WFIRST Overview

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Summary

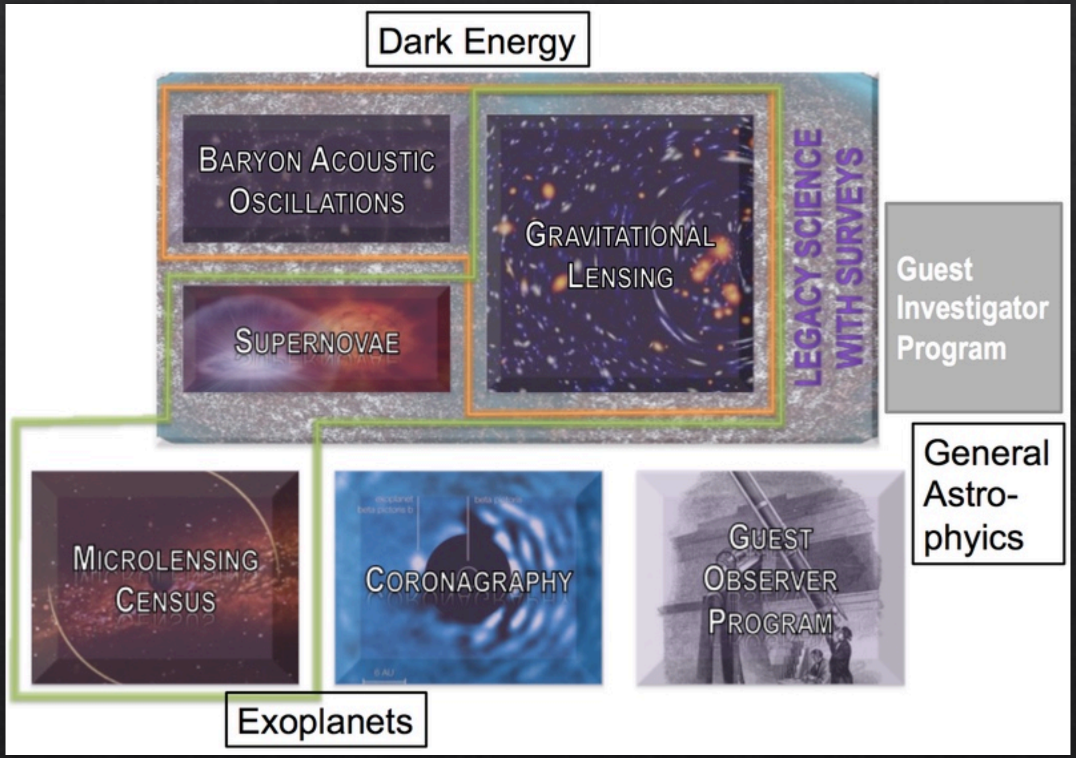
- WFIRST is moving along quickly
- Everything I show you here is subject to change
- Will be finalized around 2020

The Mission

- Wide Field Infrared Survey Telescope (WFIRST)
- Top Priority of US 2010 Decadal Review
- Donated 2.5m reconnaissance telescope
- Currently undergoing design and risk retirement
  - Budget capped at $3.4 billion
  - Several science teams selected to participate in design
  - Undergoing independent review
- Final construction estimated to start in ~2020
  - Some parts already designed/tested
  - New science teams selected then
- Estimated launch 2025

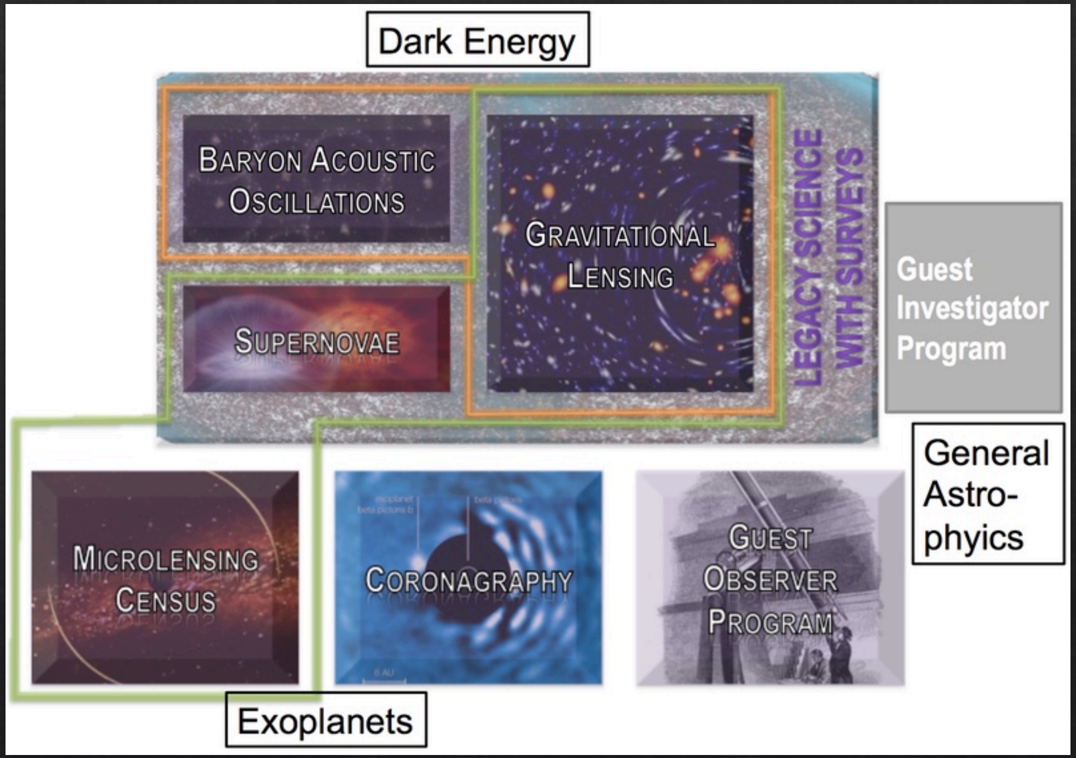
The Mission

- Nominal 6 year mission life
- All data public immediately
- 2 years for weak lensing and BAO cosmology
  - 2,200 sq deg imaging and spectroscopy survey
- 0.6 years for SNe cosmology
  - Deep imaging and IFC follow-up
- 1 year for planet microlensing
  - Continuous imaging of MW bulge for 72 day periods
- 1 year for planet imaging
  - Survey of planet host stars
- 1.4 years for general observer science



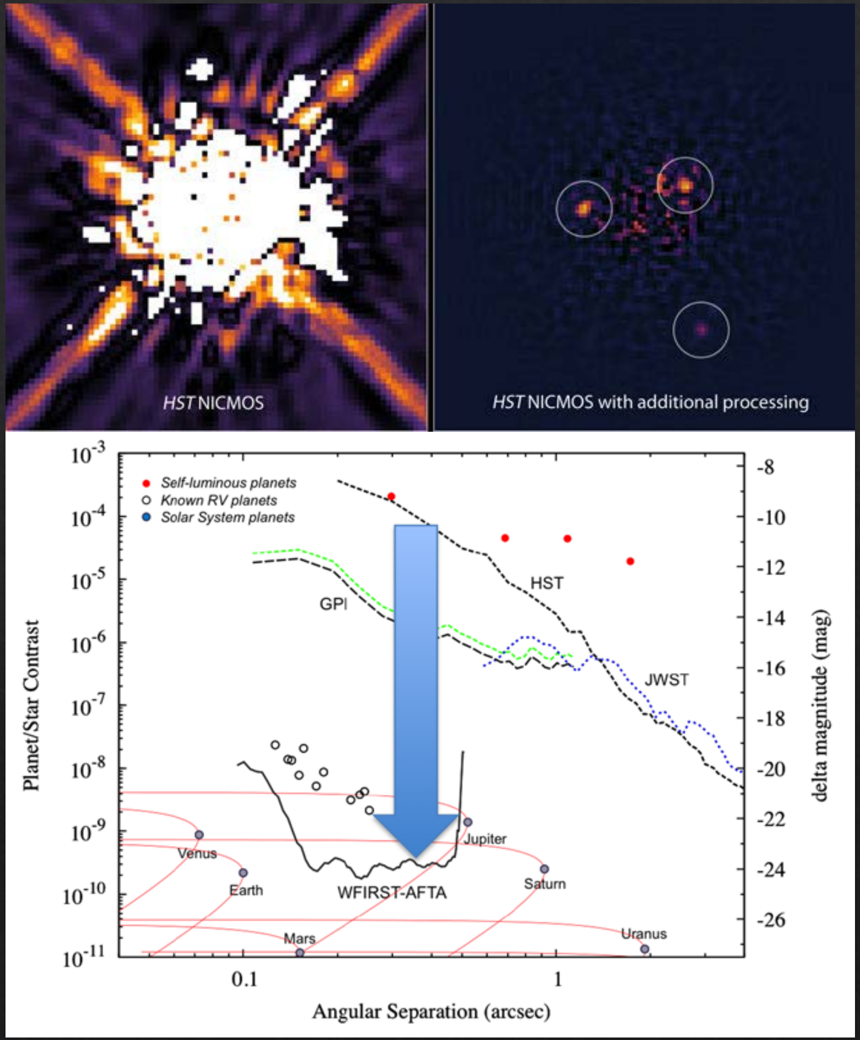
The Science

- Combination of several proposed missions
- Exoplanet Imaging
  - Two coronagraphs
    - Spectrograph and Imager
- Exoplanet Microlensing
  - Wide filed infrared imaging
- Cosmology
  - Wilde filed imaging and spectroscopy
  - Integral Field Channel (Unit) for SNe
- General observatory for surveys



The Instruments

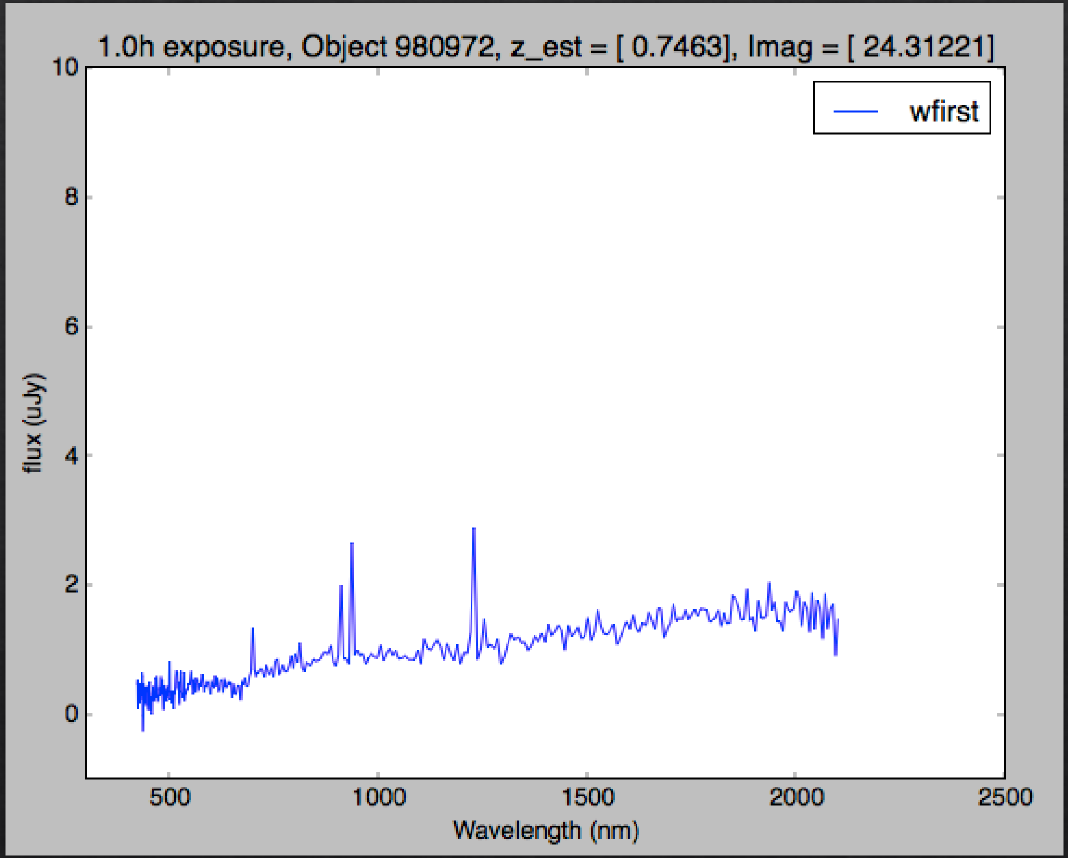
- Coronagraph
- Currently two units with different technology
- ~2.5” FOV
- 10^{-9} contrast ratio
- 0.4-1μm R~70 IFU spectroscopy
- 5 imaging filters, g,r,i,z,y
- Possible star shade addition
- Primarily for imaging planets
  - Can be used for extragalactic targets



The Instruments

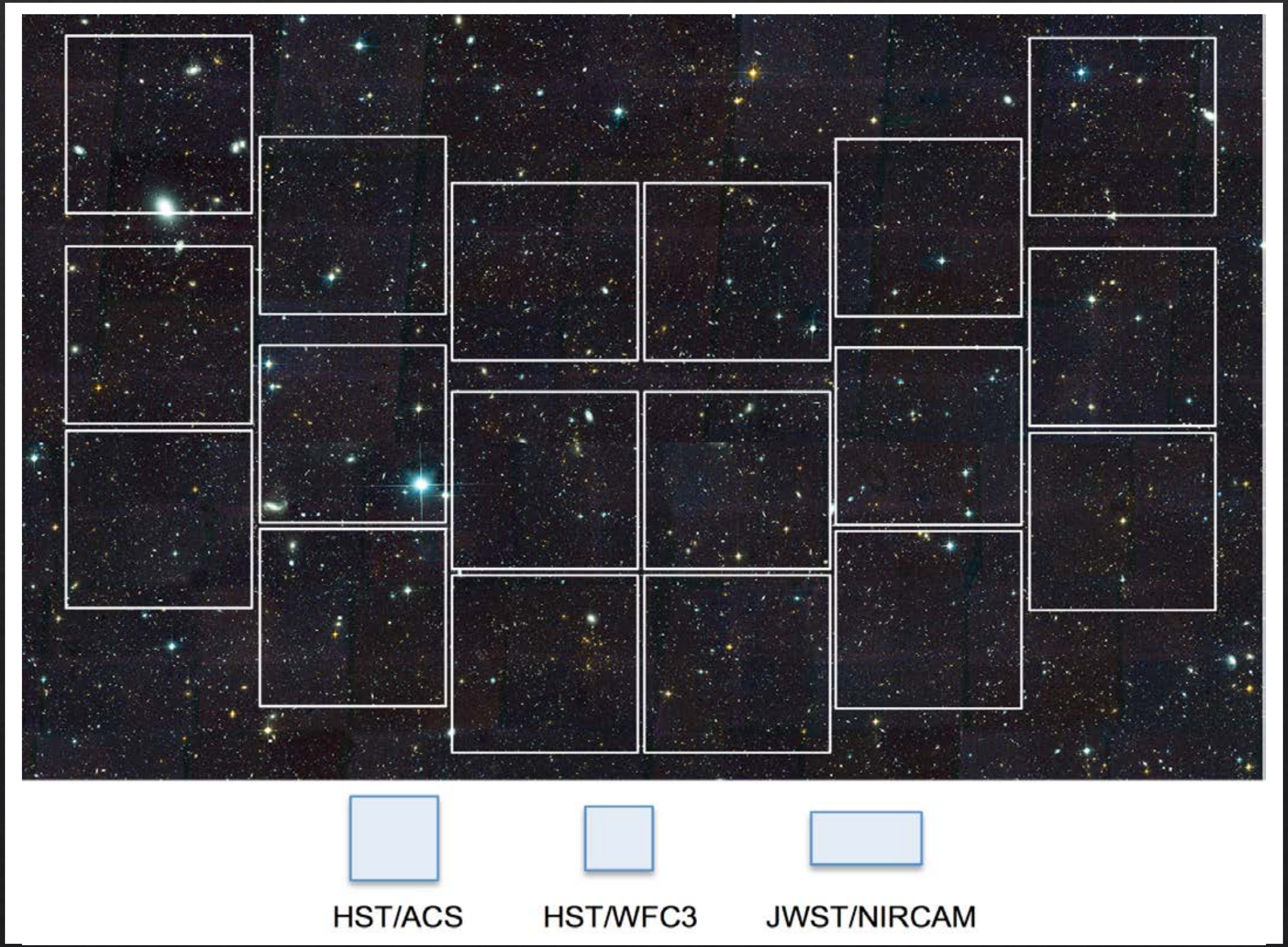
- Integral Field Channel (IFC)
- Two redundant spectrographs
- 3x3” FOV
- 0.4-2µm R~100
- Primarily for SNe follow-up
- Also for Photo-z calibration
  - Used in parallel to main imaging survey

Simulated I=24.3 galaxy spectra taken in parallel



The Instruments

- Wide Field Channel (WFC)
- 0.28 degree FOV
- 0.6-2.5μm sensitive detectors
- Up to 10 filter slots
- R~500 Grism Spectroscopy for BAO
- Primary goals are:
  - Weak lensing cosmology
  - BAO with Ha and OIII spectroscopy
  - Exoplanet statistics with microlensing



The Instruments

Baselined WFIRST Filters

New Filter Name	Wavelength (µm)*	Current/Other Names Used
R062	0.48 - 0.76	V filter, R filter, Blue Filter, Orange Filter
Z087	0.76 - 0.98	Z band, Z087
Y106	0.93 - 1.19	Y band, Y106
J129	1.13 - 1.45	J band, J129
H158	1.38 - 1.77	H band, H158
F184	1.68 - 2.00	F184
W146	0.93 - 2.00**	W149
G150* **	~1.0 - 2.0	Grism
Dark	———————	Dark

Other Options

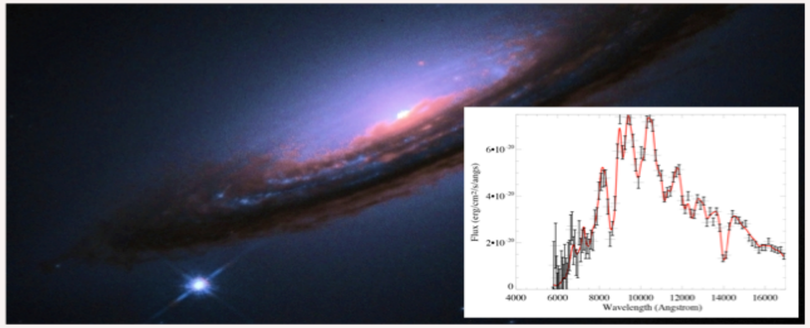
New Filter Name	Wavelength (µm)*	Current/Other Names Used
K208	1.95 - 2.20	Red filter, K band, K short
G165* **	1.35 - 1.95	Red Grism
G113* **	0.90 - 1.35	Blue Grism

Supernova Survey

wide, medium, & deep imaging
+
IFU spectroscopy

2700 type Ia supernovae
z = 0.1–1.7

standard candle distances
$z < 1$ to 0.20% and $z > 1$ to 0.34%



High Latitude Survey

spectroscopic: galaxy redshifts

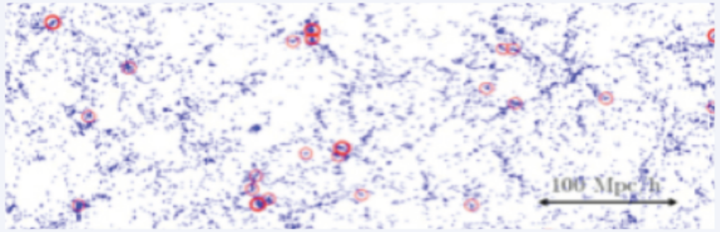
16 million Hα galaxies, $z = 1$–2
1.4 million [OIII] galaxies, $z = 2$–3

imaging: weak lensing shapes

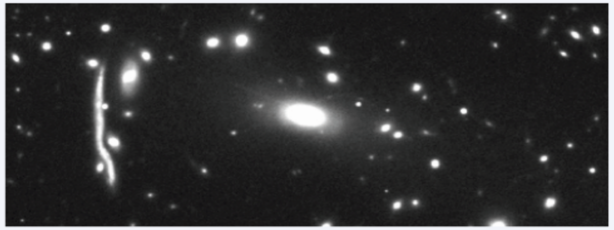
380 million lensed galaxies
40,000 massive clusters

standard ruler

distances	**expansion rate**
$z = 1$–2 to 0.5%	$z = 1$–2 to 0.9%
$z = 2$–3 to 1.3%	$z = 2$–3 to 2.1%

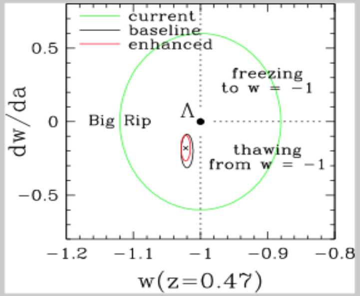


dark matter clustering
$z < 1$ to 0.21% (WL); 0.24% (CL)
$z > 1$ to 0.78% (WL); 0.88% (CL)
1.1% (RSD)



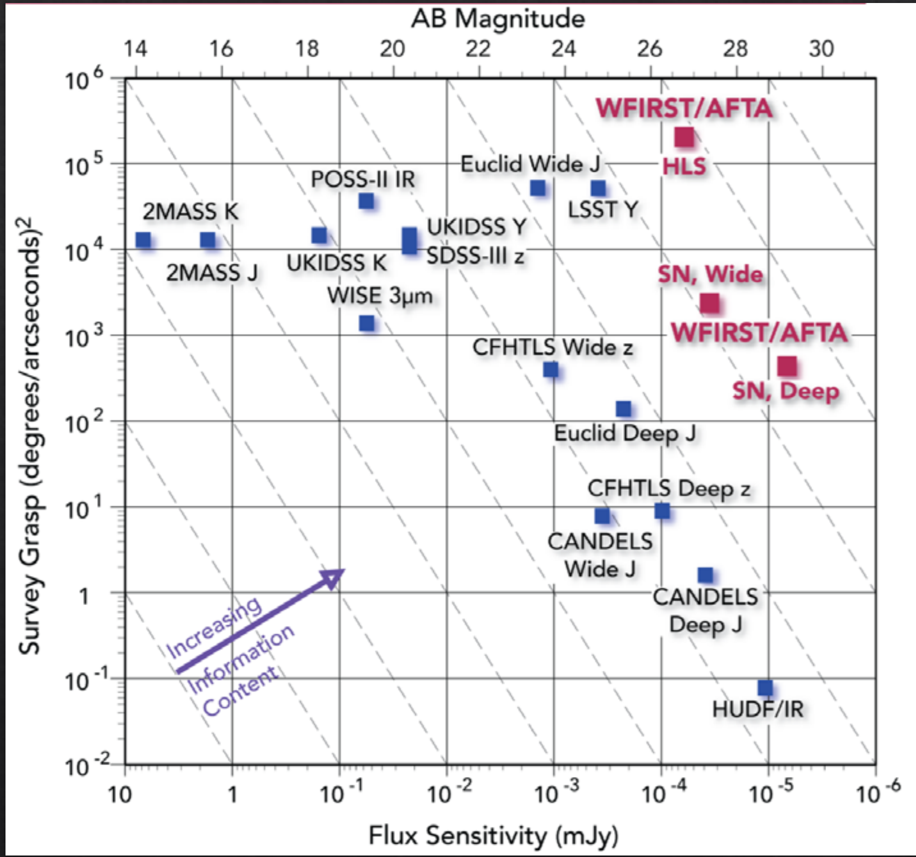
history of dark energy
+
deviations from GR

$w(z)$, $\Delta G(z)$, Φ_{REL}/Φ_{NREL}



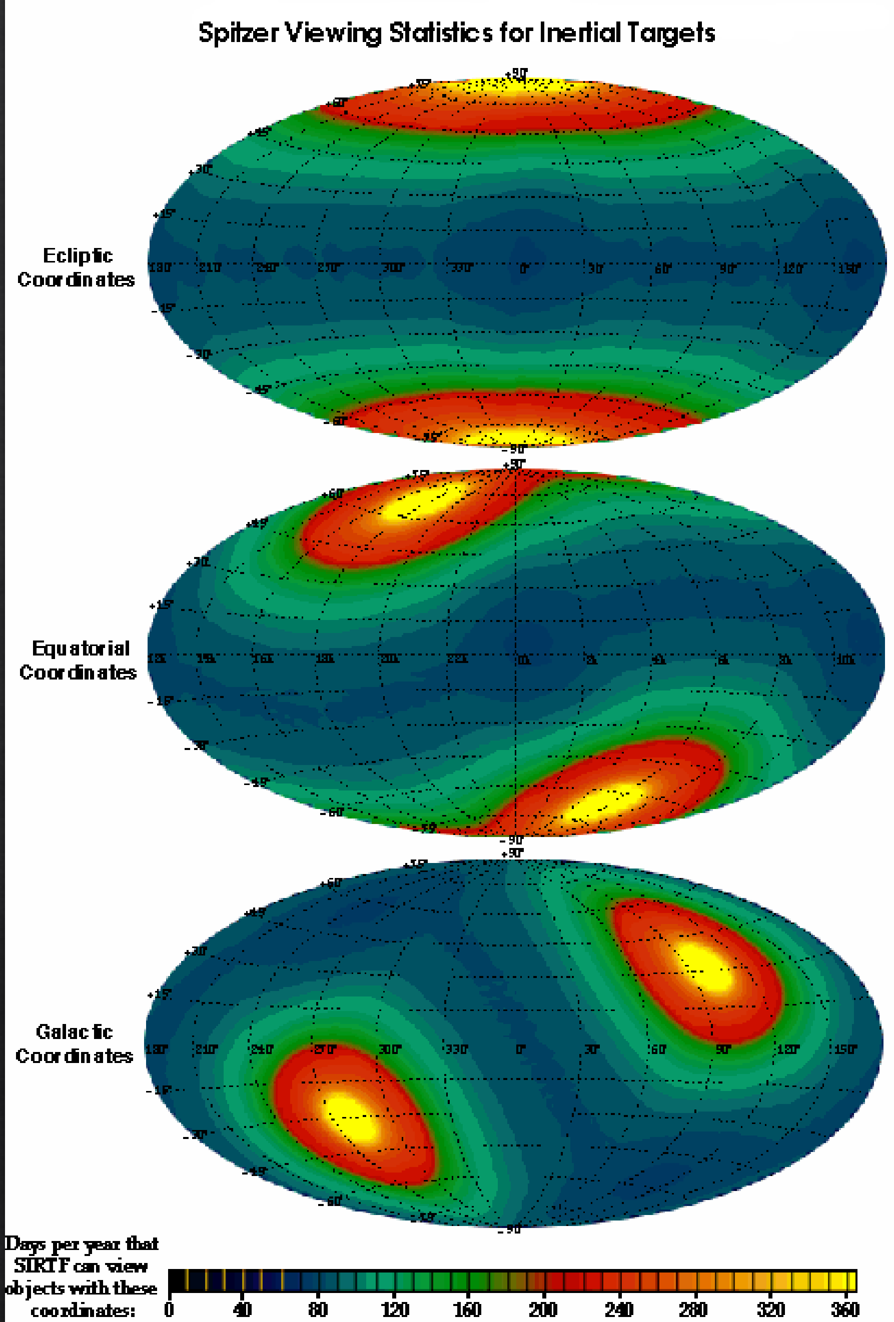
Cosmology Survey

- Baseline two surveys with three components
- Primary goal is systematics control
- High Latitude Survey (HLS)
  - ~2,200 square degrees
  - Imaging in 4 bands for weak lensing
    - Y106, J129, H158, F184
  - Spectroscopy for BAO
    - R~500, 1-2μm
  - IFC on ~50,000 random galaxies in parallel
- Deep survey for SNe and calibration
  - 5, 9, 27 deg^2 deep, medium, shallow
  - IFC Spectroscopic follow-up of identified SNe
    - F184W in parallel



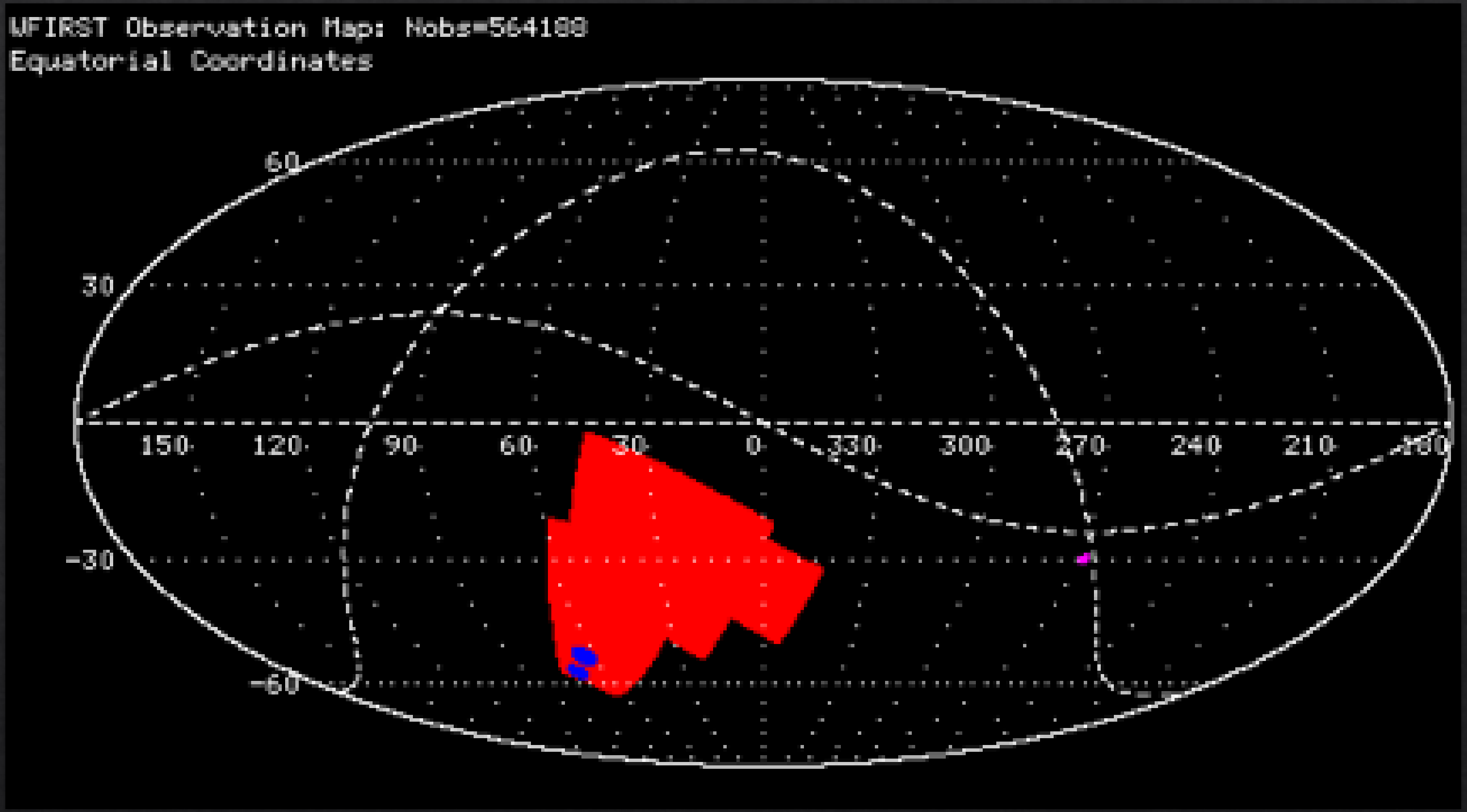
Cosmology Survey

- Space has different constraints from ground
- Sensitivity is determined by zodiacal background
- Observability is determined by ecliptic latitude
- Need to observe as close to ecliptic poles as possible
  - Especially deep/calibration fields
- Can't do a wide are survey on the celestial equator



Cosmology Survey

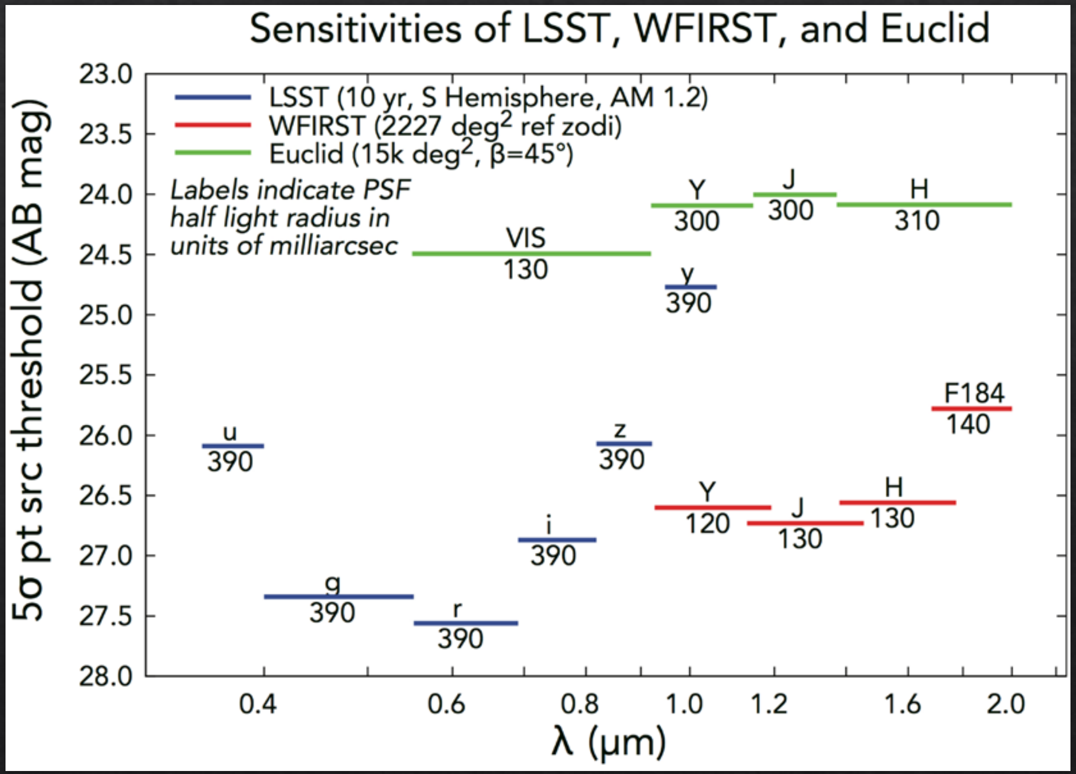
- Survey nominally designed to overlap with LSST
- Ground based u,g,r,i,z photometry needed for photo-z
- SNe deep field TBD
  - Nominally in southern LSST deep drilling field
  - Would like to allow for HSC/PFS follow-up
  - Hard to meet all constraints



Cosmology Survey

- Grism spectroscopy to 5×10^{-17} erg/s/cm^2 7σ
- IFC spectral SNR~10 per resolution element at 25th magnitude

Filter	HLS	Shallow	Medium	Deep
Y106	26.7	27.1		
J128	26.9	27.5	27.6	29.3
H159	26.7		28.1	29.4
F184	26.7			29.5

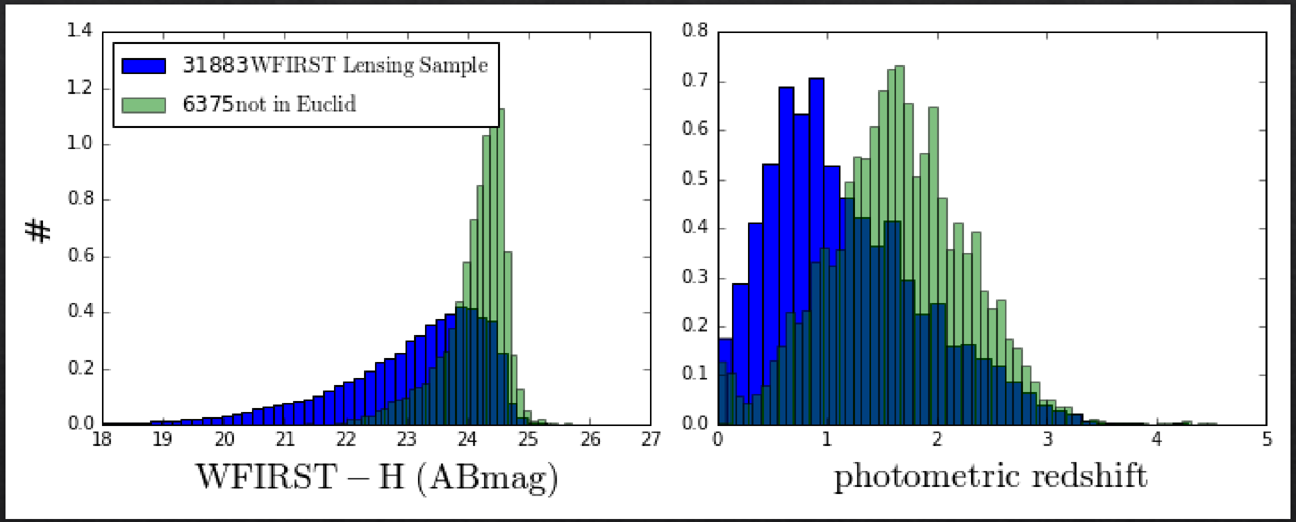


WFIRST Photo-z Problem

- WFIRST is selecting galaxies in the NIR
  - Very faint H<25
  - Many red galaxies
- This could be a very hard sample to get redshifts to
  - Bias calibration hard
- Full WFIRST lensing sample in blue, WFIRST faint sample (missed in Euclid sample) in green
  - Based on CANDELS
- Here the "Euclid sample" is defined to be RIZ<25
  - 0.5 mag deeper than nominal Euclid
  - Depth being targeted for Euclid (C3R2) spectroscopy

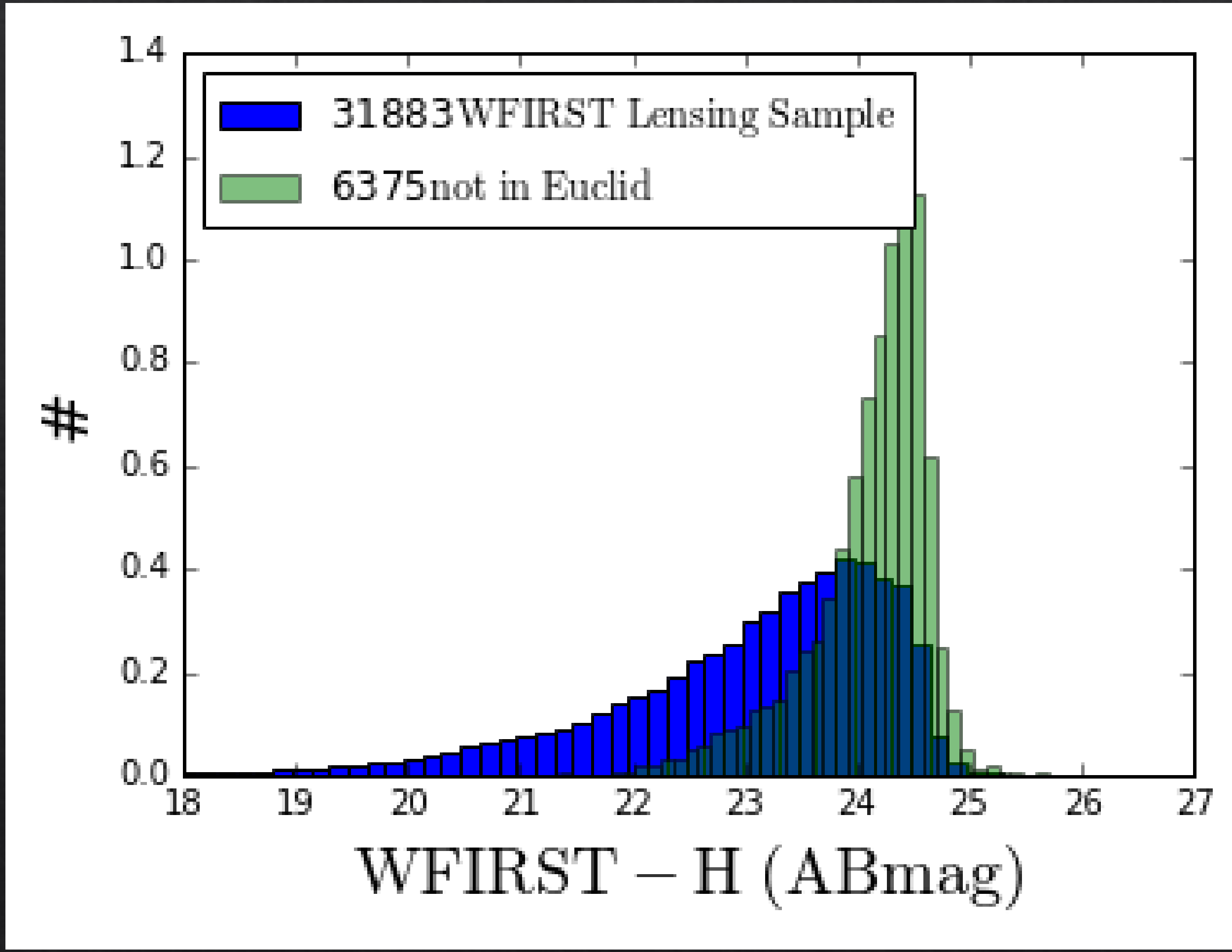
Euclid

WFIRST - Euclid



WFIRST Photo-z Problem

- Significant number of galaxies not in the Euclid Sample
  - 20% of WFIRST sample have RIZ>25
- These will be hard to get spectra for from the ground
- What fraction don't have colors in current spectroscopic samples?
- How hard will it be to get redshifts?



Self Organizing Map (SOM)

- We adopt a widely-used technique known as the Self-Organizing Map (SOM), or Kohonen Map
- Easy to visualize
- Easy to understand

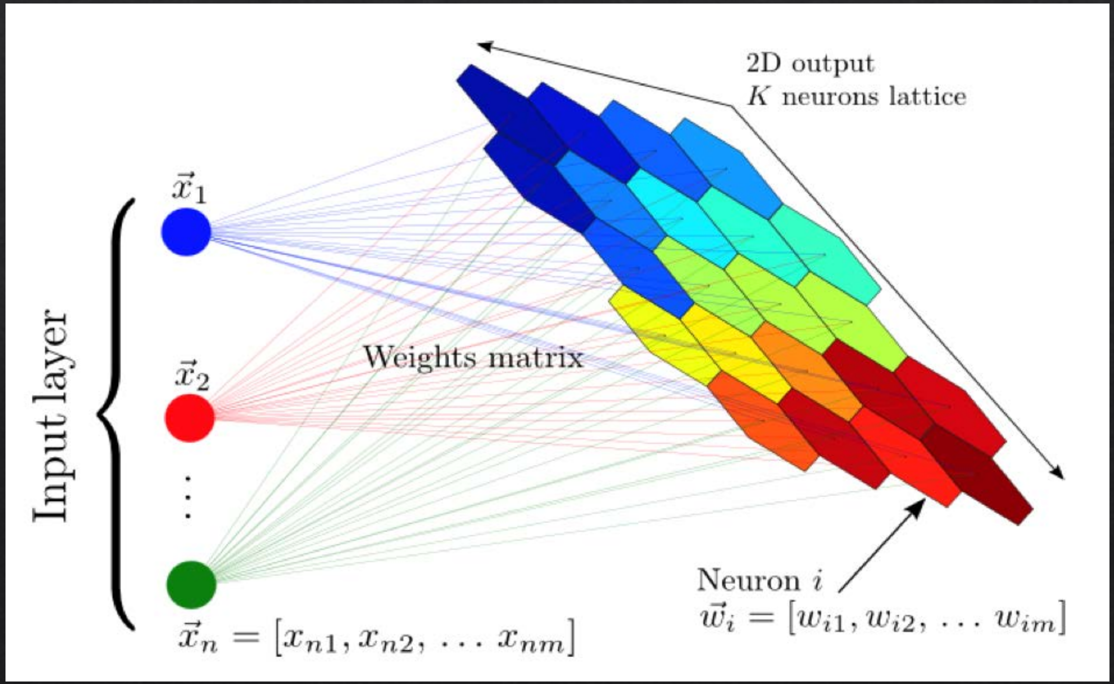
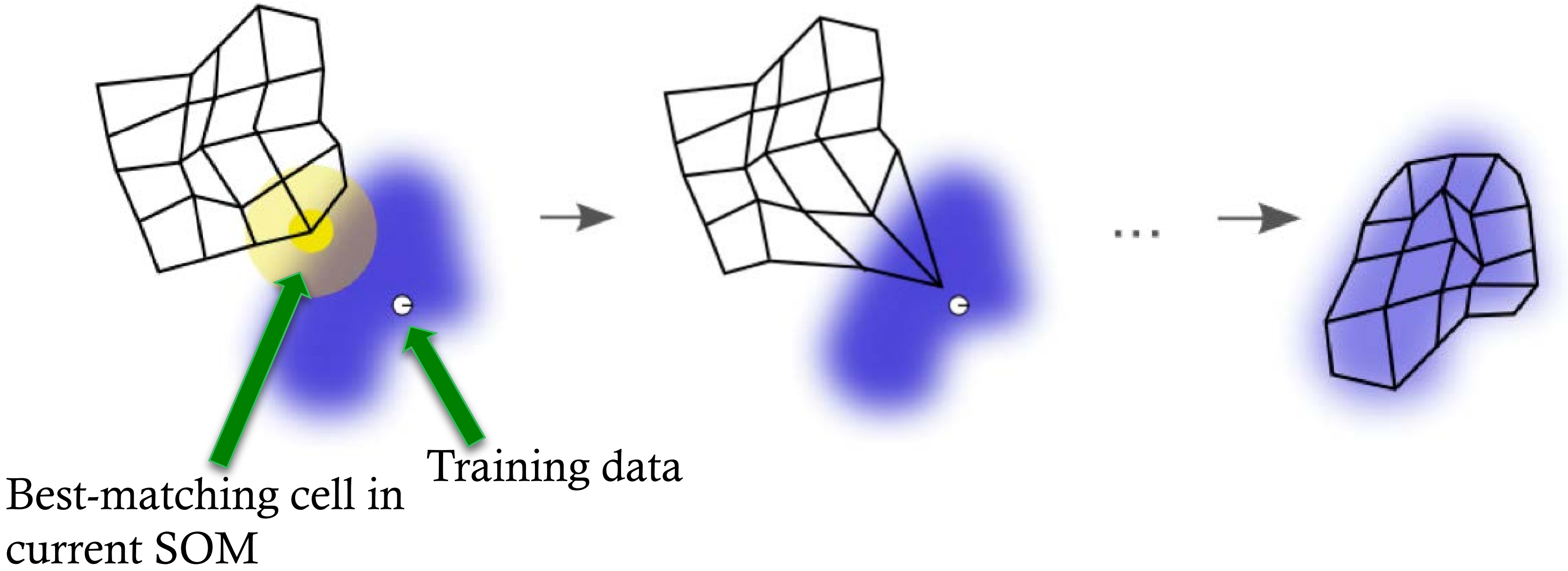


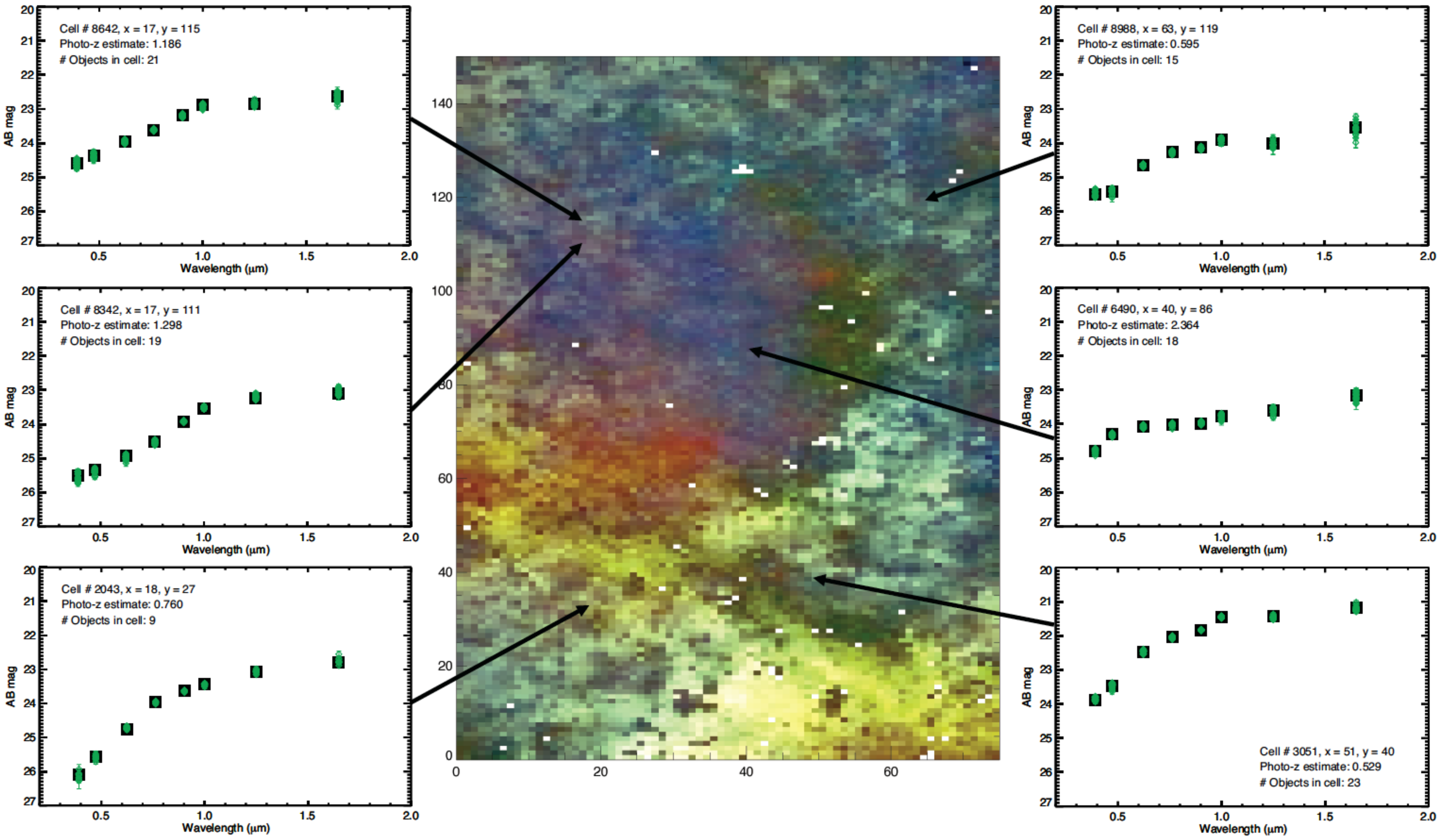
Illustration of the SOM (From Carrasco Kind & Brunner 2014)

Self Organizing Map (SOM)



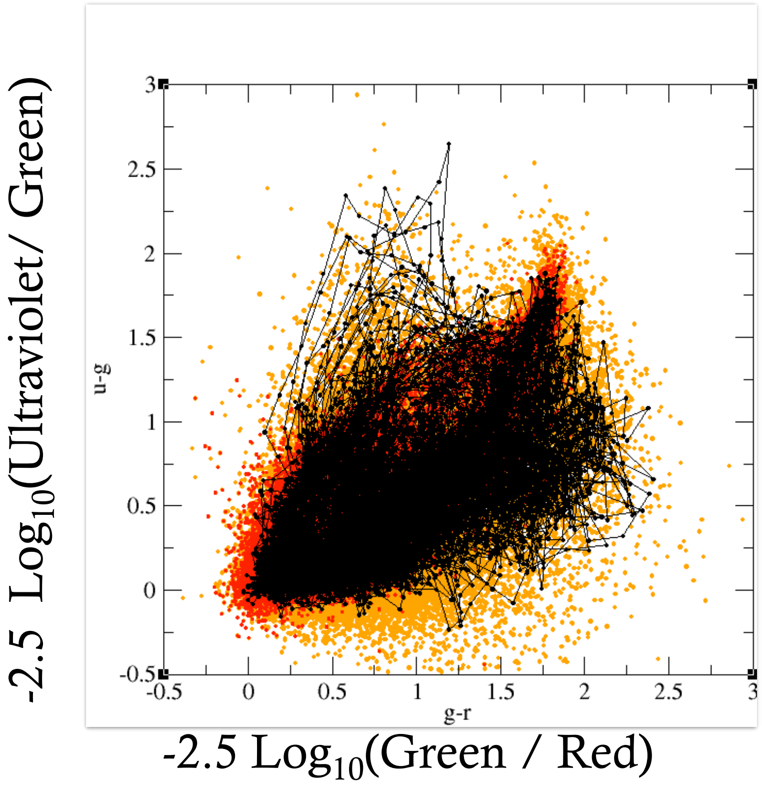
1. Initialized map is presented with training data, i.e. the colors of one galaxy from the overall sample.
2. Map moves towards training data, with the closest cells being most affected.
3. Process repeats many times with samples drawn from training set until the map approximates the data distribution well.

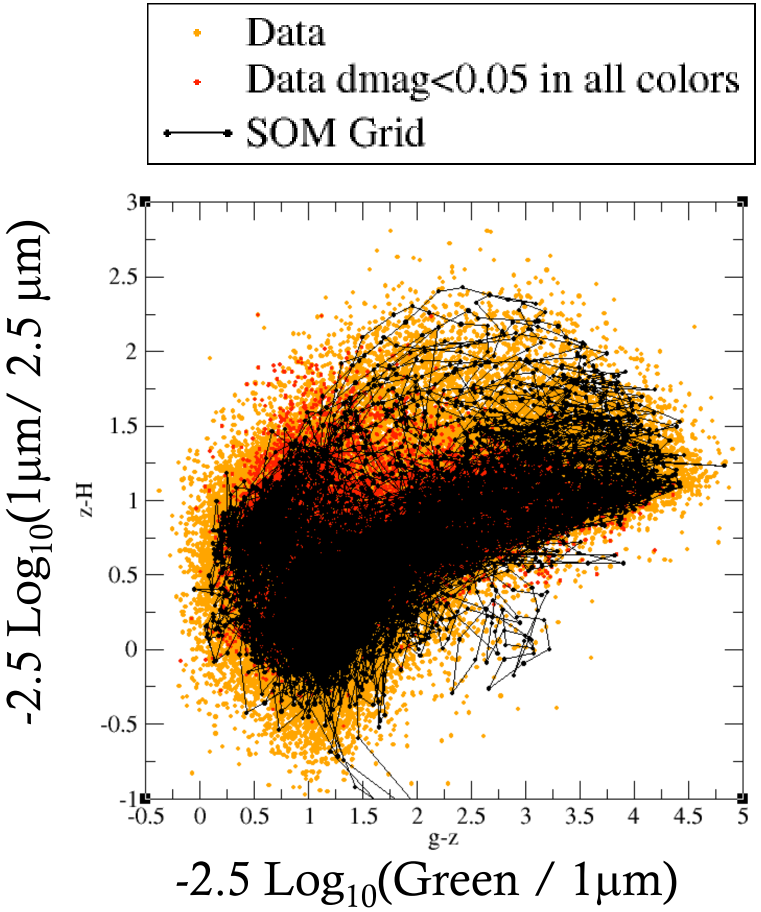
Self Organizing Map (SOM)



Self Organizing Map (SOM)

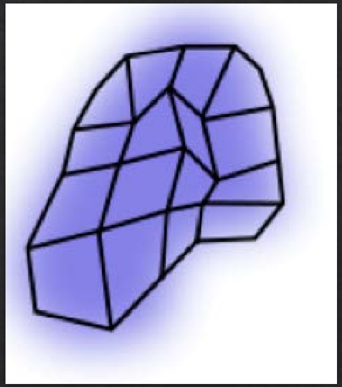
The SOM grid in color-color plots





Self Organizing Map

- SOM provides a map of the data space
- Parameterizes the data into a probability density field
- A model provides a way to map that probability density field to a physical parameter
- Could be an analytic model or a data model



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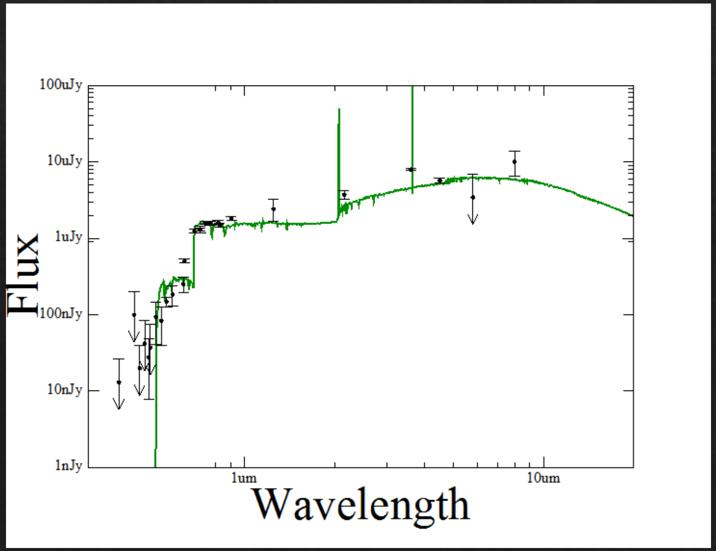
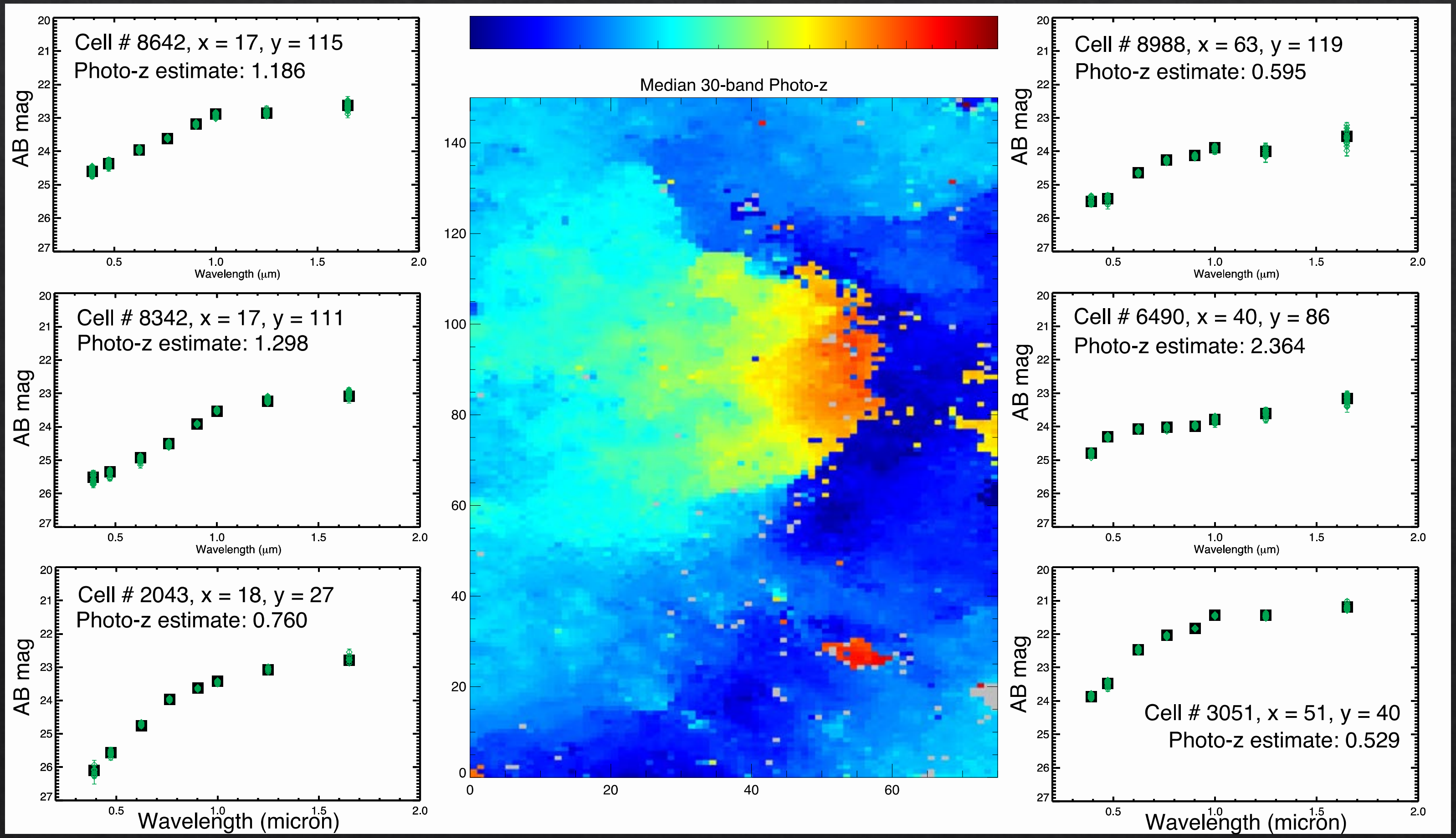


Self Organizing Map

- The properties of a particular cell can be assessed with analytic models

- Color maps smoothly to redshift over most of the manifold

Mean Redshift



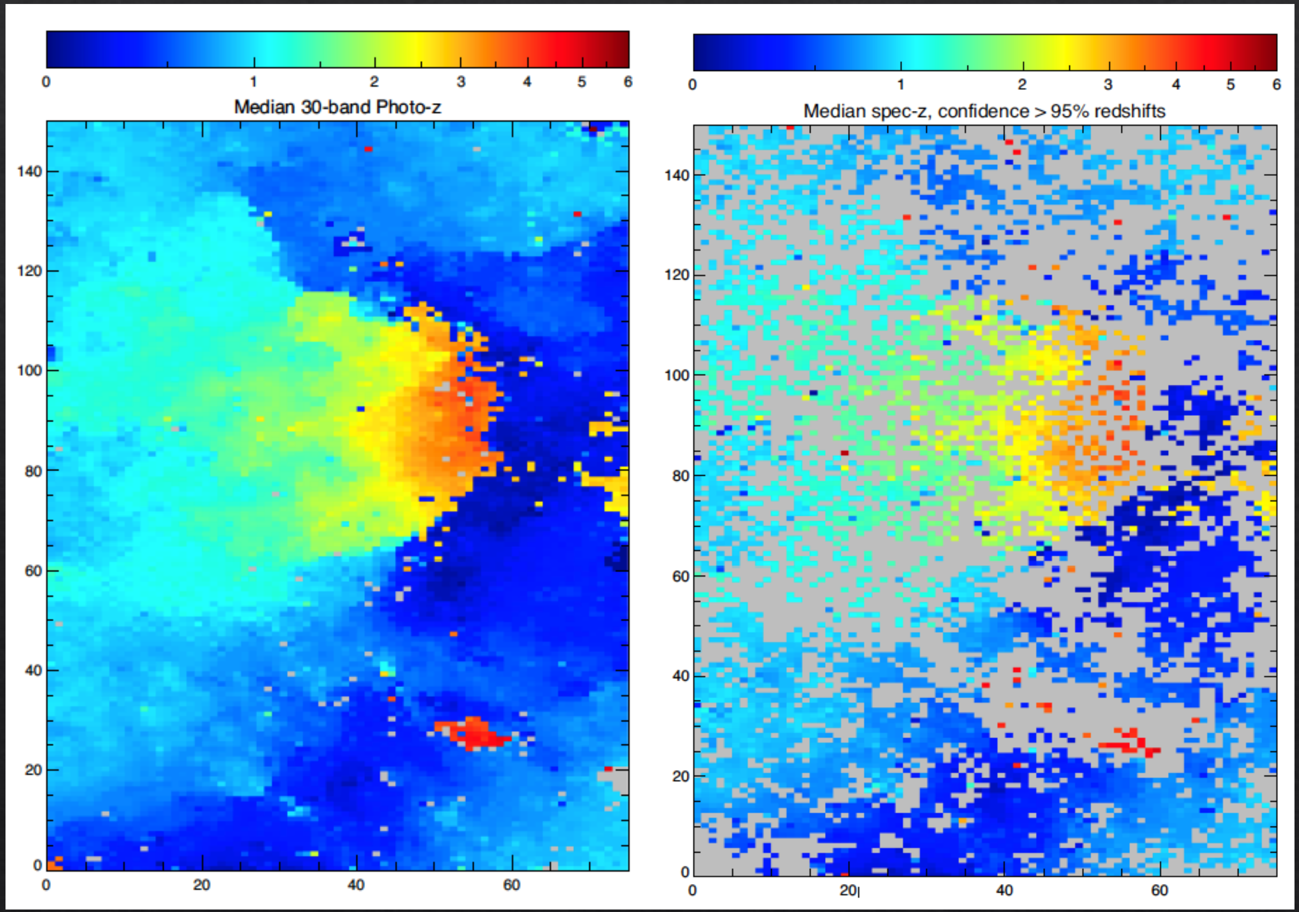
Masters, Capak et al. 2015

Self Organizing Map

- Photo-z distribution is very smooth over most of color space
- Spec-z are not representative of data
- Can use SOM to select optimal spectroscopic sample
  - Masters, Capak et al. 2015
- Reduces required spectroscopic telescope time by orders of magnitude

Redshifts from an analytic model

Redshifts from spectroscopic data

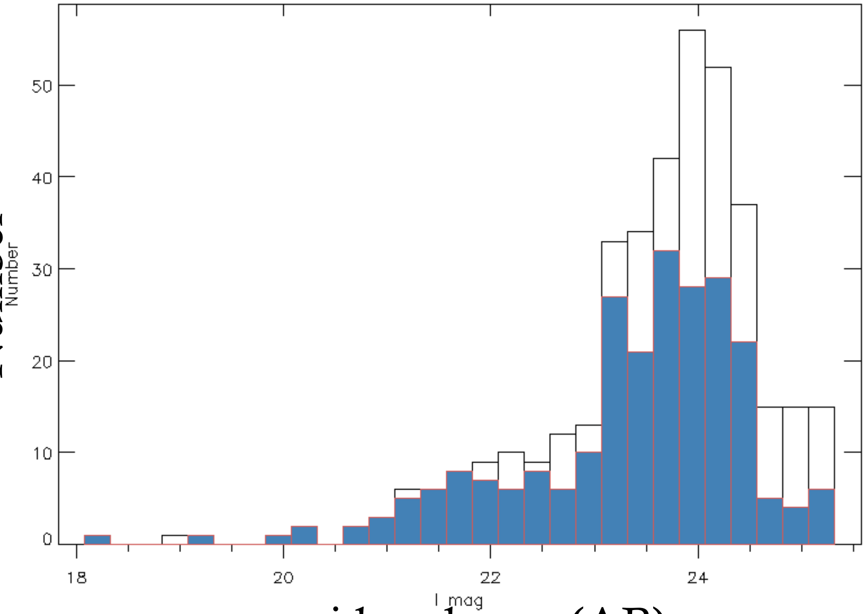


Masters, Capak et al. 2015

C3R2 Survey

- Spectroscopic sample under way
- Aiming for a color complete spectroscopic sample
- Know what we expect in each cell allows for optimal targeting
- Using multiple instruments and exposure times
- Very low failure rate

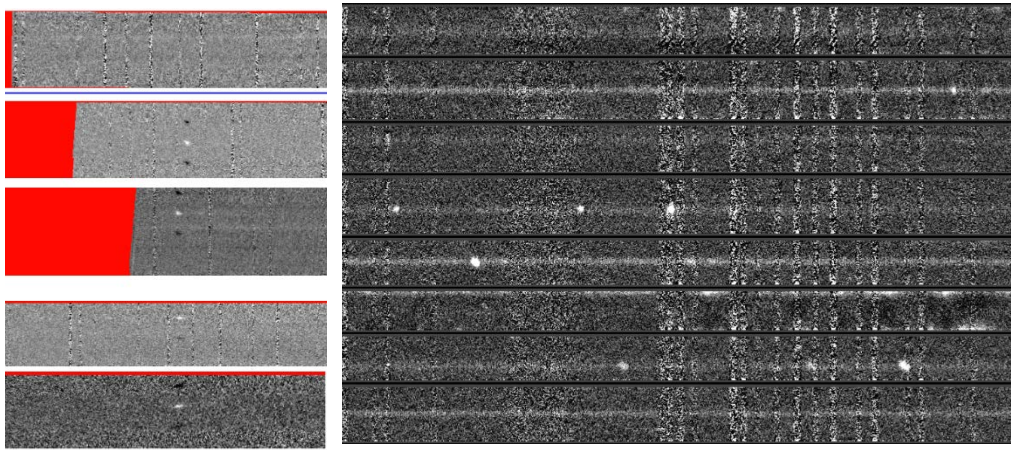
Flux Distribution Of Targets



Number

i-band mag (AB)

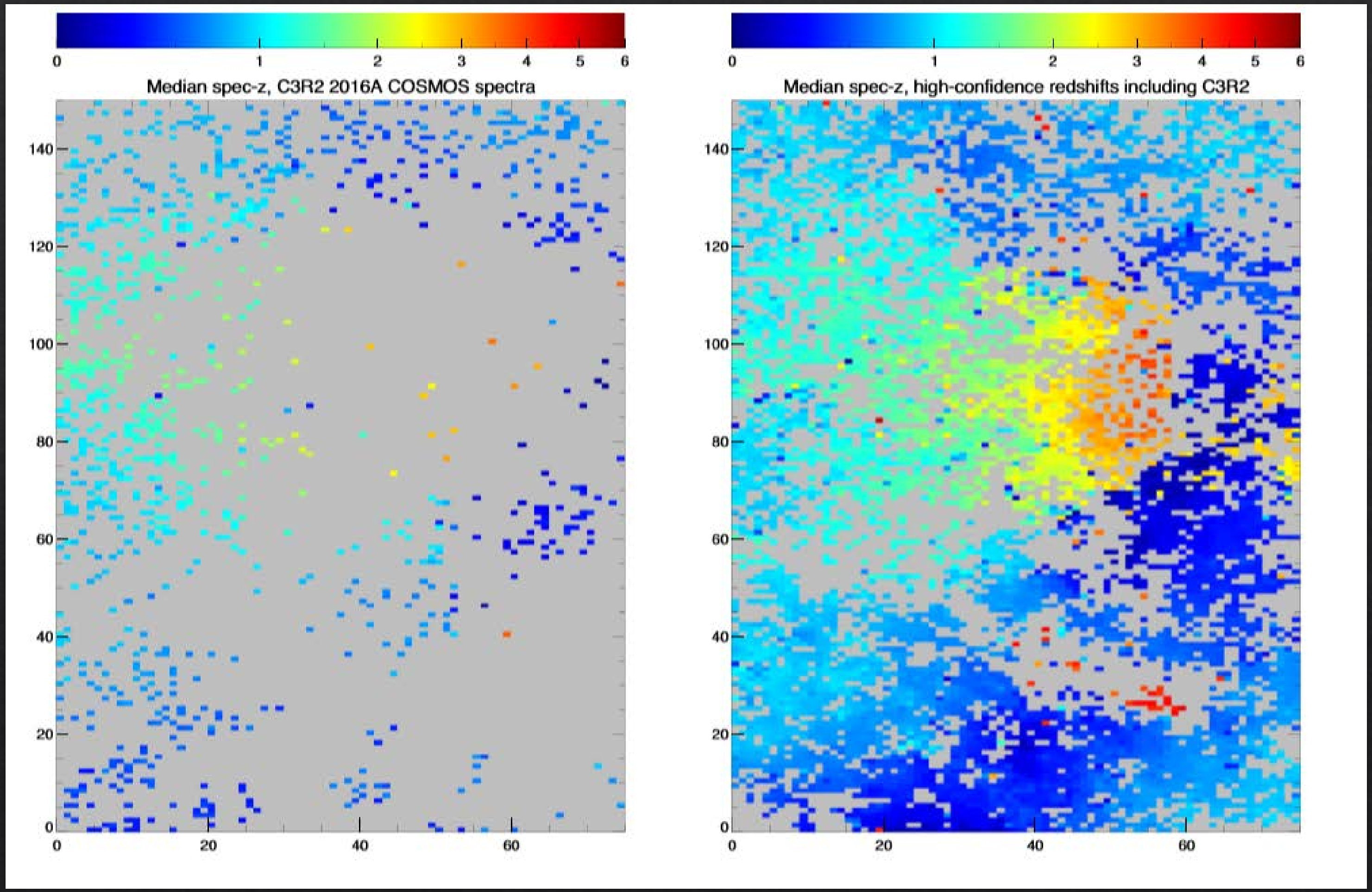
Example Spectra



C3R2 First Results

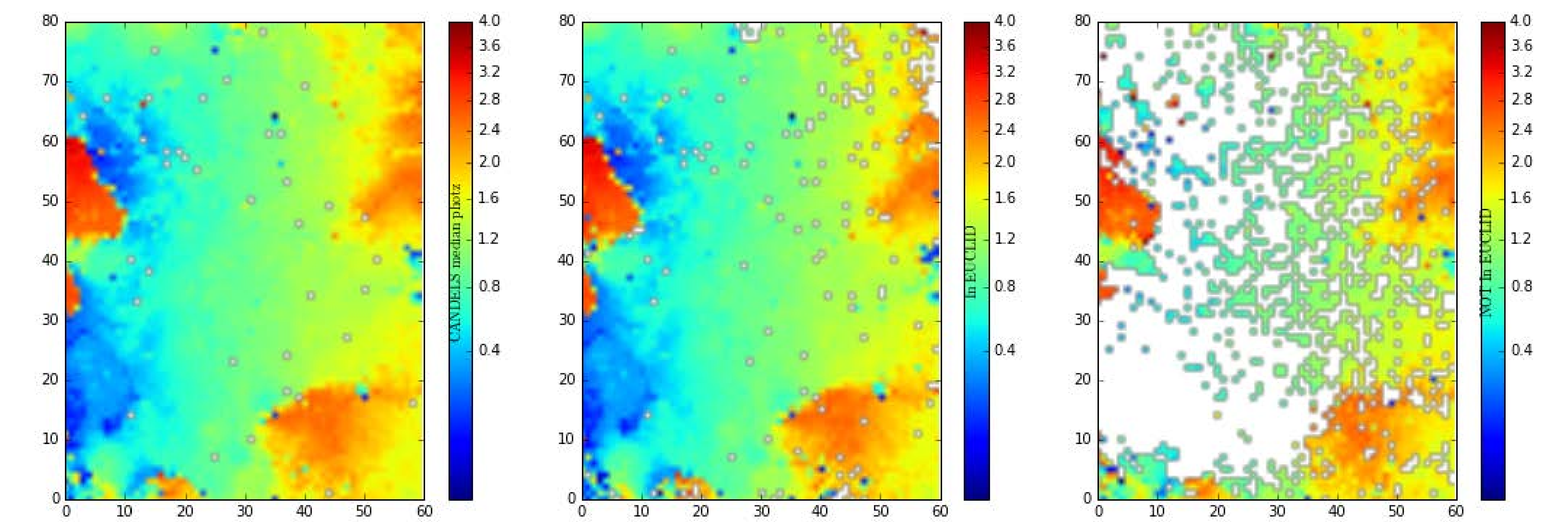
- ~608 new cells calibrated in DR1
  - 5.4% of color space
  - 80% of lensing sample now calibrated

DR1 Redshifts | All Redshifts



WFIRST Self Organizing Map

WFIRST full sample | C3R2-depth sample | WFIRST faint sample



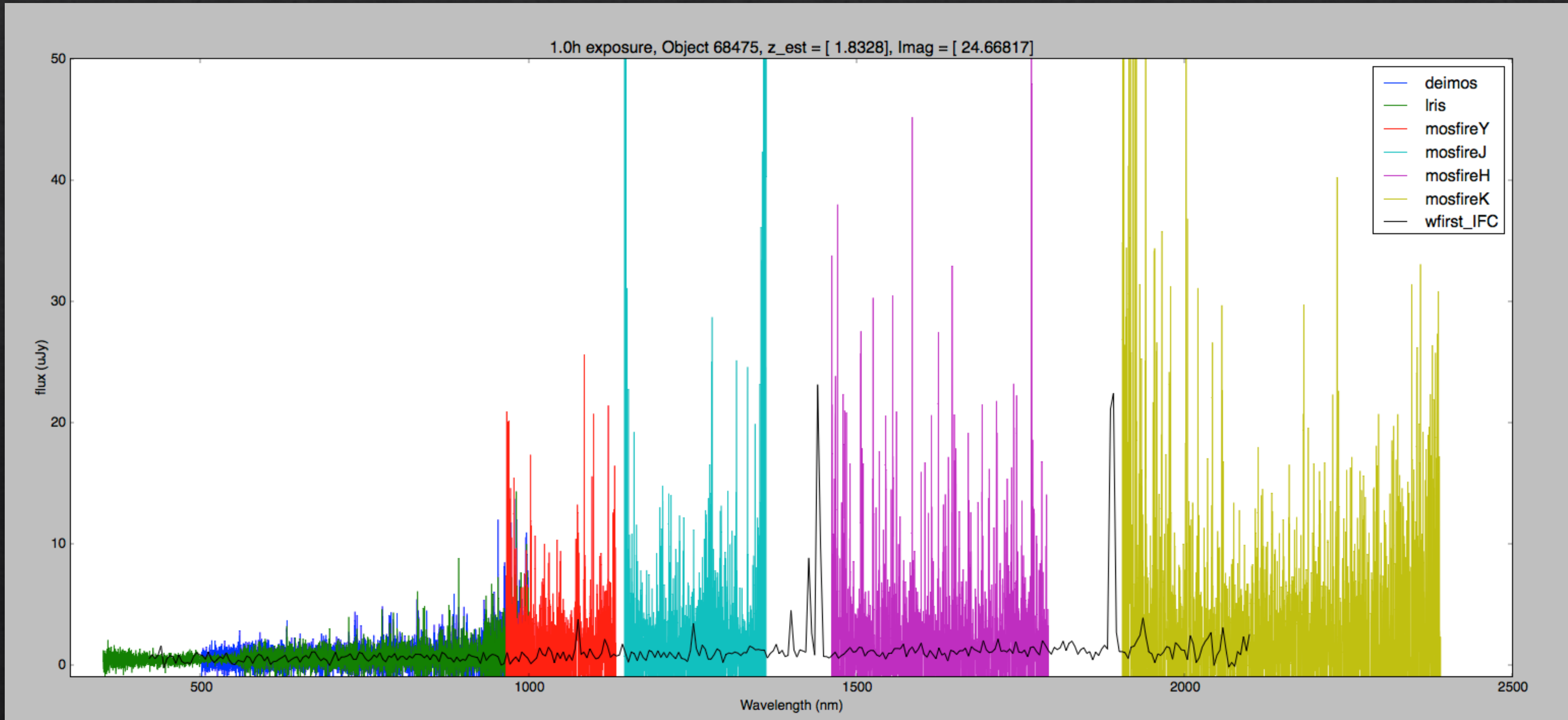
- Most faint WFIRST galaxies have colors in the C3R2 sample, ~4% do not (white cells in middle panel)
- ~2% of Euclid color space is also "Hard"
- Will need to calibrate these some other way than ground based spectra
- WFIRST faint sources have similar photo-z's as brighter galaxies with same SED (right panel)

WFIRST Calibration

- 20% of WFIRST galaxies are very hard to get spectra for from the ground
  - Need 10's of hours
  - Only practical with ~50-100h exposures on something like PFS
- 96% of WFIRST galaxies have an analog at brighter fluxes
  - May not need spectra
  - Do we trust this?
  - How do we verify this?
- WFIRST IFC Can solve faint galaxy problem
  - IFC will measure ~11k redshifts that are difficult to obtain from the ground
  - Of the 11k, ~1.3k will also be measured by the GRISM

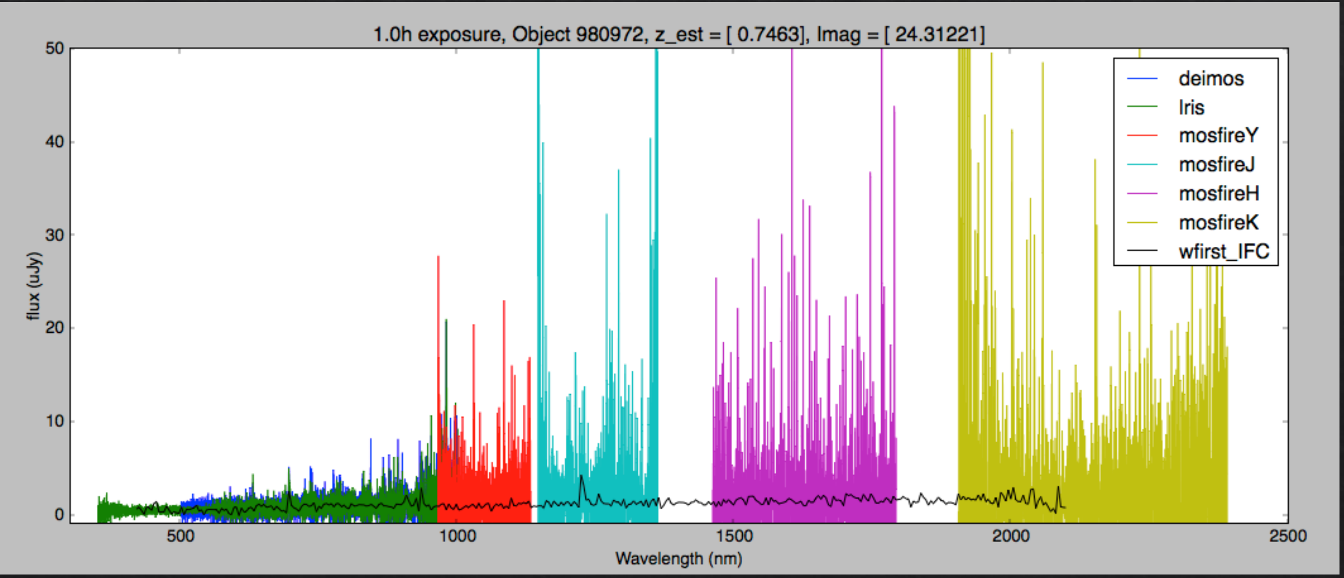
Hard Redshifts

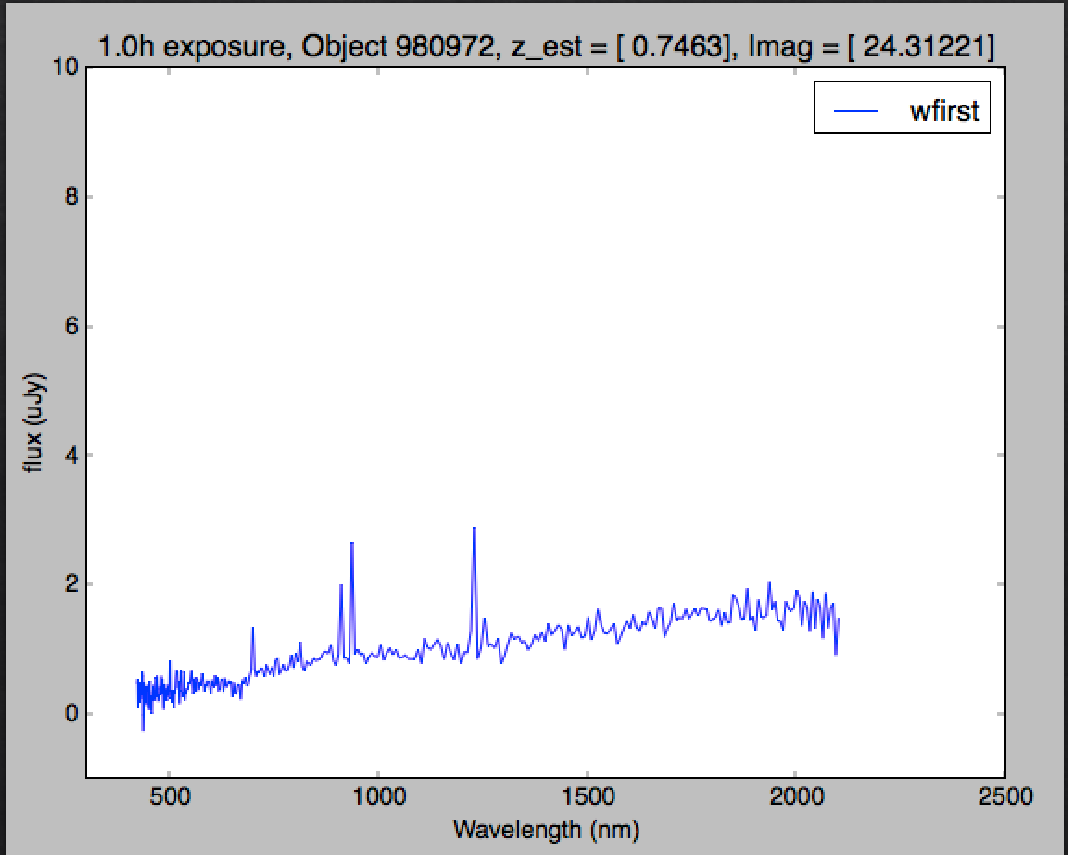
- Strong emission lines fall between ground based windows
- ~10% of "hard" sample, specific redshift ranges
- GRISM can do these too as part of HLS



Hard Redshifts

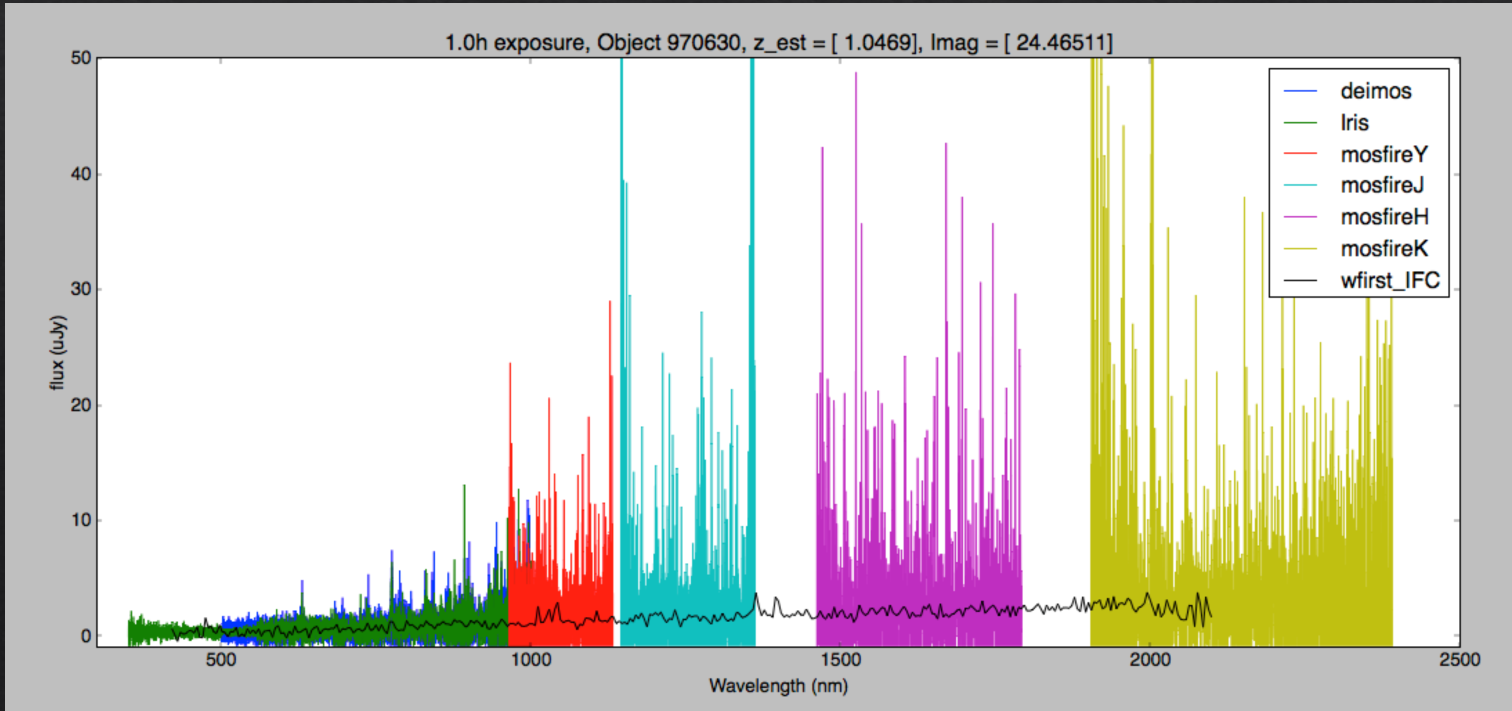
- Weak lines at >0.8um
- Can be done with IFC
- 85% of WFIRST sample (17% of total)
- Also “Hard” with GRISM
  - Need many 10’s of hour exposures





Hard Redshifts

- Continuum sources
- 15% of "hard" sample, ~4% of total
- Neither GRISM or IFC useful
- JWST?
- Don't use these galaxies?



Summary

- WFIRST is happening
- Exact definition of survey after ~2020
  - Everything I showed you is preliminary
- Primary goal of cosmology is systematics control
- Three probes, SNe, BAO, Weak Lensing
  - ~2,200 sq deg HLS
  - 5-27 sq deg SNe survey
- IFC to get redshifts to hard galaxies