VISTA-VVV high proper motion stars

Radostin Kurtev

Mariusz Gromadzki, Karla Peña, Juan Carlos Beamin, Stuart Folkes, René Mendez, Vicente Villanueva, Dante Minniti, Valentin Ivanov, Jura Borissova, Phil Lucas, David Pinfield, et al.

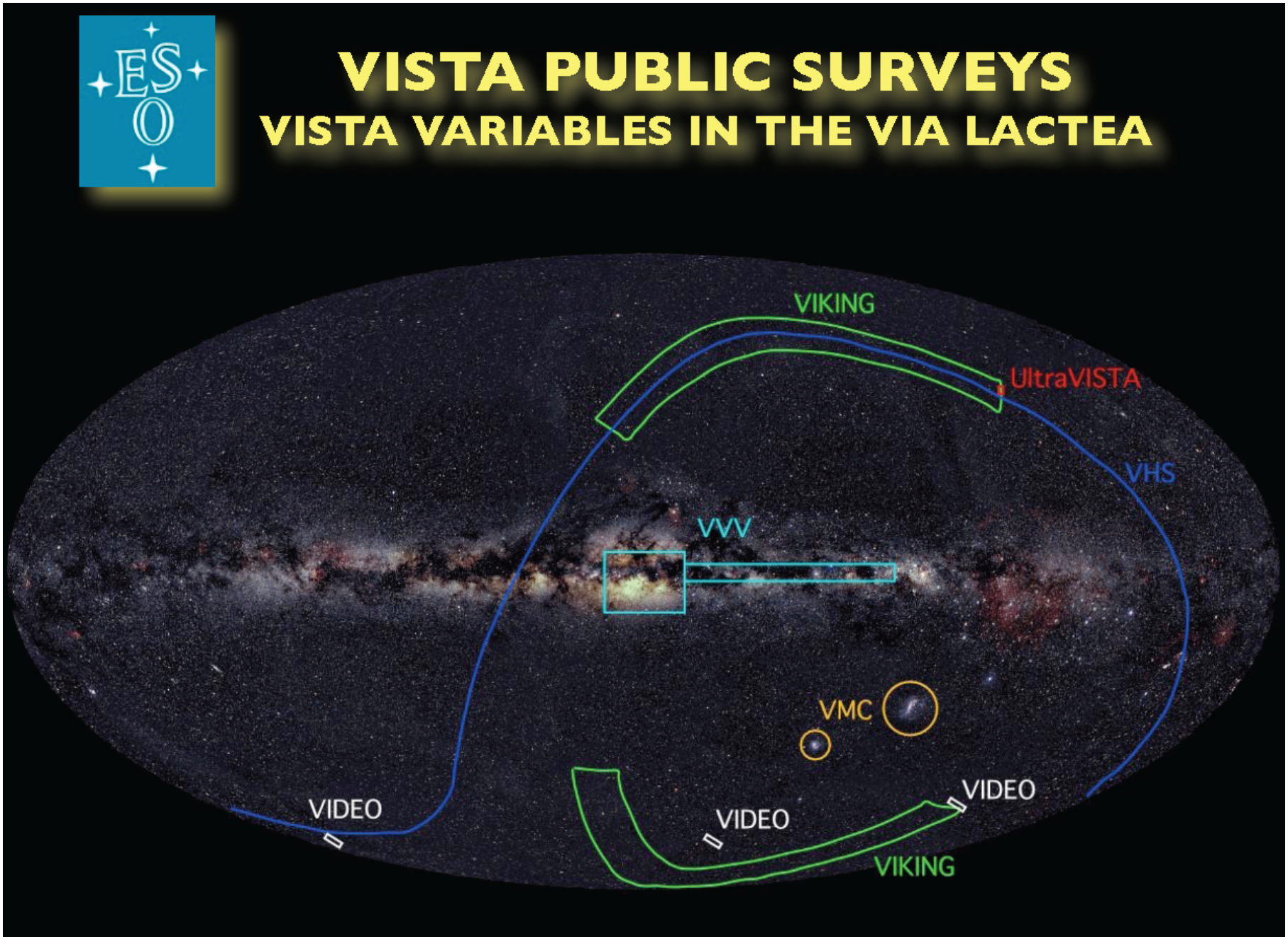
Outline

- Solar vicinity and NIR PM surveys: a search for our stellar neighbours (cool- and ultra-cool dwarfs)
- VVV and the zone of avoidance (Galactic bulge and plane)
- VVV CASU catalogues
- Search methods
- VVV high proper motion bright (Ks< 13.5) star catalogue
- First results
- Search for fainter ultra-cool and BDs
- VVV and parallax measurements
- Future plans

Solar vicinity and NIR surveys

- Complete census of stars within the solar neighbourhood
- Information: stellar mass function, stellar formation, galaxy kinematics, nearby stellar clusters and young moving groups
- Identification on low mass stars in large optical surveys: difficulties because of the low luminosity and red colours
- Confusion with reddened stars and distant red giants
- 3D IR surveys (proper motion): solution of the problem
- Low mass stars and especially M dwarfs: host exoplanets
- About 25% of all Doppler-confirmed planets with M *sin(i)* < 30 $M_{\oplus}$ are orbiting M dwarfs
- Radio velocity and AO monitoring
- New nearby brown dwarfs

VISTA IR Surveys and the VVV

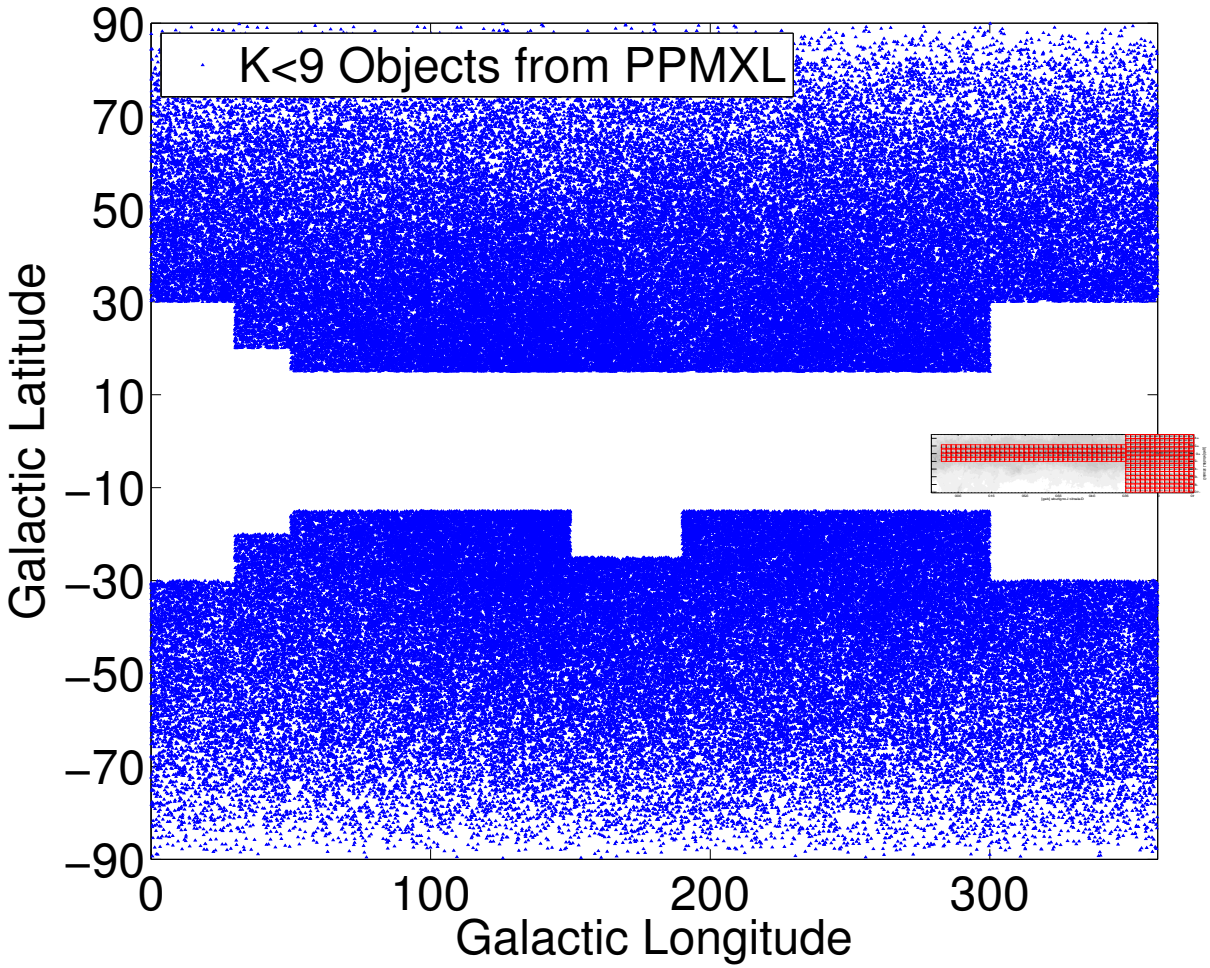


VVV top 10 science goals

- To use RR Lyrae to obtain a 3D picture of the bulge
- To identify variables belonging to known clusters
- To search for new star clusters
- To map star forming regions along the plane
- To find eclipsing binaries and planetary transits
- To search for microlensing events
- To study rare variable sources
- To monitor the variability around the Galactic Center
- To find variable stars in the Sgr dSph galaxy
- To identify background QSOs

(Also high proper motion objects, BDs, KBOs, Light Echoes...)

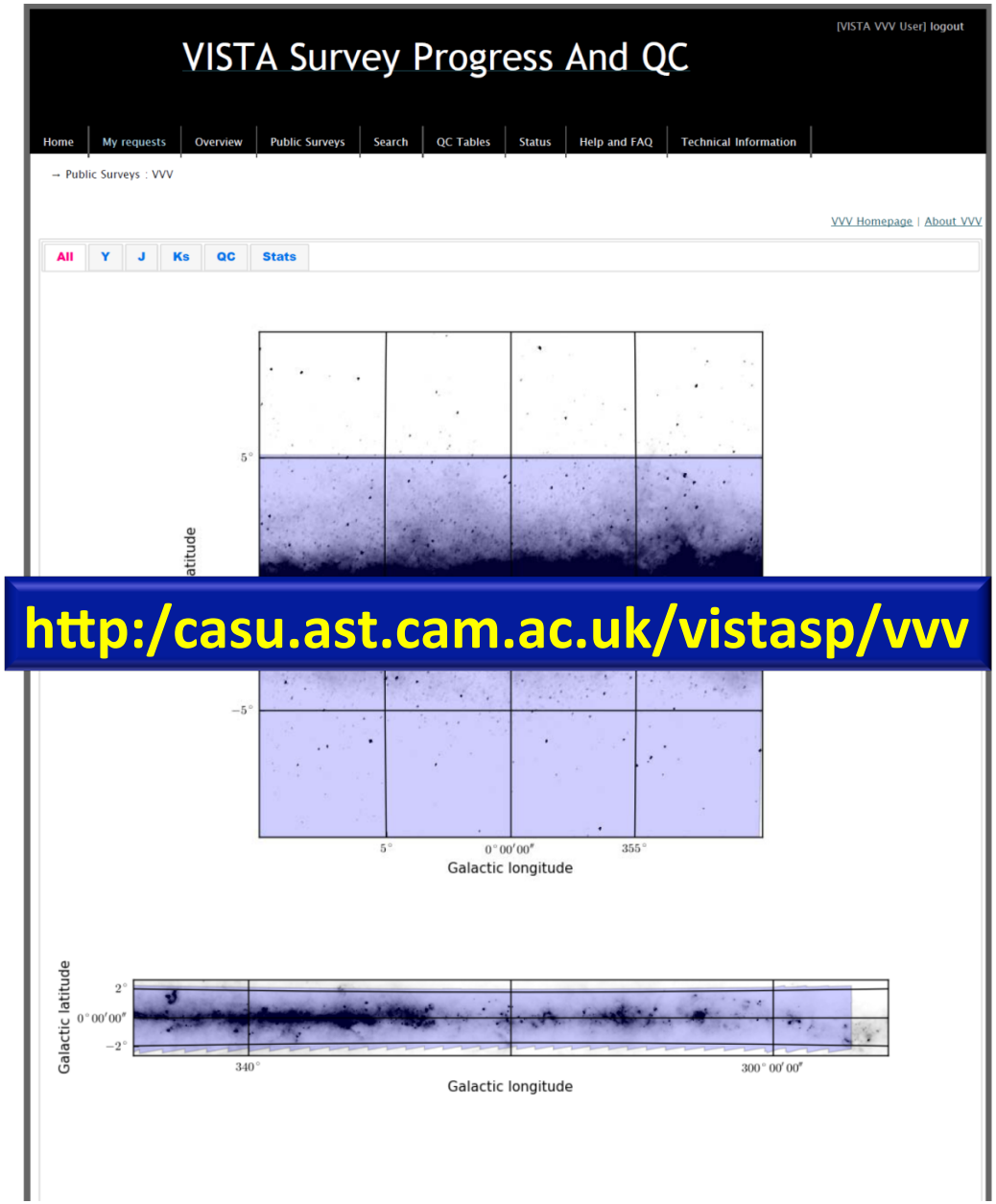
VVV and the zone of avoidance



Frith et al. 2013, MNRAS, 435, 216
A catalogue of bright (Ks<9) M-dwarfs

- **The zone of the Galactic bulge and plane: largely ignored in the PM searches**
- **Most of the nearby stars found outside this zone**
- **VVV self sustained: 5 filters and many epochs in Ks**
- **Disadvantage: small portion of the sky – about 1%**
- **Advantage: most of the stars on the plane and bulge; perfect for AO targets; good spatial resolution and limiting magnitudes**

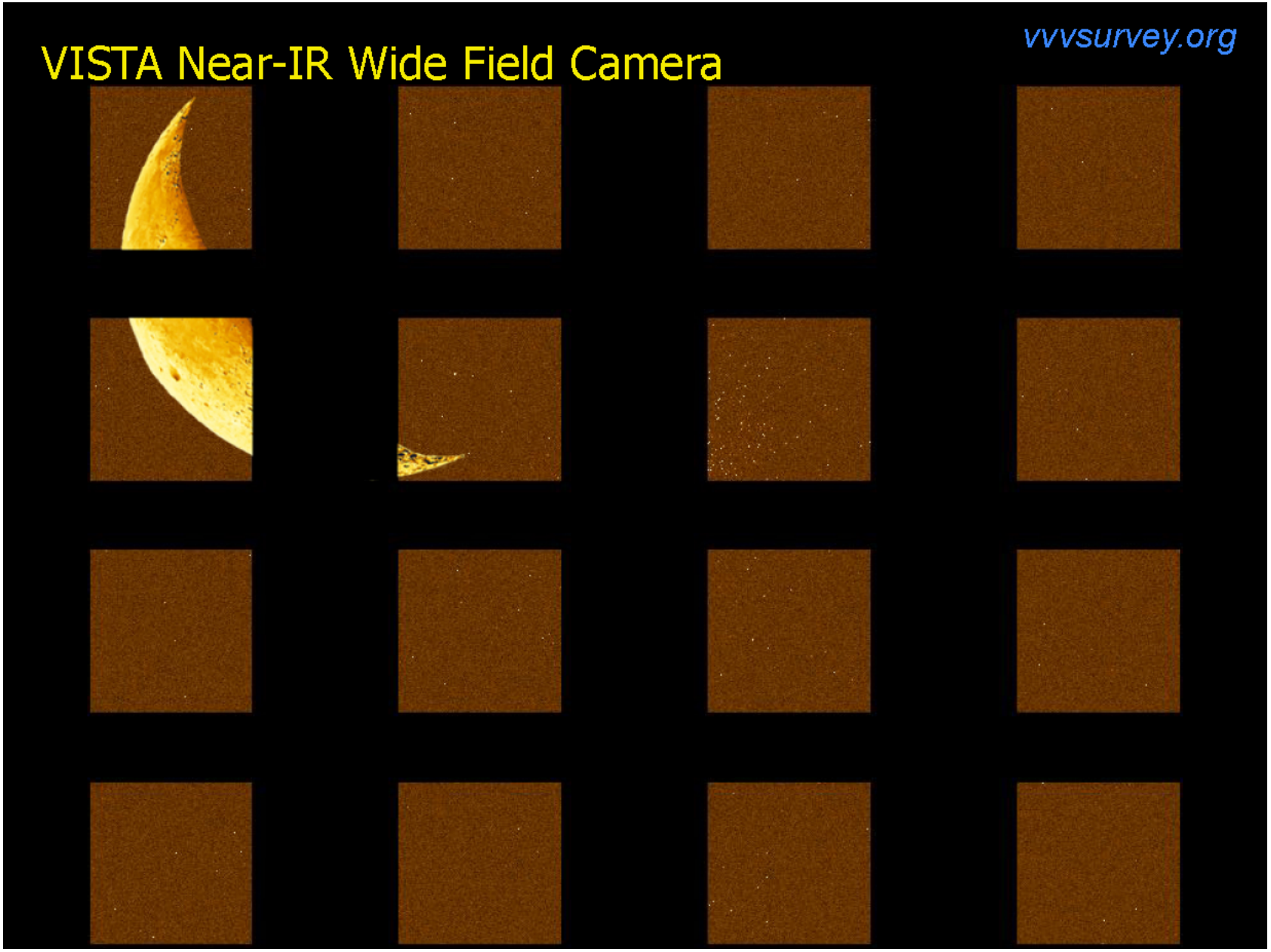
VISTA data products (CASU & VSA)



http:/casu.ast.cam.ac.uk/vistasp/vvv

http:/horus.roe.ac.uk/vsa/index.html

Astrometric calibration 2MASS - VISTA



Astrometric calibration 2MASS - VISTA

WSC – ZPN projection $r' = r + k_3 r^3 + k_5 r^5 + \ldots$

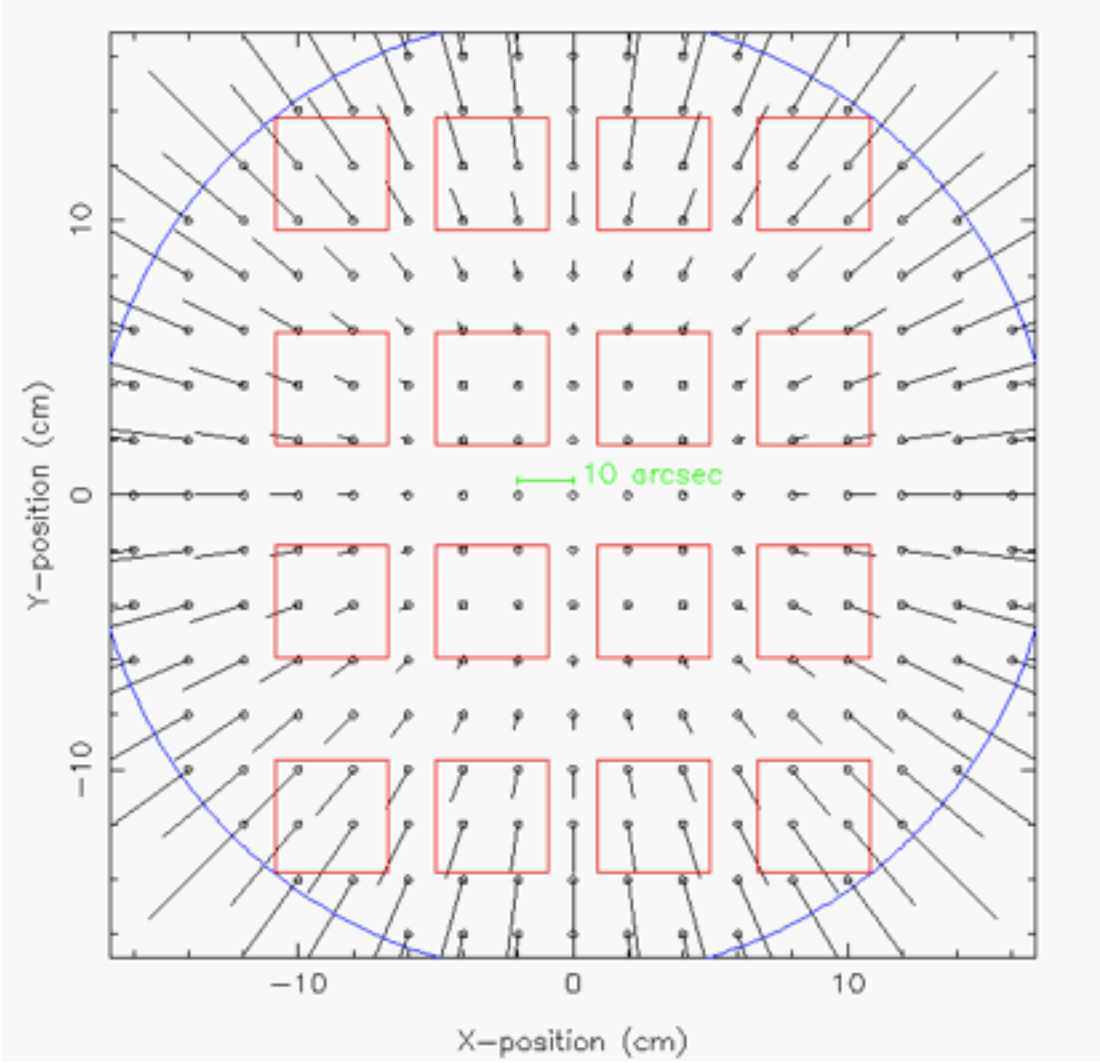
Linear solution per detector

$\xi' = ax' + by' + c$
$\eta' = dx' + ey' + f$

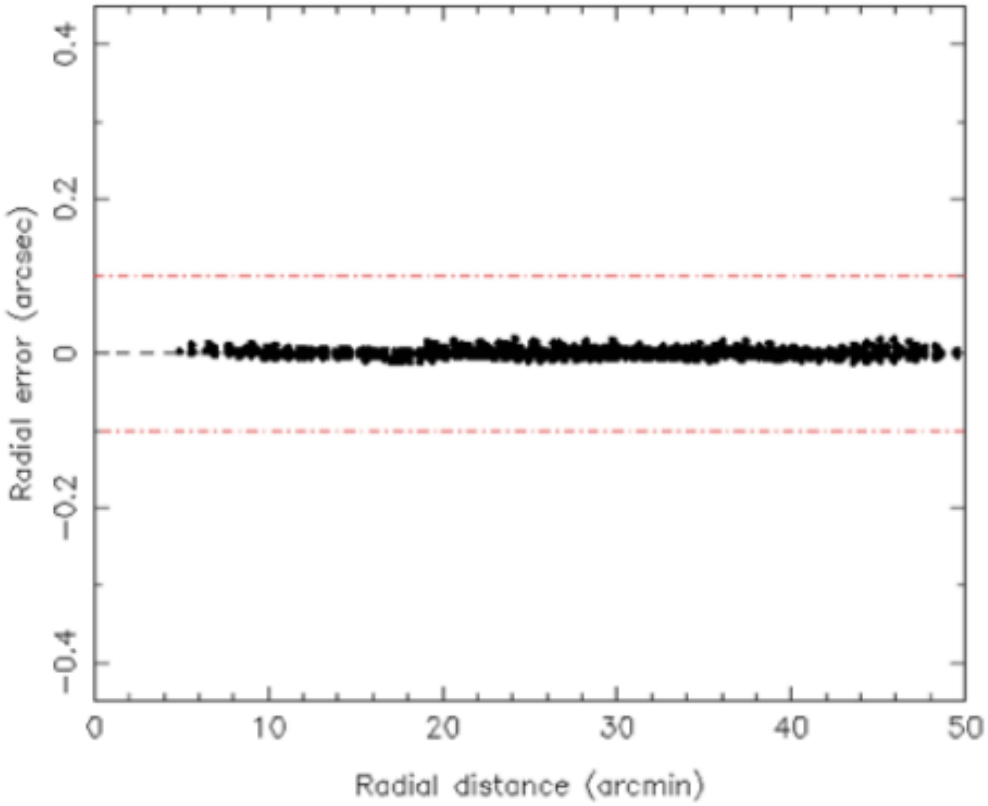
⇒ rms < 100 mas

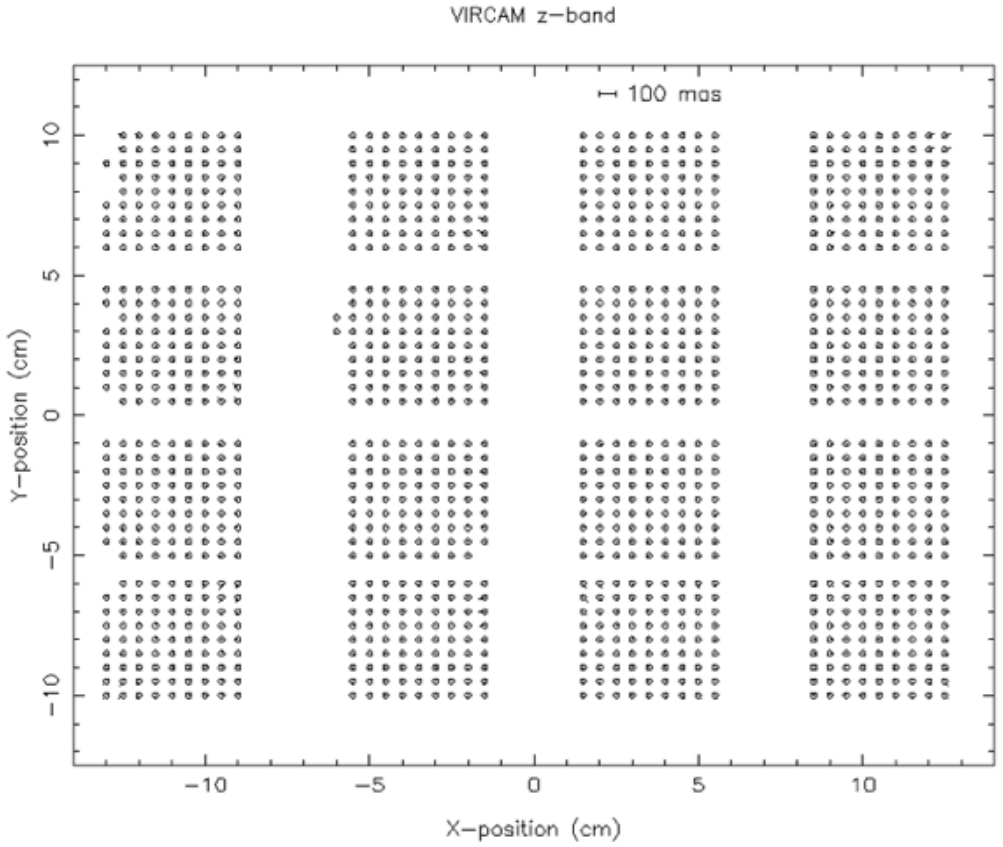
Tabulated systematics
From stacked residuals

⇒ sys < 25 mas

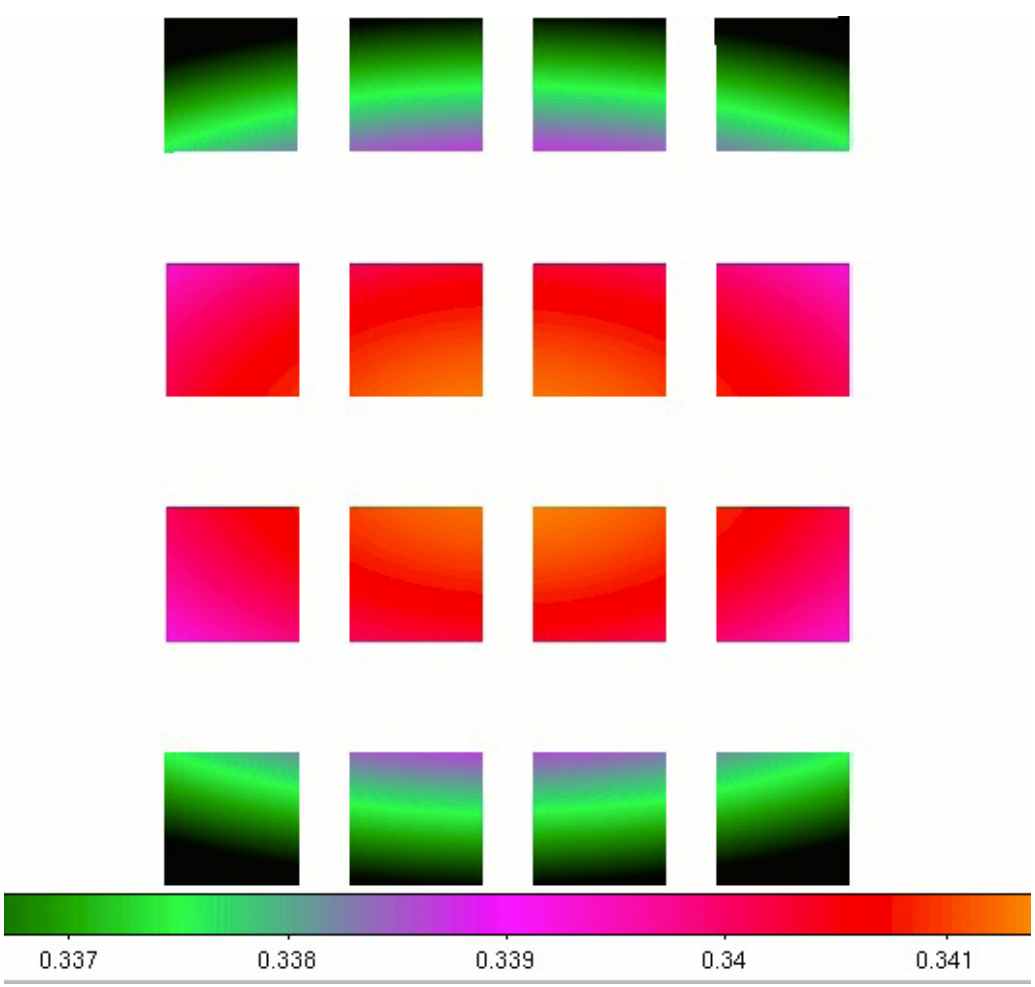


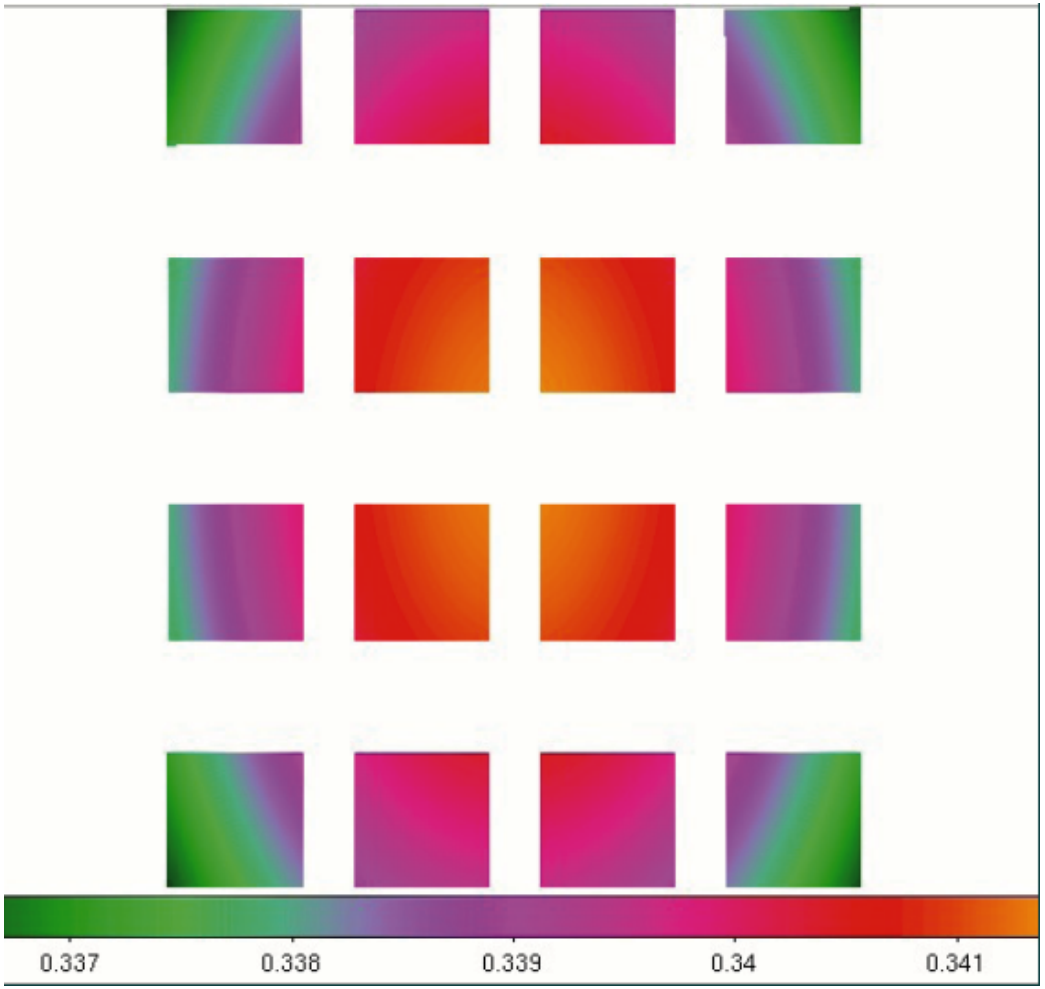
Astrometric calibration: residual distortion map





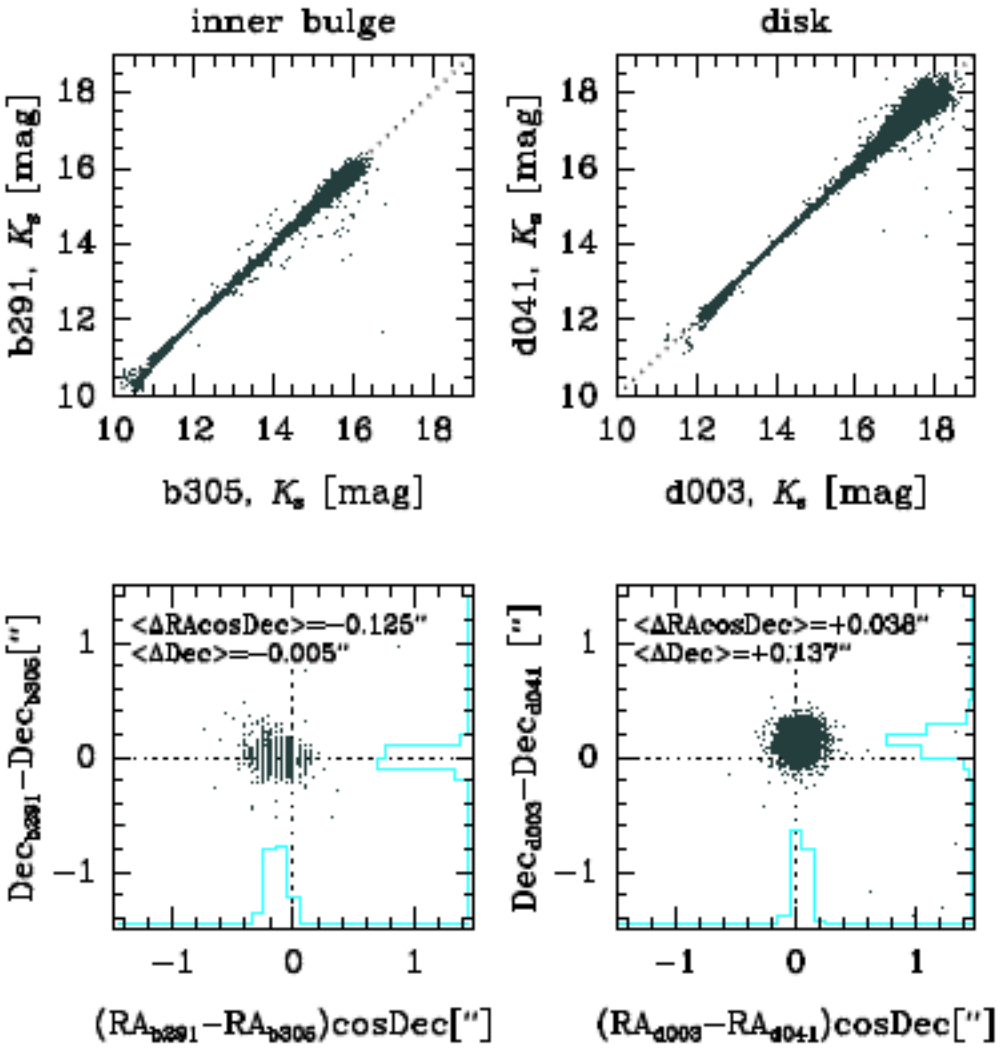
Variation of X,Y pixel scales





VVV photometric and astrometric accuracy

Saito et al. 2013, A&A, 537, 107



Photometry in the *K*s band for the over- lapping region between tiles b291 and b305 (left), and d003 and d041 (right). Only stellar sources on the plots.

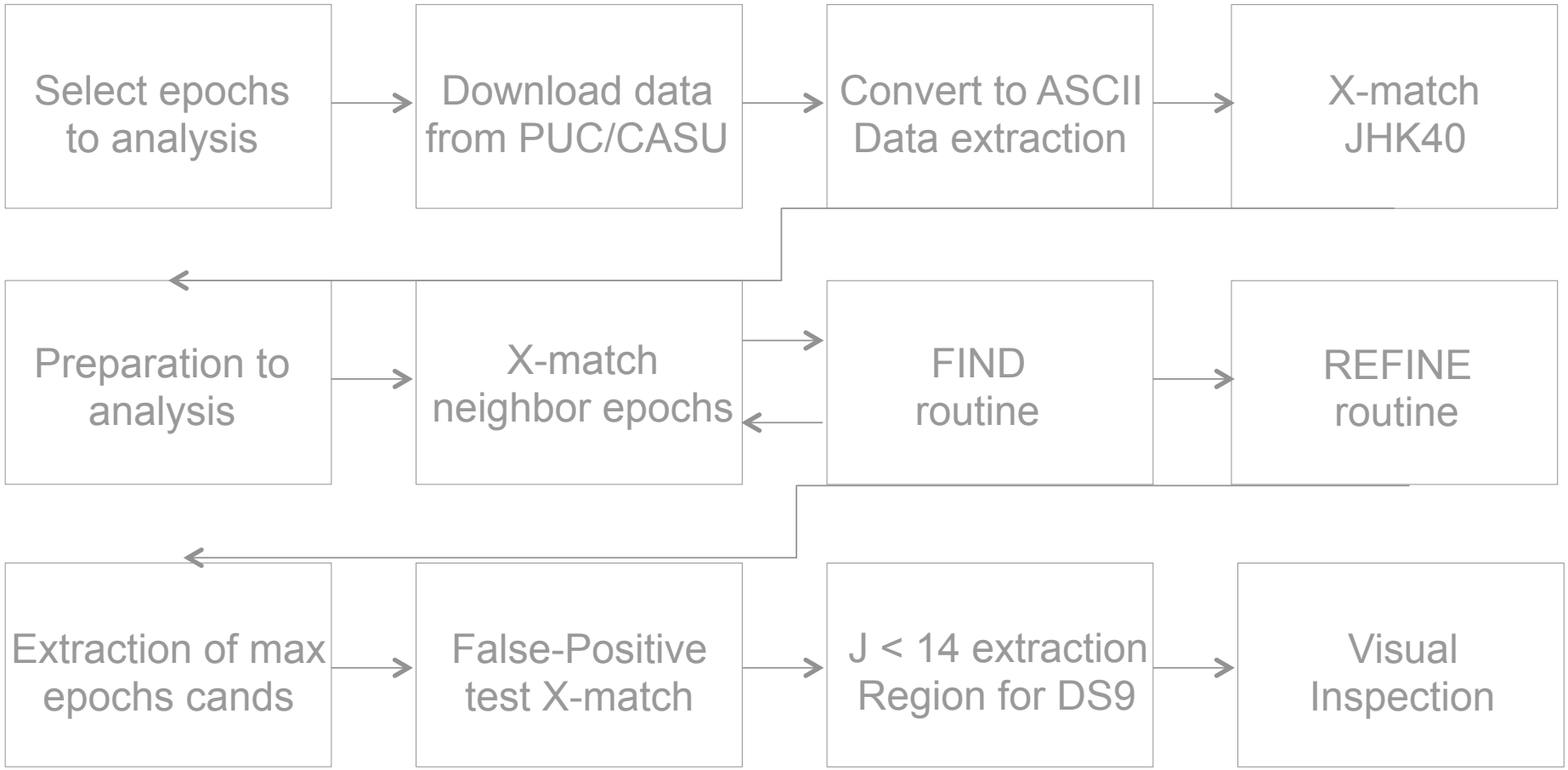
Astrometric accuracy for the same overlapping regions. The mean values for Δαcosδ and Δδ are:

-0.125”, -0.005”

+0.038”, +0.137”

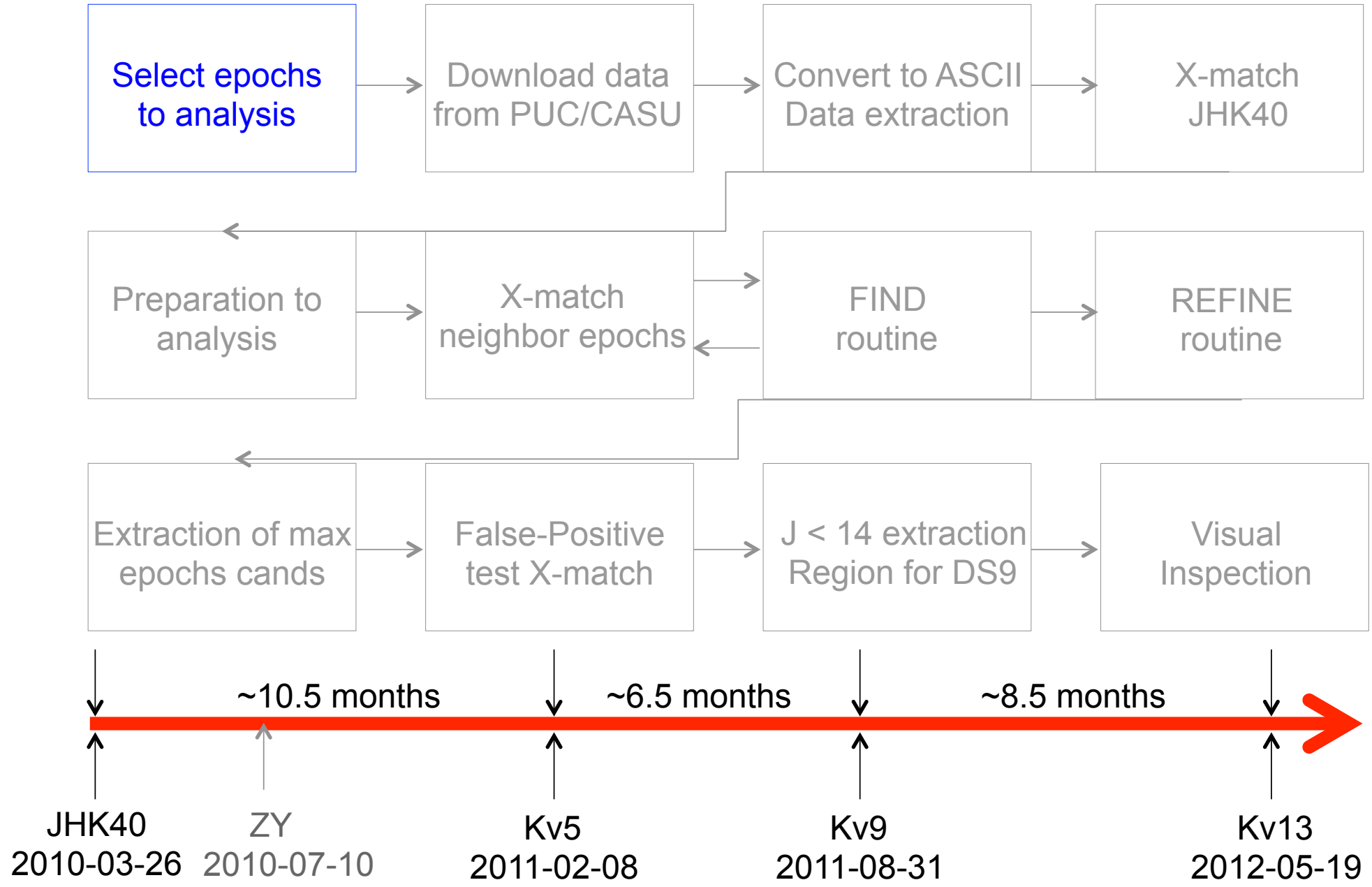
Counting histograms for the distribution are also shown for both axes.

Detection method (VVVPM)

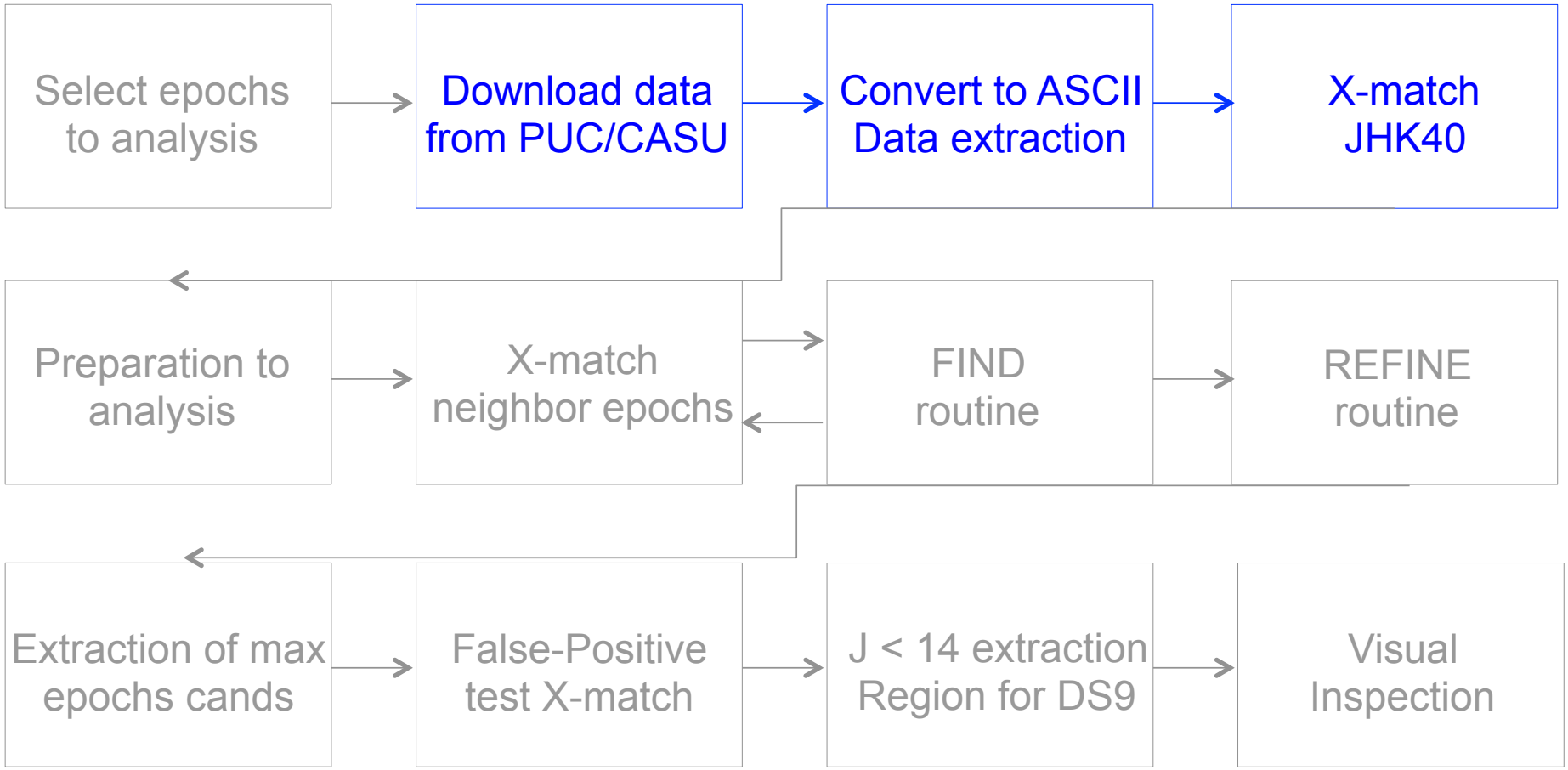


- Method developed by Stuart Folkes (only VVV for find HPM stars)
- Tools: STILTS, shell scripts, IDL routine, CASU FORTRAN procedure
- Data: CASU catalogs for various epoch in Ks
- General remark: VIRCAM pixel ~ 0.34”, WCS error ~ 0.06”-0.09”

Detection method (VVVPM)



Detection method (VVVPM)

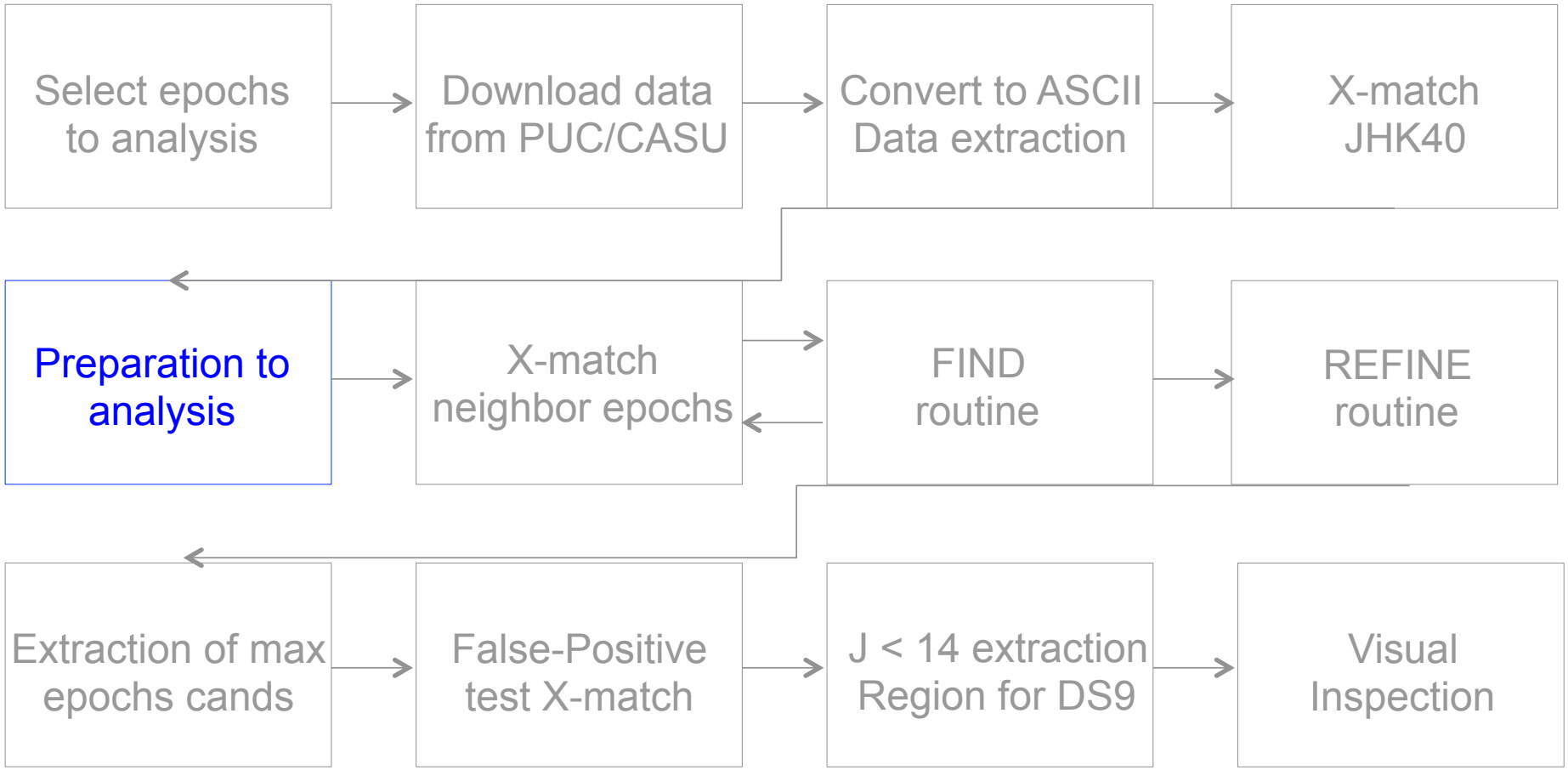


- We download (ZY)JHK40, Kv5, Kv9, Kv13 catalogs (~2 GB)
- Convert FITS -> ASCII and extract necessary information:

CASU FORTRAN procedure

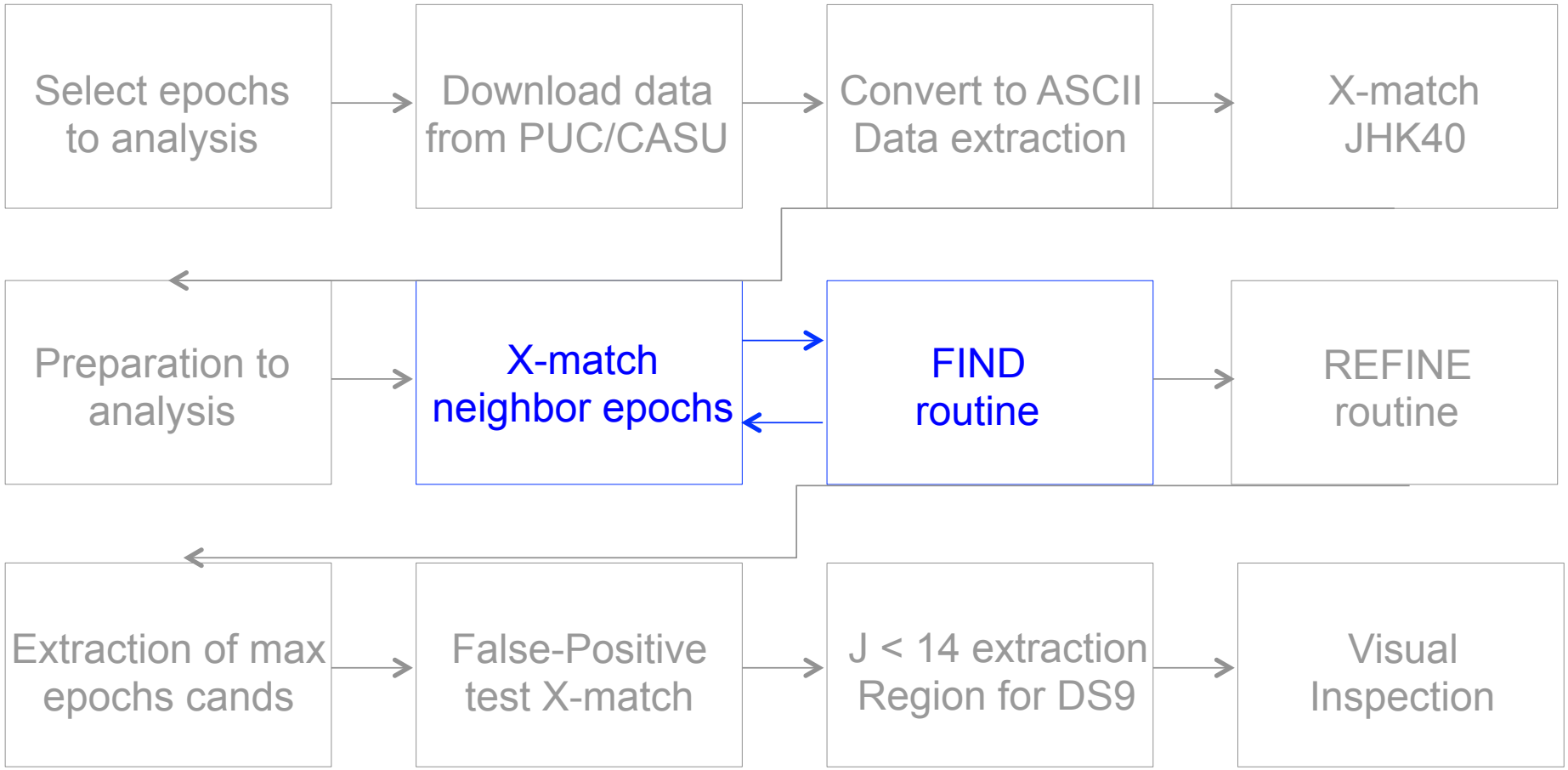
- X-match JHK40 with 0.3 arcsec radius

Detection method (VVVPM)



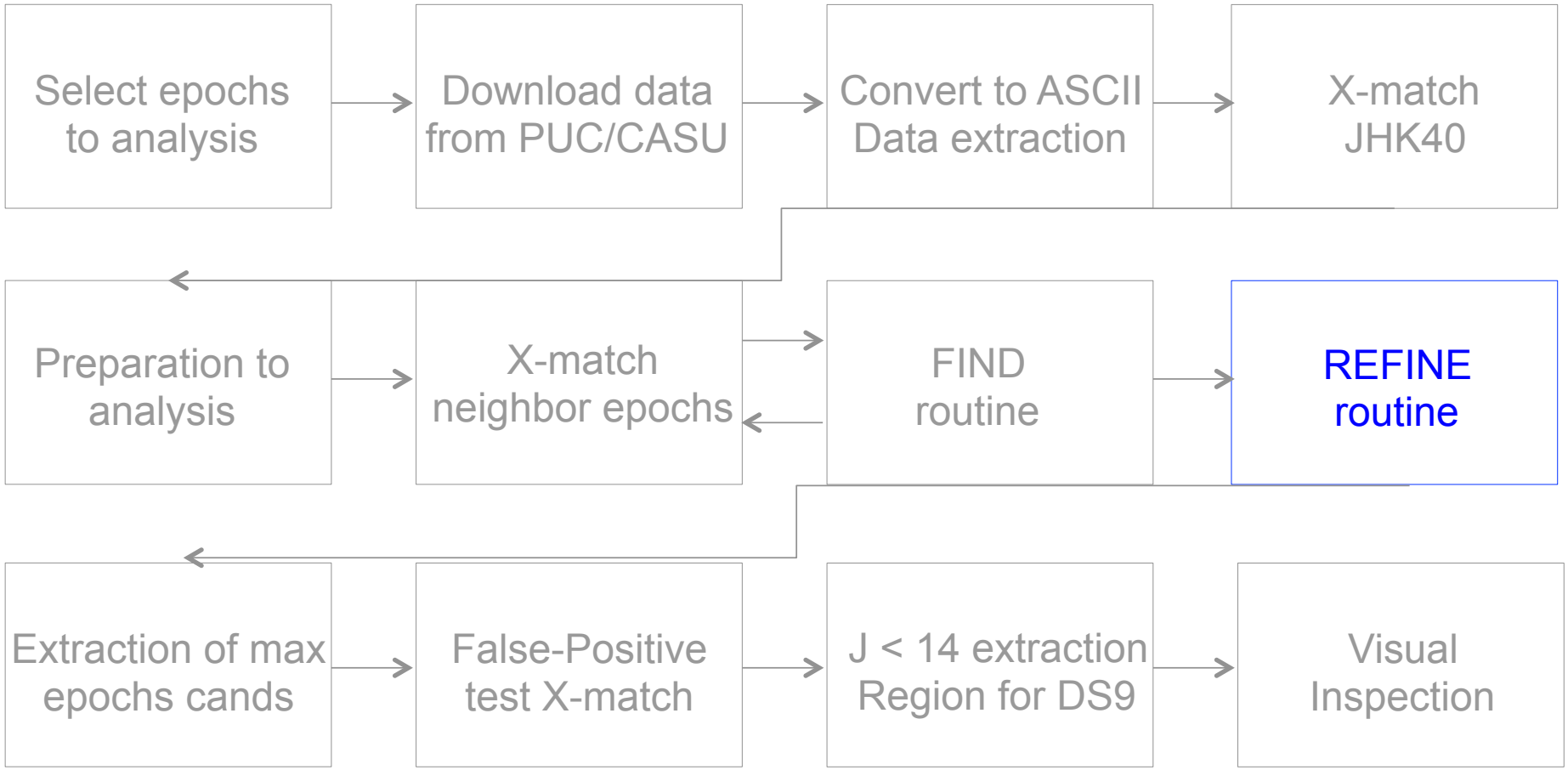
- Estimation radius for X-match in each step
- Prepare first input file to X-match (FLAG_K = -9, -2, -1)
- Create logfile

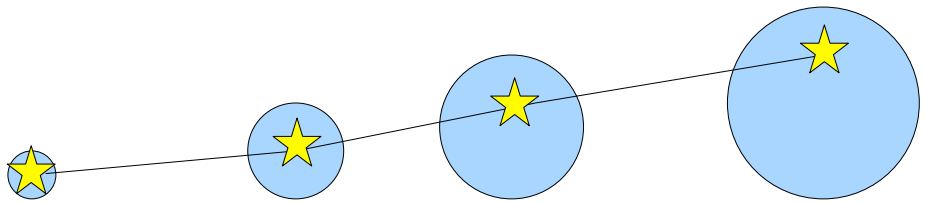
Detection method (VVVPM)



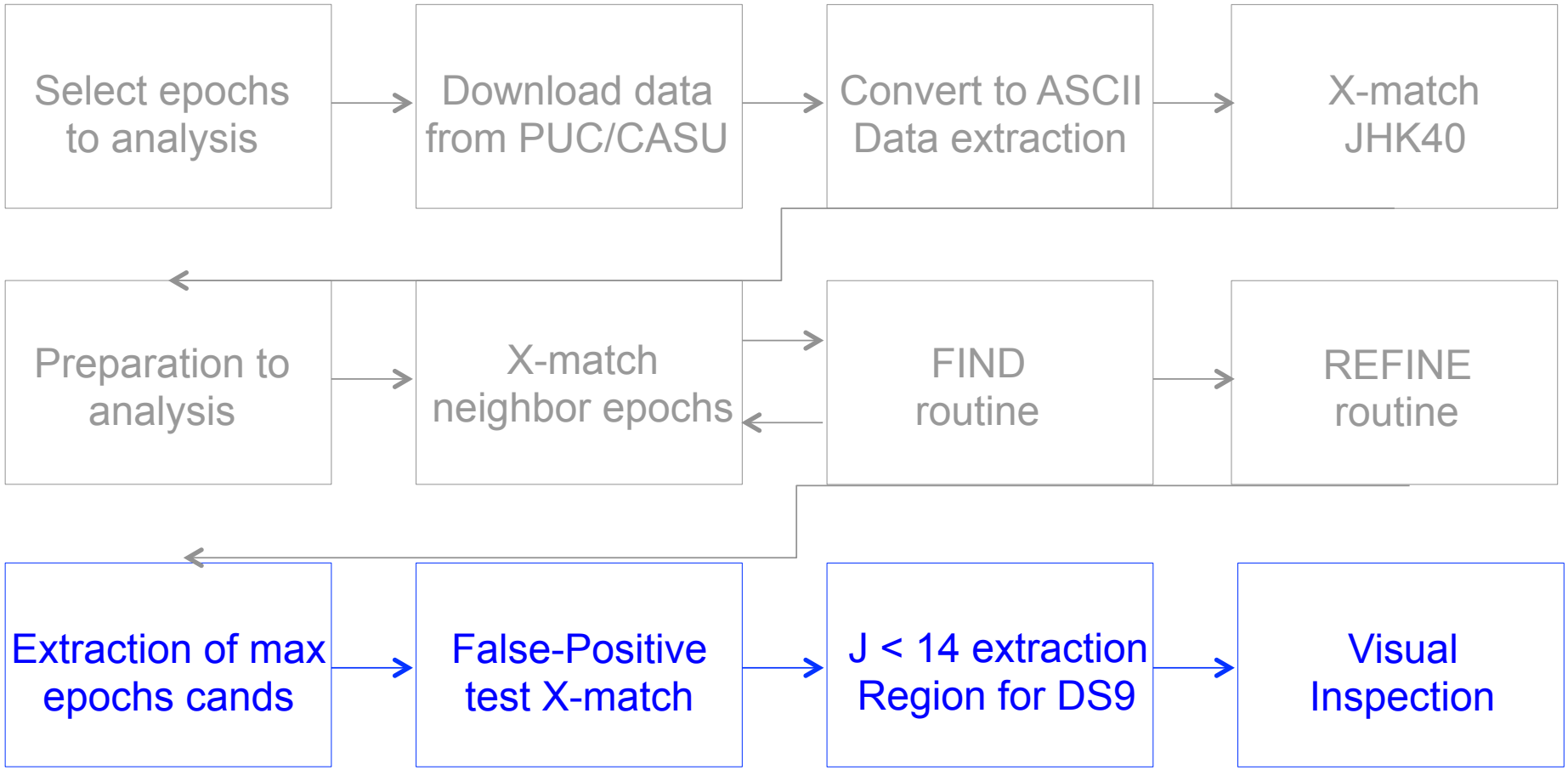
- Write PM and PA of candidates in structure file
- Prepare input file to X-match for next step
- Re-Write logfile

Detection method (VVVPM)

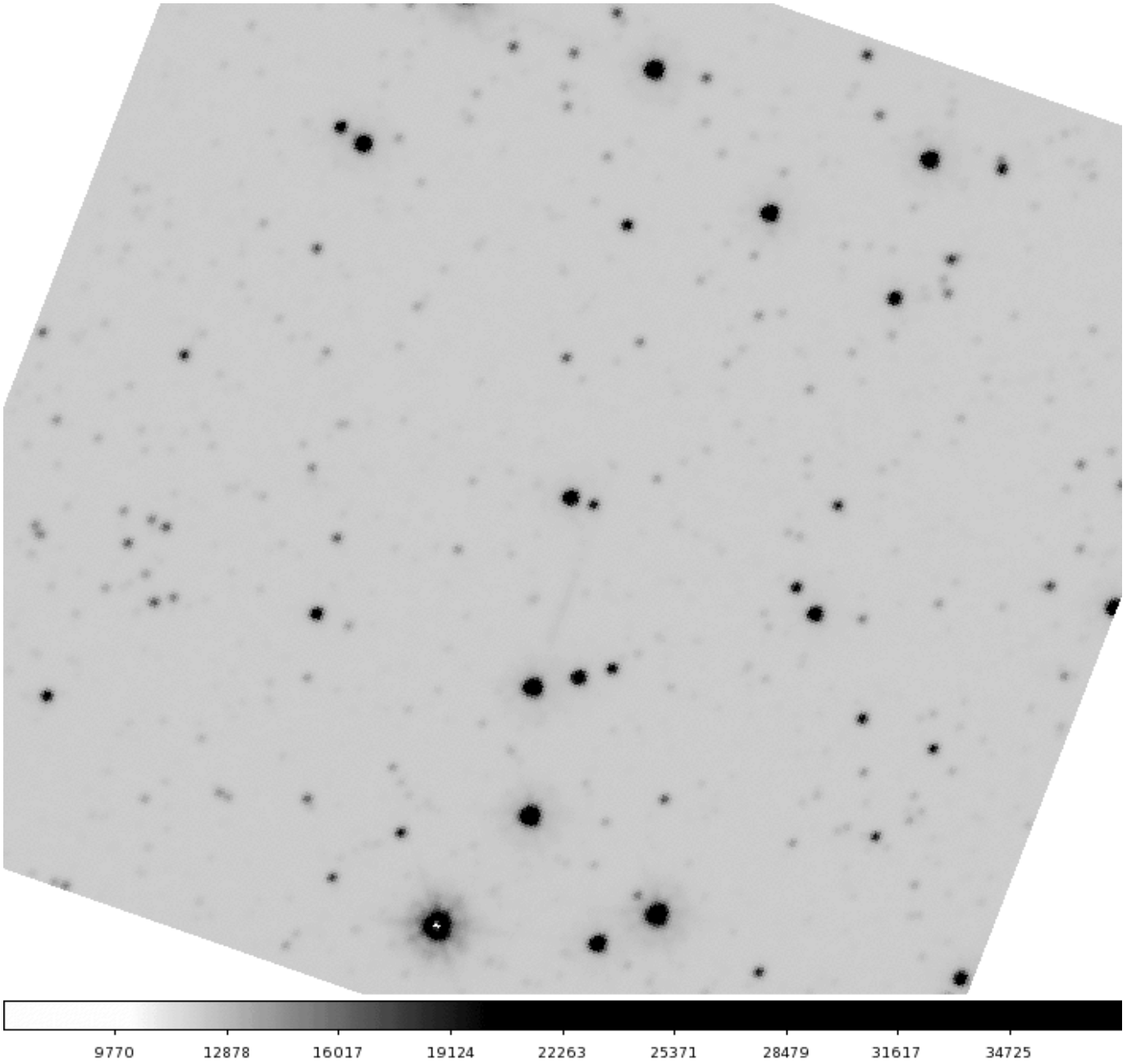




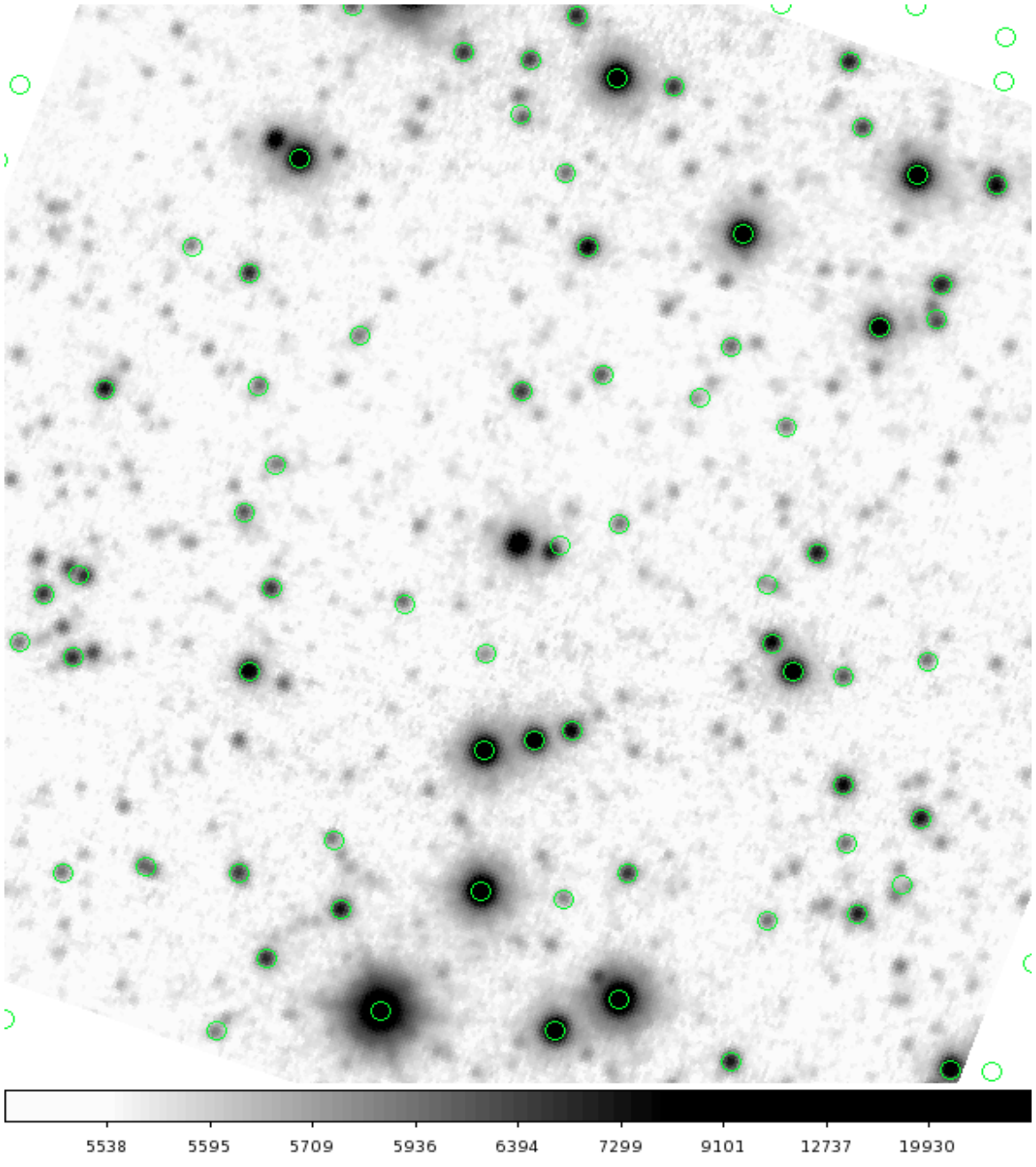
Detection method (VVVPM)



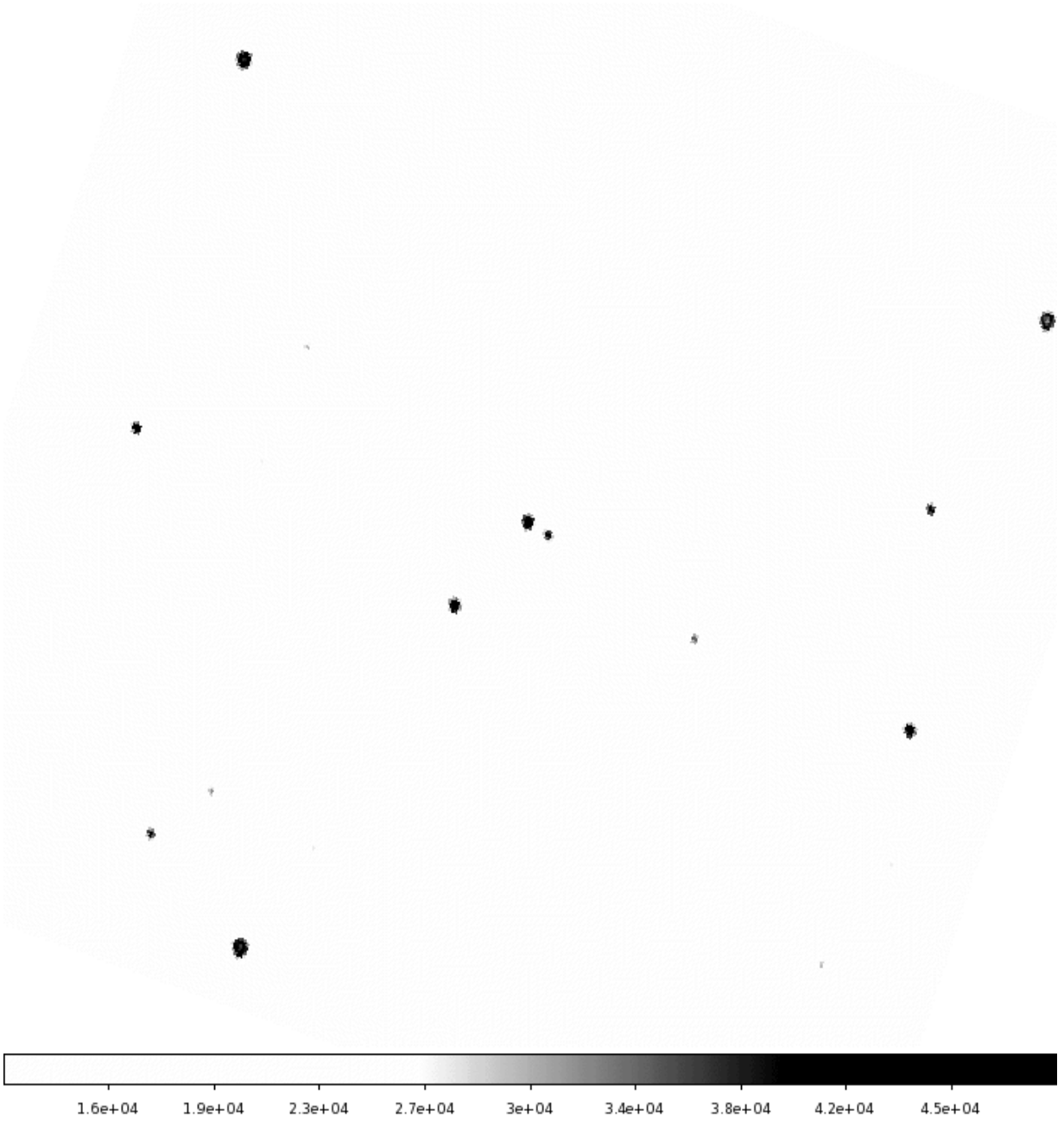
Example detection I



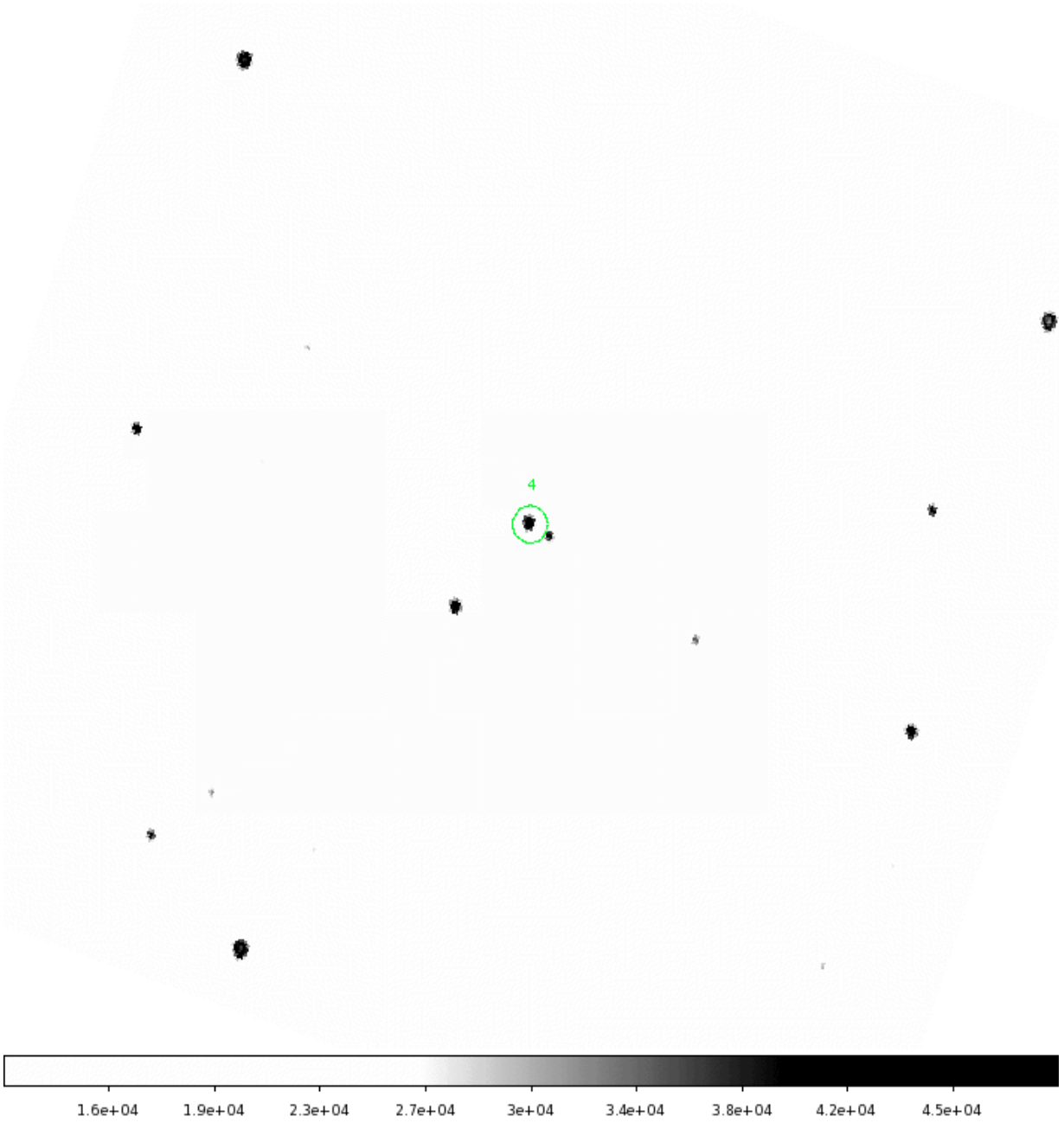
Example detection I



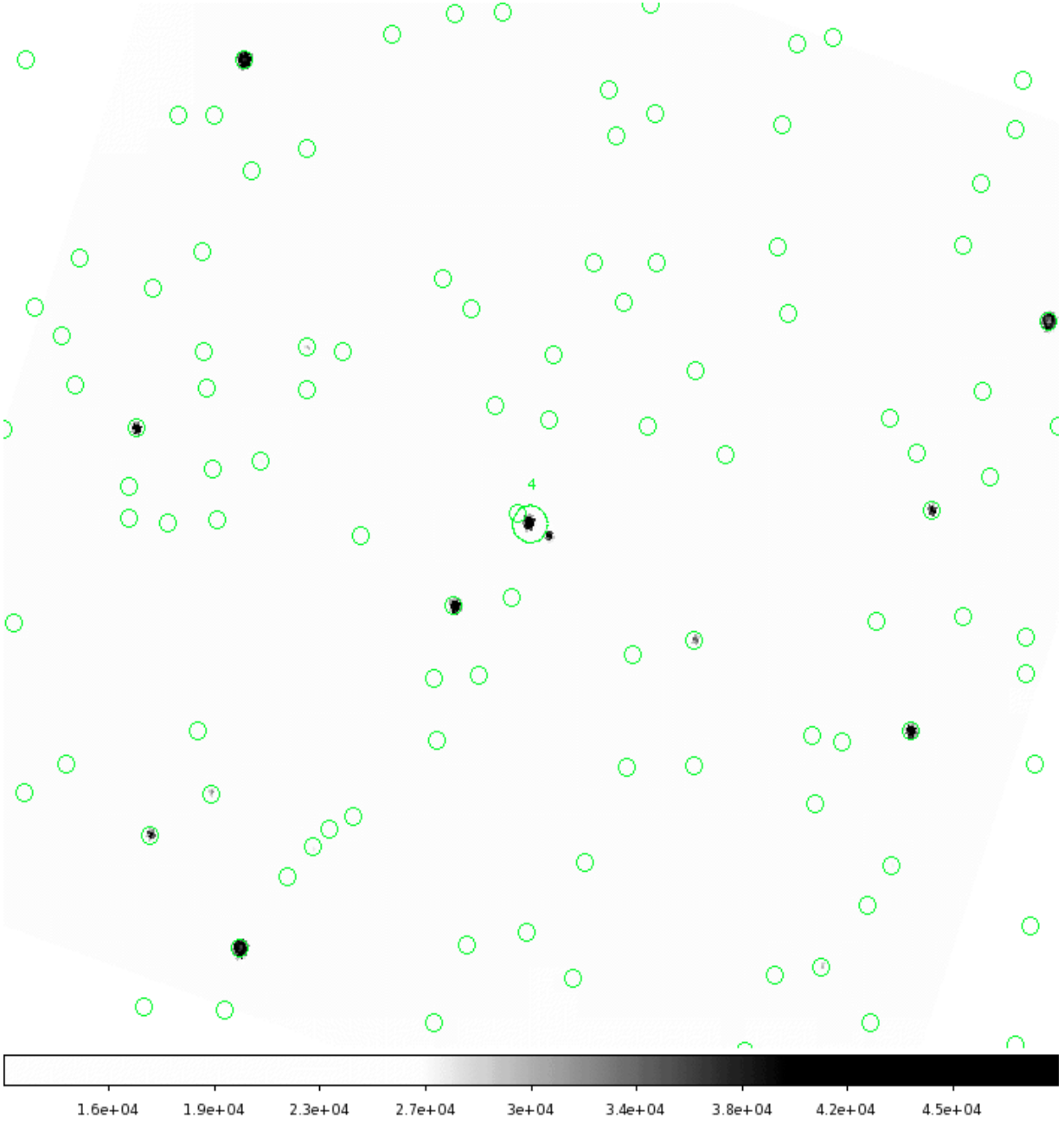
Example detection II



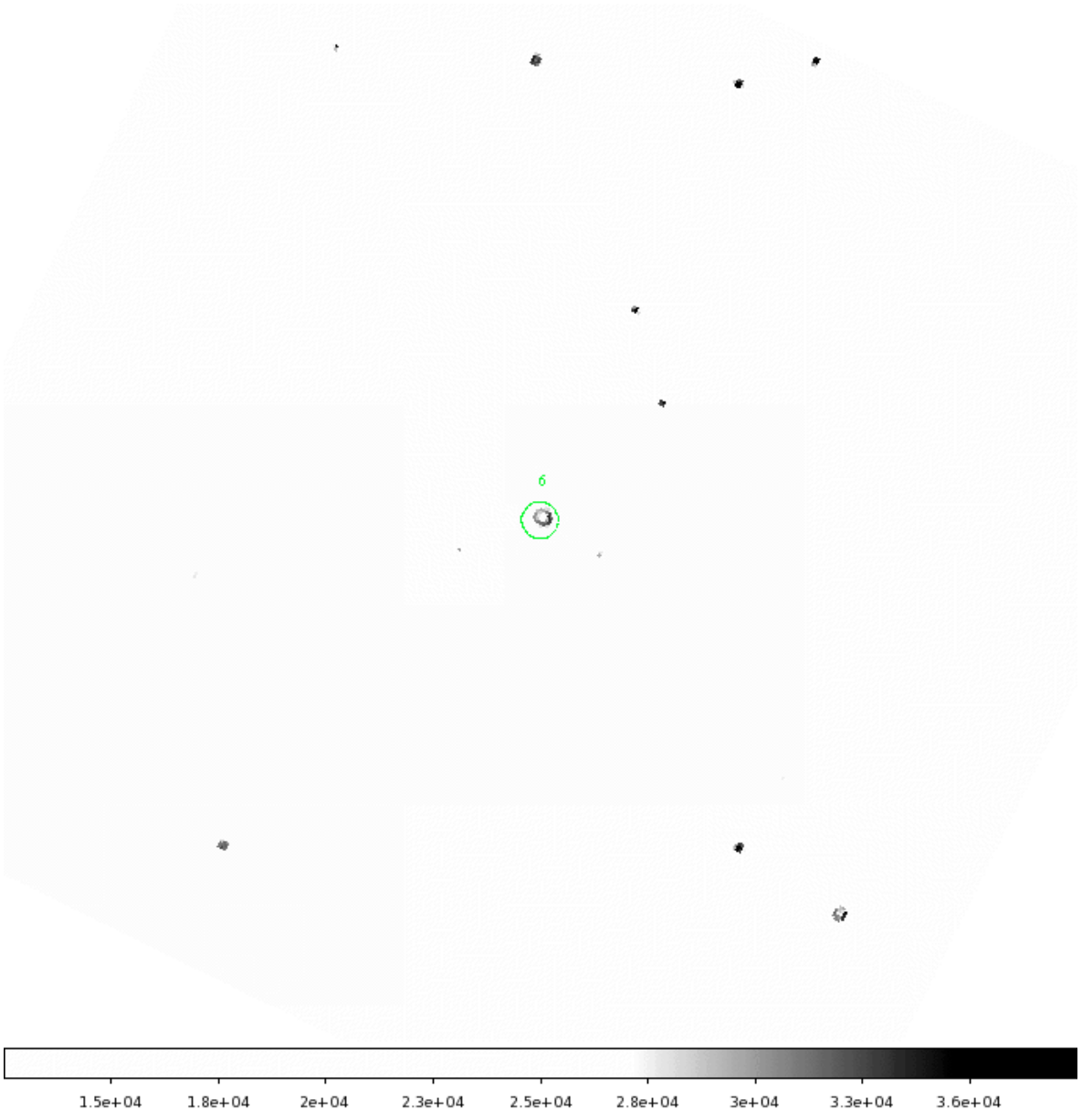
Example detection II



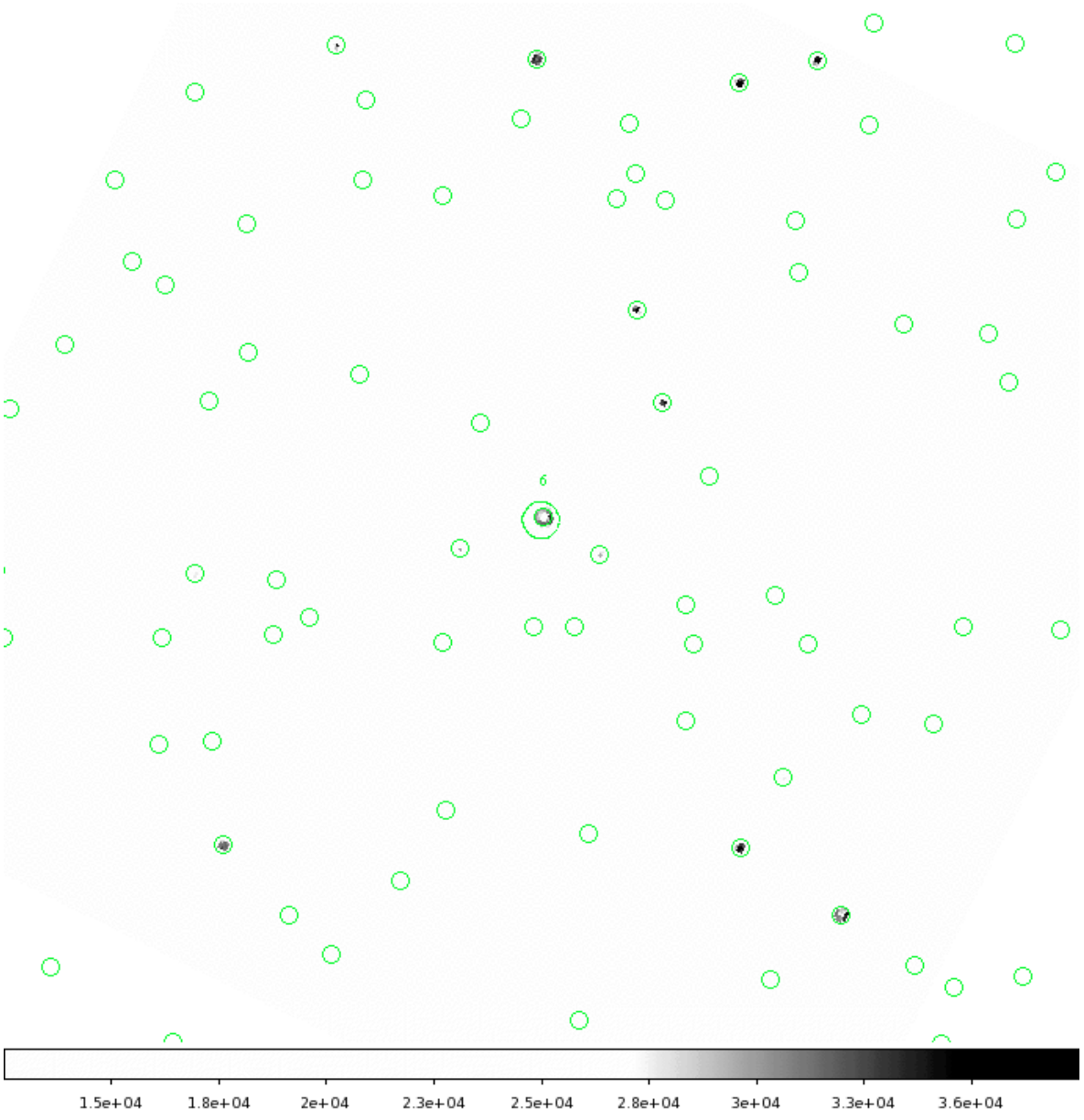
Example detection II



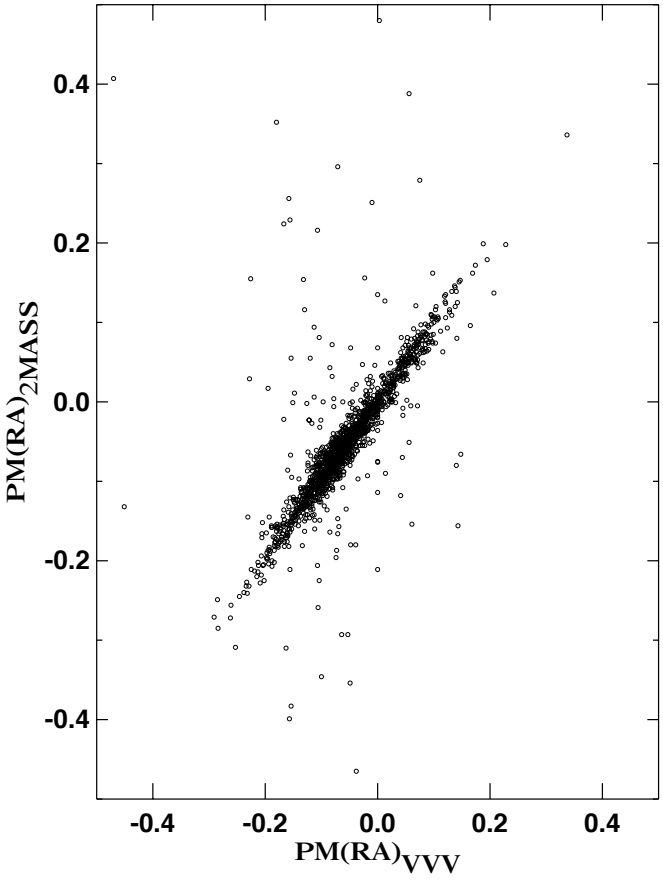
Example false detection I

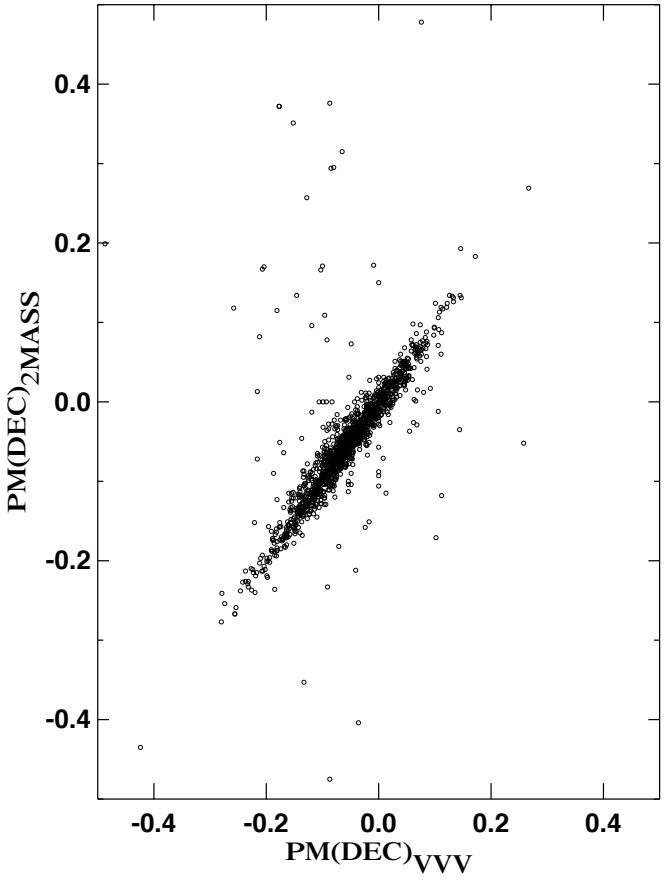


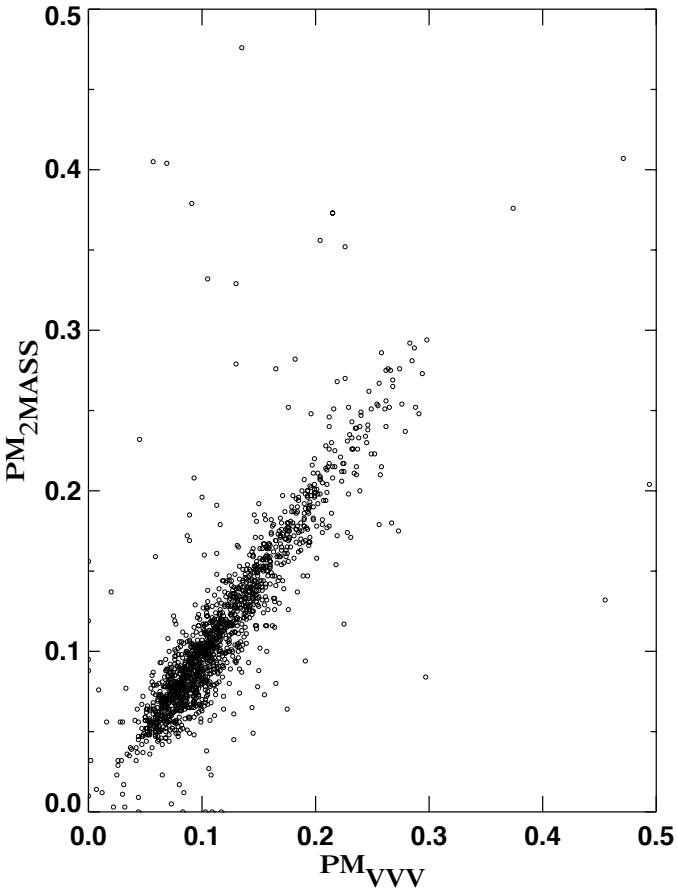
Example false detection I



PM: VVV2 vs. VVV1 and 2MASS vs. VVV1





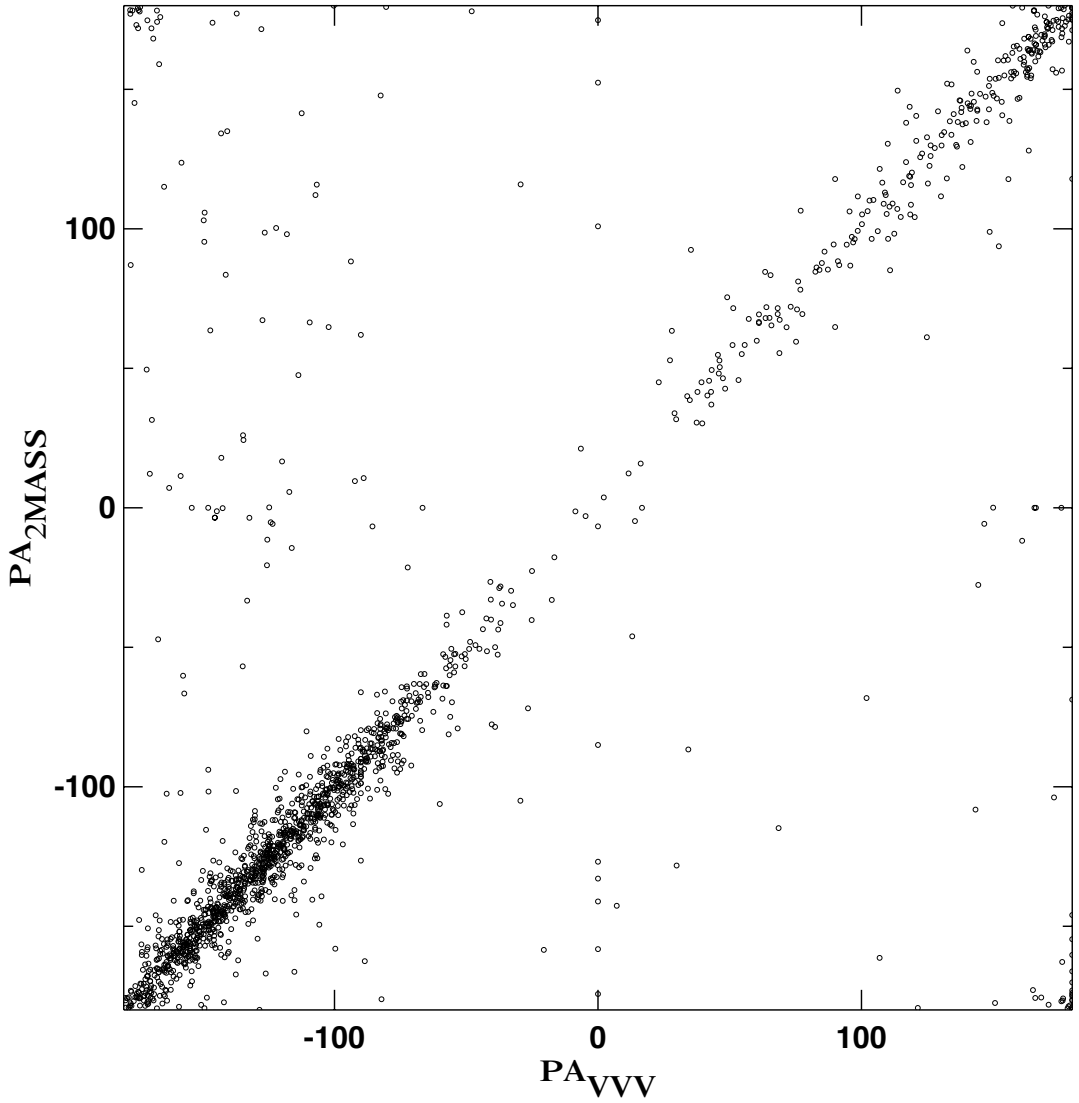


PM obtained in 2 ways: comparing 2 VVV epochs the first and the last available (> 4 years) and the first VVV and 2 MASSS (> 10 year). Good coincidence. Small number of errors. Additional check for errors.

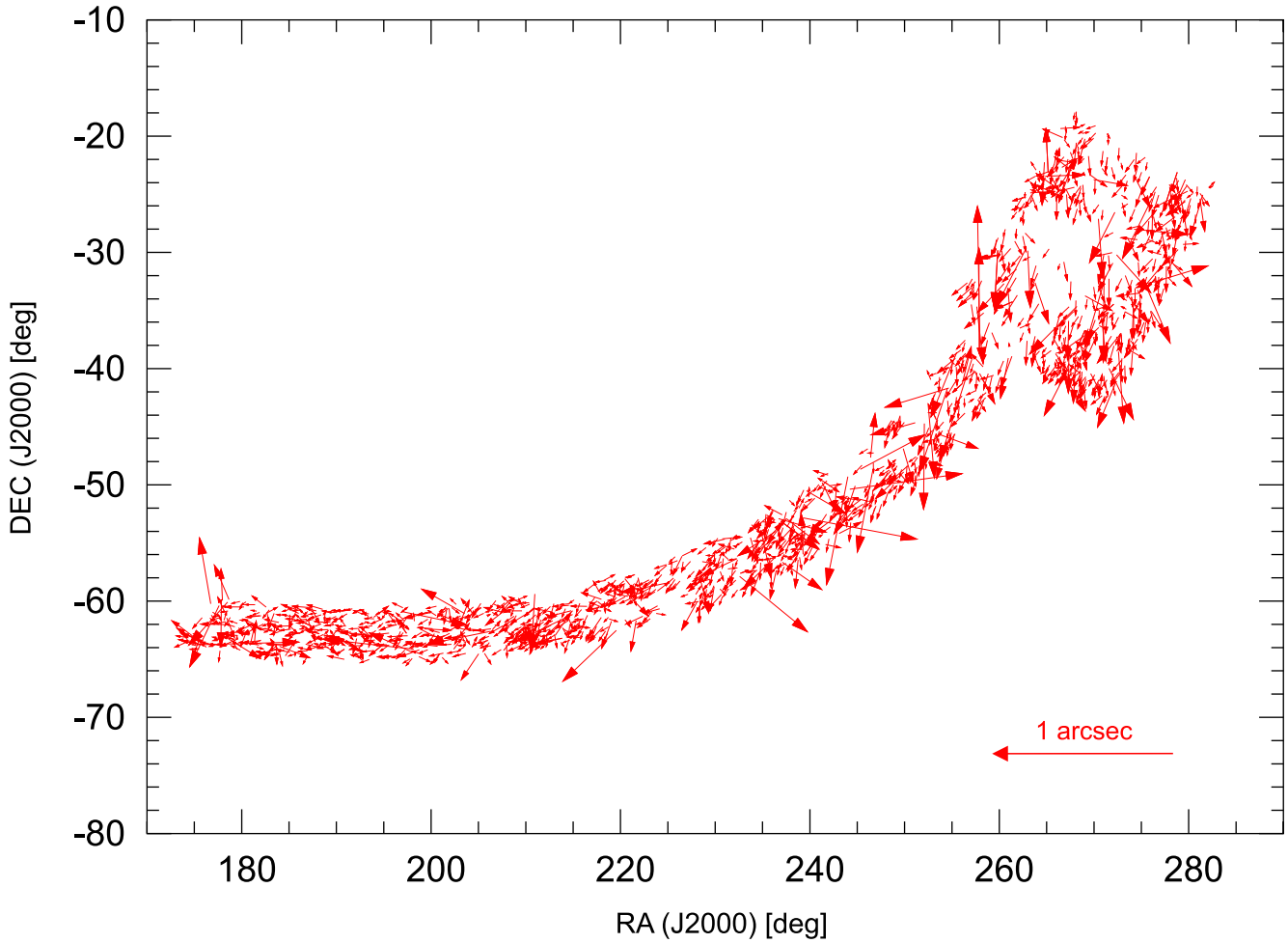
PA: VVV vs. 2MASS

Comparison of the parallactic Angles VVV and 2MASS

Good coincidence!

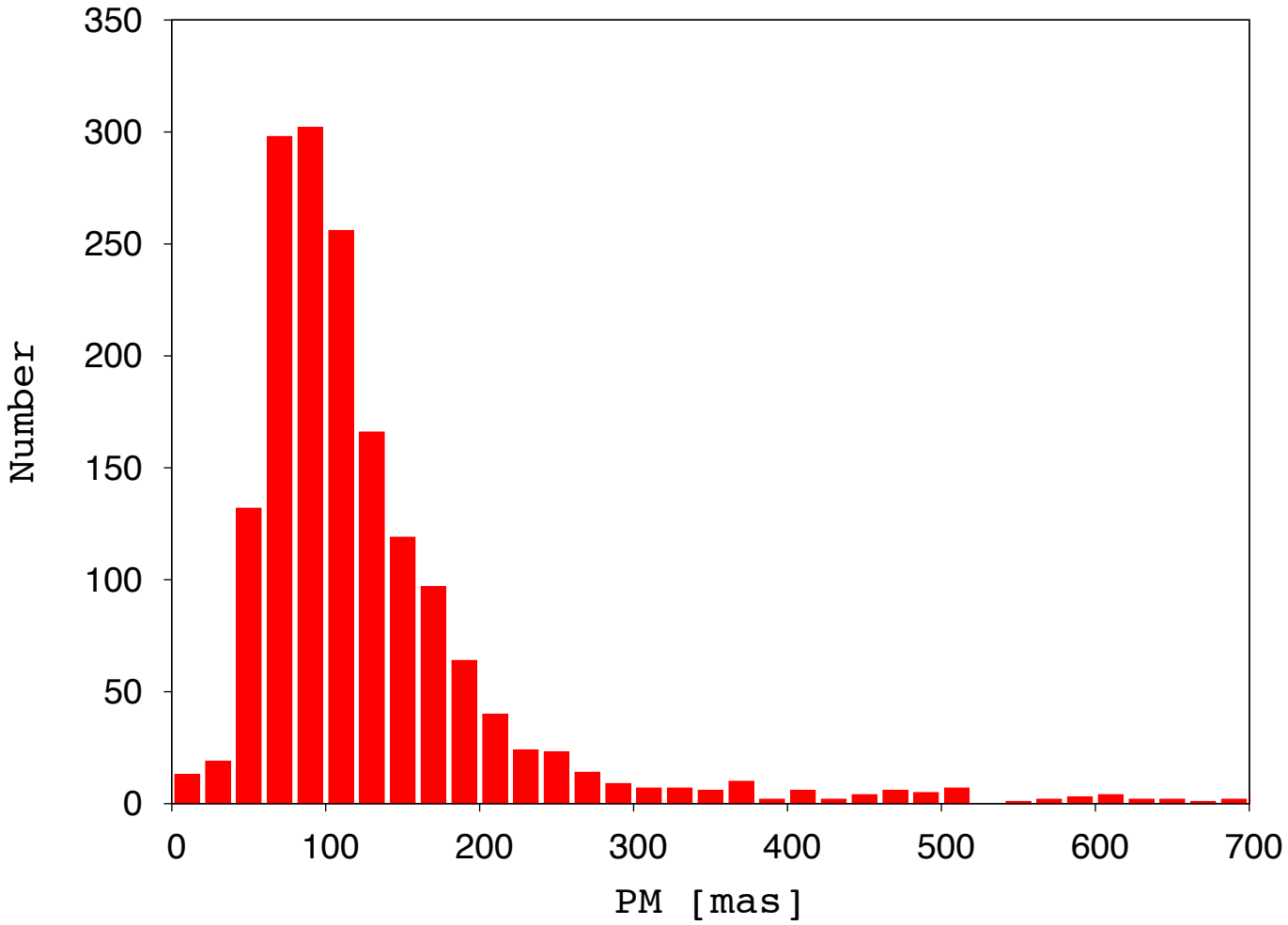


PM vector distribution



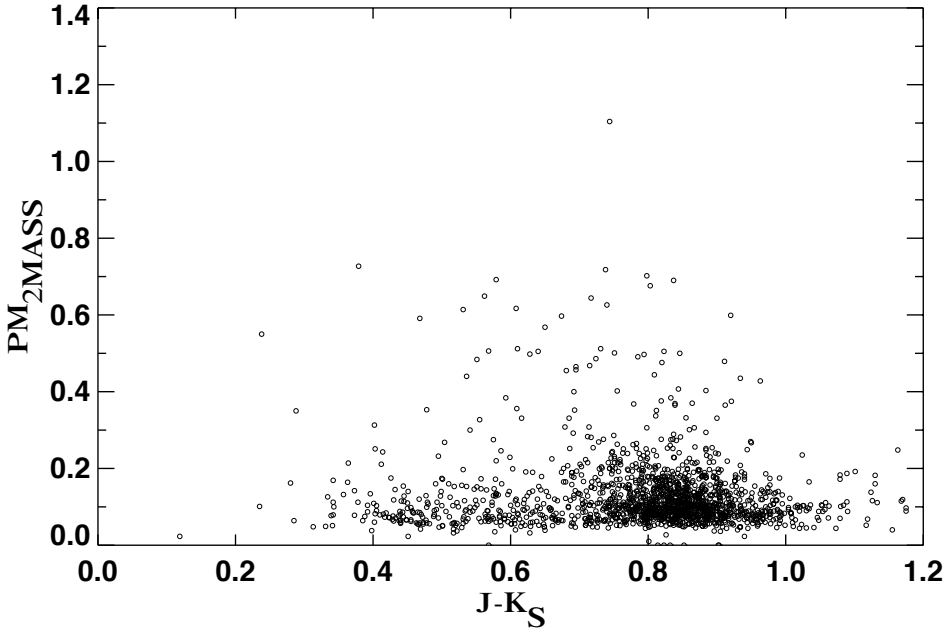
Some incompleteness. Especially around the galactic centre.
More work needed! ☹

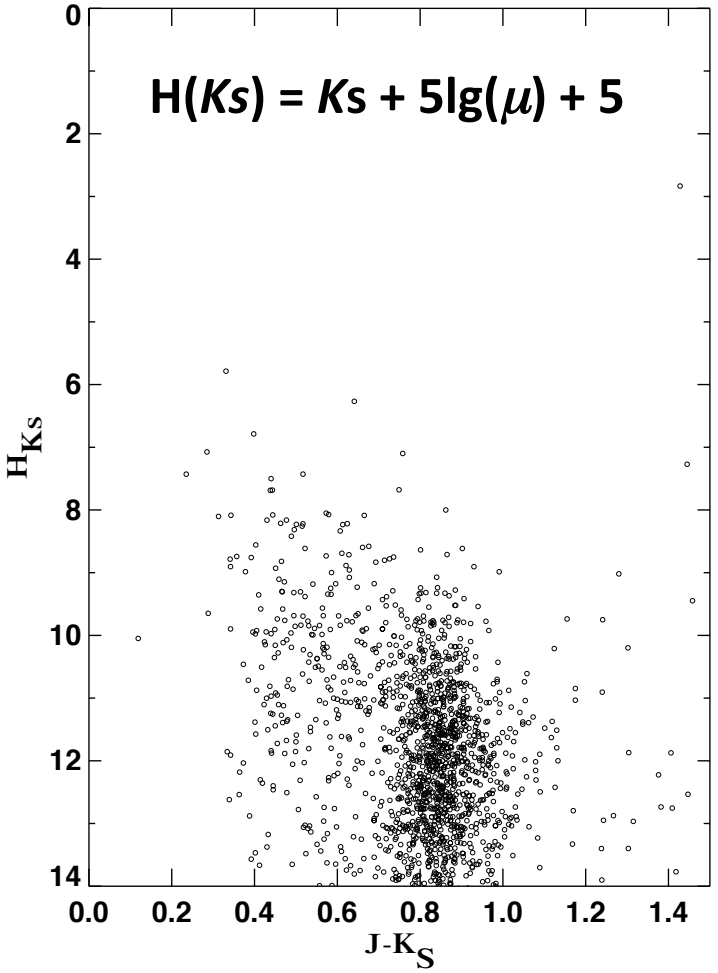
PM histogram



Significant incompleteness below 100 mas/year

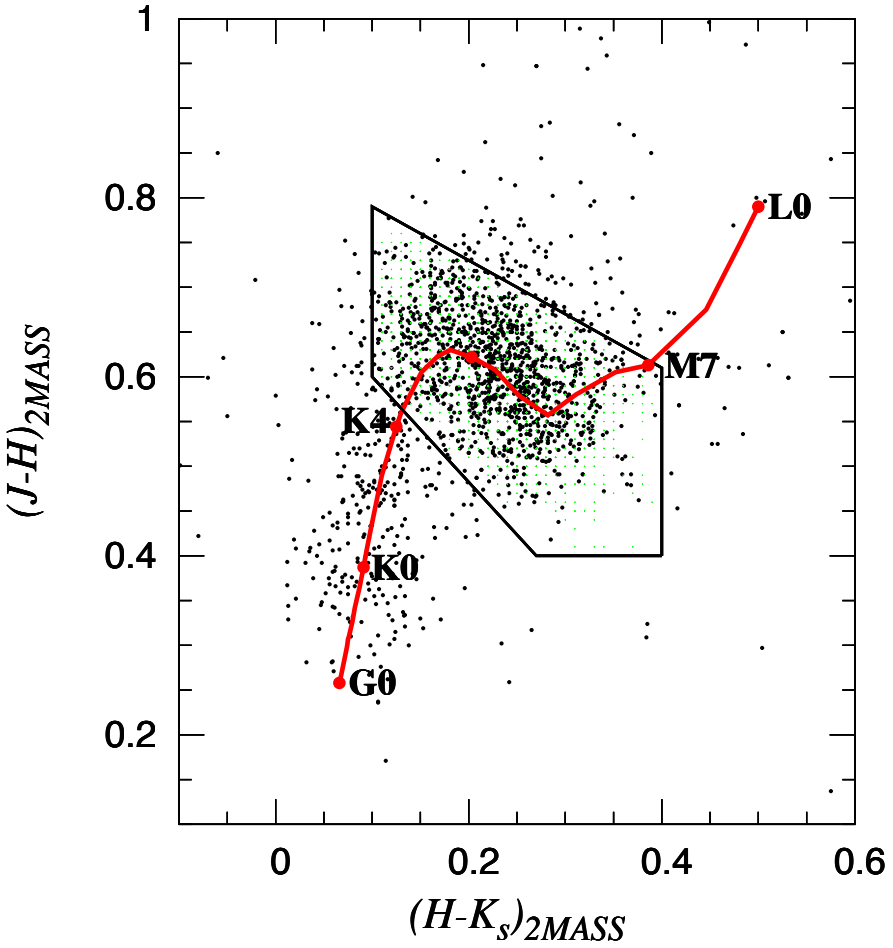
Reduced proper motion diagram

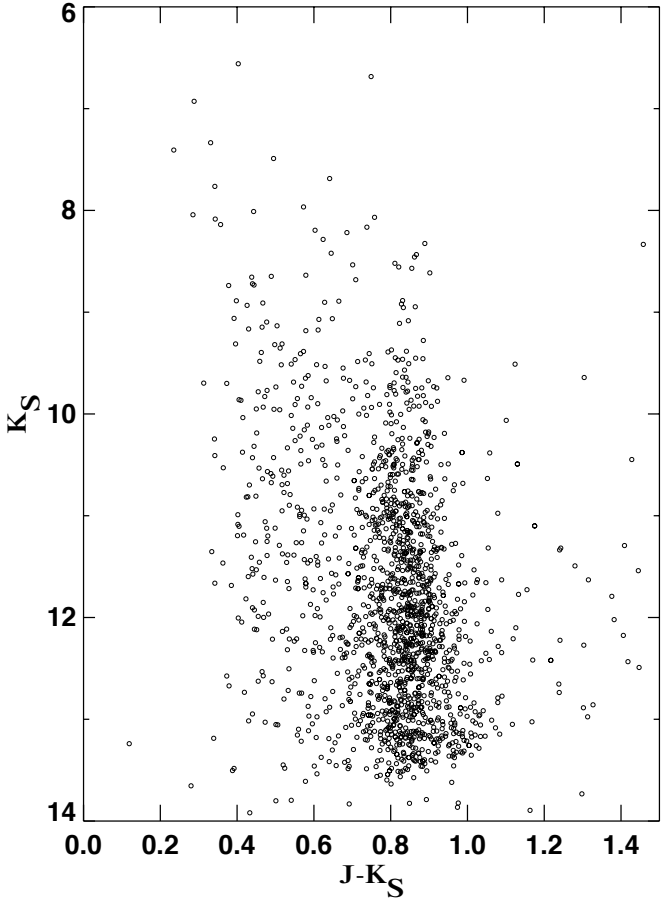




No giants in the sample

Sample: mostly early and mid M-dwarfs





Lepine and Gaidos 2011 (green points)

(J-Ks), Ks diagram separation of the M dwarfs from K and G

Distances

Finch, Ch. Et al. 2014, AJ, accepted: UCAC4 nearby star survey

TABLE 2
DETAILS OF THE 16 PHOTOMETRIC DISTANCE RELATIONS

Color	Color Range [mag]	Stars Used [number]	Coeff. 1 [× color^2]	Coeff. 2 [× color]	Coeff. 3 [constant]	rms [mag]
V–i	1.4 – 3.9	113	−0.33800	+3.663	+0.9571	0.38
V–J	3.1 – 7.0	118	−0.14260	+2.551	−1.0870	0.40
V–H	3.5 – 7.7	118	−0.13910	+2.657	−2.3950	0.41
V–K	4.0 – 8.0	118	−0.12390	+2.523	−2.4720	0.42
B–i	2.8 – 6.0	102	−0.13570	+3.091	−1.6910	0.38
B–J	4.2 – 9.0	140	−0.08928	+2.188	−2.6330	0.37
B–H	4.9 – 10.0	141	−0.09372	+2.347	−4.0930	0.39
B–K	5.0 – 10.0	141	−0.08031	+2.174	−3.8580	0.39
g–i	2.2 – 4.5	105	−0.13340	+3.619	−1.0110	0.39
g–J	3.9 – 7.8	113	−0.13290	+2.693	−2.8800	0.39
g–H	4.2 – 8.4	113	−0.11760	+2.796	−4.2560	0.41
g–K	4.5 – 8.8	108	−0.13480	+2.637	−4.2120	0.41
r–i	1.0 – 3.0	105	−0.26210	+3.237	+2.9860	0.41
r–J	2.9 – 6.2	107	−0.11530	+2.383	+0.2988	0.41
r–H	3.4 – 6.8	107	−0.28630	+2.502	−0.9758	0.42
r–K	3.5 – 7.1	102	−0.19210	+2.353	−1.0590	0.42

Cross identification with optical colours: problems

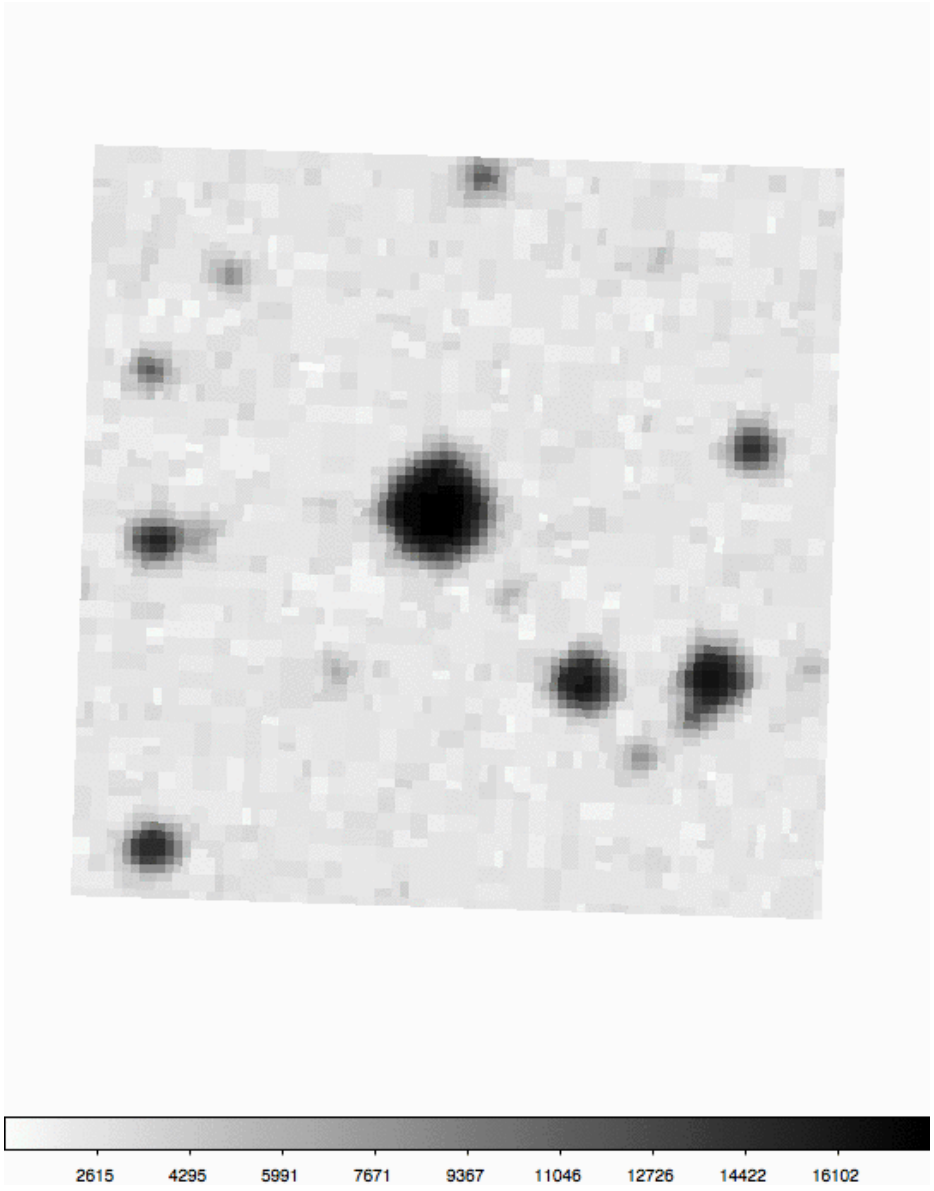
VVV high proper motion (Ks<13.5) catalogue

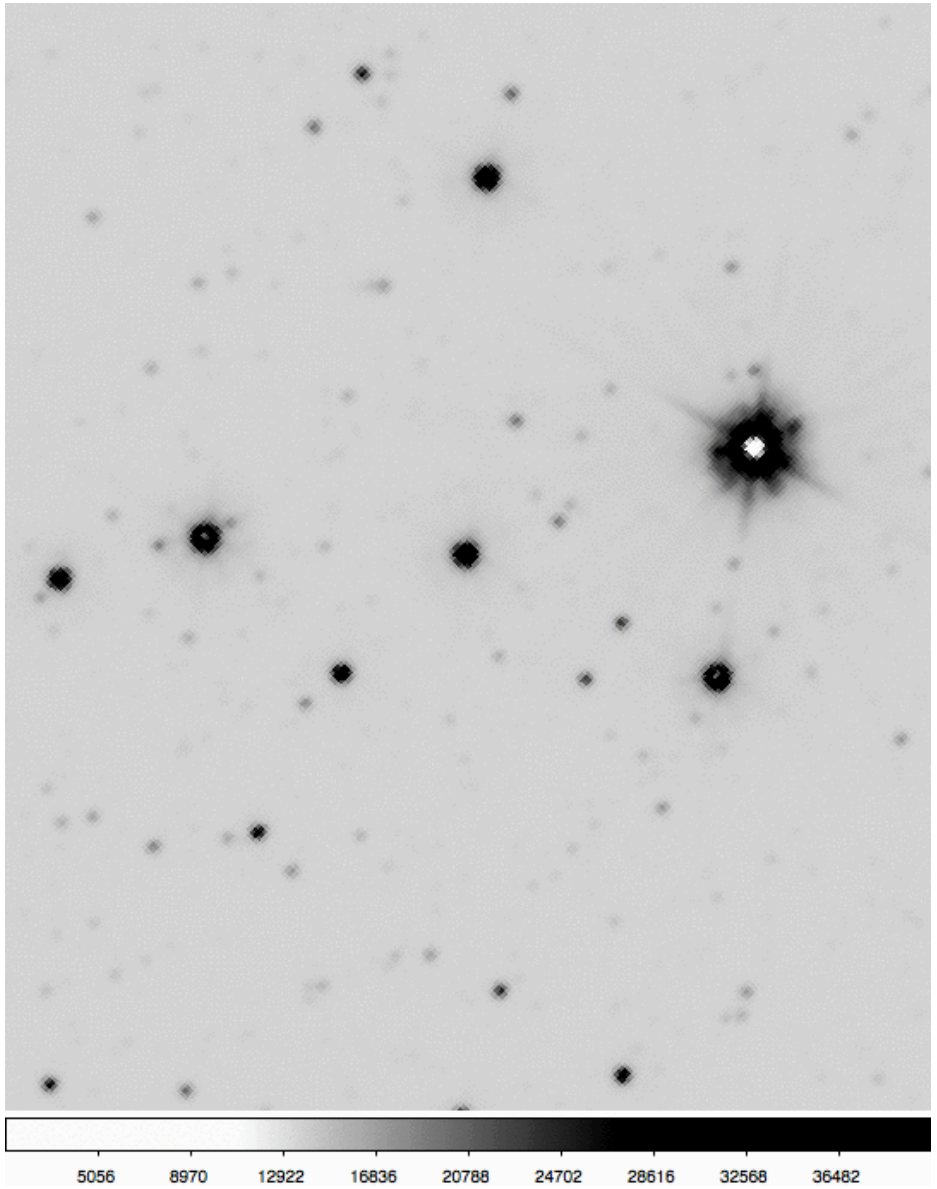
- **The catalogue contains data for 1701 PM stars:**

RA, DEC, EPOCH, J, H, K, [B, V], PM(RA), PM(DEC), PM, PA, [phot_dist]

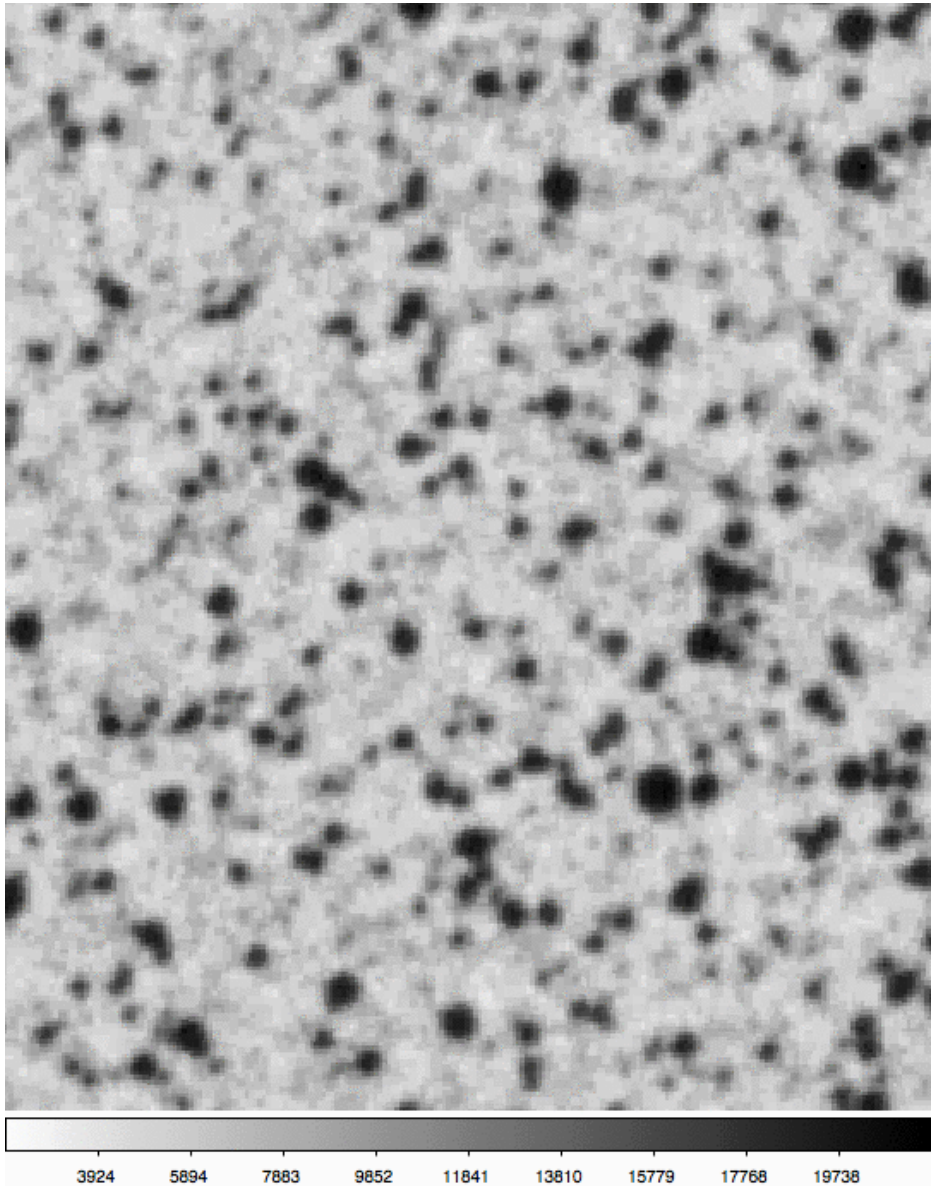
- **Lower limit ~ 30 mas/year**
- **Significant incompleteness below 100 mas/year**
- **75 stars with PM > 300 mas/yr**
- **189 stars with PM > 200 mas/yr (42 known previously *Ivanov et al. 2013, A&A, 560, 21*)**
- **35 common proper motion binaries (the search for CPMB is pending)**
- **3 dM+WD binaries**
- **1 nearby (very cool?) WD**
- **At least 14 (4 new!) stars in the immediate solar vicinity of 25 pc**

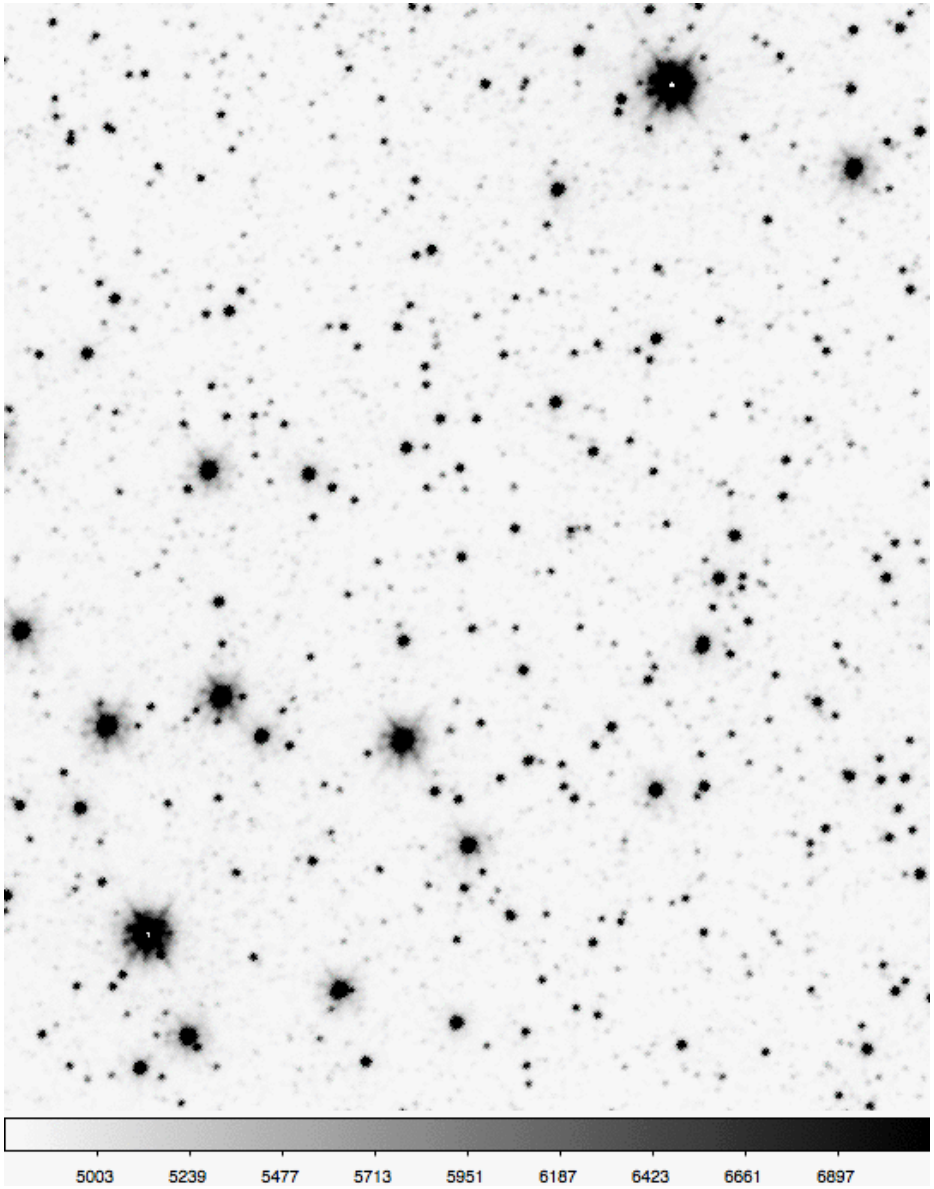
MD + WD


2615
4295
5991
7671
9367
11046
12726
14422
16102

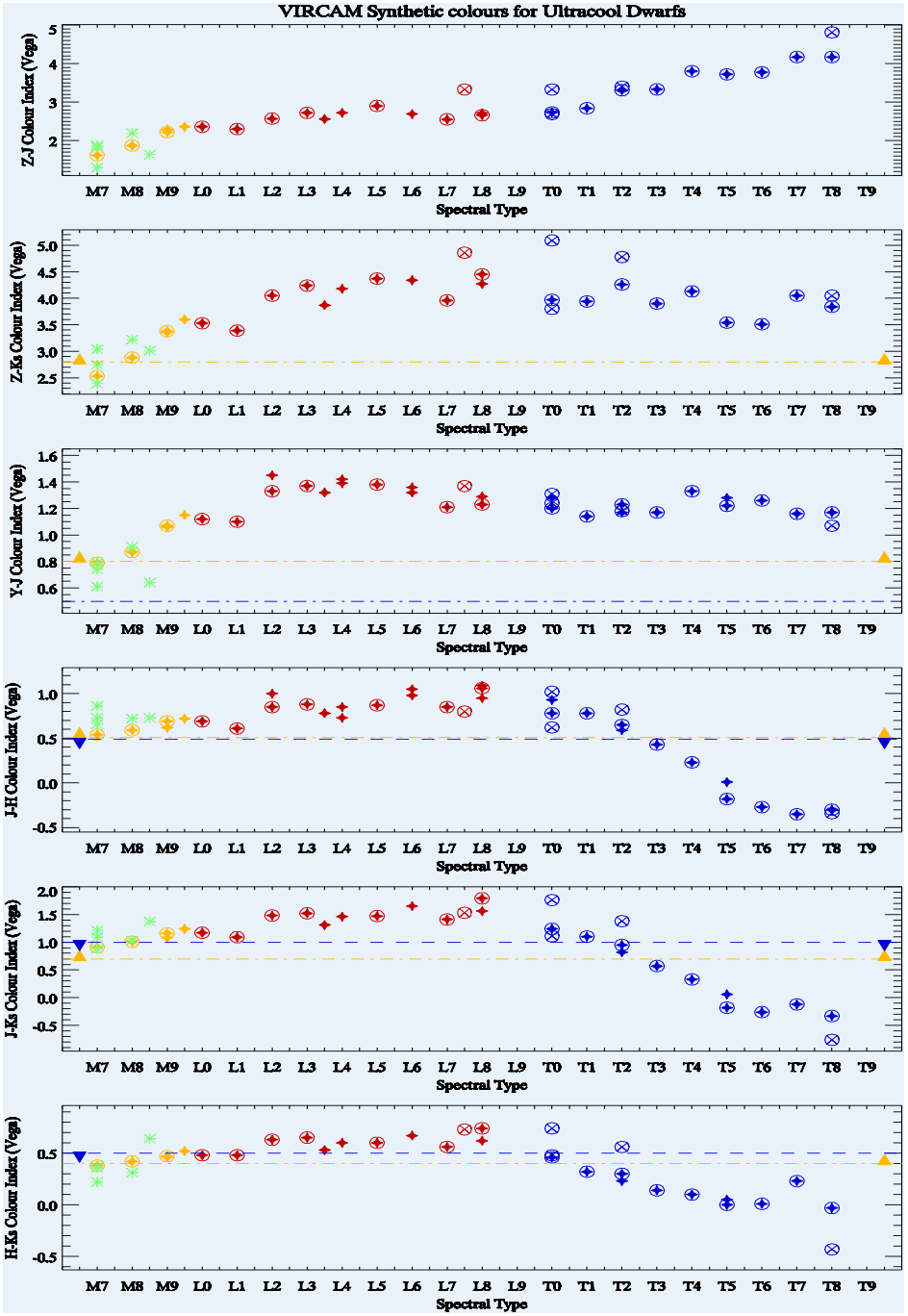

5056
8970
12922
16836
20788
24702
28616
32568
36482

First VVV BD (Beamin et al. 2014)





UCD color cuts



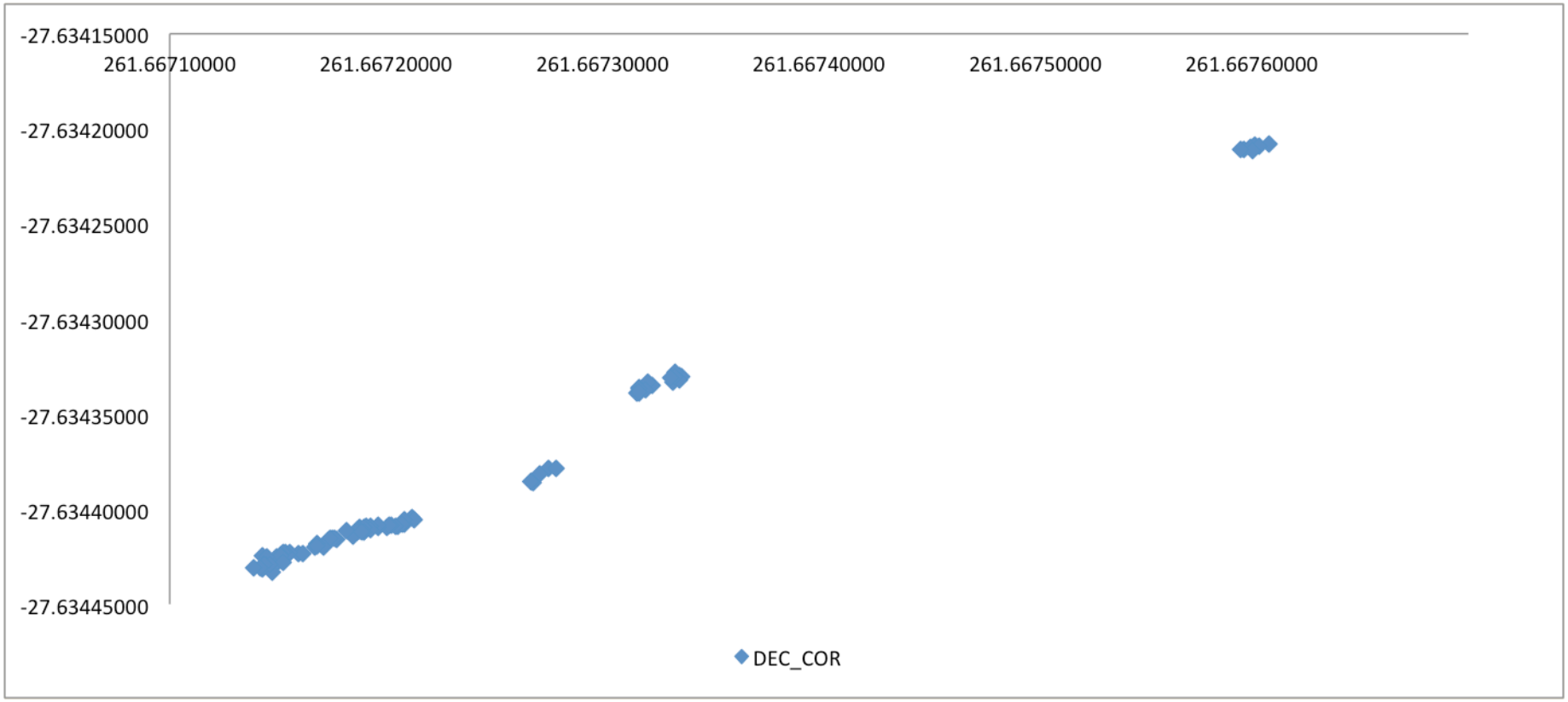
Synthetic colours of the ultra-cool dwarfs (UCD) in the VVV system based on the spectral library.

For stars fainter than 12 mag (not saturated) could apply PM + colour cuts

Search for UCD neighbours

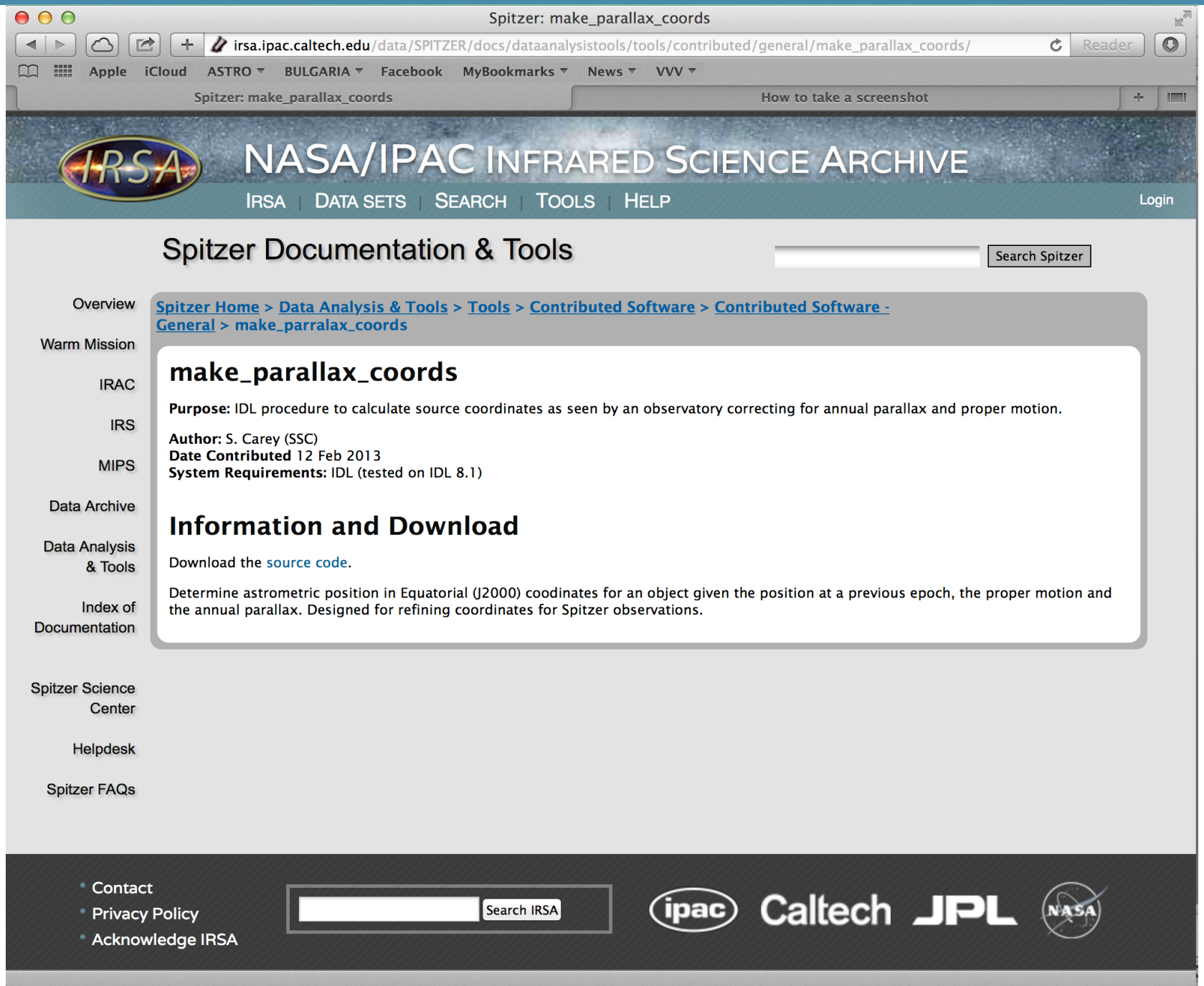
VVV parallaxes (VVV-BD1)

Beamin et al. 2013, A&A, 557, 8

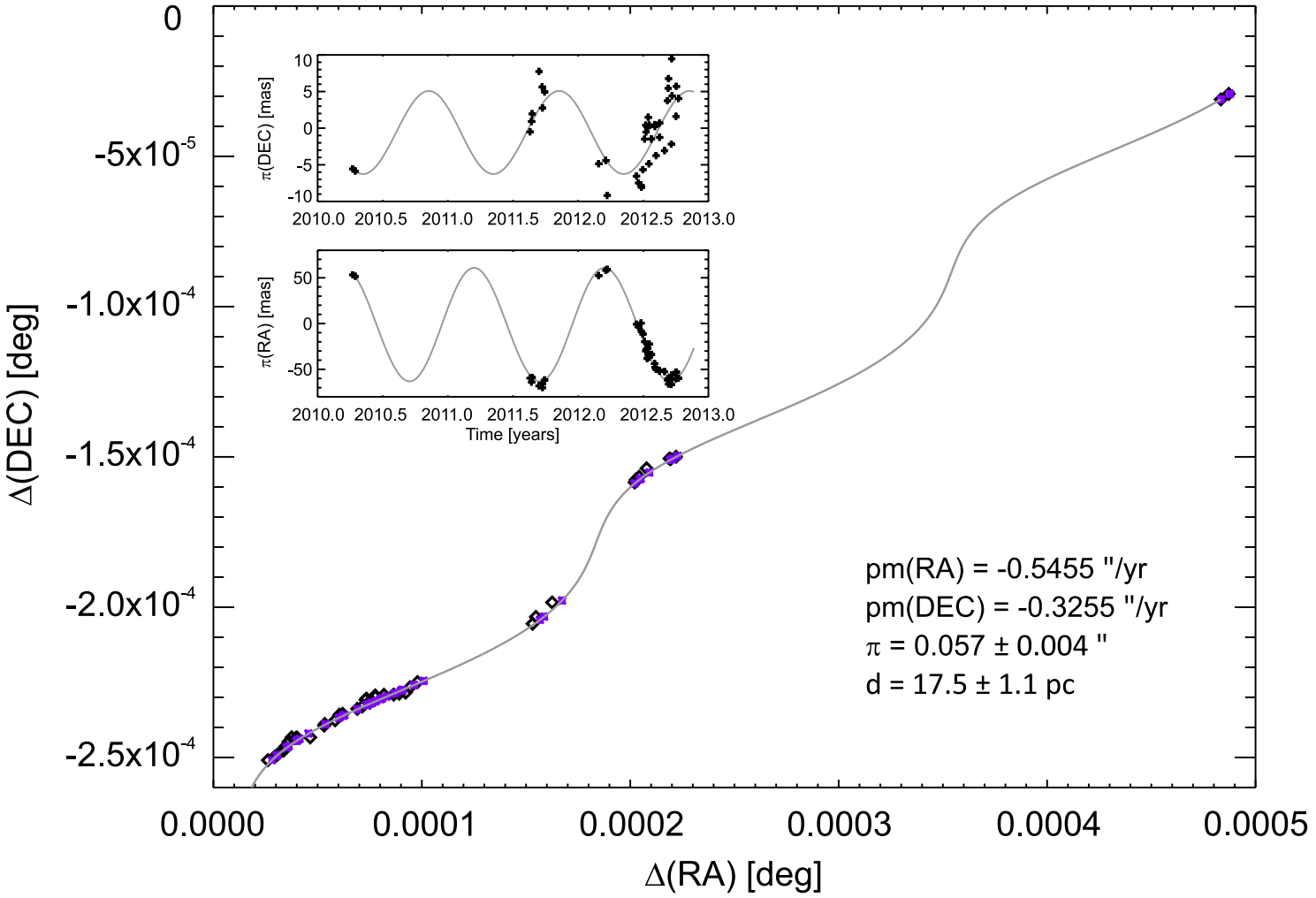


Before and after the corrections for the common local center

VVV parallaxes VVV-BD1

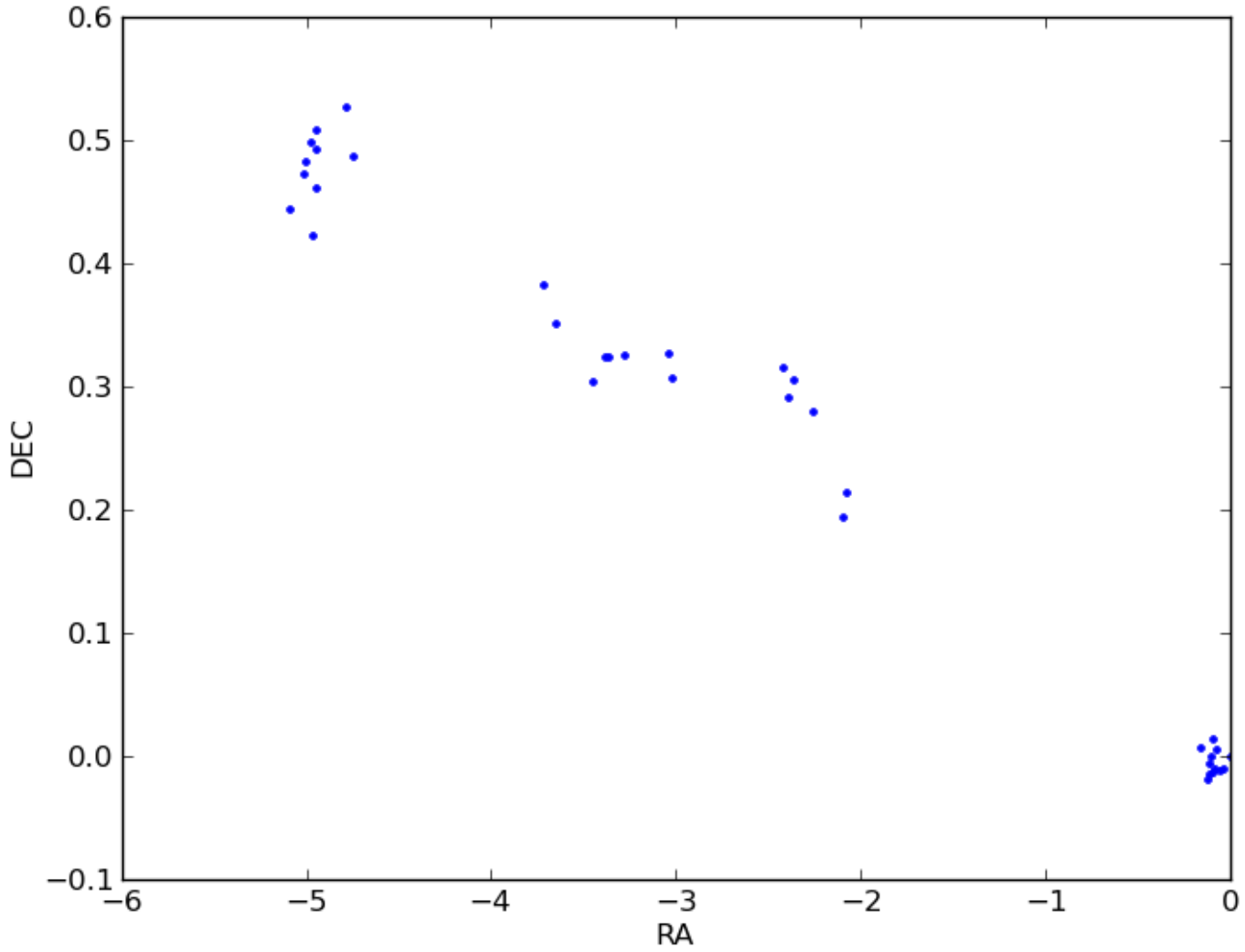


VVV parallaxes VVV-BD1



VVV parallaxes VVV-WD1

WD candidate Ks=14.9



Future work

- To continue with the fainter sample (Ks > 13.5 mag)
- Colour cuts
- Cross identification with VPHAS+
  - Correct photometrical distances (*g´, r´, Z, Y, J, H, Ks*)
  - Excess objects with IR excess (Hα)
- Cross correlation with WISE, GLIMPSE, etc.
- Parallax for the nearest ~ 50 - 80 pc objects (MD thesis of Vicente Villanueva)

Acknowledgements

This project is financed by the *FONDECYT Fund*, allocated to the project *#1130140* and the *Millennium Institute of Astrophysics - MAS*

Thanks!