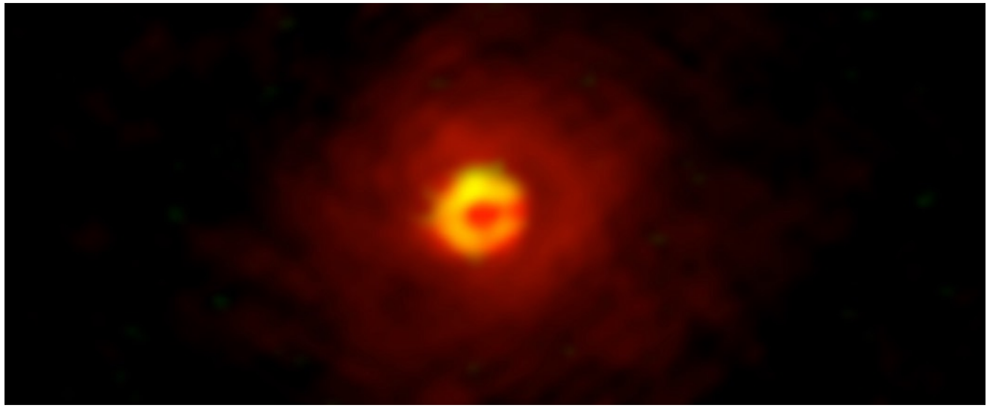


S08: Winds & Environments

Markus Wittkowski

ISSP/SPICA SG: Nicolas Nardetto, Gioia Rau, Fabrice Martins,
Andrea Chiavassa, Vincent Hocde, Anthony Meilland, Florentin Millour, Denis Mourard, Claudia Paladini

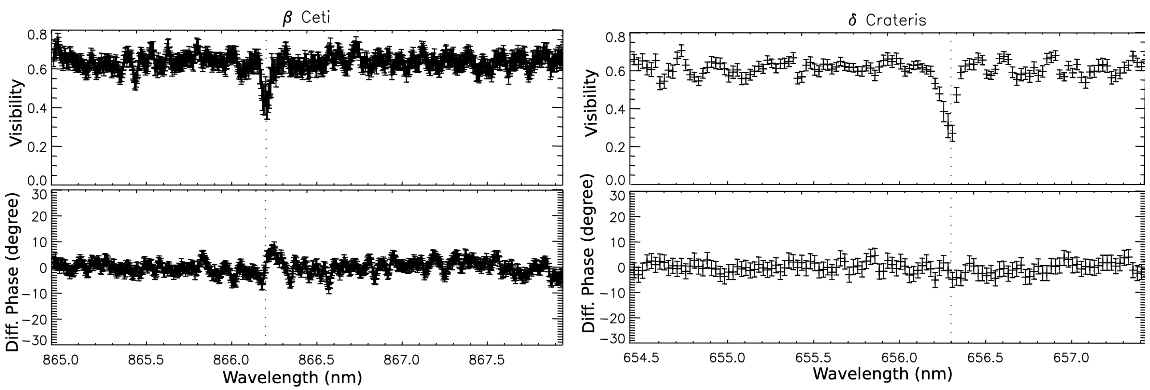
TIGRE spectra & PHOENIX models (pilot): Faiber Rosas, Klaus-Peter Schröder, Peter Hauschildt

Interferometric Survey of Stellar Parameters

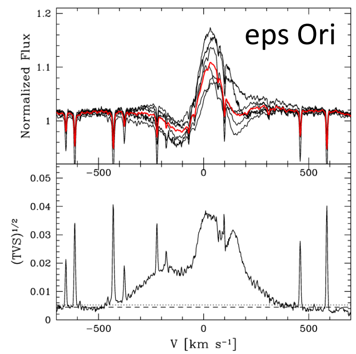
European Research Council
Established by the European Commission

Scientific Objectives: General

- How will the presence of winds & environments affect SPICA angular diameters, LD profiles, SBCR, and estimates of fundamental stellar parametes (R, Teff, M), and in which parts of the HR diagram?
- Will the survey allow us to better understand winds and circumstellar environment all over the HR diagram both for hot and cool stars



Berio et al. (2011): Chromosphere of K giant stars



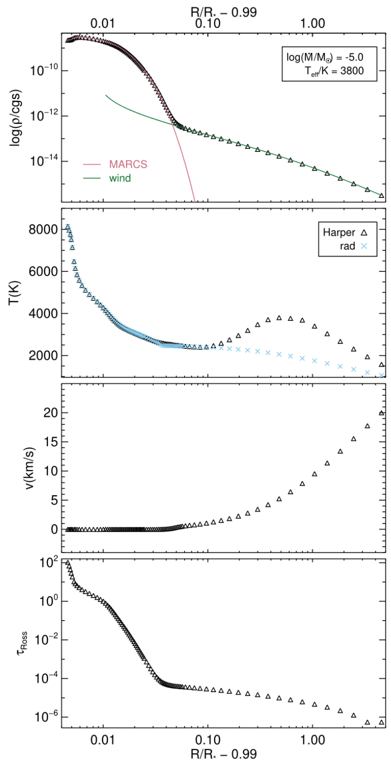
(a) Hα

Martins et al. (2015): Variability of O9-B0.5 stars

Winds across the HR diagram

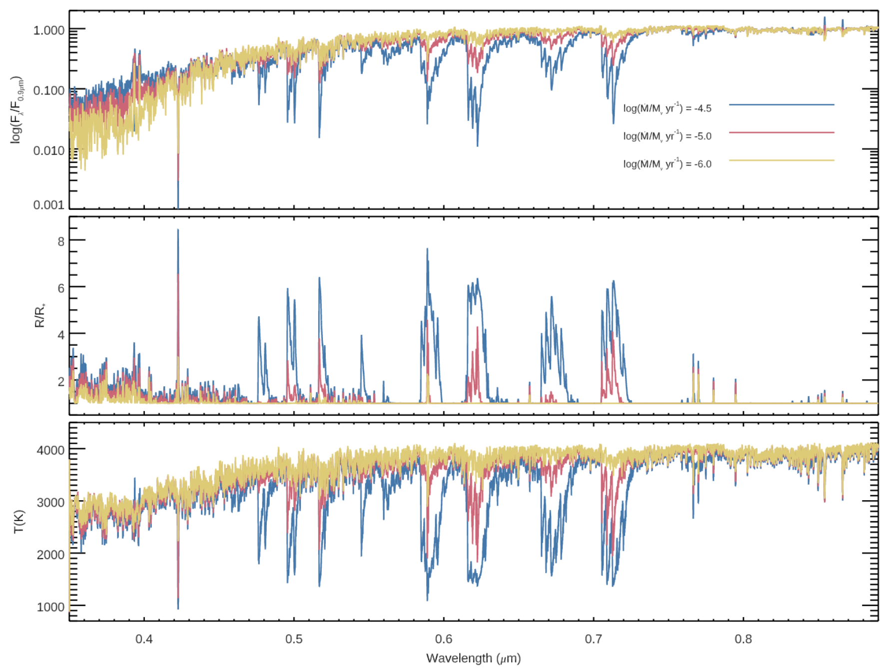
- Hot stars of spectral type O and B:
  Known to show strong winds as a result of radiative acceleration (e.g., Martins et al. 2015, Maeder & Meynet 2000).
- Evolved cool K&M giants are known to possess winds as well and also show signatures of dust environments (e.g. Groenewegen 2012).
  - Mass-loss process best understood for Mira-variable AGB stars
  - Current 3D models of convection & pulsation do not predict observed extensions of RSGs by far (Arroyo-Torres et al. 2015), pointing to missing physical process(es) in current models
  - Red giant winds even less understood
  - Possibly related to chromospheric activity, magnetic fields, radiative acceleration on molecular lines

Impact on winds on RSG spectra (Davis & Plez 2021)



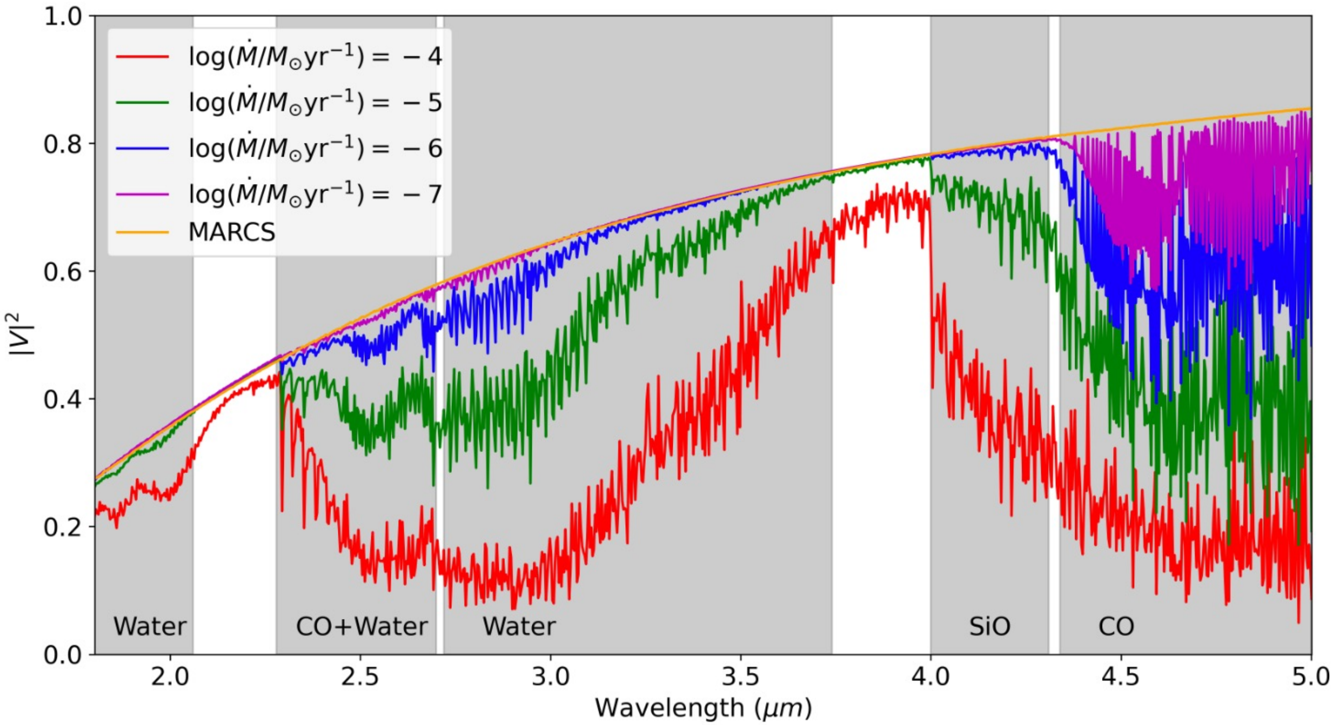
- Higher mass-loss rates result in stronger absorption in the TiO bands.

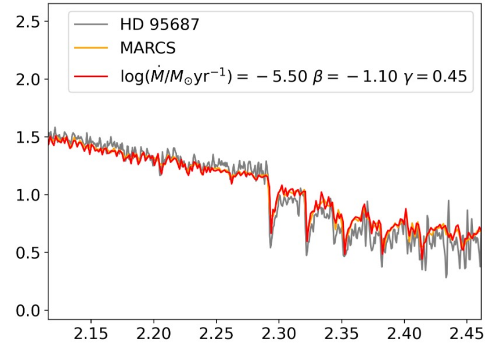
  -> Star to appear as a later spectral type despite constant Teff
- Explains mismatch between temperatures derived from the optical and IR.

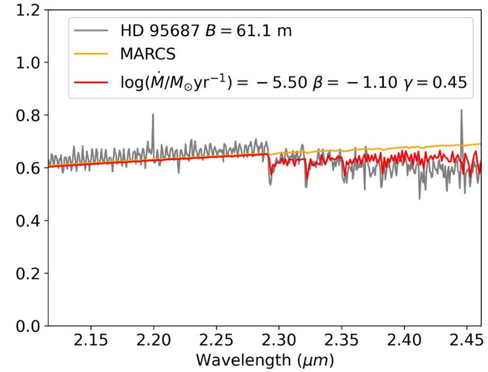


Impact on winds on RSG visibilities

(Gonzalez-Tora, Wittkowski, Davies, Plez, Kravchenko, 2023)







Scientific Objectives: Diagnostics

Winds of hot and cool stars have different underlying physical mechanisms, but diagnostics are similar:

- High spectral resolution observations of Halpha (656.2 nm), probing winds of hot stars and cool stars
- For cool stars, high spectral resolution observations of the CaII triplet (849.8, 854.2, 866.2 nm) probing the presence and extension of the chromosphere of cool giants & supergiants as a function of spectral type and luminosity (and mass)
- Low spectral resolution observations to constrain the visibility function and the fundamental stellar parameters in essentially the same way as for other ISSP programmes

Selection of targets

- Based on Simbad database and JSDC (Bourges et al. 2017)
- Hot stars:
  - Spectral types O and B
  - V<5 (high spectral resolution)
  - 0.7 mas < theta < 11
- Cool stars:
  - Spectral types K and M
  - V<4 (high spectral resolution)
  - 2 mas < theta < 11
- Declination >-30
- Both subsamples cover luminosity classes I/II/III/IV/V
- Spectral types FG not considered here. Cepheids and rotators covered by other programmes
- Be stars excluded here (targeted open time proposals expected)
- Spectroscopic binaries and stars with composite spectra excluded
- Some overlap targets with WPs 8/9 removed

Description of the sample

- Total of 96 targets:
  - Priority 0: 25 (initial coverage of different spectral types and luminosity classes)
  - Priority 1: 41 (improved coverage)
  - Priority 2: 30 (redundancy in HR diagram)
- High-priority targets:
  - 10 Hot stars:

    HD 21389 (A0 Ia), del Cyg (A0 IV), zet Sgr (A2.5 V), bet Eri (A3 IV), omi Sco (A4 II/III), alf PsA (A4 V), gam Crt (A7V), eps CMa (B1.5 II), sig Sgr (B2 V), gam Crv (B8 IIII)
  - 15 Cool stars:
    - bet Cet (G9 III), bet Gem (K0 III), tet Cep (K0 III), eta Cep (K0 IV), b01 Aqr (K1 III), omi01 CMa (K2 I), 109 Her (K2 III), bet Oph (K2 III), eta Cet (K2 III), mu Leo (K2 III), eps Eri (K2 V), gam Aql (K3 II), rho Boo (K3 III), sig CMa (K5 I), tau Aqr (M0III)

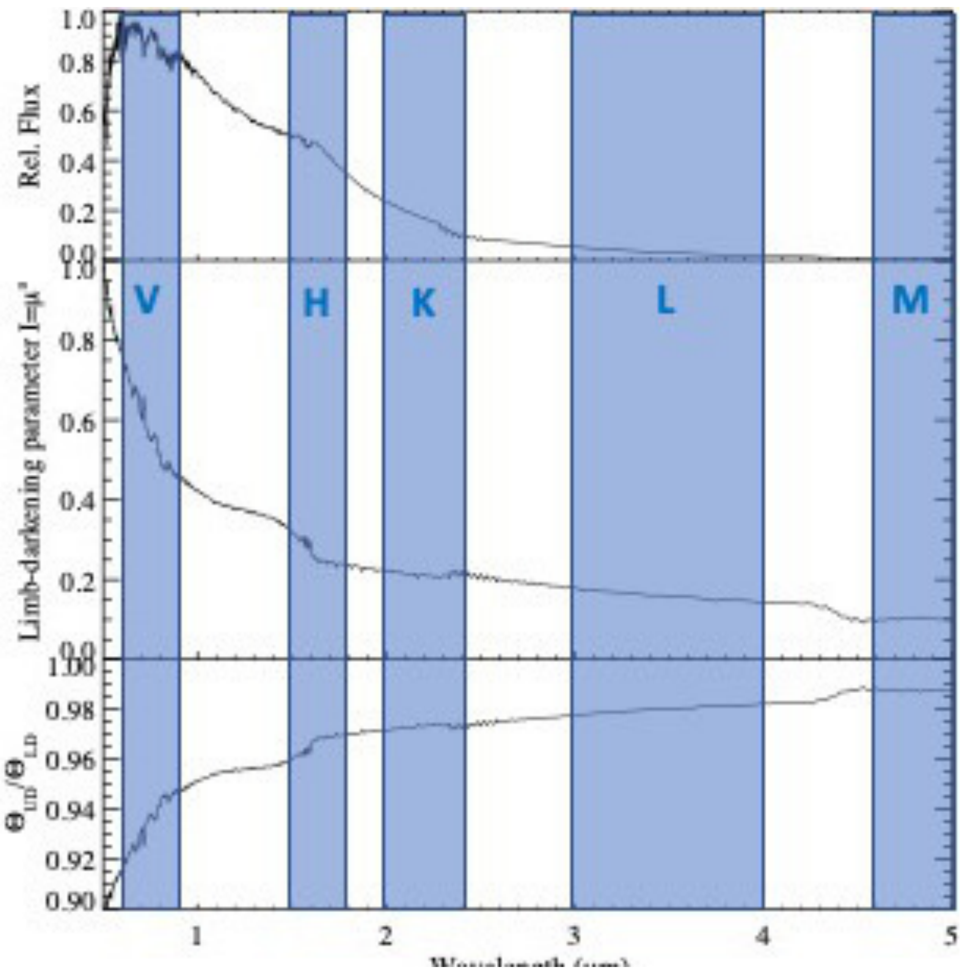
Specific aspects

- Different spectral modes (SPI):
  - All sources observed twice in LR
  - All sources observed in Halpha (656.2 nm) in HR
  - Cool stars obsered in the CaII triplet (849.8, 854.2, 866.2 nm) in HR
    These three lines are covered within the bandpass of one setting
- Estimated execution times for P0 targets (1h per observation):
  - 10 hot stars: 30h
  - 15 cool stars: 60h
  - Can possibly be shortened by observing different spectral settings back-to-back
- Groups of observations
  - Preferentially complete a star in all settings before starting another
- Overlap with other programmes
  - If LR already available from other programmes, add HR only

Complementary data with VLTI

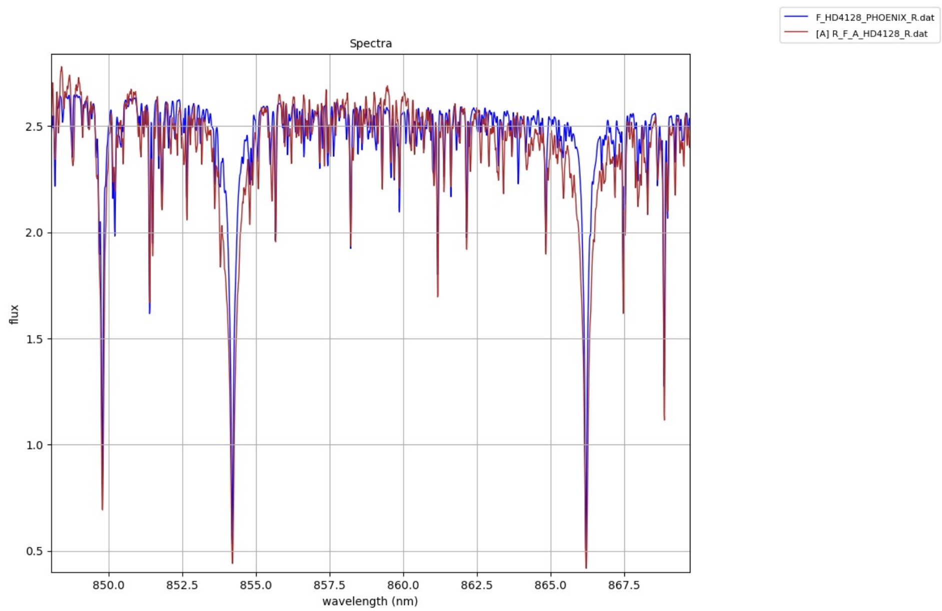
- VLTI observations with PIONIER (H-band), GRAVITY (K-band), MATISSE (L, M, [N] bands)
  - Extended wavelength coverage to constrain model atmospheres & limb-darkening including molecular layers of H_2O (K), CO (K,M), SiO (L)
  - Increase confidence in the results
  - Getting started
- High priority targets with overlap in declination and suitable angular diameters for VLTI:
  - P110 (110.23VE), October 2022 – March 2023, 27h:
    eta Cet (K1 III), omi01 CMa (K2 Iab), tau Aqr (K5 III), bet Cet (G9 III), sig CMa (K5 Ib), eps Peg (K2 Ib-II)
    80% completed
  - P111 (111.24J0) April - September 2023, 18h:
    gam Sge (M0 III), del Sgr (K2.5 III), nu Hya (K1.5 III), lam Sgr (K1 III)
    Ongoing

Comparison to model atmospheres



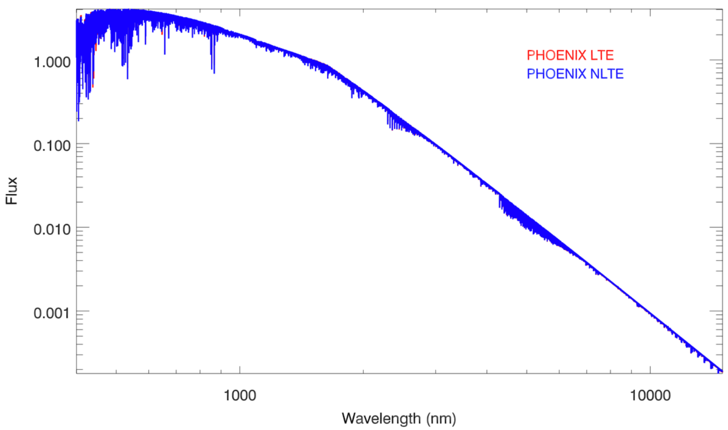
- Compare observations to model atmospheres
- Constrain stellar parameters as well as possible, as for other SPICA programmes
- Where available, use a broad spectro-interferometic coverage (VLTI complement)
- Look for deviations caused by a wind/environment
- Correlation with extensions in Halpha and CaII triplet

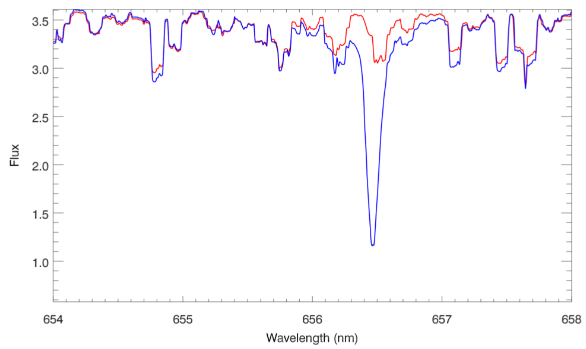
Pilot study on beta Ceti
(Faiber Rosas, Klaus-Peter Schroeder, Peter Hauschildt)

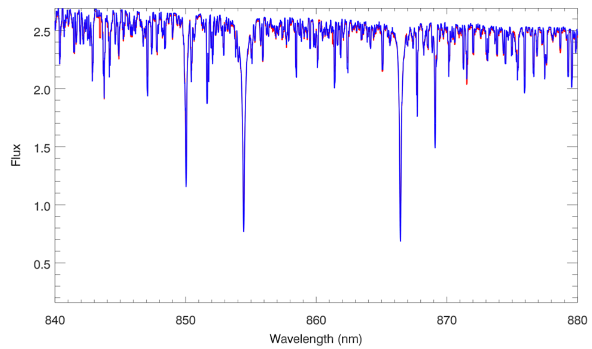


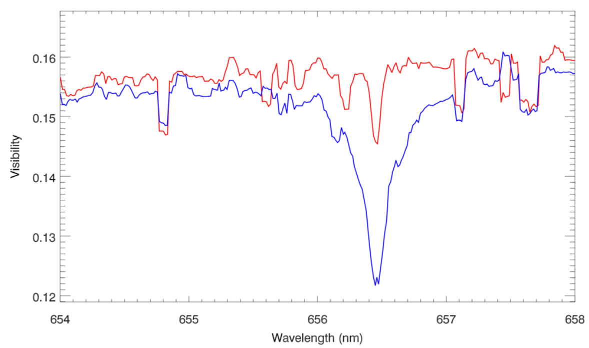
- TIGRE spectrum of beta Ceti in the CaII triplet compared to a PHOENIX model
- TIGRE: Robotic telescope operated by the University of Guanajuato, Mexico
- Spectrograph: HEROS spectrograph from Heidelberg Observatory
  Spectral range:
  350-560nm (blue channel) and
  580-880nm (red channel)
  Spectral resolution: R=20000

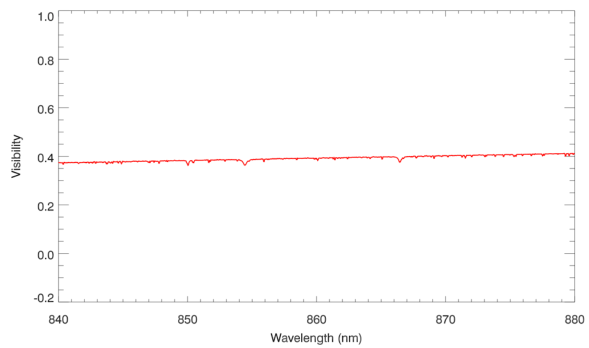
Pilot study on beta Ceti: PHOENIX LTE & NLTE models (Faiber Rosas, Klaus-Peter Schroeder, Peter Hauschildt)











Other aspects

- Tools to follow the execution:
  - ISSP tools
  - Inspection of reduced data
  - Updates of priorities, possibly on strategy
- Data analysis:
  - Reduced data
  - Model atmospheres in a common ISSP approach?
  - Nice to have: f_{bol} based on photometry (common), high-res spectra (TIGRE?)
- Publication strategy:
  - Description of the sample and first results (P0 targets) without much modeling but with first correlations
  - Full sample
  - Improved model, possibly with pilot study first