Testing iSpec for the determination of atmospheric parameters and abundances of delta Cephei and RR Lyrae

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Abstract

Classical Cepheids and RR Lyraes are radially pulsating stars where the spectral type varies depending on their phase (Cepheids: F-type at maximum, G-K type at minimum; RR Lyraes: A or F-types). Several studies used synthesis and the equivalent width method to determine the evolution of effective temperature, surface gravity and metallicity for classical cepheids and RR Lyraes (Luck and Andrievsky 2004; Kovtyukh et al. 2005; Andrievsky et al 2005; Luck et al 2008; Takeda et al. 2013; Fossati et al. 2014). We evaluate the applicability of iSpec (Blanco-Cuaresma et al. 2014), which has been extensively used with non-pulsating FGK stars, and derive atmospheric parameters as a function of phase for **δ Cephei** and **RRLyrae** (the two prototypes stars for each class).

Method

Ingredients: MARCS model atmospheres (Gustafsson et al. 2008), solar abundances from Grevesse et al. (2007), VALD atomic line list and SPECTRUM code for synthetic spectra generation (Gray & Corbally, 1994).

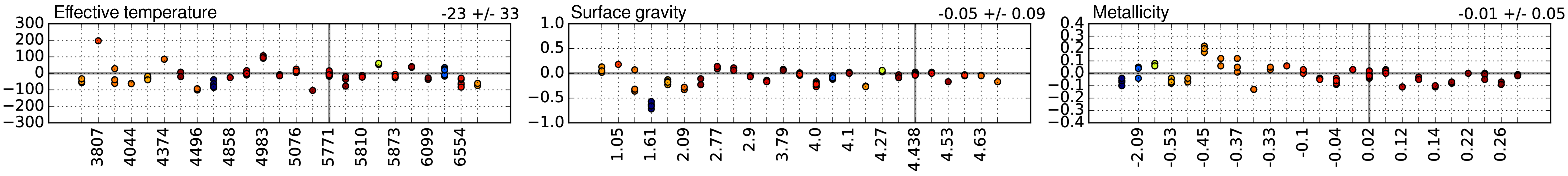

Fig 1. Atmospheric parameters derived by iSpec minus the reference values (Y-axis) for the Gaia FGK Benchmark Stars. Results are sorted by effective temperature, surface gravity and metallicity, respectively, and reference values are shown in the X-axis. Color code represent the reference metallicity (blue being metal poor and red corresponds to metal rich). On the upper part, the median difference and dispersion is indicated.

iSpec[1] is an open source spectroscopic framework that implements routines for spectral treatment and the determination of atmospheric parameters + chemical abundances by using the spectral fitting technique (Blanco-Cuaresma et al. 2014). Given a selection of spectral regions and absorption lines, iSpec computes **synthetic spectra** on-the-fly and minimizes the differences with the observed spectra following a Levenberg–Marquardt (least squares) algorithm.

The selection of absorption lines is optimized and calibrated to reproduce the **Gaia FGK Benchmark Stars** reference values (Heiter et al. 2015, Jofré et al. 2014, Jofré et al. 2015 and Hawkins et al. 2016) as shown in Fig.1, which is also useful to better estimate typical errors for each parameter and reduce correlations. This group of very well-known stars have reference parameters derived independently from spectroscopy and it does not contain any pulsating star.

To evaluate iSpec with pulsating stars, we analyzed 176 spectra of **δ Cephei** and 136 of **RRLyrae** observed with the HERMES spectrograph (resolution ~ 85,000) installed on the Flemish Mercator telescope at la Palma (Observatorio Roque de los Muchachos). As shown in Fig. 2, the spectra have strong variations over the whole pulsating cycle and the line selection based on the Gaia FGK Benchmark stars might not be the best for this kind of stars.

[1] http://www.blancocuaresma.com/s/

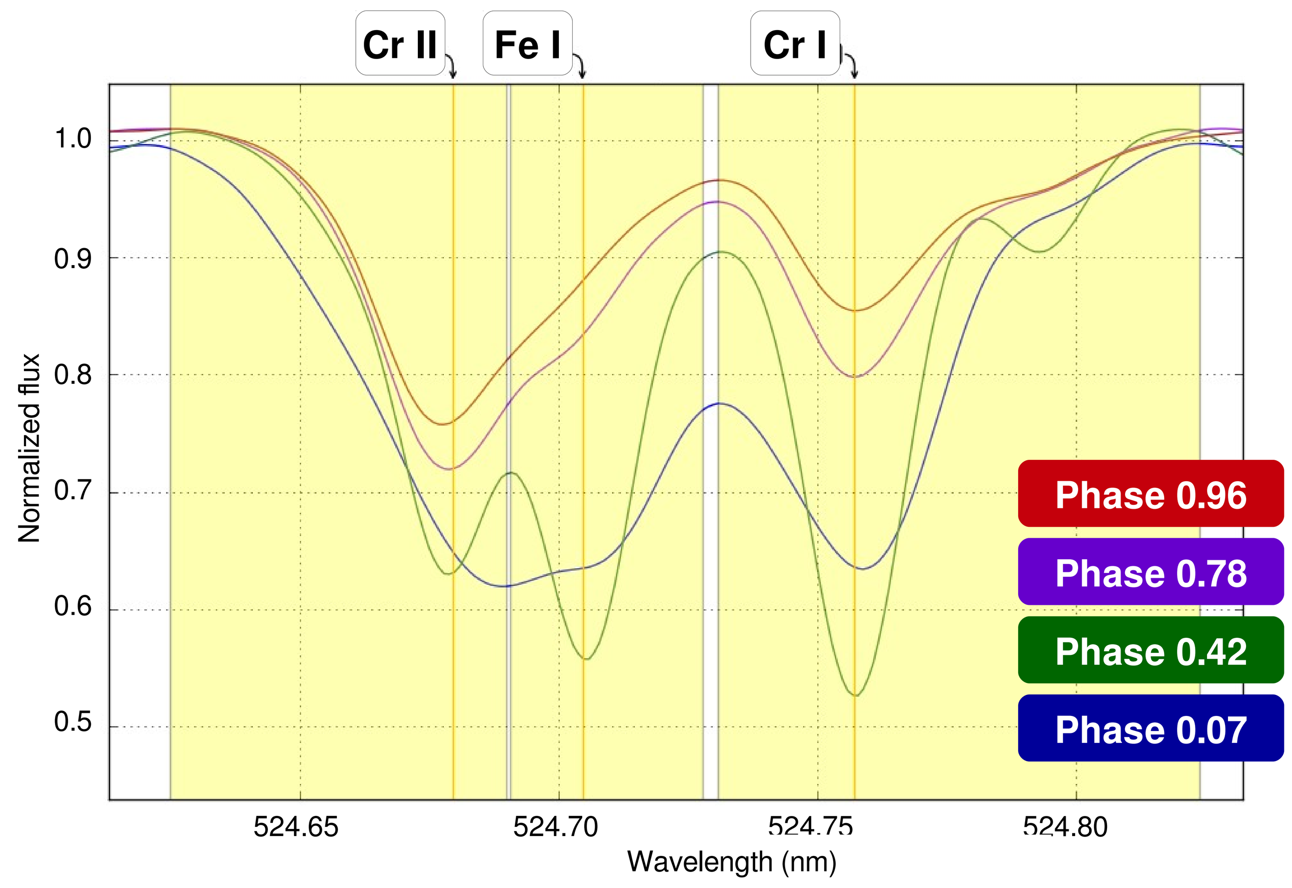

Fig 2. Absorption lines from observed spectra corresponding to different phases of the pulsating cycle for **δ Cephei**.

Preliminary results and future work

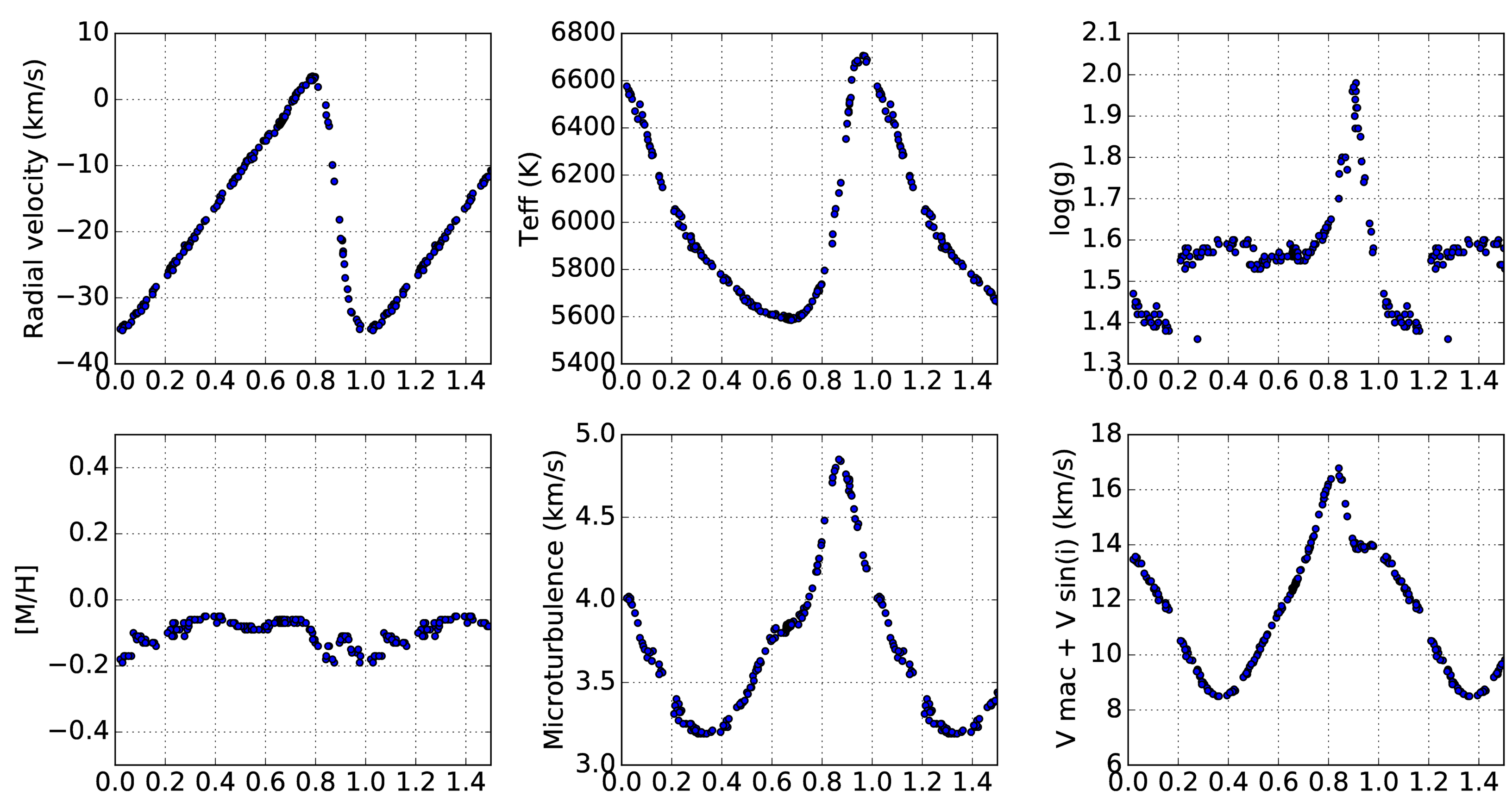

Fig 3. Radial velocity as reported by Anderson et al. (2015) and atmospheric parameters derived by iSpec for **δ Cephei**. Results are folded in phase considering a period of 5.366367120 days and the epoch of maximum light of 2455506.7628.

Individual **chemical abundances** in function of phase (Fig. 4) are stable as it was expected (the chemical composition of the star should not vary). We plan to use this information to identify absorption lines that are reliable and stable (less affected by turbulence) during the whole pulsating cycle. This new **line selection** will help to improve the determination of atmospheric parameters and it will allow us to be more confident in the study of other less known Cepheids and RR Lyrae.

Traditionally, from the three main atmospheric parameters, the most difficult to derive from stellar spectra is the **surface gravity** (i.e. log(g)) because its effects are more subtle than the effects of the effective temperature or the metallicity. In Fig. 3, we can clearly observe these difficulties: when we apply a non-adapted traditional spectroscopic method to pulsating stars, derived gravities do not seem to follow a physically logical evolution. Nevertheless, metallicity is globally stable (-0.09±0.03 dex) and **effective temperature** is beautifully reproduced with minimum close to the maximum contraction and maximum at fastest expansion. Ranges and average results agree with Andrievsky et al. 2005.

In terms of **broadening parameters**, macroturbulence velocity (Vmac) and projected rotation (V sin(i)) are very difficult to disentangle even if their profiles are not exactly the same.

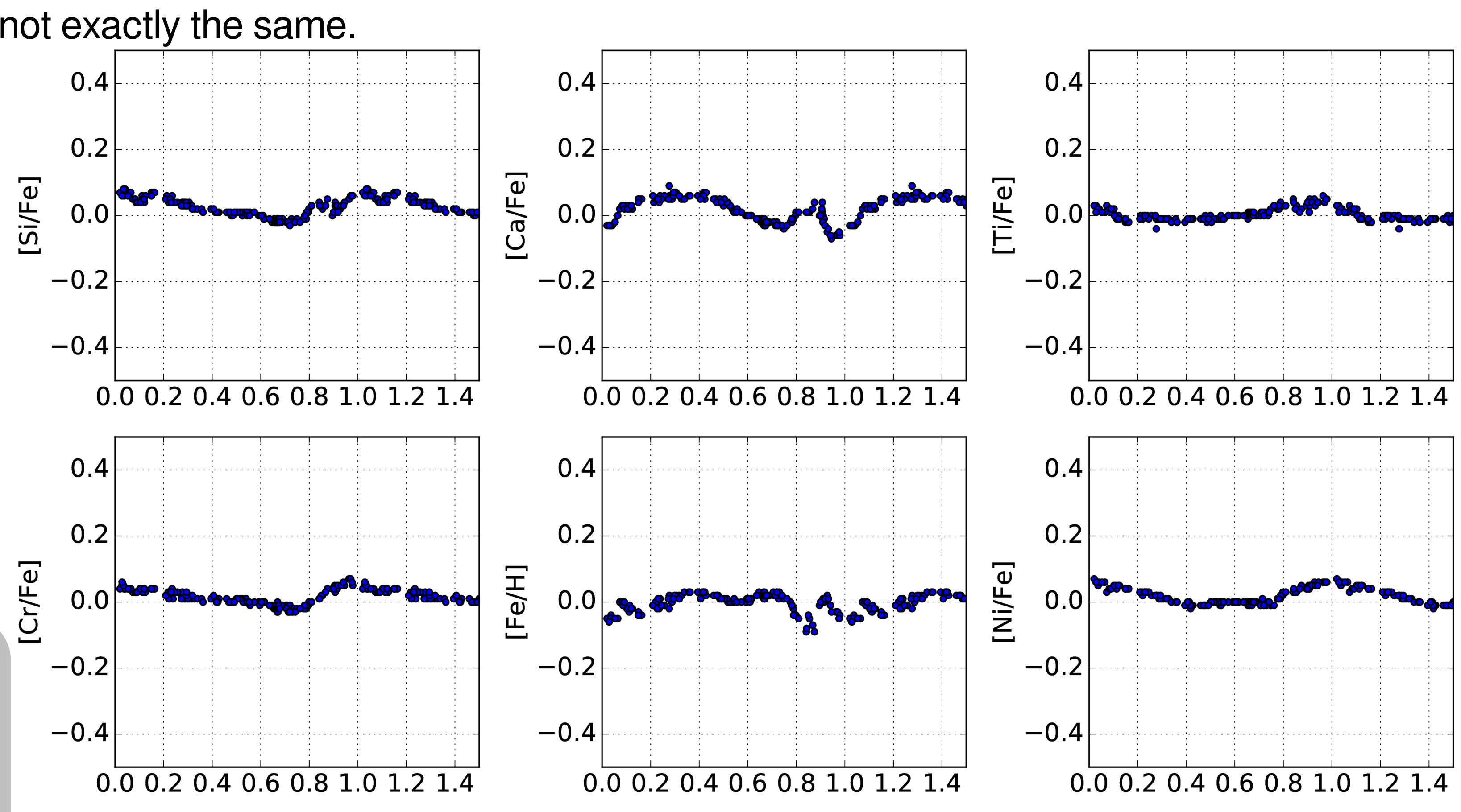

Fig 4. Differential chemical abundances relative to a **δ Cephei** spectra. Silicon, Calcium and Titanium are alpha elements, while Chromium, Iron and Nickel are iron peak elements..

RRLyrae: Results are similar to **δ Cephei** although metallicity is less stable over the pulsating cycle. RRLyrae is a metal-poor star (~ -1.45 dex) that complicates even more its analysis

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