Modules for Experiments in Stellar Astrophysics (MESA)

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Ap J Supplements, 192, 3 (2011)

Are you on this Map?

Green=4+
Blue=1-3

MESA Philosophy

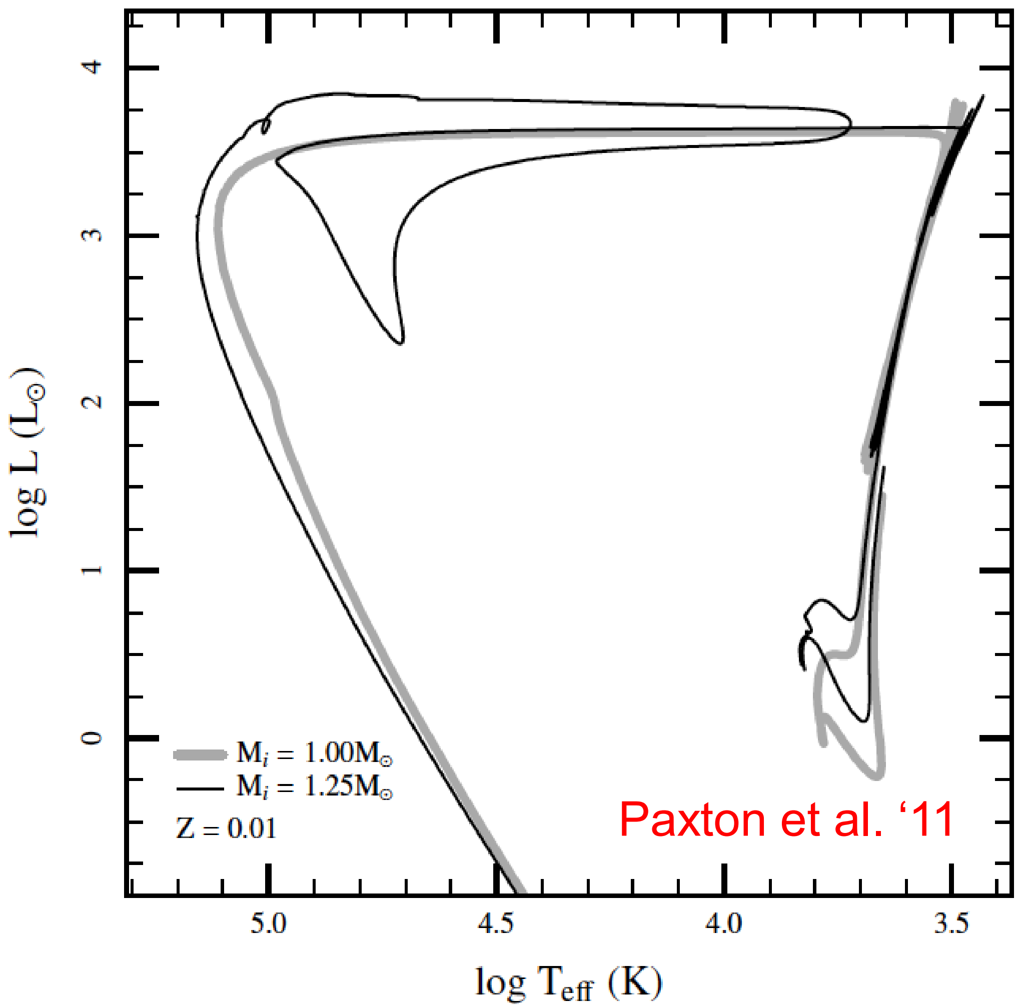
MESA is open source: anyone can download the source code, compile it, and run it for their own research or education purposes.

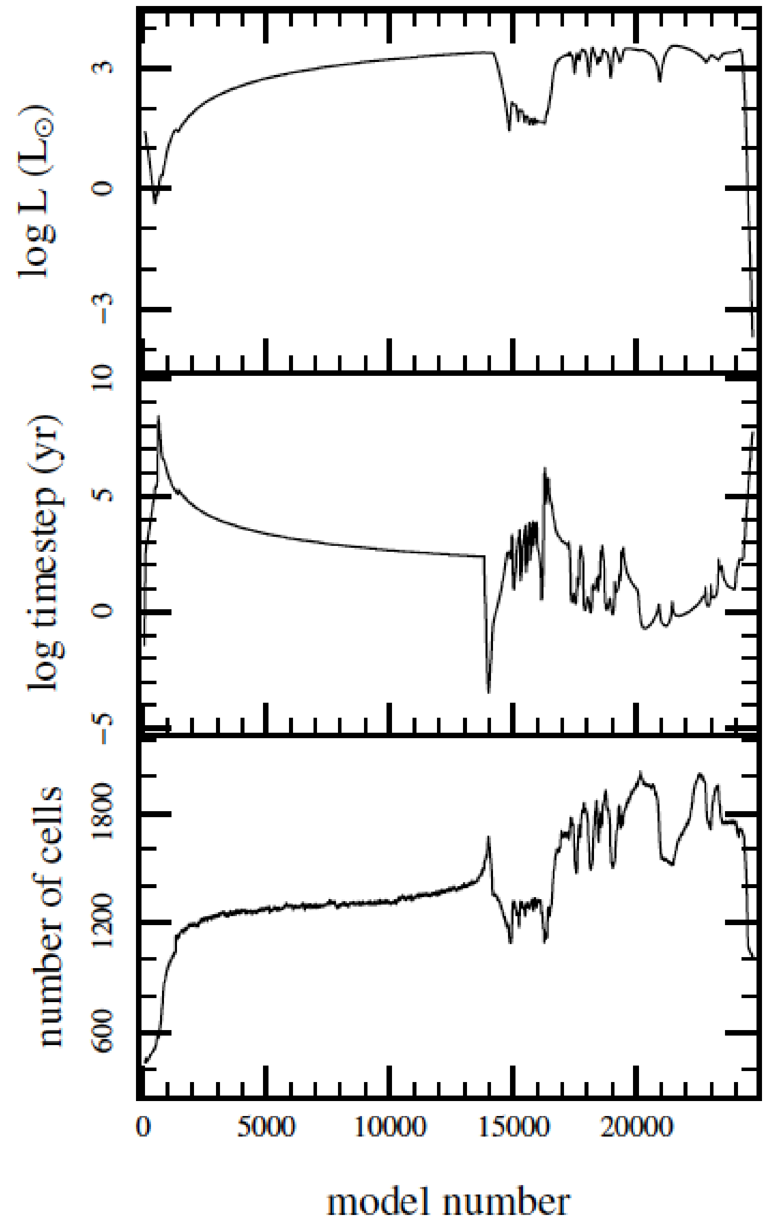
It is meant to engage the broader community of astrophysicists in related fields and encourage contributions in the form of testing, finding and fixing bugs, adding new capabilities, and, sharing experience with the MESA community.

http://mesa.sourceforge.net/

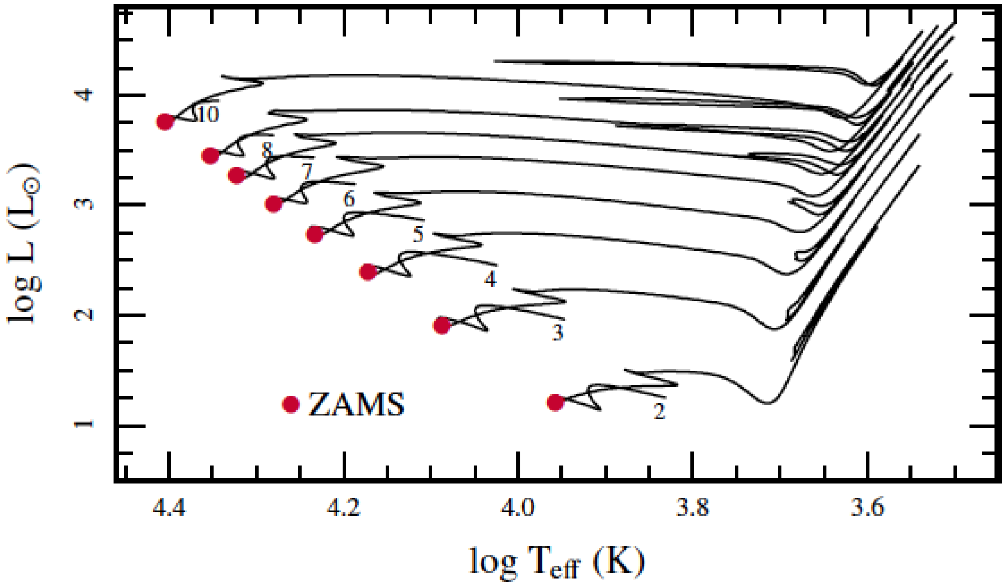
What Can it Do?

Run time=2hr, 22 minutes on mac with gfortran, 4 threads





Intermediate Mass Stars



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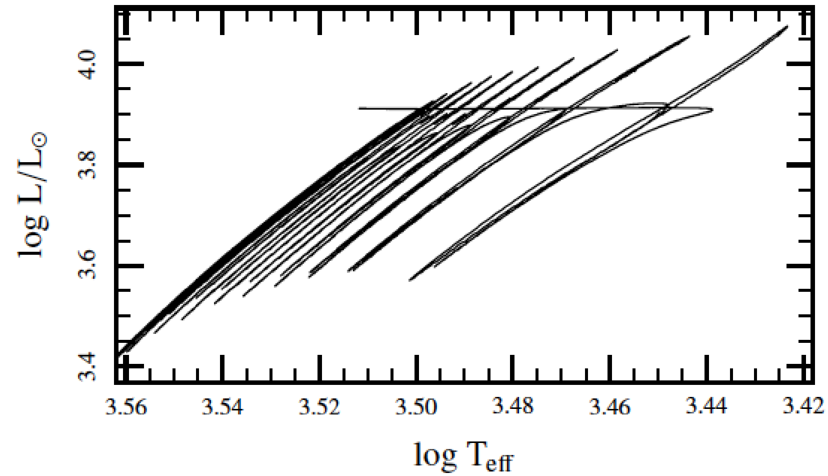
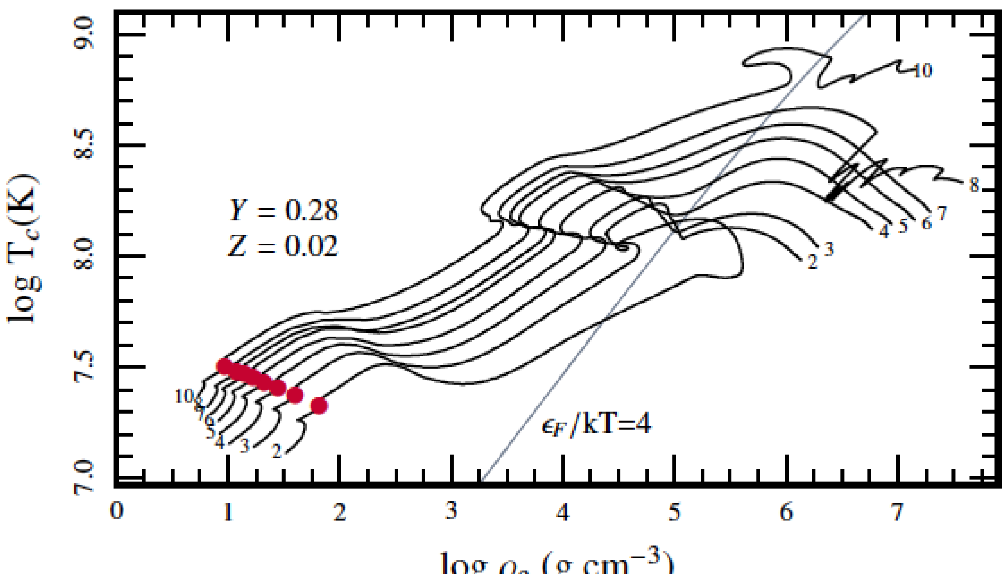
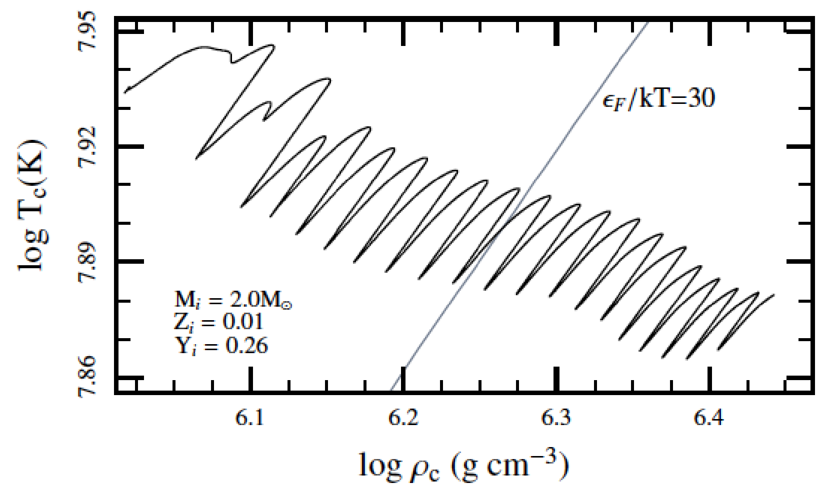
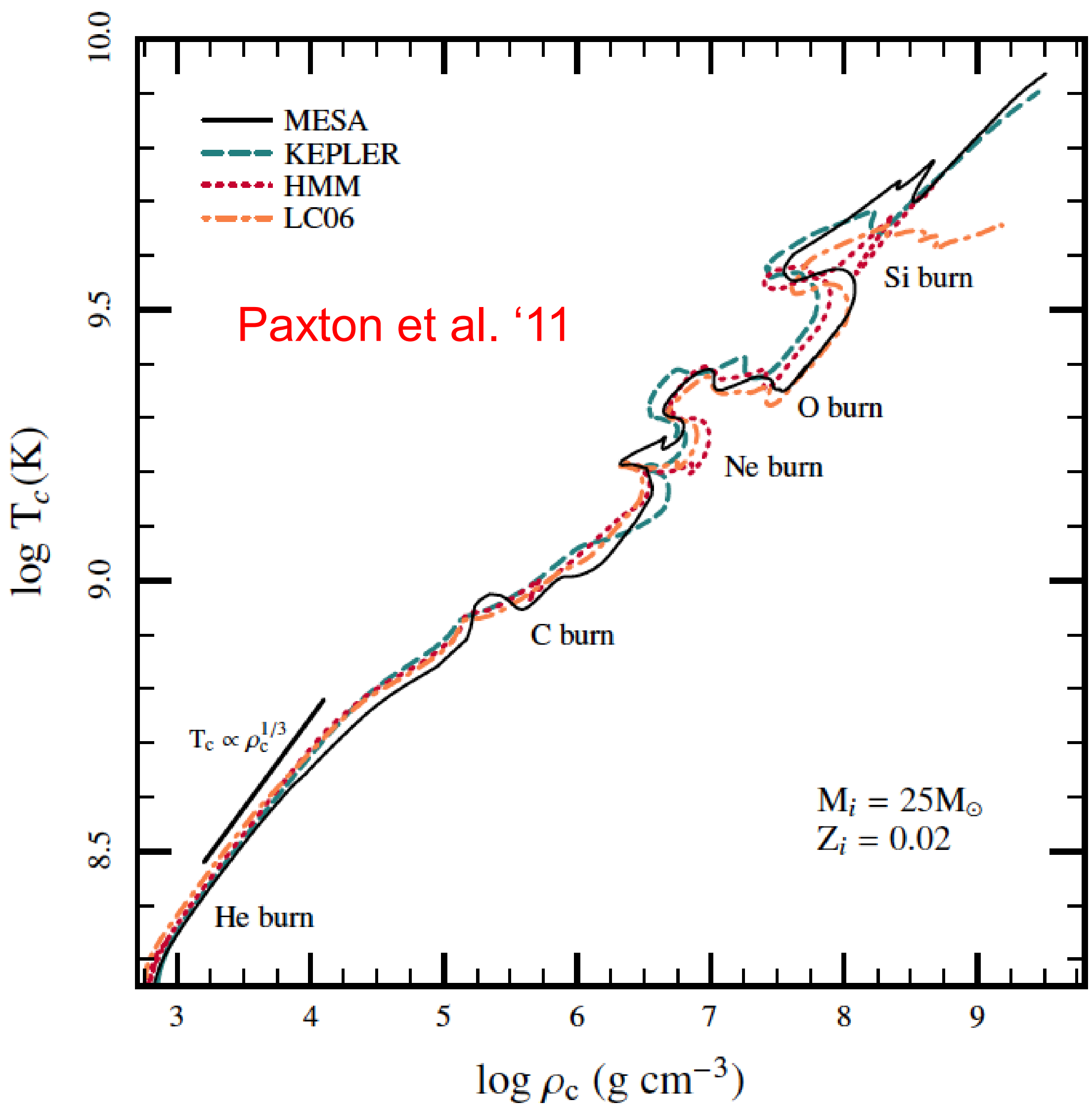






Massive Stars up to Core Collapse



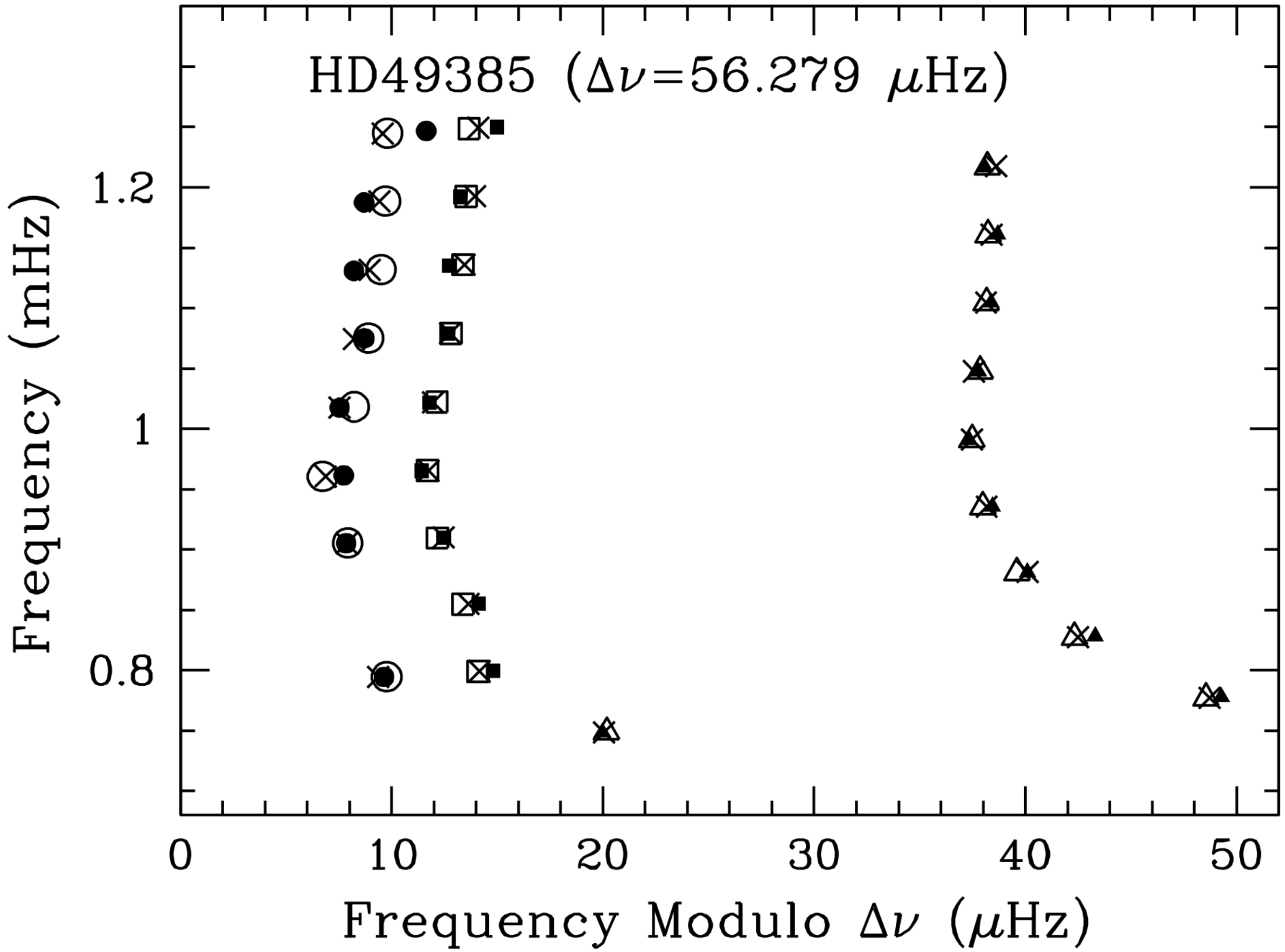
- Can evolve these stars up to the point of core collapse
- Massive winds are allowed and incorporated

Is it ‘Right’?

- Carried out substantial convergence studies to show how time and space resolution converges ==> We are ‘correctly’ solving the equations
- MESA microphysics modules were tested in other codes (DSEP and EVOL), and compared to independent runs
- Most of our ‘testing’ is comparisons to other models or, in a few cases, observational data.

Echelle Diagram for HD49385

MESA/ADIPLS are open symbols, compared to the data (filled) from Deheuvels et al. (2010), and theory (crosses) from Deheuvels and Michel (2011) (See Poster in back of room)



Acoustic Signatures of the Helium Core Flash

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Submitted to Ap J Letters Nov 5, 2011

Slides after here modified from talk to match the submitted paper

Helium Core Flash in 1967

Zeitschrift für Astrophysik 67, 420—455 (1967)

Sternentwicklung VIII.
Der Helium-Flash bei einem Stern von 1.3 Sonnenmassen

H.-C. Thomas

Eingegangen am 24. August 1967

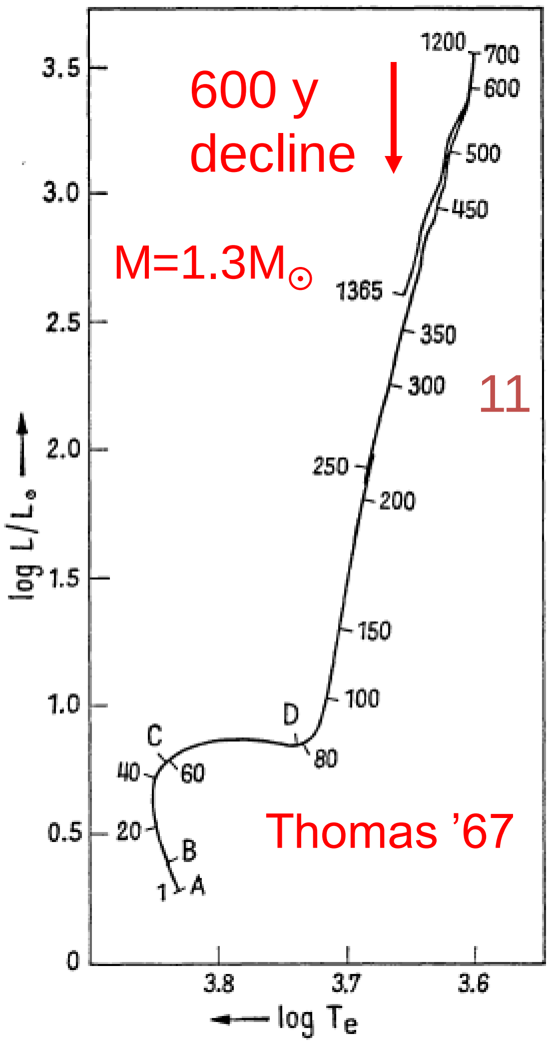
The results of evolutionary computations for a star of 1.3 solar masses are given, starting with the chemically homogeneous main sequence model. During the core contraction phase after the central hydrogen burning has ceased, neutrino production, according to the weak interaction theory, started, leading to cooling in the central region of the star. This resulted in a helium flash, starting in a spherical shell around the center. After the helium flash there was no overall mixing, but partial mixing occured. By this mixing the carbon content of the surface layers increased by a factor four. When the helium flash had slowed down, a thermally unstable helium burning shell was built up. The calculations followed nearly four of the resulting thermal pulses.

‘Textbook’ view of the Helium Core Flash

Binney and Merrifield “Galactic Astronomy”, pg 342:

“This explosive phenomena causes an almost instantaneous mass loss and a re-arrangement of the structure of the star, which we have no hope of modeling in detail. It is thus not possible to follow the evolution of a star from the RGB on to the HB where it settles down to core helium burning.”

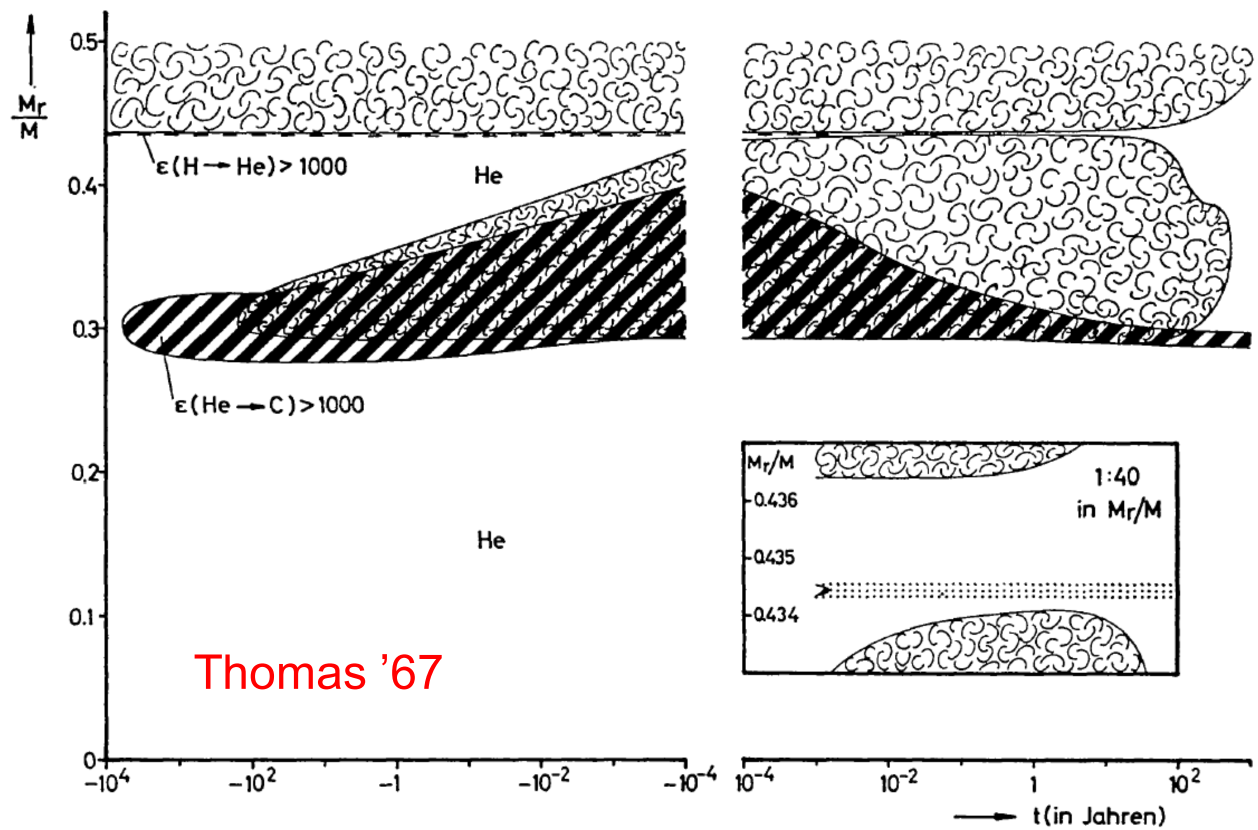
Red Giant Branch Evolution
($M<2M_\odot$)



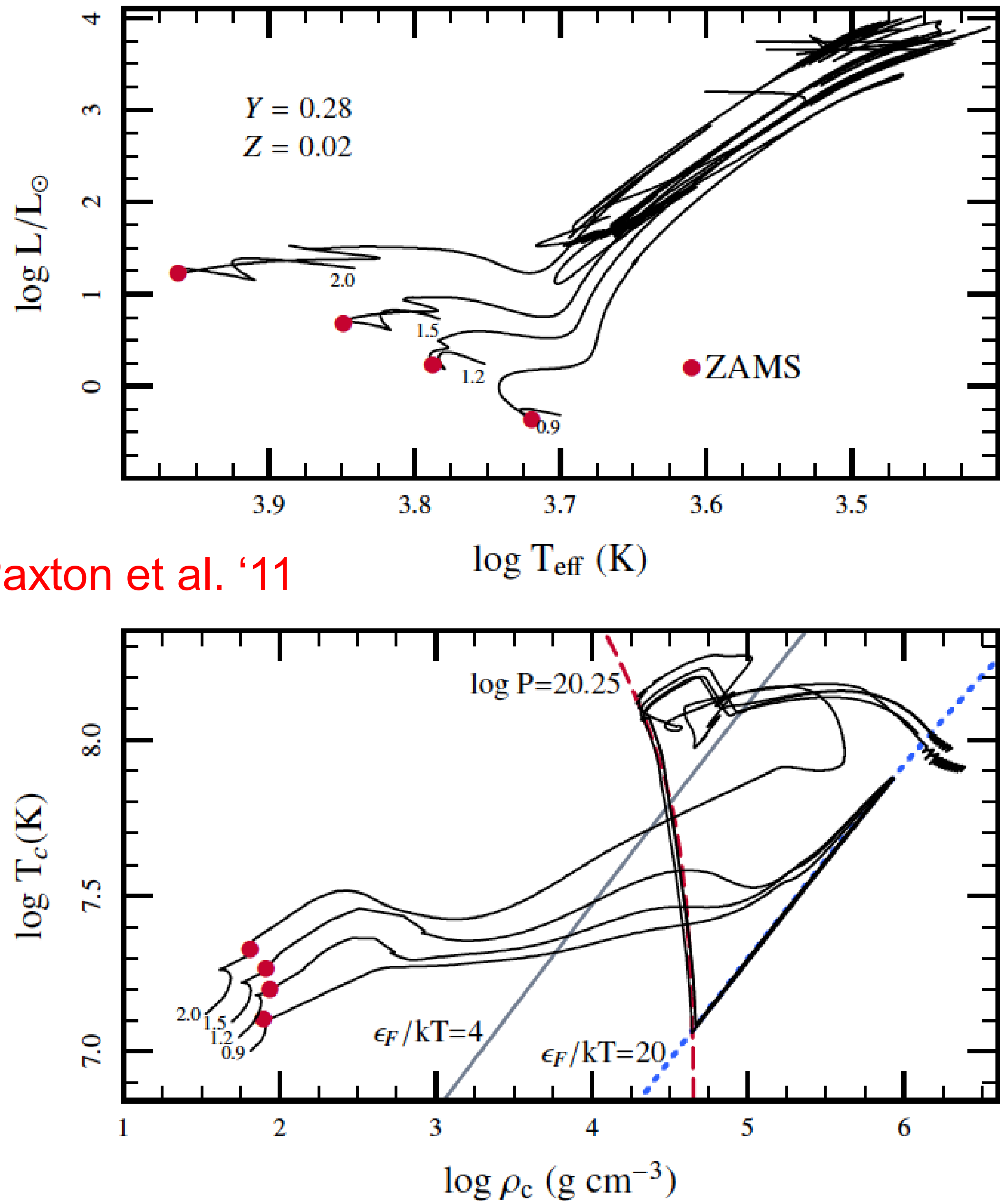
2.4 My

11 My

Timescales can be Short, but not dynamic !



Low Mass Stellar Evolution



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- MESA integrates through the He core flash
- No need for ad-hoc 'transition' from RGB to HB
- Also possible in GARSTEC and other codes. .

It’s neither explosive nor hopeless!

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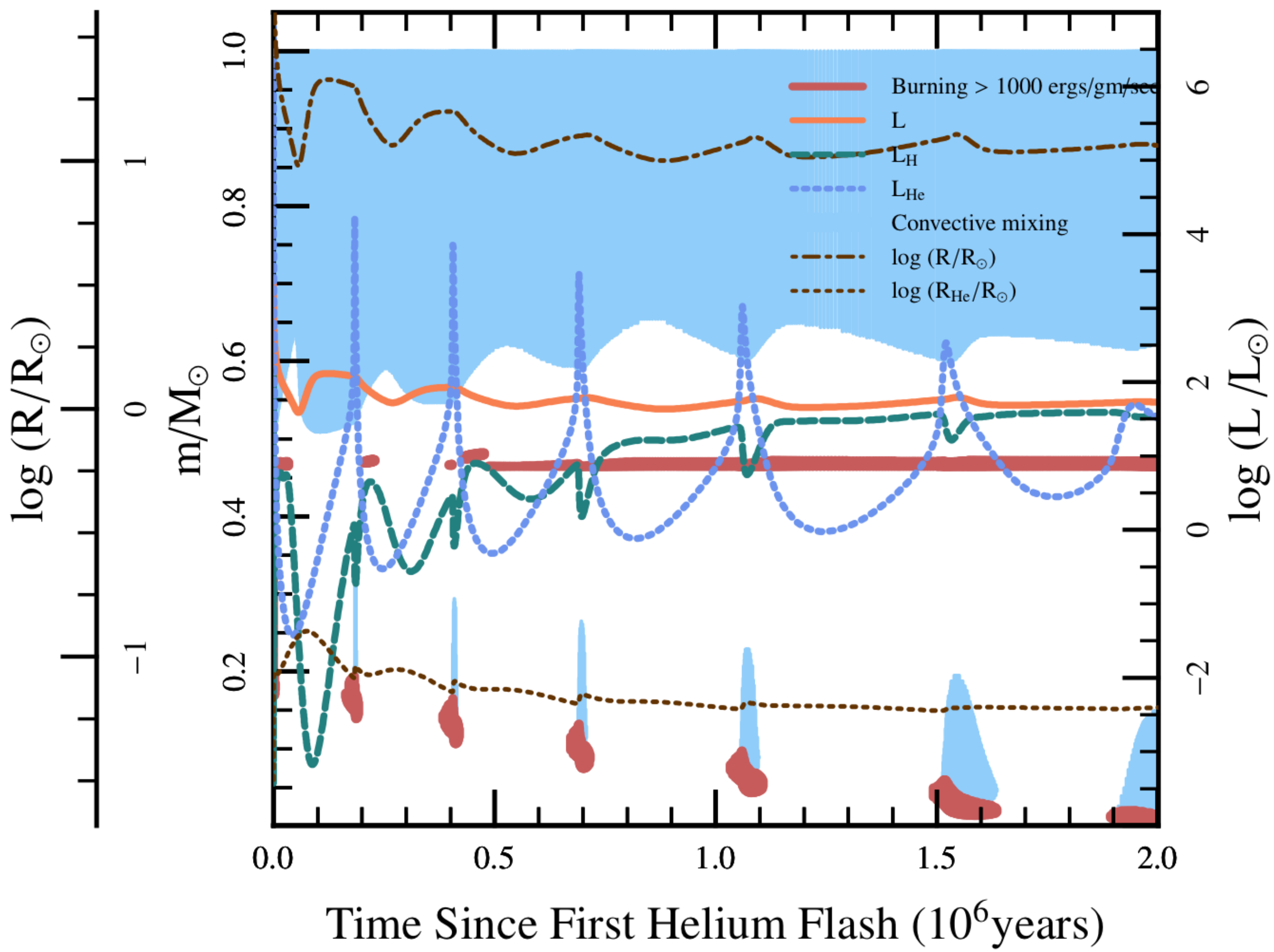
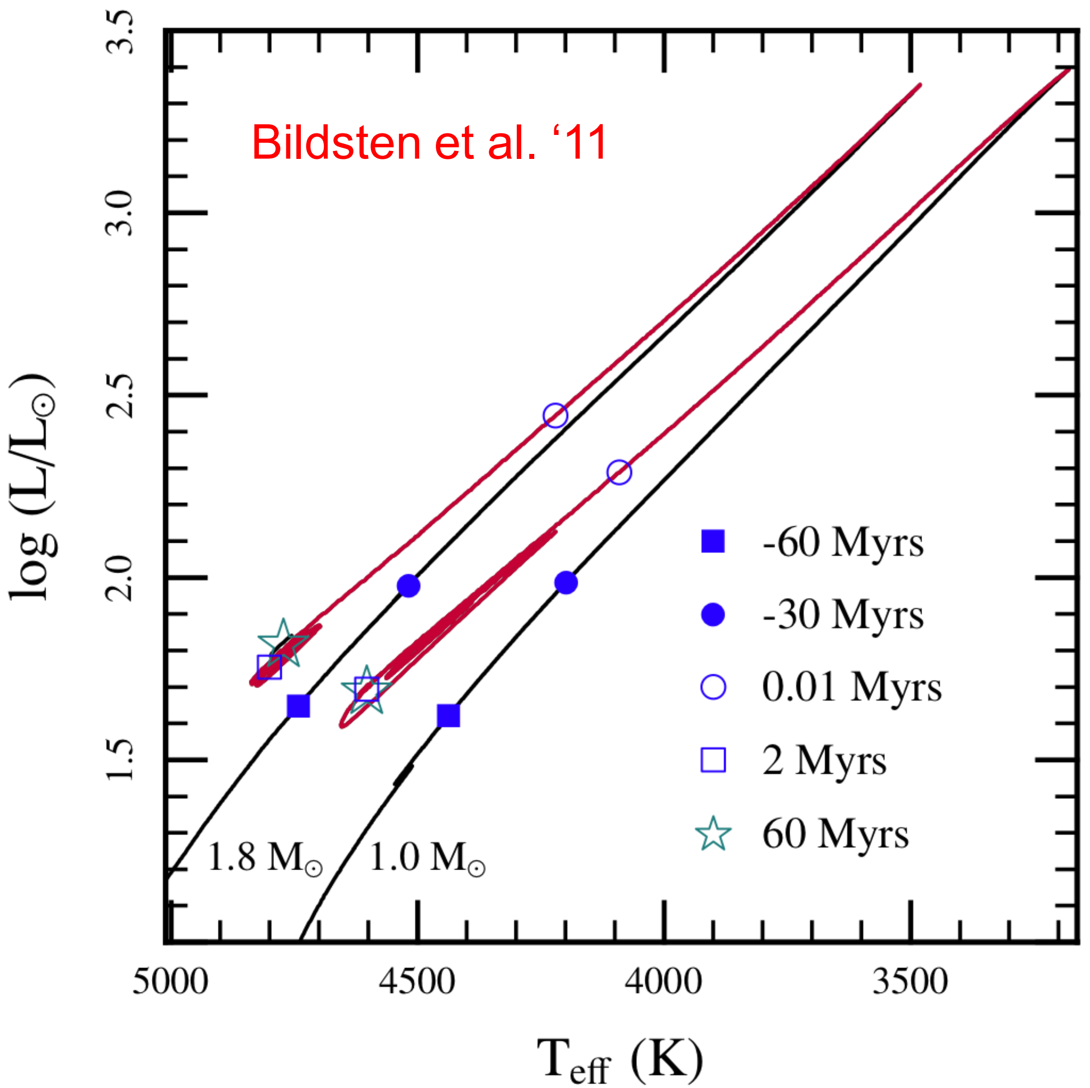
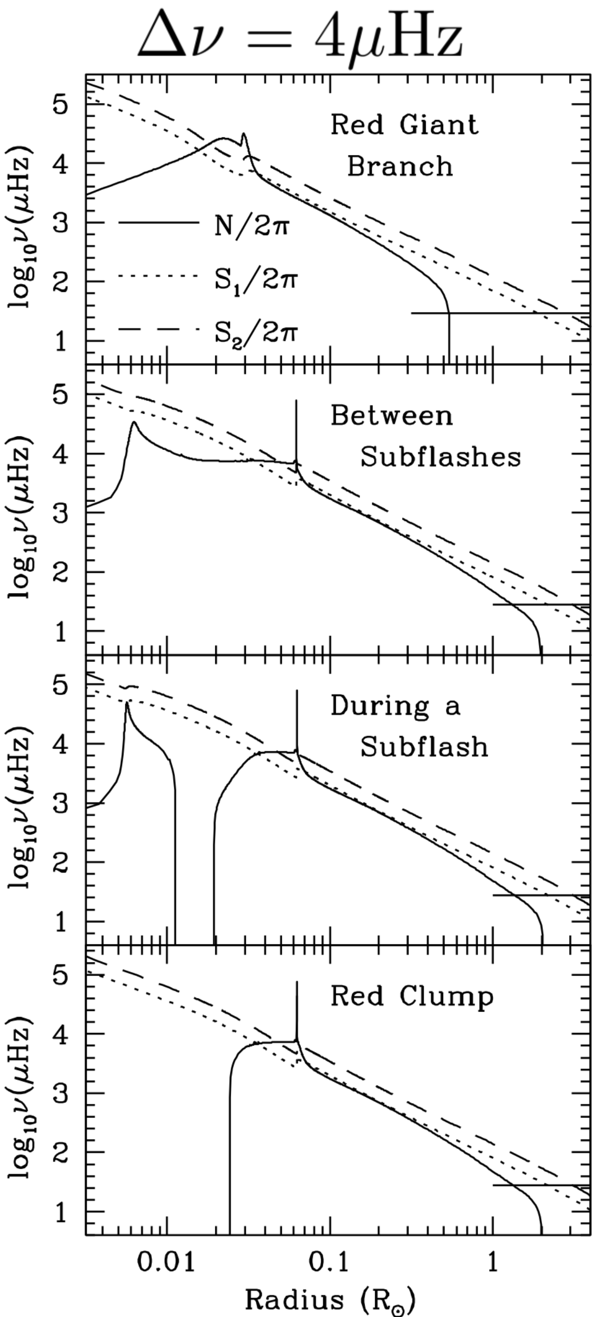


H Shell Turnoff Leads to KH Contraction



- Time spent on the RGB at L>30L$_\odot$ is comparable to that spent on the red clump.
- Within 10^5 years after core flash, the star reaches the clump region



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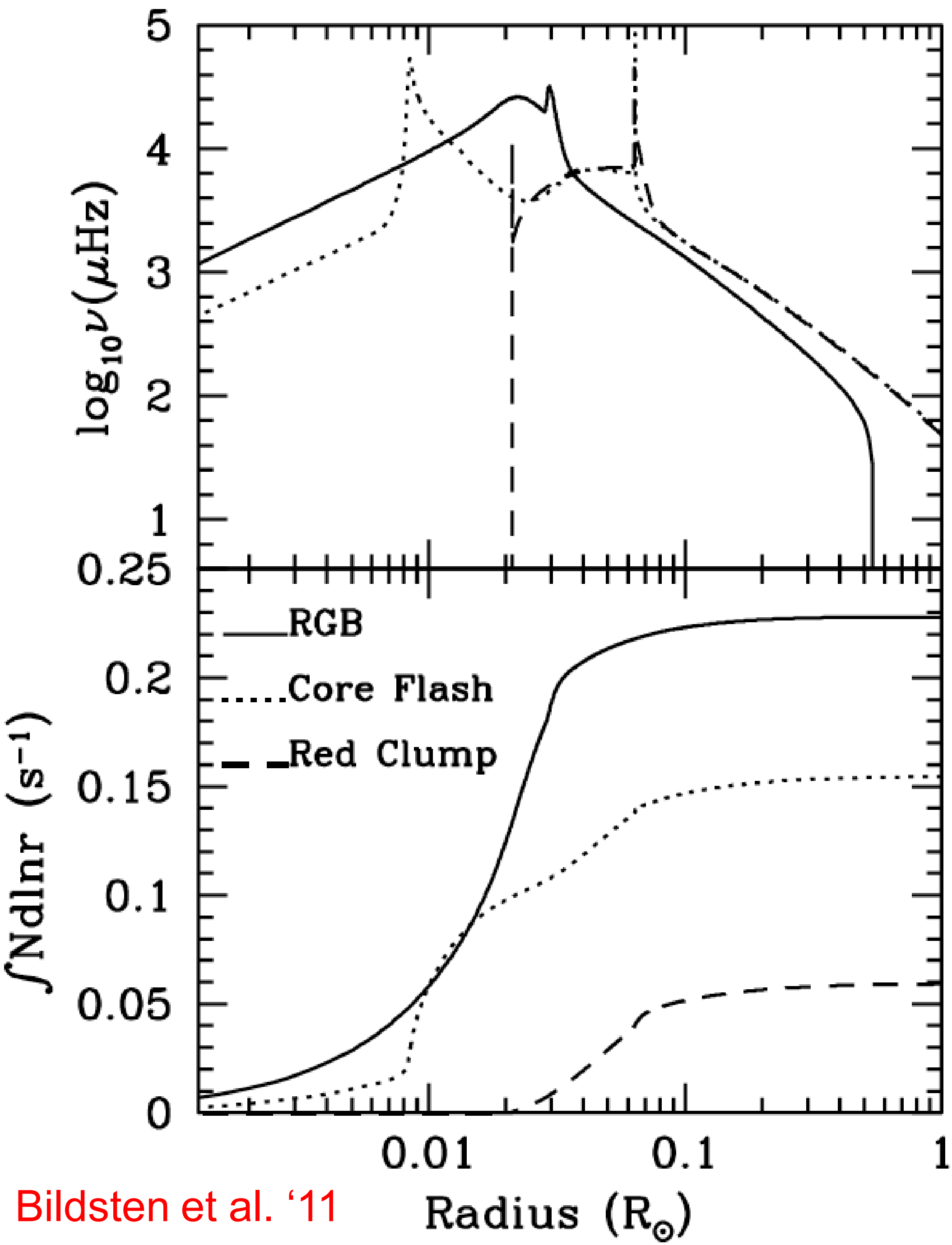
Propagation Diagrams

- Contraction leads to outer envelope profiles during the flash nearly identical to the red clump
- Coupling to core modes during the flash will be as strong as on clump.

$$k_r^2 = \frac{1}{c_s^2\omega^2}\left(\omega^2 - N^2\right)\left(\omega^2 - S_\ell^2\right)$$

Contrasts in Brunt-Vaisala



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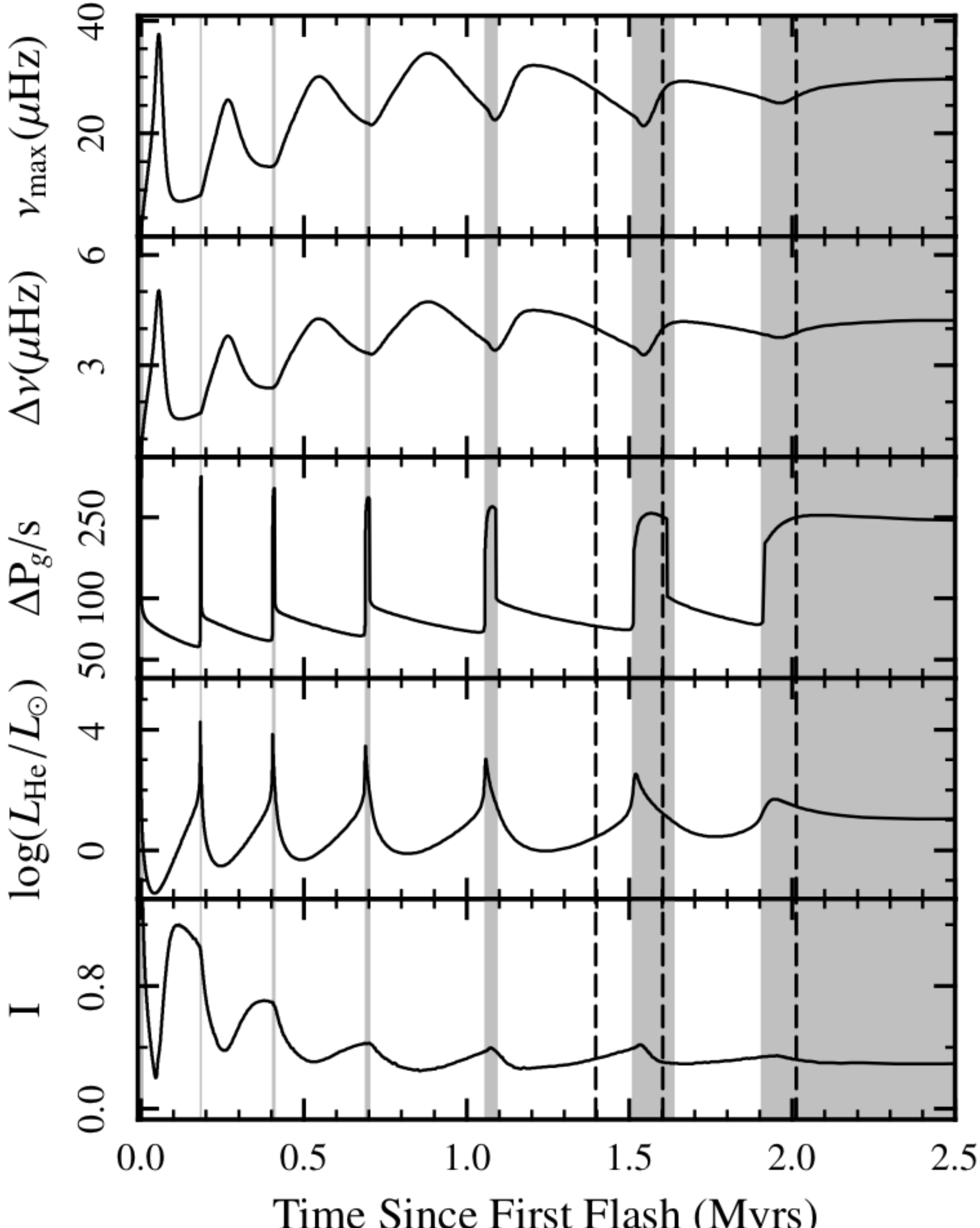
- Outer part is nearly identical in clump and flash stars
- Degenerate core provides buoyancy, so period spacing stays between that on RGB and clump

$$\Delta P_g(\ell = 1) = \frac{2^{1/2}\pi^2}{\int N d\ln r}$$



$$\nu_{max} \approx 31\mu\text{Hz}\left(\frac{M}{M_\odot}\right)\left(\frac{10R_\odot}{R}\right)^2\left(\frac{5777\text{ K}}{T_{eff}}\right)^{1/2}$$

$$\Delta\nu^{-1} = 2\int_0^R \frac{dr}{c_s}$$

$$I = \int_{r_1}^{r_2} k_r dr$$

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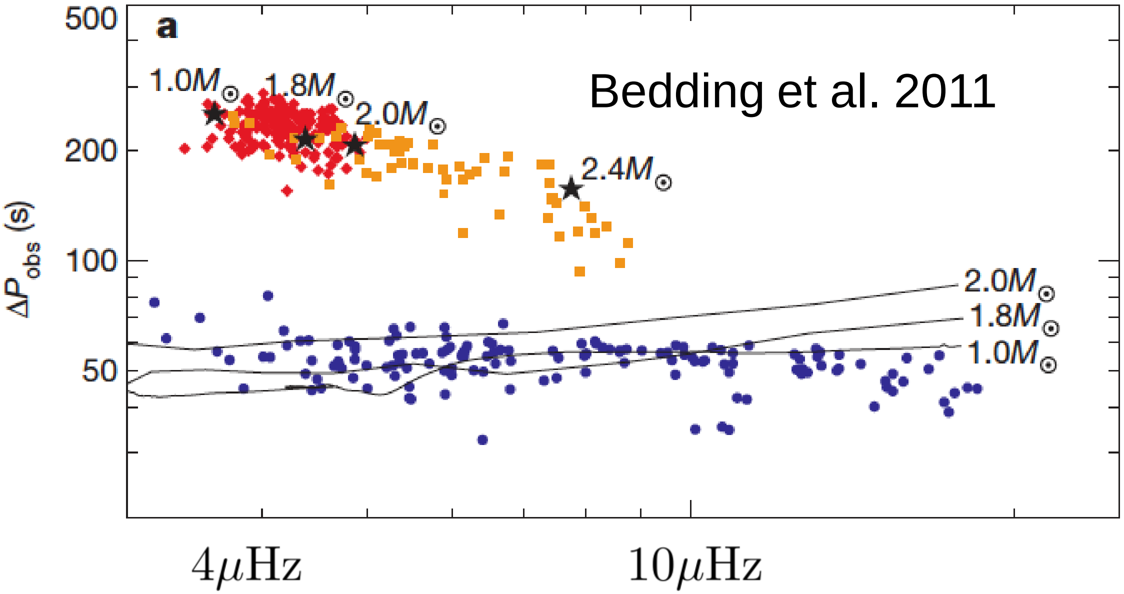
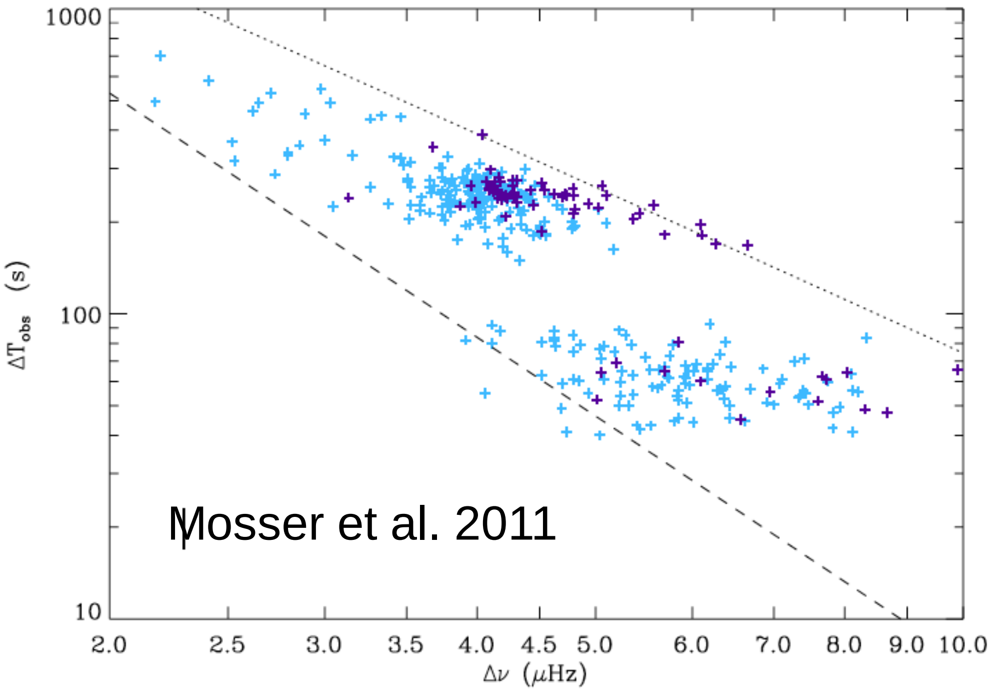
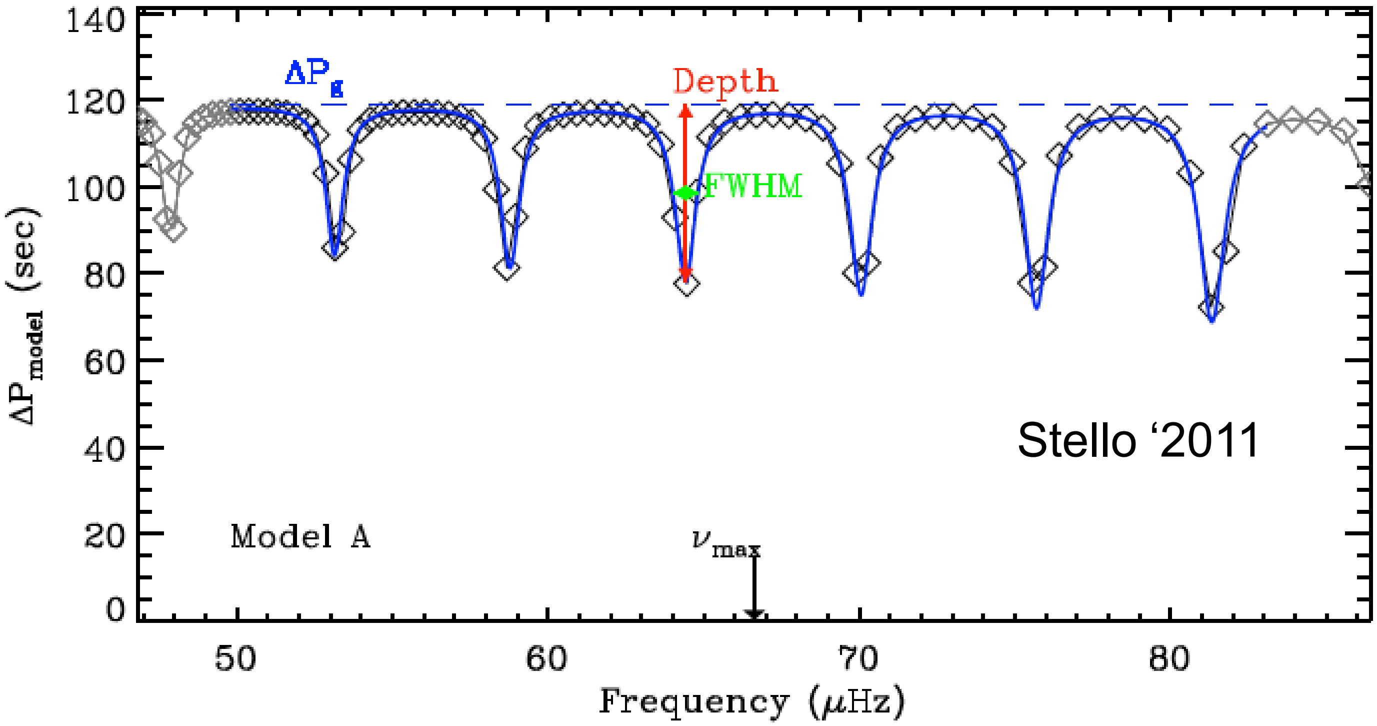
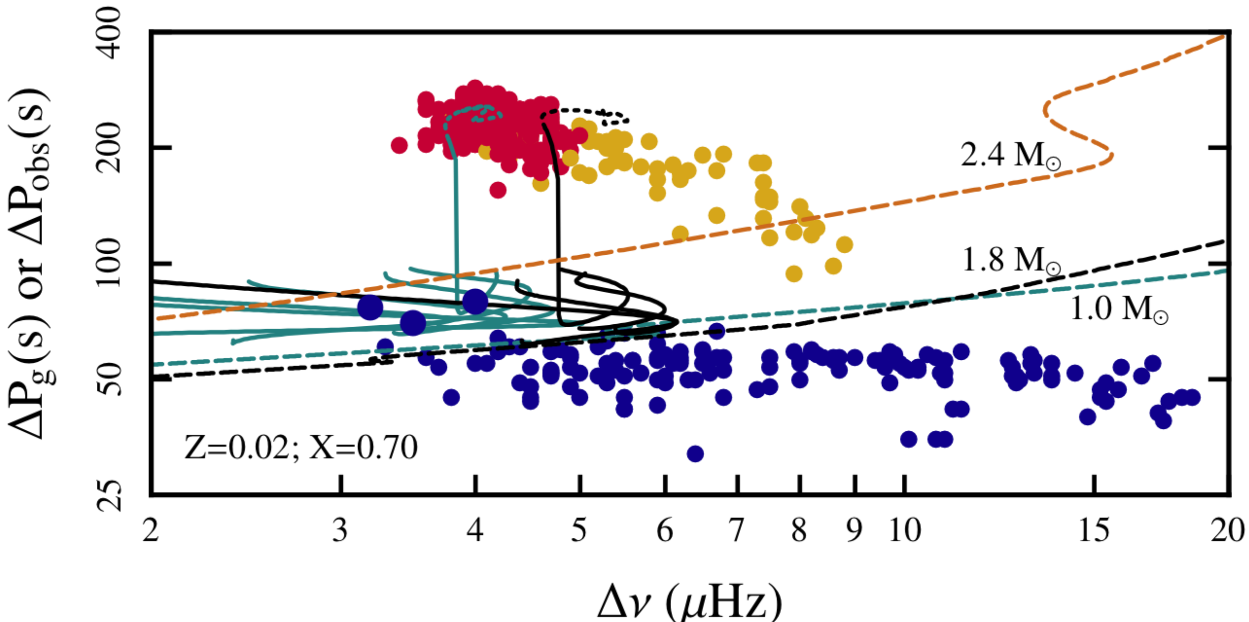

a
Bedding et al. 2011
1.0$M_\odot$
1.8$M_\odot$
2.0$M_\odot$
2.4$M_\odot$
2.0$M_\odot$
1.8$M_\odot$
1.0$M_\odot$
500
200
100
50
ΔP_{obs} (s)
4μHz
10μHz


Mosser et al. 2011
1000
100
10
ΔT_{obs} (s)
2.0
2.5
3.0
3.5
4.0
4.5
5.0
6.0
7.0
8.0
9.0
10.0
$\Delta\nu$ (μHz)

Measuring Delta P vs. Delta P_g



Comparison to Kepler & CoRot



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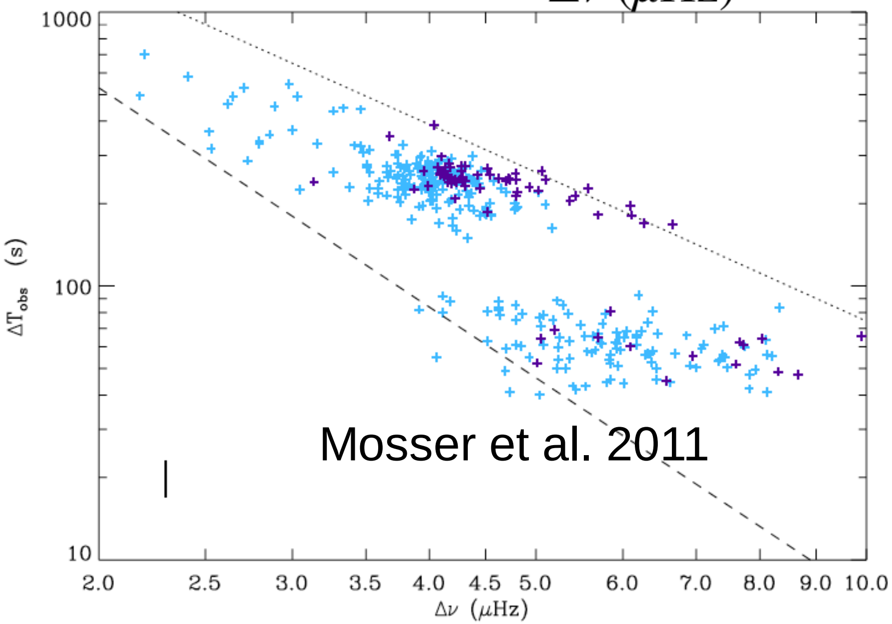
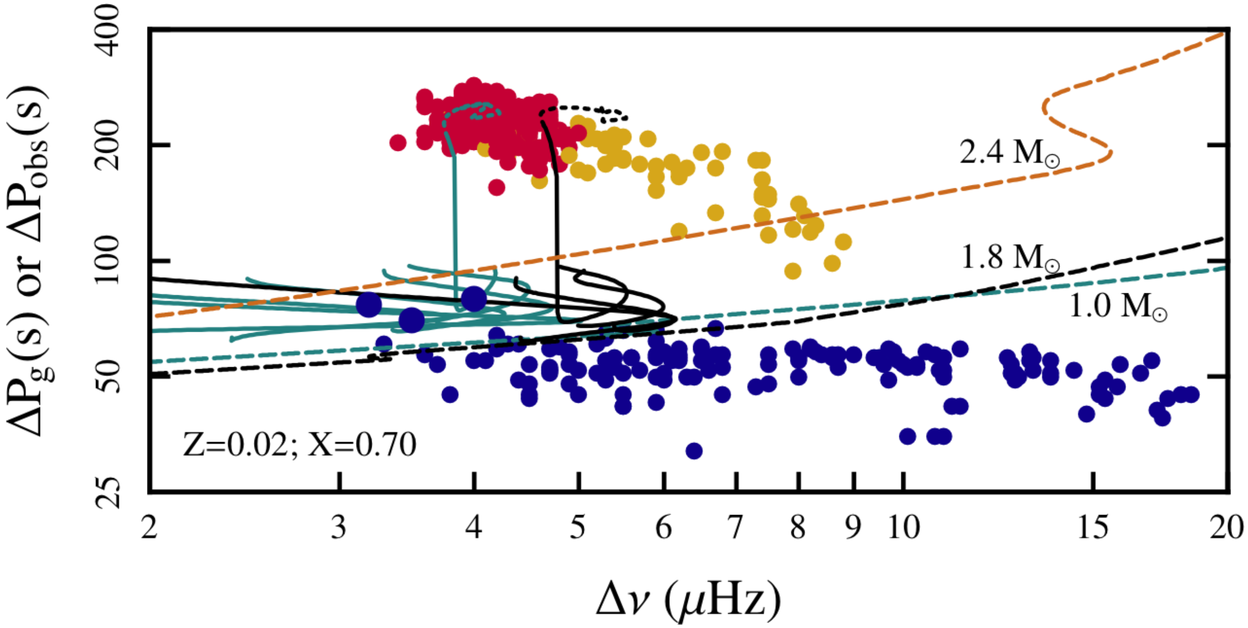


Mosser et al. 2011



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- Should be one in 35 compared to the clump
  - The number of 'Unusual' objects on this diagram is ~ 3-5
- Would be interesting to identify where in the 2 Myr evolution these systems reside
- With a core that has just undergone radius expansion, rotation will be interesting !