Reaction rate uncertainties and NeNa/MgAl in AGB stars

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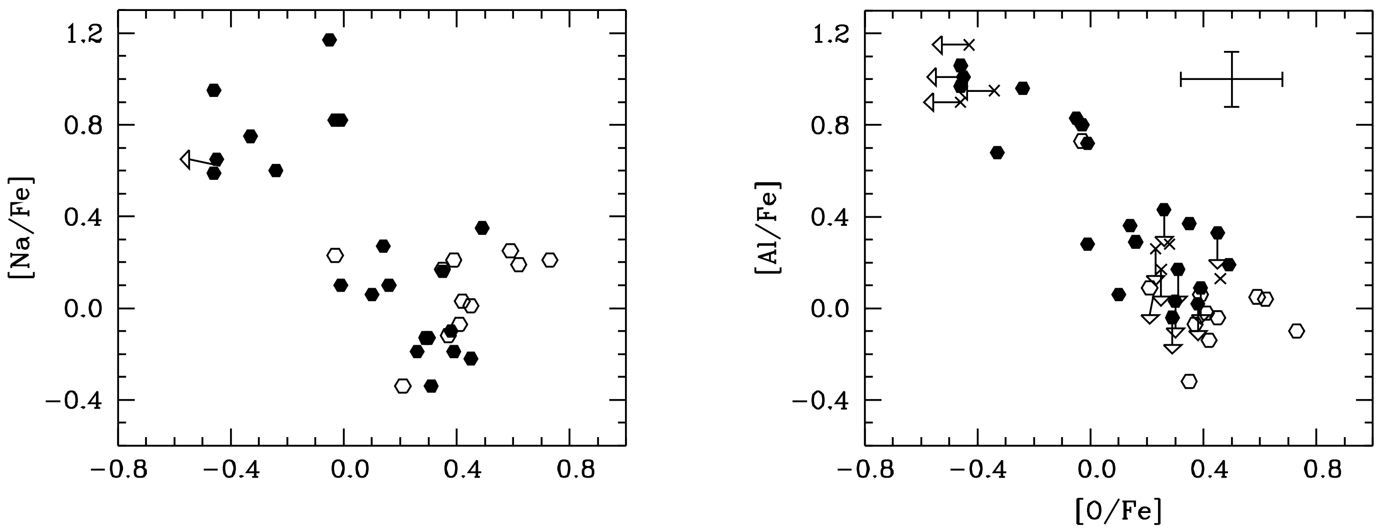
Importance of Ne,Na,Mg and Al

- Globular cluster stars show anomalies e.g. Na and Al vs O anticorrelation, H-burning source is unknown (AGB?)

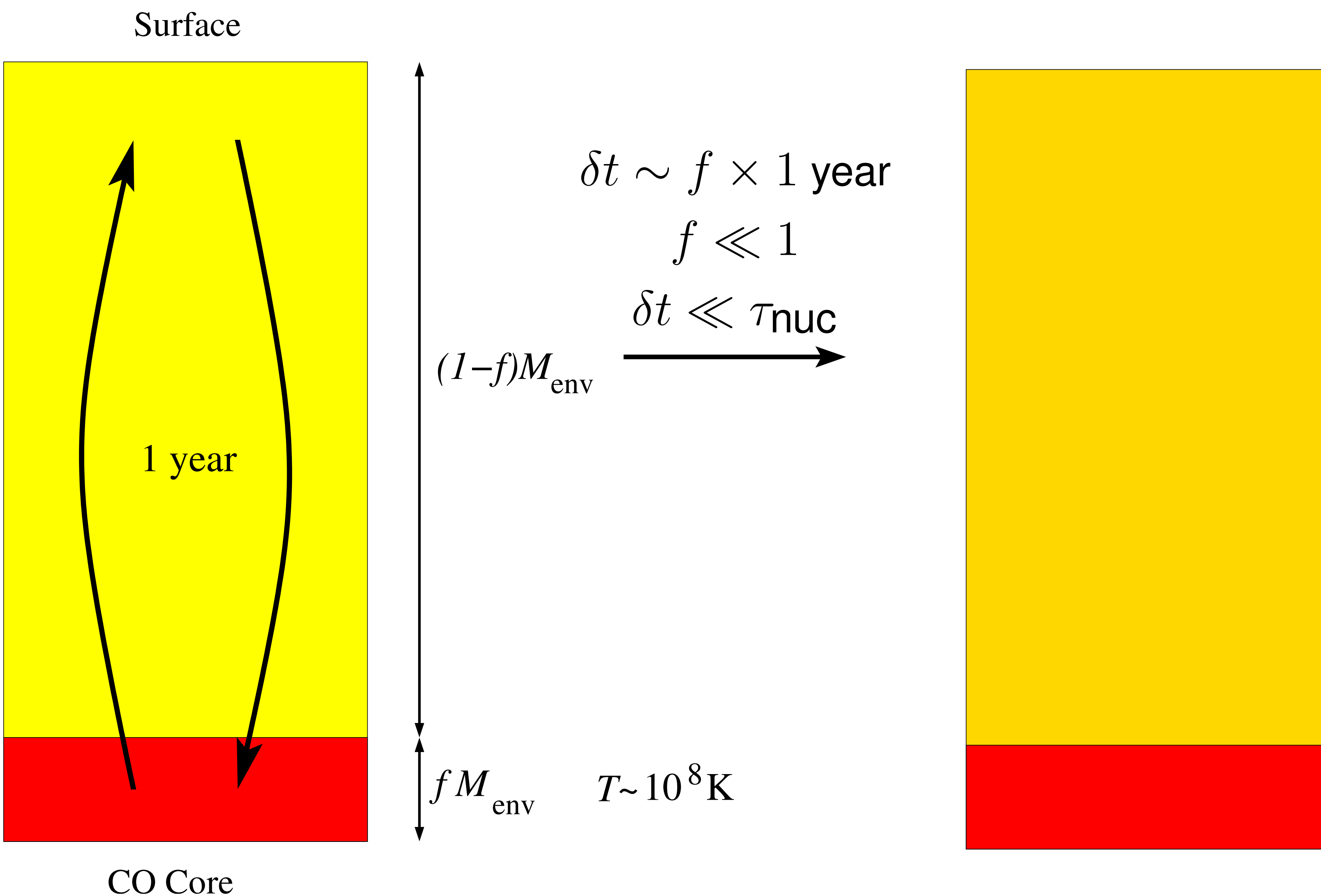


- The observed apparent variation of the fine structure constant deduced from quasar absorption lines at redshift < 2 depends on the abundance of the Mg isotopes
- Galactic chemical evolution studies require chemical yields of Ne-Al from AGB stars

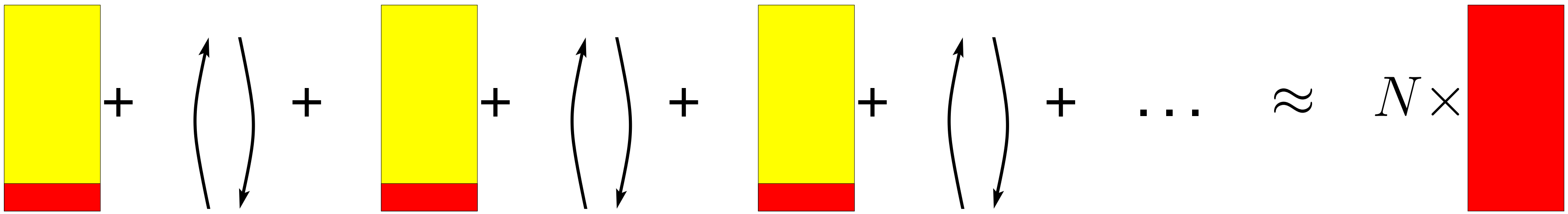
AGB stars

- Final nuclear phase of most stars ($M \lesssim 7-8\,\mathsf{M}_\odot$)
- Twin H- and He shell-burning over a CO core
- Convective envelope ($\tau_{\mathsf{conv}} \sim 1\,\mathsf{yr}$), cool surface
- Thermal pulses, dredge-up, He-burnt products (C,O,Ne,Mg) in envelope
- Mass-loss limits lifetime to 1-few Myr
- If $M \gtrsim 4-5\,\mathsf{M}_\odot$ H burning is *inside* the convective envelope
- CNO, NeNa and MgAl burning cycles up to $\log_{10} T \sim 8$
- Result: C,O→N, Ne→Na, Mg→Al

Our Model

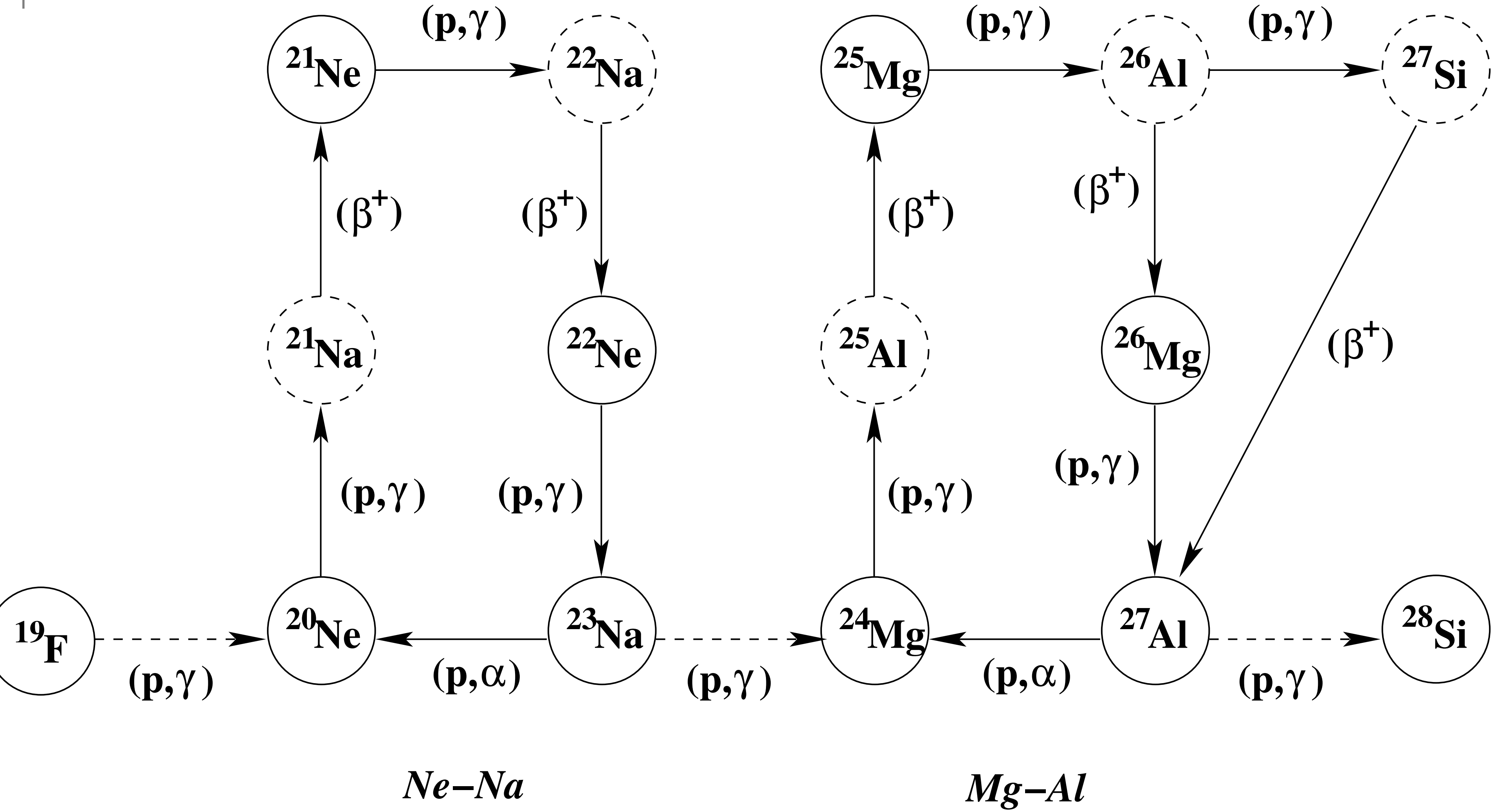

Surface
1 year
CO Core
(1−f)M_env
f M_env
T~10^8 K
δt ∼ f × 1 year
f ≪ 1
δt ≪ τnuc

Our Model



- N, T etc. from full stellar evolution models (Karakas/Lattanzio 2002,3,4,5. . .)
- Simple nuclear burning network for CNO, NeNa and MgAl
- Assume structure depends on (fixed) CNO rates, *not* NeNaMgAl
- Vary NeNa and MgAl reaction rates . . .

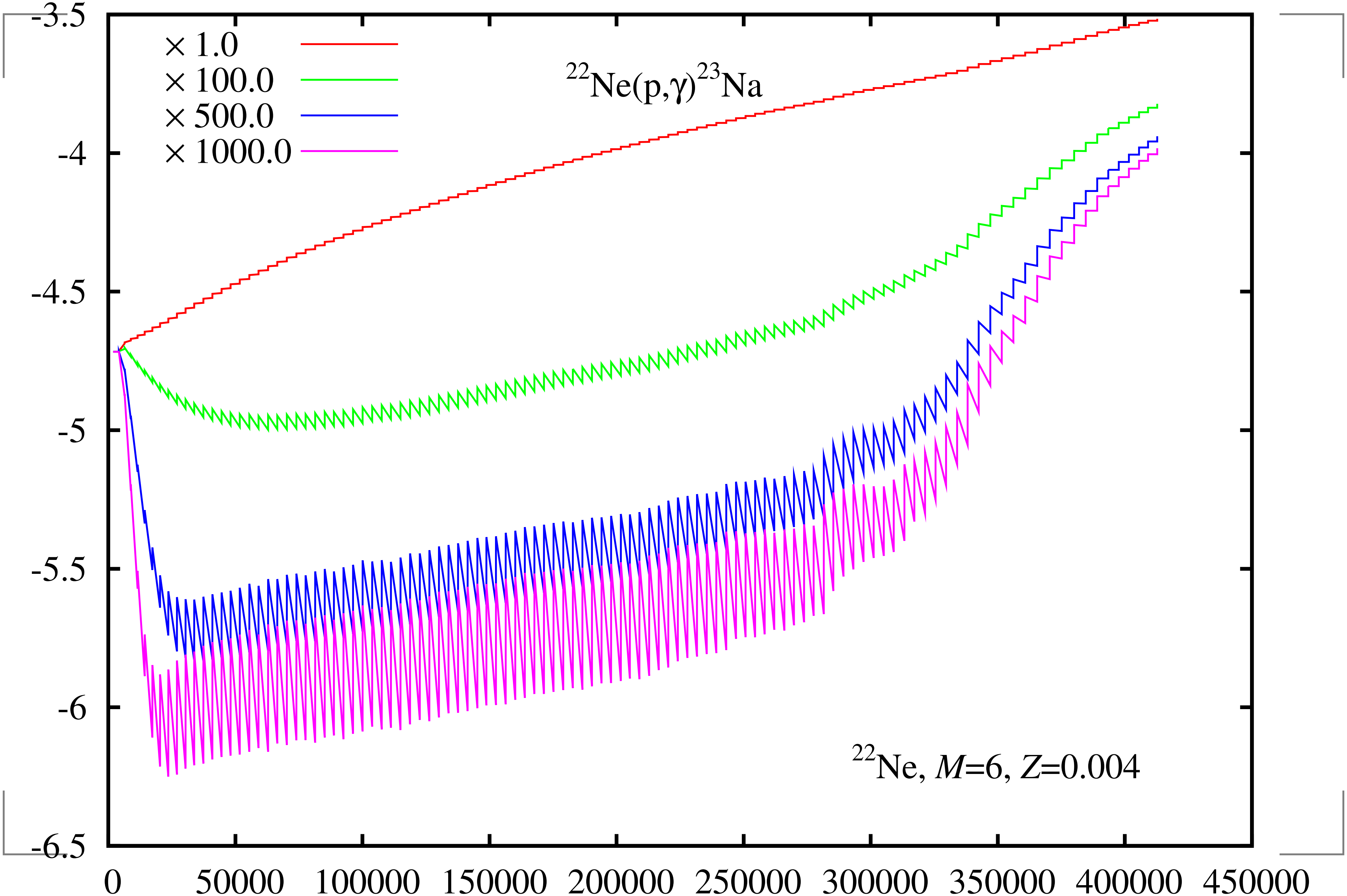
Reaction Chain



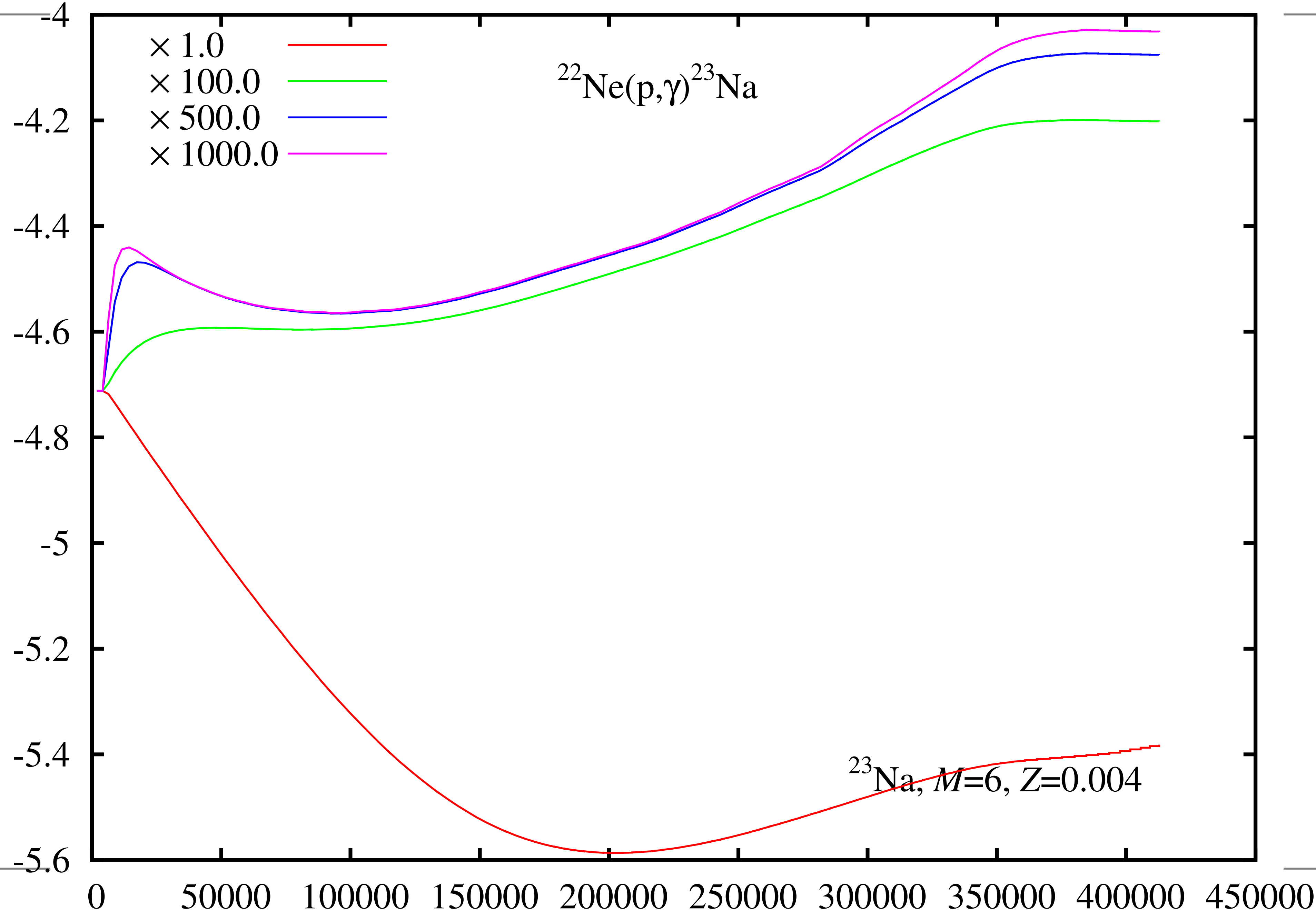
Rate Uncertainties around $T \sim 10^{7.7-8}$K

^{20}Ne$(p,\gamma)^{21}$Na$(\beta^+)^{21}$Ne	-50%	$+50\%$	NACRE
^{21}Ne$(p,\gamma)^{22}$Na$(\beta^+)^{22}$Ne	-25%	$+25\%$	Iliadis et al. 2001
^{22}Ne$(p,\gamma)^{23}$Na	-50%	$\times 2000$	Hale et al. 2001
^{23}Na$(p,\alpha)^{20}$Ne	-30%	$+30\%$	Rowland et al. 2004
^{23}Na$(p,\gamma)^{24}$Mg	$/40$	$\times 10$	Rowland et al. 2004
^{24}Mg$(p,\gamma)^{25}$Al$(\beta^+)^{25}$Mg	-20%	$+20\%$	Powell et al. 1999
^{25}Mg$(p,\gamma)^{26}$Al$(\beta^+)^{26}$Mg	-50%	$\times 1.5$	Iliadis et al. 2001
^{26}Mg$(p,\gamma)^{27}$Al	$/4$	$\times 10$	Iliadis et al. 2001
^{26}Mg$(p,\gamma)^{27}$Al	-25%	$\times 3$	Iliadis et al. 2001
^{26}Al$(p,\gamma)^{27}$Si	$/3$	$\times 300$	Vogelaar et al. 2001

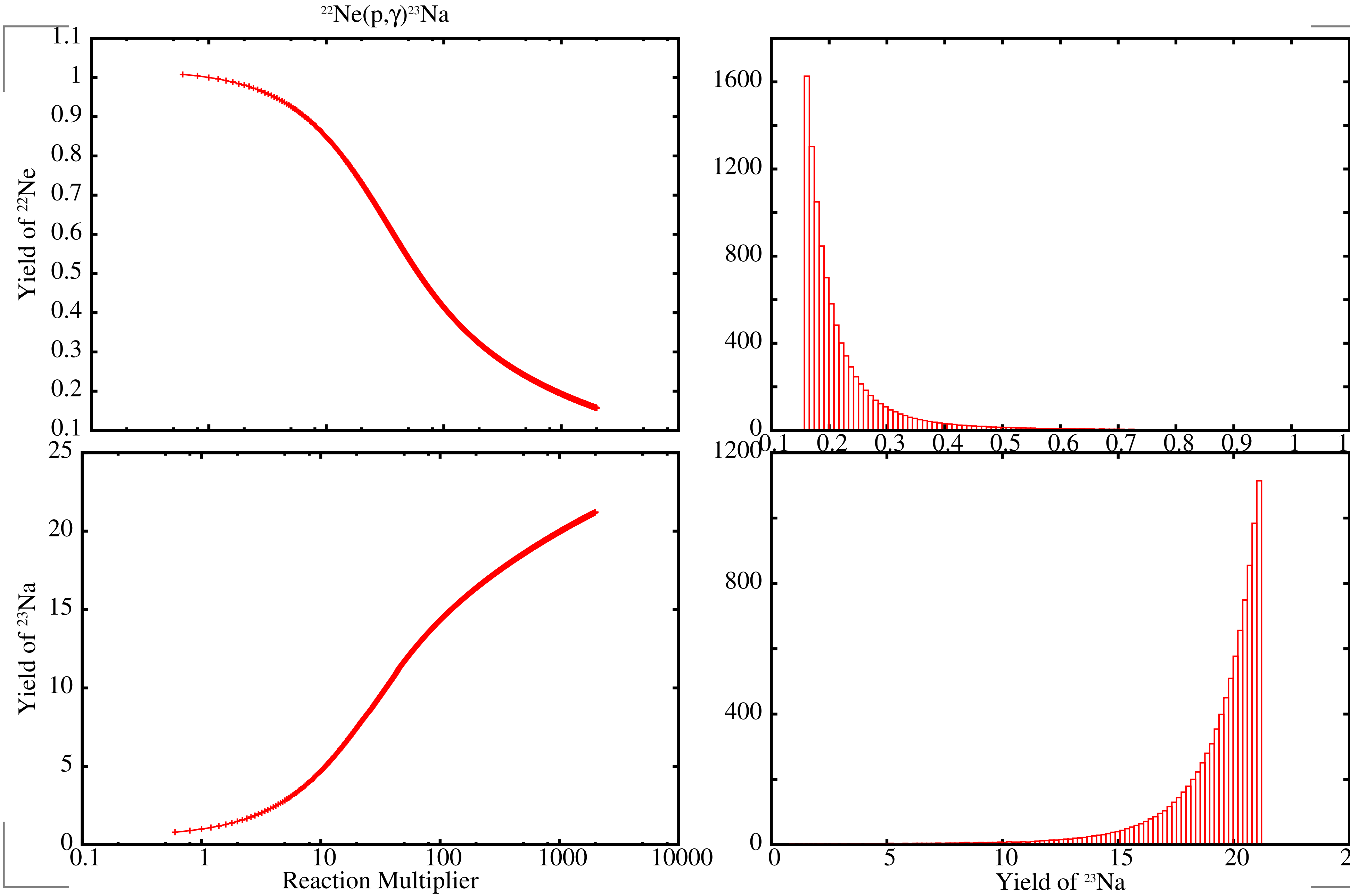
Effect on surface abundances



Effect on surface abundances

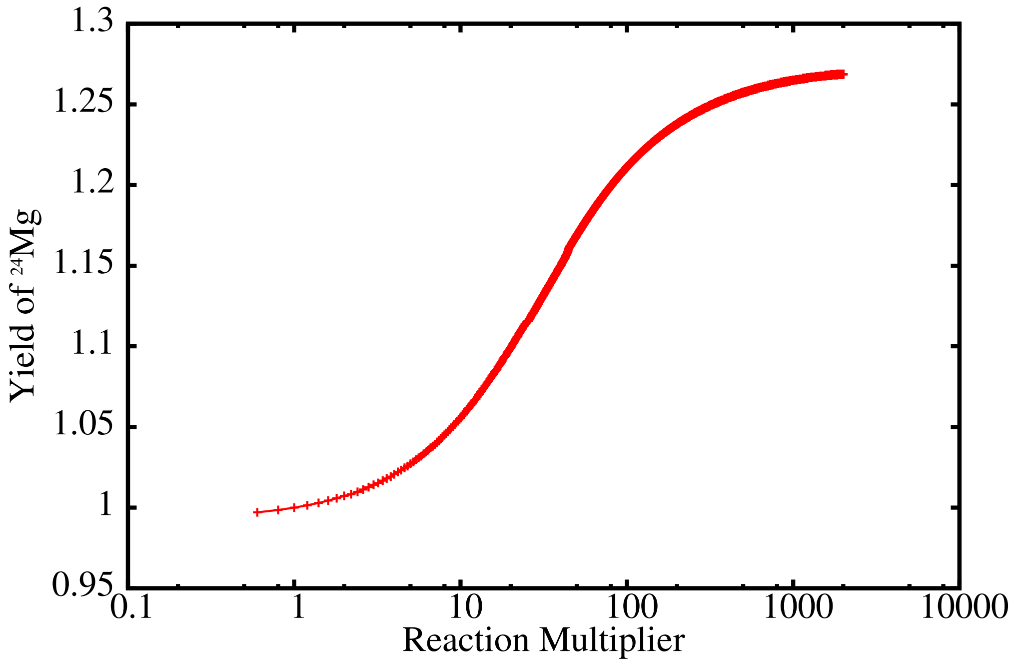


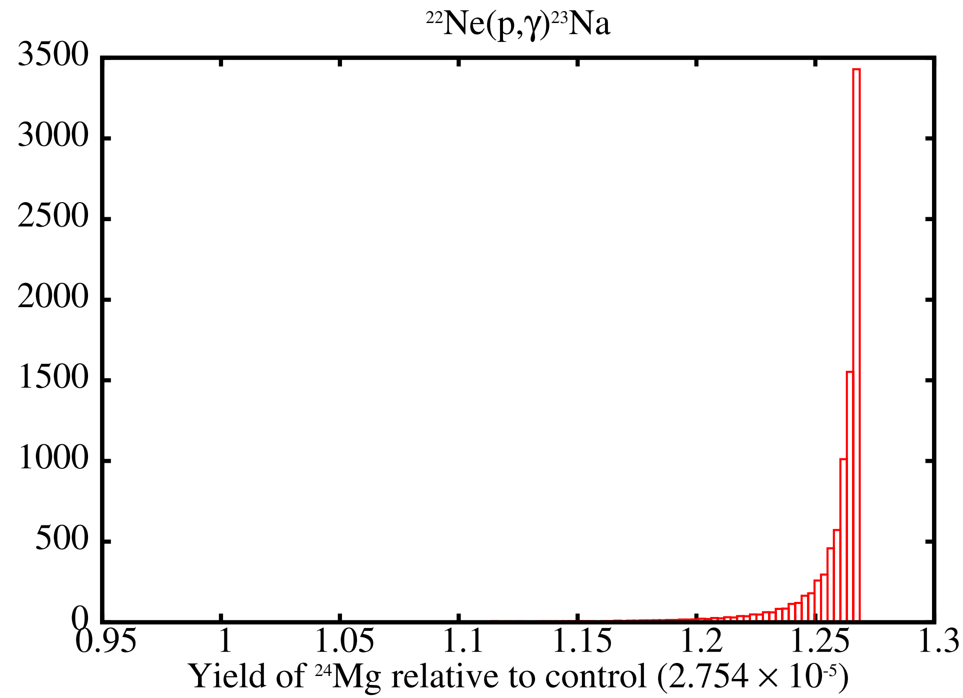
Effect on chemical yields



Effect on chemical yields

- ^{22}Ne$(p,\gamma)^{23}$Na affects ^{24}Mg yield via ^{23}Na$(p,\gamma)^{24}$Mg:





% yield difference from control

	$M = 5$	$M = 6$	$M = 5$	$M = 6$
	$Z = 0.02$	$Z = 0.02$	$Z = 0.004$	$Z = 0.004$
^{20}Ne	< 1	< 1	$+20$ -4	$+19$ -3
^{21}Ne	$+8$ -10	$+8$ -6	$+5$ -4	$+12$ -3
^{22}Ne	$+0$ -22	$+0$ -68	$+0$ -80	$+2$ -85
^{23}Na	$+170$ -0	$+520$ -1	$+3000$ -7	$+2200$ -11
^{24}Mg	< 1	< 1	$+55$ -7	$+250$ -20
^{25}Mg	< 1	$+2$ -2	$+6$ -6	$+13$ -11
^{26}Mg	< 1	$+1$ -4	$+2$ -18	$+4$ -25
^{26}Al	$+35$ -35	$+47$ -35	$+42$ -85	$+35$ -95
^{27}Al	< 1	$+12$ -1	$+235$ -1	$+200$ -40

Future plans

- Make full stellar models to reproduce large yield differences
- Reduce Z to 10^{-4}, $\log_{10} T \rightarrow 8.1$!
- Vary all NeNa/MgAl reaction rates at once