

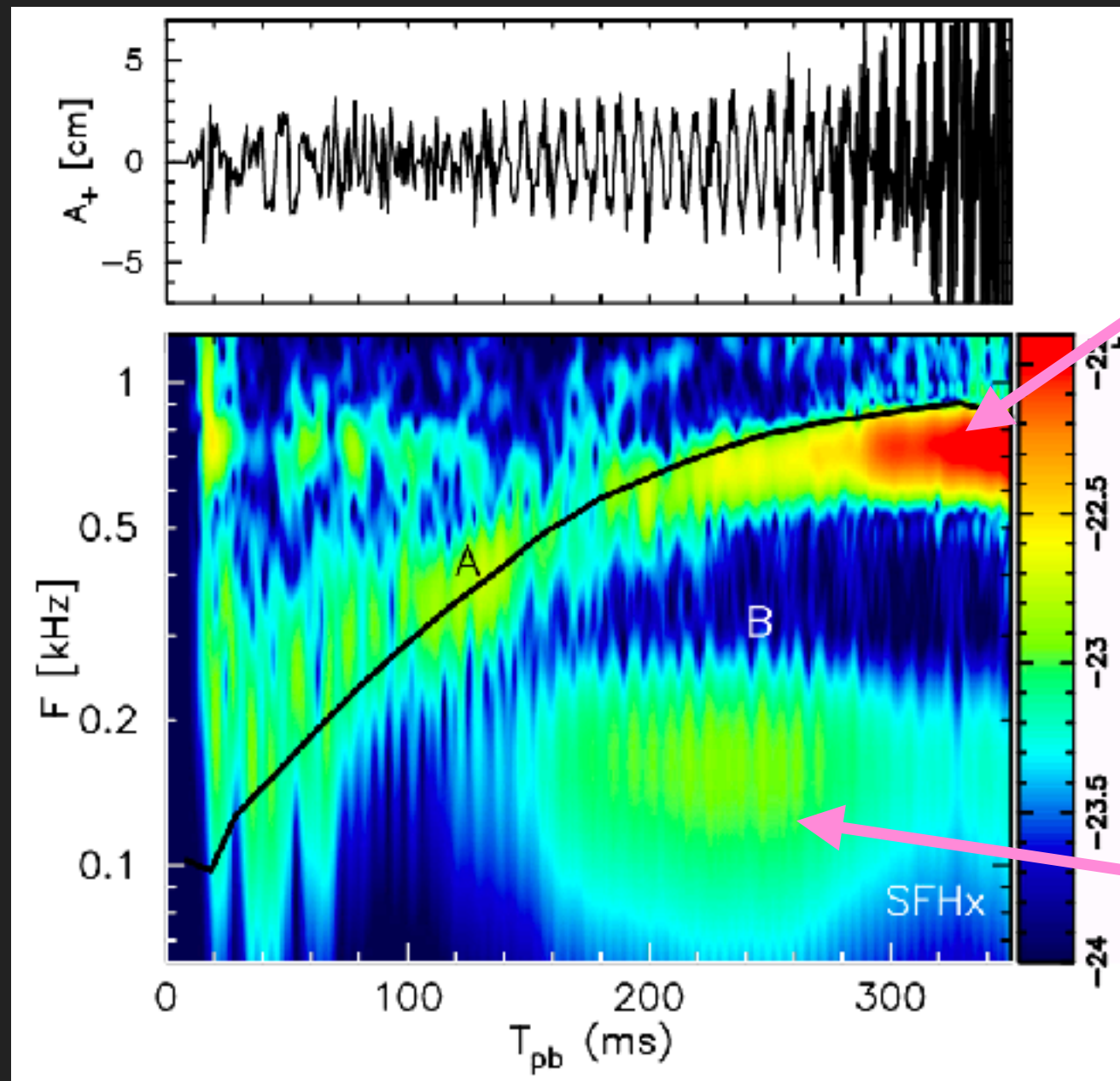
SARAH GOSSAN (CALTECH)

GRAVITATIONAL WAVES FROM CORE-COLLAPSE SUPERNOVAE

GWS FROM CORE-COLLAPSE SUPERNOVAE

- ▶ Strongly dependent on the total angular momentum and its distribution throughout the progenitor core
- ▶ Slowly rotating; turbulent convection and standing accretion-shock instability
- ▶ Rapidly rotating; proto-NS bounce/ringdown, low $T/|W|$ instabilities
- ▶ Excess-power search typically used; messy and complicated signal, no templates

THE 99%: SLOWLY ROTATING PROGENITOR CORES



Buoyancy modes (g-modes) of proto-neutron star (PNS) surface

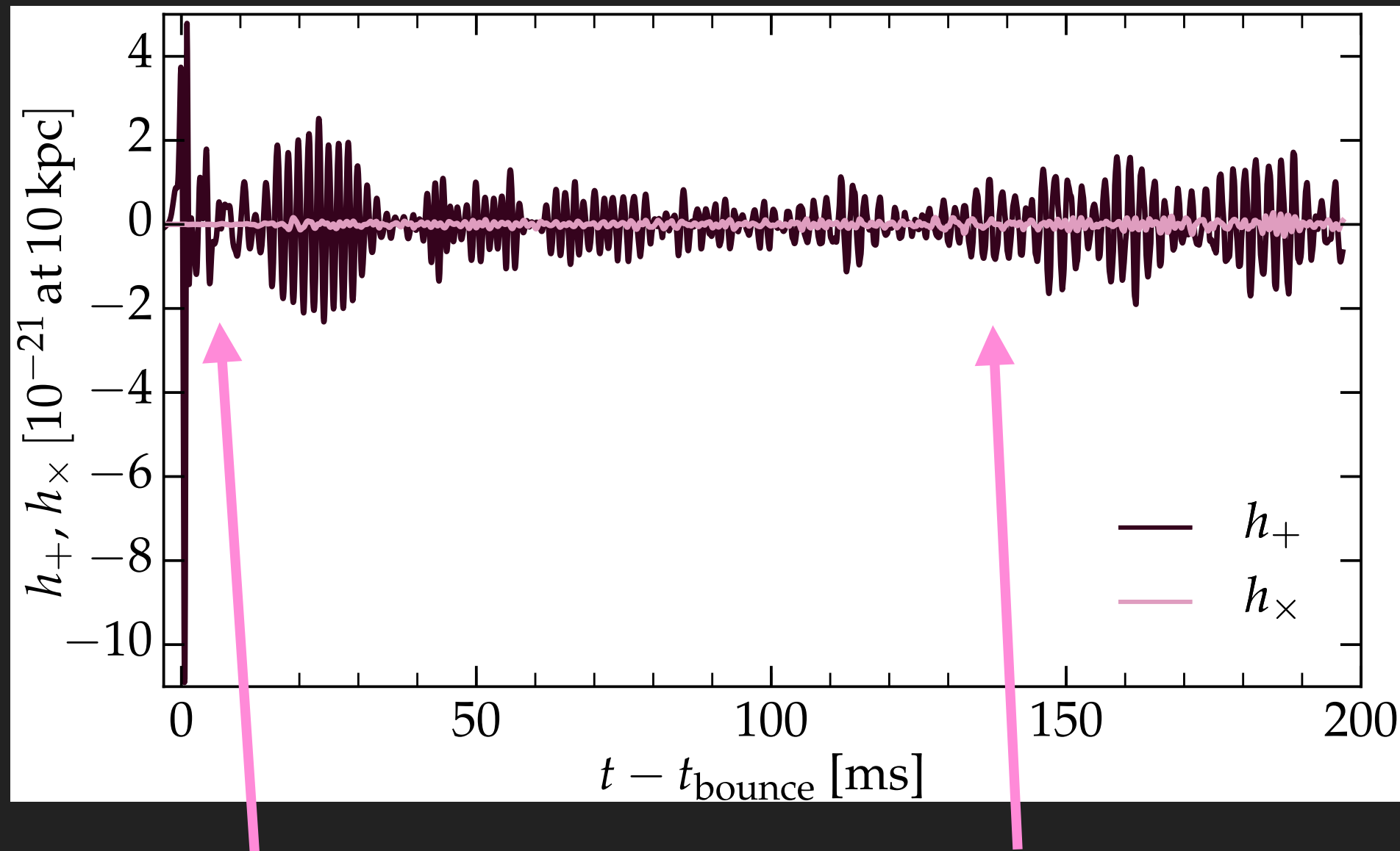
PNS accretion modified by SASI downflows

Kuroda *et al.* (2016)

THE 99%: SLOWLY ROTATING PROGENITOR CORES

- ▶ Use time-frequency evolution to preferentially search along astrophysically motivated t-f tracks [improve detectability, waveform reconstruction]
- ▶ Time-frequency evolution dependent on PNS properties, evolution of the explosion:
 - ▶ Use theory to develop phenomenological models linking observables to progenitor properties
 - ▶ Use simulation data to tune and improve models

THE 1%: RAPIDLY ROTATING PROGENITOR CORES



Bounce/ringdown of PNS

low $T/|W|$ triaxial
instabilities

THE 1%: RAPIDLY ROTATING PROGENITOR CORES

- ▶ PNS ringdown frequencies dependent on PNS mass, rotation rate of precollapse core, nuclear matter EOS
- ▶ Observed ringdown spectra can uniquely probe precollapse angular momentum distribution
- ▶ Low $T/|W|$ instabilities indicative of rapid precollapse rotation

HOW CAN THE SN SIMULATION COMMUNITY HELP?

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Share data!

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Gravitational Wave Signal Catalog

Observed AS Masses

Observed BH Masses

Simulations/Results

Gravitational Wave Signal Catalog

Codes

Other Resources

People

Contact and Acknowledgements

Home

Here we provide theoretical gravitational-wave signal predictions from a variety of core-collapse supernova and neutron star merger simulations carried out in recent years. This is a service to the community and in an effort to further and nurture collaboration between theorists, modelers, and the gravitational-wave data analysis community. All waveforms are freely available for download and we strongly request that, in the case of a publication involving these GW signal data, stellarcollapse.org be acknowledged and the original paper in which the waveforms were first published be cited.

If you have GW signal predictions you would like to make available on our link to Form at stellarcollapse.org, please email us at admin@stellarcollapse.org.

For a review of gravitational-wave emission in core-collapse supernovae, see the Classical & Quantum Gravity Tutorial Review: C.D. Ott, [CQG 36, 102801 \(2019\)](https://arxiv.org/abs/2010.02801) [[link](#)].

GW signal data from the following studies are available on stellarcollapse.org. Please feel free to contact Christian D. Ott for any technical questions or comments you might have.

- [Peters, Ott, Abdikamalov, O'Connor, and Spera \(2017\)](#), submitted to Phys. Rev. D, [[arXiv](#)].
Equation of State Effects on Gravitational Waves from Rapidly Rotating Core Collapse.
- [Peters, Peters, and Ott \(2016\)](#), Phys. Rev. D, 94, 064011 [[link](#)].
The One-Arm Signal Instability in Neutron Star Mergers and Its Detectability in Gravitational Waves.
- [Gerosa, Sperhake, and Ott \(2012\)](#), Class. Quantum Grav. 29, 125002 [[link](#)].
Numerical Simulations of Stellar Collapse in Scalar-Tensor Theories of Gravity.
- [Abdikamalov, Gossan, Cenko, Ott \(2014\)](#), Phys. Rev. D, 90, 044001 [[link](#)].
Modeling the Angular Moments in 3D Simulations of Core-Collapse Supernovae: Implications with Gravitational Waves.
- [Ott, Abdikamalov, Mosser, Hotokez, O'Connor, Hotokez, Morsink, Schmitz \(2013\)](#), [ApJ](#) 768, 115 [[link](#)].
General-Relativistic Simulations of Three-Dimensional Core-Collapse Supernovae.
- [Ott, Abdikamalov, O'Connor, Ruffing, Hotokez, Mosser, O'Connor, Schneider \(2012\)](#), Phys. Rev. D, 85, 124005 (2012) [[link](#)].
Correlated Gravitational-Wave and Neutrino Signals from General-Relativistic Rapidly-Rotating Core Collapse.
- [Ott, Ruffing, Schneider, O'Connor, Sperhake, Usher, Abdikamalov, Hotokez, and Burrows \(2011\)](#), Phys. Rev. Lett. 106, 101102 [[link](#)].
Dynamics and Gravitational-Wave Signatures of Core-Collapse Formation.
- [Abdikamalov, Ott, Ruffing, Hotokez, Mosser, O'Connor, Mosser, and Janka \(2012\)](#), Phys. Rev. D, 85, 044001 (2012) [[link](#)].
Asymptotic General-Relativistic Simulations of the Accretion-Induced Collapse of White Dwarfs.
- [Hotokez, Ott, and Mosser, \[ApJ\]\(#\) 755, 1174 \(2012\) \[\[link\]\(#\)\].](#)
A Model for Gravitational-Wave Emission in Rapidly Rotating Core-Collapse Supernovae.
- [Cao, CQG 26, 023001 \(2009\) \[\[link\]\(#\)\].](#)
GW signals from asymmetric (2D) convective overturn and the standing-accretion-shock instability (SASI).
- [Cao, CQG 26, 023001 \(2009\) \[\[link\]\(#\)\]](#) and [Ott et al., PRL 96, 231102 \(2006\) \[\[link\]\(#\)\]](#) and [Ott, PhD Thesis, University of Frankfurt \(2007\) \[\[link\]\(#\)\]](#).
GW signals from asymmetric (2D) accretion-induced star-core pulsations associated with the accretion mechanism for core-collapse supernovae ([Burrows et al. 2006, 2017](#)).
- [Ott et al., \[ApJ\]\(#\) 680, 1468 \(2008\) \[\[link\]\(#\)\]](#).
GW signals from asymmetric rotating stellar core collapse.

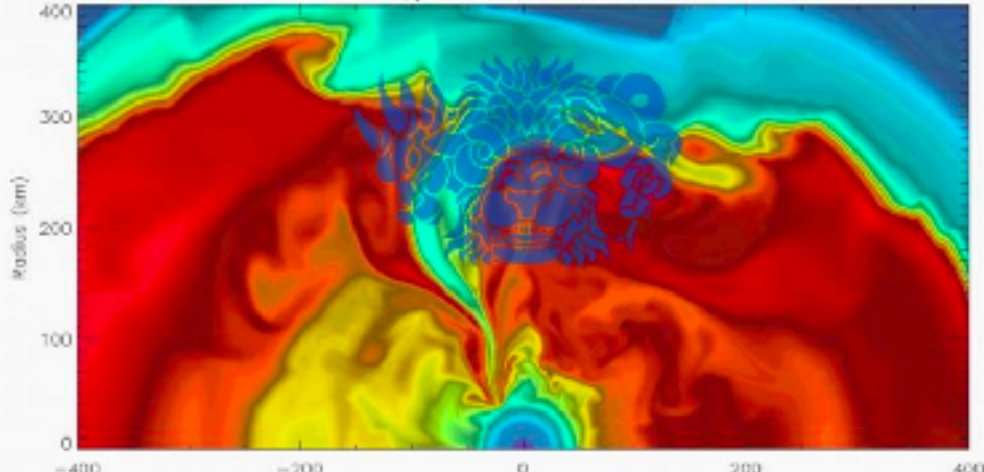
The GW signals from the following core-collapse and binary merger studies are available at Tidal:

- [Giacomazzo and Perna \(2013\)](#), [ApJ](#) 771, L26 [[link](#)].
Formation of Stable Magnetars from Binary Neutron Star Mergers.
- [Giacomazzo et al., \[MNRAS\]\(#\) 420, 2062 \(2012\) \[\[link\]\(#\)\]](#).

Welcome to ChimeraSN.org

Table of Contents

- Welcome to ChimeraSN.org
- Current Interest
- Other links



ChimeraSN.org is the online home of the [Chimera collaboration](#), the Chimera [code](#), and our results.

Our group is dedicated to the study of core-collapse supernova explosions. CHIMERA is our multi-dimensional numerical [code](#), capable of tracking the evolution of these systems from the pre-collapse stellar stage to up to a second of evolution time after the core bounce.

Current Interest

New 3D [C Series](#) results.

Updated 2D [B Series](#) results.

[Gravitational wave](#) signals from A and B Series simulations.

Other links

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► Share data!

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- [Other stuff](#)

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HOW CAN THE SN SIMULATION COMMUNITY HELP?

- ▶ Share data!
- ▶ Include waveform families in Advanced LIGO-Virgo searches
- ▶ Encourage collaboration between data analysts and simulation groups
- ▶ Improve interpretation of observations and search methods

IMPROVING INTERPRETATION OF OBSERVATIONS

- ▶ GWs from core collapse: all about the PNS
- ▶ Turbulent convection/SASI -> fluid downflows strike PNS -> excite g-modes of PNS -> GWs
- ▶ Early time SASI -> modifies PNS accretion rate -> GWs
- ▶ Bounce/ringdown of PNS -> GWs
- ▶ Low $T/|W|$ instability -> triaxial deformation of PNS -> GWs

IMPROVING INTERPRETATION OF OBSERVATIONS

▶ GWs

▶ Turbulence
excitation

▶ Early

▶ Bourne

▶ Low

More 3D GR

PNS →

sims resolving

√s

the PNS pls!

· GWs

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