Progenitors, Supernovae, and Neutron Stars

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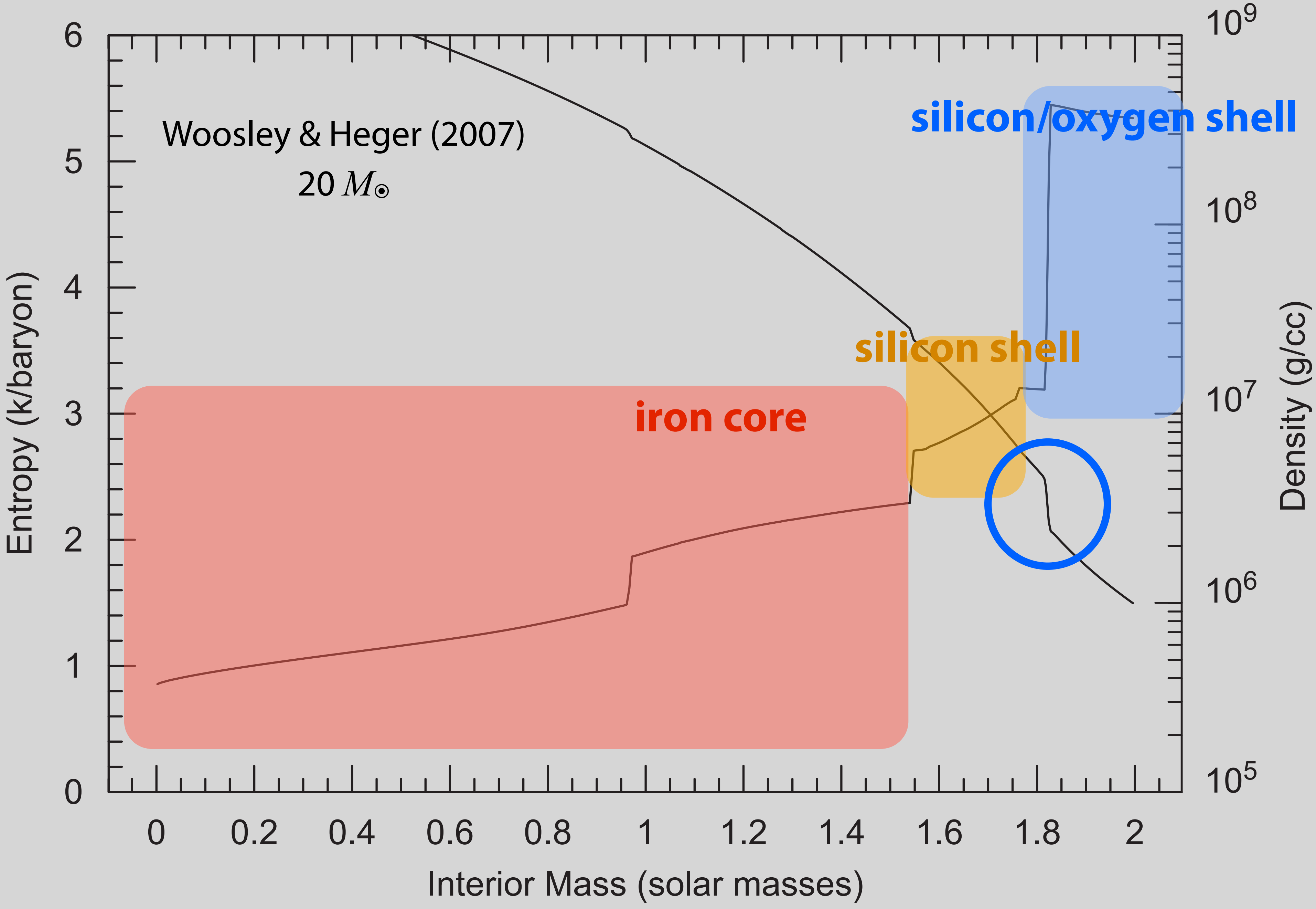
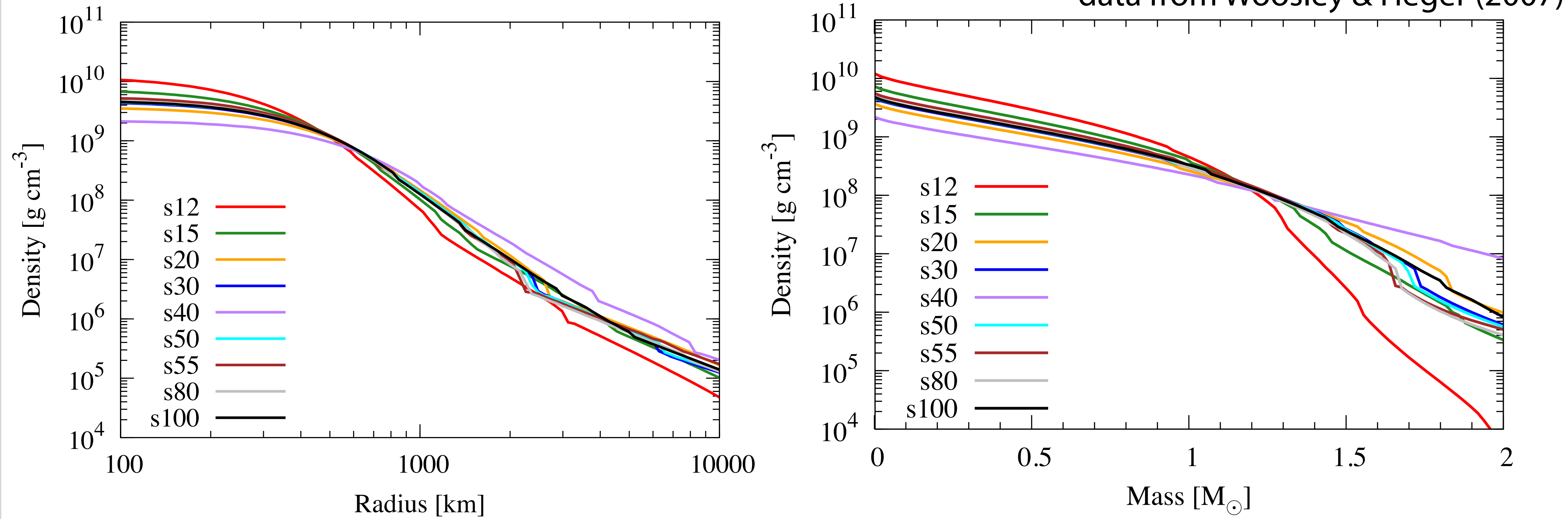
Progenitor structures-1

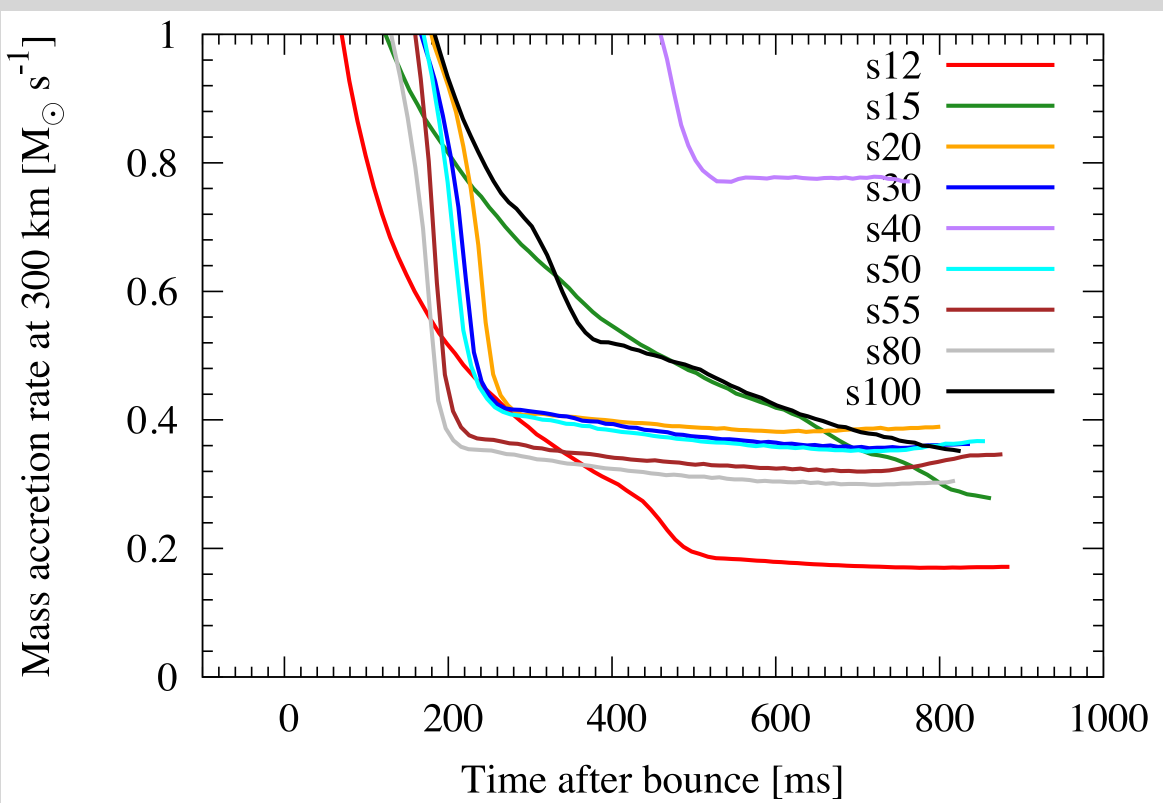


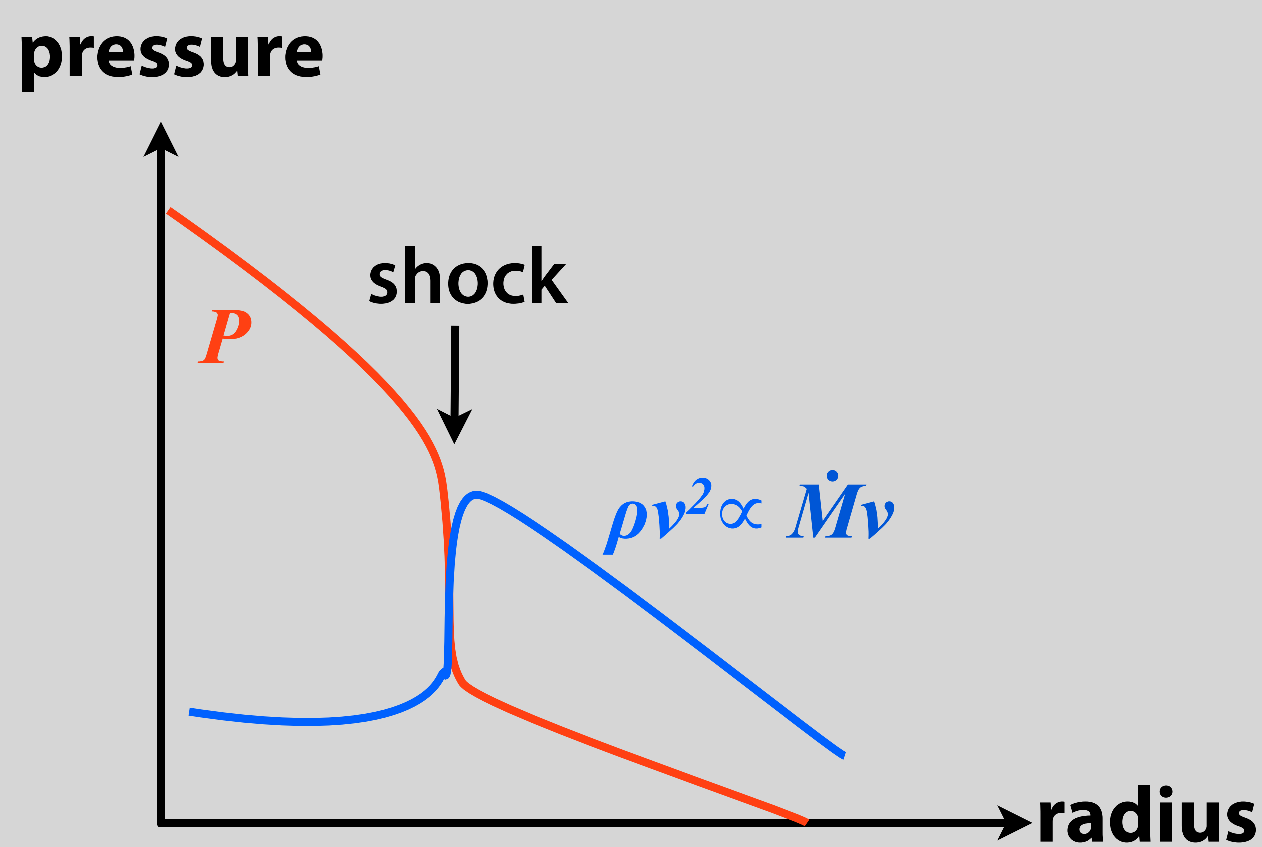
See also talk by Sukhbold and poster by Thomas

Progenitor structures-2

data from Woosley & Heger (2007)



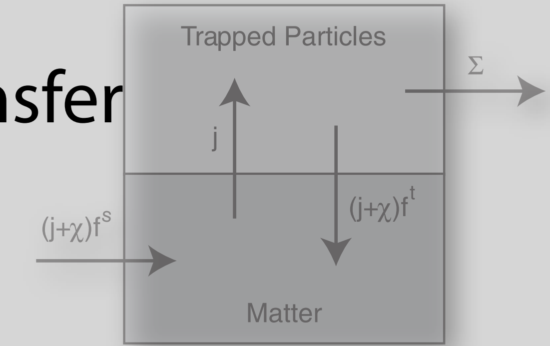




Explosion simulations-1: setups

See
Suwa et al., PASJ, 62, L49 (2010)
Suwa et al., ApJ, 738, 165 (2011)
Suwa et al., ApJ, 764, 99 (2013)
Suwa, PASJ, 66, L1 (2014)
Suwa et al., arXiv:1406.6414
for more details

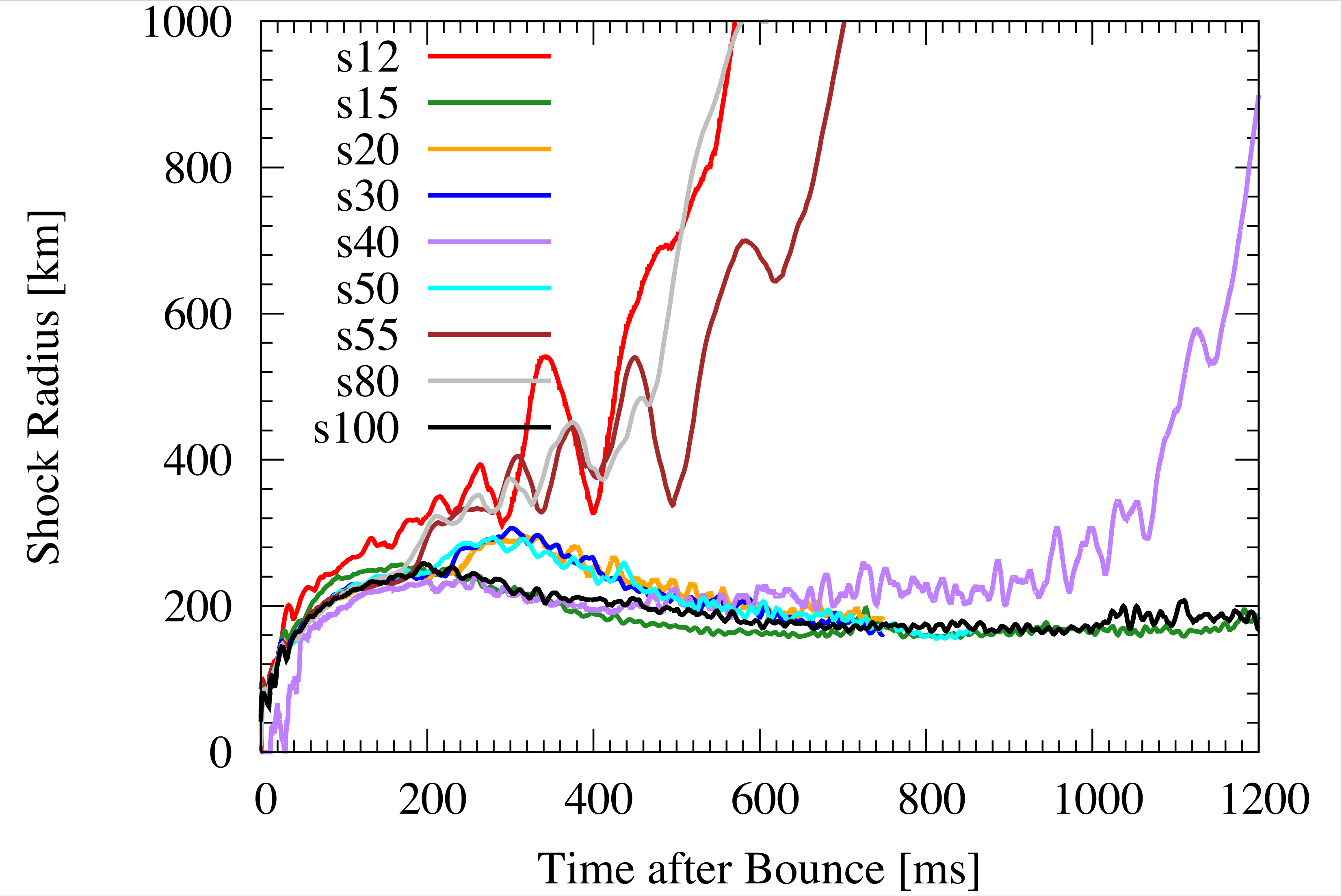
- **Progenitor: 12-100 $M_\odot$** (Woosley & Heger 07)
- **2D (axial symmetry)** (ZEUS-2D; Stone & Norman 92)
- **MPI+OpenMP hybrid parallelized**
- **Hydrodynamics+neutrino transfer** (*neutrino-radiation hydrodynamics*)
  - Isotropic diffusion source approximation (*IDSA*) for neutrino transfer (Liebendörfer+ 09)
  - ***Ray-by-ray plus*** approximation for multi-D transfer (Buras+ 06)

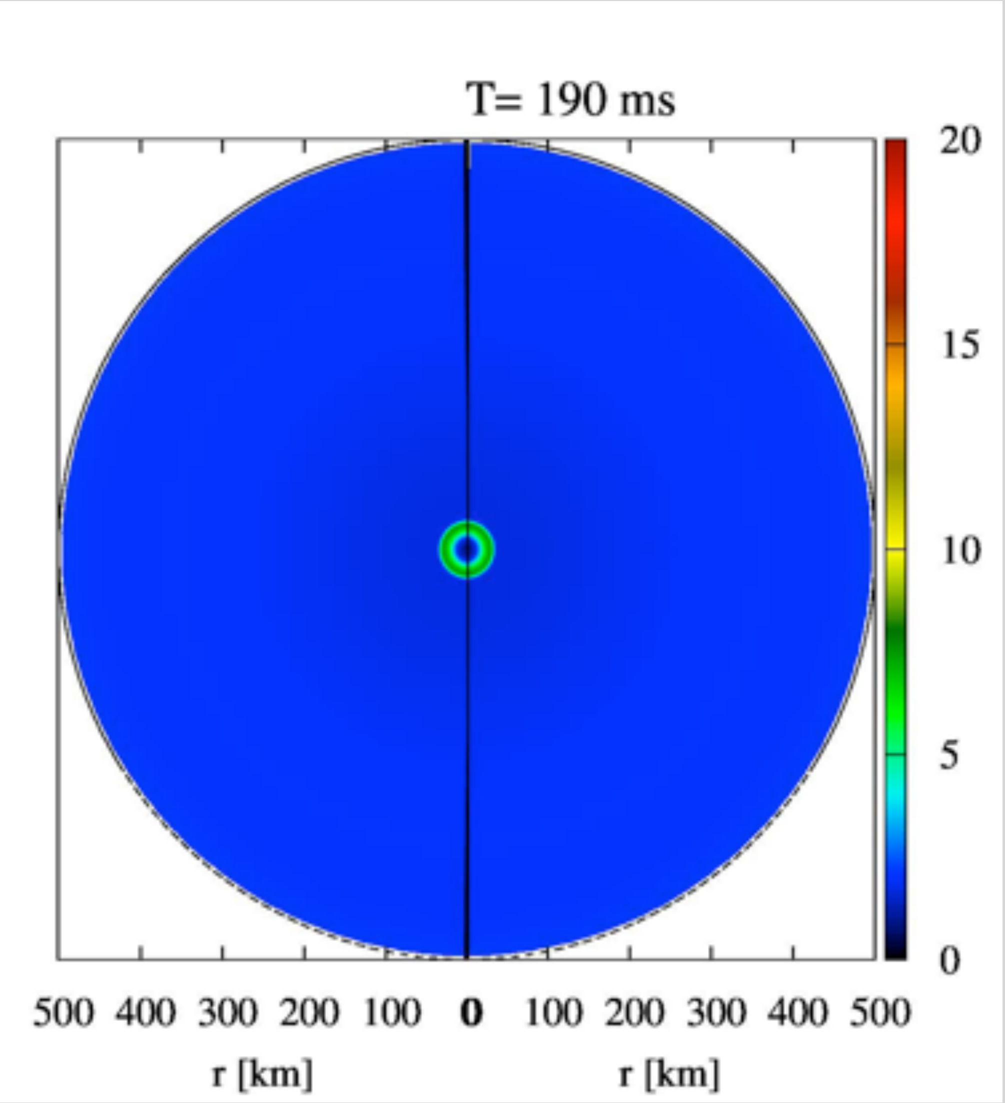


- **EOS: Lattimer-Swesty** (K=180,**220**,375MeV) / H. Shen

Explosion simulations-2: results

YS, Yamada, Takiwaki, Kotake, arXiv:1406.6414

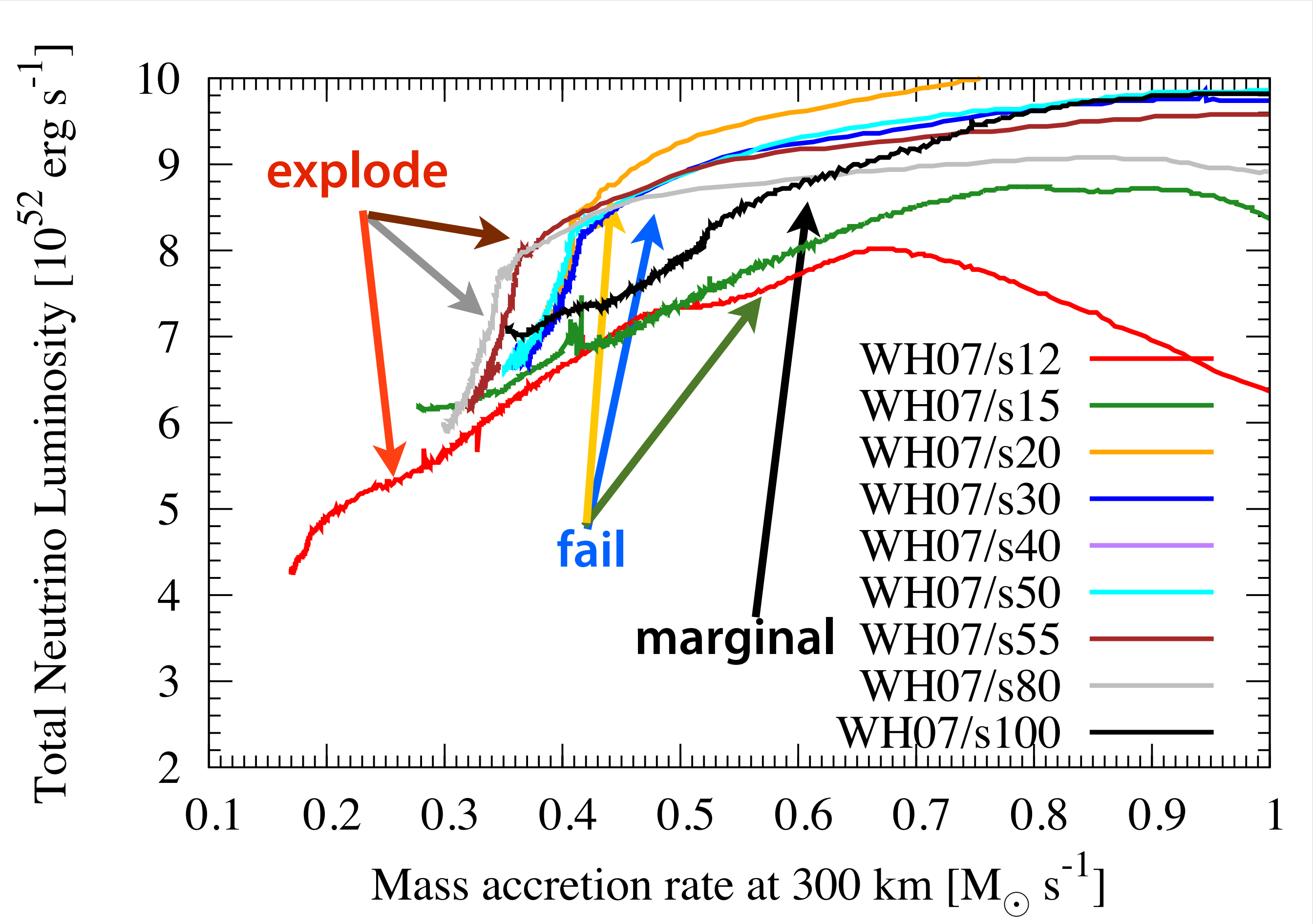


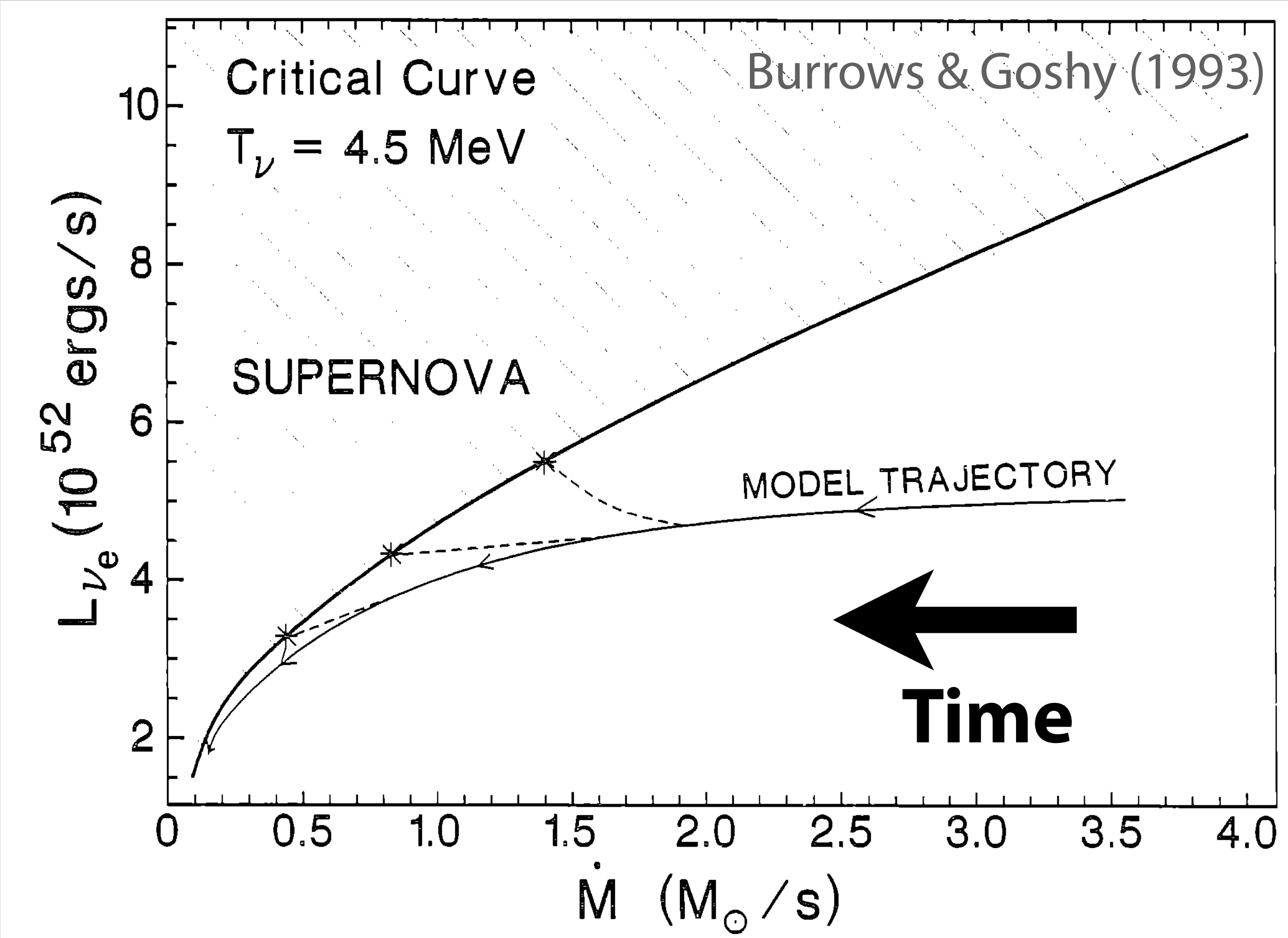


- Several progenitors lead to shock expansion
- No monotonic trend with ZAMS mass is found
- What makes difference?

What makes difference?: $\dot{M}$-L_ν

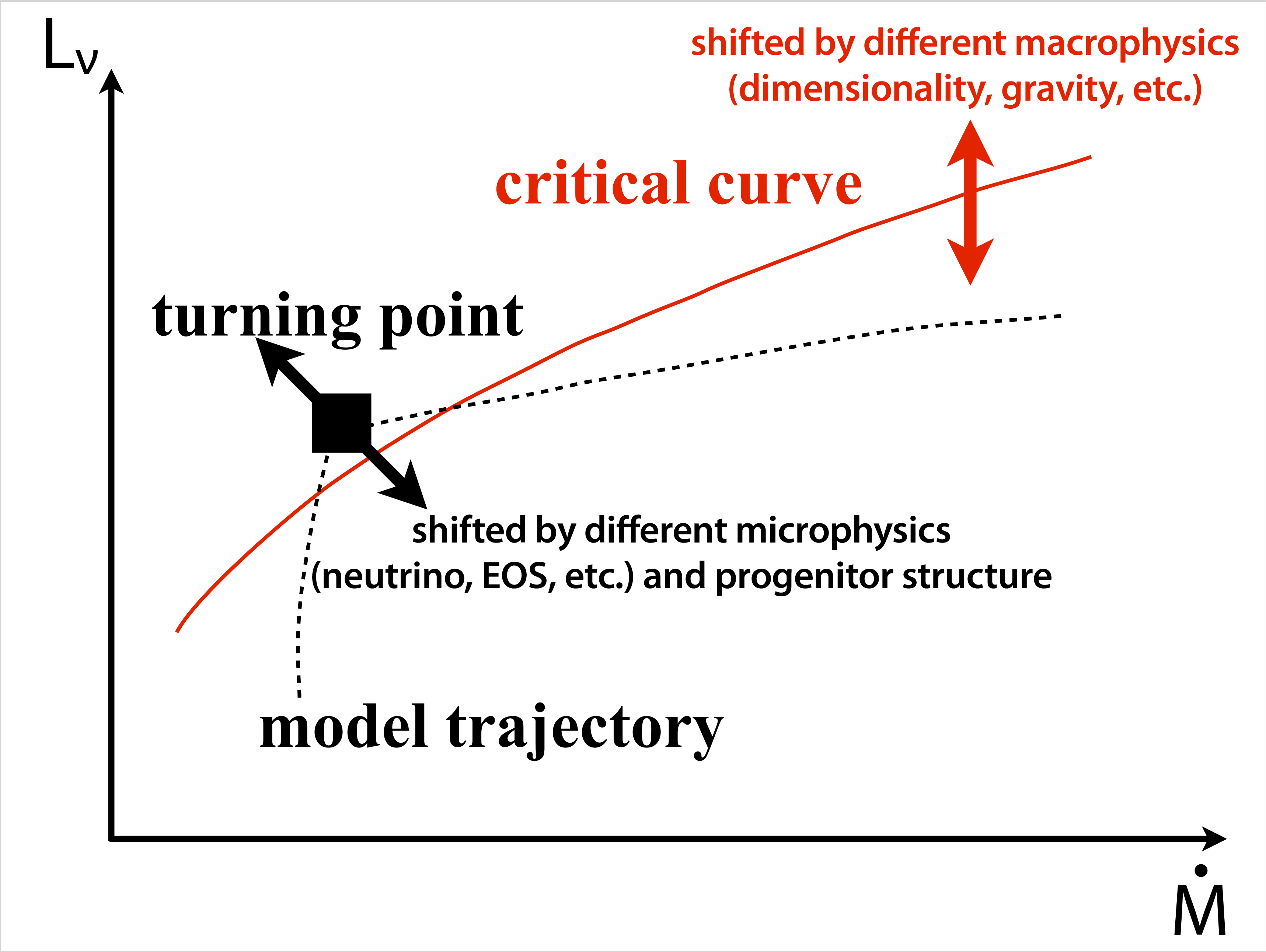
YS, Yamada, Takiwaki, Kotake, arXiv:1406.6414





- Low $\dot{M}$ and high L_ν are achieved for exploding progenitors
- Accretion of multiple shells makes different dependence of L_ν on $\dot{M}$

Critical curve and model trajectory

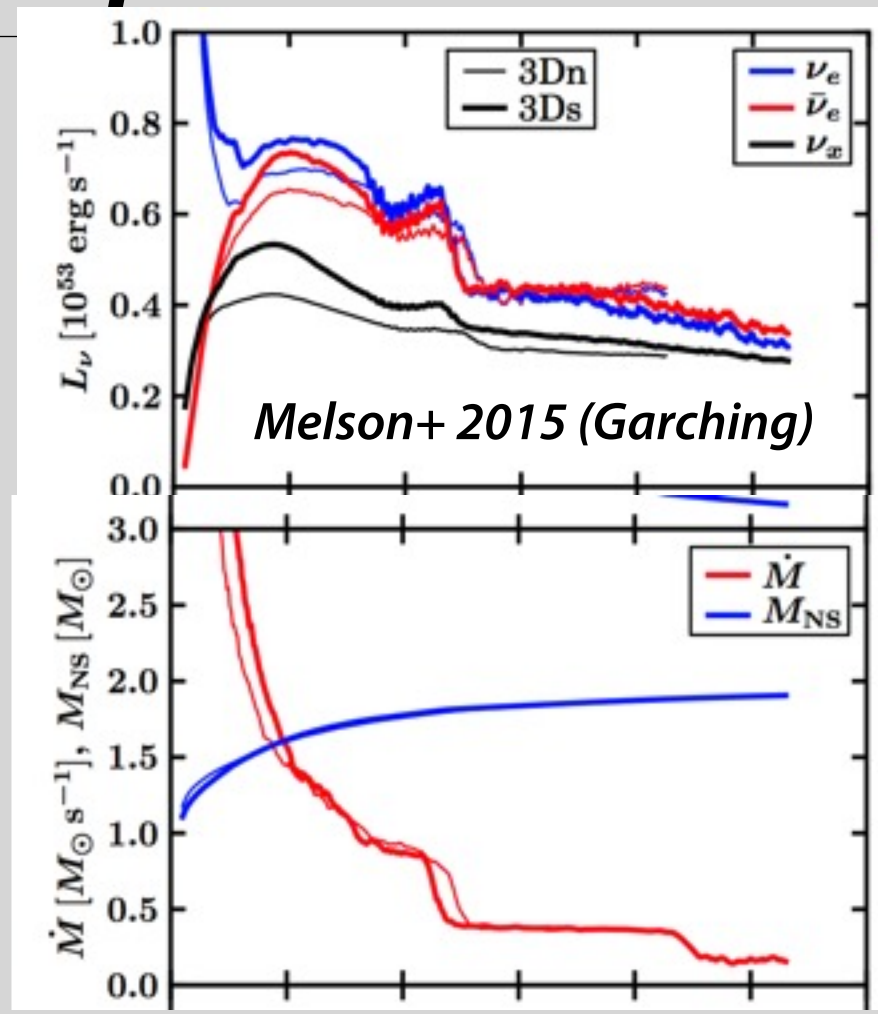


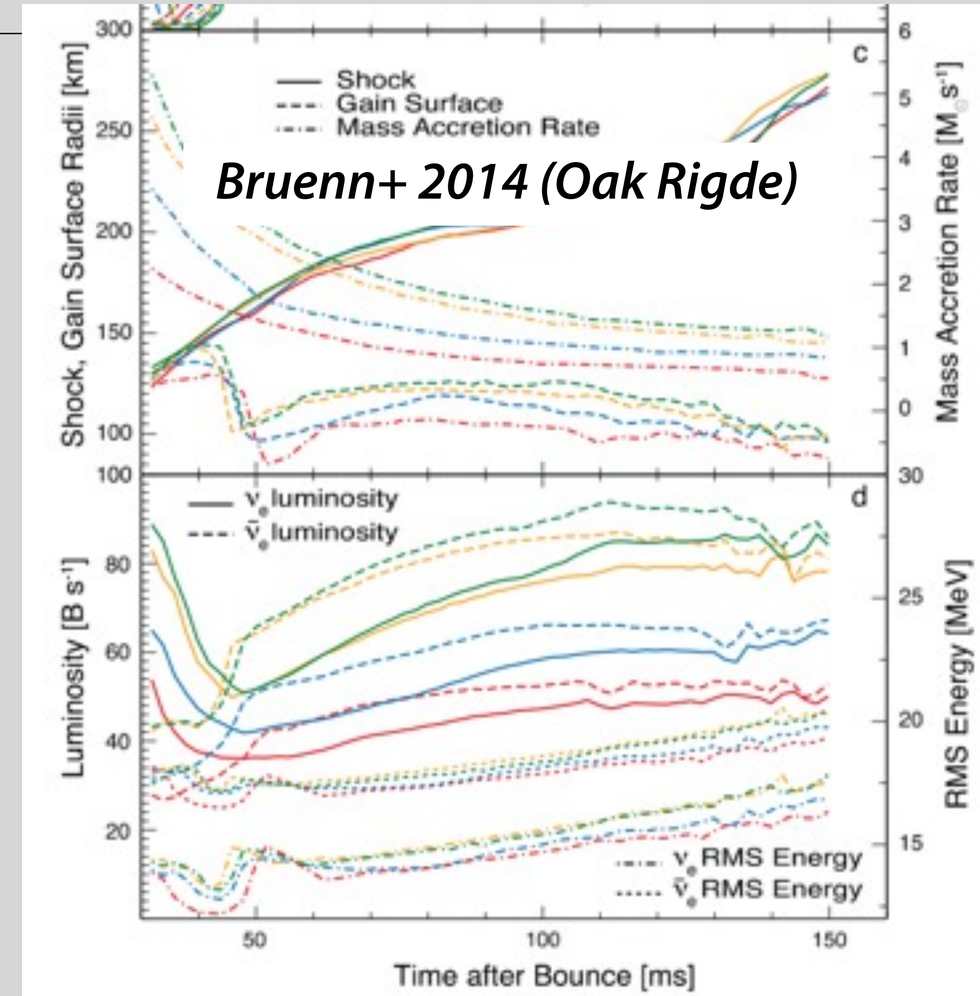
e.g.,
Burrows & Goshy (1993)
Murphy & Burros (2008)
Nordhaus+ (2010)
Hanke+ (2012)
Couch (2013)
Handy+ (2014)
Pejcha & Thompson (2012)
Keshet & Balberg (2012)
Janka (2012)
Müller & Janka (2015)

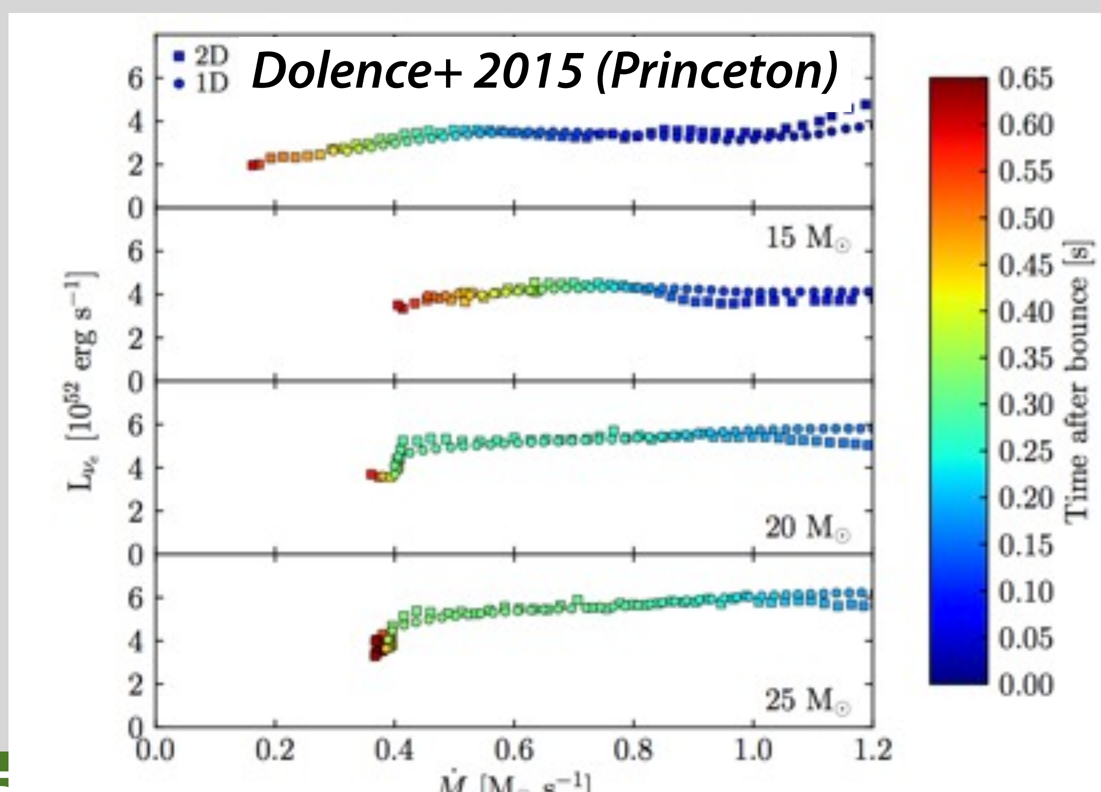
Dolence+ (2015)
Suwa+ (2014)

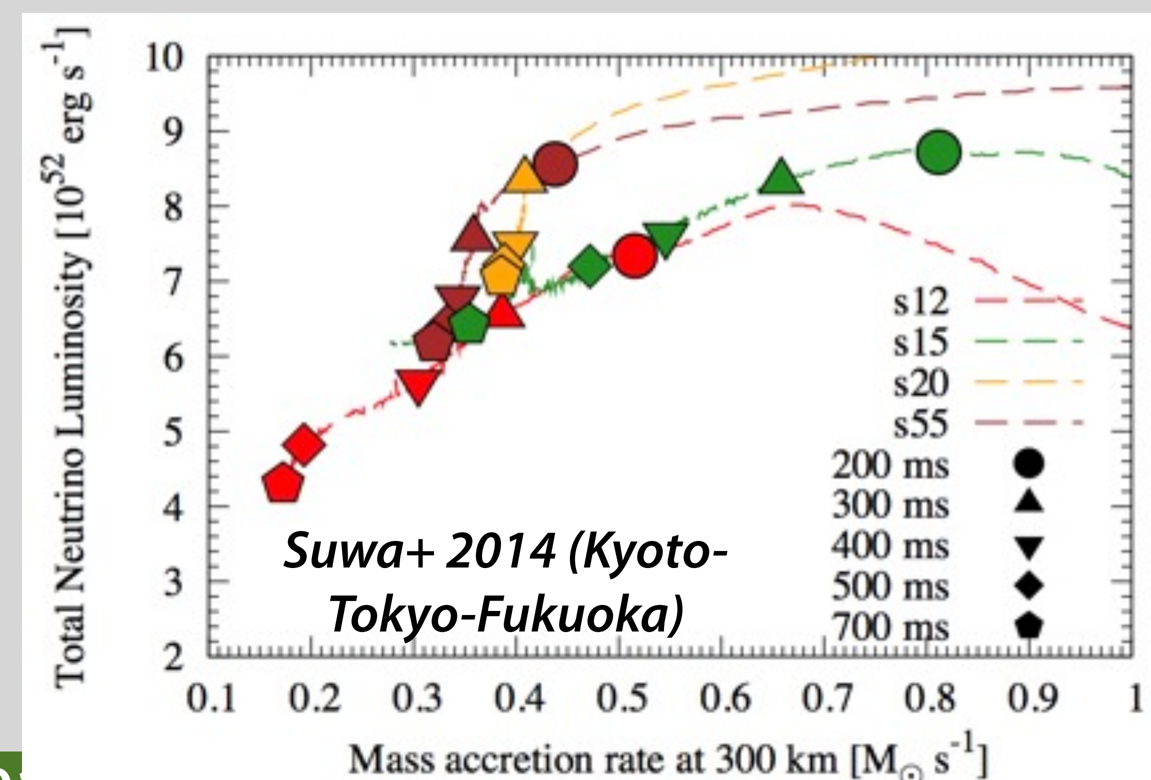
Semi-analytic expressions of trajectories available in Suwa et al. (2014)

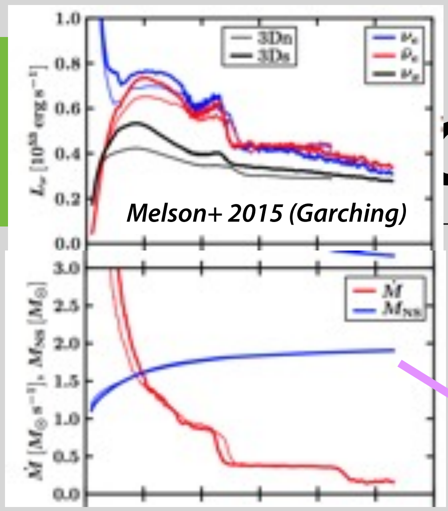
Code comparison











PROMETHEUS-VERTEX

GR correction

variable Eddington factor

ray-by-ray plus

Lattimer-Swesty EOS

explode in 2D

CHIMERA

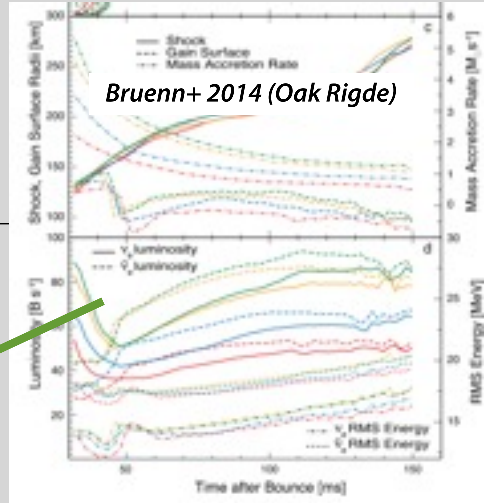
GR correction

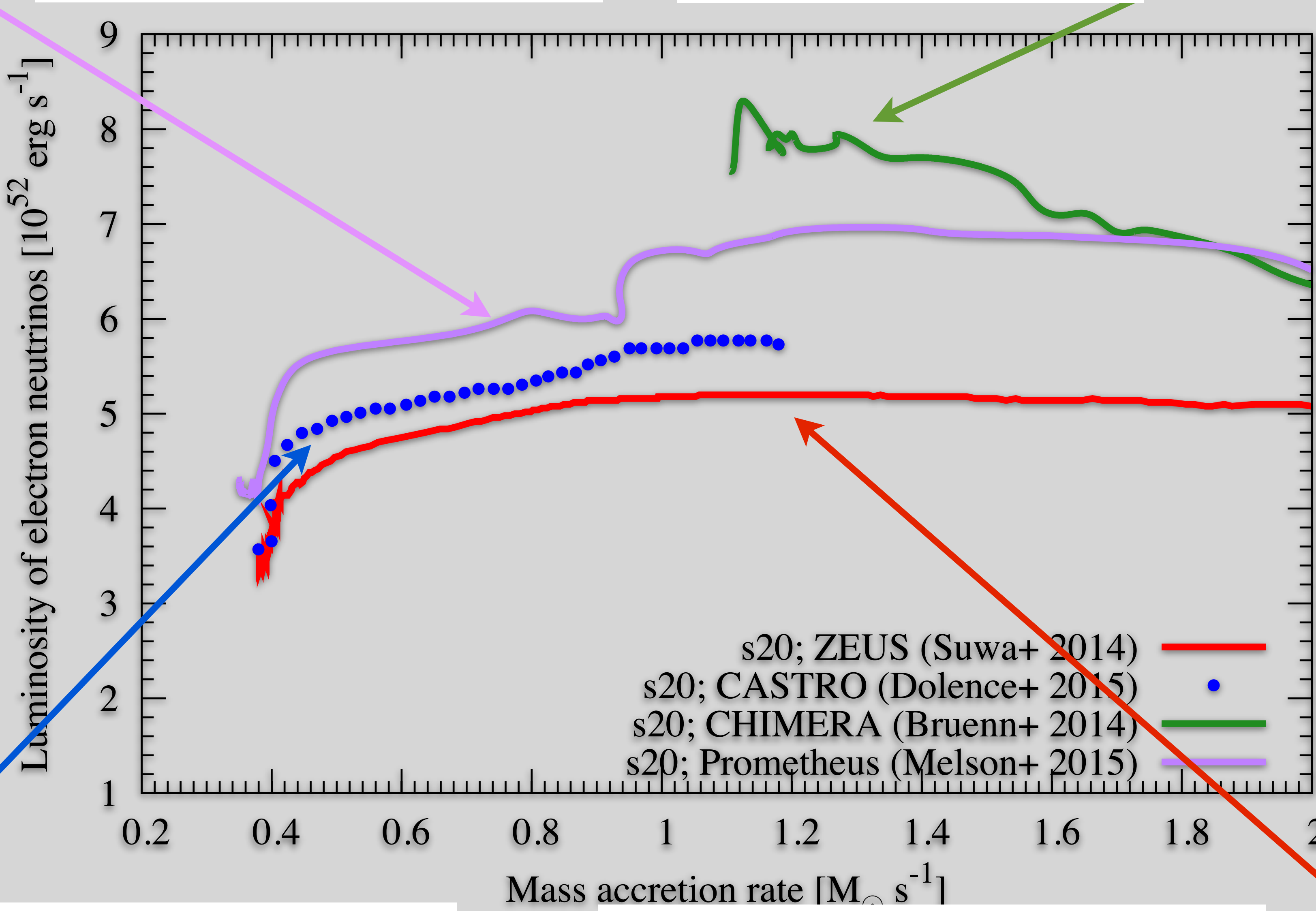
flux limited diffusion

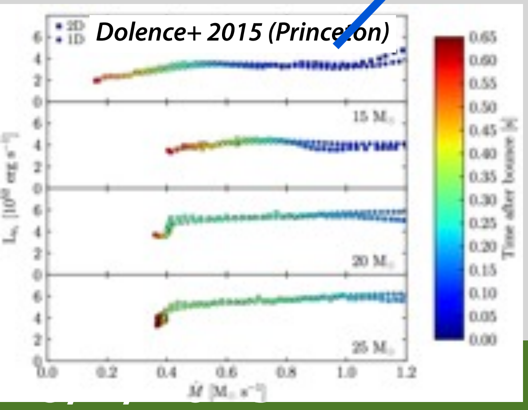
ray-by-ray plus

Lattimer-Swesty EOS

explode in 2D







CASTRO

Newton

flux limited diffusion

multi-D transfer

H. Shen EOS

NOT explode in 2D

ZEUS

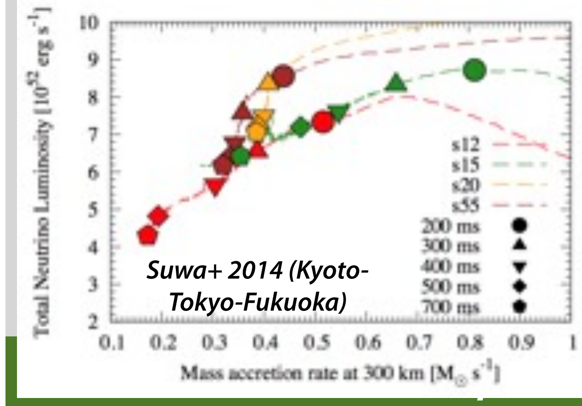
Newton

isotropic diffusion source app.

ray-by-ray plus

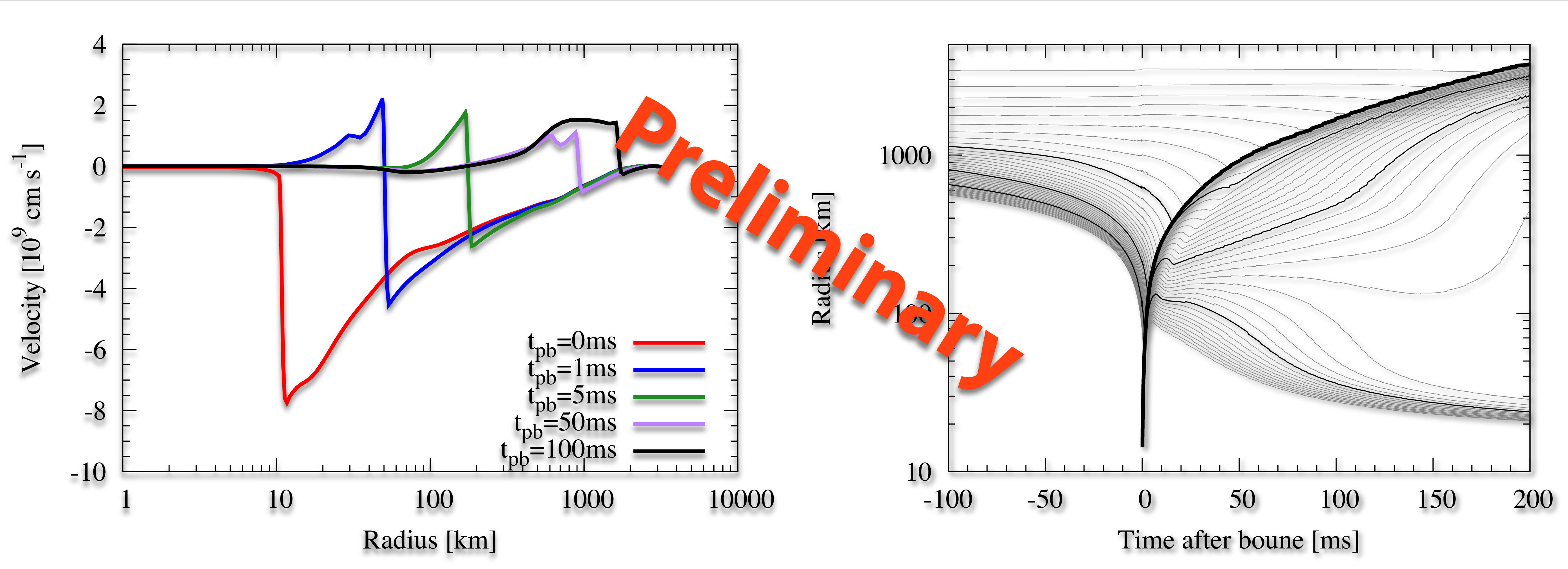
Lattimer-Swesty EOS

NOT explode in 2D



How much do initial conditions matter?

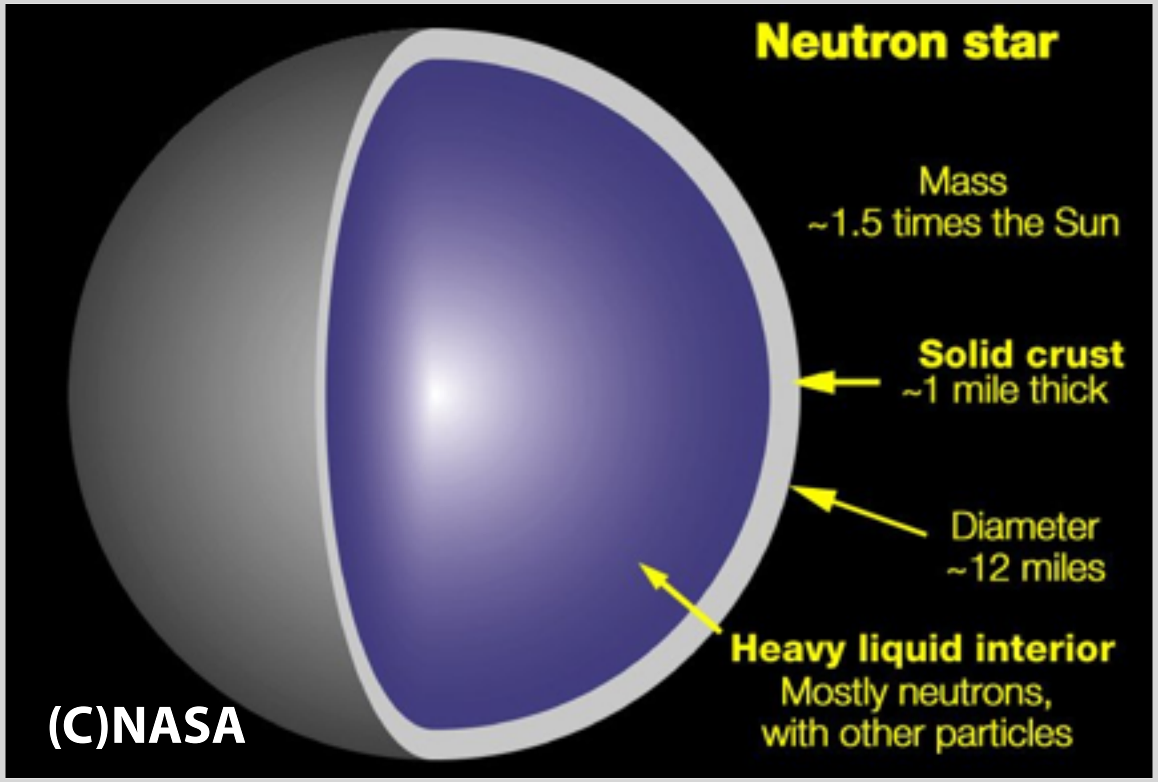
- Starting from hydrostatic NSE cores
- 1D, GR, neutrino-radiation hydro code; ***Agile-IDSA*** (public code!)
- **Neutrino-driven explosions are possible in 1D**



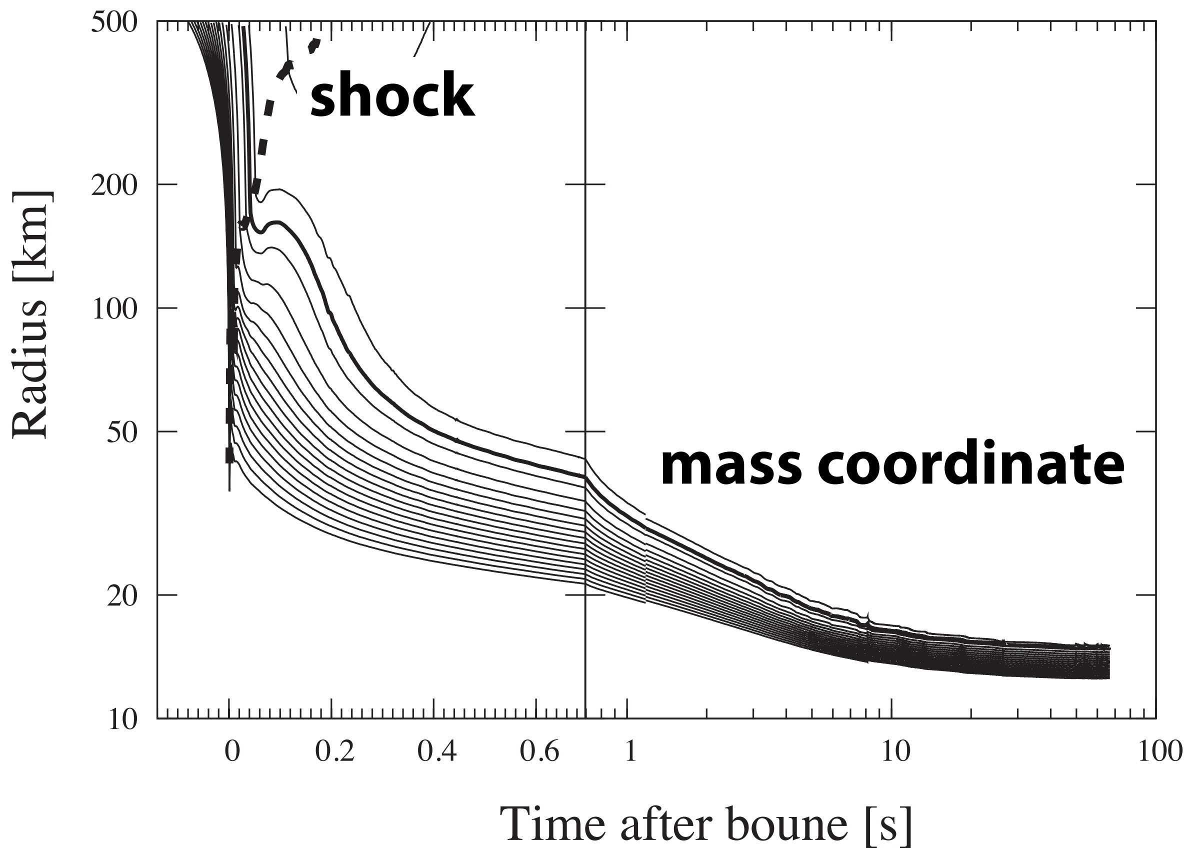
YS, Müller+, in prep.

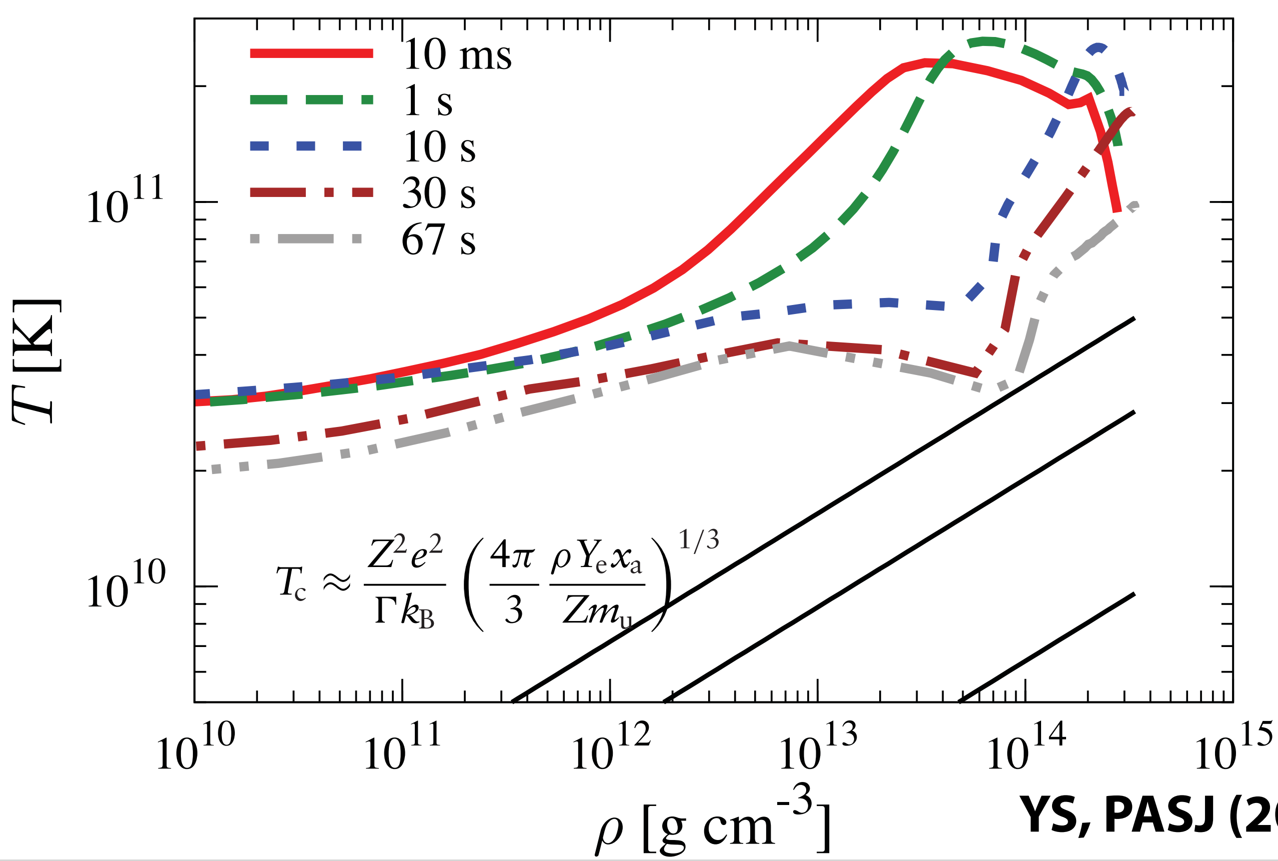
See also poster by Yu

Long-term simulations from PNS to NS



- NS consists of core and **crust**
- When a PNS (w/o crust) becomes a NS (w/ crust)?
- From core collapse up to NS formation was followed with neut.-rad. hydro. simulation, for **67** s





YS, PASJ (2014)

Summary

- **Progenitor structure is one of the most important ingredients for core-collapse supernova explosion**
  - initial condition
  - mass accretion history

- **We performed simulations of multi-dimensional neutrino-radiation hydrodynamics**
  - 4 of 9 models exploded
  - Low-$\dot{M}$ and high L_ν are favorable for explosion

- **By performing further simulations, NS crust formation was reached from precollapse consistently** *(from supernovae to neutron stars)*