PennState
Eberly College of Science

CoRe collaboration

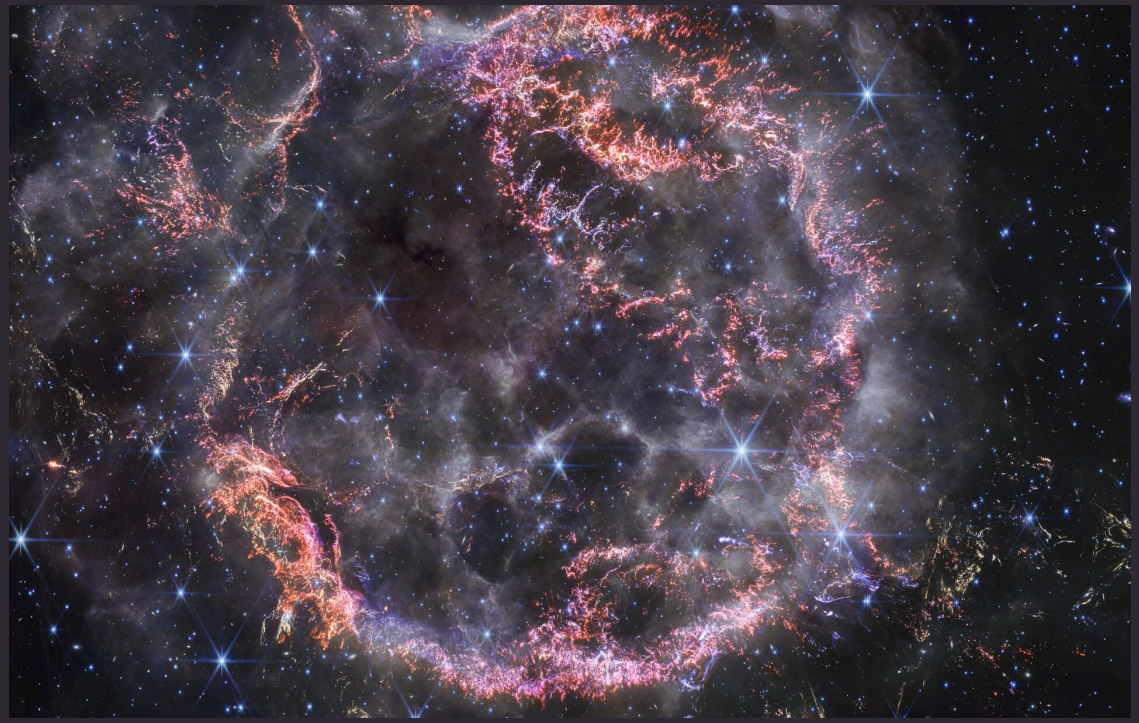
Gravitational-Waves from Core-Collapse Supernovae

David Radice

CE Symposium – April 25 (2024)

Network for Neutrinos, Nuclear Astrophysics, and Symmetries
PHYSICS FRONTIER CENTER

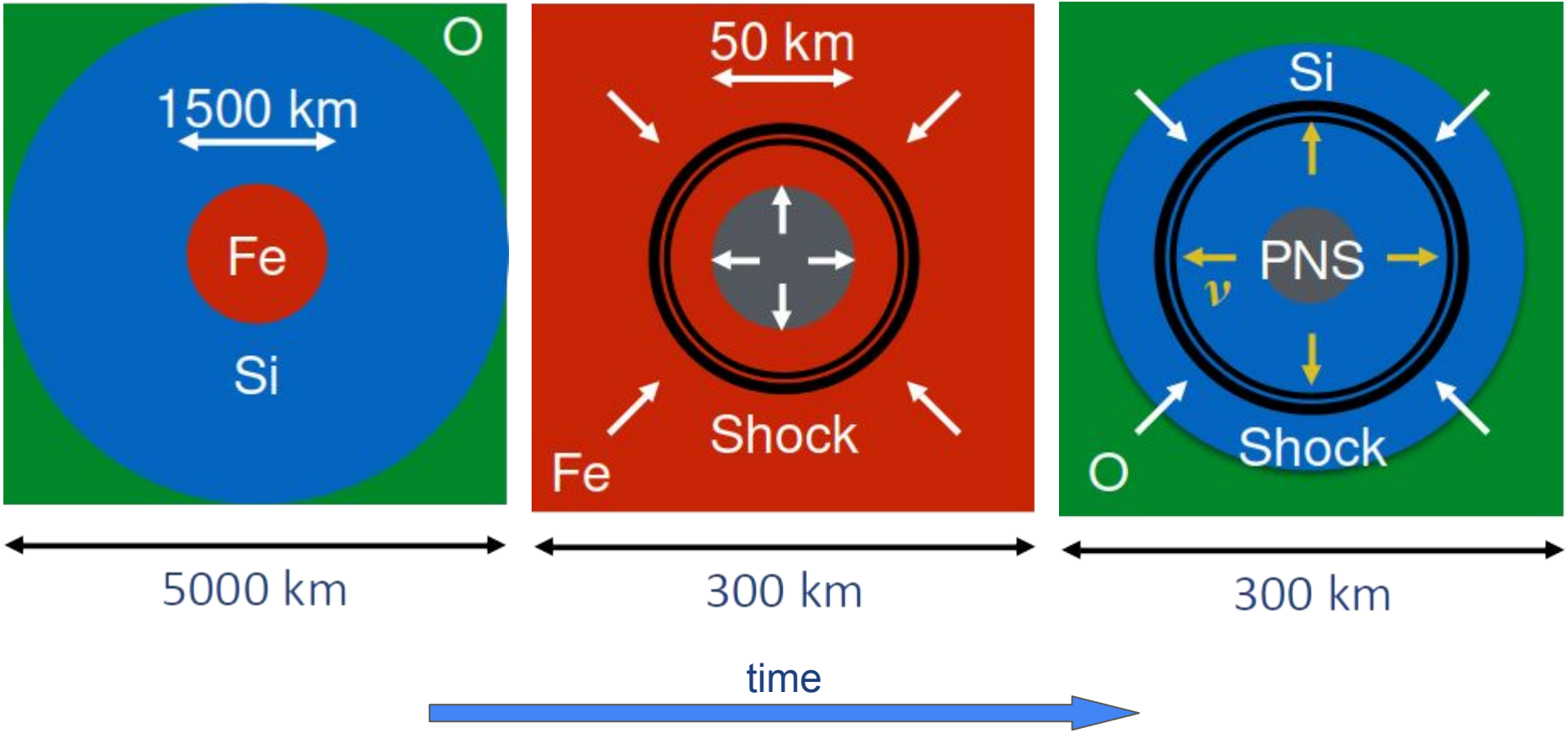
Supernovae in numbers



- ~$(50\ \mathrm{yr})^{-1}$ per galaxy
- Tens going off every second in the Universe
- 10^{48} erg EM radiation
- 10^{51} erg kinetic energy
- 10^{53} erg neutrinos

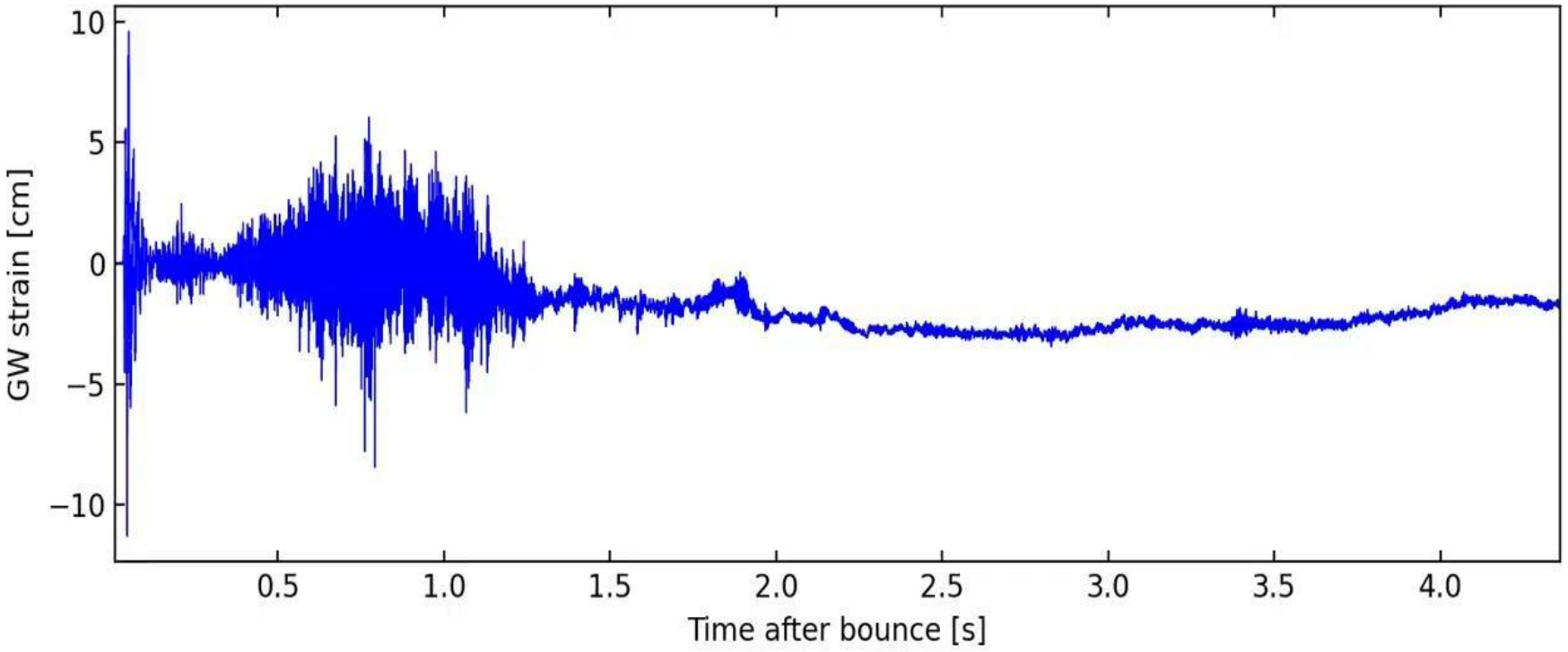
10^{46} erg GWs

Mechanism for explosion



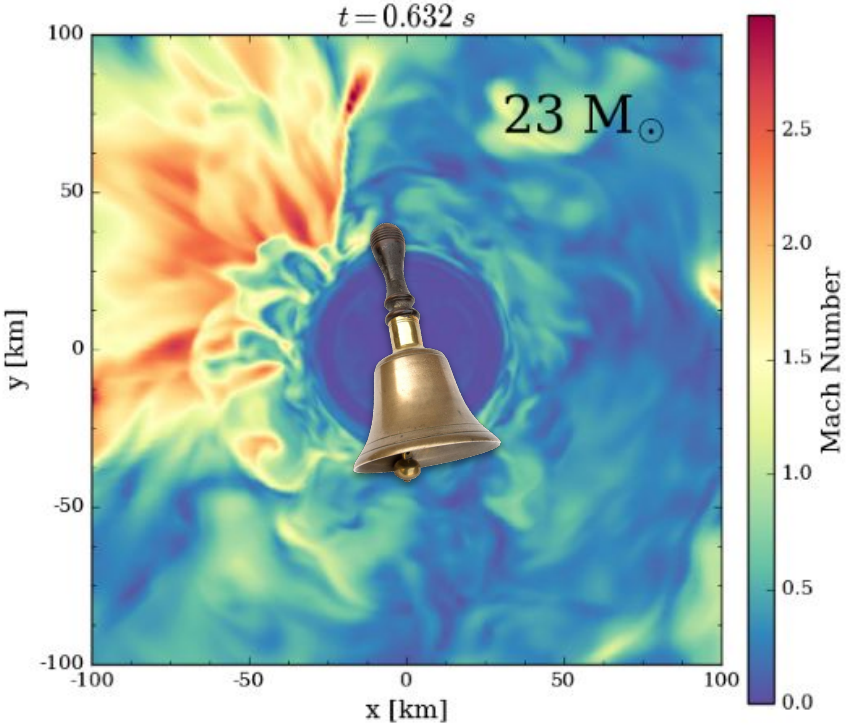
t = 0.011 s

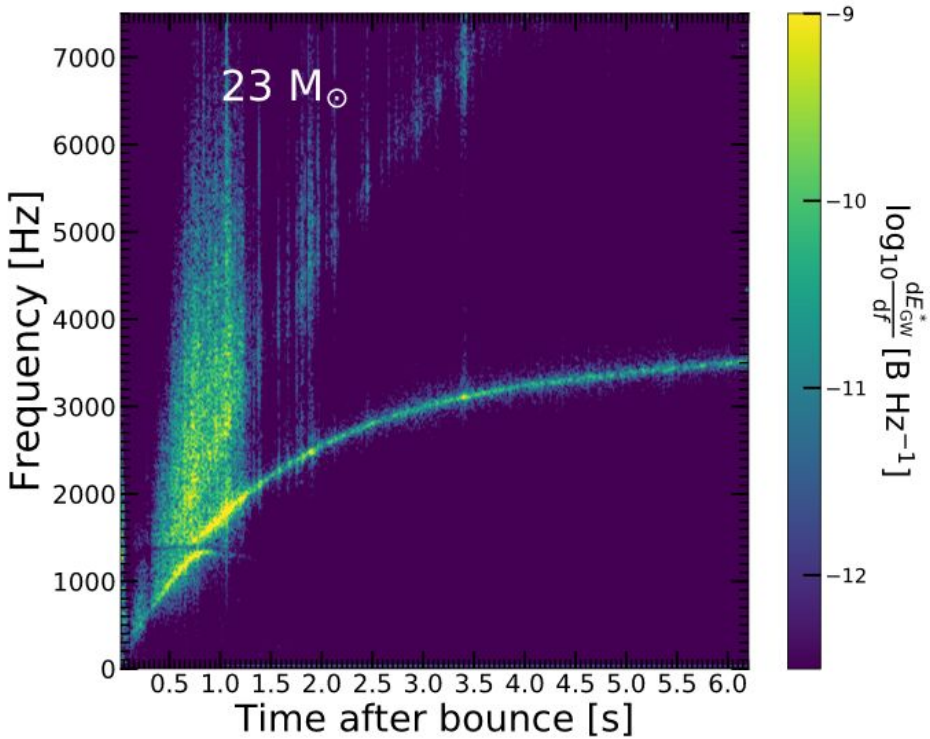
Gravitational-wave signal



From Vartanyan+, PRD 107:103015 (2023)

Gravitational-wave spectrum

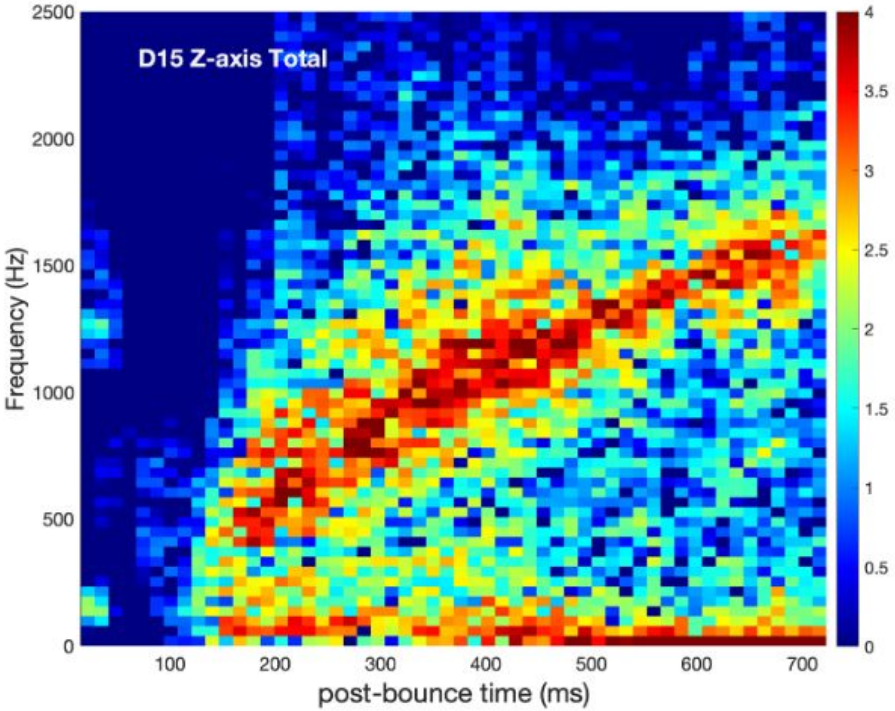




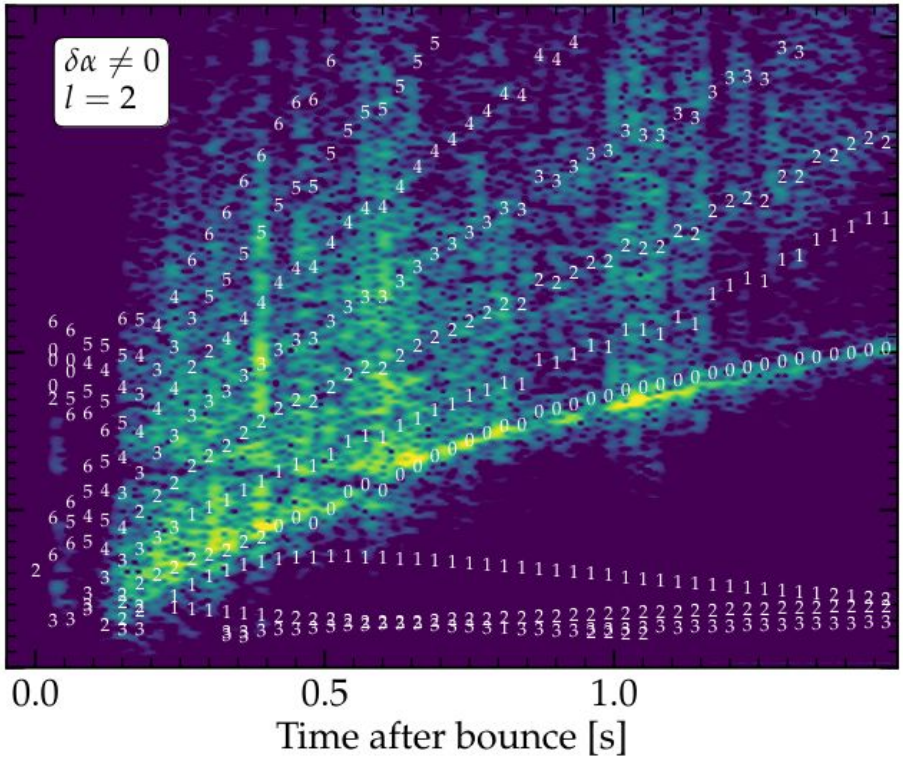
See also Murphy+ 2009; Andresen+ 2017; Mezzacappa+ 2023; …

From Vartanyan+, PRD 107:103015 (2023)

Protoneutron star astroseismology

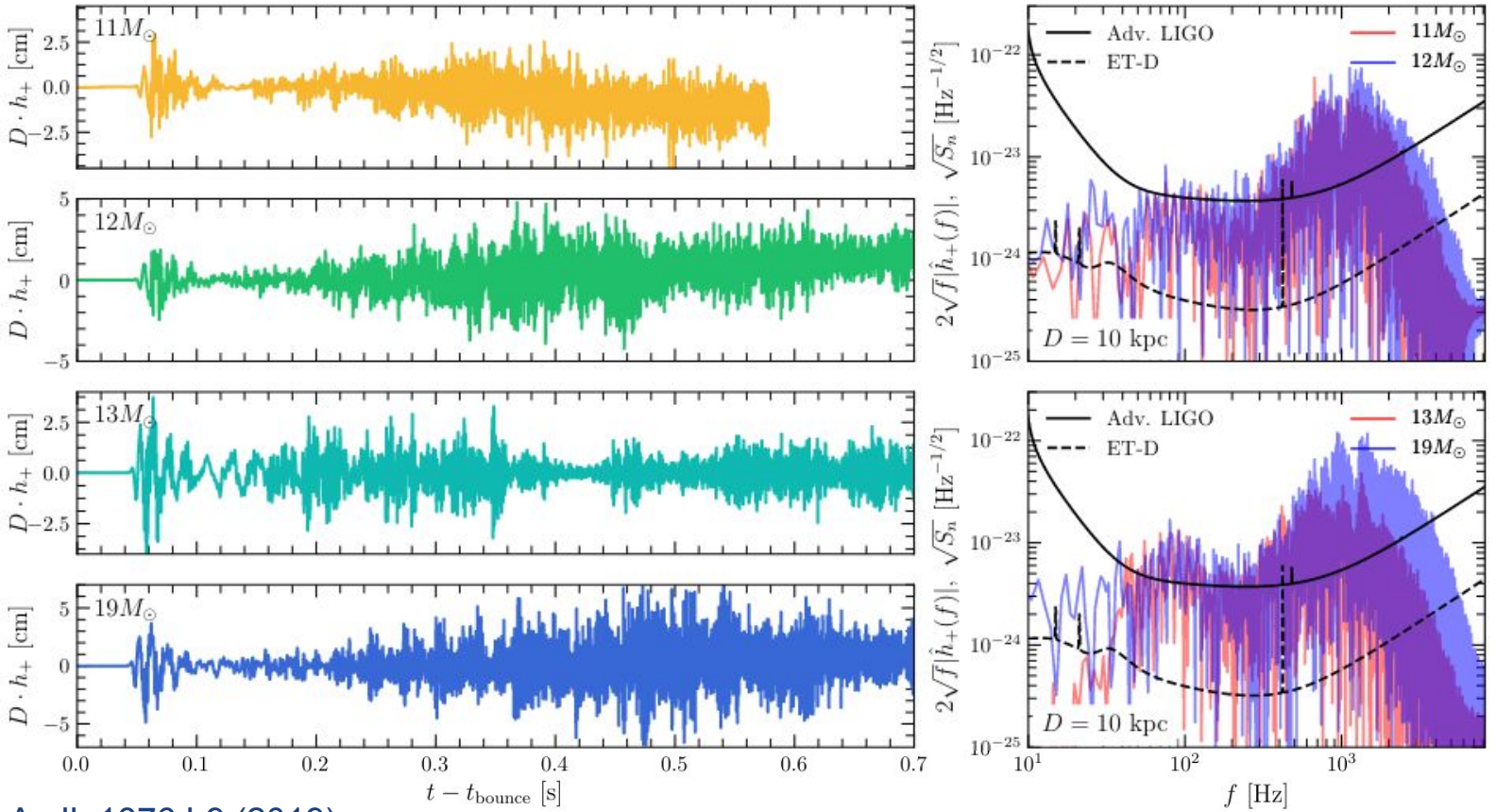


Mezzacappa+, PRD 107:043008 (2023)



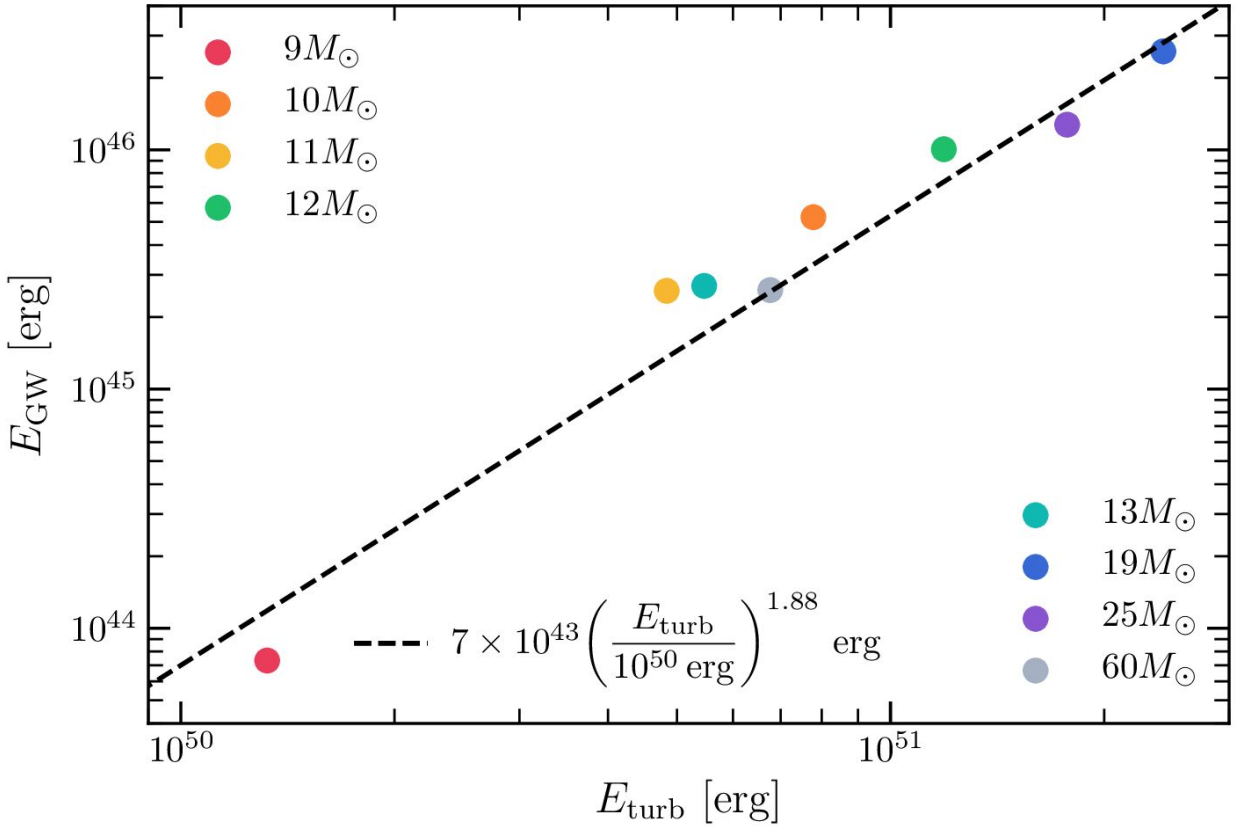
Morozova+, ApJ 861:10 (2018)

Detectability



Radice+, ApJL 1876:L9 (2019)

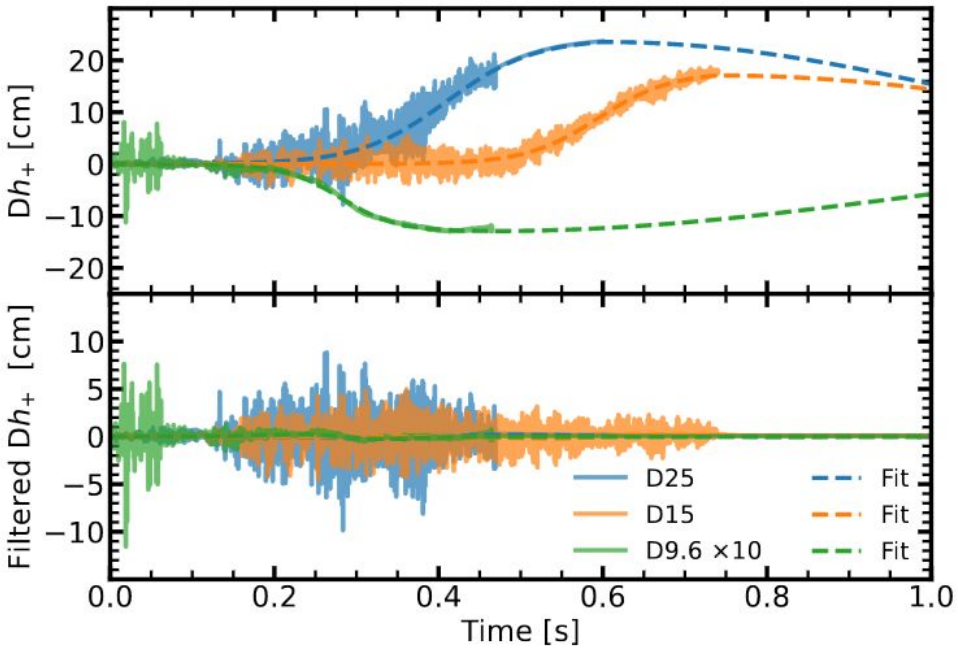
Gravitational-wave power

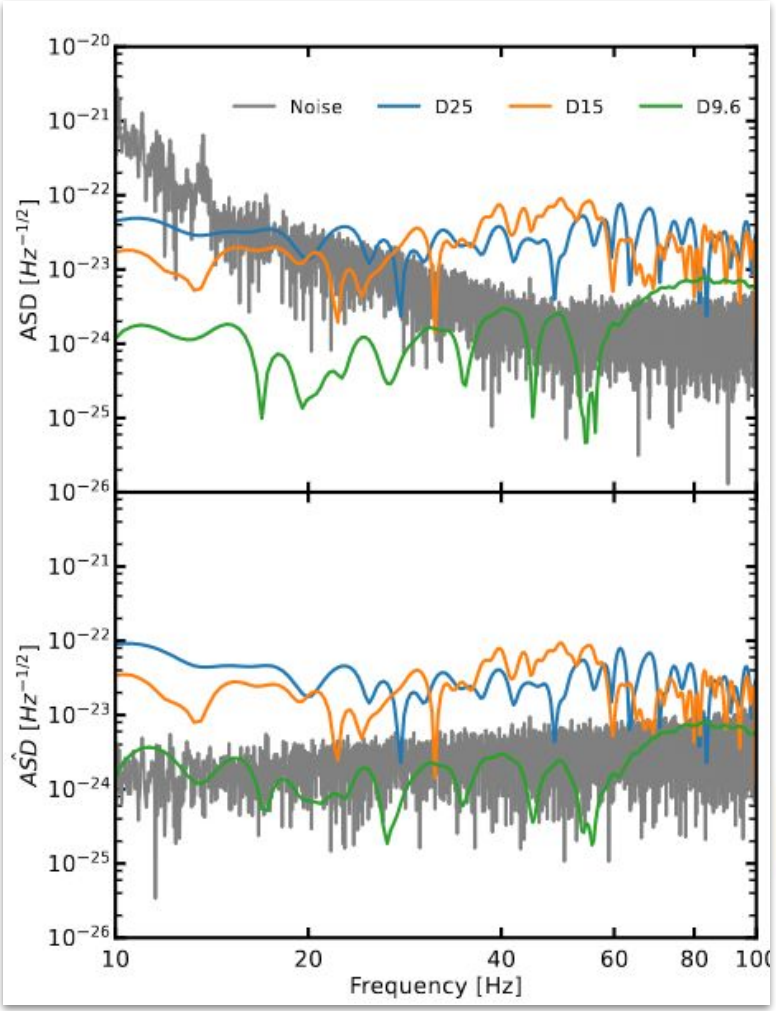


See also Powell+2019, Vartanyan+ 2023, …

Radice+, ApJL 1876:L9 (2019)

Gravitational-wave memory

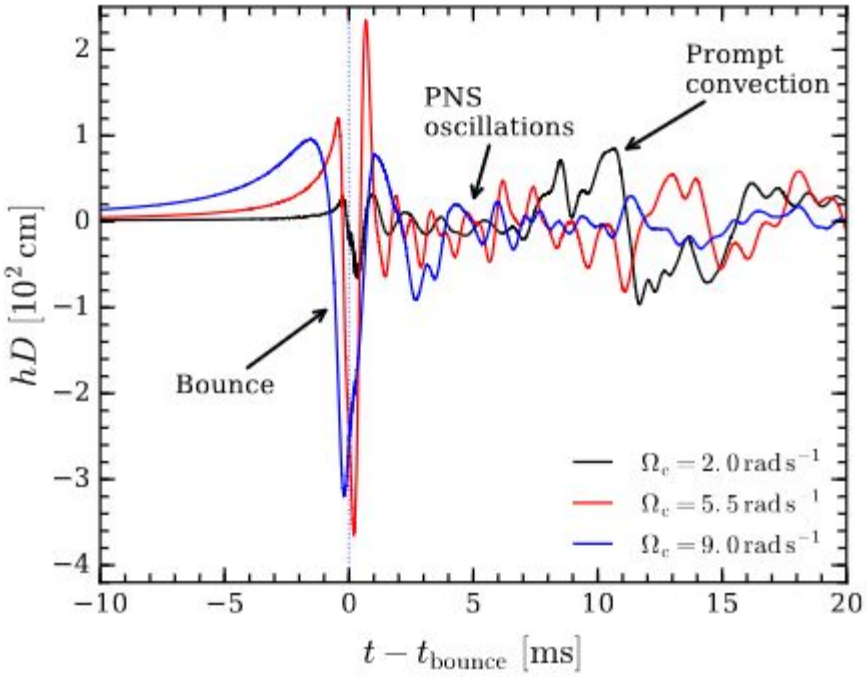




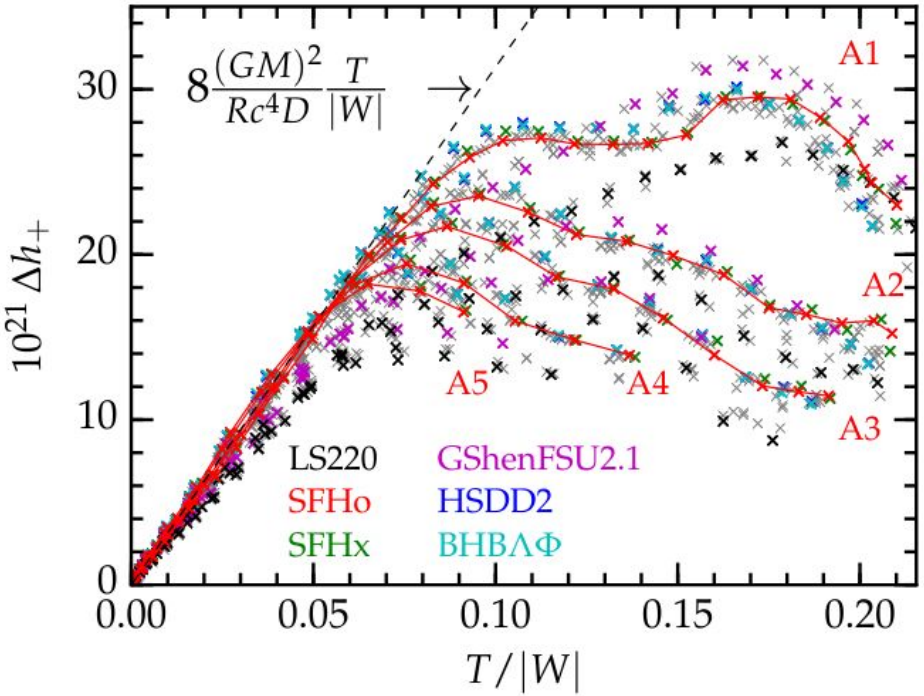
GW memory from the next galactic CCSN!

From Richardson+, 2404.-2131

Rotating collapse

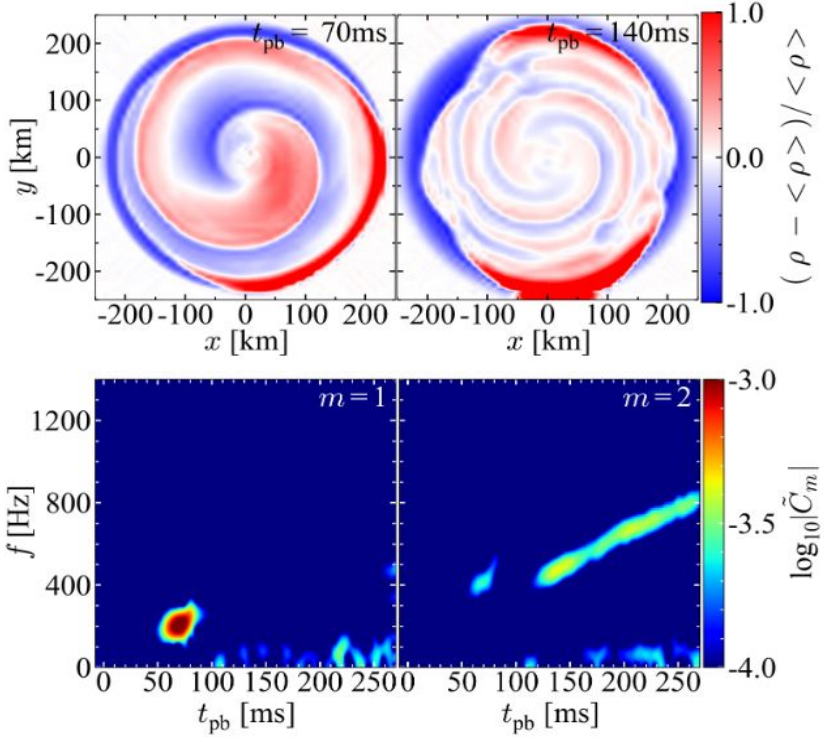


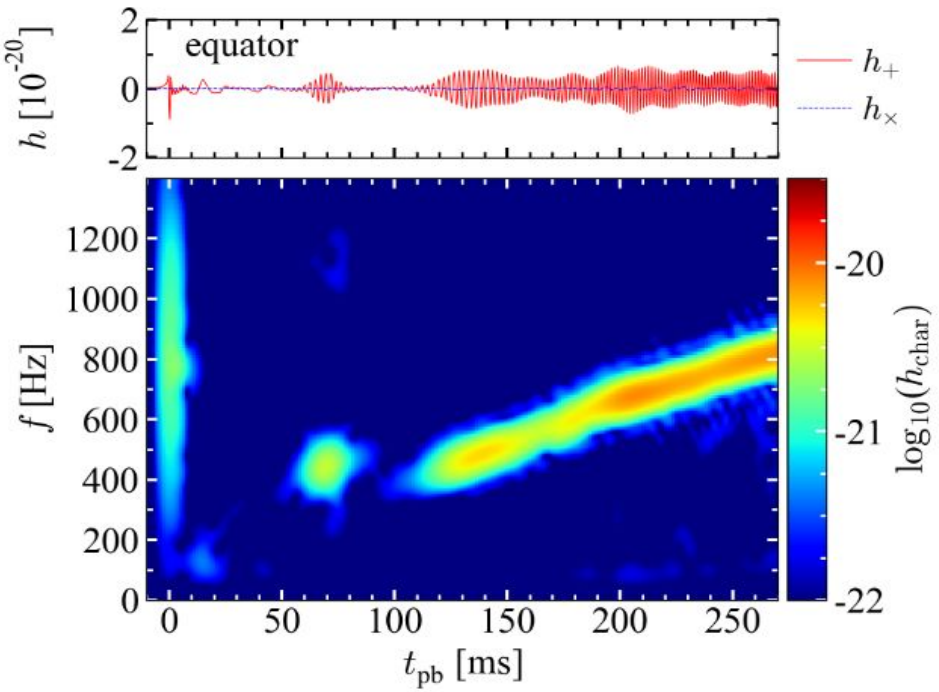
From Abdikamalov+ 2017



From Richers+ PRD 95:063019 (2017)

Low-T/|W| instability

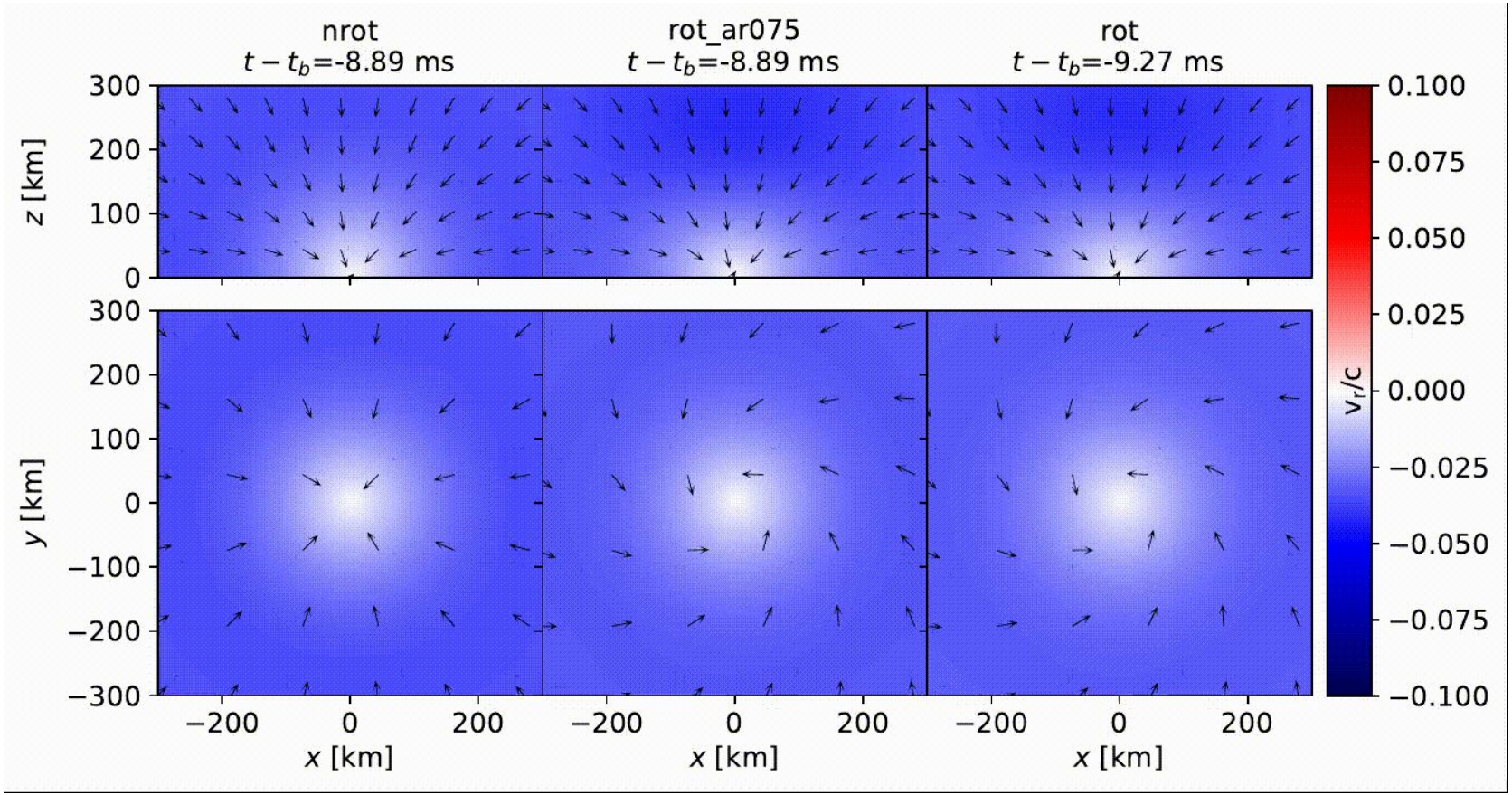




See also Kotake 2013; Bugli+ 2022; Longo+ 2023; …

From Shibagaki+, MNRAS 493:L138 (2019)

Accretion induced collapse of white dwarfs



From Longo+, MNRAS 525:6359 (2023)

Conclusions

The next galactic CCSN will be the multi-messenger event of the century!

- Slowly rotating supernovae (~99%)
  - Protoneutron star astroseismology
  - Turbulence energy in the engine
  - Explosion asymmetries
- Fast-rotating supernovae (~1-?%)
  - Strong, deterministic rotational signal
  - Low-T/|W| instability is detectable to few Mpc (with CE)
  - Unclear rate
- Theory challenges
  - Simulations are very expensive
  - Excitation mechanism for PNS unclear
  - Stellar evolution models are only provisional
  - …