



Blowing up a polytropic star

Justin Lietz – Code

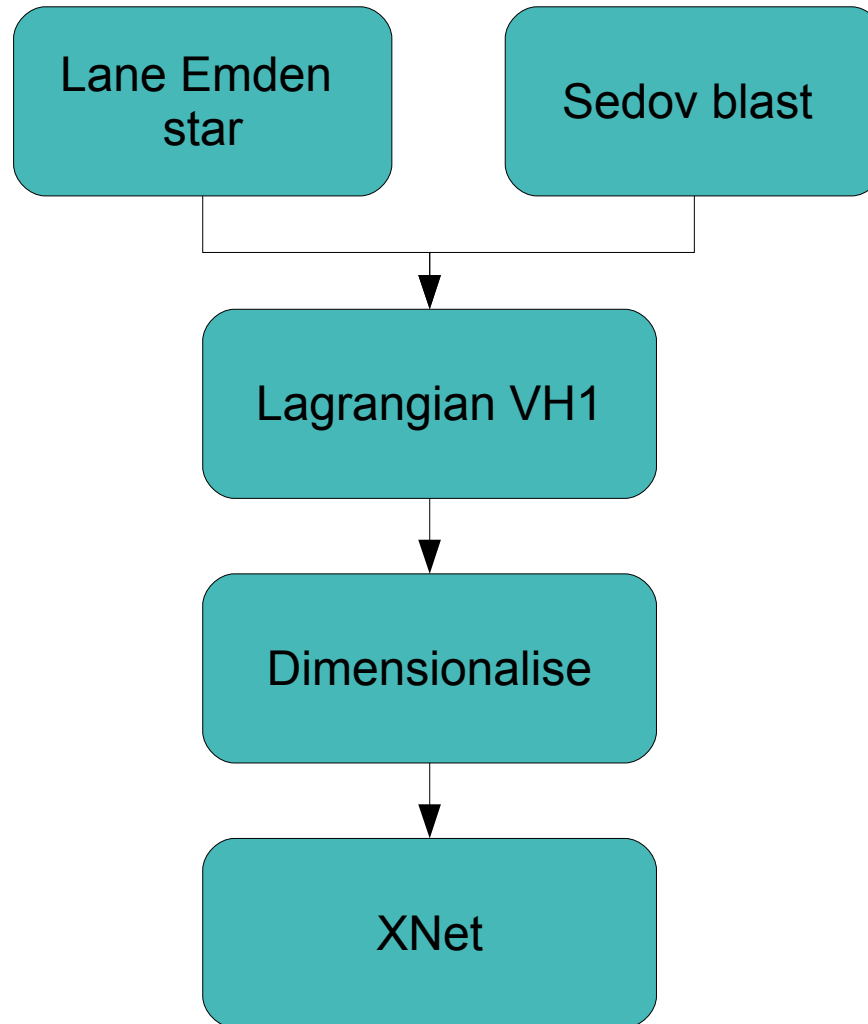
Kaitlin Cook – Analysis

Sherwood Richers – Inputs

Motivations

- Toy model of a star + toy model of a shock
= toy supernova.
- We can then follow the nucleosynthesis.
- Acts as a good way to combine the tools from last week.

Aims

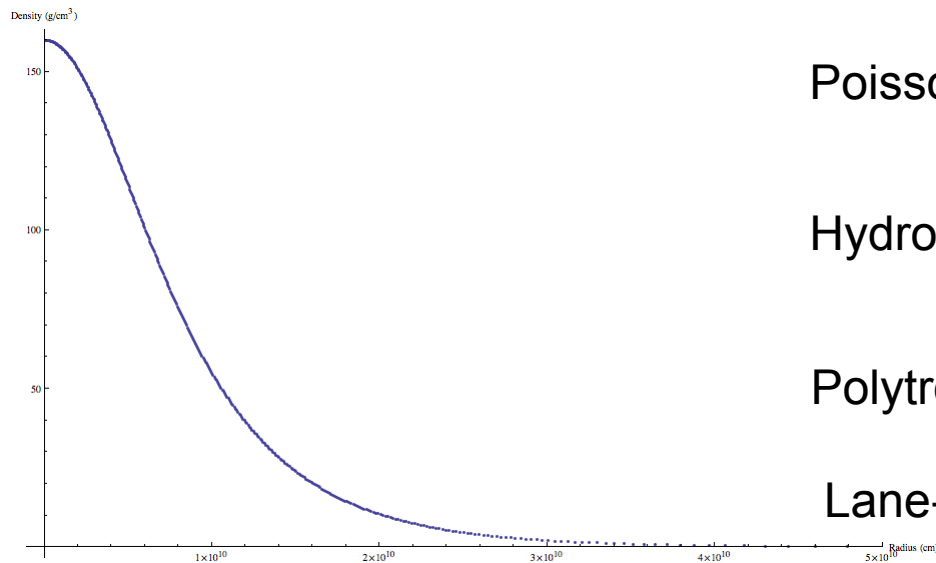


Key Challenges

- Working out units
- Recasting VH1 in Lagrangian coordinates
- Writing a wrapper script to take output from VH1 to XNet
- Displaying the results in a meaningful way

Polytropic Stars: Lane-Emden Solutions

Plot of a solution to Lane-Emden $n = 3/2$



Poisson Equation:

$$\nabla^2 \Phi = \frac{1}{r^2} \frac{d}{dr} \left(r^2 \frac{d\Phi}{dr} \right) = 4\pi G \rho$$

Hydrostatic Equilibrium:

$$\frac{d\Phi}{dr} = -\frac{1}{\rho} \frac{dP}{dr}$$

Polytropic EOS:

$$P = K \rho^{1 + \frac{1}{n}}$$

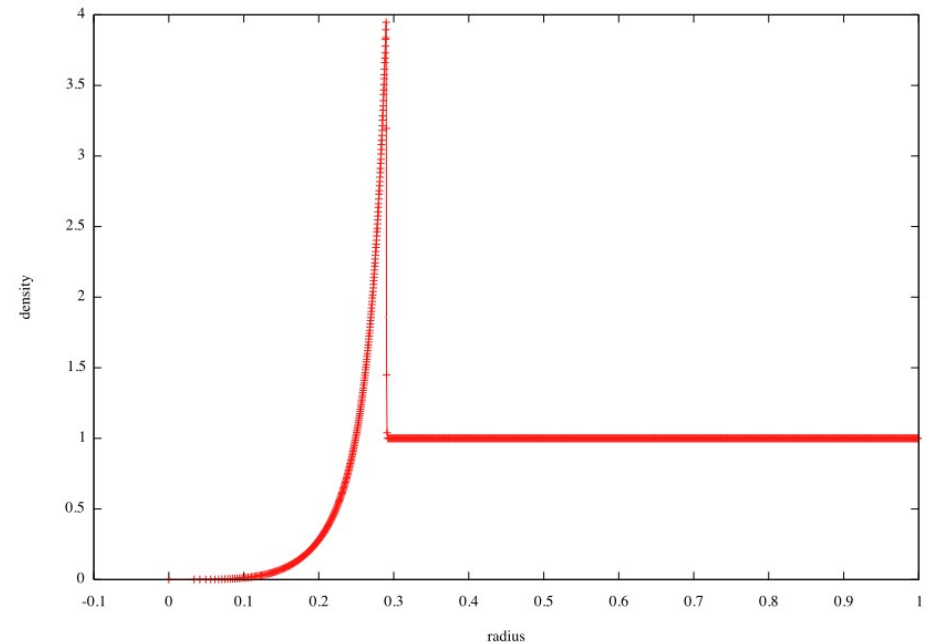
Lane-Emden:

$$\frac{1}{\xi^2} \frac{d}{d\xi} \left(\xi^2 \frac{d\theta}{d\xi} \right) + \theta^n = 0$$

Energy of the Blast = 10^{49} Ergs

Sedov Blasts

- The Sedov blast - a large amount of energy in a small region.
- Very high pressure in the first zone, smaller pressures in all of the other zones (from star model)

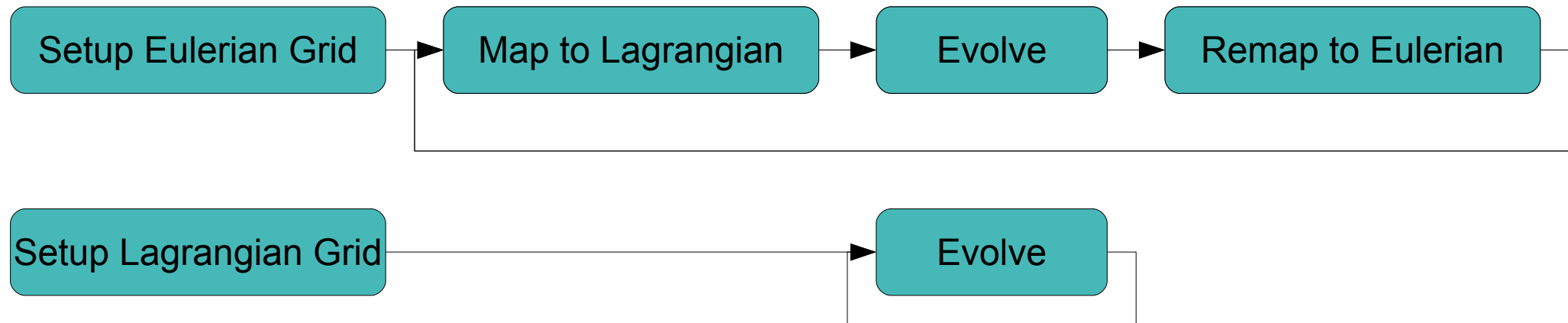


Lagrangian Coordinates

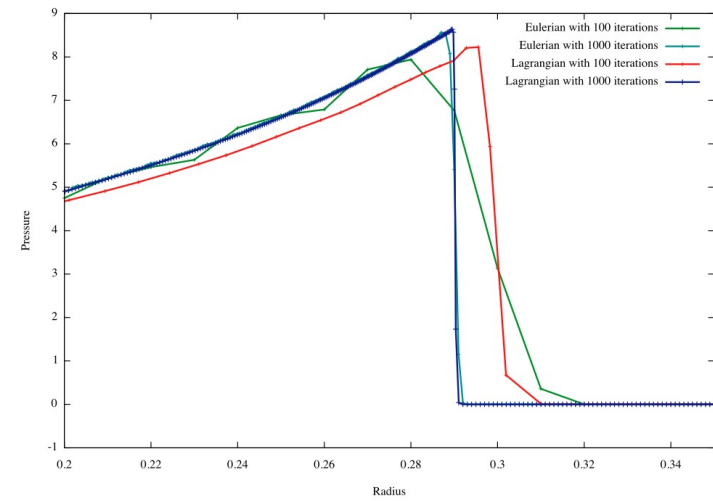
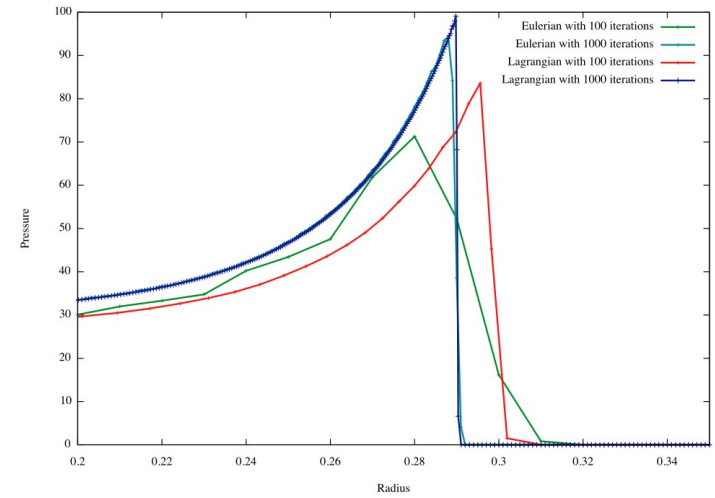
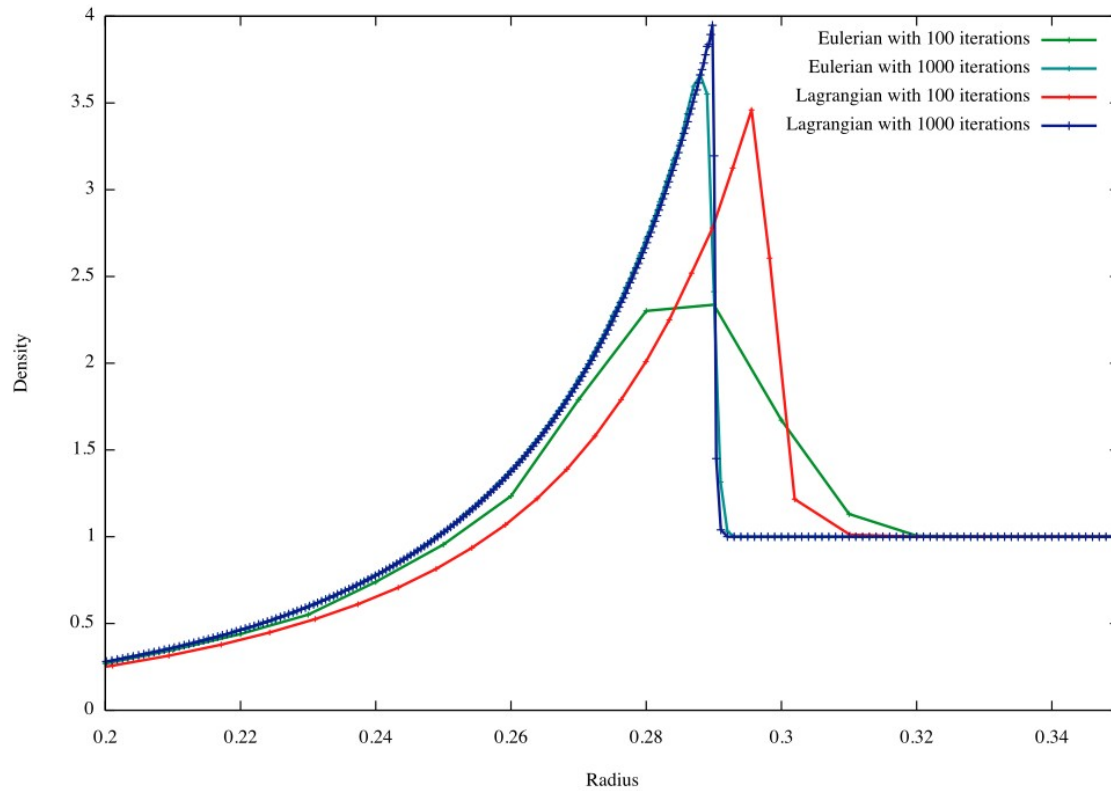
- Eulerian coordinates – zones transfer matter
- Lagrangian coordinates – zones follow matter
→ Follow nucleosynthesis without advecting species

VH1 Lagrangian

- `ppmlr.f90`



Lagrangian vs Eulerian



Connecting VH1 to Xnet

- VH1 output looks familiar to a lot of you by now:

```
l3375@ubuntu: ~/talent/project1/sedov-solution/VH1/output
l3375@ubuntu: ~/Downloads$ xpdf chap_05_cloudcores.pdf &
[9] 6291
l3375@ubuntu: ~/Downloads$ cd ..
l3375@ubuntu: ~$ cd talent/
l3375@ubuntu: ~/talent$ cd project1/
l3375@ubuntu: ~/talent/project1$ ls
sedov-solution
l3375@ubuntu: ~/talent/project1$ cd sedov-solution/
l3375@ubuntu: ~/talent/project1/sedov-solution$ ls
branches          LaneEmden.nb      presentation.odp  VH1
laneEmden.dat     nuclearchart     README.md
l3375@ubuntu: ~/talent/project1/sedov-solution$ cd VH1/
l3375@ubuntu: ~/talent/project1/sedov-solution/VH1$ ls
indat  output  src  vh1orbitty.sh  vh1-starter
l3375@ubuntu: ~/talent/project1/sedov-solution/VH1$ cd output/
l3375@ubuntu: ~/talent/project1/sedov-solution/VH1/output$ ls
10sm                EUL1000sedov1025.dat  EUL100sedov1005.dat  EUL100sedov1036.dat  LAG1000sedov1011
1sm                 EUL1000sedov1026.dat  EUL100sedov1006.dat  EUL100sedov1037.dat  LAG1000sedov1012
animate_hydro.py   EUL1000sedov1027.dat  EUL100sedov1007.dat  EUL100sedov1038.dat  LAG1000sedov1013
animate_hydro.py~  EUL1000sedov1028.dat  EUL100sedov1008.dat  EUL100sedov1039.dat  LAG1000sedov1014
basic_animation.mp4 EUL1000sedov1029.dat  EUL100sedov1009.dat  EUL100sedov1040.dat  LAG1000sedov1015
density_animation.mp4 EUL1000sedov1030.dat  EUL100sedov1010.dat  EUL100sedov1041.dat  LAG1000sedov1016
EUL1000sedov1000.dat EUL1000sedov1031.dat  EUL100sedov1011.dat  EUL100sedov1042.dat  LAG1000sedov1017
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EUL1000sedov1019.dat EUL1000sedov.hst      EUL100sedov1030.dat  EUL100sedov1049.dat  LAG1000sedov1034
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EUL1000sedov1023.dat EUL100sedov1003.dat  EUL100sedov1034.dat  EUL100sedov1049.dat  LAG1000sedov1038
EUL1000sedov1024.dat EUL100sedov1004.dat  EUL100sedov1035.dat  EUL100sedov1049.dat  LAG1000sedov1039
l3375@ubuntu: ~/talent/project1/sedov-solution/VH1/output$
```

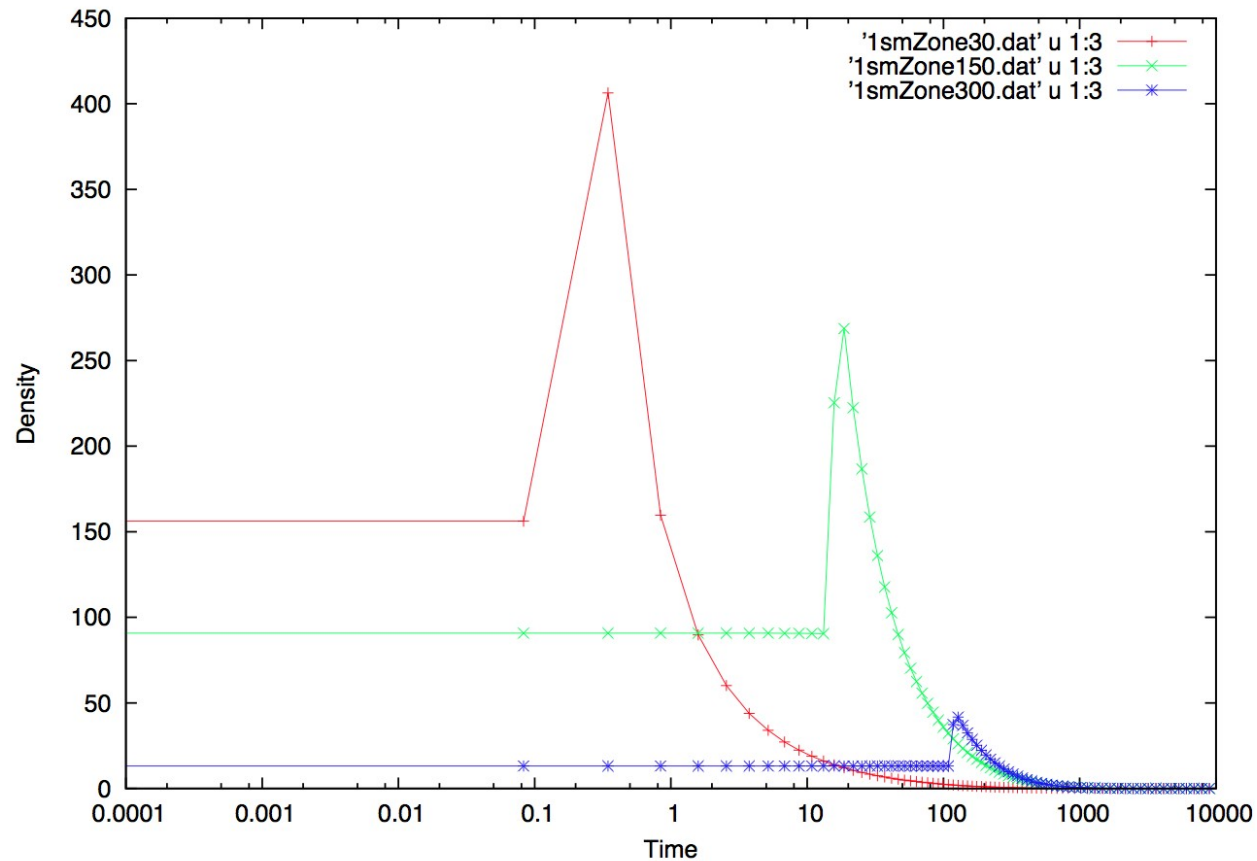
Hydro Results – $1 M_{\text{sol}} + 10^{49}$ ergs



$10 M_{\text{sol}} + 10^{49} \text{ ergs}$

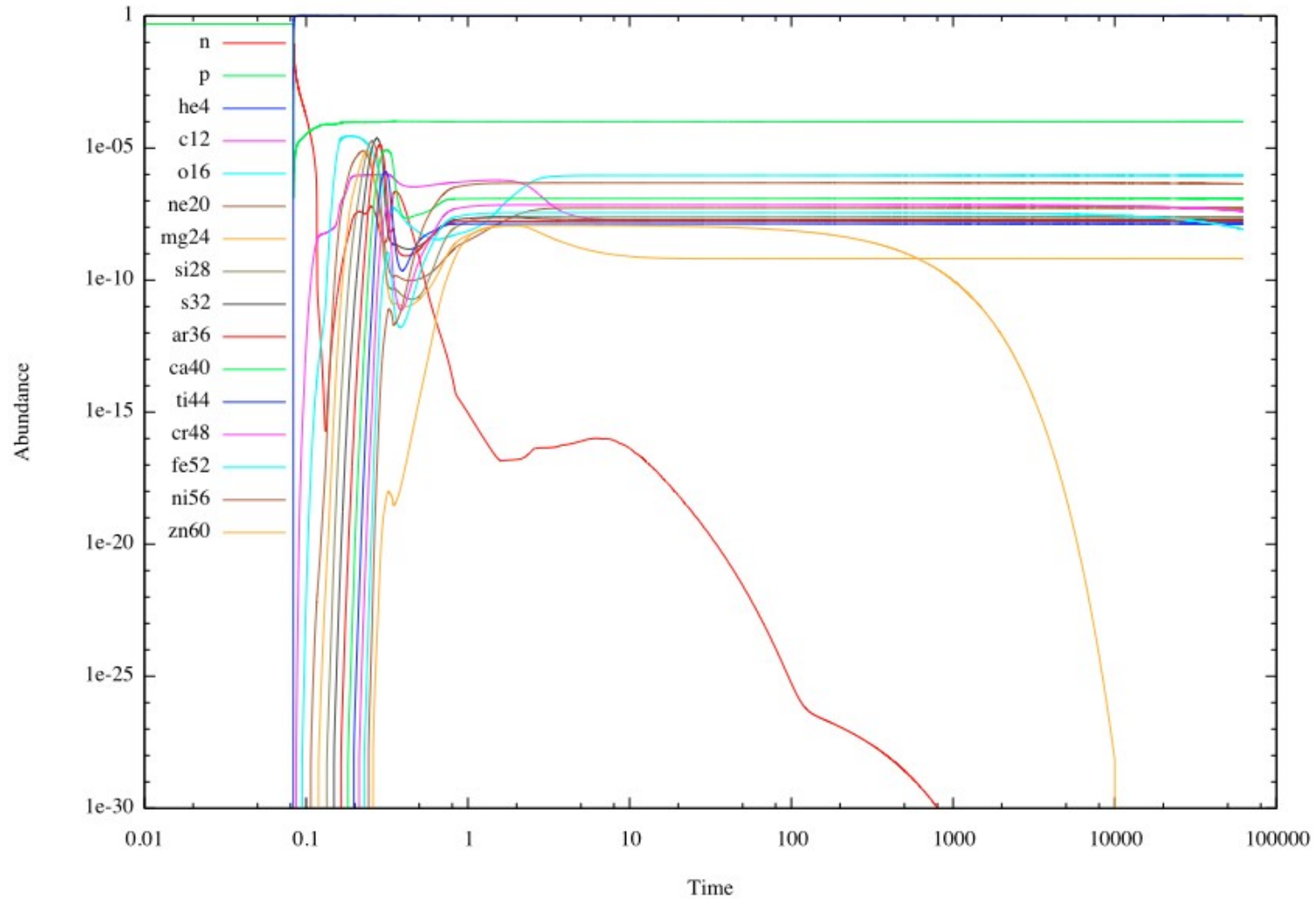


$1 M_{\text{sol}}$ Blast at different radii



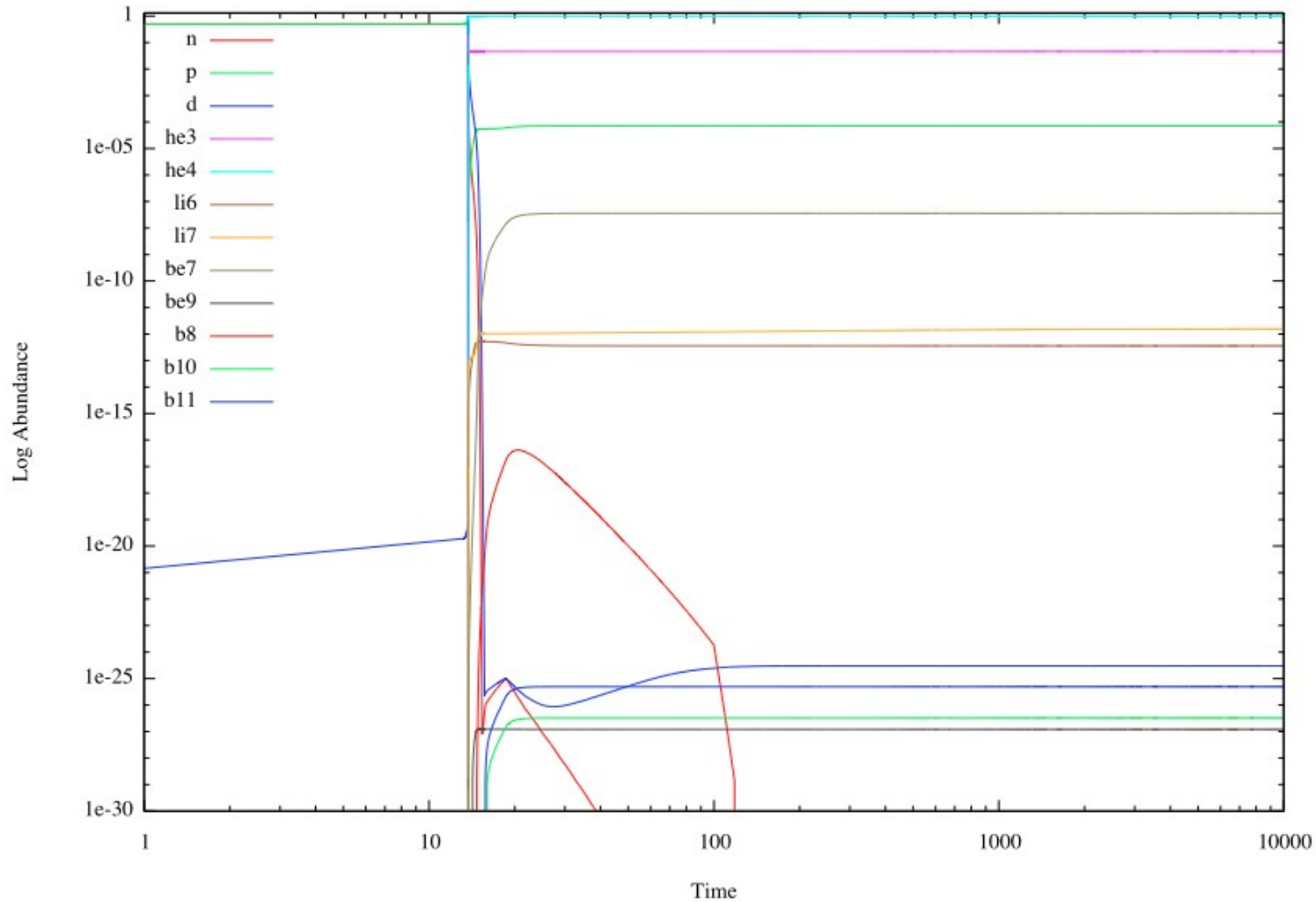
Nucleosynthesis $1 M_{\text{sol}} + 10^{49}$ ergs

$0.03 R_{\text{sol}} - \text{Peak } T = 3.3 \text{ GK}$



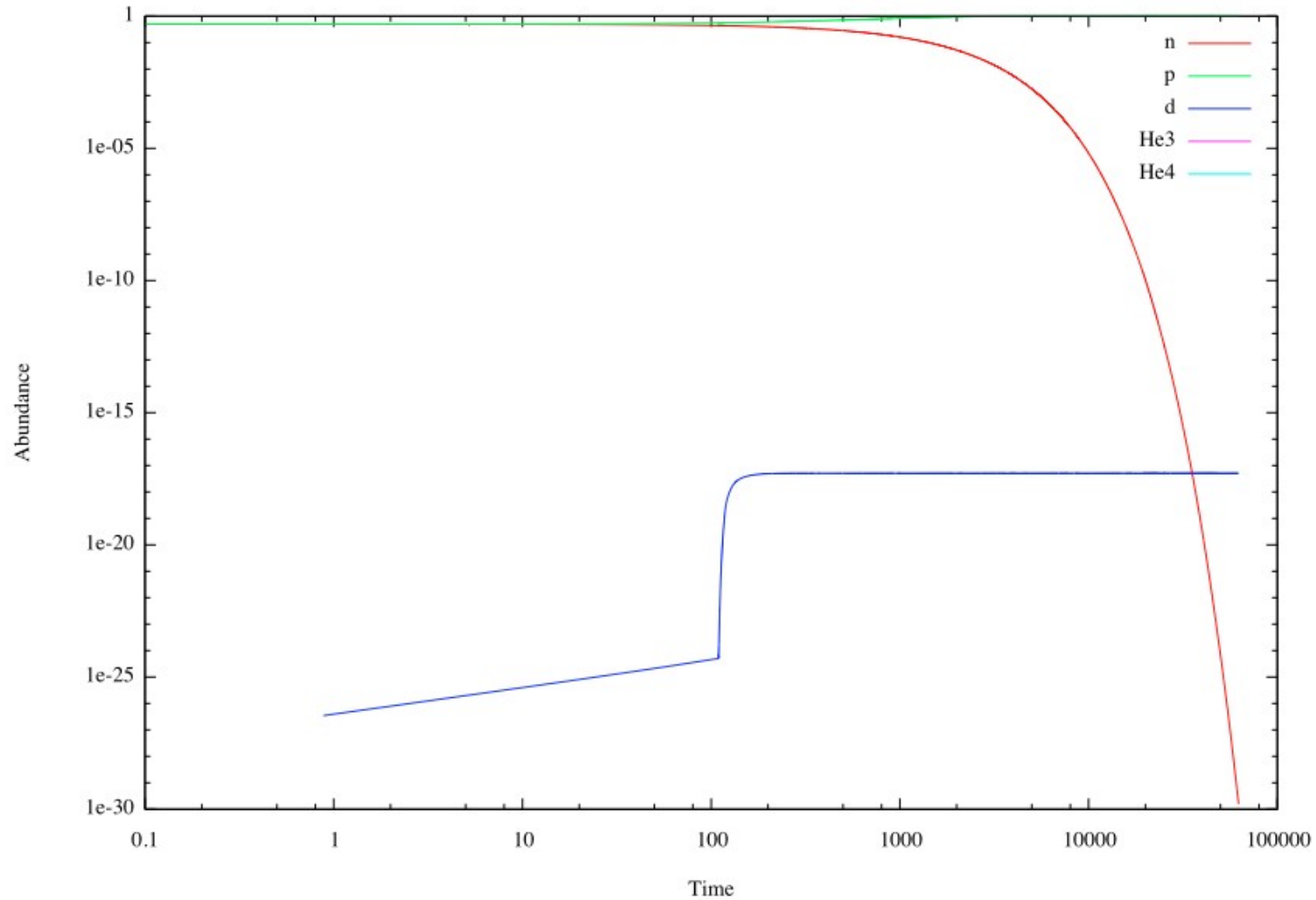
Nucleosynthesis $1 M_{\text{sol}} + 10^{49}$ ergs

$0.10 R_{\text{sol}}$ – Peak $T = 0.04$ GK



Nucleosynthesis $1 M_{\text{sol}} + 10^{49}$ ergs

$0.17 R_{\text{sol}} - \text{Peak } T = 0.001 \text{ GK}$



50/50 n/p progenitor



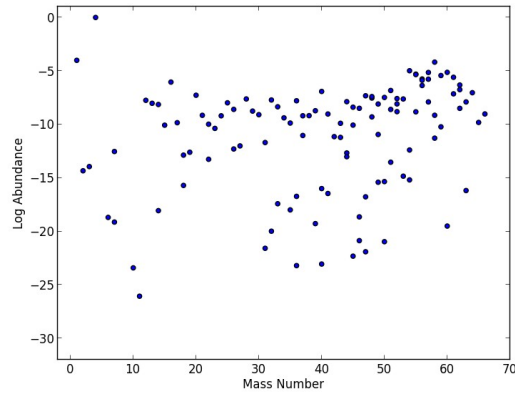
^4He progenitor



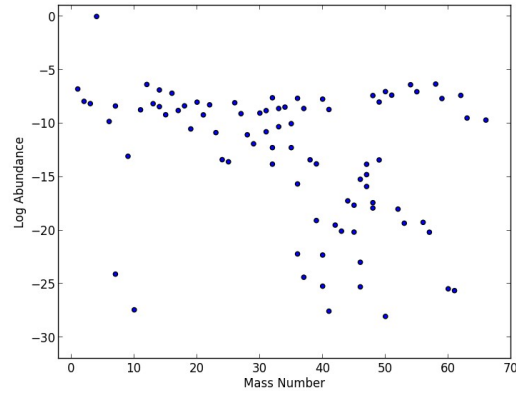
^{56}Fe progenitor



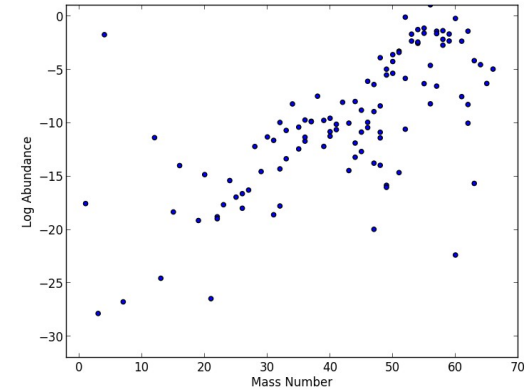
Abundances at $t = 10^5$



$n+p$ initial



${}^4\text{He}$ initial



${}^{56}\text{Fe}$ initial

With a few more days?

- Add in gravity
- Realistic EOS
- Realistic initial conditions for hydro
- Further variation of initial abundances
- Larger Network
- Vary blast energy
- Nucleosynthesis on all zones
- Feed the Nucleosynthesis energy into the hydro