

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

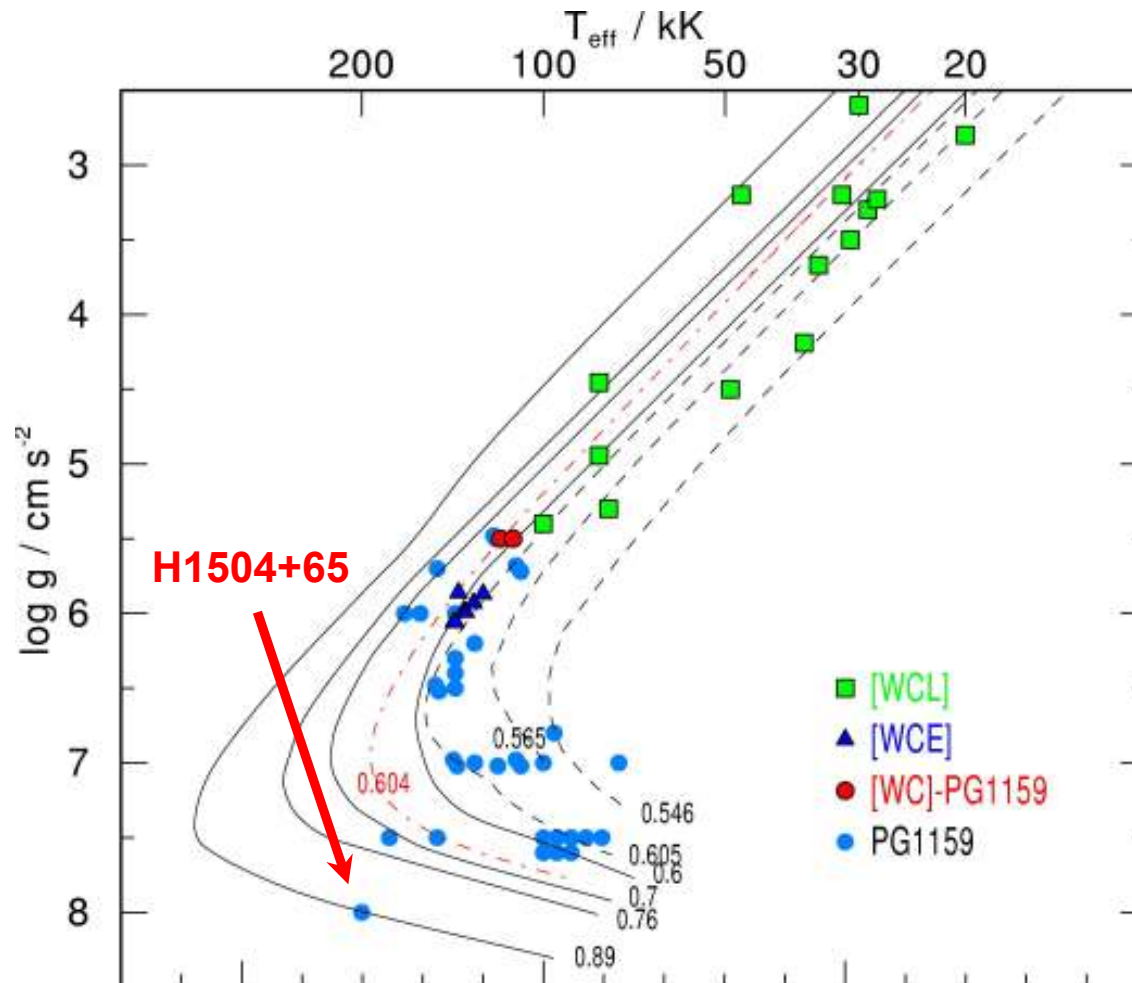
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H1504+65 is spectroscopically related to the **PG1159 stars**, a group of 40 very hot hydrogen-deficient (pre-) white dwarfs:

$$T_{\text{eff}} = 75,000 - 200,000 \text{ K} \quad \log g = 5.5 - 8$$

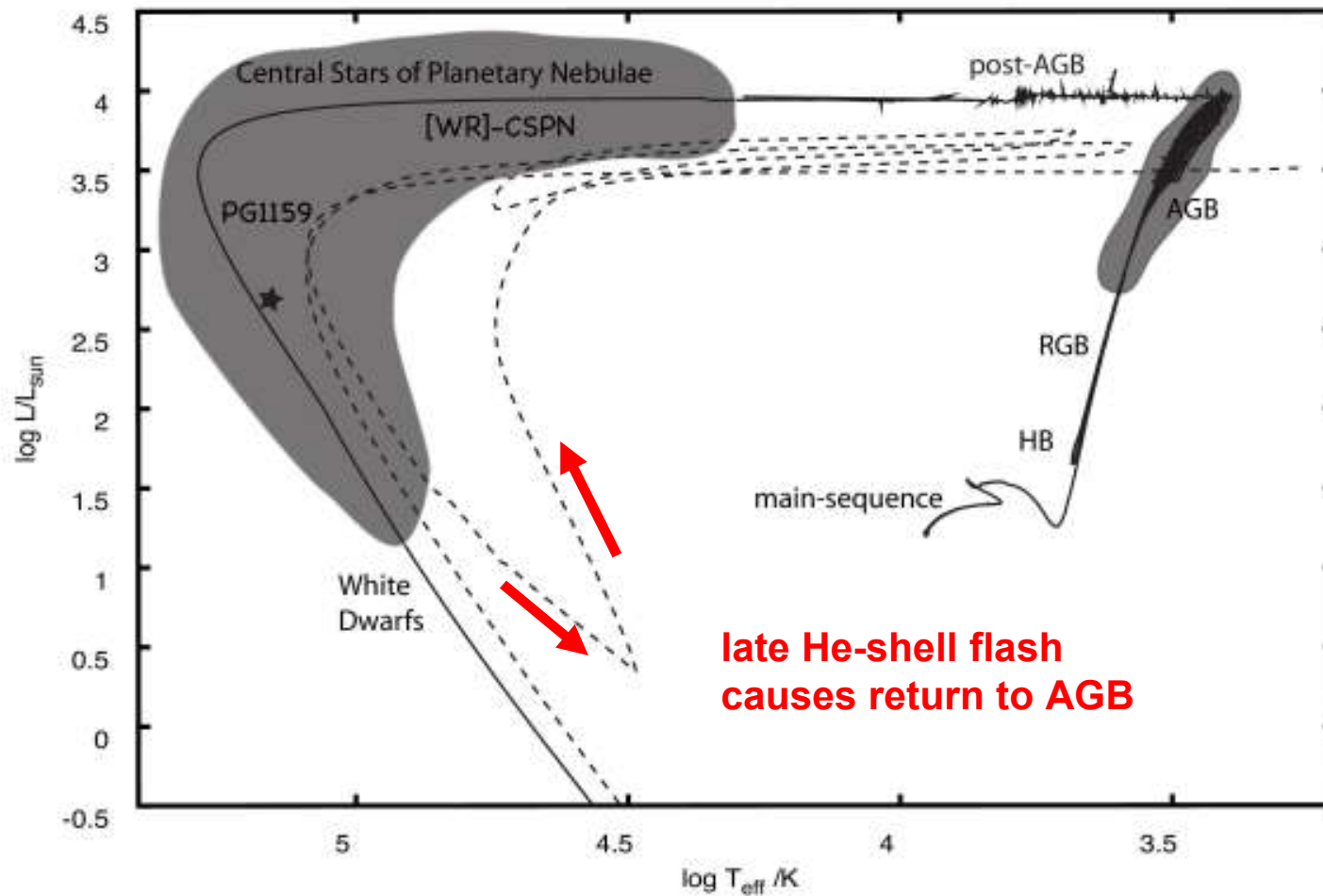
$$M/M_{\odot} = 0.51 - 0.84 \text{ (mean 0.57)} \quad \log L/L_{\odot} = 1.1 - 4.2$$



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

Red track: H-deficient VLTP (Herwig 2003)

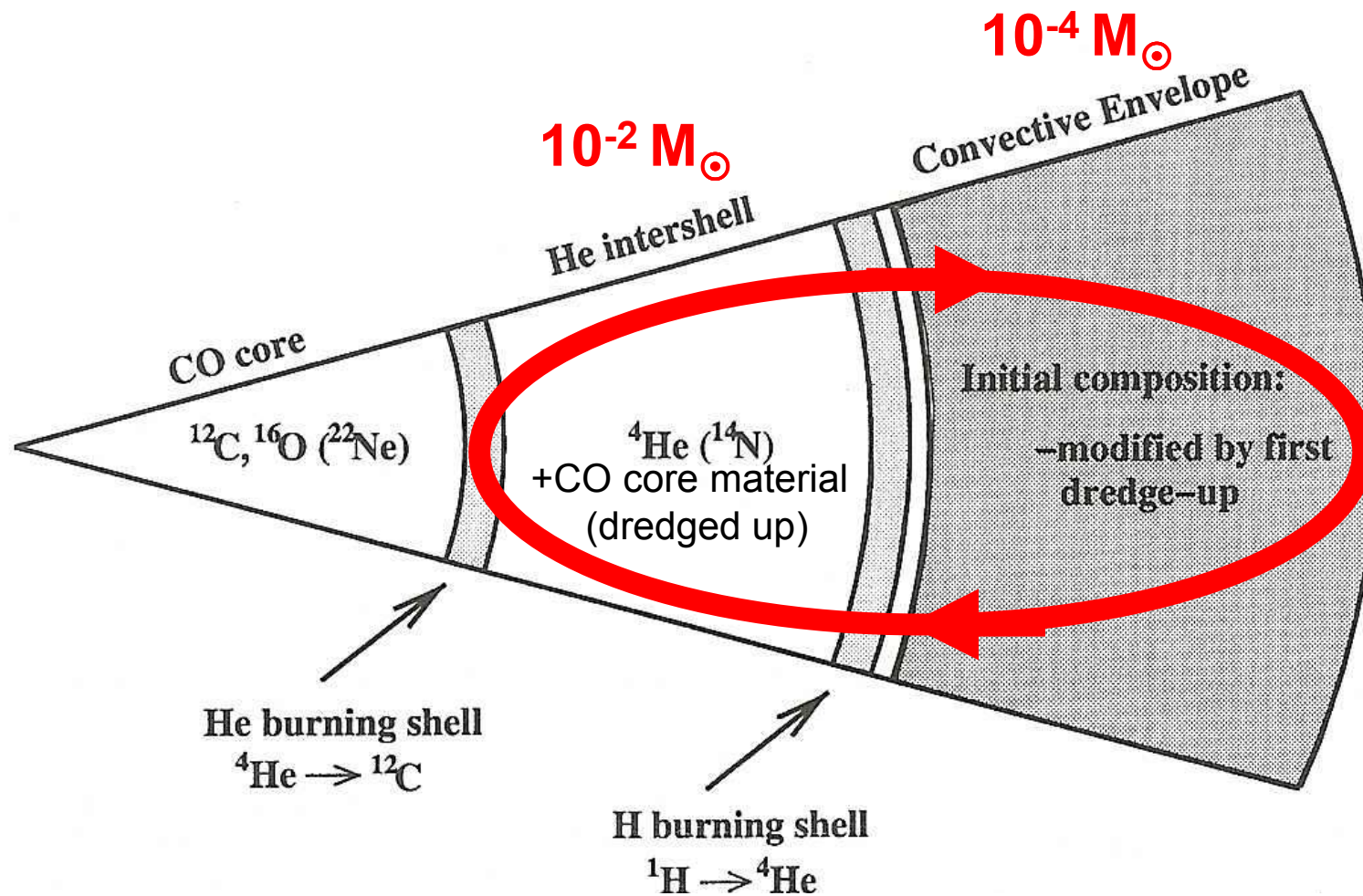
- Atmospheres of PG1159 stars dominated by C, He, O, Ne, e.g. prototype PG1159-035: He=33%, C=48%, O=17%, Ne=2% (mass fractions)
- = chemistry of material between H and He burning shells in AGB-stars (**intershell abundances**)
- Probably result of late He-shell flash



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

**late He-shell flash
causes return to AGB**

- 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**



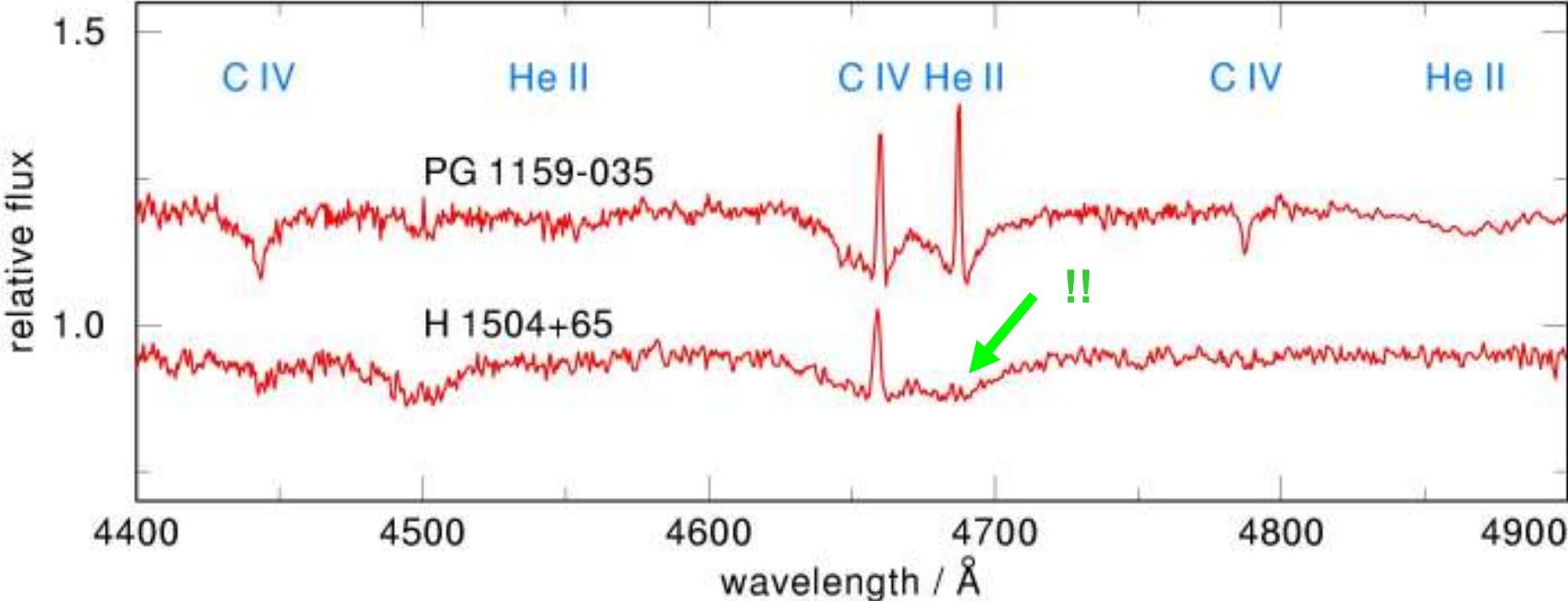
Properties of H1504+65

- 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)

hydrogen and helium deficiency in H 1504+65



H1504+65 is the hottest star ever analysed!

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



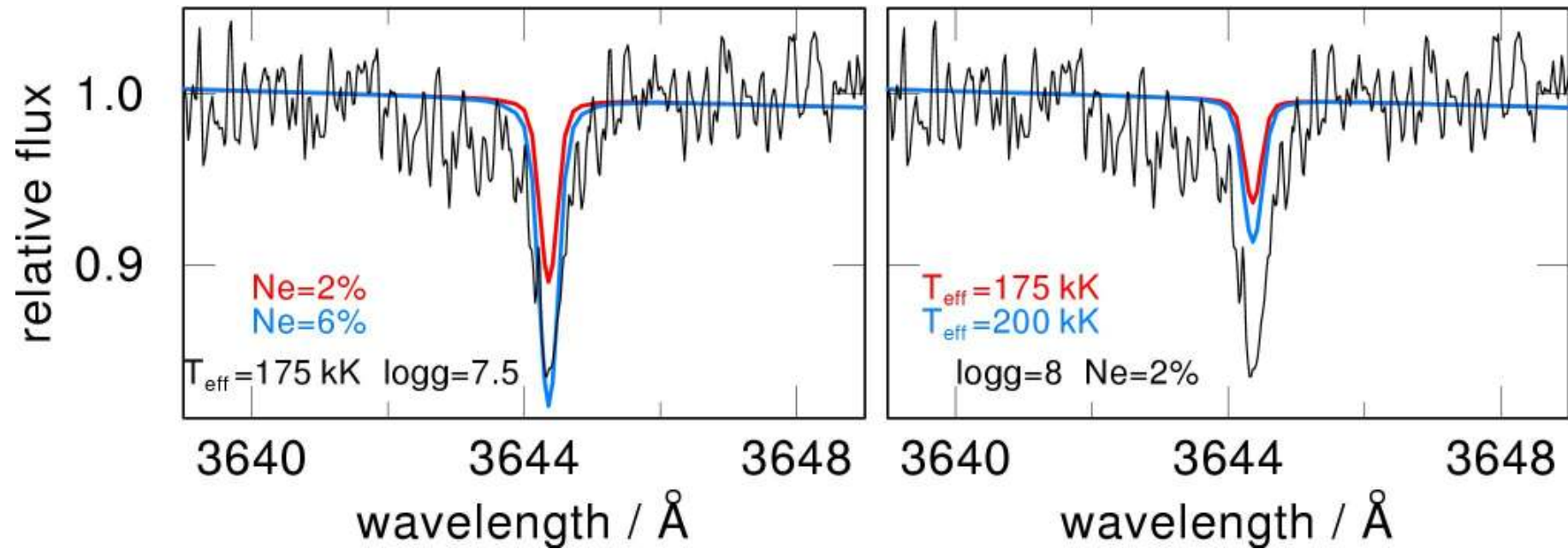
CERTIFICATE

**A study led by
Professor Klaus Werner (Germany)
of the Universität Tübingen
measured the highest surface
temperature on a white dwarf star
of around 200,000 C (360,000 F)
on H1504+65
announcing the results
in May 2004**

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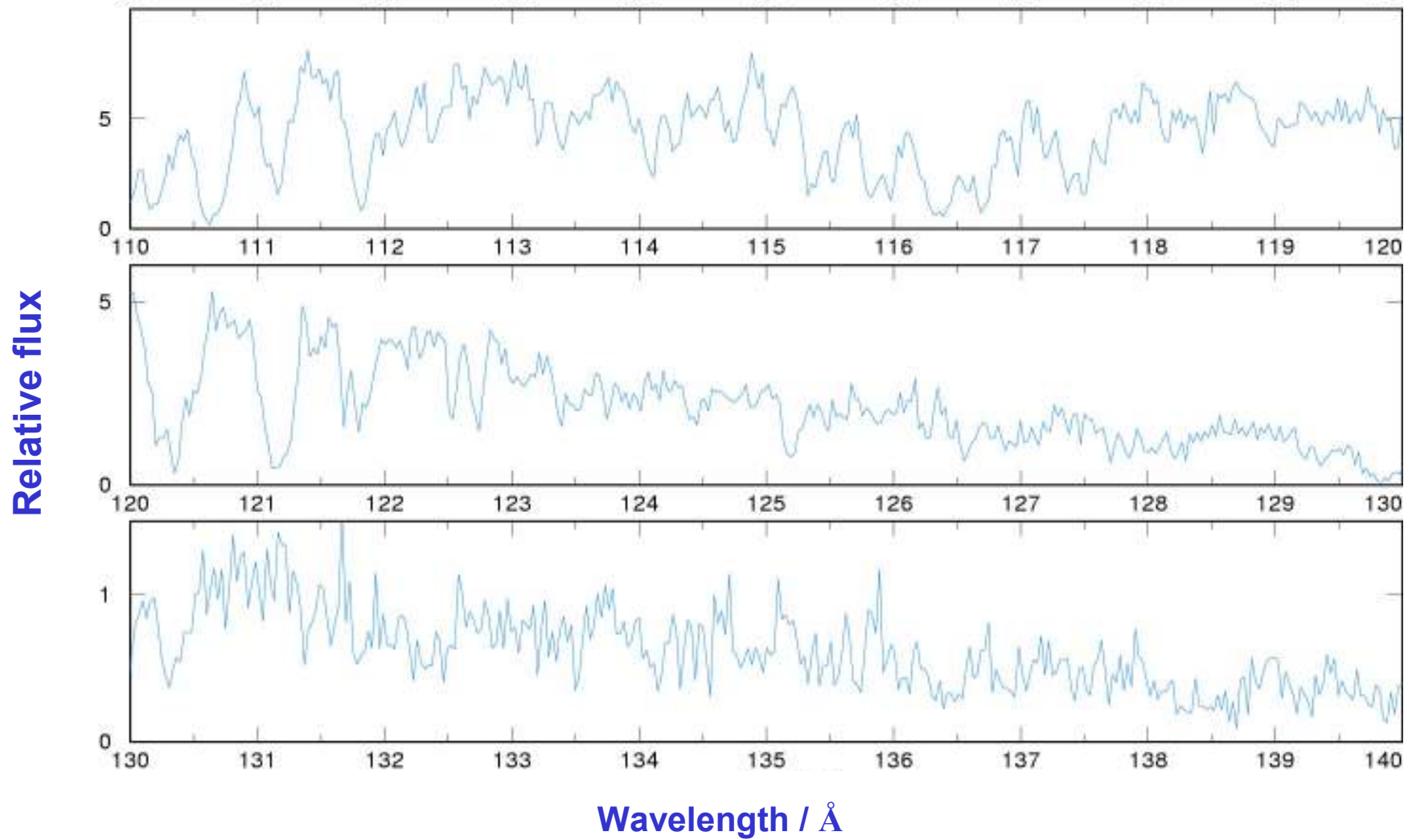
A handwritten signature in black ink, appearing to read "S. Barstow", is written over the printed text of the Guinness World Records Ltd.

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

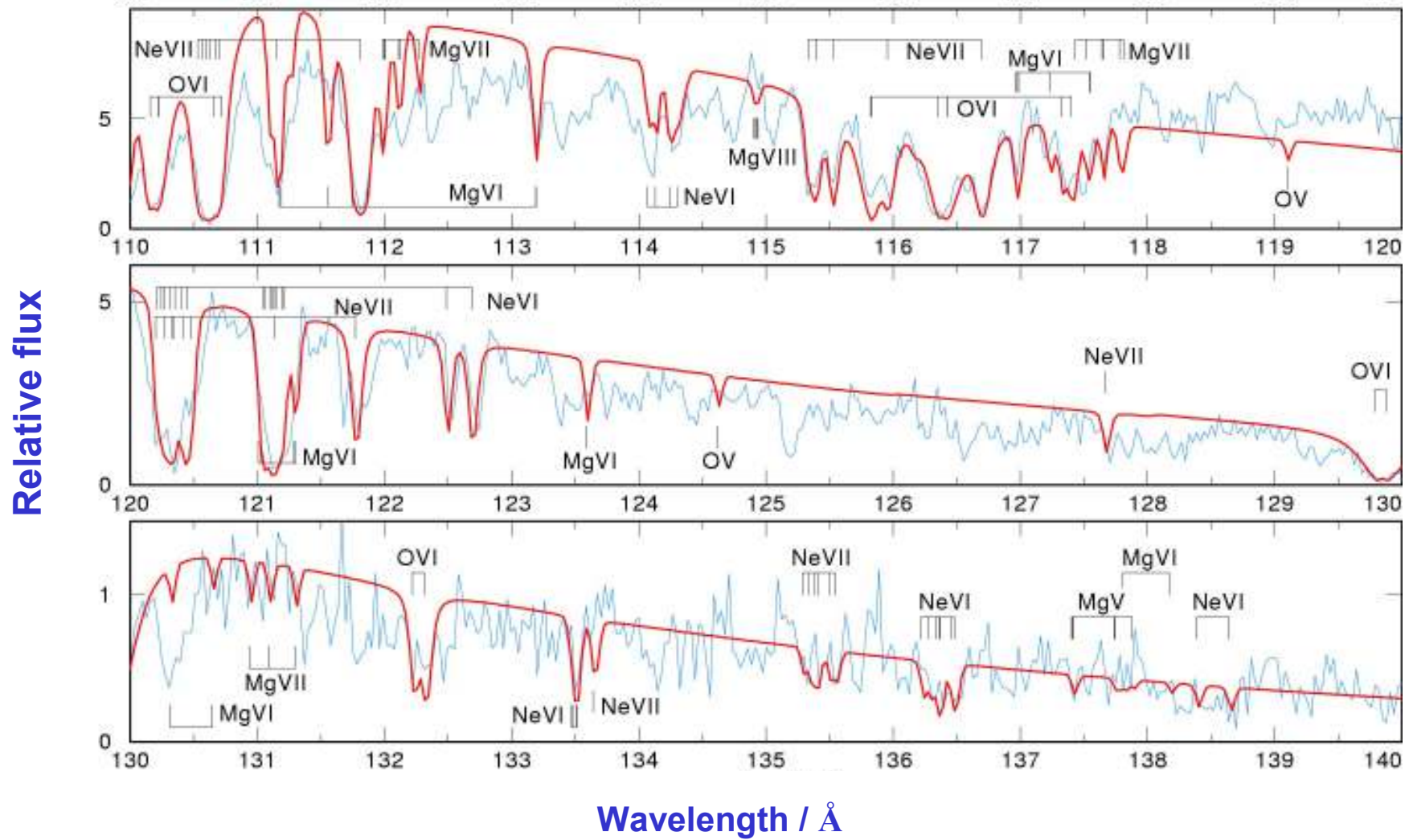


- Chandra LETG+HRC-S observation of H1504+65:
Sept. 27, 2000, integration time 7 hours
- **Richest absorption line spectrum ever recorded from a stellar photosphere**
(Werner et al. 2004, A&A 421, 1169)
- Examples for spectral fitting:

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

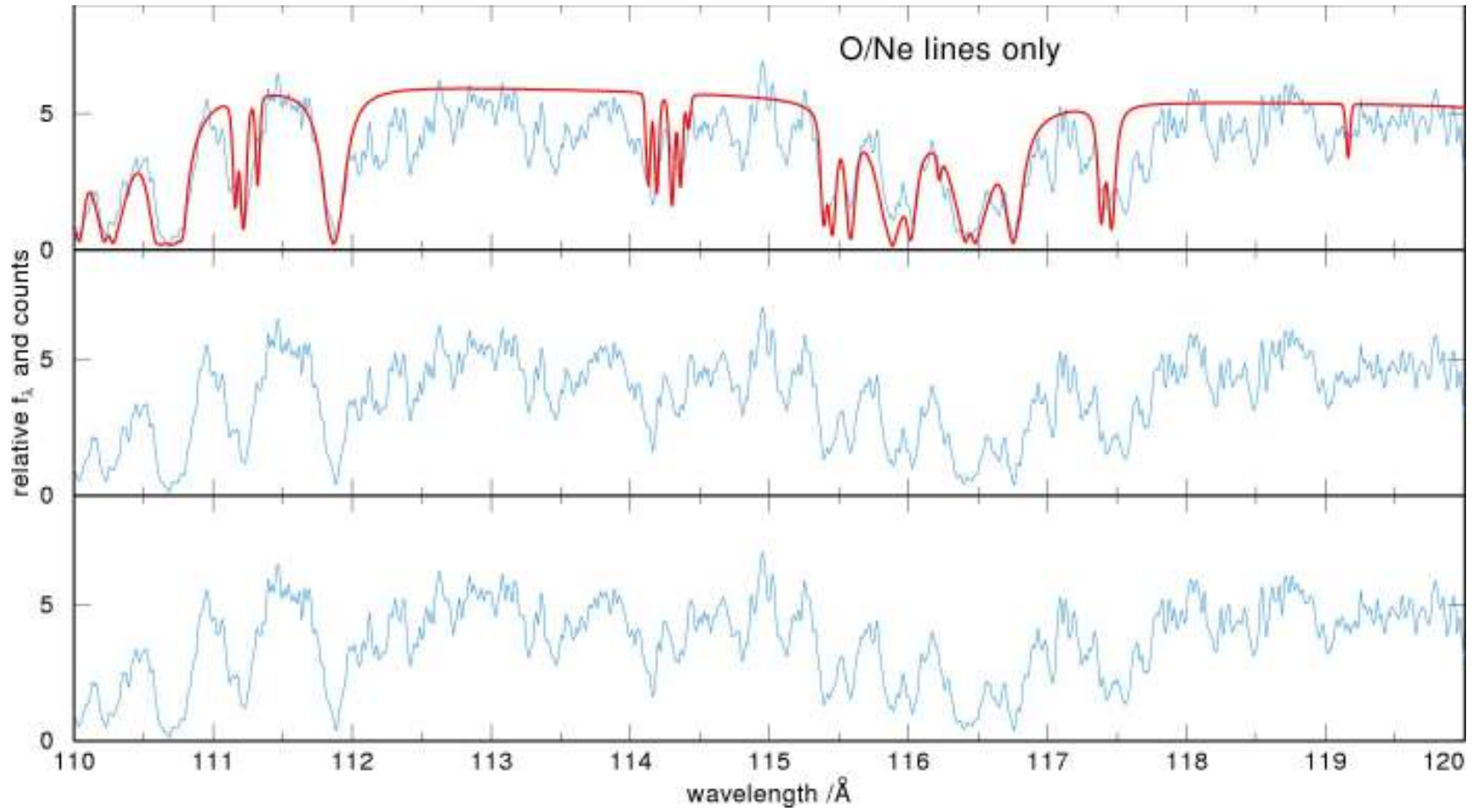


Model fit to H1504+65 Chandra spectrum 110-140 Å

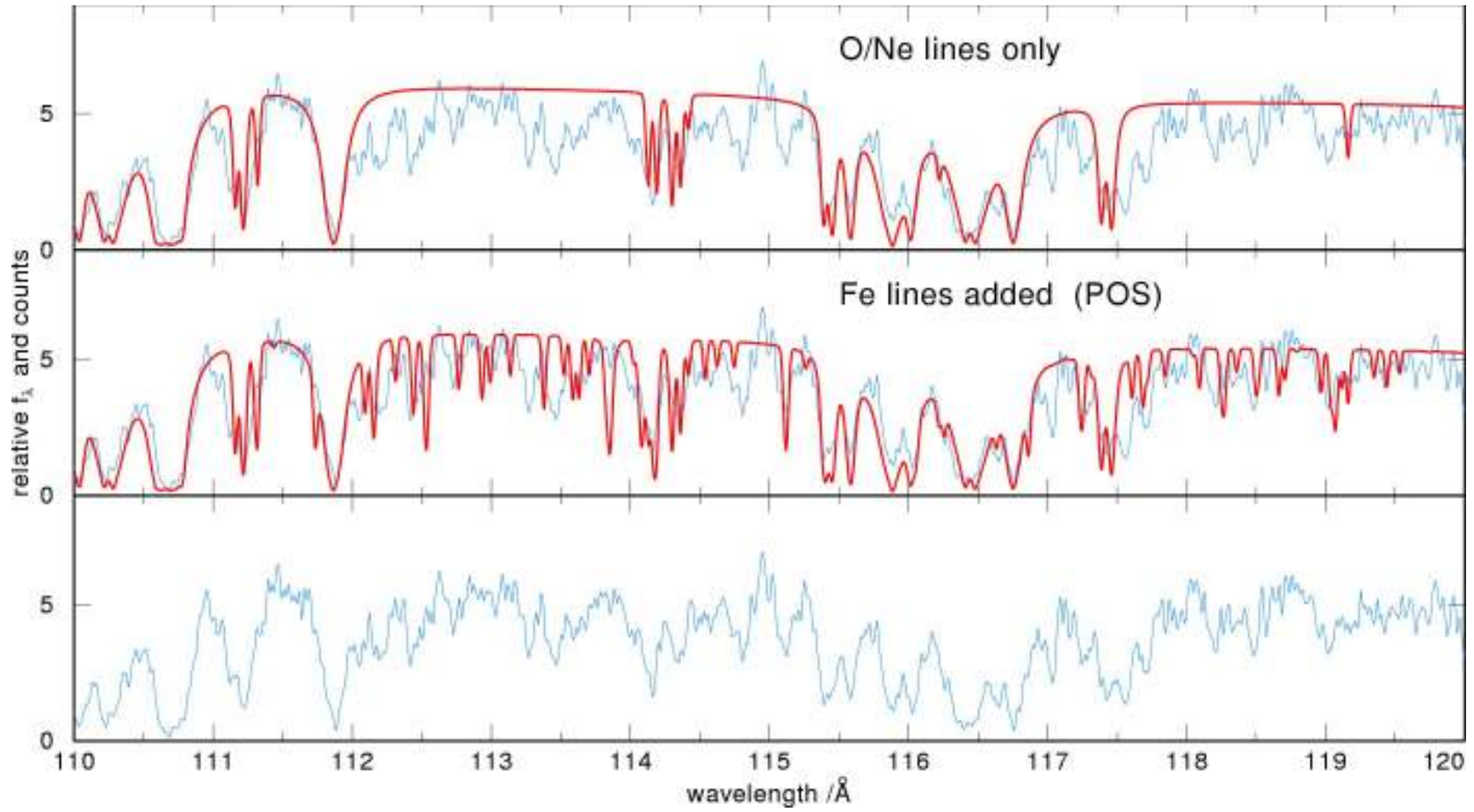


Mg abundance $\approx 2\%$

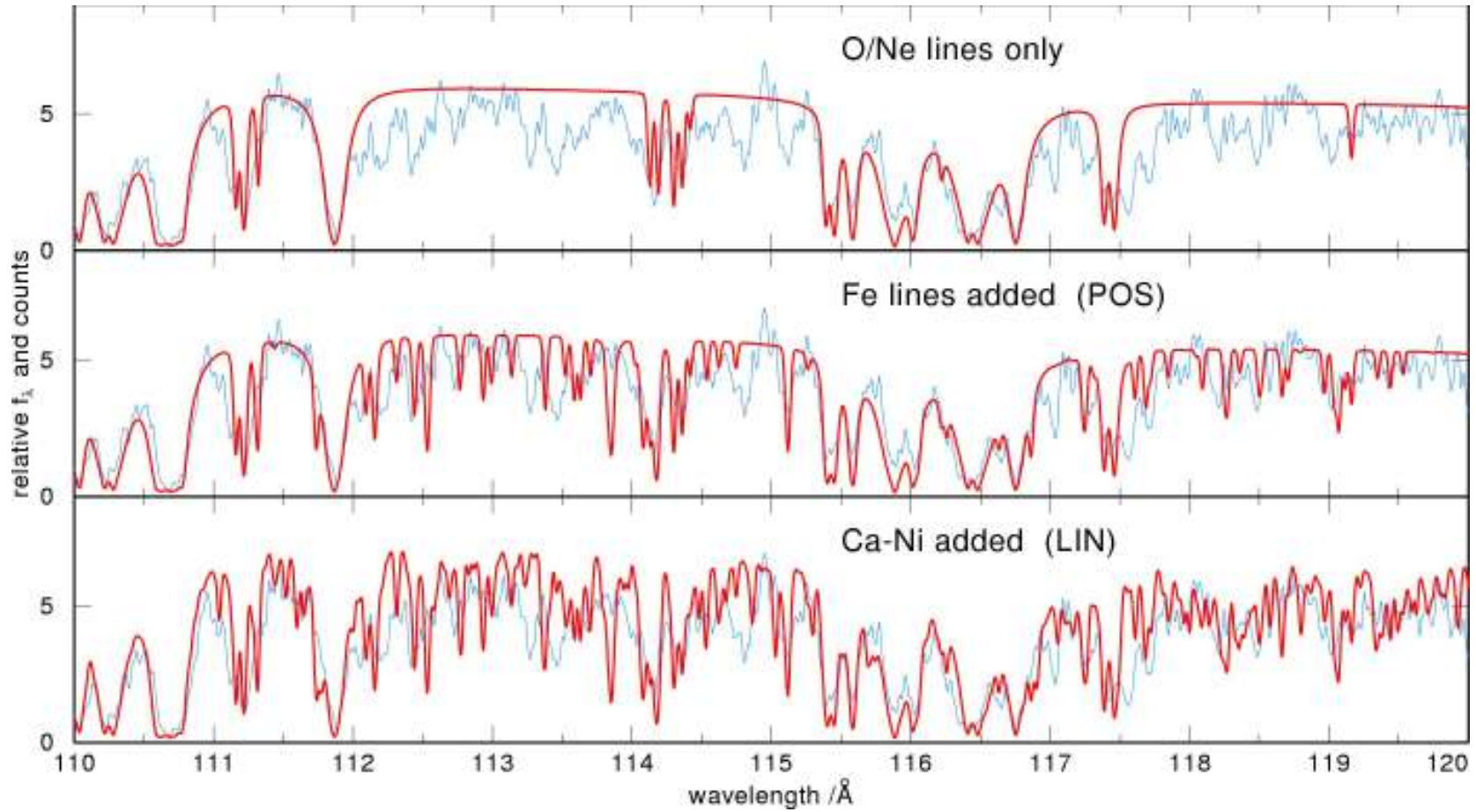
Strong Fe-group line blanketing



Strong Fe-group line blanketing



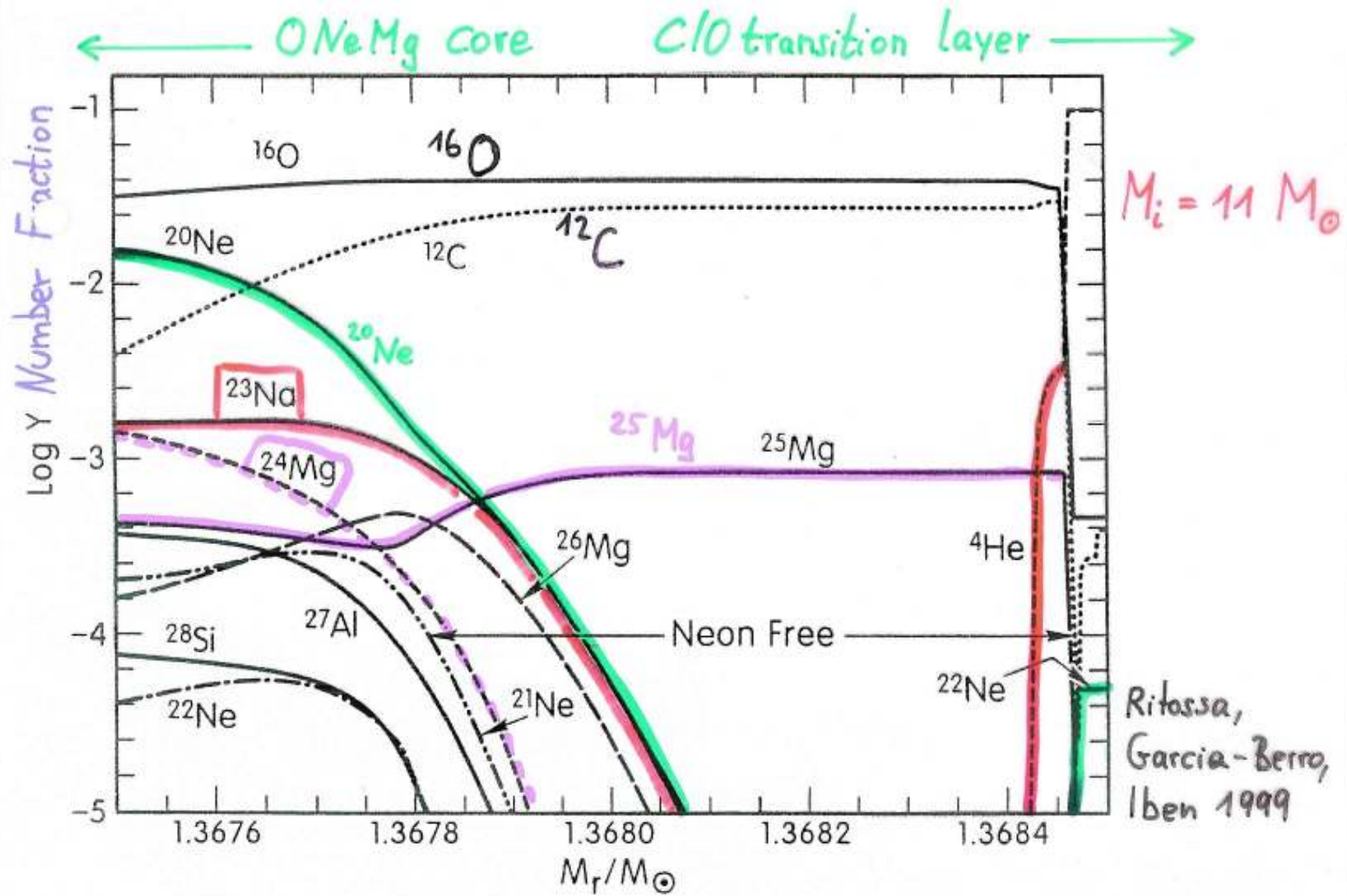
Strong Fe-group line blanketing



Abundance of iron-group elements roughly solar

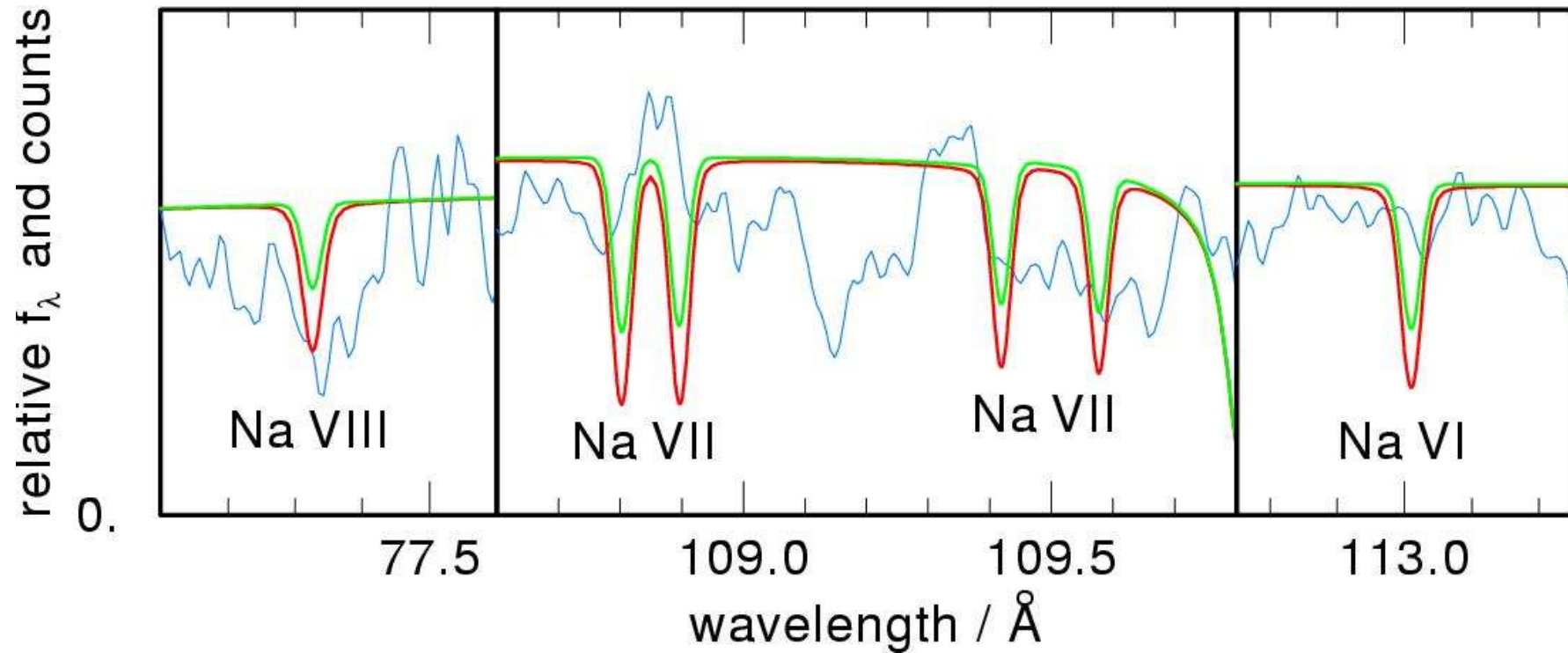
Is H1504+65 just an extreme PG1159 star, i.e., a post-AGB object that suffered a late He-shell flash? Possibly not, because:

- He-deficiency is a unique phenomenon, as well as the very high O/C ratio (\approx 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% \rightarrow (uncertain) upper limit about 0.1%

Summary: properties of H1504+65

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

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?