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β Pictoris b Orbital Properties

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Abstract. We present the results of the astrometric monitoring of β Pictoris b,the closest exoplanet imaged so far, using all VLT/NaCo data we obtained so far.

Keywords. stars: individual (HD39060)

1. Introduction

Direct imaging of planets is very challenging and confirmed imaged planetary-mass ($M \leqslant 13\ M_{Jup}$) companions to stars are still very rare, especially at small separations. Fewer than ten planets have been detected closer than 100 AU from stars and three planetary-mass companions have been found orbiting brown dwarfs at separations (3-50 AU). These planets offer a unique opportunity of individual studies, in terms of physical and orbital properties, origin and evolution, and in terms of interaction with disks.

We detected with NaCo a giant planet around β Pictoris , located along the dust disk position angle (PA), with a projected separation at about 9 AU (Lagrange *et al.* 2009; Lagrange *et al.* 2010). Its observed L' luminosity indicated a 1700 K, 7-11 M_{Jup} mass planet according to "hot-start" models. The β Pictoris b SED over the 1.26-4.78 micron range support a mass in the range 6–10 M_{Jup} (Bonnefoy *et al.* 2013). β Pictoris b is particularly precious to constrain evolution models and brightness-mass relations as we can get direct constraints on the planet mass and on its orbital properties on a reasonable timescale. It is also precious to study disk-planet interactions; its properties can explain several of the disk characteristics, and in particular the disk inner (80 AU) warp, as well as some outer asymmetries. For details and references, see Lagrange *et al.* (2012b). Furthermore, β Pictoris b could be responsible for the infalling and evaporation of exocomets that we discovered in the late eighties. Whether it could also be responsible for a short photometric eclipse that took place in 1981 (Lecevalier *et al.* 2010) is not clear so far as its orbit is not precisely known.

Since 2009, we monitor the planet orbit. First data taken until 2011 allowed us to refine its semi-major axis, in the range 8-10 AU, and its eccentricity, less than 0.2 (Chauvin *et al.* 2012). We present here an update of its orbital properties using all available NaCo data, recorded in 2003 and between 2009 and 2012.

2. β Pictoris b orbital properties

The data (Fig. 1) were taken at Ks, L' and M' bands. They were reduced and calibrated as described in Chauvin *et al.* 2012. We see in Fig. 1 that the rate of increase of β Pictoris b

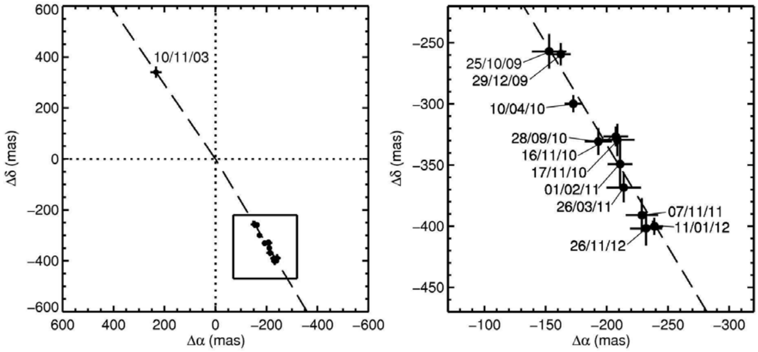

Figure 1. NaCo data obtained over the years.

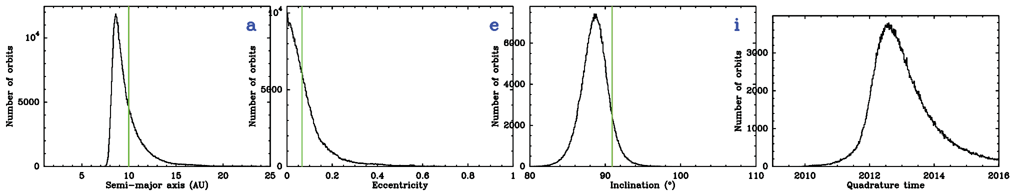

Figure 2. First 3 figures: some orbital parameters of β Pictoris b. Last figure: Distribution of quadrature times.

separation has decreased in 2012, with a possible (but yet within the error bars) decrease end of 2012. Hence β Pictoris b may have passed quadrature.

Fig. 2 shows the distributions of orbital properties deduced from the MCMC fit. We also show the best fit using a least squares Levenberg-Marquardt (LM) algorithm (green vertical lines). Both methods are described in Chauvin *et al.* 2012. We see that the present MCMC analysis confirms a semi-major axis of approximately 9 AU, as well as a low eccentricity. We also see, as in Chauvin *et al.* 2012, that the best LM-derived solution is far from the distribution peaks derived from the MCMC analysis. The LM approach is not robust enough and the MCMC approach should be preferred.

Still using our MCMC analysis, we show in Fig. 2 the distribution of times of quadrature. We see that β Pictoris b has indeed very probably passed quadrature. Hence, the planet is now coming in front of the star. We are not able yet to provide a precise date for the next transit time (Fig. 2). Finally, the present data are still compatible with β Pictoris b being responsible for the 1981 eclipse in terms of timing.

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