The impact of rotation, magnetic fields and the equation of state on core-collapse supernovae

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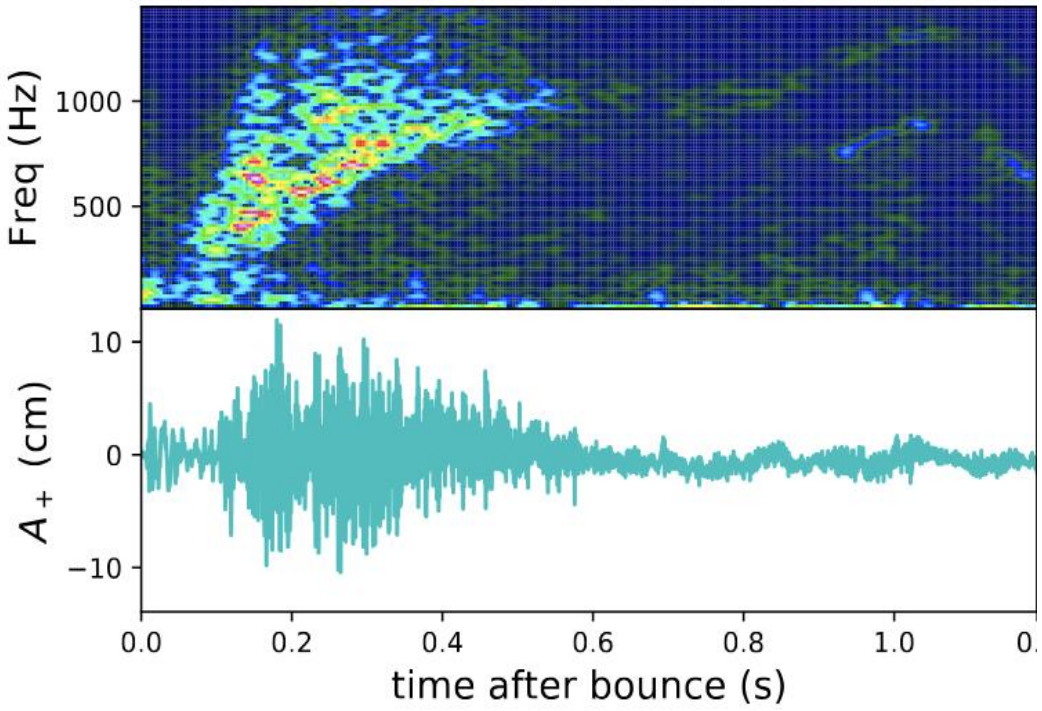
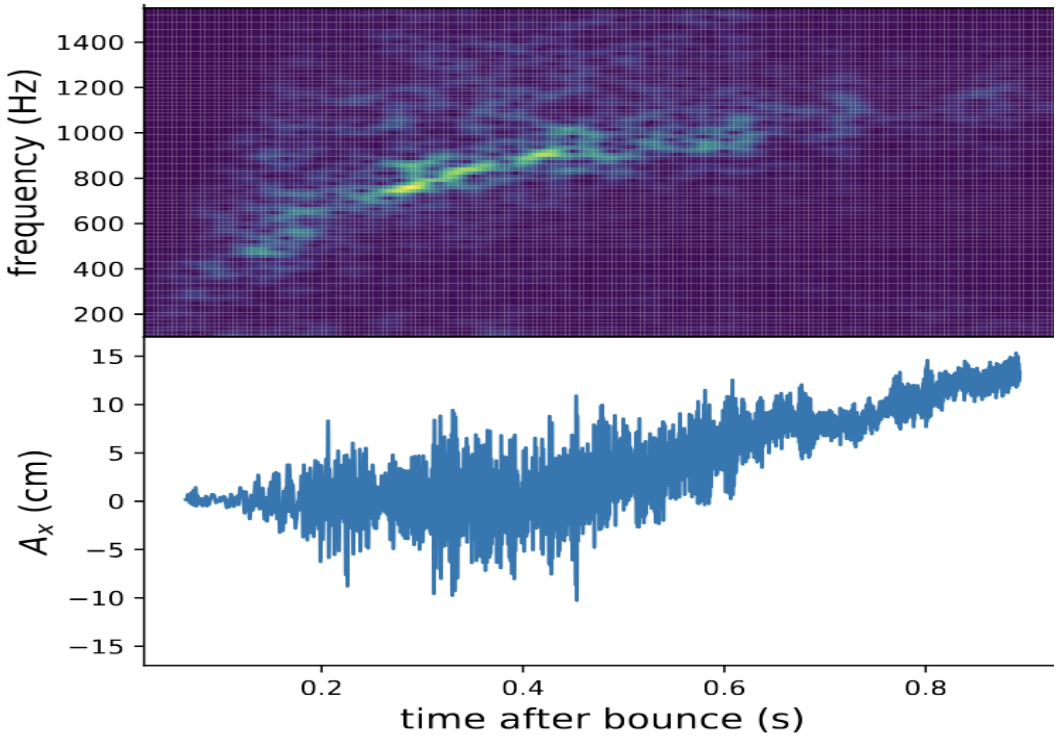
LIGO VIRGO KAGRA

Neutrino-driven Explosion Waveforms



Model y20

Powell & Muller arXiv:2002.10115

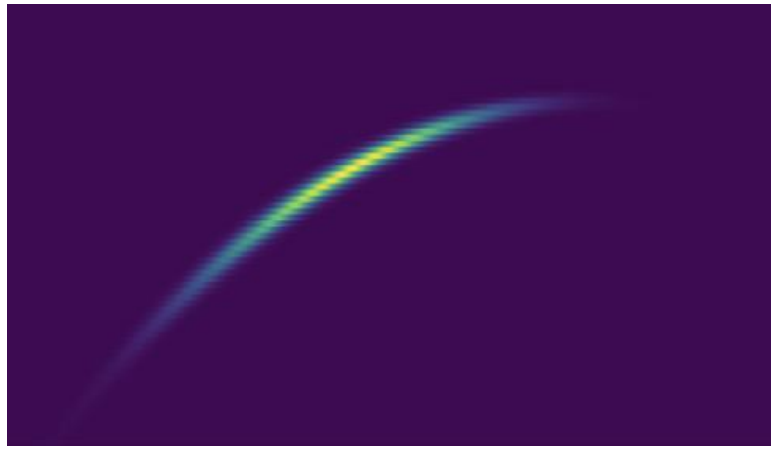


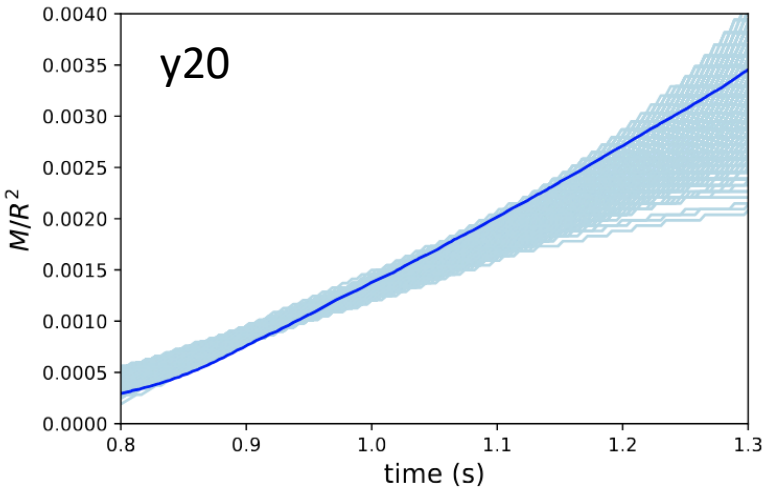
Model s18

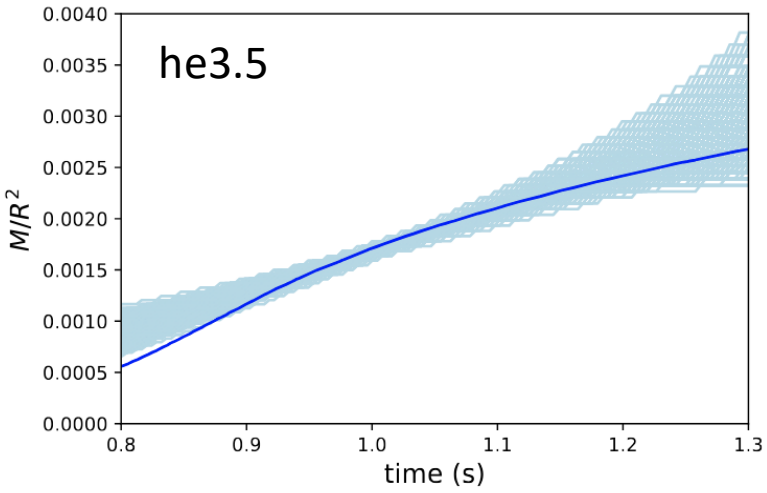
Powell & Muller arXiv:1812.05738

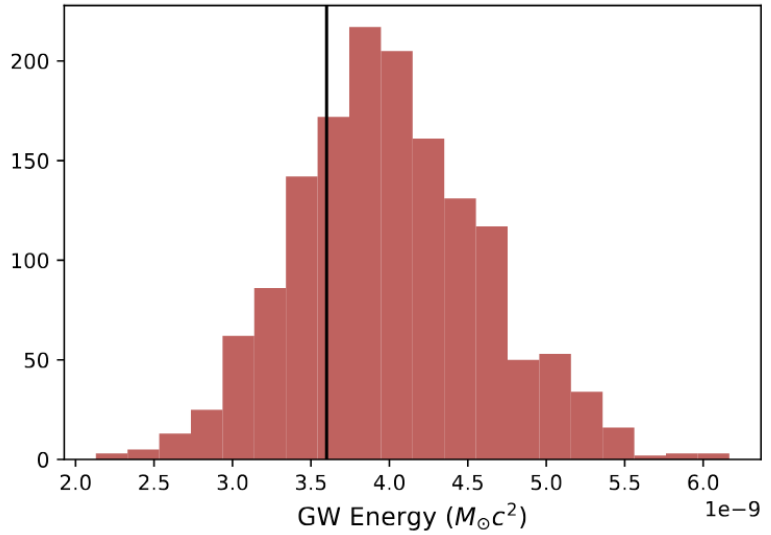
Parameter Estimation

- Powell & Mueller arXiv:2201.01397
- We make a Chirplet signal model to reconstruct the dominant mode.



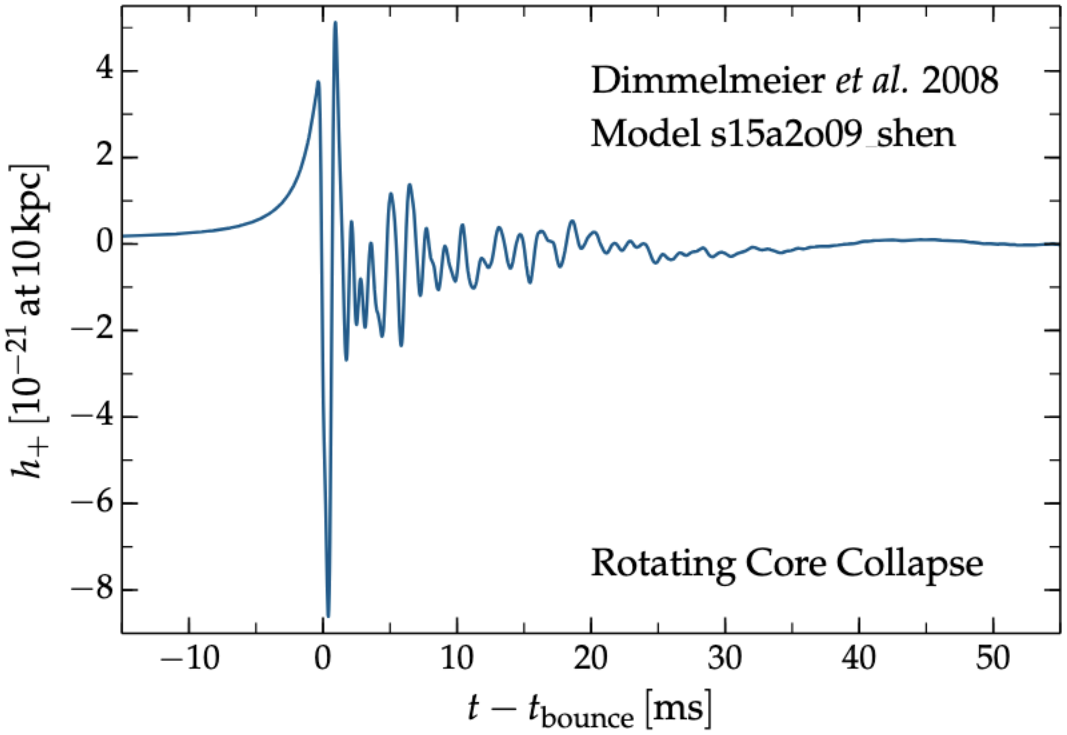






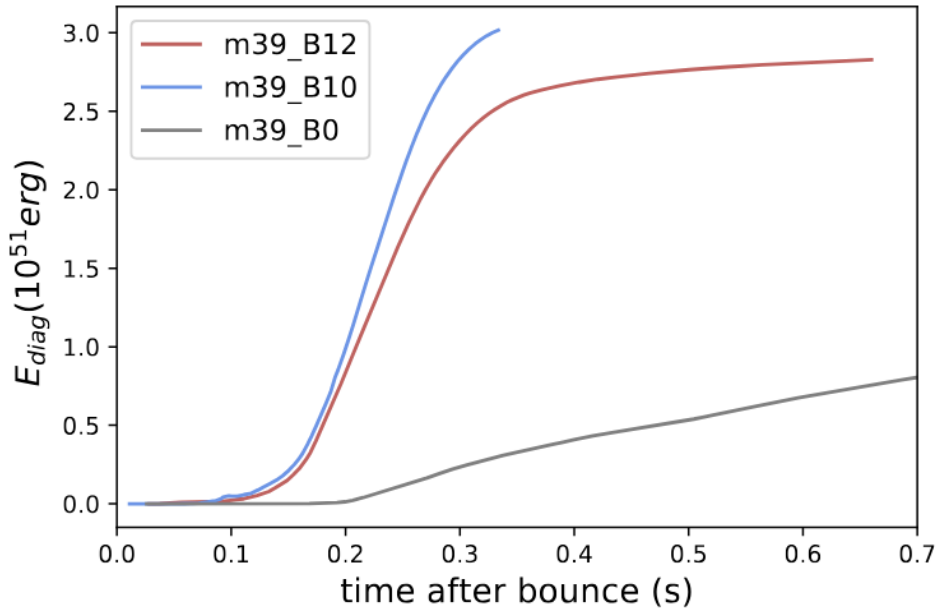
Explosion Mechanism

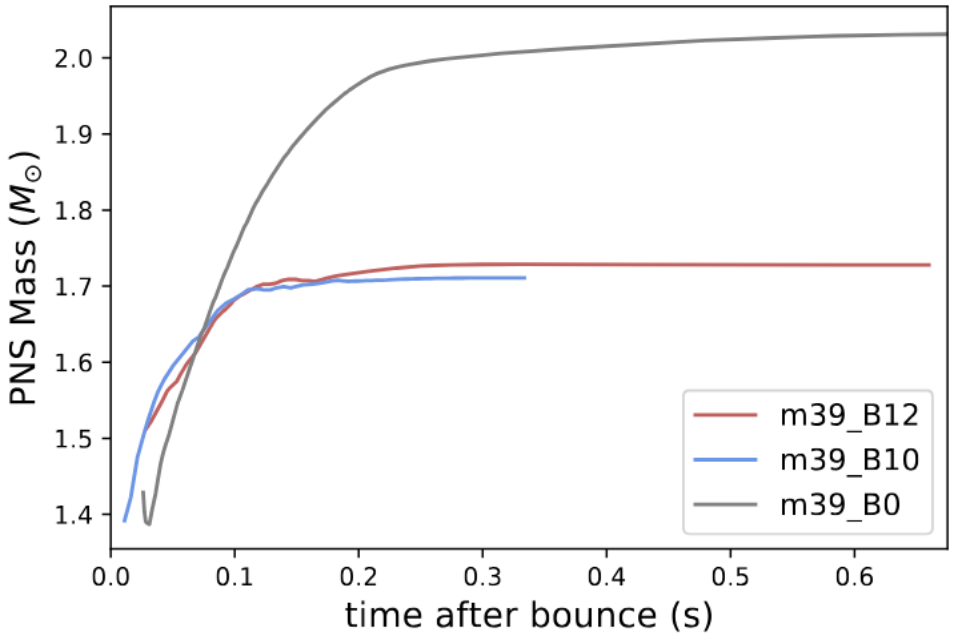
- Waveforms ended before the explosion phase.
- Do they even power a magnetorotational explosion?
- Do they look like neutrino-driven explosion waveforms at later times?



m39 models

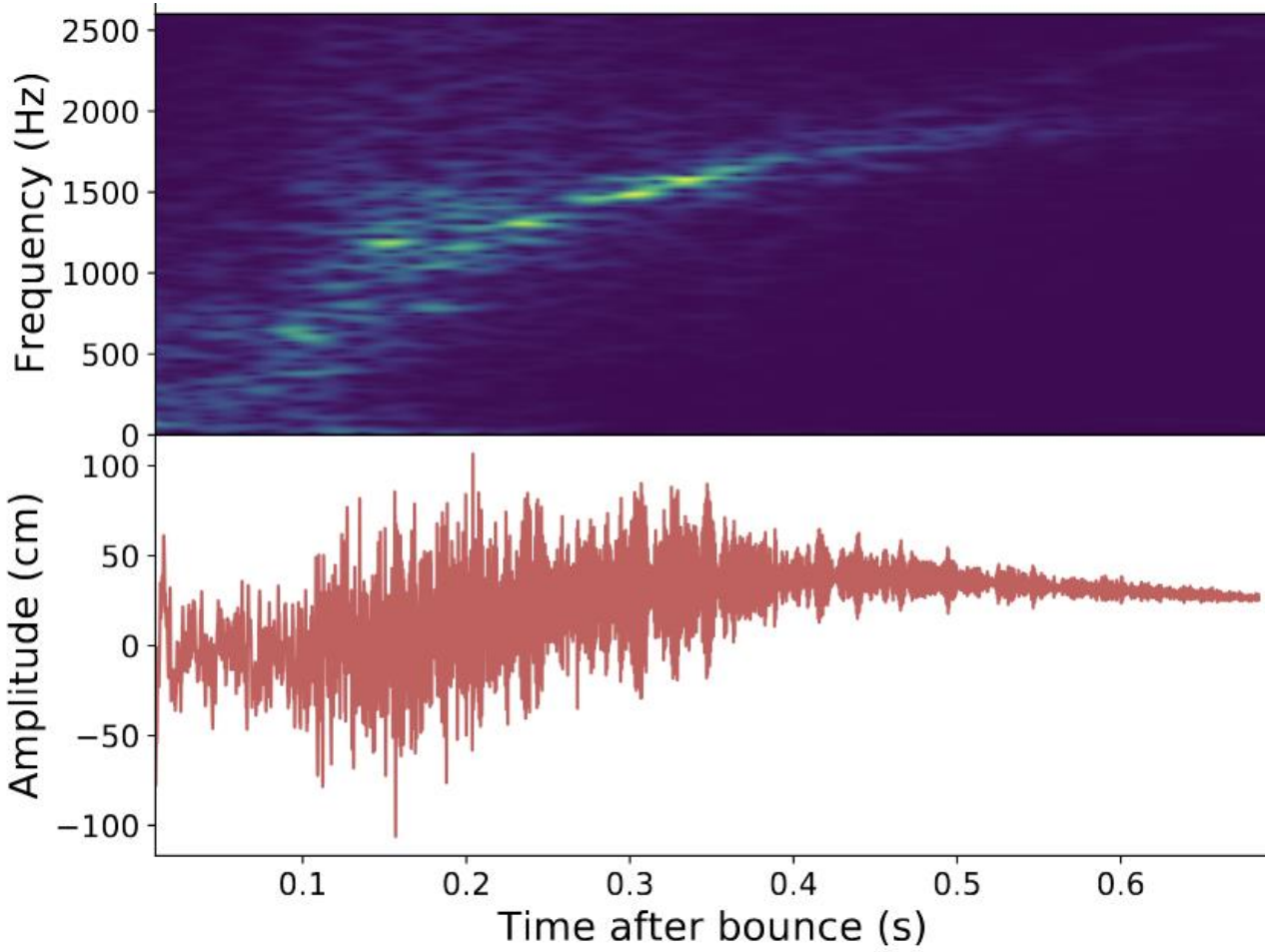
- All models rapidly rotating.
- Two have strong magnetic fields.
- Powell & Mueller et al. arXiv:2212.00200
- Rapid, high energy explosions.
- Lower mass neutron stars.





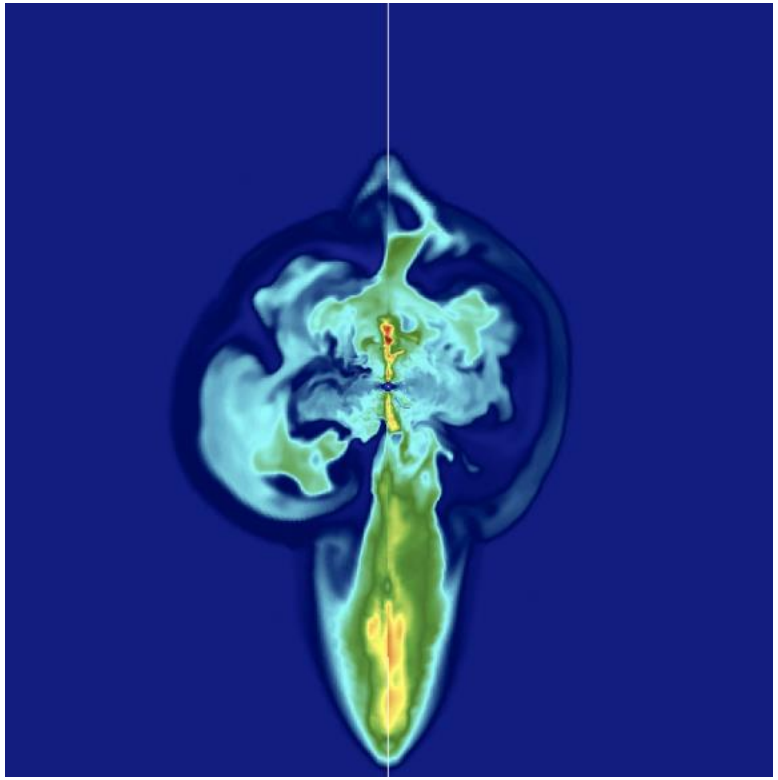
m39 models

- Significantly higher gravitational wave amplitudes.
- Higher gravitational wave frequencies.
- Determining the explosion mechanism is harder than we previously thought! (See arXiv:2311.18221)

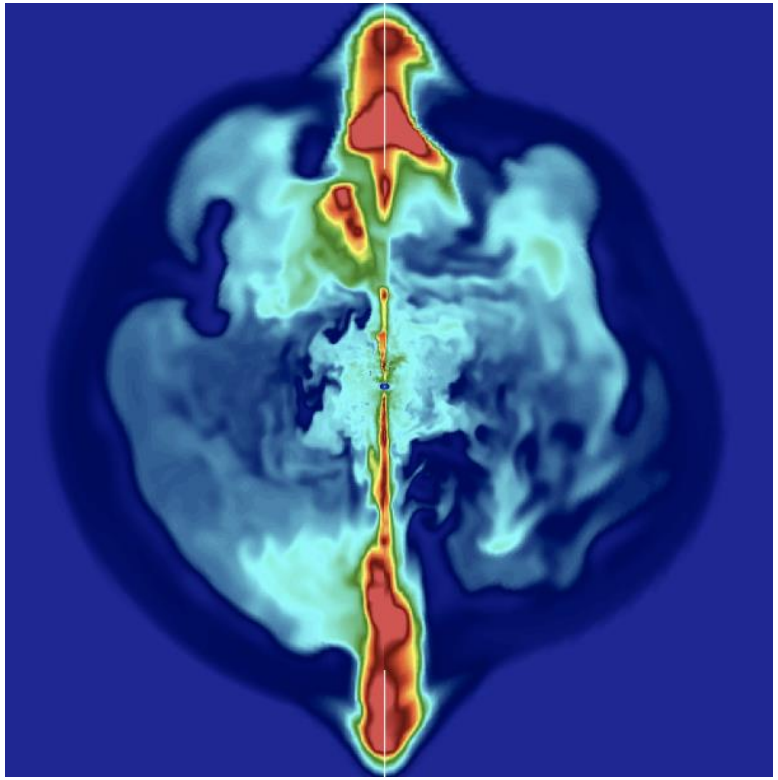


m39 models

m39_B12

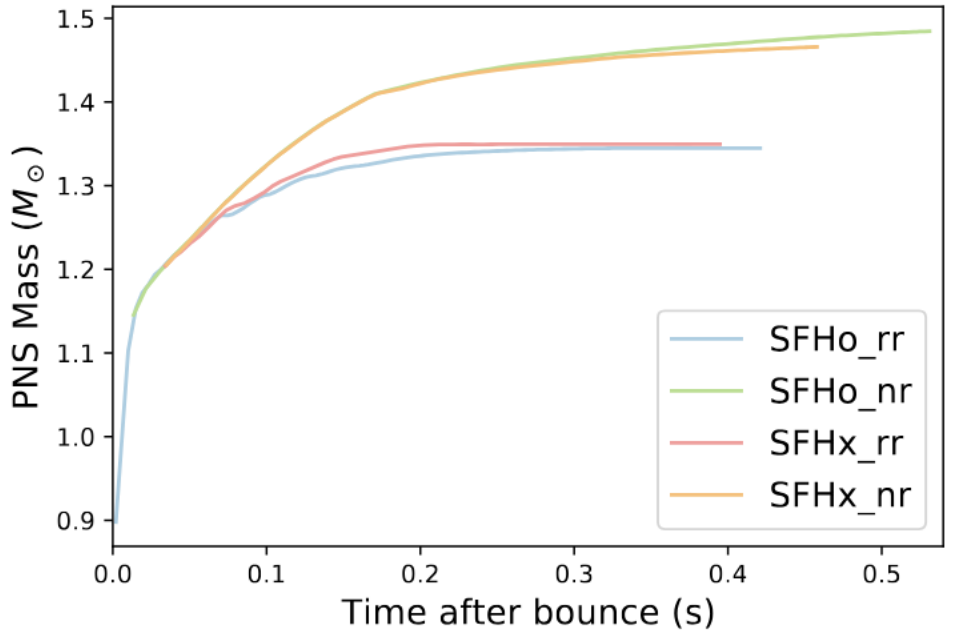


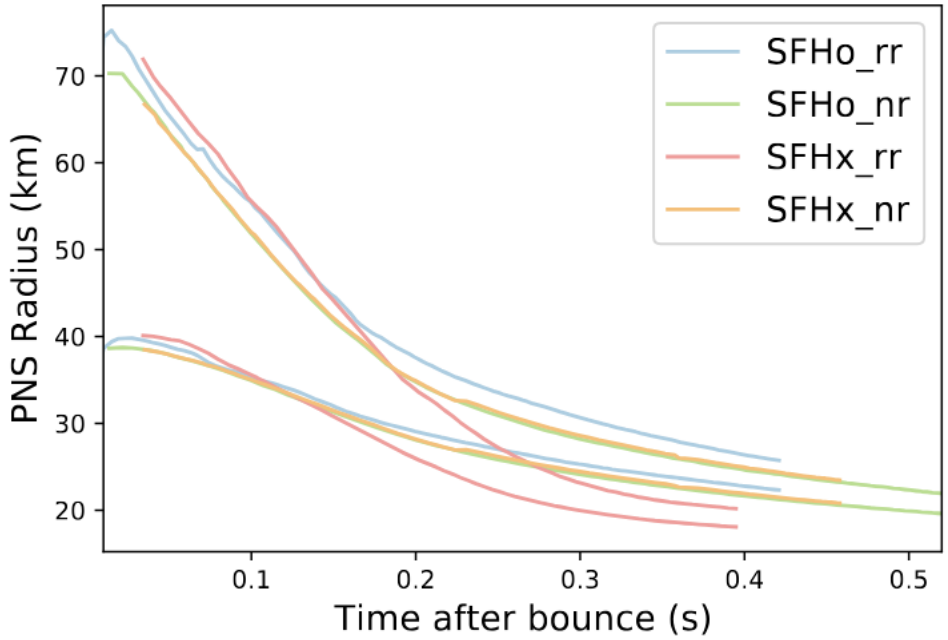
m39_B10



s15 models

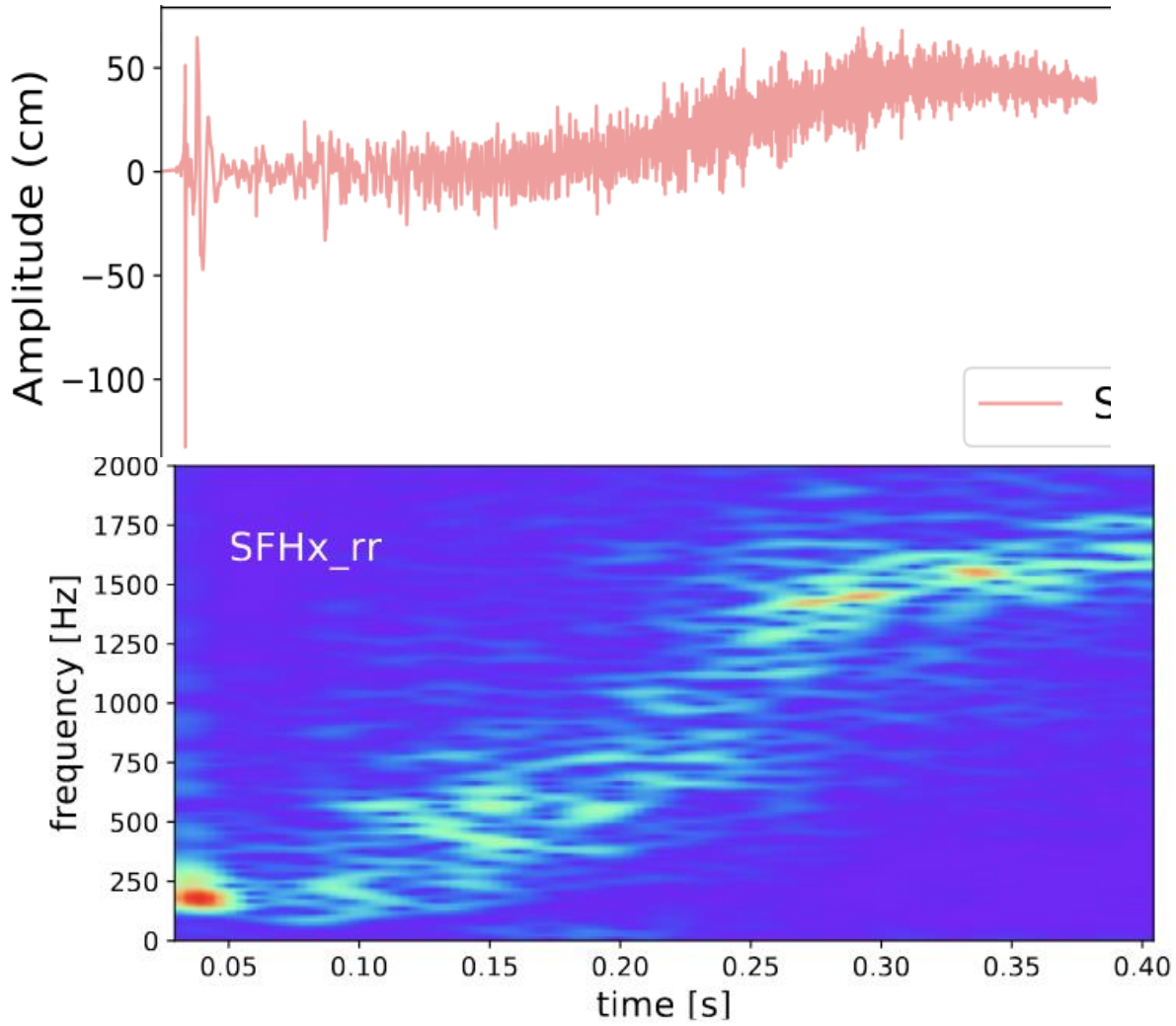
- Weak magnetic fields 10^8G.
- Two equations of state.
- Rotating and non-rotating.
- Rotating models exploded earlier with more energy.
- Powell & Müller arXiv:2406.09691



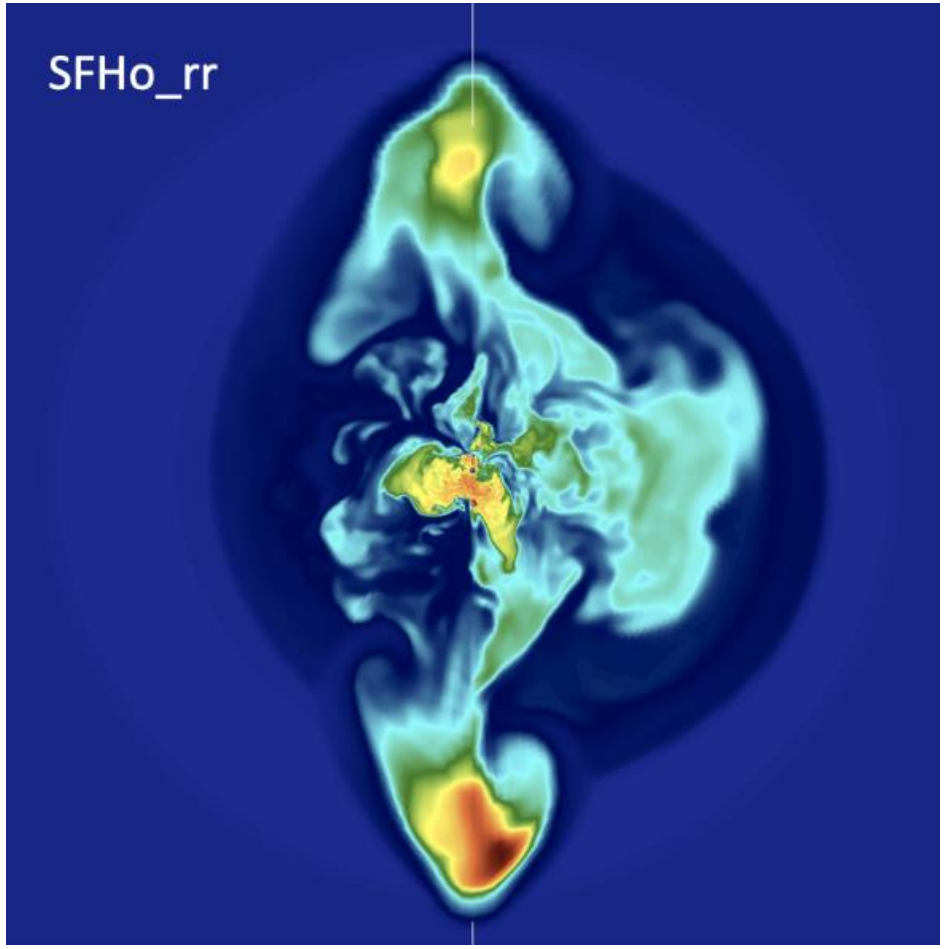


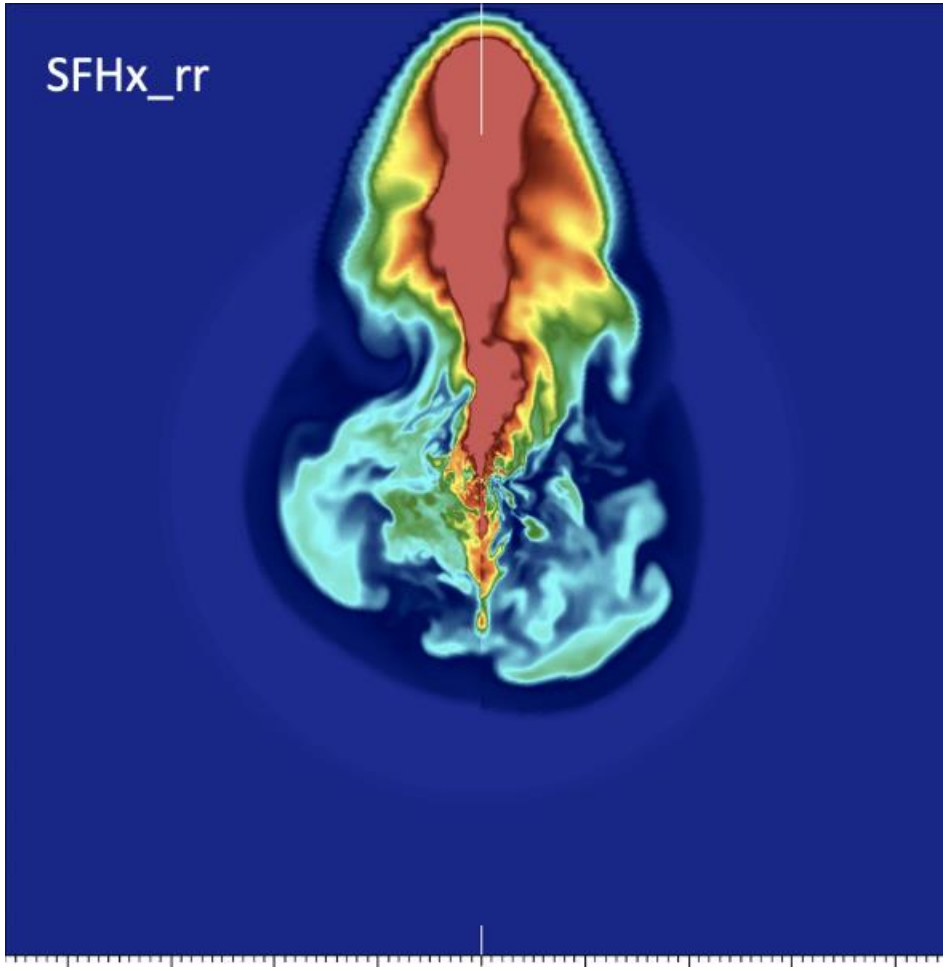
s15 models

- Weak magnetic fields do not impact the gravitational-wave emission.
- Rotation always gives you more amplitude.

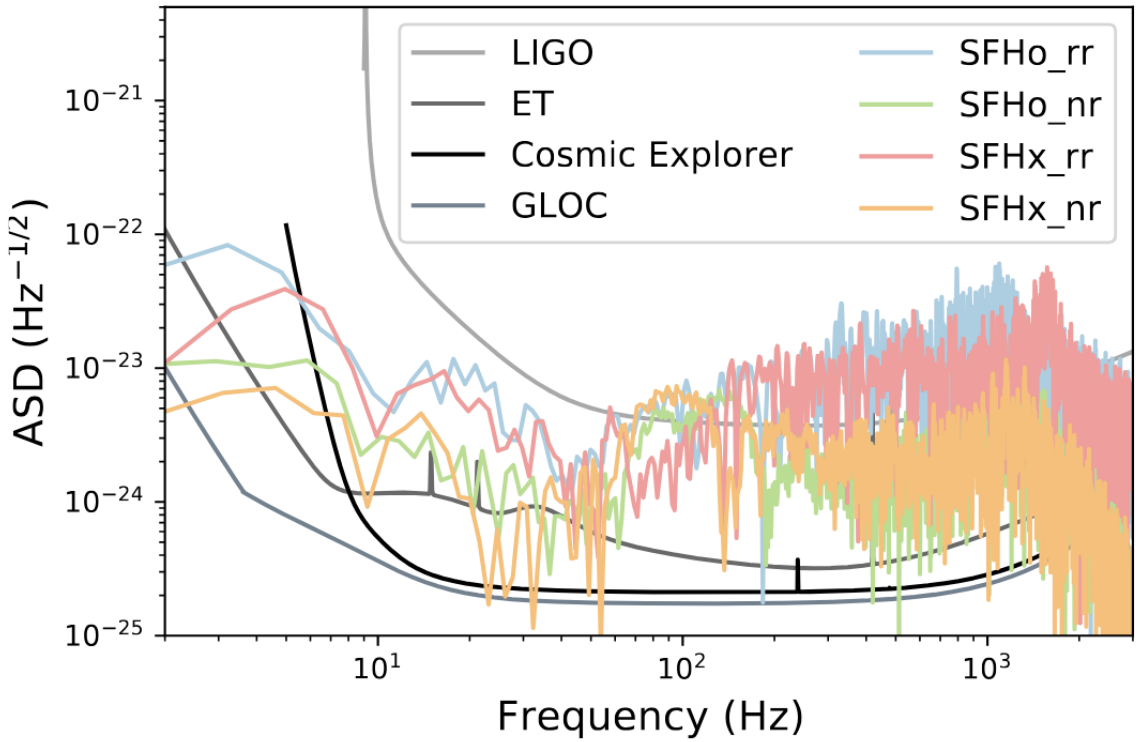


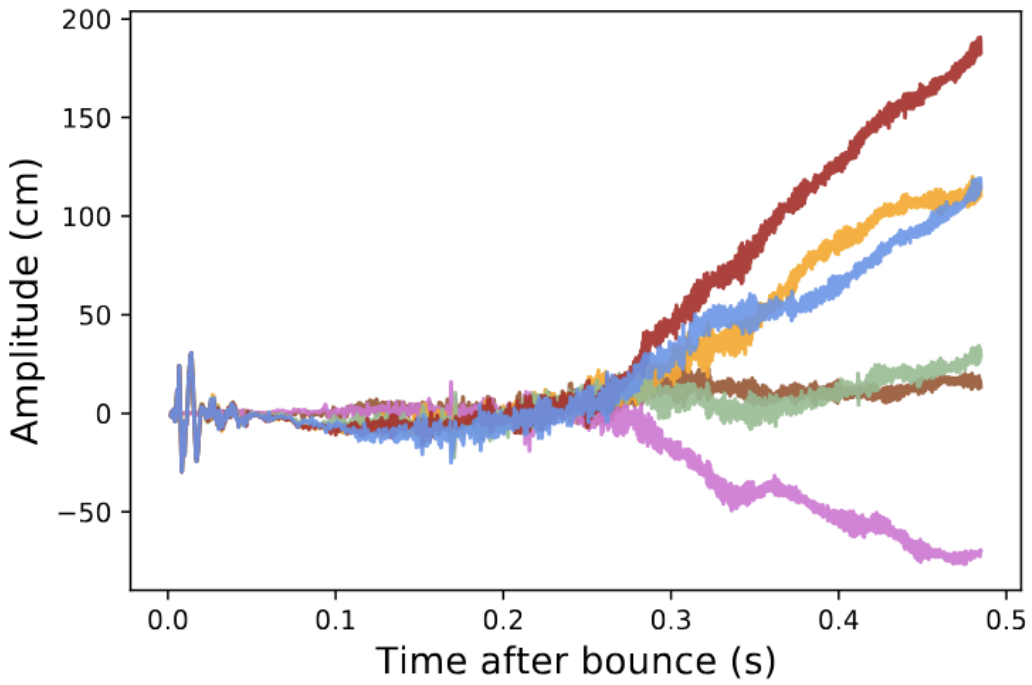
s15 models





Gravitational Wave Memory

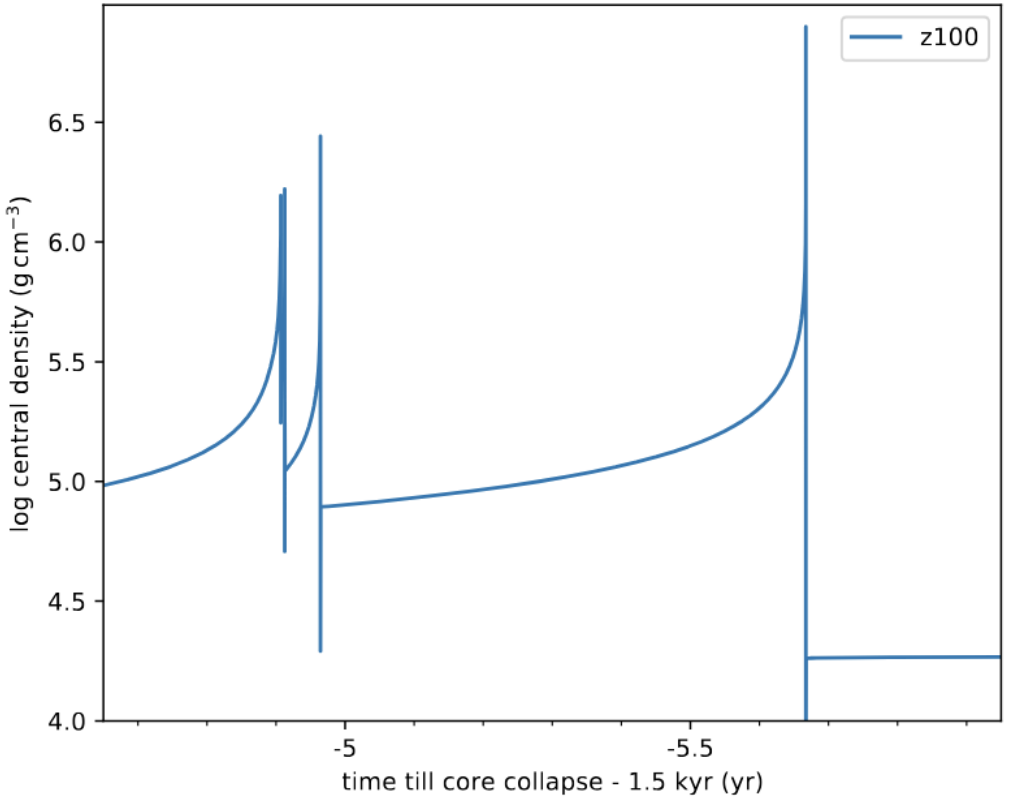




s15 SFHo, no rotation

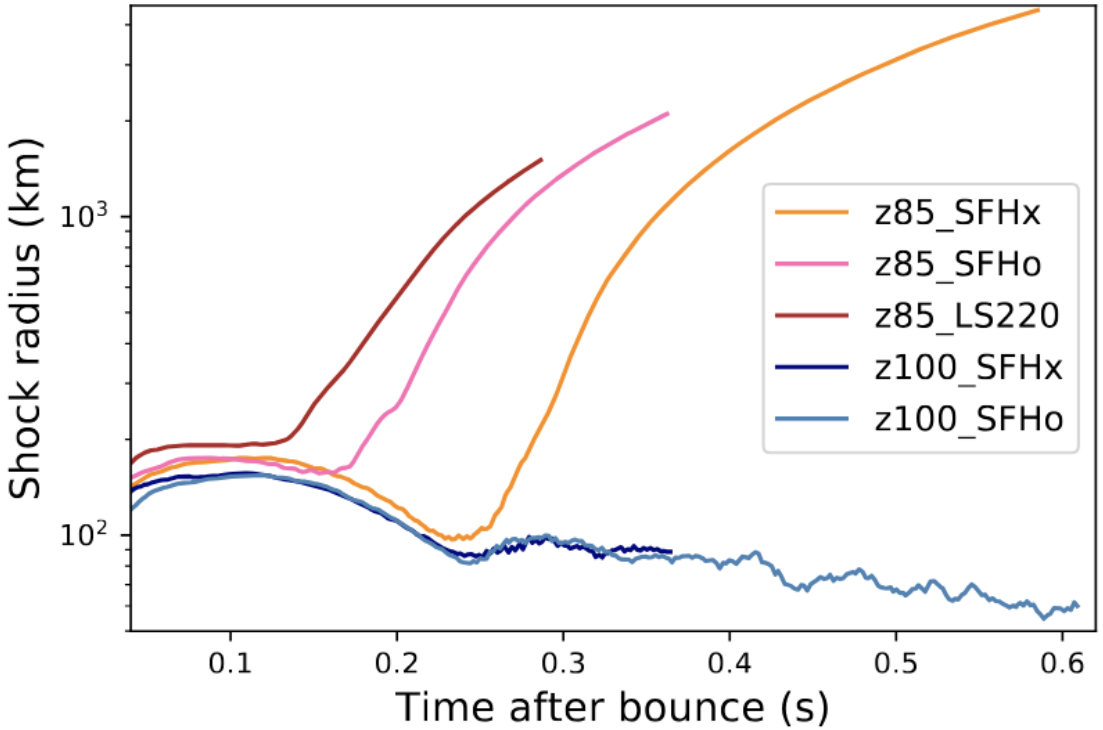
Pulsational Pair Instability Supernovae

- Two models z85, z100
- Two equations of state
- z100 undergoes 4 pair instability pulses before core-collapse.
- Powell, Müller & Heger arXiv:2101.06889



Pulsational Pair Instability Supernovae

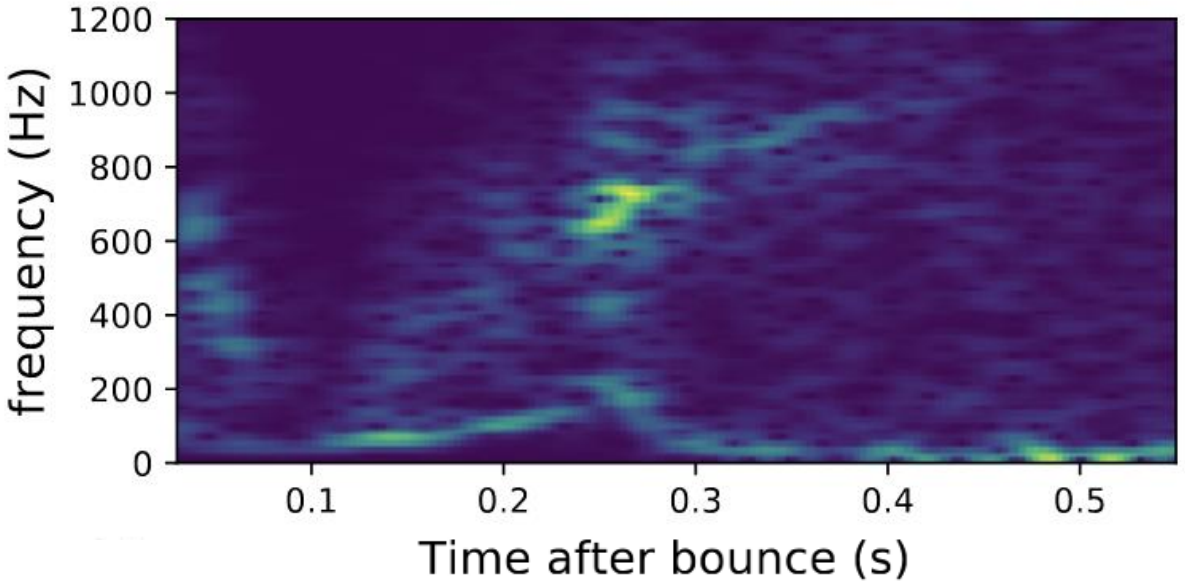
- Observe rapid shock revival before black hole formation.
- Black hole formation impacted by equation of state.
- Final black hole masses are
  - 30.7 solar masses z85_SFHx
  - 32.4 solar masses z85_SFHo
  - 33.2 solar masses z85_LS220



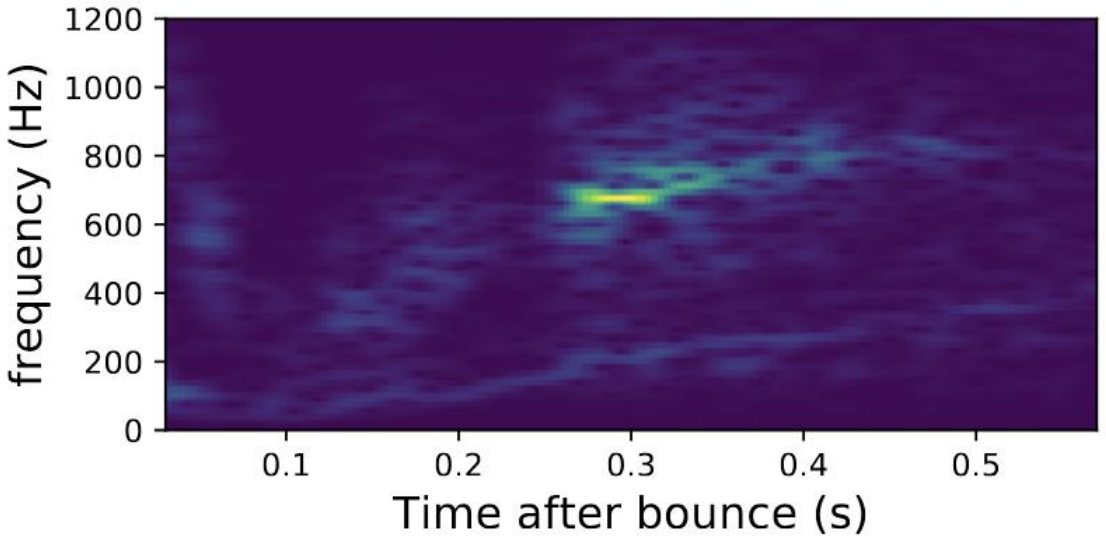
Pulsational Pair Instability Supernovae

Observed strong SASI before explosion or black hole formation.

z85

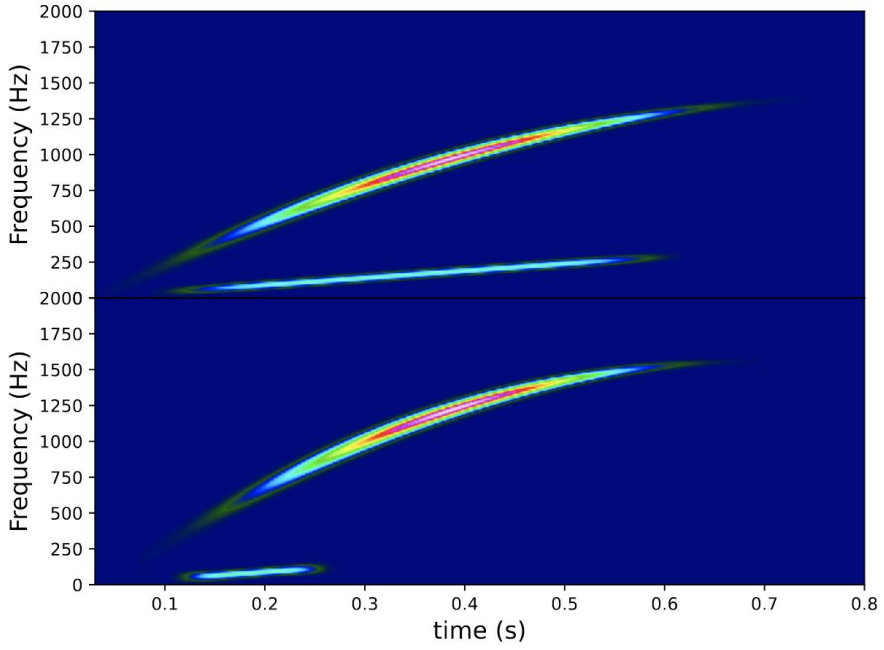


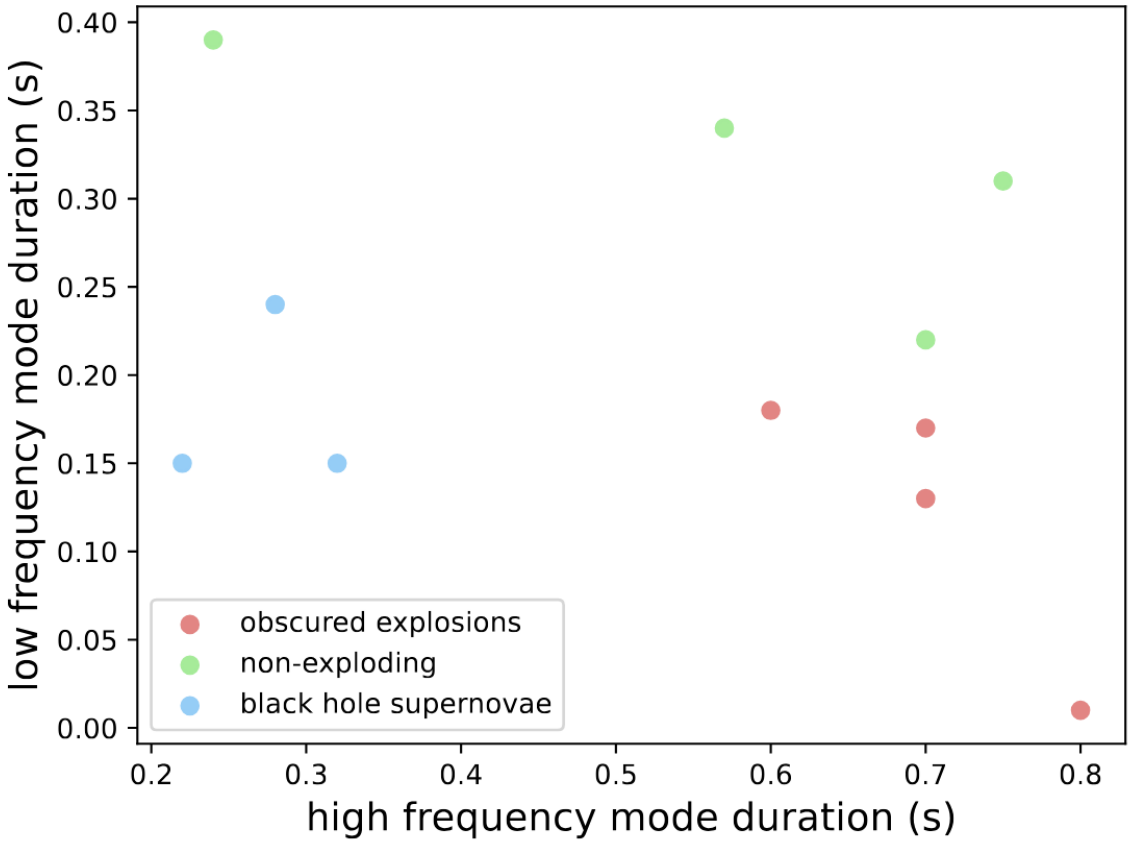
z100



EM dark Supernovae

- Paper submitted. arXiv:2506.03581
- Added a SASI mode to our parameter estimation model.



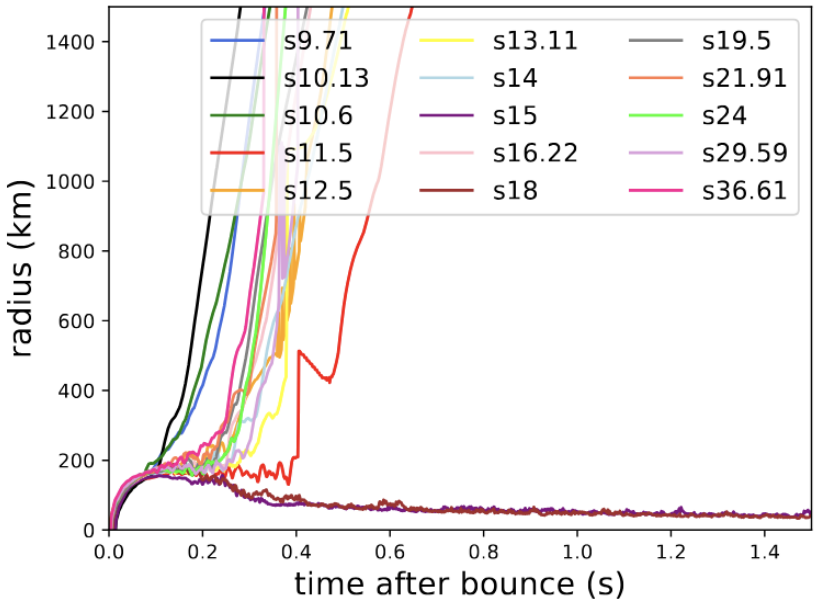


Our Work in Progress

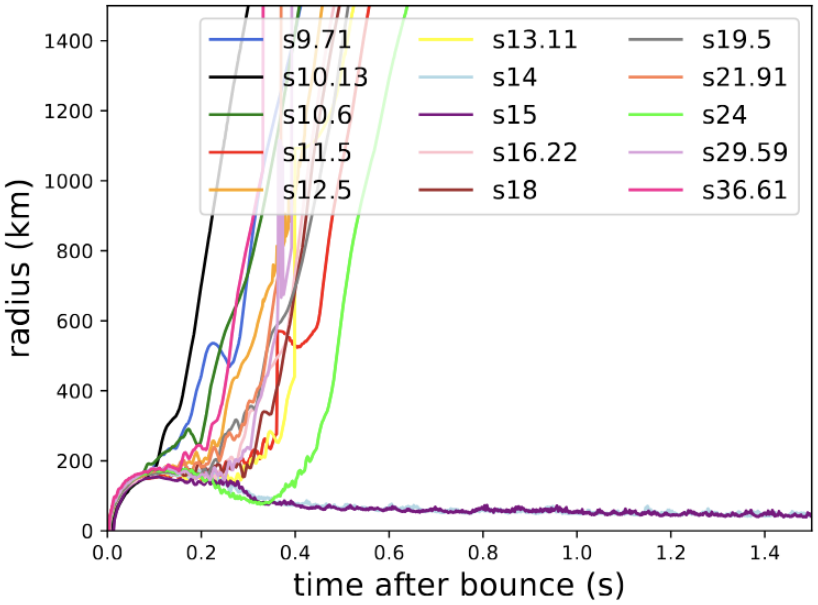
- 150 simulations in 2D with CoCoNuT
- Three different equations of state
- Three different rotation rates
- Progenitor star masses from 9.71 to 36.61 solar masses

Equation of State

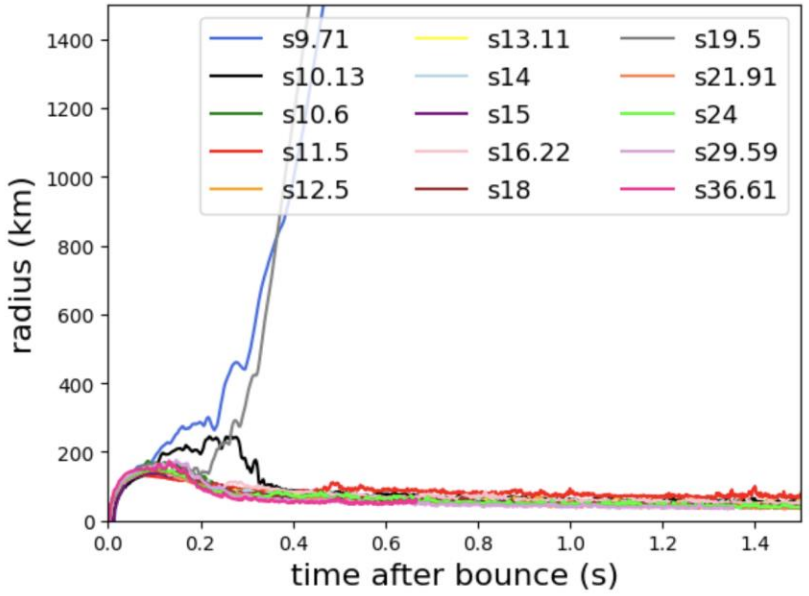
No Rotation



SFHo: s15 and s18 models do not explode.

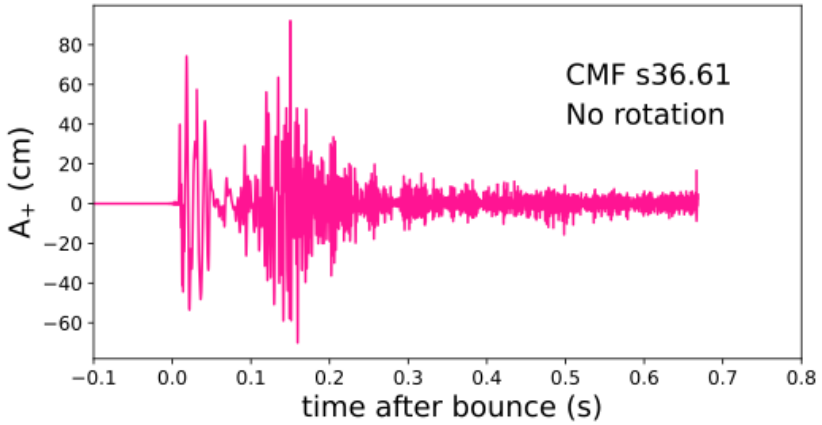


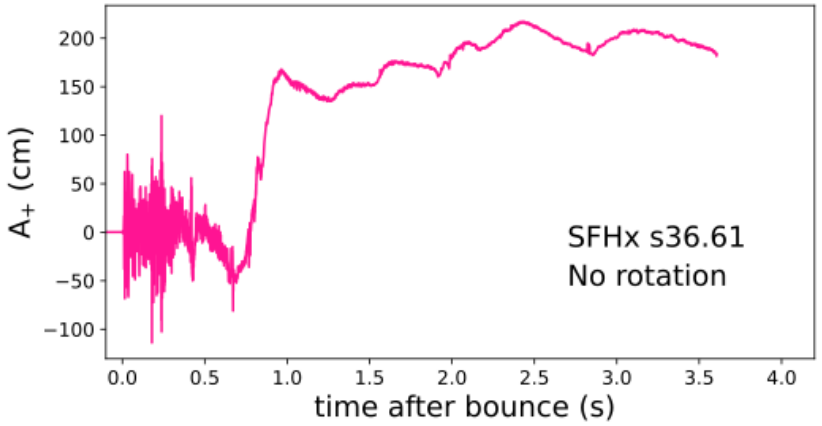
SFHx: s14 and s15 models do not explode.

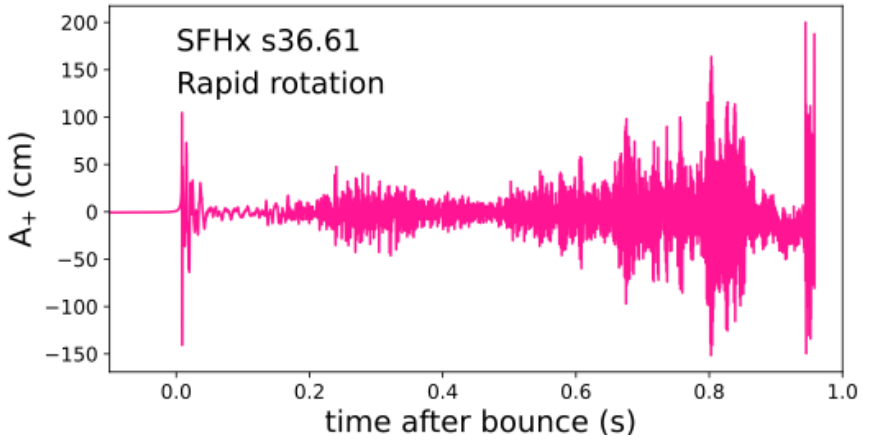


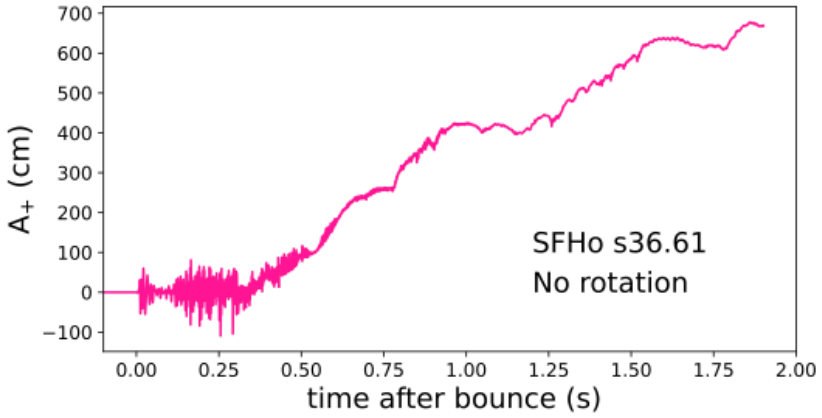
CMF: only s9.71 and s19.5 models explode.

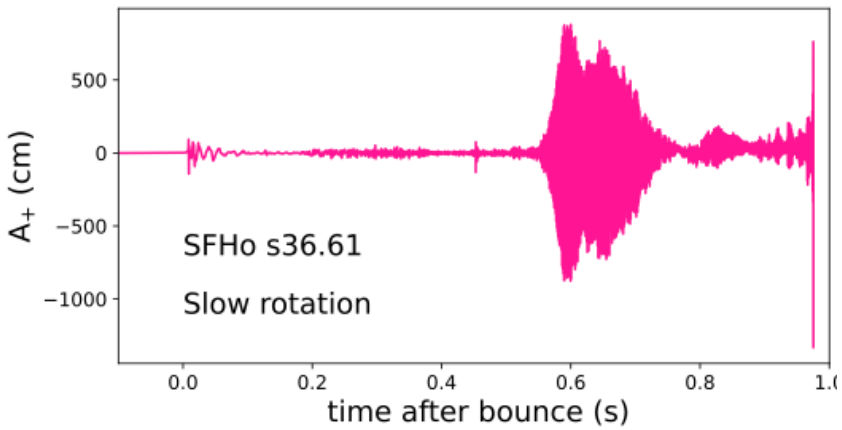
Gravitational Waves

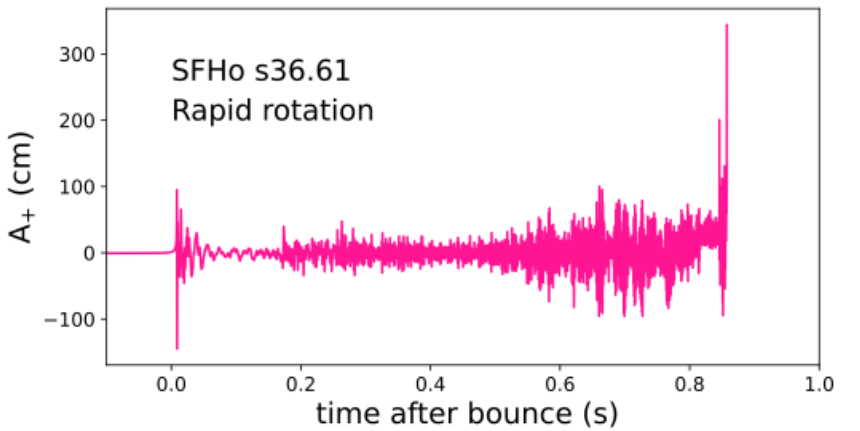












The ones you don’t normally get to see