The origin of the Elements – Astro Seminar

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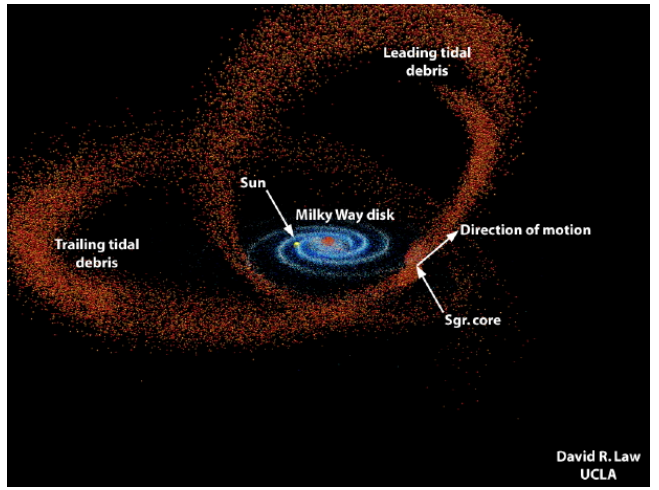
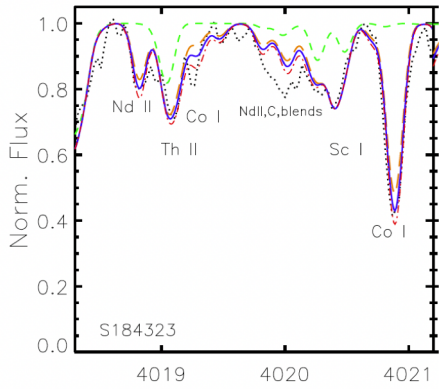
Camilla's Science

- I work on cool stars. These are typically in the Milky Way (MW) halo or disk, but also in dwarf galaxies.
- By observing stars with different ages, we can piece together the chemical enrichment of galaxies, and learn how these larger systems form and evolve → *Galactic archeology!*
- I have analysed variable stars (RR Lyr) as well as high velocity stars, but mainly focus on remote halo stars to learn about the long gone nucleosynthetic processes that formed heavy elements like Ag, Eu, Th.
- As a result we have traced both the r- and the s-process in different parts of the Galaxy and nearby dwarf Spheroidals.
- By comparing to theory, we showed that there are likely more than 1 r-process.



Sgr merges with MW



First Th detections in Sgr with UVES/VLT

Tanja's Science

Experiments to understand nucleosynthesis

- Especially for the s-process
- Experiments at GSI, Los Alamos, CERN, … and GUF ☺
  - TOF experiments and activation method
- Developing new experimental techniques to measure neutron capture cross sections for radioactive nuclei
- Results can be proven by nucleosynthesis models of the stars

The course & structure

- Mittwoch 10-12 lectures → 4CP
- First I will give introductory lectures – and following you will get the full time to read and make computations. You select your topic by 24 April.
- First lecture: April. 24
- Groups of two per topic – no less than 3 topics (min 6 participants)

Practical things

- The course will be in English – but we will make a ‘dictionary’ and a ‘take away messages’
- The course is part of the Wahlpflichtmodul VKEXASTM/Astro3 – no immediate exam, but you need to read papers and book chapters, make illustrative computations (your own or using an online tool) and present your topics to the other groups
- Does everyone have a laptop? A linux laptop/virtual machine? → needed for the analysis of the observations
- Who had astro I+II etc? What is your background?

Course material

- Articles – ~3 will be specified for each topic – more will be added later

- Carroll and Ostlie (supplement)

The Goal of the Course

What can we learn about open questions in astrophysics and nucleosynthesis?!

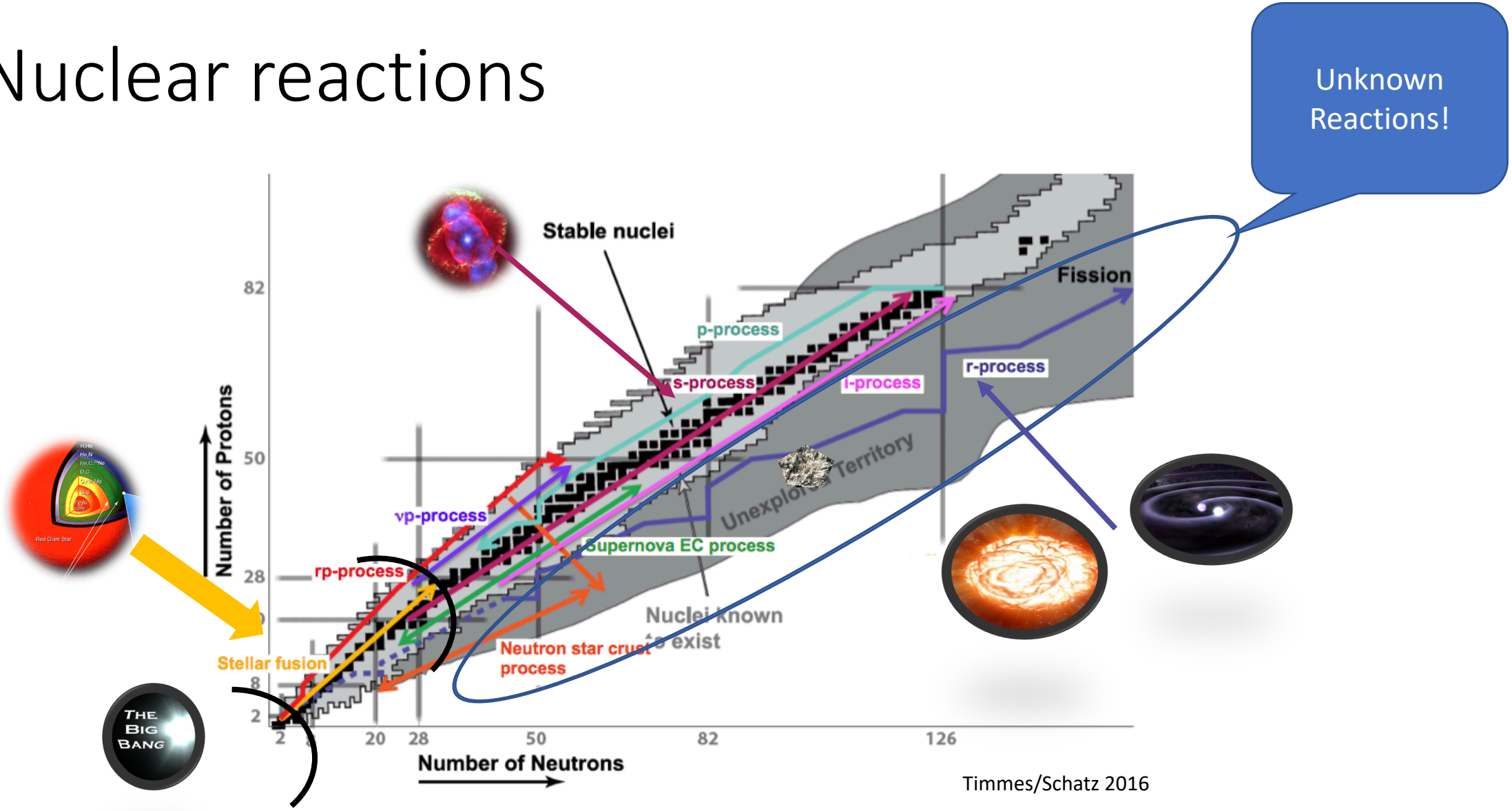
→ How can you model, illustrate and pass this on to others what you leaned?

- Big Bang Nucleosynthesis (BBN)
- Early r-process (SN/NSM)
- S-process
- i-process
- Low-mass stellar burning
- Massive star nucleosynthesis (Supernovae – all elements – possibly vp-process)
- Galactic chemical evolution (GCE)

Link to codes in general

- https://www.jinaweb.org/science-research/scientific-resources/codes

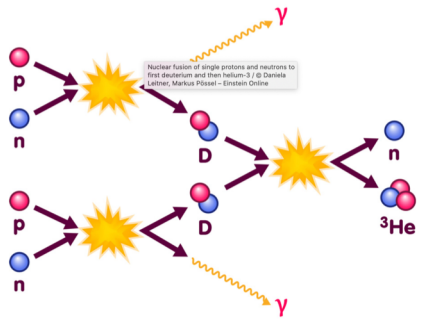
Nuclear reactions

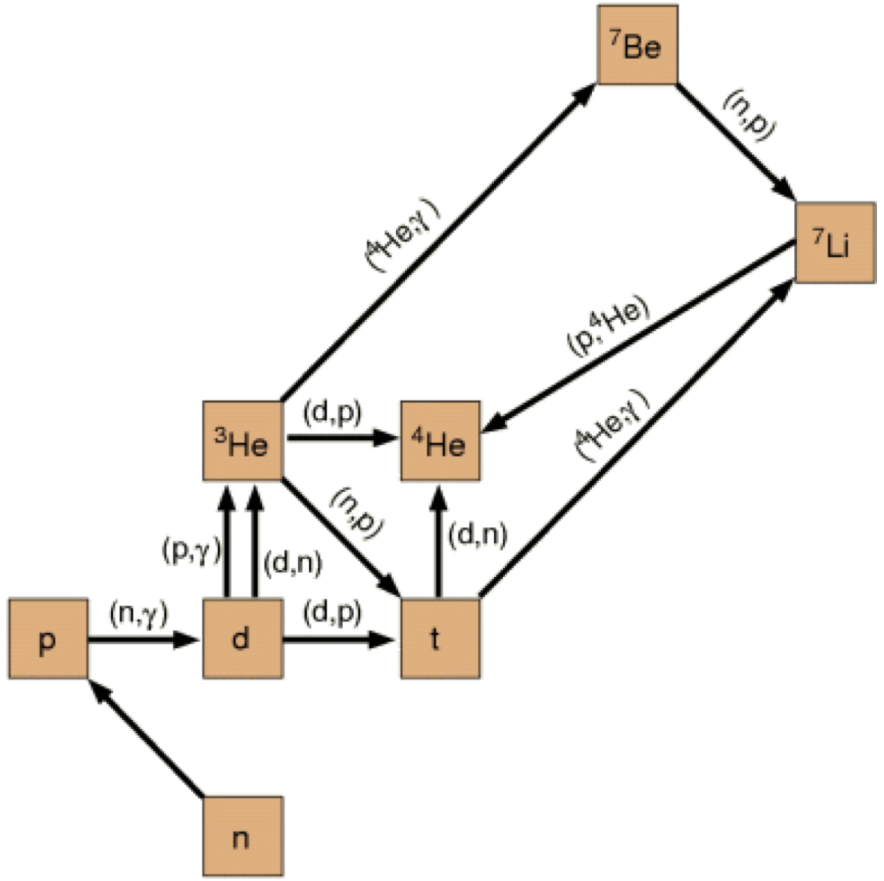


Timmes/Schatz 2016

BBN

Online tools:
http://parthenope.na.infn.it/

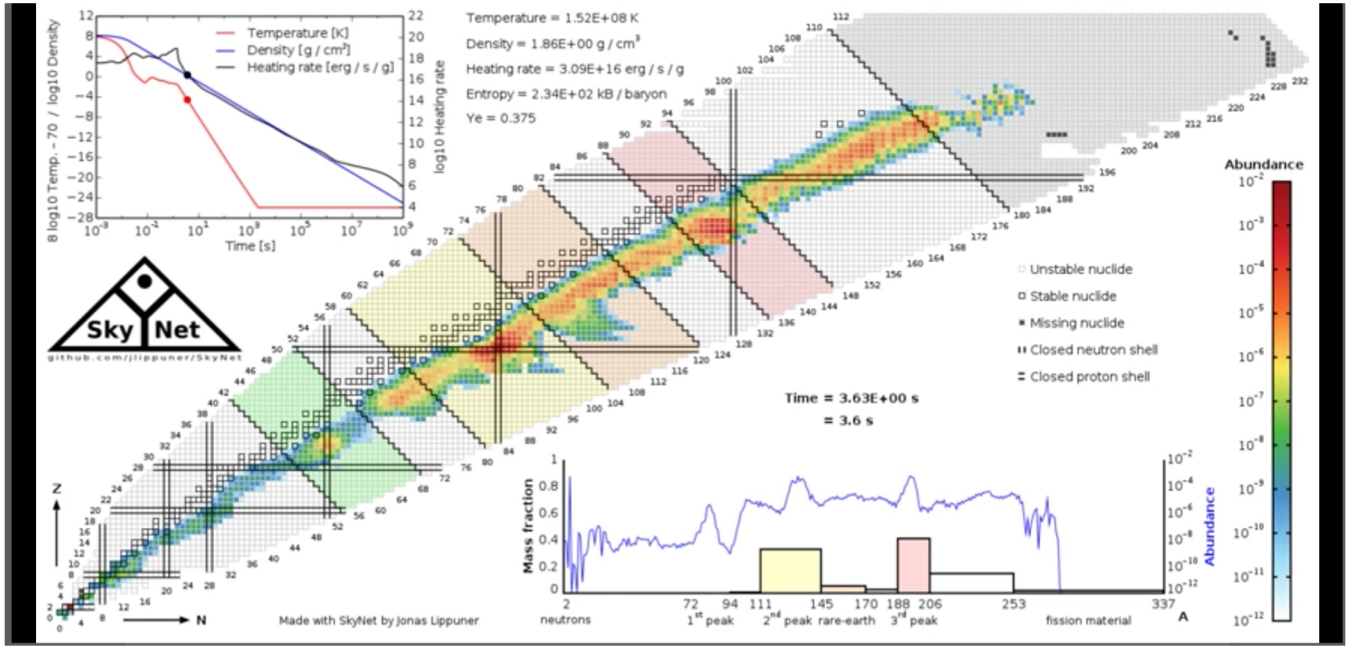




https://arxiv.org/abs/astro-ph/0303073
Background:
Coc + 2014+2012:
https://arxiv.org/pdf/1403.6694.pdf
https://iopscience.iop.org/article/10.1088/0004-637X/744/2/158/pdf
R. Cyburt on Li problem

R-process

- Skynet: https://jonaslippuner.com/research/skynet/

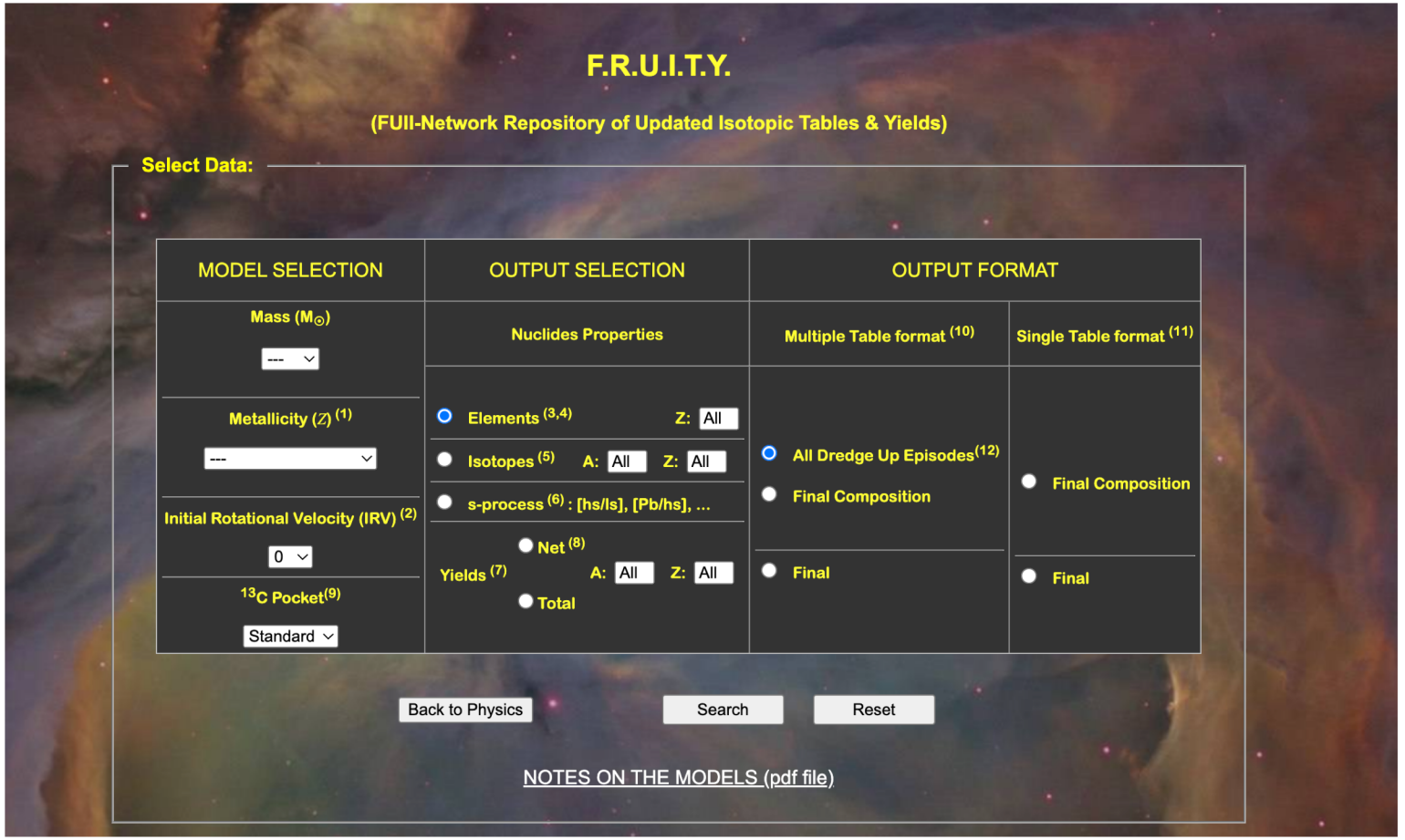


- Arcones & Thielemann 2013, Winteler et al. 2012, Rosswog et al. 2018, Cowan et al. 2021

S-process

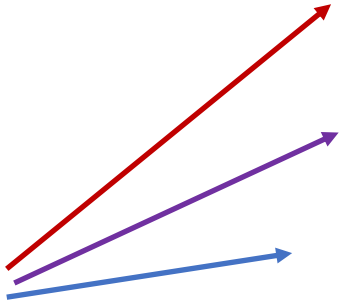
- FRUITY: http://fruity.oa-teramo.inaf.it/modelli.pl

- Karakas & Lattanzio 2014, Lugaro et al. 2012, Cristallo et al. 2015…



I-process

- Contact: R. Stancliffe



s-process
i-process
r-process

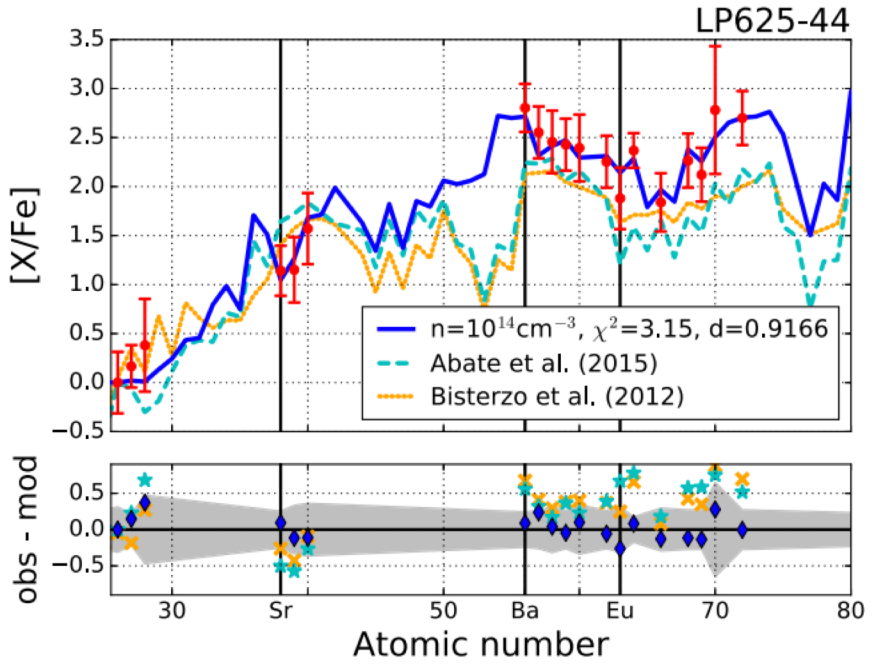


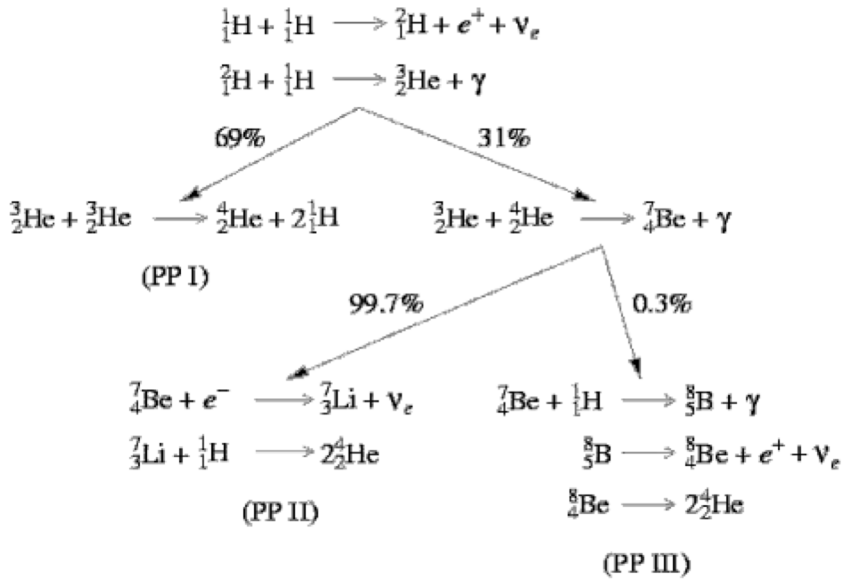
Figure 4. Best-fitting model for CEMP-s/r star LP625-44 (red dots): the best-fitting models from Abate et al. (2015a) with AGB nucleosynthesis (cyan) and from Bisterzo et al. (2012) with the s process and initial $[r/\mathrm{Fe}] = 1.5$ (orange) compared to the best-fitting model from the neutron capture nucleosynthesis calculations with a neutron density of $n = 10^{14}$ cm^{-3} (blue). Lower panel, vertical lines and uncertainties, as in Figure 3.

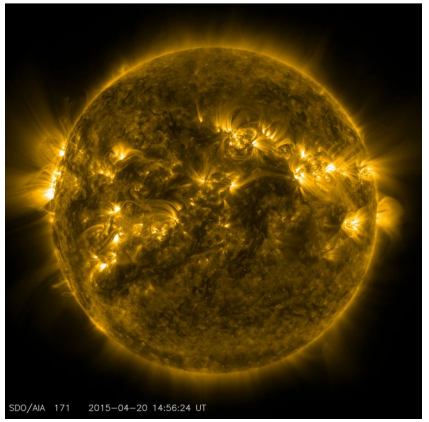
- Denissenkov et al. 2019, 2021, Hampel et al. 2016, Abate et al. 2015, Bisterzo et al. 2012

Low-mass stars (~1Mo)

- Back-ground on low-mass stars and their burning processes → J. Christensen-Dalsgaard

- https://neutrinos.fnal.gov/sources/solar-neutrinos/
- https://www.nature.com/articles/d41586-018-07099-1





$4\ {}^{1}H \rightarrow {}^{4}He + 2e^{+} + 2\nu_e$

Massive stars (SN)

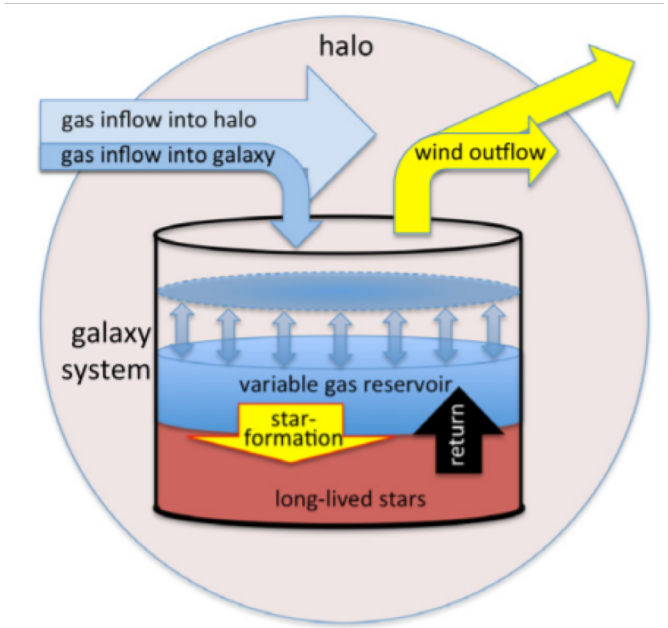
- Online tool: https://starfit.org/. (A. Heger)
- vp-process (Pruet +06, Froehlich+06)

- J. Christensen-Dalsgaard + Arnett (Background)
- Kobayashi +2006, Tominaga +2009, Nomoto+2006, Heger +2010

GCE

- OMEGA: https://nugrid.github.io/NuPyCEE/overview.html

Contact: Kate Womack



- Literature: Kobayashi+2020, Prantzos+2018, Cescutti+2015 Cote+2018-19…

Next steps

- Select topics
- Form groups
- Lectures
- Start reading

- End of semester – give a seminar talk about your topic to the rest of the class