

# LOCAL SYSTEMATIC DIFFERENCES IN 2MASS POSITIONS

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## RESUMEN

Se ha encontrado que las posiciones en el catálogo 2MASS de fuentes puntuales muestran diferencias sistemáticas locales en escalas de  $\sim 5$  a  $\sim 8$  minutos de arco cuando se comparan con otros catálogos. Se observa que cuando las posiciones 2MASS son empleadas en el cálculo de movimientos propios, dichas diferencias sistemáticas causan errores sistemáticos en los movimientos propios resultantes. Se ha desarrollado un método para rectificar localmente 2MASS con respecto a UCAC4 con el fin de reducir las diferencias sistemáticas entre estos catálogos. El catálogo 2MASS rectificado con el método propuesto puede considerarse como una extensión de UCAC4 para la astrometría con precisión de alrededor de  $90\text{mas}$  en sus posiciones, con errores sistemáticos despreciables. También se muestra que el uso de estas posiciones rectificadas eliminan el patrón sistemático observado en movimientos propios derivados de las posiciones 2MASS.

## ABSTRACT

We have found that the positions in the 2MASS All-sky Catalog of Point Sources show local systematic differences with characteristic length-scales  $\sim 5$  to  $\sim 8$  arcminutes when compared with several catalogs. We have observed that when 2MASS positions are used in the computation of proper motions, the mentioned systematic differences cause systematic errors in the resulting proper motions. We have developed a method to locally rectify 2MASS with respect to UCAC4 in order to diminish the systematic differences between these catalogs. The 2MASS catalog rectified with the proposed method can be regarded as an extension of UCAC4 for astrometry with accuracy  $\sim 90\text{mas}$  in their positions, with negligible systematic errors. Also we show that the use of these rectified positions remove the observed systematic pattern in proper motions derived from 2MASS positions.

*Key Words:* astrometry — catalogs — proper motions — methods: data analysis — methods: miscellaneous

## 1. INTRODUCTION

This contribution is based on the results presented in two previous papers: Bustos Fierro & Calderón (2016a) and Bustos Fierro & Calderón (2016b).

Initially this work was motivated by the systematic errors found in positions derived from deep CCD images that were reduced using 2MASS (Skrutskie et al. 2006) as reference catalog. When position differences between 2MASS and other catalogs such as UCAC4 (Zacharias et al. 2013), SPM4 (Girard et al. 2011) and SDSS-DR9 (Ahn et al. 2012) were computed, the same patterns of systematic differences were found.

When we compared the proper motions in catalogs derived from 2MASS positions -namely PP-MXL (Roeser et al. 2010) and URAT1 (Zacharias et al. 2015)- with proper motions that are independent of 2MASS -namely UCAC4, SPM4 and USNO-B1

(Monet et al. 2003)- we found patterns in the systematic differences with characteristic features that match with similar features in the differences of 2MASS positions.

## 2. RECTIFICATION OF POSITIONS

In Bustos Fierro & Calderón (2016a) we proposed a method to locally rectify 2MASS with respect to UCAC4 on working fields  $3^\circ \times 3^\circ$  on the sky where we defined a square grid of step  $\rho$ , aligned with the coordinate axes RA and DEC. On each node of the grid  $(\alpha_g, \delta_g)$  we calculated the weighted mean difference  $(\alpha_{2MASS} - \alpha_{UCAC4}, \delta_{2MASS} - \delta_{UCAC4})$  inside a *smoothing area* centered in that node. As result of this procedure we obtained the mean systematic differences between 2MASS and UCAC4 evaluated in the nodes of a grid of size  $3^\circ \times 3^\circ$  that was used for the rectification of 2MASS.

In order to perform the rectification, for each position  $(\alpha_{2MASS}, \delta_{2MASS})$  we computed the correction  $(\Delta\alpha, \Delta\delta)$  by means of a two-dimensional cubic spline interpolation of the mean differences in the nodes of the grid. The corrected coordinates  $(\alpha_{2MASS-R}, \delta_{2MASS-R})$  were computed by

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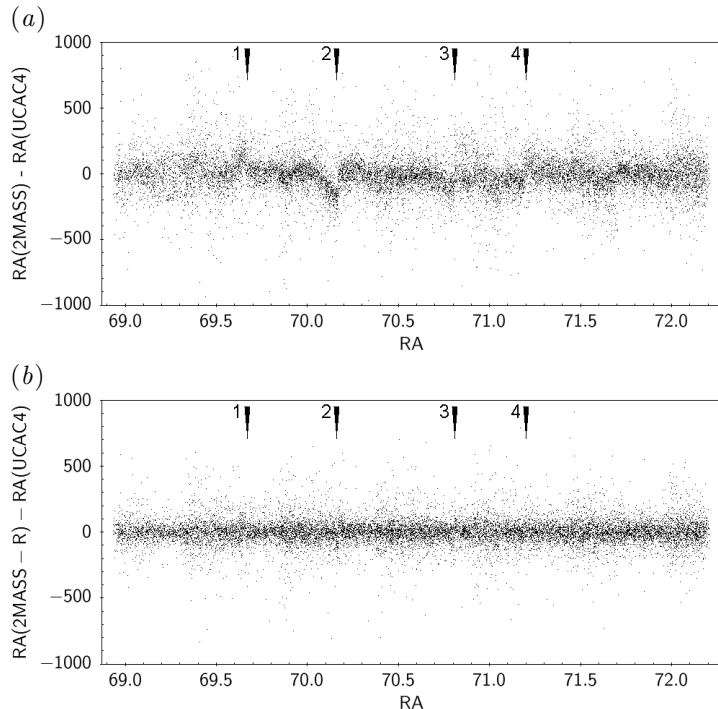


Fig. 1. Differences of right ascensions 2MASS–UCAC4 in mas. (a) Before rectification. (b) After rectification. The arrows numbered 1 through 4 point to some characteristic features of the systematics that are easily recognized.

$\alpha_{2MASS-R} = \alpha_{2MASS} - \Delta\alpha$  and  $\delta_{2MASS-R} = \delta_{2MASS} - \Delta\delta$ . Figure 1 shows the differences between RA in 2MASS and UCAC4 before and after the rectification in one of the analyzed fields.

### 3. PROPER MOTIONS DERIVED FROM RECTIFIED 2MASS POSITIONS

We calculated the proper motions in one of the zones previously analyzed, using first epoch positions from the rectified 2MASS and second epoch positions from URAT1. We call these proper motions  $\mu_\alpha(2MrUR1)$ ,  $\mu_\delta(2MrUR1)$  and they are defined in the usual way. We computed the differences between these the proper motions and the ones in UCAC4 and USNO-B1. The differences with UCAC4 are shown in Figure 2, where it can be seen that the systematic differences were greatly reduced.

### 4. CONCLUSIONS

The proposed method was able to reduce the systematic differences between 2MASS and UCAC4 well below the random differences in all the fields analyzed in this work. After rectification the mean differences 2MASS–UCAC4 are null, and the rms differences are reduced from  $\sim 140mas$  to  $\sim 90mas$ . The 2MASS catalog rectified with the proposed method can be regarded as an extension up to  $K_s = 15$

of UCAC4 for astrometry with accuracy around  $\sim 90mas$  in their positions and with lower accuracy up to  $K_s = 15.5$ , with negligible systematic errors.

We have proved that the proper motions of PPMXL and URAT1 are strongly affected by the systematic differences in positions observed in 2MASS, more noticeably in URAT1 than in PPMXL. We have also shown that using Rectified 2MASS as first epoch and URAT1 as second epoch for the determination of proper motions, in a similar way to the determination in URAT1, the systematic effects become negligible.

### 5. ACKNOWLEDGMENTS

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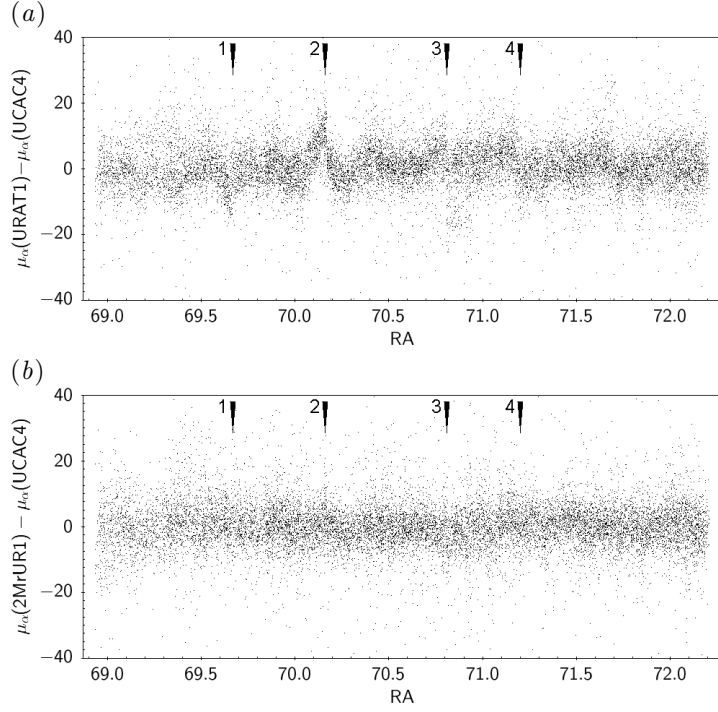


Fig. 2. (a) Differences of  $\mu_{\alpha}$  URAT1–UCAC4 in mas/yr. (b) Differences of  $\mu_{\alpha}$  2MrUR1–UCAC4 in mas/yr. The positions of the arrows are the same as in Figure 1.

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