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PRESENTACIÓN MURAL

CN and CH bands in exoplanet host stars

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Abstract. We measured the strength of CN and CH molecular bands in a sample of stars with and without exoplanets (indices δS3839, δS4142 and δCH4300). The index δS3839 seem to present smaller values for stars without exoplanets. No correlation is found between molecular bands and exoplanet parameters, supporting the primordial hypothesis of planet formation. The CN band strength seem to increase with C, N and Fe abundances. This could explain at least in part the dissimilar distributions of CN observed for stars with and without exoplanets. We caution that this is an initial result based in relatively small number of objects.

Resumen. En este trabajo medimos la intensidad de las bandas moleculares CN y CH en una muestra de estrellas con y sin exoplanetas (indices δS3839, δS4142 y δCH4300). El índice δS3839 parece ser menor en estrellas sin exoplanetas. El hecho de que la banda CN aumente con la metalicidad, puede explicar al menos en parte las diferentes distribuciones observadas en estrellas con y sin exoplanetas. Advertimos que hasta el momento las muestras son relativamente pequeñas.

1. Introduction

Main-sequence exoplanet host (EH) stars are, on average, metal-rich in comparison to no-EH stars (e.g. Santos et al. 2004). Fischer & Valenti (2005) showed that the probability to present an exoplanet increase with the metallicity of the star. On the other hand, the molecular content in the atmospheres of EH stars does not received the same attention in literature. In particular, molecular bands of CN and CH are readily observed in the spectra of solar-type stars.

Different molecules are commonly detected in protoplanetary disks, such as bright lines of CO and HCO^+. Also lines of DCO^+, CN, HCN, CCH and other molecular species are observed (see e.g. the review of van Dishoeck 2009). Different works shows that molecules are present in protoplanetary disks and could be important ingredients in the planet formation.

Then, the aim of this work is to directly compare (to our knowledge, for the first time) the molecular strengths in the atmospheres of stars with and without low-mass companions or exoplanets. This study will help to determine if the strength of certain molecular bands observed in main-sequence stars could play a role in the planet formation process. Also we search for possible correlations between the molecular indices and exoplanet parameters (semi-major axis a, eccentricity e and planet mass m seni).

This comparison allow us to support the primordial scenario of planet formation, follow a reasoning similar to Bond et al. (2006). In this scenario the abundance content of the star is similar to their original parent cloud. However, we caution that the accretion hypothesis (i.e. the increase of abundances due to external pollution of material) could not be totally excluded.

2. Observational material

We observed 38 southern EH stars from the California and Carnegie and the Geneva Observatory planet search lists[1]. The 38 stars we observed have V magnitude between 1.5 and 8.9 and spectral types FGK (5, 26 and 7 objects, respectively), as specified in the Hipparcos database. We also observed a sample of 19 stars not known to have any planetary-mass companions (Santos et al. 2004, Bond et al. 2008, Gilli et al. 2006). The 19 stars we observed have V magnitude between 2.8 and 8.3 and spectral types FGK (2, 11 and 6 objects, respectively). The stars studied in this work do not present IR excess indicative of circumstellar dust.

The spectra were obtained at Complejo Astrónomico El Leoncito (CASLEO) between April 21 and 25, 2008 and October 10 and 15, 2010. We used the 2.15 m telescope equipped with a REOSC echelle spectrograph and a TEK 1024x1024 CCD detector. We have used a grating with 400 lines mm^{-1}. The spectra cover a range 3500-6500 **Å** and the S/N ratio is $\sim$150. The data were reduced using IRAF procedures and the *sbands* task was used to measure the strength of the molecular bands.

3. Spectral indices

We measure the strength of 2 CN bands at $\sim$3883 Å, $\sim$4215 Å and a CH band at $\sim$4300 Å using the spectral indices S3839, S4142 and CH4300 defined in literature (e.g. Harbeck et al. 2003). The index definitions are:

$$\mathrm{S3839} = -2.5 \log \frac{F_{3861-3884}}{F_{3894-3910}},$$
$$\mathrm{S4142} = -2.5 \log \frac{F_{4120-4216}}{0.5F_{4055-4080}+0.5F_{4240-4280}},$$
$$\mathrm{CH4300} = -2.5 \log \frac{F_{4285-4315}}{0.5F_{4240-4280}+0.5F_{4390-4460}},$$

where $F_{3861-3884}$, for instance, is the summed spectral flux in ADU counts from 3861 to 3884 Å. To determine the uncertainty, we assumed pure photon noise statistics and added the dispersion of the indices derived from individual spectra. The average dispersions are 0.151, 0.098 and 0.064 for S3839, S4142 and CH4300, respectively. We applied a temperature and gravity correction similar to Harbeck et al. (2003) and referred the corrected indices to as δS3819, δS4142 and δCH4300.

There is a general agreement between the δS3839 and δS4142 values, however S4142 is less sensitive to the intensity of the CN molecule (Harbeck et al. 2003, Pancino et al. 2010). Then, we adopt the index S3839 to measure the strength of the CN band, similar to these literature works.

[1] http://exoplanets.org, http://obswww.unige.ch/exoplanets

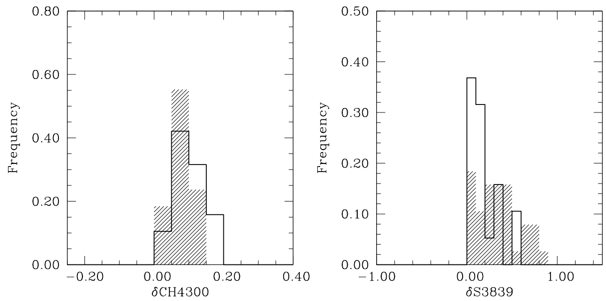

Figura 1. Distribution of the indices δCH4300 and δS3839. EH and no-EH stars are showed by filled and empty histograms, respectively.

4. Molecular bands in EH and no-EH stars

We present in the Figure 1 the distribution of the indices δCH4300 and δS3839. EH and no-EH stars are showed by filled and empty histograms, respectively. In the Table 1 we present the average and dispersion of the indices. The Figure 1 and the Table 1 shows that the distribution of δCH4300 values for EH and no-EH stars are similar. However, for δS3839 no-EH stars seem to concentrate in relatively smaller values (δS3839$<\sim$0.6). The difference is also present in the values of Table 1. A Kolmogorov-Smirnov test gives a probability of $\%20$ that both distributions represent the same population. We caution that this is an initial result and more stars are needed to verify a significative difference.

No clear relation is apparent between molecular indices and exoplanet parameters (a, e and m seni), which is naturally explained by the primordial scenario of planet formation (e.g. Bond et al. 2006). However, the accretion hypothesis could not be totally excluded.

5. Carbon abundances from atomic lines

The stellar parameters T_{eff}, log g, [Fe/H] and ξ (microturbulence velocity) have been derived by requiring excitation and ionization equilibrium of Fe lines with the program FUNDPAR (Saffe 2011). The C I abundances are determined from equivalent widths of 2 lines (5380.34 **Å** and 5052.17 **Å**) measured with the SPLOT task of IRAF. Our spectra do not include relatively intense N I lines, then we collect N I abundances from literature (Ecuvillon et al. 2004b). There is a good agreement between the C I abundances and literature (Ecuvillon et al. 2004a) for 26 stars in common (average difference $\sim$0.05 dex).

Tabla 1. Average and Dispersion of molecular indices for EH and no-EH stars.

	EH stars (n=38)	no-EH stars (n=19)
δCH4300 $\pm\sigma$	0.08±0.04	0.10±0.05
δS3839 $\pm\sigma$	0.34±0.24	0.20±0.17

The strength of the CN molecular band seem to increase with the abundances of C, N and Fe, as showed in the Figure 2. Then the CN molecule depends on their individual

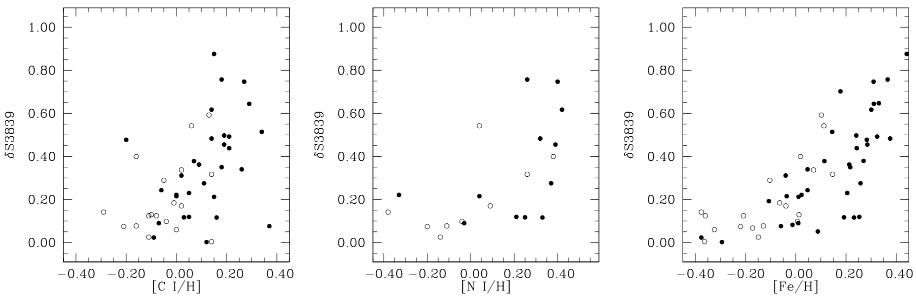

Figura 2. Index δS3839 vs abundances of C I, N I and Fe, respectively. EH and no-EH stars are showed by filled and empty points, respectively.

components C and N, and both abundances scales with Fe. If EH stars are metal-rich, then we could expect different distributions for the CN molecule. This could explain, at least in part, the dissimilar distributions of CN presented in the Figure 1 and Table 1. The dependence between the molecular intensity and abundance of their elements is expected in the case of molecular equilibrium. We caution again that these results are based on relatively small samples.

6. Summary

We measured the strength of the CN and CH molecular bands in a sample of EH and no-EH stars. The index δS3839 seem to present a different distribution for EH and no-EH stars. The difference in the distributions could be explained, at least in part, with the fact that the strength of the CN molecule scales with Fe (EH stars are metal-rich). We expect to increase the number of stars to verify the tendences observed in this work.

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