Unveiling QSO host galaxies and their Lyα emission at z~6 by SHELLQs

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What is a quasar (QSO)?

A QSO is an extremely luminous active galactic nucleus (AGN), which is a compact region at the center of a galaxy.

QSOs & its host galaxies

Many astronomers have concluded that most, if not all, galaxies host massive black holes at their centers.

It is very important to study the relationship between the QSOs and its host galaxies for establishing whether QSOs are in fact as distant and luminous as we think they are, and second, for clues as to what can produce such an energetic phenomenon.

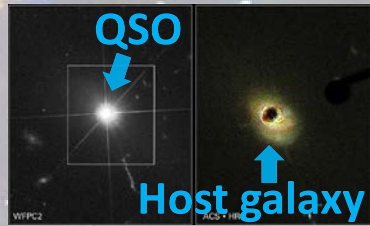


Fig. 1: Images of QSO 3C 273. At right, a coronagraph is used to block the quasar's light, making it easier to detect the surrounding host galaxy. Credits: Hubble Space Telescope

QSO host galaxies at different redshift

There has been research for host galaxies of QSOs at different redshift, (e.g. Kotilainen et al. 2007; Falomo et al. 2008). However, QSO host galaxies at the highest redshifts of z > 6 have not yet been studied extensively, since due to high QSO-to-host light ratios (QSO is too bright compare with its host galaxy).

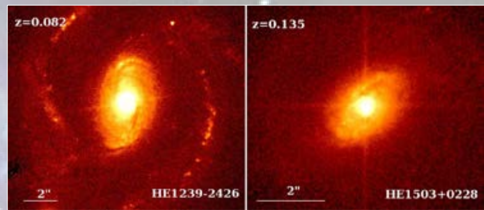


Fig. 2: Two examples of low-z QSOs with its host galaxies.
Credits: Hubble Space Telescope

➢ **We want to study QSO host galaxies at the earliest epoch of the Universe, with the most luminous black holes.**

Introduction

Subaru Telescope, National Astronomical Observatory of Japan (NAOJ)

Sample

From 2016, the Subaru High-z Exploration of Low-Luminosity Quasars (SHELLQs) team has spectroscopically identified 93 QSOs at 5.7<z<7.0 from the Hyper Suprime-Cam (HSC) Subaru Strategic Program (SSP) survey (Matsuoka et al., 2016, 2017, 2018a,b, 2019).

We have visually inspected each QSO and removed contaminated images. After applying the above selection criteria, we were left with a sample of 46 clean QSOs (z_{median}= 6.13). This sample was contamination-free and was thus an ideal sample to study the QSO host properties.

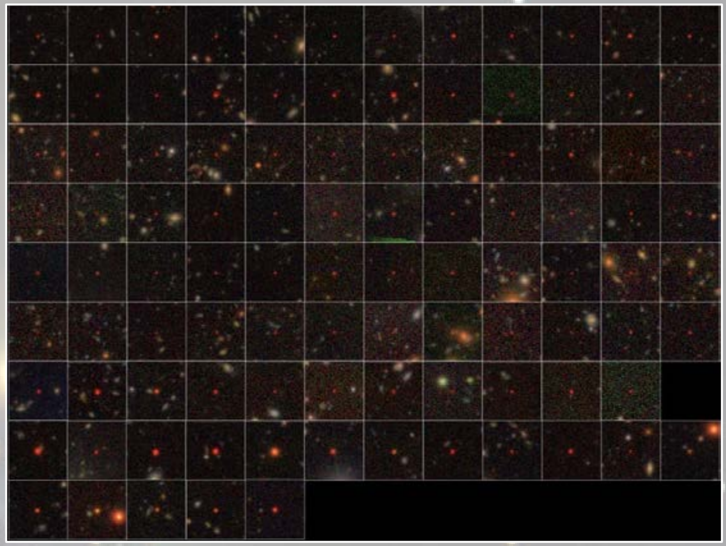


Fig. 3: SHELLQs QSO samples. The red dots inside the small squares are the QSOs. Credits: NAOJ

Why stacking the QSOs?

QSO host galaxies at redshift z~6 are very faint due to the absorption by the interstellar medium between us. For a QSO at z=6.42, its emission is more than 10 times higher than a z=6.96 galaxy (See Fig. 4).

By stacking the QSO images, we can increase the signal-to-noise ratio of the image. Thus, extending the limiting magnitude of the observing instruments.

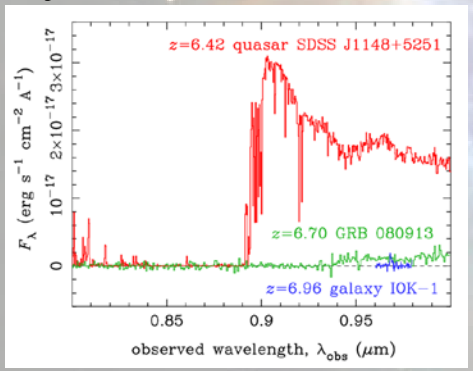


Fig. 4: Spectra of high redshift sources Credits: Mortlock et al. 2015

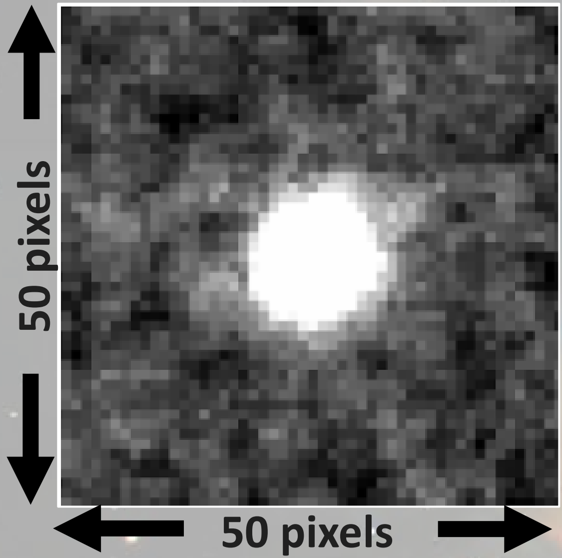
Increase of depth after stacking: 2.5*log(50^0.5)=**2.12** mag

HSC_z band depth=25.9 mag
New HSC_z band depth: 25.9+2.12=**28.02** mag

Typical galaxies around QSO field in z-band=**26.5** mag (Ota et al. 2018)

Methodology

Stacked image of the QSOs

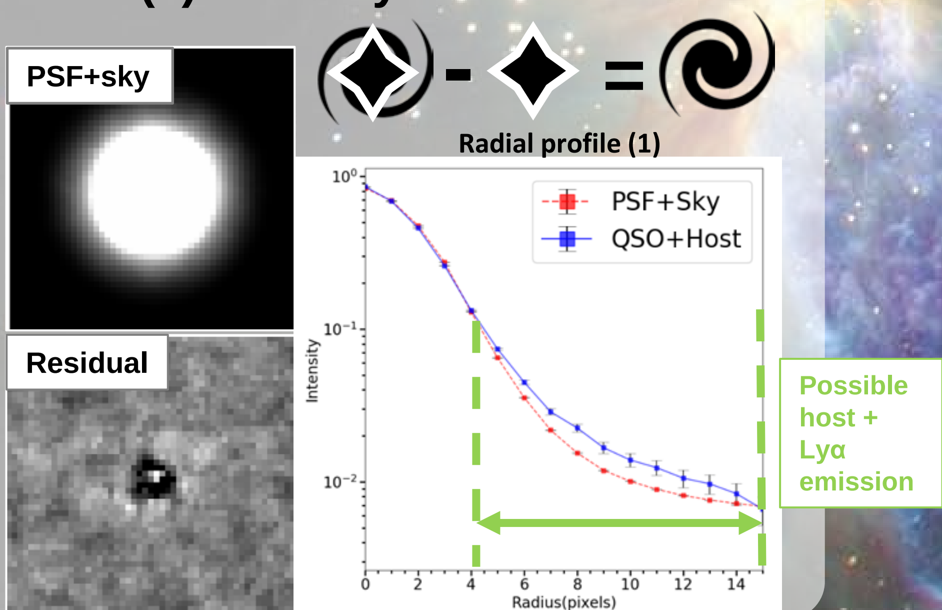


QSO subtraction

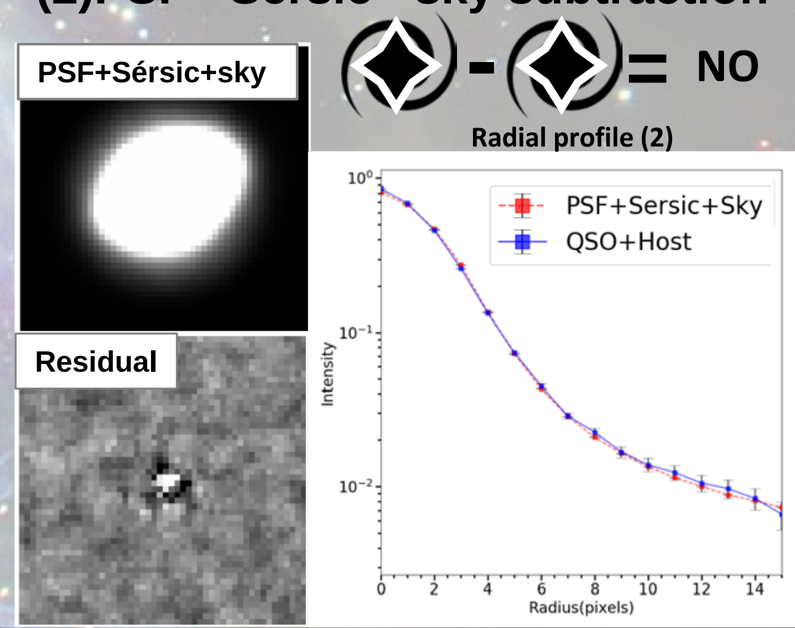
In the stacked QSO image, we use GALFIT (Peng et al., 2002) to subtract **(1)PSF+sky**, **(2)PSF+Sérsic+sky** components from the stacked QSO image.

- **Point Spread Function (PSF)** is a mathematical function that is very similar to QSO in the image
- **Sérsic profile** is a profile that most galaxy profiles can be fitted with

(1)PSF+sky subtraction



(2)PSF+ Sérsic +sky subtraction



In conclusion…

We detected for the first time!

The QSO+host has an excess over the PSF in radii at 4-15 pixels in the radial profile. This implies there is an extended structure (host galaxies + Lyman α emission). The size of the extended structure is ~8.75 pixels (1.49" or 9.3 kpc) in half-light radius.

To do list:

1. PSF subtraction in Y-band

This is to check whether the extended structure includes Lyman α emission

2. SED fitting to the extended structure

Then, we can calculate the stellar mass and do modeling (we can check the composition of the extended structure)

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