Revista Mexicana de Astronomía y Astrofísica, Volumen 2, Abril 1978

# A DETERMINATION OF GALACTIC ROTATION PARAMETERS FROM O-TYPE STARS

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*Received 1977 November 30*


## RESUMEN

La constante A de Oort fue calculada usando las velocidades radiales de una muestra de estrellas O con distancia conocida, tomada del *Catalogue of Galactic O Stars* (Cruz-González *et al* 1974). Un valor alrededor de 13 km s$^{-1}$ kpc$^{-1}$ fue obtenido.

Las componentes del movimiento solar $U_0$, $V_0$ y las constantes de rotación $\alpha$, k se determinaron suponiendo la componente perpendicular de movimiento solar como $W_0 = 7$ km s$^{-1}$ y la distancia del sol al centro galáctico $R_0 = 10$ kpc.

## ABSTRACT

Radial velocities for a sample of O stars with known distances, from the *Catalogue of Galactic O Stars* (Cruz-González *et al.*, 1974), have served to calculate Oort's constant A. A value around 13 km s$^{-1}$ kpc$^{-1}$ has been obtained.

The solar motion components $U_0$, $V_0$ and the rotation constants $\alpha$, k were determined assuming the perpendicular components of the solar motion as $W_0 = 7$ km s$^{-1}$ and the distance from the sun to the galactic center, $R_0 = 10$ kpc.


*Key words:* **GALACTIC ROTATION — O STARS.**

## I. INTRODUCTION

Many investigations have been carried out to determine Oort's constant A; at present a value of 15 km s$^{-1}$ kpc$^{-1}$ is accepted as the most plausible one. However it is interesting to observe how this value has decreased through the past decades. Morgan and Oort (1951), based on proper motions from FK3 catalogue, reported a value of A = 20 km s$^{-1}$ kpc$^{-1}$. Later, Petrie *et al.* (1956) using radial velocities of 79 B stars found A = 17.7 km s$^{-1}$ kpc$^{-1}$ and Feast and Thackeray (1958) using a larger number of stars obtained A = 17.5 km s$^{-1}$ kpc$^{-1}$. Johnson and Svolopoulos (1961), from 36 galactic clusters found A = 15 km s$^{-1}$ kpc$^{-1}$. From proper motions of FK4, Fricke (1967) concluded that the value of A was between 14 and 17 km s$^{-1}$ kpc$^{-1}$. Clube (1972), with the same data as Fricke's but using a different model, obtained for A, 10 km s$^{-1}$ kpc$^{-1}$ or even lower values.

Some studies based on young objects yield small values of A: Georgelin and Georgelin (1970) with H II regions found, A = 14.3 km s$^{-1}$ kpc$^{-1}$; Balakirev (1973) with O and B stars, A = 12.5 km s$^{-1}$ kpc$^{-1}$; Feast and Shuttleworth (1965) with B Stars, A = 14.3 km s$^{-1}$ kpc$^{-1}$; Rubin and Burley (1964) with O and B stars, A = 14.5 km s$^{-1}$ kpc$^{-1}$; Petrie (1965) with O and B stars, A = 15.1 km s$^{-1}$ kpc$^{-1}$; Crampton (1968) with B0-2e stars, A = 11.8 km s$^{-1}$ kpc$^{-1}$ Miller (1963) with H II regions, A = 15.3 km s$^{-1}$ kpc$^{-1}$.

For all the stars of our sample, radial velocity, distance and galactic coordinates *l, b* were taken from the *Catalogue of Galactic O Stars* (Cruz-

González *et al.* 1974). Stars without distance determination were excluded.

## II. METHOD AND EQUATIONS

The following well-known equations were employed to obtain the solar motion components and the galactic rotation constants (Kraft and Schmidt 1963).

$$V_r = -U_0 \cos l \cos b - V_0 \sin l \cos b - W_0 \sin b - 2A(R - R_0) \sin l \cos b - 2\alpha(R - R_0)^2 \sin l \cos b + k.$$

Here $U_0$, $V_0$ and $W_0$ are the components of solar motion.

$$A = -\frac{1}{2} R_0 w_0', \text{ Oort's constant.}$$

$$\alpha = -\frac{1}{4} R_0 w_0'', \text{ coefficient of the second order term.}$$

k represents a possible systematic effect in radial velocities, the so called k-term.

$R_0 = 10$ kpc (adopted).

The values of the solar motion components and the galactic rotation constants were obtained by the method of least squares as described by Fischer (1969). Different cases were calculated with different samples; these cases will be described later. All the computations were carried out at the Centro de Servicios de Cómputo, UNAM with a Burroughs 6700 computer.

## III. RESULTS

The results are presented in Table 1. A brief description of the content of each column is given below:

1) Number of the case.
2) N, number of stars in the sample.
3) $U_0$, radial component of the solar motion and standard deviation in km s$^{-1}$. Positive direction is towards the galactic center.
4) $V_0$, tangential component of the solar motion and standard deviation, in km s$^{-1}$.
5) V, space velocity of the sun, in km s$^{-1}$.
6) A, Oort's constant and standard deviation, in km s$^{-1}$ kpc$^{-1}$.
7) $\alpha$, the coefficient of the second order term and standard deviation, in km s$^{-1}$ kpc$^{-2}$.
8) k, systematic error in radial velocity and standard devation, in km s$^{-1}$.
9) d, the adopted upper limit of the distances of the stars in the sample to the sun, in kpc.
10) R, limiting distances to the galactic center, of stars in the sample, in kpc.
11) $V_{pr}$, the adopted upper limit of radial components of peculiar velocities of stars in the sample, in km s$^{-1}$. The radial component of the peculiar velocity was defined as $V_{pr} = V_{LSR} - V_r$. In these cases $V_r$ was calculated by the equation

TABLE 1

SOLAR MOTION AND ROTATION CONSTANTS

| Case (1) | N (2) | $U_0$ (3) | $V_0$ (4) | V (5) | A (6) | $\alpha$ (7) | k (8) | d (9) | R (10) | $V_{pr}$ (11) | Sp. Type (12) | Lum.Class (13) | (14) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 231 | 9.3±2.1 | 14.0±2.6 | 18.2 | 13.9±1.2 | -1.1±0.8 | -1.3±1.5 | <3.5 | ... | ... | ... | ... | * |
| 2 | 219 | 6.8±1.6 | 11.8±1.9 | 15.3 | 12.7±0.9 | -0.4±0.6 | -1.1±1.1 | <3.5 | ... | <45 | ... | ... | * |
| 3 | 252 | 9.6±2.1 | 12.4±2.4 | 17.2 | 12.9±1.0 | 4.3±0.7 | 1.6±1.5 | ... | 7-13 | ... | ... | ... | * |
| 4 | 228 | 7.6±1.5 | 10.5±1.8 | 14.7 | 12.4±0.8 | 1.1±0.5 | -1.5±1.1 | ... | 7-13 | <45 | ... | ... | * |
| 5 | 231 | ... | ... | 17.1 | 13.7±1.3 | 0.7±0.7 | -1.4±1.6 | <3.5 | ... | ... | ... | ... | * |
| 6 | 218 | ... | ... | .... | 12.2±1.0 | 1.3±0.5 | -0.6±1.2 | <3.5 | ... | <45 | ... | ... | * |
| 7 | 252 | ... | ... | .... | 13.0±1.1 | 0.8±0.6 | -1.5±1.6 | ... | 7-13 | ... | ... | ... | * |
| 8 | 238 | ... | ... | .... | 11.9±0.8 | 1.7±0.4 | -0.6±1.2 | ... | 7-13 | <45 | ... | ... | * |

$$V_r = -2A(R - R_0)\ \sin l \cos b - 2\alpha(R - R_0)^2 \sin l \cos b,$$

using A, $\alpha$ from the previous case.

12) Range in spectral type considered.
13) Luminosity classes considered.
14) An asterisk in this column means that stars with poor determination of distance, radial velocity, UBV photometry and unknown luminosity class were excluded.

Dots in a column —from 9 to 12— indicate that the stars in that sample have not been selected with regard to the value of the parameter appropriate to that column.

Equation (1) was solved by the method of least squares, in cases from 1 to 4. Case 1 includes stars in a sphere of 3.5 kpc radius. Case 2 is for the same region but high velocity stars were excluded. In case 3, the region is a band with $\Delta R = 6$ kpc. In case 4, high velocity stars were eliminated again. In cases from 5 to 8 the solar motion was not calculated but adopted as

$$U_0 = 10 \text{ km s}^{-1},\ V_0 = 12 \text{ km s}^{-1},\ W_0 = 7 \text{ km s}^{-1},$$

(Penston *et al.* 1969).

We present in Table 2 other relevant results which may be of interest to the reader. The meaning of the columns is the same as those in Table 1.

## IV. DISCUSSION

Table 2 gives the results of a large number of solutions using different criteria for the selection of O stars from the sample at large. We believe that the results presented in Table 1 are more reliable than those in Table 2 because in all cases appearing in Table 1 we have neglected stars with poor determination of radial velocity, distance, spectral type and luminosity class. In addition, the number of stars in the samples treated is satisfactorily large. In Table 2 these two conditions are not satisfied simultaneously.

We note from Table 1 that when solar motion terms are included in the solution with all O stars,

TABLE 2
SOLAR MOTION AND ROTATION CONSTANTS

| Case | N | $U_0$ | $V_0$ | V | A | $\alpha$ | k | d | R | $V_{pr}$ | Sp. Type | Lum. Class | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) |
| 9 | 404 | 12.9±2.5 | 12.6±2.4 | 19.3 | ... | ... | ... | ... | ... | ... | ... | ... | * |
| 10 | 30 | 27.8±9.1 | 16.9±8.8 | 33.3 | ... | ... | ... | <1 | ... | ... | ... | ... | * |
| 11 | 168 | 17.2±2.9 | 11.1±3.4 | 21.6 | ... | ... | ... | <2 | ... | ... | ... | ... | * |
| 12 | 304 | 10.8±2.6 | 12.7±2.7 | 18.1 | ... | ... | ... | <3 | ... | ... | ... | ... | * |
| 13 | 169 | 26.5±4.5 | 8.3±2.9 | 28.6 | ... | ... | ... | ... | 9-11 | ... | ... | ... | * |
| 14 | 310 | 13.7±2.8 | 12.7±2.4 | 19.9 | ... | ... | ... | ... | 8-12 | ... | ... | ... | * |
| 15 | 330 | 7.1±2.0 | 15.0±2.4 | 18.0 | 14.7±1.1 | -1.6±0.8 | -3.1±1.5 | <3.5 | ... | ... | ... | ... | * |
| 16 | 306 | 6.9±1.5 | 11.3±1.8 | 15.0 | 13.0±0.8 | -0.7±0.5 | -2.7±1.0 | <3.5 | ... | <45 | ... | ... | * |
| 17 | 363 | 7.1±2.0 | 13.7±2.3 | 16.9 | 13.5±1.0 | -1.2±0.6 | -3.4±1.4 | ... | 7-13 | ... | ... | ... | * |
| 18 | 337 | 7.2±1.4 | 10.7±1.6 | 14.7 | 12.0±0.7 | -0.4±0.4 | -3.0±1.0 | ... | 7-13 | <45 | ... | ... | * |
| 19 | 51 | ... | ... | ... | 13.7±2.6 | 2.3±1.6 | -2.4±3.3 | <3.5 | ... | ... | 3-8.5 | V | * |
| 20 | 48 | ... | ... | ... | 15.3±1.8 | -0.5±1.2 | 3.1±2.3 | <3.5 | ... | <45 | 3-8.5 | V | * |
| 21 | 32 | ... | ... | ... | 16.1±4.8 | -1.6±2.6 | 4.9±4.9 | <3.5 | ... | ... | 9-9.7 | V | * |
| 22 | 30 | ... | ... | ... | 13.9±3.1 | -0.3±1.7 | -0.7±3.2 | <3.5 | ... | <45 | 9-9.7 | V | * |
| 23 | 40 | ... | ... | ... | 13.8±2.5 | 1.4±1.7 | 2.8±2.9 | <3.5 | ... | ... | 3-8.5 | II,III,IV | * |
| 24 | 39 | ... | ... | ... | 12.7±2.2 | 2.2±1.5 | 1.6±2.7 | <3.5 | ... | <45 | 3-8.5 | II,III,IV | * |
| 25 | 39 | ... | ... | ... | 10.1±2.7 | 1.6±1.3 | -1.6±3.3 | <3.5 | ... | ... | 9-9.7 | II,III,IV | * |
| 26 | 38 | ... | ... | ... | 9.4±2.6 | 1.8±1.2 | -3.0±3.1 | <3.5 | ... | <45 | 9-9.7 | II,III,IV | * |
| 27 | 34 | ... | ... | ... | 16.3±4.3 | -2.8±2.5 | -14.7±6.5 | <3.5 | ... | ... | 3-8.5 | I,Ia,Ib | * |
| 28 | 30 | ... | ... | ... | 14.9±2.9 | -1.0±1.7 | -9.3±4.7 | <3.5 | ... | <45 | 3-8.5 | I,Ia,Ib | * |
| 29 | 35 | ... | ... | ... | 11.9±3.0 | 1.8±1.6 | -0.8±3.9 | <3.5 | ... | ... | 9-9.7 | I,Ia,Ib | * |
| 30 | 35 | ... | ... | ... | 11.9±3.0 | 1.8±1.6 | -0.7±3.9 | <3.5 | ... | <45 | 9-9.7 | I,Ia,Ib | * |

we obtain a space velocity for the sun, V, larger than the solution without high velocity stars. The constant A does not appear to vary for solutions with or without solar motion terms. The mean A from Table 1 is $12.8 \pm 0.7$ km s$^{-1}$ kpc$^{-1}$. As to the values of $\alpha$ and k they are not significant. This conclusion is in agreement with that of Georgelin and Georgelin (1970).

From Table 2 we see that the value of the solar motion is smaller when rotation terms are included in the solution as compared to the solution without rotation terms. There is again a tendency for the solar motion to be lower when high velocity stars are excluded. We also note that in this case the value of A is also smaller than for the solution without restriction of velocity.

One of us (A.A.F.) wishes to thank Dr. Paris Pişmiş for her help and encouragement during the last stages of this work which was incomplete at the time of the death of the senior author.

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