Impact of spatial and temporal resolution on pre-supernova properties

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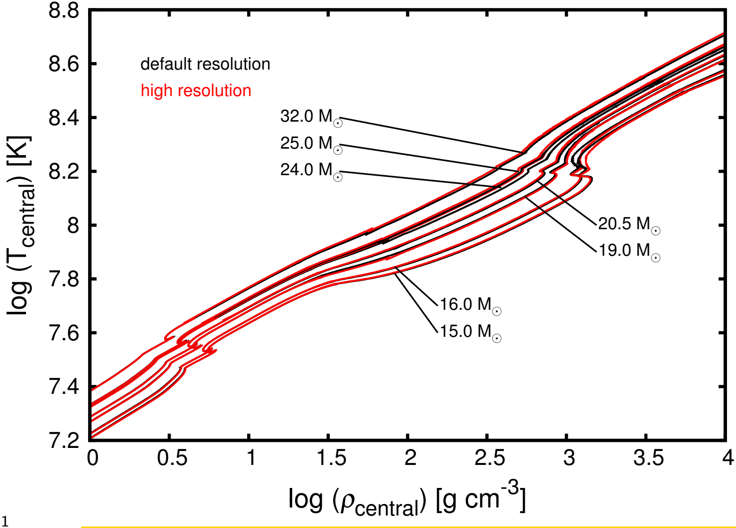
Motivation and Method

Massive stars are essential to the evolution of galaxies due to their intense radiation and strong winds as well as their powerful deaths as supernovae.
Crucial properties like iron-core masses or the compactness shows a **non-monotonic** behavior: physical? Numerics?
Connections ZAMS mass $\leftrightarrow$ final fate

Study evolution with/ for

- open-source package 'Modules for Experiments in Stellar Astrophysics' **MESA**, version 7624
- increased **spatial resolution** (from ∼1500 to ∼30000 zones; MESA parameter max_dq), increased **temporal resolution** to better control central fuel depletion at latest stages of evolution
- model grid 15-32 $M_\odot$, Z=0.005-0.02, no rotation/ mass loss

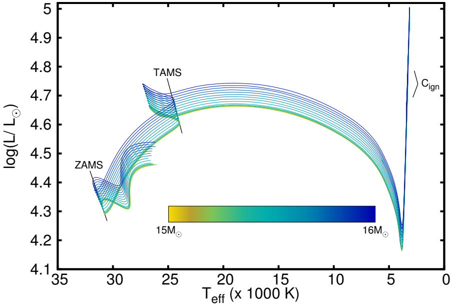
H-/ He-burning: default vs. high resolution

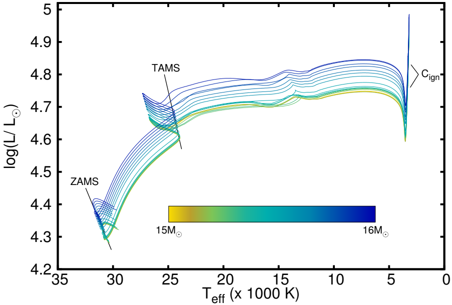


15 to 16 $M_\odot$: default vs. high resolution

- Mass grid with ΔM between 0.05 and 0.2 $M_\odot$
- Differences due to variations in shell ignition
- Similar endpoints for default and high resolution models

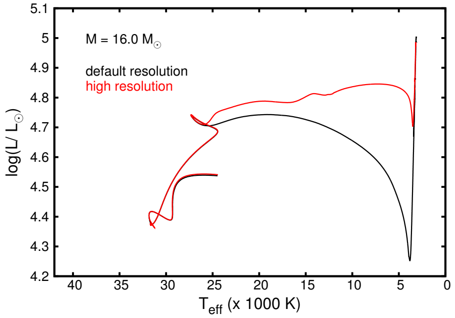
default *vs.* *high resolution*

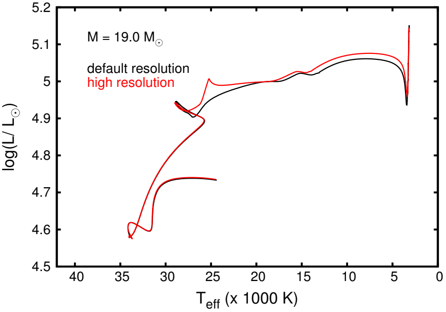




16 & 19 $M_\odot$: default vs. high resolution

- Merger of secondary convective zone of H-shell: fresh fuel being injected in the shell
- Dredge-up events only activated in high resolution models

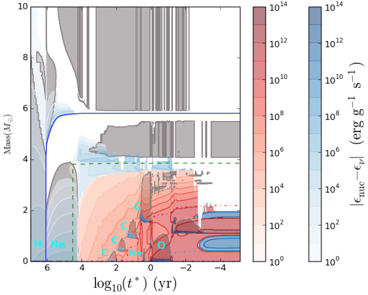


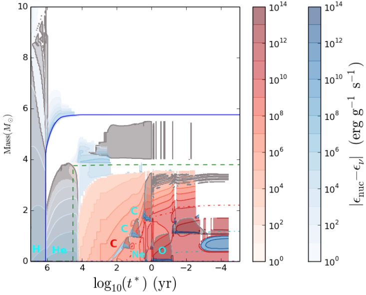


Carbon burning: convective or radiative?

- If carbon abundance is high enough, central carbon burning overcomes neutrino losses and burns in a convective core
- The lower the C abundance, the further out the first shell forms: impact on progenitor? Brown+2001, Meakin&Arnett2006, Sukhbold&Woosley2013

19 $M_\odot$: default *vs.* *high resolution*

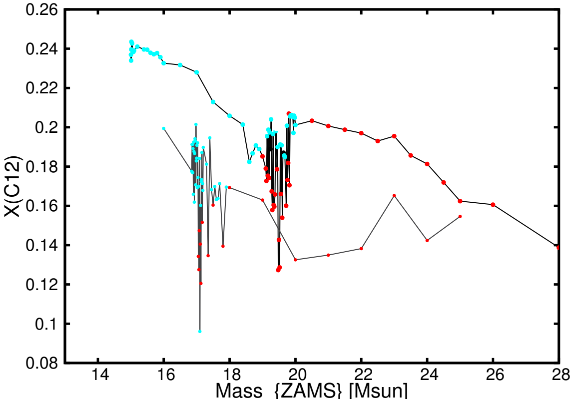




Carbon burning: Z=0.01 and 0.02, high resolution

Transition from convective to radiative towards lower M_{ZAMS} with metallicity; irregular 'switch region'

Next: very low metallicity, models including mass loss



Compactness parameter

Characterize the possibility of a (neutrino powered) explosion based on the 'compactness parameter' O'Connor and Ott (2011 and 2013):

$$\boxed{\xi = \frac{M/M_\odot}{R(M)/1000km}\bigg|_{t=t_{bounce}}}$$

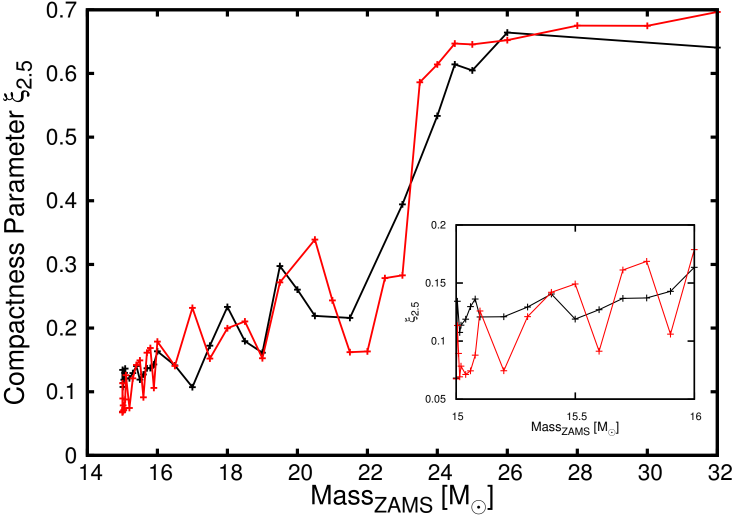
with M=2.5$M_\odot$

2.5 $M_\odot$ $\rightarrow$ relevant mass scale for BH formation: maximum mass at which a range of EoS can no longer support a neutron star against gravity

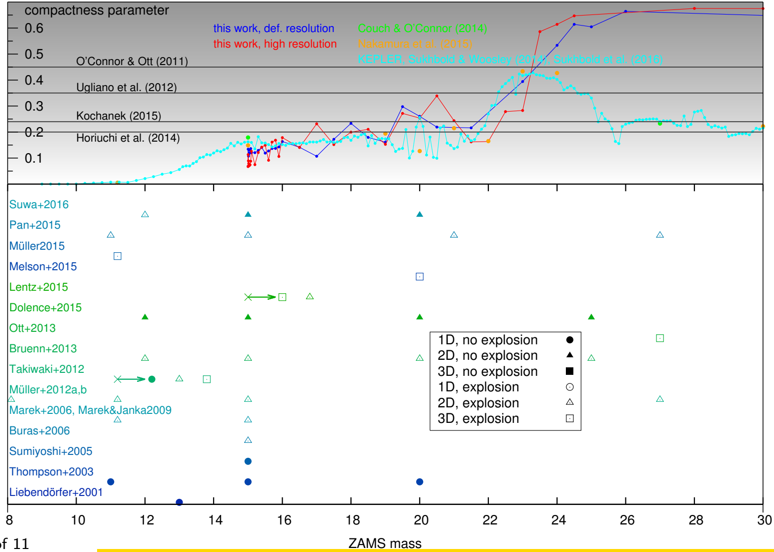
ξ big: R is small, the 2.5 $M_\odot$ point lies close in $\rightarrow$ hard to explode

Black Hole formation:
O'Connor & Ott (2011): $\xi_{2.5} \gtrsim 0.45$
Ugliano et al. (2012) : $\xi_{2.5} \gtrsim 0.30$

Compactness: default vs. high resolution



Compactness and explosiveness



Outlook: Occurrence of blue loops

Variations in core properties?

Further studies → influence of different model atmospheres?