Heavy Elements Nucleosynthesis On Accreting White Dwarfs surface: seeding the the p-process

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NuGrid Collaboration

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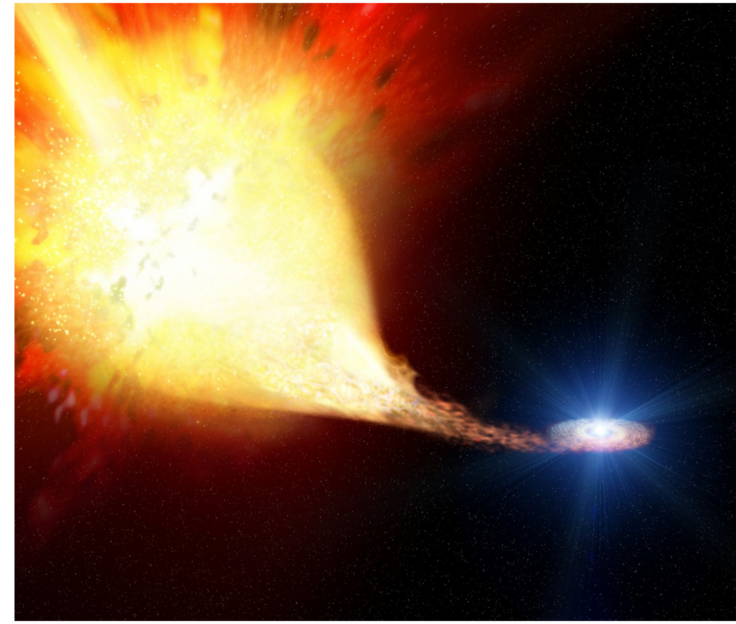
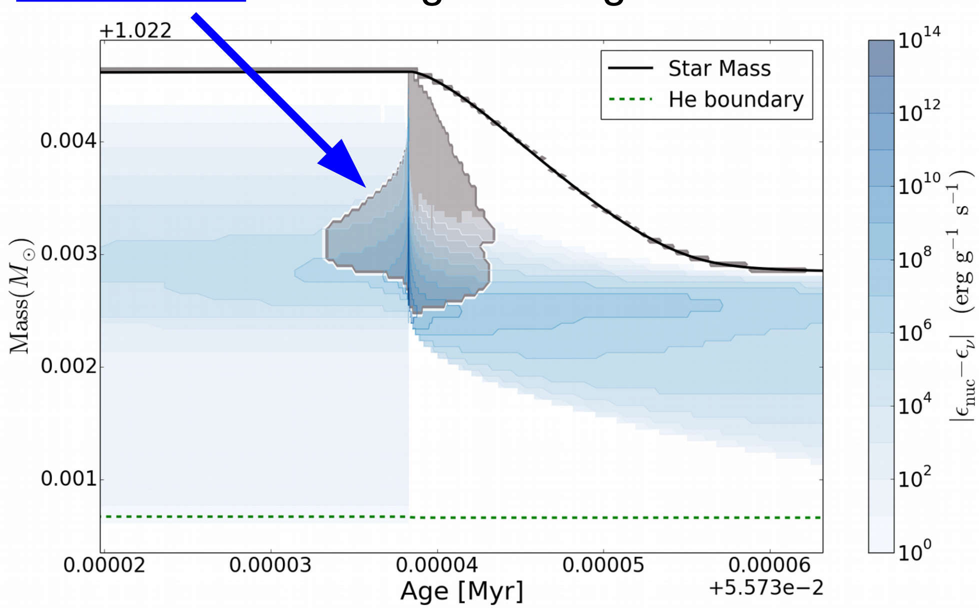
Nuclei in the Cosmos, June 24-29, 2018
Laboratori Nazionali del Gran Sasso, Assergi, Italy

Type Ia Supernovae

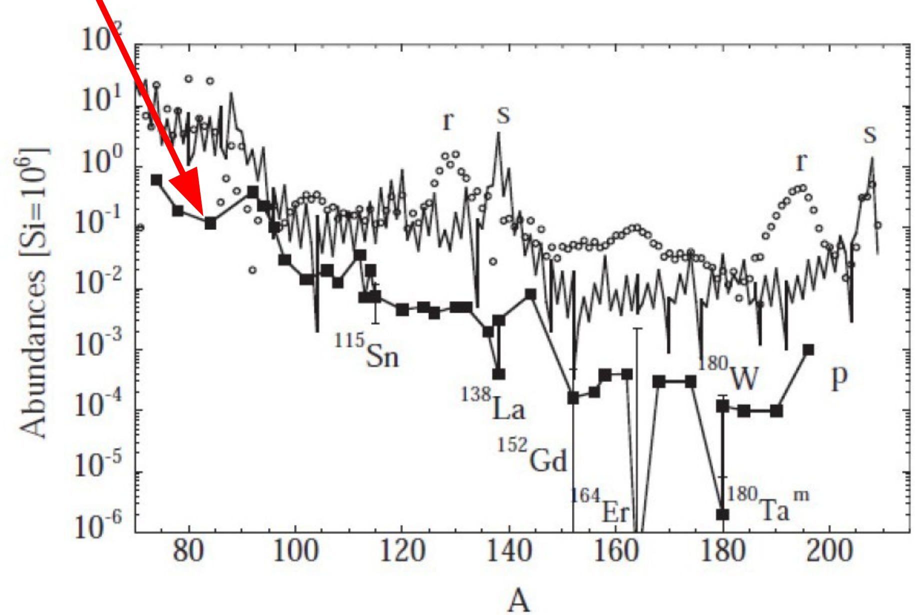
- Type Ia supernovae (SNIa) are luminous stellar explosions which marks the fatal destruction of accreting white dwarfs in binary systems.
- The two scenatios to make SNIa explosions are **Single-Degenerate** (SD, here considered; Whelan & Iben 1972) and Double Degenerate (DD; Iben et al. 1984).
- Travaglio et al. 2011 showed how SNIa could be a relevant source for the ***p*-process isotopes** made by (γ,n), (γ,p) and (γ,α) photo-disintegrations reactions on **ASSUMED** **pre-existing heavy-element seeds distribution** formed from the neutrons released during the **He-flashes** occurring all along the accretion.



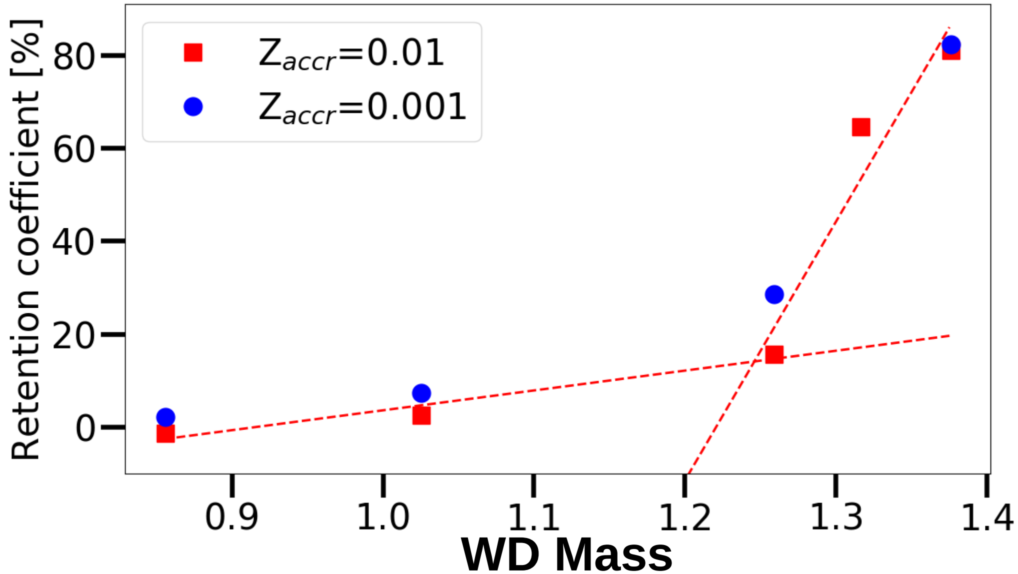
SD scenario artist's impression (from Wikipedia)



M. Arnould, S. Goriely / Physics Reports 384 (2003) 1–84



Can we reach the Chandrasekhar mass?



- The maximum CO-core mass in NON-rotating AGB stars cannot exceed **~1.1 Msun**… this fact and the lack of He II lines detection from elliptical galaxies seems to indicate that the SD-channel for SNe is highly unlikely (Woods+ 2013, Denissenkov+ 2017)

- Low retention-coefficient values for Mwd < 1 Msun in agreement with Denissenkov et al. 2017, the resulting minimum WD mass required to reach the Chandrasekhar is **1.2 Msun** at <u>solar metallicity</u> (p-process seeds are <u>secondary</u>!!!). A similar and very interesting work on He-accreting WDs has been done by Piersanti et al. 2014.

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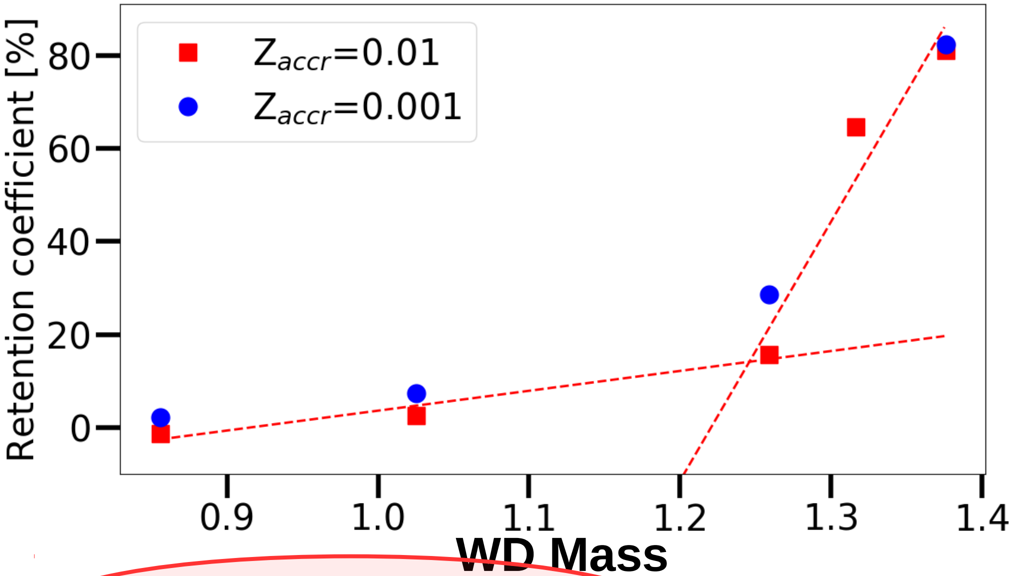

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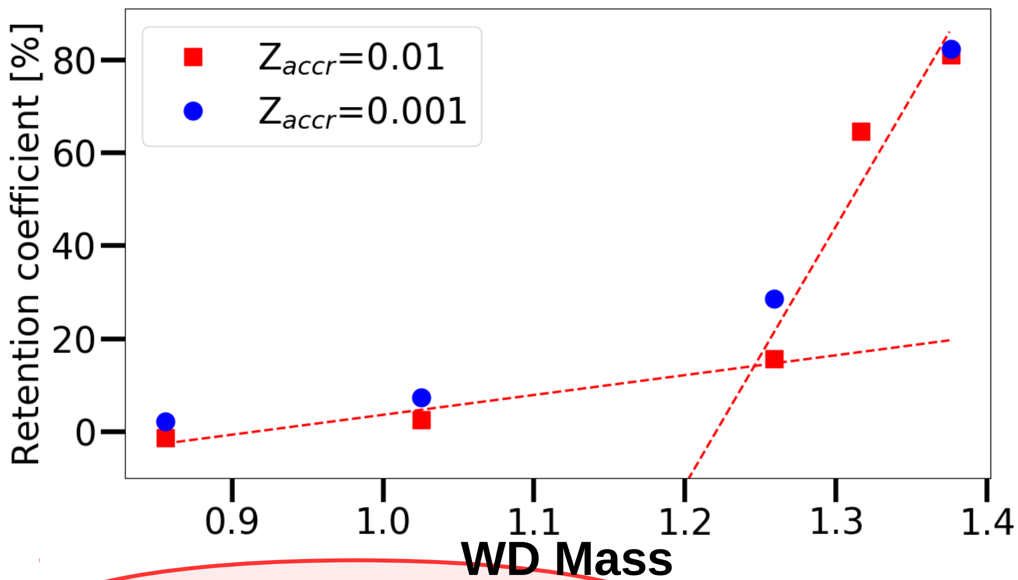

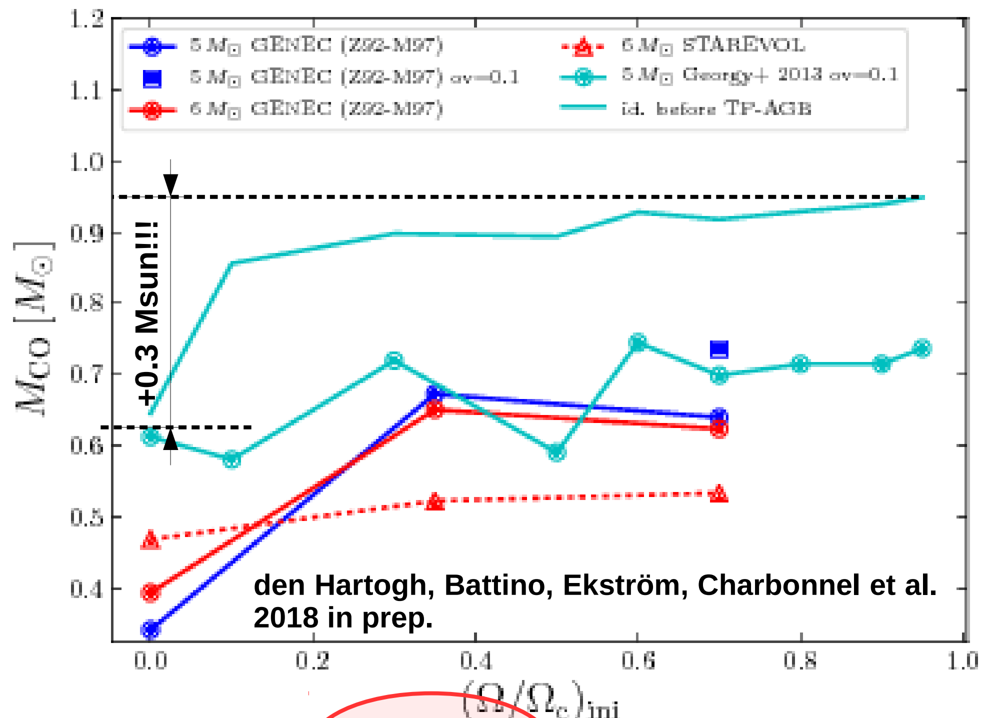

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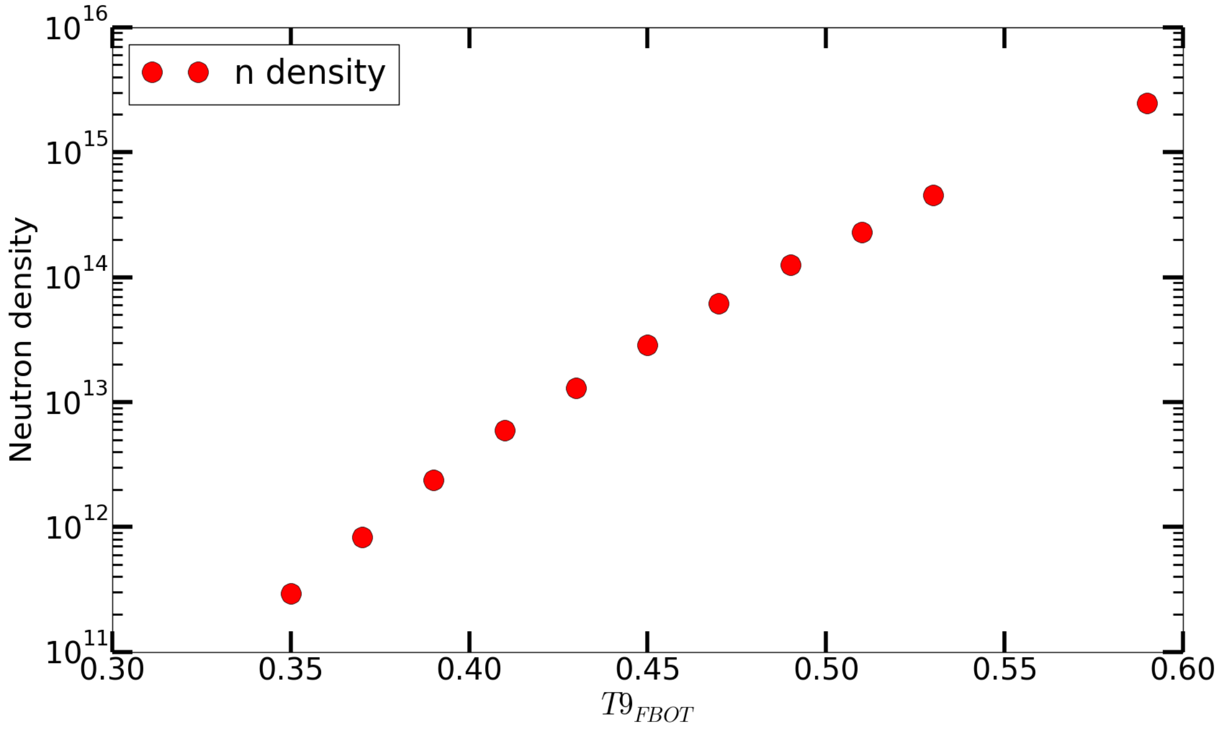
- **!!!** On the other hand, Dominguez et al. 1996 showed that in rotating massive AGB stars the final CO-core mass is markedly increased (**<u>in the range 1.1-1.4 Msun!!</u>**). Stellar models with MESA, GENEC and STAREVOL stellar codes including self-consistent treatment of stellar rotation are under analysis: preliminary results seems to confirm Dominguez et al. results!! (den Hartogh, Battino, Ekström, Charbonnel et al. 2018 in prep.)**!!!**

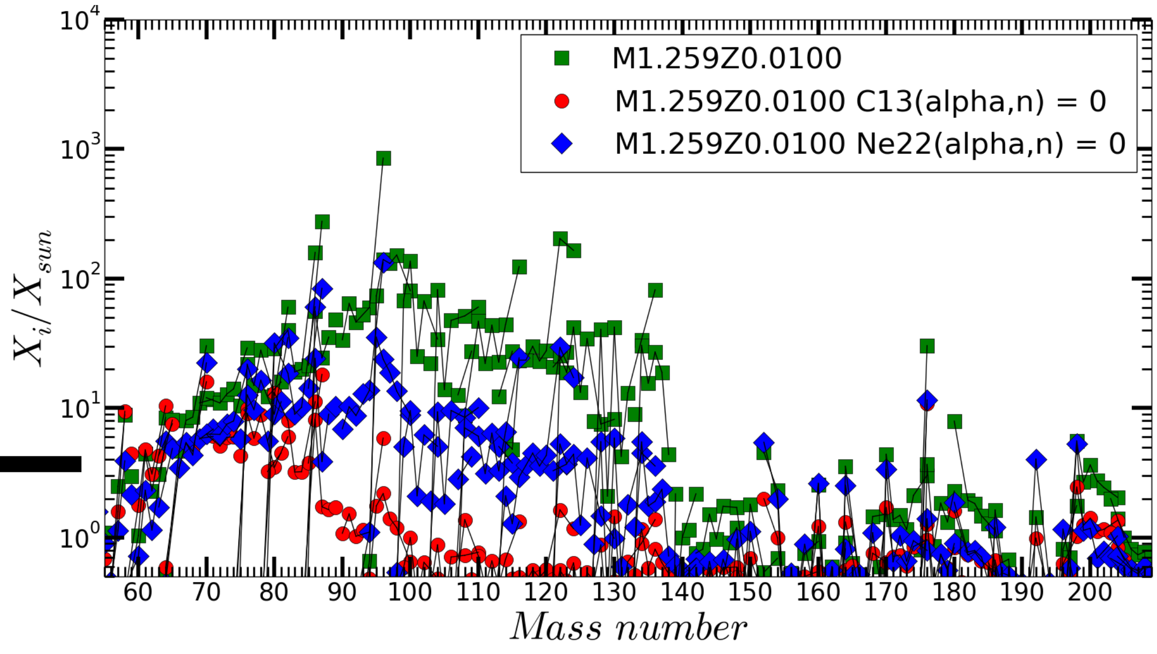
Nuclear rates tests: what is the main neutron source?



T at the bottom of the TP ranging from 0.35GK (M=0.85 Msun) to ~ 0.59 GK (M=1.376 Msun)

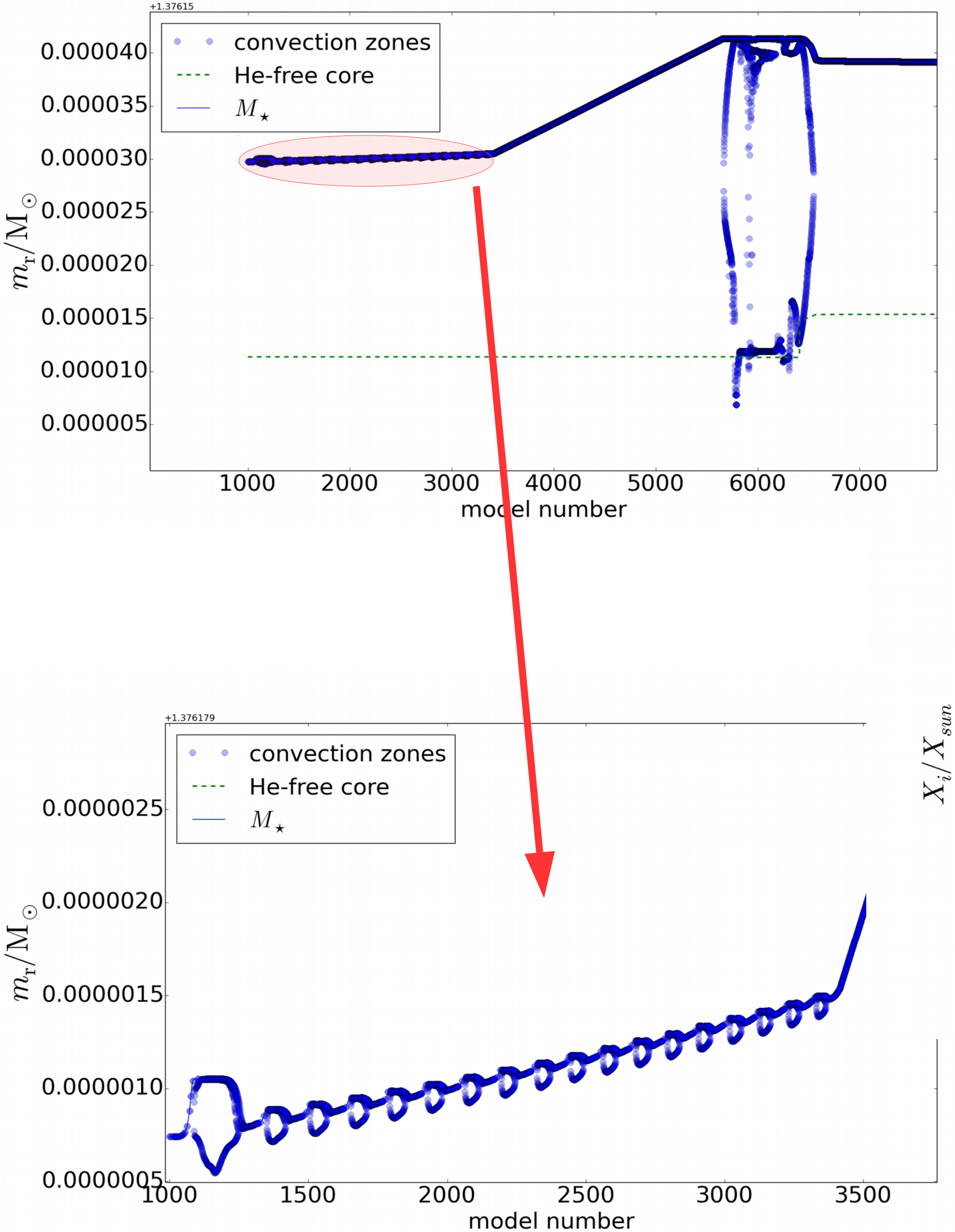
Neutron densities reaching 10^{15} n cm^{-3}

Many branching-points activated (Rb and Zr in particular)

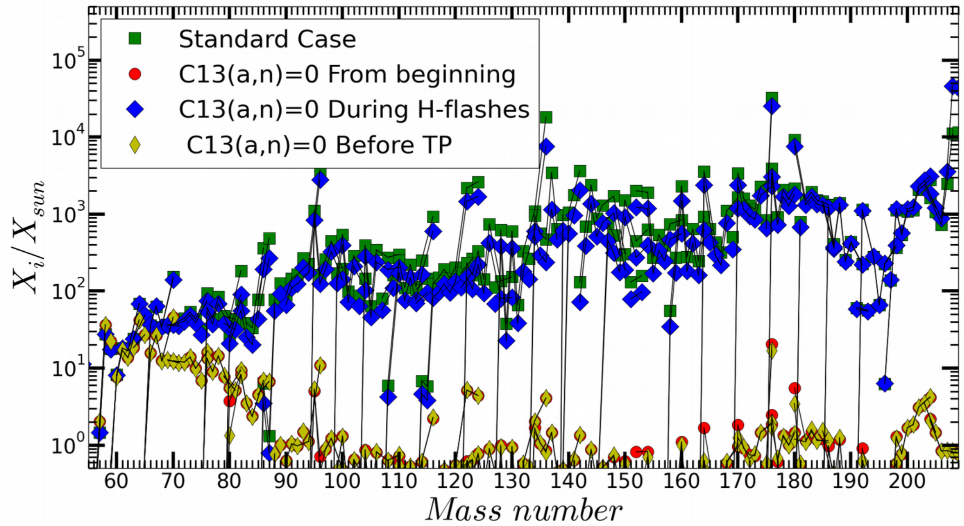


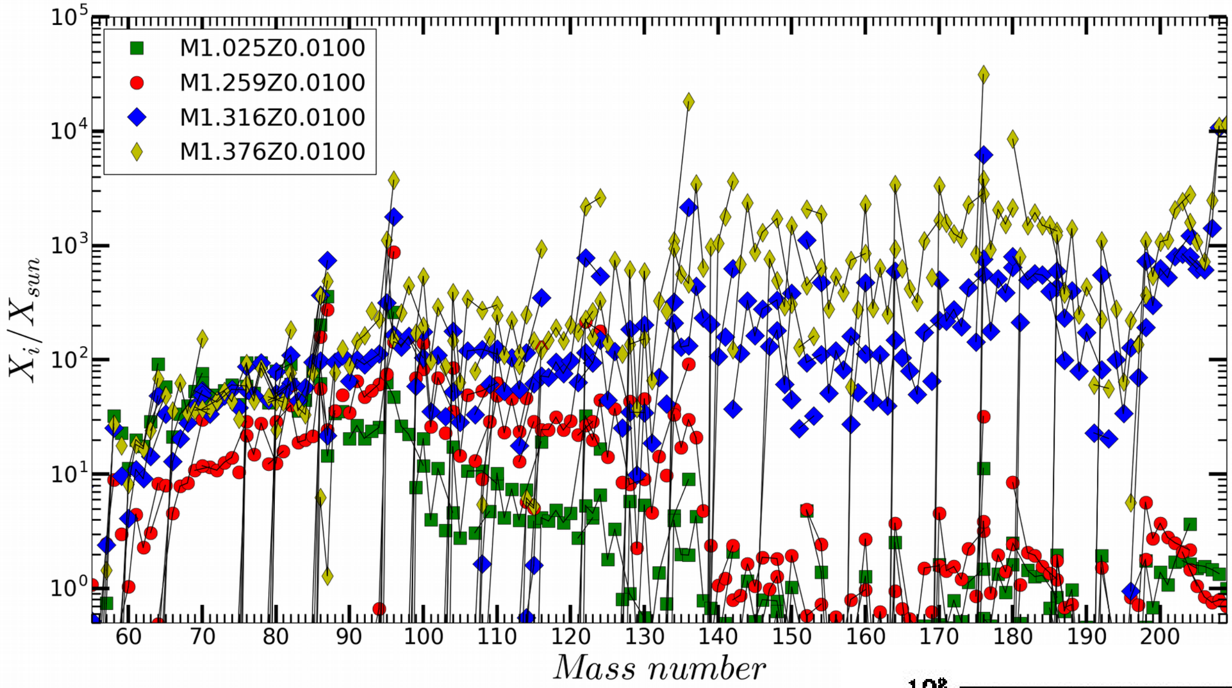
Production on the 1.26Msun and higher masses model is impacted by C13(alpha,n)O16 <u>(C13 coming from HIF events!)</u>

1.38 Msun Model: A peculiar case

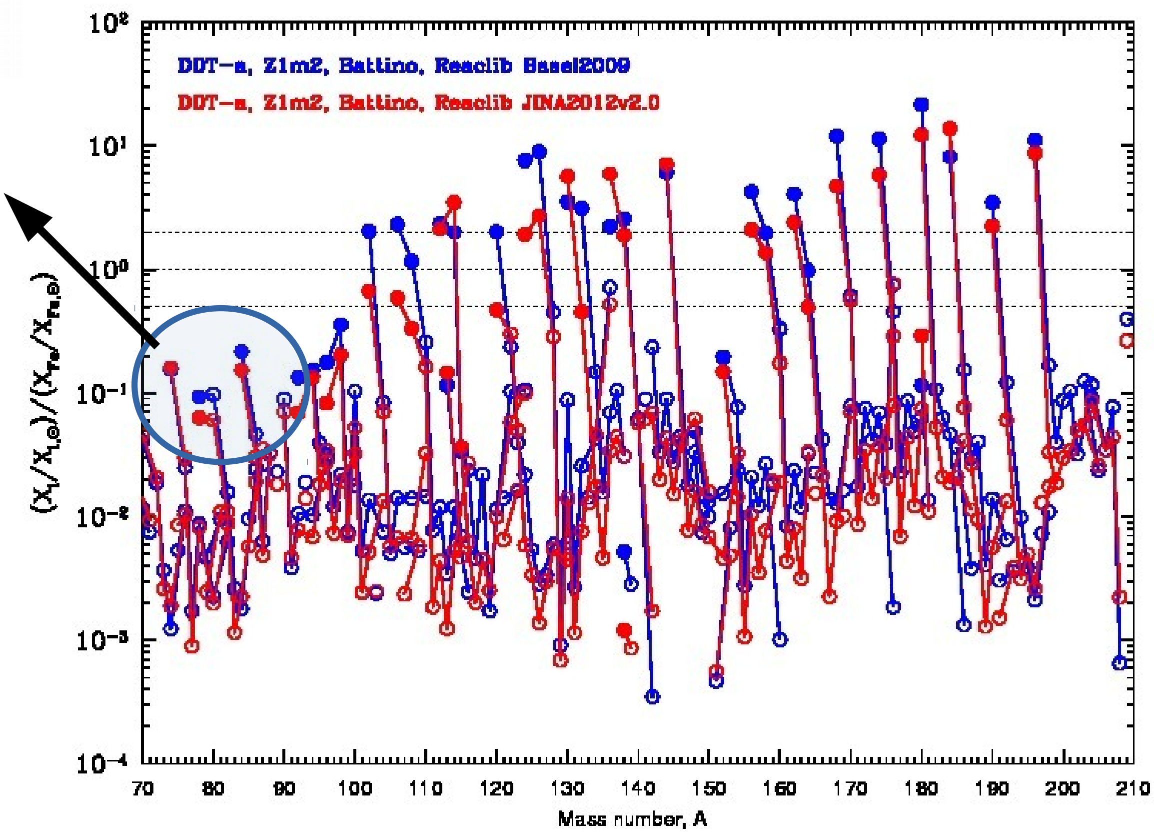


- H-flashes temperature = 3 T8
- Interpulse temperature= 1.15 T8
- Everything happens in 10^-7 Msun





Results



Contribution from Type II Sne (Travaglio, Rauscher et al 2018; Rauscher et al 2018)

***^{14}N(n,p)^{14}C** may have a big impact on the seeds production, possibly favoring lighter elements and hence explosive nucleosynthesis of **^{94}Mo**???*
Tests are under way ;)

Battino et al 2018; in prep.

Conclusions

- I presented for the first time a heavy-element distribution calculated from realistic simulations of WD-accretion phase in the single degenerate scenario channel to SNIa.
- Such distribution arised for recurrent TP events very similar to those happening during the AGB phase and characterized by very high temperatures, ranging from 0.35 to 0.59 T9 at the bottom of the PDCZ.
- The main effect of such high temperatures is the occurrence of very high neutron densities, reaching 10^{15} n cm^{-3} when the WD has reached the Chandrasekhar mass, activating many branching-points and producing large quantities of Rb,Kr, Zr, Ba-peak isotopes and Pb .
- Is therefore globally very similar to the one adopted in Travaglio et al. (2011), when used as a starting abundance distribution, p-nuclei are significantly produced in the mass range $96<A<196$. **Full results to be published in Battino et al. 2018, in prep.**
- SD-scenario possibly produces a non-negligible fraction of SNIa **(see also den Hartogh, Battino, Ekström, Charbonnel et al. 2018 in prep.)** and hence could significantly contribute to p-nuclei abundances in the Solar System.

Grazie mille per la vostra attenzione!!!

Mersì per la vostr atensiun!!!

Thank you so much for your kind attention!!!

Vielen Dank für Ihre Aufmerksamkeit!!!

Gratias vobis ago!!!

THE ASTROPHYSICAL JOURNAL, 472:783–788, 1996 December 1

ON THE FORMATION OF MASSIVE C-O WHITE DWARFS: THE LIFTING EFFECT OF ROTATION

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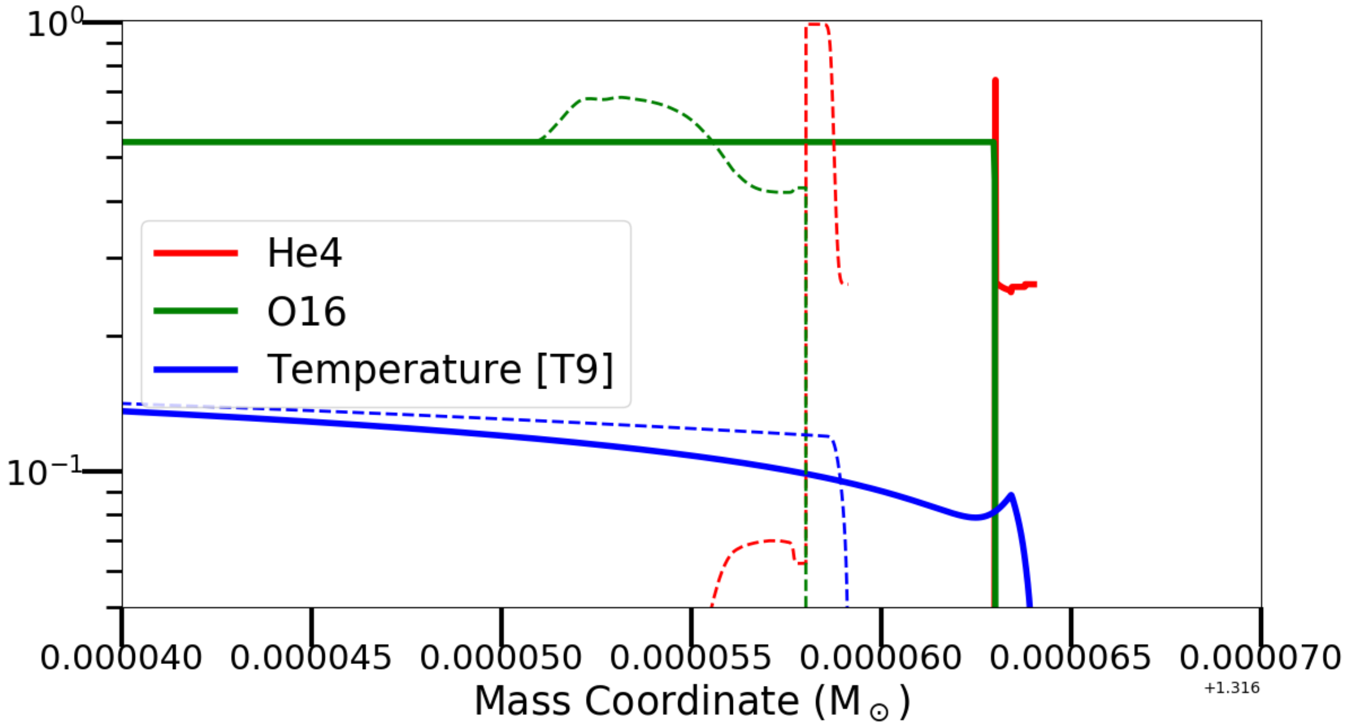
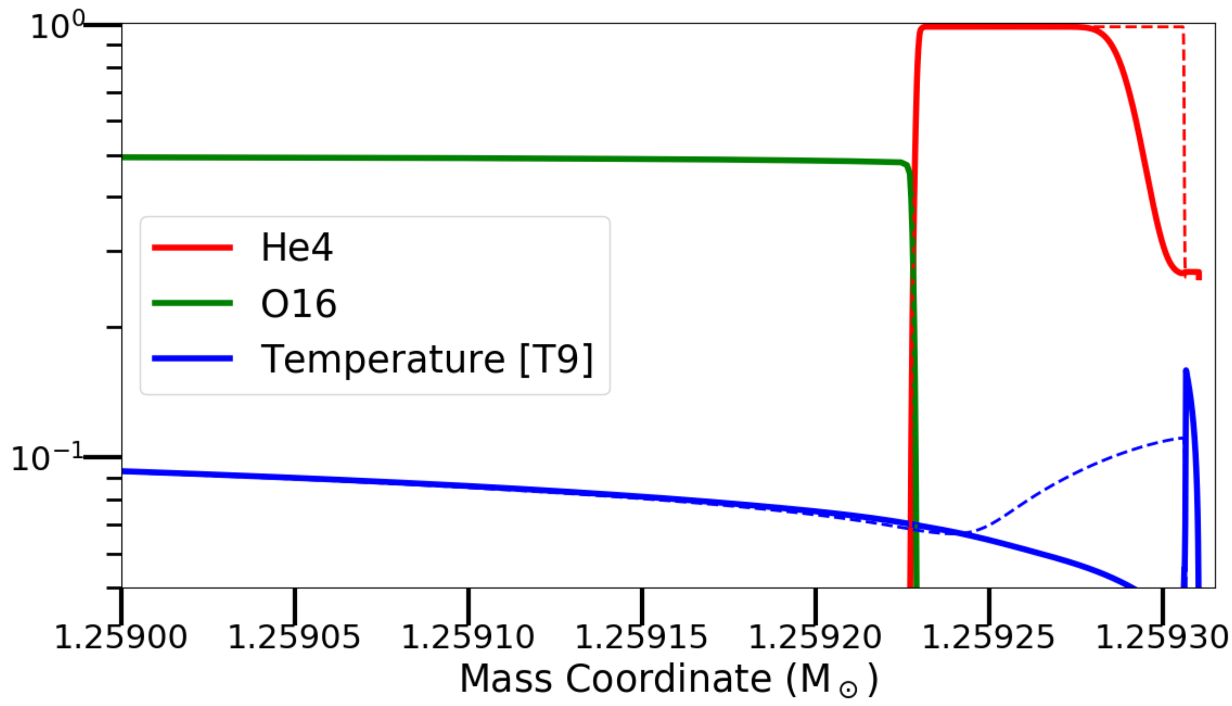
Received 1995 December 11; accepted 1996 June 25

ABSTRACT

The effect of stellar rotation on the late evolution of intermediate-mass stars has been explored, employing very simple numerical methods. At the epoch of central He exhaustion and C-O core formation, even an initially small rotation may induce, for the first time, a nonnegligible effect on the evolutionary outcome, as a consequence of the huge contraction of the core radius that occurs at this stage. The role of various hydrodynamic instabilities is discussed, verifying the consistency of our approach. The most important characteristic of the rotating models is the slow increase in temperature in the region where He burning occurs. As a consequence, the elapsed time before the onset of the second dredge-up is greater than that found for nonrotating models, and the C-O core mass is markedly increased during the early asymptotic giant branch (AGB) phase. In such a way, massive C-O white dwarfs, near the Chandrasekhar limiting mass for nonrotating stars, would be formed after envelope



10^0
10^{-1}
He4
O16
Temperature [T9]
0.000040
0.000045
0.000050
0.000055
0.000060
0.000065
0.000070
+1.316
Mass Coordinate ($M_\odot$)



10^0
10^{-1}
He4
O16
Temperature [T9]
1.25900
1.25905
1.25910
1.25915
1.25920
1.25925
1.25930
Mass Coordinate ($M_\odot$)

Reaction rates uncertainties impact:
Results from Monte Carlo variations

Nuclide	$r_{corr,0}$	$r_{corr,1}$	$r_{corr,2}$	Key rate Level 1	Key rate Level 2	Key rate Level 3	X_0 (2 GK) capture	X_0 (3 GK) capture
^{78}Kr	−0.84			^{77}Br + p ↔ γ + ^{78}Kr			9.63×10^{-2}	4.44×10^{-2}
	0.34	0.87			^{79}Kr + n ↔ γ + ^{80}Kr		1.28×10^{-1}	7.94×10^{-2}
^{92}Mo	−0.74			^{91}Nb + p ↔ γ + ^{92}Mo			8.88×10^{-1}	8.24×10^{-1}
^{96}Ru	−0.73			^{92}Mo + α ↔ γ + ^{96}Ru			1.00	9.86×10^{-1}
	−0.43	−0.69			^{95}Tc + p ↔ γ + ^{96}Ru		7.64×10^{-1}	6.60×10^{-1}
^{102}Pd	−0.87			^{101}Pd + n ↔ γ + ^{102}Pd			5.62×10^{-1}	3.97×10^{-1}
^{112}Sn	−0.88			^{111}Sn + n ↔ γ + ^{112}Sn			7.79×10^{-1}	6.73×10^{-1}
^{114}Sn	−0.77			^{113}Sn + n ↔ γ + ^{114}Sn			1.82×10^{-1}	1.28×10^{-1}
^{120}Te	−0.64	−0.66			^{119}Te + n ↔ γ + ^{120}Te		2.43×10^{-1}	1.77×10^{-1}
^{124}Xe	−0.74			^{123}Xe + n ↔ γ + ^{124}Xe			8.25×10^{-2}	4.38×10^{-2}
^{126}Xe	−0.75			^{125}Cs + p ↔ γ + ^{126}Ba			1.17×10^{-1}	7.41×10^{-2}
	0.30	0.64	0.65			^{127}Ba + n ↔ γ + ^{128}Ba	5.78×10^{-2}	3.59×10^{-2}
^{130}Ba	−0.66			^{129}Ba + n ↔ γ + ^{130}Ba			5.77×10^{-2}	3.55×10^{-2}
^{132}Ba	−0.77			^{131}Ba + n ↔ γ + ^{132}Ba			1.07×10^{-1}	5.85×10^{-2}
^{136}Ce	−0.69			^{135}Ce + n ↔ γ + ^{136}Ce			1.86×10^{-1}	8.94×10^{-2}
	0.31	0.72			^{139}Ce + n ↔ γ + ^{140}Ce		8.56×10^{-1}	6.09×10^{-1}
^{138}Ce	−0.66			^{137}Ce + n ↔ γ + ^{138}Ce			4.16×10^{-1}	2.54×10^{-1}
	−0.16	−0.19	−0.66			^{136}Ce + n ↔ γ + ^{137}Ce	7.57×10^{-1}	4.70×10^{-1}
^{144}Sm	0.70			^{145}Eu + p ↔ γ + ^{146}Gd			8.06×10^{-1}	6.02×10^{-1}
^{152}Gd	−0.74			^{151}Gd + n ↔ γ + ^{152}Gd			6.18×10^{-1}	3.87×10^{-1}
	0.43	0.76			^{153}Gd + n ↔ γ + ^{154}Gd		5.38×10^{-2}	2.78×10^{-2}
	−0.14	−0.26	−0.73			^{148}Sm + α ↔ γ + ^{152}Gd	8.14×10^{-1}	5.22×10^{-1}
^{164}Er	−0.78			^{160}Er + α ↔ γ + ^{164}Yb			2.13×10^{-1}	1.24×10^{-1}
^{180}W	−0.83			^{176}W + α ↔ γ + ^{180}Os			1.83×10^{-1}	1.04×10^{-1}
	−0.19	−0.60	−0.68			^{179}Os + n ↔ γ + ^{180}Os	4.89×10^{-2}	2.49×10^{-2}
^{196}Hg	−0.83			^{195}Pb + n ↔ γ + ^{196}Pb			2.97×10^{-1}	1.89×10^{-1}
	0.31	0.70			^{197}Pb + n ↔ γ + ^{198}Pb		3.28×10^{-1}	2.39×10^{-1}
	0.17	0.35	0.67			^{199}Pb + n ↔ γ + ^{200}Pb	6.37×10^{-1}	3.47×10^{-1}
^{92}Nb	0.76			^{90}Zr + p ↔ γ + ^{91}Nb			1.00	9.95×10^{-1}
^{146}Sm	−0.57	−0.75			^{144}Sm + α ↔ γ + ^{148}Gd		9.99×10^{-1}	9.65×10^{-1}
	0.34	0.44	0.79			^{147}Gd + n ↔ γ + ^{148}Gd	9.92×10^{-1}	9.28×10^{-1}

Rauscher et al 2018