Composite spectrum
hot subdwarf binaries

Peter Nemeth
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 \(\sim\)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 = \(\sim\)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.
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

- 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

- 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 $\chi^2$ 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

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**Hot subdwarf**

- non-LTE analysis
- Few lines, strong broadening
- Non-solar abundance pattern

**Companion**

- 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
A nice example
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/
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/
MCT 0146-2651: orbit

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<th></th>
<th>sdB</th>
<th>MS</th>
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<tr>
<td>$P$ (d)</td>
<td>760 ± 15</td>
<td></td>
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<tr>
<td>$e$</td>
<td>0.08 ± 0.04</td>
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<tr>
<td>$q$ (MS/sdB)</td>
<td>0.66 ± 0.07</td>
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<tr>
<td>$K$ (km/s)</td>
<td>6.6 ± 0.5</td>
<td>10.0 ± 0.08</td>
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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
Reflection effect in AA Dor: provides albedos!
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!