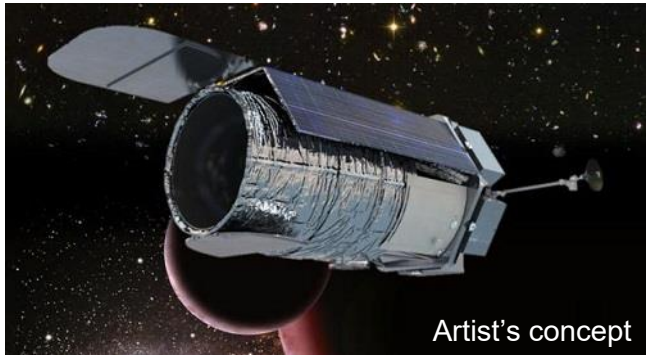
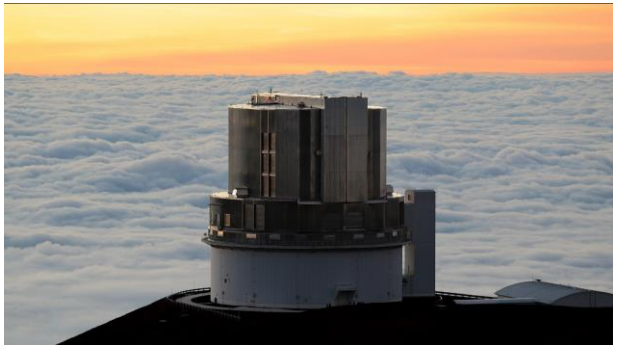


Jet Propulsion Laboratory
California Institute of Technology

Subaru/WFIRST Synergies for Cosmology and Galaxy Evolution

Dan Masters (JPL/California Institute of Technology)

Collaborators: Peter Capak, Olivier Doré, Jason Rhodes, Shoubaneh Hemmati, Daniel Stern, Judy Cohen, WFIRST Cosmology SIT (http://www.wfirst-hls-cosmology.org)



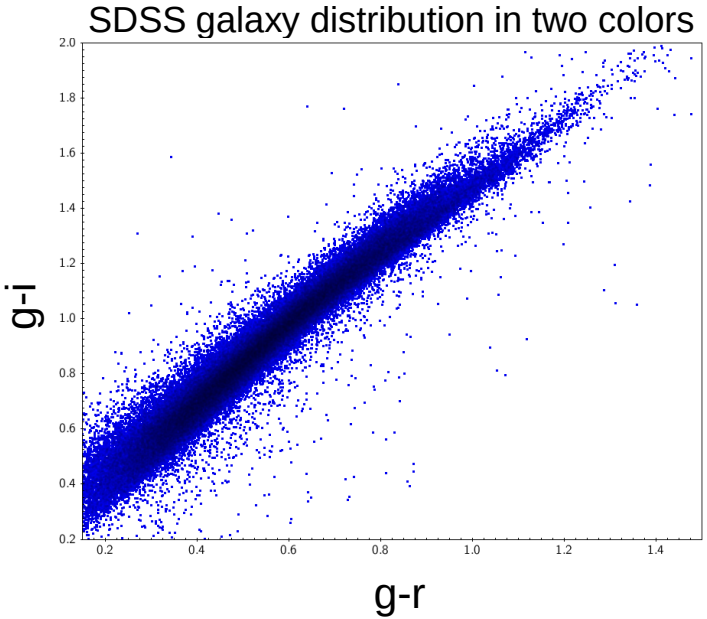
WFIRST/Subaru cosmology in the 2020s

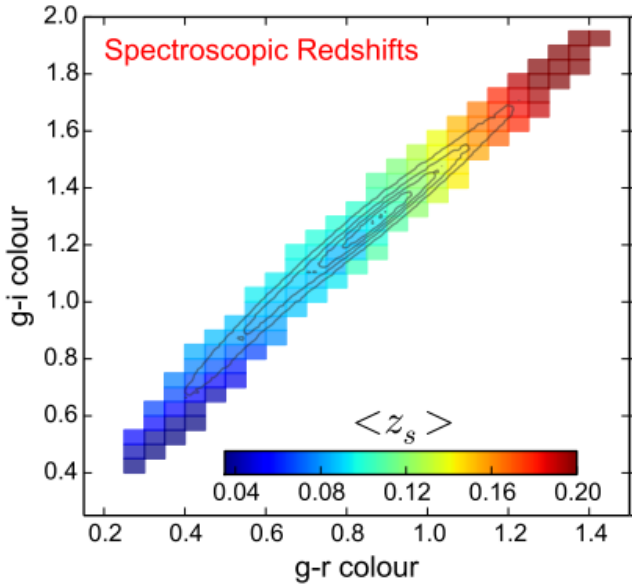
- WFIRST HLS would measure weak lensing over ~2000 deg^2
  - Accurate photo-z distributions are critical
  - NIR-selected WFIRST shear sample → many faint optical sources
- HSC/PFS could conduct observations that greatly enhance WFIRST cosmology
  - PFS spectroscopy to calibrate WFIRST photo-zs
  - HSC complementary imaging observations
- In turn WFIRST would enhance cosmology with Subaru

WFIRST photometric redshift calibration

- Different approaches possible
- Need to know *N*(z) distribution of ~10-20 tomographic bins to high accuracy (~0.2%)
- Combination of cluster-z (e.g. Newman 2008, Menard et al. 2013) + “direct” calibration (e.g. Masters et al. 2015) of P(z|C) relation likely
- Independent methods important to validate calibration

The empirical P(z|C) relation





Rahman et al. 2015

Photo-z's are fundamentally a mapping of galaxy colors to redshift
Color distribution of galaxies to a given depth is *limited* and *measurable*

The Self-Organizing Map

- The problem of mapping a high-dimensional dataset arises in many fields, and a number of techniques have been developed
- We adopt the widely-used Self-Organizing Map (SOM), or Kohonen Map

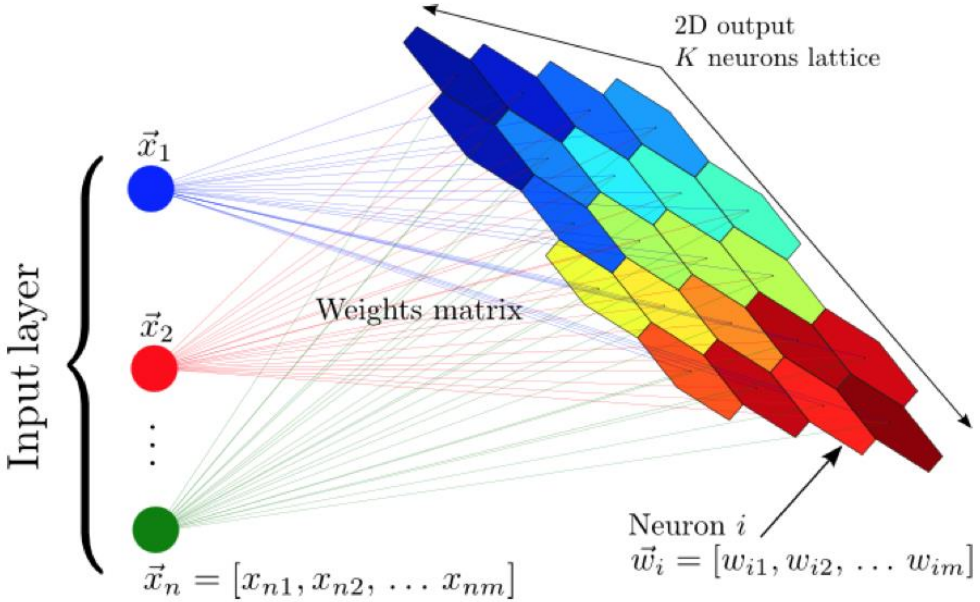
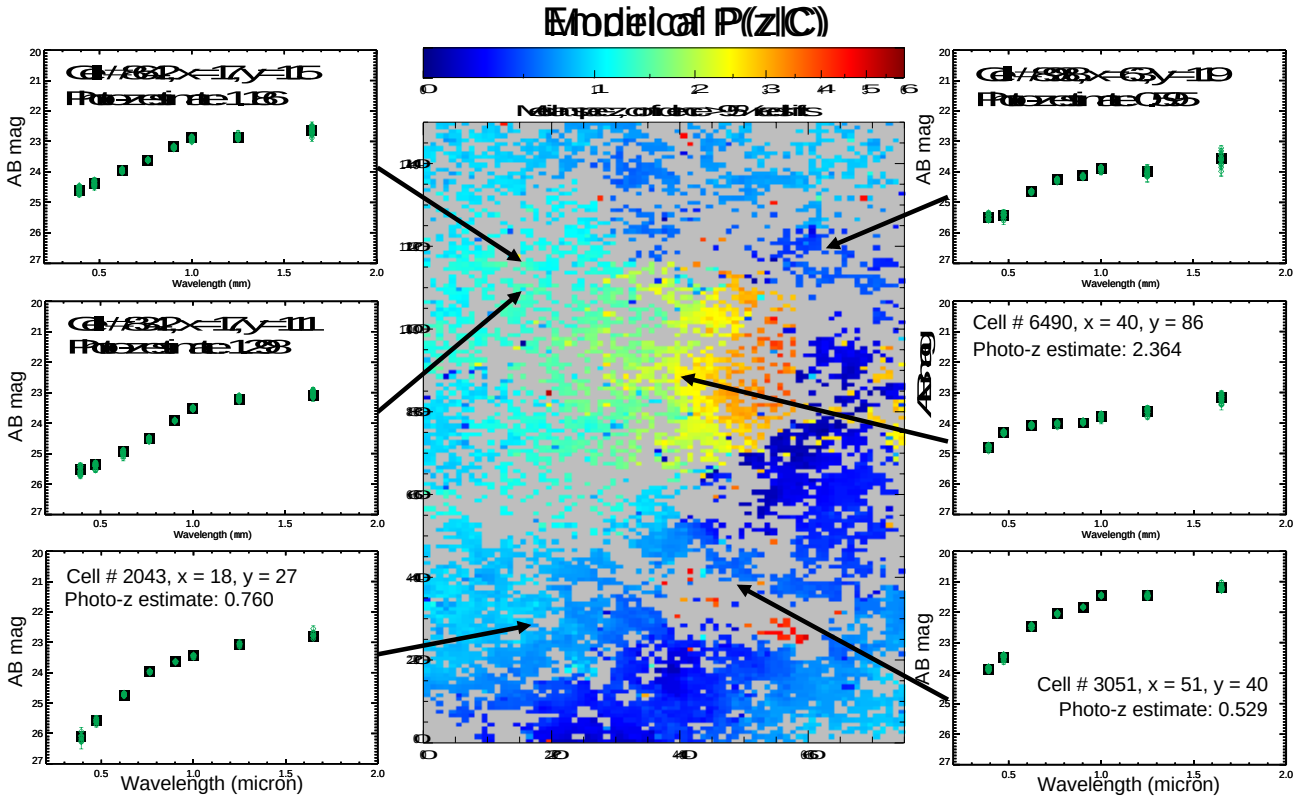


Illustration of the SOM (From Carrasco Kind & Brunner 2014)

Self-organized map of galaxy colors



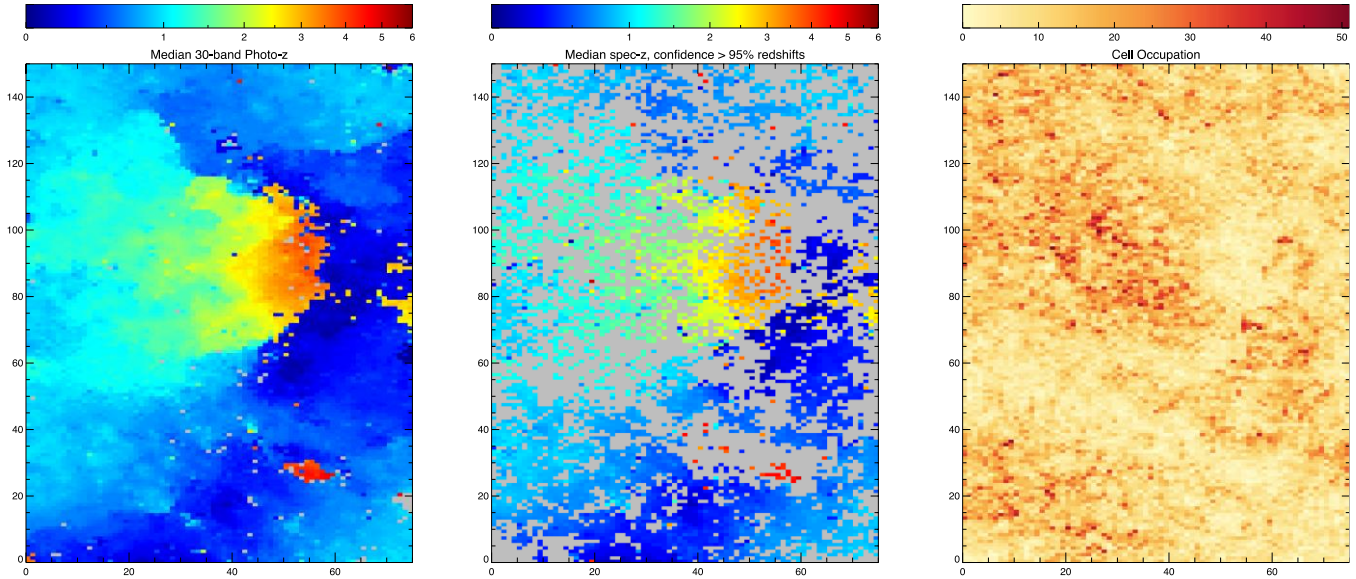
Masters et al. 2015, ApJ, 813, 53

C3R2: Mapping the galaxy P(z|C) relation

Complete Calibration of the Color-Redshift Relation (C3R2) Survey:

- Designed to “fill the gaps” in our knowledge of the color-redshift relation to Euclid depth
- Collaboration of Caltech (PI J. Cohen, 16 nights), NASA (PI D. Stern, 10 nights, PI D. Masters, 10 nights (2018A/2018B)), the University of Hawaii (PI D. Sanders, 6 nights), and the University of California (PI B. Mobasher, 2.5 nights), European participation with VLT (PI F. Castander)
  - Multiplexed spectroscopy with a combination of Keck DEIMOS, LRIS, and MOSFIRE and VLT FORS2/KMOS targeting VVDS, SXDS, COSMOS, and EGS
  - DR1 published (Masters, Stern, Capak et al. 2017) with 1283 redshifts, DR2 (in prep) will bring total to >4000 redshifts, observations in 2017B and later will comprise DR3
  - New Hawaii program (H20) led by Dave Sanders will also contribute
- Currently a total of 44.5 Keck nights awarded (29.5 observed in 2016A-2017A, 5 nights each in 2017B/2018A/2018B)

C3R2 survey strategy



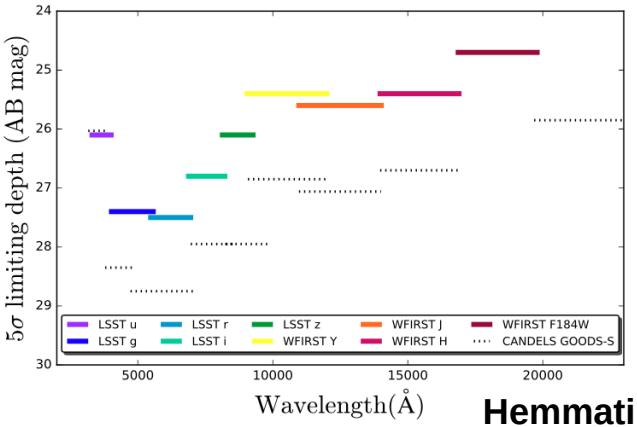
The ingredients of the survey:

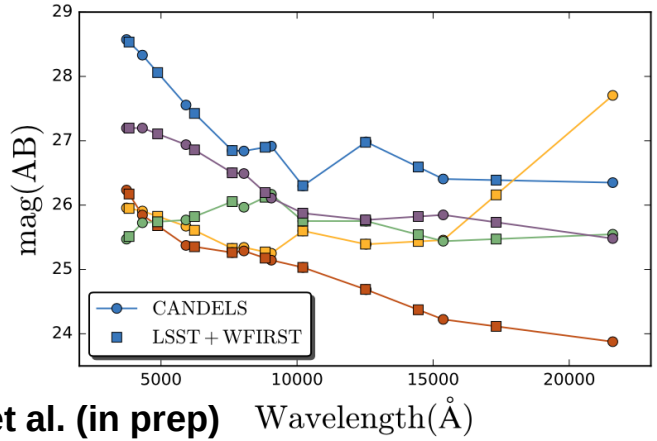
Left: Prior on galaxy properties across color space from deep, multiband data
Center: Shows parts of color space that have redshifts and that don't
Right: Density of sources across color space to Euclid depth

C3R2: The challenge of WFIRST

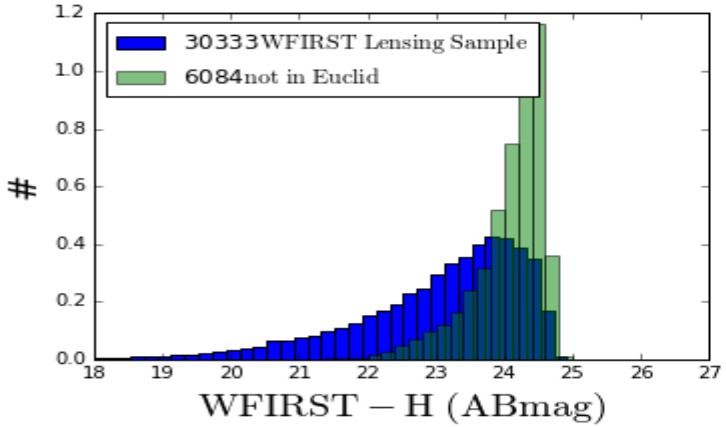
- C3R2 designed to map galaxy color space to *i*~25
  - Euclid depth, also well-matched to HSC survey
- WFIRST shear sample would be significantly deeper
- Need an analog to anticipated WFIRST photometric sample – CANDELS is only current dataset that can match the depth in optical-NIR
- It is small (~0.2 deg^2) and heterogeneous
  - Impacted by cosmic variance, shot noise
- Best current option

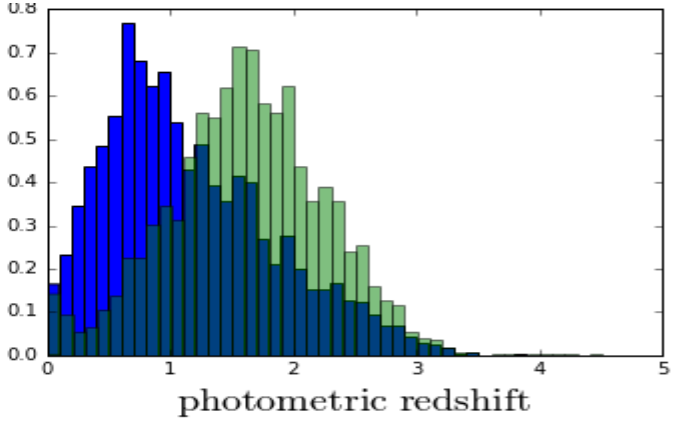
CANDELS interpolated to LSST+WFIRST



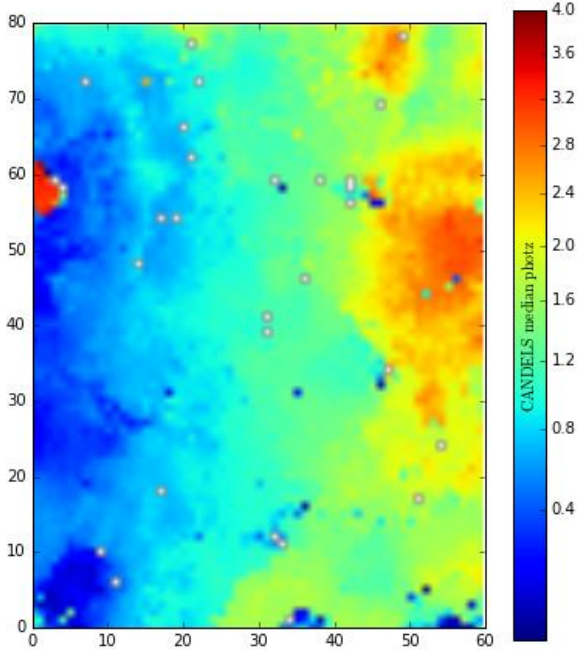


Hemmati et al. (in prep)

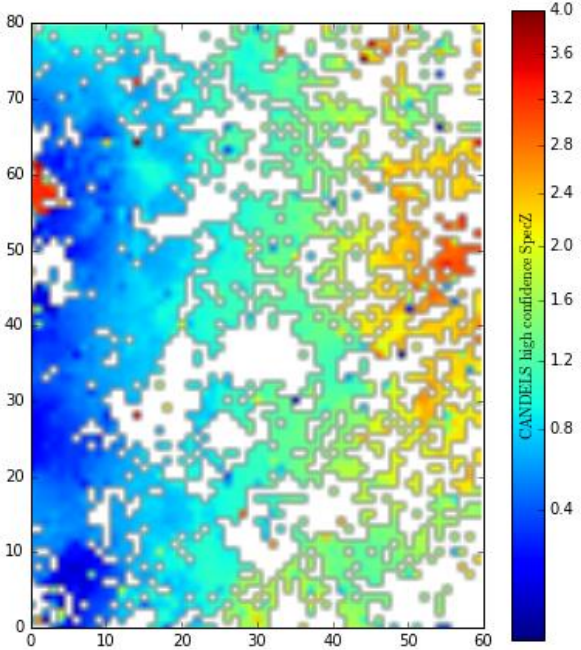




Redshifts on WFIRST-analog SOM



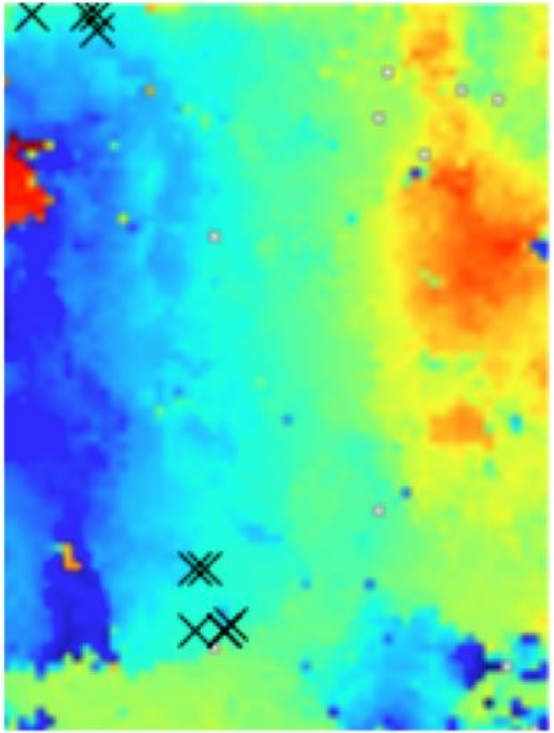
CANDELS median photo-z

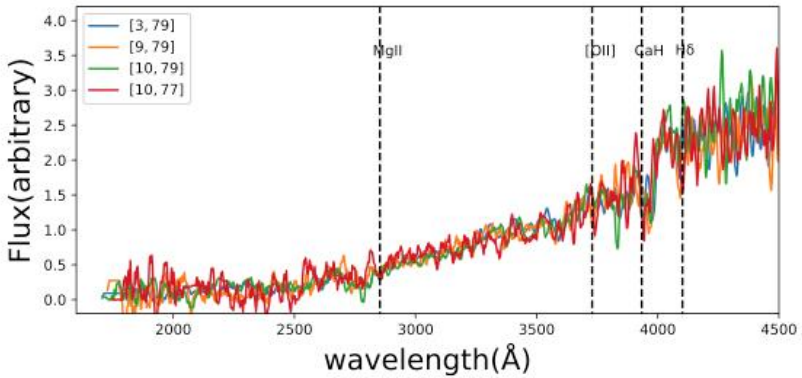


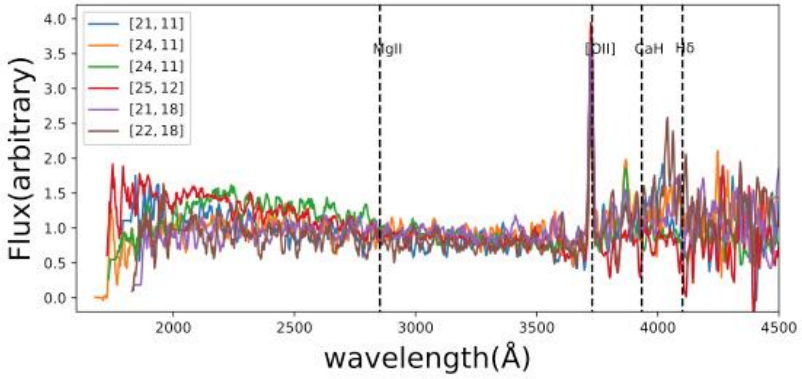
CANDELS median spec-z

Hemmati et al. (in prep)

Position on SOM predicts spectral properties

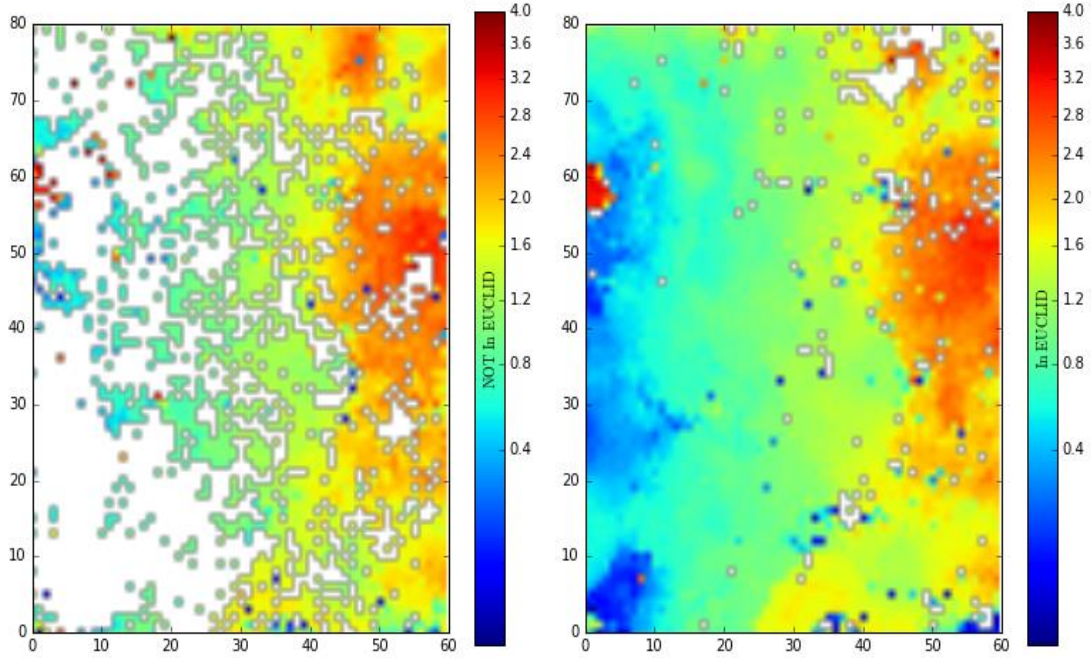






Hemmati et al. (in prep)

WFIRST “faint” vs. “bright” sample



Left: Distribution of WFIRST **faint** (i > 25) sample on SOM; fills ~50%
Right: Distribution of WFIRST **bright** (i < 25) sample; most cells filled

Key issues for WFIRST photo-z calibration

- Do faint galaxies that share colors with brighter galaxies have the same redshift?
  - i.e., is there are meaningful luminosity prior when using ~7 colors spanning optical-NIR
  - How to demonstrate the answer short of lots of spectroscopy of very faint sources?
- How to calibrate the WFIRST-faint sample that has no bright counterparts?

Targeted spectroscopy with PFS

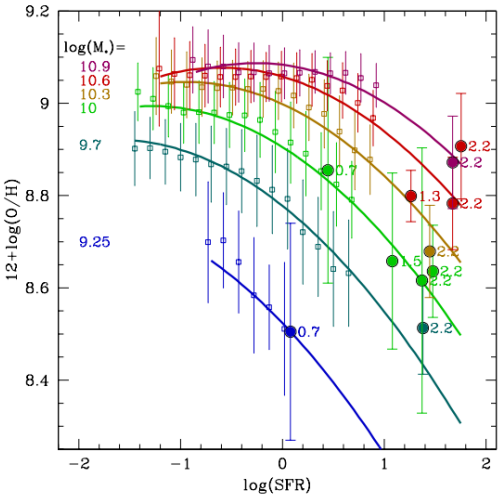
- PFS has significant potential to contribute to photo-z calibration for WFIRST
- Two notional uses are:
  1. Targeted samples calibrating P(z|C) relation to faint magnitudes directly, like C3R2 (difficult)
  2. Observe a bright sample selected to facilitate cluster-z
- The latter option may be appropriate for the faintest WFIRST sources

Flexible observations with HSC

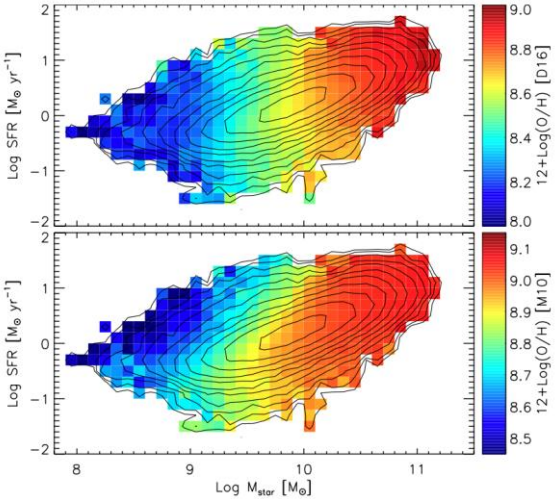
- Intermediate band surveys with HSC may be able to improve WFIRST photo-zs substantially
  - Stronger constraints on emission lines, weak spectral breaks
- Could design ideal deep field complementary to WFIRST
- Time to refine strategy as we learn more

Galaxy science with Subaru/WFIRST

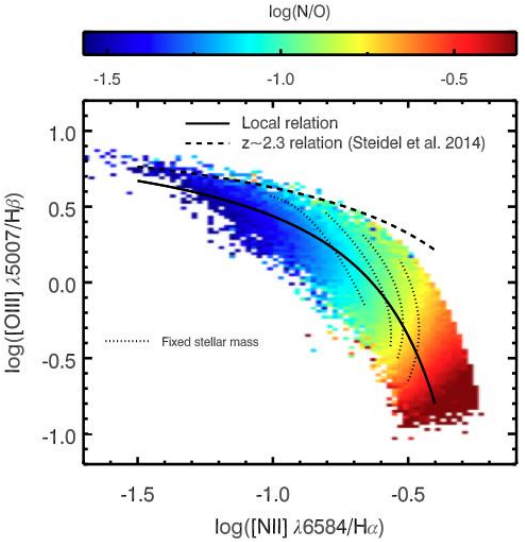
- Statistical power!
- Surveys like SDSS reveal relationships (FMR, dust-mass relation, N/O-mass relation, star-forming main sequence) that become apparent only with large samples with high-quality rest-optical spectra
- This level of study at intermediate-to-high redshift not currently possible



Mannucci et al. 2010



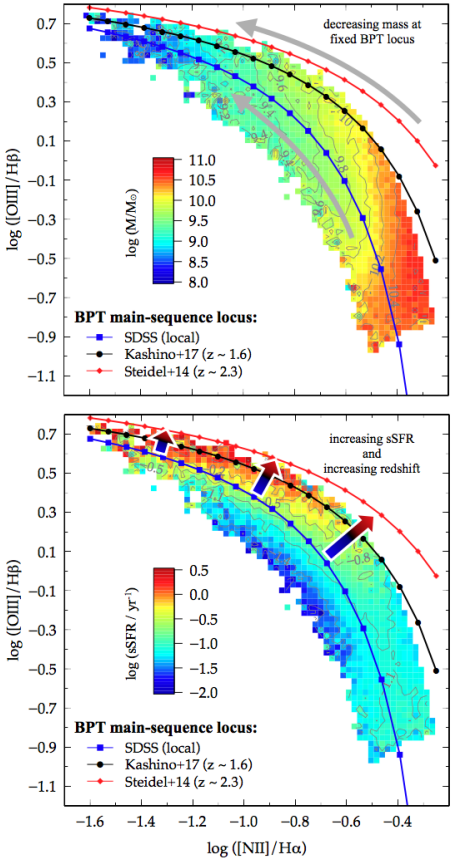
Kashino et al. 2016



Masters et al. 2016

Emission line science with PFS+WFIRST grism

- Possible to get full suite of optical emission lines to z~2, or up to [OIII]5007 to z~3
- Incredible statistical power
  - JWST will focus on very high redshift
  - Limited total numbers
- Could build Sloan-like sample at z~0.5-3 with stellar masses, rest-optical spectra, etc. for many thousands of galaxies



Faisst, Masters, Wang et al. 2017 (submitted)