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COMPARISON OF ASTROMETRIC CATALOGUES UCAC4, XPM, PPMXL

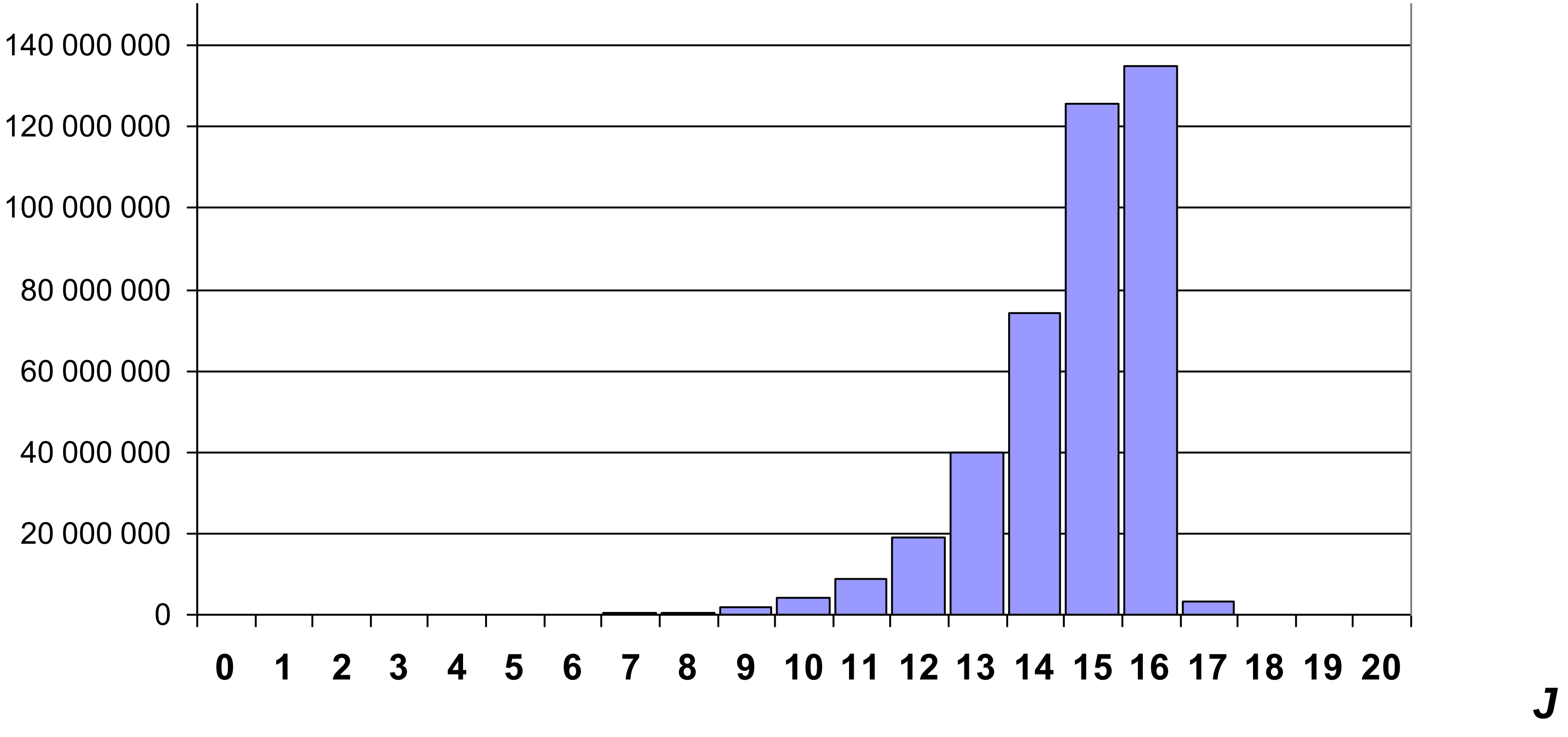
MOTIVATION

The pre-GAIA modern astrometric catalogues UCAC4, PPMXL and XPM with full coverage of the sky provide a qualitatively new material for investigations in various fields of astronomy.

According to inner logics of astrometry, the catalogues containing common stars should be compared. Aiming at the application to the stellar kinematics, we declare the first results of the comparison concerning the systematic differences of proper motions in the Galactic coordinate system

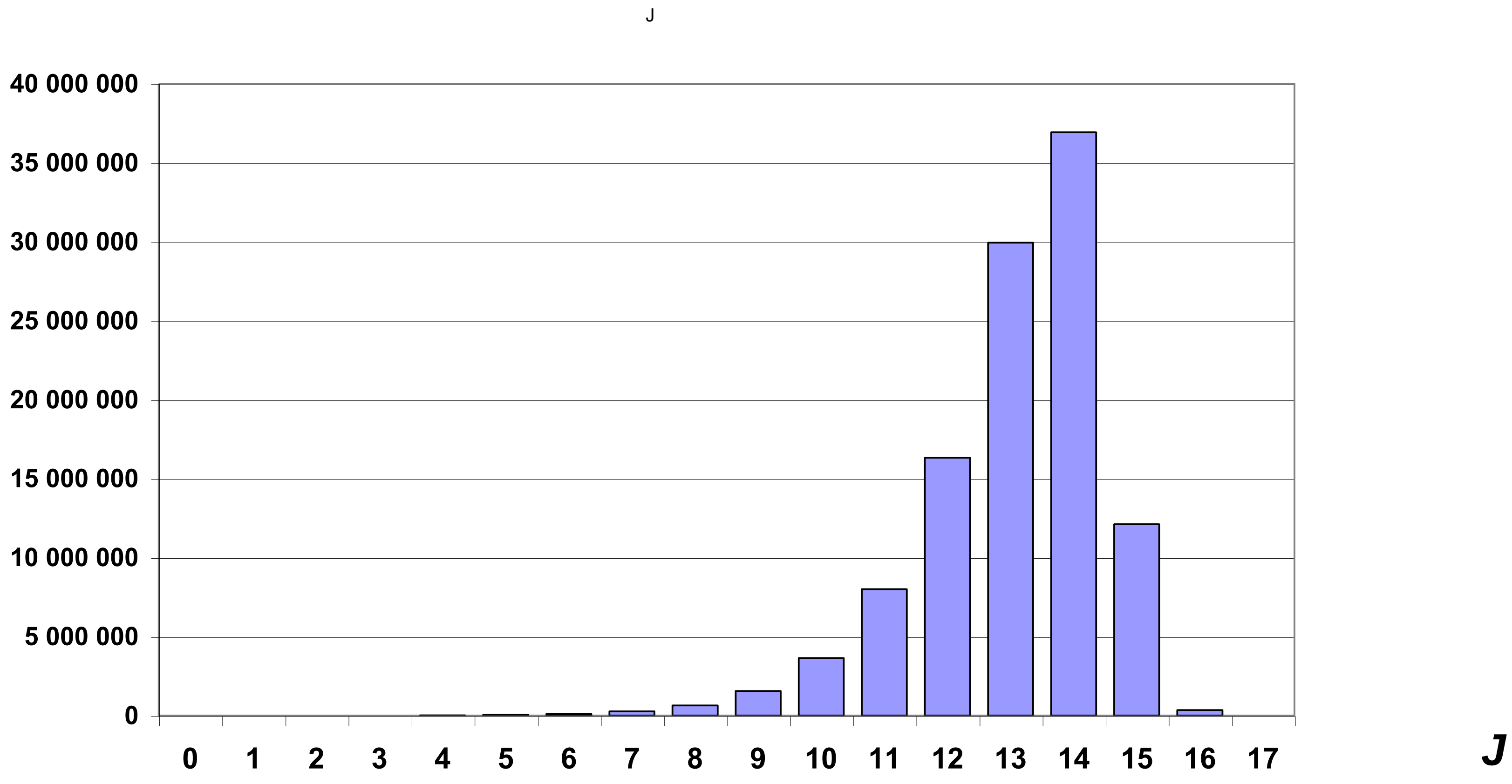
PPMXL

- At present, the largest catalogue of positions and proper motions is PPMXL
- It contains about 900 million objects and is probably full from the brightest stars down to about magnitude V=20 full-sky.
- In this work the stars down to J=17 are used only.
- The **proper motions are in the ICRS reference frame.**
- The mean errors of the proper motions range from 4 mas/y to more than 10 mas/y.



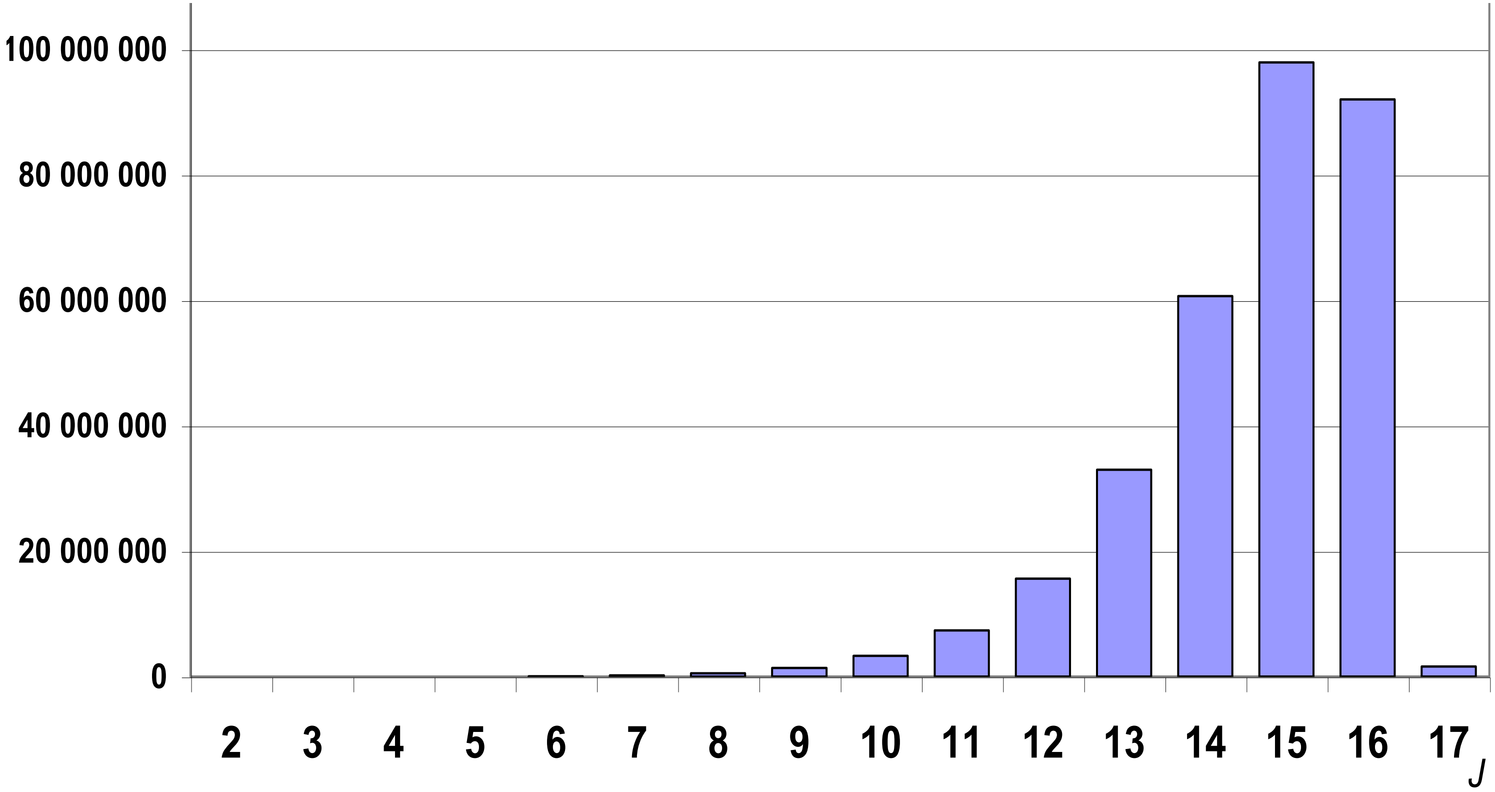
UCAC4

- The UCAC4 is an all-sky catalogue containing about 113 million stars covering mainly the 8 to 16 magnitude range in a single bandpass between V and R.
- The formal errors in PMs range from about 1 to 10 mas/y depending on magnitude and observing history.
- Systematic errors in PMs are estimated to be about 1-4 mas/y.
- The UCAC4 may be considered complete to about R=16.
- It contains accurate positions and **proper motions on the ICRS** at a mean epoch around 2000

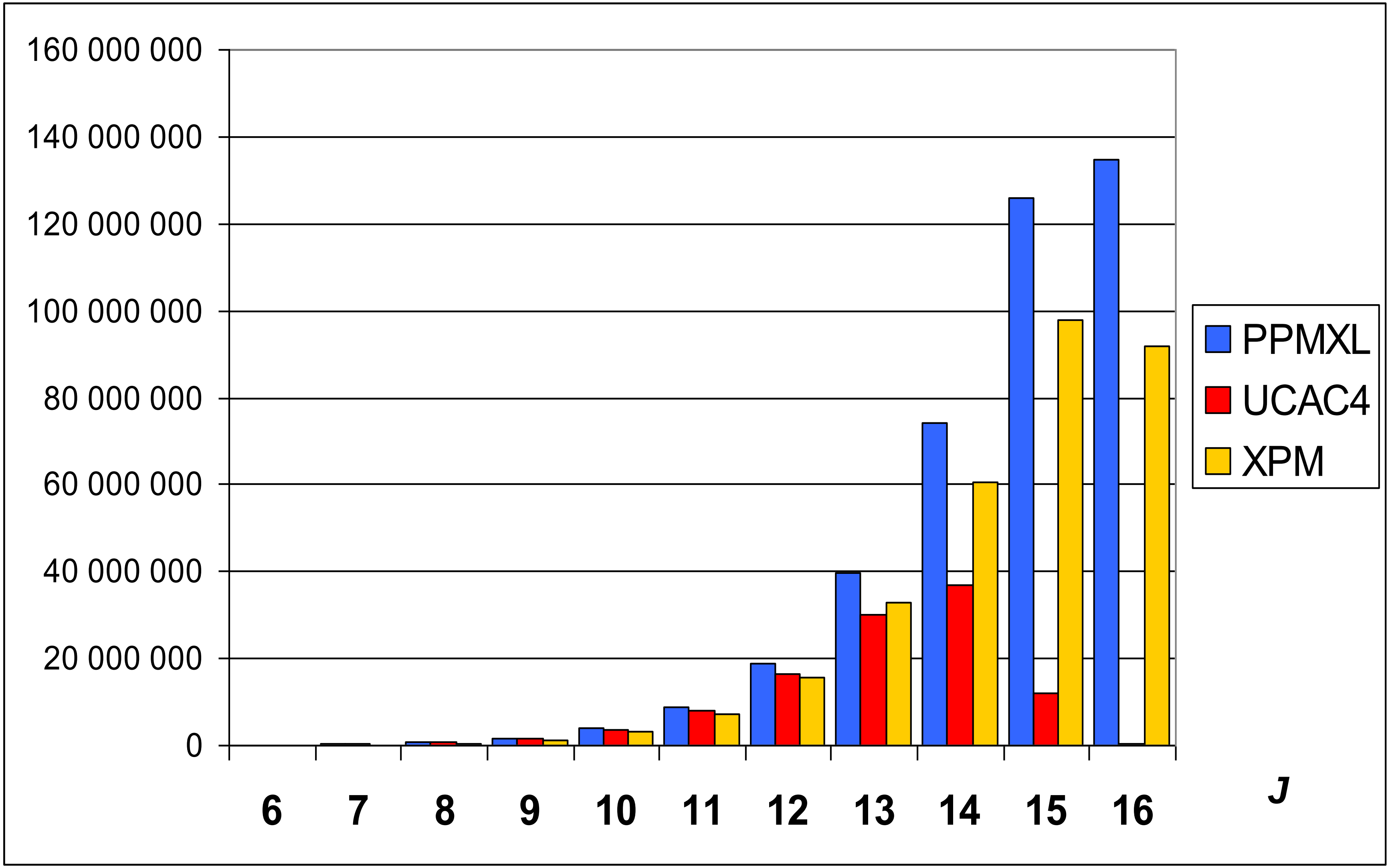


XPM

- The XPM catalogue (2009) lists about 280 million stars distributed all over the sky in the magnitude range 12<B<19
- The generated catalogue contains the ICRS positions of stars for the J2000 epoch, as well as B, R, J, H and K magnitudes.
- **The zero-point of the absolute proper motion frame (the absolute calibration) was specified with more than 1 million galaxies from 2MASS and USNO-A2.0**.

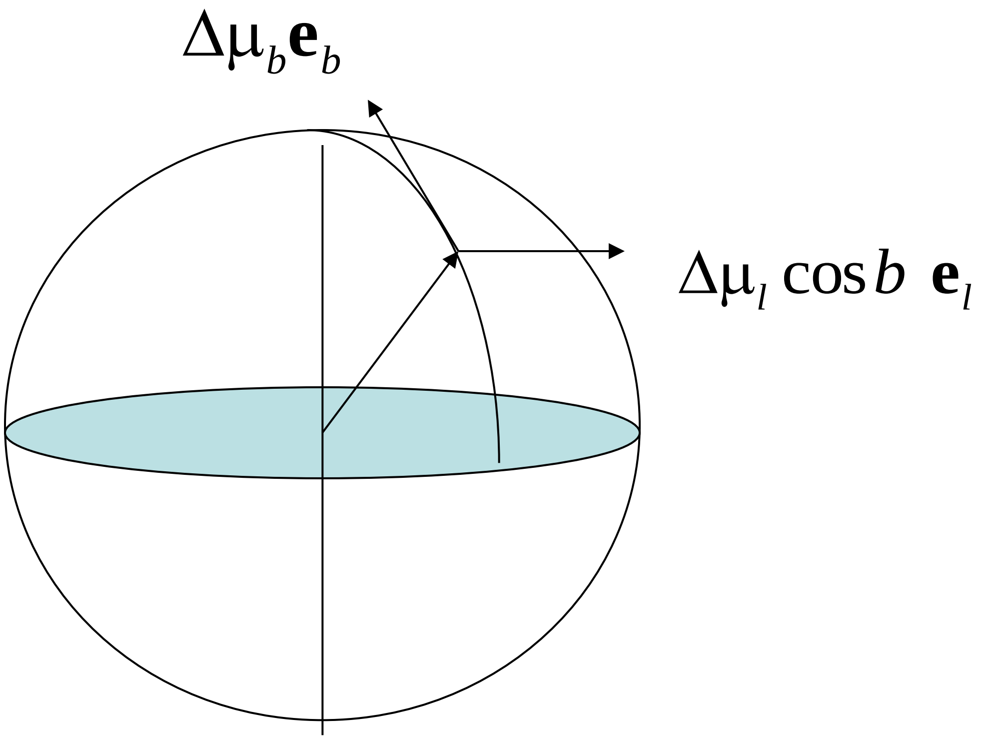


Distribution of common stars



Systematic differences as Vector Field on a sphere

$$\mathbf{U}(l,b) = \Delta\mu_l \cos b\, \mathbf{e}_l + \Delta\mu_b \mathbf{e}_b$$



Representation of systematic differences by VSH

$$\Delta\mu_l \cos b\, \mathbf{e}_l + \Delta\mu_b \mathbf{e}_b = \sum_{nkl} t_{nkl} \mathbf{T}_{nkl} + \sum_{nkl} s_{nkl} \mathbf{S}_{nkl}$$

Toroidal (Magnetic) Functions

$$\mathbf{T}_{nkl}(l,b) = \frac{1}{\sqrt{n(n+1)}} \left(\frac{\partial K_{nkl}(l,b)}{\partial b}\, \mathbf{e}_l - \frac{1}{\cos\delta} \frac{\partial K_{nkl}(l,b)}{\partial l}\, \mathbf{e}_b \right)$$

Spheroidal (Electric) Functions

$$\mathbf{S}_{nkl}(l,b) = \frac{1}{\sqrt{n(n+1)}} \left(\frac{1}{\cos b} \frac{\partial K_{nkl}(l,b)}{\partial l}\, \mathbf{e}_l + \frac{\partial K_{nkl}(l,b)}{\partial b}\, \mathbf{e}_b \right)$$

Differences of the mean PMs

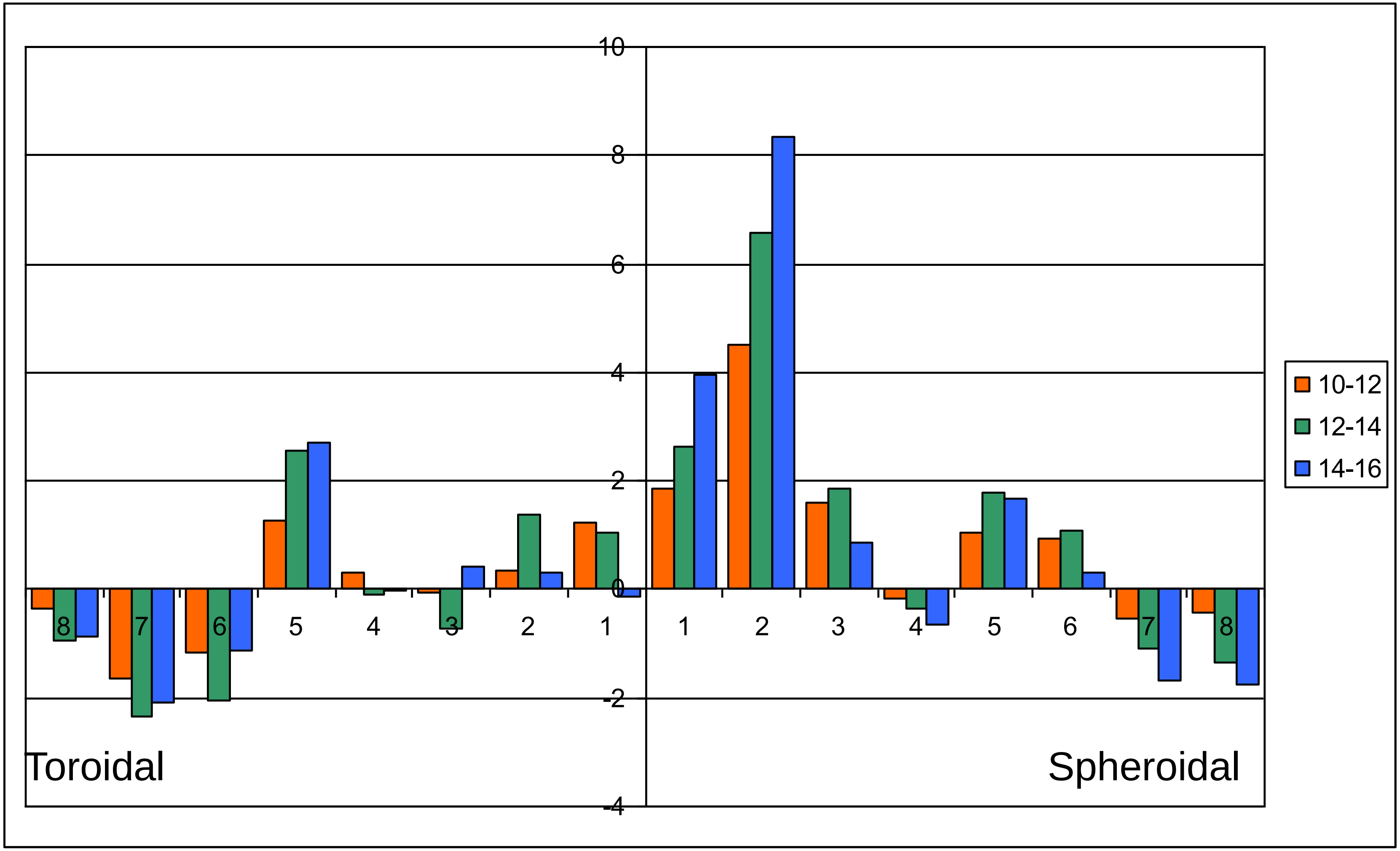
To avoid a lot of problems with cross identification of stars we worked not with the PM differences of individual stars but with the differences of the mean PMs in the HEALPix areas. The number of pixels was taken to be 4800 with the area of each pixel 8.6 square degrees. After averaging the PMs of stars inside each pixel the differences UCAC4-PPMXL, XPM-UCAC4 and XPM-PPMXL were formed and referred to the centers of the pixels. These data was collected for the stars in the J magnitude bins 10-12, 12-14 and 14-16. Since the numbers of stars from different catalogues in the same pixel does not differ more than several per cents, we believe that our approach does not differs significantly from the case if the individual differences were used.

We calculated the expansion coefficients for the PM differences up to n=4

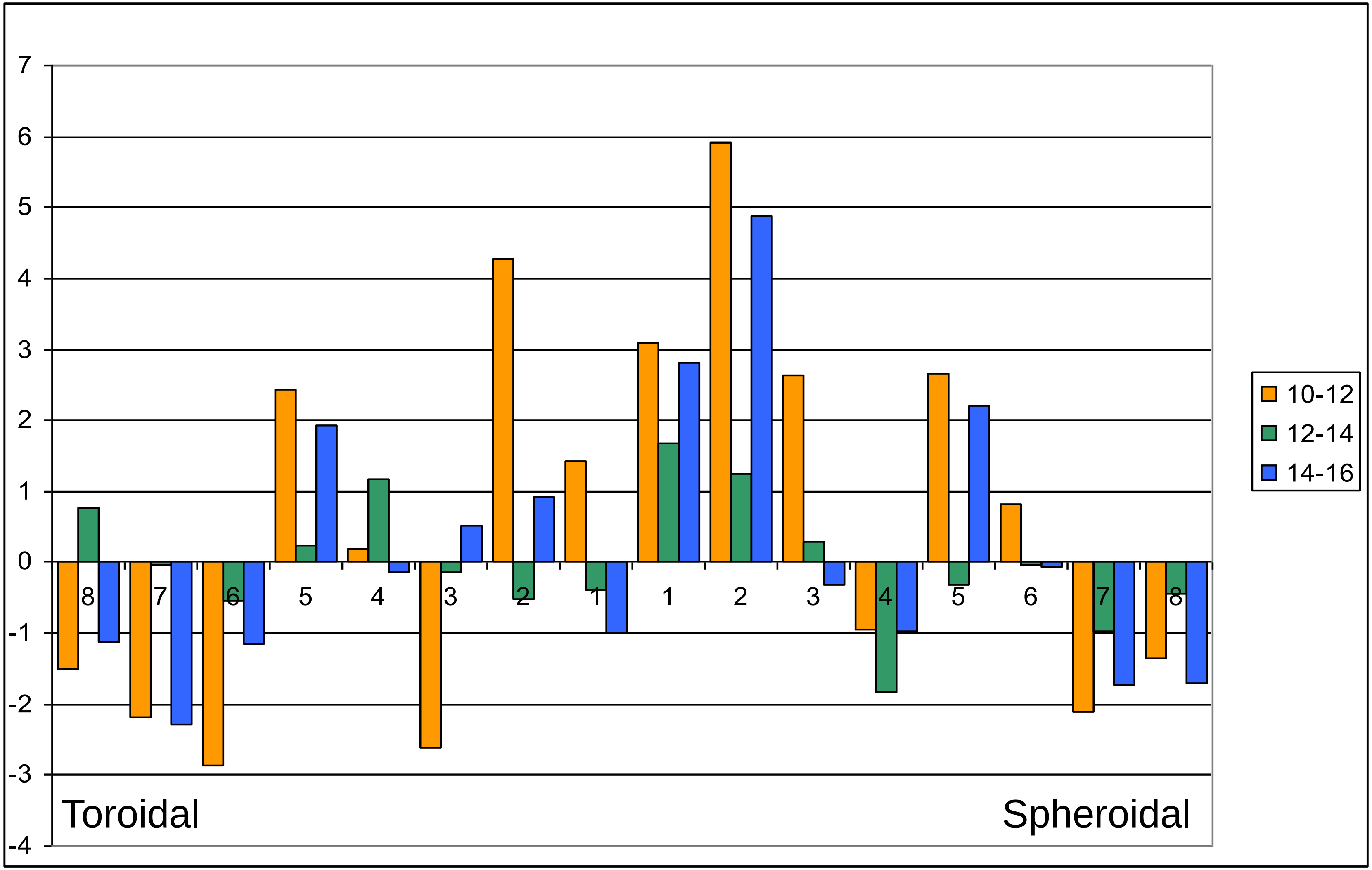
The coefficients for representation of the systematic differences in PM on VSH. Galactic coordinate system (mas/yr)

		Triple index			$J=10\text{-}12^m$		$J=12\text{-}14^m$		$J=14\text{-}16^m$	
T S	Par	N	K	L	UCAC4-PPMXL	XPM-PPMXL	UCAC4-PPMXL	XPM-PPMXL	UCAC4-PPMXL	XPM-PPMXL
T	ω_3	1	0	1	**1,25**	**1,42**	**1,04**	**-0,40**	-0,14	**-1,01**
	ω_2	1	1	0	**0,35**	**4,28**	**1,38**	**-0,53**	**0,30**	**0,93**
	ω_1	1	1	1	-0,07	**-2,60**	**-0,71**	-0,15	**0,41**	**0,51**
		2	0	1	**0,32**	0,19	-0,08	**1,16**	-0,01	-0,14
		2	1	0	**1,27**	**2,43**	**2,57**	0,23	**2,70**	**1,93**
		2	1	1	**-1,16**	**-2,87**	**-2,03**	**-0,55**	**-1,12**	**-1,15**
		2	2	0	**-1,65**	**-2,18**	**-2,34**	-0,03	**-2,09**	**-2,28**
		2	2	1	**-0,37**	**-1,50**	**-0,94**	**0,76**	**-0,88**	**-1,13**
S	W	1	0	1	**1,87**	**3,09**	**2,62**	**1,67**	**3,95**	**2,80**
	V	1	1	0	**4,50**	**5,91**	**6,56**	**1,25**	**8,36**	**4,87**
	U	1	1	1	**1,60**	**2,64**	**1,85**	**0,29**	**0,88**	**-0,31**
	$M_{11,33}$	2	0	1	-0,15	**-0,94**	**-0,37**	**-1,82**	**-0,63**	**-0,96**
	M_{23}	2	1	0	**1,05**	**2,65**	**1,77**	**-0,31**	**1,66**	**2,20**
	M_{13}	2	1	1	**0,92**	**0,83**	**1,09**	-0,03	**0,32**	-0,06
	M_{12}	2	2	0	**-0,53**	**-2,10**	**-1,09**	**-0,97**	**-1,69**	**-1,73**
	M_{11}	2	2	1	**-0,44**	**-1,35**	**-1,35**	**-0,44**	**-1,76**	**-1,70**
				σ	*0,07*	*0,13*	*0,08*	*0,09*	*0,09*	*0,09*

Expansion coefficients UCAC4-PPMXL (mas/yr)



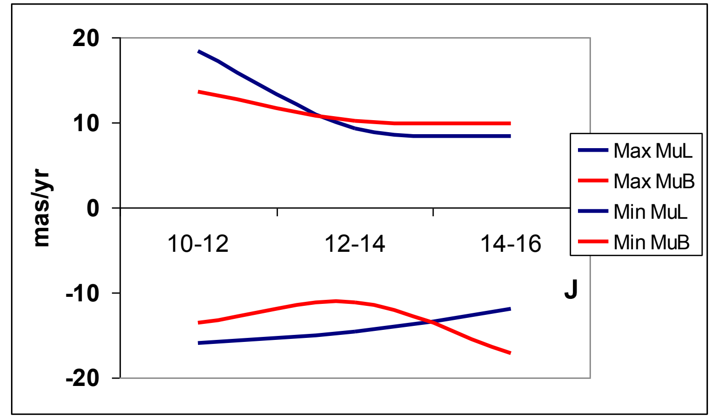
Expansion coefficients XPM-PPMXL (mas/yr)



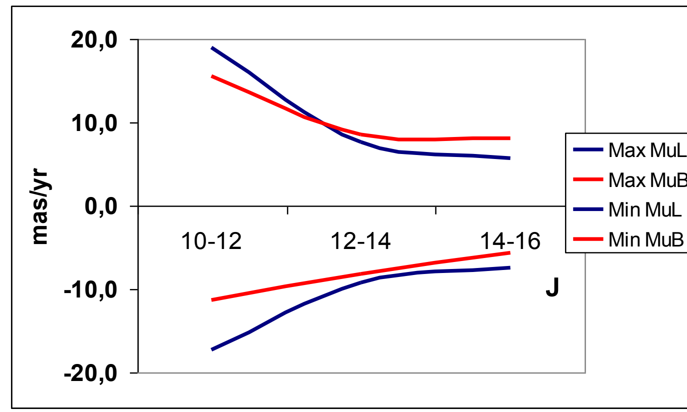
Extreme values are [-20; +20] mas/y

Ranges of Systematic Differences via Magnitude

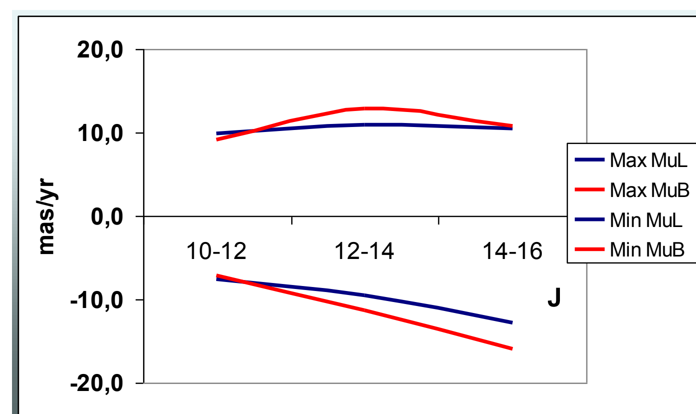
XPM-PPMXL	Max MuL	Max MuB	Min MuL	Min MuB
10-12	18,3	13,6	-15,9	-13,6
12-14	9,2	10,1	-14,6	-11,2
14-16	8,4	9,8	-11,9	-17,1



XPM-UCAC4	Max MuL	Max MuB	Min MuL	Min MuB
10-12	18,9	15.5	-17,3	-11,3
12-14	7,6	8,5	-9,3	-8,2
14-16	5,7	8,0	-7,5	-5,7

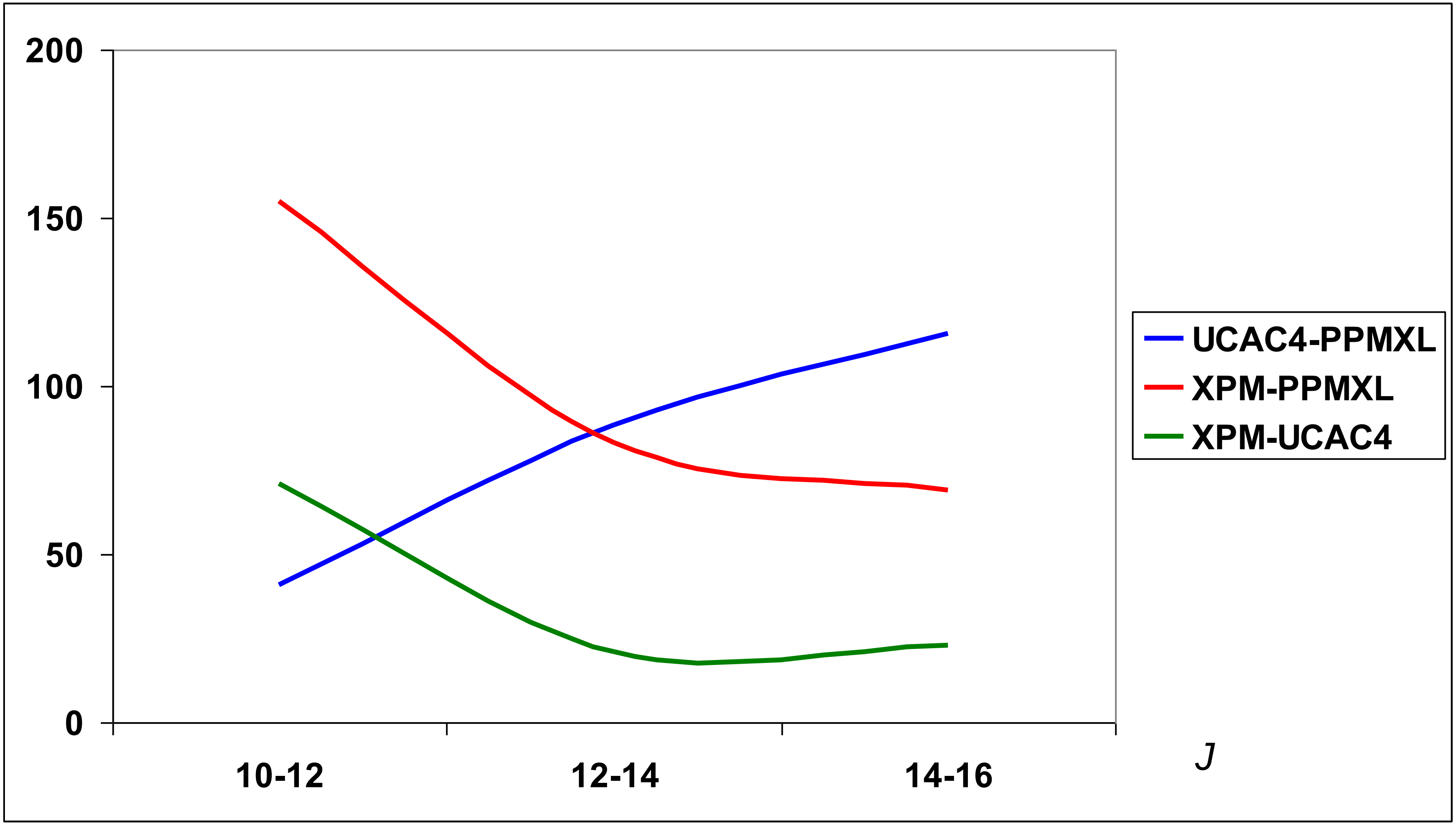


UCAC4-PPMXL	Max MuL	Max MuB	Min MuL	Min MuB
10-12	9,8	9,1	-7,6	-7,1
12-14	10,9	12,8	-9,6	-11,3
14-16	10,5	10,7	-12,9	-16,0



Total power of the field via magnitude

$$P = \sum_{nkp} (t_{nkp}^2 + s_{nkp}^2)$$



How close the XPM is to PPMXL and UCAC4

The PPMXL and UCAC4 realize the reference frames which does not rotate with respect to the **quasars**, whereas the XPM frame is claimed not to be rotating with respect to **galaxies**. Theoretically both quasars and galaxies form quasi-inertial reference systems but due to different techniques of measurement the corresponding reference frames may differ systematically. The main goal of this paper is to calculate the systematic differences in proper motions and to see is there significant differences between the XPM galaxies frame and the PPMXL and UCAC4 quasars frames.

MUTUAL SPIN of frames (mas/y)

$$\Omega = \sqrt{\omega_1^2 + \omega_2^2 + \omega_3^2}$$

	10-12	**12-14**	**14-16**
UCAC4-PPMXL SMALL	0.45 ± 0.21 **SMALL**	0.65 ± 0.24 **SMALL**	0.18 ± 0.26 **SMALL**
XPM-PPMXL	1.80 ± 0.38 **LARGE**	1.22 ± 0.27 **LARGE**	0.51 ± 0.26 **SMALL**
XPM-UCAC4	1.62 ± 0.36 **LARGE**	0.65 ± 0.22 **SMALL**	0.37 ± 0.18 **SMALL**

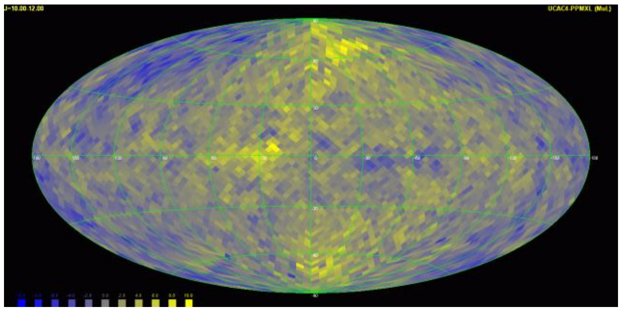
MAGNITUDE EQUATION

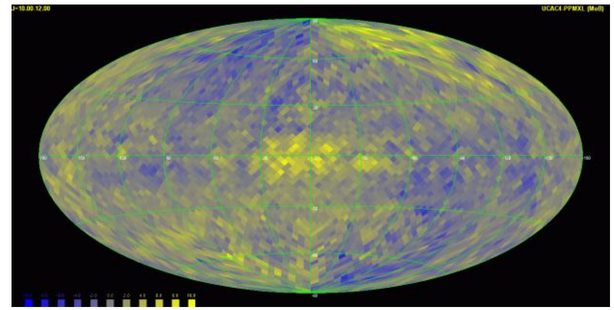
UCAC4-PPMXL

PM in longitude

PM in latitude

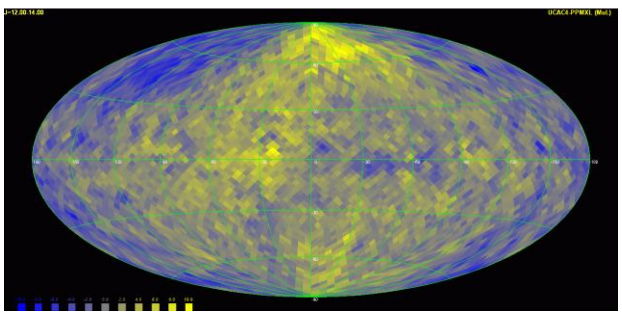
Power
40,7

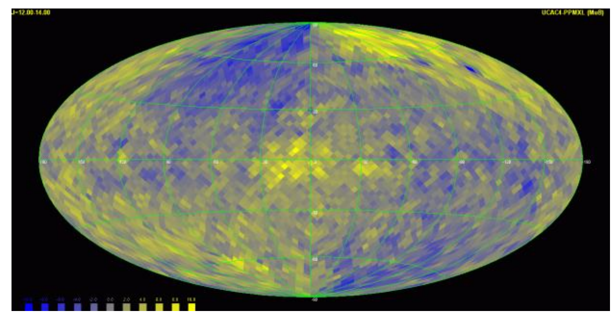




Magn.
10-12

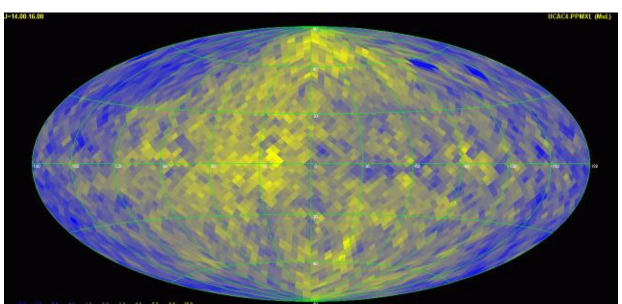
Power
88.3

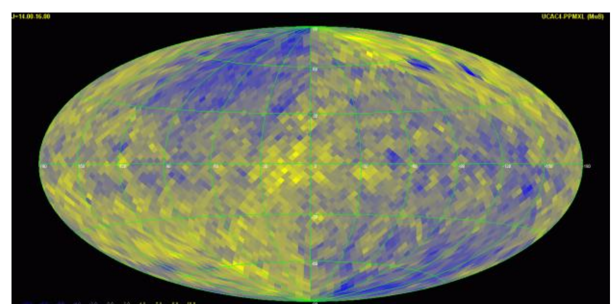




Magn.
12-14

Power
115.7





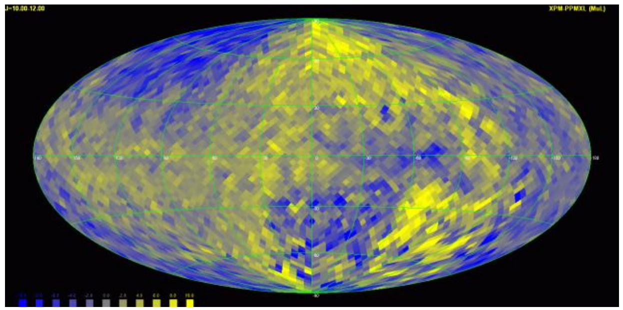
Magn.
14-16

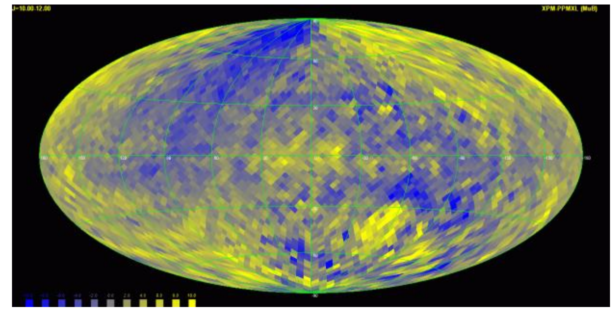
MAGNITUDE EQUATION
XPM-PPMXL

PM in longitude

PM in latitude

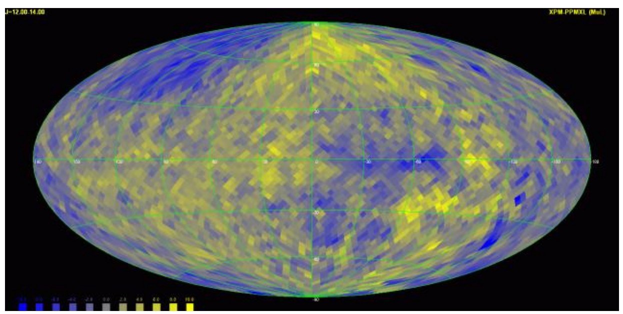
Power
155,0

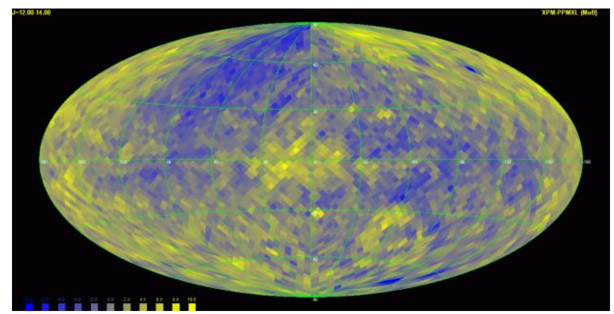




Magn.
10-12

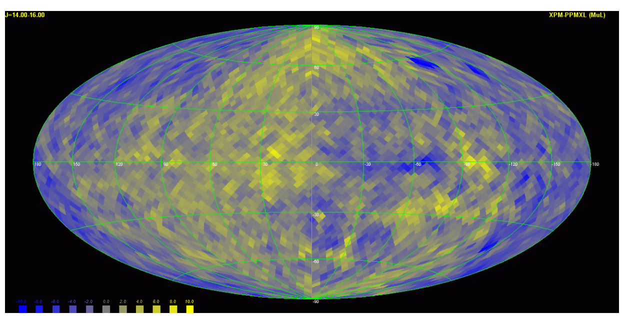
Power
82,8

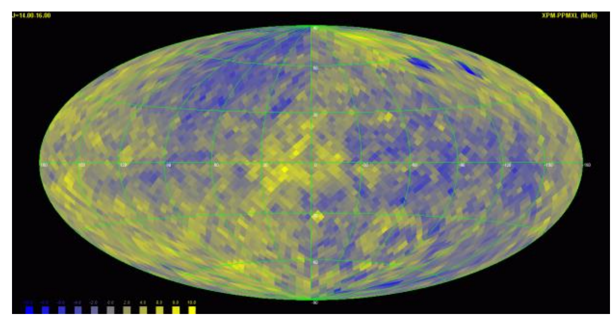




Magn.
12-14

Power
68,7



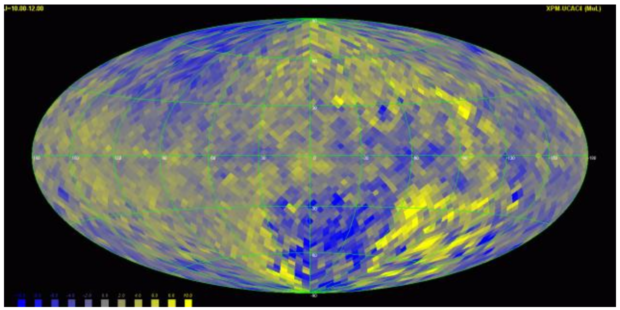


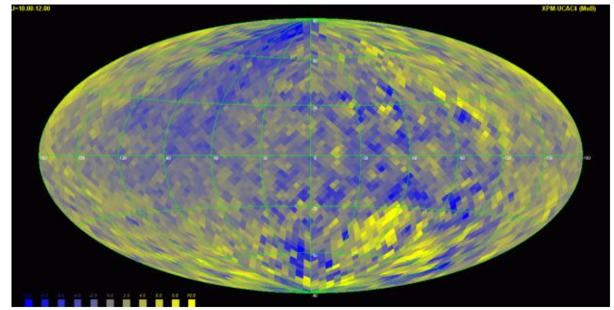
Magn.
14-16

MAGNITUDE EQUATION
XPM-UCAC4

PM in longitude | PM in latitude

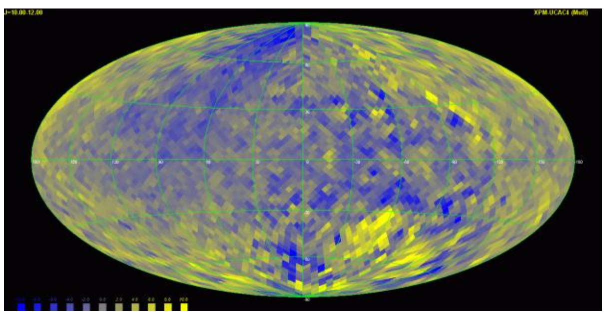
Power
71,7

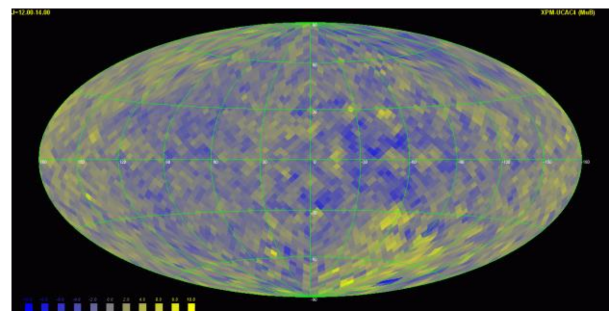




Magn.
10-12

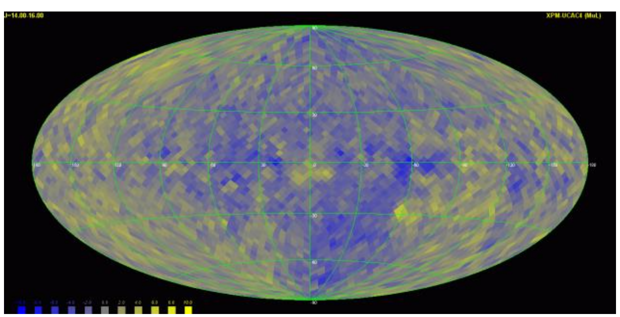
Power
21,0

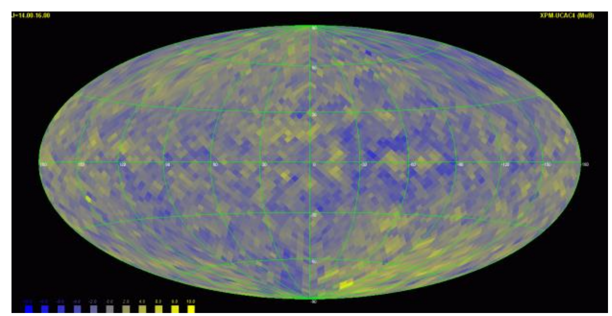




Magn.
12-14

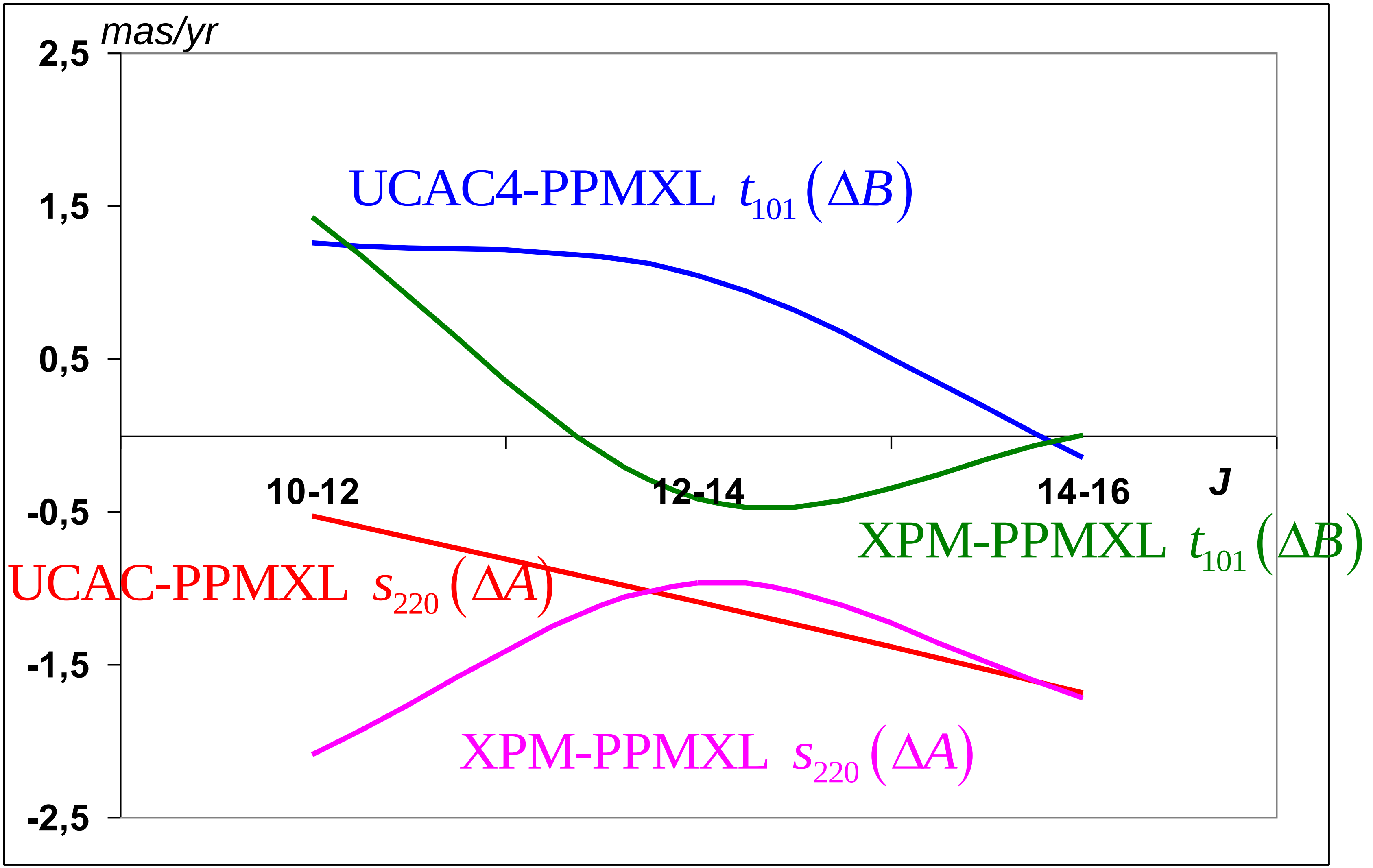
Power
22,6





Magn.
14-16

Dependence of VSH coefficients on magnitude



Stellar kinematics

Since the connection of low order VSH coefficients of the PMs decomposition with the Ogorodnikov-Milne coefficients is known the VSH coefficients of the systematic differences in PM may be used for direct reducing a kinematical parameter from the system of one catalogue to the system of another catalogue.

For example, the UCAC4-PPMXL coefficients

$$t_{101} = 1.25 \pm 0.07 \qquad s_{220} = -0.53 \pm 0.07 \; mas/y$$

yield the differences of the Oort constants

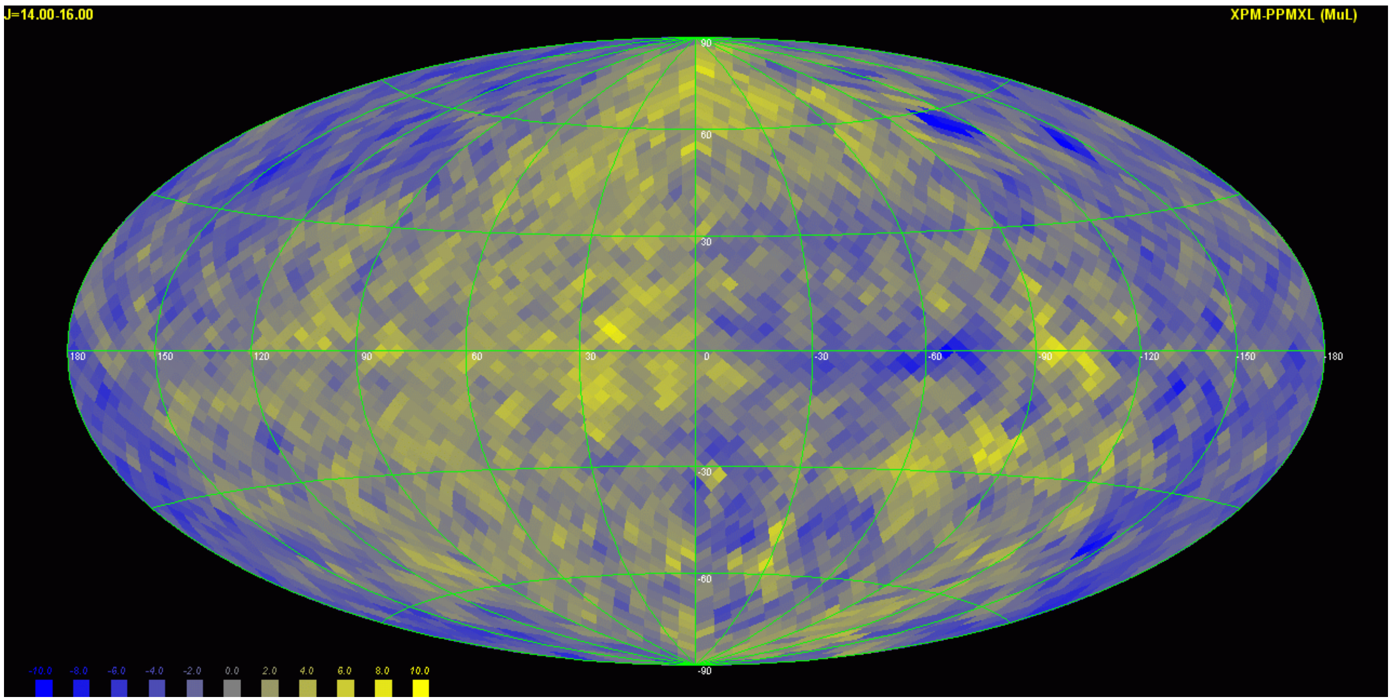
$$\Delta B = 2.06 \pm 0.12 \qquad \Delta A = -1.12 \pm 0.16 \;\; km/s/kpc$$

what is confirmed by direct evaluation of these parameters from proper motions of both the catalogues.

CONCLUSION

- The representation of the differences UCAC4-PPMXL, XPM-UCAC4 and XPM-PPMXL by vector spherical harmonics is made in the 10 to 16 J mag. range.
- The PM systematic differences turned out to be in the -20 to +20 mas/y range which surpass the announced values of the random errors
- The proper motion XPM catalogue has the least systematic deviation from the ICRS proper motion catalogue UCAC4 in the 12-16 J mag range. In other words the **XPM and UCAC4 are more consistent than each of the two with the PPMXL.**
- With 3 sigma confidence large spin of XPM with respect to PPMXL and UCAC4 was found in the 10-14 J mag range
- The values of spin for UCAC4 on PPMXL are small
- Magnitude Equation is manifested by the dependence of the maps and the VSH coefficients on J magnitude
- The influence of low order VSH coefficients on the determination of the Ogorodnikov-Milne coefficients is clarified.

THANK YOU!



J=14.00-16.00
XPM-PPMXL (MuL)
90
60
30
0
-30
-60
-90
180 150 120 90 60 30 0 -30 -60 -90 -120 -150 -180
-10.0 -8.0 -6.0 -4.0 -2.0 0.0 2.0 4.0 6.0 8.0 10.0