CNO isotopic ratios and light element abundances in stars undergoing hot bottom burning (HBB).

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Outline:

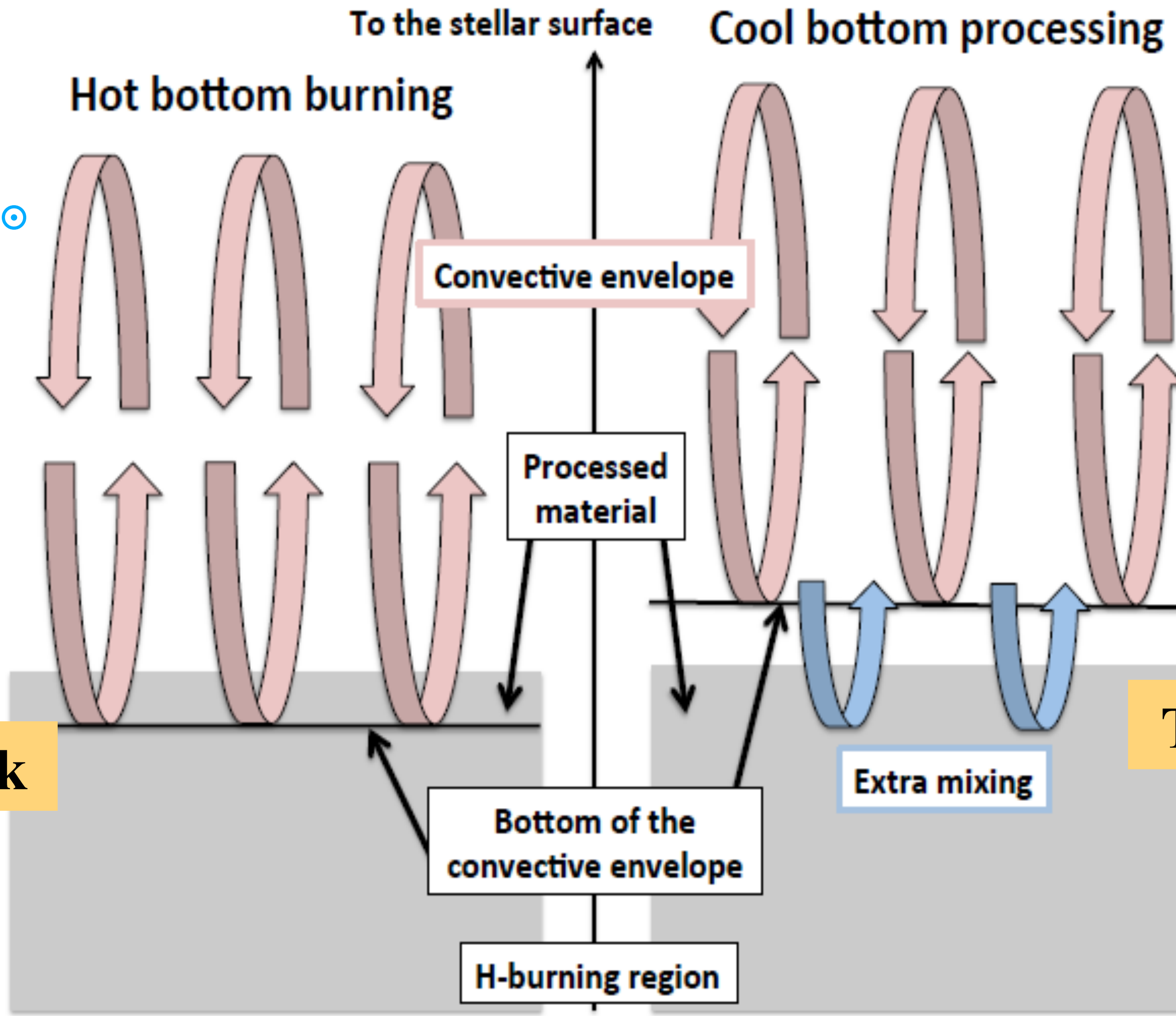
1.- HBB in massive AGBs : expected surface abundance changes

2.- The stellar sample

3.- CNO & light elements in massive (?) AGBs

4. Summary

HBB (Scalo, Despain & Ulrich 1975)



AGB
M > 4-5 $M_{\odot}$

RGB-AGB
M < 2 $M_{\odot}$??

T > 40 Mk

T < 40 Mk

Some embarrassment in current HBB models

- Mixing & burning produce feedbacks on physics parameters (L,T,P and their gradiets). Current models assume decoupling or partial coupling (mixing+burning, but no physics coupling).

- Mixing scheme? Instantaneous, Diffusive or Advective …

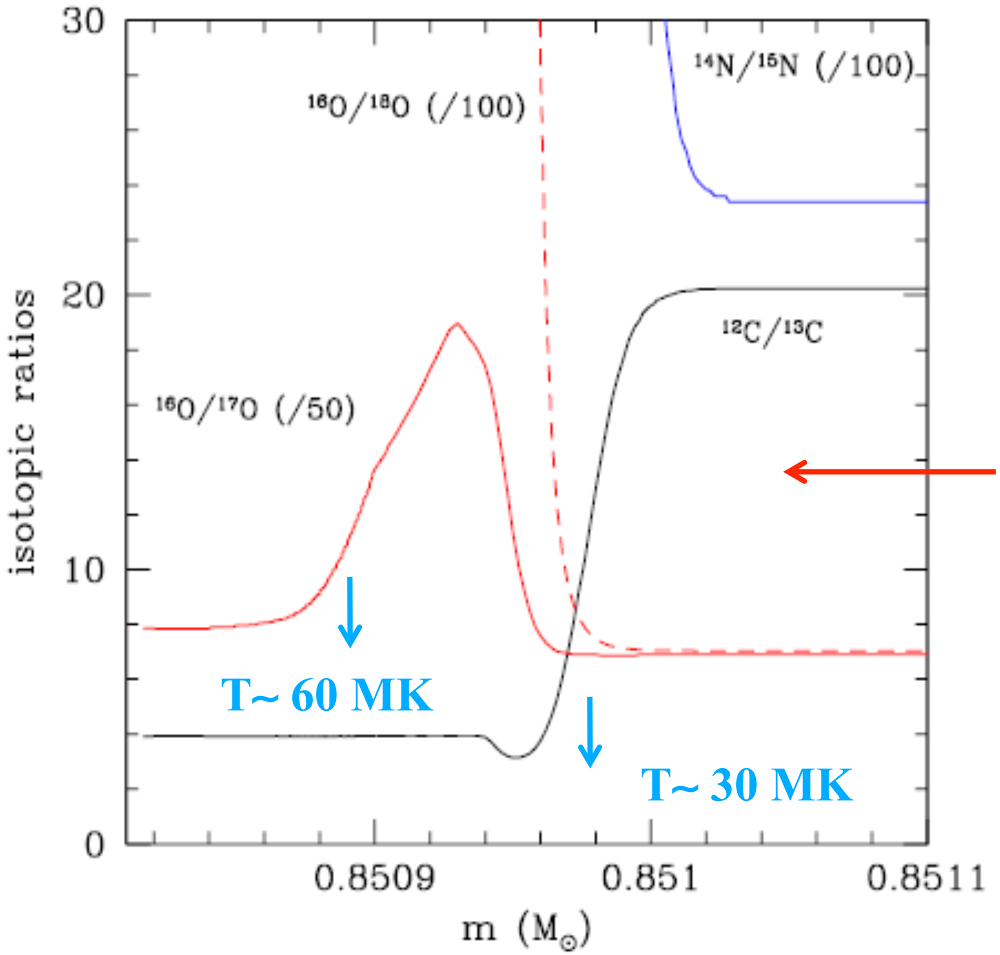
$$\frac{dX}{dt} = -\frac{d}{dm}\left[(4\pi r^2 \rho)^2 D \frac{dX}{dm}\right] \qquad \frac{dX}{dt} = \pm \frac{d}{dm}(4\pi r^2 \rho V X)$$

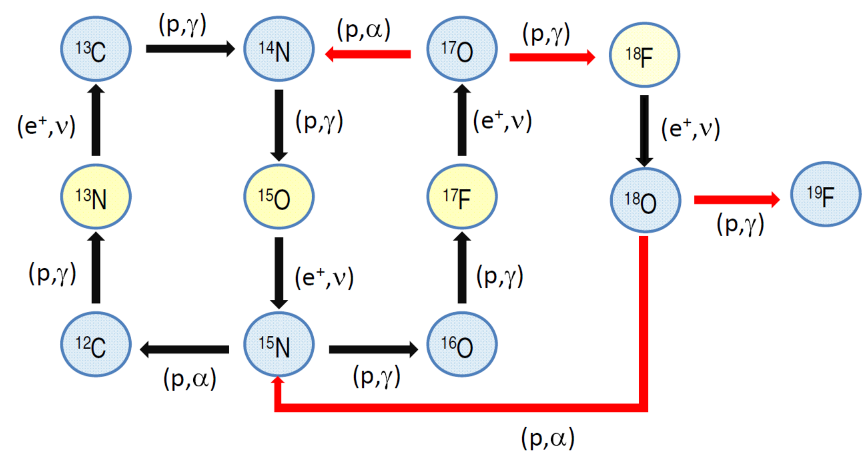
- Convective boundary: is the mixing-length adequate and, if yes, how we can calibrate the free parameter(s)?

- Overshoot ? This is similar to the overshoot at the base of the PDCZ in thermal pulsing AGBs (see Lattanzio talk)

Main effects on the CNO isotopes

5 $M_\odot$, Z=0.014 FUNS





- **C/O < 0.5** ↓
- **$^{12}C/^{13}C$ < 20** ↓
- **$^{14}N/^{15}N$ > 10^4** ↑
- **$^{16}O/^{18}O$ > 10^4** ↑
- **$^{16}O/^{17}O$** ↓ ↑

Other chemical effects

- $T_{BCE} > 20$ MK **Li can be produced during some phases**
- $T_{BCE} > 60$ MK **Na and Al are enhanced and ^{16}O, ^{19}F depleted**
- $T_{BCE} > 80$ MK **$^{25,26}Mg$ enhanced and ^{24}Mg depleted**

✓ **However... exact figures extremely depend on the model parameters: mass-loss, convection & mixing treatment, nuclear rates etc..**

works by D'Antona, Lattanzio, Ventura, Karakas, Siess, Doherty, Straniero...

↓

Need of observational constraints to guide theoretical models

Very few direct observational evidences, so far

- Bright stars in SMC/LMC show Li enhancement and low $^{12}C/^{13}C$, compatible with HBB (Smith & Lambert 1990-91; Plez et al. 1993)
- O-rich AGB stars in the Galaxy with Rb/Zr ↑ : Li ↑ → mild HBB (García-Hernández 2007-13)
- Extreme OH/IR do not show $H_2{}^{18}O$ → HBB (Justtanont et al. 2015)

➢ Full set of CNO isotopic ratios never derived in the same object
➢ No attempts to derive F, Na, Al, Mg abundances

The stellar (Galactic) sample

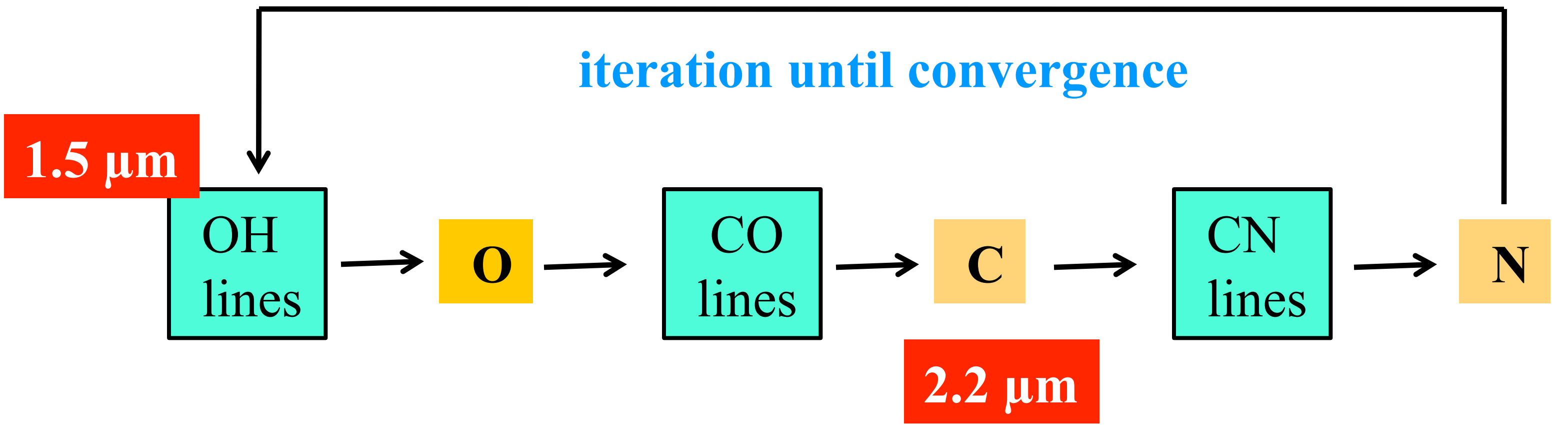
Selection criteria: indirect evidences of high mass.

- **Galactic OH/IR stars are located at low scale height in the disk**
- **Long period variables (log P > 2.6)**
- **Large expansion (OH) velocities > 6-8 kms^{-1}**
- **Large infrared (IRAS) excesses → thick circunstellar envelopes**
- **Maser OH, SiO, H_2O emissions**
- **Gaia distances (for a few) → luminosity**
- **s-process enhancement with high neutron density signature (if any)**

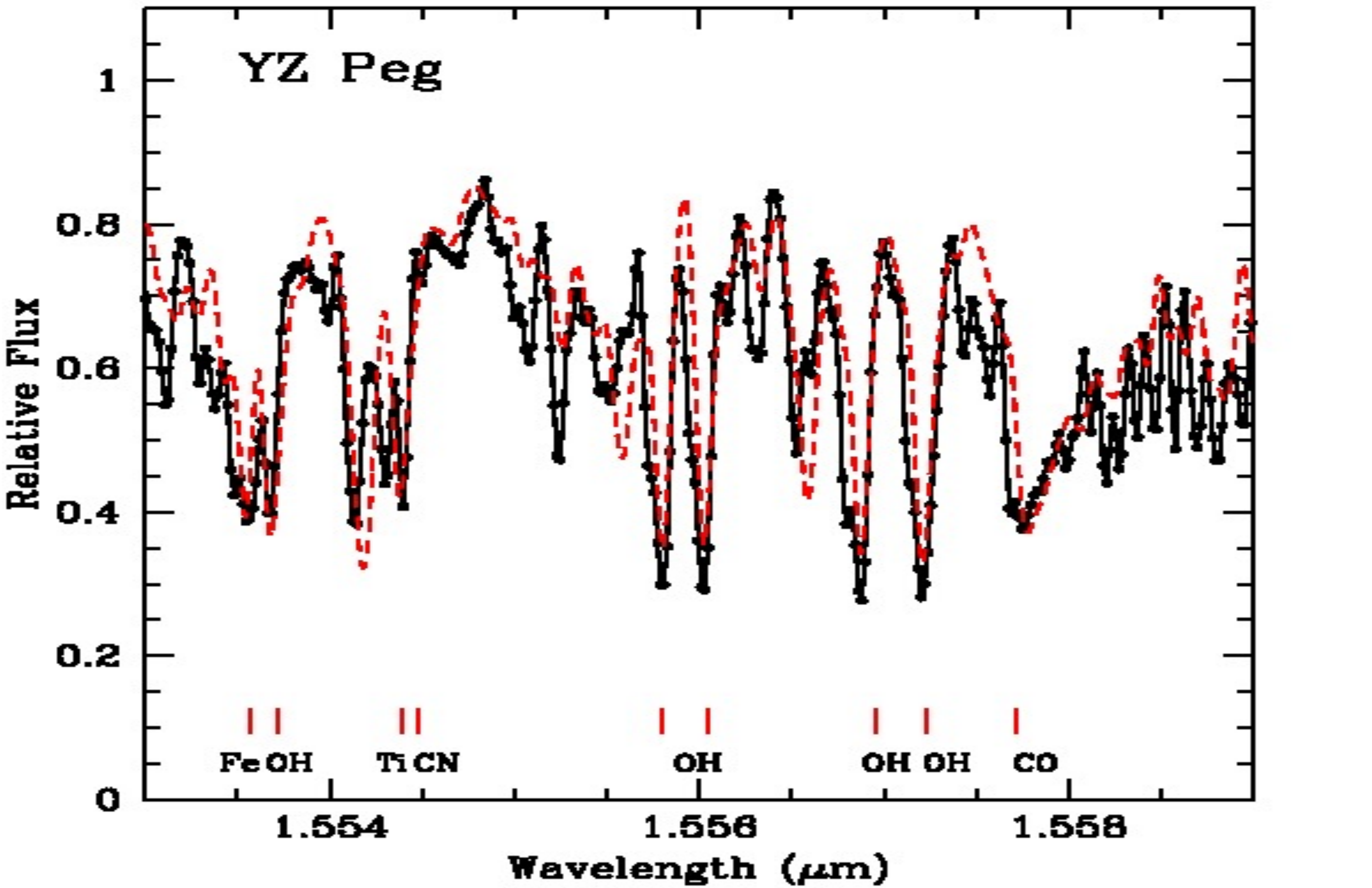
Litle, Little-Marenin & Bauer (1987)
García-Hernández et al. (2007)

Analysis of the massive (?) AGBs

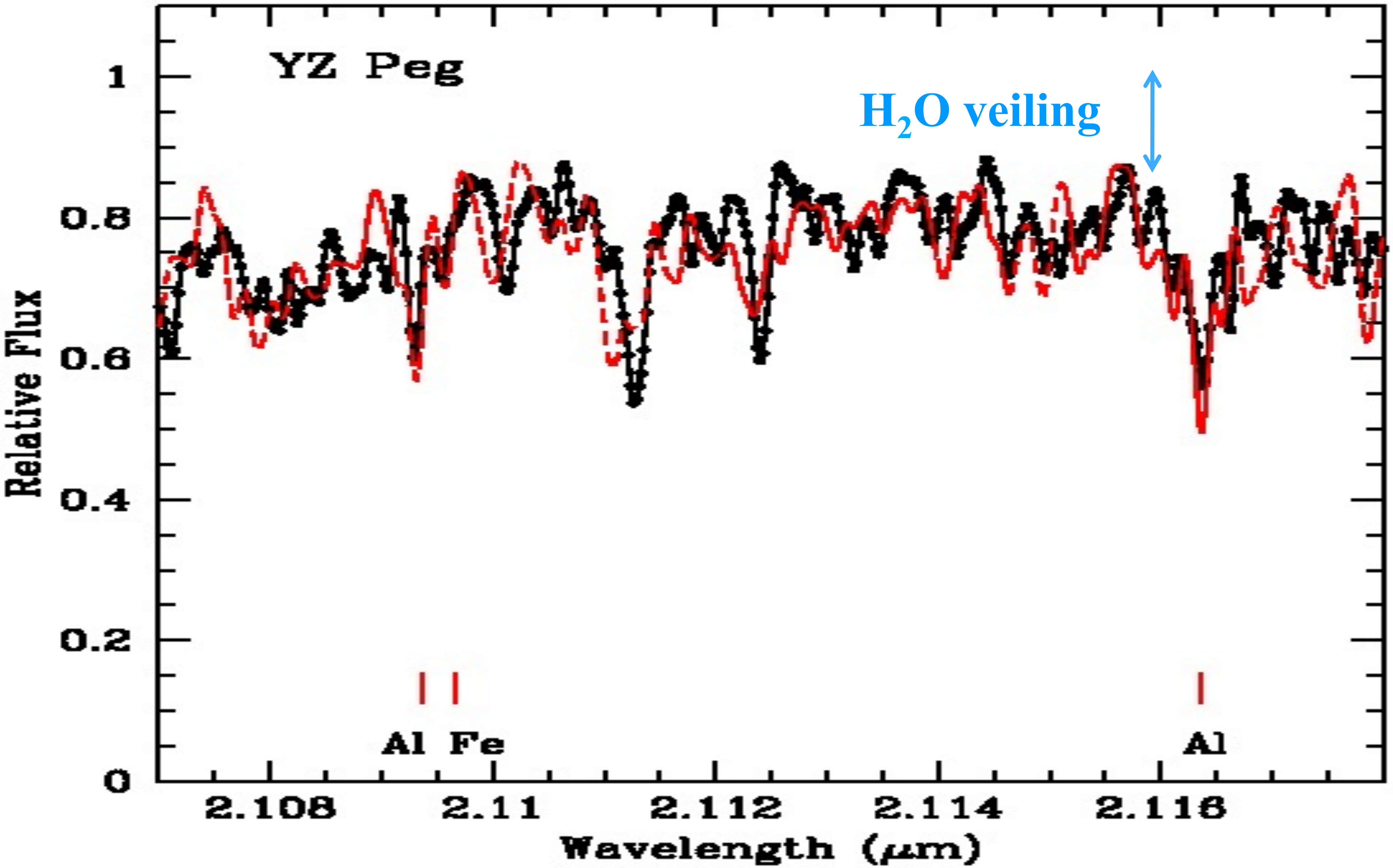
- ~ 50 O-rich AGBs will be observed with TNG/GIANO @ J,H,K bands
- New O-rich, s-elements enhanced spherical model atmospheres (S. Van Eck et al.)
- Updated molec-atom line lists: OH, C_2, CO, CN, HCN...H_2O (APOGEE survey)
- CNO abundances derived in a consistent way...when possible



Teff= 3400 K, Fe/H]=0.0,   C/N/O=8.43/7.87/8.69

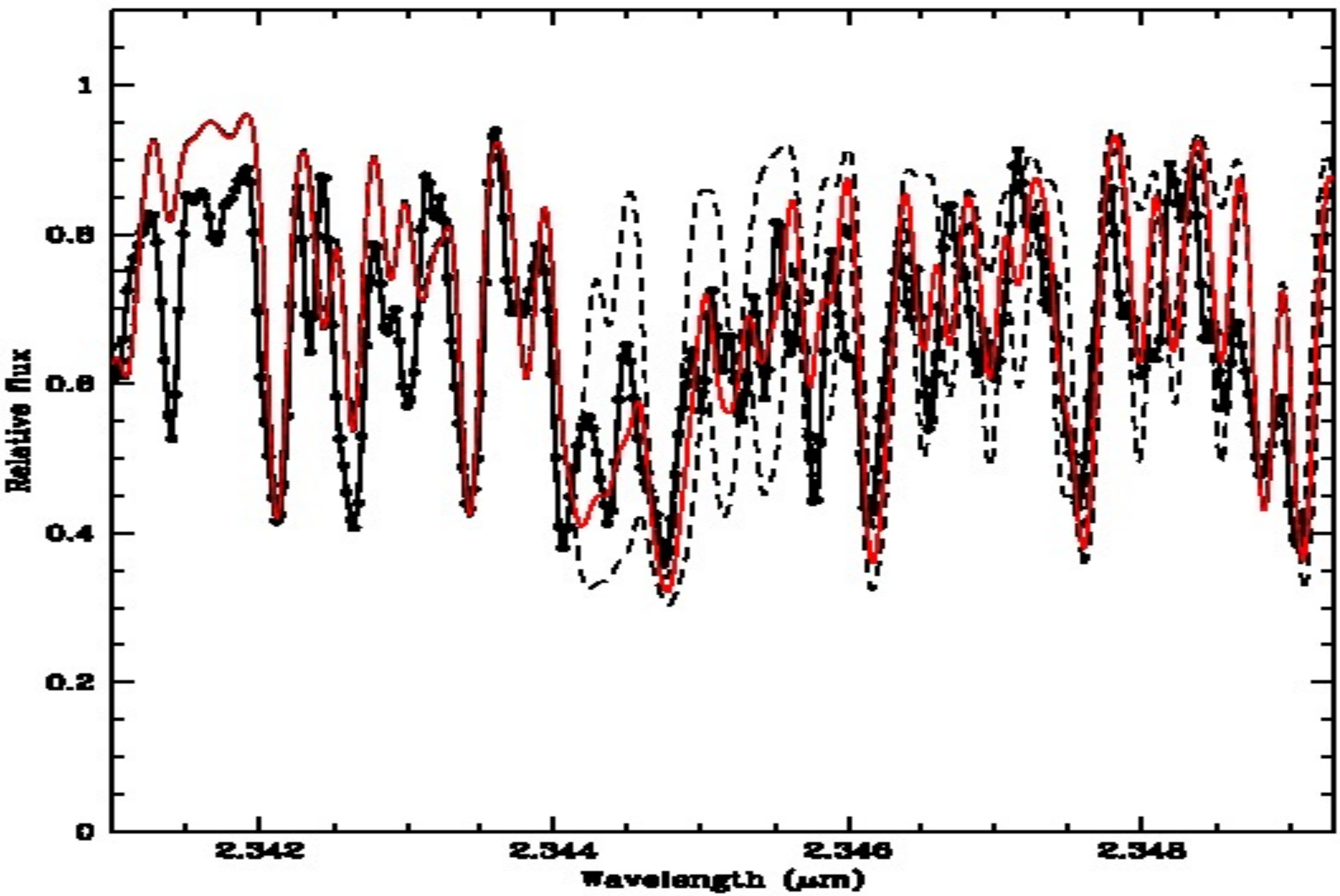


log (Al/H) + 12 = 6.3

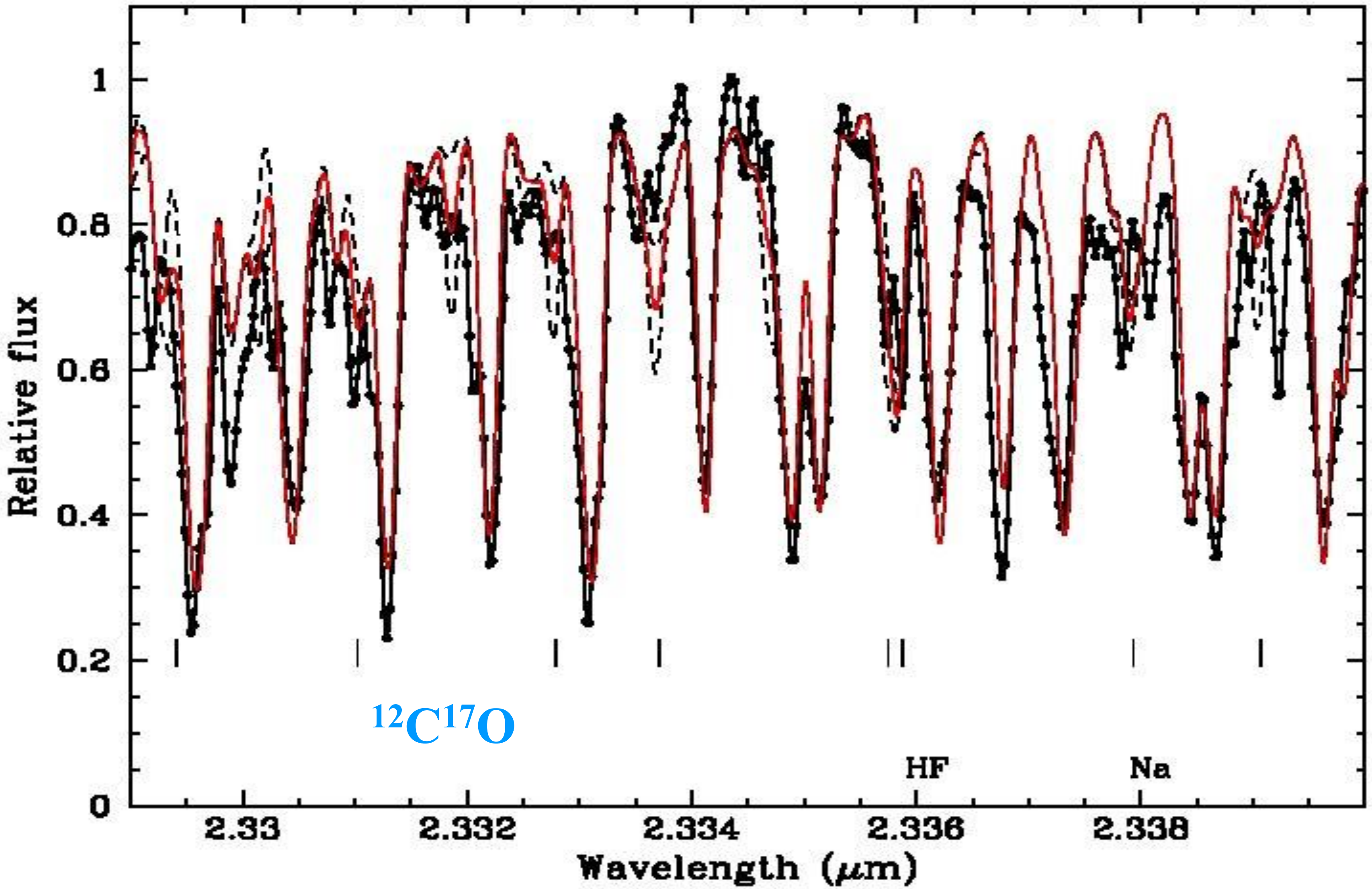


YZ Peg
H_2O veiling
1
0.8
0.6
0.4
0.2
0
Relative Flux
Al Fe
Al
2.108
2.11
2.112
2.114
2.116
Wavelength (μm)

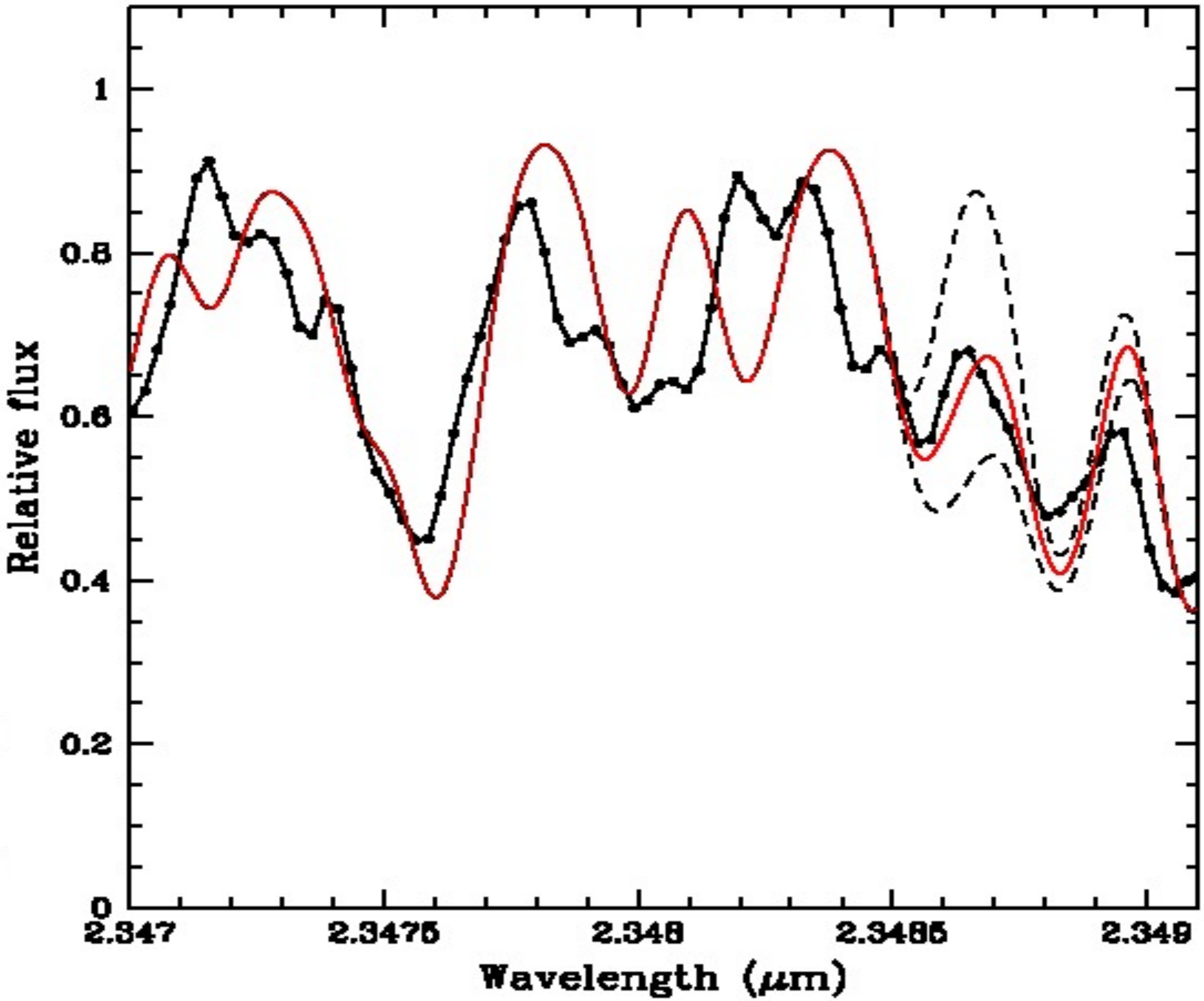
$^{12}C/^{13}C$ = 100, 35, 4



$^{16}O/^{17}O = \infty, 500, 200$ F = 4.35, Na= 6.1



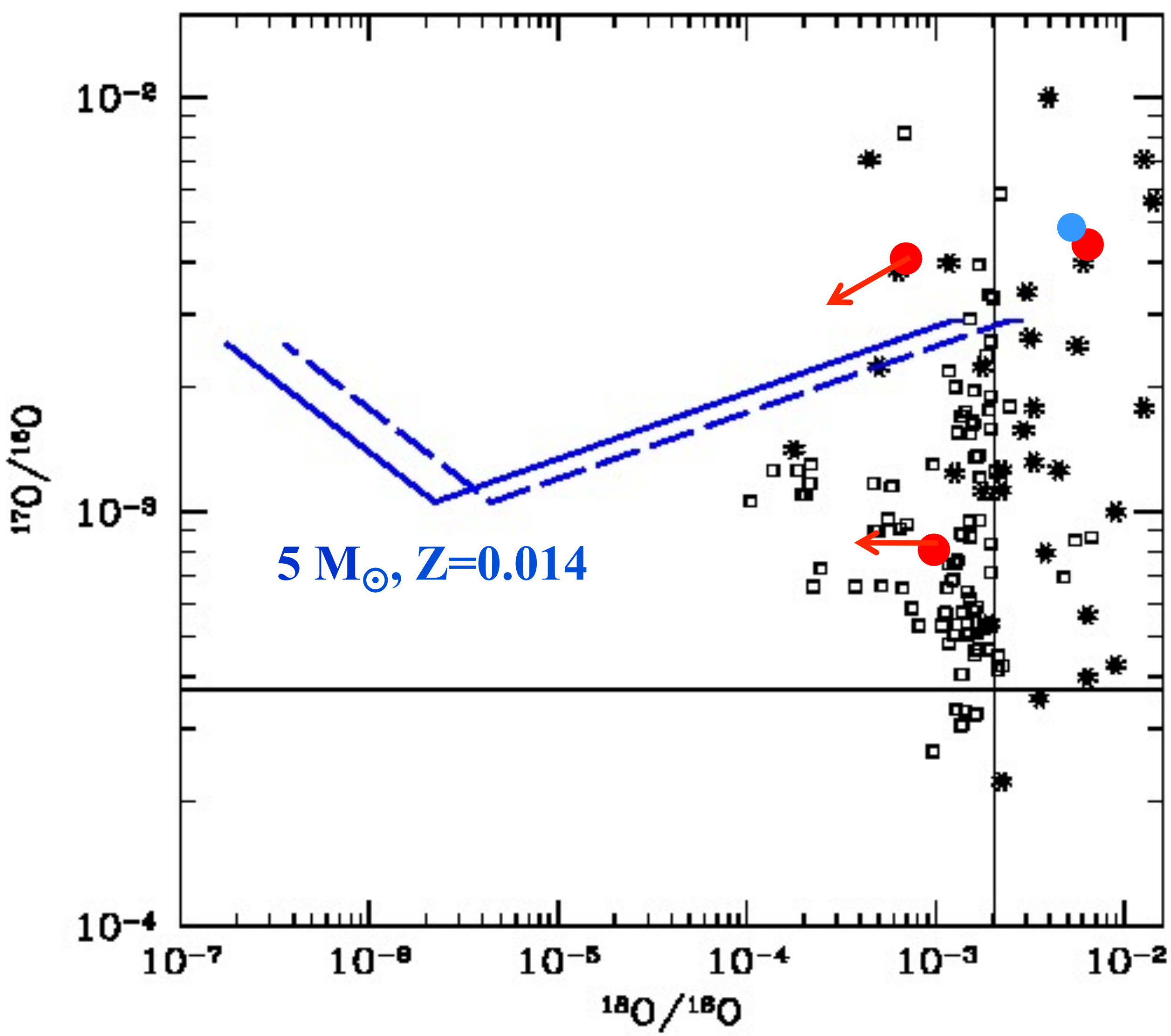
$^{16}O/^{18}O = \infty$, 600, 100



Preliminary results of the feasibility test

Star	C/O	12/13	14/15	16/17	16/18	lights	HBB ?
WX Cyg	1.01	4	10	463	610	Li ↑	✗
YZ Peg	0.77	40	?	570	560	solar	✗
V1415 Aql	0.30	20	?	>600	>1000	solar	?
V1416 Aql	0.90	>35	?	800	400-700	F ↓	✗
V697 Her	0.45	30	?	?	>1000	Li ↑	??
....							

O-rich Miras (Hinkle et al. 2016) (stars)
O-rich presolar grains (Nittler 2011) squares



Summary

1. **Work in progress...more results next time**

2. **Very difficult task: Accurate CNO ratios and abundances might be only determined in the warmest (T_{eff} > 3000 K) massive O-rich AGBs if observed near minimum light**

3. **F, Na, Al, Mg abundances uncertain ~ expected change if HBB is working**

4. **More complete-accurate mole-atom line lists are needed: H_2O calibration... Dynamical model atmospheres should be used**

5. **Search for other accessible spectral ranges (GIARPS)**