Dynamical Mass Determination of the Young Nearby System HD 160934

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We present phase-reference EVN observations that are part of a program to study the radio emission and kinematics of a sample of stars belonging to the AB Doradus moving group. The main aim of this program is to obtain precise estimates of the dynamical mass of young, low-mass stars, which in combination with photometric measurements will provide precise benchmarks for calibrating pre-main-sequence (PMS) stellar evolutionary models. Calibration of PMS models appears essential, as they are widely used to predict the masses of low-mass objects as brown dwarfs and planets. Previous studies show that model predictions are in disagreement with experimental results for masses below 1.2 $M_\odot$. Among the stars included in our program, we emphasize the results obtained in the stellar system HD 160934 A/c.

Keywords: VLBI, Astrometry, Binary Stars.

1 Introduction

The study of binary stars belonging to young, moving groups is a reasonable approach to increase the number of PMS stars with mass dynamically determined, which is essential to calibrate the stellar evolution models [7, 13, 11]. The AB Doradus moving group is the most suitable to carry out this study, as it is the closest one, the estimated age is relatively accurate, and it contains stars with significant emission at radio wavelengths. This last property allowed us to start a program to monitor possible binary systems using radio interferometry techniques. HD 160934 is one of the stars included in the program.

2 Observations

It is a young, very active, close binary (with components HD 160934 A and HD 160934 c, separated ~ 200 mas) placed at a distance of ~ 30 pc [17, 10, 16].

We observed this target in phase-reference style between 2012 and 2014 with the European VLBI Network (EVN) at 5 GHz using the antennas at Effelsberg, Westerbork, Jodrell Bank, Onsala, Medicina, Noto, Torun, Yebes, Svetloe, Zelenchukskaya, Badary, Urumqi, and Shanghai. The phase-referenced maps can be seen in Fig. 1 of [2]. These were the first VLBI images of the system where we confirmed that both components are compact and strong radio emitters [1].

3 Results

With the images, we could determine the relative position of one component respect to the other and the absolute position of each component respect to an external quasar. Simultaneously, and also including NIR data available in the literature [8, 9, 6], we determined both the relative and the individual orbits (using a least-square fit similar to that described in [3]). Accordingly, we calculate the masses of the components, that are 0.70 ± 0.07 $M_\odot$ and 0.45 ± 0.04 $M_\odot$ for HD 160934 A and HD 160934 c, respectively.

In order to calibrate the stellar evolution models for PMS stars we have considered isochrones and isomasses corresponding to the models of BCAH98 [4], S00 [12], TDP12 [14, 15], and BHAC15 [5]. The different models can be shown in Fig. 1.

The theoretical masses predicted by the models agree with our dynamical estimates just at the extreme of their uncertainties. All four sets of tracks predict masses for the component A ~ 10 % lower than our dynamical values, while predictions for the component c vary according to the model: BCAH98 and BHAC15 predict masses ~ 20 % lower, S00, ~ 40 % lower, and TDP12, ~ 30 % lower. In terms of age, TDP12 and BAHC15 models suggest that both stars are younger than 50 Myr, BCAH98 favor slightly older ages but younger than 65 Myr, meanwhile S00 predict younger ages, below 40 Myr.

4 Conclusions

We presented some results of a program focused to determine dynamical masses for PMS stars using radio techniques. Specifically, we show the results of the orbital analysis of the binary star HD 160934 A/c, that yields values of 0.70 ± 0.07 $M_\odot$ and 0.45 ± 0.04 $M_\odot$ for components A and c, respectively, which are larger than the theoretical values predicted by evolutionary tracks. These results are very useful to provide new observational data to calibrate evolution models for PMS stars, so necessary because there are not much values.

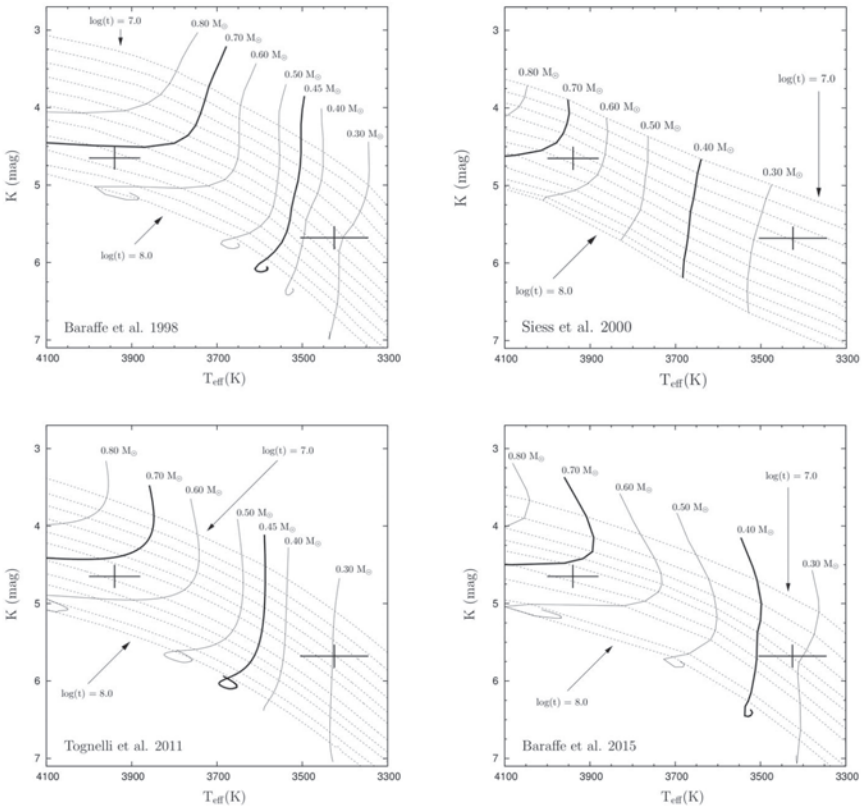

Fig. 1. Comparison of HD 160934 components with some PMS theoretical models (Baraffe et al. 1998, *top left*; Siess et al. 2000, *top right*; Tognelli et al. 2011, *bottom left*; Baraffe et al. 2015; *bottom right*). For each model, isomasses (solid lines) and isochrones (dashed lines) are plotted. We highlight the nearest tracks available corresponding to our dynamical mass values. The theoretical masses are consistent with our dynamical estimates just at the extreme of their uncertainties

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