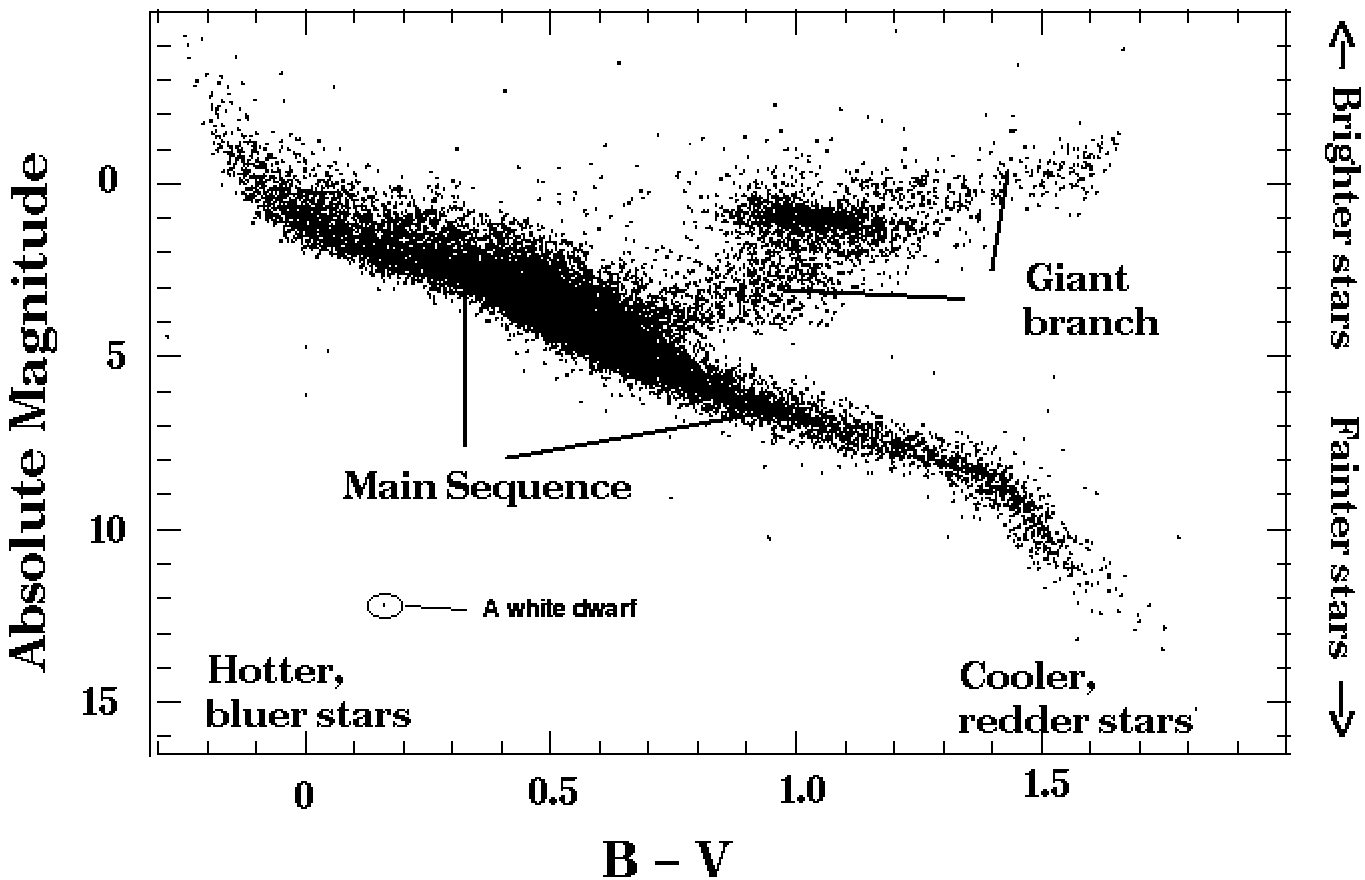
Exotic elements and isotopes in Chemically Peculiar Stars of the Upper Main Sequence

Charles R. Cowley (University of Michigan)
Swetlana Hubrig (ESO, AIP Potsdam)

June 2009

Herzsprung–Russell (HR) Diagram



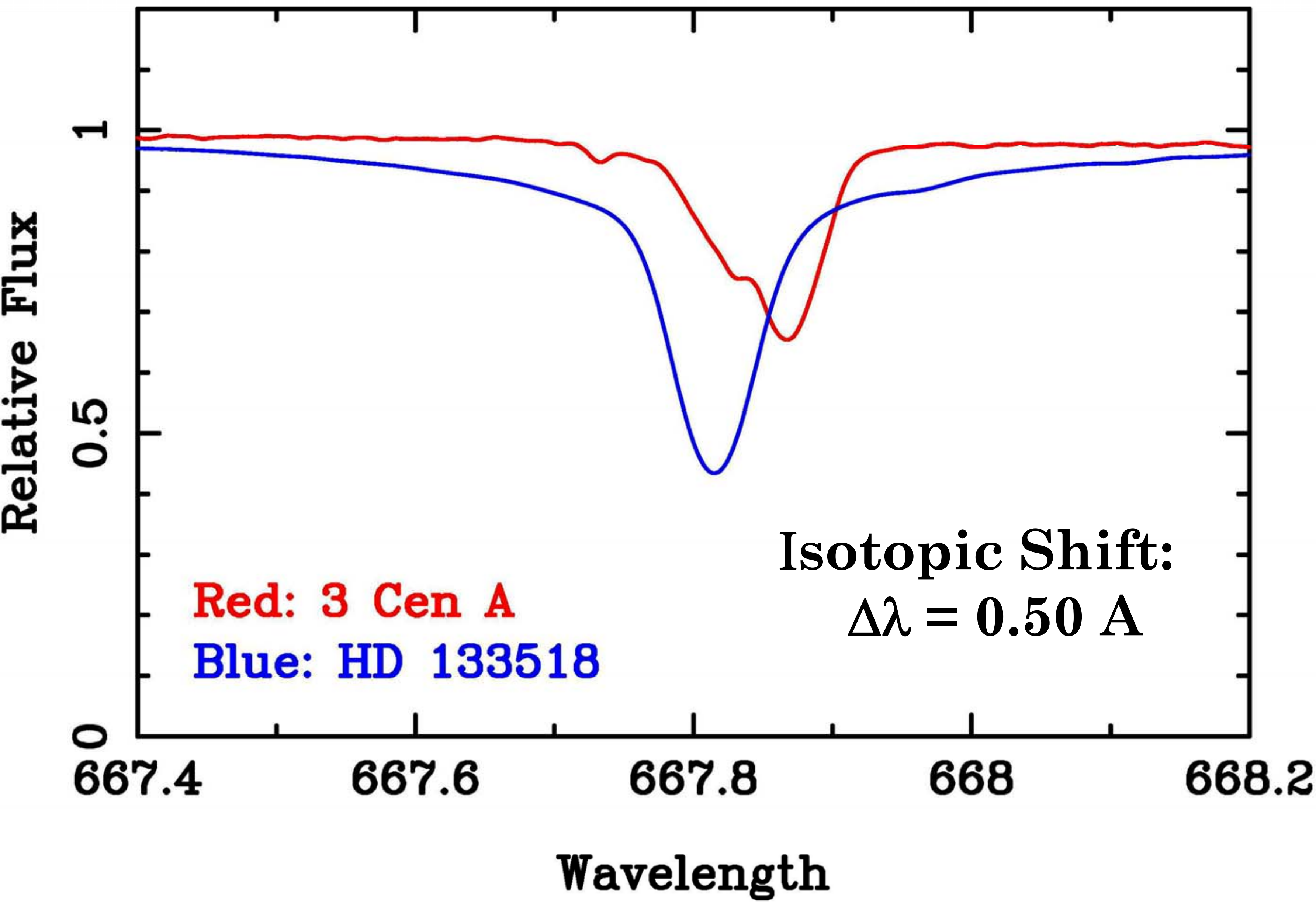
Astronomers measure the colors of stars with an index they call B – V. The larger B – V, the redder the star. Absolute magnitude is a logarithmic measure of brightness set up so the larger the number, the fainter the star.

Chemical peculiarities (CP) occur in most regions of the HR Diagram.

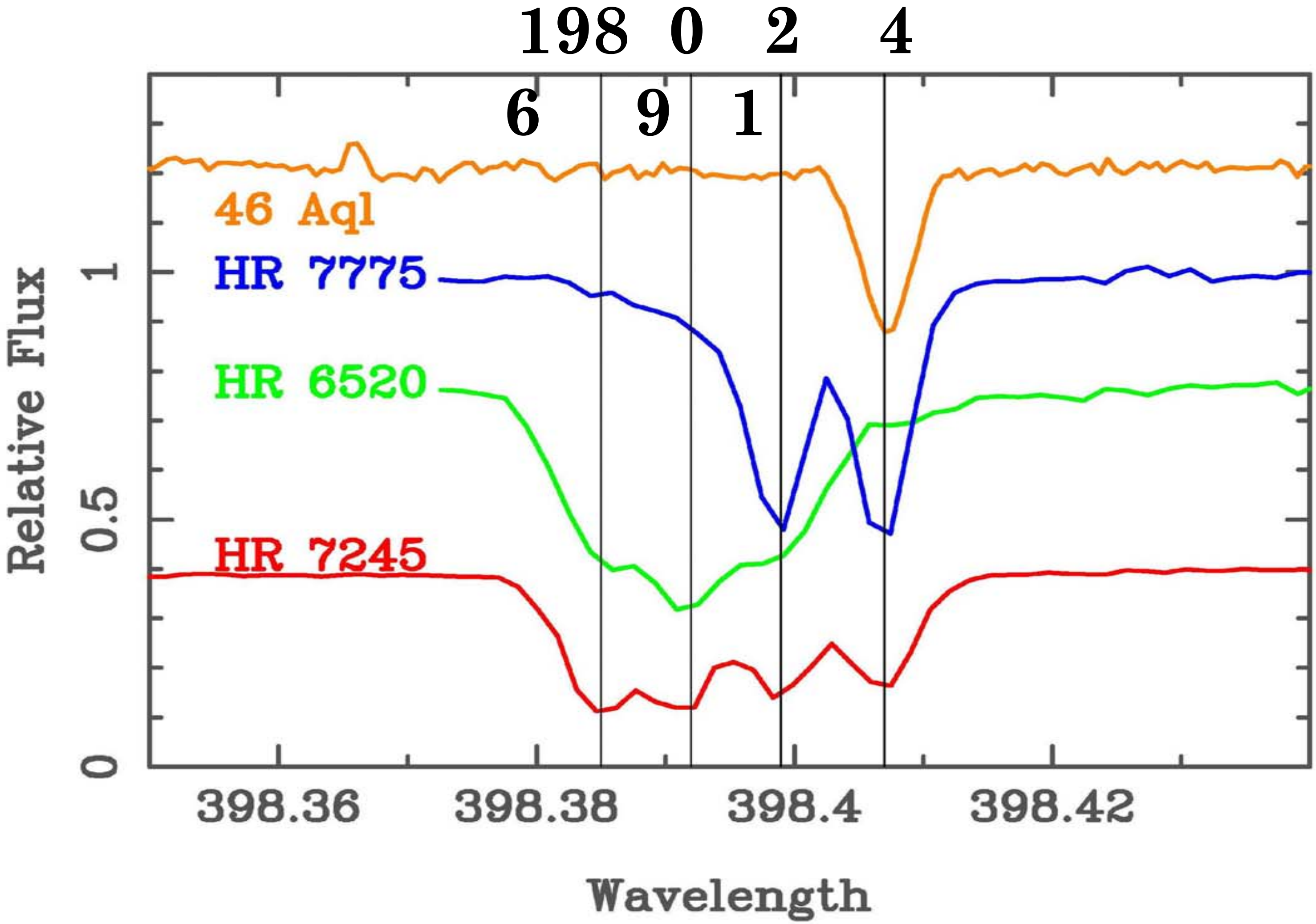
The most extreme examples of metal-to-metal fractionations occur in CP stars of the upper main sequence. Fractionation means a departure from a solar or near solar abundance pattern.

The most widely accepted theory for these anomalies is in situ fractionation under gravity and upward levitation by radiation pressure.

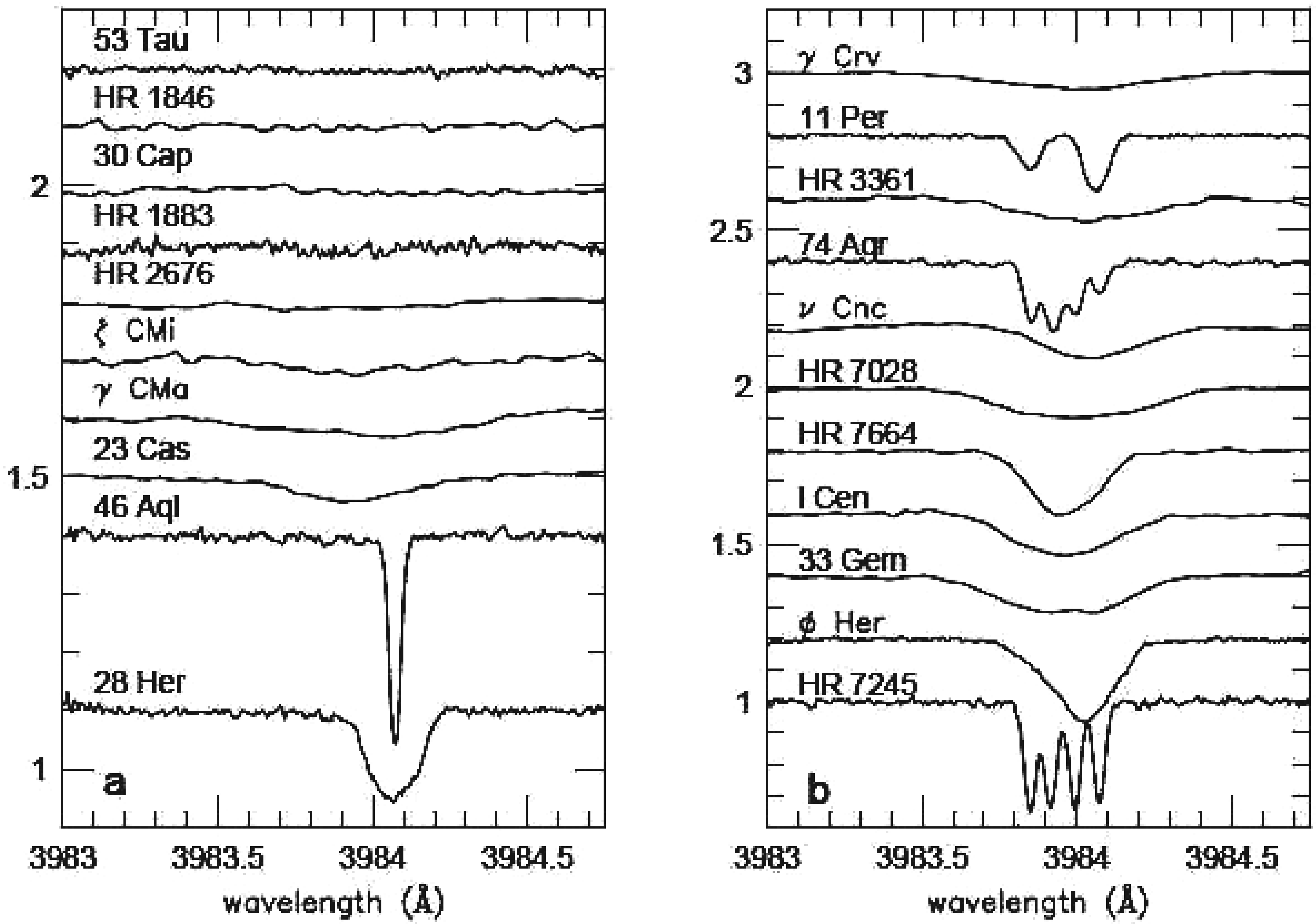
“Solar” He-3/He-4 is of order 10**-4



Hg II 3984 in several HgMn stars as observed with UVES



Somewhat higher resolution was employed in a 1999 paper by Woolf and Lambert.



Woolf and Lambert 1999

Some Pt isotopic Abundances from Hubrig, Castelli, and Mathys AA, 341, 190 (1999). Resolution: R = 118,000

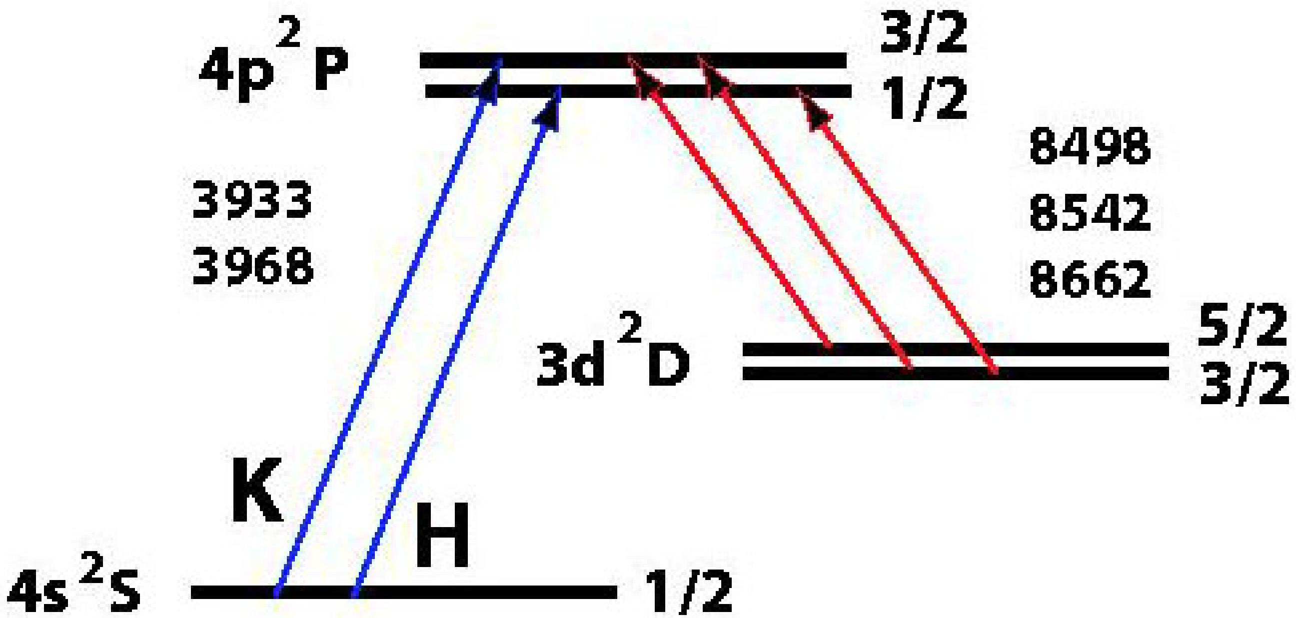
Isotope	Terrestrial abundance	HD 35548 HR 1800	HD 141556 χ Lup	HD 193452 HR 7775
194	32.9	0.00	0.00	0.00
195a	19.1	0.00	0.00	10.00
195b	14.74	0.00	0.00	7.50
196	25.2	0.00	10.00	55.00
198	7.19	100.00	90.00	27.50
$\log(N_{\rm Pt}/N_{\rm tot}$	$-10.24_{\odot}$	-6.84	-6.24	-5.65
[Pt]		+3.40	+4.00	+4.59

Castelli and Hubrig announced the presence of Ca-48 in HD 175640 or HR 7143 in 2004 (AA, 421, L1)

The Ca II infrared triplet has a large specific mass shift.

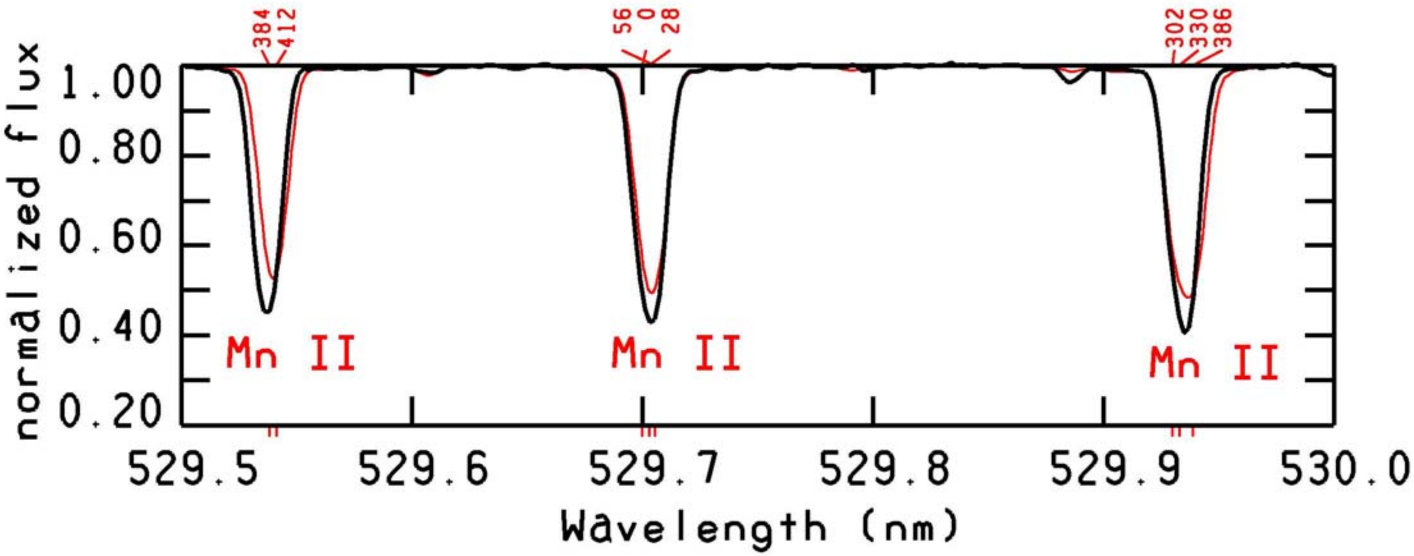
Shifts known in laboratory, but extensive measurements made recently in Mainz, Germany by Nörtershäuser, et al. 1998.

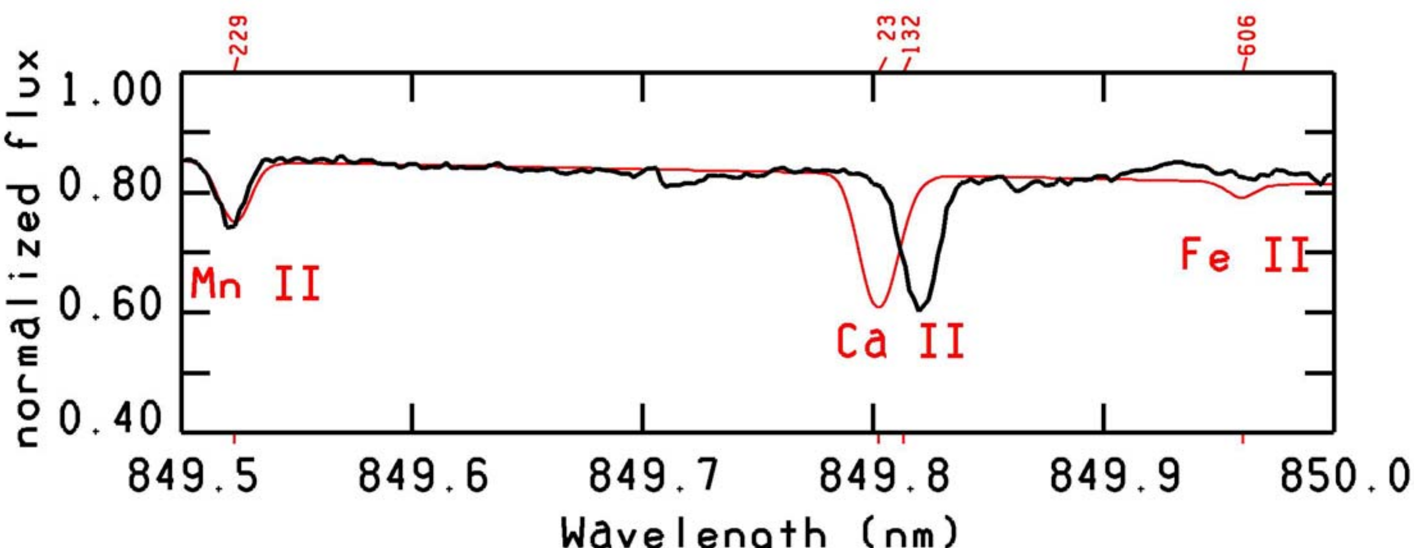
Low Levels of Ca II

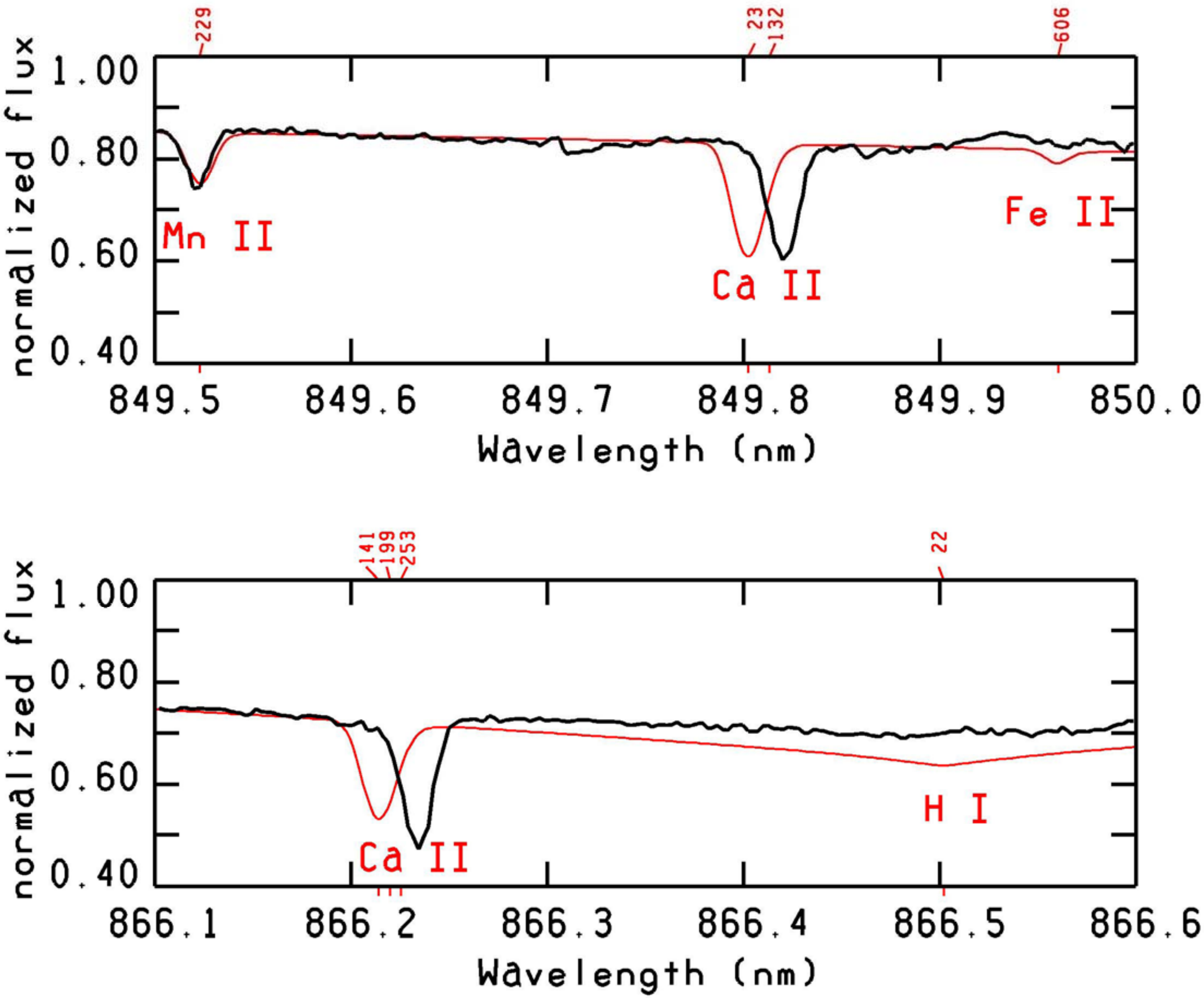


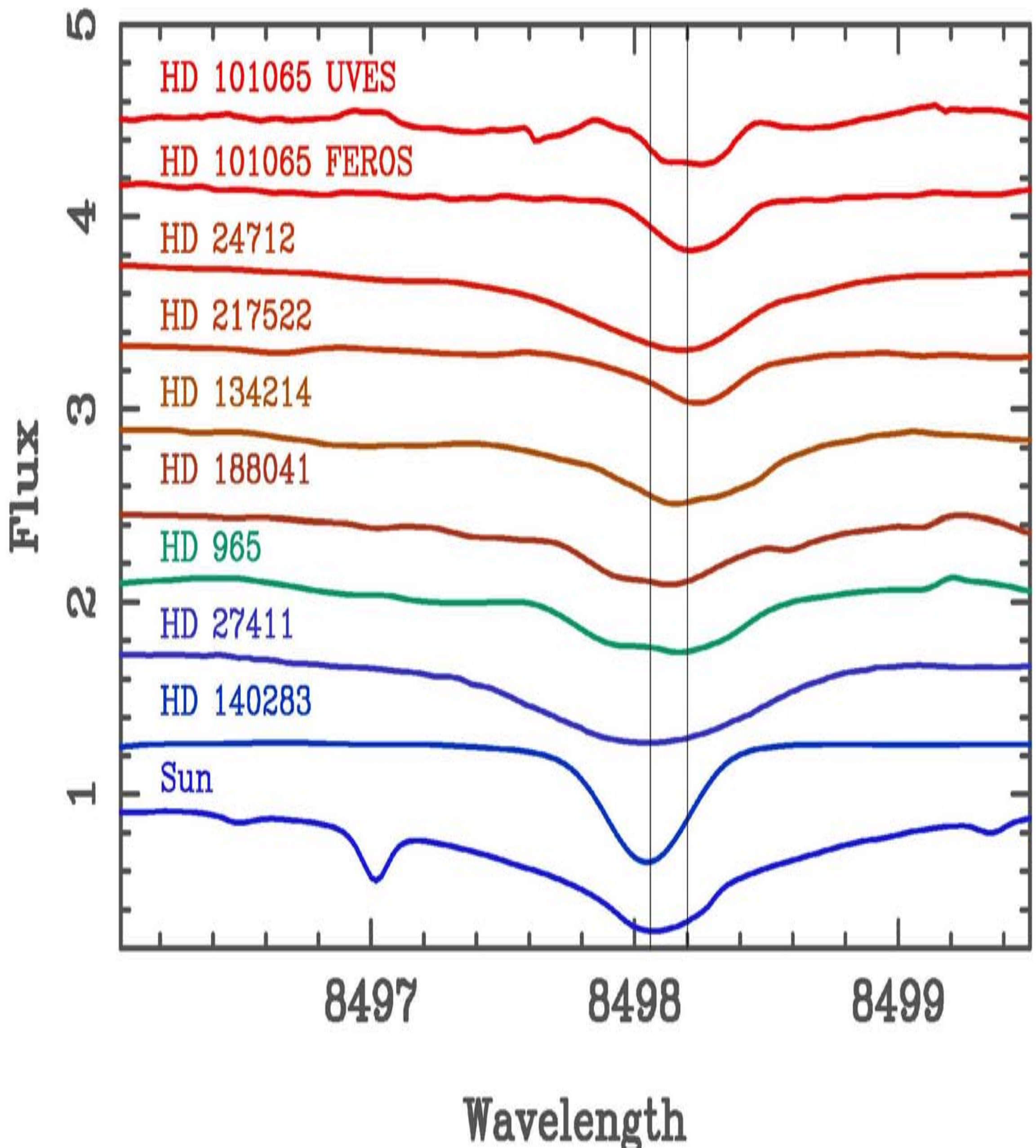
Small piece of Nuclide Chart

23	43V >800 MS ε	44V 111 MS ε	45V 547 MS ε	46V 422.50 MS ε	47V 32.6 M ε	48V 15.9735 D ε	49V 329 D ε	50V 1.4E+17 Y 0.250% ε	51V STABLE 99.750%
	42Ti 199 MS ε	43Ti 509 MS ε	44Ti 60.0 Y ε	45Ti 184.8 M ε	46Ti STABLE 8.25%	47Ti STABLE 7.44%	48Ti STABLE 73.72%	49Ti STABLE 5.41%	50Ti STABLE 5.18%
21	41Sc 596.3 MS ε	42Sc 681.3 MS ε	43Sc 3.891 H ε	44Sc 3.97 H ε	45Sc STABLE 100%	46Sc 83.79 D β-	47Sc 3.3492 D β-	48Sc 43.67 H β-	49Sc 57.2 M β-
	40Ca >3.0E+21 Y 96.94% 2ε	41Ca 1.02E+5 Y ε	42Ca STABLE 0.647%	43Ca STABLE 0.135%	44Ca STABLE 2.09%	45Ca 162.61 D β-	46Ca >0.28E+16 Y 0.004% 2β-	47Ca 4.536 D β-	48Ca 2.3E19 Y 0.187% 2β-
19	39K STABLE 93.2581%	40K 1.248E+9 Y 0.0117% β-	41K STABLE 6.7302%	42K 12.321 H β-	43K 22.3 H β-	44K 22.13 M β-	45K 17.3 M β-	46K 105 S β-	47K 17.50 S β-


384
412
56
0
28
302
330
386
normalized flux
1.00
0.80
0.60
0.40
0.20
Mn II
Mn II
Mn II
529.5
529.6
529.7
529.8
529.9
530.0
Wavelength (nm)


229
23
132
606
normalized flux
1.00
0.80
0.60
0.40
Mn II
Ca II
Fe II
849.5
849.6
849.7
849.8
849.9
850.0
Wavelength (nm)

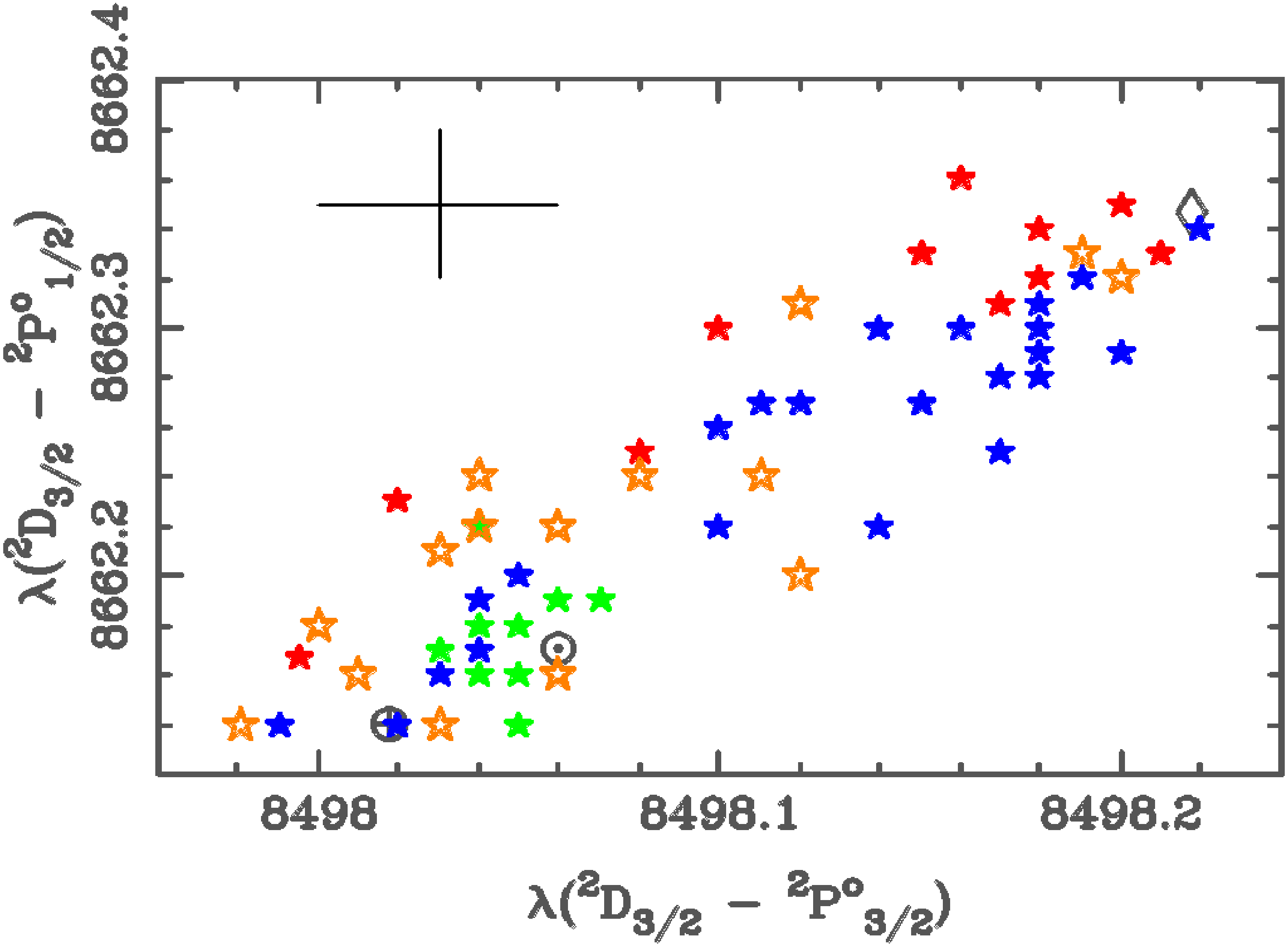

229
23
132
606
1.00
0.80
0.60
0.40
normalized flux
Mn II
Ca II
Fe II
849.5
849.6
849.7
849.8
849.9
850.0
Wavelength (nm)
141
199
253
22
1.00
0.80
0.60
0.40
normalized flux
Ca II
H I
866.1
866.2
866.3
866.4
866.5
866.6
Wavelength (nm)



HD 101065 UVES
HD 101065 FEROS
HD 24712
HD 217522
HD 134214
HD 188041
HD 965
HD 27411
HD 140283
Sun
Flux
Wavelength
1
2
3
4
5
8497
8498
8499

Frankly, the presence of Ca-48 seemed so bizarre, that one wonders if some blunder had been made. The first thing to do is ask if blends might be responsible. Random blends would be unlikely to affect all three lines of the IRT in the same way.

In the next slide we plot the wavelength measurement for the 8662-line vs that for the 8498-line.

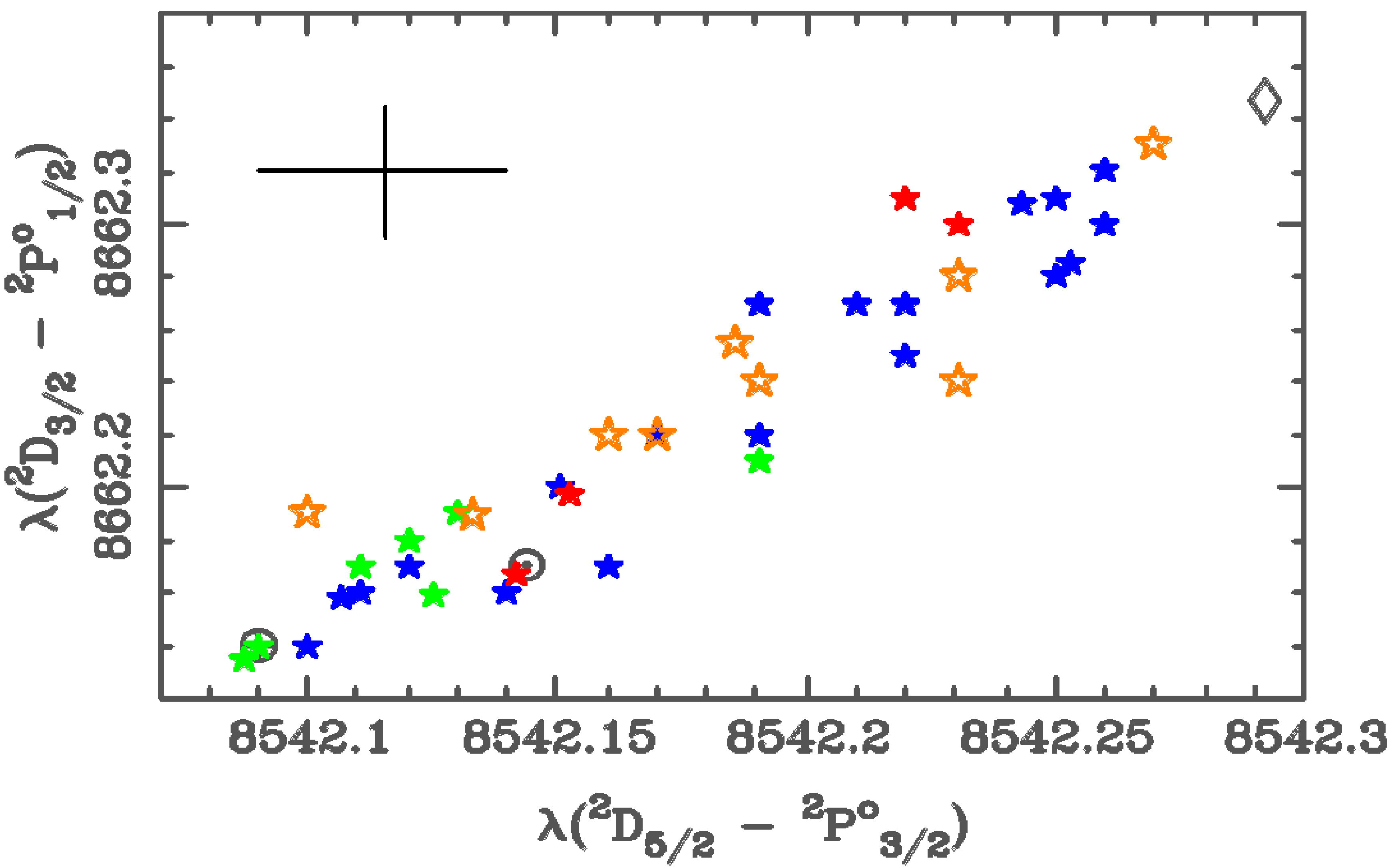


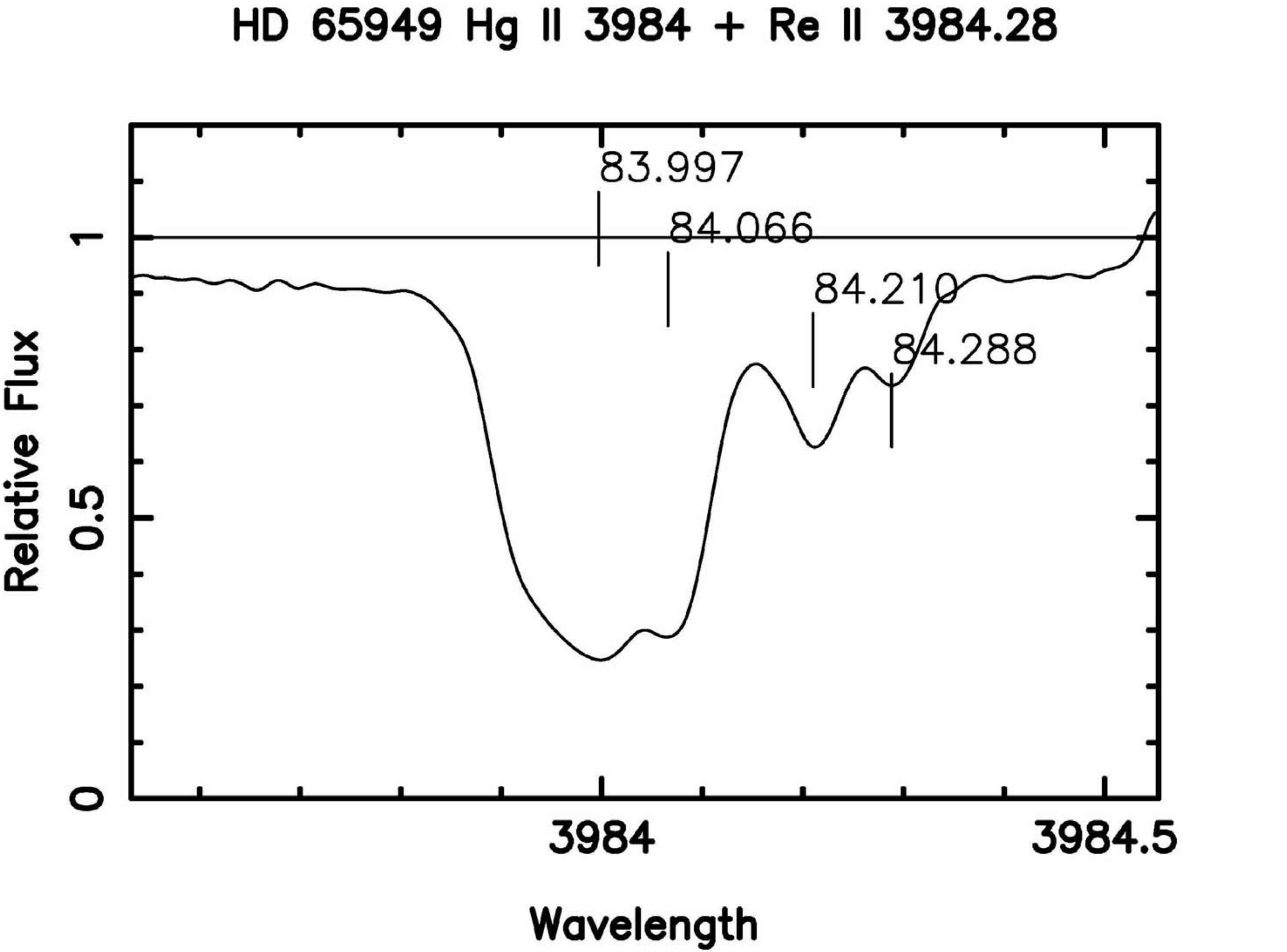
8662.4
8662.3
8662.2
8498
8498.1
8498.2
λ(^{2}D$_{3/2}$ − ^{2}P°$_{3/2}$)
λ(^{2}D$_{3/2}$ − ^{2}P°$_{1/2}$)

Prior to Nov. 2004, only the 8498- and 8662-lines were available, because of an order gap in the UVES configuration. The 8542-line was also unavailable on a number of the FEROS spectra.

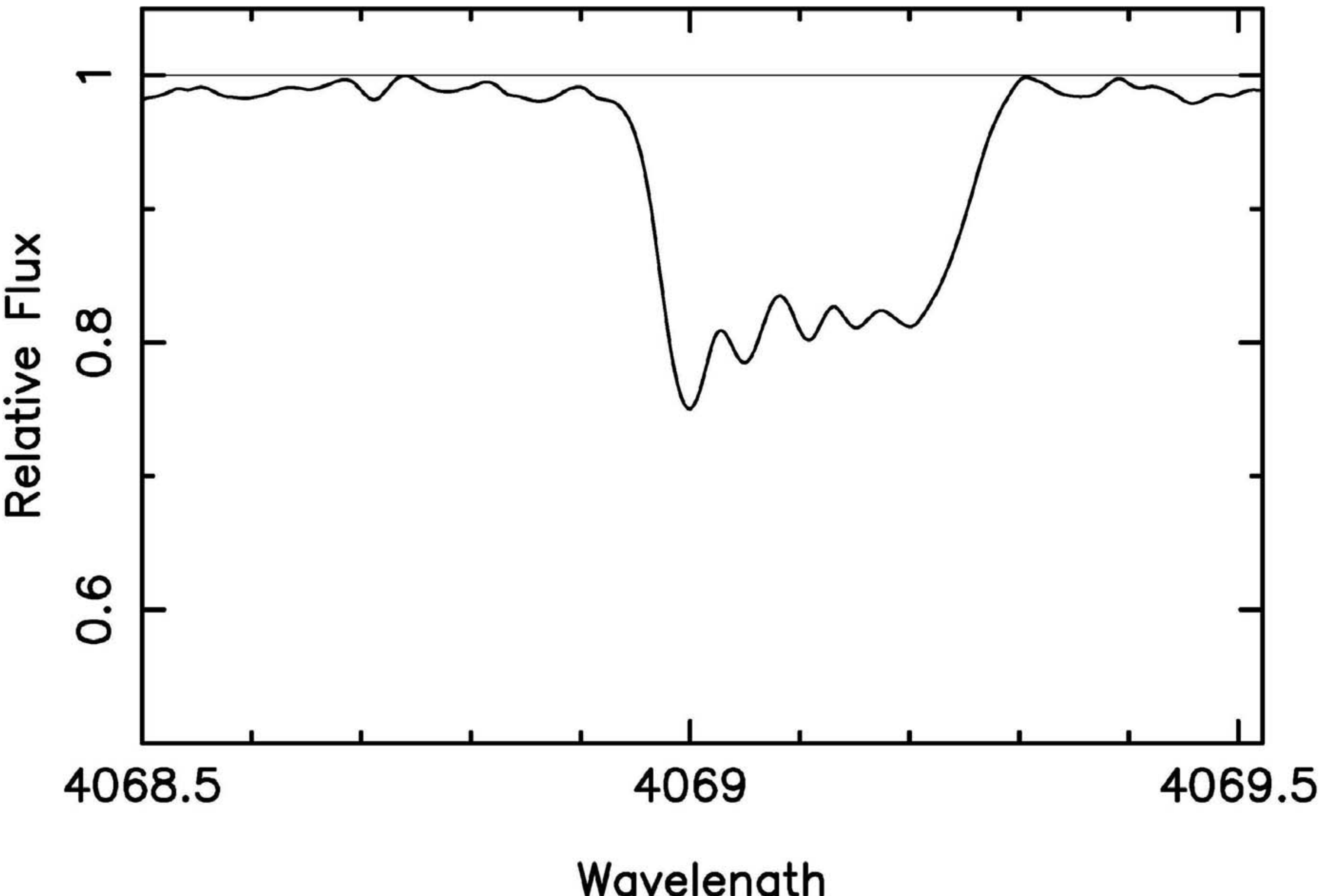
After the reconfiguration of the UVES, all three lines were available. We show in the next slide, the 8542-line plotted vs. the 8662-line.

There can be no doubt now that all three shifts are highly correlated, making the Ca-48 identification secure.

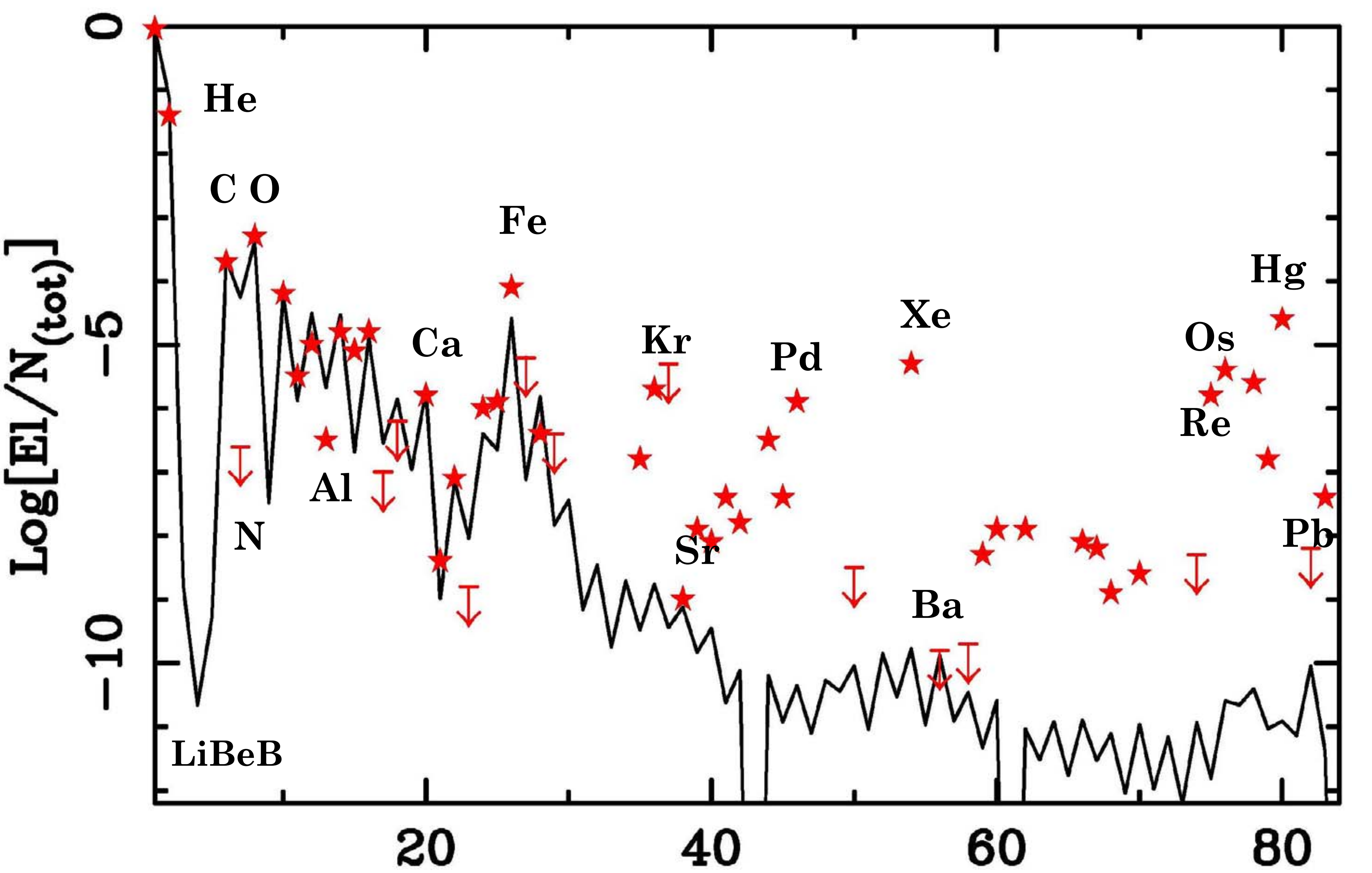

8662.2
8662.3
$\lambda(^2D_{3/2} - {}^2P^o{}_{1/2})$
8542.1
8542.15
8542.2
8542.25
8542.3
$\lambda(^2D_{5/2} - {}^2P^o{}_{3/2})$


HD 65949 Hg II 3984 + Re II 3984.28
83.997
84.066
84.210
84.288
Relative Flux
1
0.5
0
3984
3984.5
Wavelength

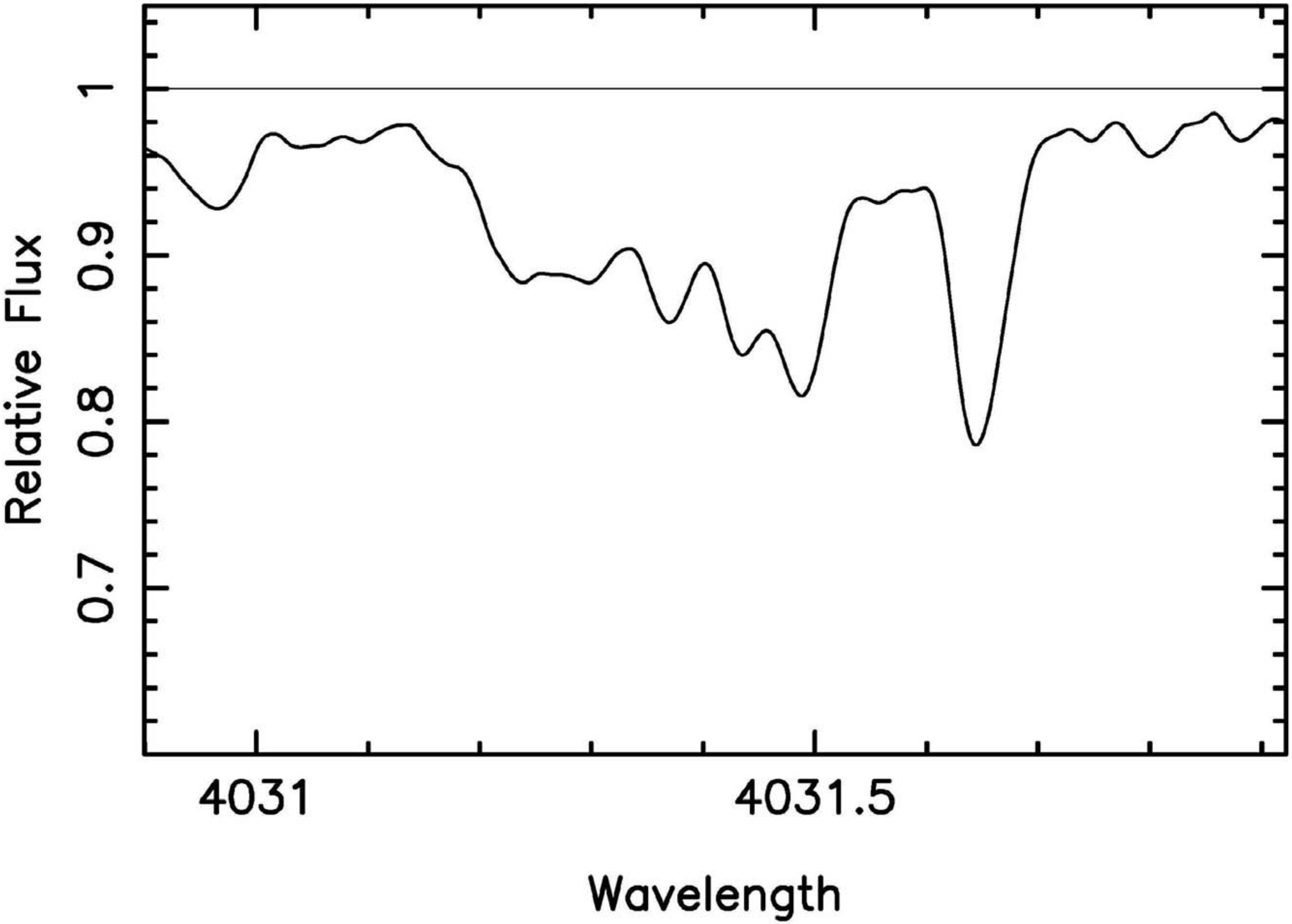
Unclassified Re II line in HD 65949



HD 65949 Provisional Abundances



Classified line in HD 65959
Re II (a5G3 – z7P °2)



Thank you, The End