

Gravitational Signals from Supernova

What can we reconstruct?

Konstantin Yakunin

Anthony Mezzacappa

Department of Physics and Astronomy

University of Tennessee

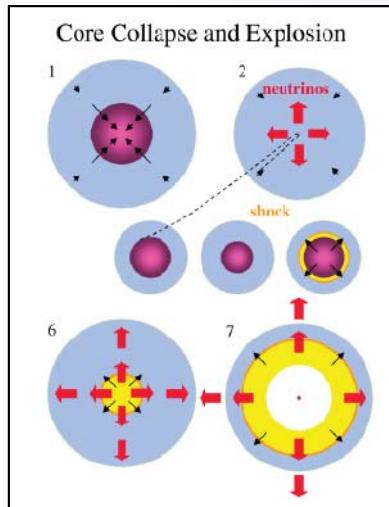
Joint Institute for Computational Sciences

Oak Ridge National Laboratory

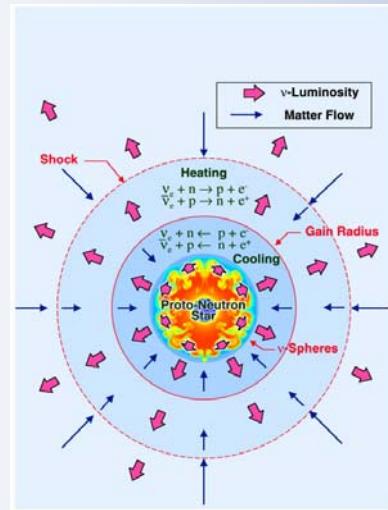
Connection between simulations and signal search

- **Simulations:** signal characteristics (f , A , etc); physical mechanism producing GW signals, bank of waveforms
- **Signal Search:** search algorithms based on the most reliable parts of waveforms, proposal of detector design to observe physical properties of supernovae via GW signals

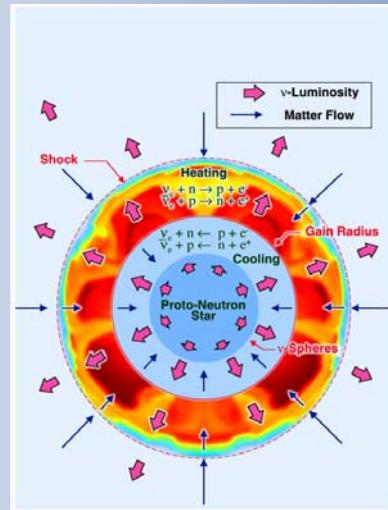
Sources of Gravitational Waves



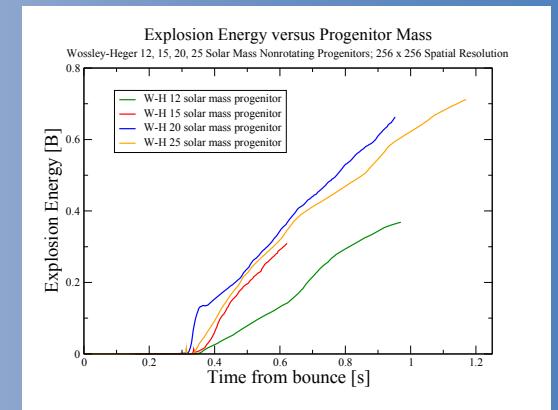
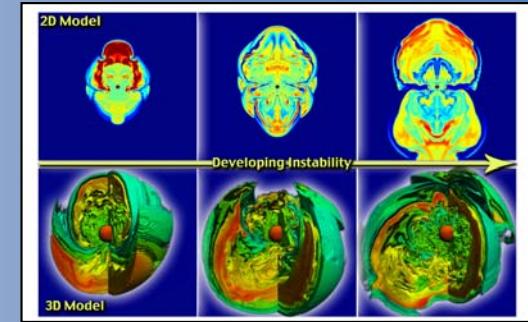
Core Bounce



PNS Instabilities



Neutrino-Driven
Convection



Explosion

Two main types of signals

Non-rotating progenitors

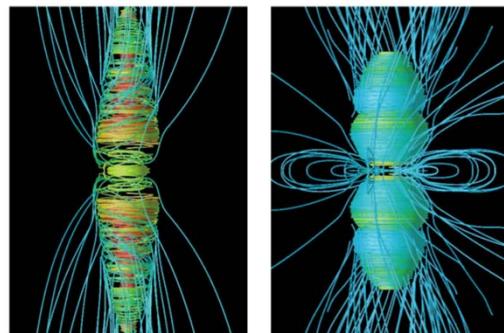


Long signal (> 1 sec), low, moderate amplitude



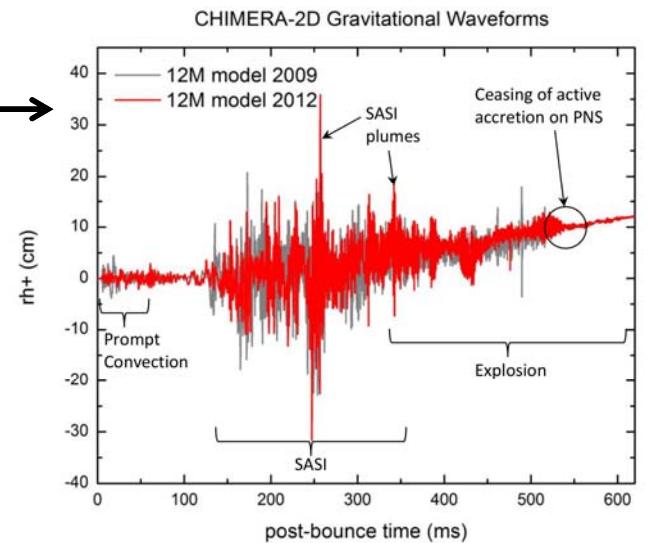
Bruenn et al. 2016, *Ap.J.* **818**, 123

Rotating progenitors

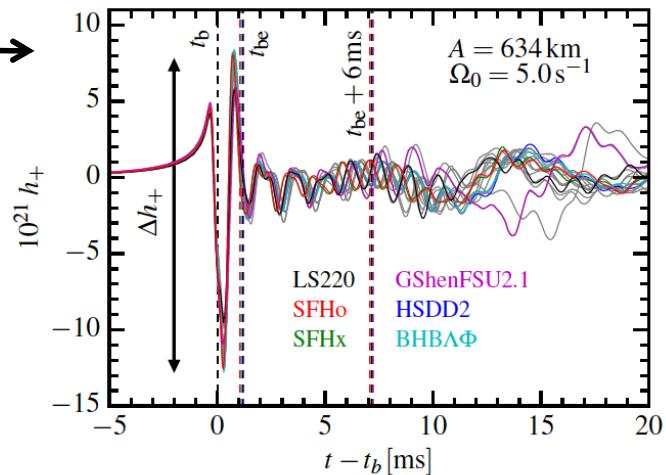


Burrows et al. 2007, *Ap.J.* **664**, 416

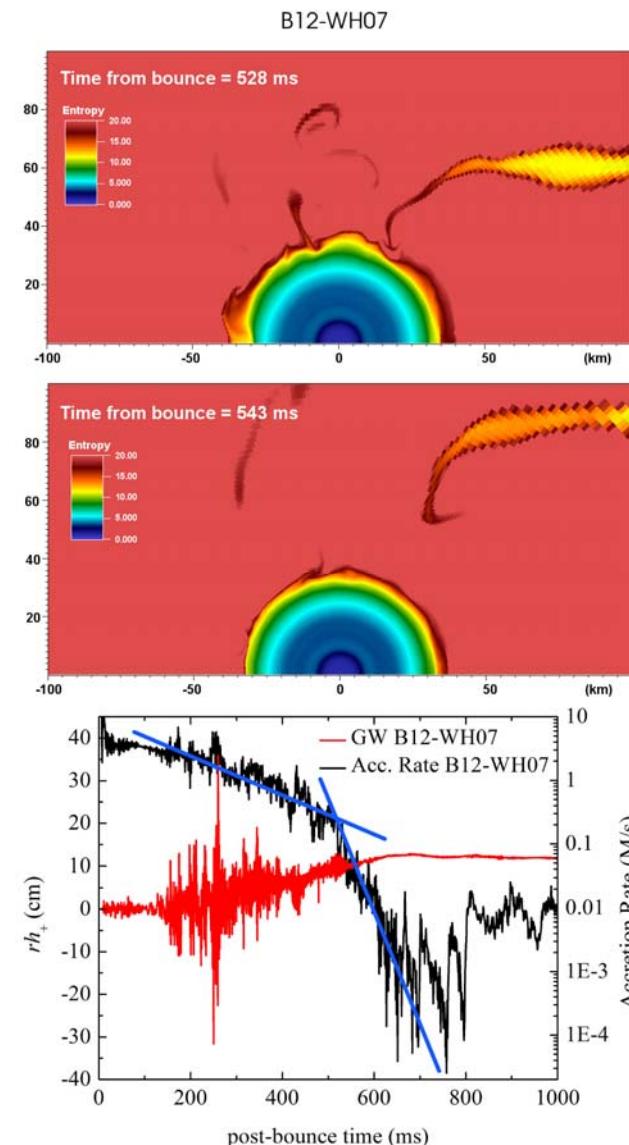
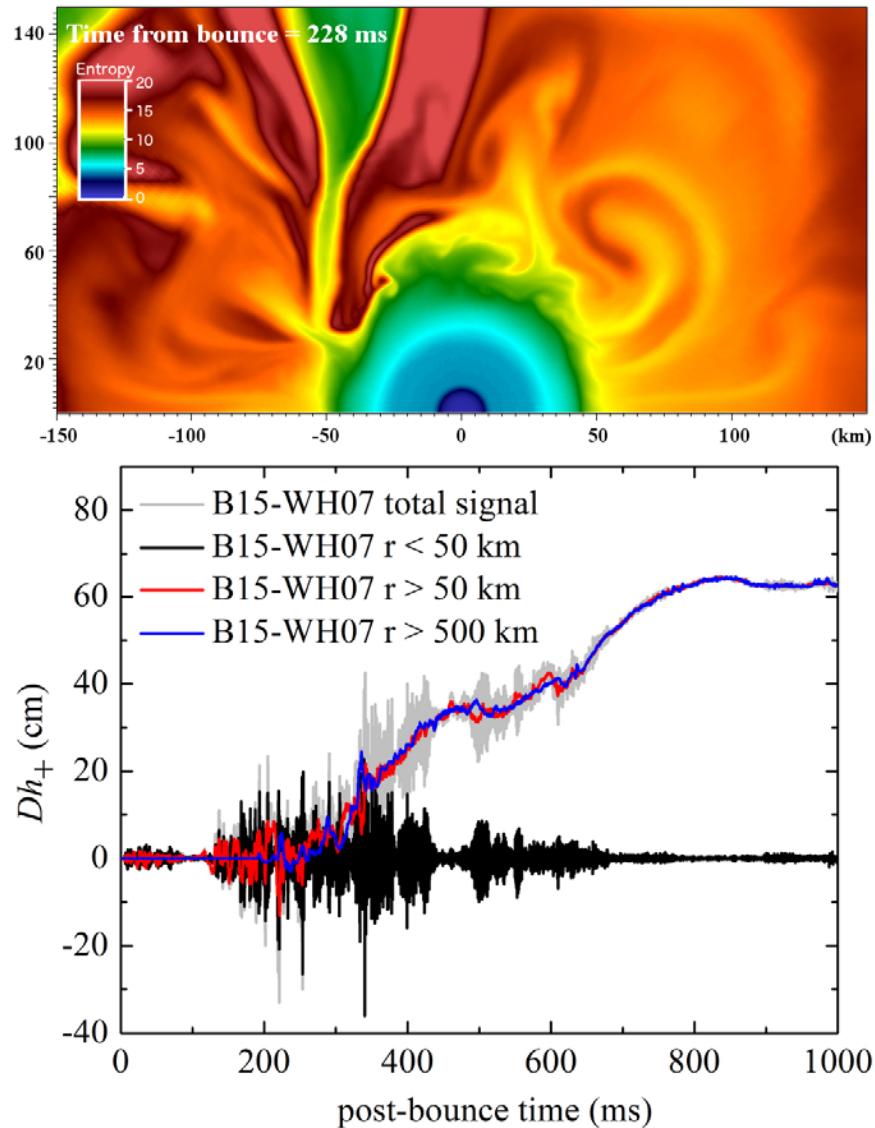
Short signal (< 50 ms), high amplitude at bounce



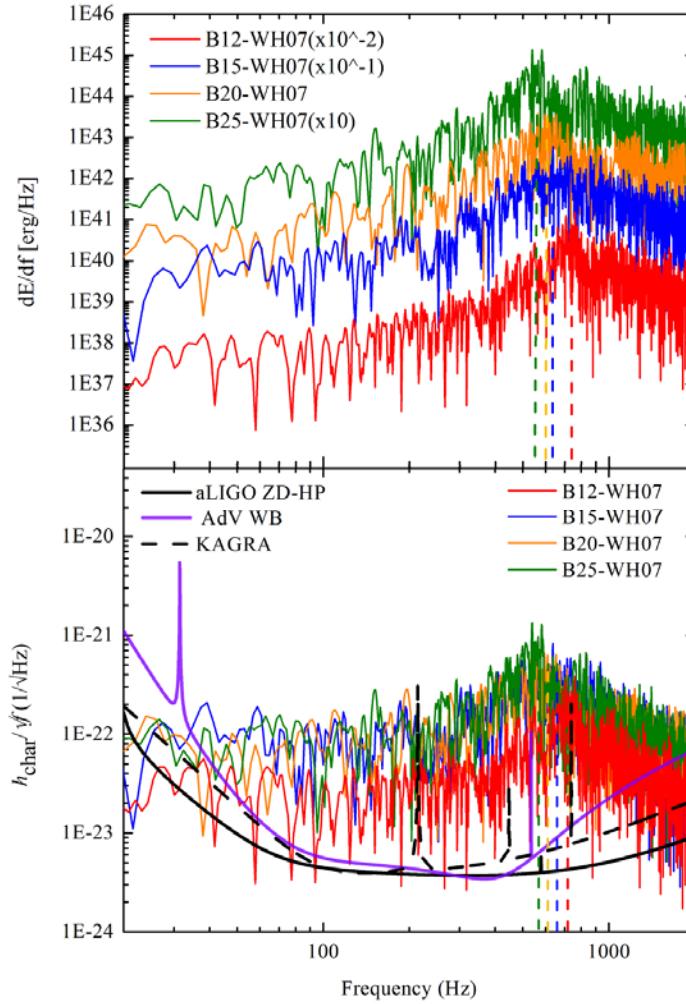
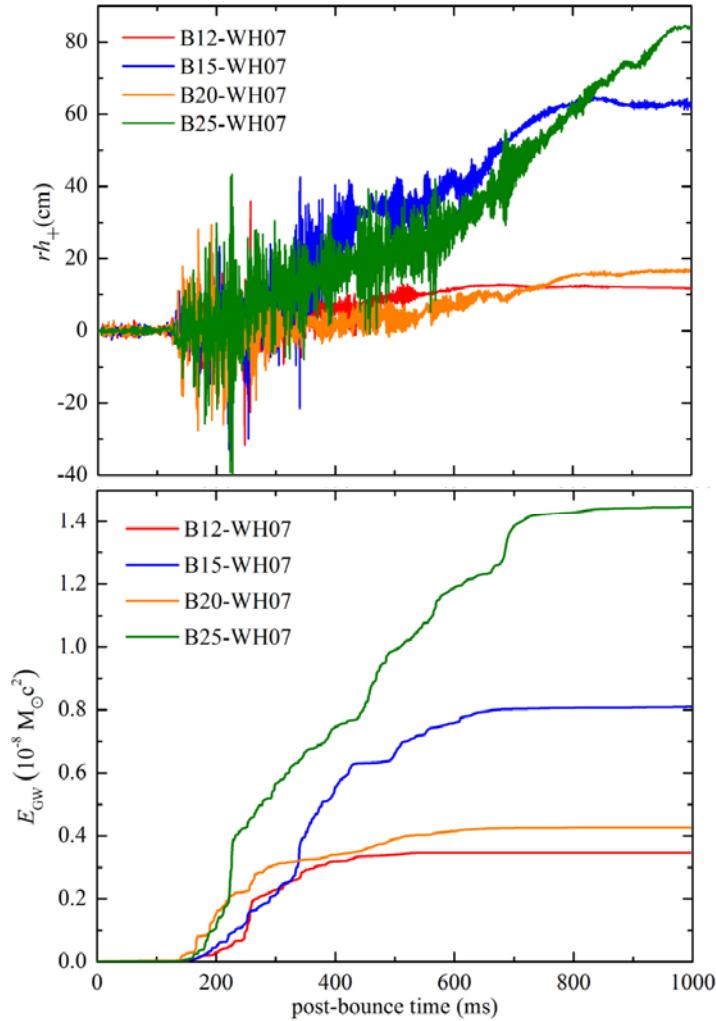
Richers et al. 200=17, *arxiv:1701.02752*



Gravitational Wave Signals: Phenomenology



Gravitational Wave Signals: 2D

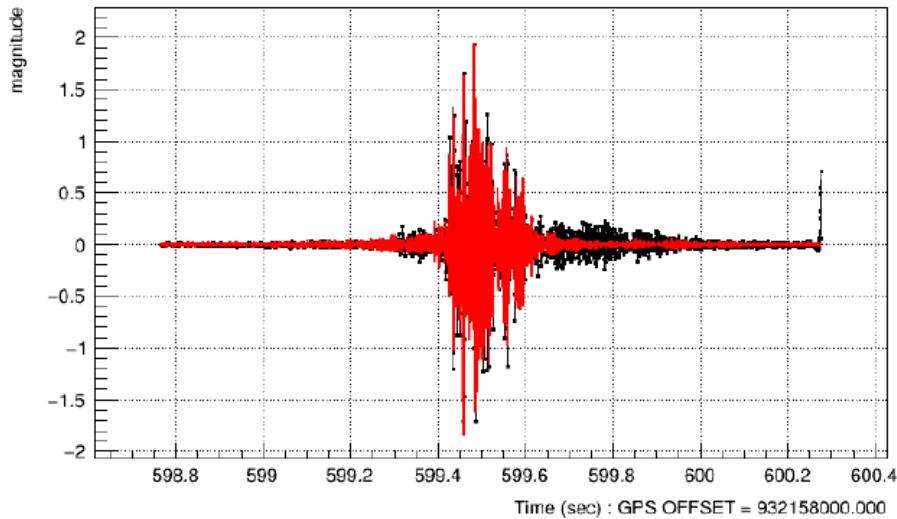


Results obtained with the CHIMERA GR multiphysics supernova code with state-of-the-art neutrino interactions.

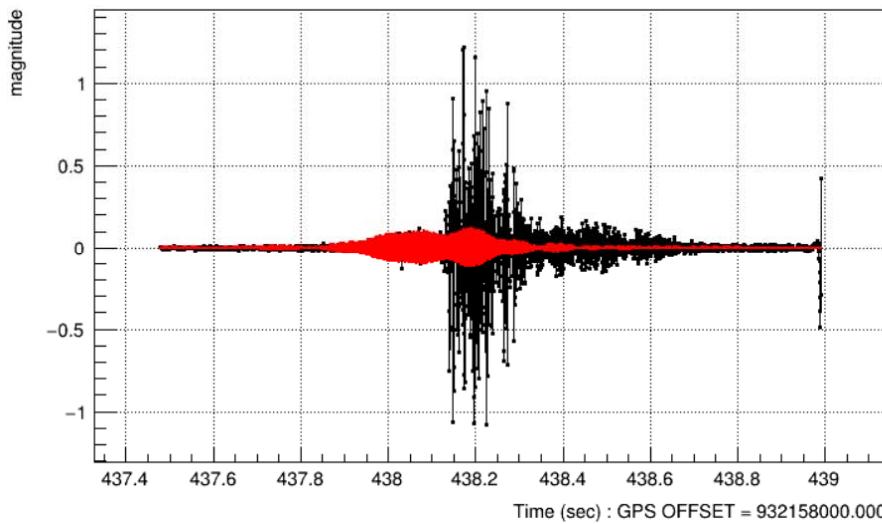
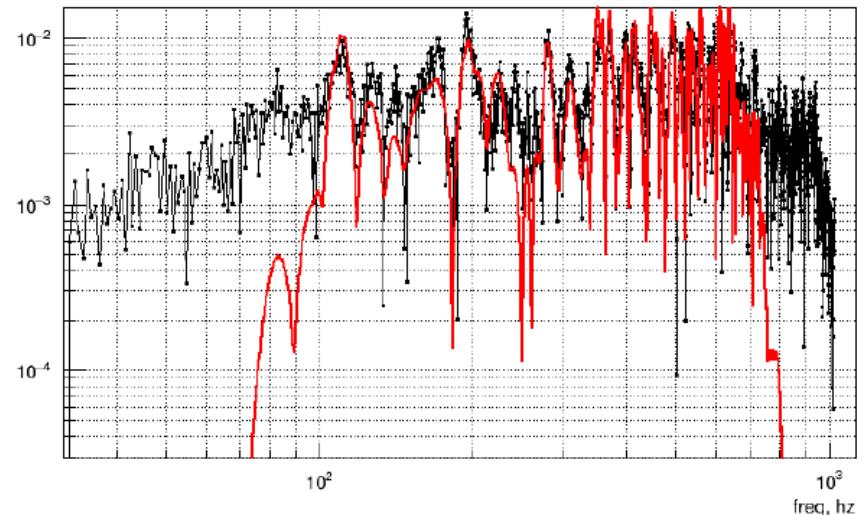
Injected vs Reconstructed B20 Waveform

Time Plot

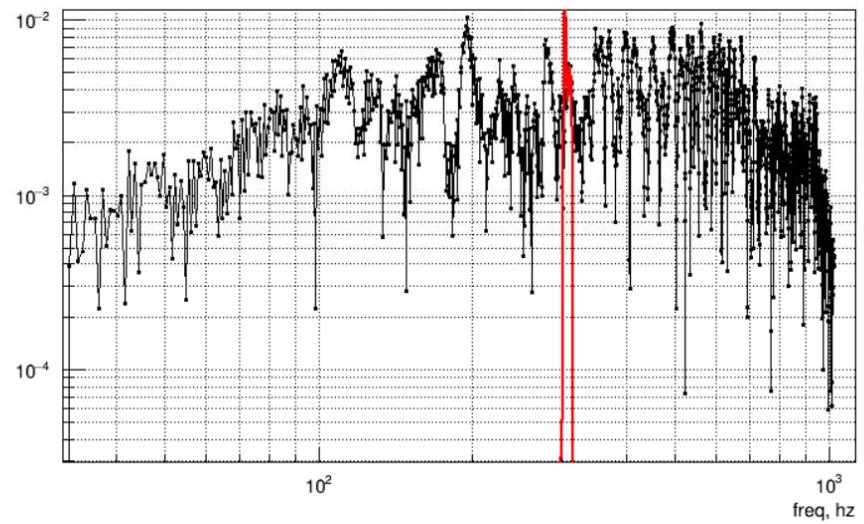
SNR = 41



Frequency Plot

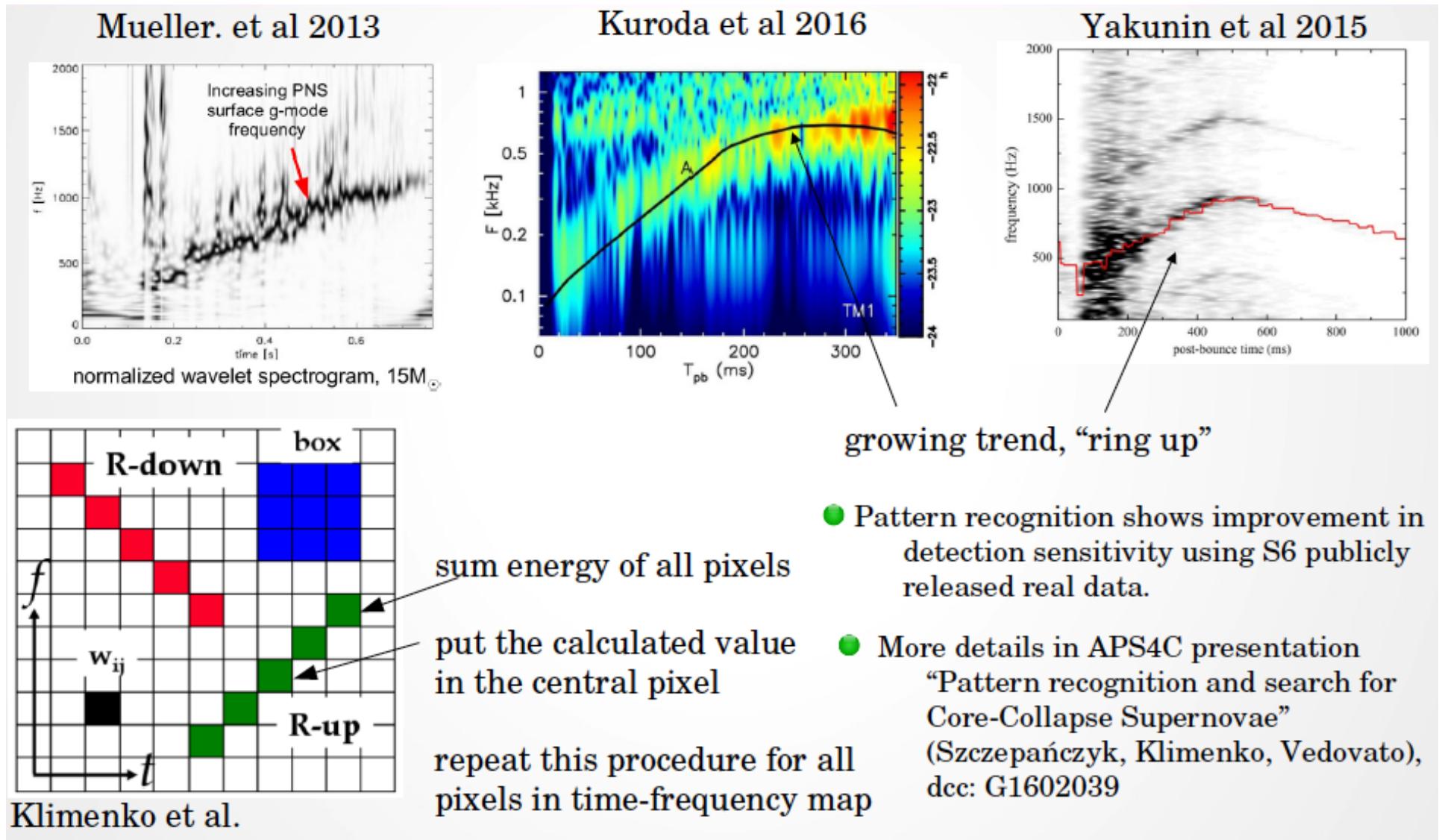


SNR = 6

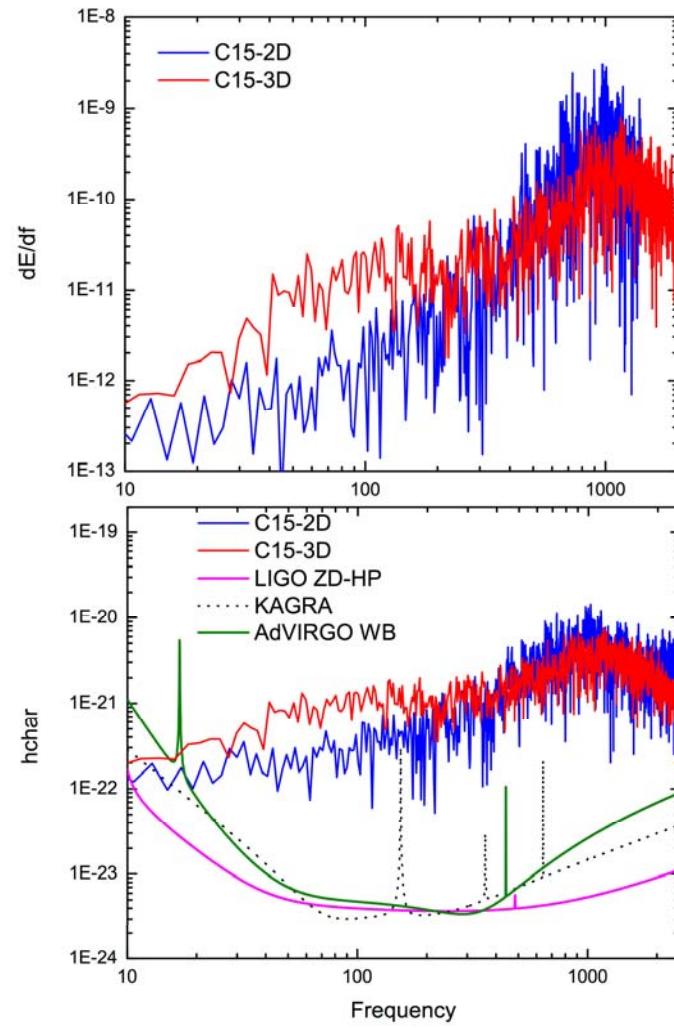
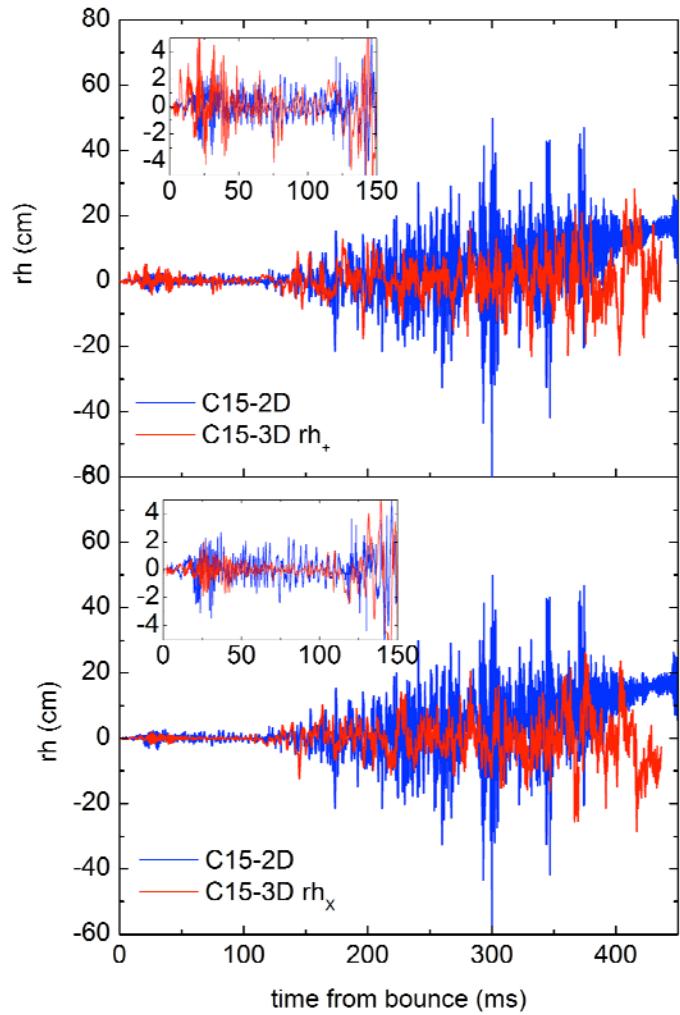


How can simulations help data analysis?

example by M. Szczepański



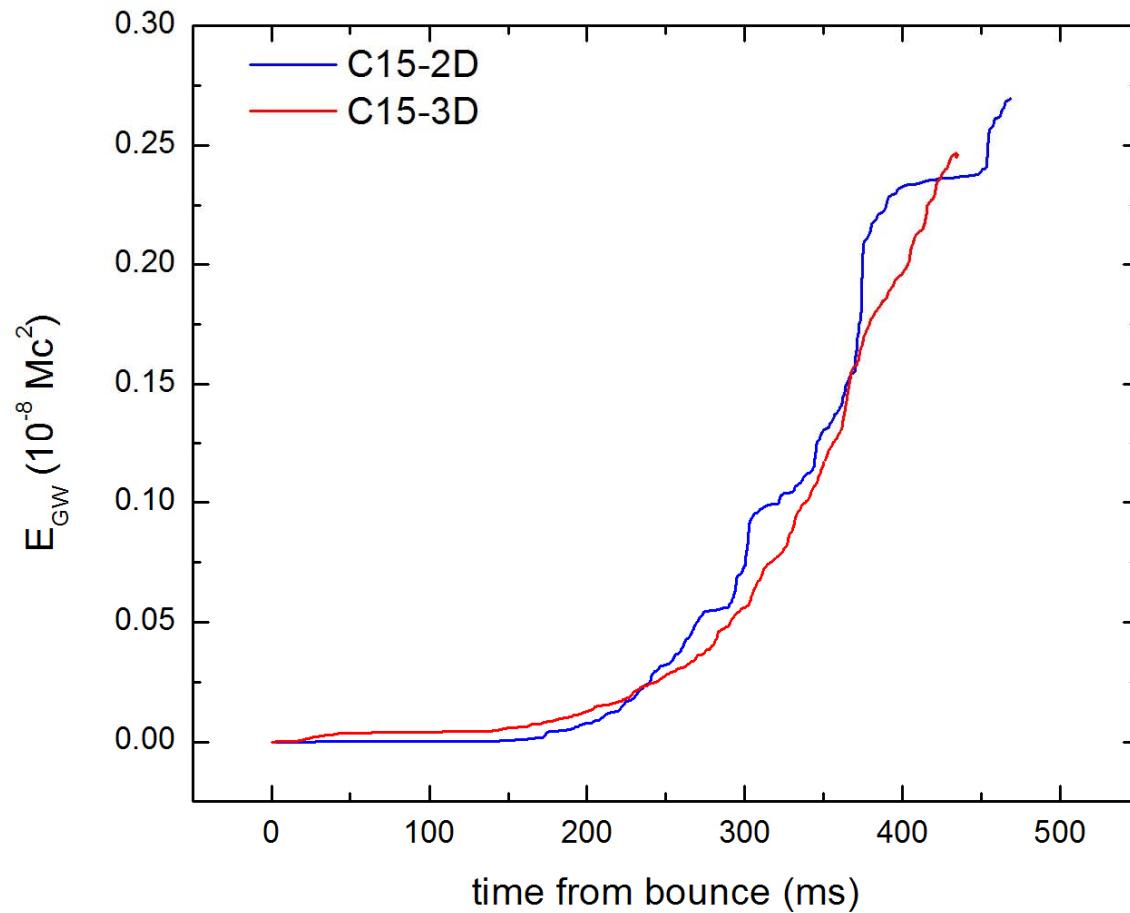
Gravitational Wave Signals: 3D



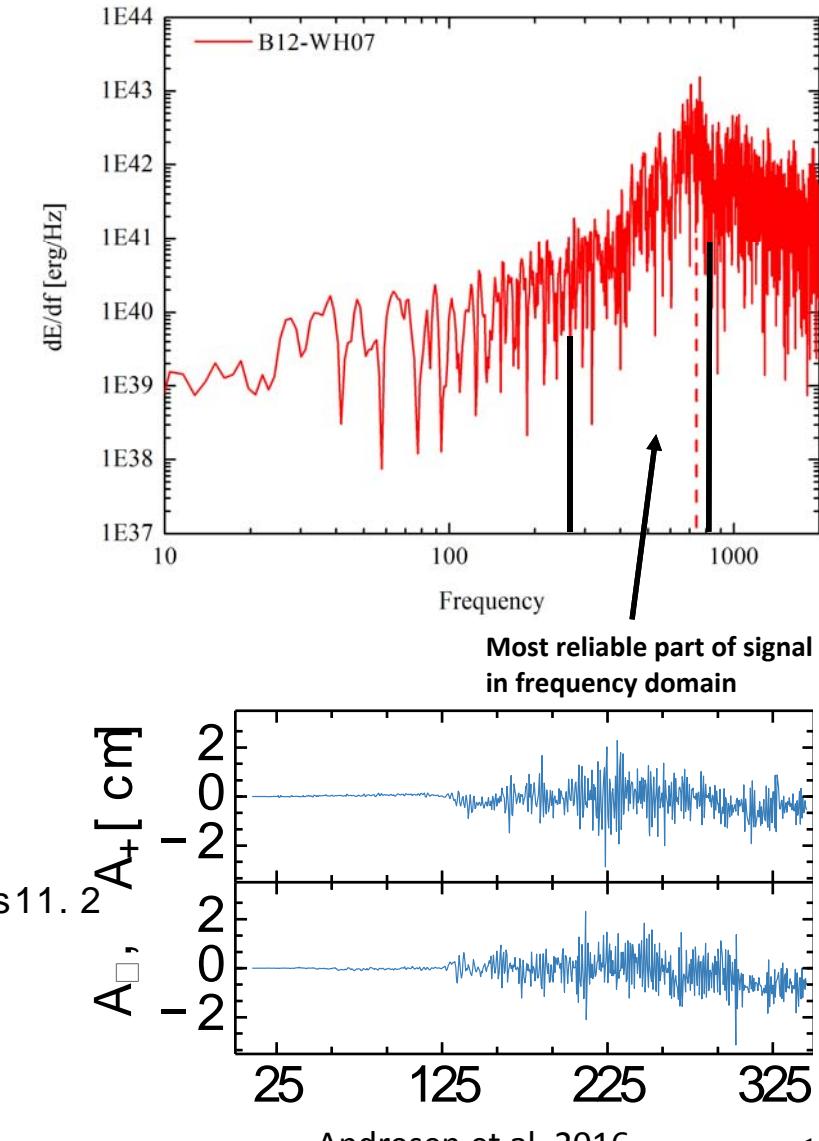
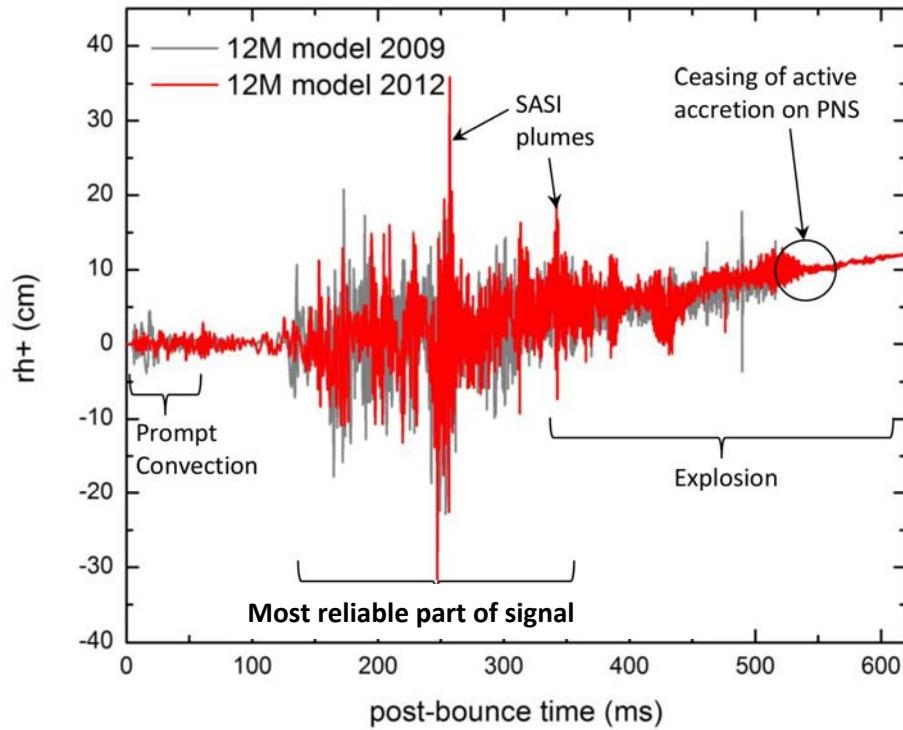
Comparisons use same time window (from 3D)
and temporal resolution (from 2D).

Results obtained with the CHIMERA GR multiphysics supernova code with state-of-the-art neutrino interactions.

Gravitational Wave Energy: 2D and 3D

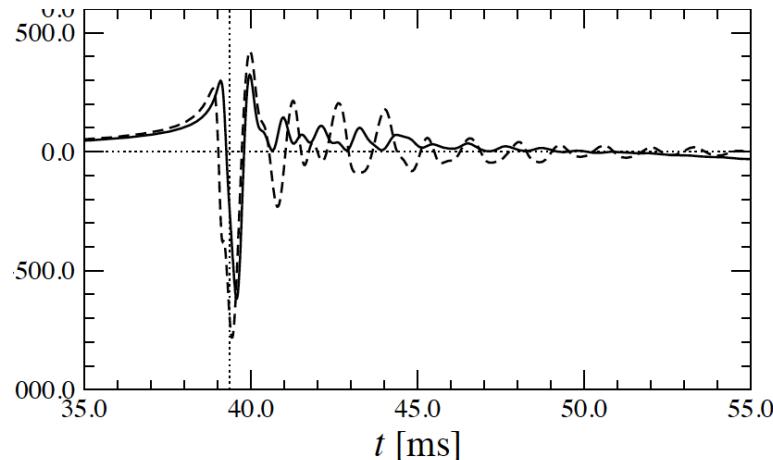


Non-rotating progenitors

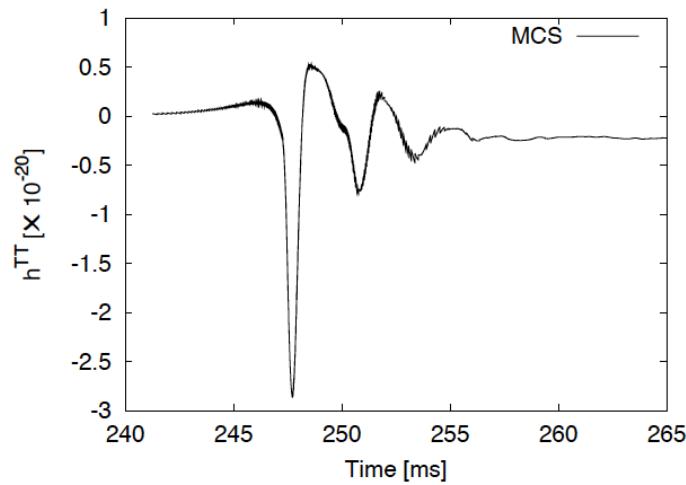


Rotating progenitors

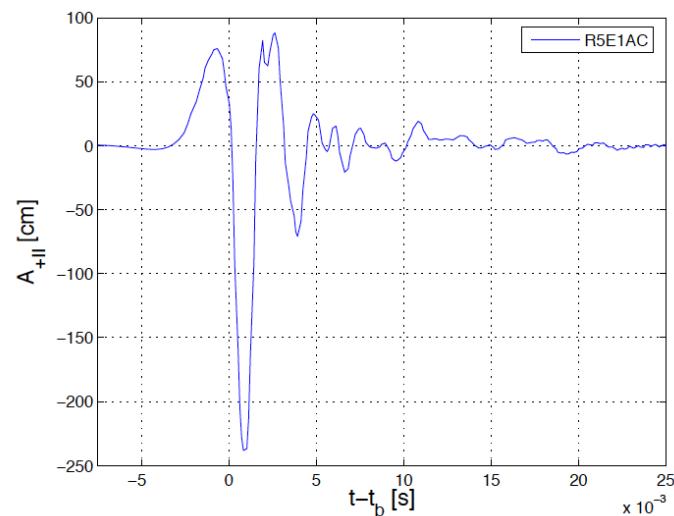
Dimmelmeier et al. PRD, 064056, 2008



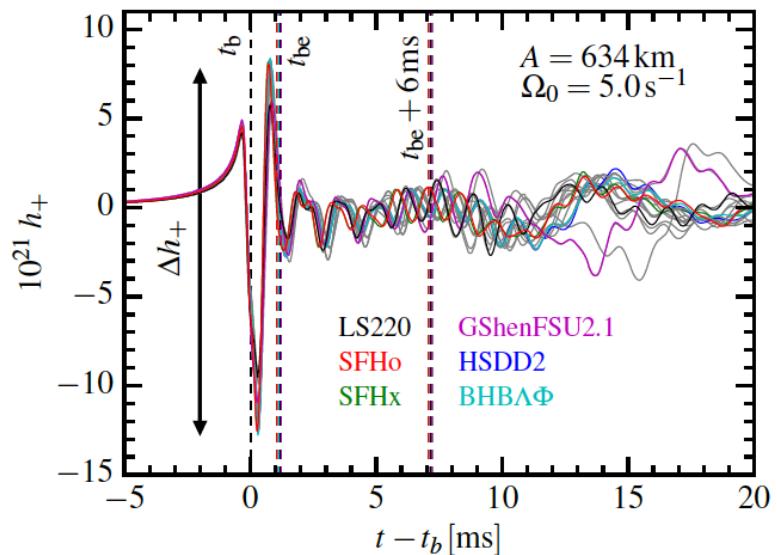
Kotake et al. PRD, 044023, 2003



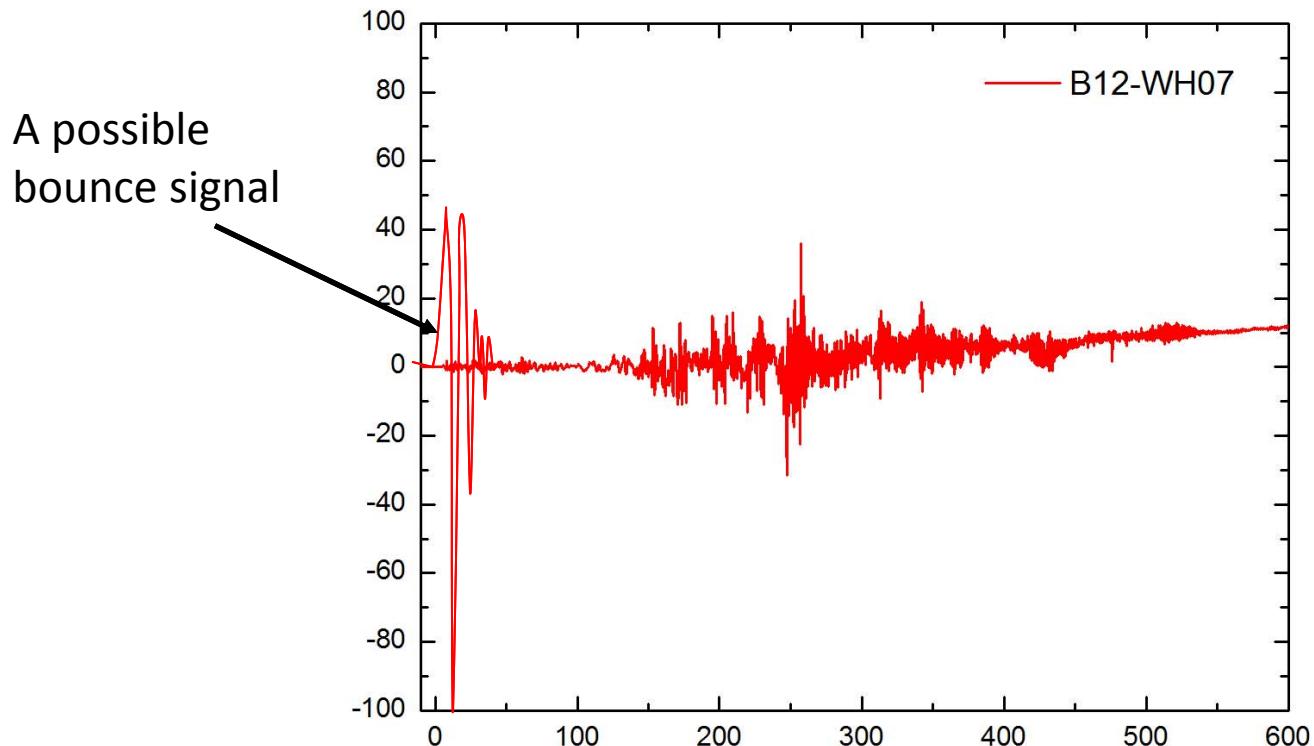
Schreidegger et al. A&A, 2010



Richers et al. arxiv:1701.02752



Slow-rotating and neutrino-driven explosion

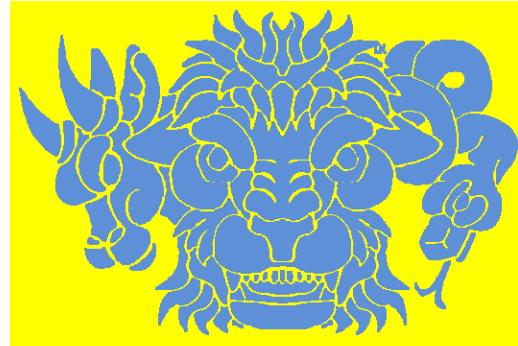


Emission process	Duration (ms)	f_{peak} [Hz]	Typical h at 10 kpc	E_{GW} [Mc^2]
Core Bounce	10	300	3×10^{-21}	$\sim 10^{-8}$
Prompt convection	50	200	0.3×10^{-21}	$\sim 10^{-12}$
SASI/ND convection	450	700	1×10^{-21}	$2 \times 10^{-9} \Delta t / 100\text{ms}$
Explosion	>400	800	0.7×10^{-21}	2×10^{-9}

Conclusions and Outlook

- Simulations help to improve data analysis and increase chances for detection!
 - We are able to perform realistic 3D simulations and produce reliable waveforms.
 - Waveforms from 2D simulations have similar characteristics as 3D ones. Thus, 2D simulations can be used to create a bank of waveforms. Now, even realistic 2D simulations are computationally inexpensive.
 - It would be good to summarize the main characteristics of GW signals into a table in any publication that presents new waveforms
 - To produce more realistic waveforms we have to perform realistic CCSN simulations with slow-rotating progenitor (bounce signal + neutrino-driven explosion signal)

CHIMERA Collaboration



Casanova
Chu
Endeve
Hix
Landfield
Lentz
Lingerfelt
Messer
Mezzacappa
Roberts
Yakunin



Bruenn
Marronetti



Harris

NC STATE UNIVERSITY

Blondin
Mauney

Funded
by
 **Office of
Science**
U.S. DEPARTMENT OF ENERGY

