High Redshift Quasar Hunting with the Dark Energy Survey

Quasars in the Epoch of Reionisation

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Why?

Theories of black hole formation and evolution

Metal abundances in the early universe

Gas distribution and reionisation

$z = 2$
peak of galaxy and quasar activity

$z = 6 - 15$
Epoch of Reionization

$z = 20 - 30$
first stars “Population III”

$z = 1100$
matter-radiation decoupling (CMB)

$z = 6 - 8$
Start of Reionization

$z = 1100$ matter-radiation decoupling (CMB)

$z = 6 - 8$
Start of Reionization
Quasar Spectrum at $z \sim 6$

Spectrum of a $z = 5.86$ quasar from Venemans et al 2007

Continuum break across rest frame Lyman-alpha ($\lambda_{\text{rest}} = 121.6\text{nm}$) gives distinctive colours
Quasar Spectrum at $z \sim 6$
The Dark Energy Survey (DES)

First Light September 2012

Very large area when completed: ~5000 deg$^2$, currently have ~2000 deg$^2$

Deep imaging: 10 σ limits for i and z are AB = 23.4 and AB = 23.2

Sophisticated camera, DECam

Credit: DES Collaboration
DECam

Mosaic of 62 2k by 4k CCDs (0.27” pixels)

Multi waveband imaging: Visible (400 nm) to Near IR (1050 nm), g, r, i, z and Y bands covered

Much more sensitive to red light than SDSS

Credit: DES Collaboration
DES - SDSS Comparison

SDSS was most sensitive to bluer light in the r band

DES is most sensitive to redder light in the z band
The VISTA Hemisphere Survey (VHS)

Will cover 10,000 deg$^2$ in the infrared when completed

VHS-DES (J, H and K) overlaps DES and is deeper

VHS-ATLAS (Y, J, H and K) is a shallower survey
Currently Known Objects

Lots of quasars known at $z < 4.0$ (~88,000 in SDSS DR9)

Between $z = 5.7$ and $z = 6.5$ there are ~60 known objects

$z > 6.5$ there are 8, one is above $z = 7$

Expected Numbers

5,000 deg$^2$ of DES footprint
$z > 6.5$ 50-80 with Y < 22 [AB]
$z > 7.0$ 3-10 with J < 21 [AB]

10,000 deg$^2$ of VHS + DES/VST-ATLAS
$z > 6.5$ 20-30 with Y < 21 [AB]
$z > 7.0$ 2-5 with J < 20 [AB]
Note brighter limits

Based off Manda Banerji’s calculations from Willott et al 2010
Point source (star galaxy separation) criteria taken from SDSS (step 3)

MAG_PSF - MAG_MODEL < 0.145

After all the steps there were 43 objects remaining

These were then narrowed down using $\phi_{izY}$
z ~ 6 Selection Criteria

- Saturation
- Diffraction Features
- Not Imaged
- Nothing There
- Badly Deblended
- Near Bright Object
- Satellite Trail
i - z > 1.69
z - Y < 0.5; used to remove cool dwarf stars

The M/L/T dwarfs shown here are simulated colours
The grey track is a simulated quasar track
The black points are stars from one DES SVA1 tile

Reed et al 2015
$\phi_{iz}$: Error Weighted Selection Metric

$$\phi_{iz} = \frac{i_z - (i_{psf} - z_{psf})}{\sqrt{i_{err}^2 + z_{err}^2}}$$

$$\phi_{zY} = \frac{(z_{psf} - Y_{psf}) - z_Y}{\sqrt{z_{err}^2 + Y_{err}^2}}$$

$$\phi_{izY} = \sqrt{\phi_{iz}^2 \phi_{iz}^2 + \phi_{zY}^2 \phi_{zY}^2}$$

Here $i_z$ and $z_Y$ are the colour cuts used.

Reed et al 2015
The spectrum shows the strong Lyman alpha peak

Confirms it as a $z = 6.1$ quasar

Spectrum taken by Michael Rauch, reduced by George Becker
z > 6.5 Selection

z-Y > 0.5
Y-J < 0.8

Objects that satisfied criteria matched to VISTA Hemisphere Survey to get J band magnitudes
Photometric Redshift Selection

Fit of a model at a range of redshifts using all available photometric data

Chi squared fit

Dependent on treatment of non detections

Min $\chi^2$: 4.06
Min red. $\chi^2$: 0.45
Final Selection

Use photometric redshift fit to a quasar model with a range of reddening

$E(B-V) = 0.0$ to $E(B-V) = 0.1$

Blue points narrowed down with $\chi^2 < 1.0$ for $E(B-V) = 0.0$
Spectroscopic Follow up

Confirms the object as a quasar

Spectrum taken by Michael Rauch
What is a Near Zone?

Credit: Michael Rauch
What is a Near Zone?

Credit: Michael Rauch
What is a Near Zone?

Us

Quasar

Near Zone

Gunn Peterson Trough

Observed Wavelength /Å

Flux (erg/s/cm²/Åx10⁻¹⁷)

Rest Frame Wavelength /Å

DES-VHS J02-50, z = 6.74
Comparative Near Zone Sizes

ULAS J1120+0641
z = 7.085, $R_{NZ} = 1.4 \pm 0.2, -0.1$ Mpc

DES-VHS J02-50
z = 6.74, $R_{NZ} = 3.4 \pm 0.7$ Mpc

DES J0454-4448
z = 6.1, $R_{NZ} = 4.6 \pm 1.7$ Mpc
Future Work

Higher Redshift
Combine the DES and VHS datasets to look for Y-J dropouts ($z > 7$)

Larger Sample at $z > 6.5$
Applied for telescope time to follow up other high redshift candidates

Near Zones
Collect spectra of $z > 6$ objects to look at changing near zone size in a consistent manner.
Summary

Two new quasars found

The DES is a rich dataset for finding high redshift quasars

Near zones can be used to make observations about the neutral hydrogen level