Structure of Binary Neutron Star Merger Remnants

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Binary Merger Observations & Numerical Relativity

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Overview

- Fluid flow & post-merger GW
- Remnant rotation profile & lifetime
- Relevance of initial NS spin

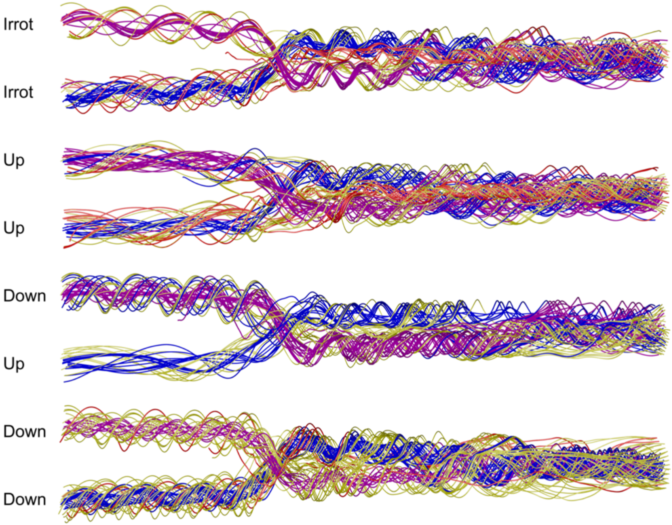
W. Kastaun, R. Ciolfi, B.Giacomazzo, Structure of stable binary neutron star merger remnants: A case study, **Phys. Rev. D 94, 044060 (2016)**

W. Kastaun, R. Ciolfi, A. Endrizzi, B. Giacomazzo, Structure of Stable Binary Neutron Star Merger Remnants: Role of Initial Spin, **arXiv:1612.03671 (2016)**

R. Ciolfi, W. Kastaun, B. Giacomazzo, A. Endrizzi, D.M. Siegel, R. Perna General relativistic magnetohydrodynamic simulations of binary neutron star mergers forming a long-lived neutron star, **Phys. Rev. D 95, 063016 (2017)**

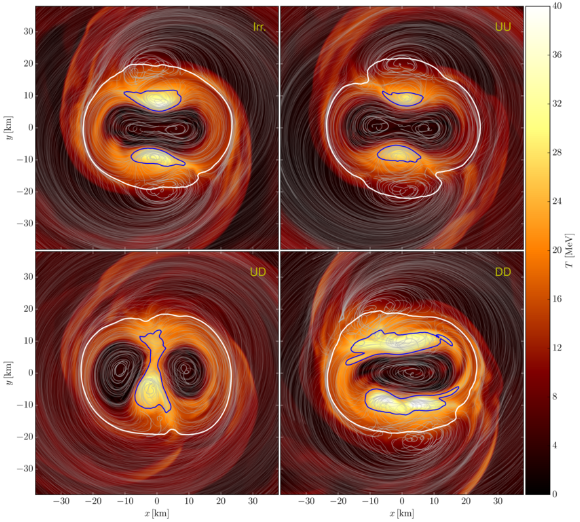
Fluid Flow

- Complex fluid flow after merger with several vortices



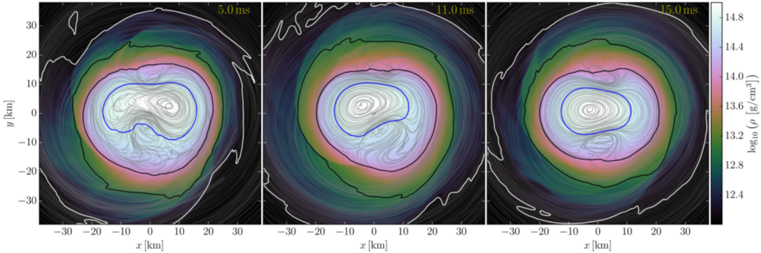
Fluid Flow

- Density perturbation, hot spots, and vortices strongly related



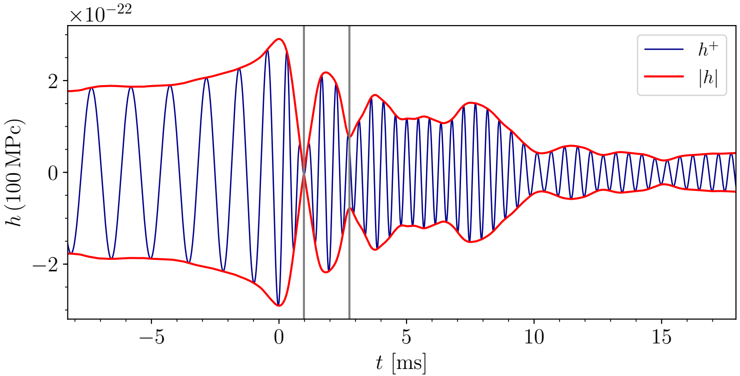
Fluid Flow

- Density perturbation, hot spots, and vortices strongly related
- Perturbation seems tied to vortex evolution
- Deformation by secondary vortices phase-shifted
- Partial cancellation of quadrupole moment contributions?



Post-Merger GW

- Typical: very short minimum at merger
- Irregular-looking amplitude variations



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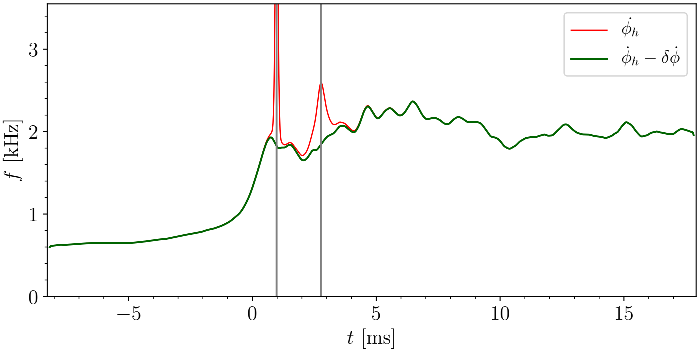

Post-Merger GW

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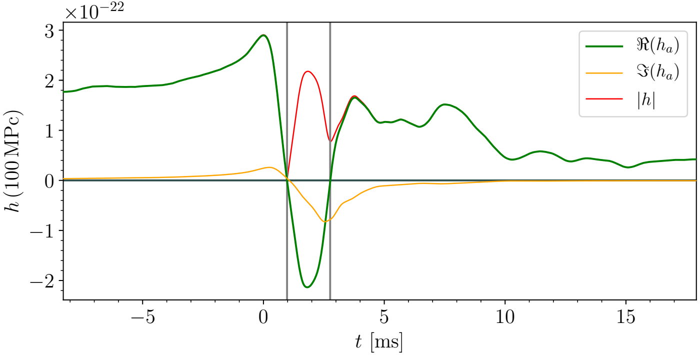
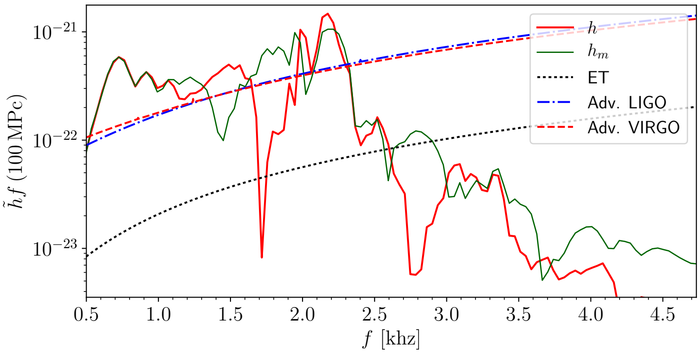
- Explained as near-zero crossings of quadrupole moment



Post-Merger GW

- Typical: very short minimum at merger
- Irregular-looking amplitude variations
- One or more phase jumps
- Explained as near-zero crossings of quadrupole moment
- Phase jump causes cancellation effects in Fourier spectrum



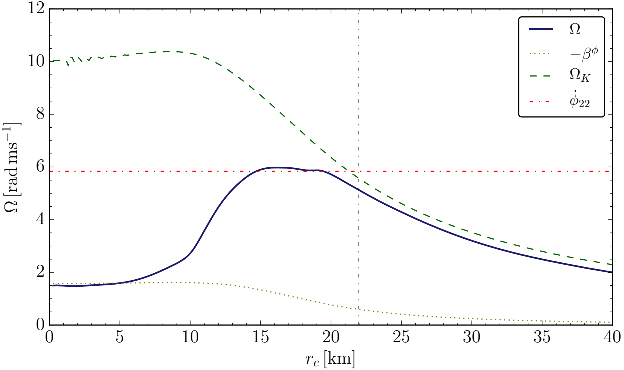
Rotation Profile

Common notion:

- Hypermassive remnants
  - Core rotates more rapid than outer layers
  - Collapse when differential rotation of core is reduced
- Supramassive remnants
  - Uniformly and rapidly rotating core
  - Collapse when angular momentum of core is reduced
- Lifetime related to angular momentum evolution of core

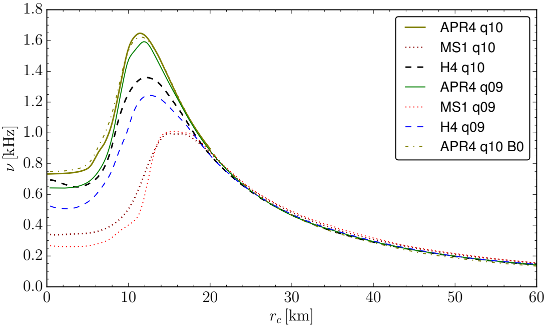
Rotation Profile

- Numerical simulations yield different picture
- Slowly rotating core
- Instead, **outer** layers approach Kepler orbital velocity



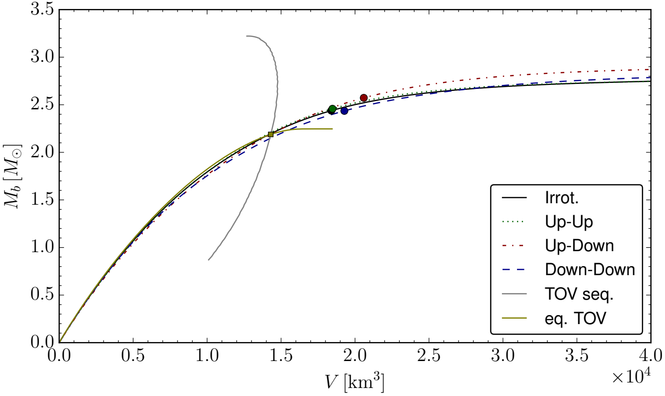
Rotation Profile

- Numerical simulations yield different picture
- Slowly rotating core
- Instead, **outer** layers approach Kepler orbital velocity
- Found for hypermassive, supramassive, stable mass range
- For different EOS, mass ratios, initial spins (aligned)



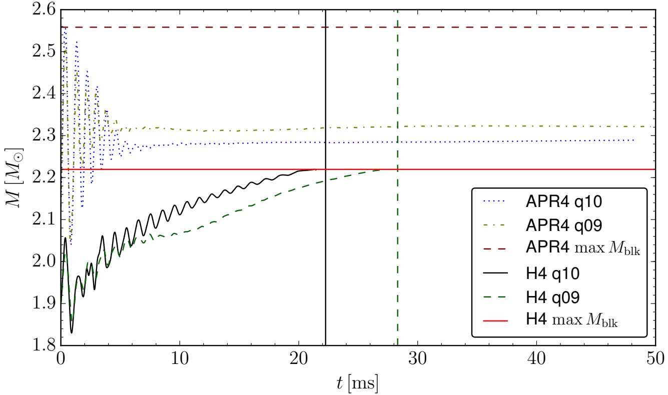
Remnant Lifetime

- Slow rotation $\to$ expect almost spherical core
- Radial profiles of remnant cores indeed similar to TOV cores $\Rightarrow$ “TOV core equivalent”



Remnant Lifetime

- Found core equivalents up to maximum TOV mass
- Core mass increases over time
- Found collapse when core equivalent reached maximum mass



Remnant Lifetime

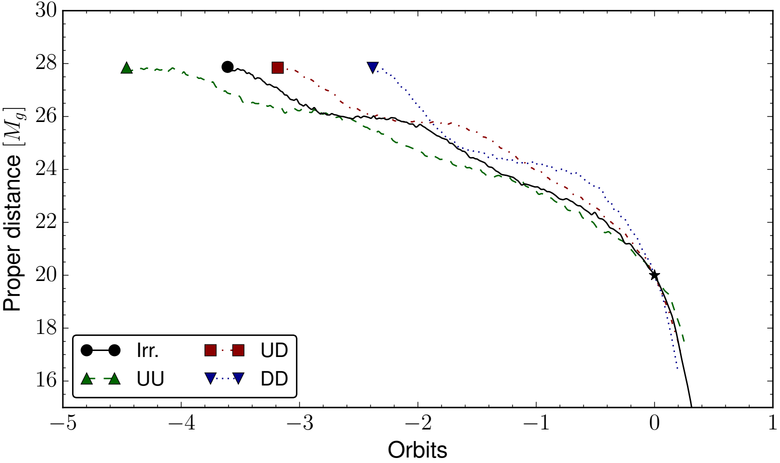
New picture emerges:

- Remnants cores similar TOV cores
- Surrounded by centrifugally supported equatorial bulge
- Angular momentum loss of core irrelevant
- Stability only depends on **core mass**
- Core mass changes if **outer** layers loose angular momentum
- Lifetime depends on evolution of the **outer** layers

$\Rightarrow$ More study needed

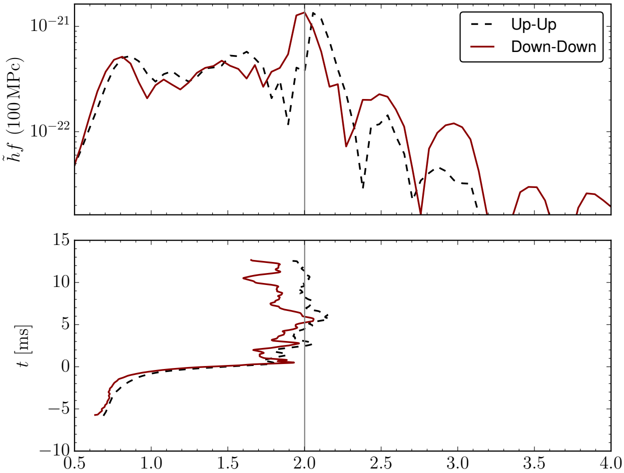
Influence of Spin

- Spin causes orbital hangup during inspiral
- Ballpark figure: $F_{\mathrm{rot}} \pm 160\mathrm{Hz} \Rightarrow \pm 1$ orbit on last 4 orbits.



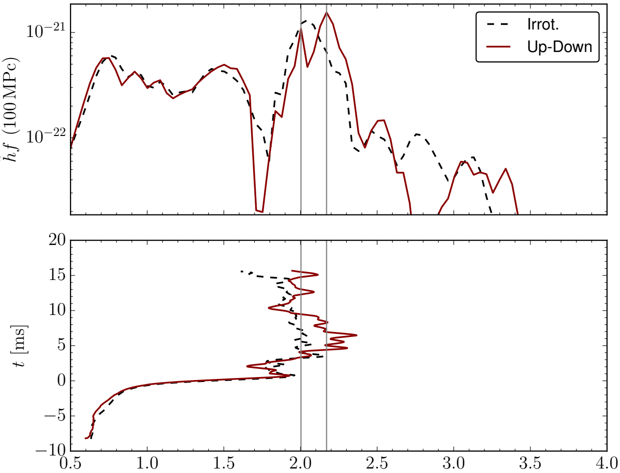
Influence of Spin

- Small changes in post-merger GW spectrum



Influence of Spin

- Small changes in post-merger GW spectrum
- Splitting of peak for spin alignment ↑↓



Thanks!