Boletim da Sociedade Astronômica Brasileira, **30**, no. 1, 81-82

Does environment matter? The rotational scenario of low mass stars in the young Cygnus OB2 association

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Abstract. As part of the results of a near-infrared variability survey (WFCAM/UKIRT JHK bands) in the Cygnus OB2 association, we investigated the rotational properties of low mass candidate members in the association. The general scenario for the rotational evolution of young stars seen in other regions is confirmed by Cygnus OB2 rotational period distributions, with disk-bearing stars rotating on average slower than diskless stars. A mass-rotation dependence was also verified, but as in NGC 6530, very low mass stars rotate on average slower than higher mass stars. The disk and mass-rotation connection were also analyzed while considering the incident UV radiation arising from O-type stars in the association. Results compatible with the disk-locking scenario were verified only for stars with low UV incidence, suggesting that massive stars may have an important role on regulating the rotation of nearby low mass stars.

Resumo. Como parte dos resultados de um levantamento de variabilidade no infravermelho (WFCAM/UKIRT nas bandas JHK) na associação Cygnus OB2, investigamos as propriedades rotacionais das estrelas de baixa massa candidatas a membro da associação. O cenário geral para a evolução da rotação de estrelas jovens observado em outras regiões foi confirmado pelas distribuições de períodos rotacionais em Cygnus OB2, com estrelas com disco girando em média mais devagar do que estrelas sem disco. Uma dependência da rotação com a massa também foi verificada, mas conforme em NGC 6530, as estrelas de massa muito pequena giram em média mais lentamente do que as estrelas com maior massa. A dependência da rotação com a presença do disco também foi analisada considerando-se a radiação UV incidente vinda das estrelas tipo O na associação. Resultados compatíveis com o cenário do trancamento por disco foram verificados apenas para estrelas com baixa incidência de radiação UV, o que sugere que as estrelas de massa muito grande podem ter um importante papel na regulação da rotação de estrelas de massa pequena em sua vizinhança.

Keywords. Stars:Low-mass – Stars:Rotation – Stars: Pre-Main sequence

1. Context

Along with the mass and initial composition, the angular momentum is a fundamental stellar parameter and it influences directly the stellar structure and its evolution. The study of the angular momentum evolution of magnetically active low mass stars is heavily based on the study of their rotational properties, which is a direct product from observations, and the current angular momentum evolution models are constrained by observations of the rotational properties of groups of coeval stars assembled as an evolutionary sequence. The use of such observational constraint assumes that the environmental conditions do not influence the angular momentum evolution of low mass stars, in the last decade this assumption has been put in check by observational evidences that the rotational properties of low mass stars in the early pre main sequence, such as the mass dependence of rotation and disk-locking scenario, can be sensitive to environmental conditions such as the presence of ionizing sources in their neighborhood.

2. Cygnus OB2, a ‘massive’ environment

Cygnus OB2 is 1.33 kpc away from the Sun (Kiminki et al. 2015). Wright et al. (2014, 2016) suggested that the association formed as it is today: a highly sub-structured, globally unbound association. Cygnus OB2 is a notoriously massive OB association with more than 160 confirmed OB stars among its members(Wright et al. 2015). Beyond the interest on its rich massive population, Cygnus OB2 is also a valuable target for studying the environmental influence during low mass star formation and early evolution. Guarcello et al. (2016) recently investigated the dissipation timescale of protoplanetary disks around low mass stars in the vicinity of massive stars and found evidences that disks are more rapidly dissipated in regions with higher stellar density and more intense UV radiation within the Cygnus OB2 association. They also found that disk dissipation due to close encounters is negligible, and that disk dissipation is dominated by photoevaporation. While some massive stars have ages under 2 Myr (Hanson 2003), the low mass population ages are in the range 2.5-6.7 Myr (Wright et al. 2010).

OB stars are ionizing sources and can influence their environment due to their strong UV field. Far ultraviolet (FUV) photons (6 eV $< h\nu <$ 13.6 eV) can dissociate H_2 molecules, and extreme ultraviolet (EUV) photons ($h\nu >$ 13.6 eV) are capable of ionizing hydrogen atoms. A higher concentration of OB stars would therefore imply a higher UV radiation local incidence, that in turn could influence the evolution of neighbor low mass stars. The environmental influence of OB stars is exemplified in Figure 1. For example, regions with intense local UV field can be hostile to the evolution of circumstellar disks, and to the processes of star formation (e.g. Guarcello et al. 2016).

3. The rotational scenario of Cygnus OB2

The observational dataset used was obtained through the 3.8 m United Kingdom Infrared Telescope equipped with the Wide Field Camera (programs U/07A/H16 and U/07B/H60), and covers a field of 0.87 squared degrees centered on Cygnus OB2. We measured reliable periods for 894 stars among the candidate

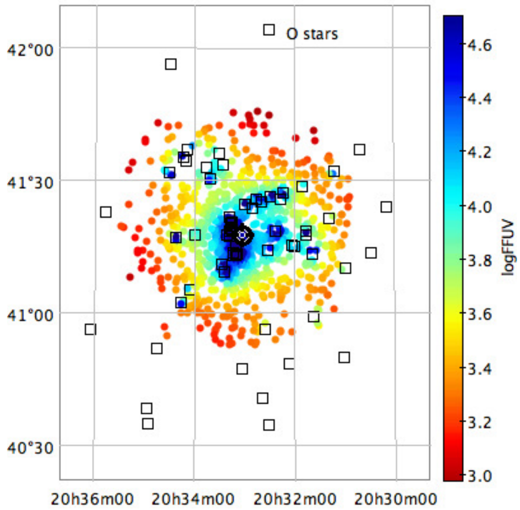

FIGURE 1. OB stars FUV incident flux in the Cygnus OB2 association. As in Guarcello et al. (2016): the FUV flux of each O and WR stars (shown as black empty squares) was propagated to the position of each low mass candidate member by using 2D-projections for the distance between each pair of sources. The position of each low mass star is shown as a dot, and the color of each dot indicates the FUV incident flux on that position according to the color bars to the right of the plot. Using the FUV local fluxes as criteria, we defined as stars submitted to high UV incidence those with $\log(F_{FUV}) > 3.7\ G_0$, and low UV incidence those with $\log(F_{FUV}) \leq 3.7\ G_0$.

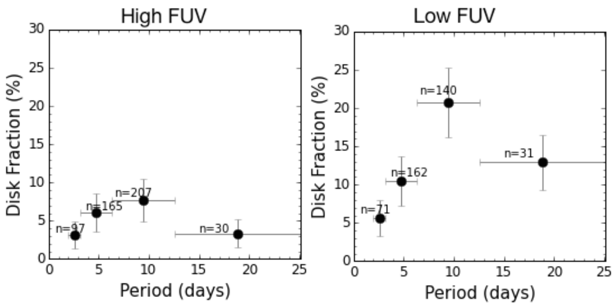

FIGURE 2. While the difference between the rotational properties of disk-bearing and diskless stars is stronger in regions with low UV incidence, in regions with high UV incidence it was not possible to statistically distinguish between the two samples. The increase of the disk fraction with period is stronger for the former than for the later. A maximum disk fraction of ∼21%, and ∼7.3% for slow rotators was found for low and high local UV incidence respectively.

members in the association, with periods in the range 2.0 – 32.5 d, and in the mass range $0.1 - 1.4 M_\odot$. Due to some completeness and contamination issues, most of our analysis was limited to the intermediate ($3.1 \leq P \leq 6.3$ d) and slow ($P > 6.3$ d) rotators, with detected fast rotators only in the range 2 – 3.1 d. Disk-bearing and diskless stars in our sample are statistically distinct in their rotational properties, with the former rotating slower than the later and with a Kolmogorov-Smirnov test resulting in a probability of only 0.4% that the two samples came from same parent distribution. The disk fraction increases as a function of period, except for the very-slow rotator bin, which has smaller statistics number and seems to suffer from contamination from field stars. In the full sample, the disk fraction varies from ∼4% for fast rotators to ∼13% for slow rotators. In Figure 2 the disk-locking scenario is re-examined by considering samples of stars submitted to low and high incident FUV flux as defined in Figure 1.

A mass-rotation connection was supported by a KS-test, but lower mass stars ($M \leq 0.4 M_\odot$) in Cygnus OB2 rotate on average slower than higher mass stars ($M > 0.4 M_\odot$). Also, the statistic distinction between the two mass ranges is stronger for samples of stars submitted to higher UV incidence. This mass-rotation connection is different from most other similarly aged regions (e.g. Herbst et al. 2001), but it is not novel as it was observed before in the younger NGC 6530 (∼2 Myr; Henderson & Stassun 2012).

4. Does Environment matter?

Yes, it seems it does! As in Littlefair et al. (2010), we raised the hypothesis that the environmental conditions could act on regulating the rotational evolution of young stars. Indeed environment is a common component between Cygnus OB2 and NGC 6530 as both regions have a higher concentration of ionizing sources than other young regions of similar age: As mentioned, Cygnus OB2 is a notoriously massive OB association with hundreds of OB stars among its members and NGC 6530 is a core cluster of the Sgr OB1 association (Sung et al. 2000) and it is 3-4 times richer in OB stars than ONC (Damiani et al. 2004). Future studies correlating the UV incidence levels with the rotational properties of such clusters will help testing this hypothesis.

5. Conclusions

Our results suggest a link between environmental conditions and the rotational evolution of young stars. However, it is urgent to complement the sample presented in this study for fast rotators and lower masses, in order to achieve a better understanding of the rotational scenario in the association, and to confirm such suggestions.

Acknowledgements. More details on the development of this study can be found in the source paper: Roquette et al. (2017), and on JR PhD thesis which was granted by CNPq and CAPES. S.H.P.A acknowledges financial support from CNPq, CAPES, and FAPEMIG. JB acknowledges the support of ANR grant 2011 Blanc SIMI5-6020 01 Toupies: Towards understanding the spin evolution of stars. We thank Bo Reipurth for providing us with the WFCAM/UKIRT dataset used.

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