

The discovery of a luminous redshift 7.1 quasar

Daniel Mortlock
Imperial College London

with

Steve Warren, Mitesh Patel, Bram Venemans,
Richard McMahon, Paul Hewett, Chris Simpson,
Tom Theuns, Huub Rottgering, Ernst Kuiper
Jamie Bolton, Martin Haehnelt
and the UKIDSS collaboration

Quasars



Super-massive $M_{\text{BH}} \simeq 10^9 M_{\odot}$
black holes in galaxy centres

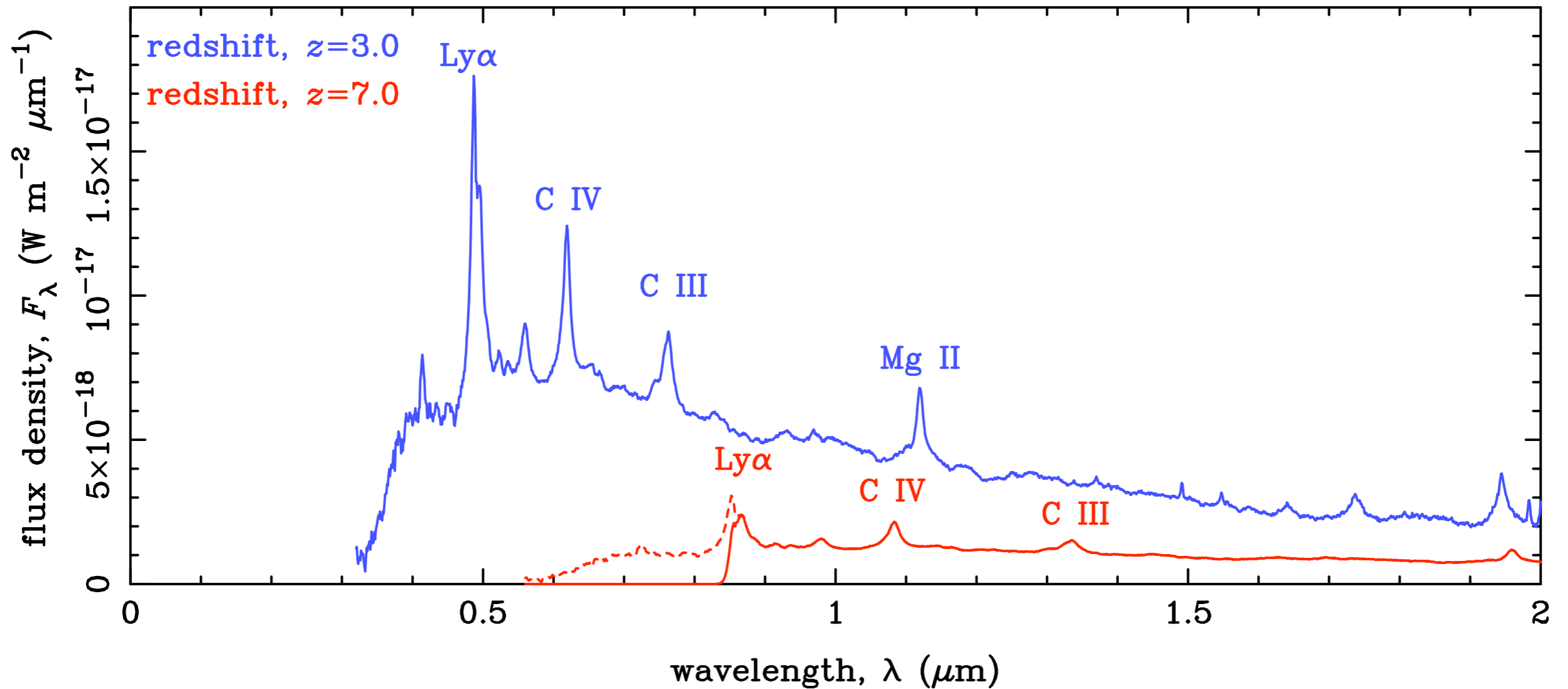
Emits more powerfully
than rest of galaxy:

$$L_{\text{q}} \simeq 10^{14} L_{\odot}$$

Only ~ 50 known in
first Gyr of universe
(i.e., with redshift > 6) ...

... none with redshift > 6.5

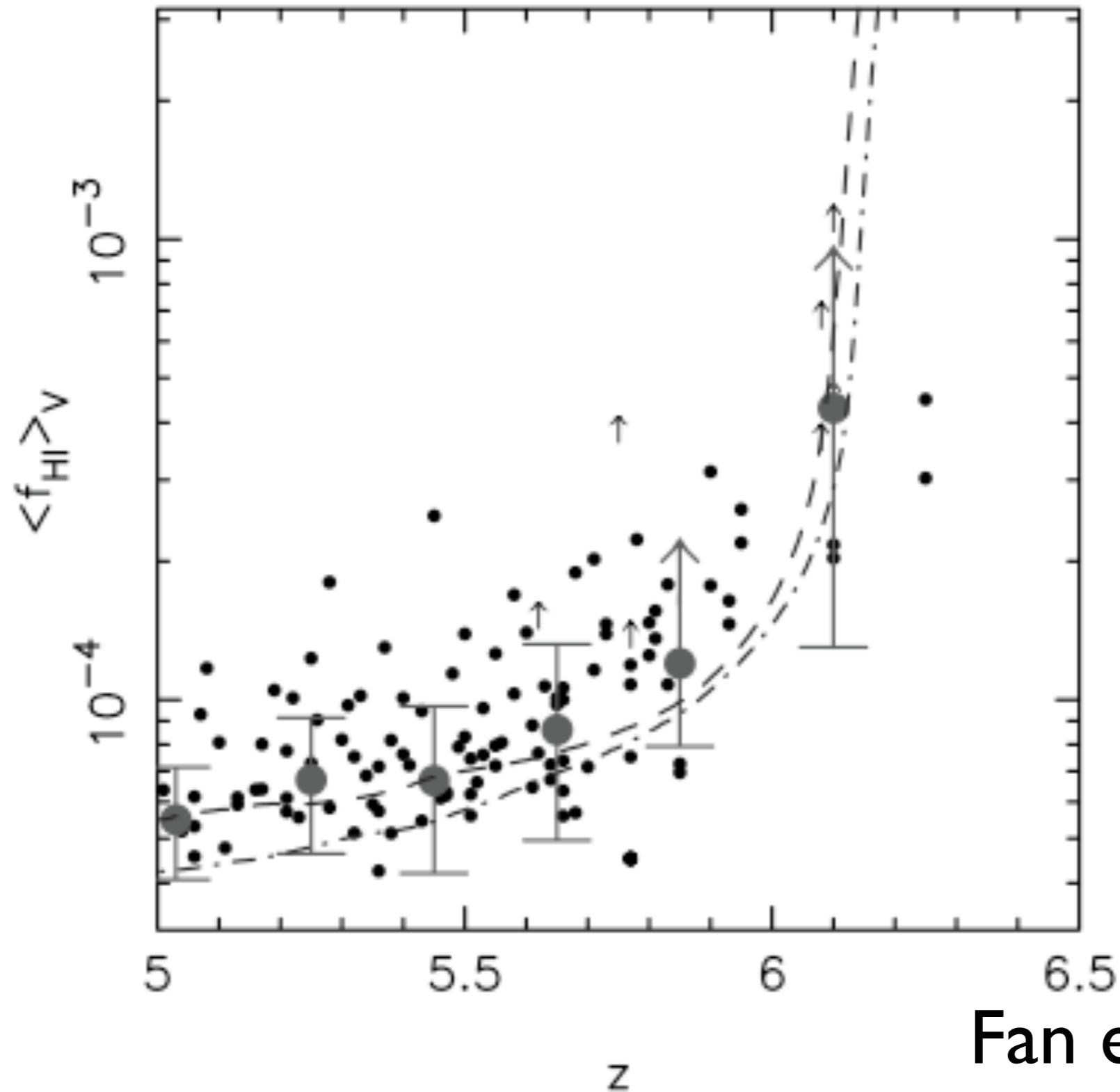
Quasar spectra



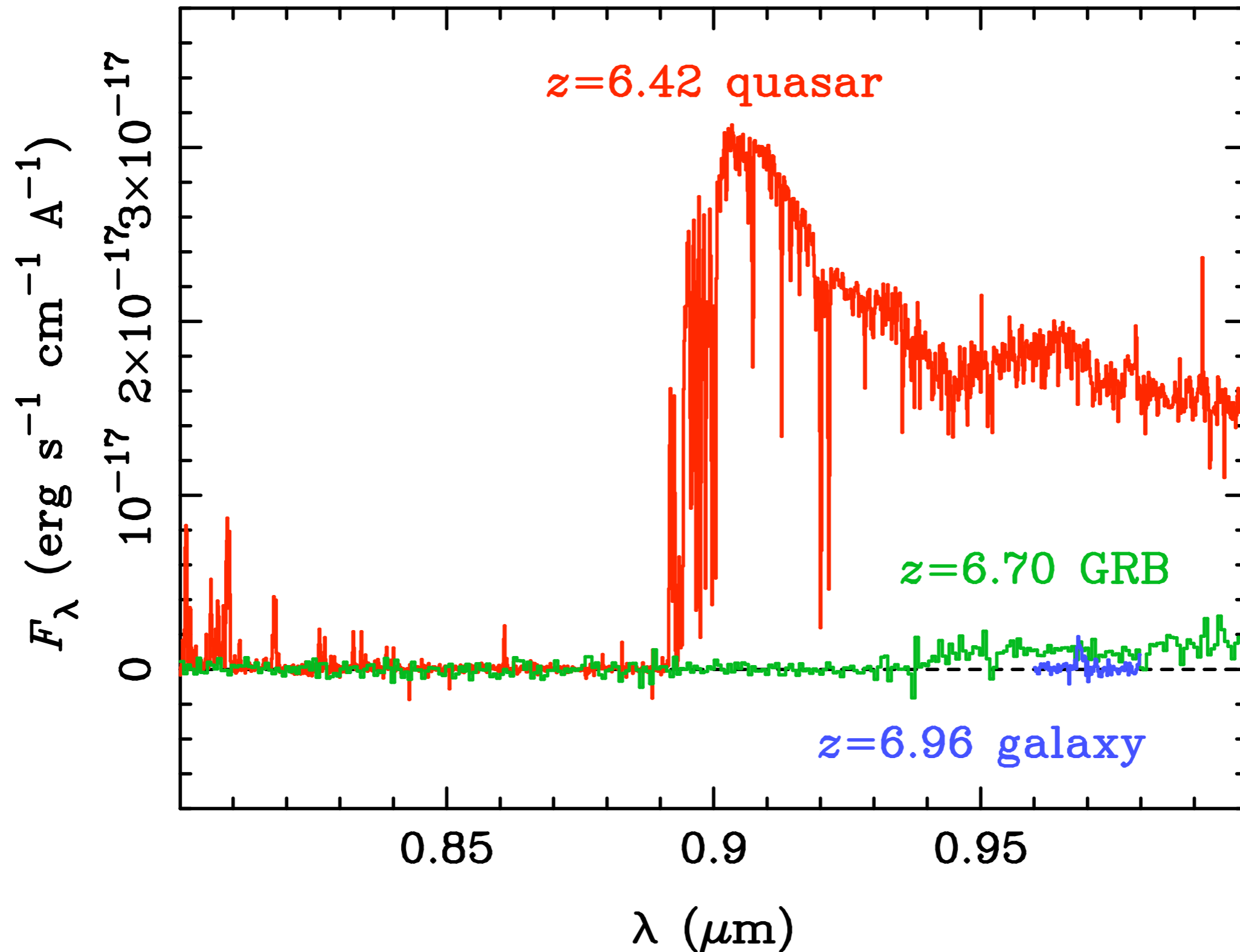
Quasars have very similar spectra

Absorption blueward of Ly alpha - reionization

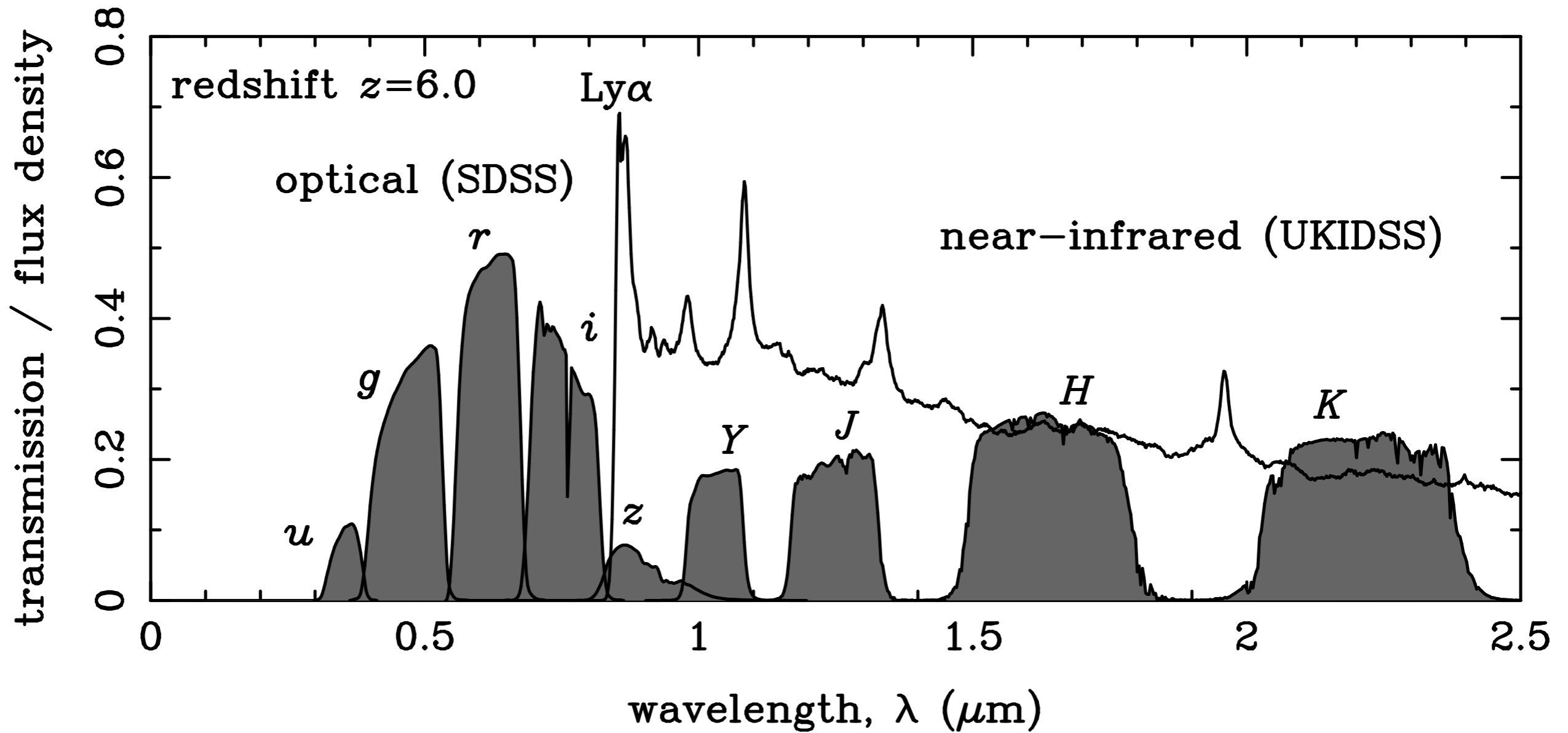
Reionization



High-redshift sources



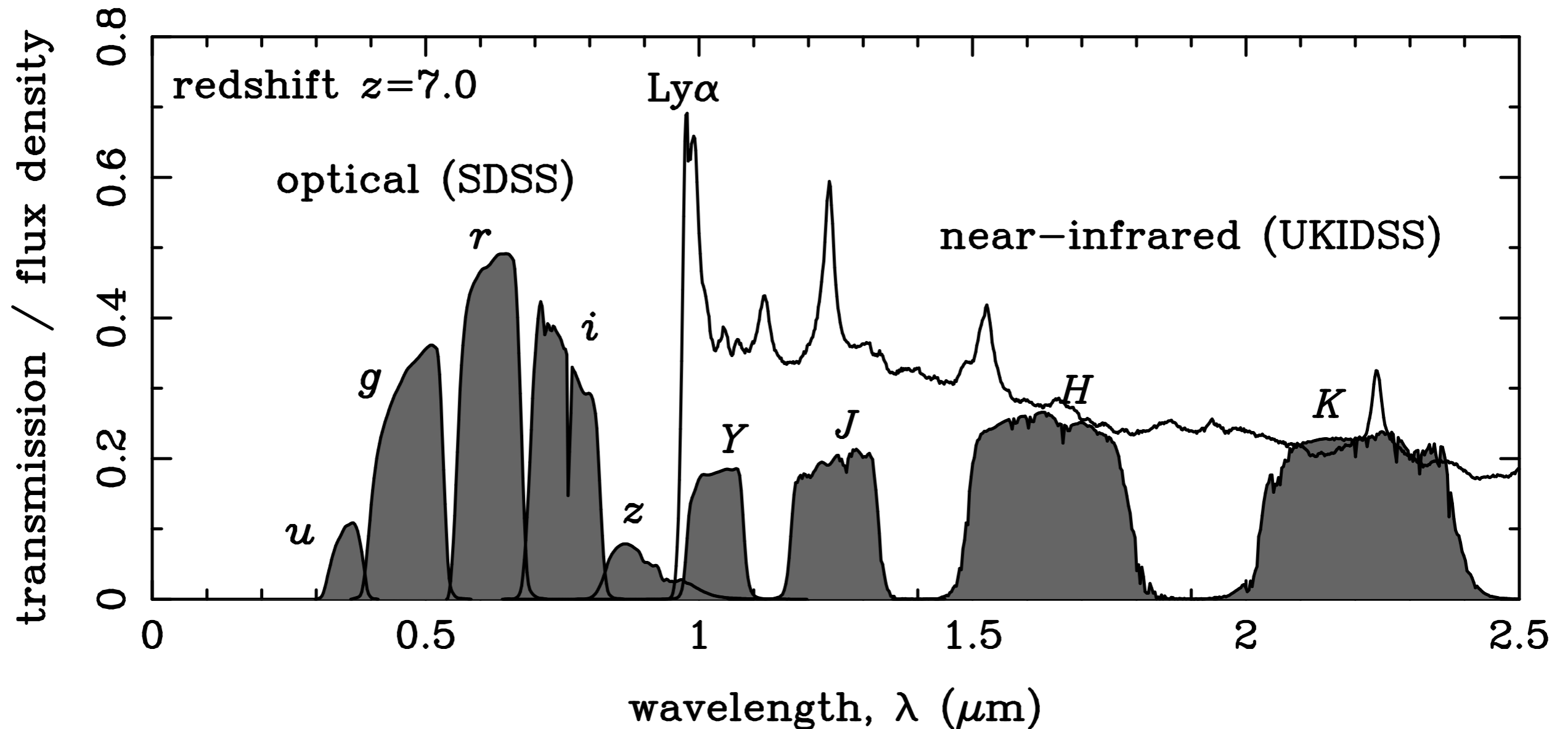
Quasar searches



optical
SDSS/Pan-STARRS

near-infrared
2MASS/UKIDSS/VISTA

Quasar searches



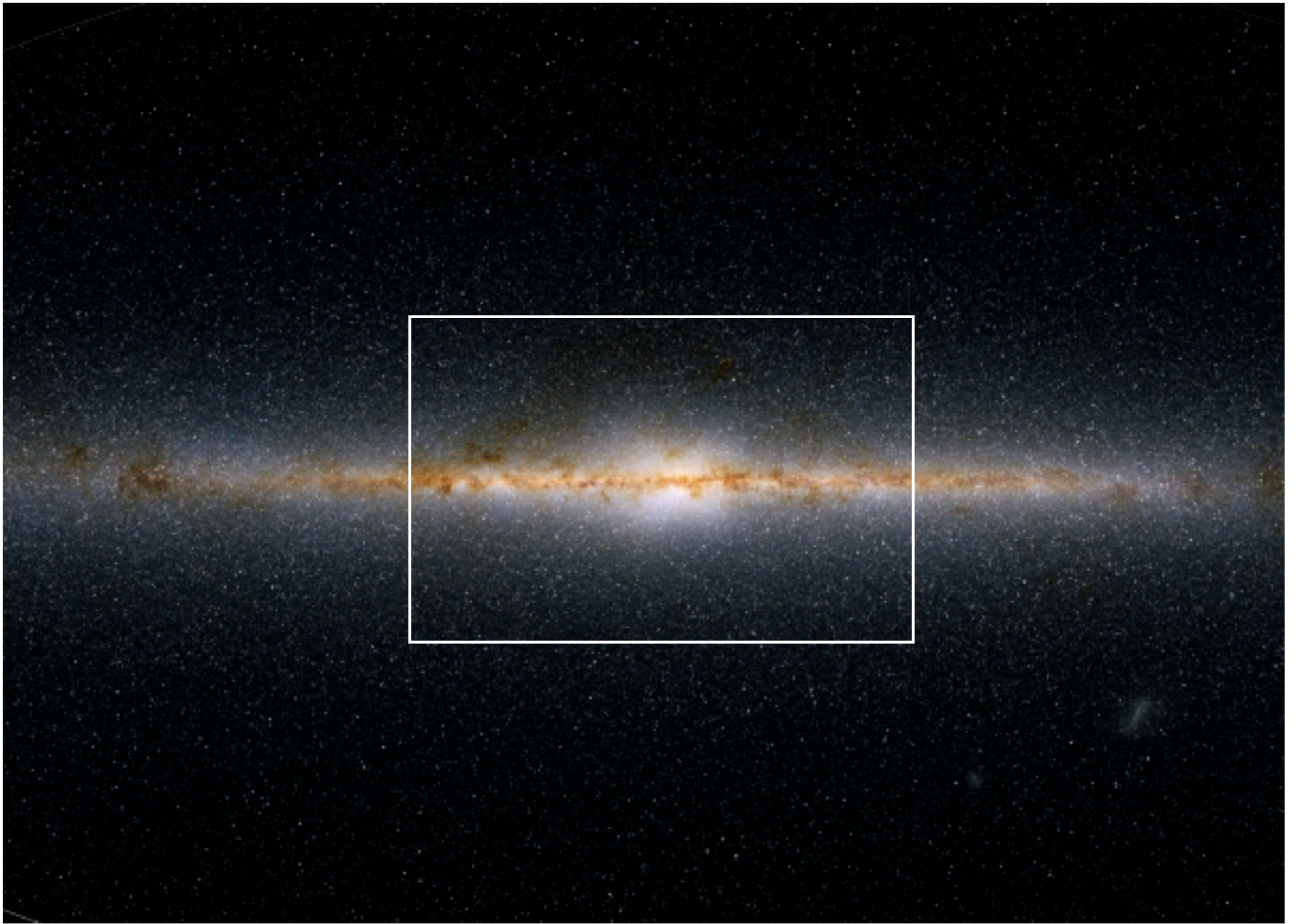
optical
SDSS/Pan-STARRS

near-infrared
2MASS/UKIDSS/VISTA

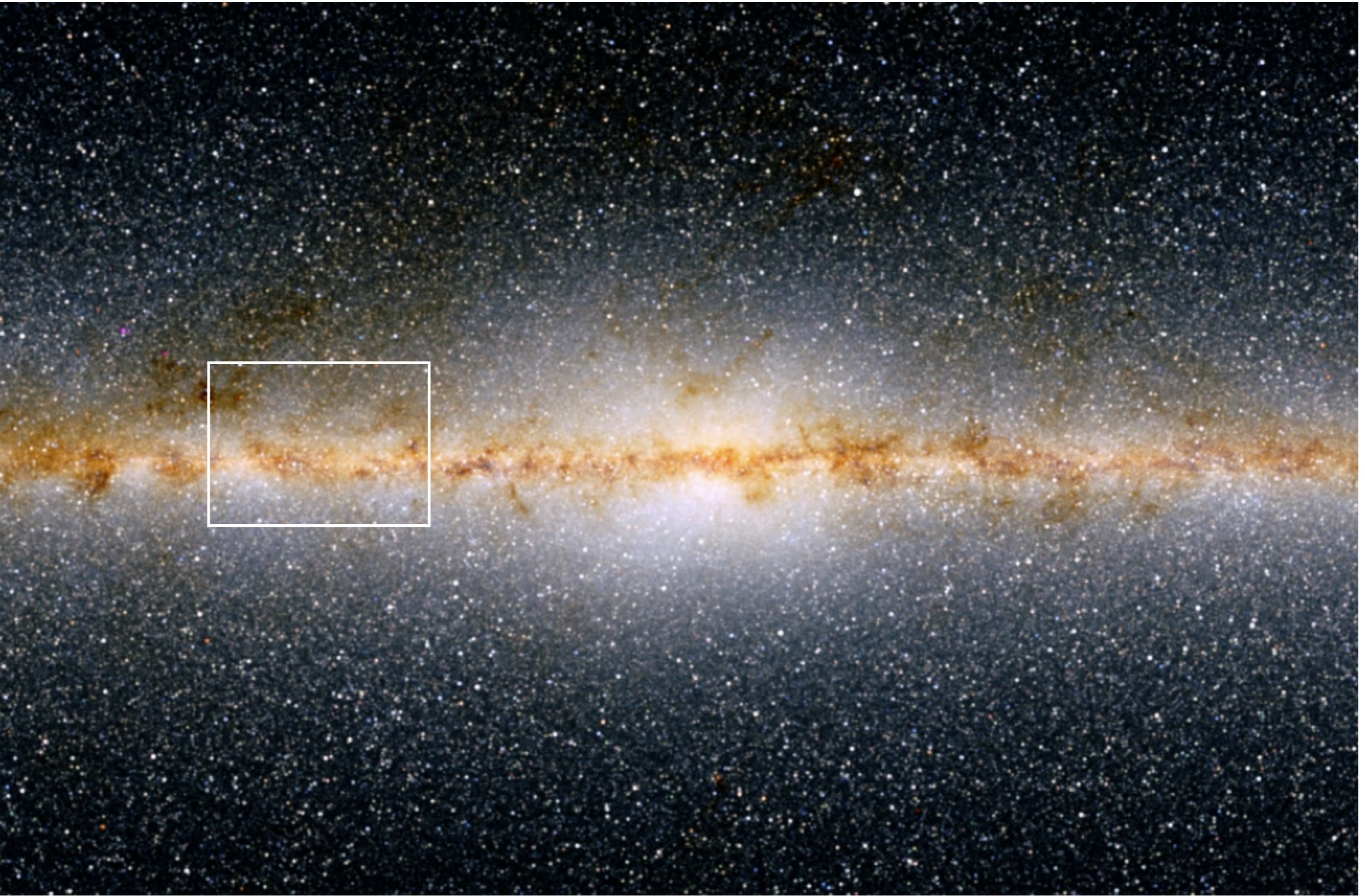
The UKIRT Infrared Deep Sky Survey (UKIDSS)



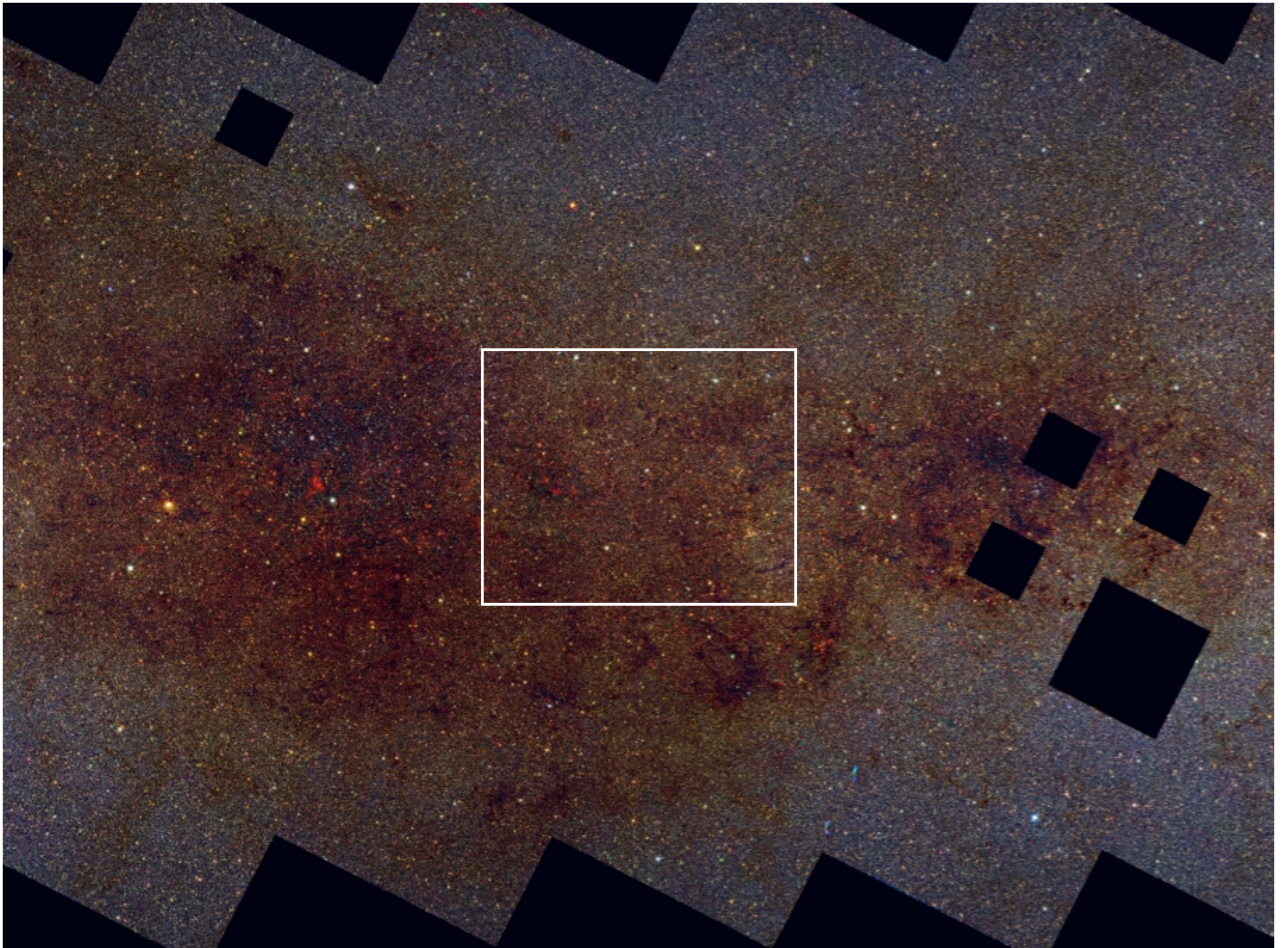
SDSS-like
imaging survey
at
2MASS
wavelengths



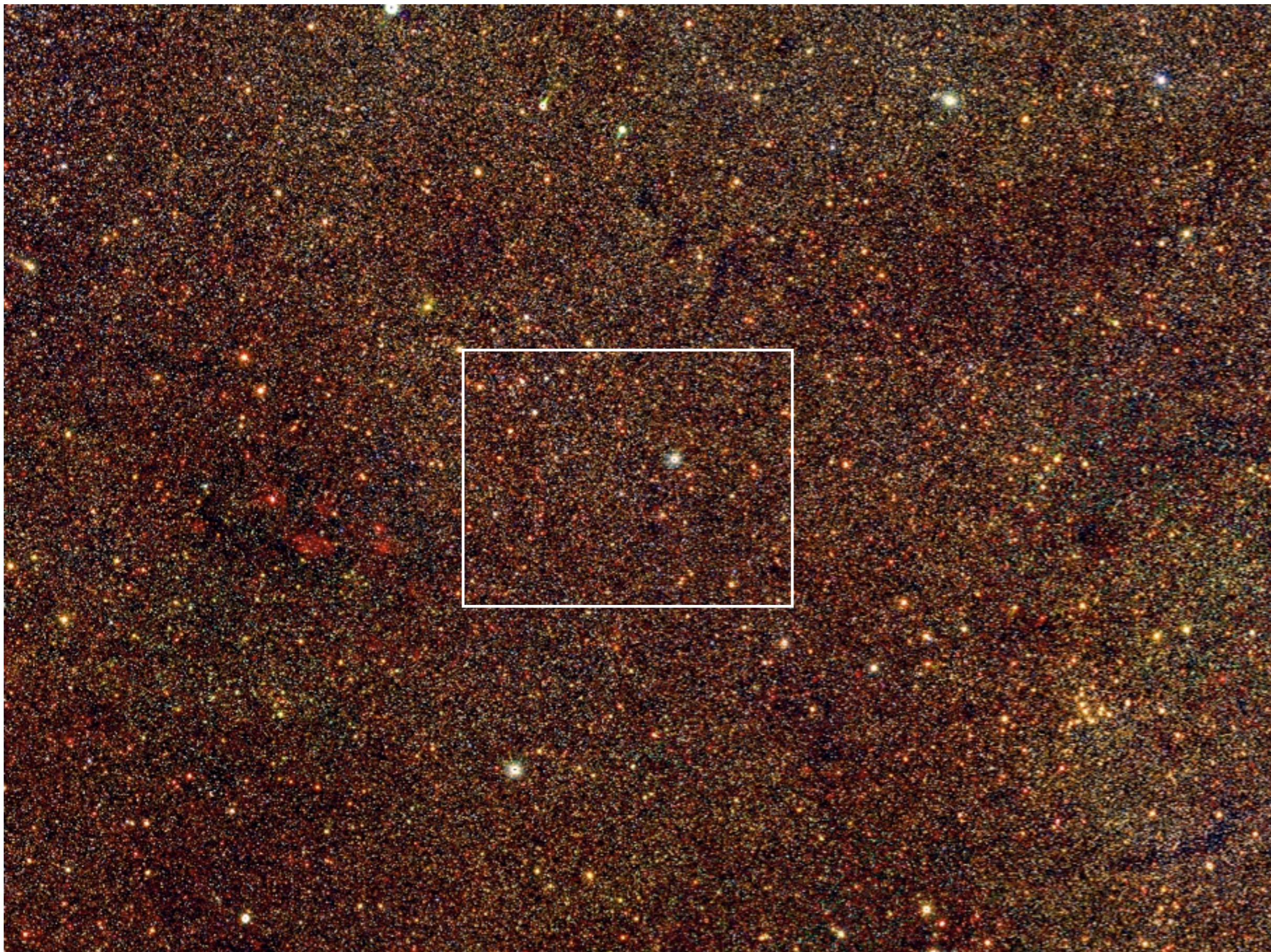
2MASS



2MASS



UKIDSS



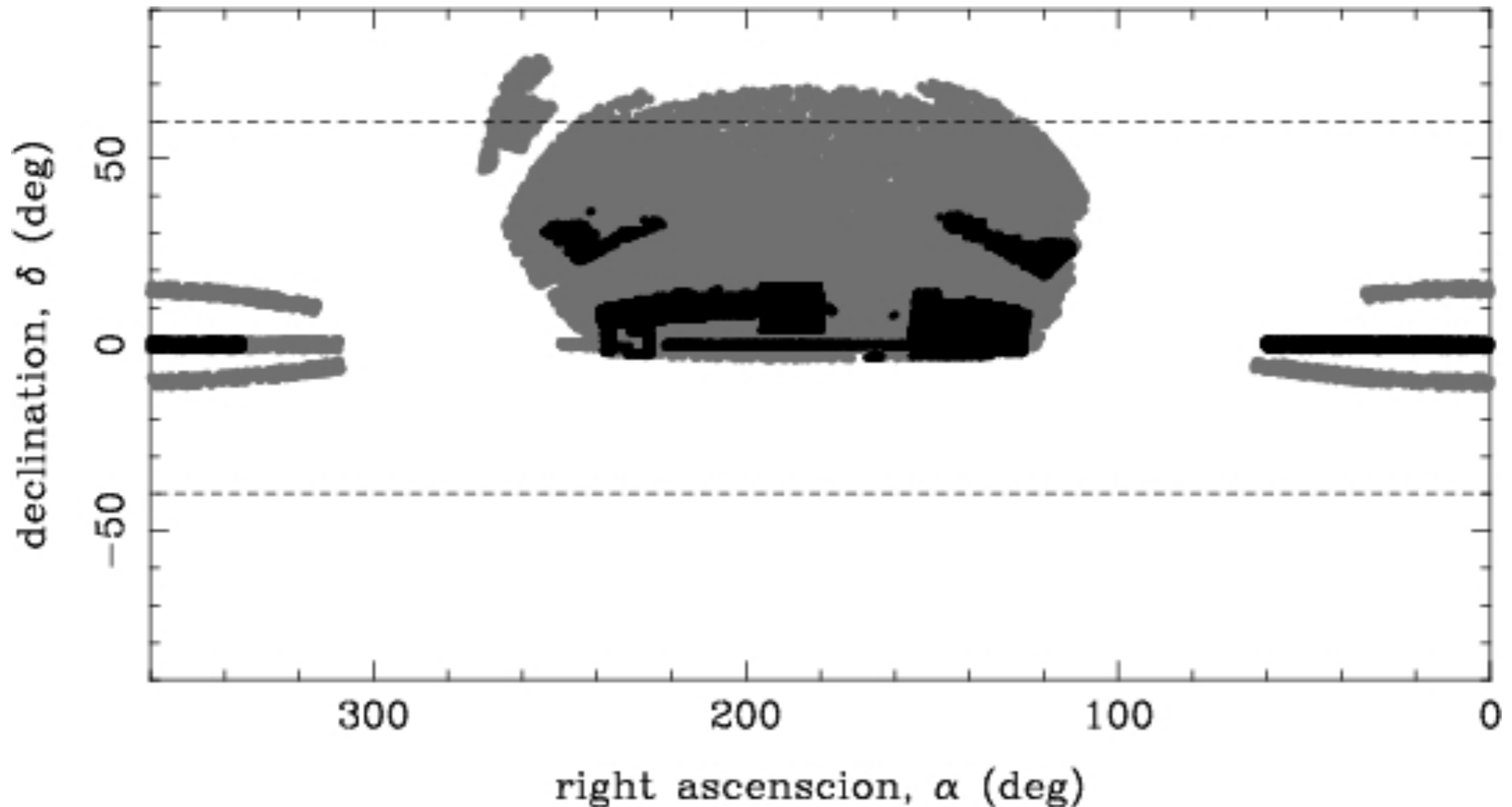


UKIDSS



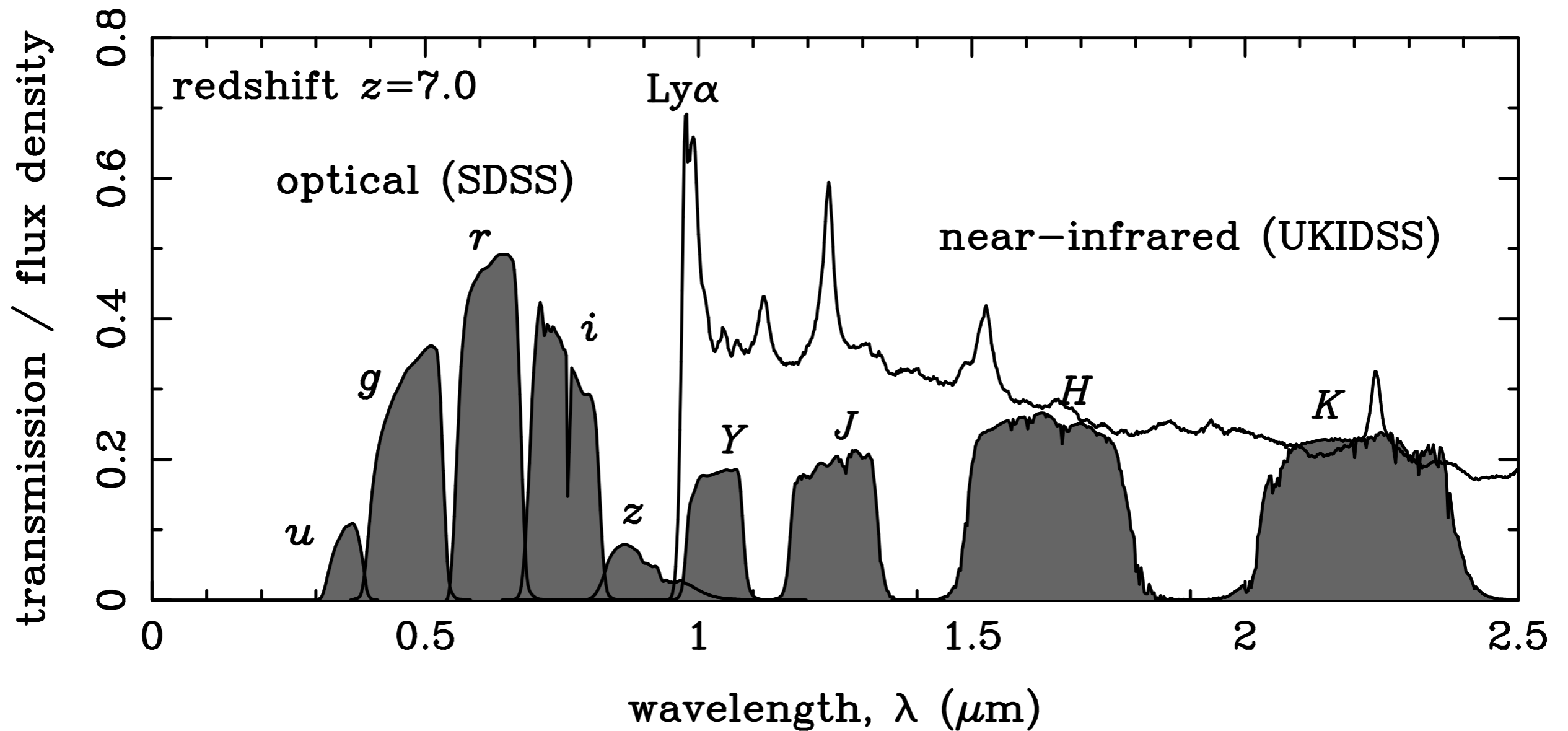
UKIDSS

UKIDSS Large Area Survey

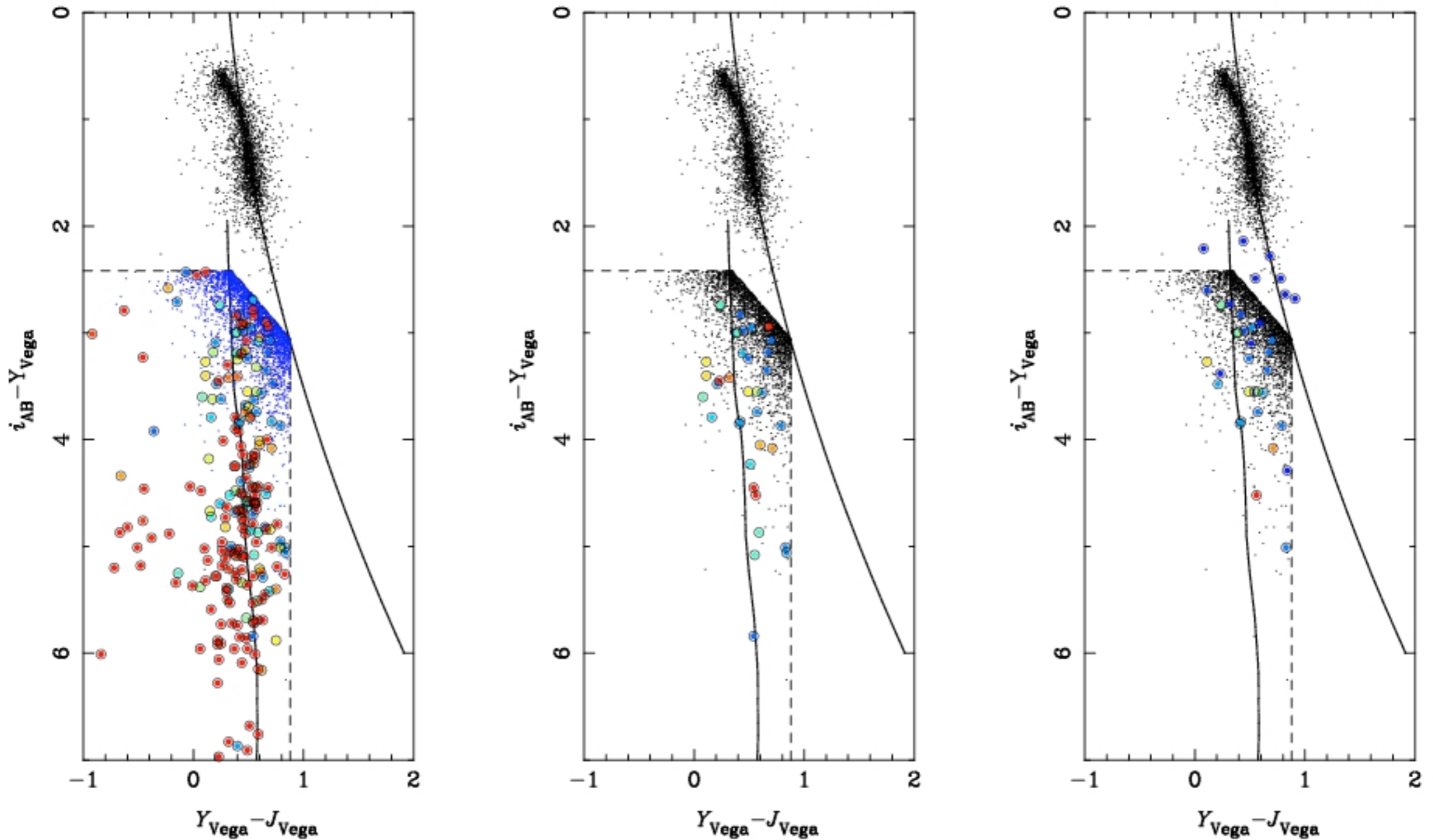


UKIDSS DR8 LAS: 2250 deg² of ~3800 deg² analysed
Coverage matched to SDSS

UKIDSS quasar survey

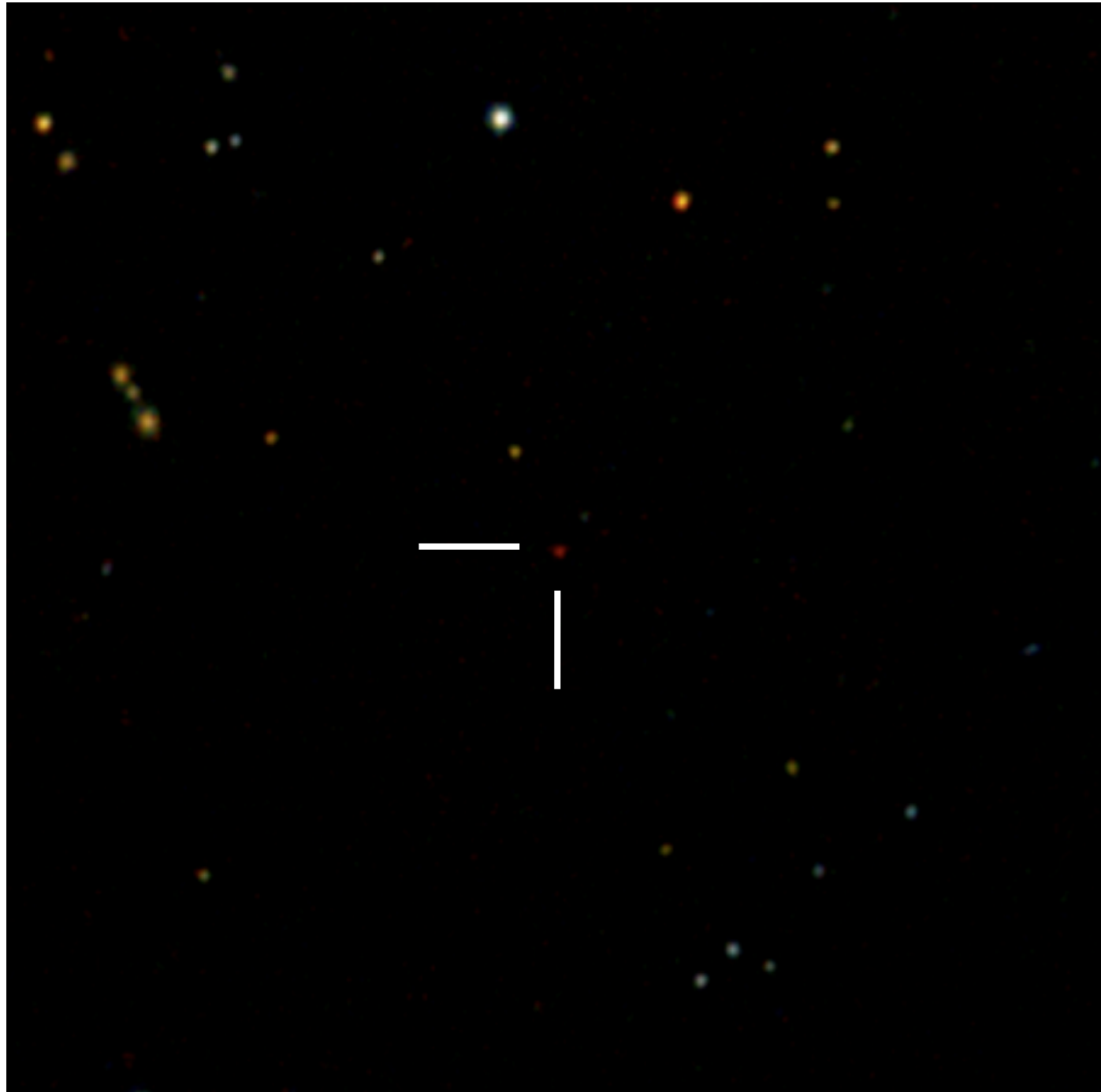


UKIDSS quasar search



Probabilistic (Bayesian) candidate selection

Redshift ~ 6 quasars

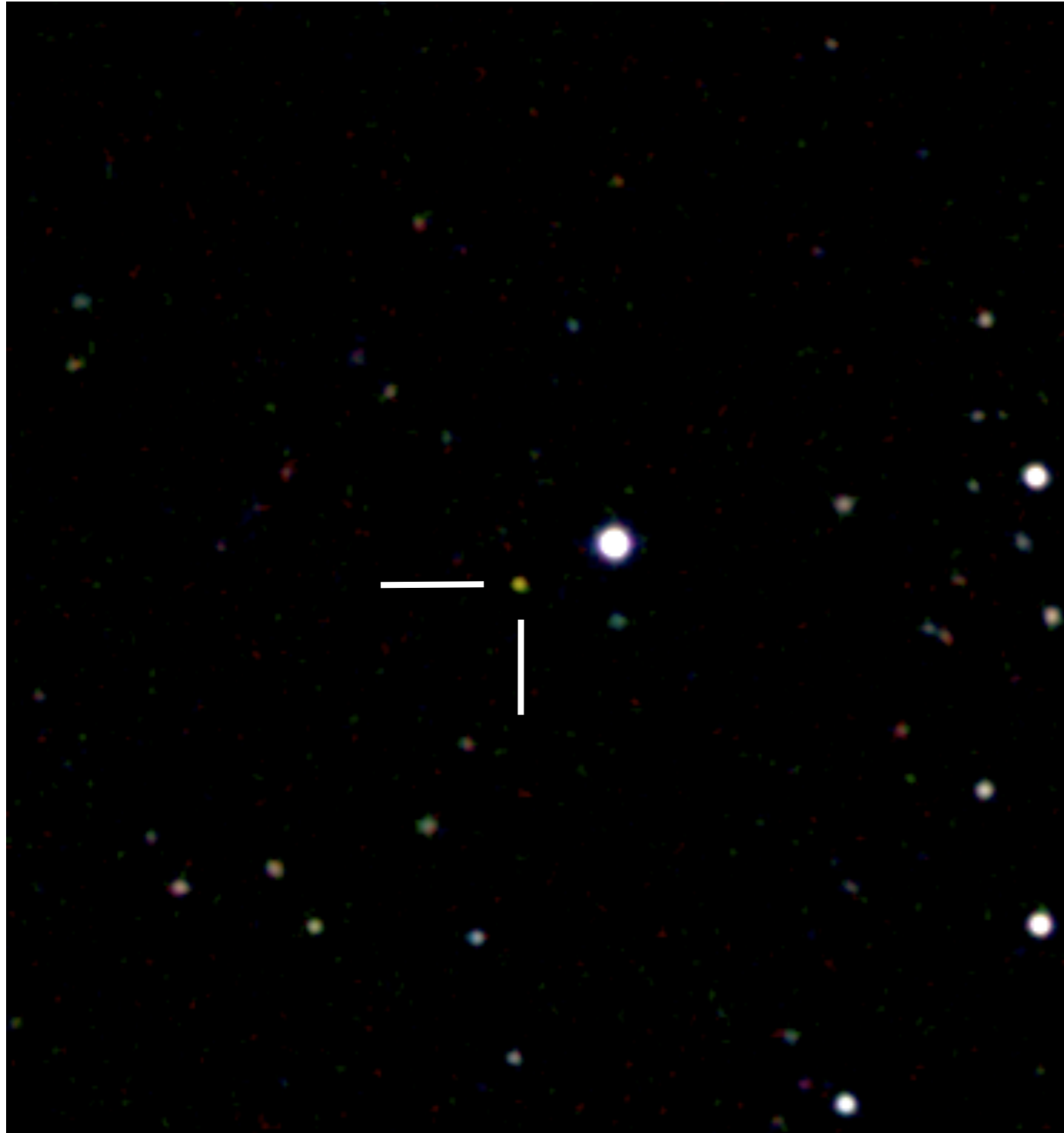


UKIDSS DR8:
2250 sq. deg.

Discovered 8 new
redshift ~ 6 quasars

Recovered 6 SDSS
redshift ~ 6 quasars

The first redshift >6.5 quasar



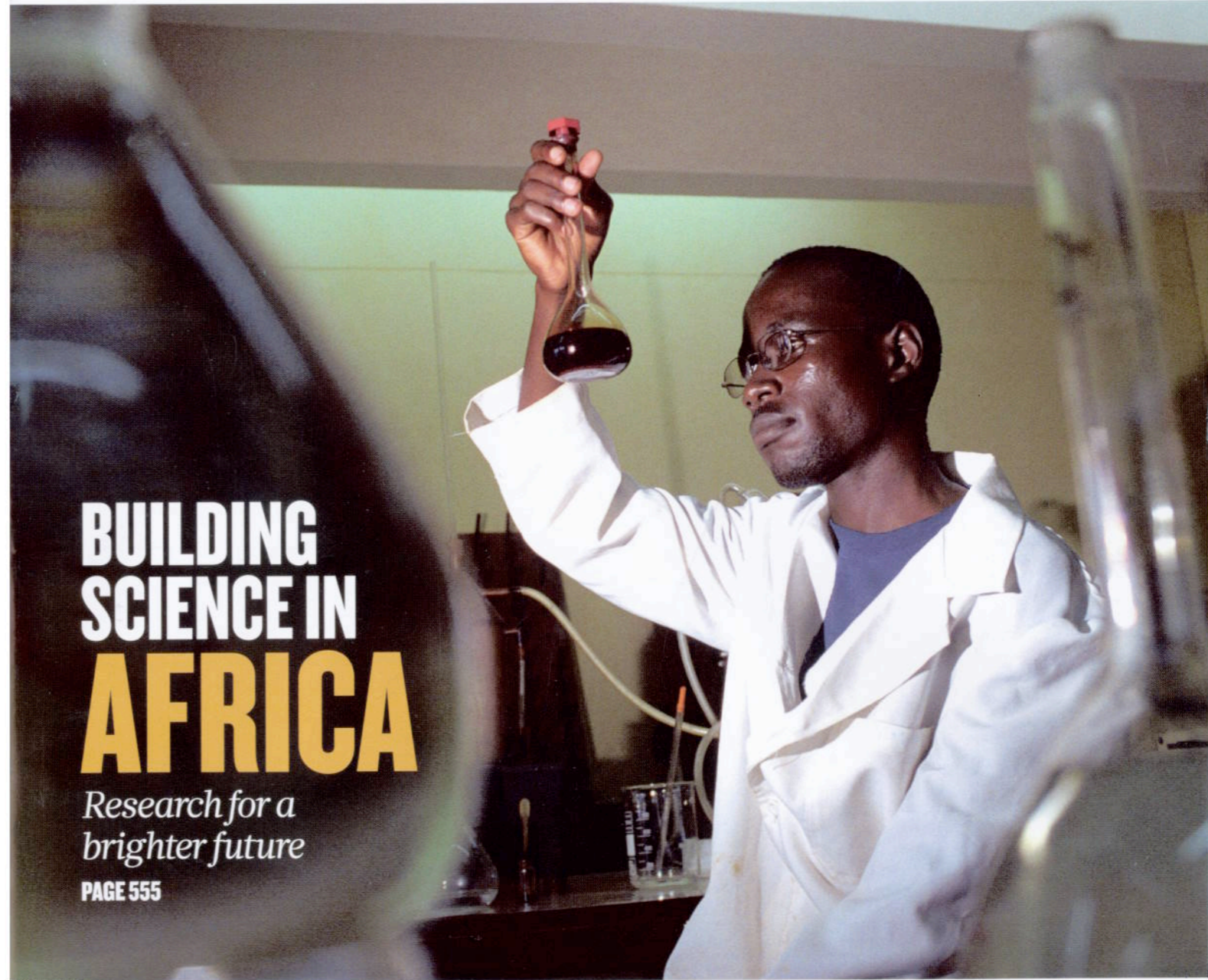
ULAS J1120+0641
redshift = 7.085

Seen 100 Myr earlier
than any other highly
luminous source

Only ~ 100 brighter
and more distant
sources over whole
sky

nature

THE INTERNATIONAL WEEKLY JOURNAL OF SCIENCE



BUILDING SCIENCE IN AFRICA

*Research for a
brighter future*

PAGE 555

COSMOLOGY

GOING THE DISTANCE

*High-redshift quasar
beats the record*

PAGES 583 & 616

EVOLUTIONARY THEORY

WON IN THE EYE

*Fossils confirm early arrival
of complex vision*

PAGE 631

ECOLOGY

A NEW WORLD VIEW

*The lasting legacy of the
Whole Earth Catalog*

PAGE 578

NATURE.COM/NATURE

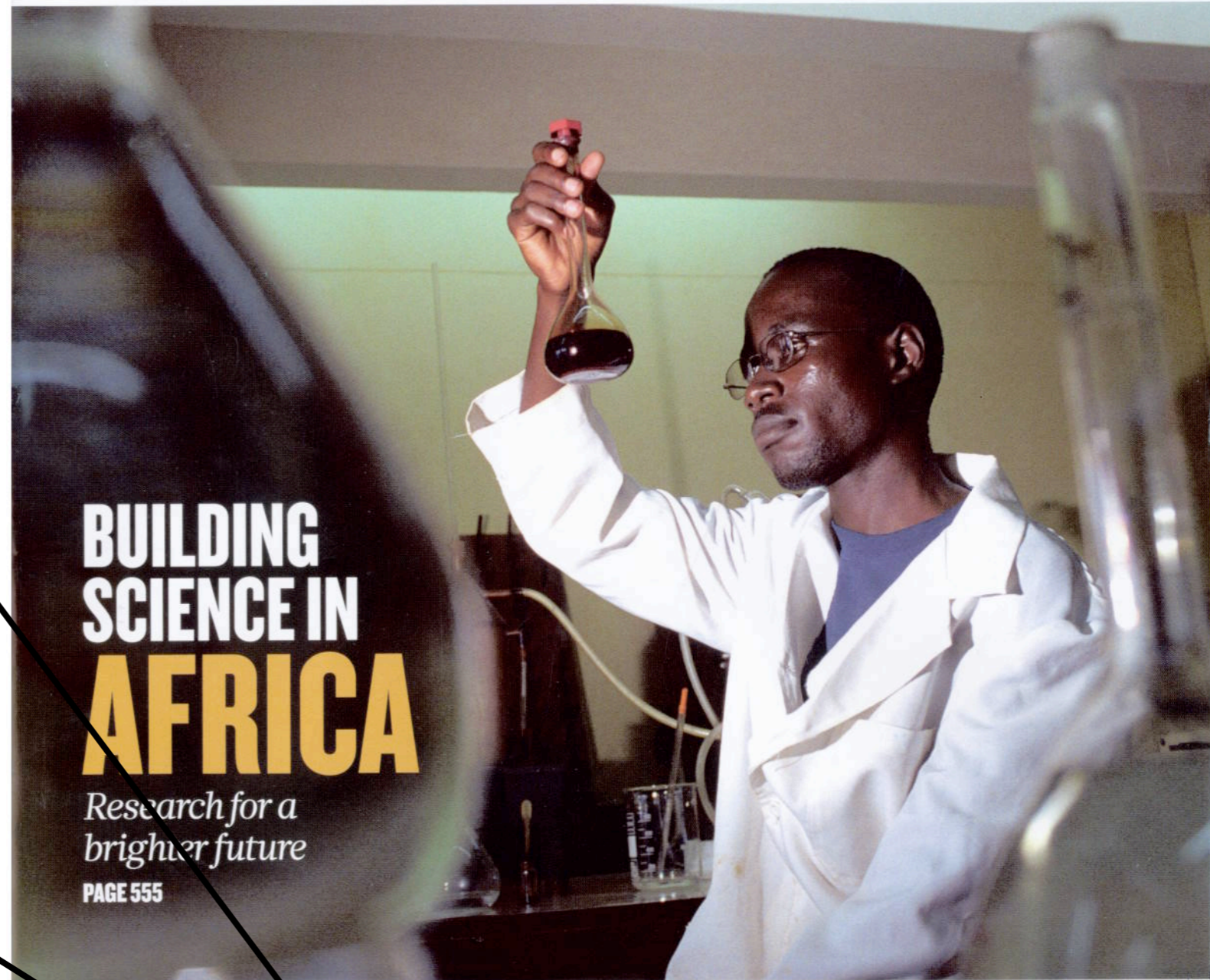
30 June 2011 £10

Vol. 474, No. 7353



nature

THE INTERNATIONAL WEEKLY JOURNAL OF SCIENCE



BUILDING SCIENCE IN AFRICA

*Research for a
brighter future*

PAGE 555

COSMOLOGY

GOING THE DISTANCE

*High-redshift quasar
beats the record*

PAGES 583 & 616

COSMOLOGY

GOING THE DISTANCE

*High-redshift quasar
beats the record*

PAGES 583 & 616

EVOLUTIONARY THEORY

WON IN THE EYE

*Fossils confirm early arrival
of complex vision*

PAGE 631

ECOLOGY

A NEW WORLD VIEW

*The lasting legacy of the
Whole Earth Catalog*

PAGE 578

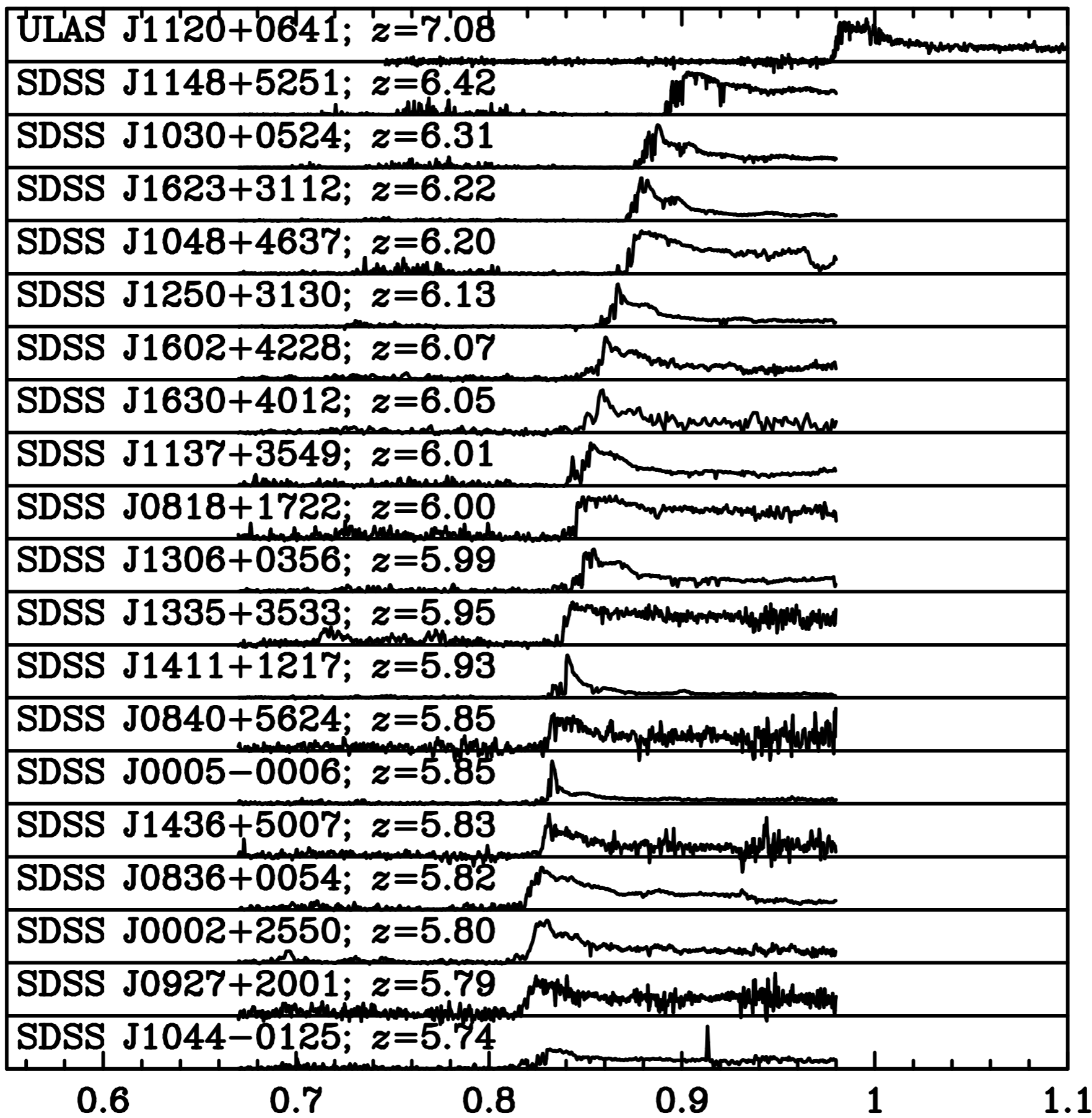
NATURE.COM/NATURE

30 June 2011 £10

Vol. 474, No. 7353

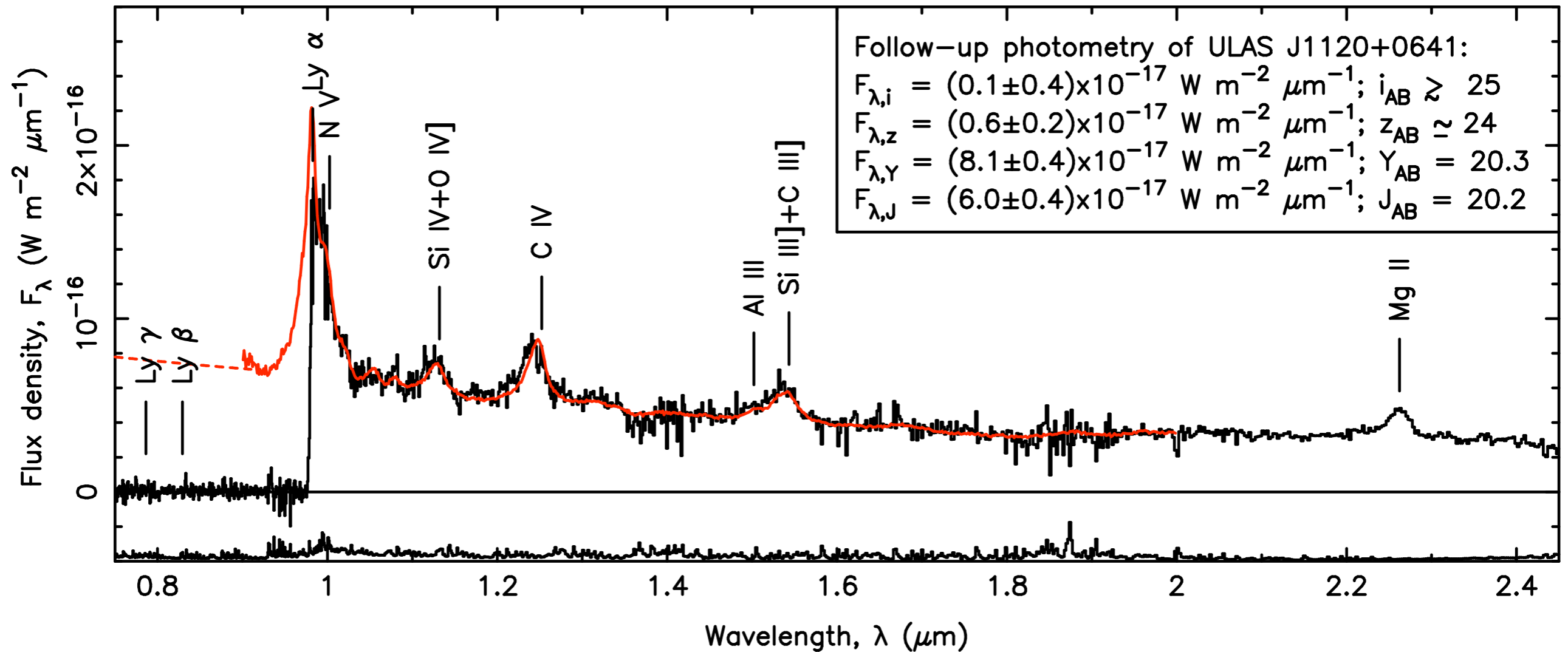


relative flux density, $F_\lambda / F_{\lambda, \text{peak}}$



observed wavelength, λ (μm) (after Fan et al. 2006)

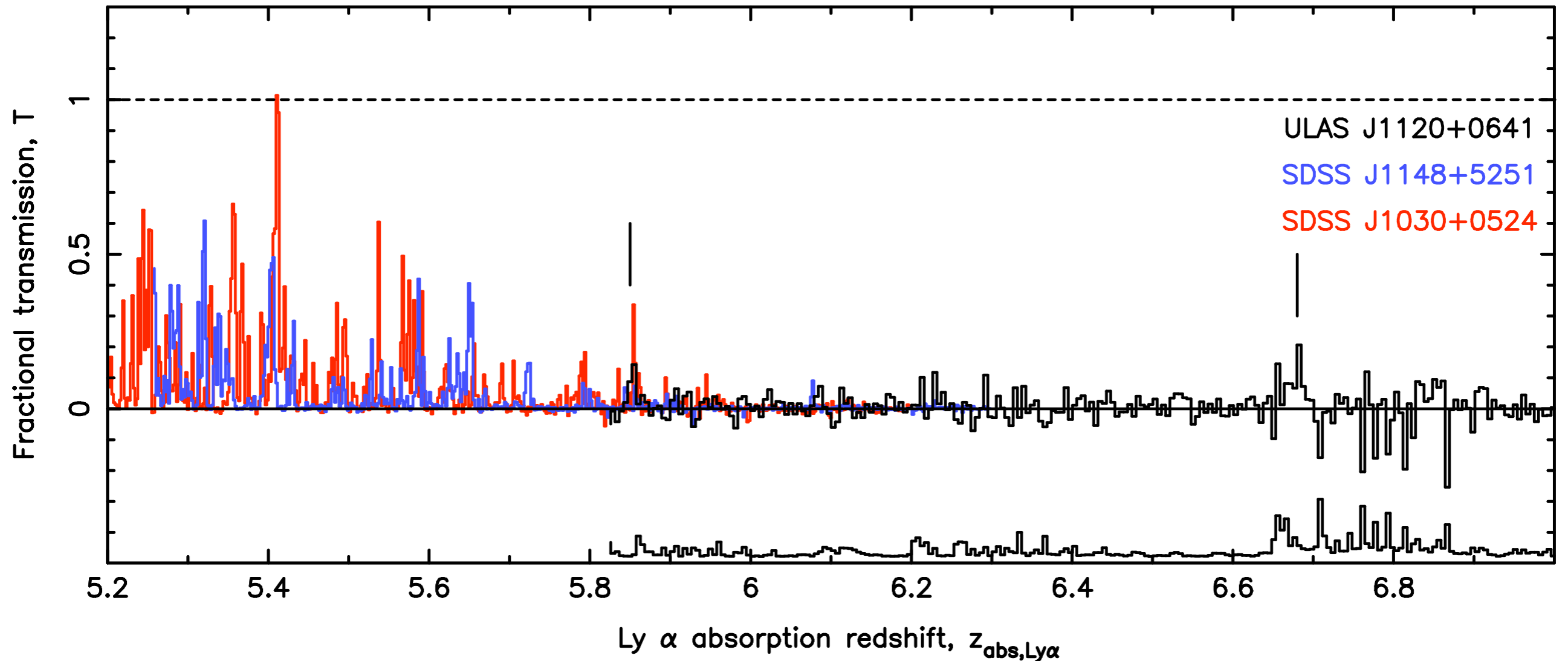
ULAS J1120+0641



Unabsorbed spectrum very similar to low-z quasars

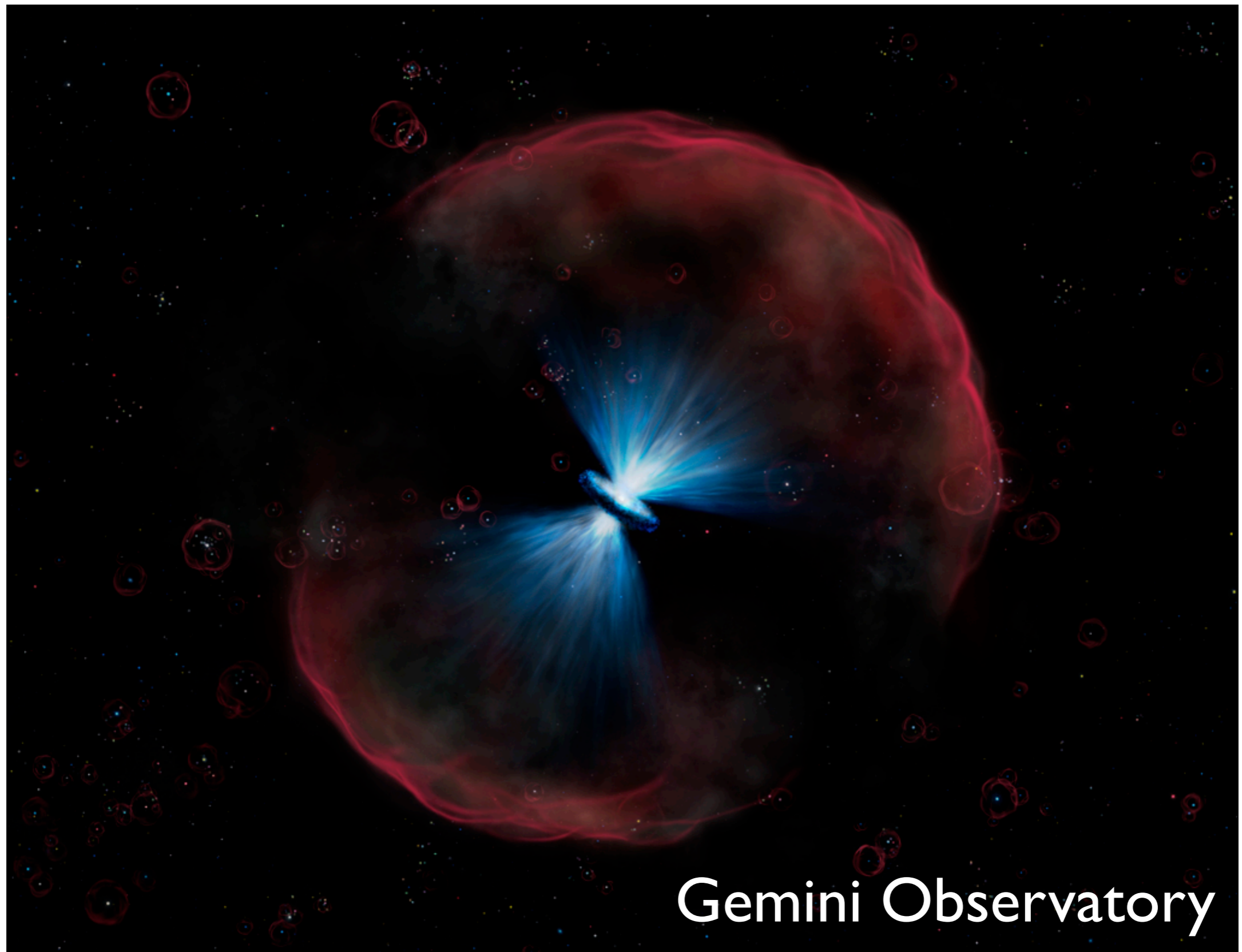
A $2 \times 10^9 M_\odot$ black hole 770 Myr after the Big Bang

Ly alpha IGM absorption



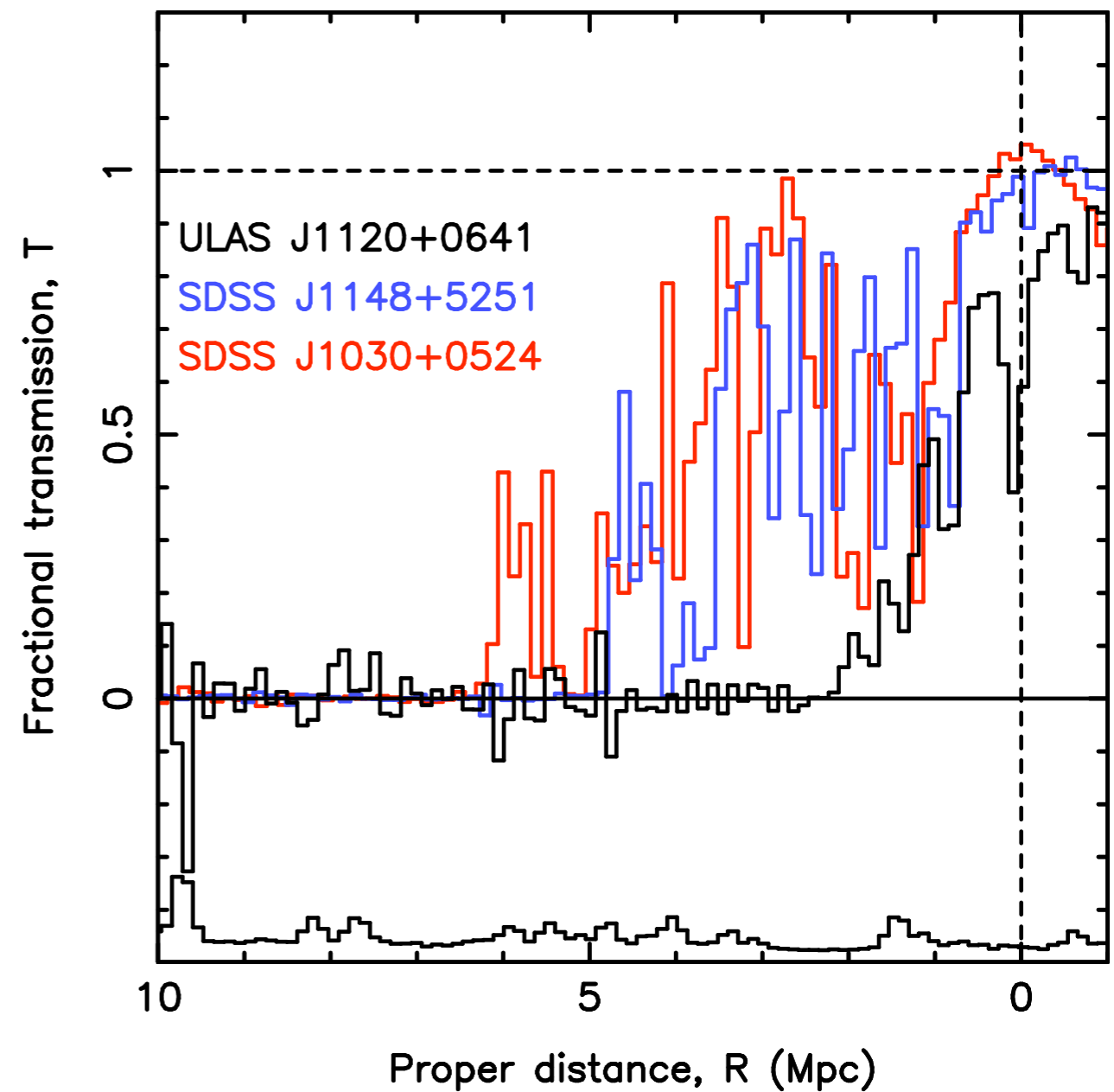
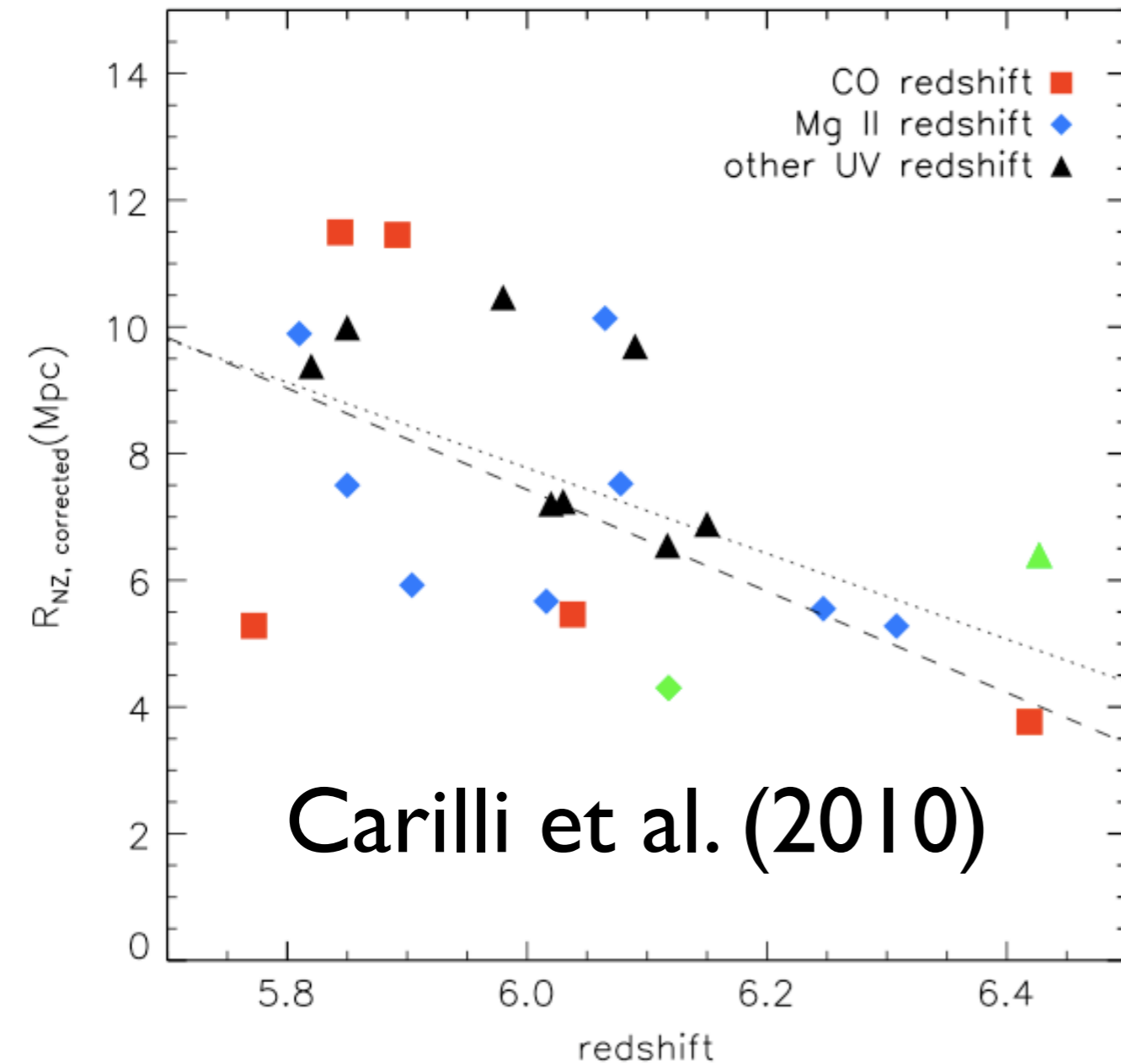
Complete Gunn-Peterson (1965) trough from $z \sim 5.85$
Optical depth too high to probe easily through Ly alpha

Quasar near zone



Gemini Observatory

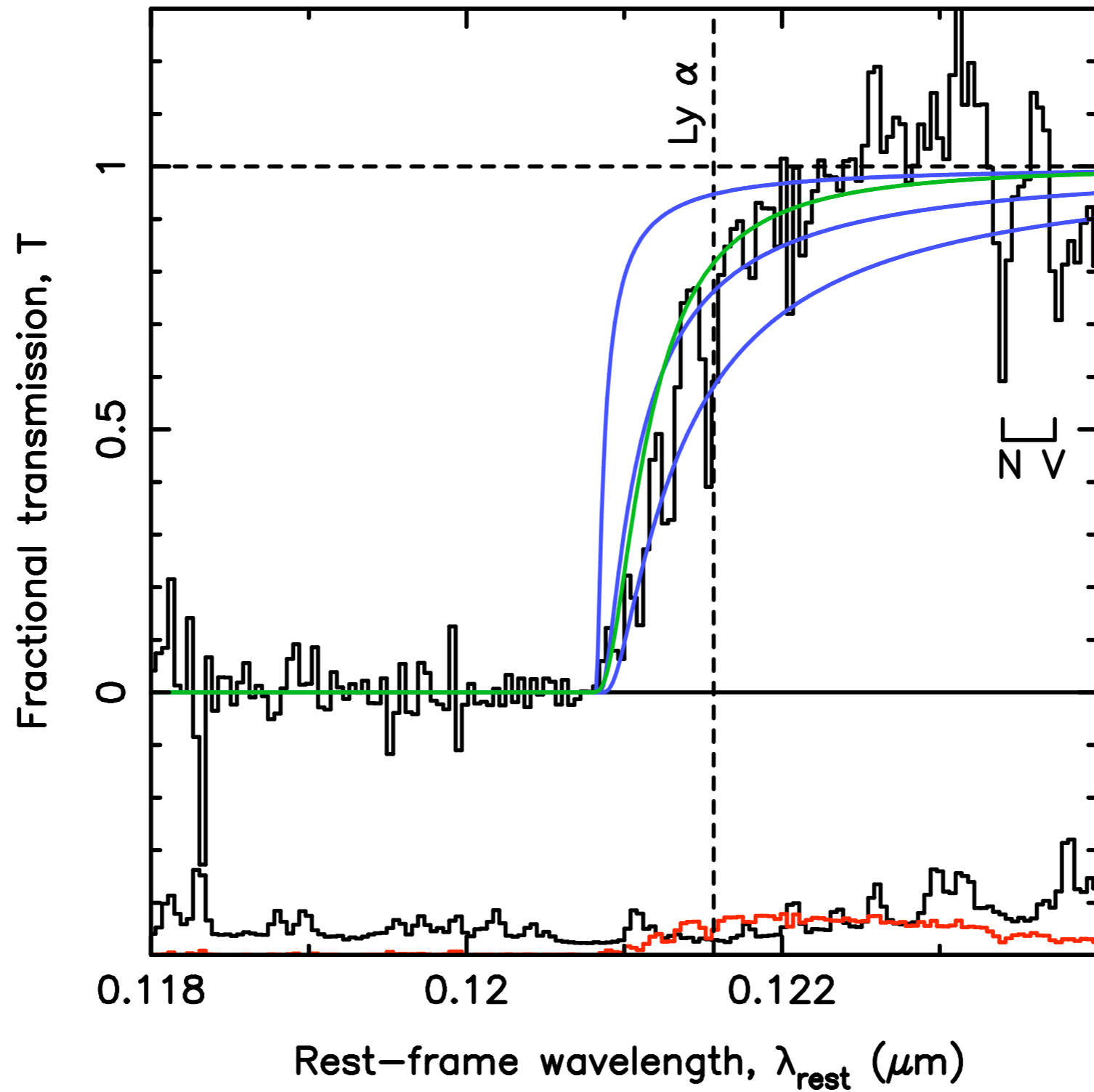
Quasar near zones



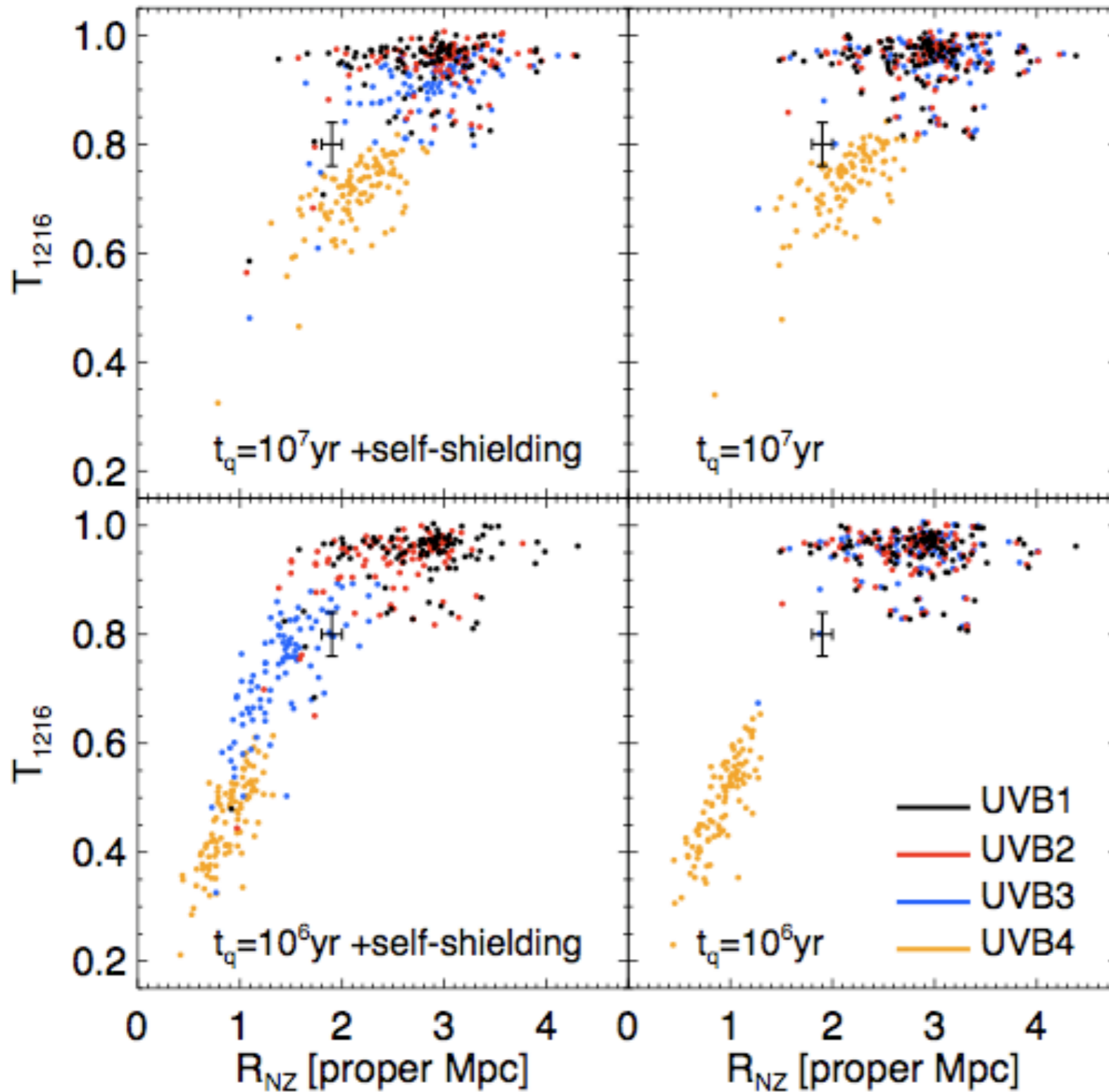
Quasar near zone ~ 4 times smaller than at $z = 6$

Extent due to ionization front or recombination?

Ly alpha damping wing?



Ly alpha damping wing?



Confirmation
of fiducial
 $f_{HI} > 0.1$
conclusion
(DLA possible
but unlikely
a priori ($P=0.05$))

Possible young
age make BH
problem worse

Bolton et al. (2011)

The Future

- UKIDSS continuing: 2500 deg² -> 3800 deg²
 - ~15 new $z \sim 6$ quasars; a few more $z > 6.5$
- Pan-STARRS: lacks J band; image quality issues
- VISTA: lacks optical imaging at present, but deep z
- DES: lacks J band; starting now
- JANUS: proposed NASA mission: tens with $z > 7$?
- EUCLID: fainter quasars with $z > 8$?
- LOFAR/SKA: will dominate . . . in a decade or more