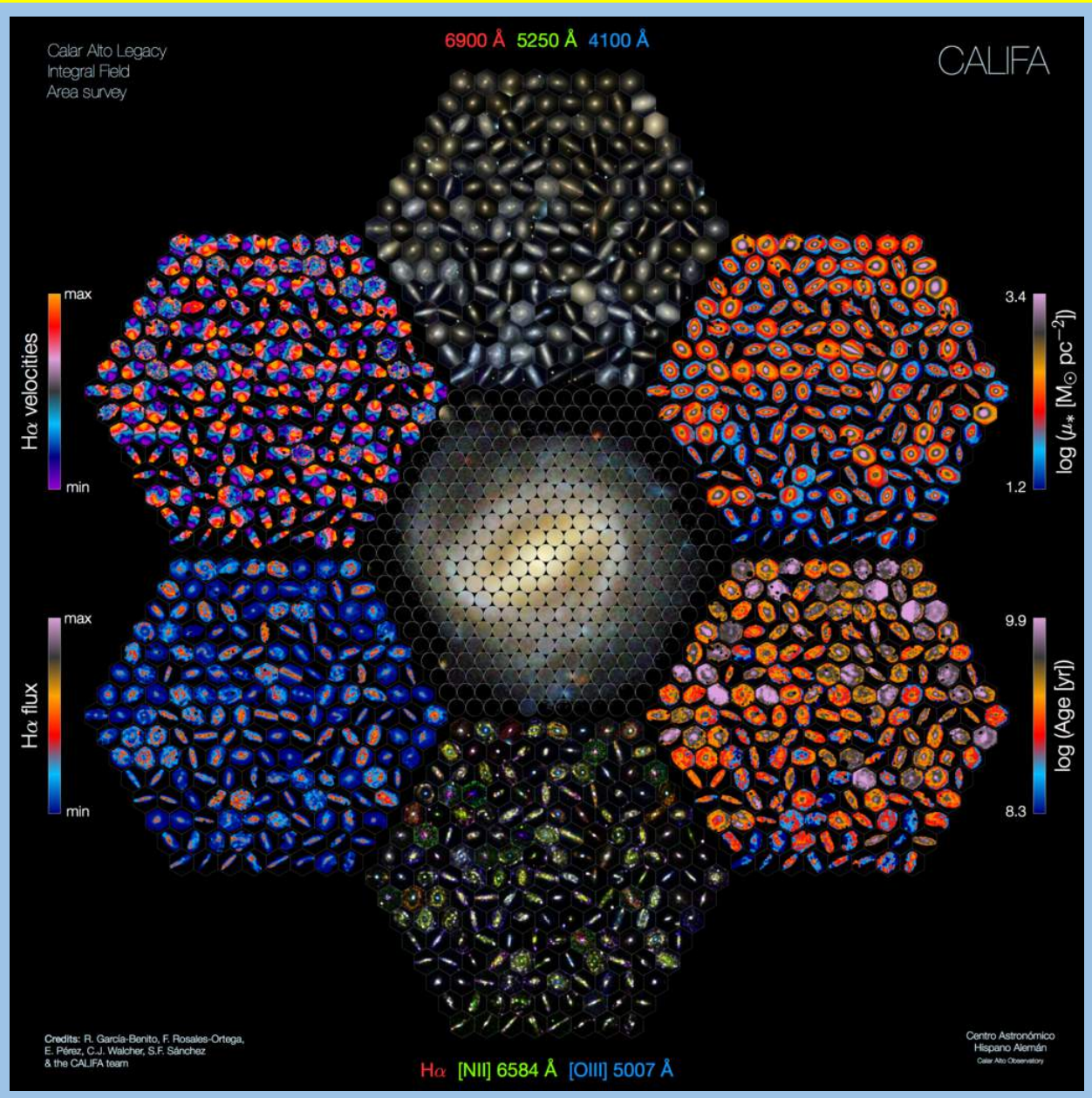
# IFU Galaxy Surveys, Now and Then - From CALIFA towards E-ELT/MOSAIC





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Christian Maier

Jose M. Perez

Ulrike Kuchner

Victor Marian

Lucas Ellmeier

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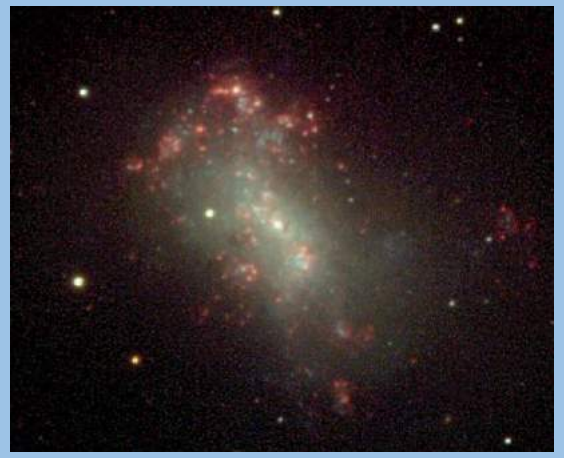
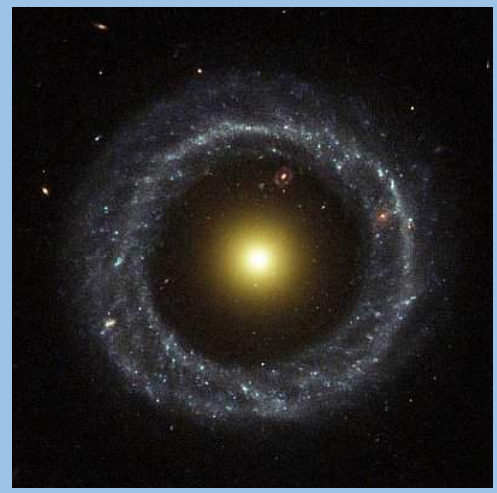
Helmut Dannerbauer (IAC)

# Realm of Galaxies



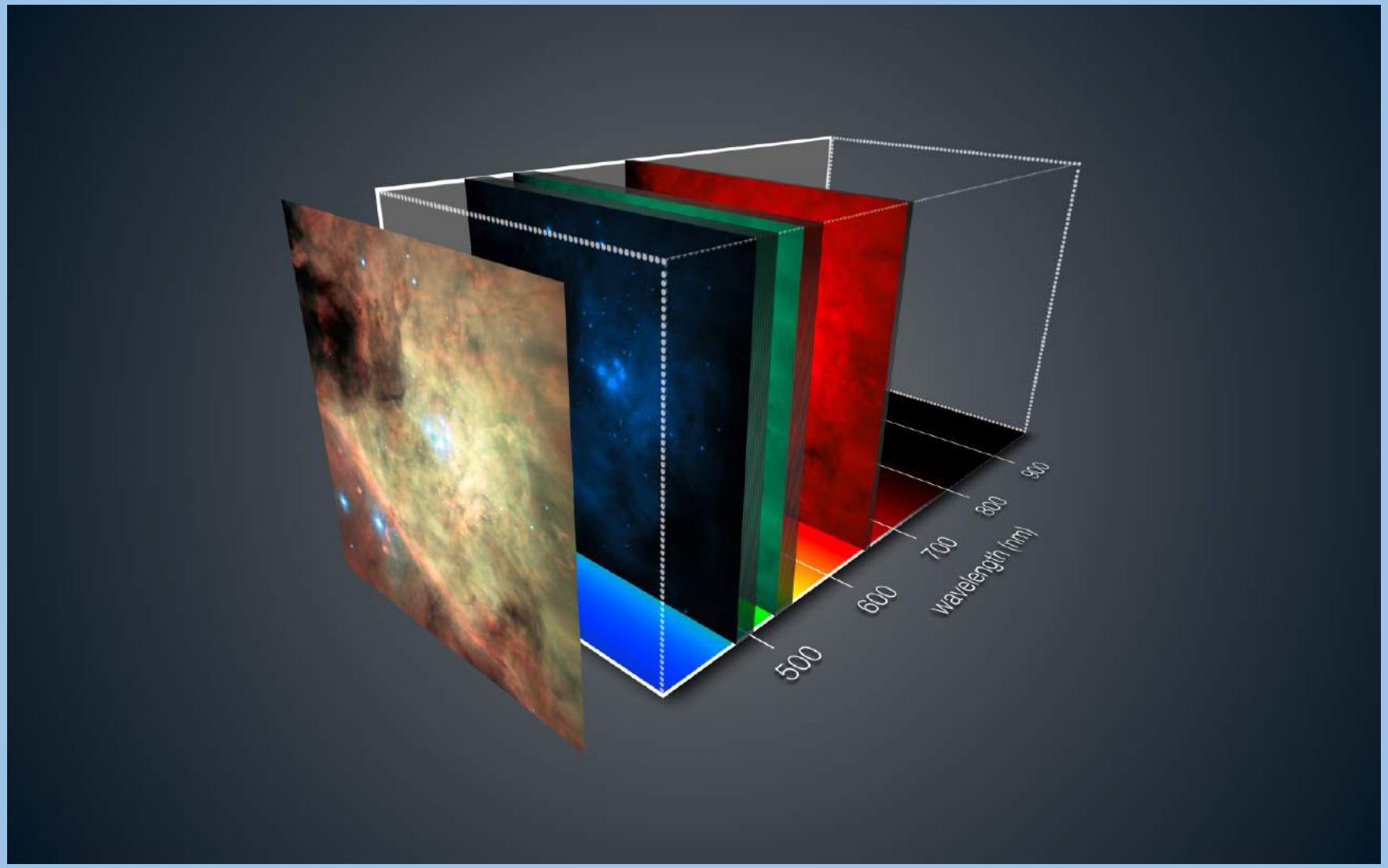





# Physics of Galaxies

- What is the total mass of a galaxy?
- Which are the physical components?
- How do stars and gas clouds orbit within a galaxy (kinematics)?
- How old are galaxies? How do they form? evolve?
- What kind of stellar populations do they have?
- What is the star formation rate at different cosmic epochs?
- What is the role of Black Holes / AGN?
- etc

# 3D Spectroscopy

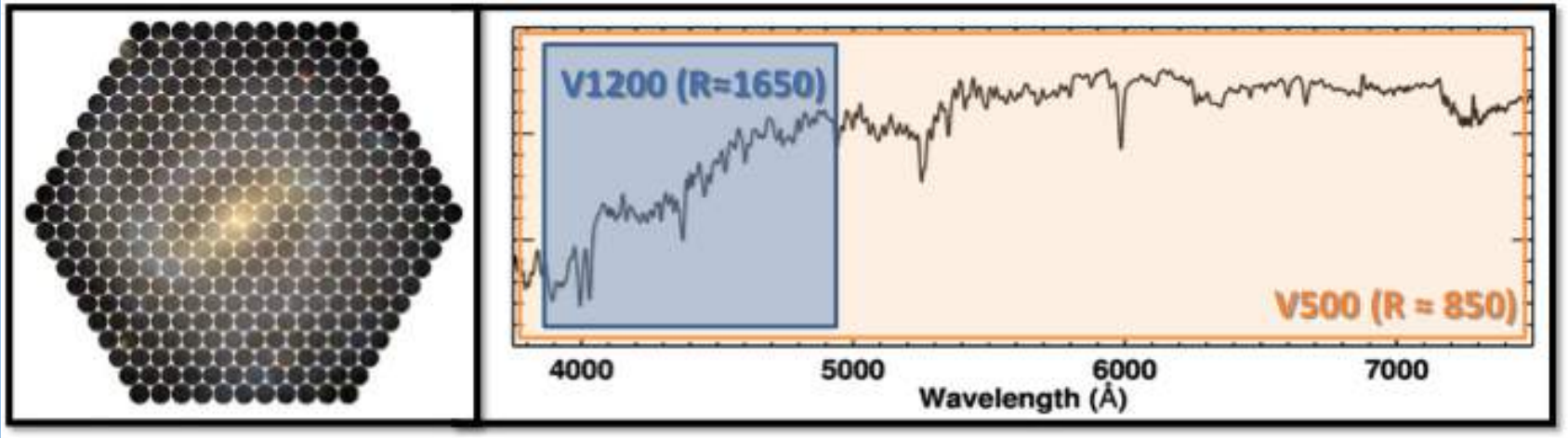


# CALIFA 3D Survey www.caha.es/CALIFA

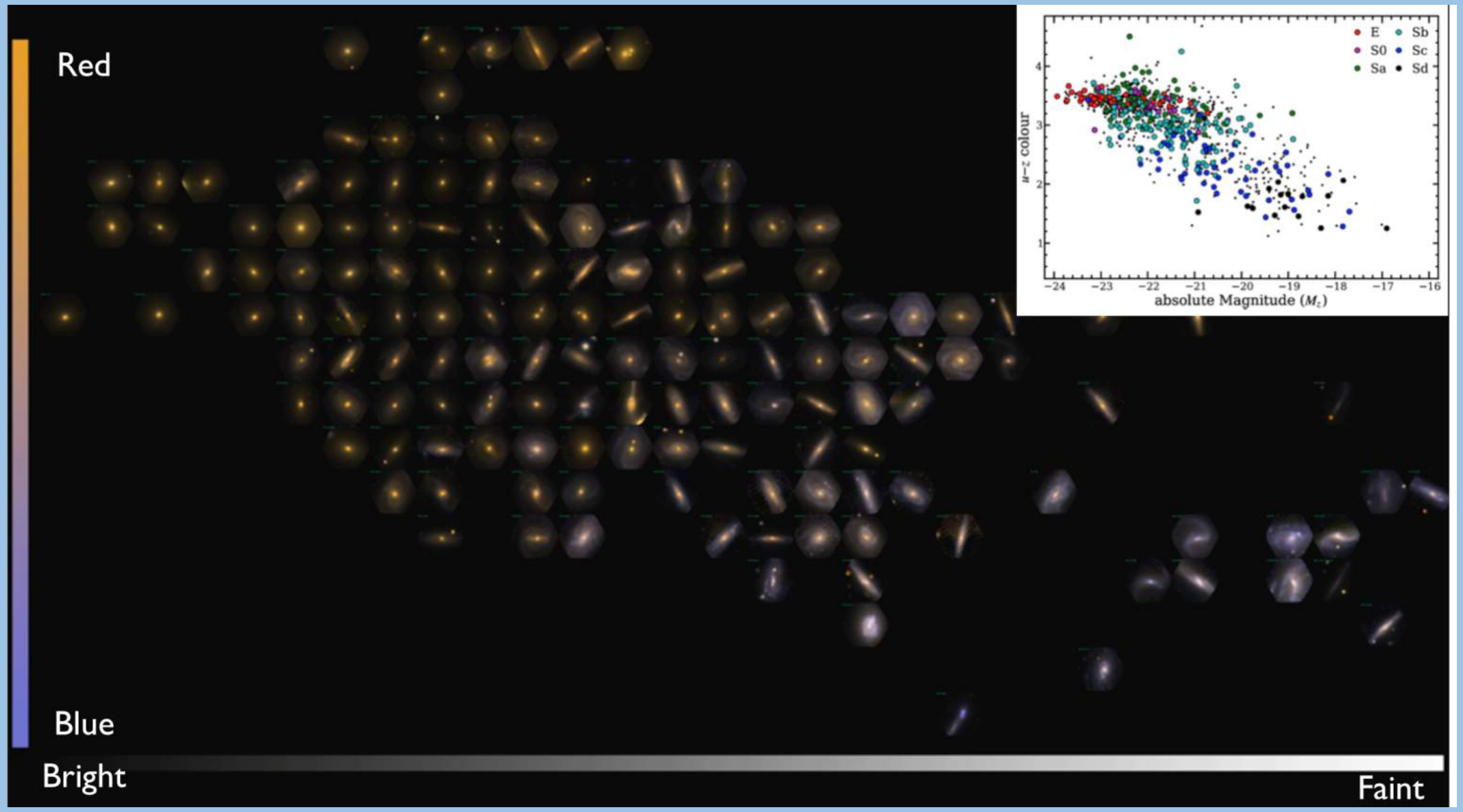
- 3D spectroscopy with PPAK/PMAS at 3.5m-T. CAHA
- ~300 (dark) nights across 3.5 years
- ~80 scientists of ~20 institutes in 7 countries
- PI: S. Sanchez (UNAM), PS: C.J. Walcher (AIP)
- **667 galaxies in local Universe** (*0.005 < z < 0.03*)
- **All Hubble galaxy types**
- 3 Public Data Releases

# CALIFA IFU spectroscopy

- Large Field-of-View: 74“ x 64“ ➡ 1.8-3.7 $R_{1/2}$
- Good spatial resolution: ~1kpc
- Large wavelength coverage: V500: R~850 370nm<λ<730nm
  V1200: R~1650 340nm<λ<475nm
- Selected by apparent size
- Fair representative mother sample from SDSS
- Volume corrections & Cosmic variance corrections

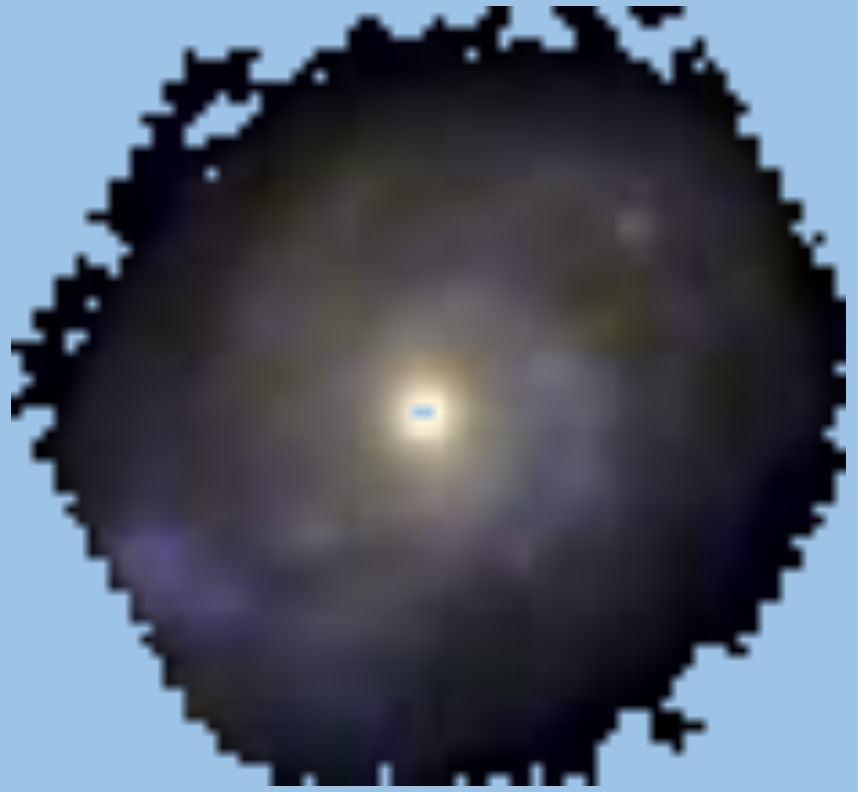


# CALIFA: Color-Magnitude Diagramm

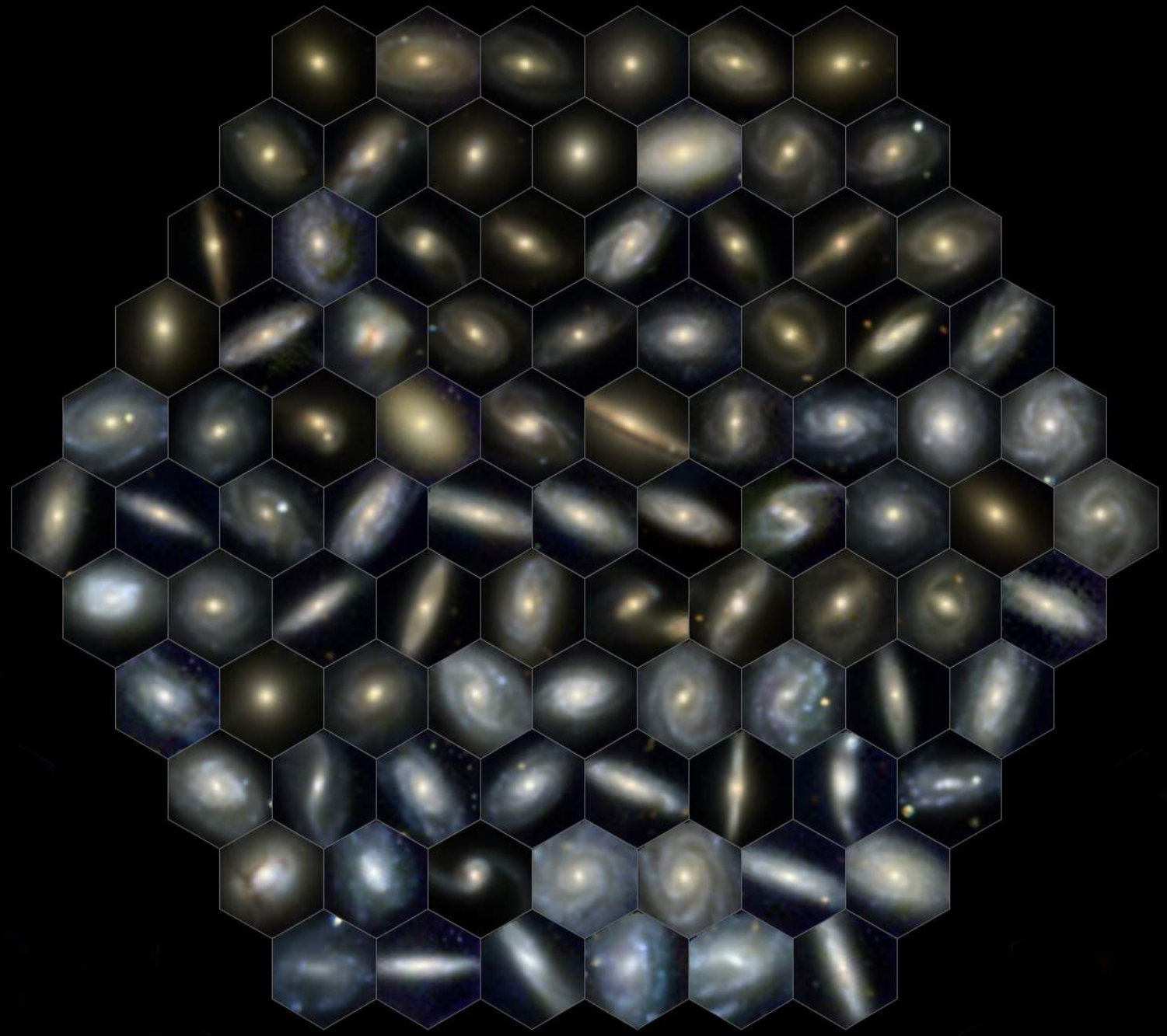


# “Our prototype”: Spiral galaxy NGC2253

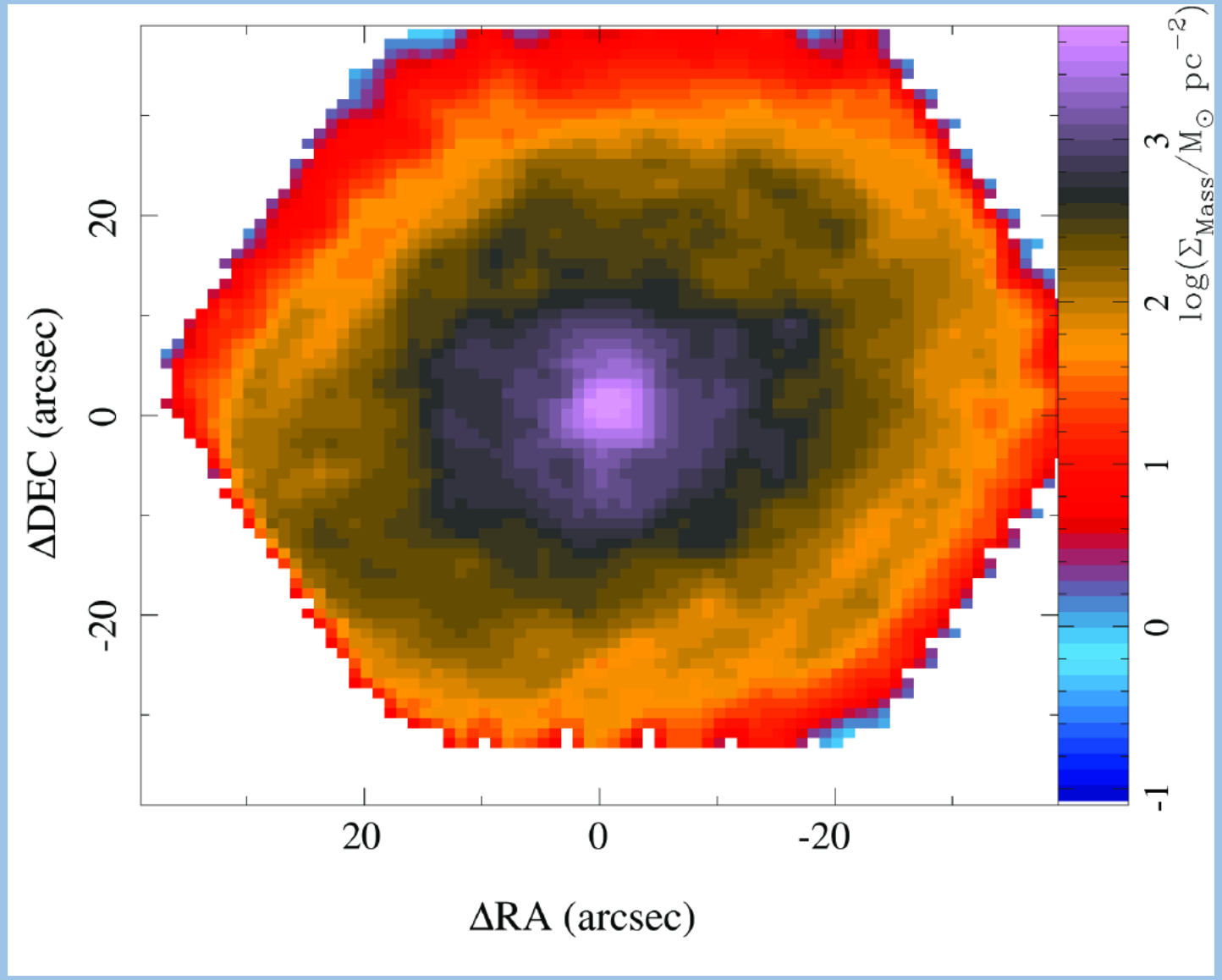
SDSS Image

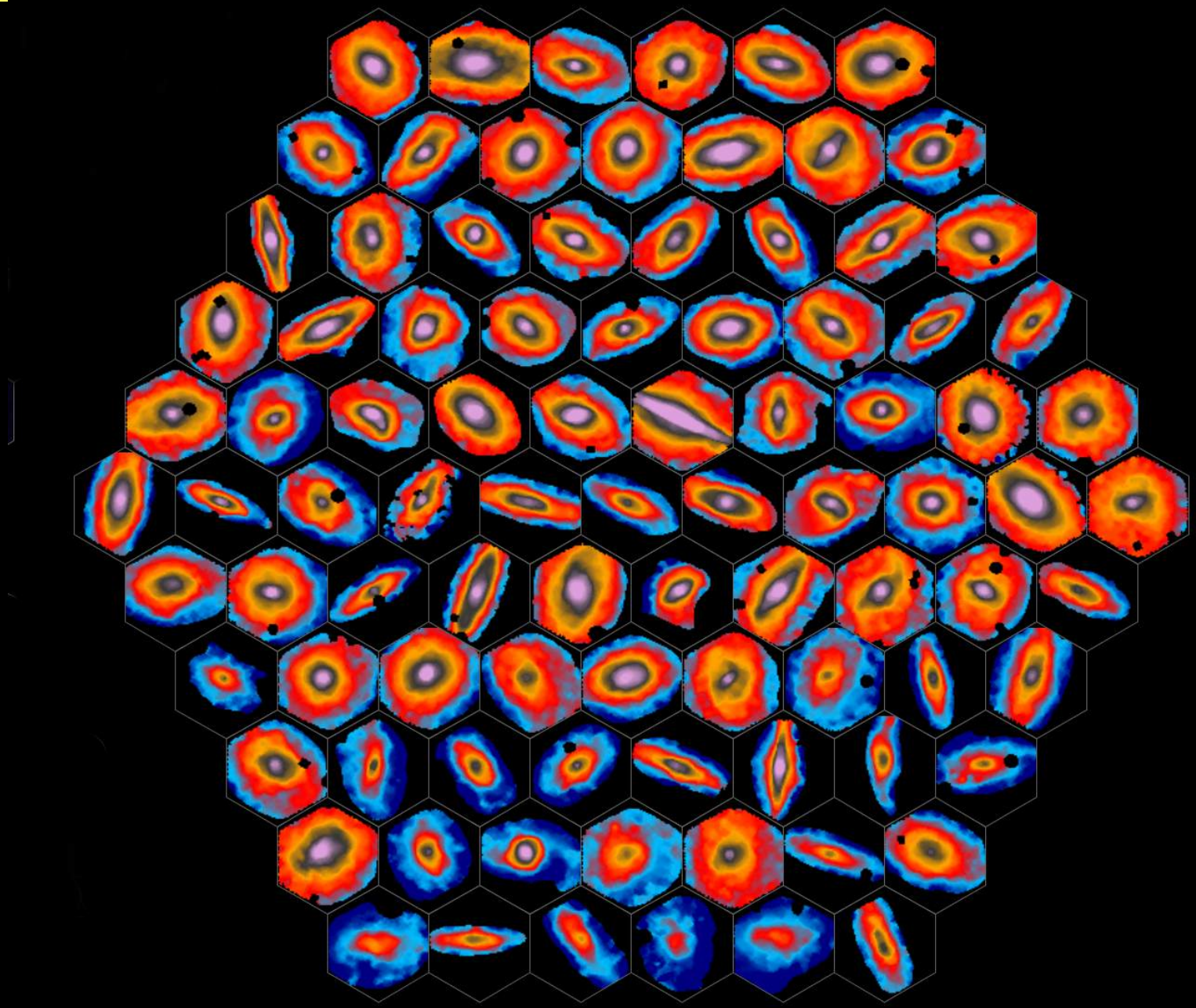


CALIFA Reconstruction

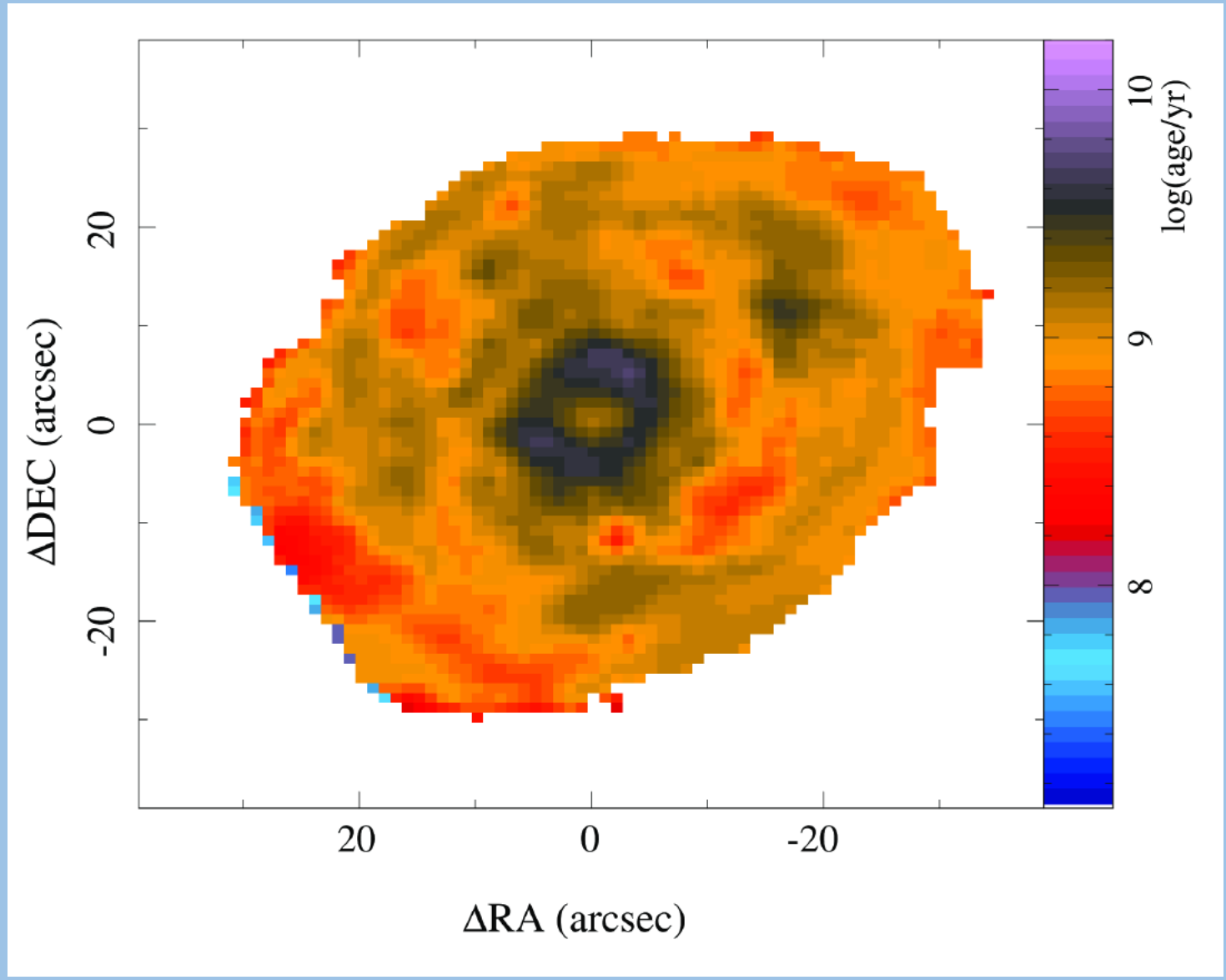


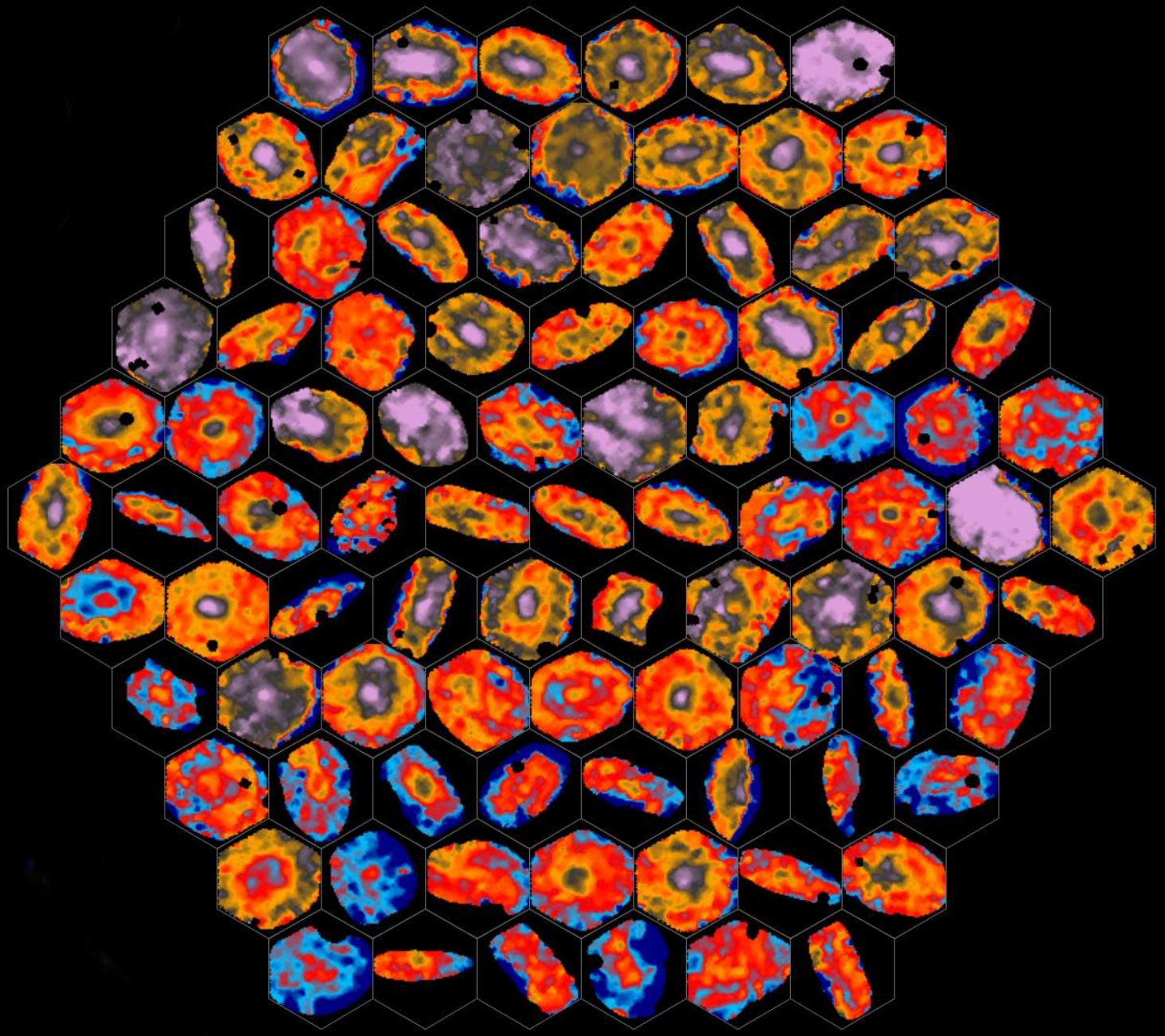
# Distribution of Stellar Mass



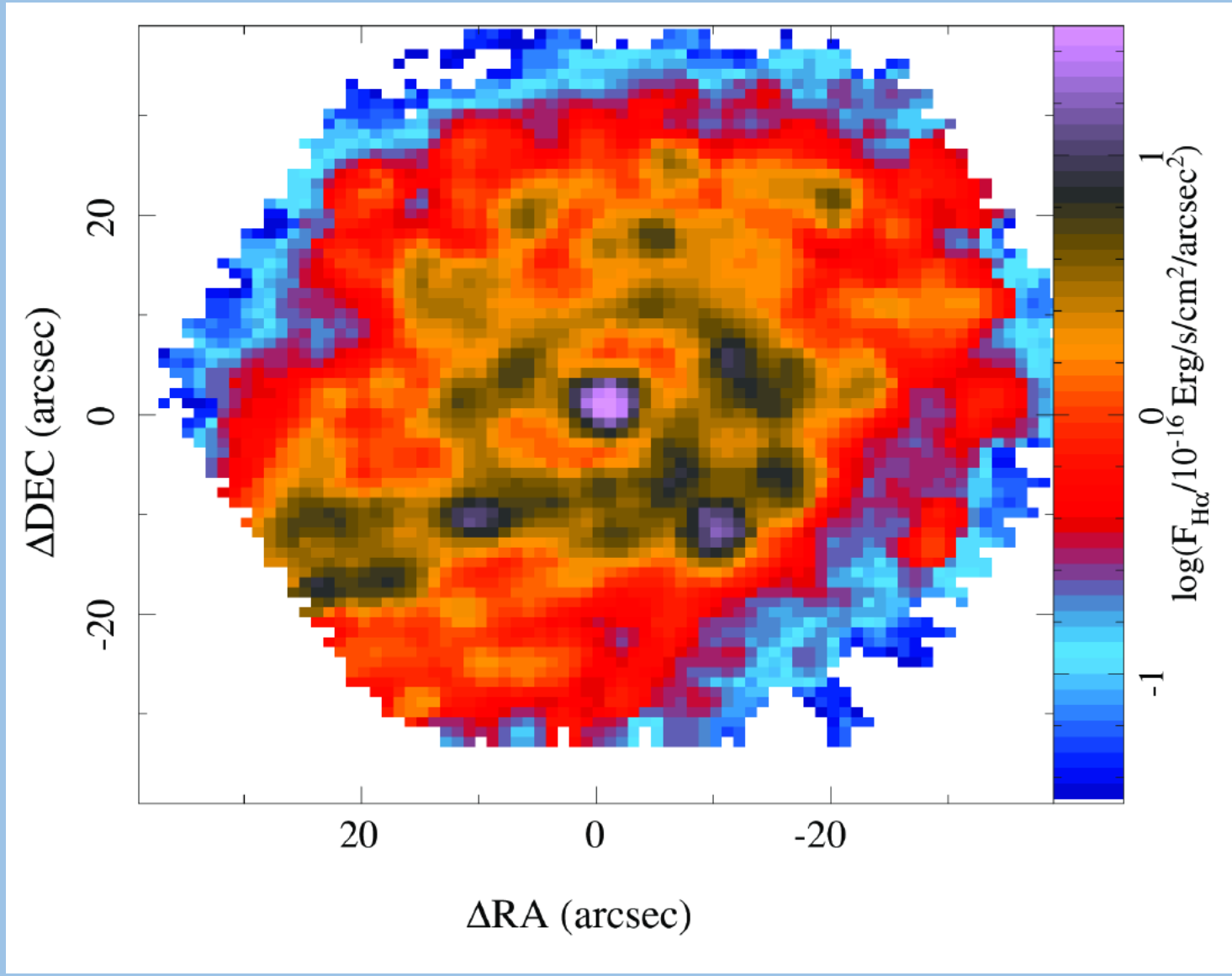


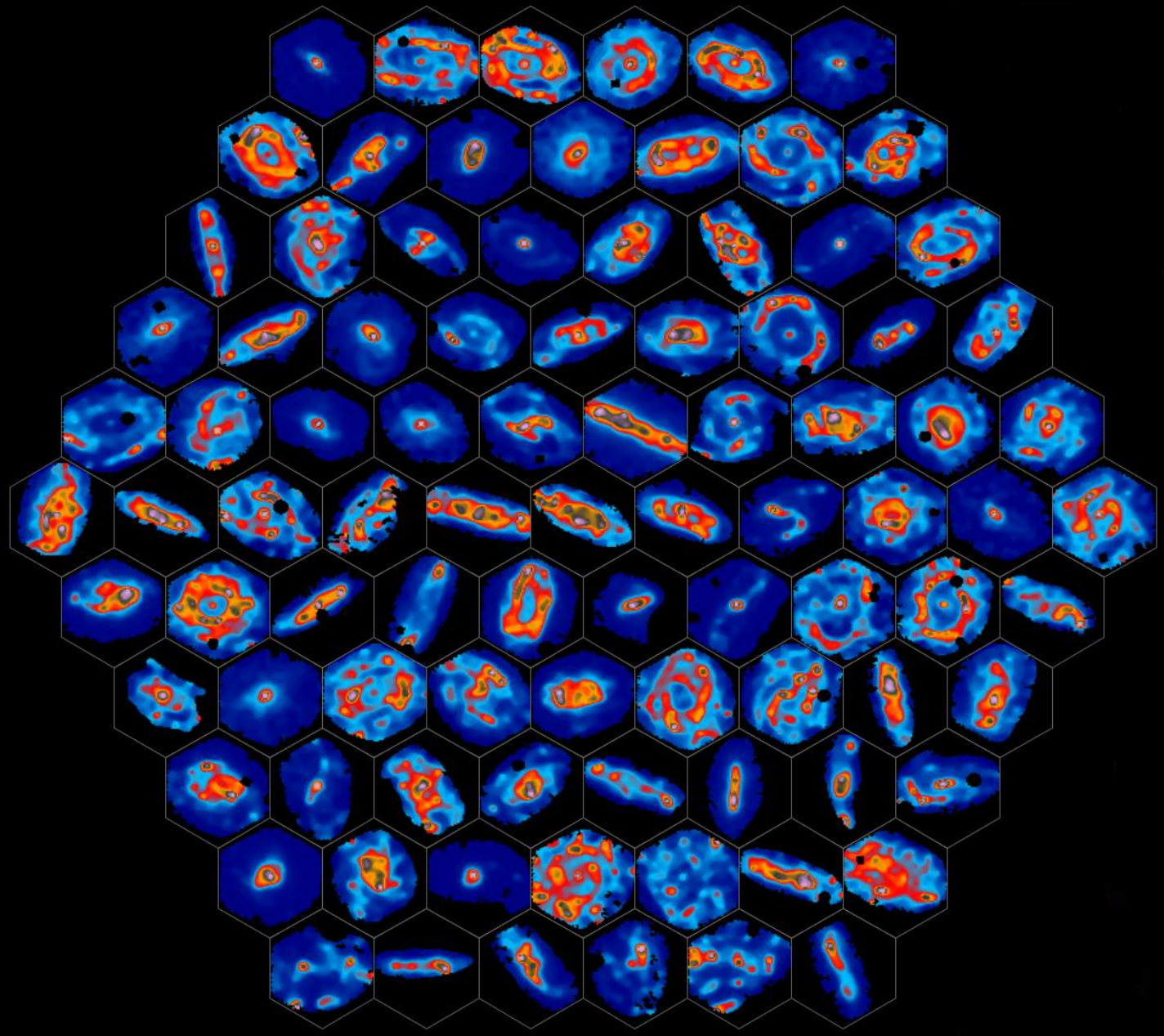
# Distribution of Stellar Ages



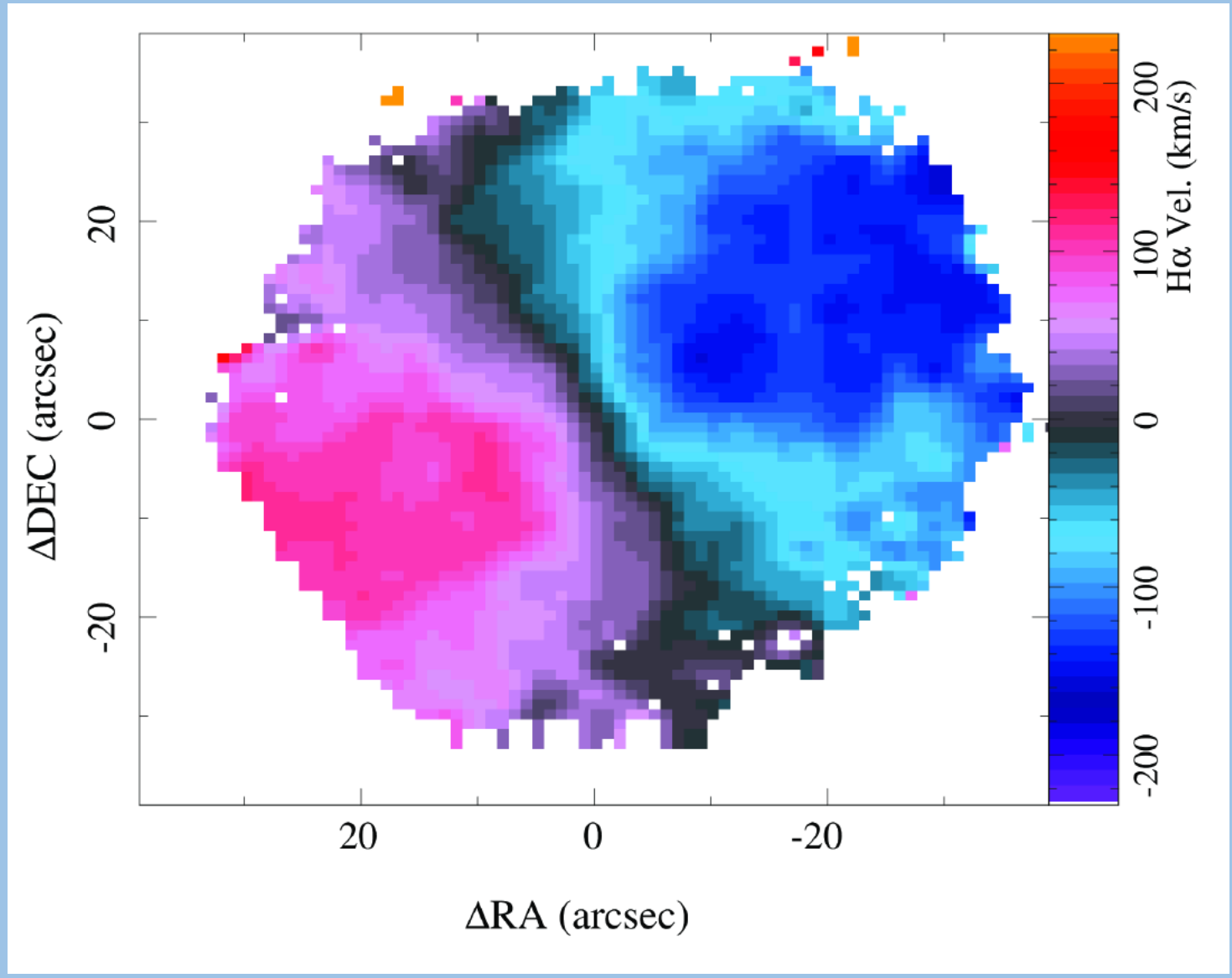


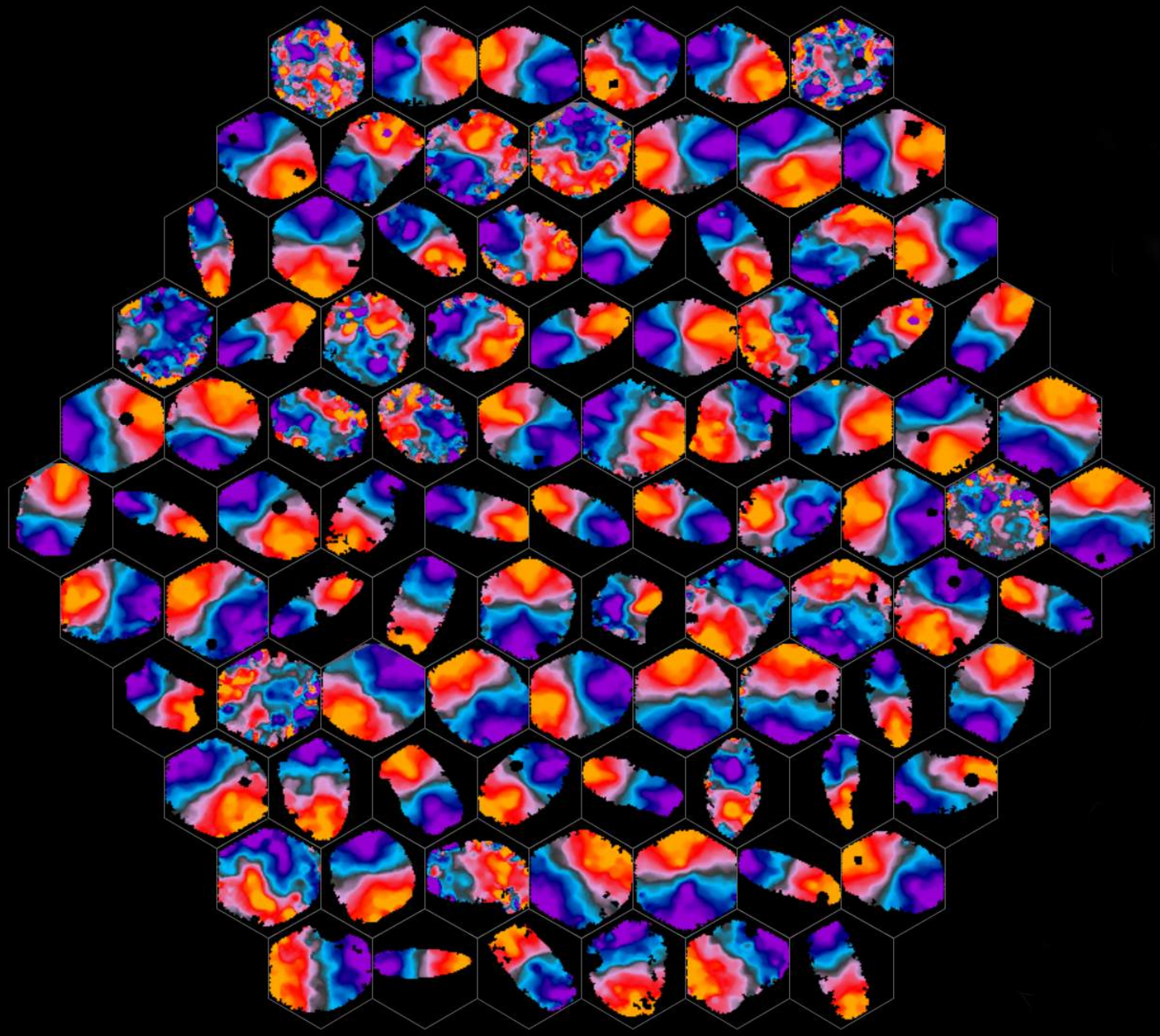
# Distribution of current Star Formation



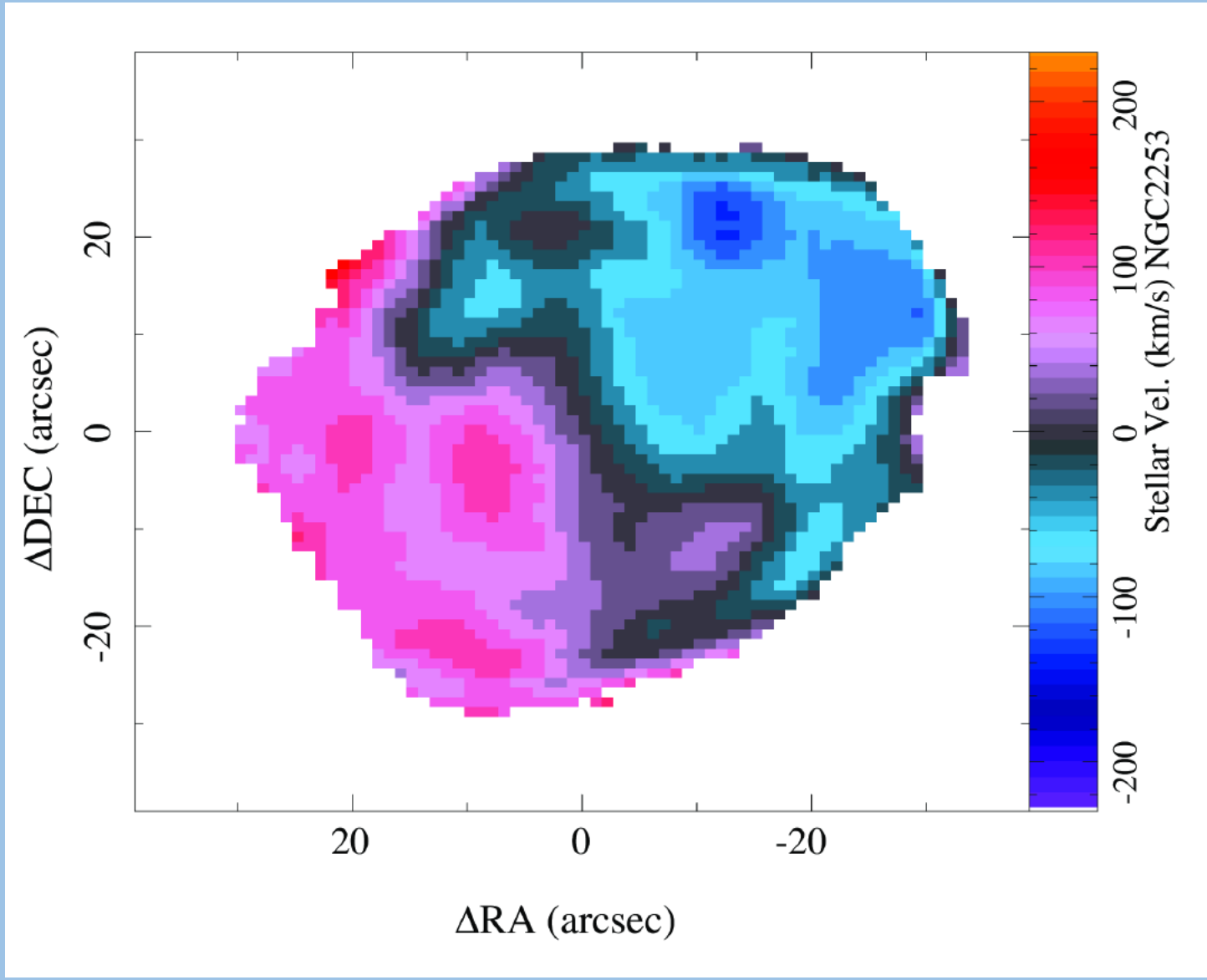


# Velocity Field of Warm Gas





# Velocity Field of Stars

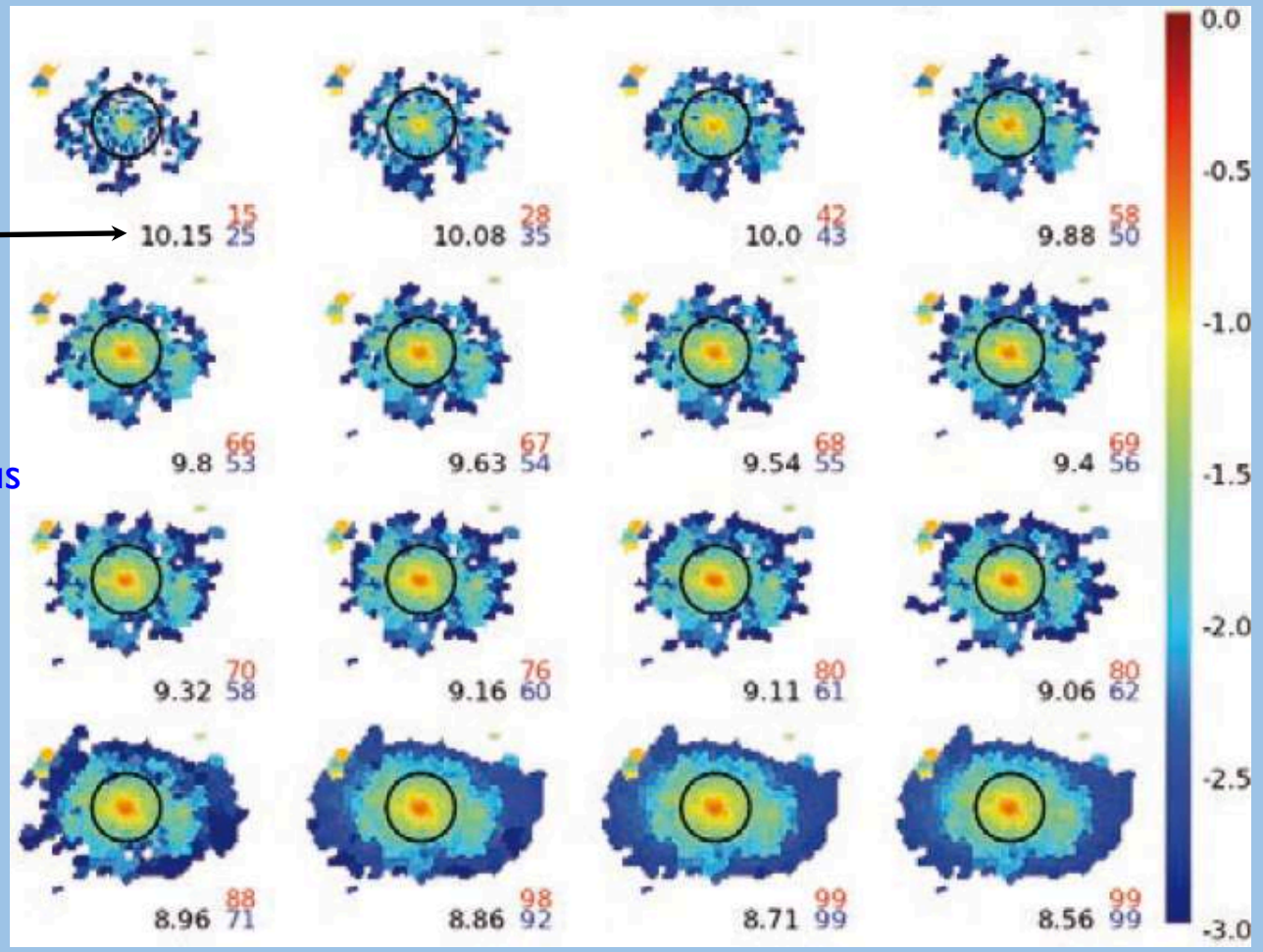


# Mass Growth

surface mass density $M_{sun}/pc^2$

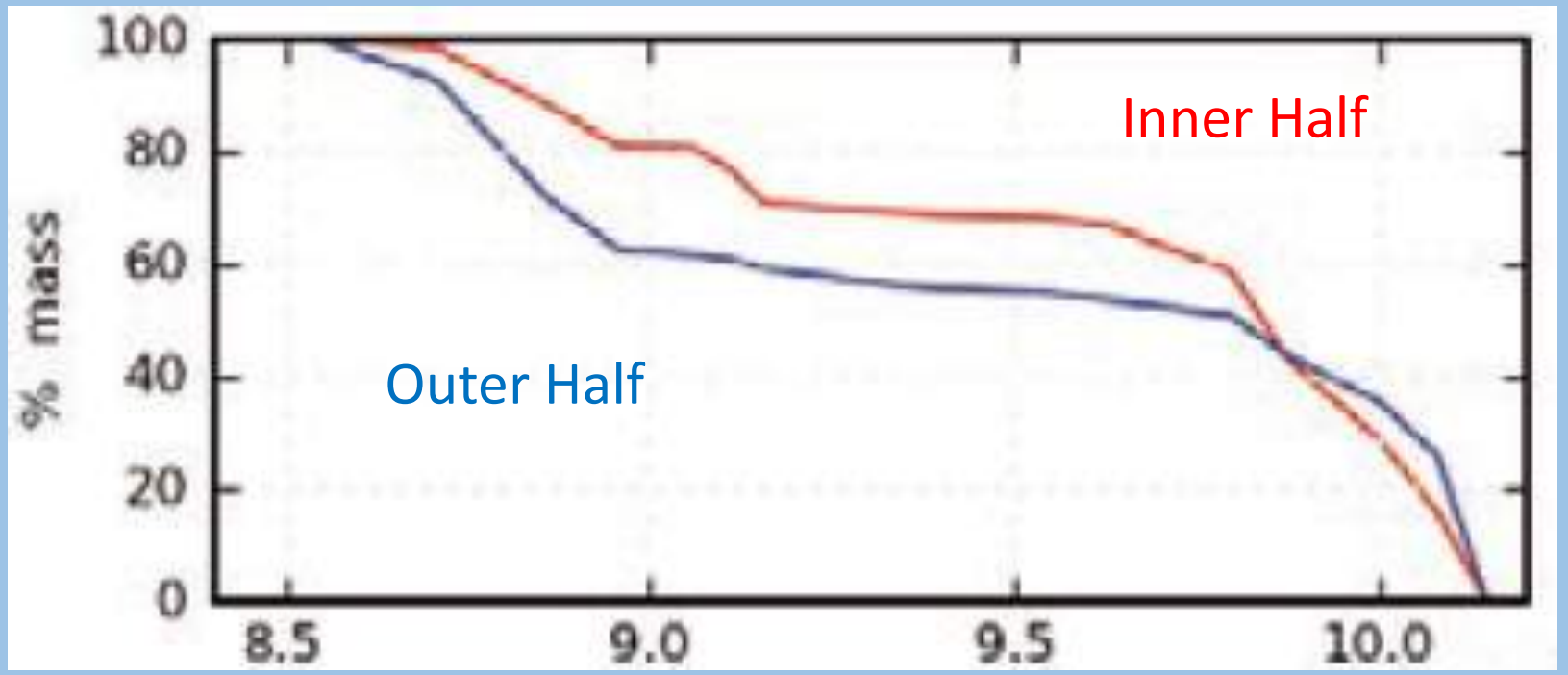
look-back time log(t/Gyr) →

inside current half-light radius
outside current half-light radius




Pérez et al. (2013)

# Mass Growth




Van de Ven

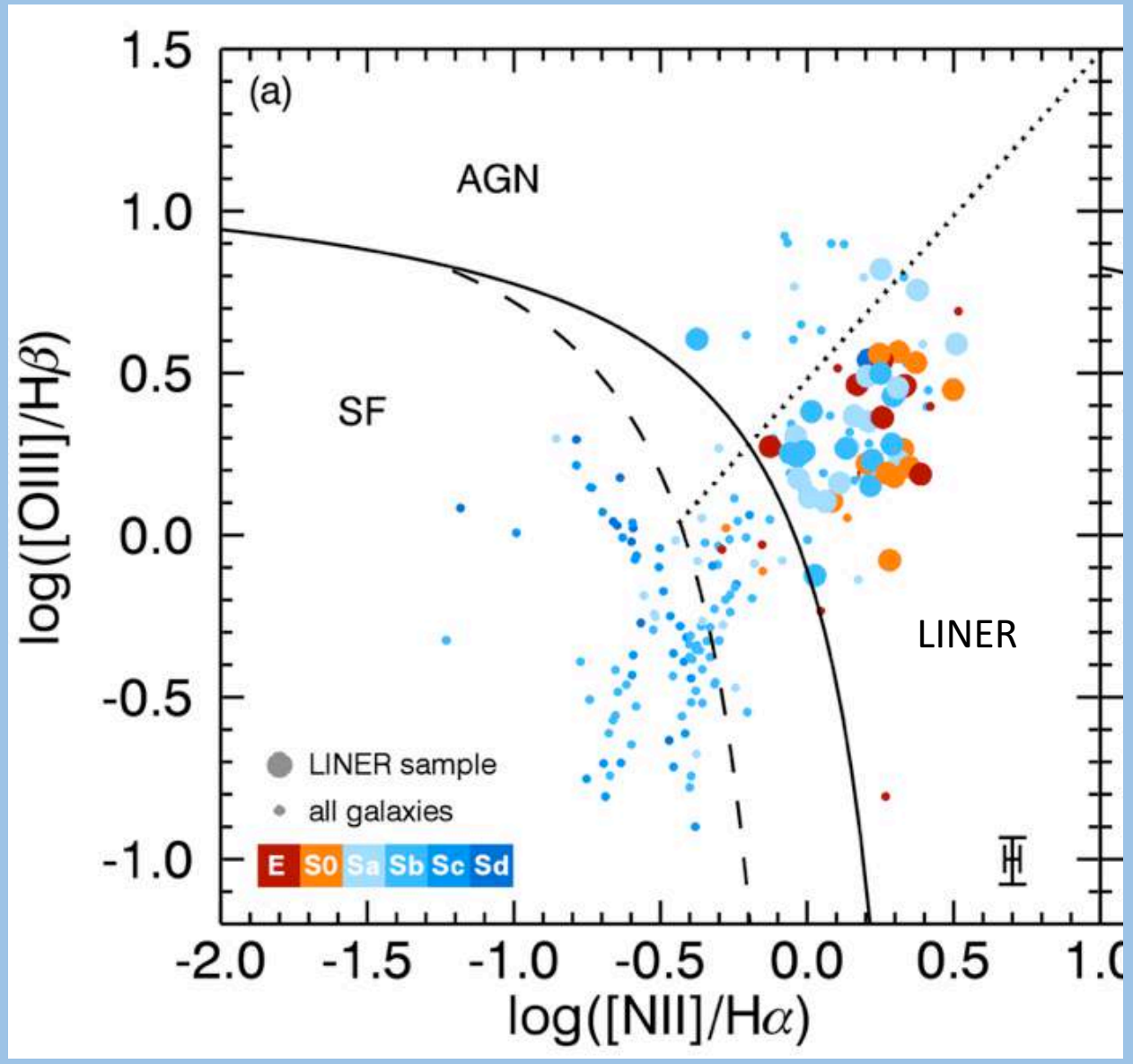
1 Gyr

10 billion years

Look-back time ->

**Inside-out Growth**

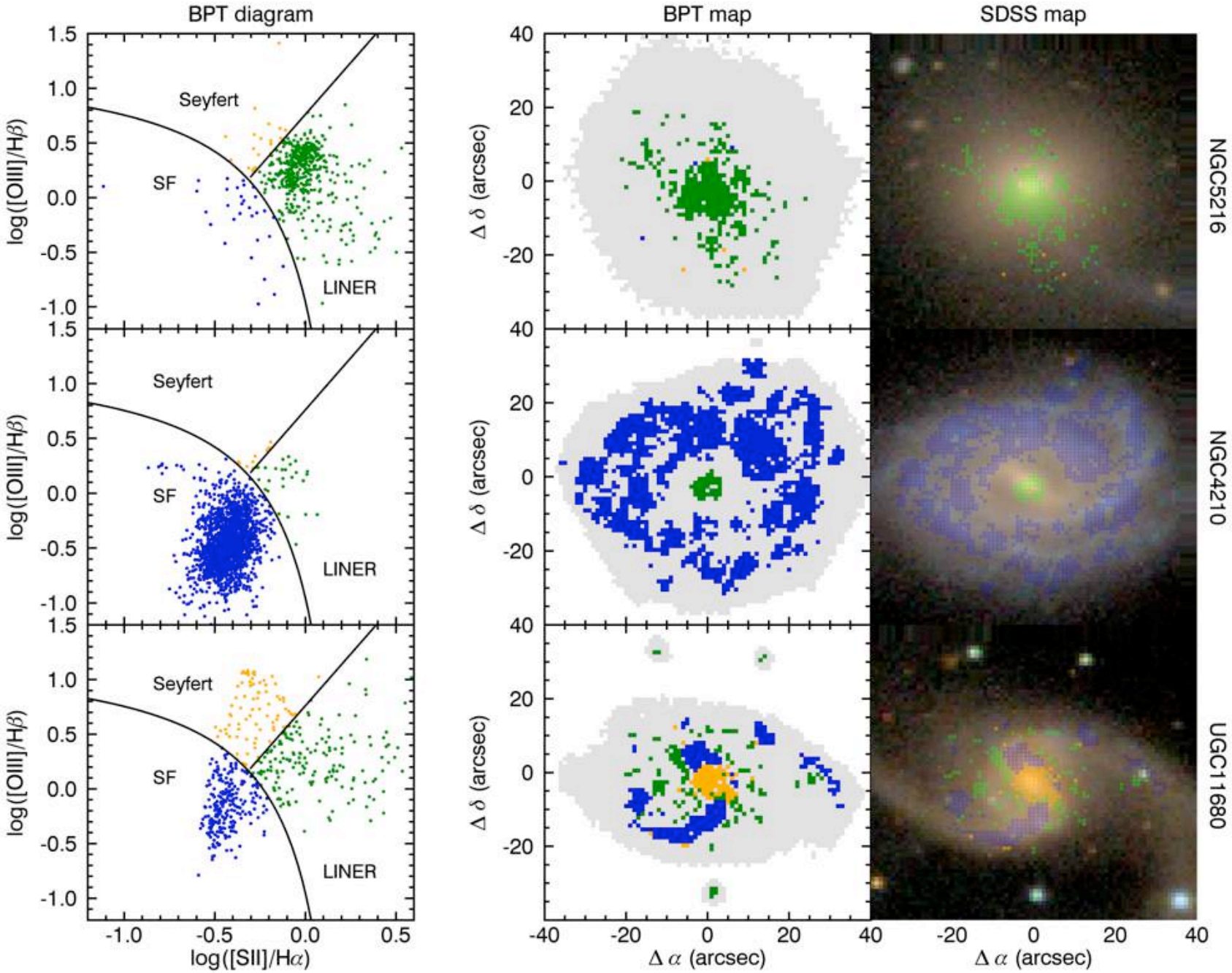
# Ionizing Sources: SF, AGN, LINER




low-ionization **nuclear** emission-line region

Singh et al. 2013

LINERs are LIERs !



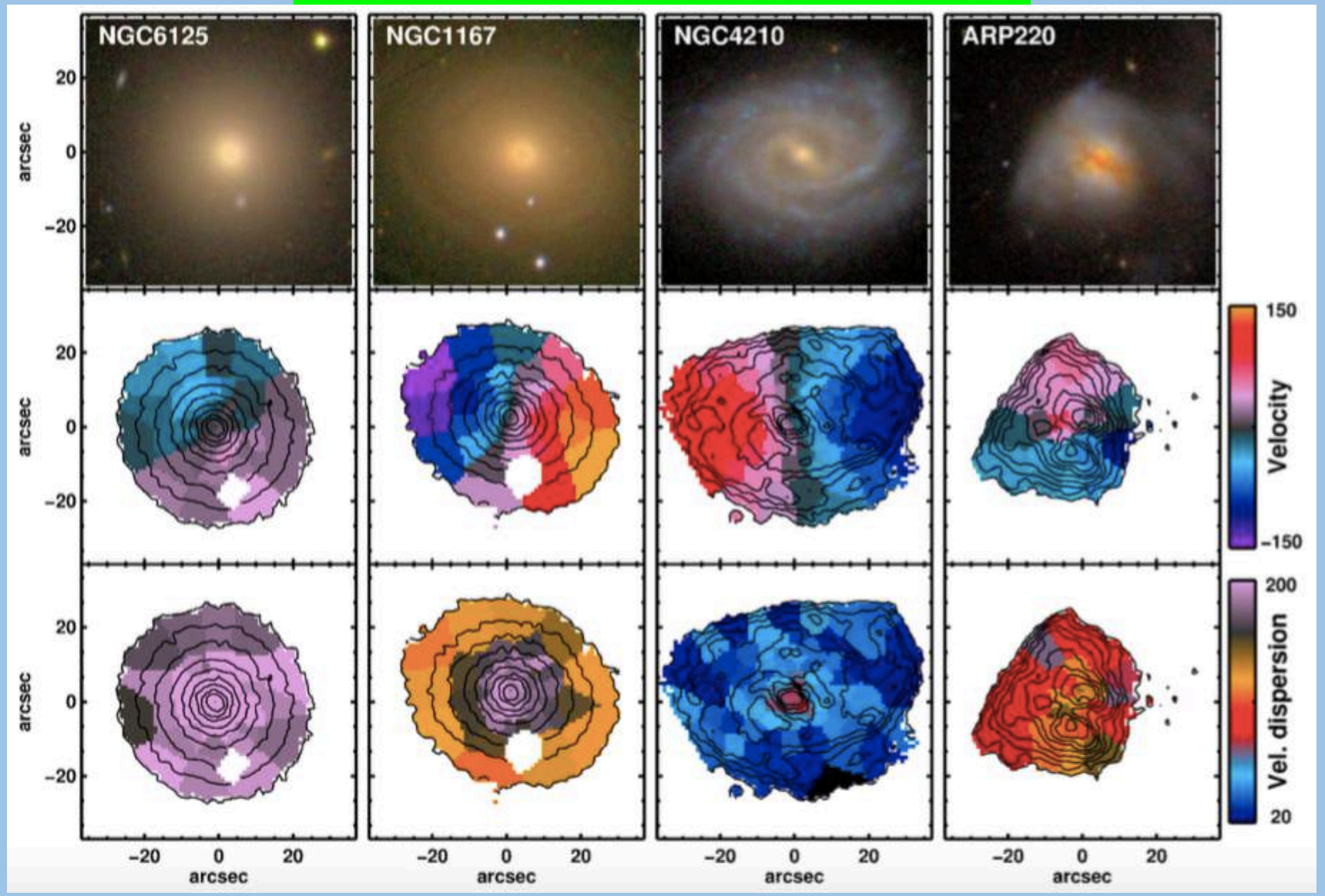

Singh et al. 2013

# Kinematics/Dynamics sub-Group in CALIFA

- Jesus Falcón-Barroso (IAC)
- Glenn van de Ven (MPIA)
- Mariya Lyubenova (Vienna)
- BZ

# Stellar Kinematics of Galaxies





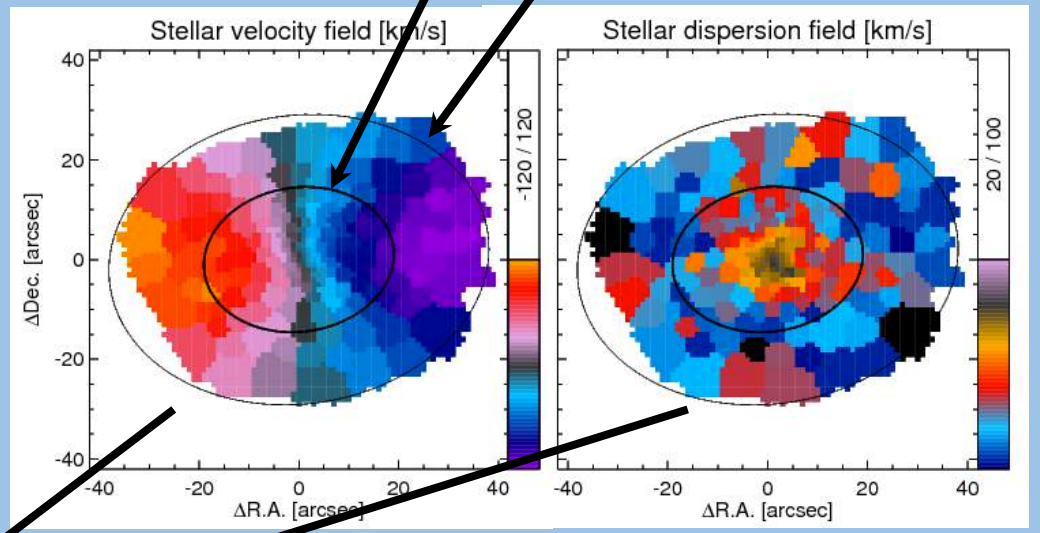

**Slow Rotator (low V, high σ)** | **Bulge + Disk (high V, high σ)** | **Pure disk (high V, low σ)** | **Interacting (e.g. ARP220)**

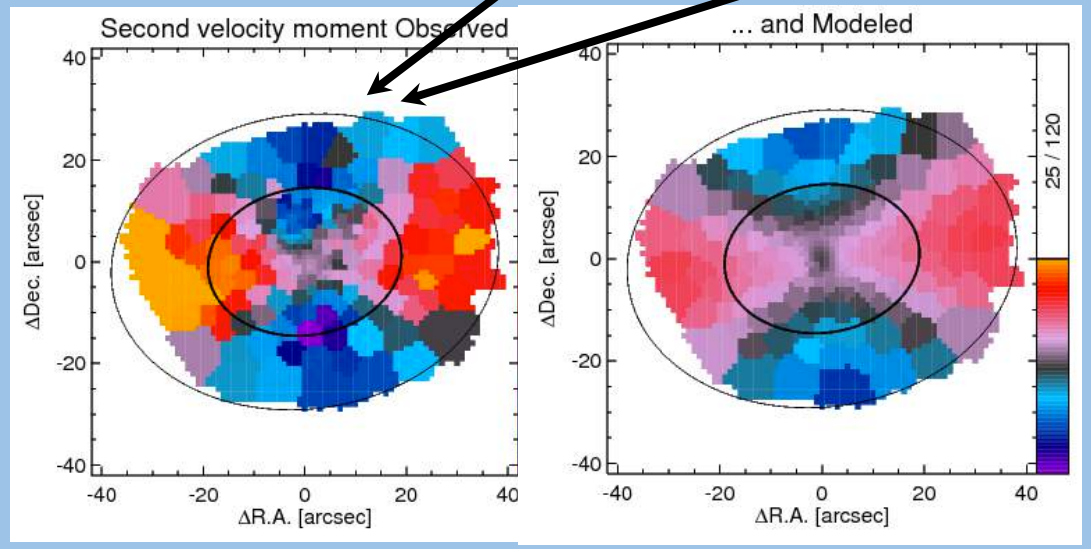
Falcón-Barroso+16

# Total Mass Distribution

1 and 2 $R_{eff}$

NGC4210




Jeans &
Schwarzschild
dynamical models

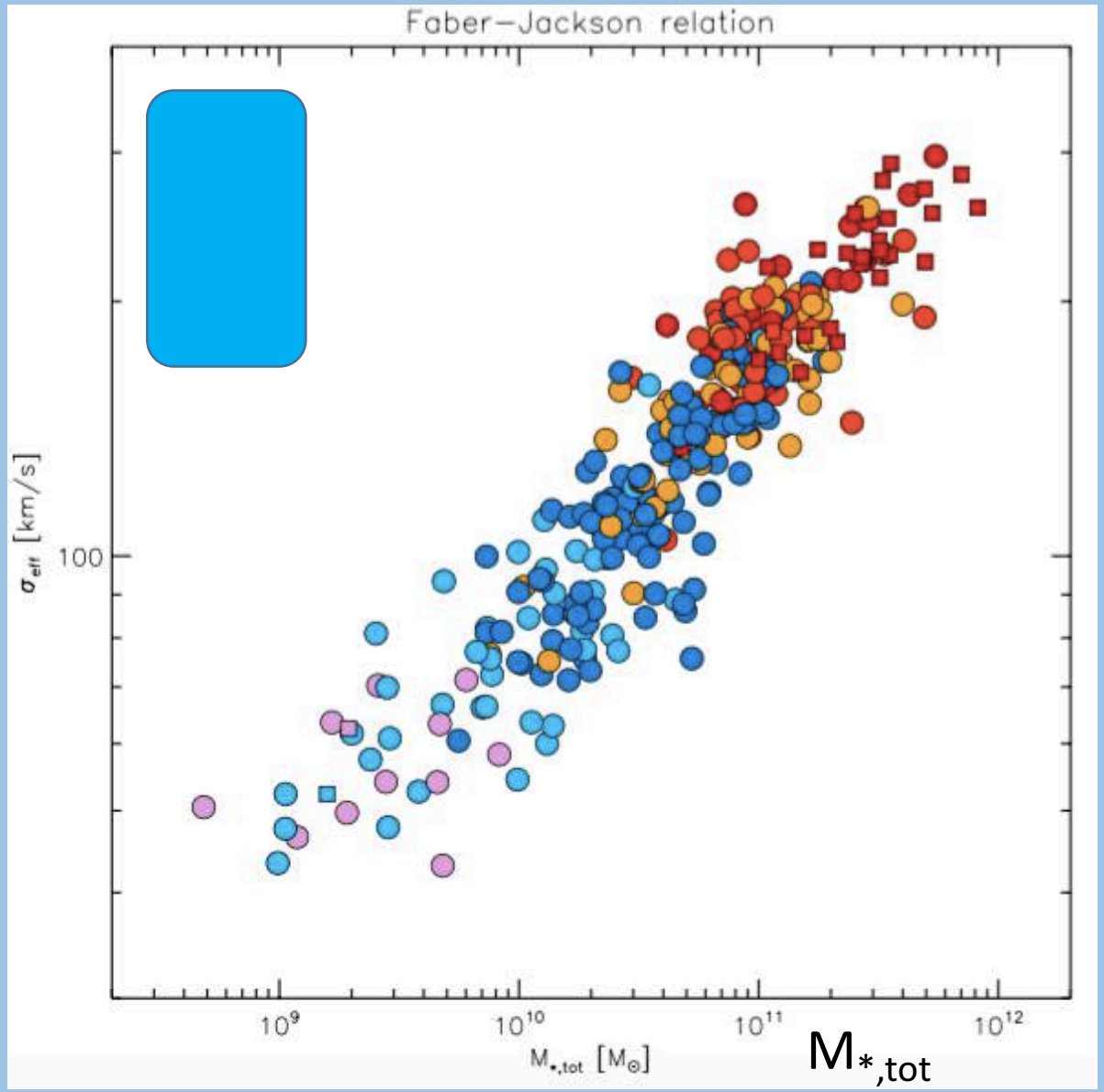
$M_{tot}(<R)$

Lyubenova+16

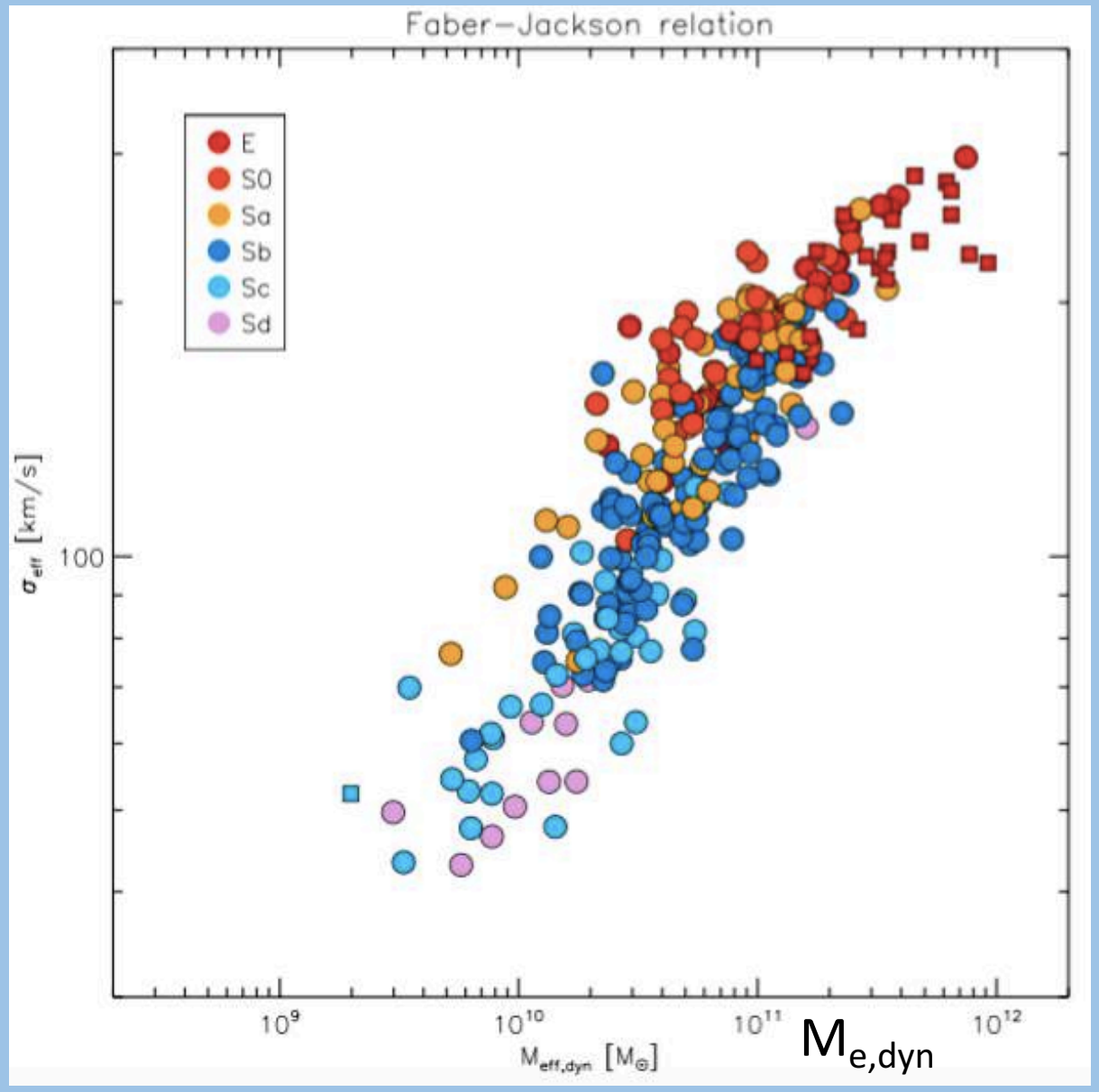
# BZ: Scaling Relations

- Faber – Jackson relation
- Fundamental Plane
- Tully - Fisher relation
- Mass – Size relation
- Mass – sSFR relation

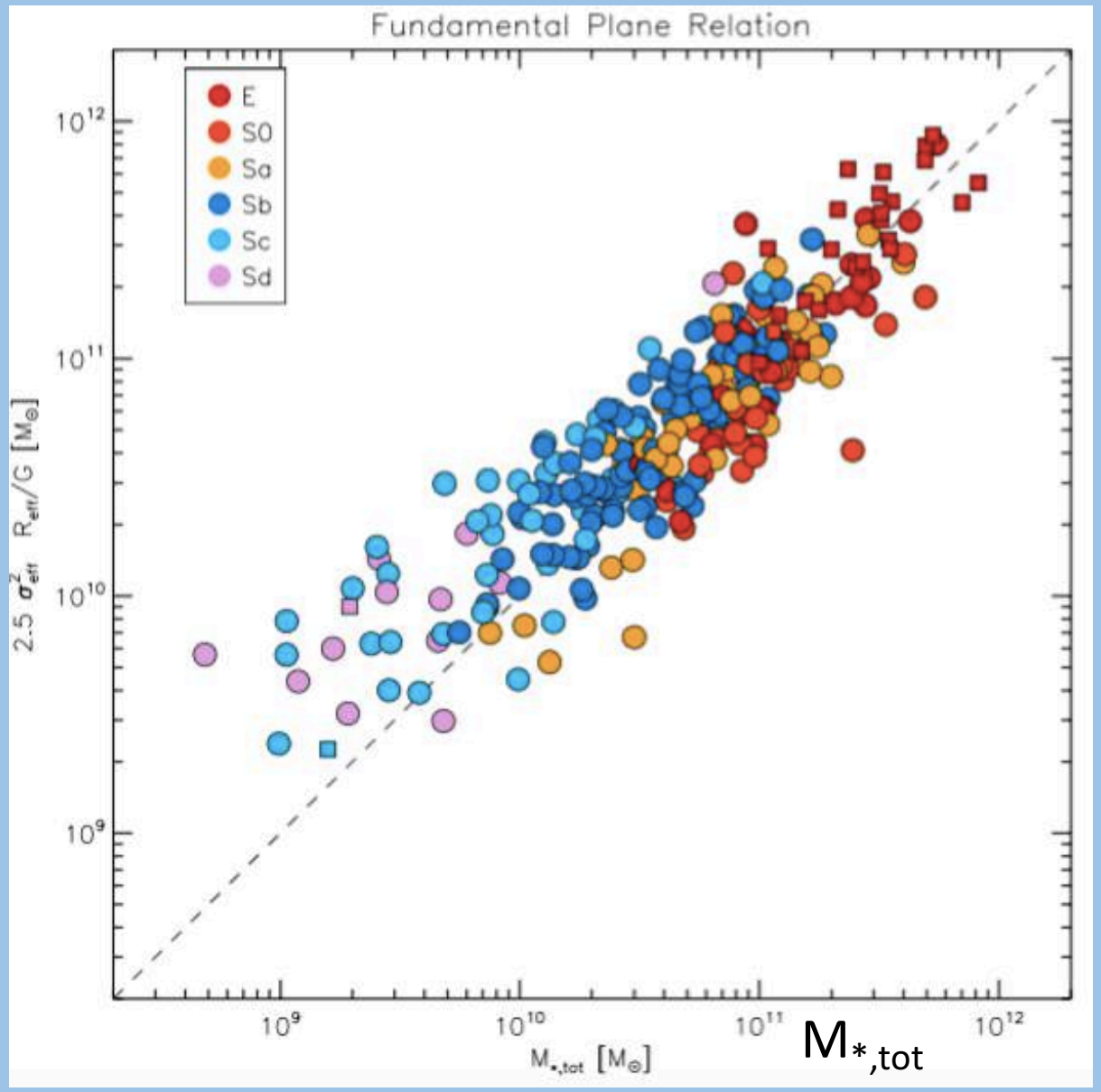
# Faber-Jackson Relation



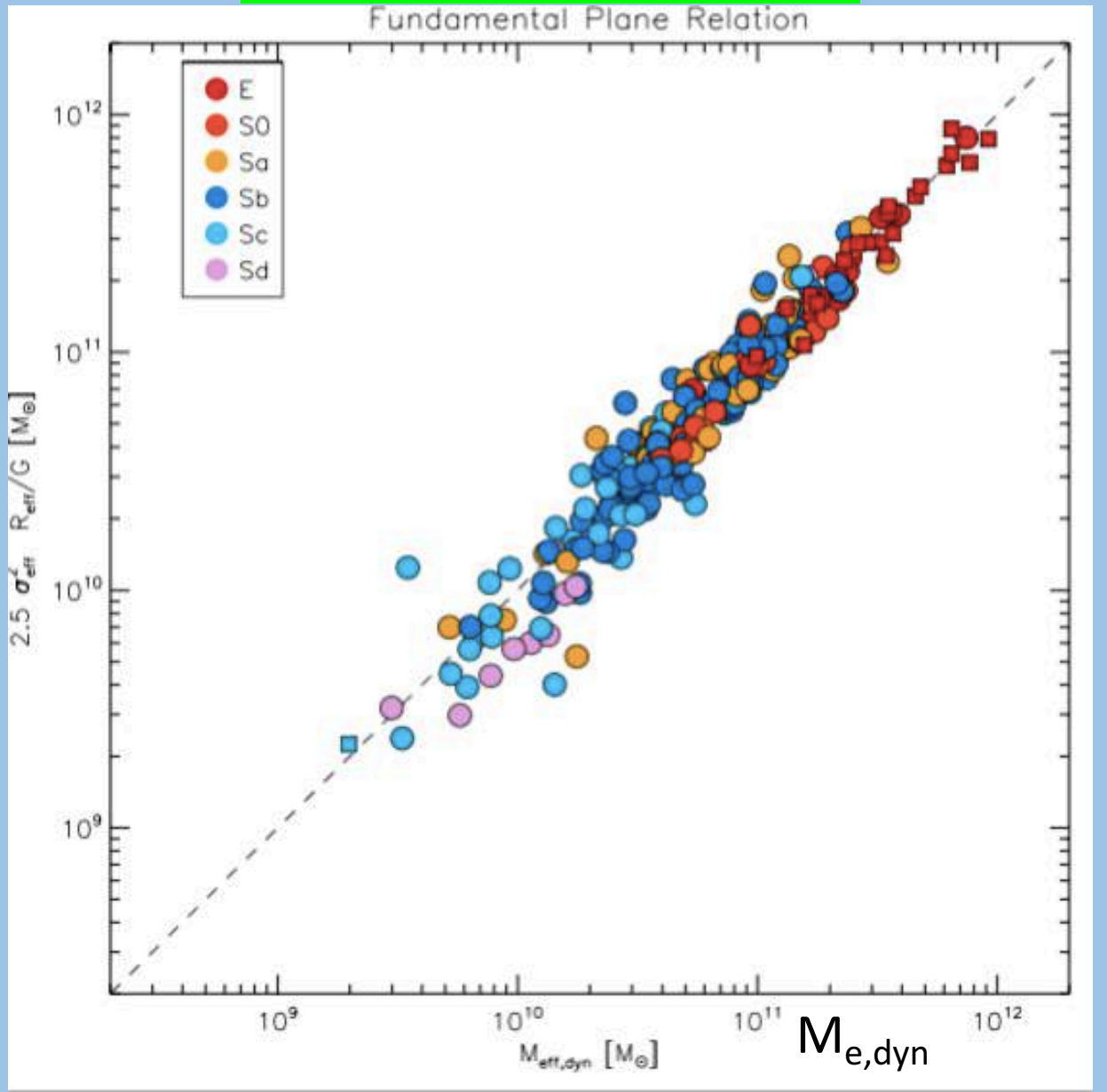
# Faber-Jackson Relation



# Fundamental Plane



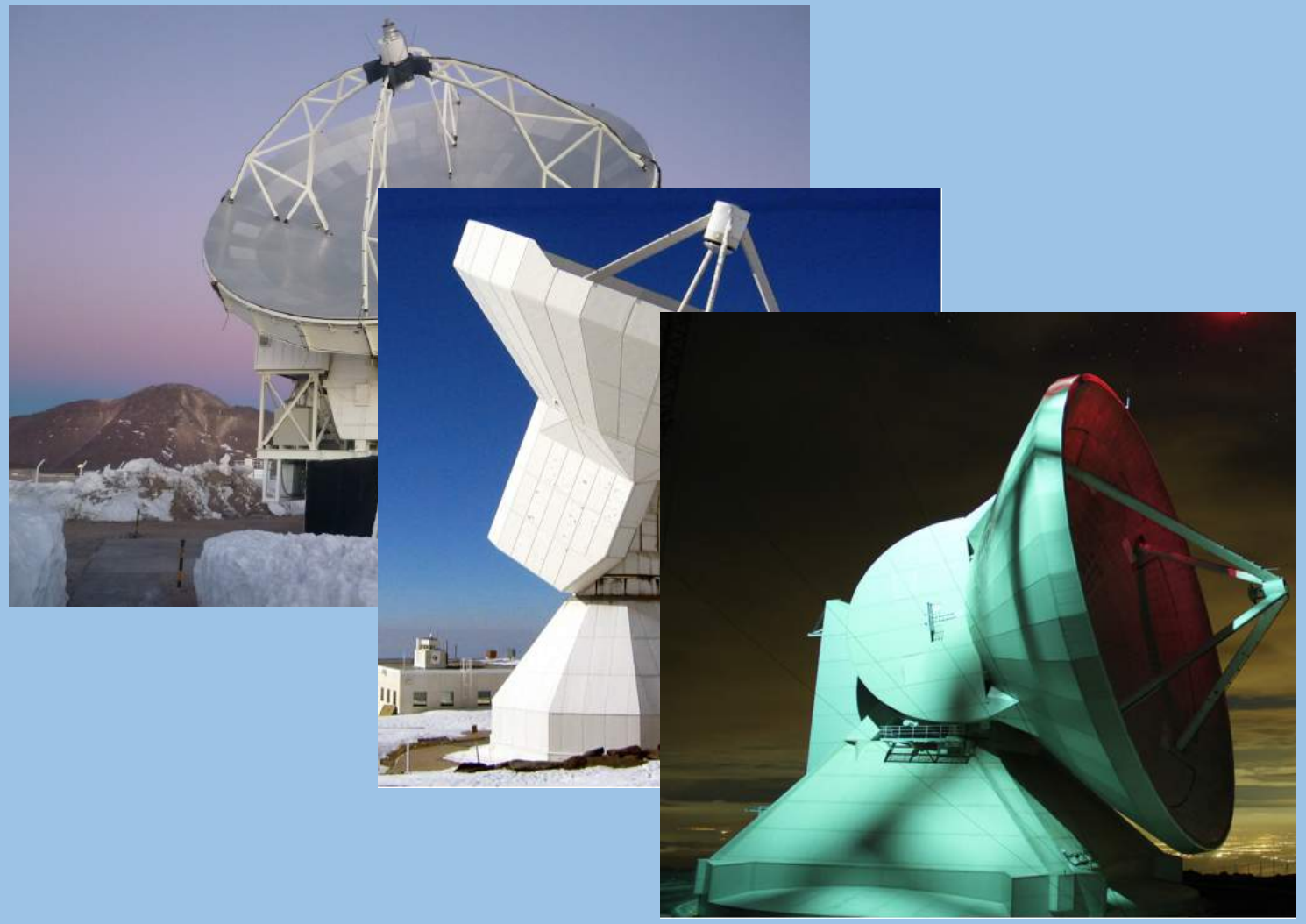
# Fundamental Plane



# Vienna leads Radio follow-up: molecular gas

Single Dish:

- APEX
  CO 2-1
- IRAM 30m
  CO 1-0
- LMT
  HCN 1-0



Dannerbauer, Ellmeier

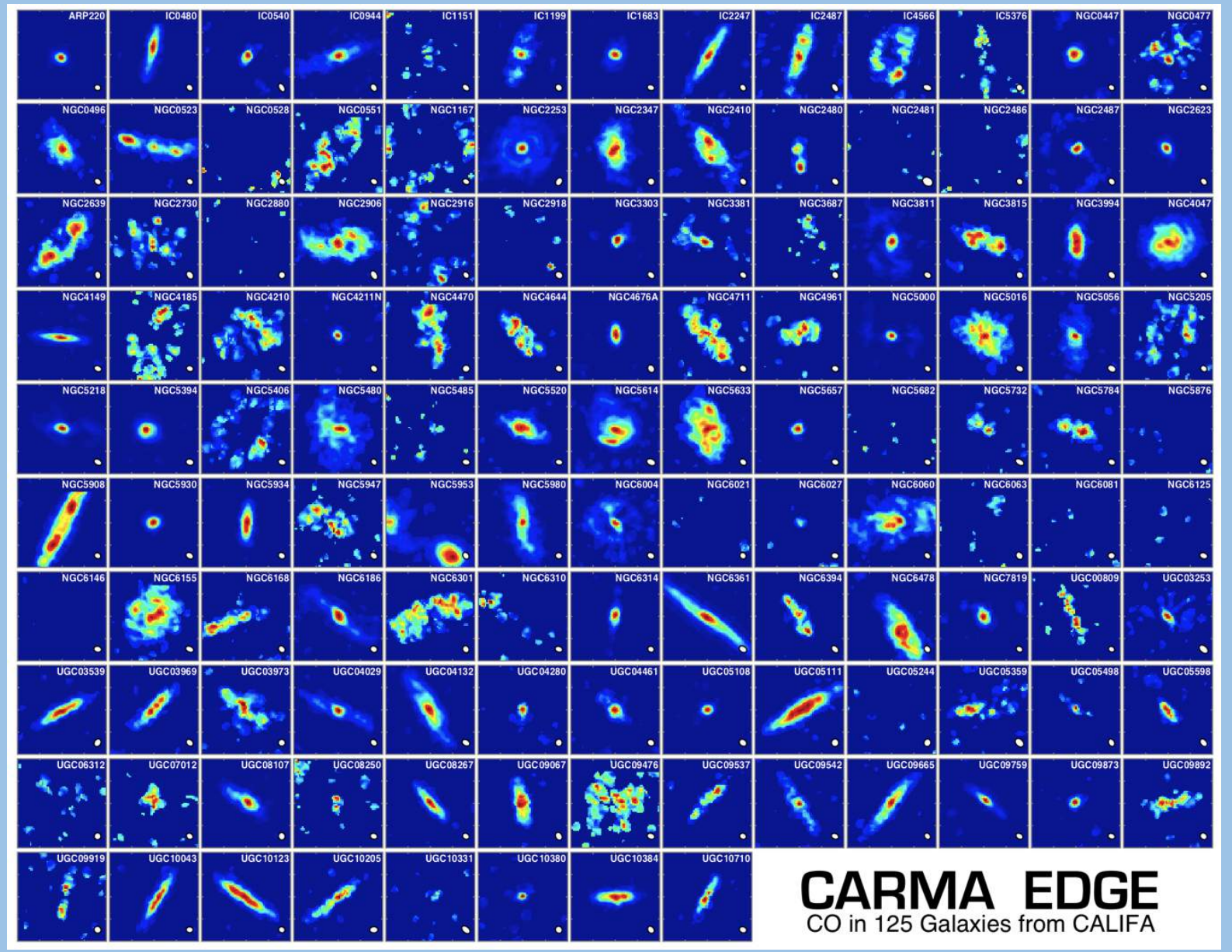
# Vienna leads Radio follow-up: molecular gas

Radio Interferometry:

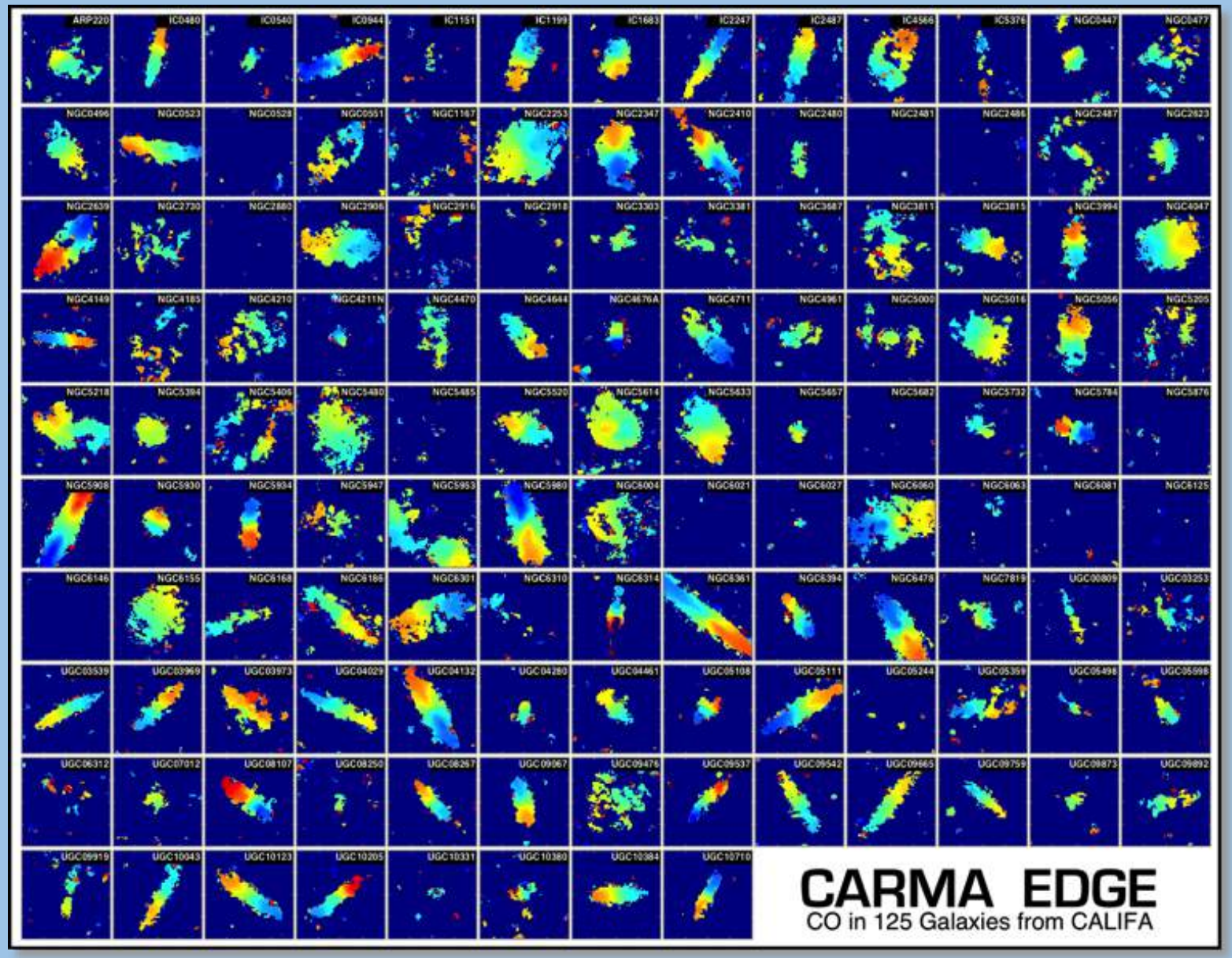
- CARMA
  CO 1-0

**EDGE: Extragalactic Database for Galaxy Evolution survey**

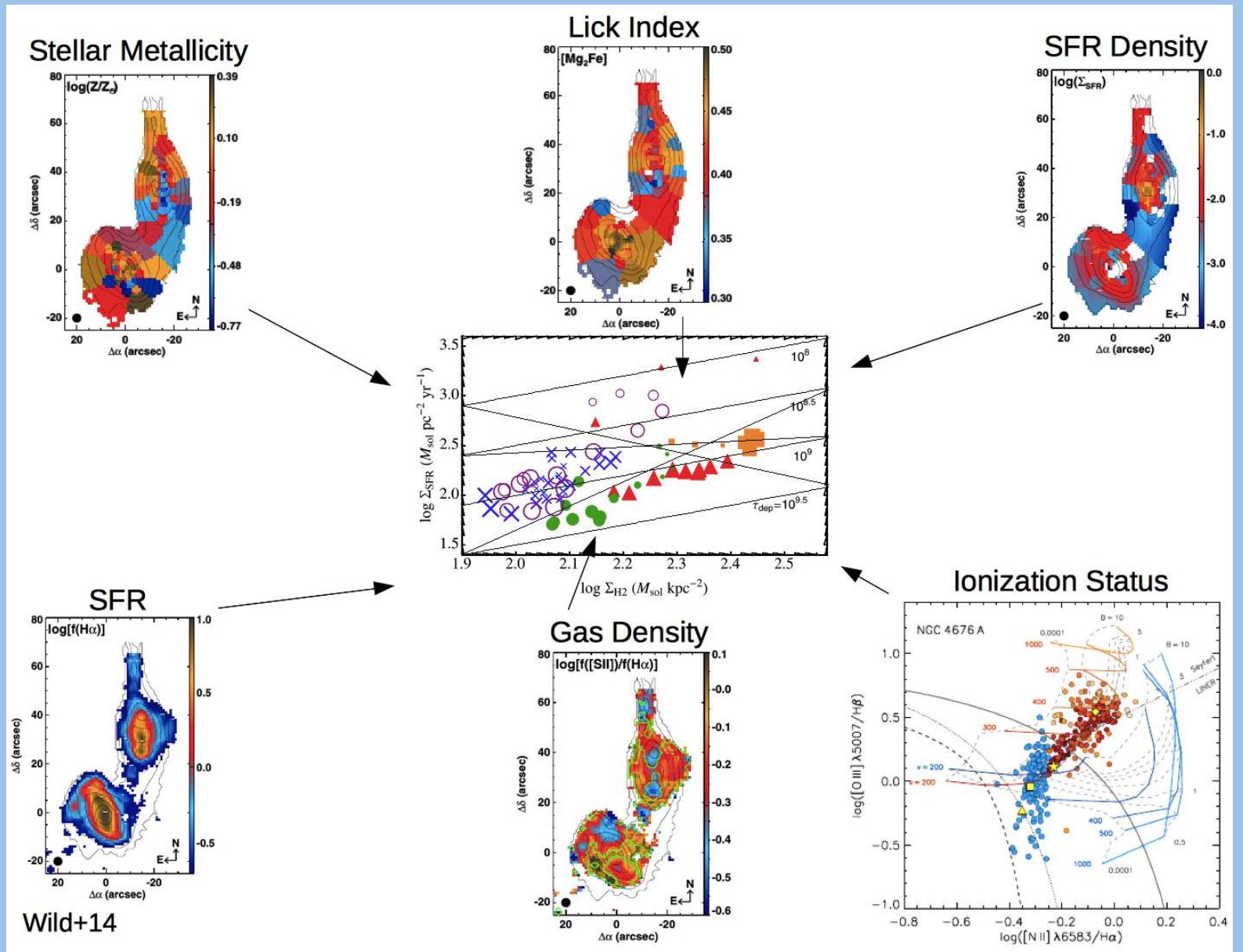
# CO maps


ARP220 IC0480 IC0540 IC0944 IC1151 IC1199 IC1683 IC2247 IC2487 IC4566 IC5376 NGC0447 NGC0477
NGC0496 NGC0523 NGC0528 NGC0551 NGC1167 NGC2253 NGC2347 NGC2410 NGC2480 NGC2481 NGC2486 NGC2487 NGC2623
NGC2639 NGC2730 NGC2880 NGC2906 NGC2916 NGC2918 NGC3303 NGC3381 NGC3687 NGC3811 NGC3815 NGC3994 NGC4047
NGC4149 NGC4185 NGC4210 NGC4211N NGC4470 NGC4644 NGC4676A NGC4711 NGC4961 NGC5000 NGC5016 NGC5056 NGC5205
NGC5218 NGC5394 NGC5406 NGC5480 NGC5485 NGC5520 NGC5614 NGC5633 NGC5657 NGC5682 NGC5732 NGC5784 NGC5876
NGC5908 NGC5930 NGC5934 NGC5947 NGC5953 NGC5980 NGC6004 NGC6021 NGC6027 NGC6060 NGC6063 NGC6081 NGC6125
NGC6146 NGC6155 NGC6168 NGC6186 NGC6301 NGC6310 NGC6314 NGC6361 NGC6394 NGC6478 NGC7819 UGC00809 UGC03253
UGC03539 UGC03969 UGC03973 UGC04029 UGC04132 UGC04280 UGC04461 UGC05108 UGC05111 UGC05244 UGC05359 UGC05498 UGC05598
UGC06312 UGC07012 UGC08107 UGC08250 UGC08267 UGC09067 UGC09476 UGC09537 UGC09542 UGC09665 UGC09759 UGC09873 UGC09892
UGC09919 UGC10043 UGC10123 UGC10205 UGC10331 UGC10380 UGC10384 UGC10710
CARMA EDGE
CO in 125 Galaxies from CALIFA

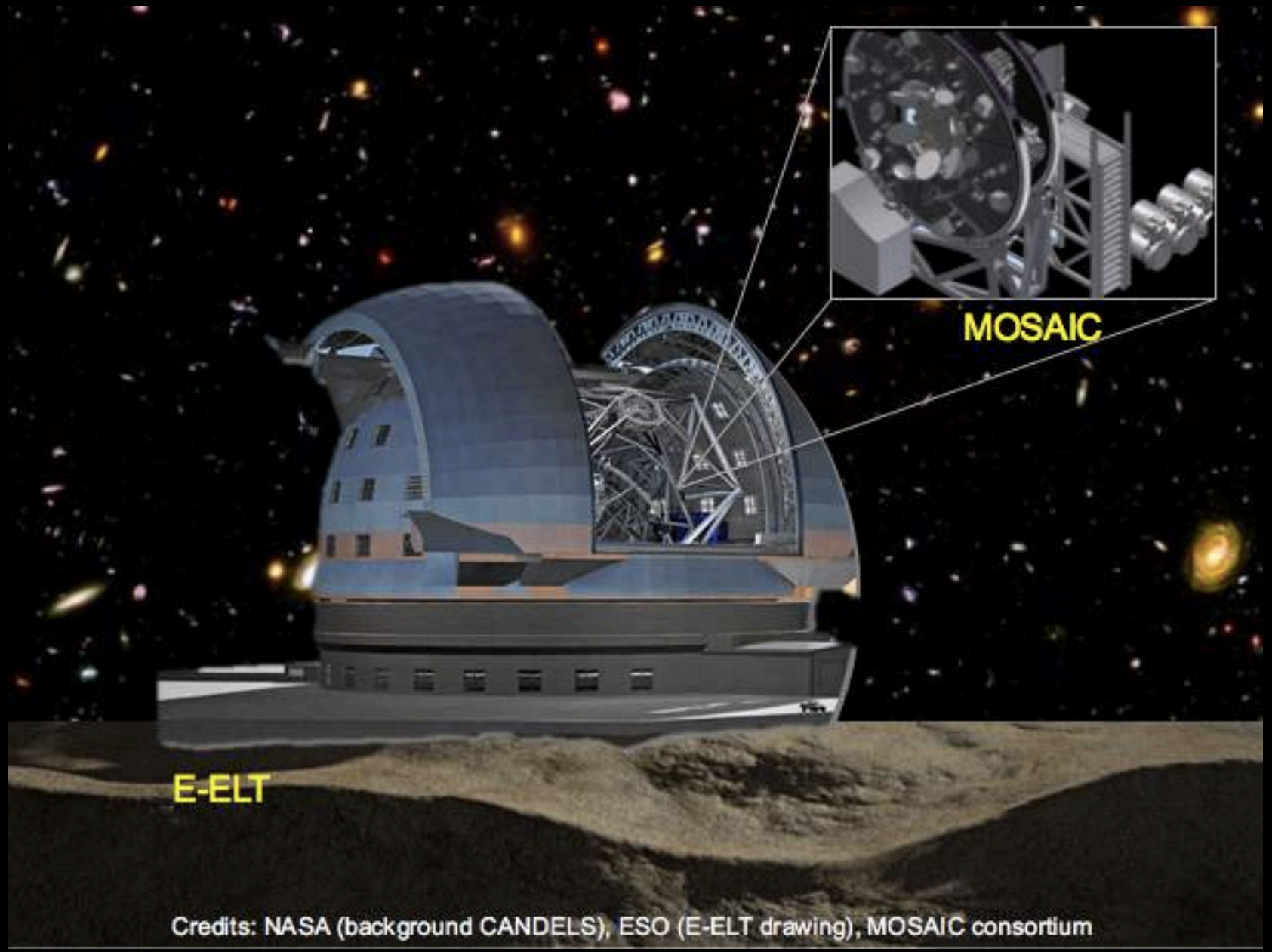
# CO velocity fields



# Scatter in Kennicutt-Schmidt Law



# MOSAIC: The E-ELT Multi-Object Spectrograph




# MOSAIC Team

L'Observatoire de Paris

Durham University

IRAP-Toulouse

UK Astronomy Technology Center

Observatorio de Sao Paulo

University of Oxford

ONERA

Laboratoire D'Astrophysique de Marseille

Universiteit van Amsterdam

Leibniz Institute for Astrophysics Potsdam

CNRS

University of Vienna

Stockholm University

University of Helsinki

Universidade do Porto

Universidad Complutense de Madrid

INAF Roma

University of Geneva

European Southern Observatory

University of Göttingen

BZ Steering Committee member

100+ scientists across Europe and Brazil


# MOSAIC Science Cases

SC1: First galaxies, Reionisation

SC2: Large scale structures

SC3: Galaxies mass assembly

SC4: AGN/Galaxy coevolution

SC5: Resolved stars beyond the Local Group

SC6: Galaxy archaeology

SC7: Galactic centre

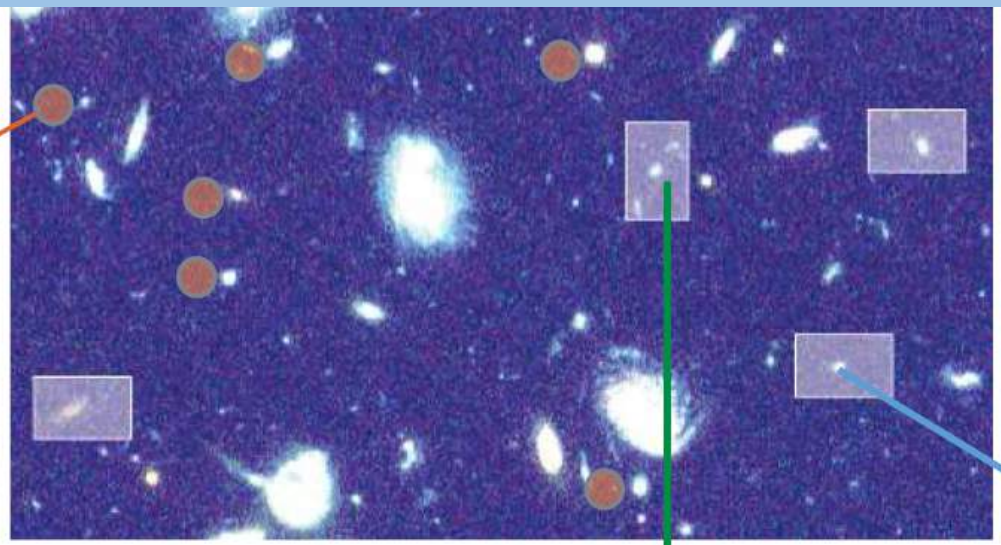
SC8: Planet formation in clusters

**ALL SCs will be tested through an 'end-to-end' simulator**

Updated White Book
Evans et at. 2015, ArXiv/1501.04726

# MOSAIC Instrument Modes

MOSAIC



*End-to-end simulations, see Disseau et al. (2014, SPIE)*

## High Multiplex Mode (HMM)

| | |
|---|---|
| On Sky aperture | 0.9″ |
| Multiplex | 200 |
| Spectral Resolution | 5000 & 15000 |
| λ coverage | 0.4 - 1.8 μm |

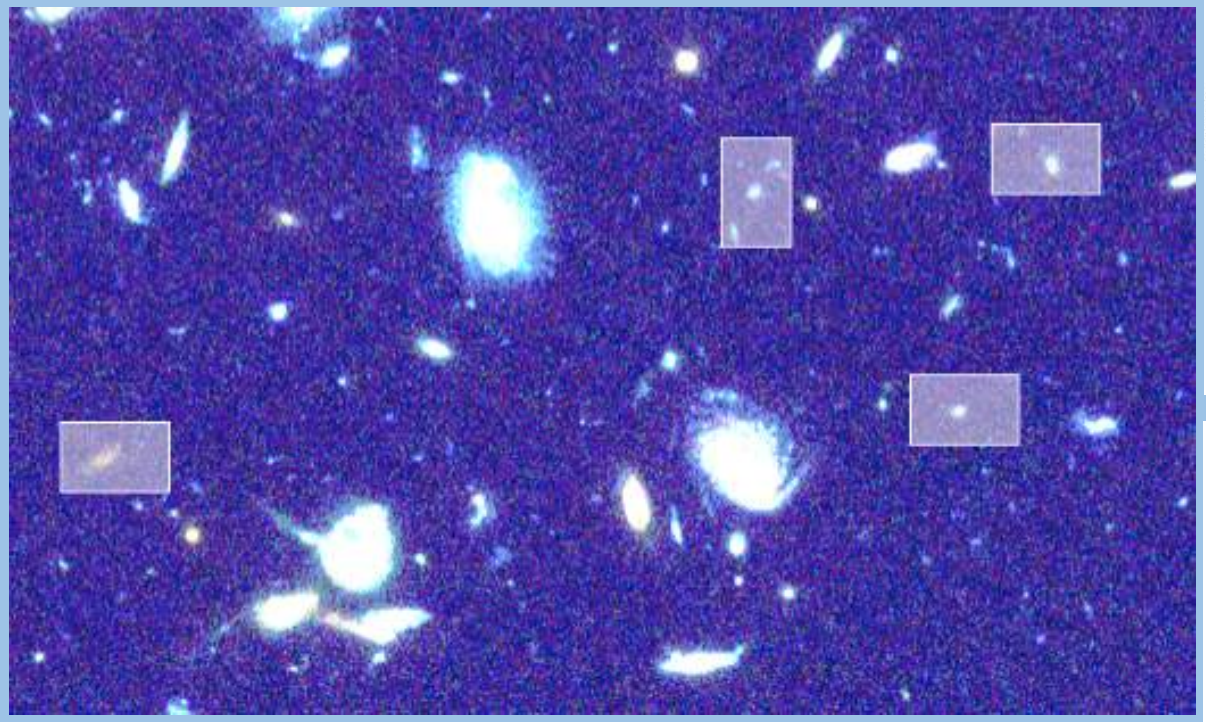
## High Definition Mode (HDM)

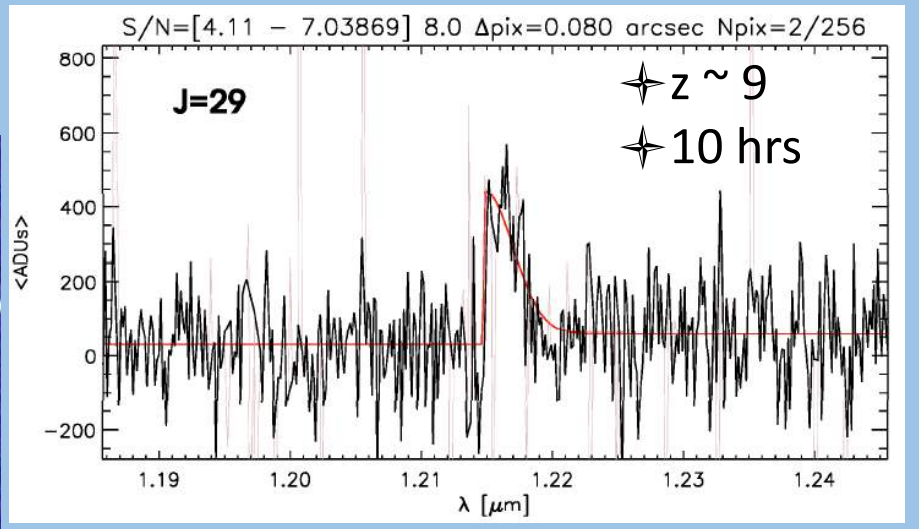
| | |
|---|---|
| IFU field of view | 2.0 x 2.0″ |
| Multiplex | 10 IFUs |
| Spatial pixel size | 75 mas |
| Ensquared Energy | > 25% EE |
| R | 5000 |
| λ coverage | 0.8 - 1.8 μm |

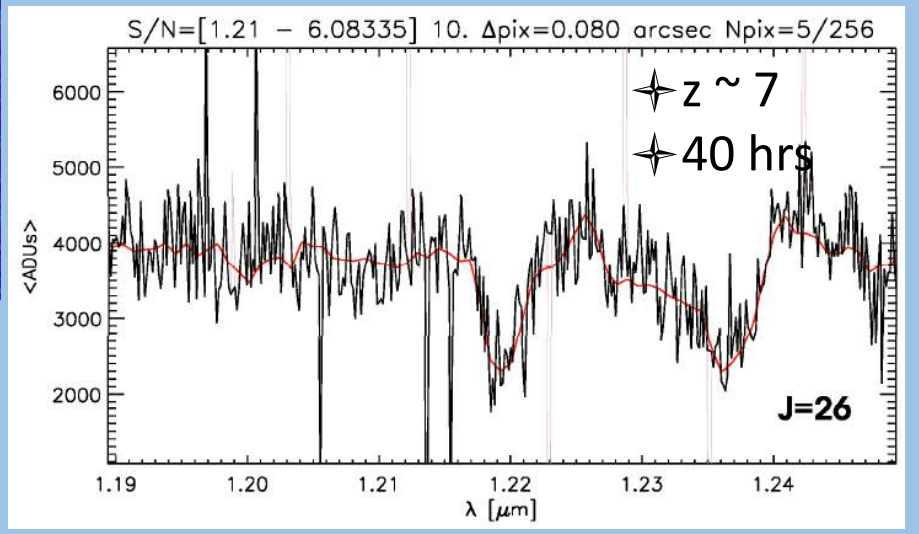
## InterGalatic Medium (IGM)

| | |
|---|---|
| IFU field of view | 2.0″ x 2.0″ |
| Multiplex | 10 IFUs |
| Spatial pixel size | 0.3 arcsec |
| R | 5000 |
| λ coverage | 0.4 - 1.0 μm |

# First end-to-end simulations (Disseau+14, SPIE)



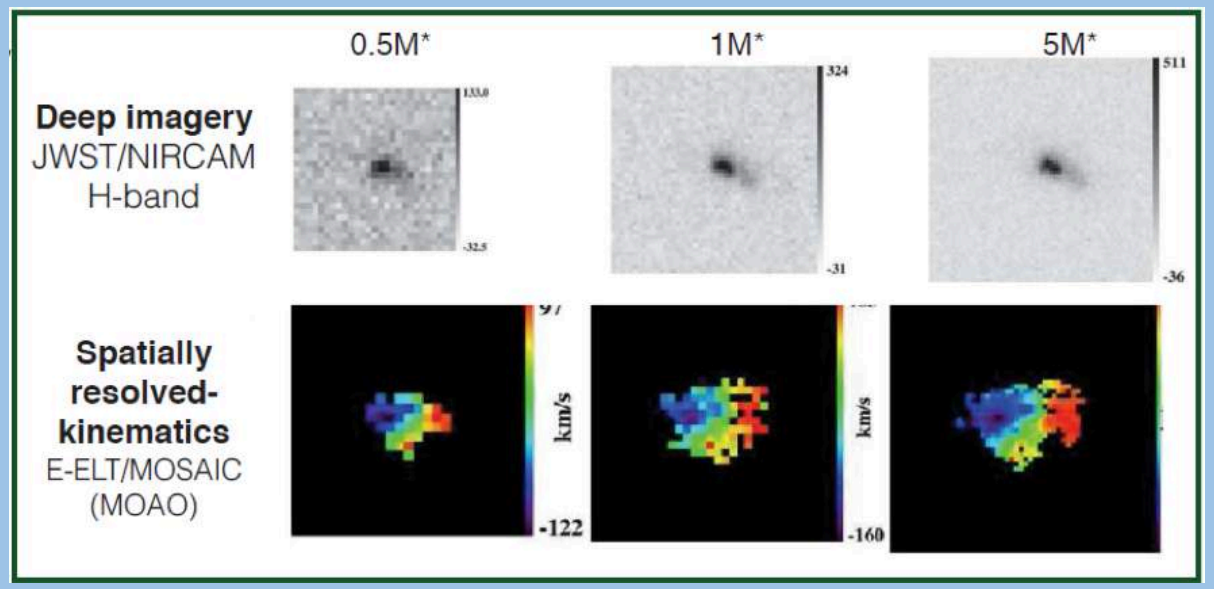



- IFUs: essential for the best sky subtraction
- (Rodrigues et al., 2014, SPIE)
- Also true for stellar astrophysics in crowded fields


Principal C...
cnb_pca....
http:/...a.pro
Principal...
SVDFIT: An ...
Citation ...
Websim-...
websim-compass.obspm.fr
tra fitting eigenvectors
CDS
ADS
GoogleAgenda
Evernote
RATP
UFE_Inscr
SpipUFE
ResaGEPI
Websim-Compass
UFE-TdS
compass
COMPUTING PLATFORM FOR ADAPTIVE OPTICS SYSTEMS
Websim-Compass
Home
Websim
Simulations (Vienna: M. Verdugo)
Login
Username
Login
Forgot login?
Register
Contact Us
Webmaster
Science Contact
Welcome to Websim-Compass!
WEBSIM-COMPASS is a scientific instrument simulator dedicated to the E-ELT, and developed in the frame of the COMPASS project. This simulator builds on the previous series of WEBSIM simulators developed during the ESO E-ELT Design Reference Mission and Instrument Phase A studies. The WEBSIM-COMPASS observations simulator consists in a web interface coupled to an IDL code, which allows the user to perform end-to-end simulations of all E-ELT optical/NIR imagers and spectrographs foreseen for the future 39m European Extremely Large Telescope, i.e., MICADO, HARMONI, and MOSAIC. The simulation pipeline produces fake simulations in FITS format that mimic the result of a data reduction pipeline with perfectly extracted/reduced data.
A global description of WEBSIM-COMPASS can be found in the SPIE2016 paper. Please cite this paper if you make use of WEBSIM-COMPASS in a publication. Read more about WEBSIM and the former versions and results here.
You are here: Home

# *MOGLIS*: MOsaic Galaxy Legacy Ifu Survey




**Public Survey: CALIFA-like at *z~1.3***

Full understanding of galaxy assembly needs *stellar* component!

- ✓ Half of stellar mass assembled
- ✓ SFR density 10x higher
- ✓ typical Main Sequence galaxy forming stars 10x more rapid
- ✓ Population of passive galaxies just settled

# *MOGLIS*: MOsaic Galaxy Legacy Ifu Survey

## Public Survey: CALIFA-like at *z~1.3*

Goal: observe 500 “representative” galaxies across wide parameter space
(in stellar/dynamical mass, morphologies, colors, SFRs, environment densities)

- ❖ sub-kpc stellar and gas kinematics
- ❖ sub-kpc stellar populations, ages, metallicities

Requirements: $10^9\ M_o$ , $V_{rot}$ ~ 50km/s ➡ $I_{lim}$~$25^m$
(remember SB dimming $(1+z)^4$ ! )
S/N > 10 per spaxel/resolution element
Basic λ coverage 370-580nm restframe (fits nicely into OH-free sky window)
Integration time: 100-300h

Assessment by M. Verdugo (Vienna)