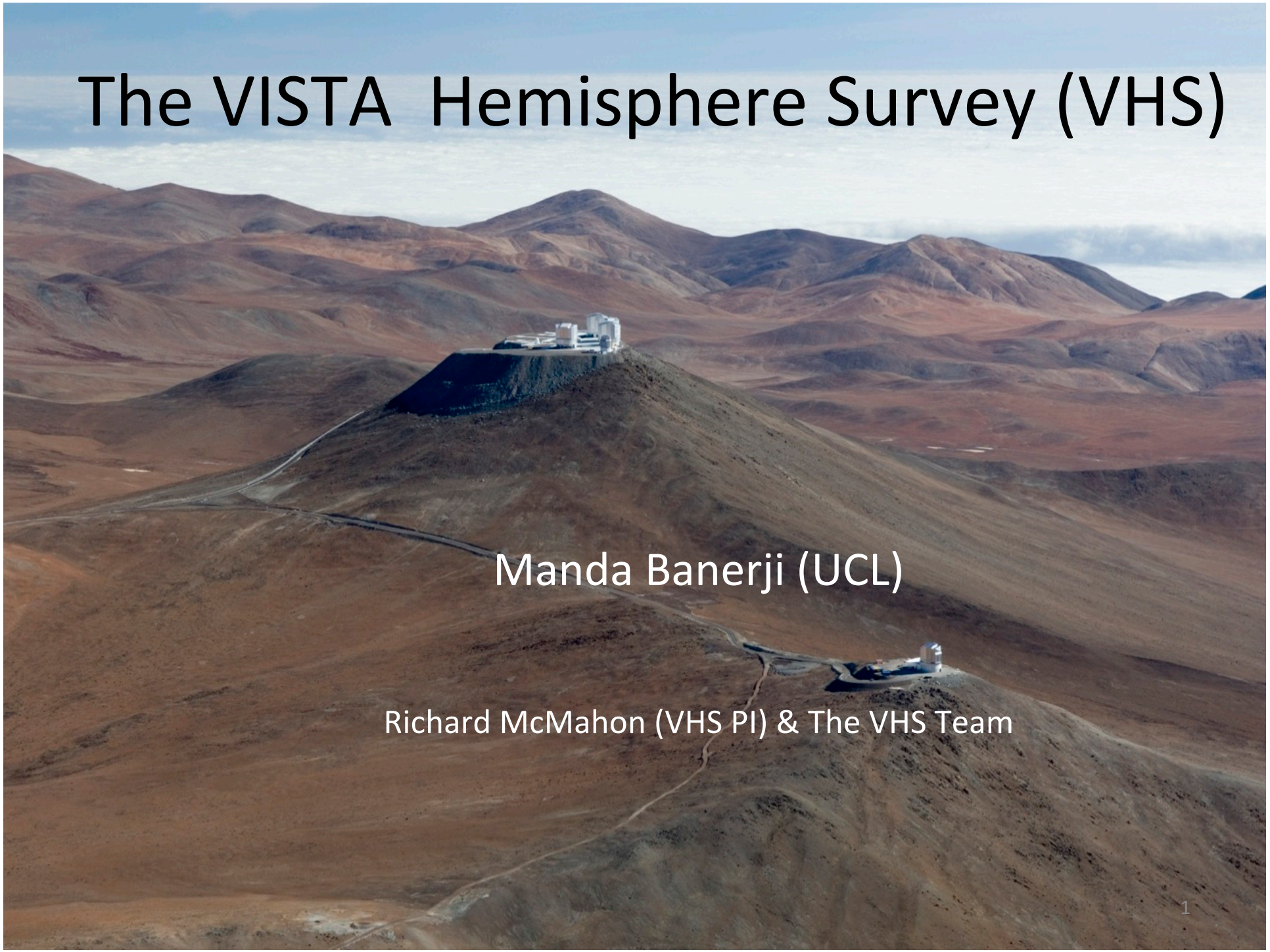
The VISTA Hemisphere Survey (VHS)



Manda Banerji (UCL)

Richard McMahon (VHS PI) & The VHS Team

Outline

- Introduction to VHS
  - Science Goals
  - Survey Progress & Data Access
- Science Highlights so far
  - Galaxy clusters at z=1
  - Cool Milky Way Dwarfs
  - Reddened Quasars
- Targets for 4MOST using DES+VHS
  - Quasar Target Selection

VHS Survey

VISTA ESO Public Surveys

- 80% of VISTA time is for large scale Public Surveys
- VISTA Hemisphere Survey: highest ranked VISTA public survey (PI: Richard McMahon)
- 3,110 clear hours (~340 clear nights) over 5 years – started 2009
- J and Ks-band coverage of entire southern celestial hemisphere not imaged by other VISTA public surveys
- Y and H-band over certain areas of sky
- Overlap with optical Dark Energy Survey (DES) & VST-ATLAS Survey

VHS Science Goals

- The nearest and lowest mass stars
- Galactic structure; formation and merger history of the Milky Way
- Evolution of large scale structure in the Universe and the nature and evolution of dark energy
- Discovery of the highest redshift quasars at z > 7 to probe EoR and baryonic content of the Universe
- A census of luminous quasars at all redshifts and the formation of the most massive supermassive black holes
- **Your science here since it is a ESO Public Survey**

- Synergy with DES, VST ATLAS, KIDS/VIKING, AKARI(Astro-F), WISE, eROSITA
- Support for ESA Survey Missions: XMM-Newton, Herschel, Planck, GAIA
- Targets for the VLT, ALMA, ELT, JWST

Survey volume compared with other near IR surveys

100 times volume of Universe compared with 2MASS
- increased depth of a factor of 40

10 times the volume of the Universe compared UKIDSS
- increased depth and area

VISTA Large (>20deg^2) Area ESO Public Surveys

Survey	Area (deg^2)	5σ point source depth (AB mag)				
		Z	Y	J	H	K_s
VHS (required depths)	**18, 000**			**21.2**		**19.8**
1. VHS-DES	4500	24.7	23.0	21.6	21.0	20.2
2. VHS ATLAS	5000		20.9	21.2	20.6	19.8
3. VHS-GPS (5°<|b|<30°)	8000			21.2		19.8
VIKING (W. Sutherland Talk)	**1,500**	**23.1**	**22.3**	**22.1**	**21.5**	**21.2**
VVV (Galactic Centre) – M. Rejkuba Talk	520	22.4	21.8	21.1	19.6	20.0
VMC (Magellanic Clouds) – M. Cioni Talk	184		23.3	23.1		23.0

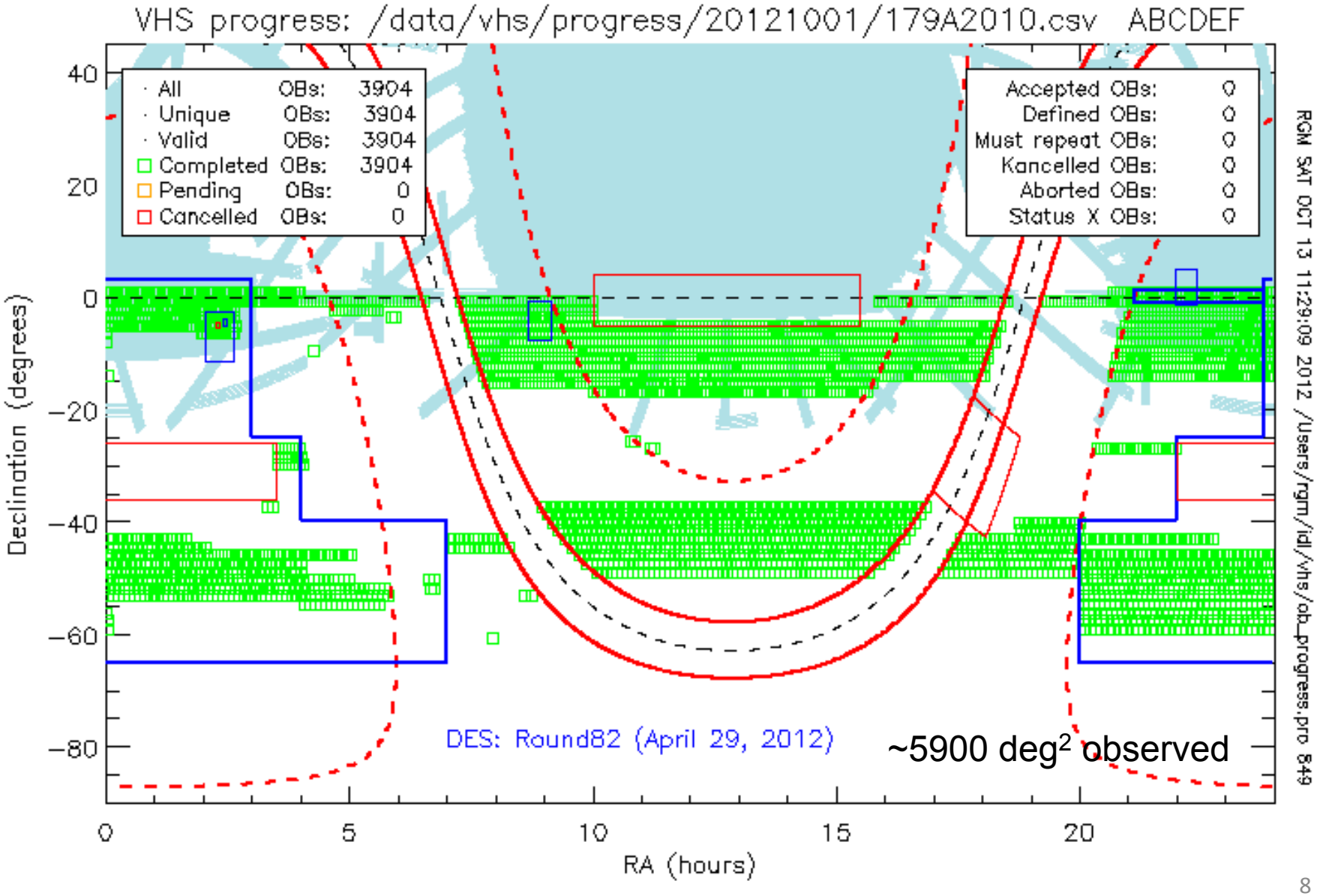
- VHS goal is full hemisphere coverage in the NIR when combined with other ESO large surveys

VHS Components

- **<u>VHS Galactic Plane Survey (VHS-GPS)</u>**
  - 5< |b| <30
  - 8200deg^2
  - J(60sec); K(60sec)
- **<u>VHS-ATLAS (cf. Optical Survey: VST-ATLAS T. Shanks Talk)</u>**
  - 5000deg^2
  - Y(60sec), J(60sec), H(60sec), K(60sec)
    - Changed April 2012 to Y(120sec), J(60sec), H(0sec), K(60sec)
- **<u>VHS-Dark Energy Survey (VHS-DES)</u>**
  - 4500deg^2 (excludes 500deg^2 from VIKING footprint)
  - J (120sec), H(120sec), K(120sec)
    - Changed April 2012 to J(240sec), H(0sec), K(120sec)

VHS observation status on Oct 1st

Each Observing Block(OB) = 1.5deg^2



VHS-DR1: Now Public

ESO – VHS Survey Data Release 1

www.eso.org/sci/observing/phase3/data_releases/vhs_dr1.html

Most Visited · Getting Started · Latest Headlines

- Observing Facilities
- Future Facilities and Development
- Observing with ESO Telescopes
- Policies and Procedures
- Telescope Time Allocation
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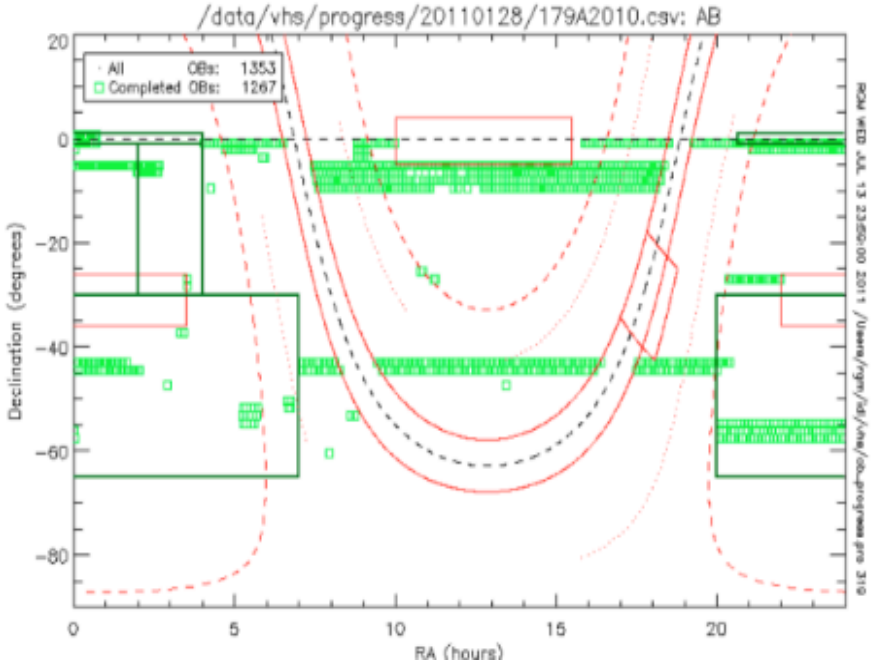
- Visiting Astronomers
- Science Software
- Data Handling and Products
- Science Archive Facility
- Science Activities
- Science and Technical Meetings
- IT Services
- Libraries
- Publications

VISTA Hemisphere Survey - Data Release 1

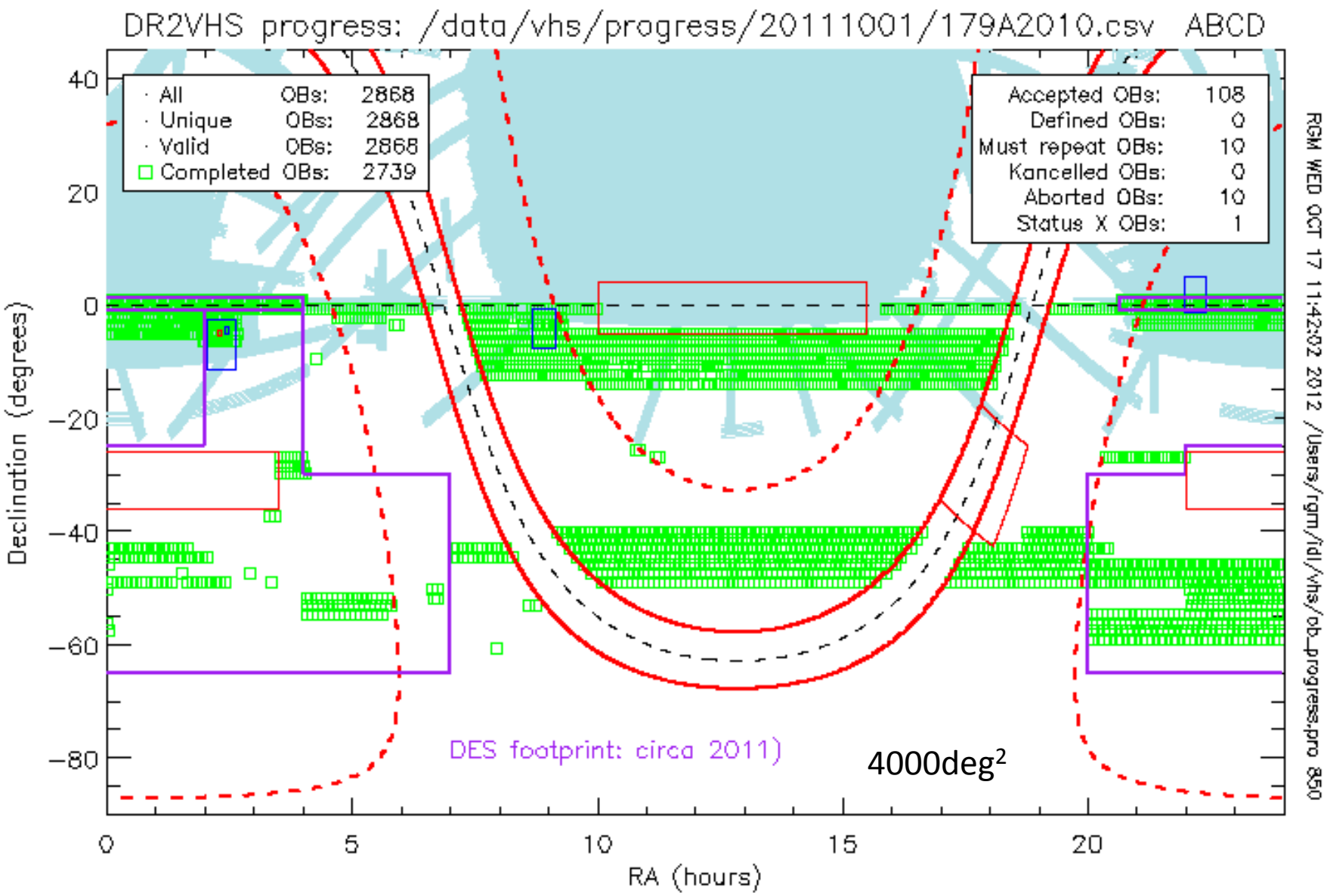
Provided by: R. McMahon, M. Banerji, N. Lodieu for the VHS Collaboration

Release Date: 17.10.2011

The aim of the VISTA Hemisphere Survey (VHS) is to carry out a near Infra-Red survey, which when combined with other VISTA Public Surveys will result in coverage of the whole southern celestial hemisphere (~20,000 deg^2) to a depth 30 times fainter than 2MASS/DENIS in at least two wavebands (J and Ks), with an exposure time of 60 seconds per waveband to produce median 5σ point source (Vega) limits of J = 20.2 and Ks = 18.1. In the South Galactic Cap, ~5000 deg^2 will be imaged deeper with an exposure time of 120 seconds and also including the H band producing median 5σ point limits of: J = 20.6; H = 19.8; Ks = 18.5. In this 5000 deg^2 region of sky deep multi-band optical (grizY) imaging data will be provided by the Dark Energy Survey (DES). The remainder of the high galactic latitude (|b|>30°) sky will be imaged in YJHK for 60 sec per band to be combined with ugriz waveband observations from the VST ATLAS survey.

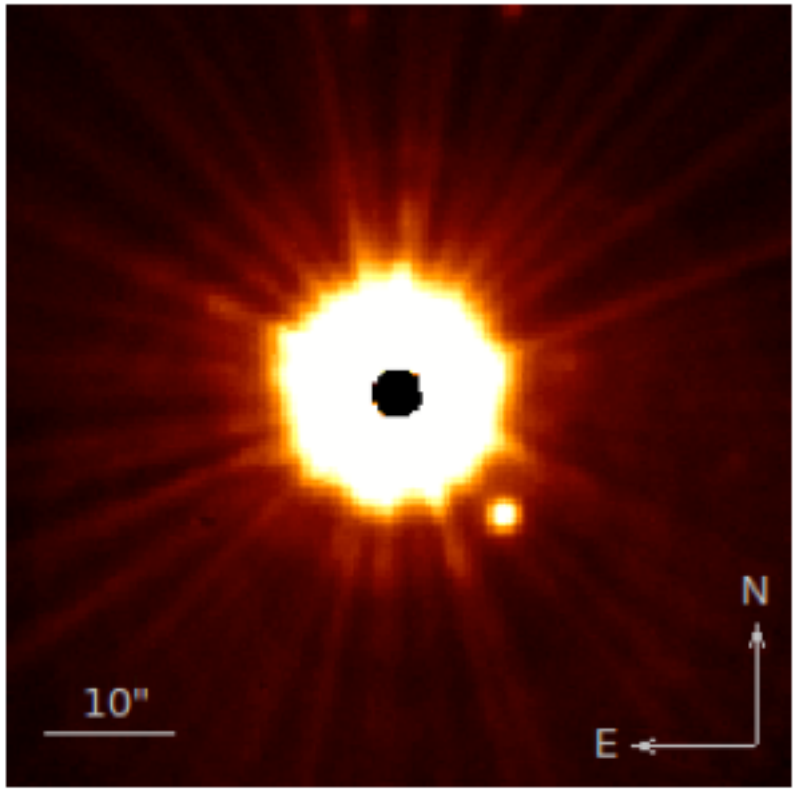


Next Public Release (observations up to 2011 Sep 30)

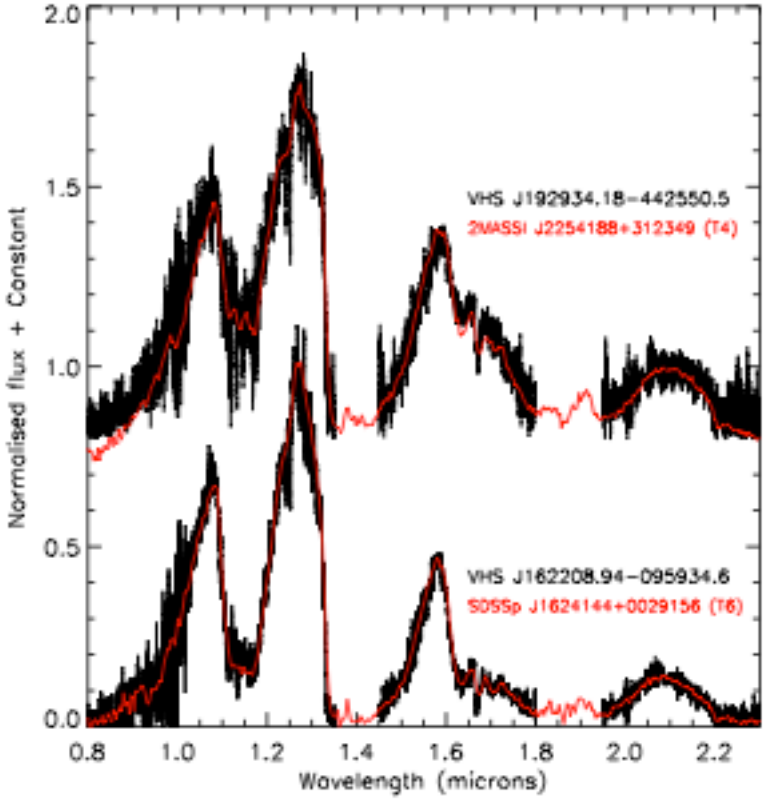


Science Highlights

LT Dwarfs in Milky Way

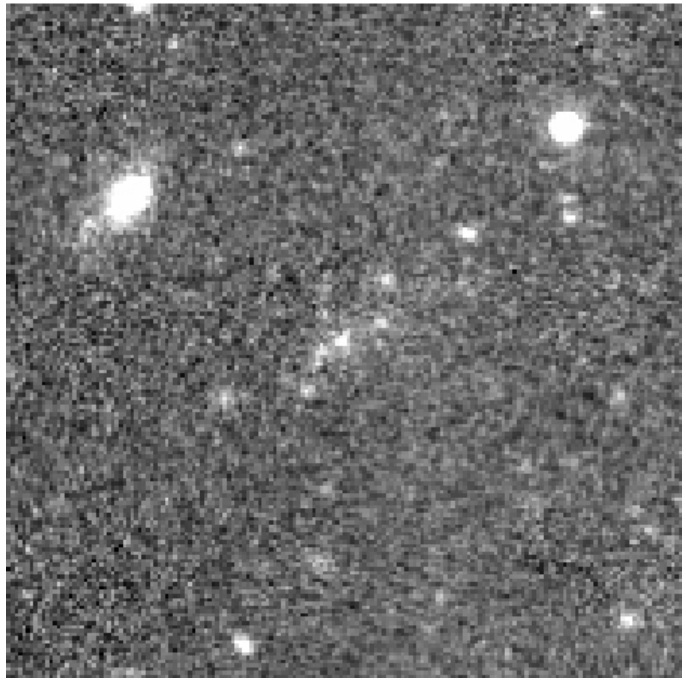


Gauza et al. (2012) arXiv: 1209.2331*: A New L-Dwarf Member of the Moderately Metal-poor Triple System HD 221356*



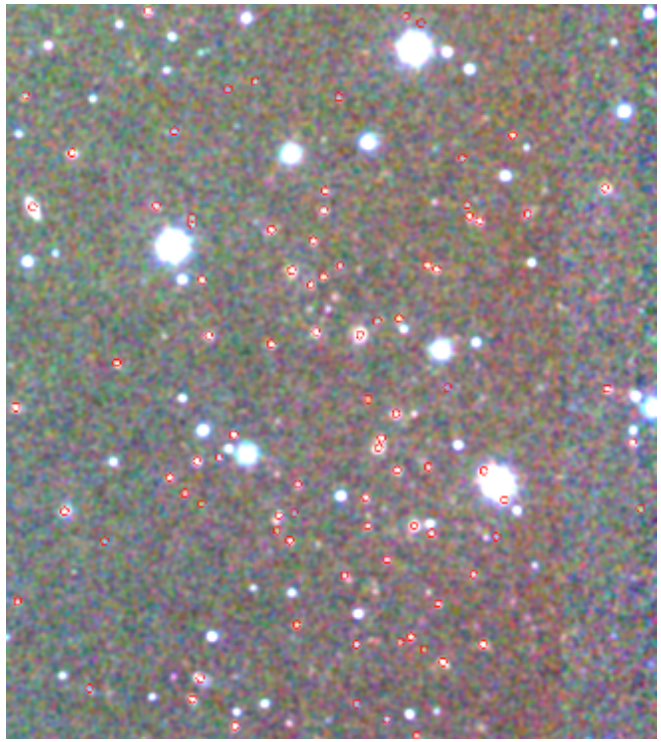
Lodieu et al. (2012) arXiv: 1210.5148: *First T-Dwarfs in the VISTA Hemisphere Survey*

SZ Selected Galaxy Clusters from South Pole Telescope



SPT-CL J0546
(z=1.06)

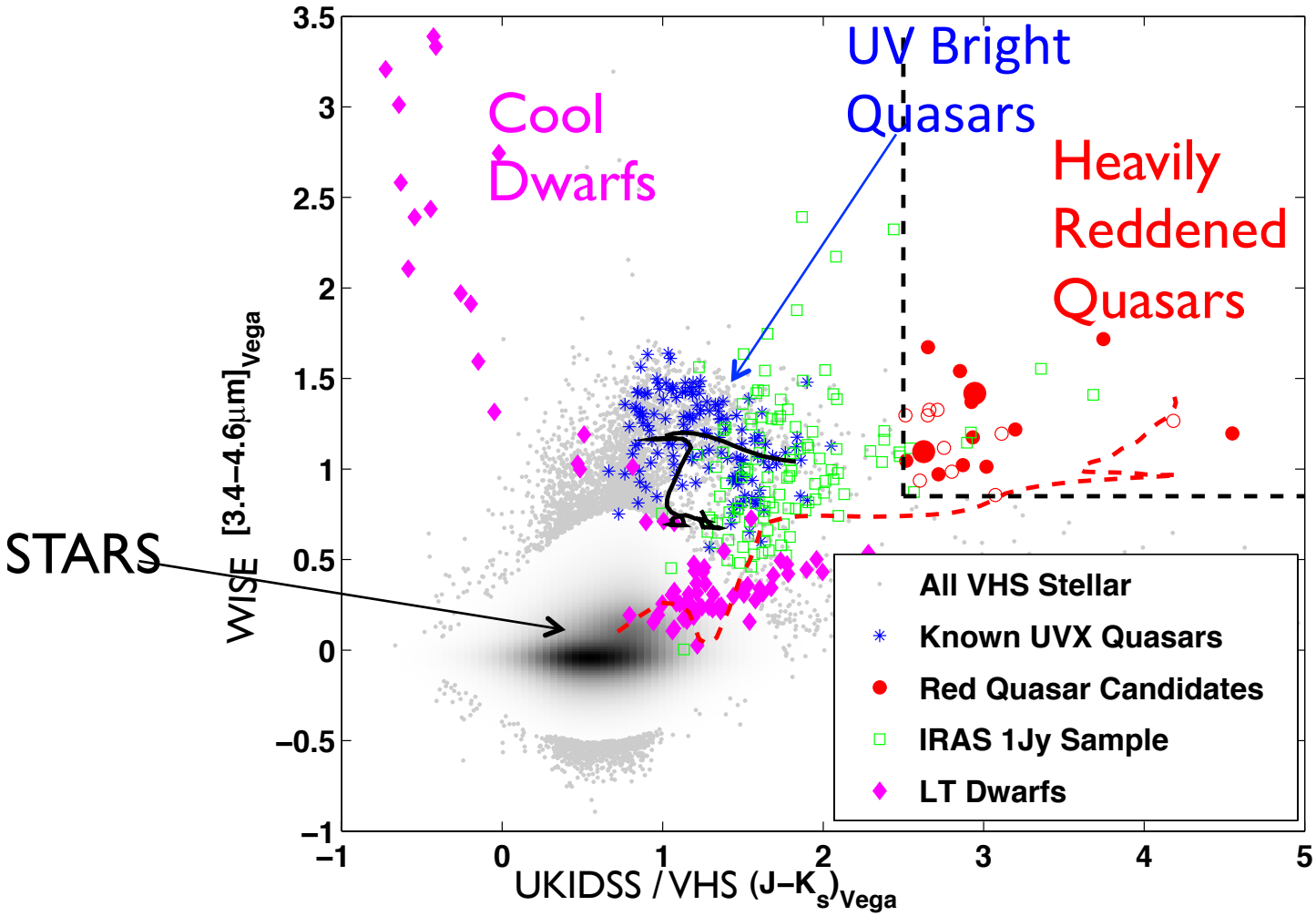
SPT-CL J2035
(z=1.02)



VHS is seeing BCGs out to z=1 – some may lie below catalogue detection threshold but forced aperture photometry can help.

Dust Reddened Broad Line Quasars at Redshift 2:

Starbursts Transitioning to UV-Luminous AGN?



K_{vega}<17.0

Not present in wide-field optical surveys like SDSS (iAB > 22)

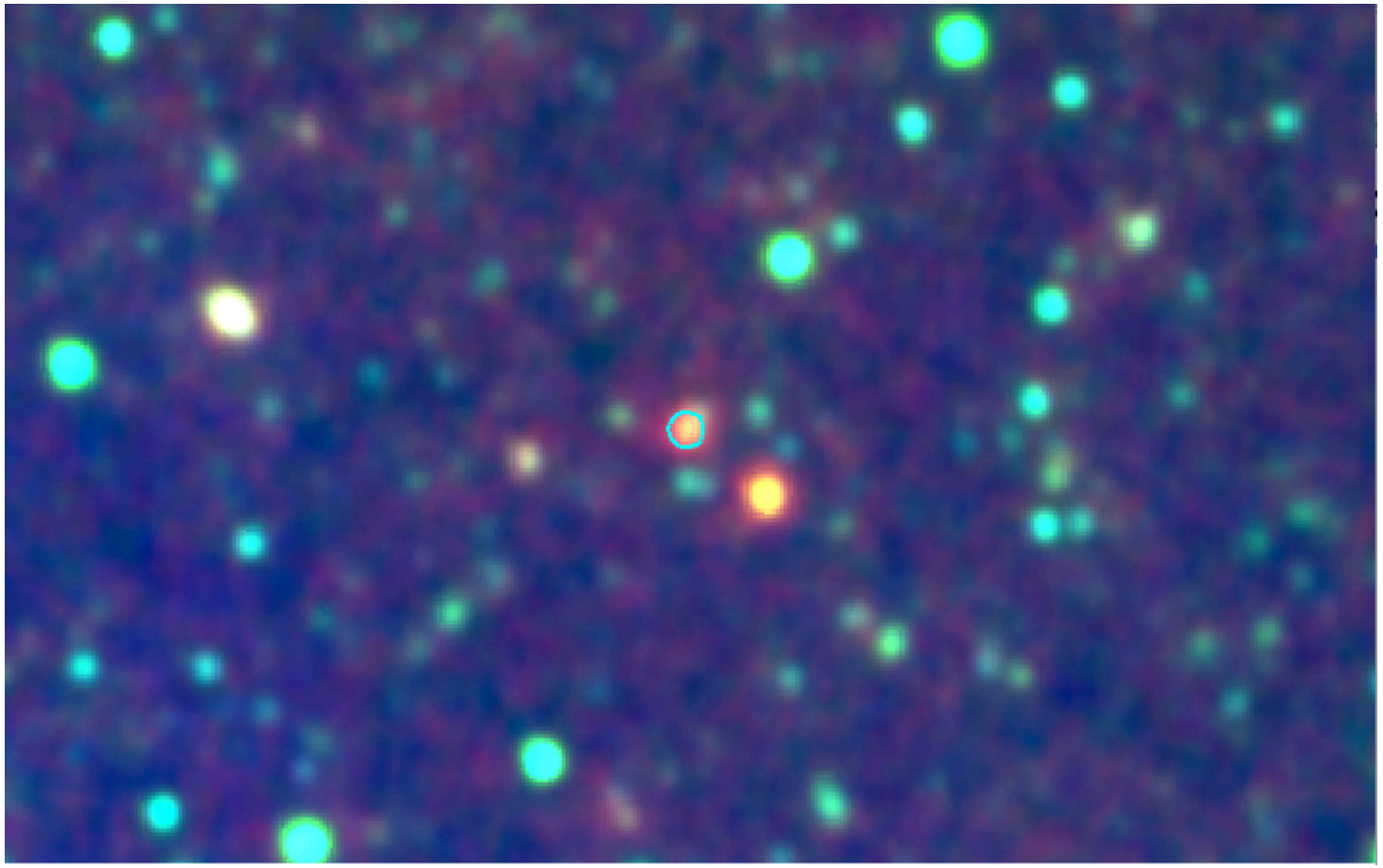
not Type 2 AGN

Banerji et al. 2012b, arXiv:1210.6668

Dust Reddened Broad Line Quasars at Redshift 2:

Starbursts Transitioning to UV-Luminous AGN?

VHSJ1409-0830 at z=2.3 with Av=2.5, $L_{bol}=10^{47}$ erg/s, $\log(M_{BH})=9.22$



$K_{vega}<17.0$

Not present in wide-field optical surveys like SDSS (iAB > 22)

not Type 2 AGN

K – 3.4um – 12um colour composite image

Banerji et al. 2012b, arXiv:1210.6668

Quasar Target Selection using DES+VHS

The missing V for Visible in VISTA

- As part of the ESO negotiations the IR field of view of VISTA was increased from 9 IR detectors to 16 detectors.

- The optical camera was deemed of secondary importance since IR capability was the highest priority and increased the unique value of VISTA to the ESO community which includes the UK.

- Thus the IR survey power of VISTA increased by a factor of 3 from larger detector focal plane coverage 100% of time would be IR.

- VST is part of the V (T. Shanks talk); the other part is the Dark Energy Survey on the CTIO Blanco 3.9m telescope

VISTA was designed for the optical and 4MOST will benefit from this.

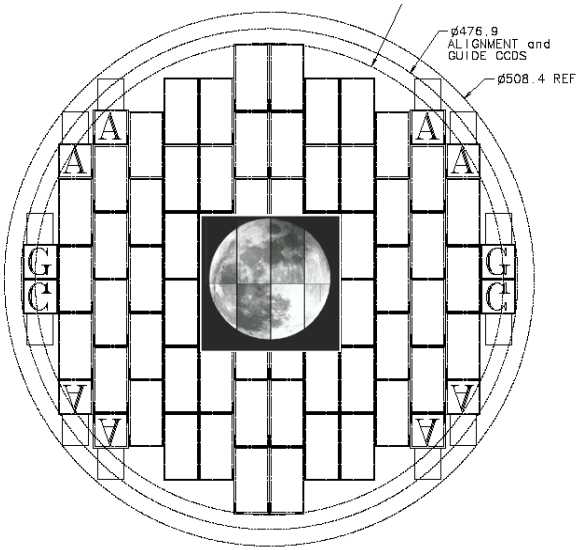
The Dark Energy Survey

(US, UK, Spain, Brazil, Germany, Switzerland collaboration)

DARK ENERGY SURVEY

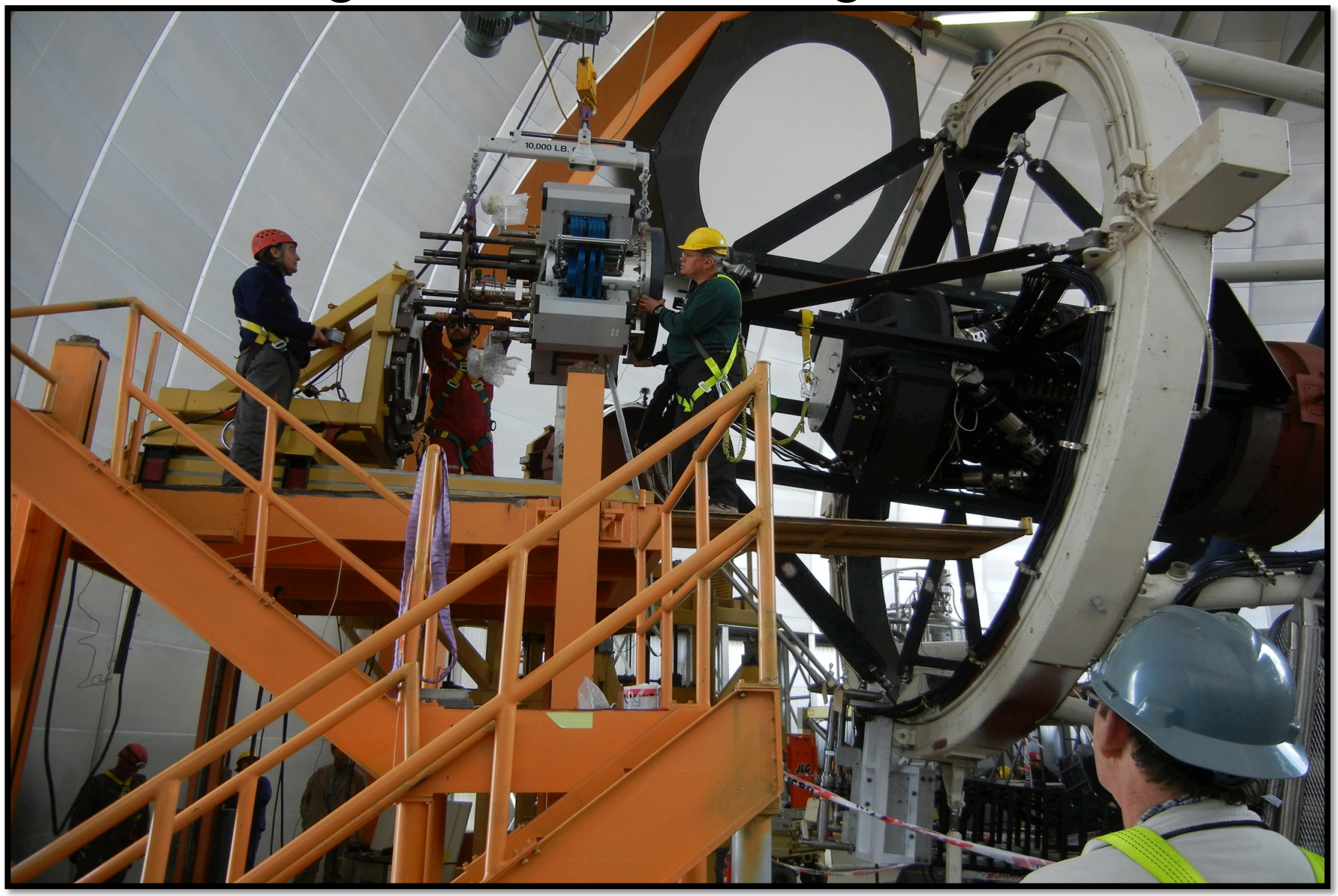
- Telescope; upgraded CTIO 3.9m
- 525 nights over 5 years
- First light in Sept 2012
- Science Verification ongoing Nov 2012; Survey to start in Dec 2012
- Multiple pass survey so coverage of 5000deg^2 in first full observing season
- Field of view
  - 2.3deg diameter; 3.0deg^2
- Very red sensitive CCDs
  - QE; 90% at 900nm; 50% at 1um
- g, r, i, z, Y wavebands

DECam Focal Plane

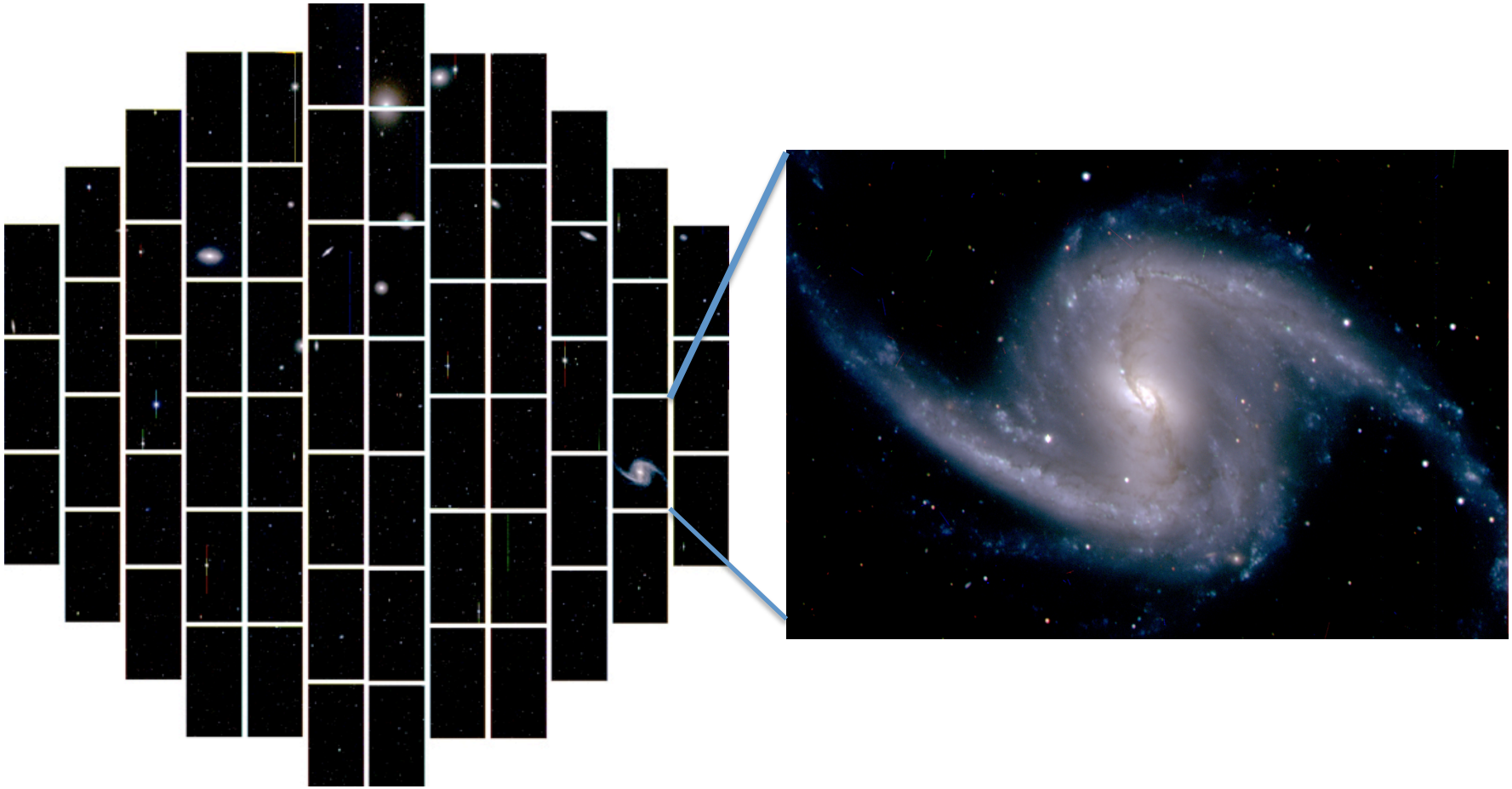


62 2kx4k Image CCDs: 520 MPix
8 2kx2k focus, alignment CCDs
4 2kx2k guide CCDs
0.27" per pixel

DES Imager Installation August 30th 2012



First light images from 12th Sept 2012
Fornax cluster and NGC 1365



DES expected depths: AB magnitudes

Table 2. Expected Cumulative Wide-Area Survey Depths and Median Delivered PSF

filter	exp (sec)	mean-PSF 5σ m_{lim}	mean-galaxy 10σ m_{lim}	90%-tile bright m_{lim}	95%-tile bright m_{lim}	median PSF(arcsec)
g	800	26.5	25.2 ± 0.12	25.03	24.99	0.83 ± 0.05
r	800	26.0	24.8 ± 0.11	24.61	24.58	0.79 ± 0.05
i	1000	25.3	24.0 ± 0.10	23.90	23.86	0.79 ± 0.05
z	1000	24.7	23.4 ± 0.08	23.34	23.30	0.78 ± 0.04
y	500	23.0	21.7 ± 0.08	21.61	21.56	0.77 ± 0.04

$n_{eff} = 11.2/\square'$ for weak lensing; survey area = 4944 deg^2; $N_{gals} = 200 \times 10^6$.
PSF $\equiv$ 1.0$*$FWHM aperture mag; galaxy mag $\equiv$ 1.6$*$FWHM aperture mag
4th & 7th column errors denote variations across the survey area

Table 2 from submitted NOAO proposal

10σ PSF mags	
g	25.8
r	25.2
i	24.4
z	24.0
y	22.3

Simulating Quasars in DES+VHS

- Set of quasar spectra from Maddox et al. (2008) known to reproduce SDSS ugriz + UKIDSS YJHK colours of known quasars
- Includes power-law component and blackbody at 1775K for the near infra-red
- Includes host galaxy contribution at low-z
- Lyman limit system at quasar redshift
- Lya absorption taken from Faucher-Giguerre et al.
- Emission line spectrum from LBQS composite (Francis et al. 91) but including variation of Halpha EW with luminosity ('Baldwin effect')
- Assume quasar luminosity function from SDSS III – BOSS (Ross et al. 2012) for $0.5 < z < 2.2$ and $2.2 < z < 3.5$

Expected Numbers of DES+VHS Type 1 Quasars to 4MOST Depths (r_{AB}=22.5)

- At 0.5 < z < 2.2: expect ~100 quasars/ sq deg with median r_{AB}=20.7
- At 2.3 < z < 3.5: expect ~60 quasars/ sq deg with median r_{AB}=21.3 (useful for Lya forest c.f. BOSS)
- Factor of 2 uncertainty due to uncertainty in faint-end of Type 1 quasar LF. Above numbers are very conservative.
- So we can easily get >100 quasars/sq deg with 4MOST from optical+NIR selected quasar samples using DES+VHS (competitive with number of eROSITA selected X-ray AGN)

Selecting the Quasars I

- Select SDSS QSO targets in "redshift desert" at $2 < z < 3$ (objtype='QSO') which were spectroscopically confirmed to be stars (class='STAR') + an equal number of real QSOs at similar redshifts.

- Train an artificial neural network (ANN) on QSO model spectra (Maddox et al. 2008) + stars modeled as a set of blackbodies with $2900K < Teff < 38000K$

- Use ANN to output probability of object being QSO from 0 -> 1. 0=STAR, 1=QSO

Selecting the Quasars II

	QSO targets confirmed to be quasars	QSO targets confirmed to be stars
SDSS Targeting algorithm (Richards et al.)	1491	1500
ANN – griz classification	1341 QSOs (90%) 150 STARS (10%)	750 QSOs (50%) 750 STARS (50%)
ANN – grizYJHK classification	1296 QSOs (87%) 195 STARS (13%)	210 QSOs (14%) 1290 STARS (86%)

WISE data will further improve on this

Quasar Science with 4MOST

- Quasar clustering for cosmology – especially when combined with other galaxy populations at lower-z
- Lyman alpha forest and IGM studies – blue cutoff?
- Faint-end of quasar luminosity function
- Quasar lifetime from clustering and LF – constraints on galaxy formation theories
- Black-hole masses
- Damped Lya systems and broad absorption line quasars – need large spectroscopic samples to identify significant numbers of these

Conclusions

- VHS has already covered 6000 sq deg of southern celestial hemisphere in (Y)J(H)Ks bands.
- VHS-DR1 now public, next public data release: Dec/Jan
- Good synergy with other multi-wavelength wide-field surveys – DES, VST-ATLAS, GAIA etc.
- First science focused on galaxy clusters at z=1, cool LT dwarfs and reddened broad-line quasars
- DES (grizY) + VHS (JHKs) – unique 8-band sky survey over 5000 sq deg
- Infrared data allows quasars to be separated from stars in the "redshift desert" at $2.0 < z < 3.0$
- Optical quasar space densities within DES+VHS down to 4MOST depths is competitive with numbers of X-ray AGN from eROSITA