Spectral Analysis of HD188112: A Low Mass SdB / Pre He-core WD

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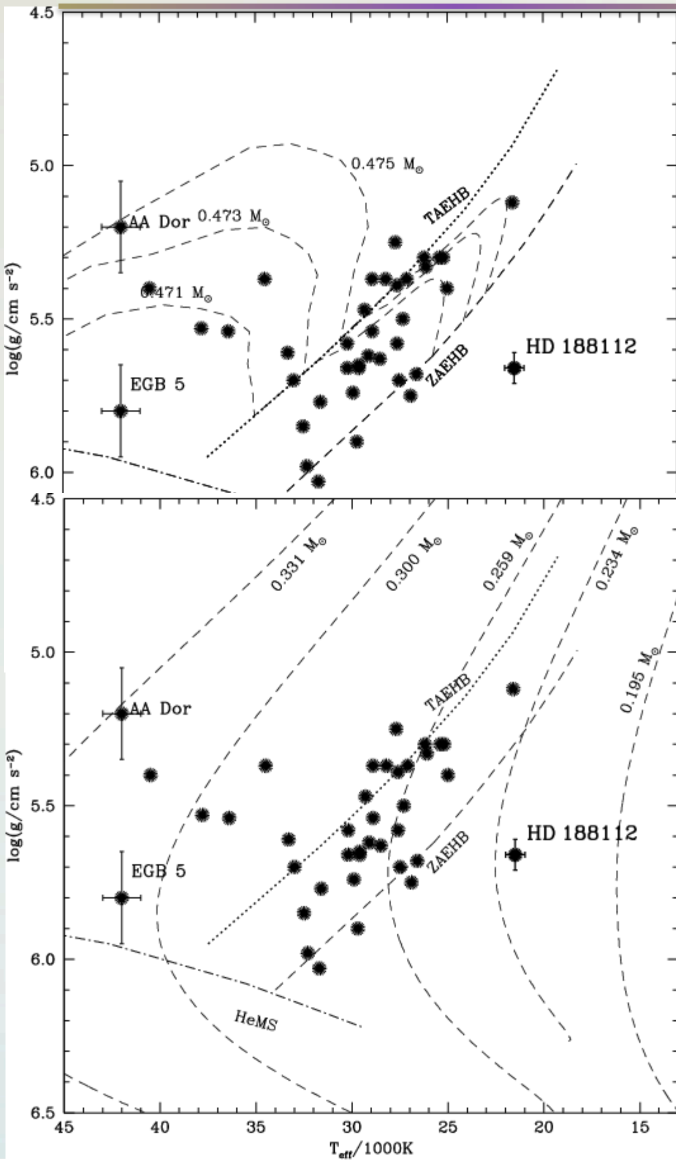
Introduction

HD 188112



Heber et al. 2003

- Radial velocity variable, close binary system
- Teff = 21 500 K
  log g = 5.66
  log N(He)/N(H) = -5.0 (weak He I 5876)
  (Heber et al. 2003, A&A 411)
- Odd position below the EHB
- M ~ 0.23 $M_\odot$ according to evolutionary tracks (Driebe et al. 1998, A&A 339)
- Low mass sdB star / pre-helium core WD

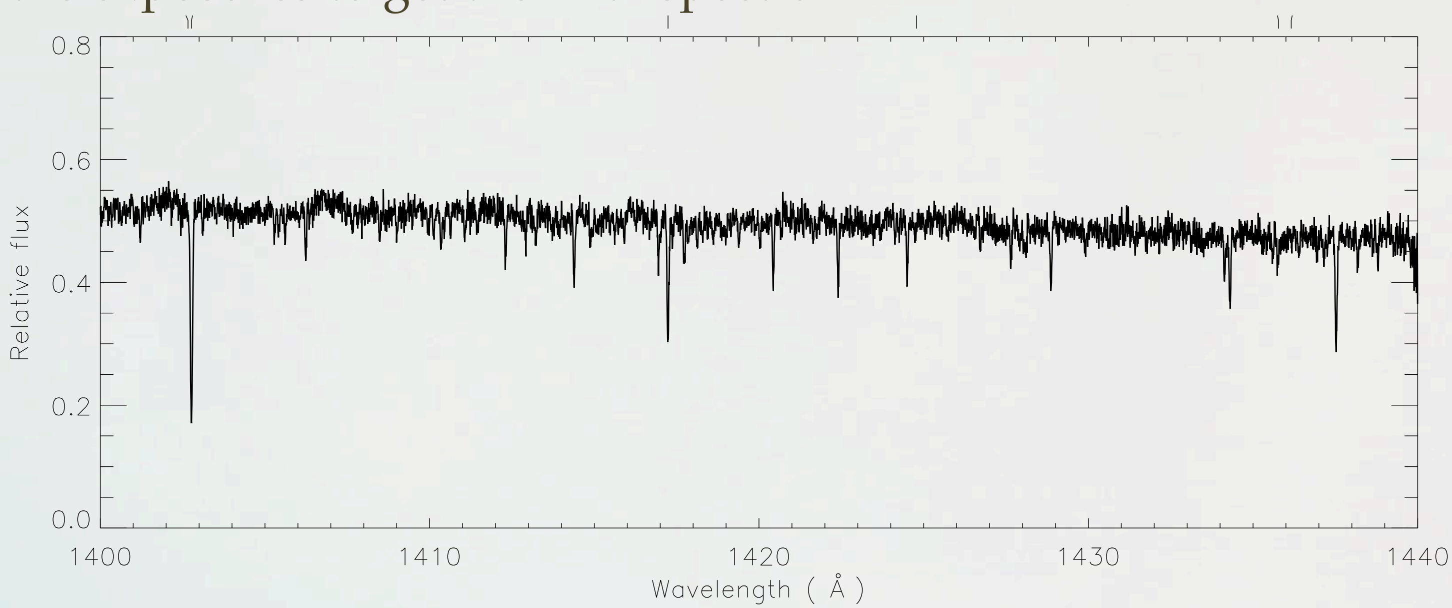
Observations

UV Spectra

- HST STIS observations, R = 114 000

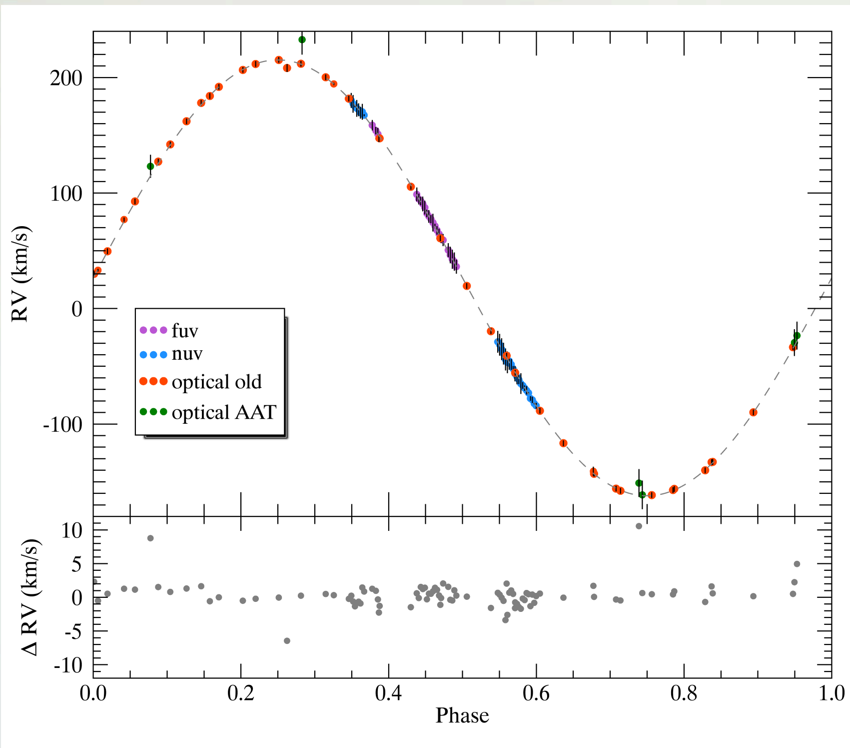
- NUV Time-Tag mode (to create short exposures) → 2660 – 2935 Å
- FUV short exposures (22x 120 s) → 1242 – 1440 Å

- Radial velocity measurements and correction before co-adding all the exposures to get the final spectra



ANALYSIS

Binary system



New radial velocity analysis combining UV RVs with published optical ones.

- $P = 0.606586 \pm 0.000007$ d
  $K_1 = 188.7 \pm 0.2$ km/s
  $\gamma_0 = 26.6 \pm 0.2$ km/s
- Circular orbit, $e < 6\text{e-}5$

<u>Mass of the sdB</u>

- Hipparcos parallax → spectroscopic mass $0.245^{+0.075}_{-0.055}\ M_\odot$
- Evolutionary sequence (Althaus et al. 2013, A&A 557) → $0.211 \pm 0.018\ M_\odot$
- $M_{comp} \geq 0.70\ M_\odot$

Analysis

Model atmospheres

- Model atmospheres and synthetic spectra (**ADS**)
  Hybrid non-LTE approach (Nieva & Przybilla 2006, 2007, 2008)
  - **A**tlas12 (Kurucz 1996) for a LTE atmospheric structure
  - **D**etail to compute NLTE population numbers (radiative transfert and statistical equilibrium)
  - **S**urface to compute the final synthetic spectrum

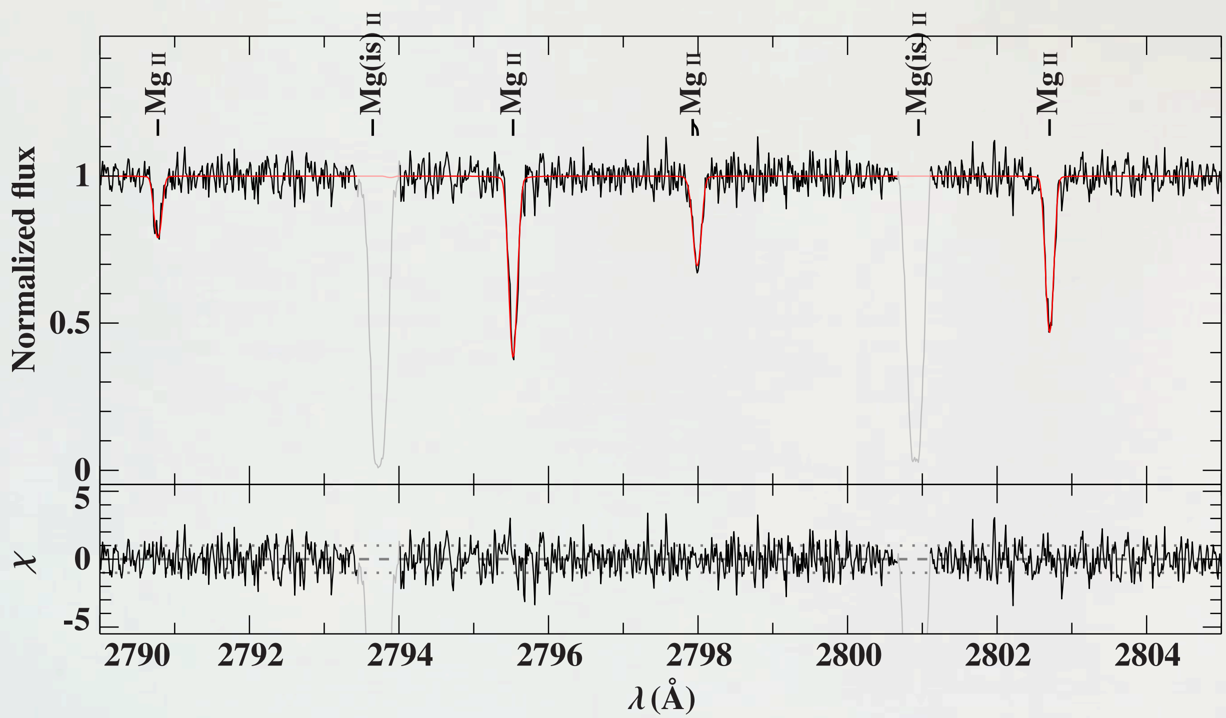
- Hybrid approach appropriate for the low temperature of the star
- Computation is faster than fully non-LTE models

- 2 goals:
  Measure the rotational broadening (v_{rot} sin i)
  Abundance analysis

Analysis

Rotational Broadening

- Mg + Si + Fe lines → $v_{rot} \sin i = 7.9 \pm 0.3$ km/s
- Assuming synchronous rotation ($P_{rot} = P_{orb}$) :
  $i = 55° \pm 6°$
  $M_{comp} = 1.13 \pm 0.2\ M_{\odot}$



Analysis

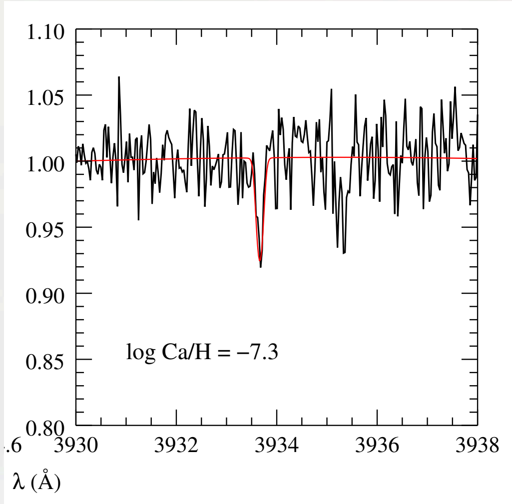
Metal Abundances

- Many elements identified and fitted in the FUV spectrum :
  Mg II – Al III – Si II-III-IV – S II – Fe II-III (NLTE)
  P III – Ti III – Cr III – Mn III – Ni II-III – Zn III (LTE)
  Trans-iron elements : Ga II-III – Sn III-IV – Pb IV

- Upper limits for **C, N, O**
  C upper limit very low: log N(C)/N(H) < -9.6

- Found a weak Ca II K line in high-resolution optical spectra

  Previous claim that all ELM WDs with log g < 5.9 shows Ca lines (Hermes et al. 2014, MNRAS 444 Gianninas et al. 2014, ApJ 795)



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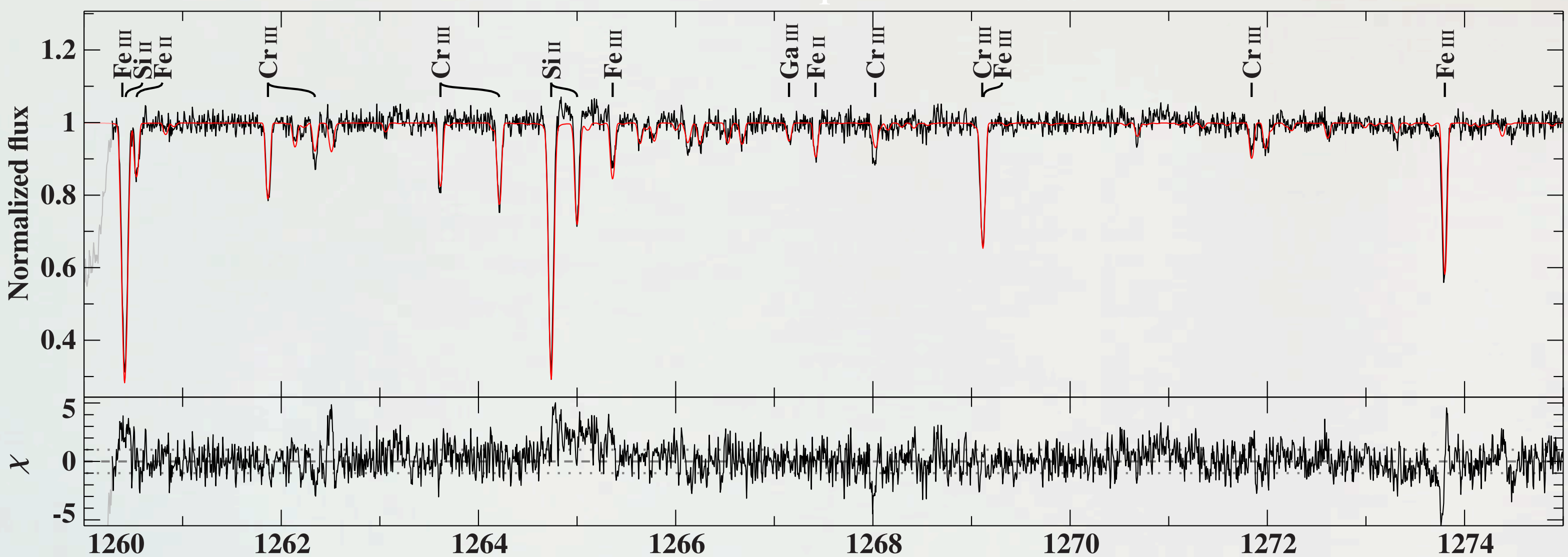

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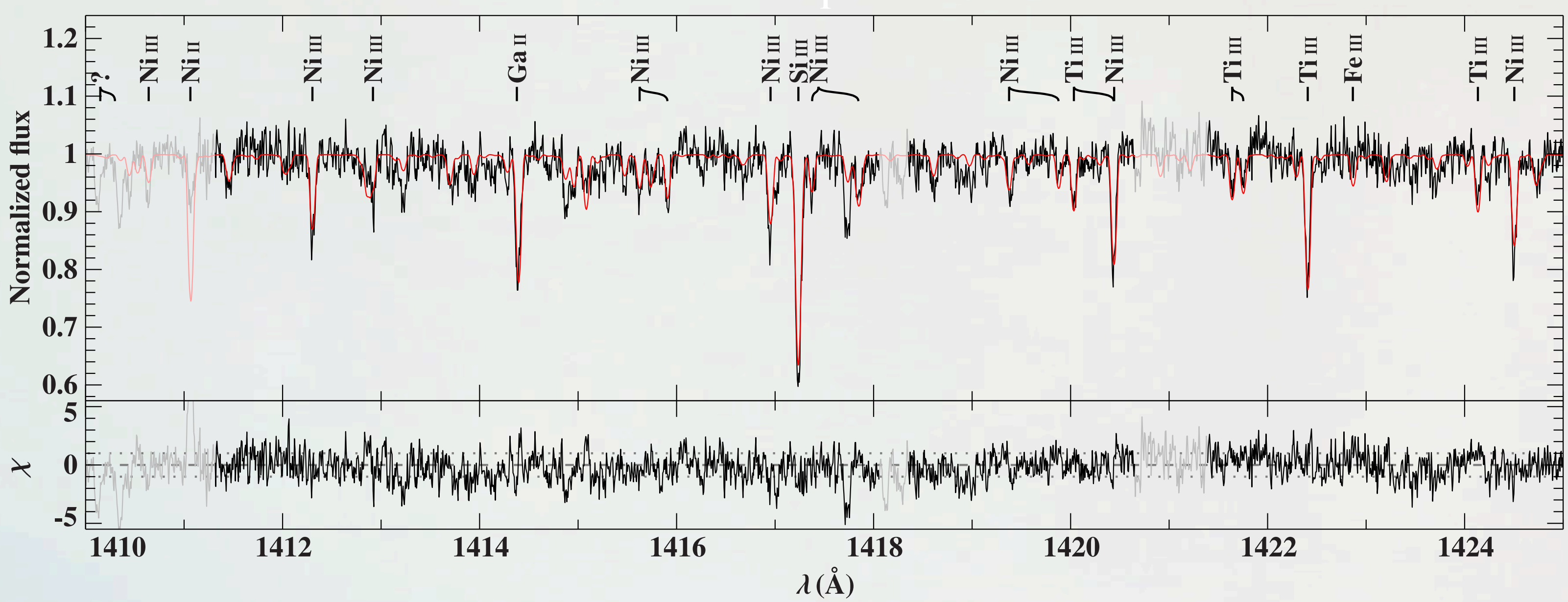

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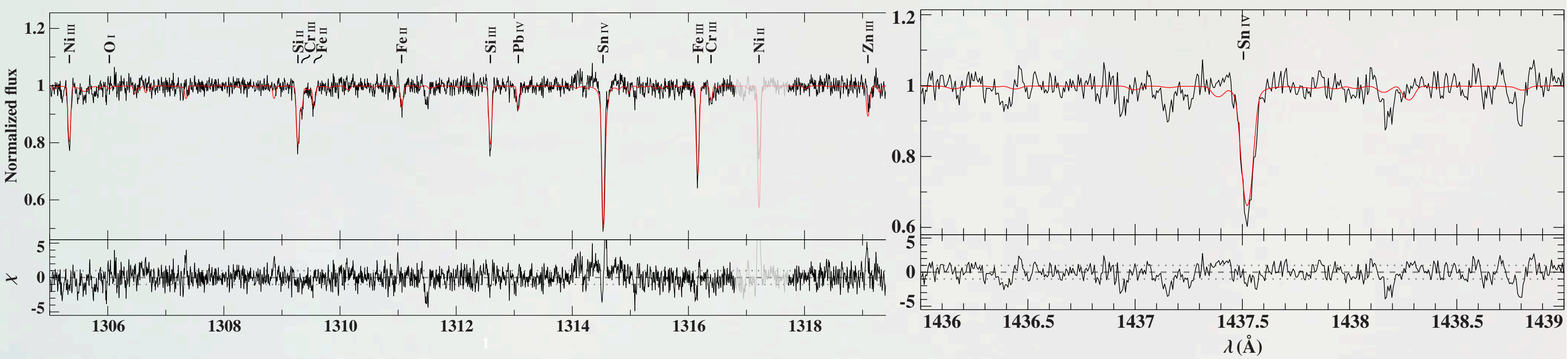
- Huge mismatch of Sn III vs the 2 Sn IV resonance lines
- Sn IV → log N(Sn)/N(H) = -8.4
- Sn III → log N(Sn)/N(H) = -10.6



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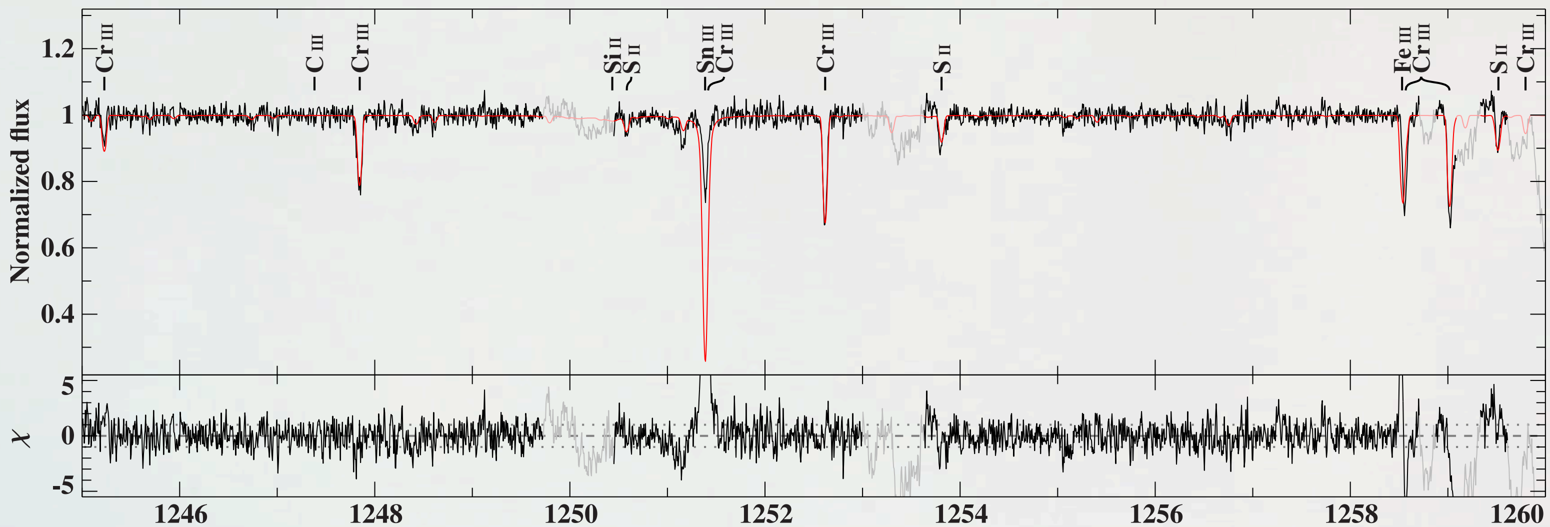

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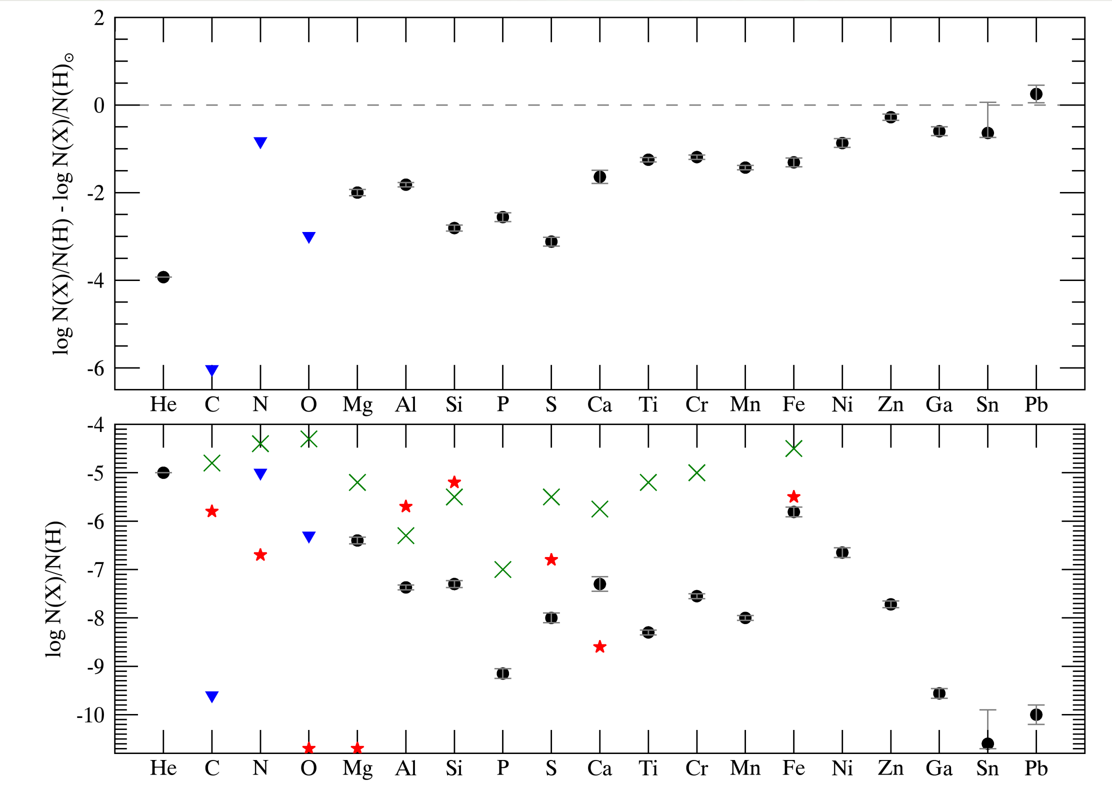

★ Prediction from radiative levitation (P. Chayer, priv. com)

✖ Average abundances for sdBs (Geier 2013, A&A, 459)

Analysis

Non-LTE Effects

- Many elements identified and fitted in the FUV spectrum :
  Mg II – Al III – Si II-III-IV – S II – Fe II-III **(LTE)**
  P III – Ti III – Cr III – Mn III – Ni II-III – Zn III (LTE)
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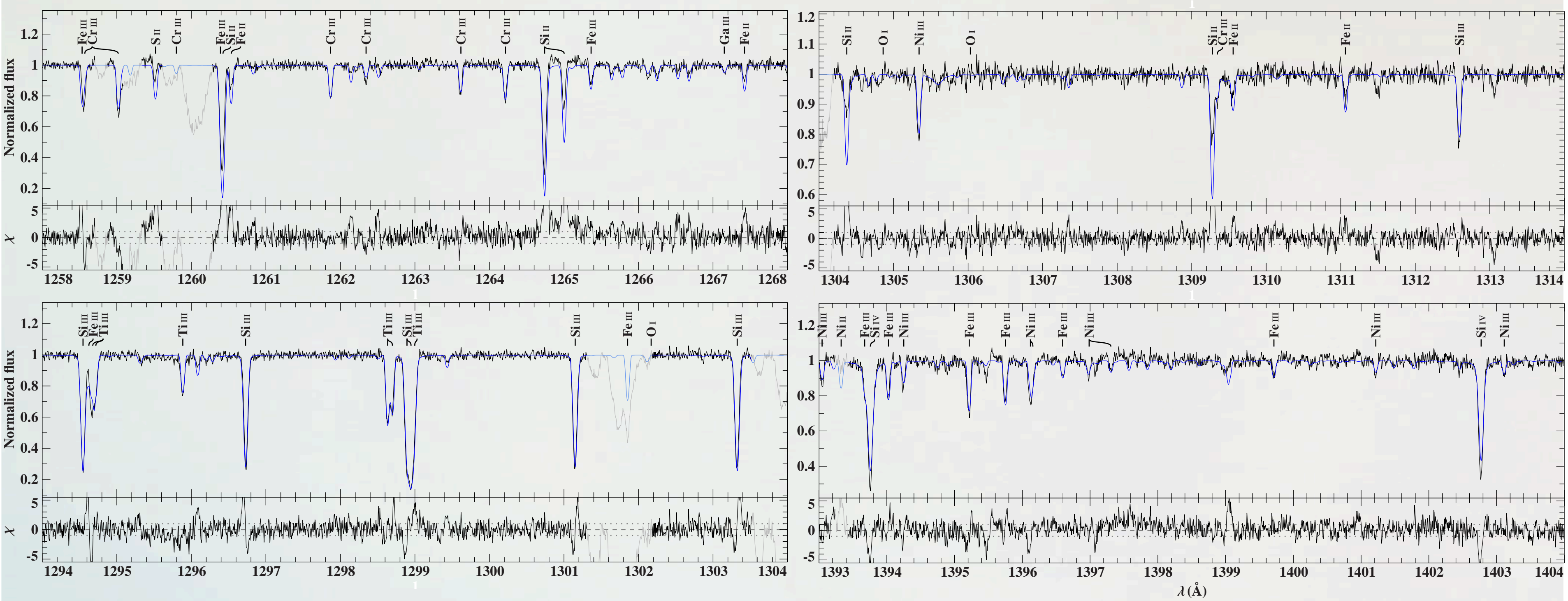
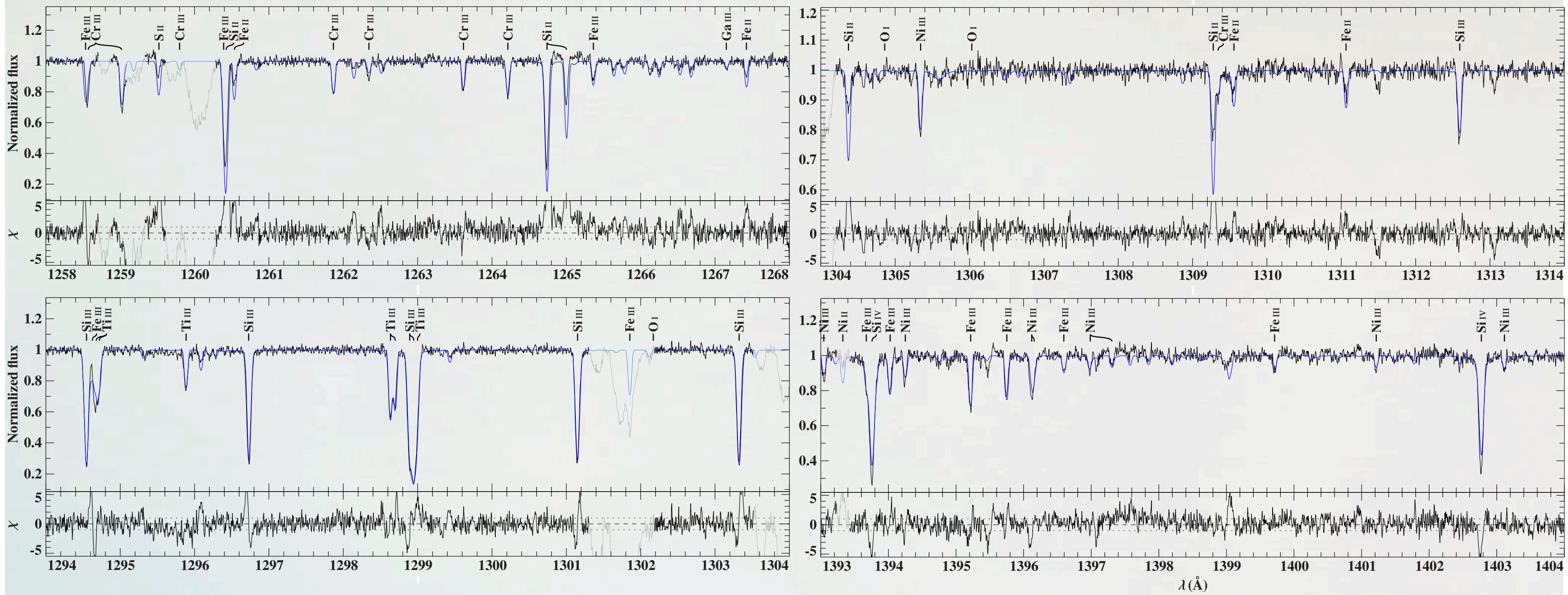


Analysis

Non-LTE Effects

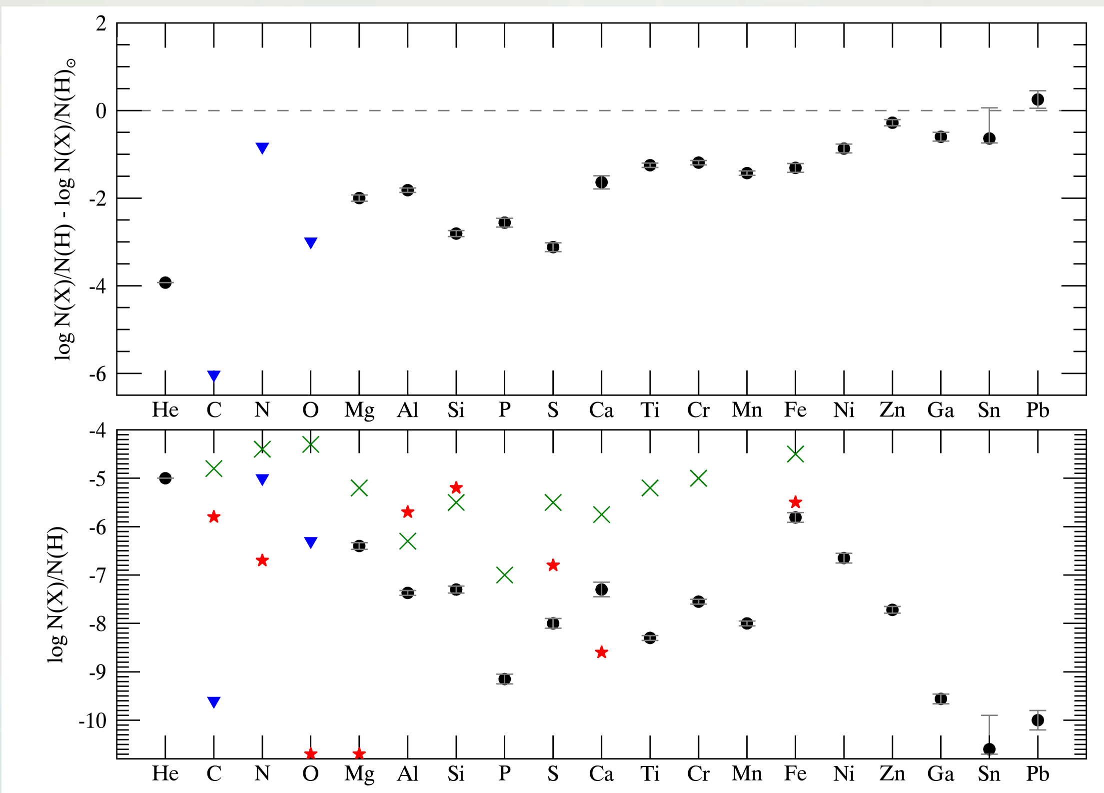
- Discrepant abundances for the different ionization stages,
  NLTE: Si → log N(Si)/N(H) = -7.3
  LTE: Si II = -7.8, Si III = -7.3, Si IV = -7.1
  + abundance discrepancies for S II, Fe II, Ni II ~0.5 dex



Analysis

Non-LTE Effects

- LTE abundances can be consider reliable only for the main ionization stage, III in the case of HD 188112
- LTE approximation for population numbers gives inconsistent results for non-dominant ionic species



Element Z	Abundance log N(Z)/N(H) NLTE	LTE
C II	<−9.6	–
N II	<−5.0	–
O I	<−6.3	–
Mg II	−6.4 ± 0.07	−6.2 ± 0.07
Al III	−7.37 ± 0.05	−7.39 ± 0.05
Si II-III-IV	−7.3 ± 0.1	−7.6 ± 0.1
P III	–	−9.15 ± 0.1
S II	−8.0 ± 0.1	−8.4 ± 0.1
Ca II	−7.3 ± 0.15	–
Ti III	–	−8.3 ± 0.05
Cr III	–	−7.55 ± 0.05
Mn III	–	−8.0 ± 0.05
Fe II-III	−5.75 ± 0.1	−6.05 ± 0.1
Ni III	−6.6 ± 0.1	−6.7 ± 0.1
Zn III	–	−7.72 ± 0.07
Ga II-III	–	−9.55 ± 0.1
Sn III	–	$-10.6^{+0.6}_{-0.1}$
Pb IV	–	−10.0 ± 0.2

Conclusion

Results

- HD 188112 is a *metal-poor* low mass sdB star / pre ELM-WD
- Detailed chemical composition only known for 3 others ELM WD so far (1 UV, 2 optical):
  PSR J1816 (Kaplan et al. 2013, ApJ 765) & SDSS J0745 (Gianninas et al. 2014) are metal-rich
  GALEX J1717 (Hermes et al. 2014), metals between 10x and 1/10x solar, also very depleted in C

- HD 188112 is on a circular orbit, if tidally locked rotation is assumed, then M_{comp} = 0.92 – 1.33 $M_\odot$
  otherwise M_{comp} > 0.7 $M_\odot$

- Non-LTE effects on population numbers affect the line-strength of non-dominant ions, even at ~21,000 K , log *g* ~5.6.
- Choose carefully your lines for abundance determination !!!