Future IFS Surveys: MaNGA
and
the separate formation of bulges & disks

Alfonso Aragón-Salamanca
Michael Merrifield
Evelyn Johnston

& the MaNGA team

Presentation credits:
Kevin Bundy, Renbin Yan
& Evelyn Johnston

MaNGA: Mapping Nearby Galaxies at APO

MaNGA

MaNGA Team: Over 250 members at more than 60 institutions

Management Team

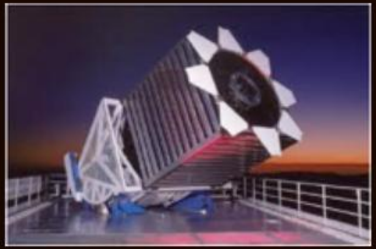
PI: Kevin Bundy
Survey Scientist: Renbin Yan
Instrument Scientist: Niv Drory
Chief Engineer/Proj. Manager: Nick MacDonald
Lead Data Scientist: David Law
SDSS-IV Project Scientist: Matt Bershady

Science Team Chair: Daniel Thomas
Sample Design Lead: David Wake
Lead Observer: Anne-Marie Weijmans
Deputy Lead Sample Design: Aleks Diamond-Stanic

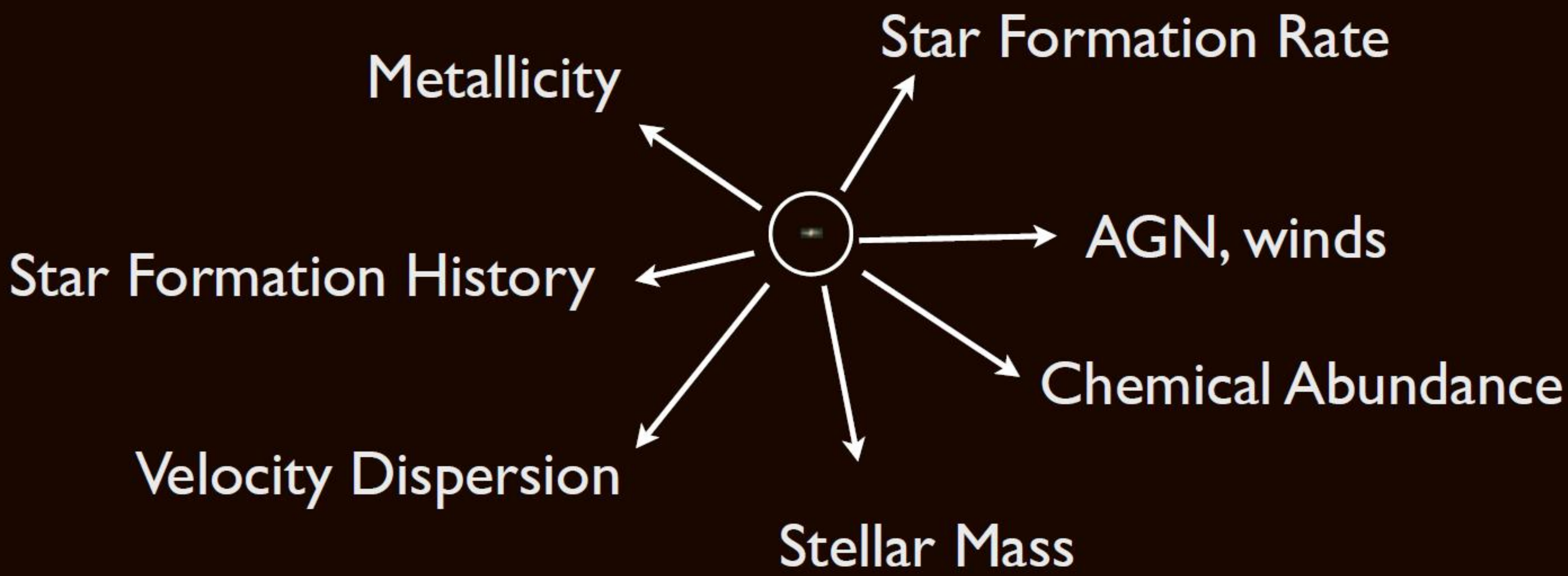
Composition Strategic Committee: Alfonso Aragon-Salamanca (Chair), Cheng Li, Roberto Maiolino, Christy Tremonti

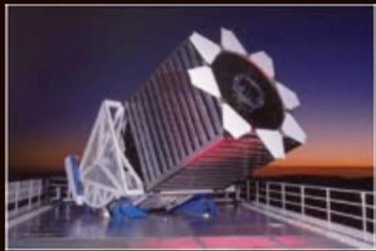
Kinematics Strategic Committee: Remco van den Bosch (Chair), Karen Masters, Mike Merrifield, Eric Emsellem

Data Products Committee: Sebastian Sanchez (co-chair)

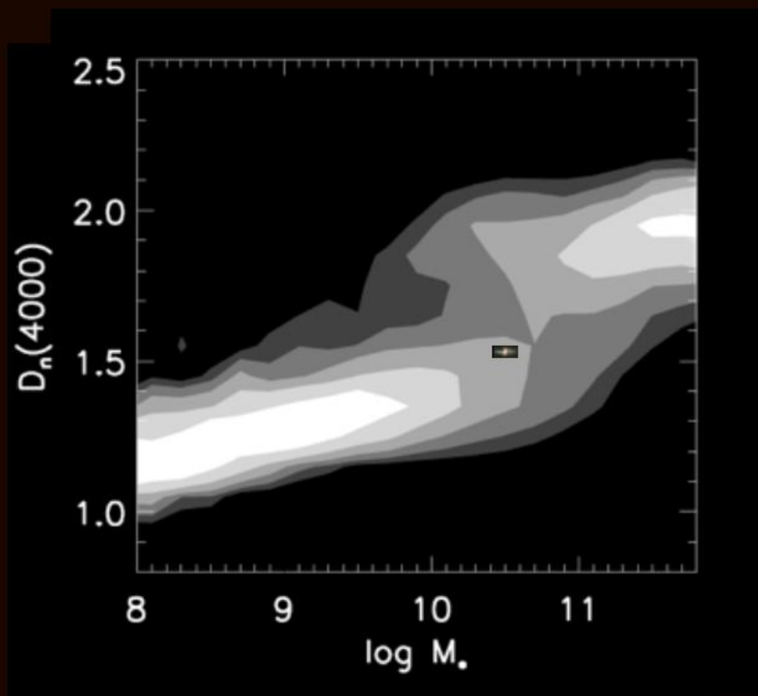


Spectroscopic Surveys (e.g. SDSS)

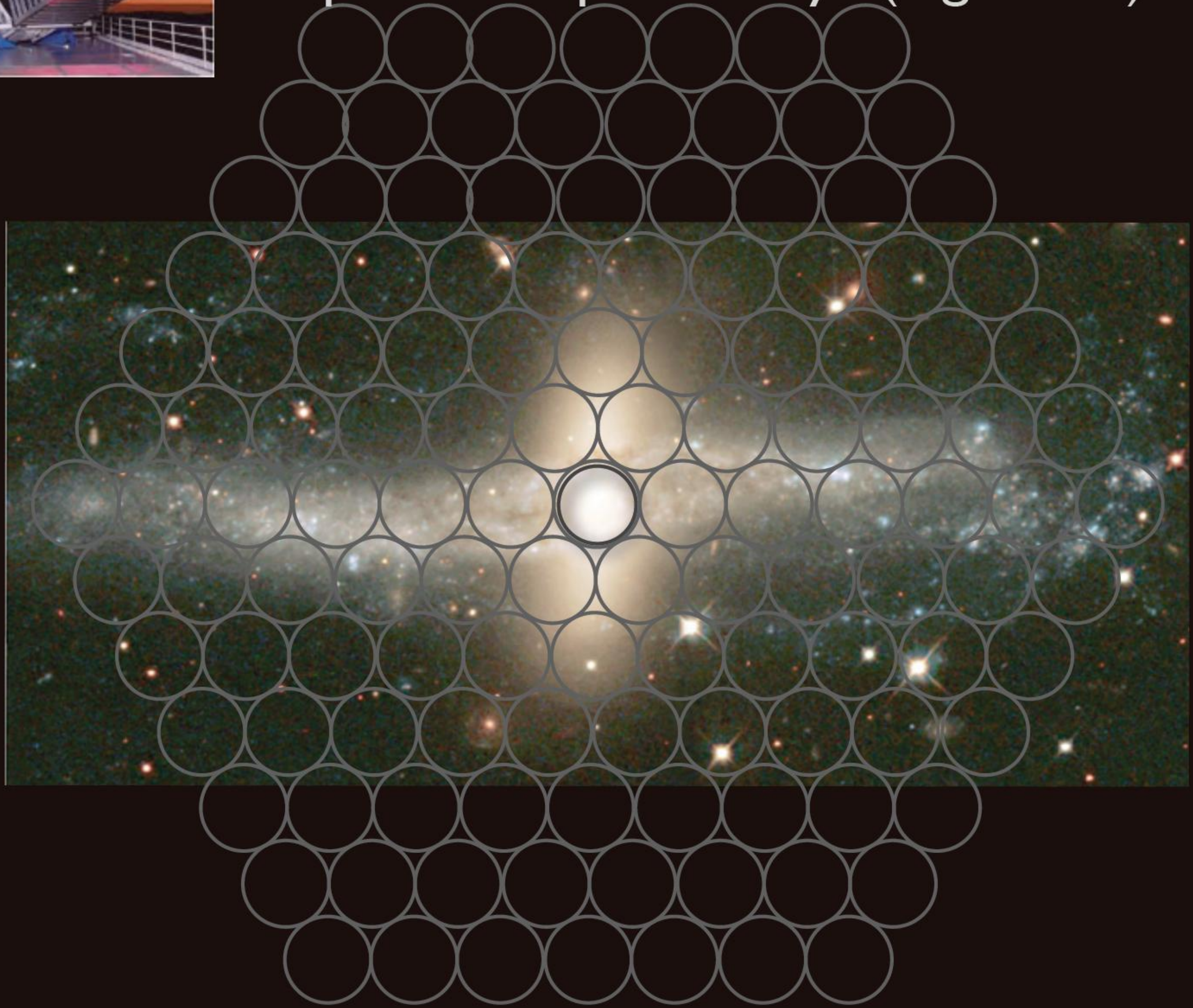




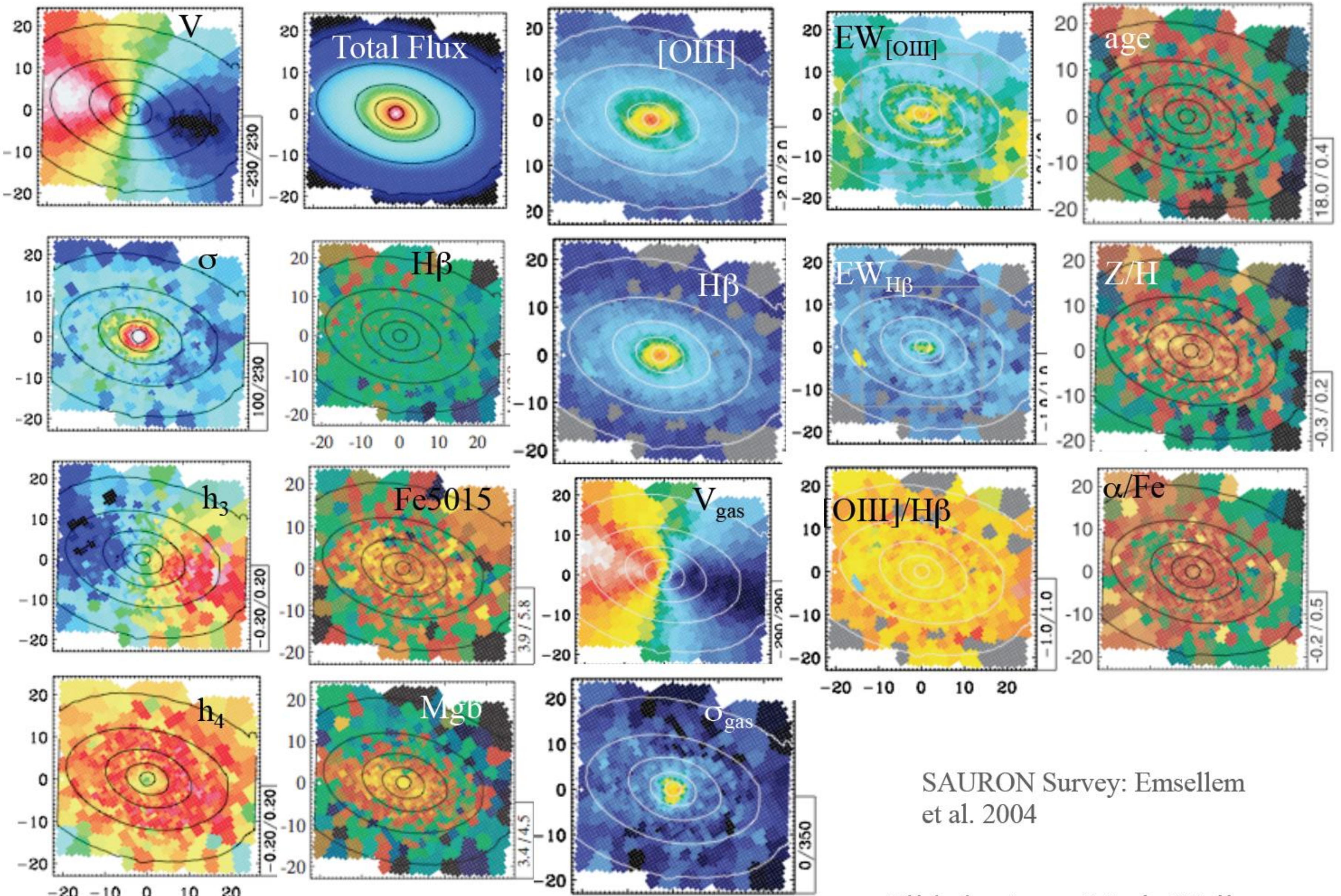
Spectroscopic Surveys (e.g. SDSS)



Spectroscopic Surveys (e.g. SDSS)



NGC 2974

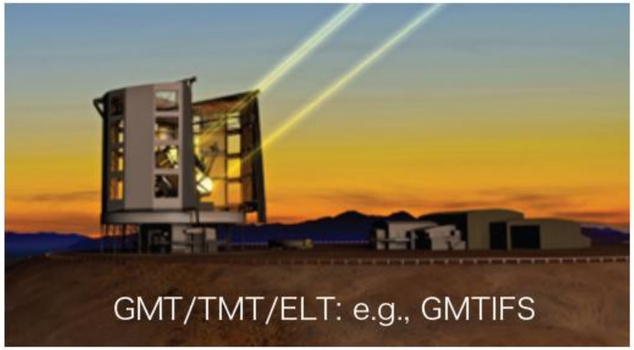


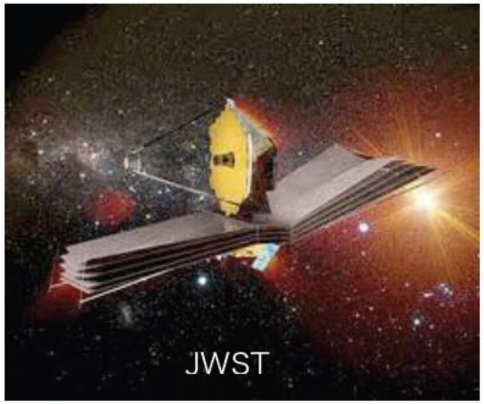
SAURON Survey: Emsellem et al. 2004

Slide by Anne-Marie Weijmans

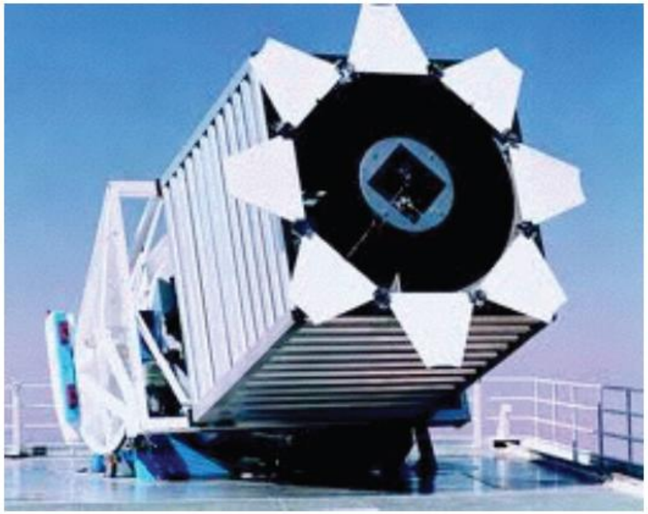
high-z landscape:

Era of high-z IFUs





We need a z=0 baseline for 2D spectroscopy

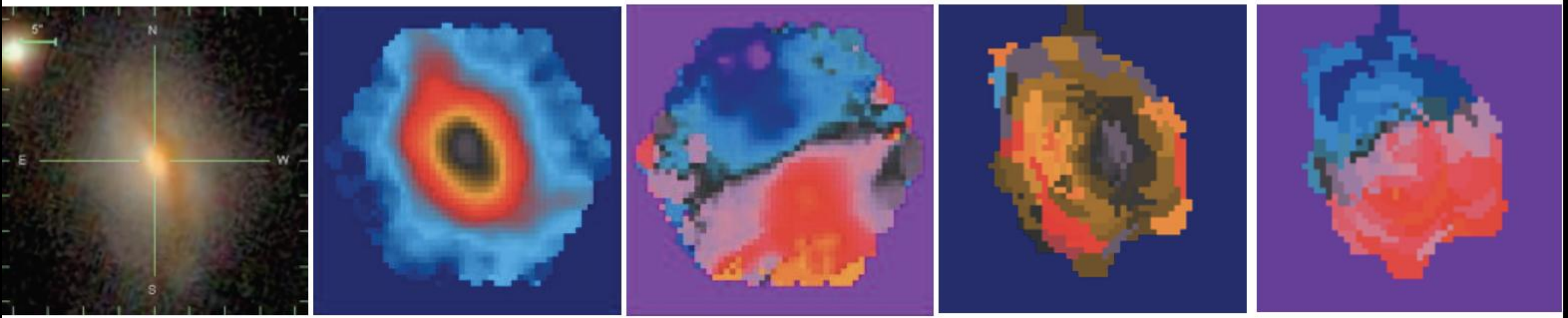


SAURON/Atlas^{3D}: 260 early-types
DiskMass: ~140 face-on disks
CALIFA (Calar Alto): 600 galaxies

SAMI at AAO: 3400 galaxies

completed or ongoing

MaNGA will survey10,000 galaxies



MaNGA Key Questions

LIFE

1. How does gas accretion drive the growth of galaxies?
2. What are the relative roles of stellar accretion, major mergers, and instabilities in forming galactic bulges and ellipticals?

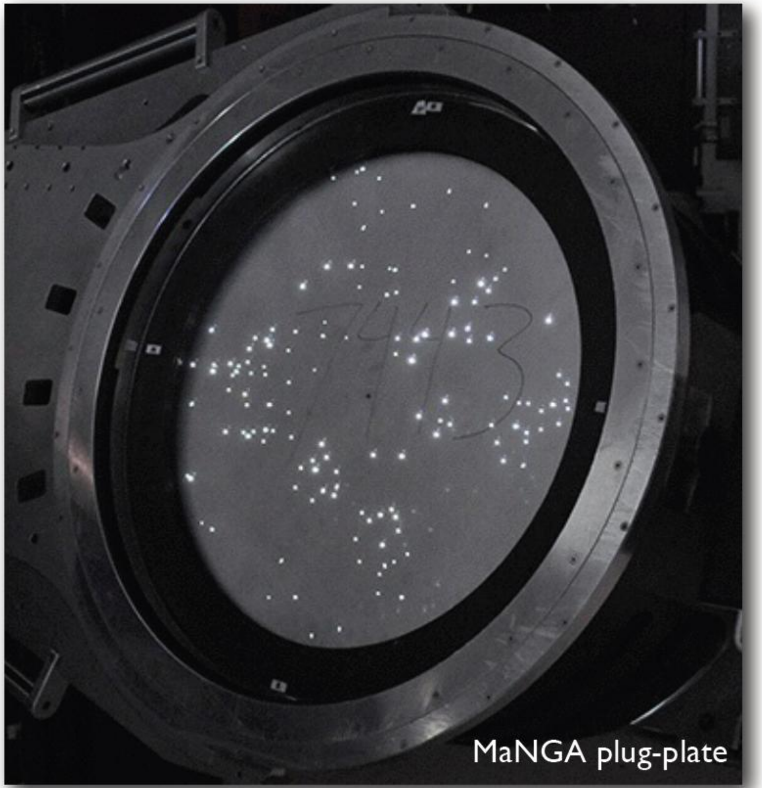
DEATH

3. What quenches star formation? What external forces affect star formation in groups and clusters?

BIRTH

4. How was angular momentum distributed among baryonic and non-baryonic components as the galaxy formed?
5. How do various mass components assemble and influence one another?

What is MaNGA?

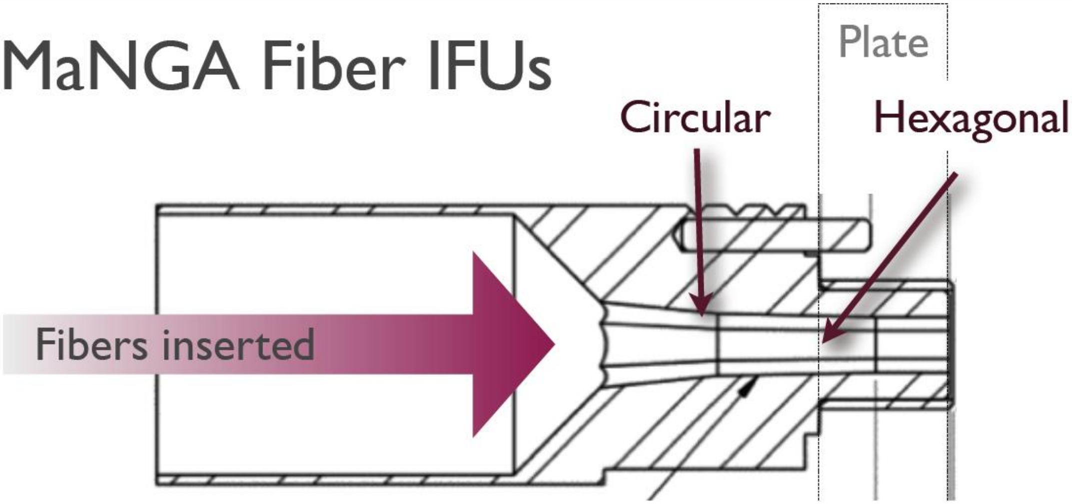


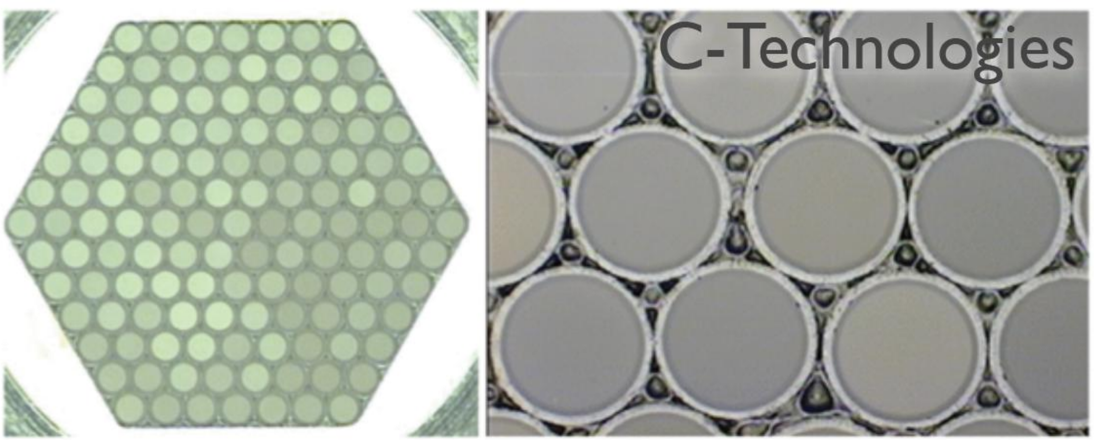
- SDSS-IV Dark time split with eBOSS
- MaNGA exploits the existing BOSS instrument (high throughput, pipeline)

- Bundle BOSS fibers to create 17 IFUs of various sizes
- IFU survey of ~10k nearby galaxies

image credit: D. Law

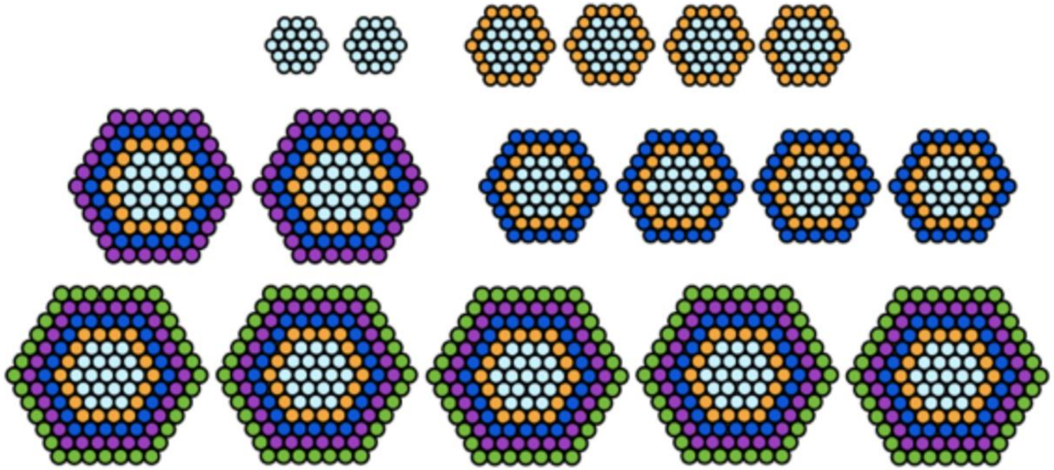
MaNGA Fiber IFUs





MaNGA bundles are more regular, but fibers are buffered

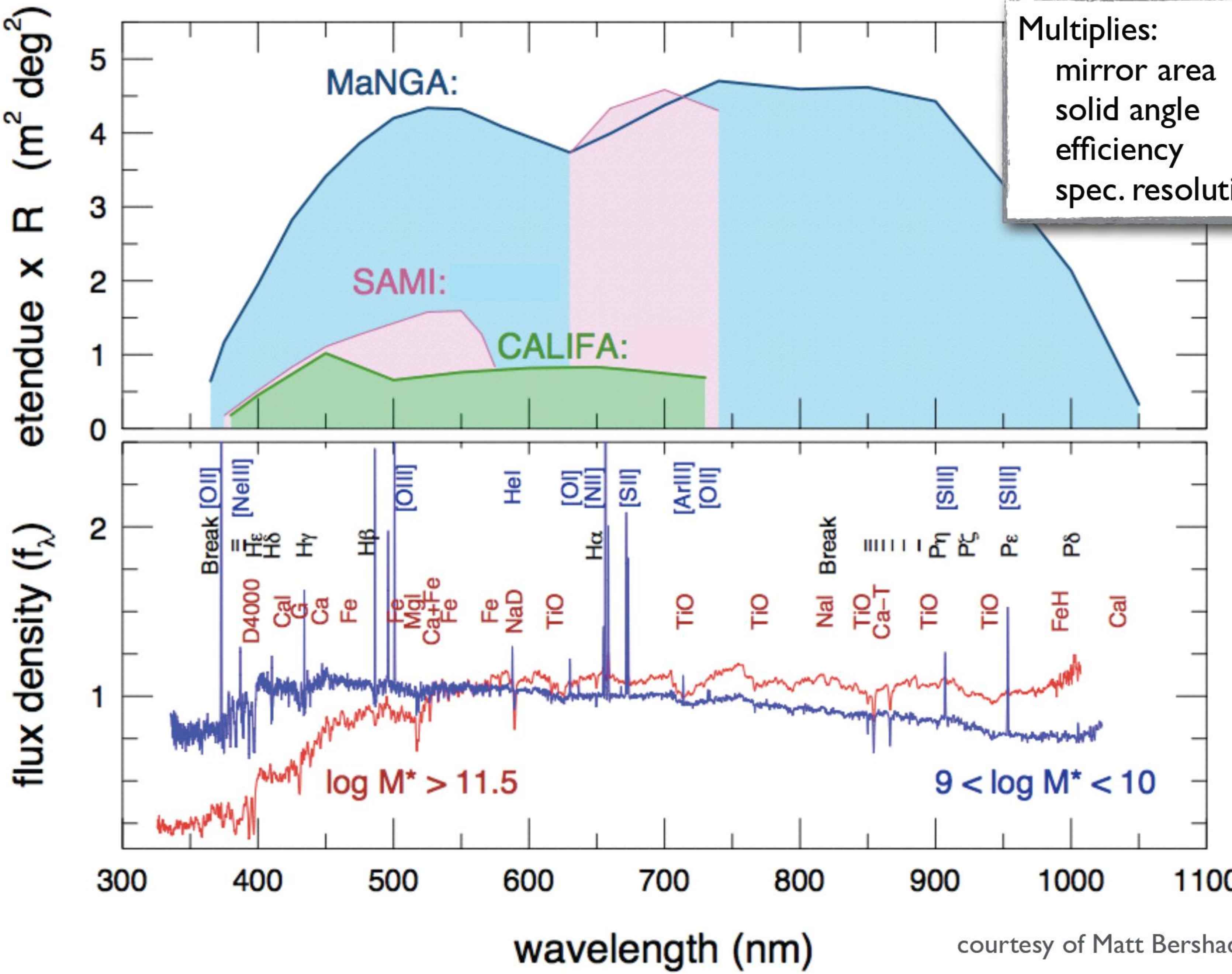
Hardware at a glance



IFU size distribution

6 cartridges
- 17 science IFUs per cartridge
- 12 "mini-bundles" (7-fiber) for calibration
- 92 IFU-associated roaming sky-fibers
- Total 1423 fibers per cartridge

MaNGA instrumentation "prowess"



Multiplies:
- mirror area
- solid angle
- efficiency
- spec. resolution

courtesy of Matt Bershady

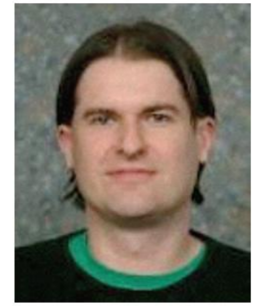
MaNGA Survey at a glance

2014-2020: 10,000 galaxies
140 galaxies per month

Spatial resolution = 2” (1-2 kpc)
Spectral resolution = 60 km/s (sigma)
S/N = 4-8 at 1.5 Re (~3 hours)

Volume-limited samples: log M_{star} > 9
Flat in stellar mass and color
Uniform radial coverage

Sample selection Requirements



David Wake

Aleks Diamond-Stanic

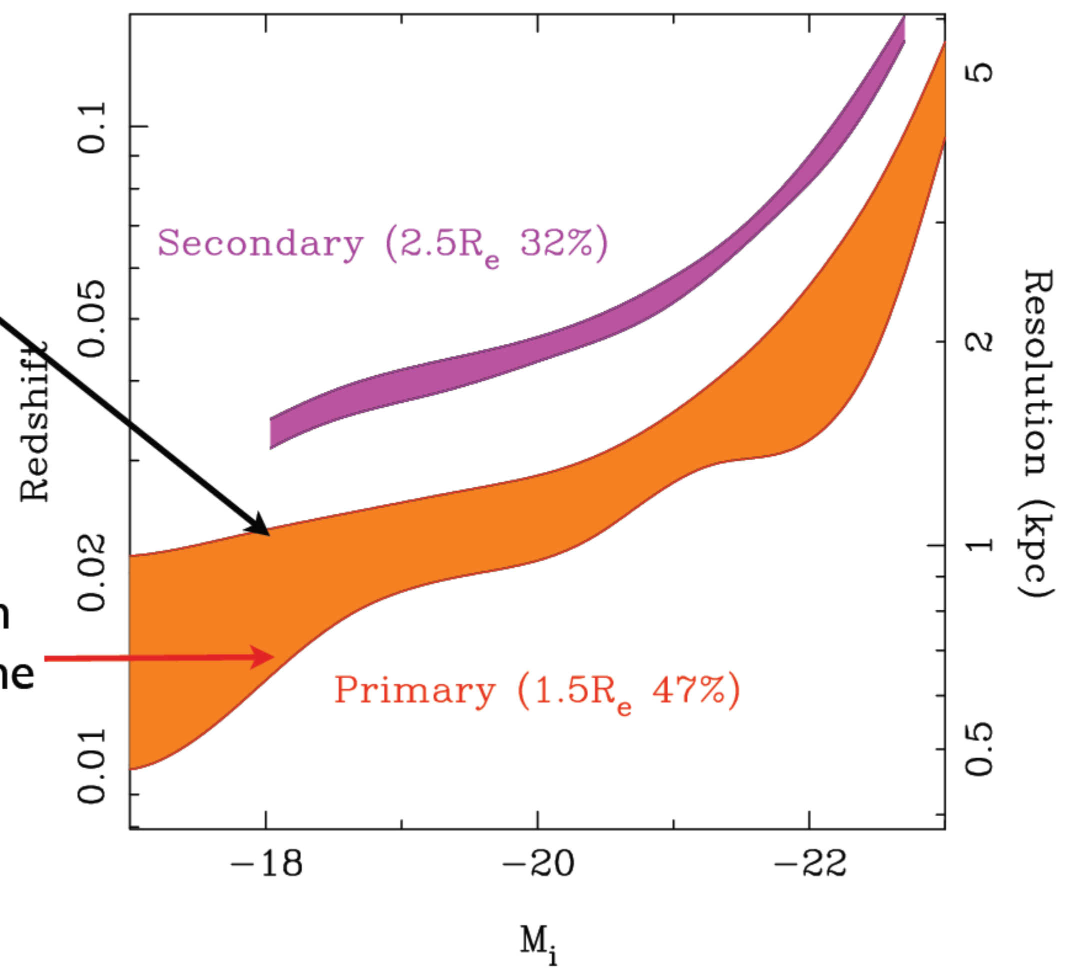
- Simple, reproducible selection
- Flat stellar mass distribution
- Uniform spatial coverage in units of R_e (1.5 or 2.5, major axis).
- Maximize S/N and spatial resolution.
- ~6000 to 1.5Re, ~3000 to 2.5Re

Main selection cuts

Maximize spatial resolution and yield a flat stellar mass distribution

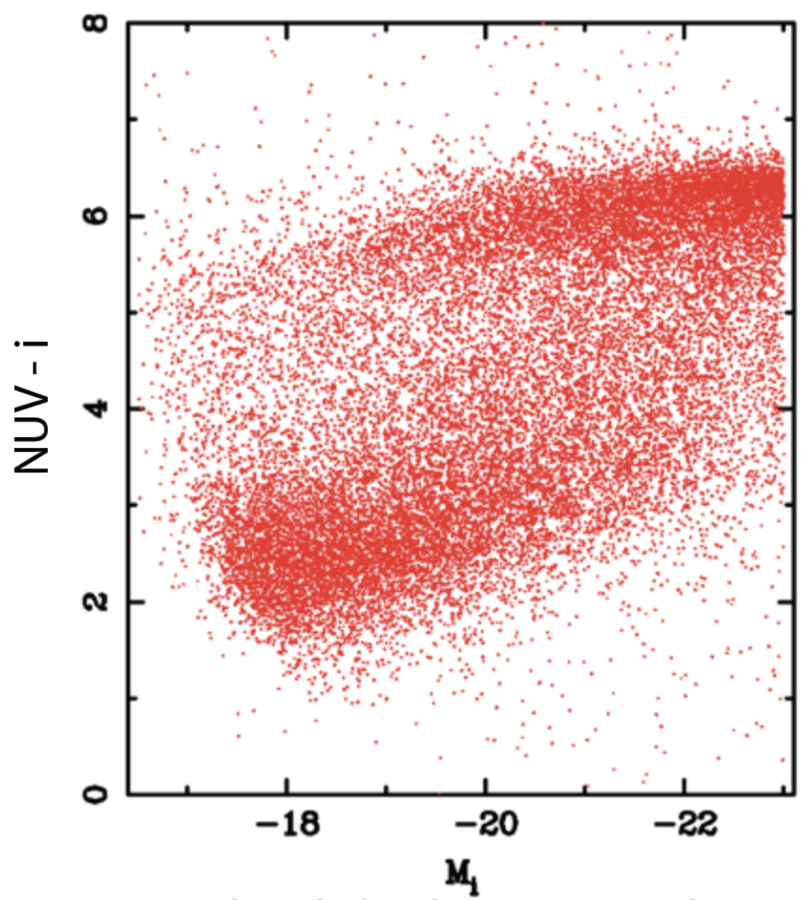
Push galaxies far enough so that they fit within the bundle

Galaxies selected from NYU VAGC and NASA-Sloan Atlas (Blanton et al.)



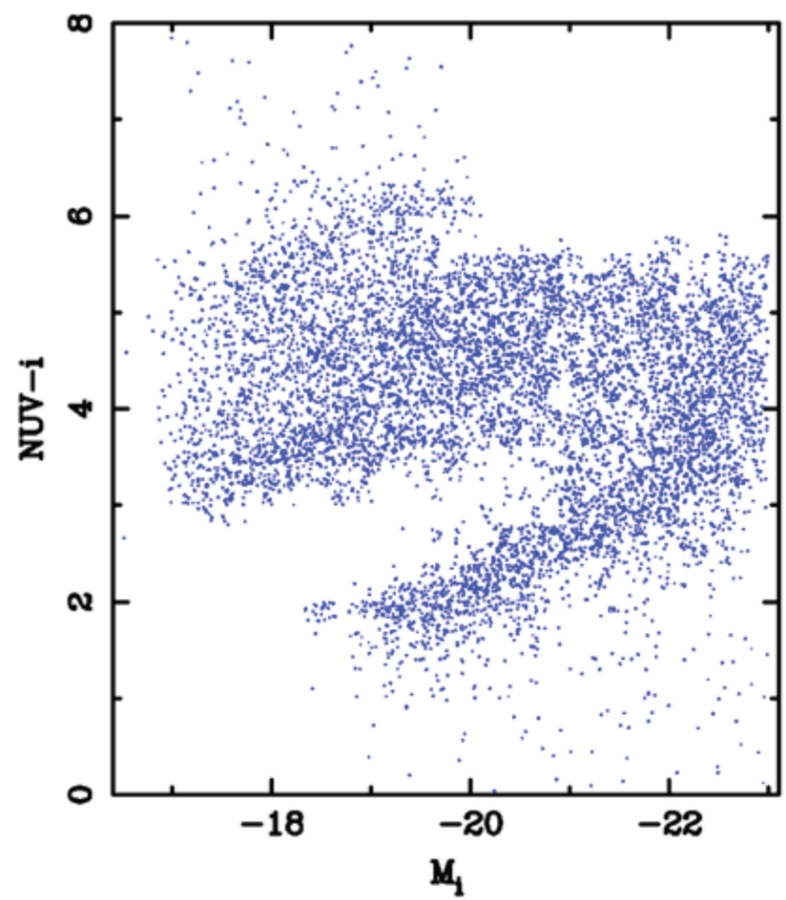
Color-enhanced Sample

Volume-limited primary sample



i-band absolute magnitude

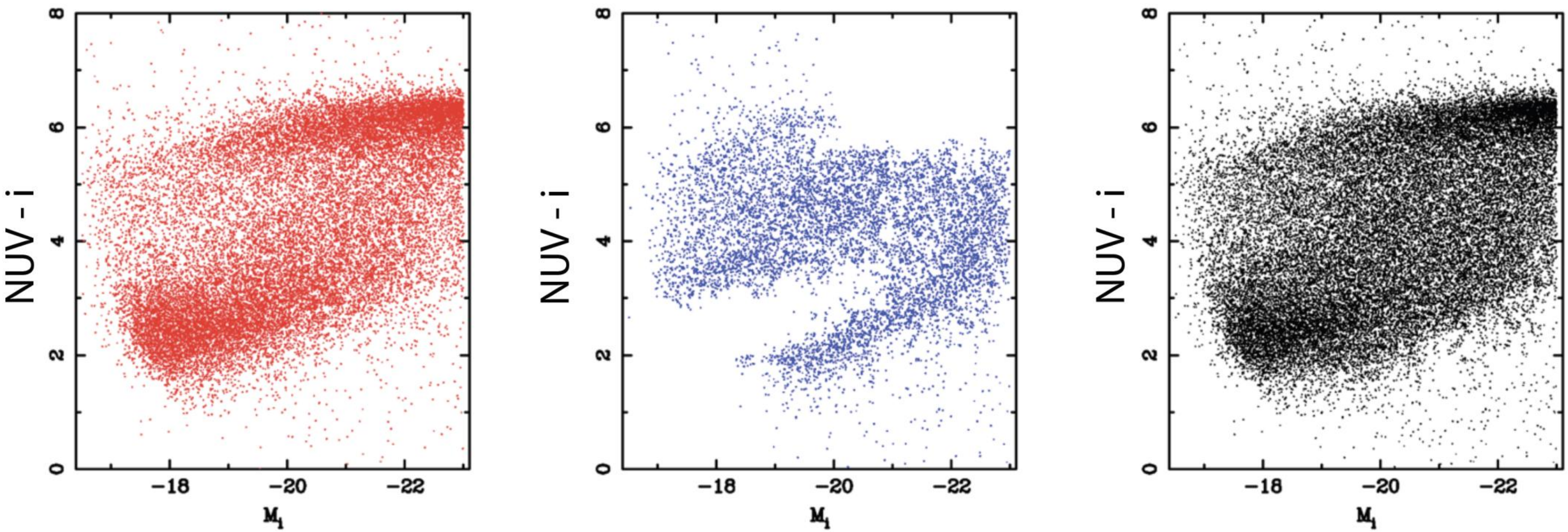
Increase minority representation!



Color-enhanced Sample

16% of the 10,000 is devoted to targeting rare galaxies in color-mag space. These are also covered to 1.5Re.

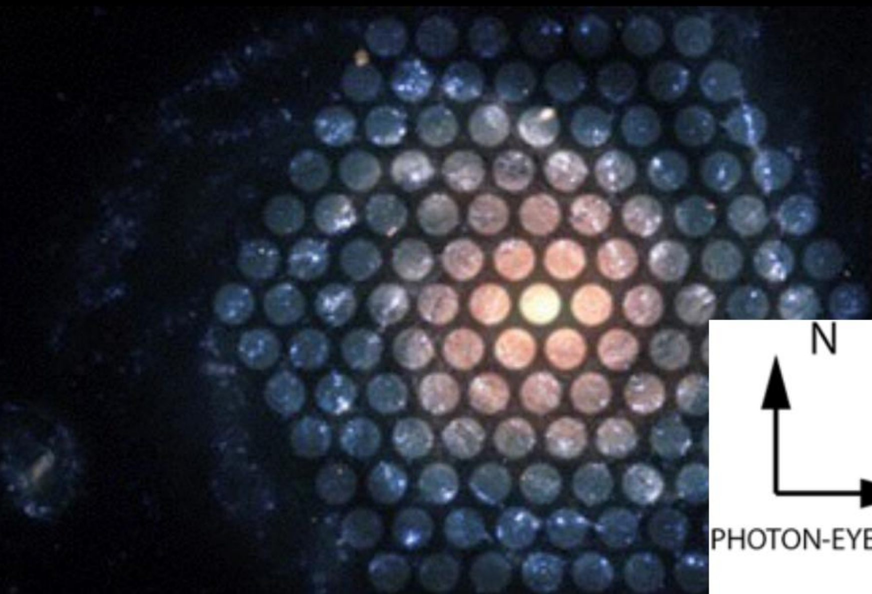
Primary + Color-Enhanced = Primary+



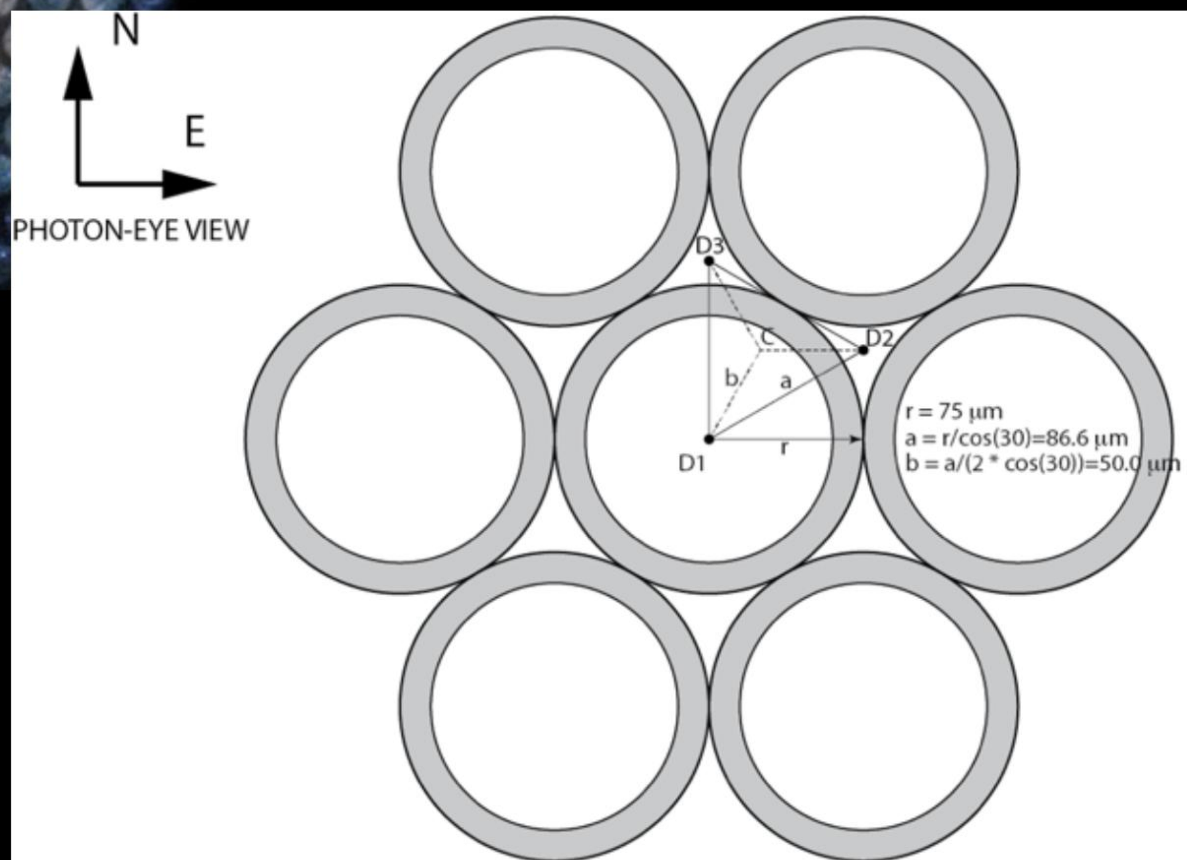
i-band absolute magnitude

The remaining ~5% of the bundles will be left for ancillary targets.

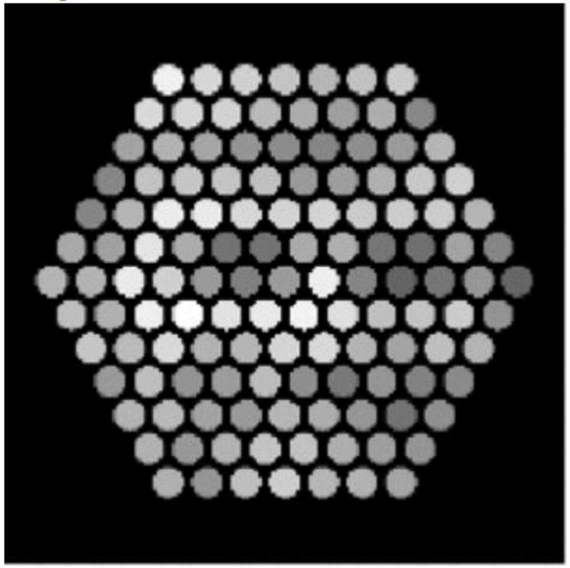
Observing Strategy

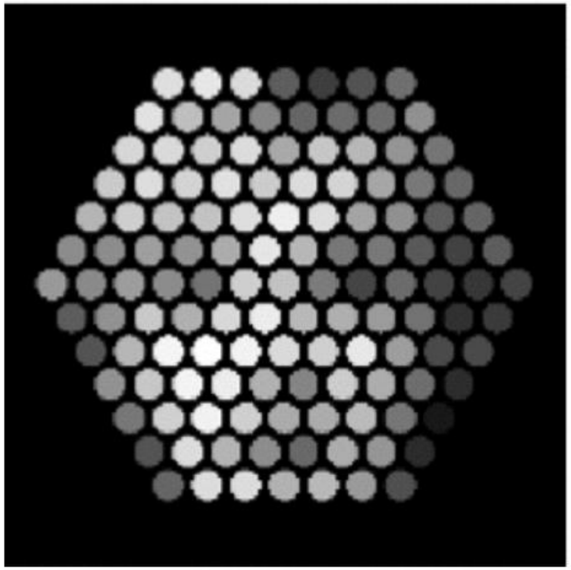


- Staring at a single position provides insufficient sampling.



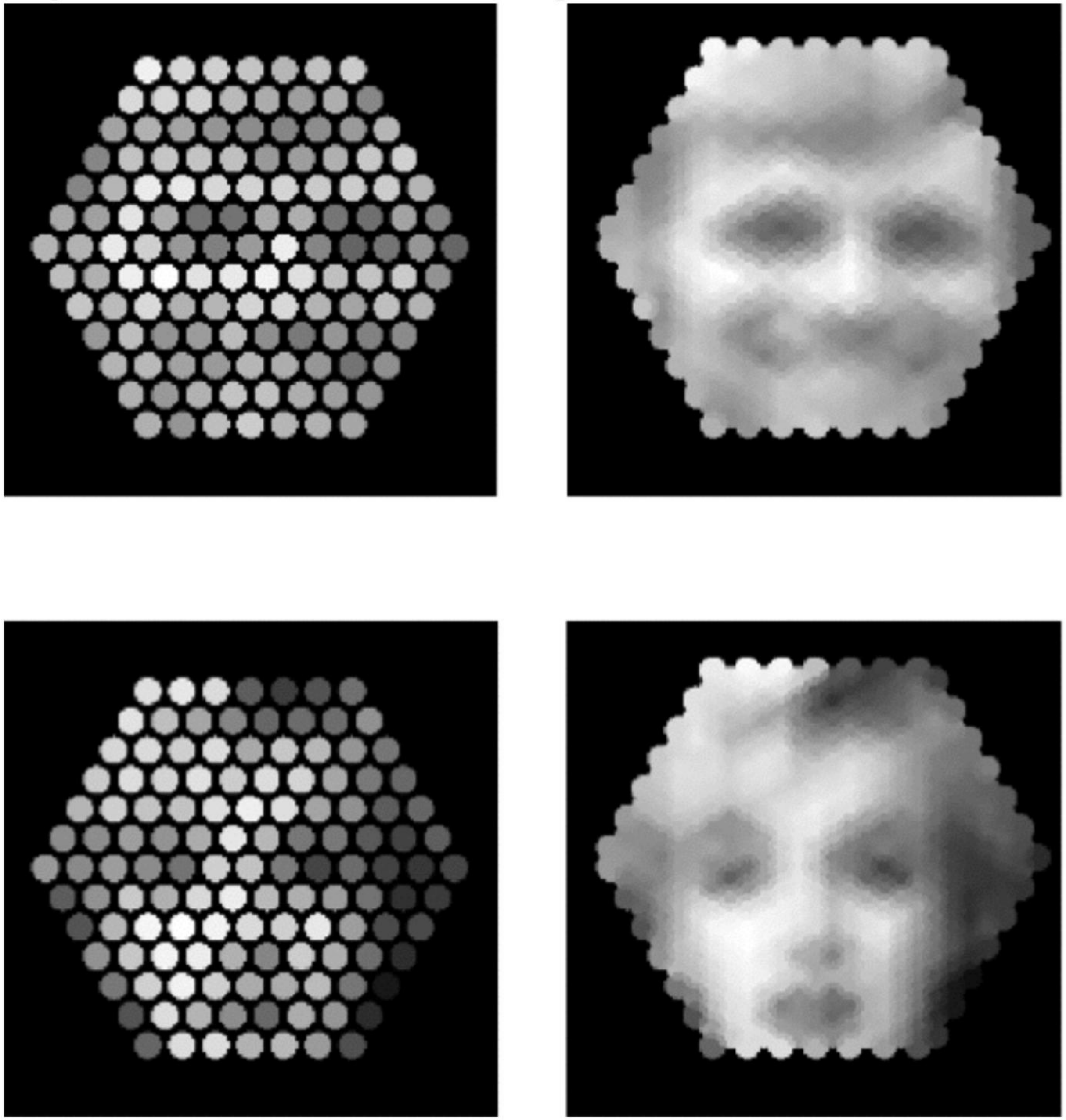
Importance of Dithering





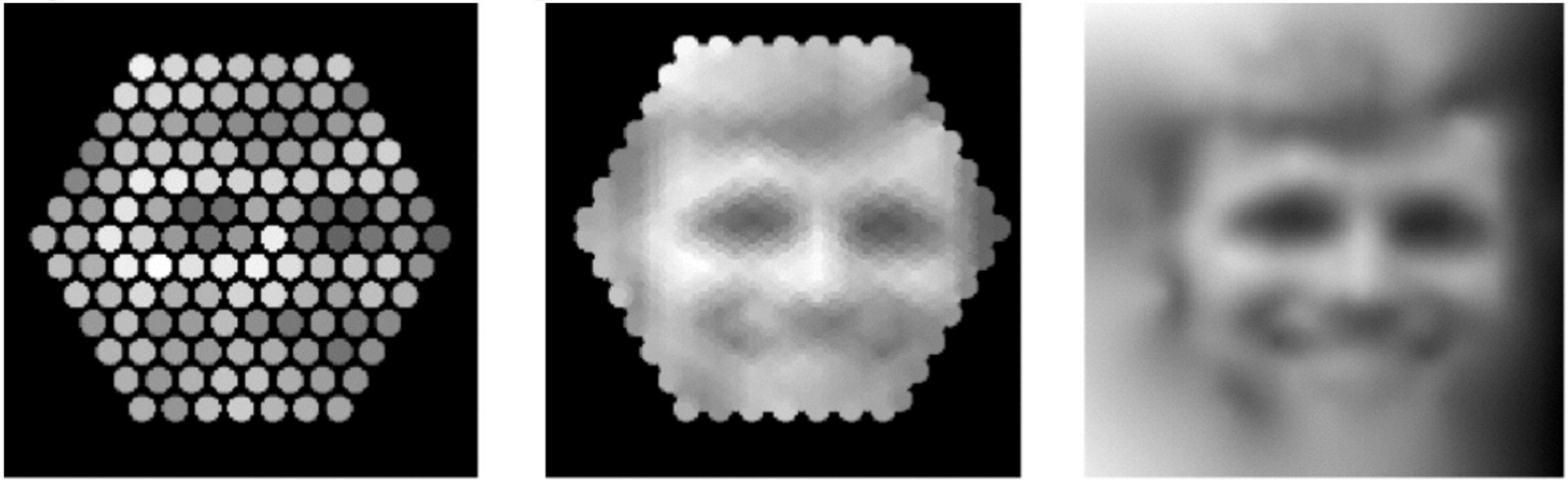
Credit: David Law

Importance of Dithering

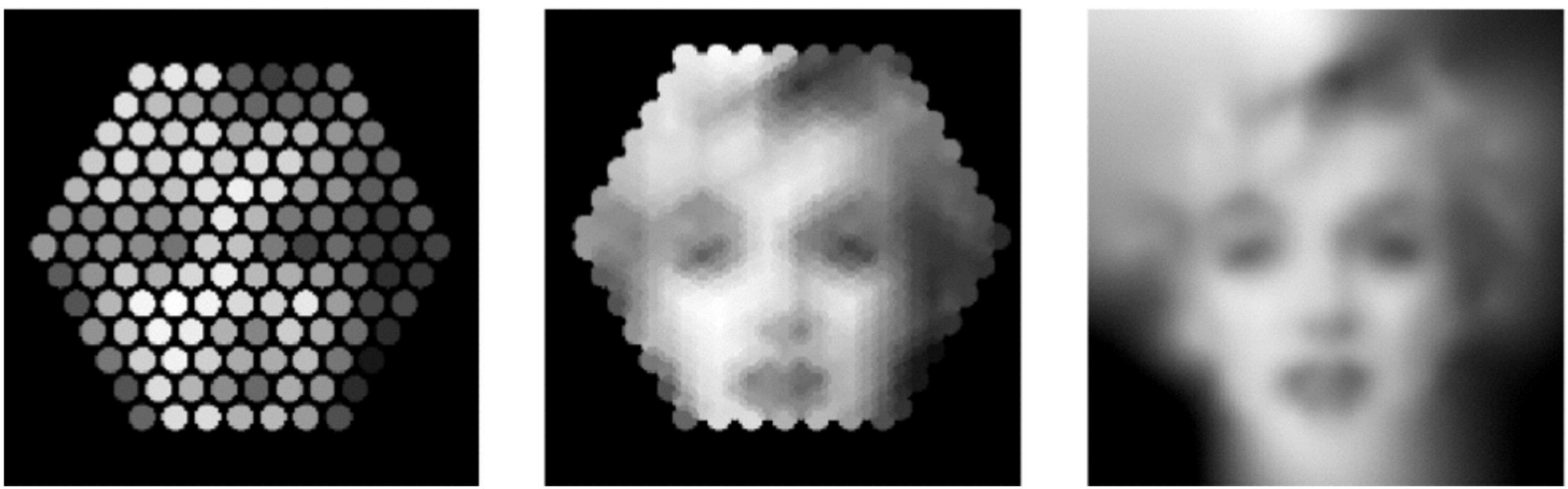


Credit: David Law

Importance of Dithering

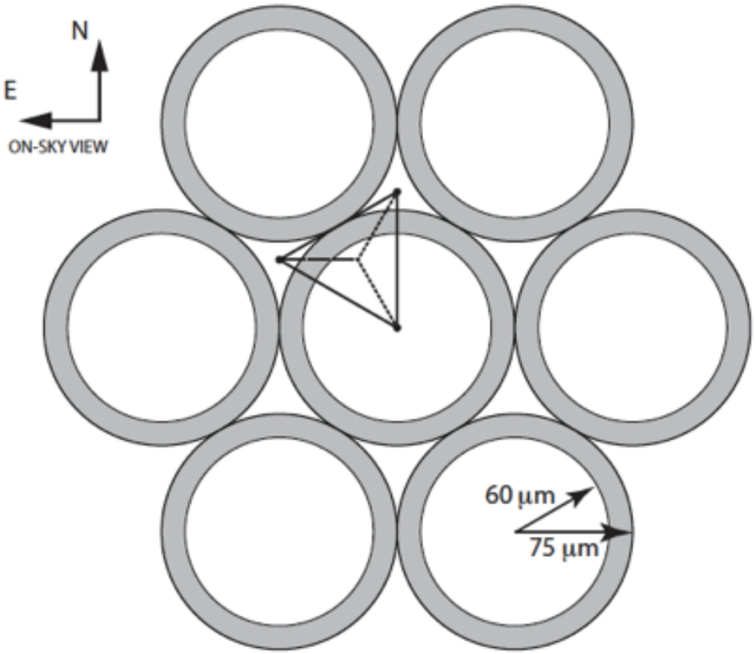


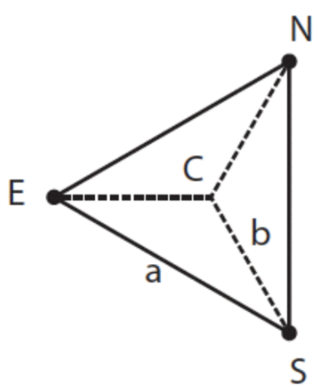
Kevin ≠ Marilyn



Credit: David Law

Observing Strategy Summary

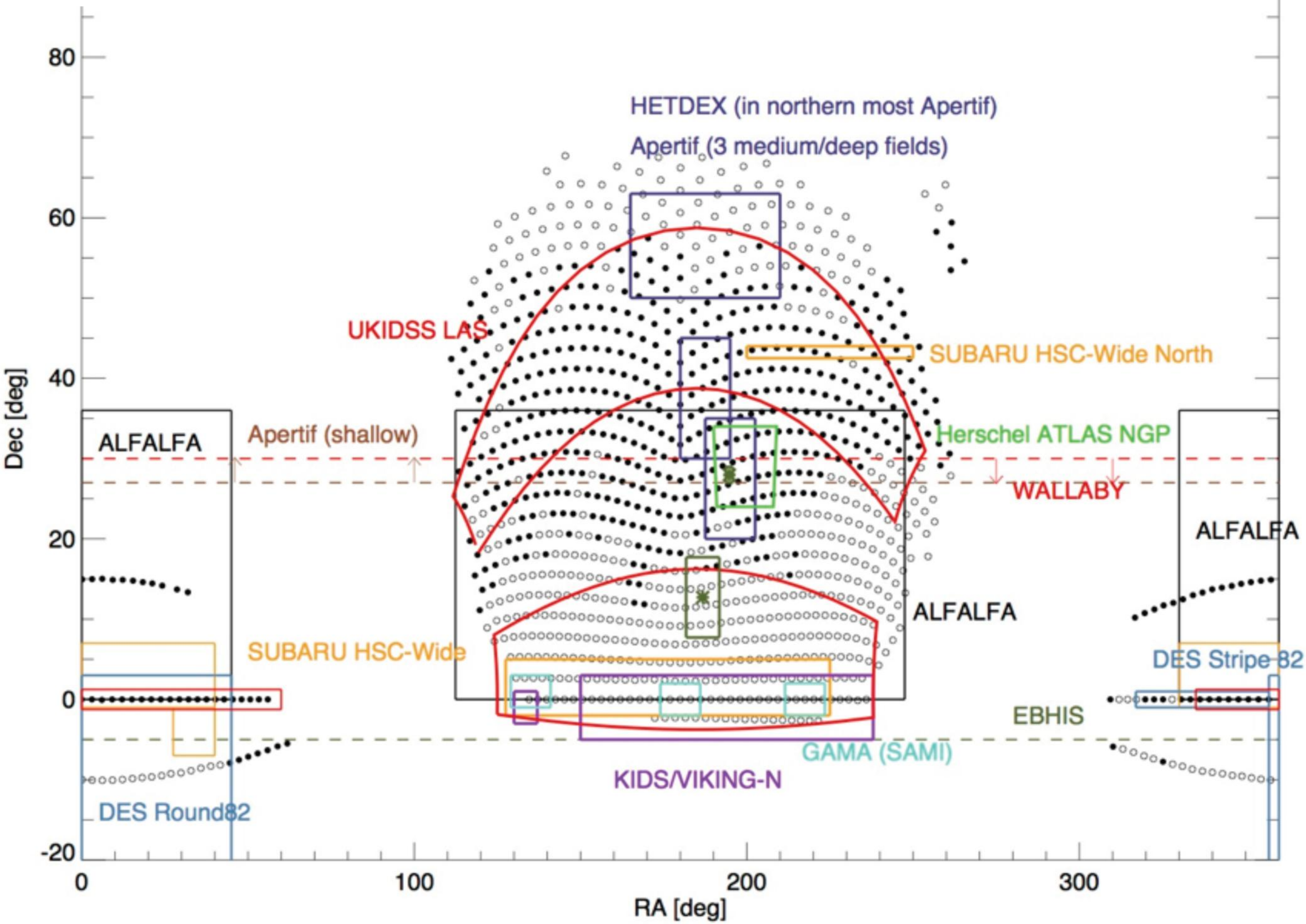


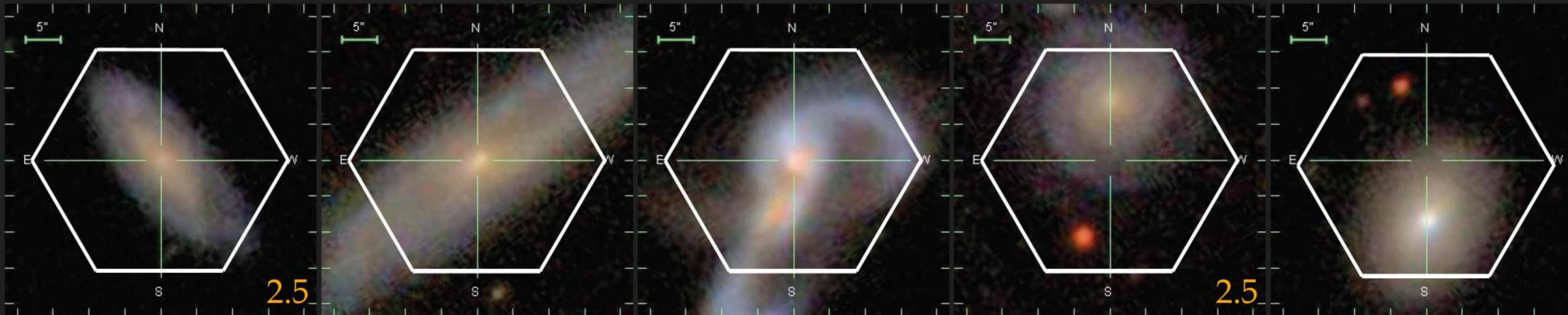


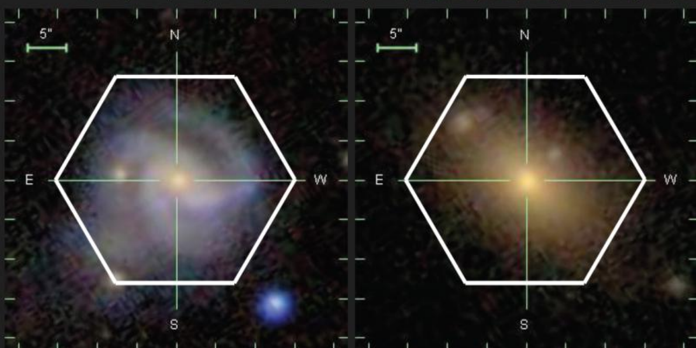
a = 86.6 μm = 1.44″
b = 50.0 μm = 0.83″

- 3 x 15min exposures, each at a different dither position.
- Obtain multiple sets of these till each plate meets the S/N requirements in blue and red for given fiber magnitudes.
  => Ensure uniform data quality
- Each set has to be finished within 1 hour to minimize image quality degradation from differential atmosphere refraction.

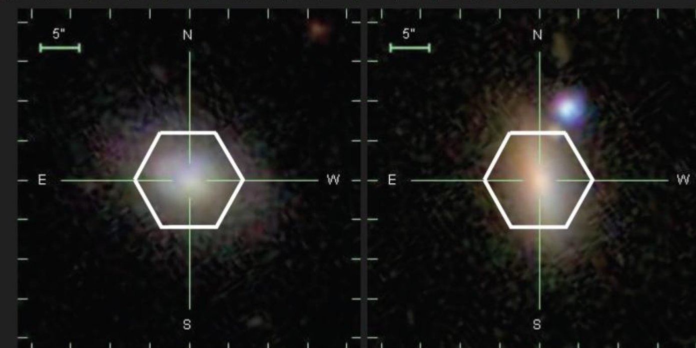
Field Overlap

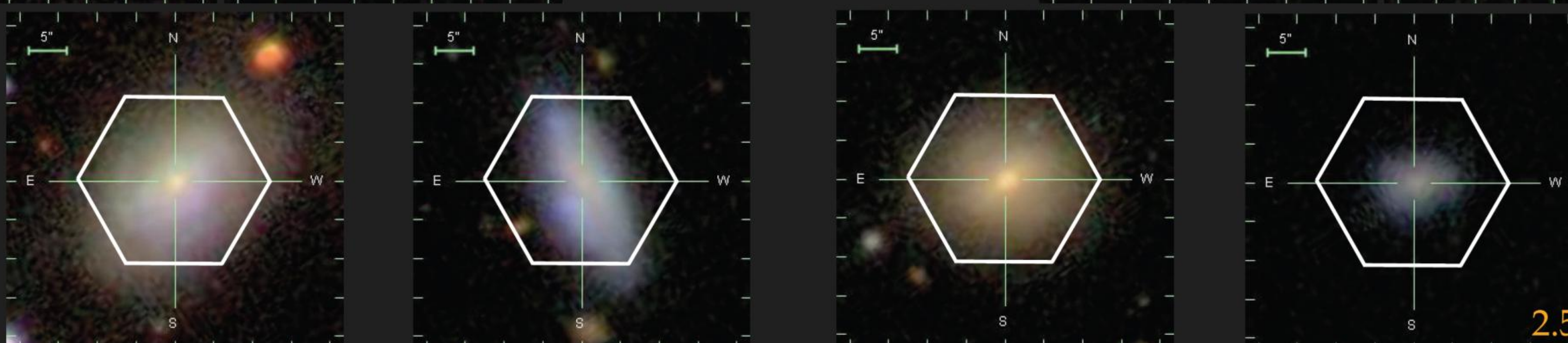


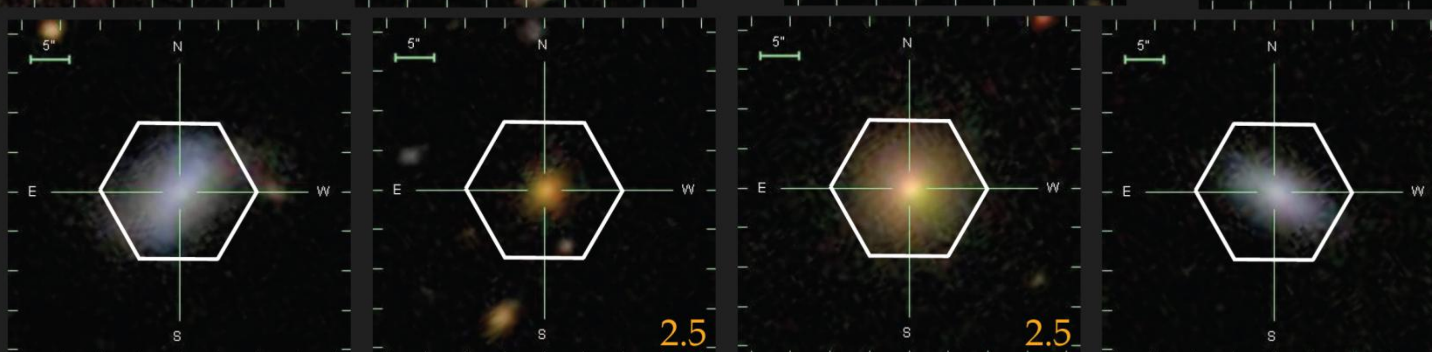




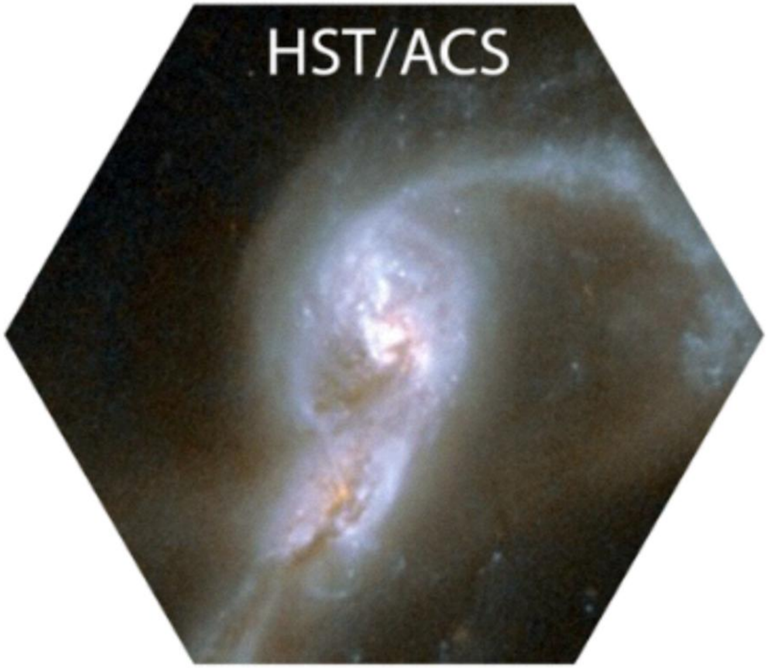
March 2014 Commissioning 1st Plate

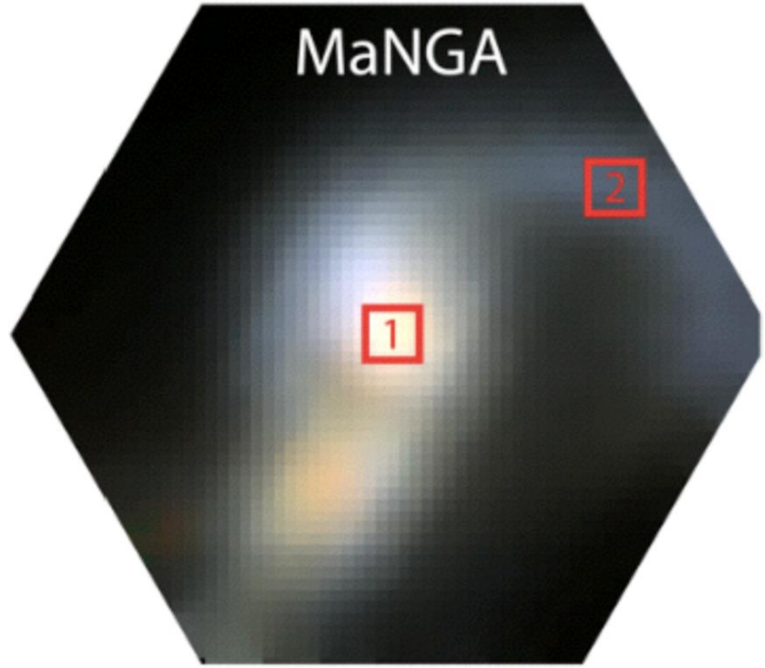


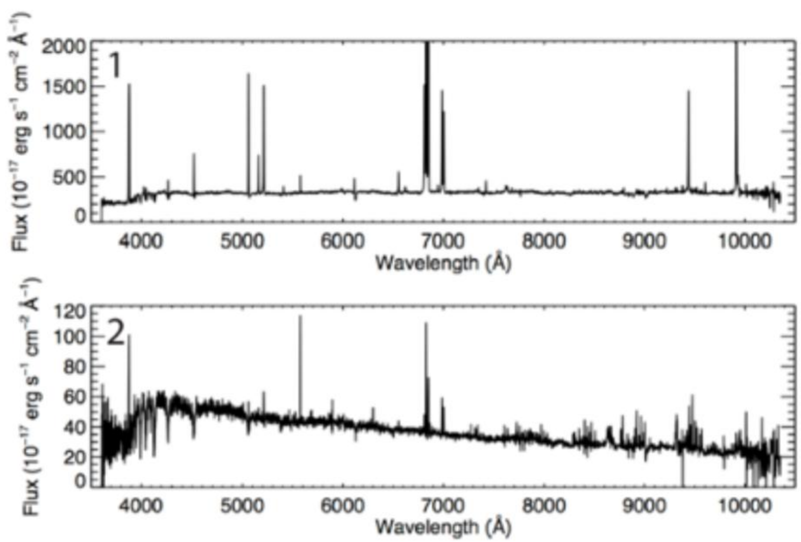




March Commissioning: Mrk 848

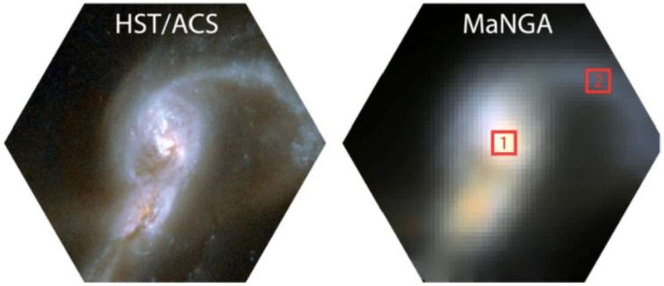


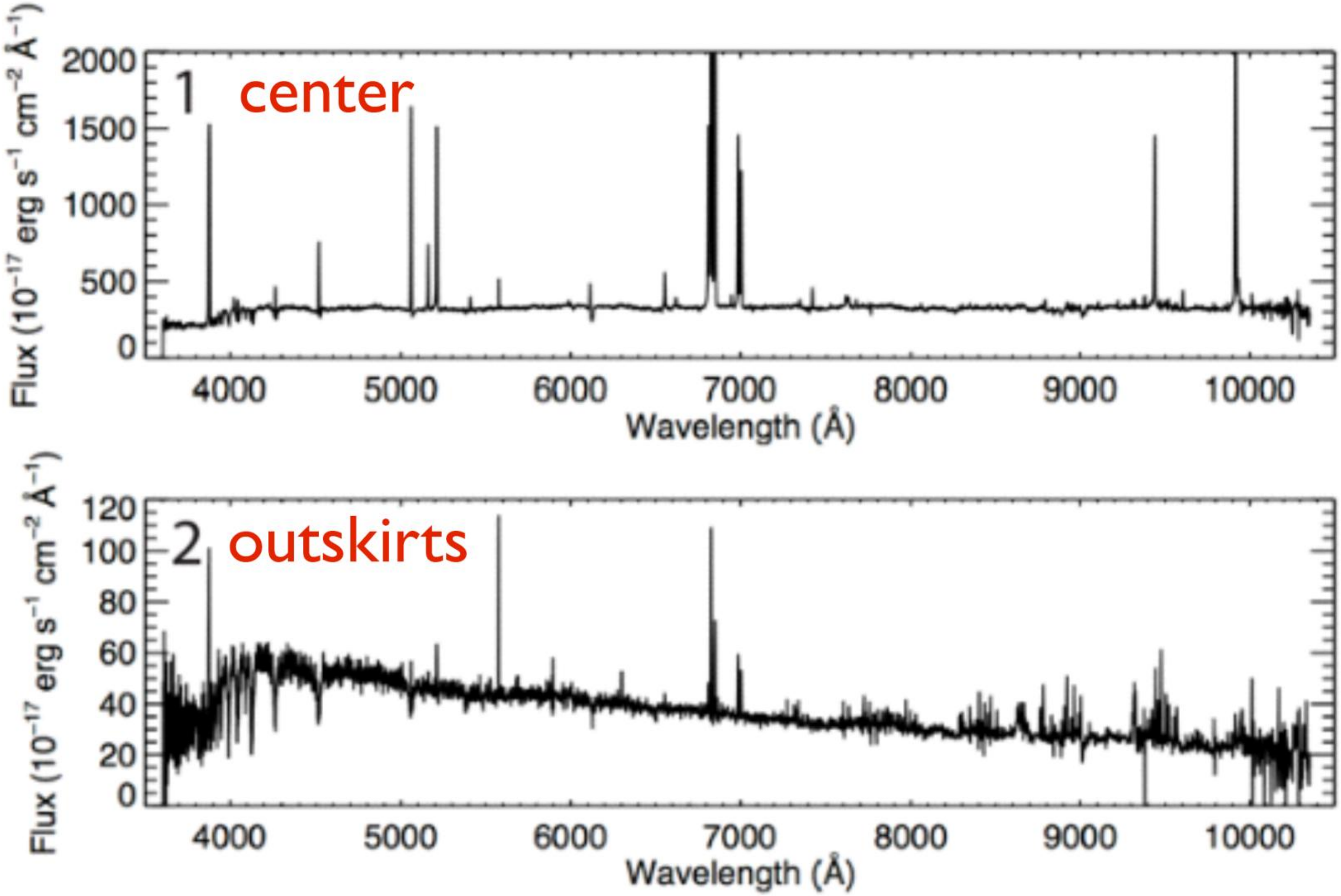




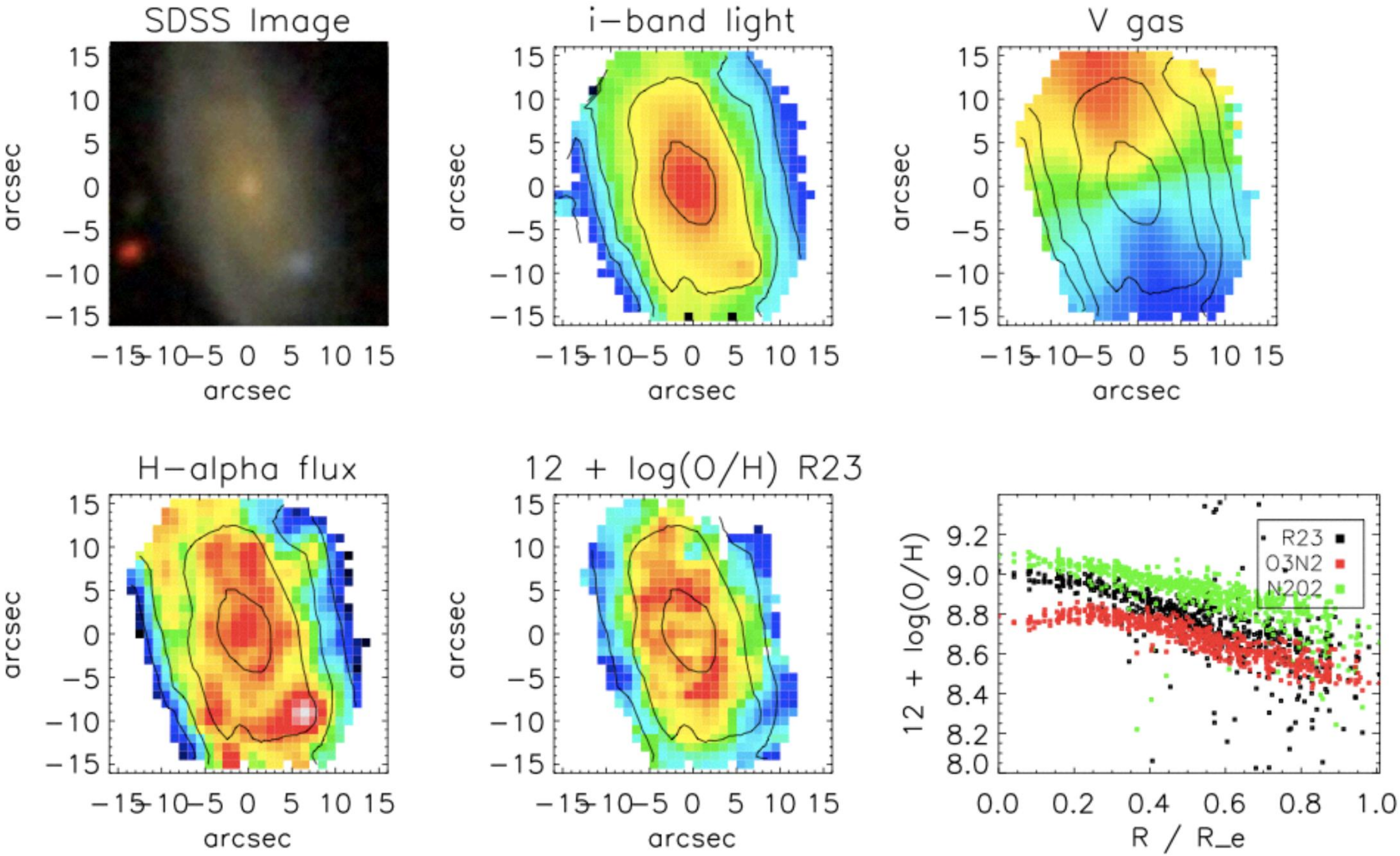
David Law

March Commissioning: Mrk 848

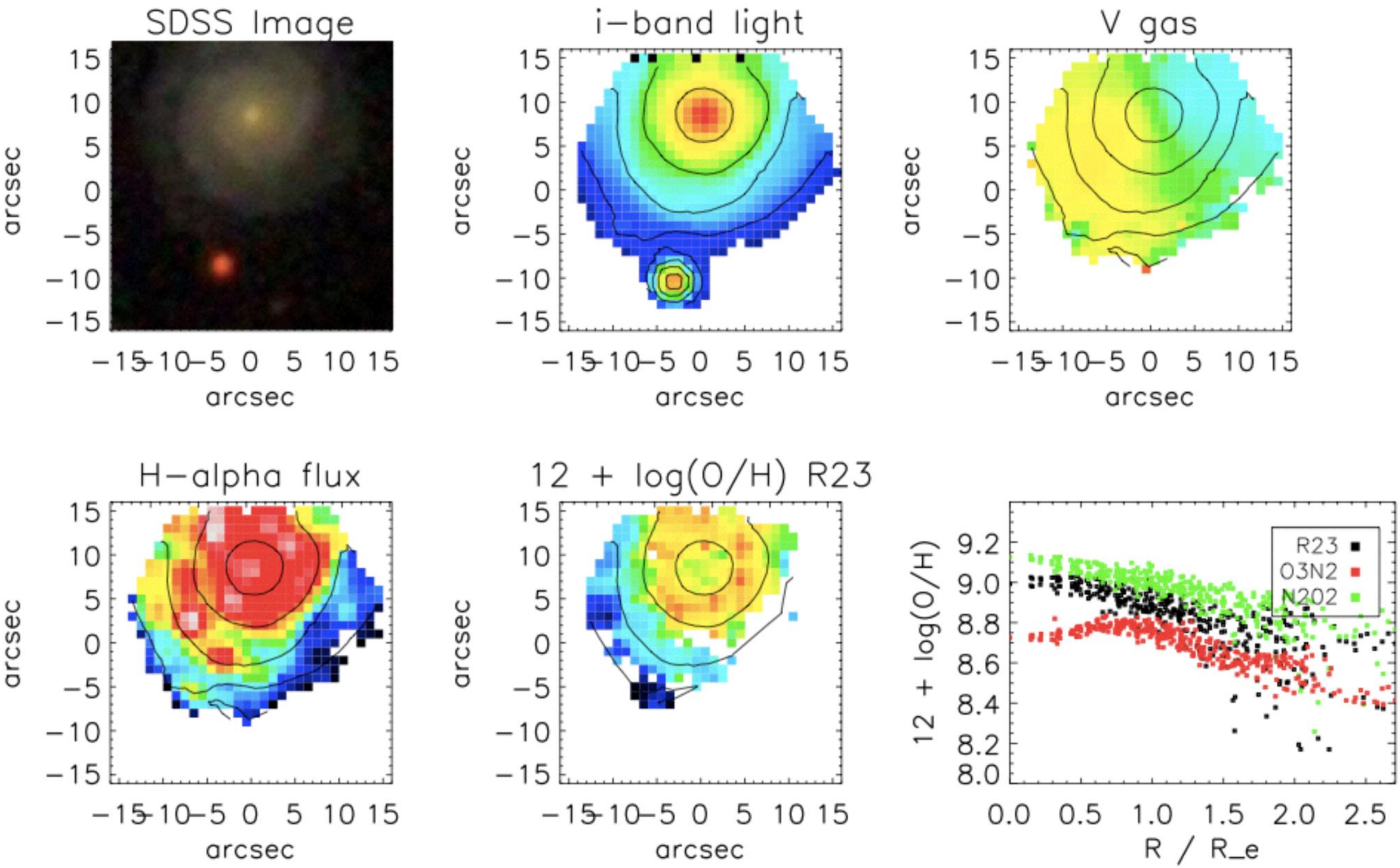




David Law



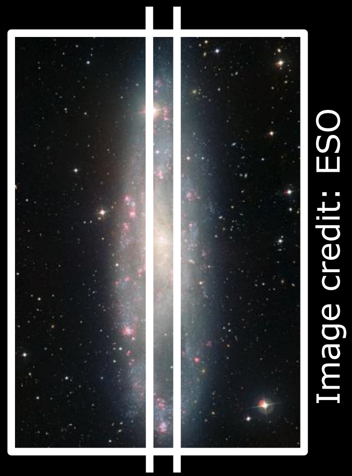
Christy Tremonti

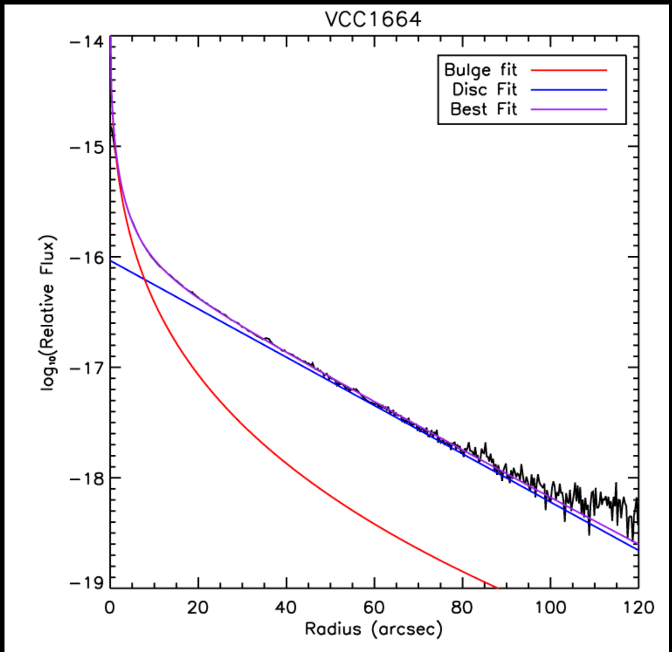


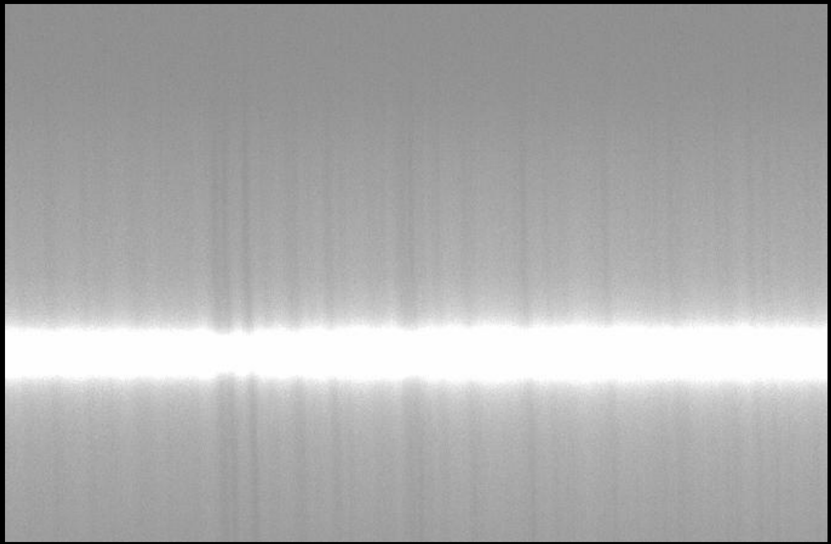
Christy Tremonti

Spectroscopic Bulge-Disc Decomposition: Long-Slit

- Obtain a good quality long-slit spectrum of a galaxy
- Correct spectrum for kinematics
- Decompose light profile at each wavelength



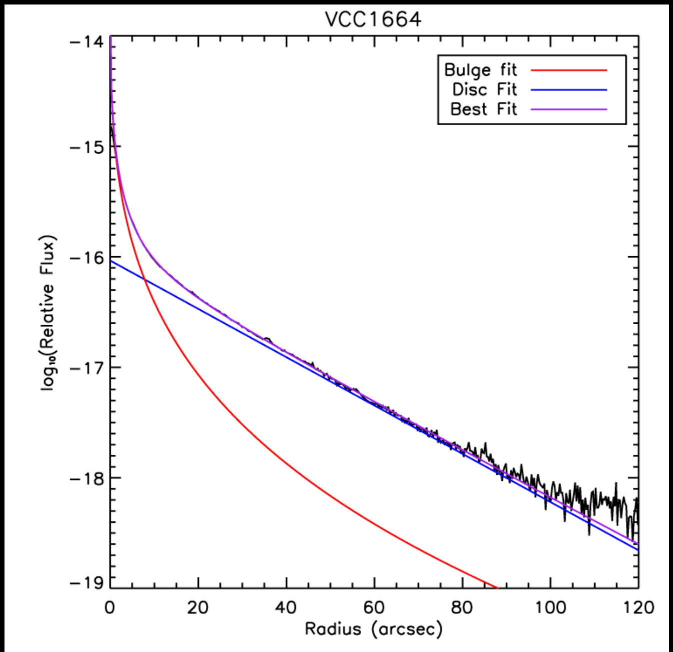


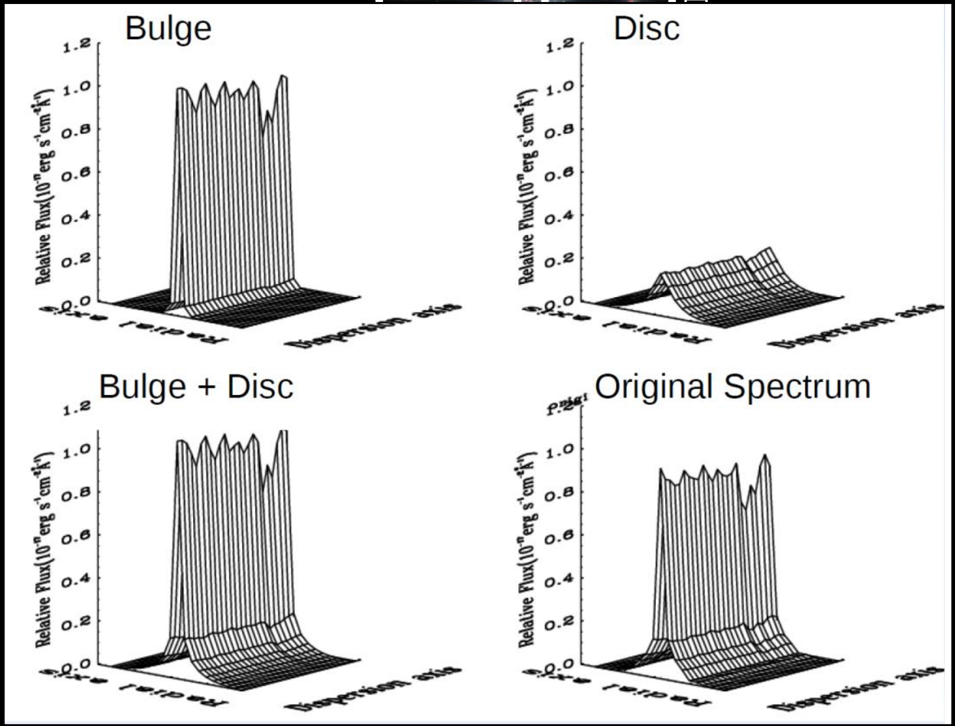


Spectroscopic Bulge-Disc Decomposition: Long-Slit

- Obtain a good quality long-slit spectrum of a galaxy
- Correct spectrum for kinematics
- Decompose light profile at each wavelength

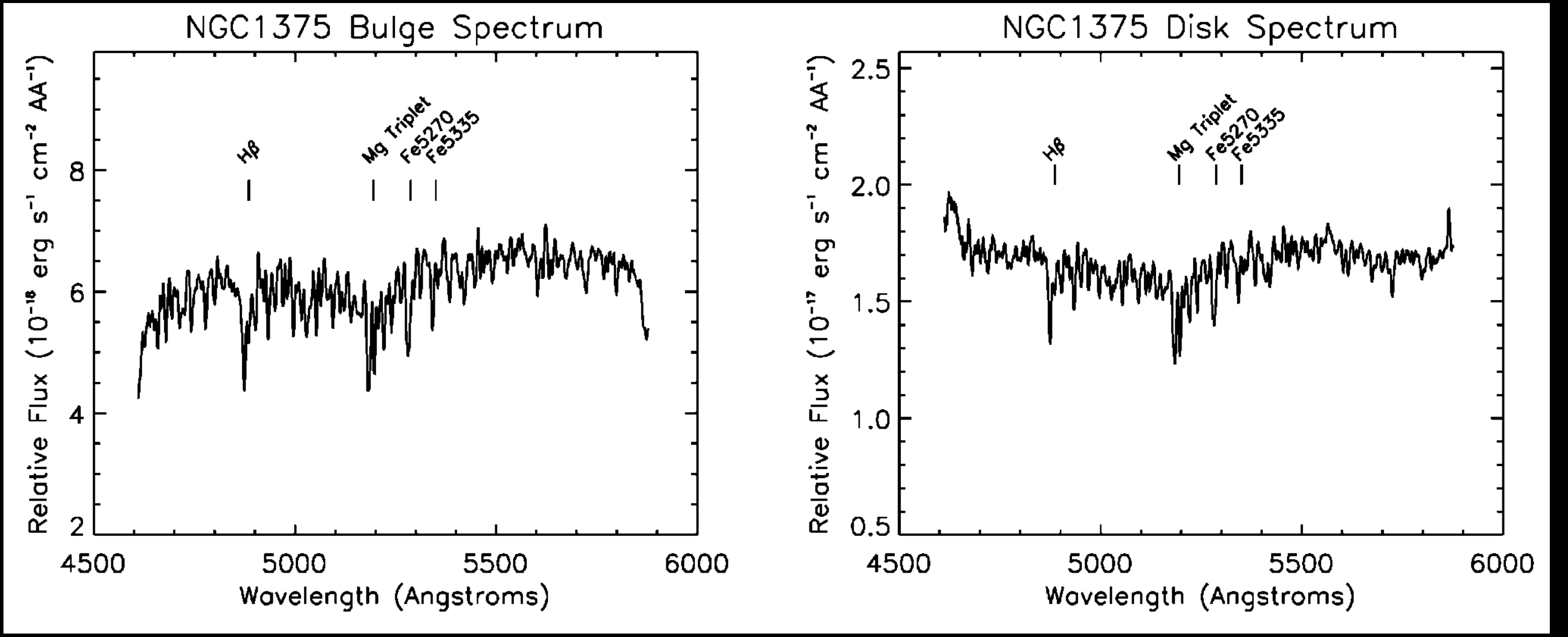
Image credit: ESO





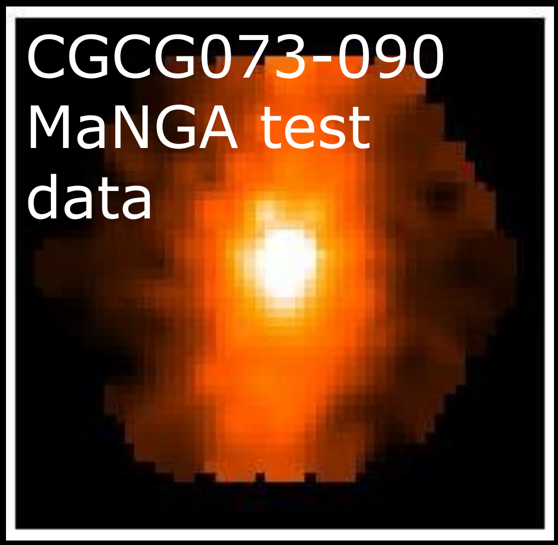
Spectroscopic Bulge-Disc Decomposition: Long-Slit

- Integrate to get total light of bulge and disc for that wavelength bin
- Plot against wavelength to obtain high-quality spectra representing purely the bulge and disc light.



Spectroscopic Bulge-Disc Decomposition: IFU data

- We experience degeneracy issues using only long-slit spectra from the major axis
- One way to resolve this would be to use wide-field, high-resolution IFU spectra, e.g. CALIFA, MaNGA
  - Spectral information over the whole structure of the galaxy
  - Large field of view
  - Long wavelength range

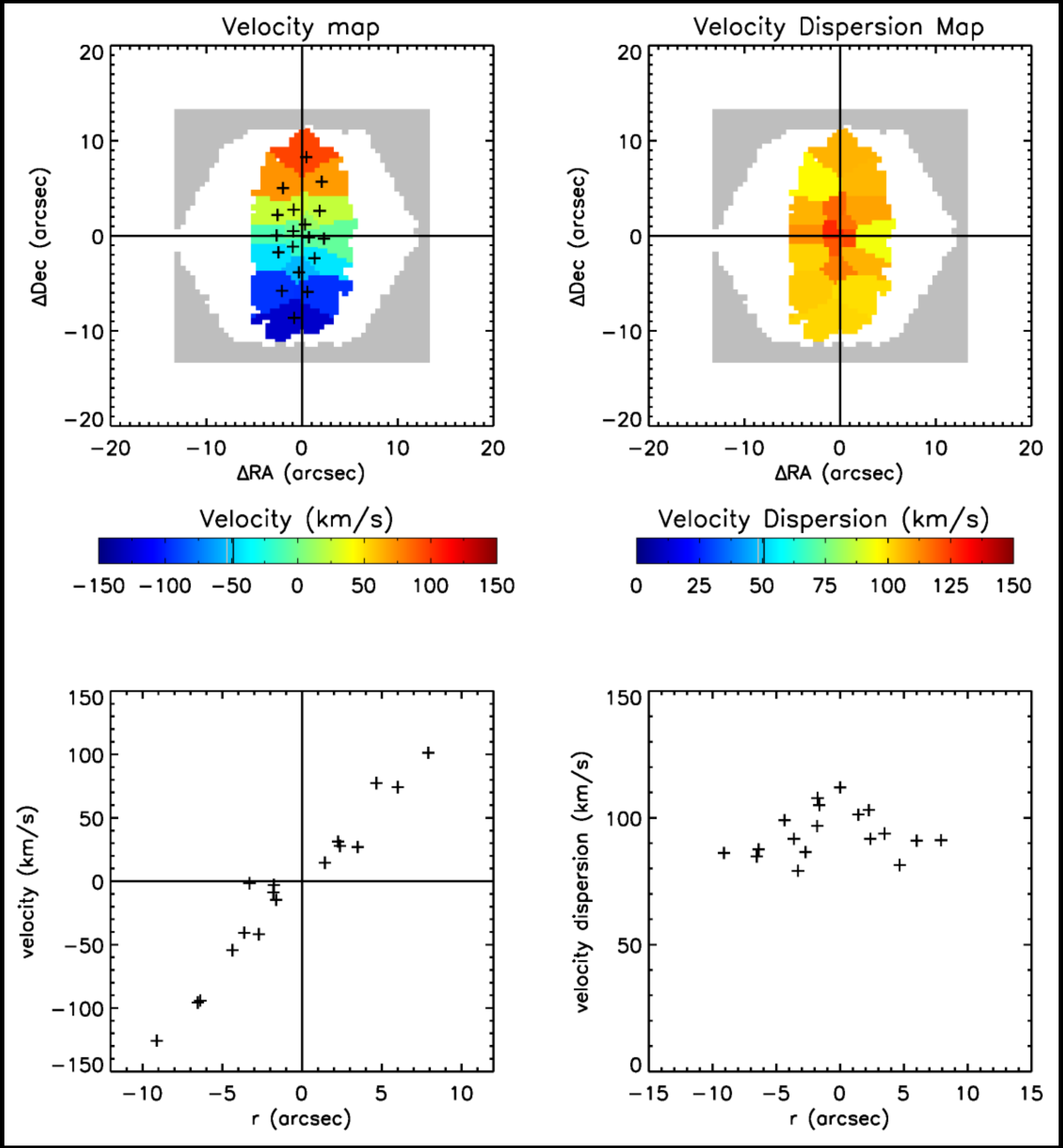


Note:
The following results are very preliminary and use many assumptions. They should be considered as a proof of concept only.

PRELIMINARY

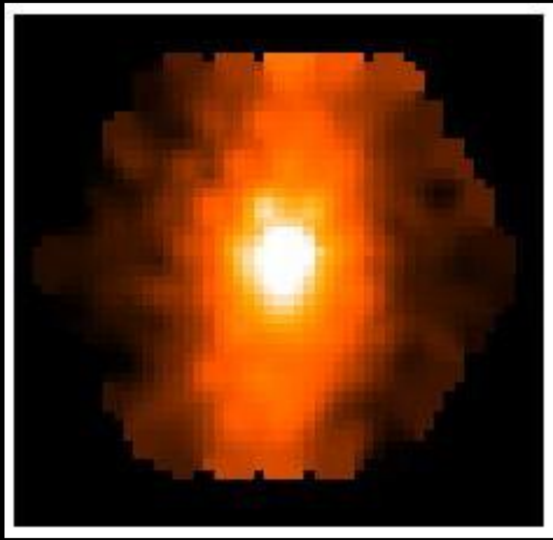
Steps to decompose IFU Spectra

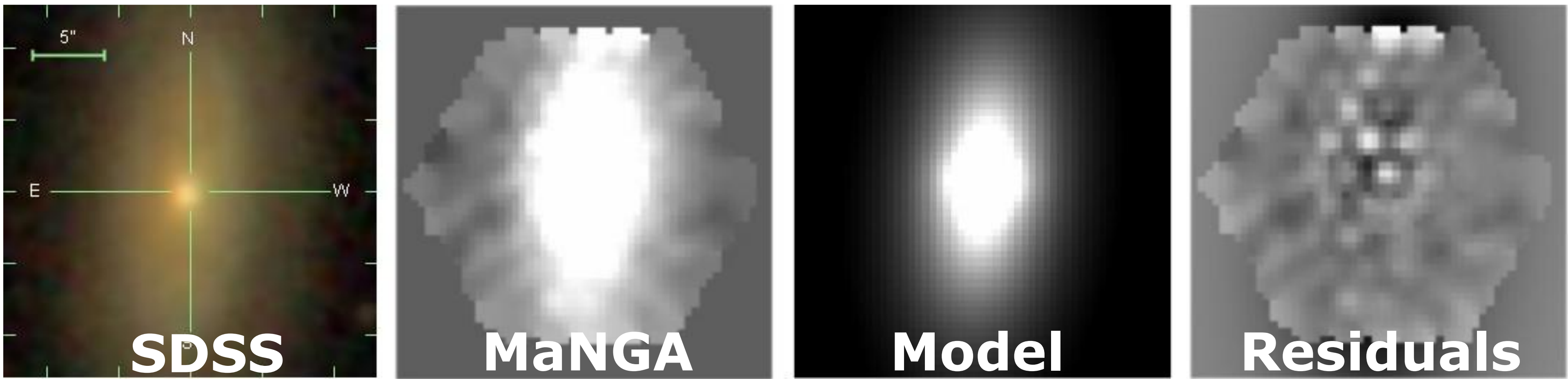
- Measure and correct the kinematics over the galaxy
  - ensures each image slice is composed of spectra at the same rest-frame wavelength



Steps to decompose IFU Spectra

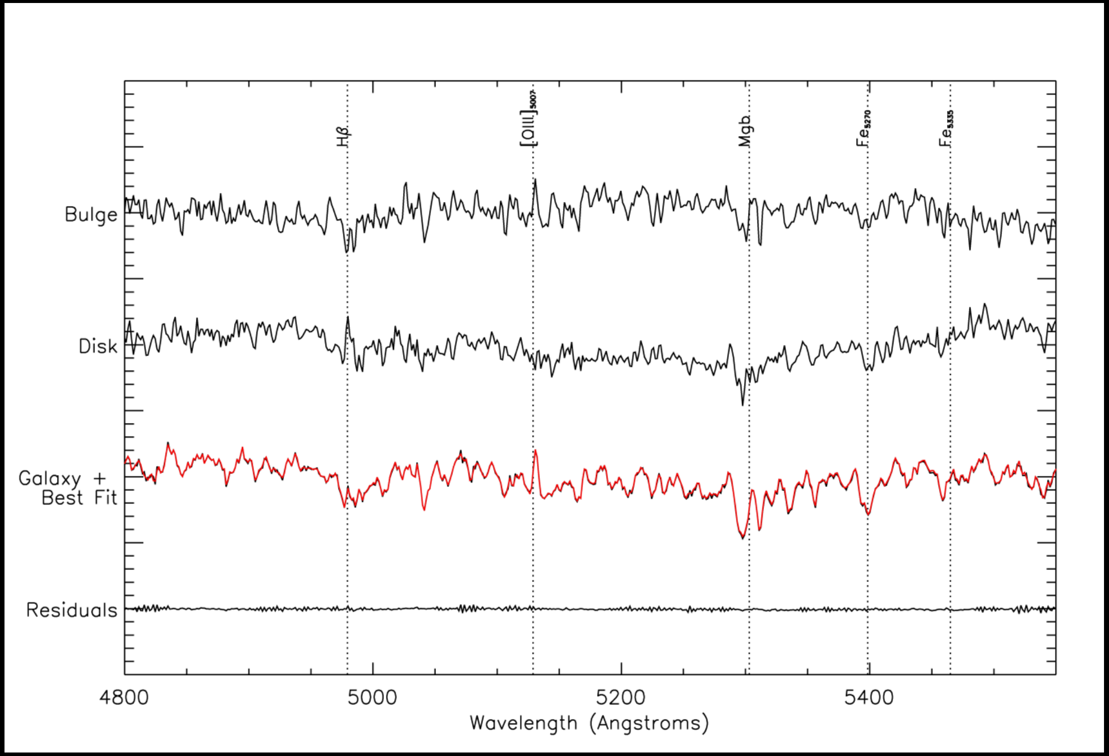
- Bin the data cube into a series of high S/N images, and decompose with GALFITM (MEGAMORPH) to see how parameters vary with wavelength.
- Print off image slices at each wavelength from the IFU datacube.





Steps to decompose IFU Spectra

- Decompose the individual image slices with GALFIT
- Plot the integrated luminosity of each component against wavelength to get its decomposed spectrum



- Use model to create separate bulge and disk data cube, preserving gradients

Future refinements and challenges

- So far we used Lick-like index analysis

  → Relatively easy to implement full spectral fitting

- So far we do not make use of kinematical information – in fact, we erase it!!! →

  → Desirable but challenging to fit kinematics and stellar populations simultaneously

- So far restricted to simple bulge/disc systems

  → Desirable but challenging to include more components (bars, spiral arms, …)