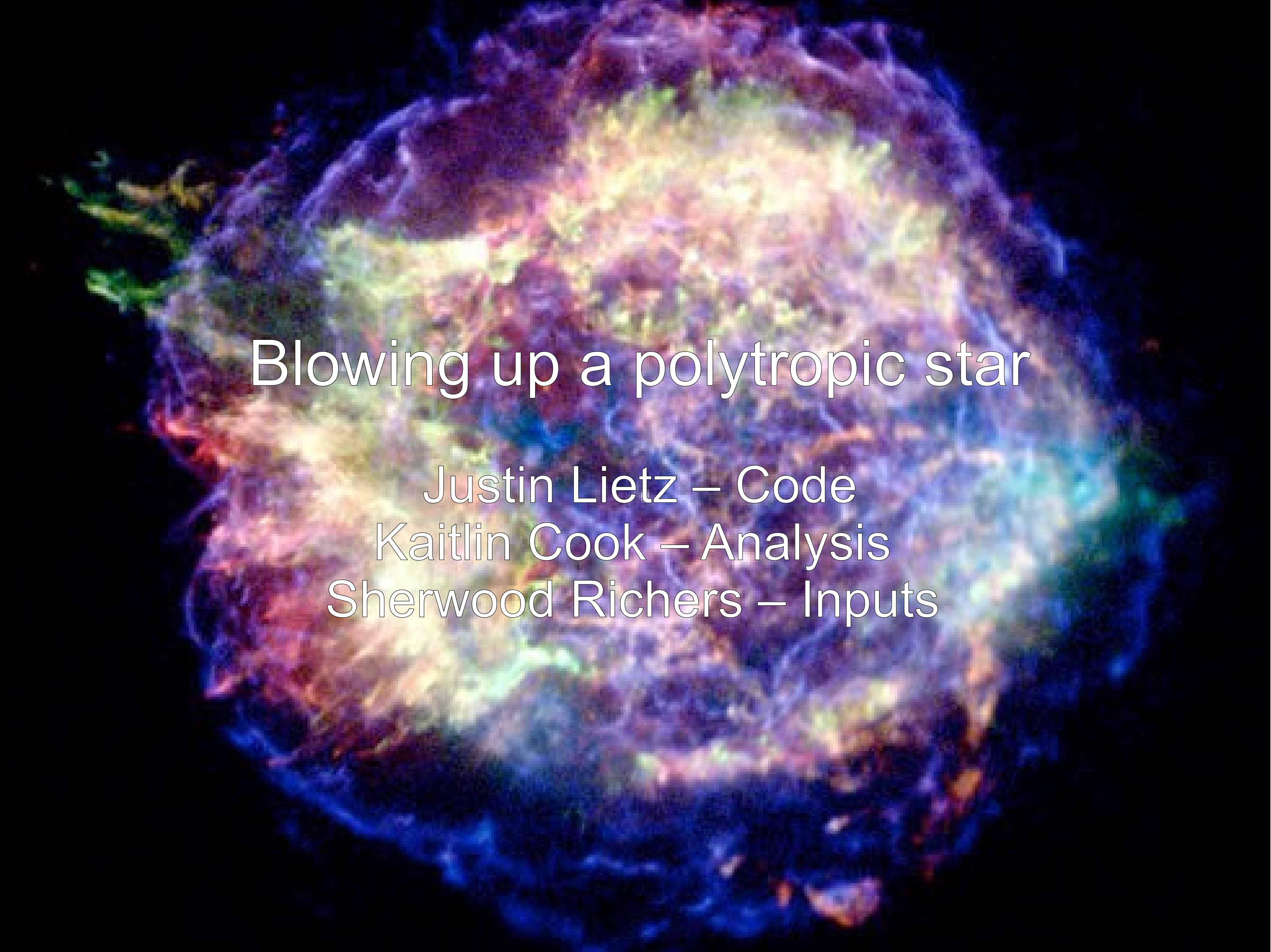


Blowing up a polytropic star

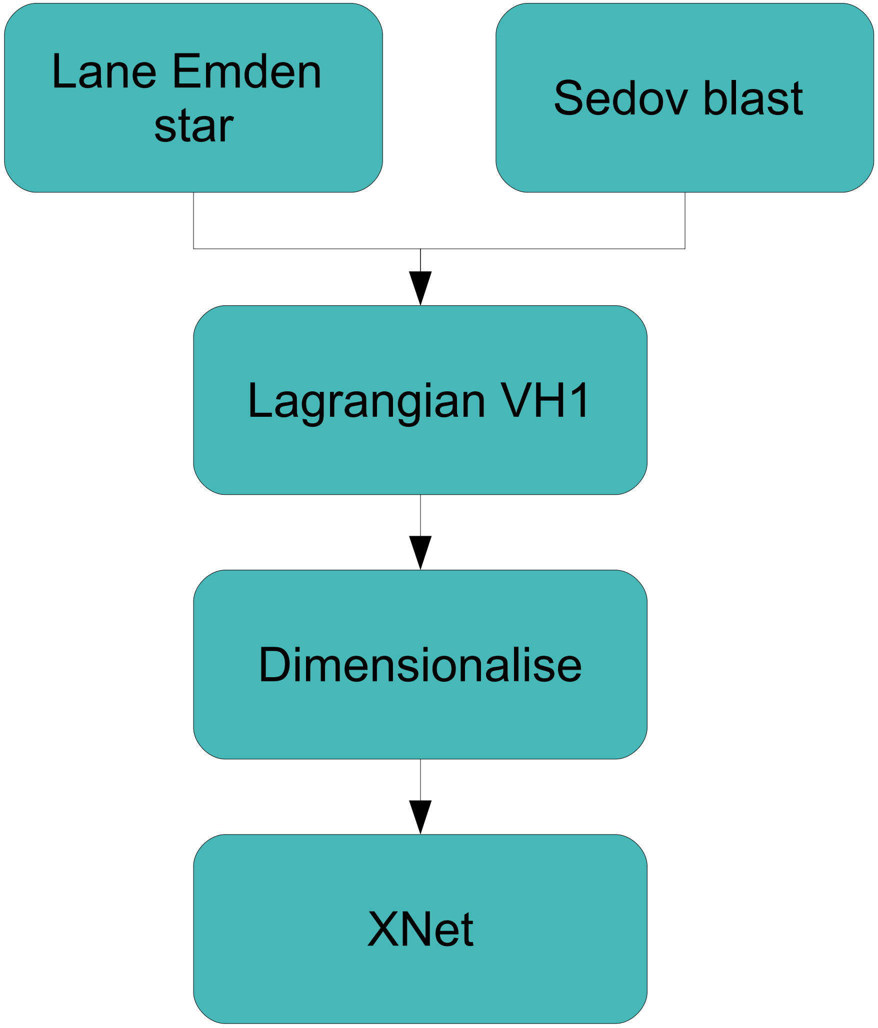
Justin Lietz – Code
Kaitlin Cook – Analysis
Sherwood Richers – Inputs

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

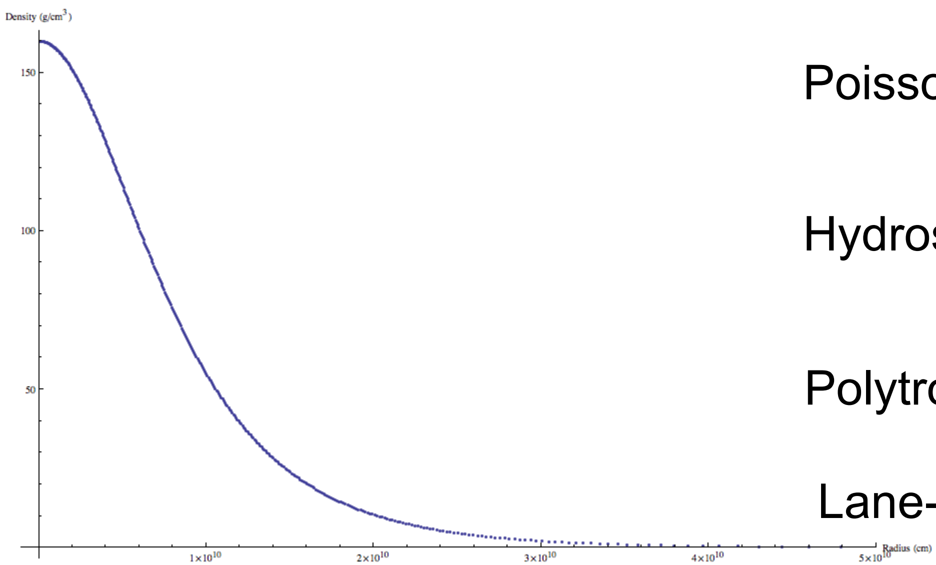

Lane Emden
star
Sedov blast
Lagrangian VH1
Dimensionalise
XNet

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:

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

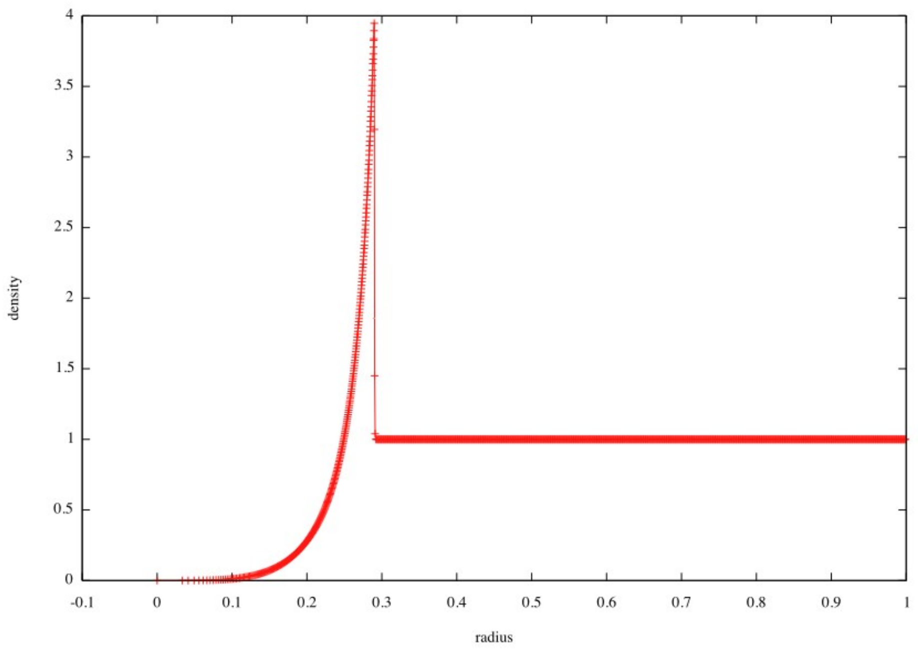
Lane-Emden:

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

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

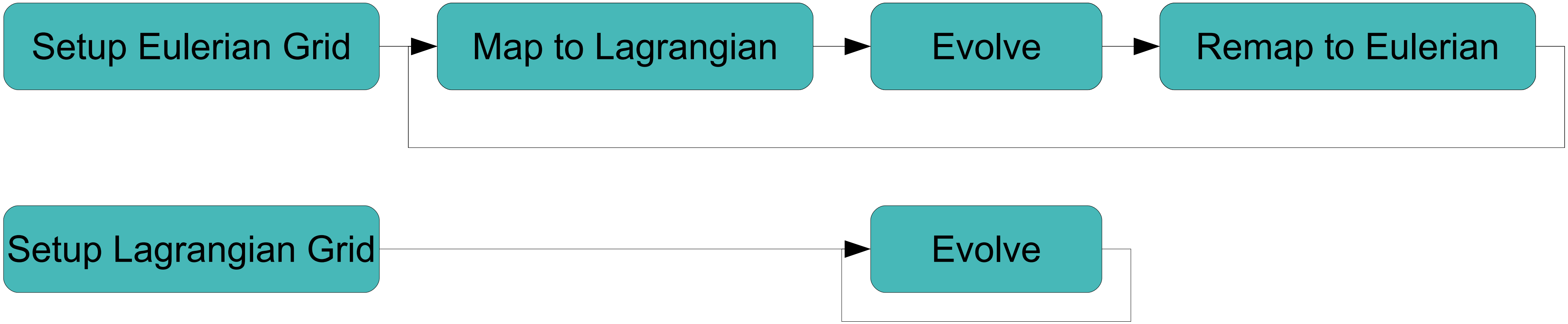
- Eulerian coordinates – zones transfer matter

- Lagrangian coordinates – zones follow matter

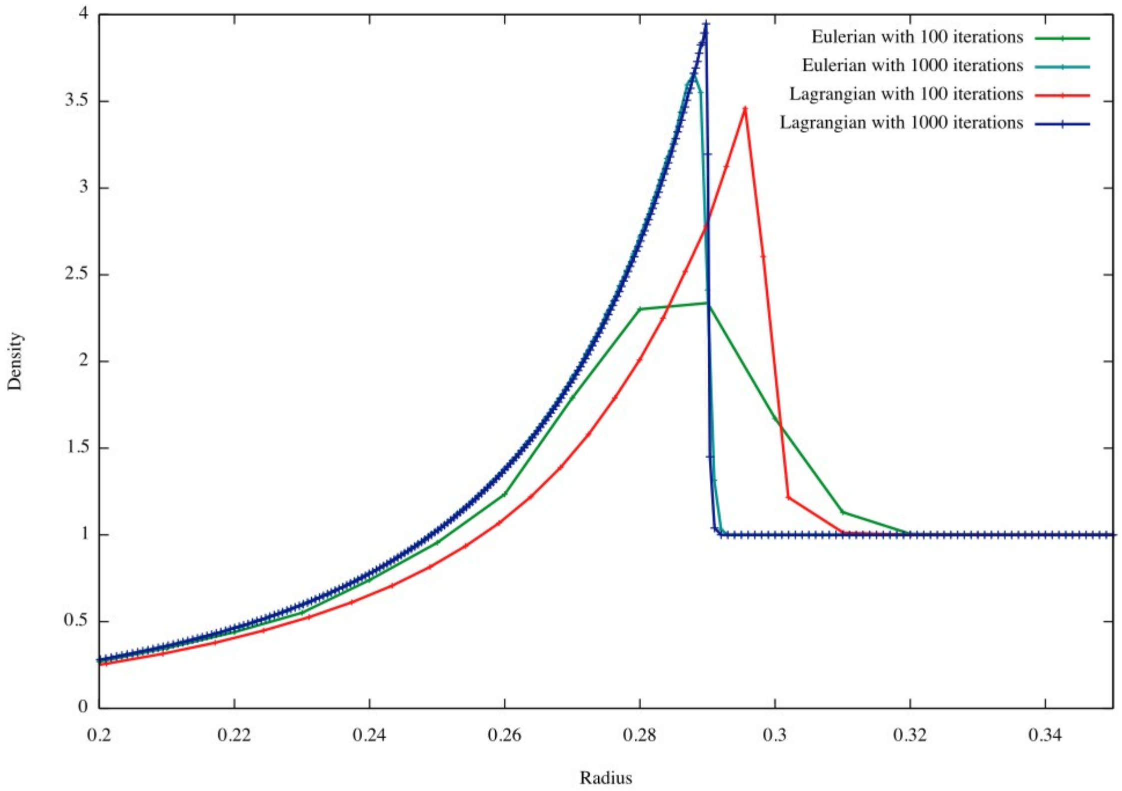
  → Follow nucleosynthesis without advecting species

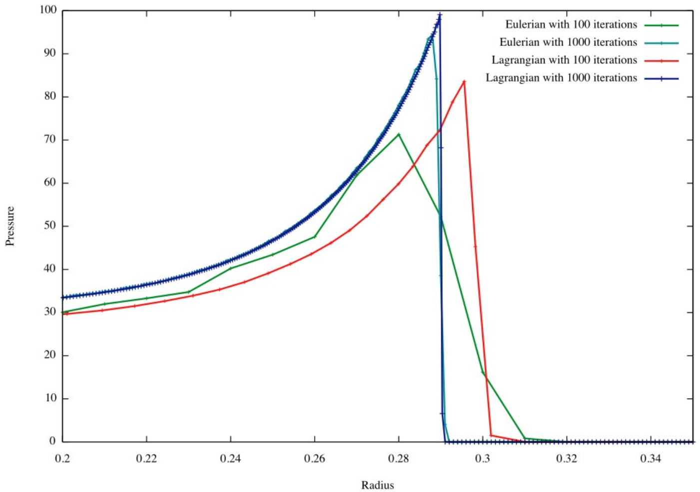
VH1 Lagrangian

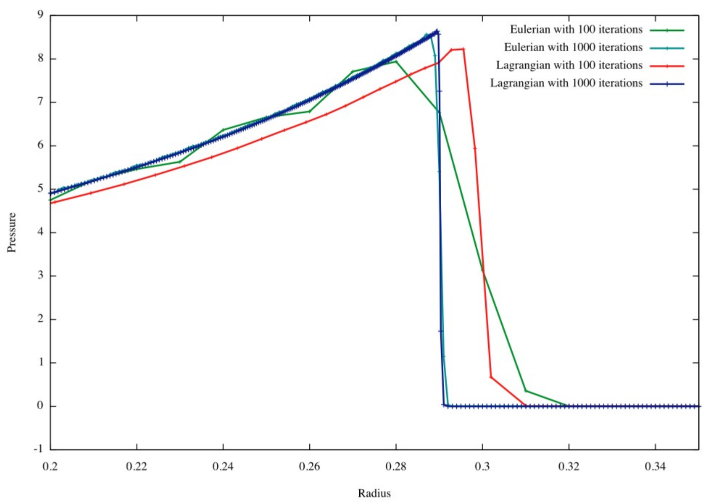
- `ppmlr.f90`



Lagrangian vs Eulerian

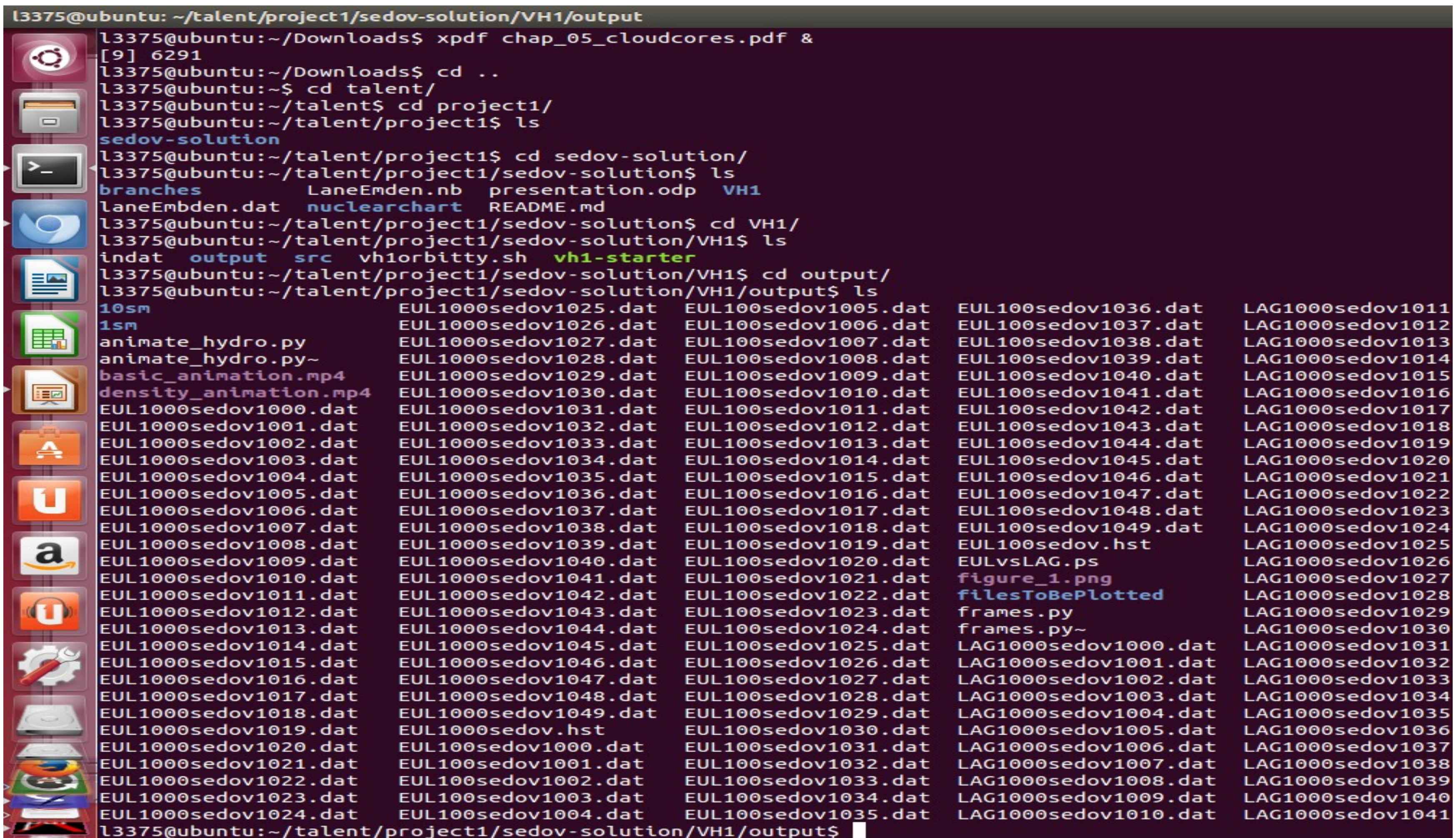






Connecting VH1 to Xnet

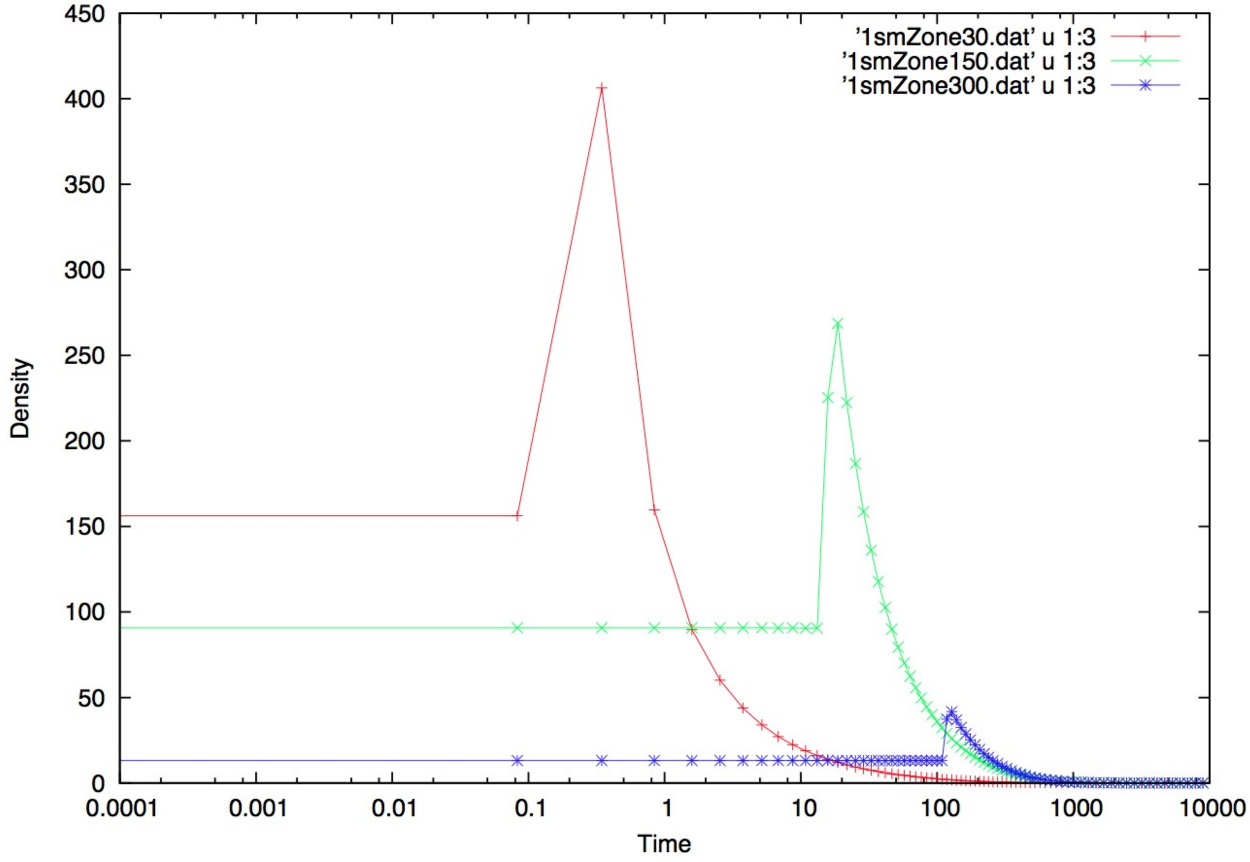
- VH1 output looks familiar to a lot of you by now:



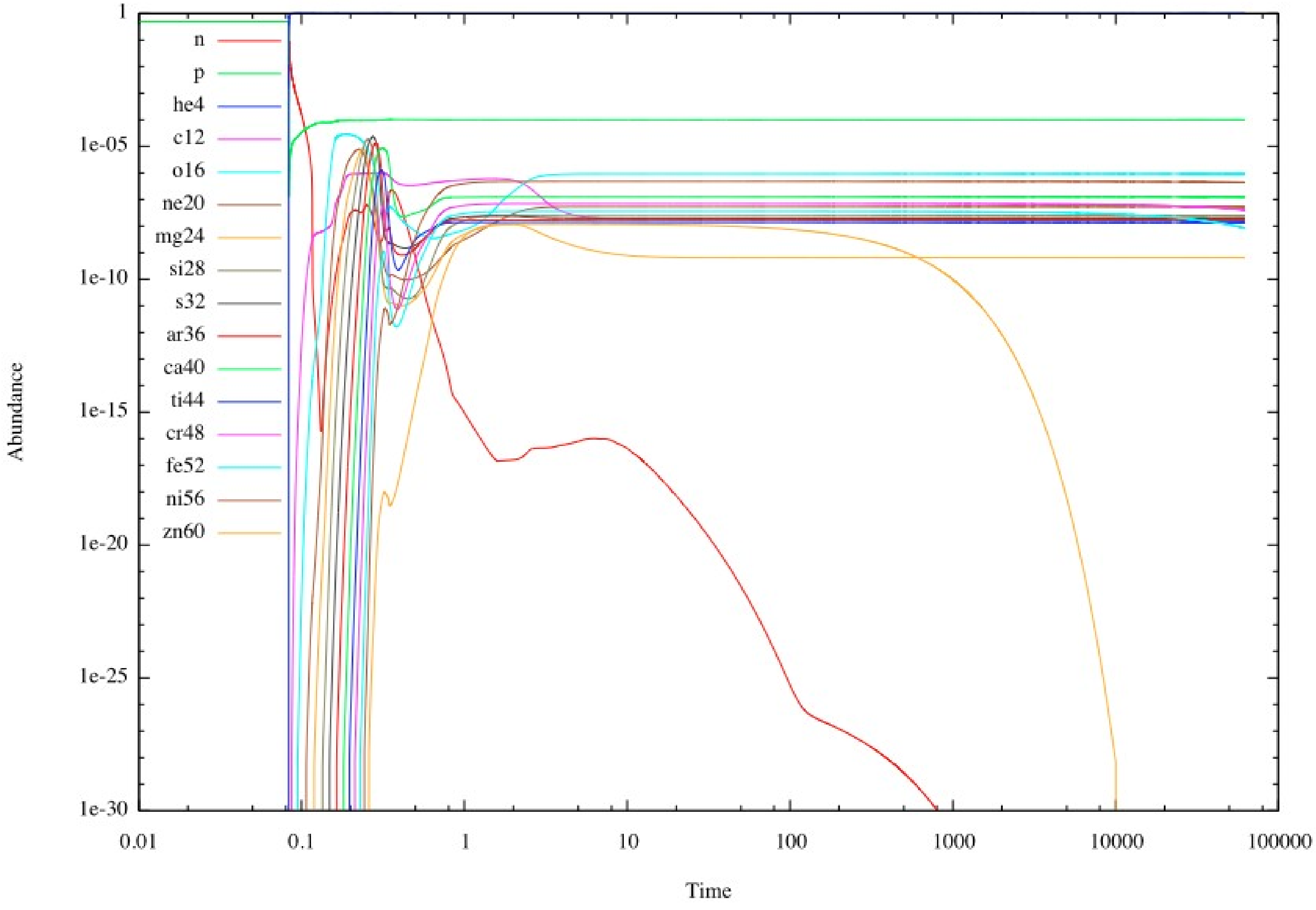
Hydro Results – 1 M_{sol} + 10^{49} ergs

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

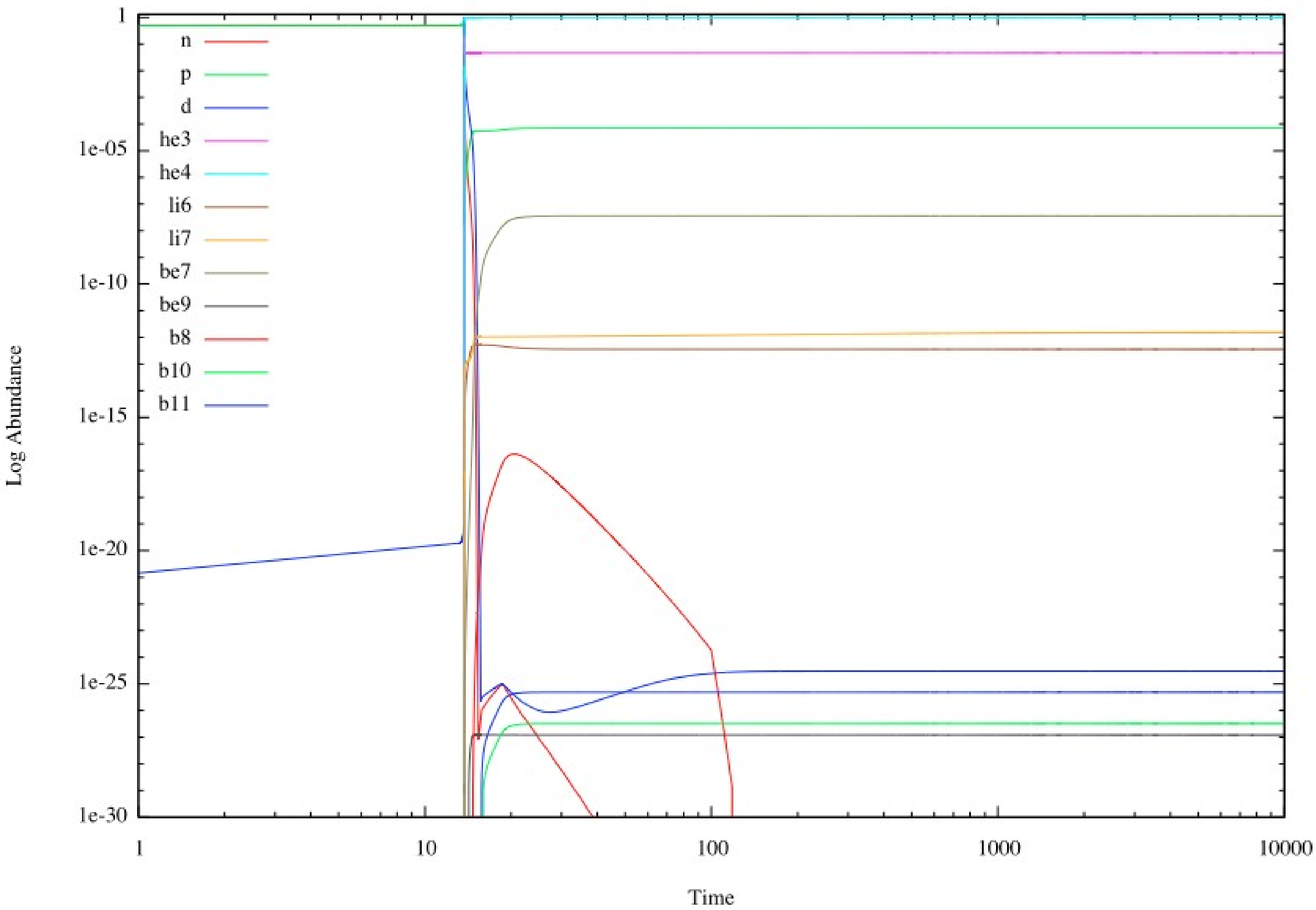
1 M_{sol} Blast at different radii



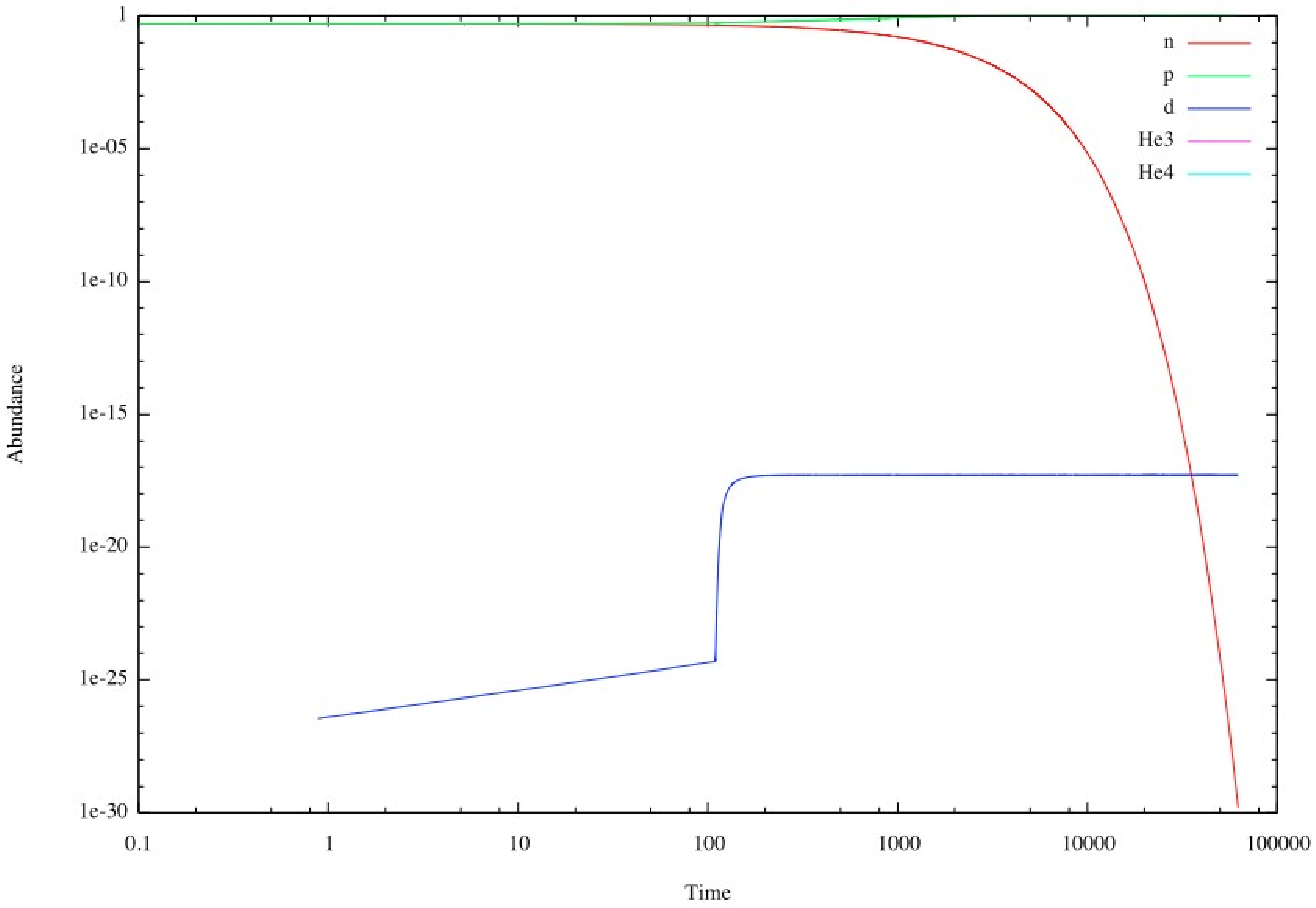
Nucleosynthesis 1 M_{sol} + 10^{49} ergs 0.03 R_{sol} – Peak T = 3.3 GK



Nucleosynthesis 1 M_{sol} + 10^{49} ergs 0.10 R_{sol}– Peak T = 0.04 GK



Nucleosynthesis 1 M_{sol} + 10^{49} ergs 0.17 R_{sol} – Peak T = 0.001 GK

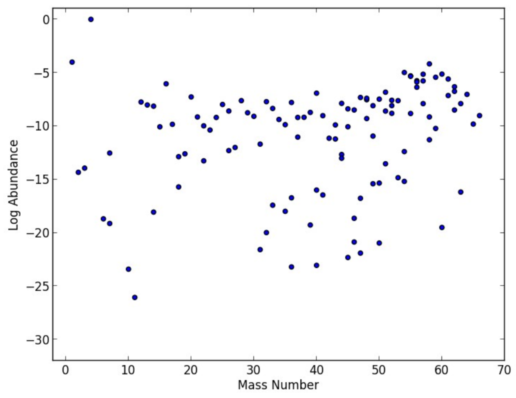


50/50 n/p progenitor

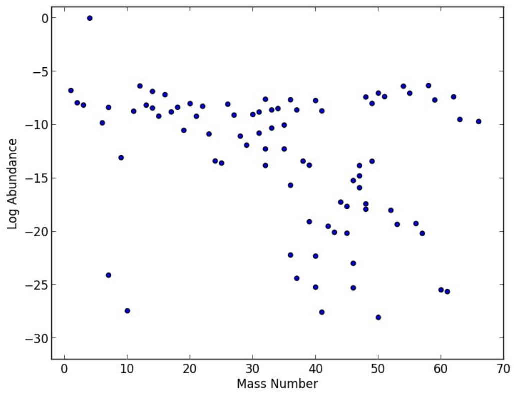
^{4}He progenitor

^{56}Fe progenitor

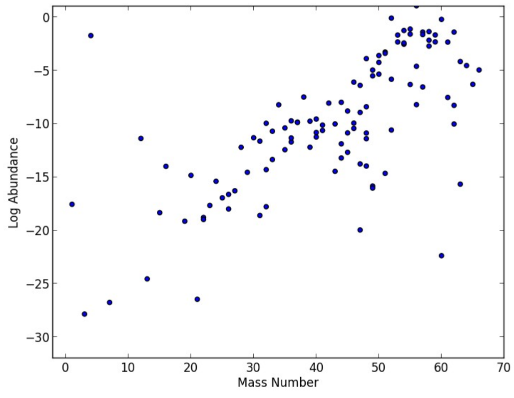
Abundances at t = 10^5



n+p initial



^{4}He initial



^{56}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