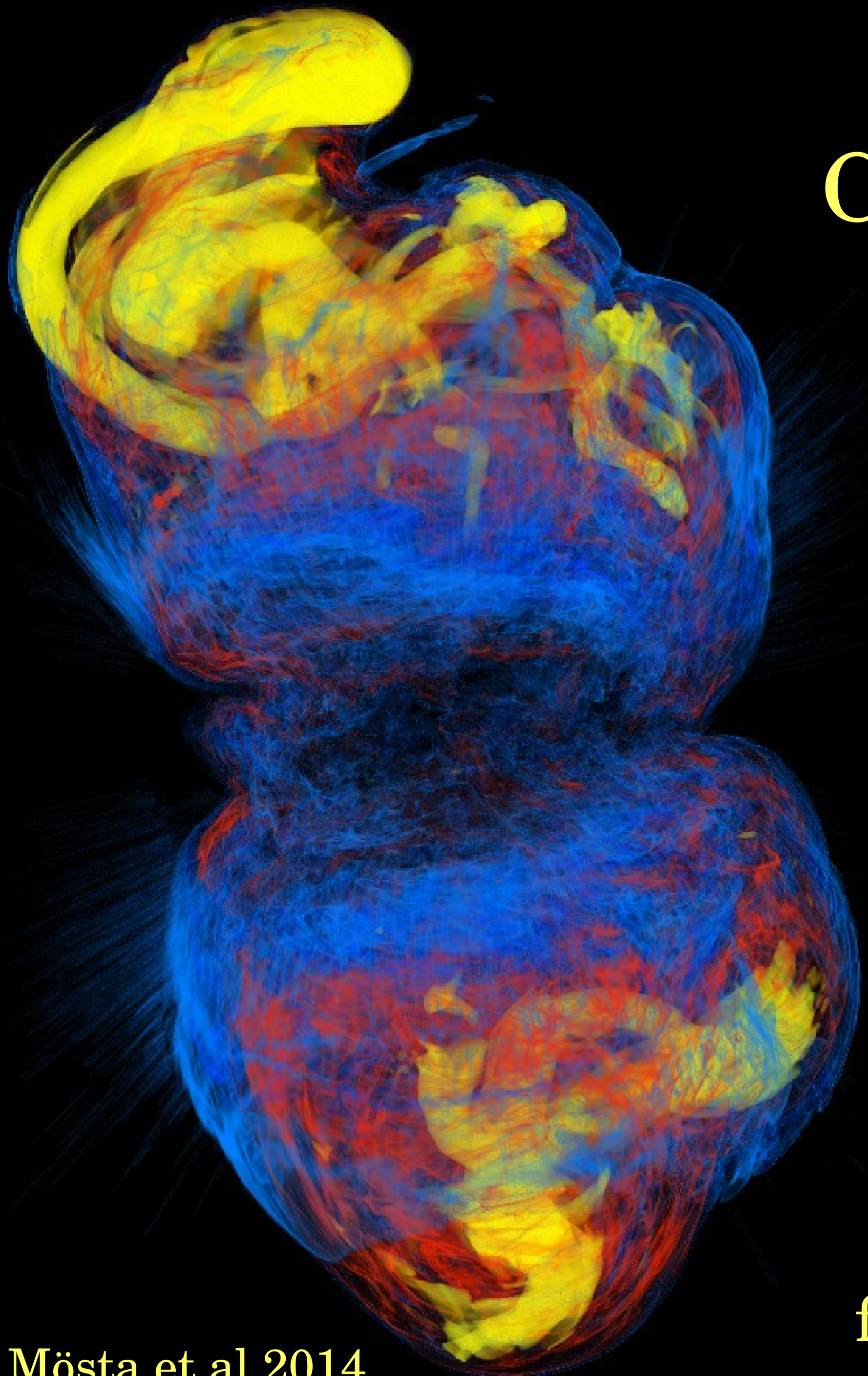


Mösta et al 2014

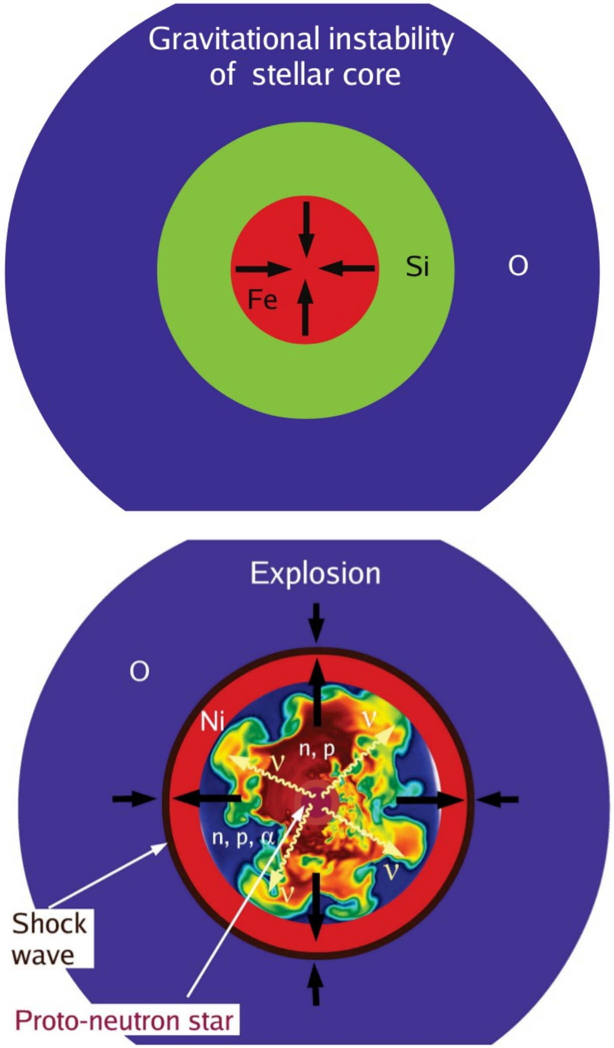
Core-Collapse Supernova Science with Advanced LIGO and Virgo

GR21
New York, 14 July 2016

Marek Szczepańczyk

for the LIGO Scientific Collaboration and Virgo Collaboration

CCSN crashcourse

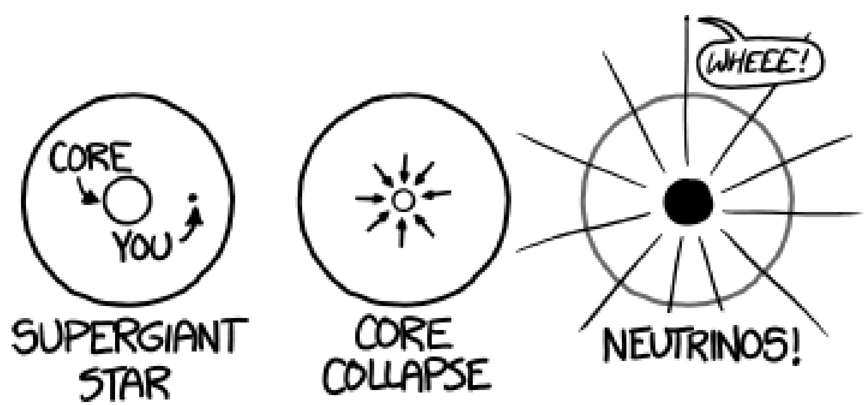


Janka+12

- Burning of the star:
  H → He → … → Fe
- Before collapse: Fe core of size 1000-2000km
  After collapse: "nucleus" core of size 10-15km
- Nuclear density of the core
- ~ 1 SN/s in Universe
  ~ 1 SN/day discovered
  ~ 4 SN/year up to 20Mpc
  ~ 2 SN/century (?) in Milky Way
- ~ 20% of all SN are thermonuclear, Type Ia
  ~ 80% of all SN are CCSN

CCSN crashcourse

- Energy available ~ 300B (1B = 0.15 $M_{Sun}c^2$)
- Energy observed ~ 3B
  Where does that energy go?
  99% of explosion energy escapes with **neutrinos**!

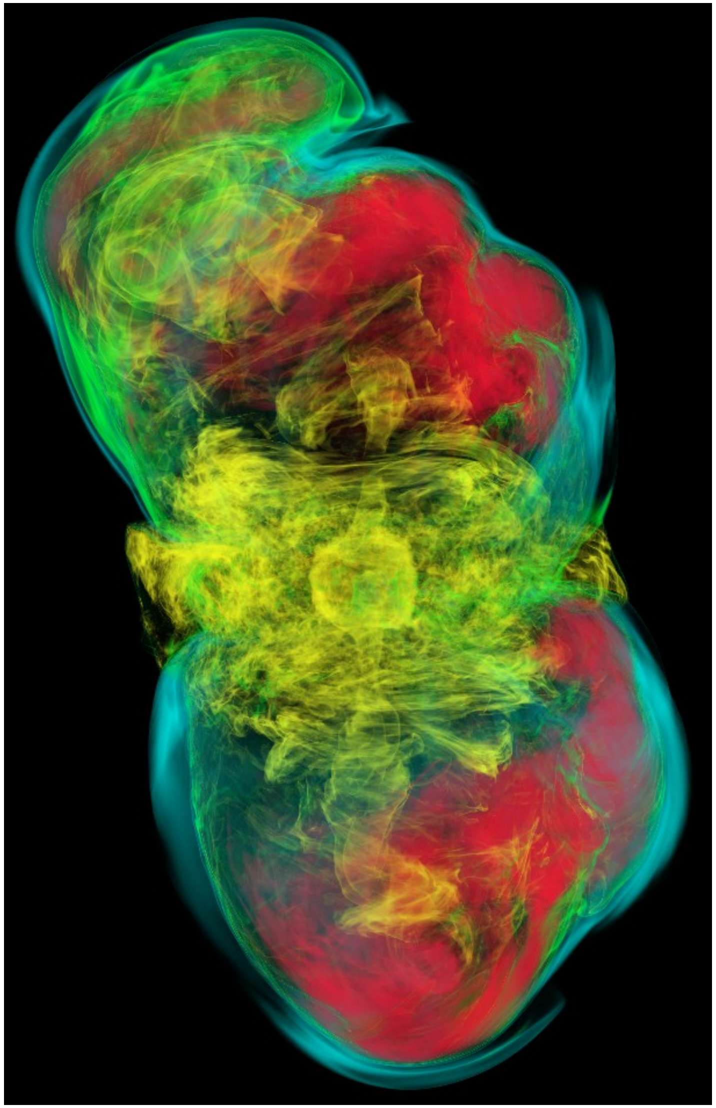


Credits: xkcd

CCSN crashcourse

What can we learn?

- Find explosion mechanism
- Study: Nuclear Equation of State, evolution of Proto-Neutron star, asymmetry of explosion
- Measure angular momentum and rotational rate of Proto-Neutron Star
- Spot formation of Black Hole at its birth
- And others…

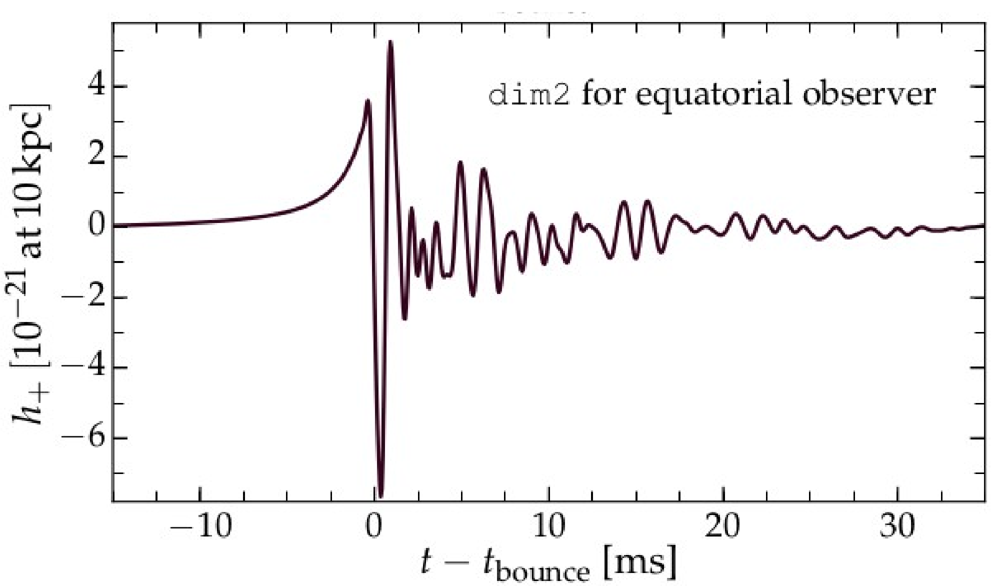


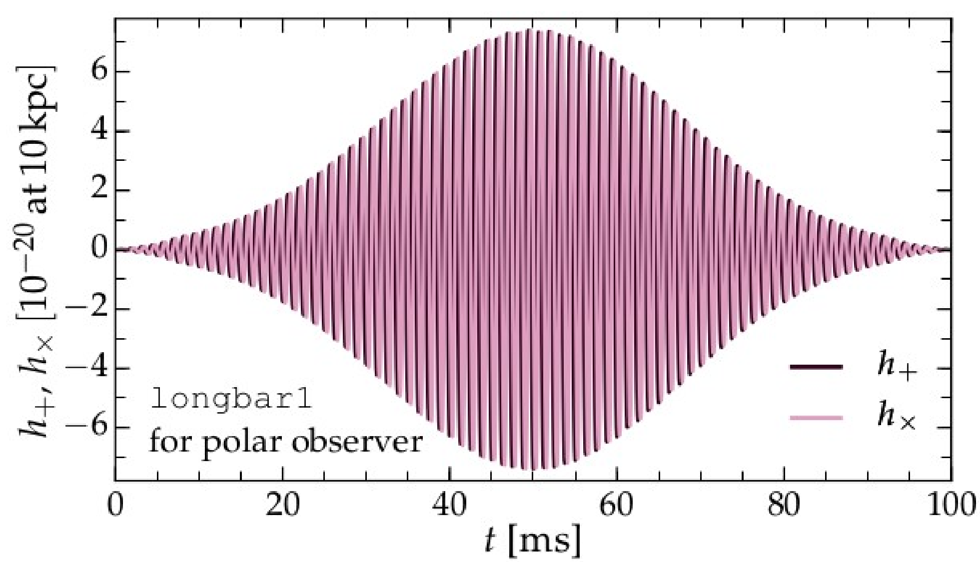
Mosta+14

Observing Gravitational Waves from Core-Collapse Supernovae in the Advanced Detector Era

Gossan S., Sutton P., Stuver A., Zanolin M., Gill K., Ott C.
Phys. Rev. D 93, 042002 (2015)

- Description of some of the gravitational wave waveforms.
- Simulated data for LIGO and Virgo network.
- Different sky locations and search time ranges considered.
- Detection sensitivity studies for different models of gravitational wave emission candidates.

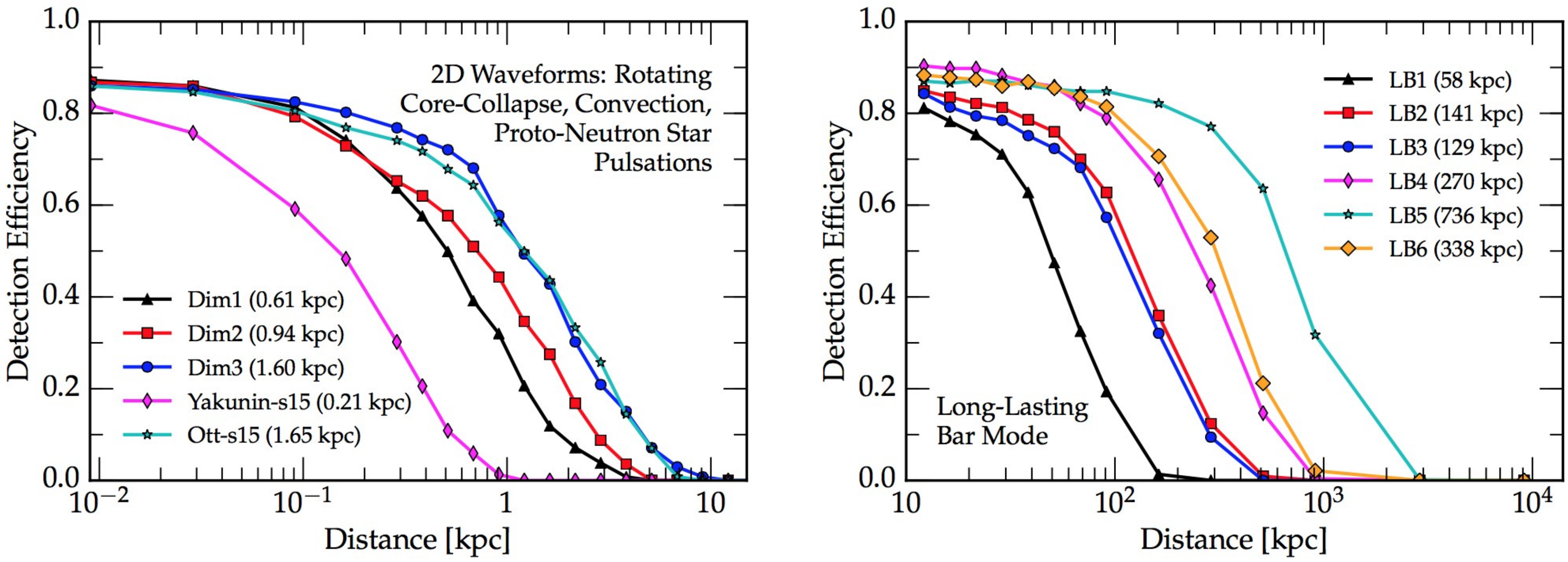




A First Targeted Search for Gravitational-Wave Bursts from Core-Collapse Supernovae in Data of First-Generation Laser Interferometer Detectors

arXiv:1605.01785 [gr-qc] (soon in PRD)

- Initial LIGO and Virgo data, 4 nearby (<11Mpc) supernovae considered.
- Search Methodology described with challenges specific to SN search.
- Results: detection efficiency, upper limits and model exclusion statements.
- No gravitational wave candidate.

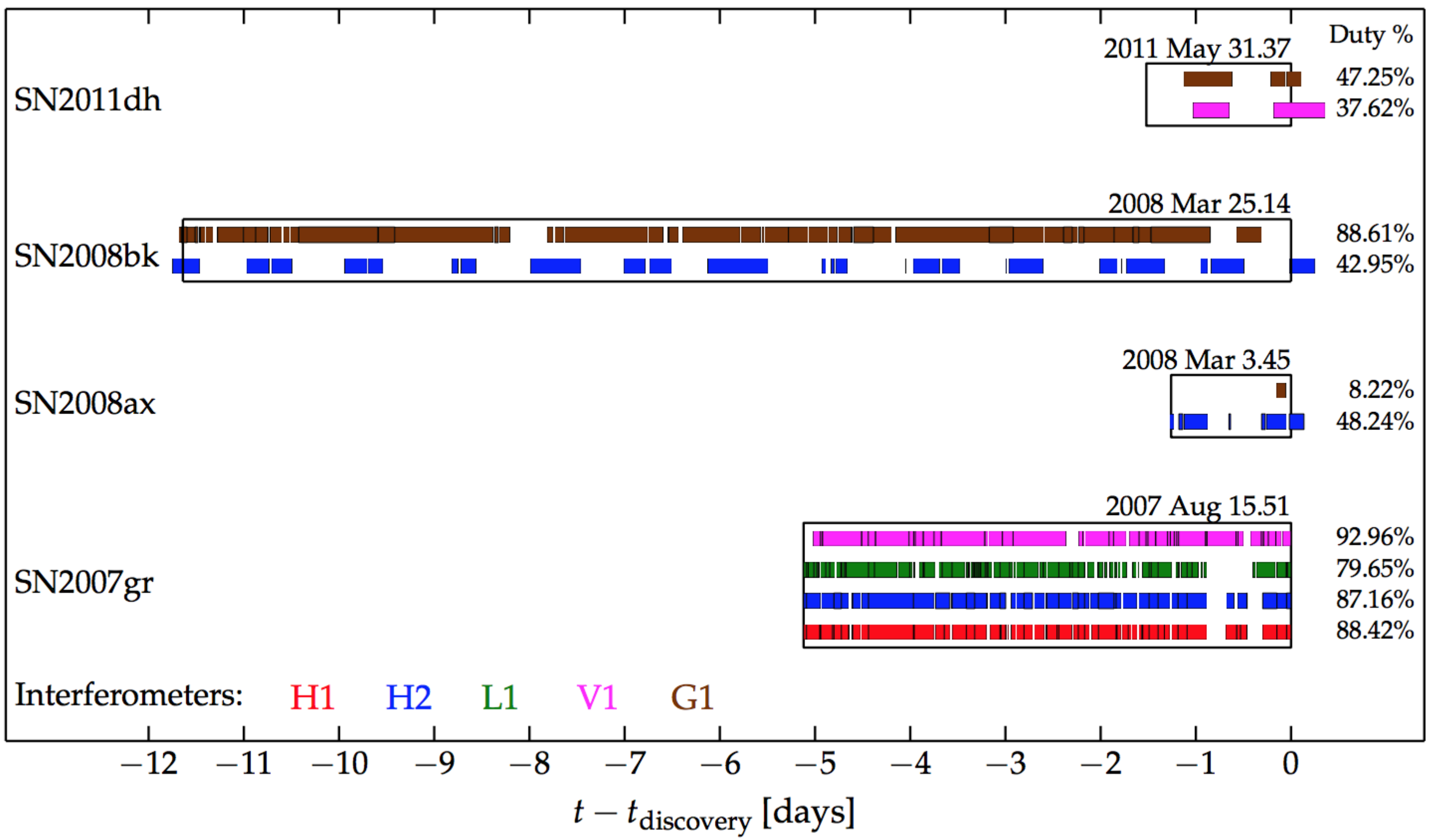


A First Targeted Search for Gravitational-Wave Bursts from Core-Collapse Supernovae in Data of First-Generation Laser Interferometer Detectors

arXiv:1605.01785 [gr-qc] (soon in PRD)

Some of the SN Search challenges:

- search for unknown waveform and they are weak,
- small SN rate in nearby universe (1-2 per century in Milky Way),
- a need for data overlap between detectors.



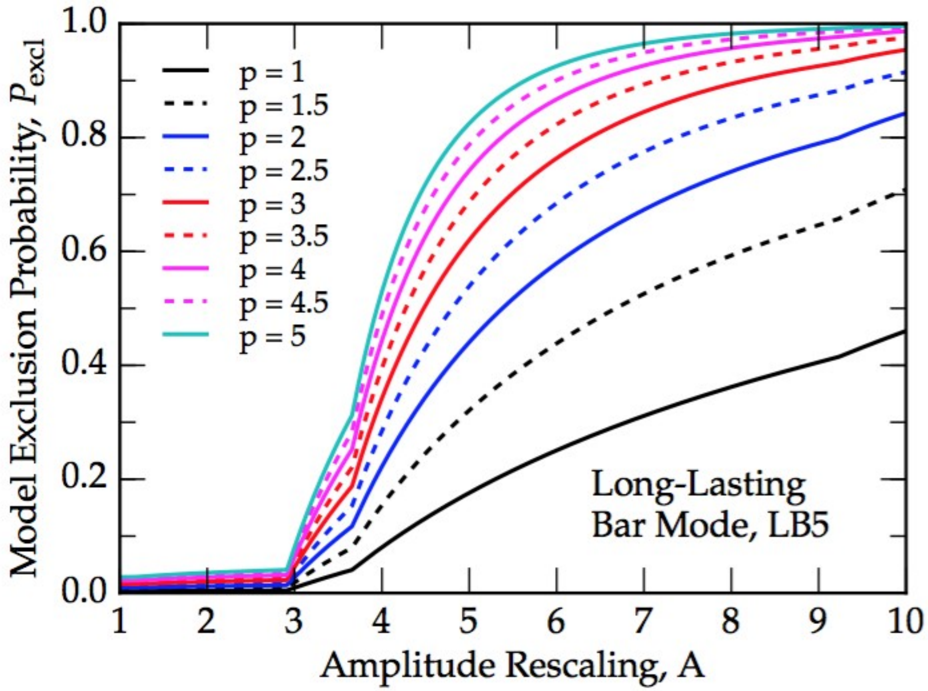
SN2008ax/bk are not used for detection statements, high False Alarm Rate

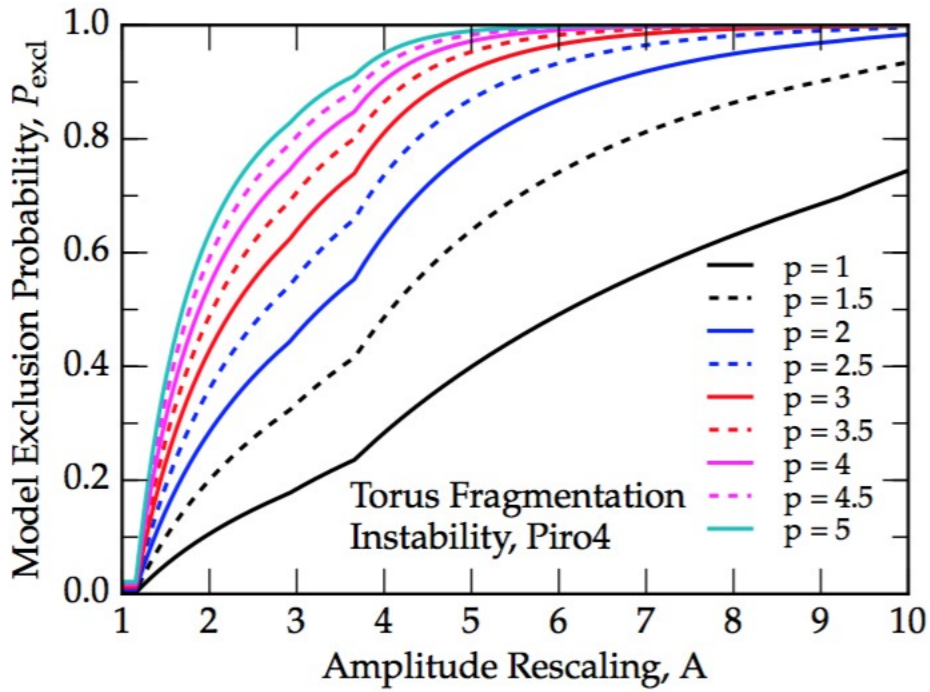
A First Targeted Search for Gravitational-Wave Bursts from Core-Collapse Supernovae in Data of First-Generation Laser Interferometer Detectors

arXiv:1605.01785 [gr-qc] (soon in PRD)

- Model exclusion probability statements.
- Standard candle assumption.

$$P_{\mathrm{excl}} = 1 - \prod_{i=1}^{N} (1 - \epsilon_i(d_i))$$



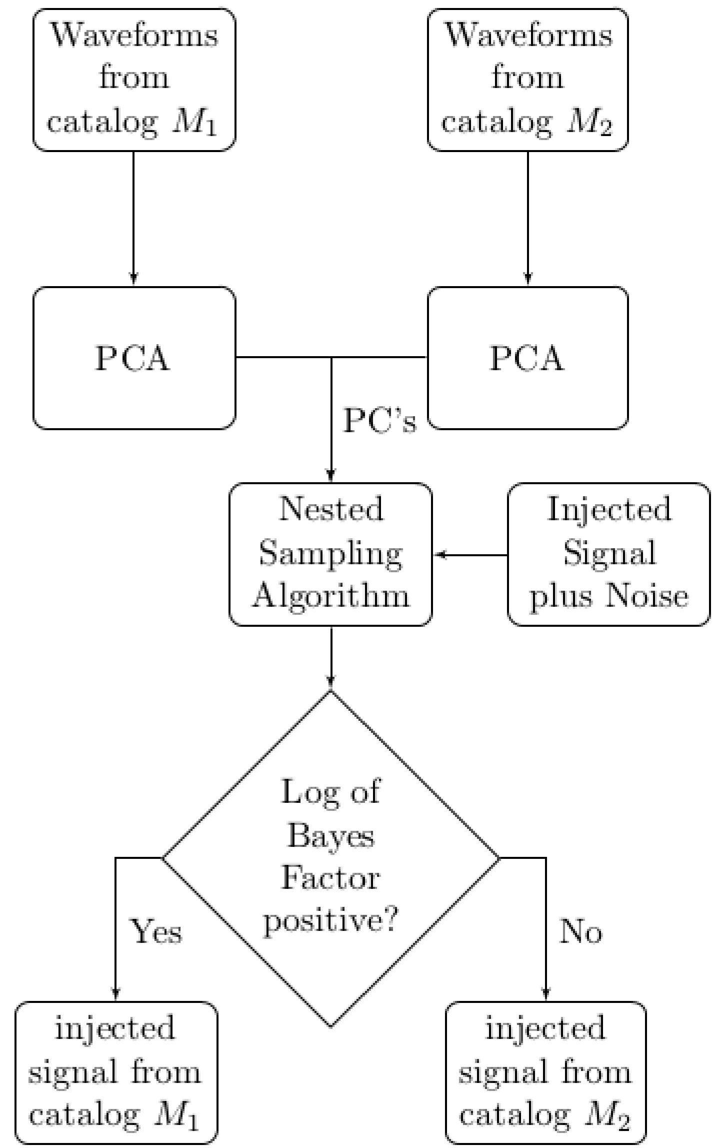


Inferring Core-Collapse Supernova Physics with Gravitational Waves

Logue J., Ott C., Heng I., Kalmus P., Scargill H.

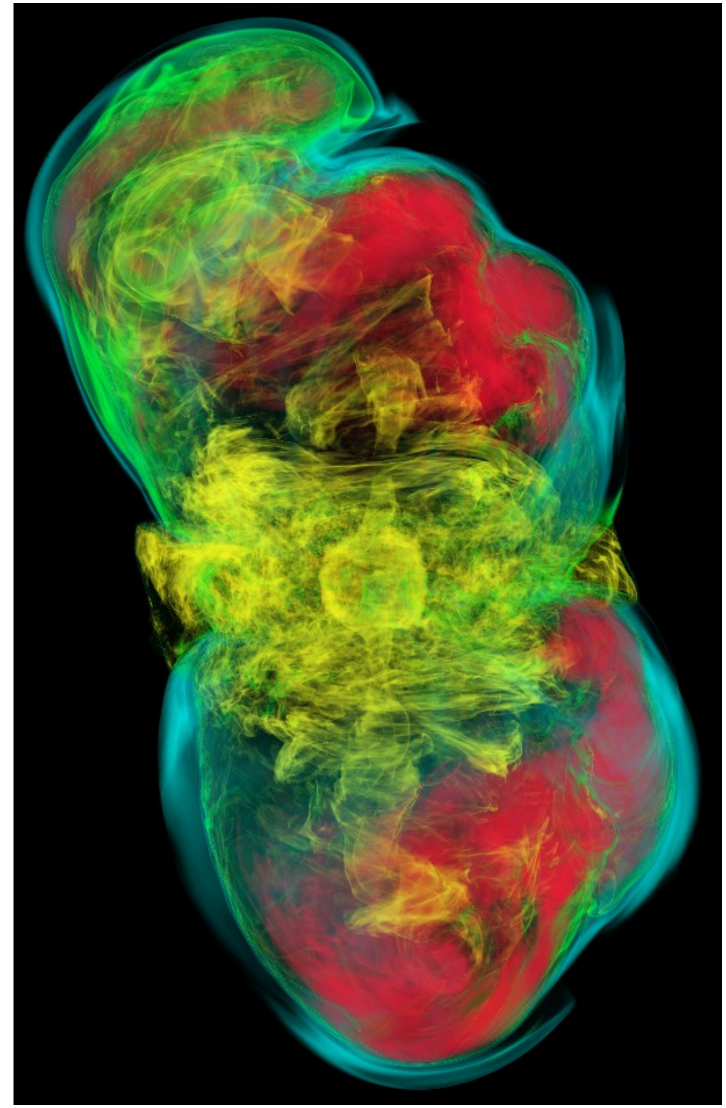
Phys. Rev. D. 86, 044023 (2012)

- Gravitational wave signals have certain distinct structures in their time series or power spectra that can be reliably used to identify the explosion mechanism.
- Bayesian Model Selection.
- Single detector, simulated aLIGO noise
- Magnetororational mechanism D<~10 kpc
- Neutrino&acoustic mechanisms , D<~2 kpc
- Paper with 3 detector network – in preparation



Summary

- Extragalactic supernovae are not likely to be detectable with aLIGO, but the waveforms are scientifically extremely rich.
- First optically targeted SN search is finalized.
- Many projects improving the search and parameter estimation are in progress.



Mösta+14