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BULGELESS EVOLUTION AND THE RISE OF DISKS

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XIII ESTALLIDOS WORKSHOP - 20/05/2022

INSTITUTO DE ASTROFISICA DE CANARIAS · IAC ·

MOTIVATION

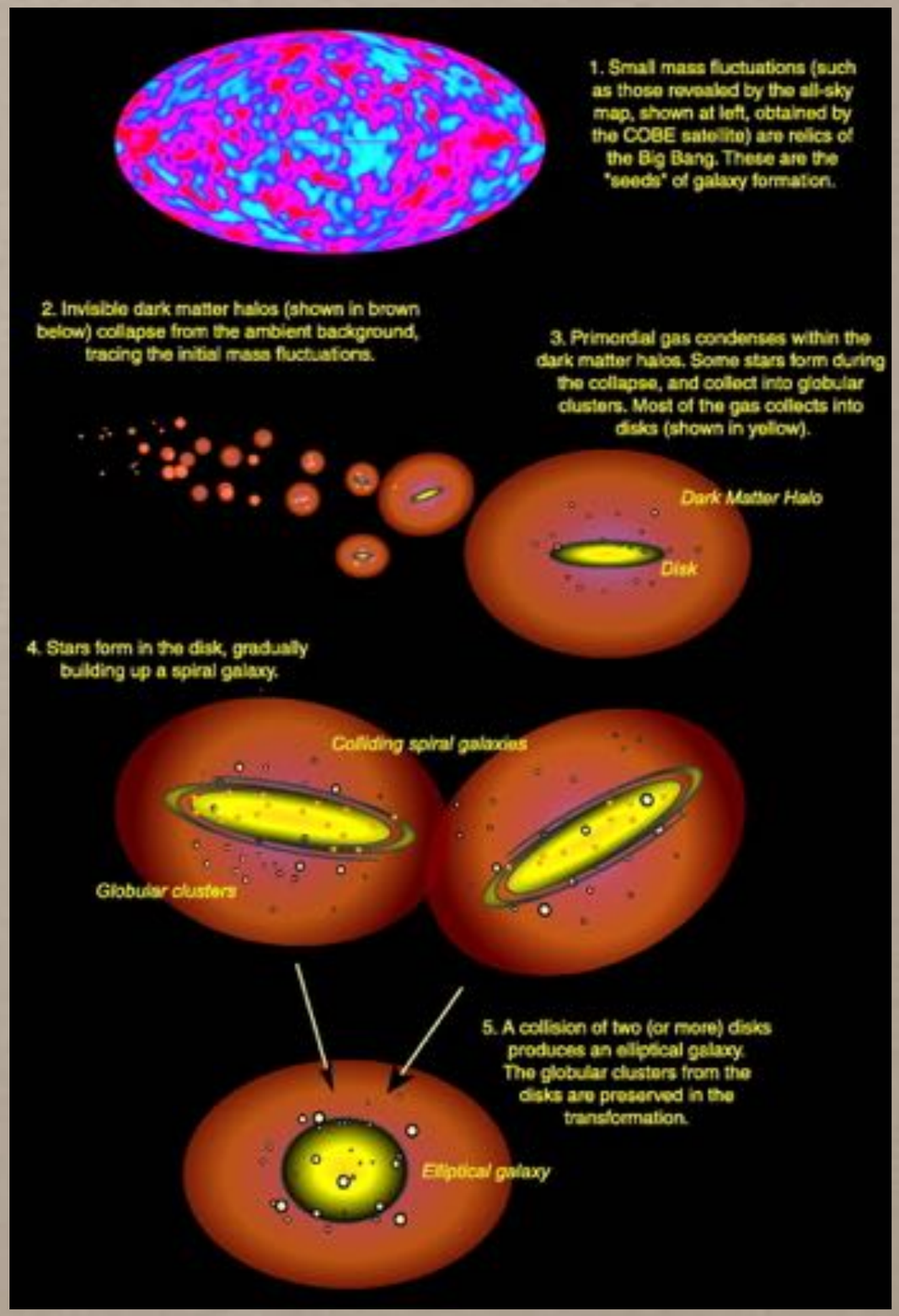
Galaxy formation in ΛCDM Universe

↓

Mergers of smaller units eventually create bigger systems

↓

Great to build ellipticals, but not so good for giant spirals



Abraham & van den Bergh (2001)

BULGELESS GALAXIES AS A CHALLENGE FOR ΛCDM HIERARCHICAL FORMATION

Disk rebuild after the merger?
(Hopkins et al. 2009)

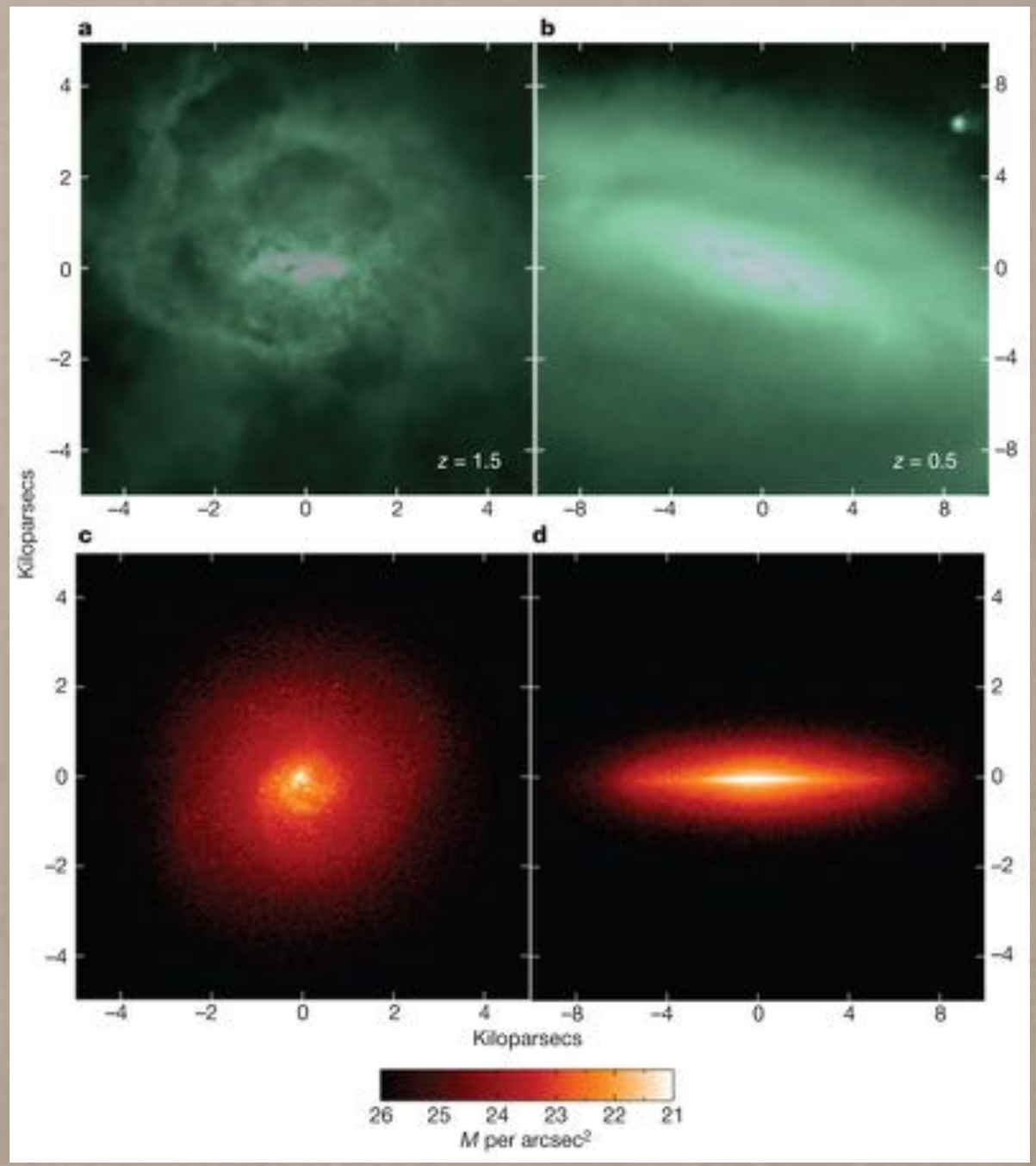
↓

Unavoidable to create a bulge

Negative feedback?
(Governato et al. 2010, Christensen et al. 2014)

↓

Works for dwarfs, but not for giants



Governato et al. (2010)

HOW IMPORTANT MIGHT THIS BE?

Most massive spiral galaxies do not have a 'merger-build' bulge

Classical vs. disk-like bulge dichotomy

Fraction of bulgeless galaxies in the nearby Universe can be as high a 74% (Kormendy et al. 2010)

Our closer example: The Milky-Way

Massive spiral with bulge accounting for < 8% of the mass (Shen et al. 2010)

Detailed studies only possible for the MW, but statistics only possible with samples of MW-like galaxies

A dedicated survey is needed to address the challenge of Milky Way-like galaxies to the ΛCDM paradigm.

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International effort (24 member from 6 countries) to provide irrefutable observational constraints to demonstrate the success or failure of the hierarchical ΛCDM scenario at forming Milky Way-like galaxies

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Awarded by the International Scientific Committee (CCI) during two consecutive years (2019 and 2020) with an International Time Programme (ITP) at the Roque de los Muchachos Observatory (78 observing nights)

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The Sample

- Volume-limited sample of 66 massive bulgeless spiral galaxies in the nearby Universe (<40 Mpc)
- Mainly selected from the SDSS-DR13 spectroscopic catalogue
- Inclination i<60 degrees, allowing for a good photometric definition of the bulge region and limiting the effects of dust lanes
- Concentration $C=R_{90}/R_{50}<2.5$, to ensure the sample is dominated by late-type disc galaxies
- Petrosian radius $R_{petro}>10$ arcsec
- Total stellar mass $M_{\star} > 10^{10} M_{\odot}$

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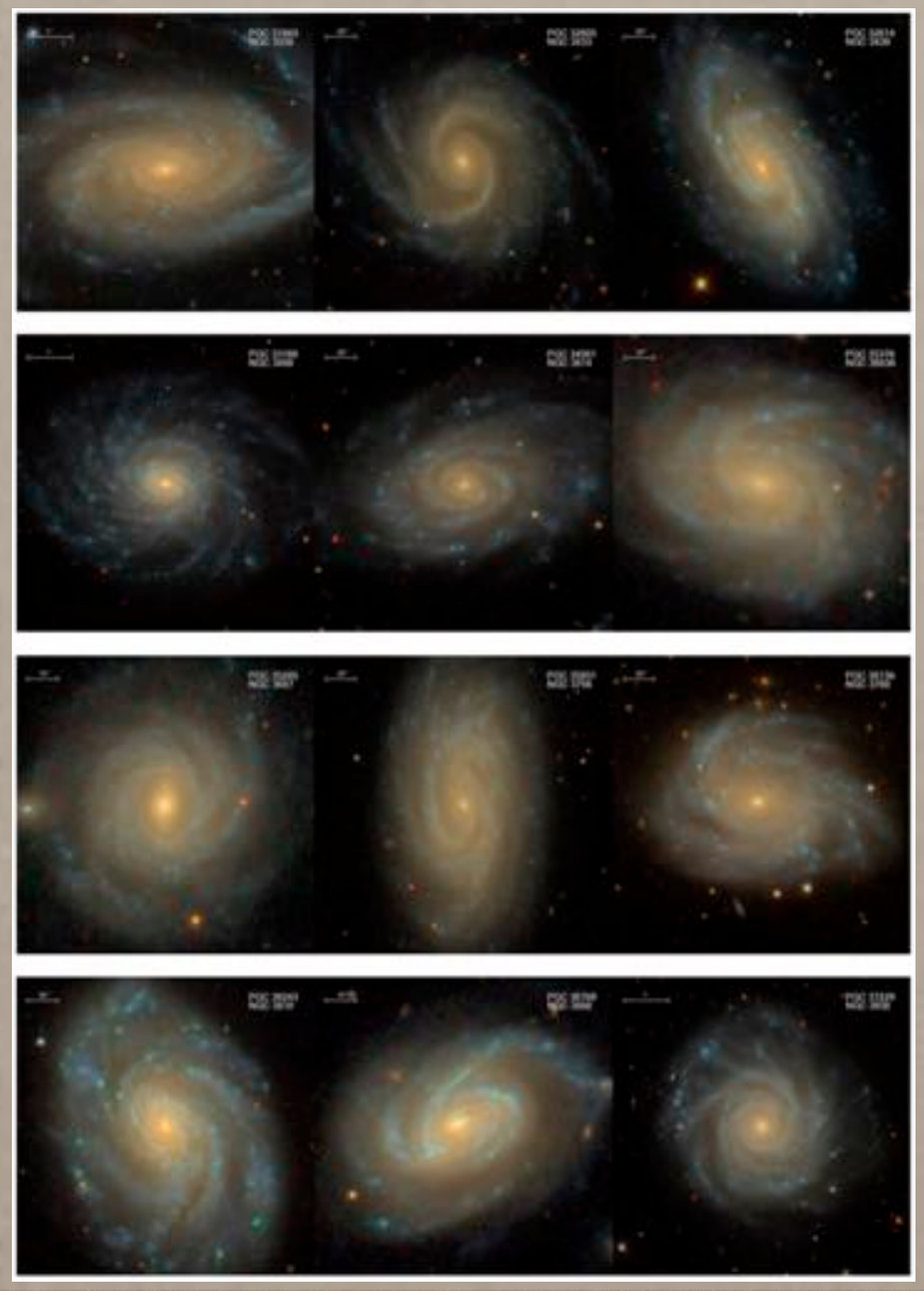
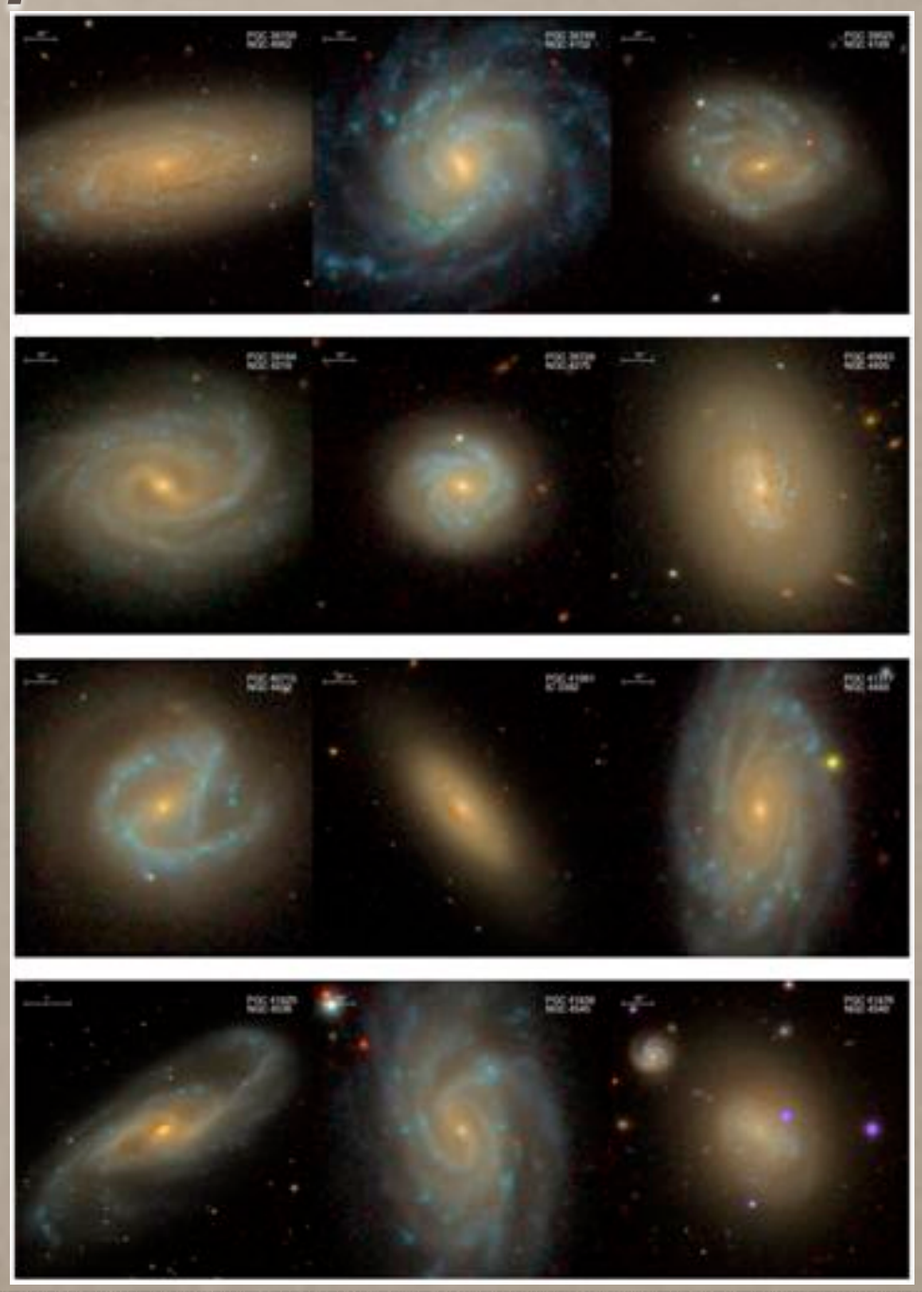
The Sample





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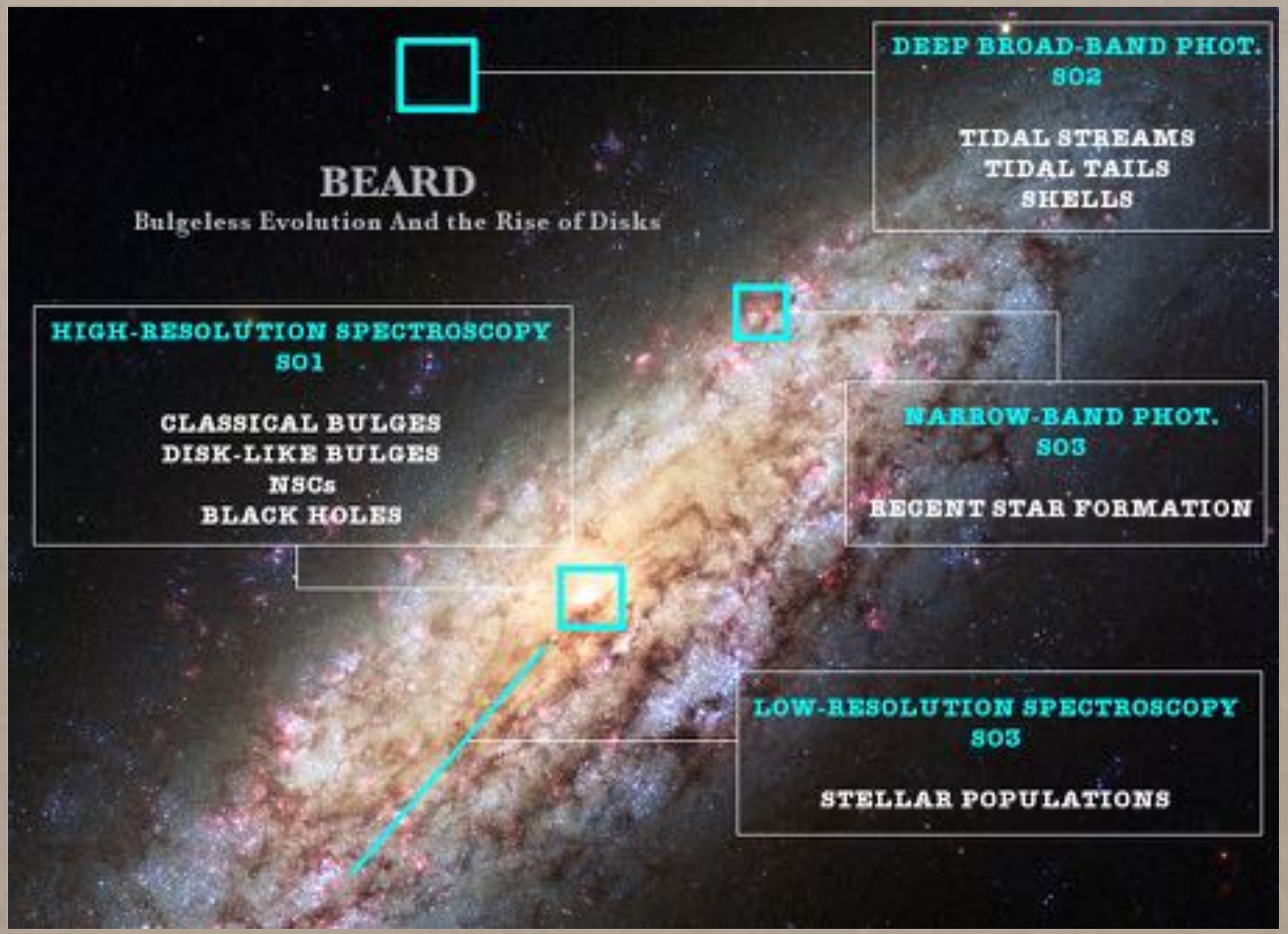
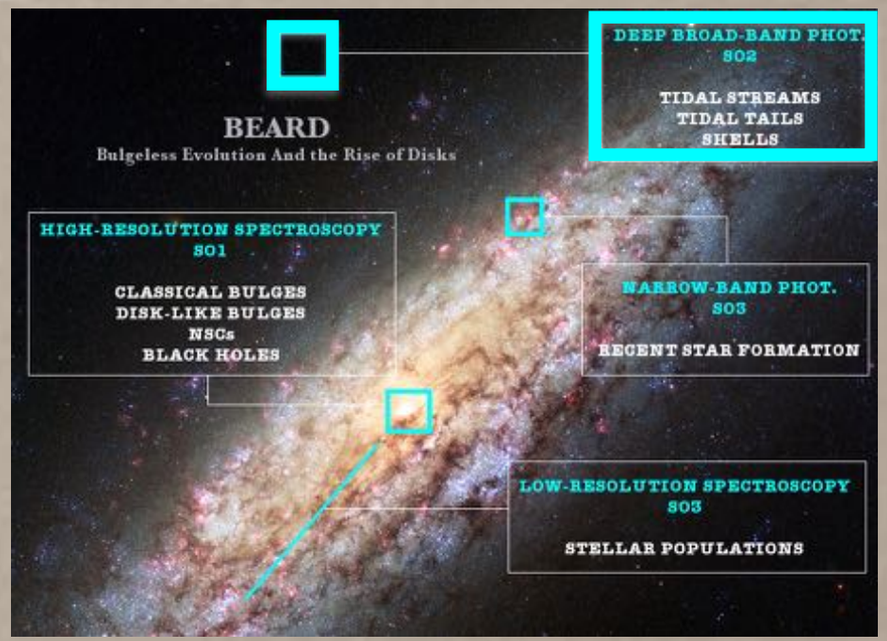
The Observations

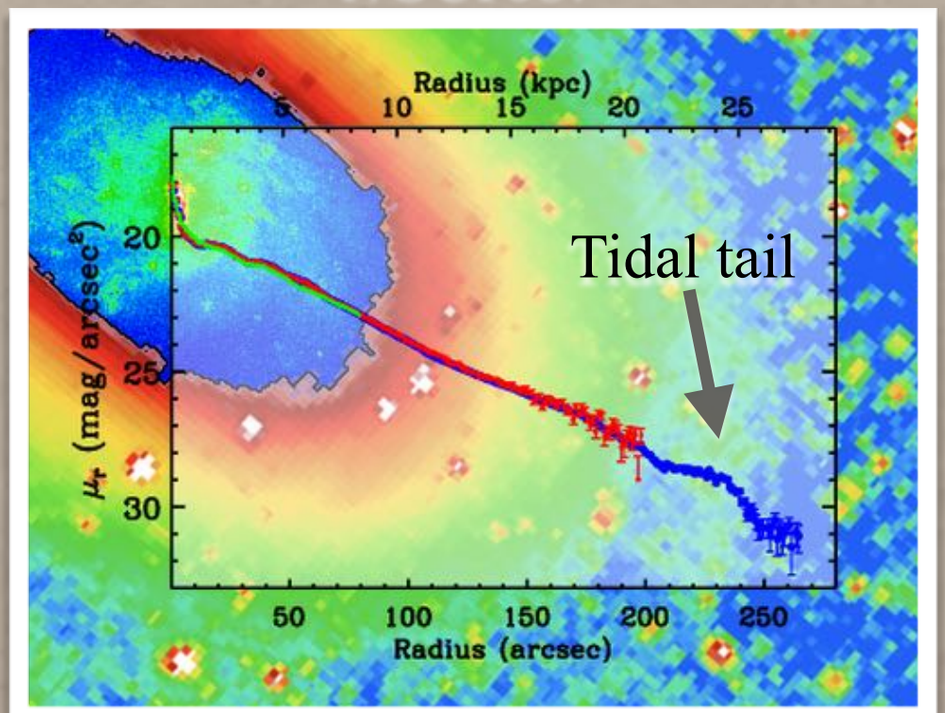


BROAD-BAND PHOTOMETRY WFC@INT

- *Deep g- (1 hour) and r-band (2 hours) photometry*
- *10 galaxies observed for > 3 hours in both bands*
- *Typical depth ~ 29 mag/arcsec² (30-31 mag/arcsec²)*

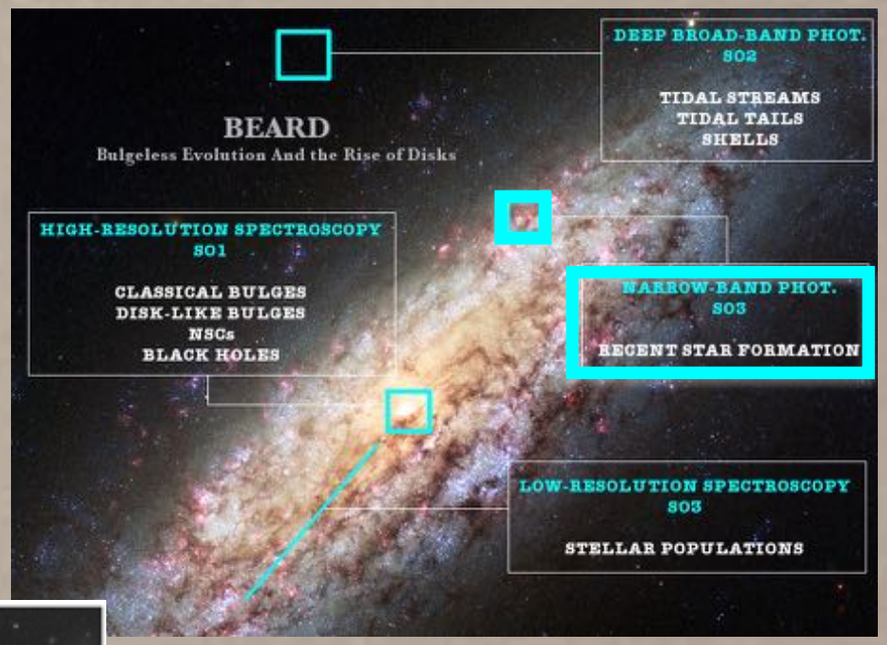


NGC1087

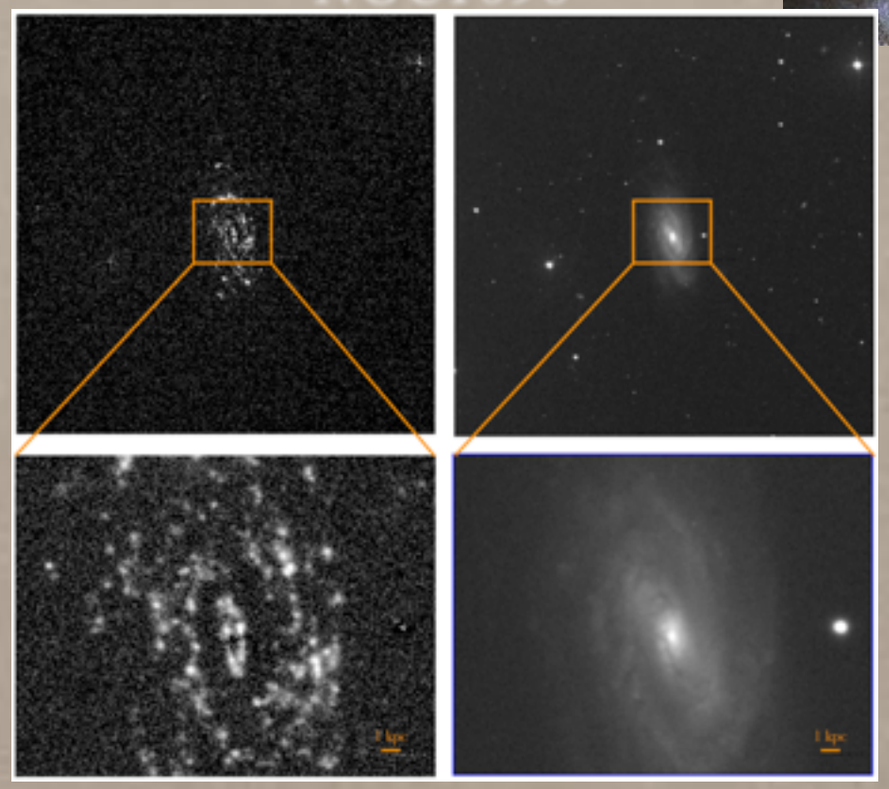


NARROW-BAND PHOTOMETRY IO:O@LT

- *Ha centered observations (30 minutes) and adjacent continuous (30 minutes) taken consecutively.*
- *Typical depth ~ 1-5E-16 erg/cm²/s/arcsec²*
- *Photometric calibration at 3-5%*

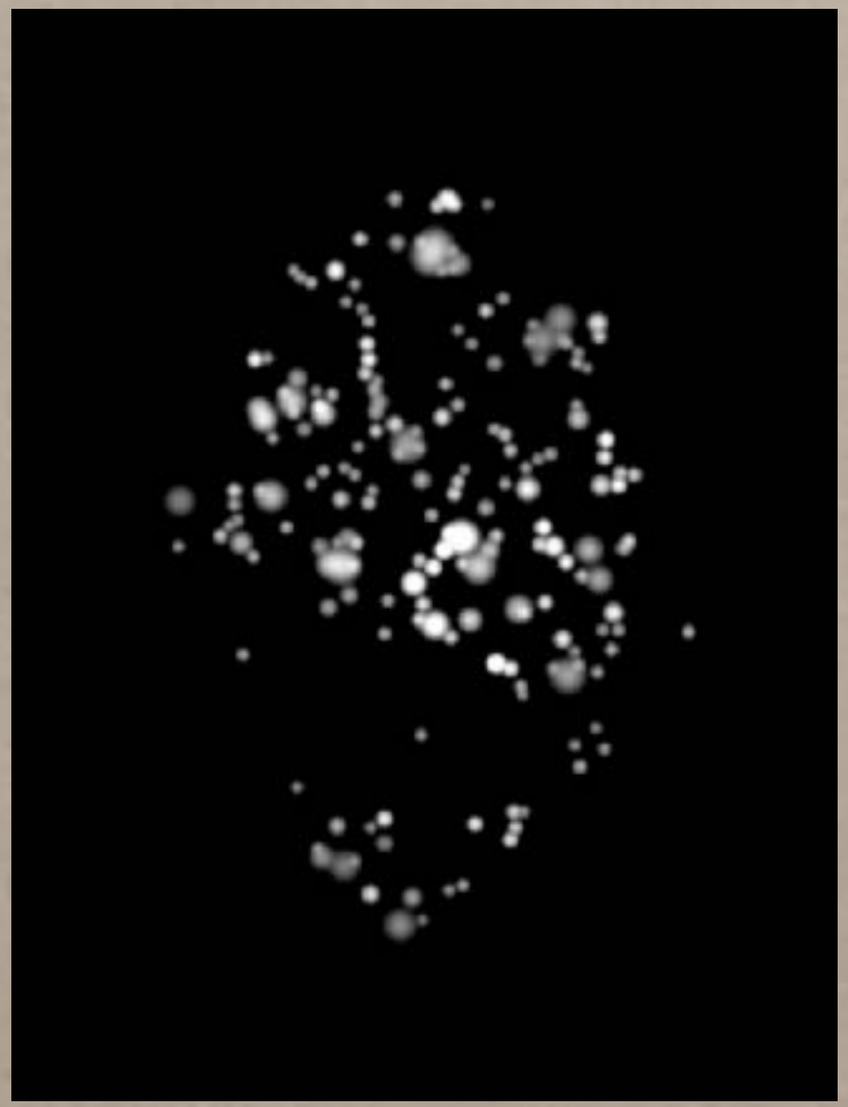


NGC1090

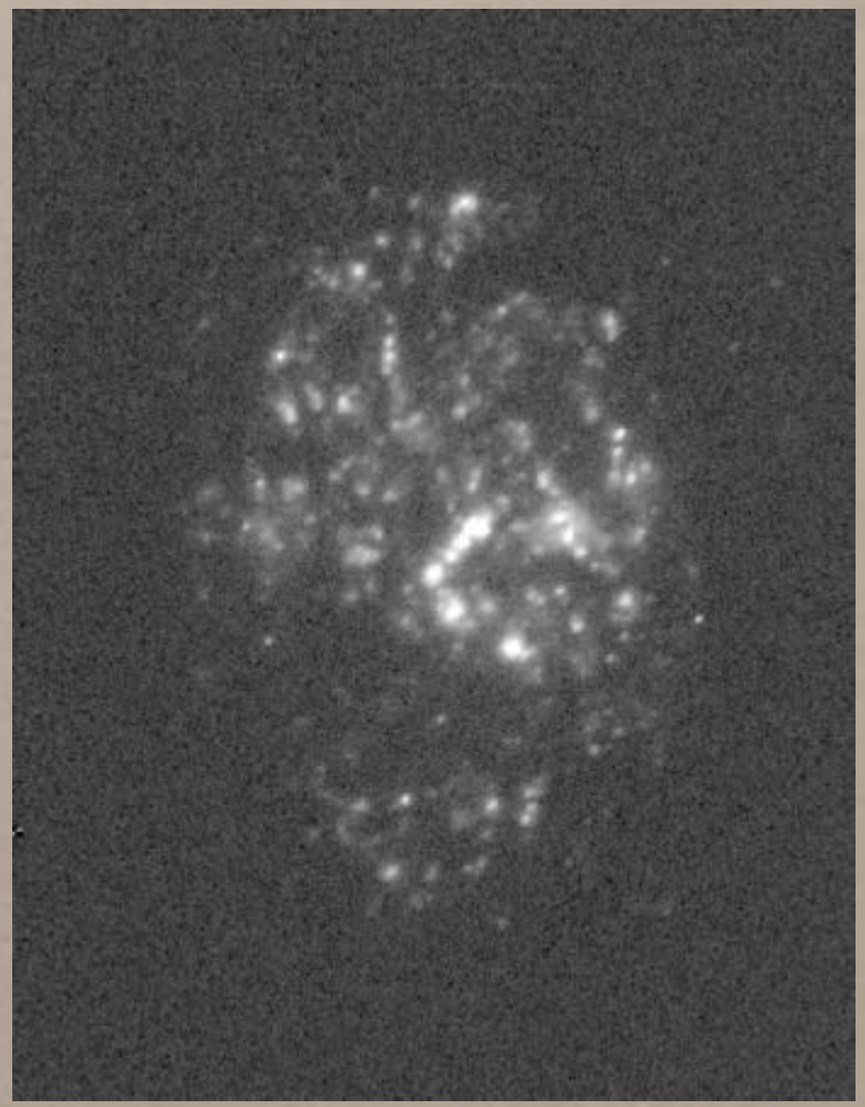


NARROW-BAND PHOTOMETRY IO:O@LT

NGC1087



PyHIIExplorer



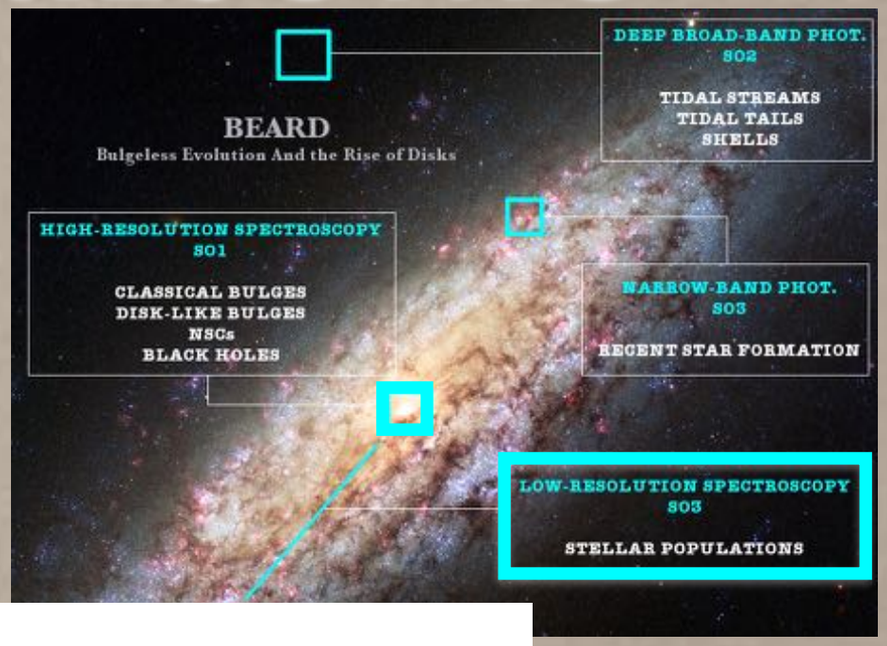
Hα image

Running PyHIIExplorer to identify HII regions (Lugo-Aranda et al. 2022)

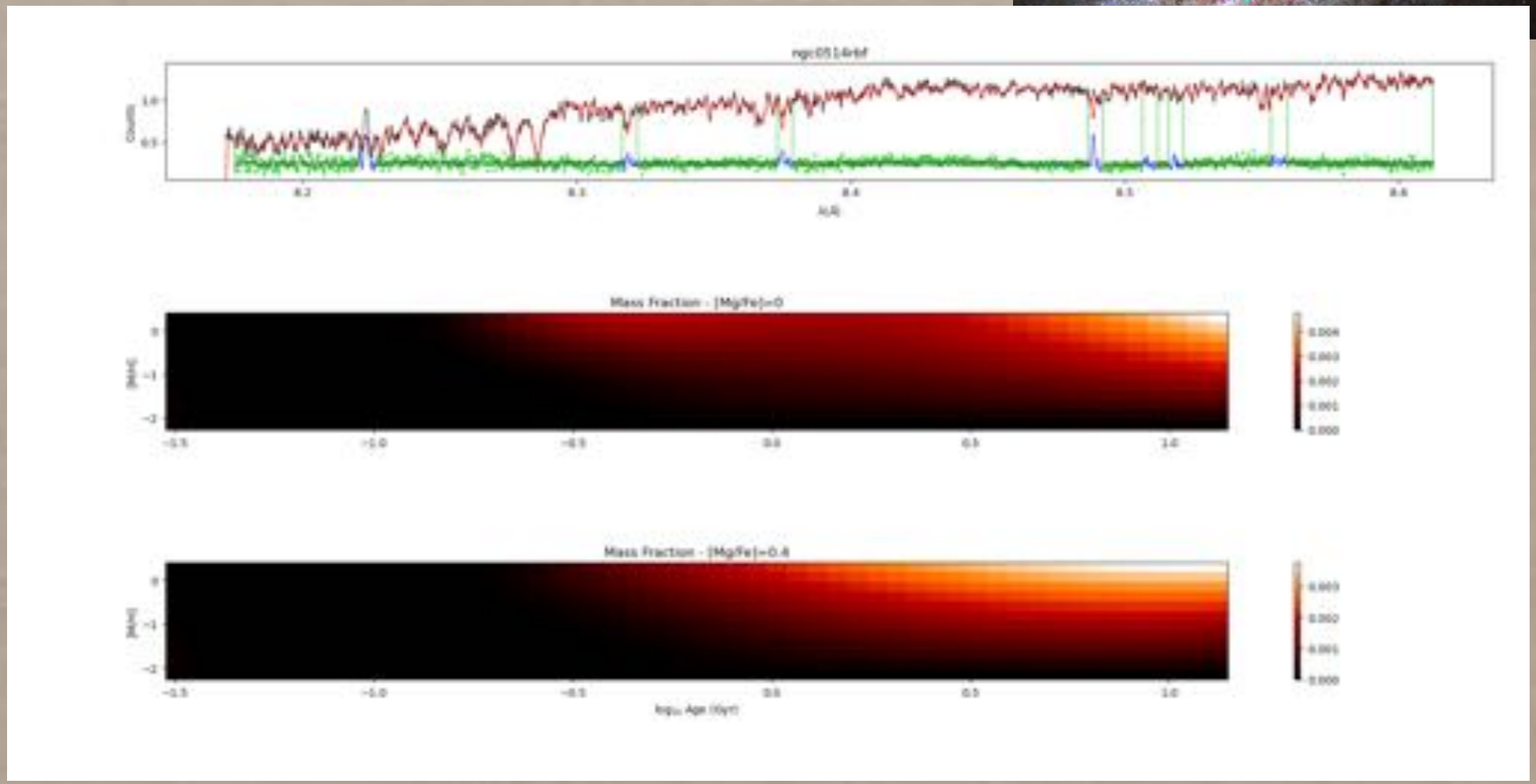
TFM A. Cerviño

LONG-SLIT SPECTROSCOPY ISIS@WHT - DOLORES@TNG

- *Low-resolution spectroscopy along the major axis of the galaxies*
- *Typical depth ~ 21 mag/arcsec² in r-band*
- *ISIS-WHT (3500-5500AA, FWHM=3.3AA)*
- *DOLORES-TNG (4700-6700, FWHM=3.5AA)*

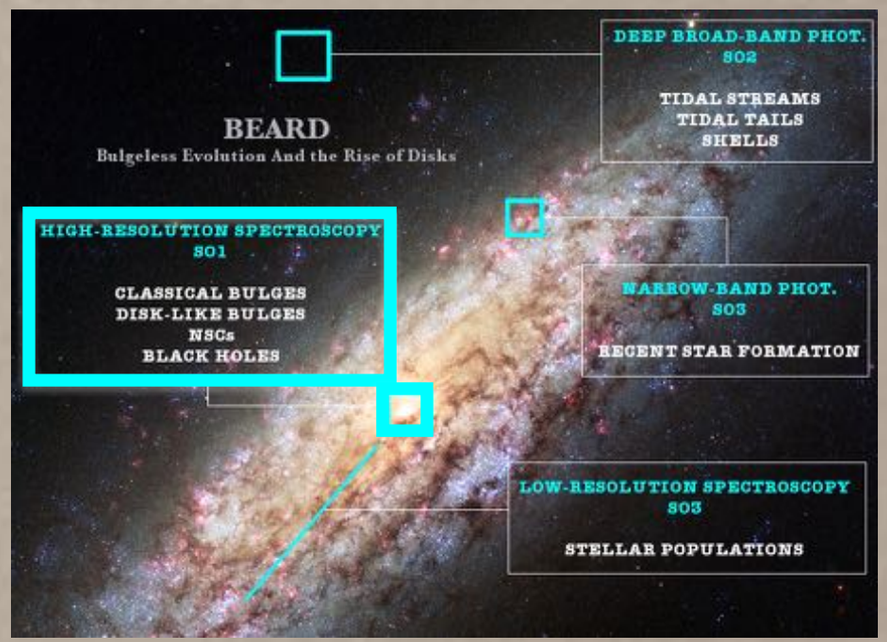


NGC514



INTEGRAL FIELD SPECTROSCOPY MEGARA@GTC

- *High-resolution spectroscopy at the galaxy center*
- *MR-G (R ~12000 - 4960-5445AA)*
- *1 hour integration (2 hours for a subsample)*
- *73 hours of MEGARA*
- *58 galaxies observed (82% of the sample)*

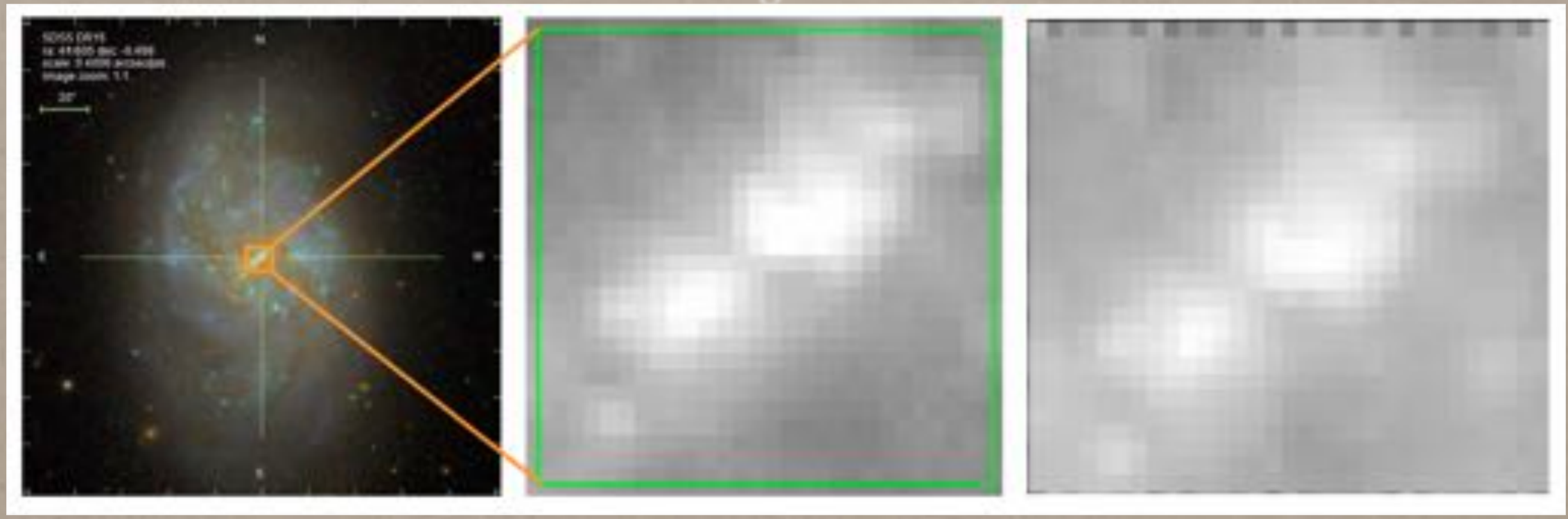


INTEGRAL FIELD SPECTROSCOPY MEGARA@GTC

Data Reduction and Cube Reconstruction

- *MEGARA DRP v0.12*
- *Including bias, tracing, wavelength and spectrophotometric calibration, cosmic rays removal, and diffuse light correction*
- *Datacubes reconstructed at 0.4x0.4 arcsec resolution*

SDSS g-band *MEGARA*

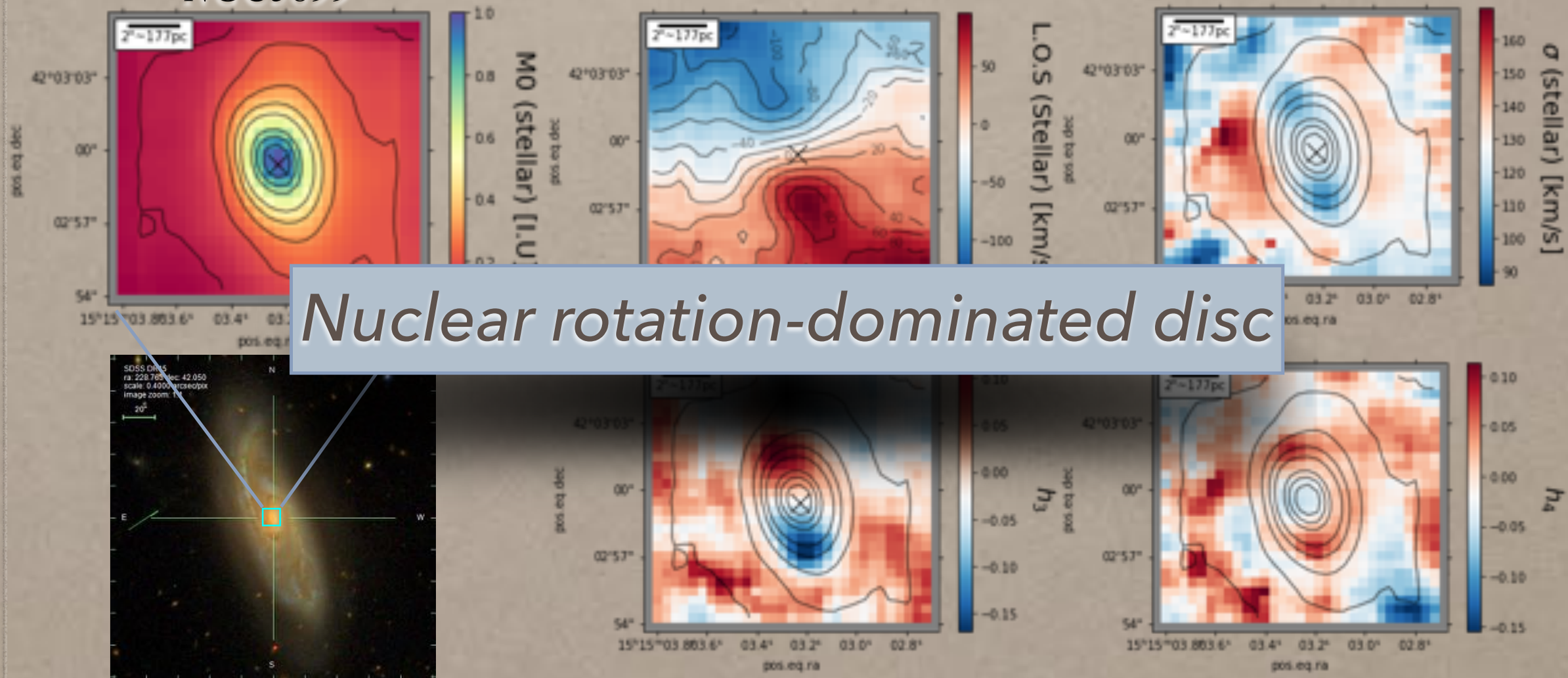


INTEGRAL FIELD SPECTROSCOPY MEGARA@GTC

Stellar kinematics

pPXF fitting using HR-pyPopStar (Millán-Irigoyen et al. 2021)

NGC5899

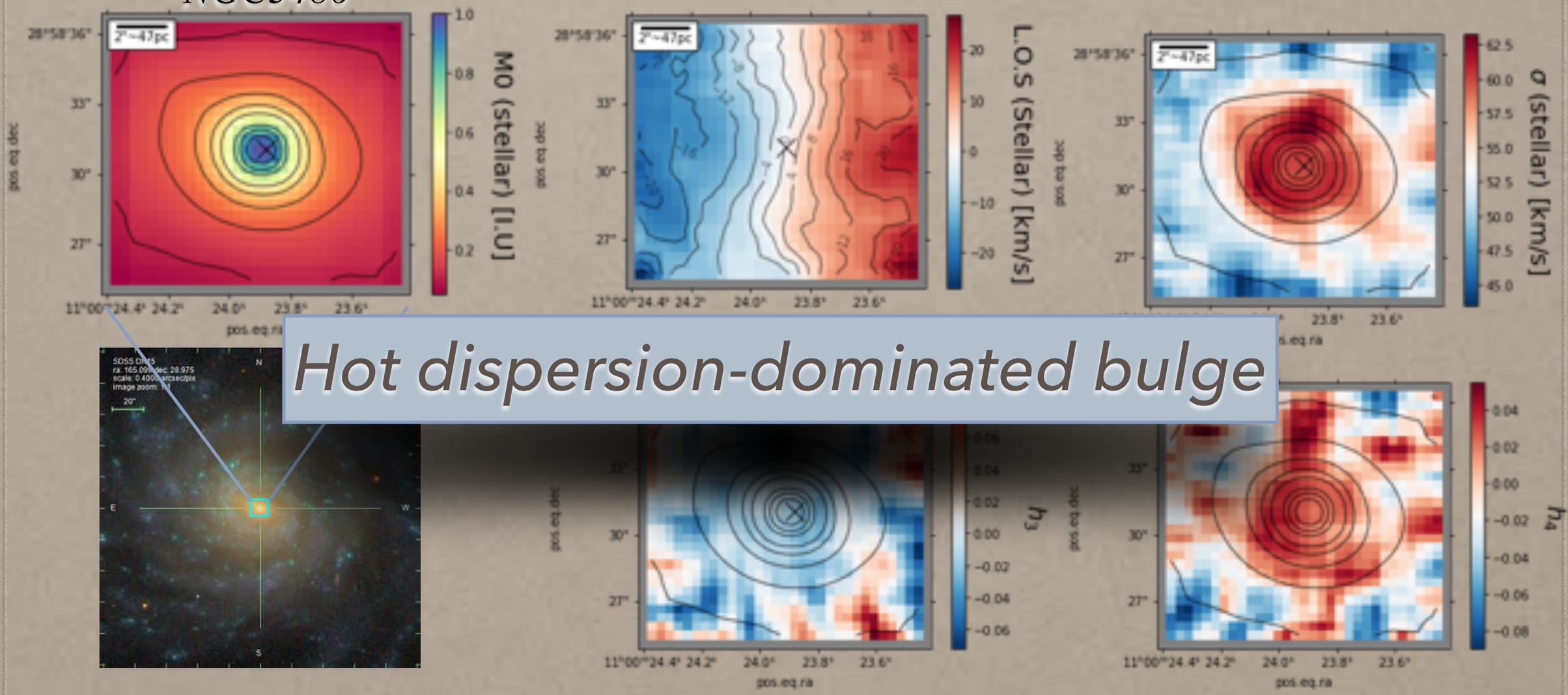


Fernández-Arenas et al. (in prep)

INTEGRAL FIELD SPECTROSCOPY MEGARA@GTC

Stellar kinematics

NGC3486

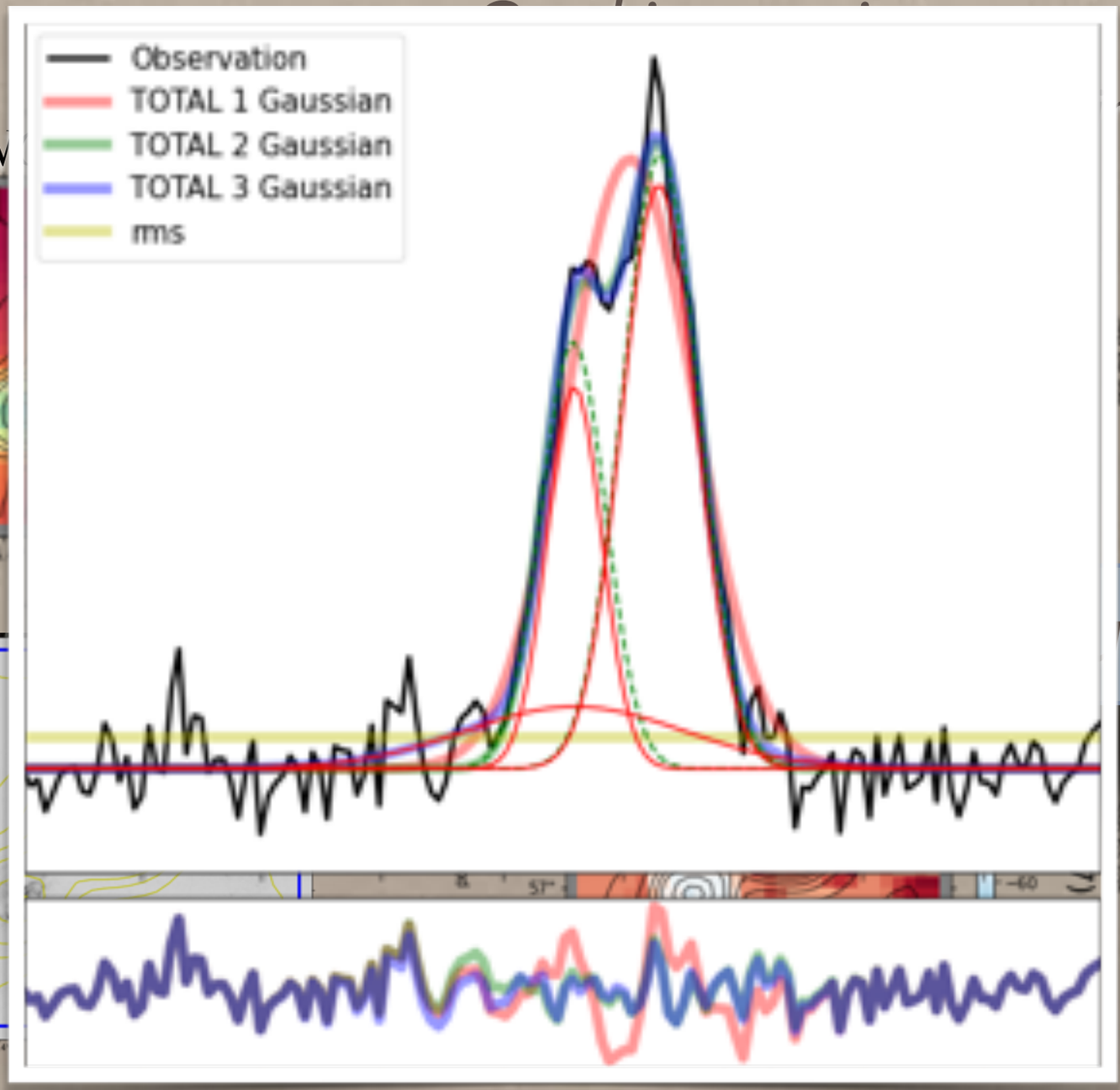


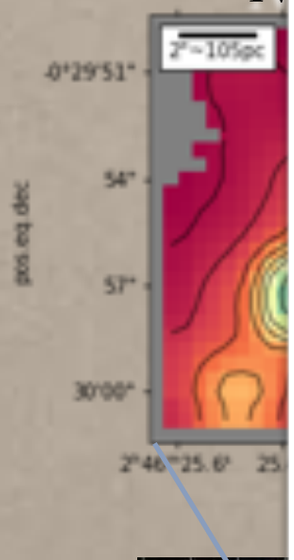
Hot dispersion-dominated bulge

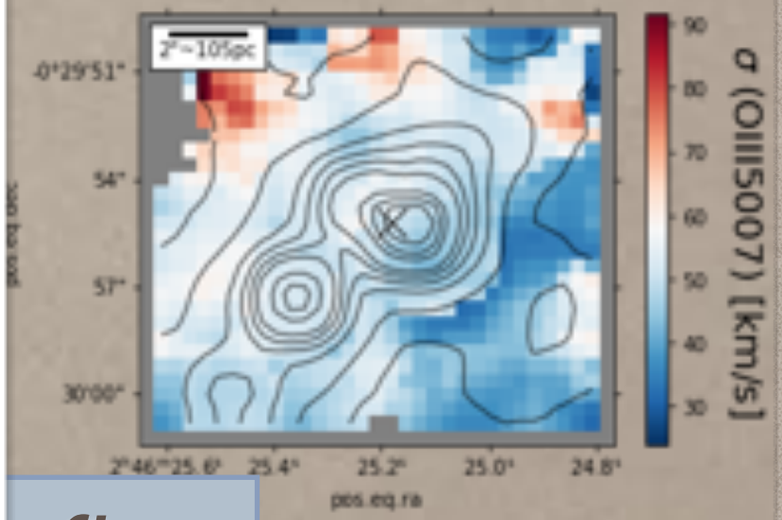
Fernández-Arenas et al. (in prep)

INTEGRAL FIELD SPECTROSCOPY MEGARA@GTC

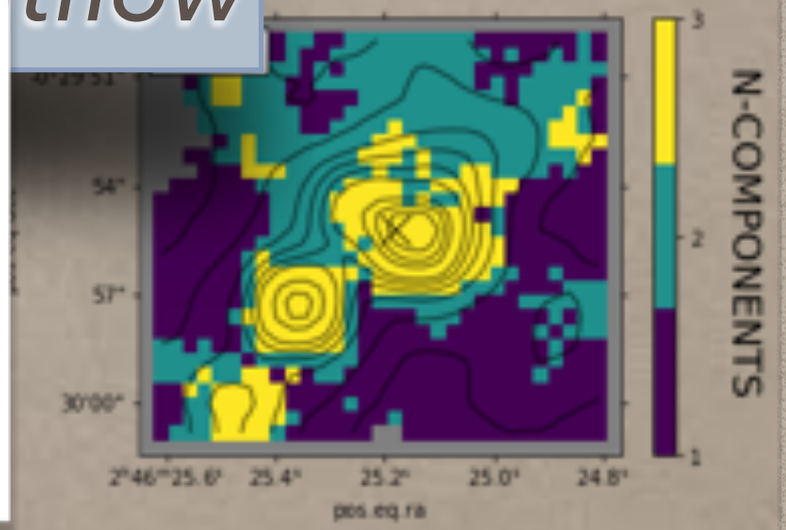
M *ng*







tflow



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Scientific Objectives

SO1: THE NATURE OF STRUCTURES AT THE CENTER OF BULGELESS GALAXIES
SO1.1 Understading the nature of the bulges (classical vs.disk like)

SO1.2 Characterization of nuclear star clusters

SO1.3 Characterise nuclear outflows of gas

SO2: LOW SURFACE BRIGHTNESS FEATURES OF BULGELESS GALAXIES

SO3: STELLAR POPULATIONS AND SF IN BULGELESS GALAXIES
SO3.1 Stellar population gradients along the galaxy major axis

SO3.2 Spatially resolved current star formation

SO4:THEORY AND NUMERICAL SIMULATIONS