



# **Luminous Red Galaxies**

## **Selection using optical and WISE photometry**

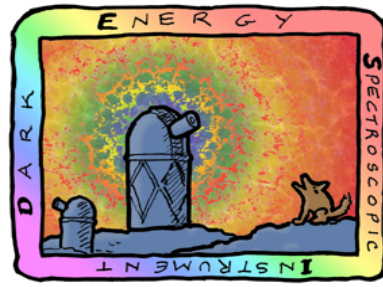
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**Jeffrey Newman**  
**eBOSS collaboration**  
**Univ. of Pittsburgh**  
**PITT PACC**

**WFIRS2014, Pasadena, CA, 16-20 Nov. 2014**





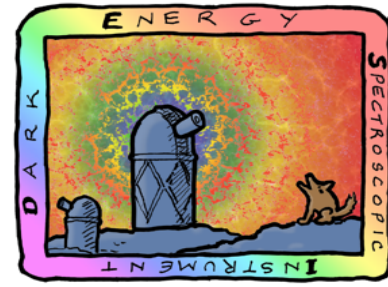
# Luminous Red Galaxies: Key for LSS Surveys



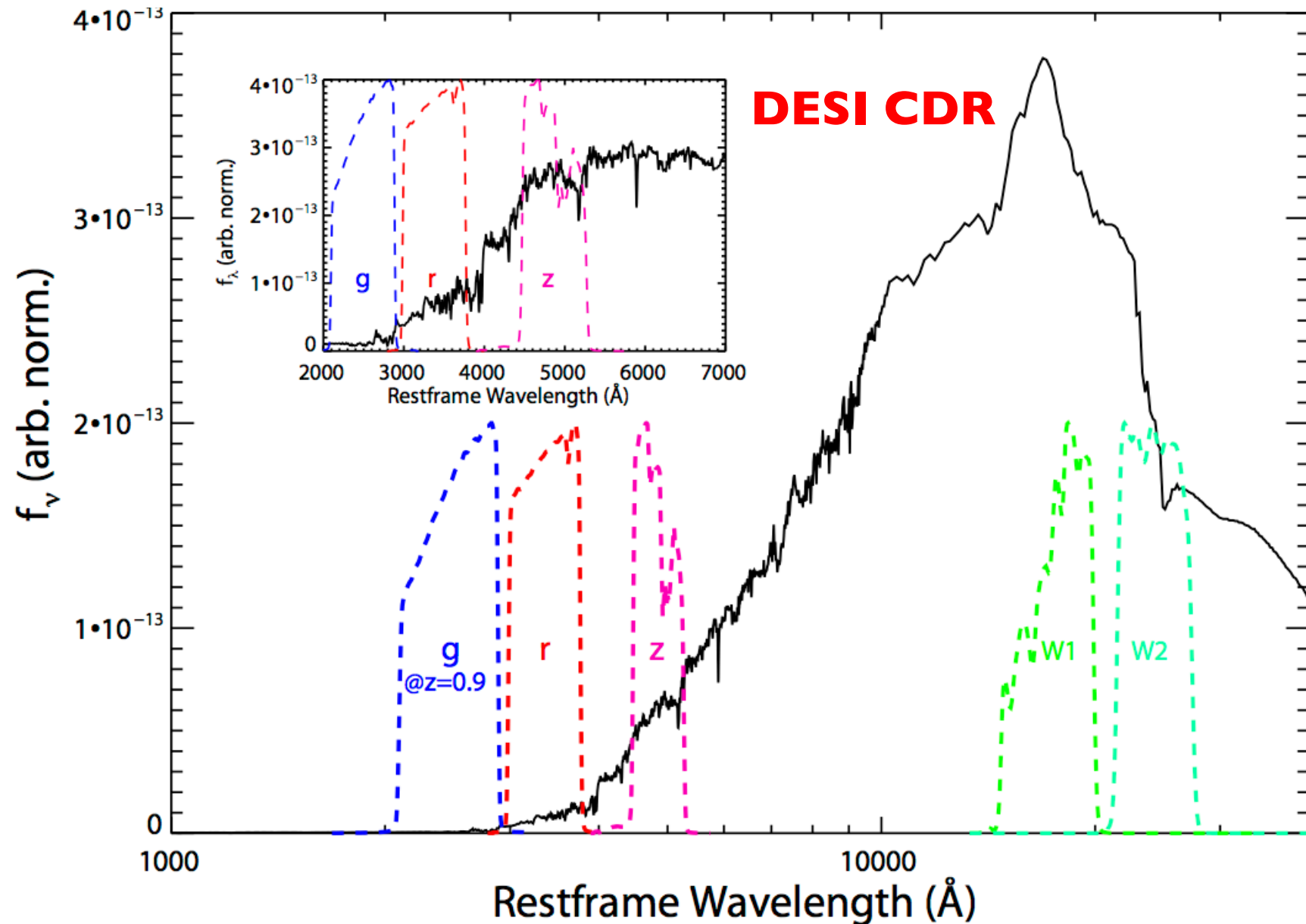
- ◆ **SDSS I/II:** 1998-2003, 100,000 LRGs,  $z < 0.38$
- ◆ **The 2df-SDSS LRGs and QSO (2SLAQ)**  
2003-2006, 15,000 LRGs,  $0.4 < z < 0.8$
- ◆ **SDSS III/Baryon Oscillation Spectroscopic Survey (BOSS)**  
2009-2014, ~1 million LRGs,  $0.3 < z < 0.65$
- ◆ **SDSS IV/extended Baryon Oscillation Spectroscopic Survey (eBOSS)**  
2014-2020, ~375,000 LRGs,  $0.6 < z < 1.0$
- ◆ **Dark Energy Spectroscopic Instrument (DESI)**  
2019- , ~4.2 million LRGs,  $0.6 < z < 1.0$



# Selecting LRGs at $z > 0.6$



- ◆ Strong clustering of LRGs enhances **Baryon Acoustic Oscillation (BAO)** measurements.
- ◆ **Primary goal:** To select targets for BAO surveys like **eBOSS** and **DESI**.
- ◆ 4000 Å break selection becomes difficult at  $z > 0.6$  due to break passing into near-IR and color overlap with stars.
- ◆ Exploit 1.6 micron bump instead.

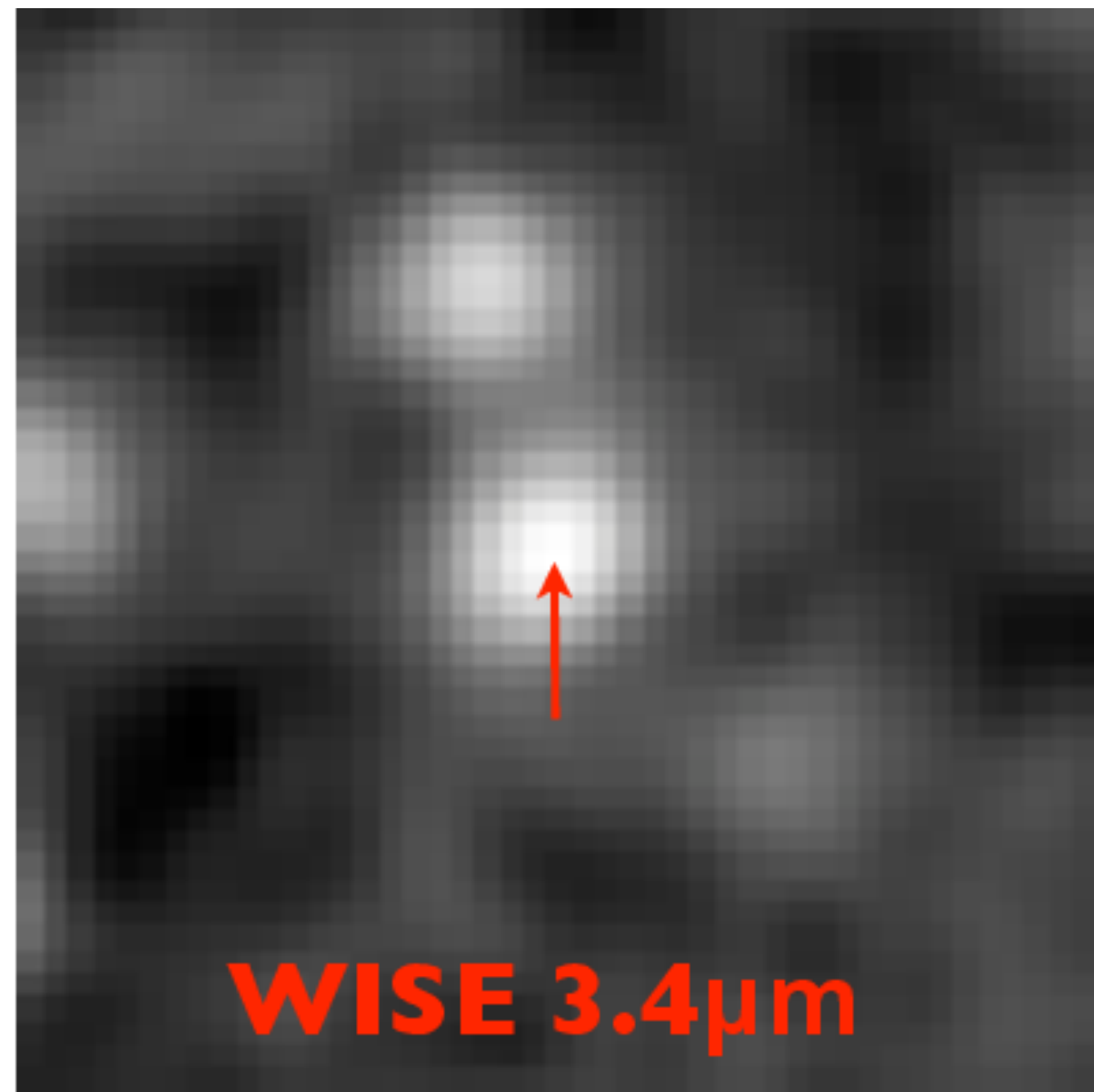
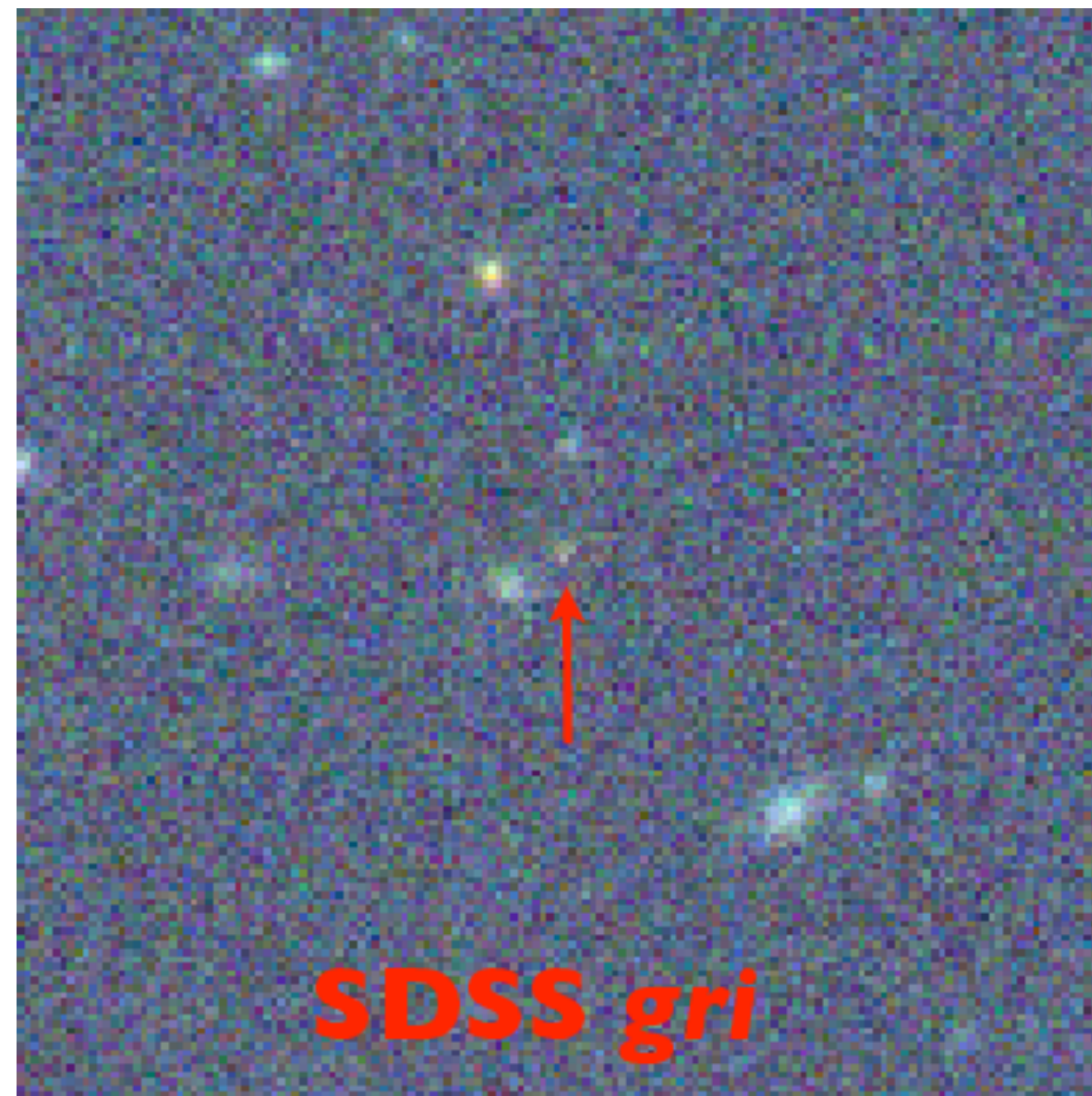


A template spectrum based upon observations of the elliptical NGC 4552.

**New method needed for targeting high-z LRGs**



# High- $z$ LRGs look much brighter in the infrared than optical !

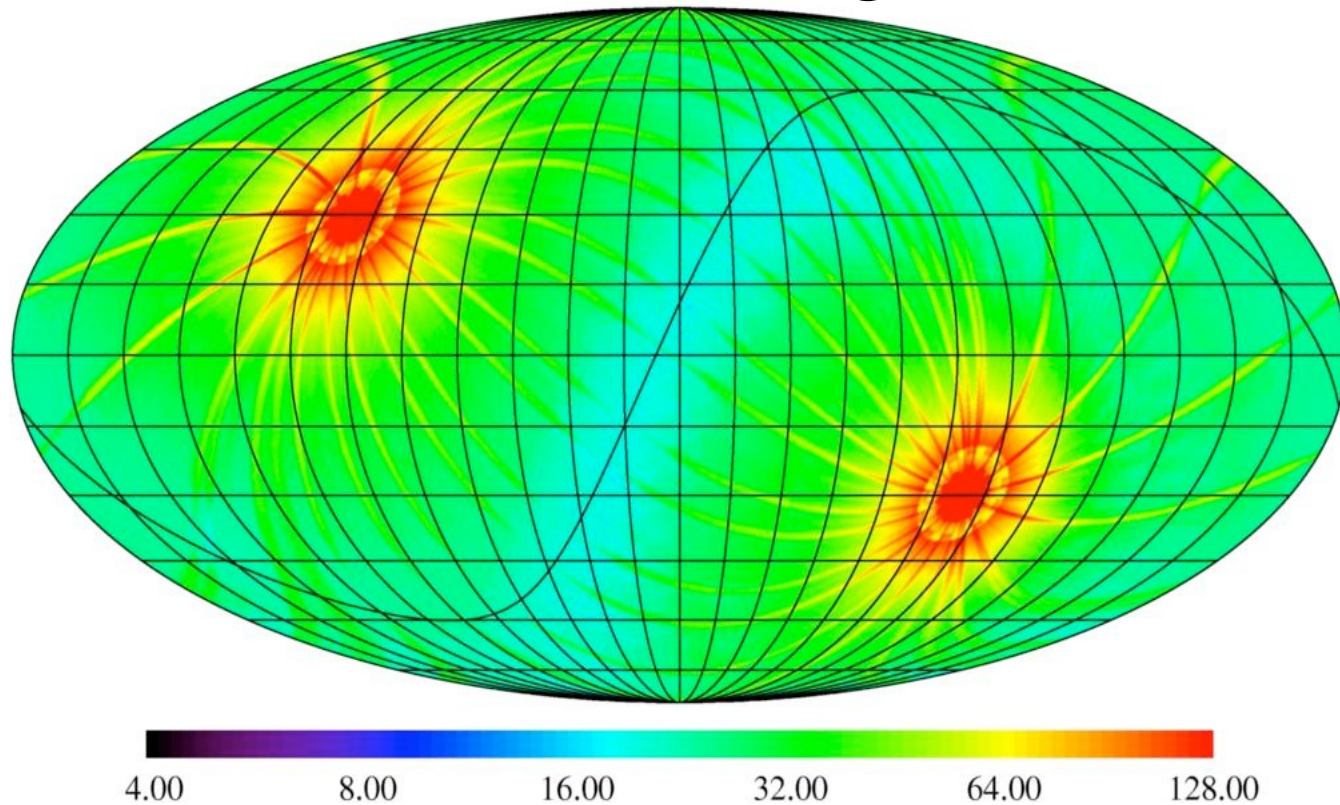


1 square arcmin SDSS and WISE W1 ( $3.4 \mu\text{m}$ ) images of  $z \sim 1$  LRG

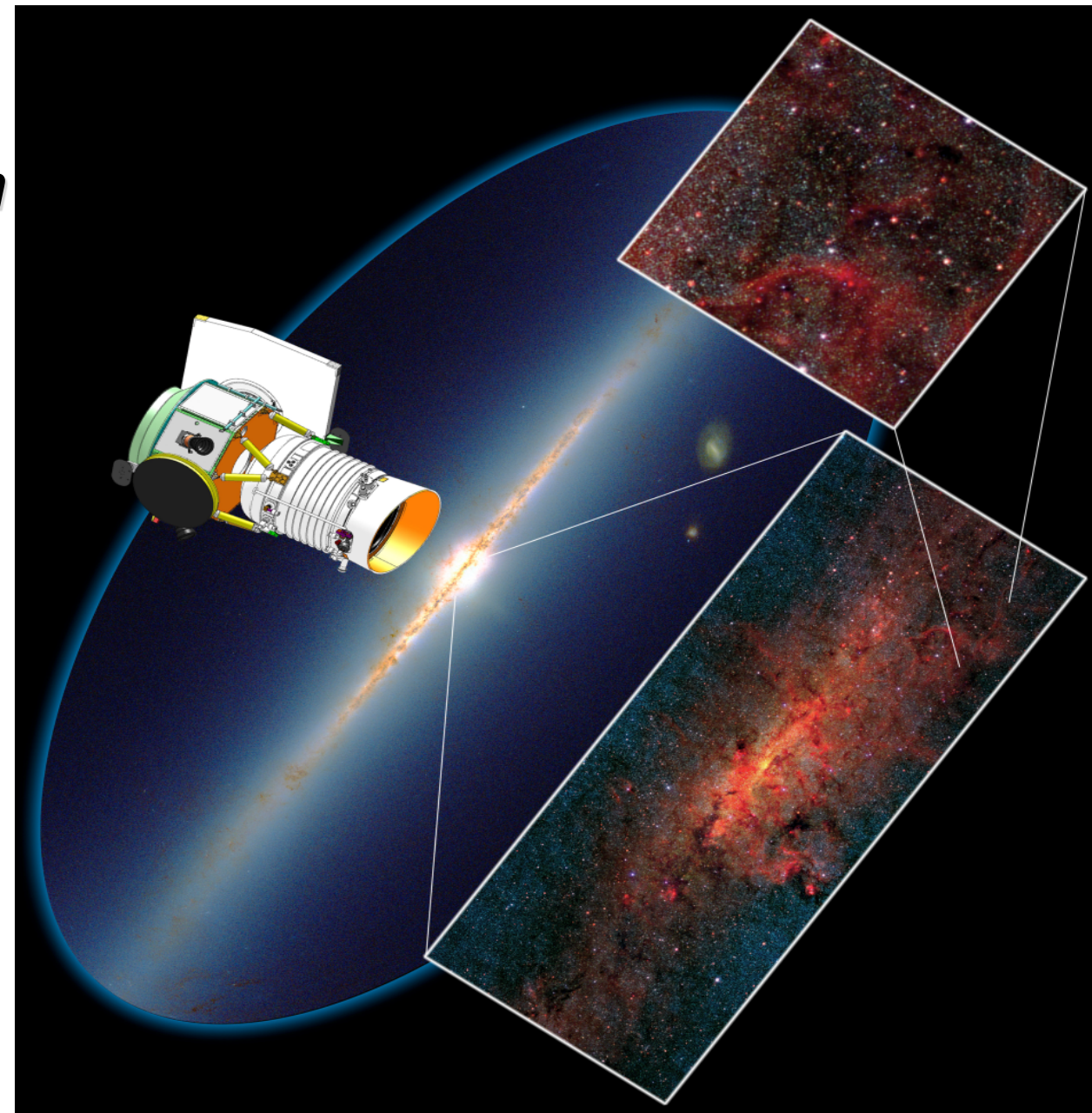
## Key Features

- ◆ Sensitive all sky survey with  $>8X$  redundancy
- ◆ 4 imaging channels: 3.4, 4.6, 12, 22  $\mu\text{m}$
- ◆ 40 cm telescope operating at  $<17\text{K}$
- ◆ **Much data has been released!**

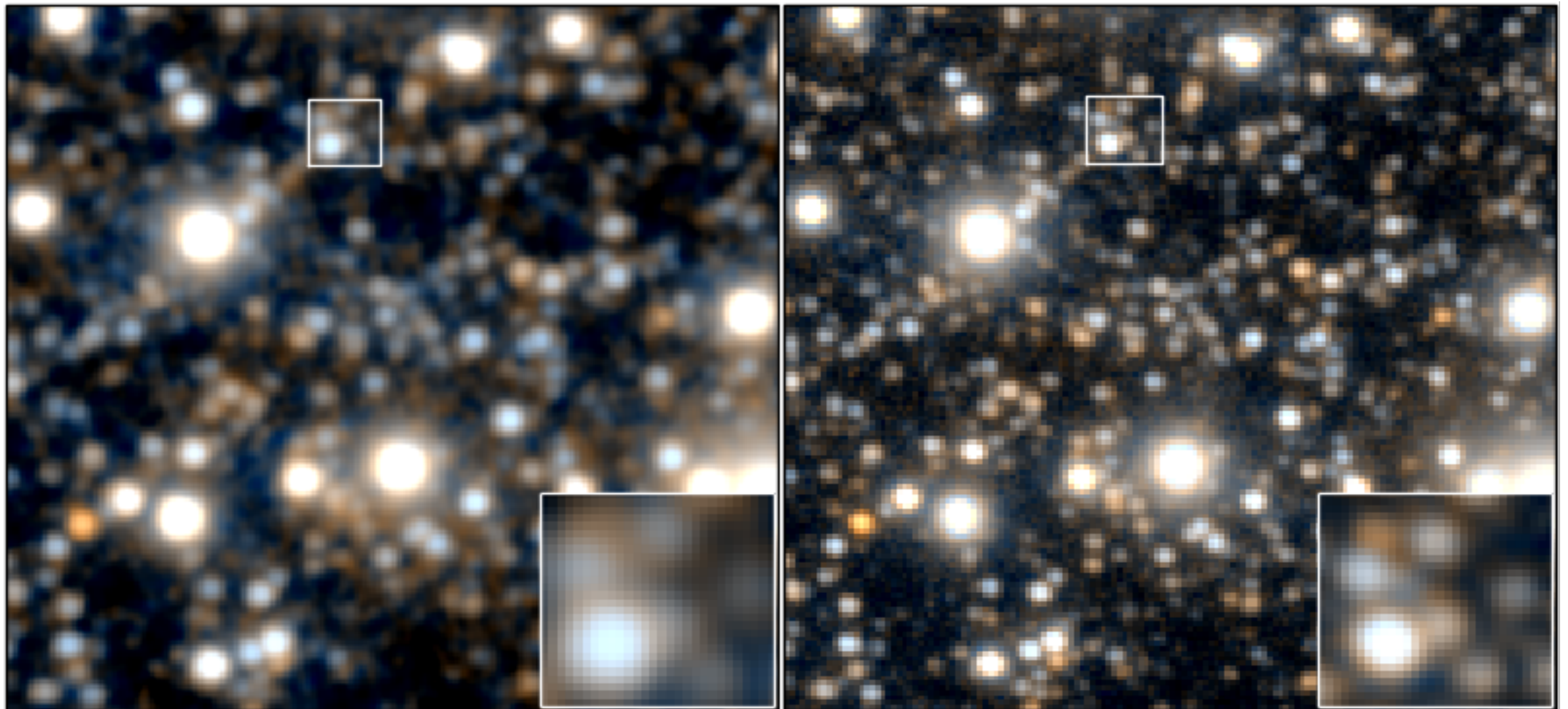
Actual coverage



## Wide-field Infrared Survey Explorer

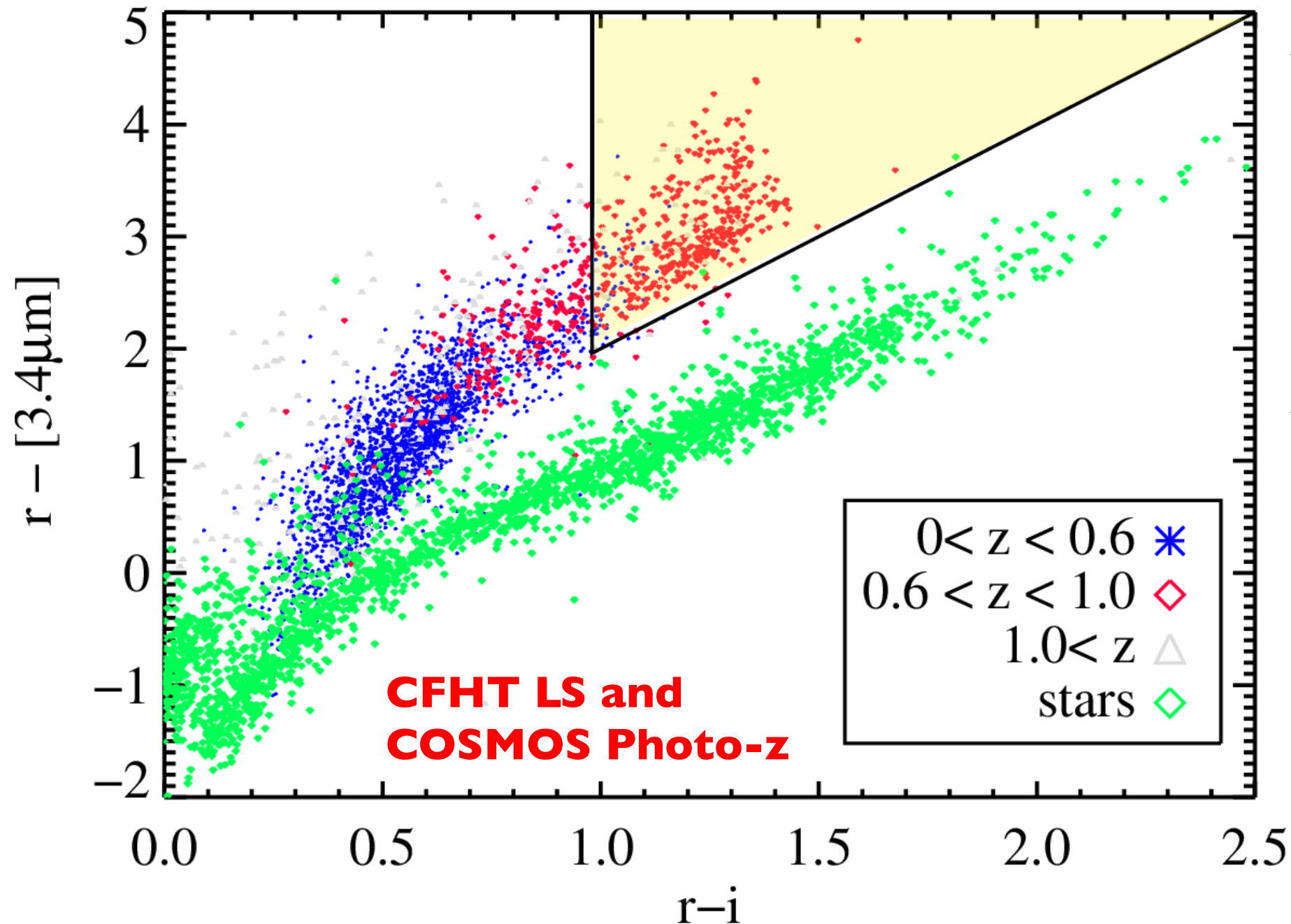


- ◆ The official image coadds have an artificial blurring.
- ◆ **Dustin Lang** made coadds at full resolution:  
<http://unwise.me> (public code & data) **Dustin Lang 2014 AJ 147 108**
- ◆ **Forced photometry on WISE at SDSS positions, fitting all blends & all frames together.** arXiv:1410.7397





# LRG selection algorithm

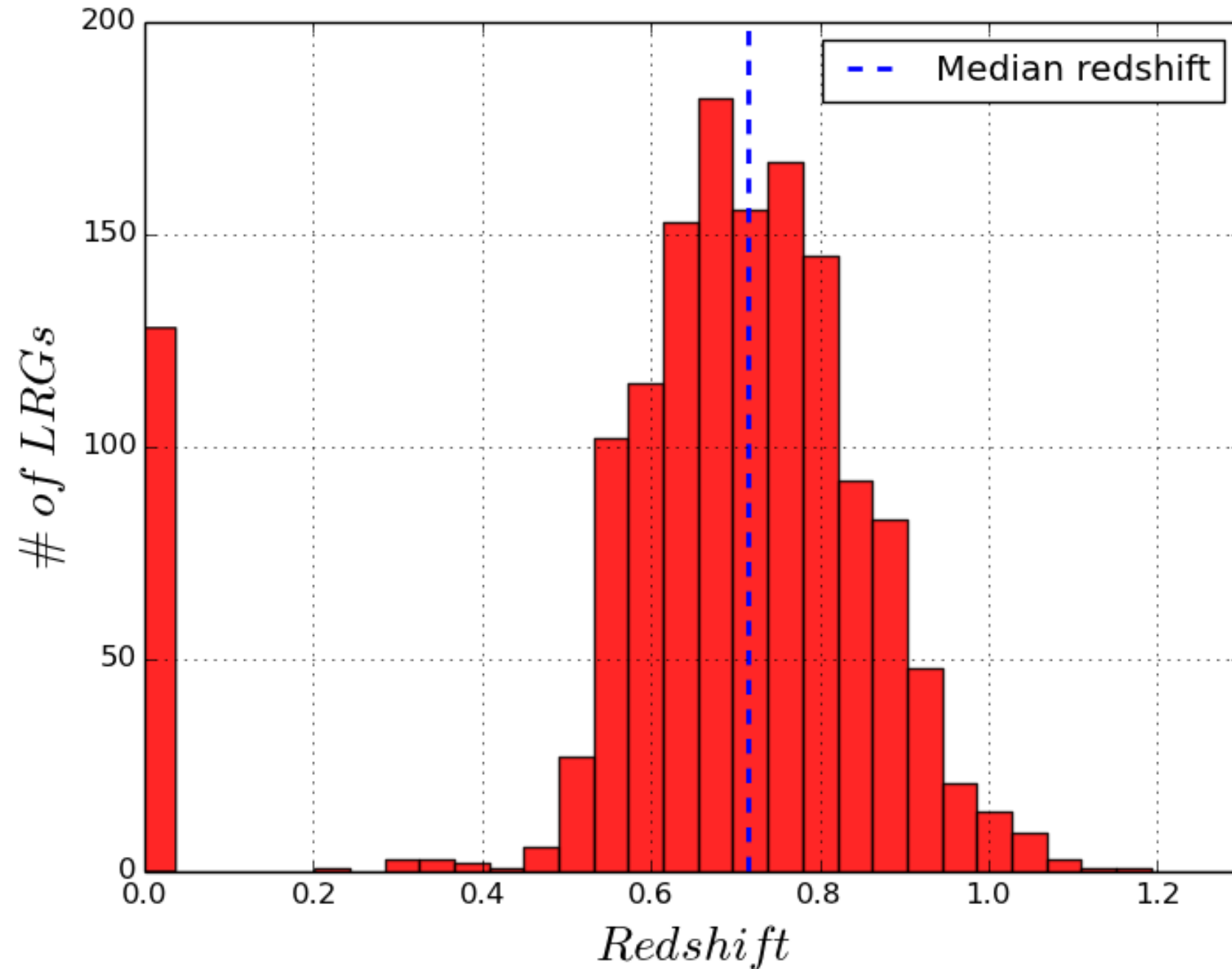


- ◆ New method combines optical and WISE (infrared) photometry to select  $z > 0.6$  LRGs.
- ◆ All objects with  $r - i > 0.98$  &  $r - [3.4\mu\text{m}] > 2.0(r - i)$  (shaded region) and  $i - z > 0.6$  are selected.

**Similar selection can be done in other optical-infrared color spaces, e.g.  $i - w1$  &  $i - z$  or  $r - W1$  &  $r - z$ .**



# Successful targeting by BOSS ancillary surveys



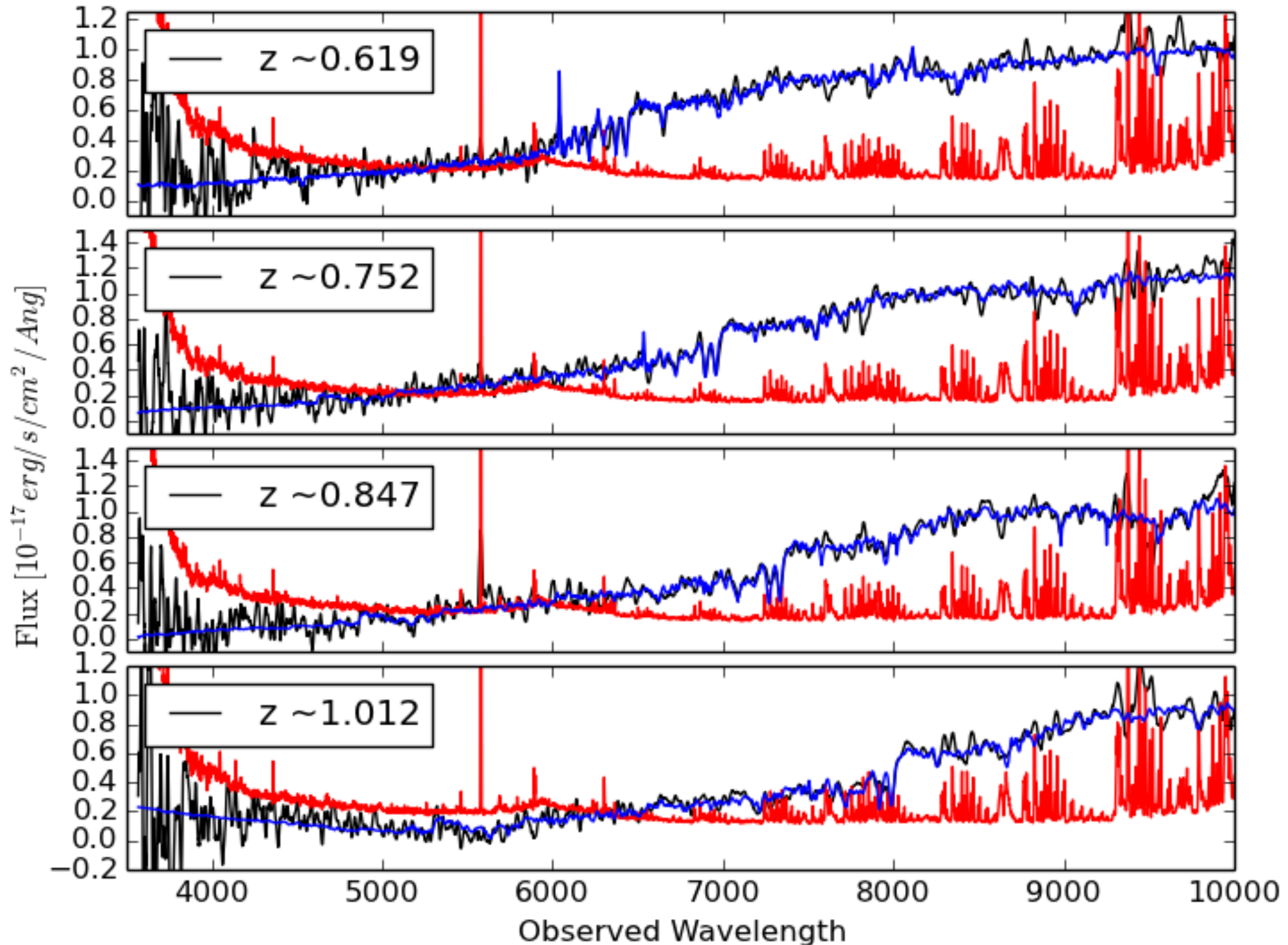
- ◆ ~10,000  $z < 20$  mag LRGs targeted via BOSS ancillary survey.
- ◆ 98% of spectra yield secure redshift measurements.
- ◆ BOSS Ancillary Program SEQUELS targeted ~70,000 LRGs with median redshift,  $z \sim 0.71$ .

**Additional color cut,  $i-z > 0.6$ , pushes the sample to higher redshifts.**



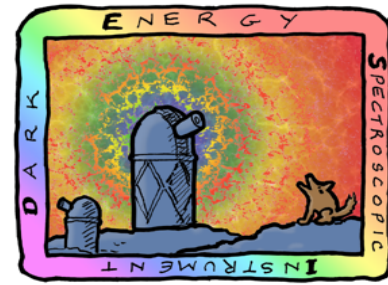


# Secure redshift measurements across the redshift range of interest $0.6 < z < 1$

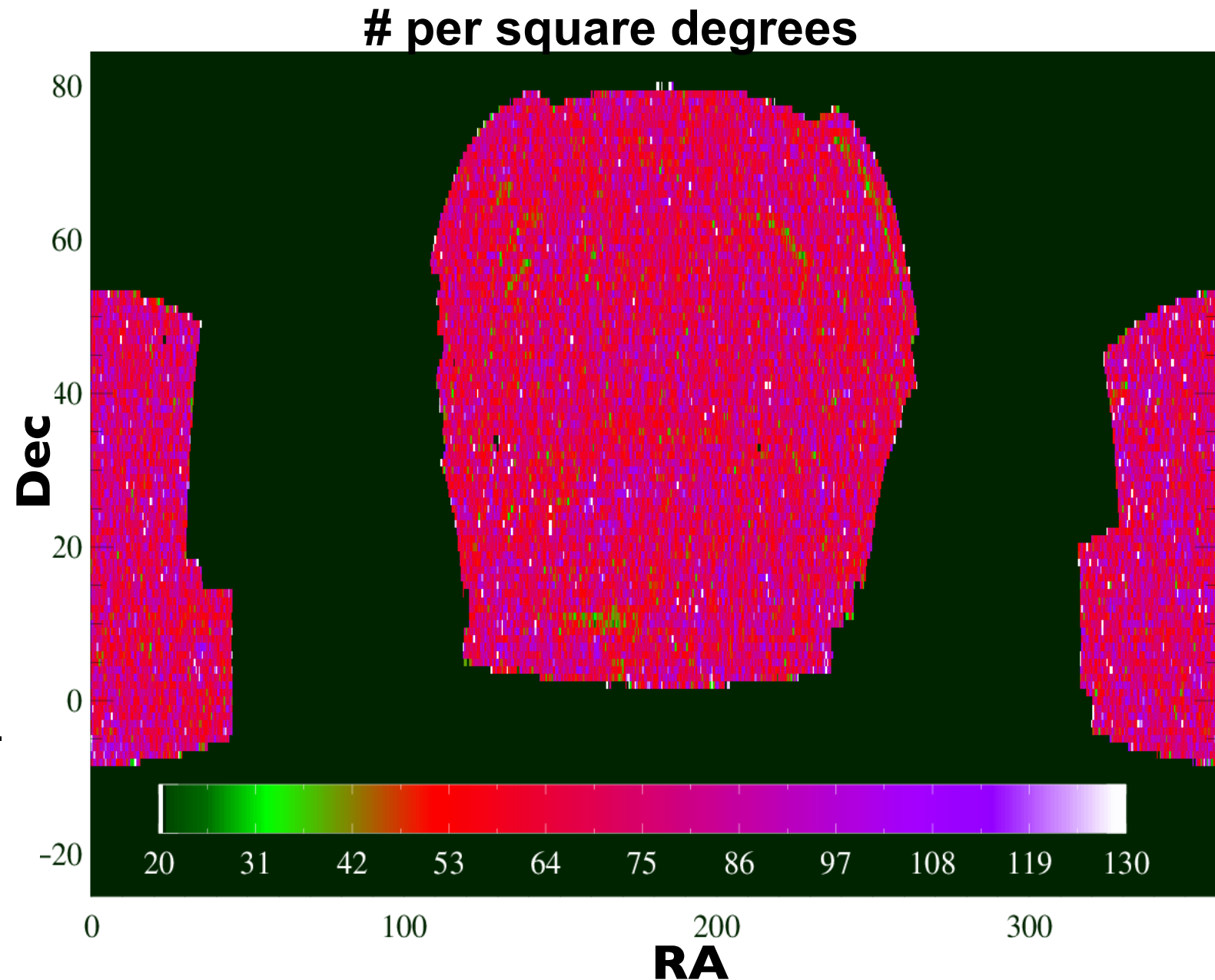




# Science with eBOSS & DESI LRGs



- ◆ eBOSS LRGs will yield  **$\sim 0.9\%$  BAO** and  $\sim 4\%$  RSD measurements over the redshift range  $0.6 < z < 1$ . **DESI will better these to  $< 0.5\%$**
- ◆ WISE provides a powerful way of selecting high- $z$  LRGs with low stellar contamination.
- ◆ LRG samples constrain the evolution of the most massive galaxies via the luminosity function, mass function etc.
- ◆ A wide variety of other science will be possible; e.g., ISW effect, cluster-finding, galaxy-galaxy lensing, etc.



**600,000 LRGs over the entire SDSS footprint for eBOSS, observing since June 2014 !**



# Extending LRG samples to higher redshifts



- ◆ LRGs are the gold standard, best-understood BAO sample. Worth pushing to even higher  $z$ 's: requires a redder selection band than  $z$ .
- ◆ LSST  $y$ -band and Euclid  $y$  &  $j$ -band can target luminous LRGs at higher redshifts,  $z > 1$



**WFIRST  $j$  band can be used to target LRGs at even higher redshifts using  $j-W1$  and  $j-W2$  color.**