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On the rotation periods of the components of the triple system TYC 9300-0891-1AB/TYC 9300-0529-1 in the Octans Association

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HIGHLIGHTS

- We confirm that the three components of the system are physically bound.
- We find that the components have same age, spectral type, mass.
- We derive photometric rotation periods of TYC9300-0891 and TYC9300-0529-1.
- The 16% rotation period difference is too small to be addressed.

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ABSTRACT

Stellar rotation depends on different parameters such as age, mass, initial chemical composition, initial angular momentum, and environment characteristics. The range of values of these parameters causes the dispersion in the rotation period distributions observed in young stellar clusters/associations. We focus our investigation on the effects of different circumstellar environments on stellar rotation. More specifically, we consider the effects of a perturber stellar companion on the accretion-disc lifetime at early evolution stages.

We are searching in stellar Associations for visual triple systems where all stellar parameters are similar, with the only exceptions of the unknown initial rotation period, and of the circum-stellar environment, in the sense that one of the two about equal-mass components has a close-by third 'perturber' component.

In the present study we analyze the 35-Myr old visual triple system TYC 9300-0891-1AB + TYC 9300-0529-1 in the young Octans stellar association consisting of three equal-mass K0V components. We collected from the literature all information that allowed us to infer that the three components are actually physically bound forming a triple system and are members of the Octans Association. We collected broad-band photometric timeseries in two observation seasons. We discovered that all the components are variable, magnetically active, and from periodogram analysis we found the unresolved components TYC 9300-0891-1AB to have a rotation period P = 1.383 d and TYC9300-0529-1 a rotation period P = 1.634 d.

TYC 9300-0891-1A, TYC 9300-0891-1B, and TYC 9300-0529-1 have same masses, ages, and initial chemical compositions. The relatively small 16% rotation period difference measured by us indicates that all components had similar initial rotation periods and disc lifetimes, and the separation of 157 AU between the component A and the 'perturber' component B (or vice-versa) has been sufficiently large to prevent any significant perturbation/shortening of the accretion-disc lifetime.

1. Introduction

The early stage of star's life is characterized by the presence of an accretion disc that is magnetically coupled with the central star (see, e.g., Ménard and Bertout, 1999). This coupling implies complex exchanges of angular momentum between the disc and the central star (see, e.g., Bouvier et al., 2007). On one hand, the star gains angular momentum from the disc, on the other hand this excess angular momentum must be somehow dissipated. In fact, observations tell us that, until the star-disc interaction is effective, the star's rotation period in most cases remains about constant (Bouvier et al.,

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1993; Edwards et al., 1993; Ingleby et al., 2014; Rebull et al., 2004). This is commonly referred to as star-disc locking. Accretion-driven winds (Matt and Pudritz, 2005; 2008a; 2008b) and mass ejection episodes caused by magnetospheric reconnection (Zanni and Ferreira, 2013) are among the possible mechanisms that have been proposed to remove the excess angular momentum. Meanwhile, other complex mechanisms, such as hydromagnetic instabilities and intense magnetic fields, also contribute to redistribute internal angular momentum to the star's external envelope (see, e.g., Spada et al., 2010; 2011). After the inner disk dispersion, the stellar radius continues to rapidly decrease while the star is approaching the Zero Age Main Sequence and the rotation rate spins up, despite the angular momentum losses due to magnetized stellar winds (Matt and Pudritz, 2007). The disc lifetime is variable, of the order of a few Myr, but rarely longer than about 10 Myr (Ingleby et al., 2014; Ribas et al., 2014). A variable disc lifetime implies variable duration of the star-disc locking phase. Indeed, the rotation rate of a PMS star at a given age depends on the accretion disc lifetime, in the sense that the shorter the disc lifetime the faster the rotation rate with respect to a counterpart star with longer disc lifetime. Therefore, the rotation rate can be used to derive information on the disc lifetime. However, the rotation also depends on the initial rotation period, on the mass and disc mass, and on the environment properties. We intend to investigate how the environment, and specifically the presence of a nearby companion, can shorten the disc lifetime and, consequently, make the rotation spin up to start earlier. Multiple stellar systems where the components a have equal age, initial chemical composition, and equal mass are best suited for this purpose. In these systems, differences between the rotation periods of the components are expected to depend only on the initial rotation periods and disc lifetimes. Specifically, we investigate the hypothesis according to which a close companion can enhance the disc gravitational dispersal allowing one component to start spinning up earlier that the other components. In our first of such cases, the triple system BD−21 1074 in the β Pictoris Association (Messina et al., 2014), we found that to explain the observed difference of rotation periods between the primary A ($P_{rot} = 9.3$ d) and the secondary B component ($P_{rot} = 5.4$ d), a significant difference of lifetimes of their discs has to be invoked. Specifically, the lifetime of the disc of component B has undergone a shortening owing to enhanced dispersal by dynamical effects from the close-by component C at 15 AU. Such disc dispersal has shortened the disc-locking phase, allowing component B to start its spinning up earlier than component A.

However, the most promising approach to distinguish between different initial rotation rates and different disc locking timescales on a firm basis is a statistical study based on a large number of cases. We are building such a sample by identifying suited stellar systems and deriving the rotation periods of their components.

In the present paper, we present the results for another of such systems that has been studied as part of the RACE-OC project (Rotation and ACtivity Evolution in Open Clusters; Messina, 2007; Messina et al., 2008; 2010), while measuring the rotation periods of the members of the about 30–40 Myr old Octans association (Messina et al., 2011).

This is the visual triple system TYC 9300-0891-1AB + TYC 9300-0529-1. This system consists of three equal-masses (0.95 $M_\odot$), ages (∼ 35 Myr), and chemical compositions components physically bound that differ only for their circum-stellar environments and, in principle, for their initial angular momenta. Whereas TYC 9300-0529-1 is quite distant (∼ 3600 AU) from TYC 9300-0891-1AB, on the contrary TYC 9300-0891-1A has a close-by (∼ 157 AU) companion TYC 9300-0891-1B that may have acted as perturber of its (by now dispersed) accretion disc. Any difference we may find in their rotation periods, should be ascribed to either the effect of the perturber on the accretion disc, and on its lifetime, or on different initial rotation periods.

To measure the rotation periods of TYC 9300-0891-1 and TYC 9300-0529-1 we carried out a dedicated photometric monitoring in two different observation seasons. In Section 2, we present the available information from the literature on these targets. In Section 3, we describe our photometric observations. Their analysis is presented in Sections 4, and 5, discussion of the results and conclusions are given in Sections 6 and 7.

2. The triple system

TYC 9300-0891-1AB and TYC 9300-0529-1 form a visual triple system, at a mean distance of 174 pc from the Sun, consisting of three physically bound components having equal mass (∼ 0.95 $M_\odot$), K0V spectral type, and an age of about 35 Myr.

TYC 9300-0891-1AB was spatially resolved into a close visual binary by Tycho ESA (1997) that measured an angular separation $\rho = 0.9''$, a position angle PA = 128.4° at the epoch 1991.25, and an integrated Johnson V magnitude $V_{AB} = 10.95 \pm 0.07$ mag (Hog et al., 2000).[1] The A and B components are listed as a physical pair with identical proper motions in the Tycho catalogue. As shown in Sections 3, we measured a similar angular separation $\rho = 0.95''$ and similar position angle PA = 135 ± 10°.

TYC 9300-0529-1 is at an angular distance $\rho = 20.5''$ from TYC 9300-0891-1AB ESA (1997) and its Johnson V magnitude (Hog et al., 2000) is V = 11.75 ± 0.11 mag.

In the WDS catalog (The Washington Visual Double Star Catalog, Mason et al., 2001), TYC9300-0891-1AB and TYC 9300-0529-1 are reported to be a physical pair on the basis of their common proper motions. We have collected from the literature the available kinematic information. Specifically, we retrieved from Tycho (ESA, 1997), WDS (Mason et al., 2001), UCAC2 (Zacharias et al., 2004), and PPMXL (Roeeser et al., 2010) catalogues the proper motion measurements, and from Torres et al. (2006) and Elliott et al. (2014) the radial velocity (RV) measurements. Both proper motions and RV measurements of TYC9300-0891-1 AB and TYC 9300-0529-1 are undistinguishable within the uncertainties (see Table 4), indicating that TYC9300-0891-1AB and TYC 9300-0529-1 are physically bound and forms a triple system.

Torres et al. (2008) found this system to be member of the young Octans stellar association. However, for no member of this association trigonometric parallaxes exist and kinematic distances are inferred. Recently, Murphy and Lawson (2014) identified 29 new low-mass members of Octans. Their study allowed to compute accurate mean space motion, the proper motions, radial velocities and, for the first time, a reliable age estimate of 30–40 Myr based on the Lithium Depletion Boundary. In their study, they inferred kinematic distances of 173 and 175 pc for TYC9300-0891-1AB and TYC 9300-0529-1. We note that the difference between the radial velocities of TYC9300-0891-1AB and TYC 9300-0529-1 is a factor 2.5 smaller that the radial velocity dispersion measured among the Octans members by Murphy and Lawson (2014), as well the difference between the proper motions is a factor 2 smaller that the proper motion dispersion measured among the Octans (see again Murphy and Lawson, 2014). These circumstances further support that the three components are physical bound.

The primary A component is a K0Ve emission-line star (Torres et al., 2006), whereas no spectral classification was provided for the secondary B component. However, considering that they have similar V magnitudes (see Section 3), we can infer for the B component the same K0V spectral type. TYC 9300-0529-1 also has K0V spectral type (Torres et al., 2006). Therefore, we deal with a system with three about identical components. We note that Torres et al. (2006)

[1] In the Tycho Double Star Catalogue (TDSC) (Fabricius et al., 2002) the following magnitudes are reported for both components $V_A = 11.50 \pm 0.07$ mag and $V_B = 11.83 \pm 0.11$ mag.