

Why ?

- **GSC2.2 is ready (without p.m.)**
- **SDSS p.m. (one π in the sky)**
- **XPM catalogue of 280 million stars**
- **NOMAD (merged list, not on a homogeneous system)**
- **UCAC3 and others**
- **Gaia being on the horizon**
- **Pan-STARRS is about to be started**

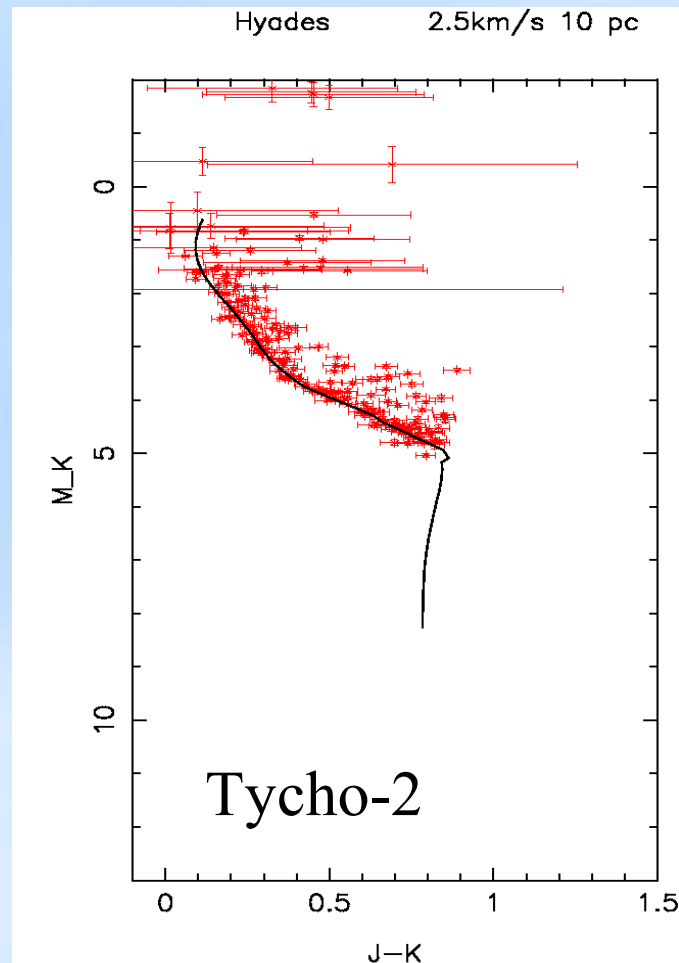
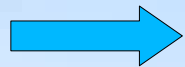
Why not?

- USNO B1.0 has no *inertial* proper motions
- 2MASS has no proper motions
- PPM-S can be completed quickly
- It will be a playground for the above !

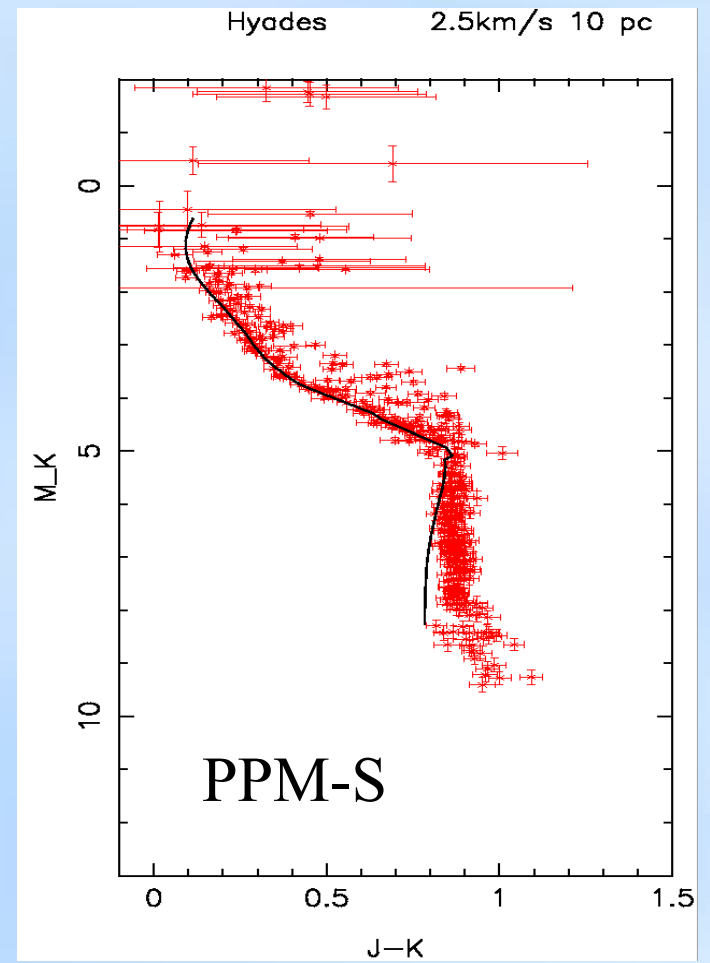
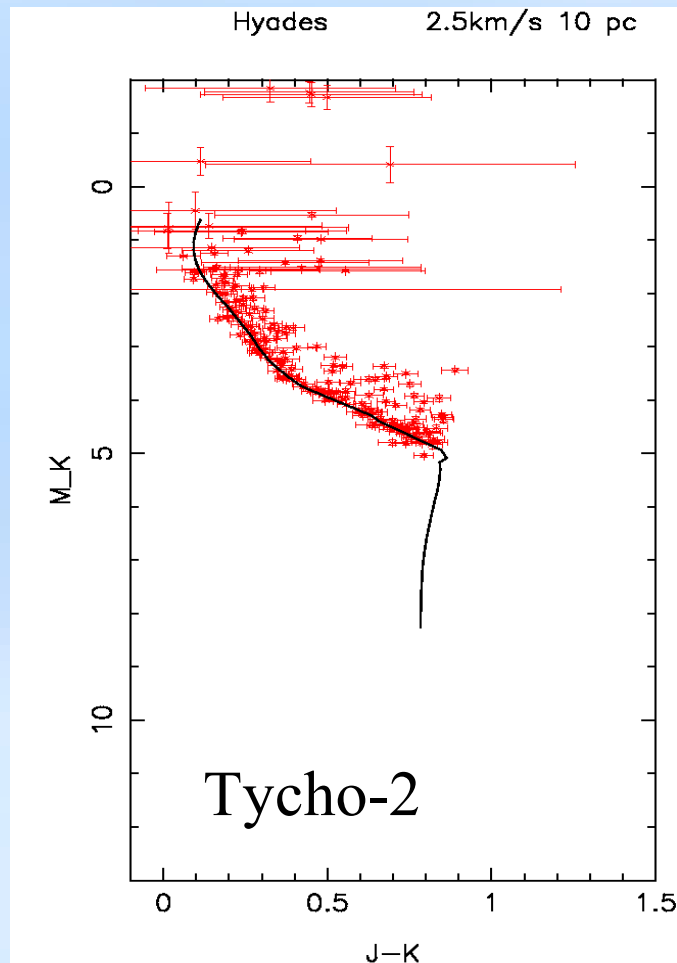
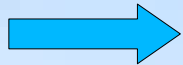
Appetizer (e.g. Open clusters)

from 2.5 Mln

from $V < 11.5$



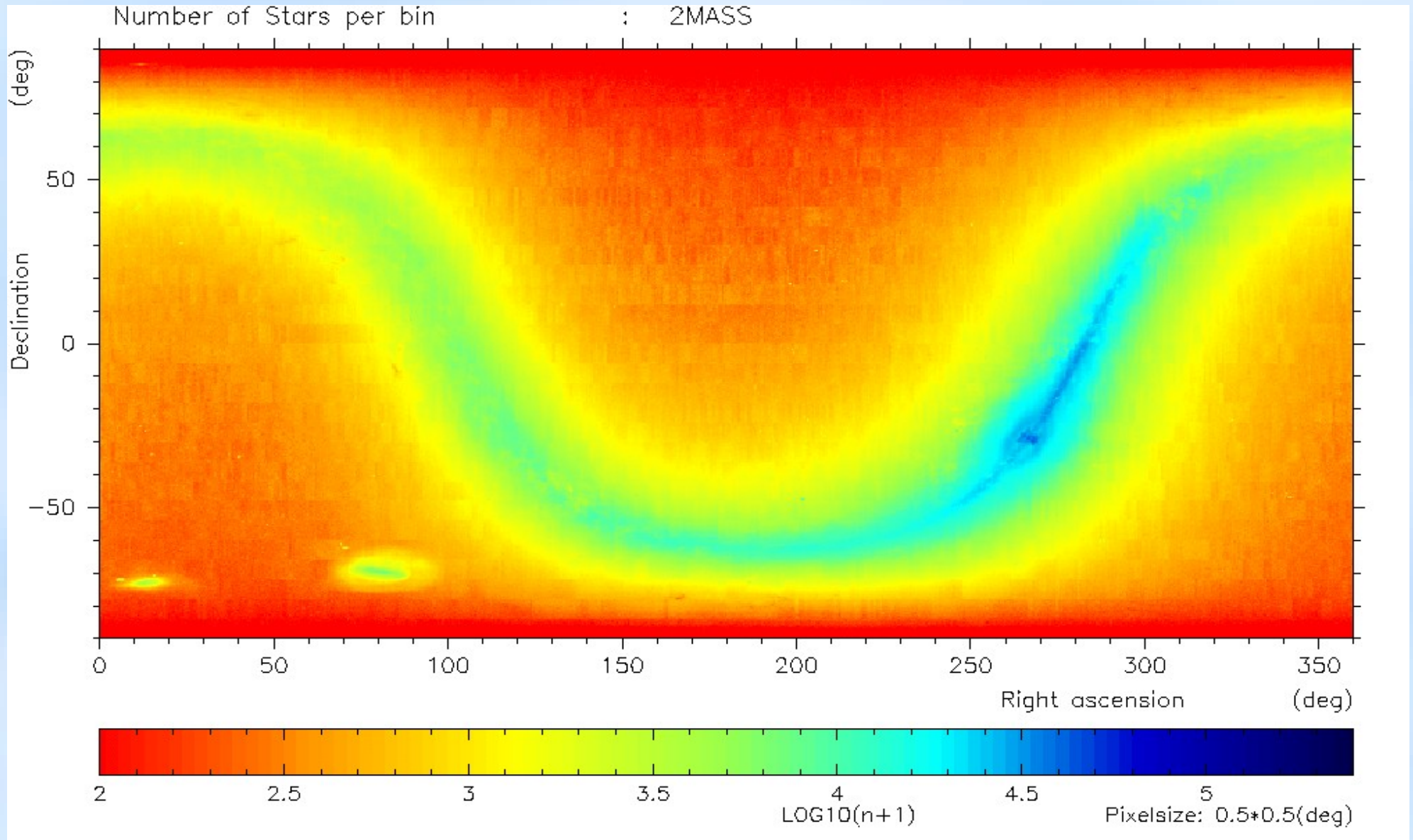
Appetizer (e.g. Open clusters)



2MASS

- 471 million objects in the PSC (point source catalogue)
- Full-sky
- J, H, K_s photometry
- complete down to $J < 15.8$, $H < 15.1$ and $K_s < 14.3$ mag
- astrometric accuracy (80 mas rms for $K_s < 14$) from comparisons with Tycho-2 and UCAC (to be verified)

The distribution on the sky (2MASS)



USNO B1.0

- 1.043 billion objects on the sky
- Completeness limit: $V = 21$
- Based on scans of 7400 plates from the Palomar, ESO and UK Schmidt telescopes
- Two epochs, 3 bands: Blue, Red and I
- Positions, proper motions, photometry

We use a cleaned version of USNO B1.0 from astrometry.net
Barron et al. 2008

2.5% false entries have been deleted (spikes etc.)

First exercise: check a subset

- 5.2 million objects with $13.0 < B < 14.0$
- 1.45m have proper motion = 0
- 0.44m have proper motions > 50 mas/year

Comparison with UCAC-2

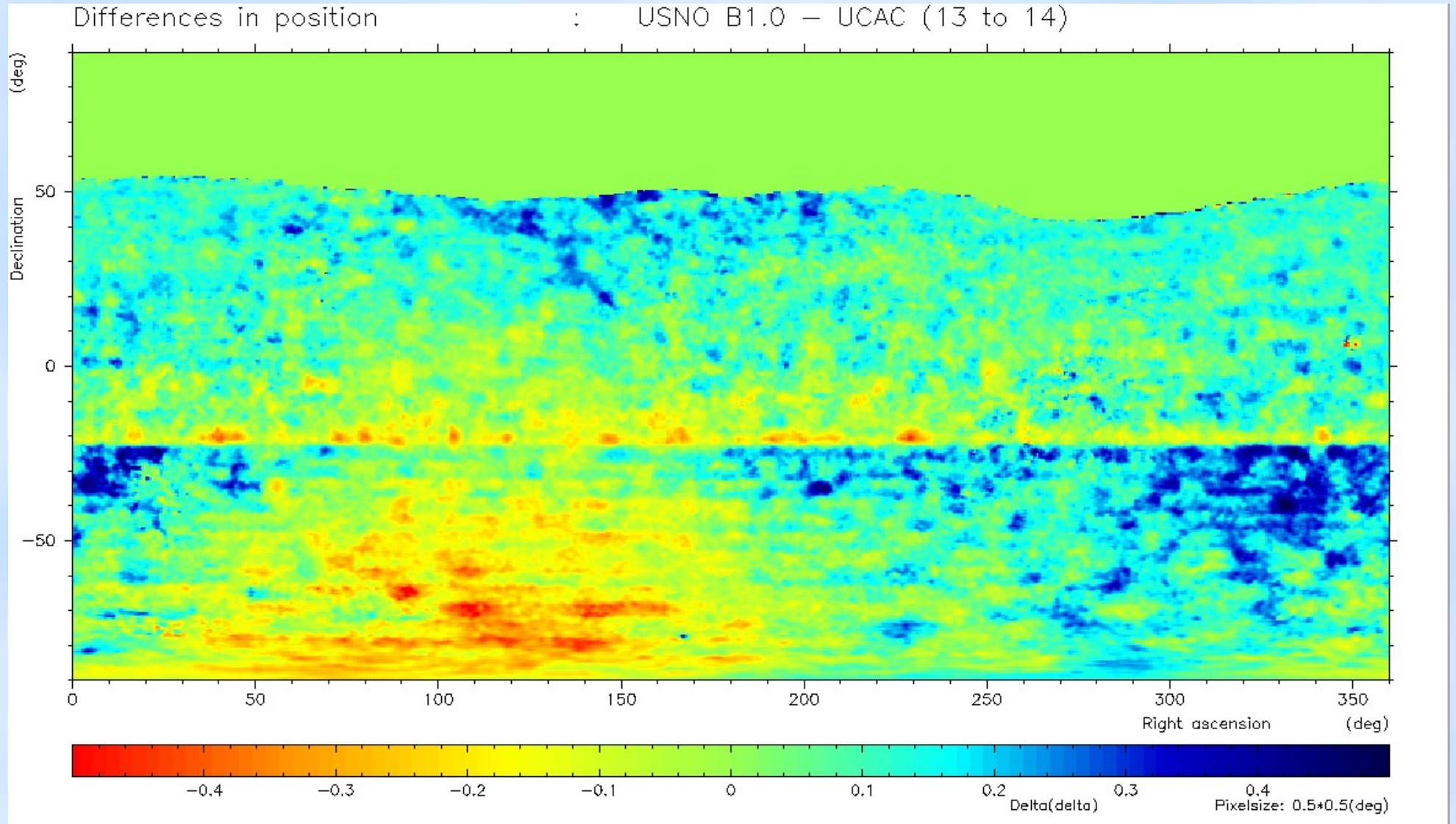
- 3.1m have $\Delta(\text{p.m.}) < 50$ mas/y
- 3.0m have $\Delta(\text{pos.}) < 2$ arcsec

Proper motions are set to zero if smaller than their mean errors (1σ)

Proper motions are set to zero if the old epoch is missing

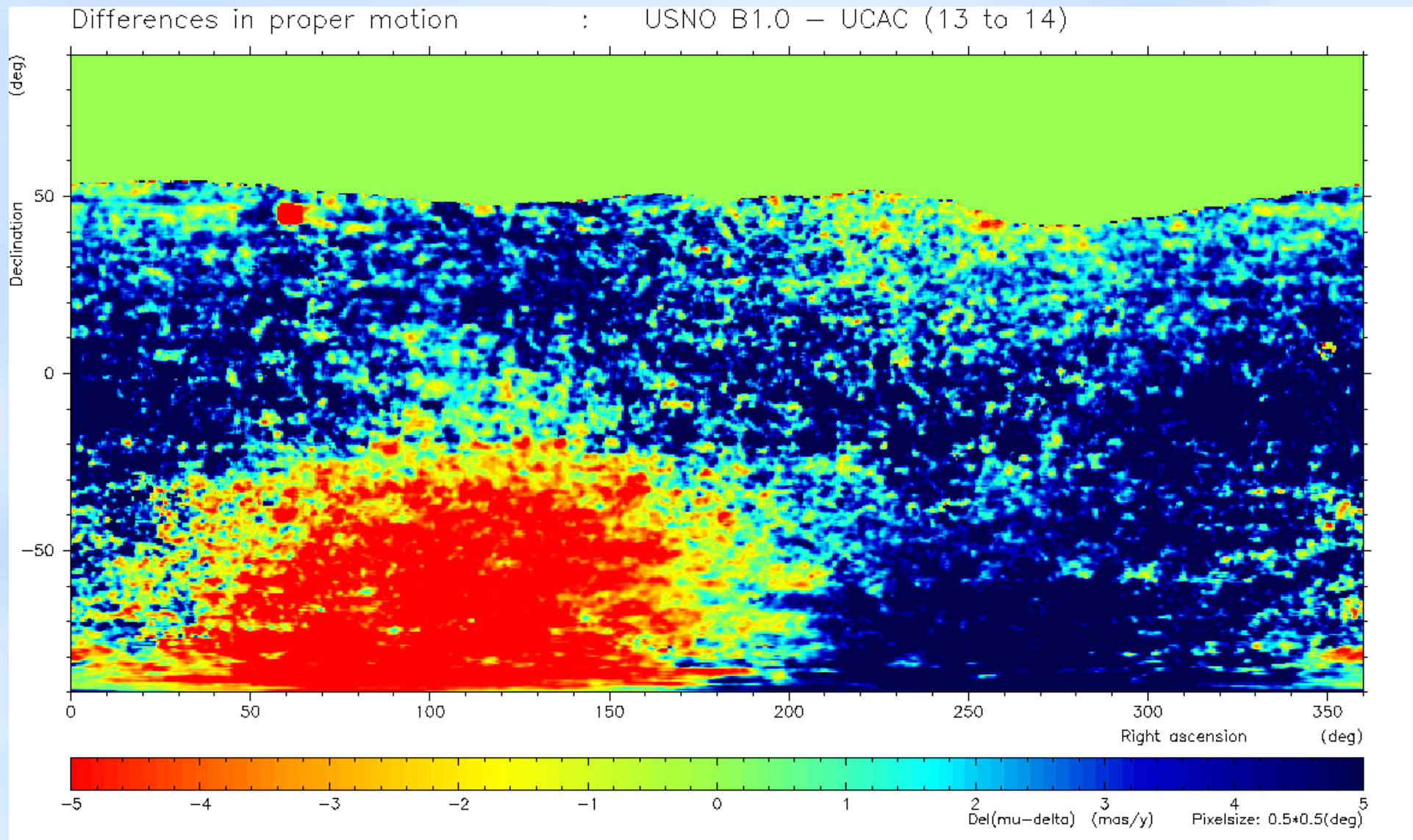
Comparison USNO B1.0 - UCAC-2

Positions (declination) at 2000.0



Comparison USNO B1.0 - UCAC-2

Proper motions (declination)



Caveats for USNO-B1.0

- USNO-B1.0 positions and proper motions are not on the ICRS. It is not **inertial** !!!!

The epoch of USNO B1.0 is 1975.0, but it claims to be 2000.

The present offset of positions with respect to ICRS is up to 0.5 arcsec

- You cannot use it for kinematics of the Galaxy

USNO B1.0 WARNING!

Monet et al., AJ 125, 984 (2003)

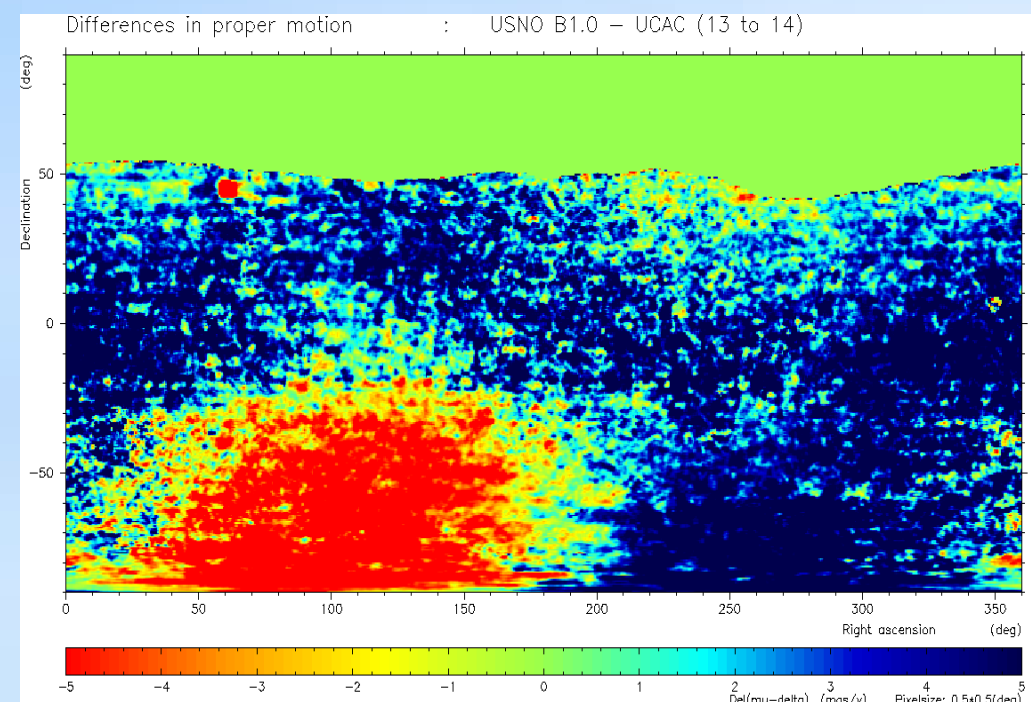
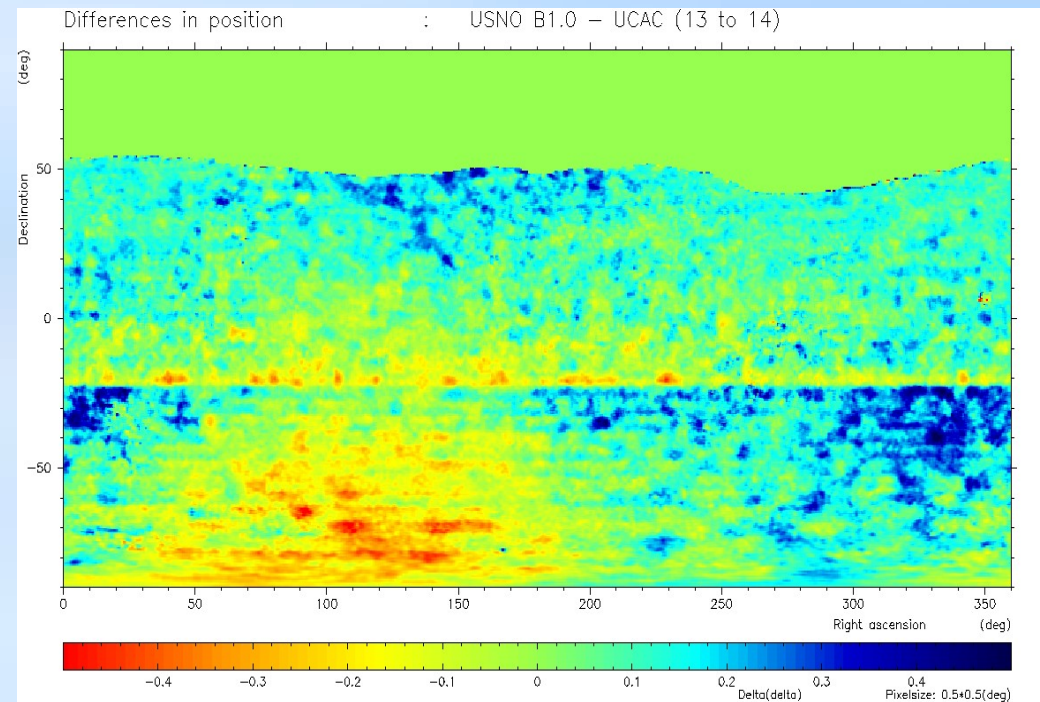
A different strategy was employed for USNO-B. As part of the PMM program, the Northern Proper Motion plates (Klemola, Jones, & Hanson 1987) and the Southern Proper Motion plates (Platais et al. 1998) were scanned, and an astrometric catalog called YS4.0 was compiled. The limiting magnitude of YS4.0 is about $V = 18$, and these stars are not saturated on the Schmidt survey plates. The advantage of this strategy is that the astrometric calibration avoids saturated stars. The disadvantage is that the mean epoch of YS4.0 is about 1975, and the mean motion between YS4.0 and the Schmidt surveys was set to zero by the least-squares solution. Hence, the proper motions in USNO-B are relative, not absolute; future releases of USNO-B will attempt to remove this bias through the introduction of a statistical model.

Task: make USNO B1.0 inertial (brute force and ignorant !)

- Step 1: Apply the zonal systematic differences from UCAC2 or PPMX

Positions 2000.0

Proper motions

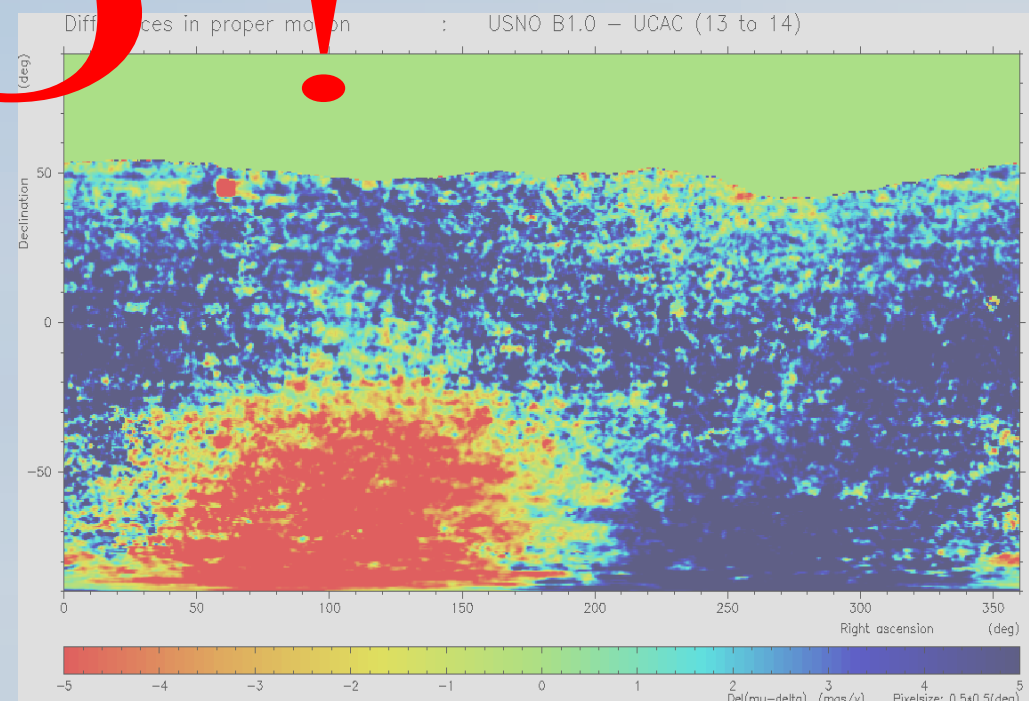
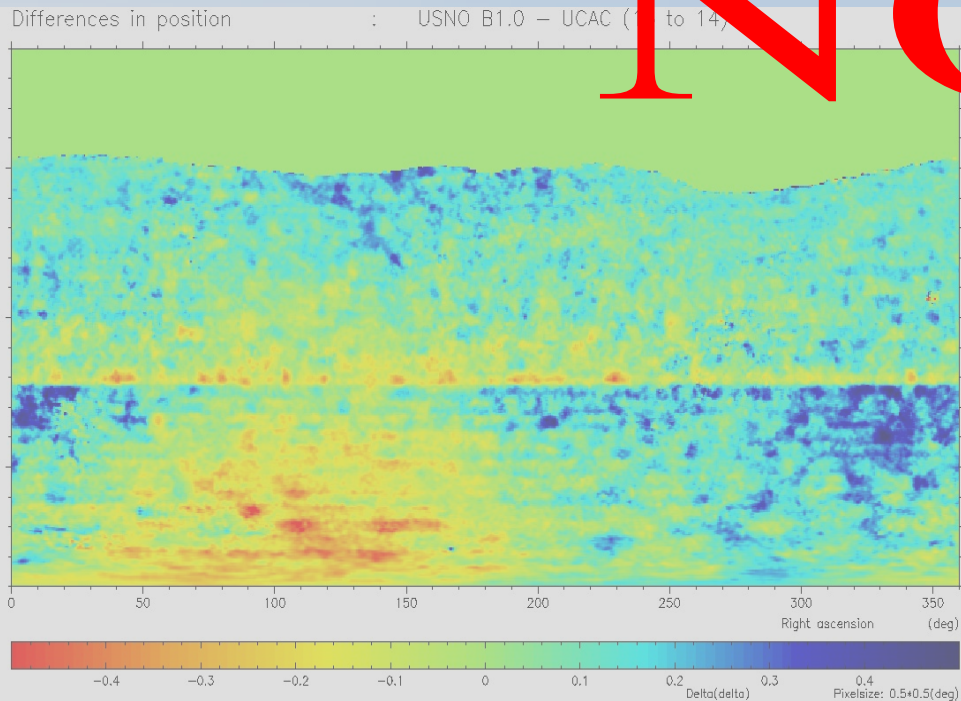


Task: make USNO B1.0 inertial (brute force and ignorant !)

- Step 1: Apply the zonal systematic differences from UCAC2 or PPMX

Positions 2000.0

Proper motions



Task: make USNO B1.0 inertial (a little more carefully)

- Step 1: Re-construct the original observations
- Step 2: Coarse reduction to PPMX
(field by field) !!
- Step 3: 2MASS crossmatching

Task: make USNO B1.0 inertial

- Step 3: Cross-match with 2MASS
(cone 2 arcsec radius)
some 70 million **RED** 2MASS objects
could not be matched, but only
30 million with good (<0.1 mag)
2 MASS photometry

Situation

- 70 million **RED** 2MASS stars are not in USNO B1.0 -- no proper motions
- Some 400 million **BLUE** USNO B1.0 stars are not in 2MASS -- proper motions with larger mean errors
- Philosophy: minimum epoch difference 8 years to enter the catalogue. This enables a cross-match between 2nd epoch POSS and 2MASS.
Do not use the p.m. of these stars

LSQ adjustment and error estimation

- Attribute weights to each observation

$$w_i = 1/\sigma_i^2$$

- Determine mean positions and motions via

$$\bar{x} = \frac{\sum_{i=1,n} w_i x_i}{\sum_{i=1,n} w_i}, \quad \mu = \frac{\sum_{i=1,n} w_i x_i (T_i - \bar{T})}{\sum_{i=1,n} w_i (T_i - \bar{T})^2}$$

- Determine the mean errors from the covariance matrix

$$w_{p.m.} = \sum_{i=1,n} w_i (T_i - \bar{T})^2$$

$$w = \sum_{i=1,n} w_i$$

- Do not use the *a posteriori* estimate of the error of unit weight. Degree of freedom too low

Here we are

- Each individual plate has been reduced to PPMX (simple means)
- A first lsq run has been completed
- Proper motions for 800m objects have been derived

Results



Preliminary weights:

- $w_i = 1/\sigma_i^2$

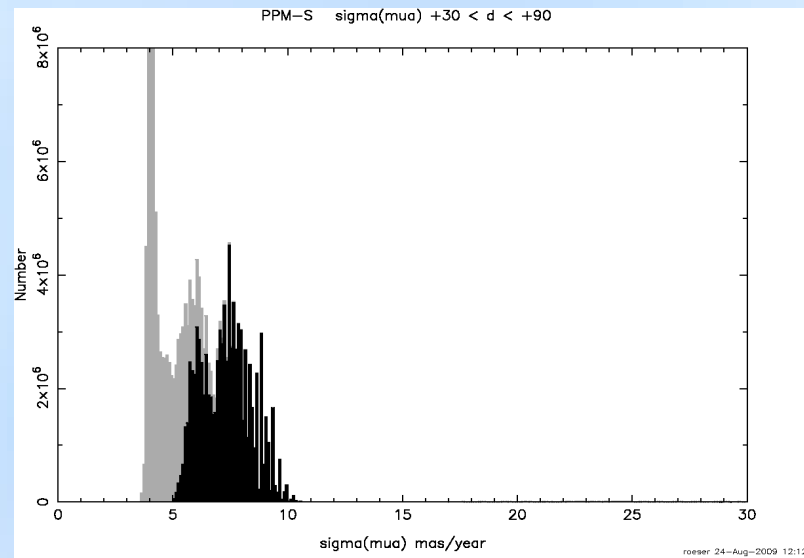
σ_i

- USNO B1.0 240 mas per obs.
- 2MASS 80 mas $K < 13$
up to 260 mas $K = 16$

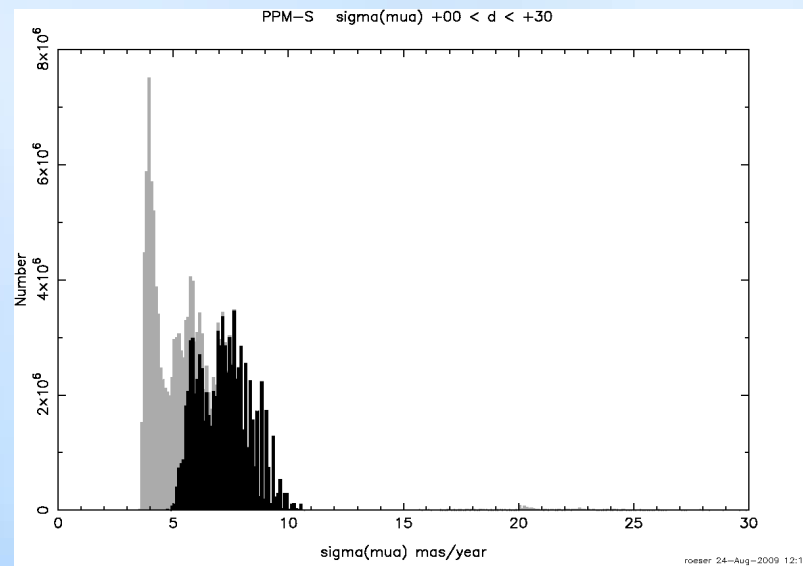
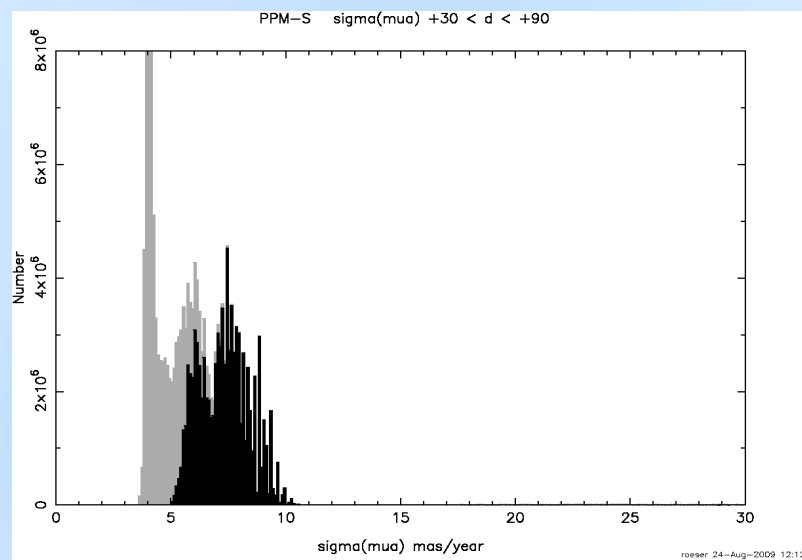
Munn gives

120 mas to a USNO B obs.

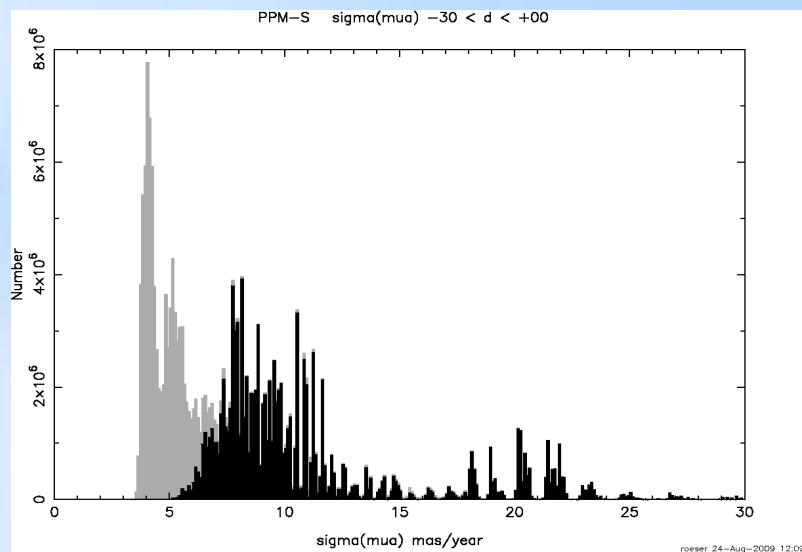
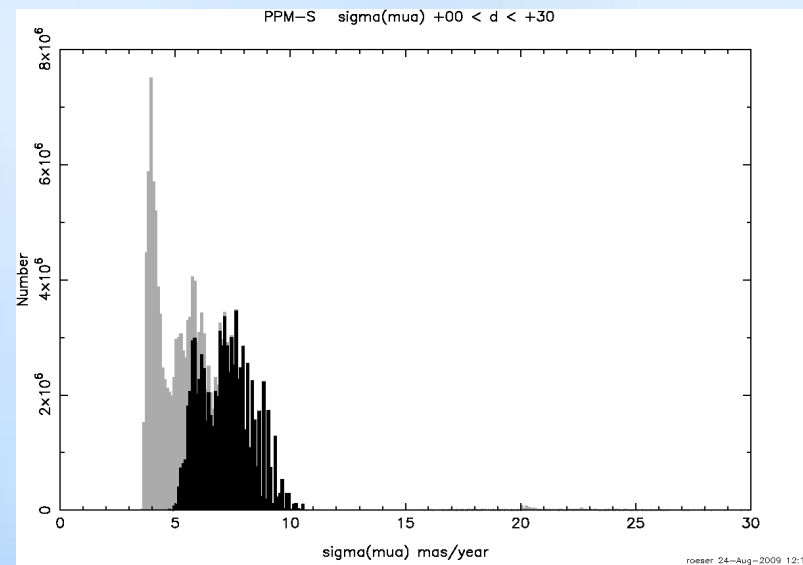
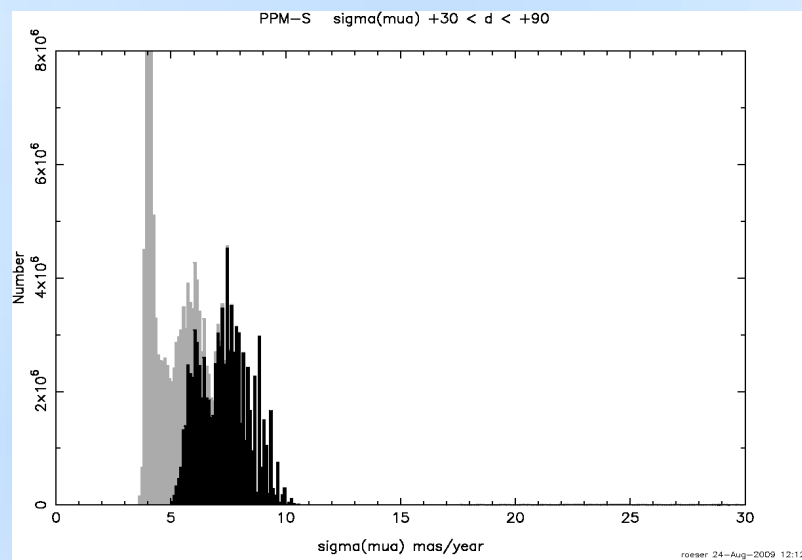
Mean errors of proper motions



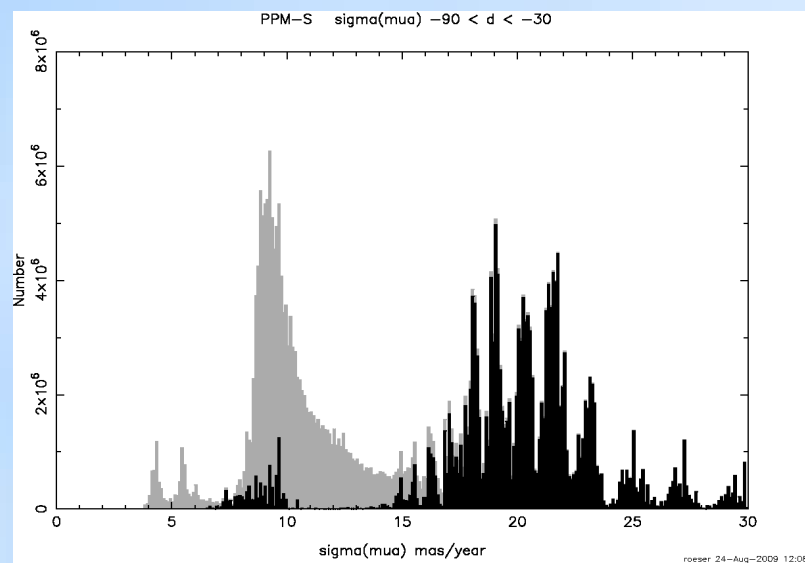
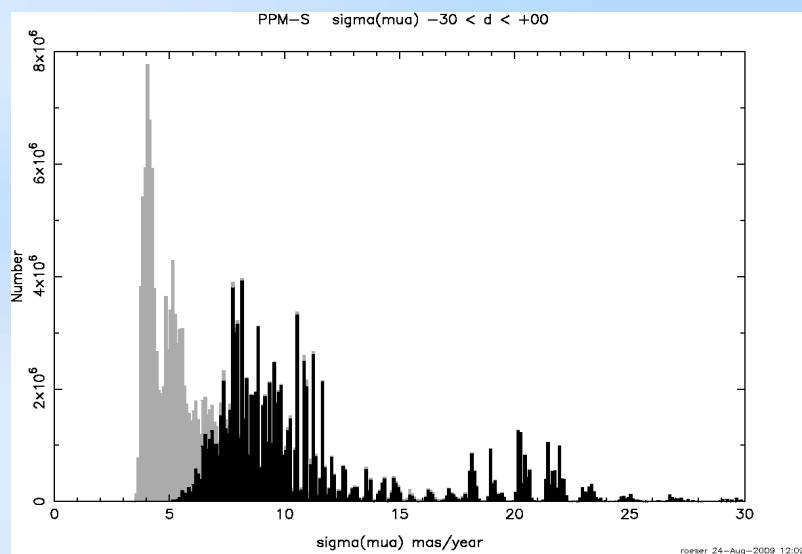
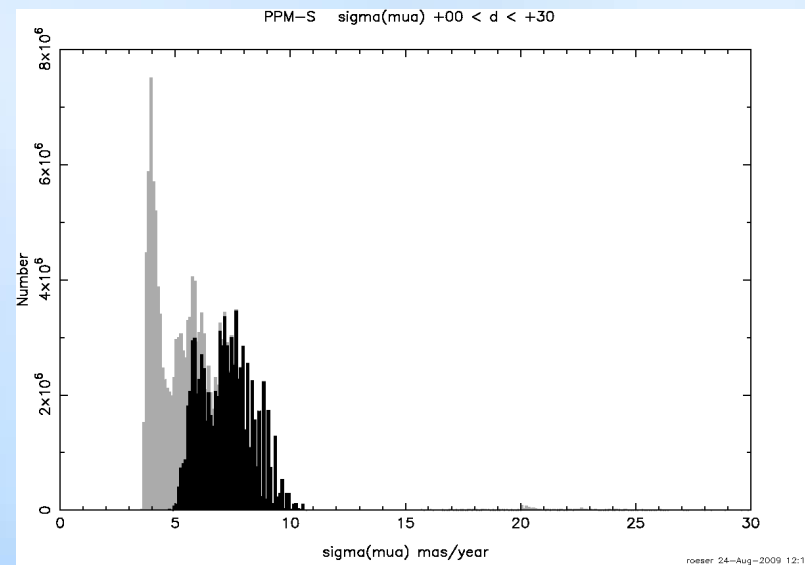
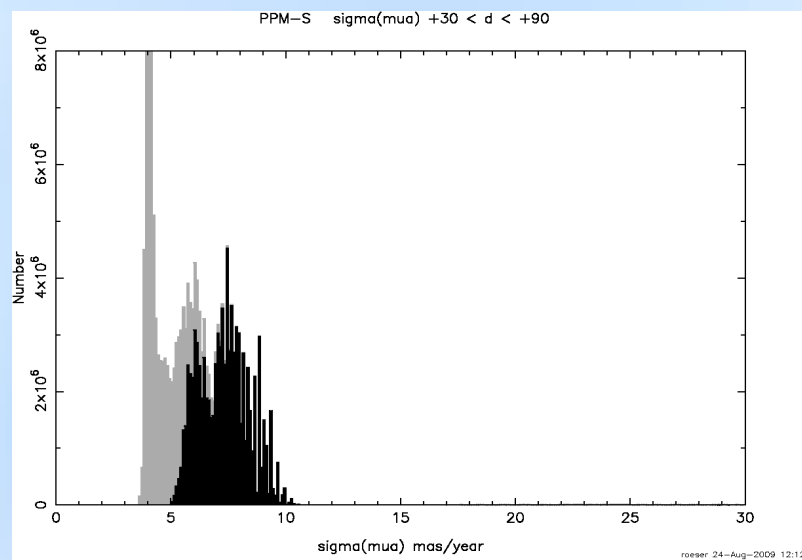
Mean errors of proper motions



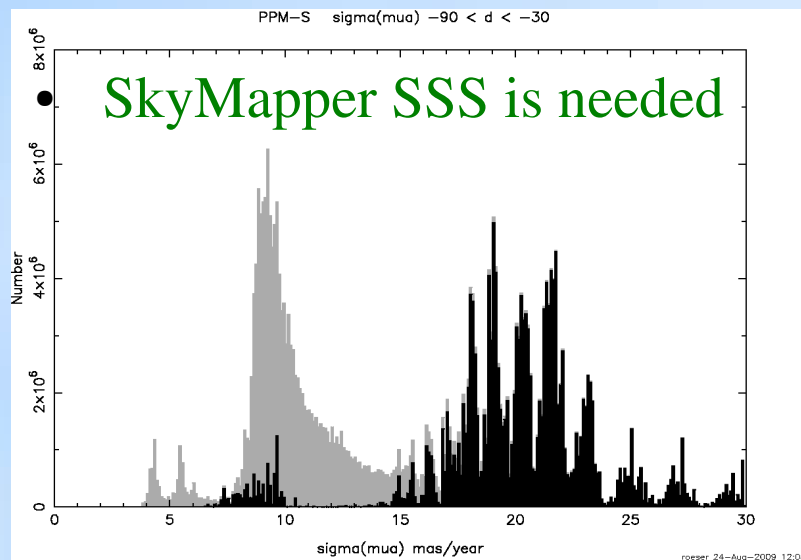
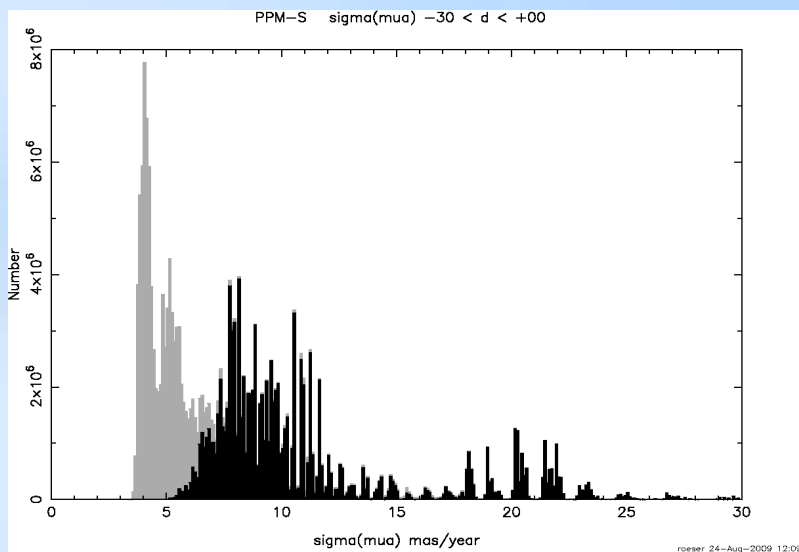
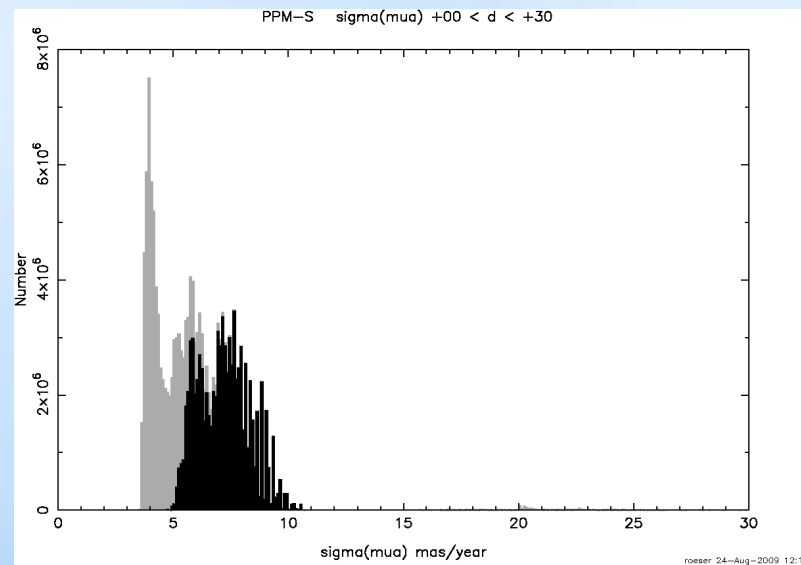
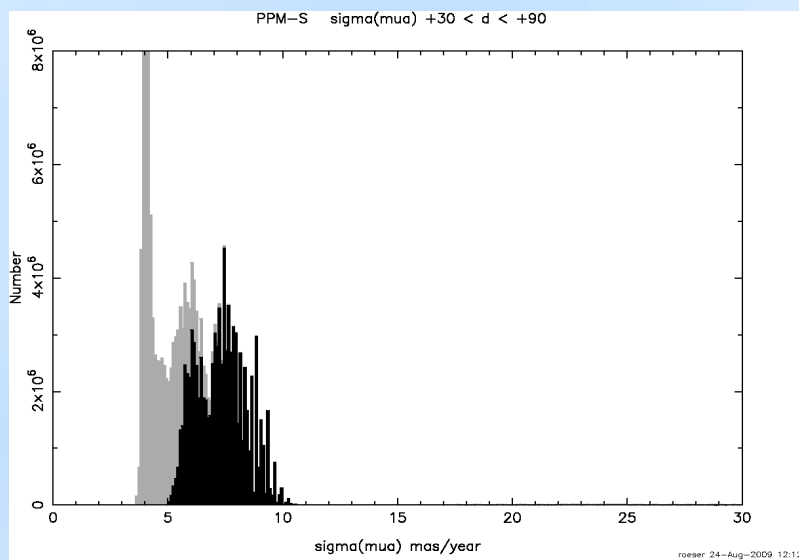
Mean errors of proper motions



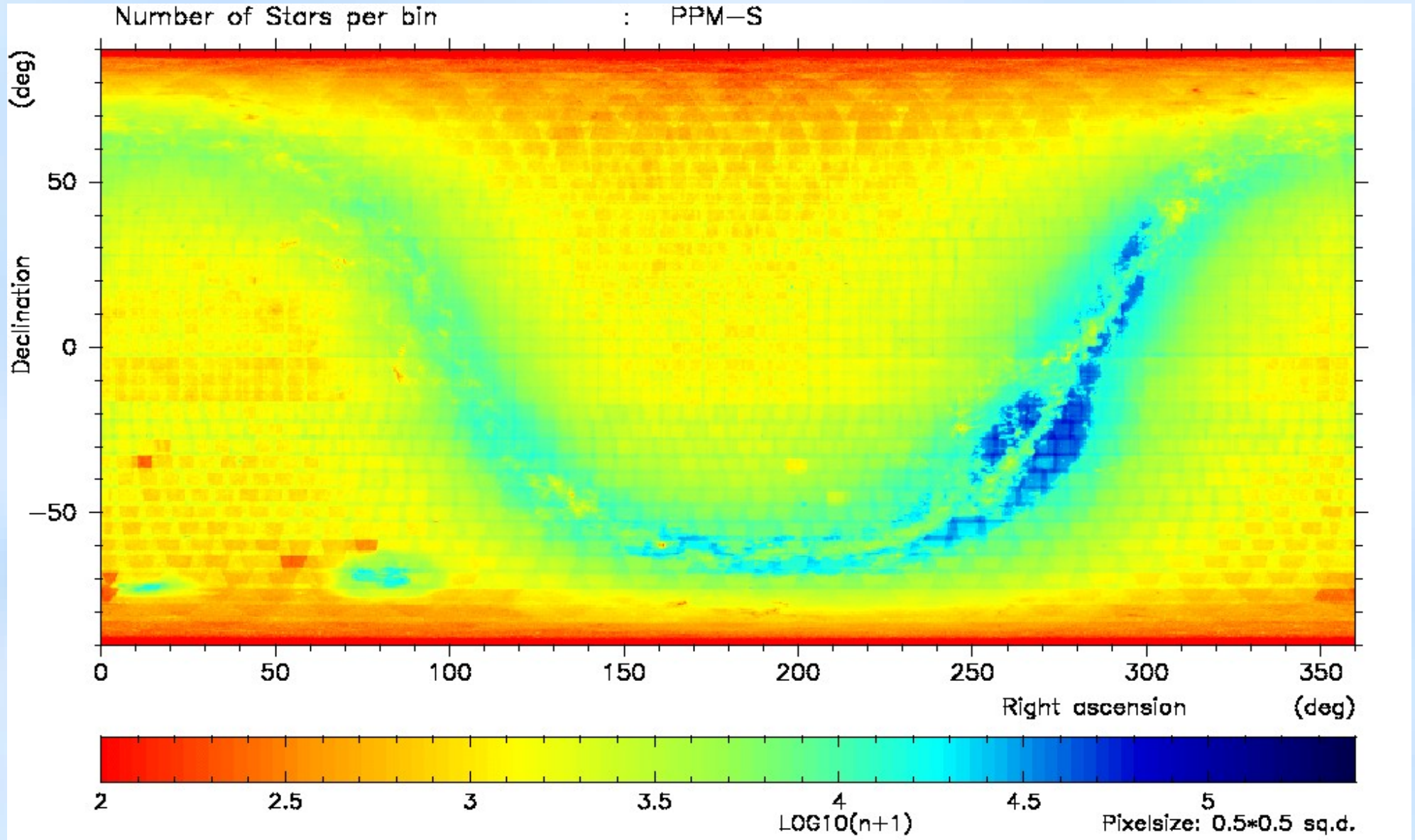
Mean errors of proper motions



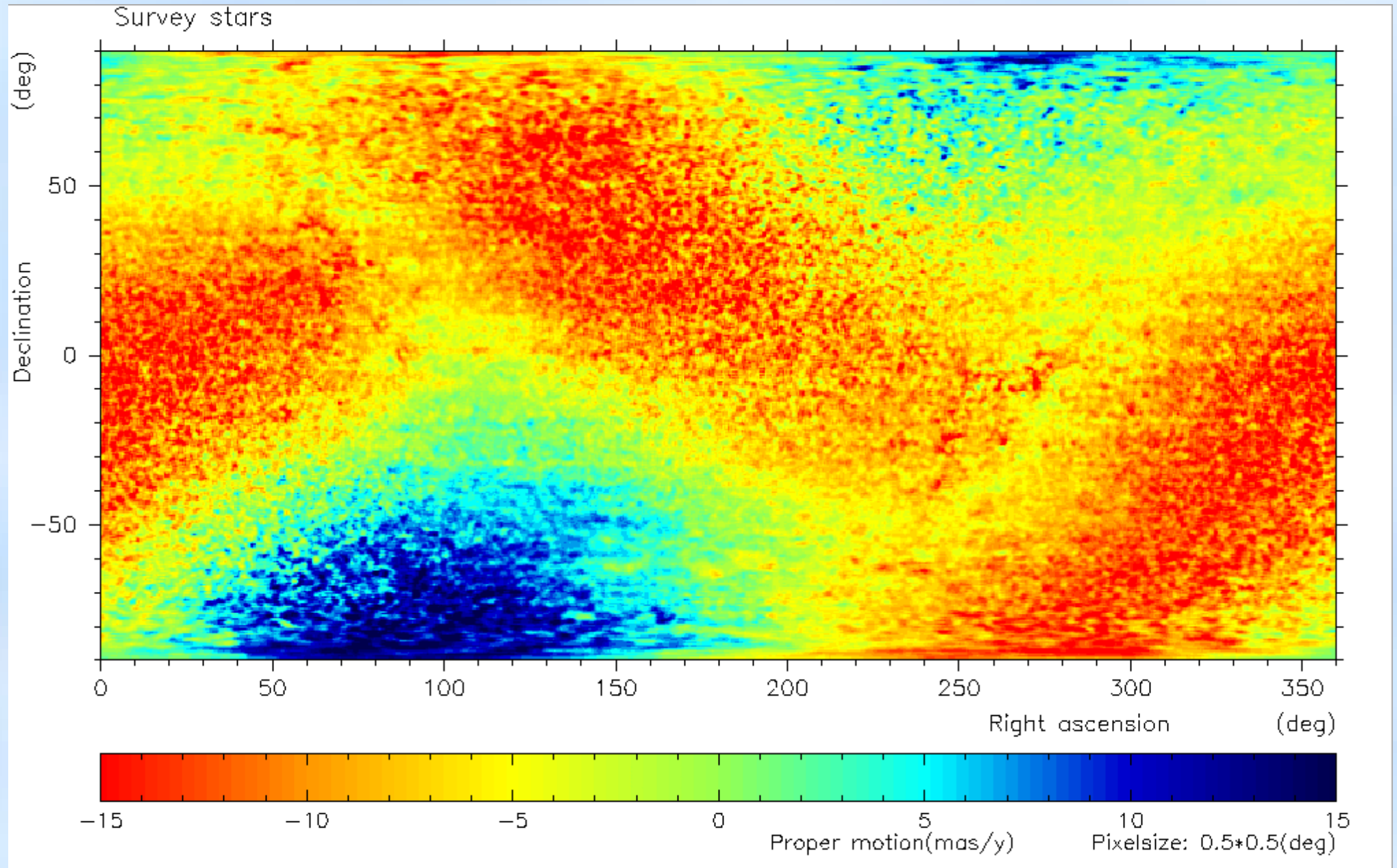
Mean errors of proper motions



The distribution on the sky(PPM-S)

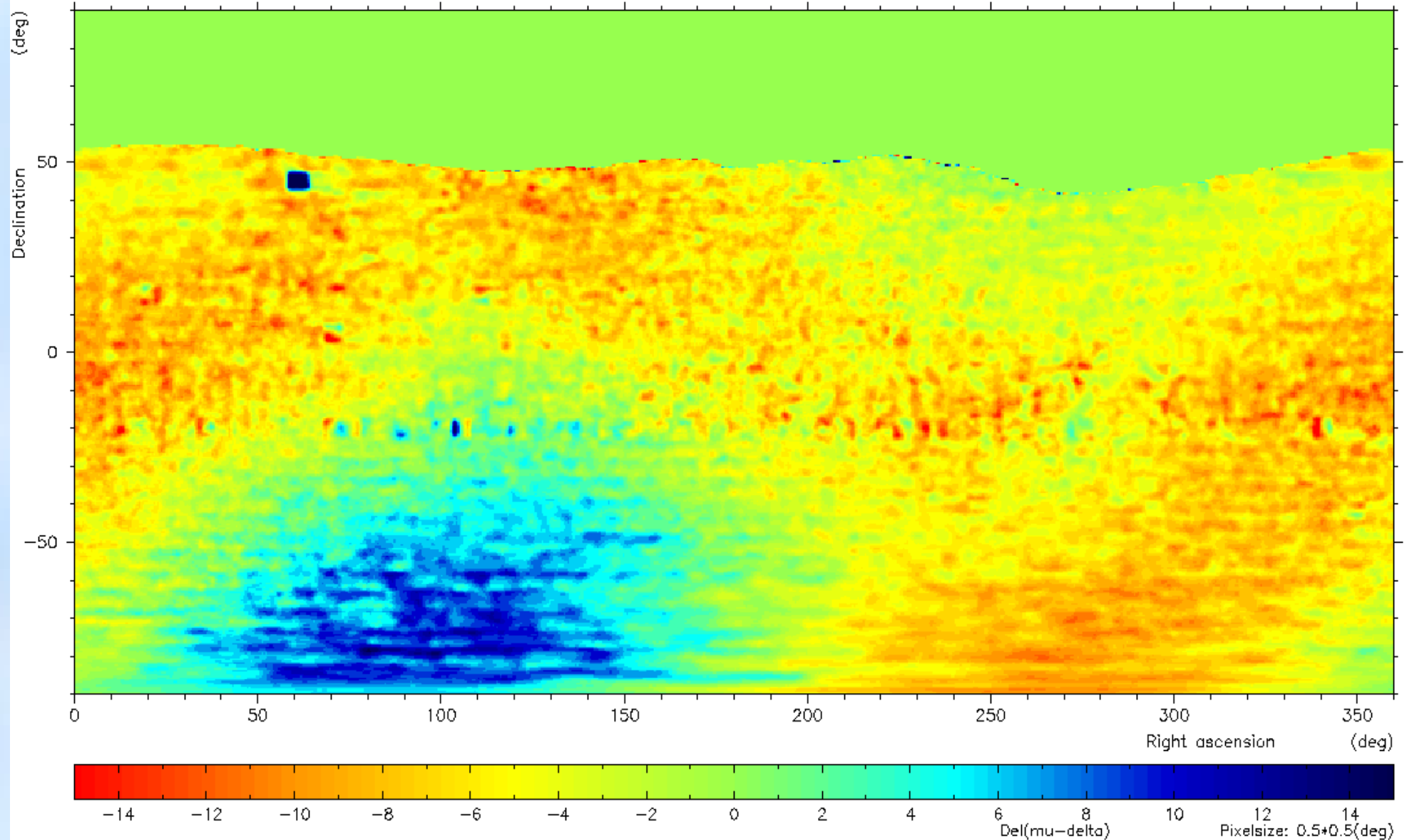


Proper motions in PPMX (Dec.)

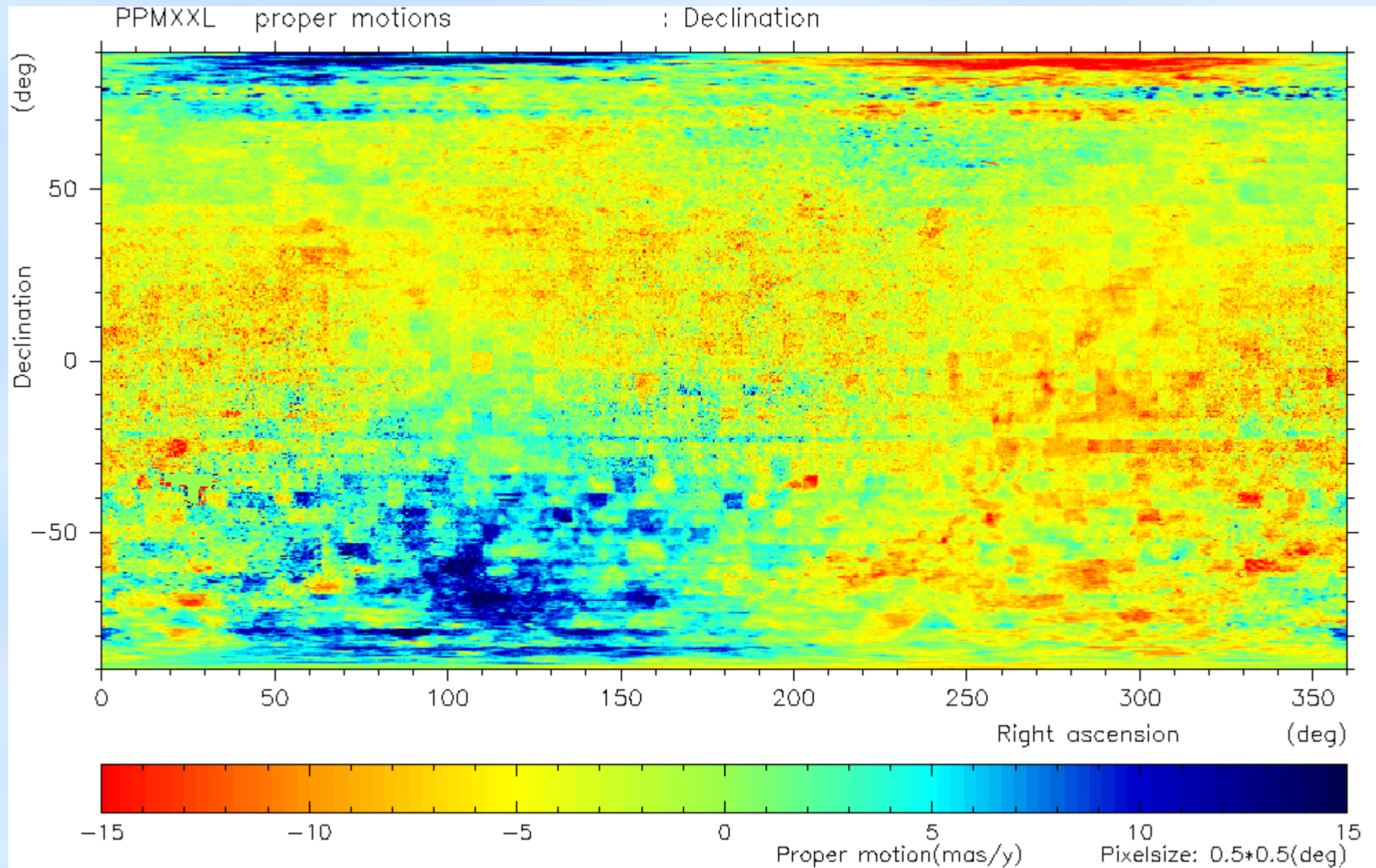


Proper motions in UCAC-2

UCAC proper motions : $\mu_{\alpha} - \Delta$



The proper motions



Things to be done

- Investigate defects (mostly coming from the obs log)
- Determine systematic corrections to PPMX and correct them. Then make a final lsq adjustment
- Merge with PPMX to construct «One entry per object» with best proper motions (v1.0)
- Collect all the magnitudes. Check magnitudes between 1st and 2nd survey. Calibrate with GSC2.2 ph. Cat. (v1.1)
- Include SDSS and CMC14 (brighter stars) (v2.1)
- Hopefully: include SkyMapper SSS
- Check «motion» of galaxies

This completes PPM-S

Applications

- Kinematics of the Galaxy
- Cool Nearby stars
- Star clusters and associations
- Astrometric reference catalogue (especially for solar system objects)
- Your ideas

Playground for Gaia

- It is a real survey, not a simulation
- About the same stellar content as Gaia (may be 0.5 mag brighter)
- Proper motions (on ICRS, but a factor of 100 less accurate individually, hopefully a factor of 50 systematically)
- Multi-band photometry
- **No** parallaxes, **no** RV

The End