Discovery of a Faint Quasar at z~6 and Implications for Cosmic Reionization

Kim et al. 2015, ApJ, 813L, 35

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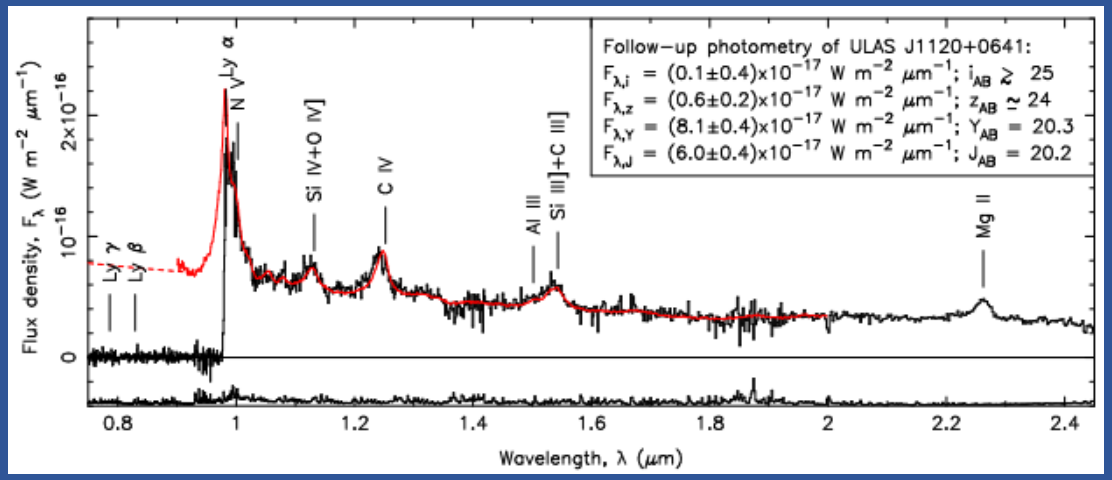
Introduction

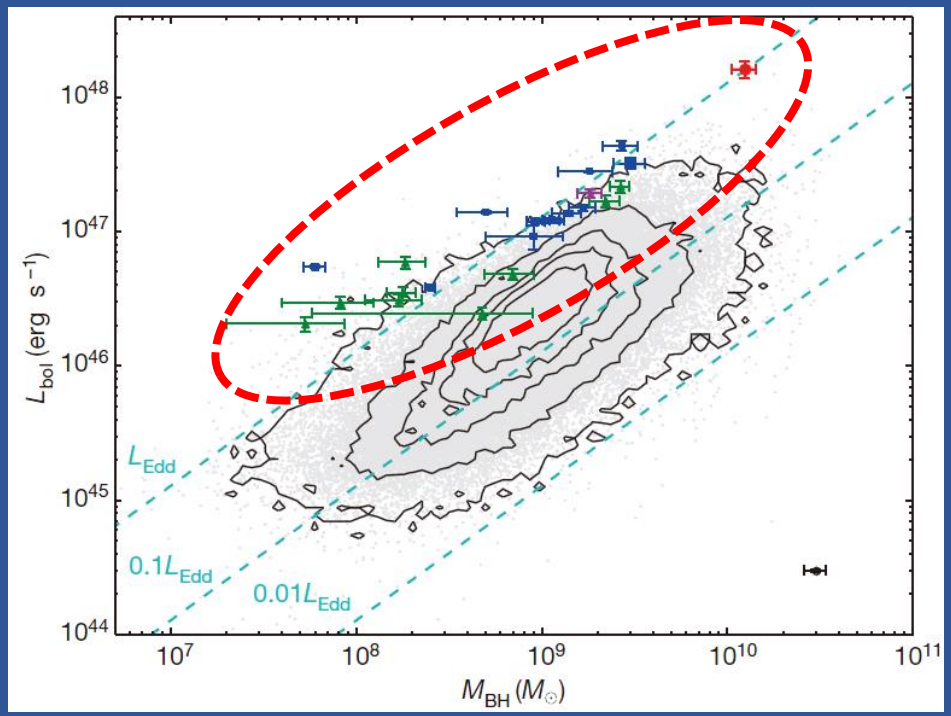
- **Quasars in the Early Universe**
  - Energetic sources in the universe
  - A unique sample to study
    - Formation of the first supermassive black holes (SMBHs)
    - Host galaxies at the epoch of cosmic reionization
- **Optical/NIR Survey for High-z Quasars**
  - SDSS (Fan+06; Jiang+08,09), CFHQS (Willott+07,09,10), UKIDSS (Mortlock+09,11), VIKING (Venemans+13,15), Pan-STARRS1 (Banados+14)



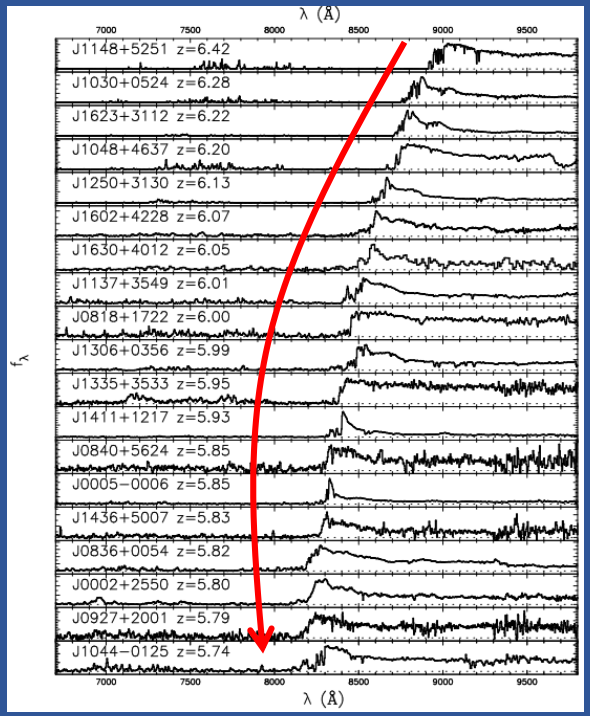
ULAS J1120+0641, z=7.085 quasar (Mortlock+11)

Introduction

- **Cosmic Implication of Discovered Quasars**
  - Formation of **$10^{8\text{-}10}$ M_{sun} SMBHs** just ~1 Gyr after Big Bang
    - Accreting mass at maximal rates (Willott+10; Jun+15)
    - Paucity of hot dust emission (Jiang+10; Jun & Im 13)
  - Significant fraction of intergalactic medium (IGM) is reionized
    - Strong Gunn-Peterson troughs (Gunn & Peterson 65; Fan+06)



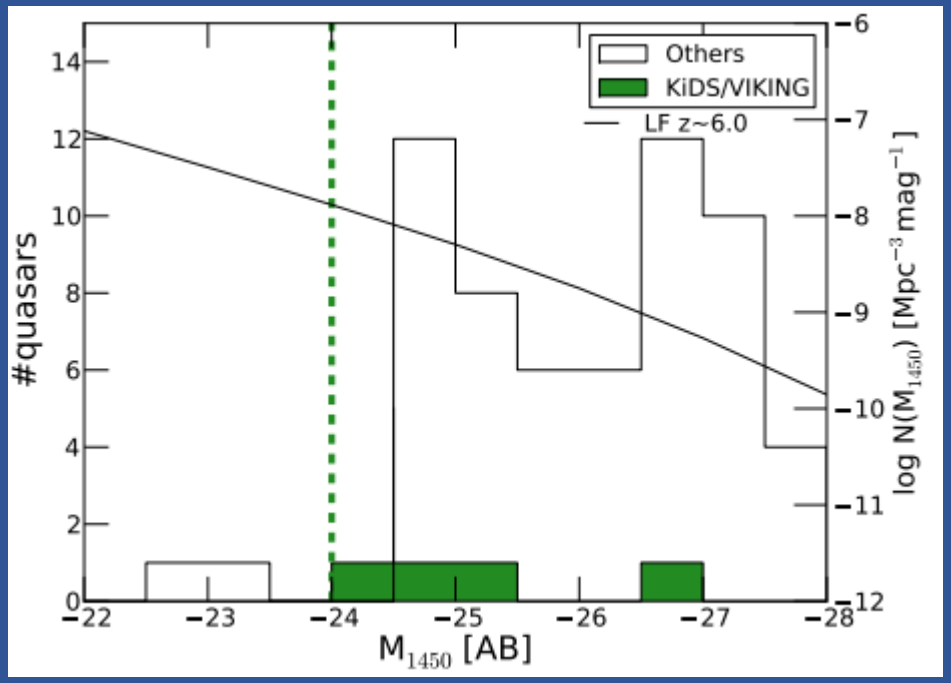
Wu+15



Fan+06

Introduction

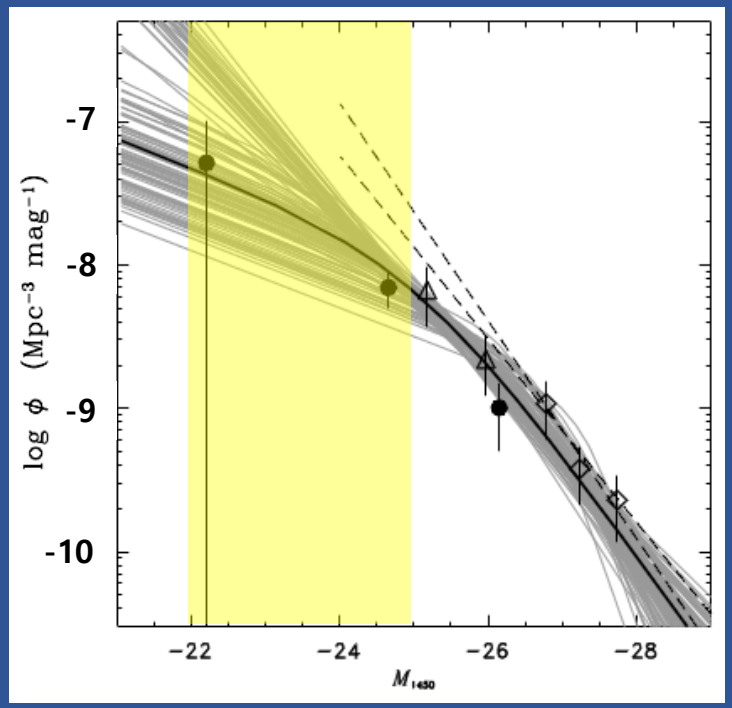
- **Lack of Faint Quasars at z > 6 (M_{1450} > -24 mag)**
  - **Biased sample** of currently discovered quasars
    - High luminosities and high accretion rates



Venemans+15

Introduction

- **Lack of Faint Quasars at z > 6 (M_{1450} > -24 mag)**
  - The **faint end of the quasar luminosity function** (QLF)
    - Significant contribution to reionization (Giallongo+15) or not (Willott+10)



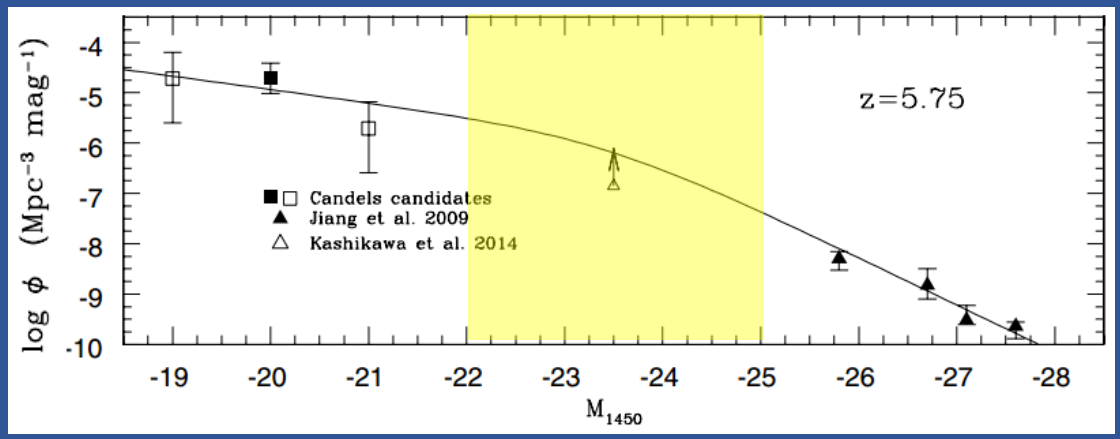
Willott+10

UV Emissivity

$\epsilon \propto \phi \times L$

ϕ: QLF L: luminosity

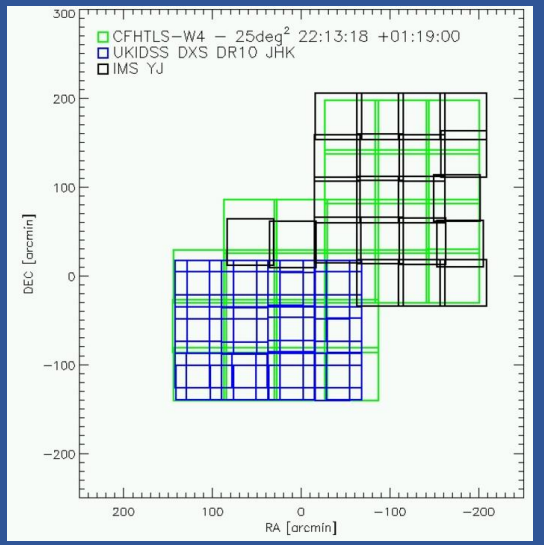
Maximum at
M_{1450} ~ -23.5 mag



Giallongo+15

IMS and CFHTLS Data

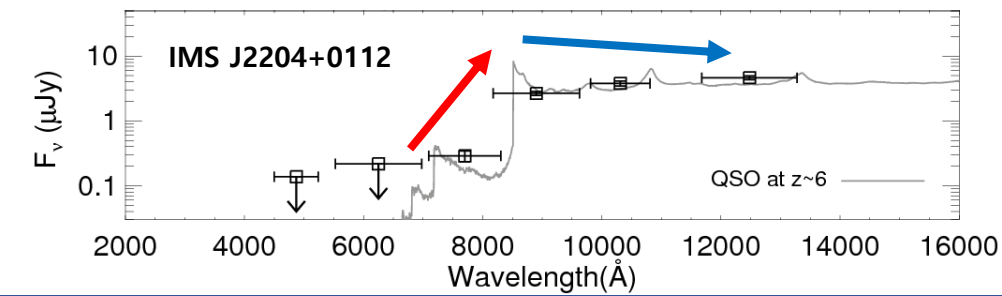
- **Infrared Medium-deep Survey (IMS)**
  - Infrared imaging (**Y/J**) survey for seven extragalactic fields (~120 deg^2) with UKIRT/WFCAM (Im et al. in prep)
  - Detection limit (5σ) : ~23.5 AB mag (Karouzos+14)
- **Canada-France-Hawaii Telescope Legacy Survey (CFHTLS)**
  - Optical imaging (**ugriz**) survey with CFHT/MegaCam
  - Completeness limit (80%) : ~24-25 AB mag (Hudelot+12)
- **Data Analysis**
  - Focus on **SA22** field (~12.5 deg^2)
  - Source detection in z′-band images by SExtractor
  - Dual mode with the identified z′-band sources

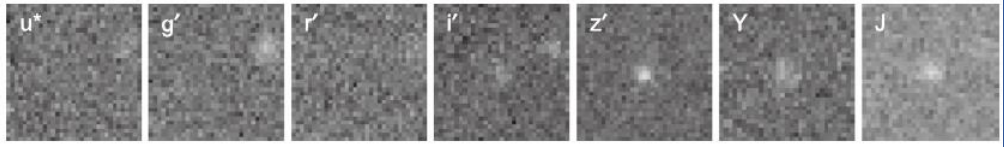


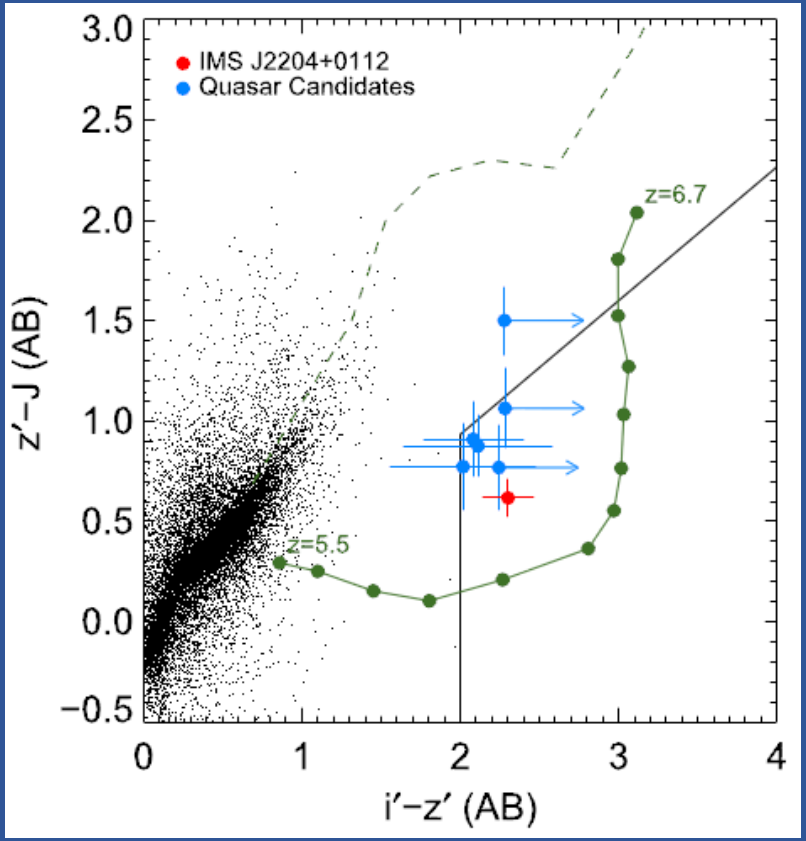
SA22 Field Coverage

Quasar Candidate Selection

- **Spectral Energy Distribution of z~6 Quasars**
  - Lyα break (1216 Å) redshifted to λ~8500 Å
  - Blue continuum beyond Lyα break
- **Selection Criteria**
  - $(i' - z') > 2$
  - $(i' - z') - 1.5\,(z' - J) > 0.6$
  - No detection (2σ) in u′, g′, and r′ (Willott+09)







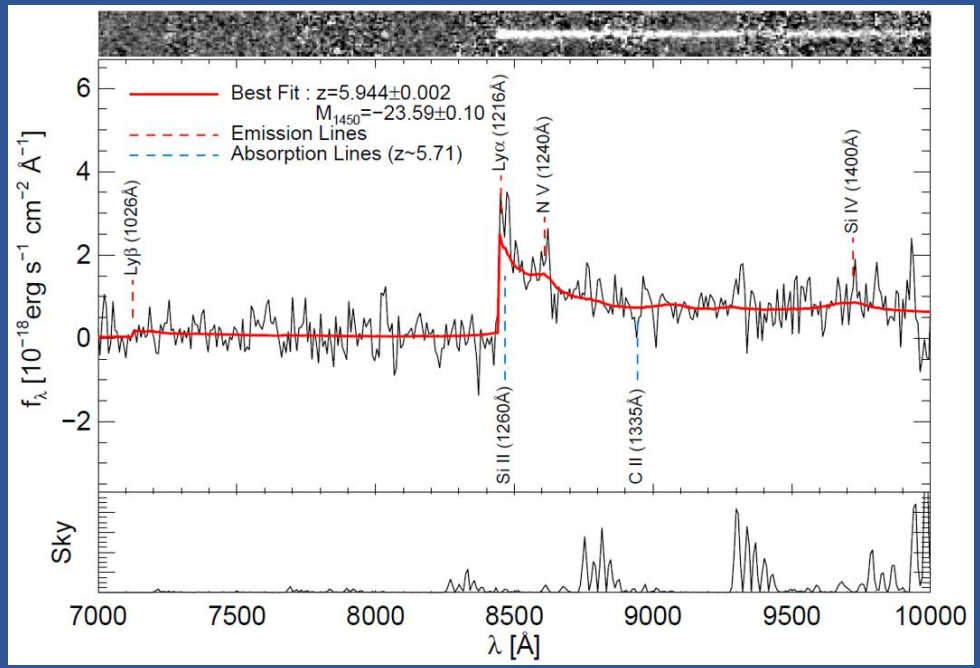
Spectroscopic Observation

- **Gemini/GMOS-S Observation (2015A)**
  - Supported by **K-GMT Science Program** of KASI
  - Instrument: Gemini Multi-Object Spectrograph (**GMOS**)
- **Technical Description**
  - **Nod & Shuffle longslit** (1″ width) mode with R150_G5326 grating
  - 4x4 binning → **7.72 Å/pixel** (~290 km/s)
  - RG610_G0331 filter to avoid the order-overlap
- **Exposure Time**
  - 12 sequences of 968 s (~3 hr)
  - Use five frames (**~1.3 hr**) with seeing < 1″

Gemini South 8 m Telescope

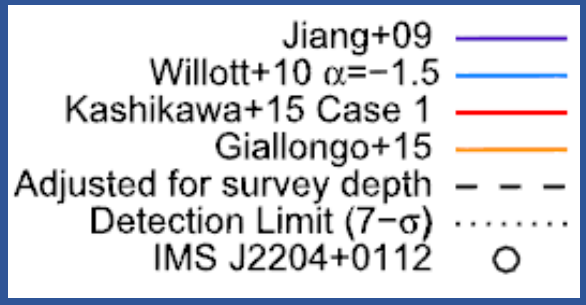
Discovery of a Faint Quasar at z~6

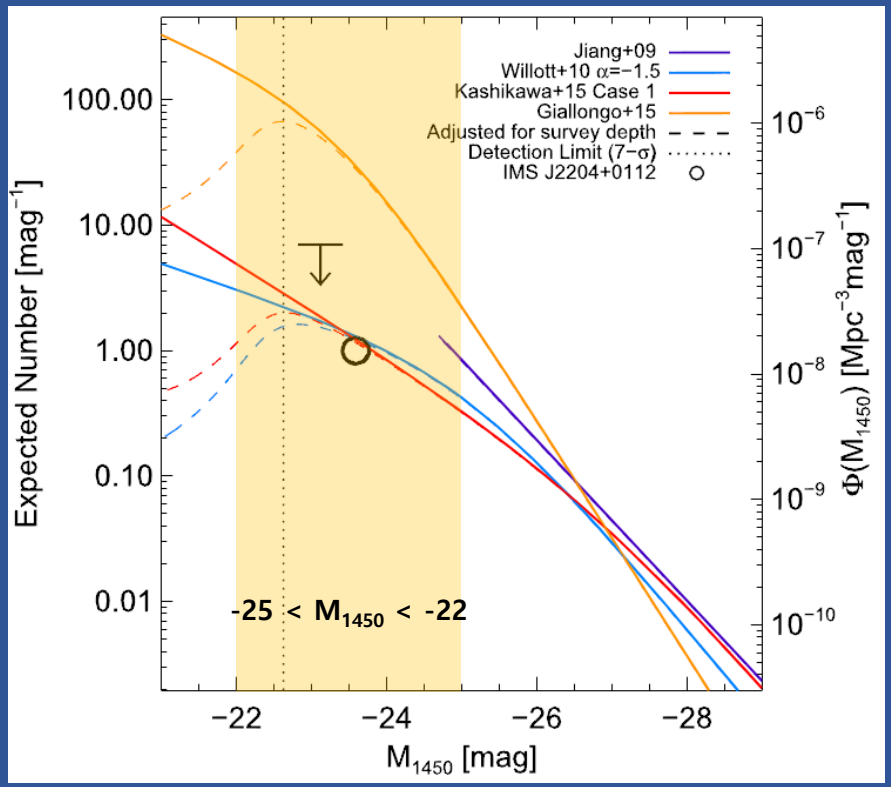
- **Spectrum of IMS J2204+0112**
  - Clear break at **~ 8443 Å** (identified as Lyα)
    - Fit the SDSS composite quasar spectrum, considering IGM attenuation (Vanden Berk+01; Madau+96)
    - **$z = 5.944 \pm 0.002$, $M_{1450} = -23.59 \pm 0.10$ mag**
  - Emission lines
    - Lyα λ1216, N V λ1240, Si IV λ1400
  - (Possible) absorption lines
    - Si II λ1260, C II λ1335
    - Absorber at z~5.71
  - Lower limit of M_{BH}
    - $M_{BH} > 10^8 M_{sun}$ ($\lambda_{Edd} = 1$)



Expected Number of Quasars in SA22

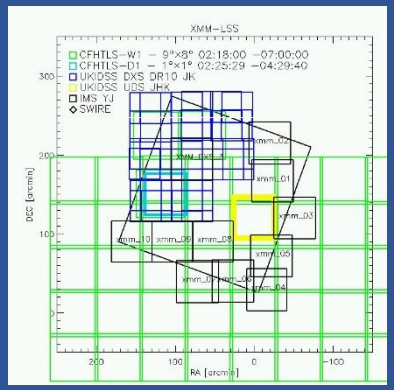
- **Expected Number in SA22 Field at M_{1450} = -23.5**
  - Hard to constrain the faint end with only one quasar
    - Optical/NIR AGNs (Willott+10, Kashikawa+15) : **1.4**
    - Faint X-ray AGN candidates (Giallongo+15) : **~40**
- **Fraction of Required UV Photons for Reionization**
  - AGNs at M_{1450} ~ -23.5
    - Giallongo+15: **~60%**
    - Willott+10, Kashikawa+15: **~3%**
    - **Our result: <15%**

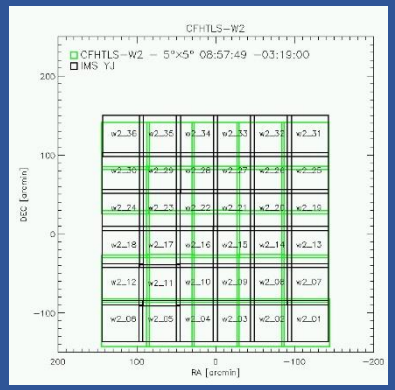


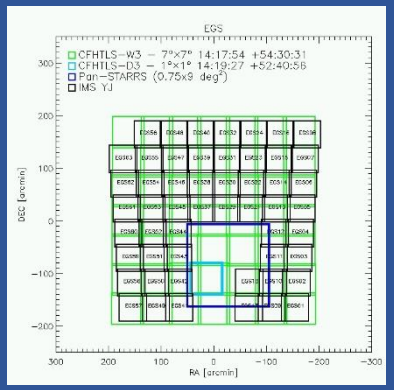


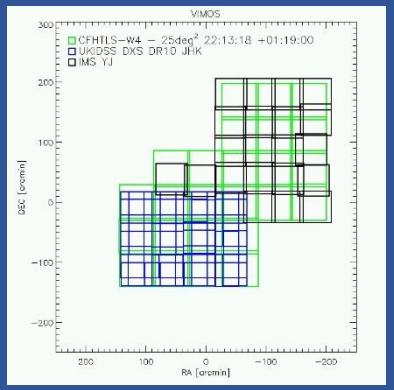
IMS as a Survey for High-z Quasars

- **Survey for Faint Quasars in the Early Universe**
  - Can be identified efficiently with IMS
  - Analysis of full IMS data → more faint quasars at z ~ 6
- **Large Sample of Faint Quasars**
  - Constrain the faint end of QLF
  - Determine M_{BH} & Eddington ratio
  - Understand low-luminous quasar population









Thank You