Chandrasekhar Mass Deflagrations as a Model for Type Iax Supernovae

Florian Lach[1,2], Friedrich Röpke[1,2], Markus Kromer

[1]Zentrum für Astronomie, Heidelberg University, [2]Heidelberg Institute for Theoretical Studies

Heidelberg Institute for Theoretical Studies HITS

UNIVERSITÄT HEIDELBERG ZUKUNFT SEIT 1386

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Characteristics of Type Iax Supernovae (Foley et al., 2013)

- Low Luminosity: $-14.2 \gtrsim M_{V,\,\mathrm{peak}} \gtrsim -18.4\,\mathrm{mag}$
- Low Expansion Velocities: $2000 \lesssim |v| \lesssim 8000\,\mathrm{km\,s^{-1}}$
- Ejected mass $\lesssim 0.6\,\mathrm{M_\odot} \longrightarrow$ Bound Remnant
- Mass of ^{56}Ni $\sim 0.003 - 0.27\,\mathrm{M_\odot}$
- Strong Mixing in the Ejecta
- Possible Scenario: **Failed Deflagration**

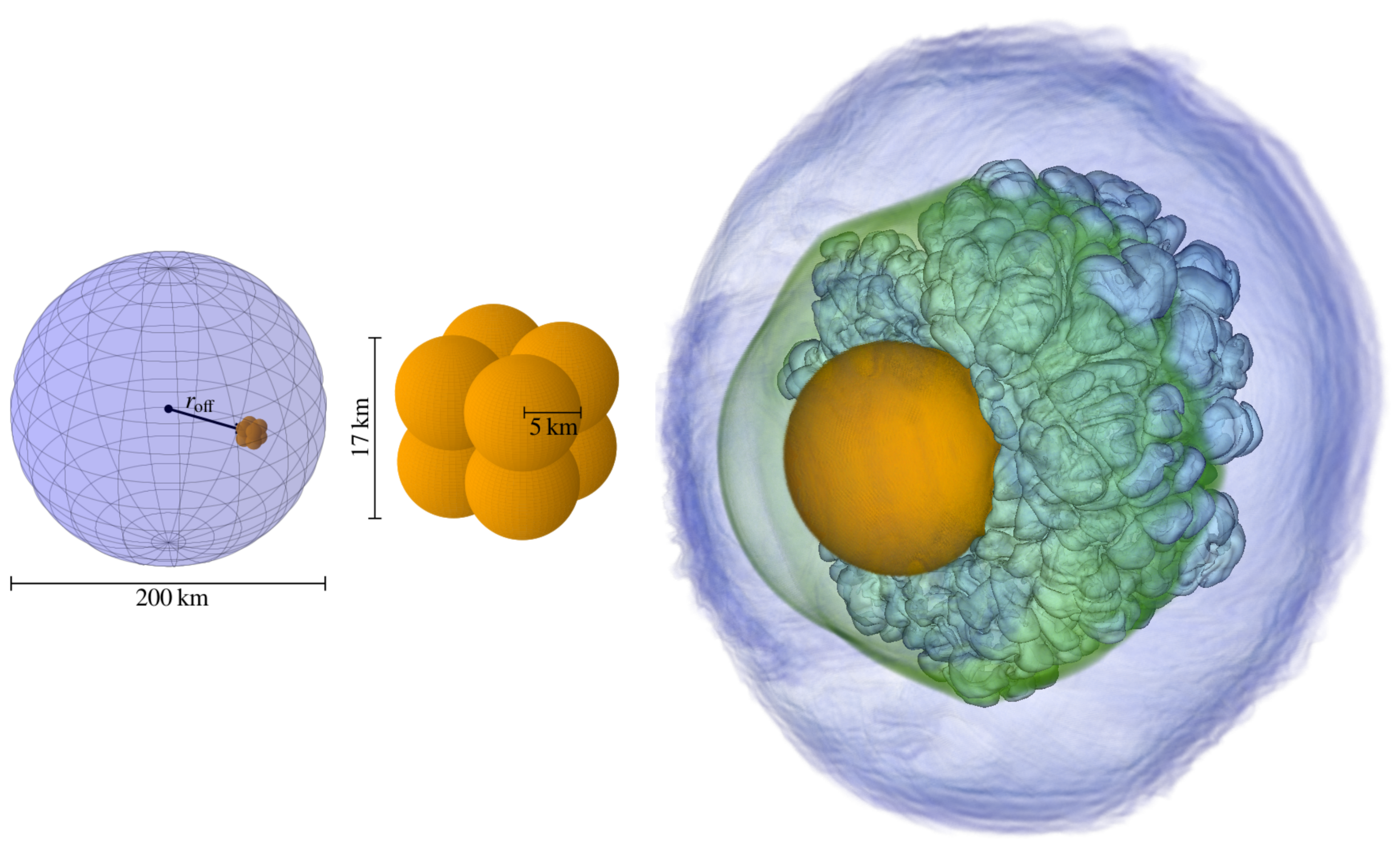
Previous Modelling Efforts

- 3D Deflagrations in $\mathrm{M_{Ch}}$ WDs from multi-spot Ignition (Fink et al., 2014)
  - → Can not account for full diversity of SNe Iax (Magee et al., 2017)
- Simmering Phase Simulations (Zingale et al., 2011)
  - → Off-Center Ignition in single spot

⇒ **Detailed Investigation of the Parameter Space needed**

Explosion Modelling & Setup

- Finite Volume Hydrocode LEAFS:
  - ▷ Levelset Approach for Flame Front
  - ▷ Moving Hybrid Grid to track Flame and WD
  - ▷ Resolution: 528^3
  - ▷ New: FFT gravity solver
- Adiabatic Temperature Profile with $T_c = 6 \times 10^8\,\mathrm{K}$
- Single Spot off-center Ignition in $\mathrm{M_{Ch}}$ WD
- Postprocessing: 384 Species Nuclear Network Code YANN

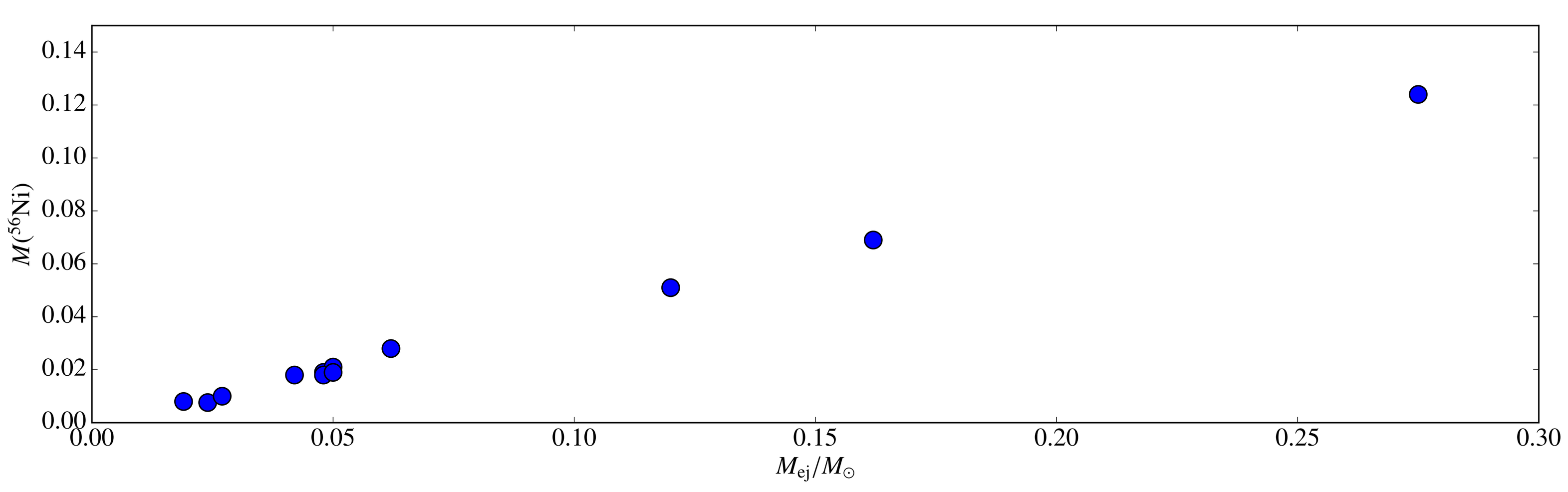


Left: Initial ignition configuration. Ignition spark consists of four bubbles to provide an initial perturbation. **Right:** Volume rendered density and flame front at $t = 1.35\,\mathrm{s}$

- Models:
  - ▷ Central Density: $1.0 < \rho_c < 2.6 \times 10^9\,\mathrm{g\,cm^{-3}}$
  - ▷ Offset Radius: $10 < r_{\mathrm{off}} < 150\,\mathrm{km}$
  - ▷ Metallicity: $0.001 < Z < 2\,Z_\odot$

Results - Hydro

- Ejected Mass and ^{56}Ni mass at lower end of expected range
  - ▷ comparable to N1def, N3def in (Fink et al., 2014)
- Large impact of varying ρ_c and r_{off}



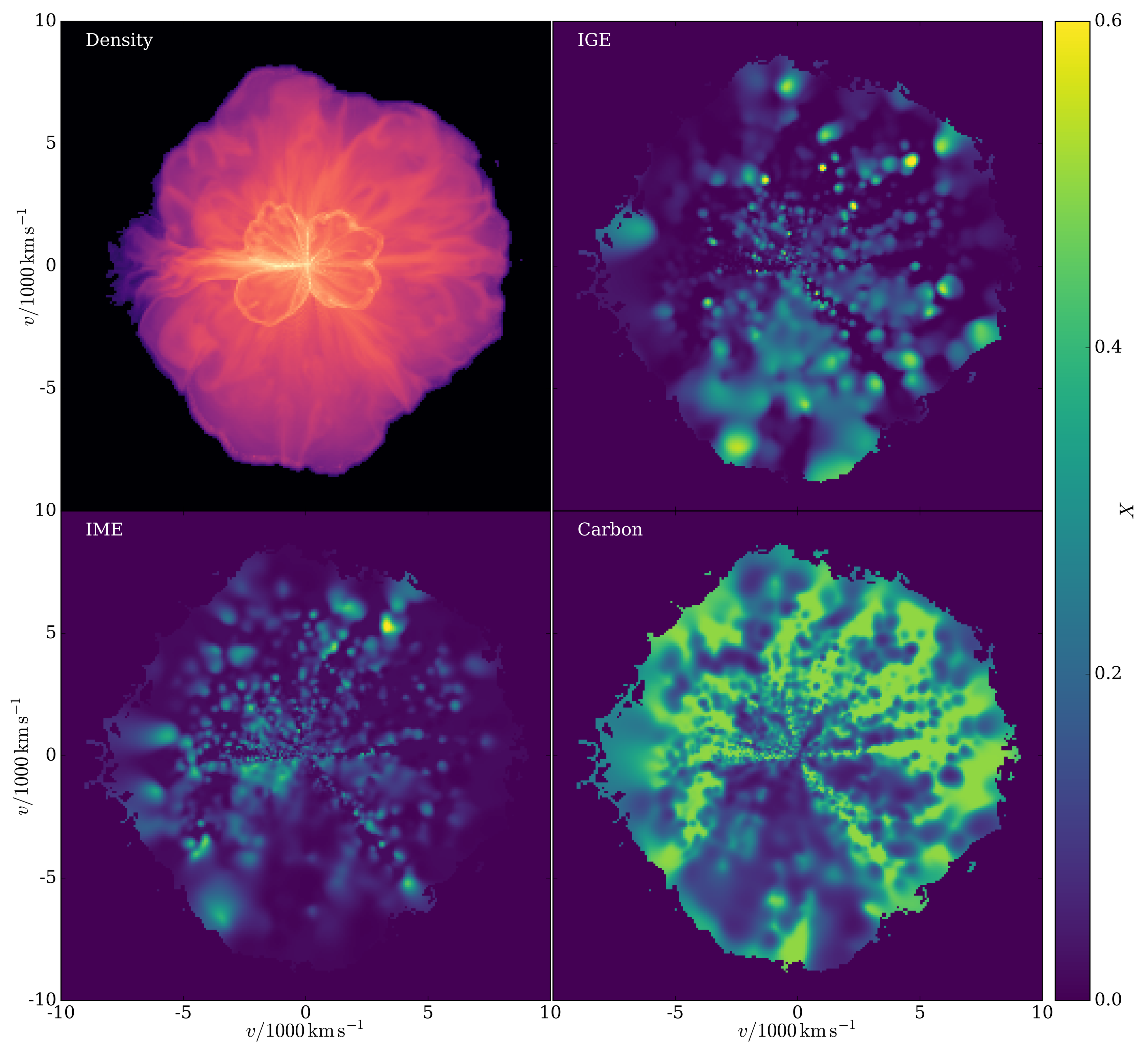
ρ_c	r_{off}	$Z_\odot$	M_{ej}	$E_{\mathrm{nuc}}/10^{50}\,\mathrm{erg}$	$\frac{E_{\mathrm{nuc}}}{E_{\mathrm{bind}}}$
1.0	60	1	0.062	1.91	0.085
2.6	60	1	0.050	1.90	0.059
2.6	60	0.01	0.050	1.93	0.060
5.0	60	1	0.024	1.15	0.029
1.0	10	0.01	0.275	4.01	0.177
2.6	10	1	0.162	3.13	0.098
2.6	150	1	0.042	1.85	0.058

Results - Nucleosynthesis

ρ_c	r_{off}	$Z_\odot$	^{56}Ni	IGE	IME	O	C
2.6	150	1	0.0178	0.026	0.0034	0.0008	0.0007
2.6	60	1	0.0189	0.025	0.0039	0.010	0.009
2.6	10	1	0.069	0.094	0.013	0.028	0.025
1.0	10*	0.01	0.124	0.140	0.035	0.053	0.0.041

Nucleosynthetic yields for the ejected material in solar masses. *) Ignited in two bubbles.

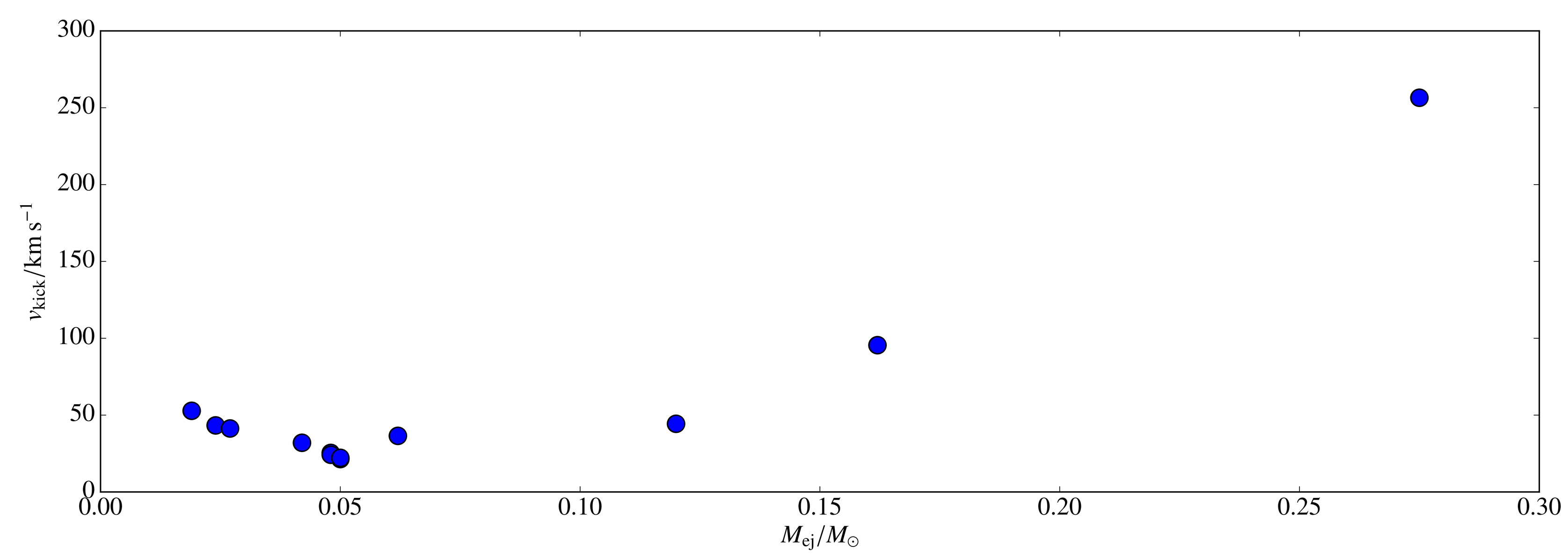
- IGE and ^{56}Ni comparable and lower than in Fink et al. (2014)
- IME significantly lower compared to Fink et al. (2014)
- Mixed Ejecta: ^{12}C , ^{16}O prominent in outer regions and ^{56}Ni in central part
- Velocities within expected range: $v_{\max} \lesssim 10000\,\mathrm{km\,s^{-1}}$



Density and mass fractions of IGEs, IMEs and carbon as a function of asymptotic velocity.

Bound Remnant

- A lot of burned material inside the core
- Bound remnant receives recoil due to asymmetric explosion
- Large spread in kick velocities
  - ▷ can the remnant leave the binary system?



Kick velocity of the bound remnant vs. ejected mass

- Work in Progress:
  - ▷ Evolve the bound remnant further and resolve its structure
  - ▷ Calculate spectra and light curves

References

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