# Gravitational Waves from 3D Rotating Core-Collapse Supernovae

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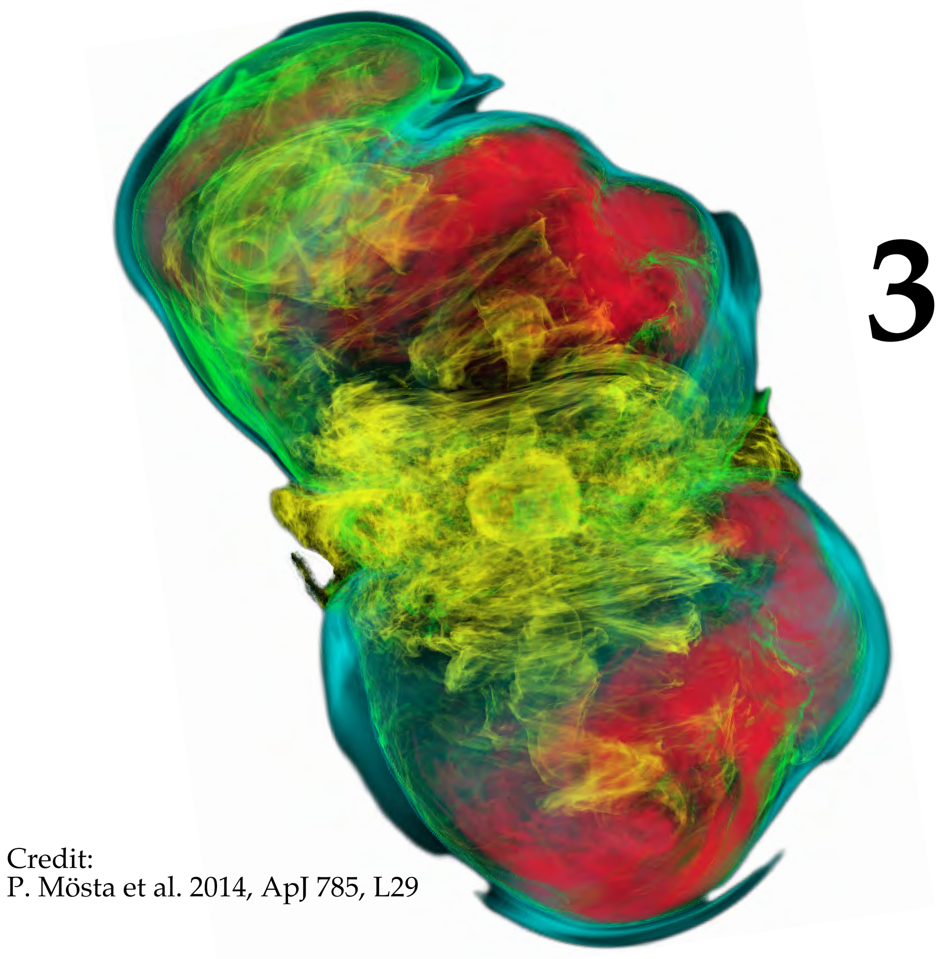


Credit:
P. Mösta et al. 2014, ApJ 785, L29

## Abstract

We present gravitational wave (GW) signals from new general-relativistic 3D simulations of rotating core-collapse supernovae. We use a realistic progenitor model, a microphysical equation of state, and neutrino leakage/heating. We explore the dependence of 3D dynamics and GW emission as a function of the precollapse rotation rate. For rapid rotation resulting in proto-neutron stars with millisecond periods, we find the development of a nonaxisymmetric (m={1,2}) rotational instability that dramatically alters supernova dynamics and GW emission.

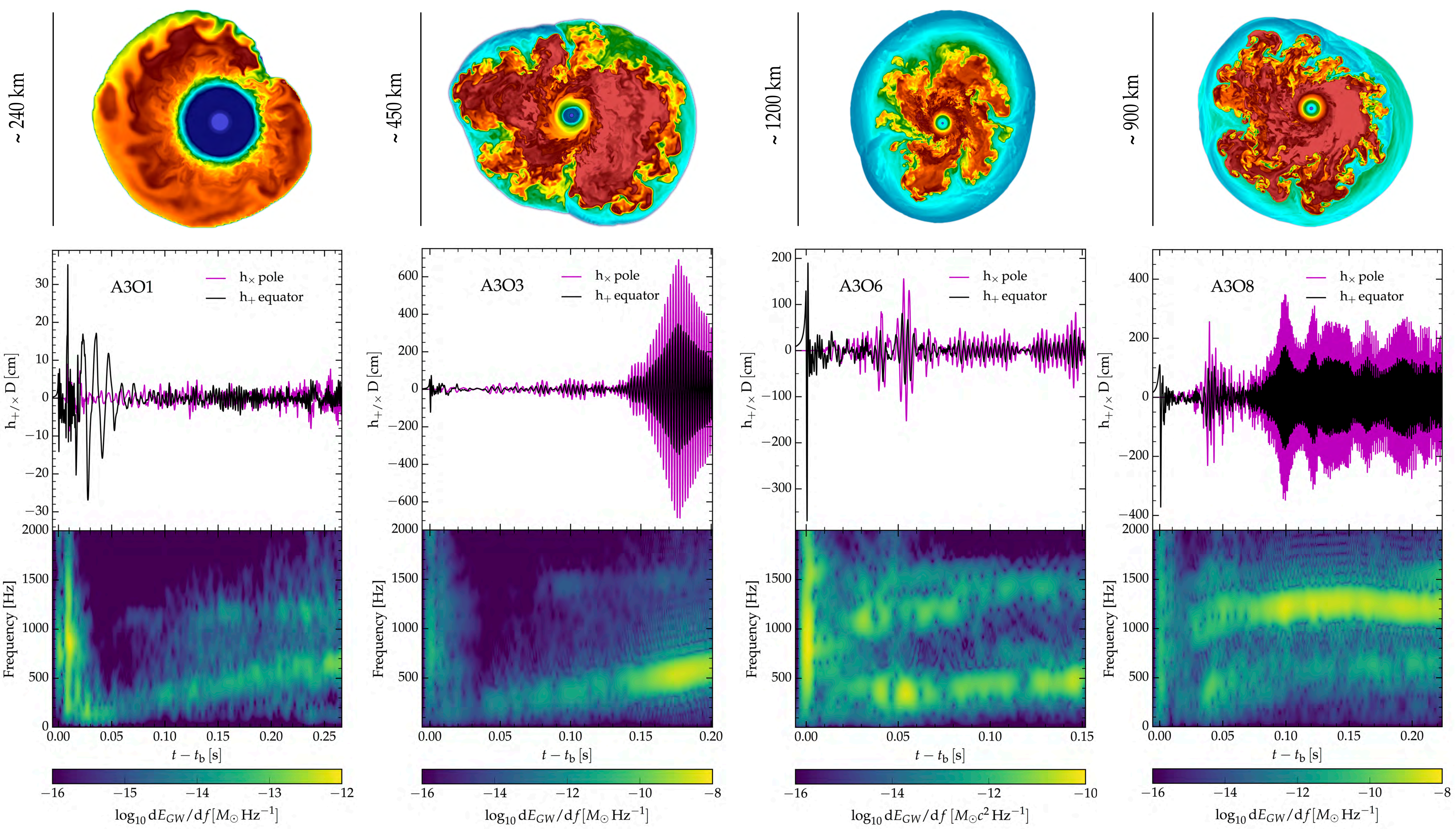
## Background

The next galactic core-collapse supernova will be observed in GWs, neutrinos, and photons. All stars rotate and some massive stars may have rapidly spinning cores. Their quadrupole deformation gives off a GW burst at core bounce when the proto-neutron star is formed. The emitted GW signal is detectable throughout the Milky Way [1] and can constrain core spin [2]. Early 3D simulations (e.g., [3]) showed that in addition to the axisymmetric GW emission at bounce, 3D rotational instability can trigger strong non-axisymmetric deformation of the proto-neturon star. This can have a dramatic impact on the supernova explosion dynamics [4]. The 3D dynamics results in a strong, quasi-circularly polarized GW signal that dramatically enhances the overall GW emission and thus detectability [3,4].

## Simulations

We carry out 3+1 general-relativistic rotating core collapse simulations using the Zelmani core collapse simulation package [6] that is based on the open-source Einstein Toolkit [7]. We employ 8 levels of AMR, the LS 220 equation of state [8] and the 12 $M_\odot$ progenitor of [9]. Electron capture during collapse is included with a $Y_e(\rho)$ fit. Neutrino transport after bounce is handled by a leakage/heating scheme [6].

We set up constant angular velocity on cylindrical shells using $\Omega(r) = \Omega_0[1+(r/A)^2]^{-1}$ with A = 634 km (A3 of [2]). We vary $\Omega_0$ from 1 rad $s^{-1}$ (model A3O1) to 8 rad $s^{-1}$ (model A3O8). These $\Omega_0$ result in rotation rates (T/|W|) of the inner core at bounce of ~0.4% to ~14%. They thus allow us to probe slow to very fast rotation and its impact on core-collapse supernova dynamics and GW signature.




## Conclusions:

We are long overdue for a core-collapse supernova within our galaxy. When it happens we need to know what kind of gravitational waveform to expect. As shown by our numerical relativity simulations, given the right observational conditions, current and next generation gravitational wave detectors will be able to observe the GWs from these core-collapse supernovae events.

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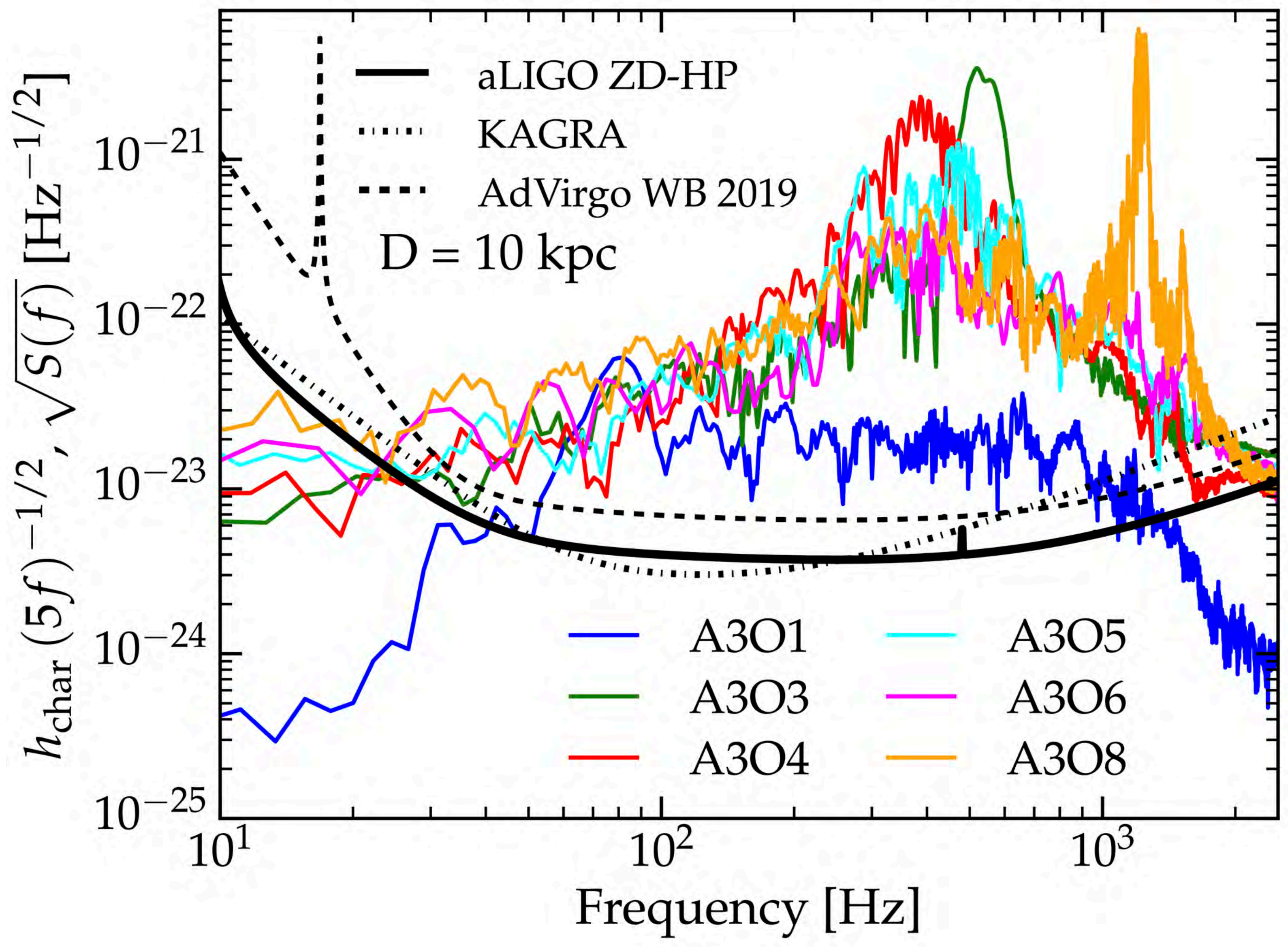


## References

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