Composite spectrum hot subdwarf binaries

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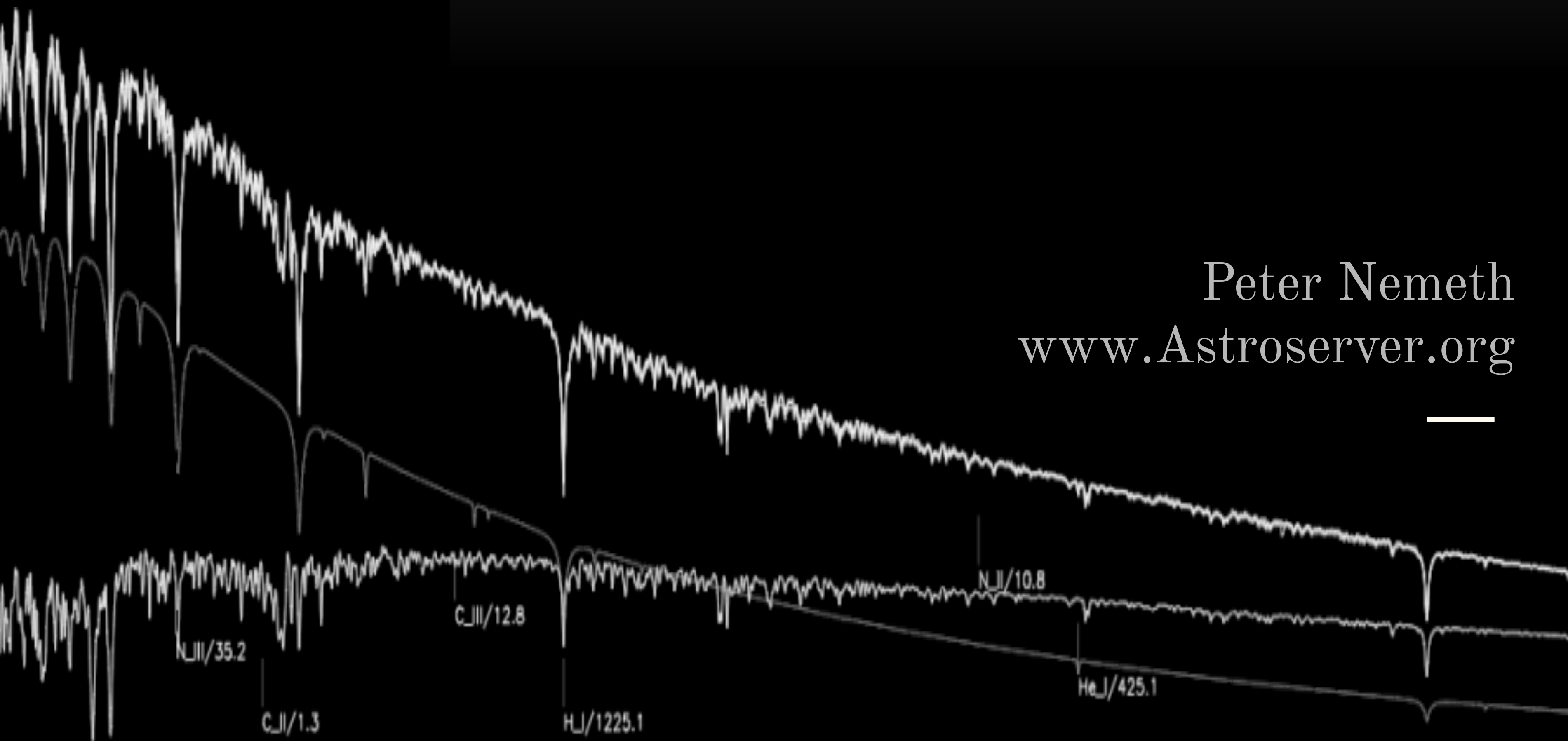
www.Astroserver.org

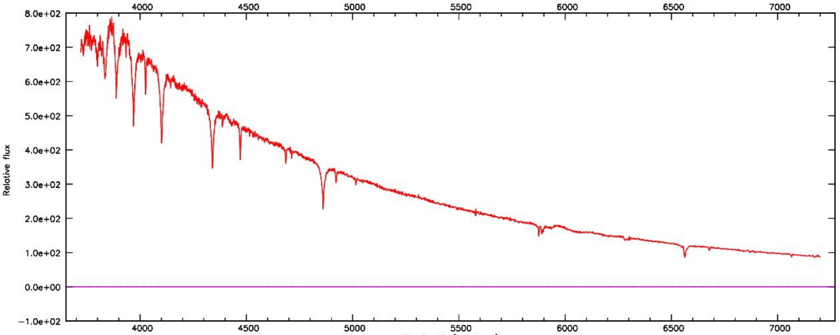


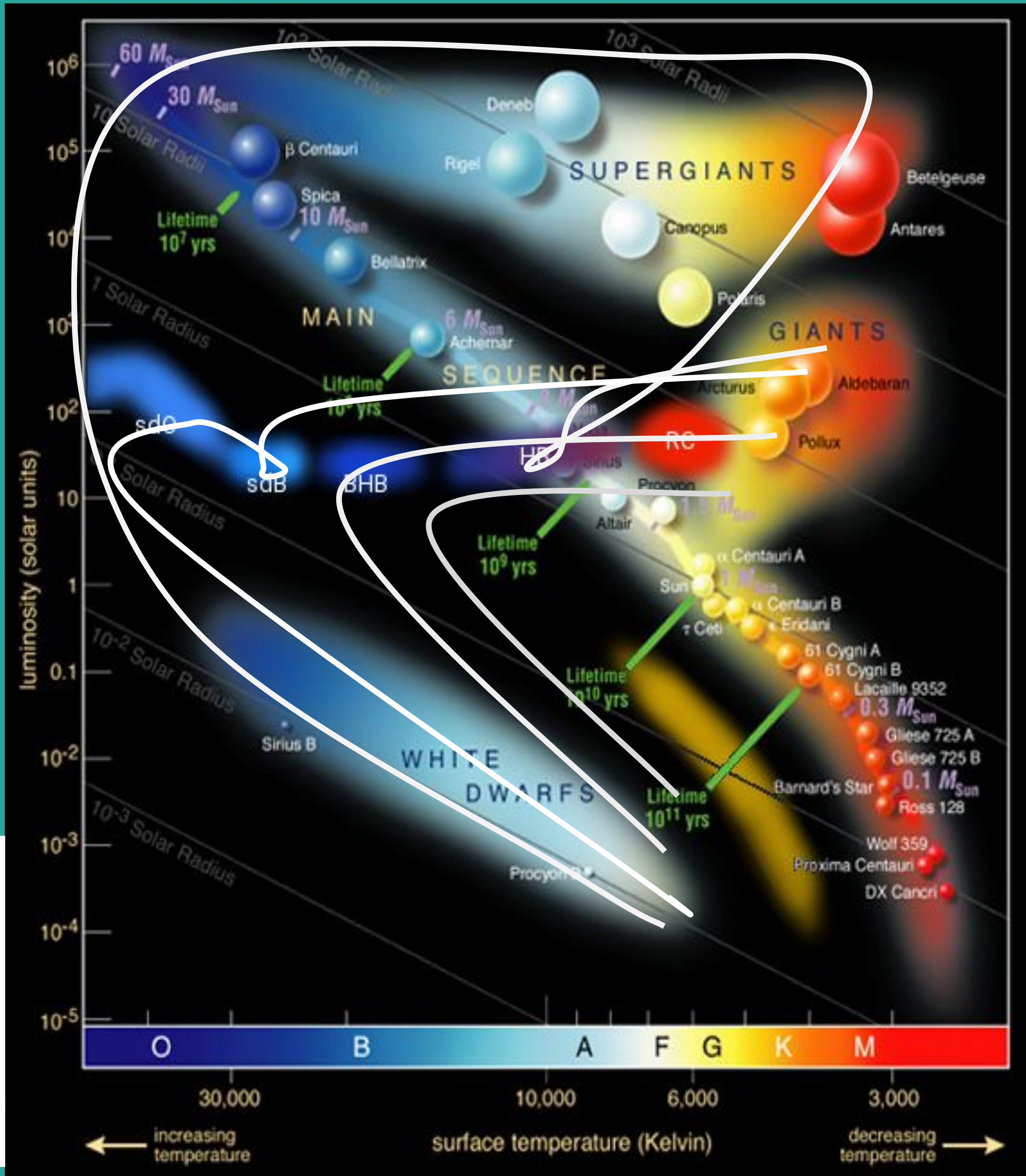
Hot subdwarfs (Heber 2016 PASP 128 082001)

- Extreme horizontal branch stars
- Evolved 0.45 $M_\odot$ core He-burning stars
- Progenitor mass above 0.8 $M_\odot$
- No, or very thin H envelope
- Luminosity of 20-50 times solar
- Lifetime ~100 Myr

- Precise mass and mass distribution is still a question!
- Stars below the He-core burning limit
- Diffusion erases all history
- Fine tuning of mass loss
- Binarity is the key!

Spectroscopically sdB stars are:
Teff = ~25000 - 36000 K
Logg = 5- 6 cm/s^2





Fit or decomposition?

Fit: one model reproduces all observed features
(space observation of the Sun, Vega or a nearby WD)

> Reduction: we remove the components, or part of the data that is not in the model

Decomposition: a combination of multiple models is applied to reproduce the observation

> The combination of two (or more) models is a tricky part!
>
> E.g.: Double lined binaries and reflection effect systems.

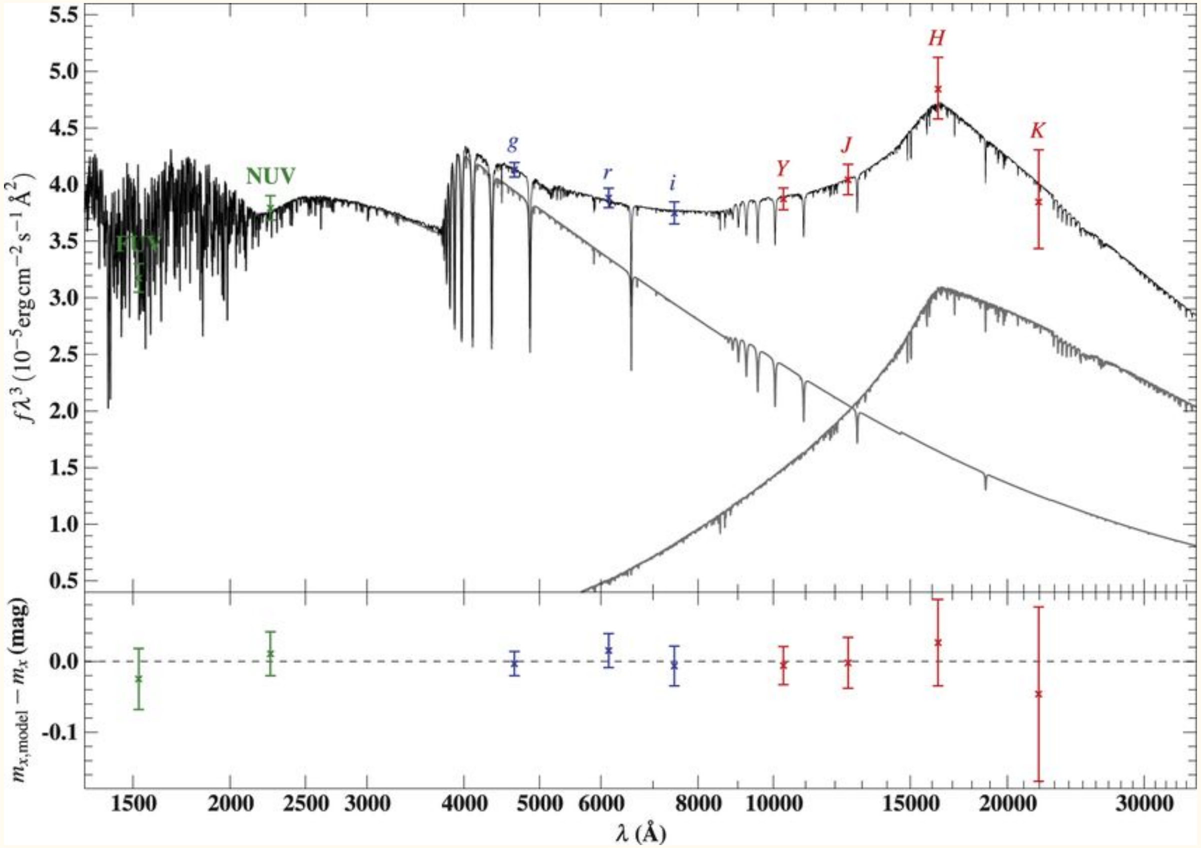
Simple case: SED fit

Spectral energy distributions give easy and fast ballpark estimates for the components

but no precision ...

No RVs, abundances or precise atmospheric parameters

Believe it only if spectroscopy confirms!



Two approaches

Fourier disentangling

Petr Hadrava (2009) arXiv:0909.0172H

- Correlation search in between orbital and spectral parameters
- Iterative minimization of the merit function by changing orbital and spectral properties
- Multiple observations, good sampling of the RV curve
- Clean spectral features are best

Wavelength space decomposition

Simon & Sturm (1994) A&A 281 286

- Direct reproduction of the observation with a linear combination of two models (synthetic spectra)
- Iterative updates of the spectral properties and radial velocities
- A single observation is enough
- Line blending is not a problem

Problems: at RV=0 or at spectral type match (target swap)!

XTGRID - fitting procedure

- Iterative updates of the stellar components along the steepest χ^2 gradient
- Each parameter is adjusted individually
- Pure spectroscopic reconstruction or added constraints
- Tlusty models for the hot component, pre-calculated spectral libraries for the cool companion
- Linear combination of models, instead of subtraction
- Online interface at: www.Astroserver.org/sandbox

Hot subdwarf		**Companion**
non-LTE analysis Few lines, strong broadening Non-solar abundance pattern	+	LTE analysis Many sharp lines Scaled solar abundance pattern

Motivation:

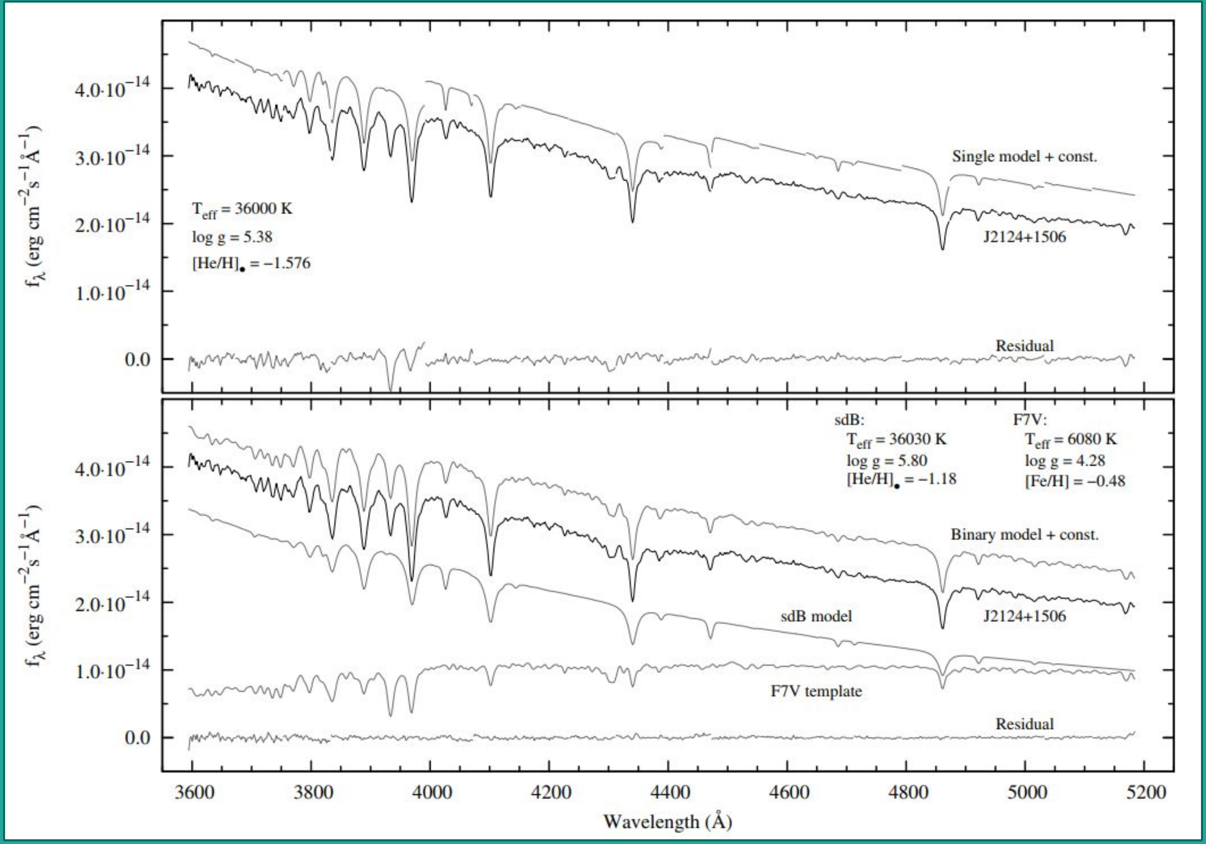
- Composite spectrum (SB2) binaries are usually neglected in surveys, and the reflection effect is overlooked
- ~20% of hot subdwarfs are in composite binaries with F-G type companions (pulsations)
- Well suited targets for decomposition in the optical!

Systematics reach:

- Teff ~ 1000s of K
- Logg ~1 dex

Expectations:

- Scaled solar abundances in cool companions
- Age of systems
- Past interactions, mass transfer
- Improved parameters for subdwarfs



Real problems: many correlations

Teff - logg - vsini vs. dilution

Metallicity - vsini vs. dilution

Dilution factor is evil!
A 10% difference is hardly noticeable!

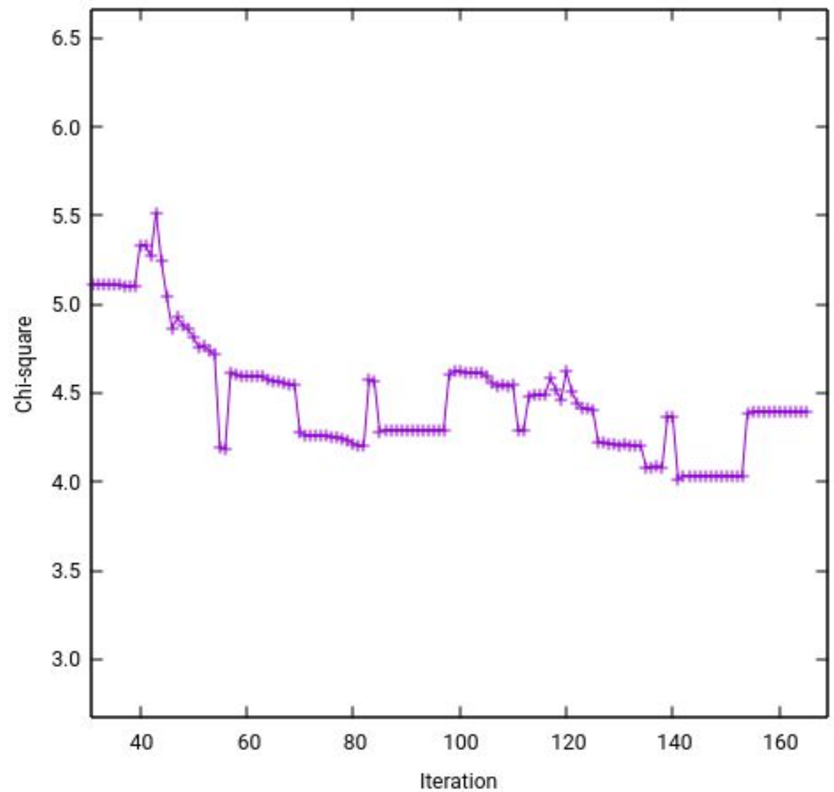
limited SNR

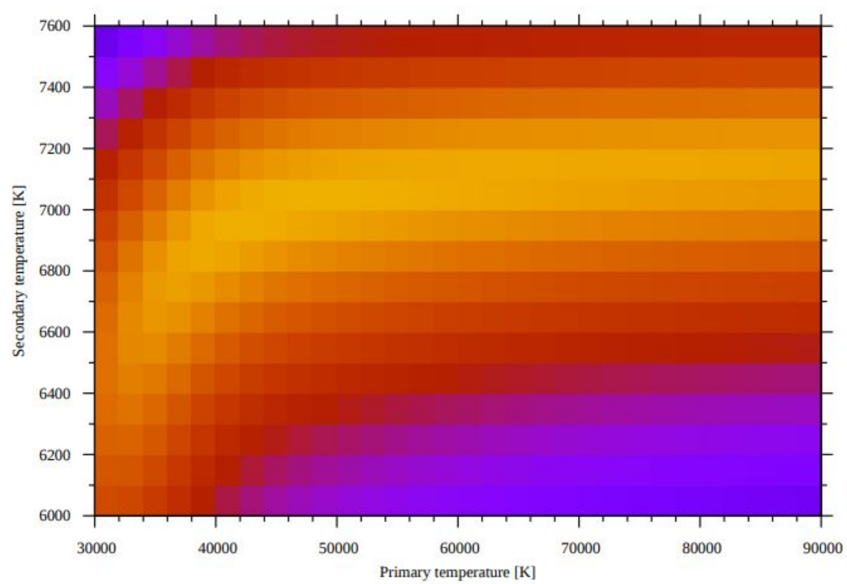
One needs signal from both components

The observation must cover a range where the stars have comparable flux

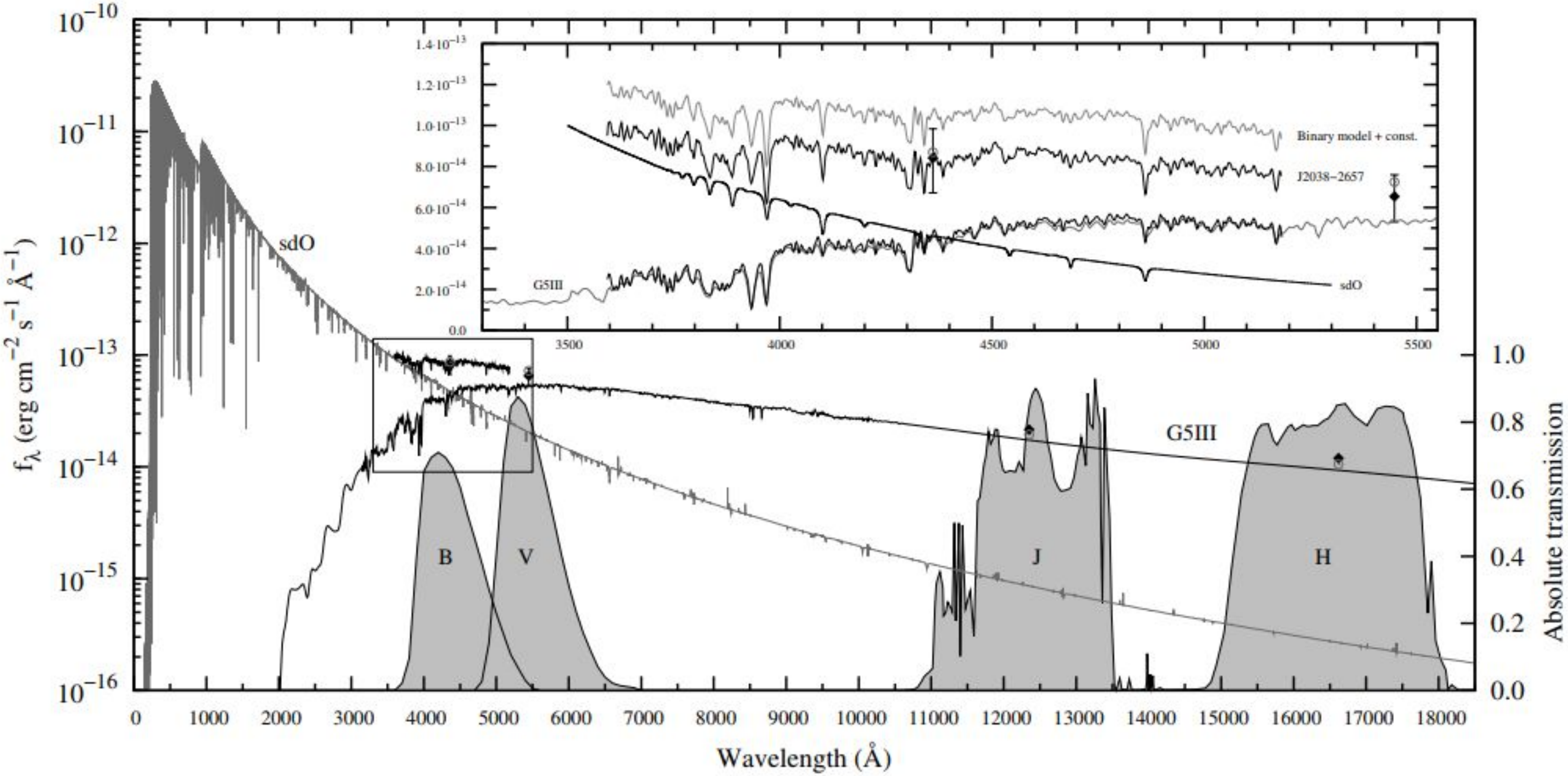
Østensen, R. H.

2012 ASPC 452 233





A nice example

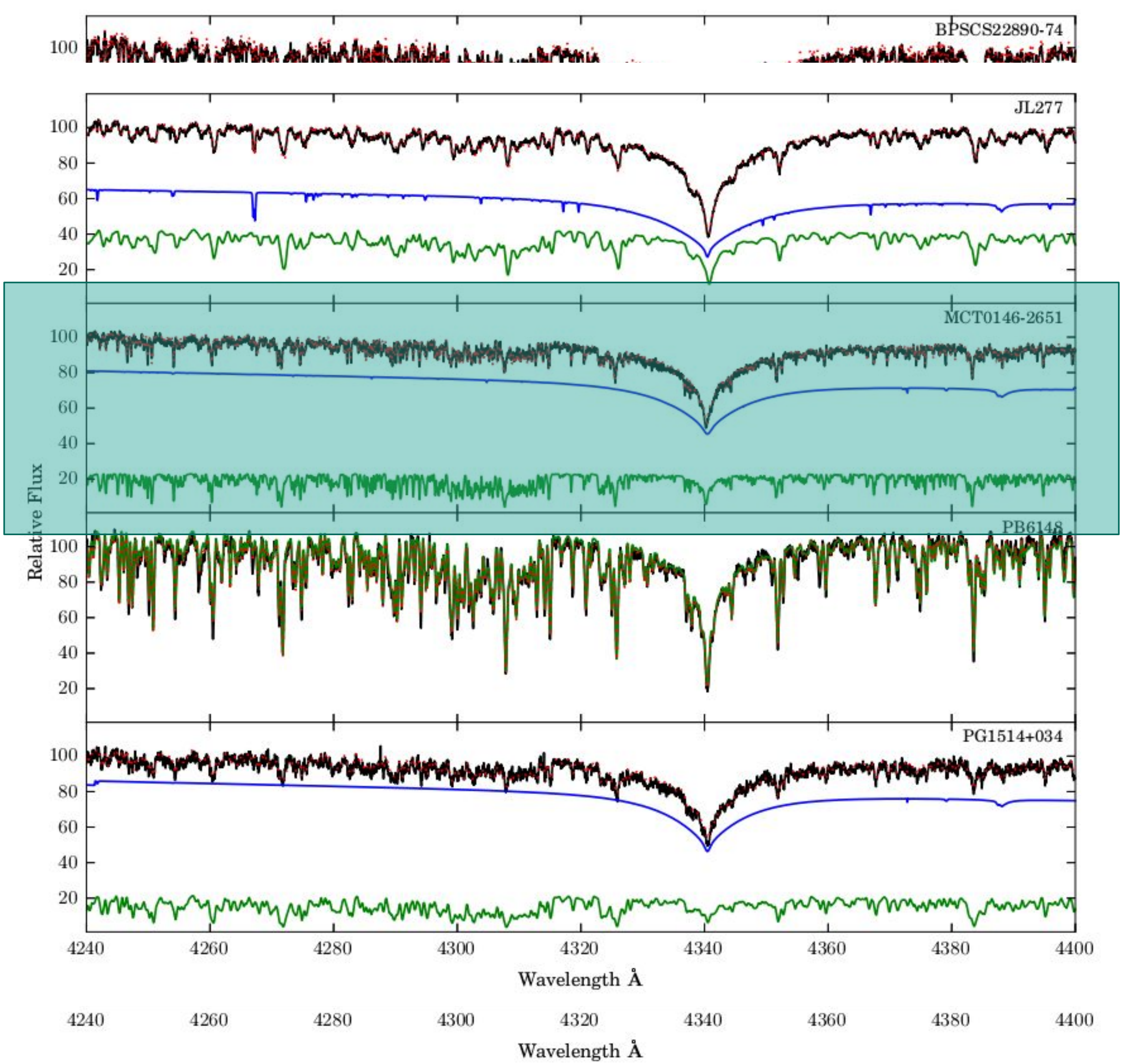


Nemeth, Kawka, Vennes 2012 MNRAS 427 2180

Sample variety

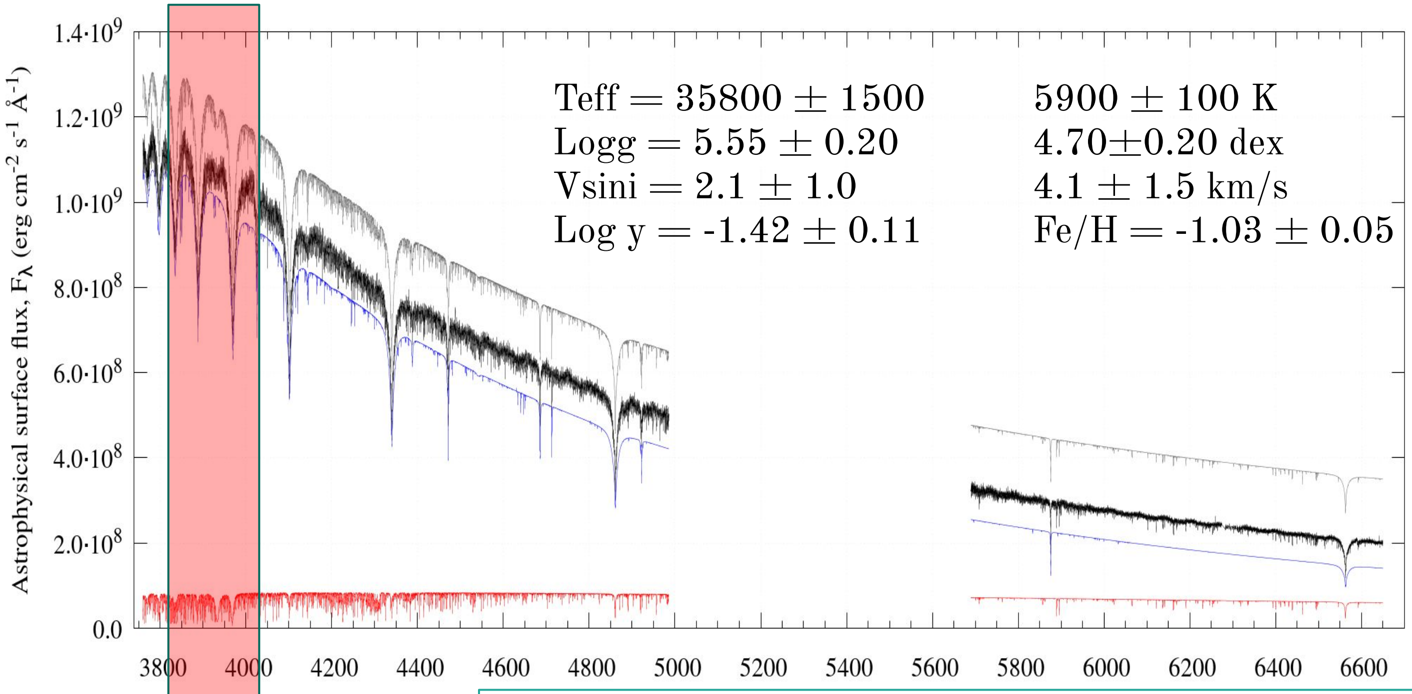
VLT/UVES filler obs. for 28 systems

Models show consistency with SED and GSSP (Tkachenko et al. 2015 A&A 581, 129) results



Vos et al. 2018 MNRAS 473 693

www.Astroserver.org/KW32YZ/



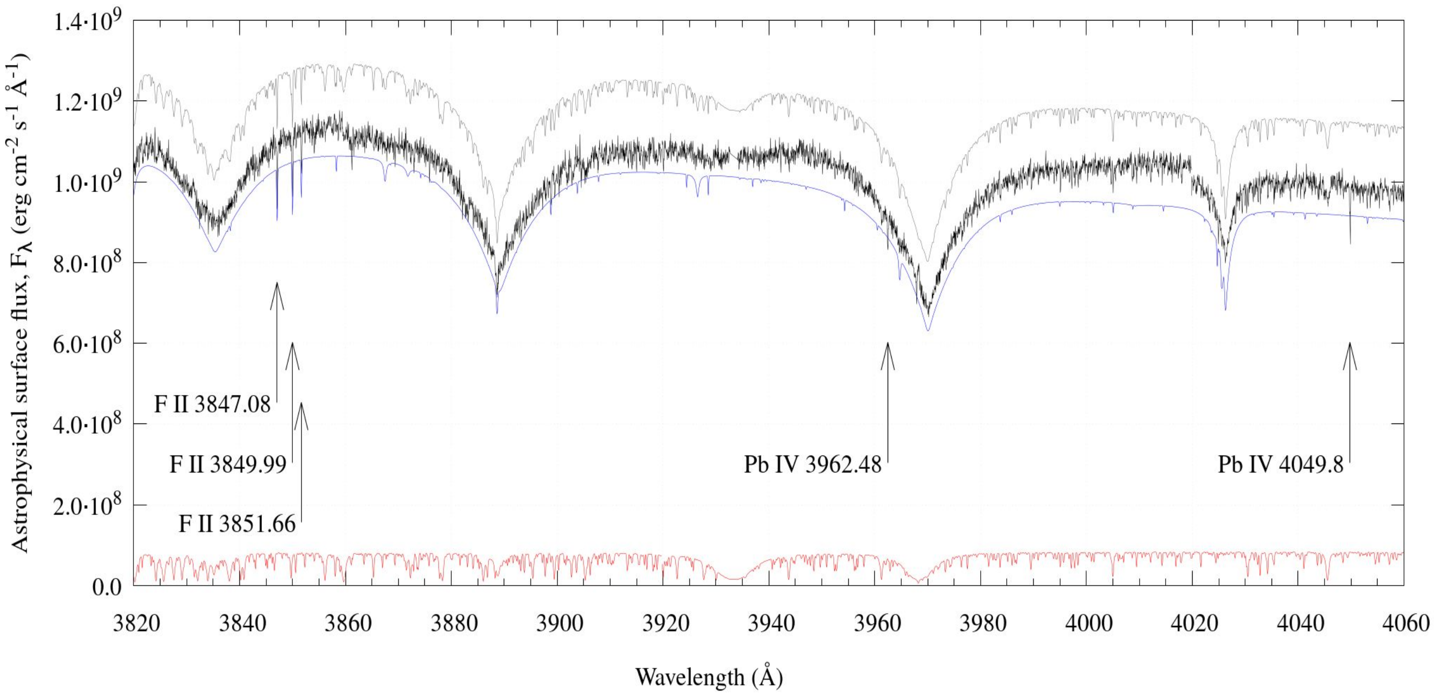
SB 744

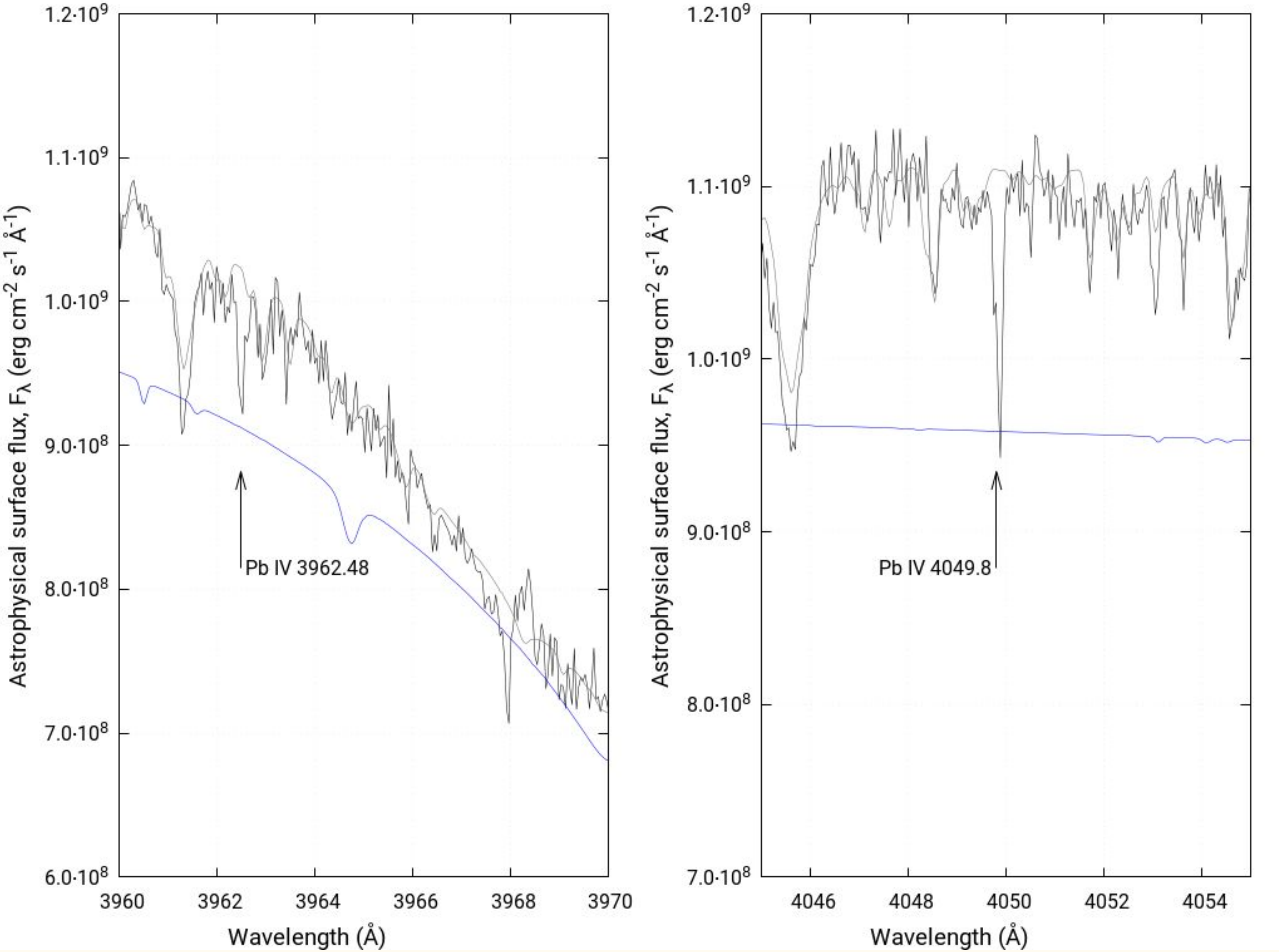
Extreme super-solar abundances of F and Pb

Puzzle: s-process elements in the subdwarf and r-process elements in the G1V companion.

Vos et al. 2018
MNRAS 473 693

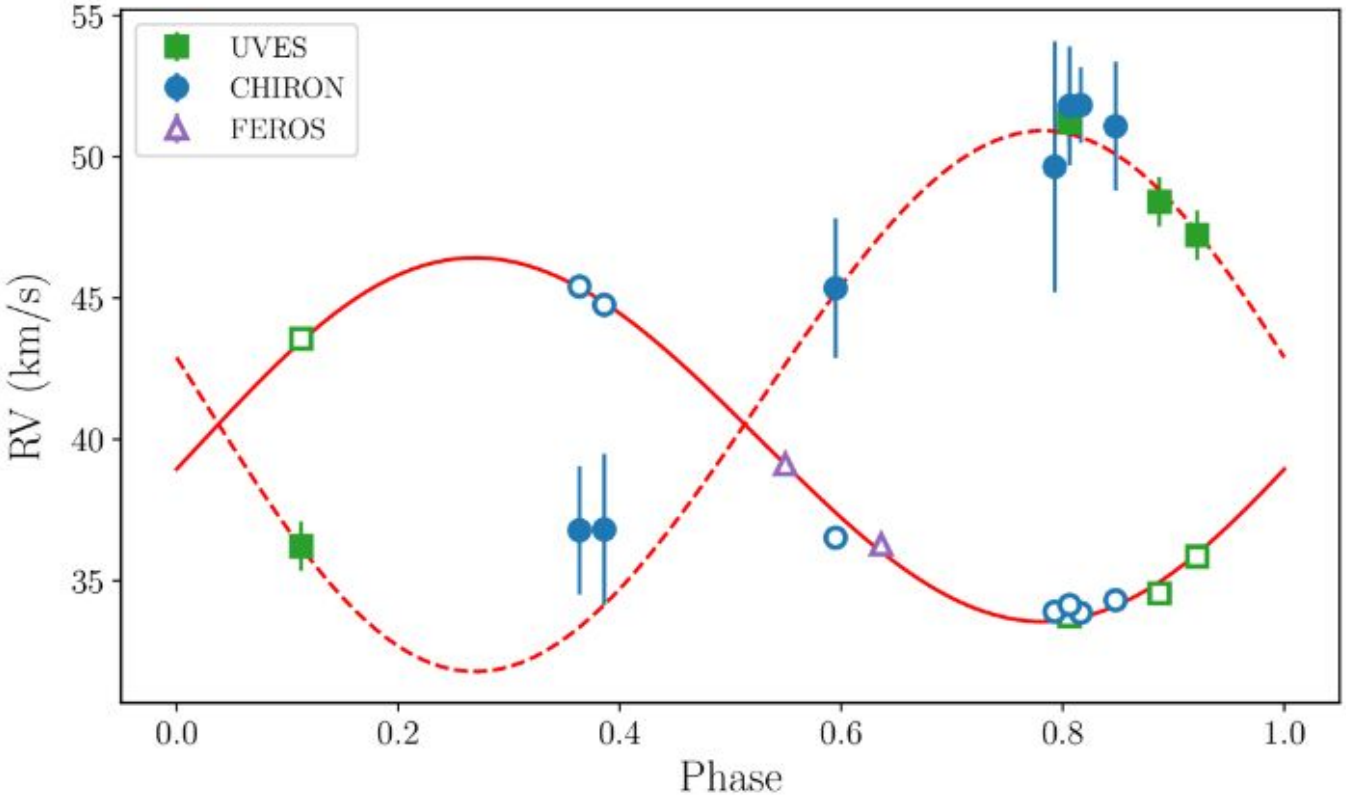
www.Astroserver.org/KW32YZ/





Astrophysical surface flux, F_λ (erg cm^{-2} s^{-1} Å^{-1})
1.2·10^9
1.1·10^9
1.0·10^9
9.0·10^8
8.0·10^8
7.0·10^8
6.0·10^8
3960
3962
3964
3966
3968
3970
Wavelength (Å)
Pb IV 3962.48
Astrophysical surface flux, F_λ (erg cm^{-2} s^{-1} Å^{-1})
1.2·10^9
1.1·10^9
1.0·10^9
9.0·10^8
8.0·10^8
7.0·10^8
4046
4048
4050
4052
4054
Wavelength (Å)
Pb IV 4049.8

MCT 0146-2651: orbit

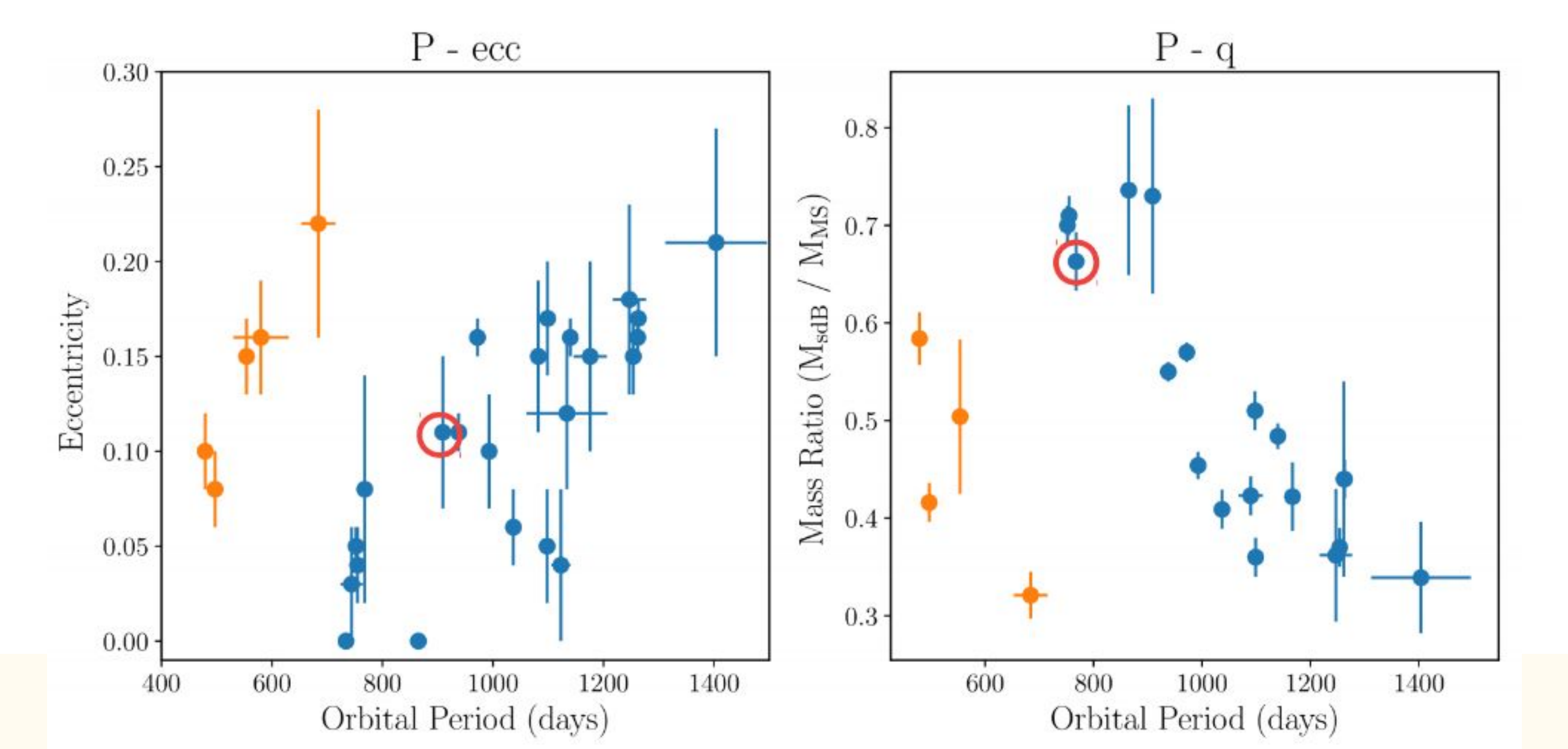


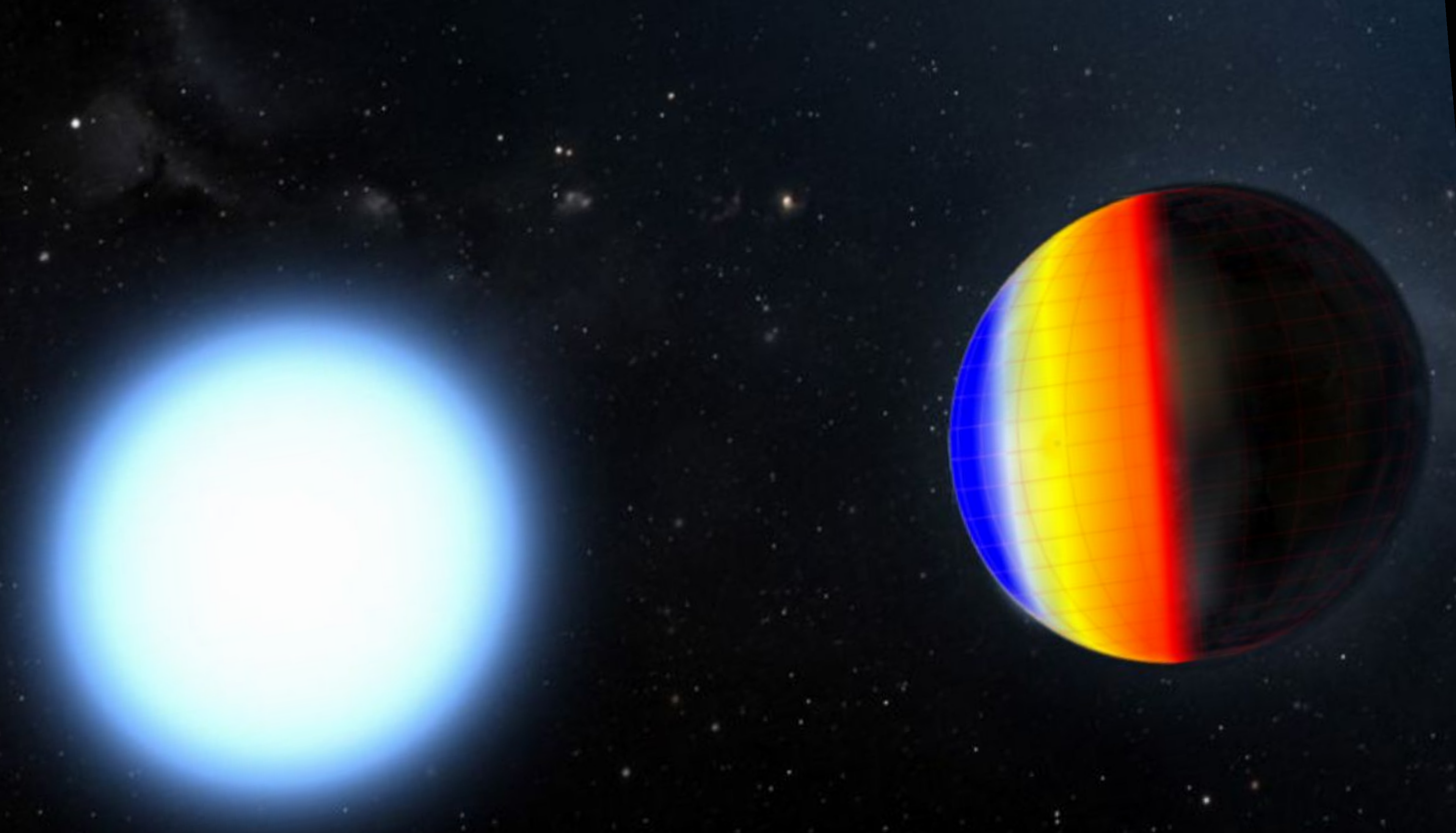
	sdB	MS
P (d)	760 ± 15	
e	0.08 ± 0.04	
q (MS/sdB)	0.66 ± 0.07	
K (km/s)	6.6 ± 0.5	10.0 ± 0.08

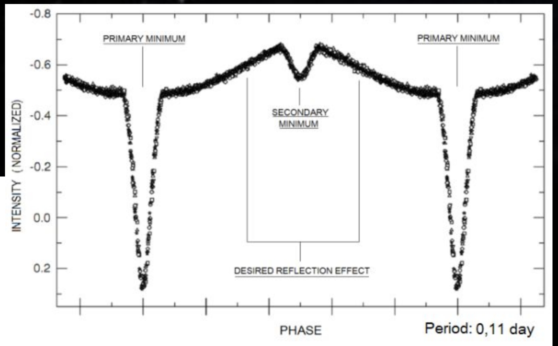
Vos et al. 2018, MNRAS, 473, 693

Results

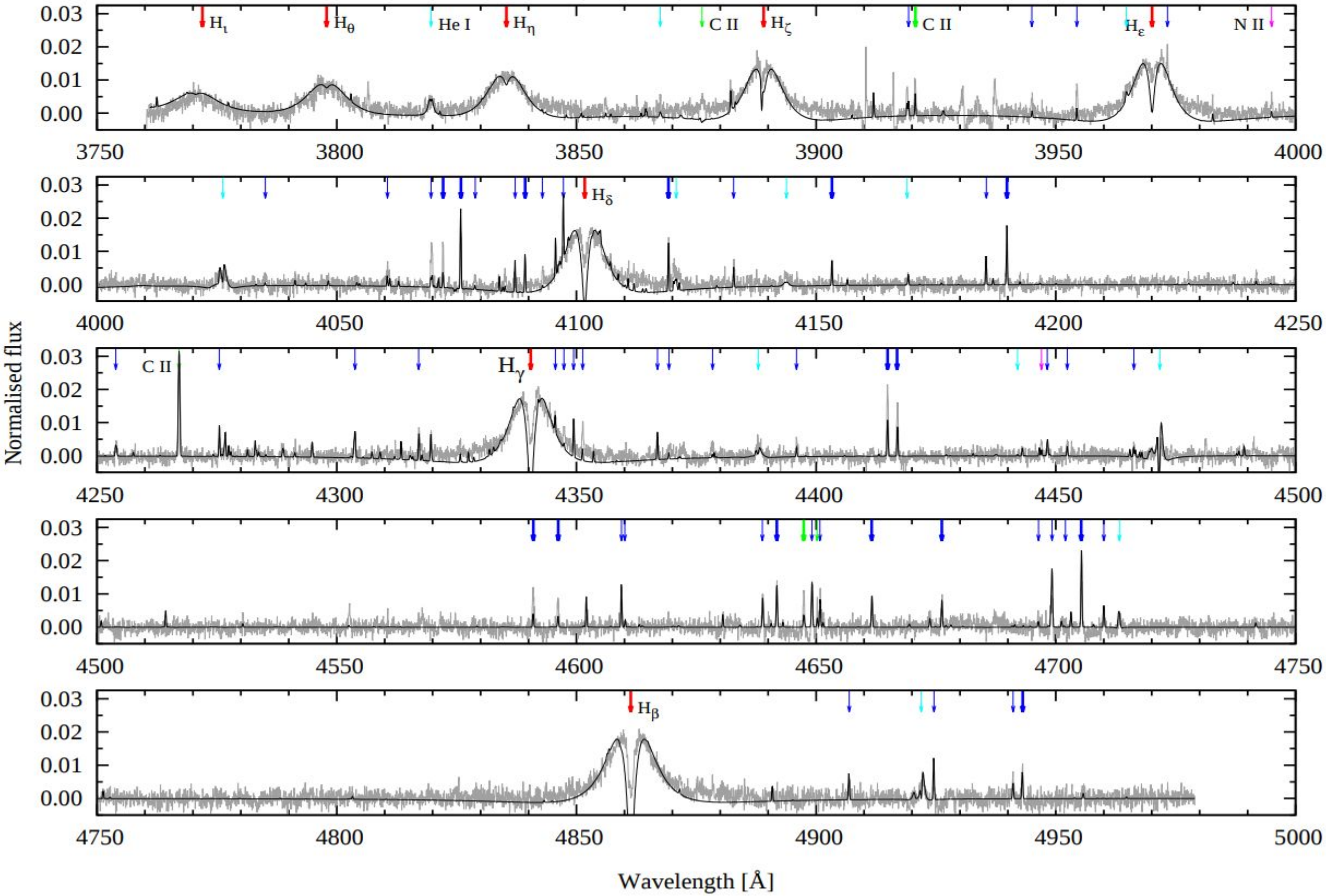
- Hot subdwarf binaries with cool companions are in a sweet-spot for decomposition and keys to a better understanding
- Out of 28 systems there are no two alike!
- Orbital periods between 400-1500 days
- P-ecc relation (Vos et al. 2018 MNRAS 473 693)
- P-q relation (Vos et al. 2019 MNRAS 482 4592)
- Chromospheric activity in some companions





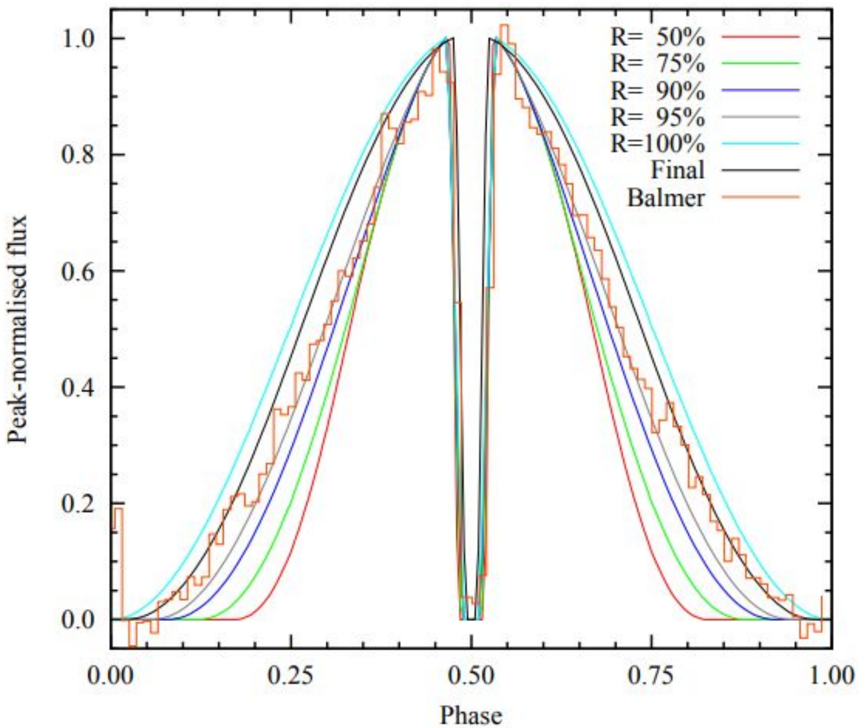


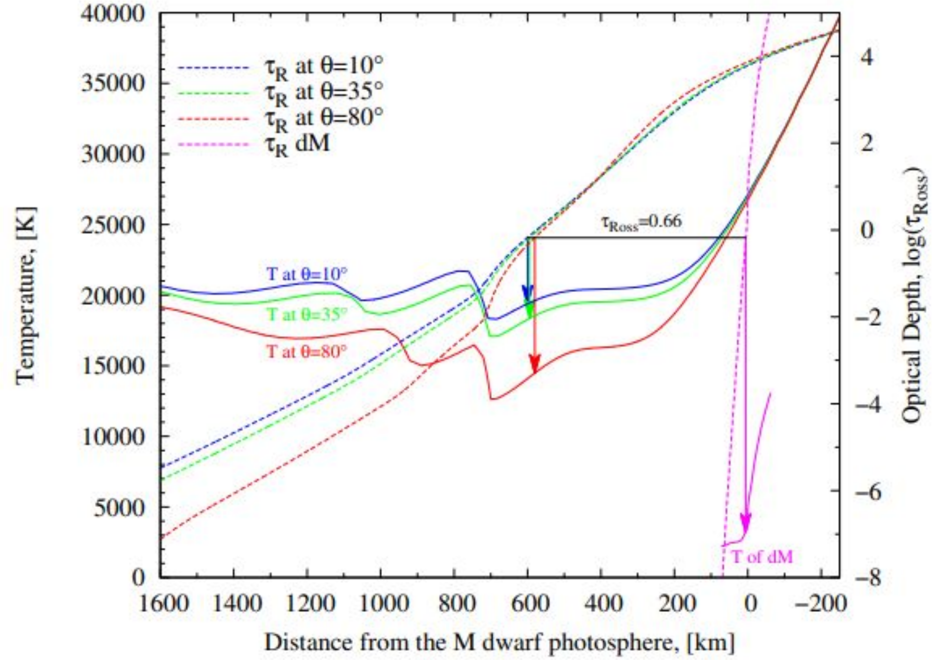
Yet one step forward: interacting components (HW Vir type)

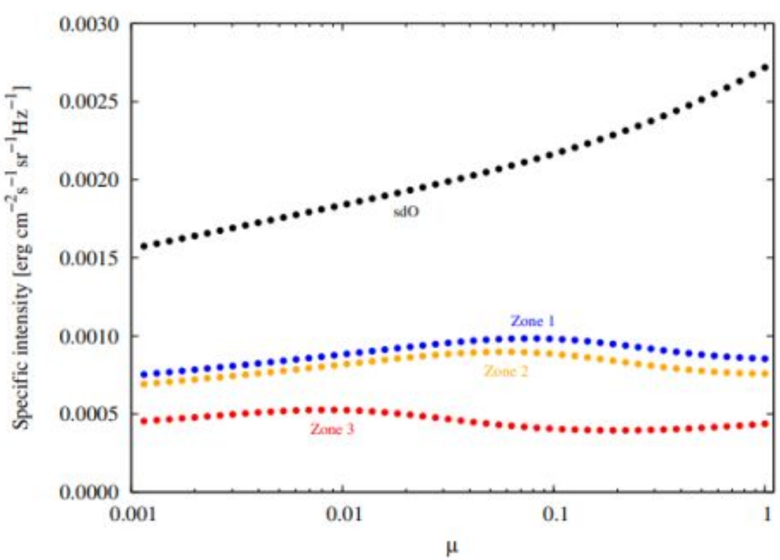


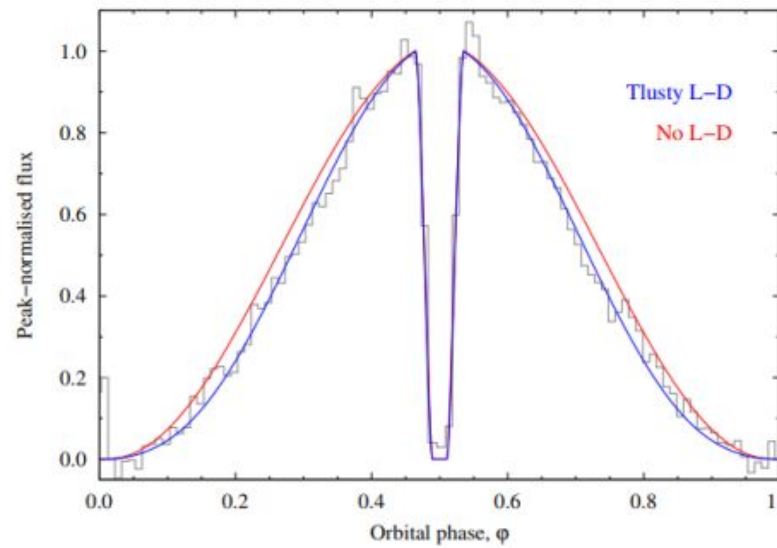
Interacting components: Reflection effect in AA Dor

Vučković, Østensen, Németh, Bloemen, Pápics
2016 A&A 586 146

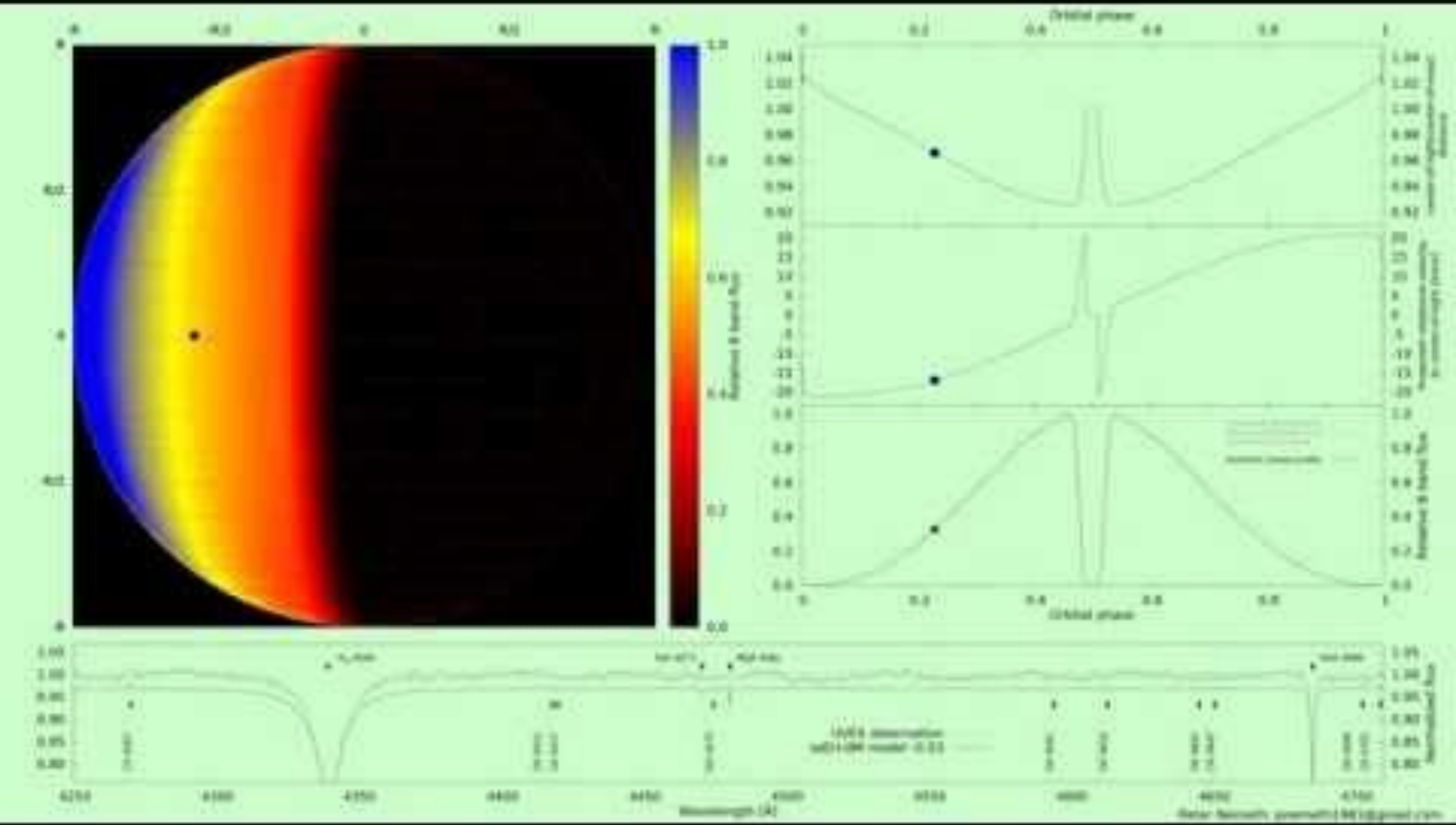








Vučković, Østensen, Németh, Bloemen, Pápics 2016 A&A 586 146



Reflection effect in AA Dor: provides albedos!

Vučković, Østensen, Németh,
Bloemen, Pápics
2016 A&A 586 146

Spectral decomposition is a great tool!

Wavelength space decomposition is handy for:

- SB2 composite spectra, binary or multiple sources with few spectra
- Spectral contamination in crowded fields
- Simultaneous interstellar or terrestrial (telluric) absorption removal
- Combined models are applied: photosphere + wind
- Radiative interactions in close binaries (host star + planet)

but:

- Care must be taken for degeneracies!
  A nice looking best fit may not reflect the true properties of the system
- Needs multi-wavelength studies

Good observational coverage: Fourier method

XTGRID is available through www.Astroserver.org!