RevMexAA (Serie de Conferencias), **38**, 123–124 (2010)

SPATIAL DISTRIBUTION OF STELLAR ROTATIONAL AXES FROM BE STARS

M. Curé,[1] A. Christen,[2] Th. Rivinius,[3] and D. F. Rial[1,4]

RESUMEN

Para conocer la distribución de velocidades de rotación de las estrellas Be, se utiliza la suposición estándar que los ejes de rotación se distribuyen uniformemente. En este trabajo usamos ángulos proyectados de polarimetría de casi 500 estrellas Be y realizamos un análisis estadístico. Además llevamos a cabo una simulación Monte-Carlo cuyos resultados explican las características observadas de los ángulos, confirmando que provienen de una distribución uniforme, pero que sus ángulos proyectados poseen una estructura bimodal. Esta última característica podría cambiar las conclusiones acerca de la distribución de velocidades de rotación de estas estrellas.

ABSTRACT

In order to know the distribution of rotational velocities of Be stars, a standard assumption is used, namely that the rotational axes are uniformed distributed. We use here polarimetric projected angles data from almost 500 Be stars and we make a statistical analysis. Furthermore we perform a Monte-Carlo simulation that explains the observed features of the angles, confirming that it is indeed uniform distributed, but the projected angles possess a bimodal structure. This last features may change the conclusion about the rotational velocity distribution of these stars.

Key Words: methods: numerical — methods: statistical — stars: emission-line, Be — stars: rotation

1. INTRODUCTION

The theory of radiation driven winds from hot stars with the inclusion of the centrifugal term due to the stellar rotation has been revisited by Curé (2004). He found that for the cases when the rotational speed is $\gtrsim 0.7\Omega (= v_{\rm rot}/v_{\rm breakup})$ there is a new wind solution, that is denser and faster than the standard solution (Friend & Abbott 1986). Thus is important to know about the mean rotational speed of Be stars. The process to calculate this mean rotational speed is from the measurement of $v_{\rm rot}\sin(i)$, where i is the inclination angle of the star and $v_{\rm rot}$ their rotational speed. After compiling a relevant sample, follows the standard assumption that the stellar axes are uniform distributed (see e.g., Chauville et al. 2001) and the numerical algorithm described by Lucy (1974) is used.

In this work we have used the 493 intrinsic polarization angles (p) from a sample of 497 Be stars compiled by Yudin (2001). Four stars with zero measured polarization have been excluded.

[1]Departamento de Física y Astronomía, Universidad de Valparaíso, Chile.
[2]Departamento de Ingeniería Matematica, Universidad de Chile, Santiago, Chile.
[3]European Southern Observatory, Vitacura, Santiago, Chile.
[4]CONICET, Argentina.

Interferometric studies so far confirm our first assumption that the polarization angle in Be stars is perpendicular to the disk. Our second assumption is that the disk is plane-parallell to the stellar equator, is supported by the stability of the polarization angle in Be stars, as a non-aligned disk would precess. Consequently, the intrinsic polarization angle of a Be star gives the projection of the stellar rotational axis on the celestial sphere.

2. STATISTICAL ANALYSIS OF THE SAMPLE

As a first step we made an histogram of the data with different bins concluding that the angles p are uniform distributed. Furthermore, from the theory of an uniform distribution function, the mean (μ) and standard deviation (σ) are $\mu = 90$ and $\sigma = \sqrt{180^2/12} = 51.96$, while from Yudin's database we get $\mu = 86.6$ and $\sigma = 52.5$ confirming our previous conclusion. But considering that statistical techniques such as histograms or the statistical parameters of an uniform distribution are *simple* techniques, we decide to apply more advances ones, such as the Kolmogorov-Smirnov (KS) test. We tested therefore if our sample do really comes from an uniform distribution function and the KS test rejected our hypothesis, i.e., the sample do not comes from an uniform distribution. The next statistical tool we used was

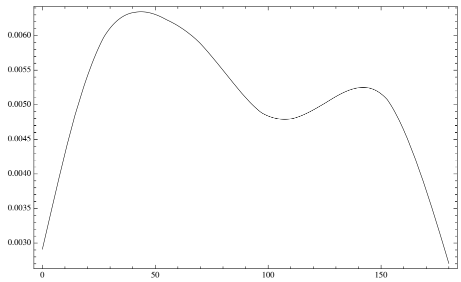

Fig. 1. Kernel density estimation from the Yudin's Sample of 493 Be Stars.

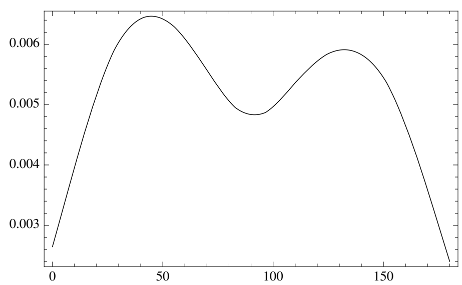

Fig. 2. Kernel density estimation from a MonteCarlo simulation with 500 Stars.

the Kernel Density Estimation (hereafter KDE, see, e.g., Royer et al. 2007, and references therein).

This kernel density estimation shows clearly that is not an uniform distribution, but has a bi-modal structure. Abt et al.(2001) measured the projected rotational velocities of 1092 northern B stars listed in the Bright Star Catalogue and calibrated them against the Slettebak et al.(1975) system. They found a bi-modal distribution of rotational velocities (see their Figure 1) that strongly resembles our Figure 1. This similarity, in both figures, opens the question if the procedure for obtain the mean rotational speed from a sample of $v_{\rm rot}\sin(i)$ do really take in account the bi-modal structure of the *projected angles*.

Thus, in order to answer this question, we performed a Monte-Carlo simulation in order to obtain a sample of projected angles.

3. MONTE-CARLO SIMULATIONS

The following assumptions for our simulation were used: (i) the orientation of rotational axes coming from an uniform distribution; (ii) the location of stars is uniform distributed over the galaxy; (iii) the galaxy structure is a flat disk, modelled with x, y, z Cartesian coordinates with the ratio $x, y, z = 10 : 10 : 1$.

Figure 2 and Figure 3 show KDE from Monte-Carlo simulations with 500 and 10000 stars respectively. Both figures are similar to the KDE from Yudin's sample.

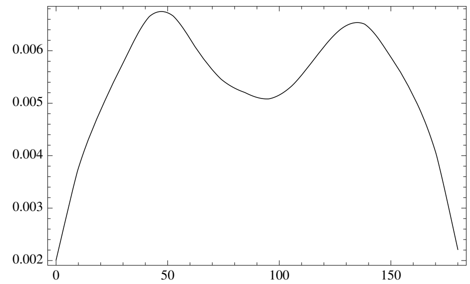

Fig. 3. Kernel density estimation from a MonteCarlo simulation with 10000 Stars.

From these simulations we can conclude that the distribution of projected polarization angles, p, is bi-modal. We have also calculated KDEs for the cases where there exists a *privileged* direction of rotational axes, but the results of the corresponding KDE is different from the observed (Yudin's) one.

Other simulations that we performed were carried out assuming that *some* percentage of the axes are from an uniform distribution and the rest are from a particular preferred direction. The results of these calculations showed that the percentage of stars coming from a uniform distribution should be at least of 85% in order that the obtainned KDE is *similar* to the observed one.

4. CONCLUSIONS

We have used some advanced statistical techniques in order to estimate how the rotational axes from Be stars are distributed. From our numerical simulations we have confirmed that indeed these axes are uniform distributed, *but* the corresponding distribution of the *projected* angles has a bi-modal structure due to the shape of the galaxy. These results opens the question if the procedure of obtaining the mean rotational speed of Be Stars do really take into account the projected distribution.

REFERENCES

Abt, H. A., Levato, H., & Grosso, M. 2002, ApJ, 573, 359

Chauville, J., Zorec, J., Ballereau, D., Morrell, N., Cidale, L., & García, A. 2001, A&A, 378, 861

Curé, M. 2004, ApJ, 619, 929

Friend, D., & Abbott, D. C. 1986, ApJ, 311, 701

Lucy, L. B. 1974 AJ, 79, 745

Royer, F., Zorec, J. & Gómez, A. E. 2007 A&A, 463, 671

Slettebak, A., Collins, G. W., II, Boyce, P. B., White, N. M., & Parkinson, T. D. 1975, ApJS, 29, 137

Yudin, R. V. 2001, A&A, 368, 912