WFIRST Grism Simulations

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WFIRST Grism Simulation Group

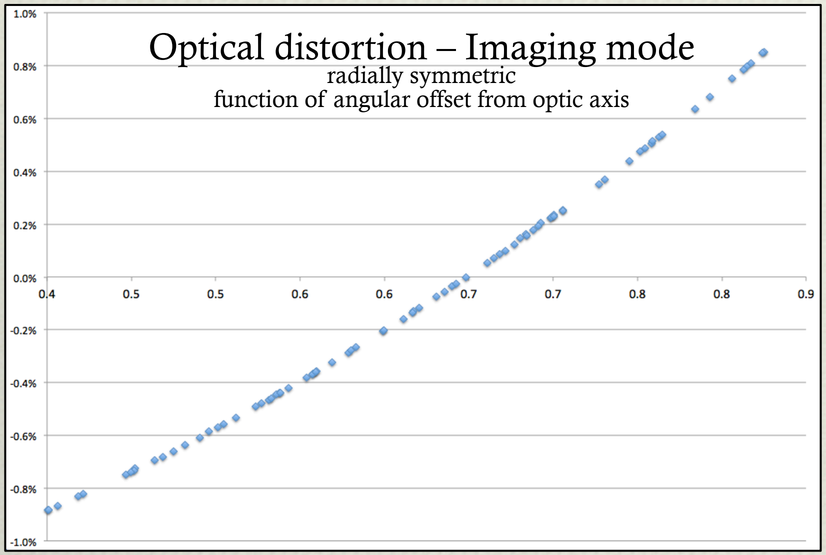
WIDE-FIELD INFRARED SURVEY TELESCOPE
WFIRST
ASTROPHYSICS • DARK ENERGY • EXOPLANETS

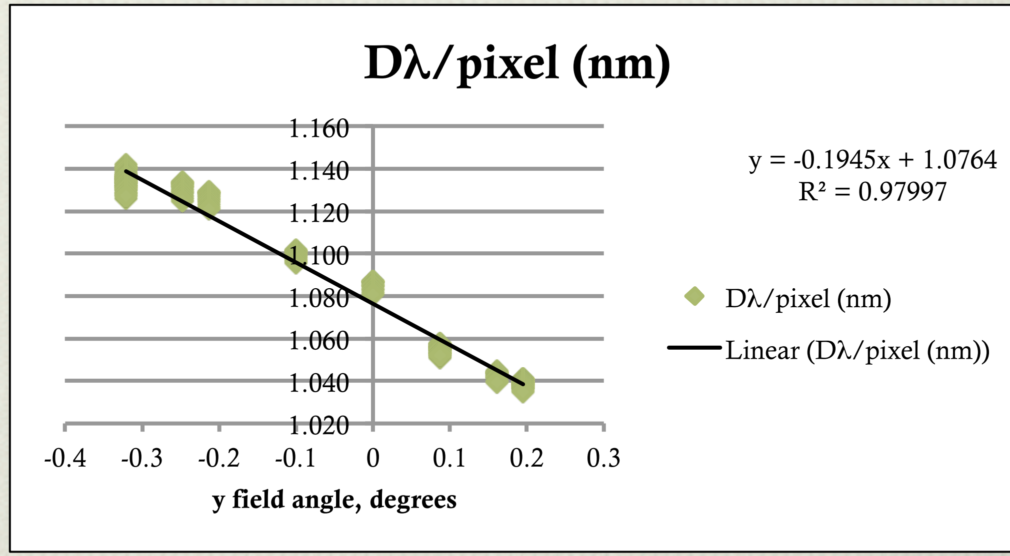
On-going WFIRST Science Centers Grism Simulation Effort

- Work being done with team members at IPAC, STScI, and GSFC.
  - Grism simulation group has been meeting regularly since late 2014
  - Efforts will continue through at least through the end of Phase A
    - Will be Co-chair of a Grism Working Group for the FSWG
  - One of our primary purposes: Aiding the Project in setting requirements so that the goals of the HLS can be met
- Simulations Have Two Main Components
  - Detector and Grism Simulation
  - Source List Simulation

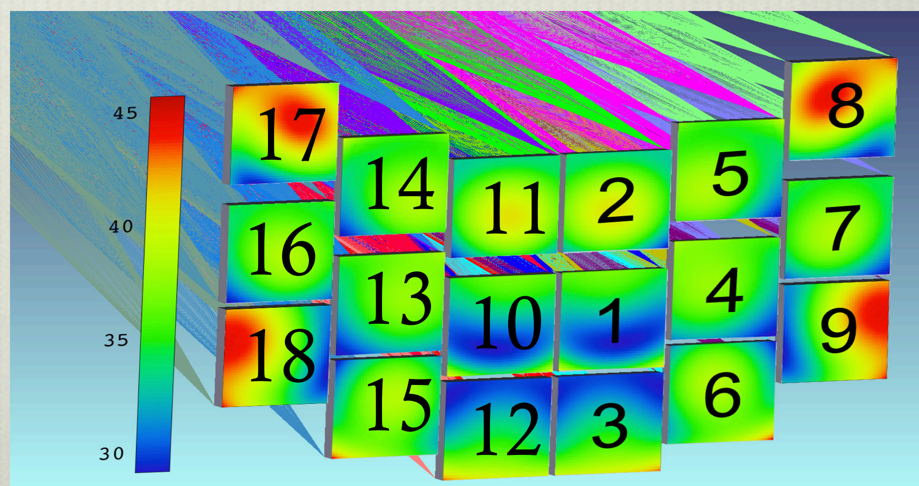
Detector and Grism Simulation

The WFI imager consists of 18 detectors, each with a different pixel by pixel solution to distortion, wavelength dispersion, spatial offset, wavelength dispersion, and spectral trace.





- Pixel Scale: 0.11”/pixel
- R~600, 10.8 Å/pixel
- Wavelength Range: 1.35-1.95 μm
- Very weak zero orders



aXeSIM

Presently using aXeSIM to perform main simulations

- Publicly available software from STScI
- Well known to HST grism user science base
- Does have some limitations (e.g., automated test spectra extraction very limited, inability to set RA and Dec), requiring additional outside processing tools.
- Added ability to simulate different dither patterns and rolls.
- Other simulation software is also being explored/ developed

Source List Simulation

Presently pursuing **Three** different approaches to source generation.

1) **Directly transfer known fields taken with WFC3 grism**

   Pro: Representative of the real universe, easily checked against true field

   Con: Still have to extrapolate to potential depths, longer wavelengths, higher spectral resolution, and, most importantly, giant field sizes of WFIRST survey.

2) **Generate random fields based on known distributions of real galaxies**

   Pro: No limitation on size or depths, allows for easy exploration of different potential distributions (e.g., different OIII luminosity functions)

   Con: No direct connection to underlying galaxy properties (SFR, mass), still requires assumptions about evolution of underlying distributions

3) **Tests of parameter space**

   Pro: Allows exploration of different observing modes, mission designs, efficiencies, and strategies without unnecessary confusion of real sky.

   Con: Clearly no connection to what real images will look like, reduced scientific (as opposed to mission design) value.

Primary Source of HST WFC3 Grism Data:

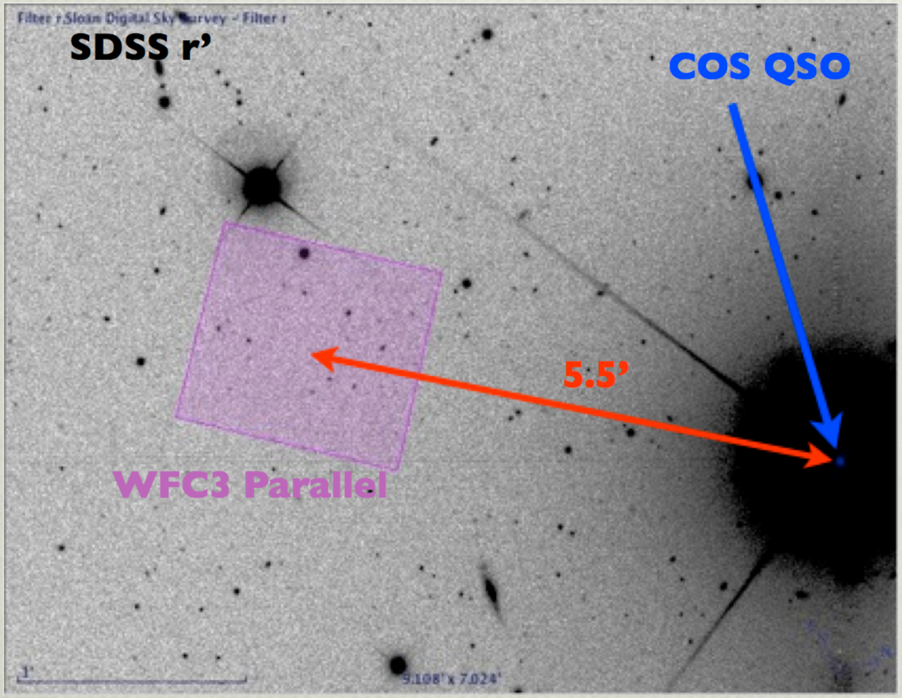
WFC3 Infrared Spectroscopic Parallel survey

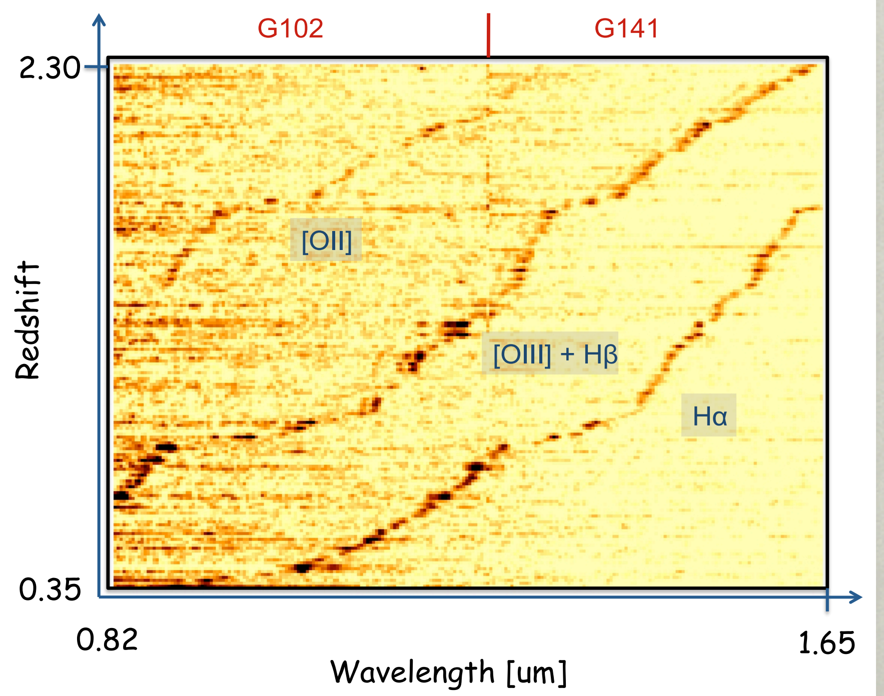
A pure parallel HST survey:

Parallel Separations

- 5.5' from COS
- 4.75' from STIS

- PI: Prof. M. Malkan (UCLA)
- Identification and analysis of emission line galaxies at moderate and high redshift
- G102 & G141 grisms, best database of H α /OIII line pairs



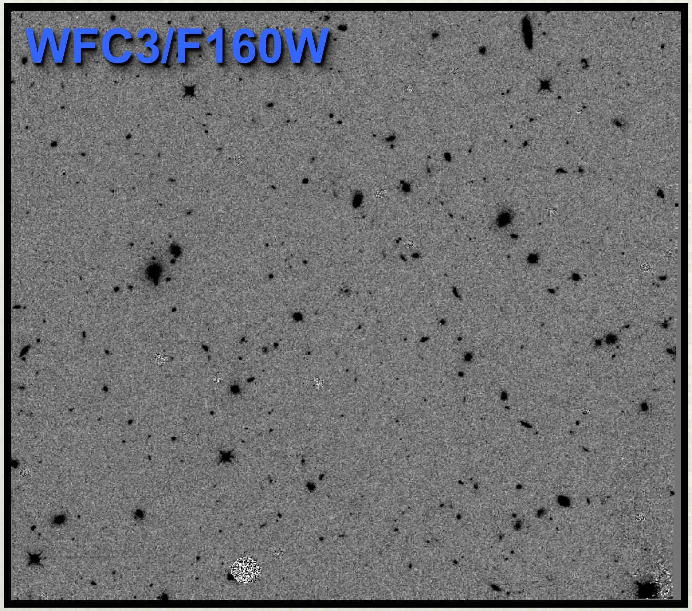


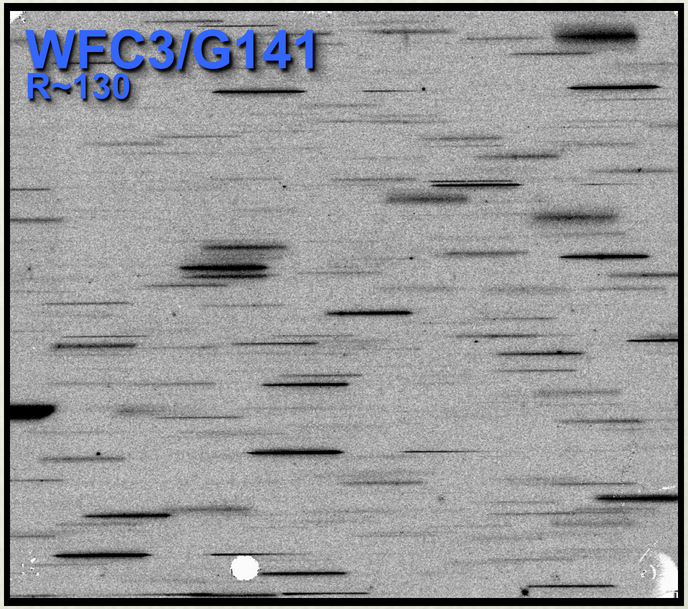
J. Colbert, WFIRST Grism Simulations

Direct Transfer, HST WFC3 to WFIRST (Approach 1)

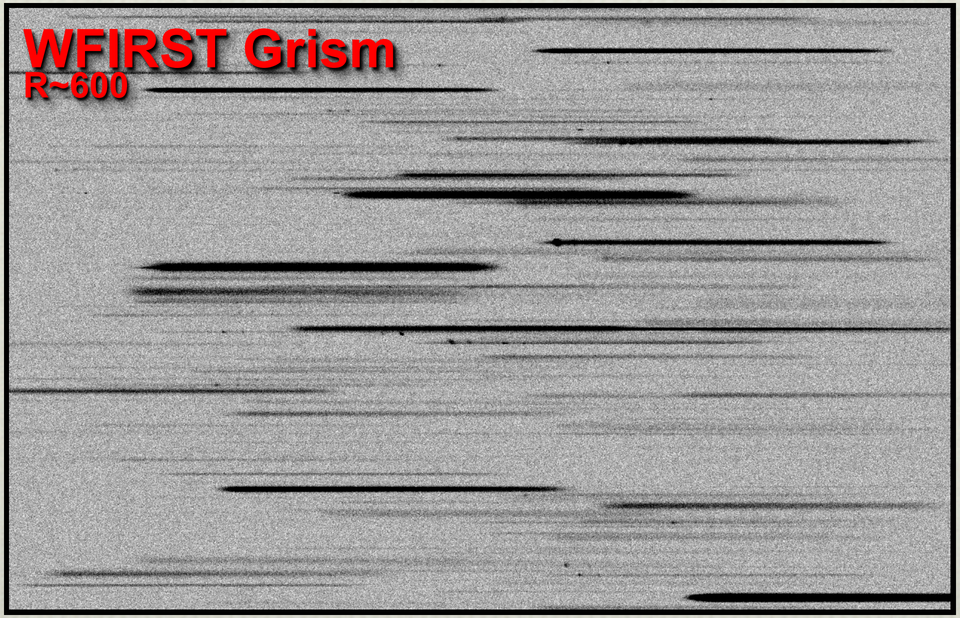
Real Sky

Contains ~30 emission line galaxies

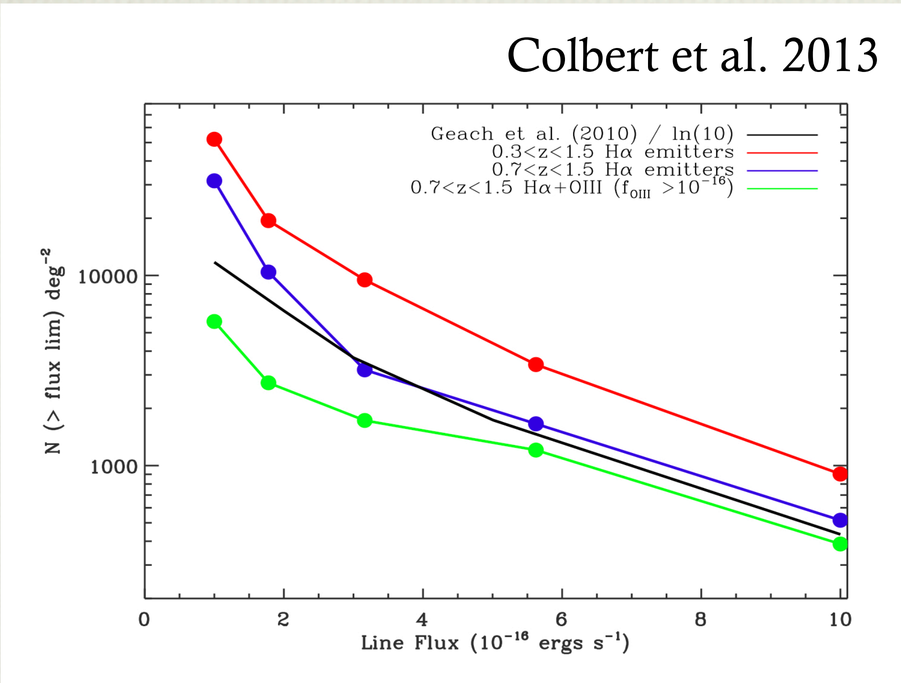


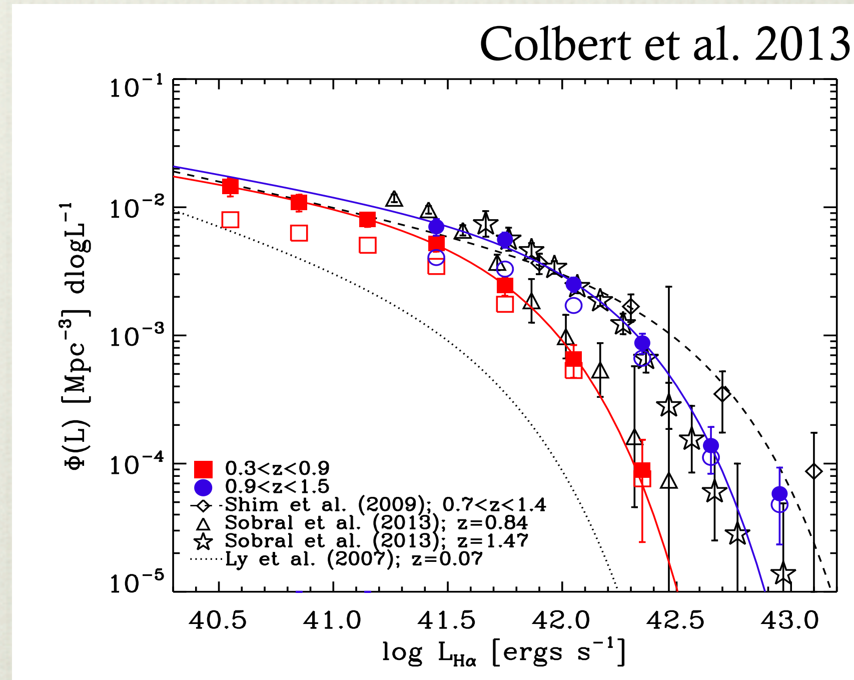


Simulation



Number Counts and Hα Luminosity Functions (Approach 2)

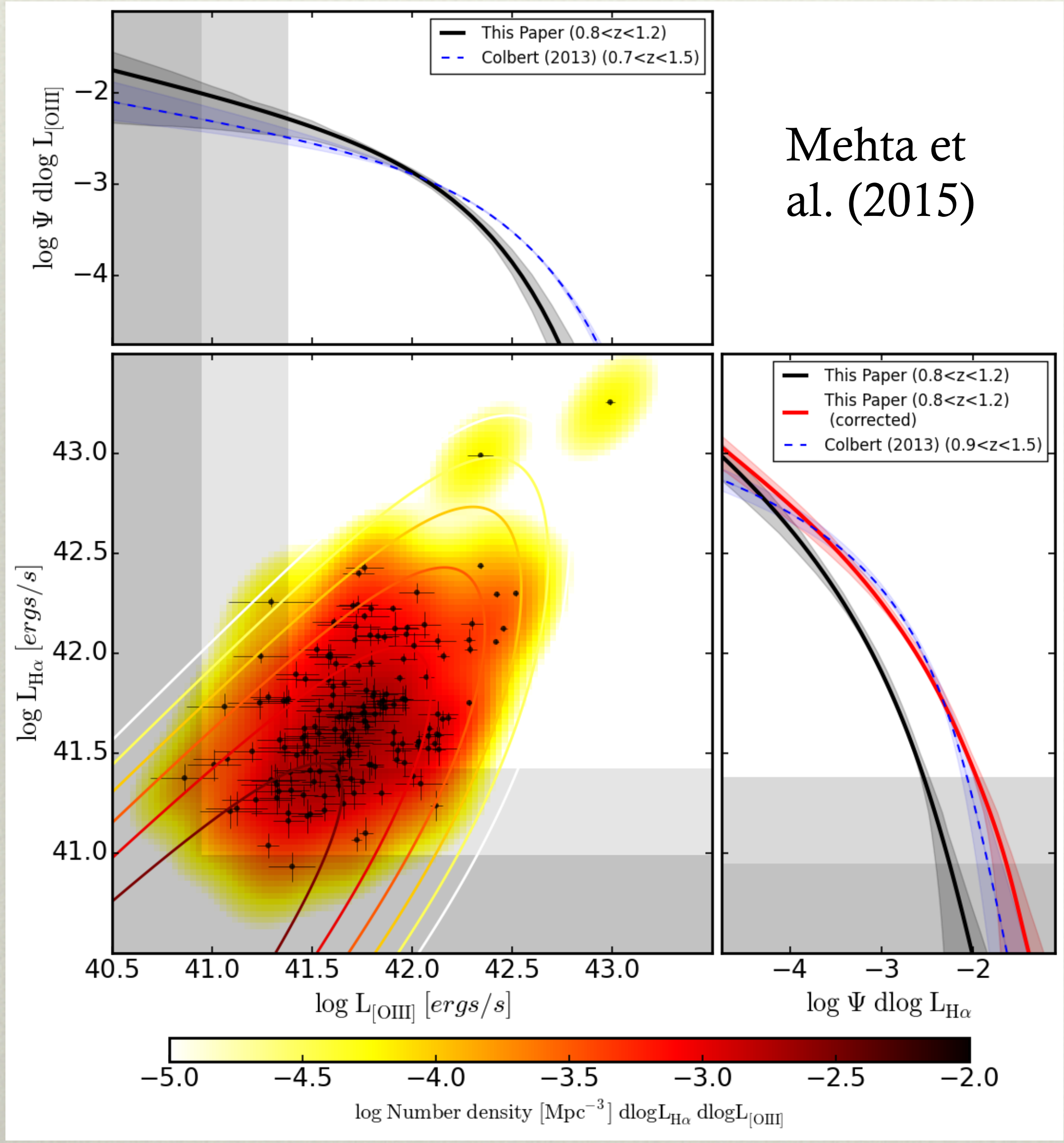




30,000 deg^{-2} for >1x10^{-16} ergs s^{-1} cm^{-2}

Luminosity functions give us the density of Hα line emitters and its evolution with redshift to z~1.5, which we can insert directly into our simulations.

Bivariate Hα - [OIII] Line Luminosity Functions



Mehta et al. (2015)

- Hα luminosity is broadly correlated with [OIII] luminosity — large scatter.
- z~1 broadly consistent w/ z~0.2
- We fit a bivariate line LF in the z range where both Hα and [OIII] are detected and use it to transform from [OIII] to Hα number counts.
- Provides improvement to z<1.5 [OIII] luminosity functions

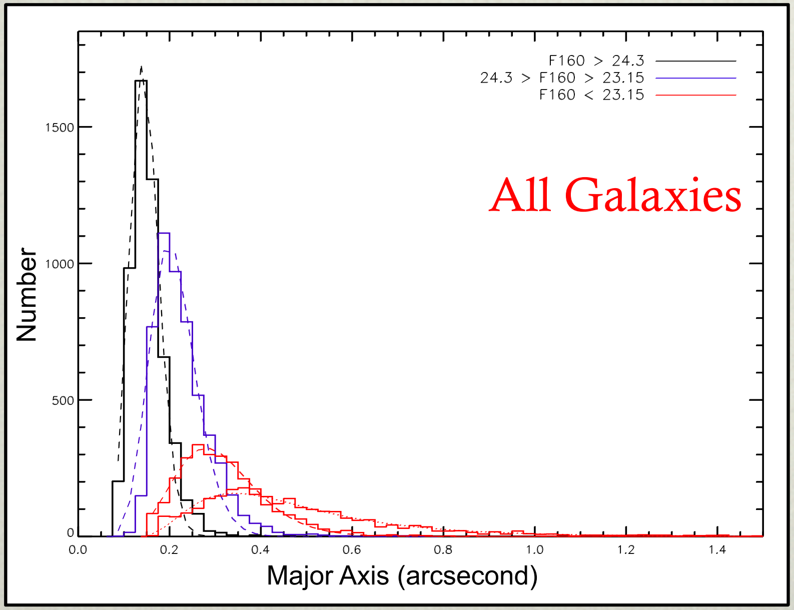
  AND

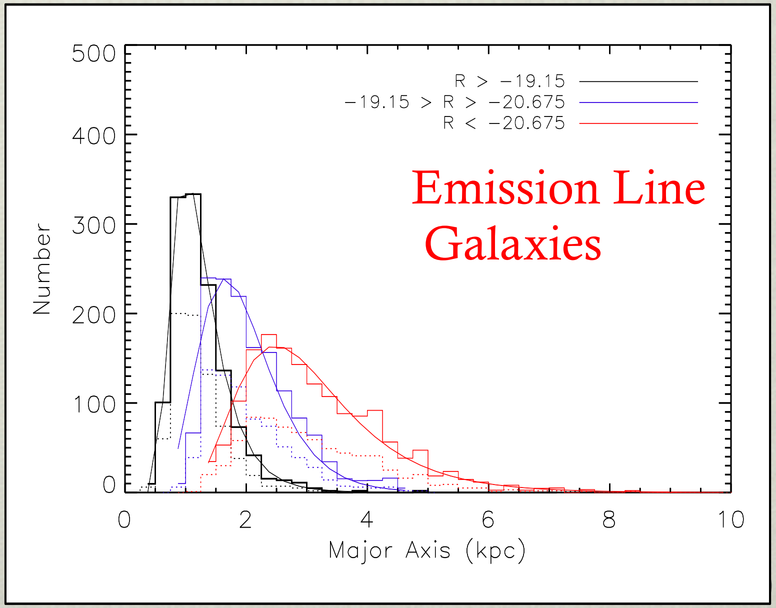
  Better estimate for the evolution of the Hα LF to 1.5 < z < 2.0.

Galaxy Parameter Distributions

- In addition to its emission line luminosity, to simulate each galaxy requires multiple other parameters: the EW, size, J-H color, and major/minor axis ratios.
  - We need to derive these for both the emission line galaxies and “background” galaxies without measurable emission lines.

- We measure these distributions from our extensive WISP galaxy catalogs. We make the simplifying assumption that the distribution shape is most strongly affected by a single other parameter (redshift or luminosity) and apply the appropriate distribution based on that parameter.

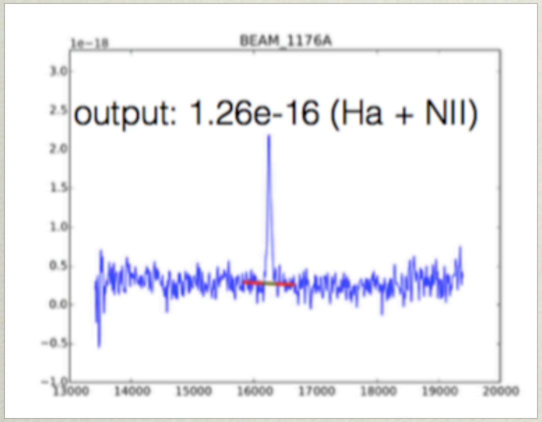


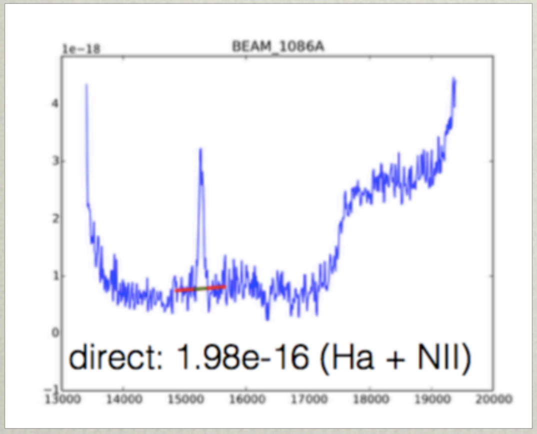


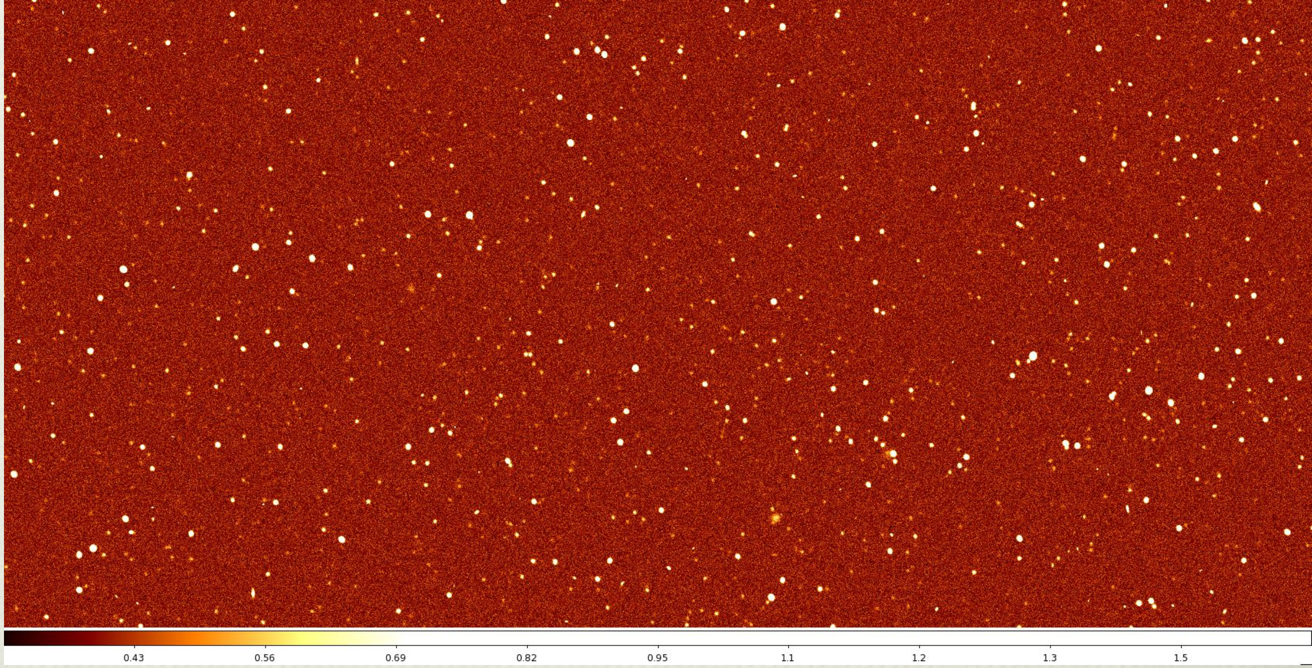
Simulation using only Luminosity Functions as Inputs

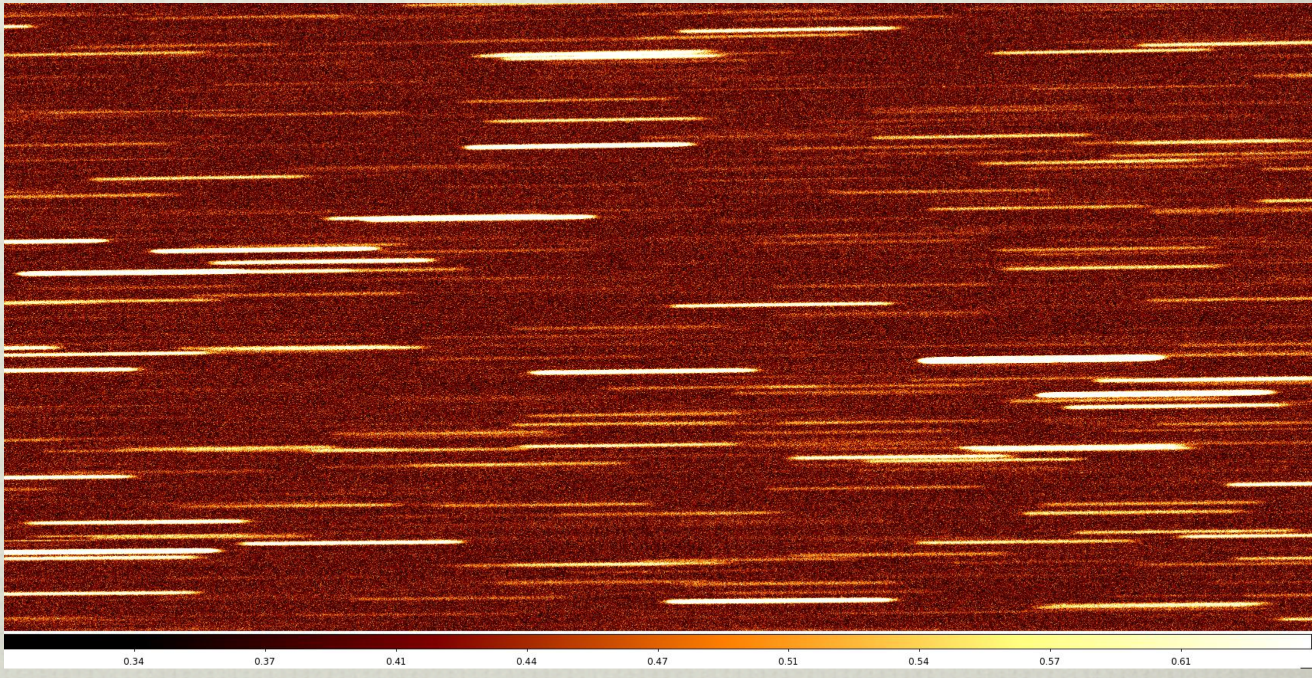
Roughly ⅓ of detector displayed.

350 s int. time (roughly planned time per frame).

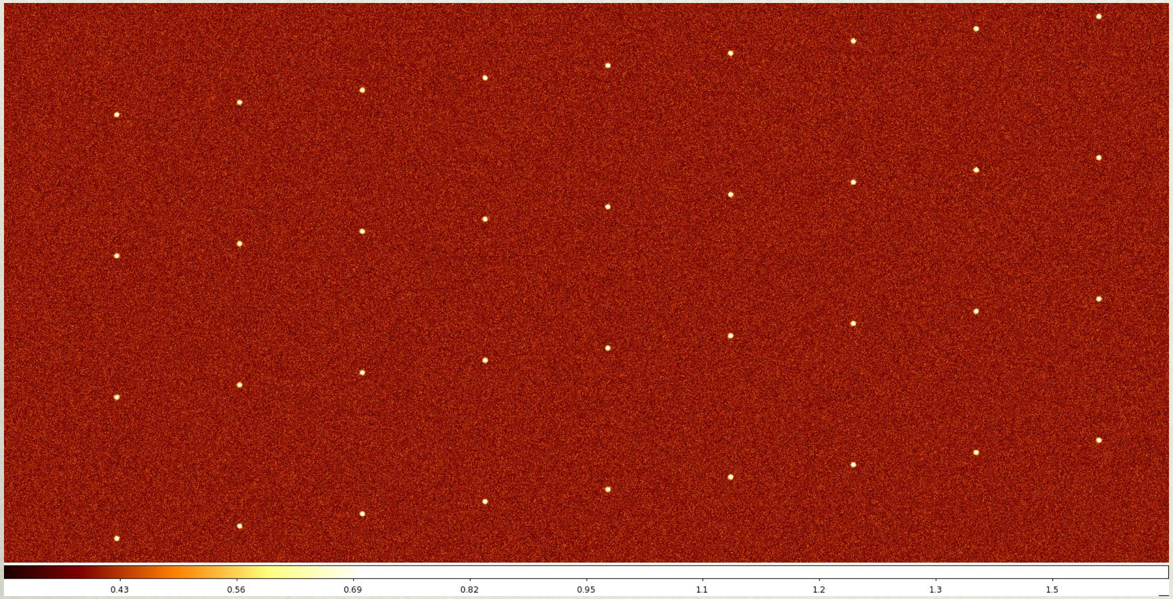


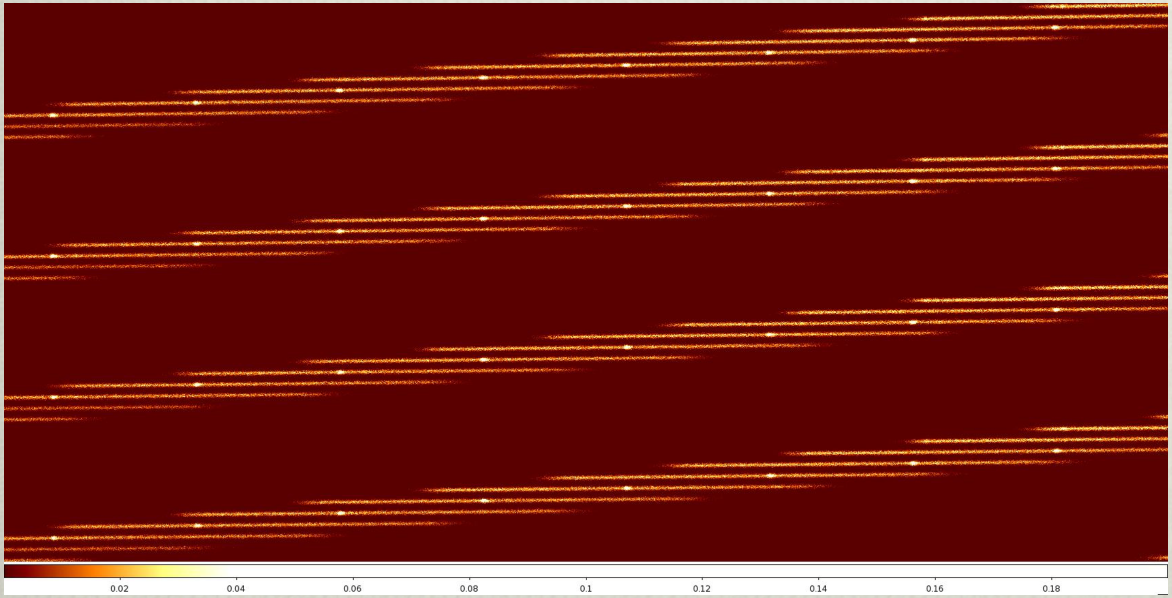






Exploring Parameter Space (Approach 3)





Early simulation, without background noise or background galaxies.

Set of galaxies with identical sizes, Ha line flux, and rest EW, distributed evenly in redshift space from z=0.95-2.1

Will be used to test line fluxes and wavelengths of spectral extractions.

The WFIRST Grism Simulation Group

STScI:

- Examination of planned HLSS observations: Exploring calibration, accuracy, and what might limit the ability to reach the desired density of sources.
  - *Slitless Grism Spectroscopy with WFIRST: Observing Modes and Strategies*
- Study of how accurately wavelength and position can be determined from spectral cut-off of bright stars.
- LINEAR: Developed an algorithm for linear reconstruction of spectra that can take advantage of data taken at multiple dispersion angles.

GSFC:

- Deployed basic python line measurement tool, fitting the emission lines with Gaussians to measure their fluxes and redshifts.
  - Among many things, providing quality assurance for IPAC grism simulations
- Development and extensive testing of an automated line extraction tool.

What's Next

- **Expand methods by which we explore different regions of parameter space (galaxy size, redshift, line flux, EW, S/N, etc.).This involves not only generation of appropriate input lists, but more useful output products.**

- **Addition of stars based on Galactic latitude.**

- **Introduction of more realistic morphologies and general improvements to the simulations, e.g., more emission lines, more variation in line ratios, better reproduction of galaxy sizes.**

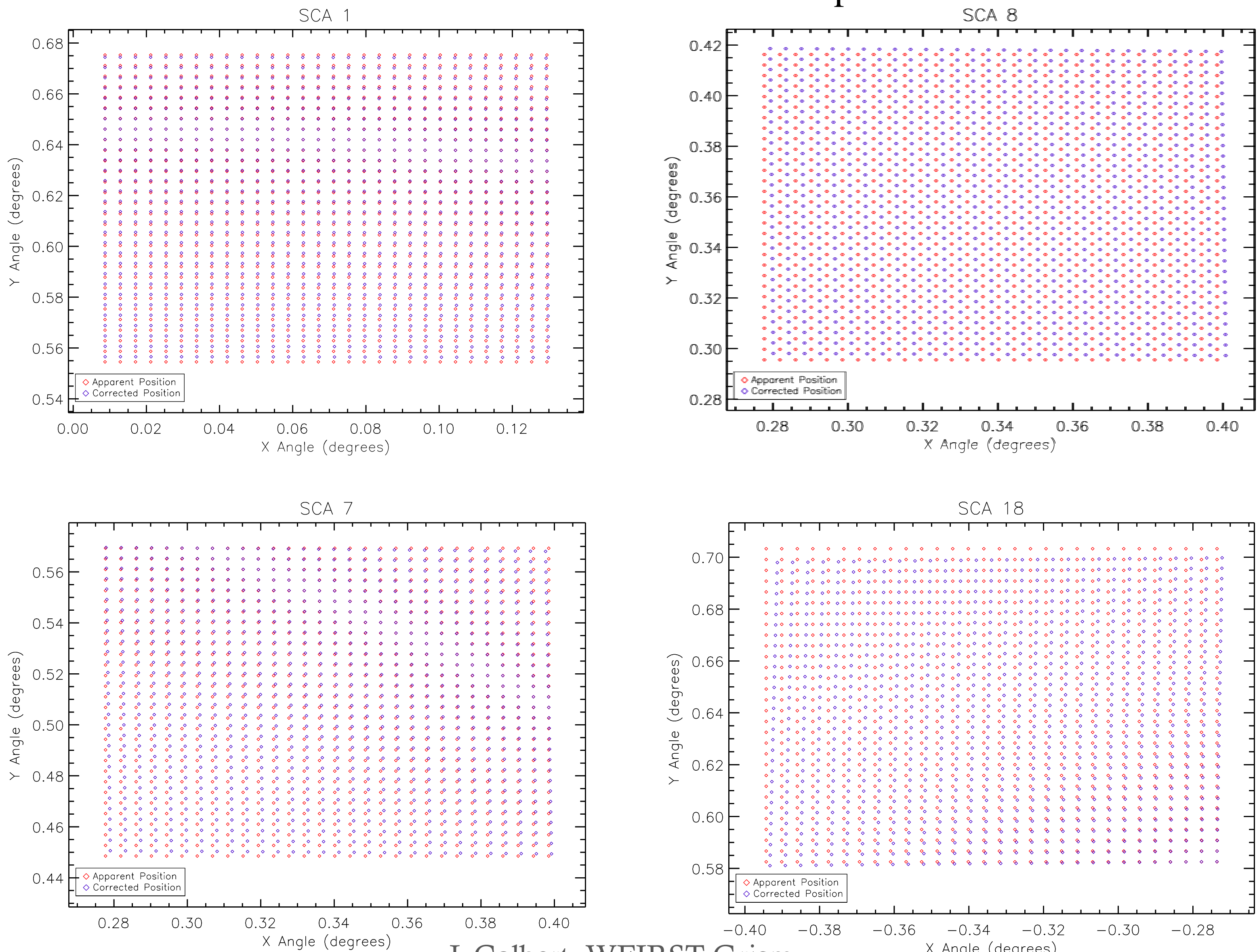
- **Addition of cosmic rays, including the transformation into sampling up the ramp and back again**

Summary

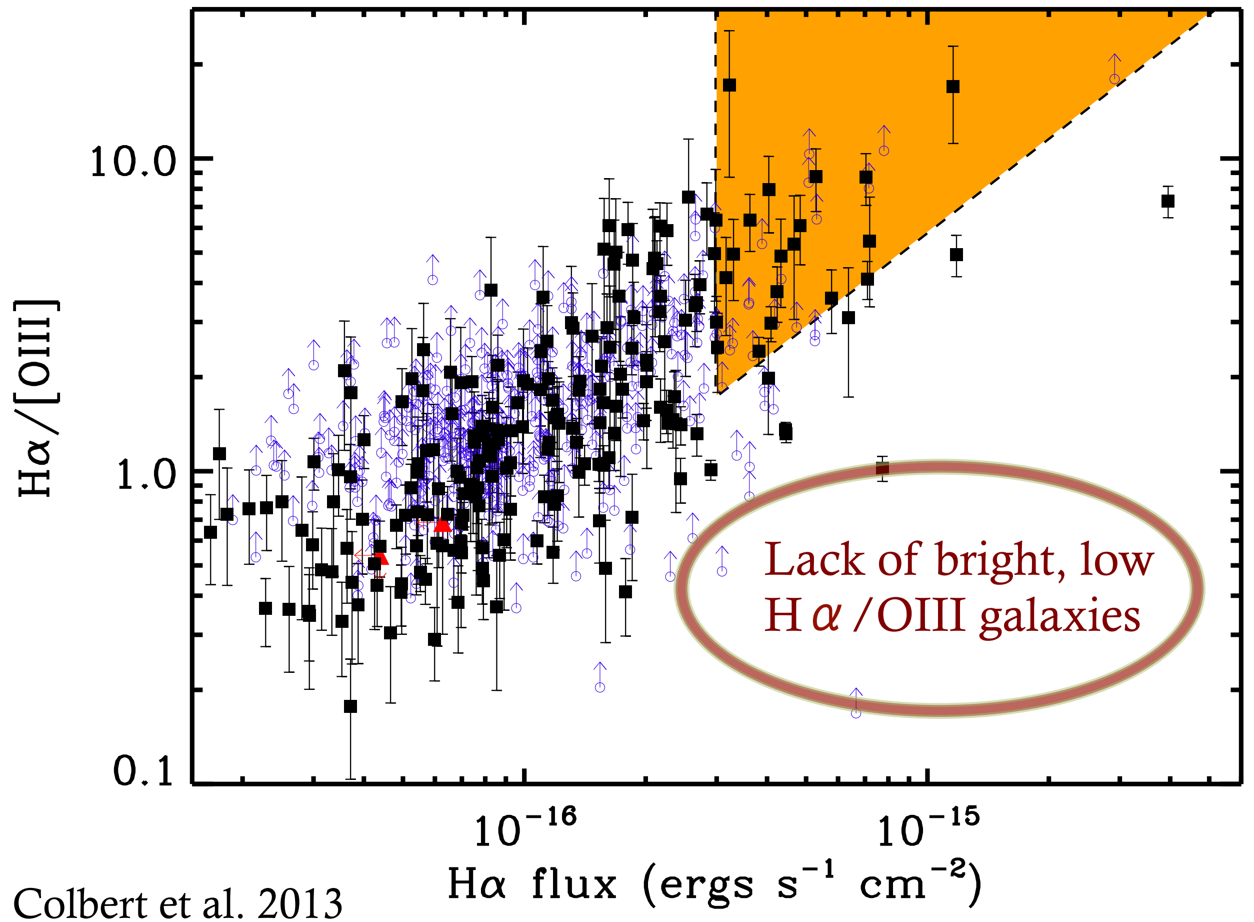
- WFIRST Science Center (IPAC, STSci, Goddard) has an active grism simulation group
  - Presently with instructions to continue at least through the end of Phase A
- Can produce simulations based on
  - List of real galaxies
  - Based on luminosity functions (like those published for WISP survey) and other parameter distributions
  - Variation of any parameter (e.g., line flux, EW) to test any observing modes, mission designs, or strategies

Examples of Distortion and Offsets For Four Detectors

Used to derive SIP distortion coefficients for output simulation files



Two emission lines likely to dominate survey : H α and [OIII]



Colbert et al. 2013

At >2x10^{-16} ergs s^{-1} cm^{-2} contamination from OIII for single line emitters will be low

Will likely become significant contaminant below 1x10^{-16} ergs s^{-1} cm^{-2}

Orange region: Predicted single emission line sources, assuming:
H α > 3x10^{-16} ergs s^{-1} cm^{-2}
OIII > 1.7x10^{-16}.