Angular Momentum Fluctuations in Helium Shell of a CCSN Progenitor

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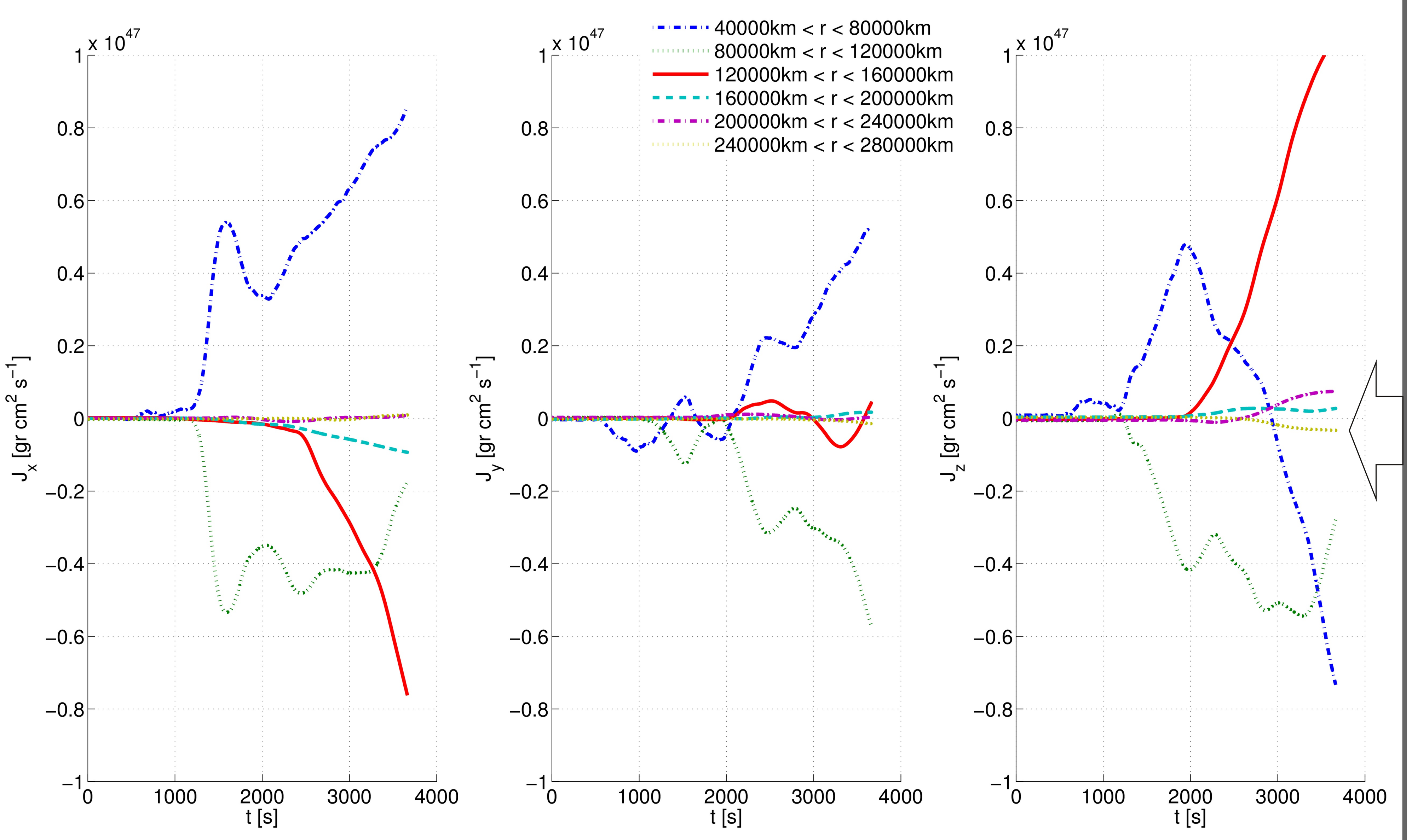
Abstract

We find significant fluctuations of angular momentum in the convective helium shell of an $M_{ZAMS} = 15M_{\odot}$ star simulated at the helium shell burning stage. This angular momentum distribution may fuel accretion and jets after core-collapse, facilitating a supernova explosion (for details see Gilkis & Soker 2015).

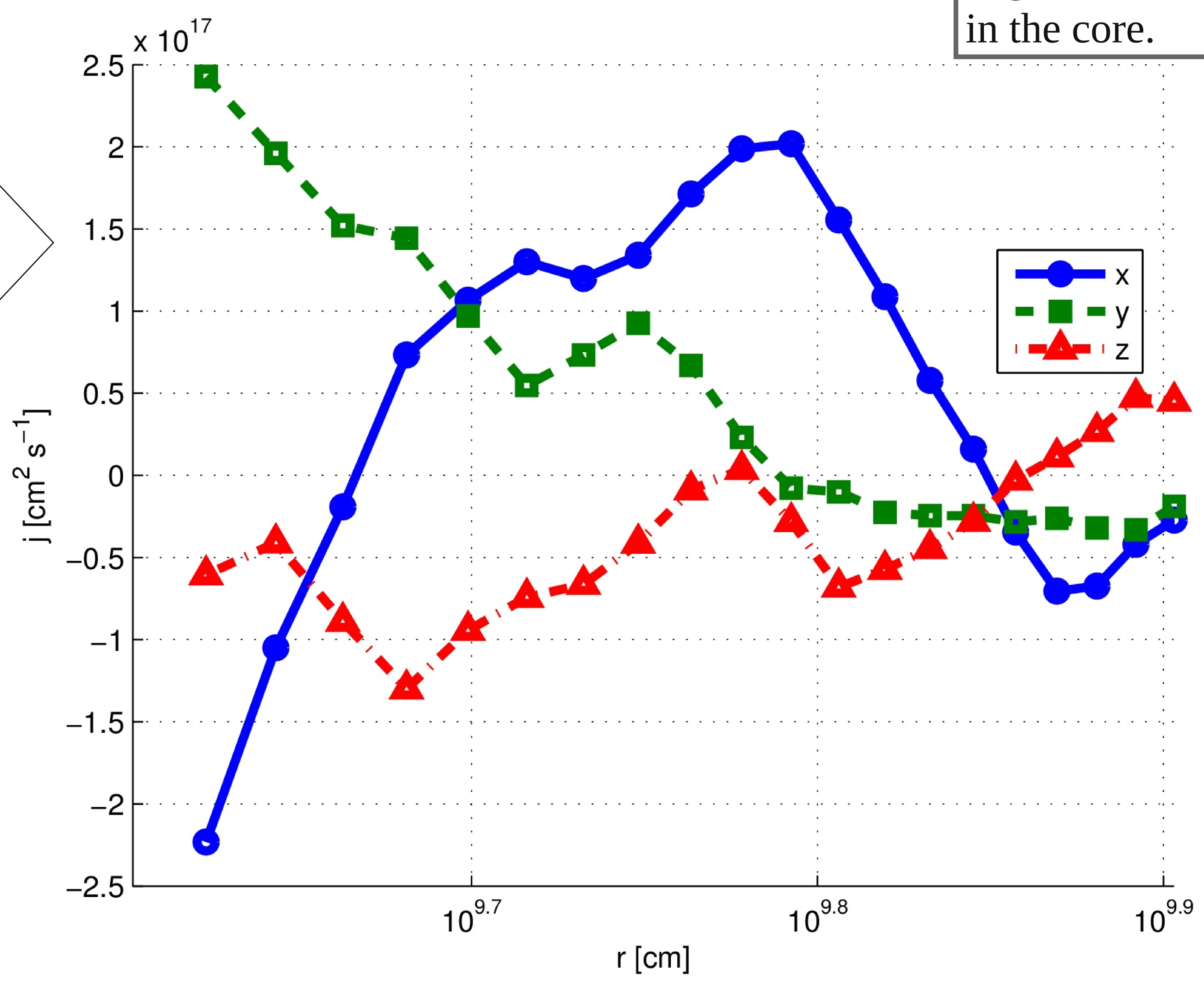


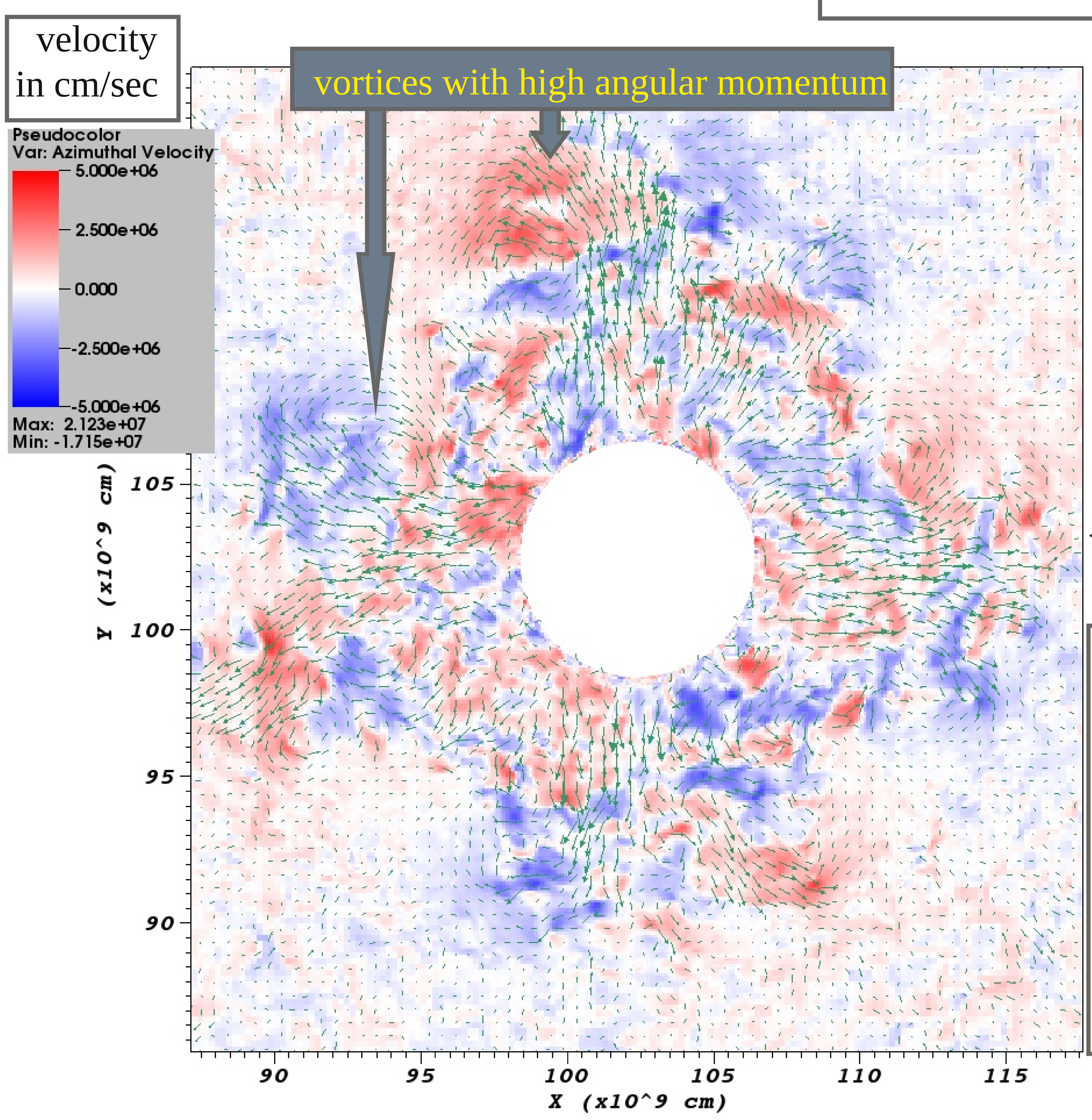
Angular momentum components of several shells within the convective region throughout the simulation time. The masses of the shells from the inner shell to the outer are 0.25, 0.25, 0.23, 0.22, 0.19 and 0.17 $M_{\odot}$. Note: Large angular momentum fluctuations with varying directions, despite total zero angular momentum in the core.

Our Scenario

* Neutrinos fail to explode the star (Papish et. al 2015).
* When the convective envelope is accreted, intermittent accretion disks with varying angular momentum direction are formed and launch jets.
* These `jittering-jets' explode the star.
* This mechanism works better even if a black hole forms.
* This scenario implies that there are no failed supernovae.

Specific angular momentum components in thins shells of Δr=2000km in the inner part of the convective region at t=3500s in the MAESTRO simulation.

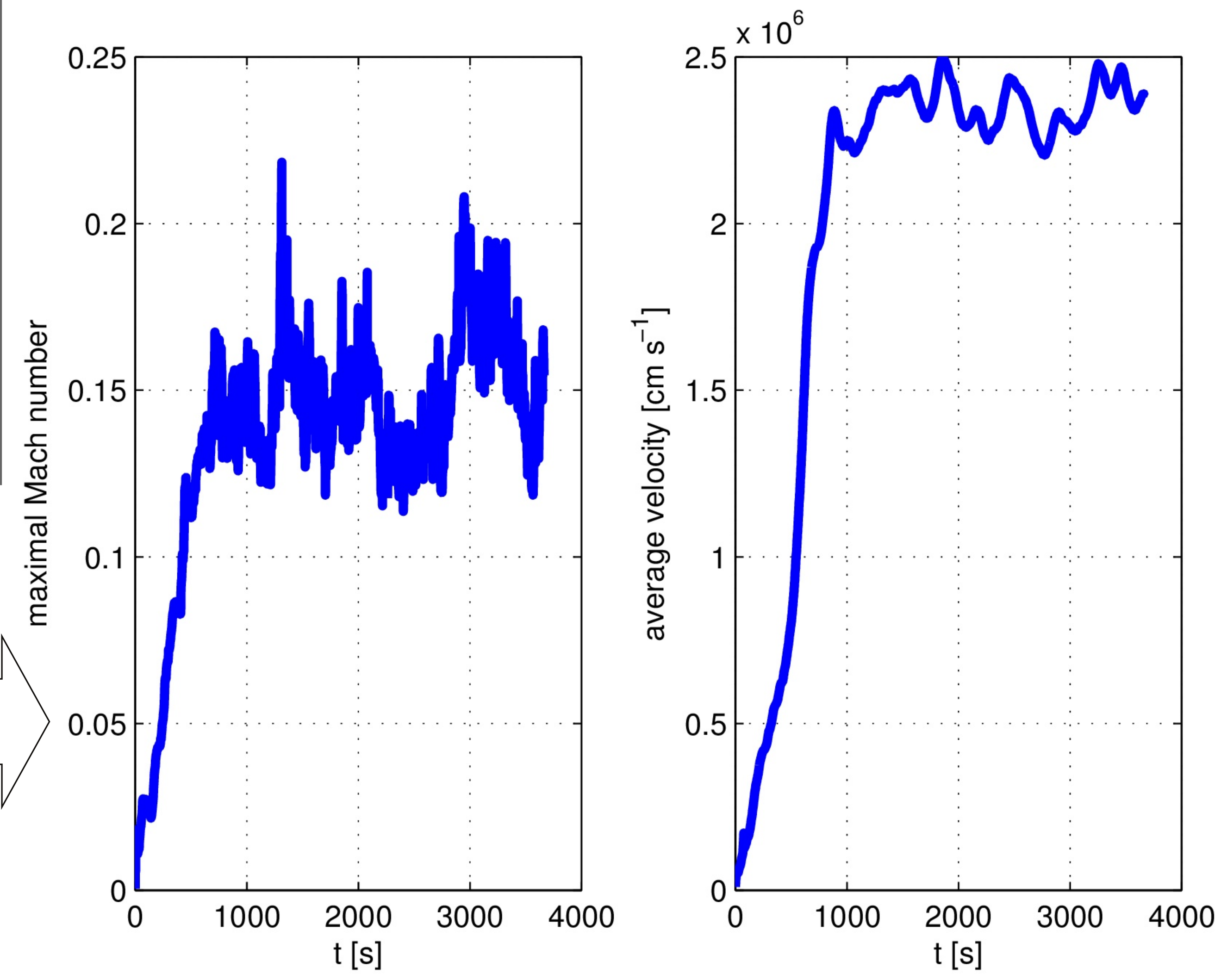




2D-slice of 3D-simulation: azimuthal velocity map (in cm/s) for an M_{ZAMS}=15$M_{\odot}$ star 5.5 years prior to collapse, after 3500 seconds run in MAESTRO.

3D hydrodynamic simulations indicate a higher convection velocity than predicted by 1D models, further strengthening the idea that CCSNe explode by jets.

The maximal Mach number (left) and average velocity (right) in the MAESTRO simulation. The velocity rises in the unstable region, described with mixing-length theory in the original MESA model. The average velocity in this region is higher than the mixing-length theory values by more than an order of magnitude!



Numerical Method

We evolve a 15$M_{\odot}$ star up to the shell helium burning stage with the MESA code (Paxton et al. 2011). This model is mapped into the low Mach-number solver MAESTRO (Nonaka et al. 2010), focusing on the convective helium shell where a 3D convective flow develops.

References

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