Nucleosynthesis Calculations for Nuclear Astrophysics

NuGrid Summer School

09/18/2018

Ondrea Clarkson

Single Zone

- What it is:
  - Single zone refers to the the representation of a single region in either T, ρ space or mass/radius for a given stellar environment.
  - In this single-zone, the abundance of each isotope is evolved at each time step (fully-implicit).
- Applications of single zone networks:
  - Approximate nucleosynthesis for a given environment and starting abundance.
  - Impact/sensitivity studies (if you have T, ρ or a trajectory you do not need the stellar model).

Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY

MNRAS **474**, L37–L41 (2018) doi:10.1093/mnrasl/slx190
Advance Access publication 2017 November 23

Pop III *i*-process nucleosynthesis and the elemental abundances of SMSS J0313−6708 and the most iron-poor stars

O. Clarkson,[1,2⋆†] F. Herwig[1,2†] and M. Pignatari[2,3†]

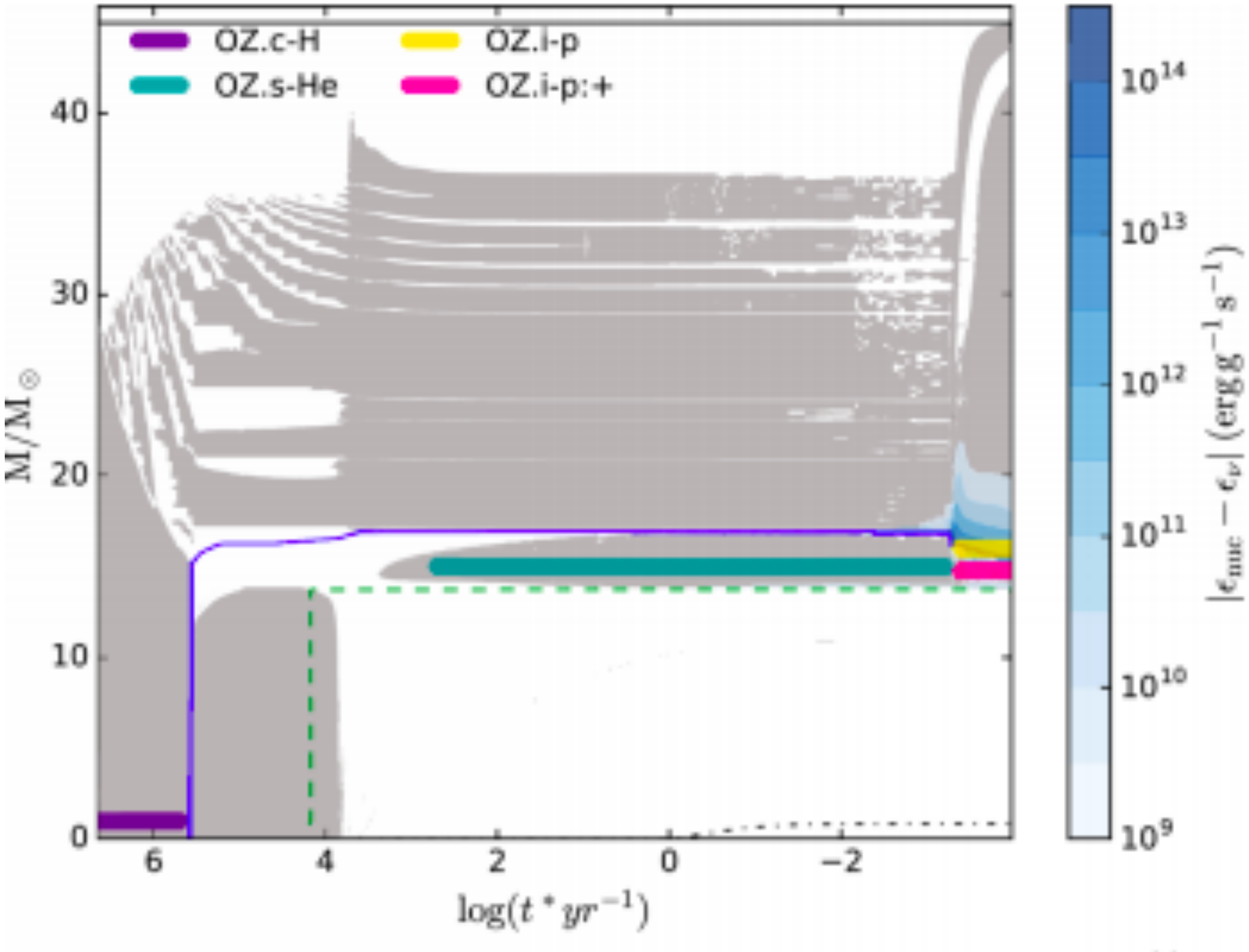
[1] *Department of Physics & Astronomy, University of Victoria, PO Box 3055, Victoria, BC V8W 3P6, Canada*
[2] *Joint Institute for Nuclear Astrophysics, Center for the Evolution of the Elements, Michigan State University, 640 South Shaw Lane, East Lansing, MI 48824, USA*
[3] *E.A. Milne Centre for Astrophysics, University of Hull, Hull, HU6 7RX, UK*

Accepted 2017 November 21. Received 2017 November 20; in original form 2017 October 8

ABSTRACT

We have investigated a highly energetic H-ingestion event during shell He burning leading to H-burning luminosities of $\log(L_{\rm H}/{\rm L}_\odot) \sim 13$ in a $45\,{\rm M}_\odot$ Pop III massive stellar model. In order to track the nucleosynthesis which may occur in such an event, we run a series of single-zone nucleosynthesis models for typical conditions found in the stellar evolution model. Such nucleosynthesis conditions may lead to *i*-process neutron densities of up to $\sim 10^{13}\,{\rm cm}^{-3}$. The resulting simulation abundance pattern, where Mg comes from He burning and Ca from the *i* process, agrees with the general observed pattern of the most iron-poor star currently known, SMSS J031300.36−670839.3. However, Na is also efficiently produced in these *i*-process conditions, and the prediction exceeds observations by ∼2.5 dex. While this probably rules out this model for SMSS J031300.36−670839.3, the typical *i*-process signature of combined He burning and *i* process of higher than solar [Na/Mg], [Mg/Al], and low [Ca/Mg] is reproducing abundance features of the two next most iron-poor stars HE 1017−5240 and HE 1327−2326 very well. The *i* process does not reach Fe which would have to come from a low level of additional enrichment. *i* process in hyper-metal-poor or Pop III massive stars may be able to explain certain abundance patterns observed in some of the most metal-poor CEMP-no stars.

- Kippenhahn diagram illustrating locations of single zone runs



- T, ρ and duration of single zone runs

Run ID	Burning phase	T (10^8 K)	ρ (g cm^{-3})	Δt (yr)
OZ.c-H	Core H	1.25	93.33	2.21×10^4
OZ.s-He	Shell He	2.6	330	1.28×10^2
OZ.s-He:+[a]	Shell He	2.95	487.1	4.45×10^2
OZ.i-p:t1,2,3	H-ingest.	2.0	191	$1,2,5 \times 10^{-2}$
OZ.i-p:+	H-ingest.	2.41	315.4	3.44×10^{-2}