The UKIDSS Ultra-Deep Survey

Survey operations and dedicated "pipeline"

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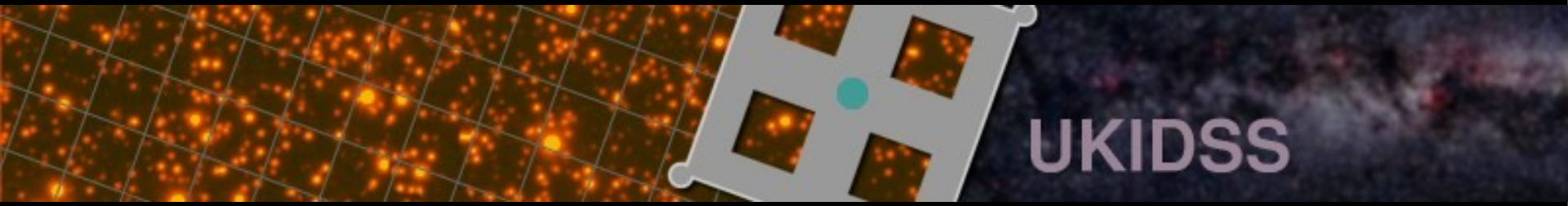
University of Nottingham

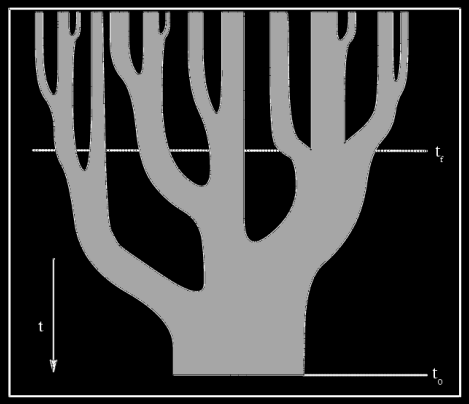
+ UKIDSS UDS Team

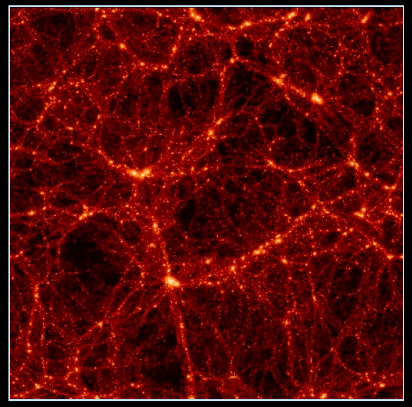
The University of Nottingham



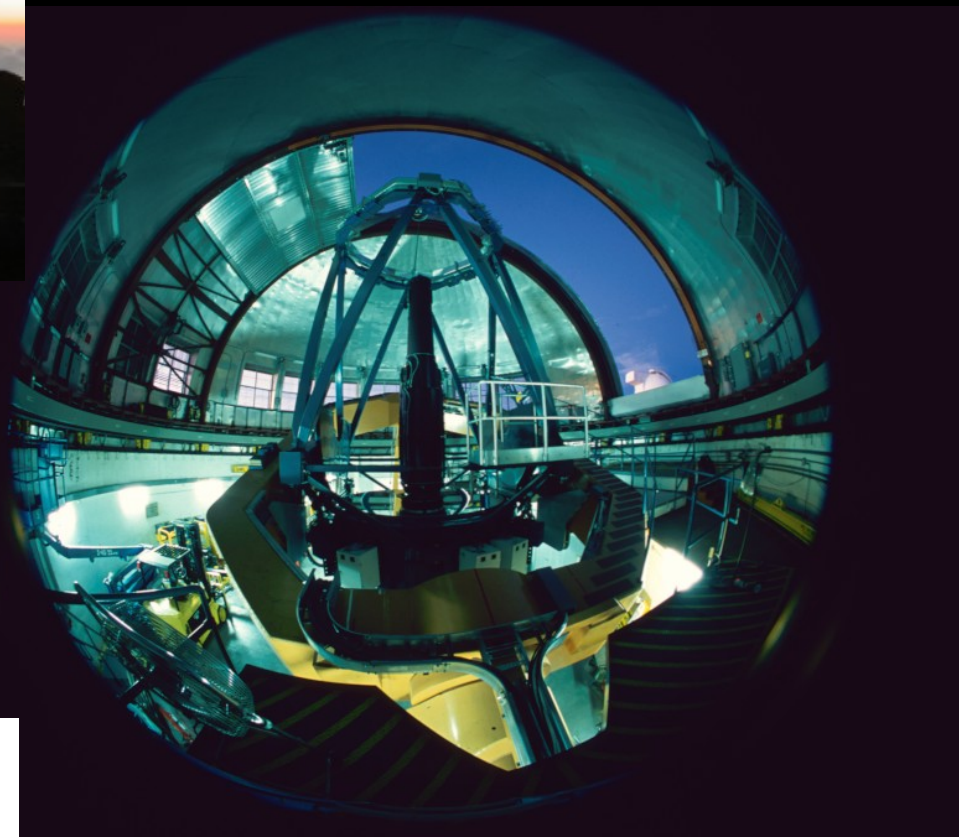
Talk Outline

- UKIRT Infrared Deep Sky Survey
- Ultra Deep Survey
- Dedicated data reduction
- Successes and failures
- Astrowise





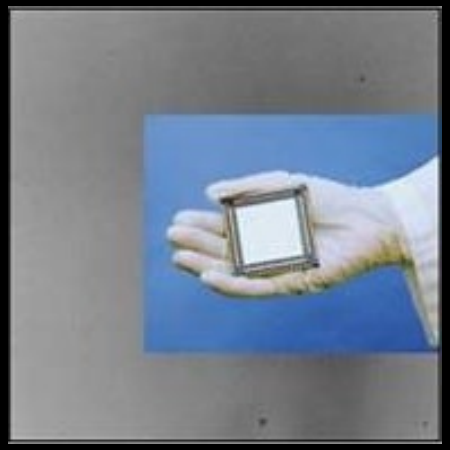
The UKIRT Wide-Field CAMera

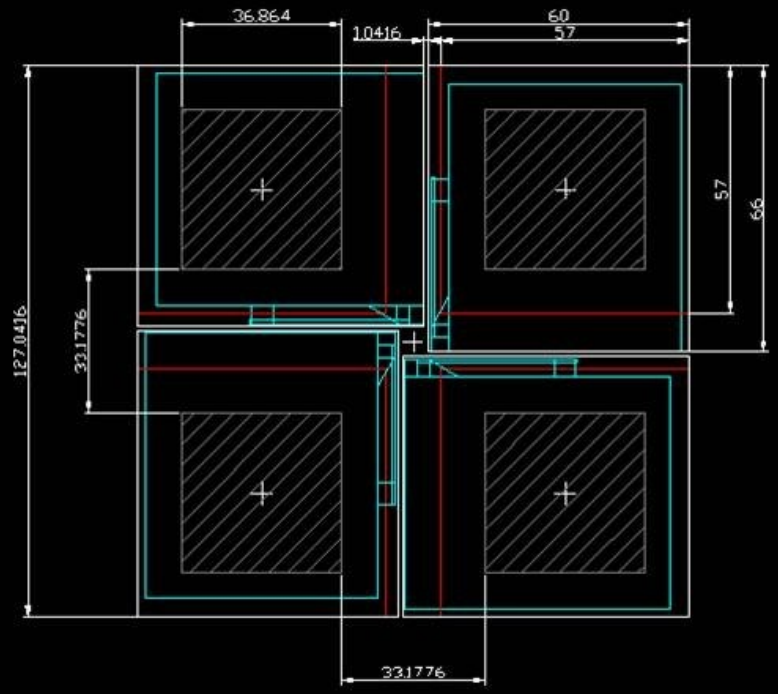


Casali et al. (2008)

WFCAM
UKIRT

WFCAM IR detectors



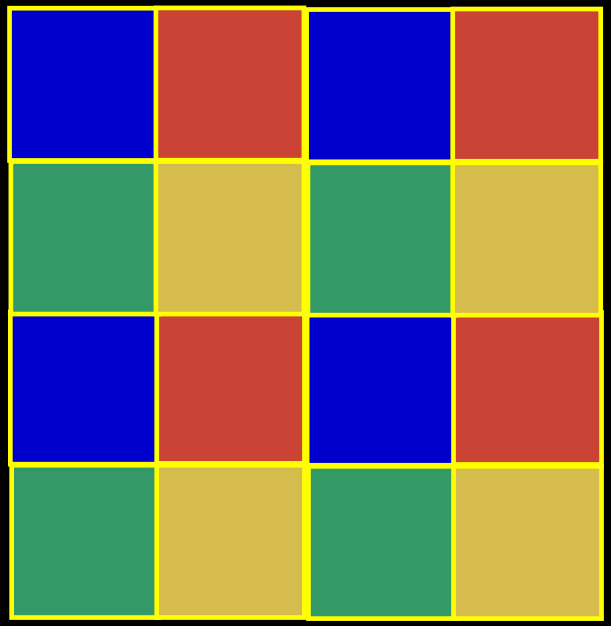


4 Rockwell Hawaii-II devices

- HgCdTe hybrids
- J, H, K (+Y, Z)
- 2048 x 2048 18 μm pixels
- detector packaging prevents close packing

Focal Plane configuration

- 90% spacing of 4 detectors
- four exposures give filled 0.88° square (0.77 sq. °)



The UKIDSS Consortium

- PI: Andy Lawrence
- Survey Scientist: Steve Warren
- Survey Heads: Almaini, Edge, Hambly, Jameson, Lucas
- + ~60 others within ESO
- + Subaru FMOS team

"UKIRT Infra-red Deep Sky Survey"

UKIDSS

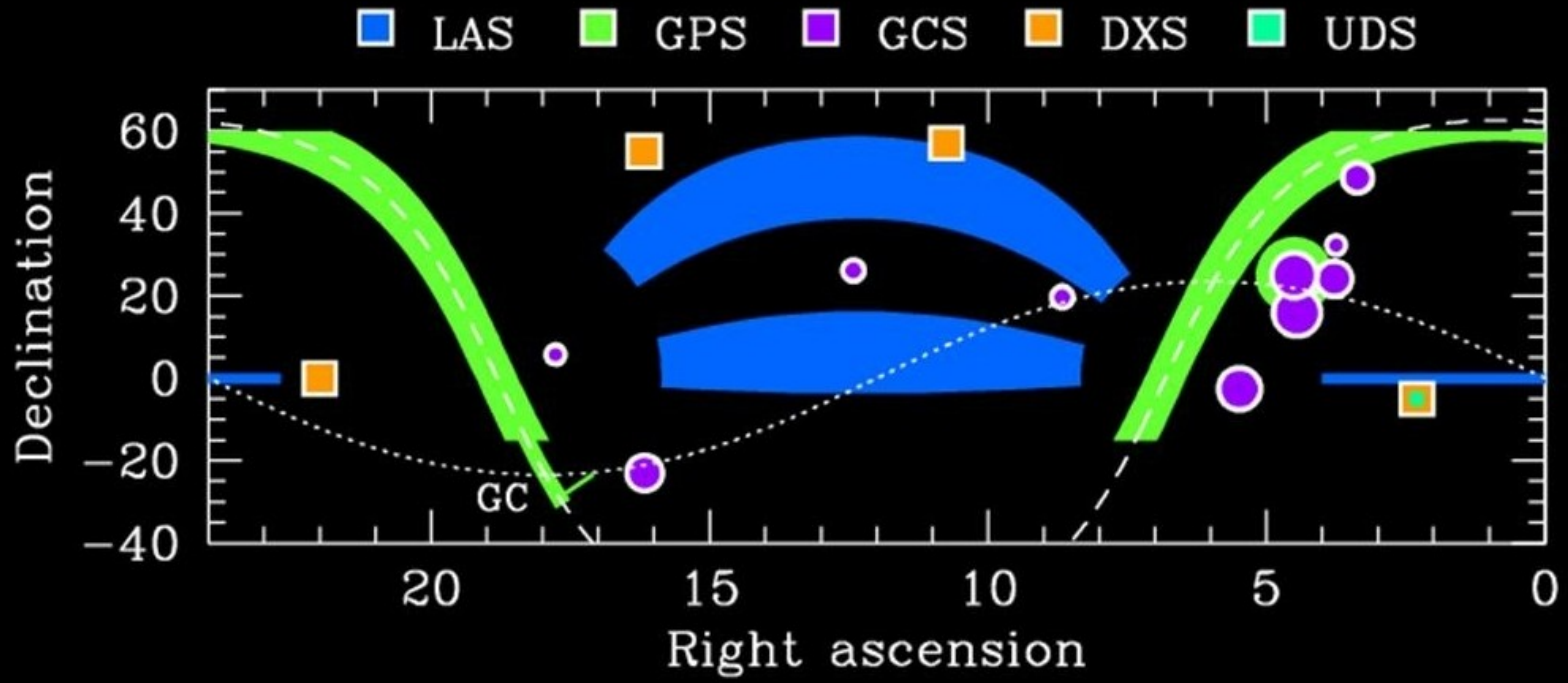
- 60% of all UKIRT time dedicated to UKIDSS
- 7-year programme (approved on 2yr roller)
- 5 sub-surveys
- Immediately public to ESO community
- World public 18 months after observation

- Started in spring 2005

http://www.ukidss.org

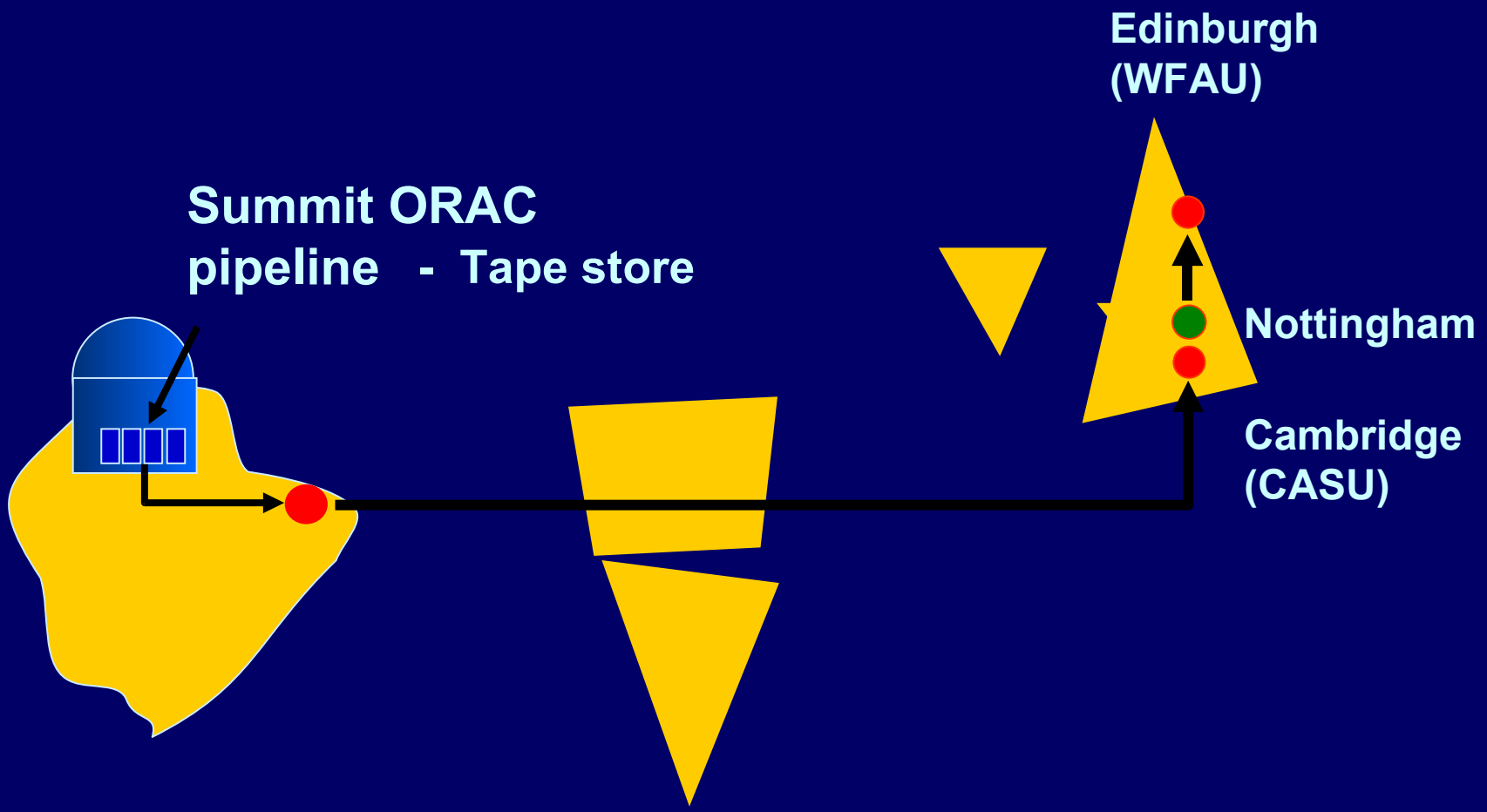
UKIDSS design

Ultra Deep Survey	UDS	JHK	K=23.0	0.77 deg^2	ExGal
Deep Extragalactic Survey	DXS	JK	K=21.0	35 deg^2	ExGal
Galactic Plane Survey	GPS	JHK	K=19.0	1800 deg^2	Gal
Galactic Clusters Survey	GCS	ZYJHK	K=18.7	1600 deg^2	Gal
Large Area Survey	LAS	YJHK	K=18.4	4000 deg^2	ExGal

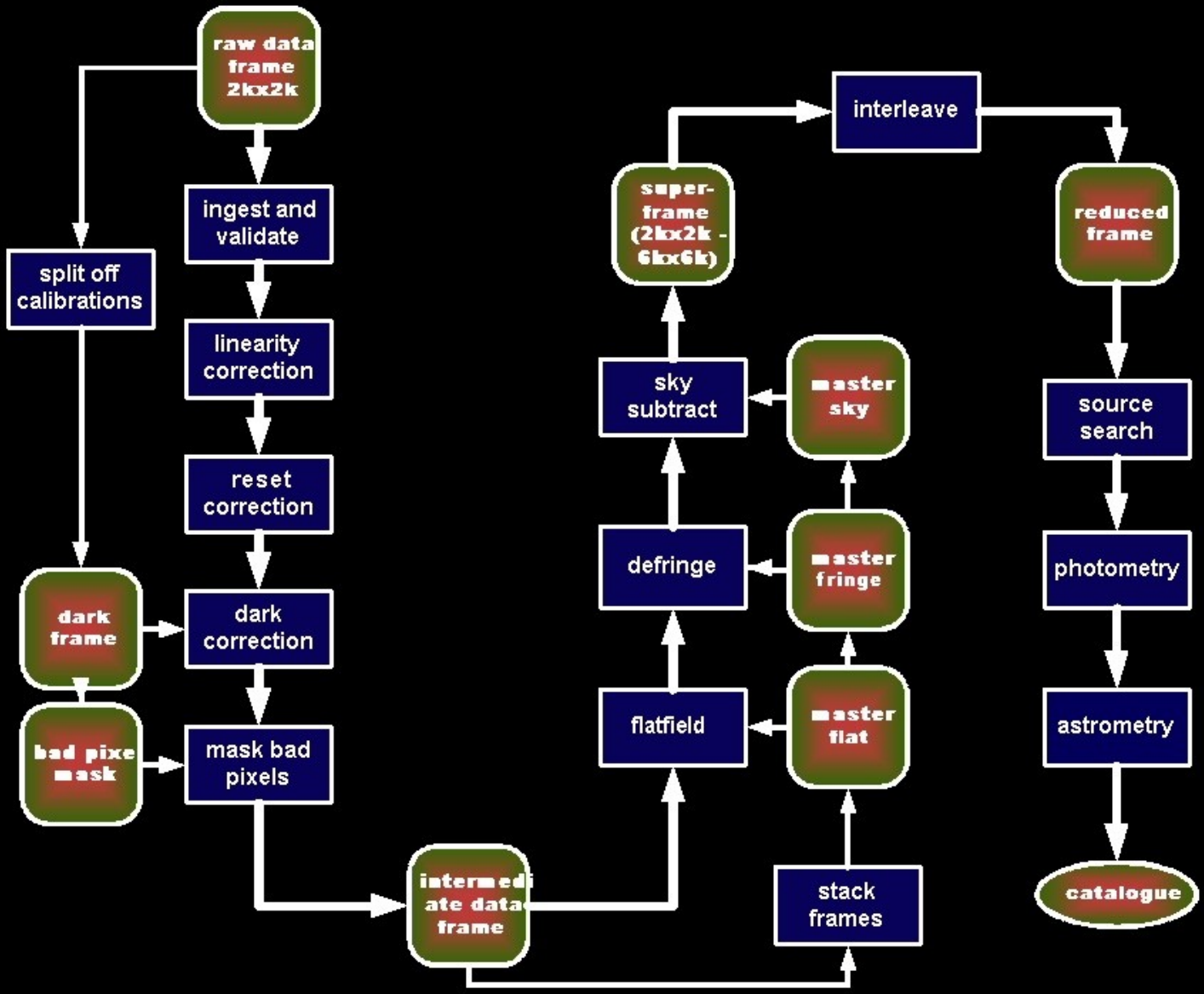


Lawrence et al. (2007)

UKIDSS Data Flow

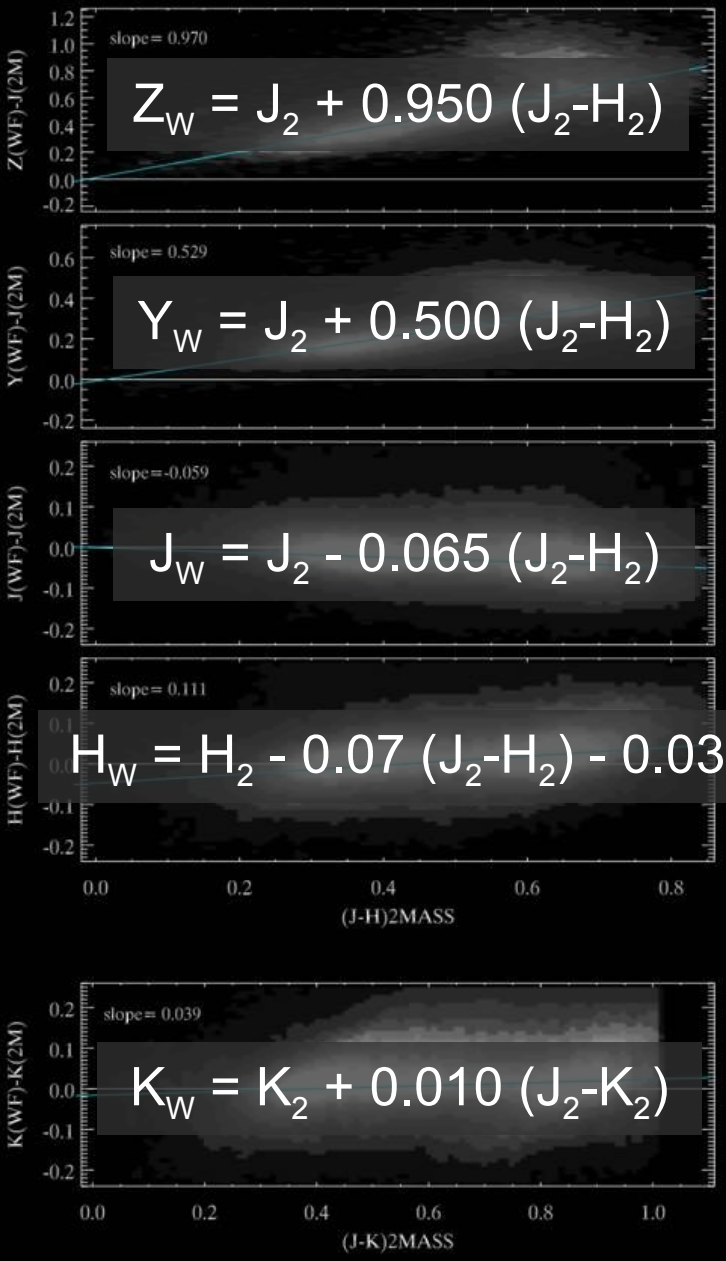


UKIDSS data reduction



Irwin et al. (in prep.)

UKIDSS photometry



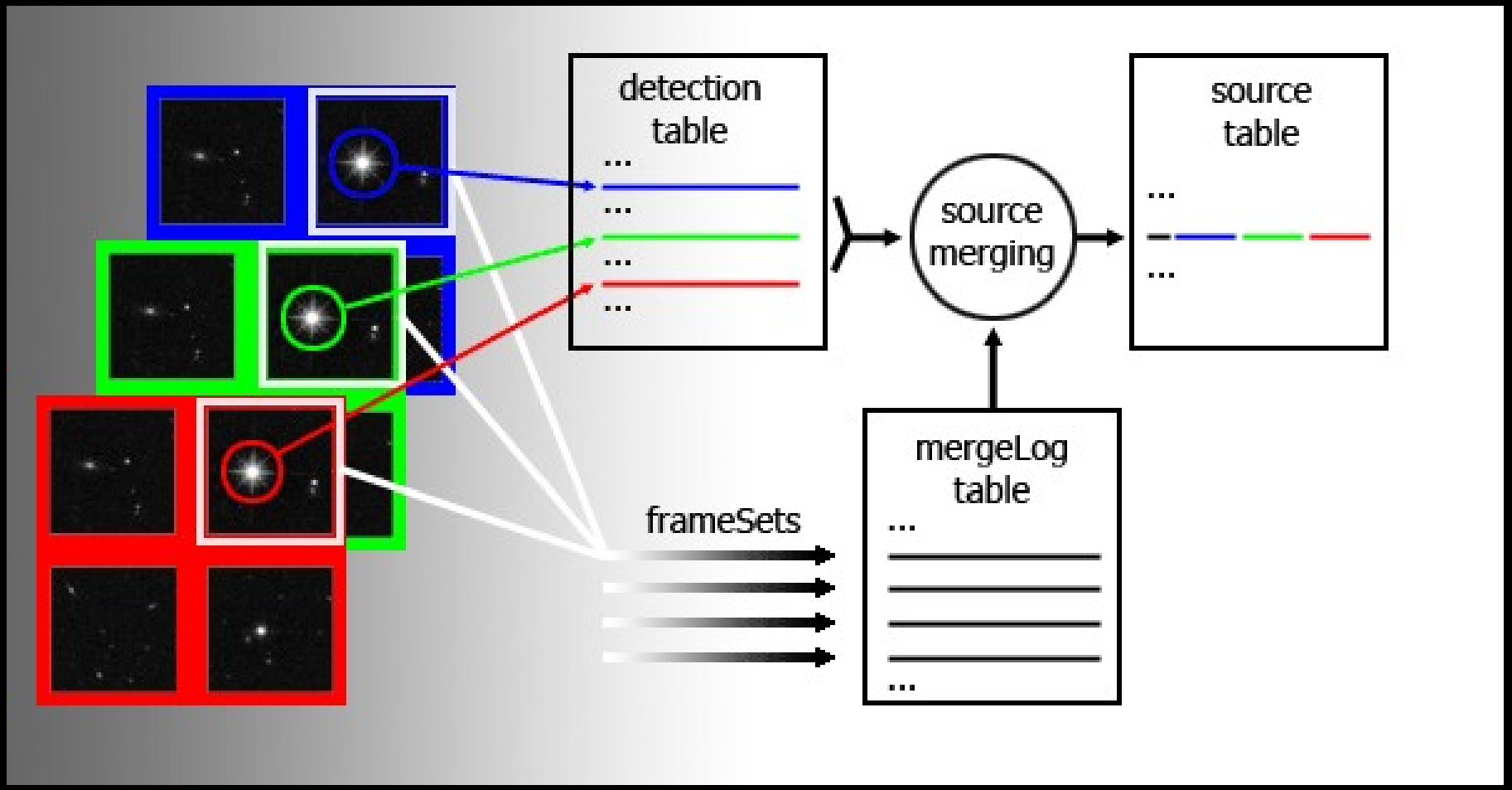
- calibration ~1% for all wavebands
- 2MASS globally consistent to ~1%
- many 2MASS stars in each WFCAM pointing

- 2MASS star photometry → WFCAM system using linear colour equations
- ZP* for every 2MASS star in the detector, combining to give a detector ZPdet

- stack residuals every month
- residuals binned spatially (1.2x1.2arcmin) and smoothed:
  - systematic detector offsets at the 1-2% level (catalogues/images updated for each HDU)
  - additional spatial systematics at the 1% level (written to file and available from CASU)

Hodgkin et al. (in prep.)

UKIDSS catalogue matching



Hambly et al. (2008)

WFCAM Science Archive
WSA Home
Start Here
Data Overview
the Surveys
Schema browser
Data access
Login
Archive Listing
GetImage
MultiGetImage
Region
Menu query
Freeform SQL
CrossID
Cookbook
Q&A
Glossary
Release History
non-Survey
Downtime
Links
Credits
IFA ROE

WSA - WFCAM Science Archive

The WFCAM Science Archive (WSA) holds the image and catalogue data products generated by the Wide Field Camera (WFCAM) on UKIRT. The primary contents of the archive will originate from the UKIRT InfraRed Deep Sky Surveys (UKIDSS): Large Area Survey, Galactic Plane Survey, Galactic Clusters Survey, Deep Extragalactic Survey and the Ultra Deep Survey.

Following WFCAM commissioning, survey data will be released in phases, firstly to the UKIDSS community and then to the public (see **data policy**).

In addition to the UKIDSS data currently held in the archive (**see surveys page**) a small amount of data have been made publically accessible to non-registered users, **see public data**.

Picture: Early Commissioning - Central region of a full tile, showing dramatic clouds of gas and dust illuminated by stars in the southern half of the Orion nebula. This is an image at three infrared wavelengths (red represents narrow-band emission from molecular hydrogen gas at 2.12 microns, green represents K-band emission at 2.2 microns, and blue represents J-band emission at 1.25 microns).
Credit: Joint Astronomy Centre. Data processing by Dr Chris Davis and Dr Watson Varricatt.

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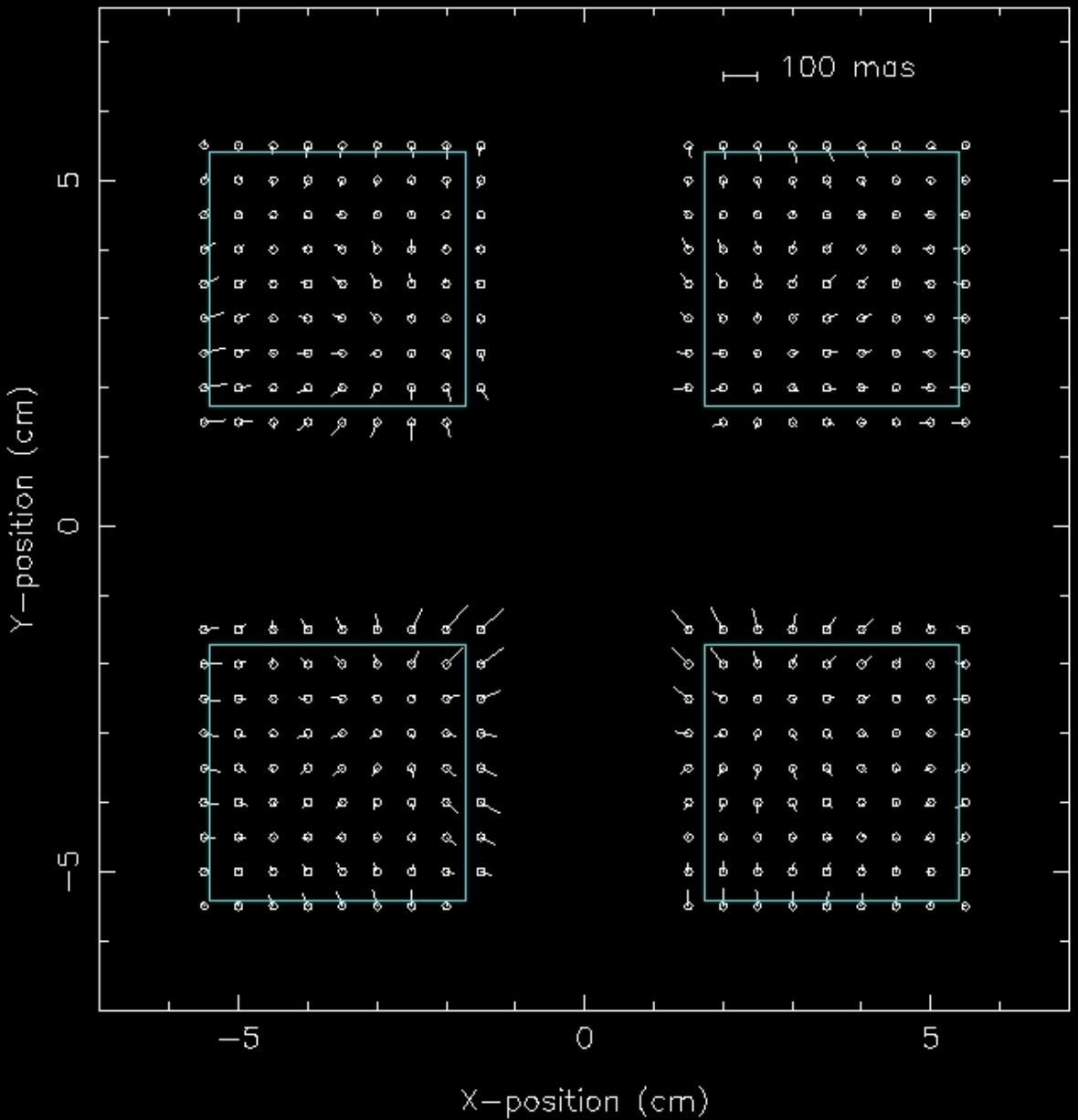
or +44 131 668 8100 (switchboard)

wsa-support@roe.ac.uk
30/1/2006

http://surveys.roe.ac.uk/wsa

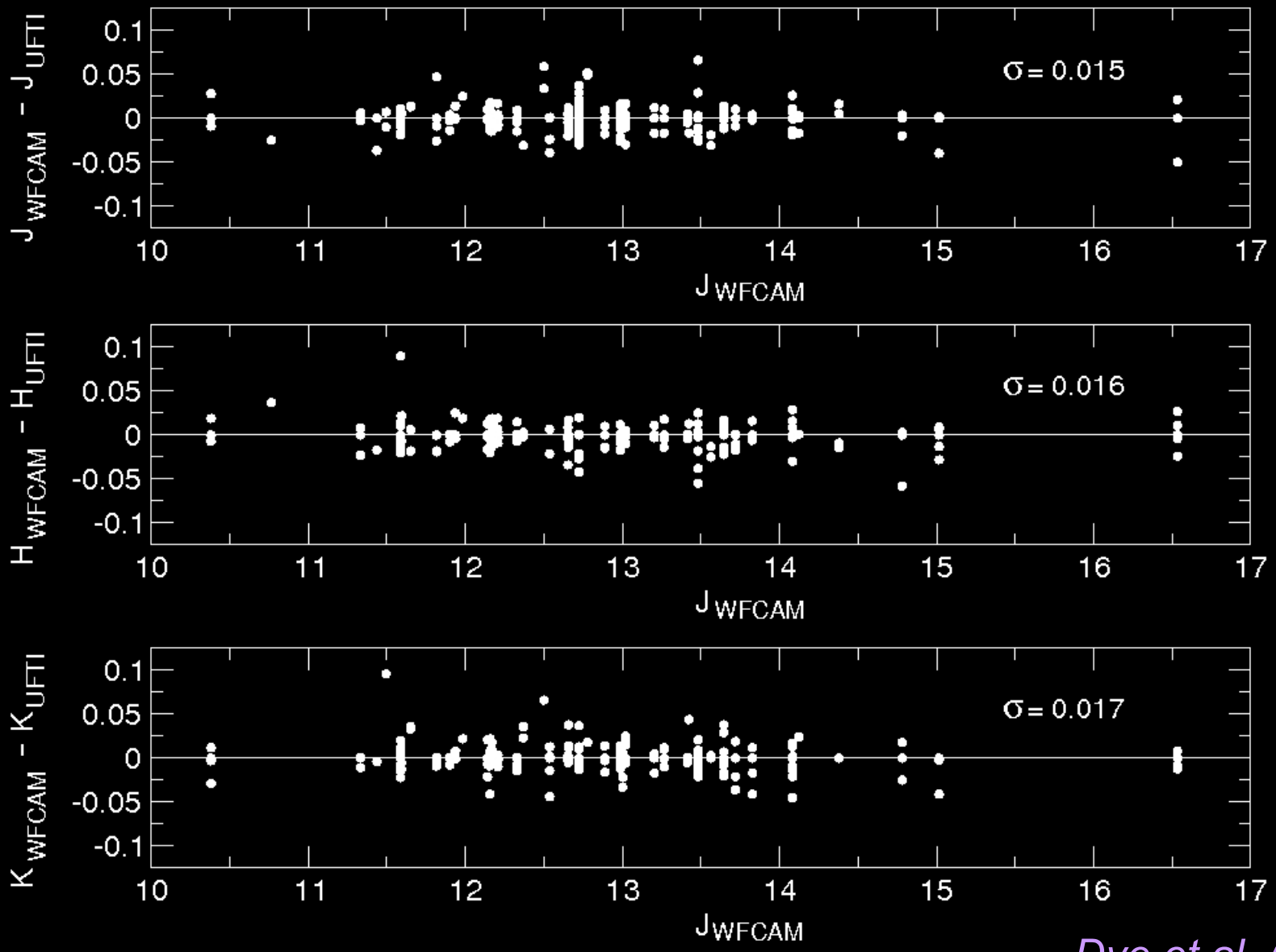
UKIDSS astrometry



- Comparison with 2MASS
- ZPN projection (radial distortions)
- σ = 23mas

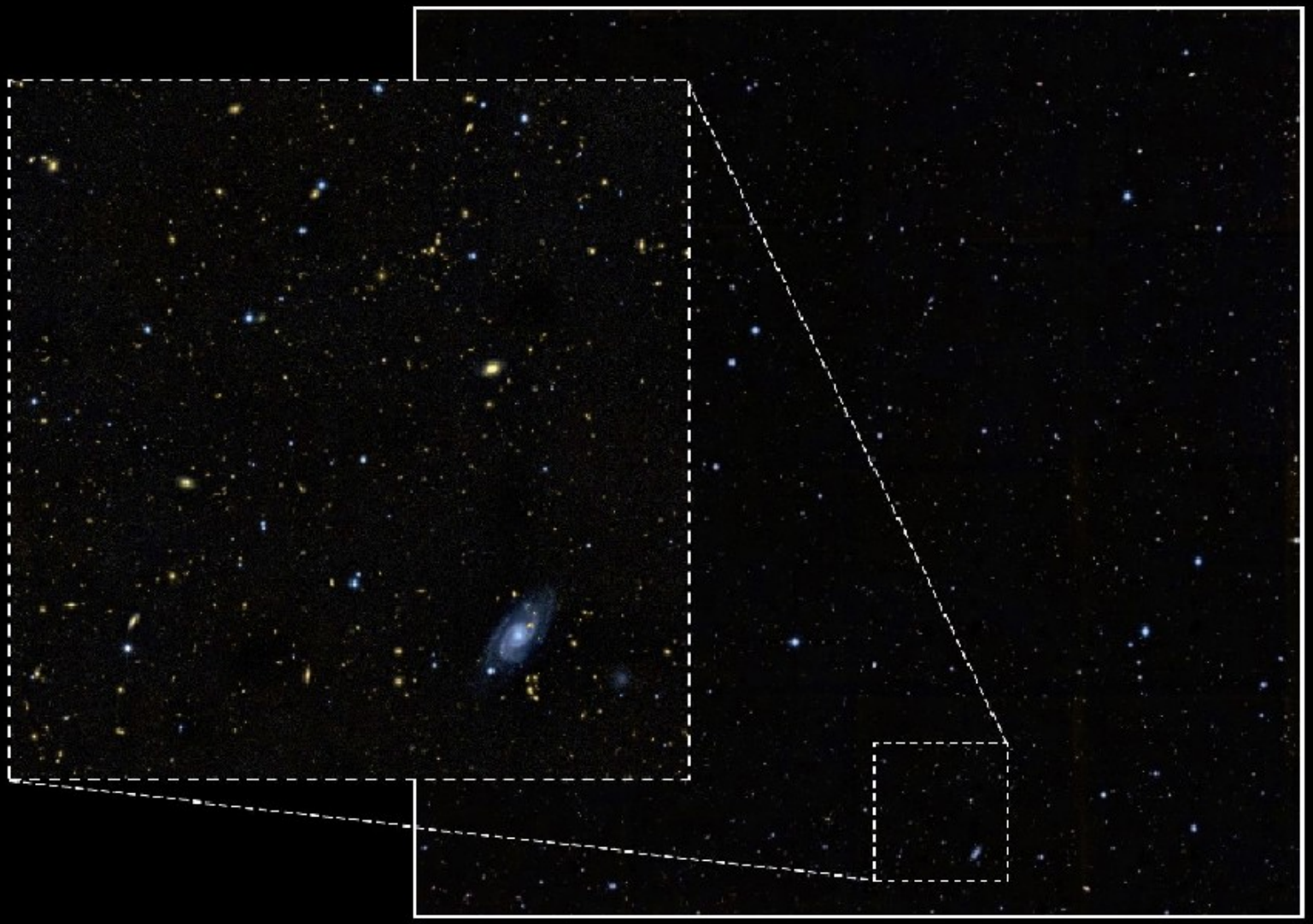
Dye et al. (2006)

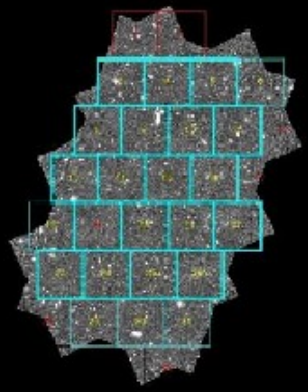
UKIDSS photometry



Dye et al. (2006)

The UKIDSS Ultra-Deep Survey





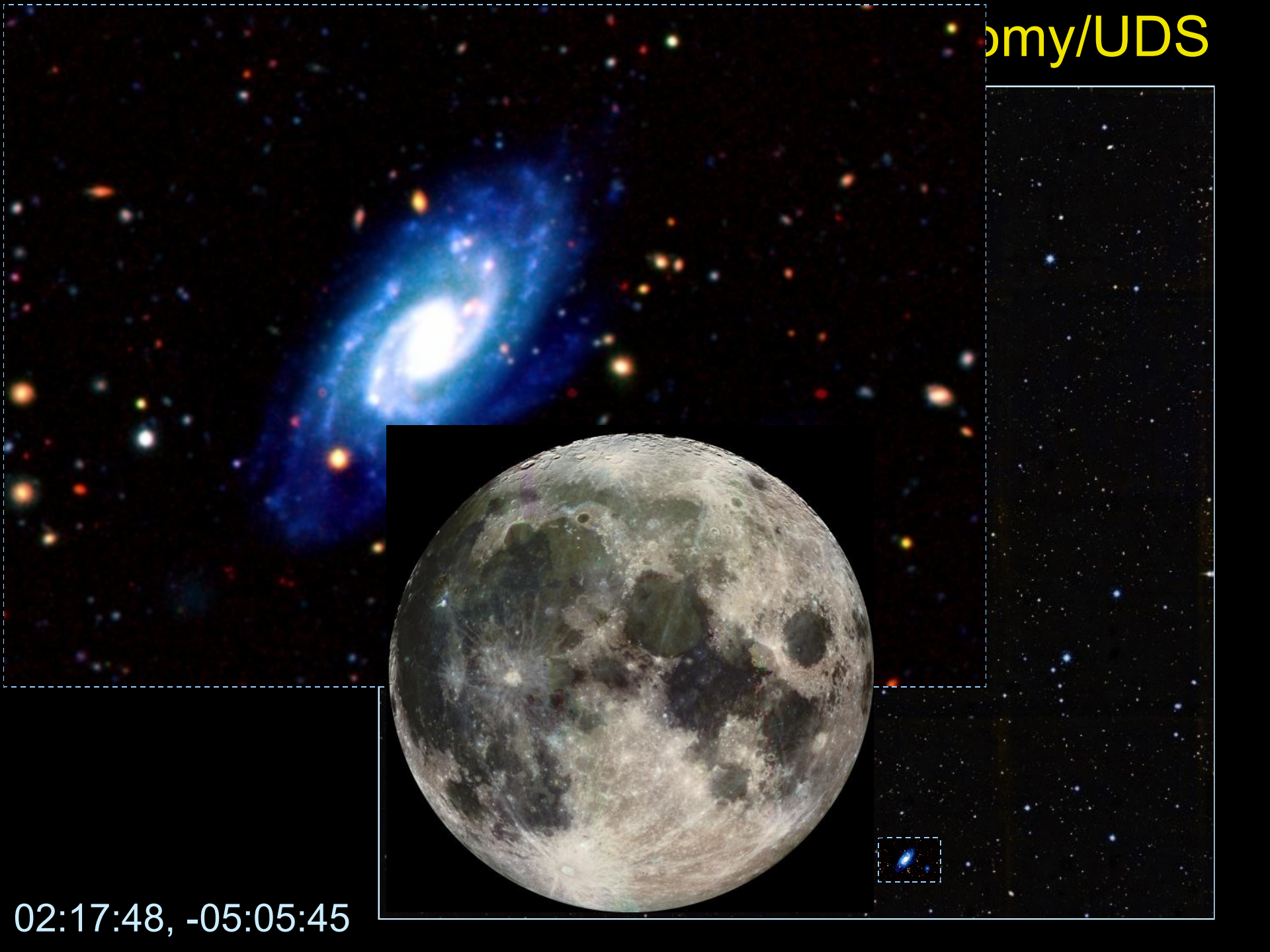
GOODS

x20

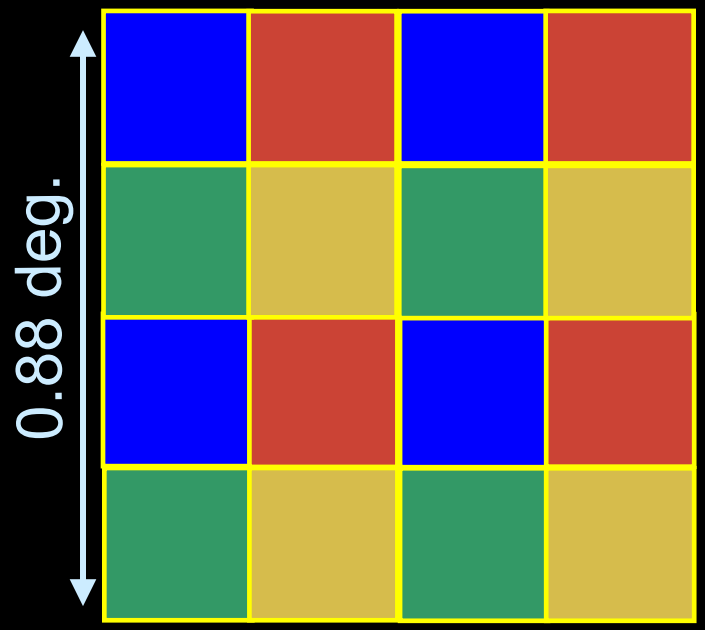
FIRES

x400

UKIDSS UDS


omy/UDS
02:17:48, -05:05:45

The UKIDSS Ultra-Deep Survey



Depths achieved so far:

(5σ, 2" apertures, AB)

DR3: K_{AB}=23.8, H_{AB}=23.4, J_{AB}=23.5

seeing : J~0.90'' H~0.85" K~0.75''

Almaini, Foucaud et al. (in prep.)

DR1: K_{AB}=23.6, J_{AB}=23.5

seeing : J~0.90'' K~0.75''

Warren et al. (2007)

EDR: K_{AB}=22.6, J_{AB}=22.6

seeing : J~0.80'' K~0.70''

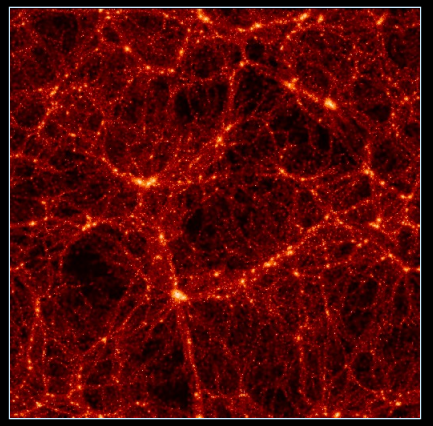
Dye et al. (2006); Foucaud et al. (2007)

World wide public

(in january 2008)

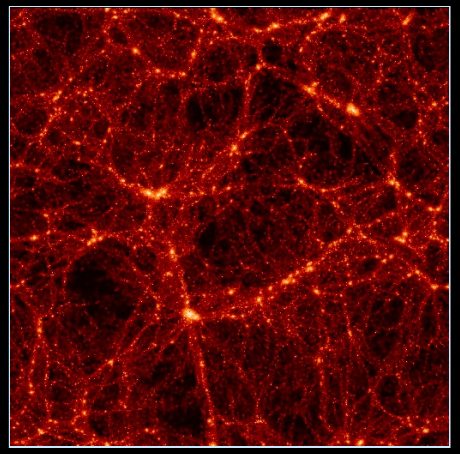
Key goals of the Ultra-Deep Survey

- When are galaxies assembled?
  - detailed luminosity functions from 1<z<6
- High-z galaxy mass function
  - Model SEDs (u,b,v,r,i',z',J,H,K + Spitzer)
- How do galaxy properties evolve with time?
  - Formation of the red sequence
  - Morphologies, prevalence of AGN etc.
- Large-scale structure
  - provides probe of dark matter halos
  - evolution of clustering & bias



Summary of UDS scientific results

- Detection of luminous LBGs at z>5
  - McLure et al. (2006), MNRAS, 372, 357
- Study and selection of EROs
  - Simpson et al. (2006), MNRAS, 373, L21
- Selection of high-z groups and clusters
  - van Breukelen at al. (2006), MNRAS, 373, L26
- Strong clustering of bright DRGs
  - Foucaud et al. (2007), MNRAS, 376, L20
- Compton-thick quasars at high redshift
  - Martínez-Sansigre et al. (2007), MNRAS, 379, L6
- Colour selection of high-z galaxies
  - Lane et al. (2007), MNRAS, 379, L25
- K-band luminosity function to z=2
  - Cirasuolo et al. (2007), MNRAS, 380, 585
- Clustering of 24μm-selected galaxies
  - Magliocchetti et al. (2008), MNRAS, 383, 1131
- FIR/Radio correlation at high redshift
  - Ibar et al. (2008), accepted, astroph/0802.2694
- Space density and clustering of passive galaxies
  - Hartley et al. (2008), submitted
- Etc…



UDS at a glance

Foucaud et al. (2007)
Almaini, Foucaud et al. (in prep.)

- 10 sec. exposures
- 3x3 microstepping – 0.133”/pixel
- 9-point jittering
- Random shift of the field centre within 1arcmin

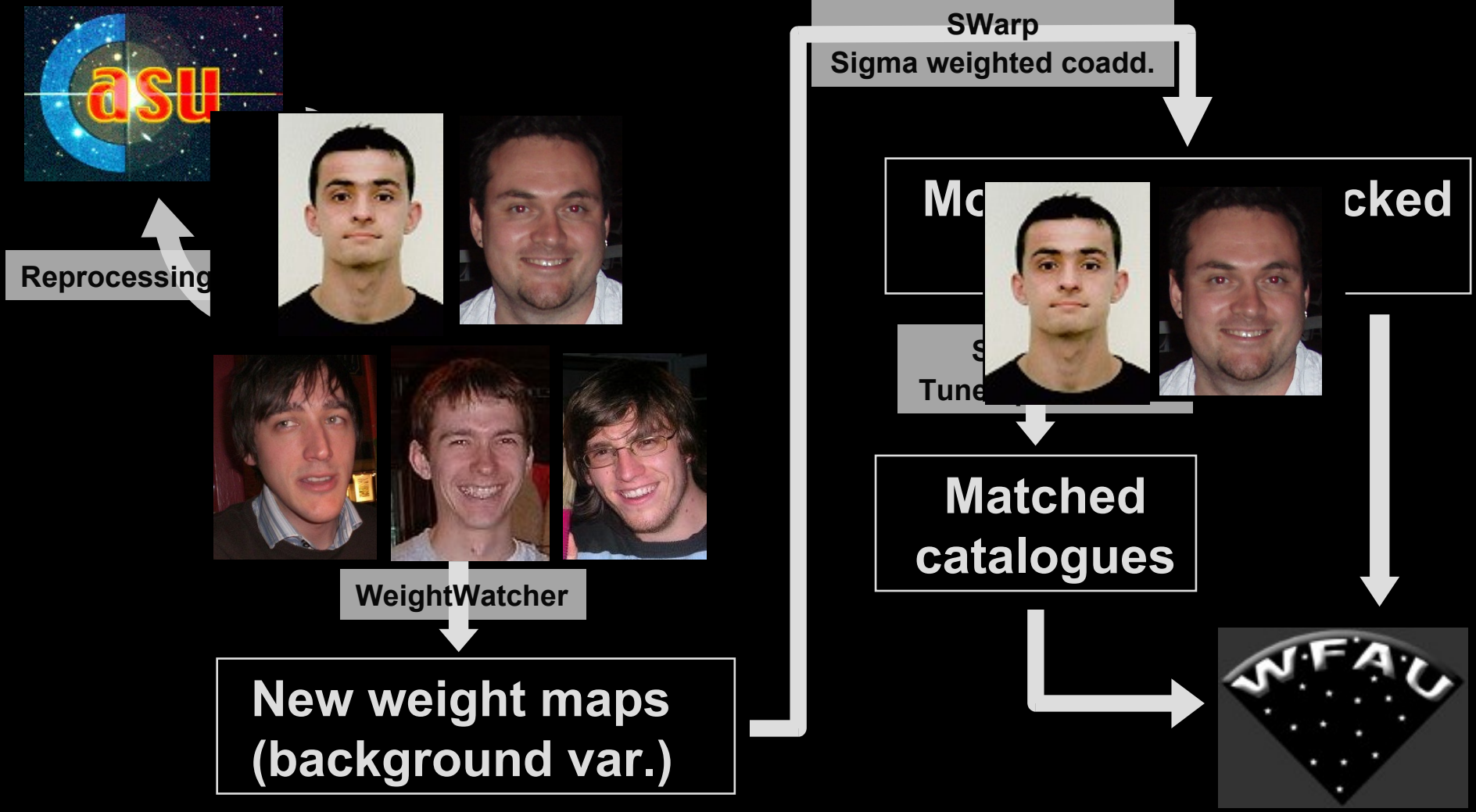
- K-band: seeing<0.8”
- J-band: seeing<1.0”

  μ_J<16 mag/arcmin^2
- H-band: seeing<1.0”

- 0.77 deg^2
- 02:17:48, -05:05:45

The Nottingham "pipeline"

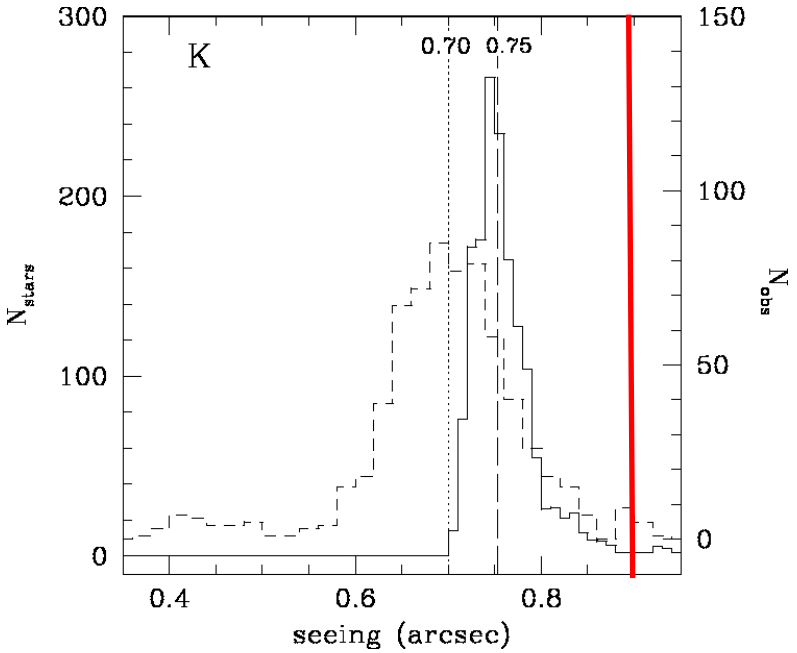
Almaini, Foucaud et al. (in prep.)

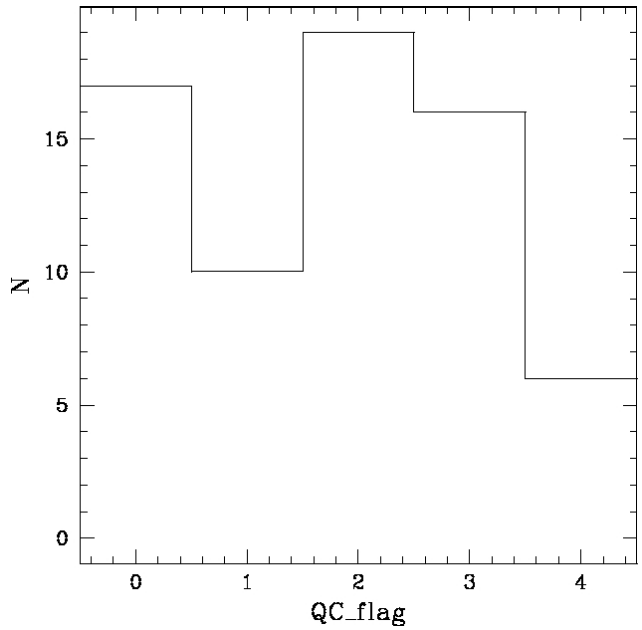


WeightWatcher, SWarp and SExtractor are TERAPIX products

http://terapix.iap.fr

UDS Quality Control





Almaini, Foucaud et al. (in prep.)

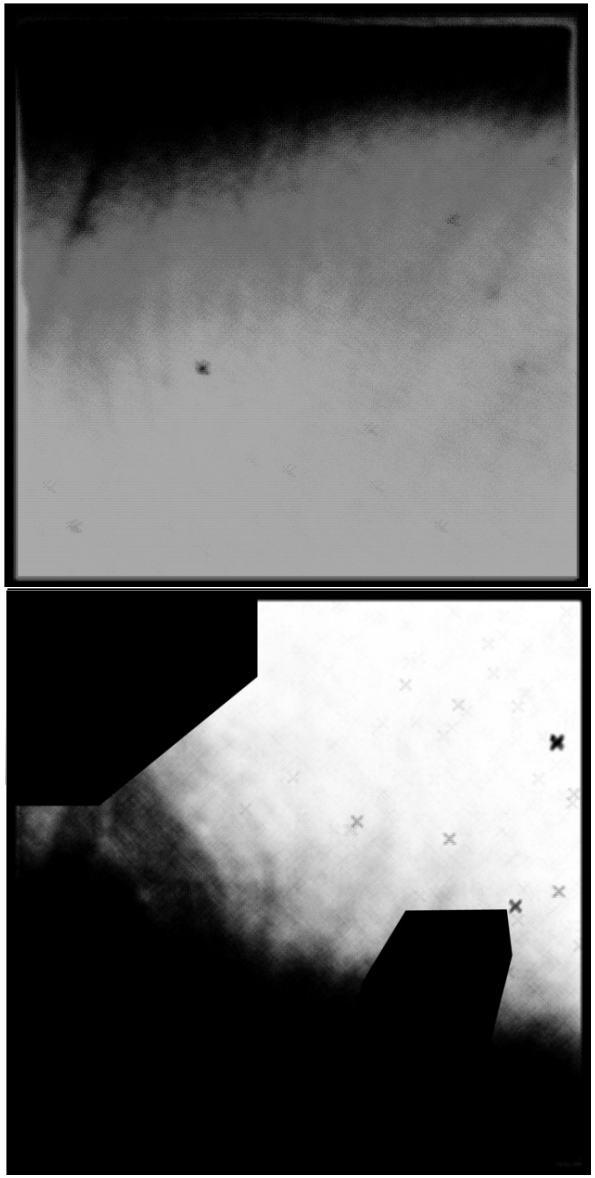
- Detailed look at individual interleaved stacks and flagging
- Conservative masking and border trimming
- Seeing rejection: in K seeing<0.9”

  none in J and H
- ~35% of images taken in bad weather contitions in K, and ~10% in J and H
- after QC:

  in K ~25% rejected, in J and H ~5-10%
  - high sky background
  - data-reduction issue
  - moon contamination
  - guide-star lost

Confidence maps, trimming and masking

Almaini, Foucaud et al. (in prep.)



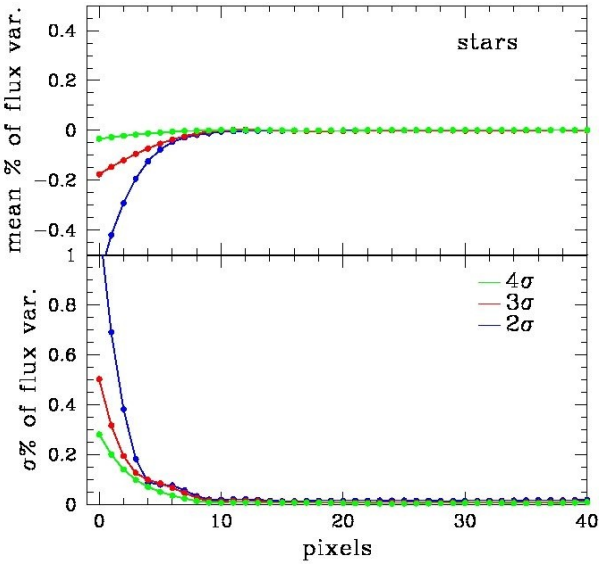
- Confidence maps from CASU: normalised inverse variance weight-map
- Weighted with the background variance of each interleave stack

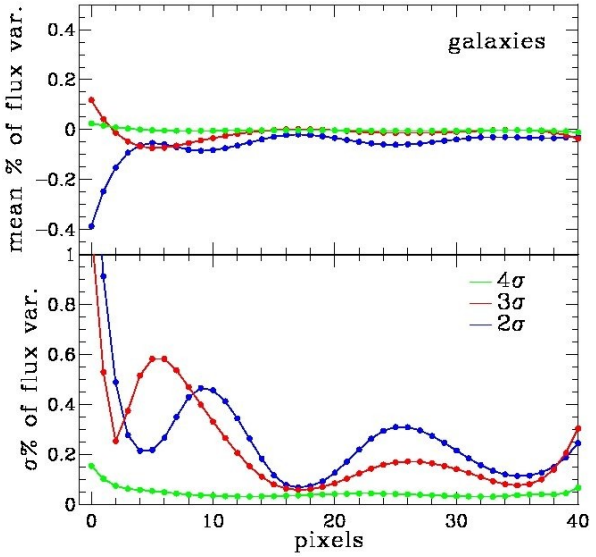
- Conservative trimming of borders
- Masking of “bad” areas

- Implementation through Weightwatcher

SWarp sigma-clipped coaddition

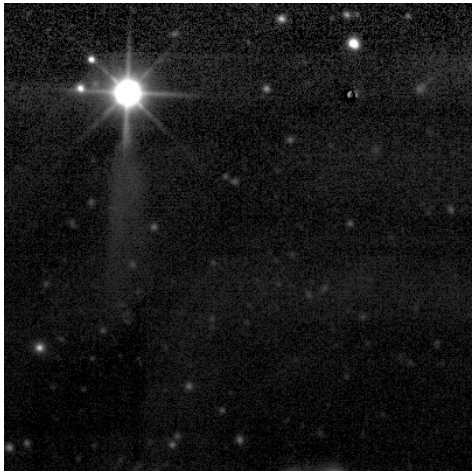
Almaini, Foucaud et al. (in prep.)





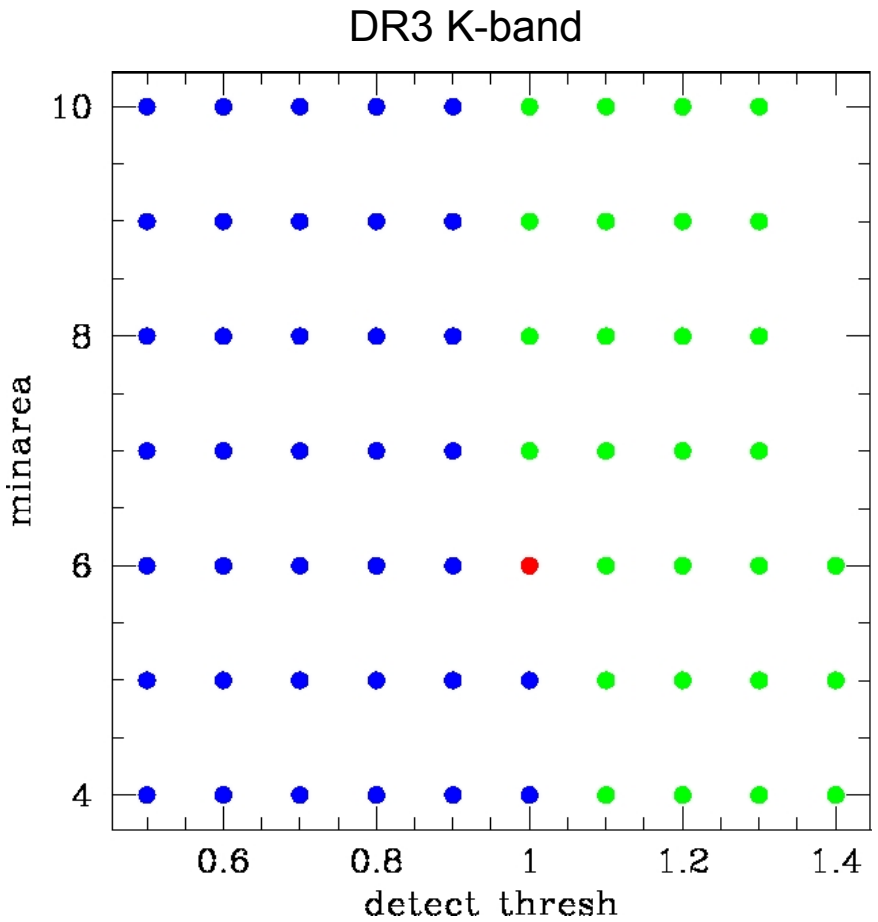
- Using a sigma-clipping rejection method
- Typically ~25 frames coadded
- Modification of SWarp

- 3σ-rejection: no noticeable impact on stars and galaxies profiles (<1%)
- Improved data quality and helped to gain in depth



SExtractor tuned parameters

Foucaud et al. (2007)
Almaini, Foucaud et al. (in prep.)

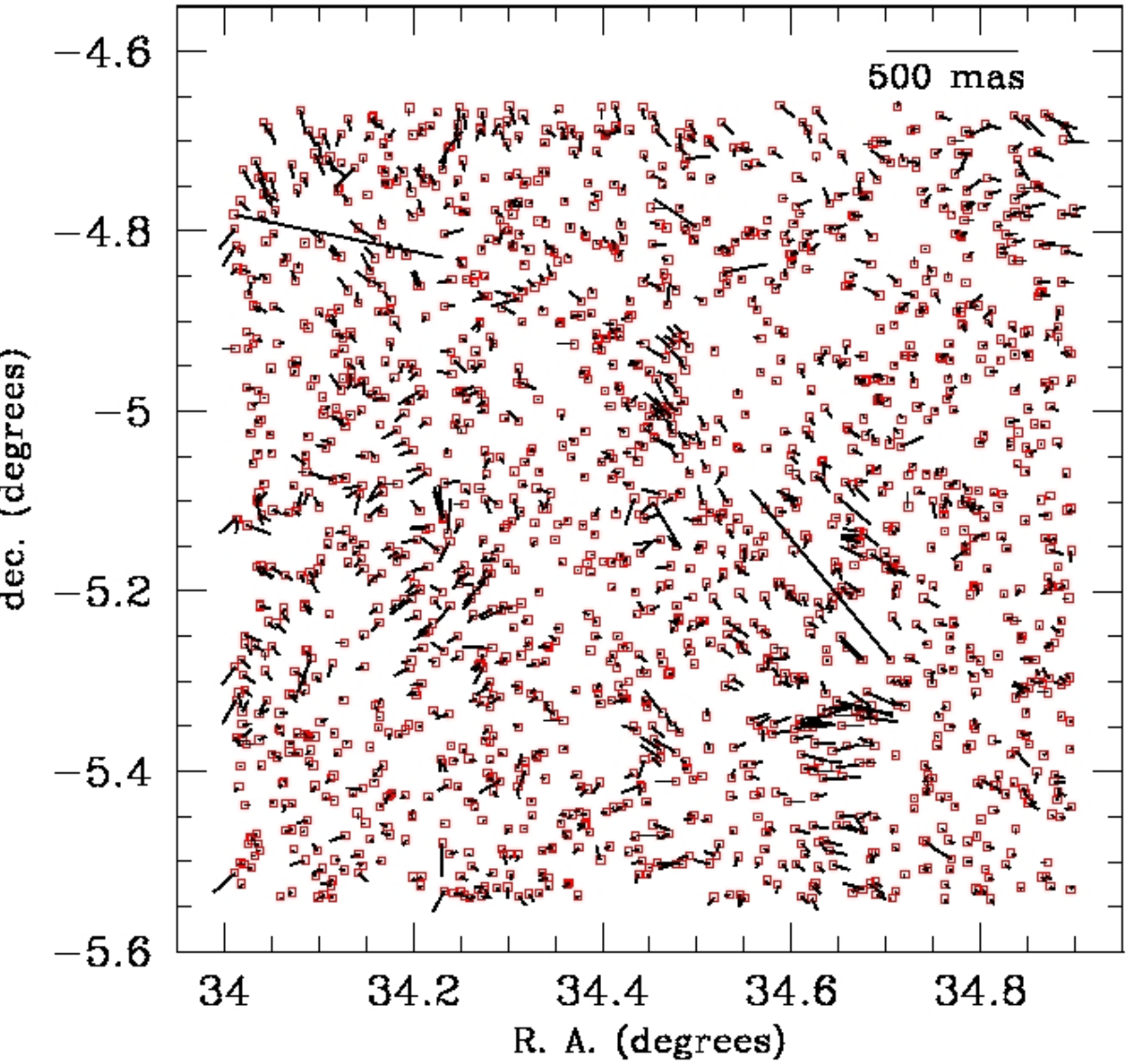


- 5σ(2”ap) magnitude limit
- Point-like sources simulations
- Completeness @ 70%
- Inverse image for spurious fraction estimation

- Best SExtractor parameters for magnitude limit and spurious<3%

UDS astrometry

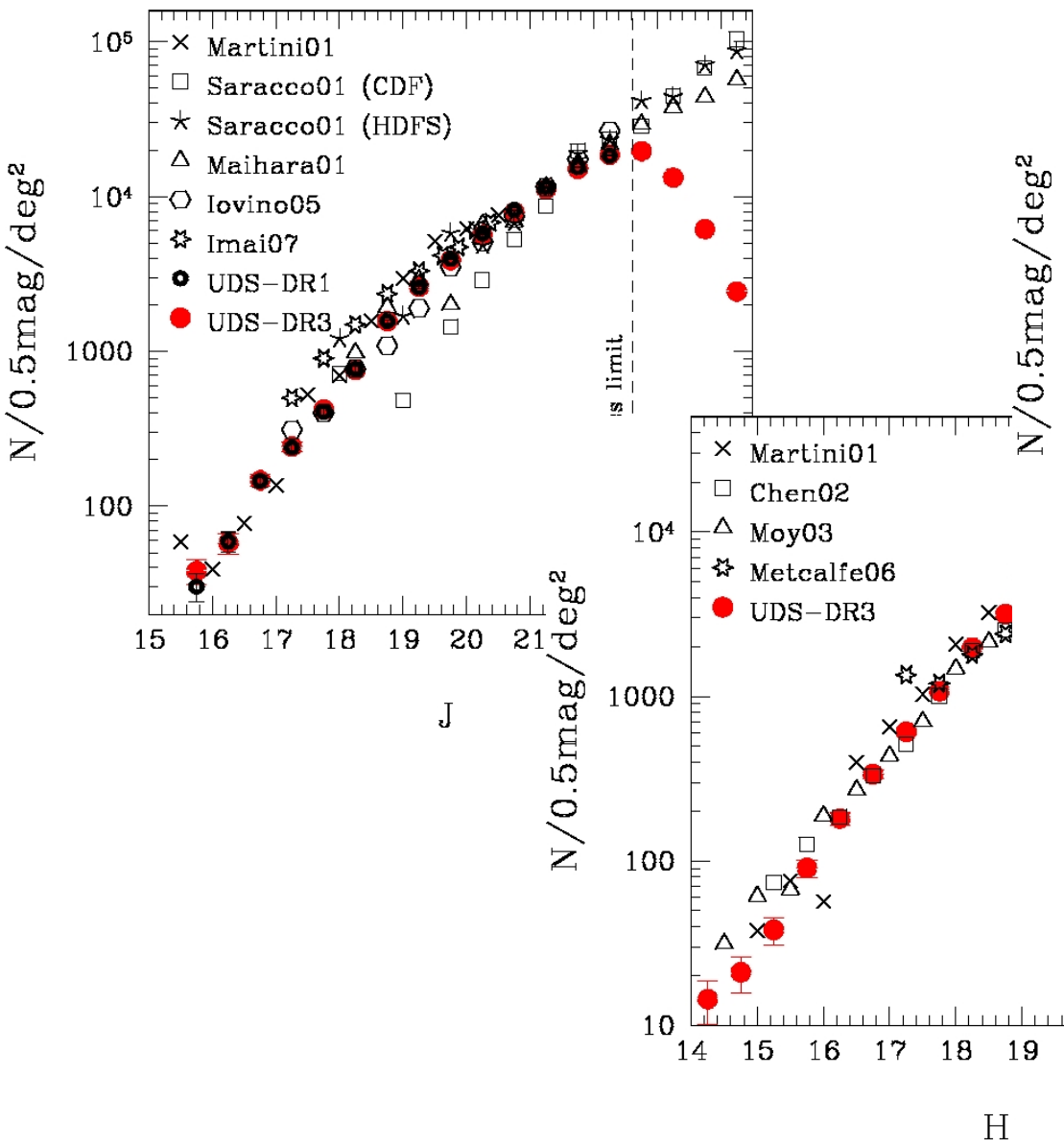
Almaini, Foucaud et al. (in prep.)



- Comparison with CASU
- TAN projection
  (no radial distortions)
- σ = 25mas (σ_{tot} = 33mas)
- On the edge of each chips high variations (<100mas)

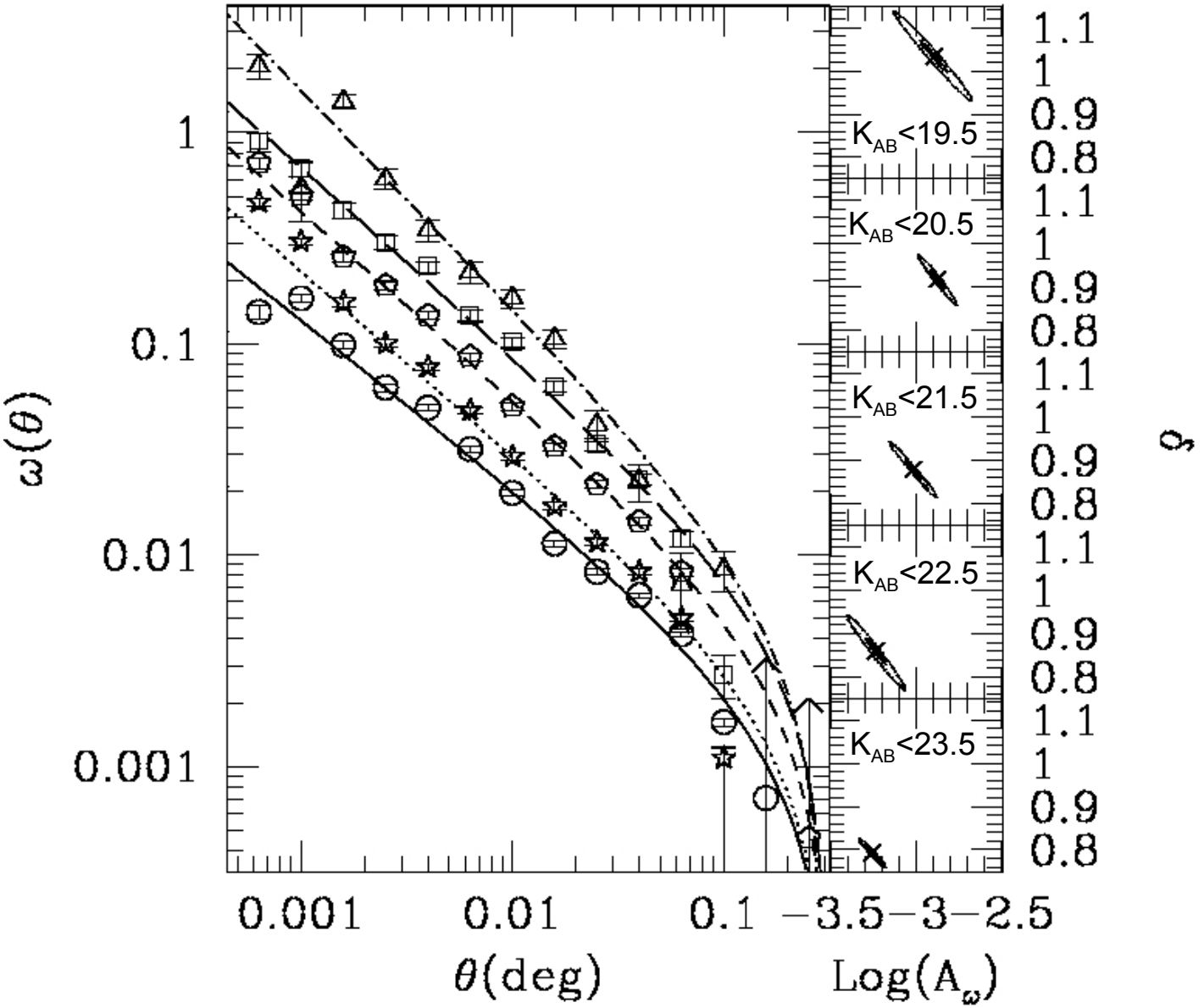
UDS galaxy number counts

Almaini, Foucaud et al. (in prep.)



Clustering of K-limited samples (DR1)

Almaini, Foucaud et al. (in prep.)



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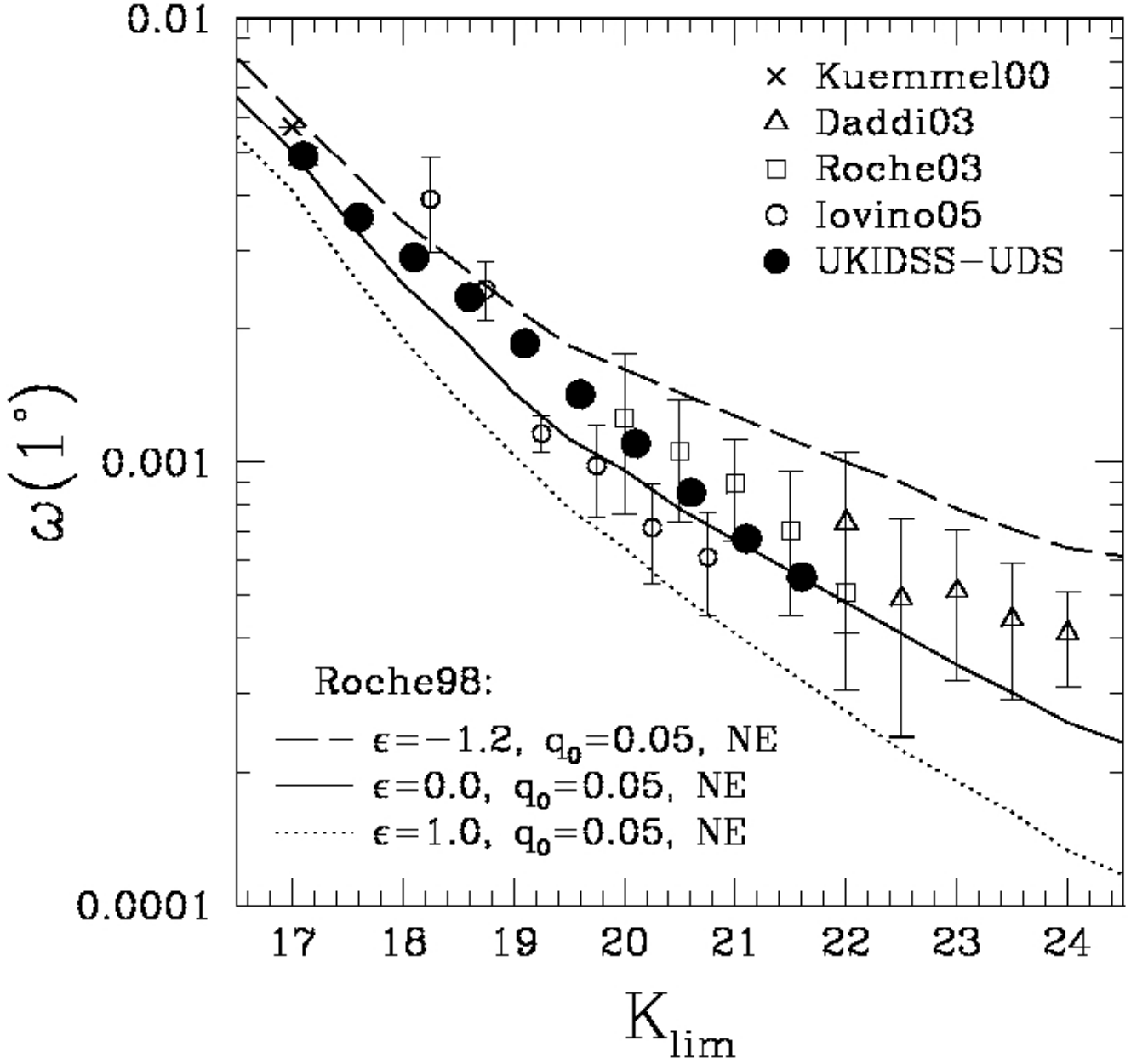


Known issues

IMAGES:

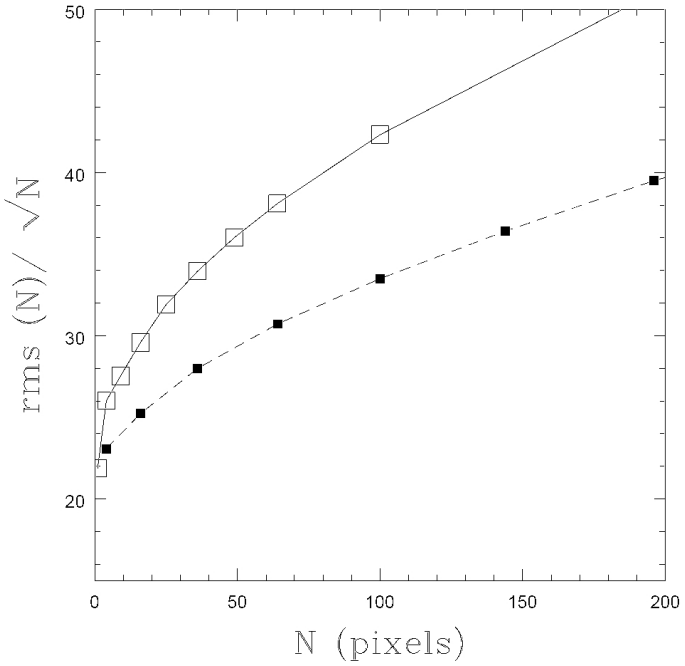
- “Hedgehogging”
- Extra background noise
- Crosstalks
- Persistence

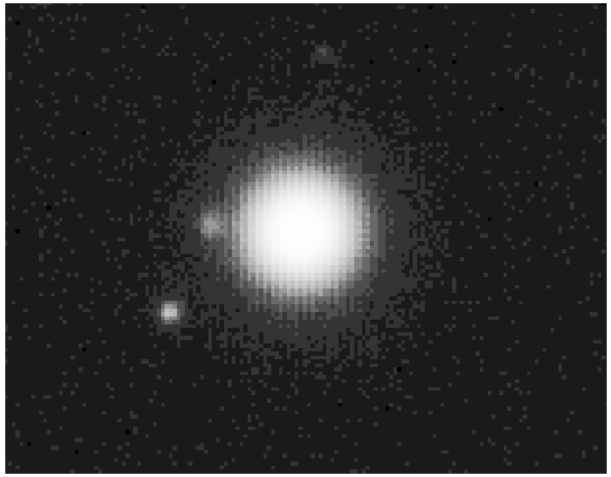
CATALOGUES:

- Bias against close pairs (deblending)

Interleave stacking

Almaini, Foucaud et al. (in prep.)





- Data undersampled (3x3 microstepping)
- Reduce drastically the amount of data to deal with
- Require ~0.1 pixel offset accuracy (generally the case)

- Extra background noise
- “Hedgehogging”

Sky-subtraction

- Scattered light within camera (*f(x,y)*)
- Artifacts fct. illumination and exposure time

- Grouping sky estimation and correction by filter, exposure time and position on the sky

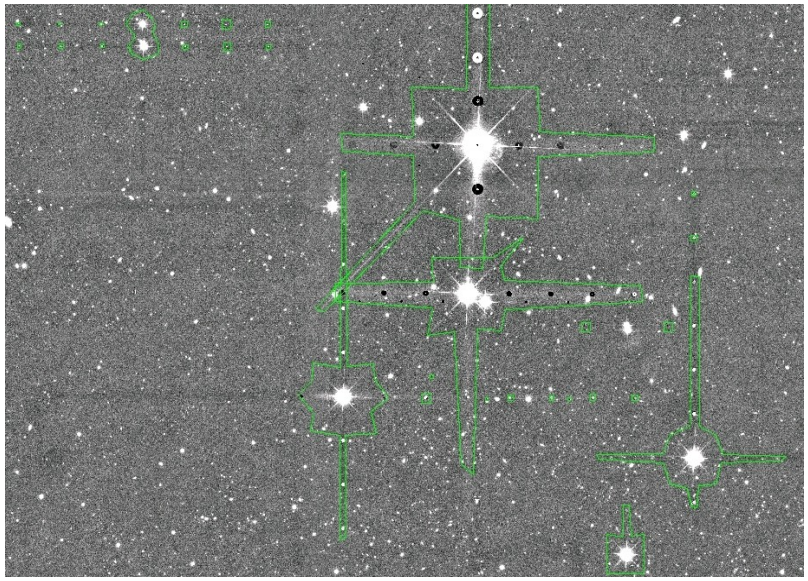
- Combination using double non-linear iteratively clipped median (roughly first a median and then a 3σ clipping)

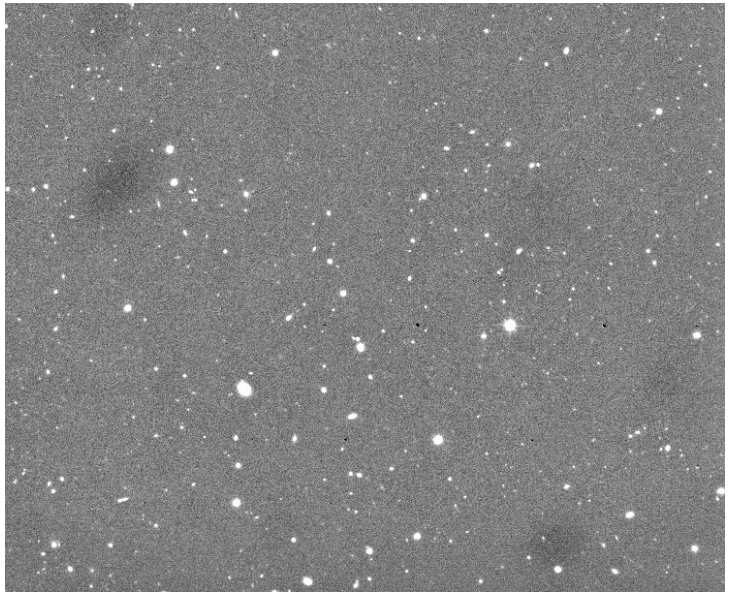
- Master sky frame formed in 2 stages:
  - Sky frames within dither offset and microstep sequence combined
  - these intermediates are then grouped and combined

  (looking at each individual intermediate frames helps improving the final bakground removal)

Irwin et al. (in prep.)

Crosstalks and persistence



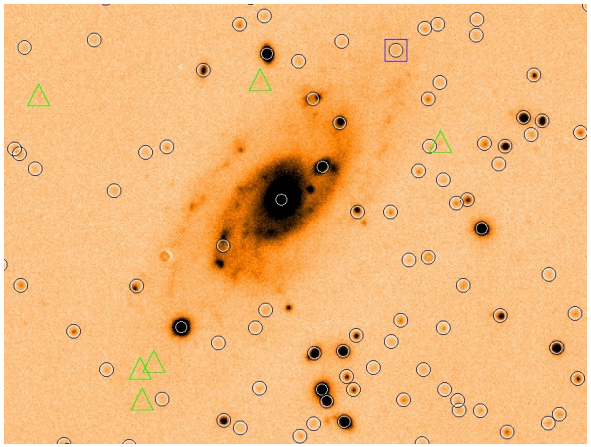


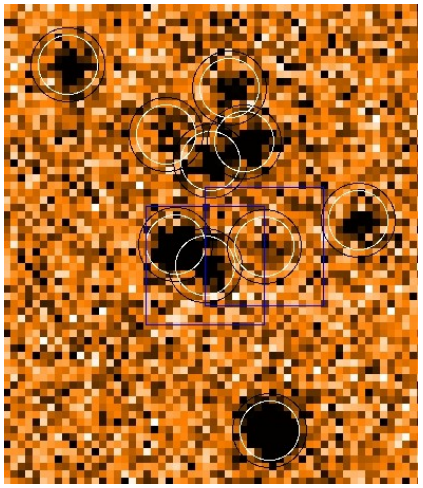
- Crosstalks: pickup in adjacent channels
  - between the 8 channels readout
  - @ (±128 pixels) xN of stars
  - ~1% of the differential flux (drop further)
  - all object with high central brightness (not only saturated stars)
- Modelling (CASU)
- Sigma-clipping (Nottingham)
- Flagging/Masking (WFAU)

- Persistence (from objects in the preceding frame)
- Flagging/Masking
- Change of observational strategy (random pattern)

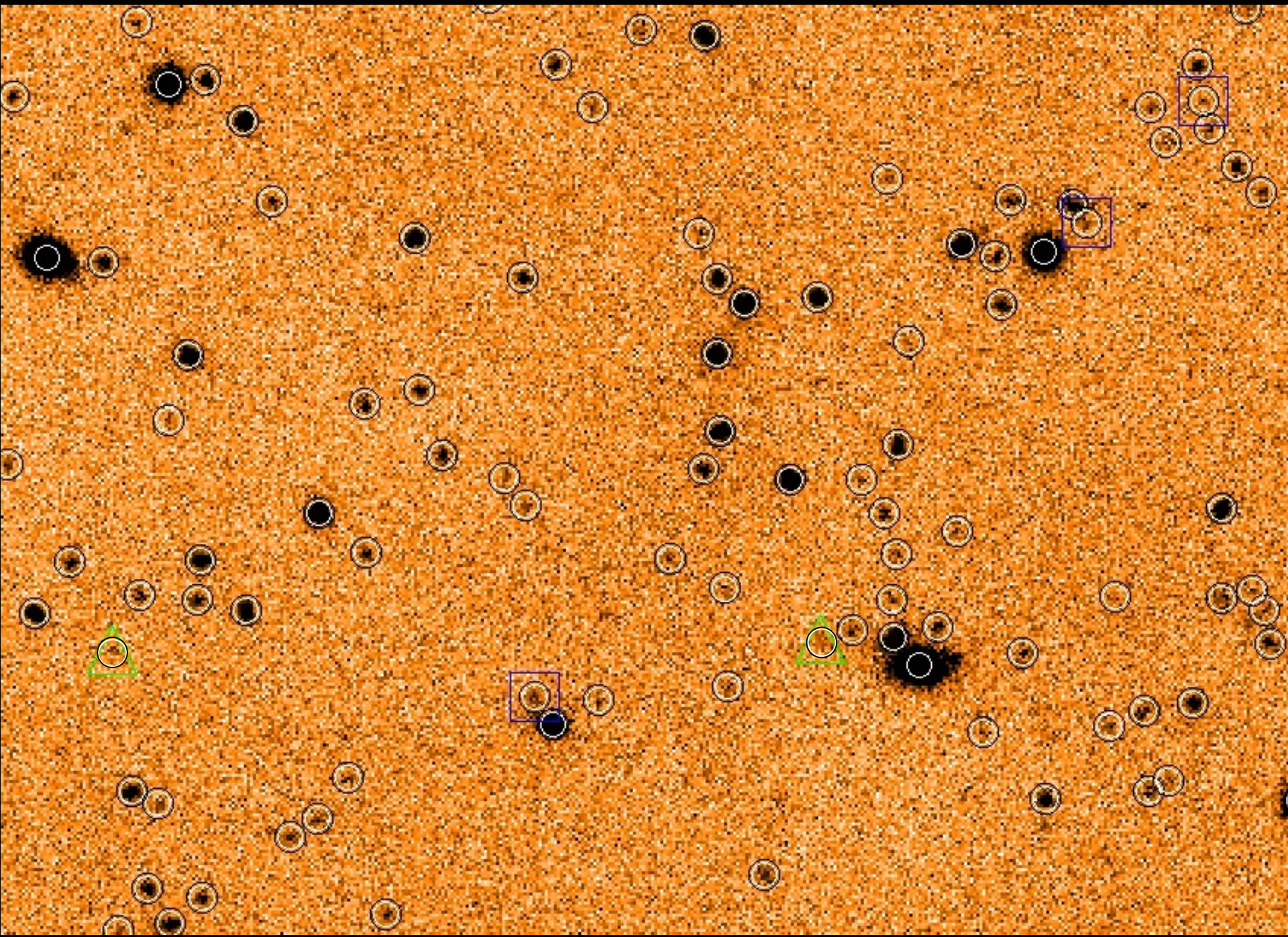
Irwin et al. (in prep.)

Catalogues: deblending issues





- Catalogues biased toward scientific goals
- SExtractor parameters tuned
- Usage of different detection filters
- Filter kernel size
  - > PSF: low surface brightness objects
  - < PSF: close pairs objects
- Official DR3 catalogue with larger kernel
- Build a alternative catalogue “best of both world”
- Going further was even more detection filters…



Lessons learned

- 2MASS ideal for the astrometry and photometry at our required level
- Large quantity of images (big computers)
- Quality control primordial (nothing can really replace the eyes)
- Avoiding interleave stacks !!!
- Sky-subtraction = critical stage of data reduction (IR)
- Sigma-clipping stacking helps a lot but “dangerous”
- Catalogues:
  - no ideal method, always biased
  - tuning helpful
  - alternative methods (variable deblending)

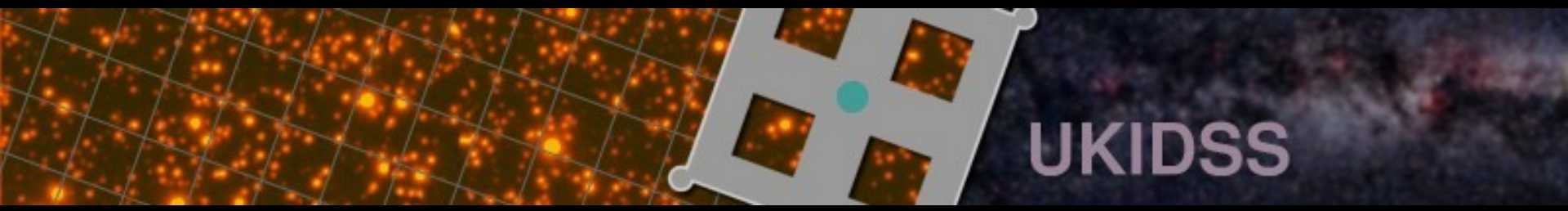
Astrowise

Pros:

- no need to deal with huge quantity of data on your disks
- fast and shareable
- direct link with “sources” (directly have access to RAW frames for instance)
- highly tested

Cons:

- No control on the software? (implementation of new stacking methods for instance)
- Quality control? (play around with images on disks)
- Tuning of parameters? (simulations)

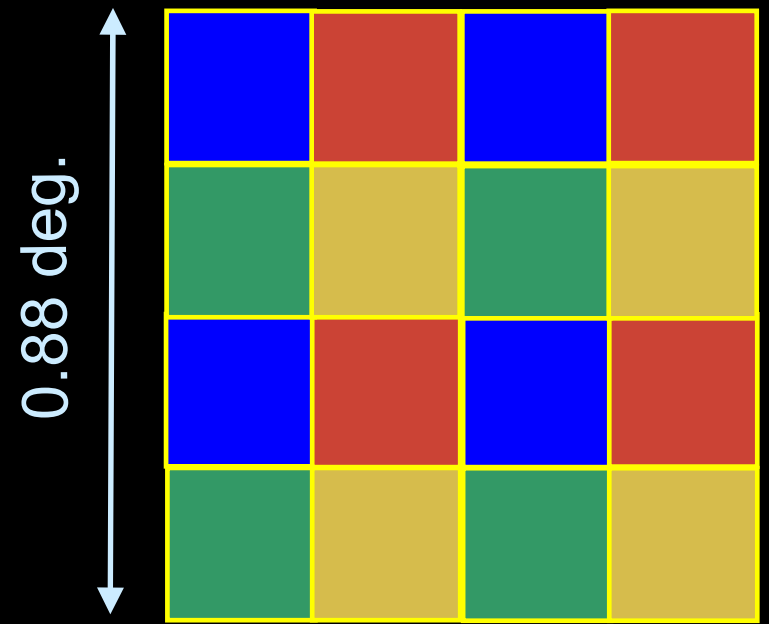


Conclusions

- UKIDSS-UDS is on-going
- DR3 available for ESO and DR1 for world
- Reach K_{AB}=23.8(23.6) H_{AB}=23.4 J_{AB}=23.5
- Improved reduction method involving TERAPIX software (WeightWatcher, SWarp, SExtractor)
- Sigma clipping coaddition
- Photometry σ~0.02mag ; Astrometry σ~33mas

The UKIDSS Ultra-Deep Survey

http://www.nottingham.ac.uk/astronomy/UDS



DR1: K_{AB}=23.5, J_{AB}=23.6

(85 hours)

World-wide public in january 2008

DR3: K_{AB}=23.7, H_{AB}=23.4, J_{AB}=23.6

(120 hours)

ESO public in december 2007

Final depth: K_{AB}=25, H_{AB}=24.7, J_{AB}=24.7

(200 nights)

Another 4 years of data to come…

…plus new spectroscopic ESO survey