Flame Evolution and the Properties of Ias in the Gravitationally Confined Detonation Scenario

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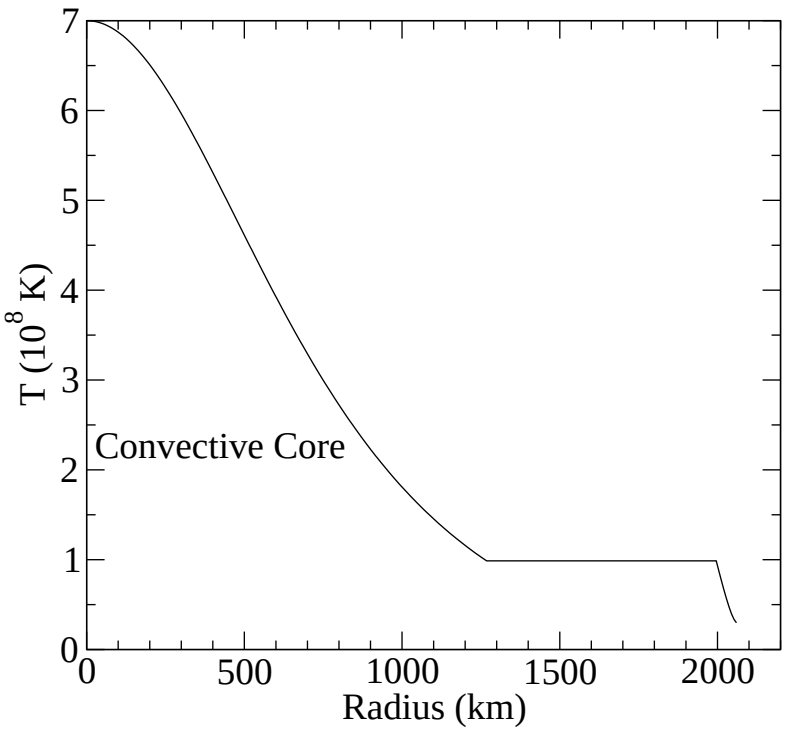
Ignition of Deflagration



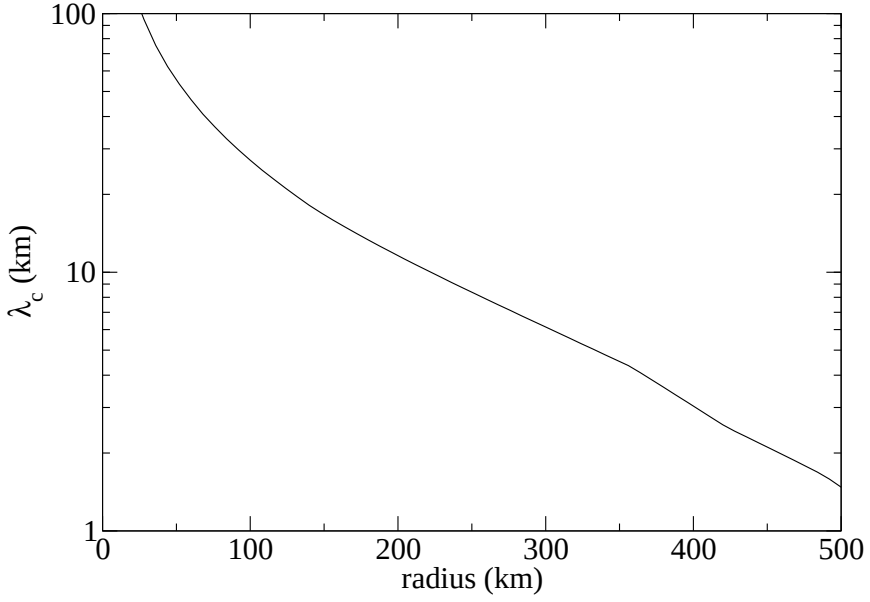
profile before flame ignition

- Deflagration ignites in convective core of WD. Convective velocities ~ 100 km/s. (Woosley, Wunsch, & Kuhlen, 2004, ApJ, 607, 921)
- Highly turbulent: significant phase space of fluctuations above average temperature.
- If ignition points are "rare" the first will appear at the small scales within the first temperature scale height of the center of the star.
- Must go out to 200 km for average temperature to drop by 10% from initial value. There is a good possibility that the first ignition point can be well off-center.

The Single Bubble Hypothesis

Start with treating an isolated region of burned material, a "single bubble".

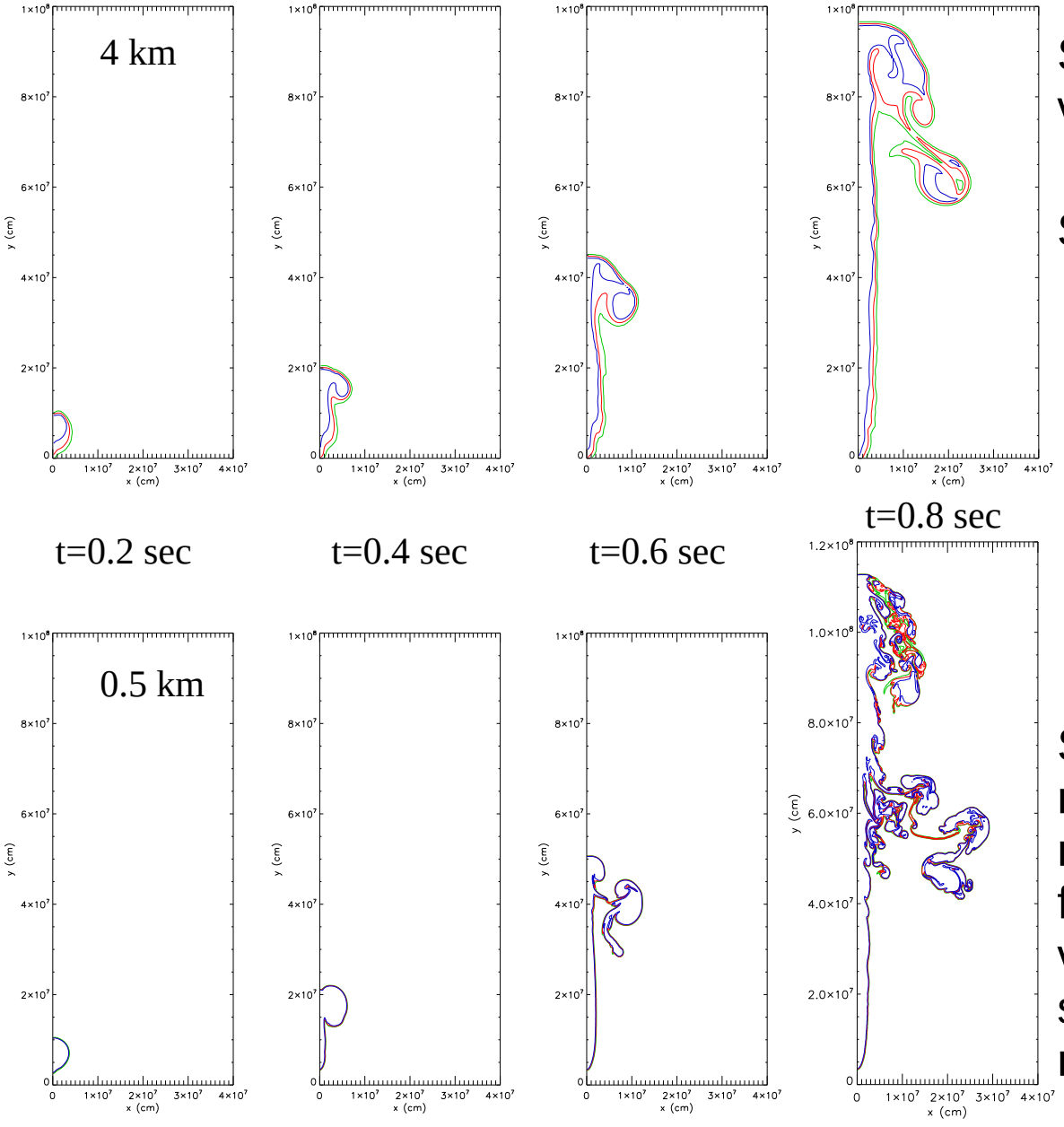
- Useful for learning about simple dynamics of bubble growth and rise, effects of bouyancy on flame surface (both direct and indirect).
- Start with a quiet background – this is *not* reality
- Useful 2-d studies can be performed because there is a natural axis of symmetry.



Do not have total freedom to place initial ash bubble – due to limited resolution, must place such that $r_{\rm bub} < \lambda_c$.

λ_c = critical wavelength above which R-T causes flame front to become unstable. Above this size starting with a spherical bubble is inconsistent.

Evolution of Flame Bubble



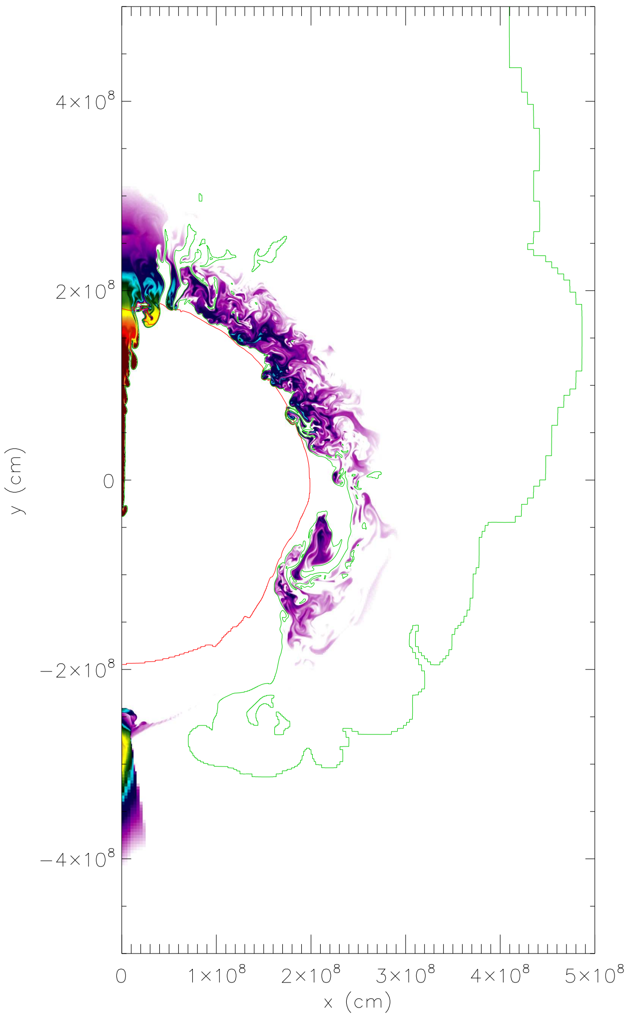
Shown: contours of progress variable $\phi = 0.1$, 0.5, and 0.9.

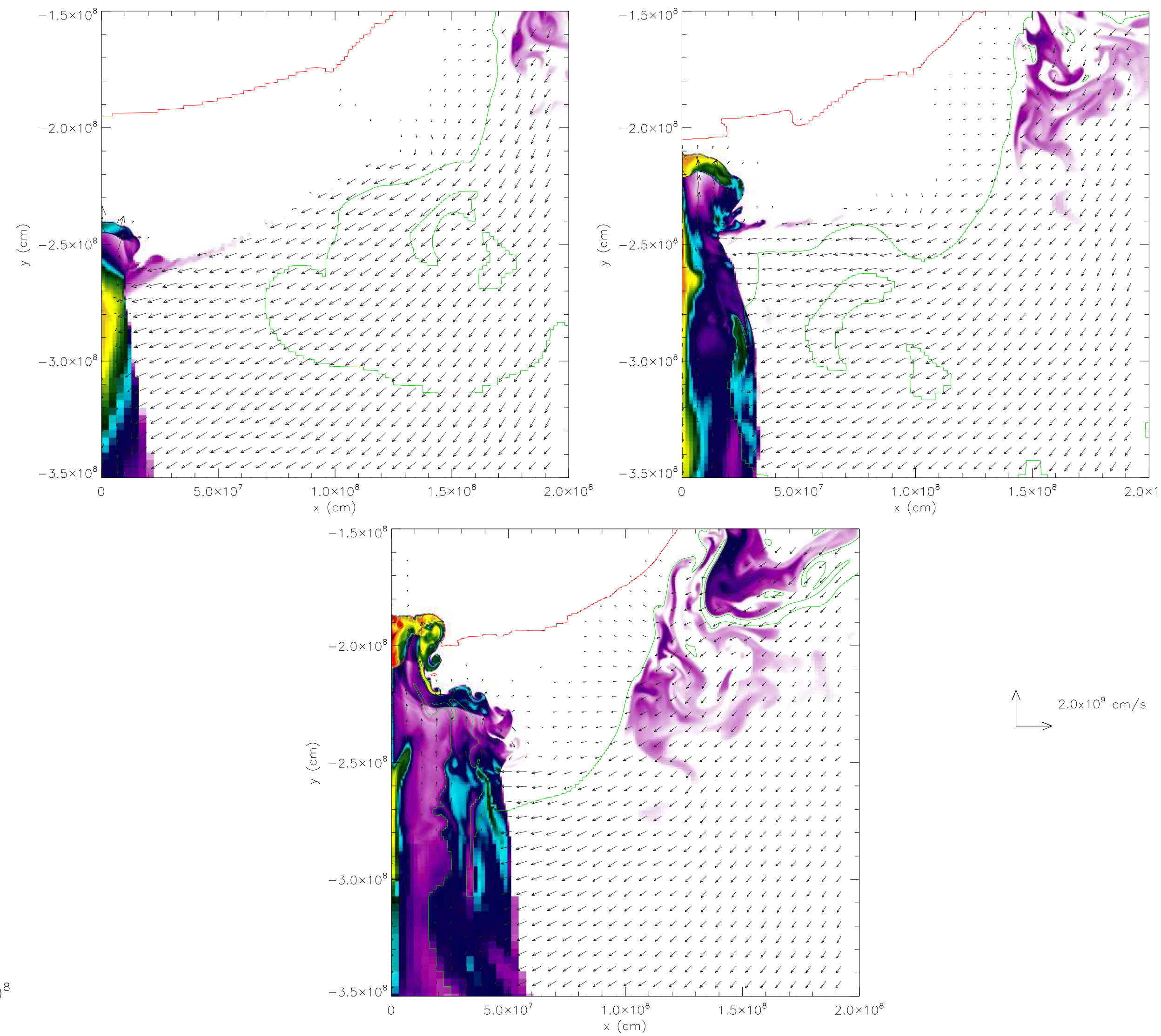
Stages of evolution:

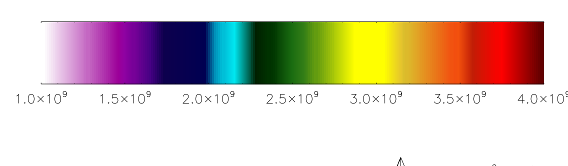
1. Laminar evolution: $r_{\rm bub} \lesssim \lambda_c$
2. Resolved R-T: $\Delta x < \lambda_c < r_{\rm bub}$
3. Unresolved R-T: $\lambda_c < \Delta x$

Some clear dependences on resolution: sharper features, more localized flame front, faster rise, different shed vortex. Also general similarities through the resolved R-T phase.

GCD: collision and compression







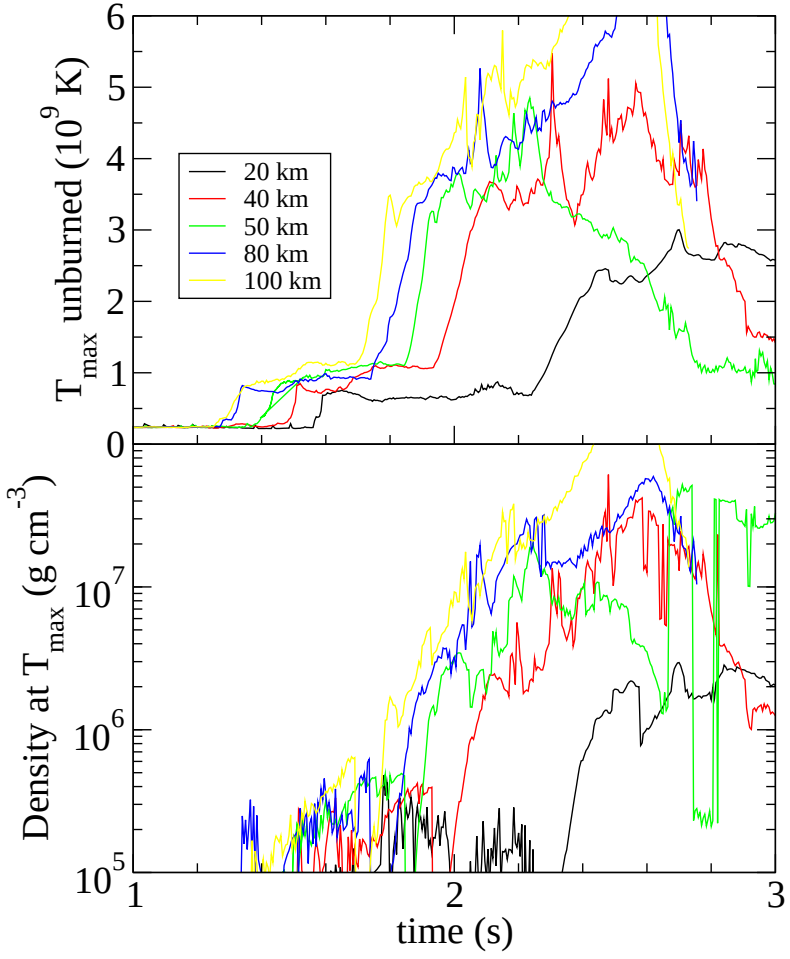
Color: T

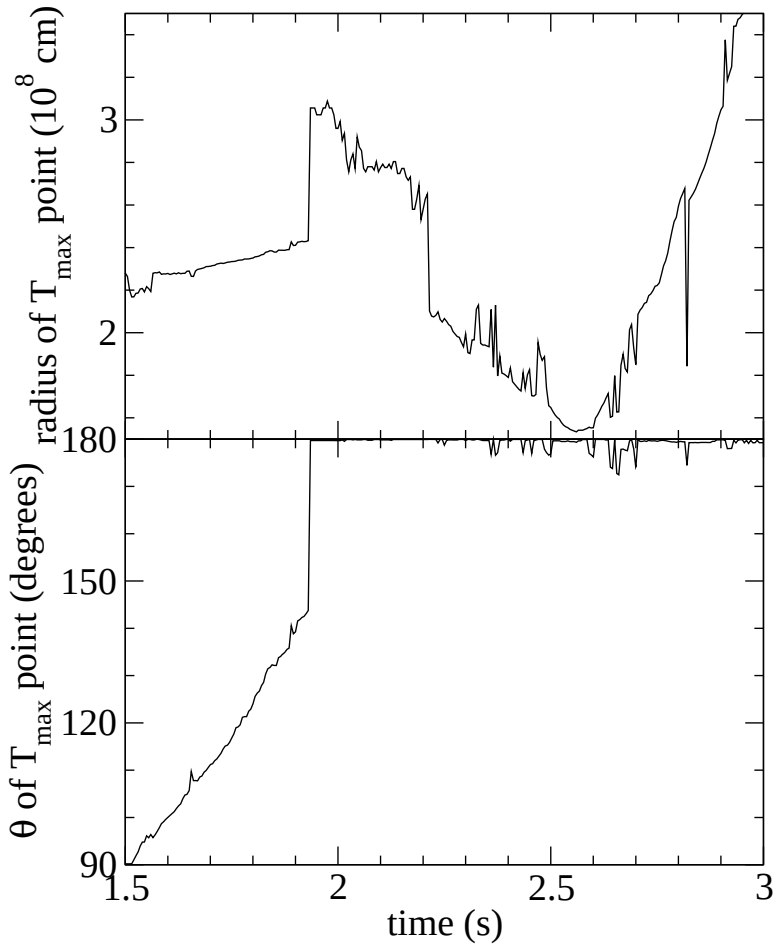
Contours: $\rho = 10^7$ g/cc, $\phi = 0.1$

Shown: $t = 2.07, 2.19, 2.32$ s

40 km initial radius

Variation in Collision

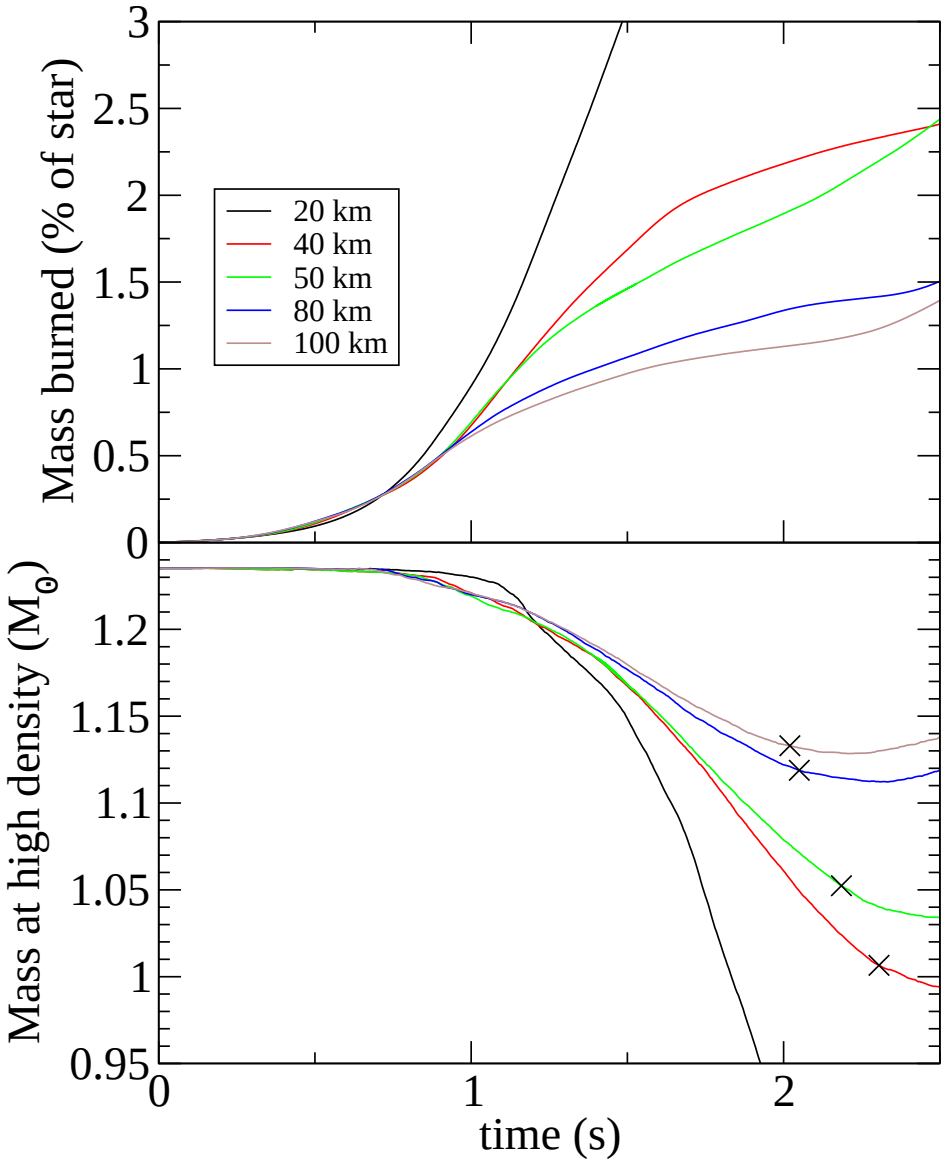




40 km case

- Larger offsets lead to earlier collision, higher densities
- Conservative ignition conditions, $T > 2 \times 10^9$ with $\rho > 10^7$ g/cc, reached for many cases.
- Most compression in jet directed toward stellar surface, *not* collision region

Dependence on Initial Condition



Outcome of deflagration phase determines density of material during detonation phase. (True for multi-d study of any Def-Det-type scenario.)

- Larger offsets burn less material, releasing less energy
- Causes less expansion and more dense material (shown is mass with $\rho > 5.5 \times 10^7$ g/cc.
- More ^{56}Ni should be be produced by larger offsets
- Timing of detonation ignition ($\times$) also significant