Neutrino Signature from Multi-D Supernova Models

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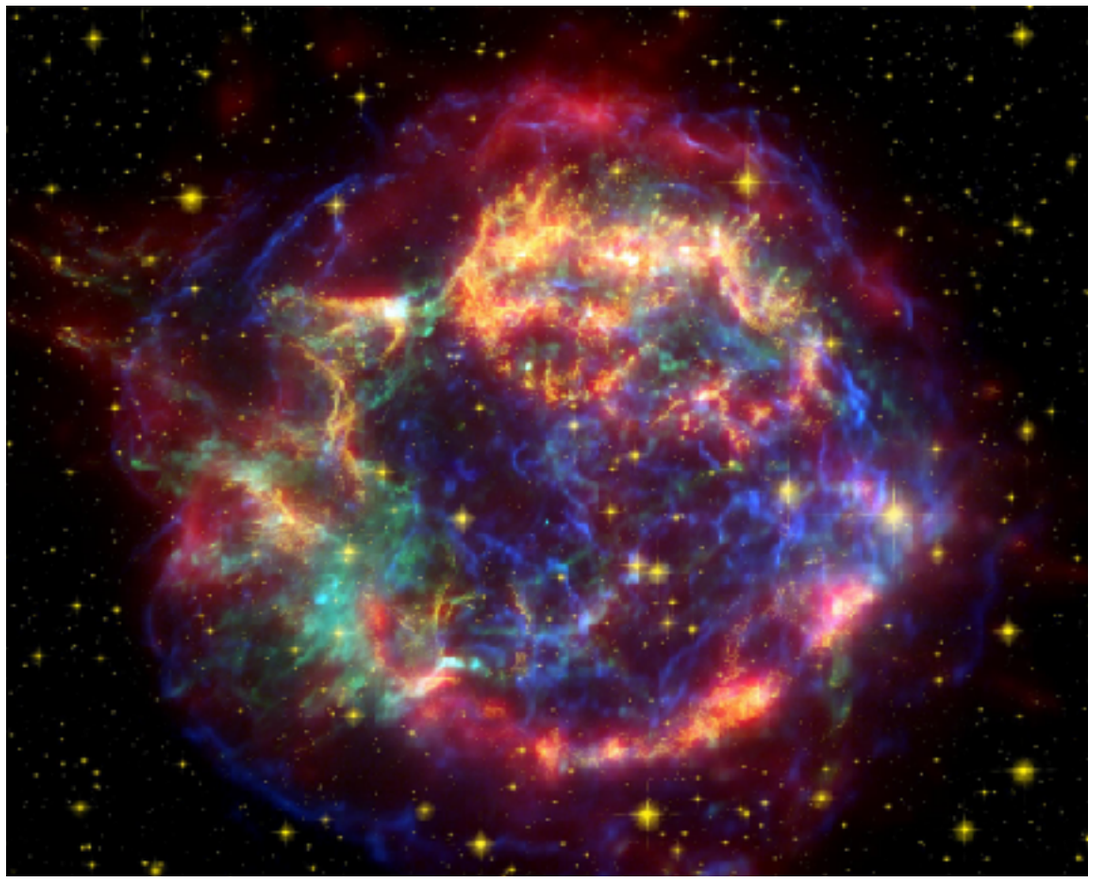
νECLIPSE 2017

Core-Collapse Supernovae



Cassiopeia-A

- ~ (50 yr)$^{-1}$ per galaxy
- few every second in the observable universe
- Peak luminosity ~10^{10} solar
- 10^{48} erg EM radiation
- 10^{51} erg kinetic energy
- 10^{53} erg neutrinos

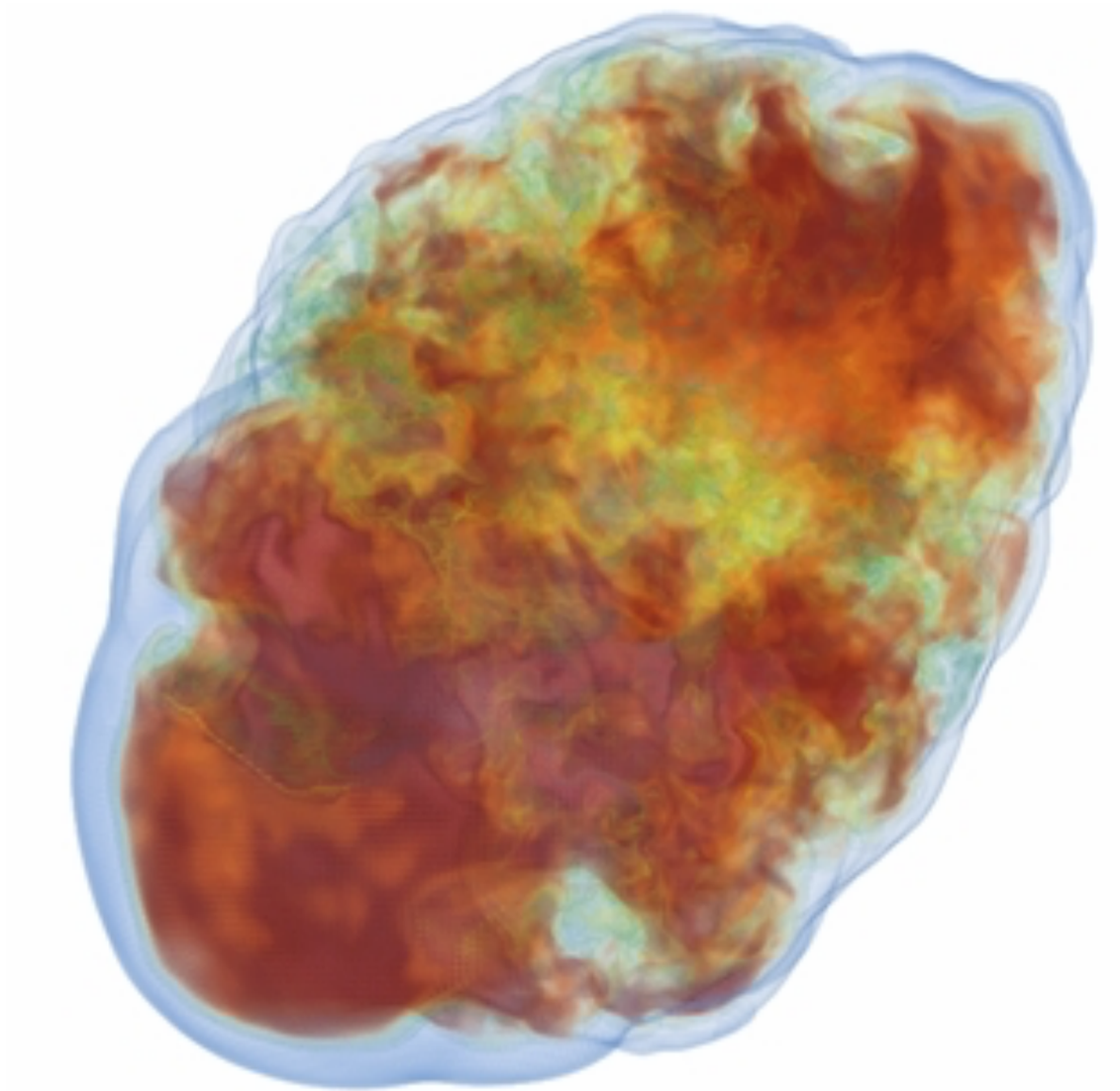
Problem: how do they explode?

Neutrinos could tell us!

Numerical Modeling

- General relativistic gravity
- Hydrodynamics
- Nuclear equation of state
- Neutrino radiation transport

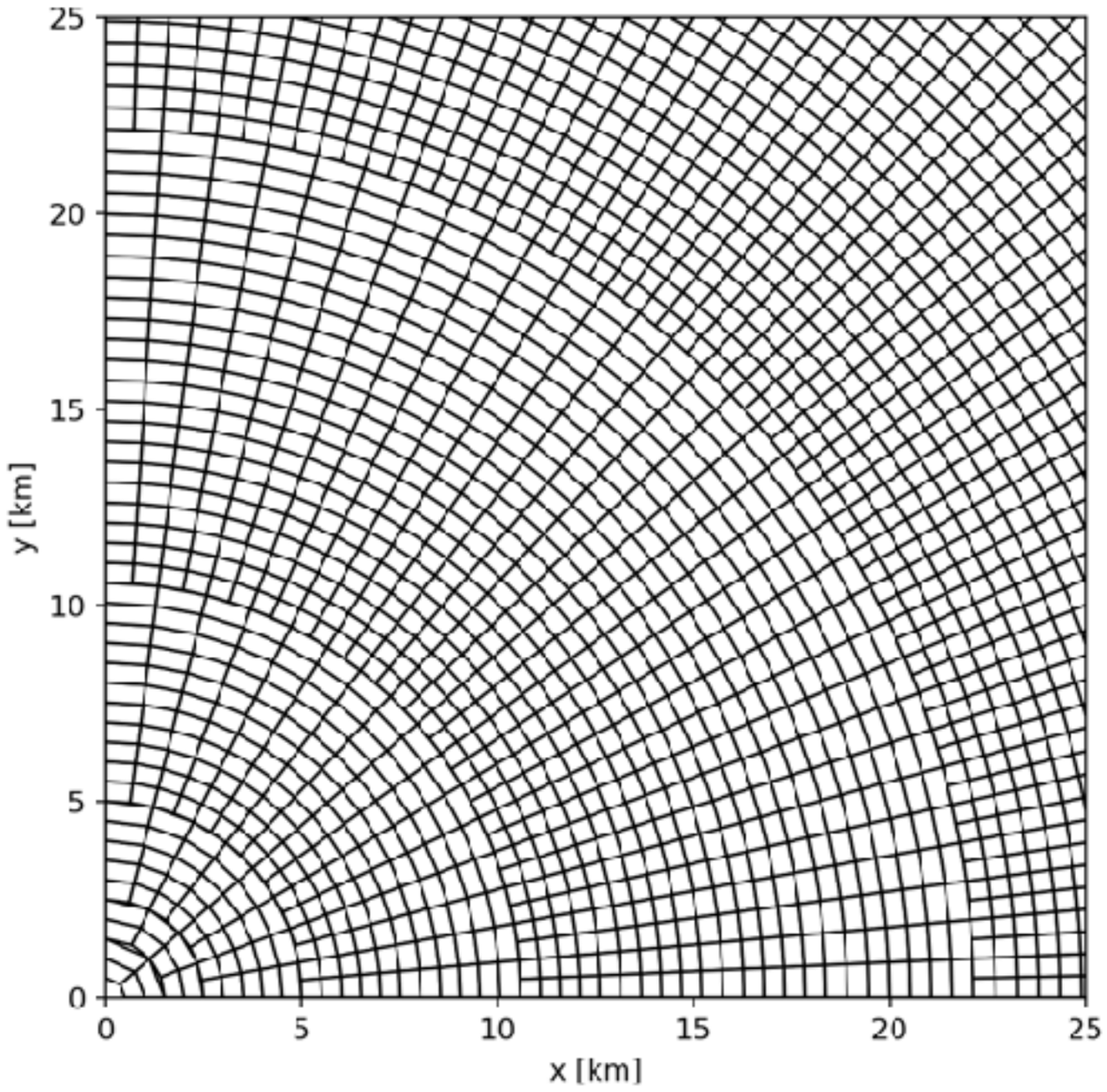
- First 1D simulations Colgate & White 1966
- First 1D full-physics simulations only early 2000s



From Dolence, Burrows, et al. 2013

No single multi-D code has everything!

Fornax



- A new CCSN code
- Spherical dendritic grid
- Multi-dimensional M1 neutrino O(v/c) transport
- Newtonian with effective GR potential
- 1D, 2D, and 3D

Dolence, Skinner, et al., in prep 2017

Current Efforts in Princeton*

- Explosion mechanism: crucial physical dependencies
  [Burrows, Vartanyan, …, DR 2016 — Vartanyan et al., in prep 2017]

- Low-mass progenitors: electron-capture vs regular CCSNe
  [DR, Burrows, et al. 2017]

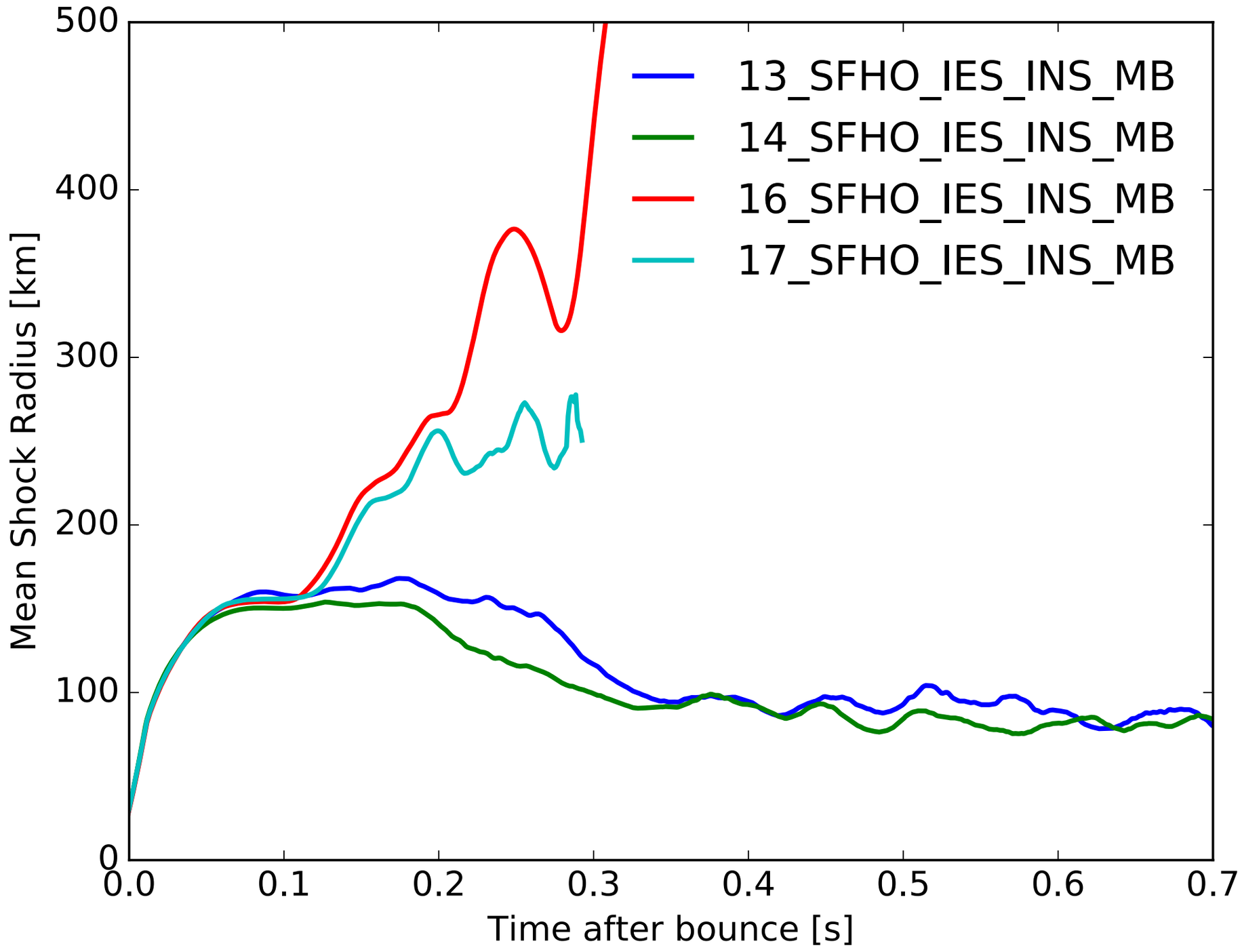
- Neutrino detection: shock-breakout burst
  [Wallace, Burrows, and Dolence 2016]

- Neutrino detection: explosion signatures
  [Seadrow et al., in prep 2017]

- Stay tuned for 3D results!

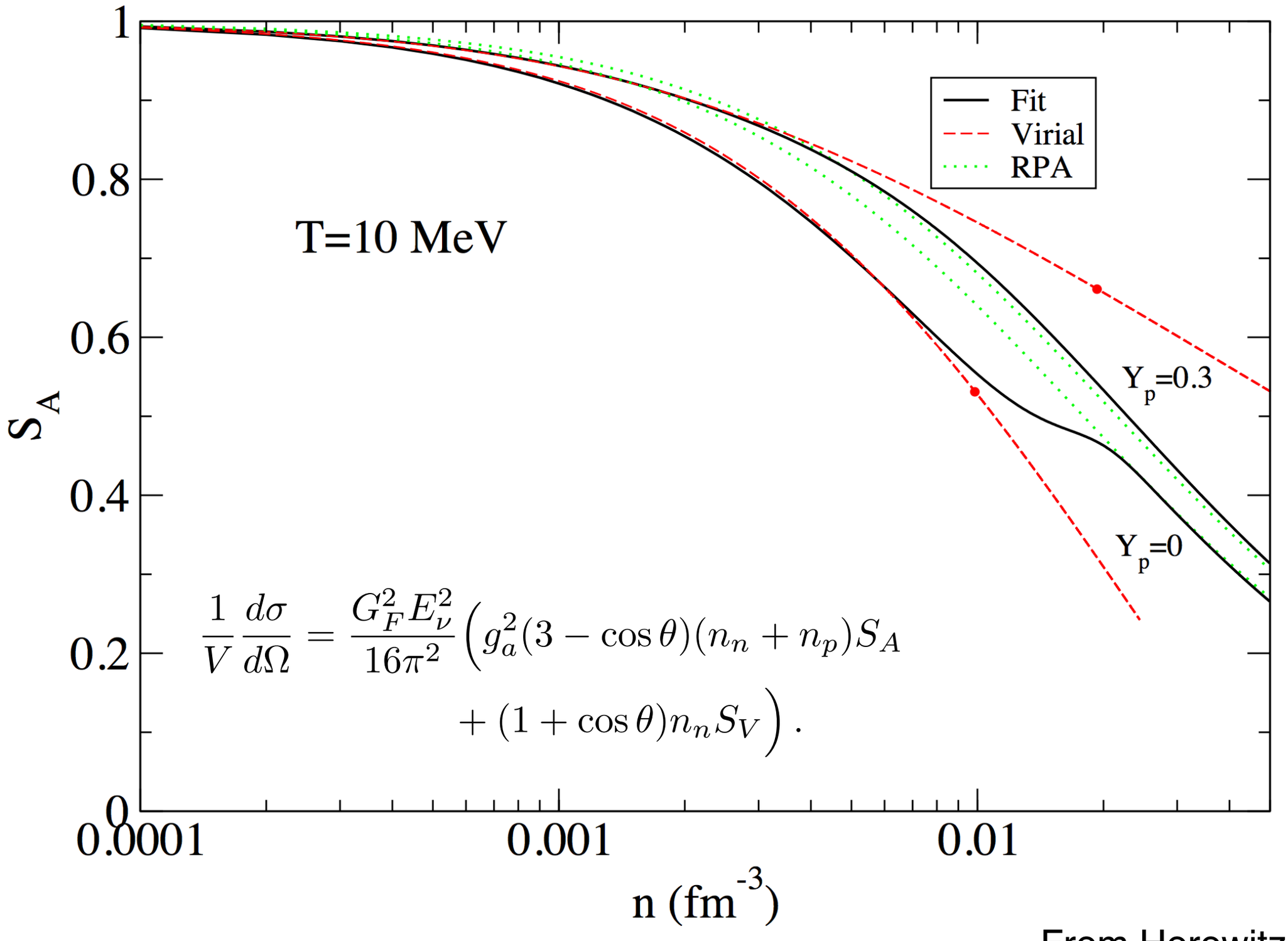
* and collaborators at LANL, LLNL

Massive Star Explosions



Vartanyan et al., in prep 2017

Many-Body Effects



From Horowitz et al. 2017

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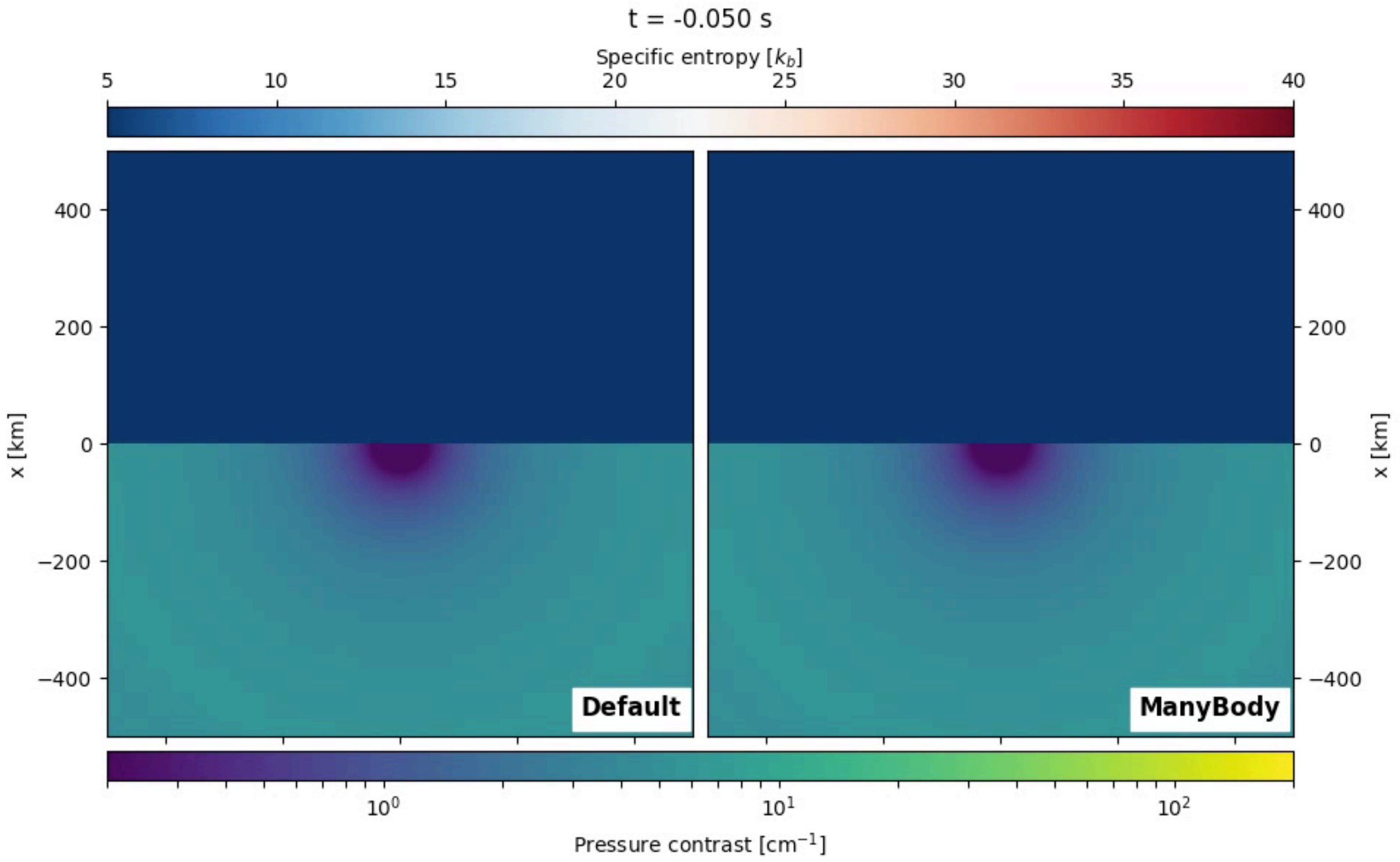

s9.0-LS220

DR, Burrows, et al 2017

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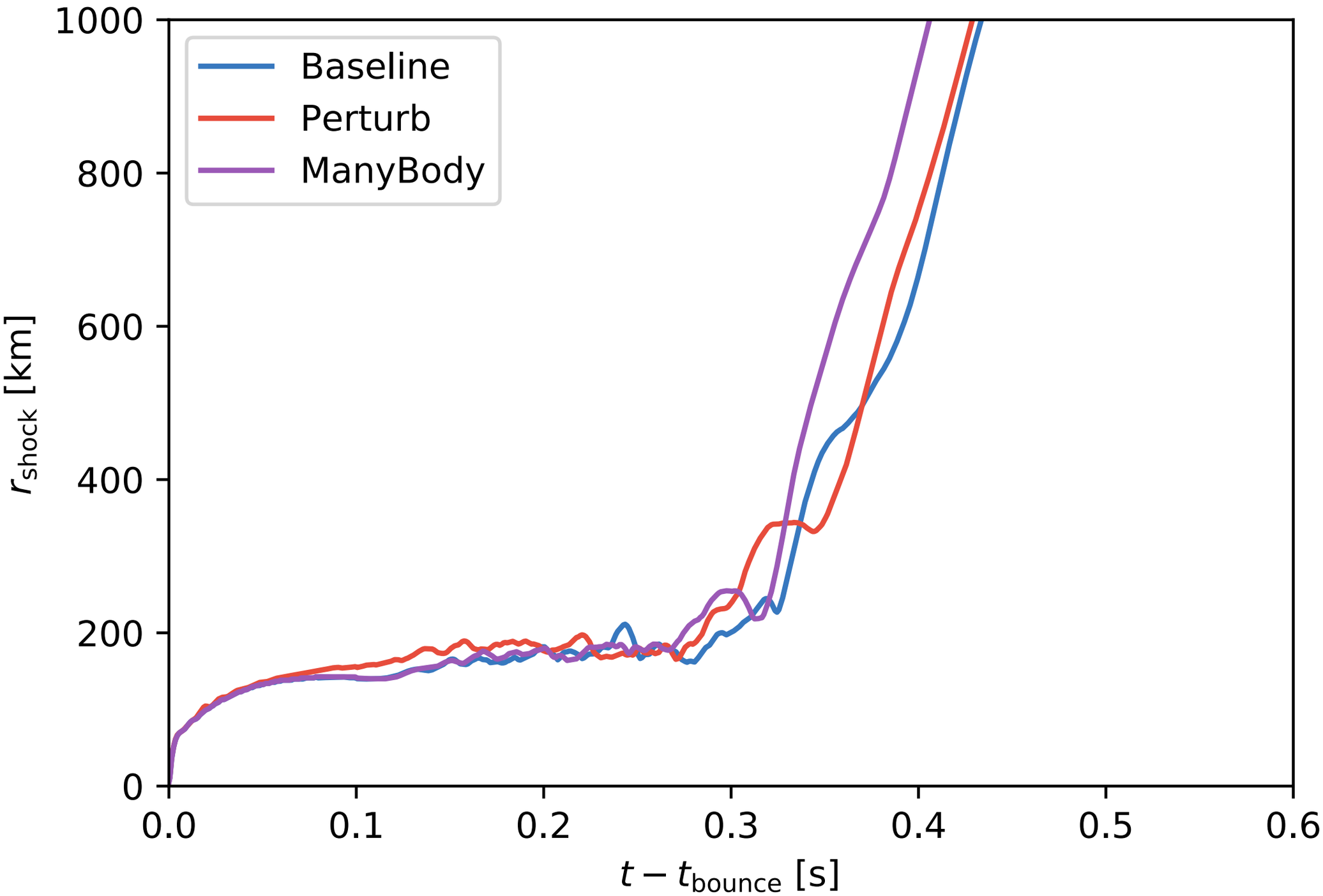

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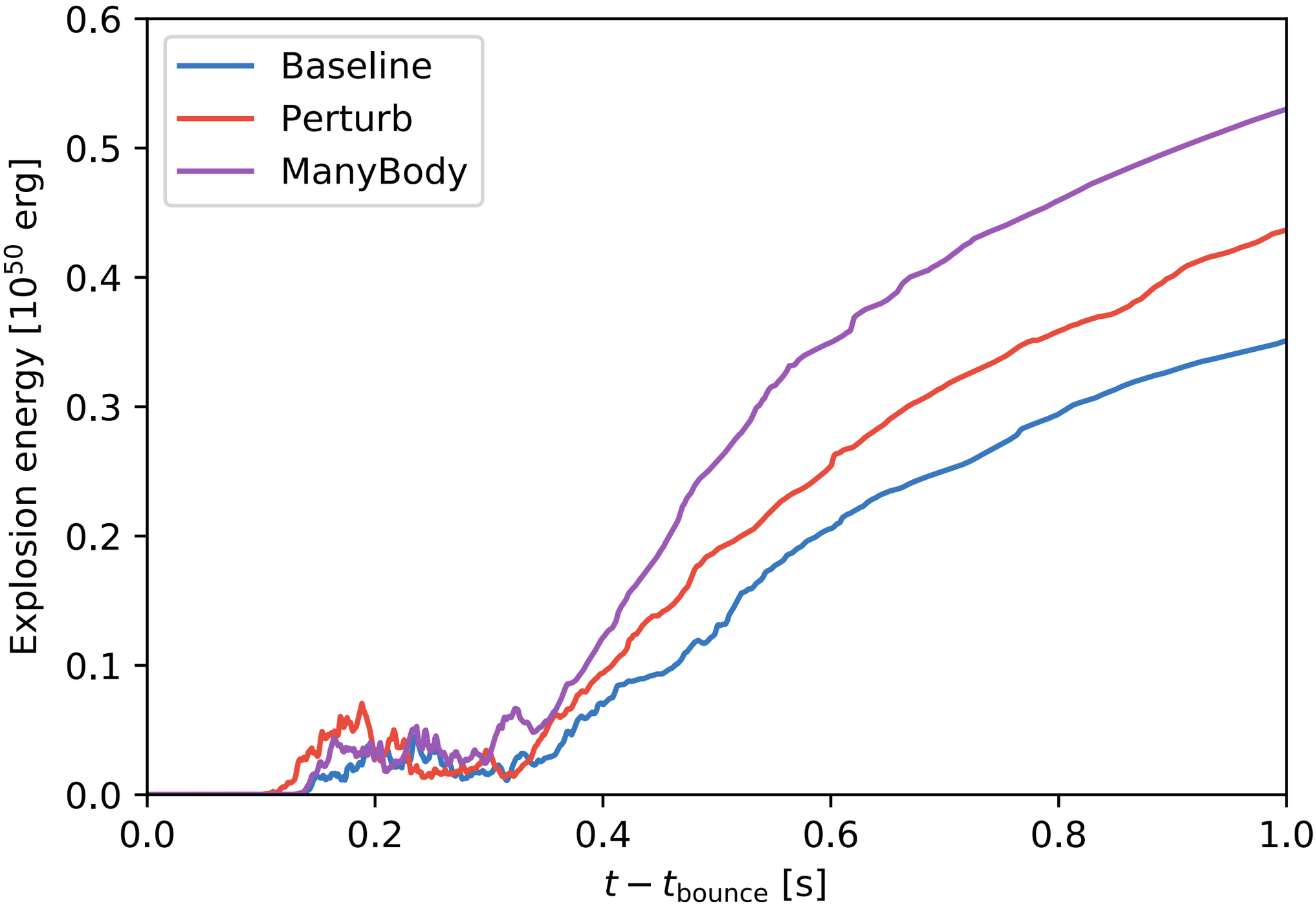

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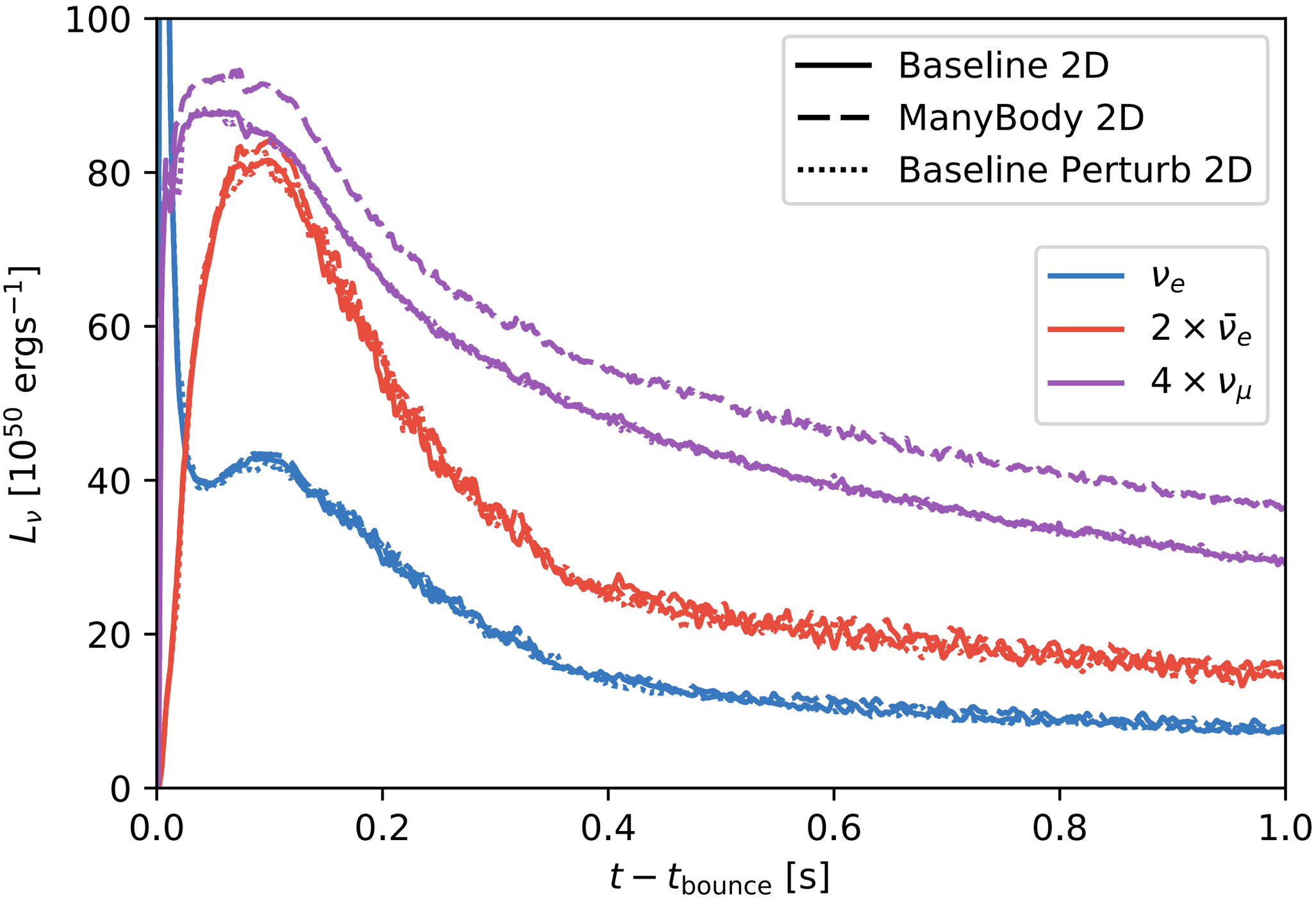

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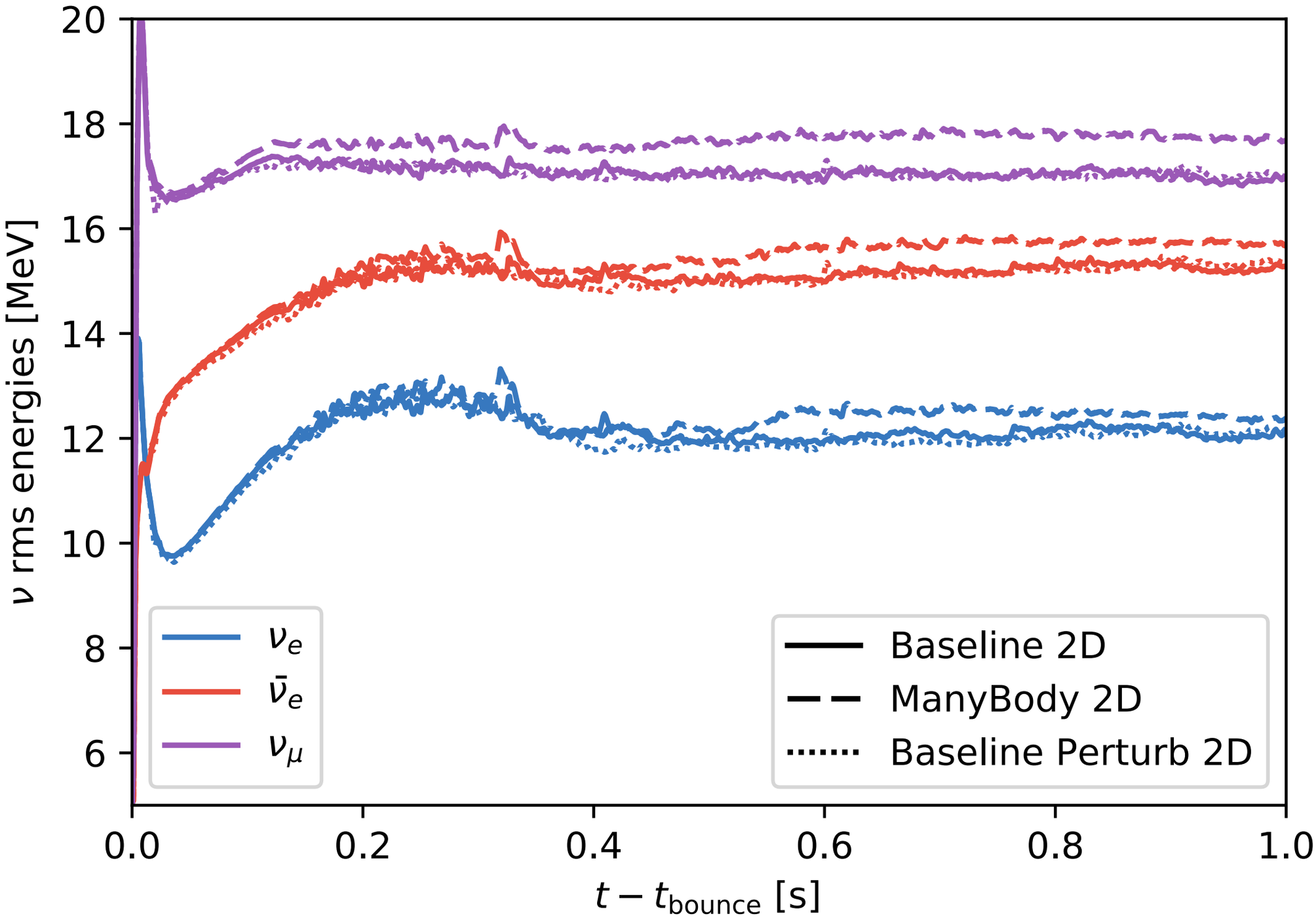

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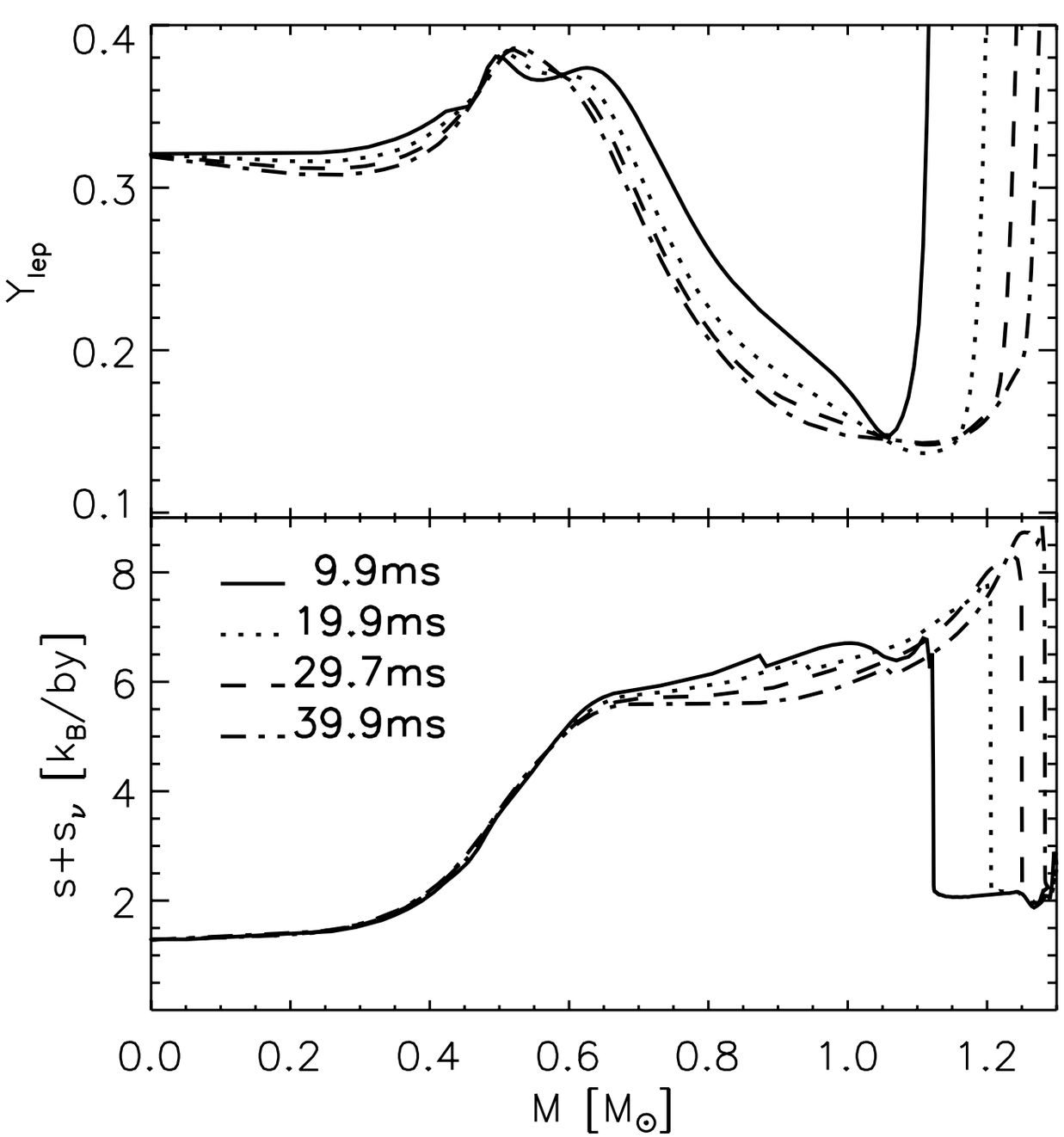
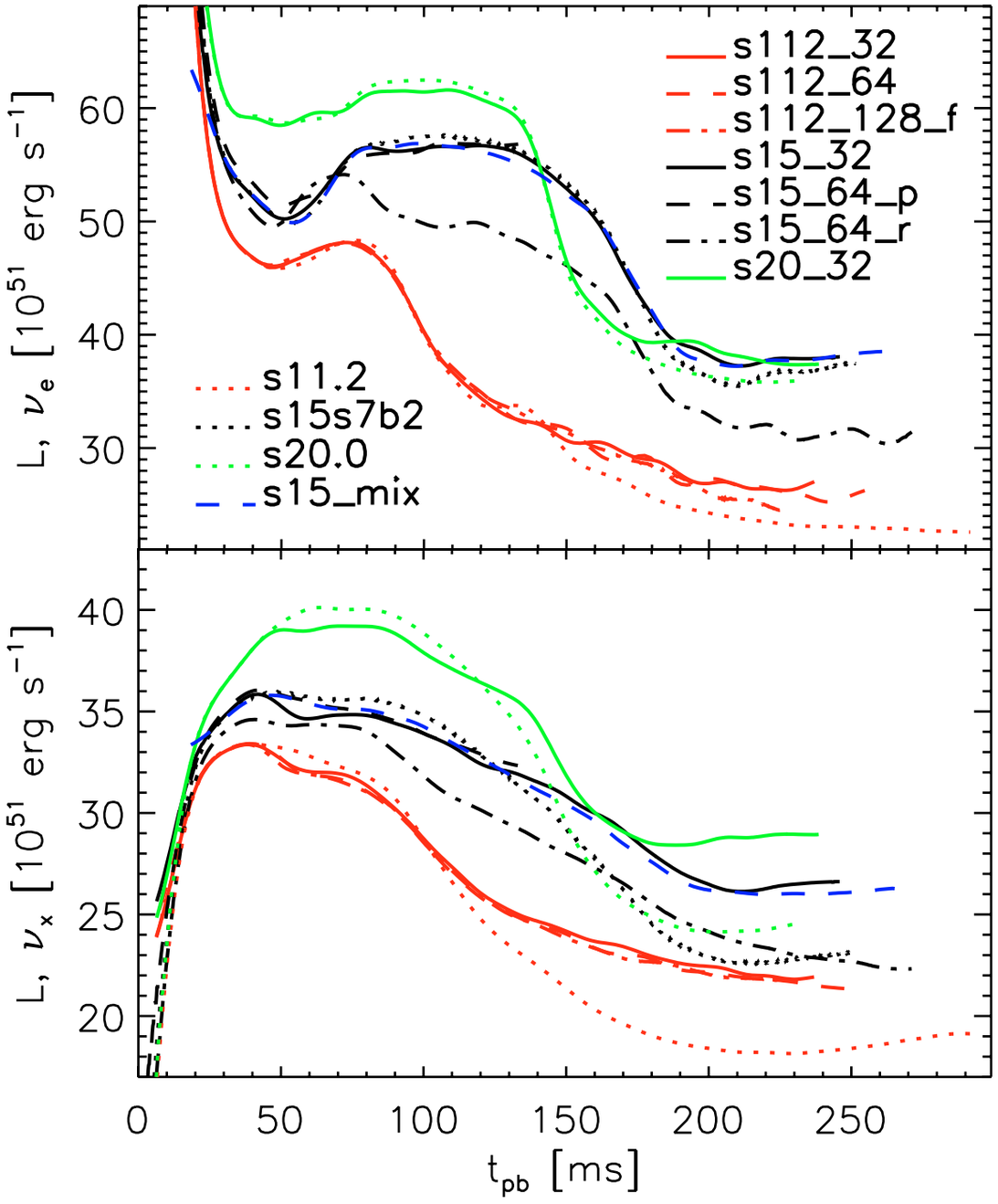
DR, Burrows, et al 2017

Protoneutron Star Convection





From Buras et al 2006

See also Dessart, Burrows et al. 2006

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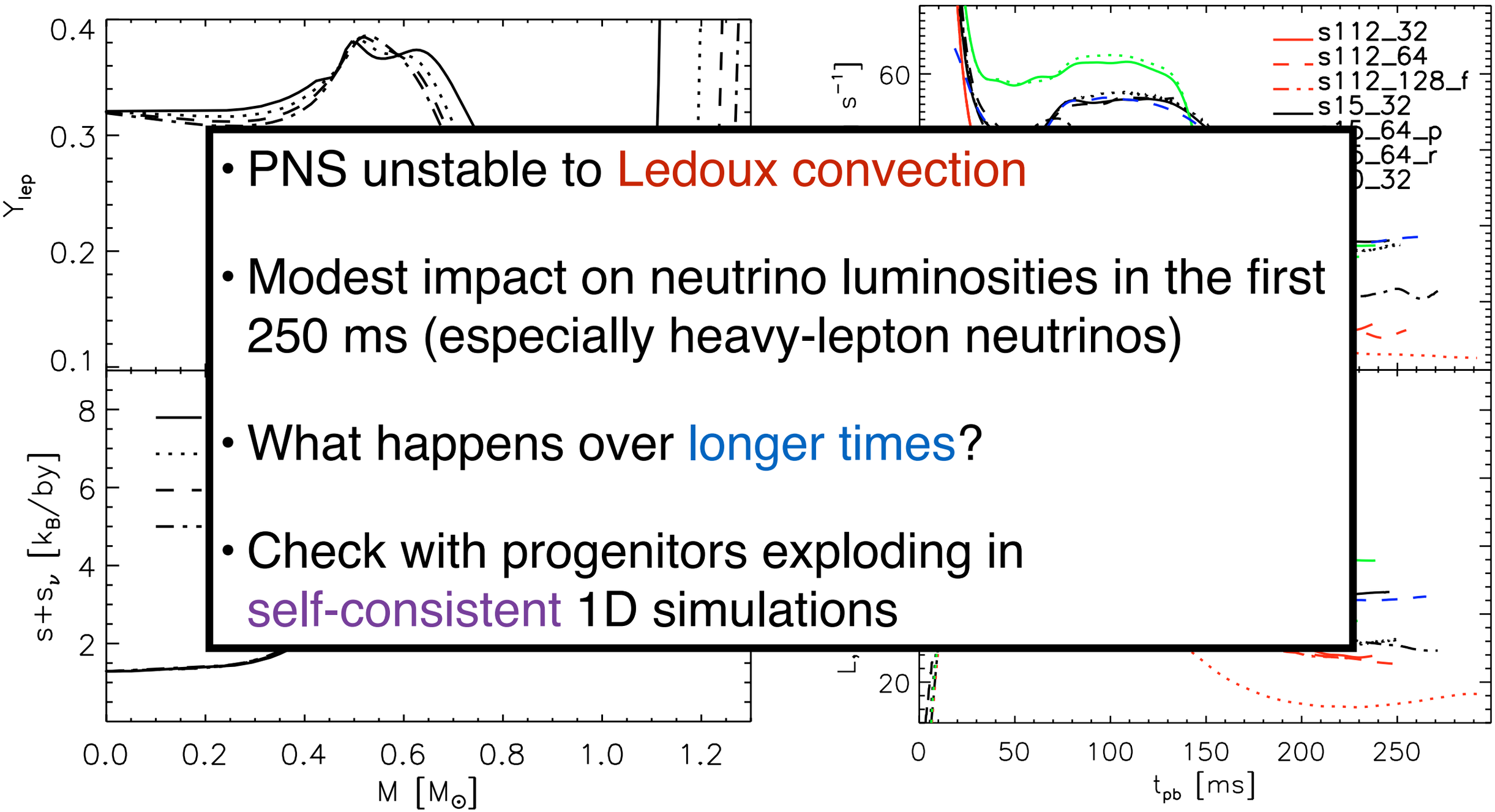
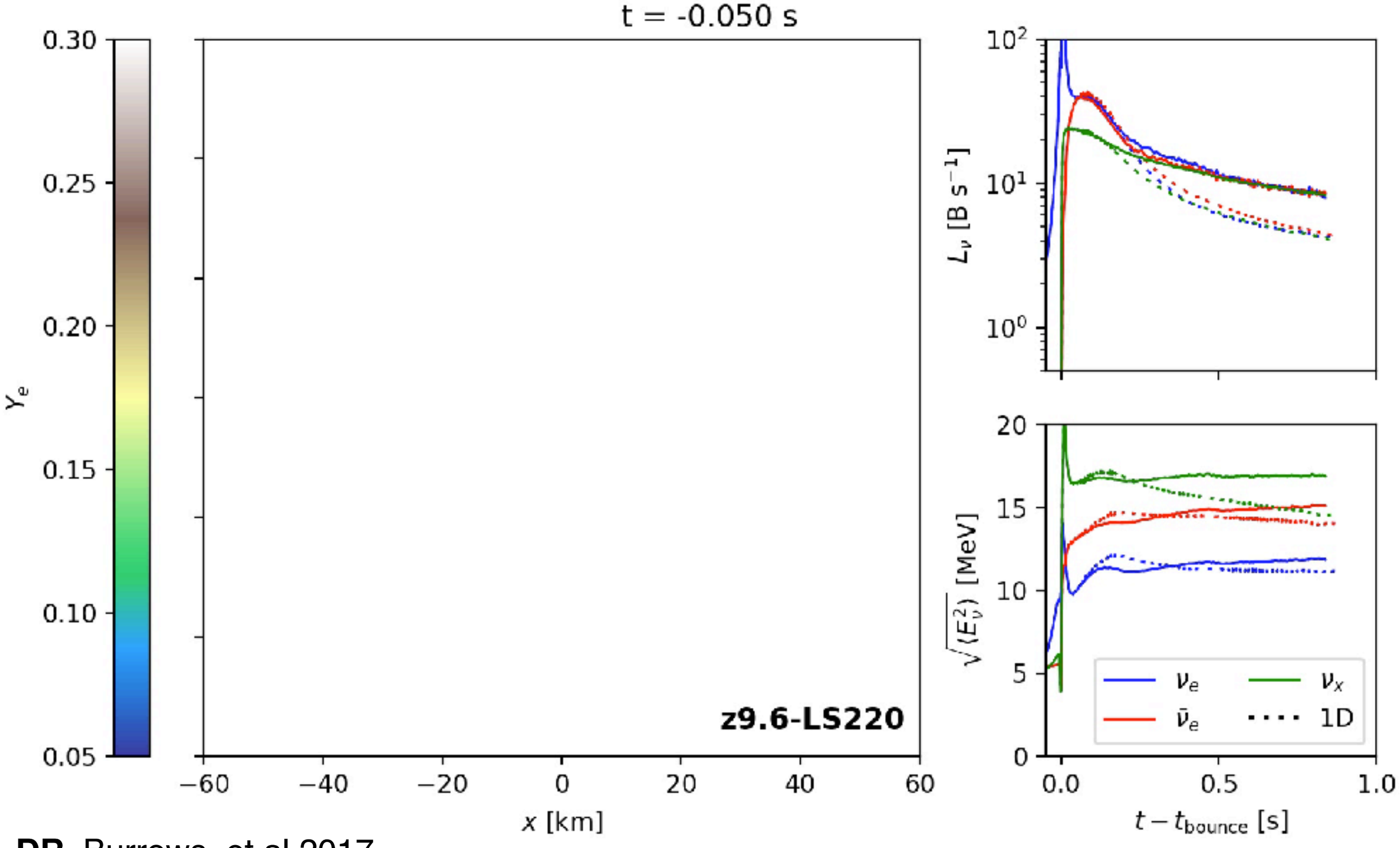


- PNS unstable to Ledoux convection
- Modest impact on neutrino luminosities in the first 250 ms (especially heavy-lepton neutrinos)
- What happens over longer times?
- Check with progenitors exploding in self-consistent 1D simulations

From Buras et al 2006

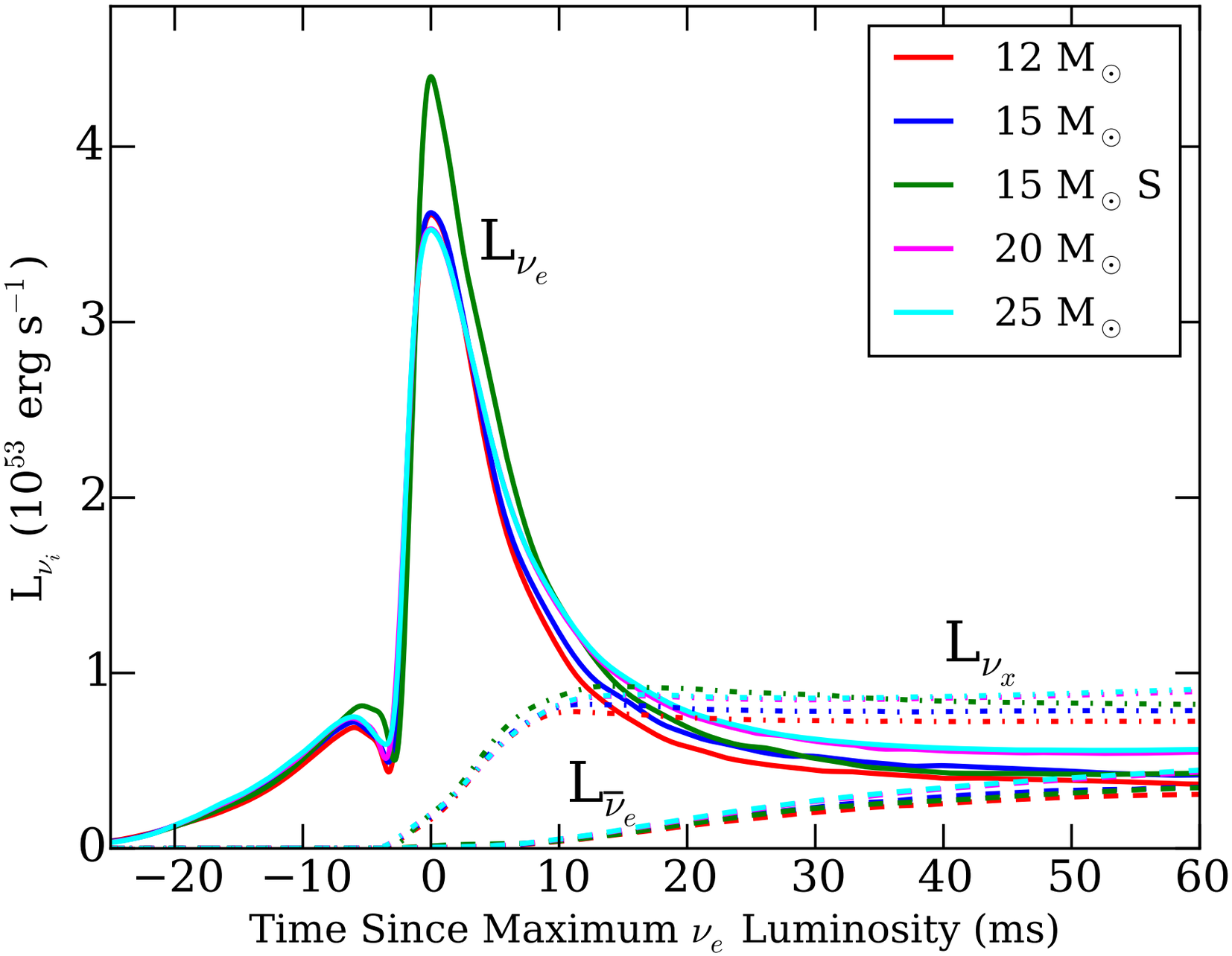
See also Dessart, Burrows et al. 2006

Protoneutron Star Convection



DR, Burrows, et al 2017

Shock Breakout Signal



Wallace, Burrows, and Dolence 2016

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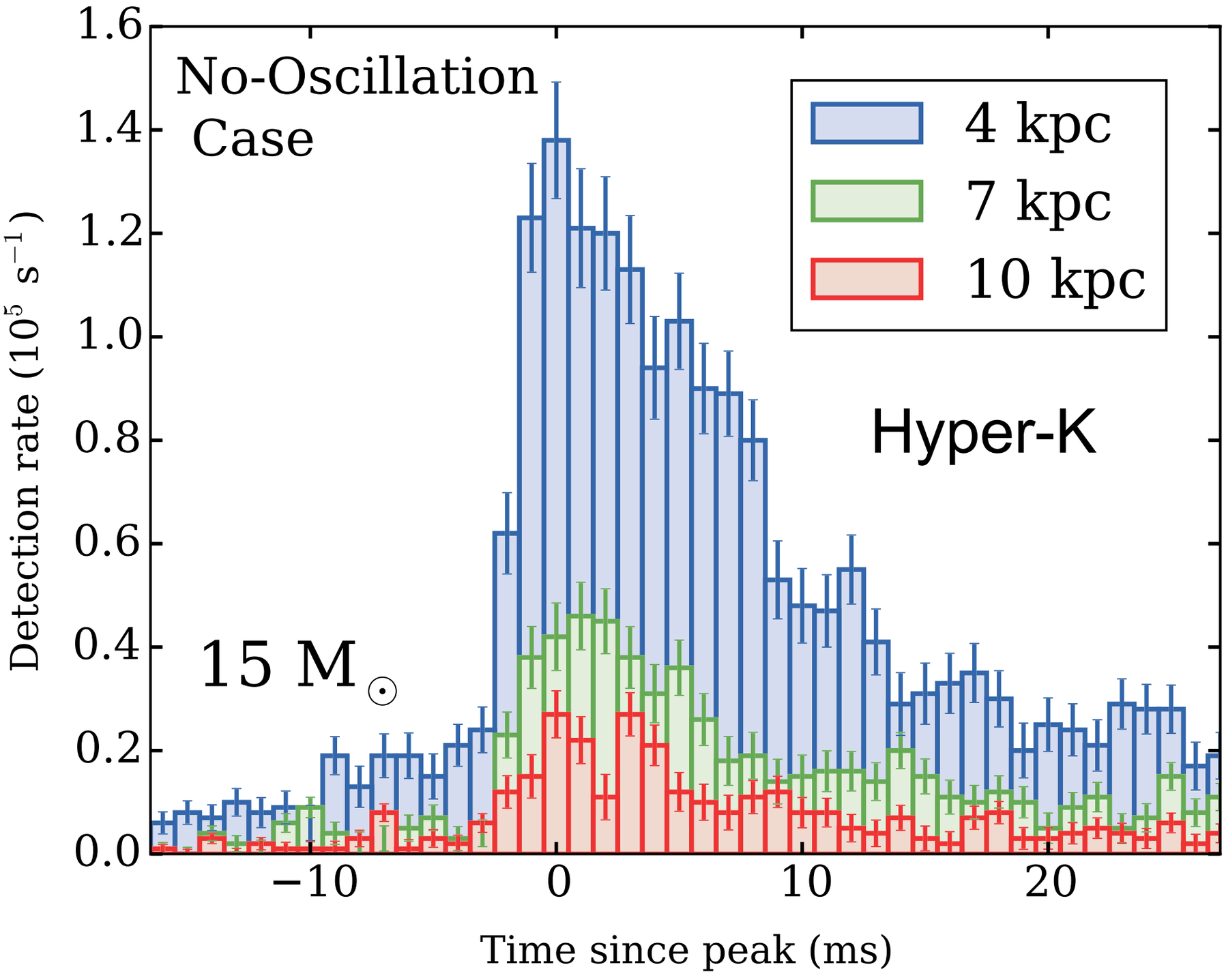

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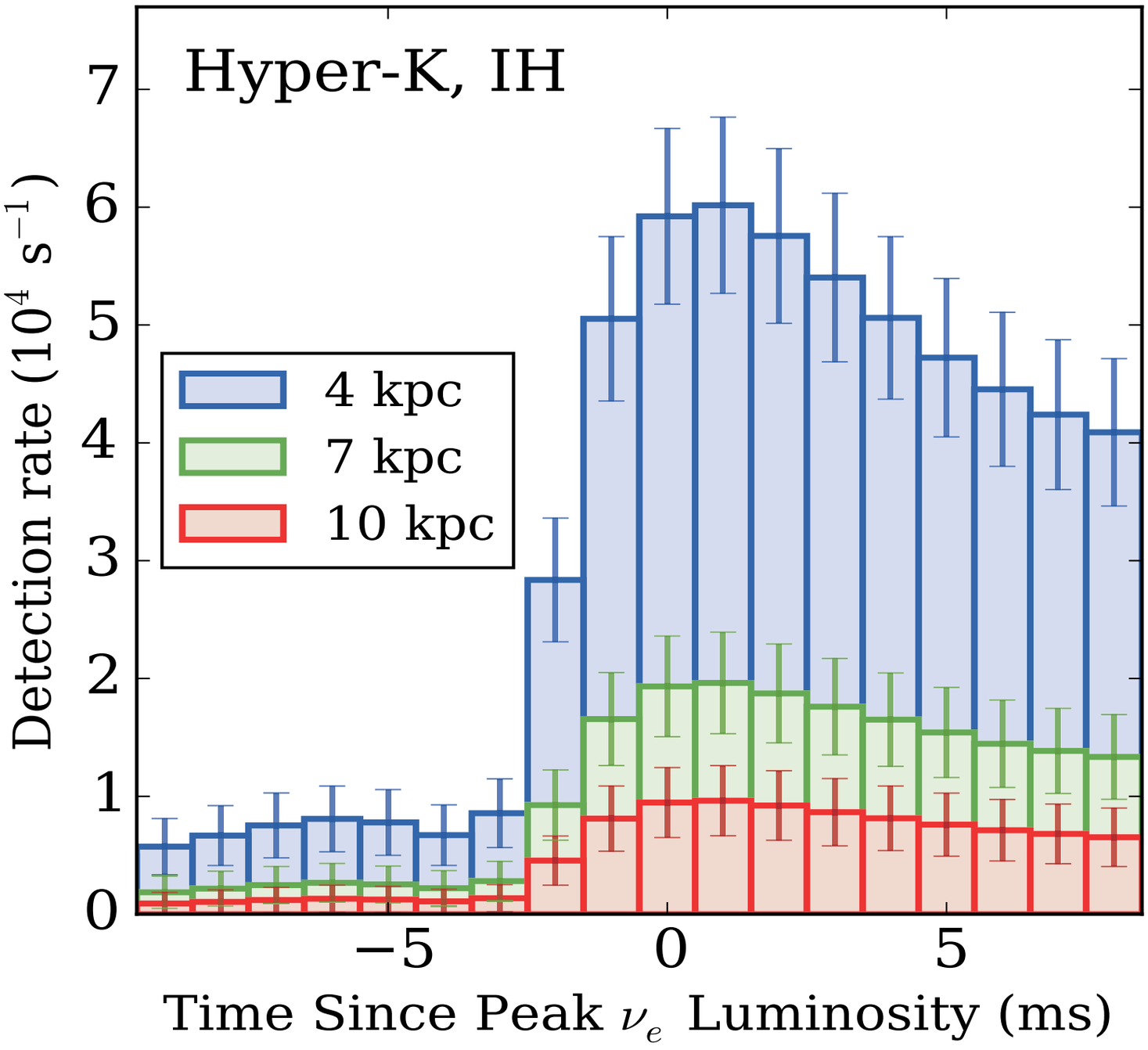

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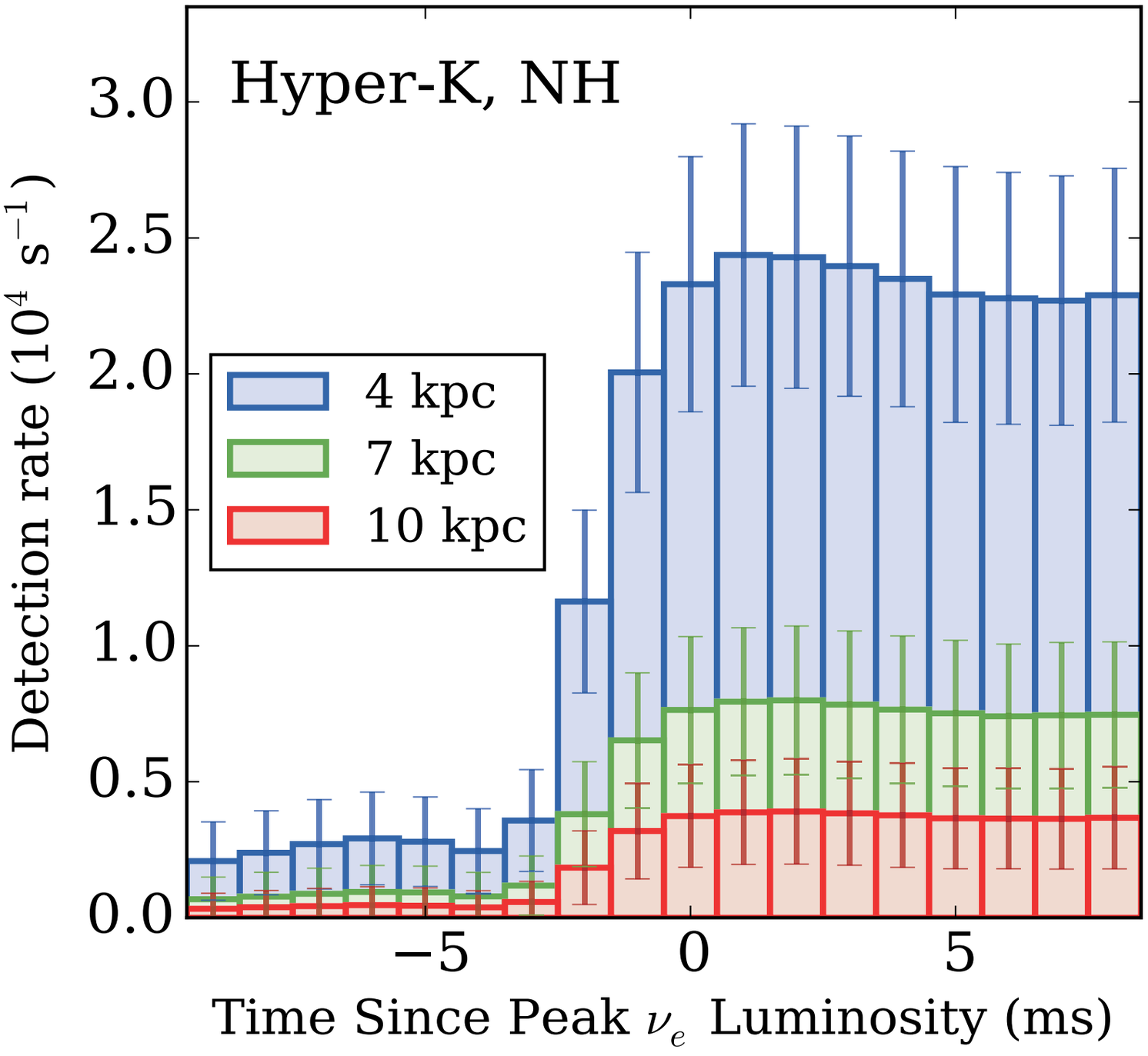

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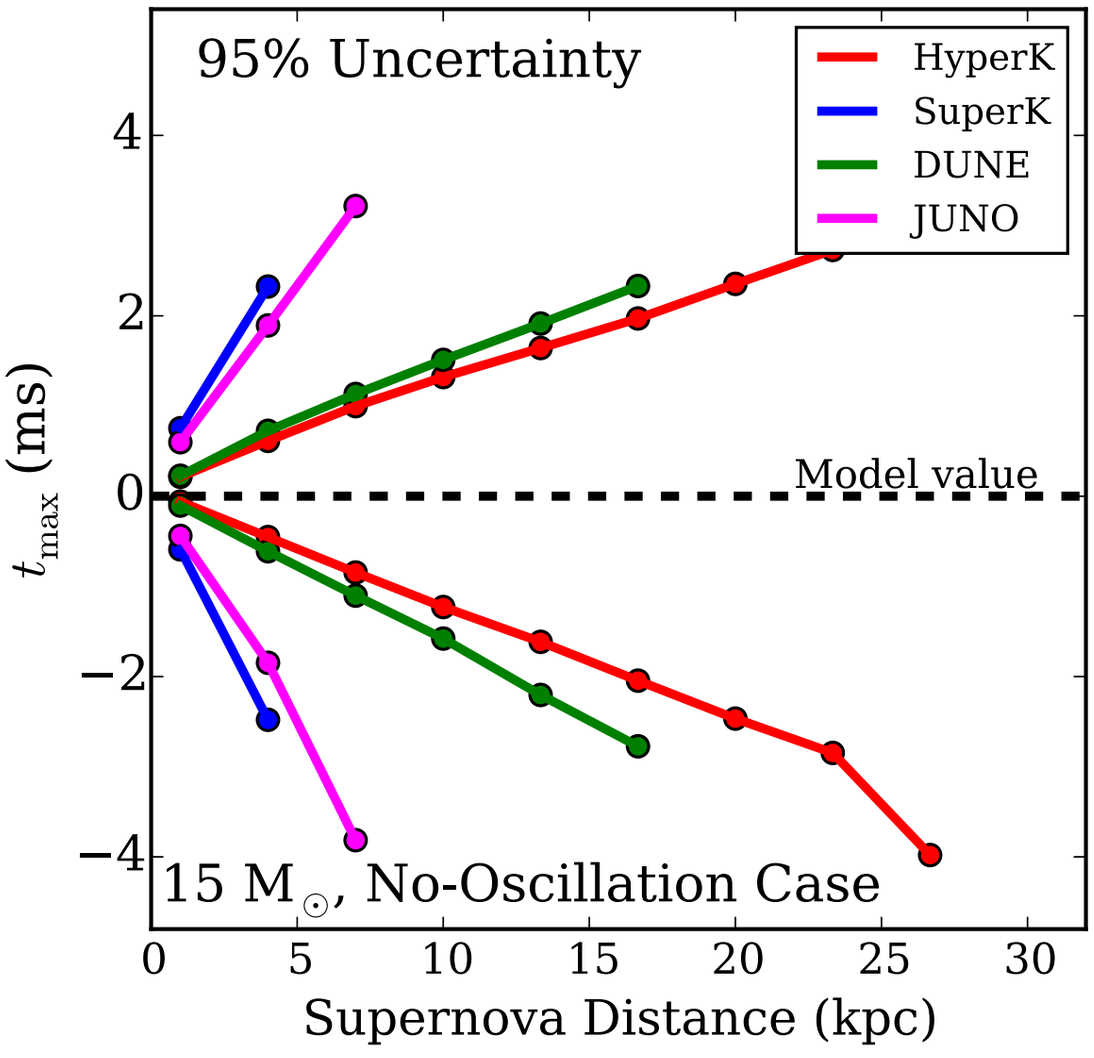
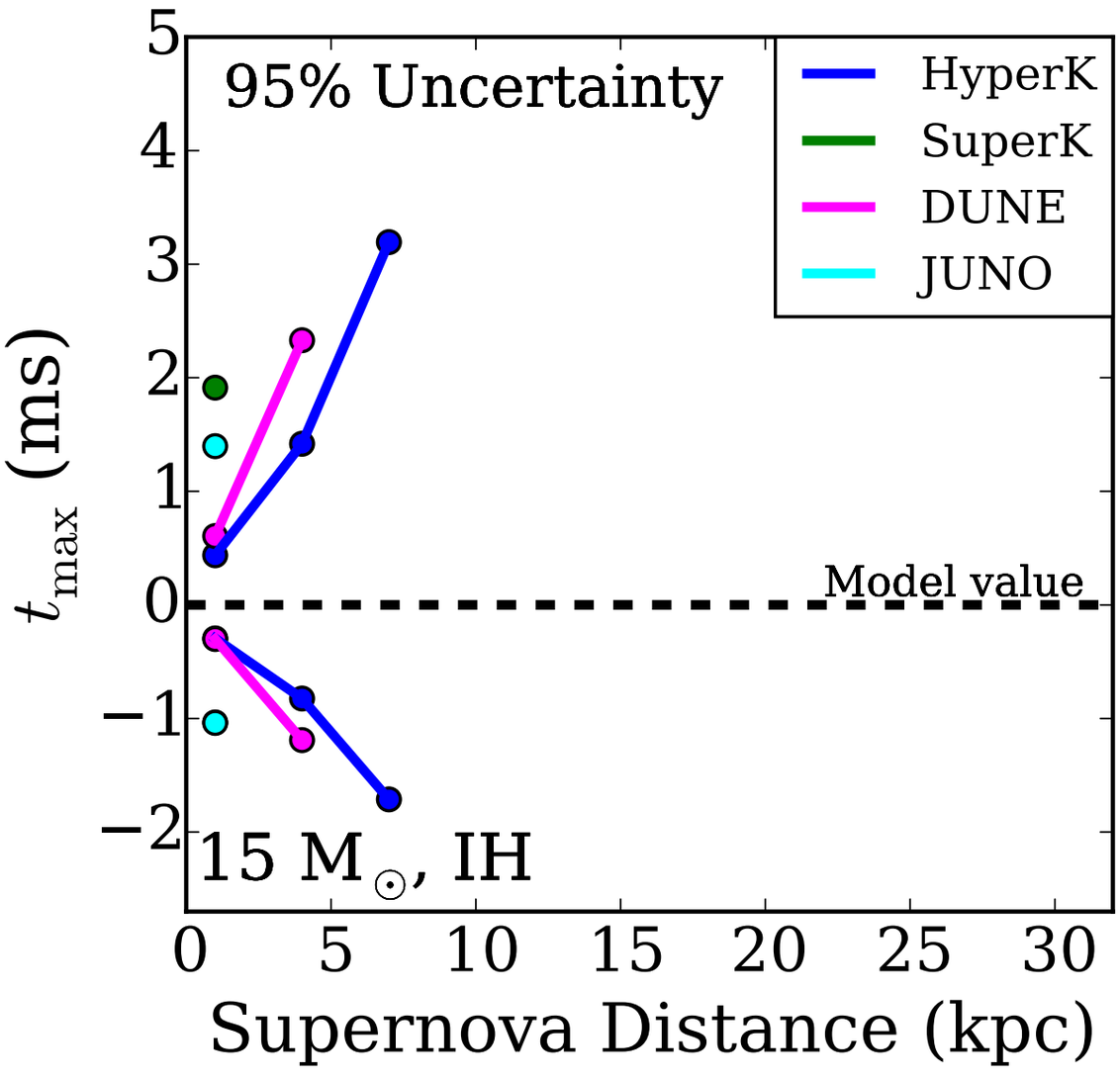
Shock Breakout: Detectability

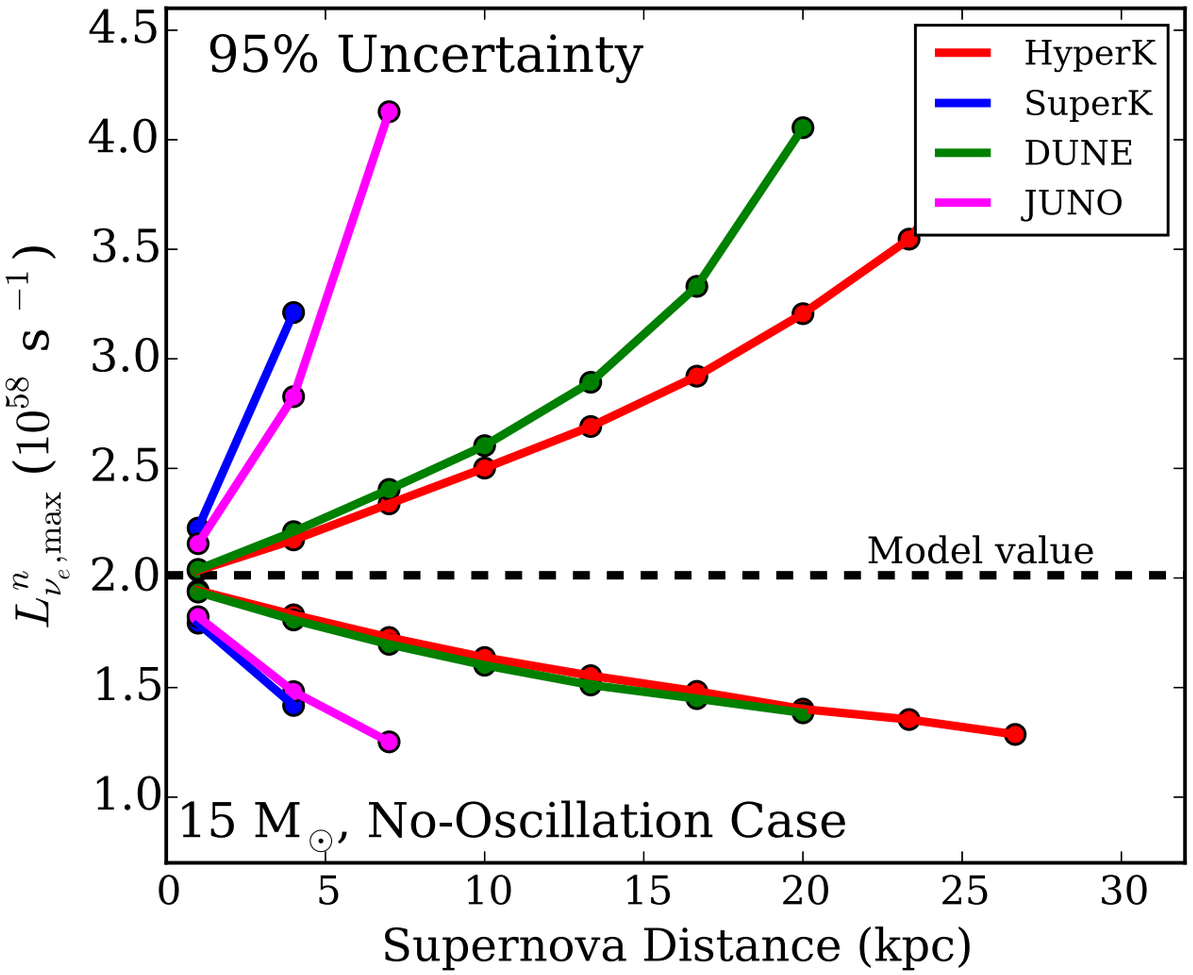


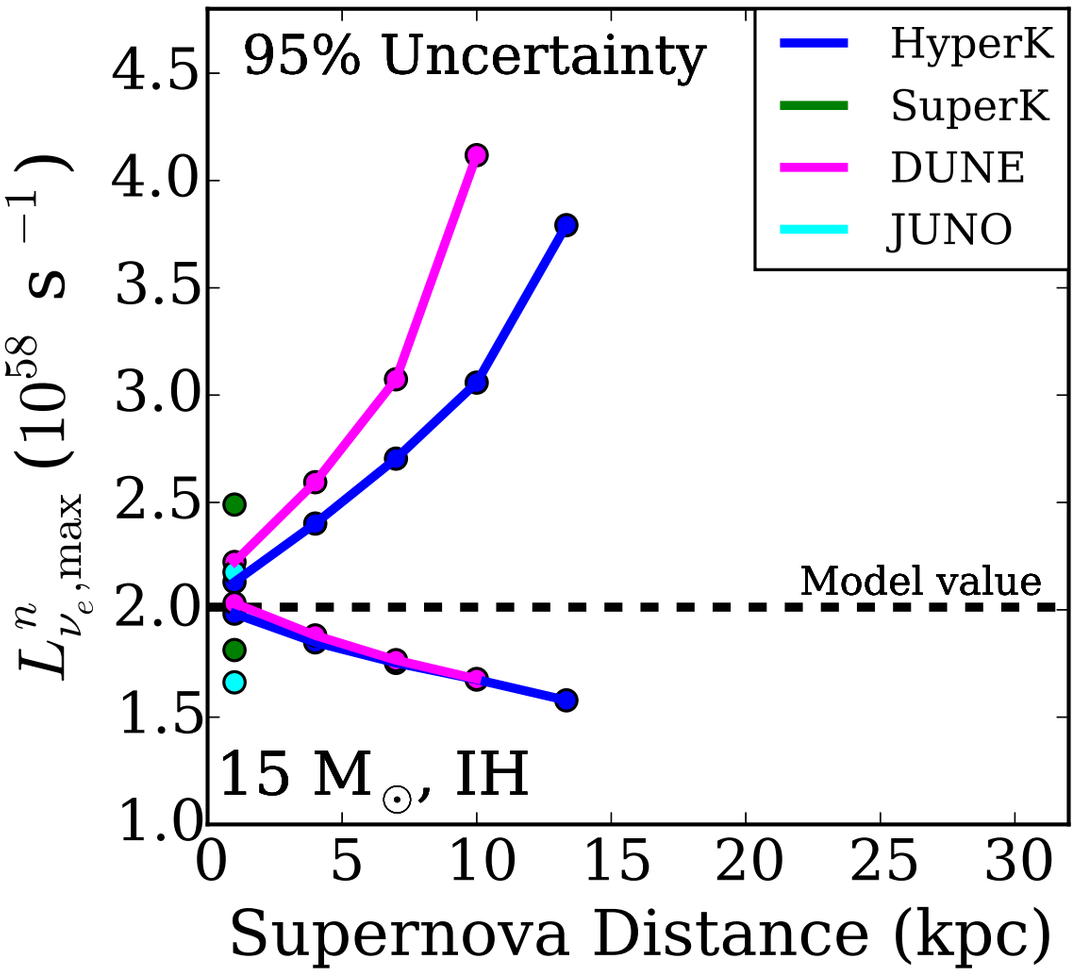


Breakout burst can provide accurate timing of core bounce

Wallace, Burrows, and Dolence 2016

Shock Breakout: Luminosity

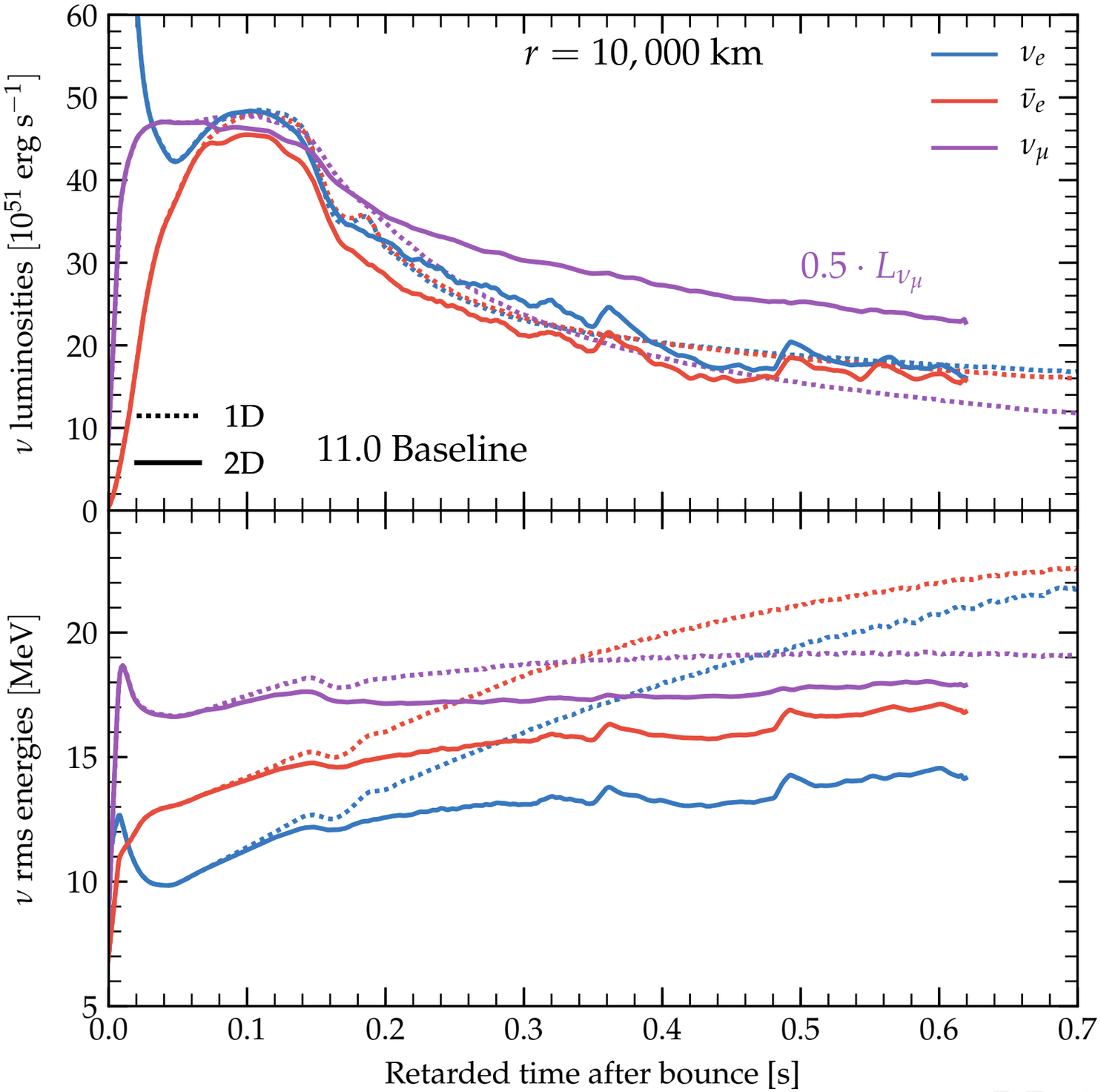




Peak luminosity measurement only for nearby supernovae

Wallace, Burrows, and Dolence 2016

Neutrino “Light-Curves”



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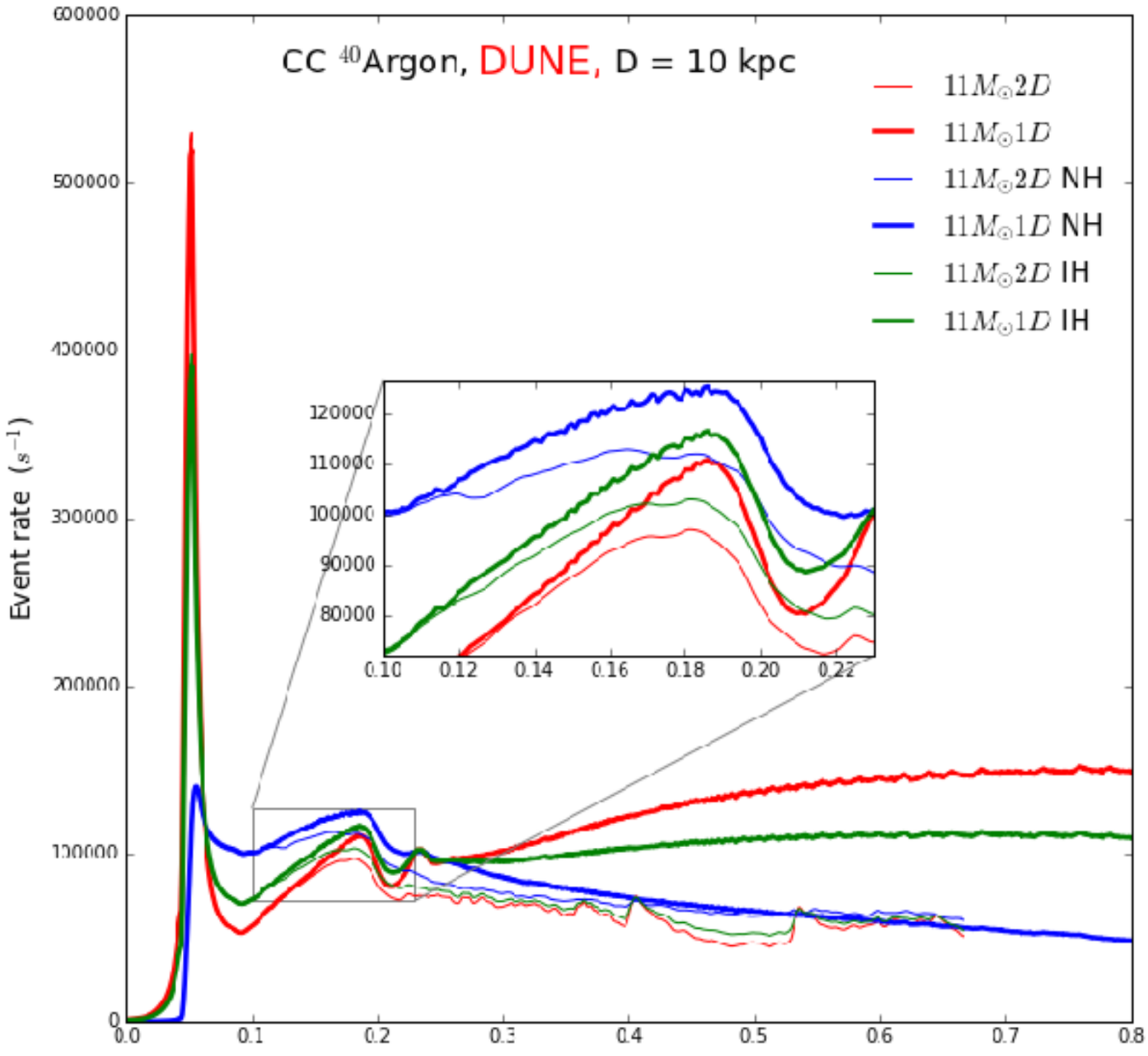

Seadrow et al., in prep 2017

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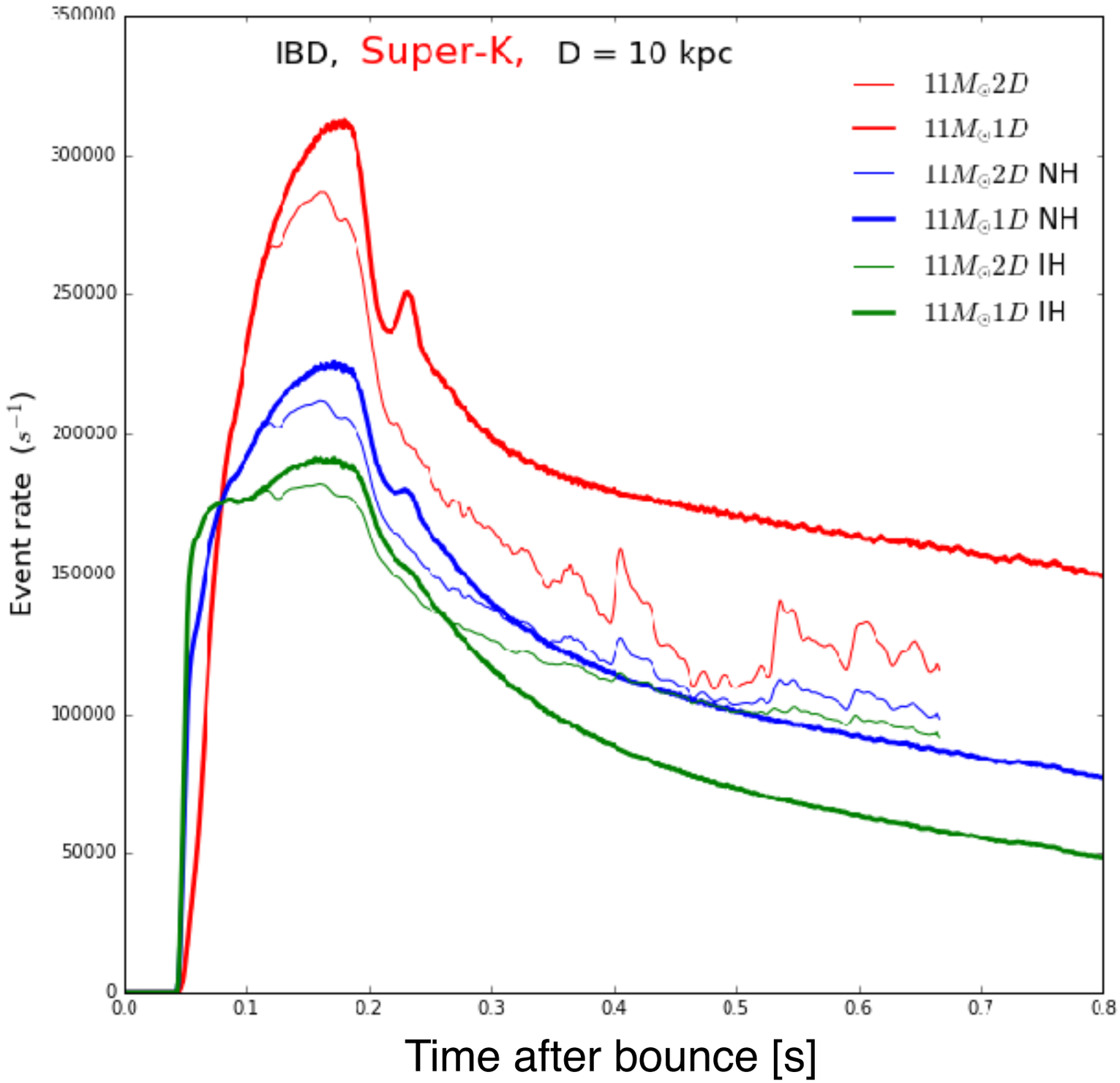

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Conclusions

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- Neutrinos from the next galactic supernova: a unique probe of the central engine
- Open issues: need accurate 3D models, oscillations

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Thank you!