URCA processes in stellar degenerate cores

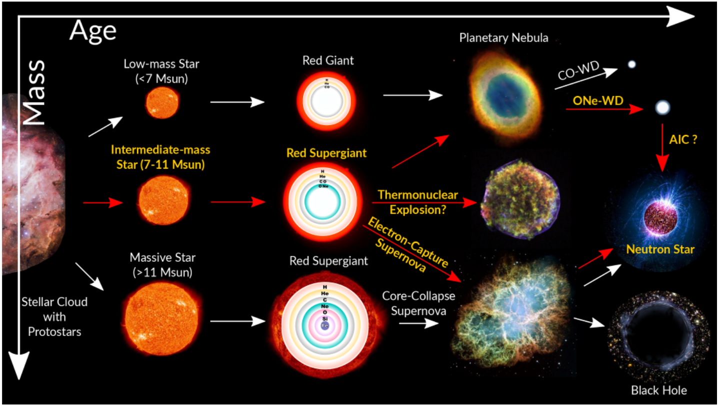
Dag Fahlin Strömberg

TECHNISCHE UNIVERSITÄT DARMSTADT

SFB 1245

The fate of stars

TECHNISCHE UNIVERSITÄT DARMSTADT



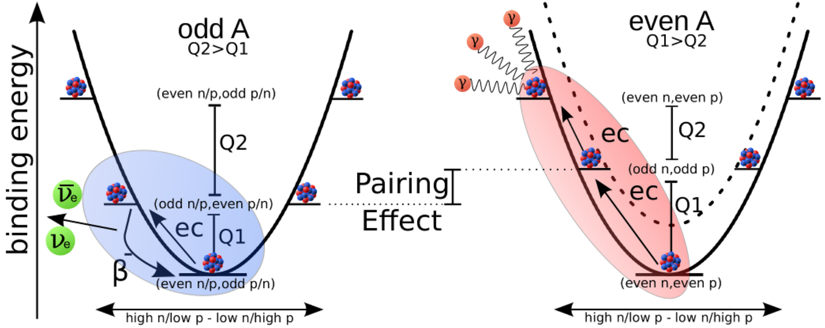
Heiko Möller, PhD Thesis (2017)

Degenerate ONe cores

- Content after carbon burning: ^{16}O, ^{20}Ne, ^{23}Na, ^{24}Mg and ^{25}Mg.
- Also other nuclei from initial composition
- Mainly supported by degeneracy pressure
- Electron Fermi energy $E_F \sim \rho^{1/3}$ increases when the core contracts
- Electron capture when E_F is larger than the Q value
- Thresholds:

Nucleus	E_F [MeV]	ρ [g $\cdot$ cm^{-3}]
^{25}Mg	3.833	1.17×10^9
^{23}Na	4.374	1.67×10^9
^{24}Mg	5.513	3.16×10^9
^{20}Ne	7.026	6.20×10^9
^{16}O	10.42	1.90×10^{10}

Urca and double electron capture processes

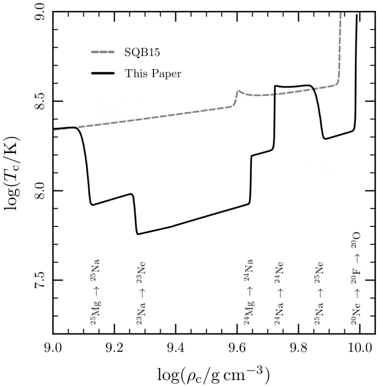


Heiko Möller, PhD Thesis (2017)

Urca cooling in acreeting ONe WD

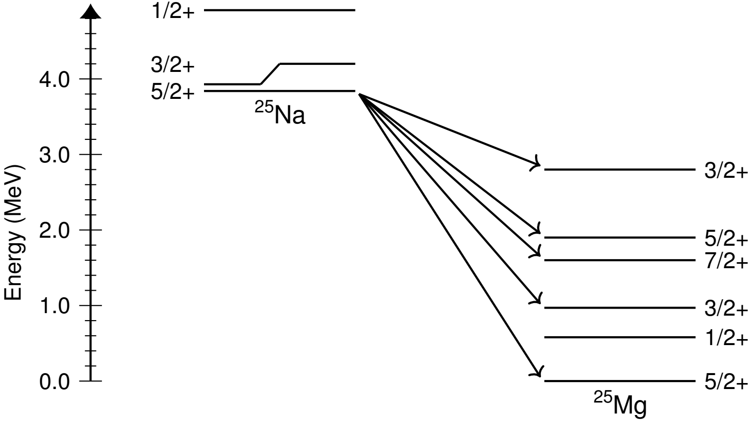
TECHNISCHE UNIVERSITÄT DARMSTADT

Schwab et. al, 2017.



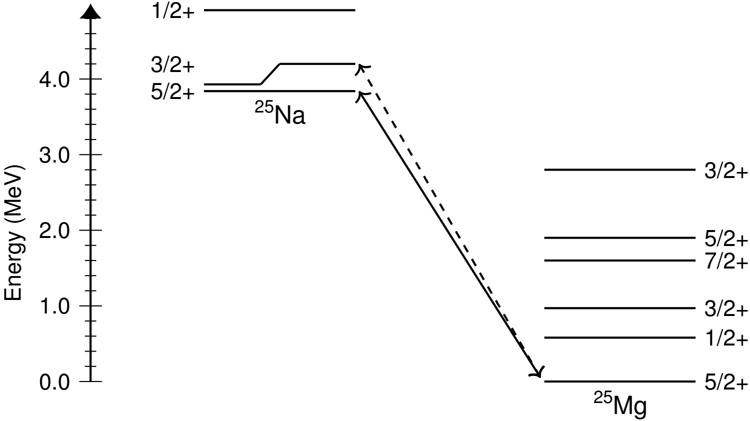
What transitions are relevant?

TECHNISCHE UNIVERSITÄT DARMSTADT



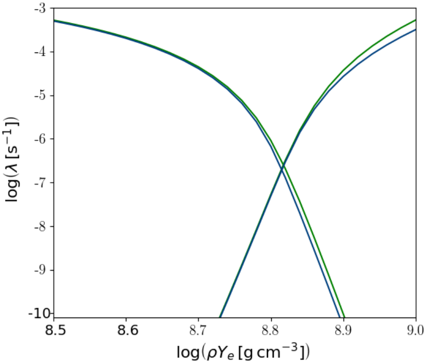
What transitions are relevant?

TECHNISCHE
UNIVERSITÄT
DARMSTADT



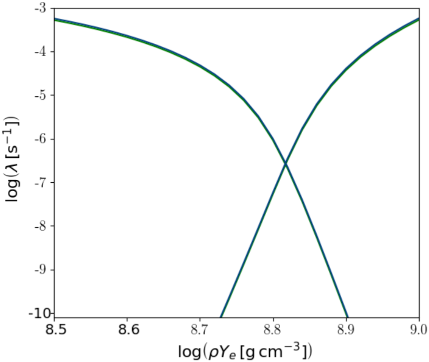
Is the Urca density affected?

- Rates for electron capture on ^{25}Mg and beta decay of ^{25}Na at $\log(T) = 8.6$:



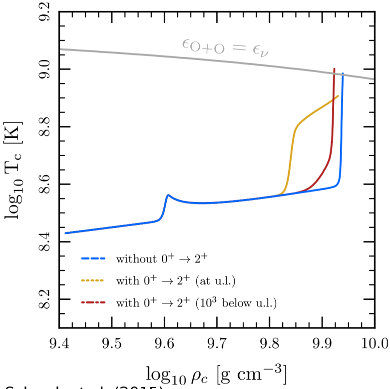
Adding additional transitions

- Compared with rates of Suzuki et al. (2016):

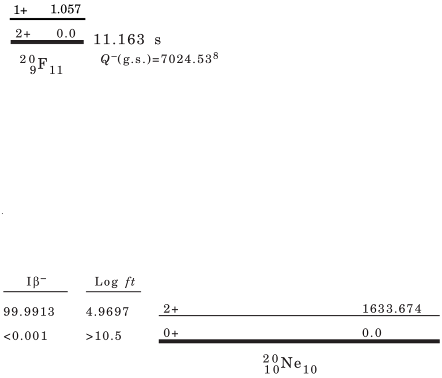


Forbidden transition from ^{20}Ne

- Martinez-Pinedo et al (2014): forbidden transition important for EC on ^{20}Ne



Schwab et al. (2015)



Effects of additional Urca pairs

TECHNISCHE UNIVERSITÄT DARMSTADT

SNe Ia Keep Memory of Their Progenitor Metallicity

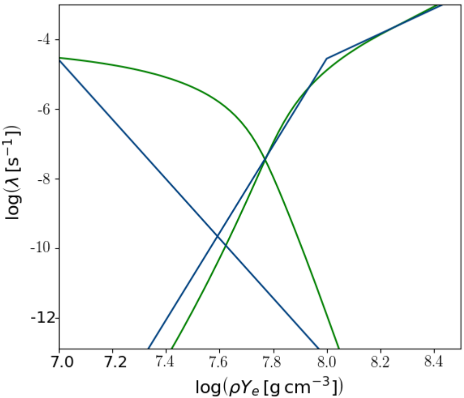
Luciano Piersanti[1,2], Eduardo Bravo[3], Sergio Cristallo[1,2], Inmaculada Domínguez[4], Oscar Straniero[1,5], Amedeo Tornambé[6], and Gabriel Martínez-Pinedo[7,8]

Table 1
URCA Pairs (Lines 1–8) and Double Electron-capture Triplets (Lines 9–10) Considered in the Present Work

Isobars	$\rho_{\rm URCA}$ or $\rho_{\rm 2EC}$ in 10^9 g cm^{-3}	$X_\odot$ [a]	Source
^{19}F–^{19}O	2.43	1.07×10^{-7}	Suzu2016
^{21}Ne–^{21}F	3.78	3.74×10^{-5}	Suzu2016
^{23}Na–^{23}Ne	1.86	1.42×10^{-4}	Suzu2016
^{25}Mg–^{25}Na	1.31	3.84×10^{-5}	Suzu2016
^{27}Al–^{27}Mg	0.104	5.60×10^{-5}	Suzu2016
^{31}P–^{31}Si	1.09	6.68×10^{-6}	Oda1994
^{37}Cl–^{37}S	2.19	3.03×10^{-6}	Oda1994
^{39}K–^{39}Ar	0.012	3.39×10^{-6}	Oda1994
^{32}S–^{32}P–^{32}Si	0.144	3.14×10^{-4}	Oda1994
^{56}Fe–^{56}Mn–^{56}Cr	1.27	1.05×10^{-3}	Lang2001

Note. Suzu2016 : Suzuki et al. (2016), Oda1994 : Oda et al. (1994), Lang2001: Langanke & Martínez-Pinedo (2001).
[a] Mass fraction abundance of the β-stable isotope in the initial ZSUN model.

The Urca density of ^{31}P and ^{31}Si



Conclusions

TECHNISCHE UNIVERSITÄT DARMSTADT

- Urca processes are important for the evolution of degenerate stellar cores
- Rates are typically determined by few transitions — analytic determination of the rates
- Accounting for initial composition of the star (metalicity) allows for additional Urca pairs that are currently being investigated
- Second forbidden transition from ^{20}Ne needs to be computed