Local systematic differences in 2MASS positions

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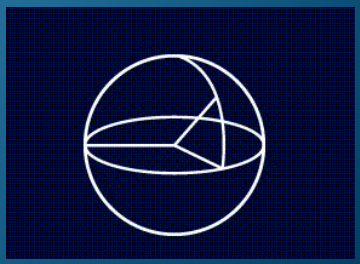

Note

This contribution is based on the following papers:

Bustos Fierro, I.H. & Calderón, J.H. 2016, RMxAA, 52, 143

Bustos Fierro, I.H. & Calderón, J.H. 2016, RMxAA, 52, 413

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A METHOD FOR LOCAL RECTIFICATION OF 2MASS POSITIONS WITH UCAC4

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RESUMEN

Se propone rectificar localmente 2MASS con respecto a UCAC4 con el fin de disminuir las diferencias sistemáticas entre estos catálogos. Se desarrolla un método de rectificación que parte del cálculo de diferencias medias ponderadas 2MASS−UCAC4 en una cuadrícula regular en el cielo. Las correcciones que posteriormente se aplican a las posiciones 2MASS se obtienen mediante una interpolación *spline* de los valores medios calculados en la malla. El método se probó en cuatro campos de 3°×3° en la zona ecliptical. Después de la rectificación en todos ellos las diferencias sistemáticas se reducen muy por debajo de las diferencias aleatorias. El catálogo 2MASS rectificado con el método propuesto puede considerarse como una extensión de UCAC4 para su uso en astrometría con una precisión de alrededor de 90 milisegundos de arco, y con errores sistemáticos despreciables, por ejemplo para la reducción astrométrica de imágenes CCD de pequeño campo.

ABSTRACT

We propose to locally rectify 2MASS with respect to UCAC4 in order to diminish the systematic differences between these catalogs. We develop a rectification method that starts computing the weighted mean differences 2MASS−UCAC4 on a regular grid on the sky. The corrections that are later applied to 2MASS positions are obtained by a spline interpolation of the mean values calculated on the grid. The method is tested in four 3°×3° fields in the ecliptical zone; after rectification in all of them the systematic differences are reduced well below the random differences. The 2MASS catalog rectified with the proposed method can be regarded as an extension of UCAC4 for astrometry, with an accuracy of around 90 mas in the positions, and with negligible systematic errors, for instance for the astrometric reduction of small field CCD images.

Key Words: astrometry — catalogs — methods: data analysis — methods: miscellaneous

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LOCAL SYSTEMATIC DIFFERENCES IN PROPER MOTIONS DERIVED FROM 2MASS POSITIONS

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RESUMEN

Queremos llamar la atención sobre las diferencias sistemáticas locales que aparecen en los movimientos propios derivados de posiciones 2MASS cuando se comparan con otros catálogos astrométricos como UCAC4, SPM4 y USNO-B1. Se demuestra que efectivamente 2MASS causa estos efectos sistemáticos en los movimientos propios de PPMXL y URAT1. También se muestra que usando posiciones 2MASS rectificadas con respecto a UCAC4 se elimina el patrón sistemático de los movimientos propios de URAT1. Por lo tanto proponemos el uso de las posiciones de 2MASS rectificadas con respecto a UCAC4 para la determinación de movimientos propios libres de los efectos sistemáticos de 2MASS.

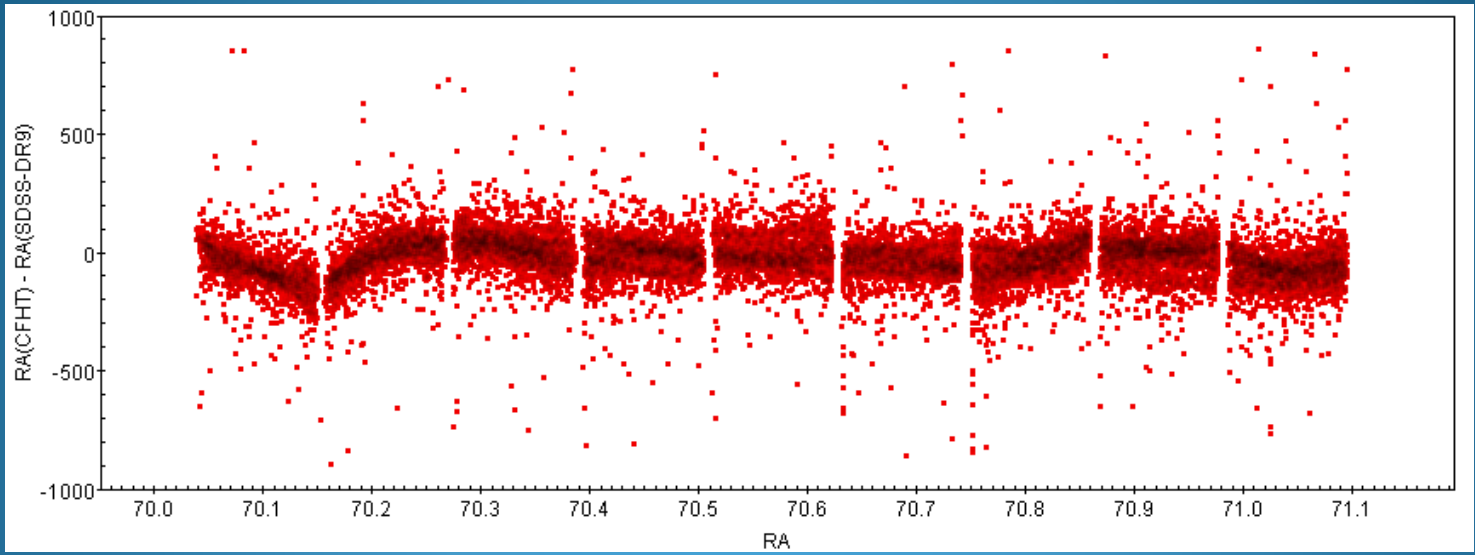
ABSTRACT

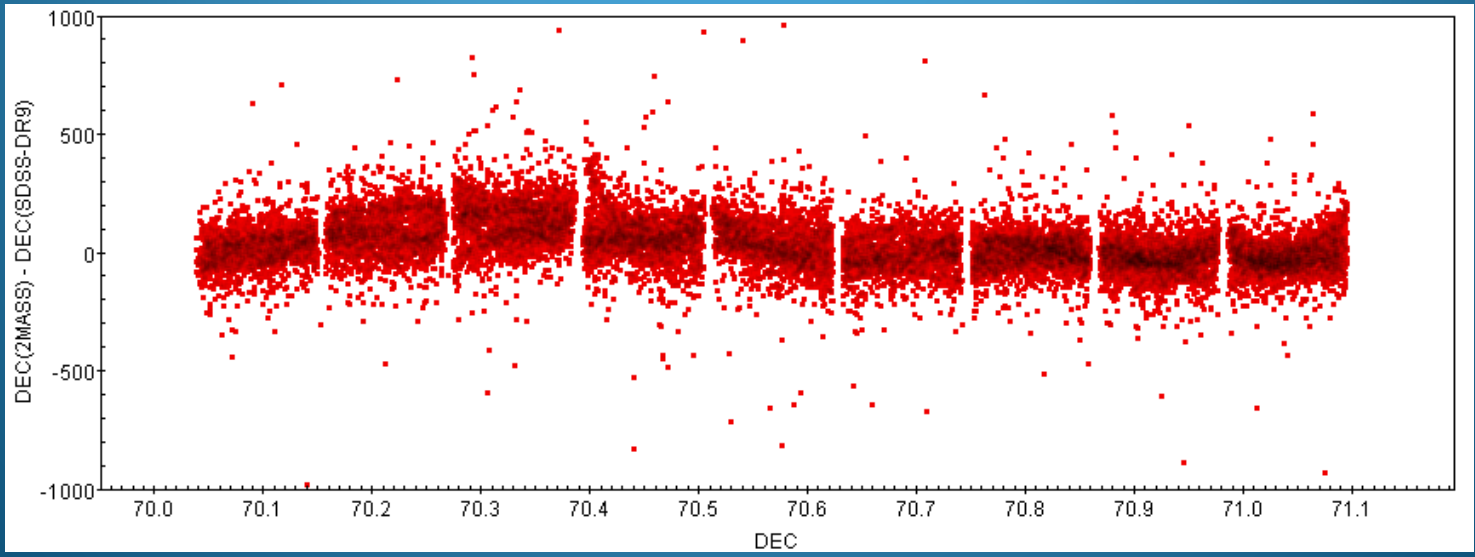
We want to draw attention to local systematic differences that appear in the proper motions derived from 2MASS positions when they are compared with other astrometric catalogs such as UCAC4, SPM4 and USNO-B1. It is shown that 2MASS effectively causes these systematic effects in the proper motions of PPMXL and URAT1. Also it is shown that using 2MASS positions rectified with respect to UCAC4 the systematic pattern of the proper motions of URAT1 is eliminated. Therefore, we propose the use of rectified 2MASS positions in order to derive proper motions free from 2MASS systematics.

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

Motivation

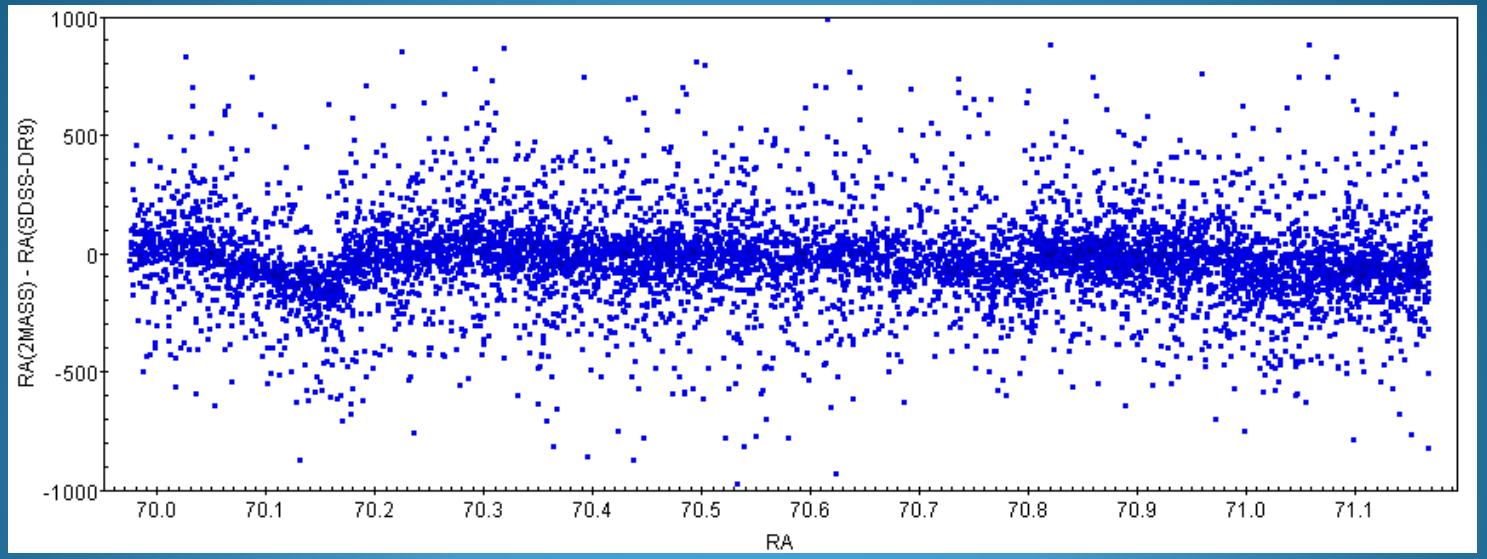
Comparison of CFHT astrometric reduction using 2MASS as the reference catalog with SDSS-DR9. (Zone1)

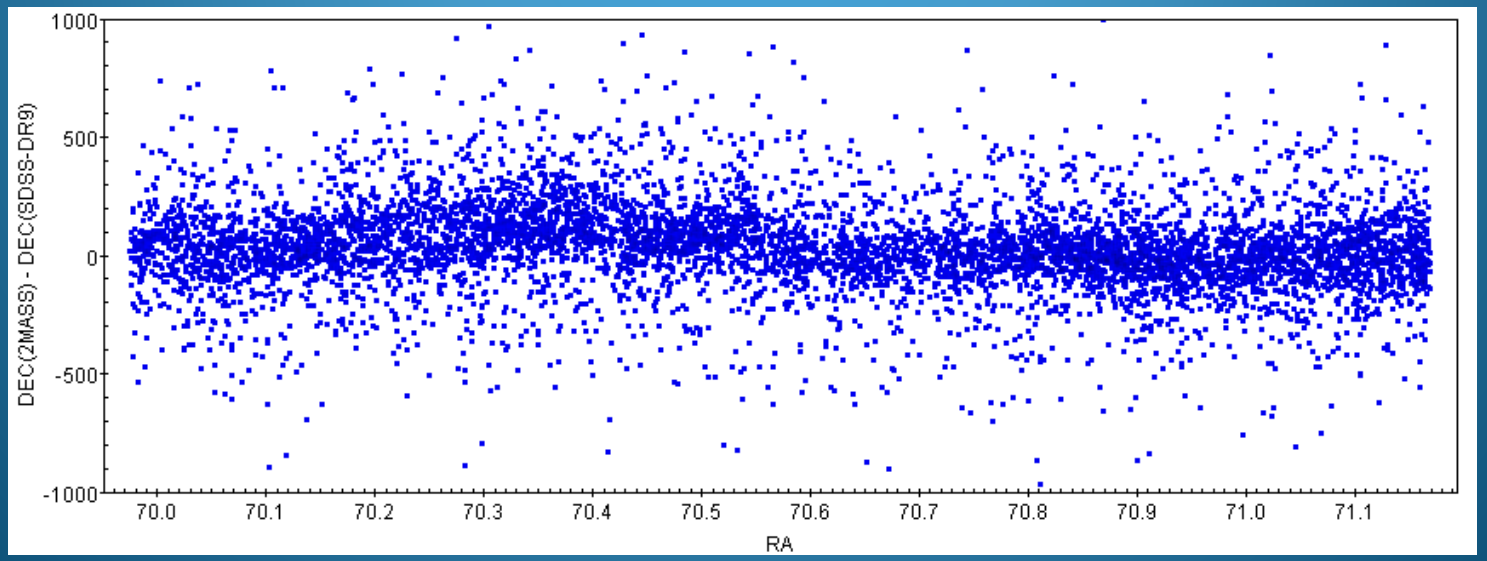




Motivation

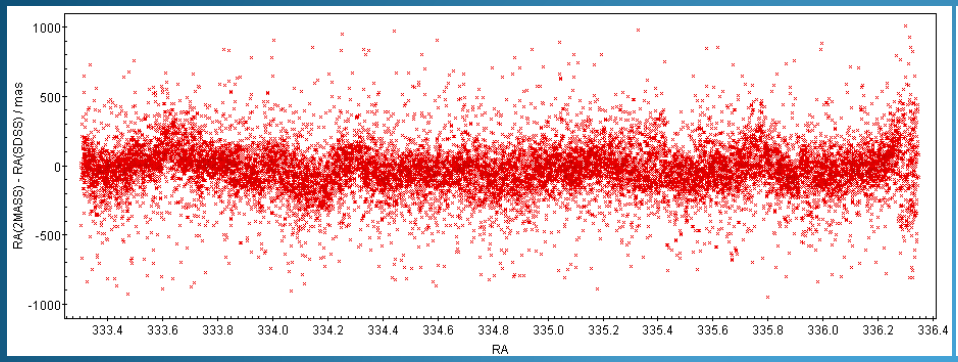
Comparison 2MASS vs SDSS-DR9. (Zone1)

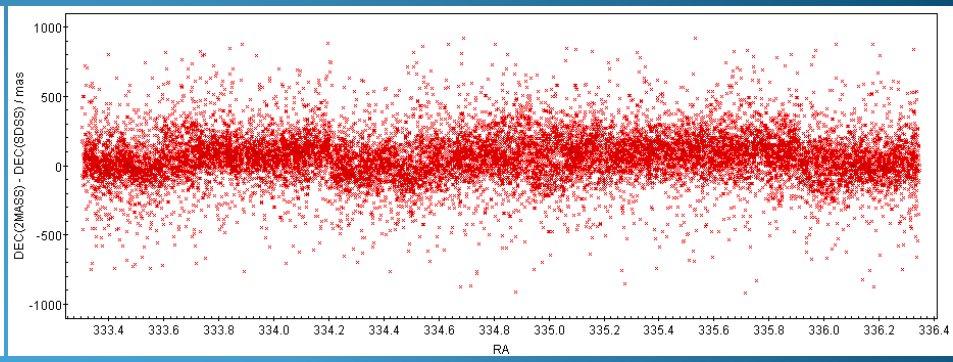




Differences in positions of 2MASS vs other catalogs

2MASS – SDSS (Zone1-90)

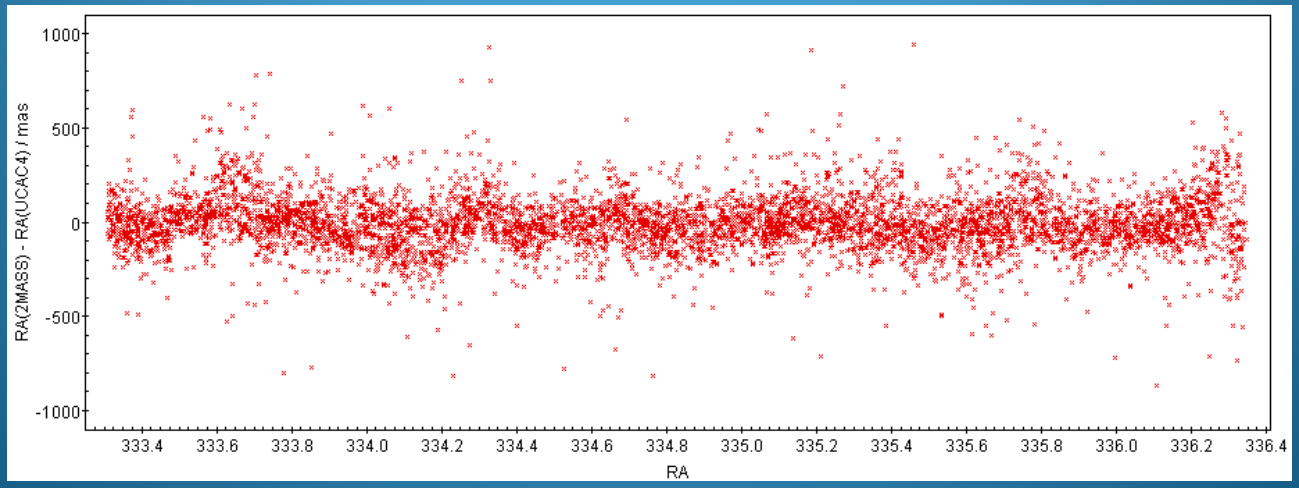




$\Delta\alpha$ = (-24 ± 193)mas

$\Delta\delta$ = (58 ± 184)mas

2MASS – UCAC4 (Zone1-90)

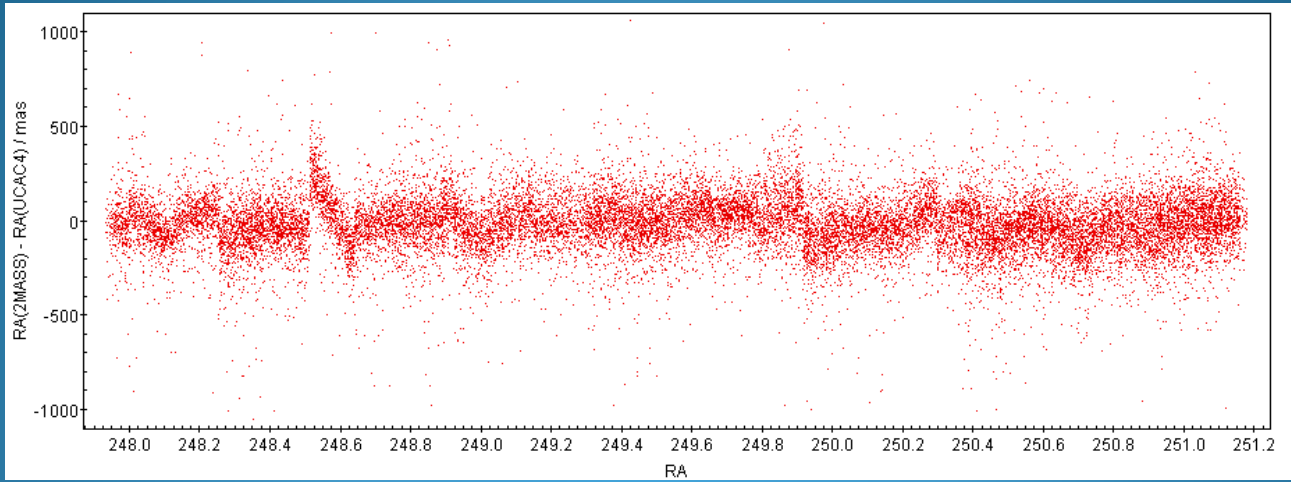


$\Delta\alpha$ = (-6 ± 148)mas

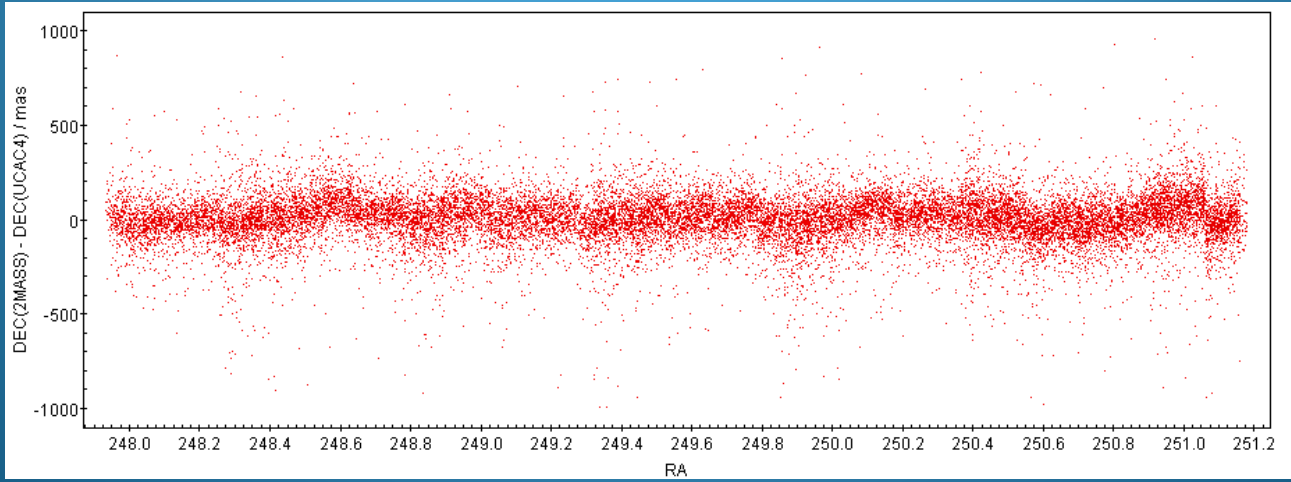
$\Delta\delta$ = (39 ± 145)mas

Differences in positions of 2MASS vs other catalogs

2MASS – UCAC4 (Zone1+180)



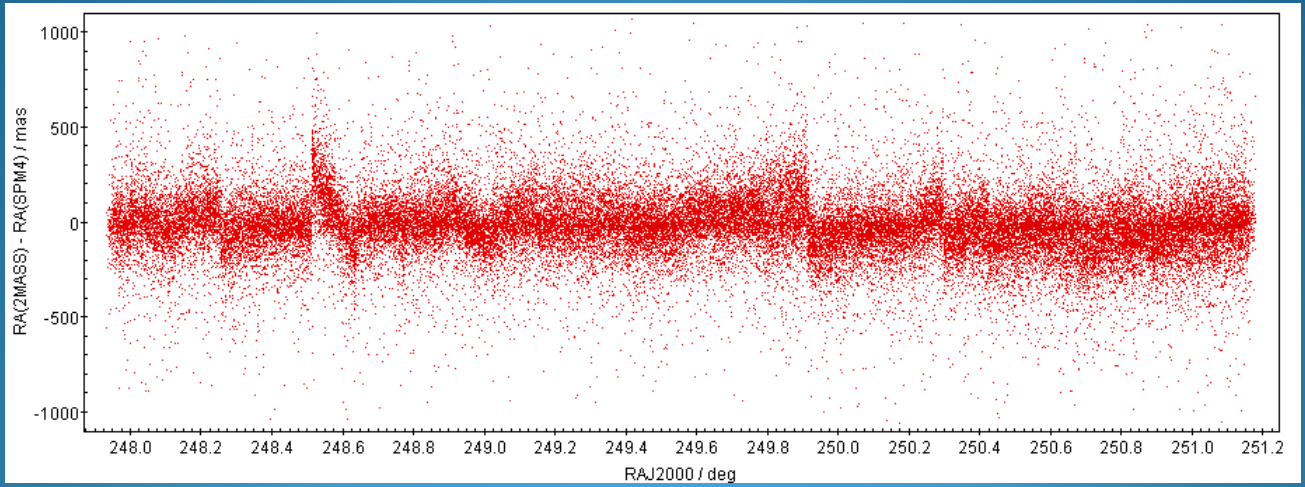
$\Delta\alpha$ = (-18 ± 156)mas



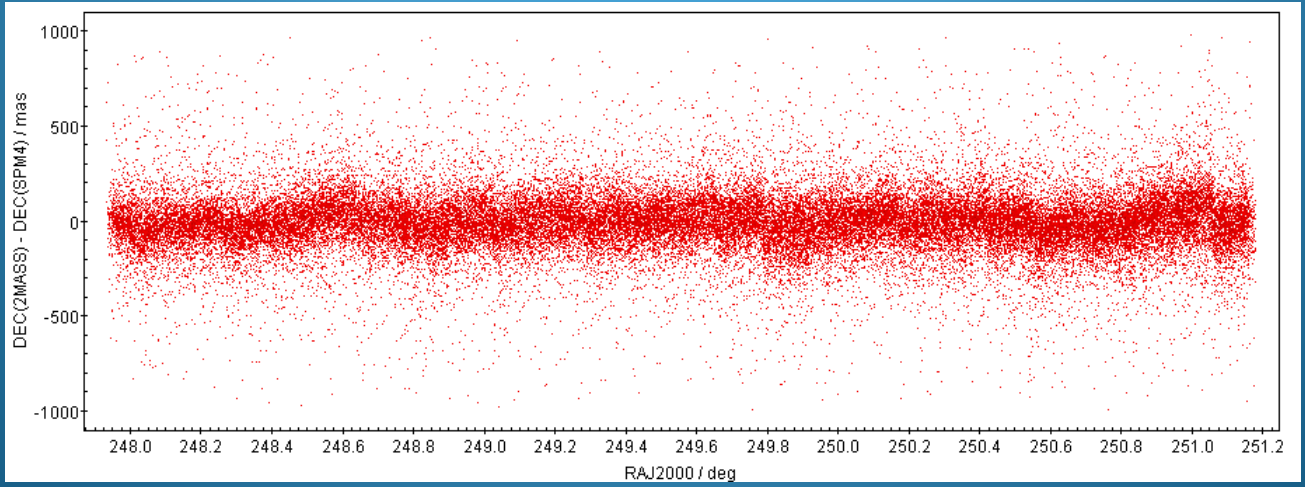
$\Delta\delta$ = (6 ± 134)mas

Differences in positions of 2MASS vs other catalogs

2MASS – SPM4 (Zone1+180)



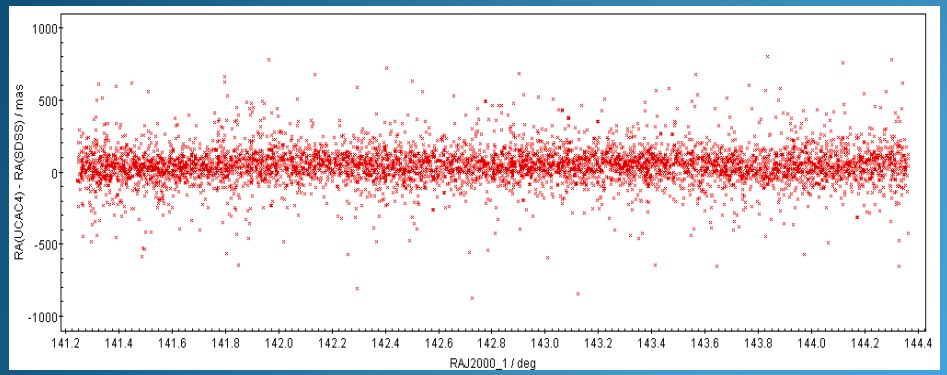
$\Delta\alpha$ = (-17 ± 181)mas

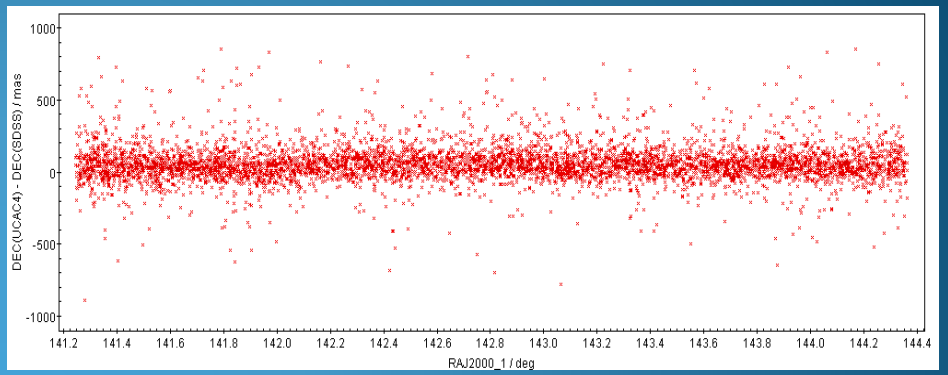


$\Delta\delta$ = (-8 ± 164)mas

Differences in positions of UCAC4 vs other catalogs

UCAC4 – SDSS (Zone1+90)

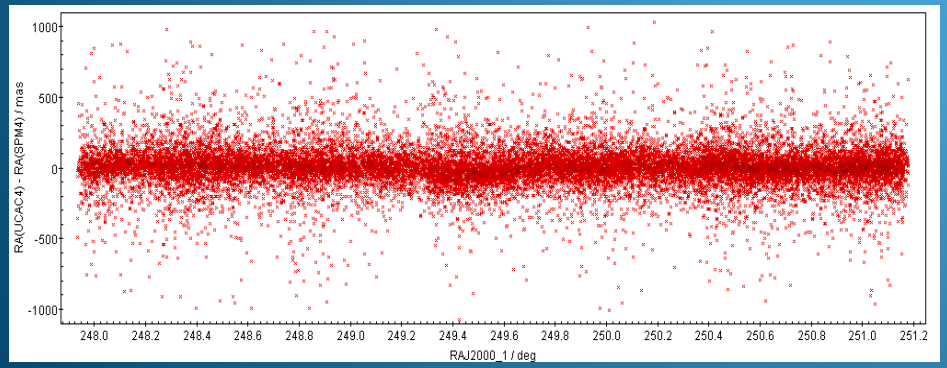


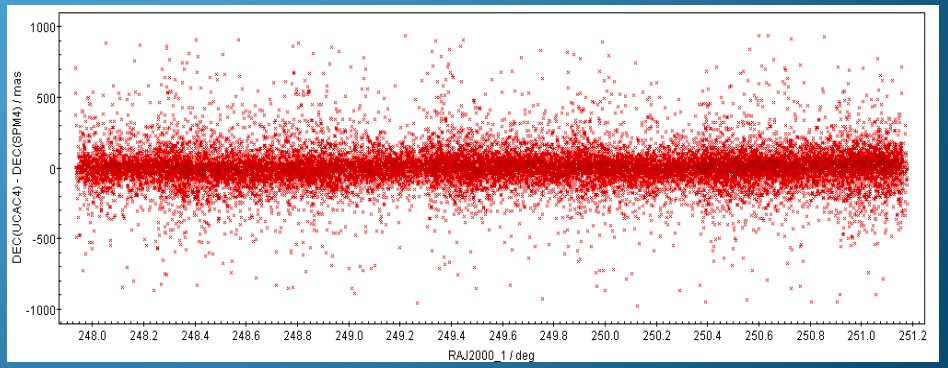


$\Delta\alpha$ = (46 ± 131)mas

$\Delta\delta$ = (57 ± 128)mas

UCAC4 – SPM4 (Zone1+180)





$\Delta\alpha$ = (7 ± 153)mas

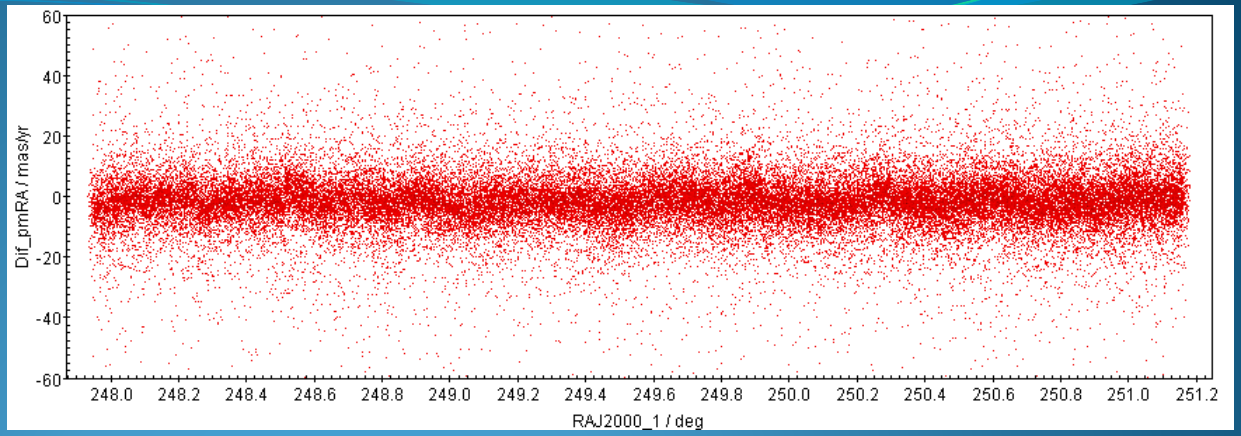
$\Delta\delta$ = (1 ± 145)mas

Differences in proper motions

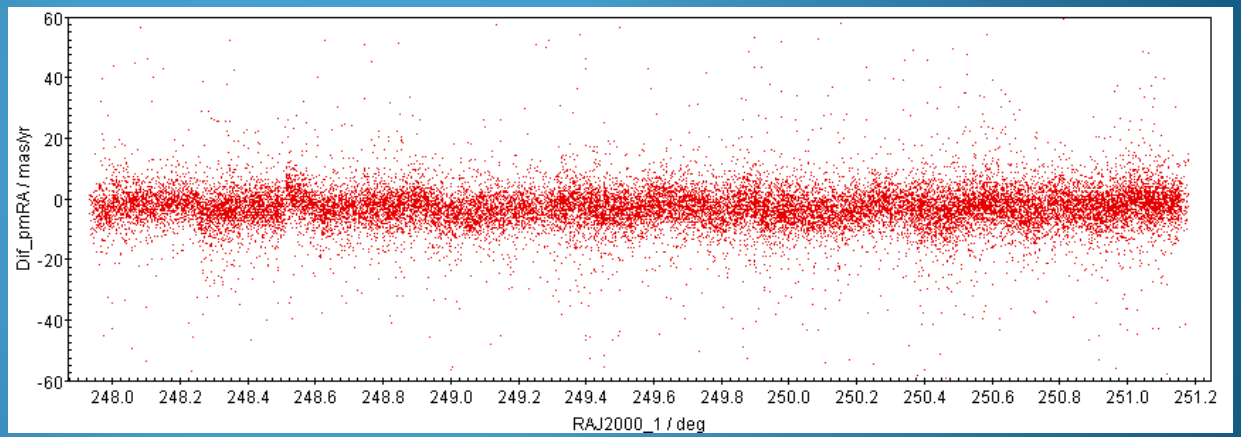
Zone1+180 (southern)

2MASS-based

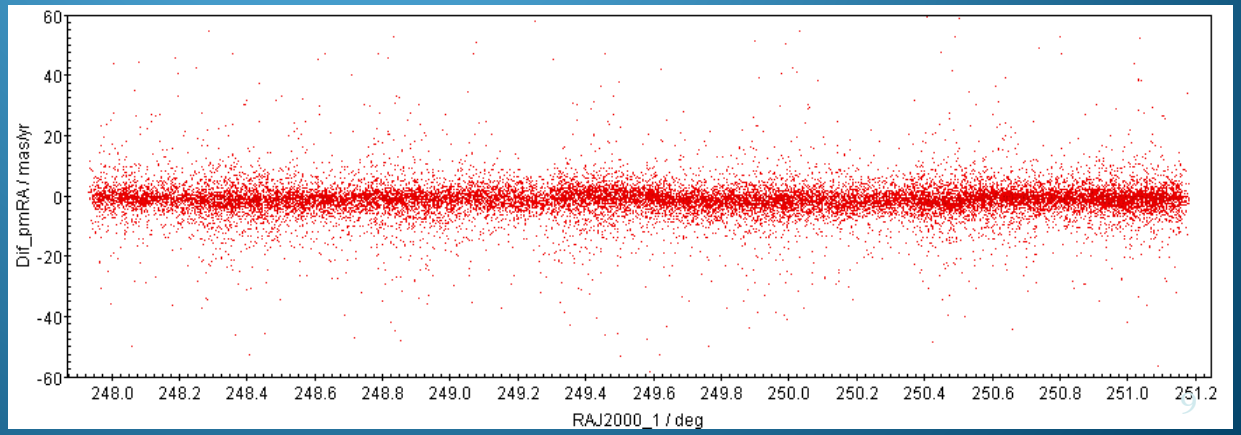
PPMXL – SPM4



PPMXL – UCAC4



SPM4 – UCAC4

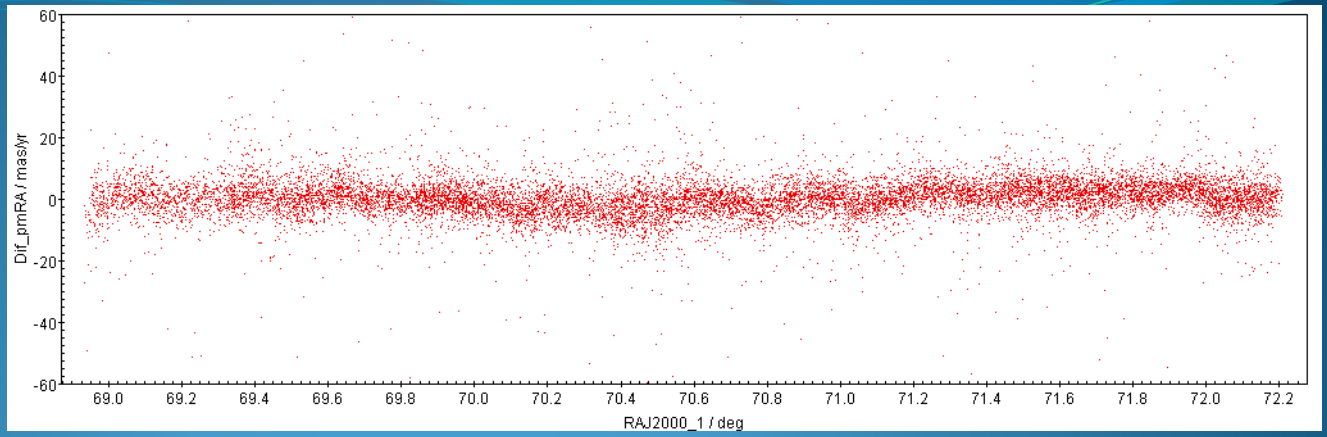


Differences in proper motions

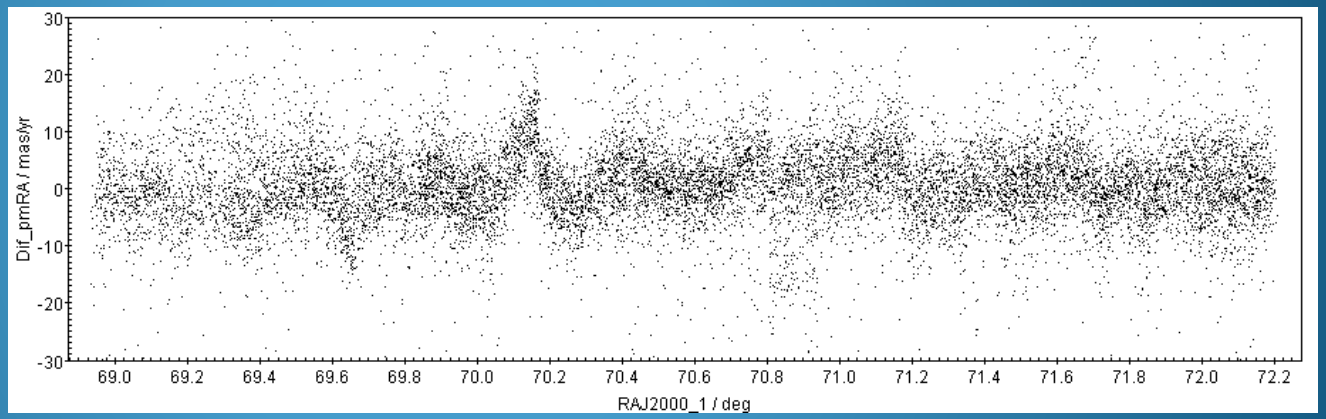
Zone1 (northern)

2MASS-based

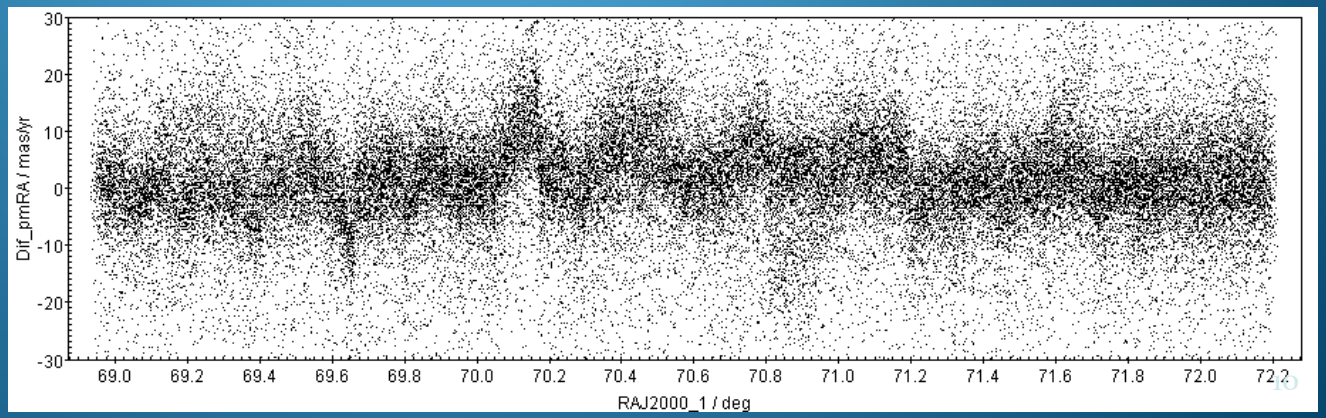
PPMXL – UCAC4



URAT1 – UCAC4



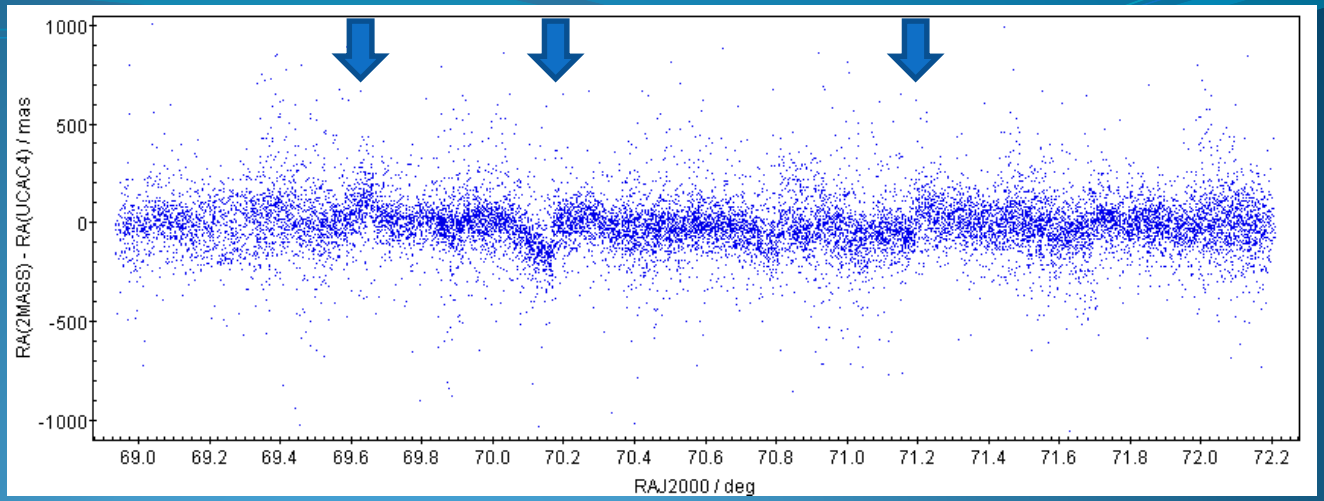
URAT1 – USNOB1



Coincidence of systematics in positions with systematics in proper motions

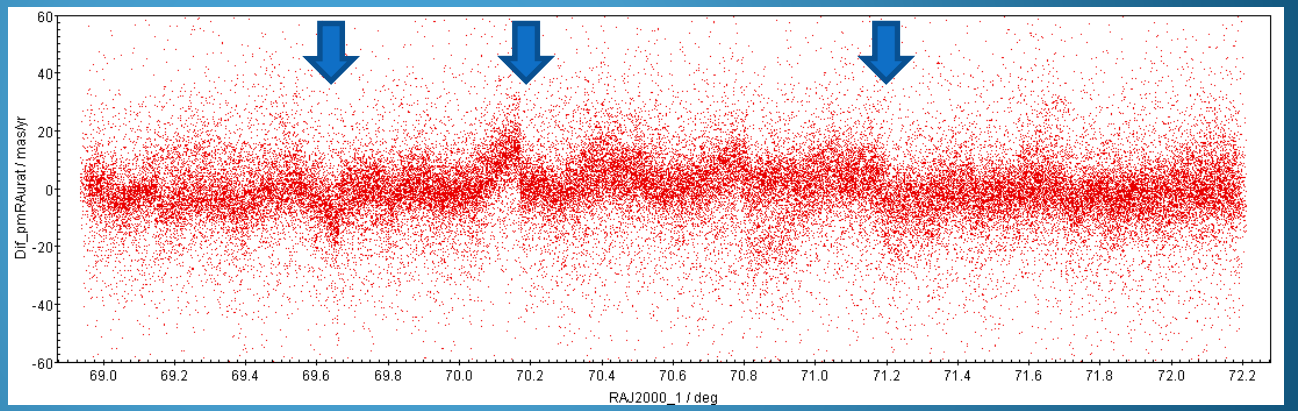
Differences in positions

2MASS – UCAC4



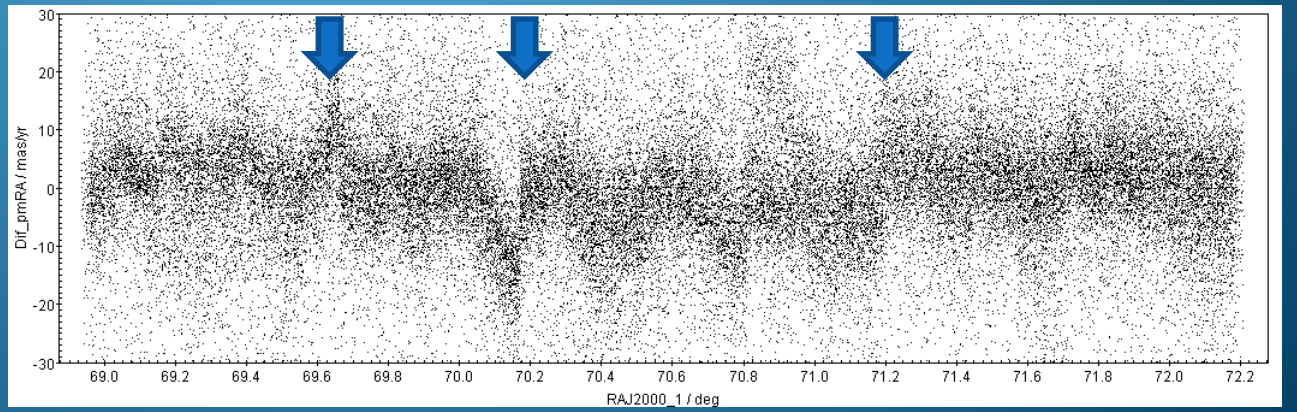
Differences in proper motions

URAT1 – UCAC4



PPMXL – URAT1

2MASS-based



Rectification method: procedure

- Define working field 3^ox 3^o
- Match UCAC4 and 2MASS positions within 1”
- Calculate differences ($\alpha_{UCAC4} - \alpha_{2MASS}$; $\delta_{UCAC4} - \delta_{2MASS}$)
- Define a square grid of step r=1’: nodes (α_g, δ_g)
- In every (α_g, δ_g) a *smoothing area* is centered
- Compute weighted mean differences ($\alpha_{UCAC4} - \alpha_{2MASS}$; $\delta_{UCAC4} - \delta_{2MASS}$)

Rectification method: weight function

We use as weight function a two-dimensional Gaussian

$$w(x.y) = w_x(x) \times w_y(y)$$

where $x = \alpha - \alpha_g \quad y = \delta - \delta_g$

$w_x(x)$ and $w_y(y)$ are computed as

$$w_x(x) = (exp\ (-\ x^2/2\sigma_x^2)\ -\ exp\ (-\ \mathcal{K}))/\sigma_x \quad \text{if} \quad |x| \le 3\sigma_x$$

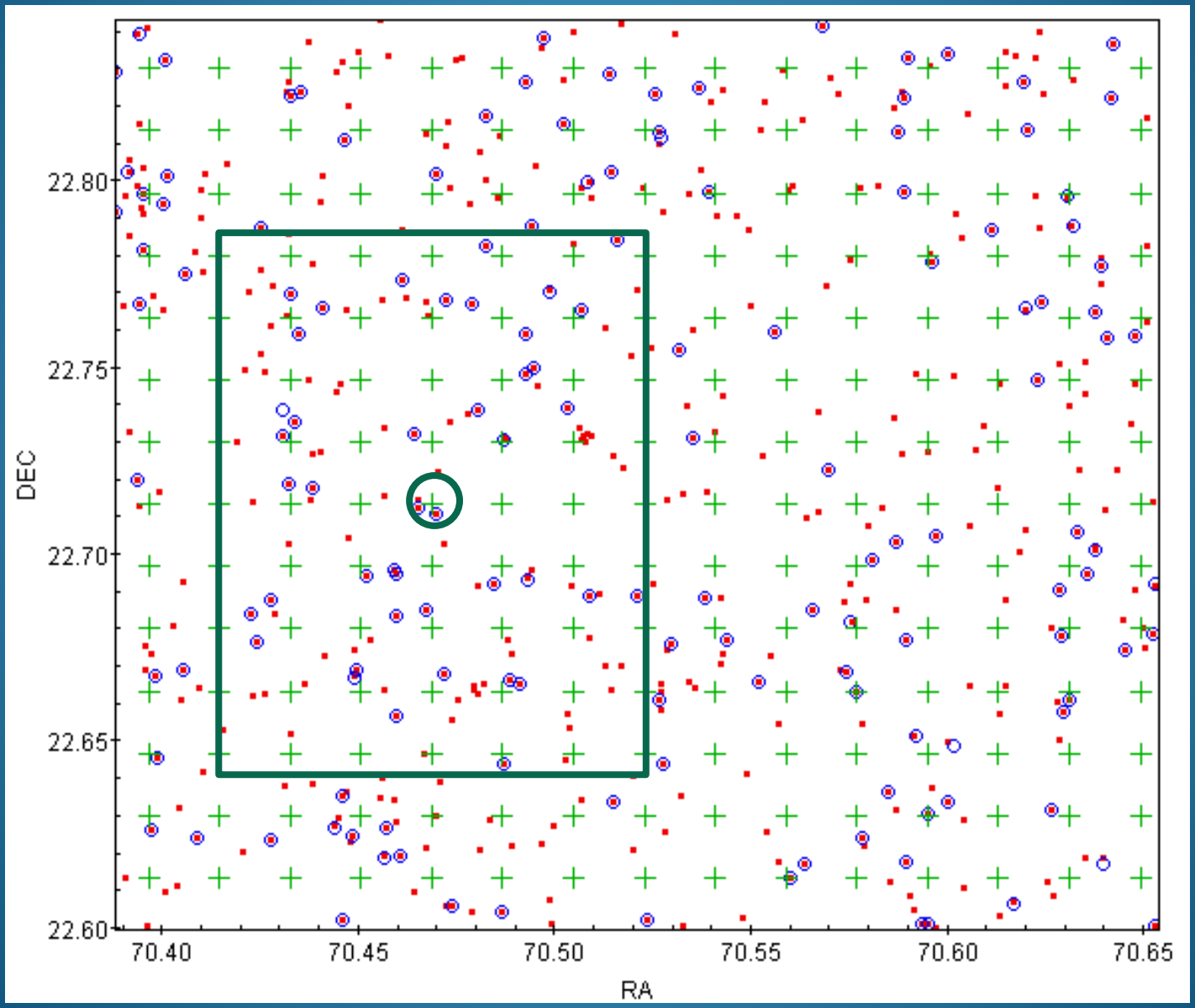
$$w_x(x) = 0 \quad \text{if} \quad |x| > 3\ \sigma_x$$

$$w_y(y) = (exp\ (-\ y^2/2\sigma_y^2)\ -\ exp\ (-\ \mathcal{K}))/\sigma_y \quad \text{if} \quad |y| \le 3\sigma_y$$

$$w_y(y) = 0 \quad \text{if} \quad |y| > 3\ \sigma_y$$

$\mathcal{K}$ was selected in such a way that when $w_x(x) = 0$ if $x = 3\sigma_x$ and $w_y(y) = 0$ if $x = 3\sigma_y$ hence $\mathcal{K} = 9/2$. Here σ_x and σ_y are the widths of RA and DEC of the weight function. With this definition the size of the *smoothing area* is $6\sigma_x \times 6\sigma_y$. The numerical value of σ_x is always between 0.5′ and 1.0′.

Rectification method: the smoothing area



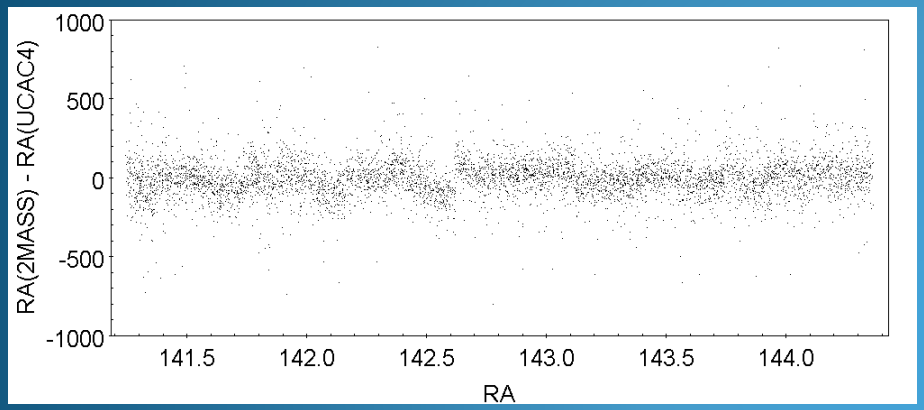
Rectification method: procedure

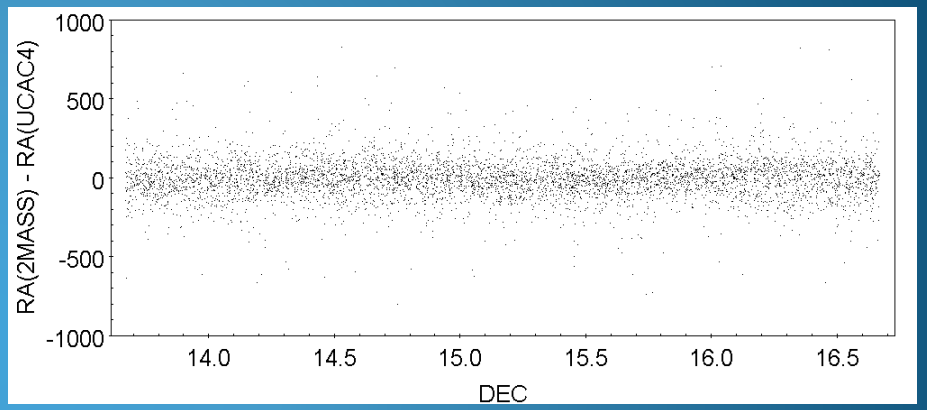
- Define working field 3^ox 3^o
- Match UCAC4 and 2MASS positions within 1”
- Calculate differences ($\alpha_{UCAC4} - \alpha_{2MASS}$; $\delta_{UCAC4} - \delta_{2MASS}$)
- Define a square grid of step r=1’: nodes (α_g, δ_g)
- In every (α_g, δ_g) a *smoothing area* is centered
- Compute weighted mean differences ($\alpha_{UCAC4} - \alpha_{2MASS}$; $\delta_{UCAC4} - \delta_{2MASS}$)
- Compute correction ($\Delta\alpha$, $\Delta\delta$) by two-dimensional cubic spline interpolation

Results – Rectification of 2MASS positions

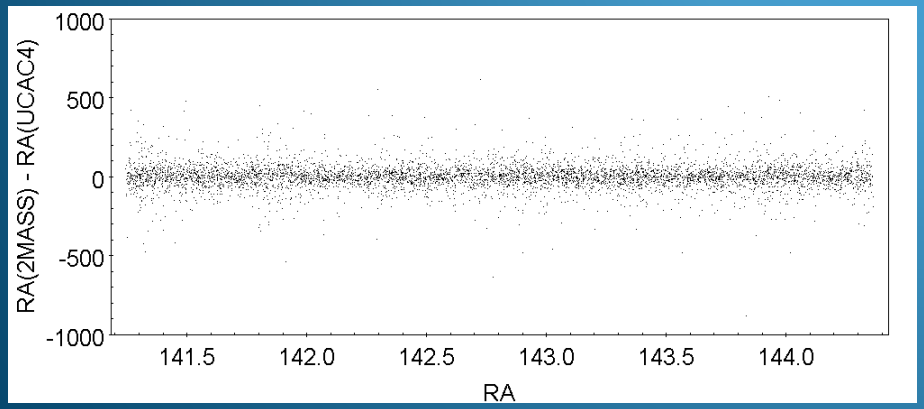
Differences 2MASS – UCAC4 in RA (Zone1+90 - North)

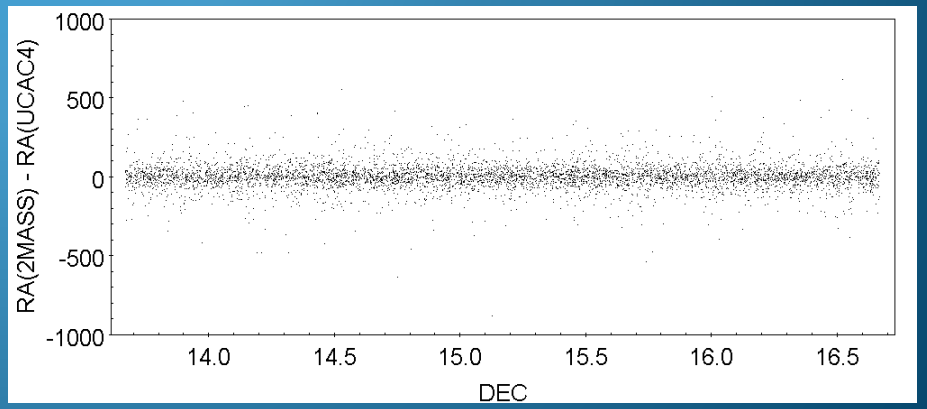
Before rectification





After rectification

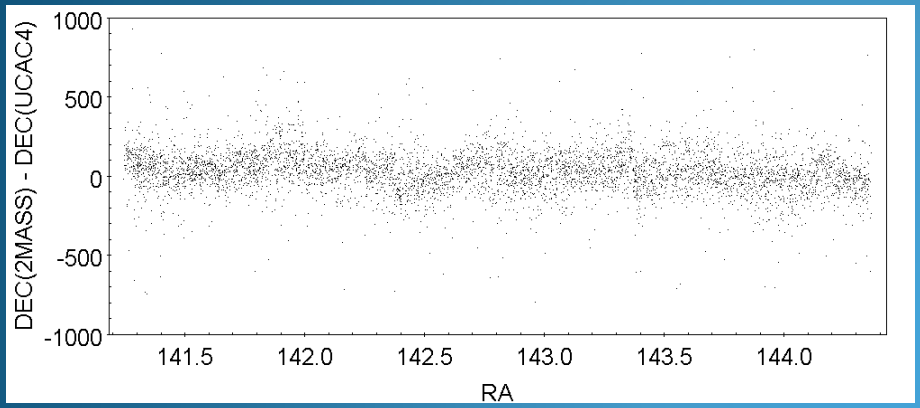


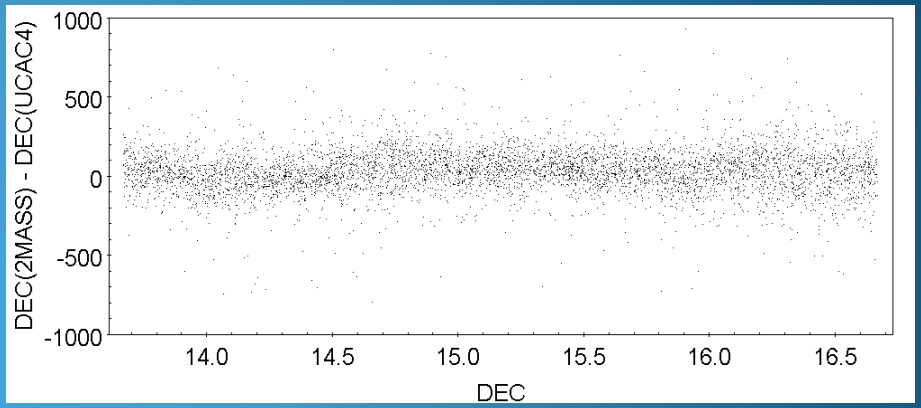


Results – Rectification of 2MASS positions

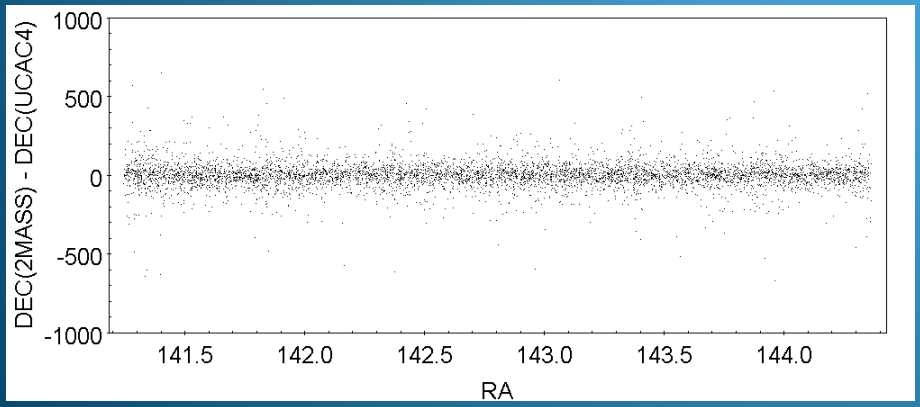
Differences 2MASS – UCAC4 in DEC (Zone1+90 - North)

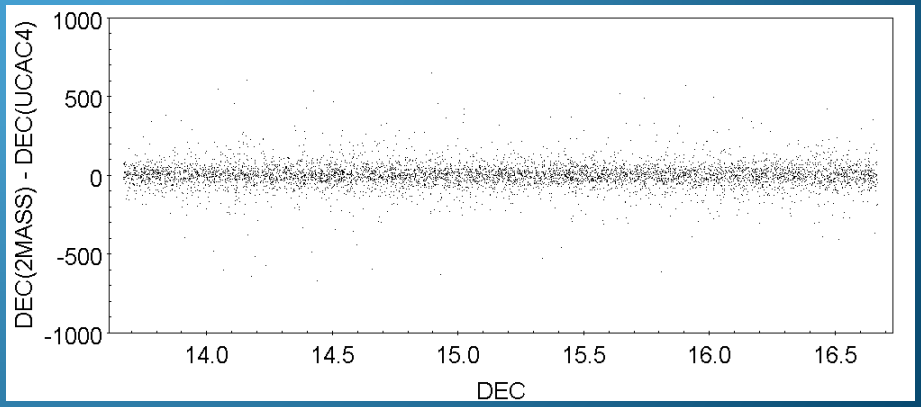
Before rectification





After rectification





Results – Rectification of 2MASS positions

Comparison of mean differences and standard deviations in four different zones on the sky

TABLE 2

COMPARISONS WITH UCAC4[a]

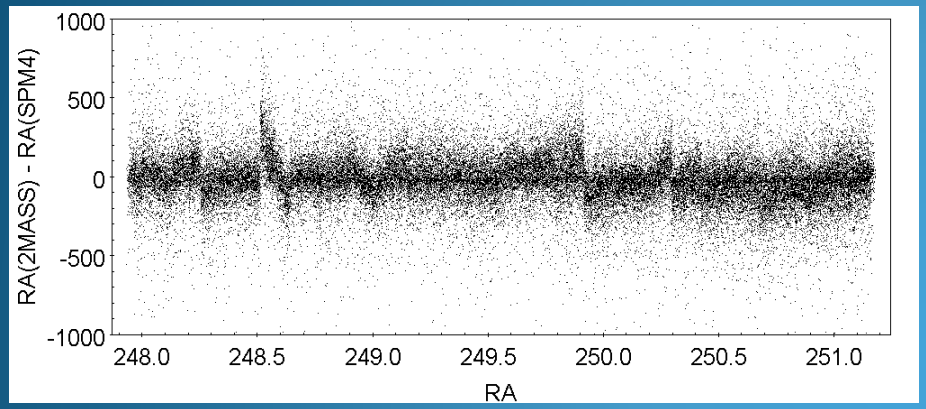
	Before rectification		After rectification	
Field	ΔRA	ΔDEC	ΔRA	ΔDEC
Zone 1	-10 ± 145	2 ± 138	0 ± 100	0 ± 96
Zone $1+90$	-5 ± 126	29 ± 137	0 ± 81	0 ± 83
Zone $1-90$	-6 ± 148	39 ± 145	0 ± 94	0 ± 89
Zone $1+180$	-18 ± 156	6 ± 134	0 ± 104	0 ± 95

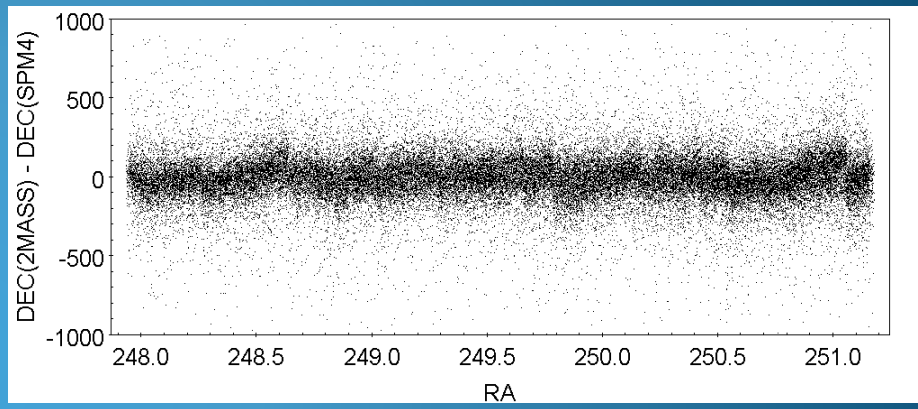
[a]Mean differences and standard deviations in mas.

Results – Rectification of 2MASS positions (RA)

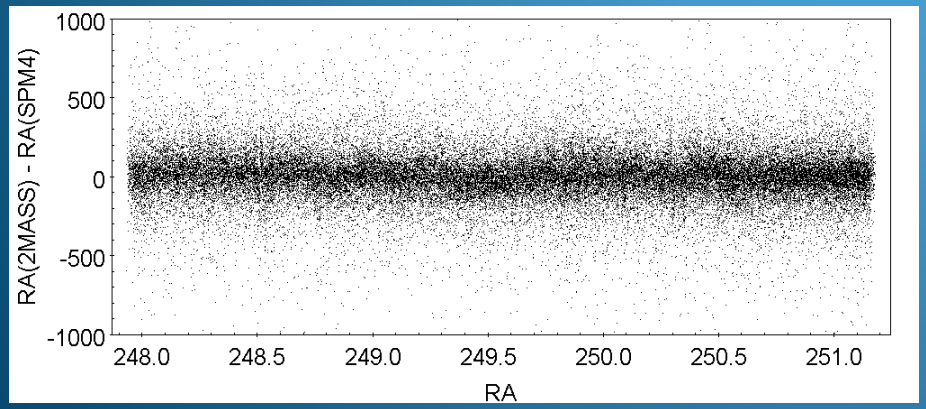
Differences 2MASS – SPM4 in RA (Zone1+180 - South)

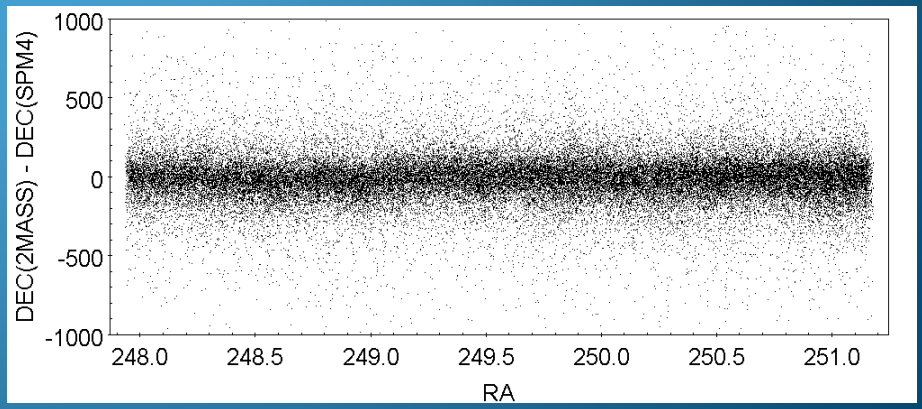
Before rectification





After rectification





Results – Rectification of 2MASS positions

Comparison of mean differences and standard deviations with external catalogs in four different zones on the sky

TABLE 3

COMPARISONS WITH EXTERNAL CATALOGS[a]

	Before rectification		After rectification	
Field	ΔRA	ΔDEC	ΔRA	ΔDEC
Zone 1	-18 ± 204	42 ± 190	-5 ± 200	40 ± 185
Zone $1+90$	38 ± 195	82 ± 194	44 ± 191	53 ± 185
Zone $1-90$	-24 ± 193	58 ± 184	-18 ± 183	22 ± 177
Zone $1+180$	-17 ± 181	-8 ± 164	3 ± 175	-15 ± 166

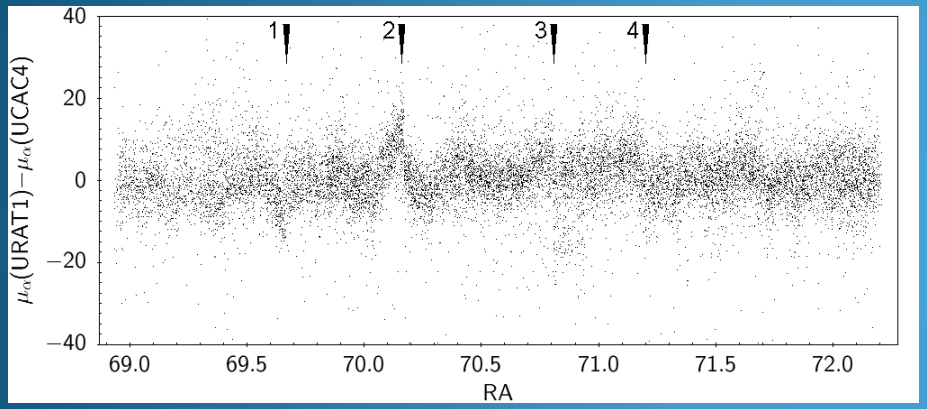
[a]SDSS-DR9 in Zone 1, Zone $1+90$, Zone $1-90$; SPM4 in Zone $1+180$. Mean differences and standard deviations in mas.

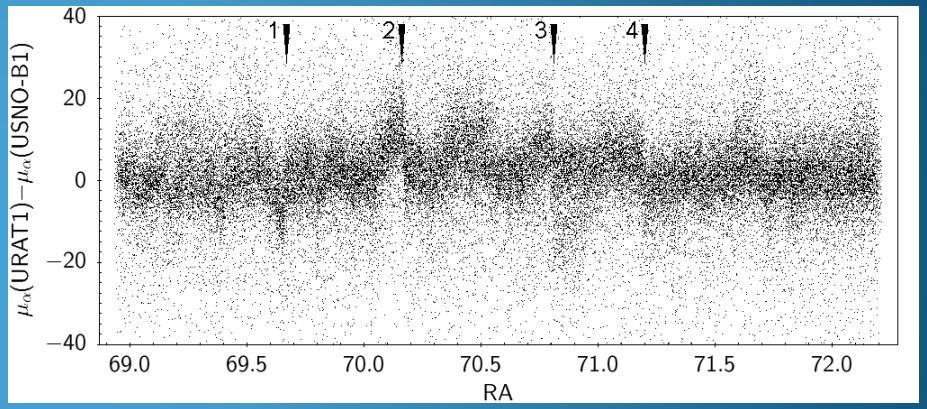
Results – Proper motions derived from rectified 2MASS positions

$$\mu_\alpha(\mathrm{2MrUR1}) = \frac{(\alpha_{URAT1} - \alpha_{2MASSr})cos\delta}{Epoch_{URAT1} - Epoch_{2MASS}}$$

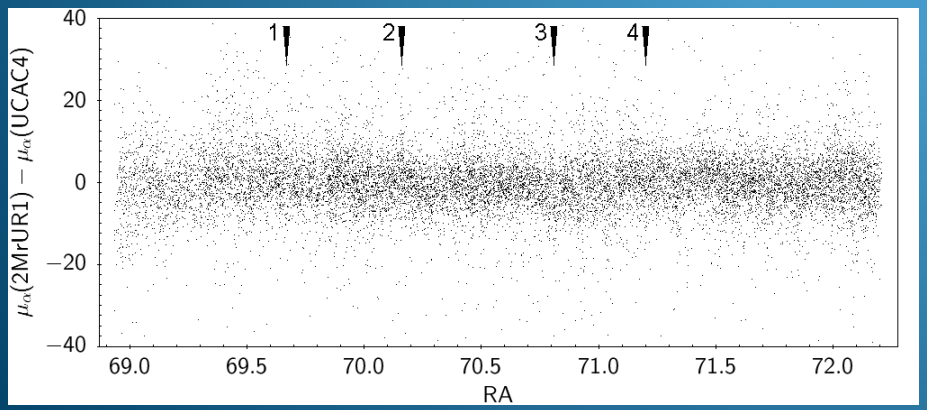
$$\mu_\delta(\mathrm{2MrUR1}) = \frac{\delta_{URAT1} - \delta_{2MASSr}}{Epoch_{URAT1} - Epoch_{2MASS}}$$

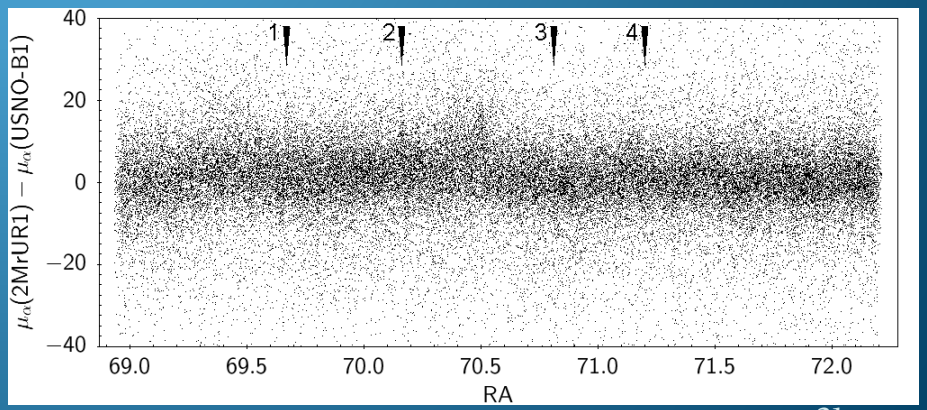
Proper motions from original 2MASS positions (URAT1)





Proper motions from rectified 2MASS positions





Work in progress:

The catalog 2MASS revised astrometry ⇔ 2MASSra

Modifications in the rectification method

Rectification performed in the tangent plane

Working fields size variable with declination from 3°x 3° to 1°x 1°

Full sky coverage

Working fields overlap ~10’ to 15’ in both coordinates

Working fields combined in declination strips

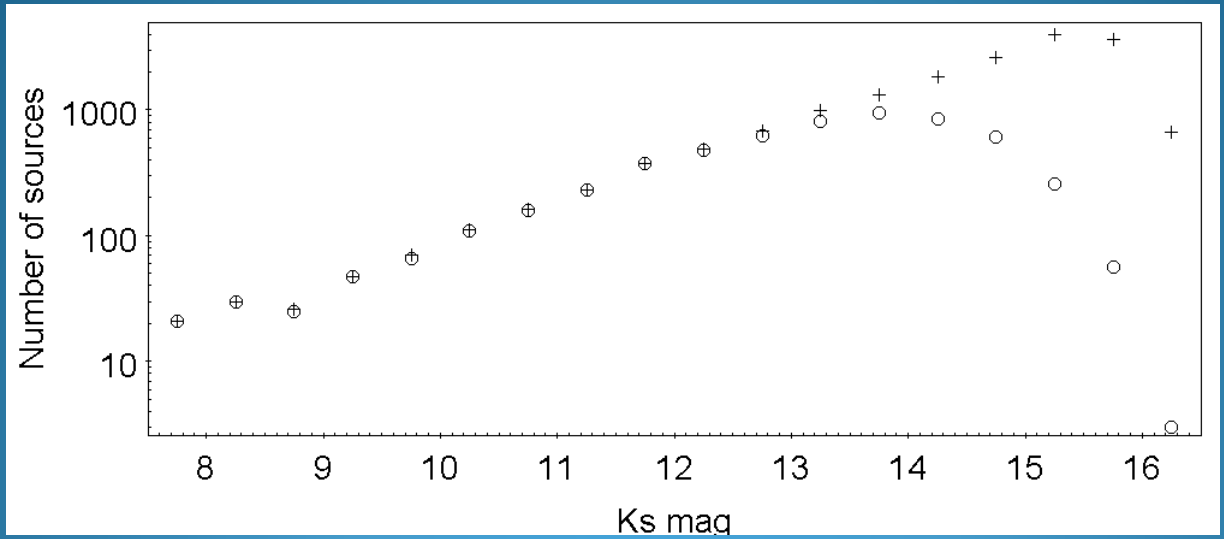
Declination strips combined in larger regions

Update for Gaia DR1 ?

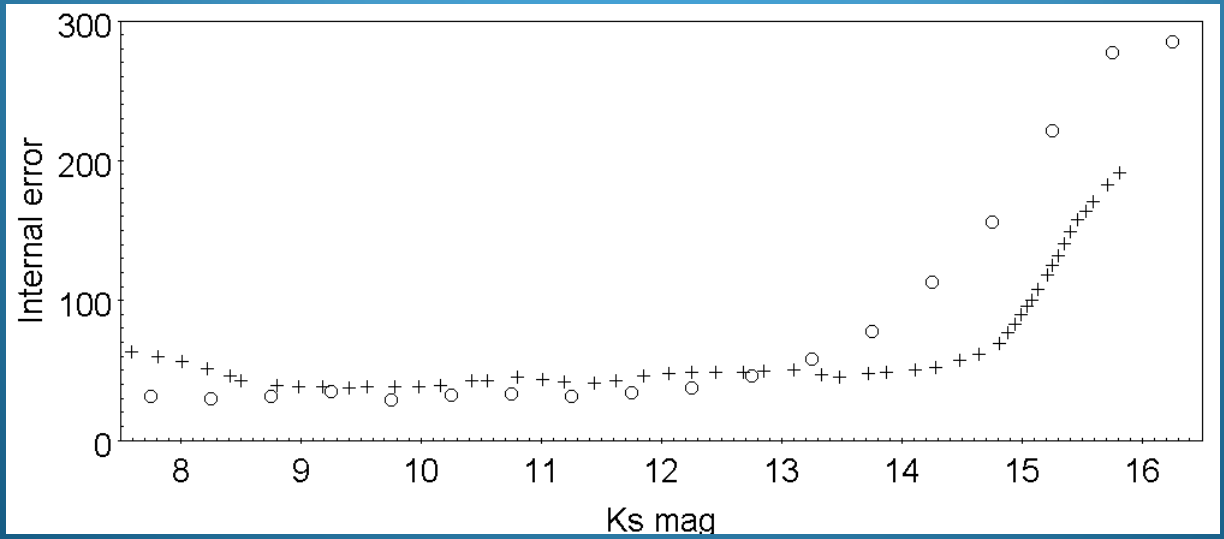
Conclusions

- The proposed method was able to reduce the systematic differences between 2MASS and UCAC4 well below the random differences.
- The rms differences 2MASS-UCAC4 are reduced from ~140 mas to ~90 mas.
- The 2MASS catalog rectified with the proposed method can be regarded as an extension to magnitude Ks = 15 of UCAC4.

2MASSra as an extension of UCAC4



Circles: UCAC4. Crosses: 2MASS.



Conclusions

- The proposed method was able to reduce the systematic differences between 2MASS and UCAC4 well below the random differences.
- The rms differences are reduced from ~140 mas to ~90 mas.
- The 2MASS catalog rectified with the proposed method can be regarded as an extension to magnitude Ks = 15 of UCAC4.
- The proper motions of PPMXL and URAT1 are strongly affected by the systematic differences in positions observed in 2MASS.
- Using Rectified 2MASS as first epoch and URAT1 as second epoch for the determination of proper motions, the systematic effects become negligible.

2MASSra to be available by December 2016

Do not hesitate to contact us: ivanbf@oac.uncor.edu

Acknowledgments

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