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THE PROPER MOTION OF THE LMC

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RESUMEN

Hemos determinado el movimiento propo de la Nube Grande de Magallanes (LMC) relativo a un objeto cuasi estelar, utilizando observaciones realizadas en siete épocas (seis años de base temporal). Nuestro movimiento propio está en concordancia con resultados previos obtenidos por otros autores, e indica que la LMC no es un miembro de la corriente de galaxias que exhiben órbitas similares alrededor de la Vía Láctea. Utilizando valores publicados de la velocidad radial para el centro de masa de la LMC, en combinación con el vector de velocidad tangencial obtendido de nuestros movimientos propios, hemos calculado la velocidad espacial total de la LMC. Este valor, junto con algunas suposiciones respecto de la distribución de masa de la Galaxia, permite estimar la masa de ésta. Este trabajo es parte de un programa mayor dedicado al estudio del movimiento espacial del sistema de las Nubes de Magallanes, y su relación con la Vía Láctea. Este conocimiento es fundamental para entender la naturaleza, origen y evolución del sistema, asi como el origen y evolución de las partes externas de nuestra Galaxia.

ABSTRACT

We have determined the proper motion of the Large Magellanic Cloud (LMC) relative to a background quasi-stellar object, using observations carried out in seven epochs (six years of base time). Our proper motion value agrees well with most results obtained by other authors and indicates that the LMC is not a member of a proposed stream of galaxies with similar orbits around our galaxy. Using published values of the radial velocity for the center of the LMC, in combination with the transverse velocity vector derived from our measured proper motion, we have calculated the absolute space velocity of the LMC. This value, along with some assumptions regarding the mass distribution of the Galaxy, has in turn been used to calculate the mass of the latter. This work is part of a program to study the space motion of the Magellanic Clouds system and its relationship to the Milky Way (MW). This knowledge is essential to understand the nature, origin and evolution of this system as well as the origin and evolution of the outer parts of the MW.

Key Words: astrometry — galaxies: kinematics and dynamics — Galaxy: fundamental parameters — Magellanic Clouds

1. SCOPE

Studying the kinematics of the Local Group galaxies nearest to our galaxy is critical to understand the formation process of our galaxy and that of its satellites. Topics such as the origin of stellar streams that seem to be related to these satellites, the role of tidal interactions in the evolution of low mass galaxies and of the halo of our galaxy, and, in general, the origin of these minor groups, could be better addressed having a precise knowledge of the space velocity vectors of the satellites. Among the objects whose kinematics could help us solve the problems outlined above are the Magellanic Clouds (MCs), which, on account of being among the closest galaxies to the Milky Way galaxy (MW), are the most suitable for kinematical studies with present techniques. In all modelings of the space motions of the MCs, their present space velocity vectors constitute a key parameter. Knowledge of this vector not only allows for reconstructing their past location and predicting their future orbit, but –assuming a reasonable value for the mass of our galaxy– they can also help us deduce if the Magellanic system is bound to the Galaxy.

At the time our program was conceived (∼2000), the observational effort had concentrated on the LMC, and only preliminary values for the proper motion motion of the SMC were available based either on photographic plates or the Hipparcos catalogue. This motivated us to start in 2001 a program to measure the proper motion of the SMC with respect to several QSOs in its background.

Given that previous theoretical/observational research indicated that the total proper motion of the SMC should be about 1.5 mas yr^{-1}, a conservative proper motion precision of ∼0.5 mas yr^{-1} (per

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QSO), to be achieved on a time-base of six years, and with seven epochs of observation, was deemed sufficient to address our goal. Based on previous astrometric experience by our group with the Iréneé du Pont 2.5 meter telescope at Las Campanas Observatory, Chile, this instrument was chosen as the smallest telescope with which our program was possible.

To check for consistency, one of LMC background QSOs (Q0557-6713) used previously by our group to determine the proper motion of the LMC was included in our program. A very large number of frames could be obtained for this field, leading to a high precision determination of the proper motion of the LMC.

The astrometric program described here is part of a more comprehensive study of the SMC-LMC-MW system, which includes the star formation history (SFH) of the MCs. This part is done in collaboration with Carme Gallart and Noelia Noel at the IAC.

2. RESULTS

Figure 1 shows the resulting vector-point-diagram for the QSO (circle with error bars) and the 62 bona-fide LMC stars that define our reference system (open circles clustered around (0,0)). In this "QSO-method" it is as if the QSO is moving with respect to the LMC stars, whereas the QSO is actually an "anchor point". Therefore the real motion of the LMC is the reflex motion of the QSO (details of the procedure will be presented in a forthcoming paper).

From our measurements we find:

$$\begin{aligned}\mu_\alpha \cos\delta &= +1.95 \pm 0.13\,[\mathrm{mas\ yr^{-1}}]\\ \mu_\delta &= +0.43 \pm 0.18\,[\mathrm{mas\ yr^{-1}}]\,.\end{aligned}$$

This "as measured" value has to be corrected for purely geometric projection effects (our field is offset the center of mass, and we want the proper motion at that point), and for effects due to the rotation of the LMC disk, which adds an spurious proper motion to the systemic motion of the LMC as a whole. After applying these corrections using the latest available rotation curve (evaluated at 50 km s^{-1}) and adequate geometric parameters for the disk of the LMC we find a center of mass systemic proper motion of:

$$\begin{aligned}\mu_\alpha \cos\delta &= +1.82 \pm 0.13\,[\mathrm{mas\ yr^{-1}}]\\ \mu_\delta &= +0.39 \pm 0.13\,[\mathrm{mas\ yr^{-1}}]\,.\end{aligned}$$

With this value we can compute now the motion of the LMC with respect to the Galactic center, adopting also a systemic radial velocity of 250 km s^{-1} from the literature, and we obtain:

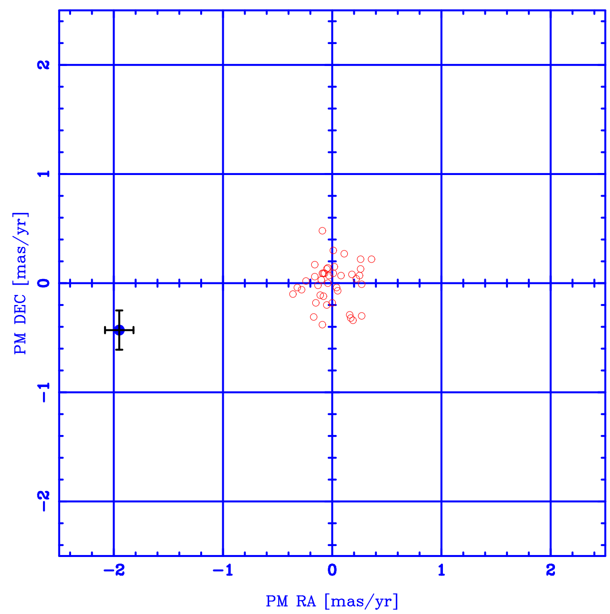

Fig. 1. Vector point diagram of the LMC QSO field described here.

$$\begin{aligned}V_T &= 315 \pm 20\,[\mathrm{km\ s^{-1}}]\\ V_R &= 86 \pm 17\,[\mathrm{km\ s^{-1}}]\,.\end{aligned}$$

The large tangential component of the motion indicates that the LMC is close to its perigalacticon. Also an estimation of the enclosed mass of the Milky Way within the radius of the orbit (50 kpc) gives $M_{\mathrm{MW}}(d < 50\,\mathrm{kpc}) = (7.3 \pm 0.9) \times 10^{11}\, M_\odot$ consistent with previous estimates.

More importantly, the position angle of the proper motion does not seem to be consistent with the hypothesis that the LMC is a member of the galaxy stream proposed by Lynden-Bell and Lynden-Bell in the mid 90's. Furthermore, the actual values of the radial and tangential components of the LMC center of mass velocity with respect to the Galactic center seem to favor the idea that the "Magellanic stream" is produced by tidal interactions rather than by ram pressure, as it has been suggested.

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