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Research Note

A search for β Pictoris-like Ca II circumstellar gas around Ursa Major Stream stars*

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Abstract. We carried out an optical spectroscopic survey of twenty one stars to search for Ca II circumstellar gas at the stellar velocity similar to that found in the β Pictoris disk. The surveyed stars are A-type stars with large $v \sin i$ in the Ursa Major stellar kinematic group. No evidence of circumstellar gas was found around any of the stars. This result suggests that β Pictoris either is a very peculiar object surrounded by an anomalous amount of gas, or is younger than the stars in the Ursa Major Group ($\sim 3\ 10^8$ years).

Key words: stars: circumstellar matter – planetary systems – line: profiles

1. Introduction

The dusty environments of main sequence stars presenting IR excess (Aumann et al. 1984) have been subject of detailed analysis (Backman & Paresce 1993). Until very recently, the β Pictoris disk remained the only disk imaged around a main sequence star despite a large survey of more than hundred stars presenting an IR excess (Smith et al. 1992). Now dust has also been observed around BD+31°643, but it is a very young star and this dust may have a different nature (Kalas & Jewitt 1997). The particularity of β Pictoris is not the consequence of the favorable edge-on geometry of the disk, nor of its short distance, but suggests that this star is very peculiar among the nearby ones surrounded by dust disks (Kalas & Jewitt 1996).

The gaseous counterpart of the β Pictoris dust has been observed in both visible and UV lines (see review by Vidal-Madjar & Ferlet 1995). The observed spectral signatures led to the explanation that the gas content was probably produced by the evaporation of many small bodies (Vidal-Madjar et al. 1994). However, the presence of the Ca II stable component around β Pictoris is still very puzzling. The radiation pressure must have expelled this gas very quickly, except if some large amount of gas is opposed to the pressure. Neither the physical process providing the stability observed over more than twelve years, nor the origin of the suspected gas were extensively explained (Lagrange 1995). Numerical modeling to solve this problem are still underway (Lagrange et al. 1997).

On the other hand, gas is routinely observed around young pre-main sequence stars. Infalling gas also has been detected in moderate resolution spectra of Herbig Ae/Be stars (Pérez et al. 1993), UX Orionis (Grinin et al. 1996), post Herbig Ae/Be stars and shell stars (Grady et al. 1996). Gas is also detected at stellar velocity around shell-stars and some β Pictoris-like stars (Lagrange et al. 1990). Unfortunately, the connection with the β Pictoris phenomenon is not clear and/or the stellar ages are not well constrained. In order to constrain the gas history and to have a more complete knowledge of the status of β Pictoris and its gaseous disk, one should compare it with other main sequence stars of similar type and well-known age. This has already been done for the IR excess and dust thermal emission at submillimeter wavelength (Yuan & Backman 1993, Zuckerman & Becklin 1993). For spectral study of the gaseous absorption lines, a sample of stars with $v \sin i$ as large as possible is required to avoid geometrical effects which give only negative results for disks not seen edge-on.

Five major questions should be addressed concerning the status of gaseous disks.

1) What is the link between the gas disks and the dust disks? Are we observing two different phenomena, both present around β Pictoris?

2) Is there a connection between the hot gas detected through ionized gas or the corresponding redshifted absorptions, and the cold gas at much lower temperature like CO or C I ($T \sim 30K$, Vidal-Madjar et al. 1994)?

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3) Is β Pictoris a very peculiar object with a particular configuration (for instance presence of strong secular resonances in a planetary system as suggested by Levison et al. 1994), or is it simply surrounded by a massive disk in the tail of the mass distribution of disks surrounding other similar stars?

4) What is the evolutionary status of β Pictoris? Is it a pre-main sequence star or is it older than the ZAMS stars?

5) What is the variation of the gas content as a function of time?

Here we present an optical spectroscopic survey to search for Ca II circumstellar gas at the stellar velocity in the Ursa Major Group. It will certainly not answer the above questions, but it is expected to bring some new understandings. The target properties are presented in Sect. 2; the observations and data analysis in Sect. 3; results and discussion in Sect. 4 and 5 respectively.

2. The Ursa Major group

One of the difficulties to diagnostic a circumstellar Ca II absorption at the stellar velocity is the possible contamination by interstellar gas. In that respect, the Ursa Major Group offers a combination of favorable properties. First, the Ursa Major region is located close to the galactic pole, and very little interstellar gas is present in that direction. For example, Hobbs (1978) gave an upper limit on the interstellar Na I column density present toward η UMa: $N(NaI) < 2\times10^{10}$ cm^{-2}. Thus, if a gaseous absorption were detected toward one of the surveyed stars at the stellar velocity, a circumstellar origin would be very likely, although still to be demonstrated.

Moreover, as the stars belong to the same kinematic stream, they form a sample with similar properties like age, distance or metallicity. Indeed, their age is rather well constrained to be about 3×10^8 years (Levato & Abt 1978, Eggen 1983). The Ursa Major Group is very nearby with most of the stars being within 50 parsecs. These bright nearby stars can thus be observed at high S/N ratios and high resolution in relatively short time, even with small telescopes. In addition, very little interstellar gas is expected for such short sight lines. Finally, the Ursa Major Group stars have about the same composition as the Sun (<[Fe/H]>=-0.1, Soderblom & Mayor 1993).

For the present program, one of the essential properties of the Ursa Major Group is its well known age. The age of β Pictoris is a matter of debate. Paresce (1991) claimed that β Pictoris may be metal deficient with an age of about 2×10^8 years. However, through observations obtained with HST-GHRS, Lanz et al. (1995) showed that β Pictoris is very close to the main sequence. This result has been reinforced by the new determination of the β Pictoris distance with the Hipparcos satellite (Crifo et al. 1997). But the age is only constrained to be between 8×10^6 years and up to $3-4\times10^8$ years. Lanz et al. prefer the youngest age because of the presence of the circumstellar disk. However, there is no evidence that this disk is "proto-planetary". Even the β Pictoris disk is certainly not the residual of a proto-planetary disk but it is continuously supplied by colliding or evaporating bodies (Weissman 1984). Thus, the presence of the disk cannot allow to conclude about the age of the star. In our own Solar System, evaporating and colliding bodies were active during few 10^8 years after its formation (Hartmann 1972, Soderblom et al. 1974). The age of β Pictoris remains an open question.

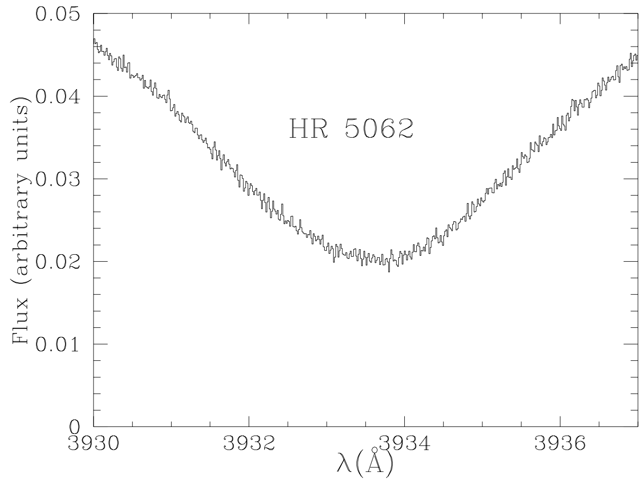

Fig. 1. Spectrum of the Ca II-K line toward HR 5062. The stellar line is rotationally broadened ($v\sin i$=218 km s^{-1}). No absorption is detected, neither interstellar nor circumstellar.

In this context, the analysis of A-type stars in the Ursa Major Group can give new insights. The age of the group ($\sim 3 \times 10^8$ years) is closed to the limit of the oldest range of possible ages for β Pictoris. Therefore, if β Pictoris is actually in this range, one might expect that some stars in the Ursa Major Group show similar characteristics. Well before the discovery by IRAS of dust shells around a large number of main sequence stars, Witteborn et al. (1982) did a pioneering and prescient search of infrared excess expected from debris disks in the Ursa Major Group. Yuan & Backman (1993) showed that, although IRAS was unable to detect emission from individual A-Type stars in Ursa Major Group, these stars may have on average a small 12 and 25 μm emission excess above their photospheric emission. Clearly evolved circumstellar disks might be present around these stars. Further comparison with β Pictoris is needed to search for spectroscopic similarities.

Spectroscopy is in fact able to detect β Pictoris-like activity, even where IRAS failed to detect the presence of large amount of dust. It is obviously the case of HR 10 and HR 2174 for which spectral signature are clearly detected (Lecavelier des Etangs et al. 1997b), although infrared excesses are only marginally suspected on IRAS scans (e.g. Cheng et al. 1991). The absence of correlation between the infrared excess and the presence of circumstellar gas features shows that spectroscopic survey are still justified even for targets which does not present IR excess.

3. Observations and reductions

We observed the brightest stars in the Ursa Major Group located between 20 and 50 parsecs and visible at the period of observations. The observations were performed at the Observatoire de Haute Provence in France, with the 1.52m telescope and the *Aurélie* spectrograph equipped with a CCD detector. The resolving power was $\Delta\lambda/\lambda \sim 110\,000$. During five nights in April 1995, we obtained more than one hundred spectra of the Ca II-K line at 3933Å for stars of the Ursa Major Group.

Standard reductions have been done with the *MIDAS* software, including the absolute wavelength calibration through fitting of narrow lines from a Thorium-Argon lamp. After co-adding individual spectra, we finally obtained spectra of the Ca II lines toward 26 stars. An example is given for HR 5062 in Fig 1.

4. Results

Except 5 stars for which the signal to noise ratio was too poor, for the 21 remaining stars, the S/N ratio between 20 and 200 was good enough to be able to conclude on the presence or absence of the Ca II absorption feature at the stellar radial velocity. With an expected FWHM similar to the Ca II β Pictoris line (< 10km s^{-1}), such feature can be separated from the photospheric absorption of the program stars ($v \sin i > 32$km s^{-1}). We did not detect any Ca II absorption out of the noise level. Table 1 lists the target stars and gives the corresponding upper limits on the equivalent width of Ca II. These must be compared to the equivalent width of the stable Ca II-K absorption toward β Pictoris: $W_{\beta Pic} \sim 100$mÅ.

5. Discussion

Most of our targets are A-F type stars with large $v \sin i$. It suggests that the inclination parameter is not responsible for the negative result. If we neglect that the present sample is biased toward large $v \sin i$ (almost 70% of the stars have $v \sin i > 75$km s^{-1}), and if we assume that the disks have a 10^o opening angle as observed for β Pictoris (Artymowicz et al. 1989), disks should have been detected around at least three stars. We can thus roughly conclude that gaseous disks with density larger than one hundredth of the β Pictoris disk density are present in less than about half of the Ursa Major Stream stars.

We come back now to the five questions listed in the Introduction. Because the result is negative, we cannot of course address the two first questions about the connection between hot gas, cold gas and dust.

Concerning questions 3 and 4, some information is provided with the non-detection of circumstellar gas in any of the surveyed stars which have the same age of 3×10^8 years. If β Pictoris is older than the ZAMS stars, then it cannot be surrounded by a classic massive disk; in this respect, β Pictoris is clearly a very peculiar object around which an exceptional phenomenon takes place.

However, if β Pictoris is a young star ($\sim 10^7$ years), the mass of its disk may merely be due to its age. Then, question 5 about the gas mass versus time can be roughly addressed. Following Zuckerman & Becklin (1993) and assuming a time variation of the form $t^{-\alpha}$, the present results imply $\alpha > 1$, which is consistent with $\alpha > 2$ found by Zuckerman & Becklin (1993) for the dust. This analysis ought to be extended to younger open clusters, but this may be more difficult. For example, the Pleiades cluster is about 10^8 years old, but Pleiades' stars are about 100 times less bright, and a large amount of absorbing material is present in this direction.

As a matter of fact, the β Pictoris age is the major hypothesis to address the issues listed in the Introduction. Either its disk is characterized by an unusual large amount of gas and supplying material, or β Pictoris is younger than previously thought.

Table 1. Program stars with their upper limit for the equivalent width of the Ca II-K absorption line (W_{lim}) at the stellar velocity. These are to be compared to the $\sim$ 100mÅ observed toward β Pictoris. The references (Ref.) are: (1) Eggen (1983); (2) Eggen (1984); (3) Eggen (1986); (4) Palous & Hauck (1986); (5) Hoffleit & Warren (1991).

Star HR	HD	m_v	Type	$v \sin i$ (km·s^{-1})	W_{lim} (mÅ)	Ref.
3572	76756	4.25	A5m	68	2.5	5
3662	79439	4.83	A5V	157	2.2	5
3974	87696	4.48	A7V	148	2.1	1,4,5
4031	89025	6.52	A0V	83	2.5	1,2,3,5
4141	91480	5.16	F1V	87	2.5	1,2,3,5
4295	95418	2.36	A1V	39	0.33	1,2,3,4,5
4357	97603	2.56	A4V	181	0.61	2,3,5
4554	103287	2.44	A0V	168	0.18	1,2,3,5
4589	104321	4.66	A5V	74	3.2	5
4660	106591	3.31	A3V	177	0.25	1,2,5
4865	111397	5.70	A1V	145	2.0	1,5
4905	112185	1.76	A0	38	0.2	1,2,5
4931	113139	4.93	F2V	92	2.0	1,5
5054A	116656	2.40	A2V	32	0.2	1,2,5
5054B		2.40	A2V	32	0.18	1,2,5
5055	116657	3.96	Am	57	1.0	1,5
5062	116842	4.01	A5V	218	0.56	1,5
5264	122408	4.26	A3V	150	3.0	5
5329	124675	4.54	A8IV	127	3.5	5
5793	139006	2.23	A0V	133	0.18	1,2,5
5867	141003	3.67	A2V	170	0.79	1,2,5

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