

VISTA-VVV high proper motion stars

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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 ($K_s < 13.5$) star catalogue**
- ❑ **First results**
- ❑ **Search for fainter ultra-cool and BDs**
- ❑ **VVV and parallax measurements**
- ❑ **Future plans**

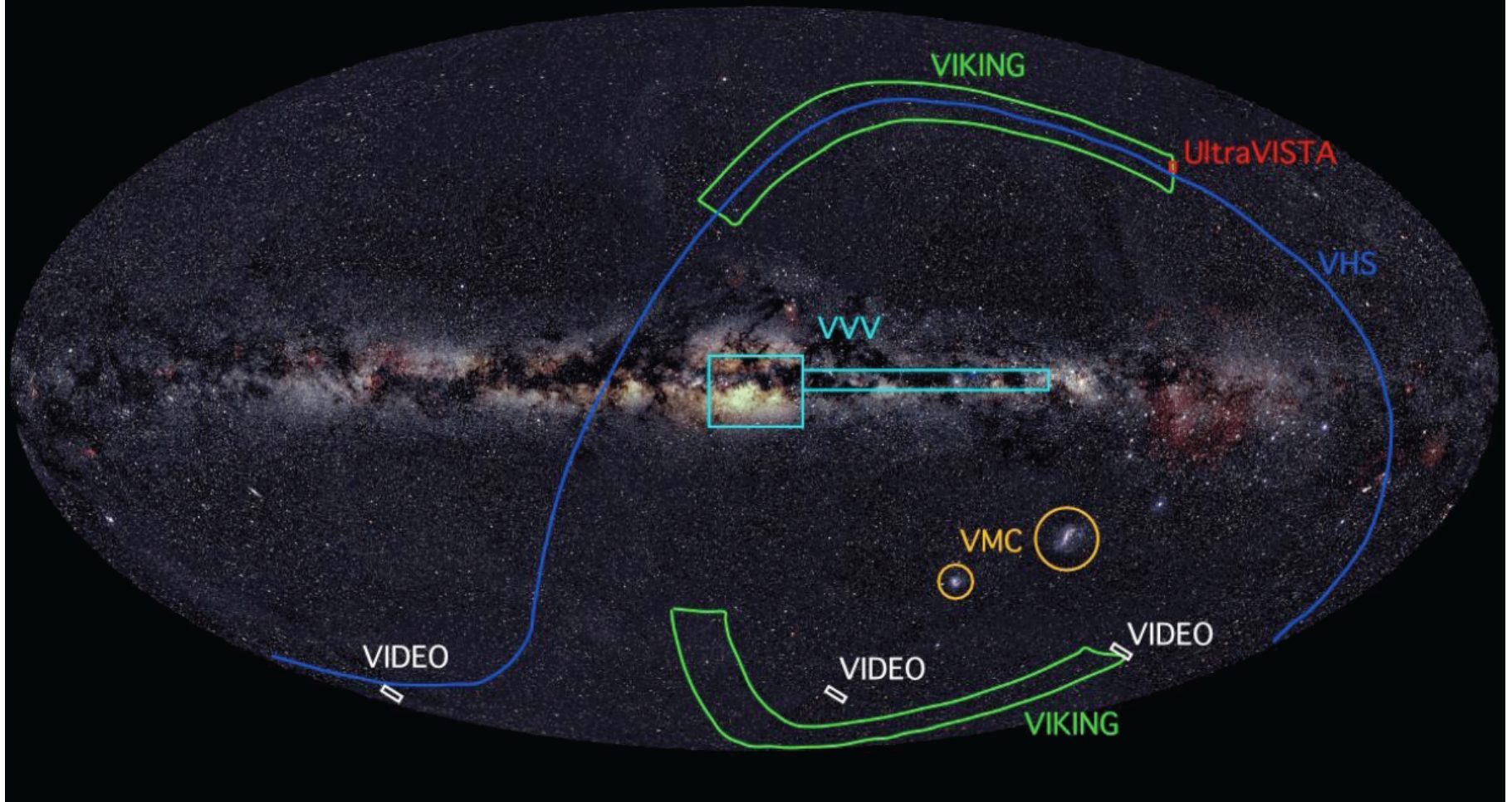
Solar vicinity and NIR surveys

- 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



VISTA PUBLIC SURVEYS VISTA VARIABLES IN THE VIA LACTEA

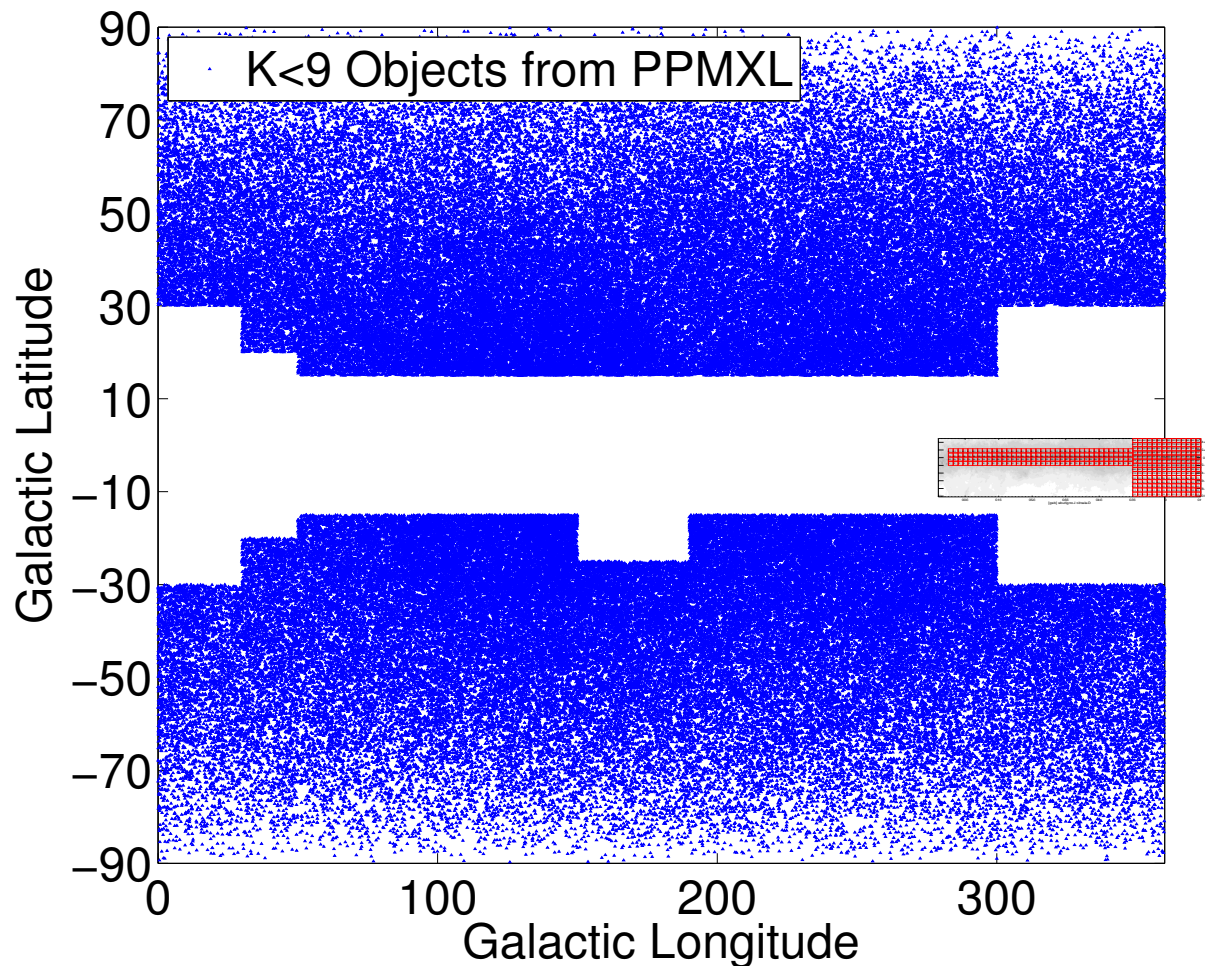


VVV top 10 science goals

- 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 ($K_s < 9$) 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)

VISTA Survey Progress And QC [VISTA VVV User] logout

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Public Surveys : VVV

VVV Homepage | About VVV

All Y J Ks QC Stats

altitude

Galactic longitude

Galactic latitude

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

VISTA SCIENCE ARCHIVE

Home | Overview | Browser | Access | Login | Cookbook

VSA - VISTA Science Archive

The VISTA Science Archive (VSA) holds the image and catalogue data products generated by VIRCAM on the Visible and Infrared Survey Telescope for Astronomy (VISTA). The primary contents of the archive originate from the VISTA Public Surveys. Survey science-ready catalogue data will be released in phases, while standard flat-file data products (both images and derived single passband catalogues) become available continually after routine observation and processing operations. Information on the various archive releases can be found on the [surveys page](#)

The history of archive releases, updates and bug fixes is recorded under the [release history](#) page. Users wishing to receive email announcements of such entries should subscribe to the VSA_Annoucelist (contact vsa-support@roe.ac.uk).

Picture: Sky coverage of VISTA surveys, overlaid on a 2MASS image of the whole sky.
Credit: VISTA

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WFAU
IFA ROE

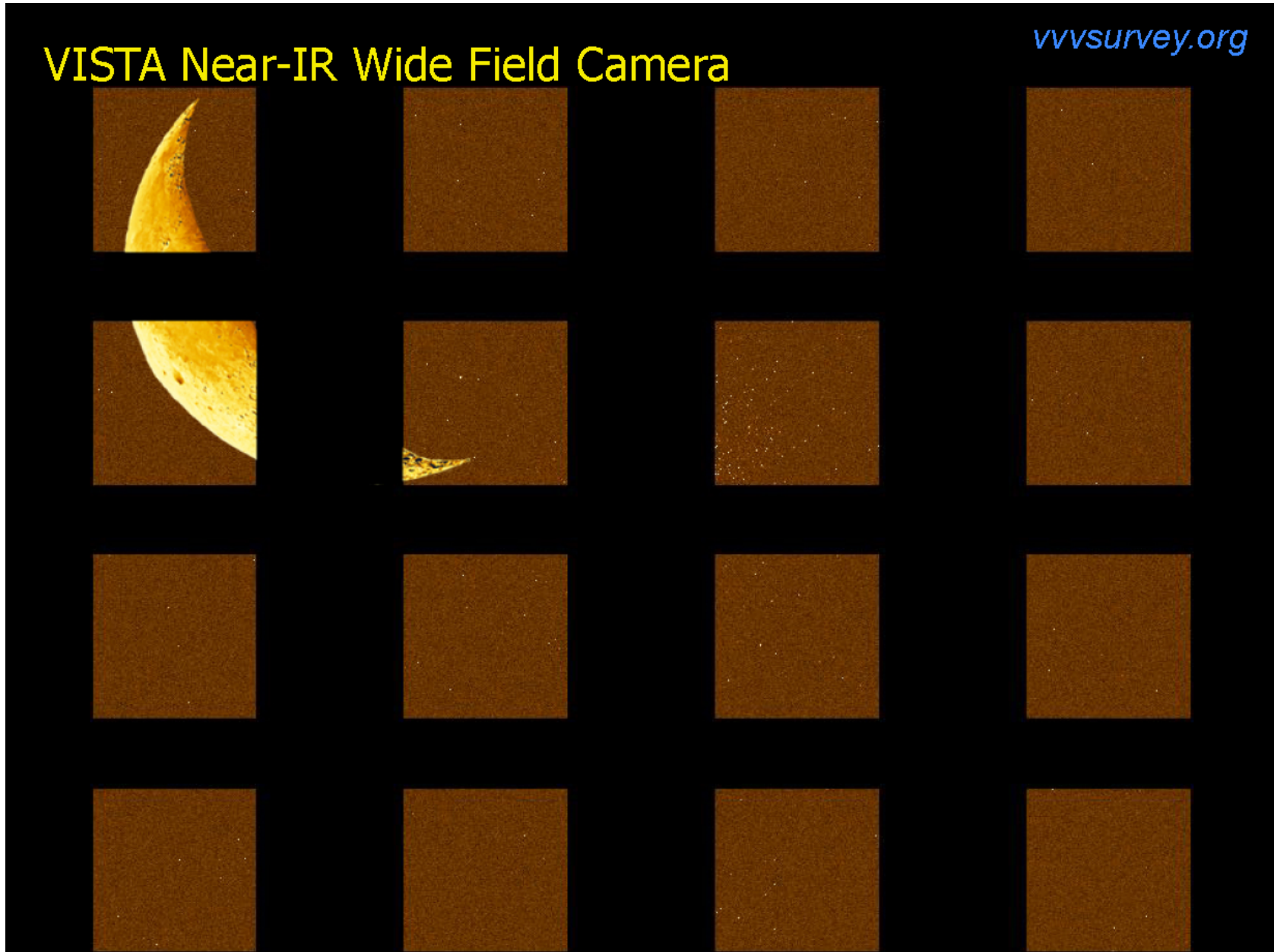
WFAU, Institute for Astronomy,
Royal Observatory, Blackford Hill
Edinburgh, EH9 3HJ, UK

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

Astrometric calibration 2MASS - VISTA

VISTA Near-IR Wide Field Camera

vvvsurvey.org



Astrometric calibration 2MASS - VISTA

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

Linear solution per detector

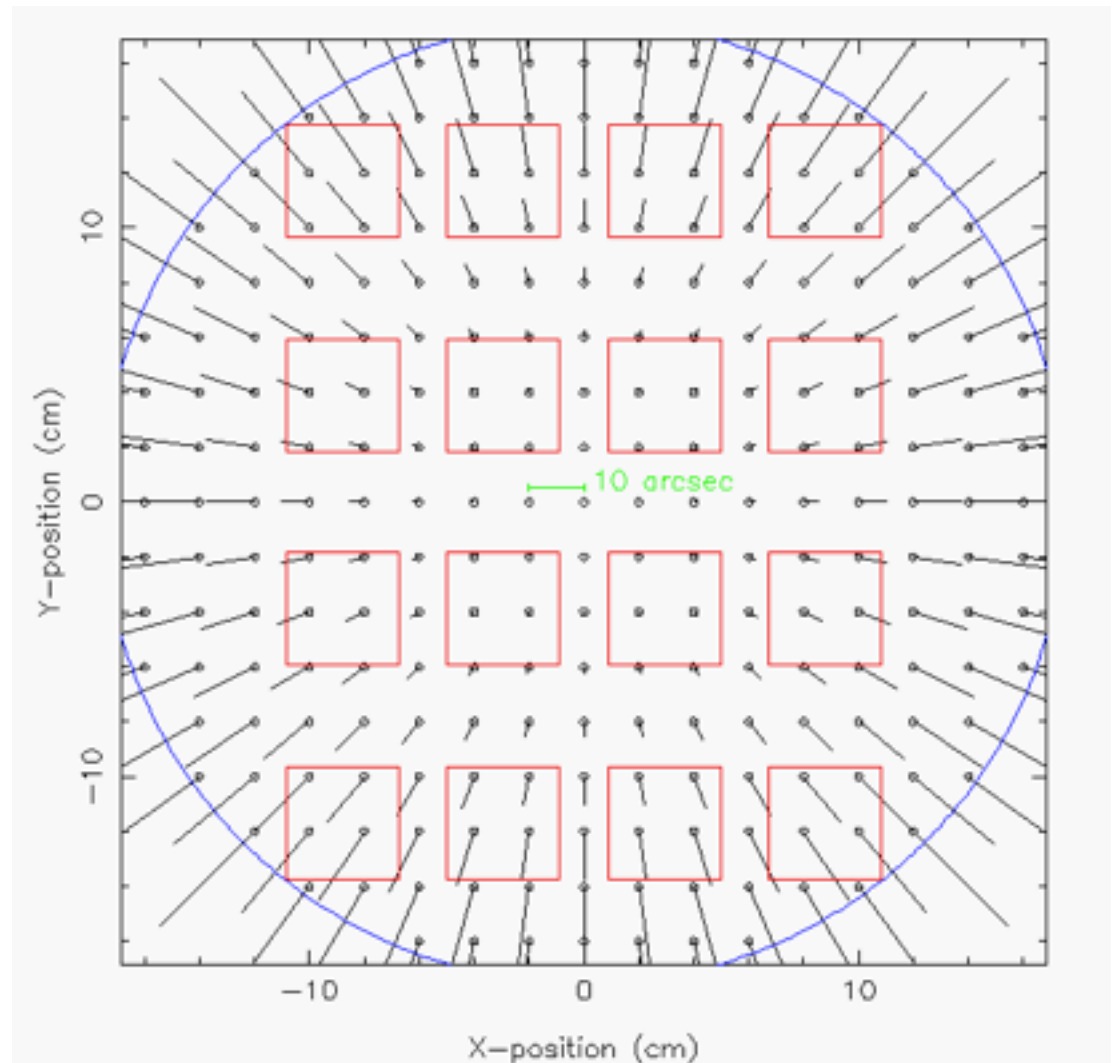
$$\xi' = ax' + by' + c$$

$$\eta' = dx' + ey' + f$$

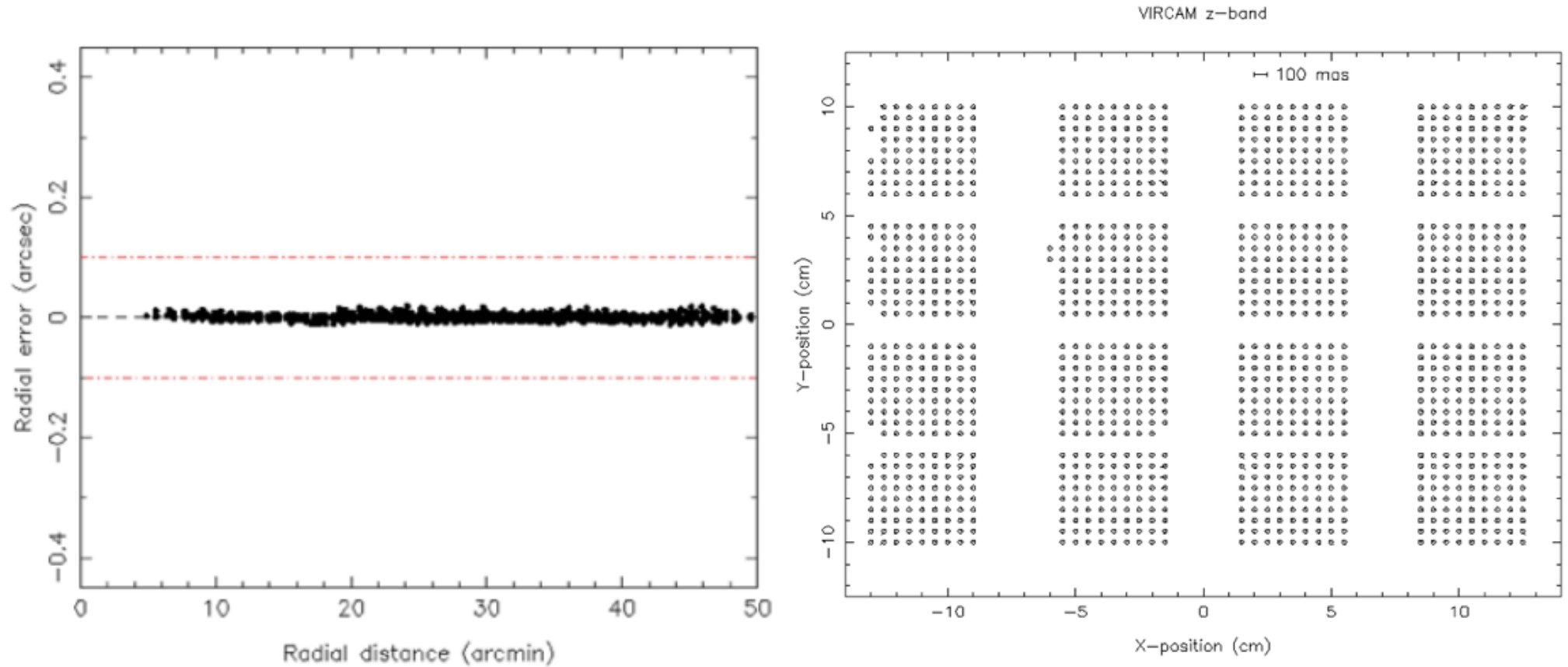
\Rightarrow rms < 100 mas

Tabulated systematics
From stacked residuals

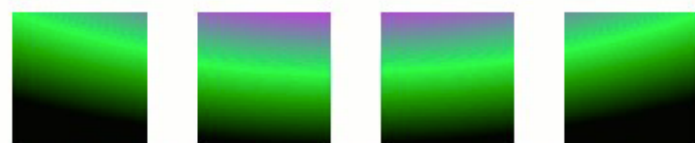
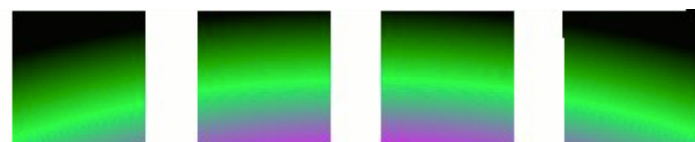
\Rightarrow sys < 25 mas



Astrometric calibration: residual distortion map



Variation of X,Y pixel scales

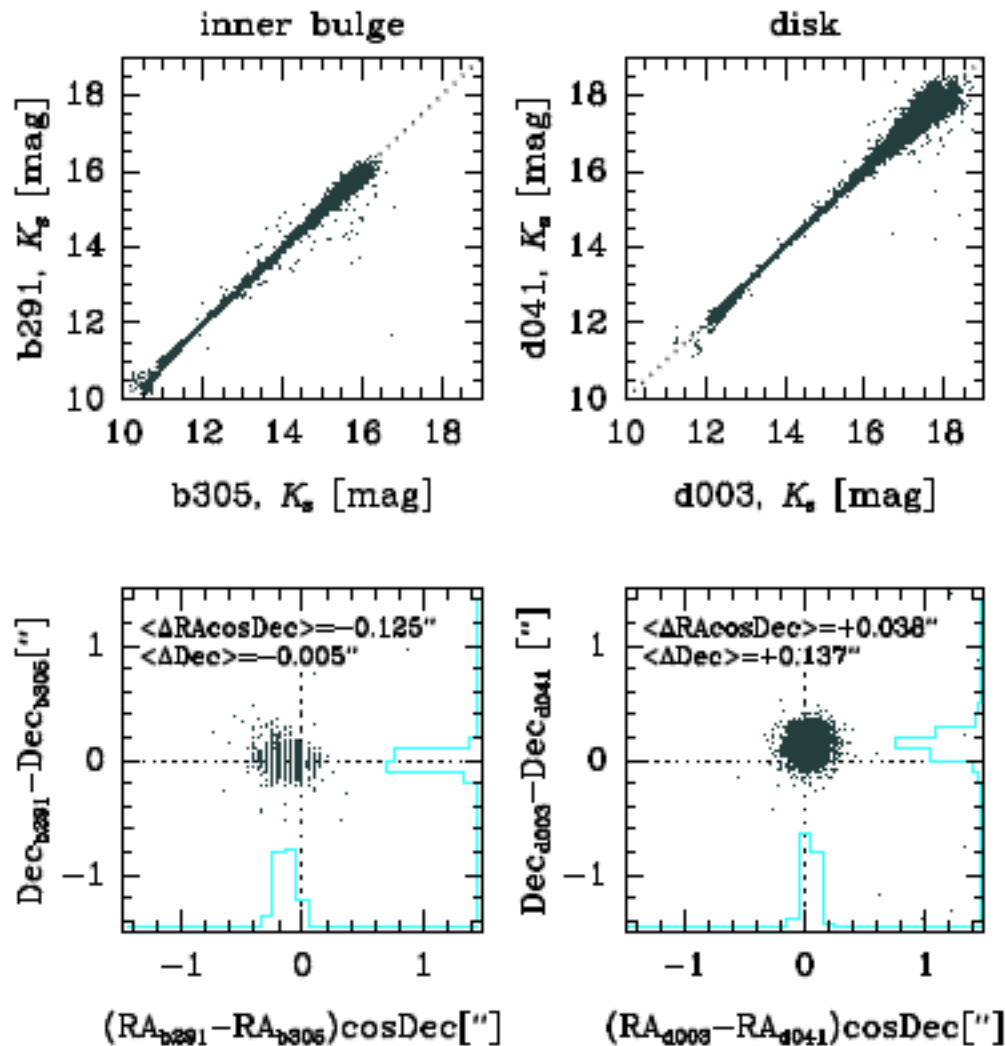


0.337 0.338 0.339 0.34 0.341

0.337 0.338 0.339 0.34 0.341

VVV photometric and astrometric accuracy

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



Photometry in the K_s band for the overlapping region between tiles b291 and b305 (left), and d003 and d041 (right). Only stellar sources on the plots.

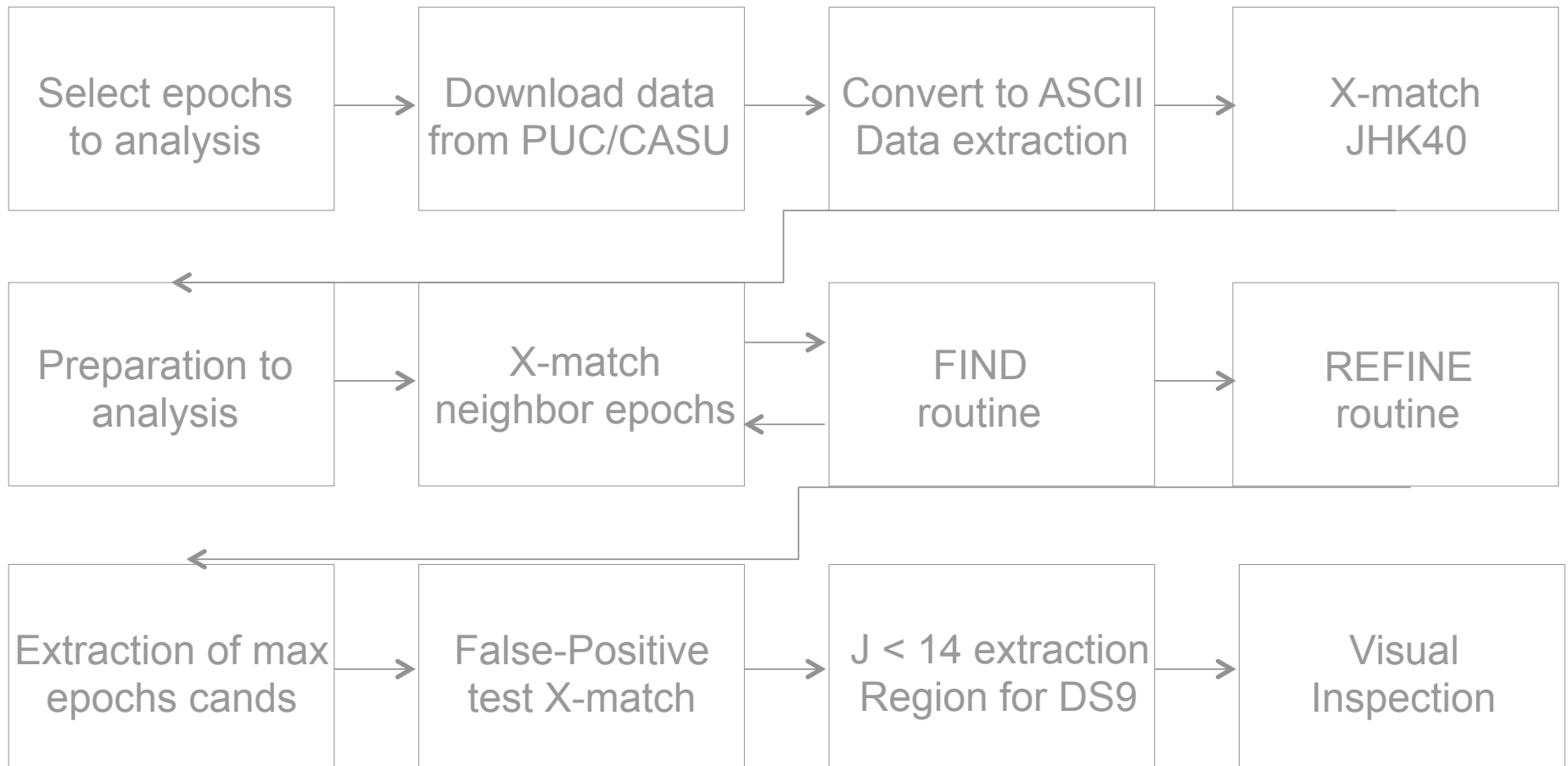
Astrometric accuracy for the same overlapping regions. The mean values for $\Delta \alpha \cos \delta$ and $\Delta \delta$ are:

$-0.125''$, $-0.005''$

$+0.038''$, $+0.137''$

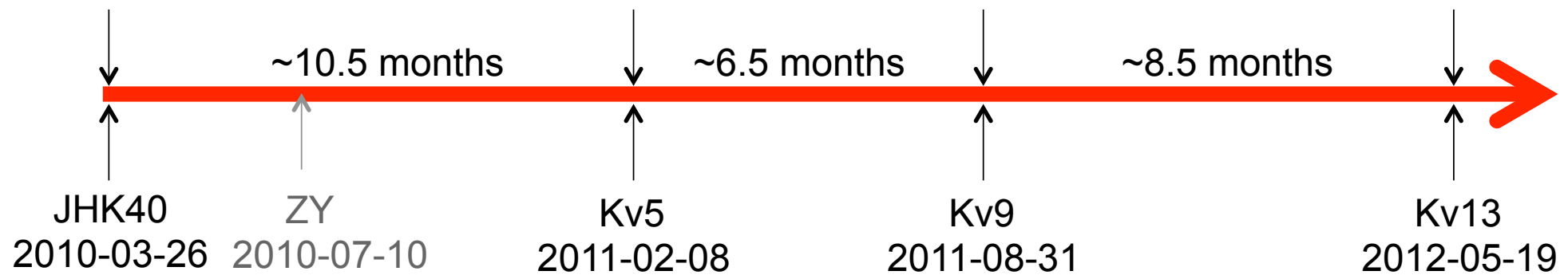
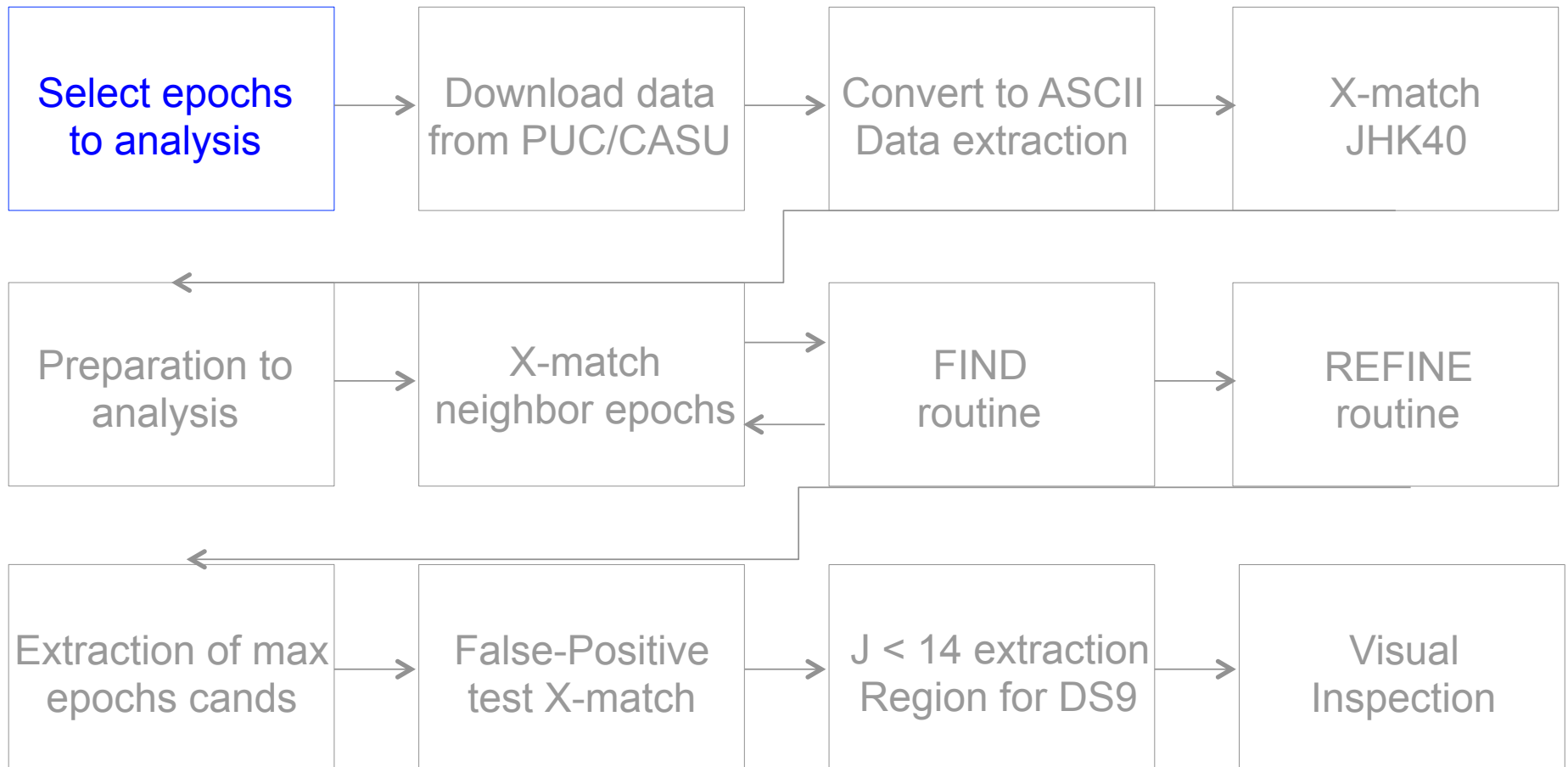
Counting histograms for the distribution are also shown for both axes.

Detection method (VVVPM)

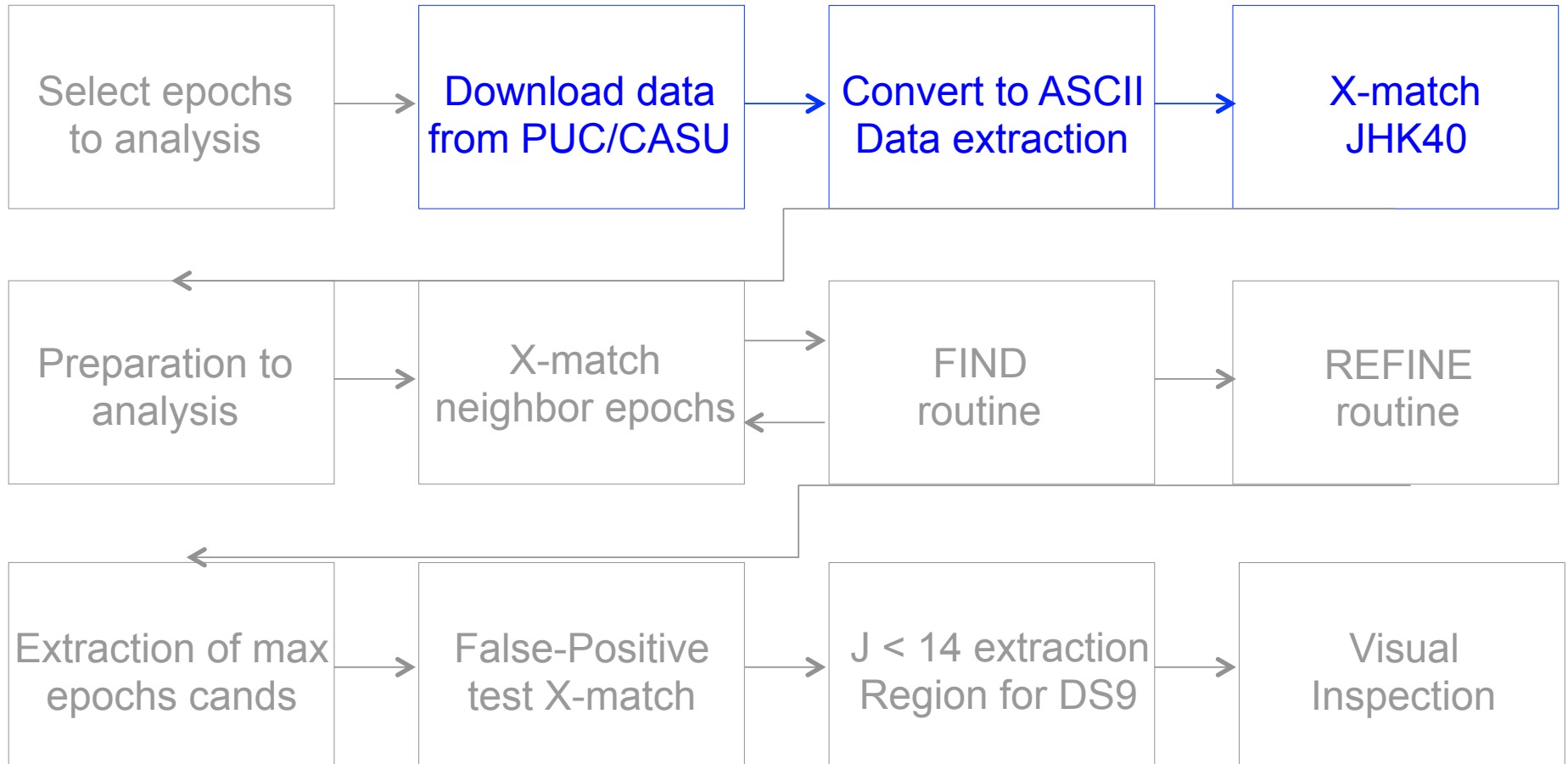


- Method developed by Stuart Folkes (only VVV for find HPM stars)
- Tools: STILTS, shell scripts, IDL routine, CASU FORTRAN procedure
- Data: CASU catalogs for various epoch in Ks
- General remark: **VIRCAM pixel ~ 0.34"**, **WCS error ~ 0.06"-0.09"**

Detection method (VVVPM)

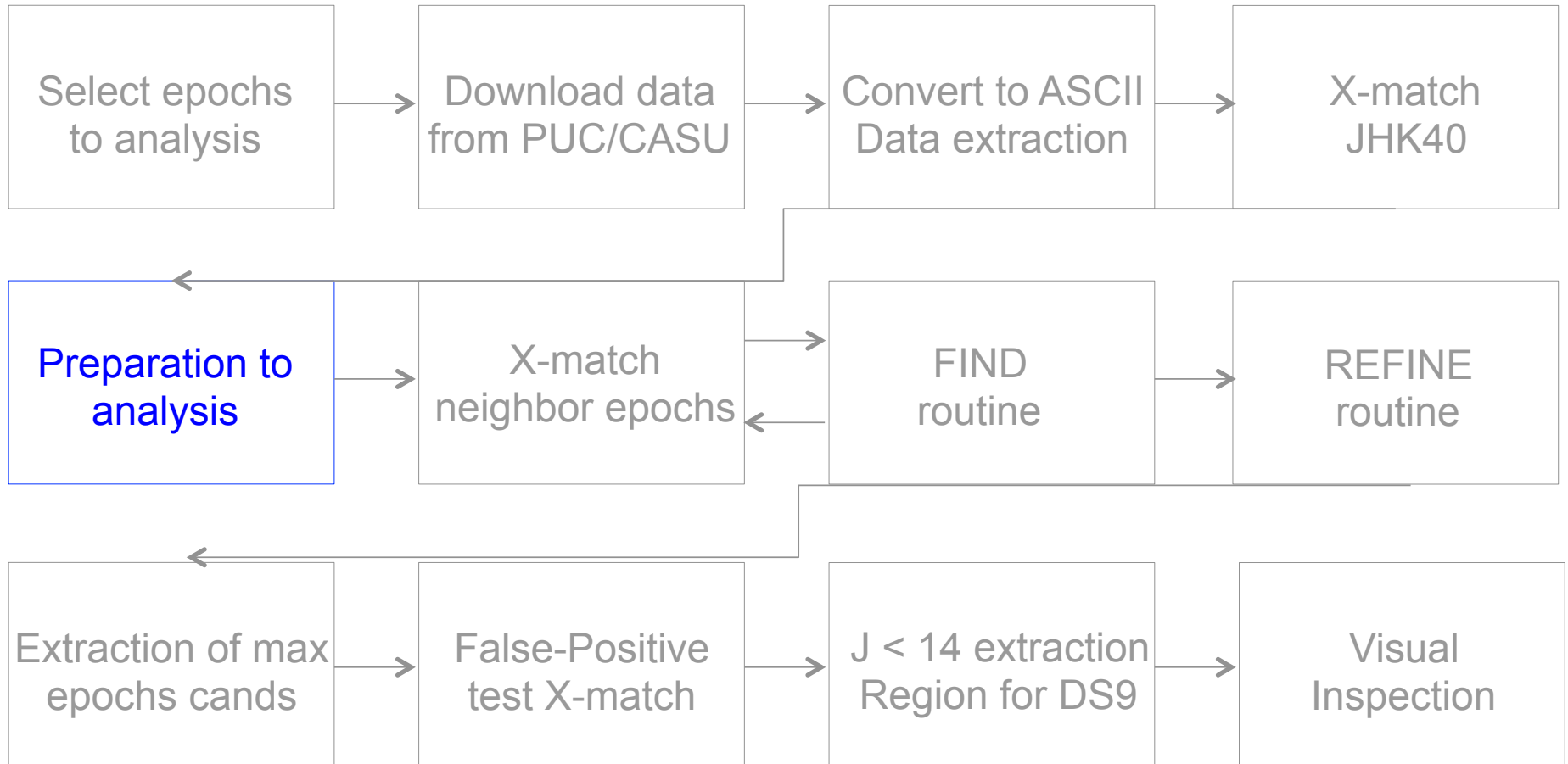


Detection method (VVVPM)



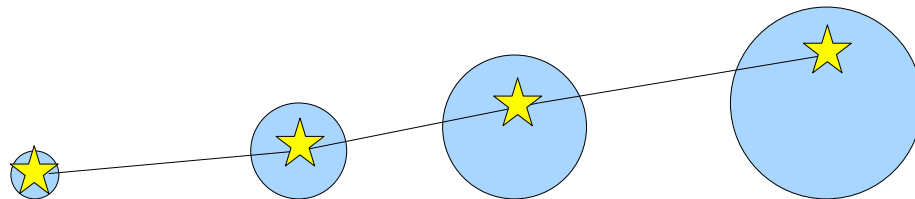
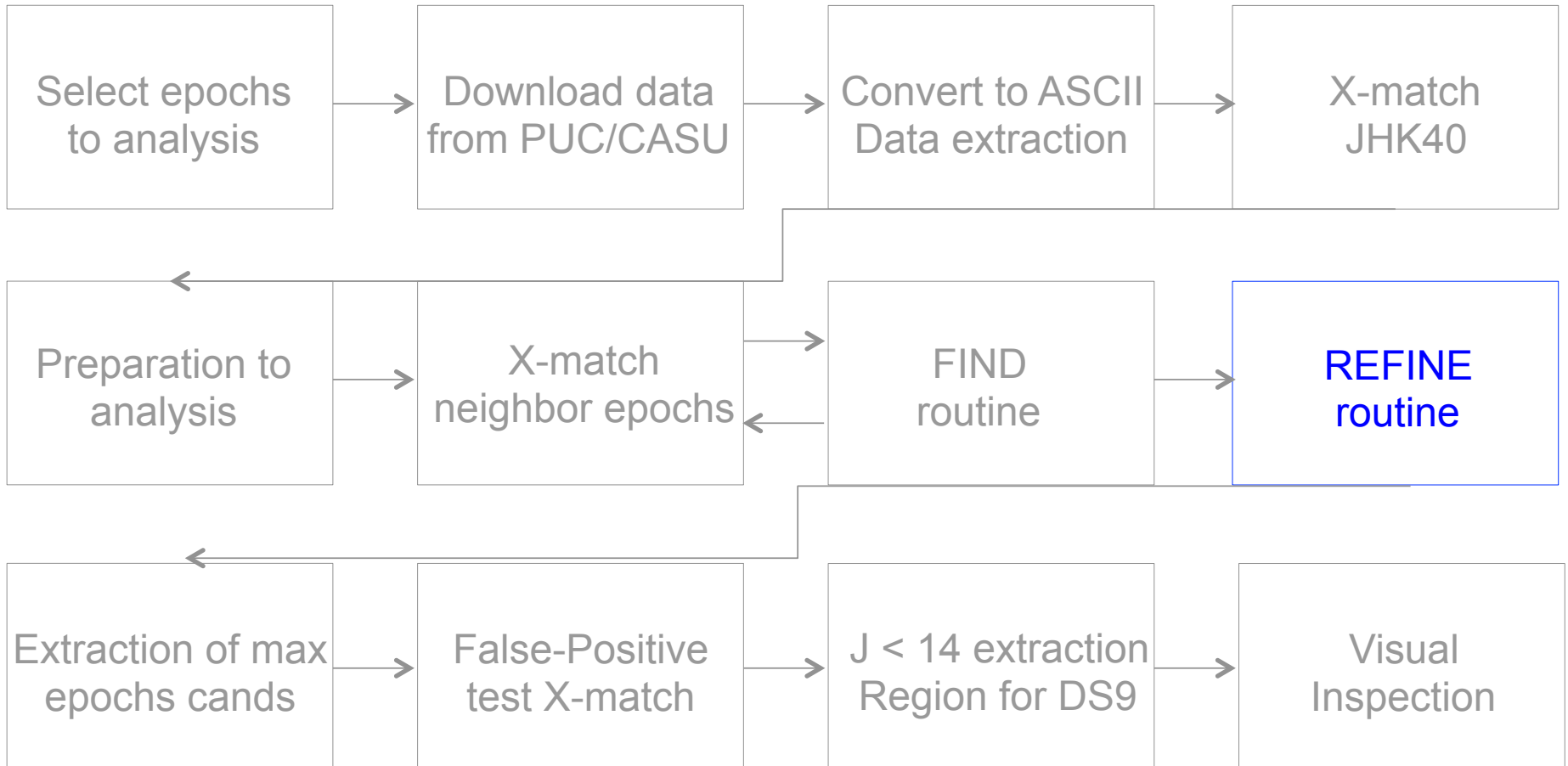
- We download (ZY)JHK40, Kv5, Kv9, Kv13 catalogs (~2 GB)
- Convert FITS -> ASCII and extract necessary information:
CASU FORTRAN procedure
- X-match JHK40 with 0.3 arcsec radius

Detection method (VVVPM)

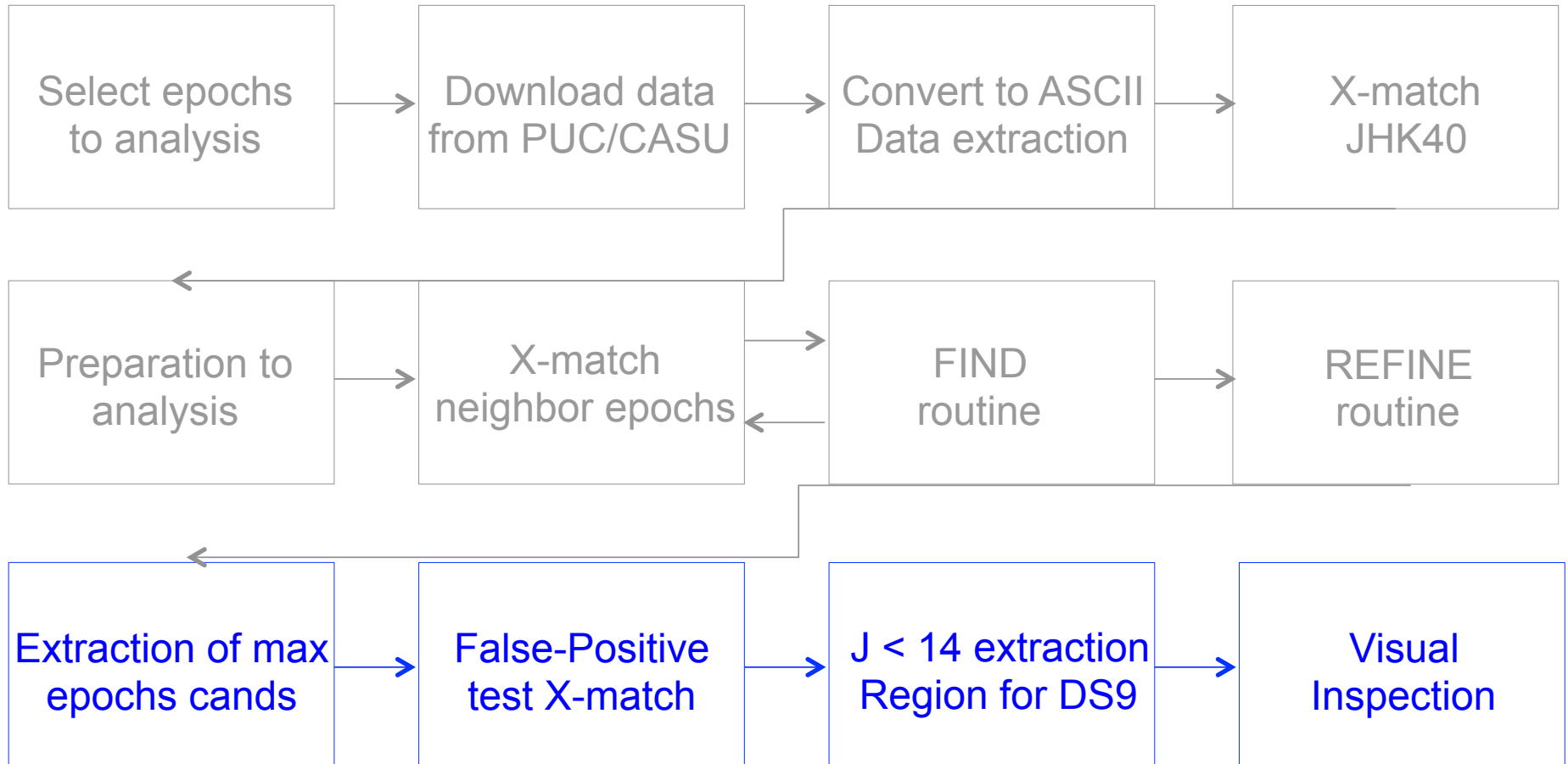


- Estimation radius for X-match in each step
- Prepare first input file to X-match (FLAG_K = -9, -2, -1)
- Create logfile

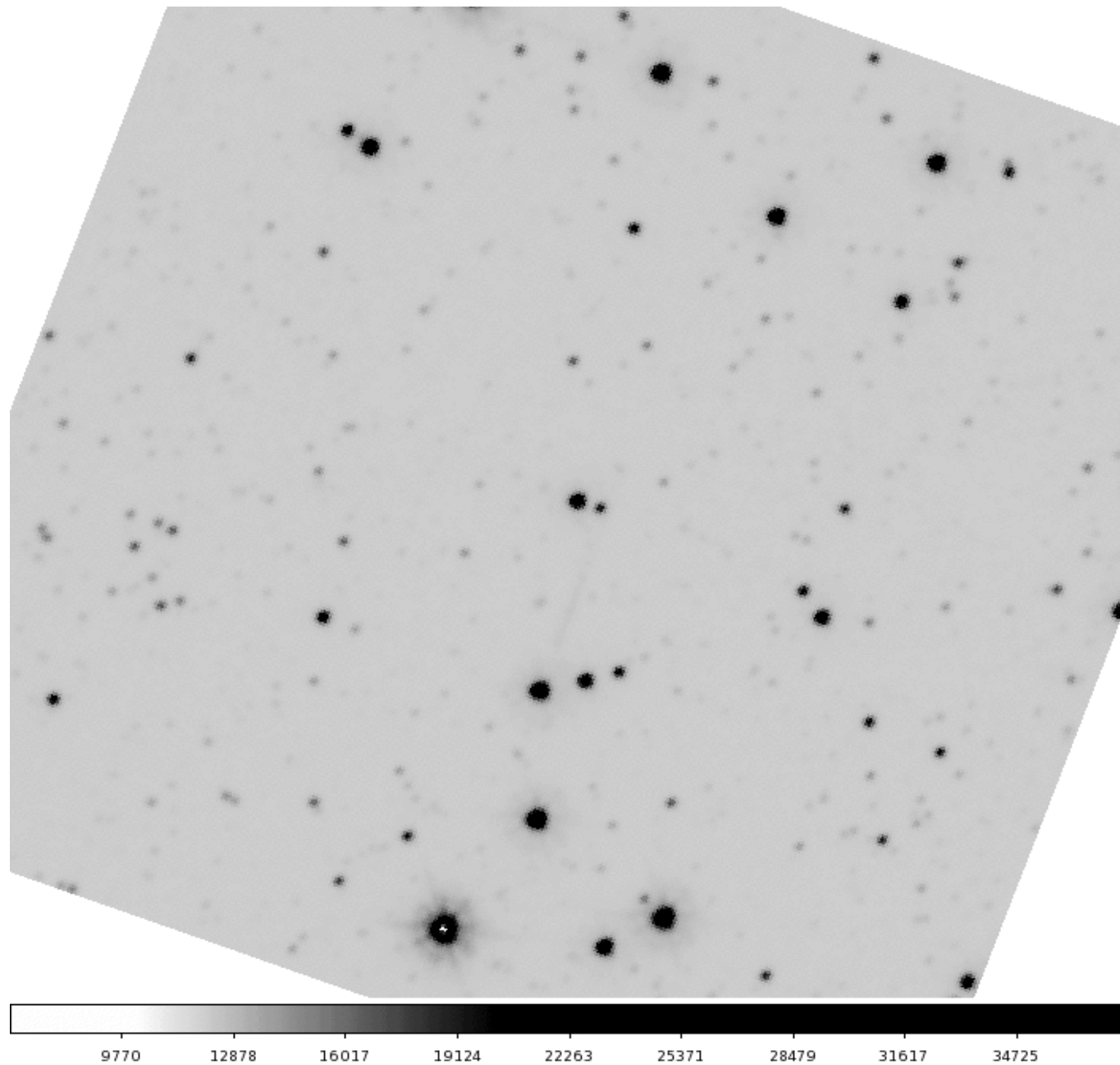
Detection method (VVVPM)



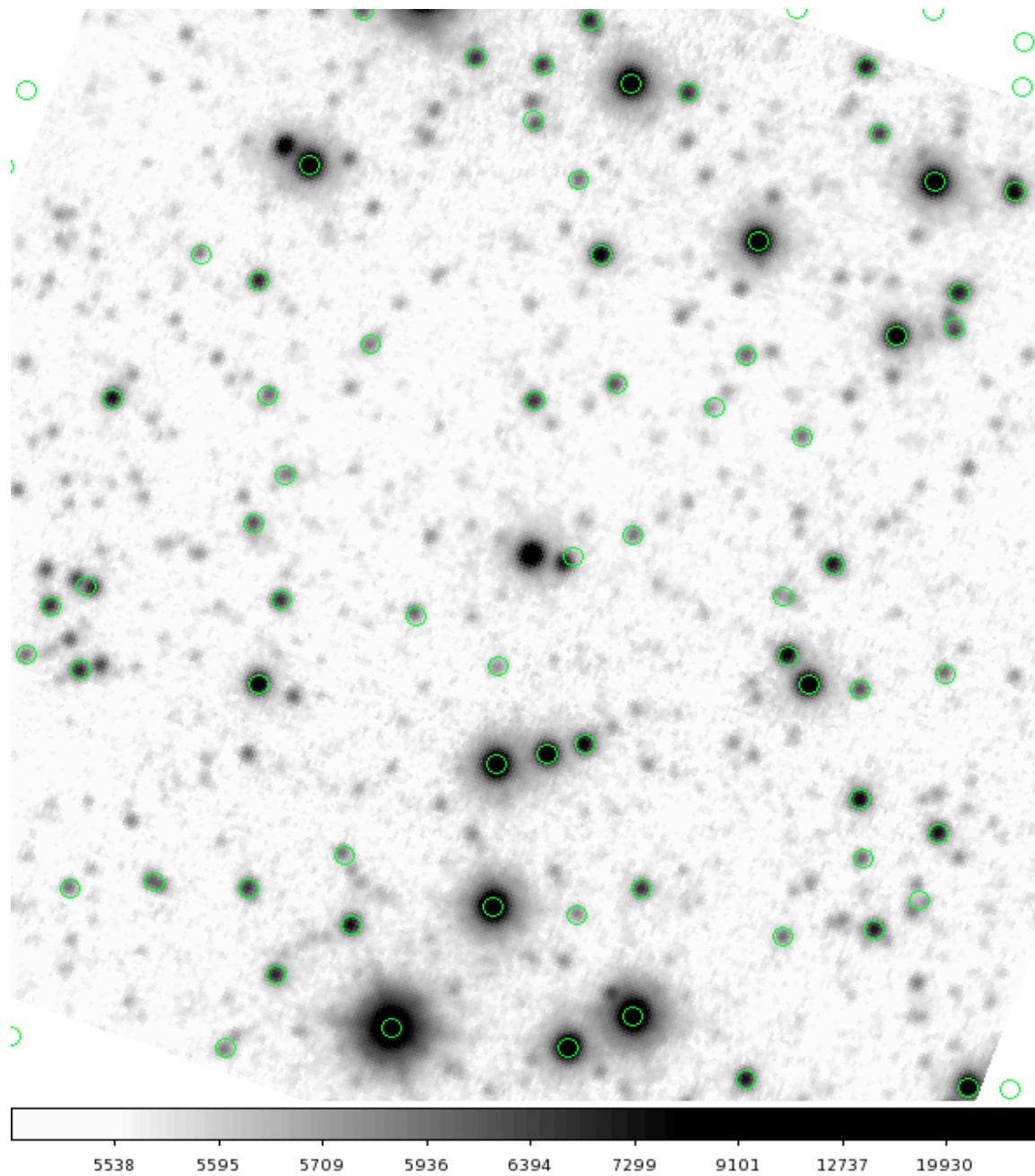
Detection method (VVVPM)



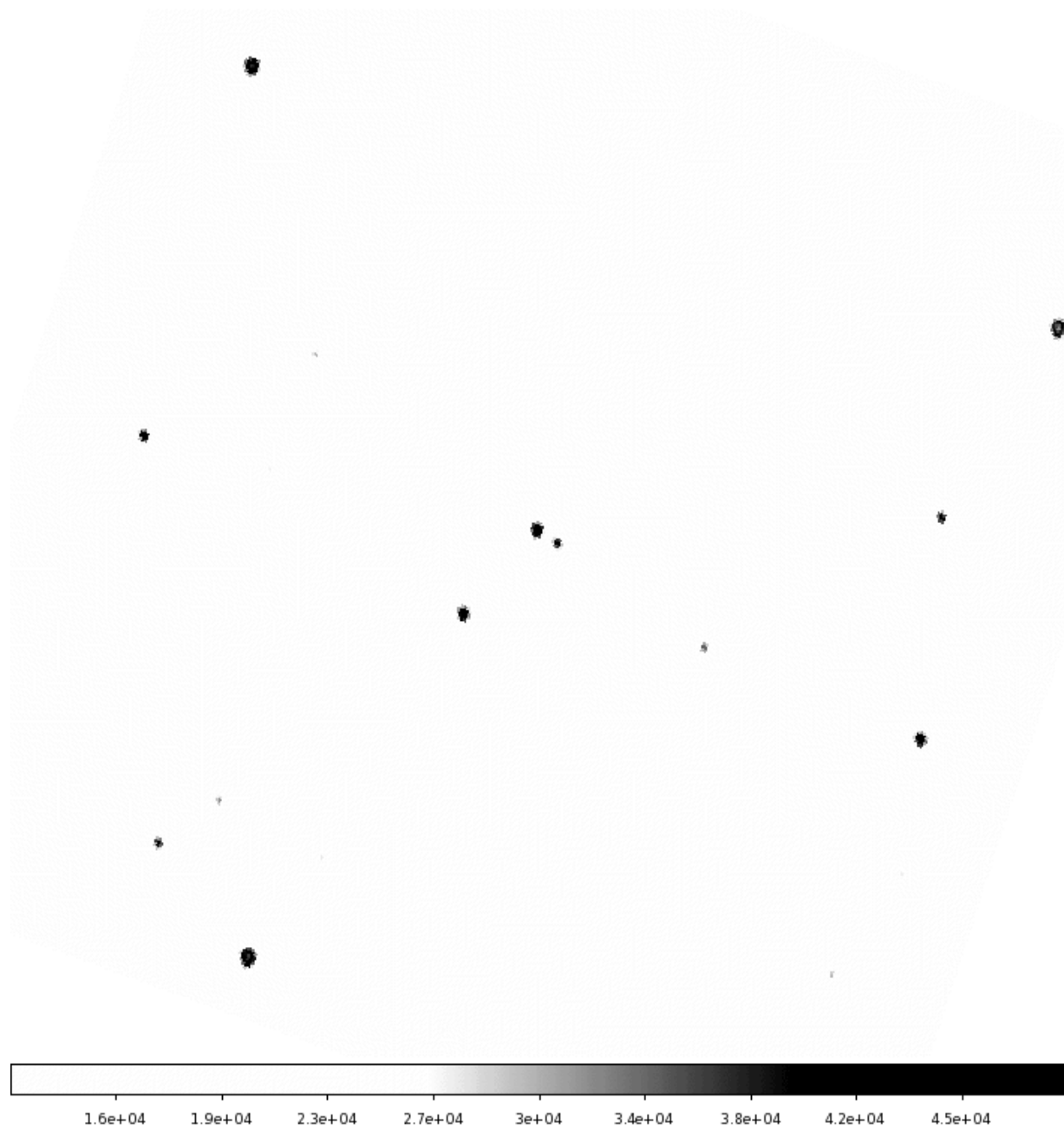
Example detection I



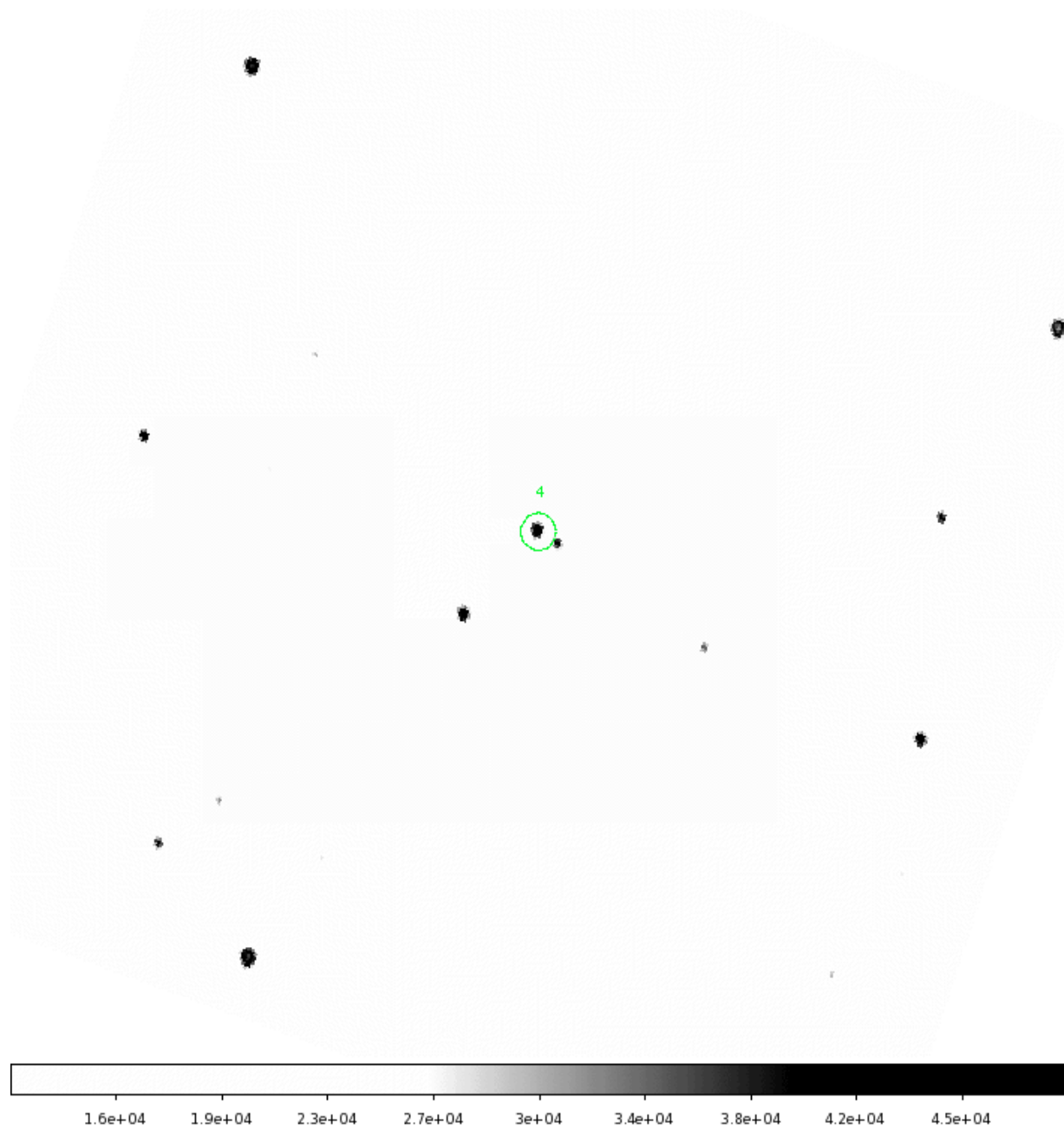
Example detection I



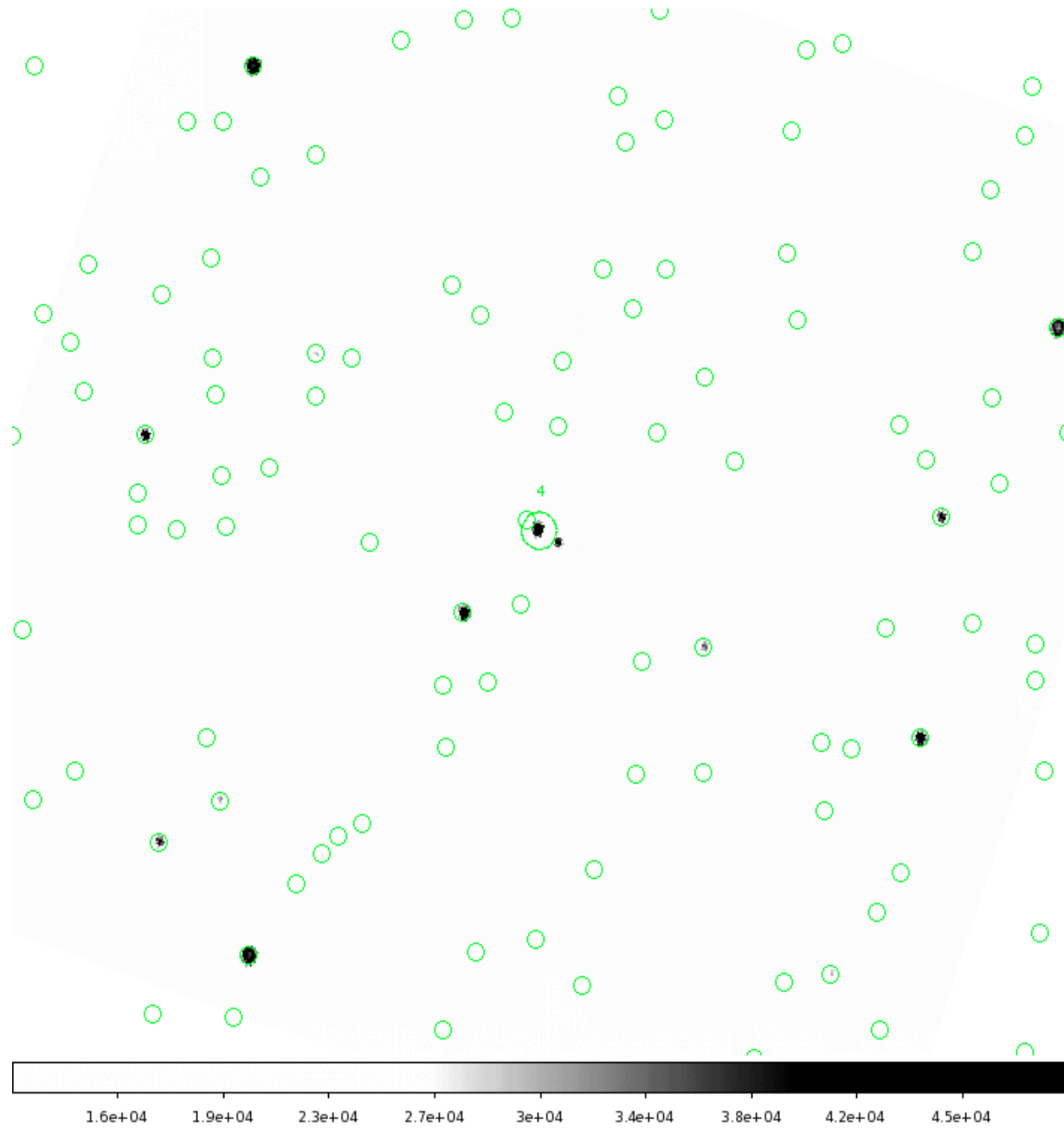
Example detection II



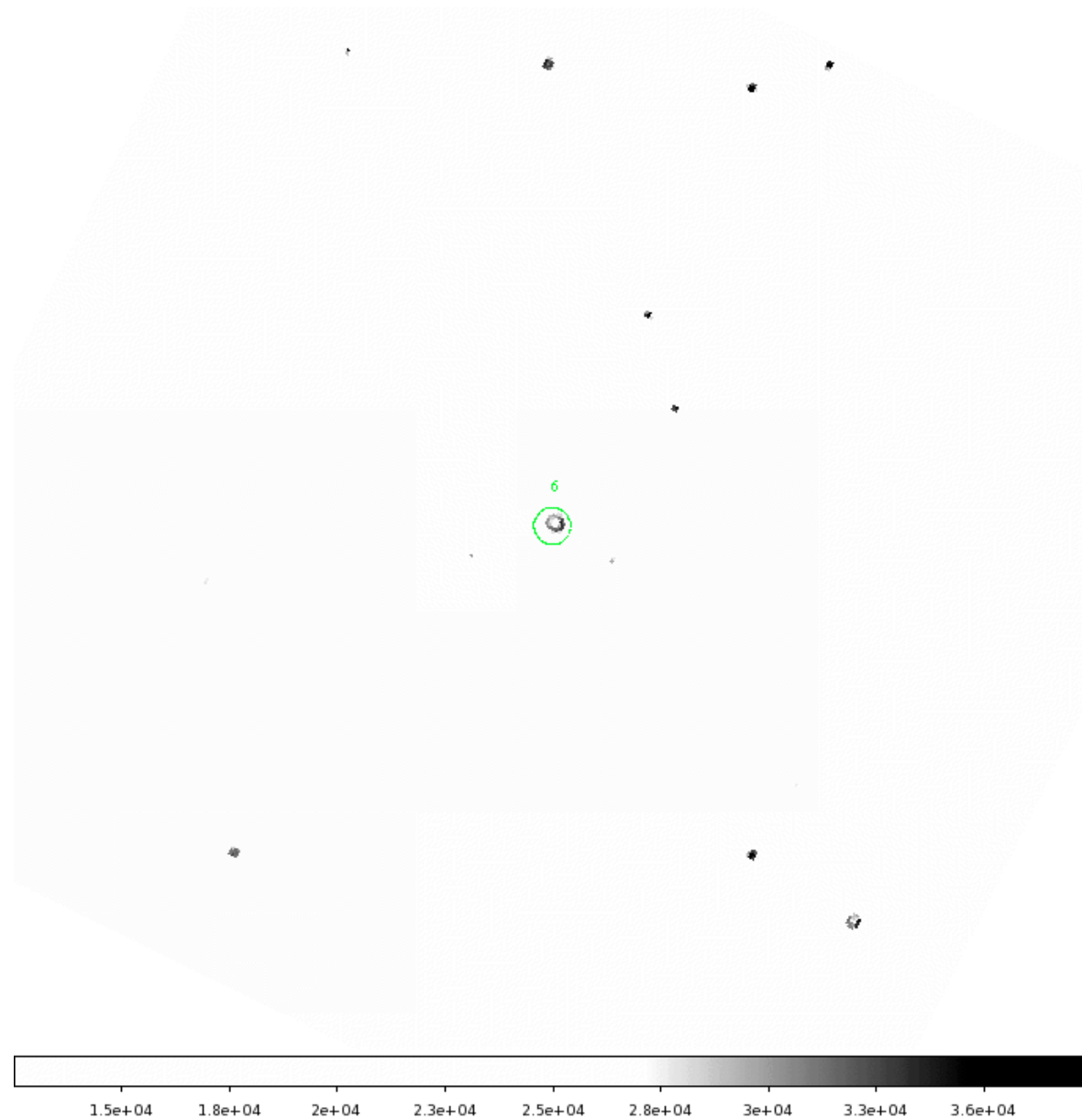
Example detection II



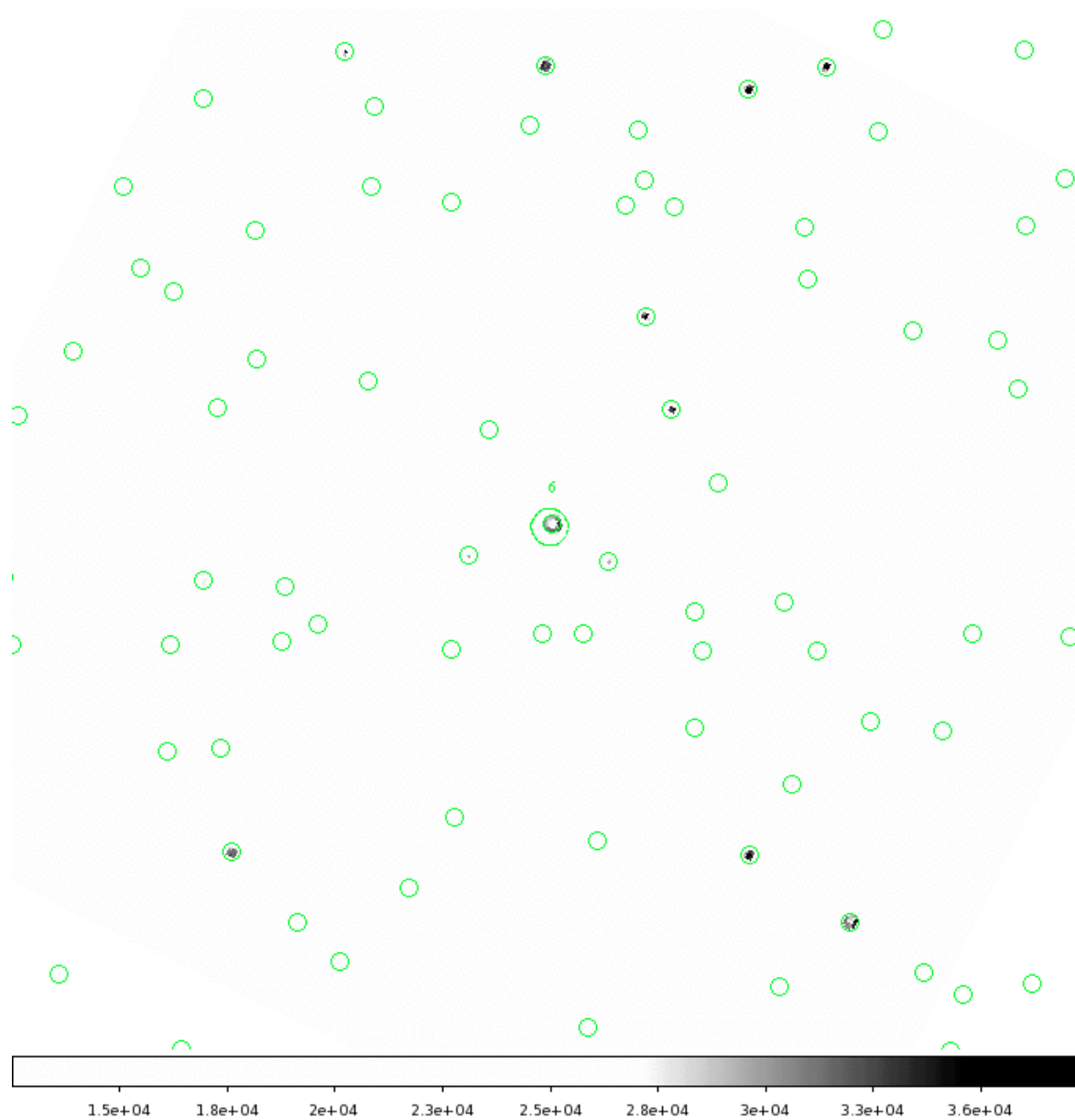
Example detection II



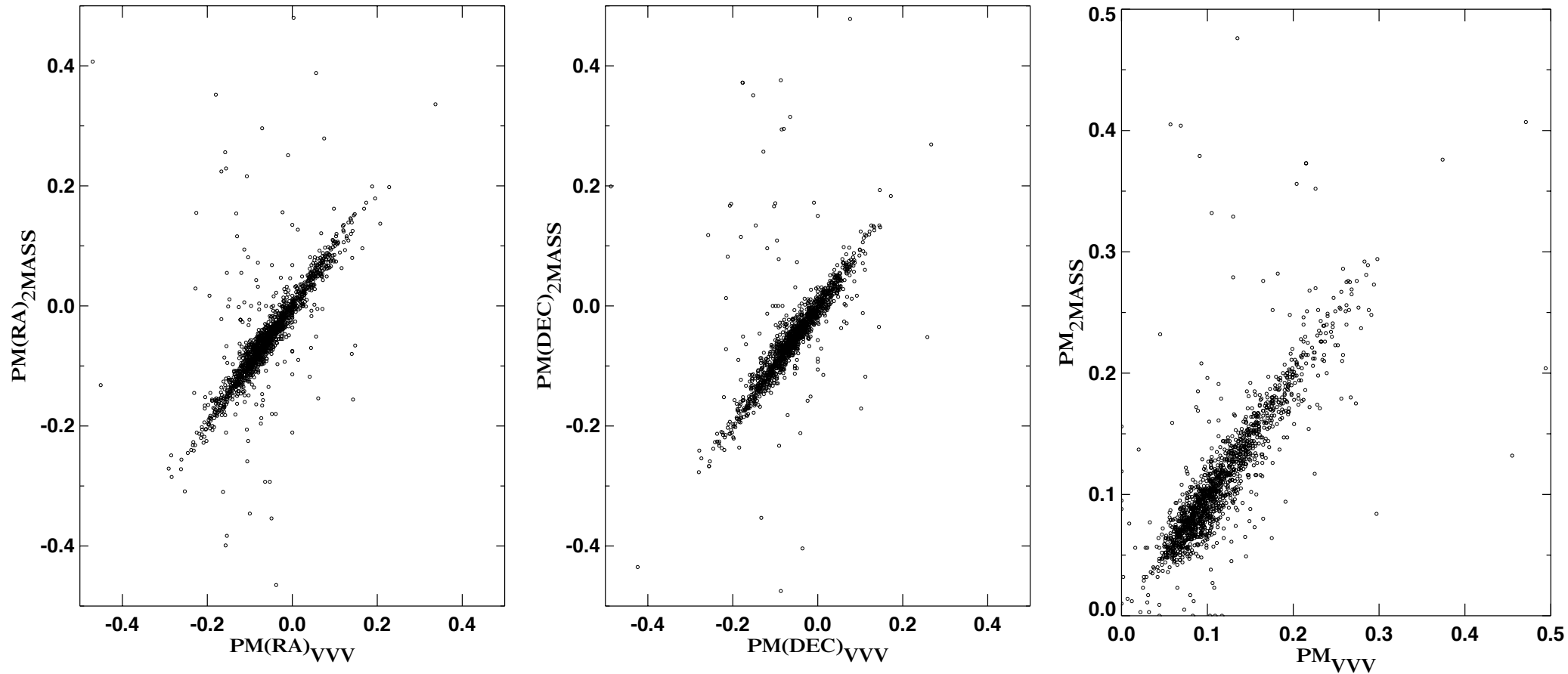
Example false detection I



Example false detection I



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

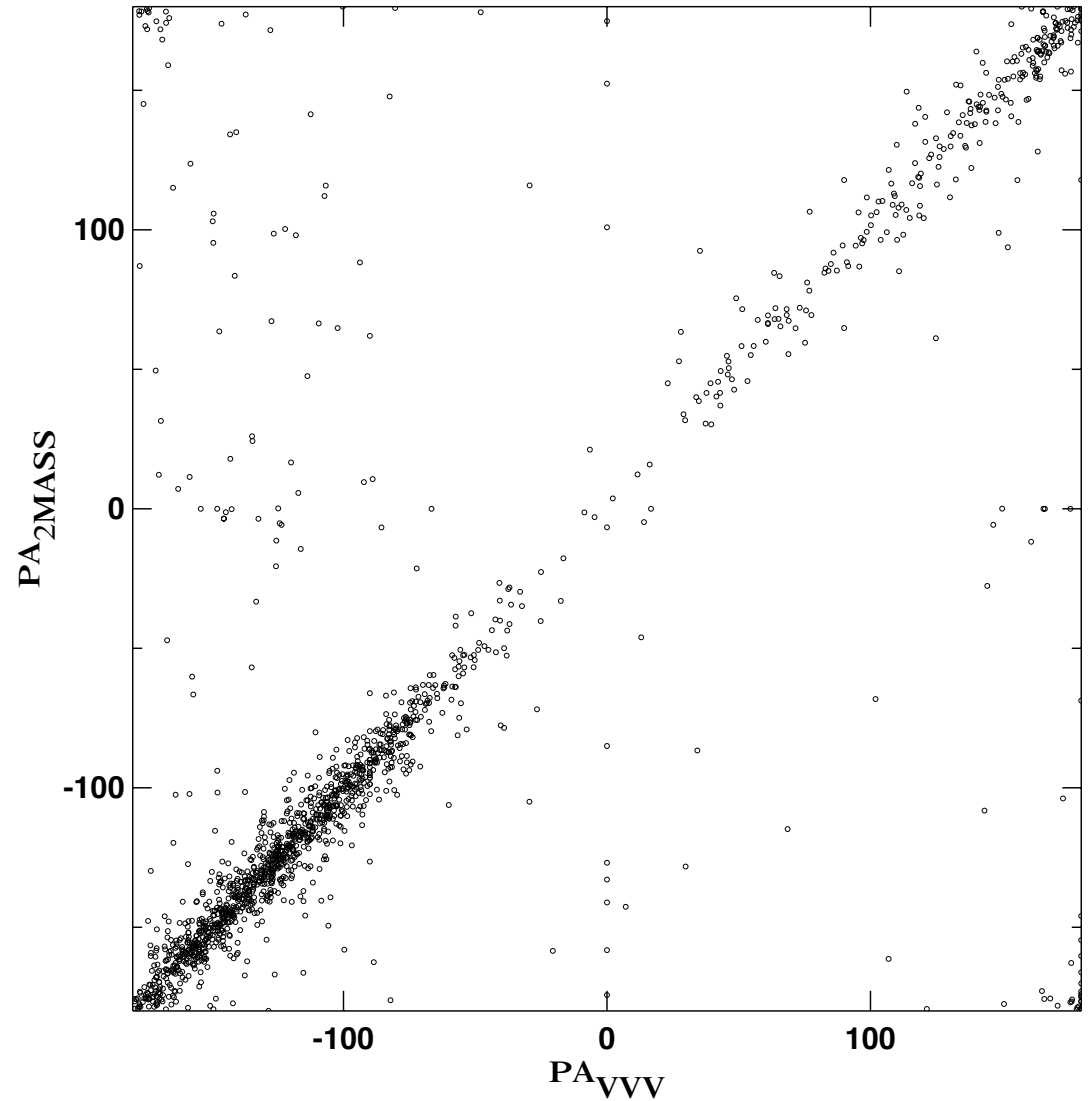


PM obtained in 2 ways: comparing 2 VVV epochs the first and the last available (> 4 years) and the first VVV and 2 MASS (> 10 year). Good coincidence. Small number of errors. Additional check for errors.

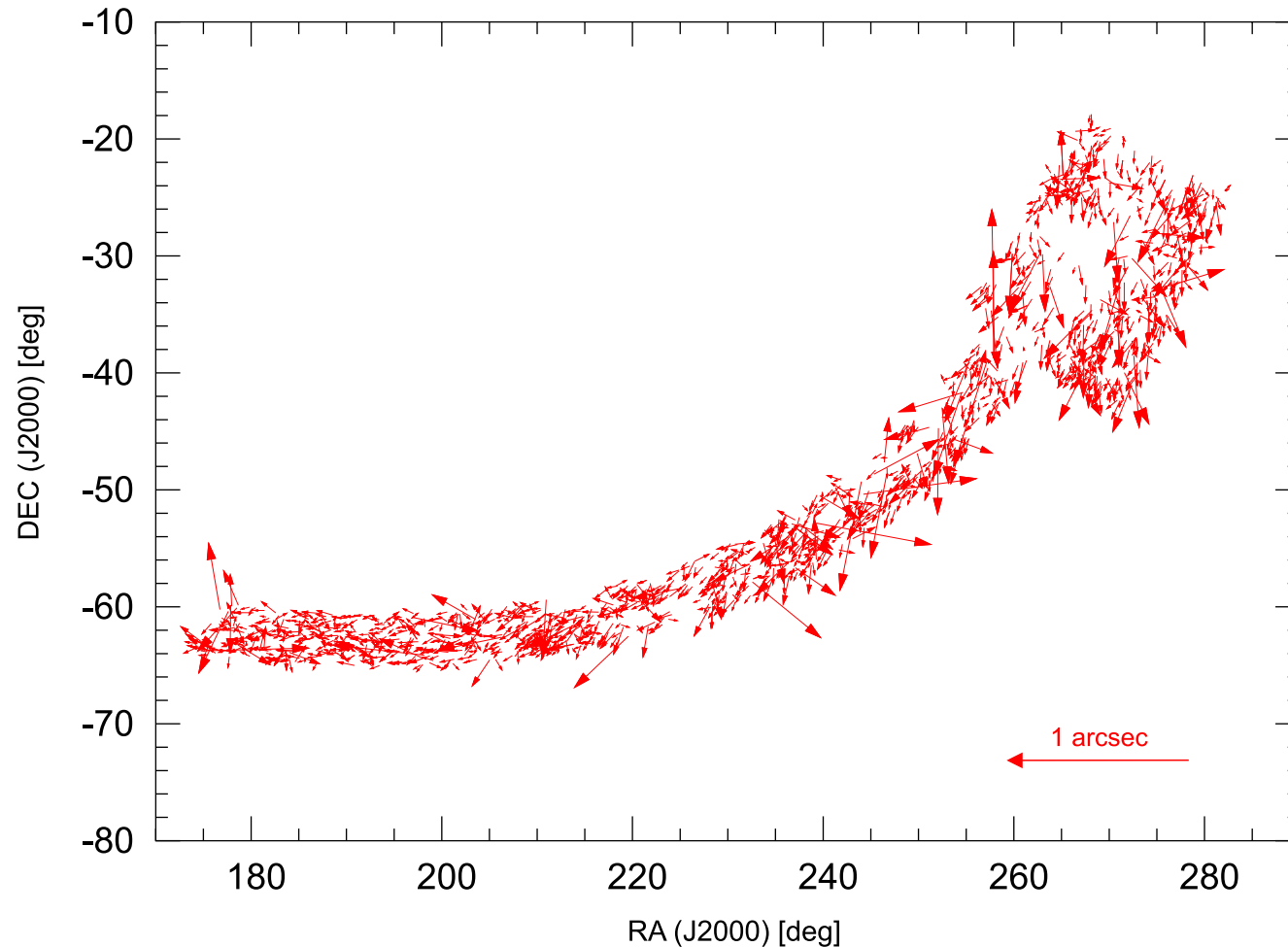
PA: VVV vs. 2MASS

Comparison of the parallactic
Angles VVV and 2MASS

Good coincidence!

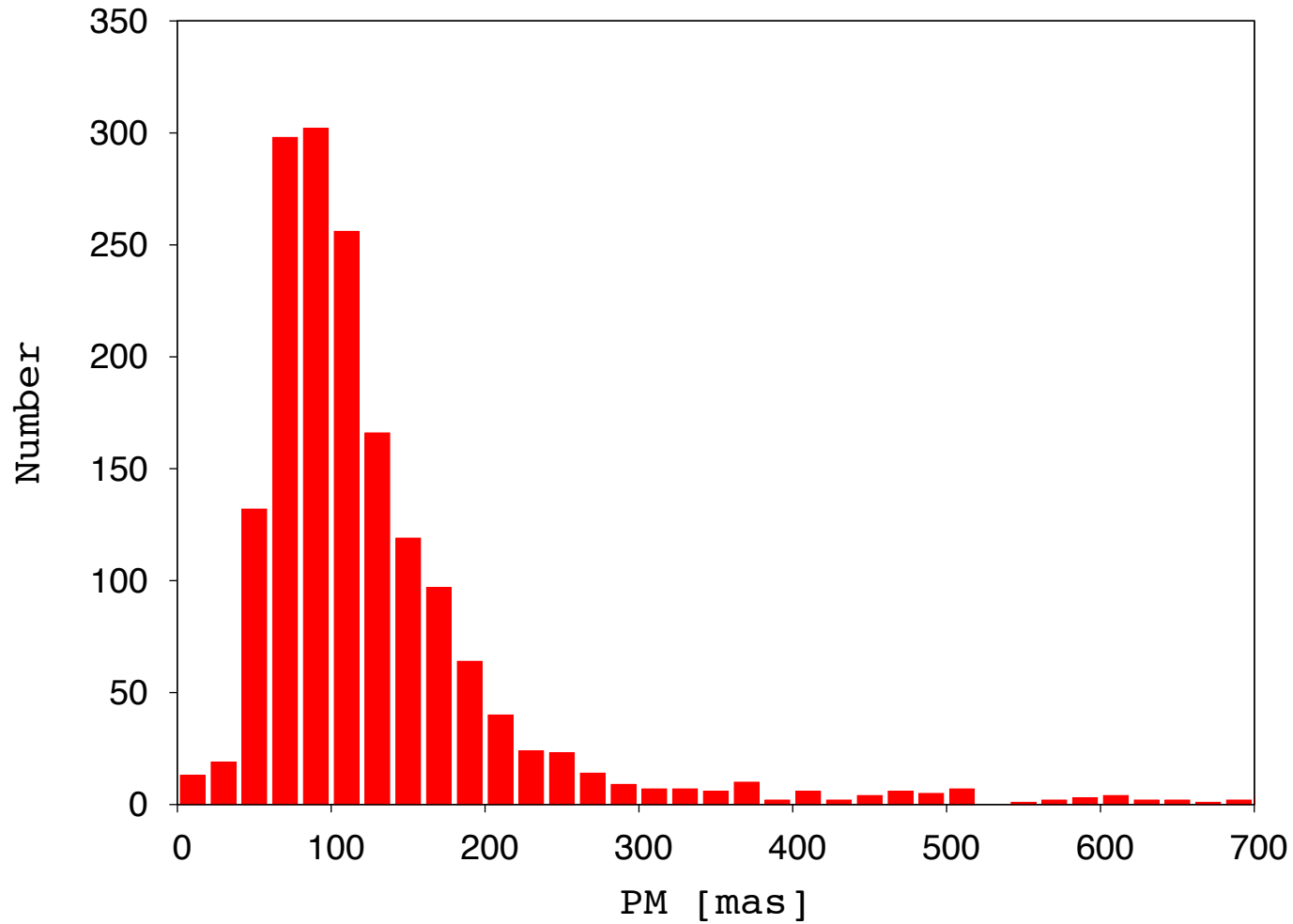


PM vector distribution



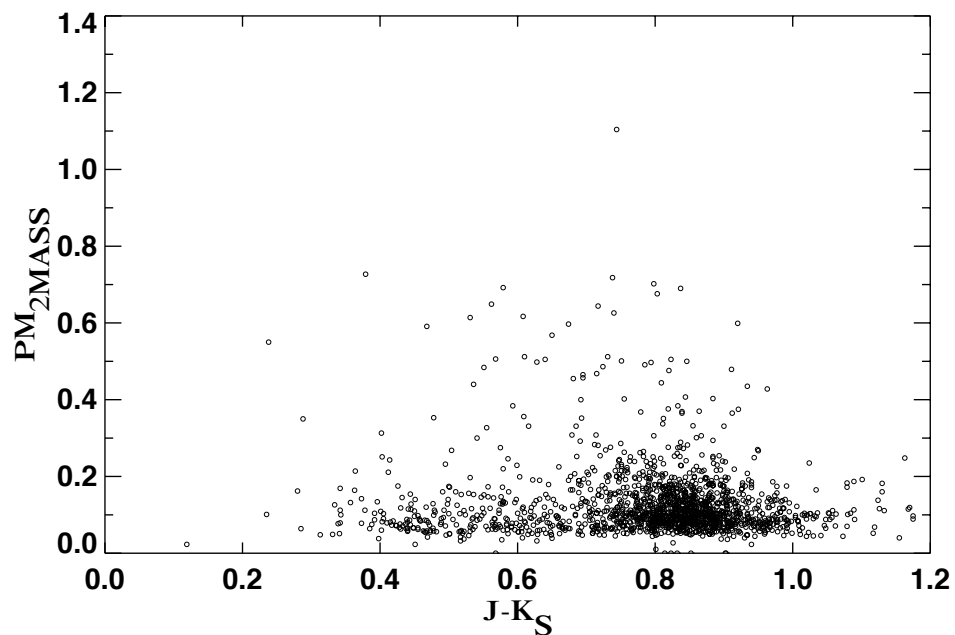
**Some incompleteness. Especially around the galactic centre.
More work needed! ☹**

PM histogram

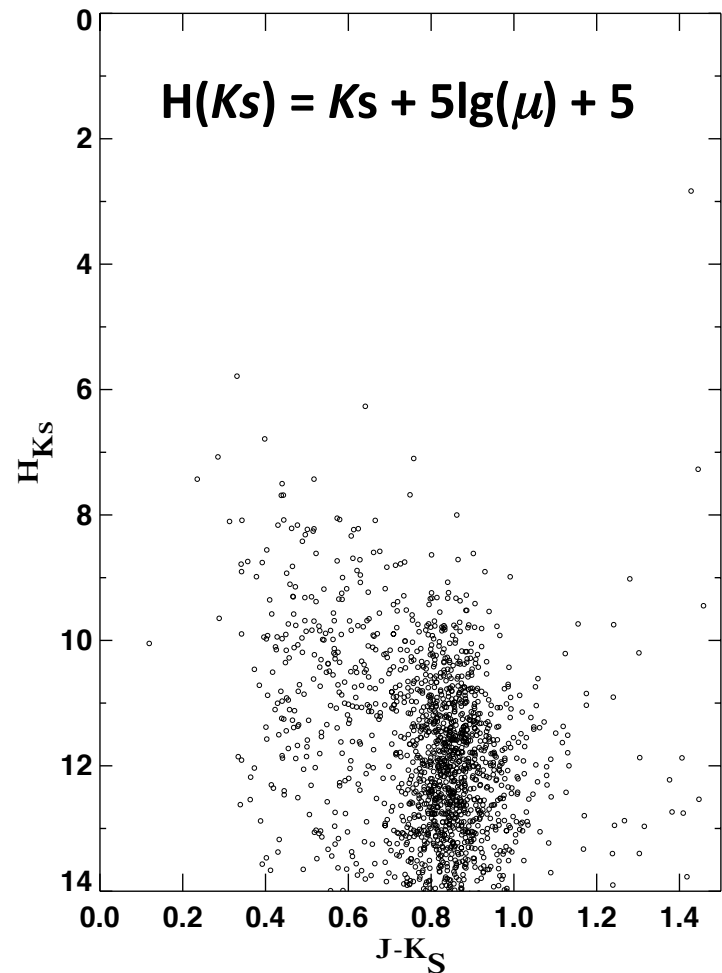


Significant incompleteness below 100 mas/year

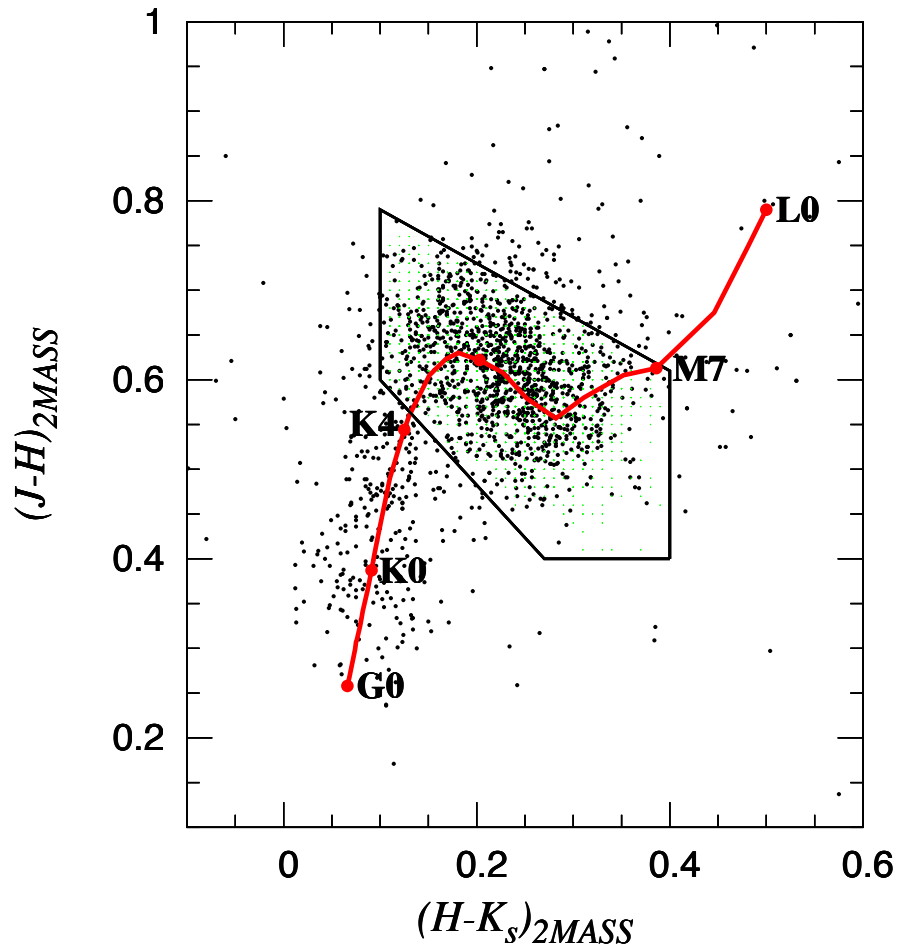
Reduced proper motion diagram



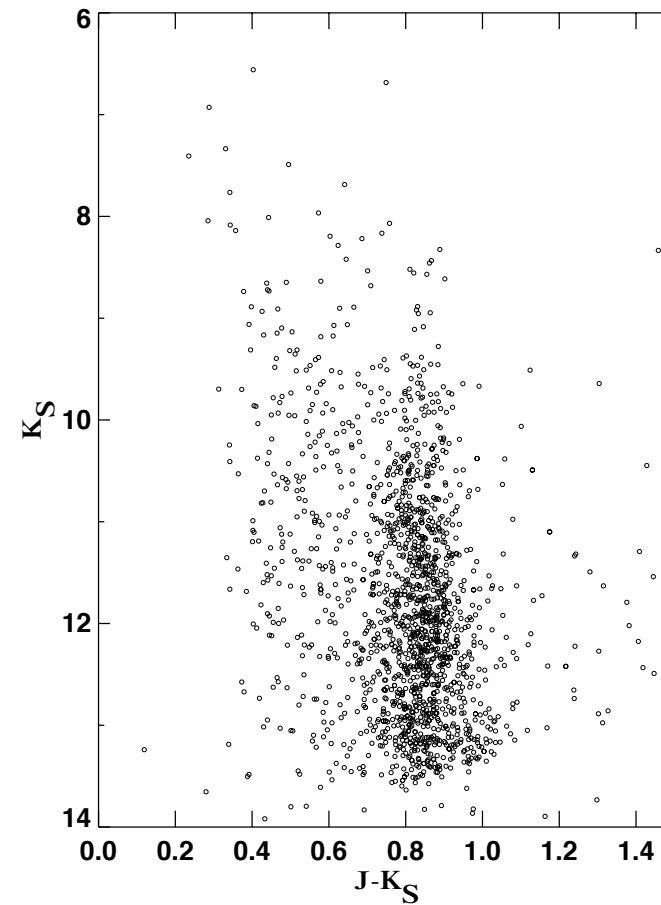
No giants in the sample



Sample: mostly early and mid M-dwarfs



Lepine and Gaidos 2011 (green points)



$(J-K_S)$, K_S 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 [\times color ²]	Coeff. 2 [\times 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

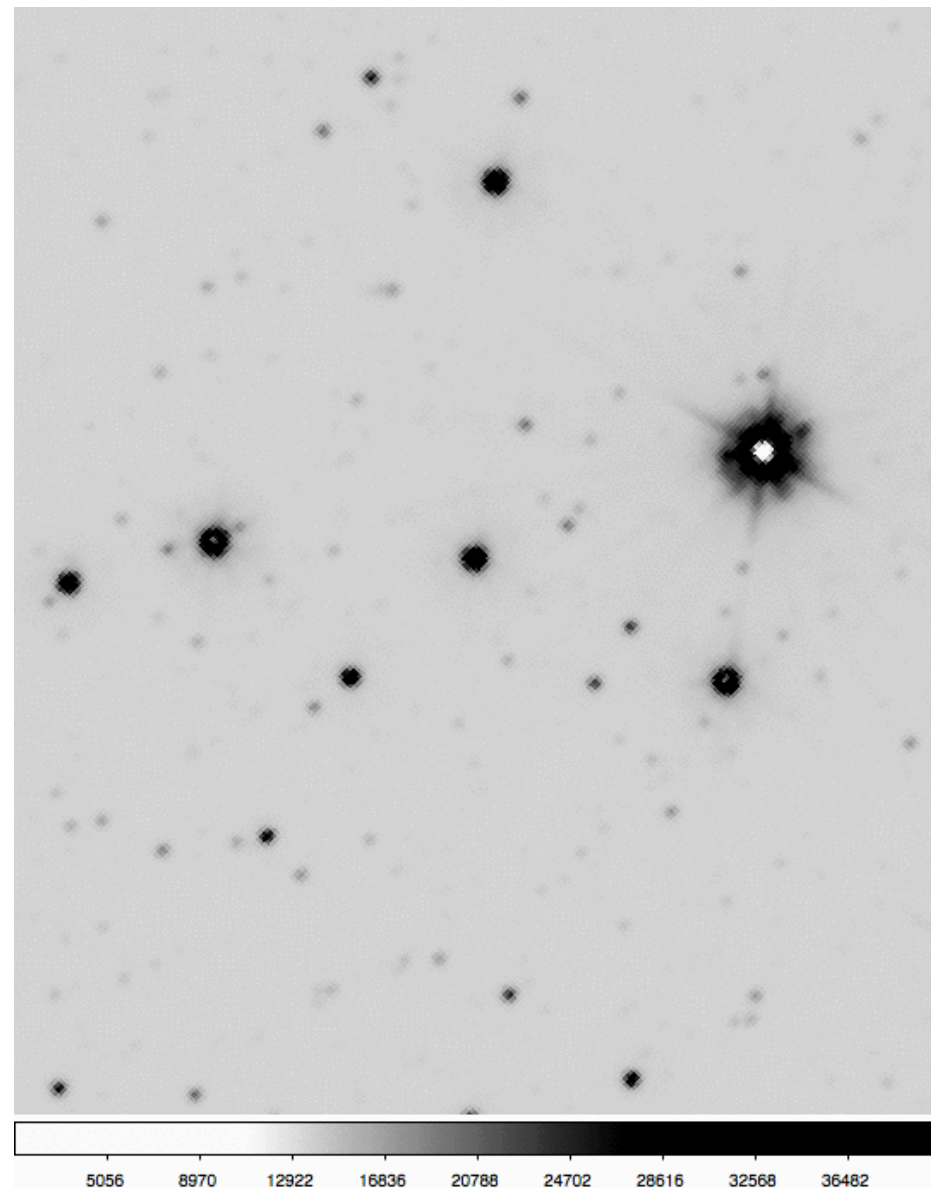
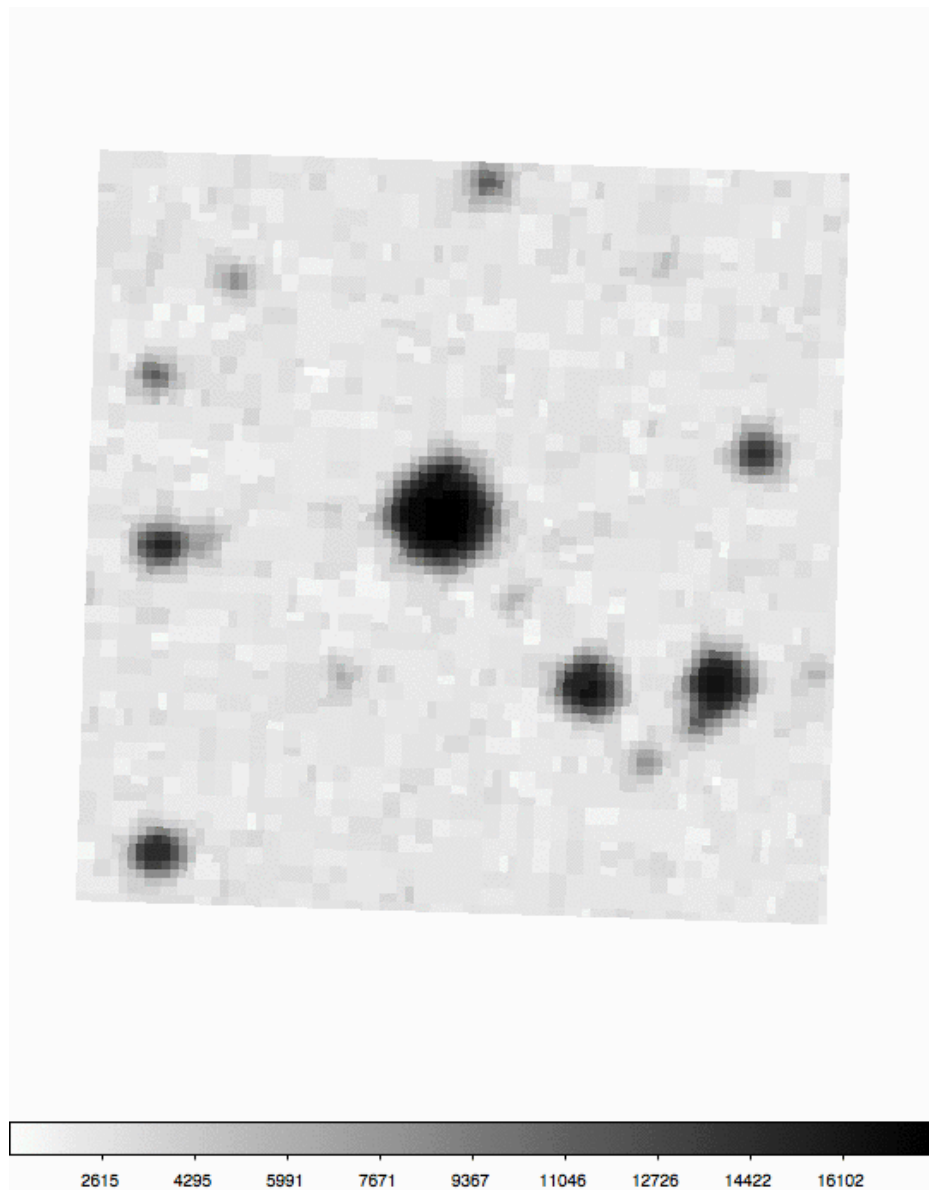
VVV high proper motion ($K_s < 13.5$) catalogue

- The catalogue contains data for 1701 PM stars:

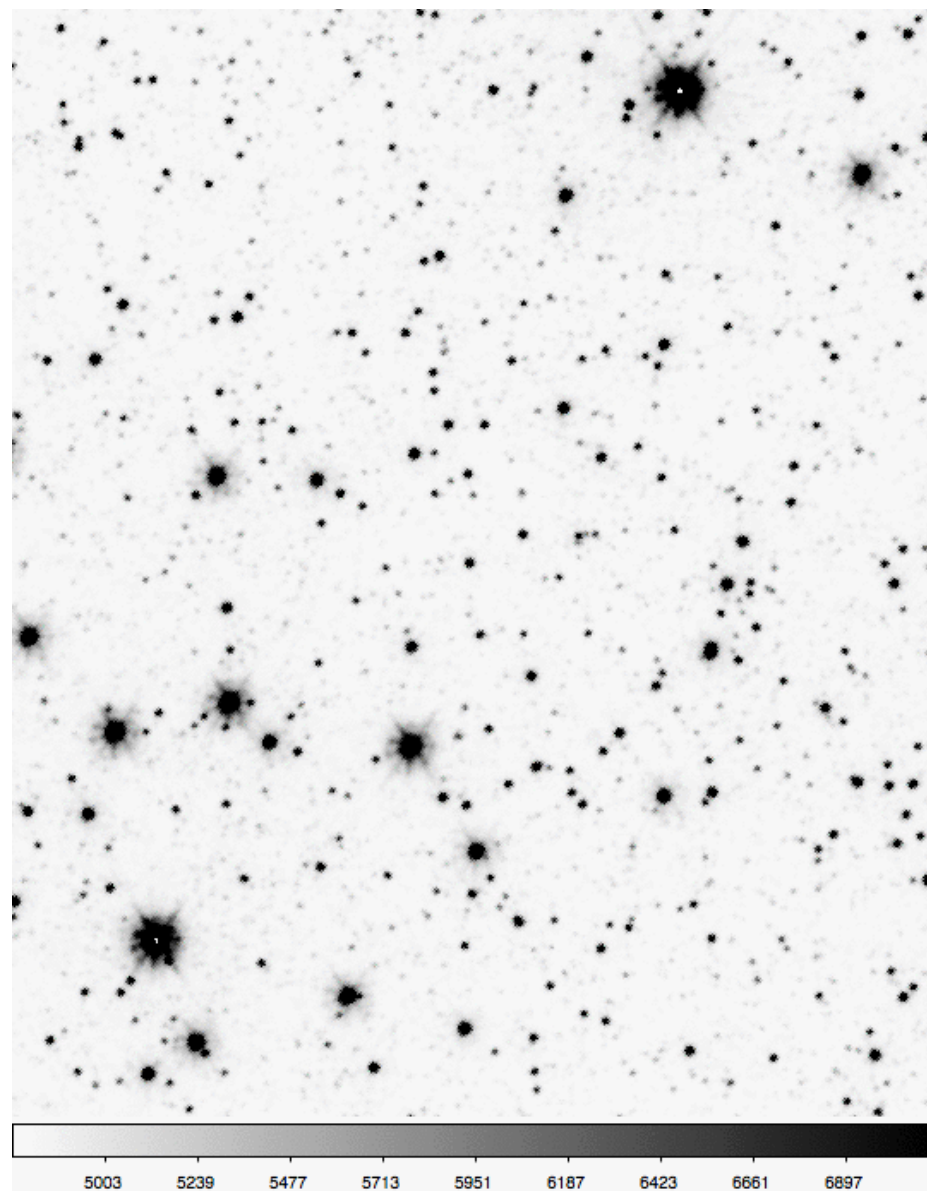
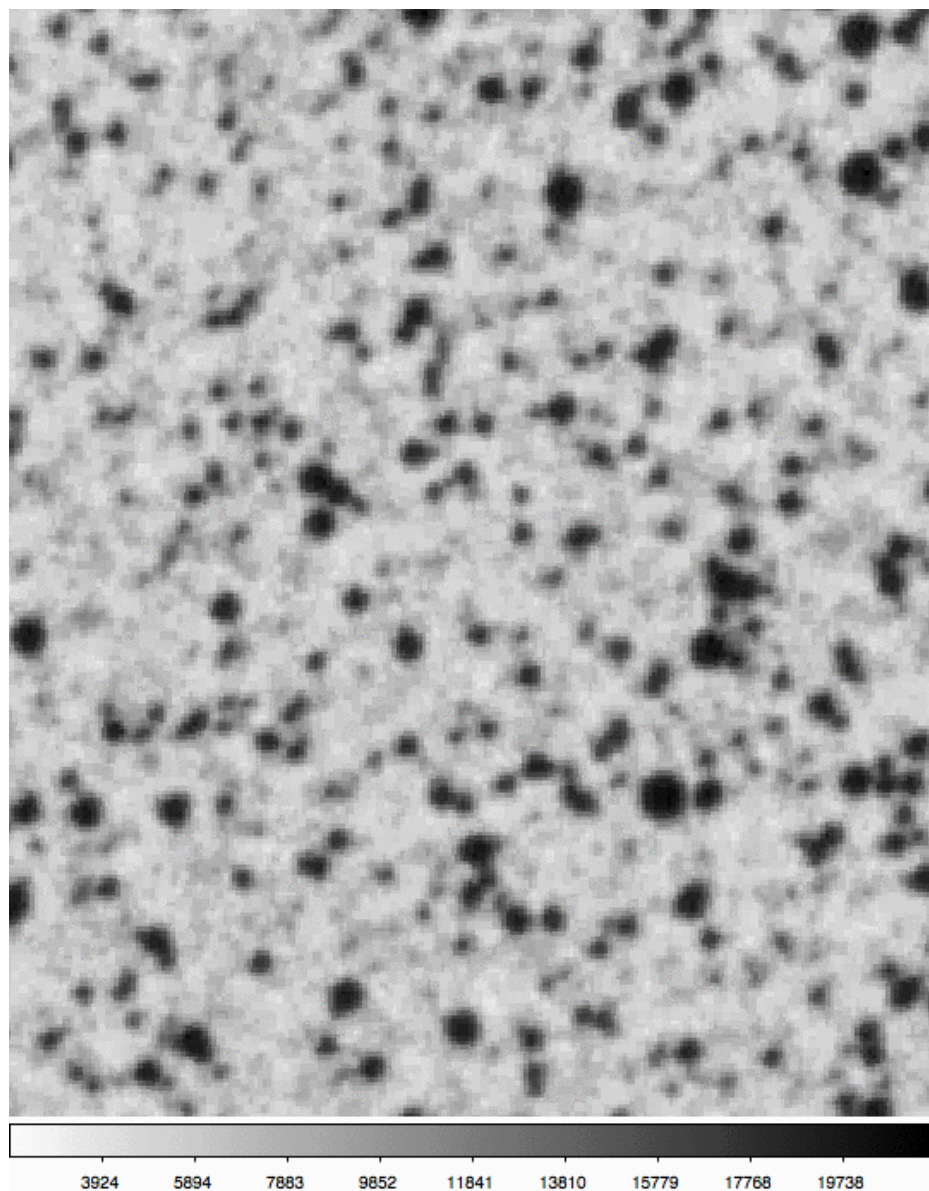
RA, DEC, EPOCH, J, H, K, [B, V], PM(RA), PM(DEC), PM, PA, [phot_dist]

- 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

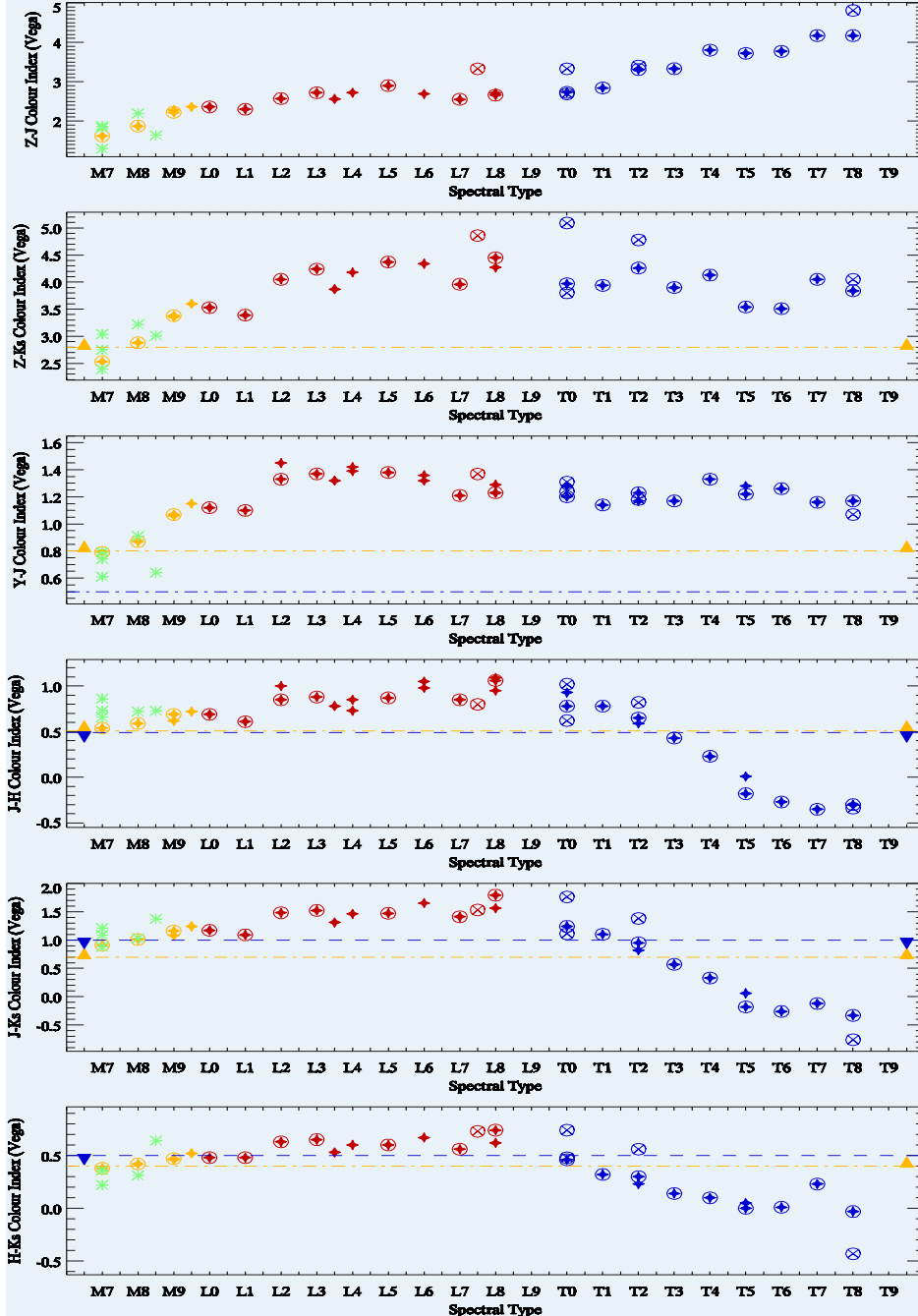


First VVV BD (Beamin et al. 2014)



UCD color cuts

VIRCAM Synthetic colours for Ultracool Dwarfs



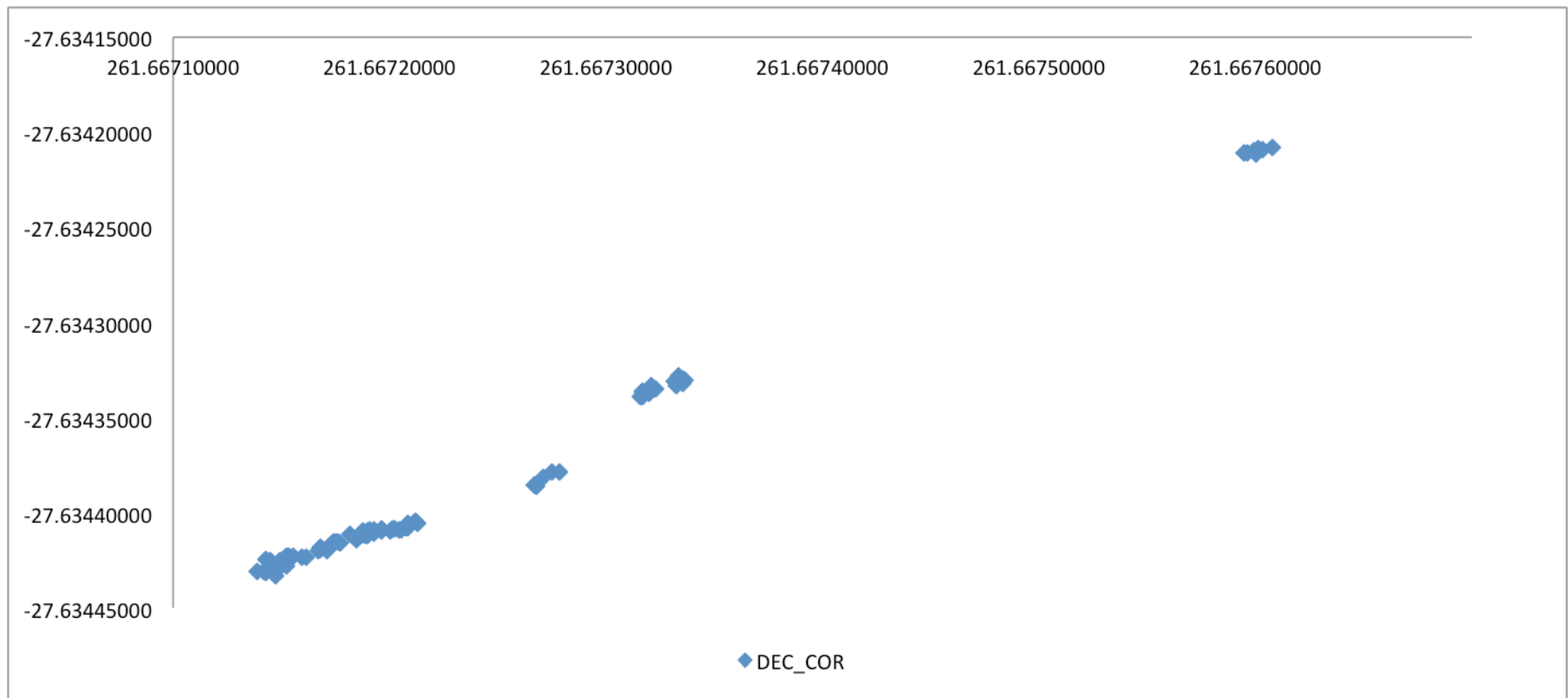
Synthetic colours of the ultra-cool dwarfs (UCD) in the VVV system based on the spectral library.

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

The screenshot shows a web browser window with the URL `irsa.ipac.caltech.edu/data/SPITZER/docs/dataanalysisitools/tools/contributed/general/make_parallax_coords/`. The page header features the IRSA logo and the text "NASA/IPAC INFRARED SCIENCE ARCHIVE". Navigation links include "IRSA", "DATA SETS", "SEARCH", "TOOLS", "HELP", and "Login".

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make_parallax_coords

Purpose: IDL procedure to calculate source coordinates as seen by an observatory correcting for annual parallax and proper motion.

Author: S. Carey (SSC)
Date Contributed: 12 Feb 2013
System Requirements: IDL (tested on IDL 8.1)

Information and Download

Download the [source code](#).

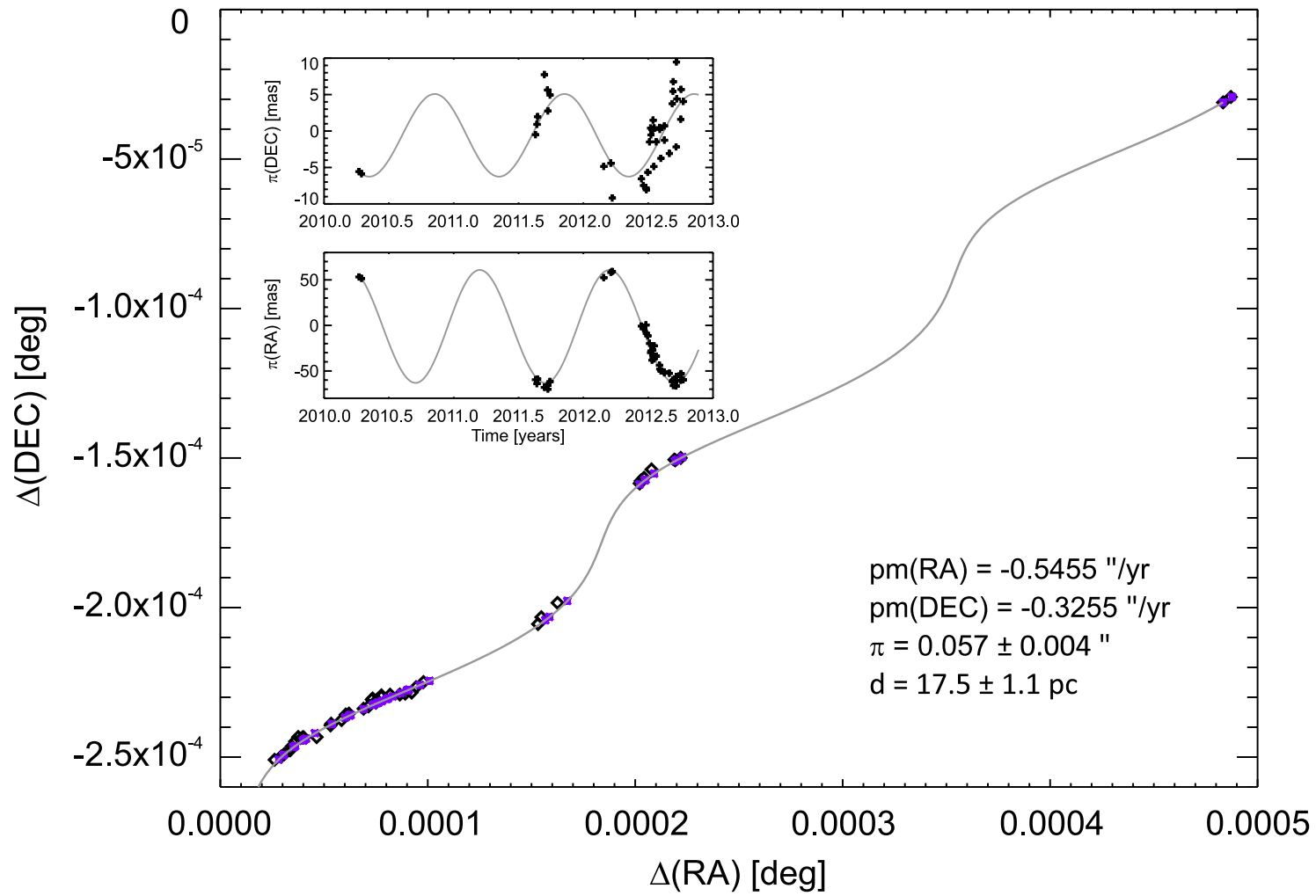
Determine astrometric position in Equatorial (J2000) coordinates for an object given the position at a previous epoch, the proper motion and the annual parallax. Designed for refining coordinates for Spitzer observations.

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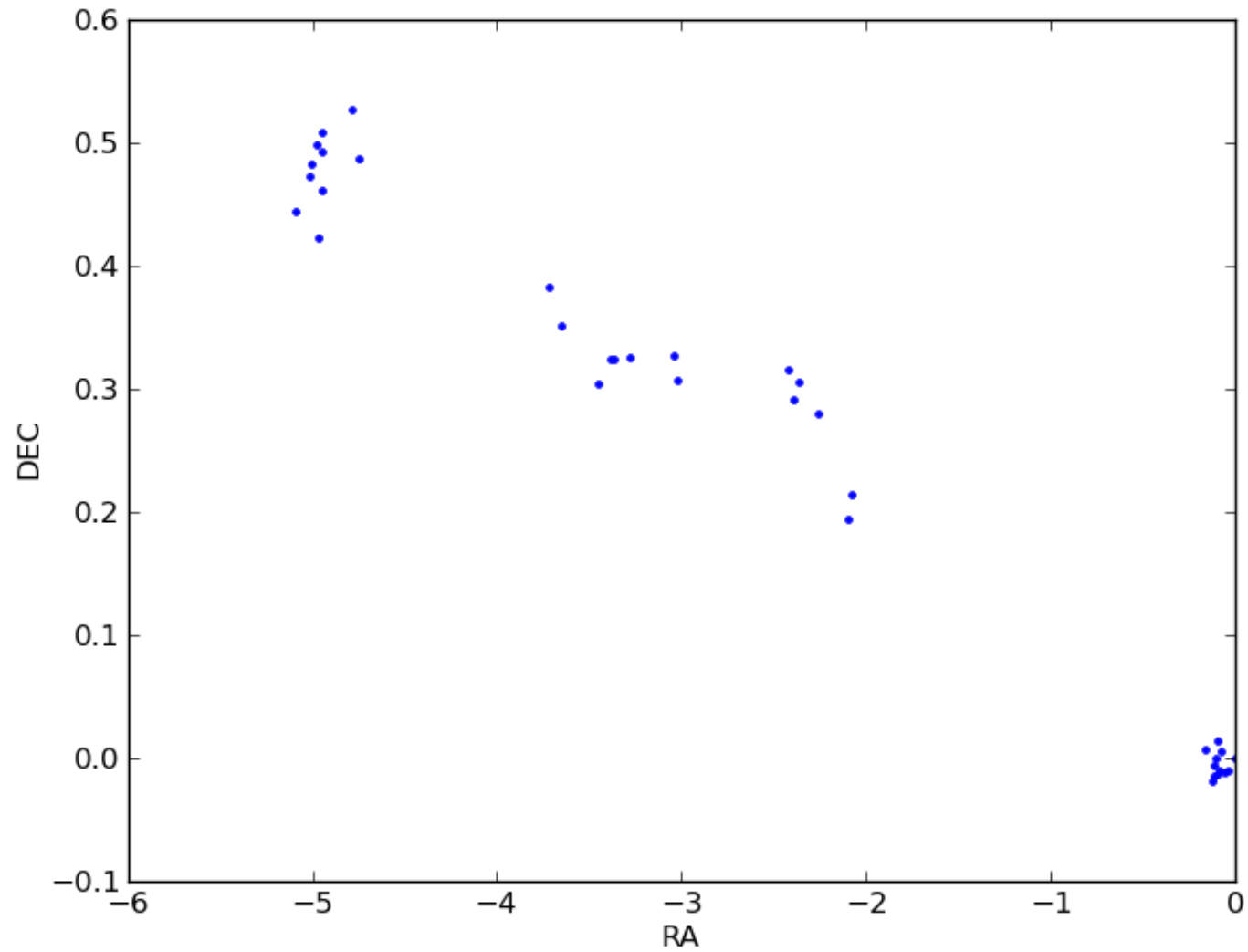
ipac Caltech JPL NASA

VVV parallaxes VVV-BD1



VVV parallaxes VVV-WD1

WD candidate Ks=14.9



Future work

- ❑ To continue with the fainter sample ($K_s > 13.5$ mag)
- ❑ Colour cuts
- ❑ Cross identification with VPHAS+
 - Correct photometrical distances (g', r', Z, Y, J, H, K_s)
 - Excess objects with IR excess ($H\alpha$)
- ❑ Cross correlation with WISE, GLIMPSE, etc.
- ❑ Parallax for the nearest $\sim 50 - 80$ 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!