

The Merian Survey: Characterizing dark matter and feedback in star-forming dwarf galaxies

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The Merian collaboration:

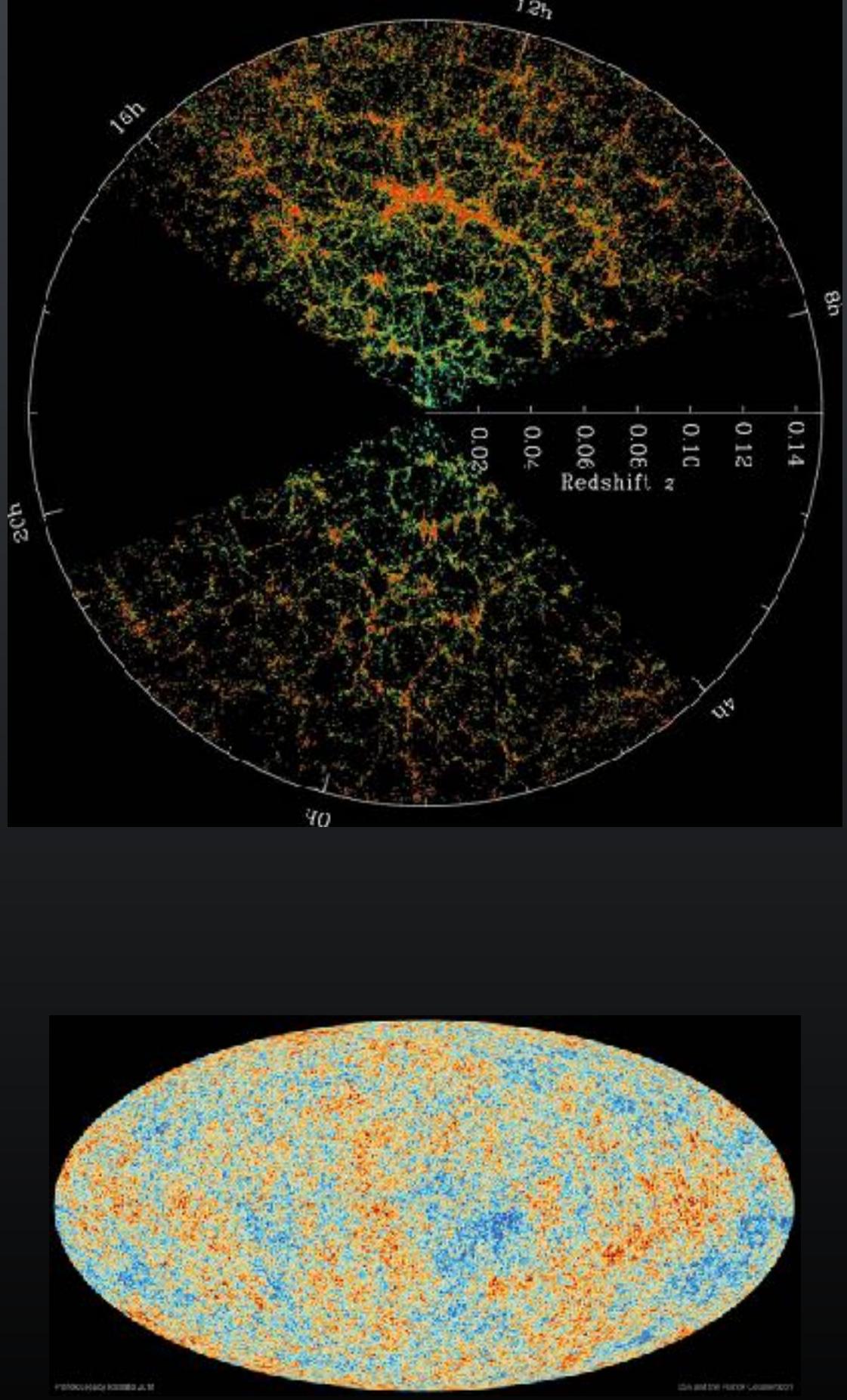
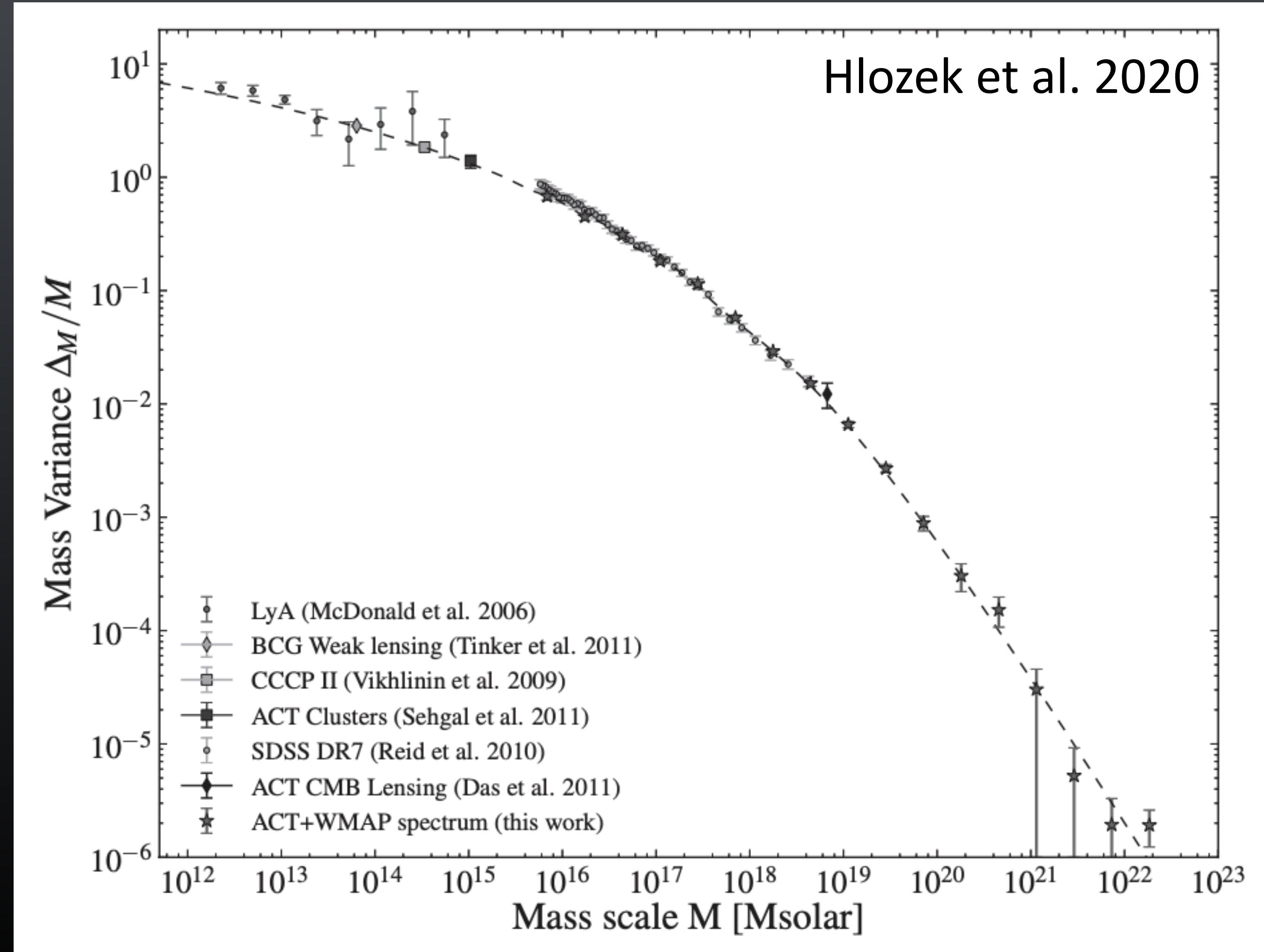
Alexie Leauthaud (co-PI), Jenny Greene (co-PI), Song Huang, Erin Kado-Fong, Shany Danieli, Ting Li, Jiaxuan Li, Abby Mintz, Annika Peter, Vivienne Baldassare, Alyson Brooks, Zheng Cai, Lee S. Kelvin, Robert Lupton, and many others

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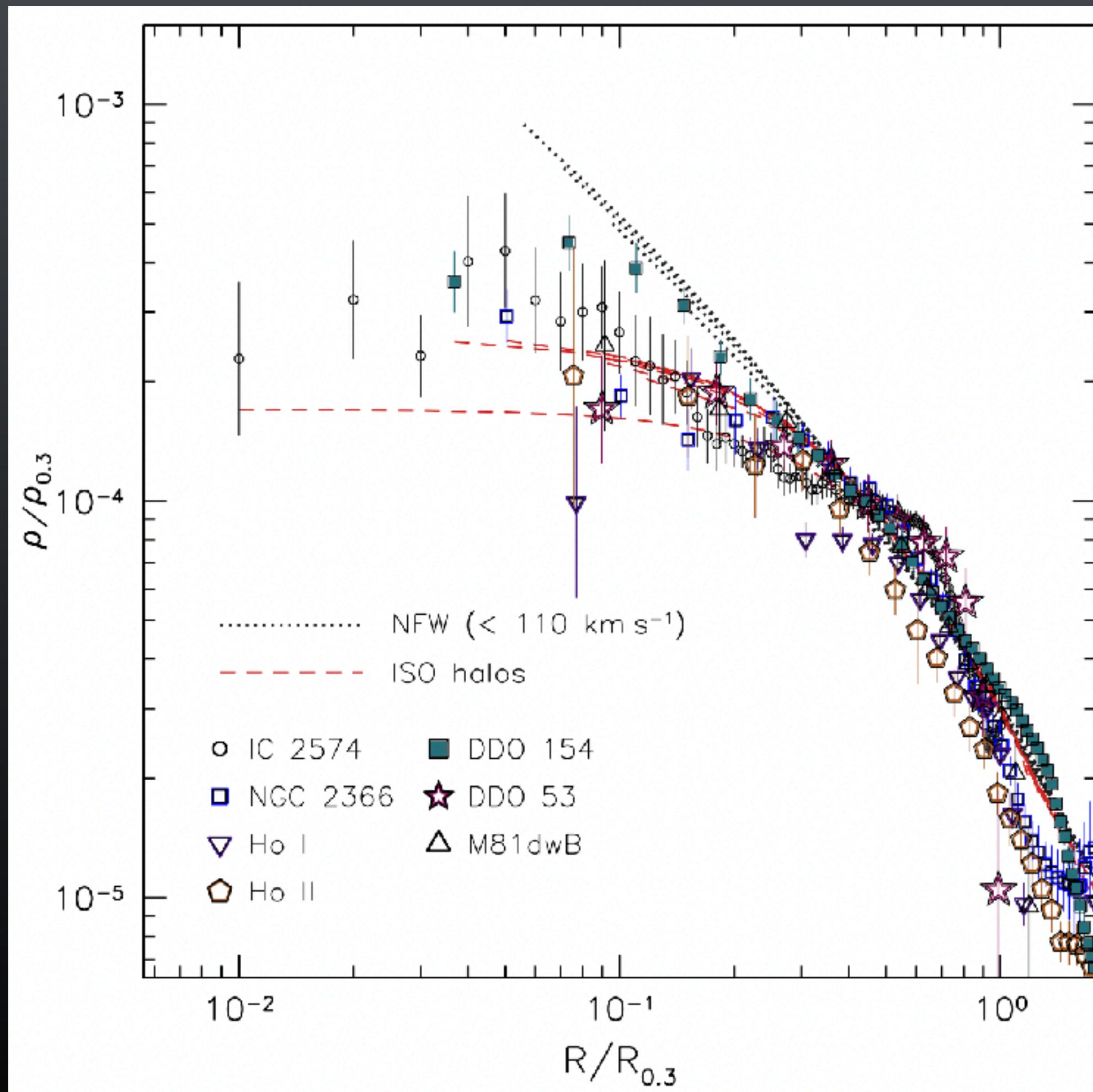
Sept 12 BCCP/Cosmology Seminar, Berkeley



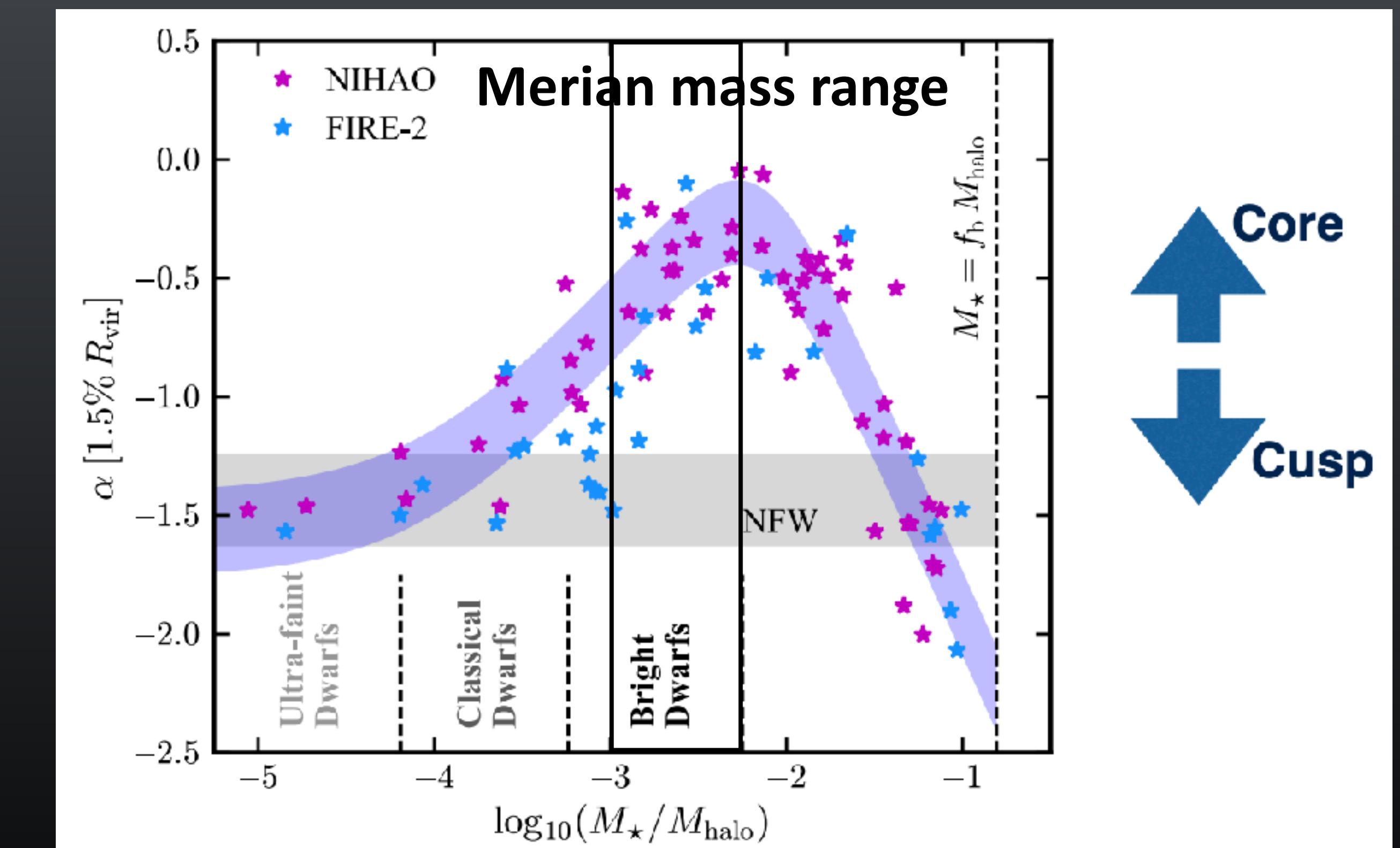
LCDM - successful on large scale



Challenges on small scale

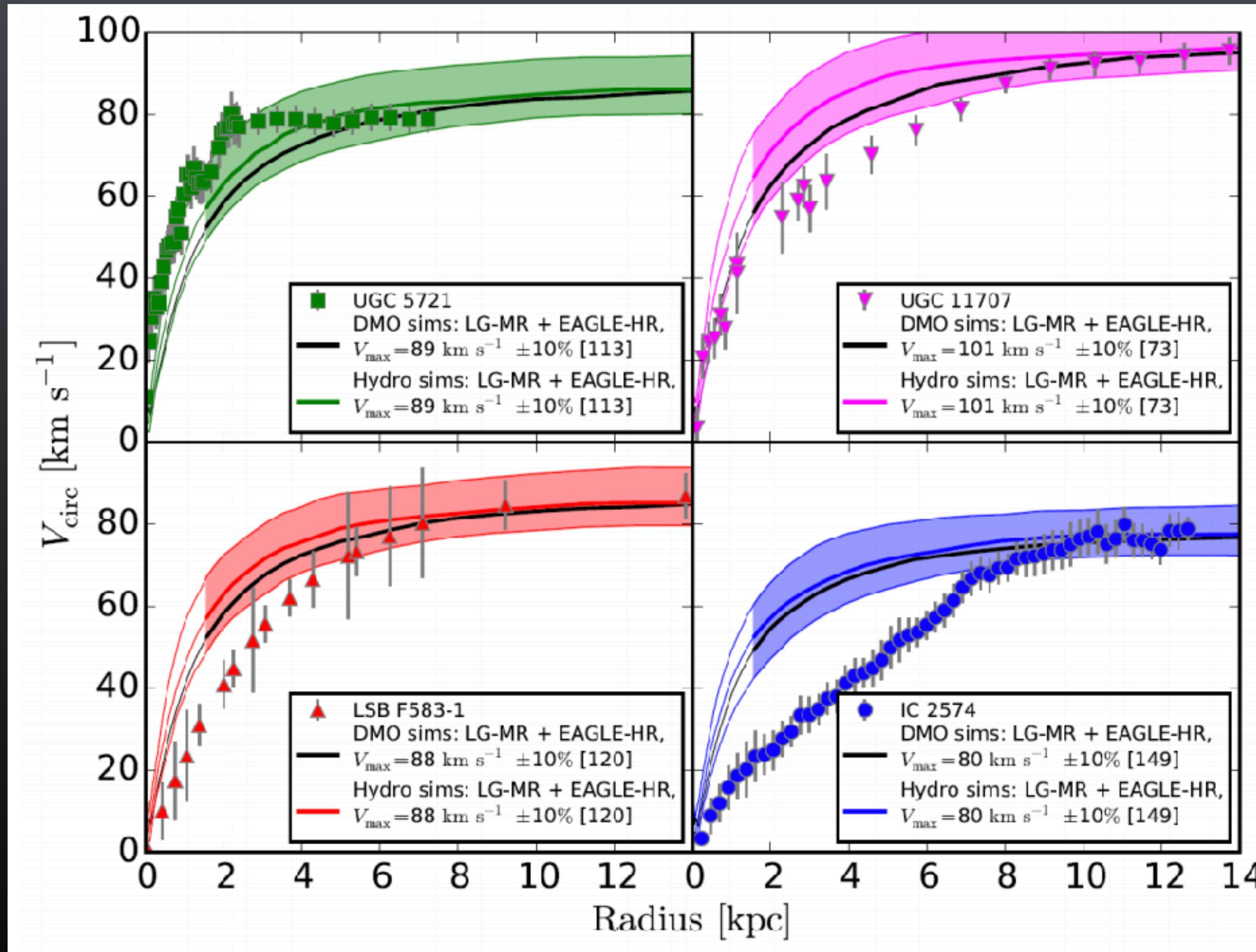


Oh et al. 2011

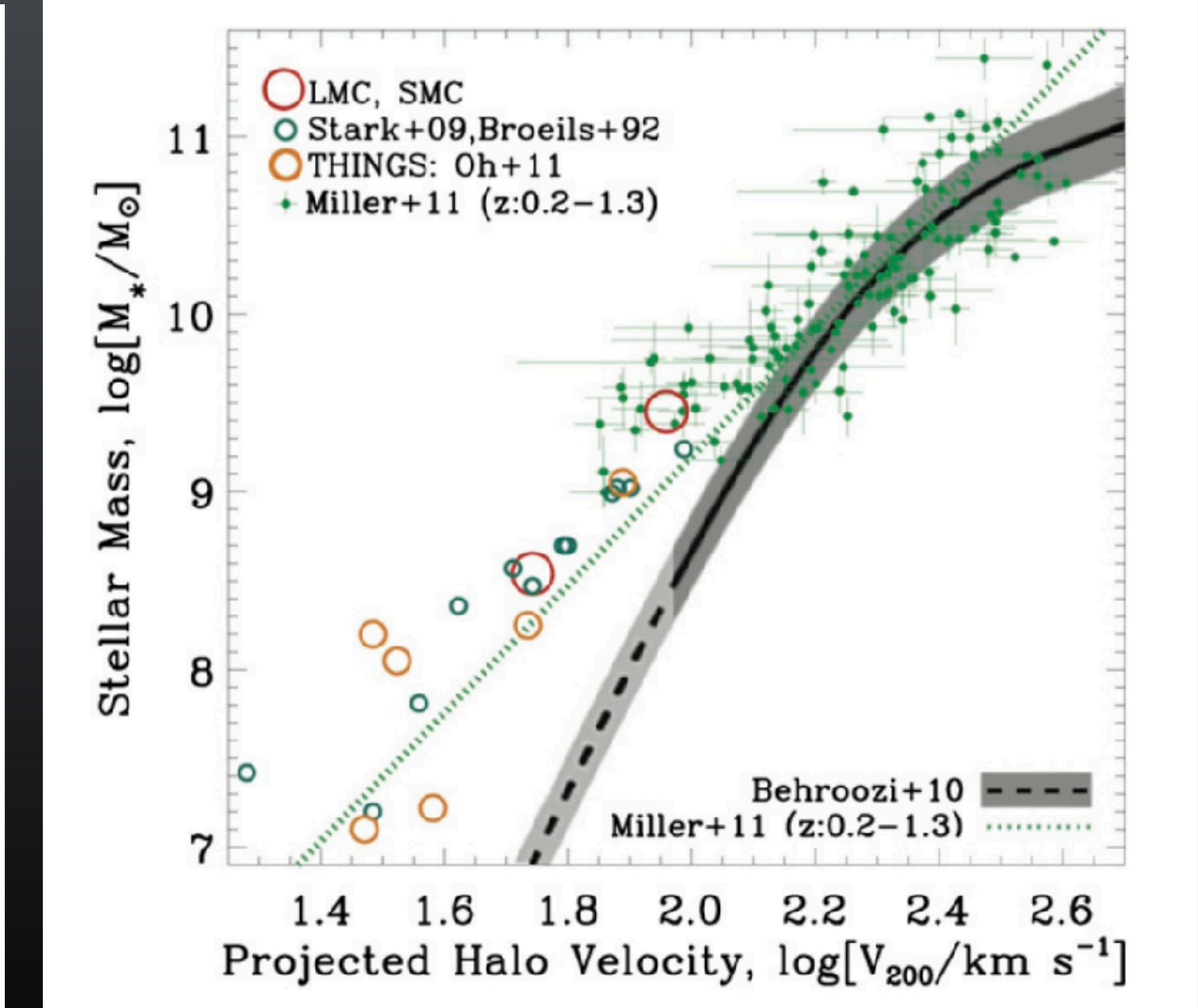


Bullock & Boylan-Kolchin et al. 2017

Challenges on small scale



Oman et al. 2015

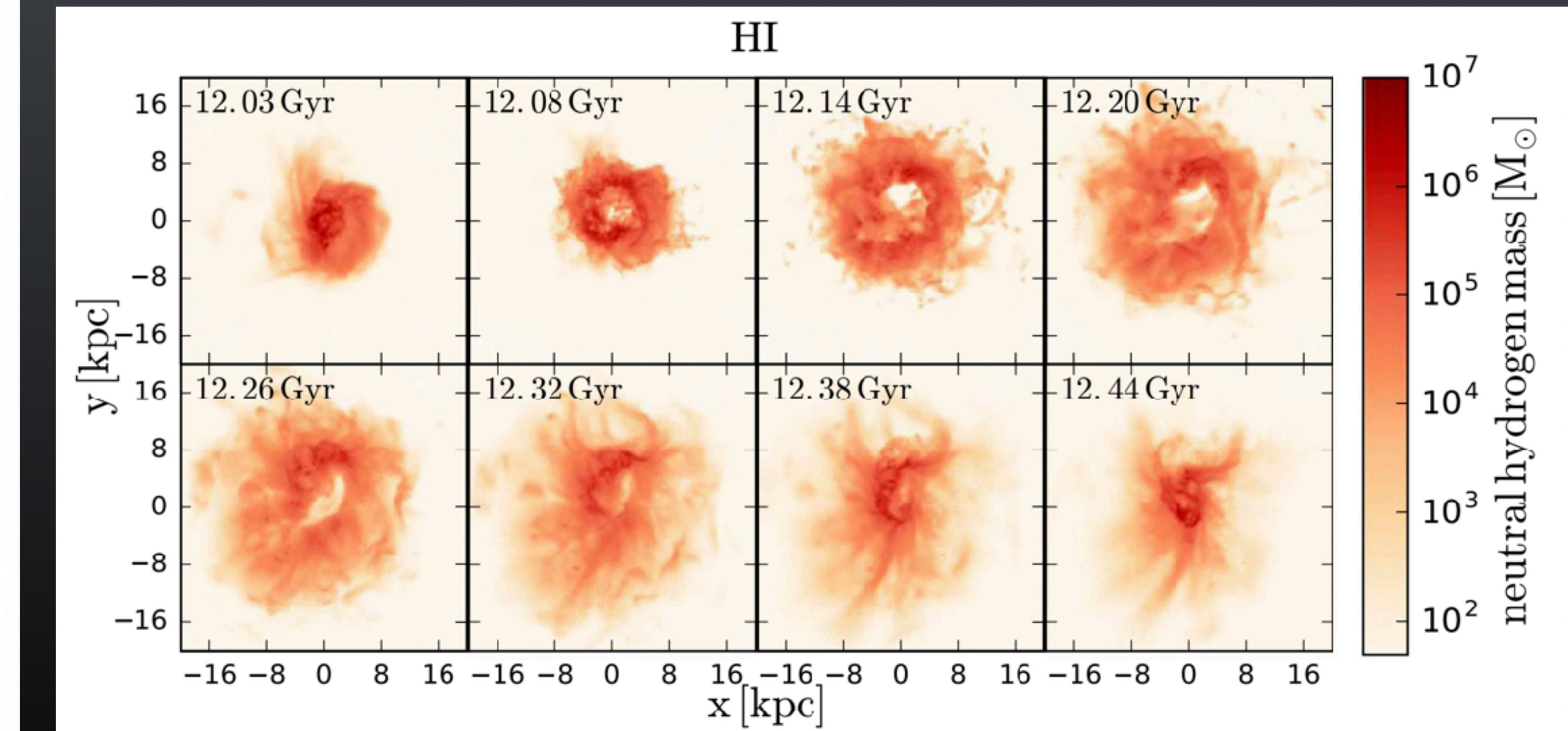
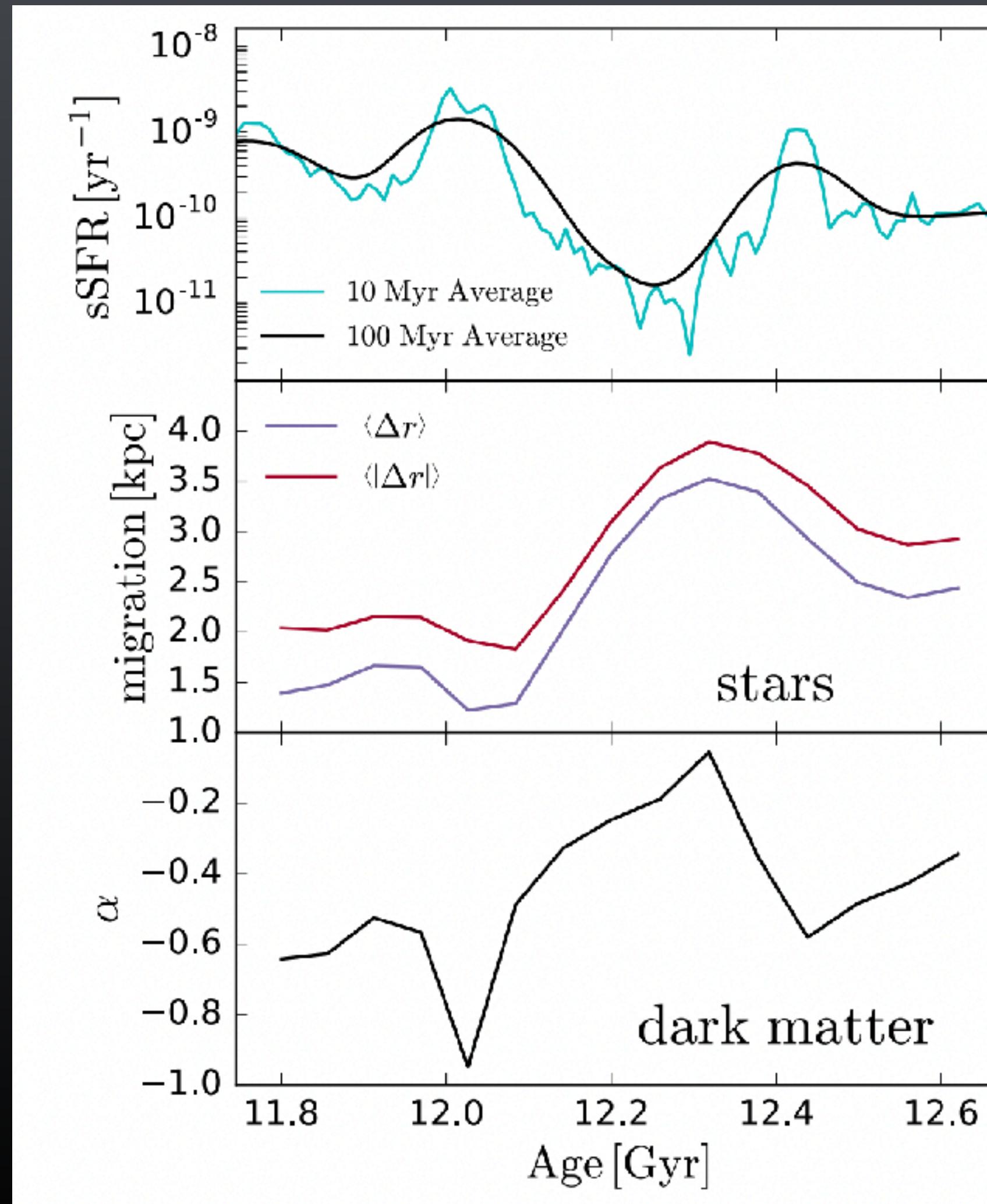


Miller et al. 2014

Solutions

- 1. Baryonic Resolutions within LCDM
 - Stellar feedback, AGNs, etc.

Core formation by stellar feedback



El-Badry et al. 2016

Solutions

1. Baryonic Resolutions within LCDM

- Stellar feedback, AGNs, etc.

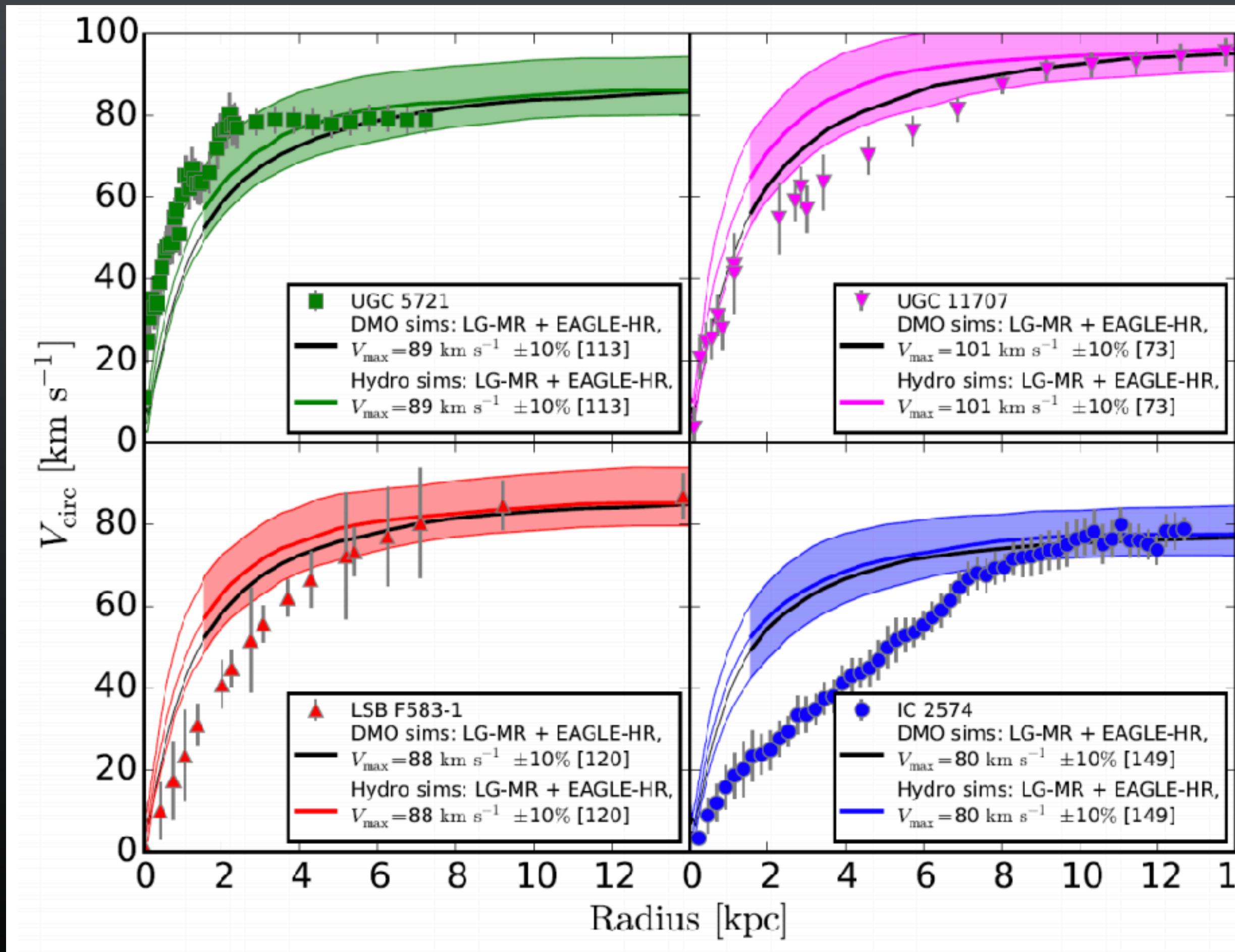
2. Alternate models of dark matter

- Self-Interacting dark matter, Warm dark matter, etc

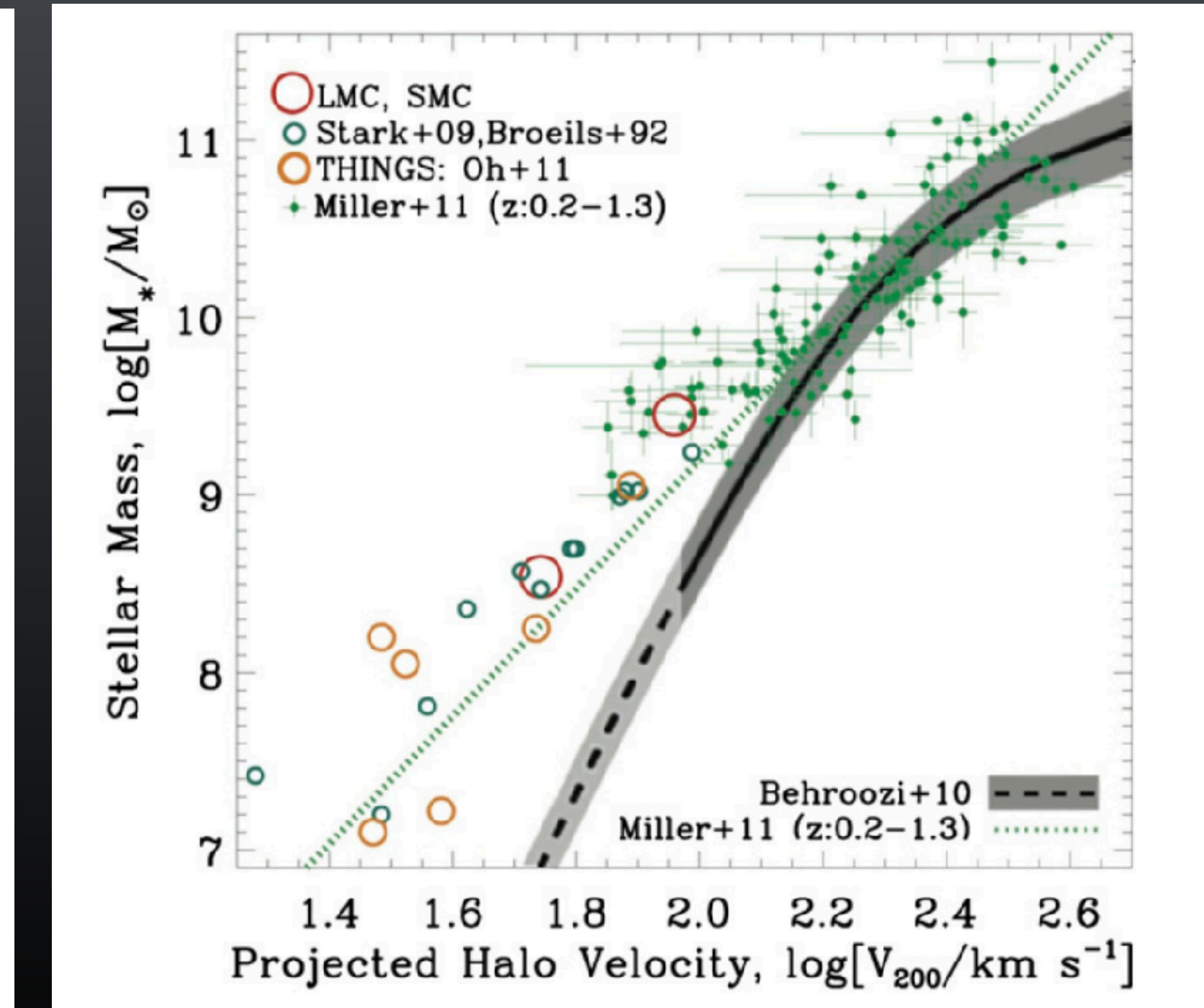
Could be more

Constrain halo properties on small scale

Inner region of the halo

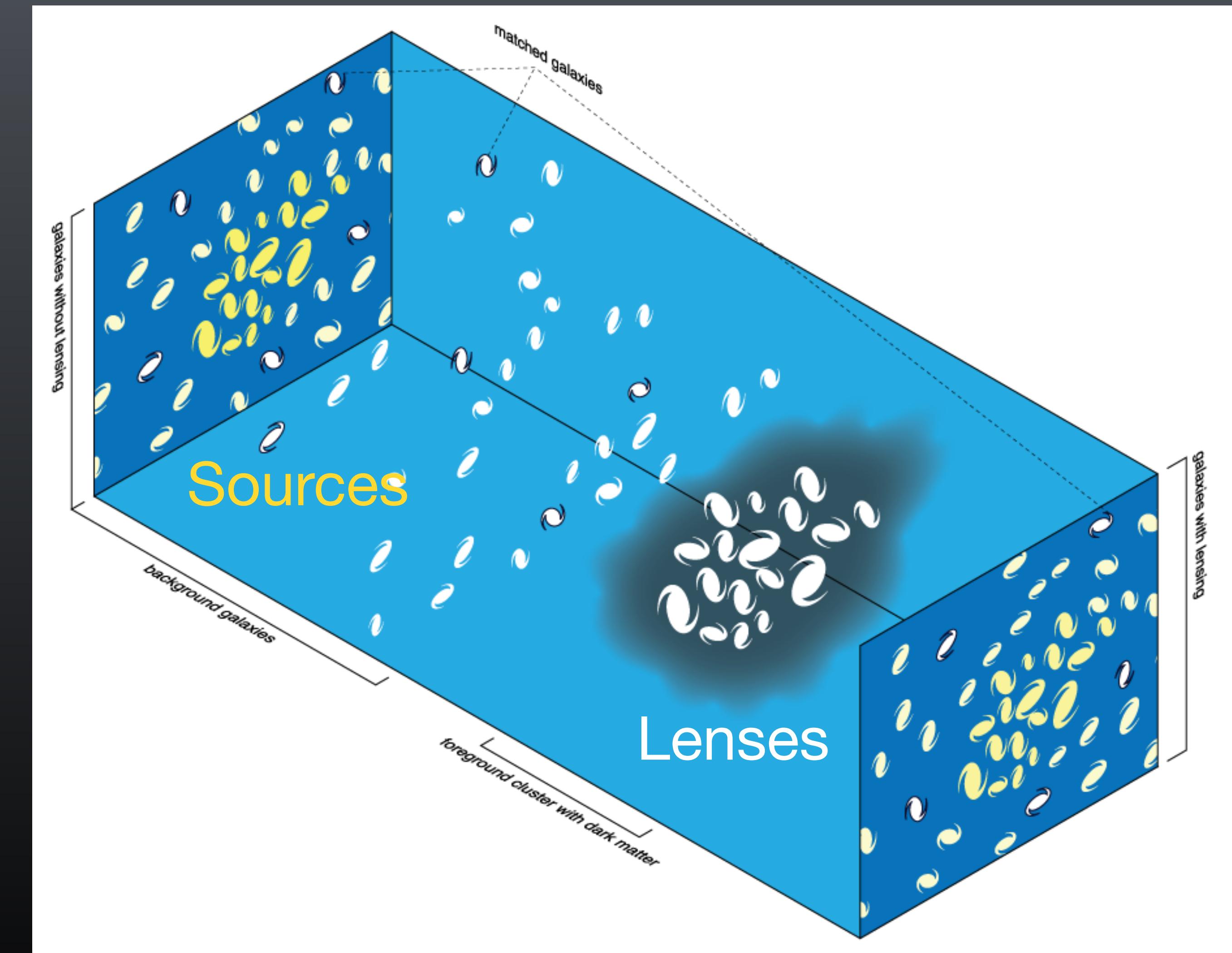


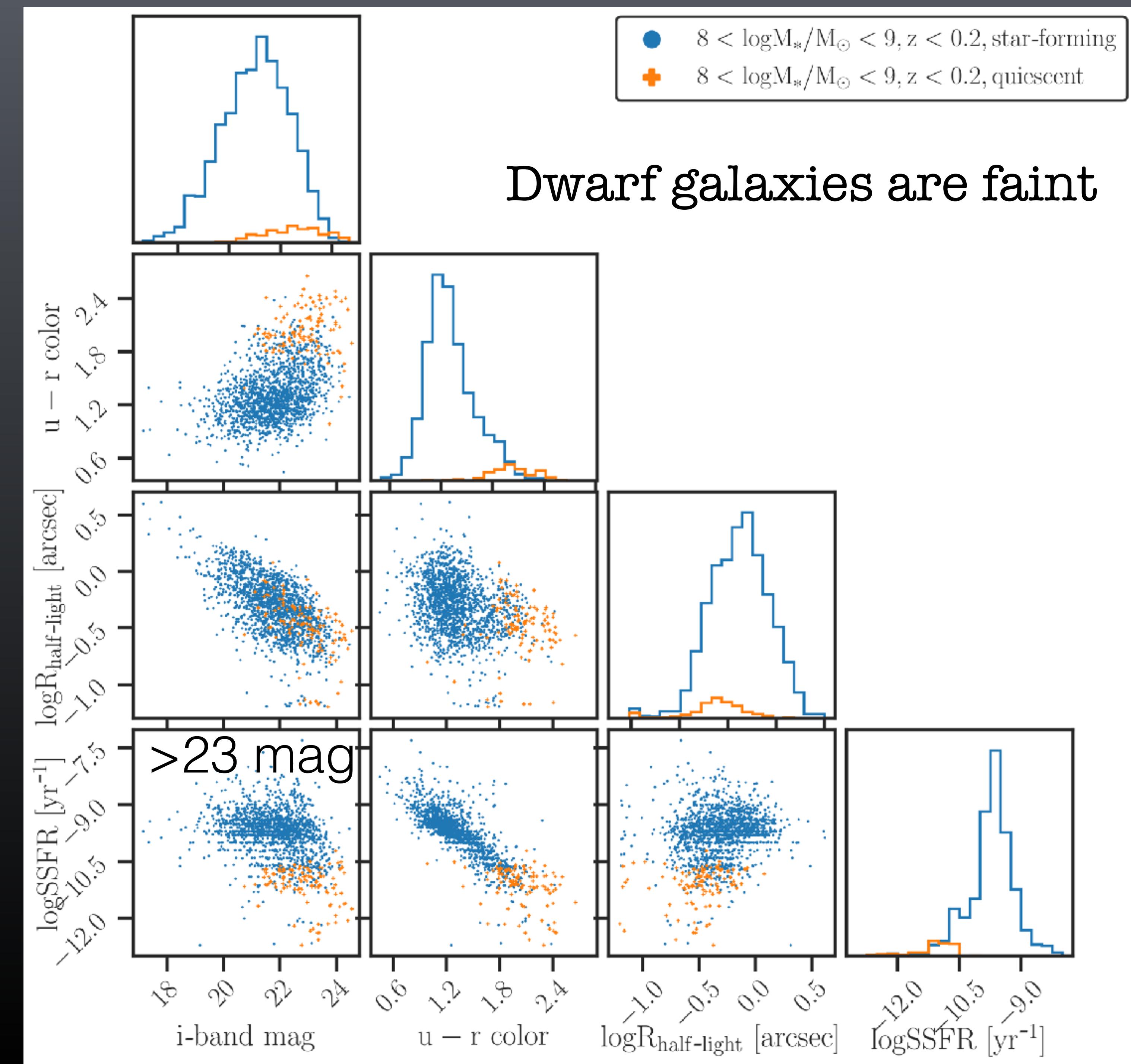
Oman et al. 2015

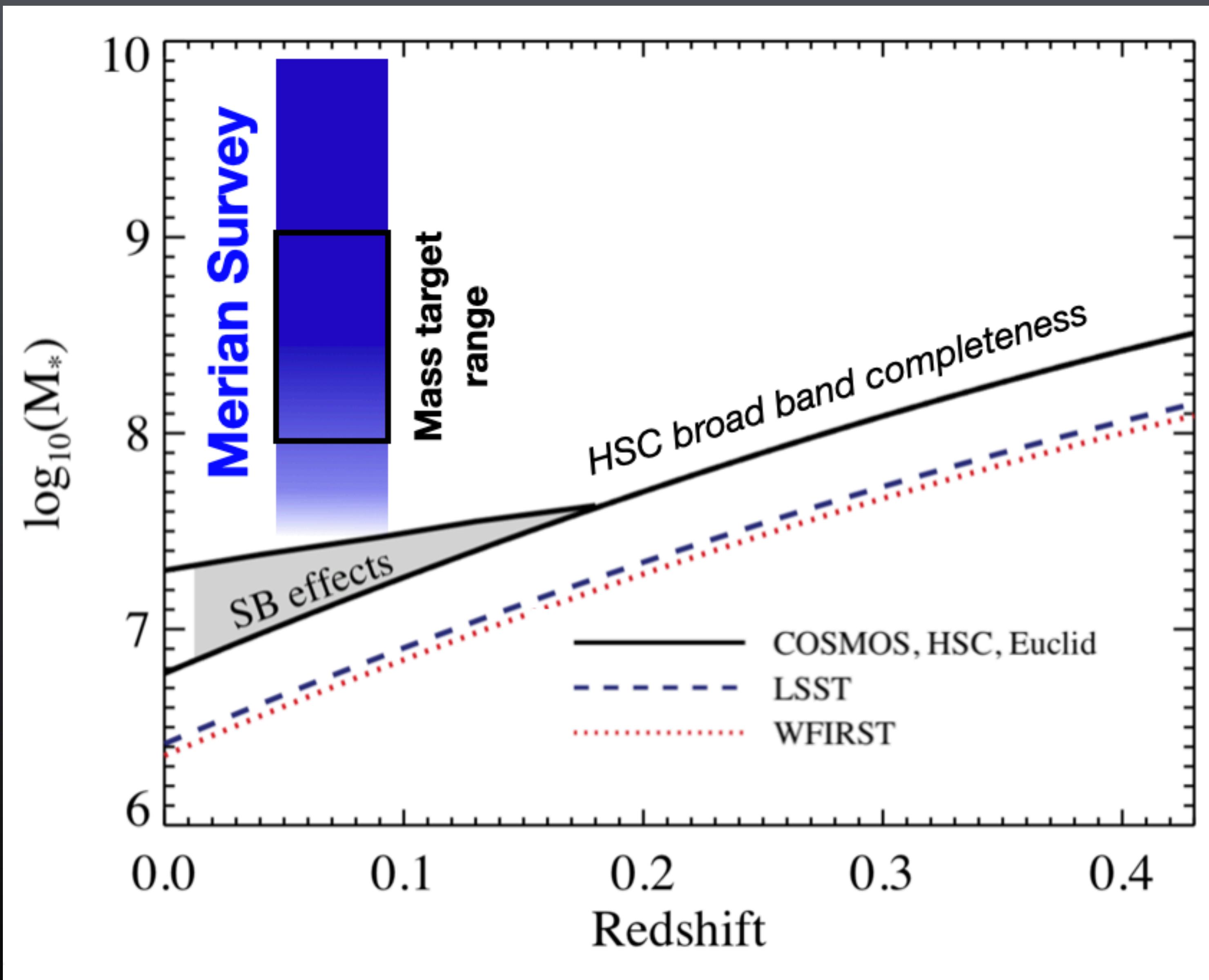


Miller et al. 2014

- Weak gravitational lensing
- Constrain halo out to R_{vir}
- Need large sample of lenses

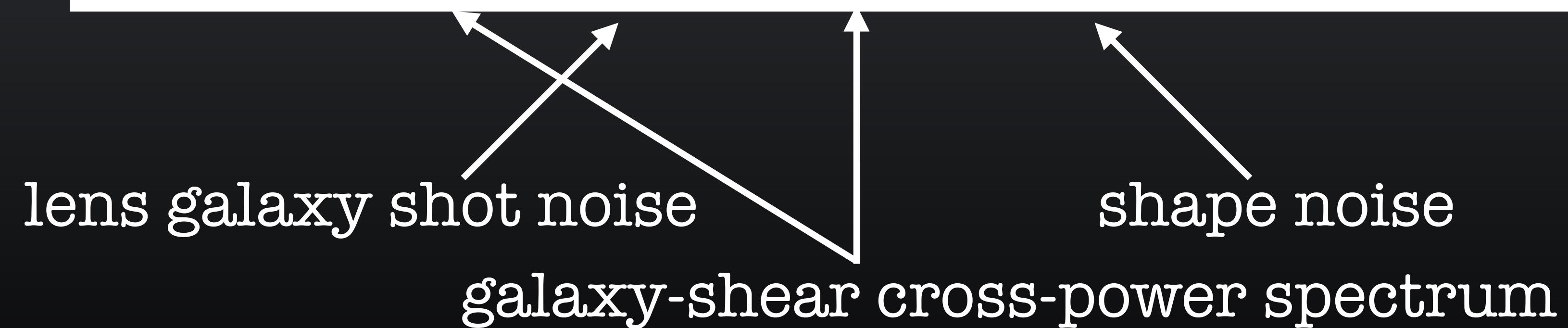




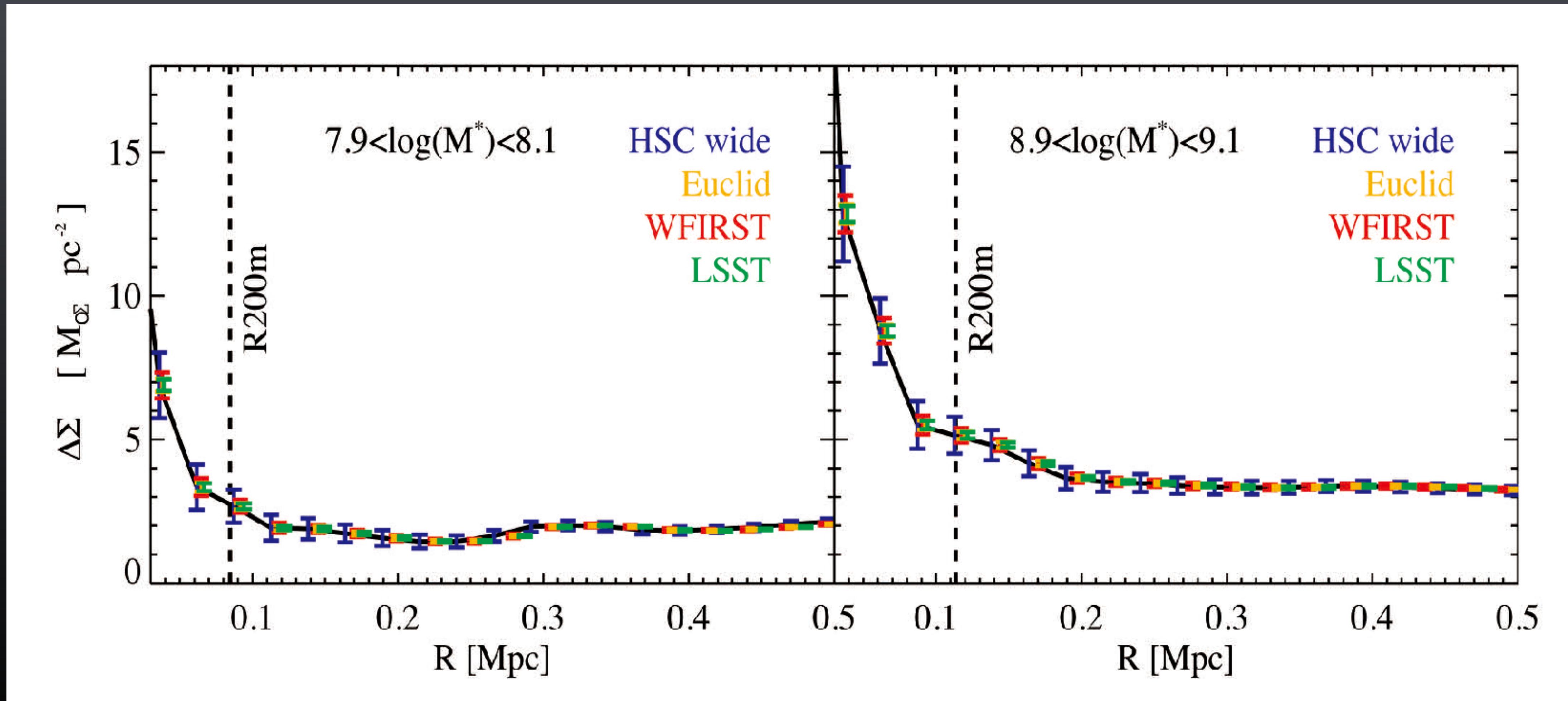


- Expected uncertainty for lensing signal (dominated by number of lenses)

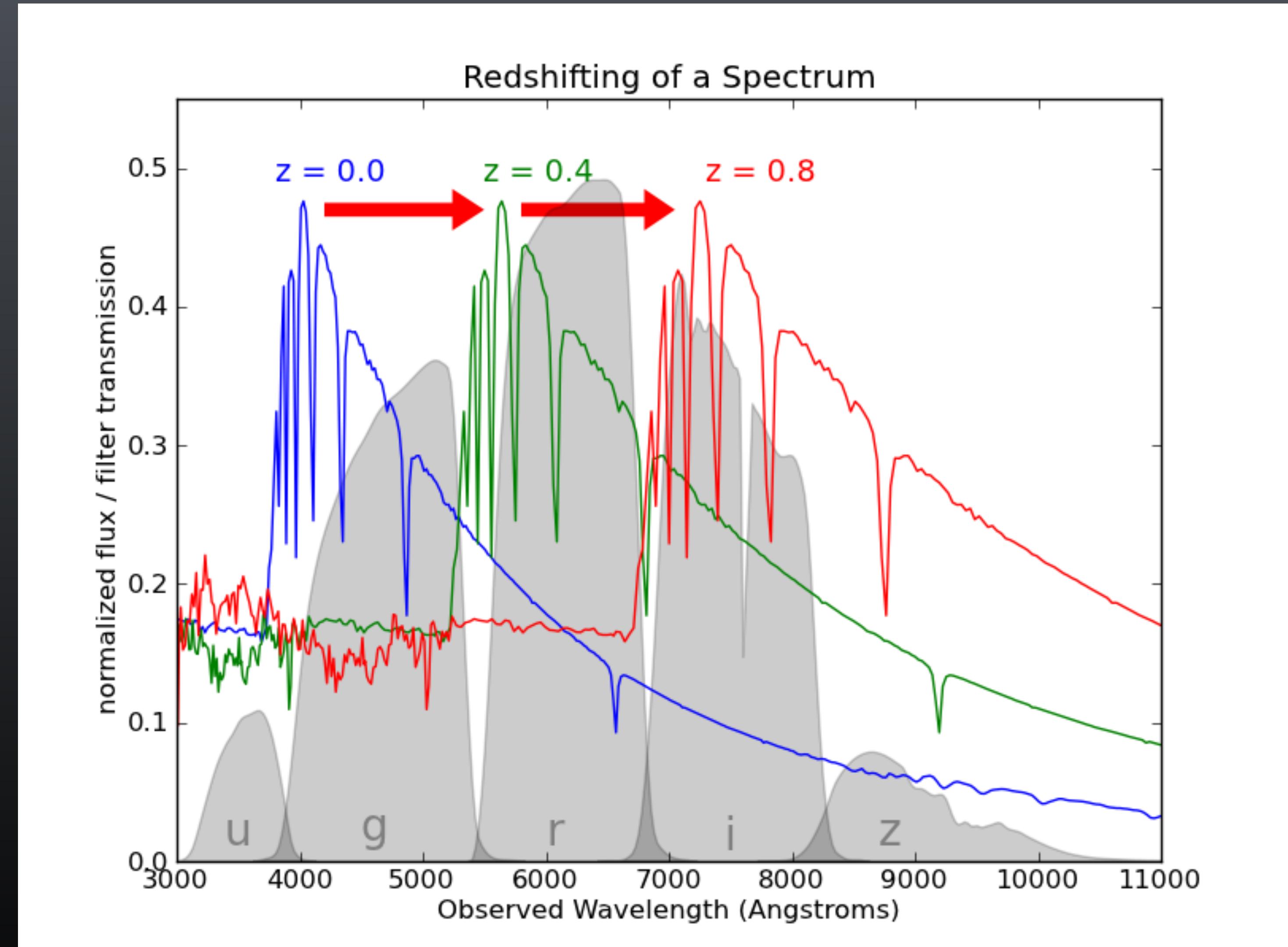
$$\text{Cov}(\Delta\Sigma(r_p), \Delta\Sigma(r'_p)) \approx \frac{\Sigma_c^2(\chi_s, \chi_g)}{V_W} \int dk_\perp k_\perp J_2(k_\perp r_p) J_2(k_\perp r'_p) \\ \left[(P_{gg}(k_\perp) + \frac{1}{n_g})(P_{\kappa\kappa}(k_\perp) + \frac{\sigma^2}{n_s}) + P_{g\kappa}^2(k_\perp) \right], \quad (1)$$



Predicted lensing measurements if we have spec-z's for future imaging surveys

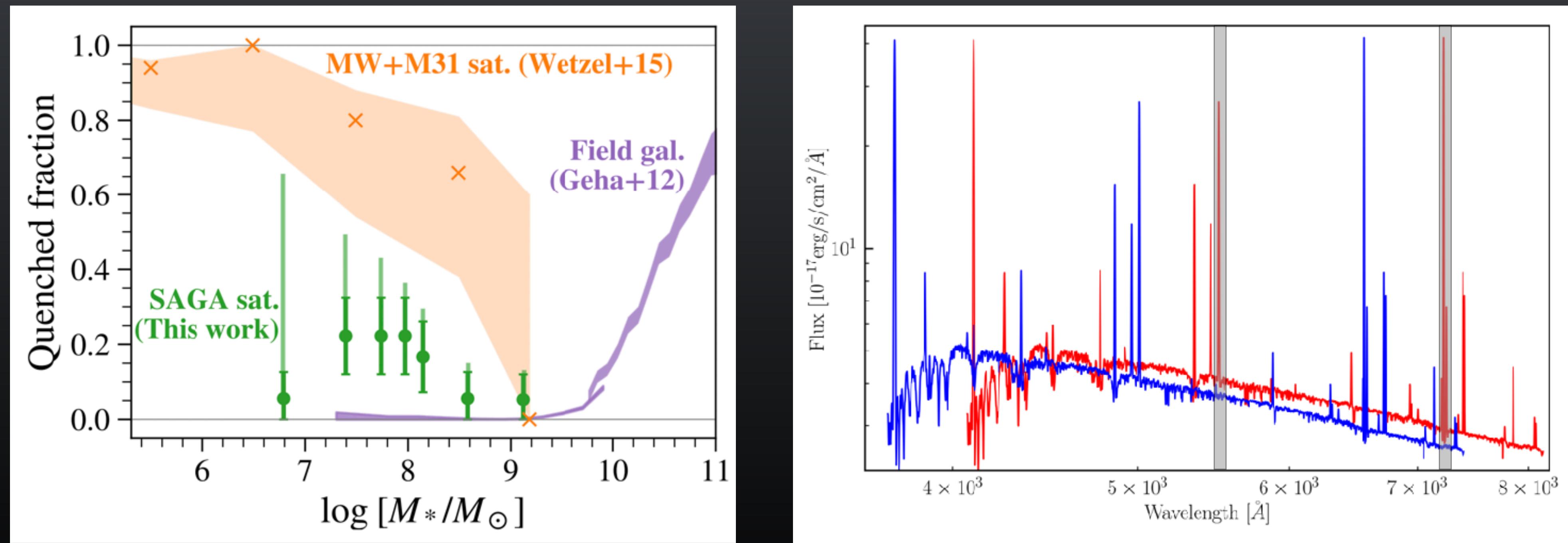


- Broad-band photo-z
- 4000\AA break is in *g*-band for $z < 0.2$ galaxies
- Dwarf galaxies in general have weak 4000\AA break



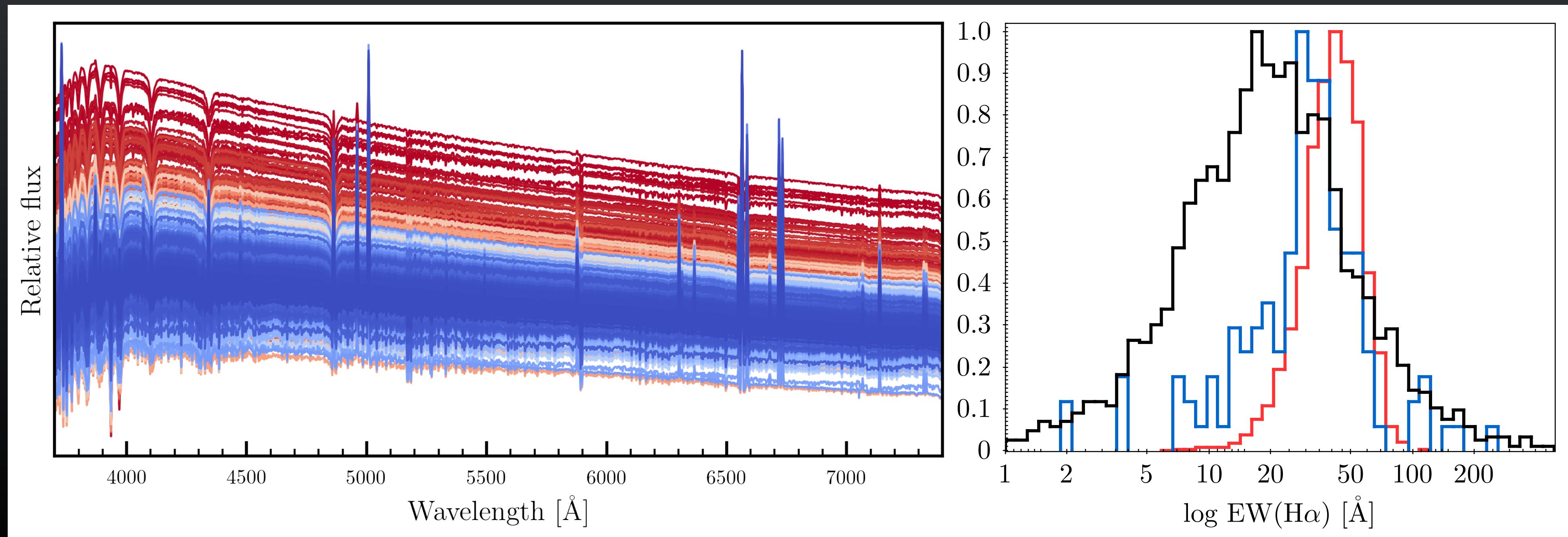
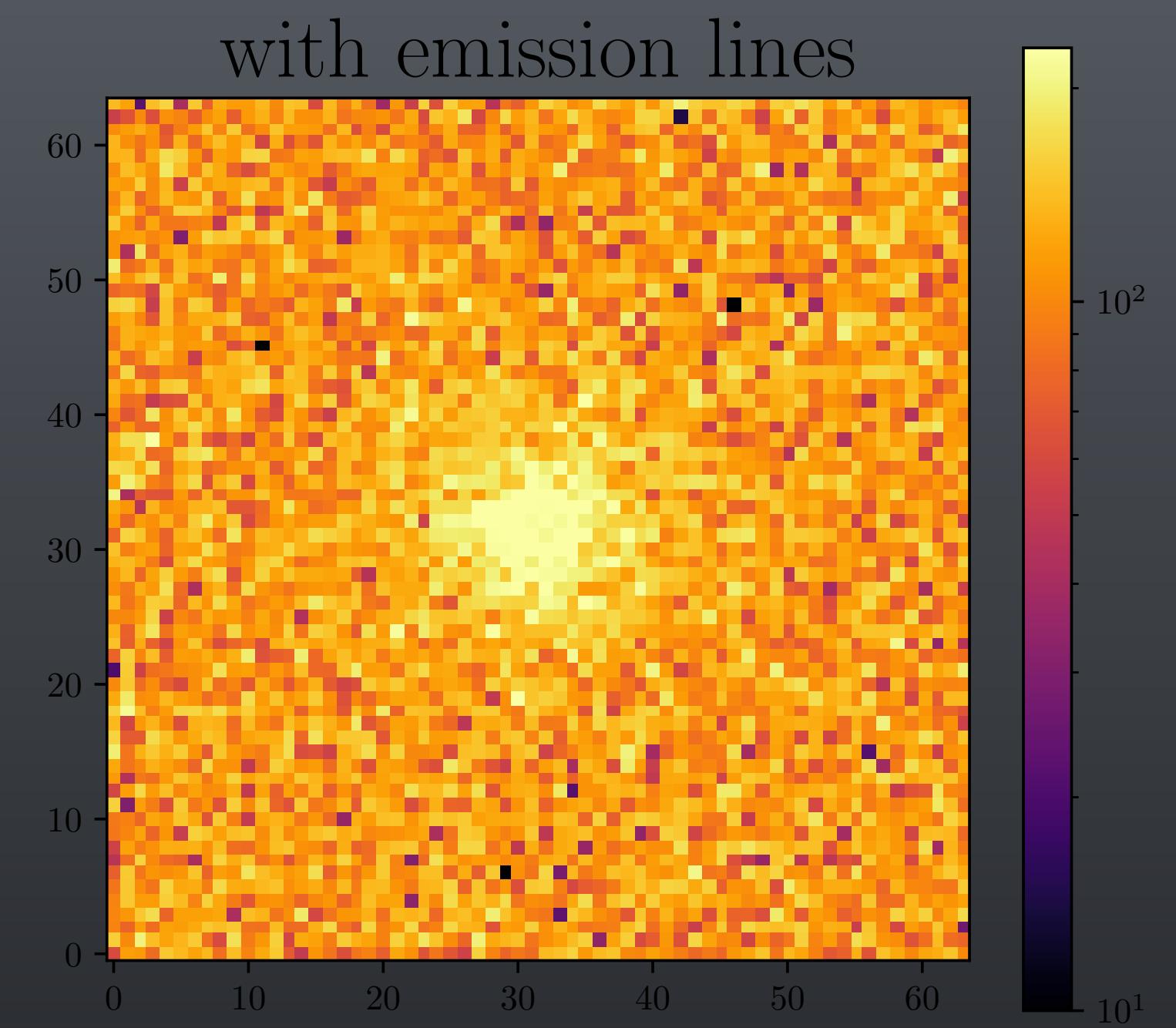
Use emission lines to improve photo-z's

- Quenched fraction for galaxies in mass range $10^8 - 10^9 M_{\odot}$ is low

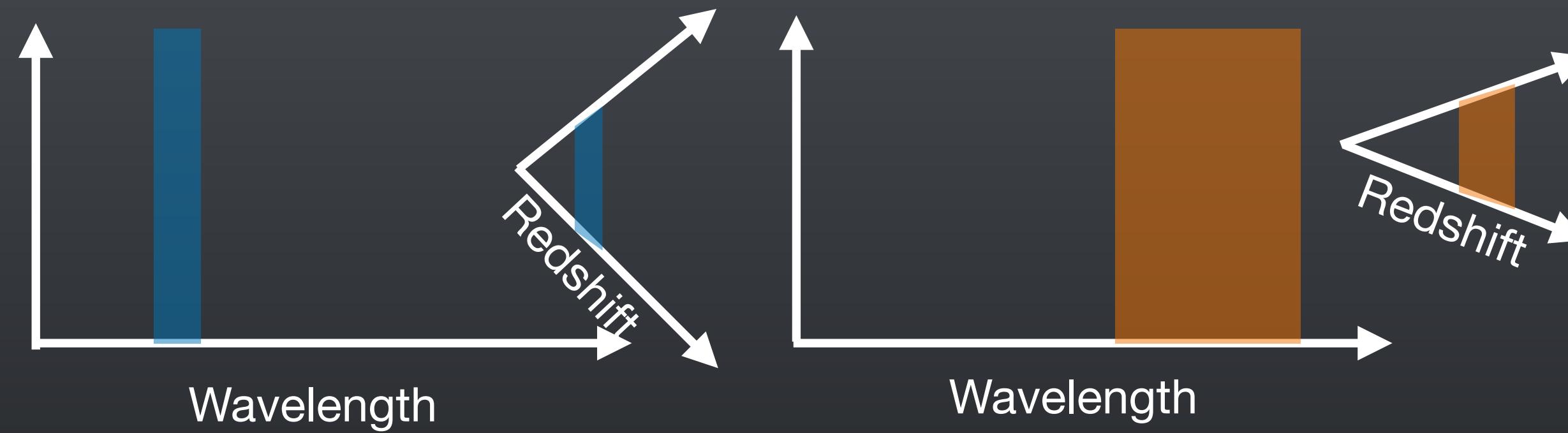


Merian filter design

- Generate dwarf SED library with COSMOS 30-bands photometry
- Simulate dwarf images given a filter design

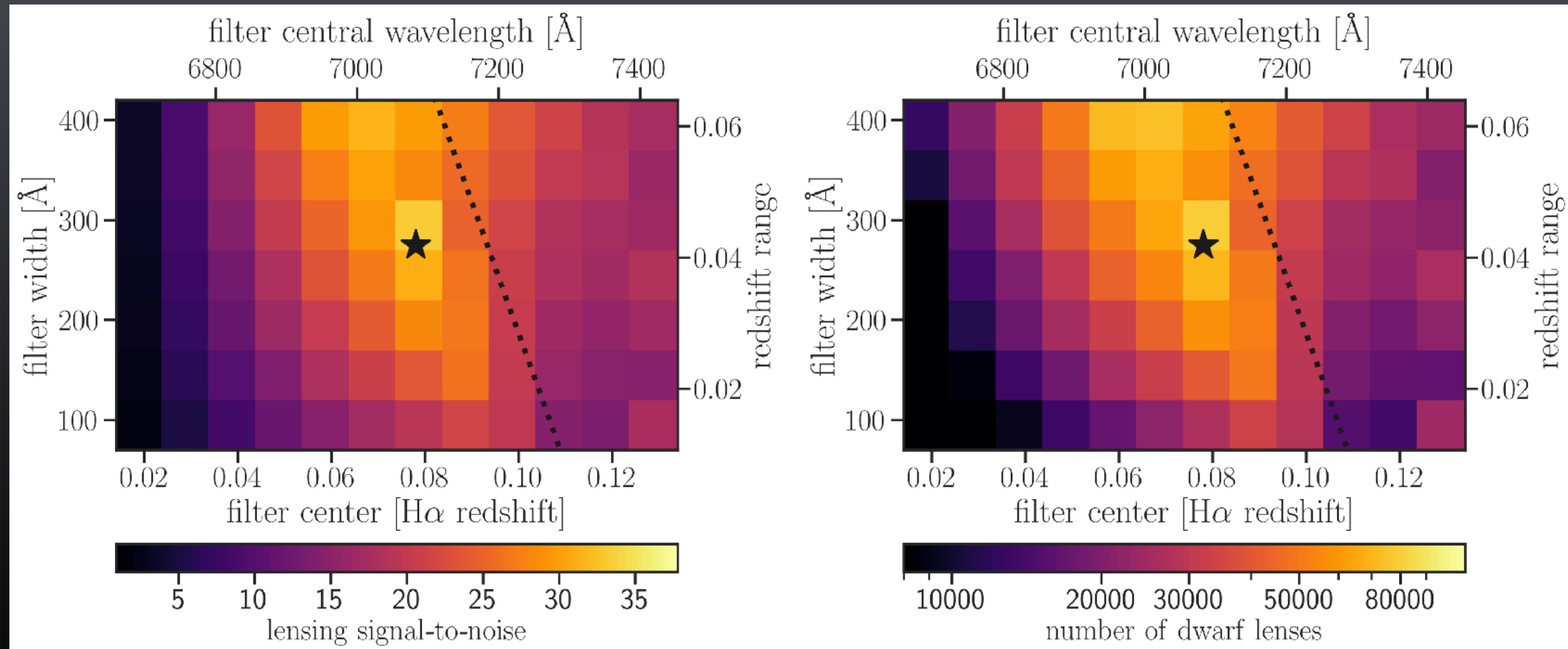


Tradeoffs in the central wavelength & filter width

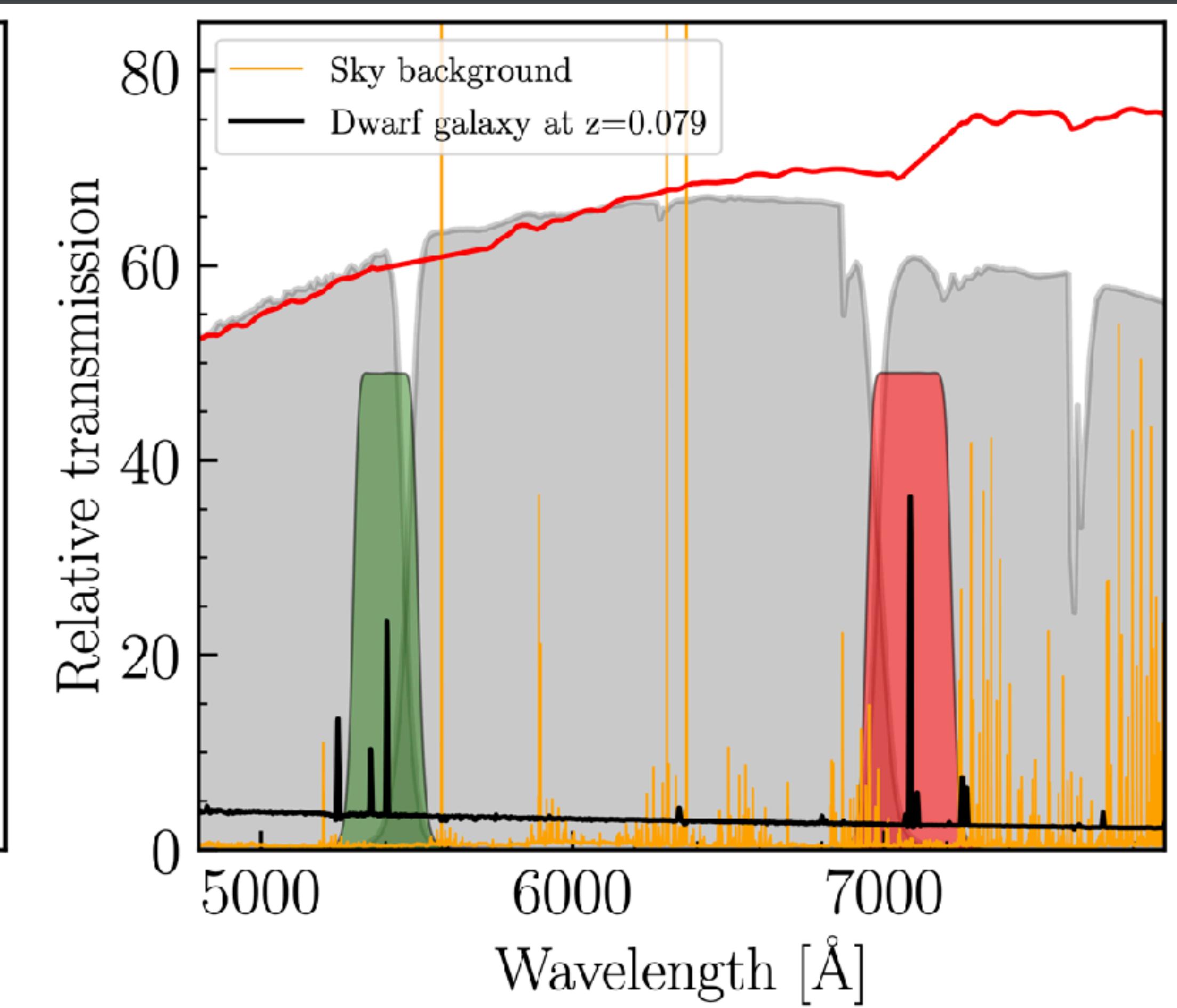
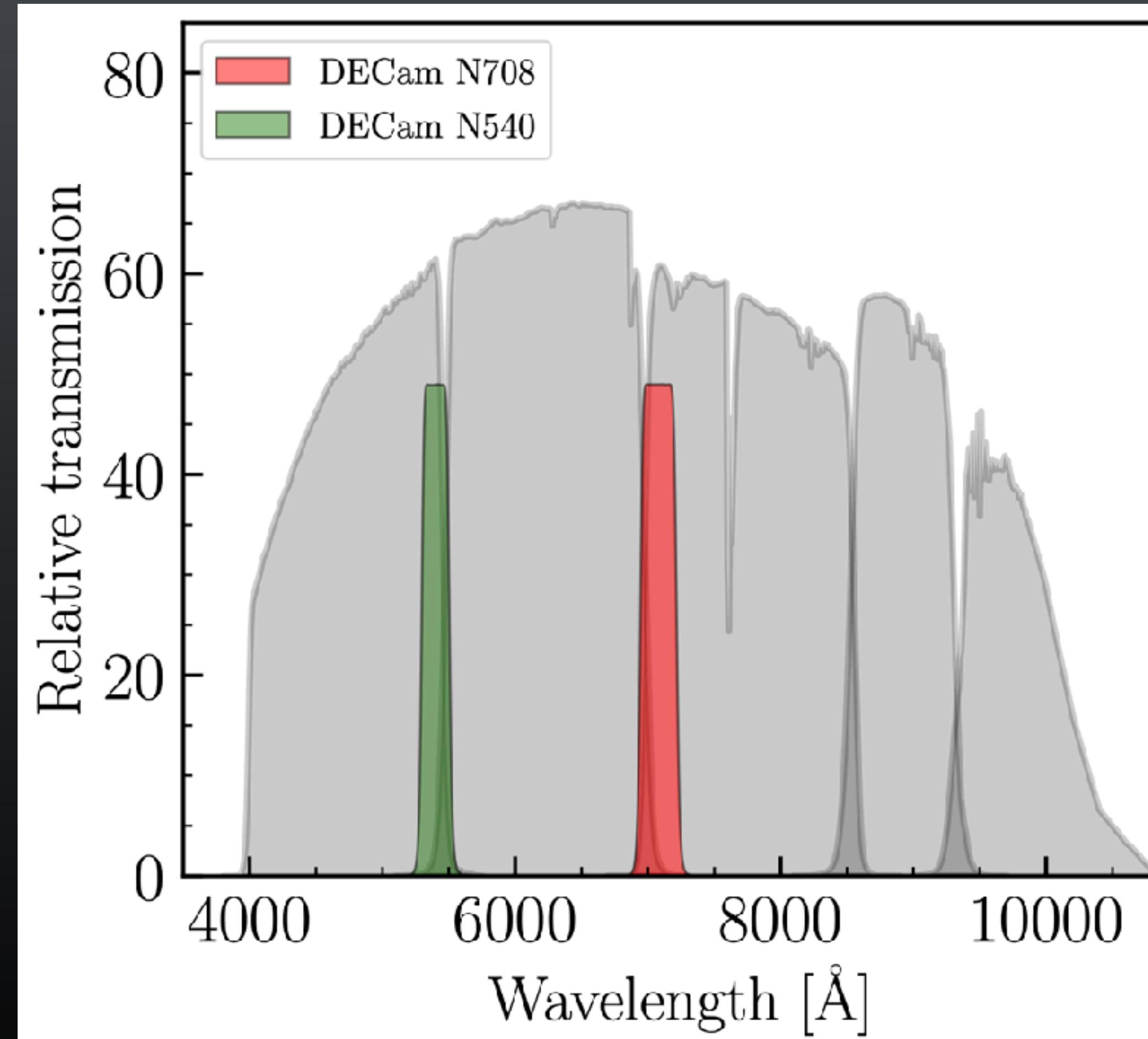


- longer central wavelength & wider filter width = larger volume = higher lensing S/N
- longer central wavelength = fainter dwarf galaxies = longer exposure time = less volume with fixed survey time
- wider filter width = weaker S/N of emission line detection = fewer dwarfs detected

Optimize lensing S/N

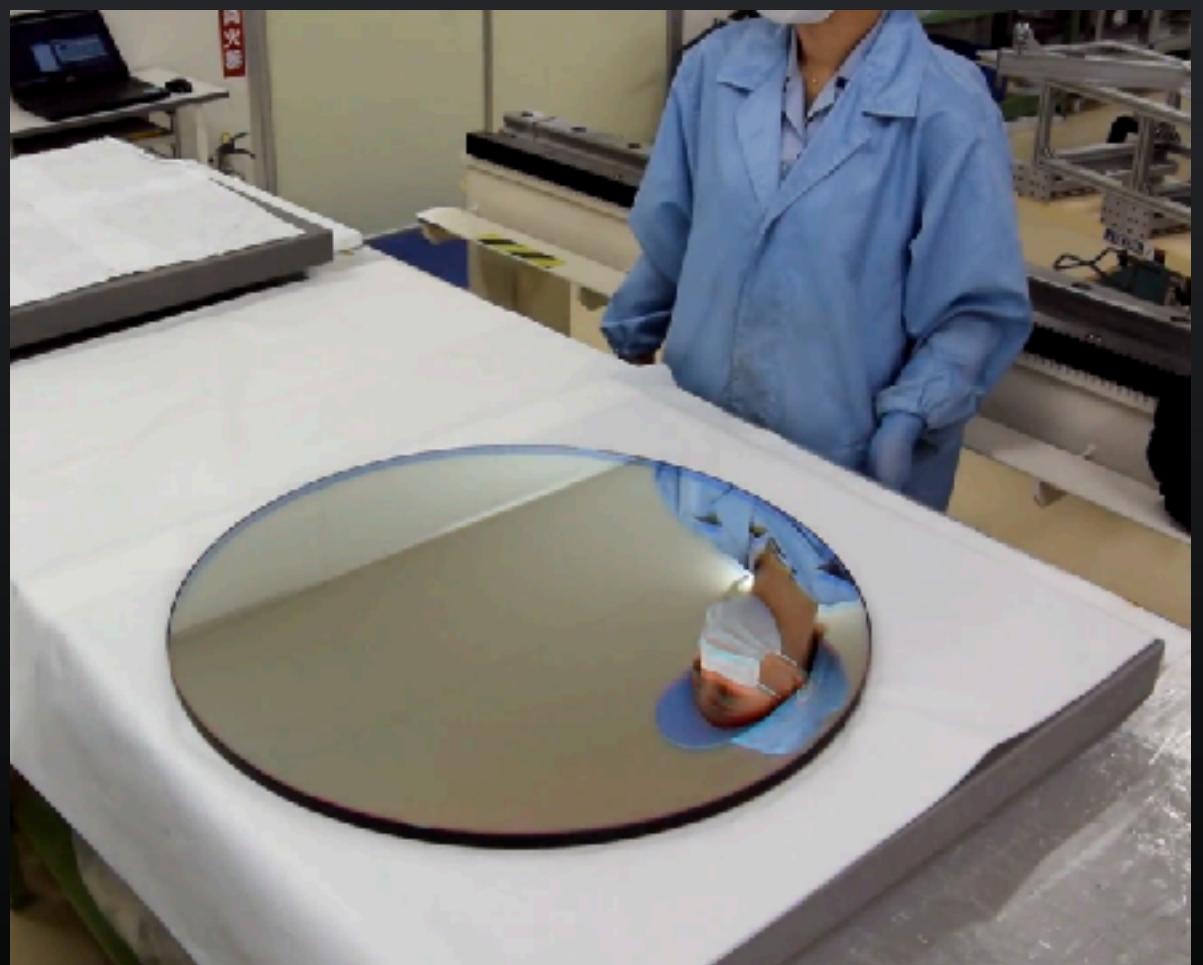


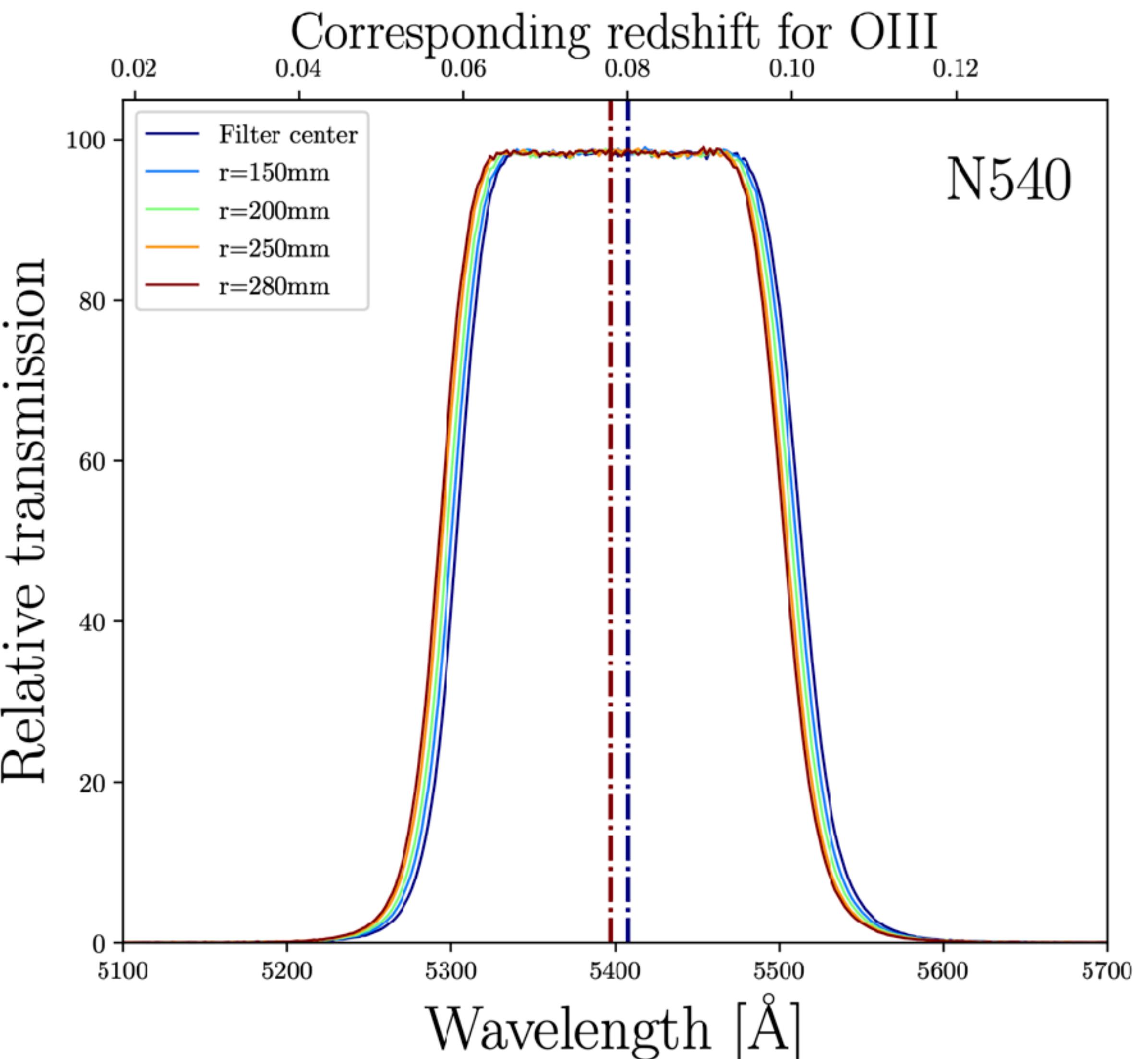
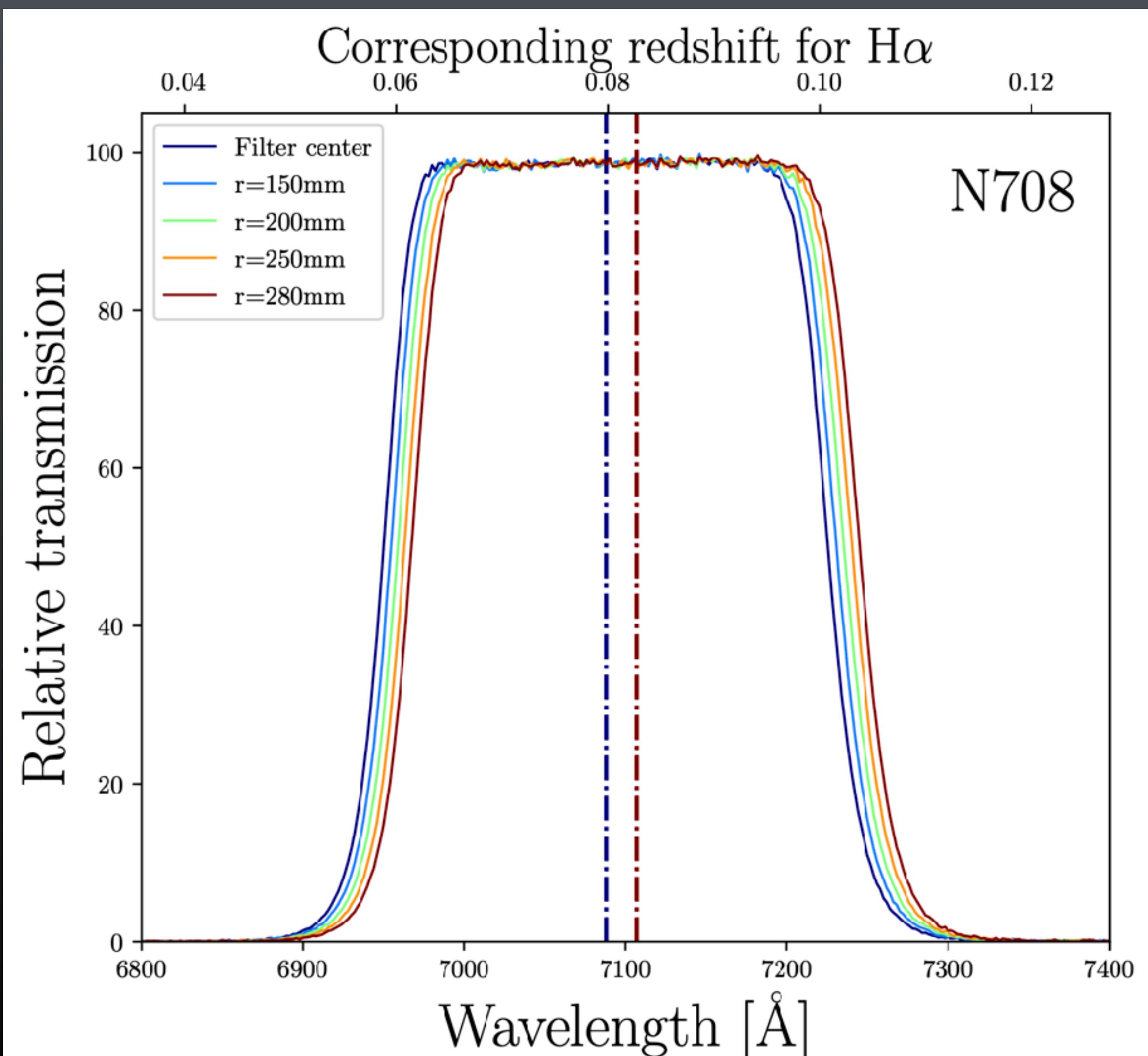
Merian filters N708/N540



The Merian Survey

- Two medium-band filters (N708 and N540) for Halpha and OIII at $z \sim 0.1$
- 64 nights on the CTIO-4m Dark Energy Camera (DECam)
- 800 deg 2 in the HSC-SSP wide field
- Core science goal: constrain halo properties for star-forming dwarf galaxies with weak gravitational lensing





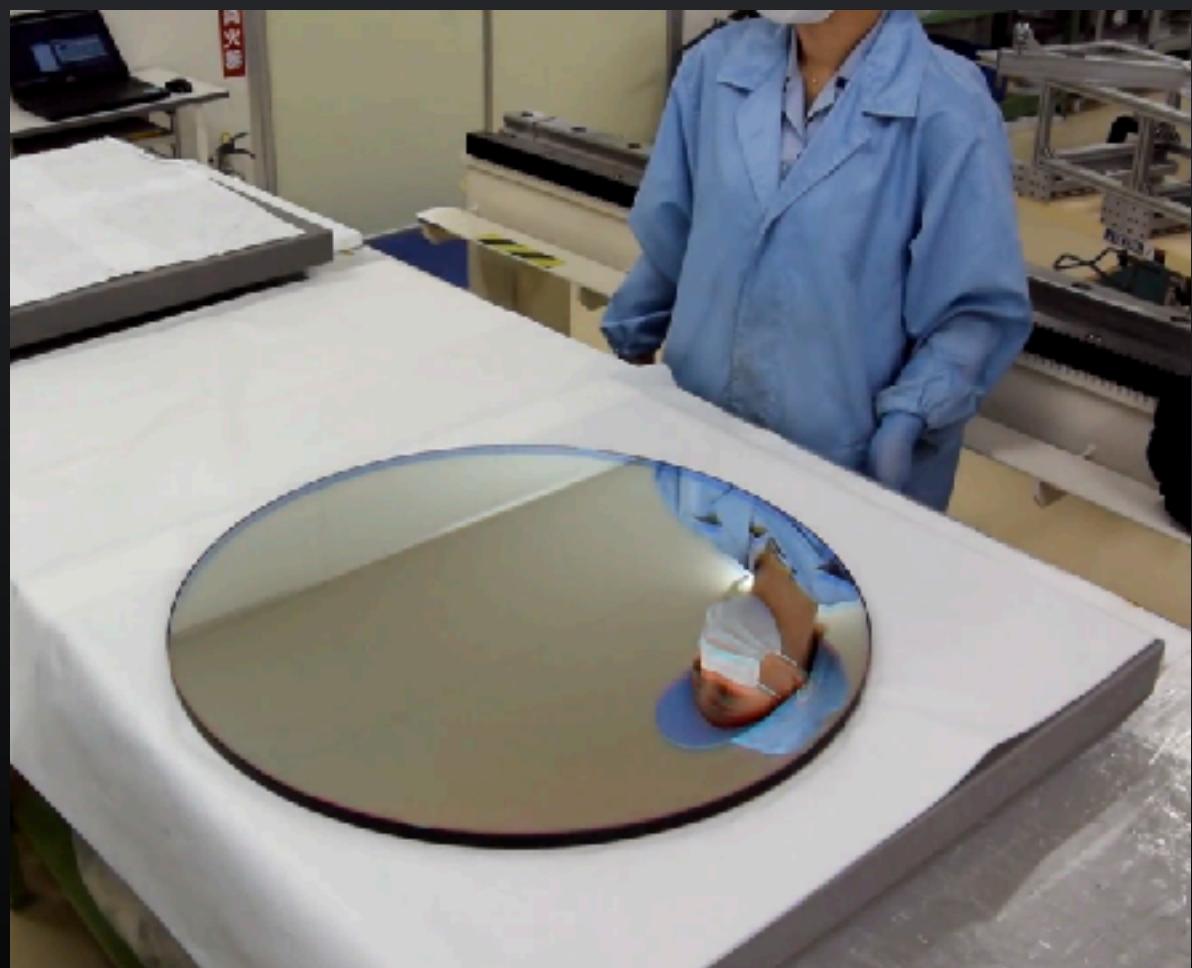
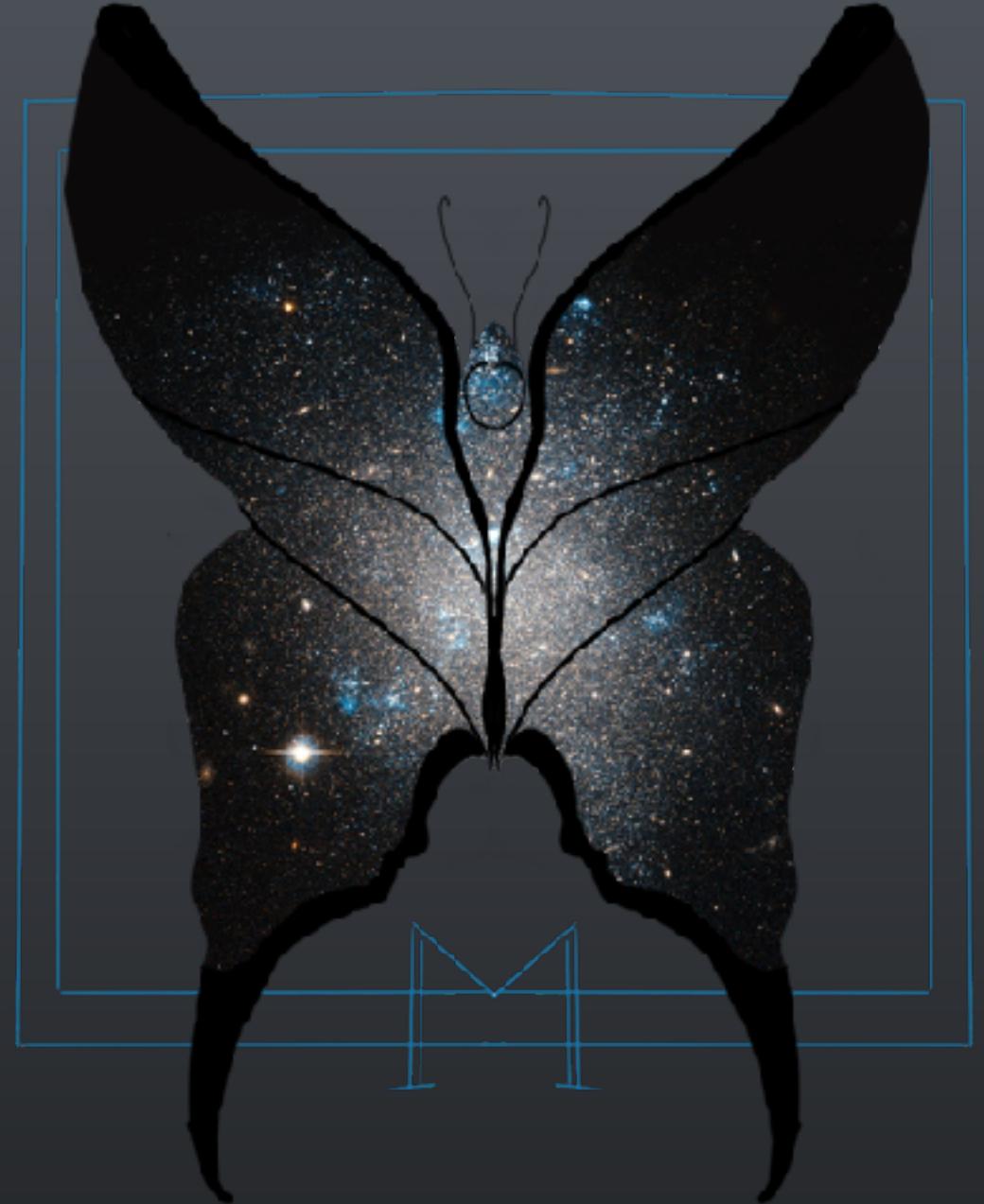
The Merian Survey

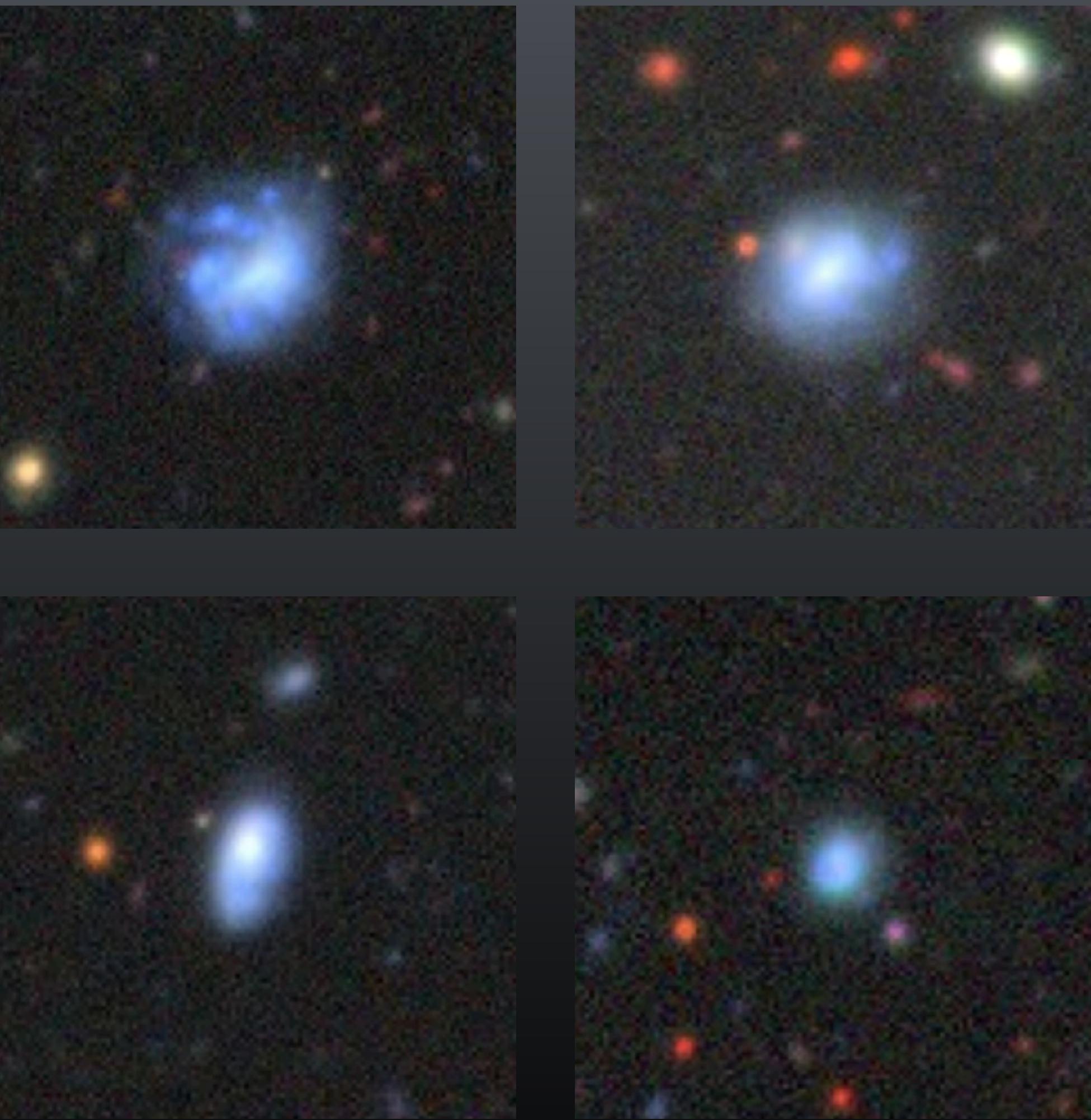
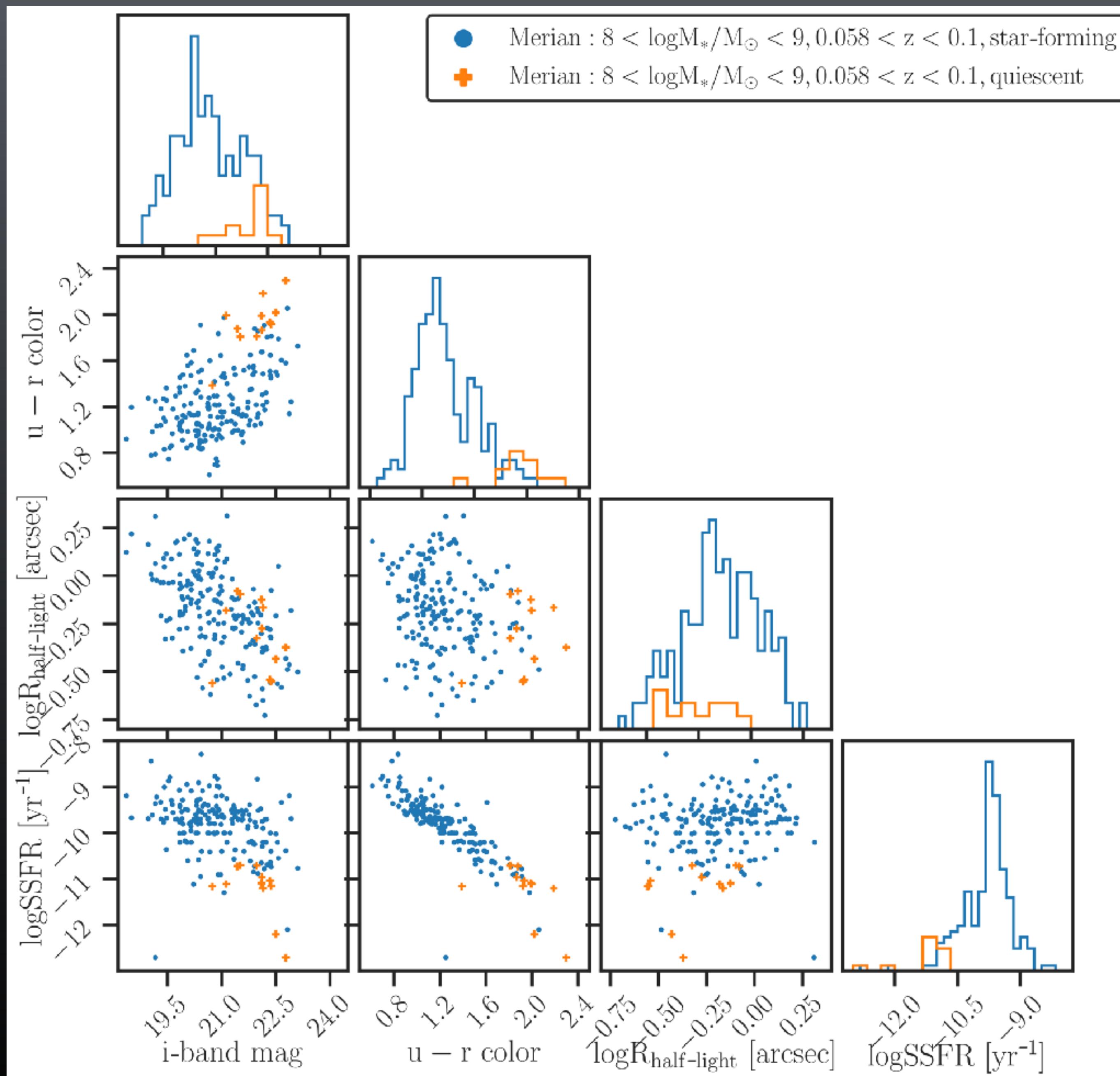
HSC-SSP wide layer:

- $g/r/i/z/y$ -band: 26.5/26.1/25.9/25.1/24.4 mag
- i-band median seeing: 0.6 arcsec

Merian wide layer:

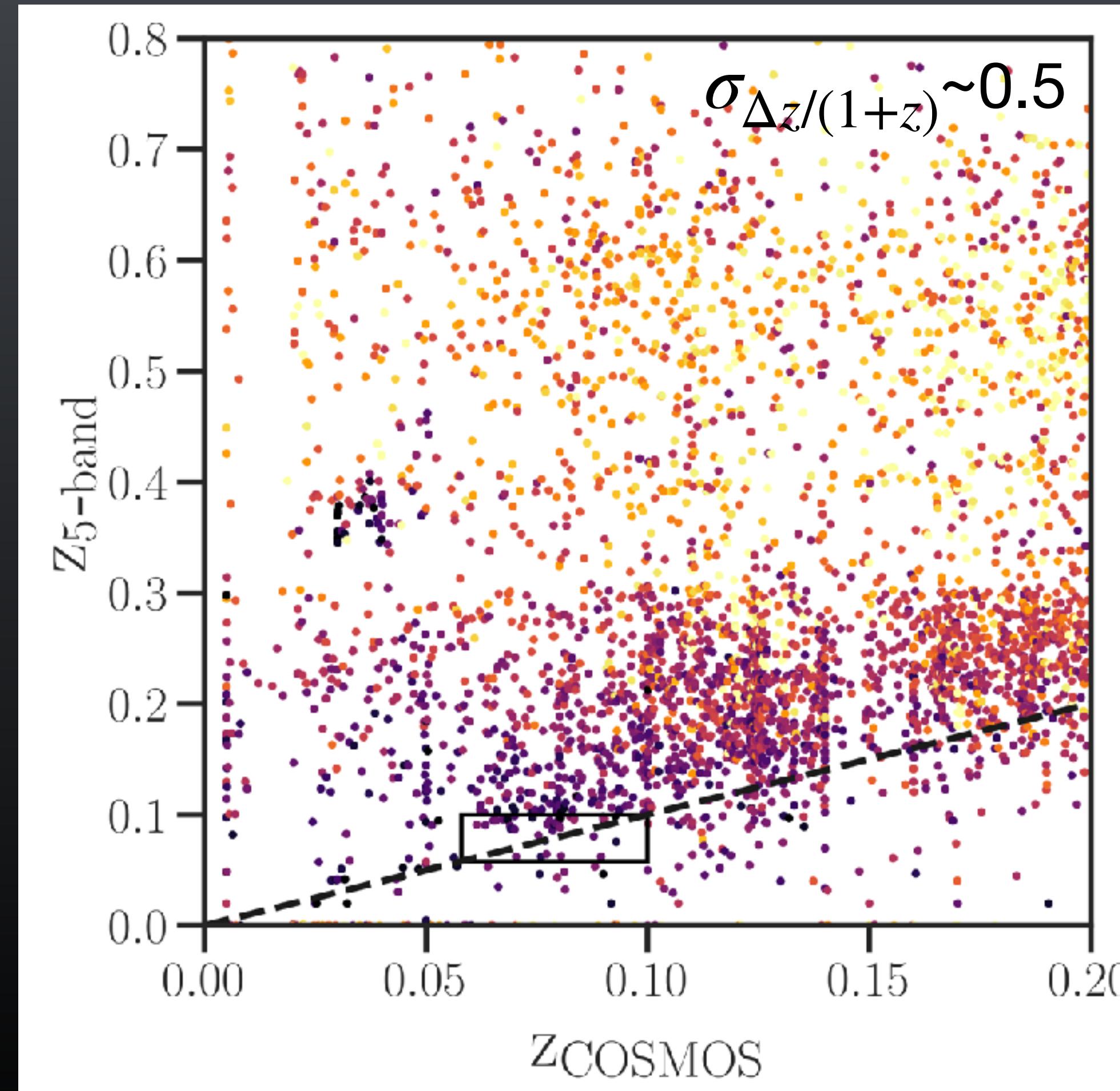
- N540/N708: 24.4/23.1 mag
- N708 median seeing: 0.9 arcsec



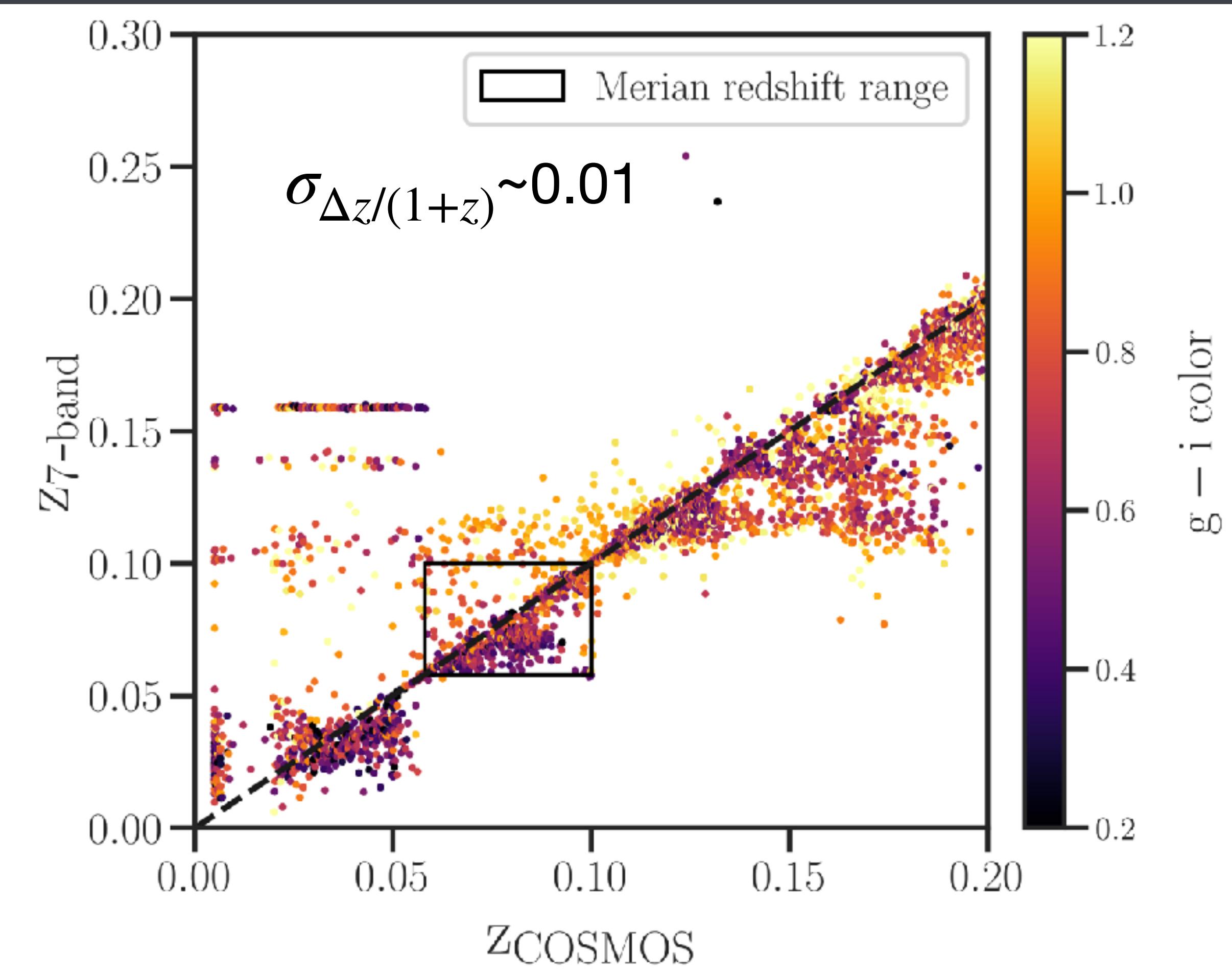


Predicted photo-z measurements

HSC broad band photo-z



Merian photo-z



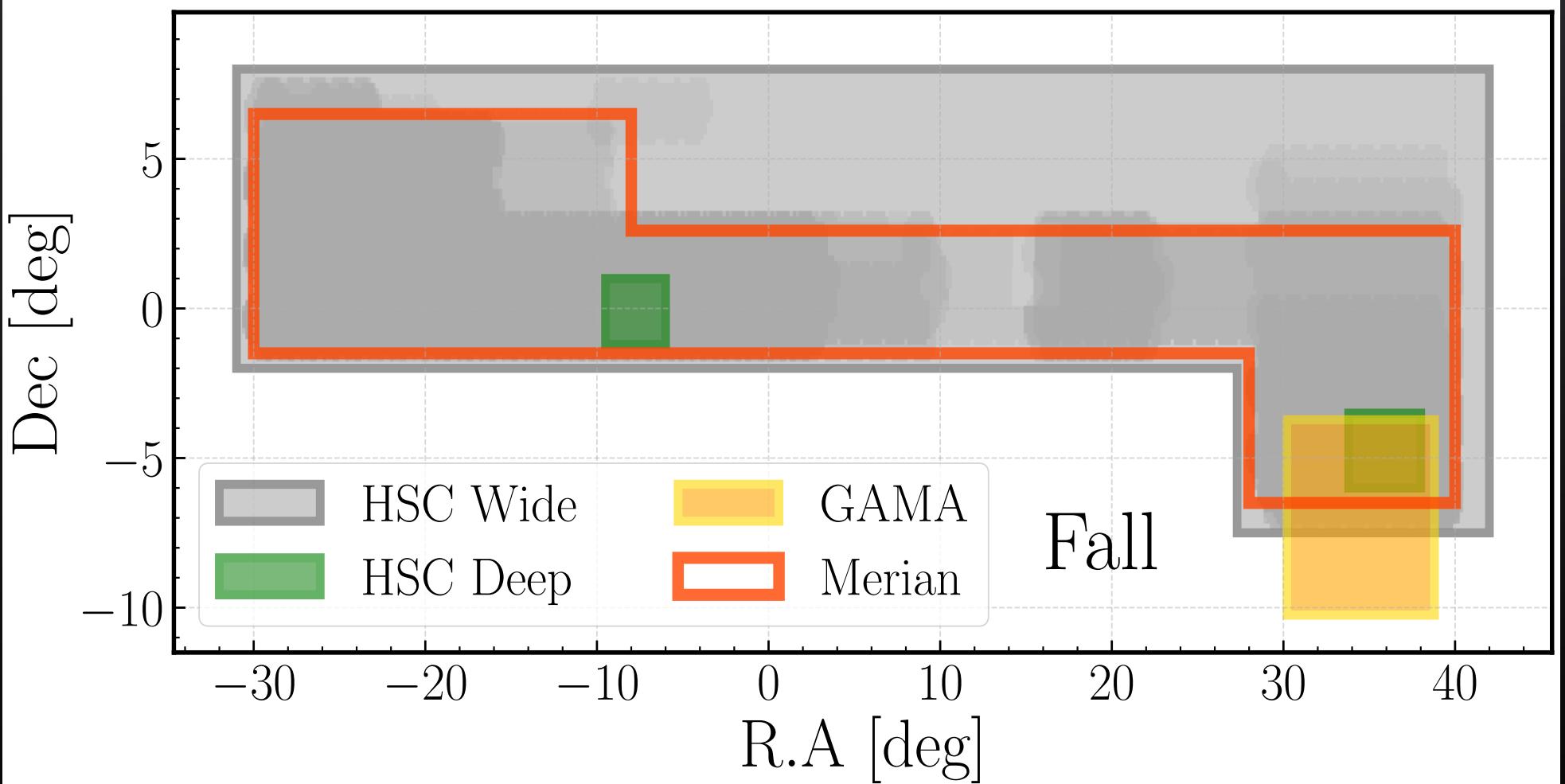
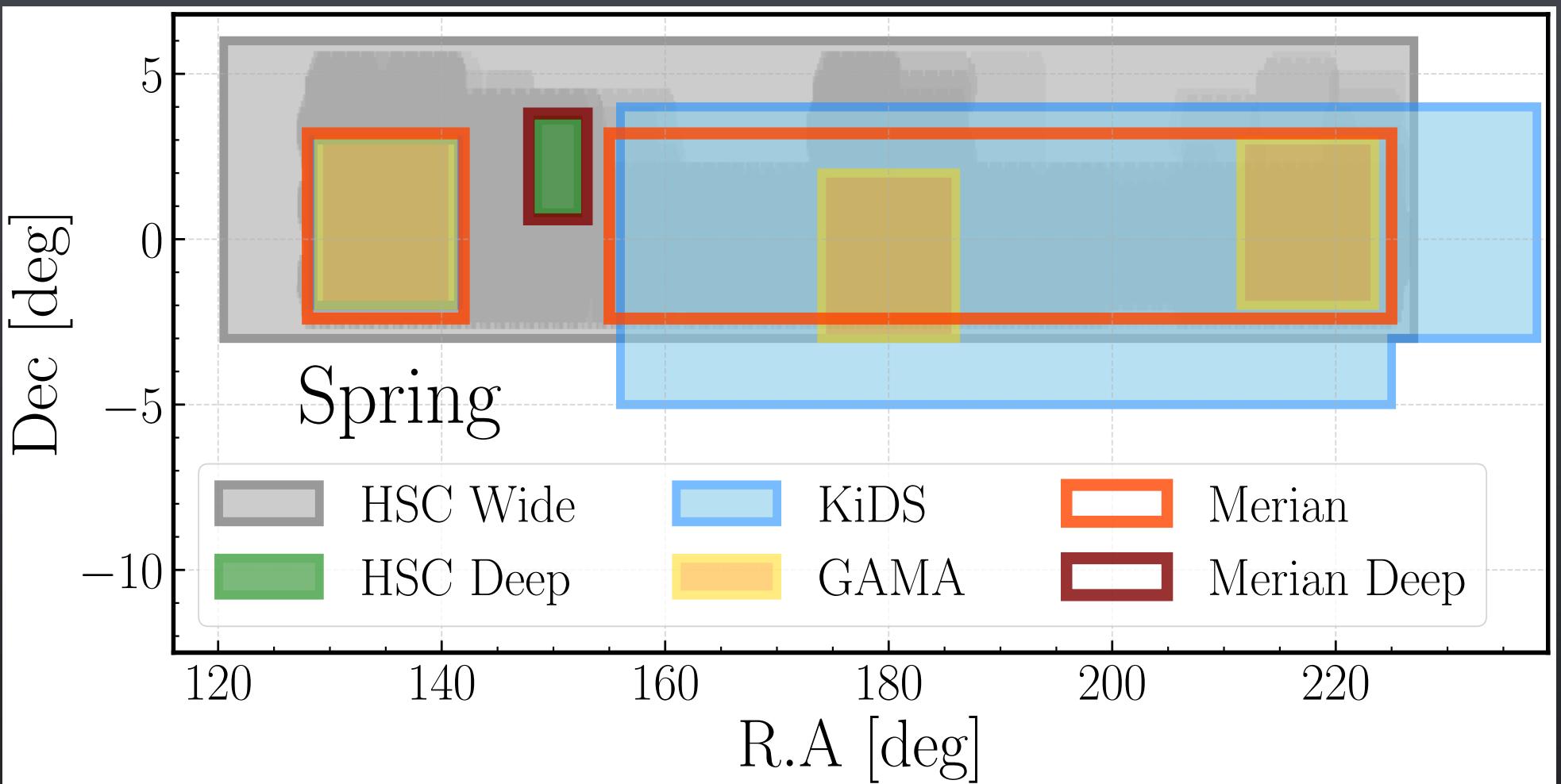
Merian observations

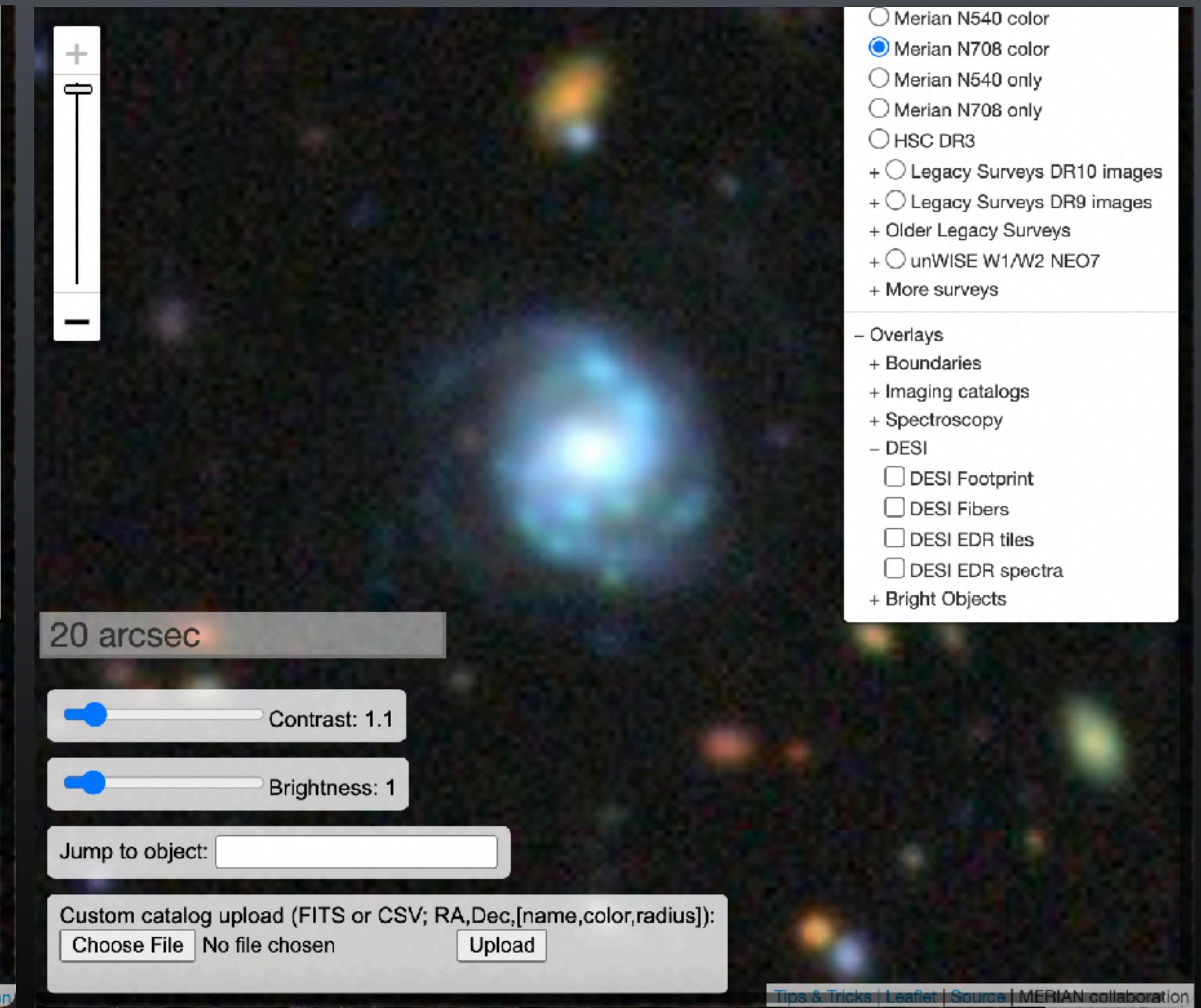
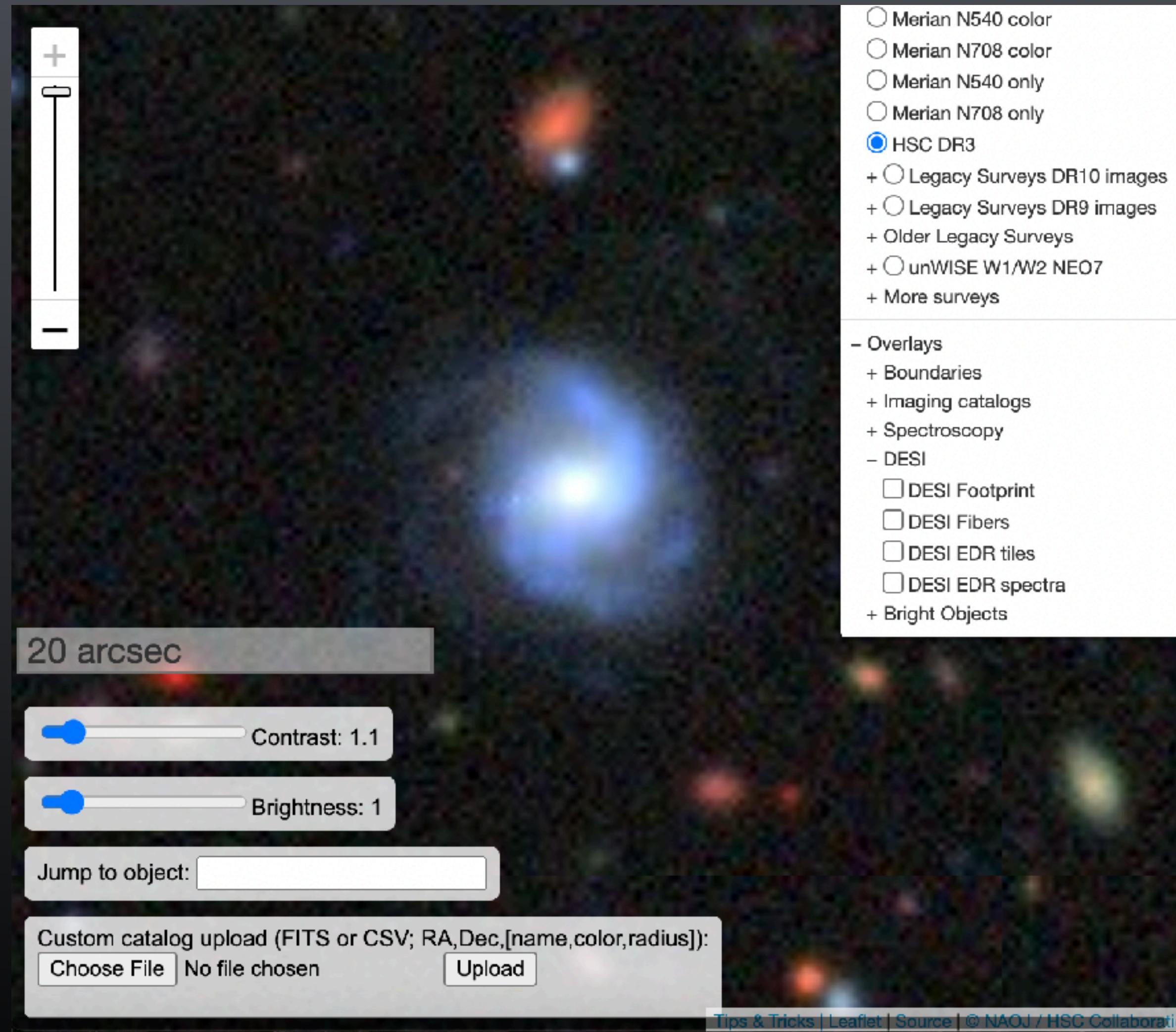
Merian Wide ($\sim 800 \text{ deg}^2$): 52/62 nights, ongoing

- 4x10 min exposure for N708 (Halpha)
- 4x15 min exposure for N540 (OIII)

Merian Deep ($\sim 2 \text{ deg}^2$): 2/2 nights, finished

- 40x10 min exposure for N708 (Halpha)
- 40x15 min exposure for N540 (OIII)

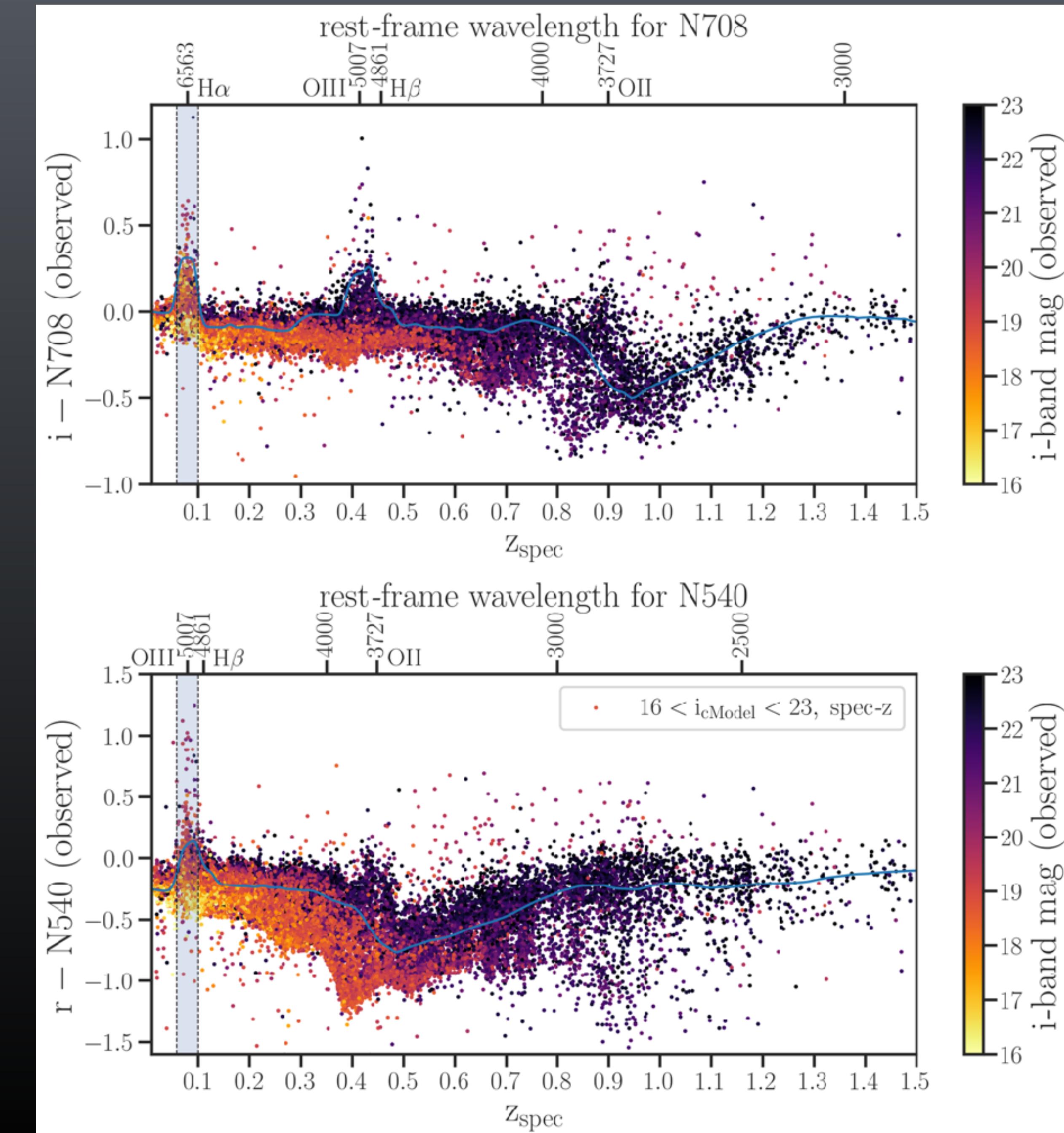


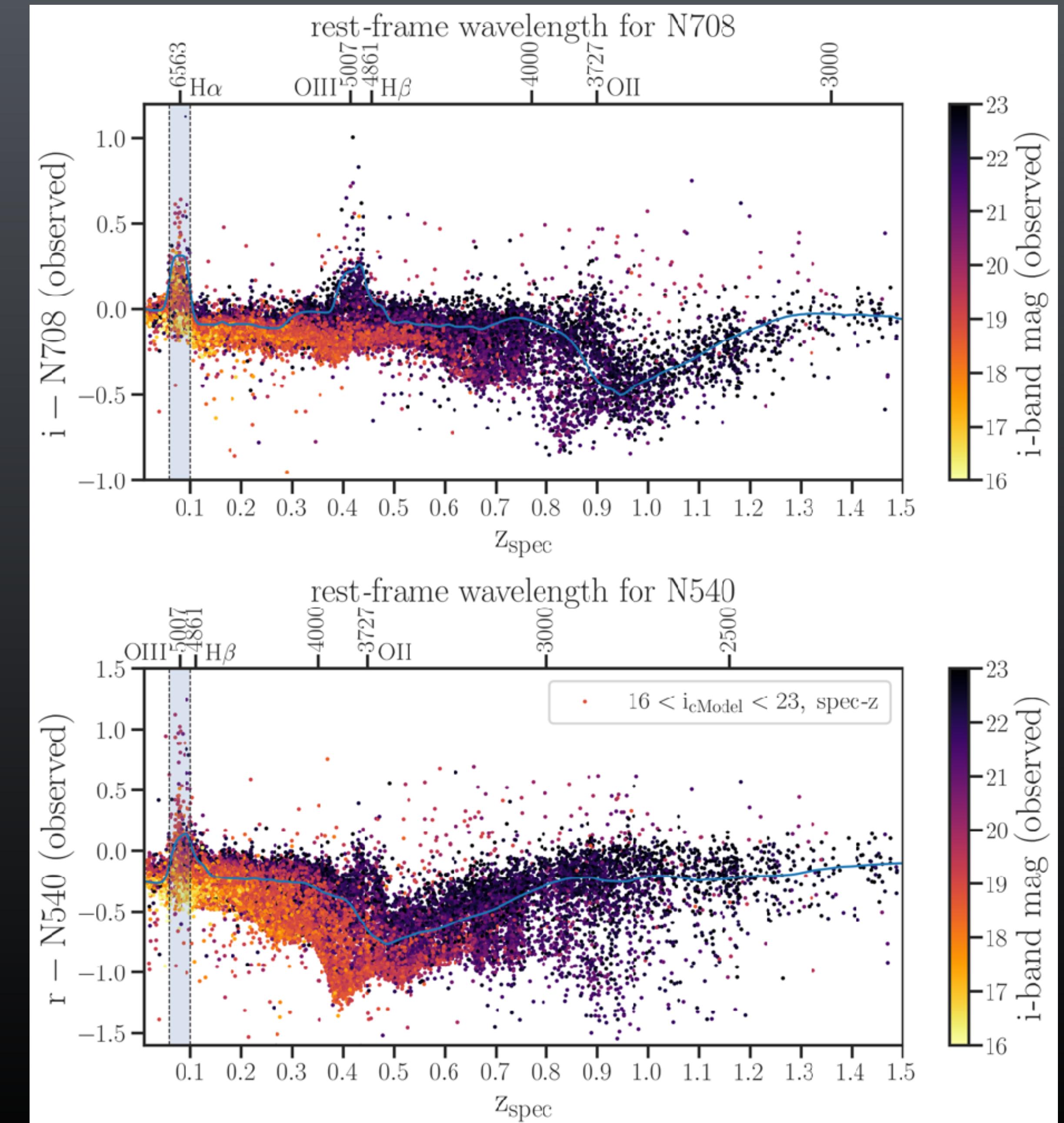
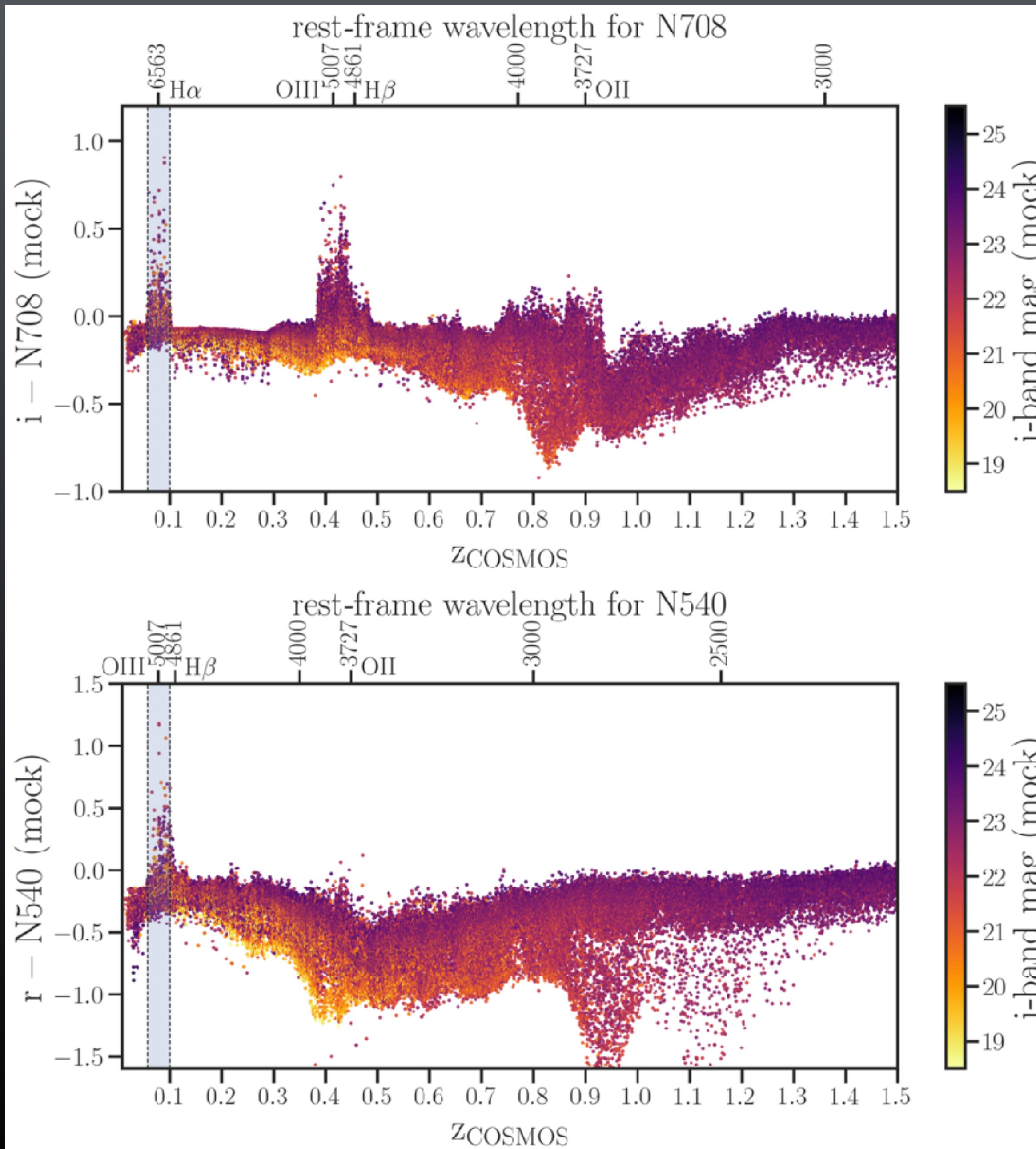


Merian images will be released on the Legacy surveys viewer

Modified LSSTpipe

- GaaP: PSF and aperture-matched photometry
- Provide better colors than traditional aperture or model fit photometry for photo-z's



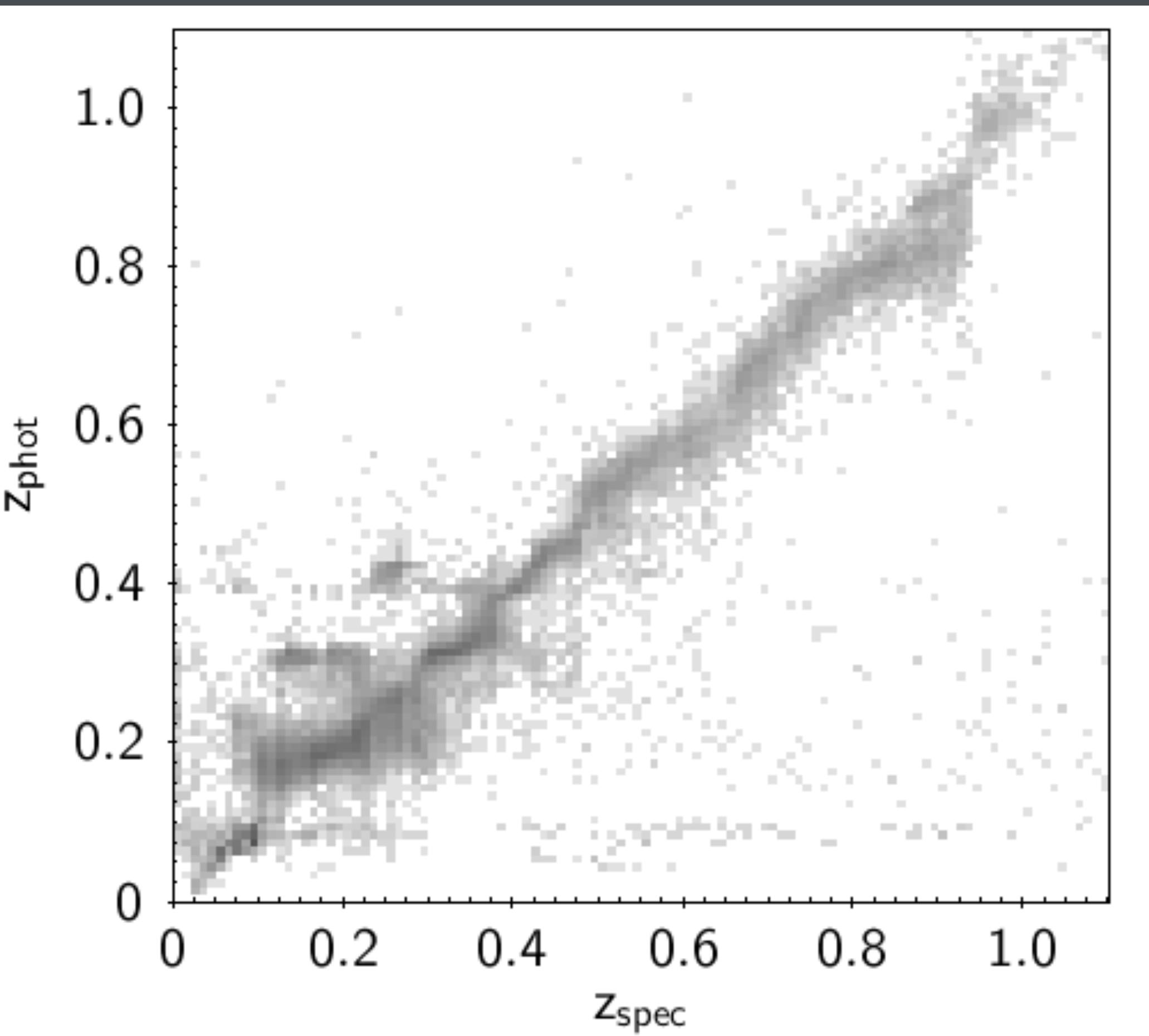
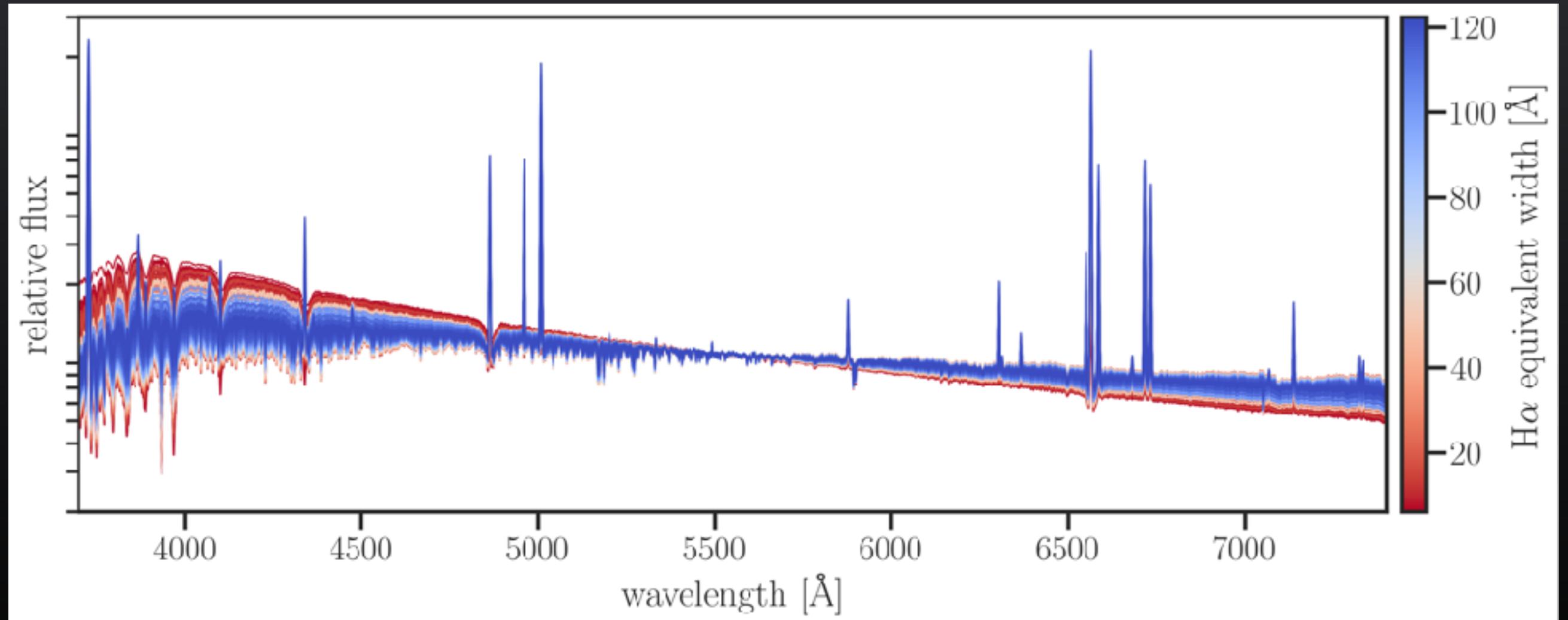


Merian spec-z calibration sample

- Collecting spec-z's with Keck/DEIMOS, Magellan/IMACS and DESI down to $i \sim 23$ mag
- >5000 spectra for Merian objects have been collected (and increasing!)
- Combining spec-z's from previous surveys (COSMOS, GAMA, SDSS, etc.)

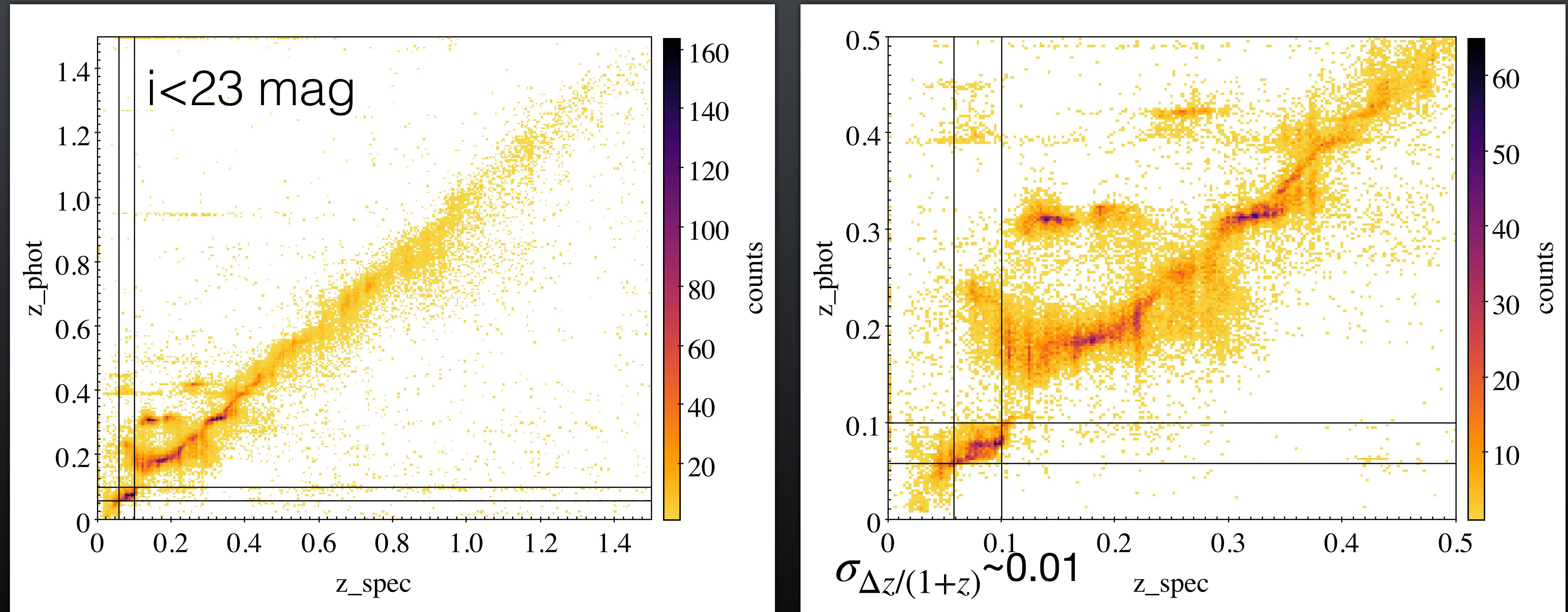
Merian photo-z

- Template fitting with EAZY photo-z
- Generate our own templates for Merian target dwarfs to improve the photo-z performance

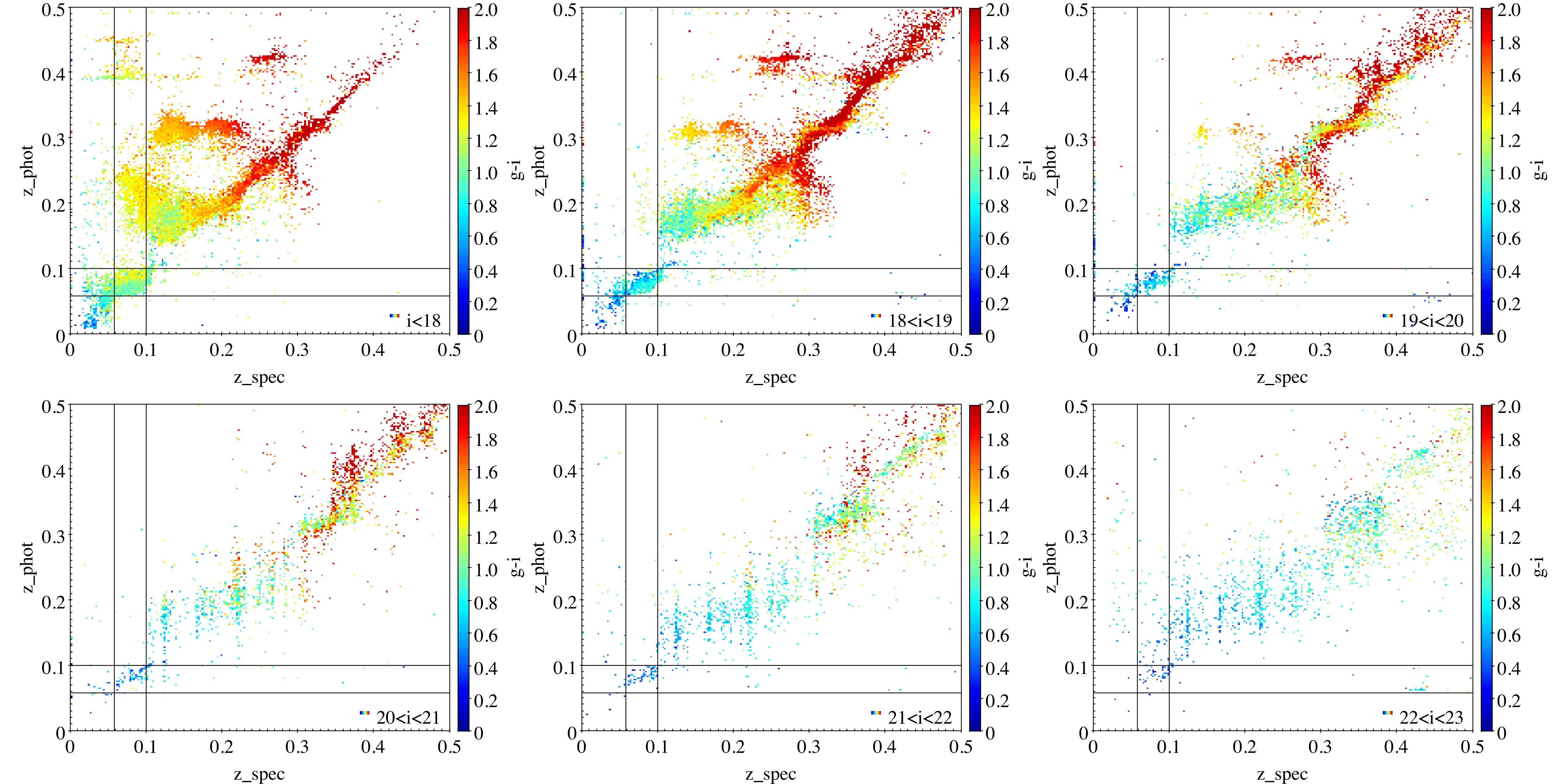


Luo et al. 2023 in prep

Merian photo-z

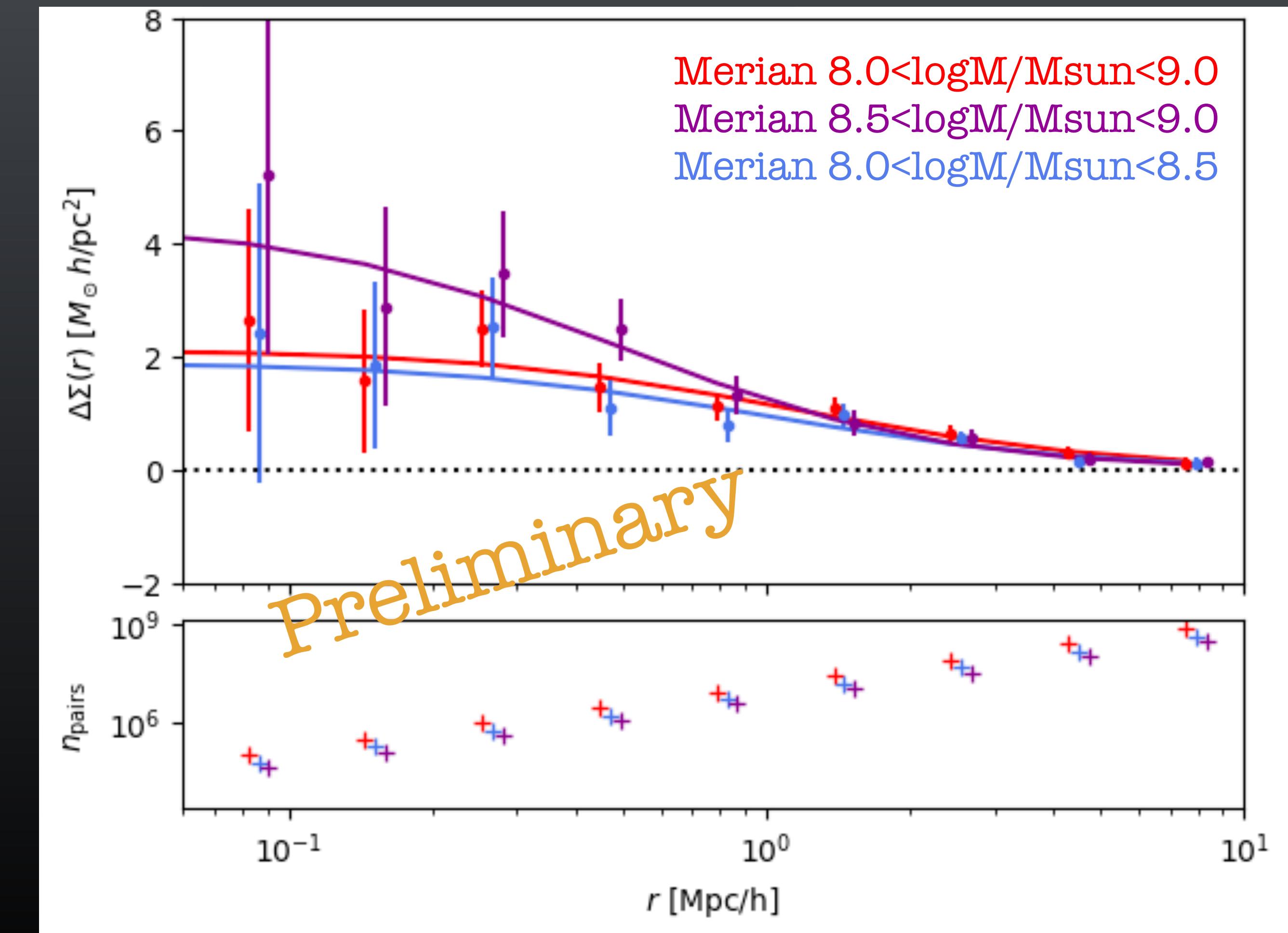


Luo et al. 2023 in prep



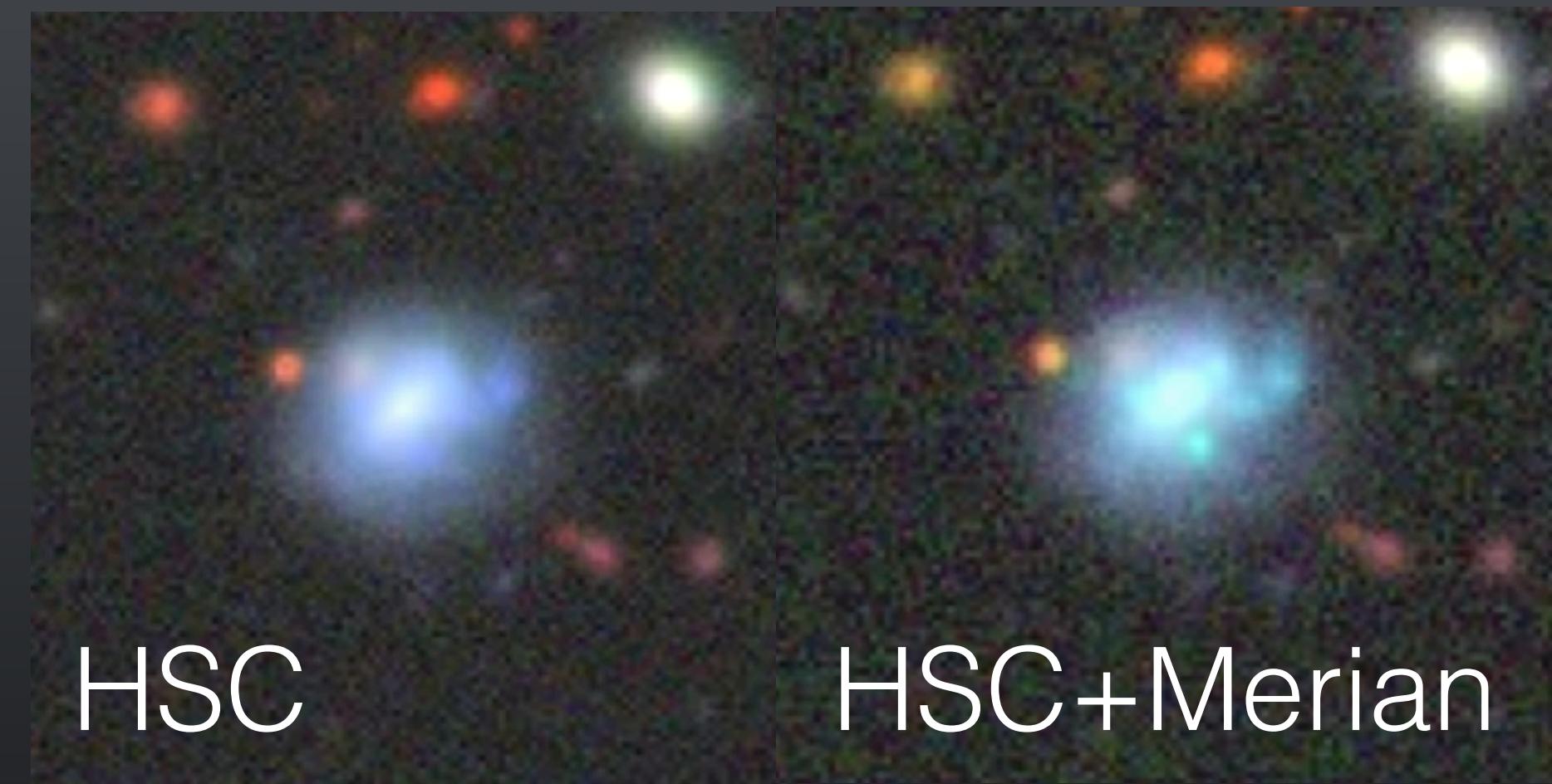
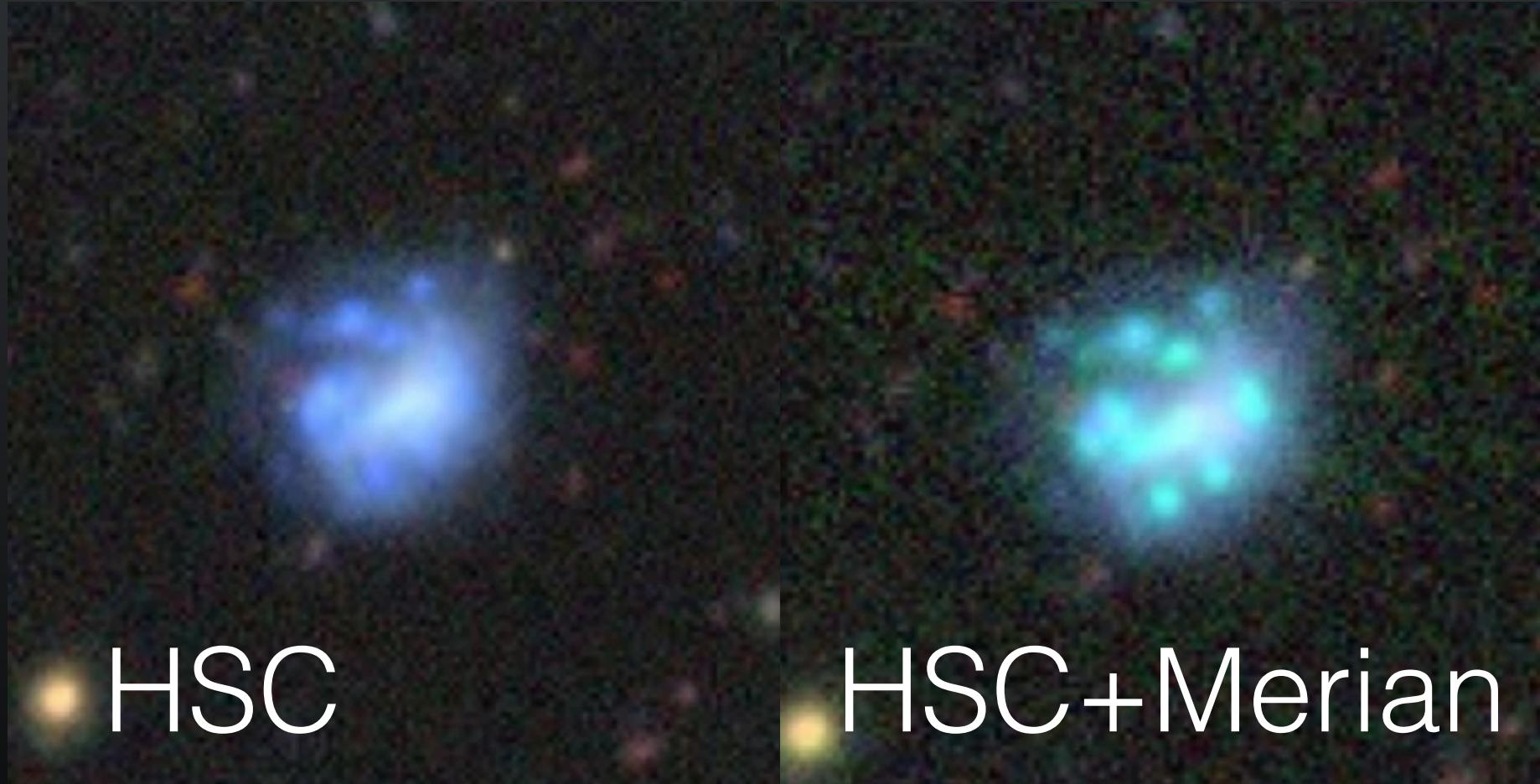
First Merian dwarf lensing measurement

- $\sim 30\%$ of the Merian final footprint
- Lensing S/N > 10

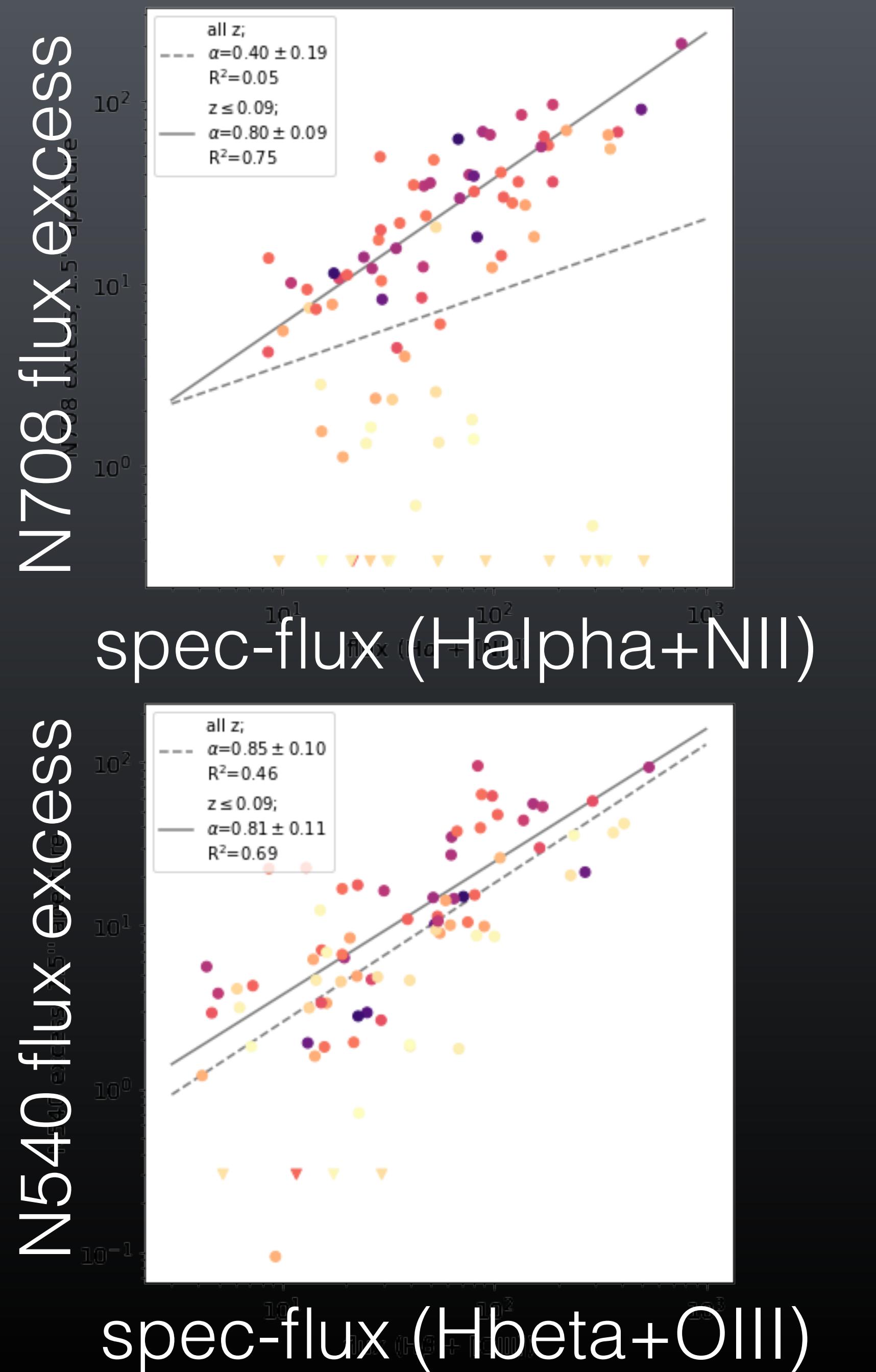
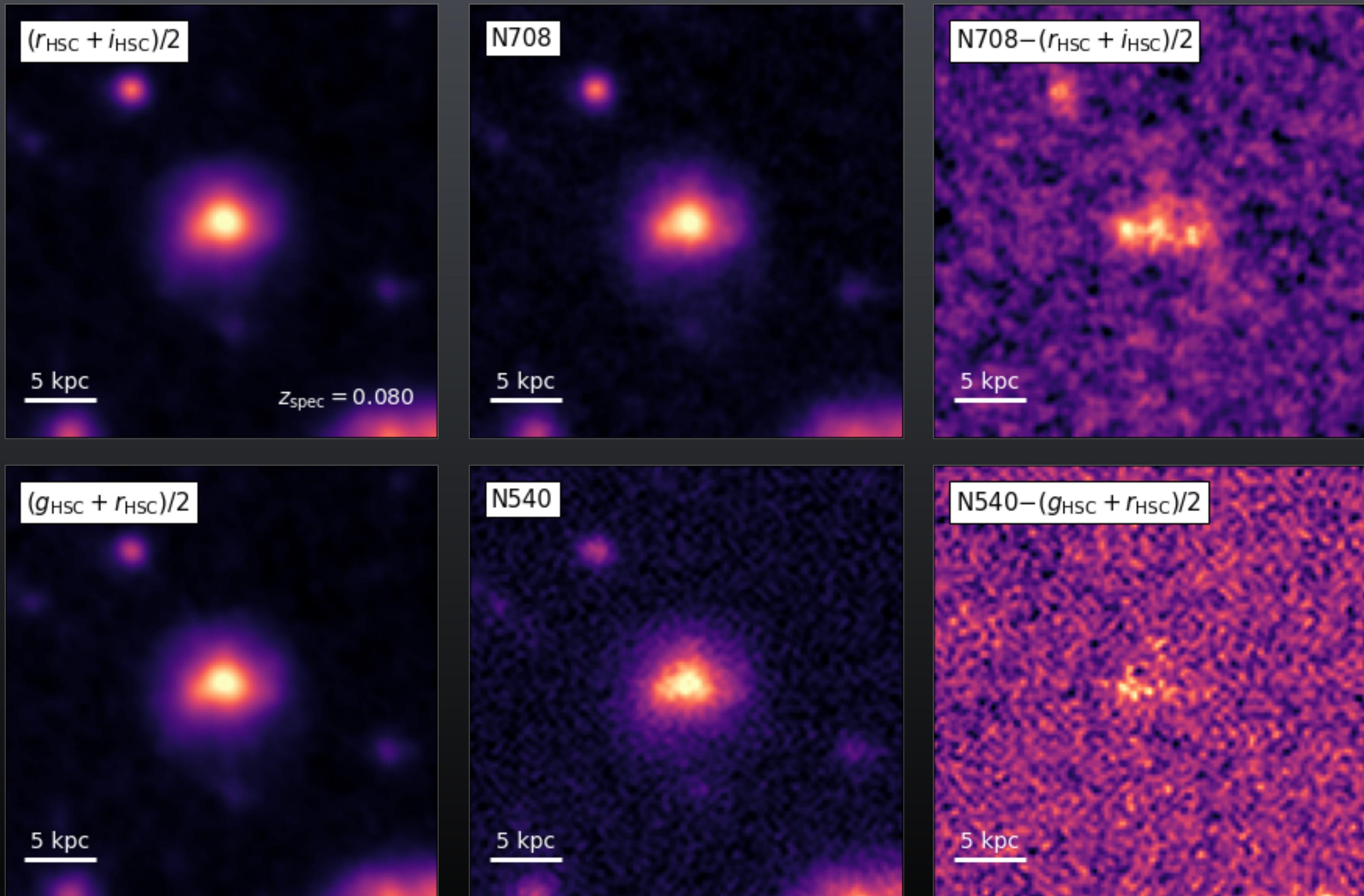


Other Merian survey science cases

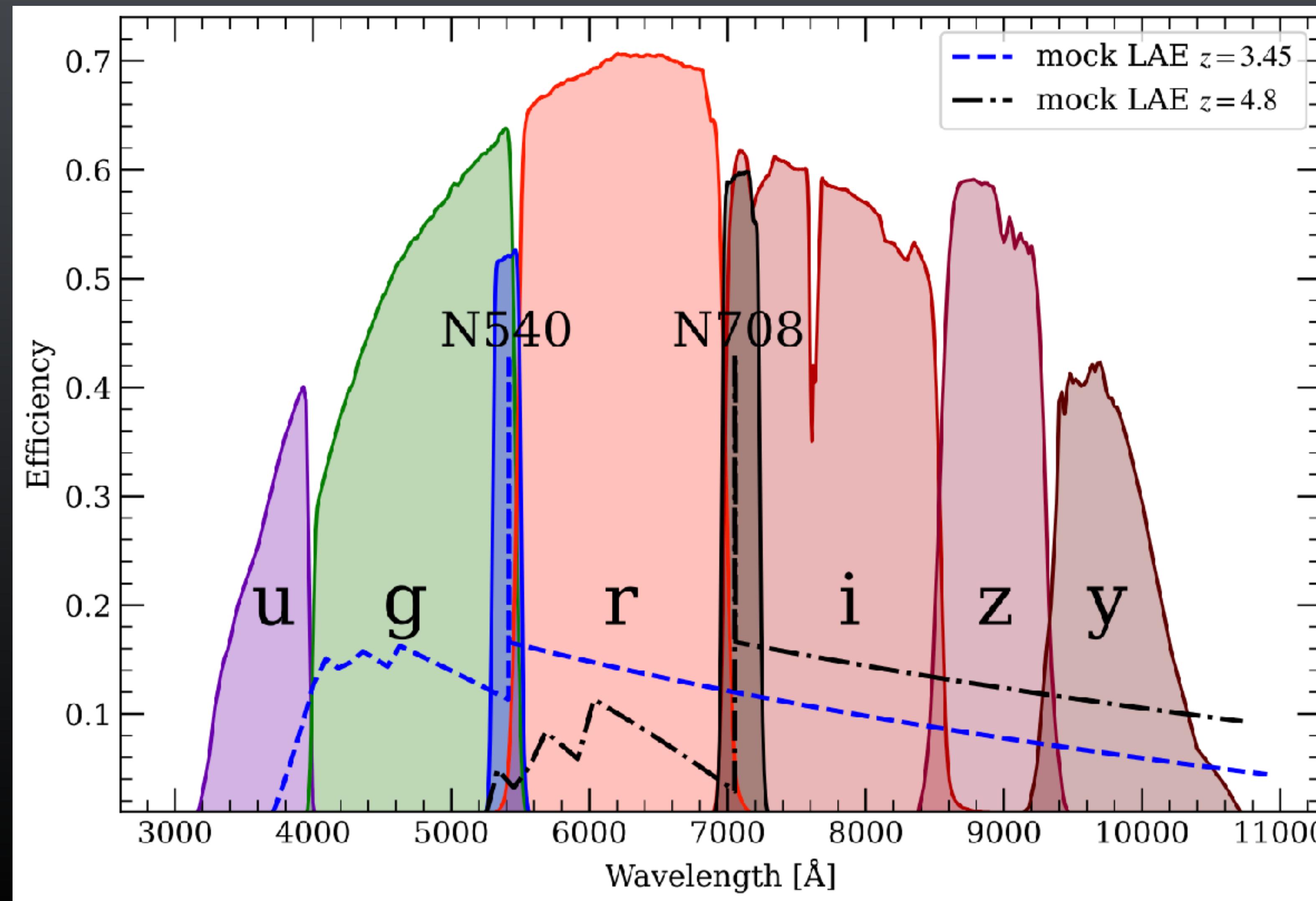
- Emission line distributions from medium-band images



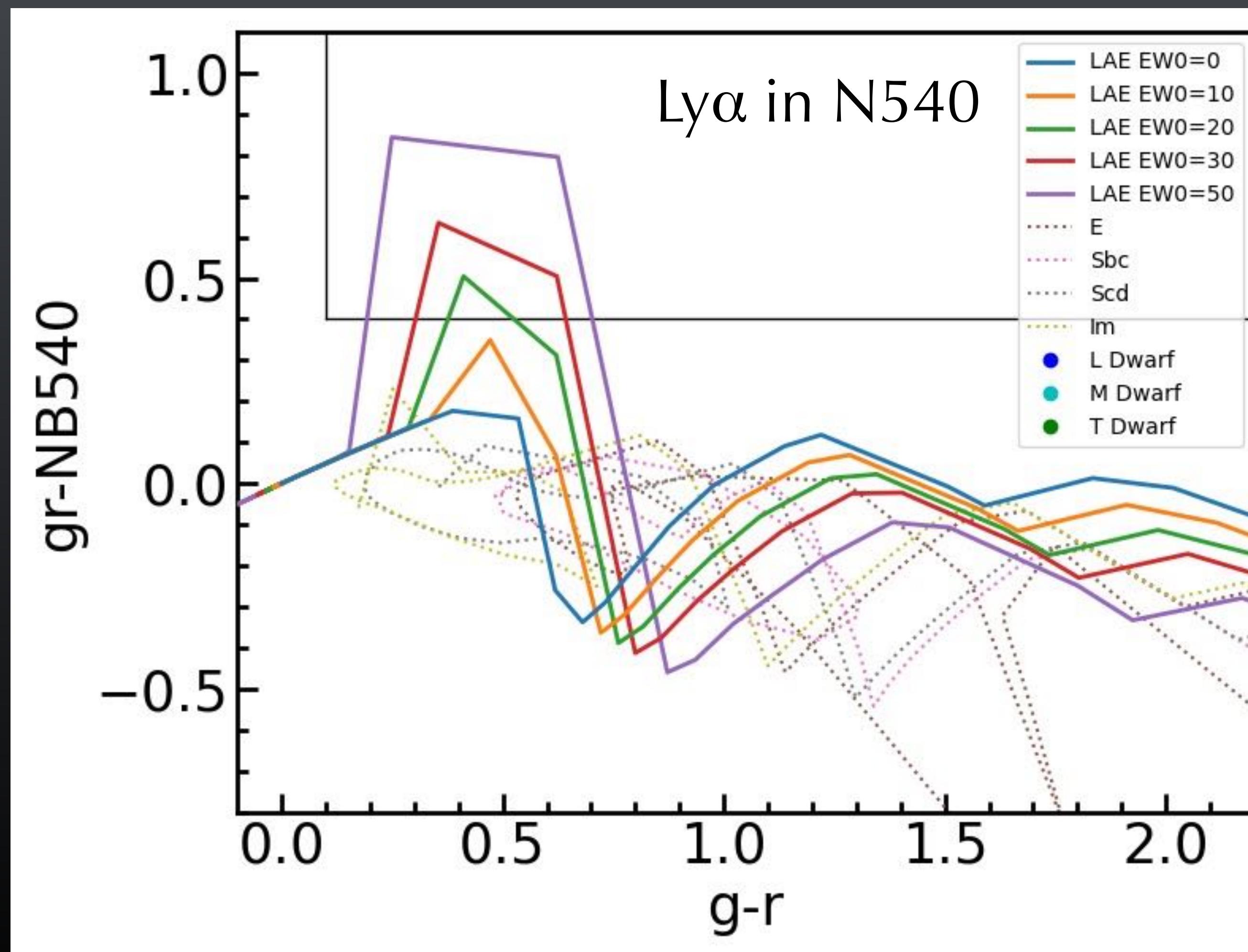
Medium-band flux excess



Ly α emitters at $z=3.4$ and $z=4.8$



Lyα emitters at z=3.4 and z=4.8



$z = 3.37 - 3.52$

LAE criteria

Medium-band color excess

$$f_{\nu}(gr) = 0.5f_{\nu}(g) + 0.5f_{\nu}(r)$$
$$gr - N540 > 0.4$$

Broad-band color

$$g - r > 0.1$$

Lyman break dropout

$$u > u_{2\sigma}$$

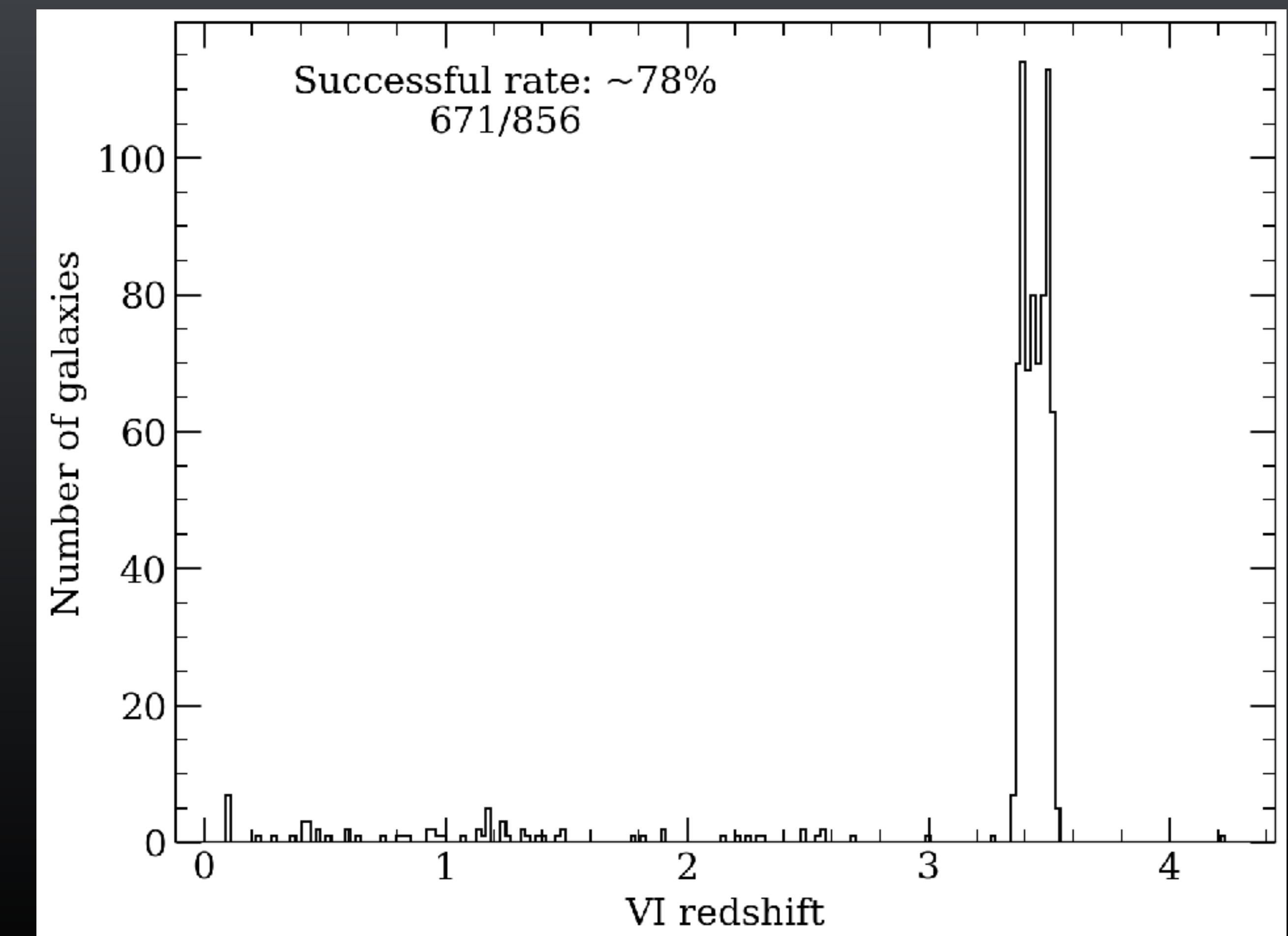
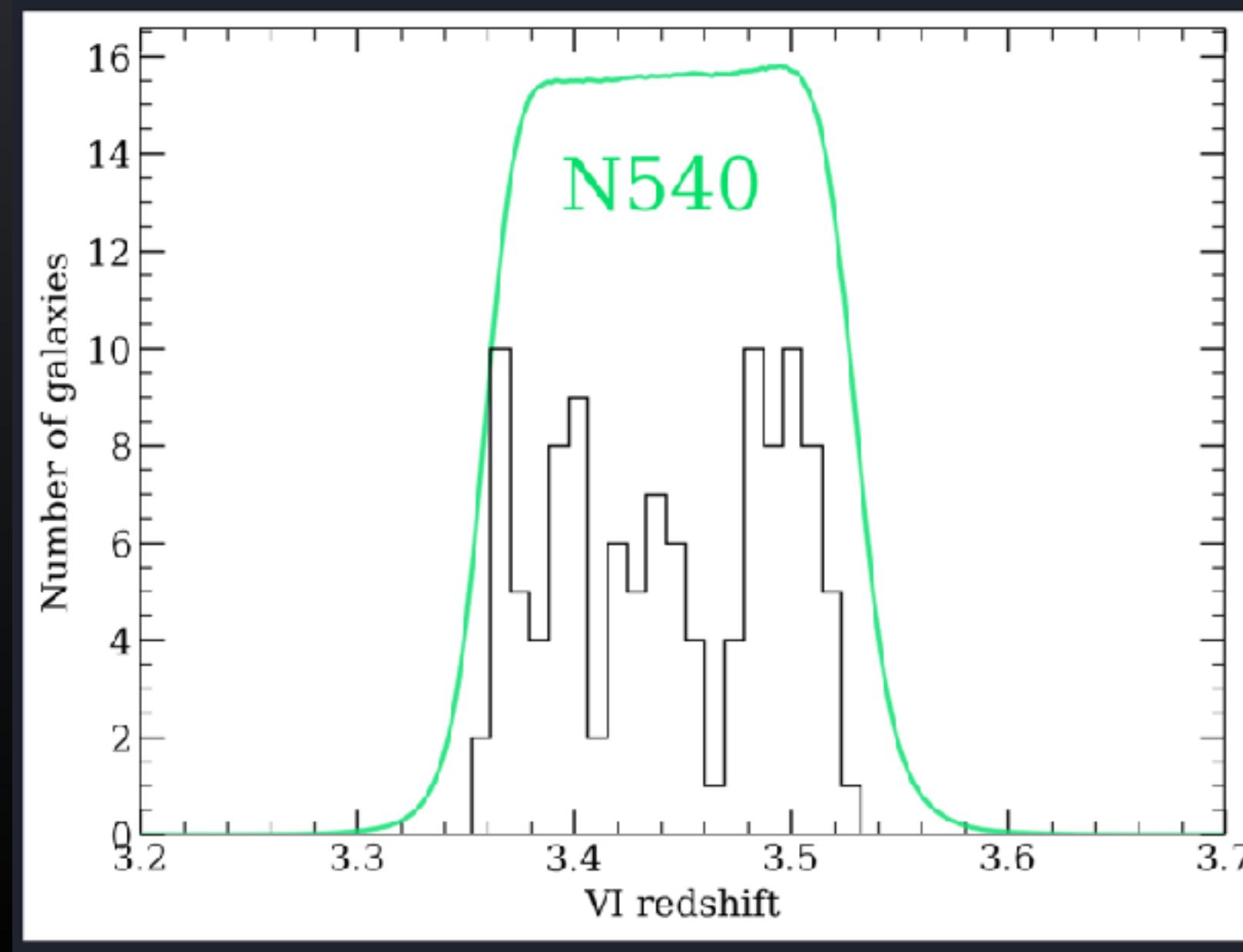
Signal-to-noise

$$gr - N540 < (gr - N540)_{3\sigma}$$
$$N540 < N540_{5\sigma}$$

Credit: Zheng Cai and Mingyu Li

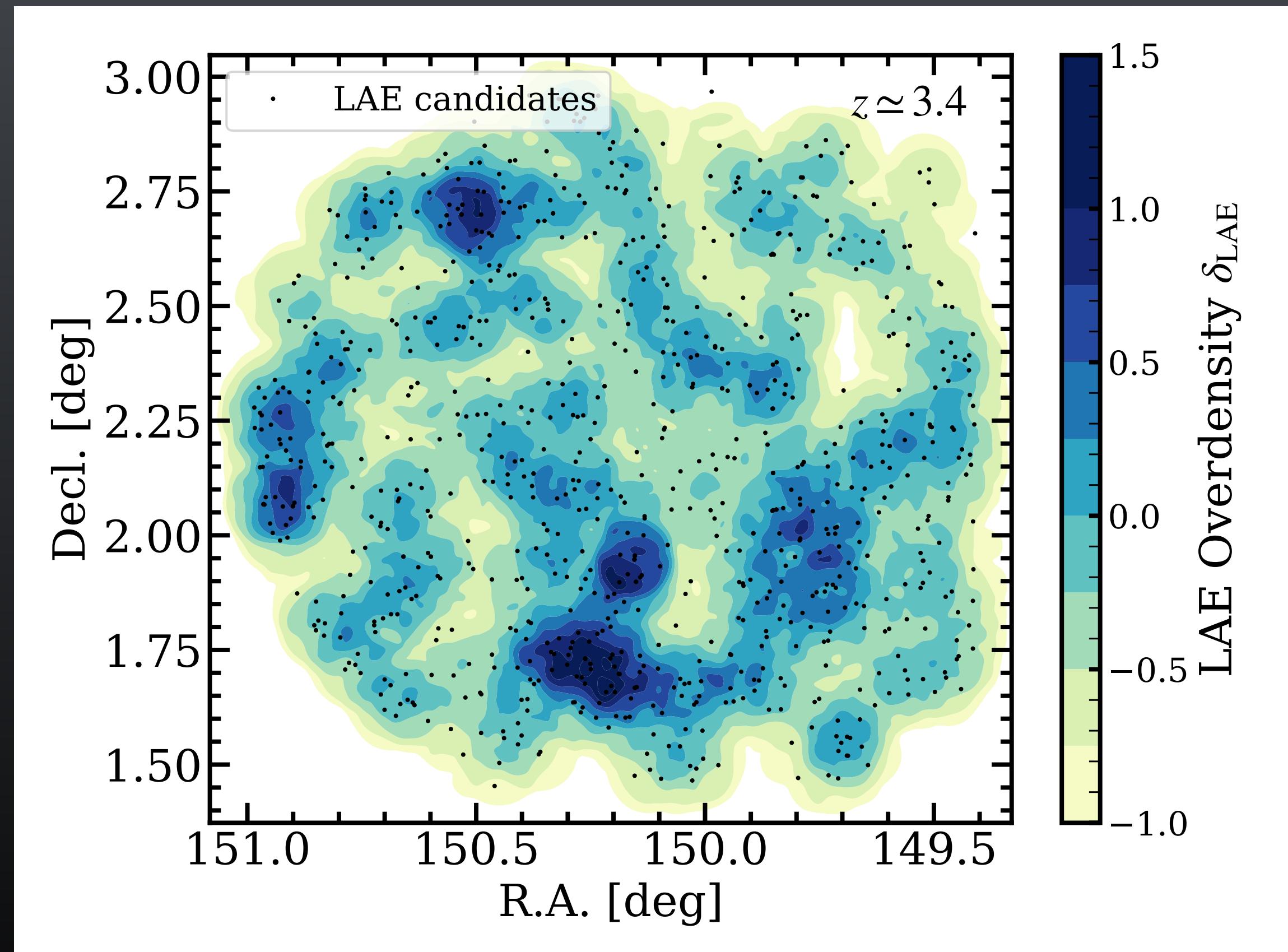
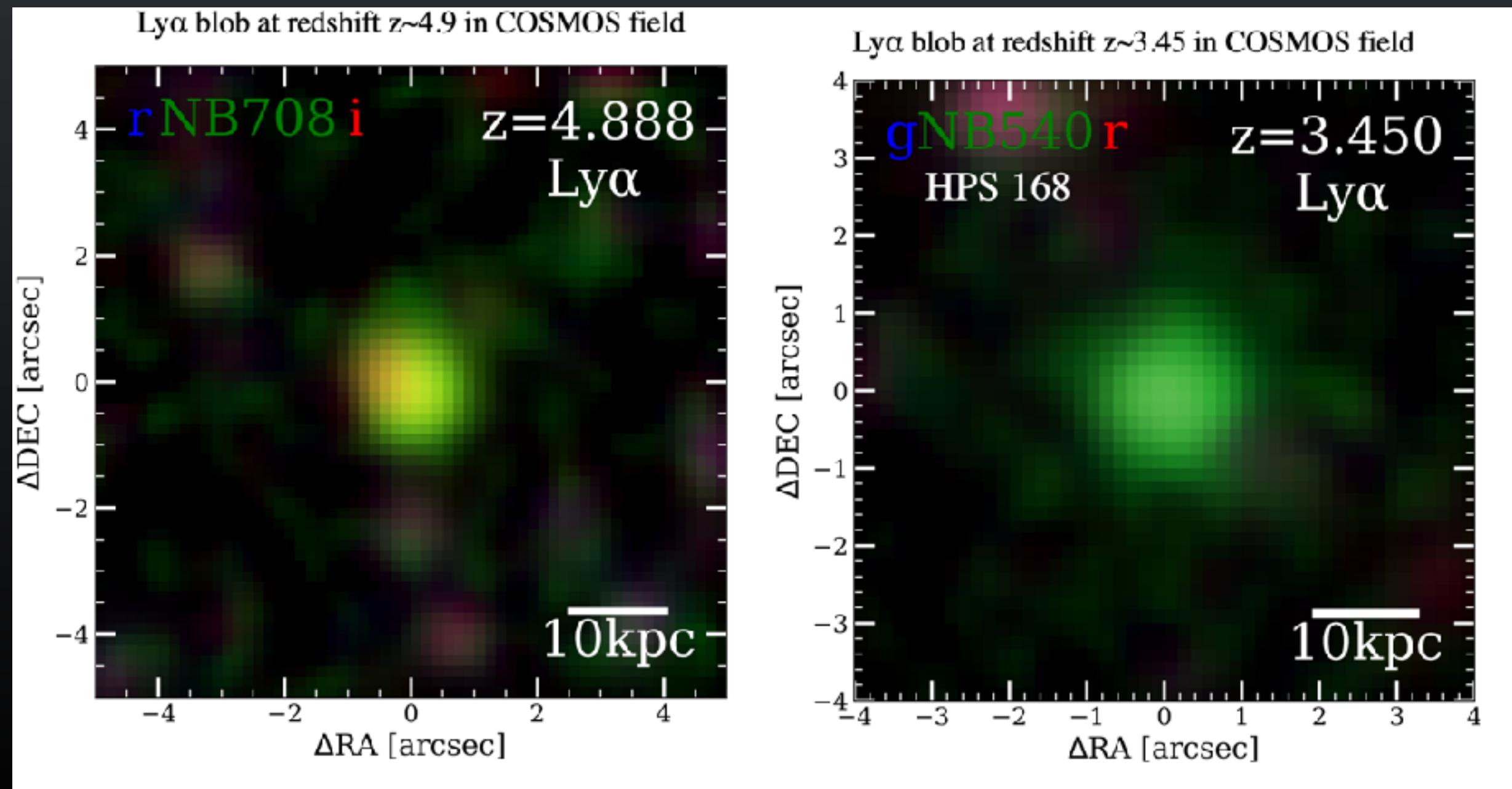
DESI follow-up on N540 Ly α emitters

- ~2.2 hour exposures on DESI
- Visual inspect the spec-z's
- Success rate >78%



Other Merian survey science cases

- Ly α emitters at higher redshifts
- Selection success rate is >70% with spec-z follow-up



Summary

- Merian survey is a new medium-band imaging survey with 64 nights on DECam to cover 800 square deg in the HSC SSP wide field
- Two new medium-band filters N708 and N540 will find $\sim 100,000$ bright dwarf galaxies ($10^8 - 10^9 M_\odot$) at $0.05 < z < 0.1$
- We detected decent weak lensing signal around dwarf galaxies within 30% of Merian total footprint.
- The unique deep and wide medium-band imaging data from Merian could also help with other science cases

