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A REDETERMINATION OF THE LMC PROPER MOTION USING FOUR QUASAR FIELDS

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RESUMEN

El movimiento propio de la Nube Grande de Magallanes (LMC) con respecto a cuatro cuasares proyectados en cada campo se determinó usando datos CCD obtenidos en el foco Cassegrain del telescopio de 1.5-m de CTIO, entre 1989 y 2001. El cuasar proyectado en el centro de cada campo es usado como punto de referencia para obtener el movimiento propio del centro de la LMC.

ABSTRACT

The proper motion (pm) of the Large Magellanic Cloud (LMC) relative to four background quasi-stellar objects is determined using CCD data obtained at the Cassegrain focus of the CTIO 1.5 m telescope, between 1989 and 2001. The background quasar projected at the center of each field is used as a fiducial point of reference to obtain the pm of the center of the LMC.

Key Words: **ASTROMETRY — GALAXIES: KINEMATICS AND DYNAMICS — MAGELLANIC CLOUDS**

This study is the follow-up of the studies by Anguita et al. (2000, hereafter ALP) and Pedreros et al. (2002, hereafter PAM) wherein the pm of the LMC was determined, for the first and second time, respectively, using this method. In the first study (ALP), the pm was calculated through observations of three LMC fields, each containing a background quasar (QSO), namely, Q0557-6713, Q0558-6707 and Q0615-6615; whereas in the second work (PAM), the same type of analysis was carried out for the LMC field Q0459-6427. The pm values obtained in the two mentioned studies turned out to be significantly different, yielding differences of -0.3 mas/yr (1.5σ) in RA and 2.5 mas/yr ($12.5\ \sigma$) in DEC, in the sense ALP$-$PAM . These results prompted us to reanalyze the existing observational data and to add some new data into the analysis.

The observational material used here consists of 47, 72, 51 and 50 CCD frames of the LMC fields around the projected quasars Q0459-6707, Q0557-6713, Q0558-6707 and Q0615-6615, observed in 9, 13, 9 and 11 epochs, respectively, ranging from January 1989 through December 2001. All of the frames were taken through an R Johnson filter to reduce the effects of differential color refraction.

The new data included in this study represent a significant increase in the time baseline and in the number of observed data points, with respect to what was available for the ALP and PAM studies. This increase corresponds to a 19%, 65%, 126% and 65% in the time baseline and to a 7%, 18%, 59% and 56% in the number of available frames (or data points) for the above QSO fields, respectively.

The method to calculate pm consists in selecting several LMC stars in the observed fields which are used as reference stars. The X and Y position of the QSO is measured with respect to these stars. In order to asses the change in the coordinates X and Y of the QSO in different epochs, they have to be referred to a common system of reference called the standard frame of reference (SFR). From the change in the QSO coordinates relative to the SFR, we determine the "proper motion of the QSO", which will actually correspond to the "reflex" motion of the barycenter of the LMC reference stars. Thus, pm of the barycenter of the LMC stars (which is what we demonstrate after) will correspond to the negative of the value of the apparent motion of the QSO.

The coordinates in RA and DEC for the reference stars and the QSO for each image are obtained by processing the observed CCD images through DAOPHOT as a task of the IRAF package. The transformation of these coordinates to the SFR is done through a series of steps explained in detail by Jones et al. (1994) and includes, among other features, a differential color refraction (DCR) correction which is fully explained in PAM.

The RA and DEC proper motion were determined through an ordinary least-square linear regression analysis on the X,Y vs. epoch data points.

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TABLE 1

PROPER MOTION OF THE FIELD AND OF THE LMC'S CENTER

Field	$\mu_\alpha \cos(\delta)$ (mas yr^{-1})	μ_δ (mas yr^{-1})	$\mu_\alpha \cos(\delta)$ (mas yr^{-1})	μ_δ (mas yr^{-1})	Frames	Epochs
Q0459-6427	1.9 ± 0.2	0.1 ± 0.2	2.0 ± 0.2	0.2 ± 0.2	47	9
Q0557-6713	1.1 ± 0.2	1.9 ± 0.1	1.2 ± 0.2	1.7 ± 0.1	72	13
Q0558-6707	1.2 ± 0.2	0.6 ± 0.3	1.3 ± 0.2	0.4 ± 0.3	51	9
Q0615-6615	1.9 ± 0.2	1.4 ± 0.2	2.0 ± 0.2	1.2 ± 0.2	50	11

TABLE 2

HIGH PRECISION DETERMINATIONS OF THE PROPER MOTION OF THE LMC'S CENTER

Source	$\mu_\alpha \cos(\delta)$ (mas yr^{-1})	μ_δ (mas yr^{-1})	Proper Motion System
Kroupa, Röser & Bastian 1994 (pm of field)	+1.3 ± 0.6	+1.1 ± 0.7	PPM
Jones et al. 1994	+1.37 ± 0.28	−0.18 ± 0.27	Galaxies
Kroupa & Bastian 1997 (pm of field)	+1.94 ± 0.29	−0.14 ± 0.36	Hipparcos
ALP	+1.7 ± 0.2	+2.9 ± 0.2	Quasars
PAM	+2.0 ± 0.2	+0.4 ± 0.2	Quasars
Drake et al. 2002	+1.4 ± 0.4	+0.38 ± 0.25	Quasars
This work (weighted average)	+1.6 ± 0.1	+1.3 ± 0.1	Quasars

The negative of the slopes of the best fitting lines are adopted as the proper motions of each field.

The resulting pm for the individual fields are shown in Table 1 as $\mu_\alpha \cos(\delta)$ and μ_δ in milliarcsec per year for RA and DEC. Columns 2 and 3 contain the "raw" proper motions of the field. Columns 4 and 5 correspond to the pm relative to the LMC's center resulting from the correction of the values in columns 2 and 3 for rotation of the LMC's plane.

The resulting weighted averages of the proper motions obtained in this work along with those by other authors using different methods are shown in Table 2, in the same way as in Table 1. It is clear that our results show significant differences (especially in DEC) with those obtained by ALP and are quite compatible with those obtained by PAM.

All of the steps concerning the method described above for obtaining the pm were carried out automatically through an ad-hoc software package, which was used for the first time by PAM.

To conclude, the LMC's proper motion values obtained here seem reasonably close to those by most other authors (especially to those from PPM by Kroupa et al. 1994) but still significantly far from those obtained by ALP. This difference suggests that ALP's results might be affected by some kind of systematic error. Since ALP's unmodified X,Y coordinate data are actually included in the data sample used here, we believe that this systematic error might arise from the processing of these data to obtain the DEC pm rather than from the X, Y data themselves.

Our "low" pm values also support the idea that the LMC is, in fact, gravitationally bound to our Galaxy.

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