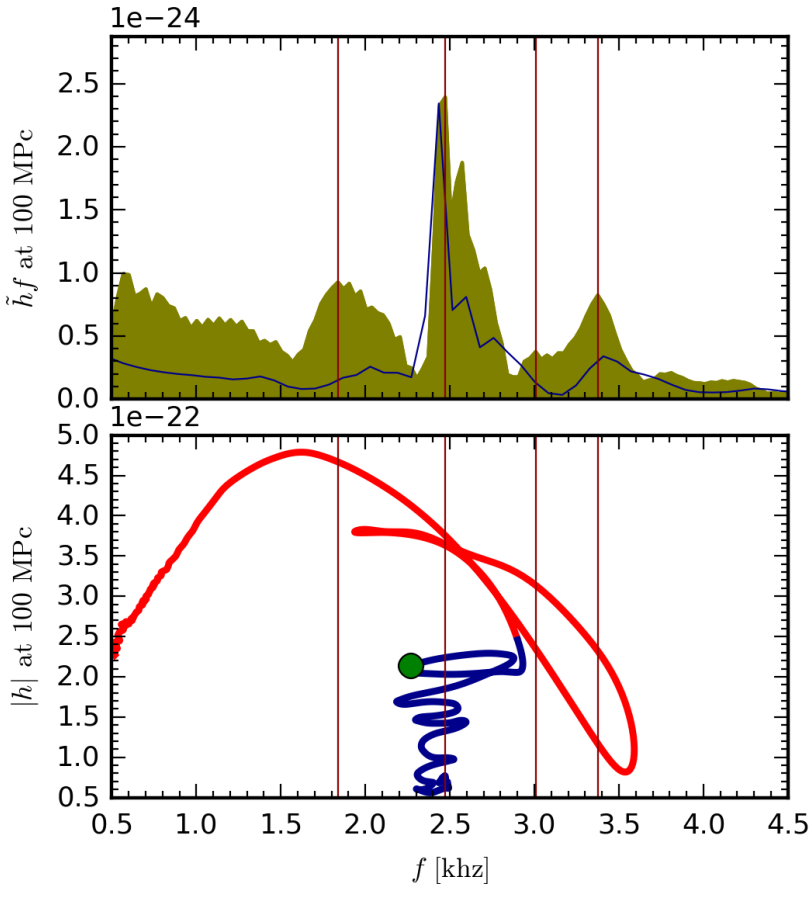


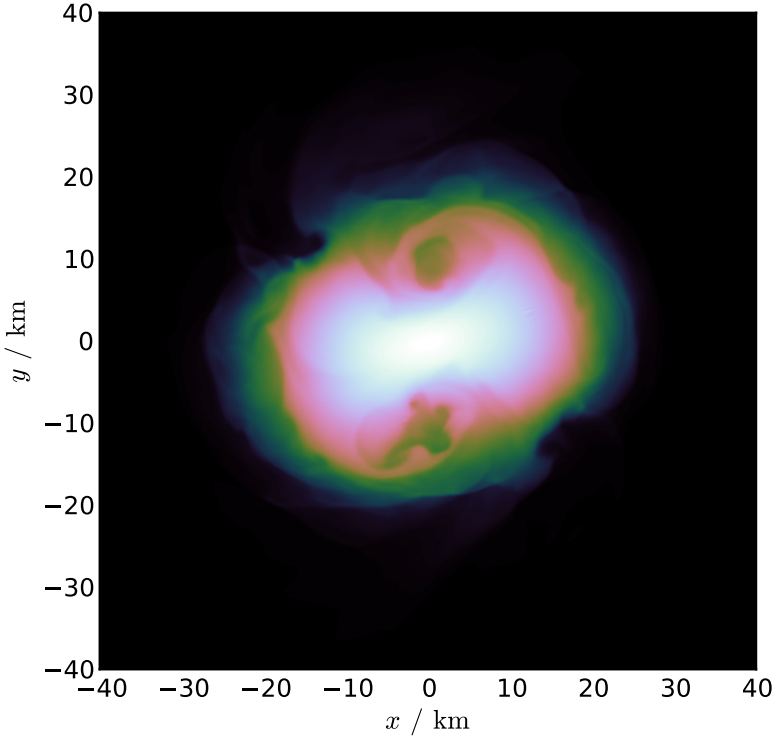
GW Spectrum



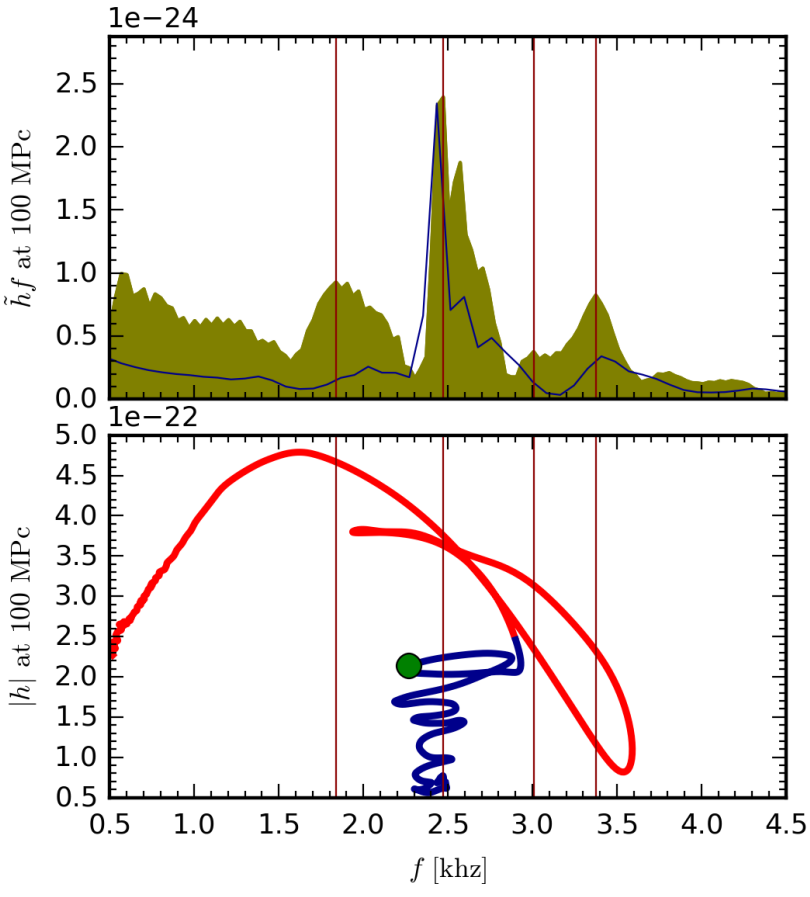


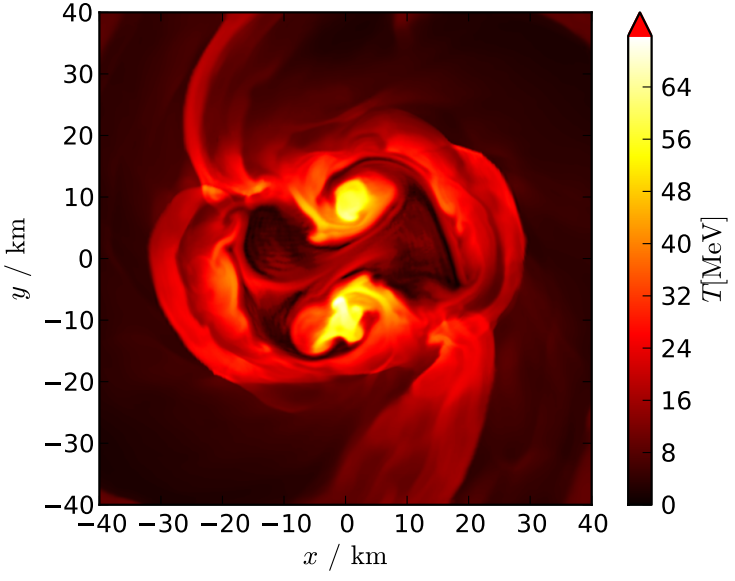
GW Spectrum



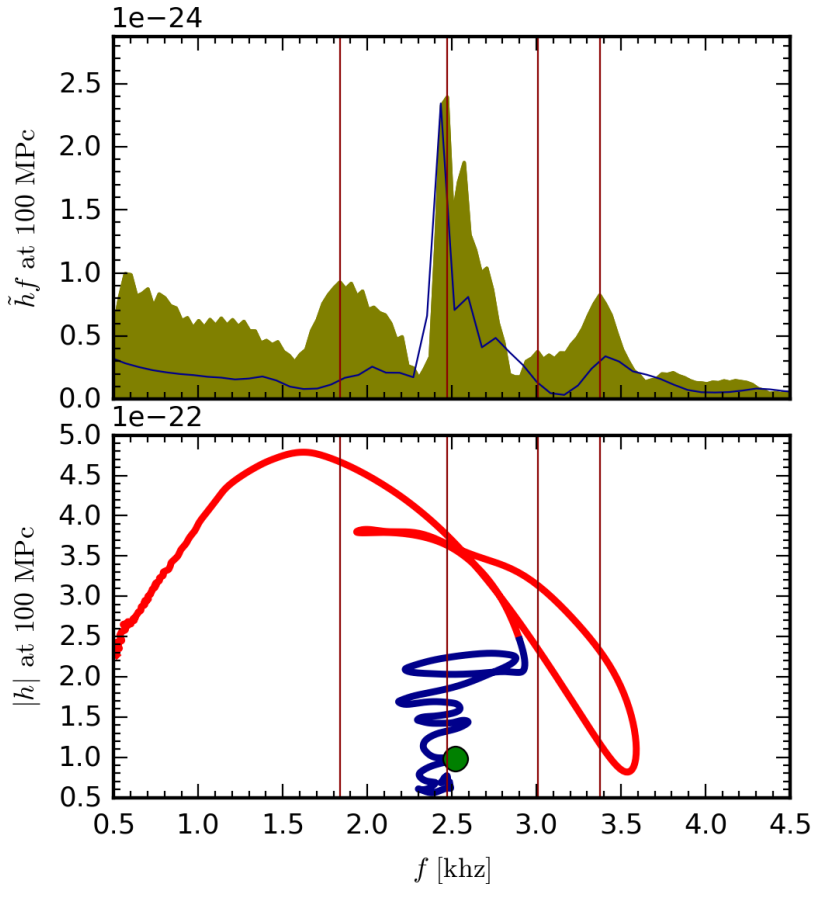


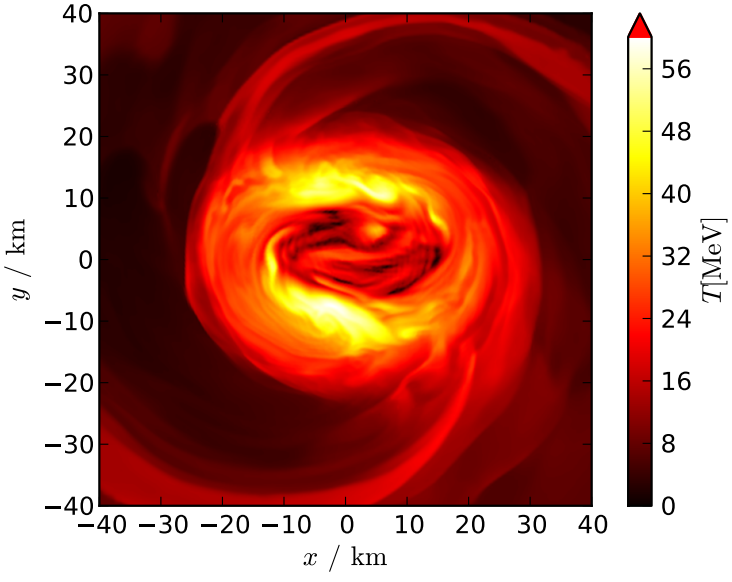
GW Spectrum



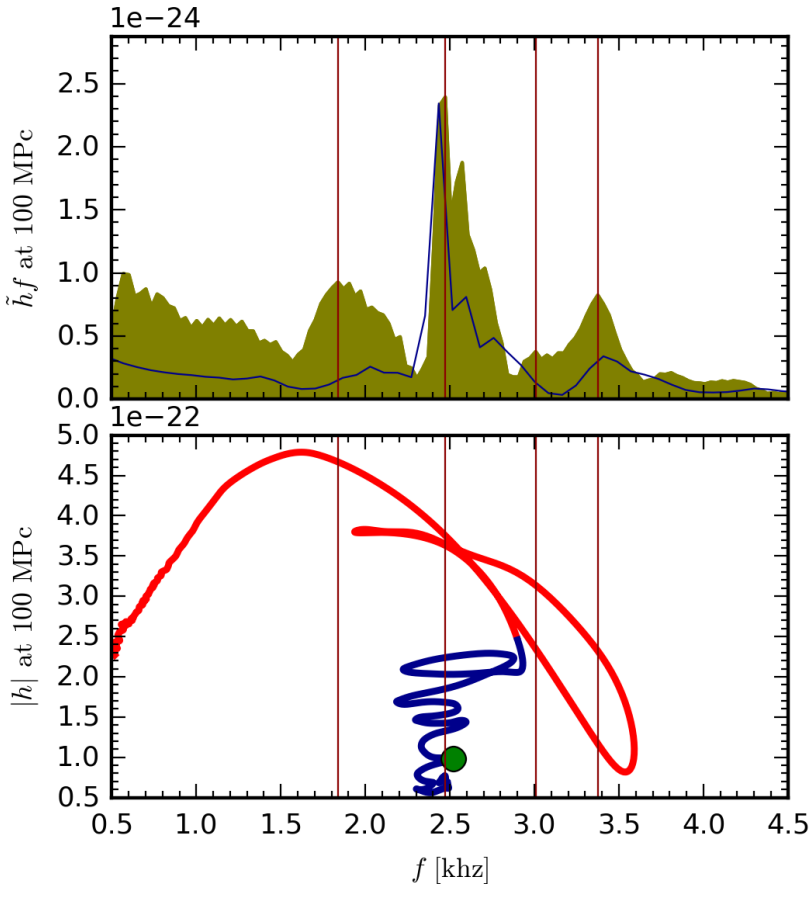


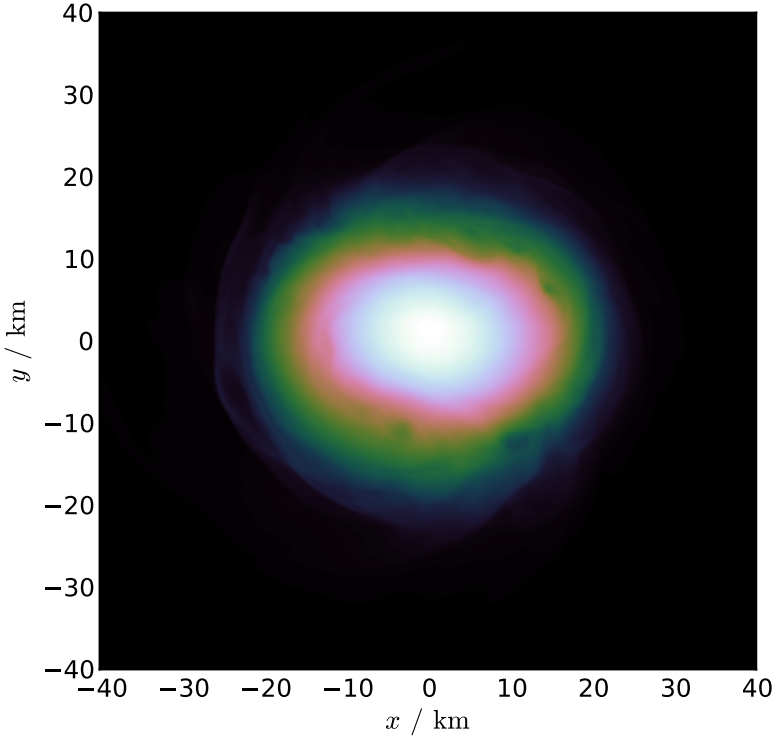
GW Spectrum





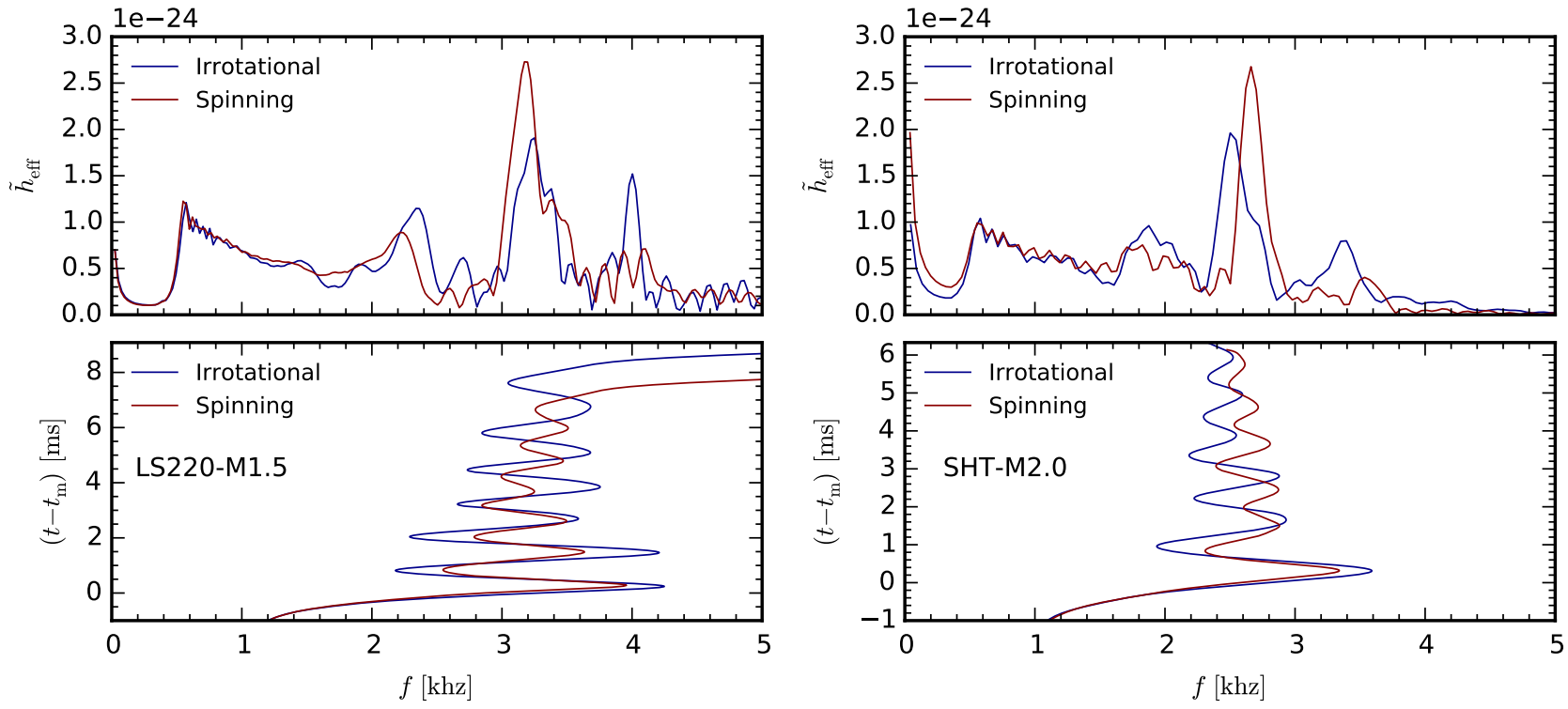
GW Spectrum





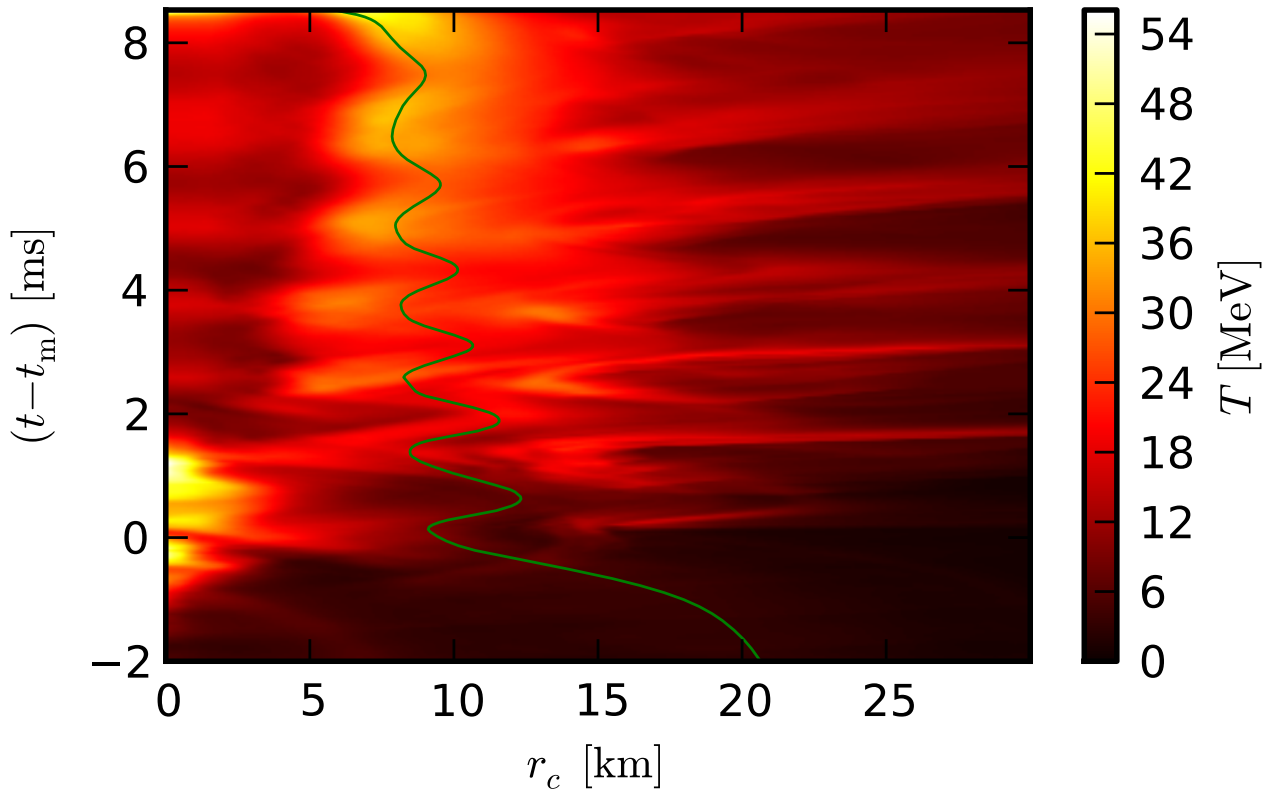
GW Spectrum – Influence of Spin

- Weak and complex influence of initial spin.
- Impossible to deduce spin from our spectra.



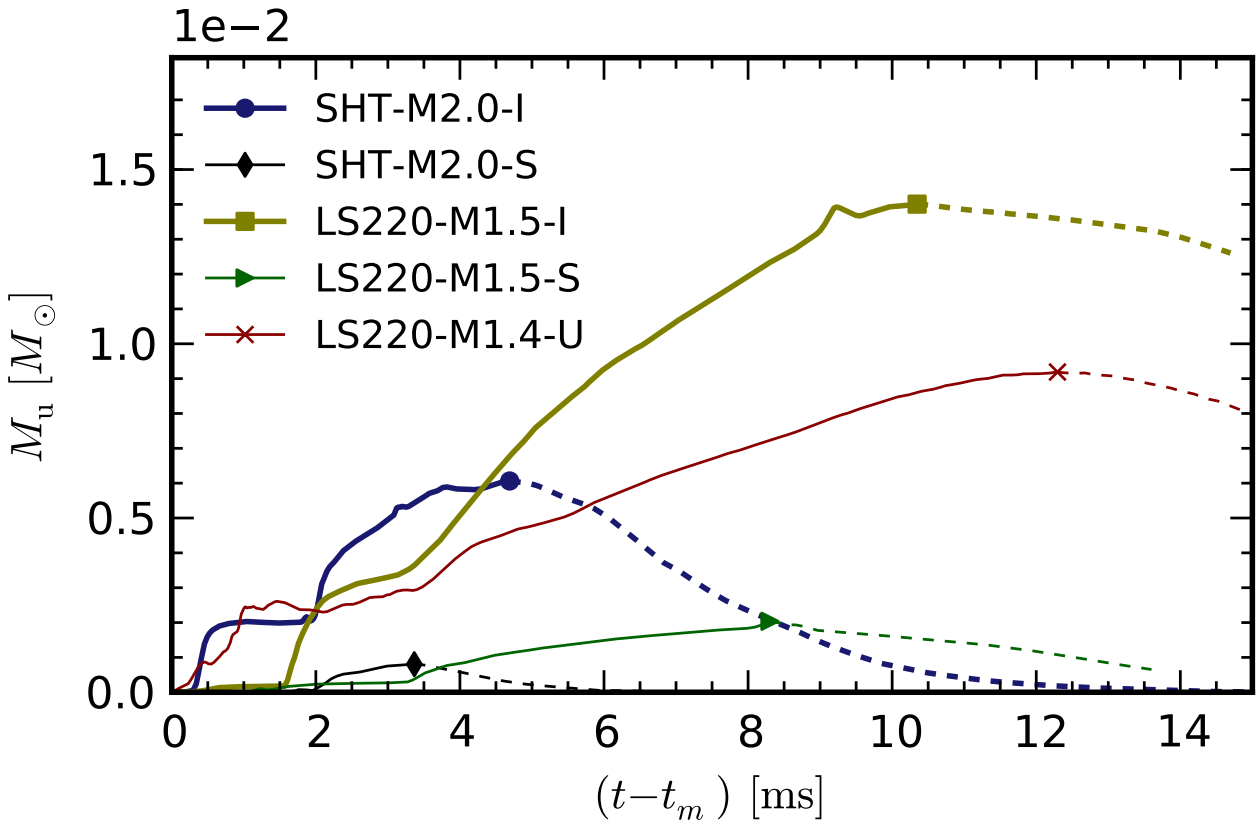
Matter ejection

- Matter ejected in spiral waves caused by $m = 2$ mode.
- Modulated by radial oscillation.



Matter ejection

- Matter ejected in spiral waves caused by $m = 2$ mode.
- Modulated by radial oscillation.
- Initial spin influences amount of ejected matter.



Summary

- HMNS do not need a rapidly rotating core.
- Radial oscillation modulates GW frequency.
- GW side-peaks are not always combination frequencies.
- Complicated, weak influence of spin on GW spectrum.
- Matter ejection might be reduced by spin.

W. Kastaun, F. Galeazzi, *Properties of hypermassive neutron stars formed in mergers of spinning binaries*, **Phys. Rev. D 91, 064027 (2015)**