Modeling Core Collapse Supernovae

Research Day of Universe Cluster: ^{44}Ti

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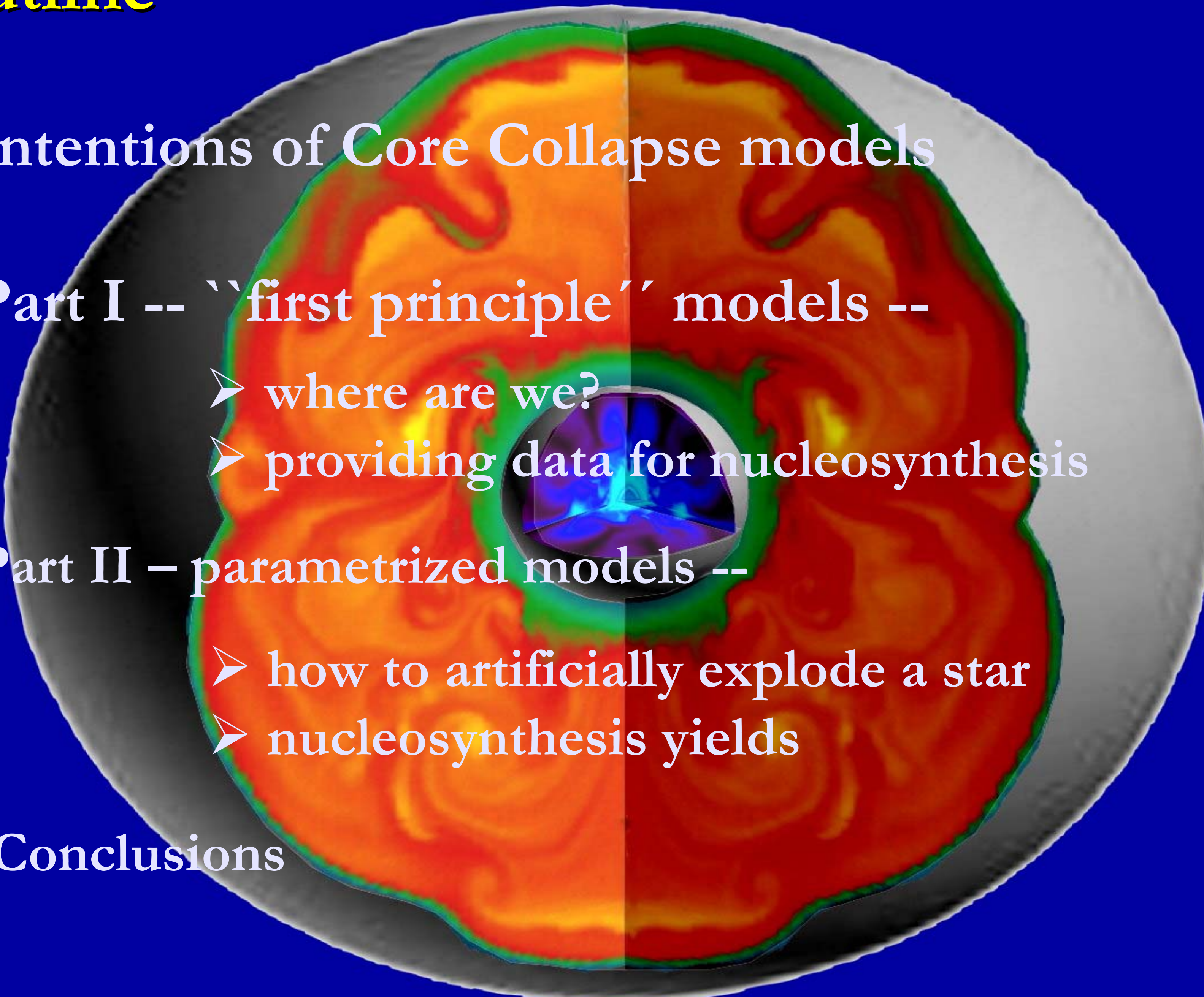
Outline



- Intentions of Core Collapse models
- Part I -- ``first principle´´ models --
  - where are we?
  - providing data for nucleosynthesis
- Part II – parametrized models --
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  - nucleosynthesis yields
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Intentions of core collapse models

two independent approaches

``first principle´´ models

nucleosynthesis models

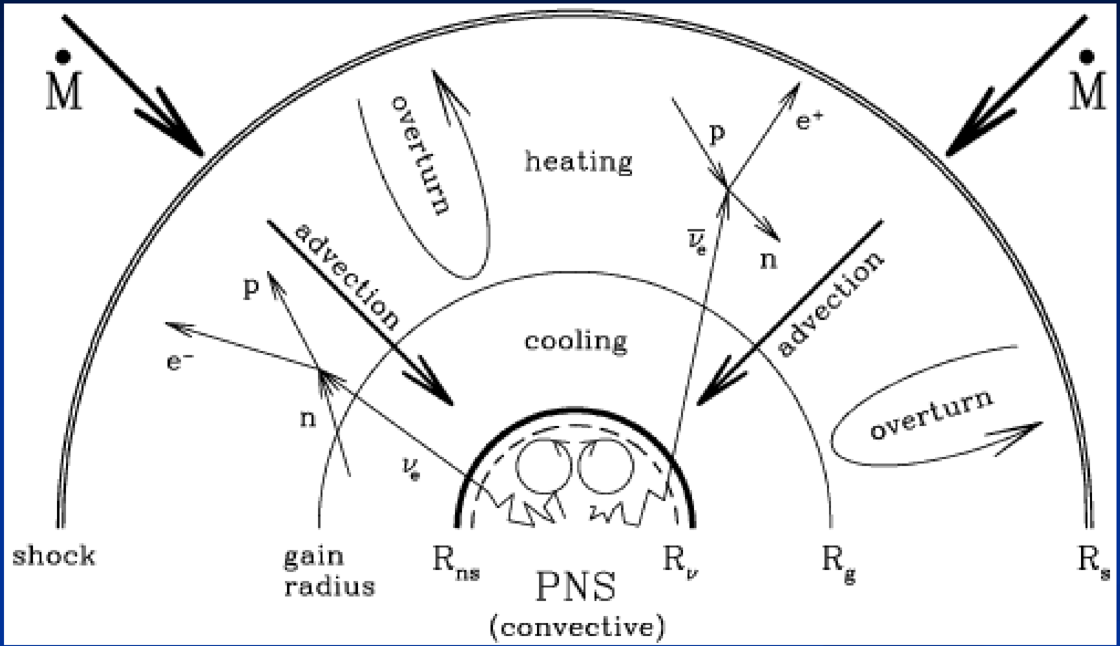
- investigate explosion mechanism with consistent models and dependence on major physics (e.g. instabilities, EoS, micro-physics…)
- very expensive => few models
- nucleosynthesis data: only if explosion AND if evolution can be followed long enough

- invert problem ?
- parametrize artificial explosion
- cheap => many models + long evolution
- nucleosynthesis data: easy

Part I

``first principle ´´ models

``First principle´´ models



Questions:

Does neutrino-heating mechanism work?

Are there other possible energy sources?

``First-principle´´ models: where are we?

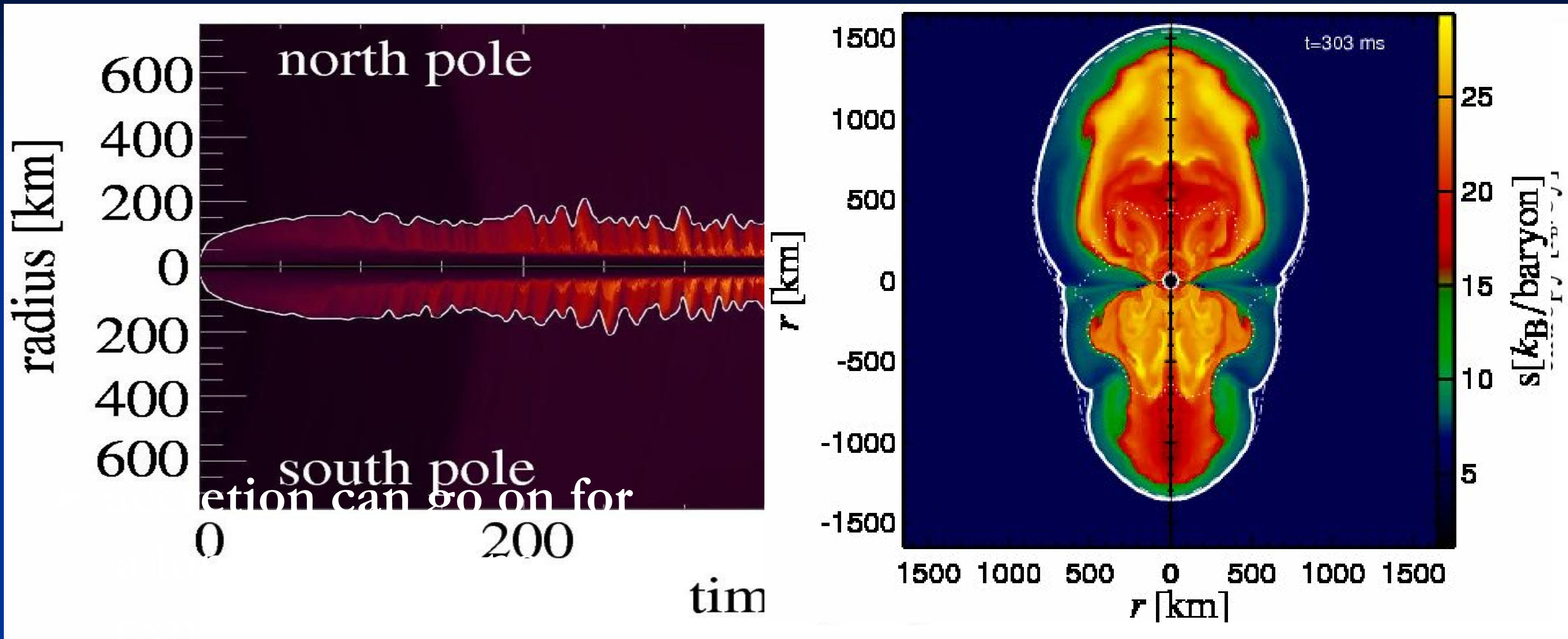
3 succesfull explosions of progenitors in the mass range $8 < M_\odot < 15$ at MPA:

- 8-9 $M_\odot$ O-Ne-Mg core; rapid explosion (F.S. Kitaura & B. Müller)
- 11.2 $M_\odot$; quite fast explosion (Buras et al. 2006)
- 15 $M_\odot$; late explosion (Marek & Janka 2007)

- other groups (Burrows et al., Mezzacapa et al.) also report explosions

$\Rightarrow$ we are far from a robust explosion mechanism but we learned a lot …

``First-princple´´ models: where are we?



influences: mass cut, neutrino emission (also Ye of expelled matter), explosion energy

``First-princple´´ models: where are we?

We are hampered by:

- expensive calculations (~ 2 a year)
  => limited ``systematic´´ studies
- unknown 2D-effects (3D is planned)
- unknown long-time evolution neutrino emission
  (in progress)
- progenitor, rotation, magnetic field dependence …

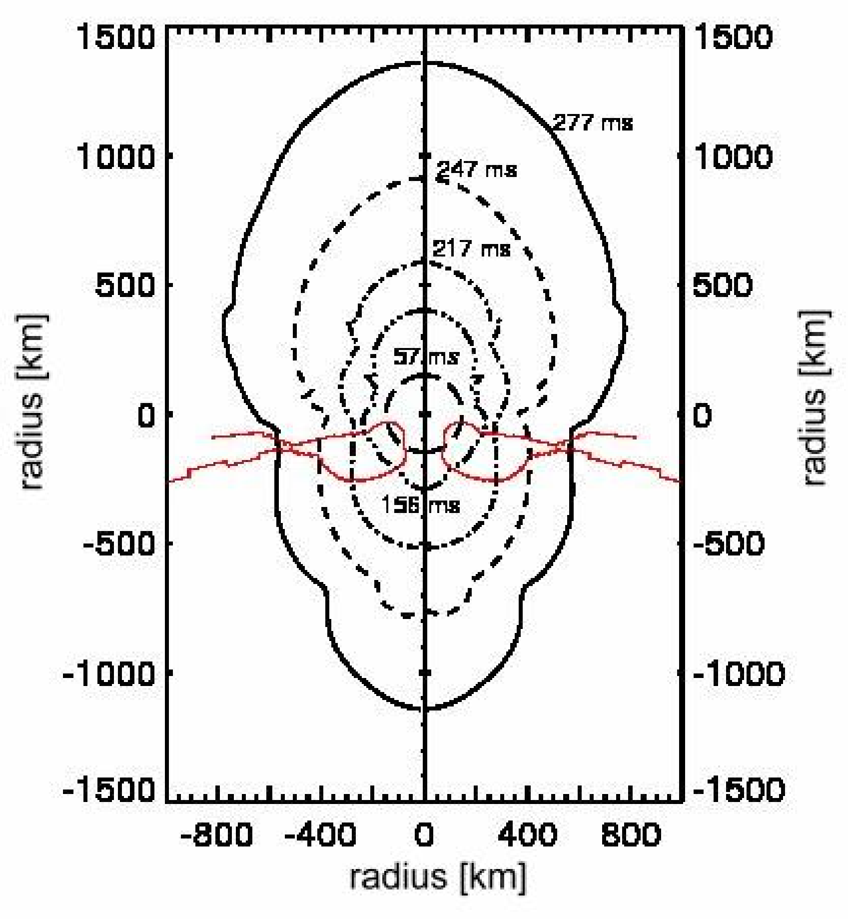
Nucleosynthesis data:

- only a few sucessful explosions so far
- hard to follow late explosion evolution (r_{Shock} < 2000 km)

Providing data fur nucleosynthesis calculations

For explosion models we provide (selected) (ρ,T, Y_e) trajectories

- start with ~50 000 marker particles
- integrate fluid flow through model evolution to get trajectories
- select from ~50 000 particles about 1000 particles
- with ρ,T, Ye information (+$X_{initial}$) network calculations can be done



Part II

parametrized models

How to artificially explode a star

Several possibilities:

- piston models (e.g. Woosley et al.)
- energy / entropy injection (Maeda et al., Fryer et al.)
- increased neutrino opacities …

Typical parameters to play arround (depending on input physics):

- mass cut
- explosion energy
- Y_e
- ....

Advantage of parametrized models:

- ✓ cheap models => many models possible in parameter space
- ✓ nucleosynthesis input for long evolution times

Disadvantage of parametrized models:

- ✓ inversion possible?
- ✓ not self-consistent

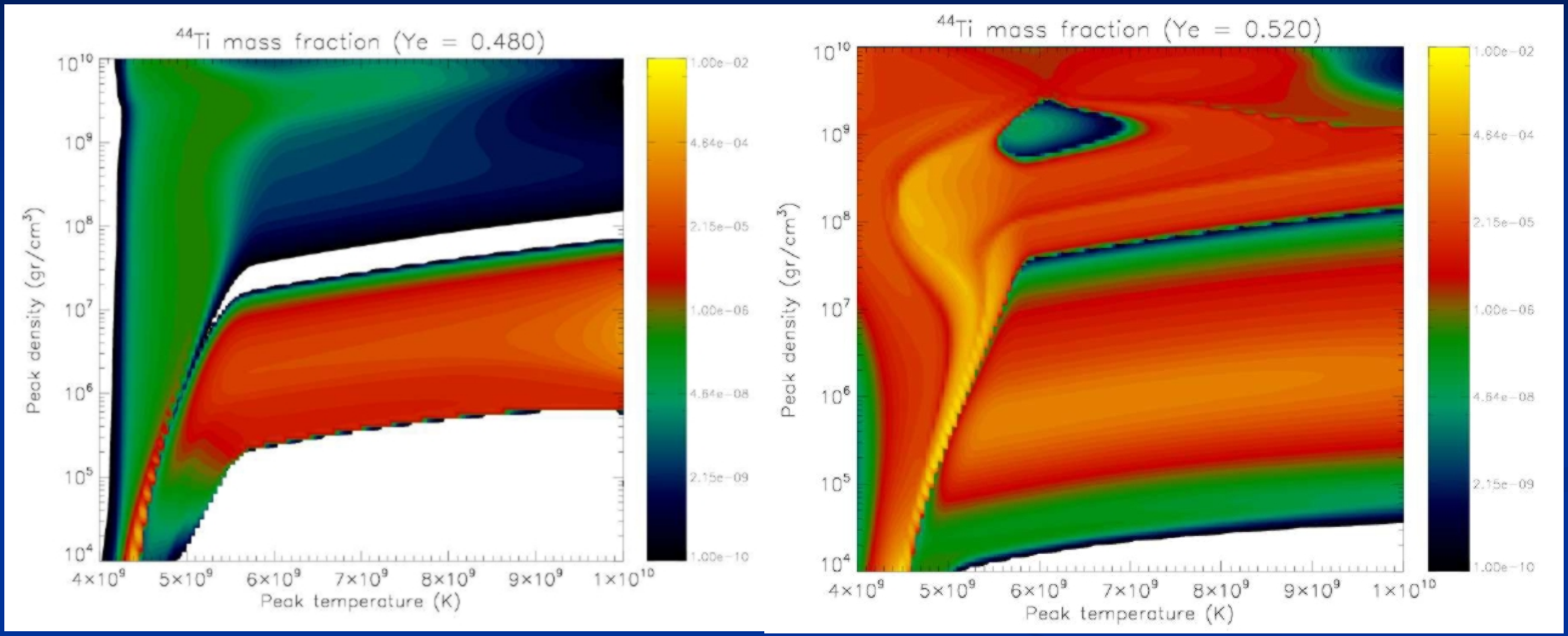
Compilation from Fryer et al. 2008

Model Name and citation	Model Charact.		Yields				
	E_{exp} 10^{51} erg	M_{rem} $M_\odot$	^{28}Si $M_\odot$	^{45}Sc 10^{-5} $M_\odot$	^{44}Ti 10^{-5} $M_\odot$	^{60}Co 10^{-5} $M_\odot$	^{56}Ni $M_\odot$
WW-S22A[8]	1.47	2.02	0.356	1.20	6.15	2.43	0.205
WW-S25A[8]	1.18	2.07	0.315	0.228	3.04	5.36	0.129
23e-1.5[7]	3.2	1.5	0.303	0.082	0.513	1.03	0.0013
23e-2.0[7]	2.6	2.0	0.461	0.080	6.95	1.04	0.283
d0.2-1.5[7]	2.6	1.5	0.463	0.081	2.62	0.99	0.240
d0.7-1.5[7]	2.3	1.5	0.482	0.091	10.0	1.01	0.216
23p-1.2[7]	3.2	1.2	0.362	0.080	0.655	0.992	0.0066
23p-1.6[7]	2.4	1.6	0.439	0.079	23.5	0.996	0.613
CL-20[9]	1.6	-	0.156	0.542	4.03	1.13	0.10
CL-25[9]	1.8	-	0.245	1.26	2.19	2.44	0.10

``parameters´´

Yields can change by factors / orders of magnitude

Magkotsios et al. 2008:



Yield of Ti44 depends strongly on Y_e (if everything else is equal) => treatment of neutrinos makes a huge difference

Conclusions:

- two approaches to simulate core collapse supernovae: ``first principle´´ and artificial explosion
- ``first principle´´ models: aim to investigate the explosion mechanism with fully consistent calculations

  => tedious approach for nucleosynthesis

- parametrized explosions: try to invert the problem by comparing nucleosynthesis yields to observations

  Does a unique solution exist?