RevMexAA (Serie de Conferencias), **40**, 106–107 (2011)

PROPER MOTION STUDY OF THE MAGELLANIC CLOUDS USING SPM MATERIAL

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RESUMEN

Se han determinado los movimientos propios absolutos de estrellas y galaxias hasta $V = 17.5$ en un área de 450 grados cuadrados que engloba a las Nubes de Magallanes. El material observacional empleado incluye placas fotográficas y observaciones CCD del programa de Movimientos Propios del Sur de Yale/San Juan. Mediciones locales de movimientos propios relativos son combinadas en una solución de traslapo, usando estrellas del disco Galáctico seleccionadas fotométricamente para definir un sistema global de referencia relativo, que luego es transformado a absoluto usando galaxias externas y estrellas Hipparcos para colocarlo en el ICRS. El catálogo resultante de 1.4 millones de objetos es utilizado para obtener el movimiento propio medio absoluto de las Nubes Grande y Pequeña de Magallanes; $(\mu_\alpha \cos\delta, \mu_\delta)_{\rm LMC} = (+1.89, +0.39) \pm (0.27, 0.27)$ msa año^{-1} y $(\mu_\alpha \cos\delta, \mu_\delta)_{\rm SMC} = (+0.98, -1.10) \pm (0.30, 0.29)$ msa año^{-1}. Estos resultados están basados en dos muestras seleccionadas con las mejores estrellas, 3822 de la LMC y 964 de la SMC. Una determinación mucho más precisa del movimiento propio relativo de la SMC con respecto a la LMC se pudo obtener; $(\mu_\alpha \cos\delta, \mu_\delta)_{\rm SMC-LMC} = (-0.91, -1.49) \pm (0.16, 0.15)$ msa año^{-1}. Este valor diferencial fue combinado con mediciones del movimiento propio de la LMC existentes en la literatura para obtener nuevas mediciones para la SMC, así como también para obtener un estimado de la diferencia de velocidad entre las dos nubes con un error de ± 54 km s^{-1}.

ABSTRACT

Absolute proper motions are determined for stars and galaxies to $V = 17.5$ over a 450 square-degree area that encloses both Magellanic Clouds. The proper motions are based on photographic and CCD observations of the Yale/San Juan Southern Proper Motion program. Multiple, local relative proper motion measures are combined in an overlap solution using photometrically selected Galactic disk stars to define a global relative system that is then transformed to absolute using external galaxies and Hipparcos stars to tie into the ICRS. The resulting catalog of 1.4 million objects is used to derive the mean absolute proper motions of the Large Magellanic Cloud and the Small Magellanic Cloud; $(\mu_\alpha \cos\delta, \mu_\delta)_{\rm LMC} = (+1.89, +0.39) \pm (0.27, 0.27)$ mas yr^{-1} and $(\mu_\alpha \cos\delta, \mu_\delta)_{\rm SMC} = (+0.98, -1.10) \pm (0.30, 0.29)$ mas yr^{-1}. These mean motions are based on best-measured samples of 3822 LMC stars and 964 SMC stars. A more precise determination can be made for the proper motion of the SMC relative to the LMC; $(\mu_\alpha \cos\delta, \mu_\delta)_{\rm SMC-LMC} = (-0.91, -1.49) \pm (0.16, 0.15)$ mas yr^{-1}. This differential value is combined with measurements of the proper motion of the LMC taken from the literature to produce new absolute proper motion determinations for the SMC, as well as an estimate of the total velocity difference of the two clouds to within 54 km s^{-1}.

Key Words: astrometry — catalogs — Magellanic Clouds — proper motions

1. INTRODUCTION

The most recent HST results on the proper motions of the Magellanic Clouds have suggested (Kallivayalil et al. 2006; Kallivayalil, van der Marel, & Alcock 2006; Piatek, Pryor, & Olszewski 2008), opposite to a long-held paradigm, that they are not bound to the Galaxy. Since it is widely accepted that the external and internal features of these galaxies, have been largely determined by the orbit they have followed in the past few Gigayears, it is critical to determine their space velocity as accurately and precisely as possible. The radial component of

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such velocity has been sufficiently measured, yet the tangential component have been much harder to obtain given the large distances (about 50 and 60 kpc) to the Clouds. Substantial effort has been put into measuring the proper motion of the Clouds, using old photographic plates, or CCD imaging over a baseline of 10 to 15 years, finally using HST to measure their displacement in a few years. The apparent contradiction between ground and space-based results is indeed a matter of current debate.

2. THIS WORK

This investigation is part of the Southern Proper Motion (SPM) program, a joint venture of Yale University and Universidad Nacional de San Juan in Argentina. The goal of SPM is to provide absolute proper motions, positions, and BV photometry for the Southern sky to a limiting magnitude of $V \sim 18$. The SPM program makes use of the 51 cm Double Astrograph of the Yale Southern Observatory, located in El Leoncito, Argentina. The first-epoch survey was taken with photographic plates between 1965 and 1974, and second-epoch plates observations were begun in 1988, but only a third of the survey was completed. In 2000 a CCD camera system was installed to complete the second-epoch coverage. This material, carefully processed to obtain the best possible astrometric and photometric information, was complemented with 2000.0 CCD-based positions from the UCAC2 catalogue (Zacharias et al. 2004) to obtain proper motions over an area of about 450 deg^2 for all objects down to $V \sim 17.5$.

First, relative proper motions with respect to a photometrically selected sample of Galactic Disk stars were measured within the CCD fields of view. Then, we combined those reference systems into a global one, taking advantage of the substantial overlap between frames, that provides linkage of the reference system across the whole region of the Clouds, limited only by measurement errors. Confirmed extragalactic objects were later used to fit a smooth function, a quadratic polynomial in (α, δ), that describes the mean motion of the global relative reference frame, that was later used to convert the relative proper motion into absolute ones. An additional zero-point correction was needed to put our proper motions into the ICRS, although theoretically, the external galaxies define an external absolute inertial system. Such difference is consequence of a known problem in the SPM photographic plates, a magnitude equation, whose effect seems to be different in extended objects (galaxies) than in stars, the latter being used to characterize and correct for this systematic problem of the plates.

Bona fide red giants in the LMC and SMC were chosen to measure the mean absolute proper motion of each Cloud. Differently from previous works, that only sampled a few very small scattered fields over each Cloud, our samples cover the LMC and SMC homogeneously and extensively, making any perspective or rotation correction unnecessary. Our measurement of each individual Cloud proper motion unfortunately includes a somewhat large error bar of about 0.3 mas yr^{-1} per coordinate, most of it from Hipparcos' zero point inaccuracy of 0.25 mas yr^{-1}. Our results are consistent with the Clouds being marginally bound to the Milky Way but cannot definitely rule out other scenarios. Conversely, our measurement of the relative proper motion of the SMC with respect to the LMC has a much smaller uncertainty of 0.15 mas yr^{-1} given the high precision achieved in the characterization of the global relative reference frame. Our results in this case suggest that the SMC is close to the binding energy limit, and despite the smaller error bar no definitive conclusion can be made about the binarity of the Clouds.

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