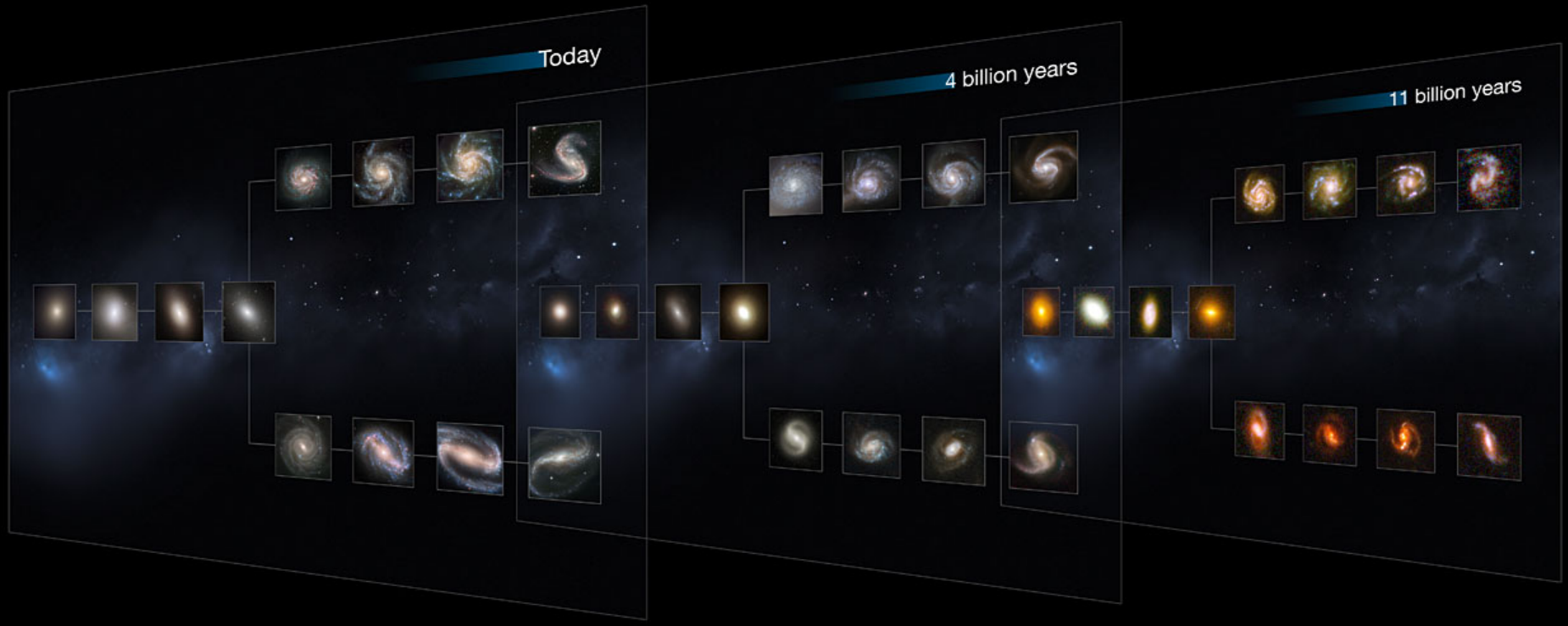
Extragalactic Surveys

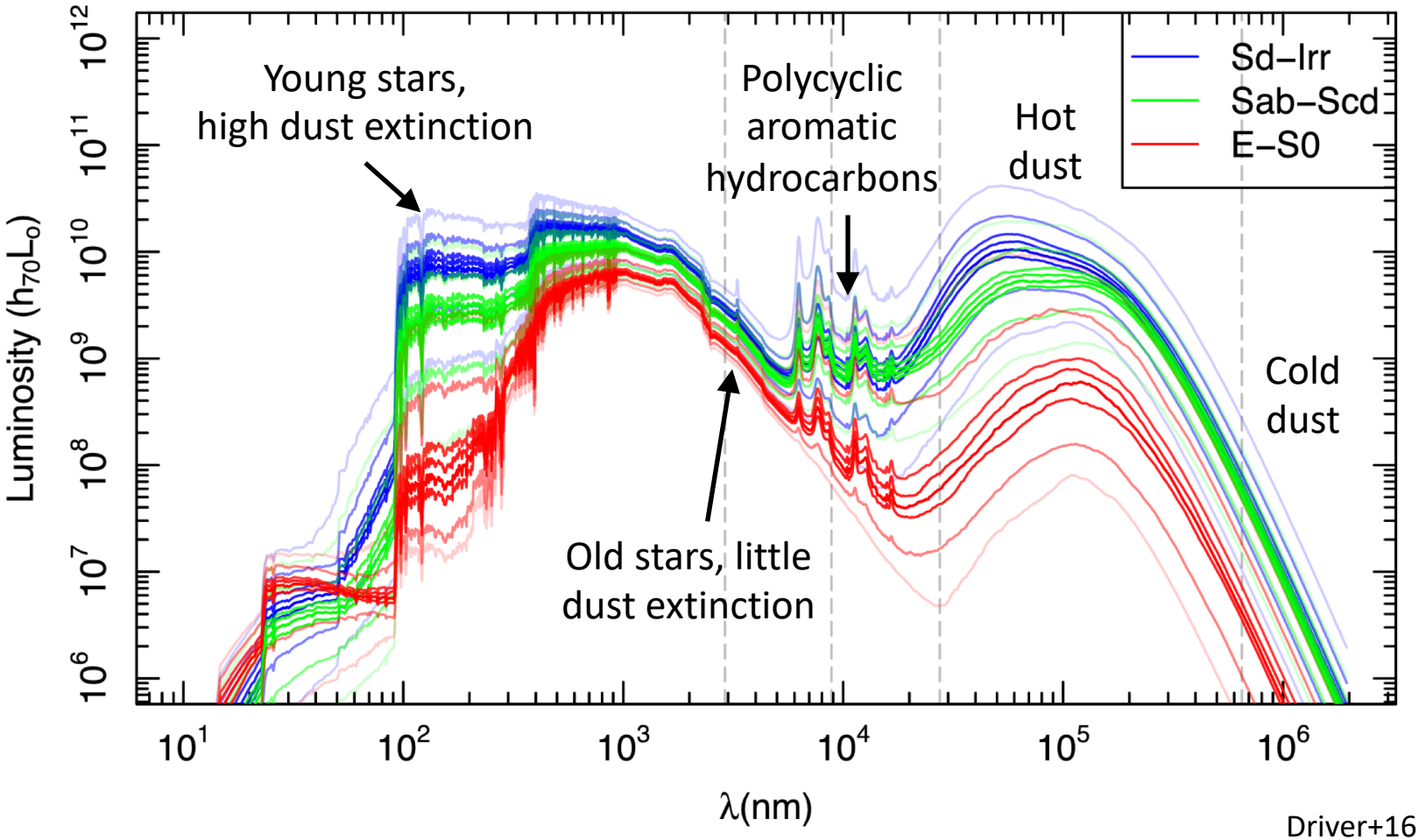
Juan Carlos Muñoz-Mateos



NASA, ESA, M. Kornmesser, CANDELS

How to design a galaxy survey

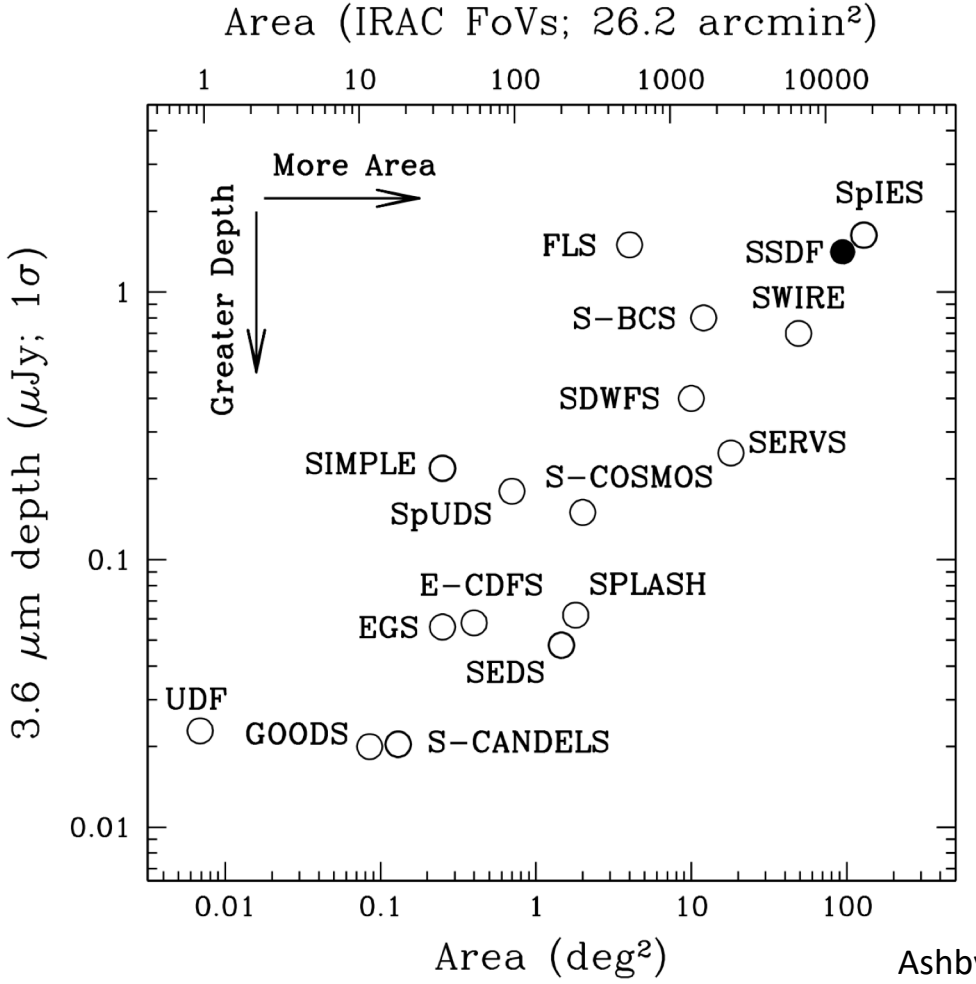
- What wavelength(s) do I need? Imaging? Spectroscopy? Which instrument/telescope?



Driver+16

How to design a galaxy survey

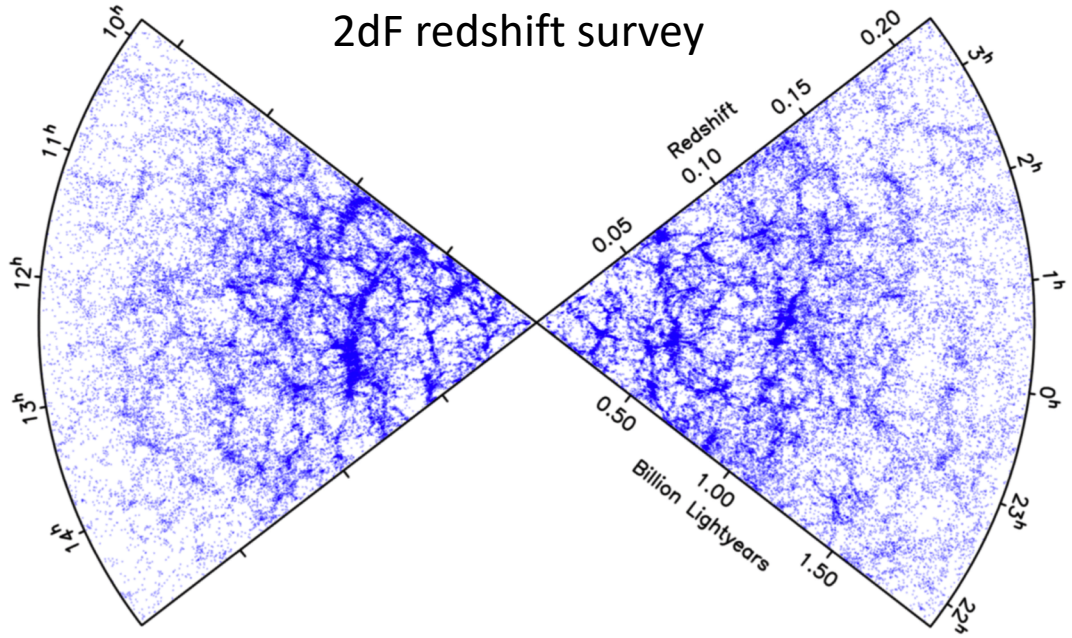
- How many objects do I need? Do I need a complete sample or just a representative one?
- Area vs depth:



Ashby+13

How to design a galaxy survey

- Environment and cosmic variance



- Where on the sky? If your field is close to the celestial equator, you can observe it from both hemispheres

The Spitzer Infrared Nearby Galaxies Survey (SINGS) Hubble Tuning-Fork

The Spitzer Space Telescope observed 75 galaxies as part of its SINGS (Spitzer Infrared Nearby Galaxies Survey) Legacy Program. The galaxies are presented here in a Hubble Tuning-Fork diagram, which groups galaxies according to the morphology of their nuclei and spiral arms. The designation of these galaxies and their placement in the diagram is based on their visible-light appearance. The main goal of the SINGS program is to characterize the infrared properties of a wide range of galaxy types. The images of the galaxies are composites created from data taken by IRAC (the Infrared Array Camera) at 3.6 and 8.0 μm, and MIPS (the Multiband Imaging Photometer for Spitzer) at 24 μm.

The infrared range probed by these and other observations taken for the SINGS project allows for the detailed study of star formation, dust emission, and the distribution of stars in each galaxy. Light from old stars appears as blue in the images, while the lumpy knots of green and red light are produced by dust clouds surrounding newly born stars. The elliptical galaxies on the left are almost entirely made of old stars, while spiral galaxies like our own Milky Way are rich in young stars and the raw materials for future star formation.

More information can be found at:
http://sings.stsci.edu/

Ellipticals

Strong Bulge

Weak Bulge

Unbarred Spirals

Intermediate Spirals

Strong Bulge

Weak Bulge

Irregulars

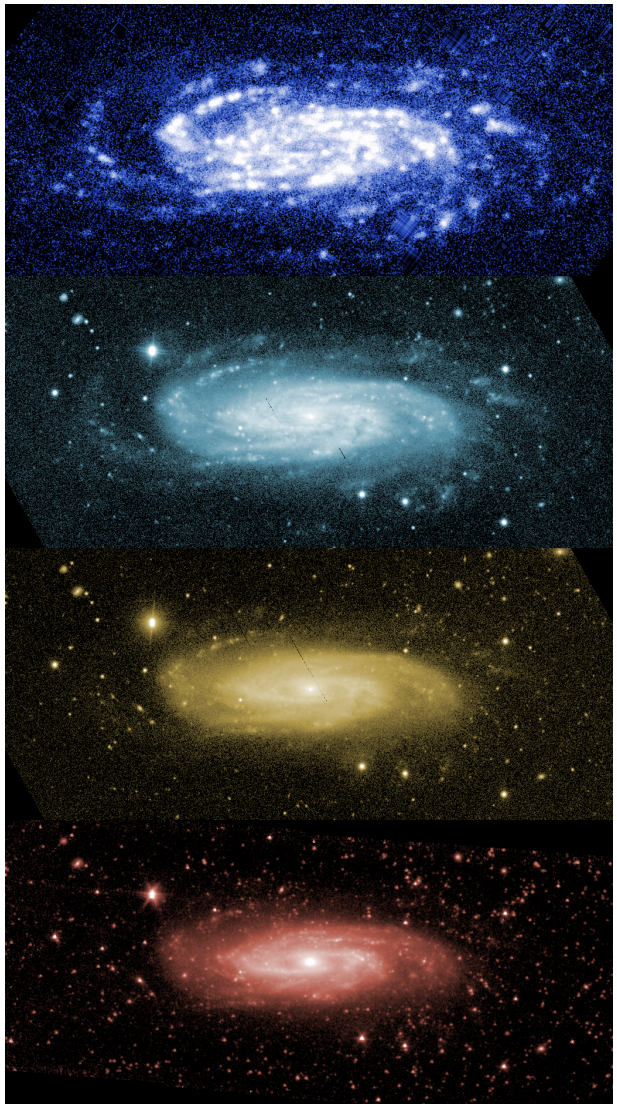
Barred Spirals

Poster and composite images created from SINGS observations by Karl D. Gordon (Oct 2007)
Blue=IRAC 3.6μm (stars)
Green=IRAC 8μm
(aromatic features from dust grains/molecules)
Red=MIPS 24μm (warm dust)

SINGS Team
Robert Kennicutt, Jr. (Principle Investigator), Daniela Calzetti (Deputy Principle Investigator), Charles Engelbracht (Technical Contact), Lee Armus, George Bendo, Caroline Bot, Brent Buckalew, John Cannon, Daniel Dale, Bruce Draine, Karl Gordon, Albert Grauer, David Hollenbach, Tom Jarrett, Lisa Kewley, Claus Leitherer, Aigen Li, Sangeeta Malhotra, Martin Meyer, John Moustakas, Eric Murphy, Michael Regan, George Rieke, Marcia Rieke, Helene Roussel, Kartik Sheth, J.D. Smith, Michele Thornley, Fabian Walter & George Helou

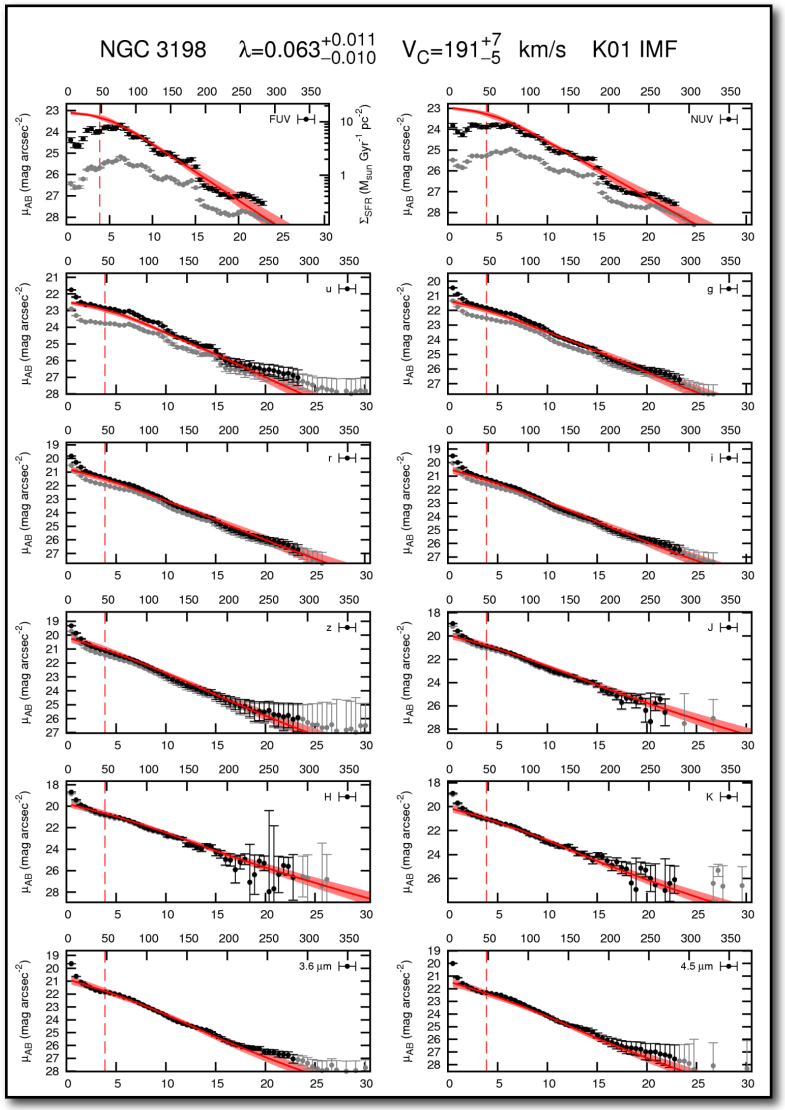
SPITZER SPACE TELESCOPE

How fast do disks grow from inside out?



young stars

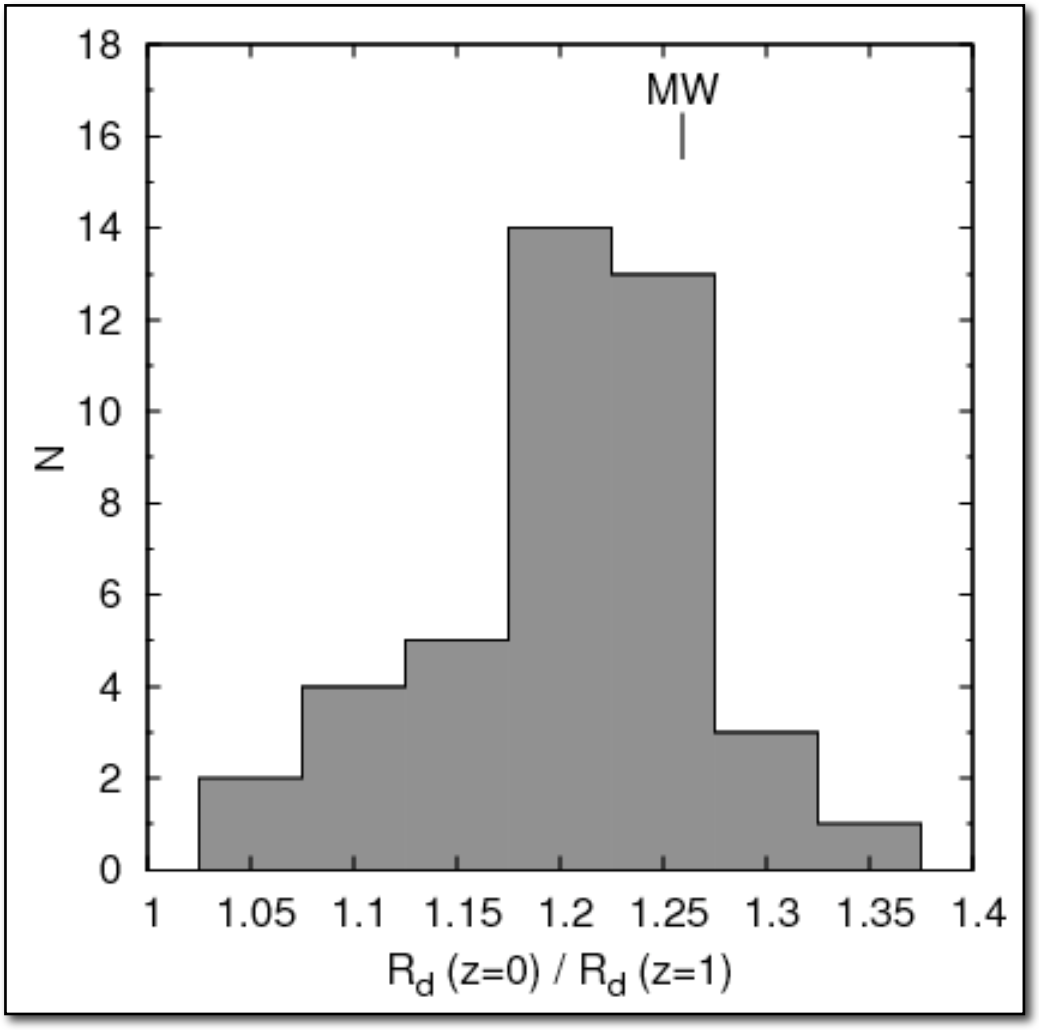
old stars



SINGS, Kennicutt et al. (2003)

Muñoz-Mateos et al. (2011)

Disks are now 20-25% larger than at z=1



Muñoz-Mateos et al. (2011)

The Spitzer Survey of Stellar Structure in Galaxies (S^4G, Sheth+10)

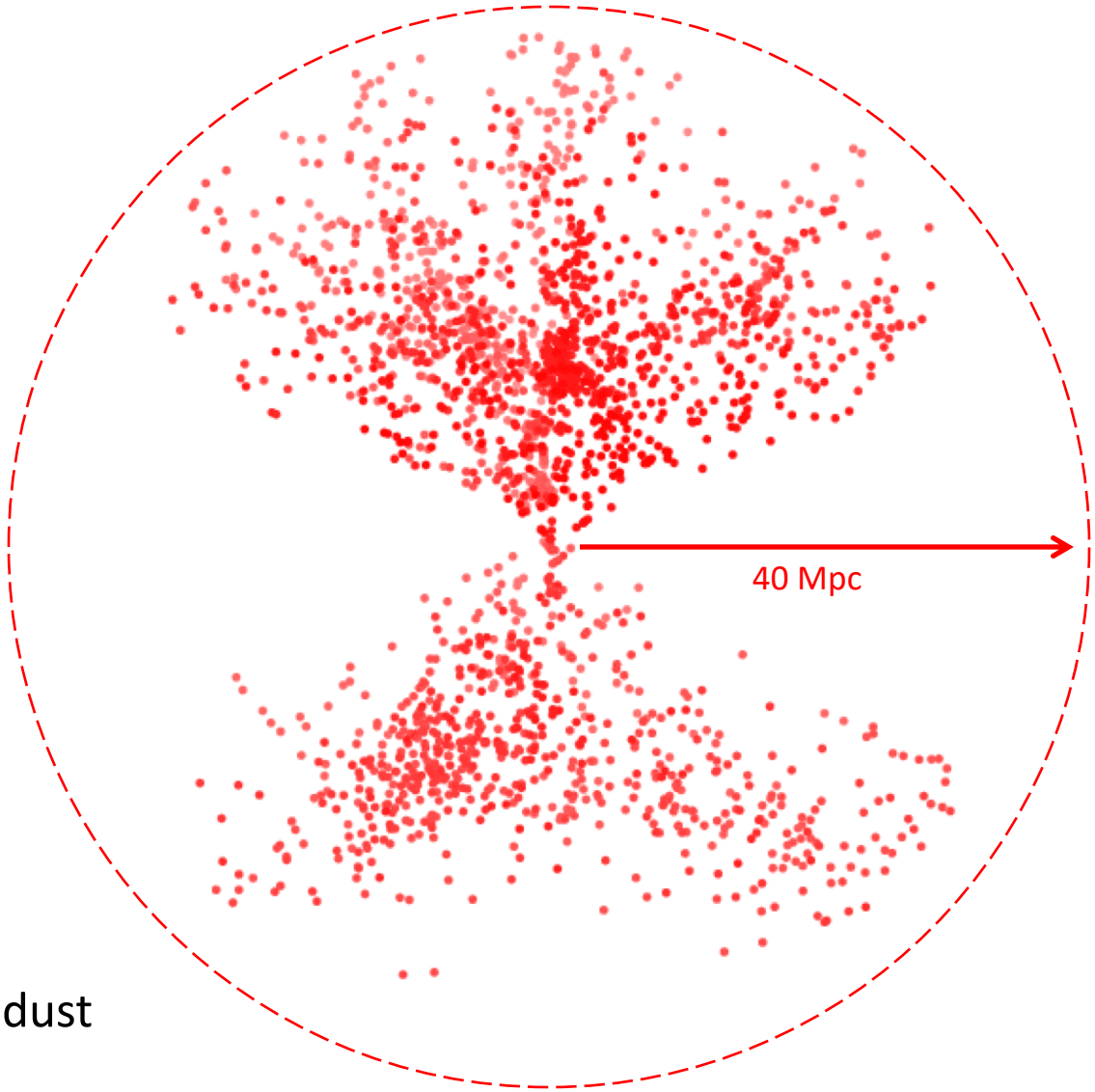
2352 galaxies (+ 465 ETGs)
observed at 3.6 & 4.5μm

Dist < 40 Mpc, |b| > 30°
m_{Bcorr} < 15.5, D_{25} > 1'

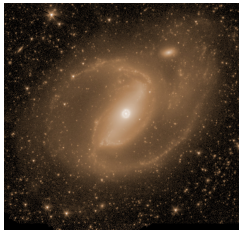
Very deep IR images
$\mu_{3.6\mu m}$ ~ 27 ABmags/arcsec^2
(~1 $M_\odot$/pc^2)

Directly probing old stars

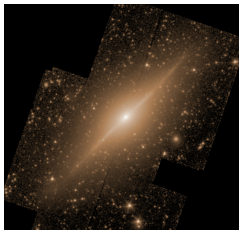
We can easily see through dust



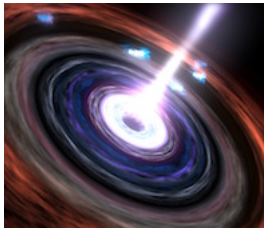
Some S^{4}G results



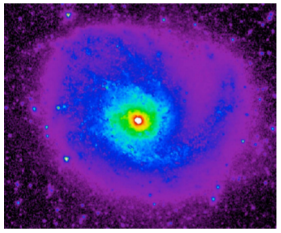
- Bar-induced resonances rearrange stars within disks (Muñoz-Mateos+2013, Kim+16, Díaz-García+16)



- Thick disks are more massive than previously thought (Comerón+11)

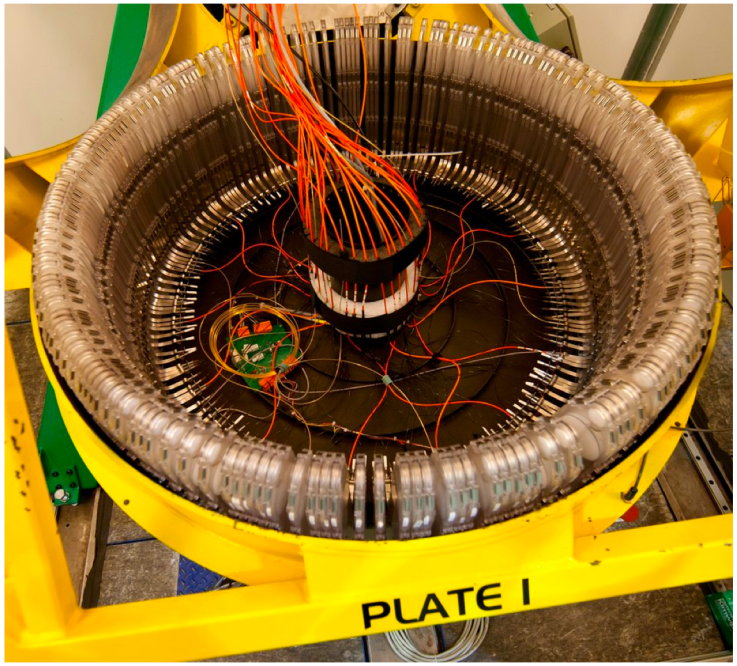


- No correlation between Active Galactic Nuclei activity and bar strength (Cisternas+15)



- Clean stellar mass maps (Meidt+12, Querejeta+15)

Multi-object spectroscopy

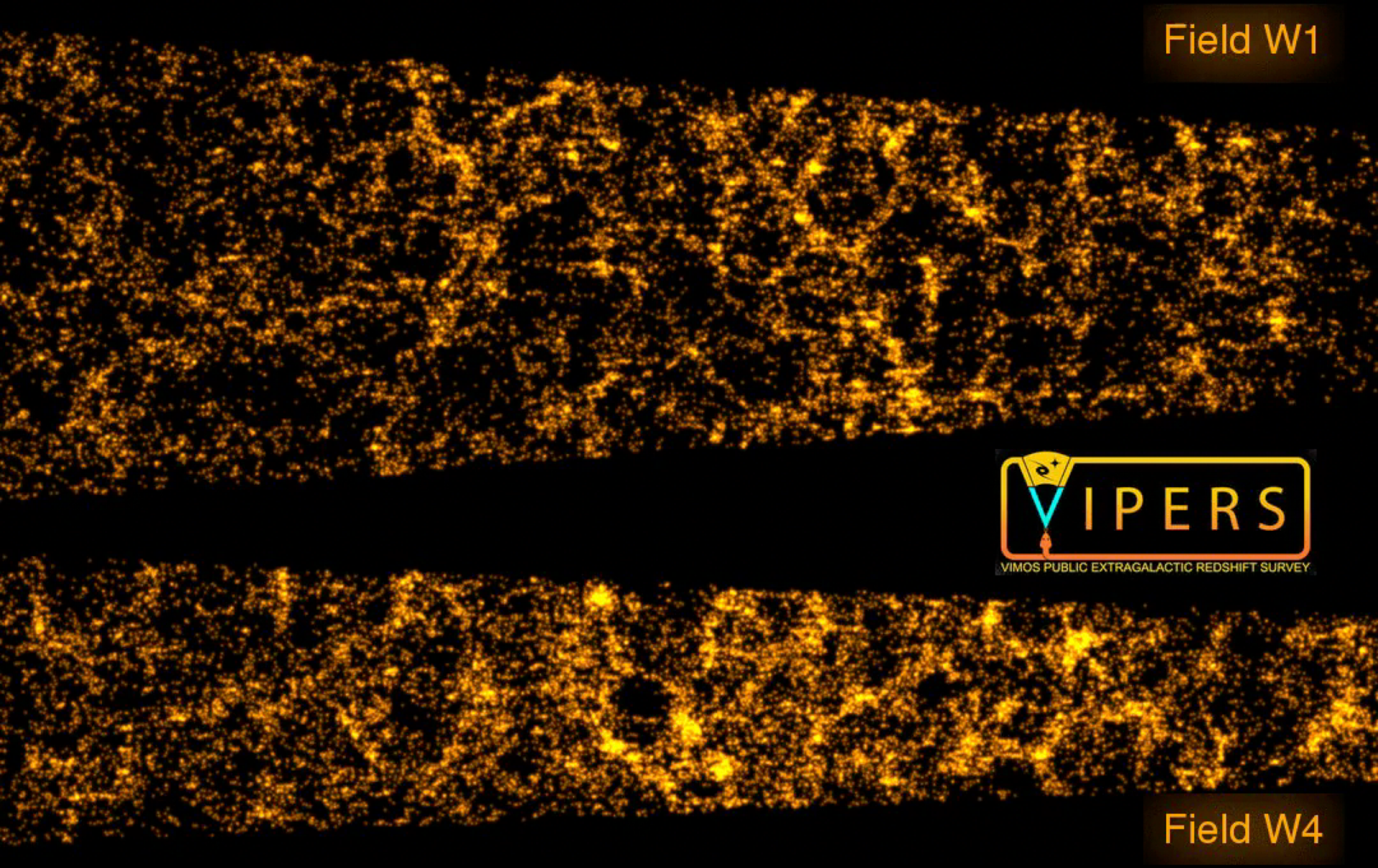


Mask-based instruments

VIMOS, FORS2 @ VLT,
GMOS@Gemini,
DEIMOS@Keck…

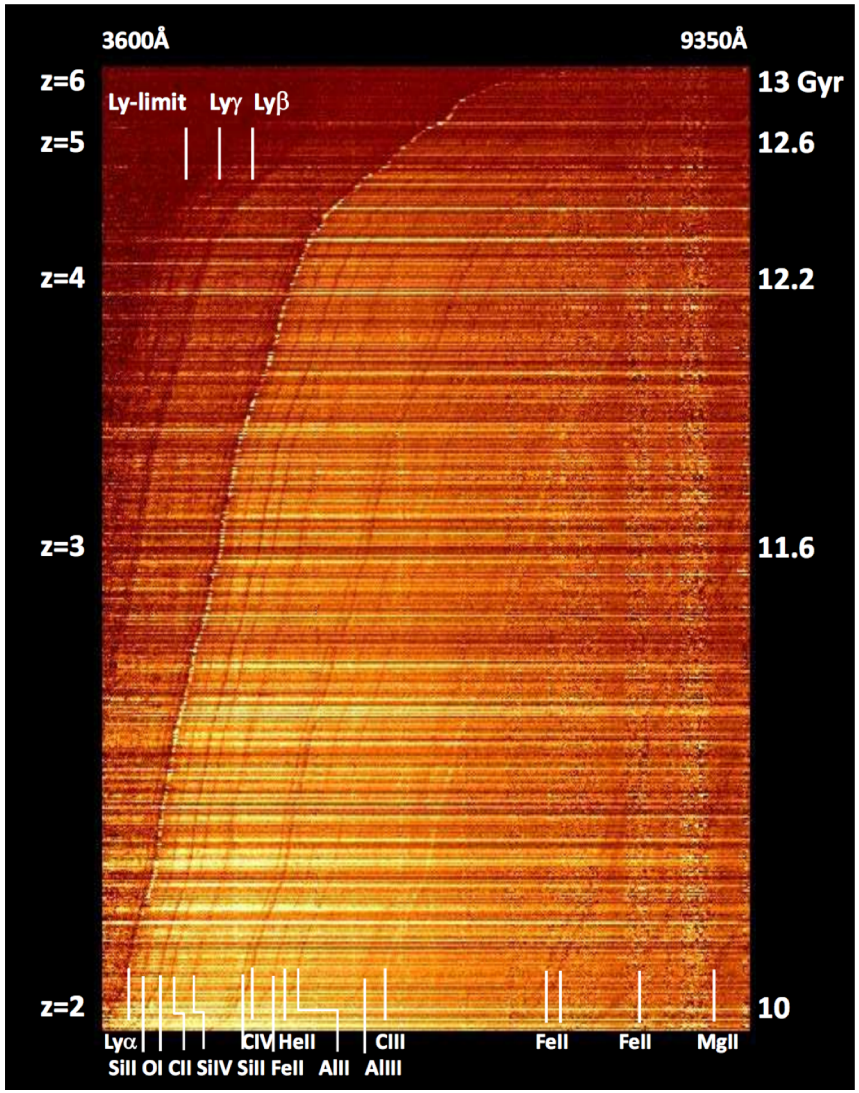
Fiber-fed instruments

FLAMES, MOONS, 4MOST@VLT,
FMOS@Subaru, WYFFOS@WHT,
SDSS, 6dF@AAO…

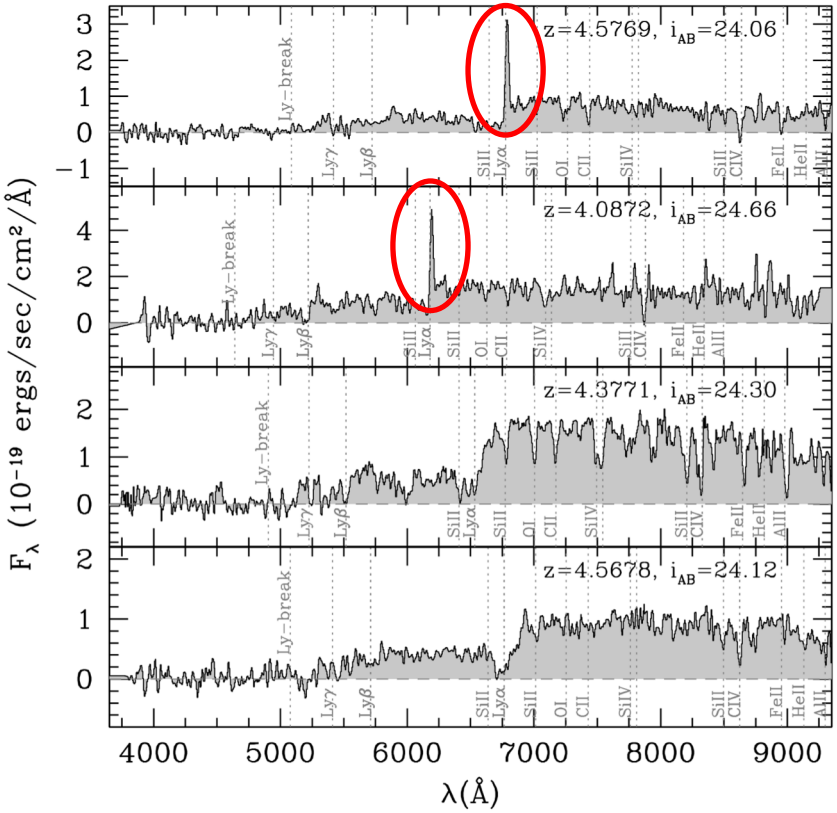


VIPERS (Guzzo+14): low-resolution spectra for ~90,000 galaxies up to z ~ 1
Follow up to previous smaller surveys like VVDS (Le Fèvre+13) and zCOSMOS (Lilly+09)

VUDS: VIMOS Ultra Deep Survey

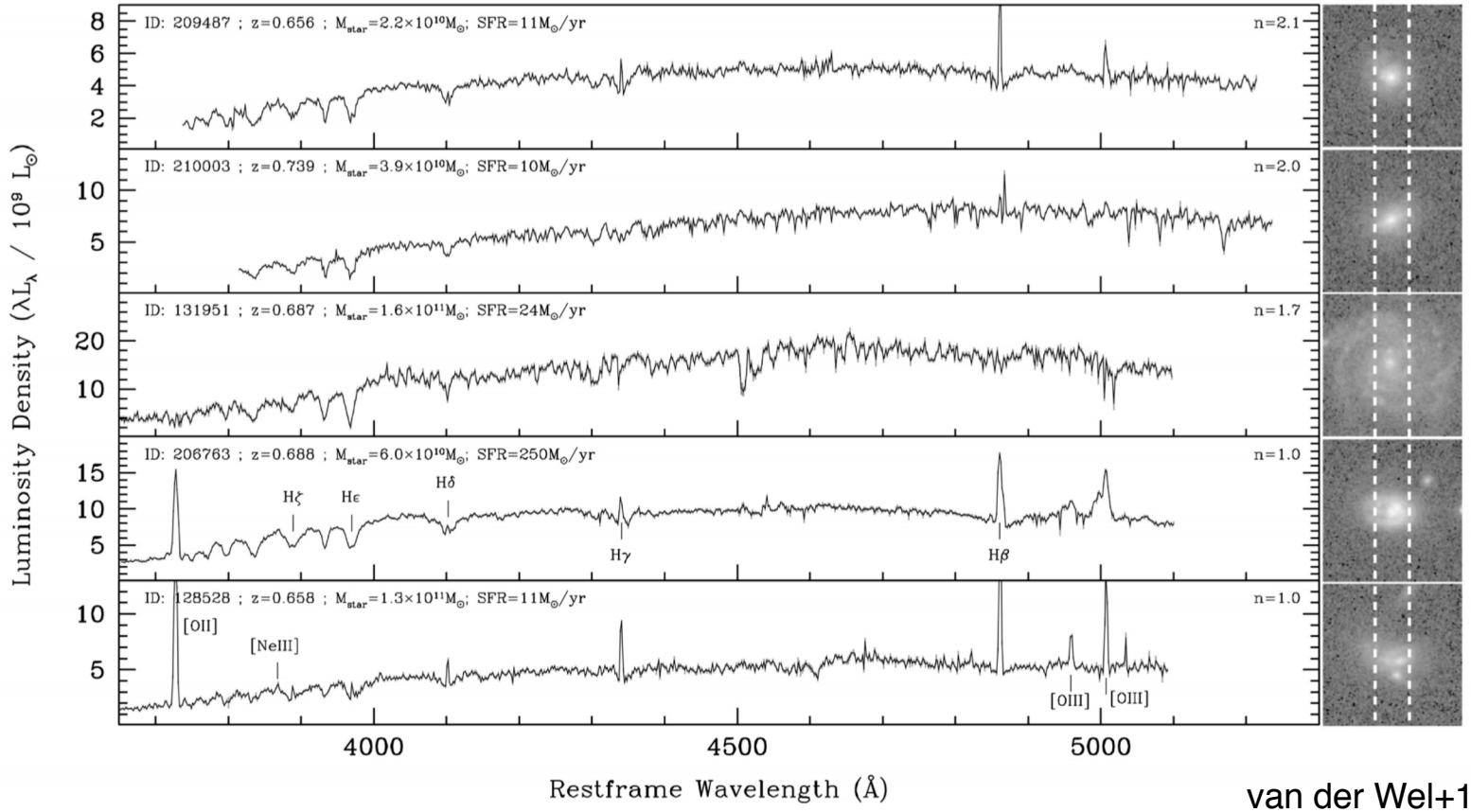


- Low-res spectra for 10,000 faint galaxies between z ~ 2 – 6
- Goal: study the early assembly of very young galaxies.



Le Fèvre+14

LEGA-C: Large Early Galaxy Census

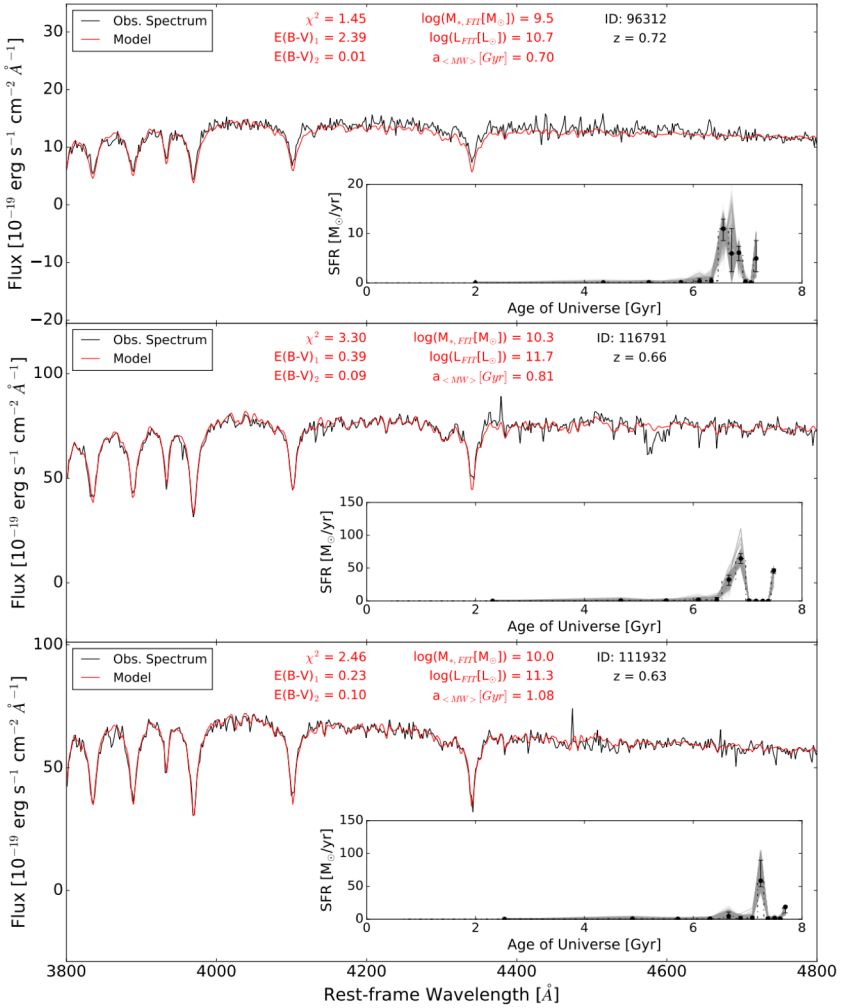


van der Wel+16

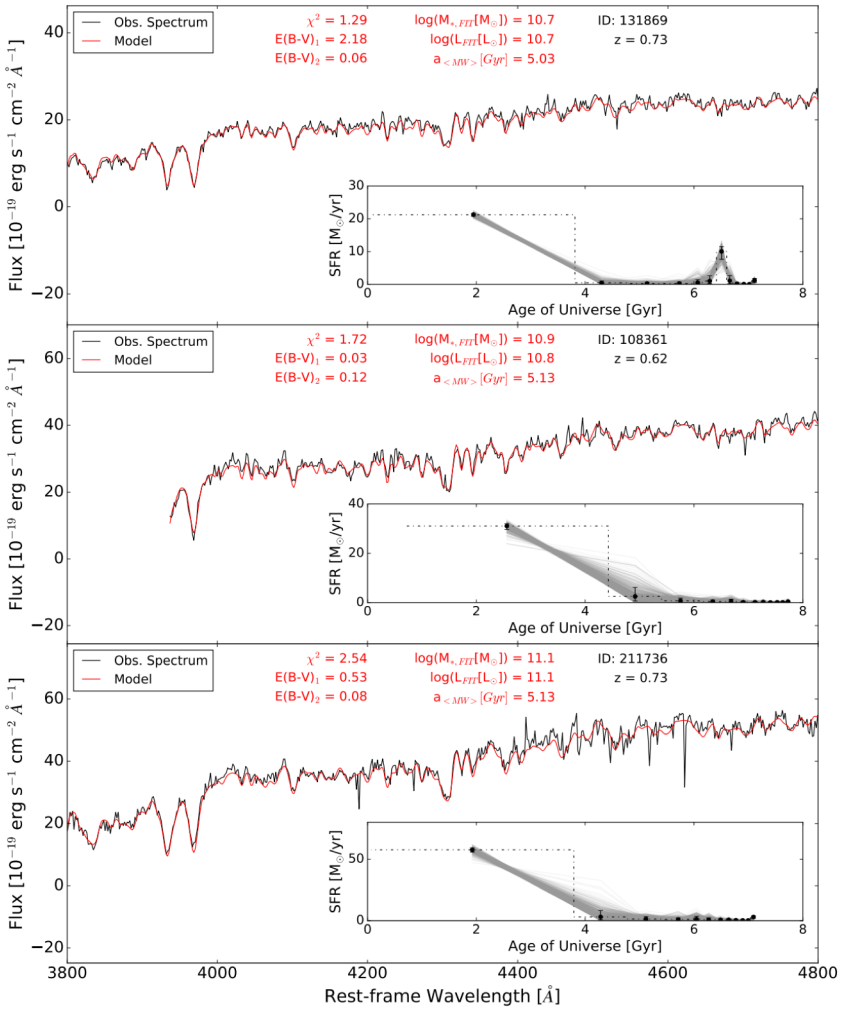
- Very deep R~2500 spectra for 3,200 galaxies up to z~1.
- Goal: study the evolution of stellar populations (ages, metallicities, kinematics…) in the last 7 Gyr.

Star formation histories of LEGA-C galaxies

Late star formation

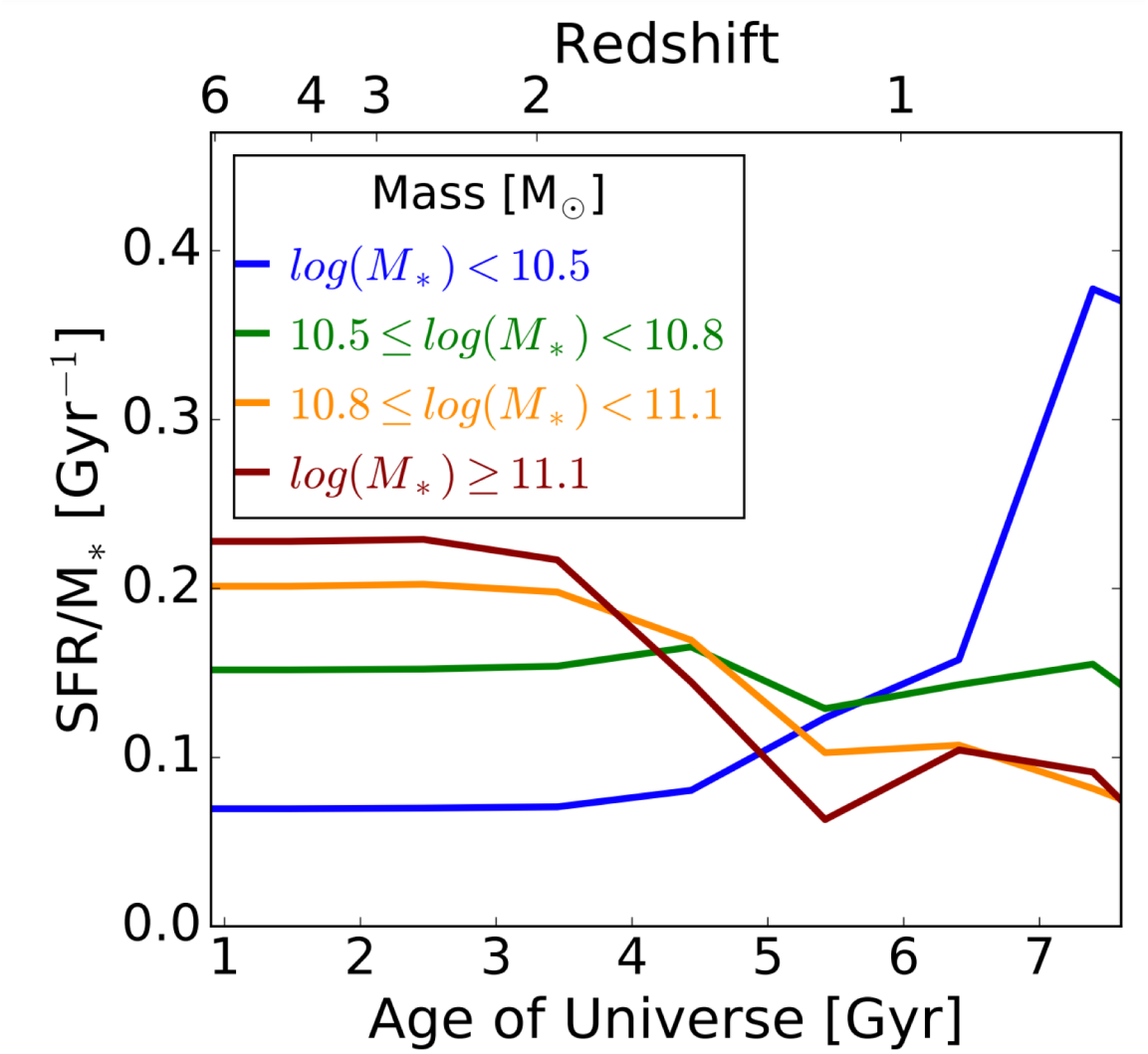


Early star formation



Chauke+18

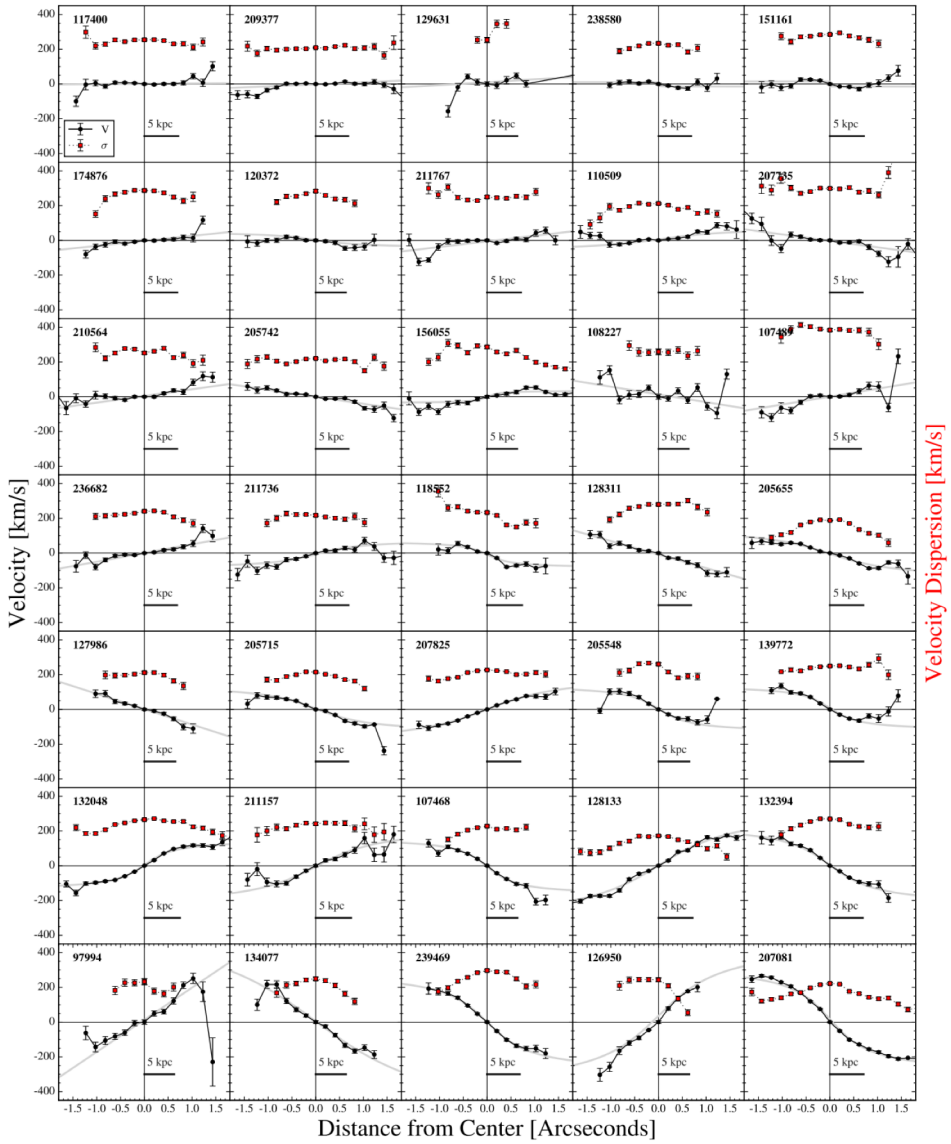
Star formation histories of LEGA-C galaxies



Chauke+18

Kinematics of quiescent galaxies

Dispersion dominated

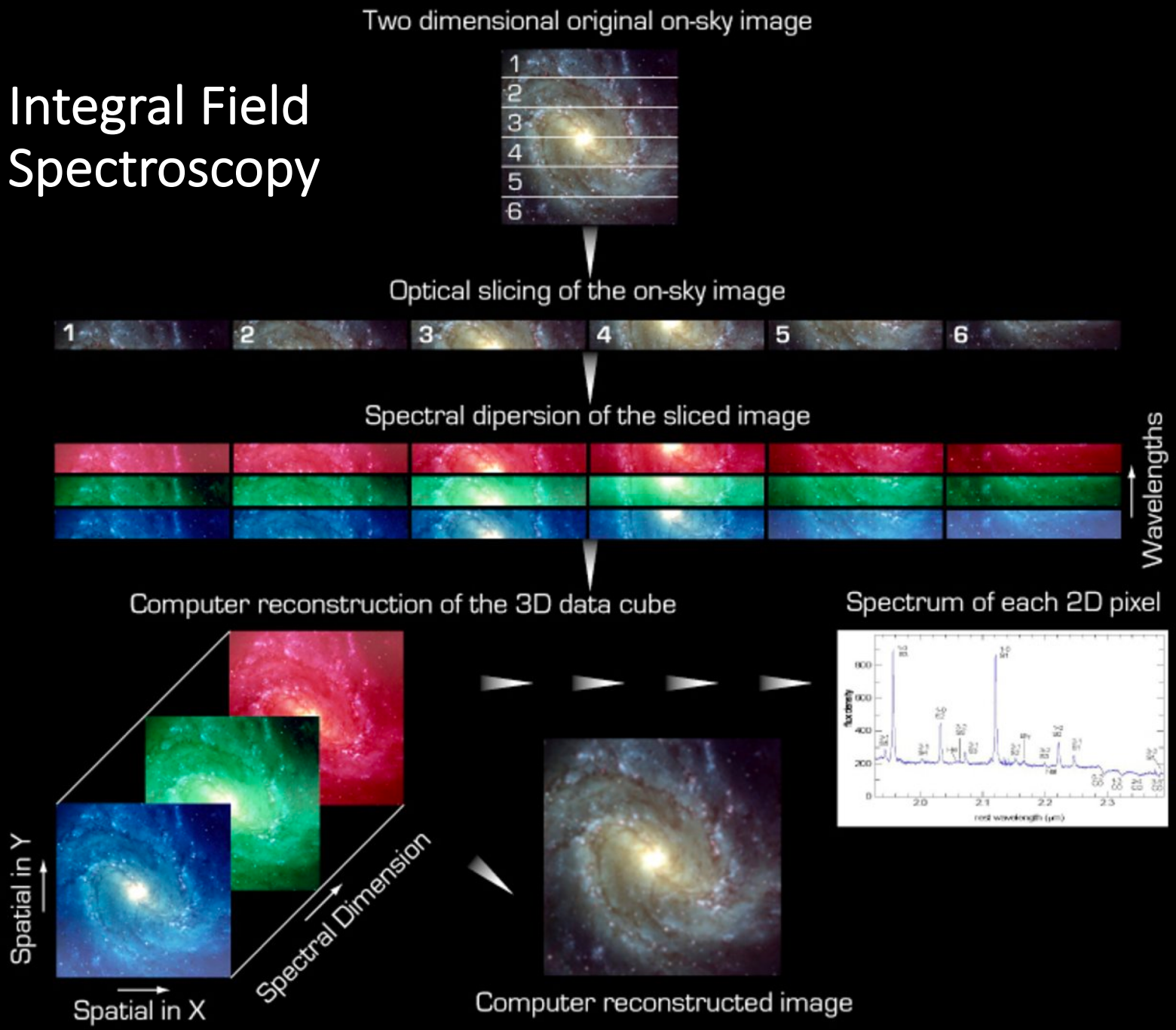


Rotation dominated

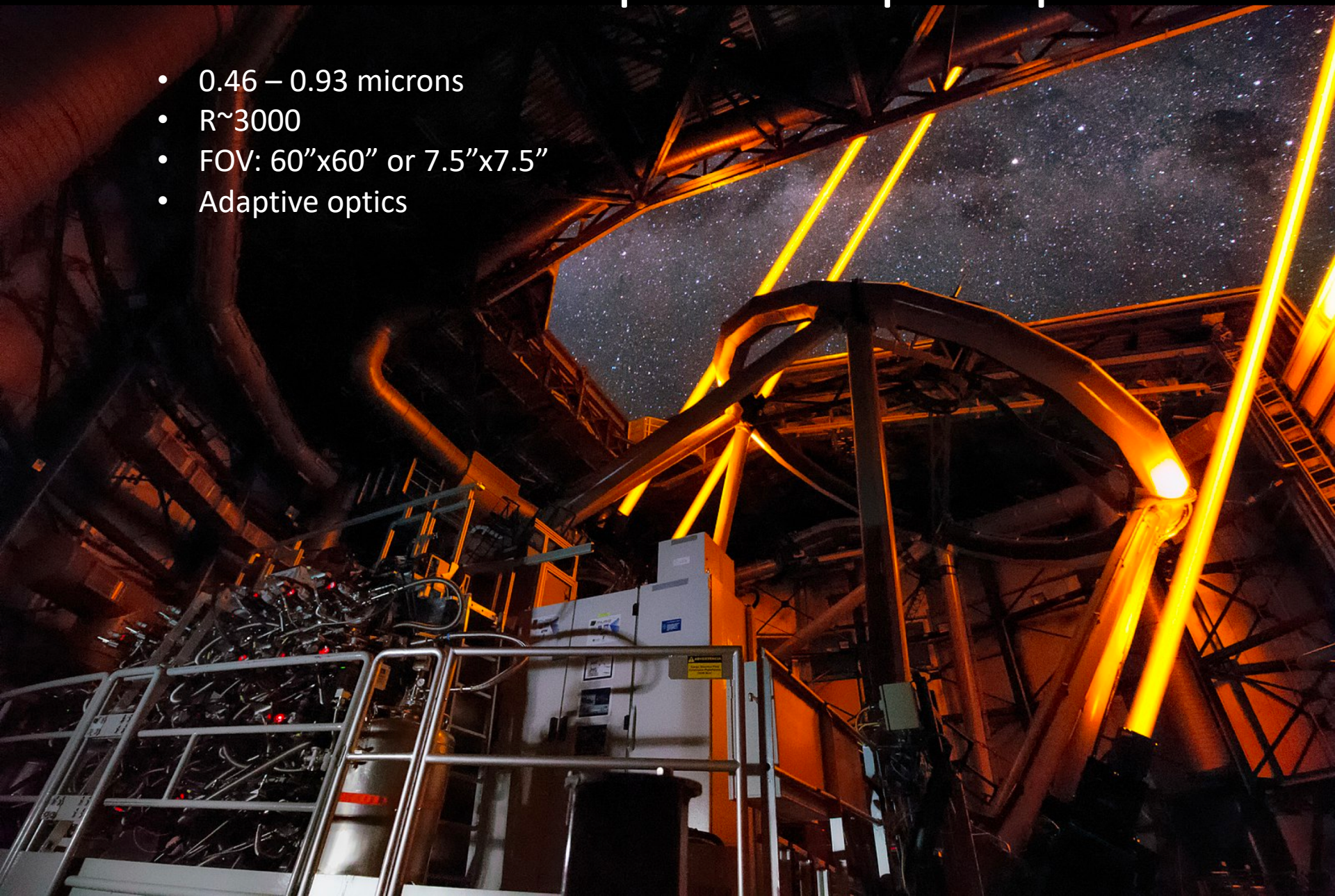
Main result:
Quiescent galaxies were more rotation supported at z~0.8 than today. They must have lost angular momentum somehow.

Bezanson+18

Integral Field Spectroscopy



MUSE: Multi Unit Spectroscopic Explorer

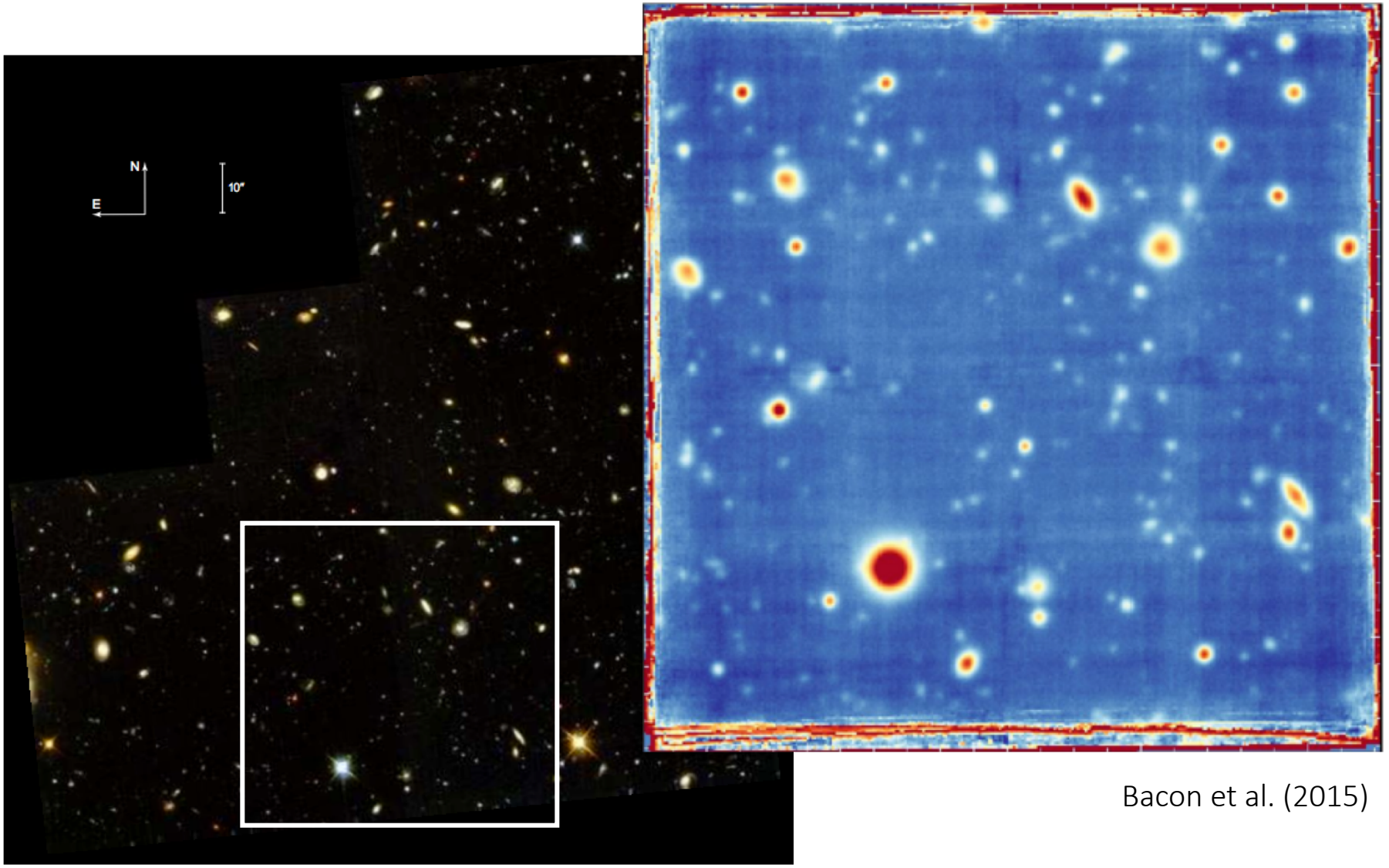


- 0.46 – 0.93 microns
- R~3000
- FOV: 60”x60” or 7.5”x7.5”
- Adaptive optics

The starburst galaxy ESO338-IG04 with MUSE-AO

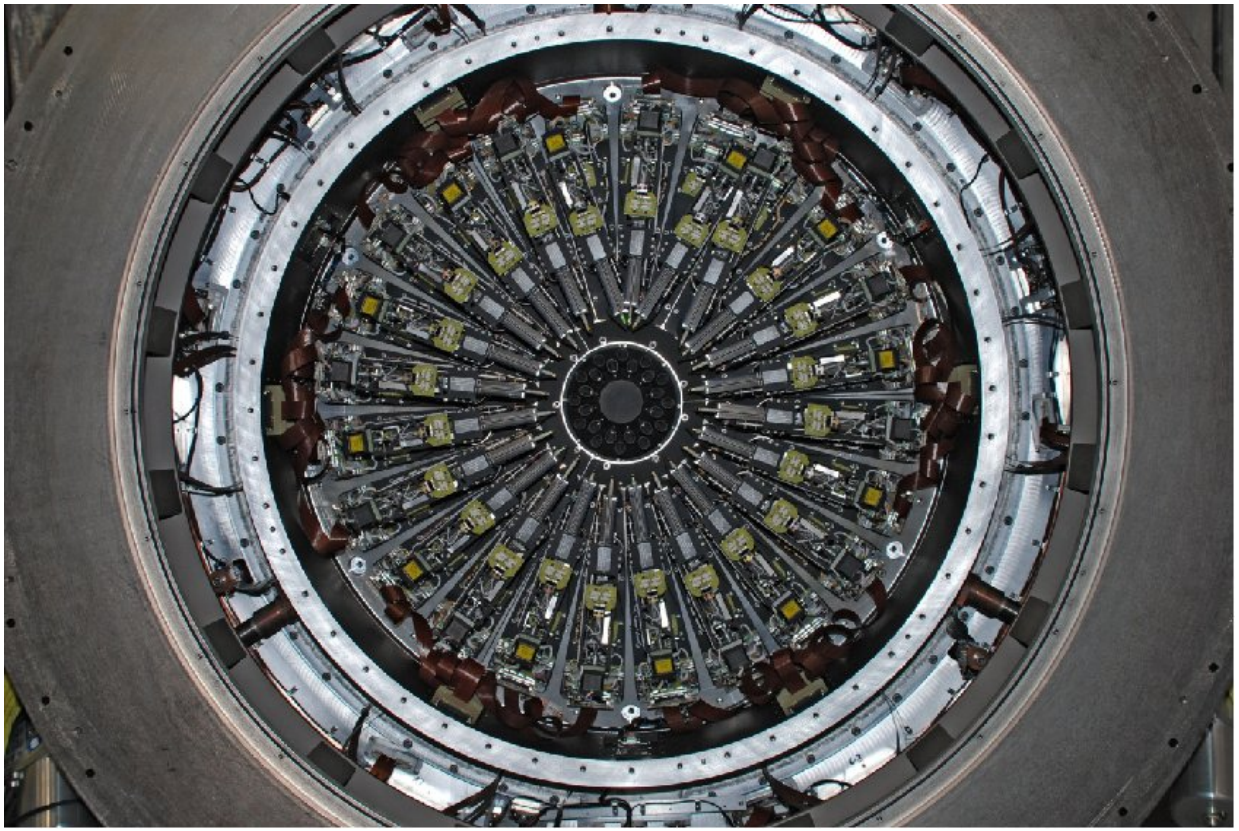
ESO / P. Weilbacher

The Hubble Deep Field South with MUSE



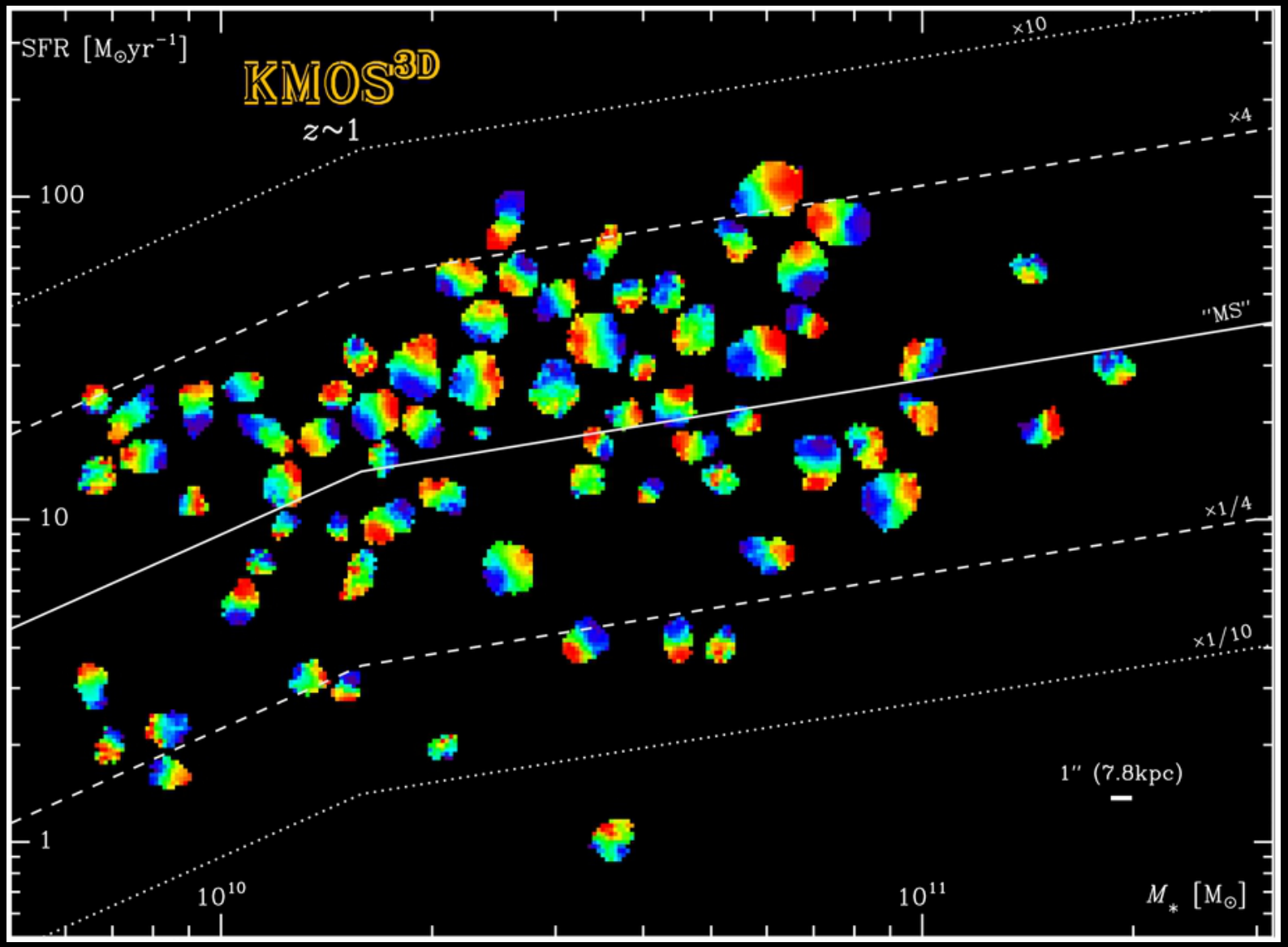
Bacon et al. (2015)

KMOS: K-Band Multi-Object Spectrograph



- 24 movable IFUs over a 7.2’ field
- IFU FOV: 2.8”x2.8”
- J, H and K band
- R~1500-5000

KMOS^{3D}: ~600 galaxies at 0.7 < z < 2.7 (Wisnioski+15)




Questions?