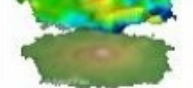
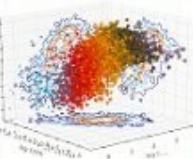


CALIFA Survey



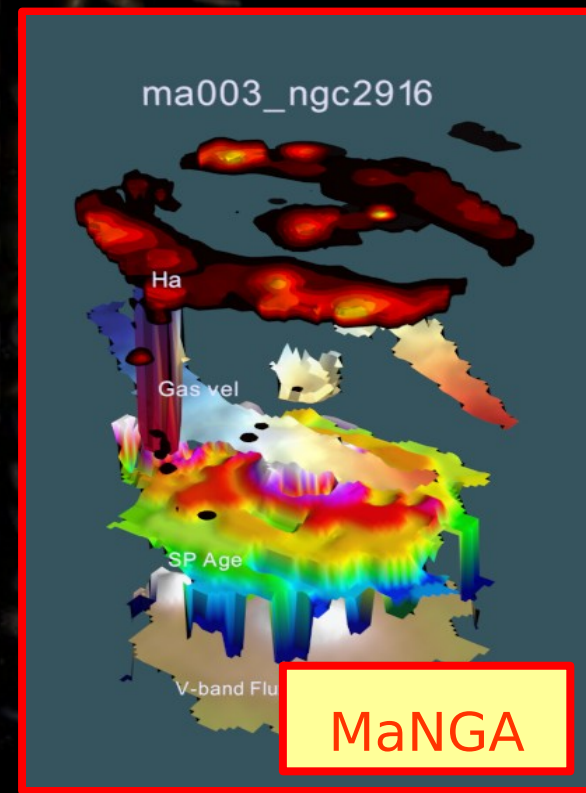
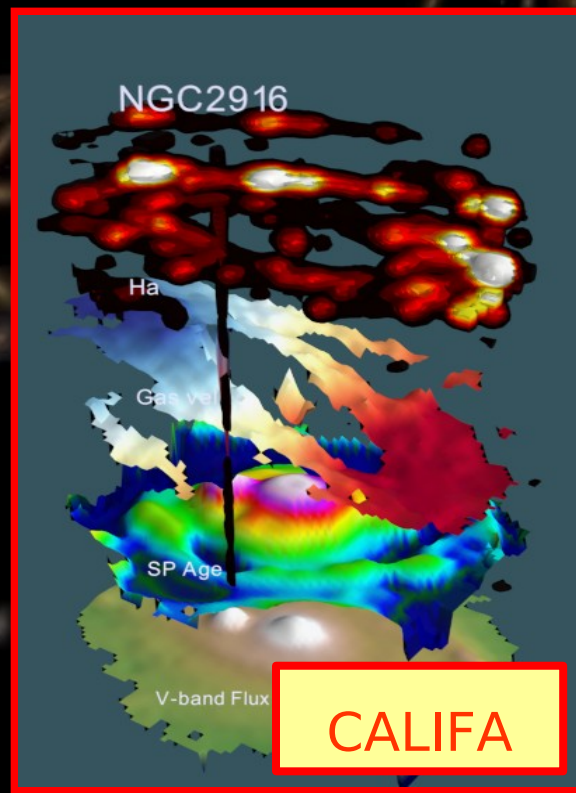
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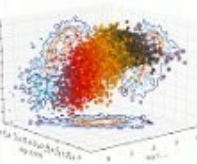
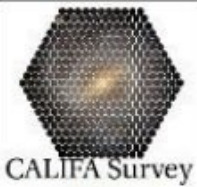


IFES Surveys. A Panoramic view of galaxies

Sebastián F. Sánchez -IA/UNAM



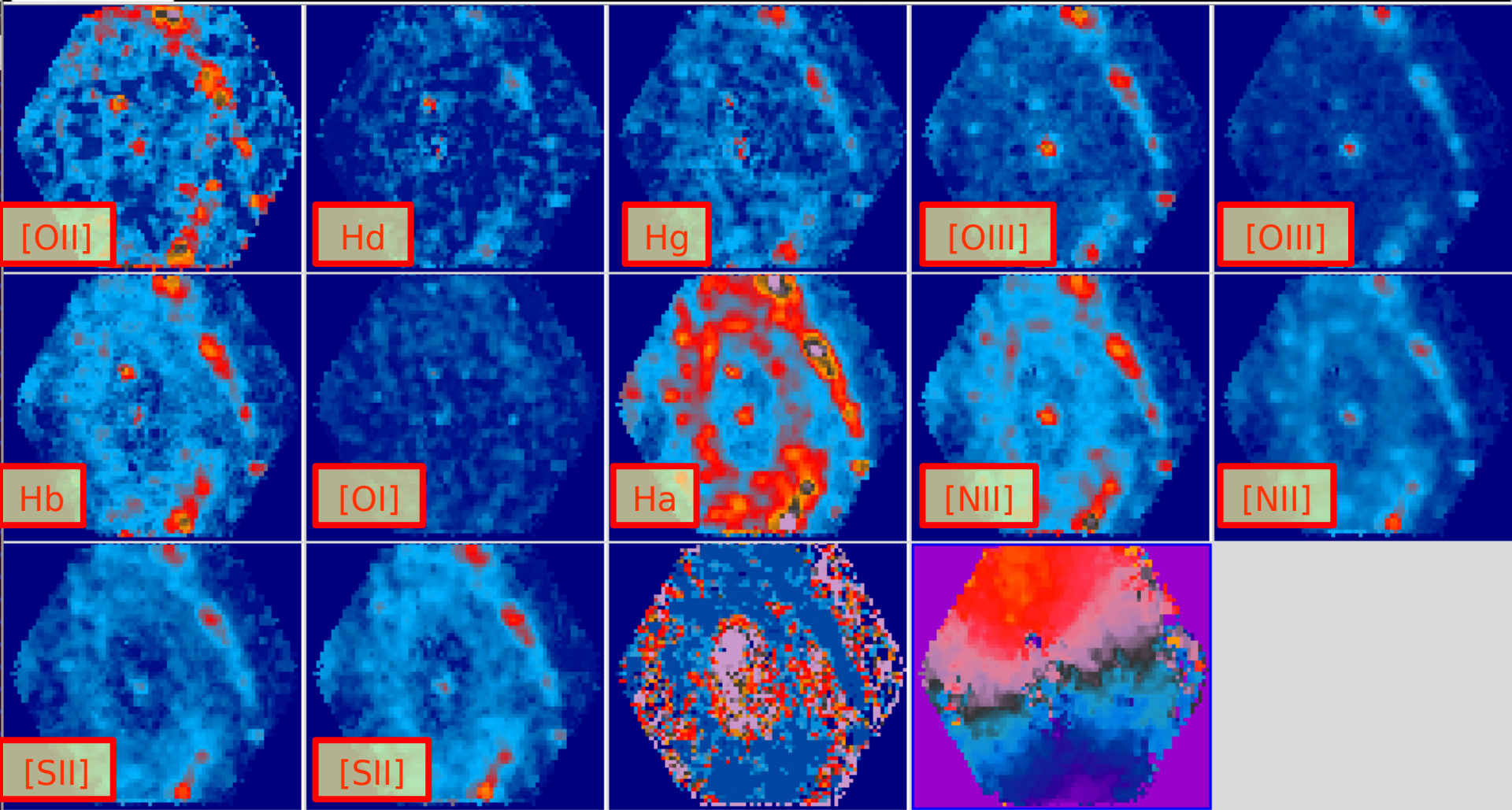
- GH2014, IFS Summer School -
- INAOE, Aug.-Sept., 2014-



IFS Galaxy Surveys

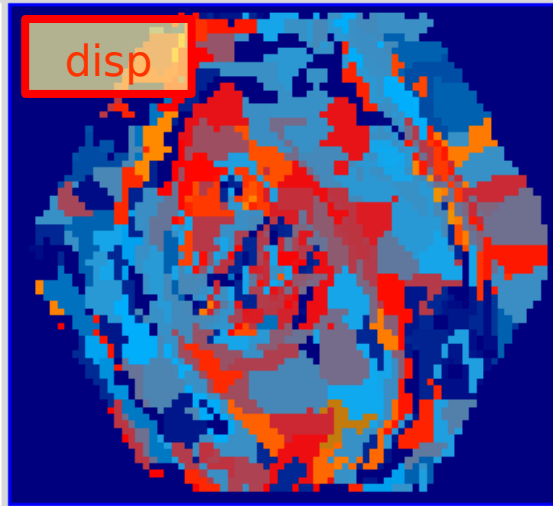
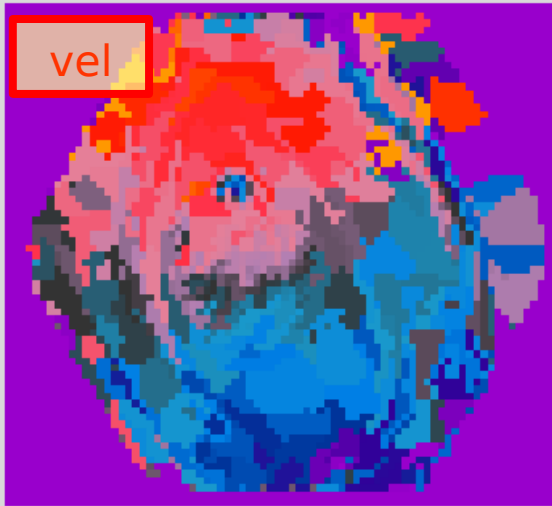
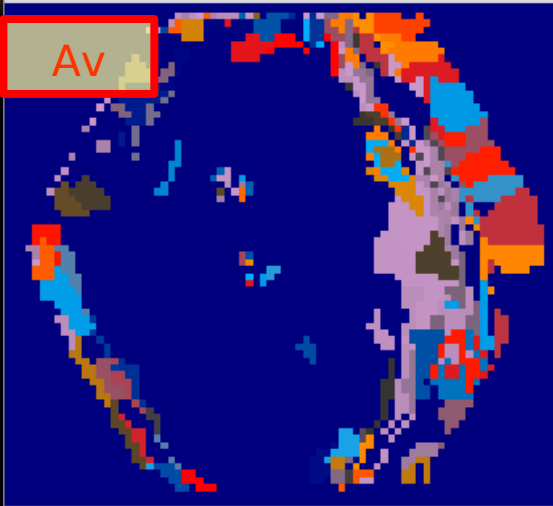
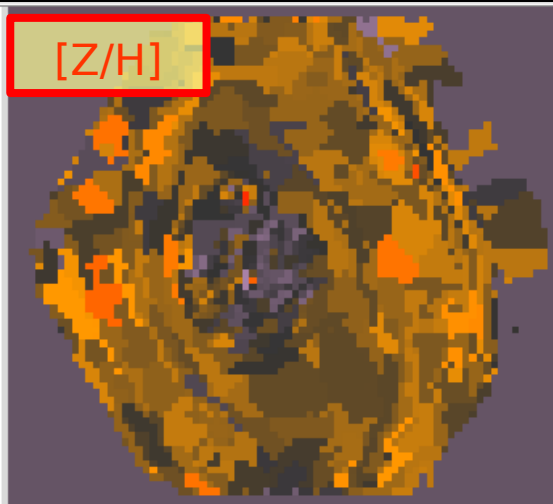
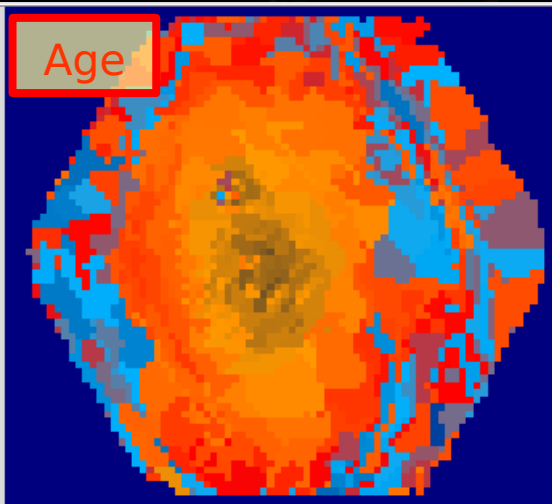
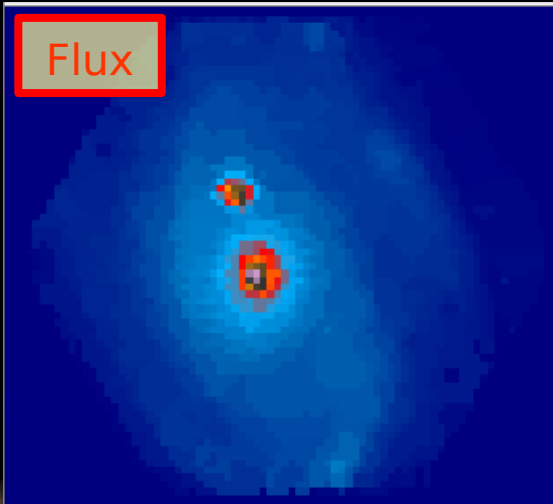
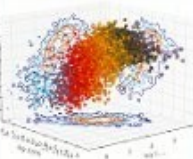
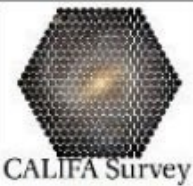
- Use Integral Field Spectroscopy: Fiber-bundles, Image slicers, Lens-arrays.
- Large Sample of galaxies (100-10000).
- Statistically & well defined samples.
- Cover a substantial fraction of the extension of the galaxies: Integrated properties ($\sim 1 R_{\text{eff}}$ or more).
- Enough spatial sampling:
 - Radial gradients.
 - 2D structure of the galaxies.
 - Resolve individual sub-structures (HII regions, spiral arms, bulges).
- Hundreds of thousand of spectra.
- Multiple Science Goals.

IFS GS: Panoramic view

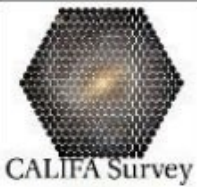


Ionized Gas: Multiple emission lines intensity maps, velocity and velocity dispersion.

IFS GS: Panoramic view



Stellar Populations: Average Properties.



CALIFA Survey

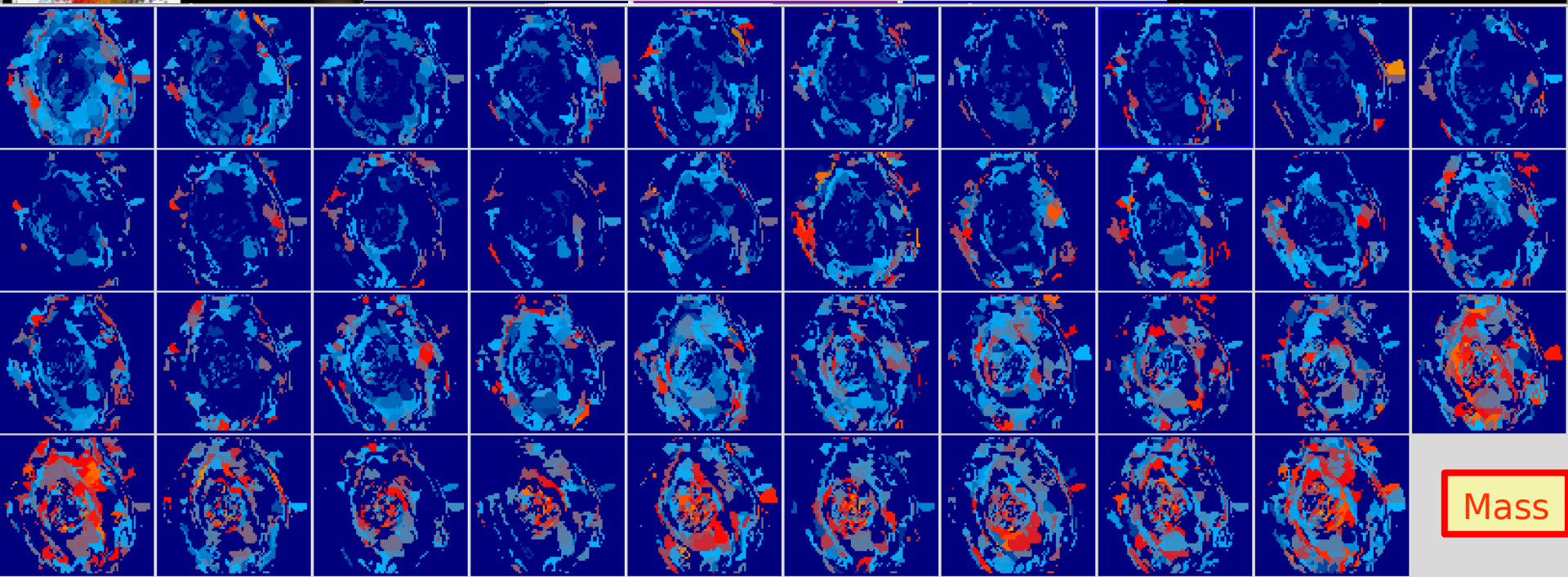
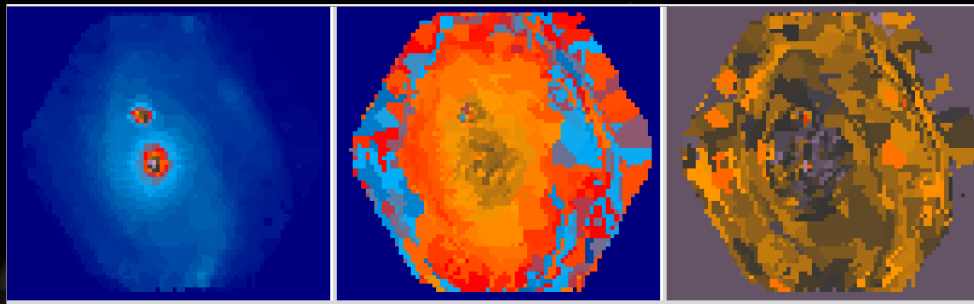


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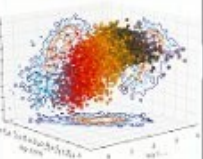
IFS GS: Panoramic view

Age →



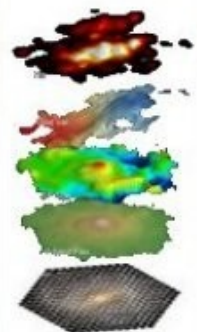
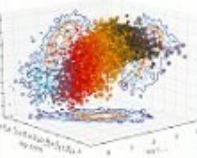
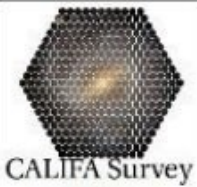
Mass

Stellar Populations: Mass Growth.



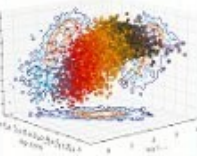
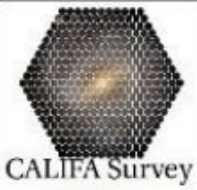
IFS Galaxy Surveys

-Precedents-



IFS GS: Precedents

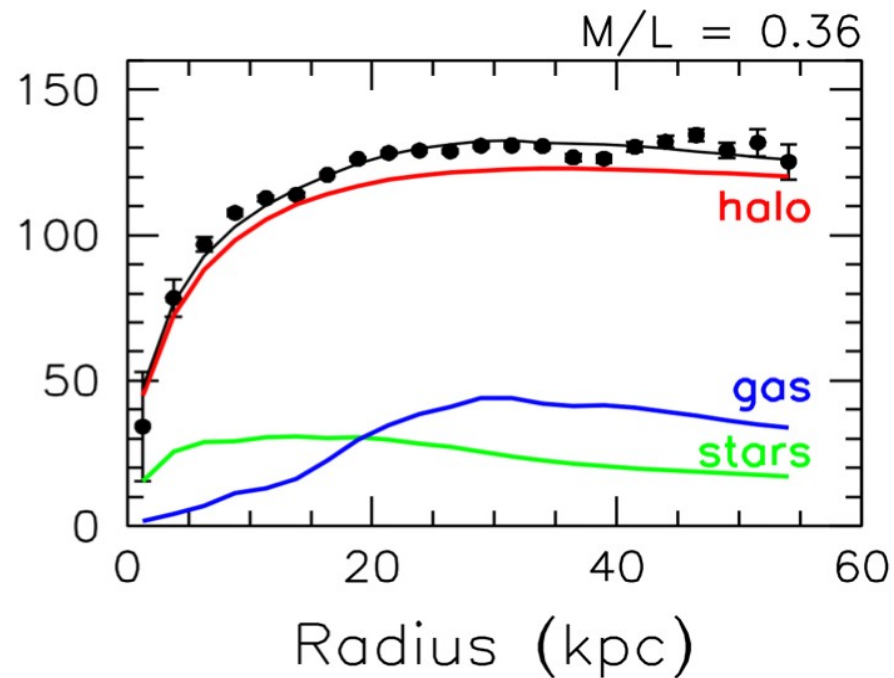
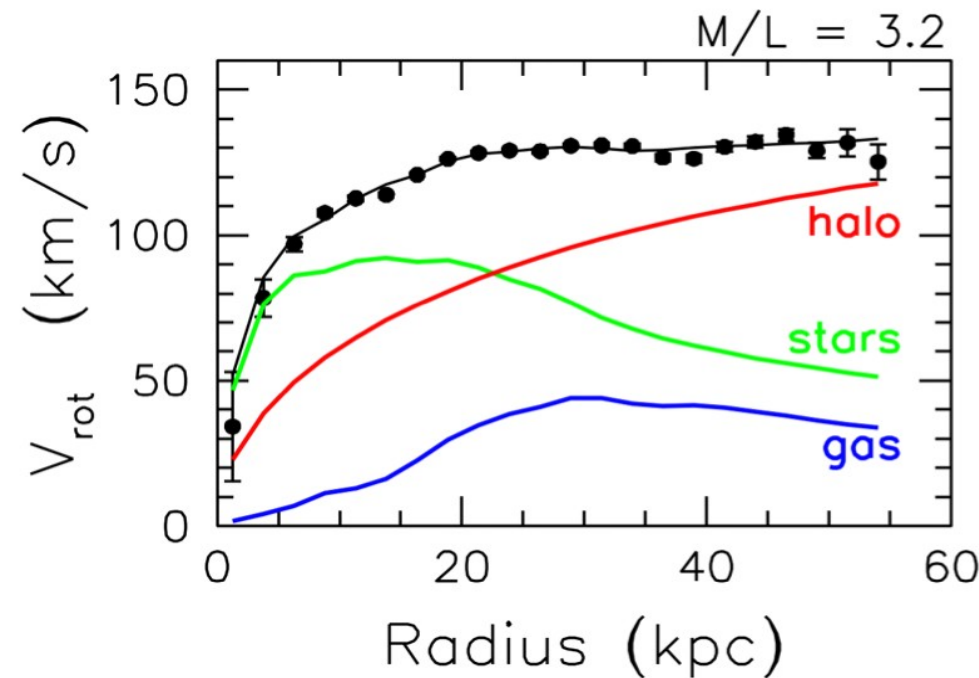
- **Disk Mass Survey**: 46 face-on spirals ($\sim 2R_{\text{eff}}$). Super-high spectral resolution.
- **SAURON**: 72 (mostly) early-type galaxies ($< 1R_{\text{eff}}$).
- **F-CALIFA**: 48 (mostly) spiral galaxies ($\sim 2R_{\text{eff}}$).
- **VENGA**: 32 spiral galaxies ($> 2R_{\text{eff}}$).
- **PINGS**: 12 (mostly) spiral galaxies ($\sim 2R_{\text{eff}}$).
- Studies on individual galaxies.

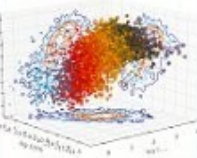
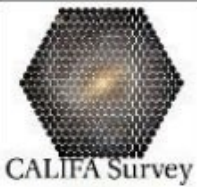


Disk Mass Survey

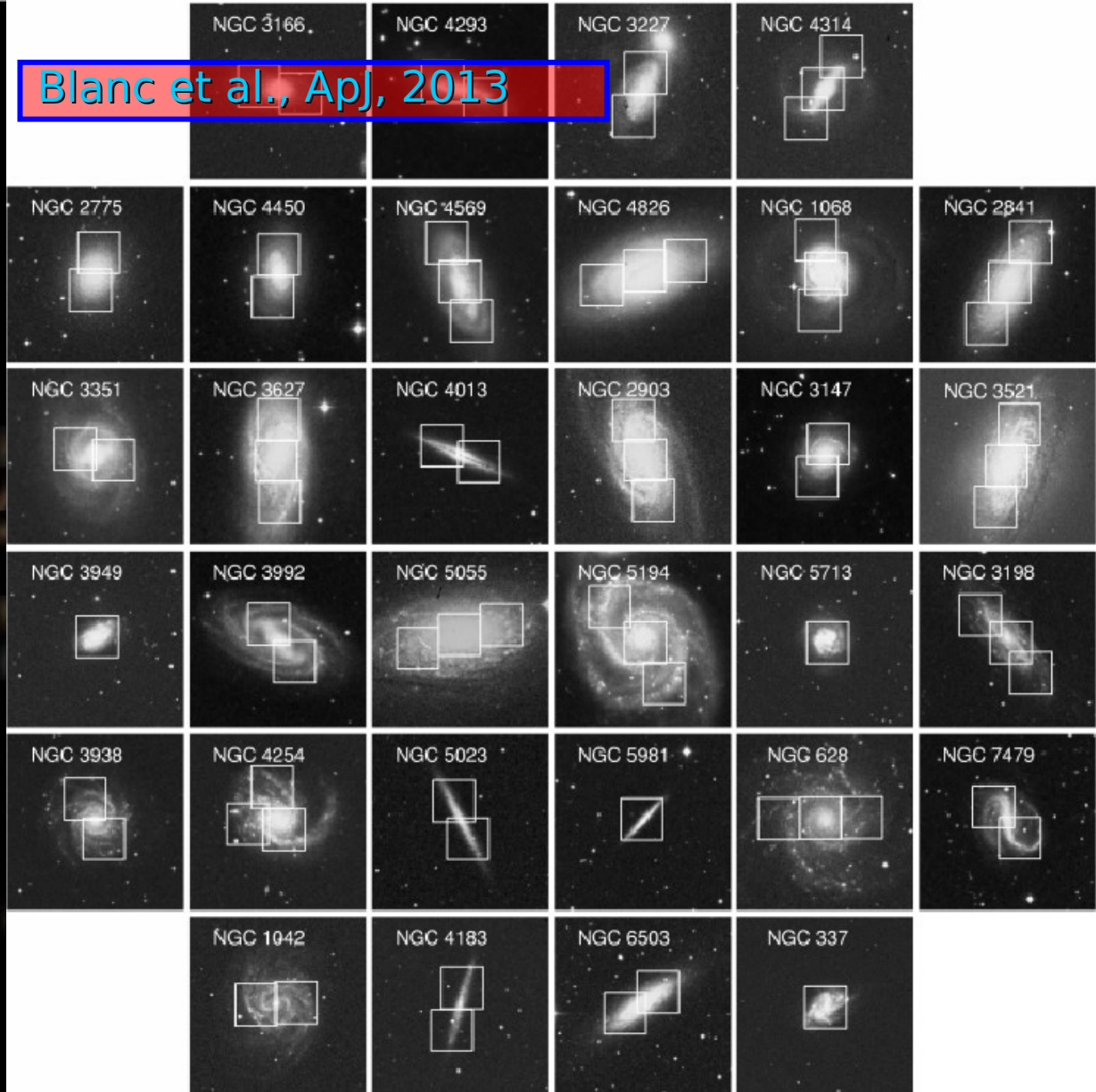
- obtain radial surface-density profiles $\Sigma(r)$ of galaxy disks
- determine M/L of stellar populations in disks
- break disk-halo degeneracy in rotation curve decompositions
- get $\rho_{DM}(r)$.

Bershady, Verheijen et al., ApJ, 2010





Blanc et al., ApJ, 2013



The VENGA Sample of 32 nearby spirals ordered morphology from early (top left) to late (bottom left) types. White boxes mark the 1.7'x1.7' FoV of VIRUS-P.

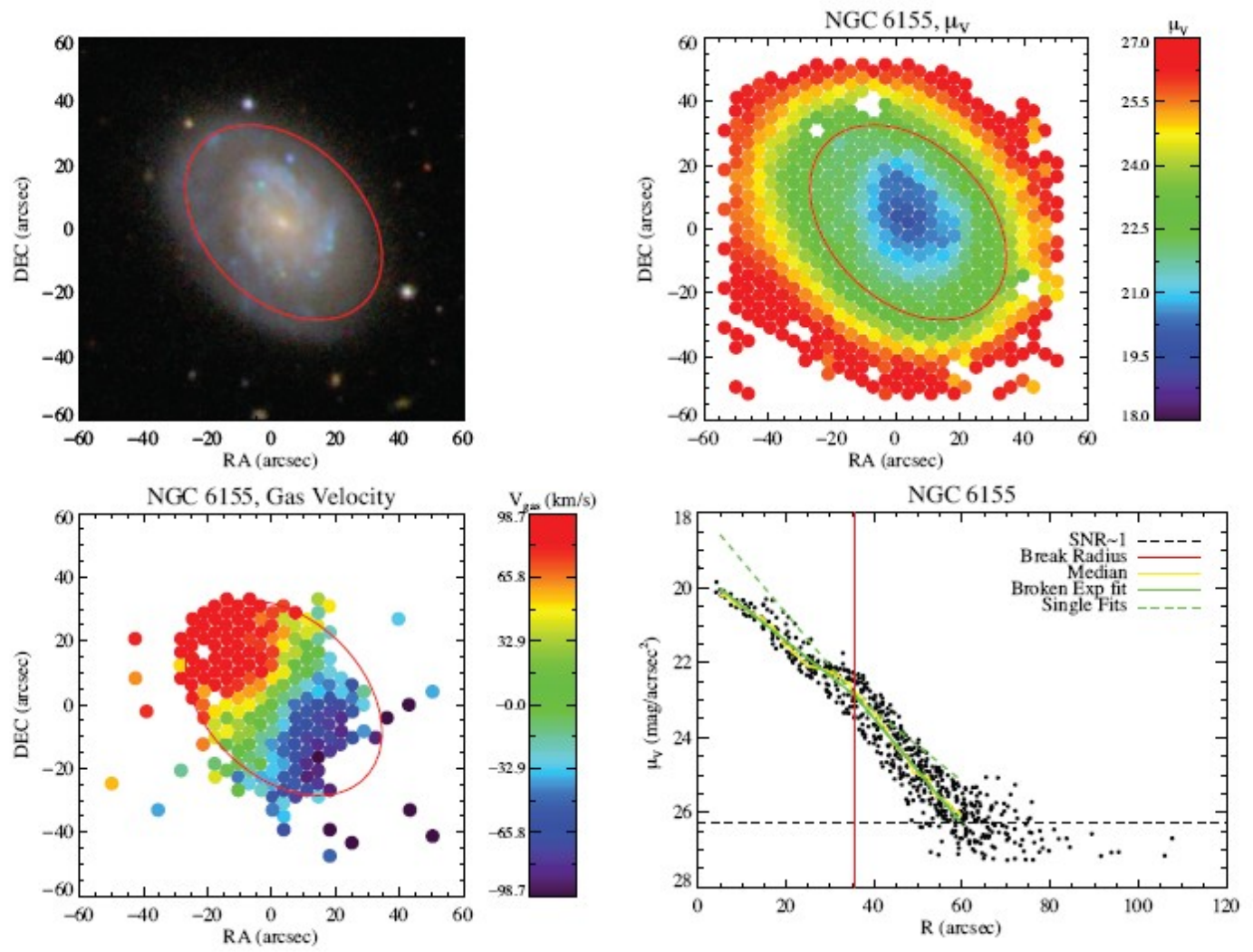
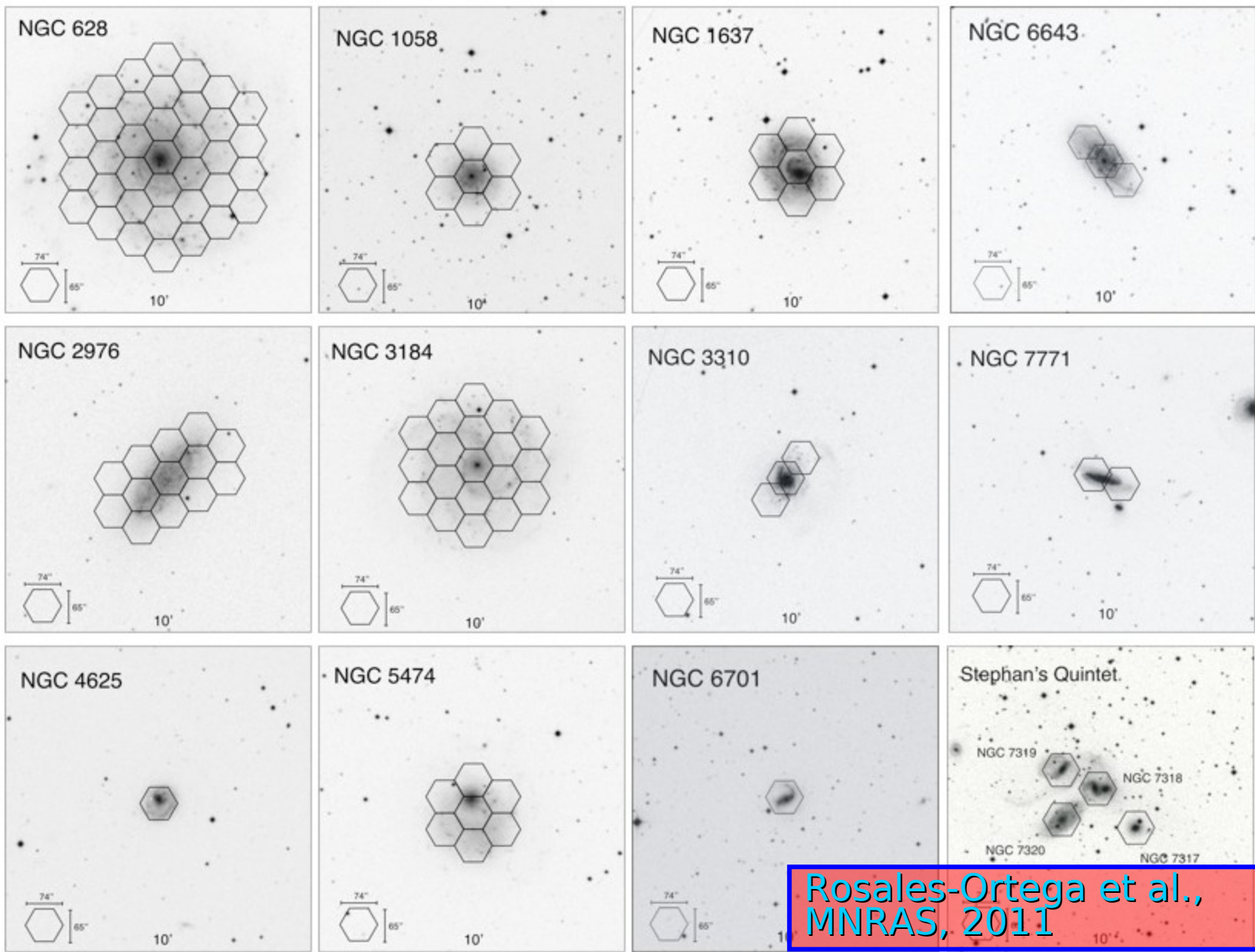
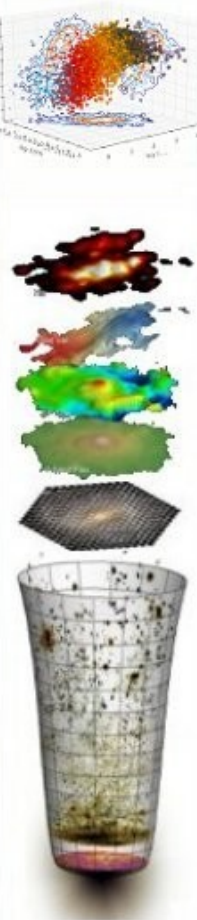


Figure 1. Upper left: SDSS image of NGC 6155 (north is up and east is right). Upper right: surface brightness measured from VIRUS-P fiber spectra. Points are the same size as the VIRUS-P fibers. Fibers containing stars or bright background galaxies have been masked. Lower left: velocity field measured from emission lines. Lower right: surface brightness profile as measured by individual fibers. The green line shows the best-fit broken exponential. The dashed green line shows the result of extrapolating the inner and outer region fits. The yellow curve shows a running median with a 5" window. The dashed line shows the level where the S/N of a single fiber is unity. In each panel, the red curve marks the best-fit break radius.

The fibers of VIRUS-P are large enough to sample galaxies in the very out-skirts with enough S/N: Truncation radius



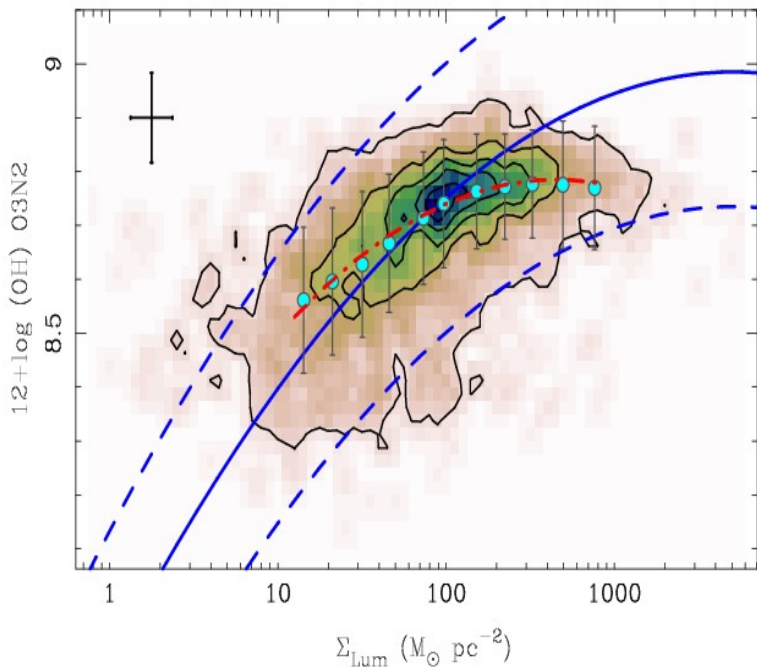
Rosales-Ortega et al.,
MNRAS, 2011

PINGS: Provided the largest IFU survey on single galaxies, detail exploration of HII regions.

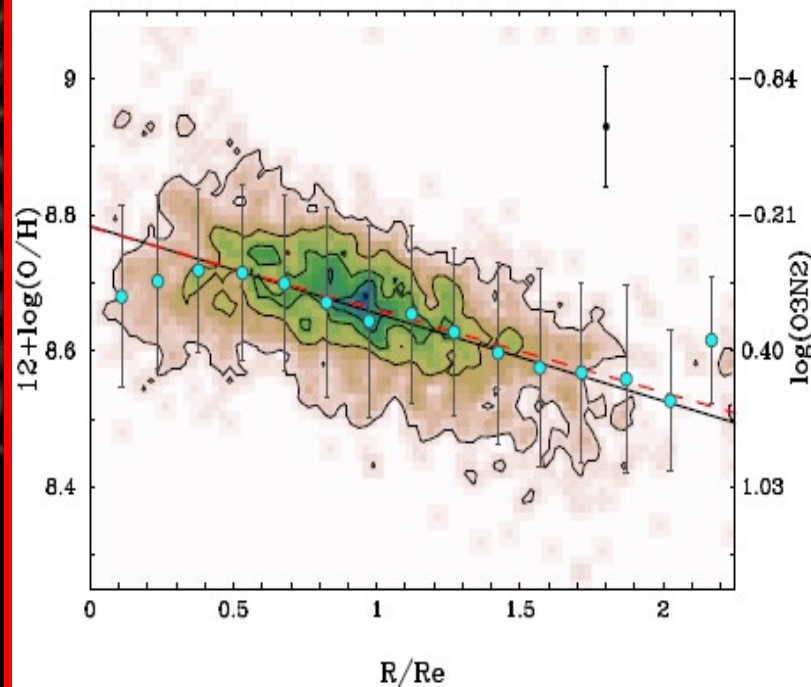
The resolved M-Z relation

Rosales-Ortega et al.,
ApJL, 2012

Abundance gradient



Sánchez et al.,
ApJL, 2012b



TINGS + F-CALIFA

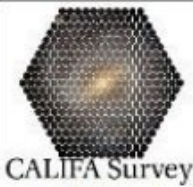
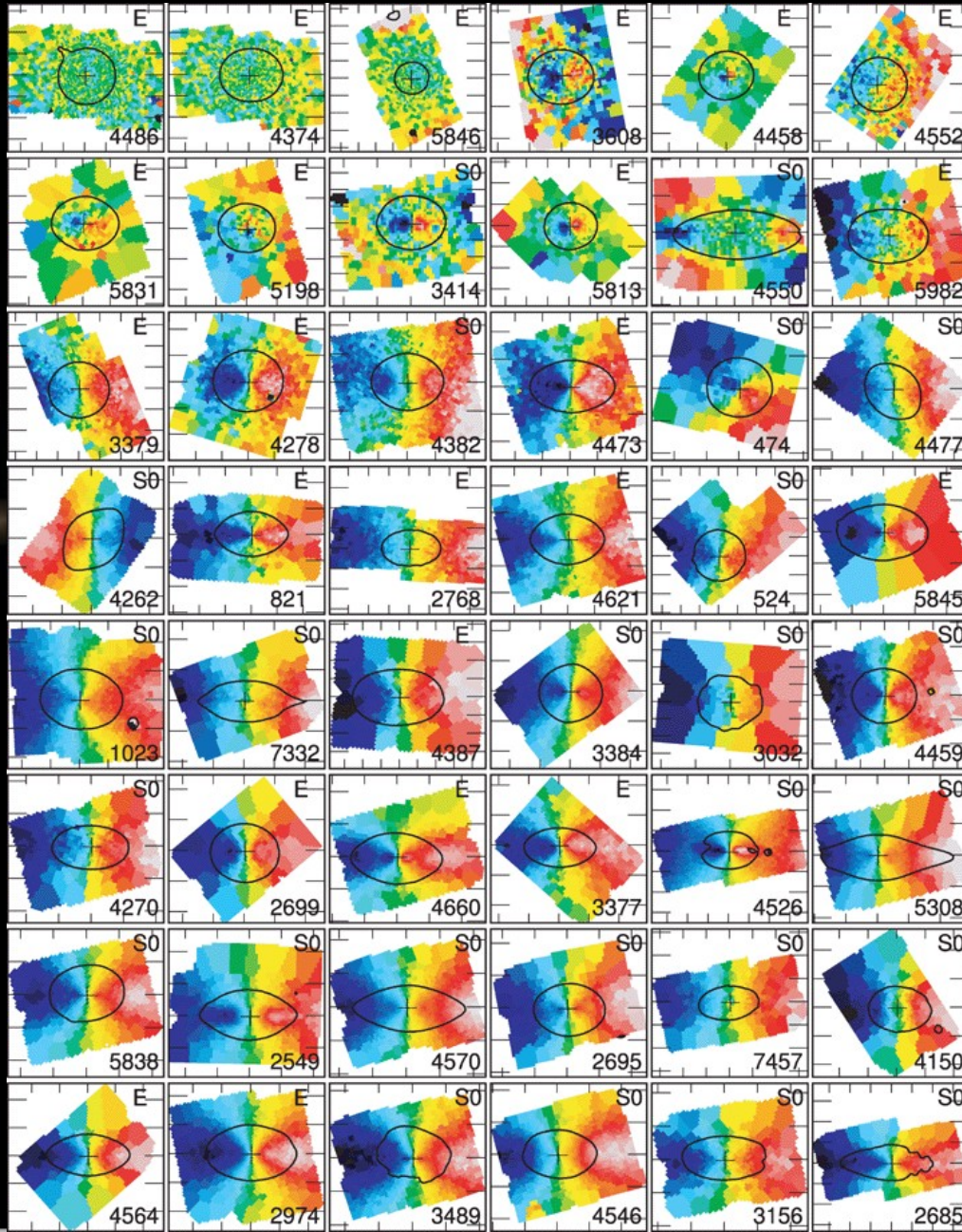


The SAURON Survey

Bacon et al., MNRAS, 2001



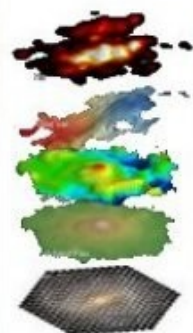
First evidence of the slow/fast rotators dichotomy.



CALIFA Survey

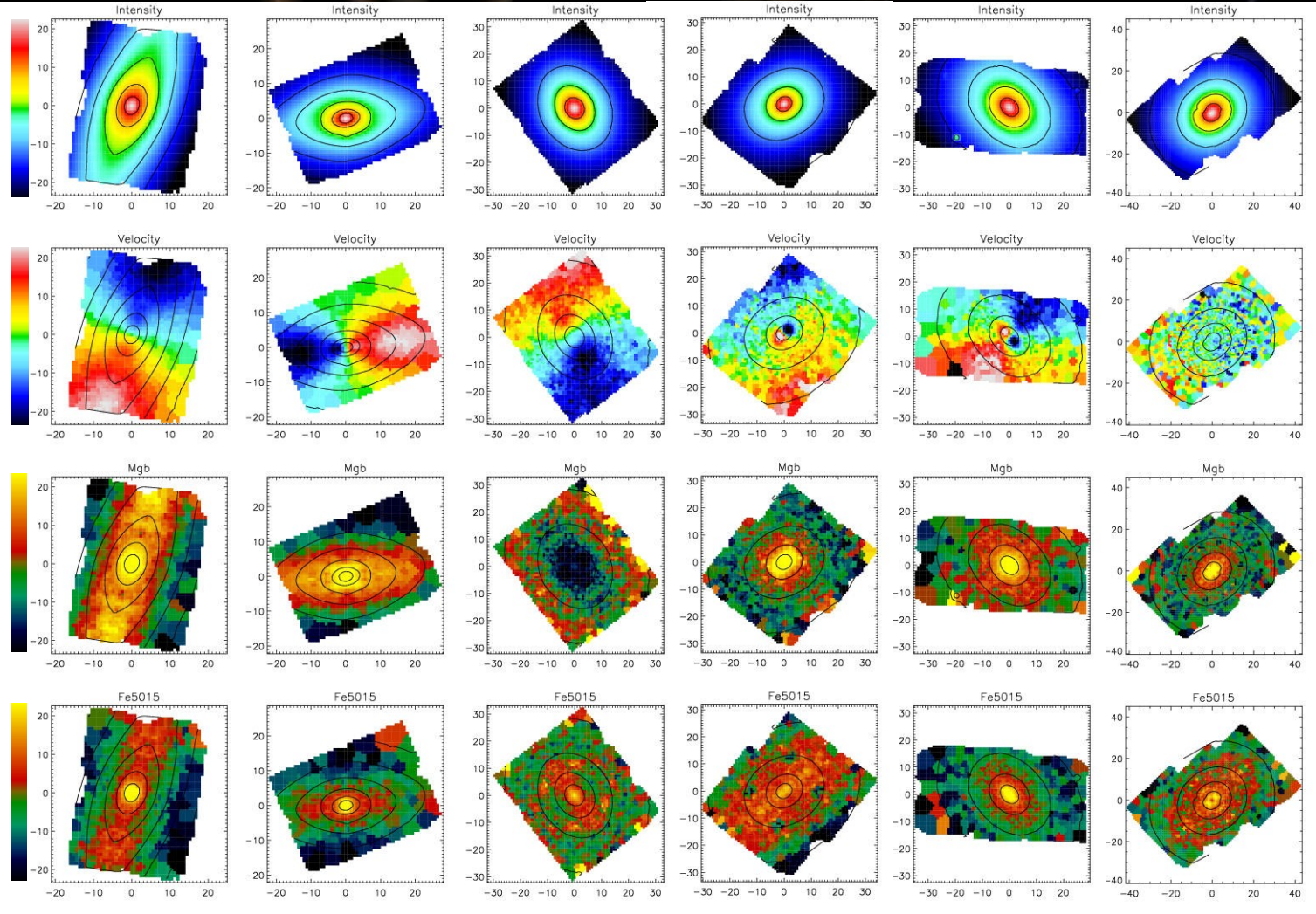


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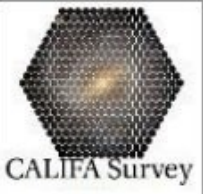
The SAURON Survey

NGC 4570 NGC 4660 NGC 4382 NGC 4406 NGC 4365 NGC 4374



SAURON allowed to study the spatially resolved properties of the stellar populations in E-type galaxies.



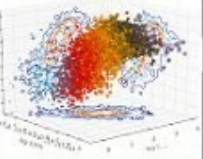


CALIFA Survey



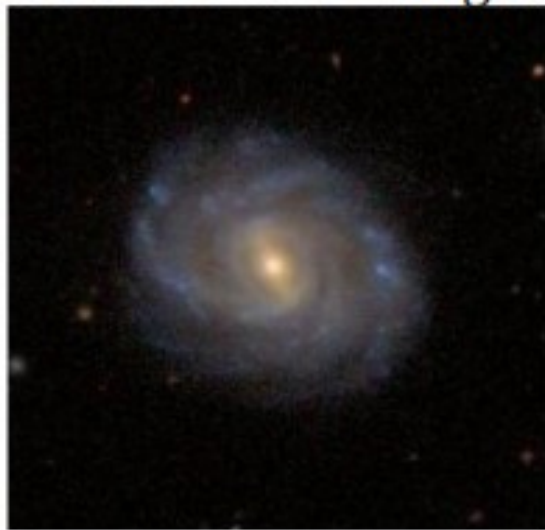
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IFS Galaxy Surveys

SDSS 90"x90" image



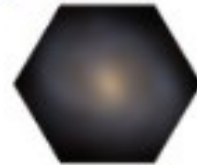
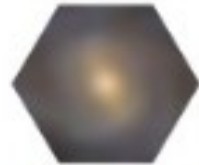
Atlas3D



Z~Z califa

Z~Z Atlas3D

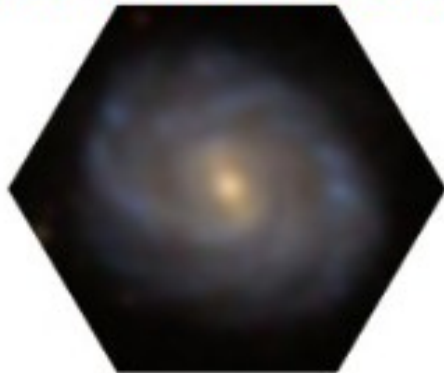
MaNGA largest FoV



FoV~1.5Re

~2.5Re

CALIFA (V500/V1200)

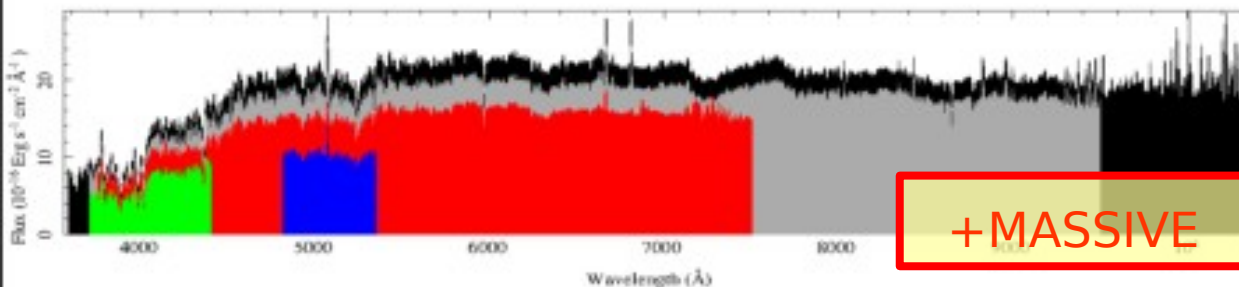


SAMI



Z~Z califa

Z~Z SAMI



CALIFA

2x3x331 spaxels; 2.7"/spaxel

600 galaxies of any type

~1.200.000 spec.; 3700-7500 Å

Atlas3D

1577 spaxels; 0.94"/spaxel

260 ETGs

~400.000 spectra; 4810-5350 Å

MaNGA

3x(19-127) spaxels; 2"/spaxel

7000 gal. of any type (~1.5Re)

2000 gal. of any type (~2.5Re)

1000 gal. of any type (any Re)

~800.000 spec.; 3550-10000 Å

SAMI

9x61 spaxels; 1.6"/spaxel

3400 galaxies of any type

~1.900.000 spec.; 3700-9500 Å

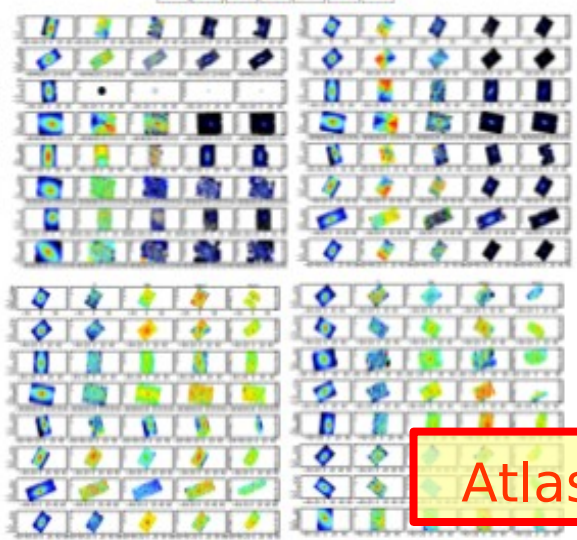
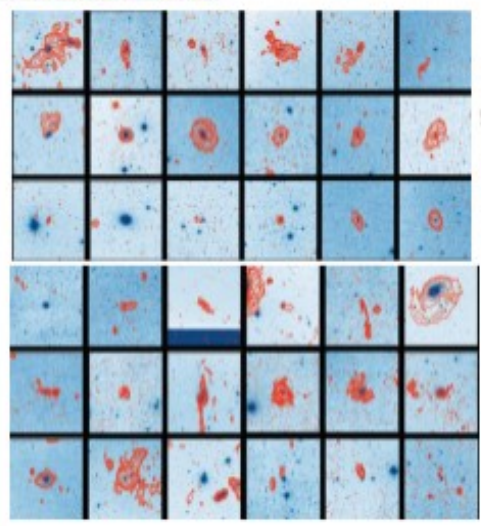
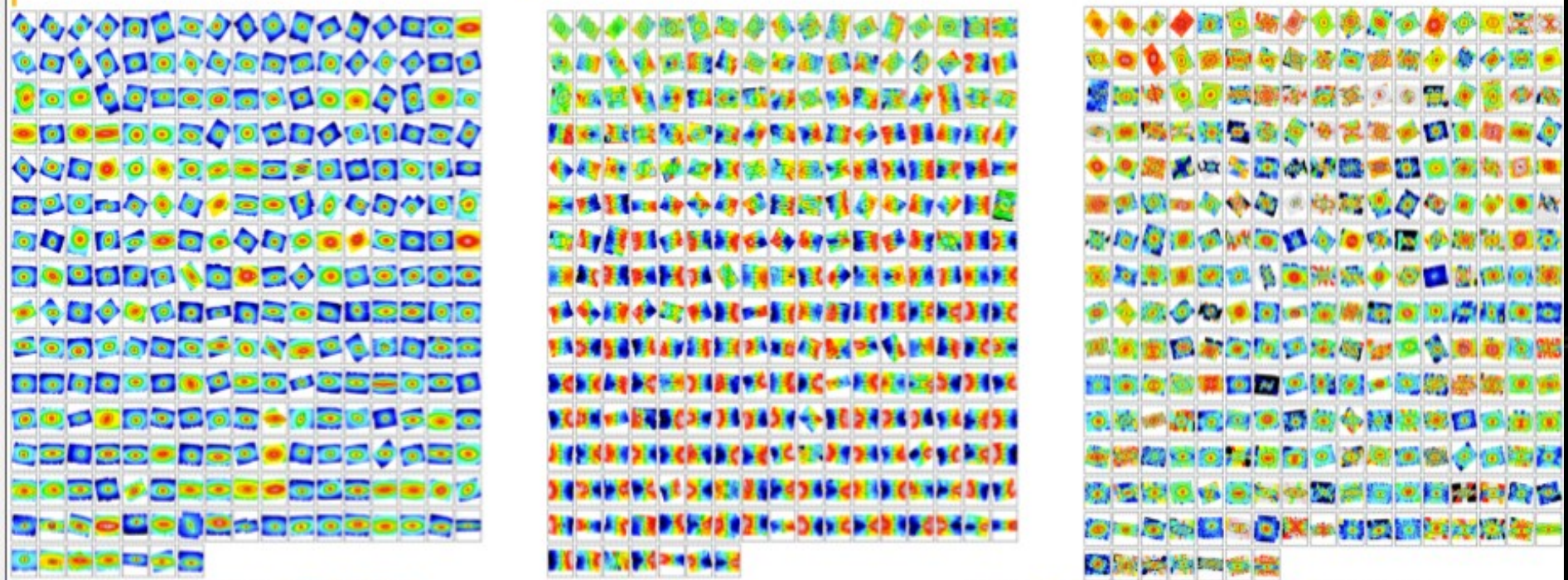
Science Goals

Color

Absolute Magnitude



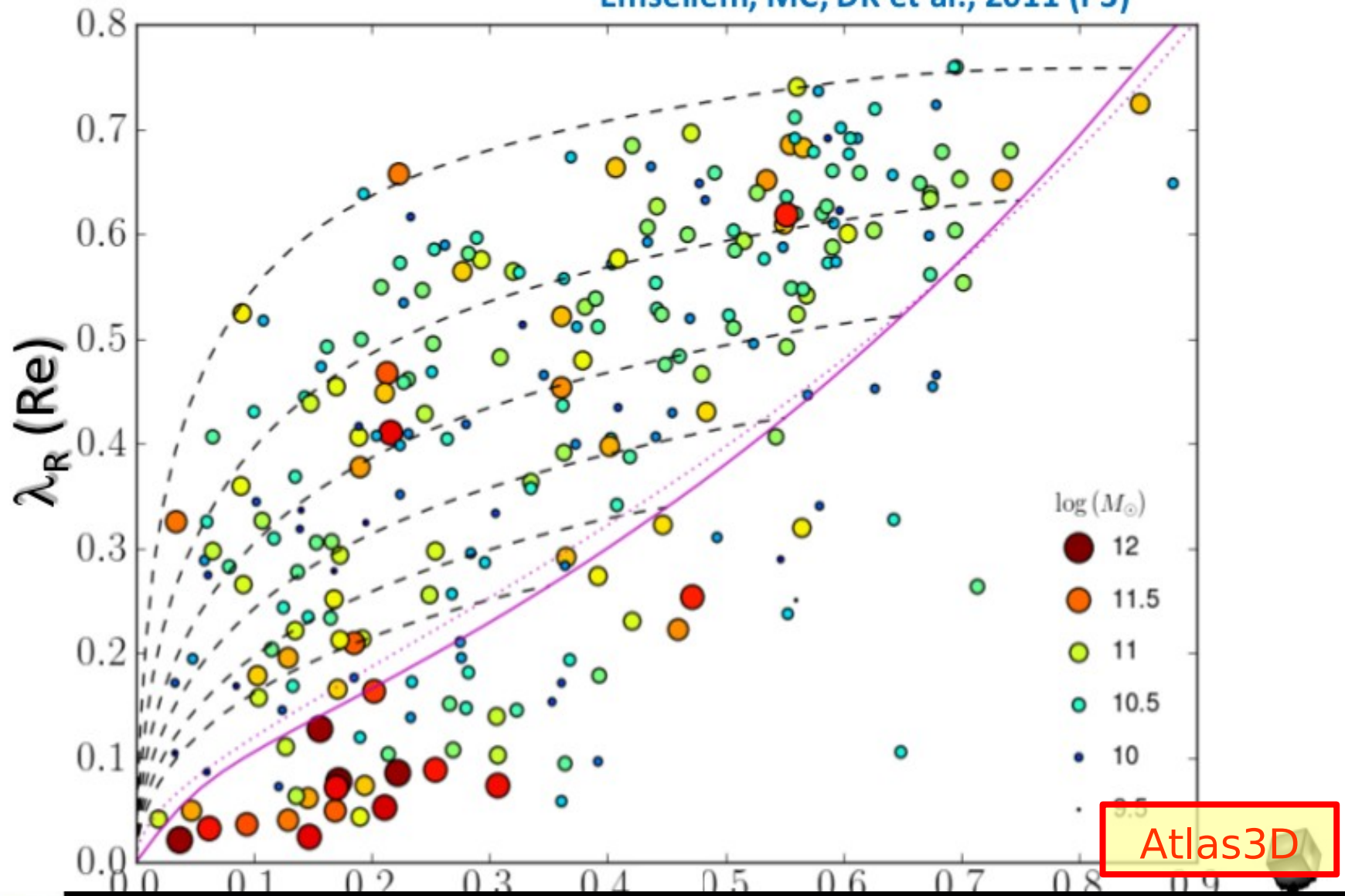
A few spectra and maps...



Atlas3D

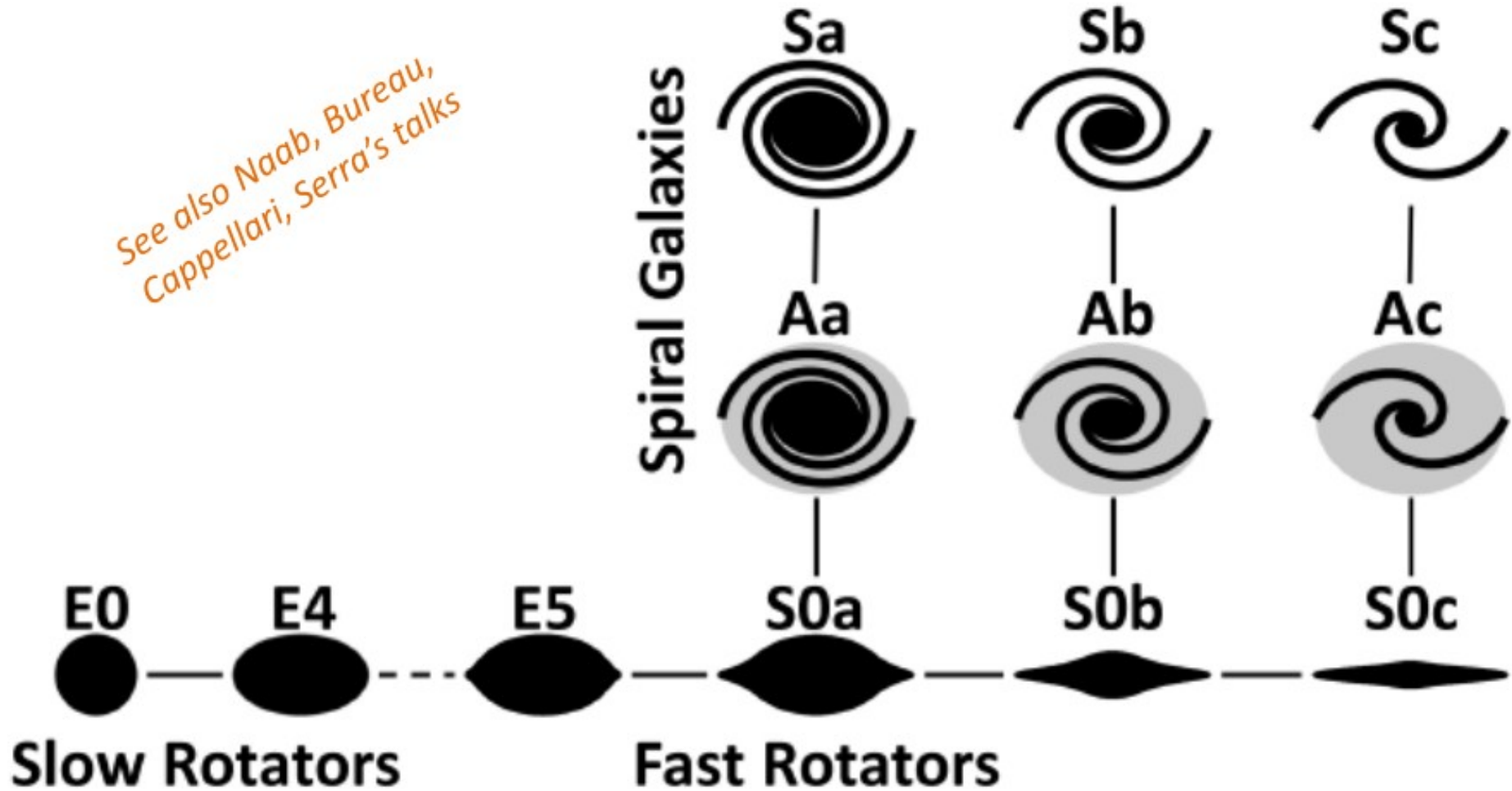
Building of angular momentum

Emsellem, MC, DK et al., 2011 (P3)



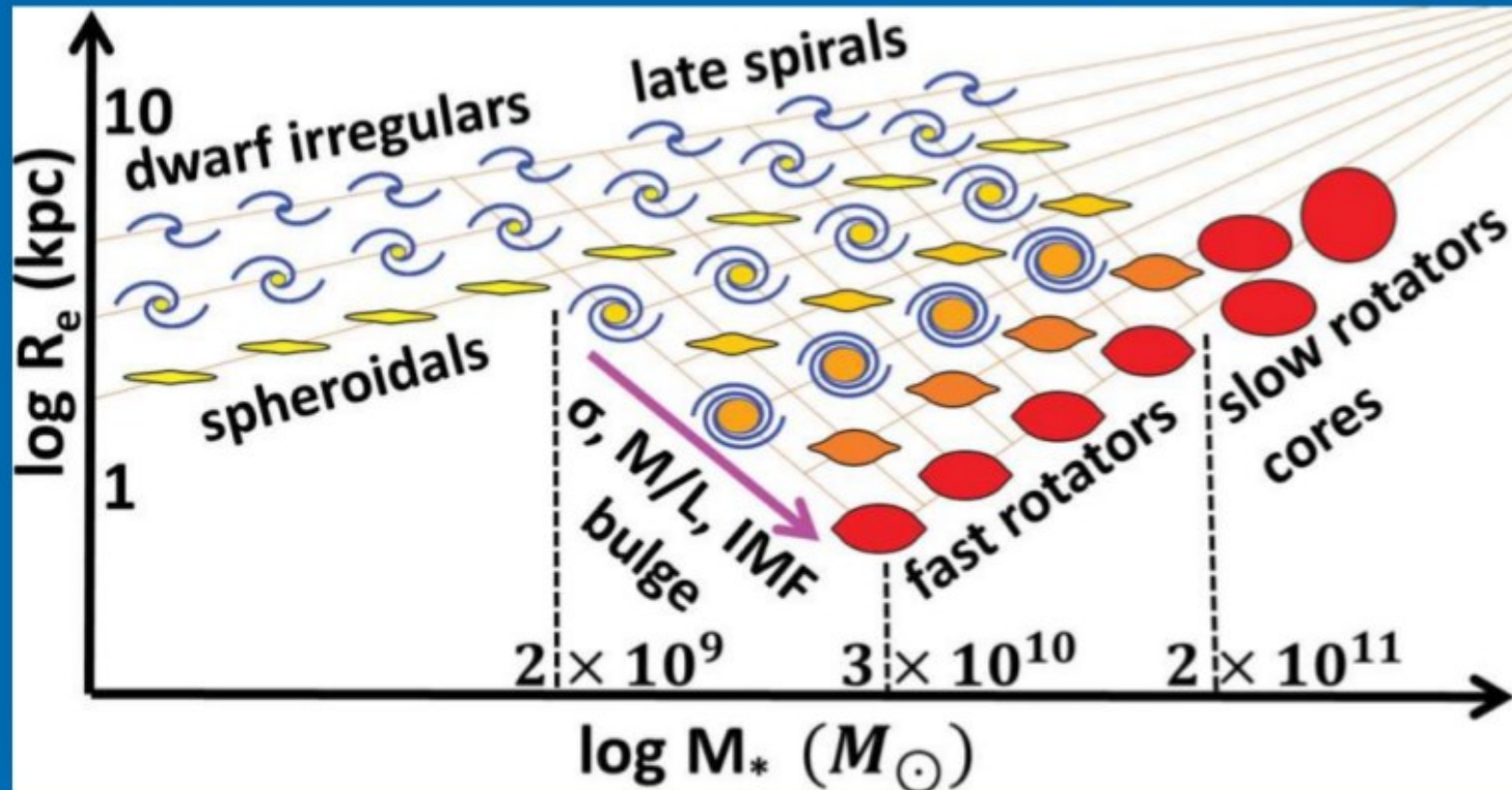
The Comb

See also Naab, Bureau,
Cappellari, Serra's talks



Atlas3D

Properties driven by bulge fraction



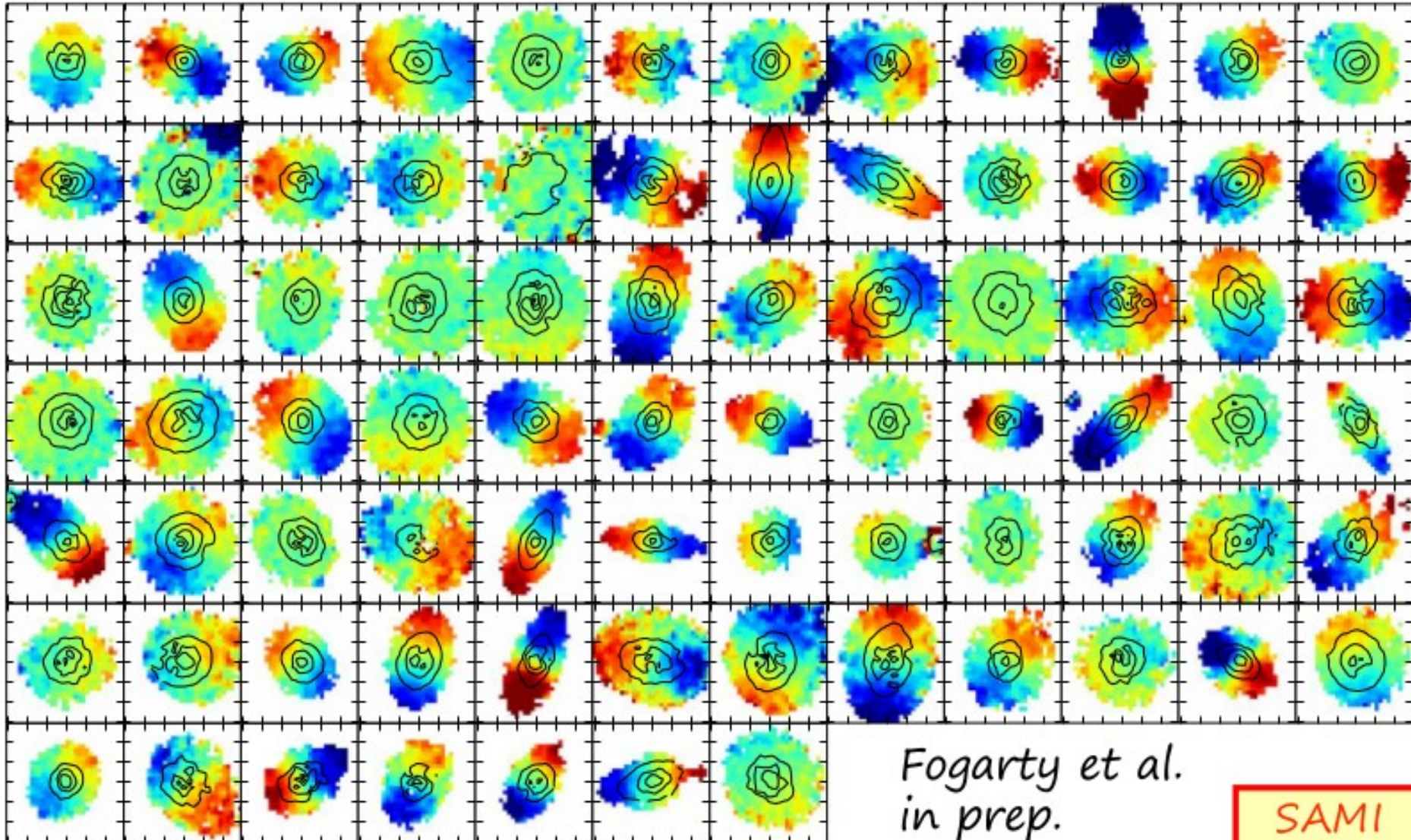
(Cappellari+13b=P20)

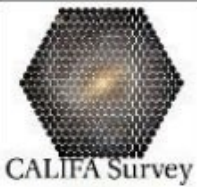
- Bulge linked to quenching for $M_* \lesssim 2 \times 10^{11} M_{\odot}$
(also Cappellari-11; Bell+12; Saintonge+12; Cheung+12; Fang+13)
- Three characteristic galaxy stellar masses

Atlas3D

(cfr. Faber+97; Kauffmann+03; van der Wel+09; Bernardi+11; Geha+12)

SAMI Stellar Kinematics

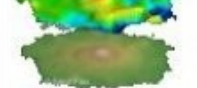
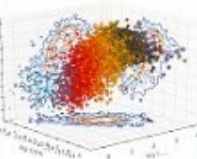




CALIFA Survey

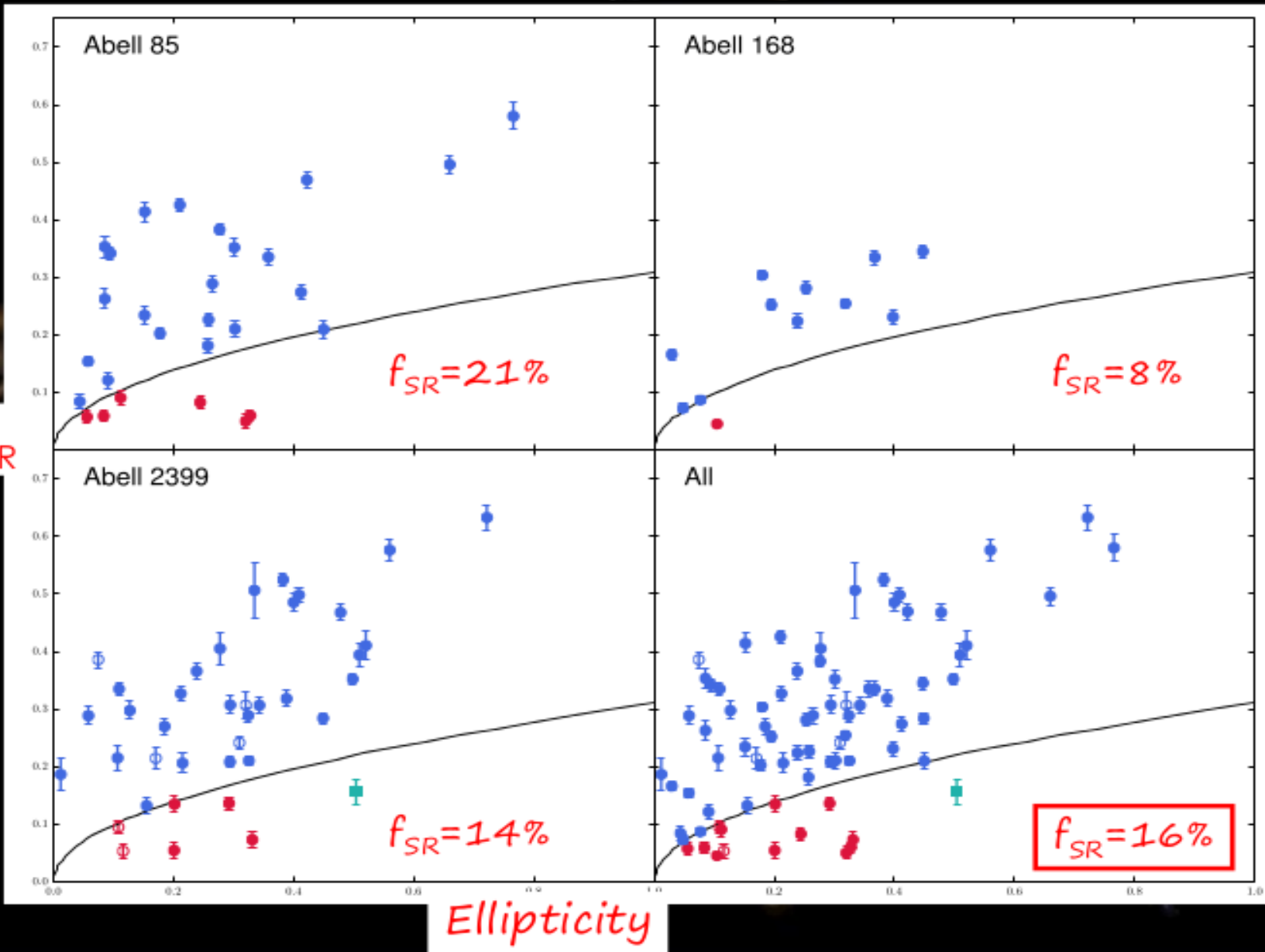


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Classification

SAMI

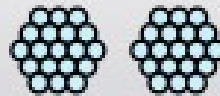


Bundle size distribution

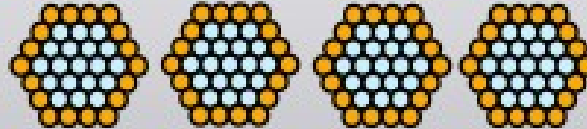
17 bundles per cartridge
(1247 bundled fibers)

6 cartridges \rightarrow 102 bundles total

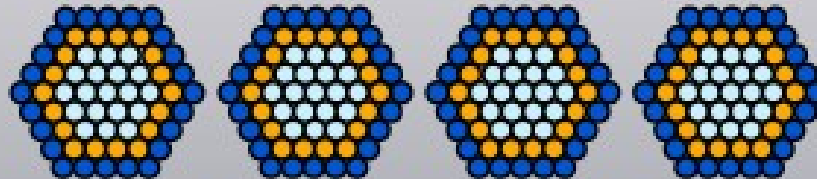
2 bundles x 19 fibers



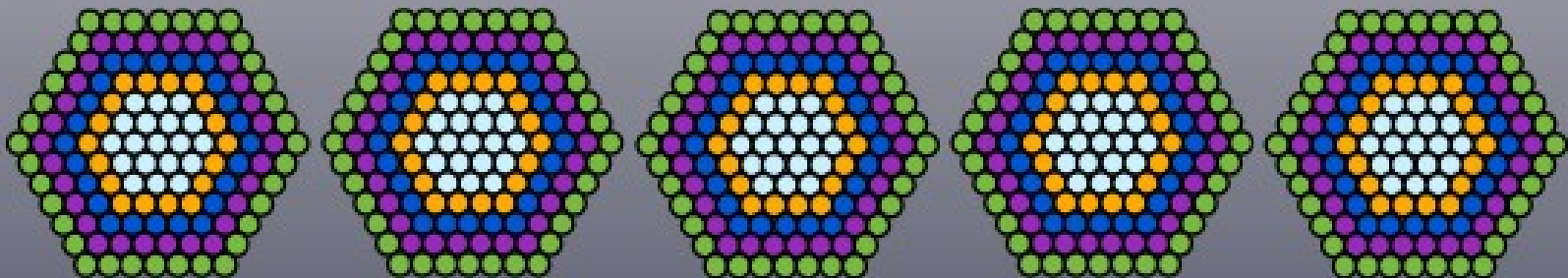
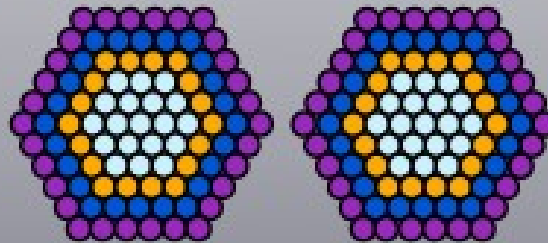
4 bundles x 37 fibers



4 bundles x 61 fibers



2 bundles x 91 fibers

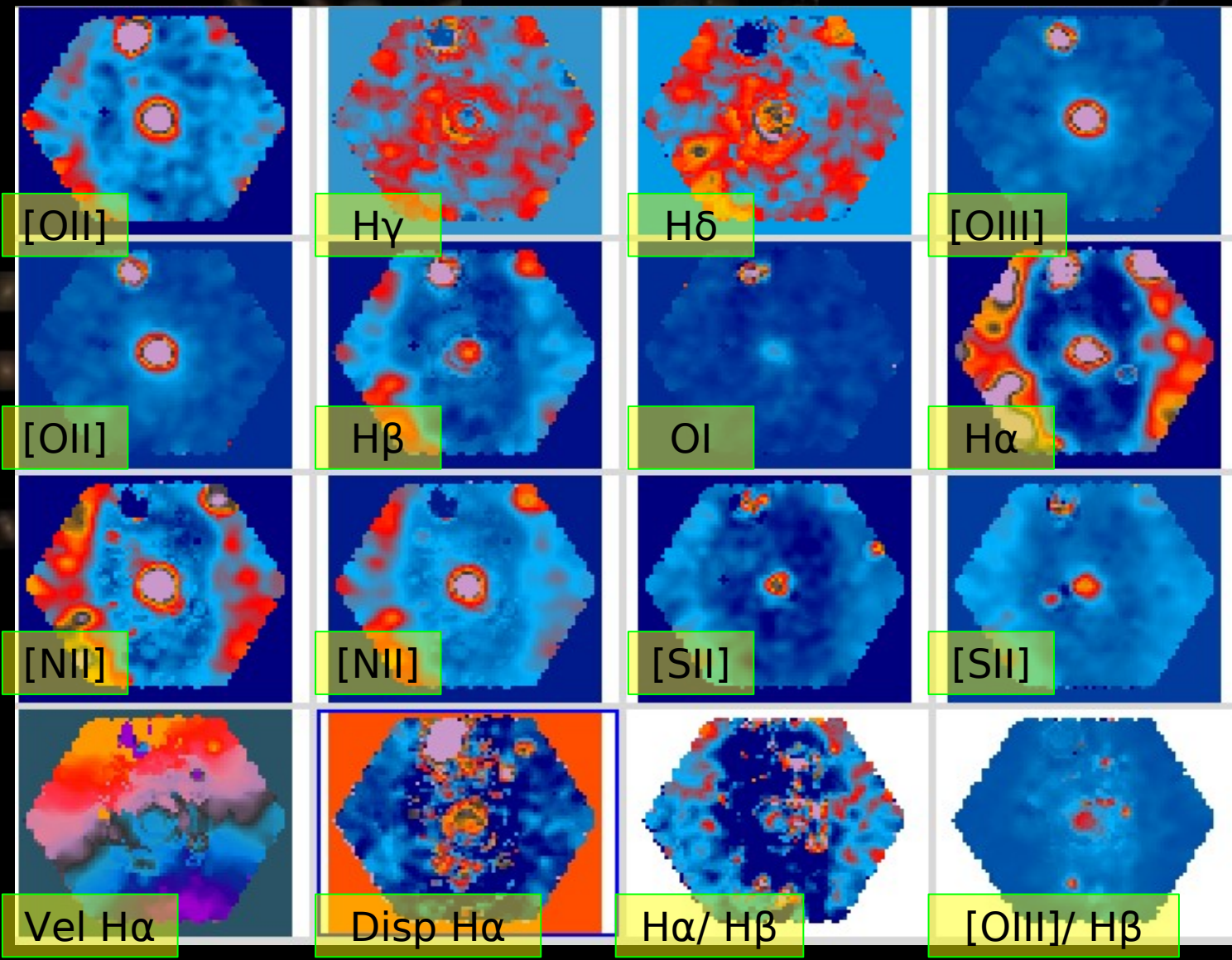
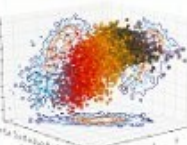


5 bundles x 127 fibers

Gas data-products



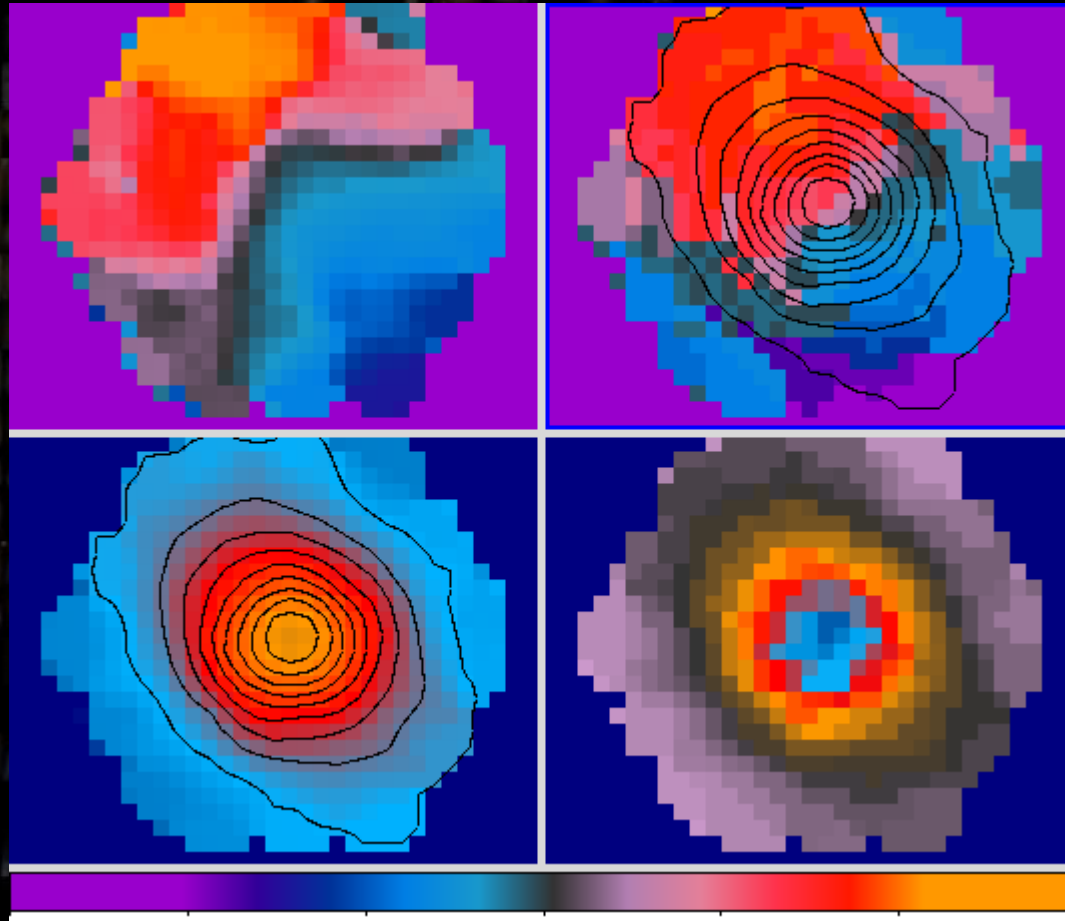
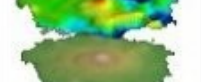
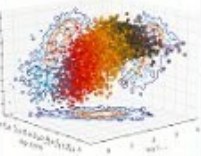
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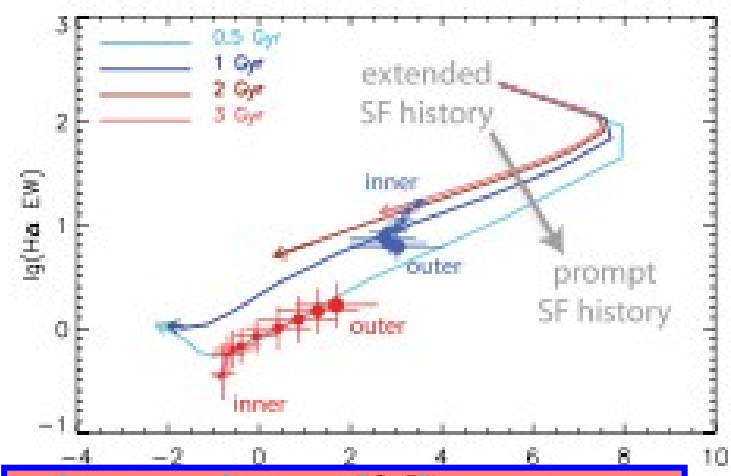
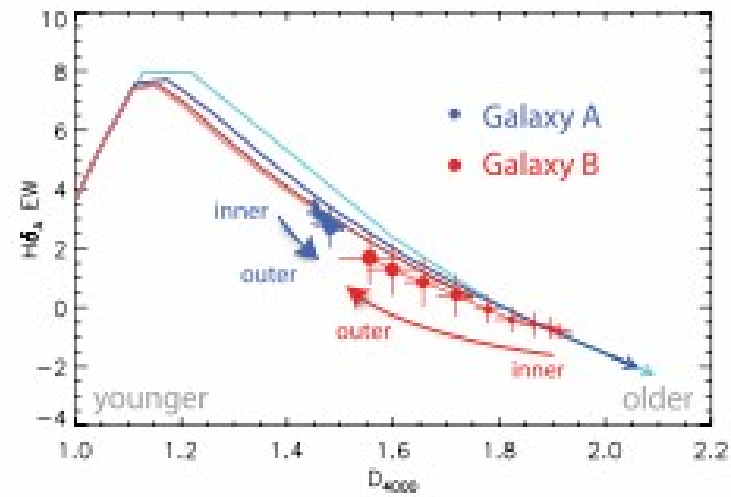
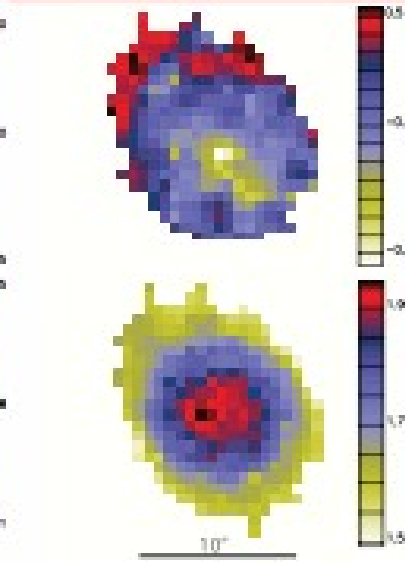
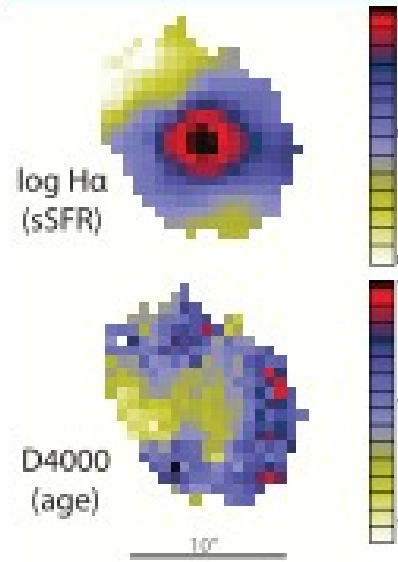
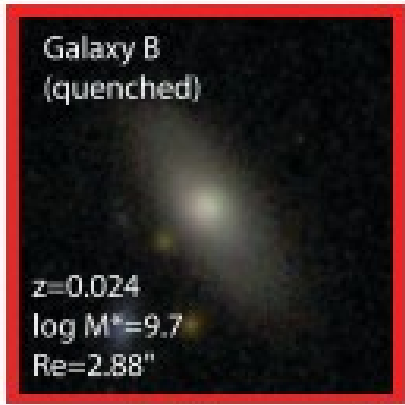
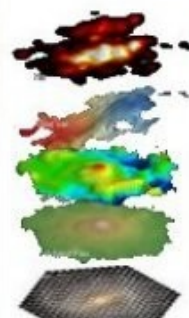
Gas vs. Stellar Kinematics (even for the smaller bundles)



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Stellar Diagnostic Maps

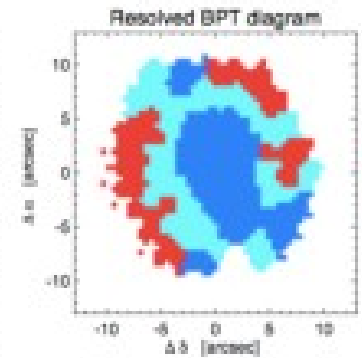
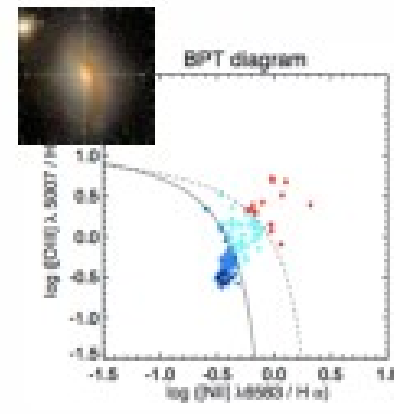
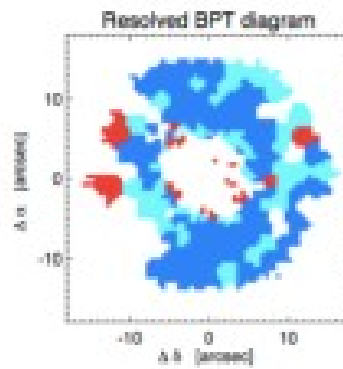
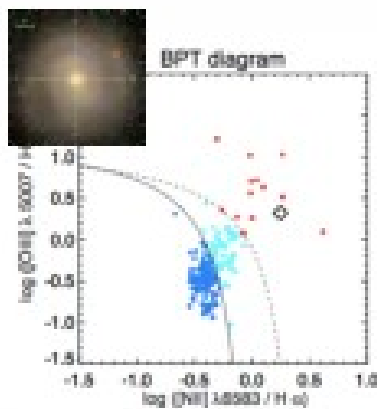
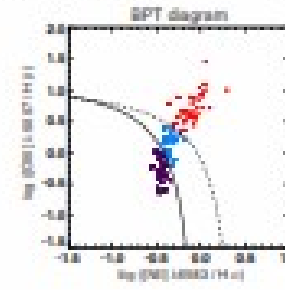
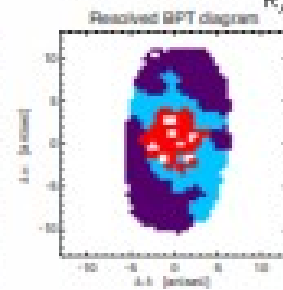
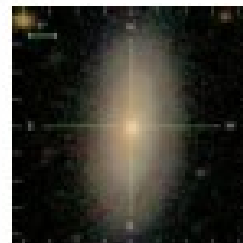
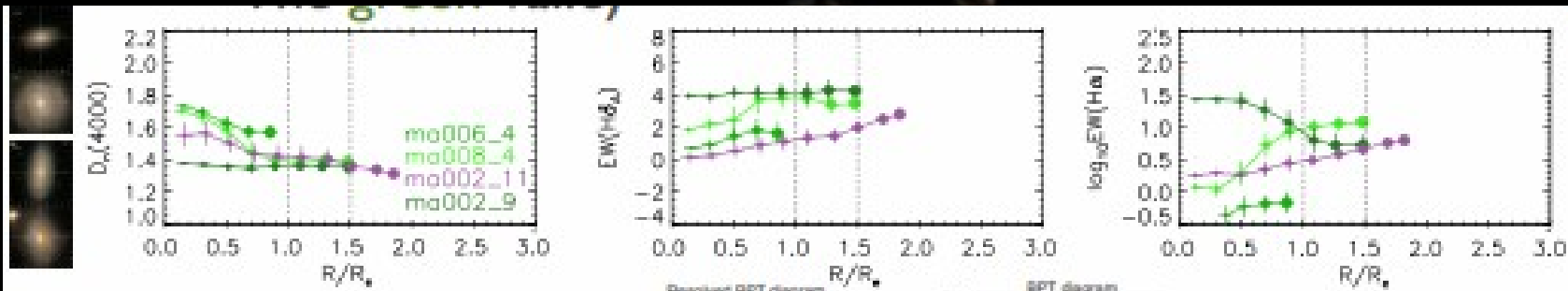
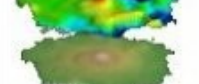
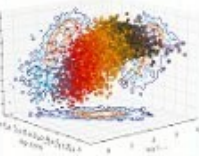


Cheng Li, et al., in prep.

Spatially resolved BPT diagrams



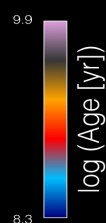
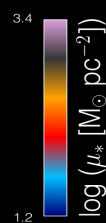
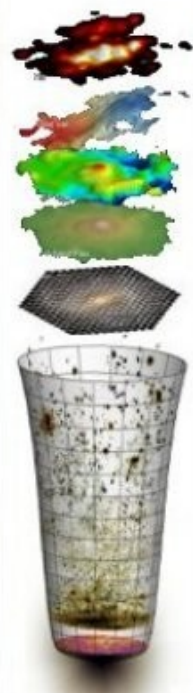
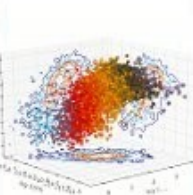
UNAM



Calar Alto Legacy
Integral Field
Area survey

6900 Å 5250 Å 4100 Å

CALIFA
Survey



DR1: 100 Objects
November 2012
DR2: Oct. 2014!!!

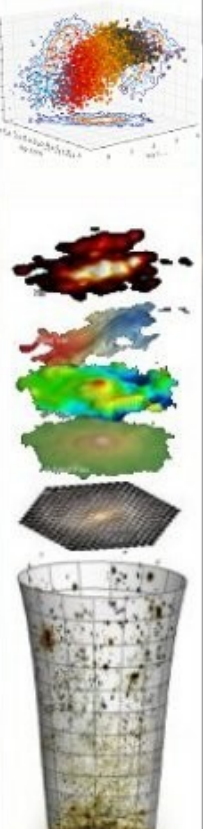
448 cal. obj. obs.
+109 ext. obj. obs.

Credit: R. García-Bermejo, F. Rosales-Ortega

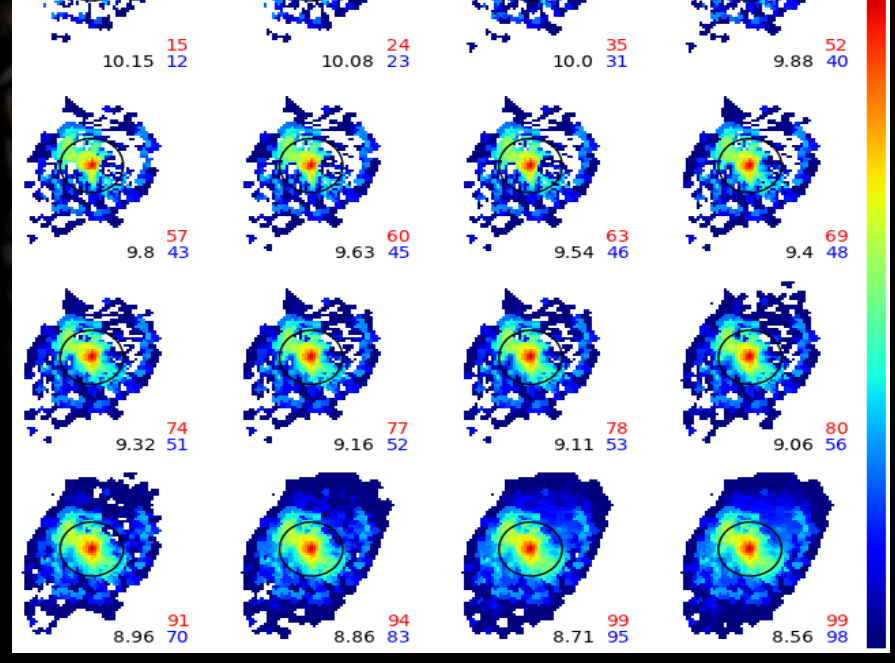
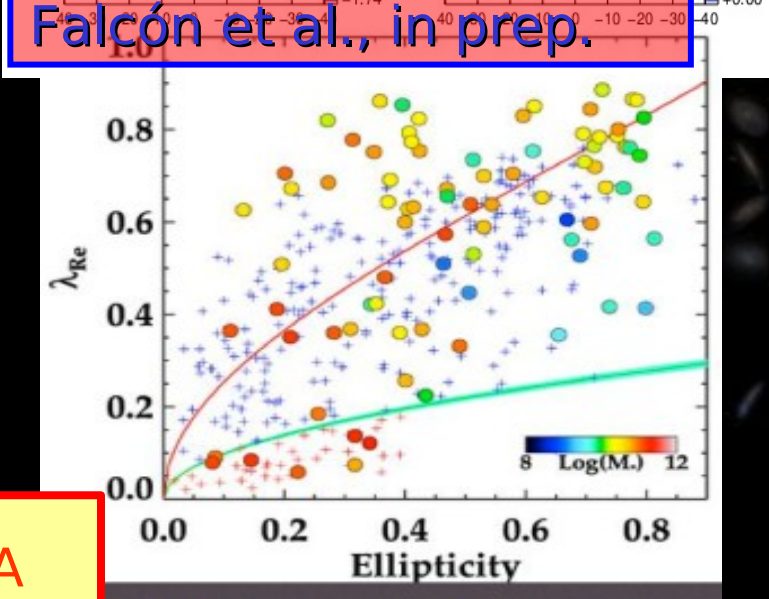
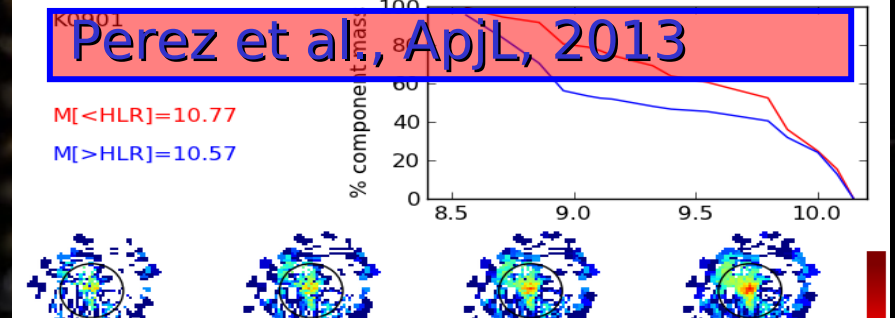
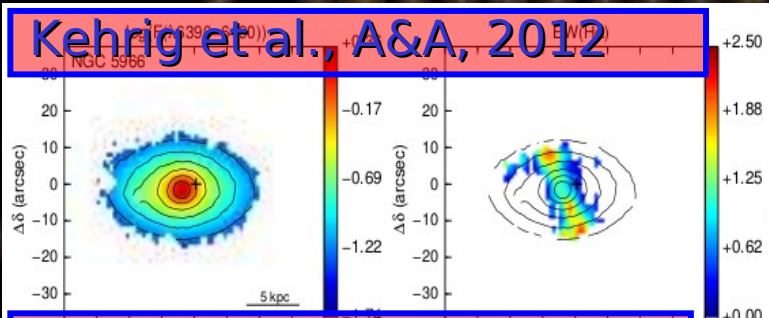
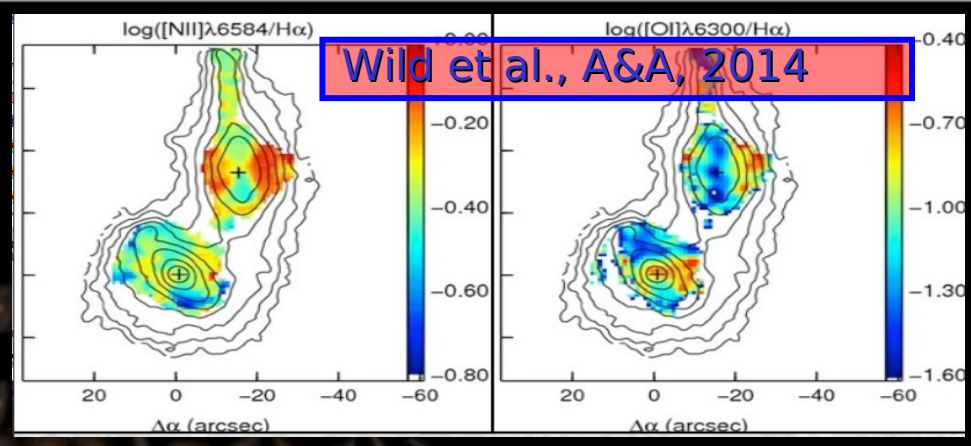
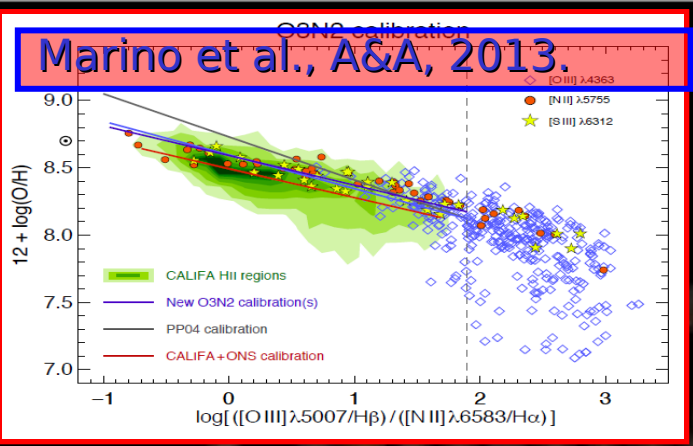
E. Pérez, C.J. Walcher, S.F. Sánchez
& the CALIFA team

H α [NIII] 6584 Å [OIII] 5007 Å

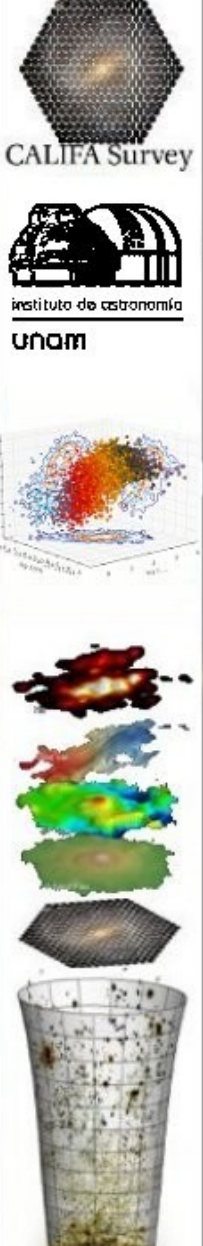
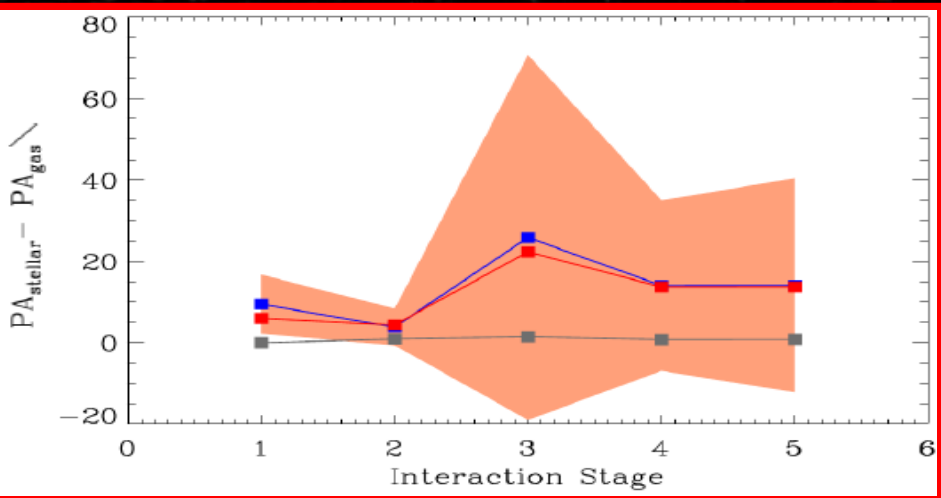
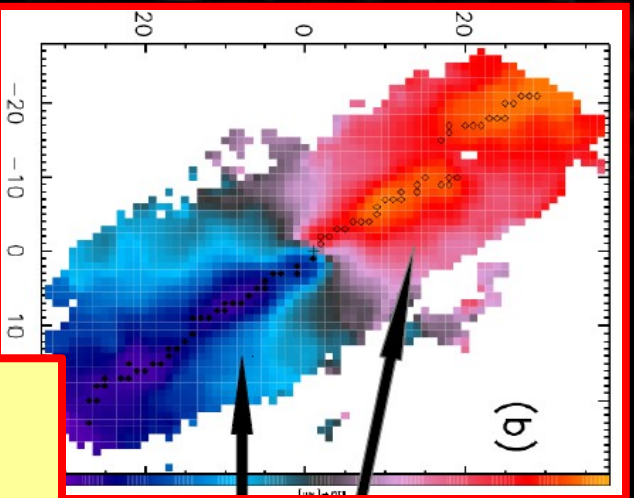
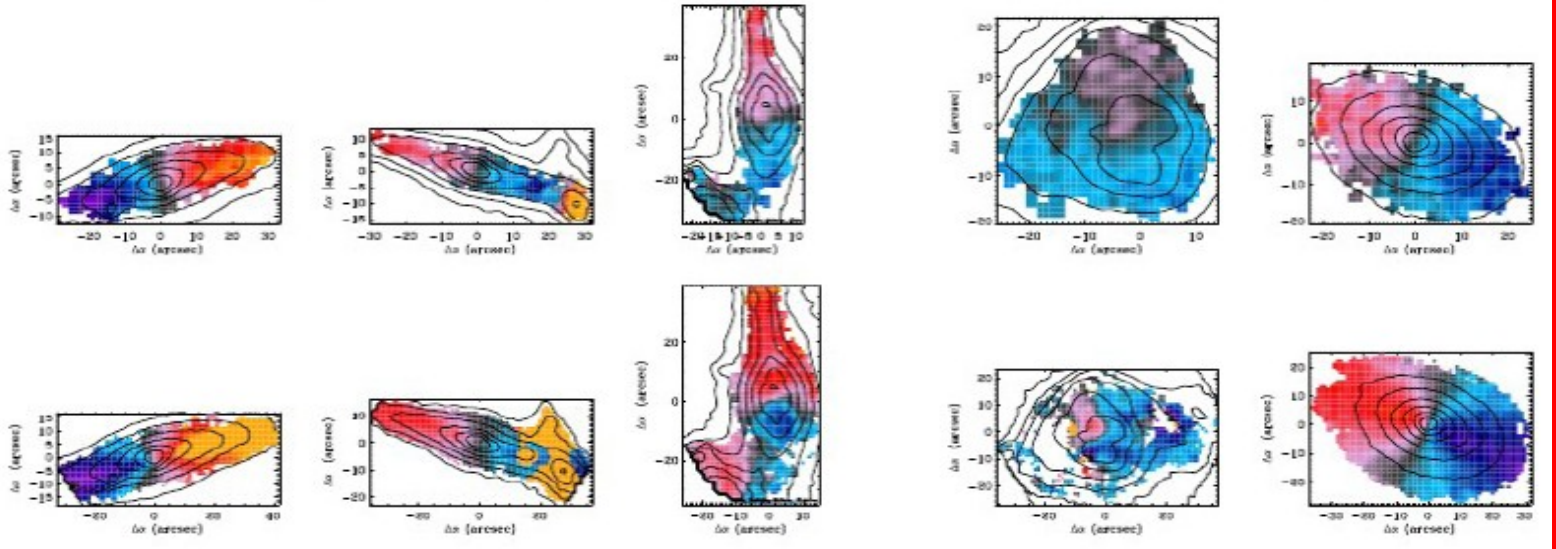
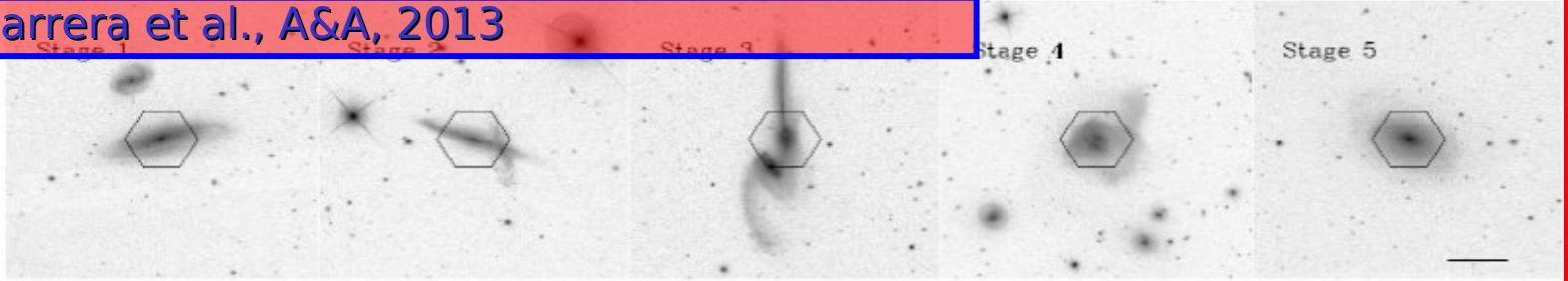
Centro Astronómico
Hispano Alemán



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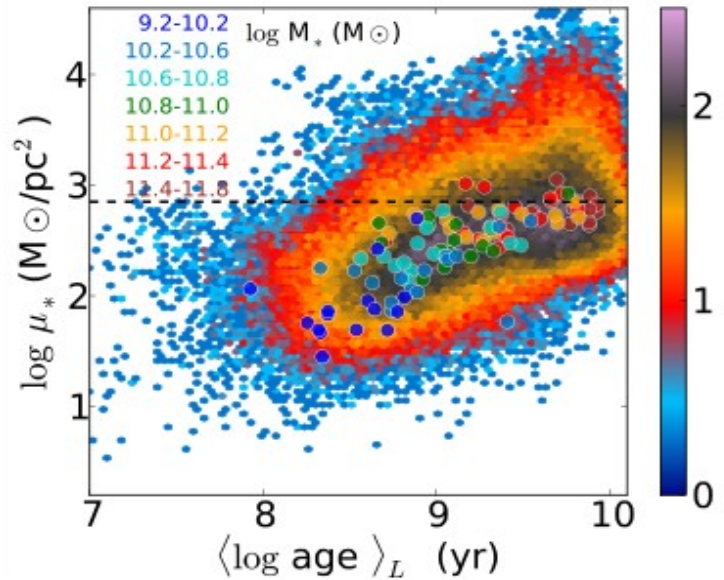
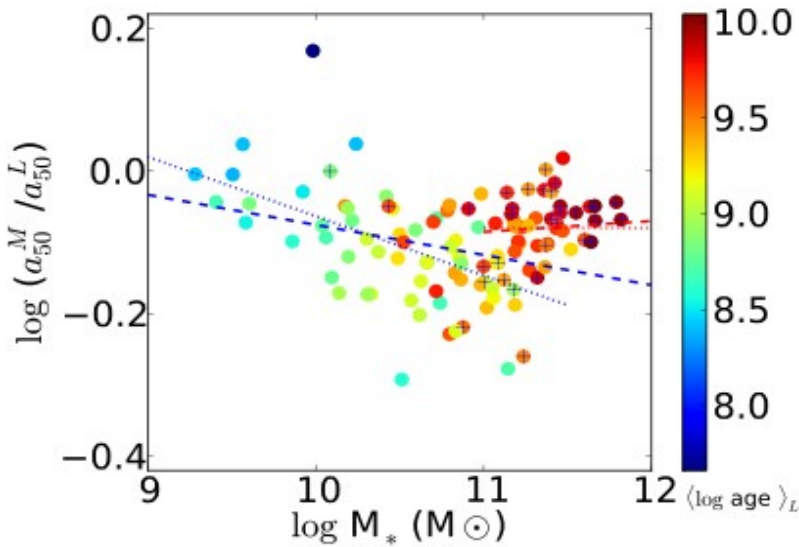
+ ATLAS3D ● CALIFA



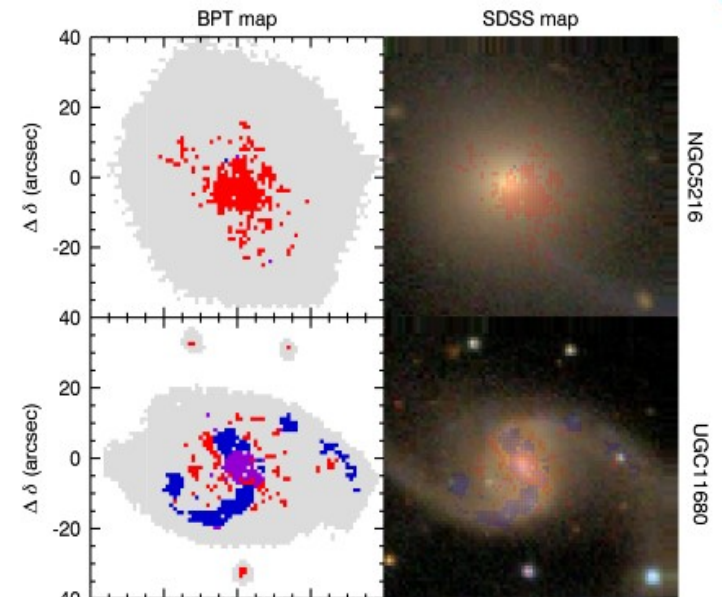
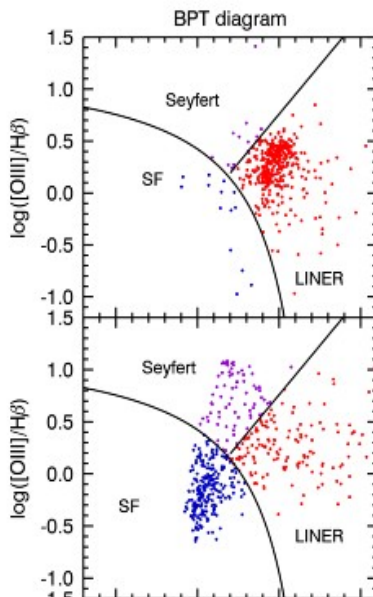
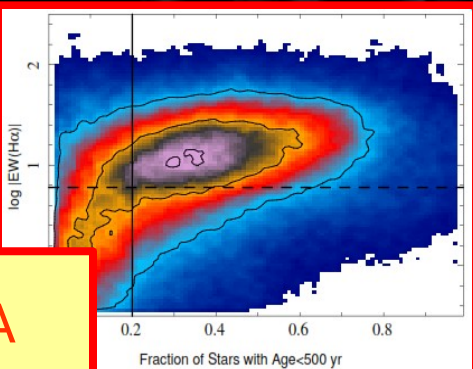
CALIFA Survey

Gonzalez Delgado, et al., A&A, 2014

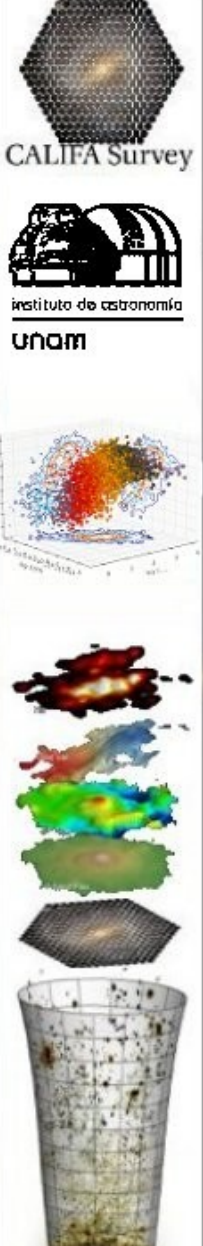
The CALIFA collaboration: The star formation history of CALIFA galaxies

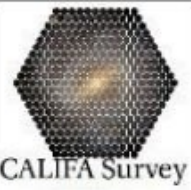


Singh et al. Paparedos et al, A&A, 2013



CALIFA Survey



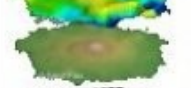
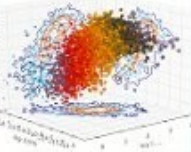


CALIFA Survey

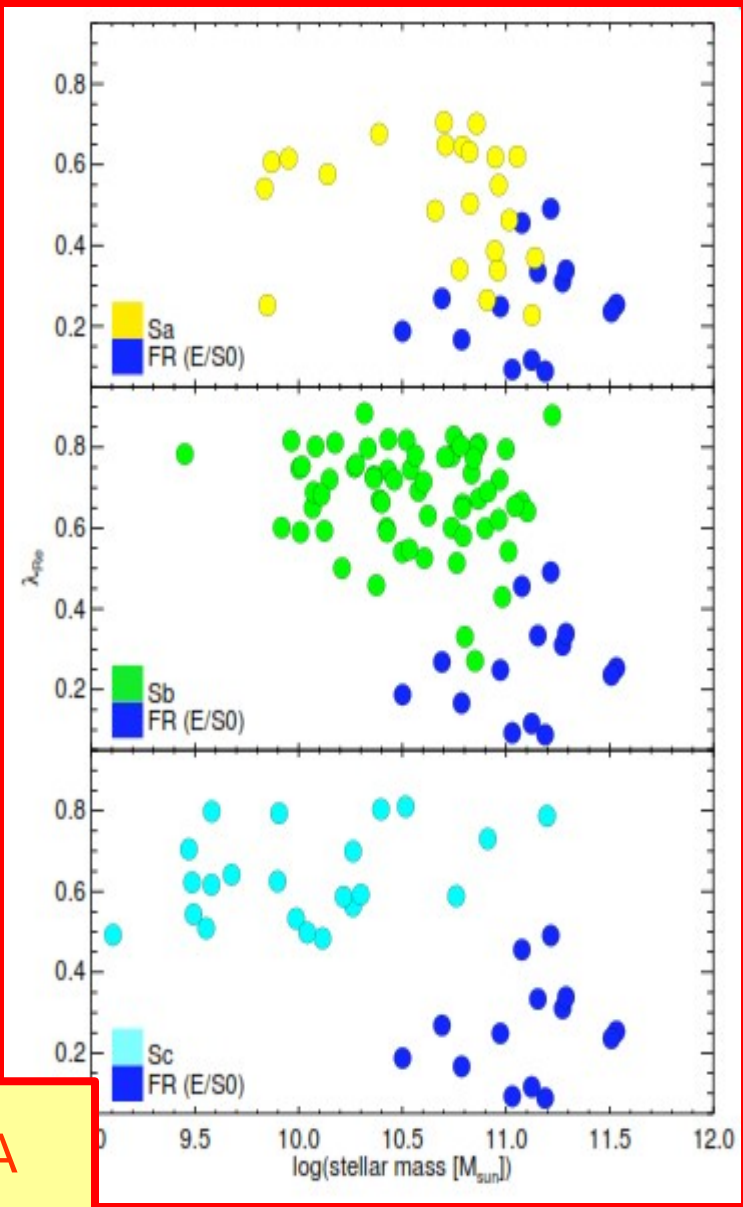


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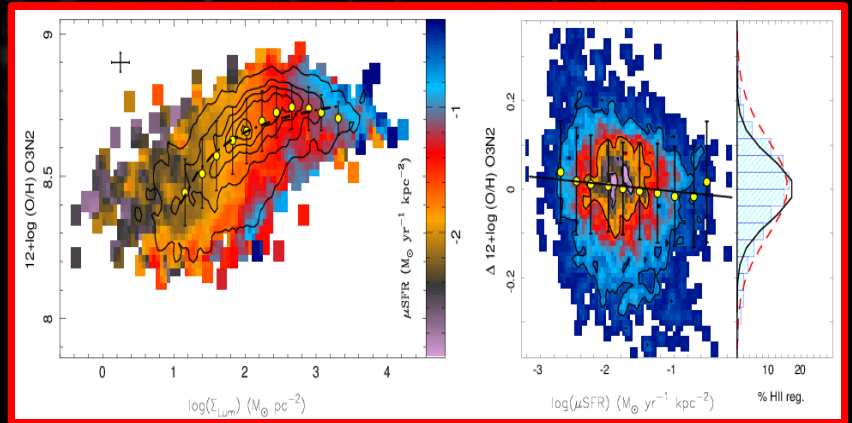
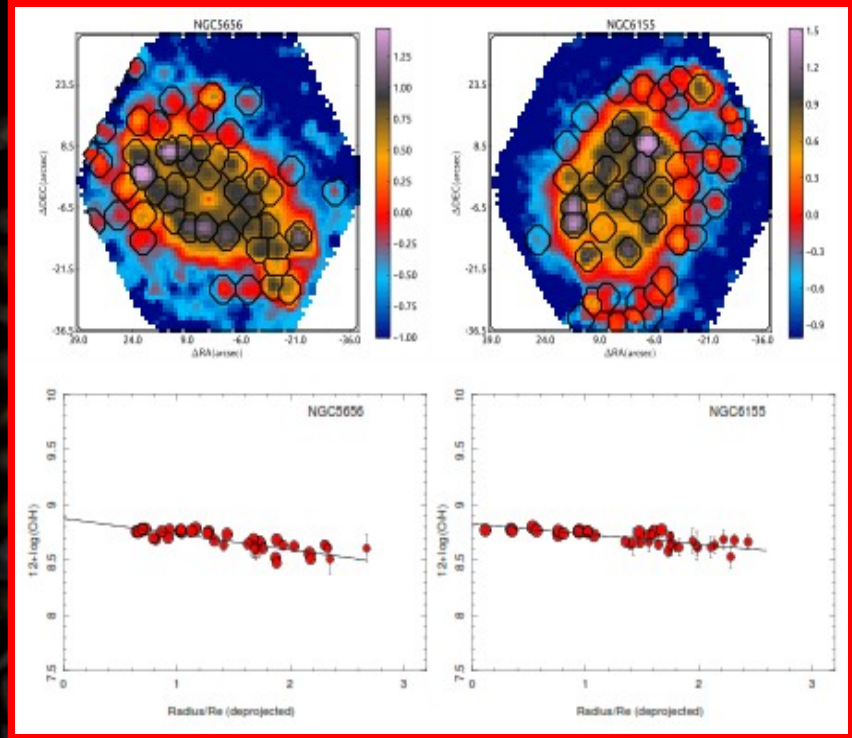
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Falcón et al., in prep.



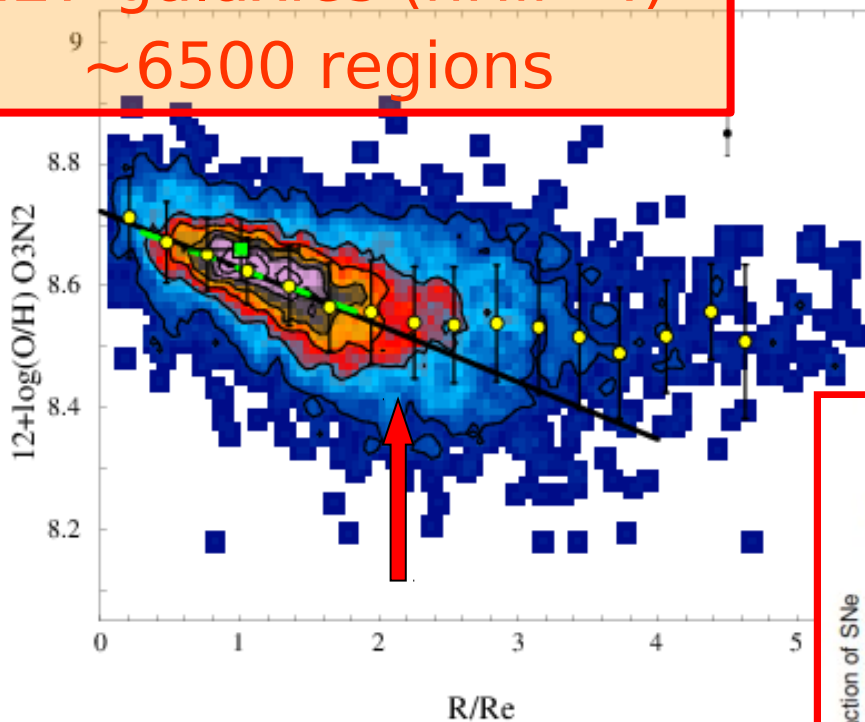
Sanchez et al., A&A, 2013



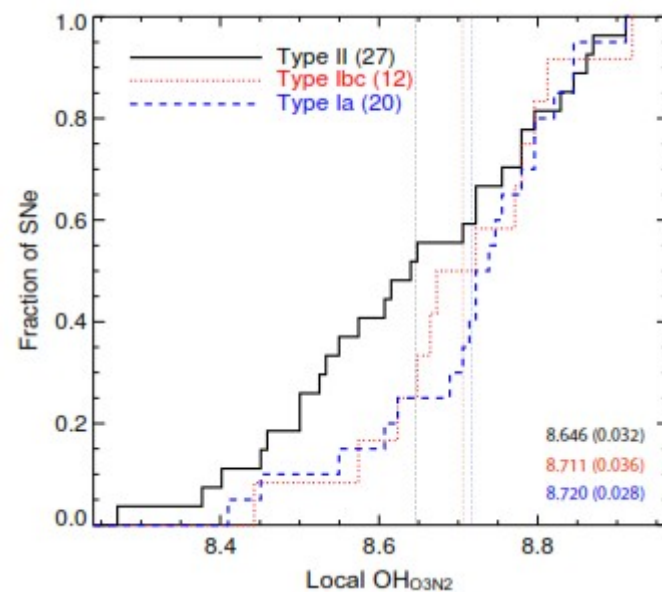
CALIFA Survey

O/H Abundance gradients

227 galaxies ($n_{\text{HII}} > 4$)
~6500 regions

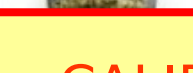
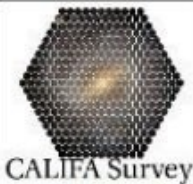


Sanchez et al.,
A&A, 2014

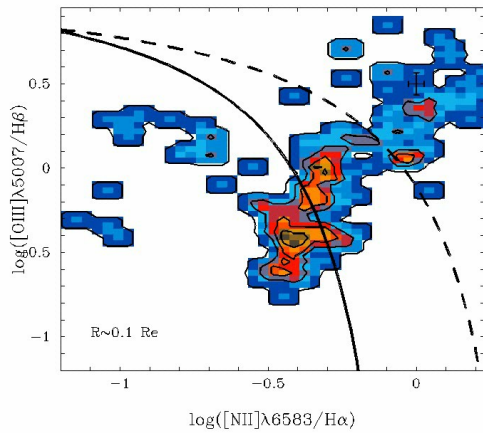
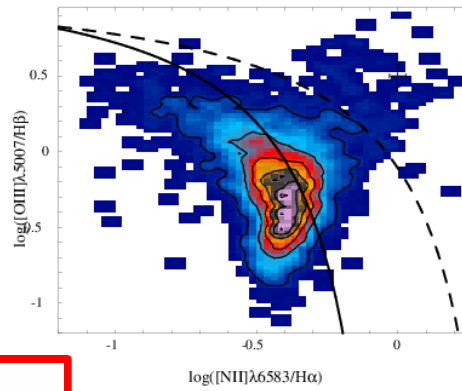
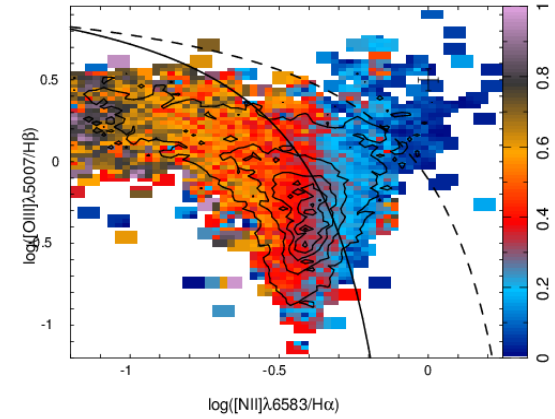
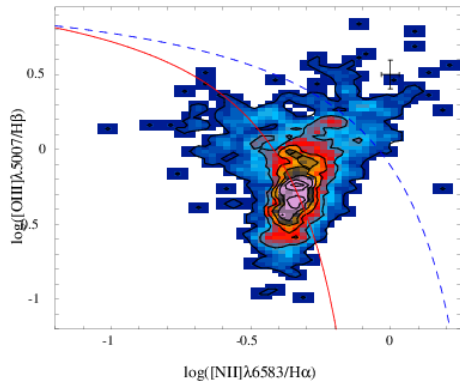


SN Hosts, Gabany
et al., in prep.

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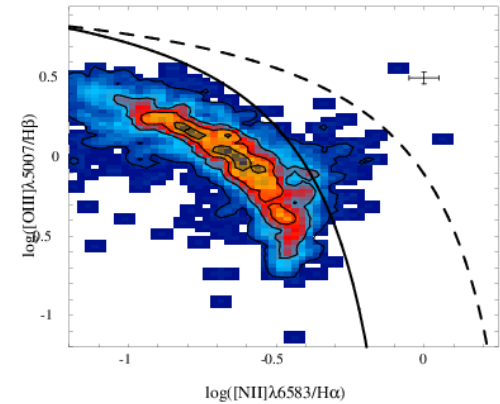


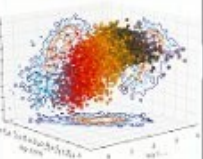
Do HII regions have memory of SFH?



Sanchez et al.,
In prep.

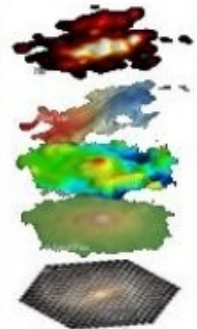
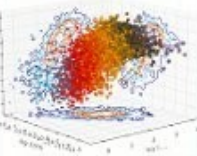
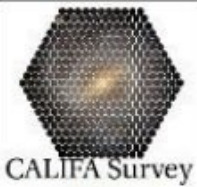
CALIFA
Survey





IFS Galaxy Surveys

- More in the Future -

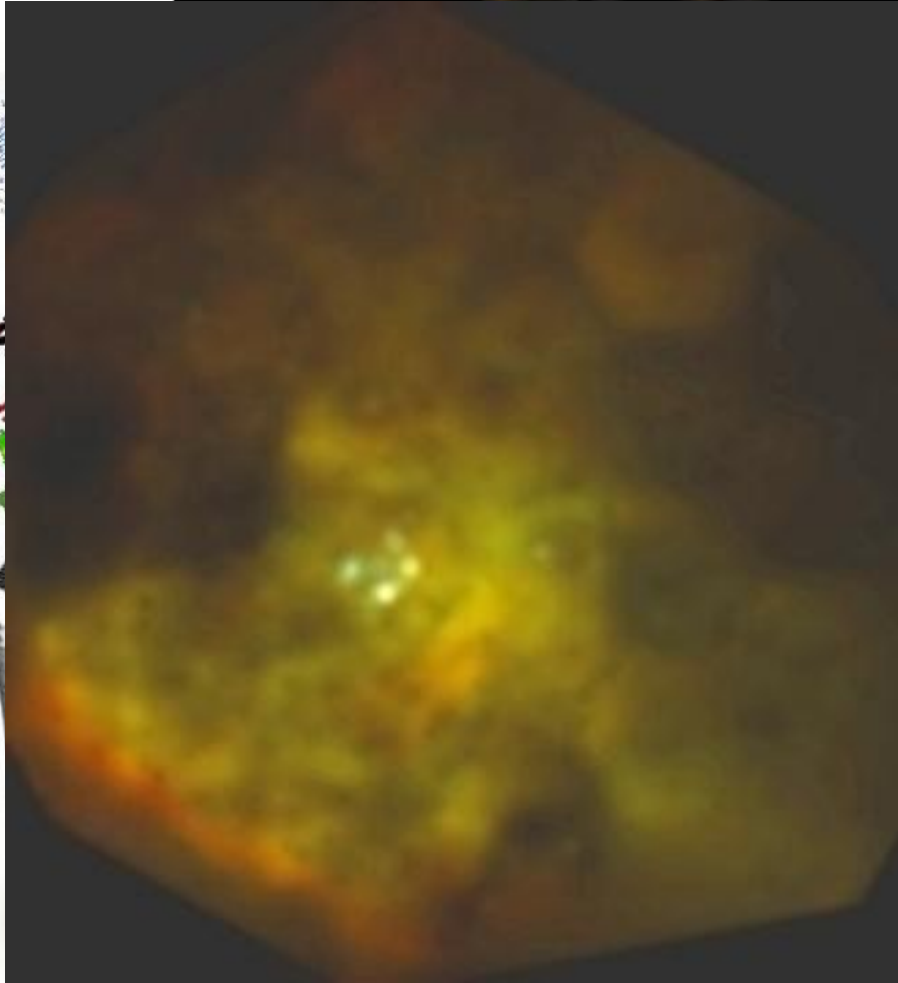


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- New sets of simulations and theoretical studies are required to understand the results.

MUSE is coming!

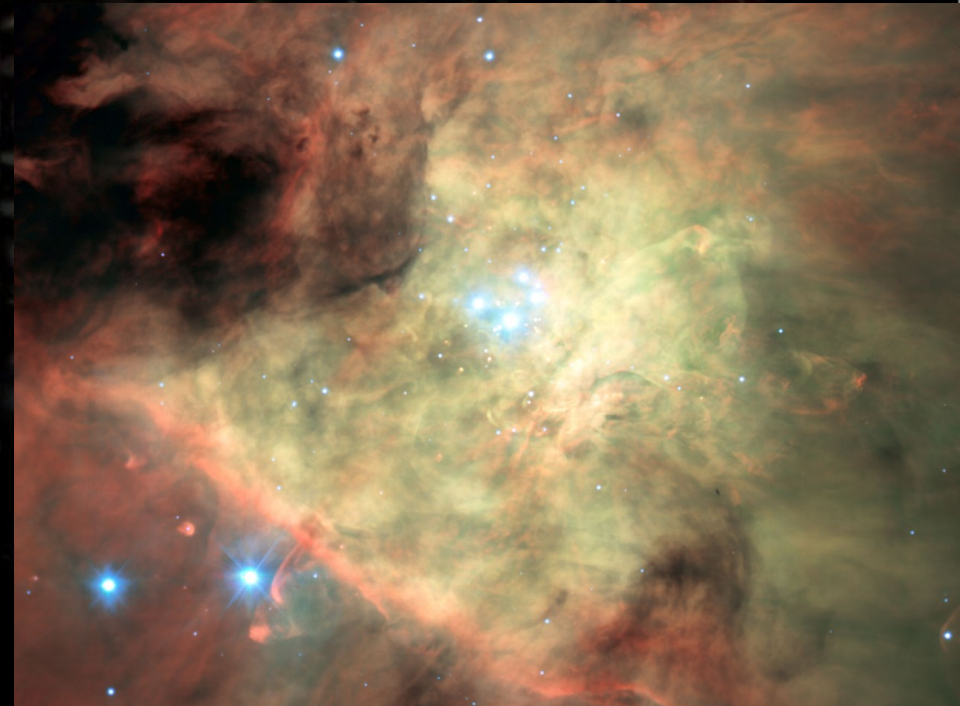
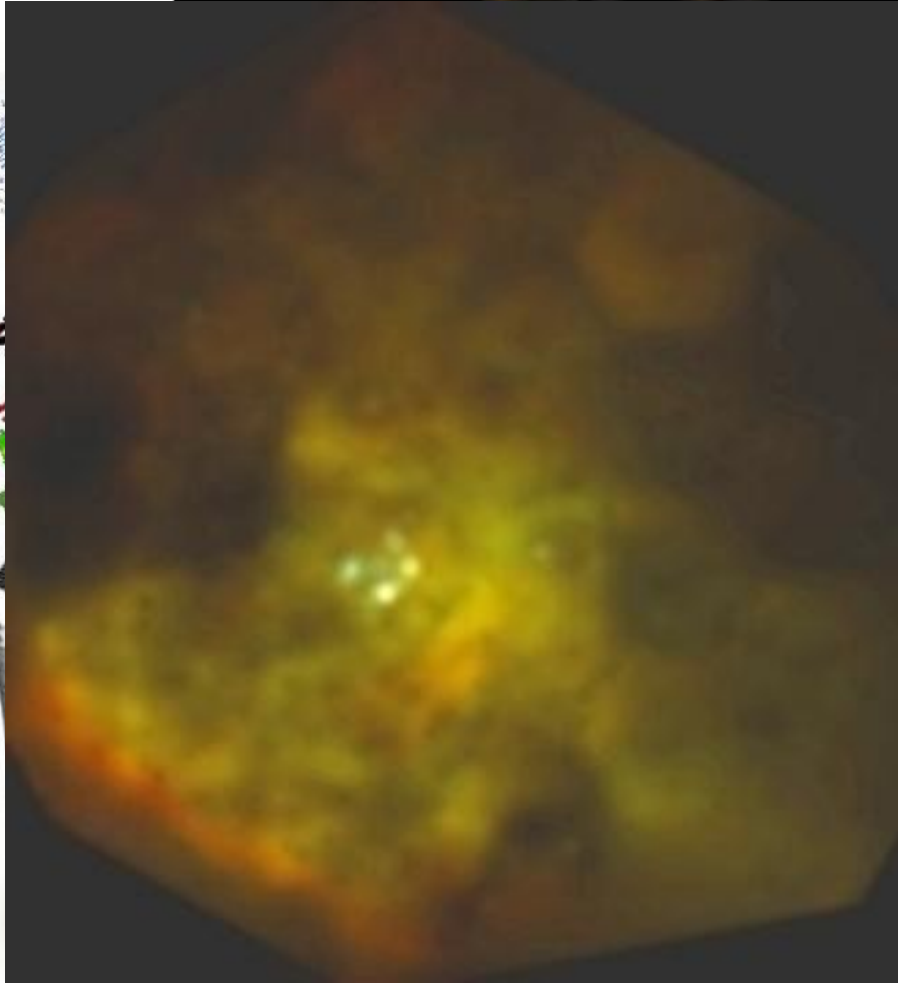
Orion Nebulae: PPAK vs. HST

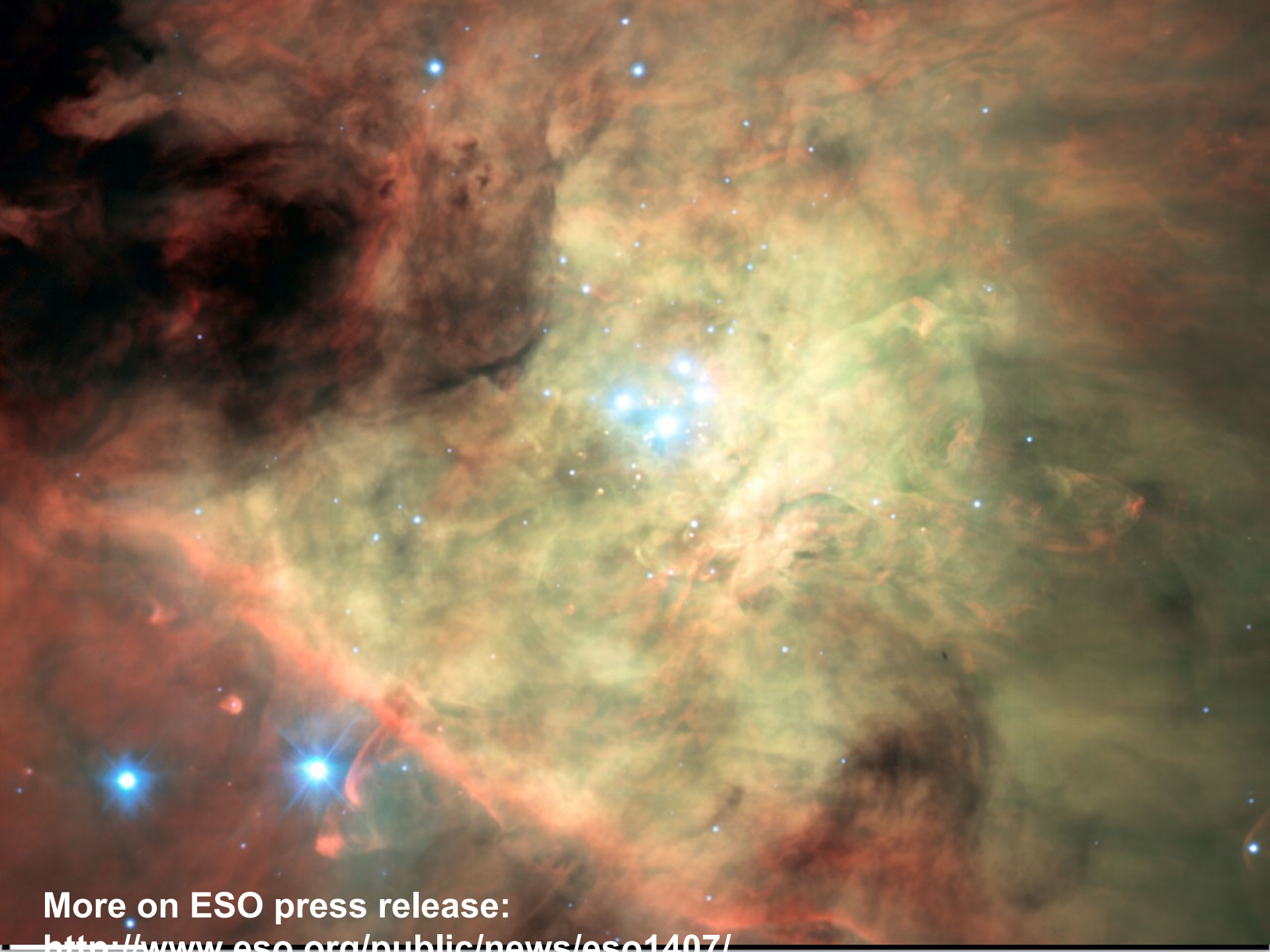


MUSE is coming!

Orion Nebulae: PPAK vs. MUSE

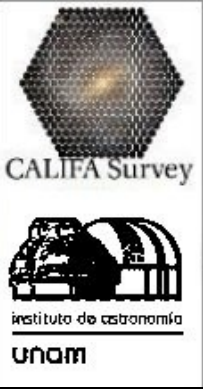
... and the winter too!



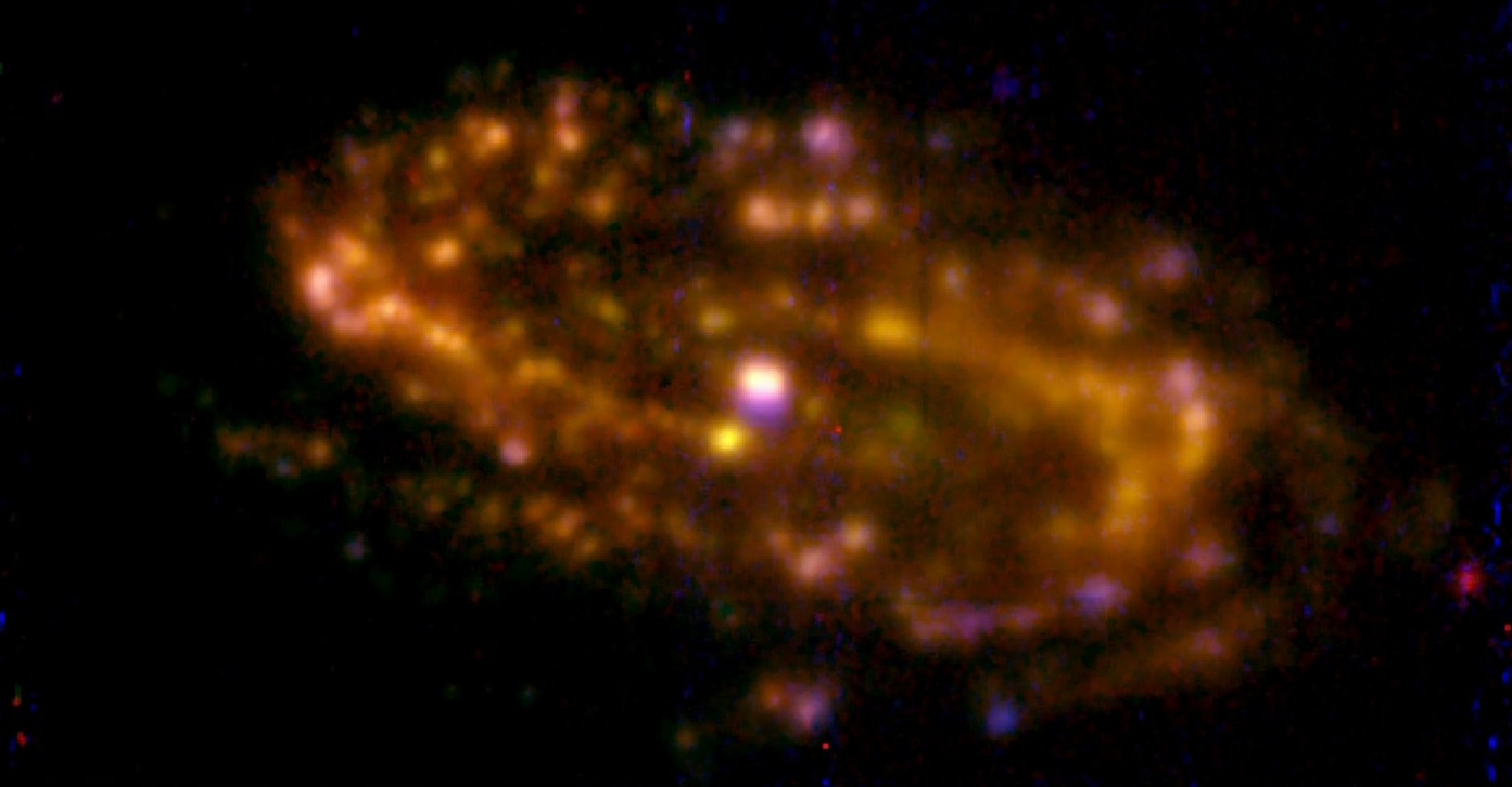


More on ESO press release:

<http://www.eso.org/public/news/eso1407/>

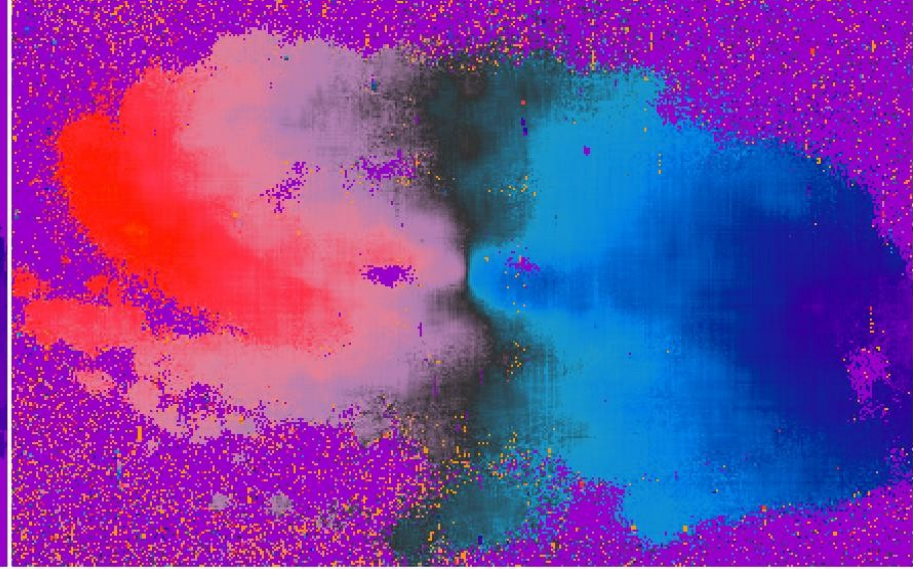
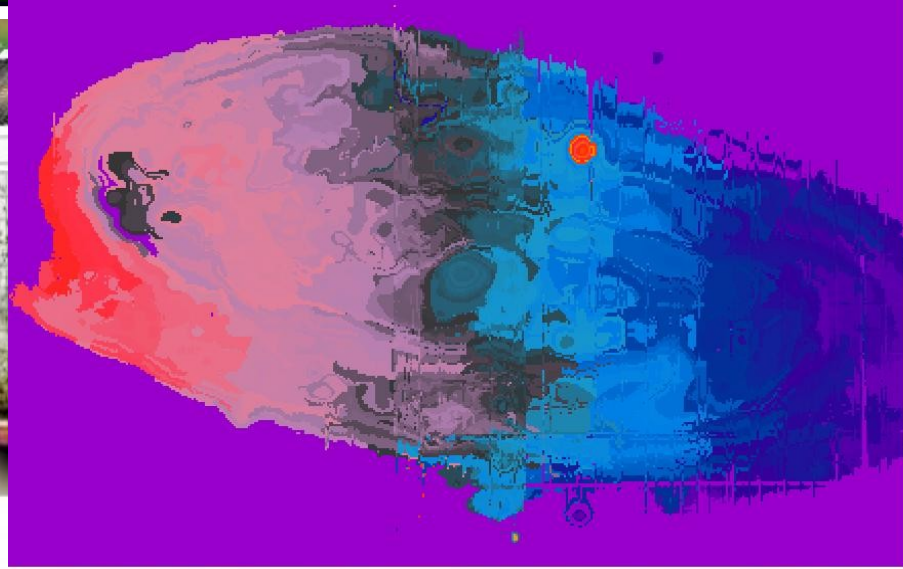
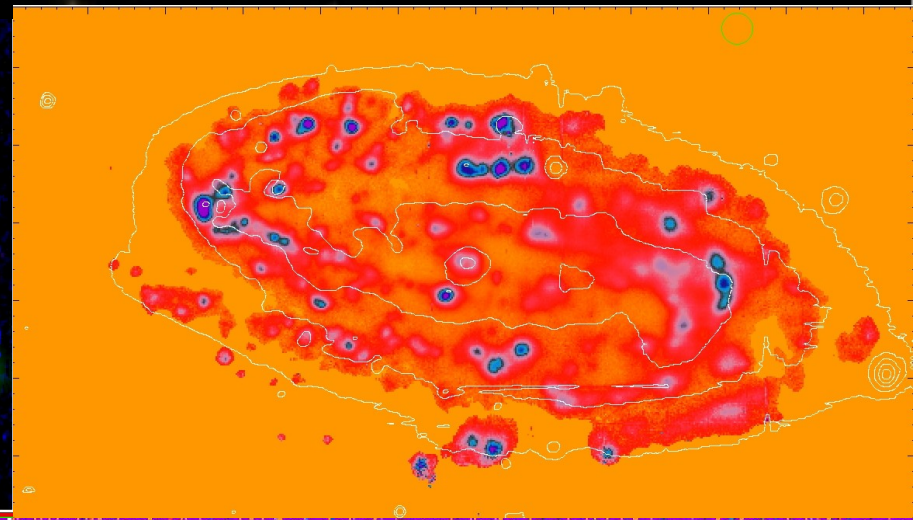
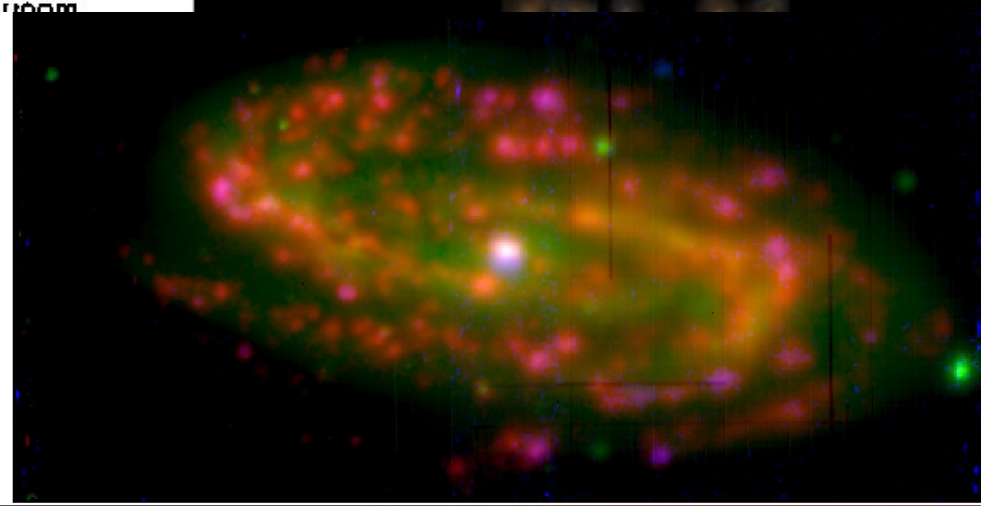


MUSE IS coming!
NGC6754: 400 Hii regions
detected!

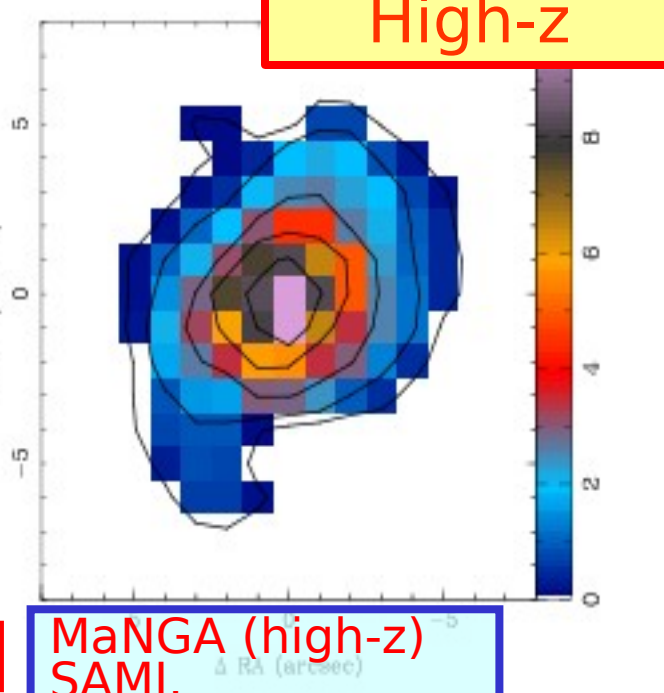
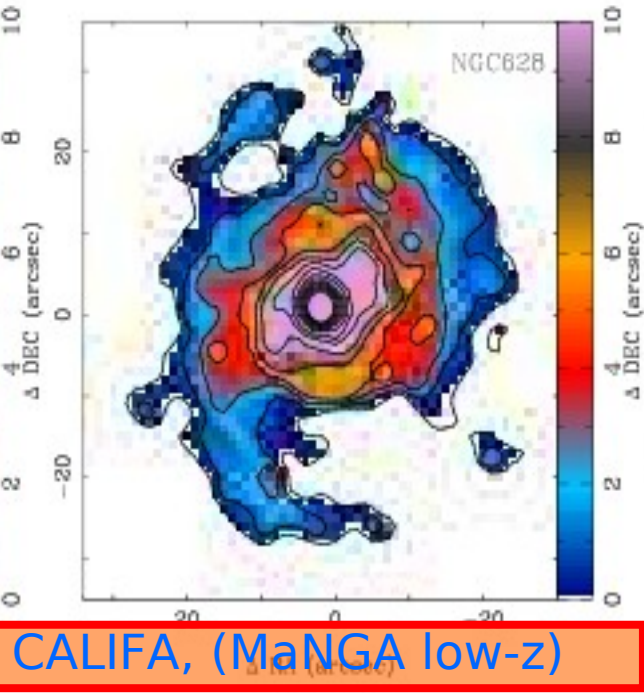
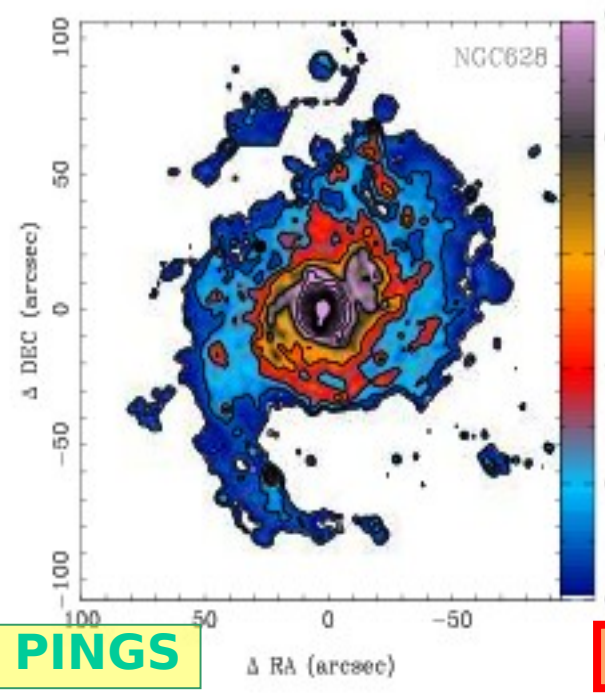




MUSE is coming: NGC6754: 400 Hii regions detected!



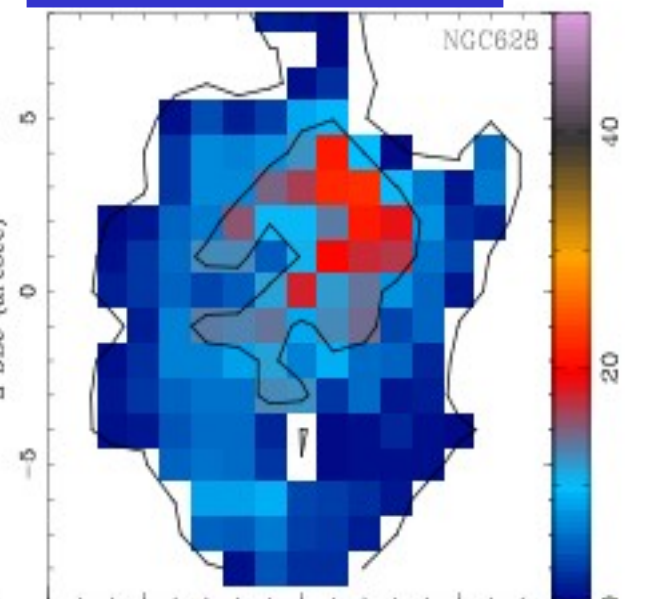
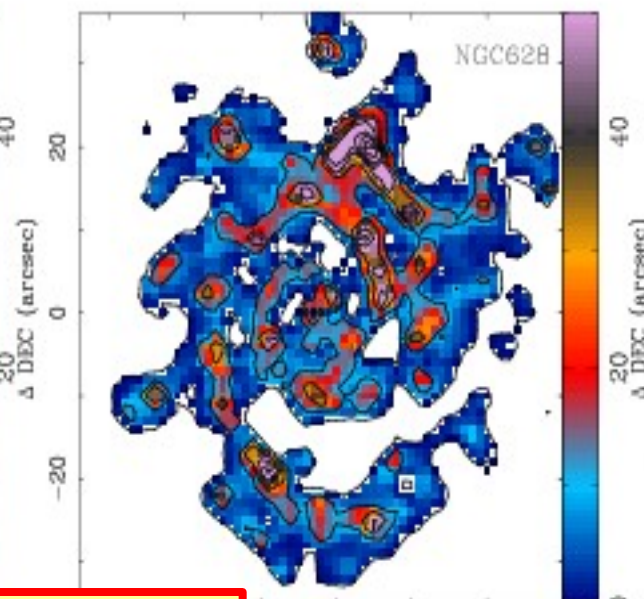
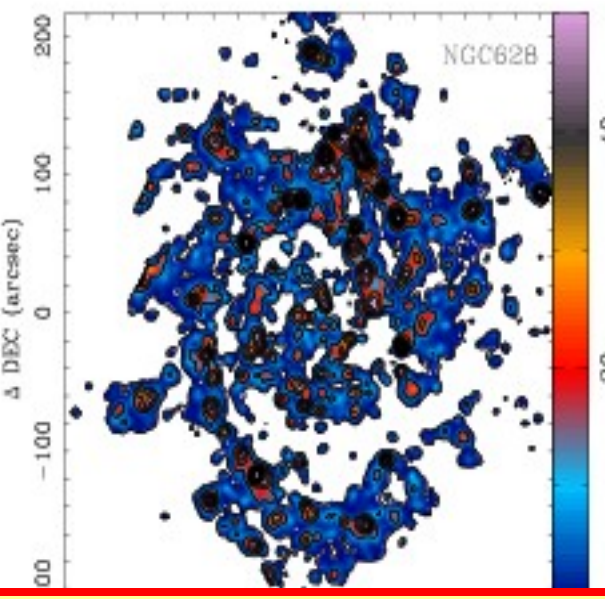
High-z



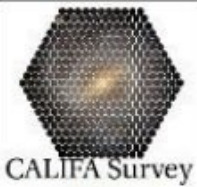
PINGs

CALIFA, (MaNGA low-z)

MaNGA (high-z)
SAMI.



Better spatial resolution

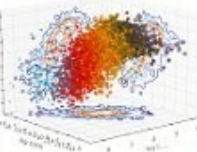


CALIFA Survey



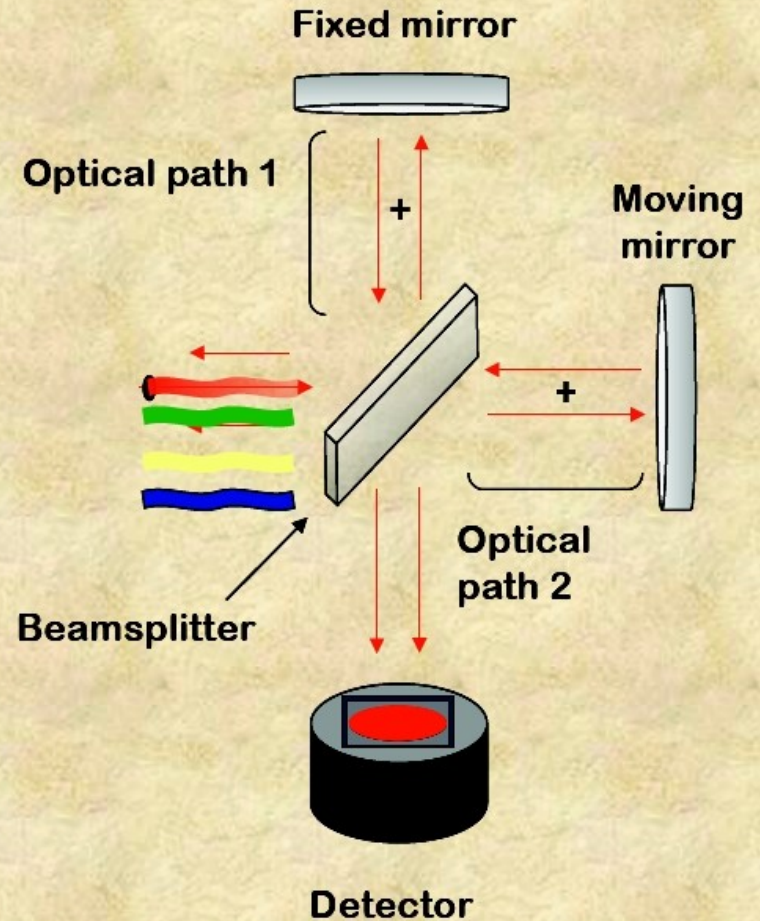
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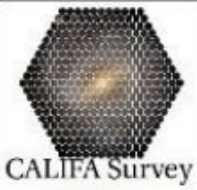
UNAM



WIDE FIELD IFUs: IFTS

IFTs (Imaging Fourier Transform Spectrometer) based on the Michelson interferometry. The result of an exposure is a data cube in the 3-D space (R.A., Dec., OPD).



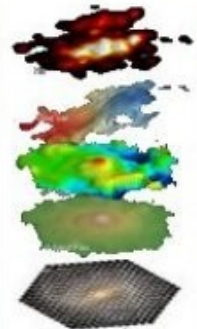
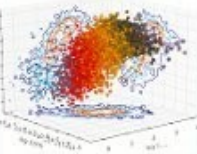


CALIFA Survey



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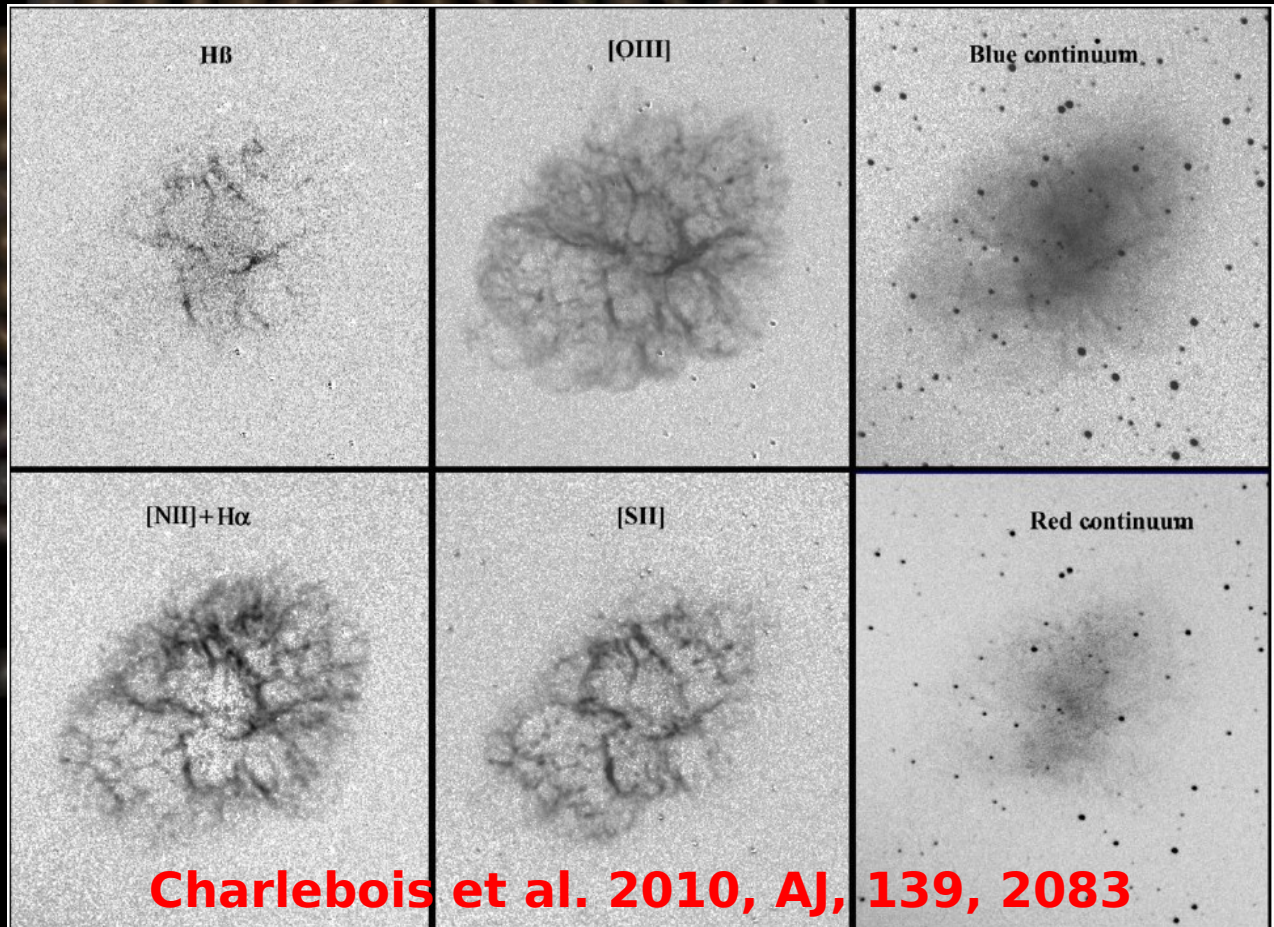
UNAM



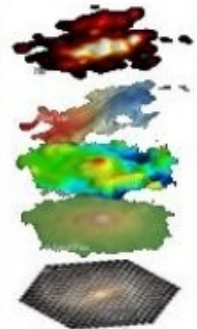
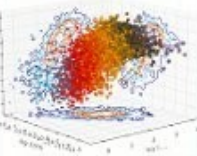
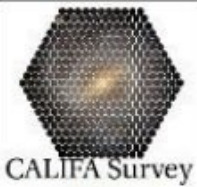
WIDE FIELD IFUs: IFTS

Example: the Crab nebula seen in 3D with SpIOMM (at 1.5m telescope Mont Mégantic, 11'x11' field-of-view).

Soon SITELLE at CFHT!



Charlebois et al. 2010, AJ, 139, 2083



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