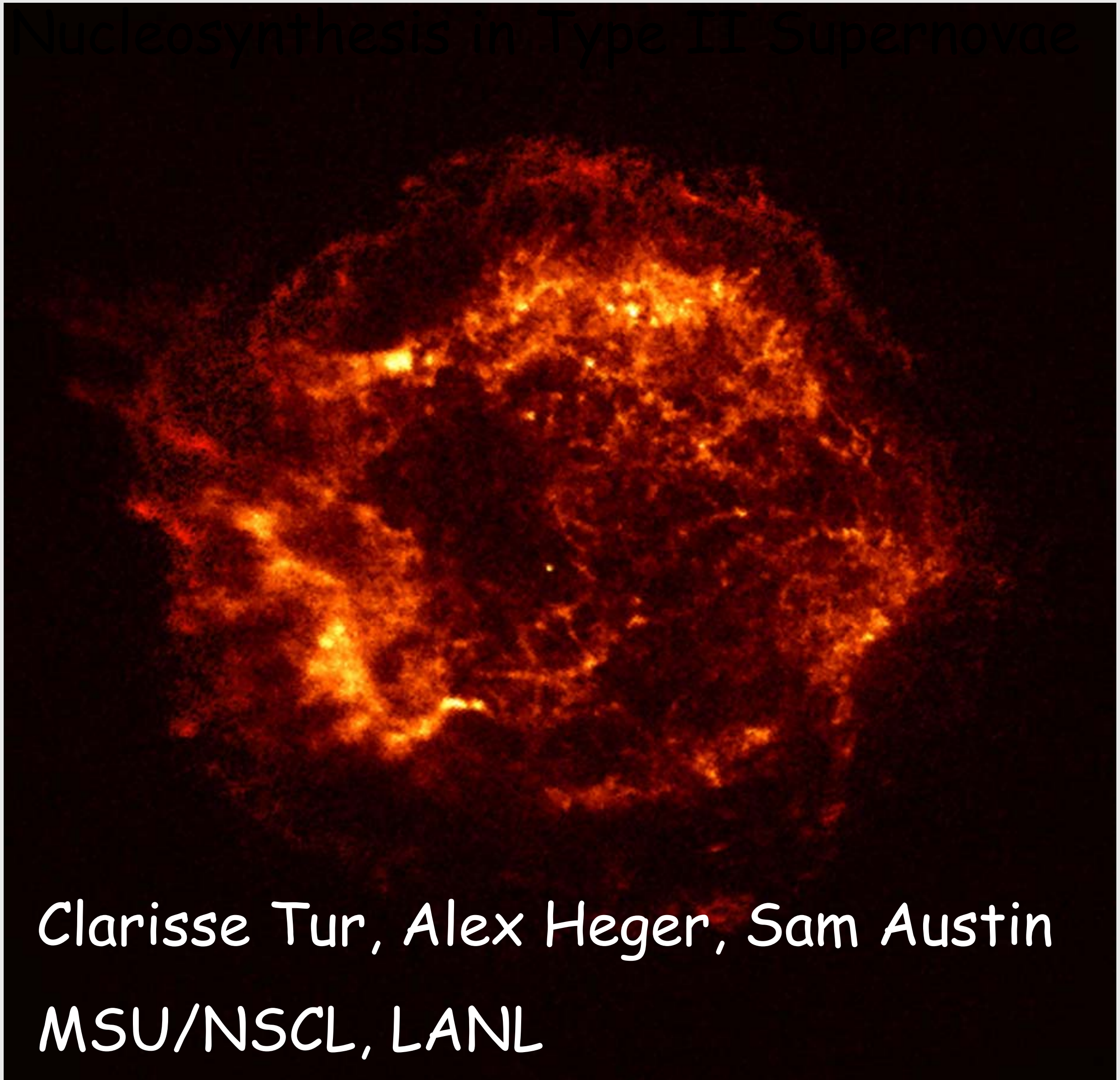
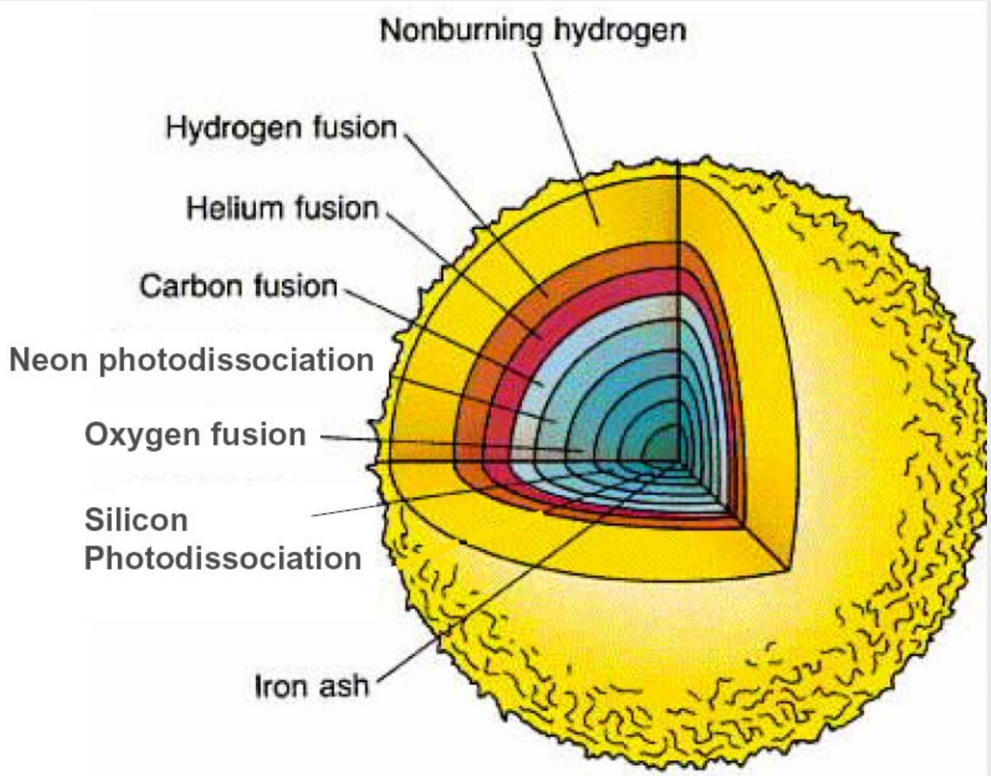
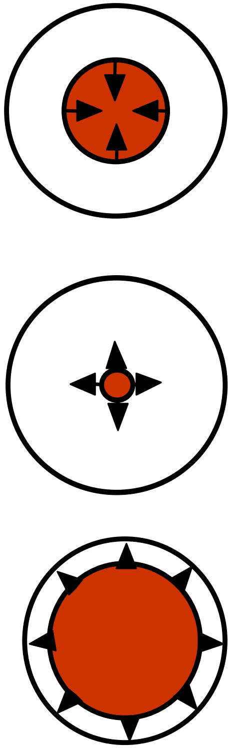
# Evolution and Nucleosynthesis in SN II



# A Reminder of the Phenomena




Massive star evolves to a layered structure with "Fe" core.

No further energy source. E-capture and $\nu$ emission reduce supporting pressure

Core Collapse

Supernova-SNII

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# Evolution of SNII

GOALS: Find dependence (1-D) of predicted nucleosynthesis, carbon fraction and remnant mass on

Rates of helium burning reactions $3\alpha$ and $^{12}C(\alpha,\gamma)^{16}O$
Assumed cosmic (solar) abundances

Can predicted nucleosynthesis fix reaction rates?

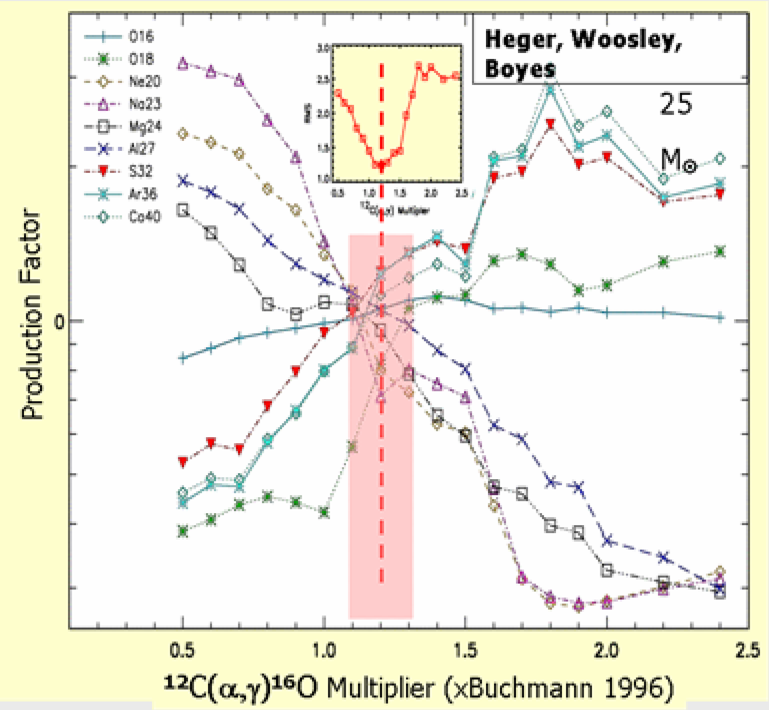
An earlier calculation:

$15 + 20 + 25\ M_{sun}$

Anders & Grevasse (1989) abundances

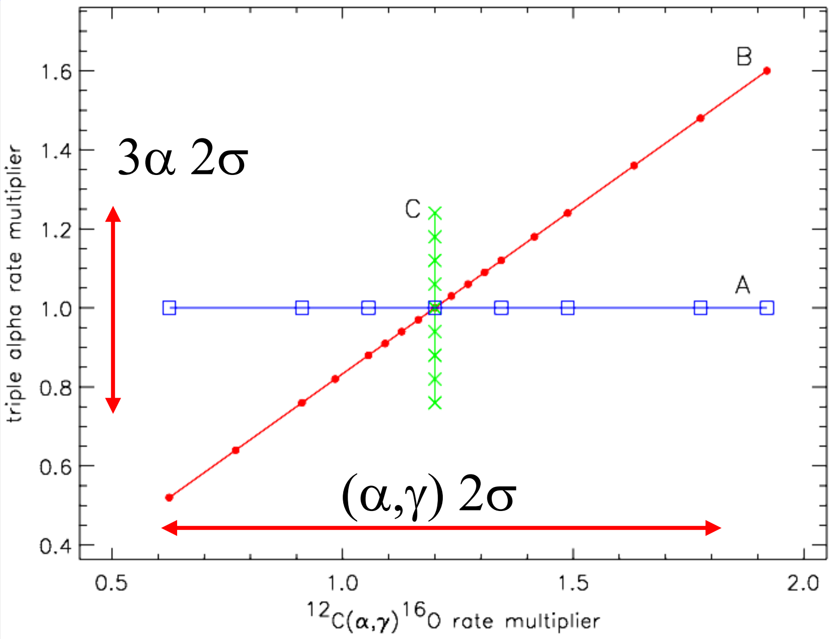
Concluded: $^{12}C(\alpha,\gamma)^{16}O$ rate must be known to 10%

**No explosive processing**



# Goals of calculations

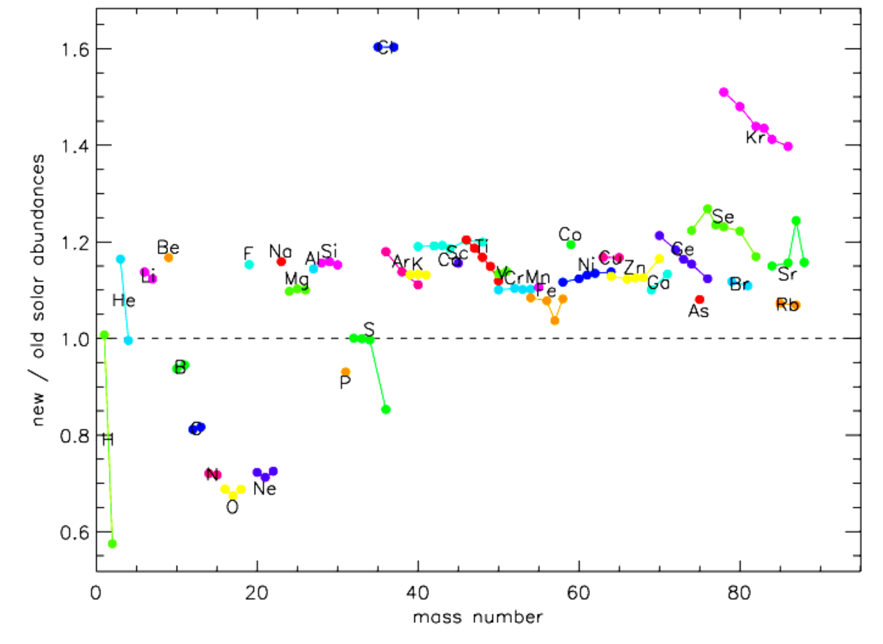
Examine effects of varying $3\alpha$ and $^{12}C(\alpha,\gamma)^{16}O$ rates over a broad range, separately and together




Compare results for abundances of

Anders-Grevesse (89)

Lodders (03)

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# Some Details of Calculations

KEPLER code, evolved stars to core-collapse, then explosion,

Calculate 15, 20 and 25 $M_{sun}$ stars, all rate, abundance choices

Do 13, 17, 19, 21, 23 and 27 $M_{sun}$ stars (Anders-Grevesse, varying $^{12}C(\alpha,\gamma)^{16}O$) as check case.

Explosion parameterized by a piston located at the base of the oxygen shell

Explosion energy 1.2 B (1 Bethe = $10^{51}$ ergs).

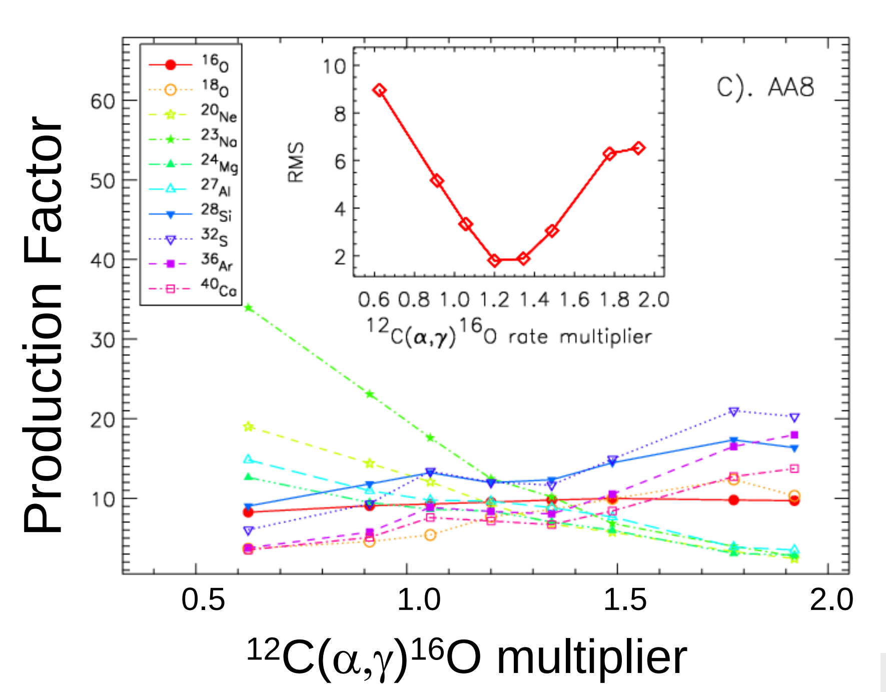
No rotation or magnetic fields.

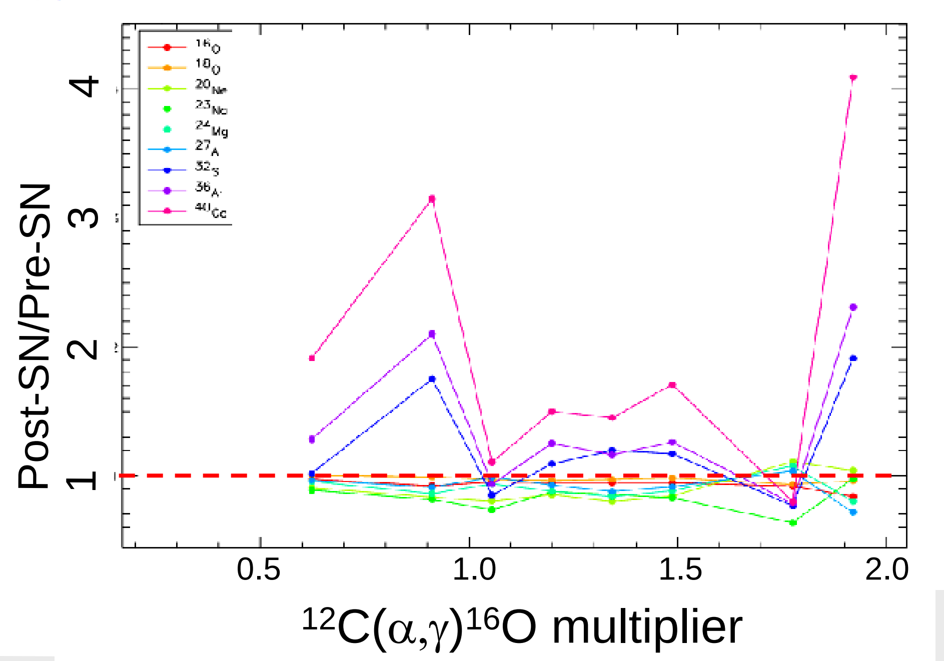
Small network to provide approximate energy generation, larger "adaptive" network to track nucleosynthesis.

# Results

Check with results of Boyes, et al. AG rates, large star set

Reasonable agreement in minimum (1.2 vs 1.3) and rms scatter at minimum




Somewhat surprising, since explosion changes abundances by >x2 for A>30

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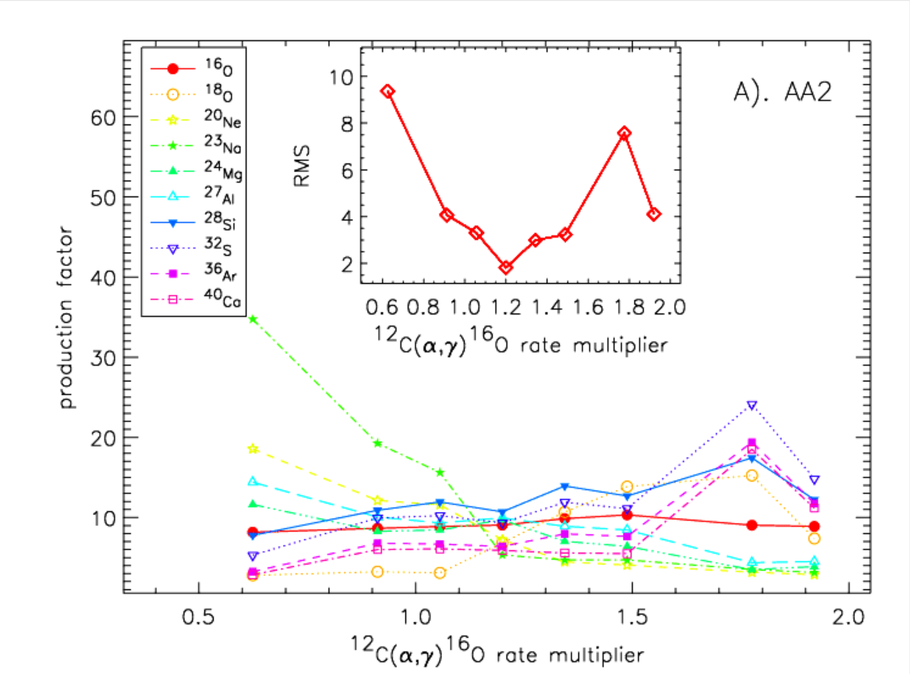
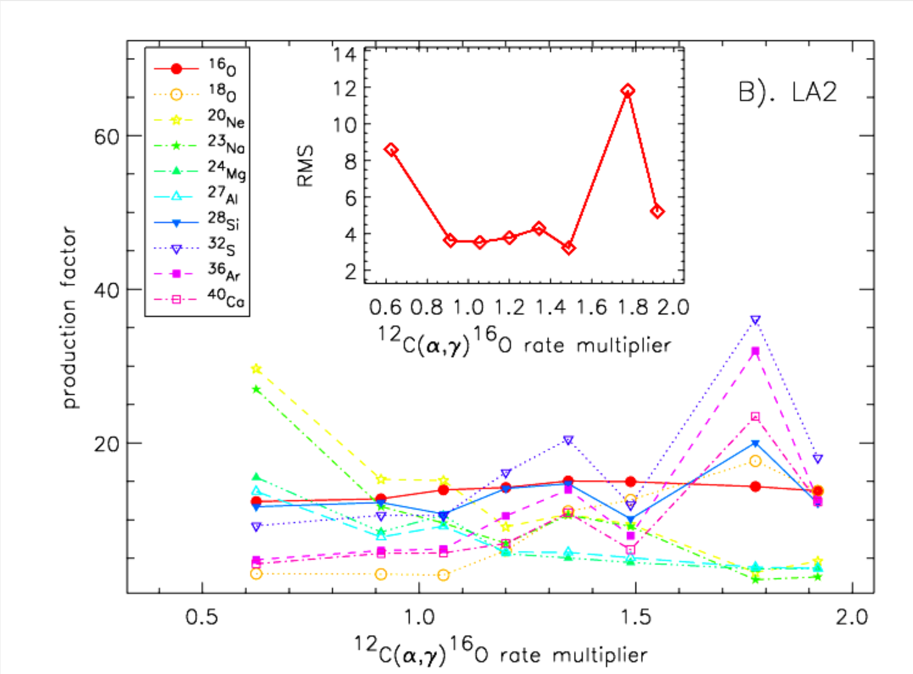
# Synthesis of medium weight elements (15 + 25 $M_{sun}$)



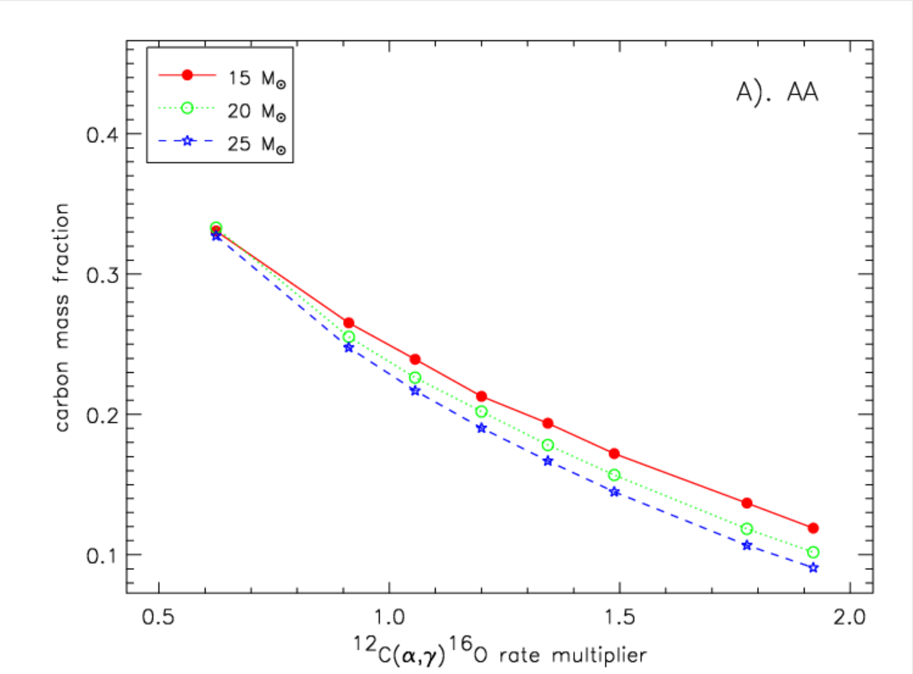

<u>Anders-Grevesse 1989</u> <u>Lodders 2003</u>

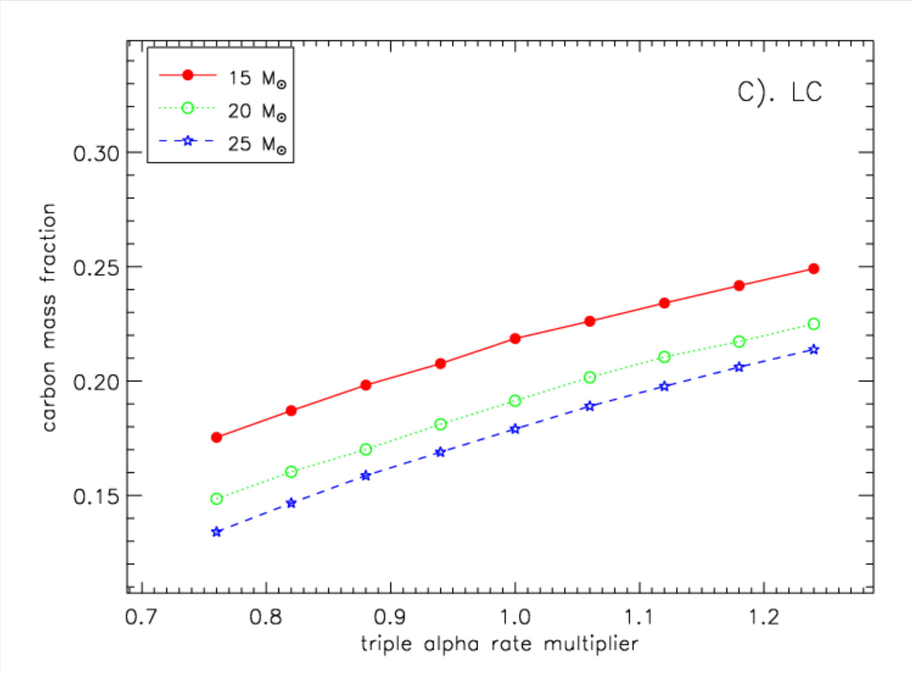
Minimum less well defined for Lodders

Spread in production factor is larger

Cannot use results to pinpoint the reaction rate

# Central Carbon Mass Fraction at C Ignition




Vary $^{12}C(\alpha,\gamma)^{16}O$ Rate — Vary Triple Alpha Rate

C fraction is larger for smaller stars

Large variations over two sigma range

Increase of 10% in $R_{3\alpha}$ same effect as 8% decrease in $R_{\alpha,12}$

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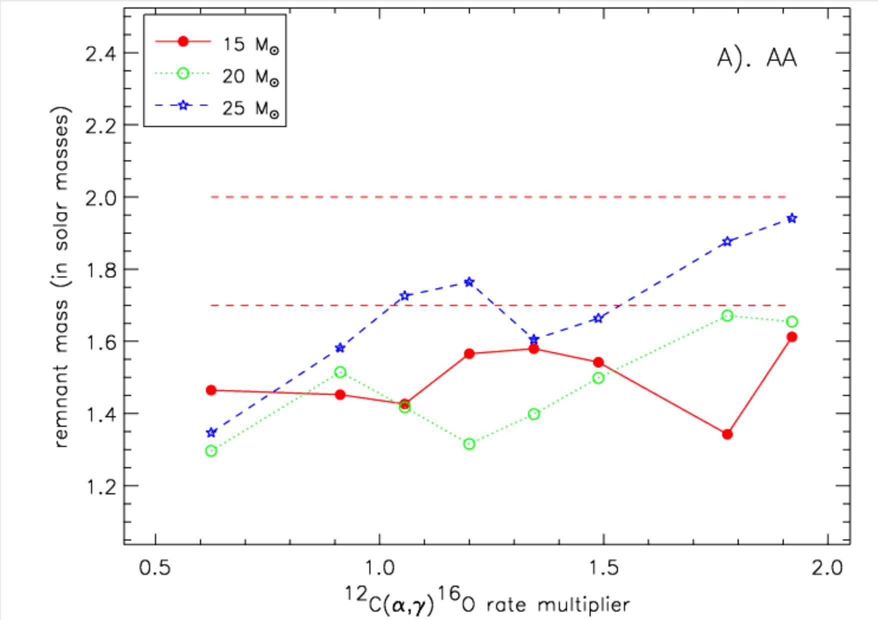
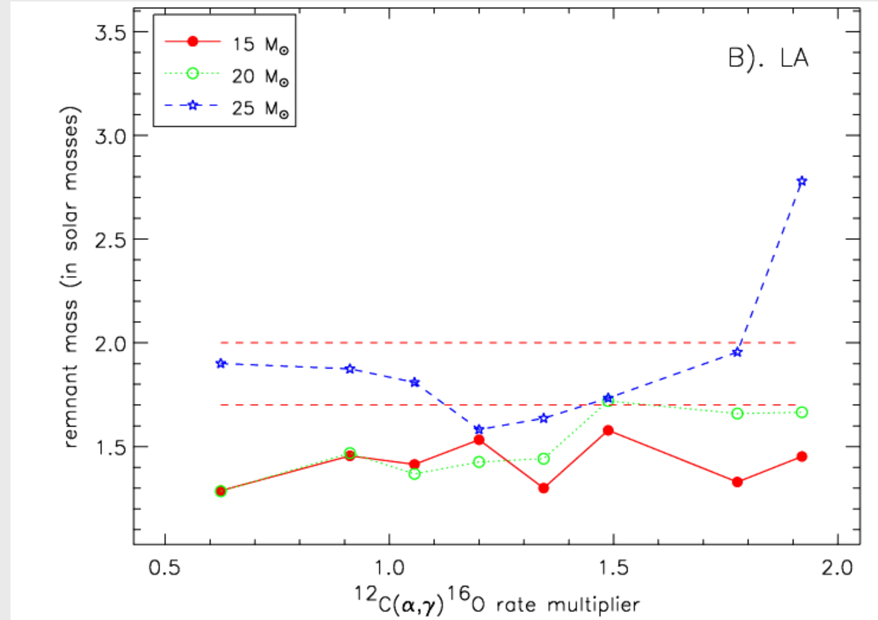
# Remnant Masses--Vary $^{12}C(\alpha,\gamma)^{16}O$ Rate



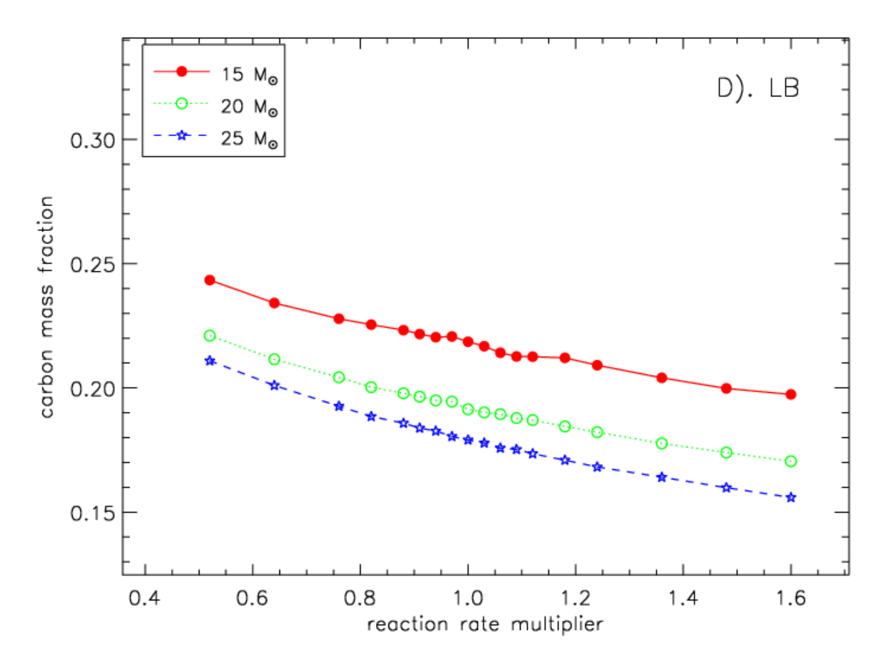

<u>Anders-Grevesse 1989</u> <u>Lodders 2003</u>

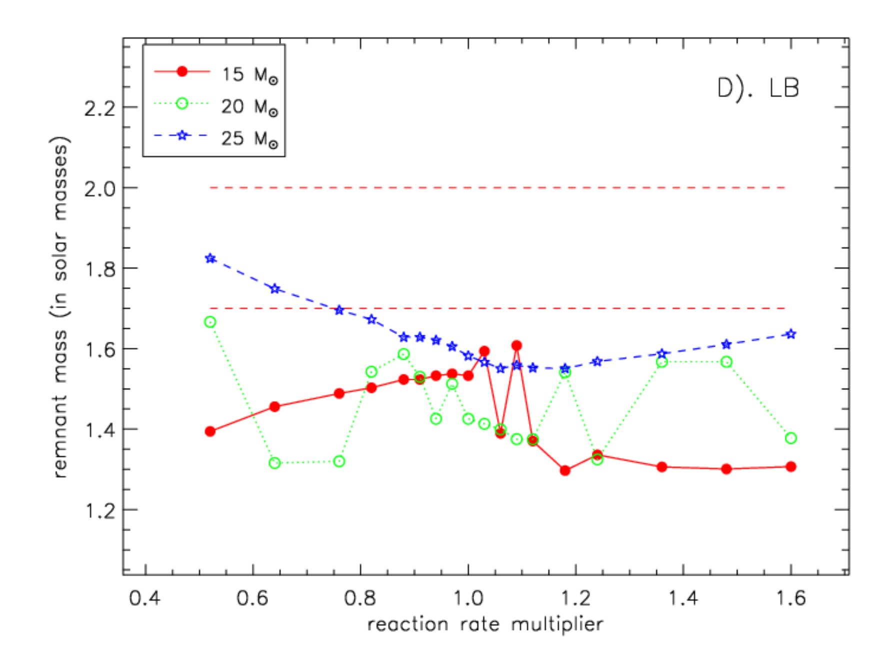
Large variations for different abundances, reaction rates

For reference, takes about $10^{51}$ ergs to dissociate 0.1 $M_{sun}$

Variations seen here might affect possibility of an explosion

# Vary 3α and $^{12}C(\alpha,\gamma)^{16}O$ rates with same ratio




Central C fraction

Remnant Mass

It is not only the ratio of rates that is important-one must know both rates independently

Some of rapid variations are likely due to rapid shifts in stellar evolution ( a shell does or doesn't ignite, etc) and to small numerical noise in calculation.

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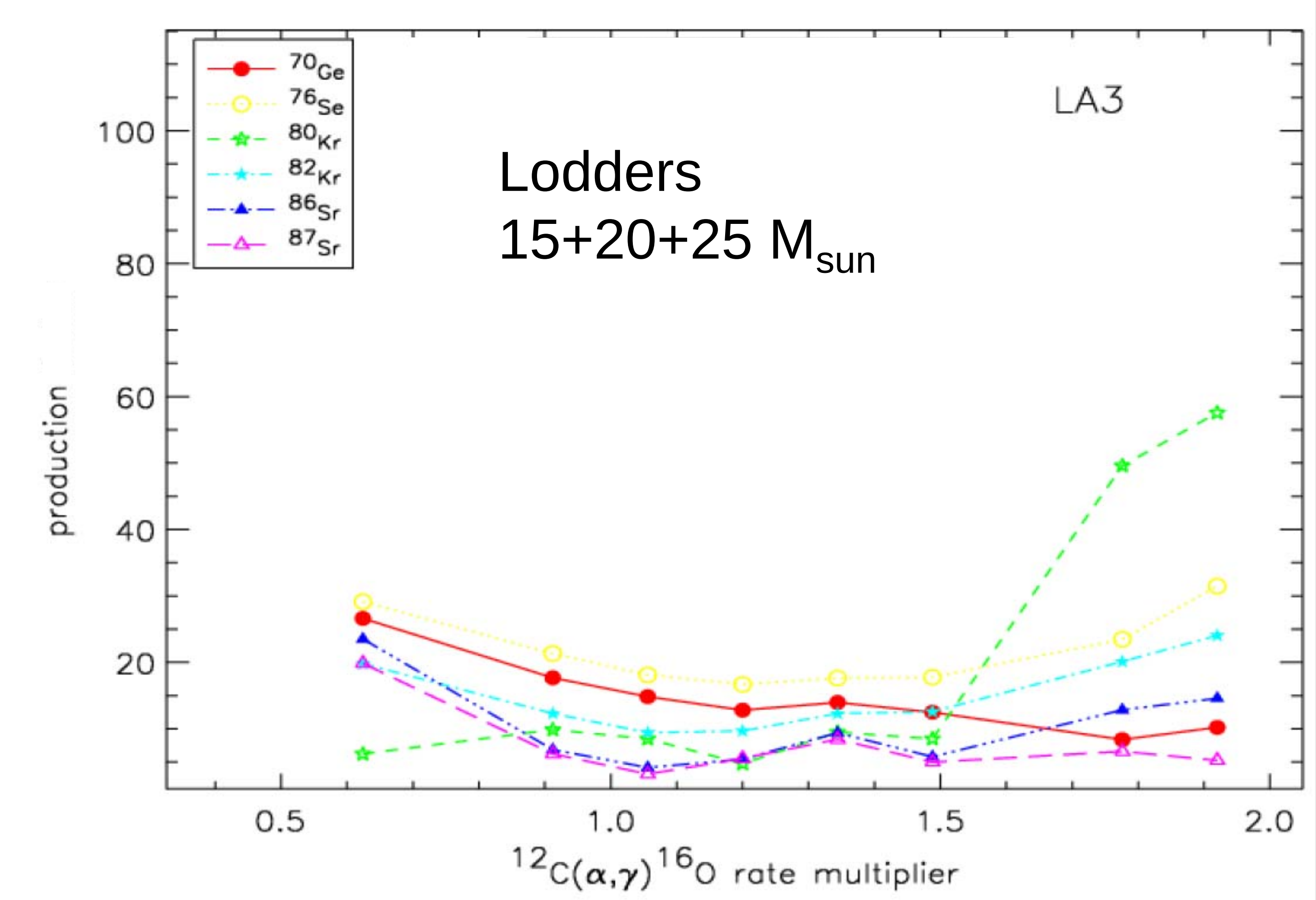
# First look at weak-s-process nuclei

## S-only nuclei, vary $^{12}C(\alpha,\gamma)^{16}O$, 15+20+25 $M_{sun}$



# Comments

- Uncertainties in solar (cosmic) abundances and in helium burning reaction rates cause large uncertainties in stellar properties and nucleosynthesis

- For Lodders abundances, can't constrain $^{12}C(\alpha,\gamma)^{16}O$ reaction rate precisely using SNII simulations

- Remnant masses are uncertain-these could affect success of theoretical SN explosions.

- Uncertainties in $3\alpha$ and $^{12}C(\alpha,\gamma)^{16}O$ rates introduce uncertainties in the weak s-process

- An experiment to better measure the $3\alpha$ rate is under way (MSU/WMU collaboration) at the WMU Tandem. Data has been taken and is under analysis.

# Other Uncertainties

- **Initial Mass Function**--Results not changed in any significant way by substituting a Salpeter IMF (slope of –2.35) to Scalo IMF (slope of –2.6) used here
- **Treatment of hydrodynamics:** convection and boundary layer mixing, such as overshoot and semi-convection
- **Uncertainties in the calculation of mass loss and the effects of a binary companion**
- **Galacto-chemical evolution** Stars of different metallicities contribute to the solar abundance pattern.