Is the hottest known white dwarf a bare O/Ne stellar core?

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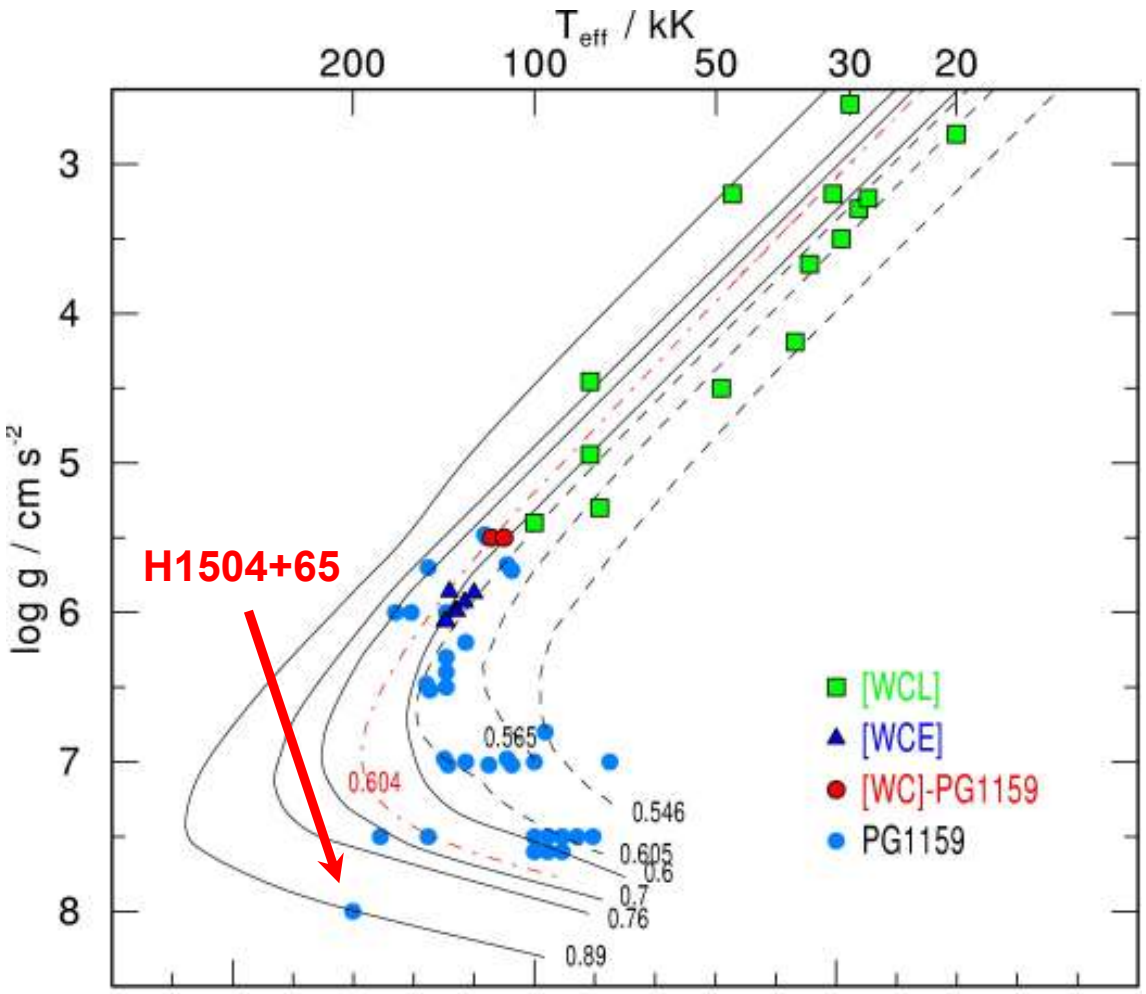
H1504+65 is spectroscopically related to the PG1159 stars, a group of 40 very hot hydrogen-deficient (pre-) white dwarfs:

T_{eff} = 75,000 – 200,000 K log g= 5.5 – 8

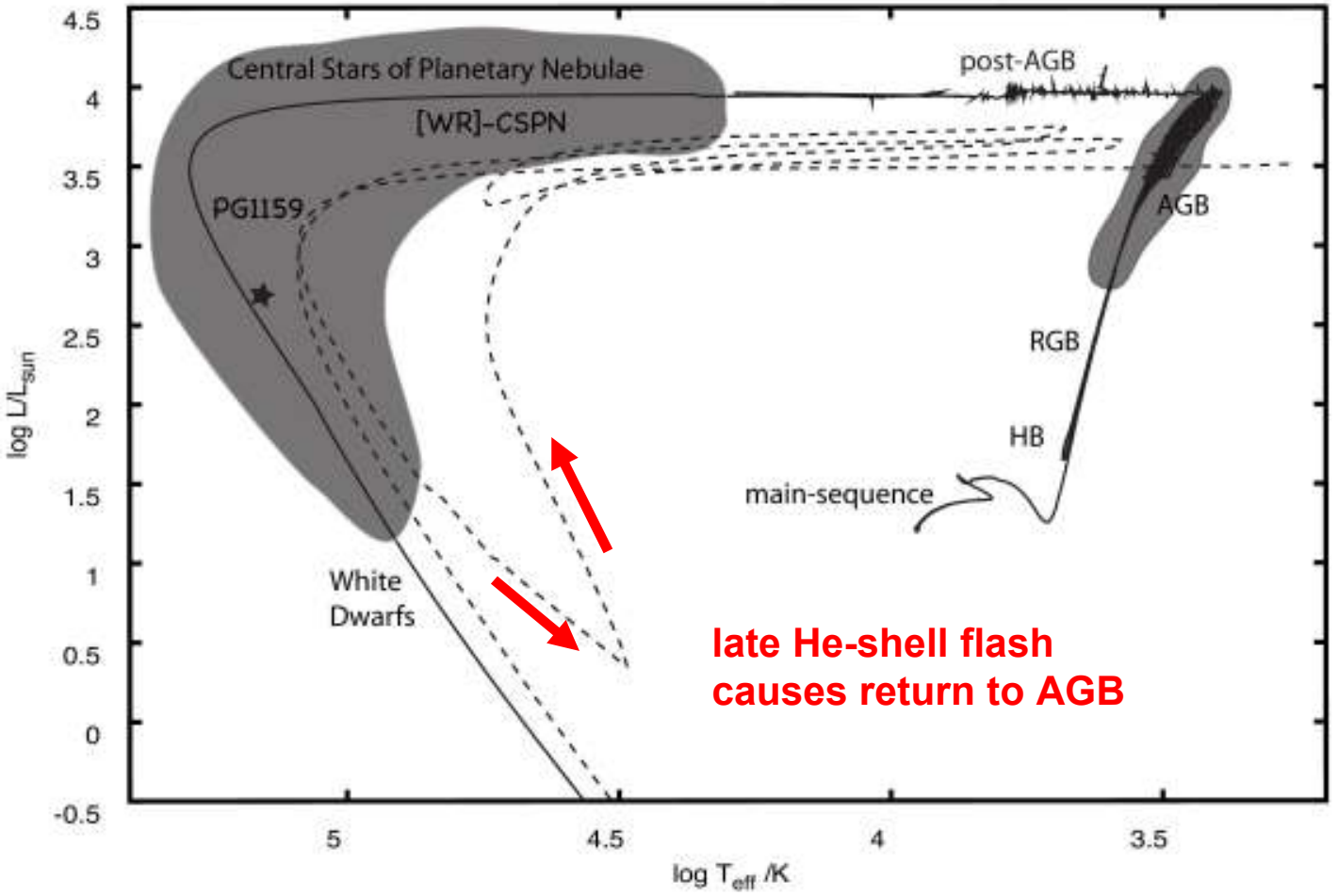
$M/M_{\odot}$ = 0.51 – 0.84 (mean 0.57) log $L/L_{\odot}$= 1.1 – 4.2



Evolutionary tracks: Wood & Faulkner (1986), Schönberner (1983), Blöcker (1995) (all with H-rich surface)

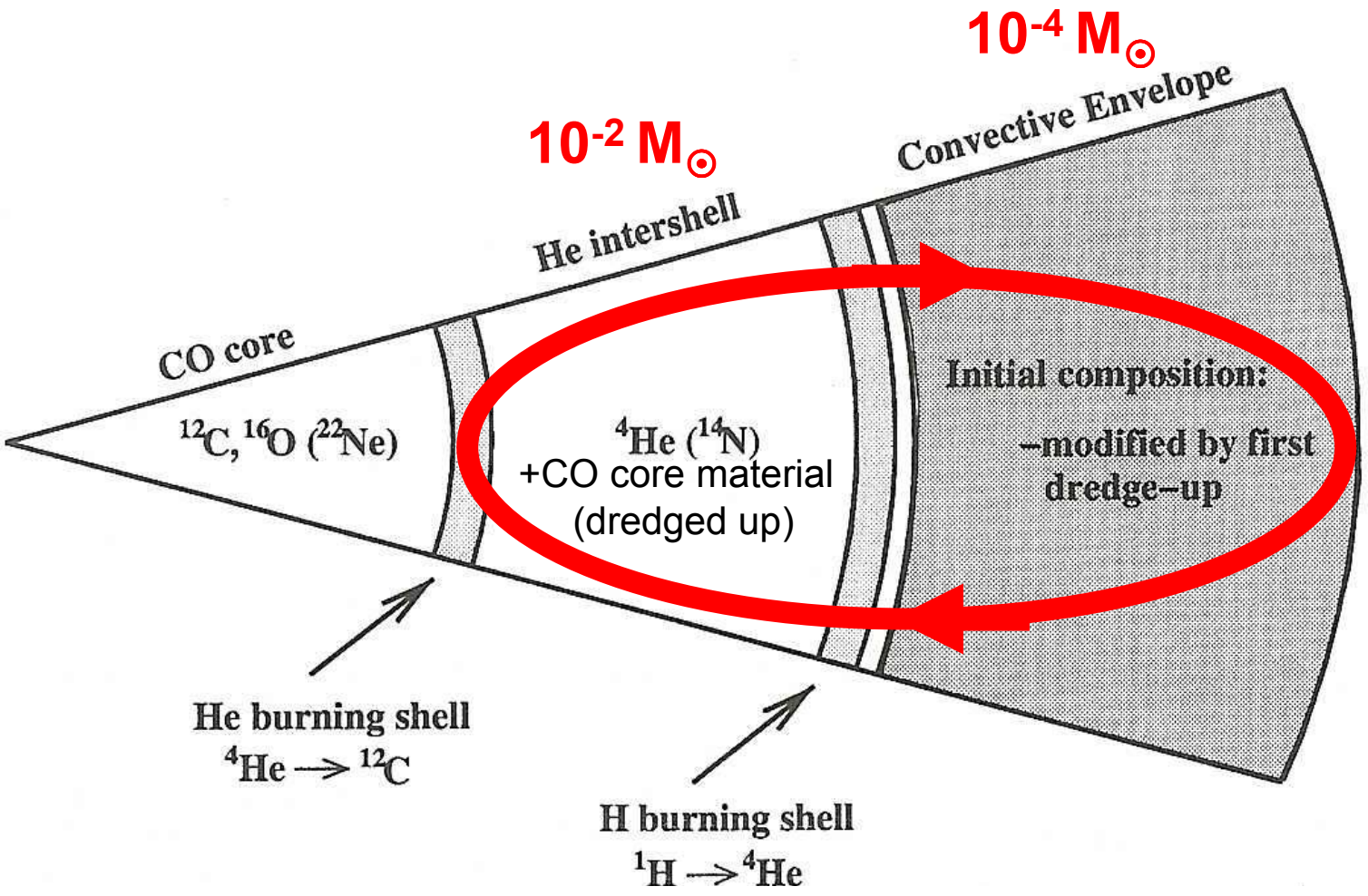
Red track: H-deficient VLTP (Herwig 2003)

- Atmospheres of PG1159 stars dominated by C, He, O, Ne, e.g. prototype PG1159-035: He=33%, C=48%, O=17%, Ne=2% (mass fractions)
- = chemistry of material between H and He burning shells in AGB-stars (intershell abundances)
- Probably result of late He-shell flash



Tracks for a 2 $M_{\odot}$ star. Born-again track offset for clarity.
(Werner & Herwig 2006)

- Hydrogen envelope (thickness 10^{-4} $M_\odot$) is ingested and burned (very late flash) or diluted (late flash) in He-rich intershell (thickness 10^{-2} $M_\odot$)
- In any case, composition of He/C/O-rich intershell region dominates completely



Properties of H1504+65

1983 – H1504 is the 7th brightest X-ray source in the 0.25 keV band
(HEAO1 survey, Nugent et al.)

1986 – Optical identification: Extremely hot white dwarf, lacking H and He lines (Nousek et al.)

1991 – NLTE analysis of optical spectra (Werner):

It is the hottest WD known (T_{eff} close to 200 000 K)

H1504 is devoid of hydrogen and helium

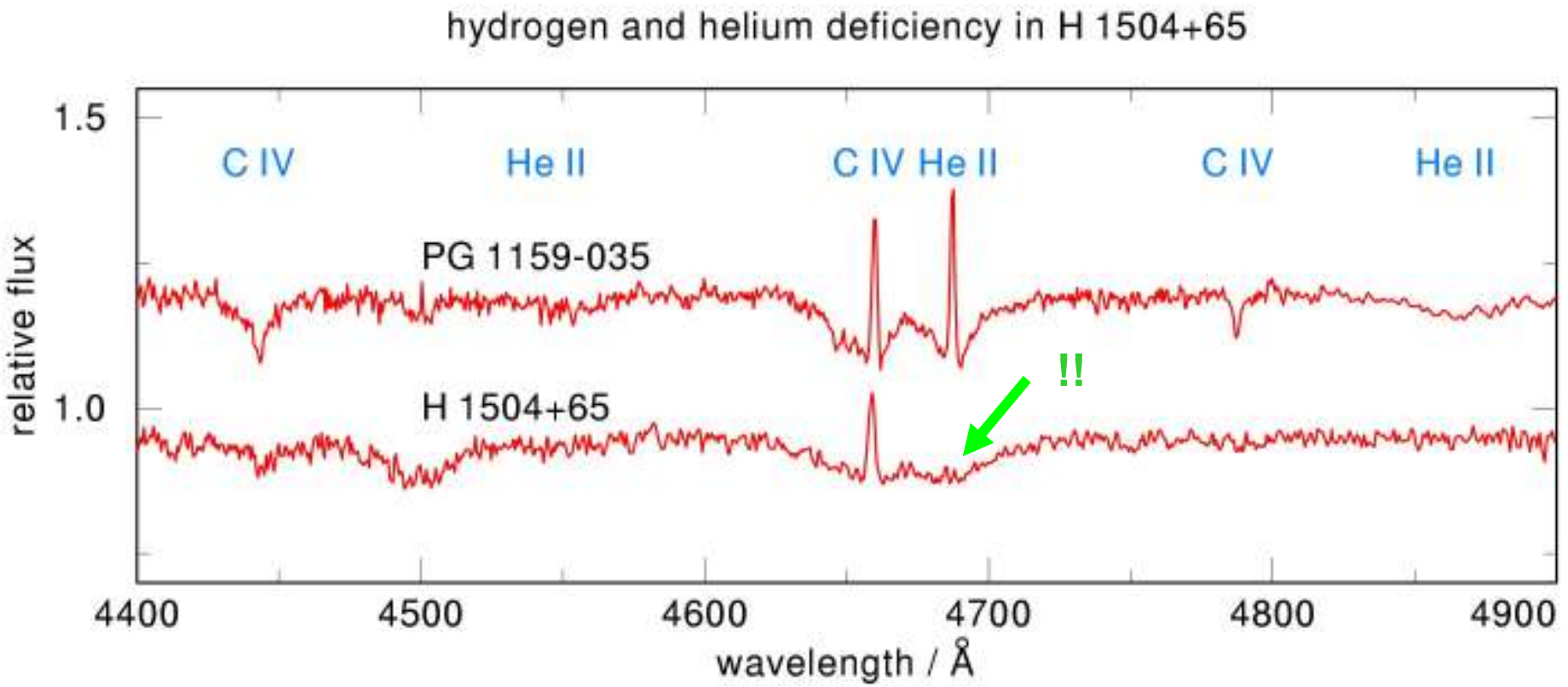
Dominant photospheric species: C and O (50:50)

1999 – Analysis of EUVE & Keck data (Werner & Wolff)

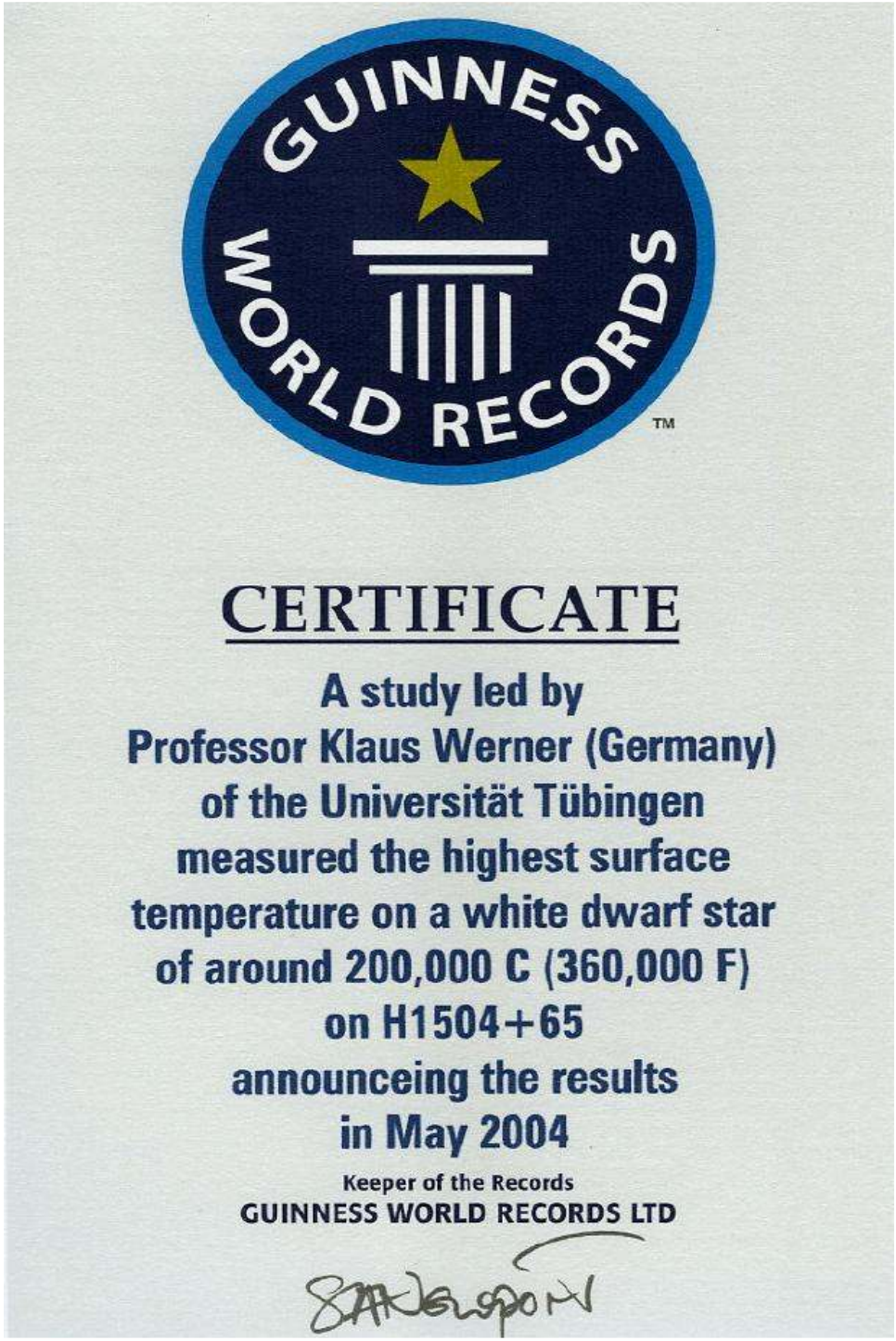
High neon abundance: 2-5% (>20 times solar)

H1504 seems to be an extreme member of the PG1159 spectroscopic class

Comparison of H1504+65 with the prototype PG1159-035 in the optical (Calar Alto 3.5m)

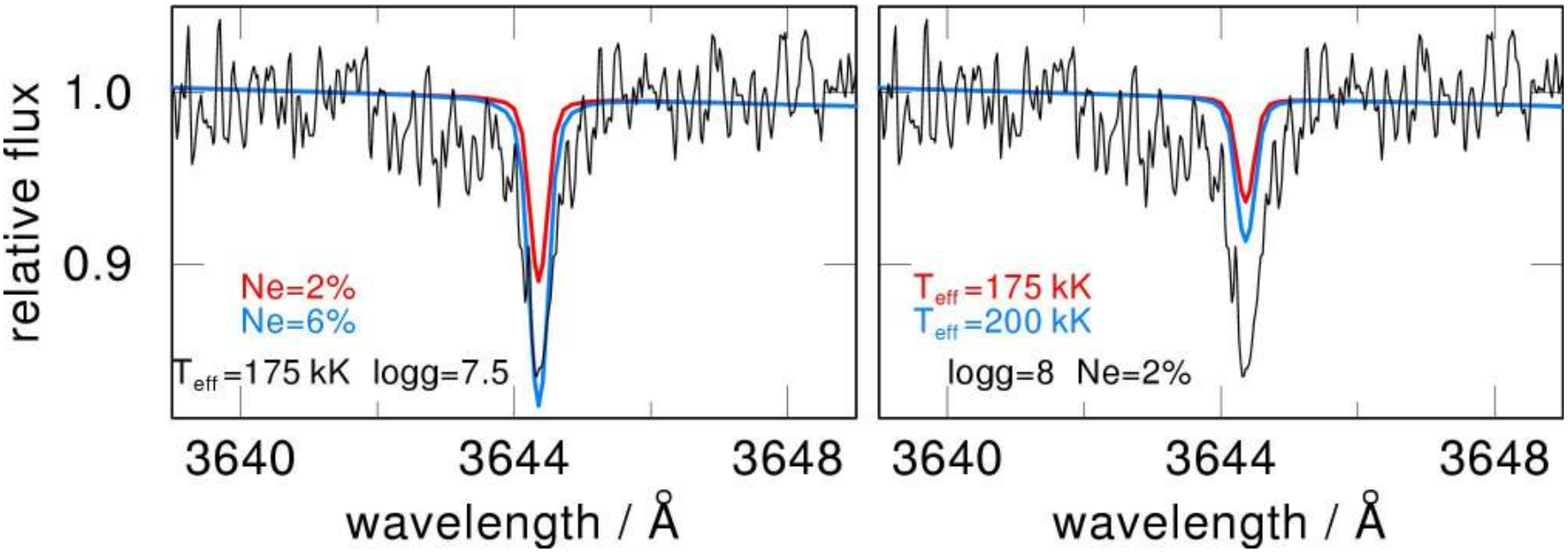


H1504+65 is the hottest star ever analysed!



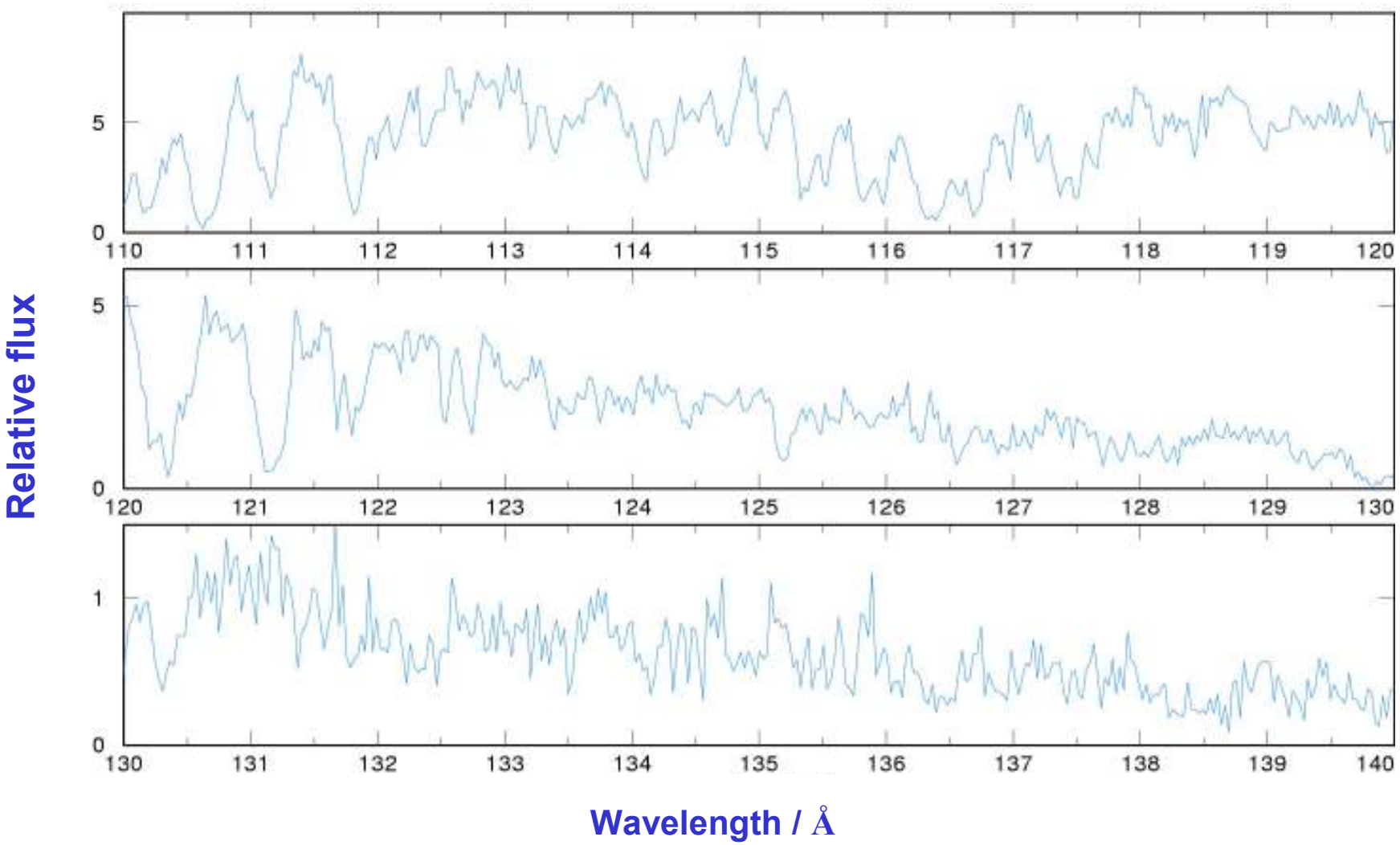
Werner, Rauch, Barstow & Kruk (2004) A&A 421, 1169

Keck spectrum showing a NeVII line: Neon abundance in H1504+65 may be significantly larger than in other PG1159 stars (>5%?)



- Chandra LETG+HRC-S observation of H1504+65:
  Sept. 27, 2000, integration time 7 hours
- Richest absorption line spectrum ever recorded from a stellar photosphere
  (Werner et al. 2004, A&A 421, 1169)
- Examples for spectral fitting:

Model fit to H1504+65 Chandra spectrum 110-140 Å



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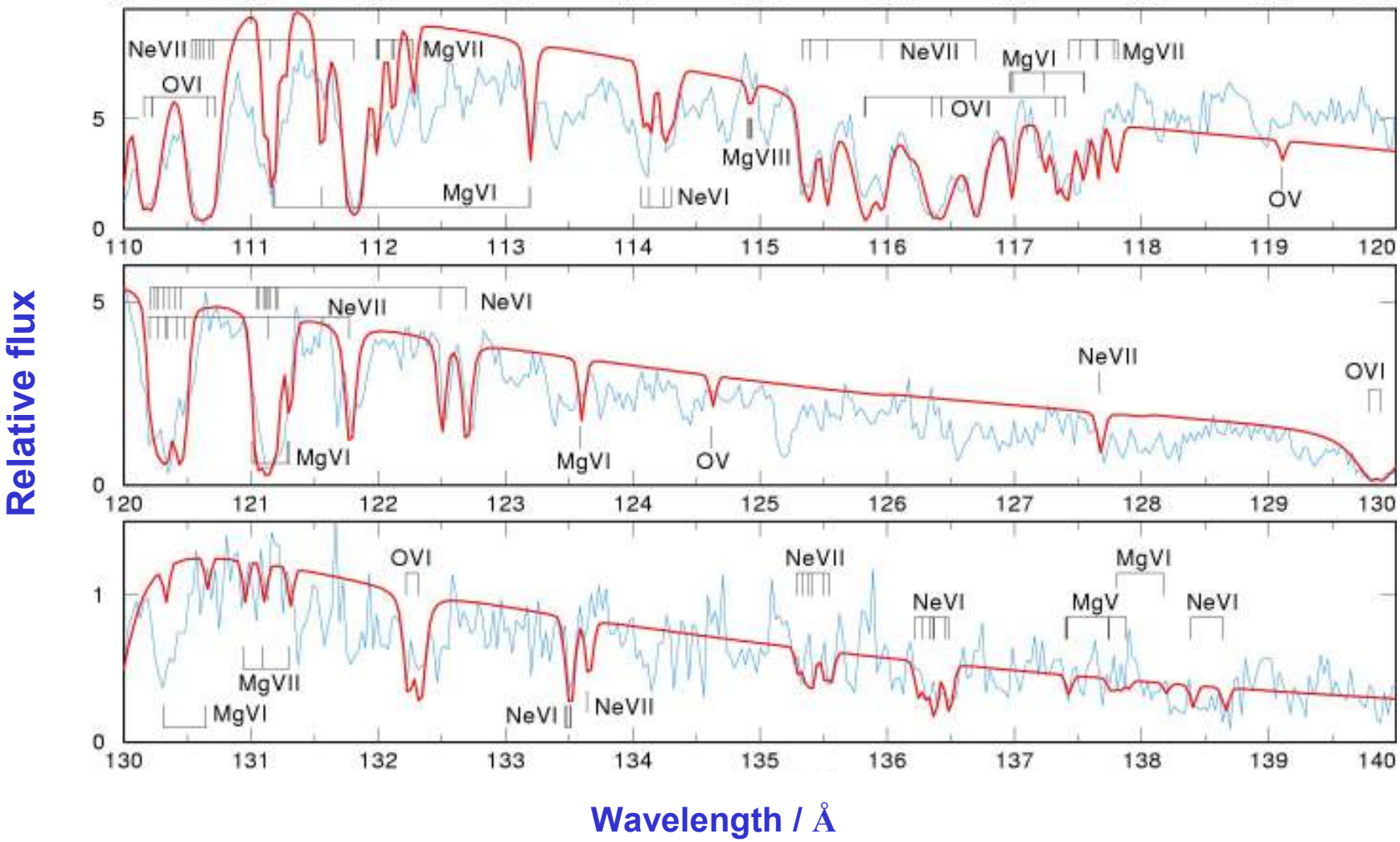
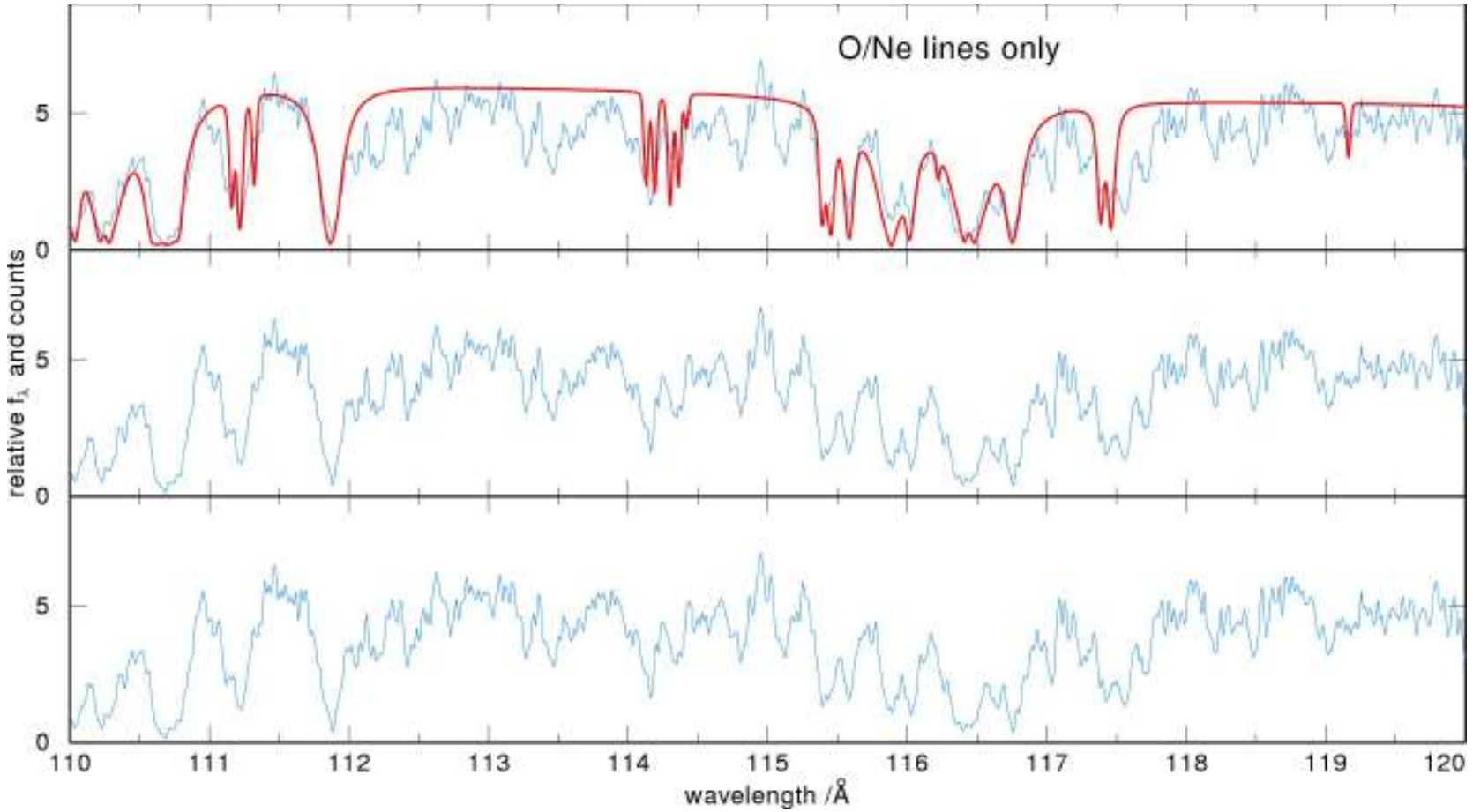


Mg abundance ≈2%

Strong Fe-group line blanketing



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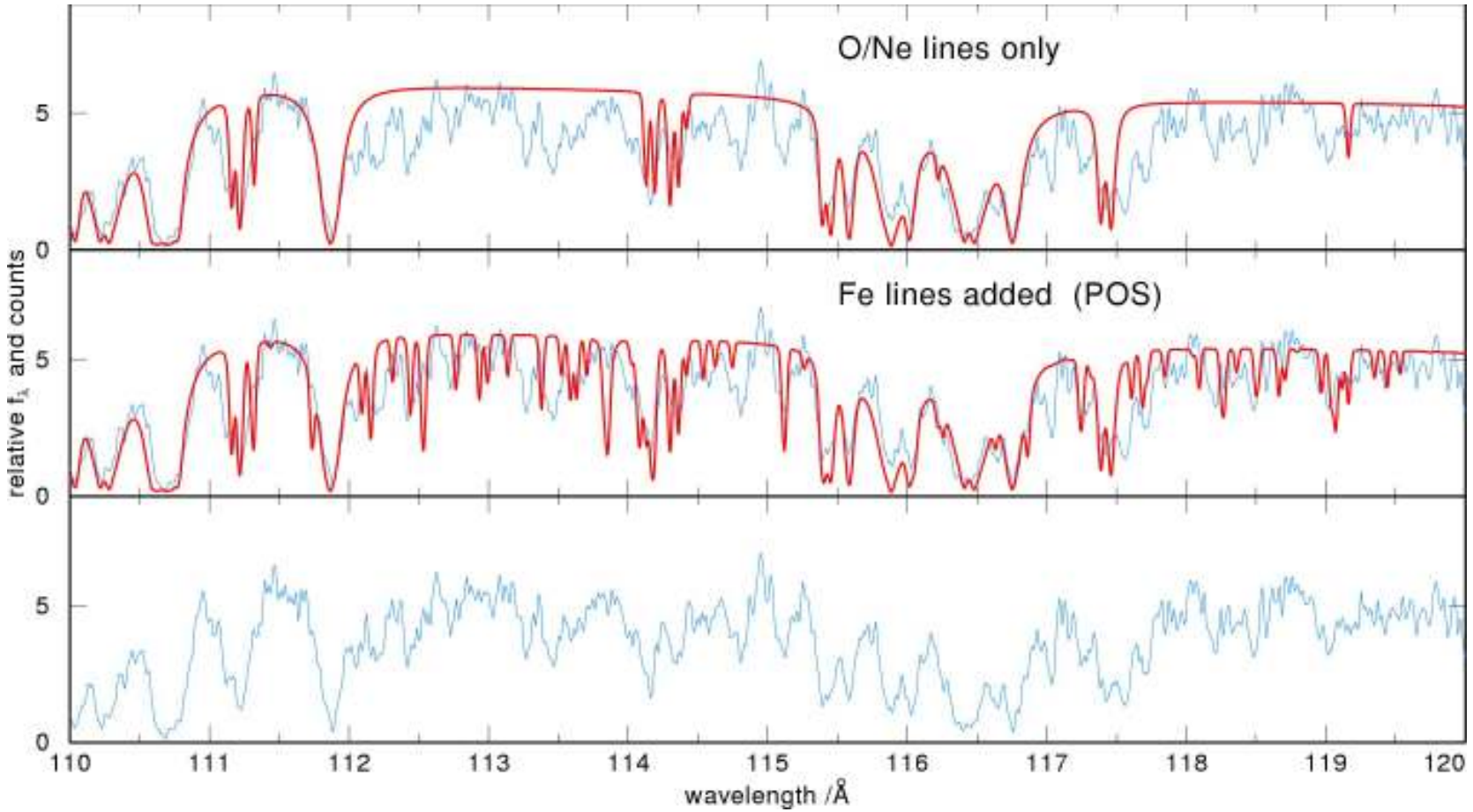

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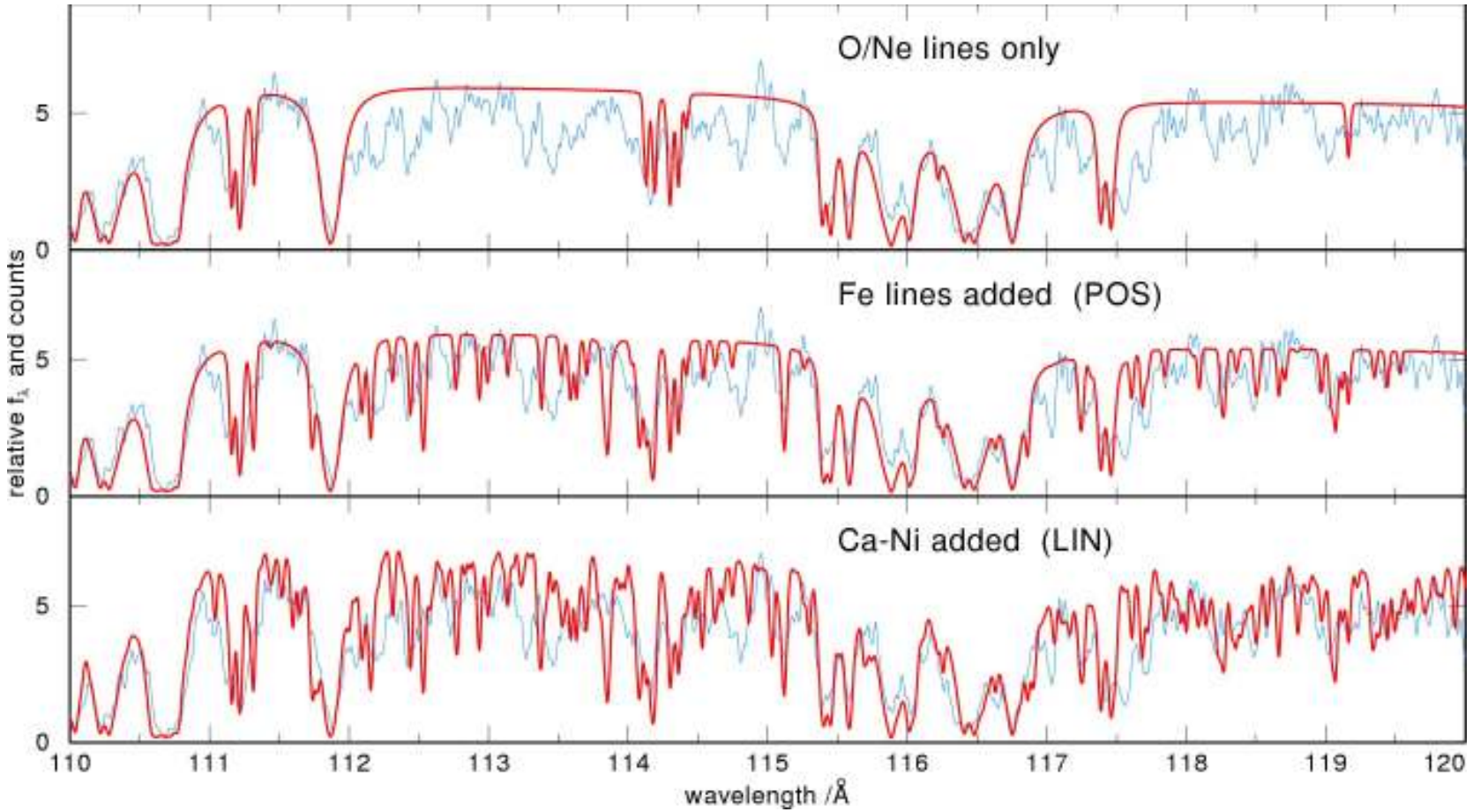
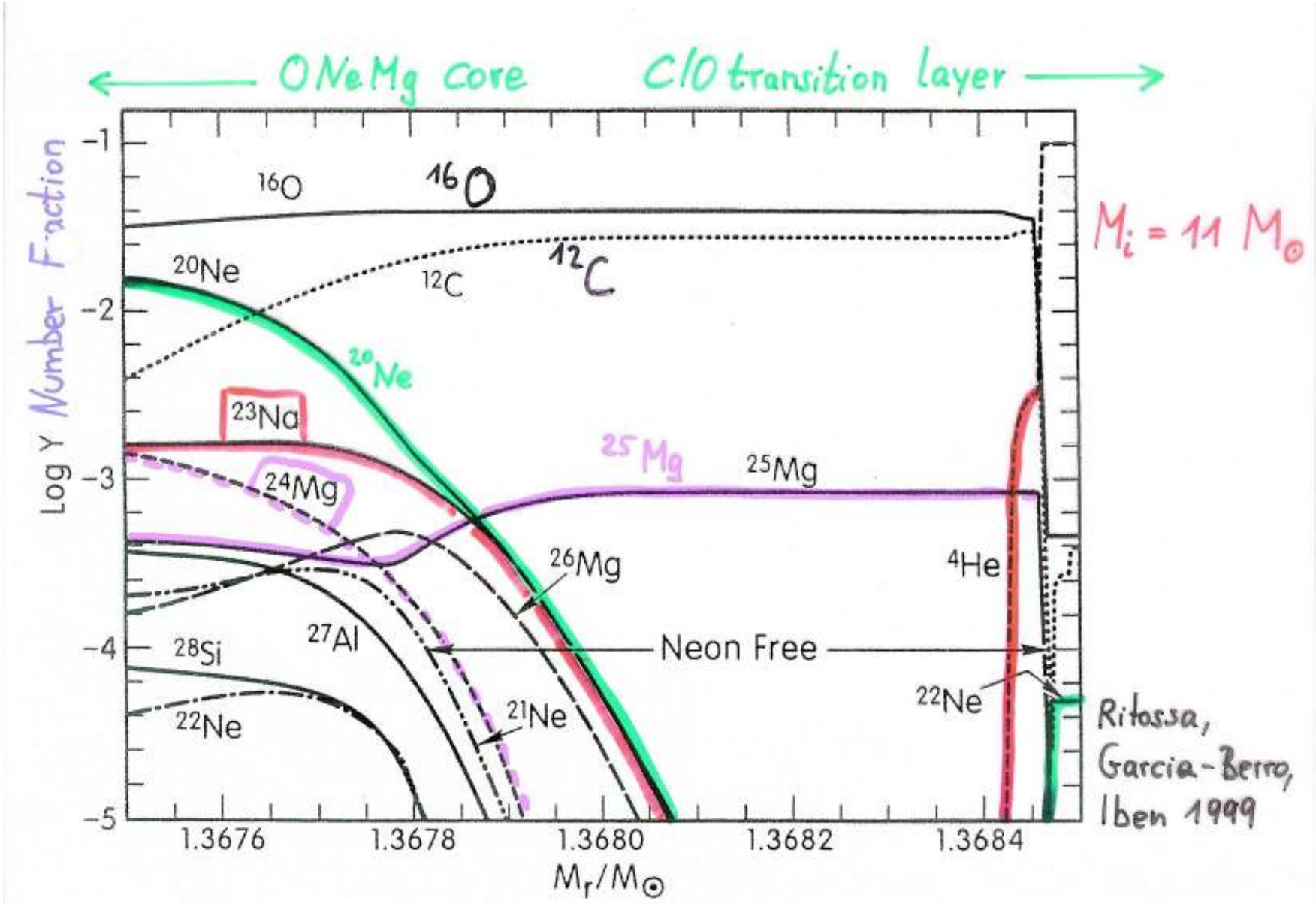


Abundance of iron-group elements roughly solar

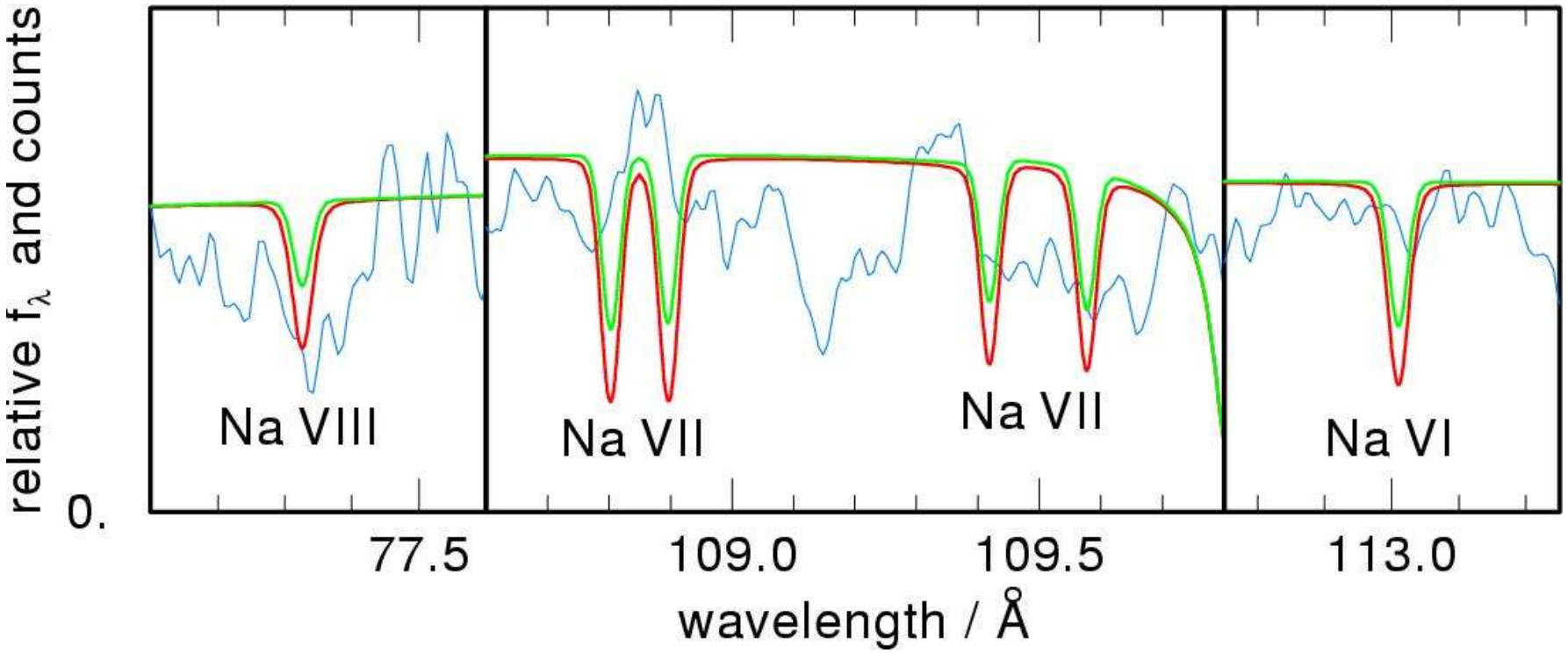
Is H1504+65 just an extreme PG1159 star, i.e., a post-AGB object that suffered a late He-shell flash? Possibly not, because:

- He-deficiency is a unique phenomenon, as well as the very high O/C ratio (≈unity)
- High Ne and Mg abundances suggest that H1504+65 could be a bare O/Ne/Mg white dwarf, i.e. first observational proof for existence of such objects (single stars)
- If so, what process caused the loss of its entire H and He envelopes: mass-loss or burning?



Sodium abundance is the key! Approved HST UV-spectroscopy (2005): Search for Na, but: failure of STIS just before observations should be done

Search for Na lines in the Chandra spectrum unsuccessful. Line blending and noise too strong.



Model abundances: Na=0.3% and 0.02% → (uncertain) upper limit about 0.1%

Summary: properties of H1504+65

T_{eff}=200,000 K log g =8.0

Mass is „high“: 0.84 $M_{\odot}$ (+0.13/-0.10) But: derived from post-AGB tracks

Surface chemistry:

no H, no He, C/O dominated (C=O=0.48, +/-20%)

Other species (factor 3 uncertainty!) :

Ne=Mg=0.02 Na and Al < 0.001 iron group solar

- H1504+65: either bare C/O white dwarf or even O/Ne white dwarf
- Future HST or deeper Chandra spectroscopy could decide
- Evolutionary scenario? Is H1504+65 a post-super AGB star? What caused loss of H and He envelopes? (no hint for binary nature)

- Note: Recent discovery of relatively cool (20,000 K) WDs with pure carbon atmospheres (Dufour et al. 2007) → evolutionary link?