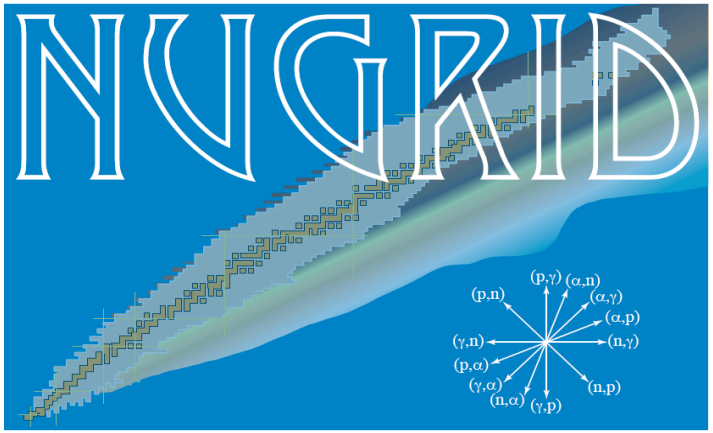
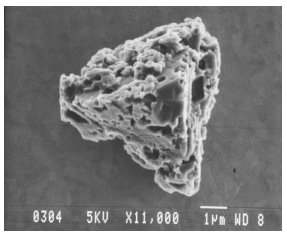


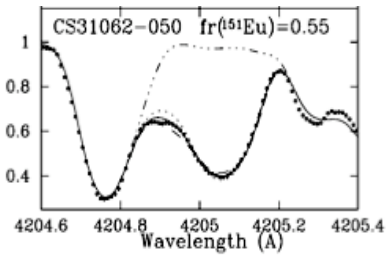
Why NuGrid?

- Fundamentally improve our understanding of the physics for the origin of the elements in order to address a wide range of astronomical problems.

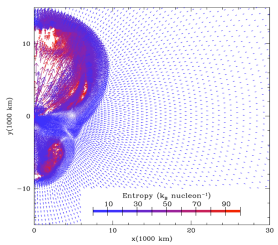
- For example:

pre-solar grains

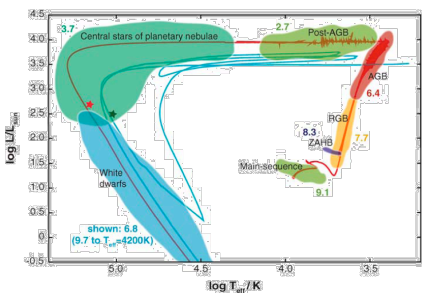




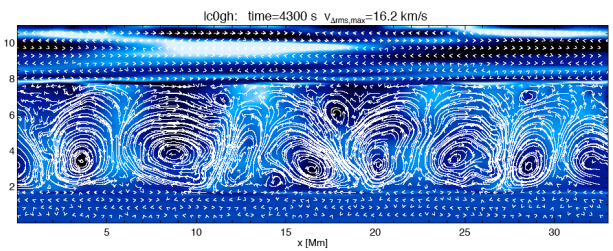
Stellar explosions

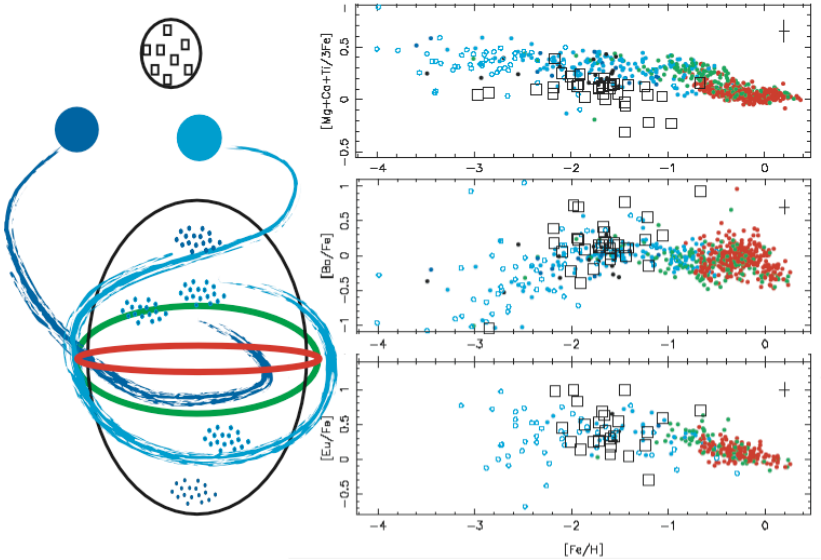


Stellar evolution



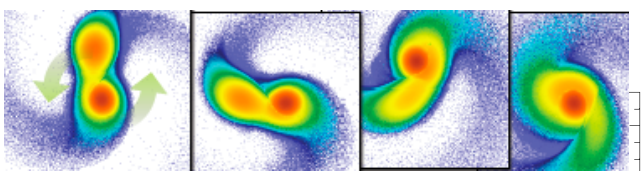
Stellar hydrodynamics



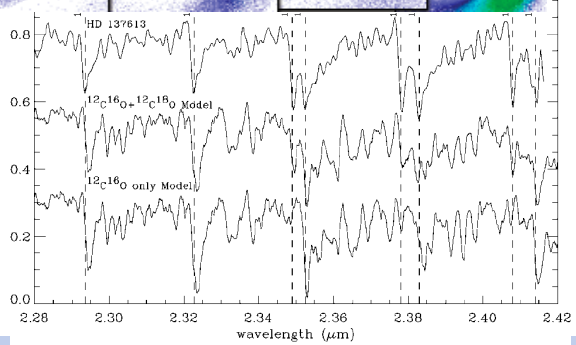


Near-field cosmology

DD merger



Observations



Why NuGrid?

- Create a framework that allows to process large, internally consistent and comprehensive yield sets:
  - include low-mass and massive stars
  - include all possible nuclear processes
  - (eventually, include explosive yields)
- facilitate easy and routine production of large sets of observables that allow simultaneous validation of stellar physics in a wide range of situations
- detach (as far as possible) stellar evolution and explosion (SEE library) business from nucleosynthesis business (PPN - post-processing network code suite)

The NUGRID (Nucleosynthesis Grid) collaboration has three goals:

1. Develop and maintain a new code that can compute the nucleosynthesis in all nuclear production regimes: PPN code suite
2. Create an up-to-date library of stellar evolution and explosion simulation data.
3. Apply the PPN code to SEE library to generate a comprehensive yield set.

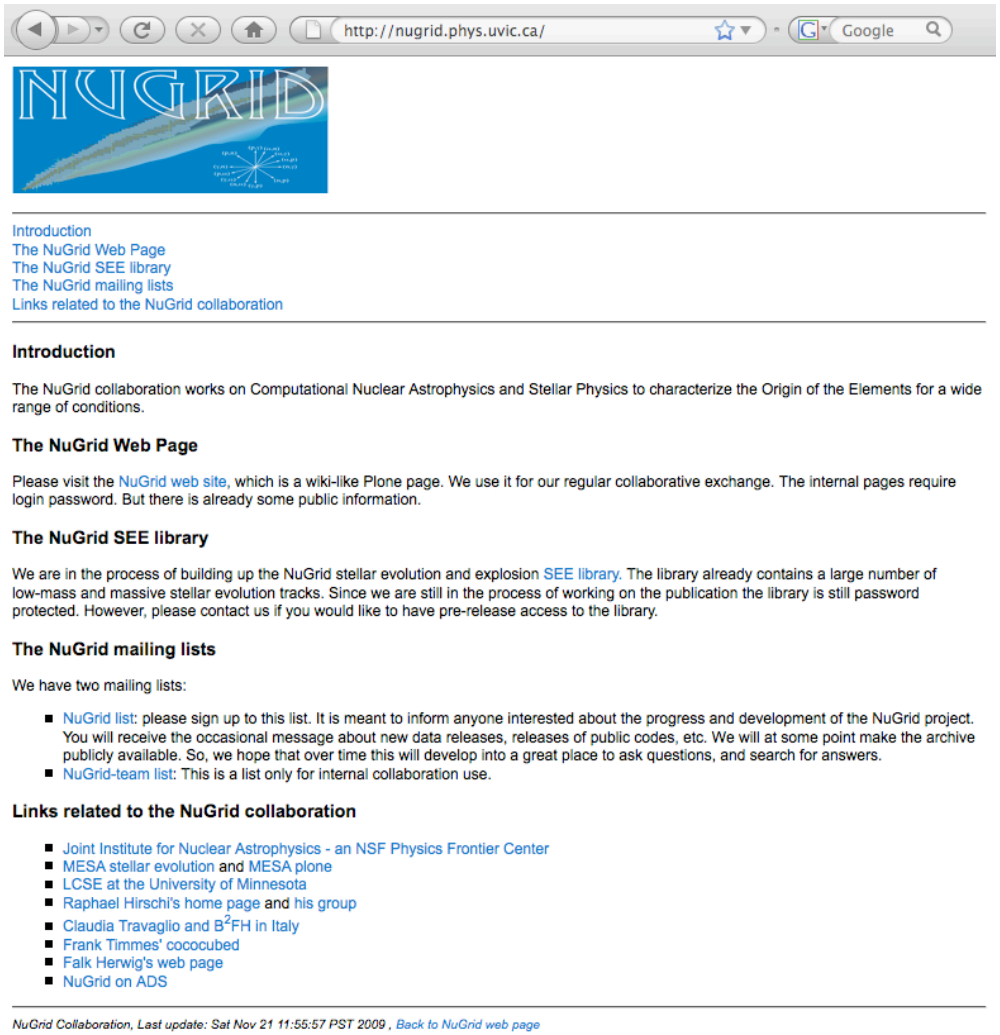
Marco Pignatari

Gabriel Rockefeller

Michael Bennett

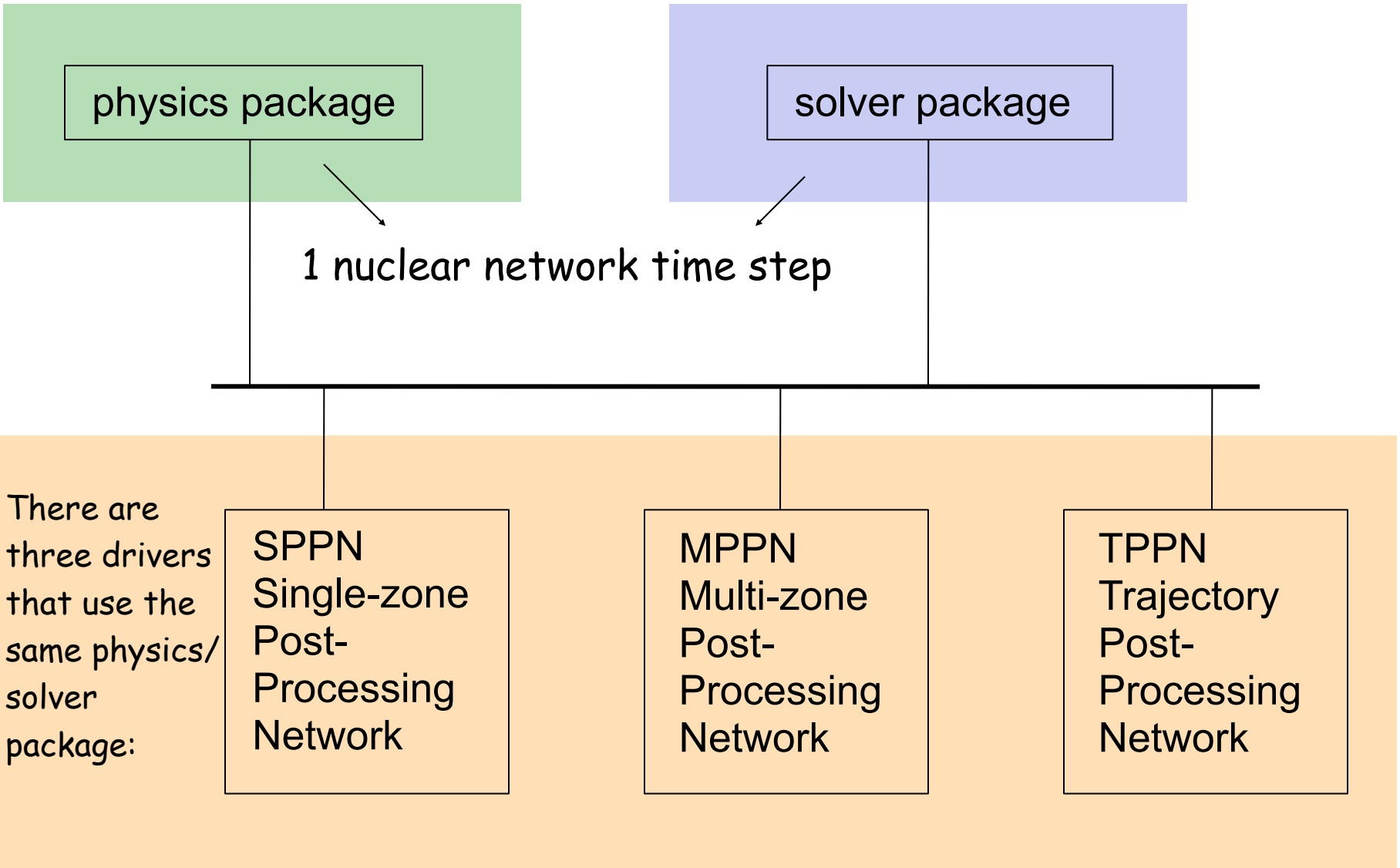
2009: Claudia Travaglio, Aaron Dotter, Aaron Courture

http://nugrid.phys.uvic.ca



University of Victoria

The PPN code suite



Drivers:

- SPPN: single zones, trajectories, analytic prescriptions
- TPPN (->BMPPN): TBD

MPPNP (multi-zone PPN)

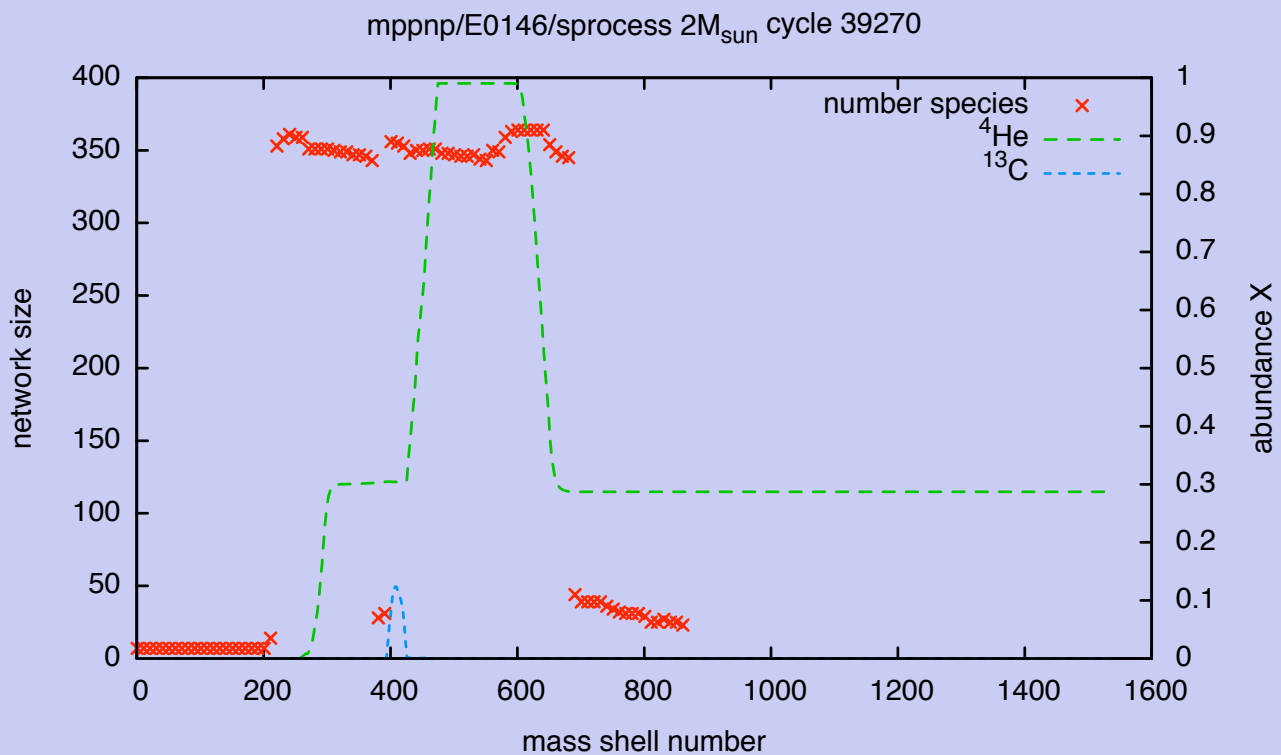
- MPI-parallel (typical runs on 50-80 procs)
- USEEPP (Unified Stellar Evolution and Explosion Post-processing) IO hdf5 library
- grid options:
  - ✓Static
  - ✓Input
  - ✓AMR
- Flexible restart and re-grid options (batch queuing system enabled)

Physics package:

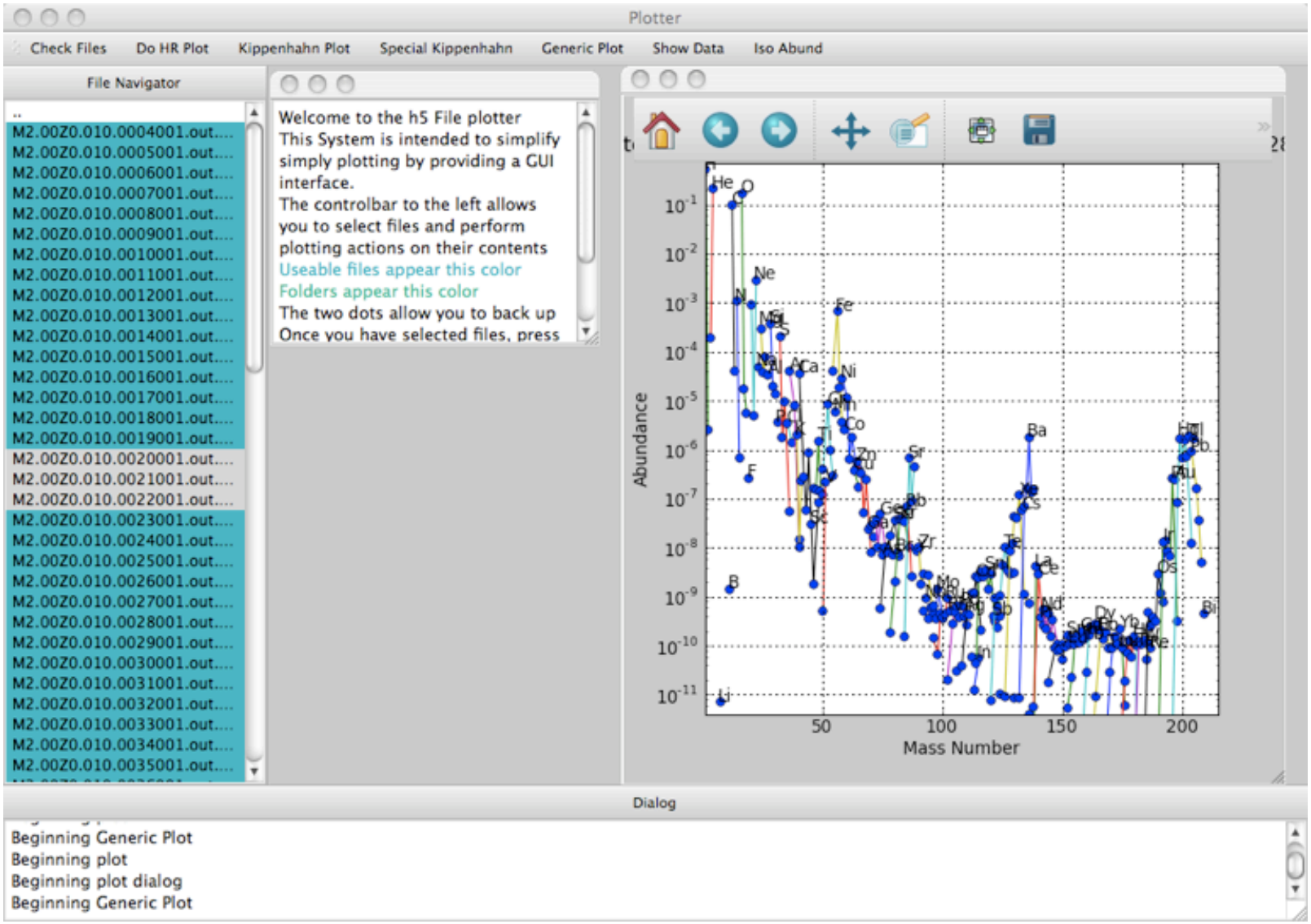
- < 5170 isotopes
- Reaction rate libraries: * NETGEN interface
  - ✓Basel reaclib
  - ✓JINA reaclib
  - ✓Dillmann etal. 2006 (Kadonis)
  - ✓Angulo etal. 1999 (NACRE)
  - ✓Iliadis etal. 2001
  - ✓Caughlan & Fowler 1988
  - ✓Aikawa etal. (BRUSLIB)
  - ✓Oda etal. 1994.
  - ✓Fuller & Fowler, 1985
- NSE:
  - ✓T-dependent partition function & mass excess (reaclib)
  - ✓Coulomb screening (Calder etal. 2007)
- Sandbox e.g. Luna N14(p,g), 3a Fynbo 2005, Kunz 2002 C12(a,g) etc
- isomeric states framework Al26, Kr85, Sn115

Solver package:

- Newton-Raphson, fully implicit
- Integrated dynamic network at iteration level
- Adaptive sub-time steps
- Sparse solver

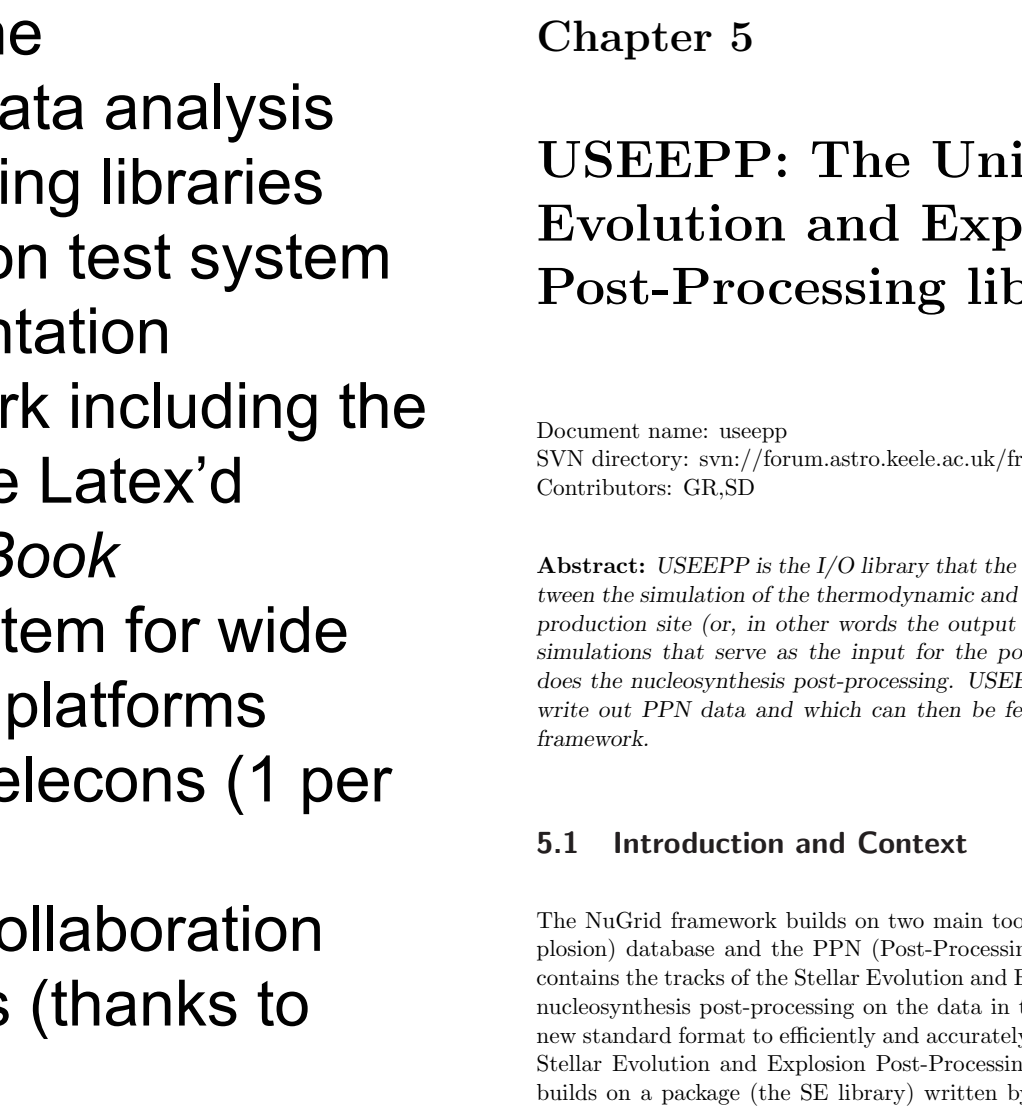


SEexplorer: interactive data exploration and visualization



And the other useful things ....

- ★ svn, plone
- ★ python data analysis and plotting libraries
- ★ regression test system
- ★ documentation framework including the ~75 page Latex'd *NuGrid Book*
- ★ build system for wide range of platforms
- ★ regular telecons (1 per month)
- ★ annual collaboration meetings (thanks to JINA!)



Chapter 5

USEEPP: The Unified Stellar Evolution and Explosion Post-Processing library

Document name: useepp
SVN directory: svn://forum.astro.keele.ac.uk/frames/utils/se/docs
Contributors: GR,SD

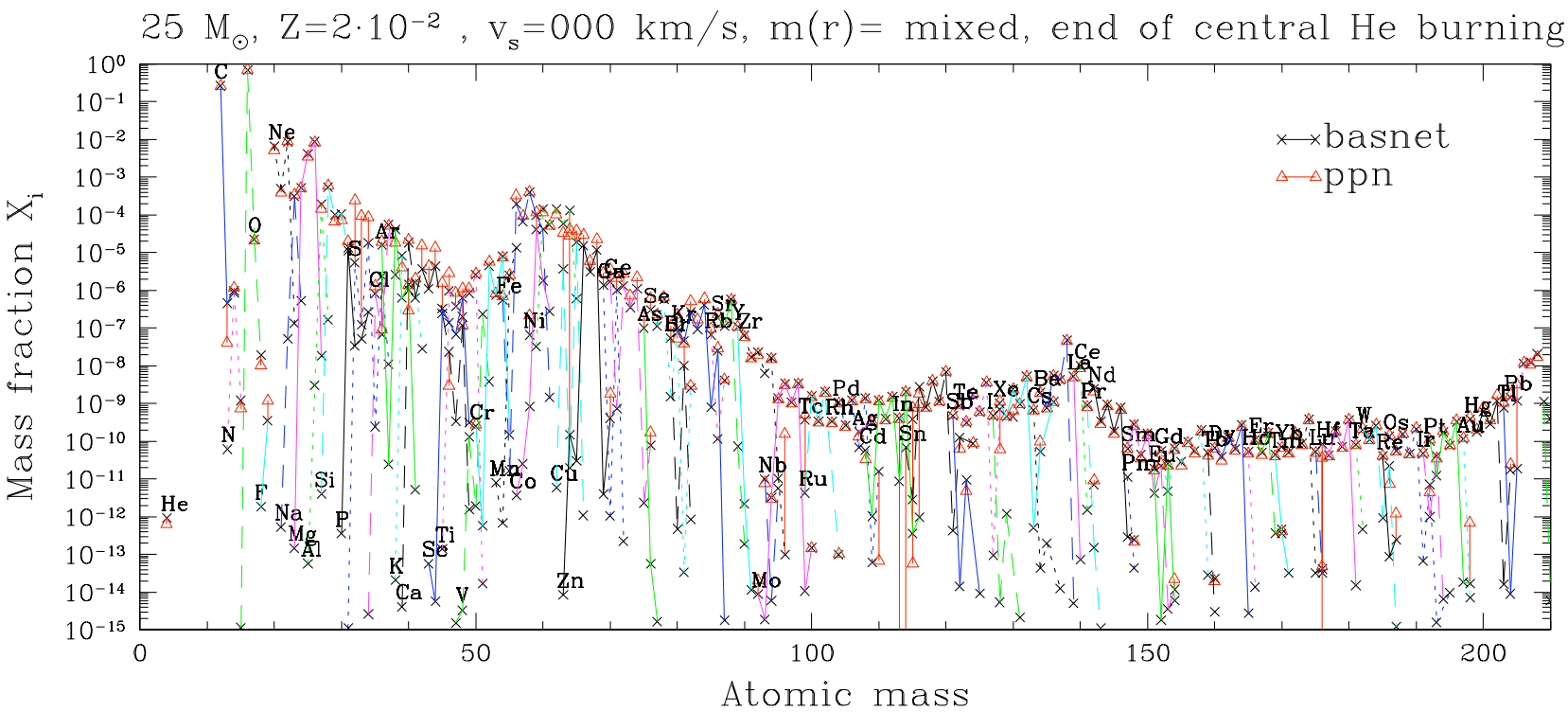
Abstract: *USEEPP is the I/O library that the NuGrid project uses as the interface between the simulation of the thermodynamic and hydrodynamic conditions in the nuclear production site (or, in other words the output of stellar evolution or stellar explosion simulations that serve as the input for the post-processing) and the PPN code that does the nucleosynthesis post-processing. USEEPP will will eventually also be used to write out PPN data and which can then be feed into a not-yet existing visualisation framework.*

5.1 Introduction and Context

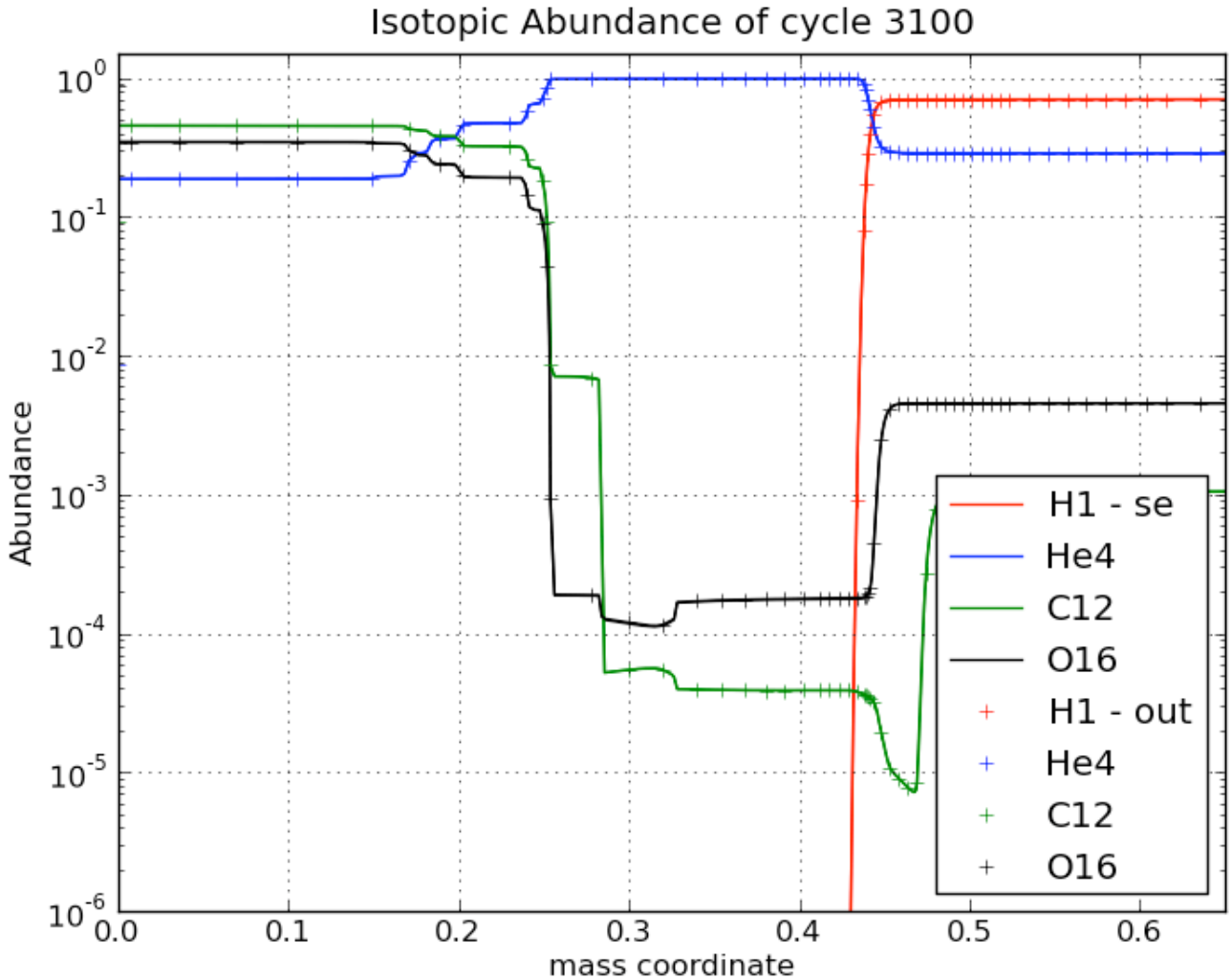
The NuGrid framework builds on two main tools, the SEE (Stellar Evolution and Explosion) database and the PPN (Post-Processing Network) codes. The SEE database contains the tracks of the Stellar Evolution and Explosion data. The PPN code performs nucleosynthesis post-processing on the data in the SEE library. We have introduced a new standard format to efficiently and accurately save stellar evolution data, the Unified Stellar Evolution and Explosion Post-Processing format, or short USEEPP. USEEPP builds on a package (the SE library) written by Steven Diehl and Gabriel Rockefeller

Code comparison:

- basel network (Friedel Thielemann)
- torch (Frank Timmes)
- Gallino s-process code
- various networks inside stellar evolution codes, incl. MESA nets, EVOL, Geneva code



Does the post-processing work?



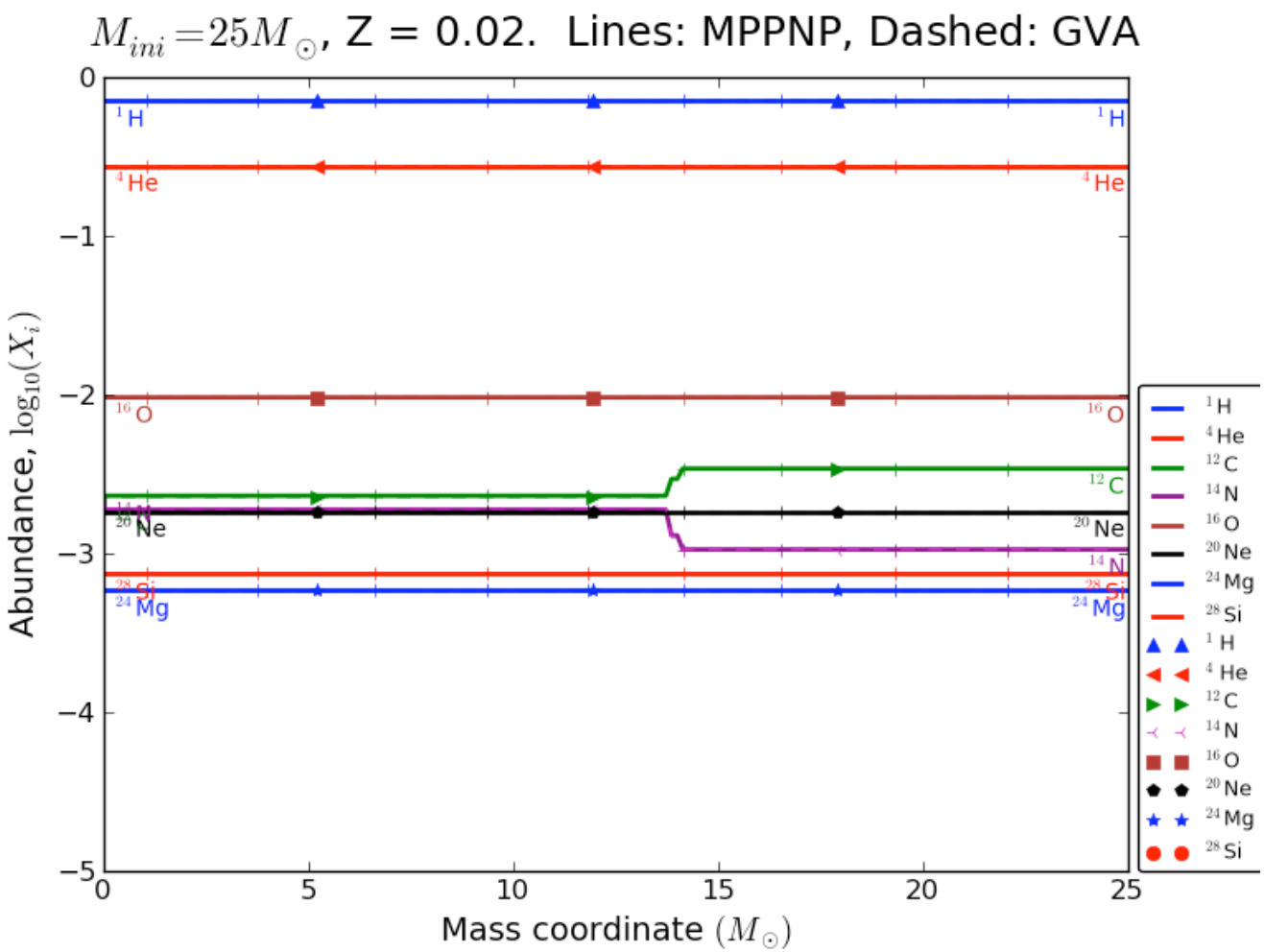
$2M_{sun}$ He-core burning to TP-AGB:

se: EVOL stellar evolution code

out: mppnp post-processing

YES!

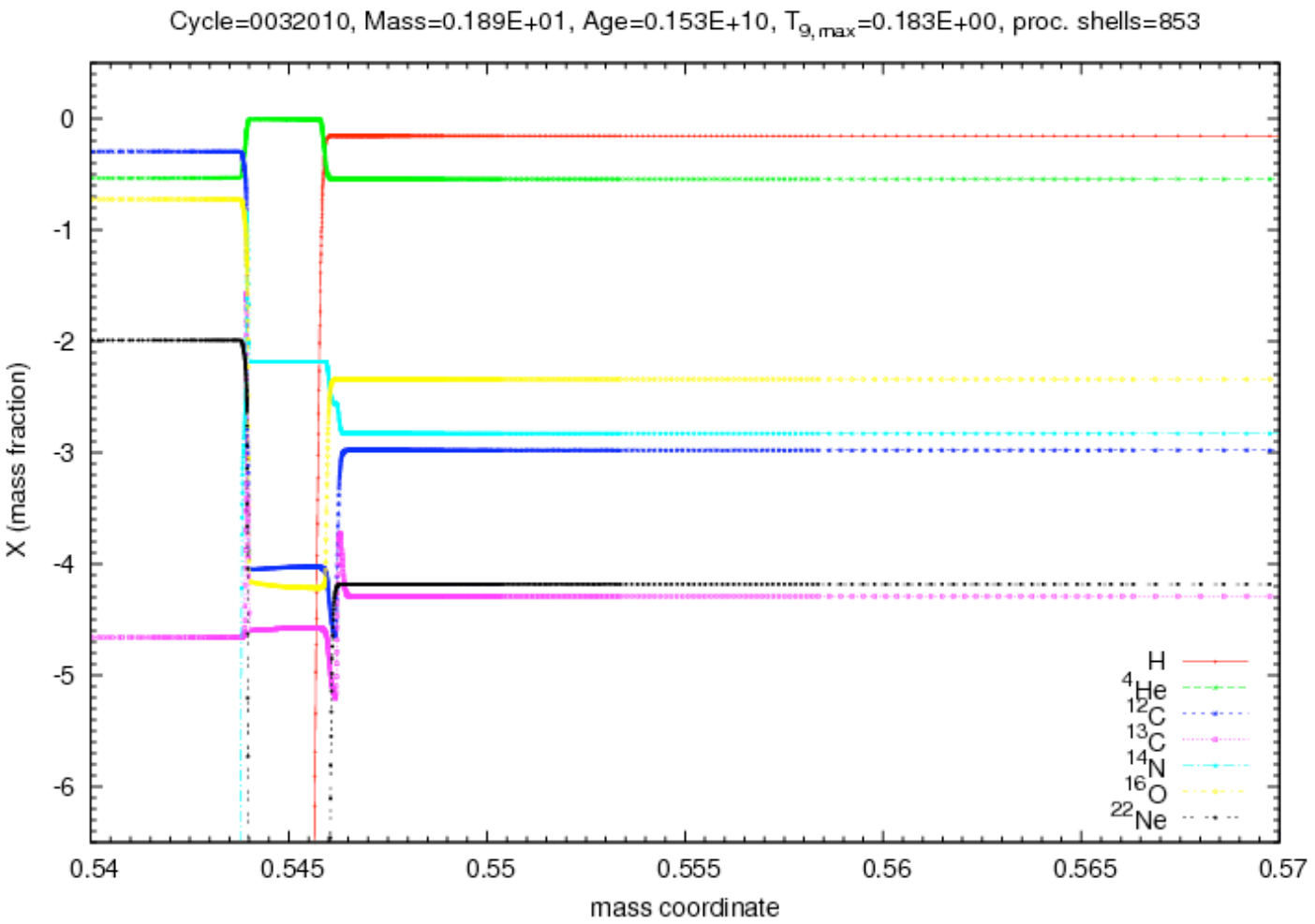
Does the post-processing work?



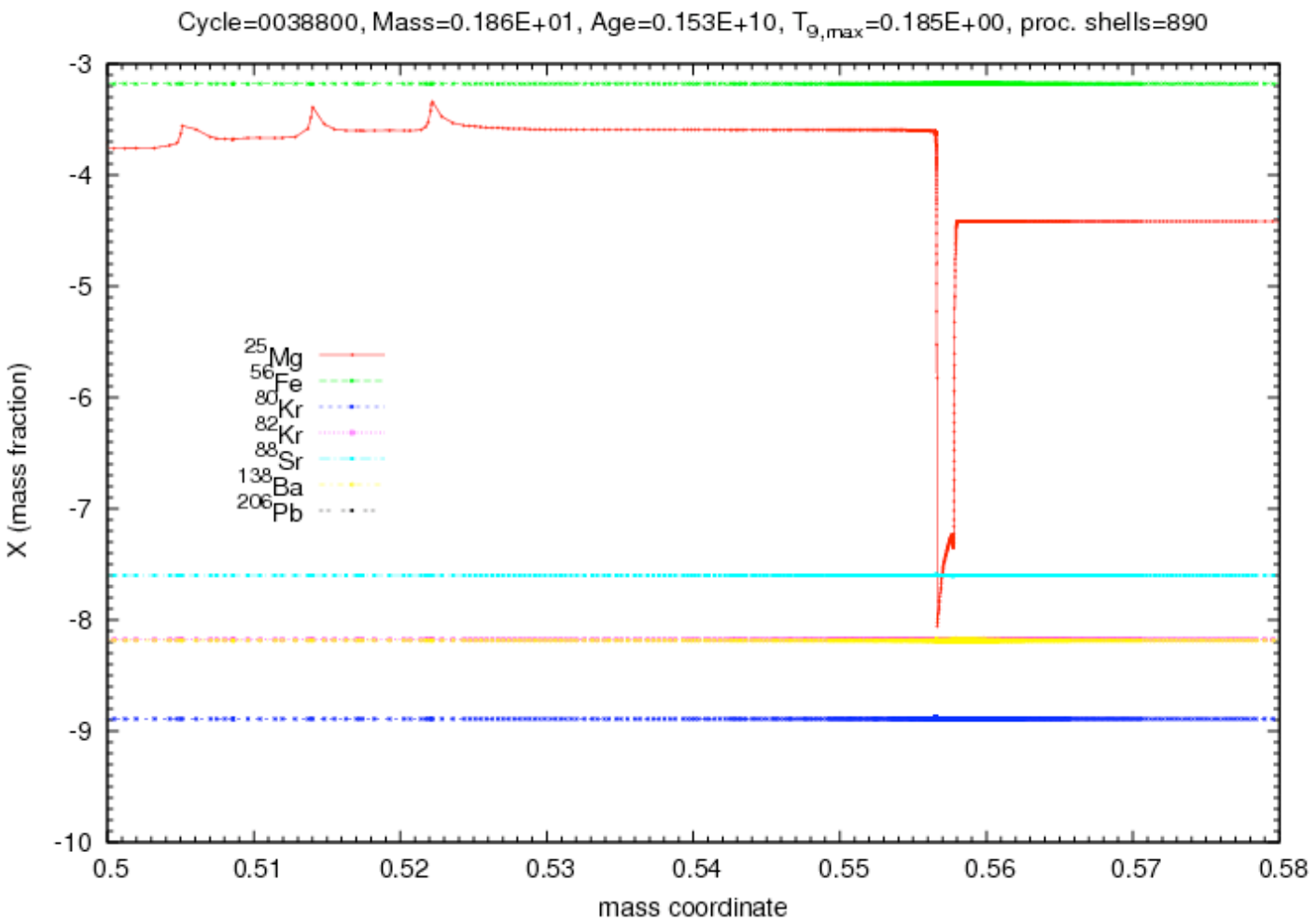
25M$_{sun}$ main-sequence to O burning

Geneva code vs. mppnp

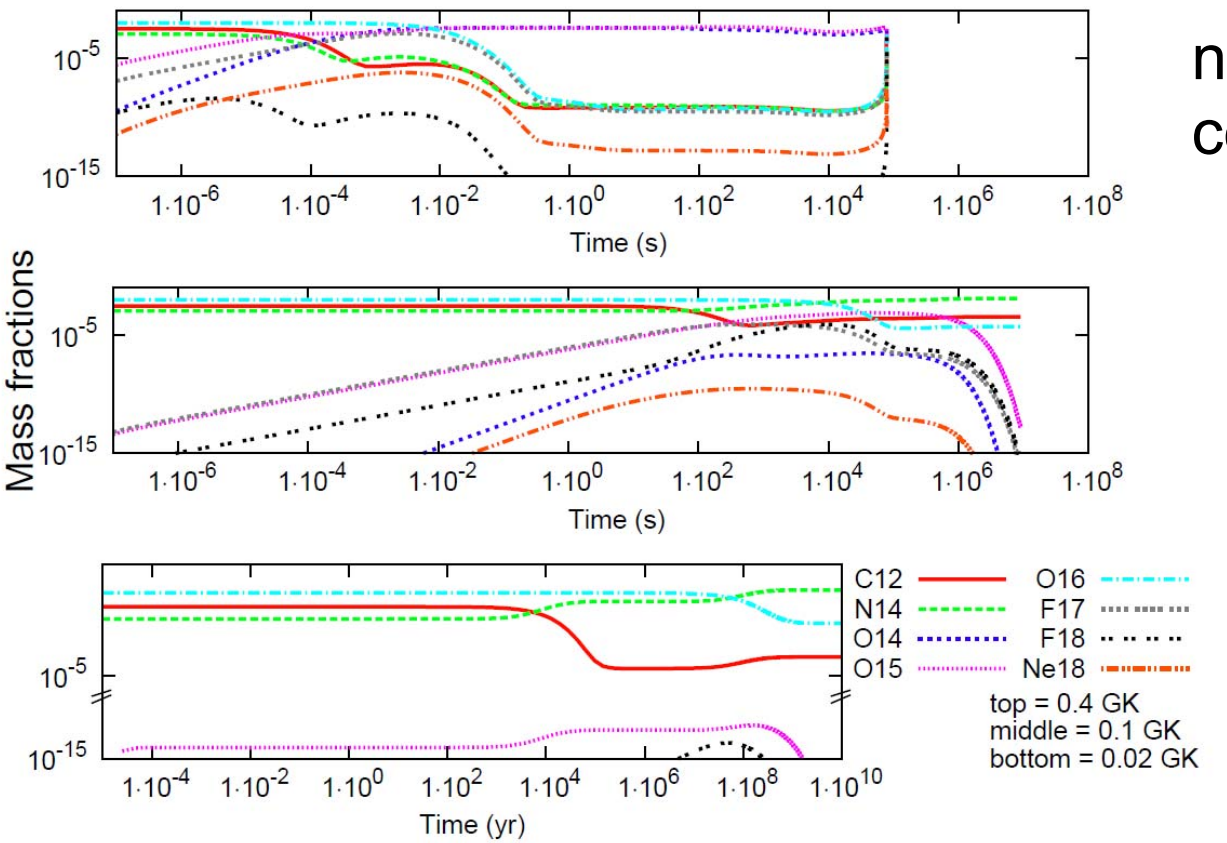
Applications: 2Msun star - light elements



Applications: 2Msun star - heavy elements



Applications: H-burning



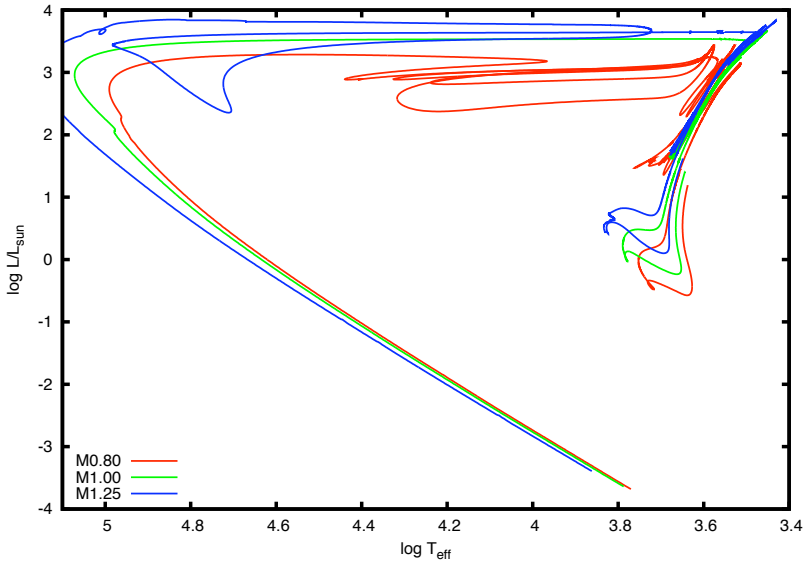
nova X-ray burst conditions

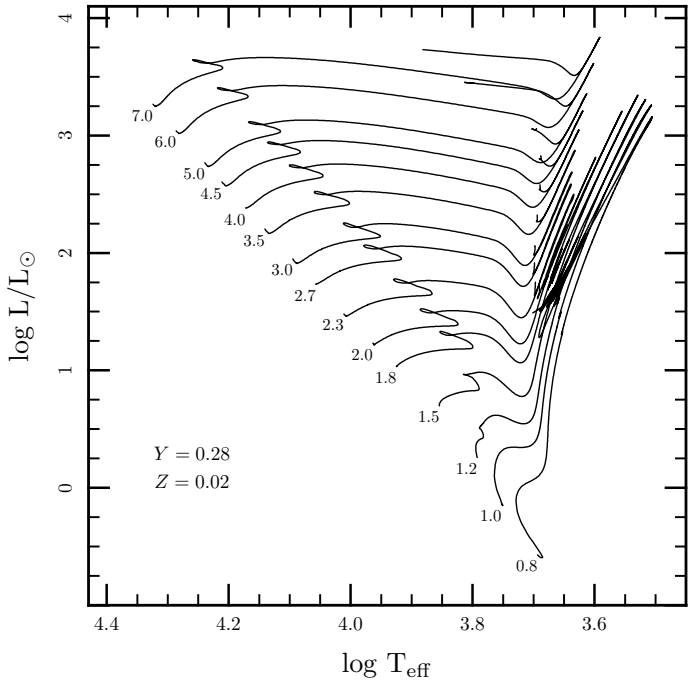
AGB shell burning

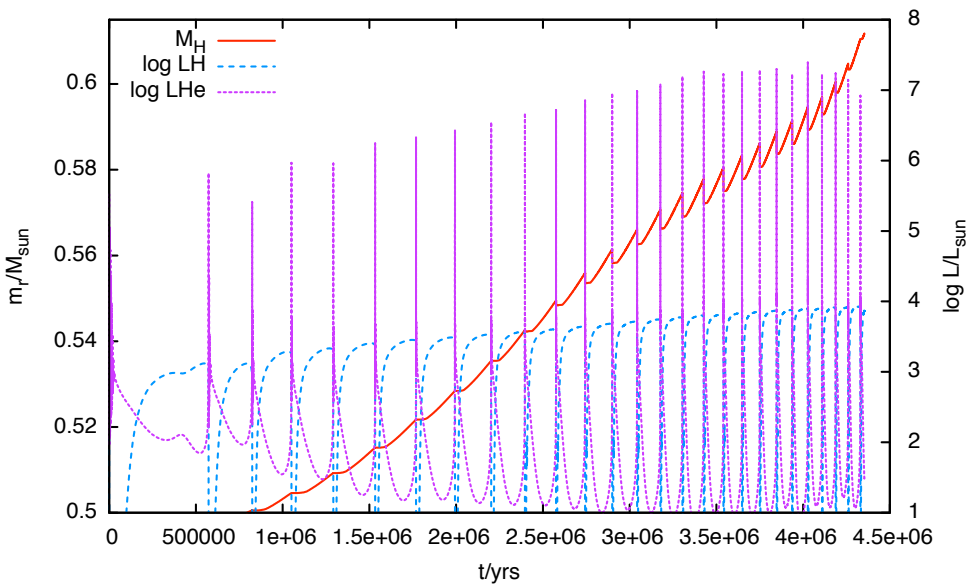
low-mass MS

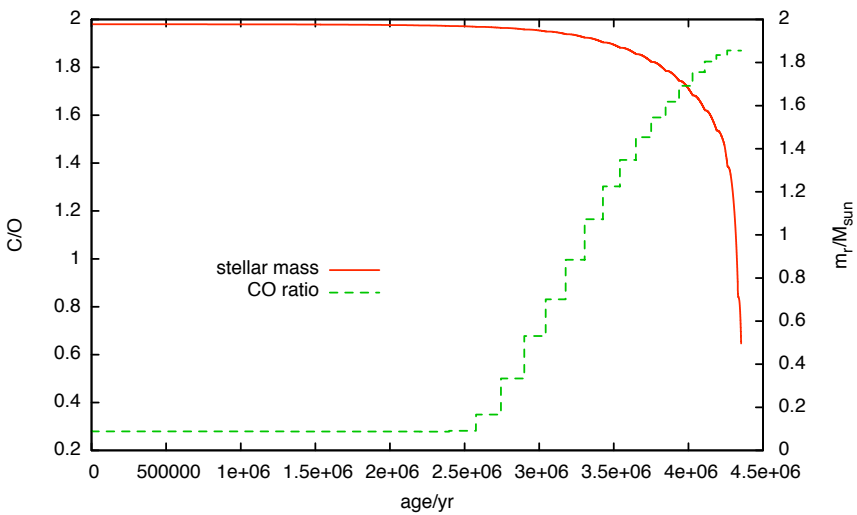
Wiescher etal 2010

MESA stellar evolution

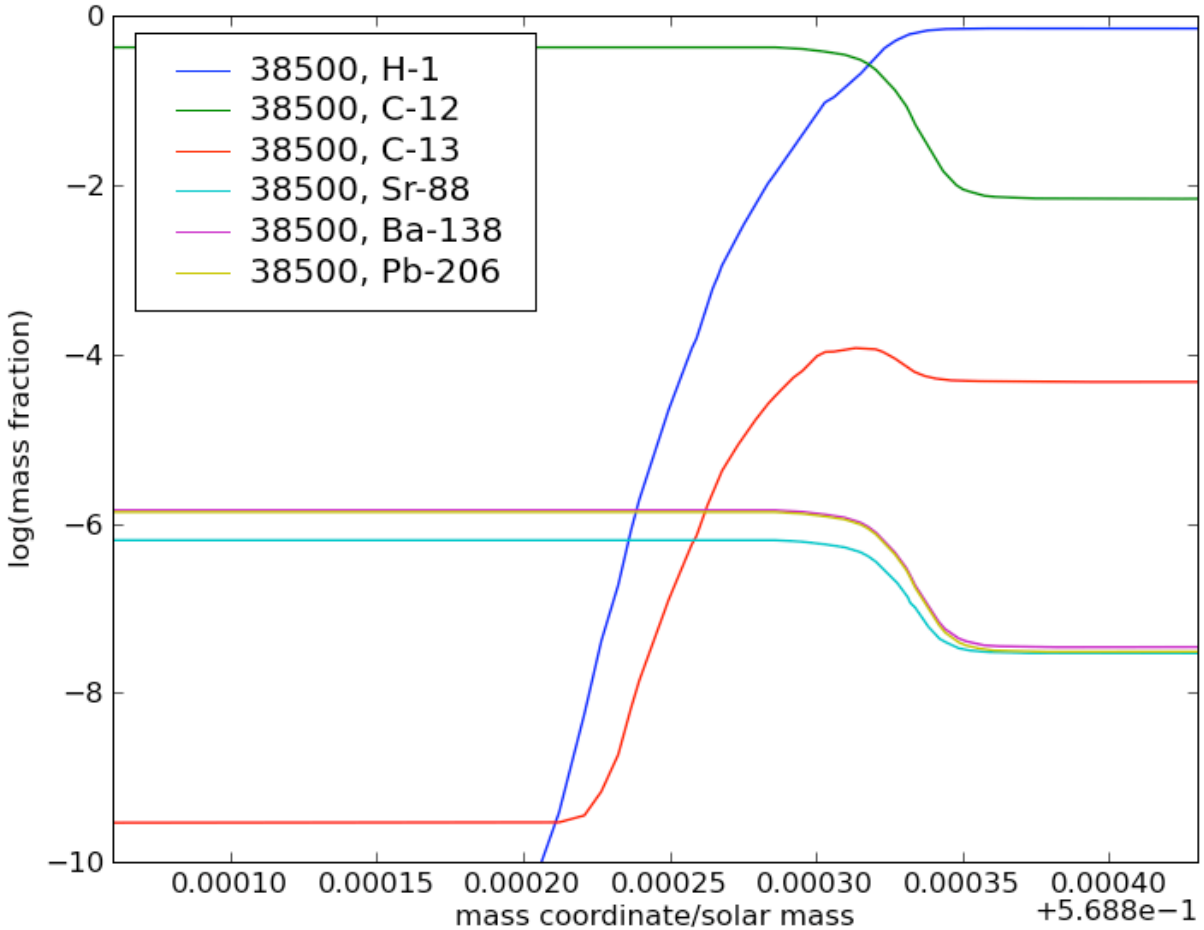








Applications: MESA post-processing, e.g. the C13-pocket



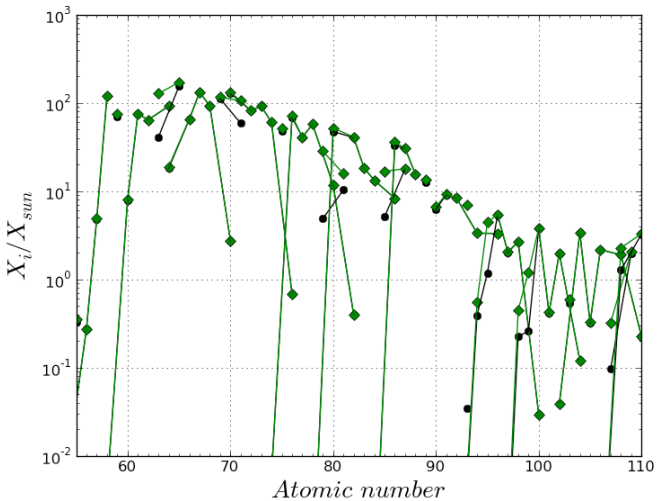
Science projects:

1. Comprehensive wind yield sets (this summer Z=0.02, 0.01)
2. Combustion nucleosynthesis in post-AGB flashers (ApJ subm., arXiv:1002.2241)
3. C12+C12 (conf proc, arXiv:1002.2788)
4. explosive He-shell burning

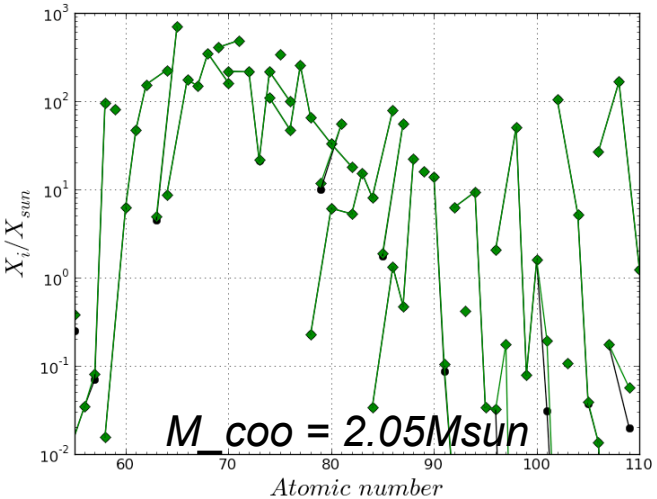
Stellar material processed by shock wave during SN explosion (temperature and density profile, e.g., Thielemann et al. 1996, 1979)

Marco Pignatari

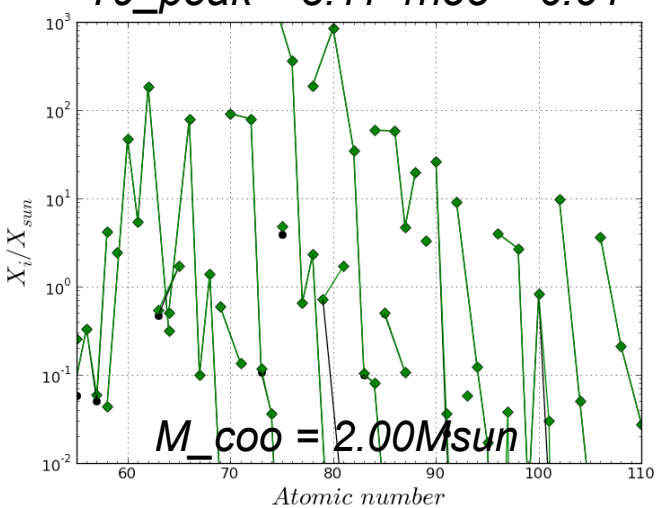
s-process seeds



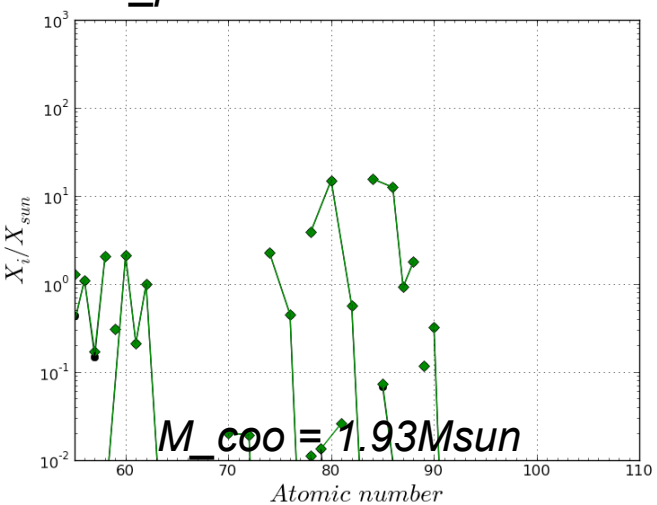
T9_peak = 2.76 rho5 = 4.82



T9_peak = 3.11 rho5 = 6.64



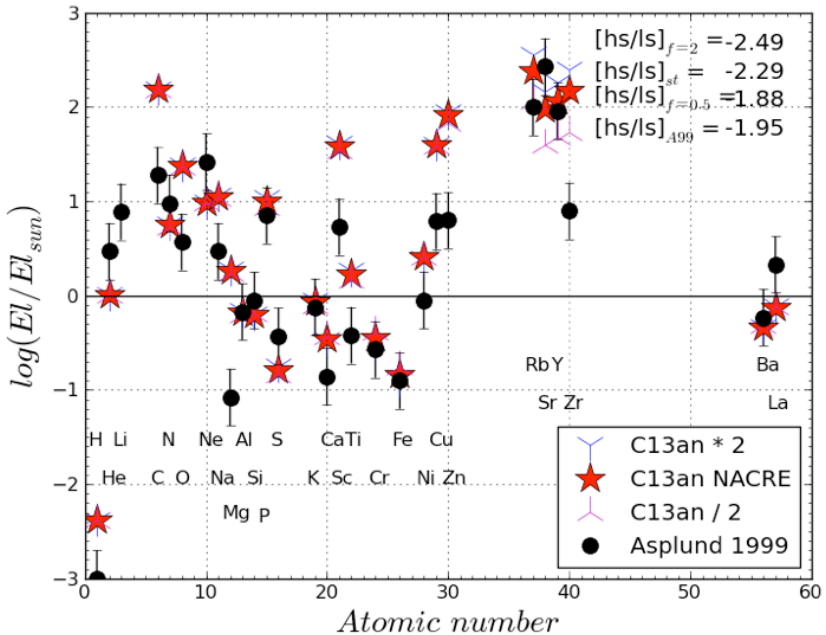
T9_peak = 3.45 rho5 = 7.85

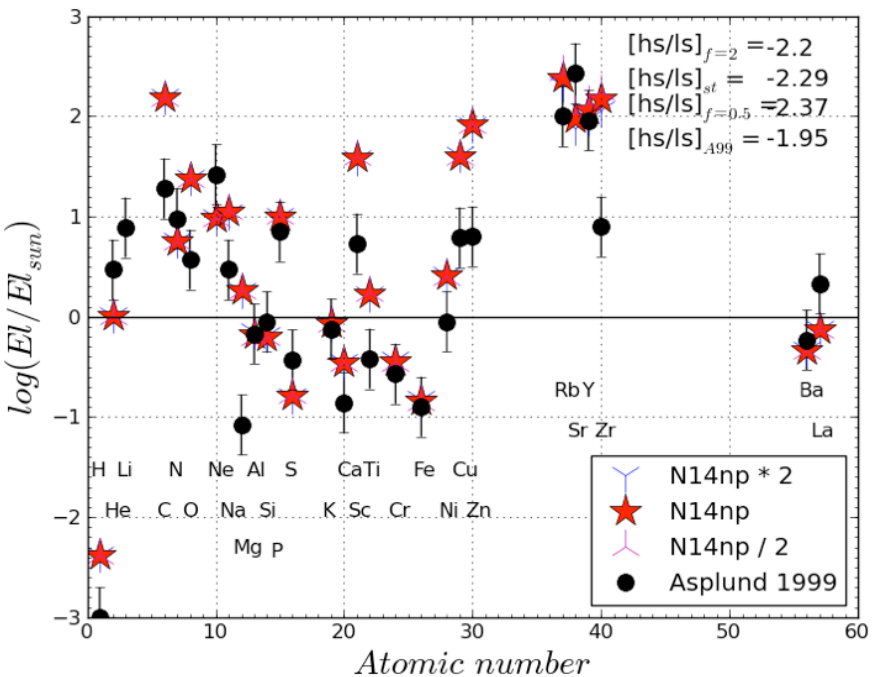


Temperature and density peaks for a given mass coordinate is given by Rapp et al. 2002

Science projects:

1. Comprehensive wind yield sets
2. Combustion nucleosynthesis in post-AGB flashers (ApJ subm., **arXiv:1002.2241**)
3. C12+C12 (conf proc, **arXiv:1002.2788**)
4. explosive He-shell burning
5. reaction rate uncertaintv analysis for (1)





Concluding remarks

NuGrid tool:

- ★ validate stellar physics processes
- ★ provide data needs of GCE models
- ★ connect astro nuclear physics to nuclear astrophysics
- ★ astro nuclear physics experiment support
- ★ tool box for experiments in nucleosynthesis
- ★ outreach potential

- ✦ (not yet) open source but open collaboration

Concluding remarks

Outlook:

- ★ explosive nucleosnthesis to complement the wind yields (Marco Pignatari, Frank Timmes, Claudia Travaglio, Chris Fryer)
- ★ adapt codes to hybrid architectures
- ★ enhance modularity to allow independent physics/ solver packages, improve integration with MESA
- ★ BGM driver