Universidad de Valparaíso CHILE

Millenium Institute of Astrophysics MAS

Proper motions and parallaxes with VISTA-VVV

Radostin Kurtev

Mariusz Gromadzki, Juan Carlos Beamin, Stuart Folkes, Karla Peña, Valentin Ivanov, Vicente Villanueva, Dante Minniti, Jura Borissova, Phil Lucas, Leigh Smith, David Pinfield, & the VVV team

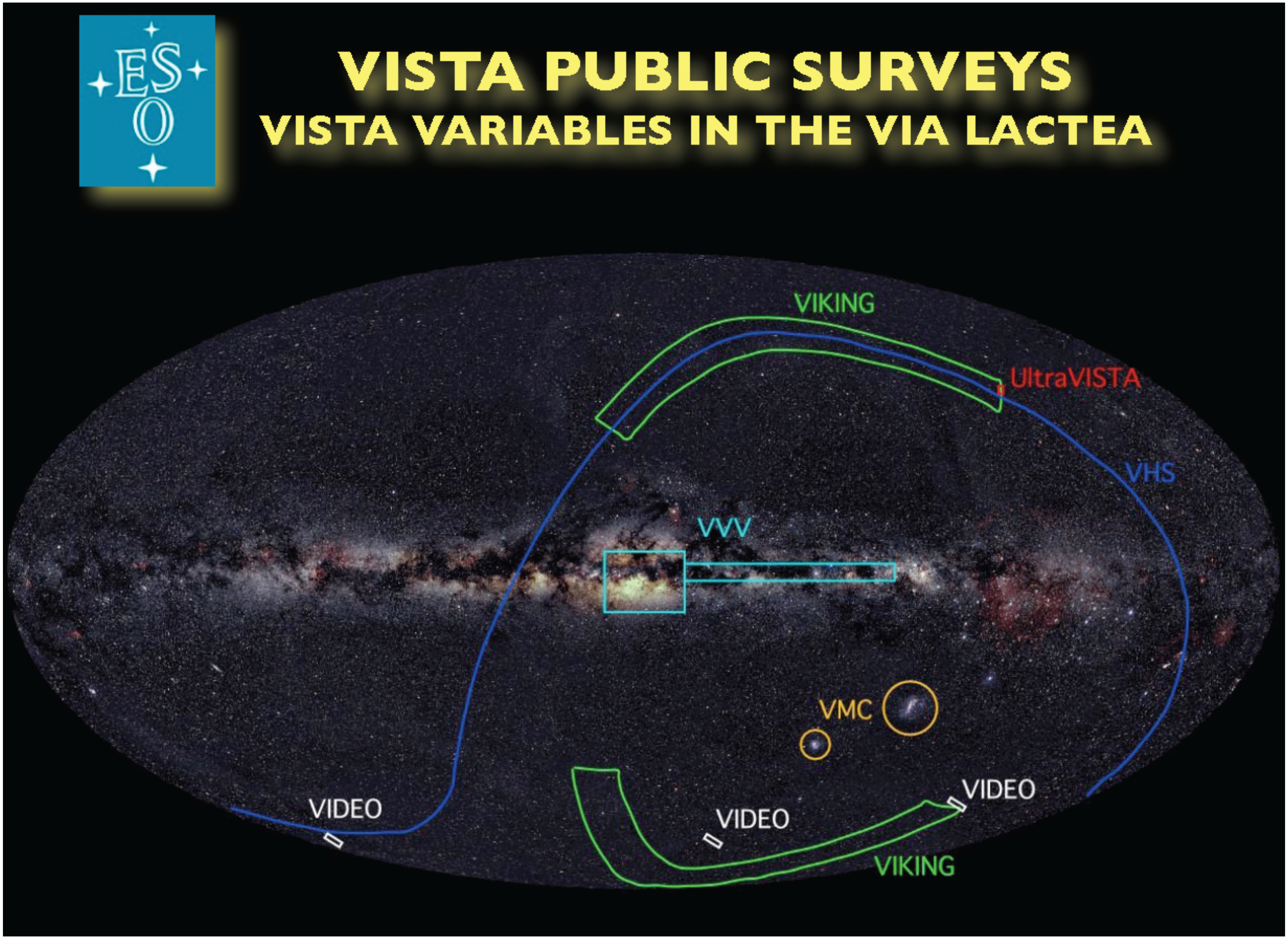
Outline

- VVV high proper motion search and the bright star (Ks<13.5) PM catalogue
- Search for fainter ultra-cool and BDs
- VVV and parallax measurements
- Interesting individual (benchmarks) objects
- VVV astrometry of clusters and SFRs
- VVV astrometry and the Galaxy structure
- VVVX

Solar vicinity and NIR surveys. Motivation

- Complete census of stars within the solar neighbourhood
- Information: stellar mass function, stellar formation, galaxy kinematics, nearby young moving groups
- Large optical surveys: difficulties because of the low luminosity and red colours
- 3D IR surveys: solution of the problem
- Low mass stars and especially M dwarfs: host exoplanets. Rv and AO monitoring
- New nearby brown dwarfs and benchmark objects

VISTA IR Surveys and the VVV

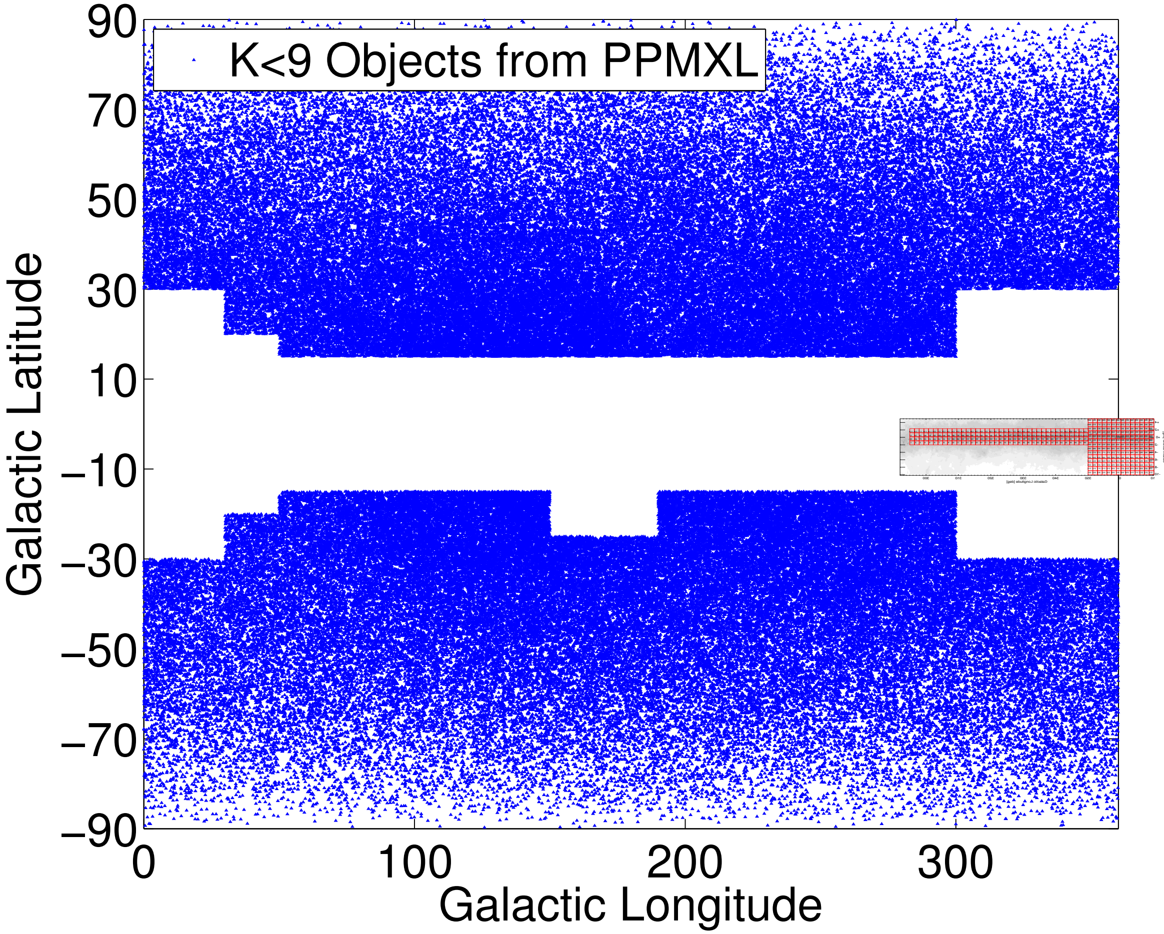


VVV top 10 science goals

- 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...)

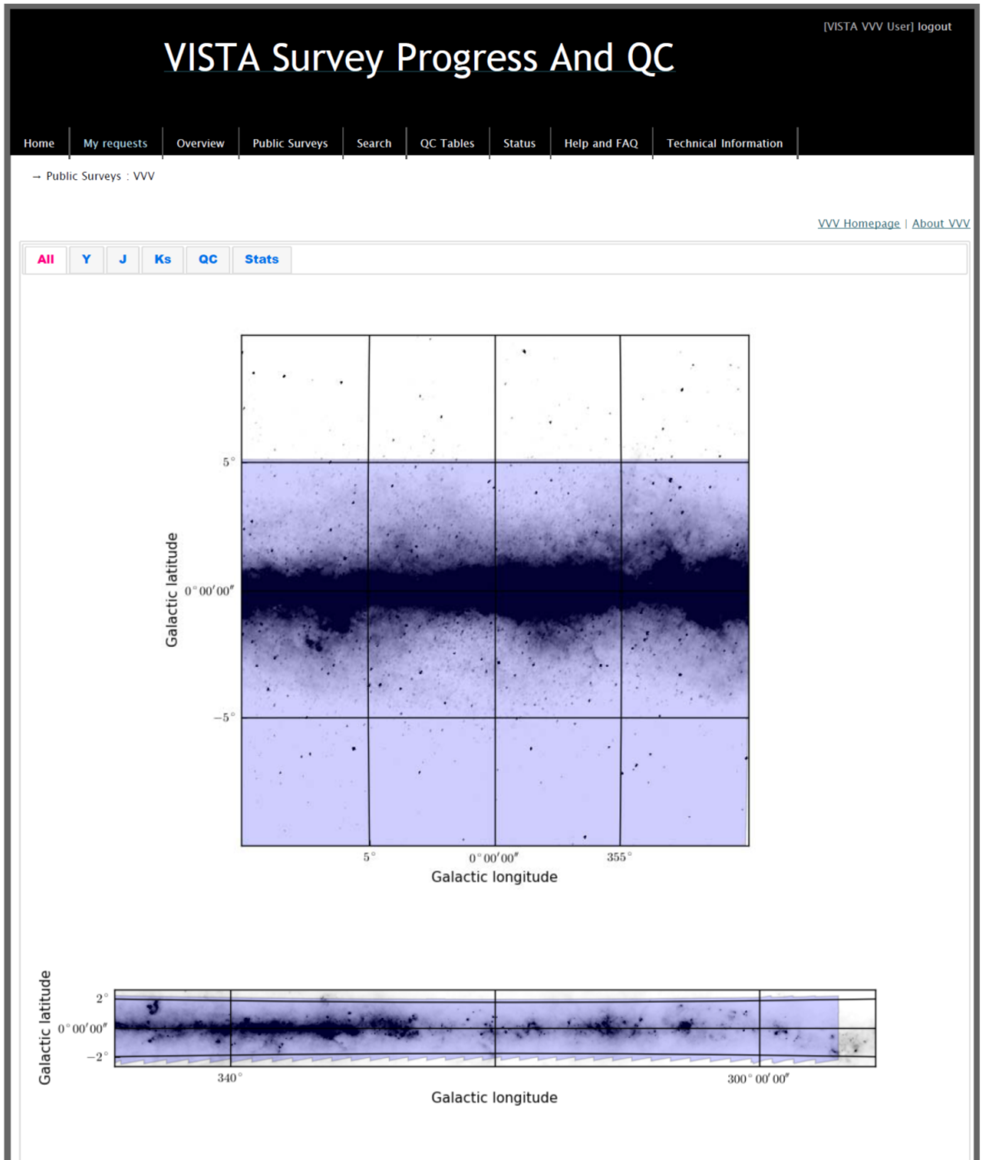
VVV and the zone of avoidance



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; good spatial resolution and limiting magnitudes**

VISTA data products (CASU & VSA)

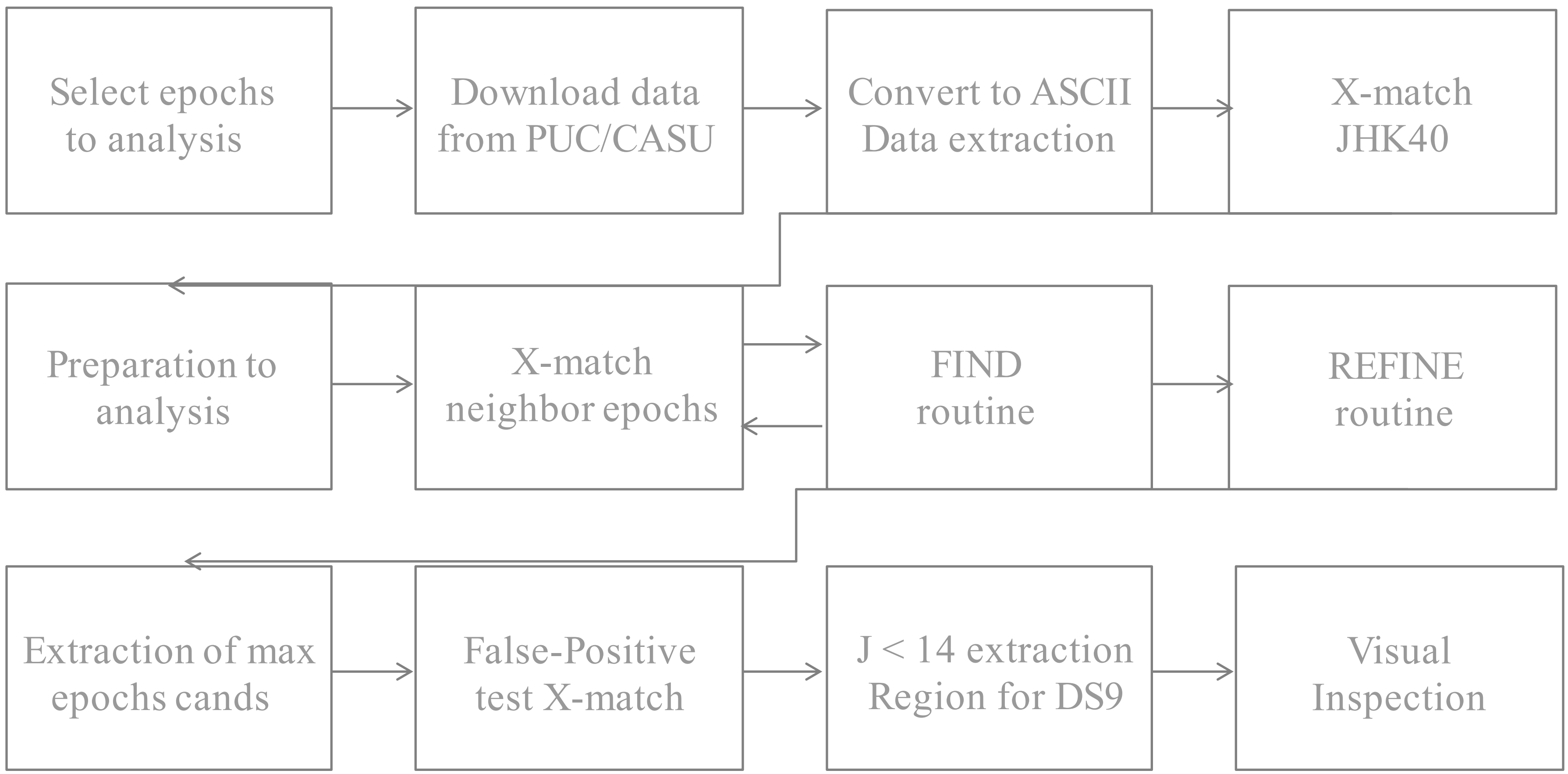


VISTA SCIENCE ARCHIVE

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

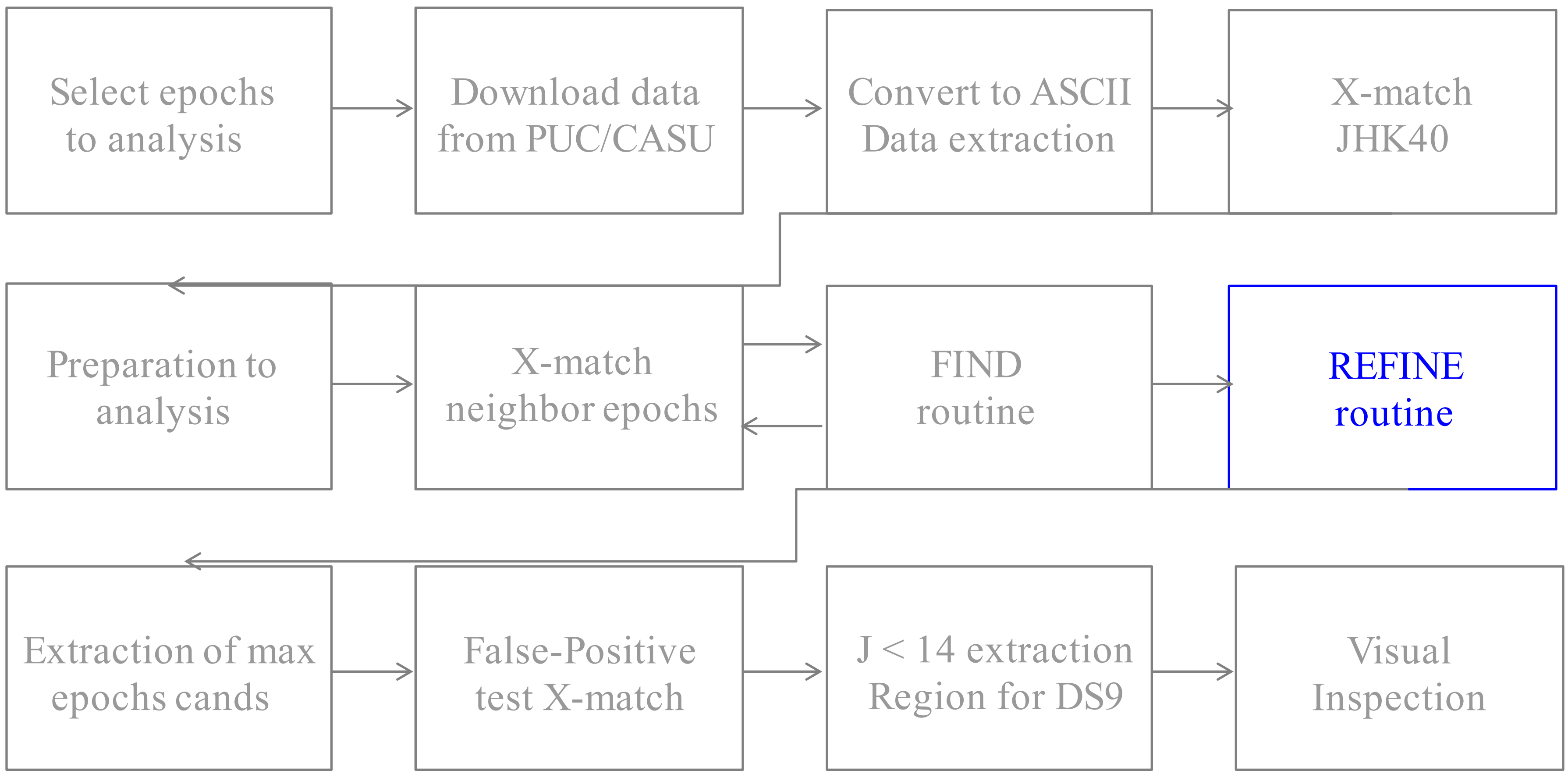
http:/horus.roe.ac.uk/vsa/index.html

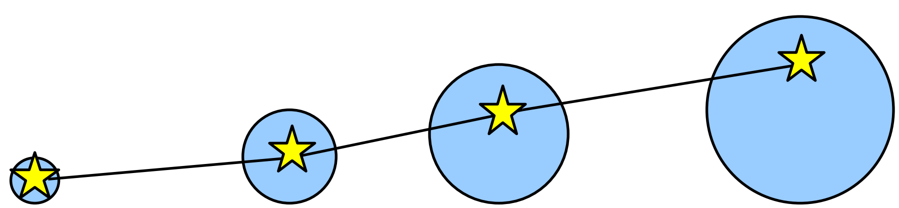
Detection method (VVVPM)



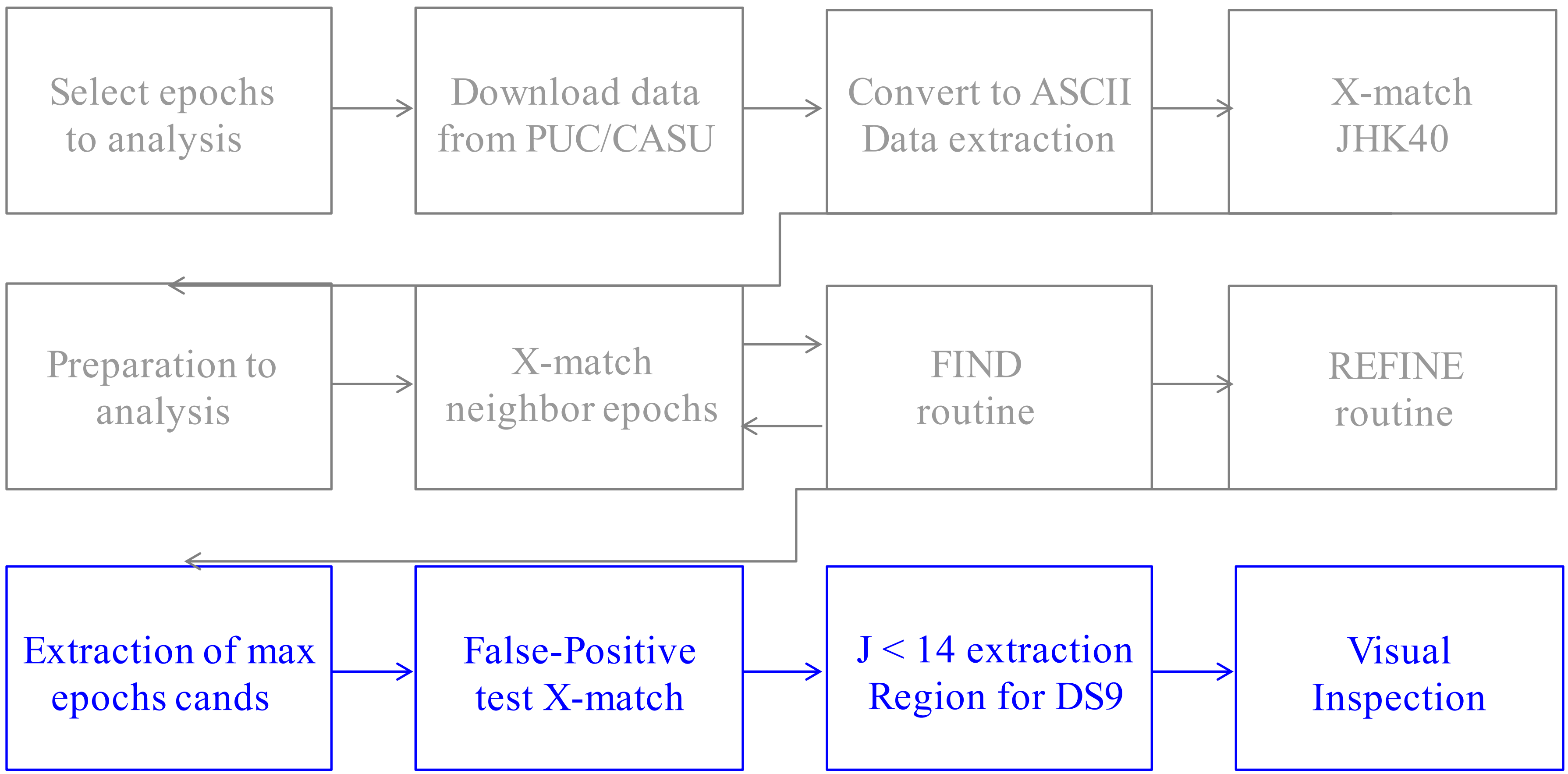
- Method developed by Stuart Folkes (only VVV for find HPM stars)
- Tools: STILTS, shell scripts, IDL routine, CASU FORTRAN procedure
- Data: CASU catalogs for various epoch in Ks

Detection method (VVVPM)

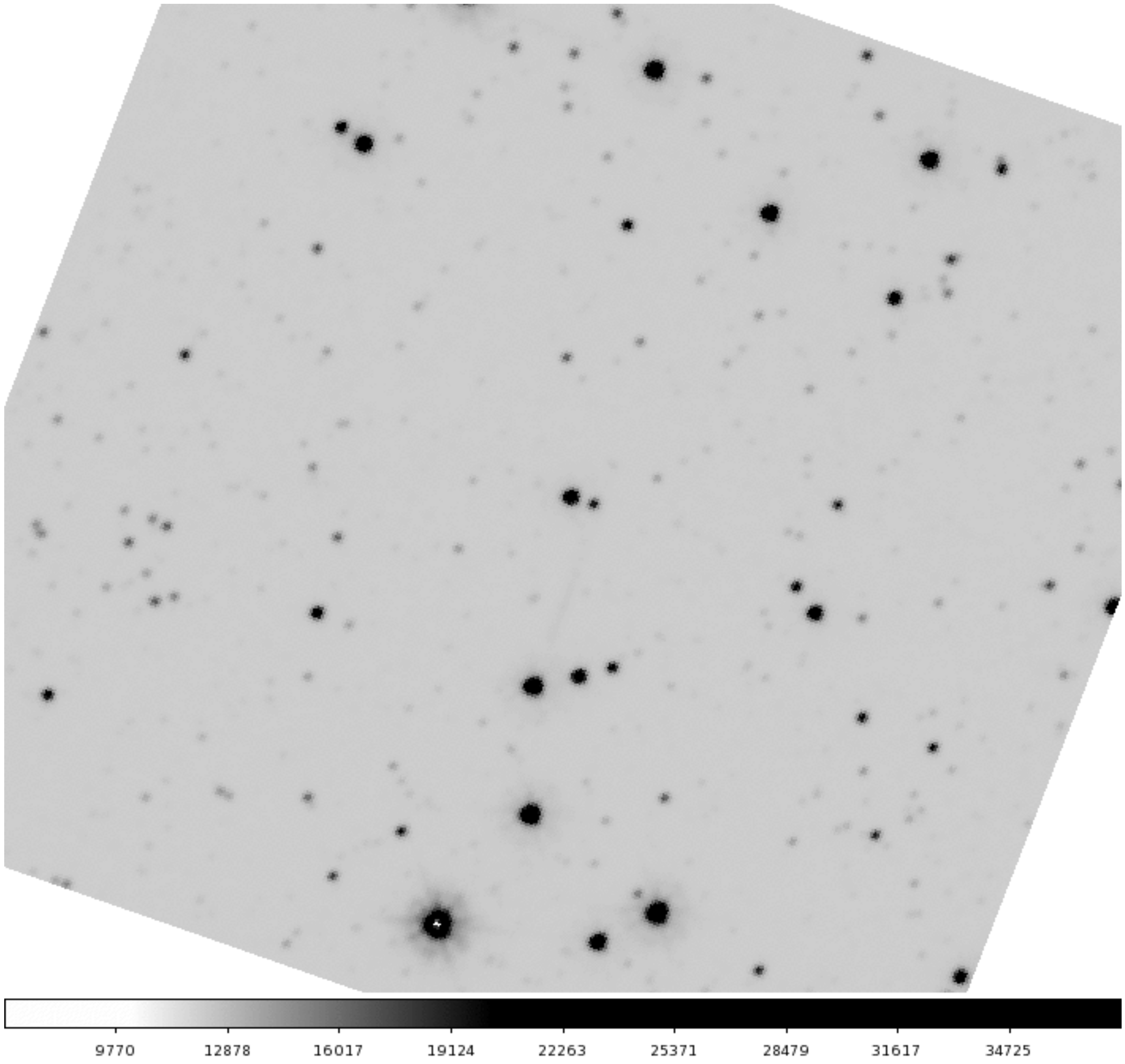




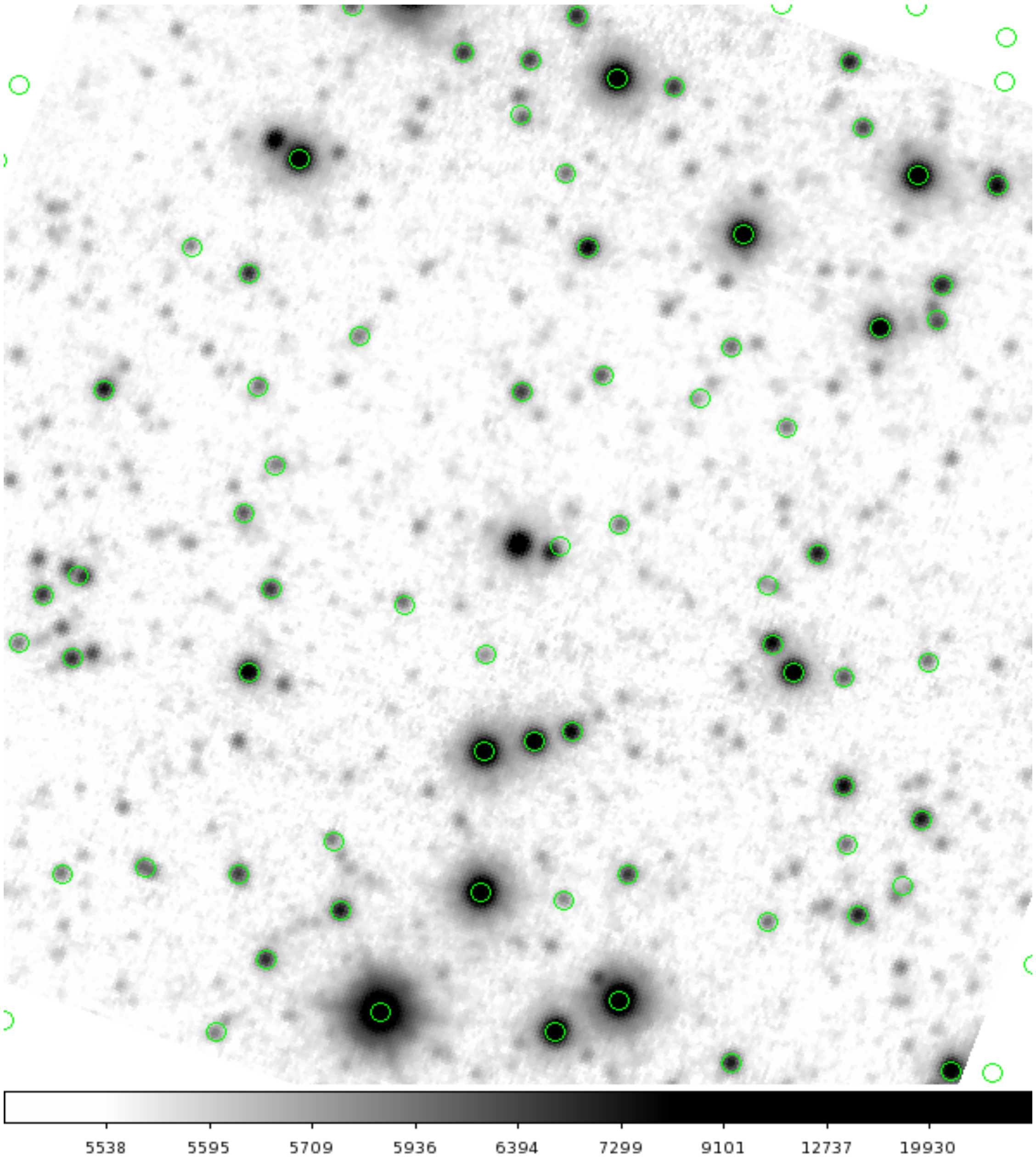
Detection method (VVVPM)



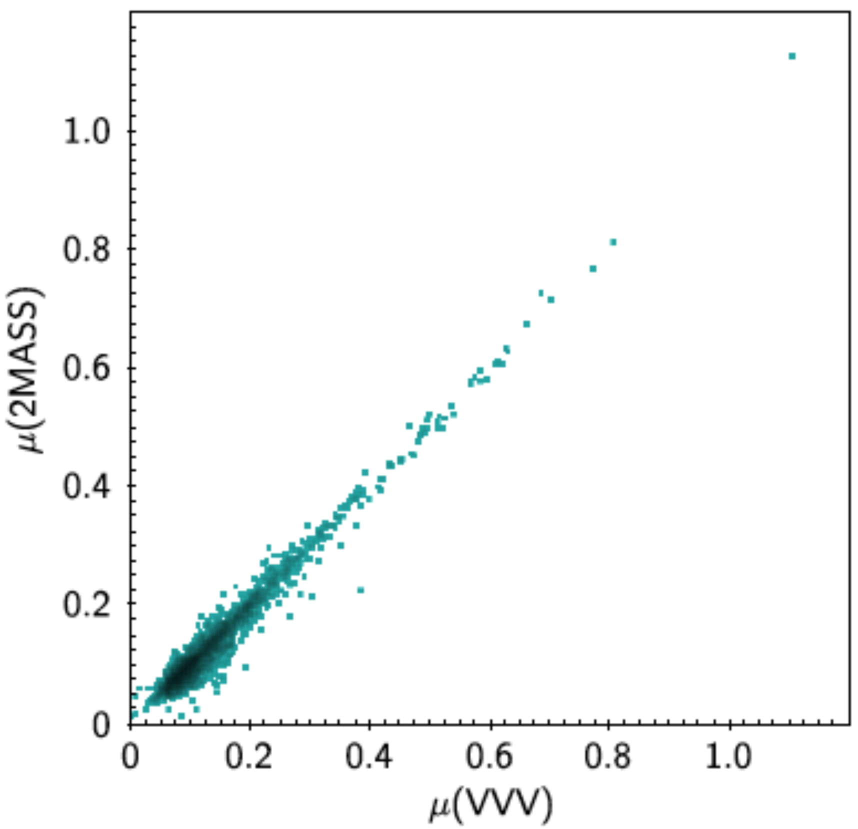
Example detection

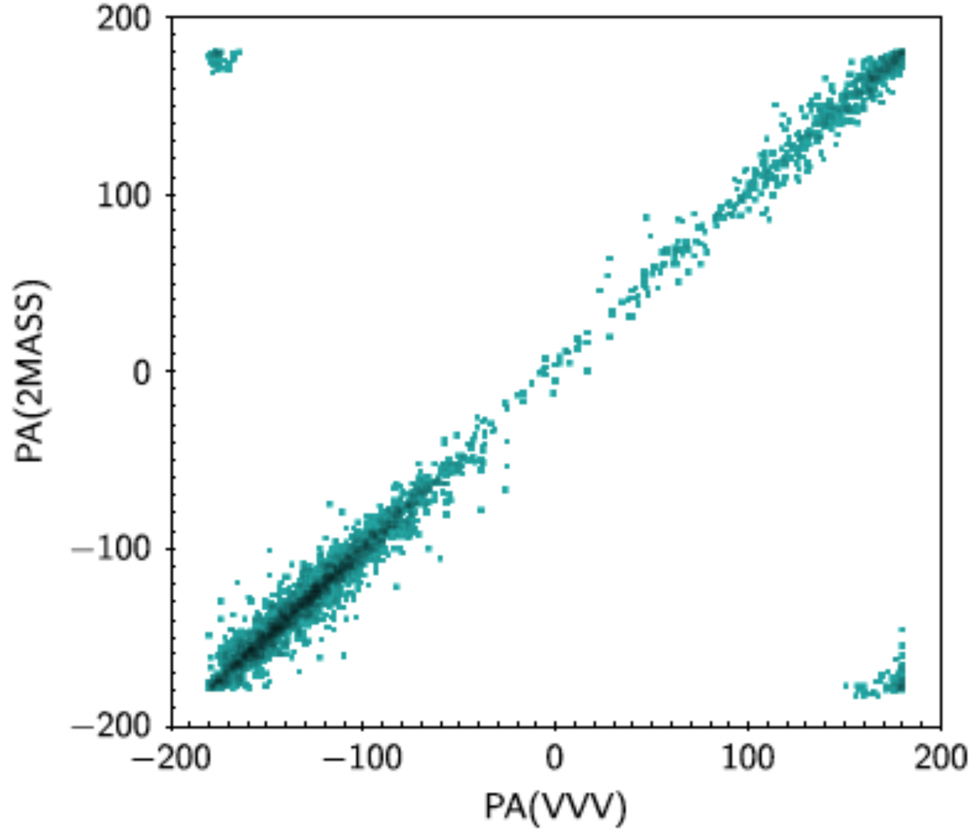


Example detection I



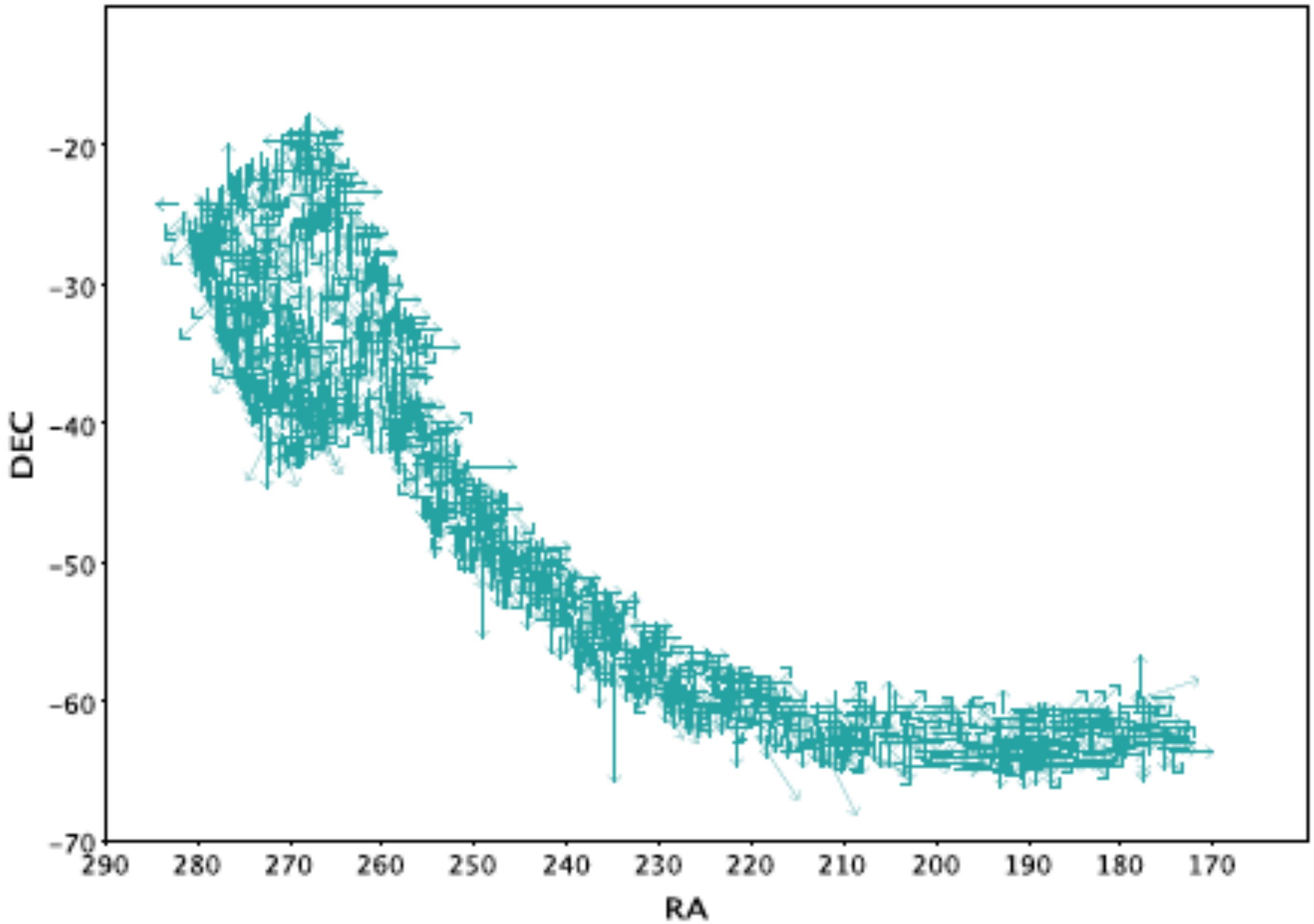
PM: (VVV2, VVV1) vs. (VVV1, 2MASS)





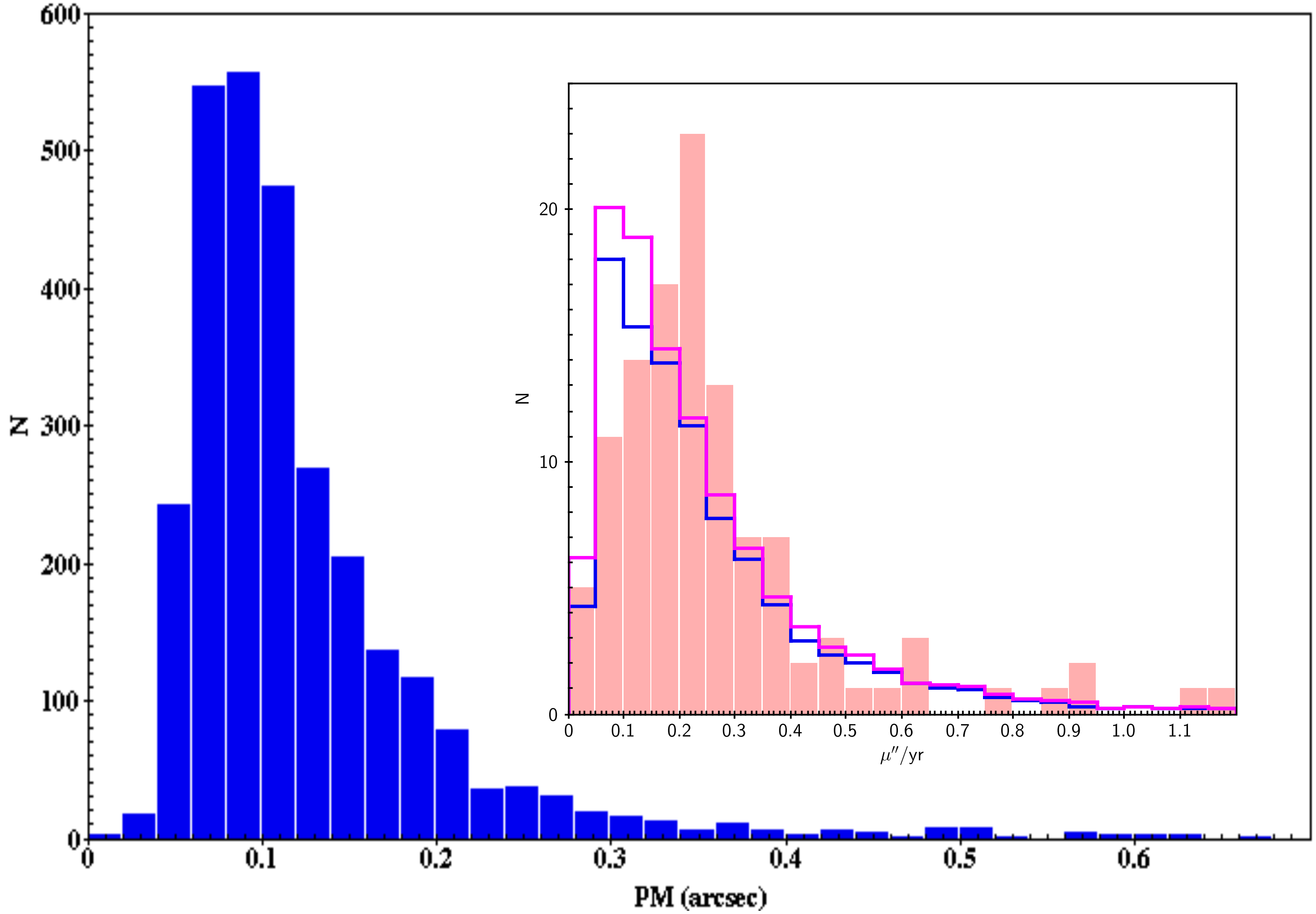
PM obtained in 2 ways: comparing 2 VVV epochs the first and the last available (~4 years) and the first VVV and 2 MASSS (> 10 year). Good coincidence. Small number of errors.

PM vector distribution



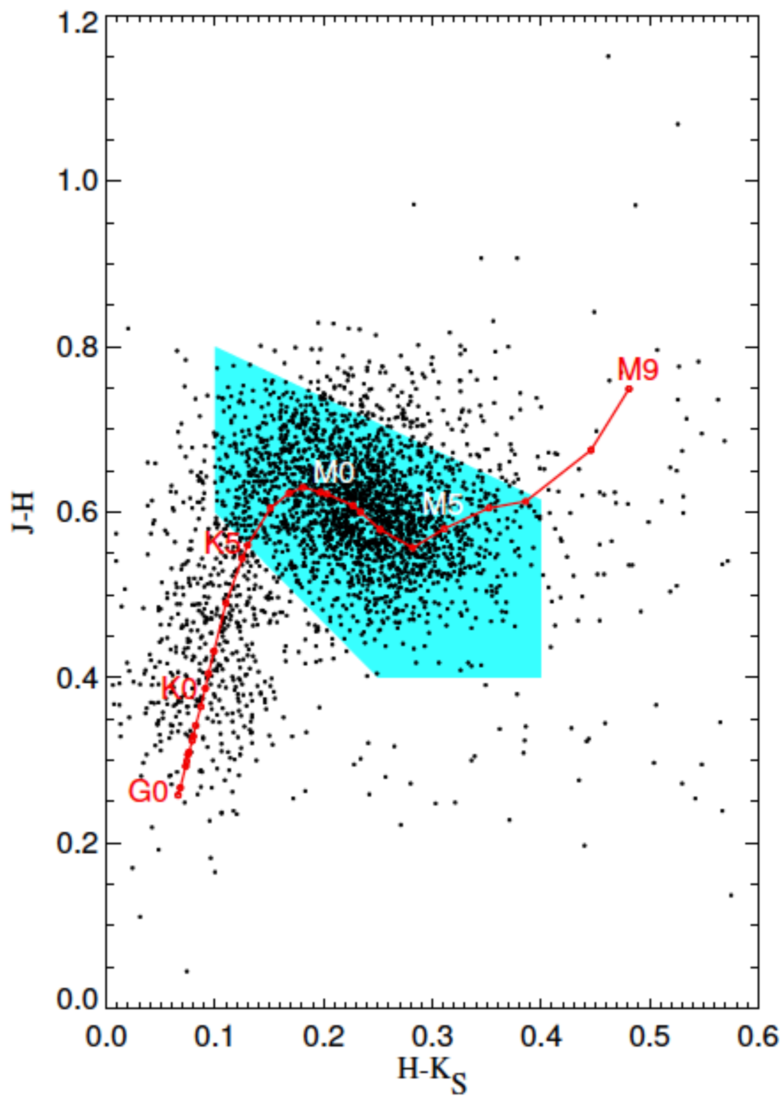
Some incompleteness. Especially around the galactic centre.
The majority of the stars: disk kinematics.

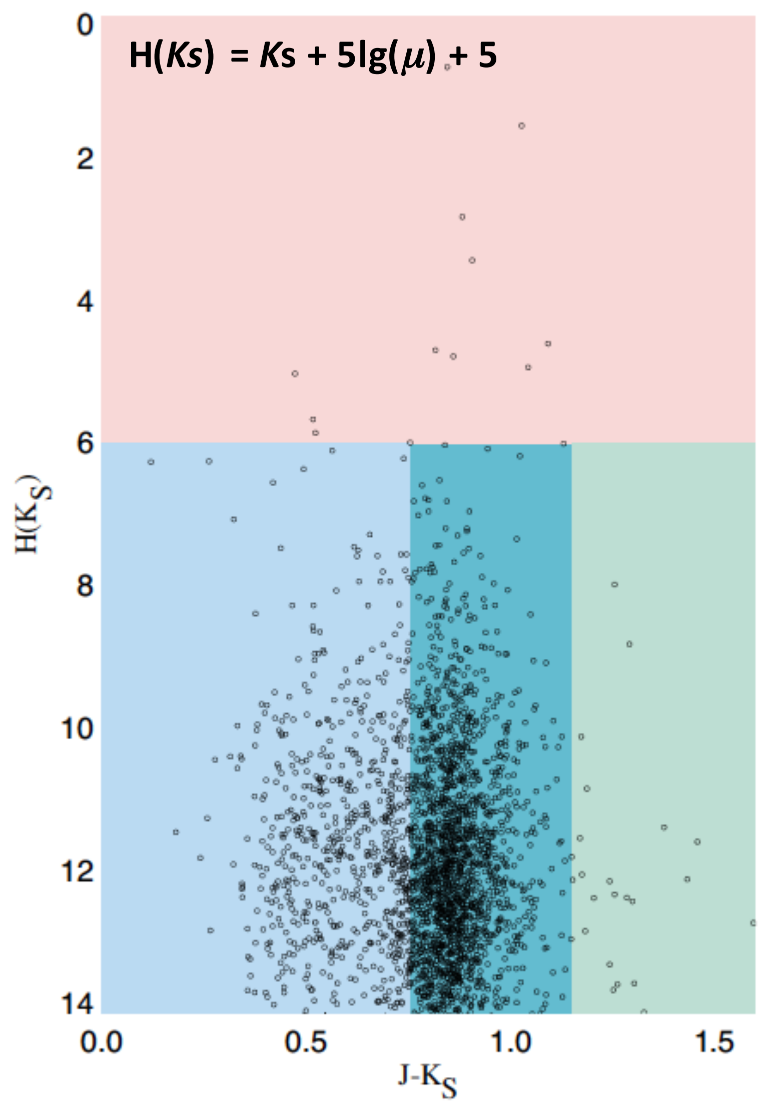
PM histogram



Significant incompleteness below 100 mas/year. Comparison with Firth et al. (2013) and Lepine & Gaidos (2011)

Sample: mostly early and mid M-dwarfs (RPD)





Summary of the VVV HPM (Ks<13.5) catalogue

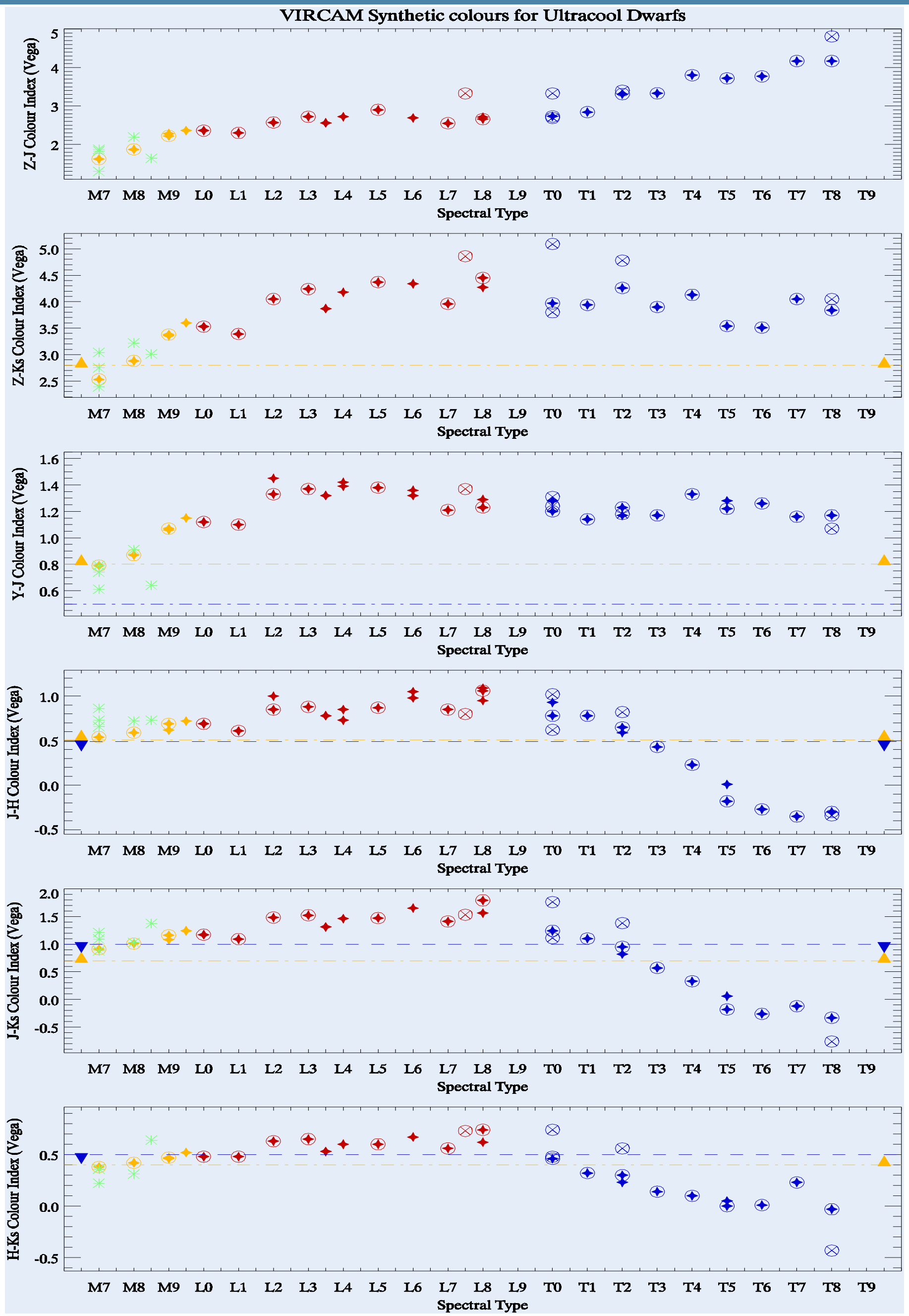
Kurtev et al. 2015, A&A, subm.

- **The catalogue contains data for 3003 PM stars:**

RA, DEC, EPOCH, Z,Y, J, H, K, PM(RA), PM(DEC), PM, PA, [phot_dist]

- **Lower limit ~ 30 mas/yr**
- **Incompleteness below 100 mas/yr and in general completeness comparable with other catalogues.**
- **96 stars with PM > 300 mas/yr (54 NEW)**
- **296 stars with PM > 200 mas/yr (210 NEW)**
- **57 common proper motion binaries and 1 triple system**
- **3 wide and 1 close dM+WD binaries**
- **1 nearby (very cool?) WD**
- **At least 4 new objects in the immediate solar vicinity of 20 pc**

UCD color cuts. Search for fainter PM. VVV T-dwarfs?



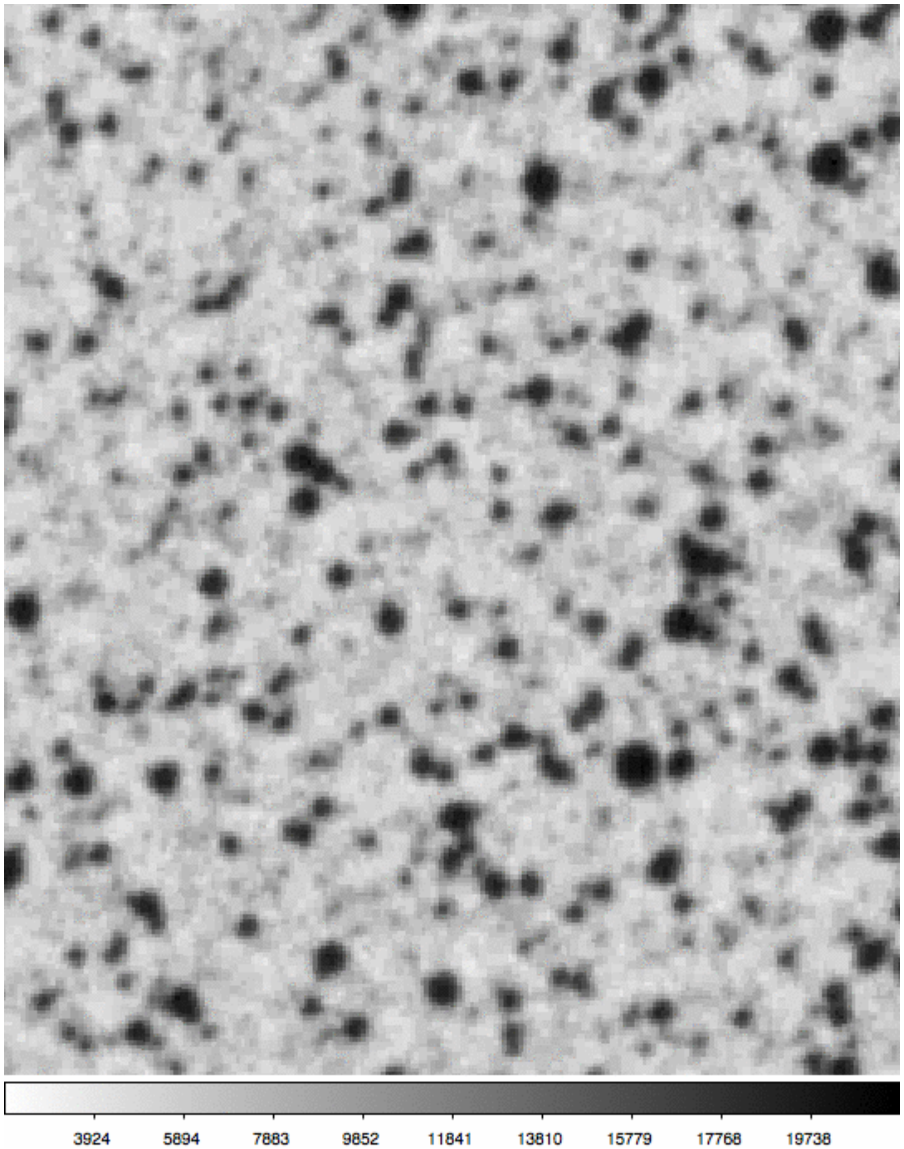
Synthetic colours of the ultra-cool dwarfs (UCD) in the VVV system based on the spectral library.

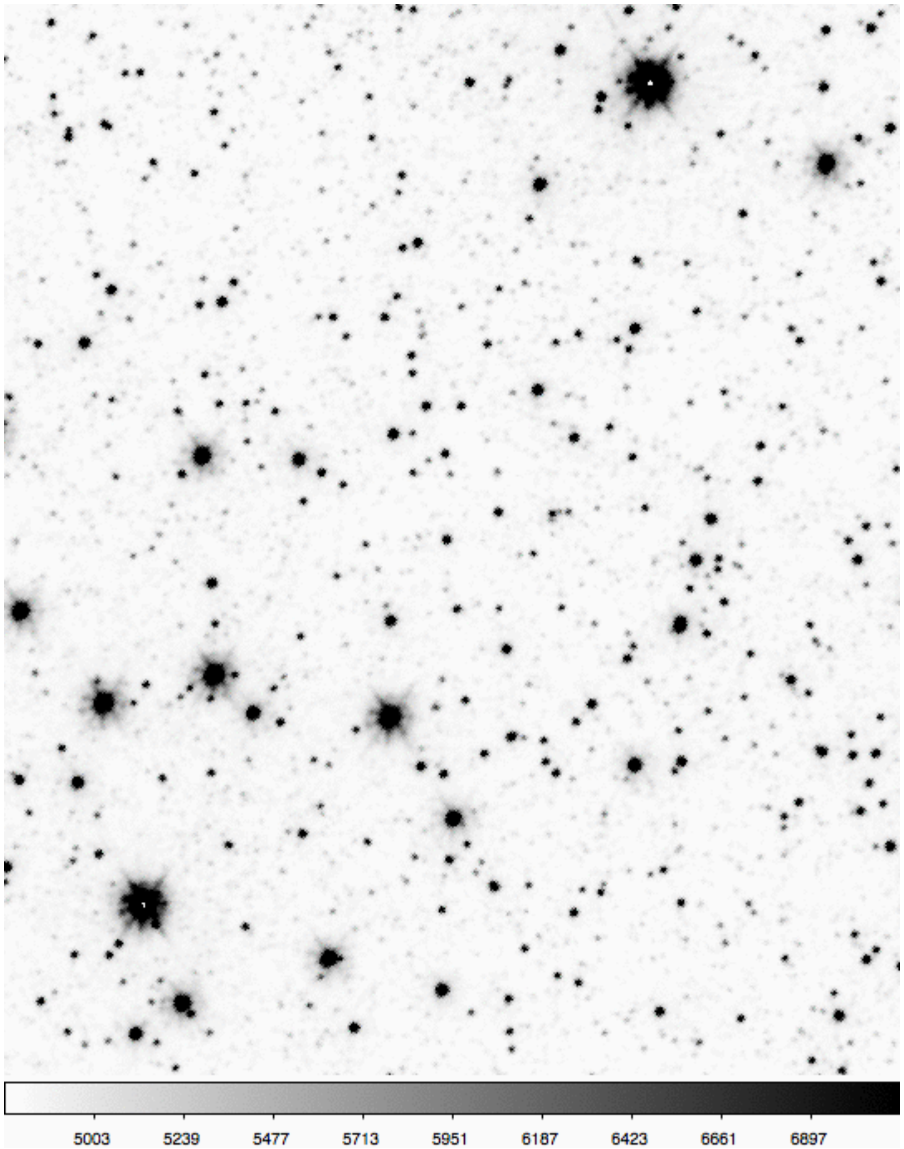
For stars fainter than 12 mag (not saturated) could apply PM + colour cuts

Search for UCD neighbours

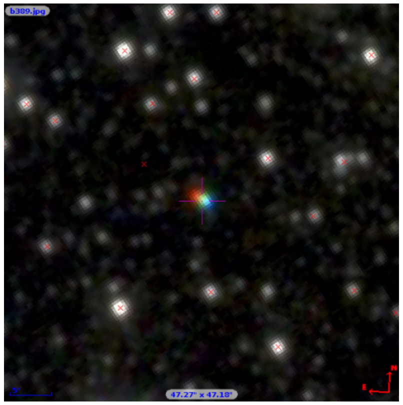
Smith, L. PhD thesis UH:
50 very late M and L dwarf candidates

First VVV BD (Beamin et al. 2014)

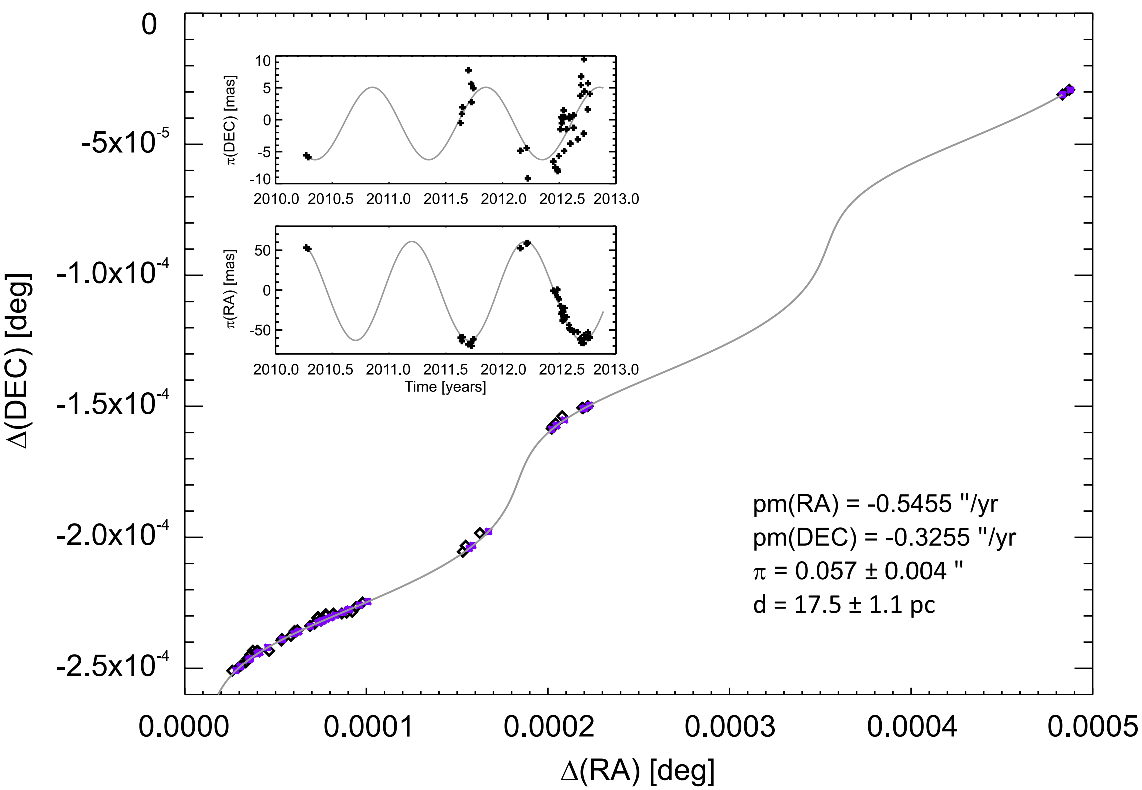


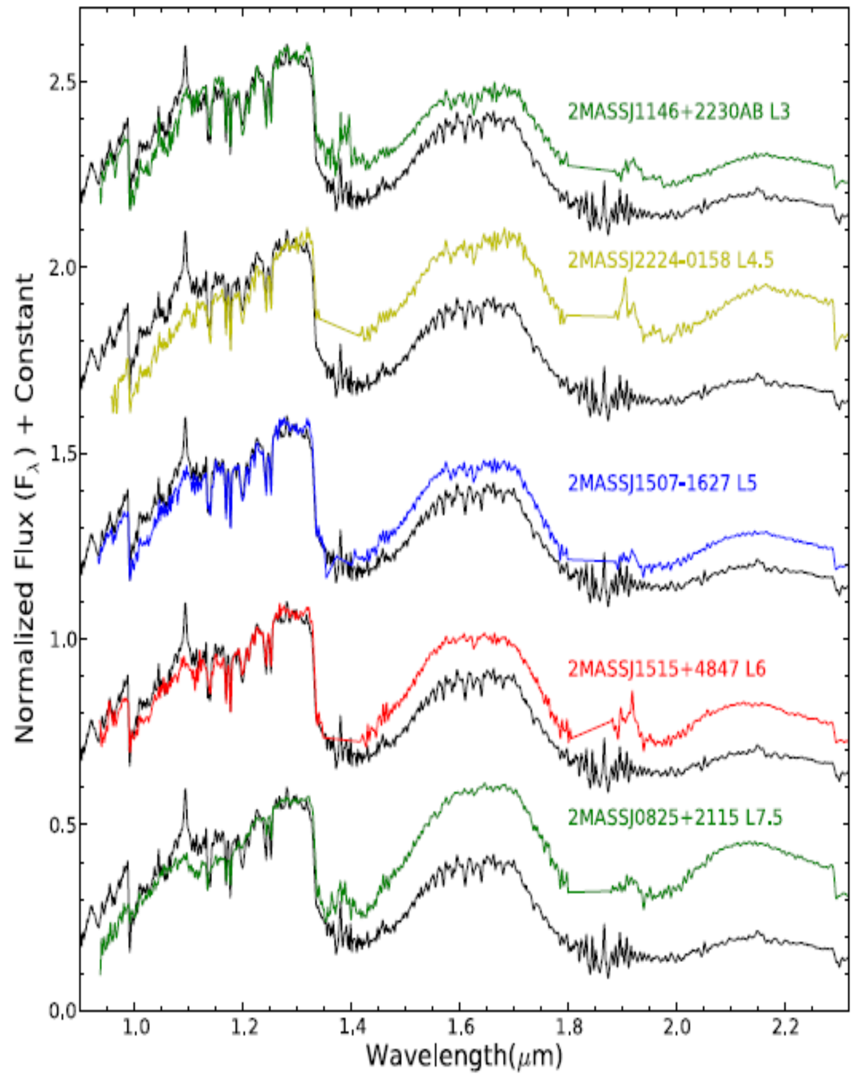


VVV parallaxes VVV-BD1



Unusually blue L5 dwarf: presence of thin and/or large-grained condensate clouds as compared to normal field L dwarfs





VVV parallaxes VVV-BD1

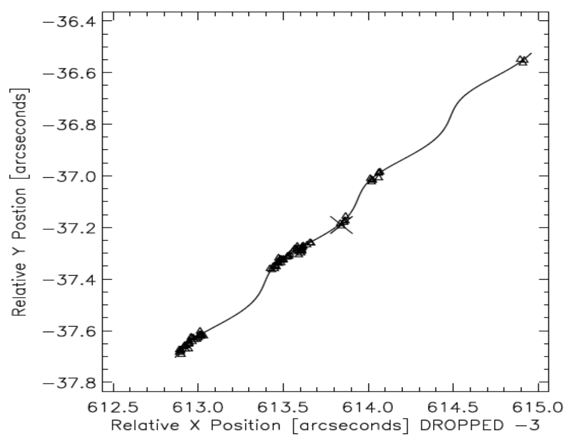
1726s27

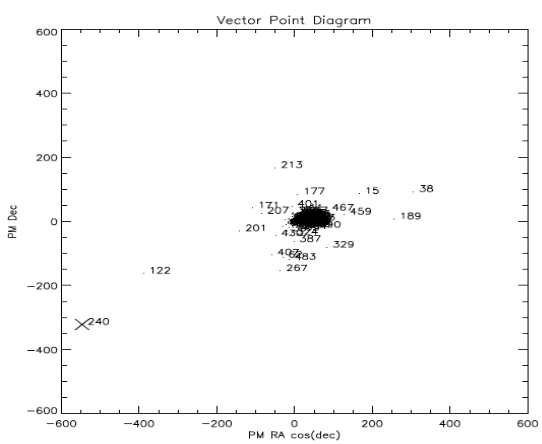
α, δ (J2000)	17:26:40.1, -27:38:03.7
Absolute parallax	53.77 ± 1.50 mas
μ_α	-546.35 ± 1.10 mas/yr
μ_δ	-321.23 ± 1.10 mas/yr
Rel-Abs$_{cor}$, N$_{obs}$, N$_{ref}$	0.15mas, 95, 278
Base Epoch, duration	2012.2218, 3.52yrs
Date Range	20100408, 20131017

Details of solution type 4(rwf)

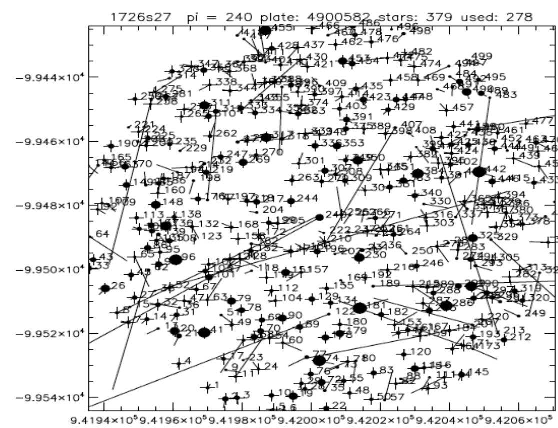
FRAME: Sky, BASE	9609452, 4900582
$N_{tot}, N_{filt}, N_{use}$	99, 98, 95
$N_{low}, N_{Efrm}, N_{exp}, N_{HA}, N_{Estr}$	0, 0, 0, 0, 3
Refs base, common 60%, used	498, 379, 278
Pi$_\xi$, Pi$_\eta$	53.706 1.5, 41.564 18
Parallax factor ξ:	-1.00237, 0.992665
Parallax factor η:	-0.0905559, 0.089439

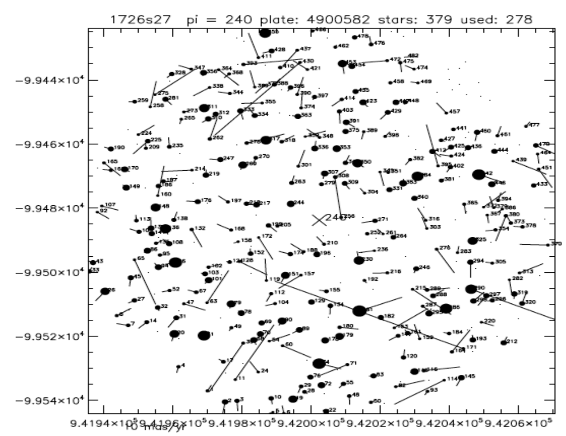
Path on sky & VPD



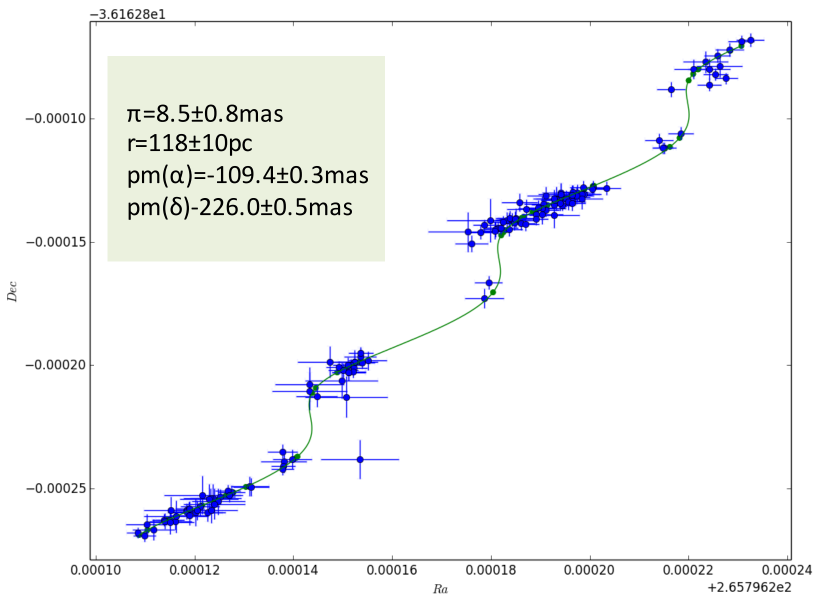


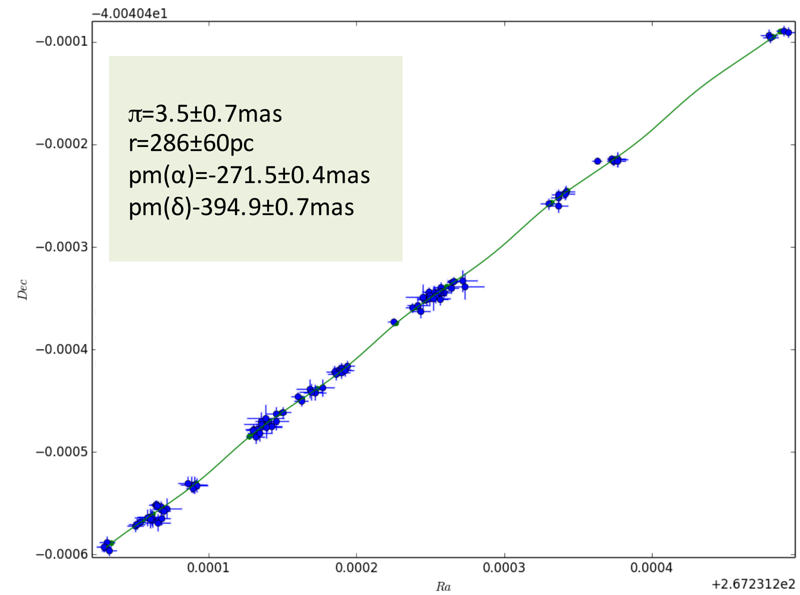
All objects and those used

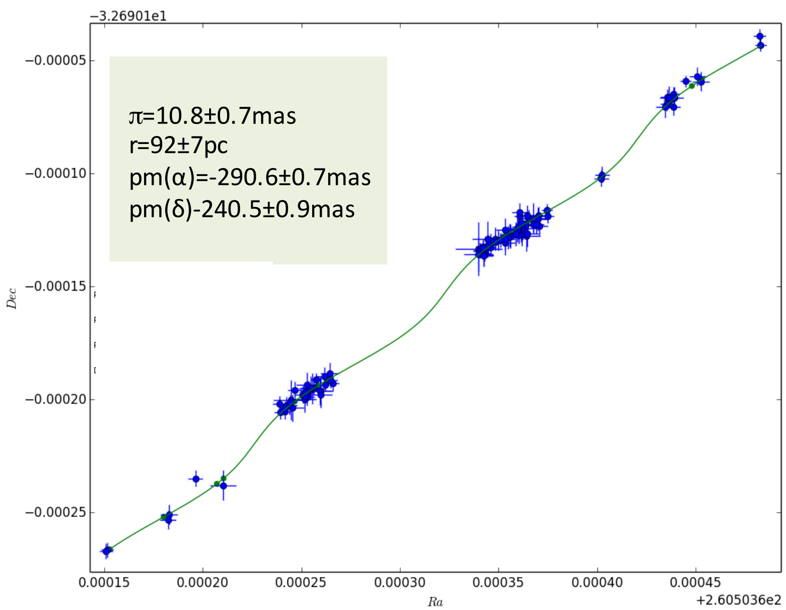


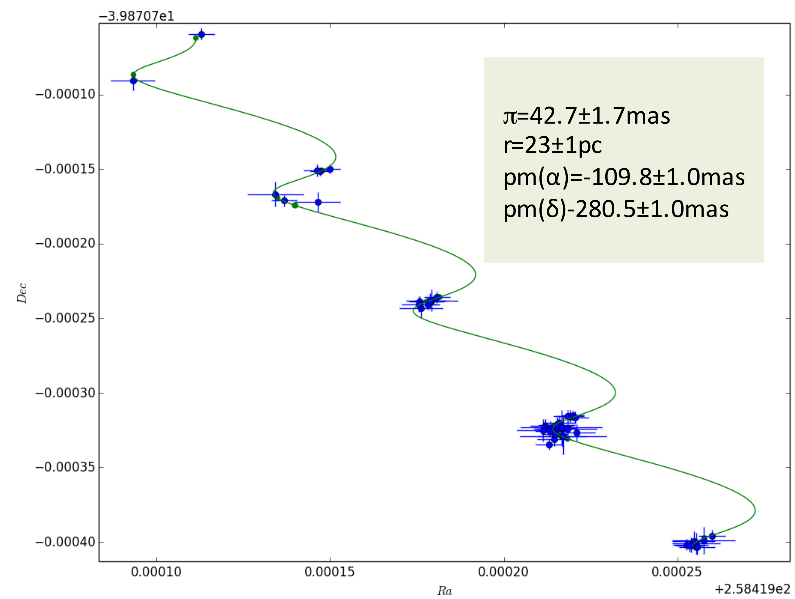


More VVV parallaxes MS thesis V. Villanueva (UV); PhD L. Smith (UH)

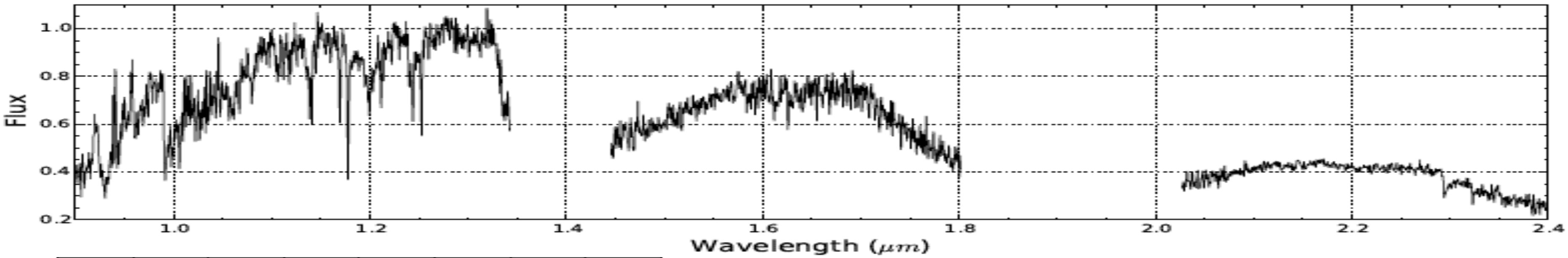


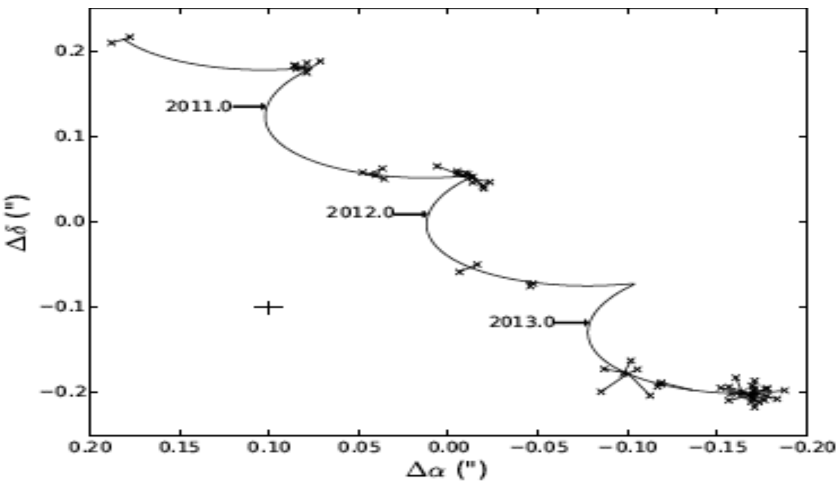


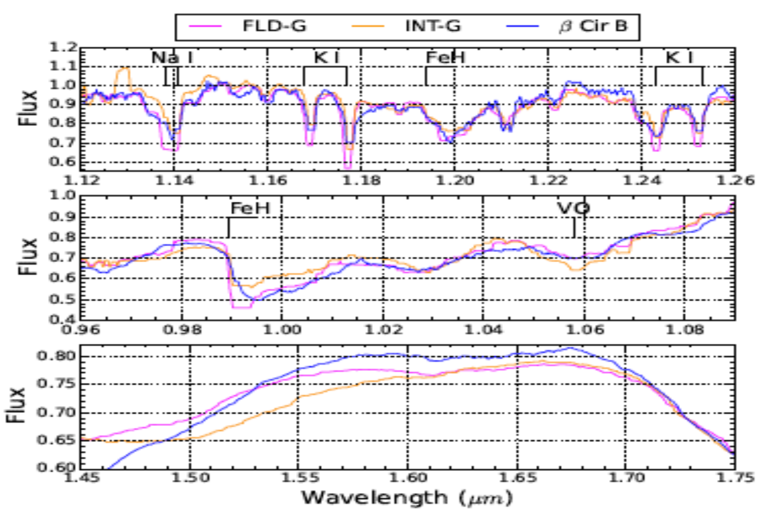




Benchmark objects: β Circinus B

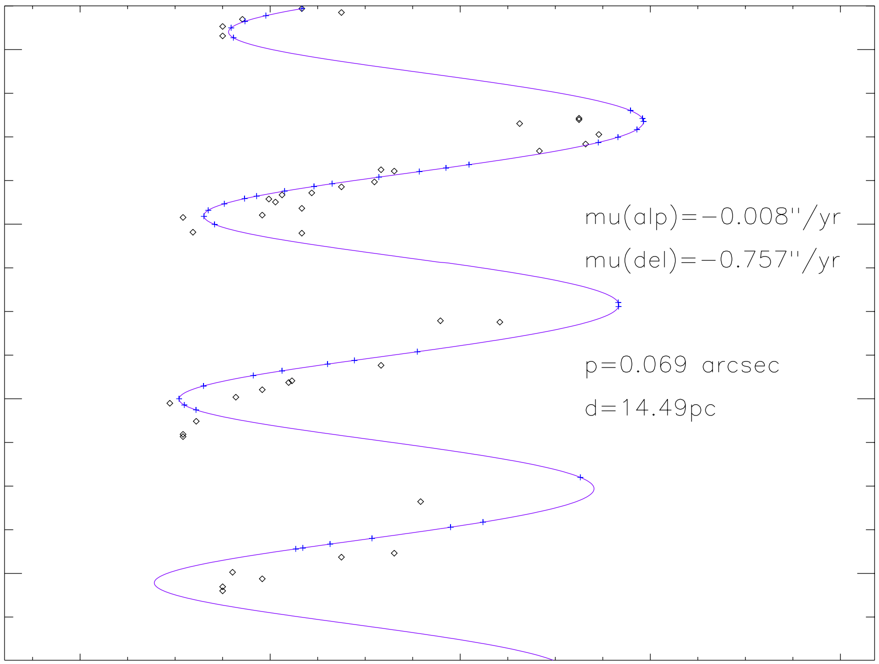


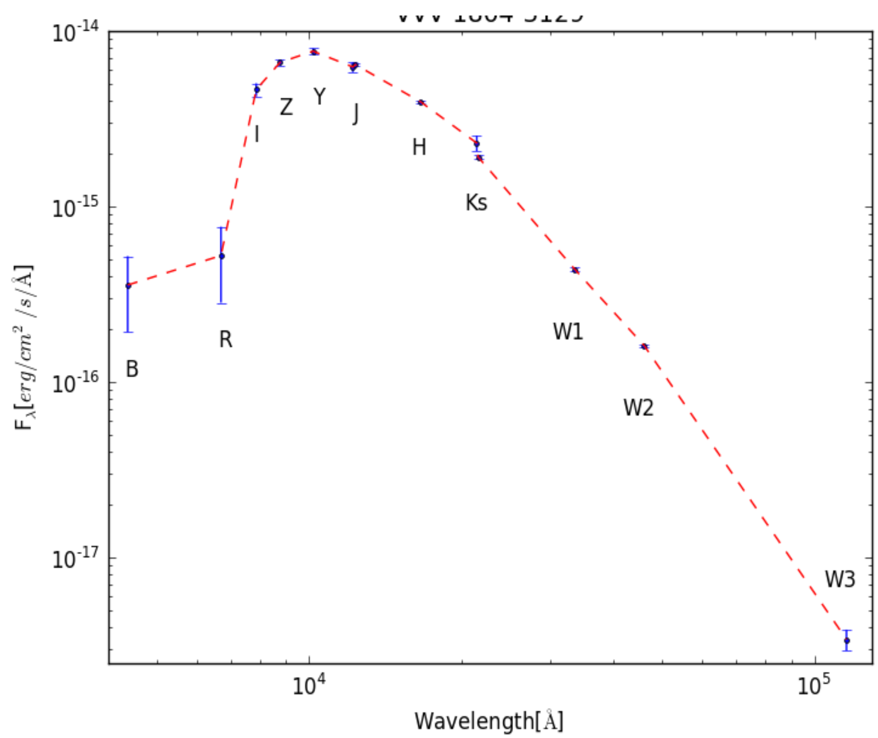




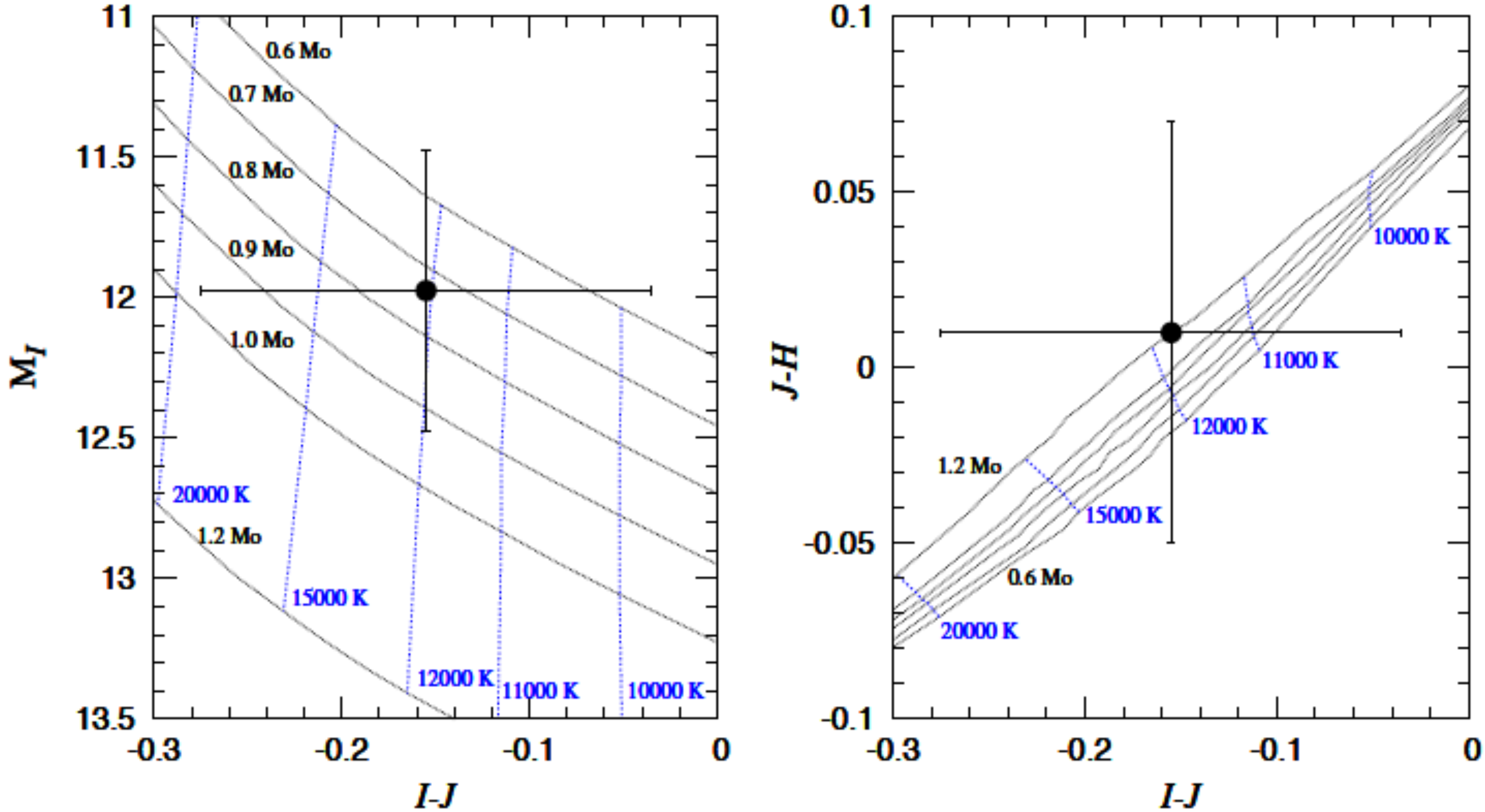
	β Cir A	β Cir B	
Right Ascension[a]	15h17m30.85s	15h17m21.60s	
Declination[a]	-58°48′04.34″	-58°51′30.0″	
Parallax	32.73 ± 0.19^b	33.6 ± 1.6	mas
$\mu_\alpha \cos\delta$	-97.4 ± 0.28^b	-96.7 ± 2.5^c	mas yr^{-1}
μ_δ	-134.15 ± 0.22^b	-133.1 ± 2.6^c	mas yr^{-1}
Radial Velocity	9.6 ± 2.0^d	9.76 ± 0.71	km s^{-1}
Spectral Type	A3V[e]	L1.0±0.5	
2MASS J	3.93 ± 0.25	14.54 ± 0.06	mag
2MASS H	3.81 ± 0.24	13.68 ± 0.04	mag
2MASS Ks	3.88 ± 0.18	13.21 ± 0.04	mag
VVV Z[1]		16.7 ± 0.1	mag
VVV Y[1]		15.6 ± 0.1	mag
VVV J		14.41 ± 0.02	mag
VVV H		13.70 ± 0.02	mag
VVV Ks		13.16 ± 0.02	mag
T_{eff}	8676 ± 33	2084 ± 150^f	K
log g	4.21^g	5.15 ± 0.04^h	dex
Age	370 to 500		Myr
Mass	$1.96^{+0.03}_{-0.01}$	0.056 ± 0.007^h	$M_\odot$
Angular Separation[a]	217.8		″
Projected Separation[a]	6656		au

Benchmark objects: WD+RD close binary





Benchmark objects: VVV J141420.55-602337.1 (M2.5) and VVV J141421.23-602326.1 (ZZCet) co-moving pair



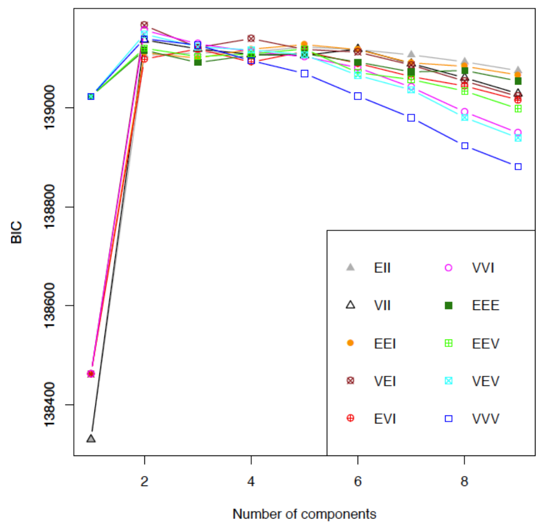
Distance 84pc. Temperature T_{eff}~12 000K; relatively high mass of ~1$M_{\odot}$; parameters place it in the the ZZ Ceti instability strip. Typically, the ZZ Ceti pulsators have log g=8.2, what correspond to mass 0.6 $M_{\odot}$ **VVV J141421.23-602326.1 could be unusually massive for this class of variables.**

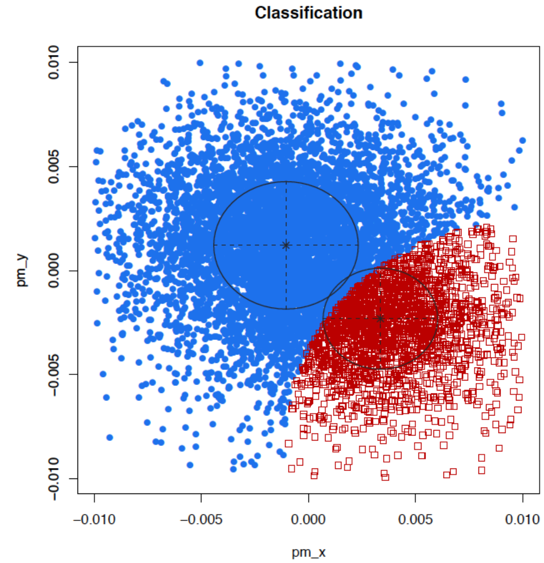
Near future: HPM with VVV

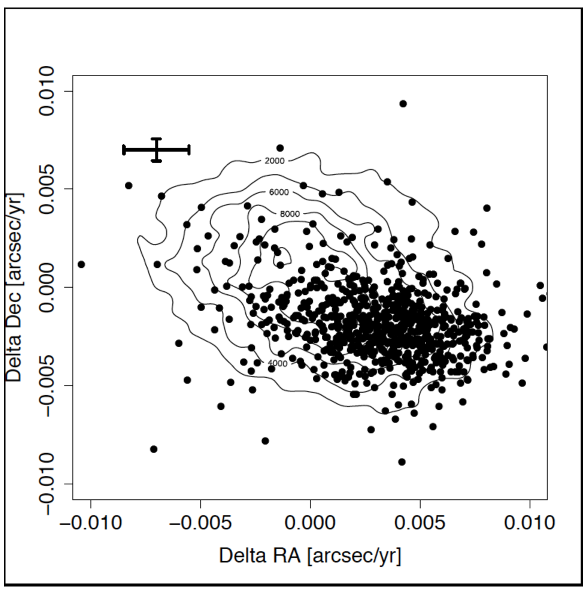
- ❑ To continue with the fainter sample (Ks > 13.5 mag)
- ❑ To apply colour cuts
- ❑ Cross identification with VPHAS+
    - Correct photometrical distances (*g*´, *r*´, *Z*, *Y*, *J*, *H*, *Ks*)
    - SEDs
    - Excess objects with IR excess (Hα)
- ❑ Cross correlation with WISE, GLIMPSE, etc.

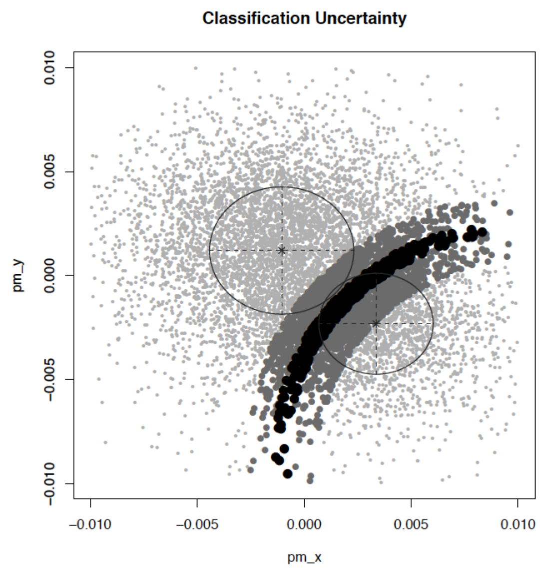
VVV PM farther away. Lagoon Nebula SFR.

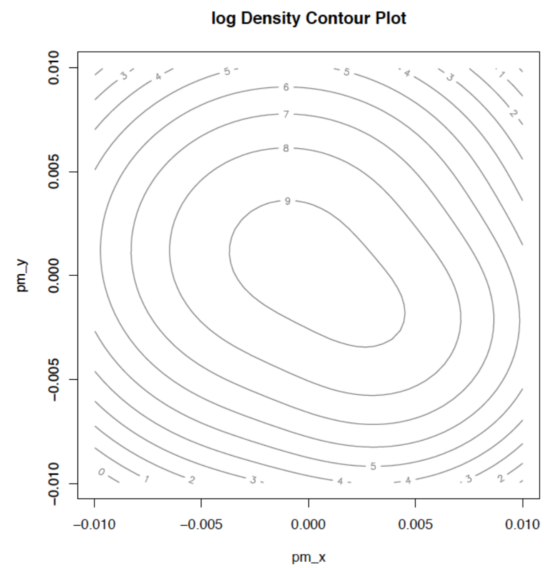
Kuhn et al. 2015



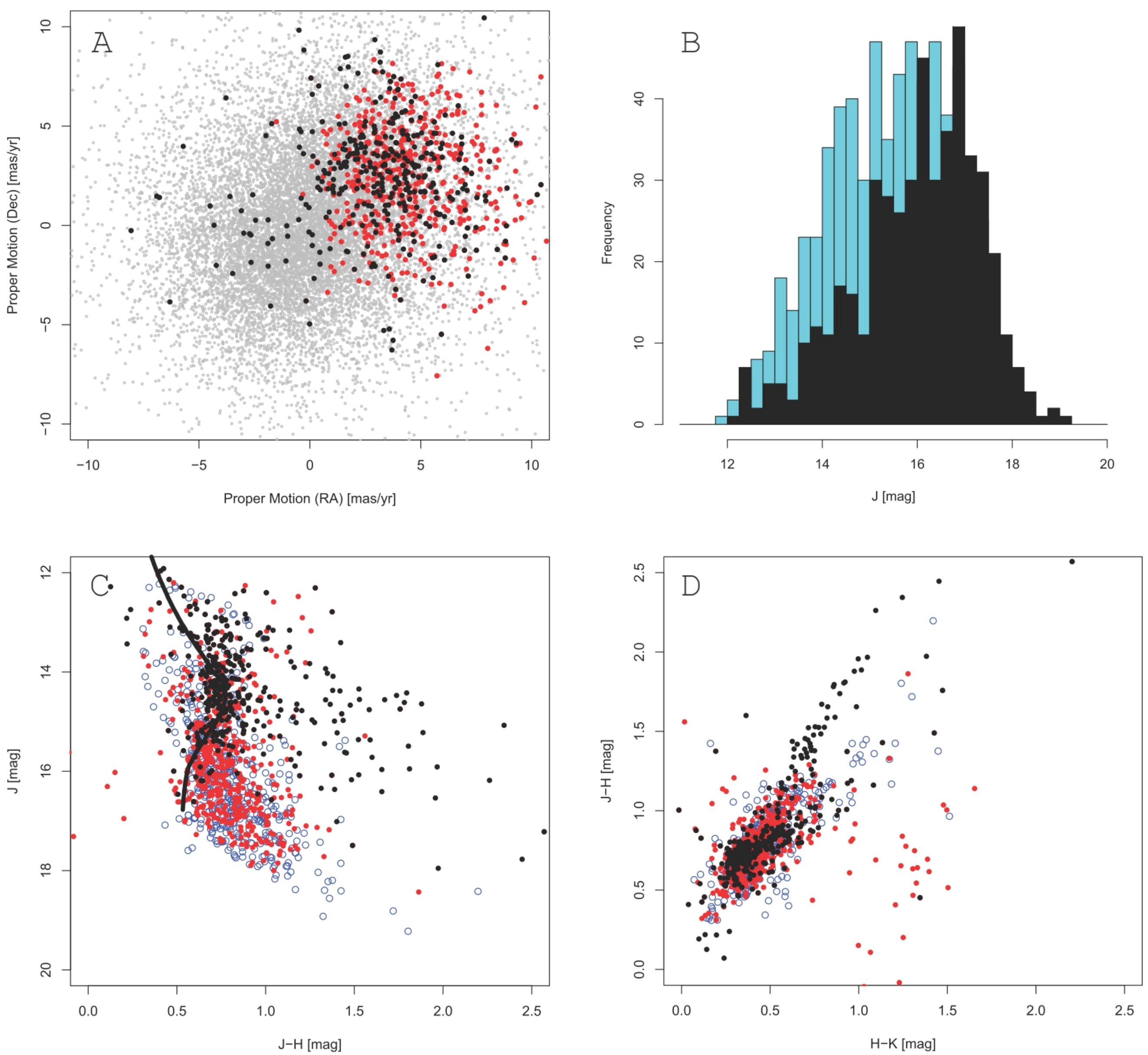








VVV PM farther away. Lagoon Nebula SFR.



A) **Gray symbols:** proper motions for the full catalog. **Red** and **black circles** show candidates and known members (from Chandra MYStIX)

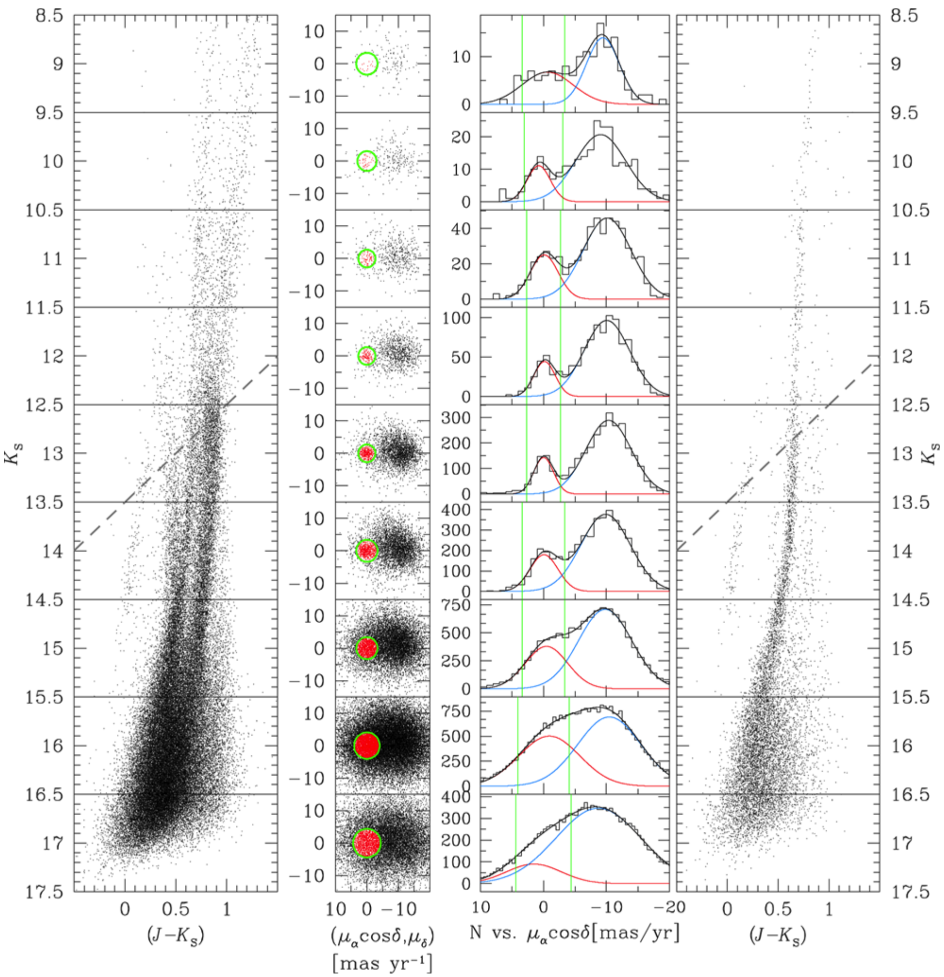
A) The histogram of J-band magnitudes: on-target sample **(cyan)**; off-target sample (black). The JLF of the cluster: subtracting one from the other. Selection based on colors, not magnitudes, so this JLF is not strongly biased by selection effects.

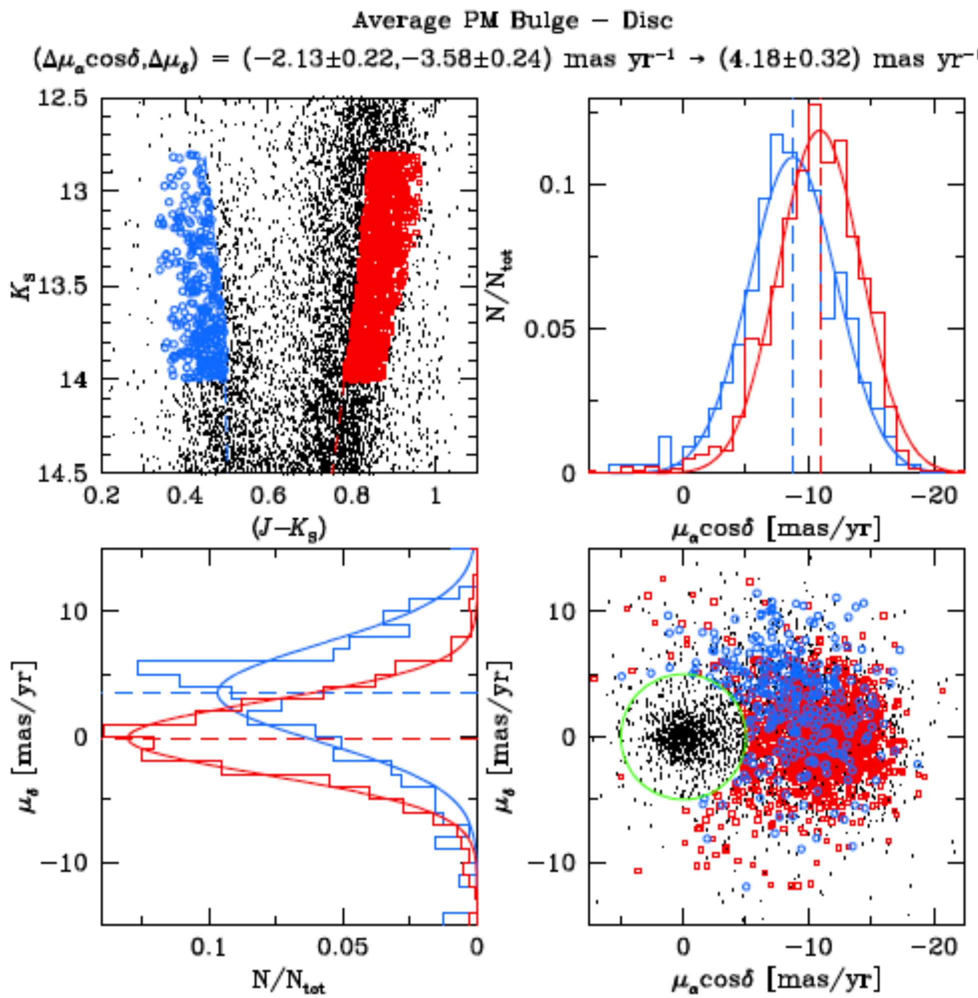
A) The CMD. False positives from the off-target sample – **blue circles**. Candidate members from the on-target sample – **red circles**. Known members are shown as black circles. The black curve is a 2 Myr isochr.

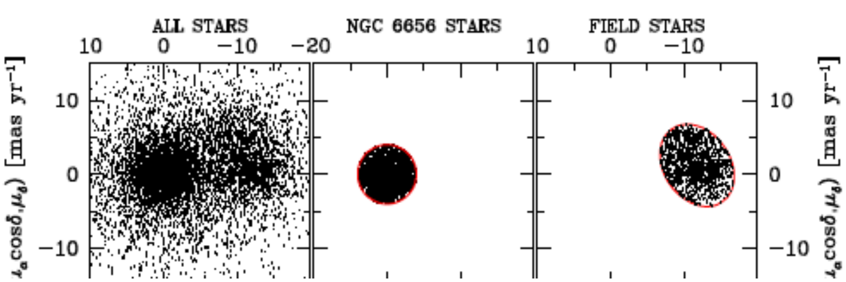
A) CCD. Point colours are the same as for C.

High precision astrometry with the VVV (NGC6656)

Libralato et al. 2014, MNRAS, 450, 1664







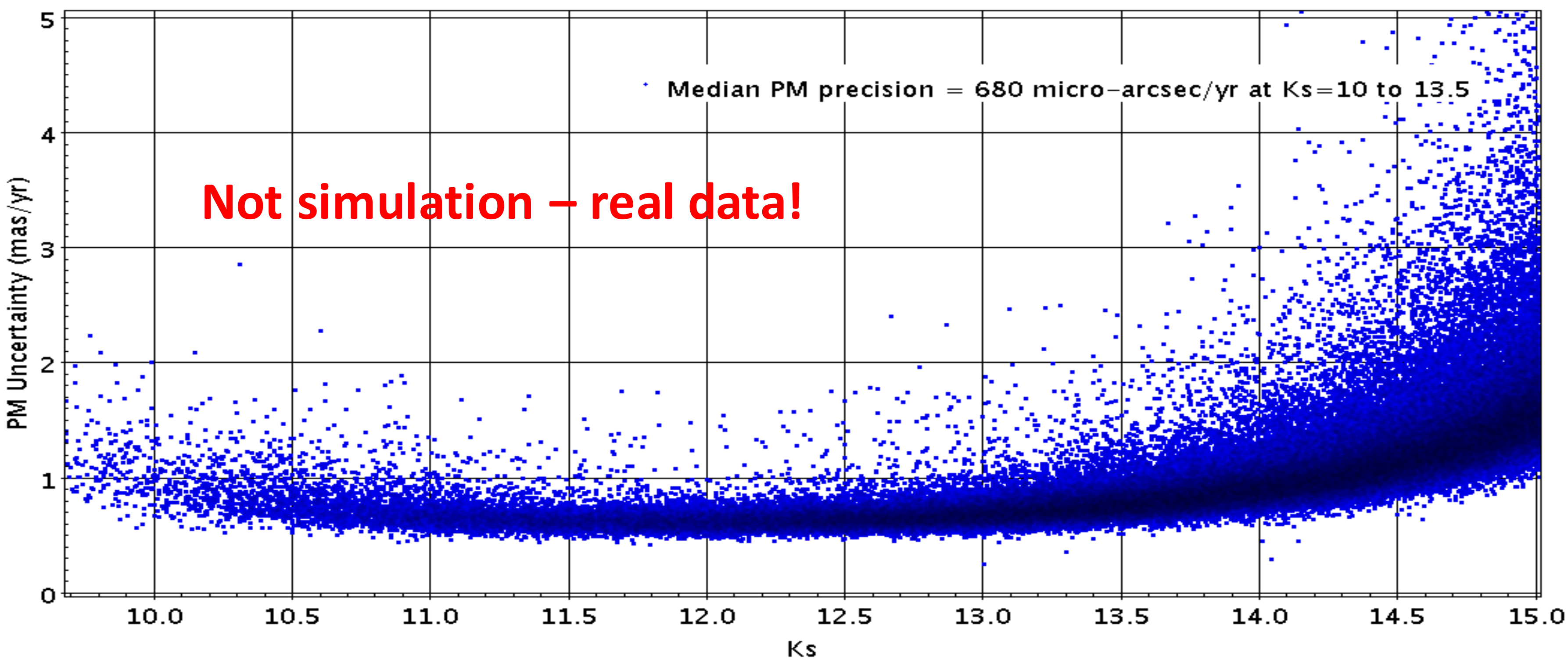
VVV+HAWK 7 years

3.79±0.98 mas yr^{-1} UCAC4
2.93±1.3 mas yr^{-1} PPMXL

High precision astrometry with the VVV

Leigh Smith & Phil Lucas (UH)

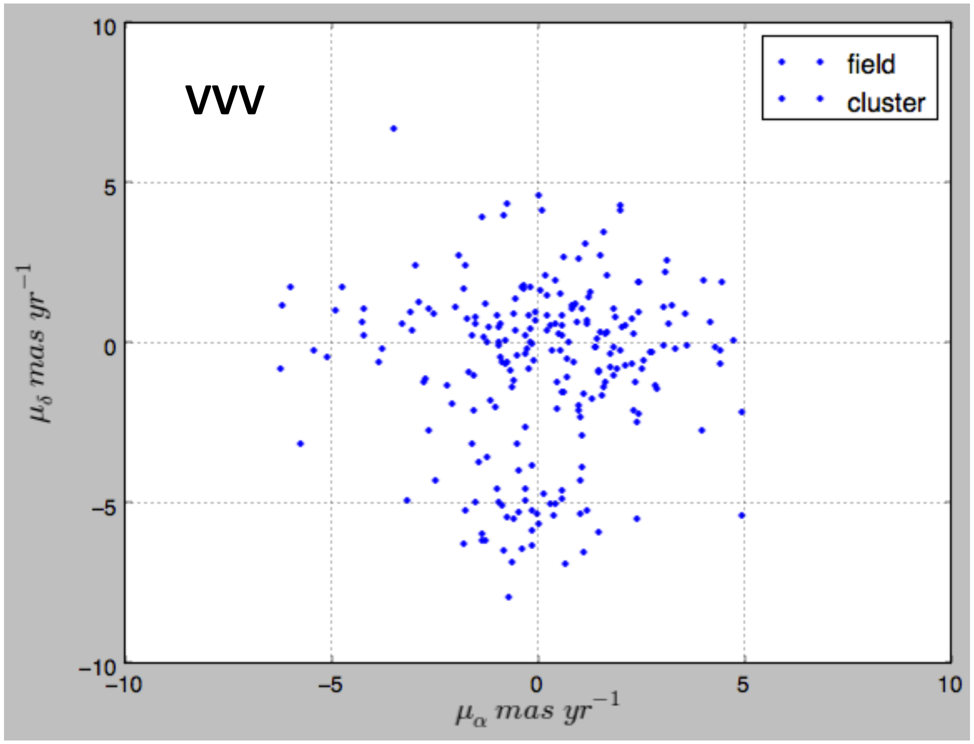
- VVV PM precision for all sources in tile d118, detected in 2 paw prints (48x2=96positions), down to K=15.
- With 9 year baseline VVV+VVVX should provide a proper motion precision of ~200 μas/yr: 1) the longer baseline; 2) benefit of more epochs

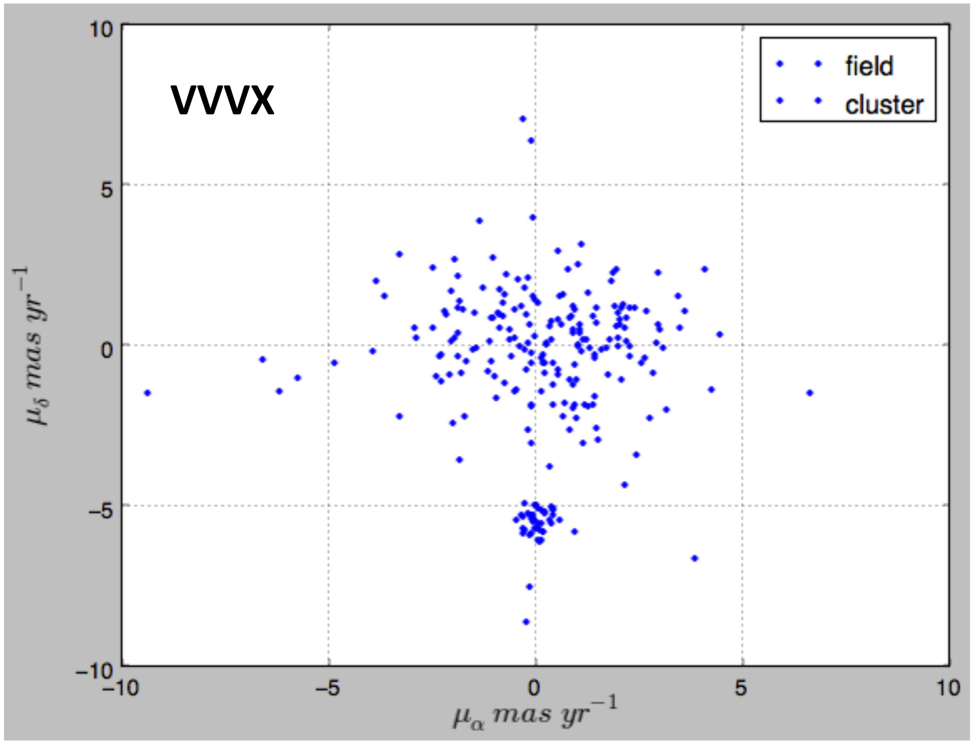


High precision astrometry with the VVV + VVVX

Simulations of a small cluster

Simulation of a proper motion of a small cluster with 40 cluster members in the environment of 200 field stars and 5.5 mas/yr proper motion with VVV and VVV+VVVX.





VVV - VVVX PM studies

- **VVV+VVVX will provide a proper motion precision of ~200 μas/yr at 10<Ks<13.5 (or Vtan=11 km/s at d=12 kpc) and ~400 μas/yr at Ks=15.**

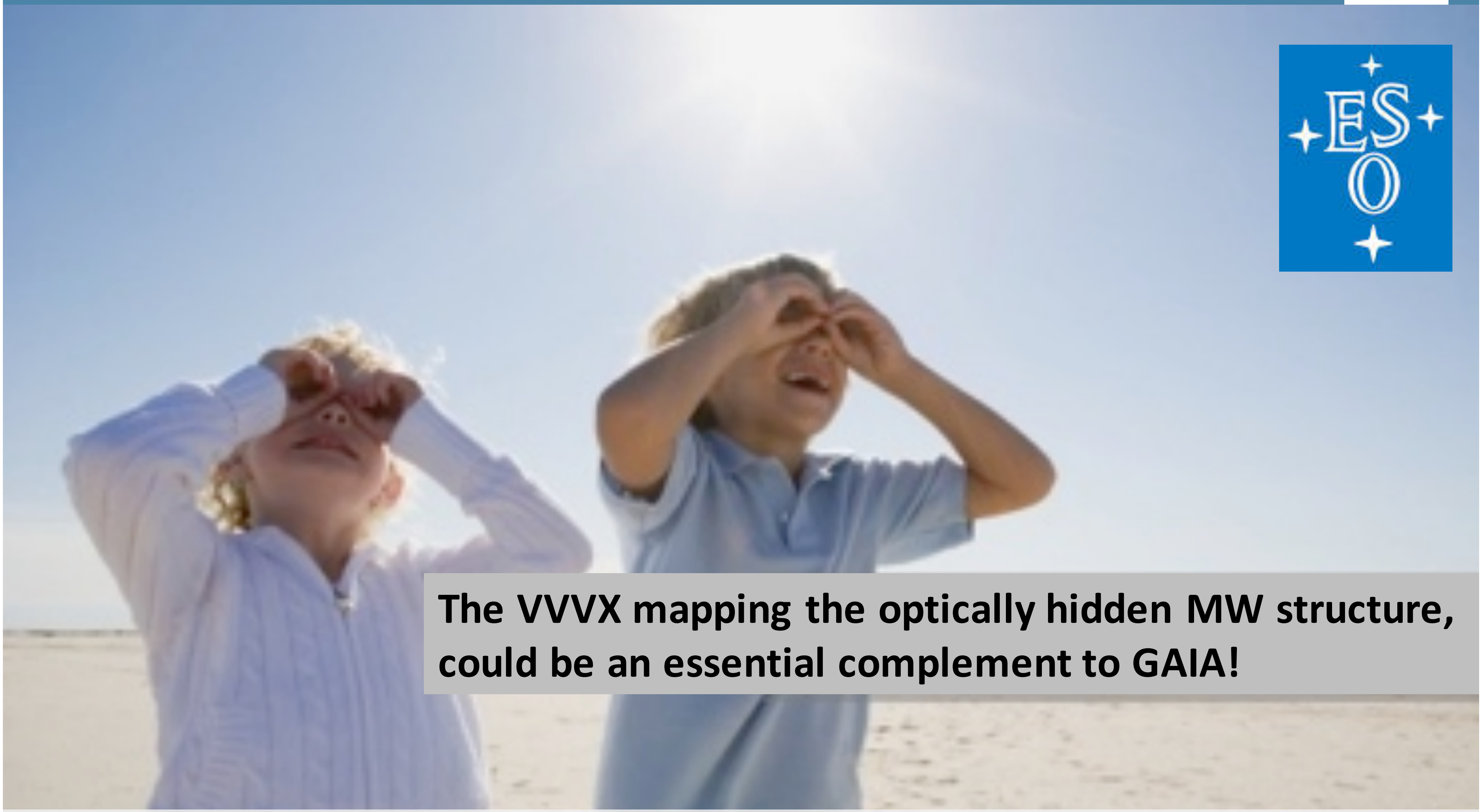
- **This will distinguish foreground disk stars from members of the Galactic bar, bulge and far disk.**

- **PM, radial (spectral follow-up) and space velocities in SFR. Subgroups and clustering in the star formation processes Difficult for GAIA, better in the IR.**

- **Cleaning the CMDs of embedded clusters**

Universidad de Valparaíso CHILE

Millenium Institute of Astrophysics MAS



The VVVX mapping the optically hidden MW structure, could be an essential complement to GAIA!

This project was possible thanks to the amazing VVV survey!
Financial support by the *FONDECYT Fund, #1130140* and the *Millennium Institute of Astrophysics - MAS*