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The search for exocomets. Gas around main-sequence stars.

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Abstract

The environment of main sequence stars is expected to be depleted of gas once they have left the protoplanetary disc phase. Thus, a replenishment mechanism, such as grain-grain collisions or evaporation of solid bodies, is required to explain the presence of gas recently reported to be present around some MS stars. Here, we present a high resolution spectroscopic survey of over 100 A to G stars, searching for gas in the form of stable and variable non-photospheric absorptions in metallic lines (mainly Ca II and Na I). The observations were carried out in both hemispheres at La Palma (Spain), La Luz (México) and La Silla (Chile) observatories. The over 2000 spectra obtained allow us to construct time-series for most of the stars in the sample. So far, we have found gas compatible with circumstellar origin in almost half of the sample, and variable absorptions which can be interpreted as the evaporation of solid bodies, i.e. exocomets, in several objects, some of them being new detections.

1 Introduction

While exoplanets are routinely detected, we still have little information about the small components of planetary systems, such as asteroids and comets, which are key in the understanding of planet formation process. This lack of knowledge can be attributed to the challenging nature of direct detection, since given their small surface they have very marginal emission in thermal or scattered light. Infrared and (sub-)mm excesses due to the thermal emission of dust grains surrounding main sequence (MS) stars are indirect hints of the presence of planetesimals. Detection of molecular and atomic circumstellar (CS) gas emission has also been proposed to be at least partially originated by the outgassing of solid comet-like bodies. In the optical range, variable red-(and less frequently blue-)shifted absorptions of Ca

II H & K and Na I D have been attributed to the evaporation or sublimation of exocometary bodies when falling onto the star (Falling Evaporating Bodies or FEBs) [2]. Since the discovery of this phenomenon in the spectra of β Pic [4], around ~ 20 A-type stars have been reported to show these variable comet-like absorption features. A large body is often invoked as a perturber, driving the exocomets into the vicinity of the star. That appears to be the case of β-Pic, where a planet has been located in the system [5] in a position compatible with the observed dynamics of its exocometary events.

In order to further study this phenomenon, we have conducted a high-resolution spectroscopic survey, aiming at detecting and monitoring variable features in Ca II and Na I metallic lines of A to G stars.

2 Sample and observations

We have built a biased, non-homogeneous sample of 117 stars following different criteria with the aim of optimizing the detection of CS gas. The criteria are: stars with previously detected FEBs; debris disc stars; stars belonging to young associations; stars with near infrared (NIR) excesses (exozodii); stars with hot CS gas as revealed by the presence of Ti II; stars surrounded by cold molecular gas; and λ Böo stars. This sample allows us to monitor previously detected FEBs, and eventually to detect new stars with non-photospheric gas related to exocomets.

We have performed observations from September 2015 until September 2017 along 22 observing campaings in four different telescopes in both hemispheres: Mercator and NOT (La Palma, Spain); 2.2 MPG (La Silla, Chile) and TIGRE (La Luz, México). All these facilities are equiped with fibre-fed echelle spectrographs. We have obtained 2046 high resolution spectra, which will allow us to construct time series for most of the stars. Fig. 1 shows an example of time-series for one of the stars in the sample in four consecutive nights, where a variable event is detected.

3 Results

Gas detection

A median spectra was constructed for each star in order to maximize the signal to noise ratio and optimize the detection of stable components. The first results of our analysis of the Ca II K line show that a stable absorption is present in 59 stars. Out of those, we identify with a high level of confidence in 36 objects the absorption arising from CS gas in the inner regions of the system, as the radial velocity (RV) of the absorption matches that of the star. In 12 other cases the absorption's RV is closer to that of the interstellar medium (ISM) and so the origin of the gas is most likely interstellar. We can not discern whether the origin is CS or ISM in 8 cases so further investigation is needed. Among the 36 objects with CS gas, 12 of them show as well variable absorption features, detected when comparing every individual spectra, and in some cases daily or campaing medians, as shown in Figure 1. We also find 3 objects with variability and without any stable absorption in Ca II K line. The origin of the

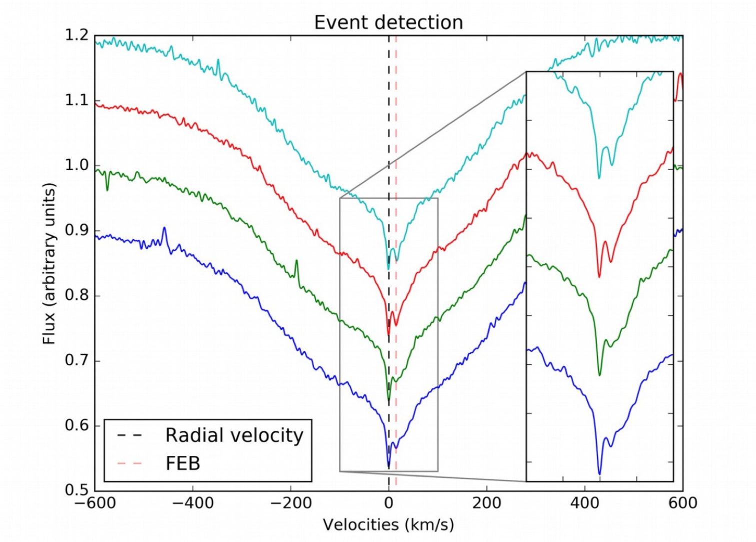

Figure 1: Ca II K line for four consecutive days of the same star. Each colour represents a different date. The vertical black dashed line shows the RV of the star, where a stable component is present. The red dashed line marks the position of the variable event.

variations could be attributed to multiple scenarios, including stellar winds or photospheric variability, so we will investigate other lines in the spectra in order to clarify this issue. Out of the 15 stars showing variability, 10 were already known in the literature to host FEB-like events, and therefore 5 are new additions. We also have 10 more stars in the sample with variability reported in the past, where we do not detect any variations in the line inspected so far. This could be due to the non-periodic nature of these events, rather than to false positives. The other 58 stars in the sample do not show any evidence of non-photospheric absorptions.

ϕ Leo

The A7 star ϕ Leo stood up in the survey sample, as it clearly shows variability in the Ca II K line [3]. This is particularly interesting, as it lacks a massive debris disc, and is much older that the rest of stars with detected exocometary activity: 500-900 Myr, against, for example, $\sim$ 20 Myr of β Pic. Since the strongest evidence of CS material found so far was the presence of Ti II [1], we investigated possible origins for the variations, but given the short time scales of the events (hourly, in some cases, as shown in Fig. 2), and the fact that they were only detected in Ca II K, we suggested exocometary activity in the inner regions of the system as the most likely explanation. We keep monitoring this object, aiming at better characterizing the absorptions, and looking for evidence of a possible massive perturber.

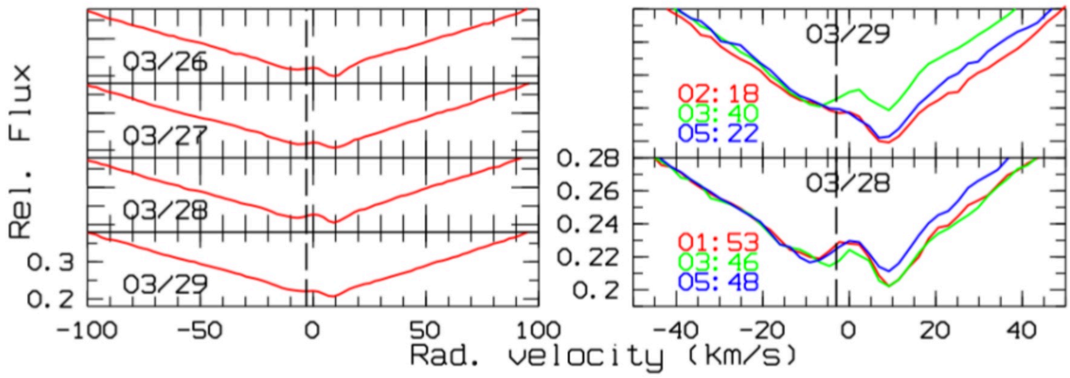

Figure 2: Detail of the Ca II K line of ϕ Leo. Left panel: Median spectra of four consecutive nights in March 2016. Right panel: Three consecutive spectra for two different nights where the hourly variations are detectable (Times are UT). Figure from [3].

Gas in debris discs

Gas-to-dust ratio is expected to decrease as planetary systems evolve their protoplanetary phase into debris discs. Nevertheless, there is a growing sample of debris discs with detected cold molecular and atomic gas in far-infrared and (sub-)mm wavelengths. To our knowledge, 17 objects show both a photometric excess related to the presence of a dusty debris disc and evidences of cold gas, located in the outskirts of the system. When analyzing the optical spectra of those 17 objects [6], we find stable non-photospheric absorptions in 10 of them, likely 7 being of CS origin (plus one of unclear origin). The narrow absorptions in the other two objects have most likely an interstellar origin. Interestingly, when considering the inclination angle of the discs, we find 7 out of 9 discs with edge-on inclination ($> 45^o$) to show non-photospheric absorption of CS origin and 7 out of 8 discs with face-on inclination ($< 45^o$) without any non-photospheric absorption, or with absorptions of ISM origin. This points towards the possibility of a geometrical effect being responsible for the detection or non-detection of the inner hot gas, revealed as stable non-photospheric absorptions when transiting the star.

4 Summary and conclusions

We have performed a non-homogeneous survey towards detecting CS gas in 117 stars, during two years in 22 observing campaings. We have found CS stable gas in at least 36 stars (plus 8 with non-clear origin) and variable gas features in 15 stars, out of which 5 are new detections. While we are still inspecting the data searching for gas evidence in other metallic lines, the results of the analysis of the Ca II K line have lead us to the discovery of highly variable absorptions in the star ϕ Leo, likely due to exocomets; and the possible geometrical effect in the detection of hot gas in cold gas bearing debris discs stars.

The available data collected on exocomets is still insufficient to fully understand how these bodies take part in planetary forming processes, therefore further time series studies are needed to better (chemically and dynamically) characterize these events.

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References

[1] Abt, H.A. 2008, ApJS 174, 499

[2] Beust, H. et al. 1998, A& A, 338, 1015

[3] Eiroa, C. et al. 2016, A&A, 594, L1

[4] Ferlet,R. et al. 1987 A&A, 185, 267

[5] Lagrange,A.M., et al. 2009, A&A 493, L21

[6] Rebollido, I., et al. 2018, A&A 614, A3