

# The Integral Field Unit Spectrograph for WFIRST



**STScI** | SPACE TELESCOPE  
SCIENCE INSTITUTE

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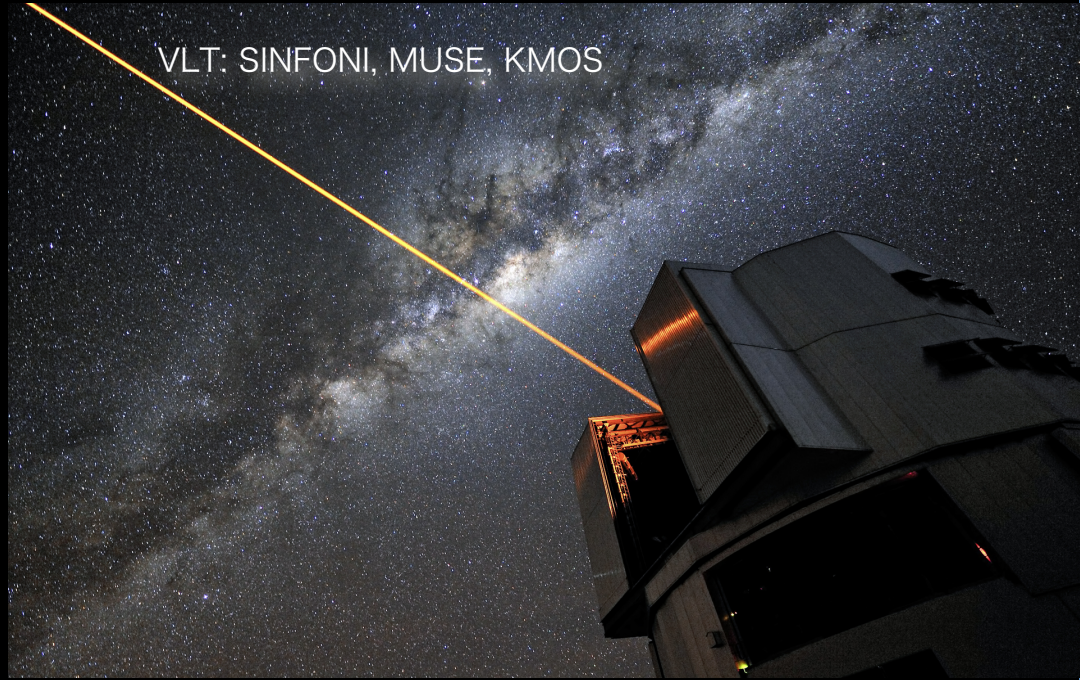
Image credit: NASA Goddard Space Flight Center/CI Lab



SDSS: MaNGA



VLT: SINFONI, MUSE, KMOS



Keck: OSIRIS



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AAT: SAMI

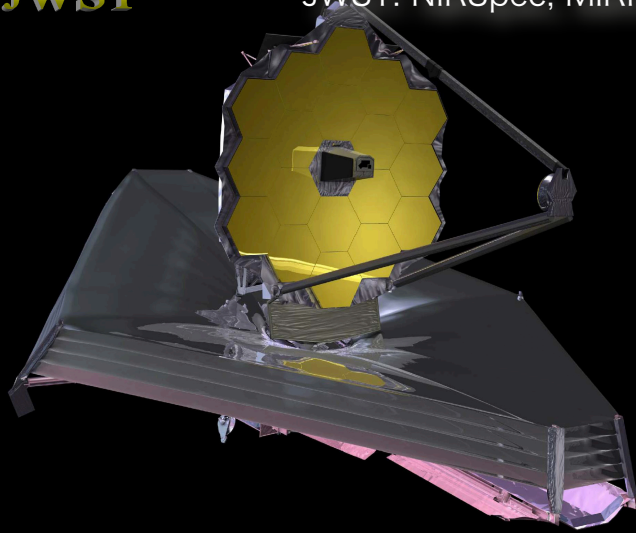


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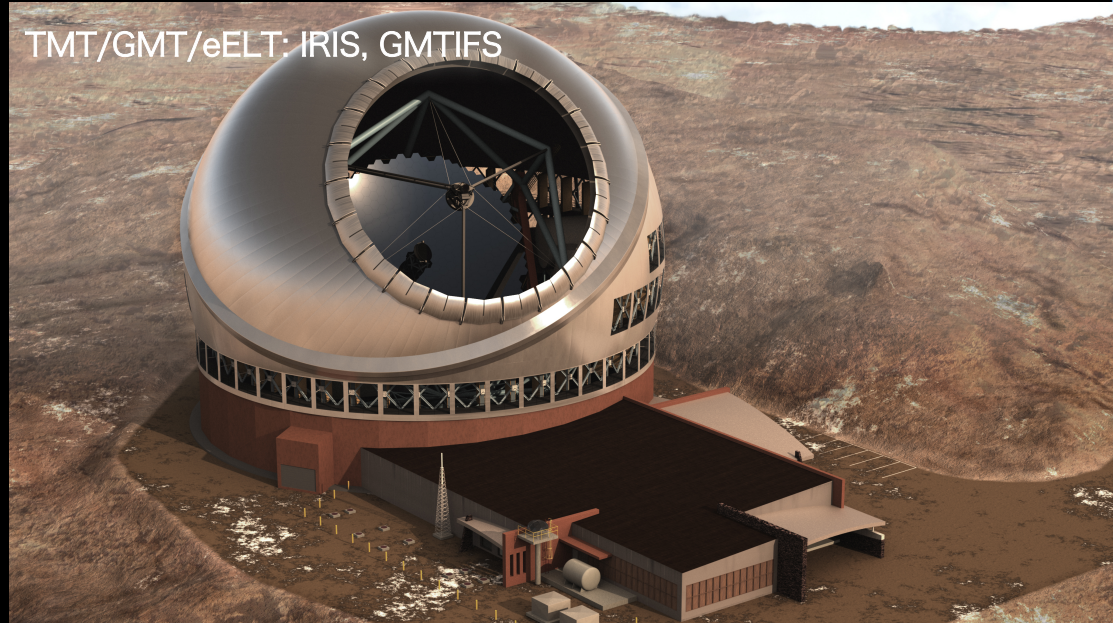


**JWST**

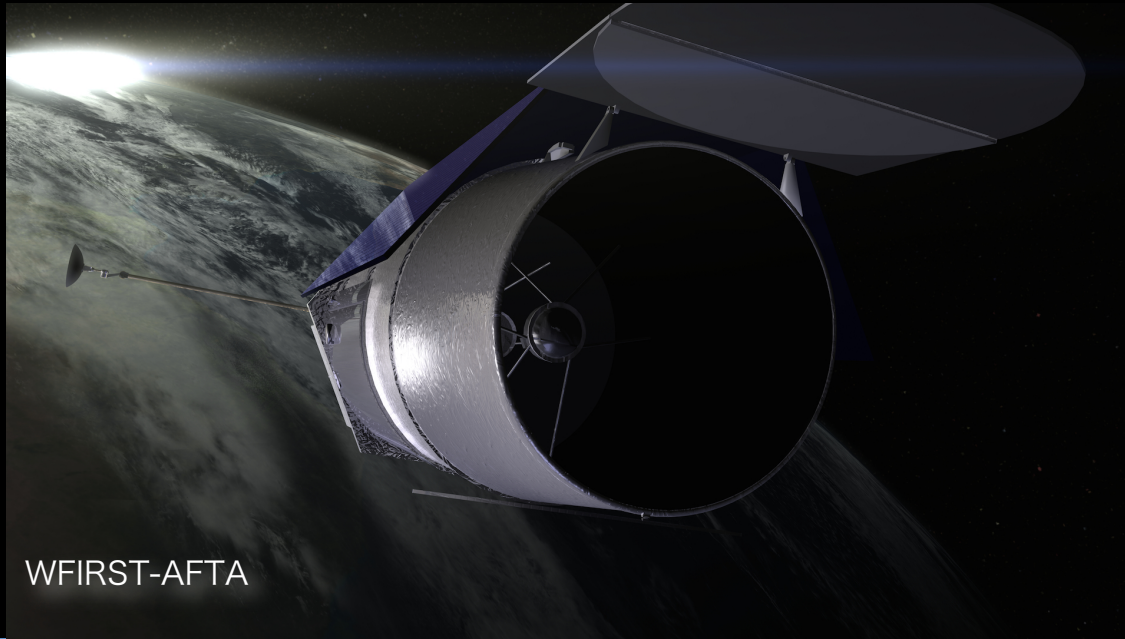
JWST: NIRSpec, MIRI



TMT/GMT/eELT: IRIS, GMTIFS



WFIRST-AFTA



Two dimensional original on-sky image



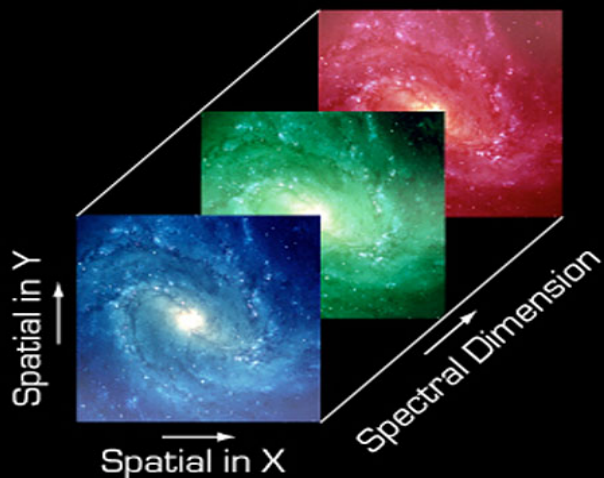
Optical slicing of the on-sky image



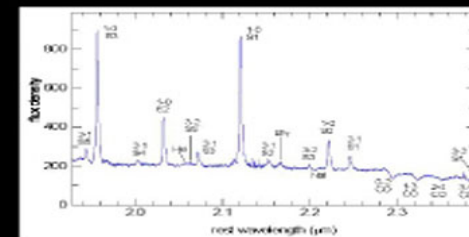
Spectral dispersion of the sliced image



Computer reconstruction of the 3D data cube



Spectrum of each 2D pixel



Computer reconstructed image

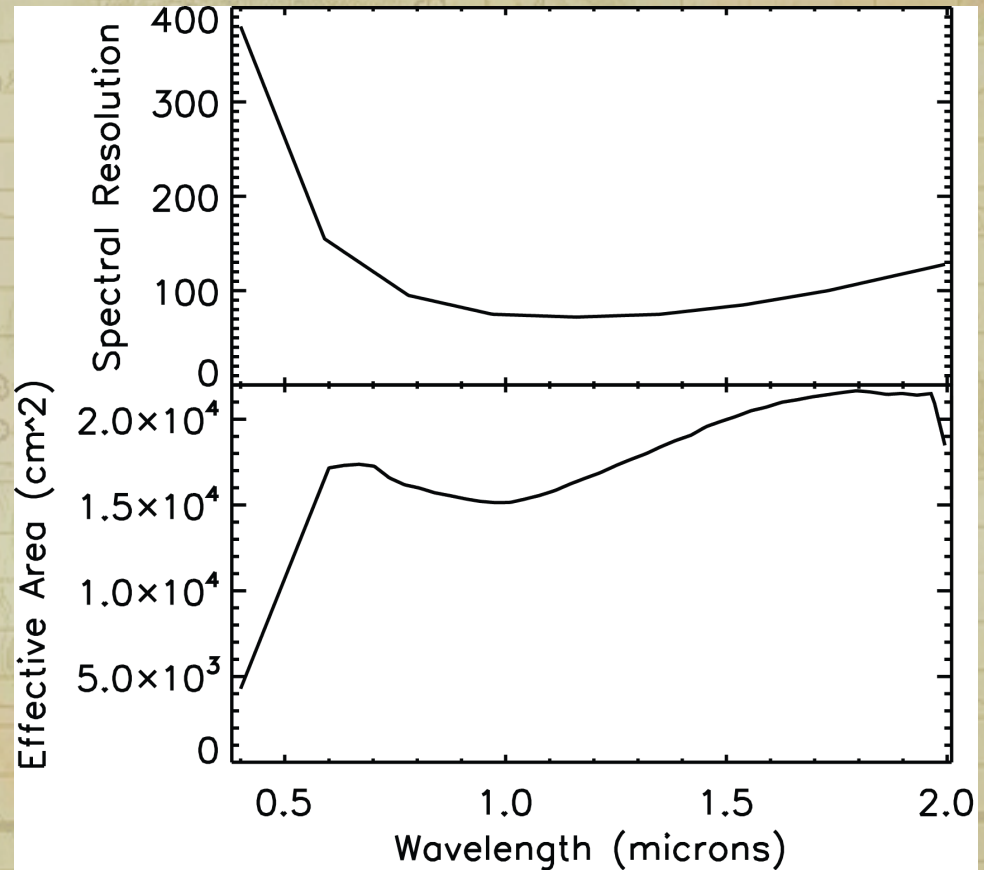


Image Credit: ESO



# WFIRST IFU: Overview

- Optical+NIR image slicer IFU
- Wavelength coverage 0.4 – 2.0 microns,  $R \sim 100$  from compound prism
- 21 slices at 0.15'' or 0.30'' per slice, 1-2 pixels per slice
- Critically sampled: 2 pixels per spectral resolution element (FWHM), H2RG
- 3.00'' x 3.15'' or 6.00'' x 6.30'' FOV



All subject to change



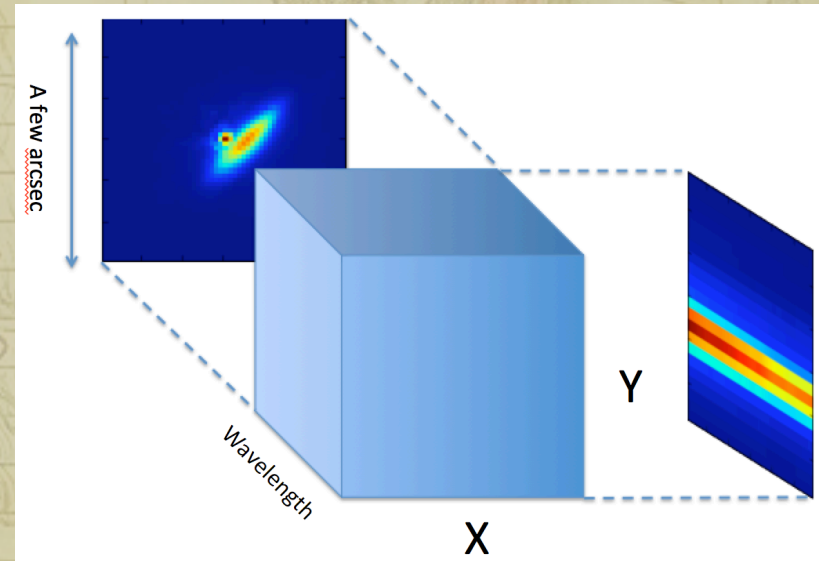
# WFIRST IFU Simulations: Pandeia ETC

- JWST will be supported by a new exposure time calculator.
- It is called Pandeia – after the Greek goddess of brightness.
- As part of the original concept, Pandeia was developed by the JWST project as a **multi-mission product**.
- Pandeia is 100% data-driven. A new observatory can be implemented by modifying a well-defined set of reference data.
- In development by a large team since 2012. WFIRST reps: Klaus Pontoppidan, Tim Pickering



# Pandeia Operational Concept

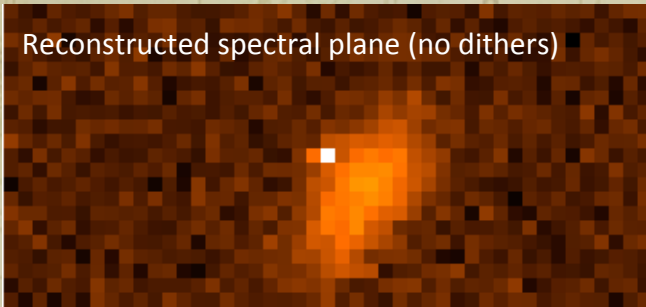
- Focus on calculating accurate signal-to-noise ratios of astronomical observables.
- Detailed scene creation for broad science cases
  - extra-galactic, galactic, stellar, etc.
- Full three-dimensional model
  - two spatial, one wavelength
- Detailed detector models with focus of IR CMOS types
  - including the HAWAII 2RG/4RG family
- Rapid parameter space exploration.
- Includes support for
  - Imaging, slitless spectroscopy, IFU spectroscopy, coronagraphy and more.
- Full version-controlled and documented development piggy-backing on the JWST ETC project





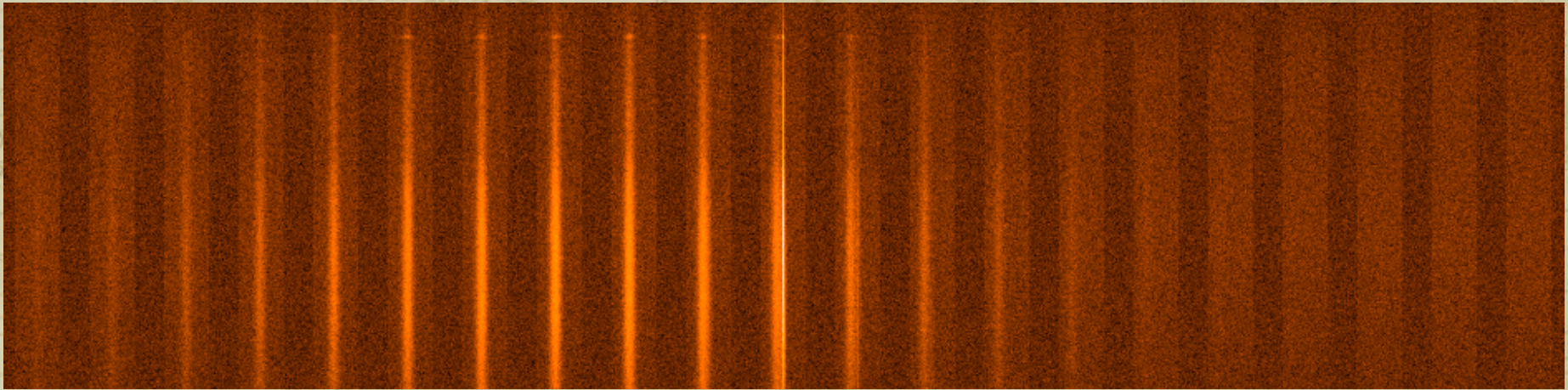
# Sample Pandeia IFU simulation

Reconstructed spectral plane (no dithers)



Example of a Pandeia/WFIRST calculation for one of the potential IFU designs (designs can be revised in seconds).

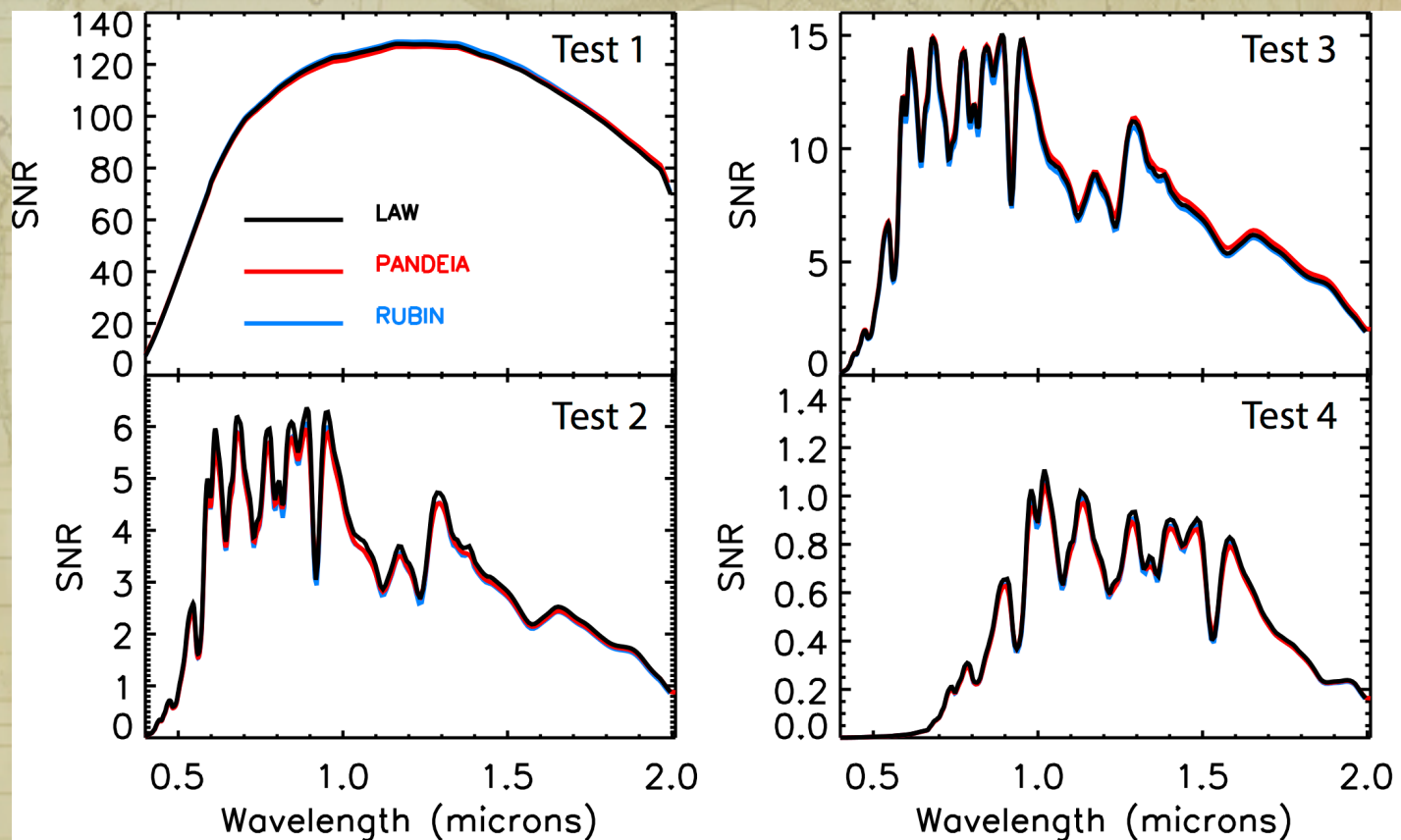
- Galaxy + point source (point source normalized to  $2.2 \mu\text{Jy}$  at 0.556 micron).
- 0.15" pixels, 1 pixel per slice, 3" slice length.



- IFU development coordinated with K. Pontoppidan, D. Law, D. Rubin, J. Kruk and S. Perlmutter
- IFU implementation benchmarked against multiple simulation tools
- Reference data aligned with the latest official version of the WFIRST data



# Cross-calibration of Pandeia IFU simulations



Three simulation tools for cross-comparison

Pandeia: Developed for JWST, extended to WFIRST

D. Law: Developed for SDSS, extended to WFIRST

D. Rubin: Developed for SNIFS, extended to WFIRST

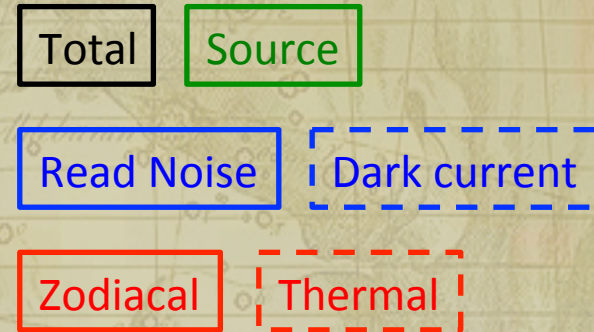
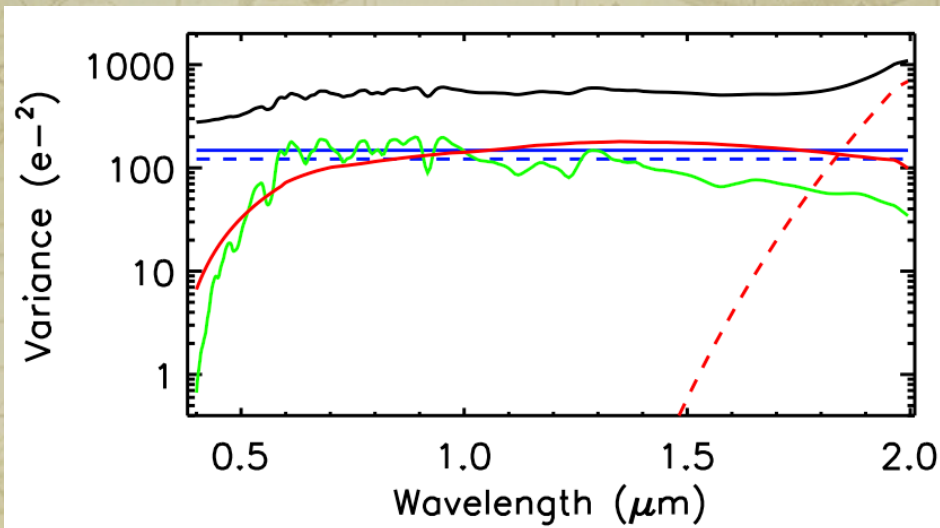
Test 1: High SNR blackbody

Test 2: Medium SNR  $z=0.5$  SN

Test 3: Dithered 2-exposure  $z=0.5$  SN

Test 4: Low SNR  $z=1.5$  SN

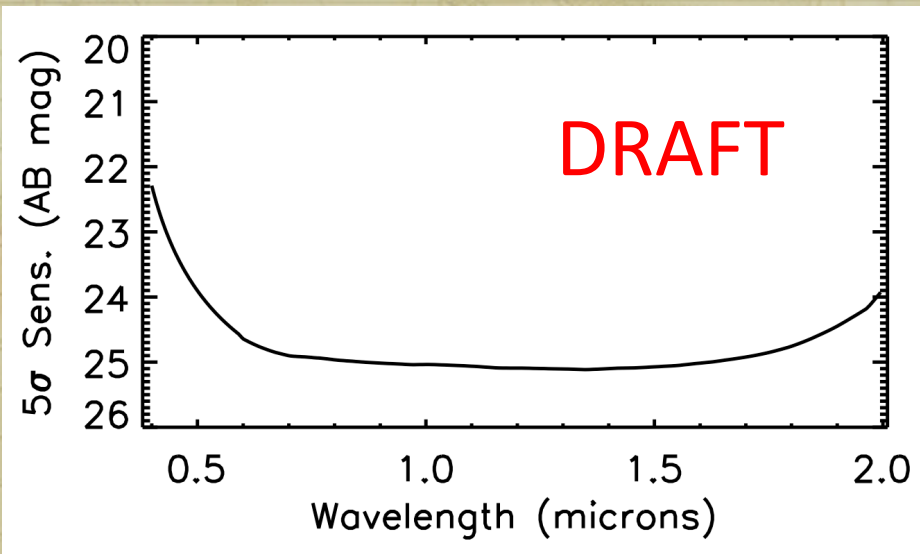
# IFU noise contribution and limiting performance



Relative noise contributions (Test3 simulation case)

Estimated limiting point source sensitivities:  $5\sigma$  in 1 hour, medium zodiacal background.

PSF-matched aperture extraction.





# WFIRST Supernova Survey

Baseline Survey Characteristics					
Survey	Bandpass	Area (deg <sup>2</sup> )	Depth	Duration	Cadence
Exoplanet Microlensing	Z, W	2.81	n/a	6 x 72 days	W: 15 min Z: 12 hrs
HLS Imaging	Y, J, H, F184	2000	Y = 26.7, J = 26.9 H = 26.7, F184 = 26.2	1.3 years	n/a
HLS Spectroscopy	1.35 – 1.95 μm	2000	0.5x10 <sup>-16</sup> erg/s/cm <sup>2</sup> @ 1.65 μm	0.6 years	n/a
SN Survey				~ 25 0.5 years (in a 2-yr interval)	5 days
Wide	Y, J	27.44	Y = 27.1, J = 27.5		
Medium	J, H	8.96	J = 27.6, H = 28.1		
Deep	J, H	5.04	J = 29.3, H = 29.4		
IFU Spec	7 exposures with S/N=3/pix, 1 near peak with S/N=10/pix, 1 post-SN reference with S/N=6/pix Parallel imaging during deep tier IFU spectroscopy: Z, Y, J, H ~29.5, F184 ~29.0				

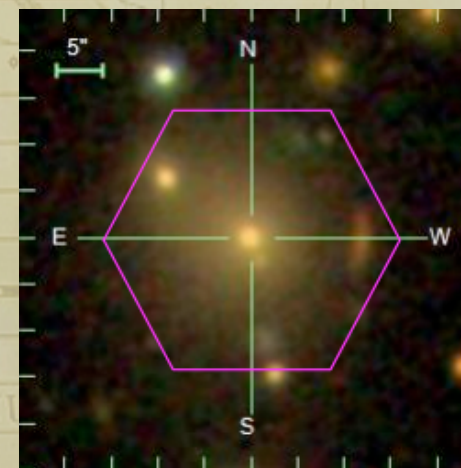
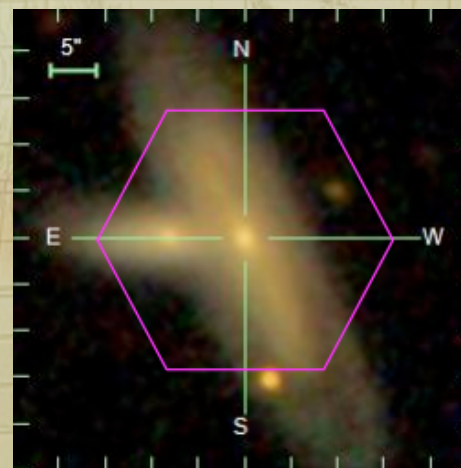
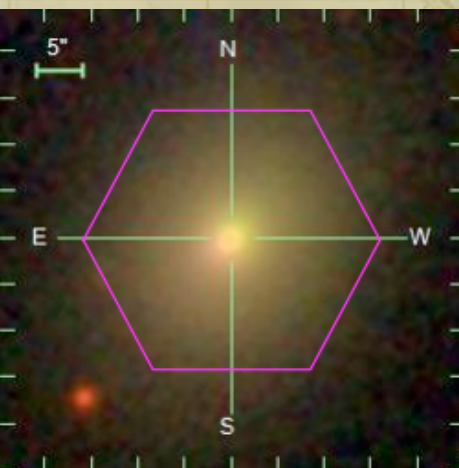
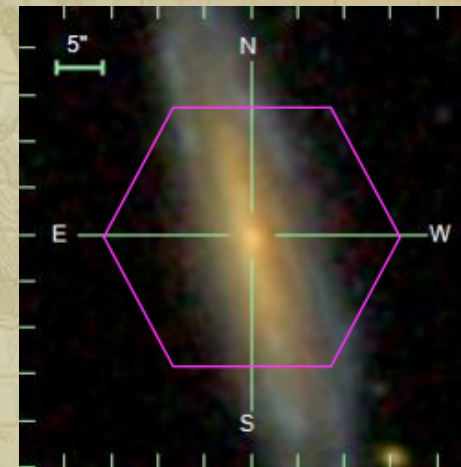
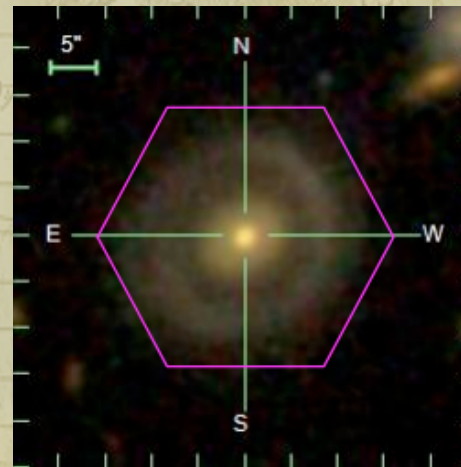
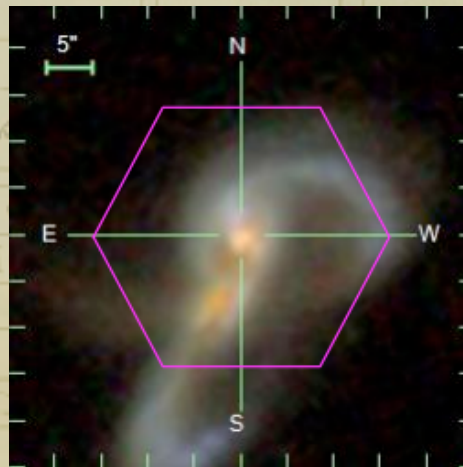
Baseline survey characteristics (from 2015 SDT report); see Foley talk, Rubin poster for details

IFU avoids K-corrections, better subtraction of host galaxy light, no slit losses

Simulate IFU observations of supernova plus host galaxy

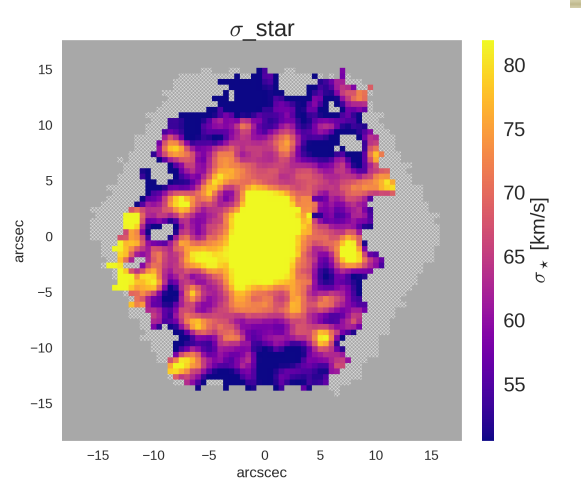
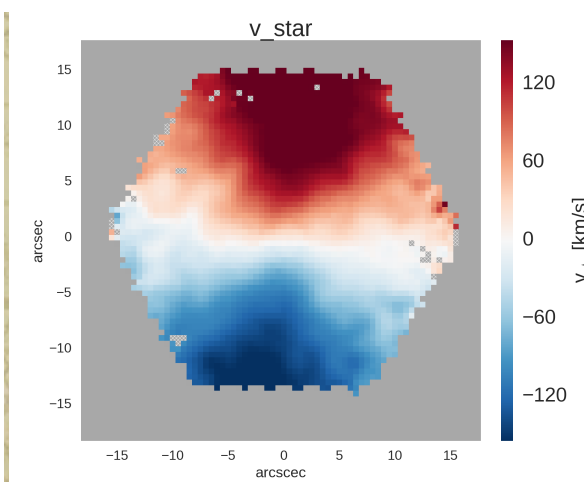
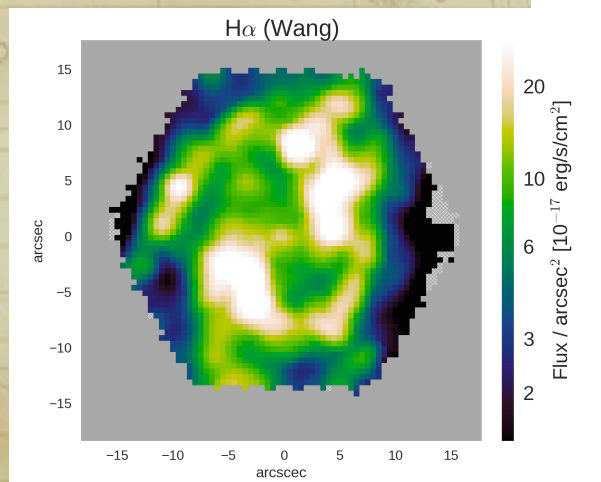
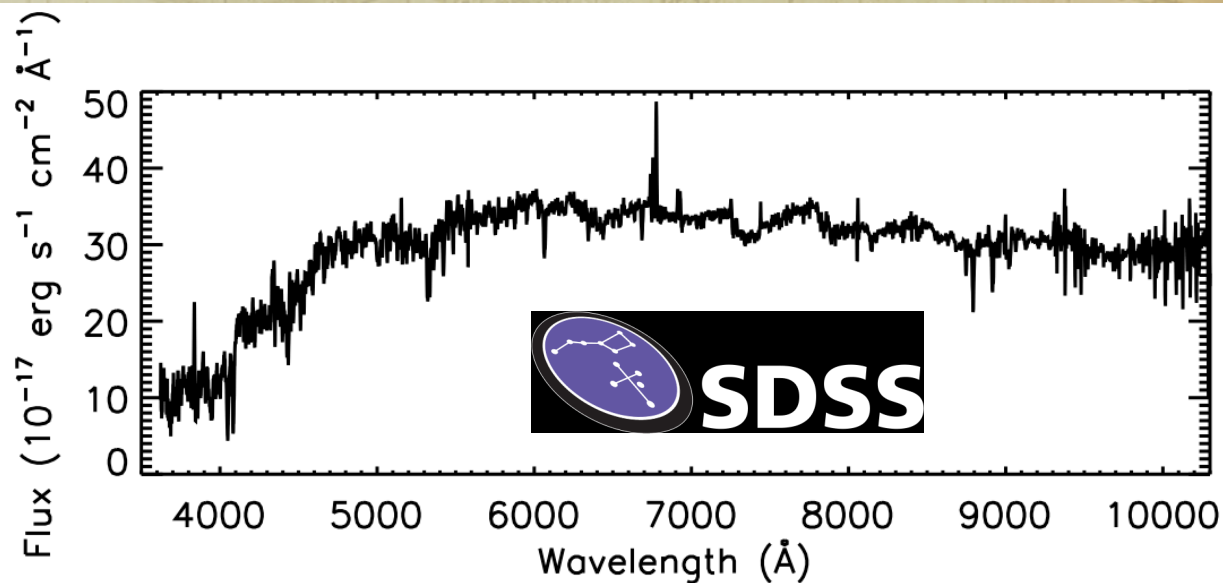
# Select a host galaxy from SDSS IFU library

Library of ~ 2000 nearby galaxies

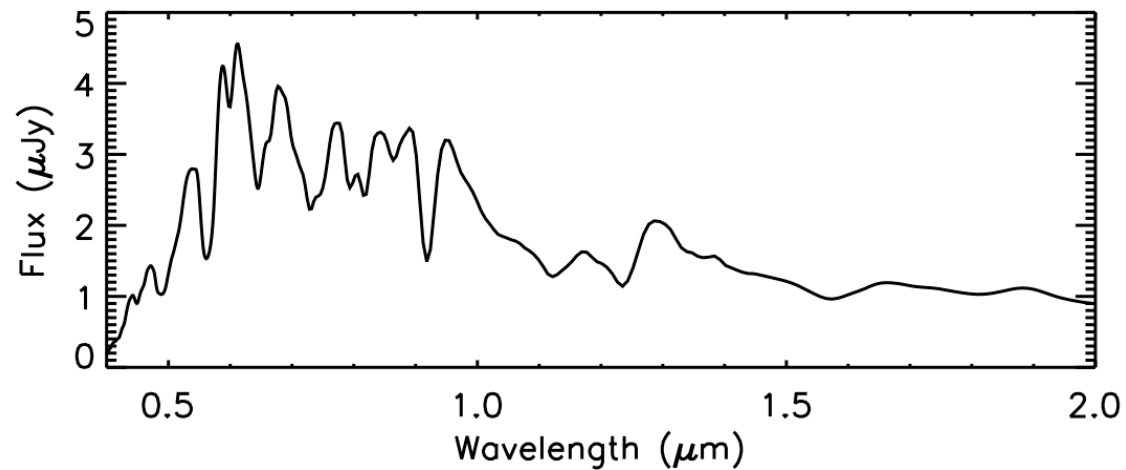
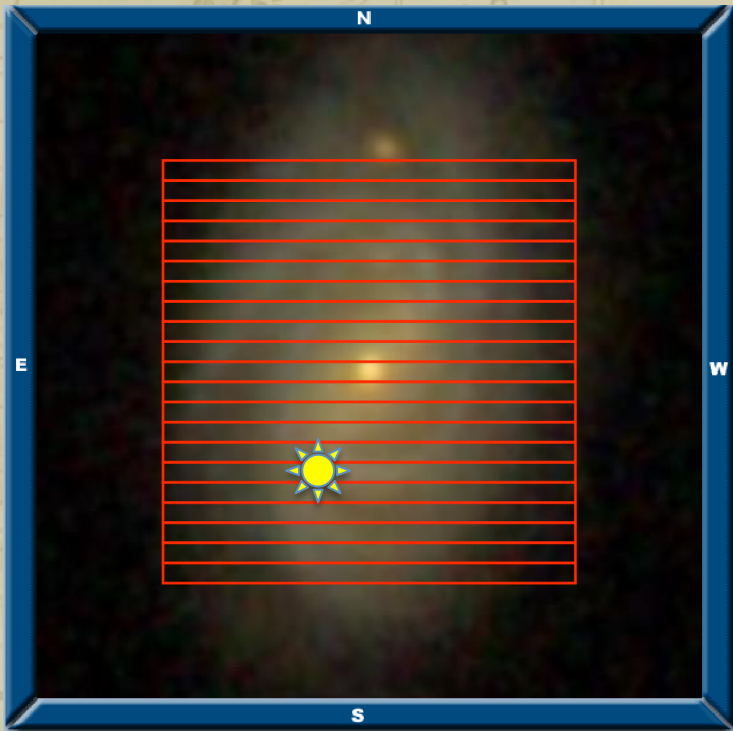




# SDSS Input Galaxy: MANGA 12-129618 (CGCG 161-122)



## Redshift to $z = 0.5$ , add a supernova

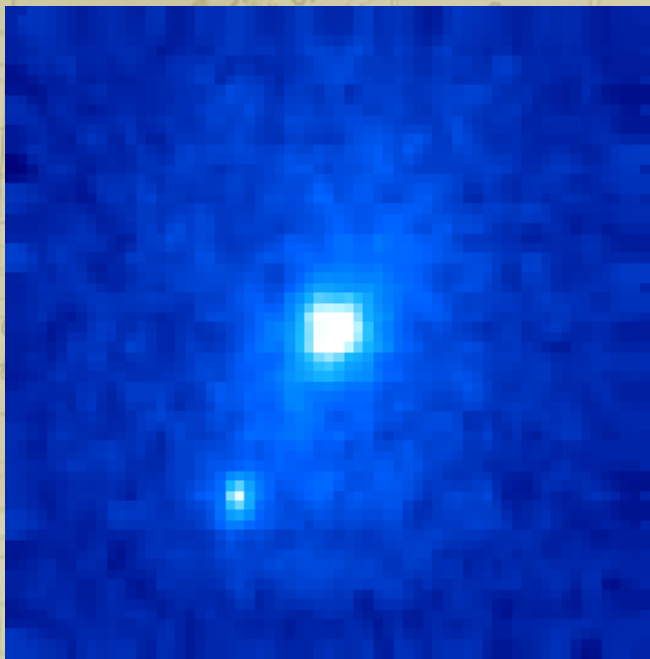


Input supernova spectrum: Hsiao Ia template

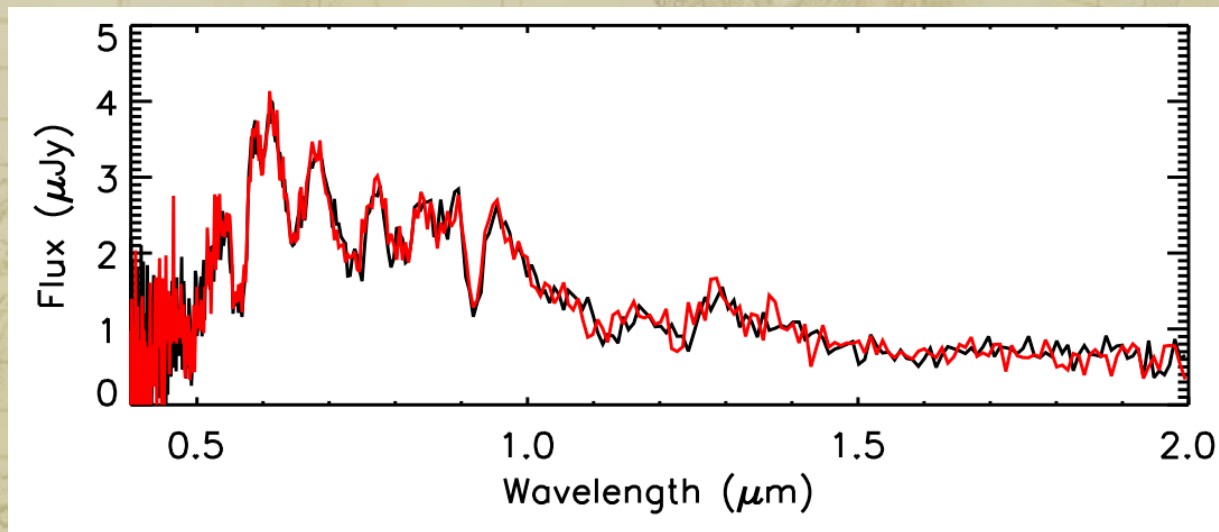


# Simulate WFIRST observations and data cube construction

4 dithered exposures, 1hr total integration time



Wavelength slice of reconstructed  
IFU data cube near 1.0 microns



Recovered SN spectrum after subtracting host galaxy  
for a SN far from/near galaxy center (black/red)

*(see also poster by David Rubin)*



# WFIRST IFU Science Cases

Current specifications driven by the supernova program

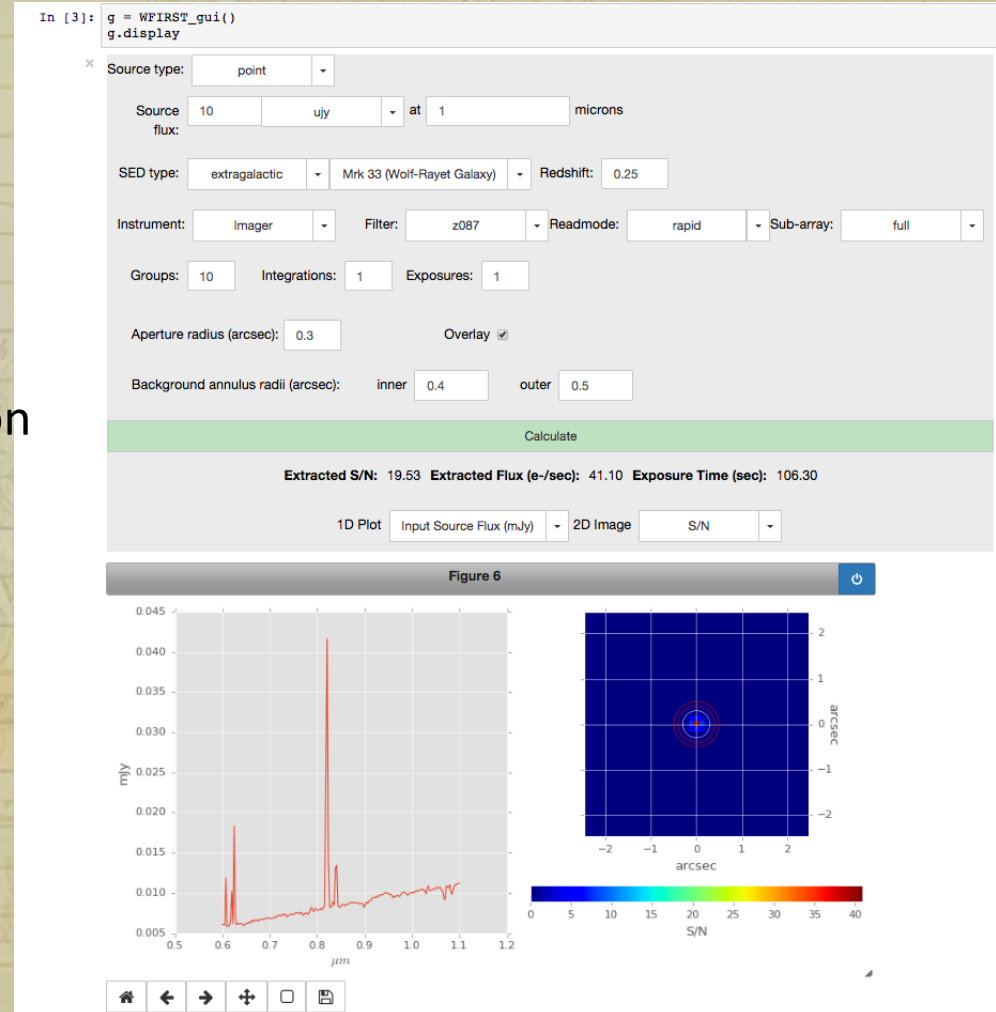
Other possible GO programs (from SDT report):

- Resolved stellar populations at high redshifts?
- Spectroscopic redshifts to calibrate photo-z?
- Exoplanet transit spectroscopy?
- Your idea here

Are there any other interesting use cases that should be considered during development? Increase FOV? Wavelength range?

# WFIRST IFU: Near Future Development

- First release (WFI imaging) of Pandeia-WFIRST now live
  - Webpage and information: <http://www.stsci.edu/wfirst/software/Pandeia>
- Ongoing Development
  - Add support and documentation for IFU calculations to the notebook GUI
  - Notebooks with example IFU calculations
  - Technical report on IFU simulations and sensitivities
  - Work with SIT to converge on final design specifications





# WFIRST IFU Development: How to Engage

IFU group has been having bi-weekly telecons since ~ April 2015, including STScI, IPAC, LBNL, GSFC, Pitt

Working group wiki page at IPAC:

[https://staffwiki.ipac.caltech.edu/WFIRST\\_Science\\_Support/IFU\\_Simulations](https://staffwiki.ipac.caltech.edu/WFIRST_Science_Support/IFU_Simulations)

(telecon minutes, reference files, early simulation results)

Formal IFU WG now formed (co-chairs Perlmutter and Law)

Contact us to get involved (dlaw@stsci.edu)