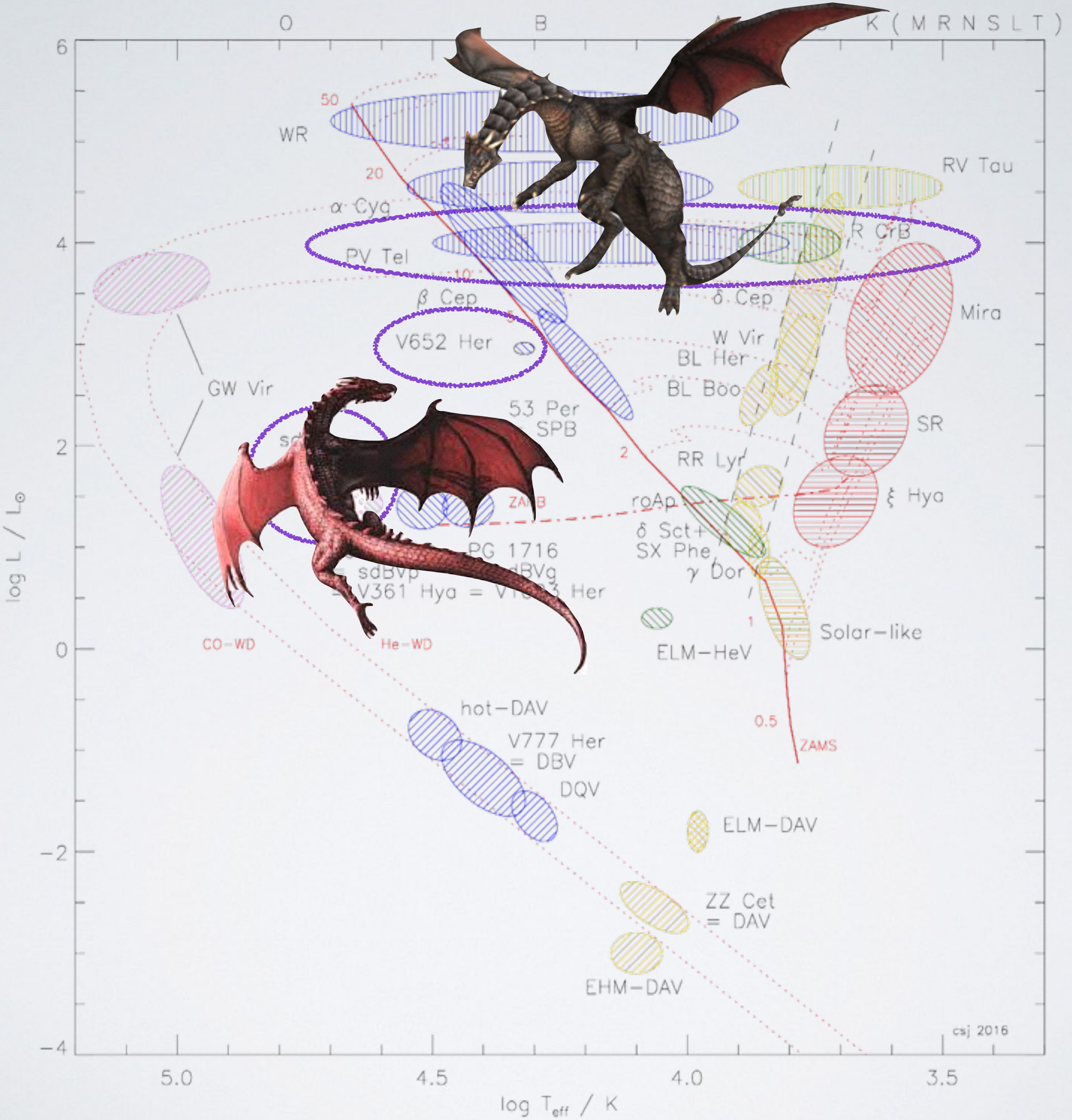
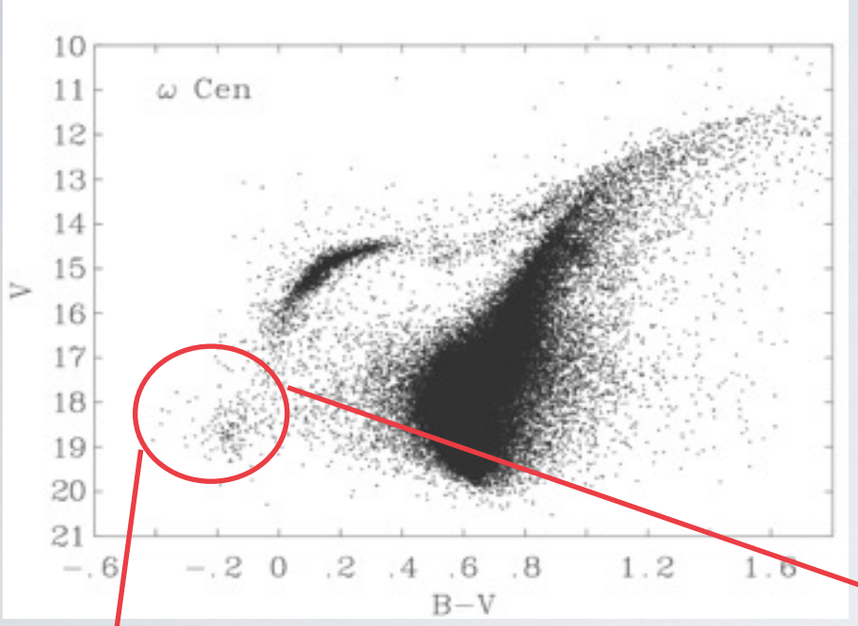
PULSATION IN THE CHEMICALLY PECULIAR HOT STAR ZOO

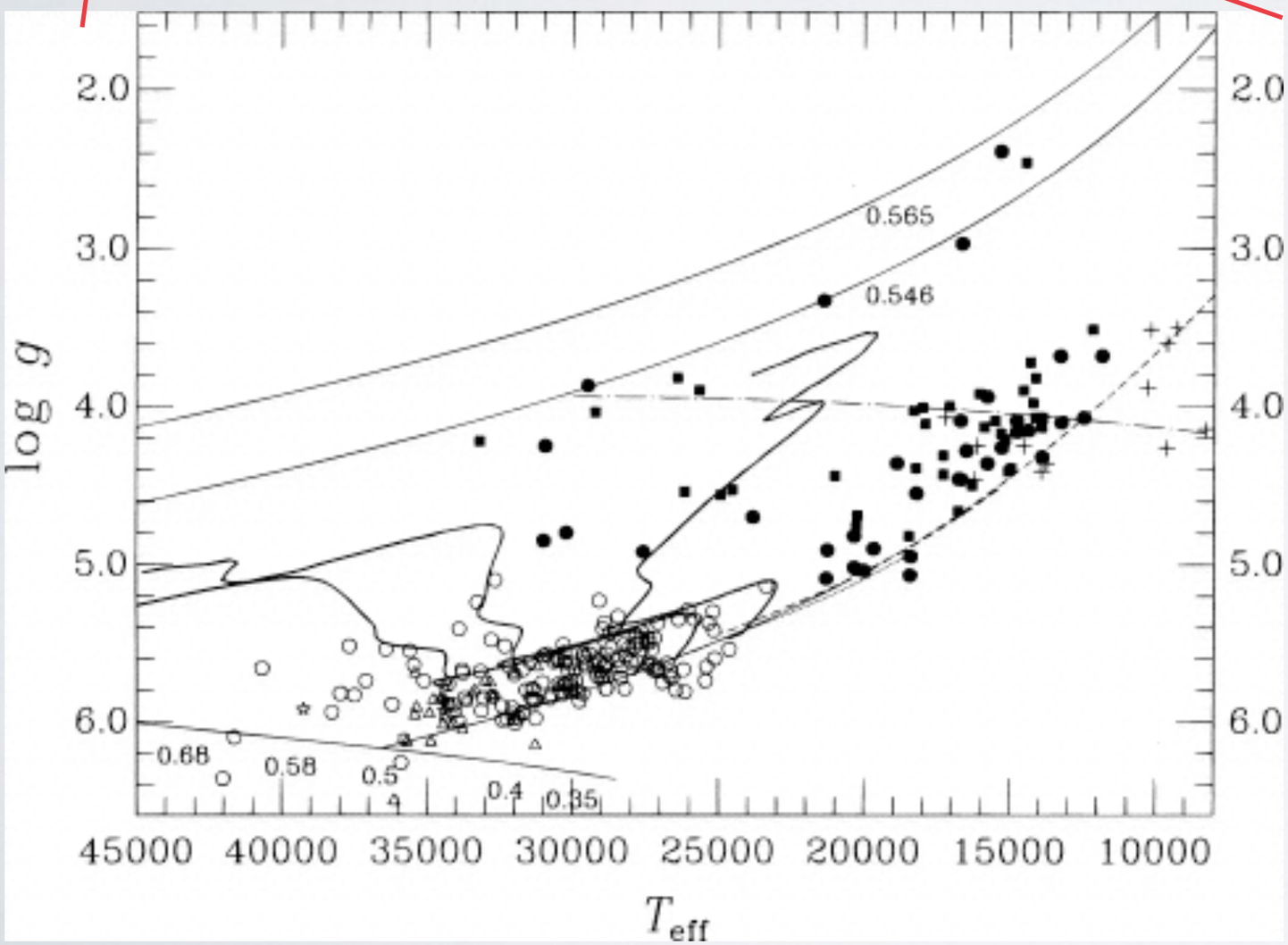
Simon Jeffery + …

Armagh Observatory & Planetarium

Department for Communities


O
B
K (M R N S L T)
6
4
2
0
−2
−4
log L / L⊙
5.0
4.5
4.0
3.5
log T_eff / K
50
20
10
5
2
1
0.5
ZAMS
WR
α Cyg
PV Tel
β Cep
V652 Her
GW Vir
53 Per
SPB
PG 1716
sdBVp
= V361 Hya = V1
CO−WD
He−WD
hot−DAV
V777 Her
= DBV
DQV
ELM−DAV
ZZ Cet
= DAV
EHM−DAV
ELM−HeV
roAp
δ Sct+
SX Phe
γ Dor
Solar−like
RR Lyr
W Vir
BL Her
BL Boo
δ Cep
RV Tau
R CrB
Mira
SR
ξ Hya
csj 2016

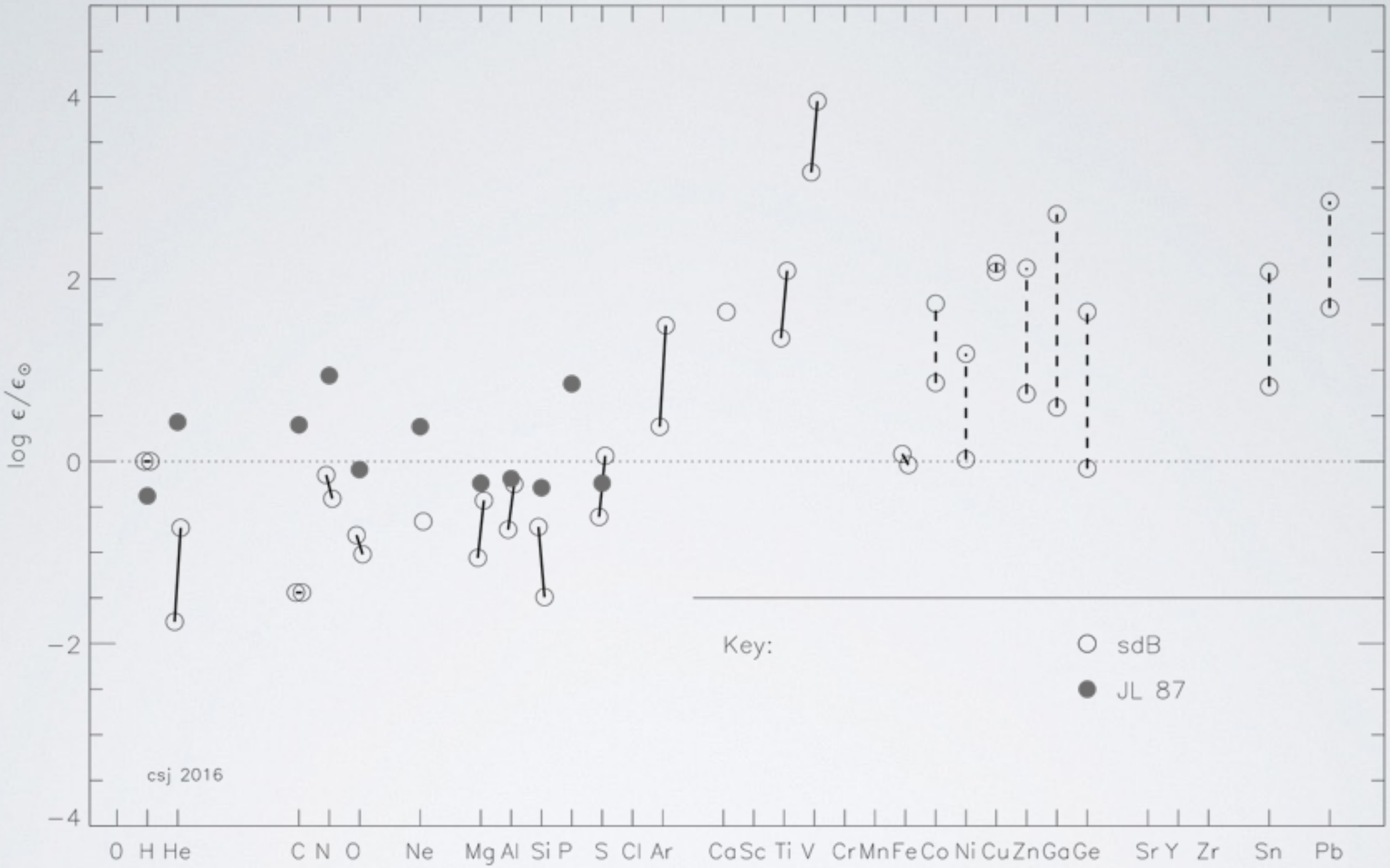




SUBDWARF B STARS

Subdwarf B stars and blue-horizontal branch stars in the field, … (Greenstein & Sargent 1966)

with evolution tracks for EHB stars with Mcore=0.5 Msun (Saffer et al. 1997)

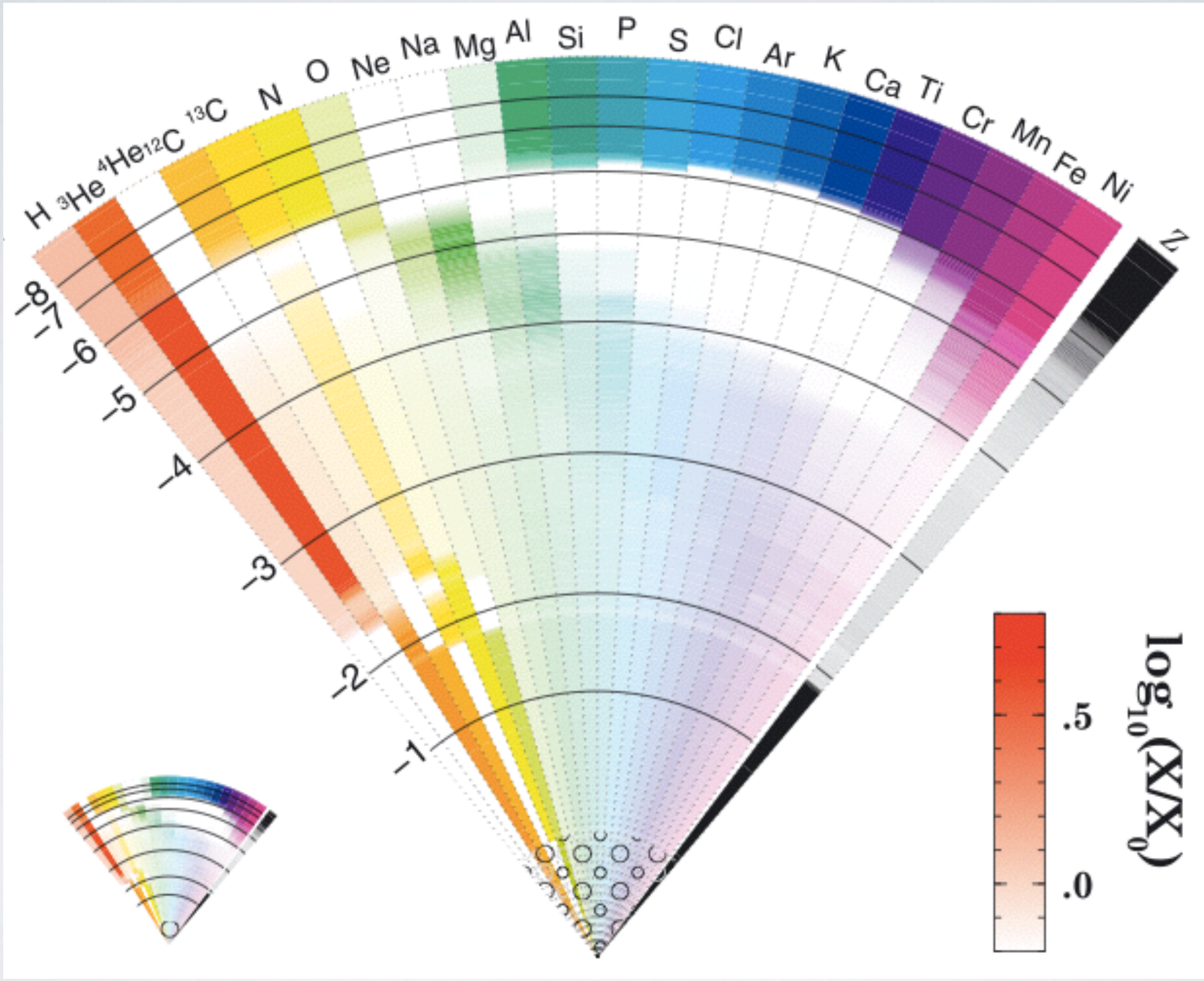


NORMAL SDB STAR SURFACES

He and C - S: ⊙ / 10
N, Fe, Ni: ⊙
Ar - Pb: ⊙ × 10-100

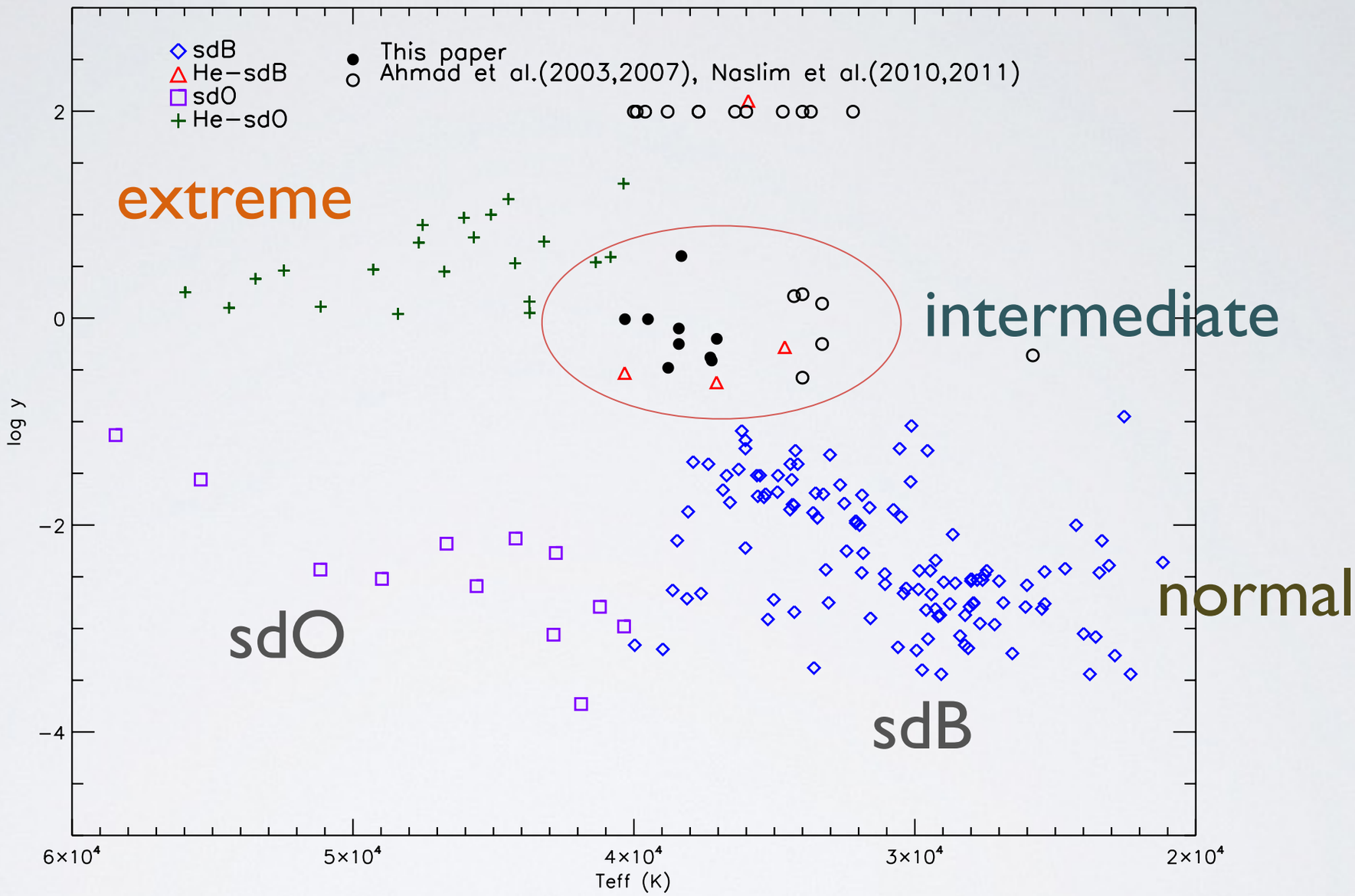
Diffusion dominates in a high gravity radiative envelope
Gravitational settling and selective radiative levitation
Data: Geier 2013, O'Toole+Heber 2006, Ahmad+2007

Michaud et al. 2011 A&A 529, 60: sdB, M=0.51 $M_\odot$, Teff=30100 K, t=25 Myr



Diffusion dominates in high gravity radiative envelope
Gravitational settling and selective radiative levitation

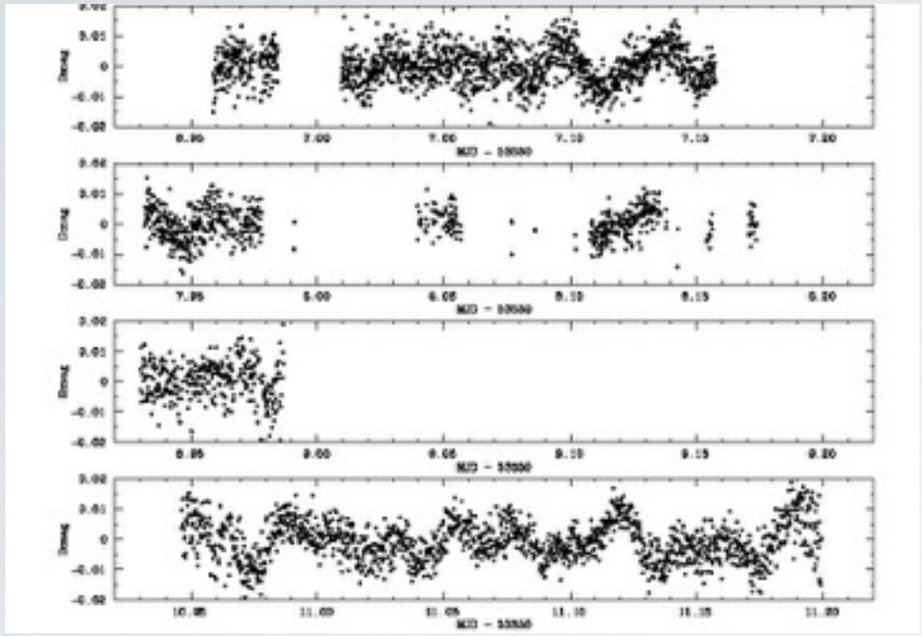
HOT SUBDWARFS BY HELIUM ABUNDANCE



Distribution of helium abundance with Teff for the Galex subdwarf sample, and including IHe subdwarfs. log y = log nHe/nH (from Nemeth et al. 2012).

What does surface composition tell us? Which ones pulsate?

LS IV-14°116: PULSATIONS



THE ASTROPHYSICAL JOURNAL, 734:59 (8pp), 2011 June 10

Table 2
Harmonic Oscillations Detected in the Light Curve of LS IV−14°116

Period (s)	Frequency (mHz)	Amplitude (%)	Phase (s)	S/N
1953.74 ± 0.04	0.51184 ± 0.00001	0.27 ± 0.02	87 ± 17	14.9
2620.27 ± 0.21	0.38164 ± 0.00003	0.11 ± 0.02	114 ± 57	5.8
2872.33 ± 0.18	0.34815 ± 0.00002	0.14 ± 0.02	1645 ± 46	8.0
3581.79 ± 0.27	0.27919 ± 0.00002	0.15 ± 0.02	969 ± 55	8.3
4259.85 ± 0.57	0.23475 ± 0.00003	0.10 ± 0.02	2714 ± 96	5.7
5083.63 ± 0.55	0.19671 ± 0.00002	0.15 ± 0.02	3561 ± 78	8.3

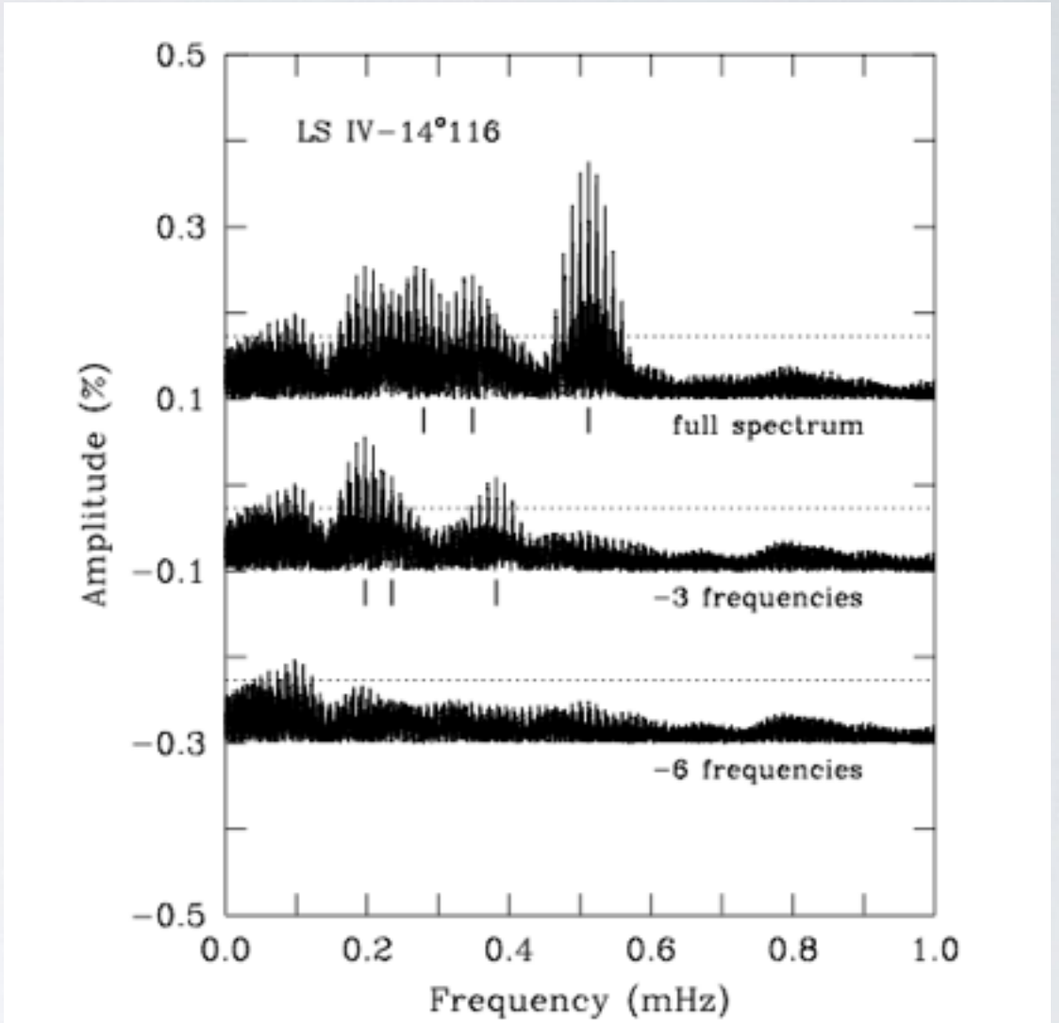
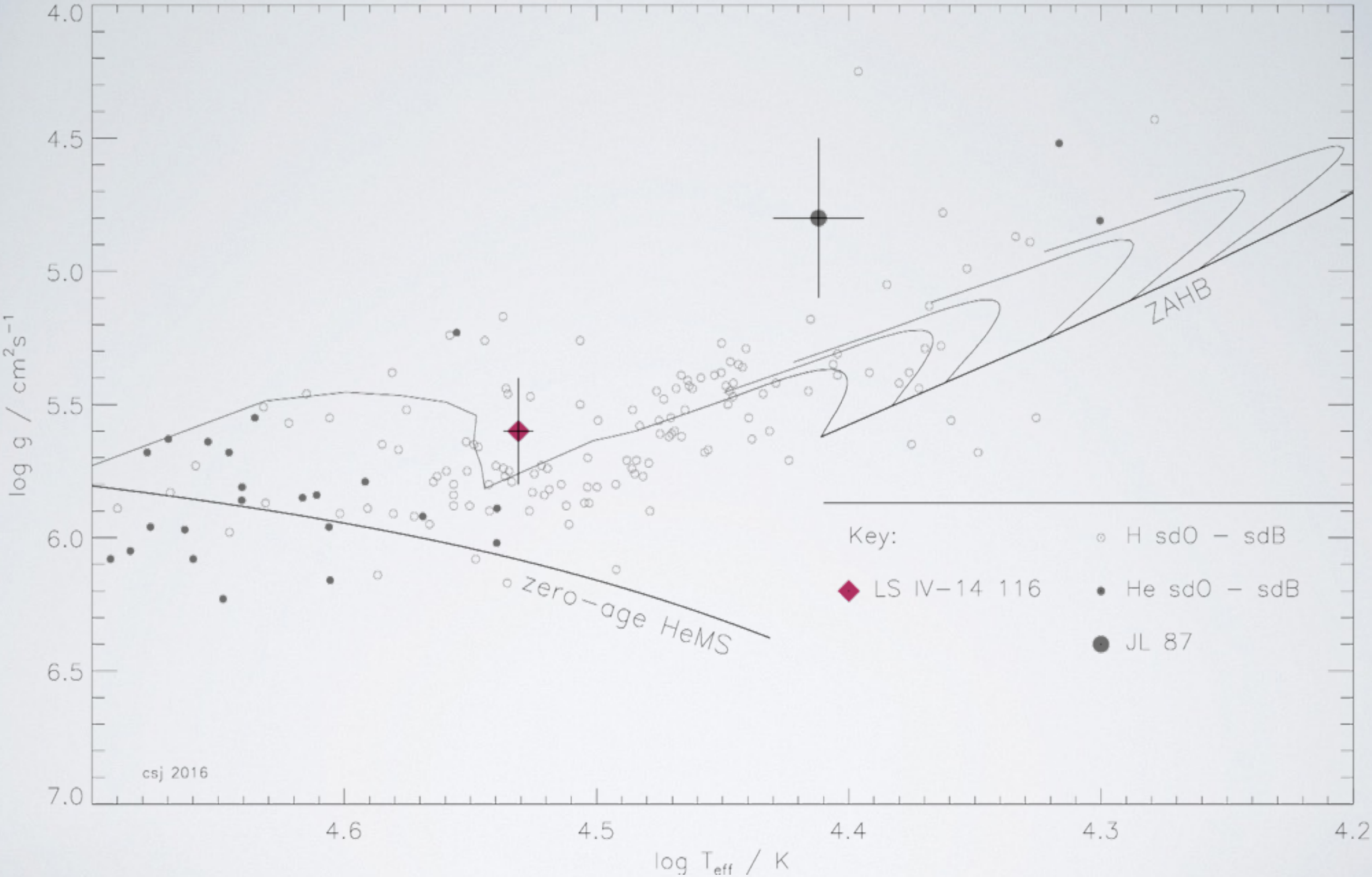


Figure 3. Zoomed-in view of the Fourier transform of the entire data set in the 0–1.0 mHz range where significant signals are found. The lower transforms show the successive steps of prewhitening by three frequencies, and finally by all six frequencies with statistically significant amplitudes. The dotted horizontal lines indicate the 4σ noise level.

Ahmad & Jeffery 2005
Jeffery 2011
Green + 2011

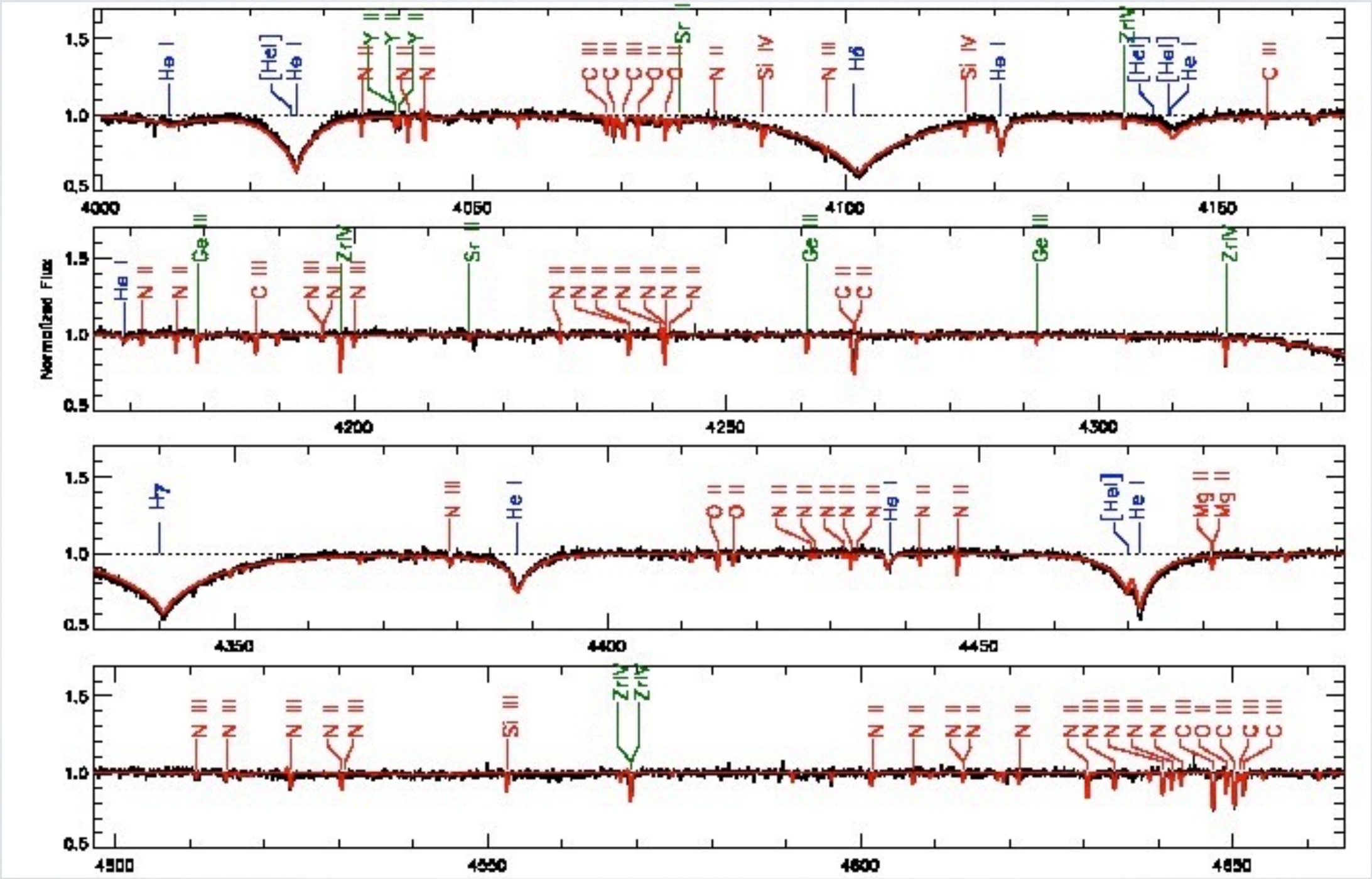


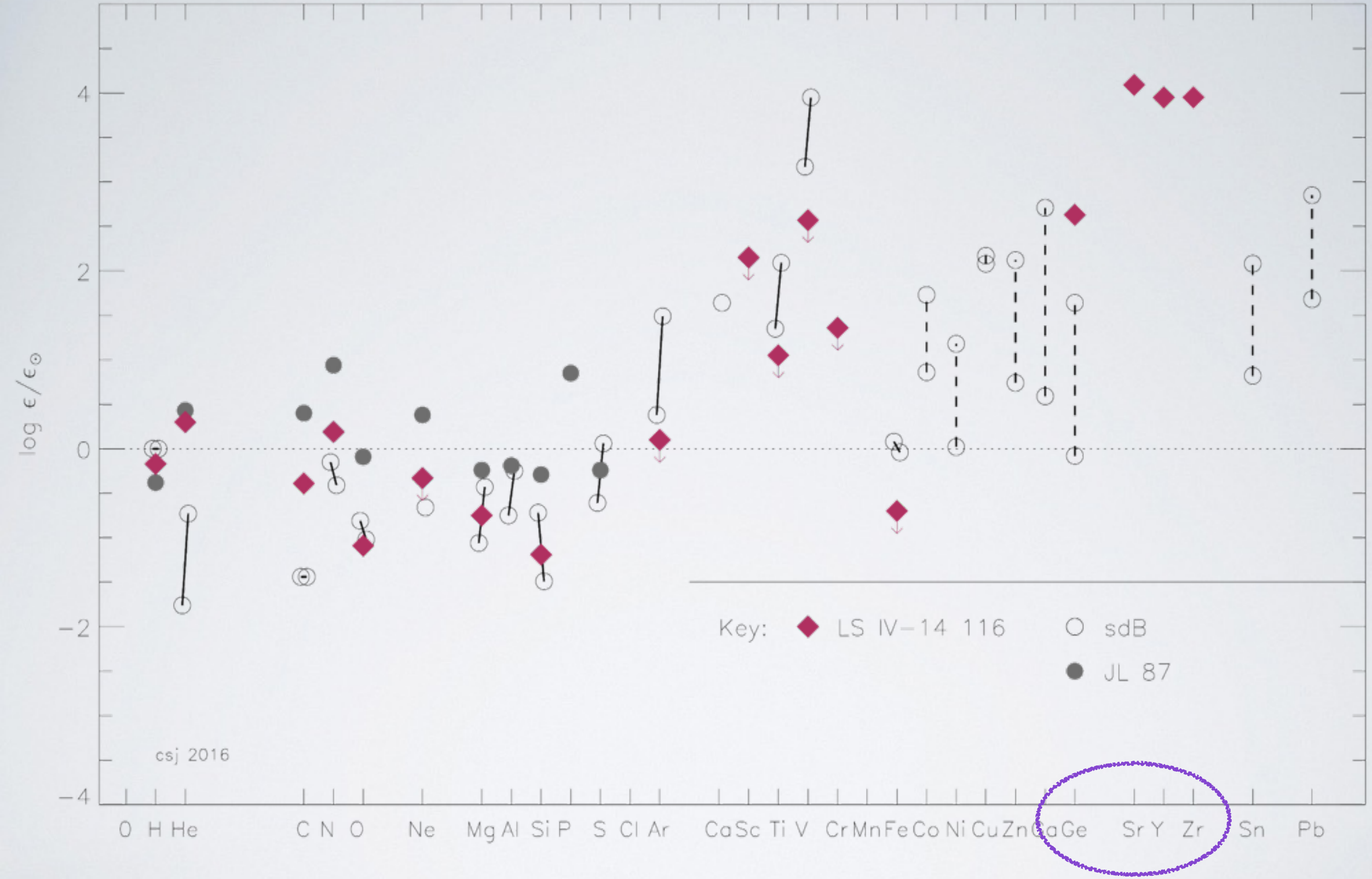
Data: Nemeth+2012, Ahmad+2007, Naslim+2010

LS IV -14°116: ZIRCONIUM +

Zr IV, Ge III and Sr III lines never previously seen in optical spectrum of a star. Not AGB, ∴ not s-process. Thin clouds in photosphere supported by radiation?

Naslim+2010





Data: Naslim+2010

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CITIES BENGALURU CHENNAI COIMBATORE DELHI HYDERABAD KOCHI KOZHIKODE KOLKATA

THIRUVANANTHAPURAM, December 28, 2012

Updated: December 28, 2012 15:41 IST

She reached for the stars, discovered one

STAFF REPORTER

Speaker G. Karthikeyan presenting a memento to Naslim Neelamkodan, who discovered a star, at a function organised by the Kerala State Higher Education Council in Thiruvananthapuram on Thursday. Photo: S. Mahinsha The Hindu

TOPICS

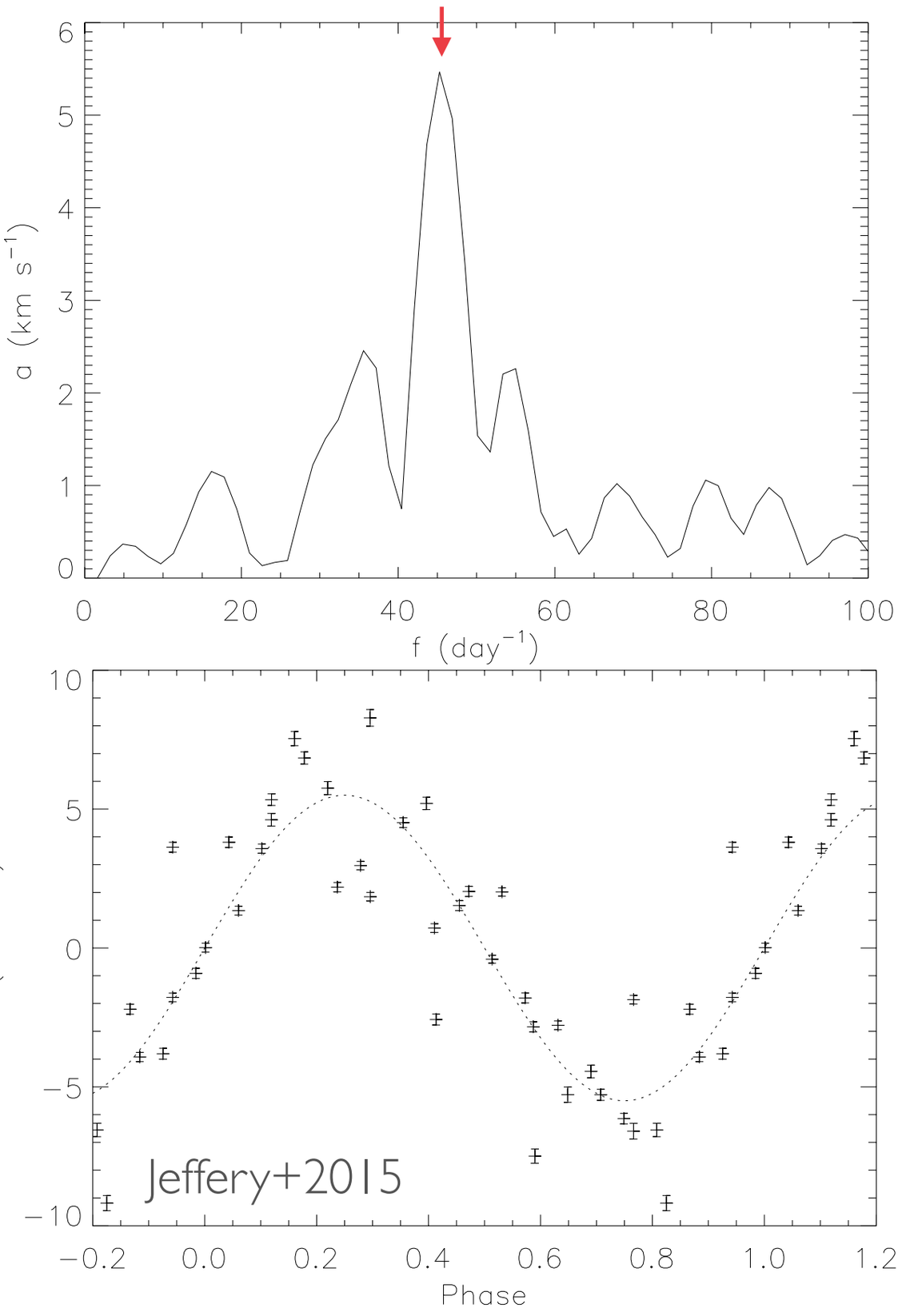
Kerala

Thiruvananthapuram

Naslim Neelamkodan was honoured during a special function organised by the Kerala State Higher Education Council

'Star' may now be an overused tag for Naslim Neelamkodan, but it is her discovery of a real star shrouded in glittering zirconium metal, 2,000 light years away, that has earned this most befitting title for the 27-year-old Ph.D. holder.

LS IV-14°116: RADIAL VELOCITIES+



2011:VLT/UVES

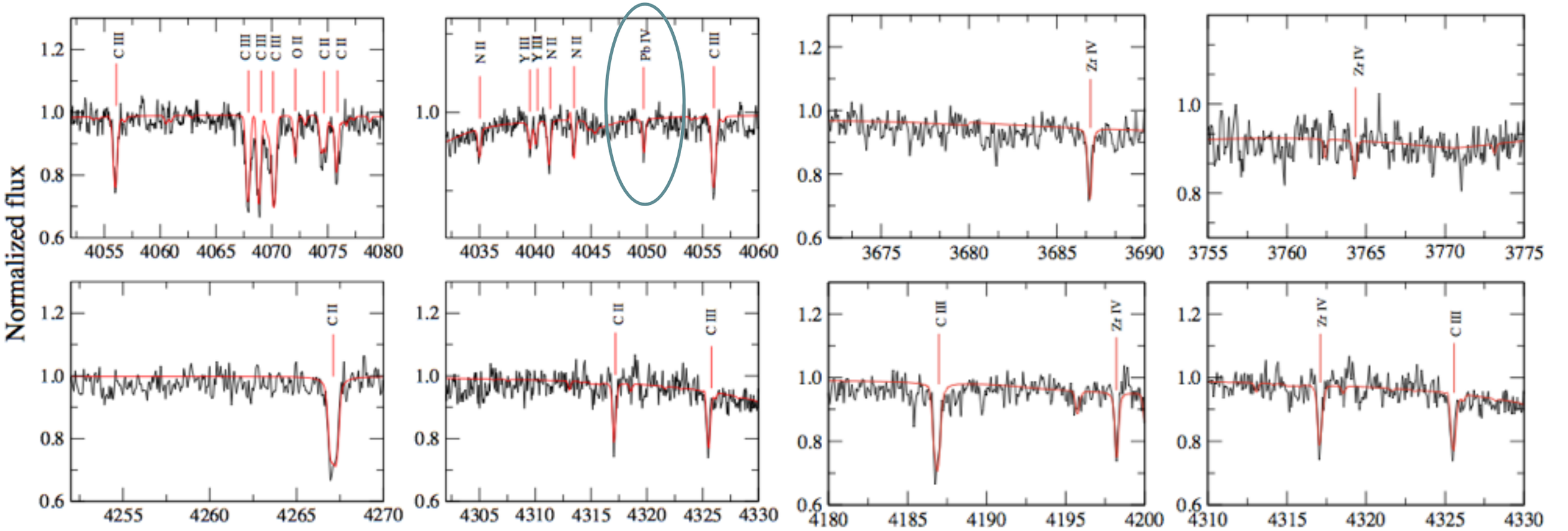
rv peak power: f_1=1953s.
rv amp ∝ line depth

2015:VLT/UVES …
being analysed
2015: HST/STIS …
failed due to high PM
~~2017: K2 Field 16~~ …

Meanwhile …

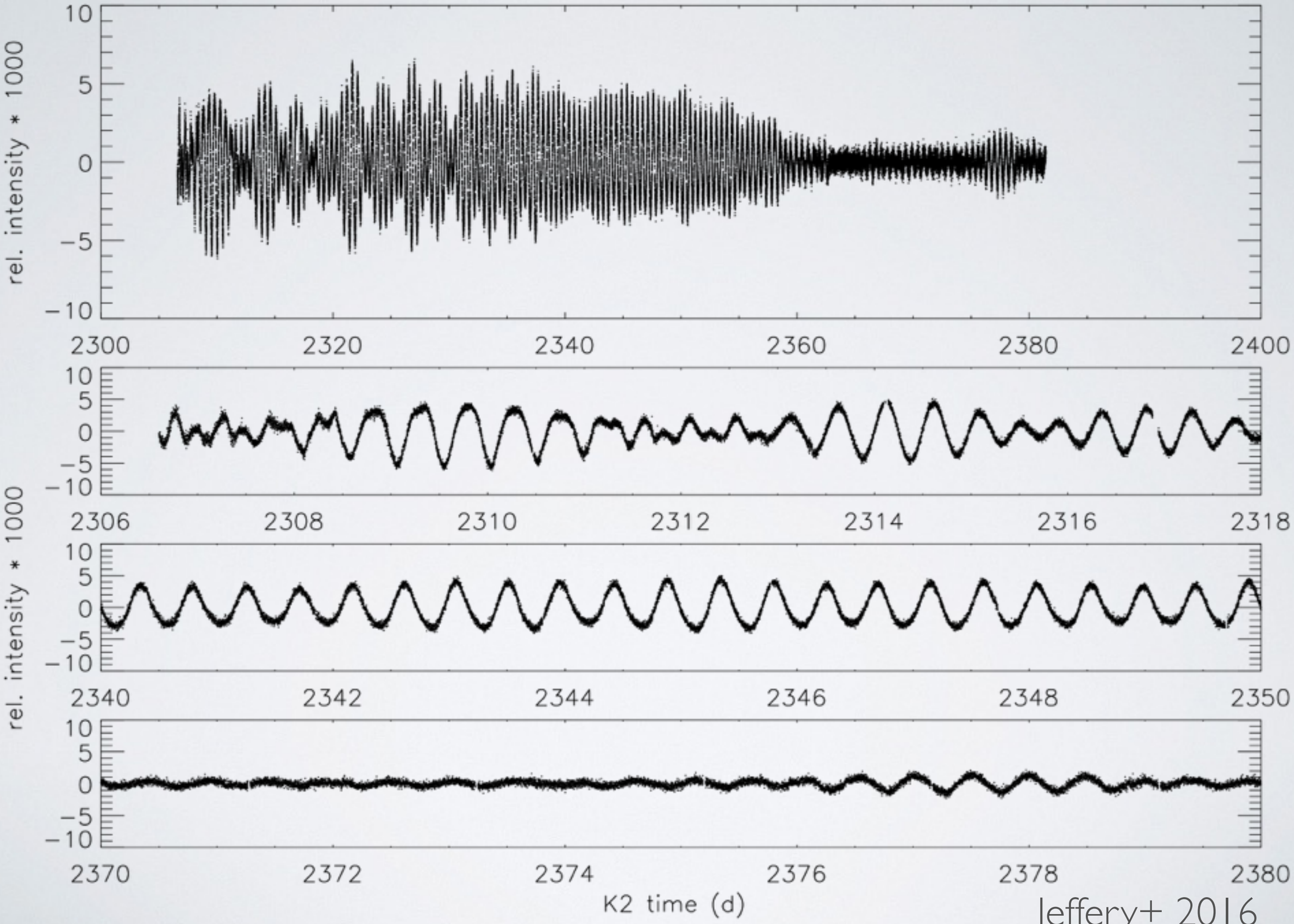
LEAD!

Pb IV never seen in optical spectra, seen in UV for some sdB stars.
Optical spectroscopy of IHe and EHe sdBs (WiFES/FEROS…)
Narrow lines: v_{rot} sin i < 5 km/s, **Pb:** 4 dex overabundant.



HE1256-2738 Naslim+2012

K2 Field 5: EPIC 211623711 "one of Simon's stars"



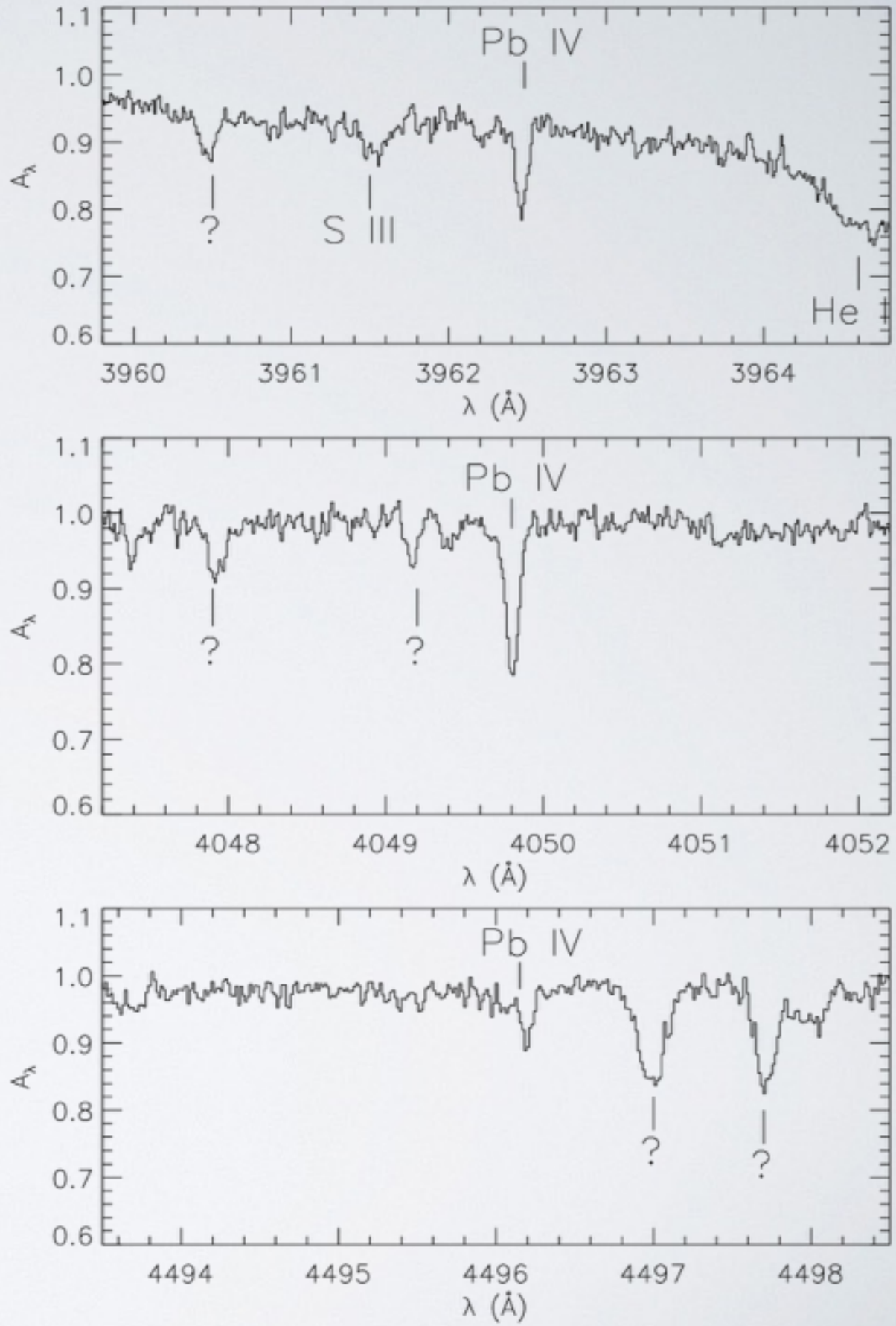
Jeffery+ 2016

Subaru/HDS service obs

a new super lead-rich
intermediate-helium subdwarf

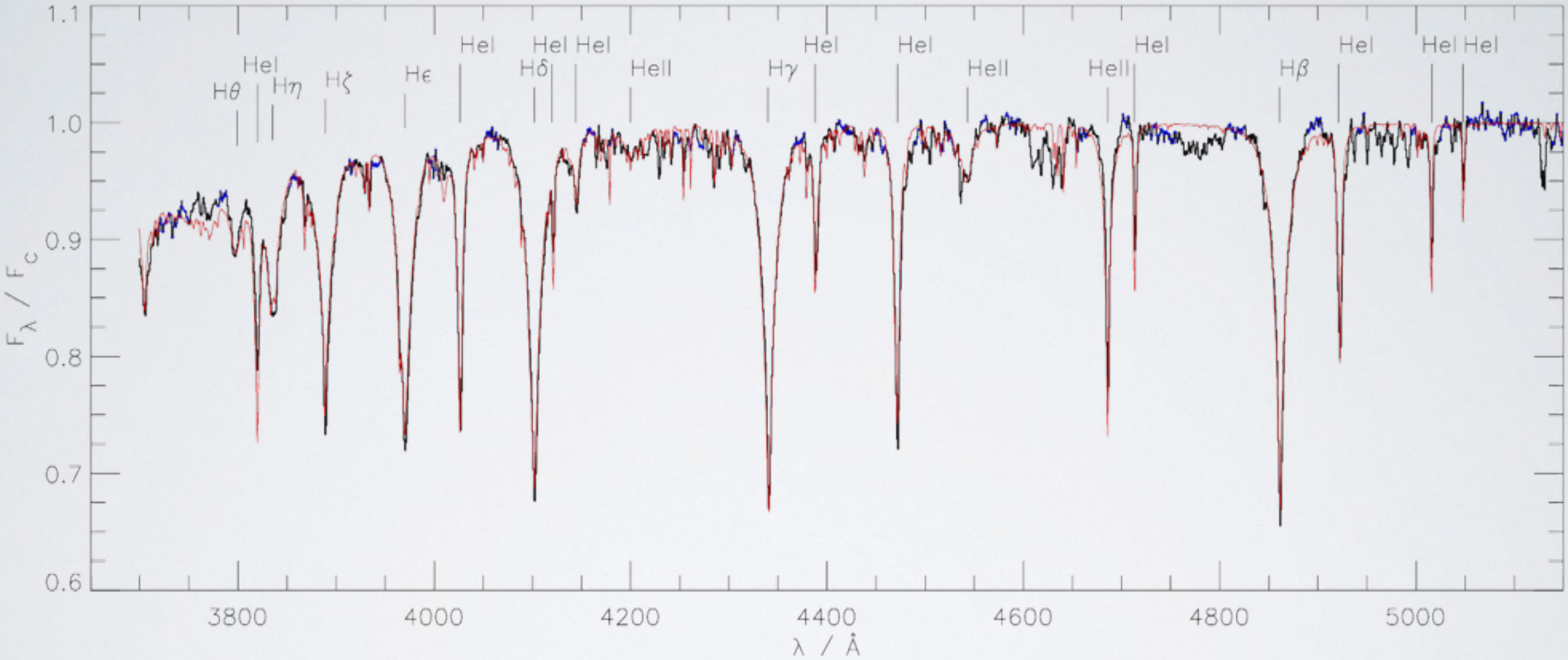
…

GALEX J082832.8+145205

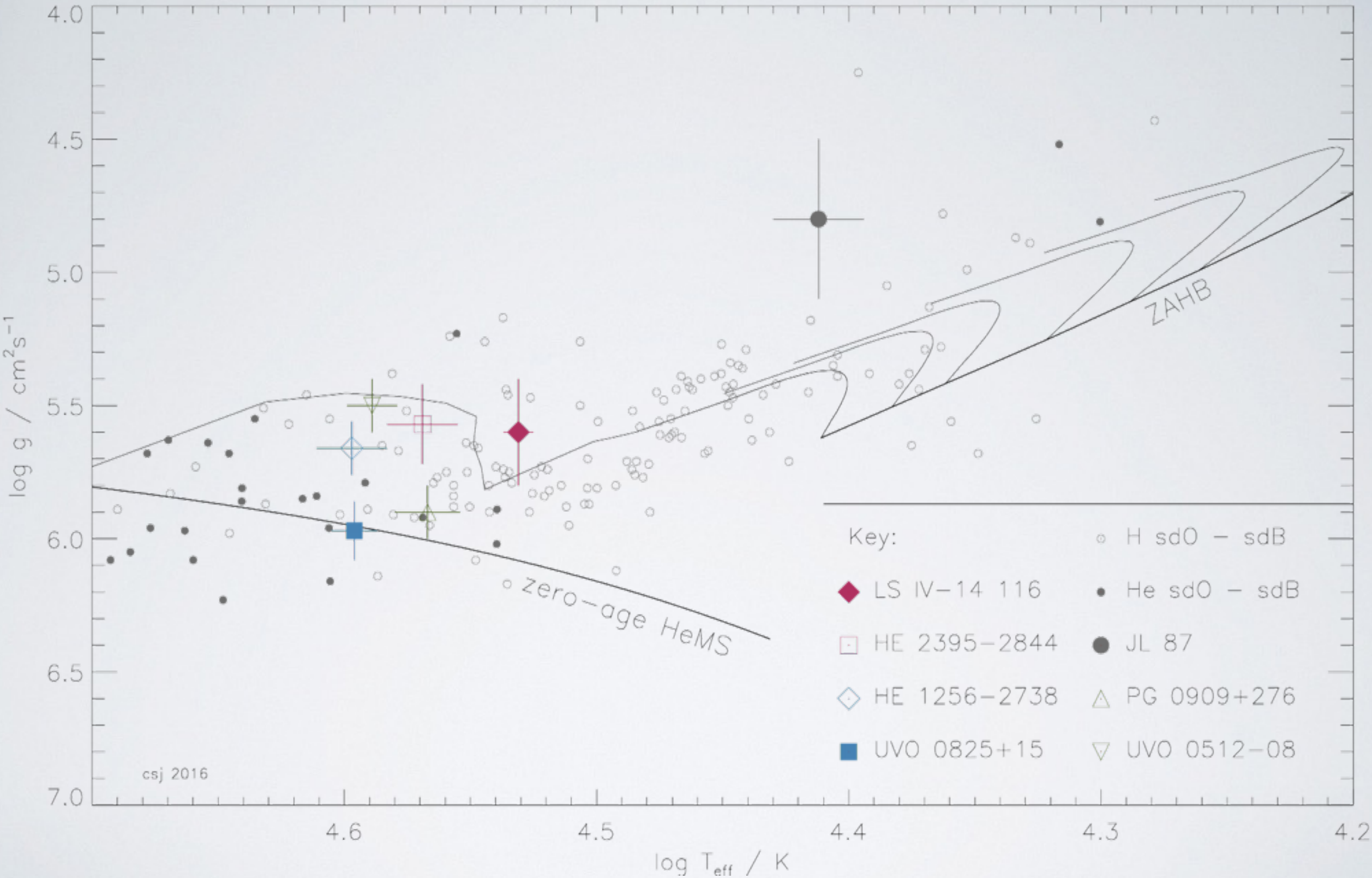


Jeffery+ 2016

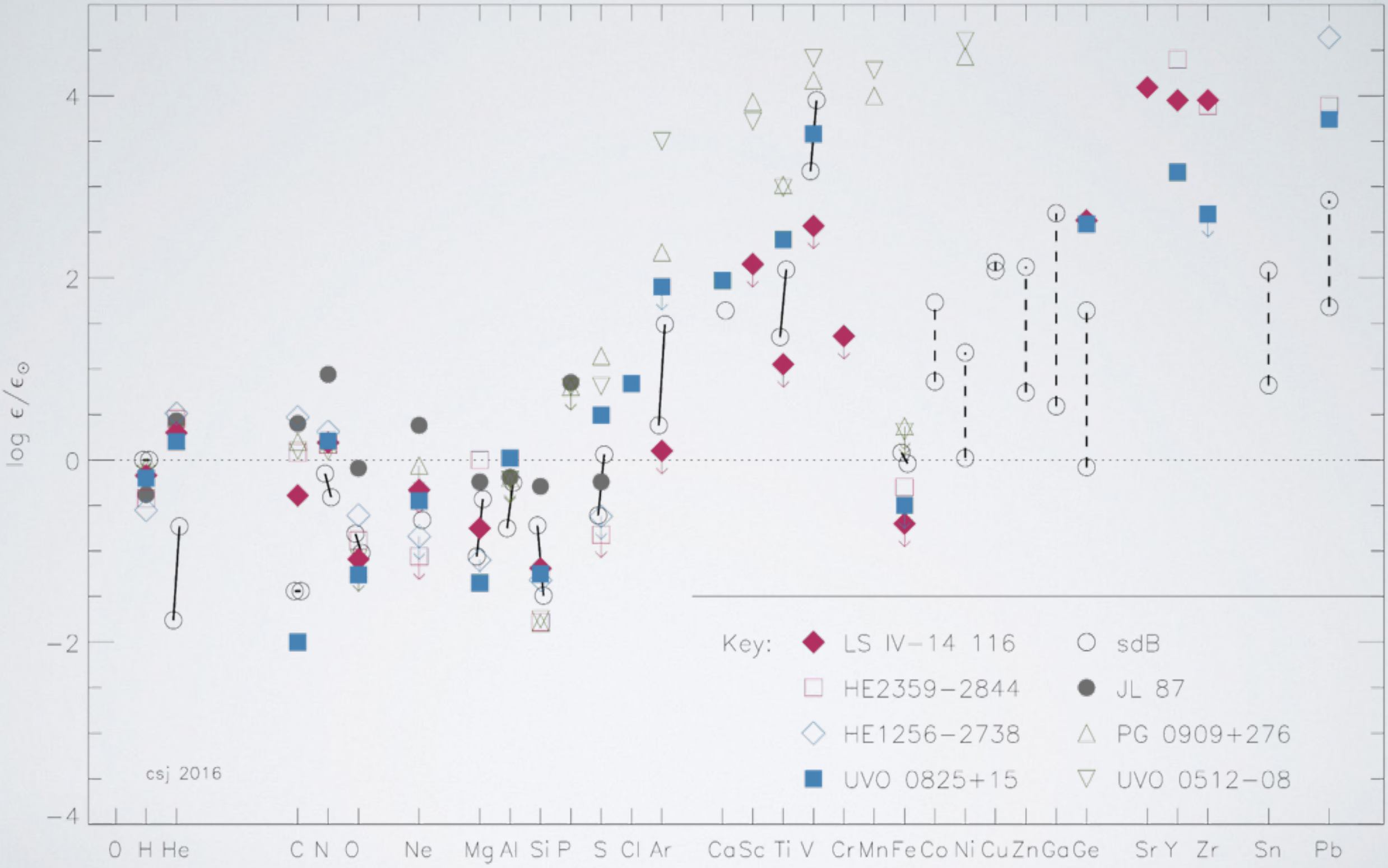
= UVO 0825+15: a UV-bright hot subdwarf



Jeffery+ 2016



Jeffery+ 2016, Data also from Edelman 2003, Naslim+2012, Dorman+1993



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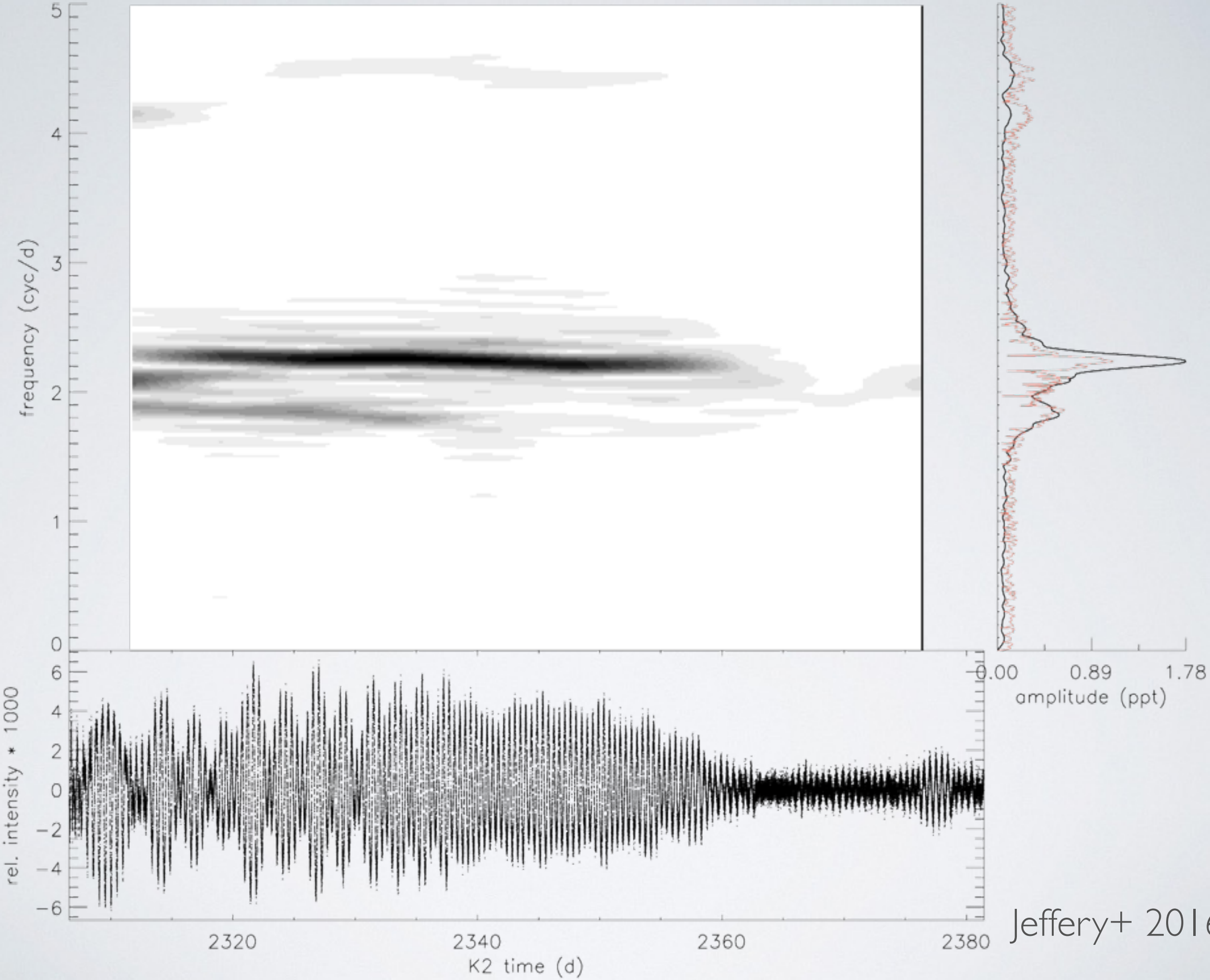


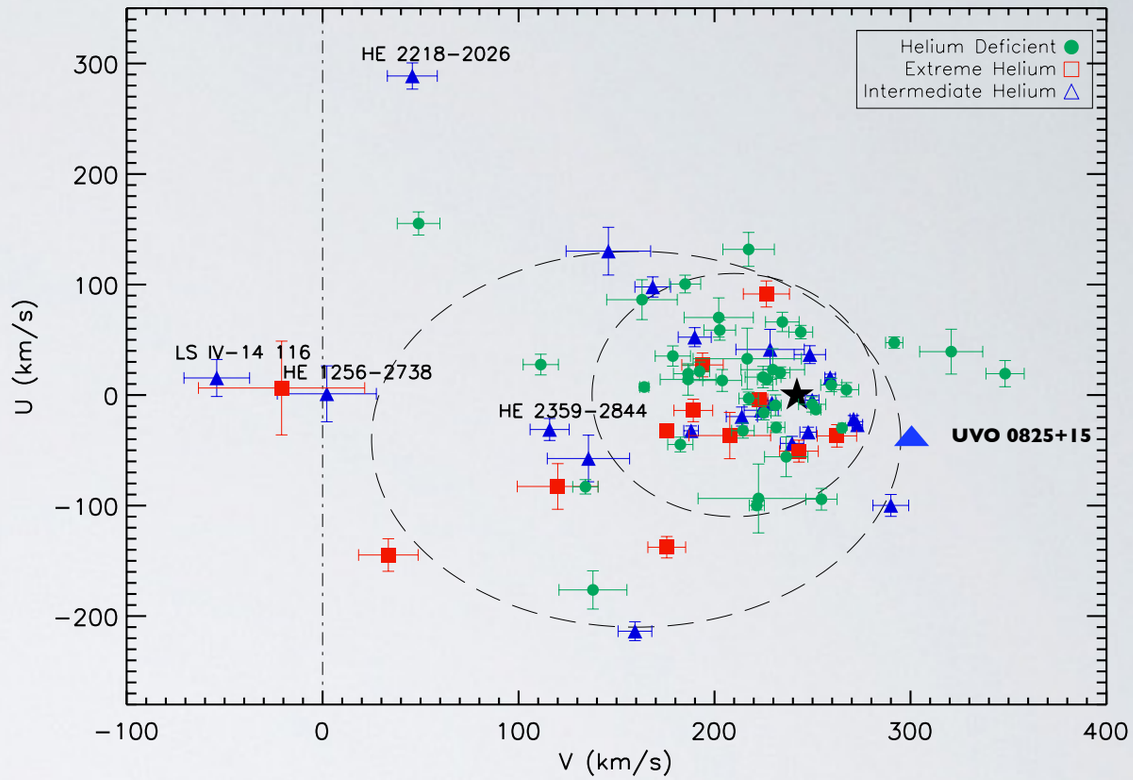
Jeffery+ 2016

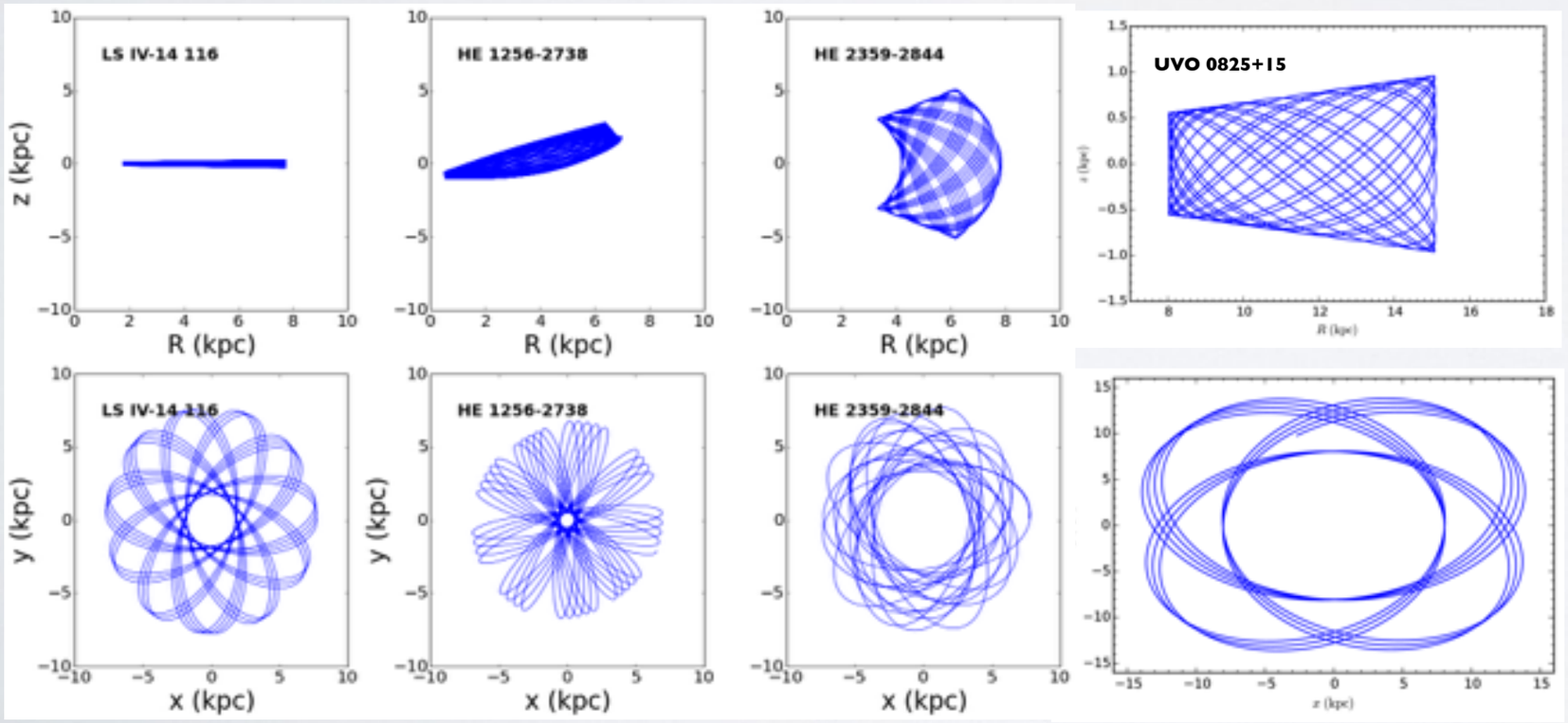
KINEMATICS

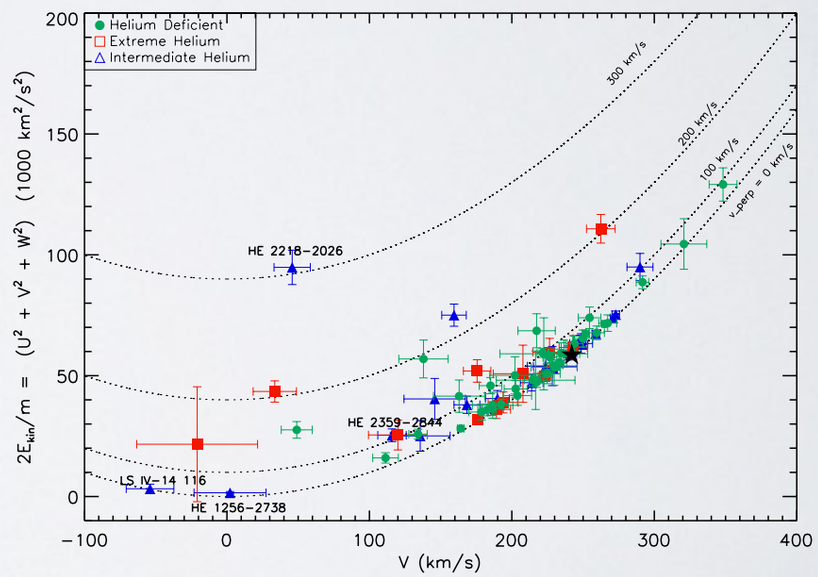
Randall+14 noted peculiar RV of LS IV-14 116.
We checked RV for other intermediate and extreme helium subdwarfs.

Normal subdwarf kinematics consistent with disk.

Several heavy-metal and other intermediate and extreme helium subdwarfs have halo-like orbits.







Martin+2016, under review

OTHER SDO PULSATORS

Pulsating hot O subdwarfs in ω Centauri: mapping a unique instability strip on the extreme horizontal branch

Randall + 2016, A&A 789, A1, 17

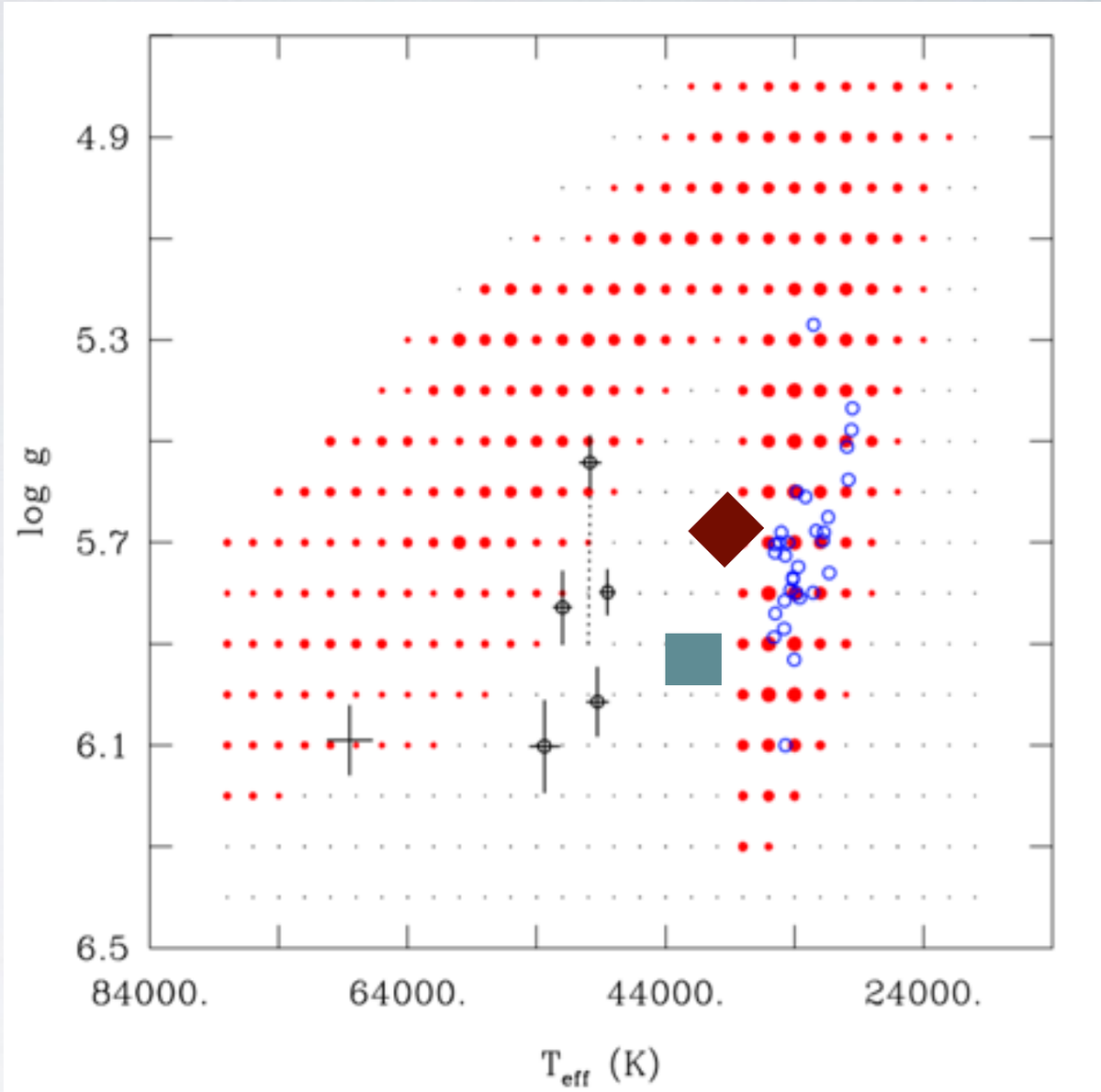
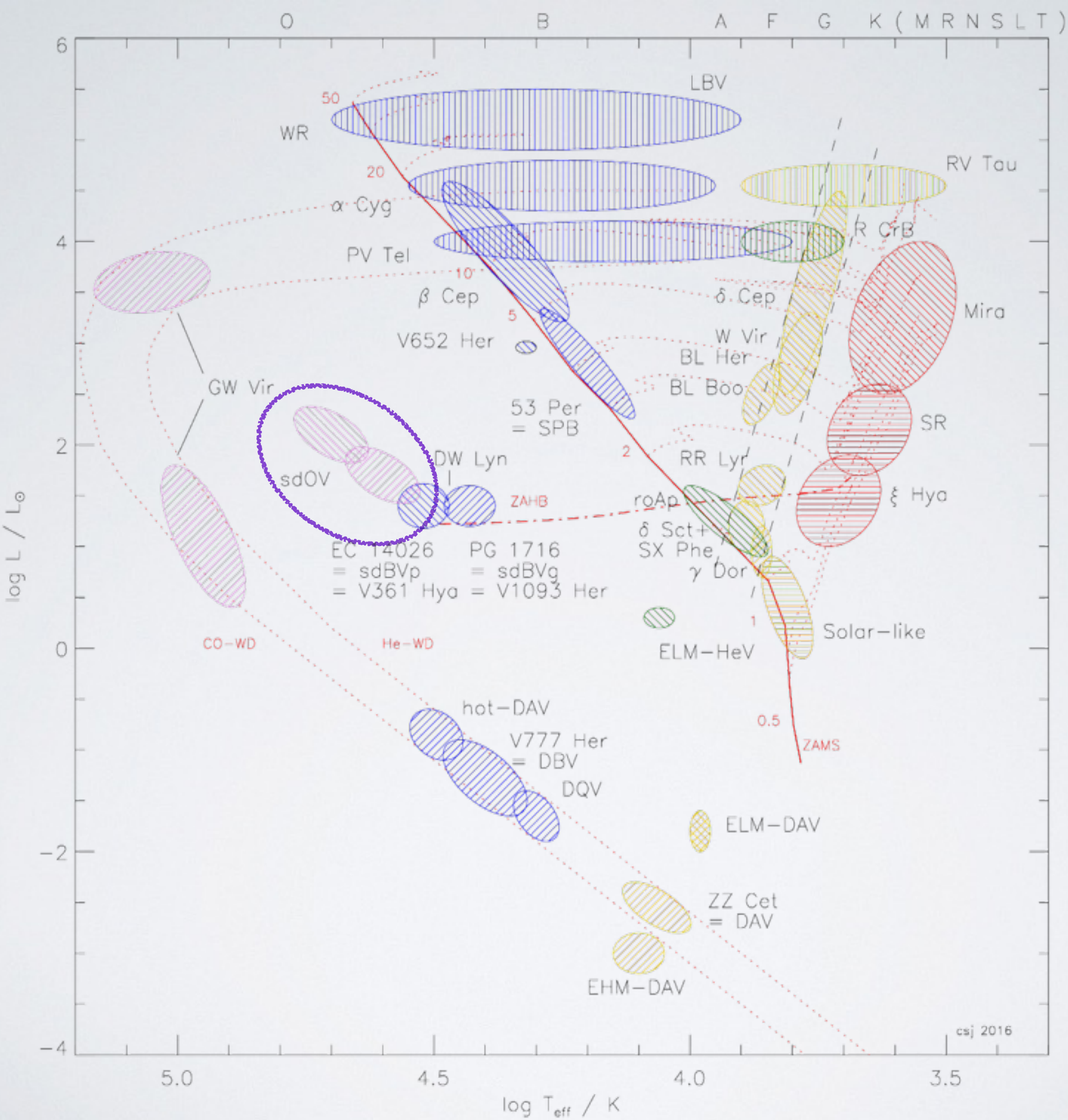


Fig. 11. Theoretical instability strip for rapid *p*-mode pulsations in hot subdwarfs. The small black dots identify grid points corresponding to stable models. Each red point identifies a model where unstable modes are predicted, the size of the dot being proportional to the number of excited modes. The large blue dots show the location of sdBV$_r$ variables among the field population, while the black cross indicates the one known rapid sdO variable in the field. The five sdO variables we found in ω Cen are represented by black circles, the dotted extension to higher log g for V2 indicating that the polluted spectrum obtained yields only a lower limit on the surface gravity.


O
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EC 14026
= sdBVp
= V361 Hya
PG 1716
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= V1093 Her
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EHM−DAV
csj 2016

Discovery of a pulsating lead-rich hot subdwarf: UVO 0825+15

CSJ + Baran, Behara, Kvammen, Martin, Naslim, Østensen, Preece, Reed, Telting & Woolf: MNRAS 2017 in press

- CP sdOs show g-mode pulsations (probably)
- CP means CP, very CP
- Lead floats on light

CHALLENGES for HEAVY-METAL SUBDWARFS

What masses and luminosities ?
Why surface chemistries ? (mixing, mass transfer, diffusion, …)
What drives pulsations ?
Why slow rotation ?
Why high space velocities ?
What origin ? (merger, common-envelope, …)

'Thermal' modes

SJ+HS

'Acoustic' modes

HS+DK

'Gravity' modes

Strangford Lough
Ireland, 2014