Determination of stellar parameters from spectroscopy

Results from HH3

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Introduction

Presentation

- Hare & Hound 3 is the third round of a series of exercises to understand what kind of ground-based additional spectroscopic data we should seek for the success of the PLATO mission.

Introduction

Motivation

- **We learned some lessons from HH1 and HH2 and designed HH3 to be the last of the series.**
- **What is the precision with which we can characterize solar-type stars?**
- **What is the best way to do it?**
- **Paper in preparation.**

Introduction

Differences with respect HH1 and HH2

- **We added two new stars and introduced different spectral resolutions, as well as noisy spectra (SNR=20 per pixel)**
- **HARPS spectra for seven stars.**
- **PEPSI spectra for four stars in common with HARPS (including the Sun).**
- **PEPSI gives us access to the Gaia RVS wavelength range.**

Introduction

Source of data for HH3

- **A compilation of degraded spectra for the stars was generated from R = 115000 (HARPS) and R = 220000 (PEPSI) data.**
- **HARPS: 4800 to 6800 Å.**
- **PEPSI: 3830 to 9130 Å.**
- **Resolutions of degraded spectra are <u>R = 5000, 20000, and 65000, plus R = 11200 for PEPSI</u>.**
- **Spectra were sampled with 4 pixels per resolution element and then normalized. Noise per pixel was given.**

Sample of stars

Fundamental parameters

Star	Name	SpT	T_{eff} [K]	logg [cgs]	[Fe/H]
1	Sun	G2V	5772	4.438068	0
2	18 Sco	G2Va	5817±4	4.448±0.012	0.052±0.005
3	β Vir	F9V	6083±41	4.10±0.02	0.24±0.07
4	η Boo	G0IV	6099±28	3.79±0.02	0.32±0.08
5	β Hyi	G0V	5873±45	3.98±0.02	-0.04±0.06
6	α CenA	G2V	5792±16	4.31±0.01	0.26±0.08
7	α CenB	K1V	5231±20	4.53±0.03	0.22±0.10

Note: subgiants in blue

Heiter et al. 2015; Bazot et al. 2018: parameters for 18 Sco; IAU 2015: for the Sun

Methods. Fundamental determinations of Teff and log g were obtained in a systematic way from a compilation of angular diameter measurements and bolometric fluxes and from a homogeneous mass determination based on stellar evolution models. The derived parameters were compared to recent spectroscopic and photometric determinations and to gravity estimates based on seismic data (Heiter et al. 2015).

Methods

We applied two kinds of methodologies:

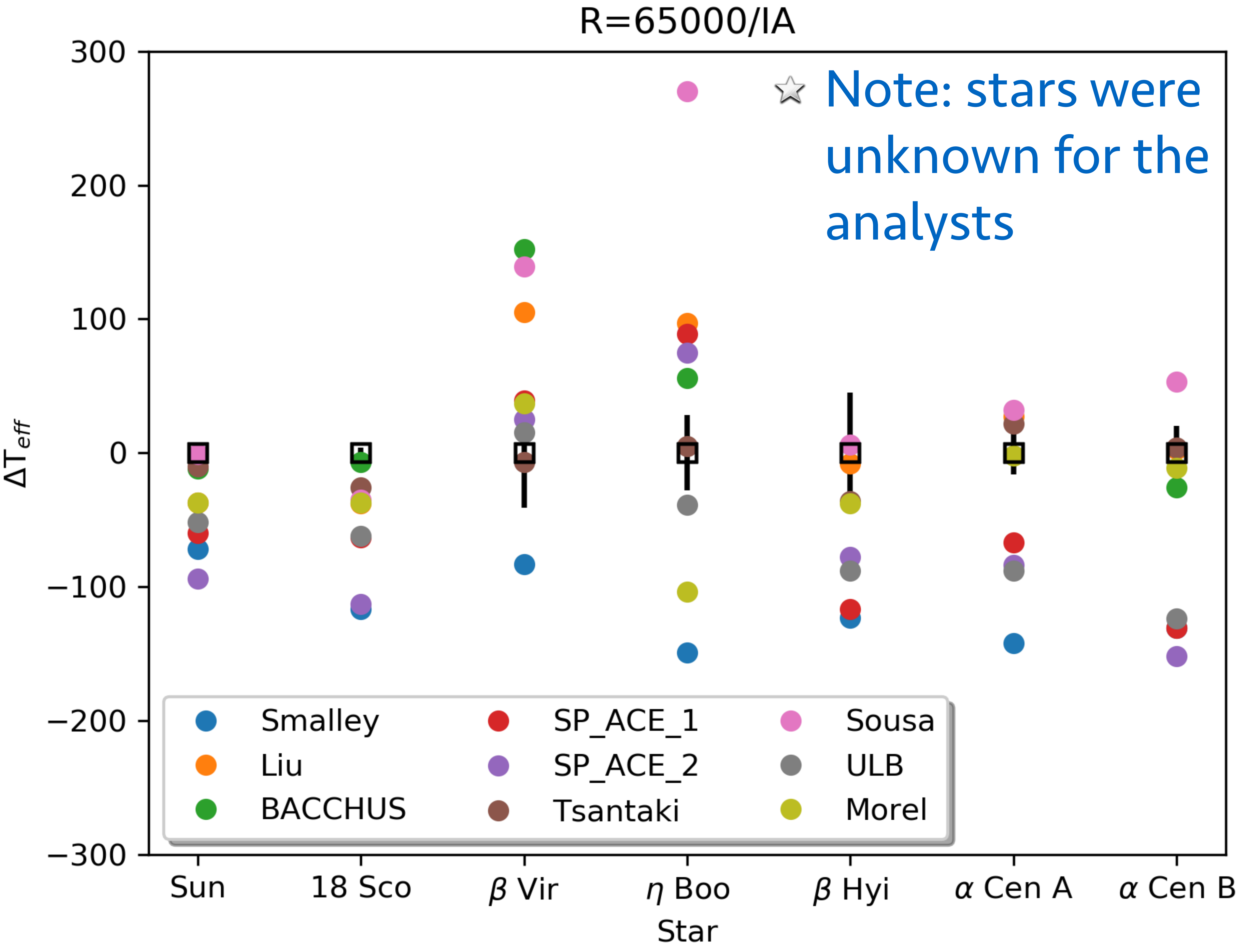
1. Spectral synthesis - normalized fluxes in the selected wavelength ranges.
2. Equivalent widths - calculated from the spectra in the selected wavelength ranges.

Here we present some cases in detail and the general conclusions.

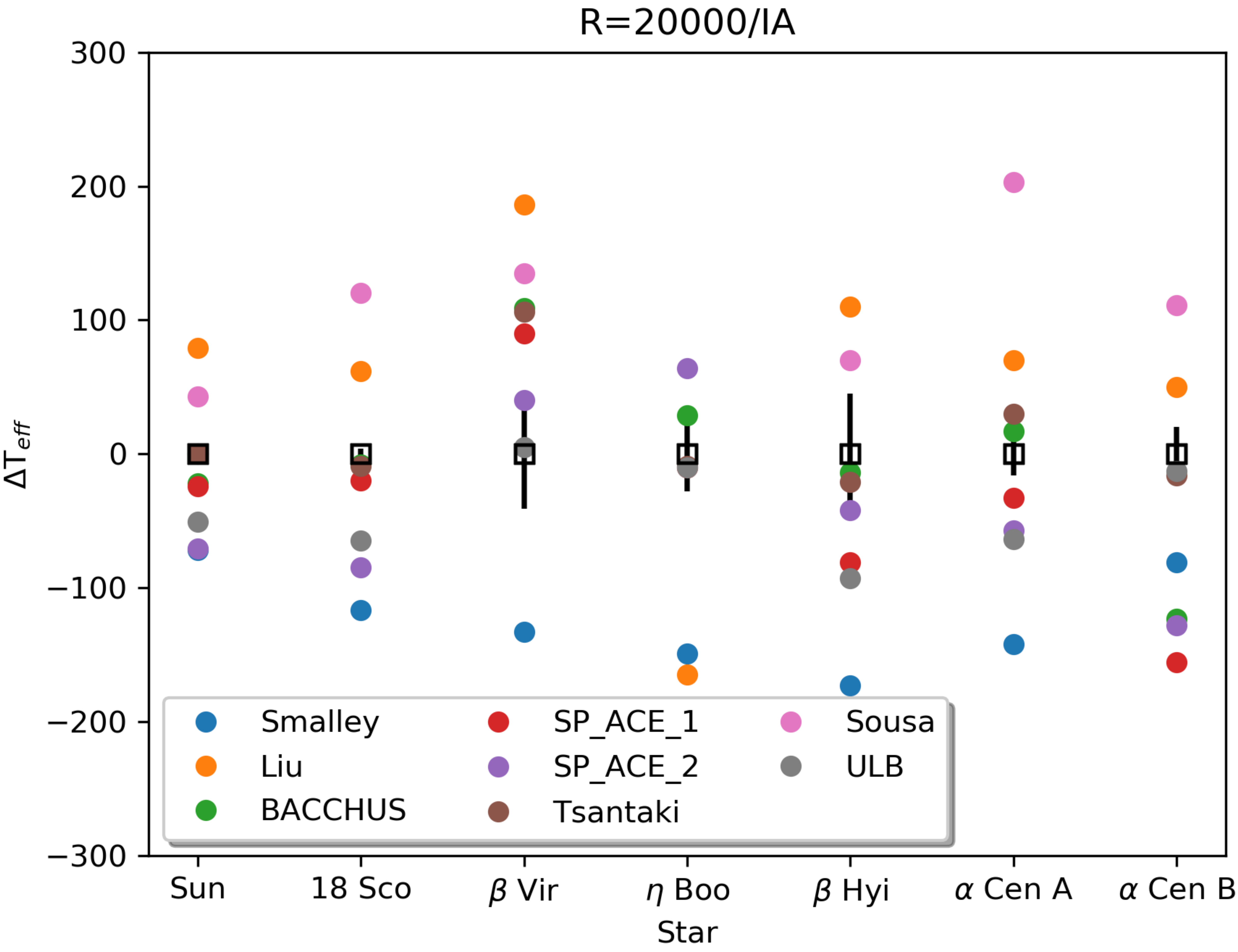
Test I

- **Analyze the spectra at <u>high</u> and low SNR to infer T_{eff}, logg, [Fe/H], and ξ_t, assuming all metals scale with Fe from the solar ratios. ξ_t could be fixed.**

- **Subcases, defined by the wavelength range:**
  A. **HARPS λ-range for HARPS spectra;**
  B. **HARPS λ-range for PEPSI spectra;**
  C. **8470-8710 λ-range for PEPSI spectra; and**
  D. **full PEPSI range.**



☆ Note: stars were unknown for the analysts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100
0
−100
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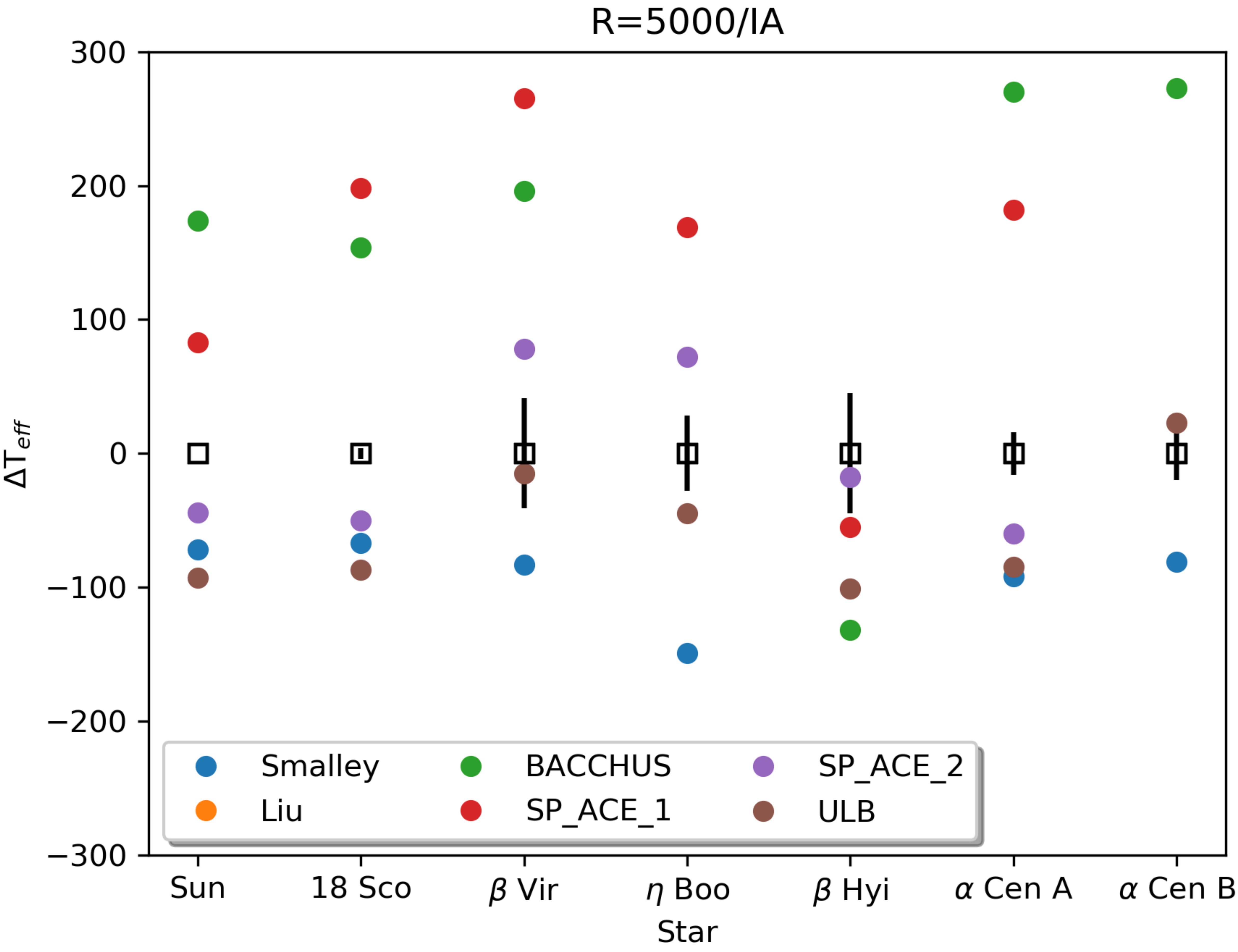
−300
ΔT$_{eff}$
Sun
18 Sco
β Vir
η Boo
β Hyi
α Cen A
α Cen B
Star
Smalley
Liu
BACCHUS
SP_ACE_1
SP_ACE_2
Tsantaki
Sousa
ULB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−300
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Liu
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ULB
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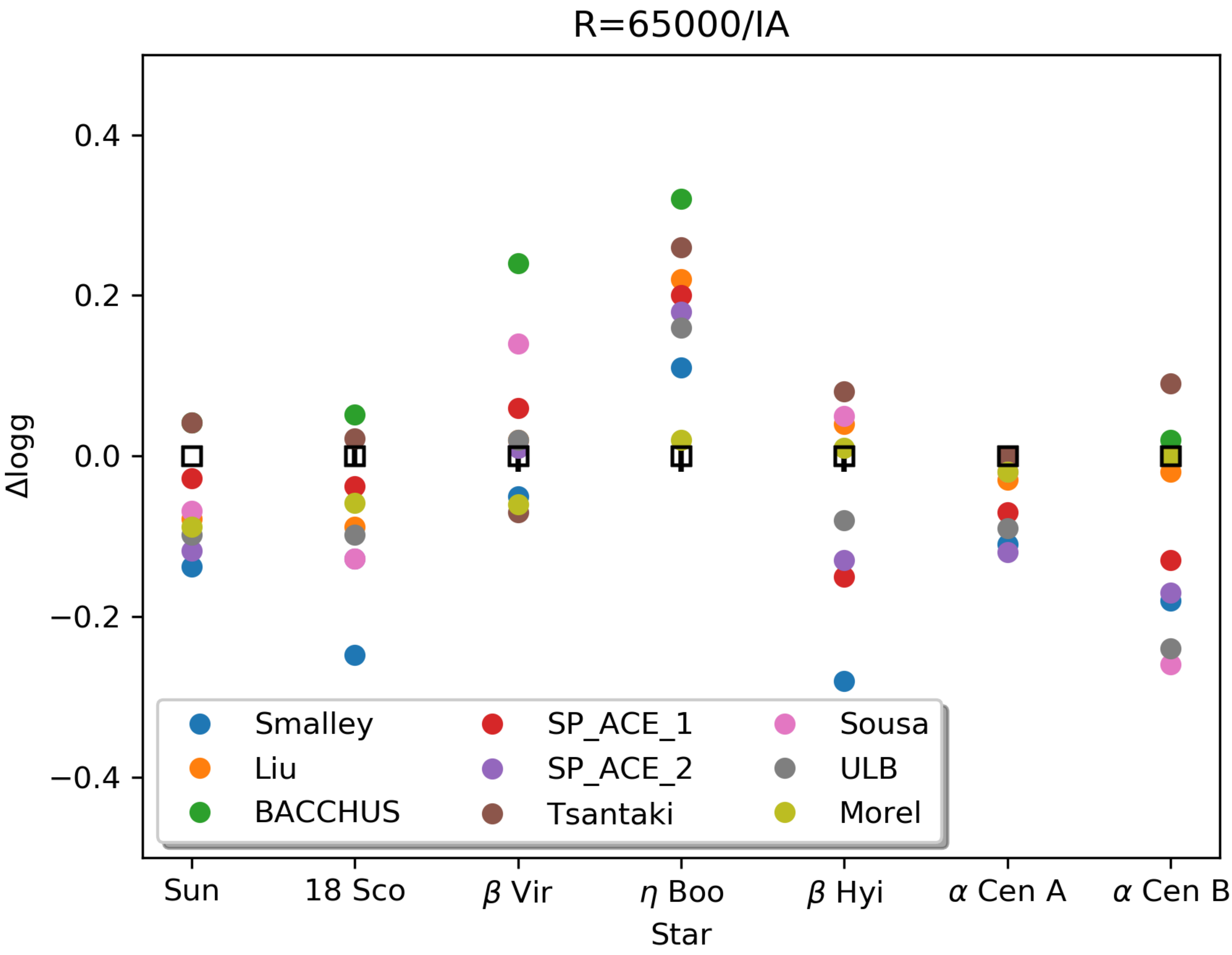
β Vir
η Boo
β Hyi
α Cen A
α Cen B
Star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0.2
0.0
−0.2
−0.4
Smalley
Liu
BACCHUS
SP_ACE_1
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Sousa
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Morel
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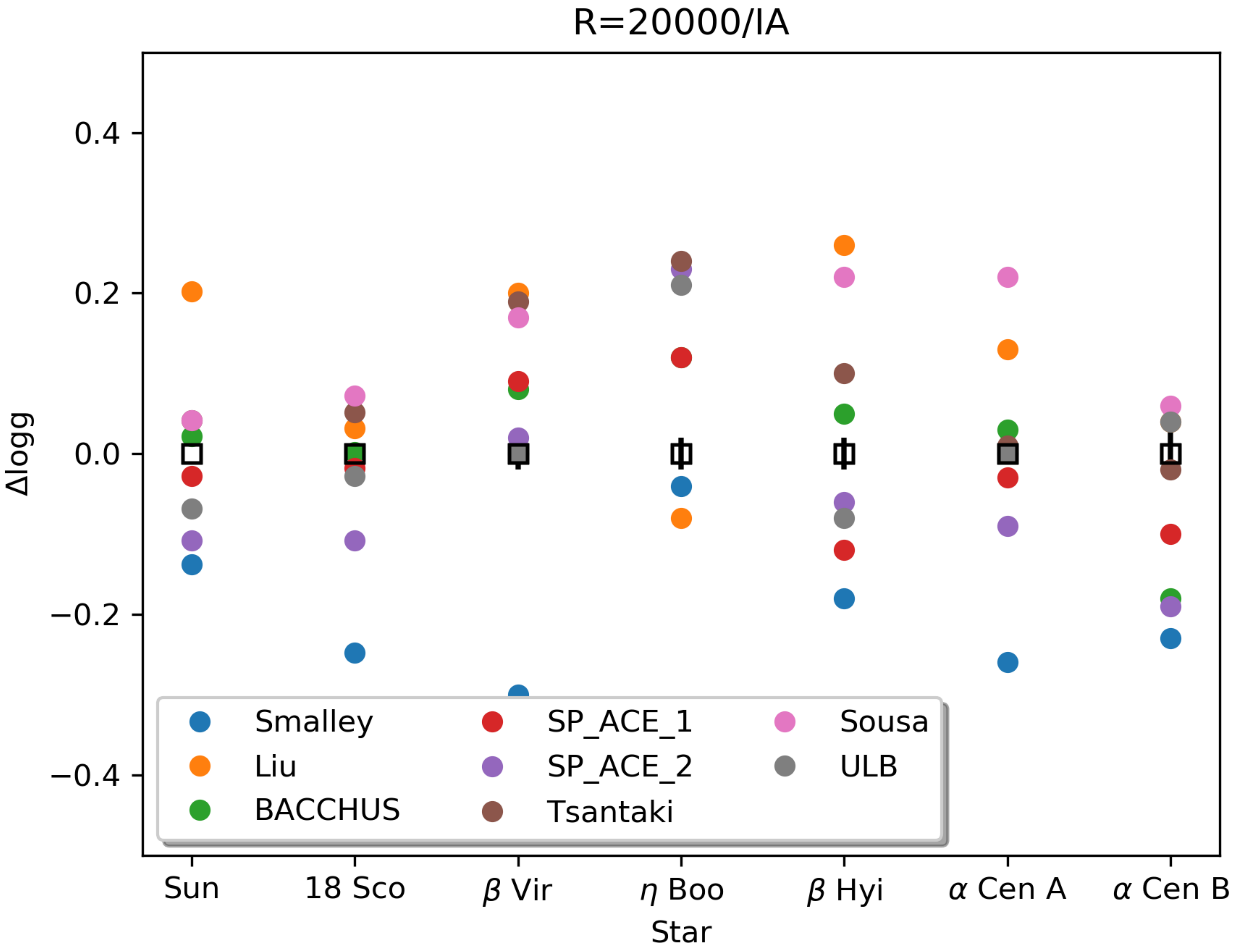
β Vir
η Boo
β Hyi
α Cen A
α Cen B
Star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η Boo
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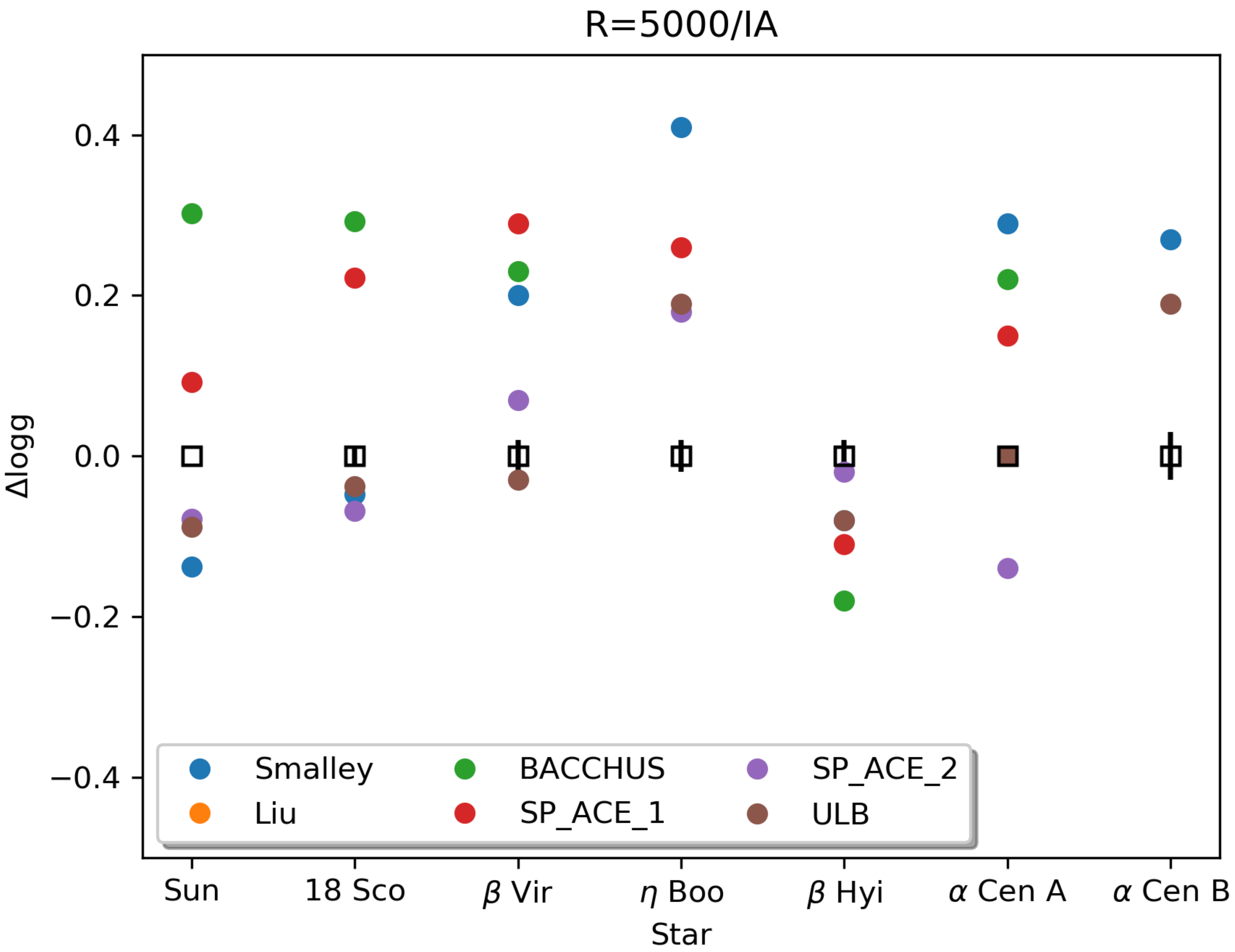
Tsantaki
Sousa
ULB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0.2
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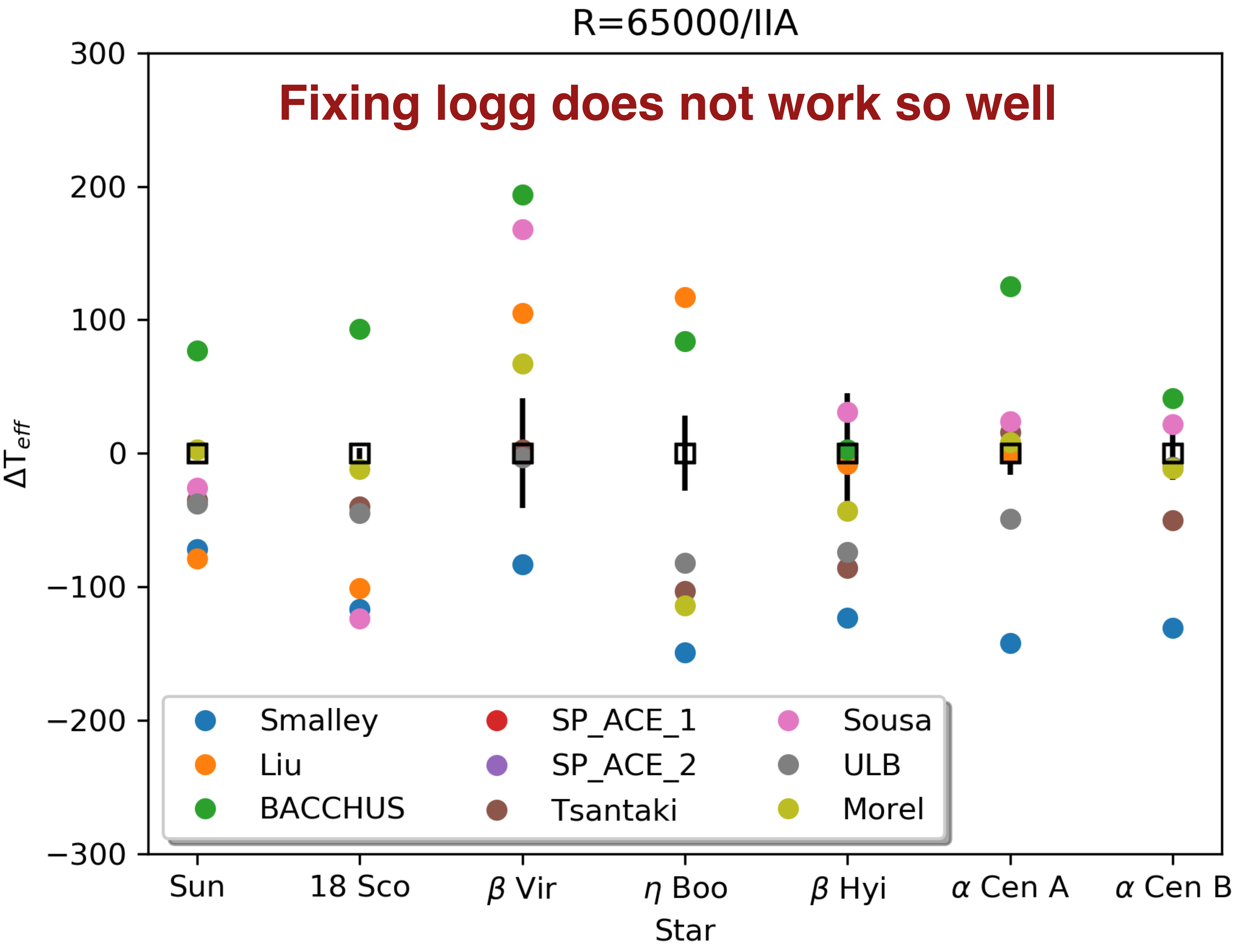
Smalley
Liu
BACCHUS
SP_ACE_1
SP_ACE_2
ULB
Sun
18 Sco
β Vir
η Boo
β Hyi
α Cen A
α Cen B
Star

Test II

- **Same as Test I, but adopting the 'truth' value for logg (from asteroseismic or fundamental data) with the rest as free parameters.**

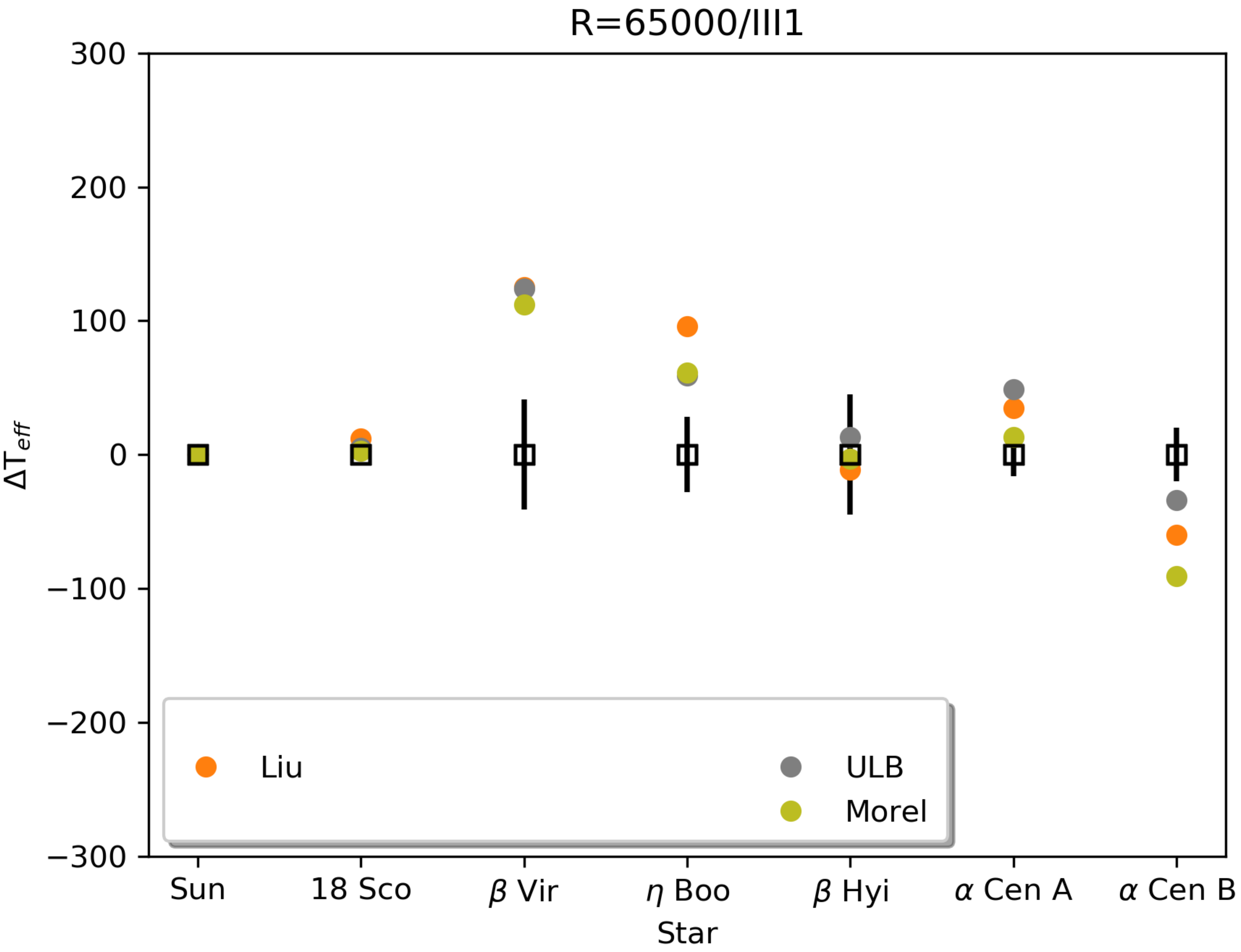
- **This will help us to evaluate to what extent incorporating the seismic logg of the PLATO target would affect the results.**



Fixing logg does not work so well

Test III

- This final test consists of a differential analysis of the stars with respect to the Sun (star 1) and a solar twin (star 2).
- This will help us to evaluate to what extent this relative approach improves the results for solar-like stars.
- Is the PEPSI spectrum of the Sun adequate for the differential analysis? How critical is the normalization of the spectra?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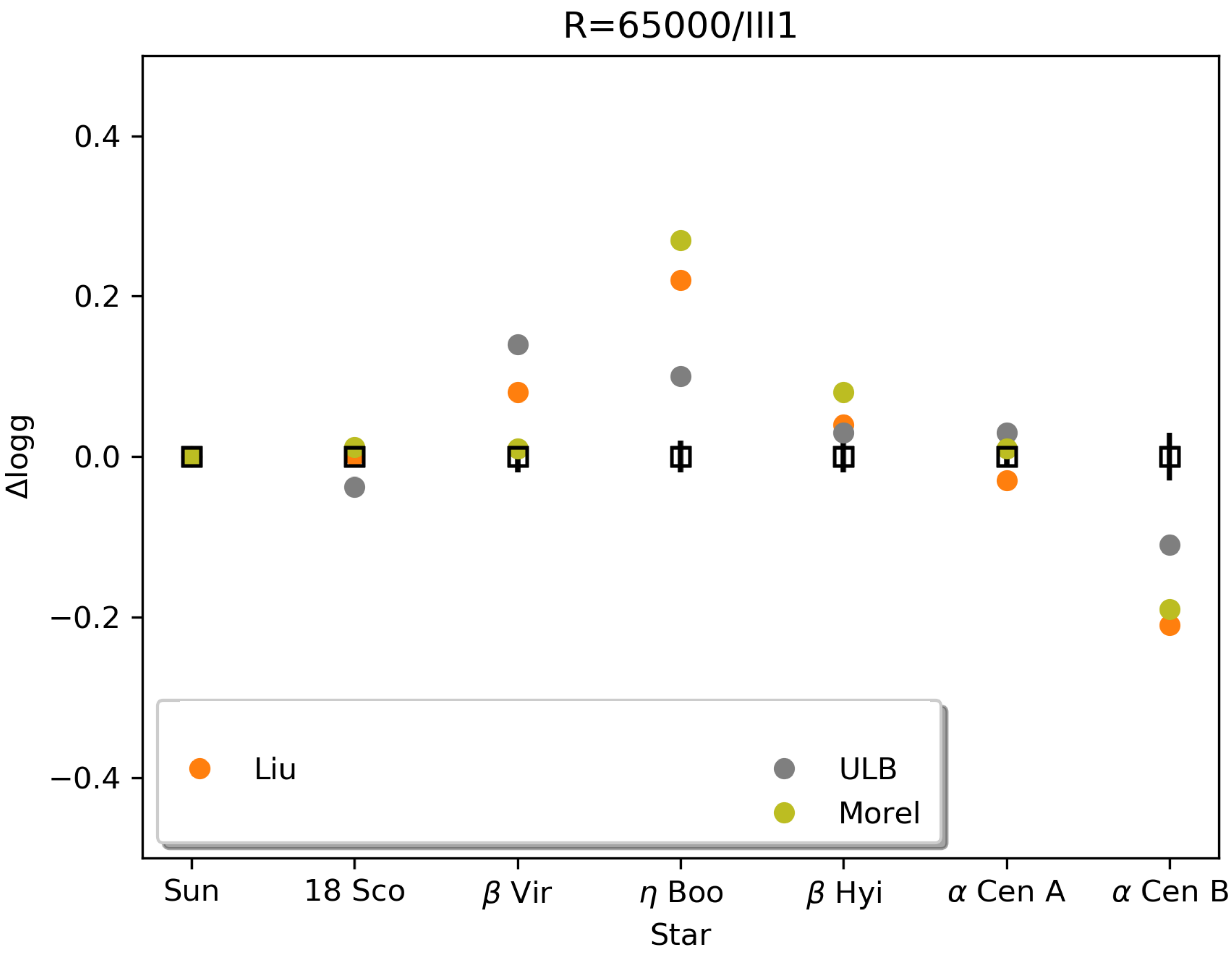
300
200
100
0
−100
−200
−300
ΔT$_{eff}$
Sun
18 Sco
β Vir
η Boo
β Hyi
α Cen A
α Cen B
Star
Liu
ULB
Morel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0.4
0.2
0.0
−0.2
−0.4
Δlogg
Liu
ULB
Morel
Sun
18 Sco
β Vir
η Boo
β Hyi
α Cen A
α Cen B
Star

I. Spectral synthesis

- **ULB: Thibault Merle, Sophie Van Eck (U. libre Bruxelles) & Bertrand Plez (U. Montpellier) performed the most extensive analysis.**
- **They used the 1D, LTE radiative transfer code Turbospectrum (v 15.1, Alvarez & Plez 1998, Plez 2012) and the MARCS model atmospheres assuming plane-parallel geometry, standard composition, and ξ=1 km/s. Some other improvements as for the Gaia -ESO survey.**

II. Equivalent Widths

- **Fan Liu (Lund Observatory)**
- **MOOG (Sneden 1973, Sobeck 2011) to perform a variety of 1D, local thermodynamic equilibrium (LTE) spectroscopic analysis.**
- **ATLAS 9 model atmospheres (Castelli & Kurucz 2003).**
- **IRAF/splot and ARES to get the EWs.**

Conclusions

- **Spectroscopic follow-up could be useful for R≥20,000.**
- **We plan to work on improving the stellar atmosphere models to characterize the RVS region.**
- **Fixing logg does not work so well.**
- **Differential analysis is expected to yield more precise parameters (need to increase statistics).**
- **18 Sco seems to be a reliable reference.**

Participants

- **Carlos del Burgo** (INAOE) (Coordinator)
- **Thibault Merle, Sophie Van Eck** (U. libre Bruxelles) & **Bertrand Plez** (U. Montpellier)
- **Jozsef Kovacs** & **Szabolcs Meszaros** (Gothard Astrophysical Observatory)
- **Fan Liu** (Lund Observatory)
- **Thierry Morel** (U. Liège)
- **Barry Smalley** (U. Keele)
- **Sérgio Sousa** (U. Porto)
- **Maria Tsantaki** (U. Porto)

Acknowledgments: Carlos Allende Prieto

Paper in preparation

We have a draft in preparation with the results of HH3

Here we have shown some representative cases together with the main conclusions

Assessing the precision of different spectroscopic techniques for the characterization of sun-like stars

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ABSTRACT

The precise determination of the parameters of stars is fundamental to characterize them as well as their planetary systems. We selected a sample of solar-type stars and prepared spectra at resolving powers R=5000, 11200, 20000, and 65000, and different signal to noise ratios from higher spectra resolution observations performed with the echelle spectrographs HARPS and PEPSI. Different spectroscopic techniques were applied to these data in order to derive stellar parameters, such as effective temperature, surface gravity, and metallicity. We have identified the best approach and required spectral resolution to achieve a certain level of precision and accuracy.

Key words: keyword1 – keyword2 – keyword3

1 INTRODUCTION

Asteroseismology, interferometry, and spectroscopy can be used to accurately determine fundamental parameters of sun-like stars, such as radius, effective temperature, mass, and chemical composition. The latter two are key since mainly drive the stellar evolution and structure.

Helioseismology is the only available technique to probe the internal structure and dynamics of the Sun. Similarly, asteroseismology is a unique tool to study the stellar interiors. For main-sequence stars, the seismic parameters together with the effective temperature ascertain the stellar radius; for sub-giants, the metallicity is also an important parameter; for read giants, it is required to include a good estimate of the parallax (Basu, Chaplin & Elsworth 2010)

Absolute flux spectrophotometry yield precise effective temperatures and angular diameters, which, when combined with excellent parallaxes, lead to accurate stellar radii. Angular diameters can be alternatively determined from interferometry. Radial velocities and light curves of detached eclipsing binaries provide masses and radii with low uncertainties.

The aforementioned methods are fundamental since they are nearly model-independent, but can be only applied to the brightest and nearest stars. Spectroscopic and photometric observations compared to stellar atmosphere models make possible the characterization of more distant stars. For instance, effective temperatures can be determined by fitting such models to spectroscopy or photometry corrected from interstellar reddening.

The classical spectral analysis involves the determination of equivalent widths (EW) of isolated, well-known absorption lines, as well as the inference of stellar parameters from the excitation equilibrium and ionization balance (e.g., the Fast Automatic Moog Analysis, FAMA, Magrini et al. 2013). Other methods employ a grid of synthetic spectra to perform the fitting of isolated absorption lines one-by-one (e.g., SPADES, Posbic et al. 2012) or the fitting of a broad wavelength range (e.g., FERRE, Allende Prieto et al. 2006). There are also codes than synthetizes on-the-fly sin-

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Thanks!