Two populations of comets in β-Pictoris

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Abstract

High resolution spectroscopic observations of β-Pictoris made with HARPS bring new information on the **exocomets** falling towards the star (Falling Evaporating Body scenario).
With a systematic analysis of **thousand spectra** gathered between 2003 and 2011 we measured the properties of about 6000 variable absorption features and the corresponding exocomets. This catalog of events allows an unprecedented **statistical and temporal study of β-Pic comets**. Here we present the results of this statistical analysis, and display the **two very different population of comets** discovered in this young planetary system.

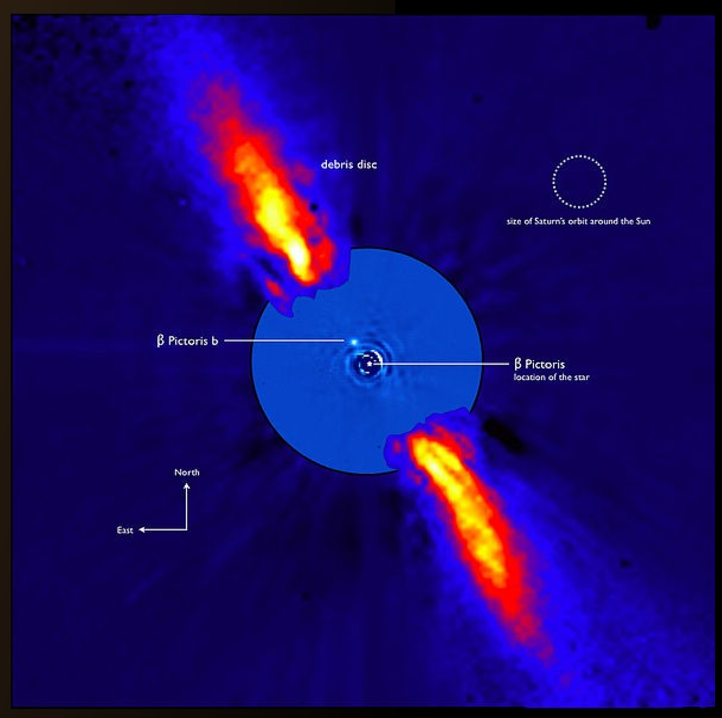

Figure 1 : β-Pic system with its circumstellar disk and planet β-Pic b (Lagrange et al. *2008*)

Introduction to β-Pic System and comets

- β-Pic is an A5V star at 19pc from Sun. It is a rather **young main-sequence star** (~10 My), hosting a circumstellar debris disk, a Jupiter-type planet and star-grazing planetesimals (**comets**).
- An IR excess has been observed in 1983. This revealed to be the thermal emission of an edge-on circumstellar dust disk, further imaged by Smith and Terrile (1984). See Fig. 1 beside.
- Intriguing **redshifted and variable absorptions** in Ca II, Al II, Mg II and Al III were observed as soon as 1984. These were further interpreted as being the result of **comets** crossing the line of sight at less than 50 R* (Ferlet et al. *1987* ; Beust et al. *1989* ; Vidal-Madjar *1994*).

Variable absorption spectra

- The absorption lines are produced by a moving ionic cloud crossing the line of sight.
- The **variations are rather quick** : from a couple of hours to a couple of days (but rarely months). They are mostly **redshifted** (some, but less, blueshifted) with respect to the circumstellar lines at the star radial velocity (RV) of 21 km/s.
- The variable absorptions appear clearly on Fig. 2 beside for **Ca II doublet**. The ionic clouds responsible for these absorptions have radial velocity between -100 and 200 km/s.

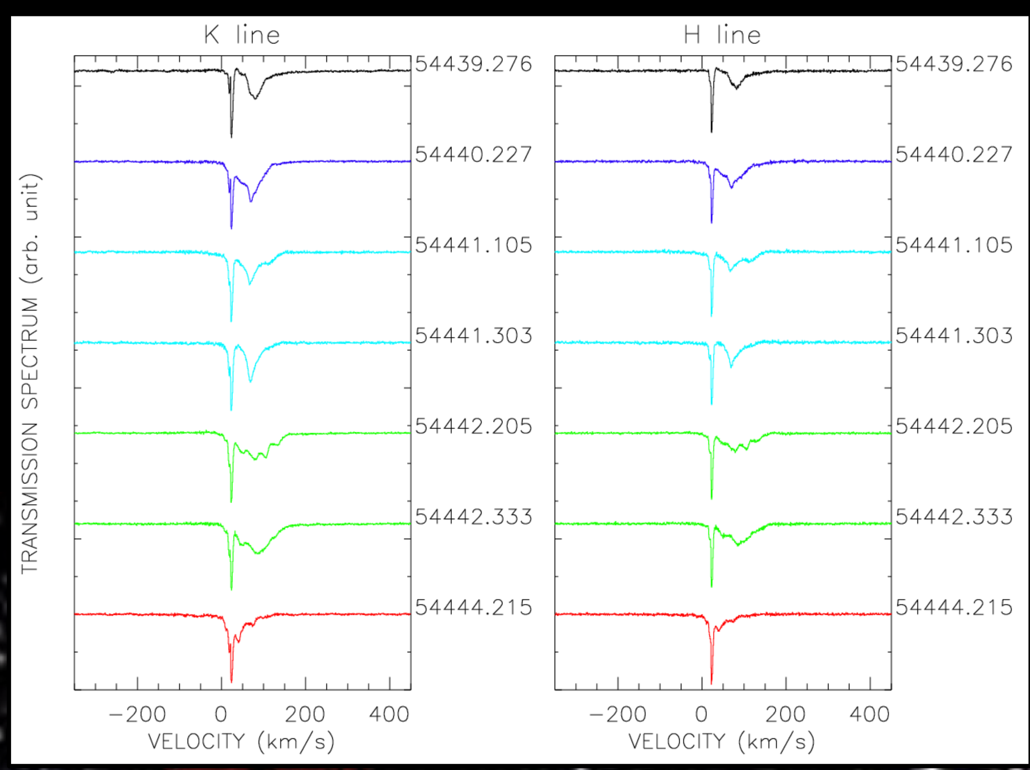

Figure 2: Time evolution of absorptions over 5 nights in 2008

Absorption line Model

- The **Ca II doublet** is of particular interest since K and H lines can be fitted simultaneously, with the same parameters.
- Each (K,H) component is modeled as being produced by an ionic cloud of **cloud-to-star surface ratio** α with an **optical depth** A_K at the center of Ca II K-line:

$$\varepsilon_{K,H}(\lambda) = \alpha\left(1 - e^{-A_{K,H}\exp\left(-\frac{(\lambda-\lambda_0)^2}{2\sigma^2}\right)}\right)$$

$$\text{with} \quad A_K = 2\,A_H$$

Two populations of comets

➔ Data analysis suggested to distinguish **faint lines**, with $p_K < 0.15$, from **deep lines**, with $p_H > 0.40$ (p_K and p_H are the respective depths of K and H lines, $p_{K,H} = \alpha(1-e^{-A_{K,H}})$)

➔ Doing so, we discovered a clear **dichotomy** in the properties of the comets producing the faint and the deep absorption lines (Fig. 3 below and the tables beside).

Faint lines	Deep lines
fast (RV > 20 km/s)	slow (RV < 20 km/s)
close to the star (d < 10 R*)	away from the star (d>10 R*)
small dust production rate (~ 10^7 kg/s)	large dust production rate (~ 10^8 kg/s)
wide range of nucleus size	small nucleus size
periastron between -20° and 40°	periastron between -6° and 20°

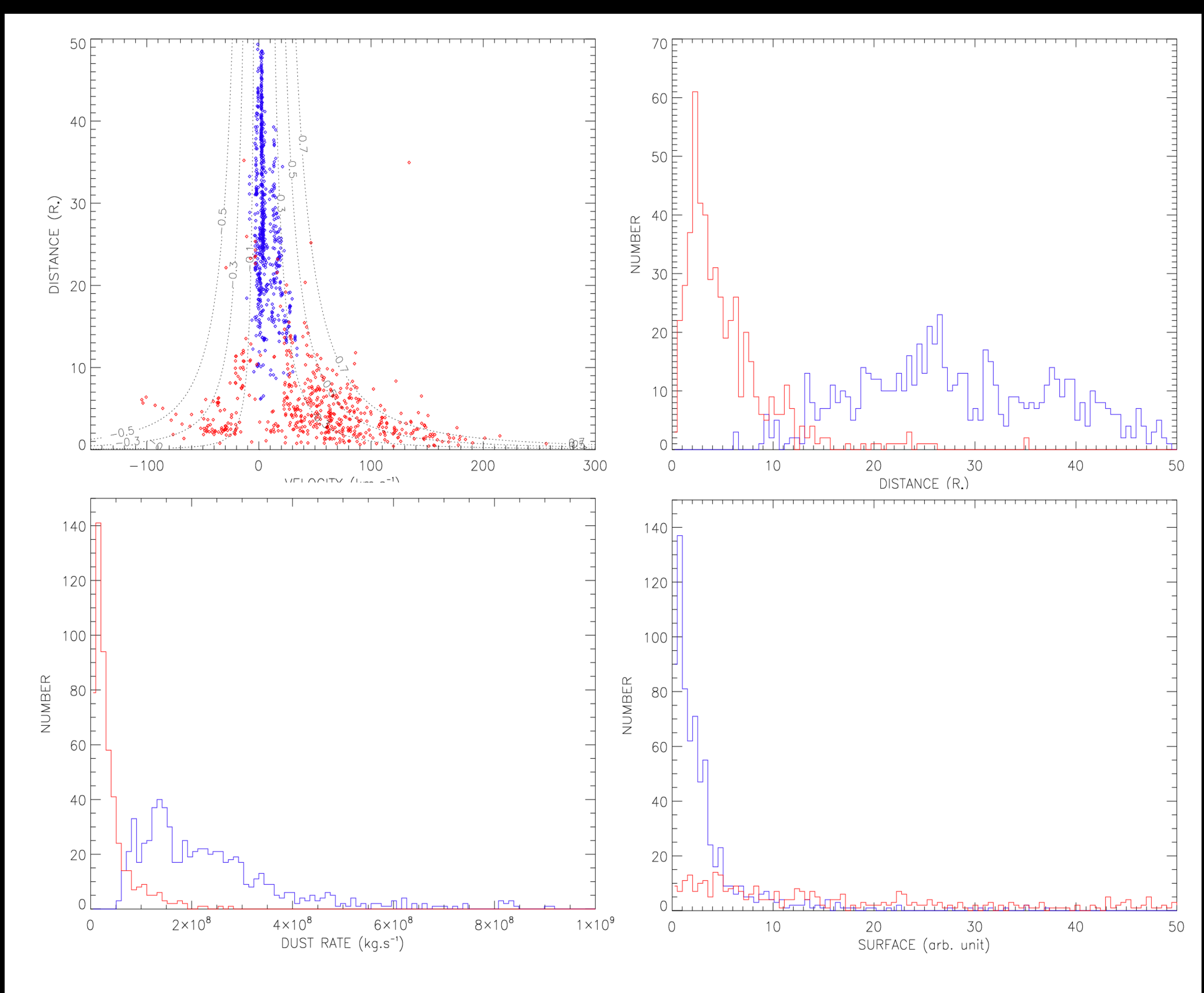

Figure 3: Histograms of comet-to-star distance, dust production rate and nucleus surface. On the top-left, a distance vs. radial velocity diagram.

➔ Fig. 3 presents physical characteristics of comets **nucleus** deduced from analysis of all clouds properties (α, A_K, σ and λ_0). Here are represented the distributions for star-to-comet distance, the dust production rate and the nucleus surface (within about a constant factor).

➔ The top-left plot shows the orbital repartition of these bodies, presenting distance against radial velocity. Values (in radians) of the periastron longitude are indicated on the dotted curves.

Interpretations and conclusions

Our analysis revealed the presence of **two different population of comets**. One is responsible for **deep absorption lines**, while the other one causes **faint absorption lines**.

These two population have **asymmetric periastron longitude distribution** around the line of sight, in consistency with the lower number of blueshifted events compared to redshifted events. A **3:1 and 4:1 mean-resonance** scenario with β-Pic *b* could explains such asymmetry and predicts small deviation of the periastron longitude (Beust and Morbidelli *1995*) as we obtained.

Dust production rate decrease can be interpreted as **nucleus aging** (dust mantle thicken with age) and as surface reduction. From the figures, it seems then that the **'deep lines'** population is **younger** than the 'faint lines' one, in compatibility with the comet-to-star distance of each population.

The difference in surface distribution is though surprising, since smaller nucleus are rather expected close to the star (because of evaporation) . This may be the indication that 'deep lines' objects are residues from the fragmentation of one or several mother comets, as happened to Shoemaker-Levy in 1994.

References :

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