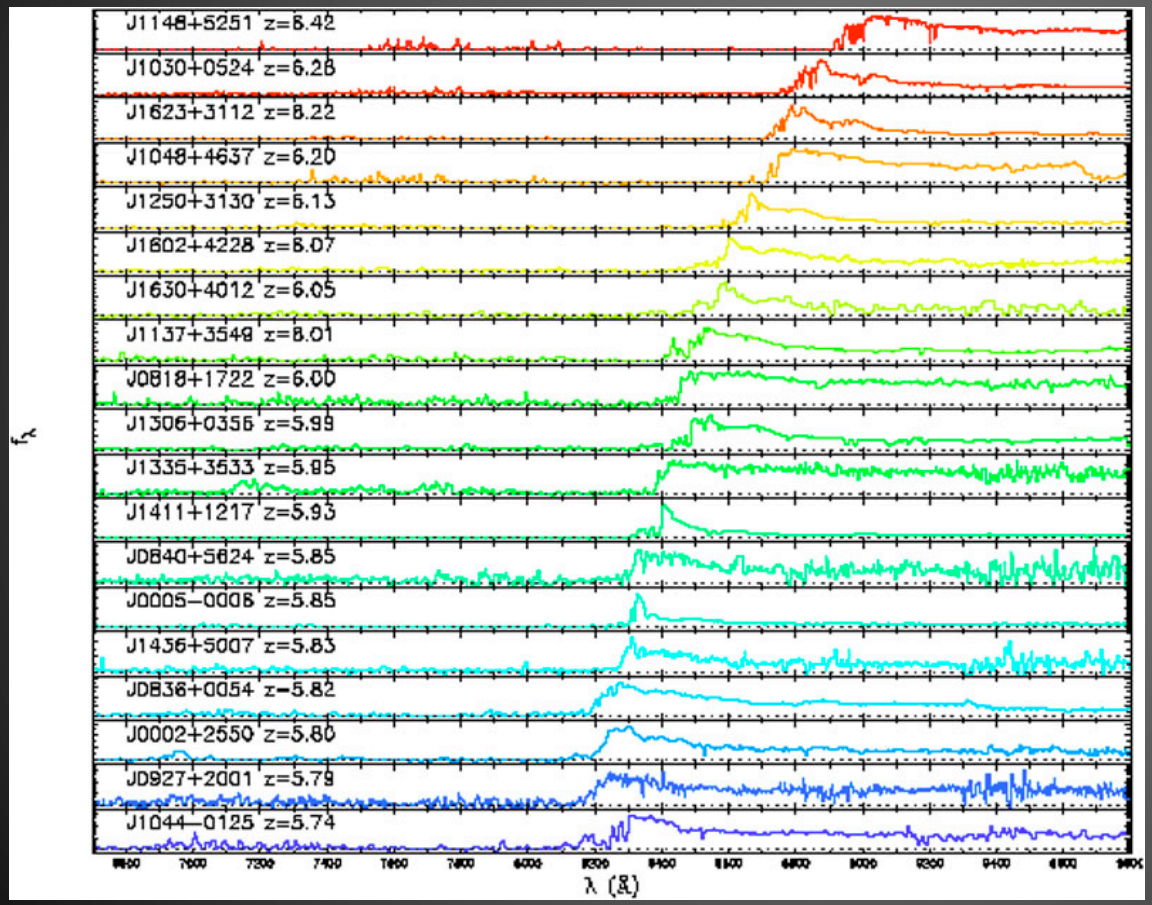
High-Redshift Quasars in Current & Future Wide-Field Surveys

Manda Banerji

(Institute of Astronomy, Cambridge;

STFC Ernest Rutherford Fellow)

State-of-the-art: The SDSS Quasar Survey



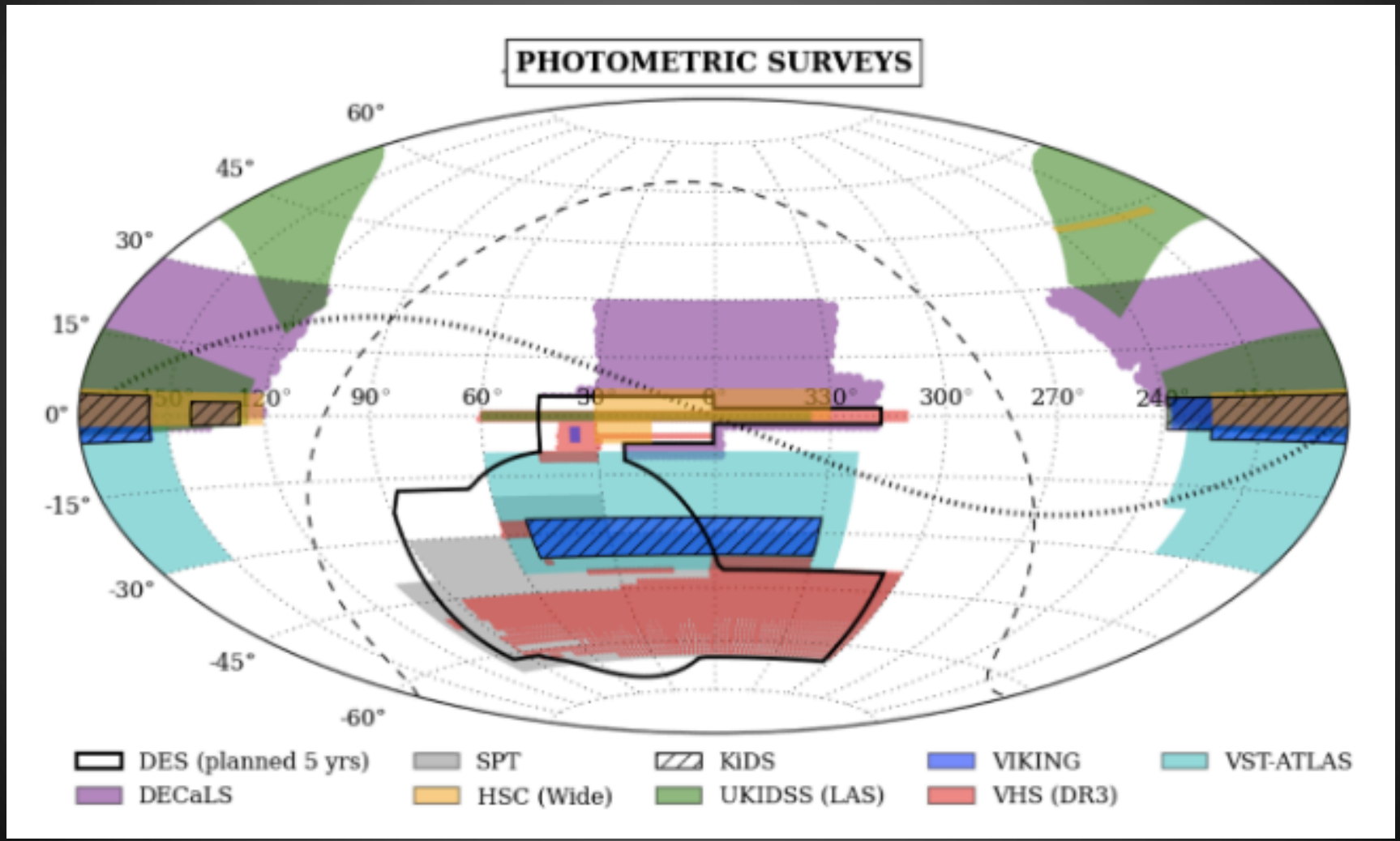
Largest sample of high-redshift quasars assembled to date

More than 50 quasars at z > 5.7

New (and unexpected!) discoveries still being made – Ultra-luminous quasar with 12-billion solar mass BH at z=6.3 (Wu+15)

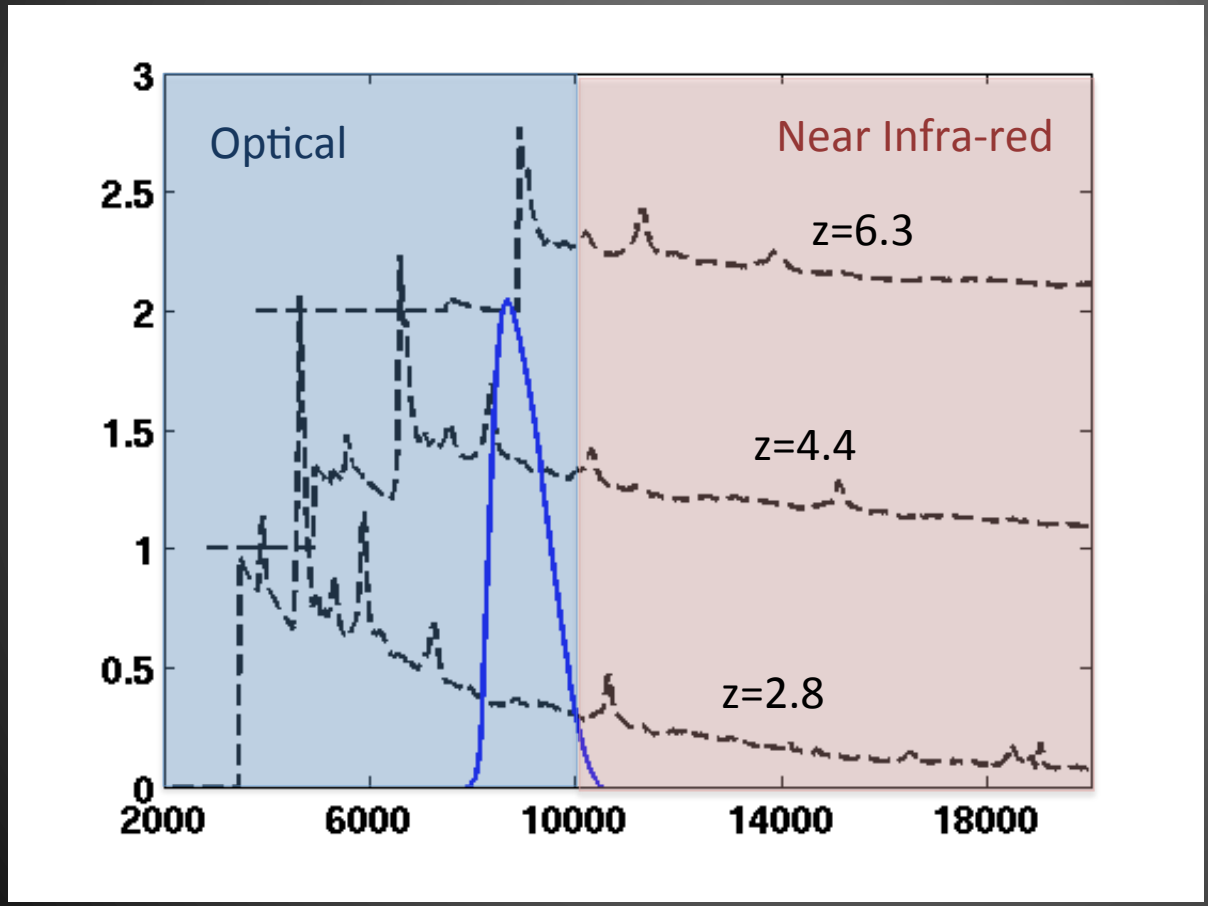
L. Jiang Talk (Monday)

The Landscape of Survey Astronomy



The DES Collaboration 2016: Non-DE Overview Paper; arXiv:1601.00329

High-redshift Quasars & Infra-red Surveys



At higher redshifts, the main quasar emission lines are redshifted out of optical wavelengths.

Increasing amounts of neutral hydrogen at early times also absorb light at optical wavelengths

Pushing to the infra-red

- Development of new CCDs with increased efficiency at redder wavelengths
- Large infra-red cameras on 4-m class telescopes e.g. VIRCAM on VISTA

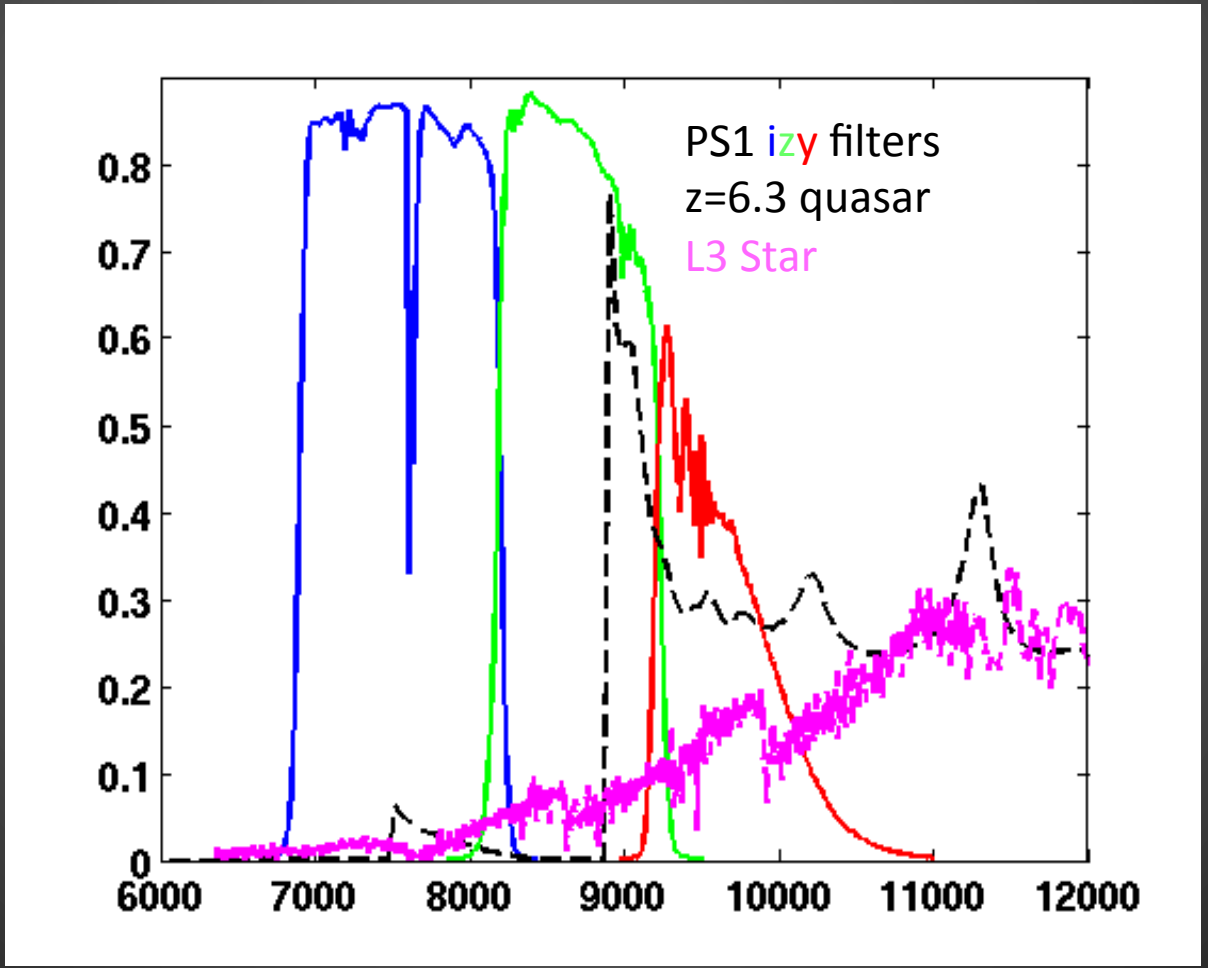
Pushing to the infra-red

- Development of new CCDs with increased efficiency at redder wavelengths

- Large infra-red cameras on 4-m class telescopes e.g. VIRCAM on VISTA

PanStarrs (2010-)

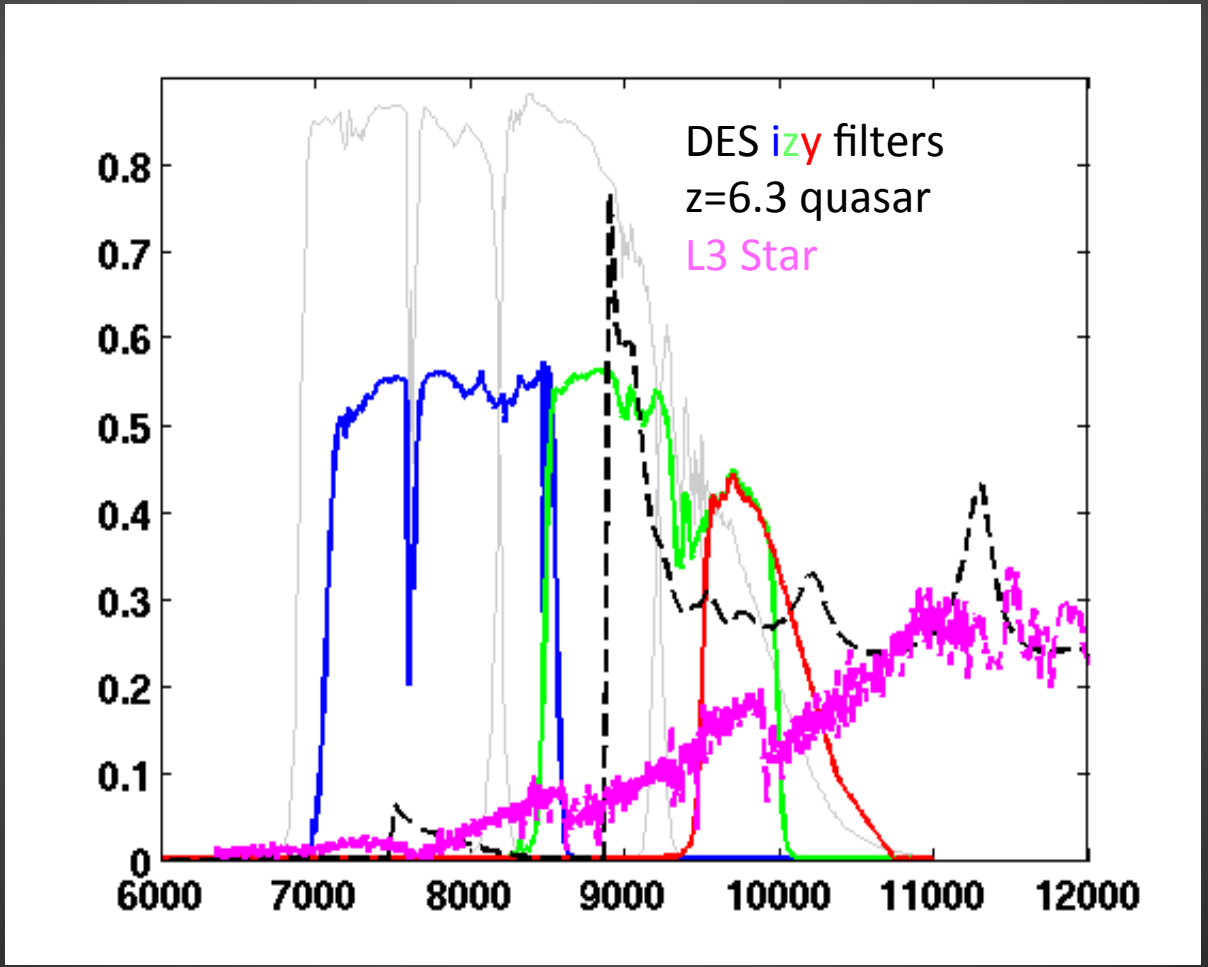
PS1: 1.8-m telescope 1.4 Gigapixel camera 7 sq-deg field-of-view 3*pi survey area



Talks by E. Banados, C. Mazzucchelli

Dark Energy Survey (2013-)

Blanco: 4-m telescope 570 Megapixel camera 3 sq-deg field-of-view 5000 sq-deg area



Talk by S. Reed

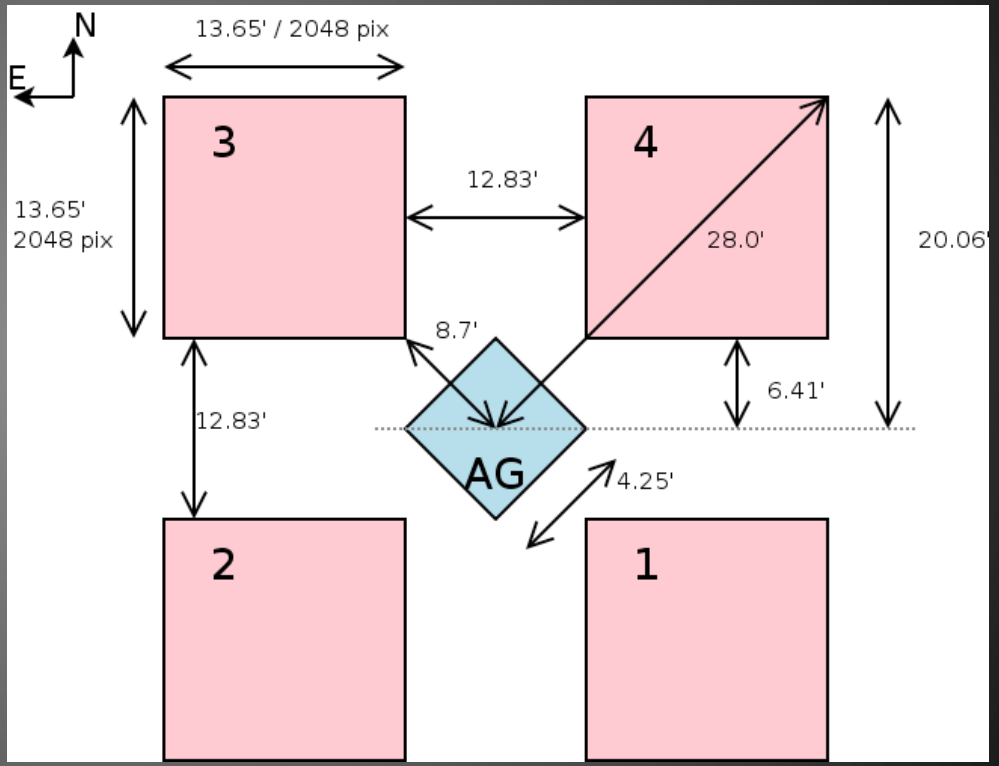
Pushing to the infra-red

- Development of new CCDs with increased efficiency at redder wavelengths

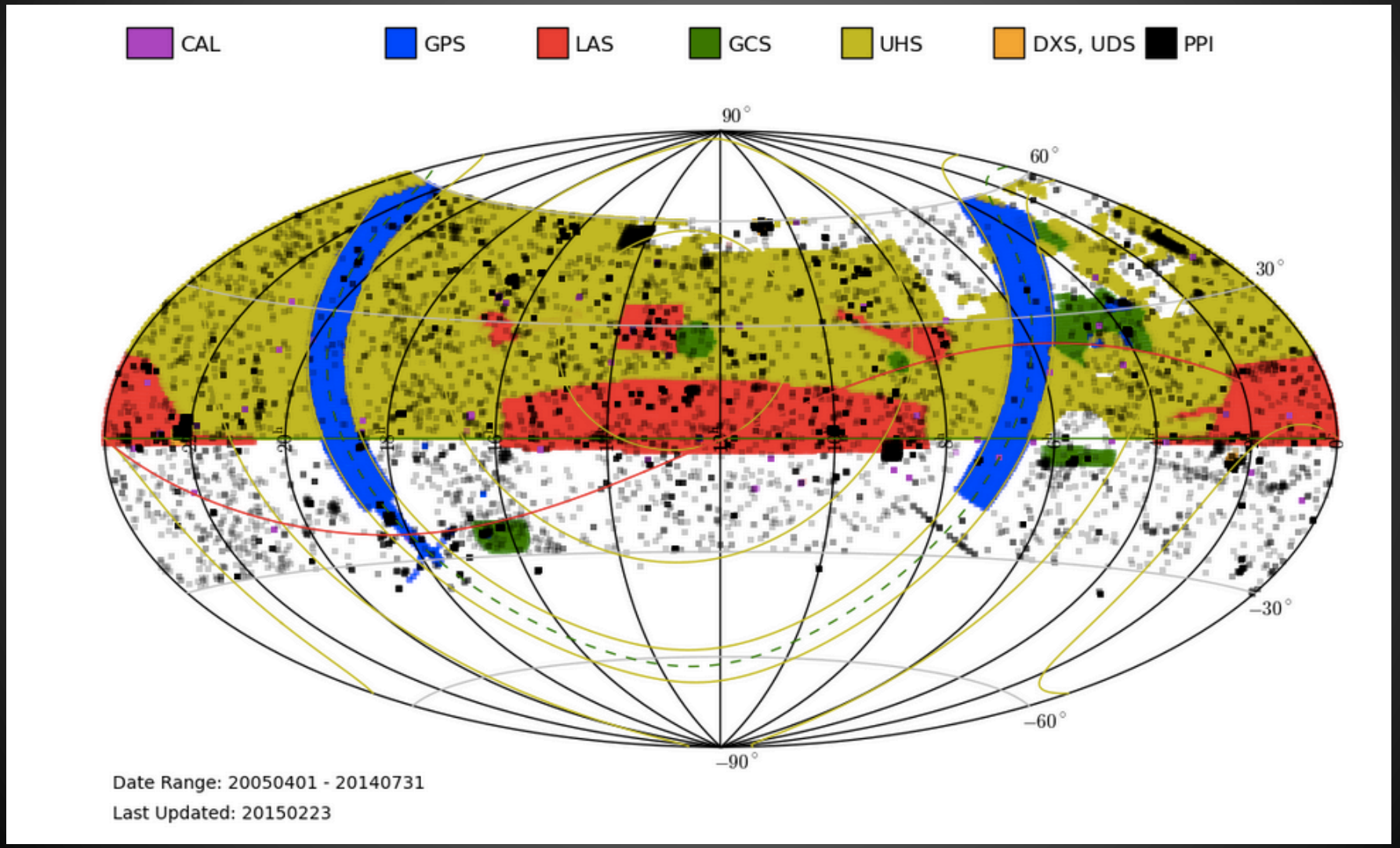
- Large infra-red cameras on 4-m class telescopes e.g. VIRCAM on VISTA

The UKIDSS Surveys

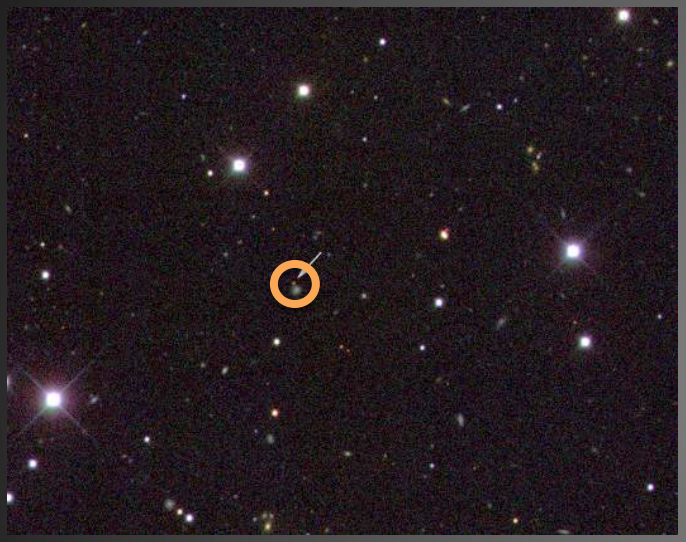
- Northern Hemisphere
- UKIRT Telescope: Mauna Kea, Hawaii
- WFCAM Camera: 0.8 sq-deg field-of-view
- Four 2048 x 2048 pixel Rockwell detectors (0.4” per pixel)

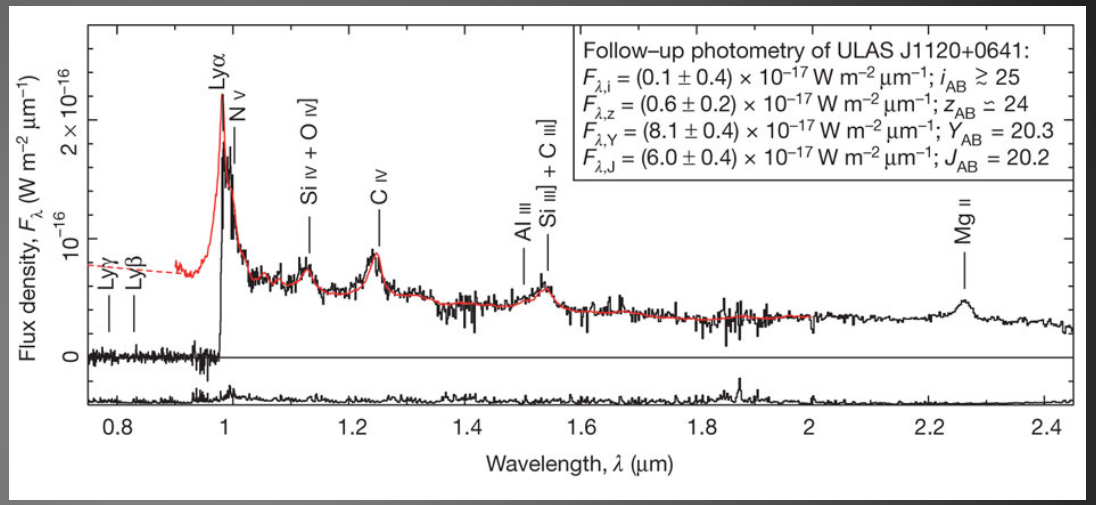


The UKIDSS Surveys



The Most Distant Quasar Known



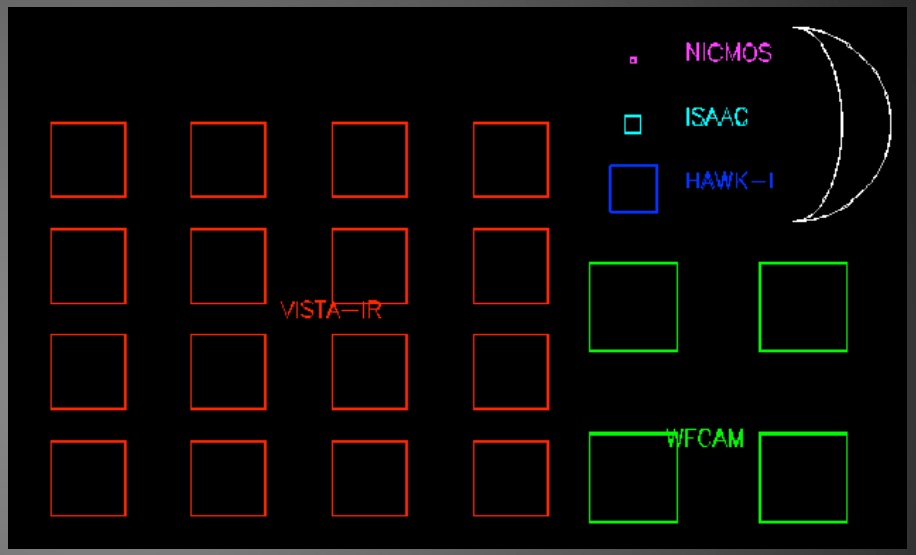


The first (and only!) quasar at z > 7 (ULASJ1120-0641) was found using the UKIDSS Large Area Survey (Mortlock+11)

Combining the near infra-red data from UKIDSS with SDSS optical data was key to the discovery.

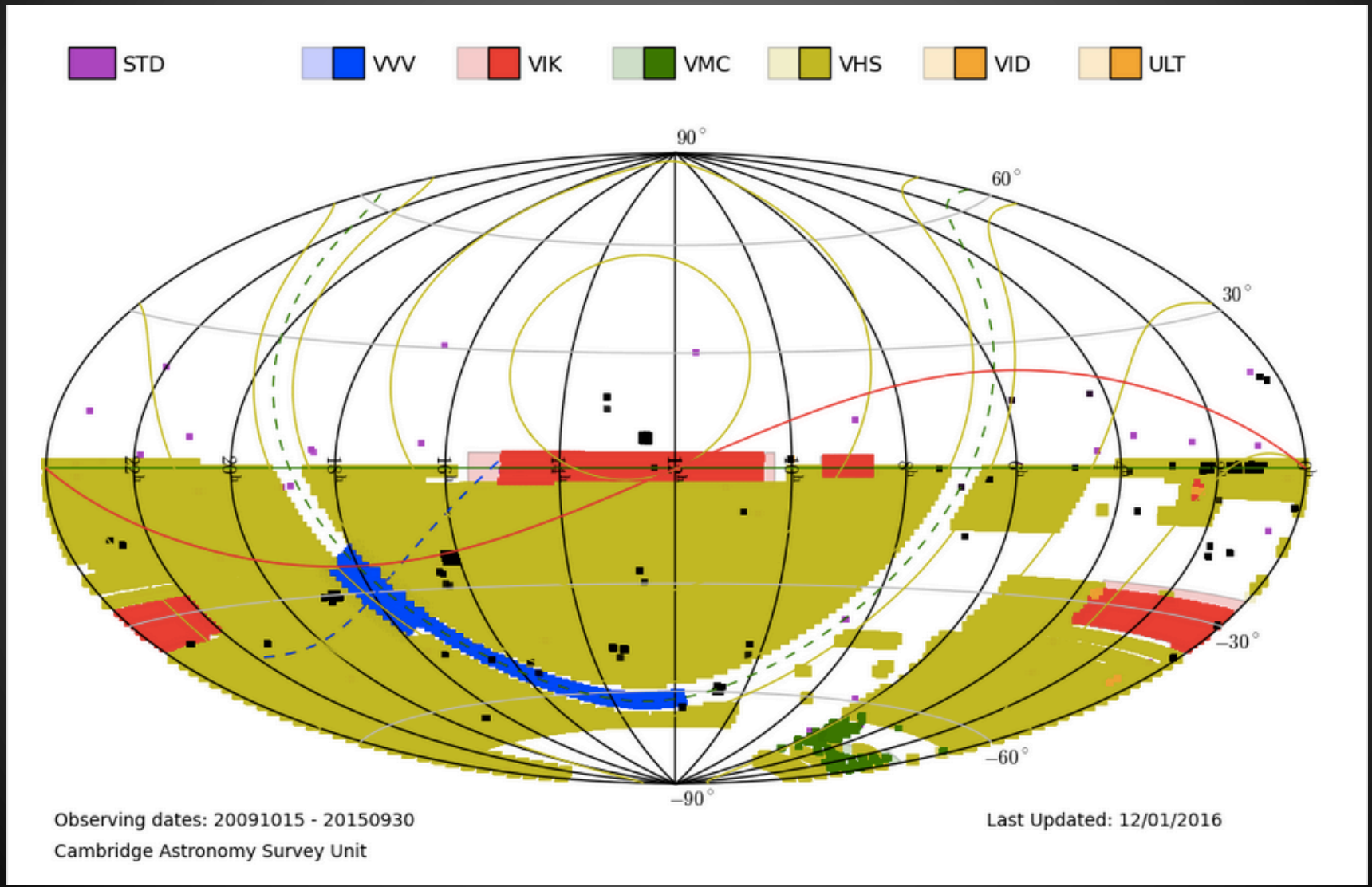
The VISTA Surveys

- Southern Hemisphere
- VISTA Telescope: Paranal, Chile
- VIRCAM Camera: 1.5 sq-deg field-of-view;
- 16 Raytheon VIRGO 2k x 2k detectos -> 67 Megapixels
- Six public surveys started in 2010



VISTA Hemisphere Survey (McMahon, MB+13)
VIKING (Edge+13)
VIDEO (Jarvis+13)

The VISTA Surveys

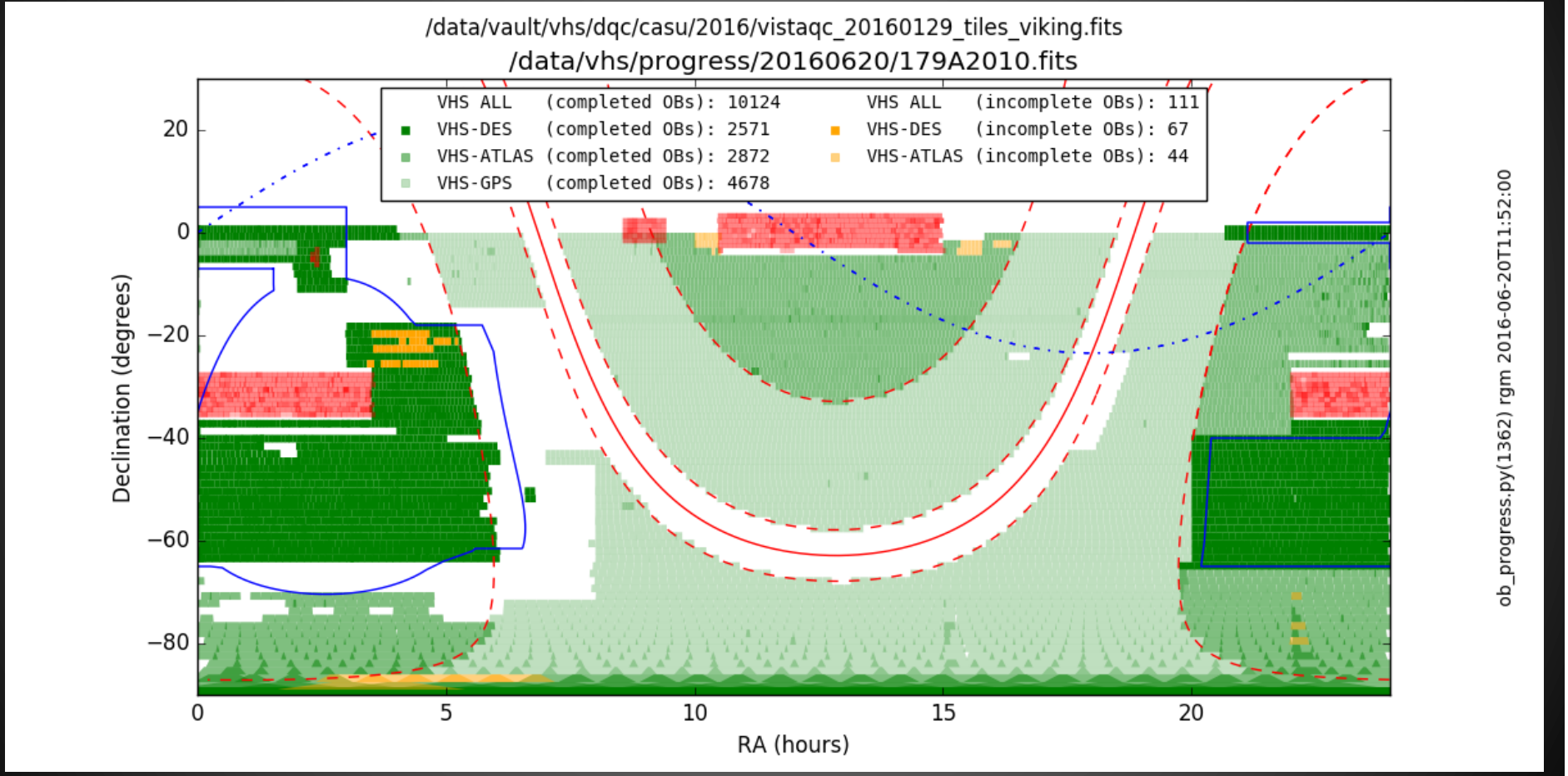


VISTA Survey Depths

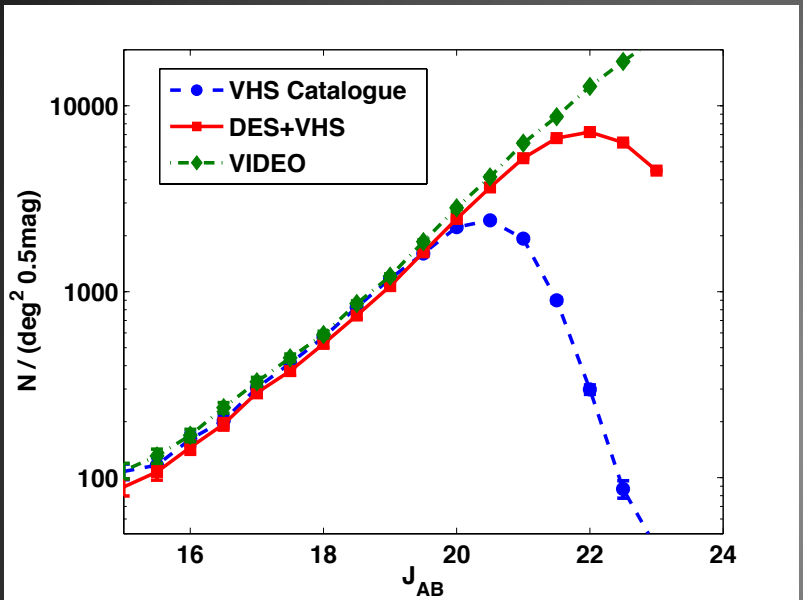
Survey	Area (deg^2)	Depths Measure (mag)	Nominal Depth (mag)
VHS	18, 000	5σ, AB	J=21.2 Ks=20.0
1. VHS-DES	4500	5σ, AB	J=21.6 (H=21.0)* Ks=20.4
2. VHS ATLAS	5000	5σ, AB	Y=21.2 J=21.2 (H=20.6)* Ks=20.0
3. VHS-GPS	8000	5σ, AB	J=21.2 Ks=20.0
VIKING	1,500 (450 deg^2 in DES, rest in VST-KIDS)	5α, AB	Z=23.1 Y=22.3 J=22.1 H=21.5 K_s=21.2
VIDEO	12	5σ, AB	Z=25.7 Y=24.6 J=24.5 H=24.0 K_s=23.5

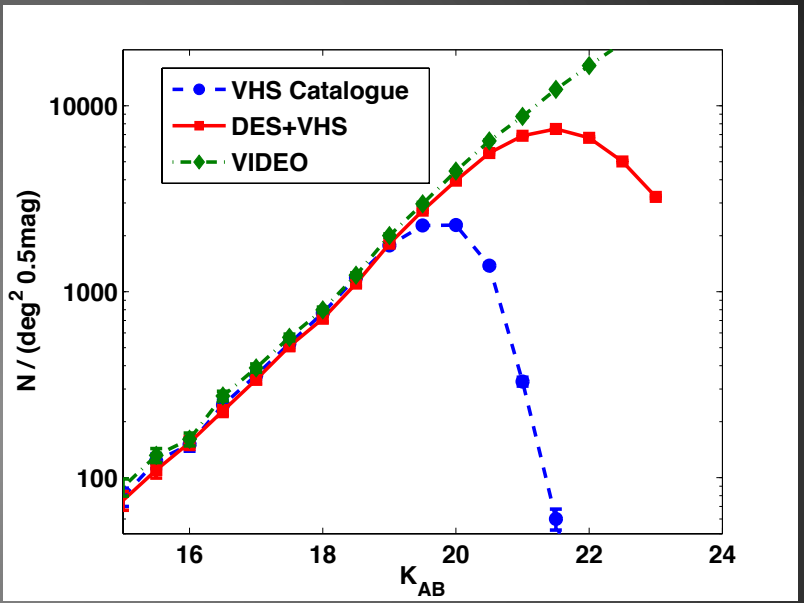
* H-band dropped in 2012 to get deeper data in J-band.

The VISTA Hemisphere Survey



DES+VHS Forced Photometry

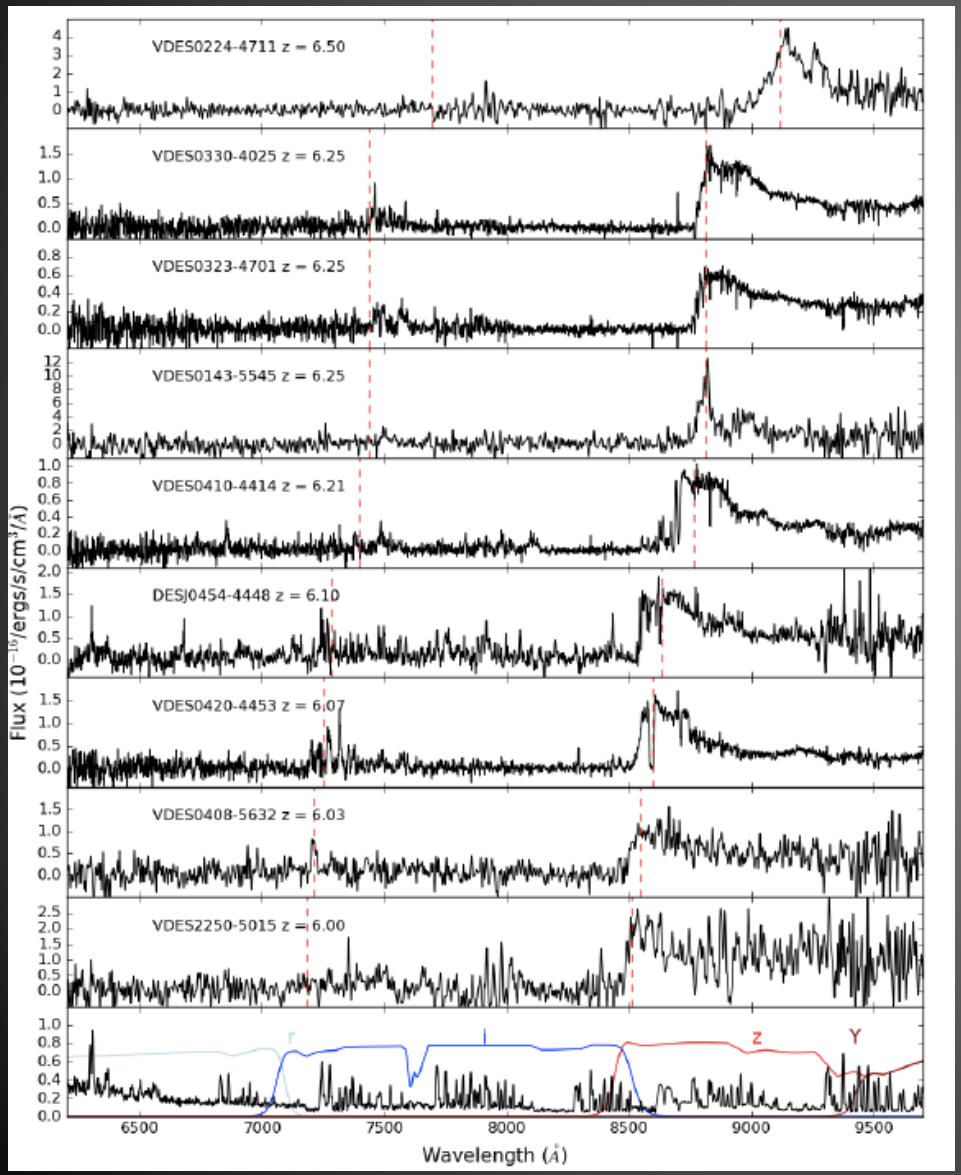




By using DES detections to extract low SNR fluxes in the shallower VHS survey, we can push the 80% completeness limit of VHS 1.5 mags fainter compared to just matching the optical and NIR catalogues (MB+2015a)

CFHQS J022743−060530 is among the faintest z~6 quasars known (Willott+09). Forced photometry -> (i-z)=3.7, (z-J)=0.4. J-band flux from DES+VHS forced photometry catalogue gives colours consistent with high-z quasars (rules out cool star identification as cool stars would be redder in z-J).

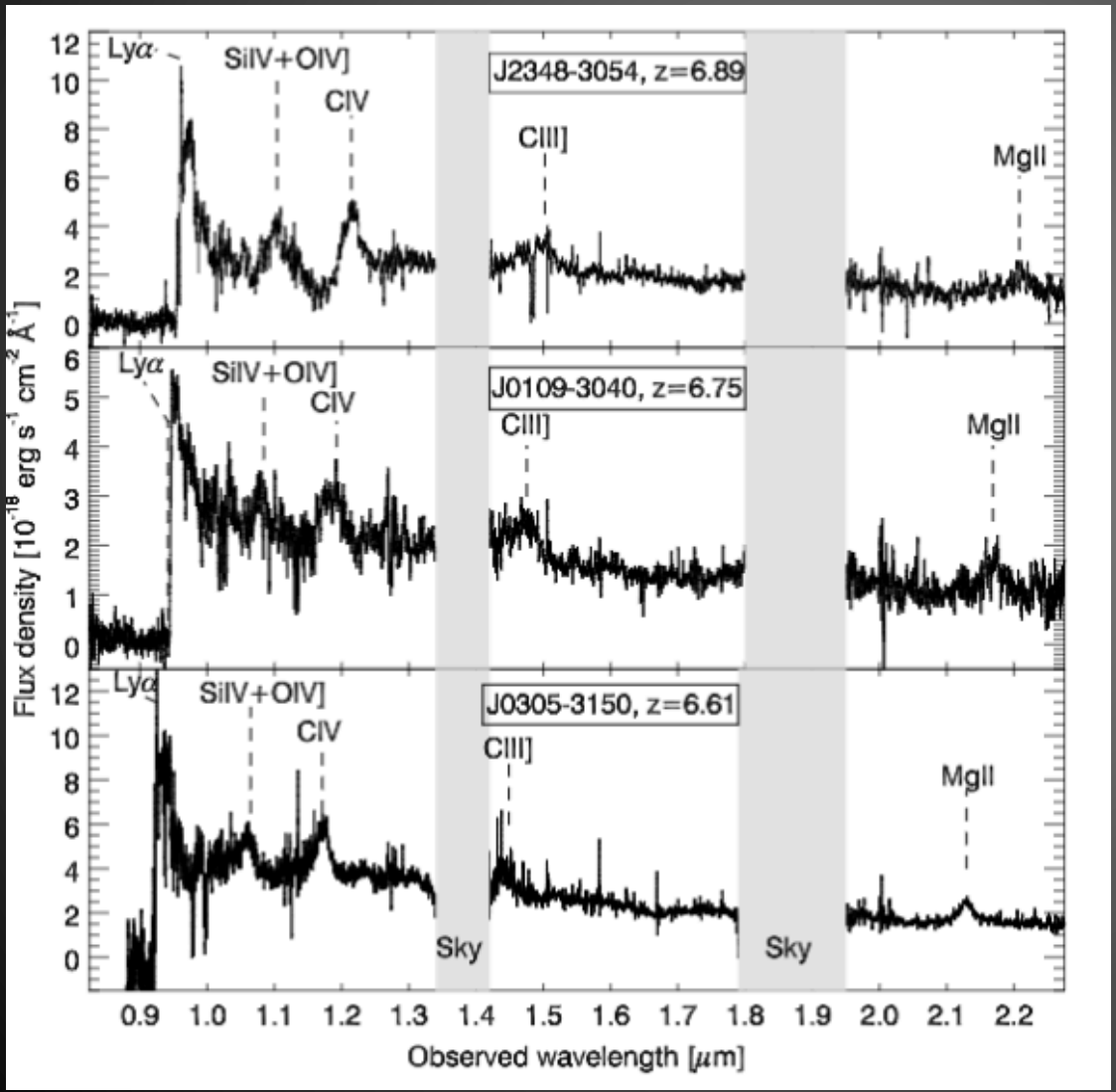
The DES+VHS High-z Quasars



- 9 new quasars at z > 6 already from DES Year 1 data combined with VHS: ~1500 sq-deg to zAB < 21.0
- Year 2+3 release expected later this summer: additional ~3000 sq-deg + deeper observations over Year 1 area
- Based on the Willott+(2010) LF we expect ~10 quasars over this area down to this flux limit

Reed, McMahon, MB + 15,16,
S. Reed Talk (Monday)

VIKING Quasars: z > 6.5

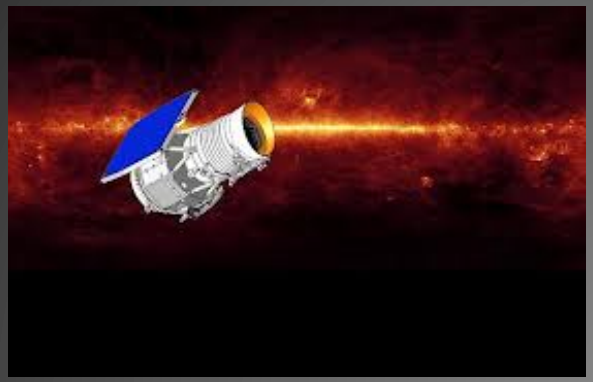


Smaller area (few hundred sq-deg) and deeper near infra-red survey allows:

- Discovery of z > 6.5 quasars
- Discovery of fainter quasars at z ~6

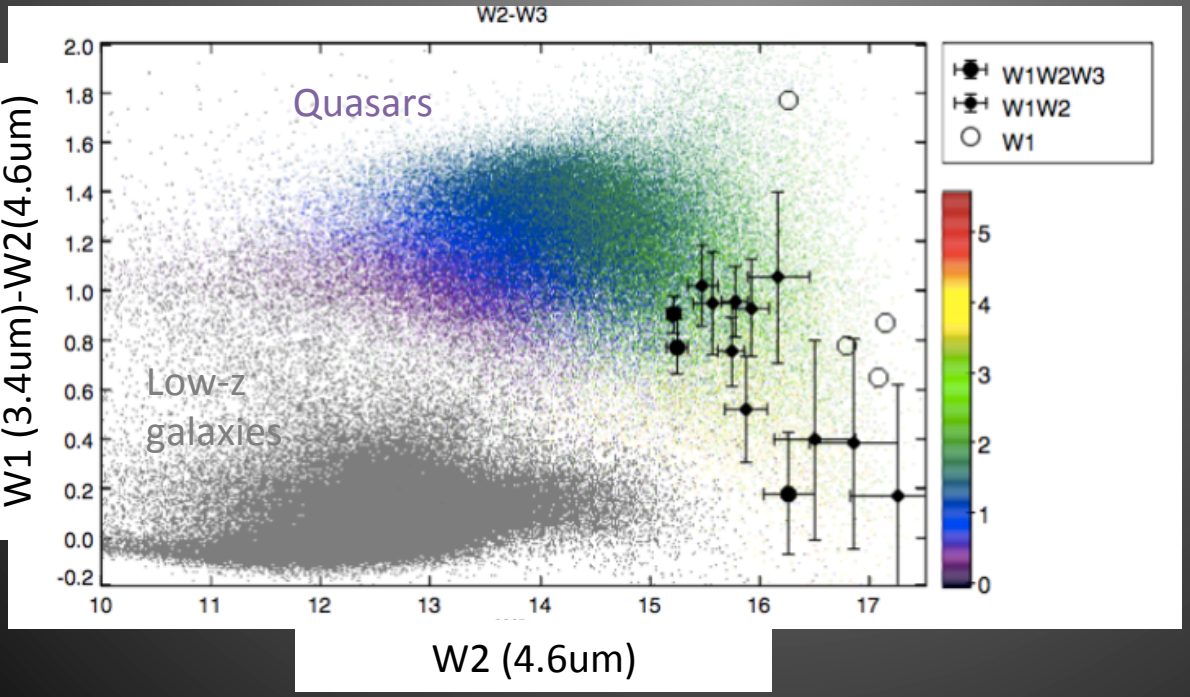
Venemans+13, 15

The WISE All-Sky Survey



Mid infra-red all-sky survey

3.4, 4.6, 12 and 22um. Shorter wavelengths most relevant for high-z quasar selection

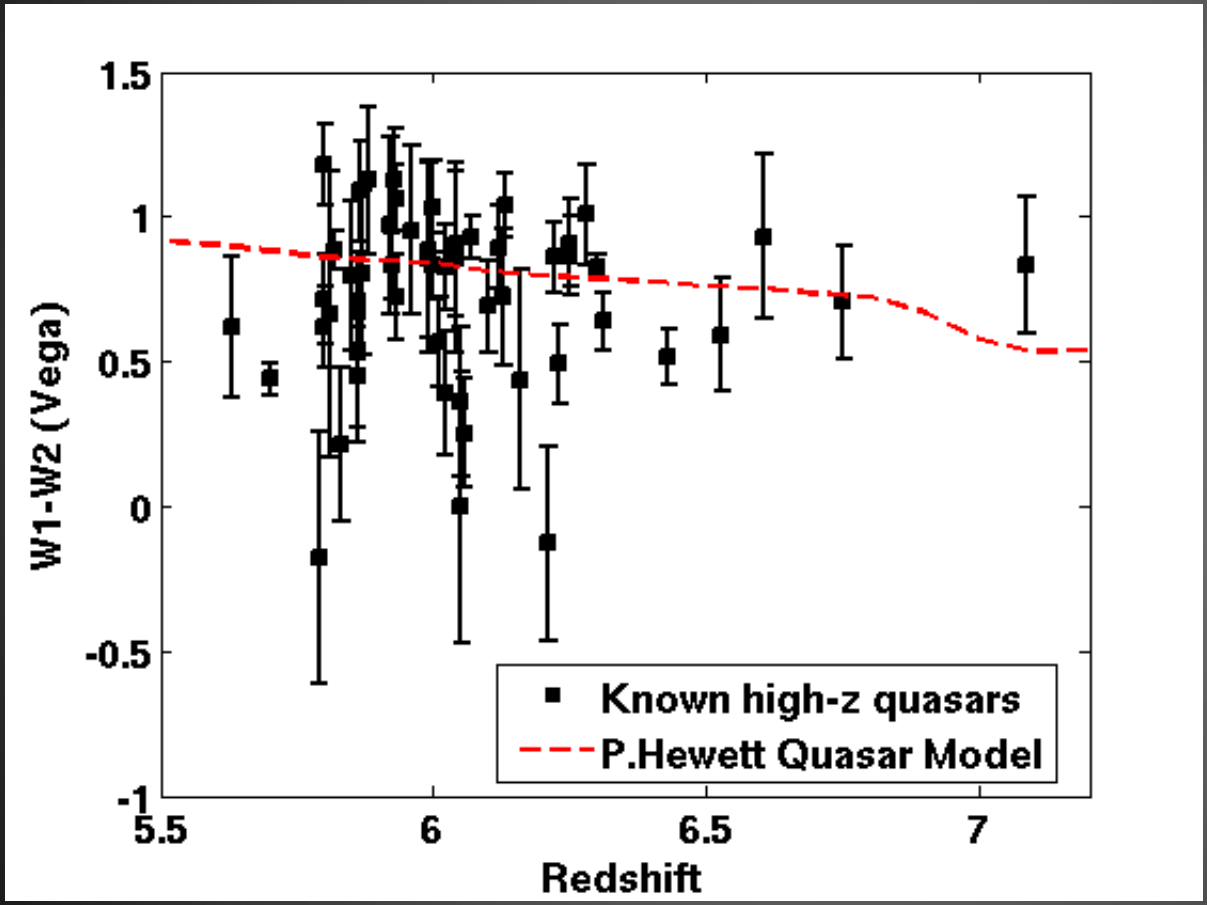


Blain+13

AllWISE Data Release: Combined data from the WISE cryogenic and NeoWISE (post-cryogenic) phases

NeoWISE Reactivation Mission: (Mainzer+14) – deeper W1 and W2 data

WISE Colours of High-z Quasars



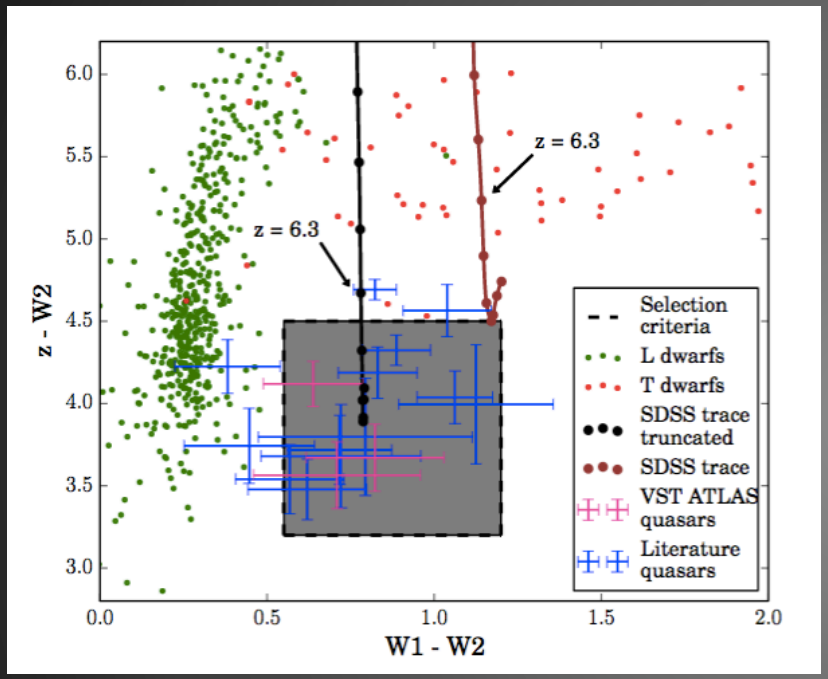
High-z quasar compilation by Sophie Reed

Almost 60 high-redshift quasars have measured WISE W1 and W2 fluxes

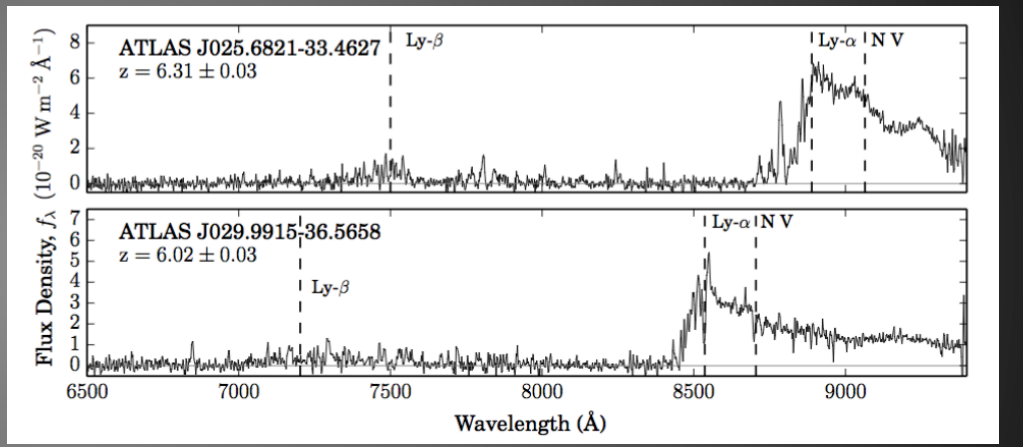
New quasar model (Hewett+ in prep) provides a good description of the WISE colours (albeit with some scatter)

Model-based photometric redshifts improves quasar selection (Reed+16)

Optical+WISE Colour Selections



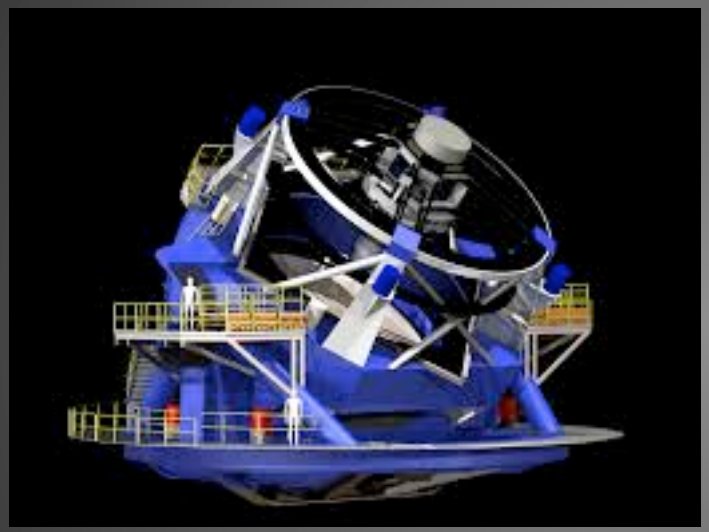
Carnall+15



- Optical + WISE colour selections used to discover bright (zAB~20) quasars at z~6
- Two new z > 6 quasars selected in this way from the combination of VST-ATLAS survey data with the WISE All-Sky Survey

Future Wide-Field Surveys

LSST



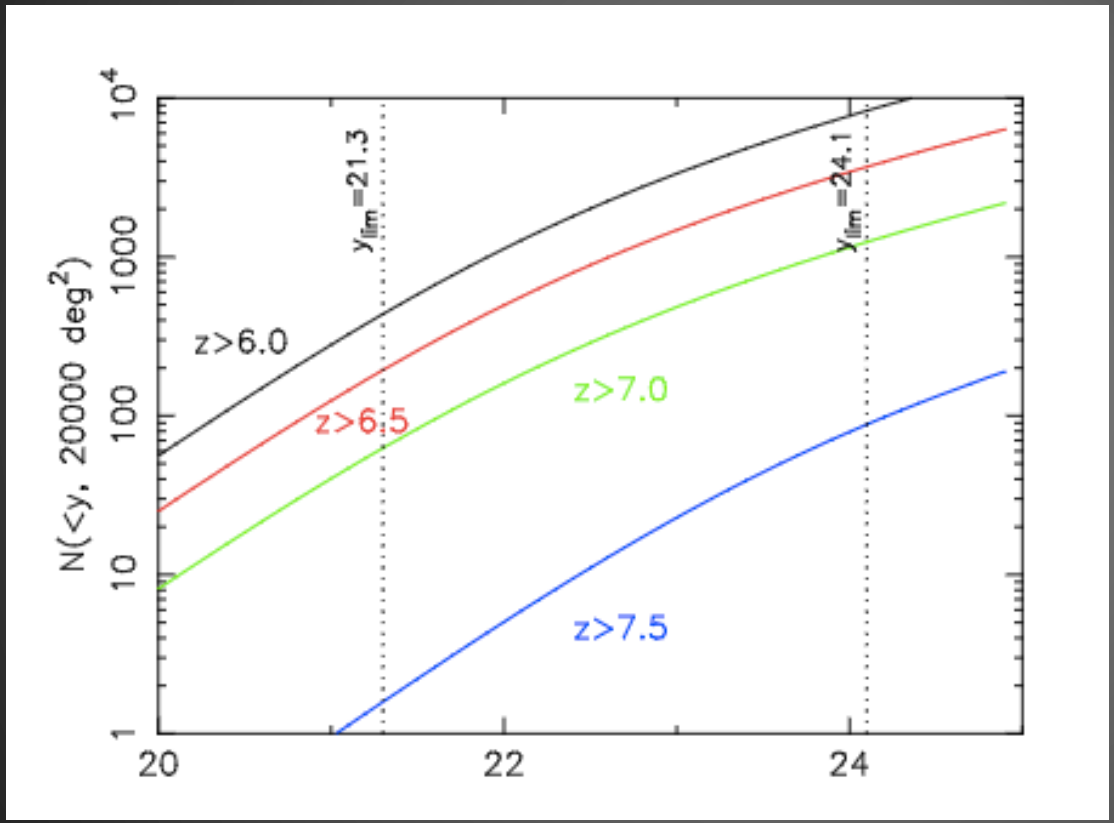
Euclid

Next leap up in terms of combination of area and depth

Will enable the selection of quasars out to the highest redshifts of $z > 8$

Redshift evolution of space-density

High-redshift quasars in LSST



13,800 quasars at 6 < z < 6.7

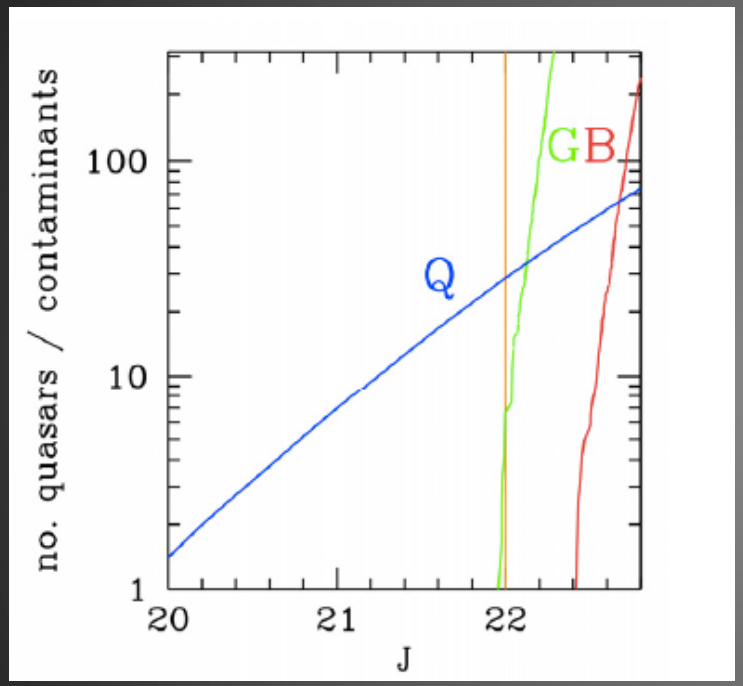
Several tens of z > 7 quasars after first epoch of LSST observations

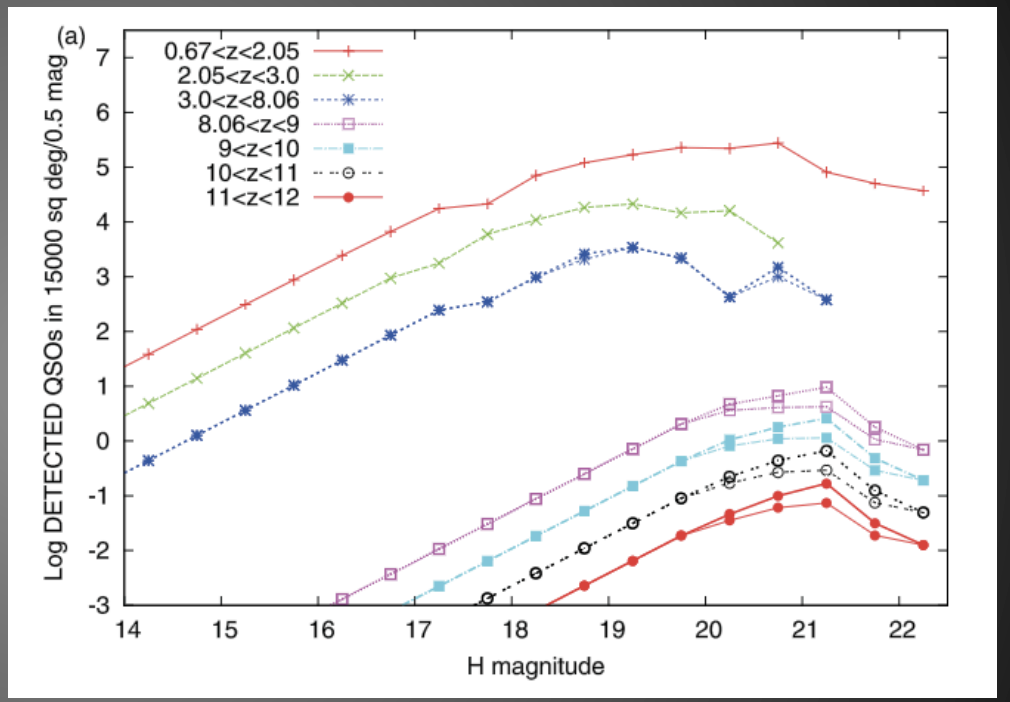
Tens of quasars at z > 7.5 down to the final co-add survey depth

Assuming Jiang+09 LF and an area of 20,000 sq-deg
From LSST Science Book (AGN Science Case)

High-redshift quasars in Euclid

Euclid Red Book, arXiv:1110.3193





- 15,000 sq-deg ; YJH < 24.0 mags (AB)
- Clean selection of quasars should be possible to J < 22: quasars outnumber contaminants
- 10-15 quasars at 8.0 < z < 9.0; 2-3 quasars at 9.0 < z < 10.0 (Roche+12)

Upcoming VISTA Surveys (2017-)

- ESO Letters of Intent for new VISTA Public Surveys: deadline October 2015
- Call for proposals for surveys selected from LoI stage: deadline March 2016
- 7 new VISTA Public Surveys recommended to be implemented (June 2016). SMP and final approval by ESO DG expected end 2016. Surveys expected to begin March 2017

VISTA Extragalactic Infra-red Legacy Survey (VEILS)

- VEILS is a new, deep (<24 mag) and wide-field (~21 sq-deg) transient survey in the J and K-bands (PI: M. Banerji; co-PI: S. Hoenig)
- Around 1200 hrs over ~3 years (until 4MOST Spectrograph goes on VISTA Telescope)
- Overlaps DES deep fields -> LSST deep drilling fields. Some overlap also with HSC deep fields
- Combined with VIDEO (PI: M. Jarvis), will provide NIR coverage over the entire (~6-8 sq-deg) XMM-LSS, CDFS and ELAIS-S1 fields with deep (zAB ~ 26) optical data + lots of legacy data

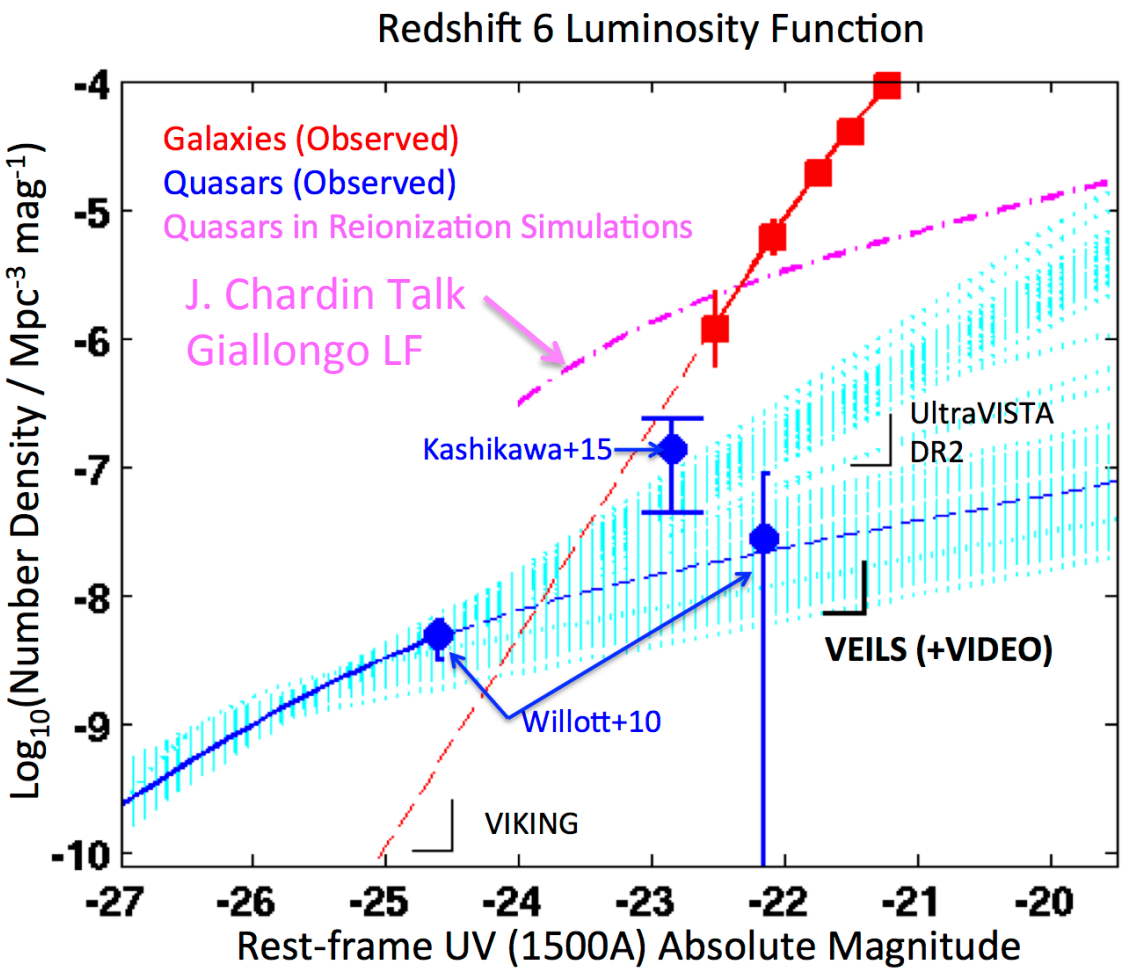
VEILS: Science Goals

- Epoch of Re-ionization
- The Build-up of Massive High-Redshift Galaxies
- Transients: Supernovae & AGN Dust Lags

VEILS: Science Goals

- Epoch of Re-ionization
  - Faint-end of quasar luminosity function at z~6: Do quasars contribute to re-ionization?
- The Build-up of Massive High-Redshift Galaxies
- Transients: Supernovae & AGN Dust Lags

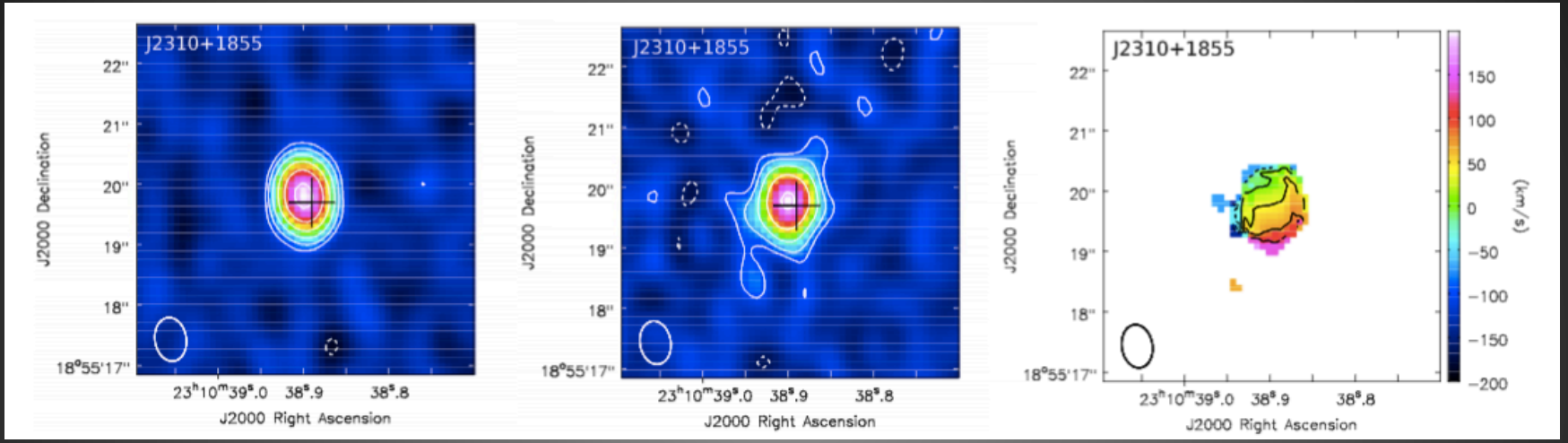
The High-z Universe with VEILS



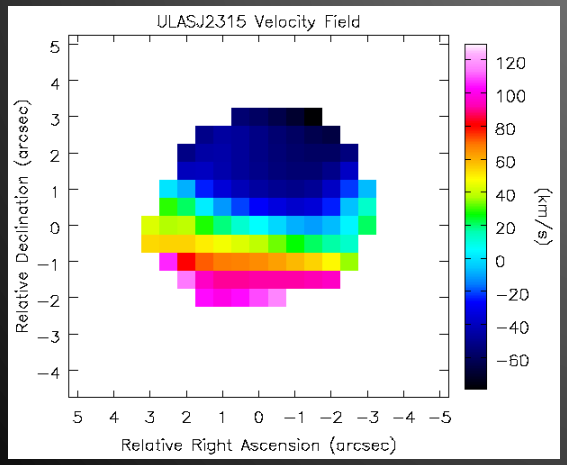
See also HSC surveys (Matsuoka talk)

Host Galaxies: ALMA

Wang+13

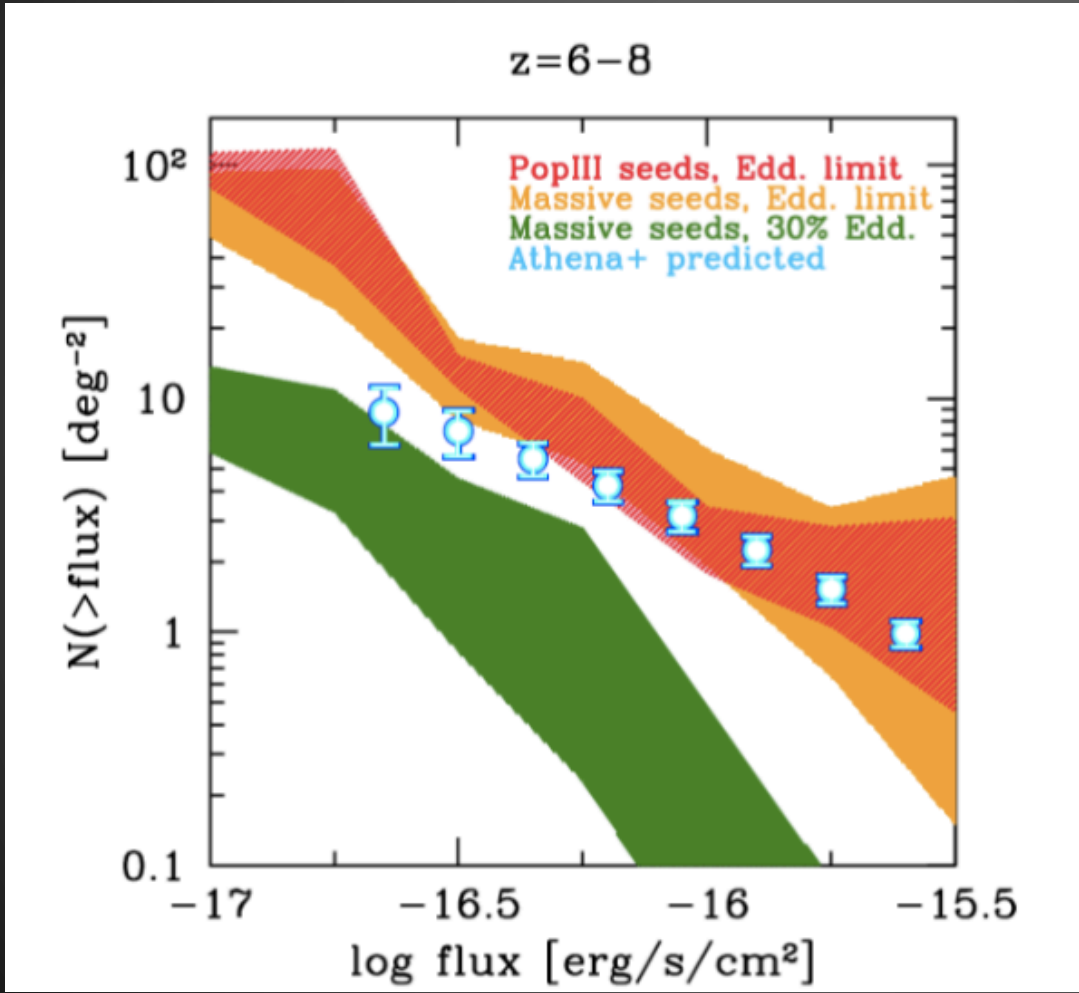


Bright quasars suitable for host galaxy follow-up with ALMA: dynamical modelling, evidence for large gas disks (see next few talks by R. Wang, B. Venemans etc.)



ALMA observations of z~2-3 hyper-luminous quasars (L_{bol} ~ $10^{14} L_0$; M_{BH} ~ 10^{10} M_0) revealing evidence for very large molecular gas disks extending to > 20 kpc (MB, Carilli+ in prep)

X-Ray AGN at High-z: Athena (2028)



X-ray detected high-redshift quasars with Athena have the potential to discriminate between different theoretical models for BH formation (e.g. Volonteri+10)

e.g. low number densities for z=6-8 X-ray AGN would imply low growth rates and rule out Pop III seeds

(Talks this morning)

Aird+13: The Hot & Energetic Universe

Summary

- Current wide-field optical surveys (e.g. DES, PS1, HSC) building on the legacy of SDSS with large samples of $z > 6$ quasars: red-sensitive detectors
- Near infra-red cameras on 4-m class telescopes (UKIDSS, VISTA) enabling the first $z > 6.5$ samples to be detected – space density evolution beyond $z=6.5$ still an open issue
- Future photometric surveys: LSST and Euclid will allow us to detect $z > 7.5 – 8$ quasars
- Pushing to fainter quasar luminosities: new VISTA Public Surveys (VEILS): overlapping DES and LSST deep fields: do quasars contribute to re-ionization?
- Multi-wavelength surveys: ALMA, Athena, SKA