BETA PICTORIS: BACK TO THE ZAMS

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ABSTRACT

According to its new Hipparcos parallax, the star Beta Pictoris is farther away and hence more luminous than previously believed. In the HR diagram, the star is now very close to, or on the ZAMS, instead of being clearly below it.

The consequences are threefold: (i) all evaluated geometrical dimensions of the Beta Pictoris circumstellar disks are larger by about 20 per cent; (ii) there is no more need for any intrinsic circumstellar extinction due to the dust disk seen edge-on, in agreement with the amount of dust directly detected through stellar coronography; (iii) the stellar age has to be of at least 8 Myr and is more probably on the order of 100 Myr, again compatible with the fact that this circumstellar disk seems to be 'post' planetary and certainly not 'proto' planetary.

Key words: Stars: Beta Pictoris; absolute magnitude; circumstellar matter.

1. INTRODUCTION

β Pictoris is a young nearby stars (A5V type) surrounded by a magnificent accretion disk discovered in 1983 by IRAS (Aumann 1984) and directly observed in coronagraphy (Smith & Terrile 1984). Because it is the closest star of that type, it is the most studied one.

The very large amount of observations of both the dust and the associated gas disk allowed the development of some modelisations of the disk, including a debate on its age. This is related to the question of its evolutionary status, i.e. is the observed disk a remnant of a 'proto-planetary" circumstellar disk, or is on the contrary its evolutionary stage more advanced so that planets may have already formed (see reviews by Backman & Paresce 1993, Vidal-Madjar & Ferlet 1994, Artymowicz 1997, and the Proceedings of the 10th IAP Meeting).

Up to now, its luminosity was found to be lower than that of a 'normal' A5V star. The star was well below the ZAMS. This lack of luminosity was tentatively attributed to gray extinction due to large grains from the disk (Lanz et al. 1995).

Table 1. Previous and new β Pictoris parameters (π, parallax in mas (10^{-3} arcsec); d, distance in pc; M_V, absolute magnitude). Authors: VA = Van Altena et al. 1995; HR = Bright Star Catalogue.

Authors	π mas	σ_π mas	distance pc	M_V
VA 95	60.1	10.6	$16.6^{+3.6}_{-2.5}$	$2.74^{+0.36}_{-0.42}$
HR	61		16.4	2.78
Hipparcos	51.87	0.51	$19.28^{+0.19}_{-0.19}$	$2.42^{+0.03}_{-0.02}$

2. HIPPARCOS PARALLAX AND GEOMETRICAL CONSEQUENCES

During the three years of the ESA Hipparcos mission, β Pic was observed 102 times. After reduction, the final parallax is:

$$\pi_{\rm Hip} \; = \; 0.05187 \; \pm 0.00051 \text{ arcsec}$$

This value is somewhat smaller than the ones derived before (see table 1). The star is therefore more distant and luminous than previously estimated.

The distance most often used in the literature is the one found in the Bright Star Catalogue $d_{\rm HR}$. Therefore all previous geometrical dimensions have to be multiplied by a factor $d_{\rm Hip}/d_{\rm HR}$ =1.176. Some consequences of this distance modification are underlined here although such a correction does not induce any fundamental change in our present understanding of the disk.

The disk is somewhat more extended and detected up to 1400 AU instead of 1200 AU as quoted by Smith & Terrile (1987). The change of slope in the inner regions takes place around 120 AU instead of 100 AU (Golimowski et al. 1993), and the central hole is of about 35 AU instead of the 30 AU as often quoted (Smith & Terrile 1984, Diner & Appelby 1986, Artymowicz 1989, Lagage & Pantin 1994, Artymowicz 1994, Lecavelier des Etangs et al. 1996)

3. LUMINOSITY

The main changes involve the star itself. As the distances have to by multiplied by 1.176, the flux emitted by the star has to be multiplied by $1.176^2 = 1.38$; and the absolute magnitude has to be decreased by 0.35.

Absolute magnitude: using a V magnitude of 3.85, as given in Lanz et al. (1995) (hereafter LHH) we obtain for the revised absolute magnitude: $M_V = 2.42 \pm 0.03$.

Bolometric absolute magnitude: LHH used for the bolometric correction the standard value of +0.15, as found in Schmidt-Kaler (1982) for A5V stars; we preferred to use the new value calculated by Bessell et al. (1997) from a grid of stellar models and covering an extended range of T_{eff}. For $T_{eff} = 8200$ K and log g = 4.25 (LHH values) they obtain: BC = +0.01, leading to: $M_{bol} = 2.42 + 0.01 = 2.43$.

Total flux: scaling the Gerbaldi et al. (1993) value ($\log(L/L_\odot) = 0.8$) gives: $L/L_\odot = 8.7$. With $M_{bol\odot} = 4.75$ (Cayrel de Strobel 1996), we obtain: $M_{mbol} = 2.40$, independently of the value deduced above from V and very close to it.

4. TEMPERATURE AND AGE

Various temperature determinations are available from the literature:

- LHH (1995), from UV GHRS spectra: $T_{eff} = 8200$ K;
- Gerbaldi et al. (1993), IR flux method, low metallicity: $T_{eff} = 7600$ K;
- Gerbaldi, same method, but solar metallicity: $T_{eff} = 8200$ K;
- Holweger et al. 1995 (model atmosphere near Ca K line): $T_{eff} = 8200$ K.

Both LHH and Holweger & Rentzsch-Holm (1995) find the metallicity to be about solar. Therefore for the HR diagram, we will adopt: $T_{eff} = 8200$ K, or $\log T_{eff} = 3.91$.

Figure 1 shows a M_{bol} versus $\log T_{eff}$ diagram in which we have located the new position of β Pic as well as the one of LHH. According to the uncertainties on both the values on the star parameters and the evolutionary tracks, we can consider that β Pic is on the ZAMS or extremely close to it. More details may be found in Crifo et al. (1997).

On Figure 1 are also drawn the evolutionary tracks of Schaller et al. (1992) for the evolution from the zero age main sequence line, and those of Palla & Stahler (1993) for the pre-main sequence evolution. We can conclude that the star is older than 8×10^6 years, and more probably around 100×10^6 years. The (possible) planets around the star have therefore formed already.

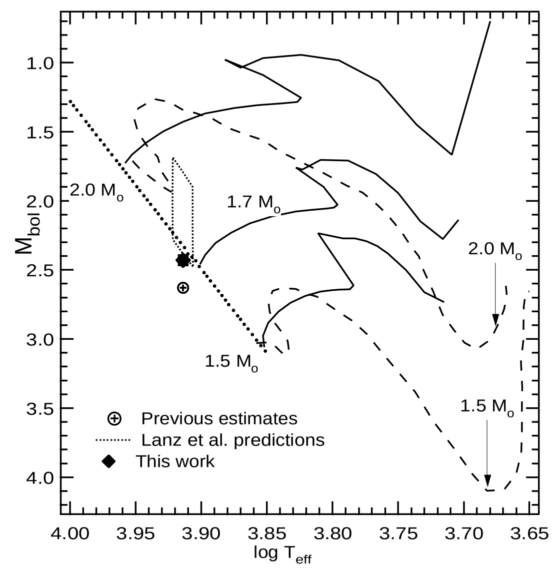

Figure 1. The location of β Pic on the HR diagram. Solid lines: post-main sequence tracks of Schaller et al. (1992); dashed lines: pre-main sequence tracks of Palla & Stahler (1993).

5. CIRCUMSTELLAR EXTINCTION

As the star is now on the ZAMS and no longer underluminous, there is no more need for extinction; or the extinction may be very small. This is in better agreement with later more model-dependent studies, some fitting simultaneously the disk diffuse starlight along with the observed IR excess (e.g. Diner & Appelby 1986, Artymowicz 1989) as well as global modelisations of the disk (Backman & Paresce 1993, Artymowicz 1994, Kalas & Jewitt 1995, Lecavelier des Etangs et al. 1996), which all lead to a very low dust extinction (0.1 magnitude or less).

6. CONCLUSION

The new Hipparcos parallax solves the problems underlined up to now for the star: (i) the star is no longer underluminous and comes back onto the ZAMS; (ii) the models requiring only a very low extinction are now in agreement with the observations. Table 2 summarizes the new set of consistent physical parameters.

Table 2. β Pictoris: summary of the new consistent physical parameters.

parallax	51.87 ± 0.51 mas	distance (pc)	19.28 ± 0.19
V	3.85	B-V	0.171
M_V	2.42 ± 0.02	M_{bol}	2.43 ± 0.03
$L/L_\odot$	8.7	Metallicity	about solar
T_{eff}	8200 K	$\log T_{eff}$	3.91
extinction	low (≤ 0.1mag)	age	≈ 100 My?

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