



Discovery of variables in WFCAM and VISTA data

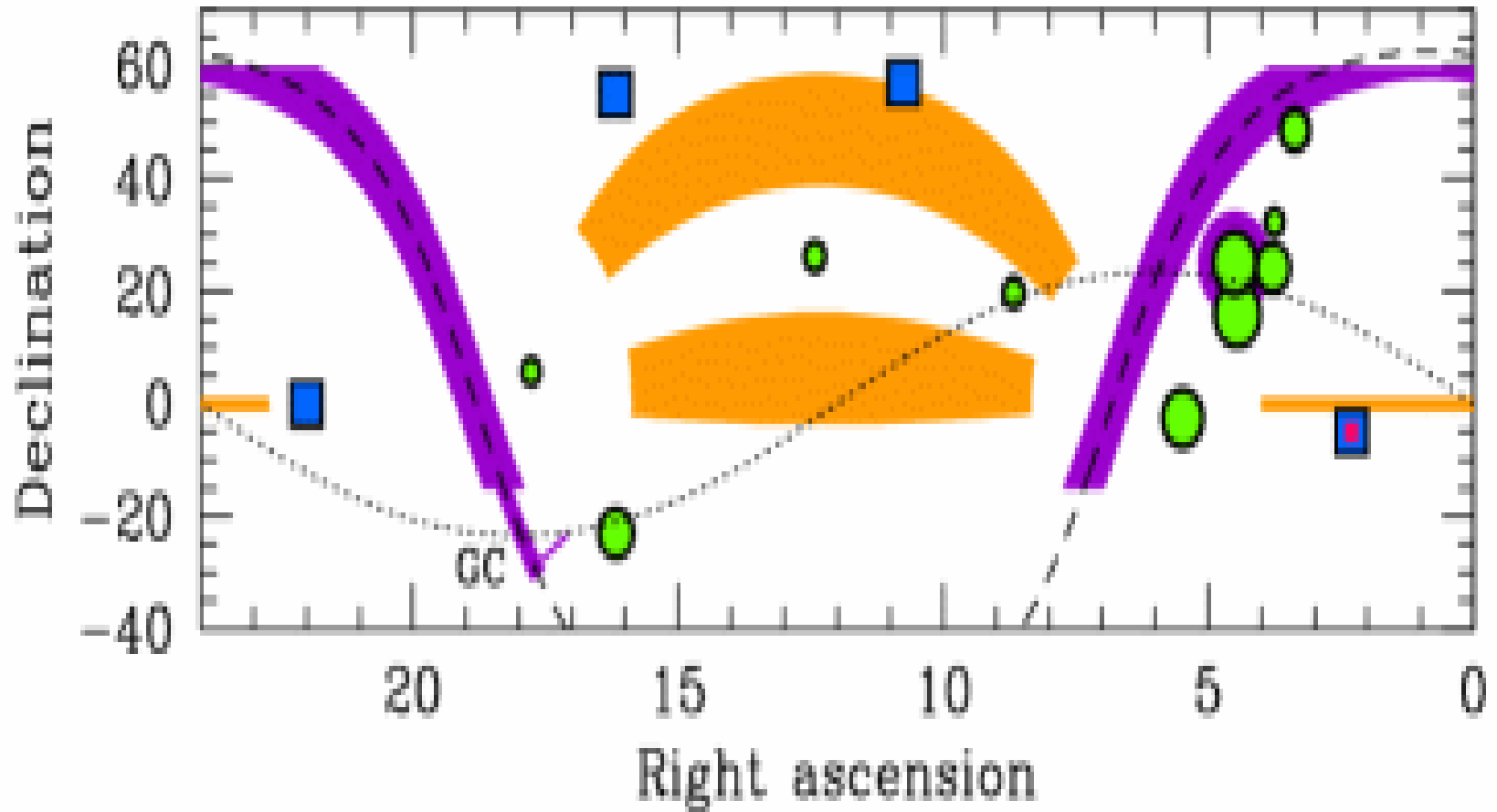
Nicholas Cross, Nigel Hambly, Ross Collins,
Eckhard Sutorius, Mike Read and Rob Blake.

njc@roe.ac.uk

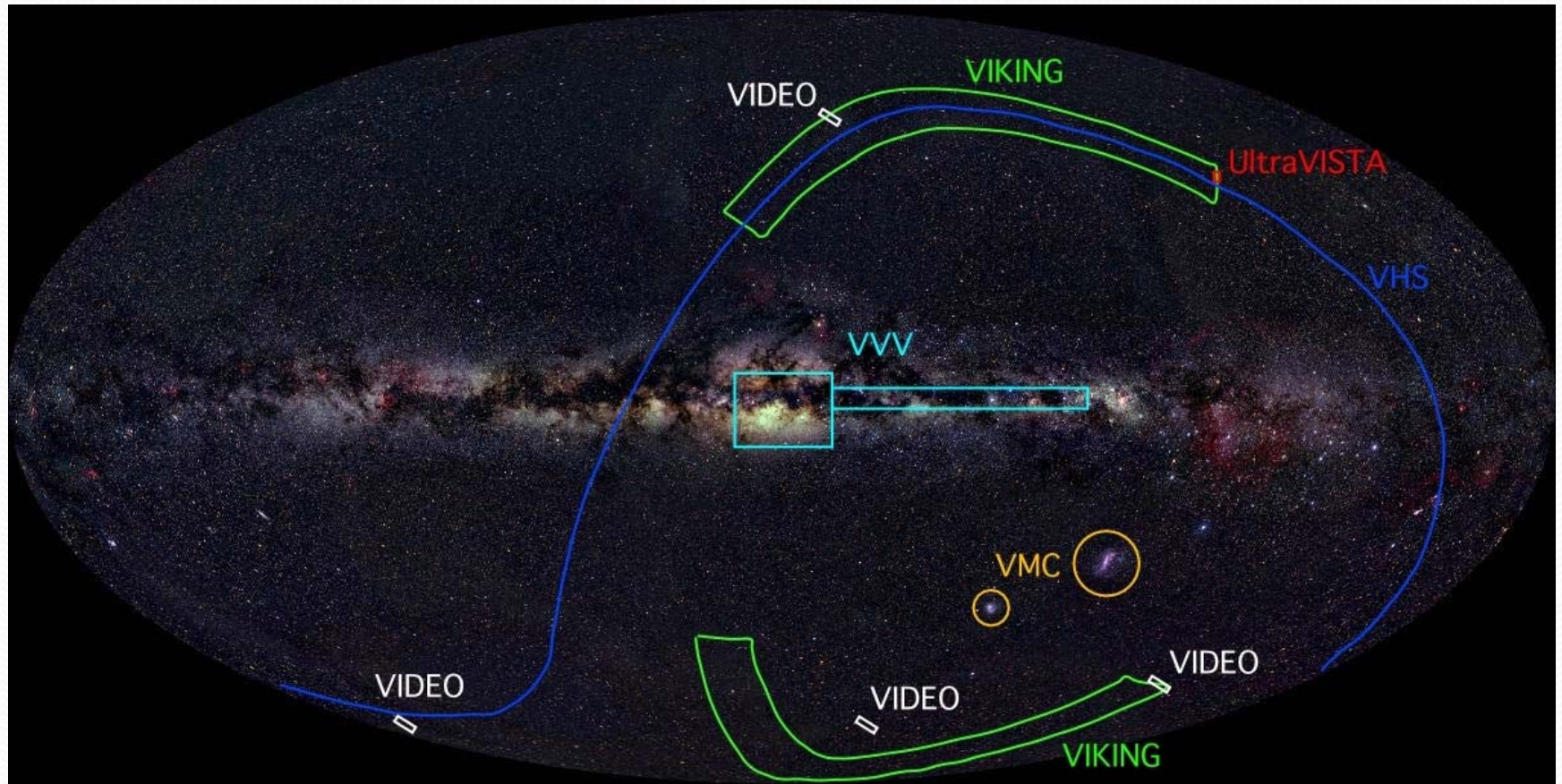
Introduction:

- New era of wide-field, multi-epoch surveys (e.g. SDSS Stripe 82, Super WASP, Pan-STARRS in the optical)
- UKIRT-WFCAM and VISTA are able to do the first wide, high-resolution, multi-epoch surveys in the near-infrared.
- Some VISTA surveys, such as VISTA Variables in Via Lactea (VVV – a multi-epoch Galactic plane survey) will produce catalogues with 10^{11} objects.
- For users to use these data effectively, an archive facility with useful selection parameters is necessary.

UKIDSS surveys



VISTA Public Surveys



Science from WFCAM and VISTA multi-epoch data

- **Calibration, new faint near-IR standards:** WFCAM standard star data
- **Transits of planets around M-dwarfs:** PTS (Campaign 2)
- **Periodic variables as distance indicators** to map out 3-D structure of bulge and Magellanic Clouds: VVV & VMC
- **Supernovae:** VIDEO
- **High proper motion stars:** DXS (Not main science goal, but secondary use of data).
- **YSOs** (Alves de Oliveira & Casali 2008): PATT data.
- Better **QC** and **flagging**.

Processing of WFCAM and VISTA data.

- Data processed and archived through VDFS:
 - Nightly data reduction, cataloguing and calibration done by CASU in Cambridge.
 - Processing of data on different nights (e.g. other filters, deep data, multi-epoch) and archiving done by WFAU in Edinburgh.
 - Matching to external surveys also done here.
- WFAU have built pipeline to process multi-epoch data and have archived the results so that data can be selected by variability attributes including cadence and a noise model for the photometric variability.

Methods Used

- Match each source from merged filter deep stacks to each observation (including where the source is missing).
- Use methods used by Monitor team: derive ZP offsets in each frame and best aperture for each source. (Irwin J. et al. (2007)).
- Use noise model and statistical methods used by SDSS – Sesar et al. (2007).
- Noise model is necessary to define what is variable and not.

Statistical Attributes

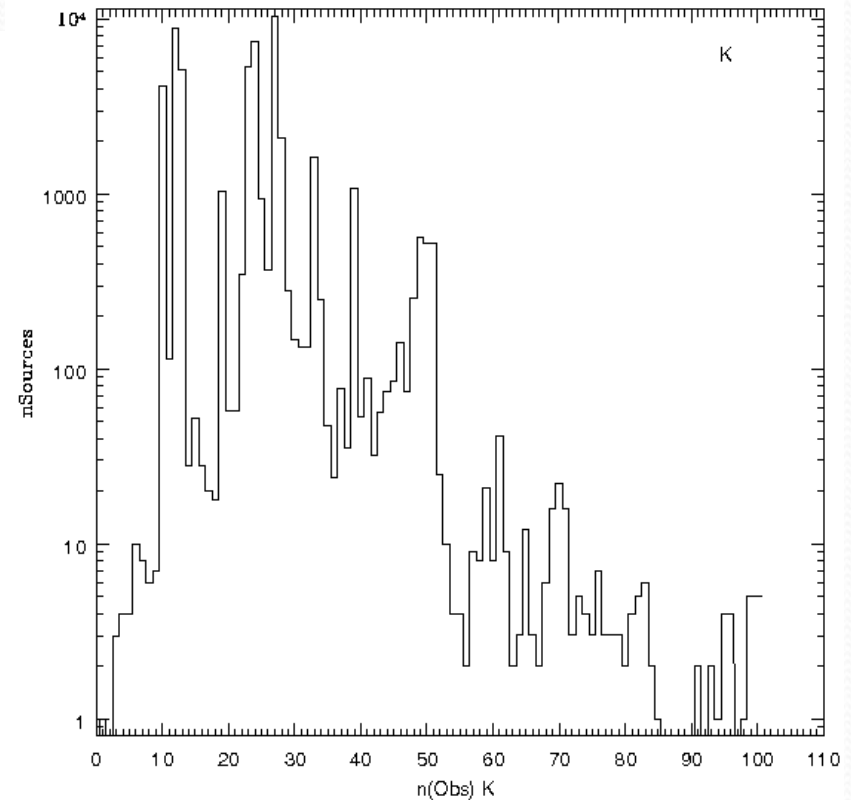
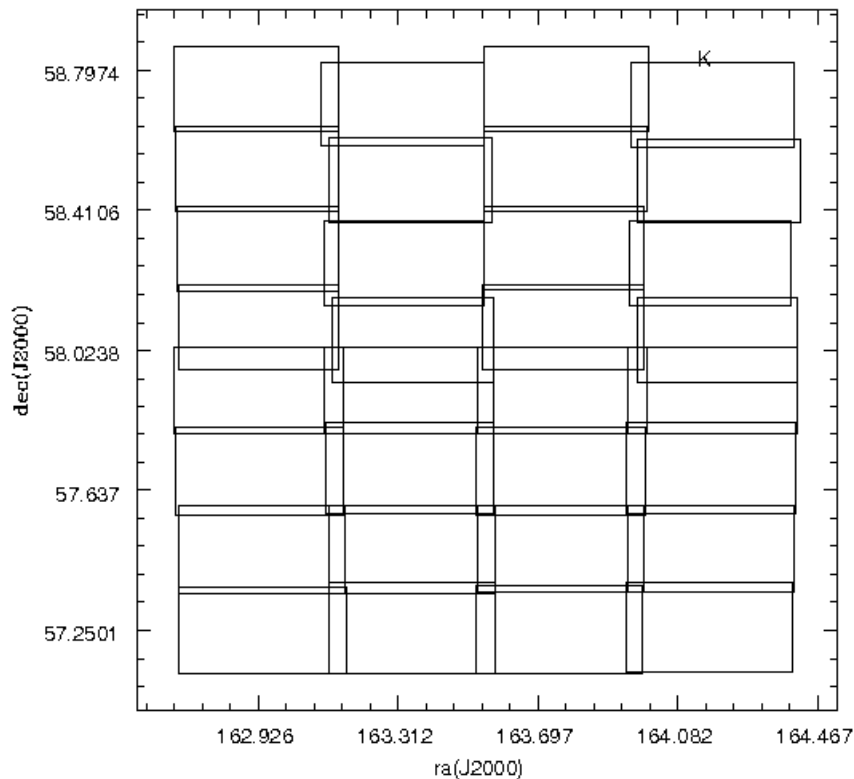
- Mean and RMS of RA & Dec (Proper motion to come)
- N(good), N(flagged), N(missing)
- min,med,max of time between observations
- Mean,median,RMS,MAD,skew of mag in best aperture
- Expected and Intrinsic RMS of object.
- $\chi(\text{Var}), p(\text{Var})$
- I_{WS} (correlations between filters in some datasets)
- Classification



Rec

- Use each detector to determine the direction of the wavefront
- If $|\Delta| > \lambda$, the detector will be in the shadow region
- $< |\Delta| < \lambda$, the detector will be in the illuminated region
- Do not become confused with the wavefront
- UD

Example – UKIDSS DXS

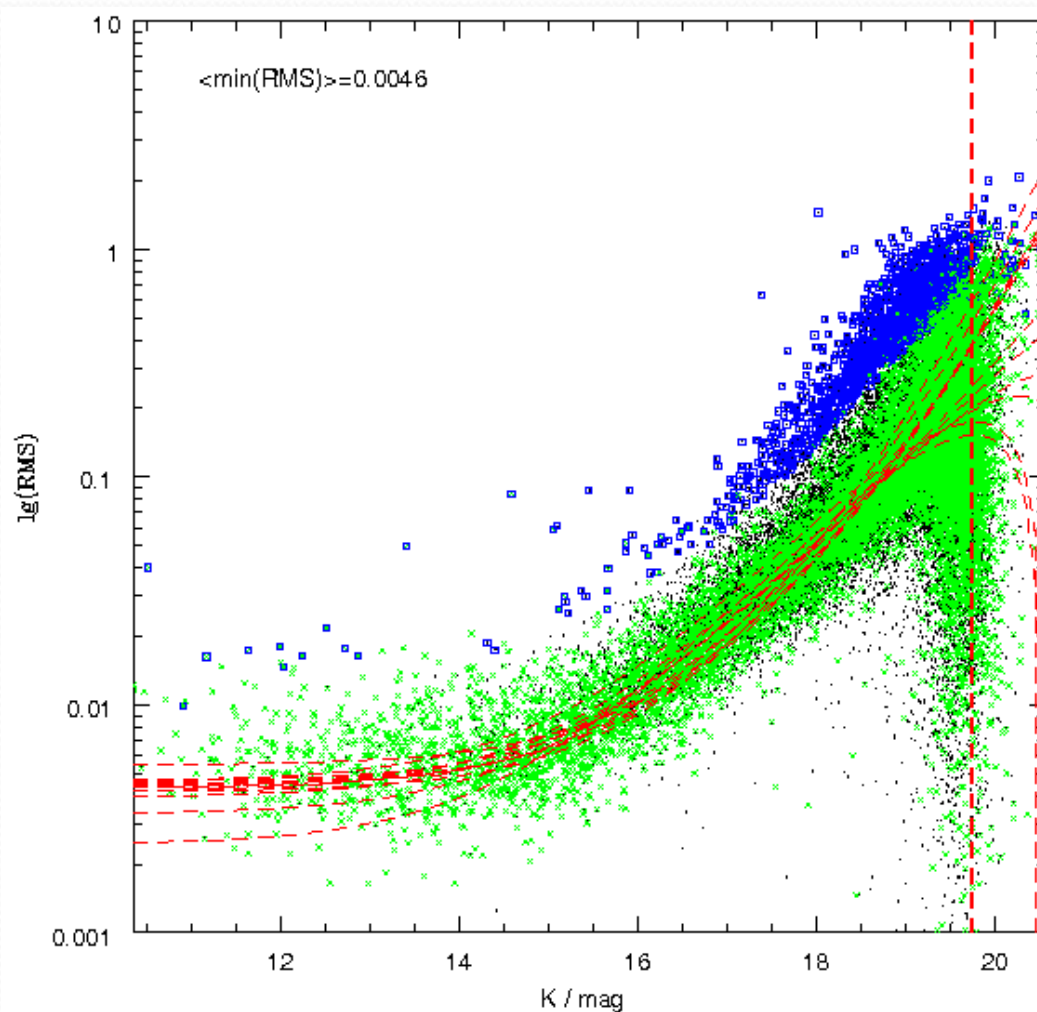


- $2 \square^\circ$ region of Lockman Hole: 32 overlapping frame sets (8 pointings).
- Each pointing different number of intermediate stacks

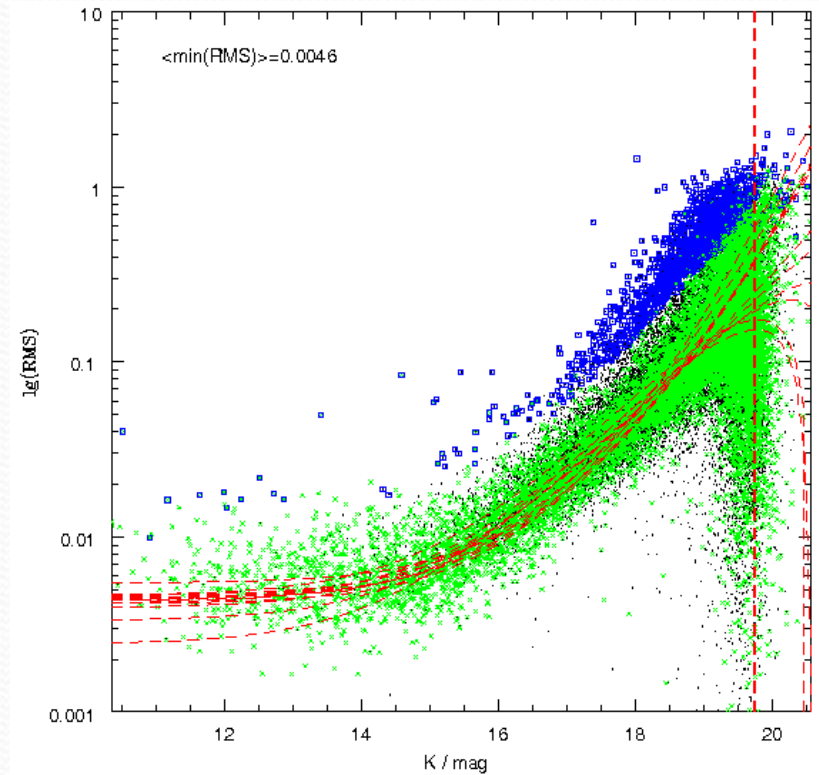
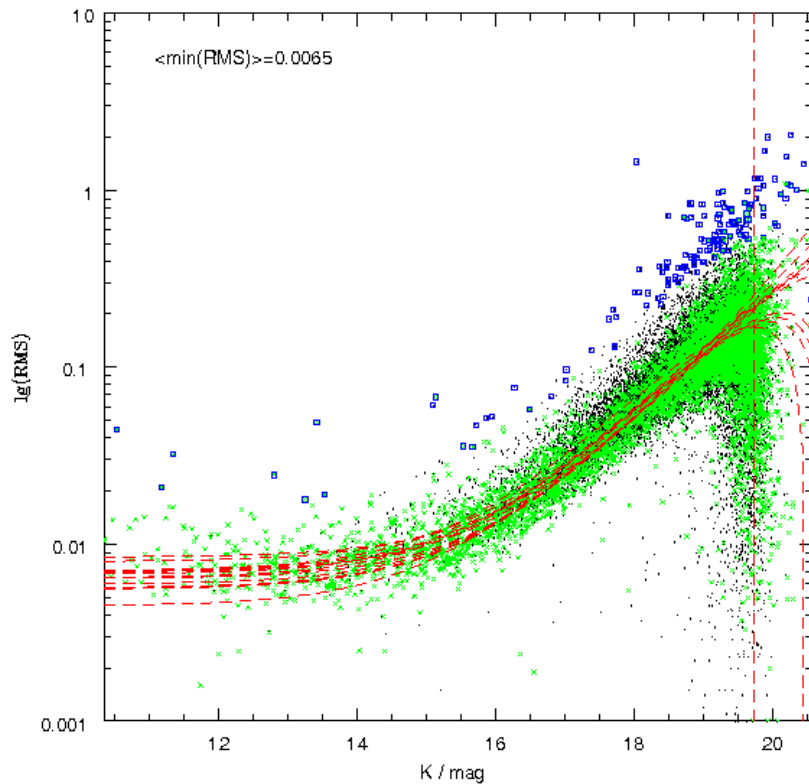
$N(\text{Obs}) = n\text{GoodObs} + n\text{FlaggedObs} + n\text{MissingObs}$
 Peaks at ~ 13 and ~ 27 : number of int stacks / pointing
 Peaks at $\sim 52, \sim 73, \sim 100$ – overlap regions.

DXS photometry

- DXS deep J and K for studies of galaxy evolution.
- Mag-RMS plot for K-band sources
 - Green – stars, black – gals
 - Red dashed curves: fit to median RMS as function of magnitude
 - Red vertical line: ML of framesets
 - Blue squares: objects classified as variables.
 - Stiletto: caused by sources with 2-3 observations and biased towards bright end.

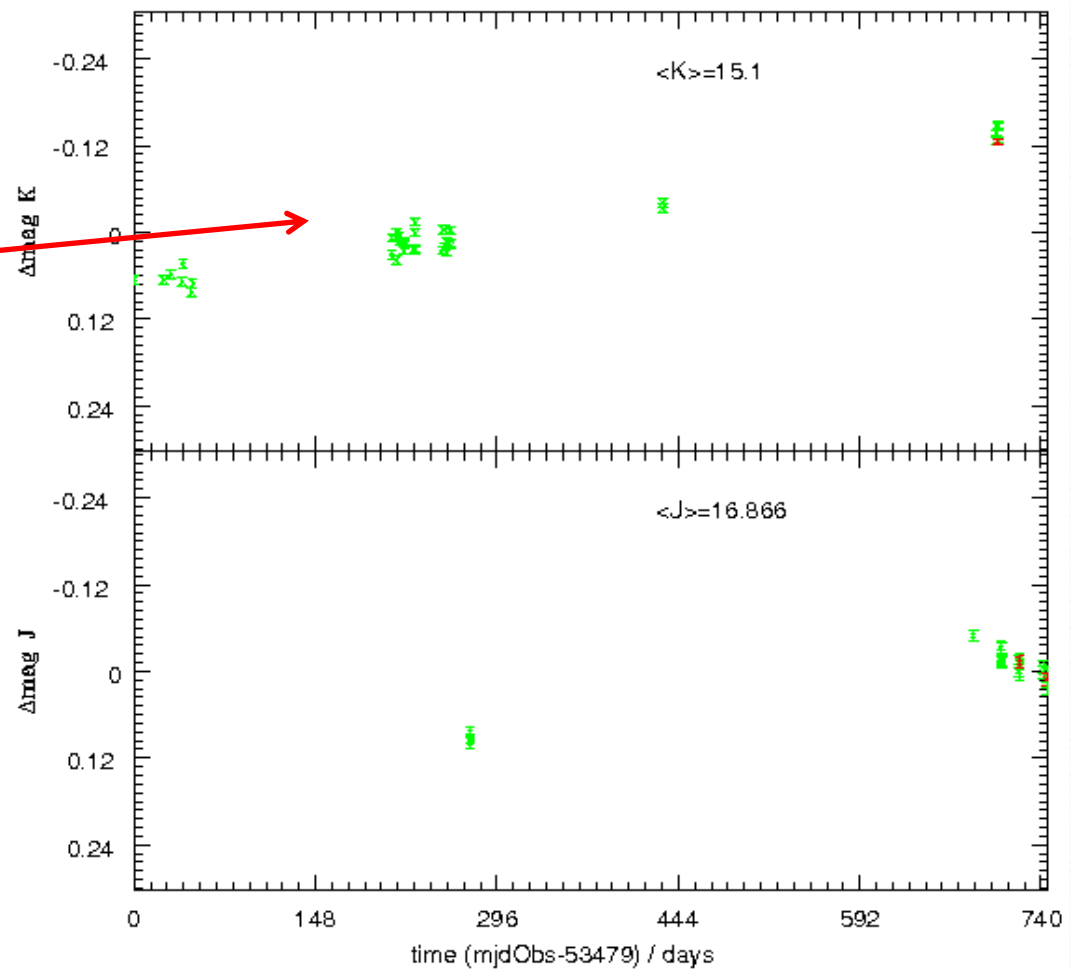
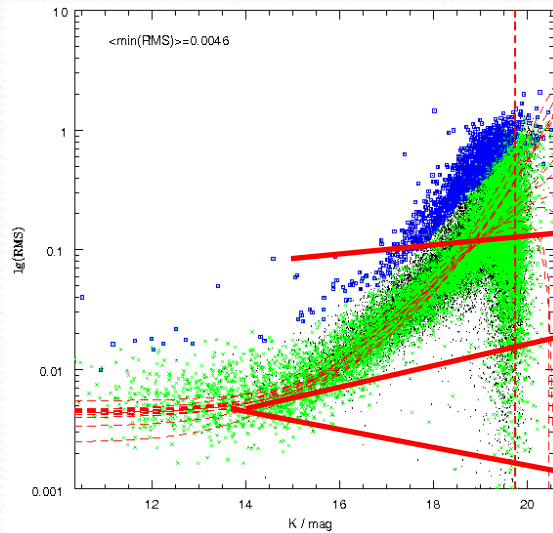


Recalibration: before and after



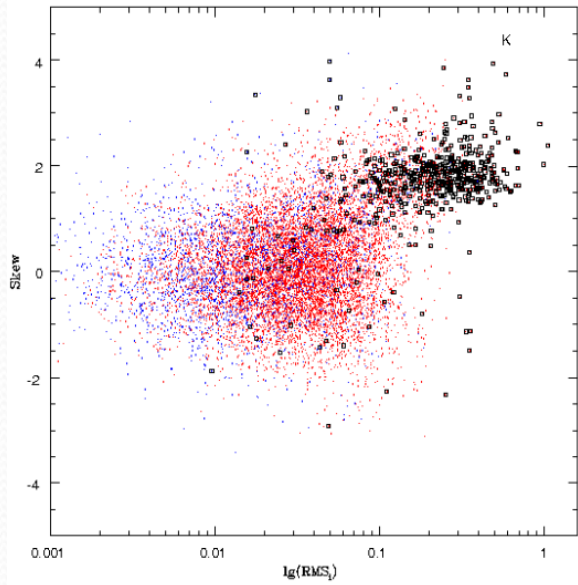
Improved RMS from 6.5mmag to 4.6mmag.

Lightcurves-DXS



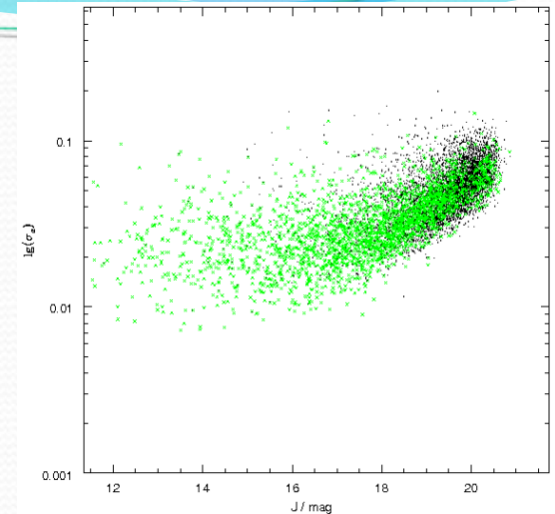
Light curves of two non-variables. Variations are 0.2 mag linear within errors. Increase in brightness over 700 days in K. Seems to rise and fall in J.

Additional attributes

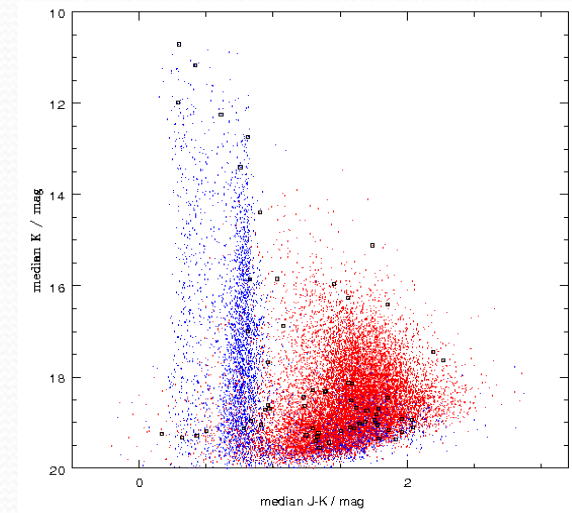


Intrinsic Rms vs skewness

WSA gives additional useful data such as star-galaxy separation and links to external surveys through neighbour tables.

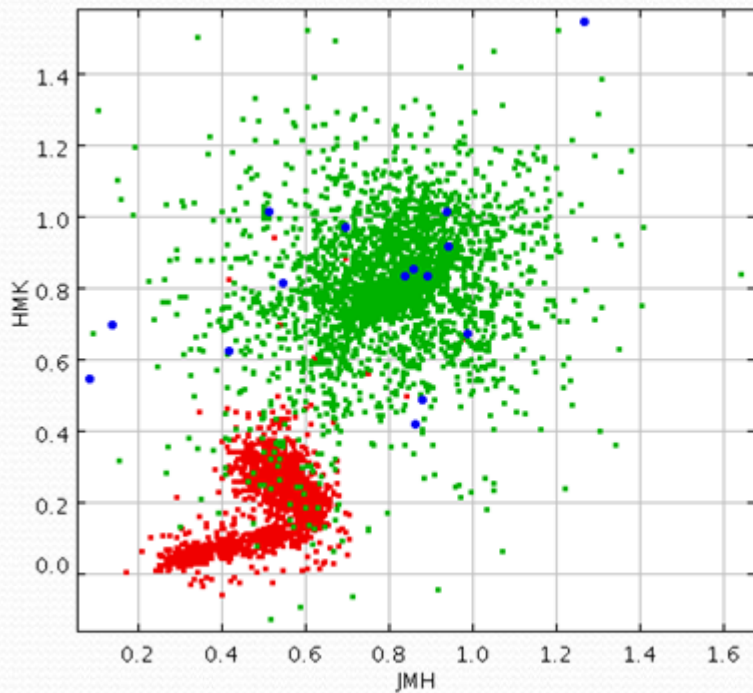


Astrometry Mag-Rms

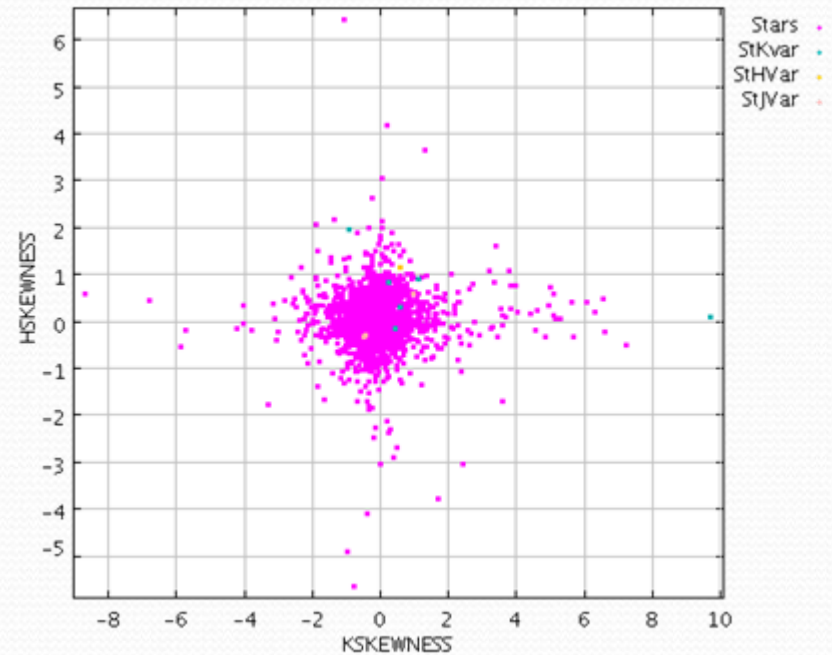


J-K vs K colour magnitude

UDS data

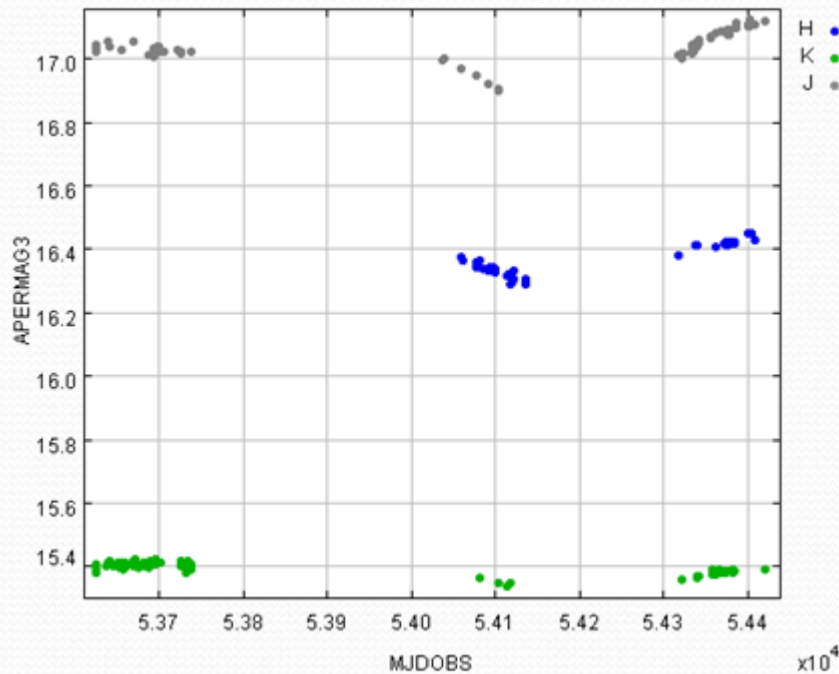


Variables in the J-H vs H-K plane.
Mostly these are galaxies.



H skewness vs K skewness. Most objects have symmetrical magnitude deviations from the mean.

UDS variable



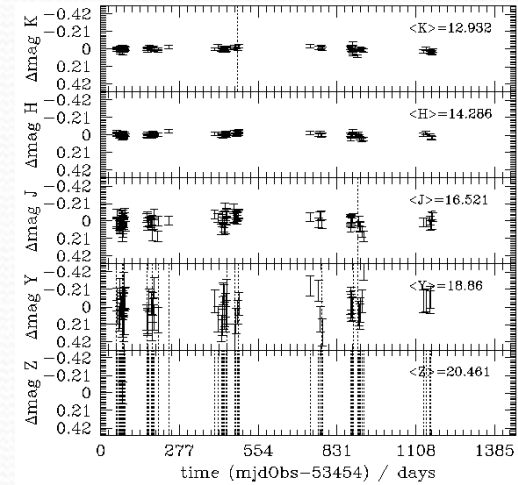
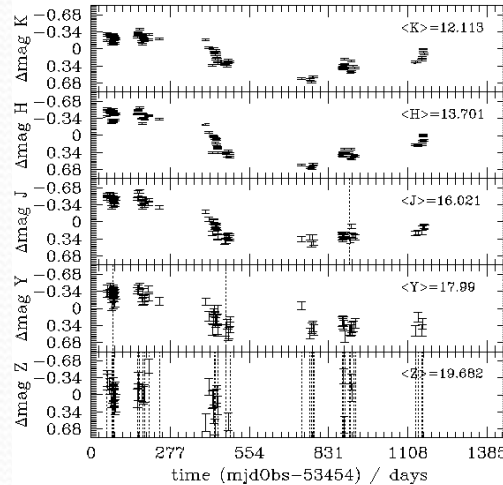
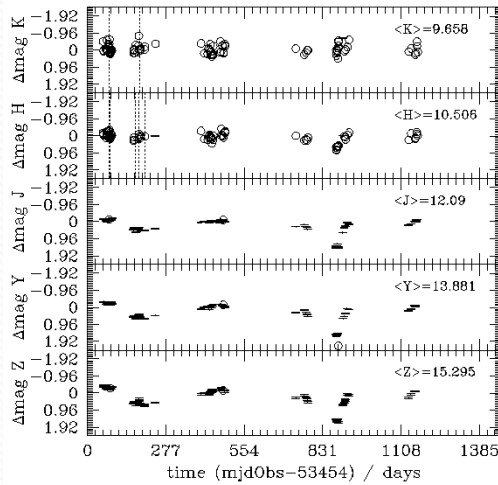
- Variable galaxy or AGB?
- Similar in J,H,K
- K variation has lower amplitude.
- Big gaps due to observing strategy.

Standard star data: Correlated observations in ZYJHK

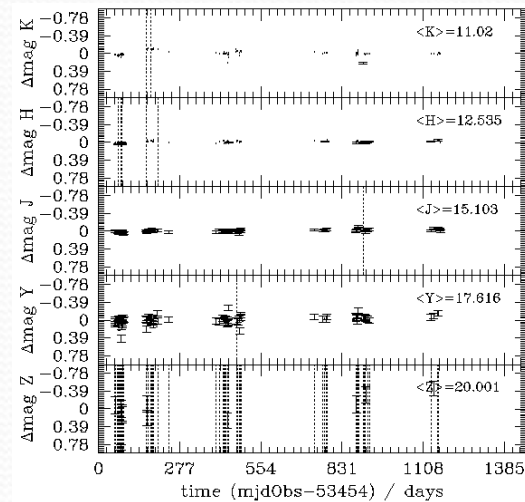


- ~90 observations in ZYJHK
- a few in H₂ and Br γ
- Filters observed over ~15 min.
- Repeat observations >1 hr
- \therefore Timescale of different filters \ll timescale of observations
- Calculate Welch-Stetson statistics.

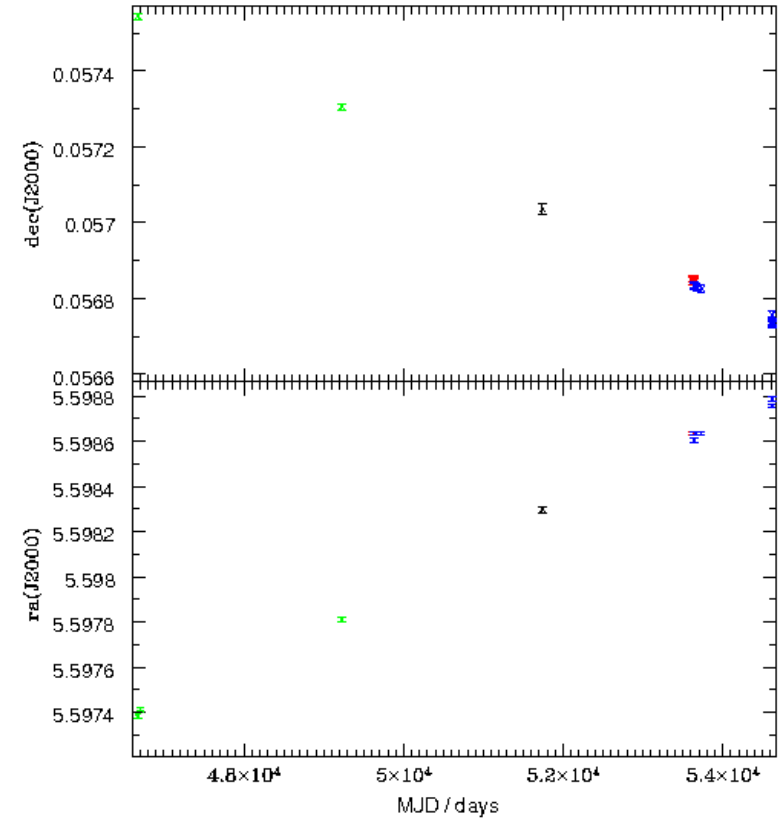
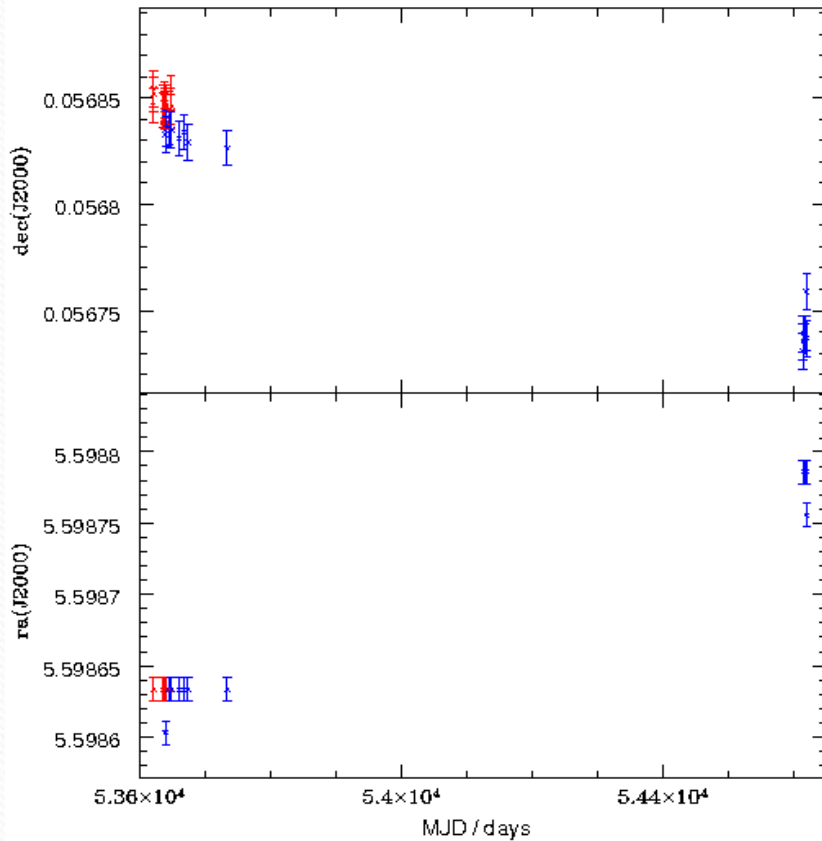
Correlated light curves



- Two variables
- Two standard stars:
 - Ser-EC 68
 - Ser-EC 84

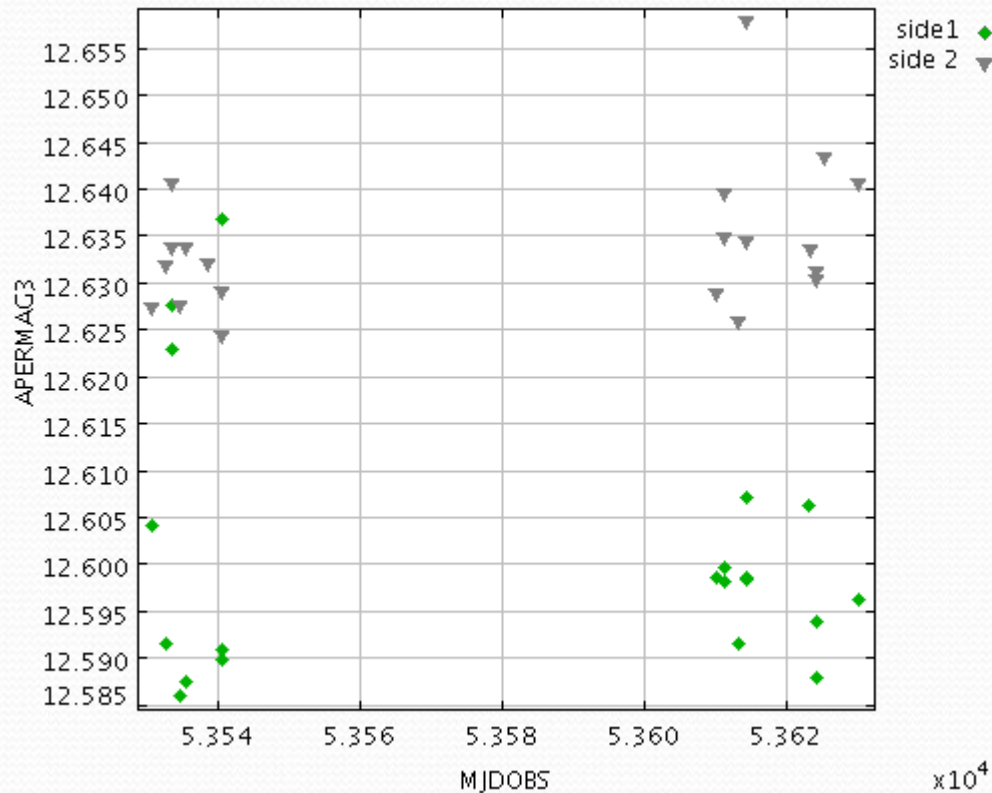


Astrometry



Some objects show astrometric variation (PM), BUT difficult to search on: WILL IMPROVE IN LATER VERSIONS

Other issues



- An object marked as variable
- Two overlapping pointings: $\Delta m \sim 0.035$ mag between frames on each side of overlap.
- Some instrumental effects persist. These vary across the focal plane.
- Overlap effects vary from < 0.001 mag to ~ 0.04 mag.

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WSA Databases

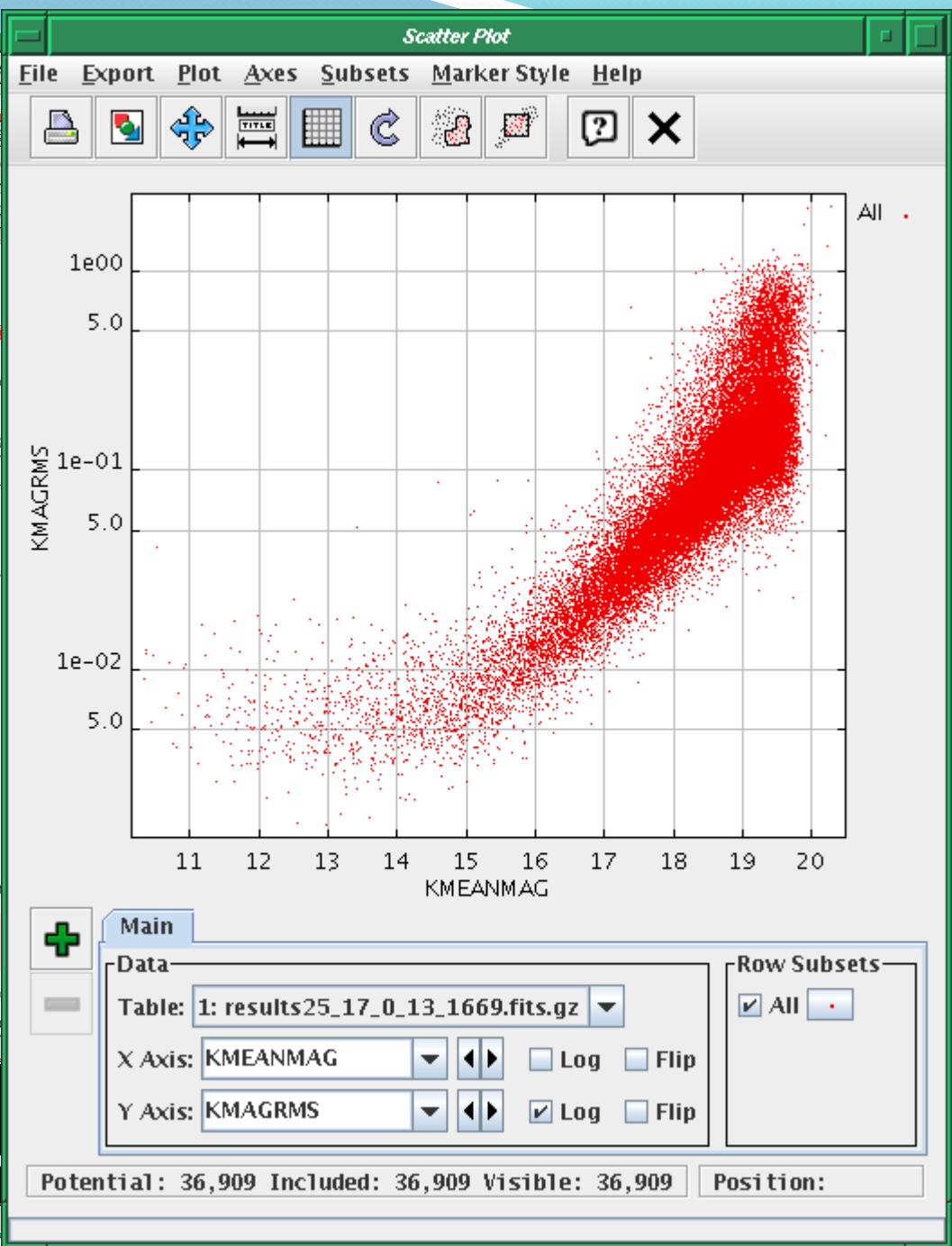
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| | kmeanMag | kmagRms |
|----|------------|-----------|
| 1 | +19.303260 | +0.168160 |
| 2 | +17.465101 | +0.028468 |
| 3 | +14.037594 | +0.006386 |
| 4 | +19.057978 | +0.309312 |
| 5 | +18.498917 | +0.115155 |
| 6 | +18.297000 | +0.066374 |
| 7 | +15.467555 | +0.009765 |
| 8 | +18.273922 | +0.079849 |
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| 10 | +18.408926 | +0.076064 |

(Query returned 36909 results)

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WSA Database - SQL Q

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A web link to your generated output file will appear

Connecting to UKIDSSDR4PLUS database
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timeout: 3600
Connected to database

Submitted query: SELECT m.mjdObs,p.aperMag3,p.aperMag3Err,ppf,amenhotep.testWSAnjc3.dbo.dxsDetectionRaw AS x.multiframeID=r.multiframeID AND x.extNum=r.extNum AND x.multiframeID=m.multiframeID AND x.sourceID=44

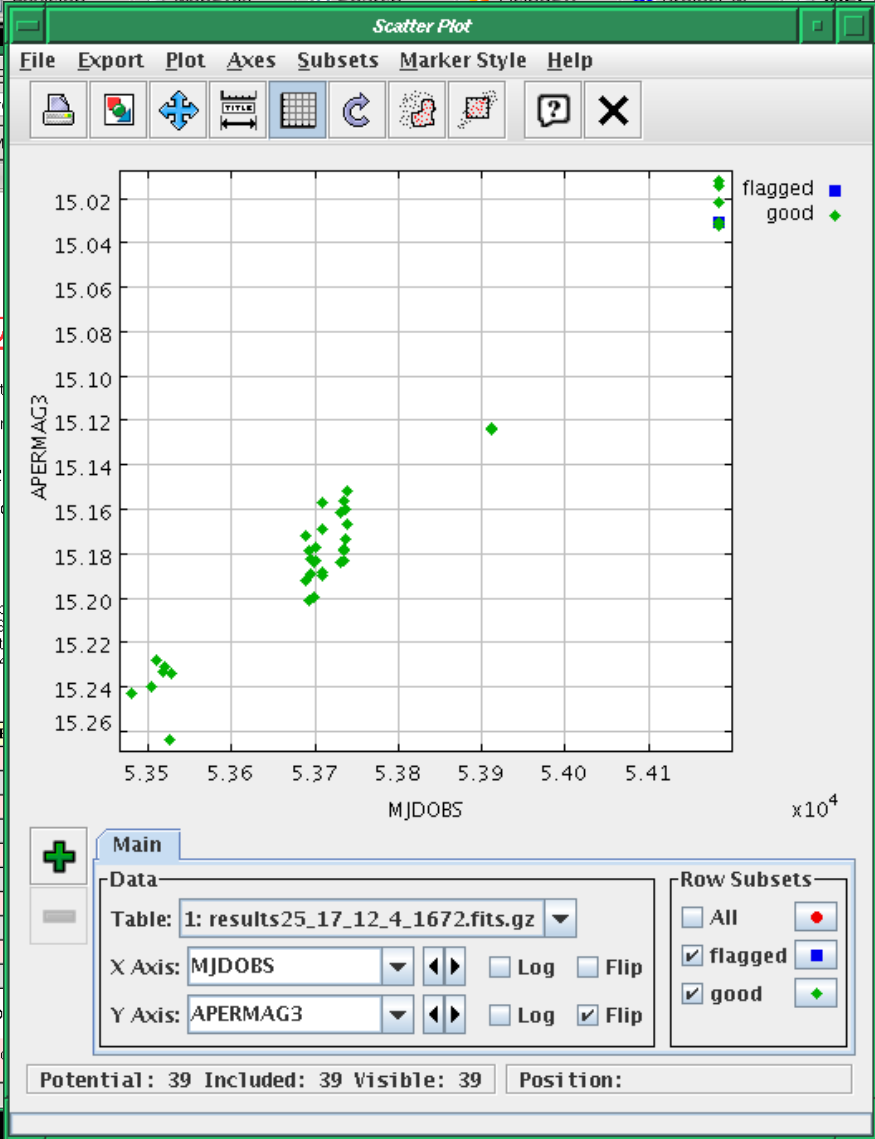
... OK

| | mjdObs | aperMag3 | aperMag3Err | ppf |
|----|-----------------|------------|-------------|-----|
| 1 | +5.3693661E+004 | +15.179670 | +0.004585 | |
| 2 | +5.3695653E+004 | +15.183502 | +0.004950 | |
| 3 | +5.3693650E+004 | +15.202039 | +0.004616 | |
| 4 | +5.3689614E+004 | +15.192929 | +0.004802 | |
| 5 | +5.3689625E+004 | +15.172518 | +0.004791 | |
| 6 | +5.3695643E+004 | +15.190150 | +0.004935 | |
| 7 | +5.3699599E+004 | +15.200391 | +0.004727 | |
| 8 | +5.3700608E+004 | +15.183734 | +0.004485 | |
| 9 | +5.3700618E+004 | +15.177868 | +0.004648 | |
| 10 | +5.3699609E+004 | +15.184334 | +0.004737 | |

(Query returned 39 result rows, only the first 10 ro

[Download Results File](#), your results in a gzippe

Done



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Timeout (seconds): 3600 your query will be halted after this time (max 10000)

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| | mjdObs |
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| 9 | +5.3731604E+004 |
| 10 | +5.3734639E+004 |

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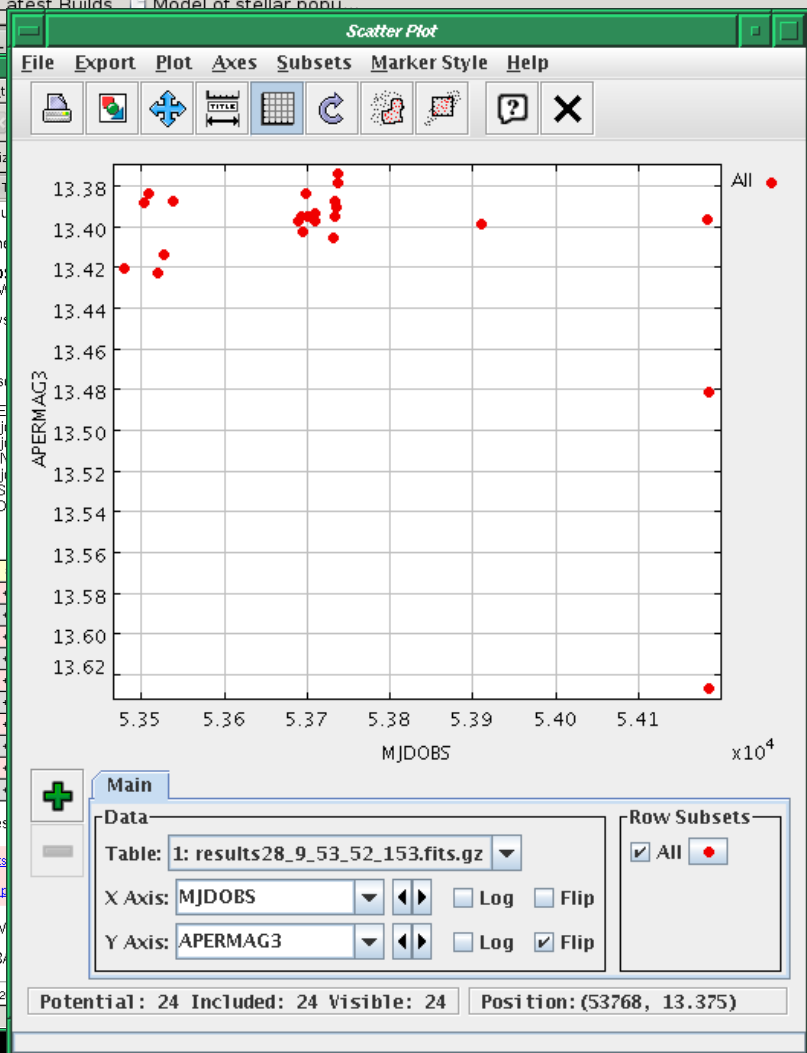
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>2. AND s.mergedClass in (-1,-2) AND

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Submit Reset

Summary

- Searches for variability possible in WSA from UKIDSS-DR5 (DXS: 6th April 2009, UDS: 28th August 2009).
- Dynamic archive:
 - adding more data,
 - improving the calibration and QC
 - adding new features.
- 1st version of synoptic pipeline: future versions will improve quality and quantity of attributes.
- VSA: massive amounts of data to trawl through – need efficient search capability.
- See Cross et al. 2009, MNRAS in press (arXiv:0905:3073)