Reaction rate uncertainties and NeNa/MgAl in AGB stars

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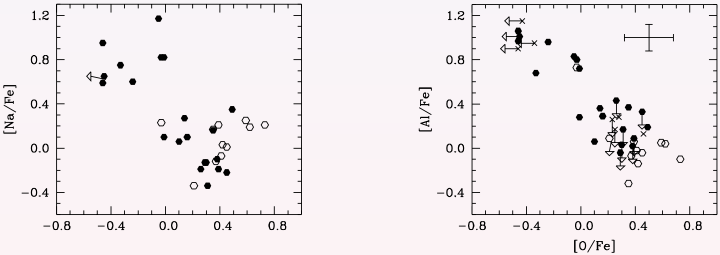
Importance of Ne,Na,Mg and Al

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

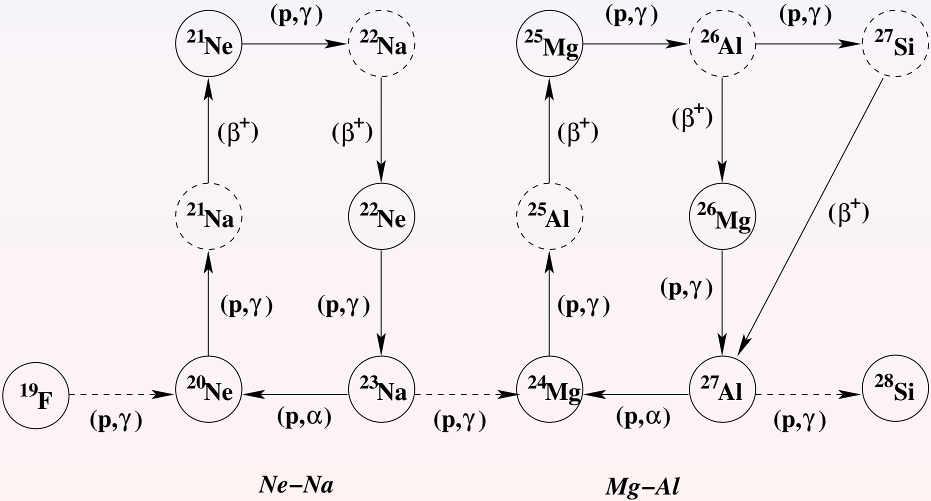


- The apparent variation of the fine structure constant from quasar absorption lines at redshift < 2 depends on the abundance of the Mg isotopes
- Galactic chemical evolution studies require chemical yields of Ne-Al from AGB stars

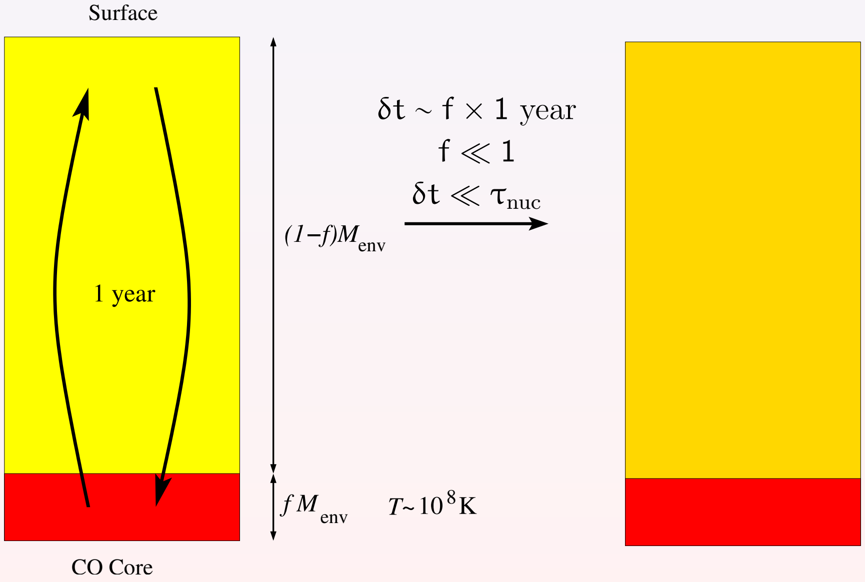
AGB stars

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

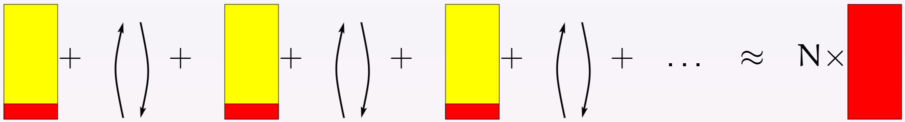
Reaction Chain



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 ≪ τ_nuc

Our Model

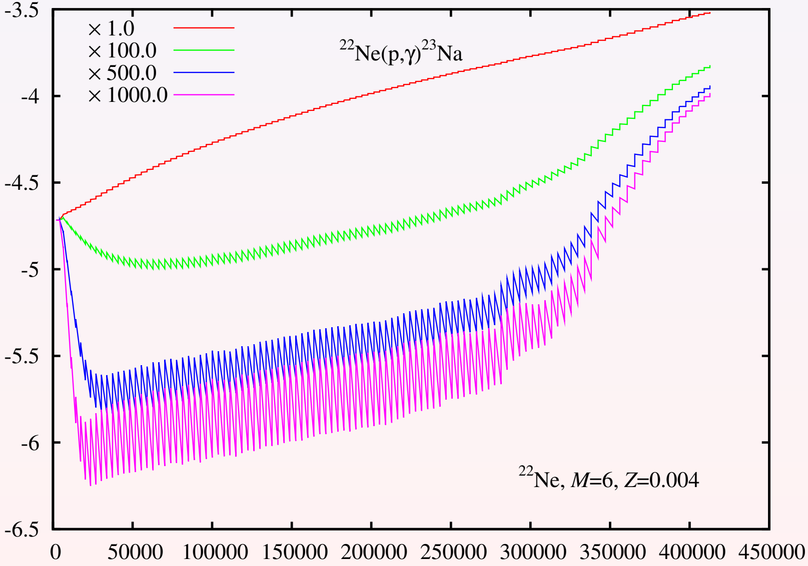


- N, T etc. from full stellar evolution models (Karakas/Lattanzio 2002-2006…)
- Simple nuclear burning network for CNO, NeNa and MgAl
- Assume structure depends on (fixed) CNO rates, *not* NeNaMgAl
- Vary NeNa and MgAl reaction rates …
- $4 \leqslant M/M_\odot \leqslant 6$, $10^{-4} \leqslant Z \leqslant 0.02$

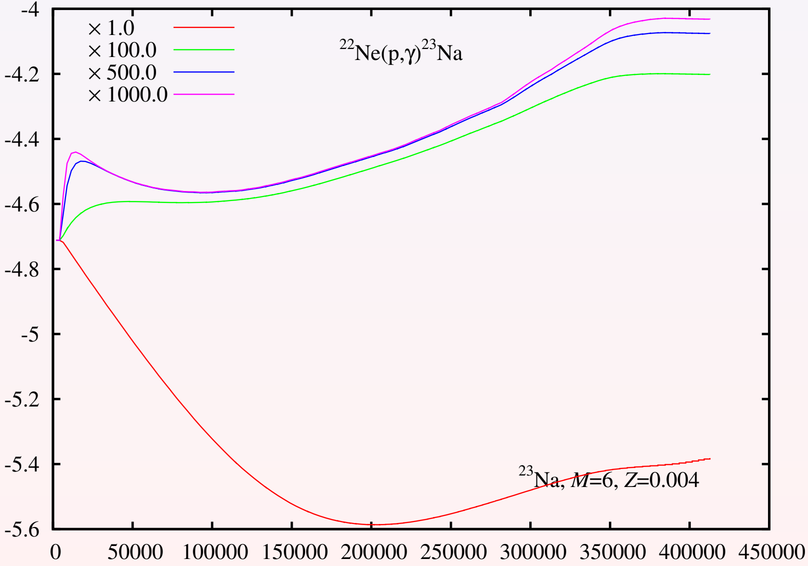
Rate Uncertainties : $\log_{10} T/K \sim 7.8$

$^{20}Ne(p,\gamma)^{21}Na(\beta^+)^{21}Ne$	-50%	$+50\%$	NACRE
$^{21}Ne(p,\gamma)^{22}Na(\beta^+)^{22}Ne$	-20%	$+20\%$	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
$^{24}Mg(p,\gamma)^{25}Al(\beta^+)^{25}Mg$	-17%	$+20\%$	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
$^{26}Al(p,\gamma)^{27}Si$	$/2$	$\times 600$	Iliadis et al. 2001

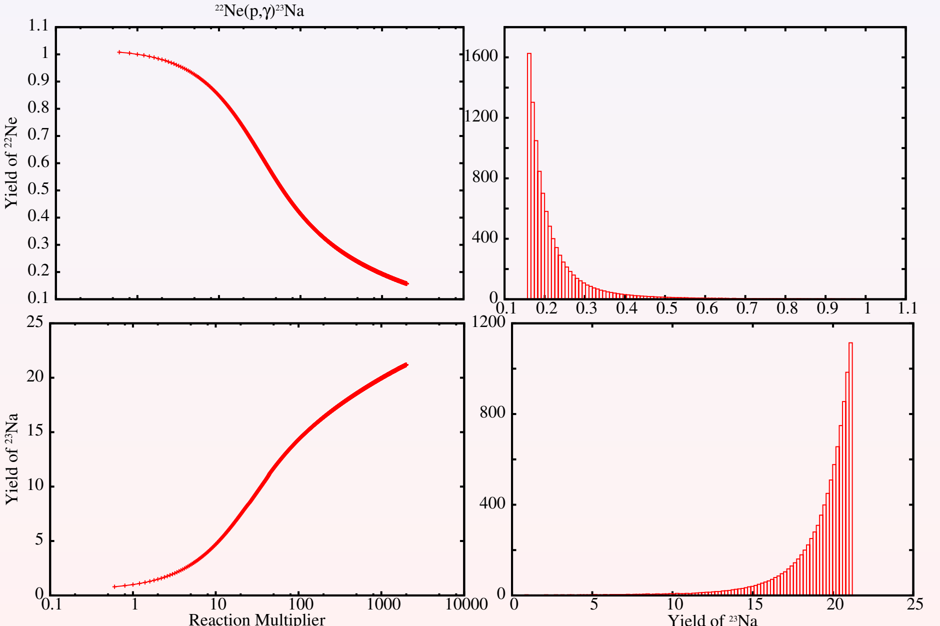
Effect on surface abundances



Effect on surface abundances

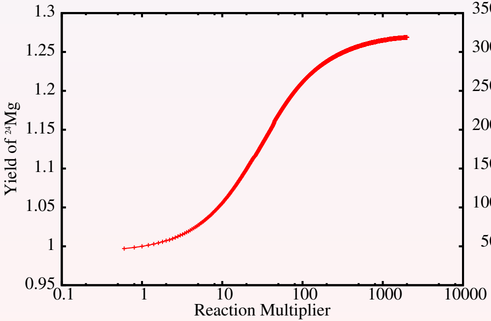


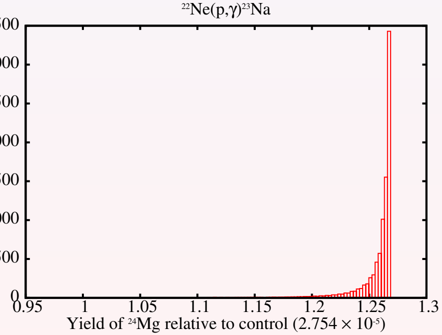
Effect on chemical yields: $^{22}Ne(p,\gamma)^{23}Na$



Effect on chemical yields

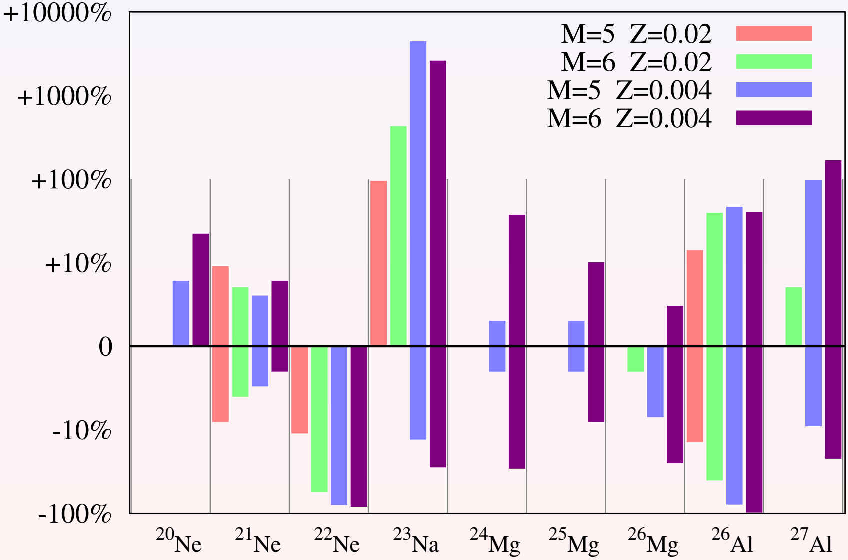
- $^{22}\mathrm{Ne}(p,\gamma)^{23}\mathrm{Na}$ affects $^{24}\mathrm{Mg}$ yield via $^{23}\mathrm{Na}(p,\gamma)^{24}\mathrm{Mg}$:





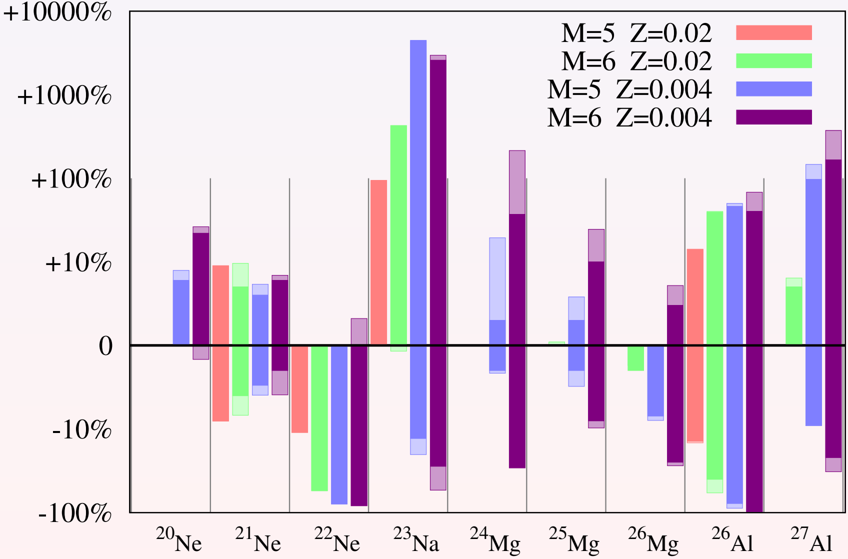
Yield difference from control

Each reaction separately...



Yield difference from control

. . . or all reactions varied together. . .



Conclusions and Plans

- Some AGB yields vary by large amounts, especially ^{23}Na
- Most vary by less, but $\times 2$ in Mg isotopes still important for $\Delta\alpha/\alpha$ studies
- As Z drops or M increases, things (generally) get worse
- Should consider previous reactions (e.g. ^{22}Ne(p, γ) effect on magnesium production)
- Check effect in Galactic Chemical Evolution models ... constraints?
- Make full stellar models to check large differences