

Kinematic distances of pre-main-sequence stars in the Lupus star-forming region

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Abstract. To reliably determine the main physical parameters (masses and ages) of young stars, we must know their distances. While the average distance to nearby star-forming regions (< 300 pc) is often known, the distances to individual stars are usually unknown. Individual distances to members of young moving groups can be derived from their radial velocities and proper motions using the convergent-point strategy. We investigate the kinematic properties of the Lupus moving group with the primary objective of deriving individual distances to all group members.

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1. Introduction

The Lupus dark cloud complex is a low-mass star-forming region that contains one of the richest associations of T Tauri stars. While the precise distance to the Lupus complex is still being debated, little recent progress has been made as regards distance determinations to individual stars in this region, such as the faint pre-main-sequence (PMS) stars. Although average distances to star-forming regions provide valuable information, what we really need to determine the main physical parameters (masses and ages) of stars are the distances to individual stars. The vast majority of PMS stars in Lupus were not observed by the *Hipparcos* satellite because of their faint magnitudes, nor do they have any trigonometric parallaxes measured from the ground owing to their distances. However, an alternative method based on determination of the convergent point (CP) of a co-moving group of stars and individual radial velocities exists and allows for the determination of individual parallaxes. This is what we are attempting to do here.

2. A Sample of Pre-Main Sequence Stars in Lupus

Our list of candidate members of the Lupus moving group consists of 258 PMS stars identified in previous surveys of this star-forming region (Krautter *et al.* 1997; Wichmann *et al.* 1997a,b; Coméron 2008; López-Martí *et al.* 2011). We obtained proper-motion data for these stars from the SPM4 (Girard *et al.* 2011), Tycho-2 (Høg *et al.* 2000) and Ducourant *et al.* (2005) catalogues. Fig. 1 shows the proper-motion vectors of Lupus stars and, as can be seen, they point towards a common direction. To develop our strategy, we took advantage of published radial velocities from various sources, which we

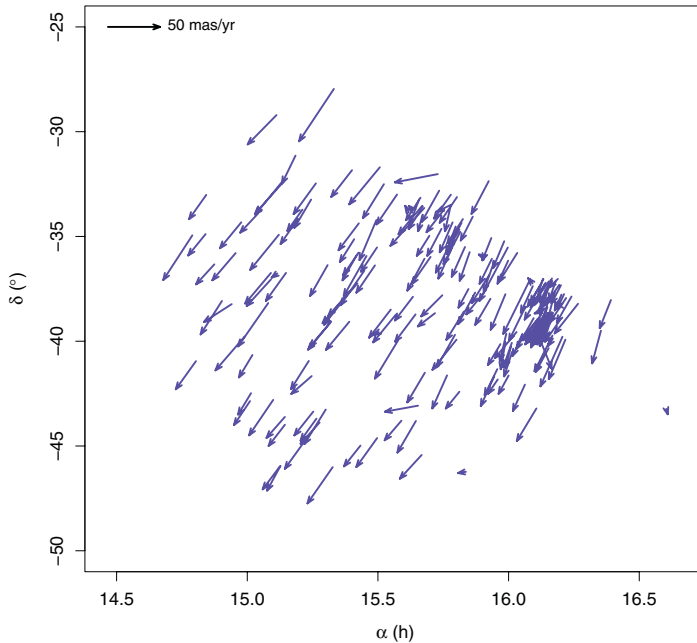


Figure 1. Proper-motion vectors of the Lupus candidate PMS stars.

supplemented with new measurements based on spectroscopic observations with FEROS on the ESO 2.2 m telescope (La Silla Observatory, Chile).

3. Convergent-Point Analysis and Kinematic Parallaxes

The technique we use to derive the CP position of the Lupus moving group is the new CP method (Galli *et al.* 2012), which was recently published. This strategy uses a maximum-likelihood analysis to simultaneously determine the CP position and the membership probabilities of the stars in the moving group.

When we apply the CP method to the sample of Lupus candidate members, we identify a moving group consisting of 114 stars. Among the 114 members, only 26 stars have reliable radial-velocity measurements, which we use to derive the individual parallaxes. These are given by

$$\pi_{\text{ind}} = \frac{4.74\mu_{\parallel}}{v_r \tan \lambda}, \quad (3.1)$$

where μ_{\parallel} is the stellar proper motion in the direction of the CP (see Galli *et al.* 2012), v_r is the radial velocity and λ is the angular distance between the star and the CP.

For the remaining 88 stars with unknown radial velocities, we adopt the hypothesis that all group members share the same space motion to derive tentative parallaxes. We first determine the average spatial velocity, v_{space} , of the moving group based on the space velocity of the 26 stars with known radial velocities and then compute the approximate parallax as

$$\pi_{\text{app}} = \frac{4.74\mu_{\parallel}}{v_{\text{space}} \sin \lambda}. \quad (3.2)$$

We compare the individual parallaxes using Eq. (3.1) and the approximate parallaxes

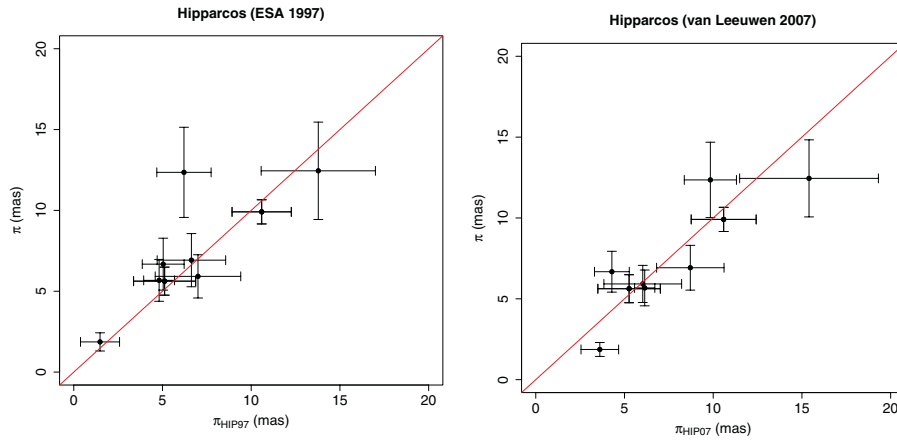


Figure 2. Parallaxes derived here compared with *Hipparcos* parallaxes.

based on Eq. (3.2) for the sample of 26 members with known radial velocities and conclude that both procedures return similar results (within the error bars).

4. Comparison with *Hipparcos* results

In Fig. 2 we compare the parallaxes derived here with the trigonometric parallaxes from the *Hipparcos* catalogue. We consider both versions of this catalogue: the original catalogue (ESA 1997; hereafter HIP97) and the new reduction of *Hipparcos* data (van Leeuwen 2007; hereafter HIP07). We found only nine *Hipparcos* stars among the 114 Lupus members selected in our CP analysis. The rms with respect to HIP97 and HIP07 is 2.28 and 1.92 mas, respectively. The mean differences between the parallaxes derived

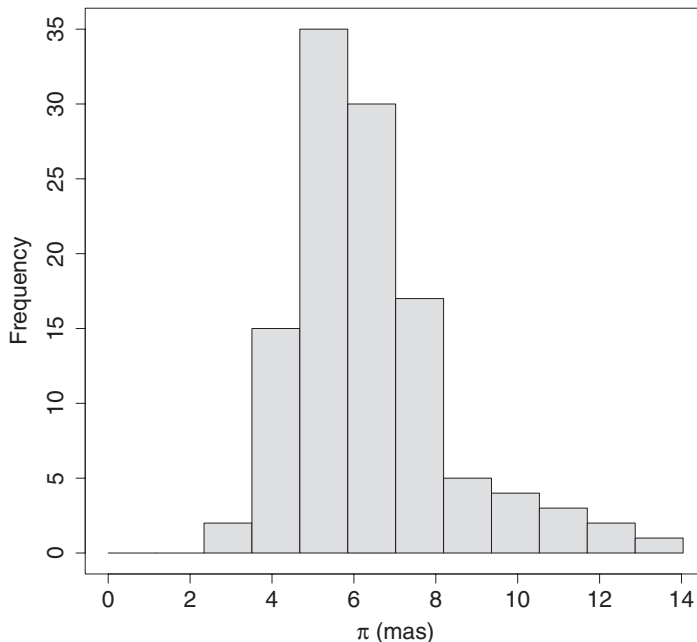


Figure 3. Parallax histogram of the 114 members of the Lupus moving group.

here and those in HIP97 and HIP07 are -0.68 and 0.35 mas, respectively. We conclude that our results are in good agreement with the trigonometric parallaxes obtained by *Hipparcos*.

5. Results

Fig. 3 shows the histogram of parallaxes for the 114 members of the Lupus moving group. The average parallax and standard deviation are $\pi = 6.4 \pm 1.9$ mas and the average error in the parallaxes is $\sigma_\pi = 1.3$ mas. We note the presence of background and foreground stars, thus confirming that the Lupus complex occupies a large volume in space. The distances derived here will be used to investigate the physical properties (luminosities, masses and ages) of the Lupus stars.

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