MaNGA
Mapping Nearby Galaxies at APO

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& MaNGA Team

Multi-Object Spectroscopy in the Next Decade
Santa Cruz de La Palma 4 March 2015

MaNGA Team: >250 members @ >60 institutes

PI: Kevin Bundy

Survey Scientist: Renbin Yan

Instrument Scientist: Niv Drory

Chief Engineer/Proj. Manager: Nick McDonald

Lead Data Scientist: David Law

SDSS-IV Project Scientist: Matt Bershady

Science Team Chair: Daniel Thomas

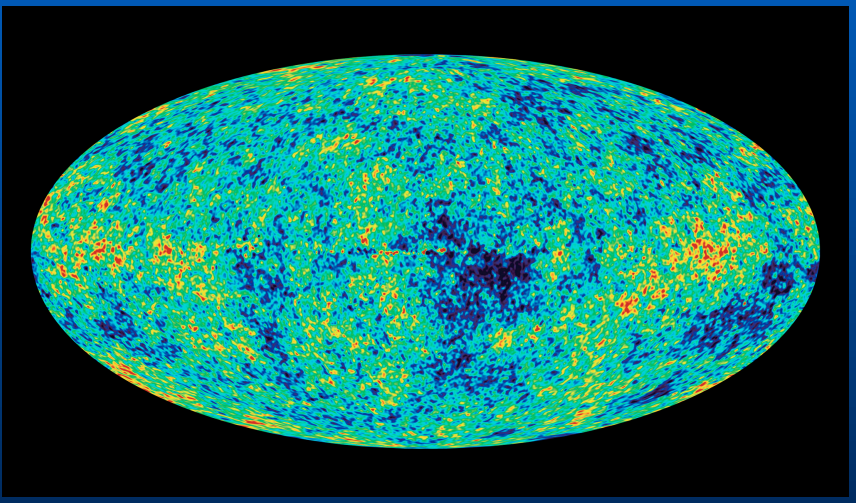
Sample Design Lead: David Wake

Lead Observer: Anne-Marie Weijmans

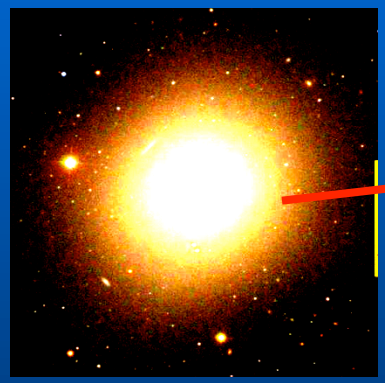
Multi-λ Science Coordinator: Karen Masters

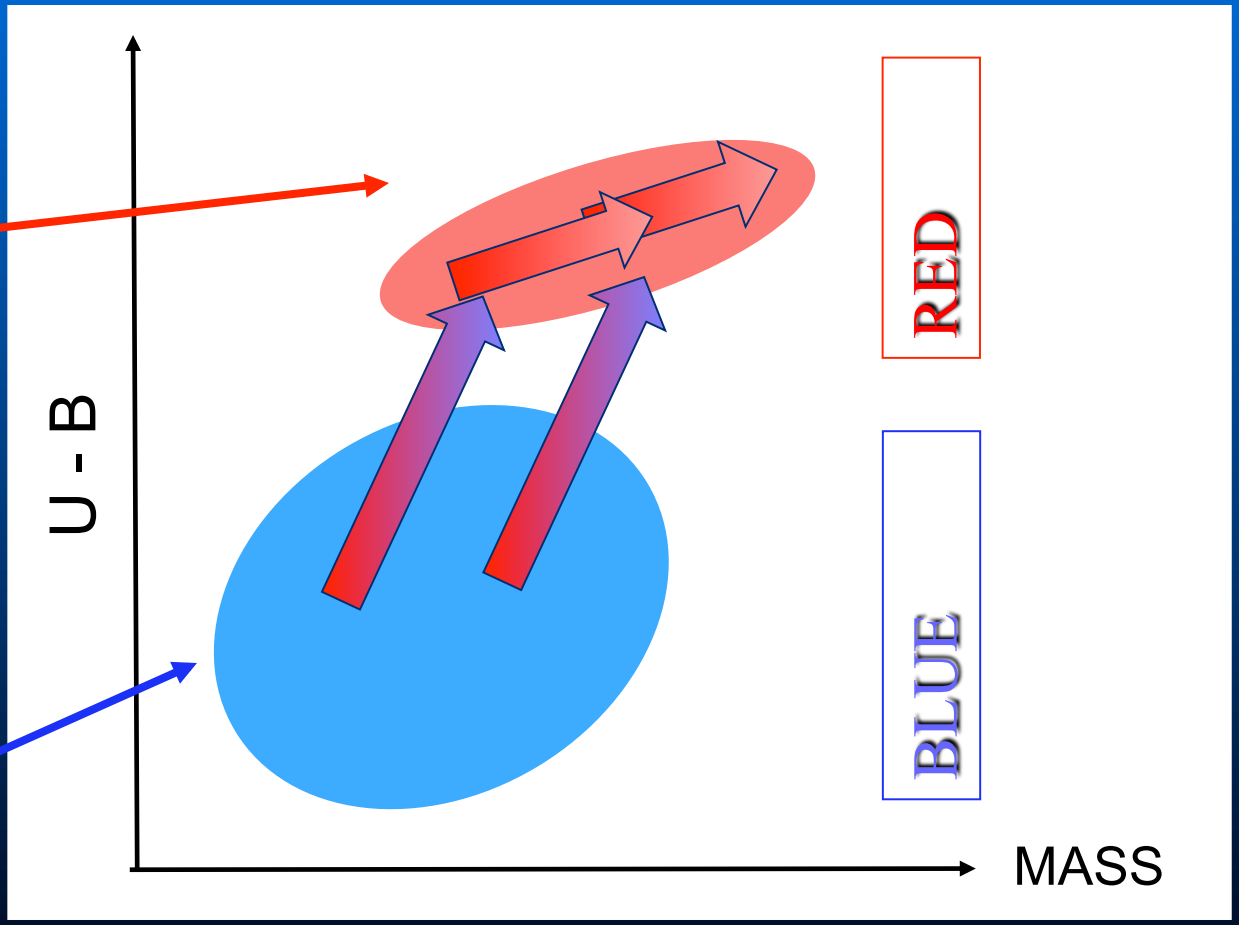
Deputy Lead Sample Design: Aleks Diamond-Stanic

Galaxy Formation and Evolution



Galaxies in the local Universe: blue cloud and red sequence

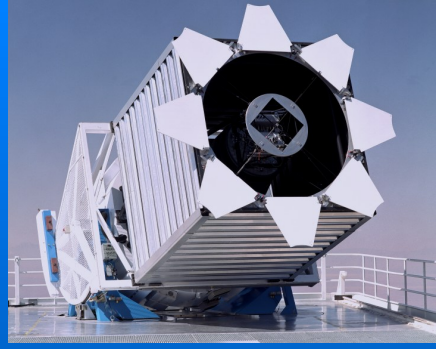




e.g. Faber et al. 2007

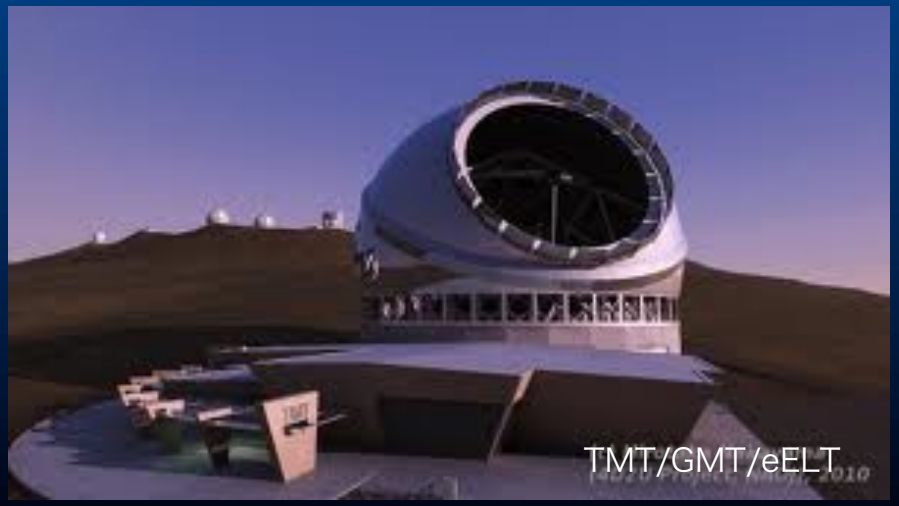
MaNGA Key Questions

Bundy et al. 2015

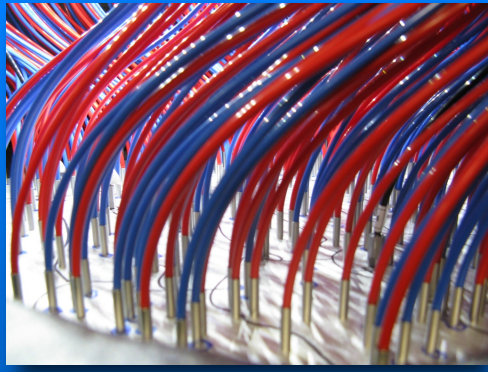


- Lives of galaxies
  - How does gas accretion drive the growth of disks?
  - What are the relative roles of stellar accretion, major mergers and instabilities for forming bulges?
- Death of galaxies
  - What quenches star formation?
  - How is star formation affected by groups and clusters?
- Birth of galaxies
  - What was the initial distribution of angular momentum?
  - How do baryons and stars trace and influence the dark halo?
  - Is galaxy growth the same at low and high z?

IFU studies at high z

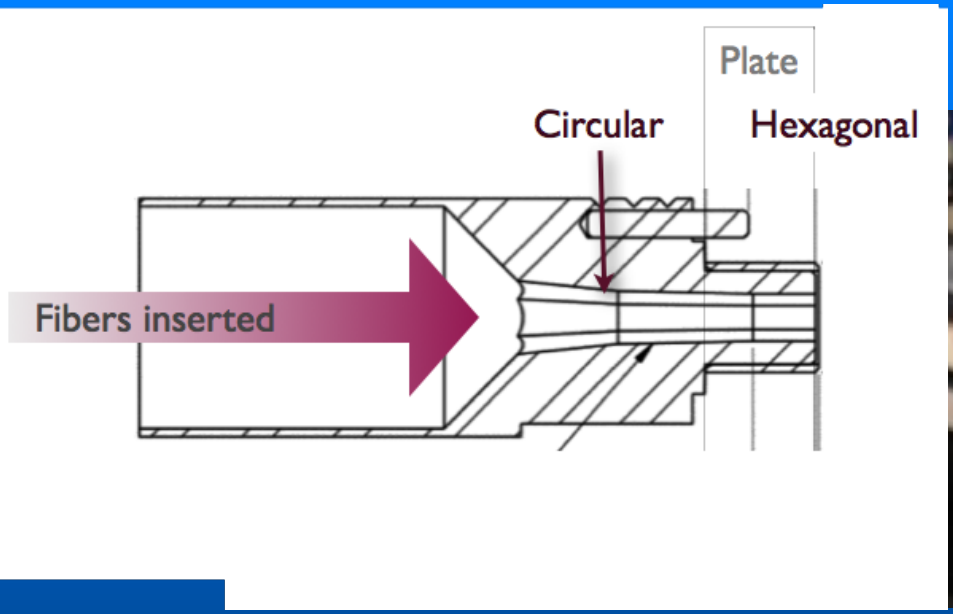


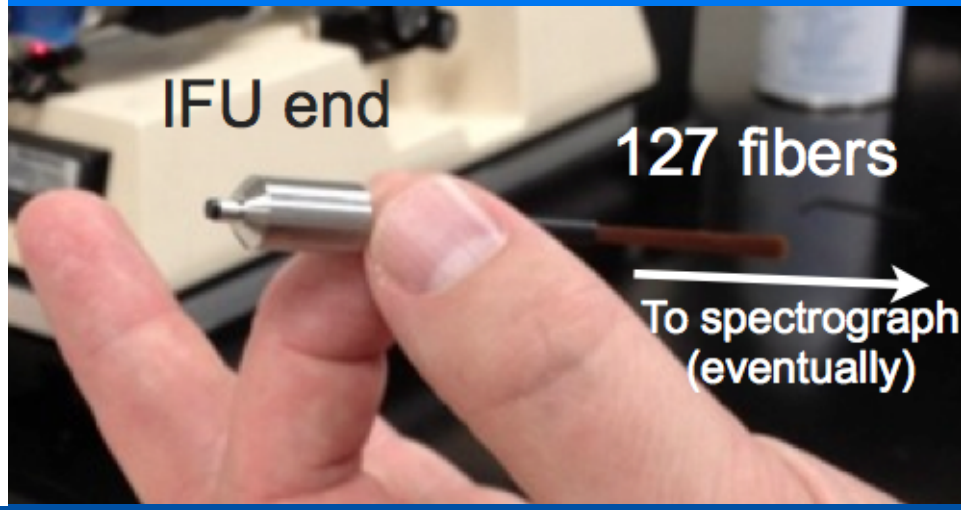
MaNGA Concept

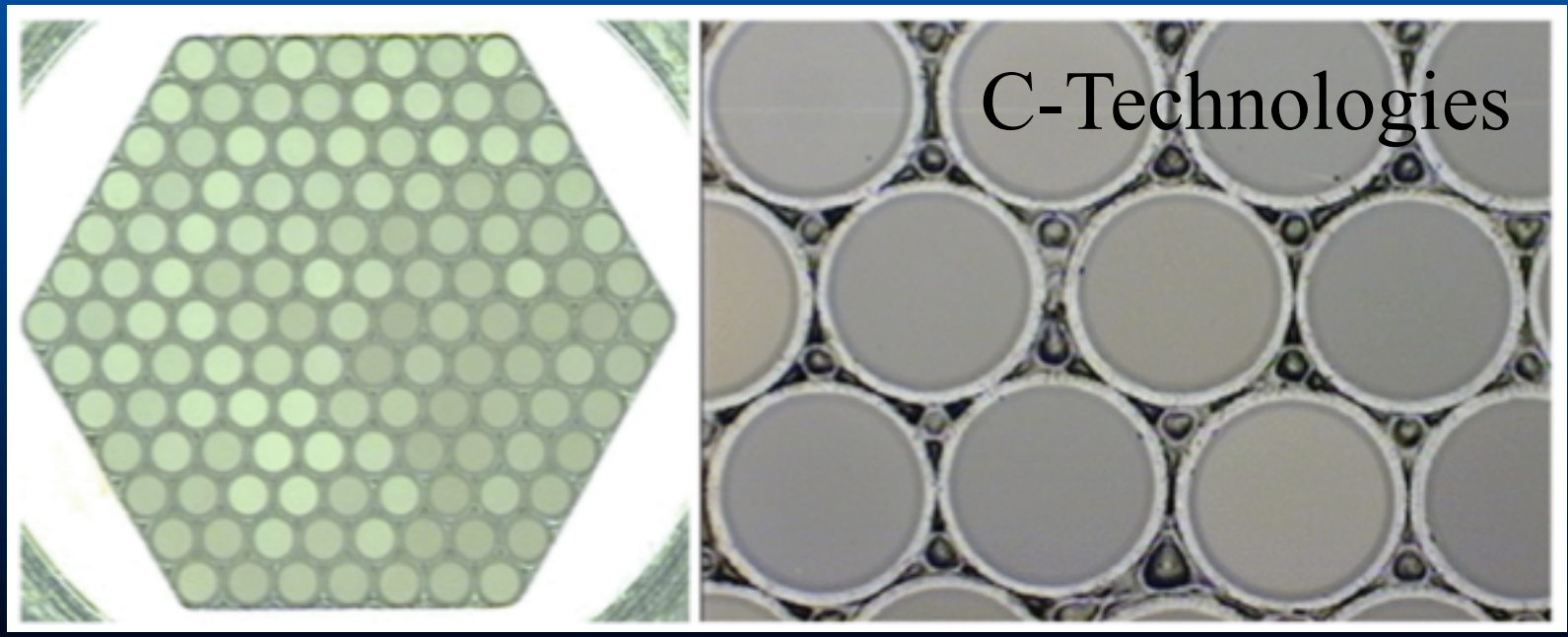


- Bundle single fibers together in IFUs
  - use BOSS spectrographs
  - create 17 IFUs, from 19 to 127 fibers per bundle
- Plug bundles in plates, similar to single fibers
  - integrate sky fibers with IFUs
  - 12 mini-IFUs for standard stars
- Observe 10,000 galaxies, 3hr dithered exposures
  - spatial resolution: 2” fibers or 1 – 4 kpc
  - spectral resolution: 50 – 80 km/s (R = 2500)
  - spectral coverage: 3600 – 10,000 A
  - S/N: ~ 30 in central fiber, ~4-8 at 1.5 R_e

Bundy et al. 2015



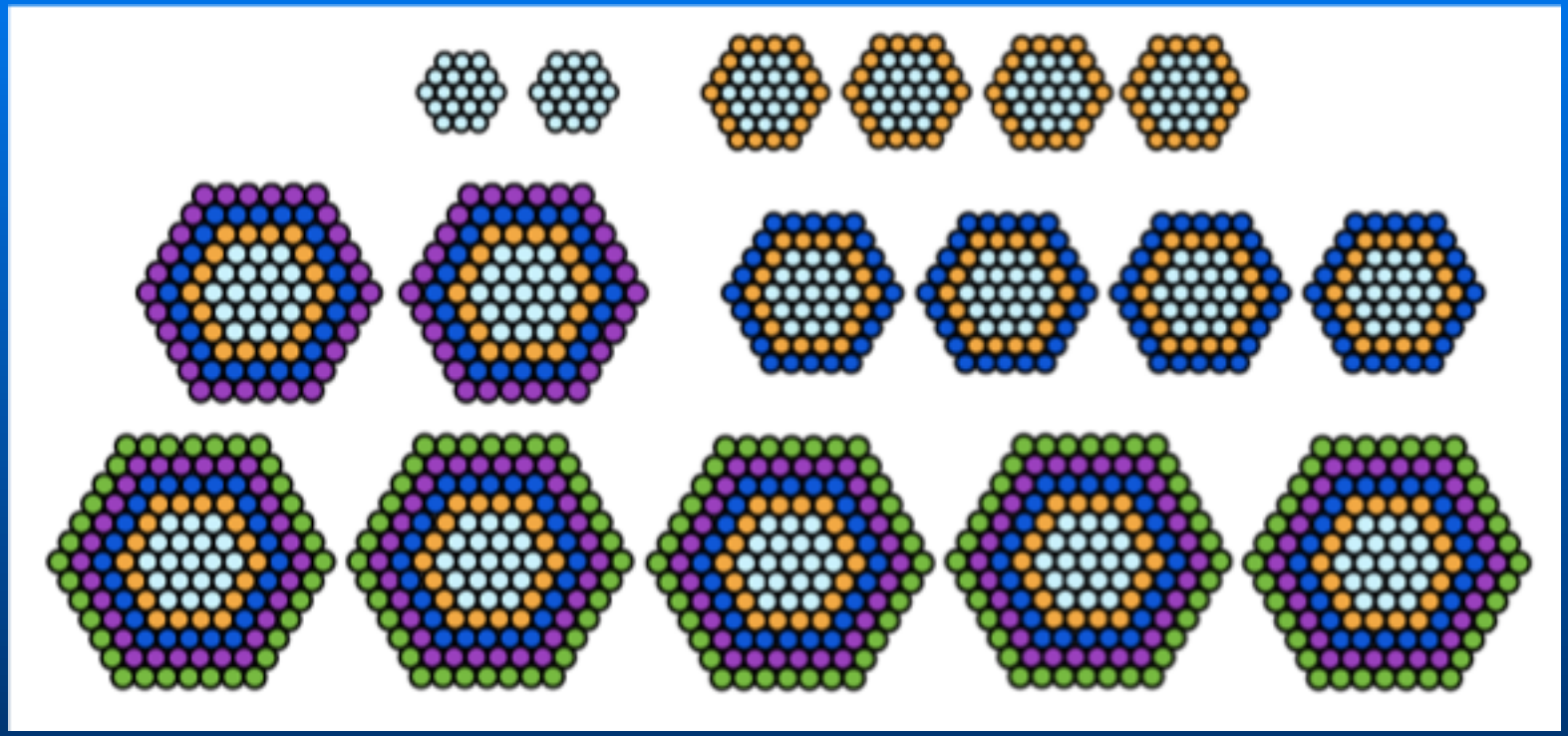




Drory et al. 2015

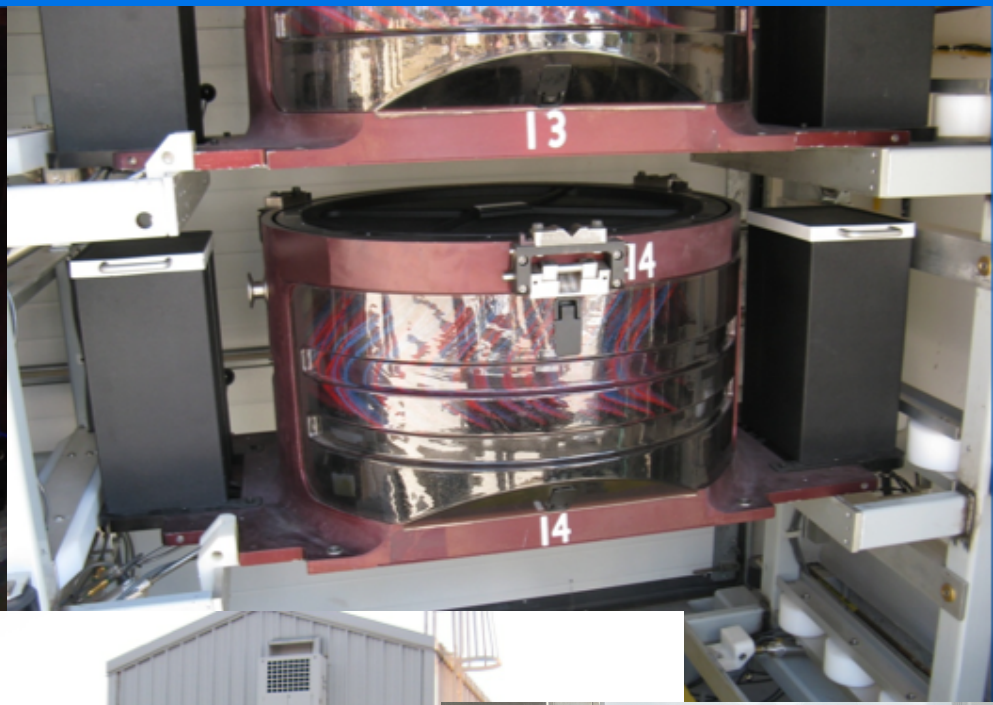
Drory et al. 2015

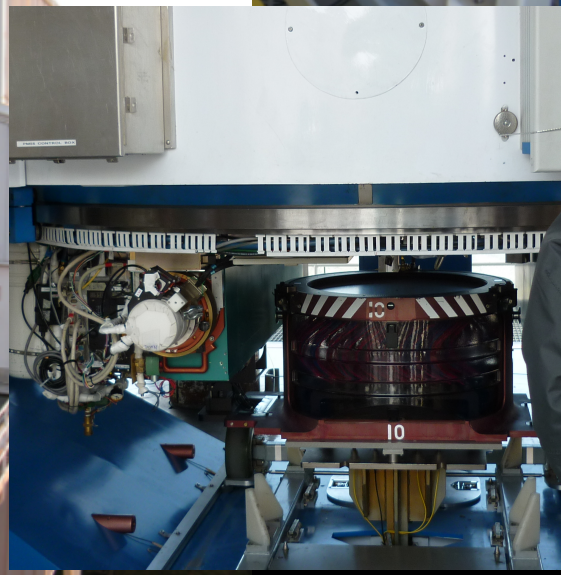
MaNGA Hardware



- 17 Science IFUs per cartridge (6 total)
  - sizes between 19 and 127 fibers (12” – 32” across)
- 12 Mini-bundles (7 fibers) per cartridge
- 92 Sky-fibers, associated with IFUs

Operations at APO

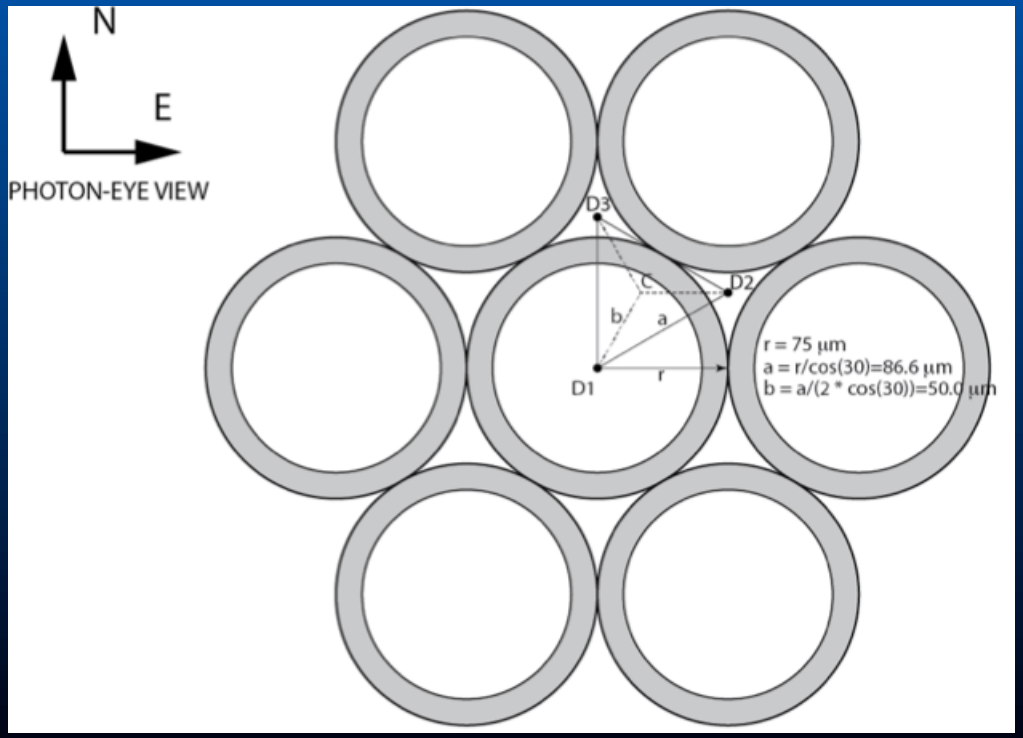




Law et al. submitted

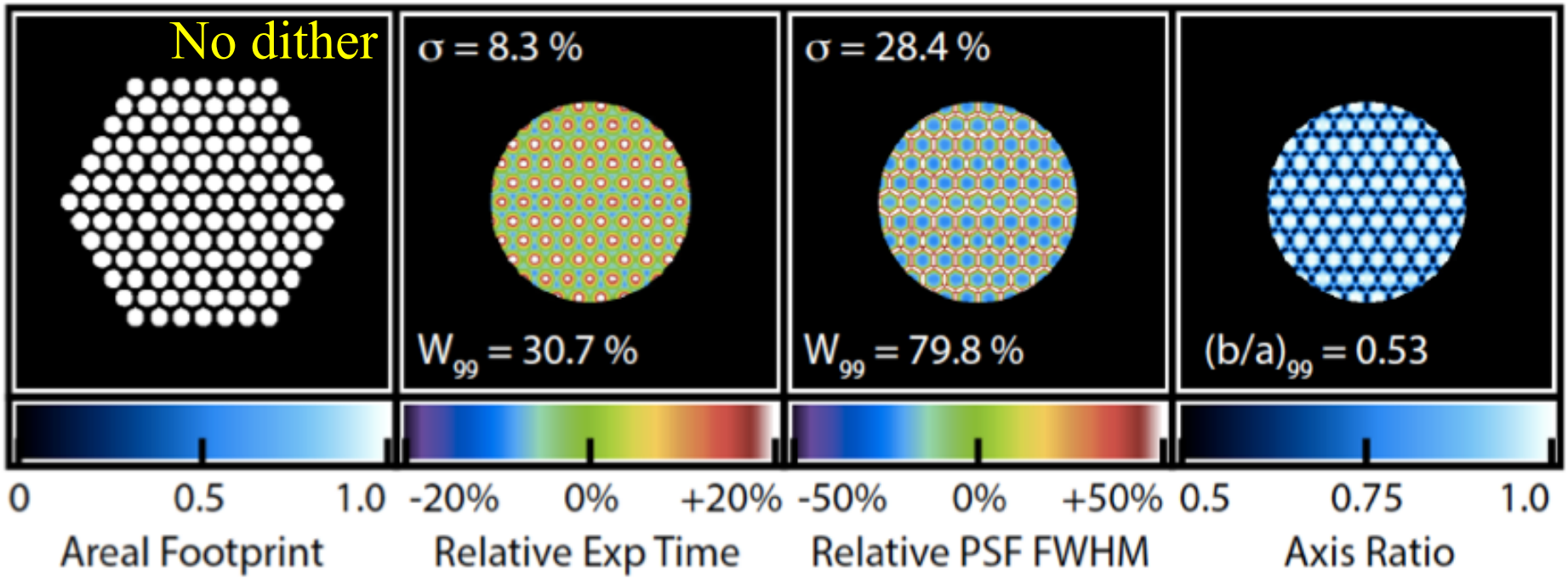
Observing Strategy

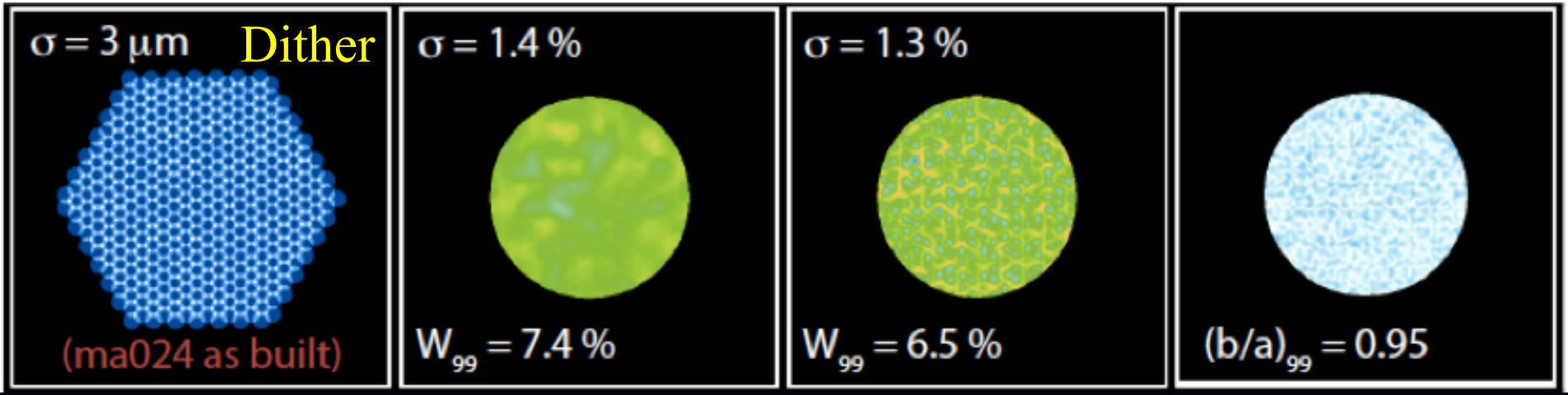
- Observe sets of three dithered 15min exposures
- Repeat until S/N threshold is reached
  - typically: 3hr
- Combine dithered sets into datacubes



Law et al. submitted

Why dither?

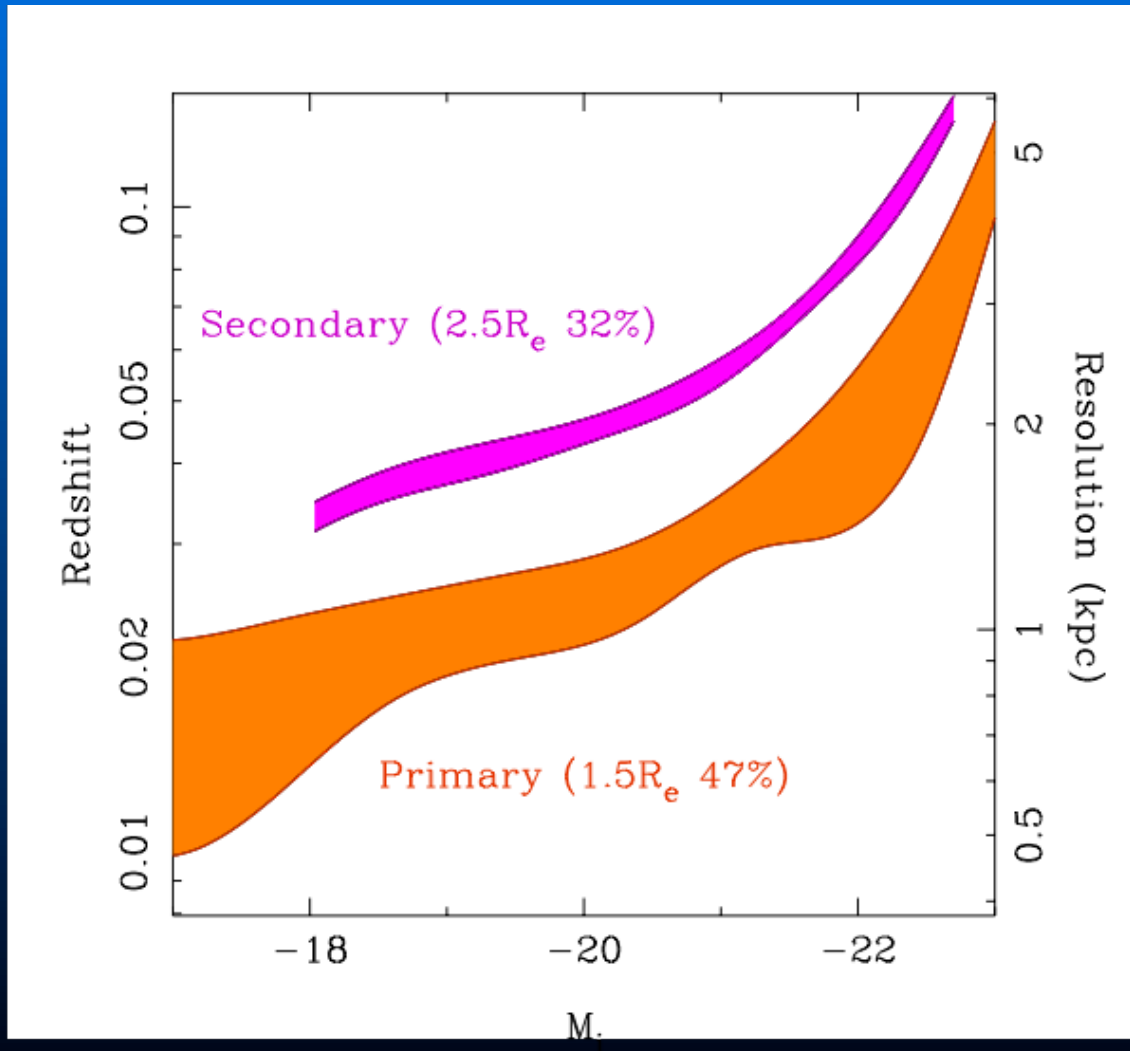




Wake et al. in prep

Sample Design

- Selection from NYU VAGC and NASA-Sloan Atlas (Blanton et al. 2011)
- Flat stellar mass distribution
- Colour-enhanced sample (16%)
- Ancillary programs



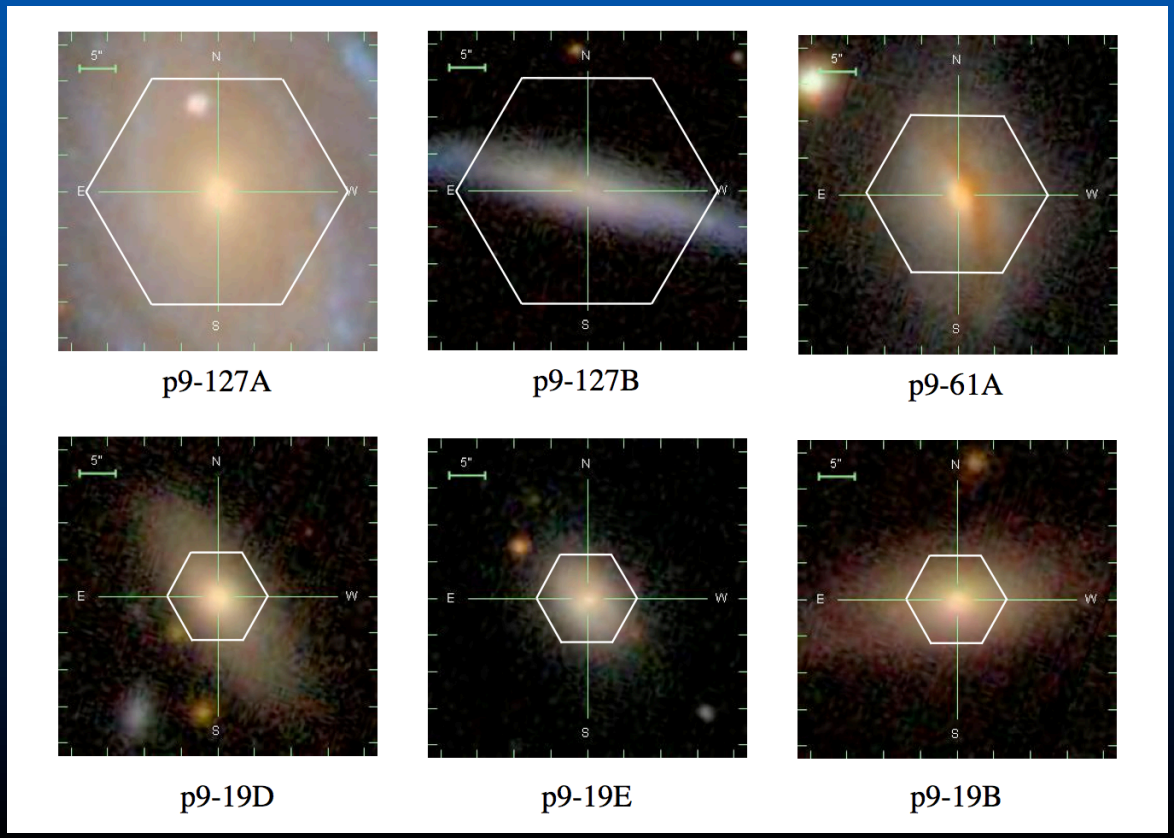
MaNGA & APOGEE

- MaNGA uses same cartridges as APOGEE
  - both MaNGA and APOGEE fibers
- MaNGA observes in dark time
  - APOGEE co-observes for halo stars
- APOGEE observes in bright time
  - MaNGA co-observes for stellar library
- Increased survey efficiency!!!

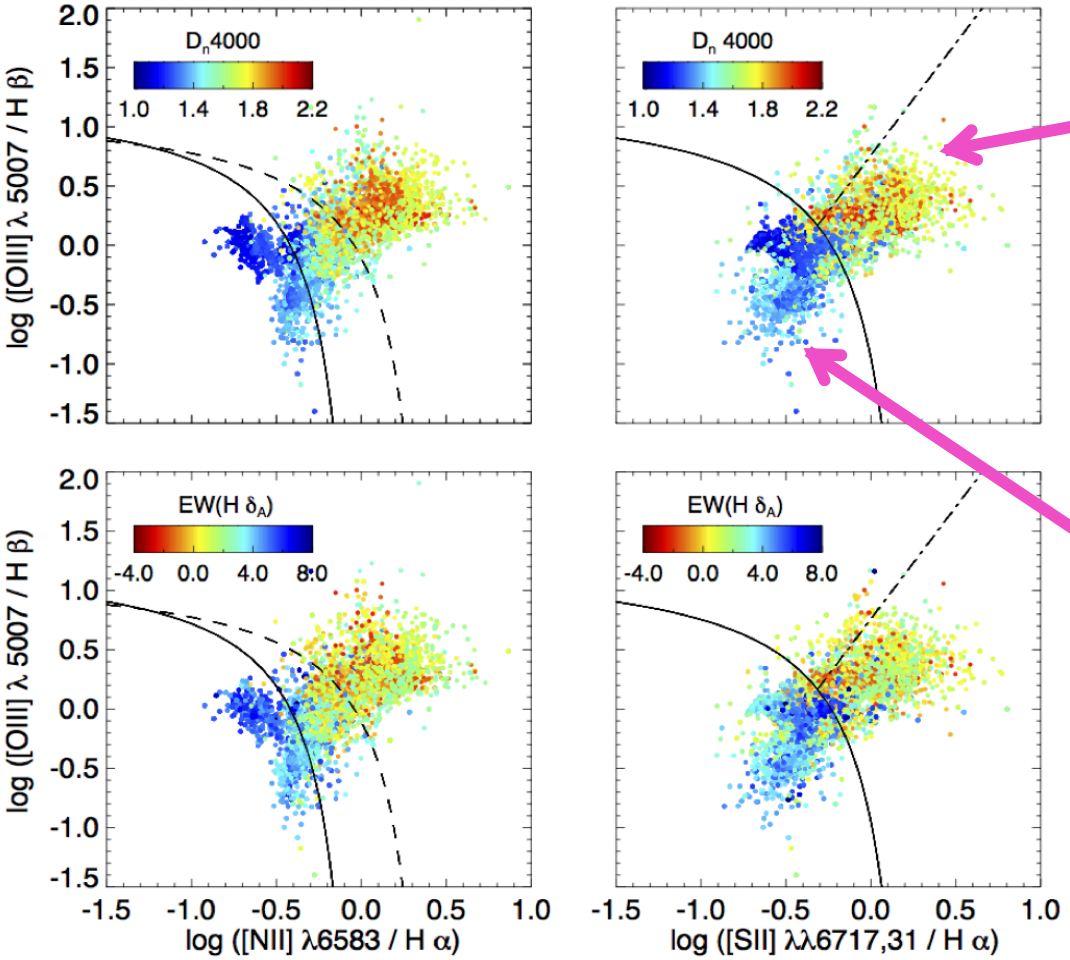
P-MaNGA

Bundy et al. 2015

- Proto-type run in January 2013
- Total science yield: 18 galaxies
  - 6 with survey quality, 12 under less optimal conditions



P-MaNGA: Resolved Gas Ionisation and Chemical Abundances

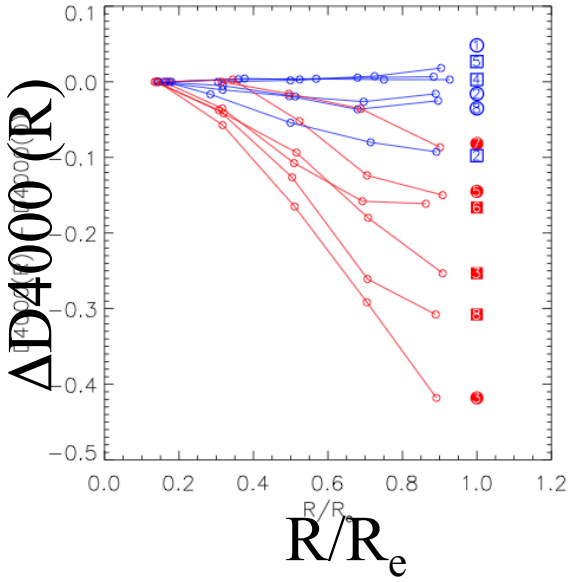


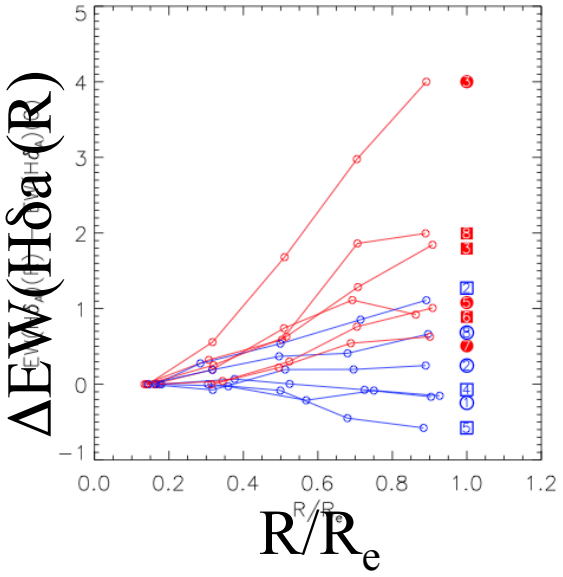
AGN

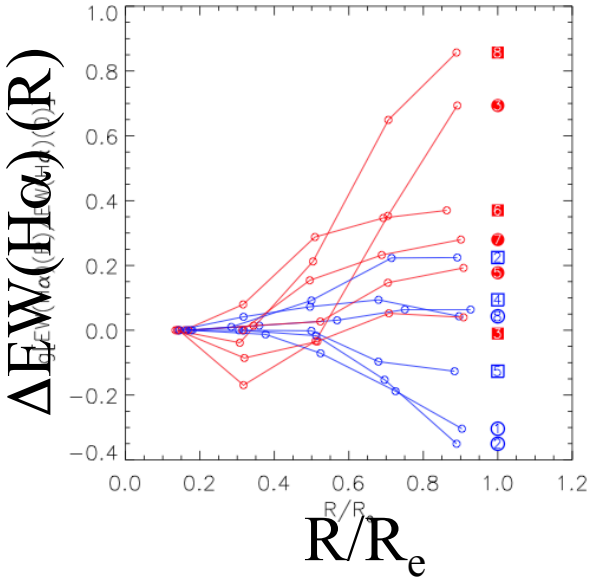
Star Forming

Belfiore et al. 2015, in press
astro-ph 1401.7781

P-MaNGA: Gradients in Recent Star Formation





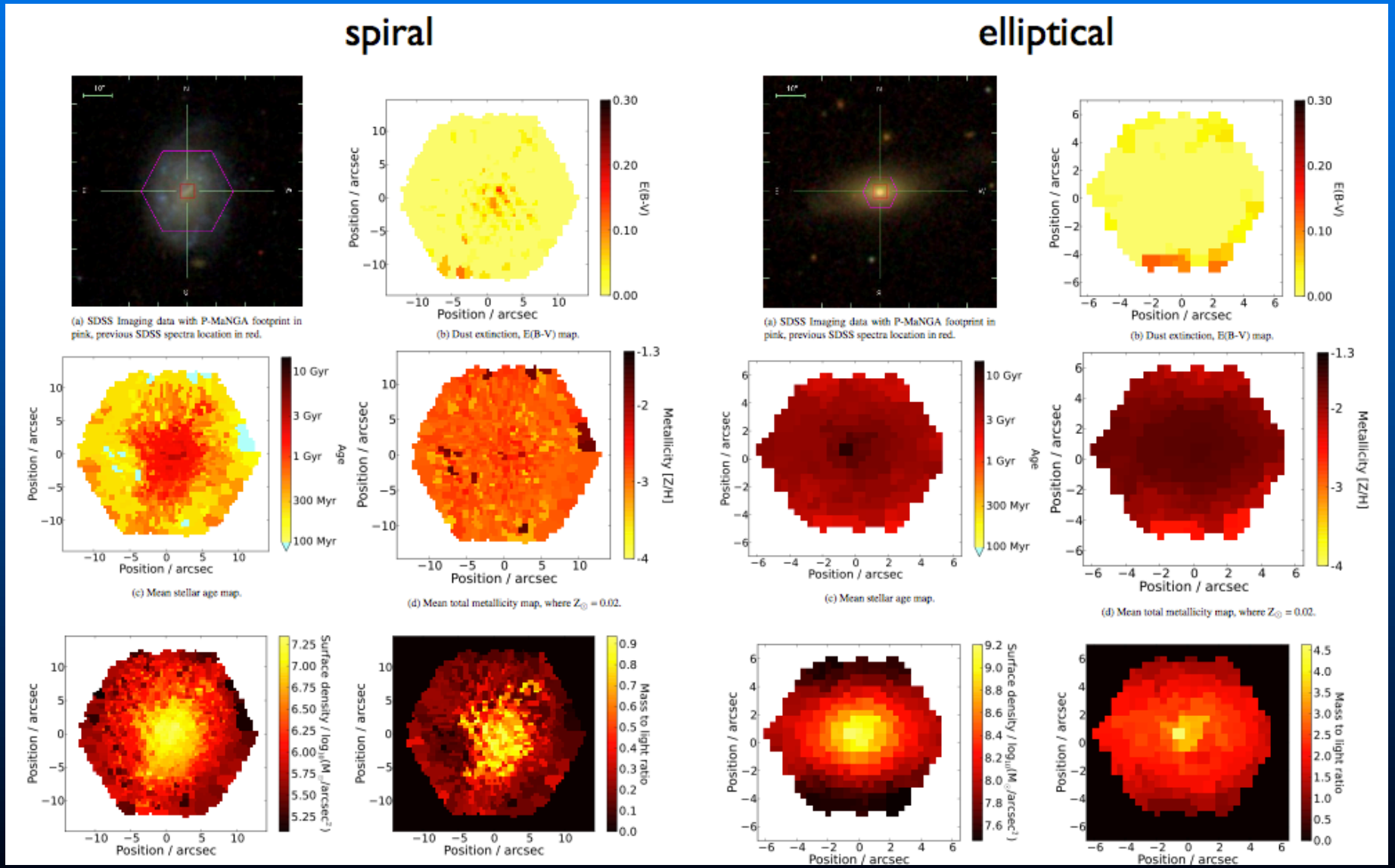


$$\Delta X\,(R) = X(R) - X(0)$$

Red = Centrally Quenched
Blue = Centrally Star Forming

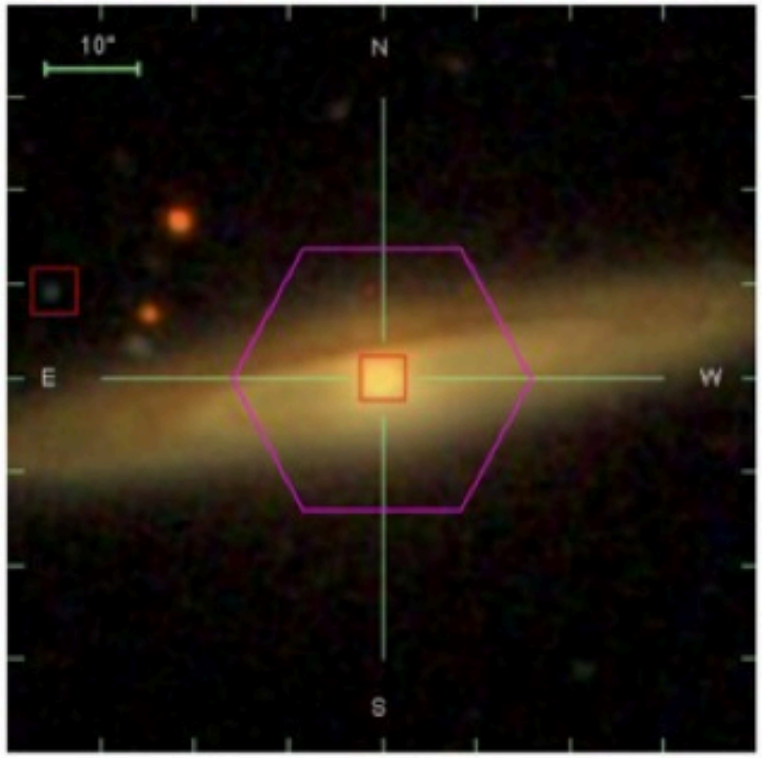
Li et al. 2015, in press
astro-ph 1502.07040

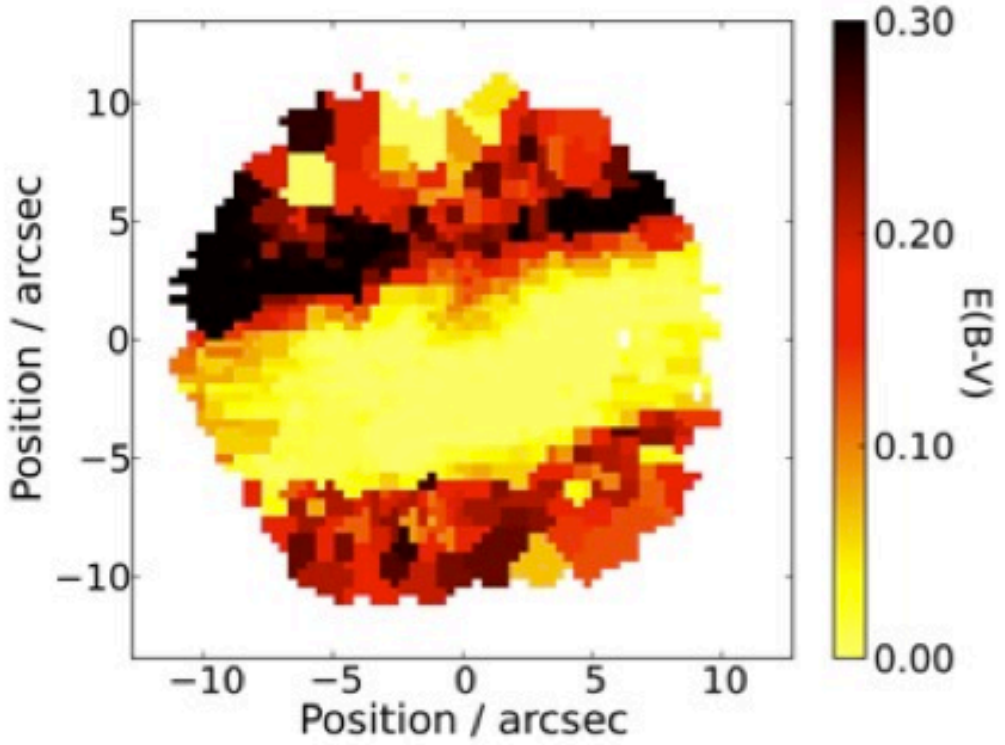
P-MaNGA: Stellar Population Maps…



Wilkinson et al. 2015, in press

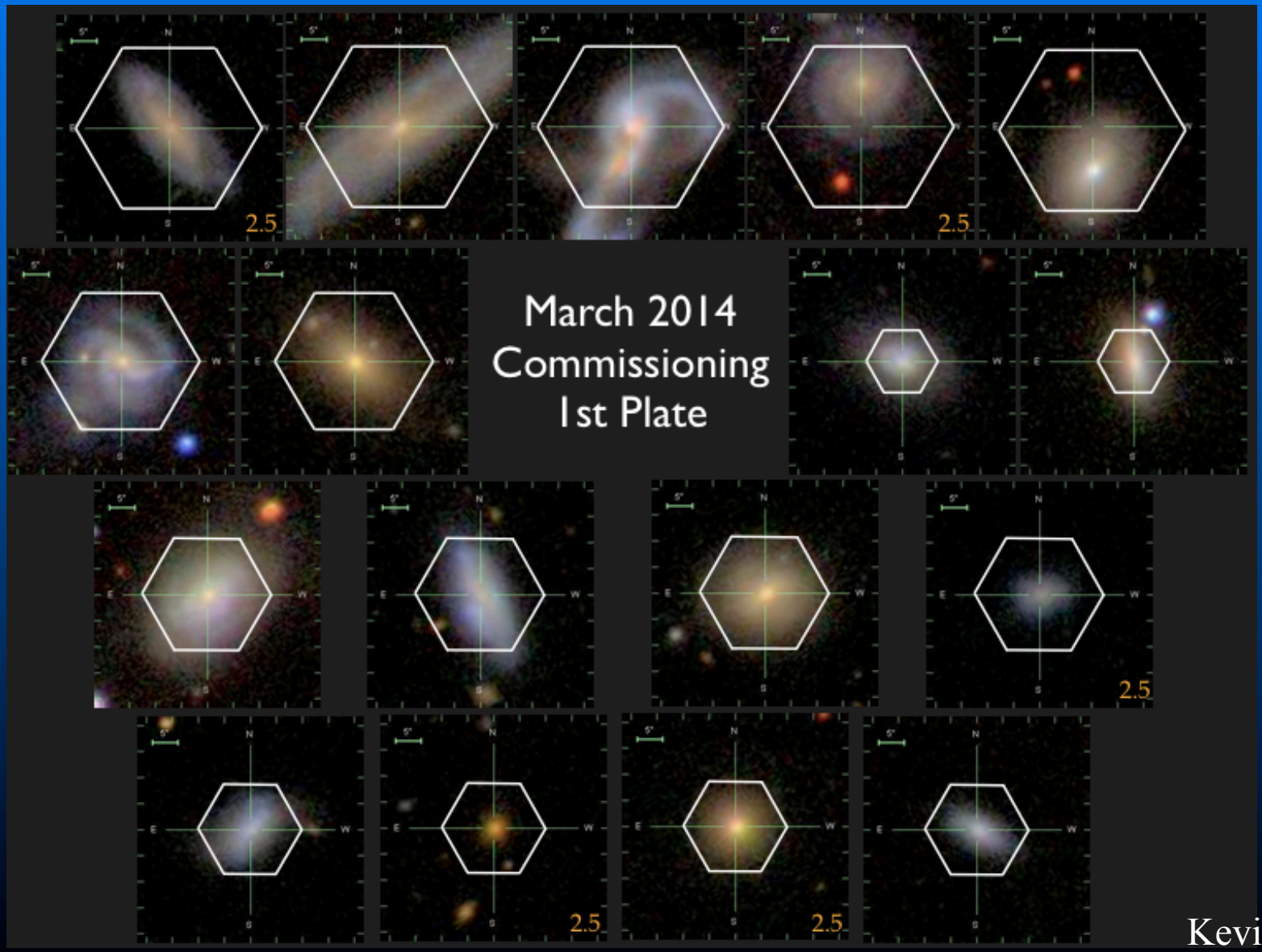
… and Dust Maps





Wilkinson et al. 2015, in press

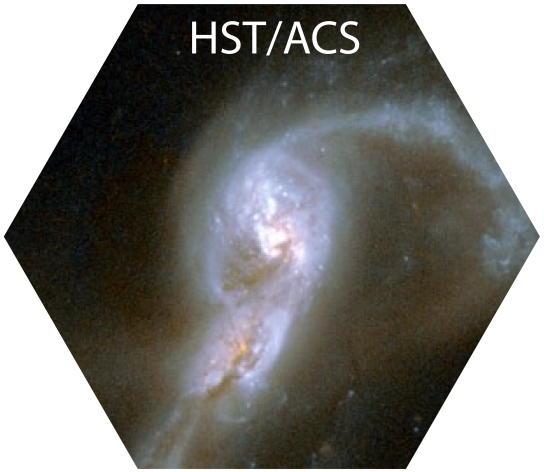
MaNGA: first plate

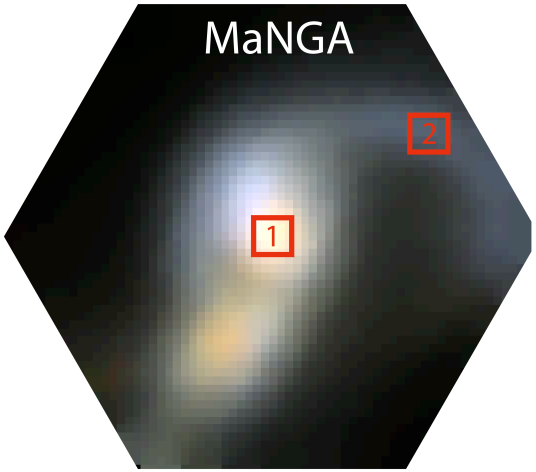


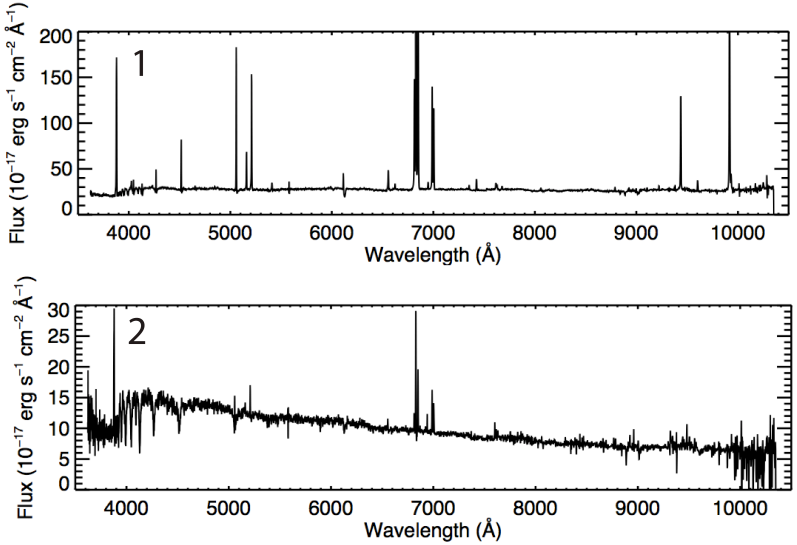
Kevin Bundy

MaNGA: first datacube

Mrk 848: SDSS-IV/MaNGA First-Article Data Cube

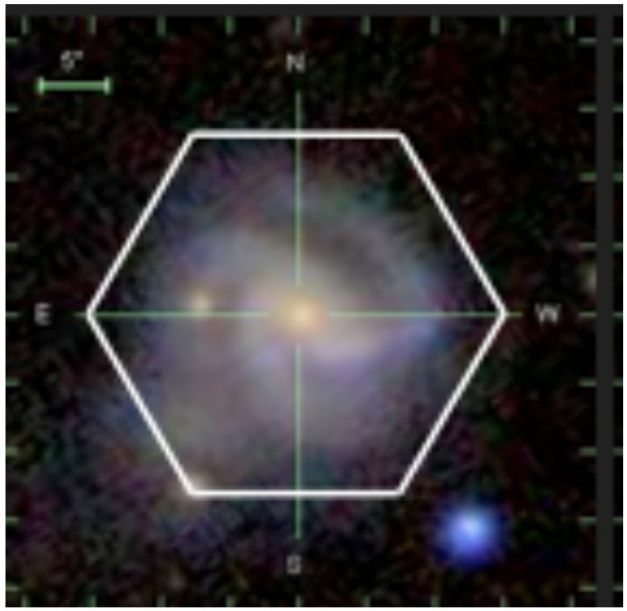






David Law

MaNGA: first bonus galaxy



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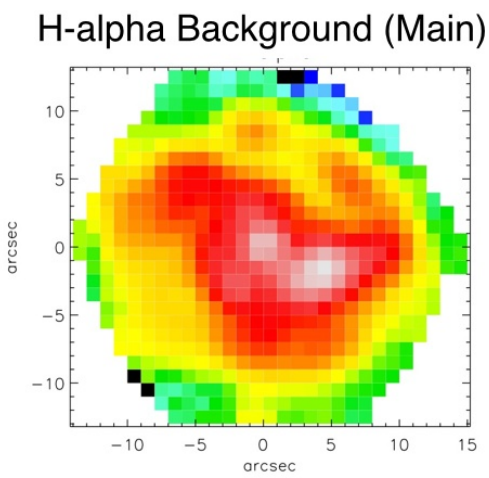
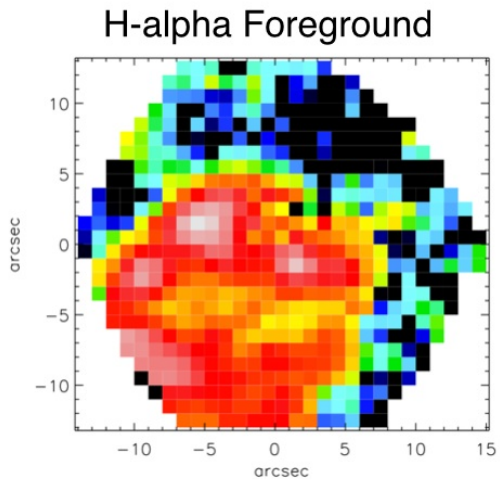




Christy Tremonti

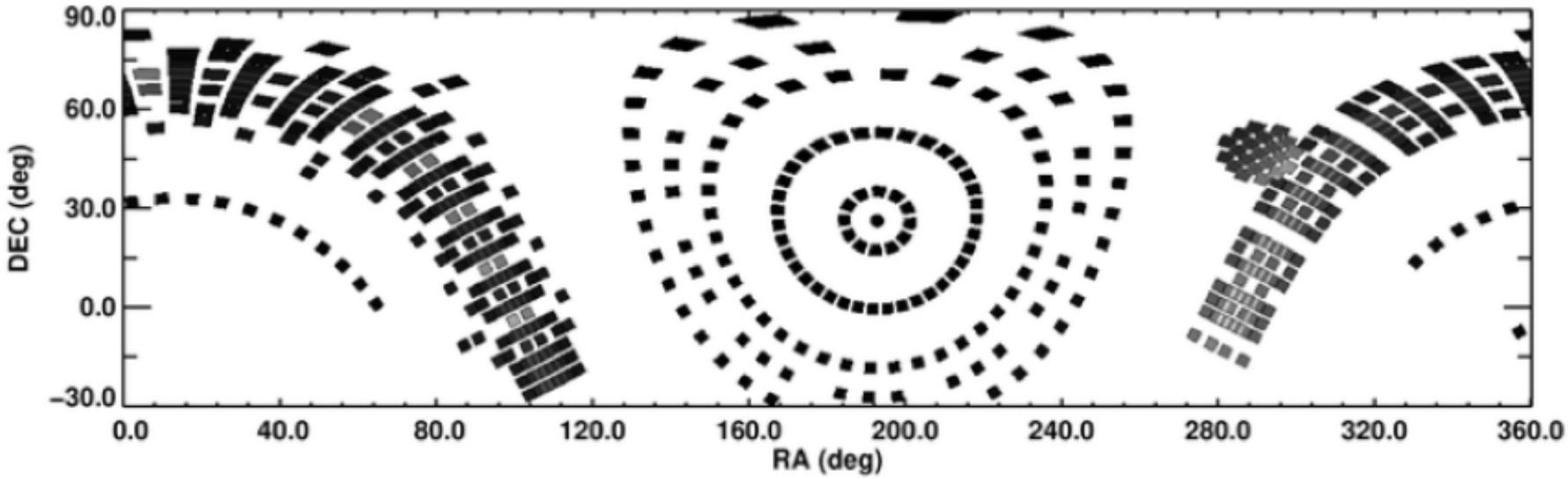
Summary

- 10,000 galaxies are coming your way
  - data cubes and data products
- Want to know more?
  - MaNGA overview paper: Bundy et al. 2015
  - MaNGA instrumentation paper: Drory et al. 2015
  - on-line: http://www.sdss.org/surveys/manga/
- Follow us @MaNGASurvey

slide by Jesús Falcón-Barroso

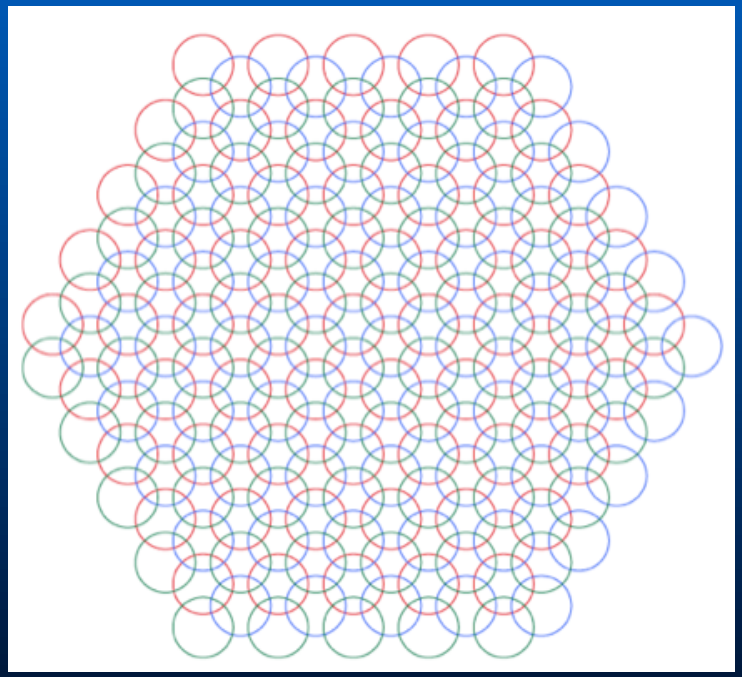
MaNGA stellar library

- Stellar library with same instrument as galaxy survey → facilitate galaxy studies
- Improve λ coverage and flux calibration
- Improve stellar parameter coverage
  - e.g., carbon-stars, high Z stars in bulge

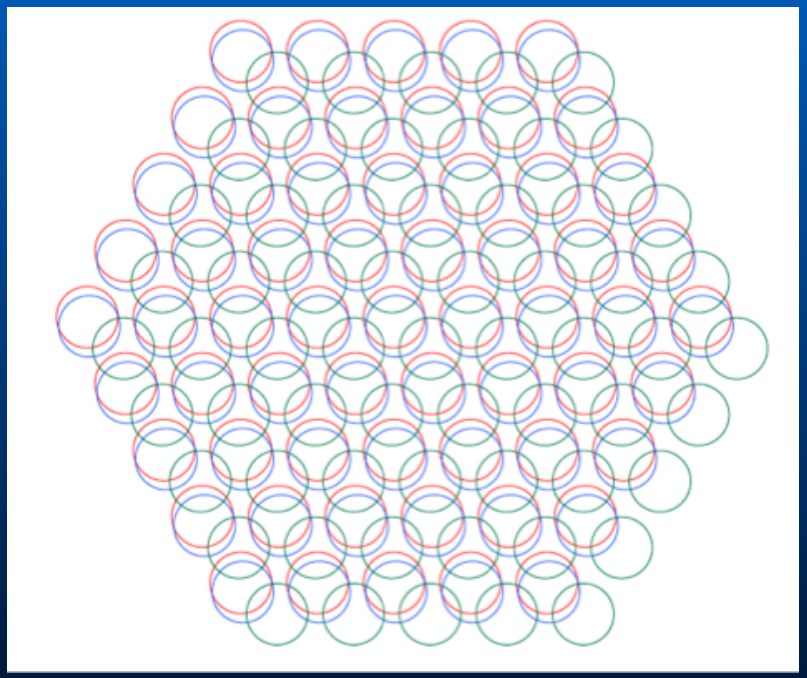


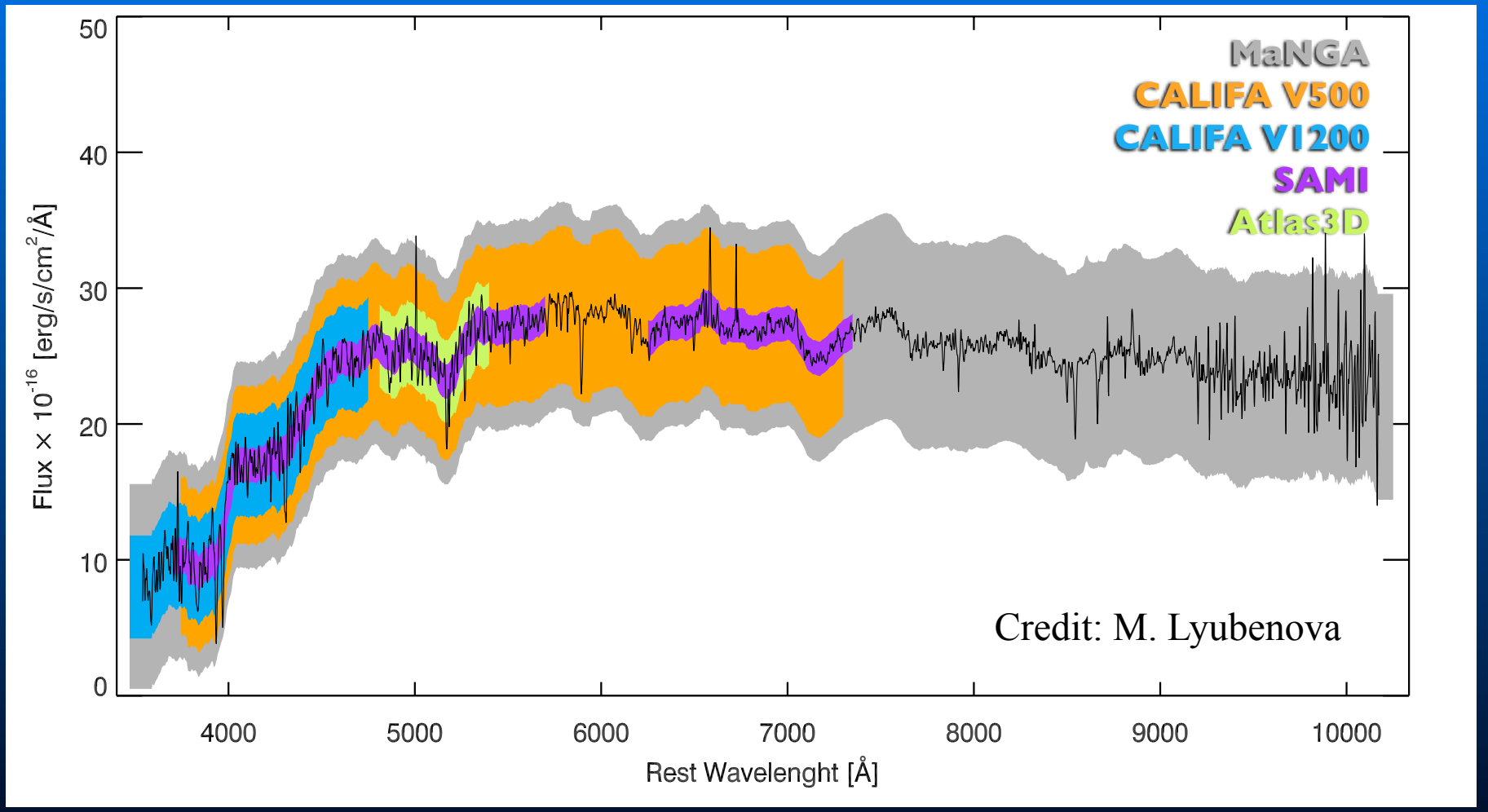
Restrictions on Hour Angle

5500 A



3600 A




MaNGA
CALIFA V500
CALIFA V1200
SAMI
Atlas3D
Credit: M. Lyubenova
Flux × 10^-16 [erg/s/cm^2/Å]
Rest Wavelenght [Å]
0
10
20
30
40
50
4000
5000
6000
7000
8000
9000
10000

IFU surveys at a glance

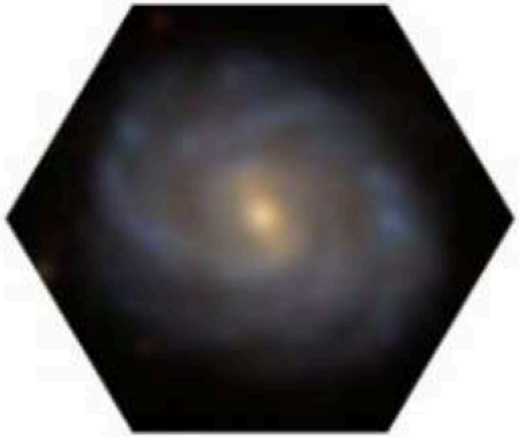
	Atlas3D	DiskMass	CALIFA	MASSIVE	SAMI	MaNGA
# of galaxies	260	46 / 146	600	116	3,400	10,000
galaxy types	early-type	face-on spirals	all types	massive early-types	all types	all types
spatial coverage	0.6 – 1.5 R_e	1.1 – 3 R_e	1.8 – 3.7 R_e	~ 2 R_e	1.1 – 2.9 R_e	1.5 / 2.5 R_e
spatial sampling	0.8”	2.7” / 4.7”	2.7”	4.1”	2.1”	2.0”
spectral coverage (nm)	480 – 538	498 – 538 648 – 689	375 – 750 370 – 475	365 – 585	370 – 570 625 – 735	360 – 1000
spectral resolution (σ in km/s)	98	16 / 13	150 / 69	100 - 150	75 / 28	50 – 80

source: Bundy et al. 2015,
Ma et al. 2014 (MASSIVE)

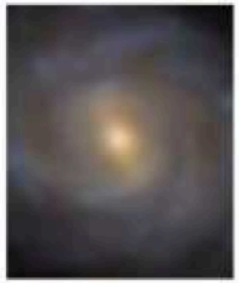
Sánchez et al. 2014

SDSS 90”x90” image

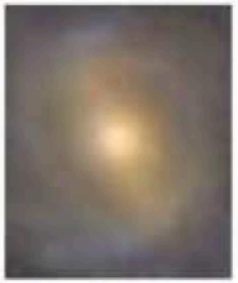
CALIFA (V500/V1200)



Atlas3D



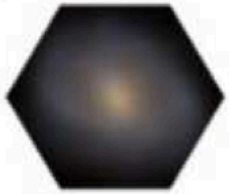
z~z$_{califa}$



z~z$_{Atlas3D}$

MaNGA largest FoV

FoV~1.5Re



~2.5Re

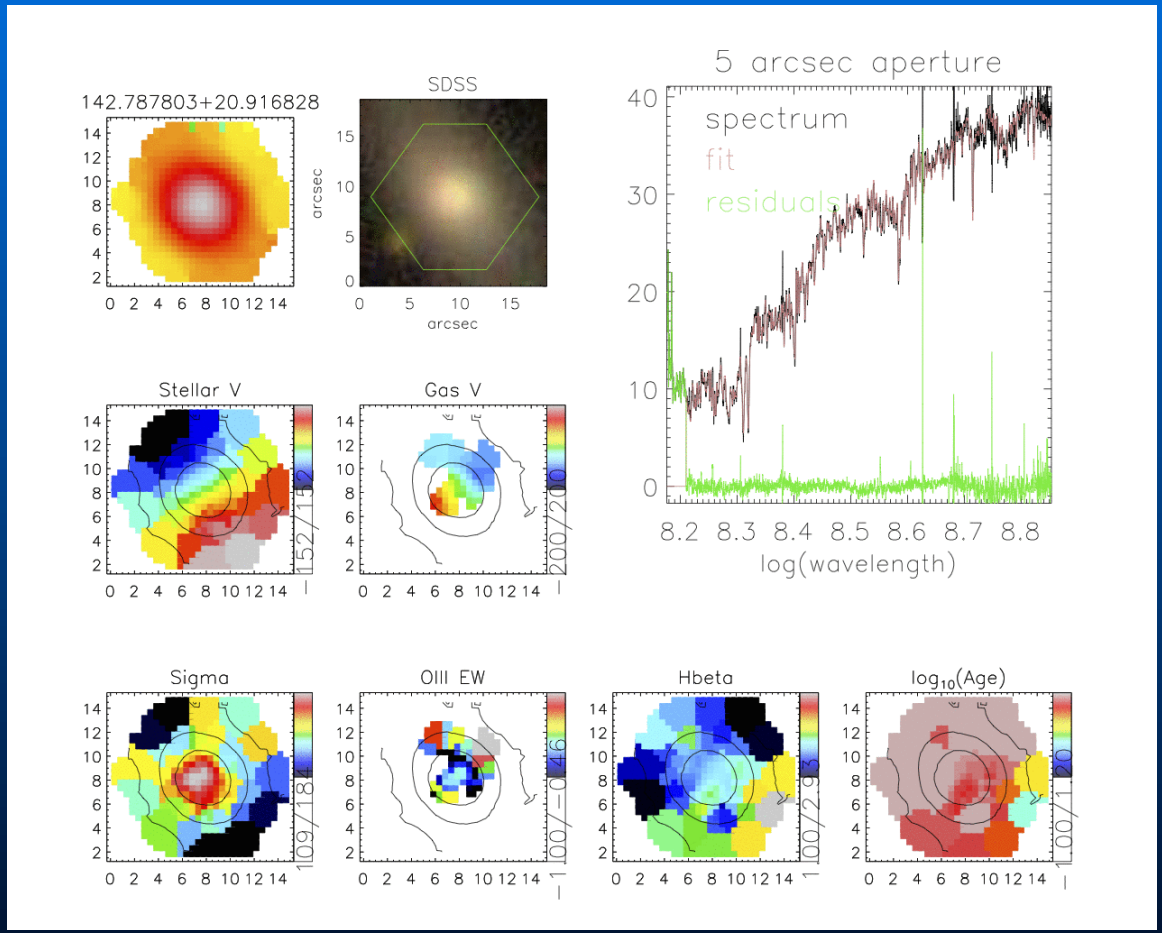
SAMI

z~z$_{califa}$

z~z$_{SAMI}$

P-MaNGA

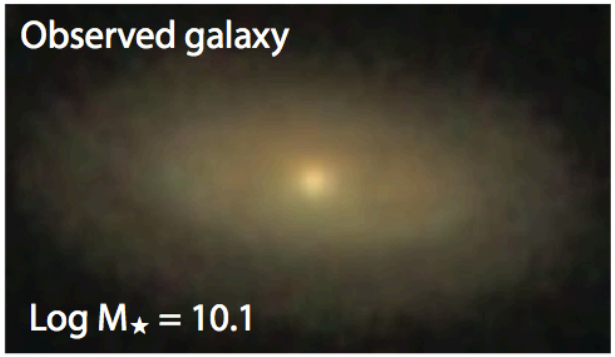
- Example: galaxy in 19-fiber IFU
  - extract stellar and gas kinematics, and line strengths
  - discovery of counter-rotating gas disc!
- Test data indicative of rich MaNGA data set
- Three papers now in referee process

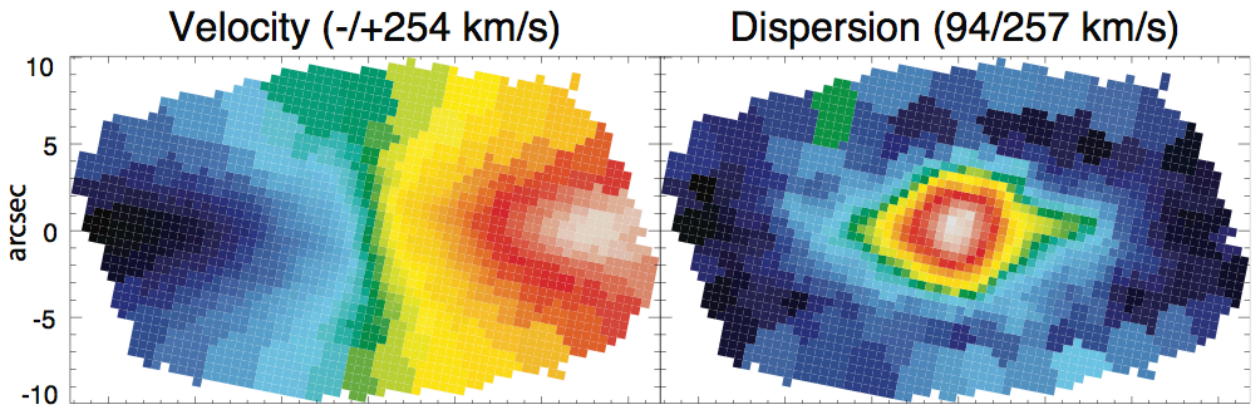


Richard McDermid & MaNGA Team

MaNGA kinematics

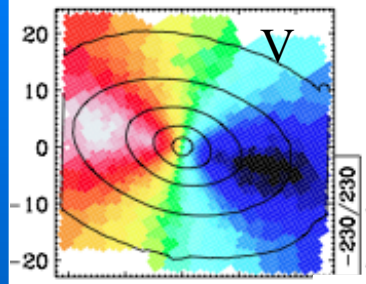
- We will provide stellar and gaseous velocity and velocity dispersion maps
- Plan: construct Jeans models for all galaxies
  - but careful with interpreting irregulars / mergers
- Schwarzschild models for larger bundles

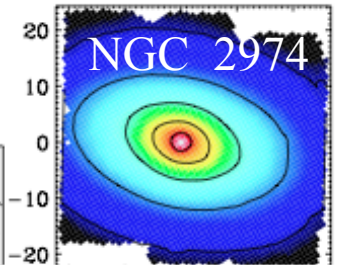


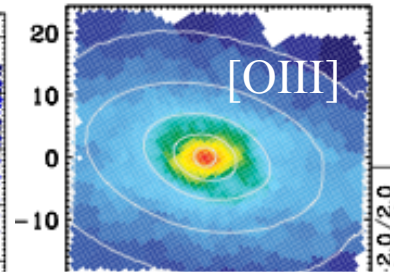


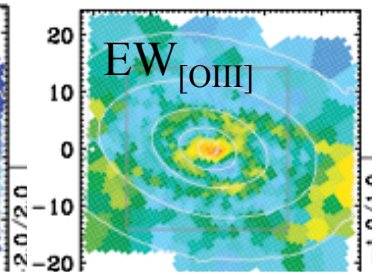
P-MaNGA 61 bundle

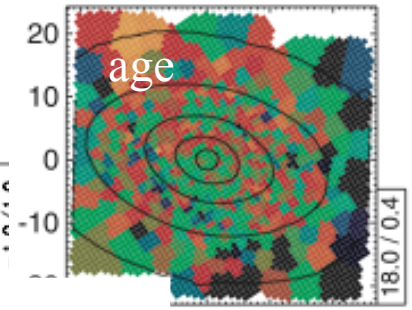
Bundy et al. 2015

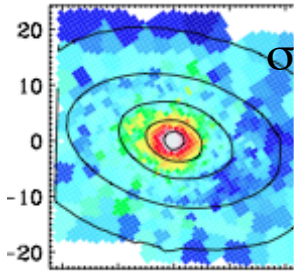


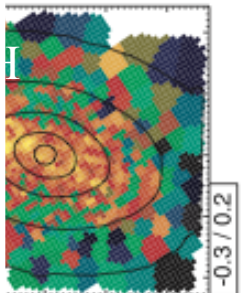


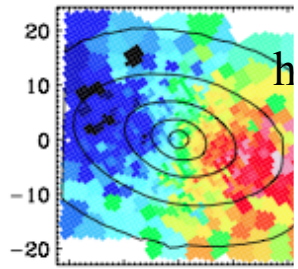


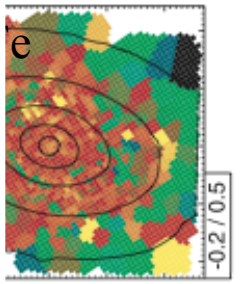


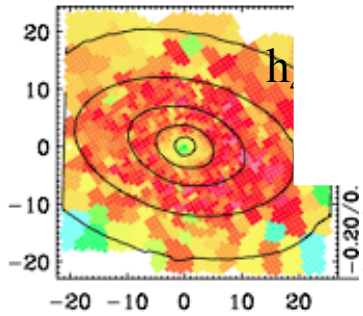


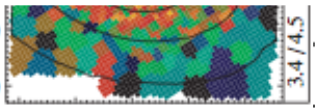


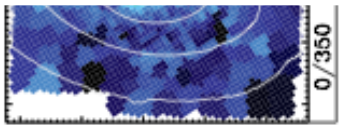












- SAURON has 4800 – 5300A range, we have 3600 – 10,000A
  - many more emission and absorption lines
- This is only one galaxy, we will have 10,000 of them!

•Star Formation Rates
•Dynamical Models
•…..

SAURON Survey: Emsellem et al. 2004, Kuntschner et al. 2006, 2010, Sarzi et al. 2006