

Spectroscopic properties of stars with debris discs

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Abstract. The question of the origin and evolution of planetary systems is of fundamental importance for astrophysics. Dusty debris discs are signatures of planetary systems and, therefore, constitute valuable tools to provide new light in our understanding of how planetary systems form and evolve. We present the first results of a spectroscopic programme of a sample of stars with debris discs. High-resolution echelle spectra are used to determine metallicities and abundances. Properties of stars with debris discs, are compared with those of stars hosting planets, as well as ‘normal’ stars.

1. Introduction

Understanding the properties of planet-host stars is of the utmost importance to constrain theoretical models of planetary systems formation and dynamical evolution. At the time of writing more than 570 extrasolar planets have been discovered¹, and the number is expected to increase in the immediate future thanks to the development of both ground-based and space deployed new facilities (e.g., ELTs, SPICA, EUCLID, ECHO). In particular, the ESA-Gaia mission is expected to detect around 8000 giant planets orbiting solar-type stars located at distances closer than 200 pc [5]. For more distant stars, the unprecedented microarcsecond-precision astrometric measurements of Gaia will significantly improve our knowledge of orbital parameters and mass distributions.

Dusty debris discs are generated by collisions of large solid bodies orbiting main-sequence stars [3]. They are direct signatures of planetesimal systems and, therefore, constitute valuable tools to understand the formation and evolution of planets. Current statistics show that around 15 % of the solar-type (spectral types FGK) stars are attended by debris discs. Typical disc characteristics are grain blackbody temperatures of ~ 50 K to 100 K, radii between 10 AU and 100 AU, and fractional dust luminosities $L_{\text{dust}}/L_{\star} \sim 10^{-5}$ and larger [20].

Whether stars with planets show (or not) special properties when compared to ‘normal’ stars has been the subject of an intensive study, and the topic is still developing. It is well known for instance, that giant planets detected by radial-velocity techniques are more likely to be found around stars with high metallicity content (e.g., [21]). When considering different chemical species individually, the results are inconclusive, for example, the finding of a higher depletion of lithium in planet host stars is the subject of an ongoing debate (e.g., [4, 10, 18]).

¹ <http://exoplanet.eu/>

There are relatively few works dealing with the properties of stars harboring debris discs [7, 11]. In this contribution, we present the first results of an observational programme aimed to characterize the properties of stars with debris discs and compare them to stars known to host planets.

2. Observational data

High-resolution échelle spectra of stars with/without debris discs were observed with the FOCES spectrograph at the 2.2 m telescope of the German-Spanish Observatory in Calar Alto (CAHA, Almería, Spain); the SARG spectrograph at the the 3.56 m Telescopio Nazionale Galileo (TNG), and the FIES instrument at the 2.56 m Nordic Optical Telescope (NOT), both on La Palma (Canary Islands, Spain). Additional spectra from the public library ‘S⁴N’ [1] and FEROS spectra from the ESO/ST-ECF Science Achieve Facility² were also used. Part of these data, including the observing runs and data reduction procedures are detailed in [14]. All these spectra have high-resolution $\lambda/\Delta\lambda\sim 57\,000$ and large signal-to-noise ratio (~ 100), covering a wide spectral range.

3. Spectroscopic parameters

Basic stellar parameters T_{eff} , $\log g$, microturbulence velocity (ξ_t), and $[\text{Fe}/\text{H}]$ are computed by using the code TGV developed by [19]. The code implements the iron excitation and ionization conditions for a set of 65 Fe I and 13 Fe II isolated lines: *i*) T_{eff} is adjusted until no dependence is found between the derived Fe I abundances and the excitation potential of the lines; *ii*) ξ_t is changed until no dependence is found between the derived Fe I abundances and the equivalent width of the lines; *iii*) the ionization condition requires that $\log g$ should be changed until the averaged abundances obtained from Fe I and Fe II lines are the same.

Starting from an initial guess of the stellar parameters, the code uses an iterative algorithm to find the set of stellar parameters which simultaneously minimizes the standard deviation of the obtained Fe I lines (conditions *i*) and *ii*)), and the difference between the averaged Fe I and Fe II abundances (condition *iii*)).

ATLAS9 models [13] are used and abundances are computed under LTE assumptions. The list of lines was specifically chosen for solar-like stars (spectral types F5/K2-K3). An example is given in Fig. 1 where the obtained abundances for a solar-type spectrum are plotted versus the excitation potential (left-hand panel) and the reduced equivalent widths of the lines (right-hand panel).

The normalized metallicity distribution of the metallicity of the stars with debris discs is plotted against the distribution of those stars without discs in Fig. 2. Both distributions look quite similar, suggesting there is no dependence of the debris disc phenomena on the stellar metallicity. This behavior is different from those stars which host gas-giant planets (e.g., [8]), although stars hosting less massive planets have recently found not to be metal rich [9].

4. Other chemical abundances

Abundances of several elements (Na, Mg, Al, Si, Ca, Ti I, Ti II, Cr, Mn, Co, Ni, and Zn) are computed by using the WIDTH9 program written by R. L. Kurucz [13], updated to work under Linux by [6]. Atmosphere models are computed for each star with the ATLAS9 code [13], updated to work under the Linux platform by [17, 16].

An exhaustive search was performed in order to identify narrow, non-blended lines for each of the aforementioned ions (e.g., [15]) although we kept the line’s parameters (i.e., excitation potential, $\log(gf)$) as given in WIDTH9 which are mostly from the Kurucz line lists. Final abundance values are expressed relative to the solar values from [2].

² <http://archive.eso.org/cms/>

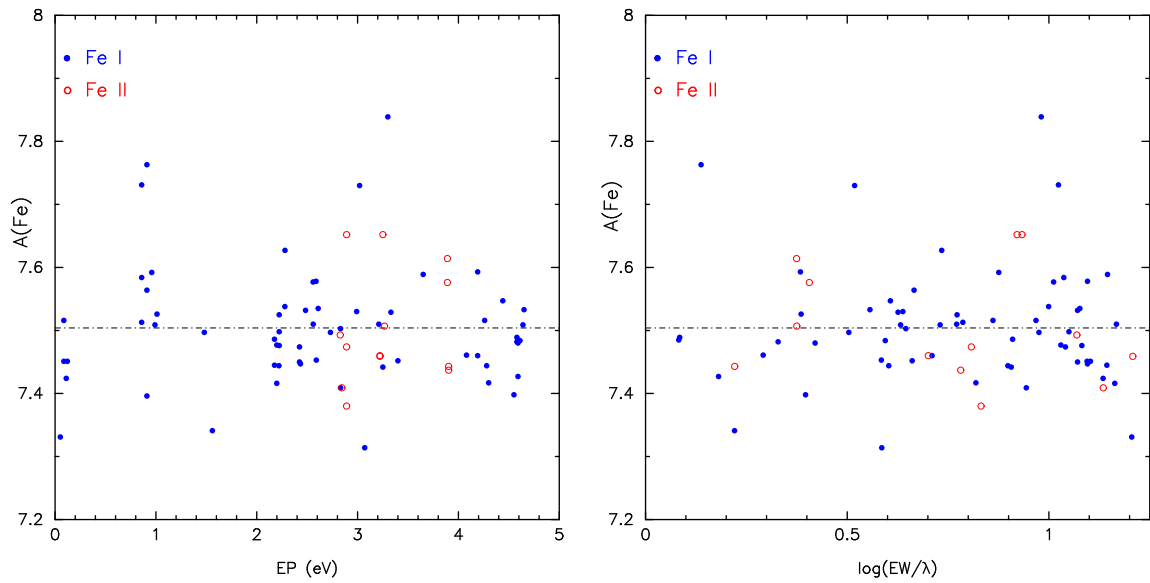


Figure 1. Solar iron abundances obtained for each individual Fe I (blue circles) and Fe II (open red circles) line versus the lower excitation potential of the lines (left-hand panel), and versus the reduced equivalent width of the lines (right-hand panel). The horizontal dashed-dotted lines represent the mean iron abundance.

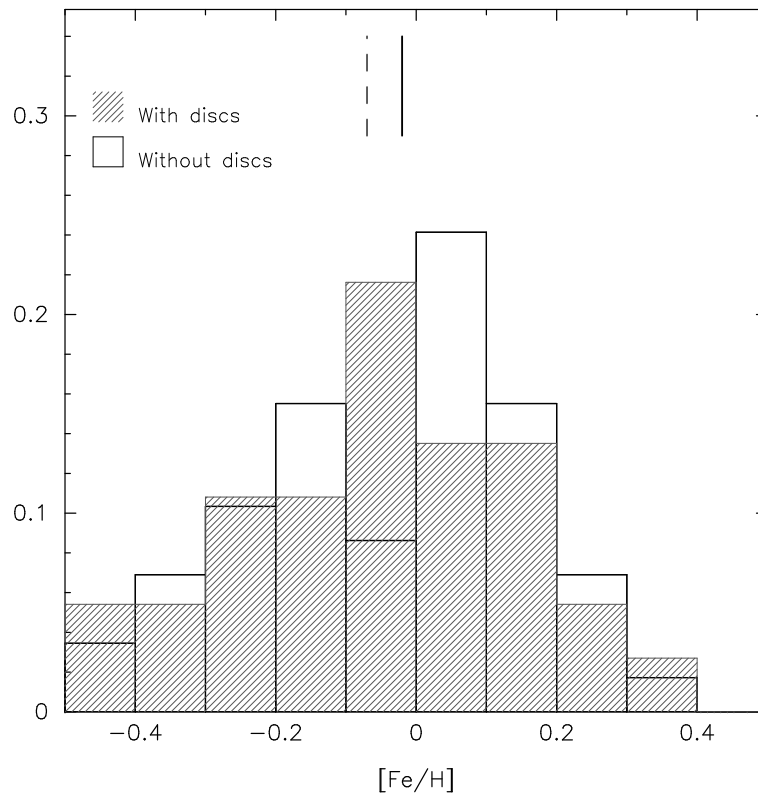


Figure 2. Normalized metallicity distribution of the stars without debris discs (empty histogram) and the stars with debris discs (grey histogram shaded at 45 degrees). Median values of the distributions are shown with vertical lines.

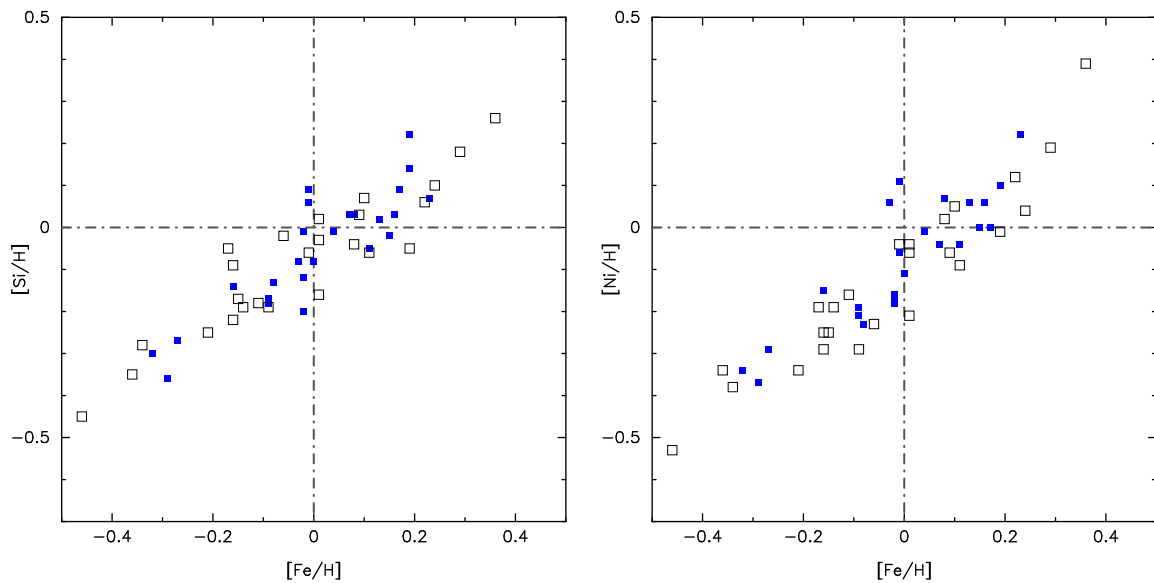


Figure 3. Abundance trend $[\text{Si}/\text{H}]$ vs. $[\text{Fe}/\text{H}]$ (left-hand panel) and $[\text{Ni}/\text{H}]$ vs. $[\text{Fe}/\text{H}]$ (right-hand panel) for stars with debris discs (blue filled squares) and stars without discs (open squares).

As an example, the abundance trends $[\text{Si}/\text{H}]$ vs. $[\text{Fe}/\text{H}]$ and $[\text{Ni}/\text{H}]$ vs. $[\text{Fe}/\text{H}]$ are plotted in Fig. 3. Again, we do not find any special distinction between stars with and without debris discs in any of the analyzed ions.

5. Discussion

The well-known planet-metallicity correlation for stars hosting giant radial-velocity planets, fits well into the framework of core-accretion models (e.g., [12]). The formation of planetary cores in this context is favored in discs with high-metal content. Here we find a lack of correlation between the presence of debris discs and high-metallicity. Although it can be explained within the current theoretical understanding of planet formation, its full implications will be discussed at length in a forthcoming paper.

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