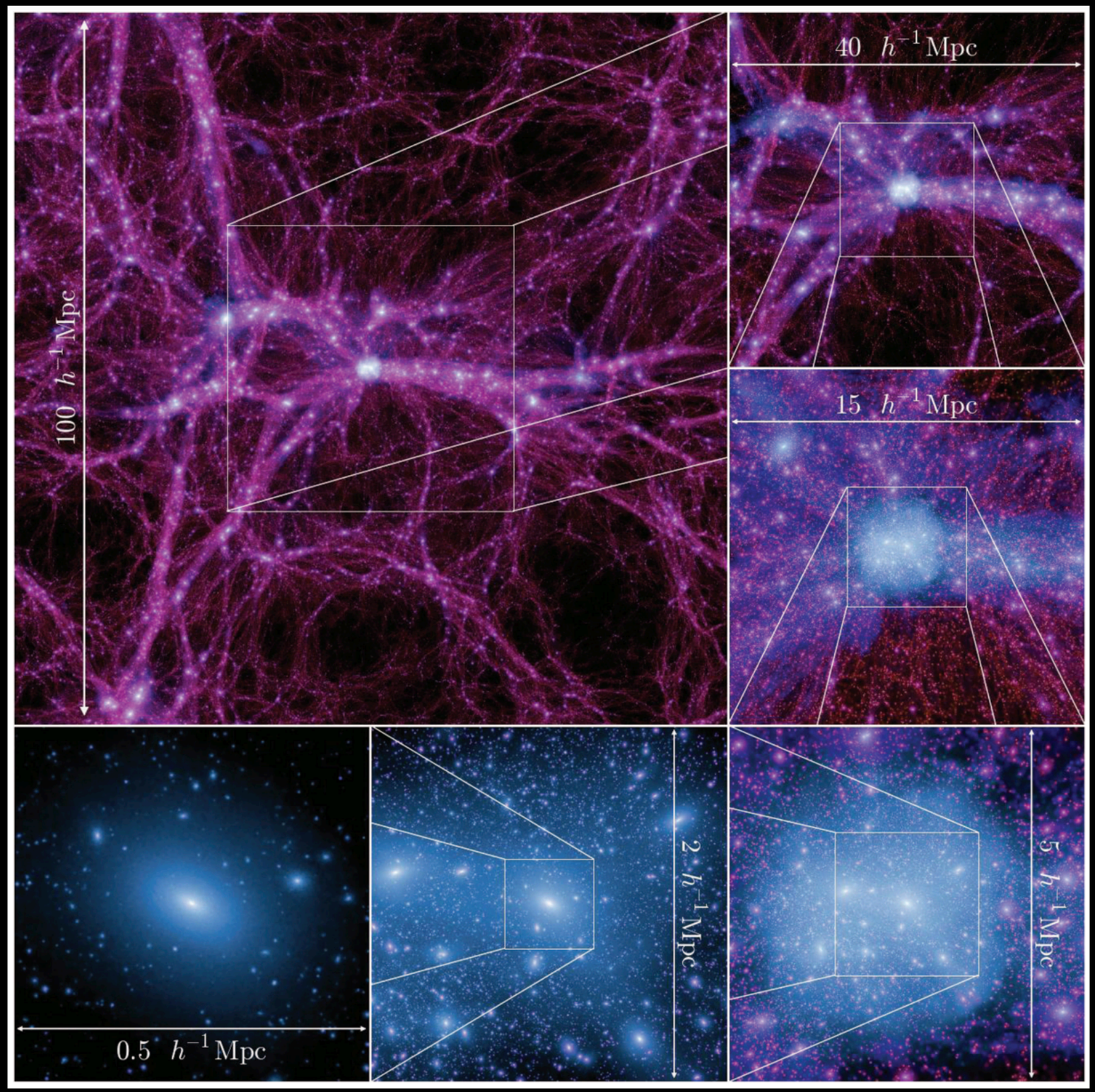
FUELING AND FEEDBACK MECHANISMS AT THE NODES OF THE COSMIC WEB

Mari Polletta

INAF IASF Milan (Italy) & UC San Diego (USA)

SHARP

WHY LOOKING AT THE NODES OF THE COSMIC WEB



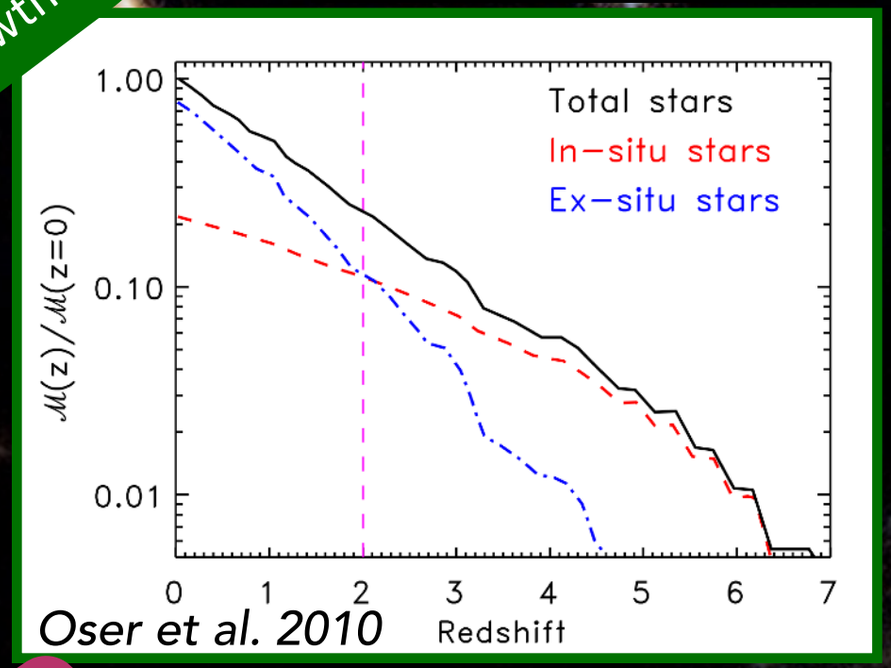
Dark Matter
Baryons

Boylan Kolchin et al. 2009

WHY COSMIC NOON ?

Transition in stellar growth

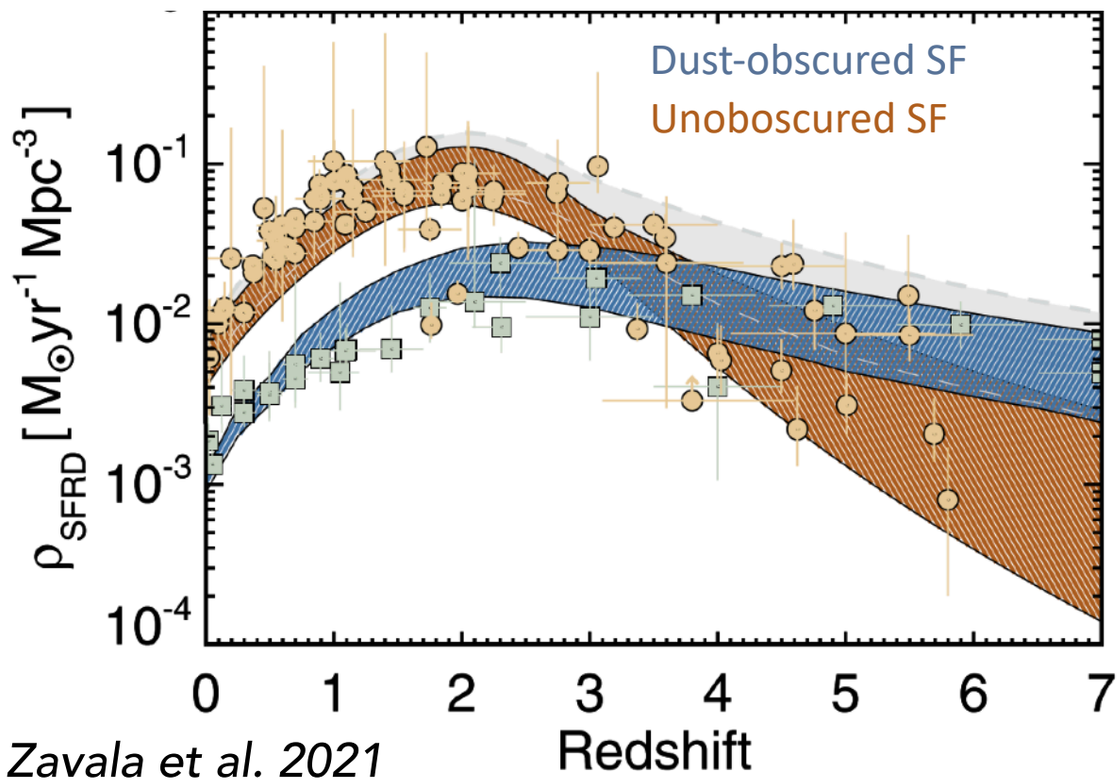
Stellar mass assembly



Oser et al. 2010

Peak of star formation activity

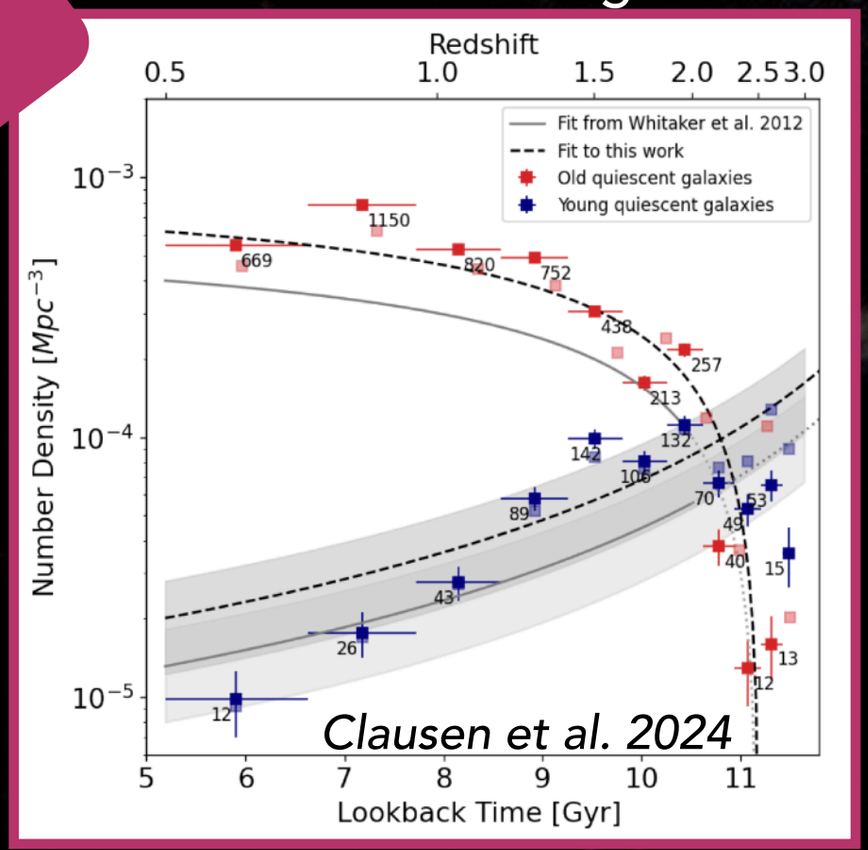
Cosmic SFR Density



Zavala et al. 2021

Rise of quenched galaxies

Quiescent galaxies



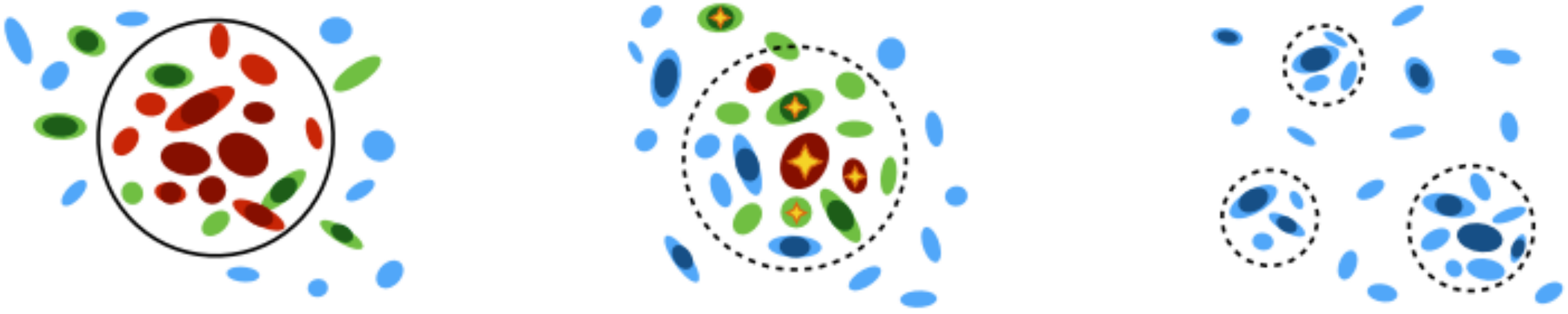
Clausen et al. 2024

+

Structures collapse
ICM build up

TRACING THE GROWING, MATURING AND DECLINING PHASES OF GALAXIES

Declining Phase (z≤2) ⇦ Maturing Phase (2≤z≤3) ⇦ Growing Phase (3≤z)

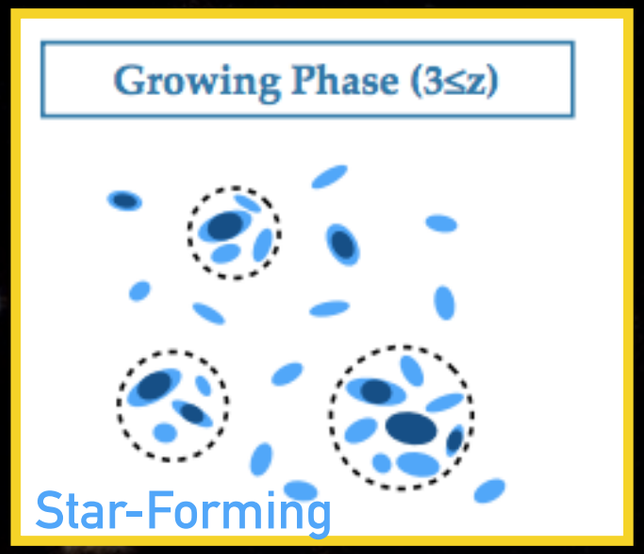


Passive Transitioning AGN Star-Forming

	Declining Phase	Maturing Phase	Growing Phase
Galaxies	Starvation / Environmental quenching	Energetic AGN feedback	Massive galaxy formation
Halo Gas	Cold gas depletion / Superheated plasma	Pre-heating / Core collapse	Cold gas stream in hot gas

Shimakawa et al. 2018

TRACING THE GROWING, MATURING AND DECLINING PHASE OF GALAXIES



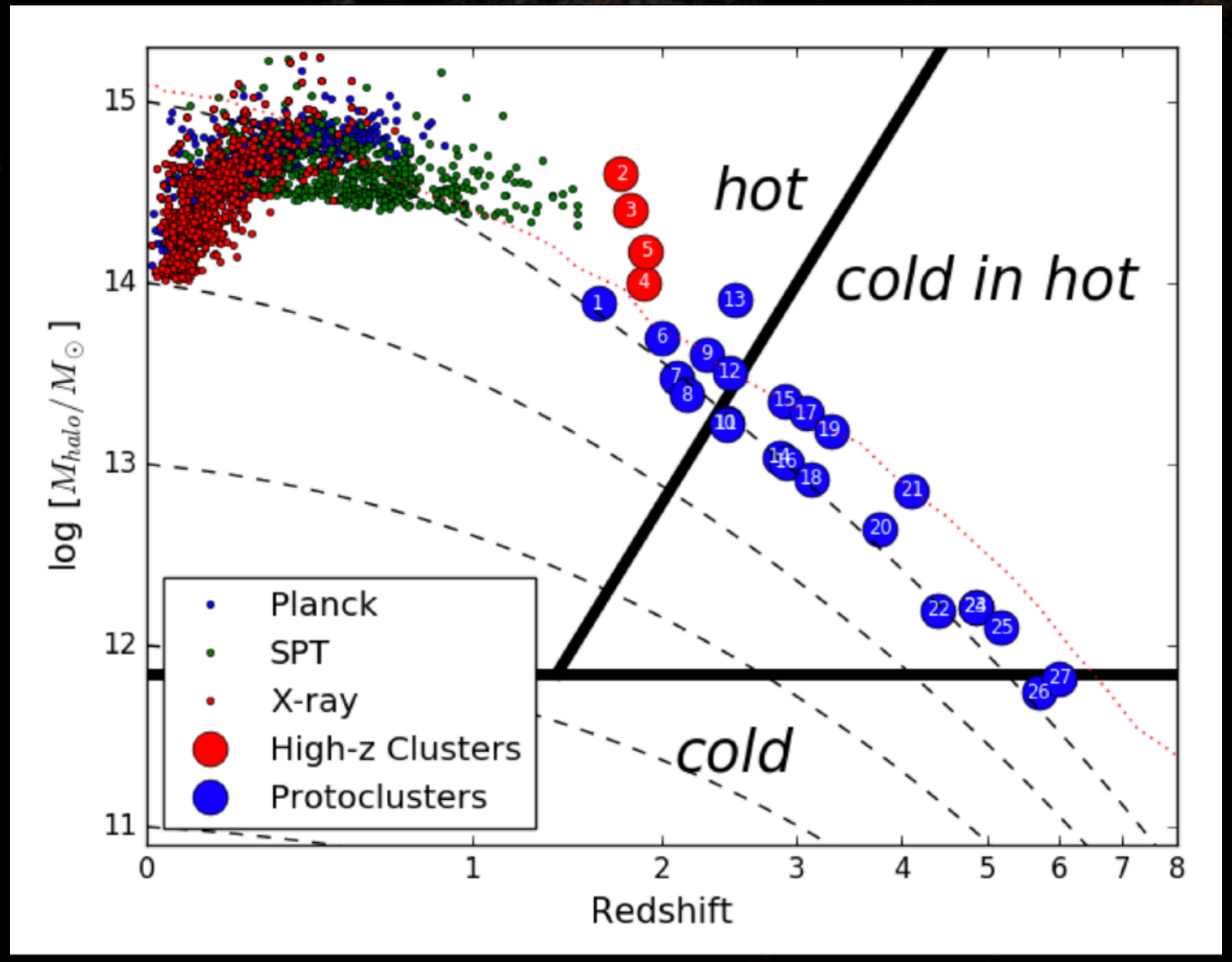
Shimakawa et al. 2018

Major mergers

Fast (<1 Gyr)

Gas accretion

Secular (>1 Gyr)

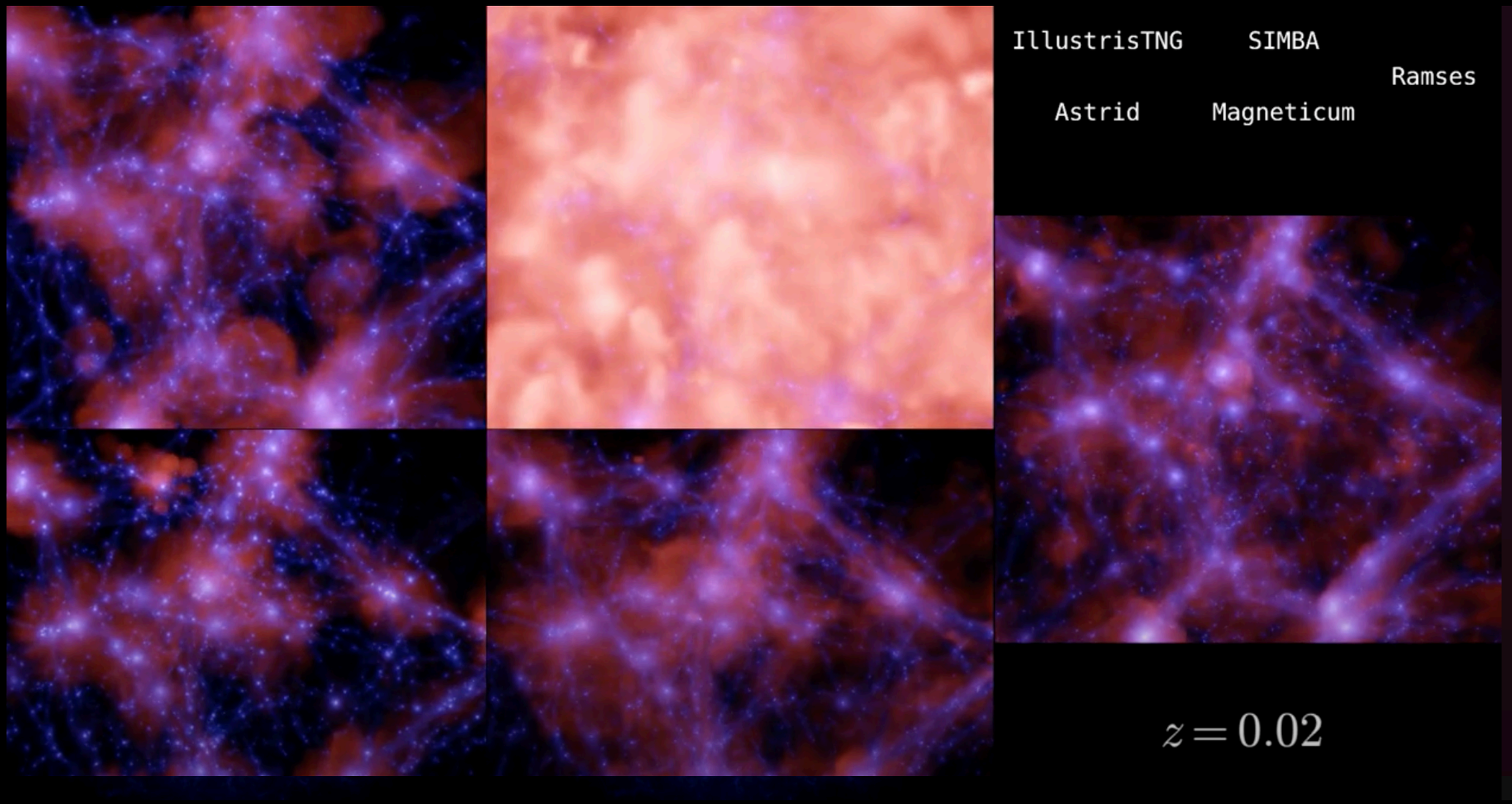


Overzier et al. 2016
Dekel e al. 2009

CAMELS

Cosmology and Astrophysics with MachinE Learning Simulations

WIDE VARIETY OF PREDICTIONS FROM SIMULATIONS

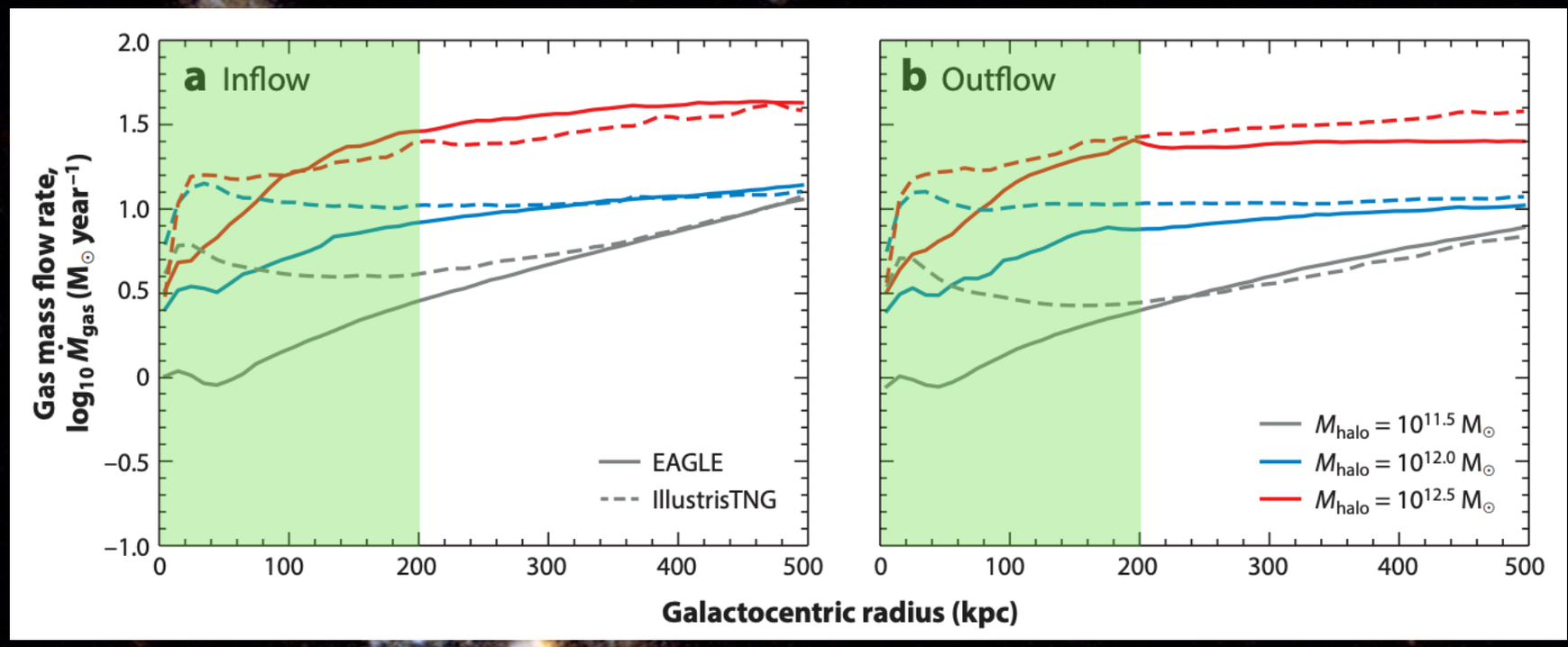


THE BARYON CYCLE IN COSMOLOGICAL SIMULATIONS

(Talks by Fossati and Tortora; Nelsom et al. 2019, Mitchell et al. 2020, Pandya et al. 2021)

M_{gas} rate
VS
Radius

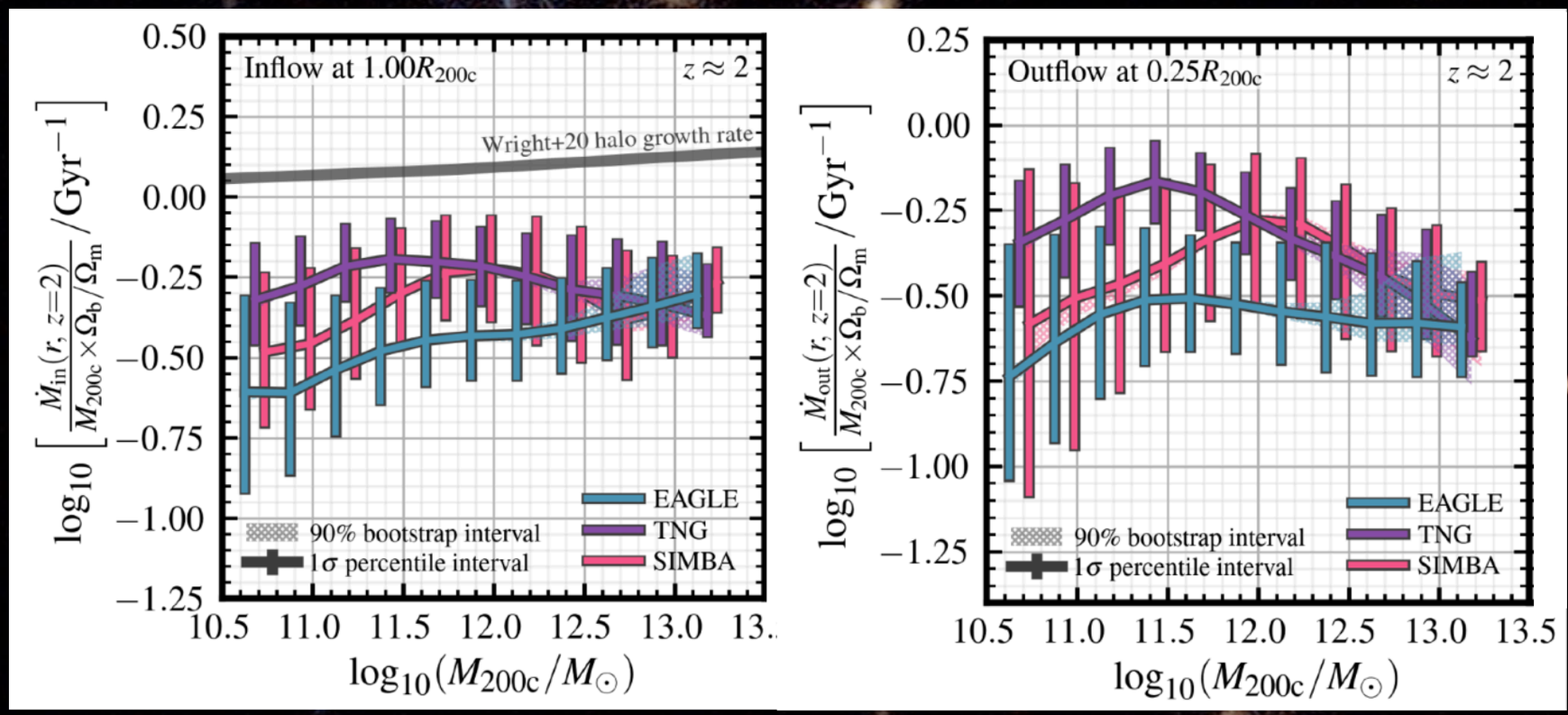
Large differences at R<200 kpc



Crain & van de Voort 2023

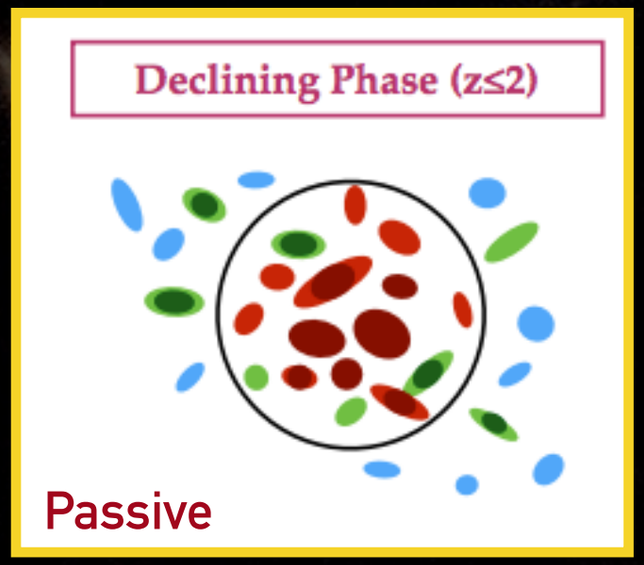
M_{gas} rate
VS
M_{halo}

SF and AGN driven feedbacks depend on halo mass



Wright et al. 2024

TRACING THE GROWING, MATURING AND DECLINING PHASE OF GALAXIES



Shimakawa et al. 2018

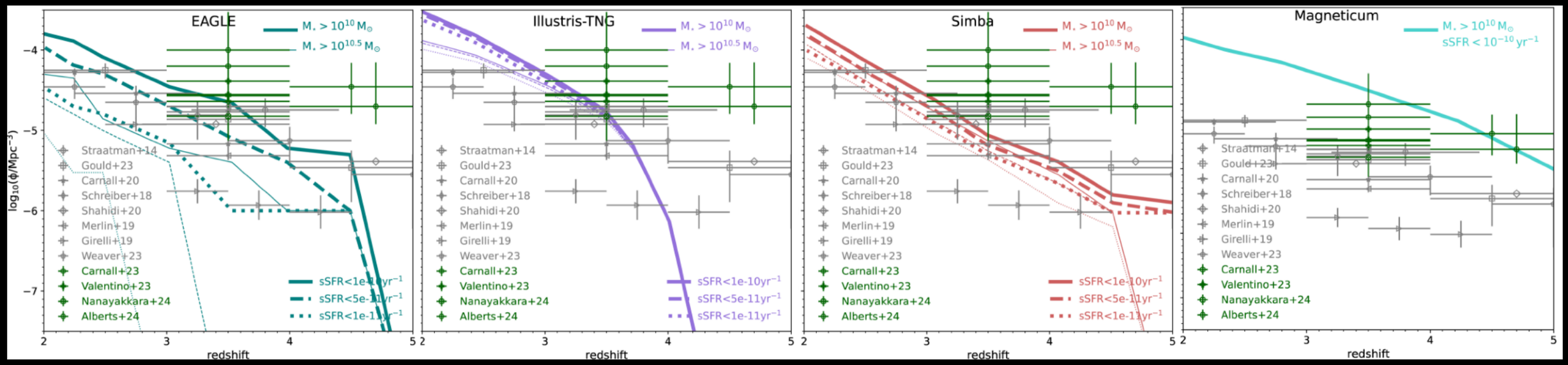
Star formation **quenching**

➥ how (gas removal, heating, stripping) and why (SNe, AGN, interactions)

Alberts & Noble 2023

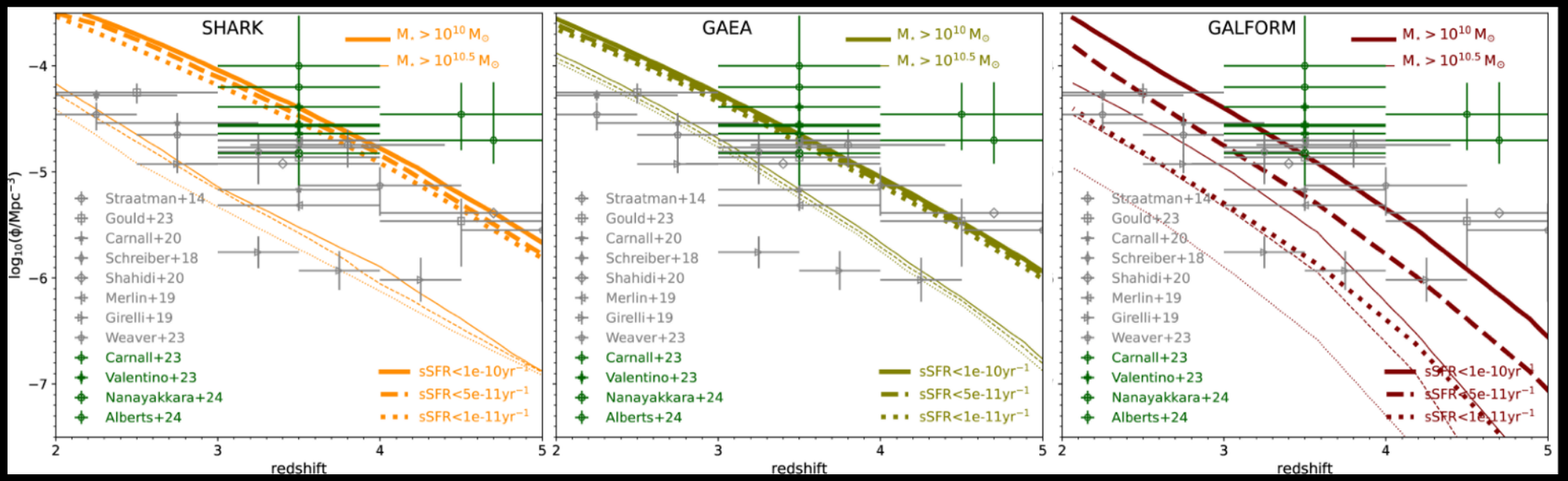
NUMBER DENSITIES OF MASSIVE PASSIVE GALAXIES AT 2<Z<5

Hydrodynamical simulations



EAGLE IllustrisTNG Simba Magneticum

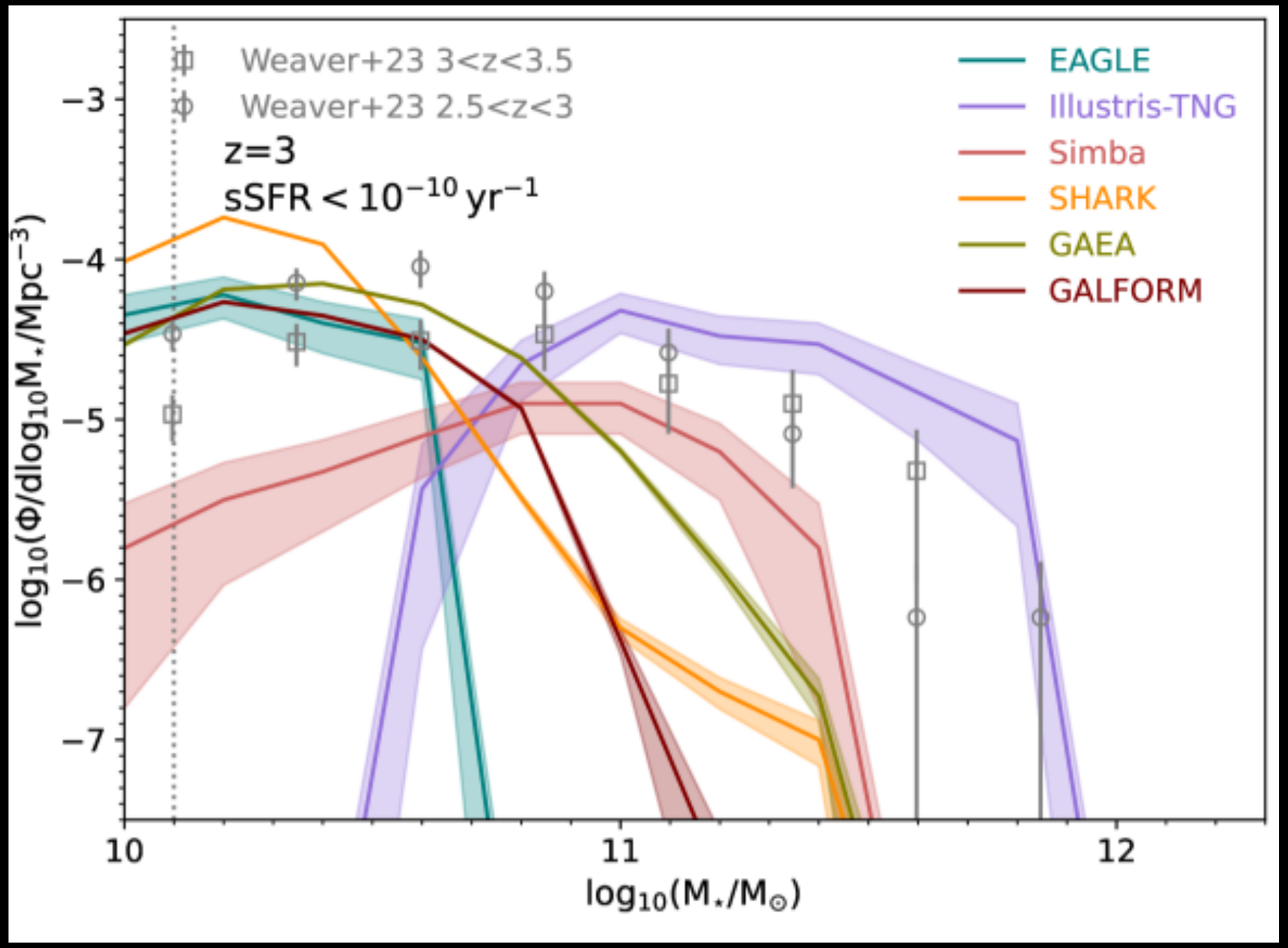
SAMs



SHARK GAEA GALFORM

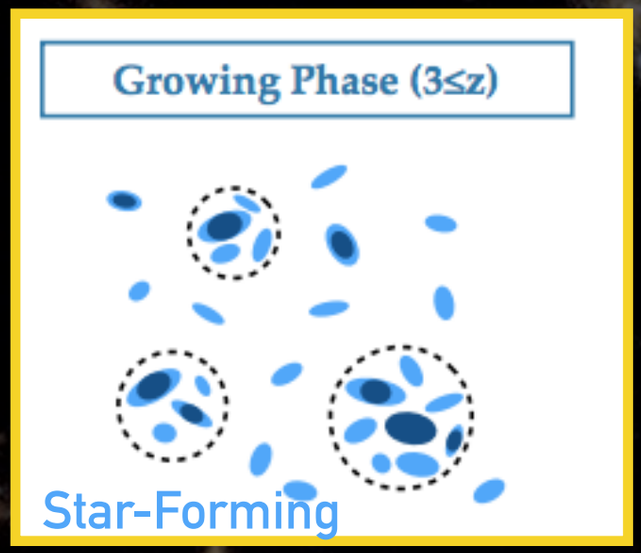
Lagos et al. 2024

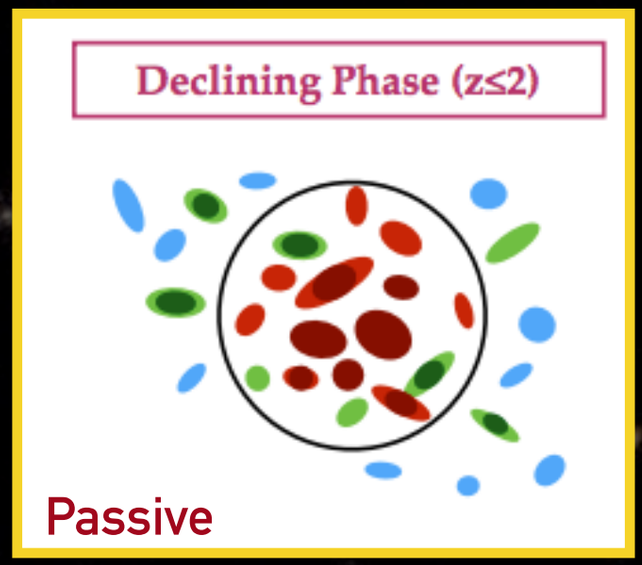
STELLAR MASS FUNCTION OF MASSIVE PASSIVE GALAXIES AT Z=3



Lagos et al. 2024

PROTOCLUSTERS : WHERE ALL THE ACTION TAKES PLACE





Triggering and fueling **activity**

➥ galaxy mergers, gas accretion,…

Dekel et al. 2009

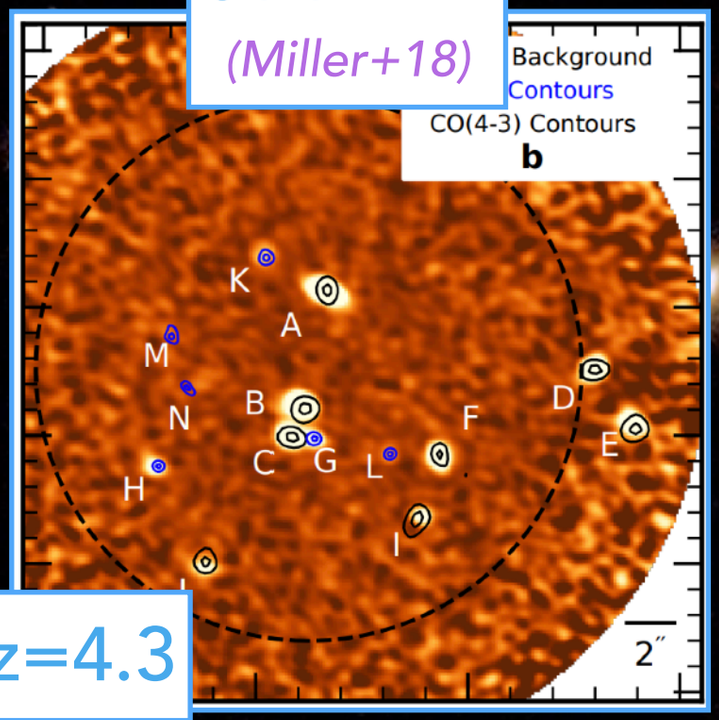
NASA, ESA, the Hubble Heritage Team (STScI/AURA)-ESA/Hubble Collaboration and K. Noll (STScI)

Star formation **quenching**

➥ how (gas removal, heating, stripping) and why (SNe, AGN, interactions)

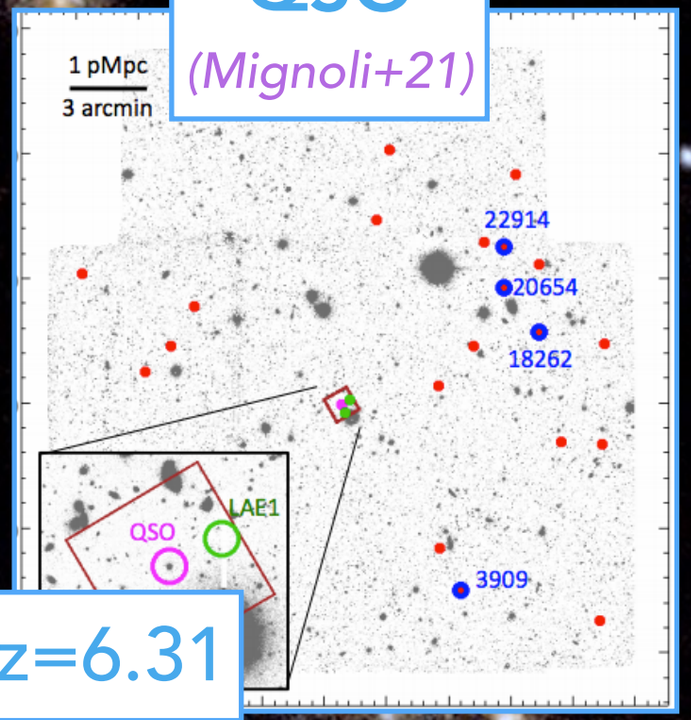
PROTOCLUSTER SEARCHES

Sub-mm
(Miller+18)



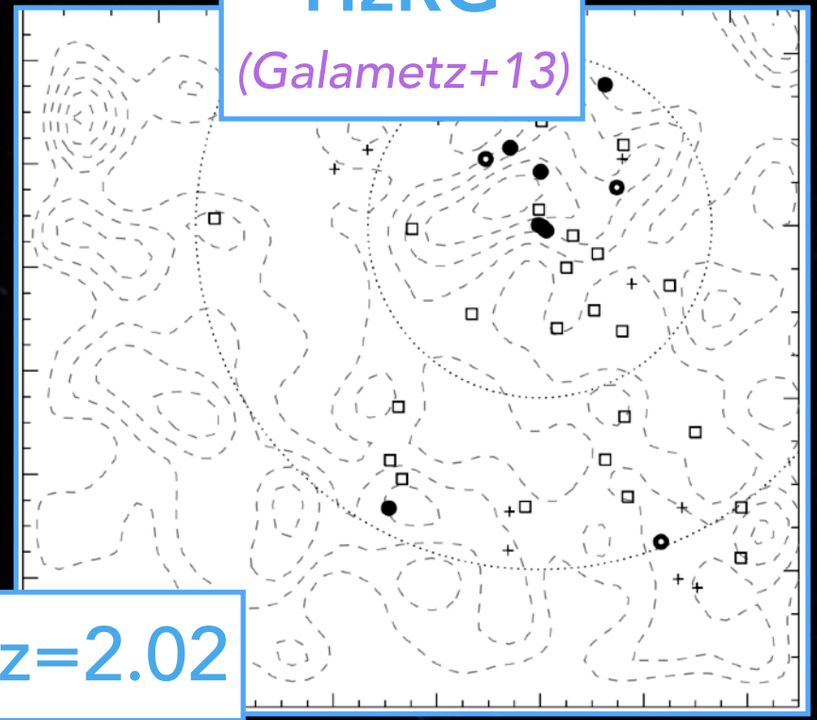
z=4.3

QSO
(Mignoli+21)



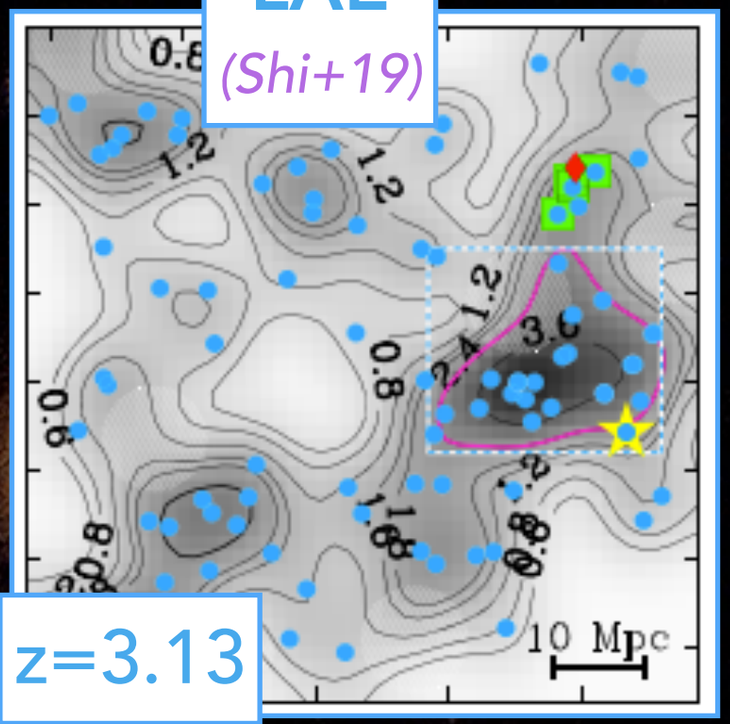
z=6.31

HzRG
(Galametz+13)



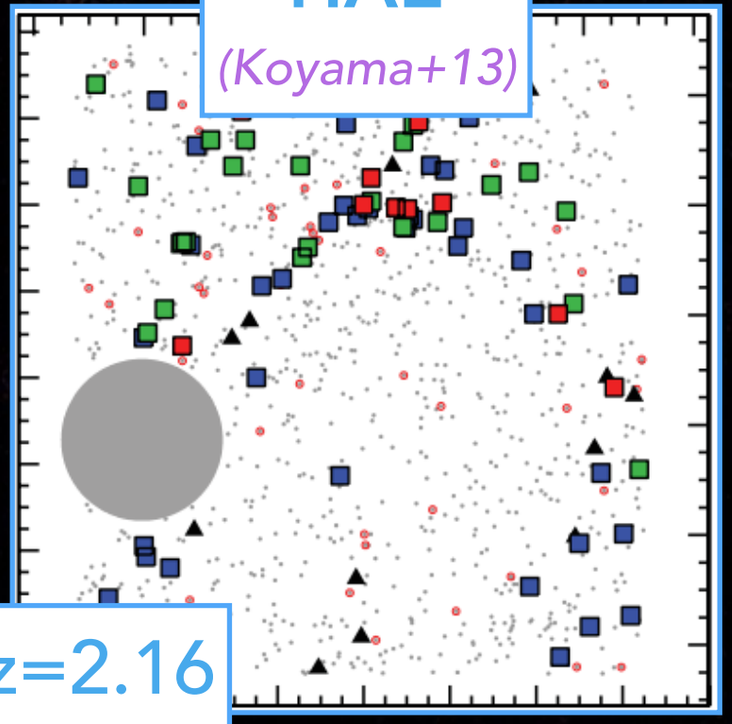
z=2.02

LAE
(Shi+19)



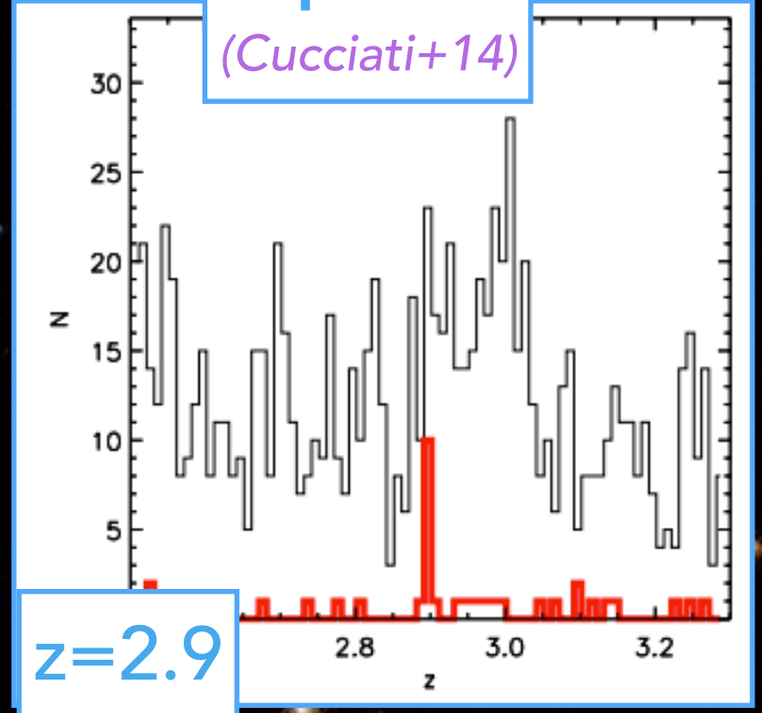
z=3.13

HAE
(Koyama+13)



z=2.16

Spec-z
(Cucciati+14)

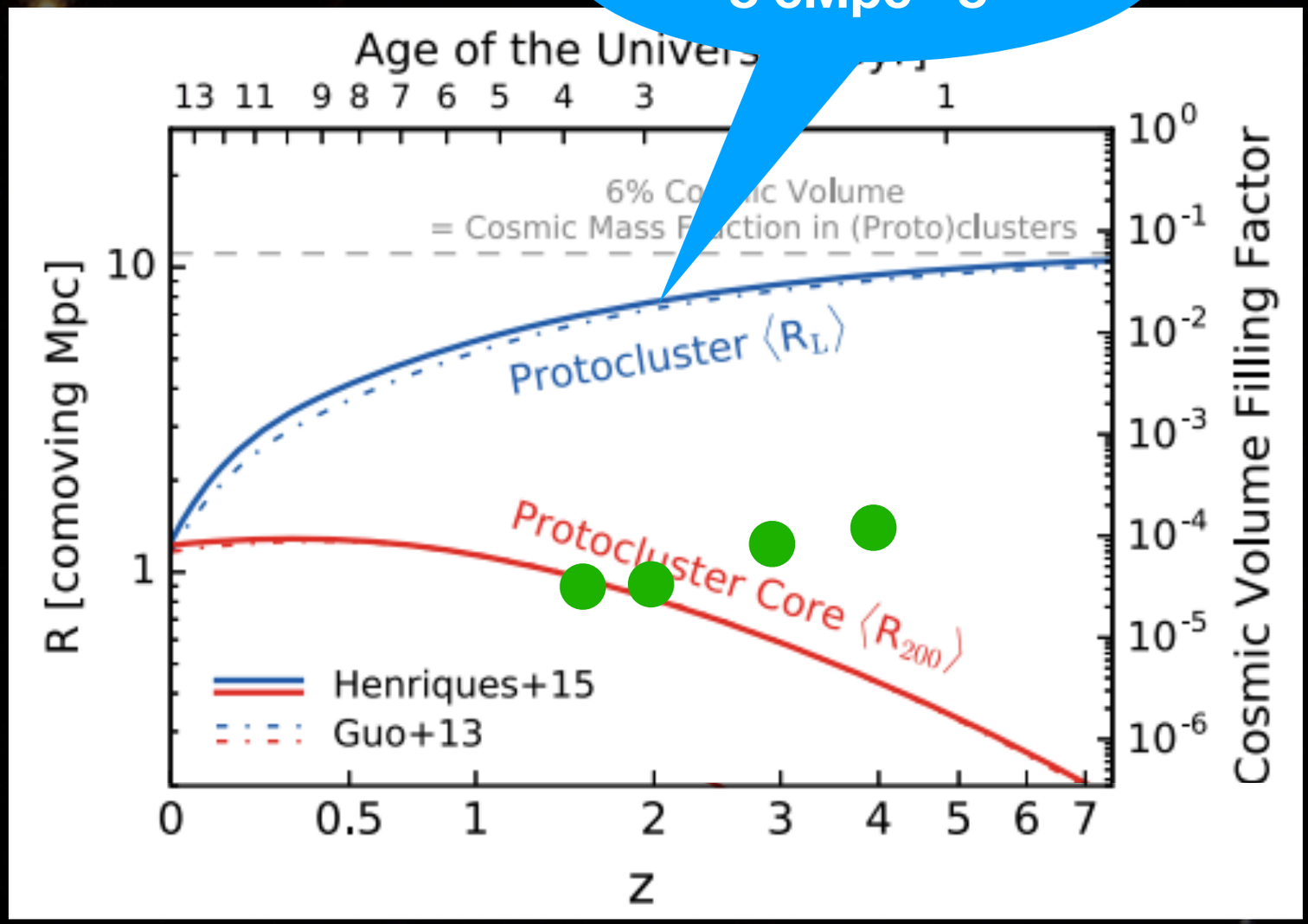


z=2.9

HOW BIG ARE PROTOCLUSTERS?

NEXUS-MOS: 72″
VESPER: 24″x72″

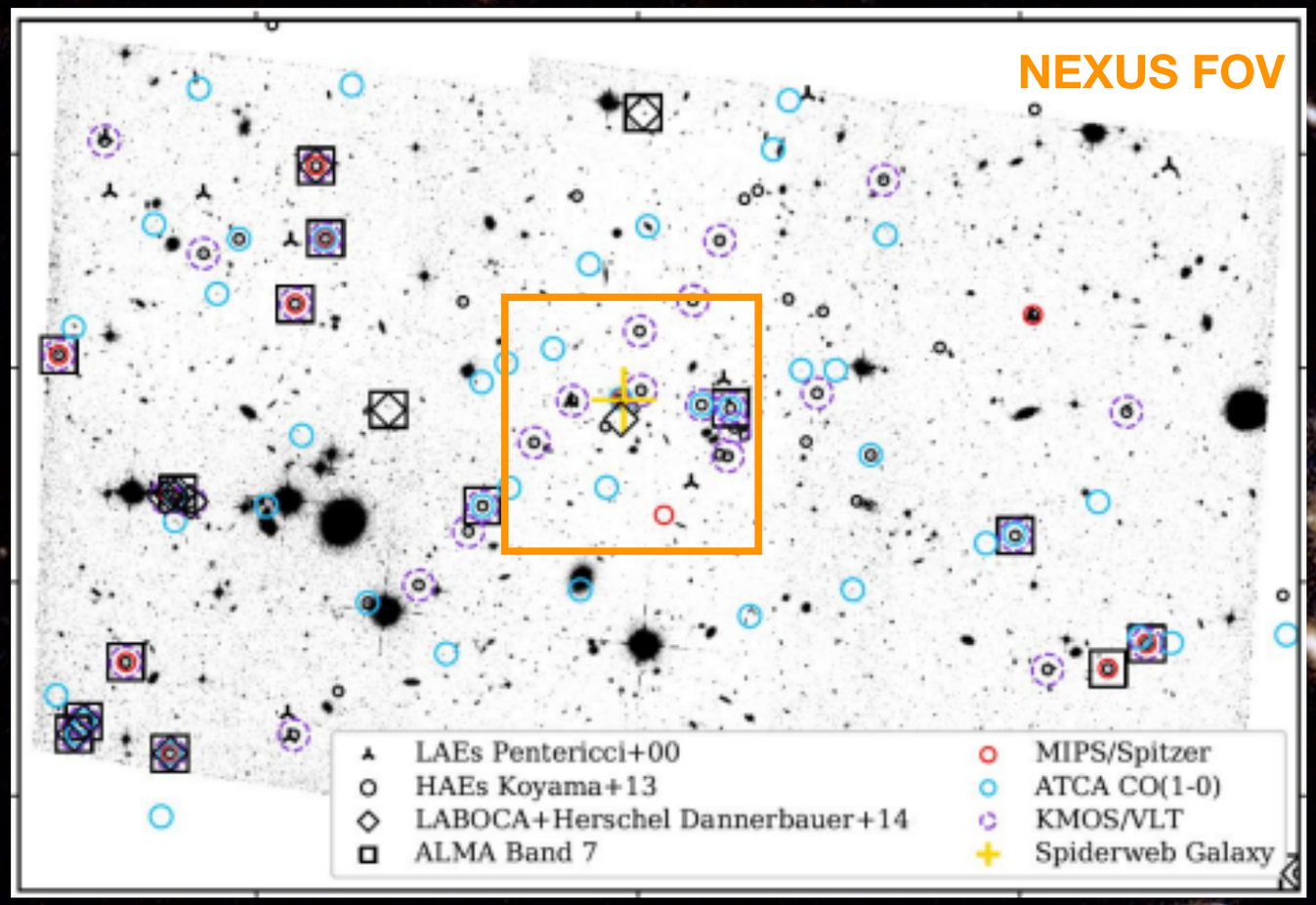
1 arcmin:
0.9 cMPc (z=1.5)
1.0 cMPc (z=2.0)
1.3 cMPc (z=3.0)
1.4 cMPc (z=4.0)



Chiang et al. 2017

NEXUS FOV vs PROTOCLUSTERS EXTENT (HAE & CO)

Spiderweb z=2.16

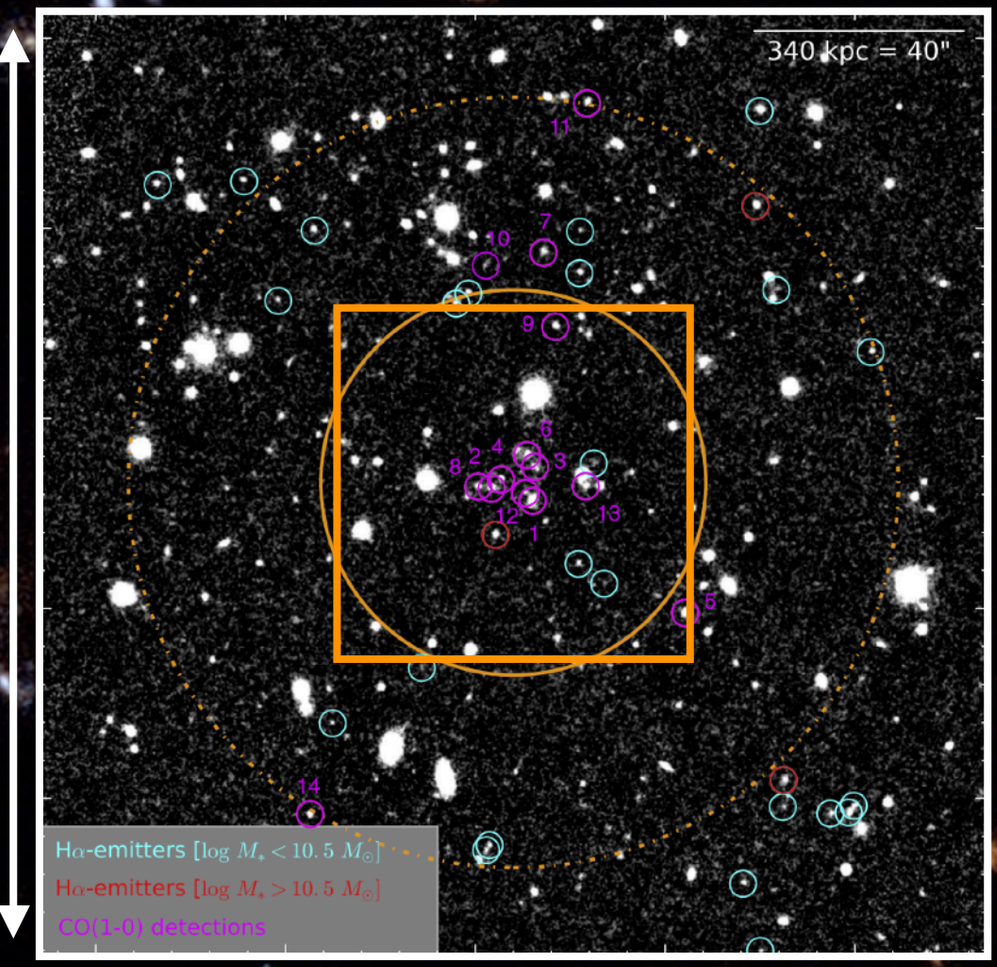


~15 members in NEXUS FOV

~5 arcmin = 5 cMPc

Perez-Martinez et al. 2023

CLJ1001 z=2.51



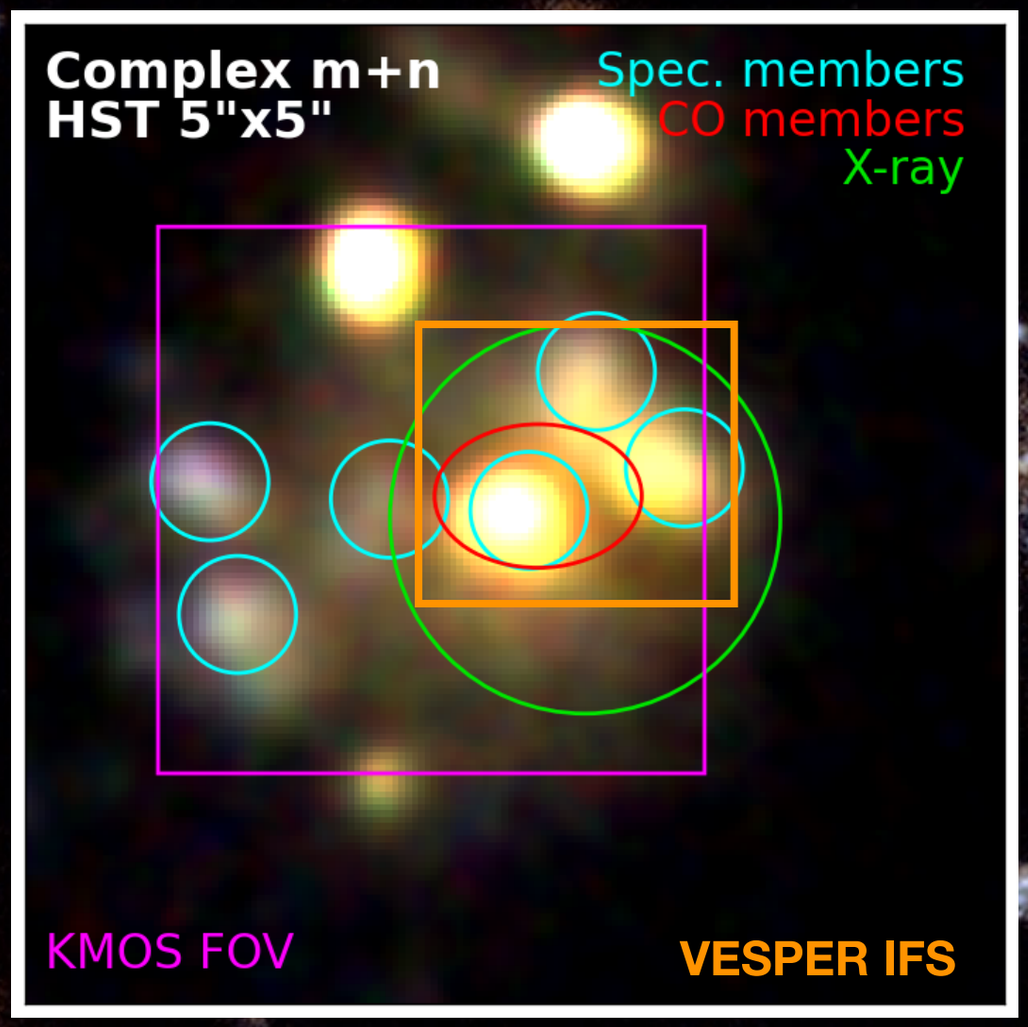
~13 members in NEXUS FOV

Wang et al. 2018

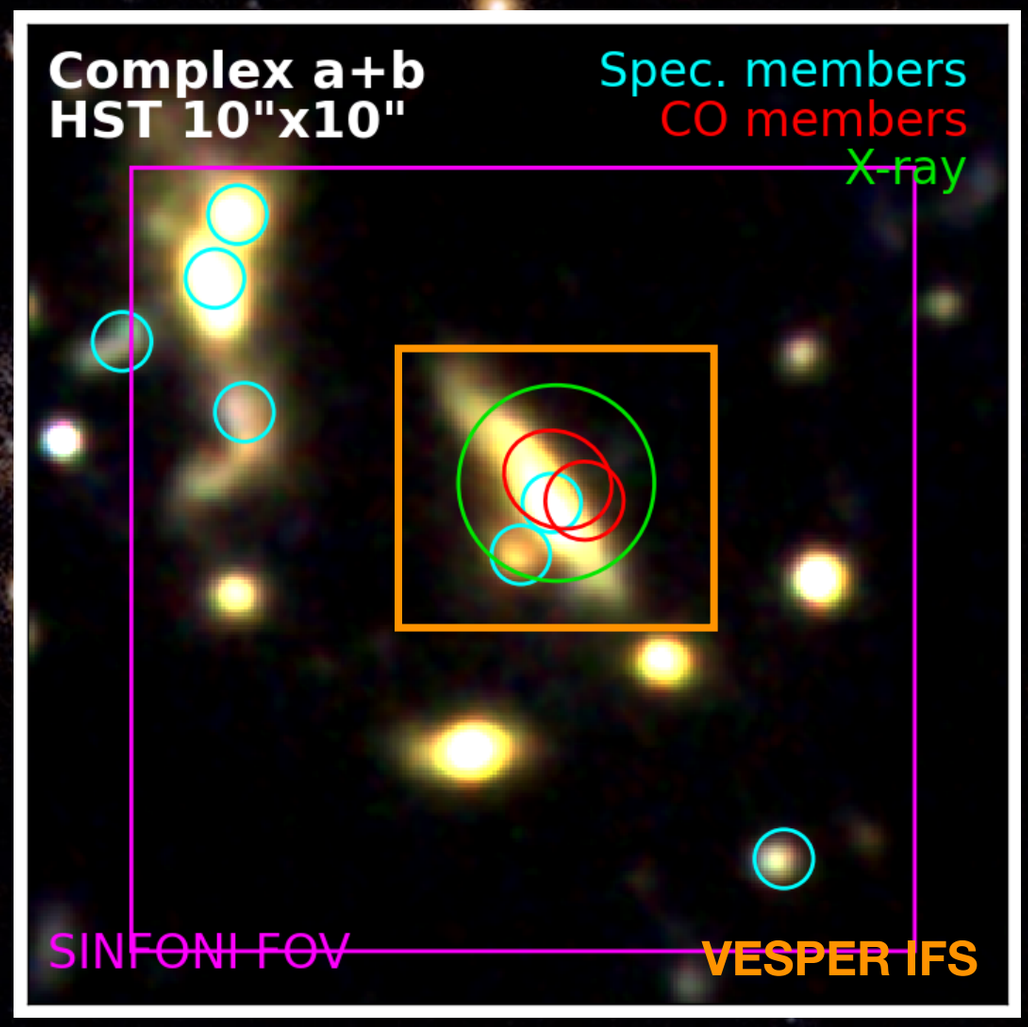
NEXUS FOV : 1.2′ x 1.2′

VESPER VS CLUSTER CORES (PROTO-BCG)

XDCP J0044.3-2033 z=1.58



Lepore et al. 2022



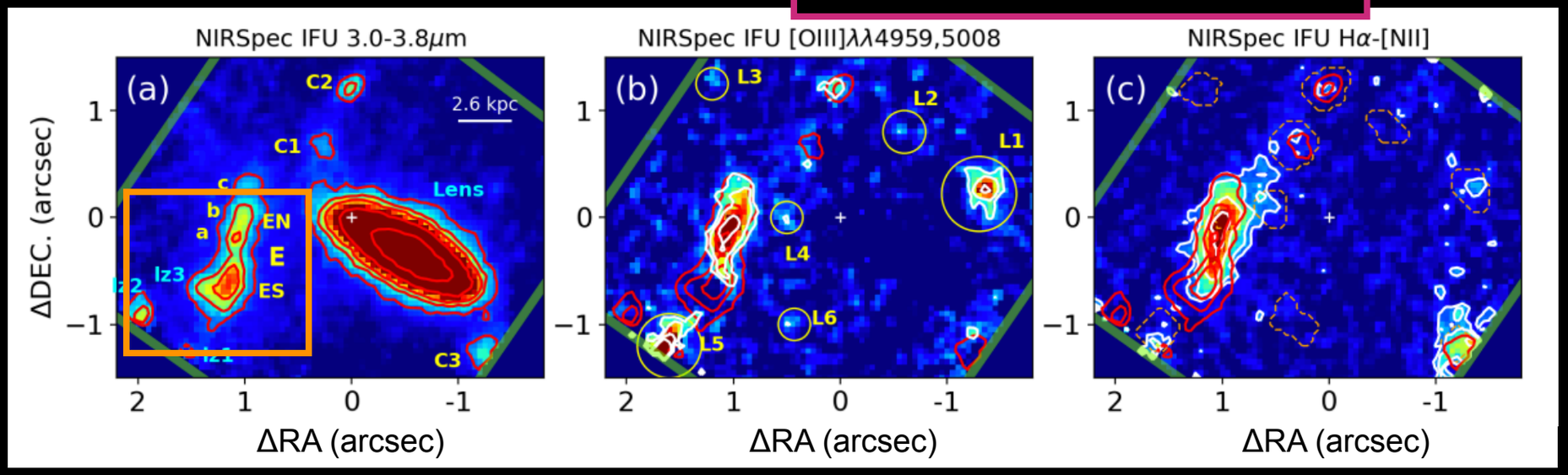
Travascio et al. 2020

VESPER FOV : 24″ x 70″
VESPER IFS: 1.7″ x 1.5″

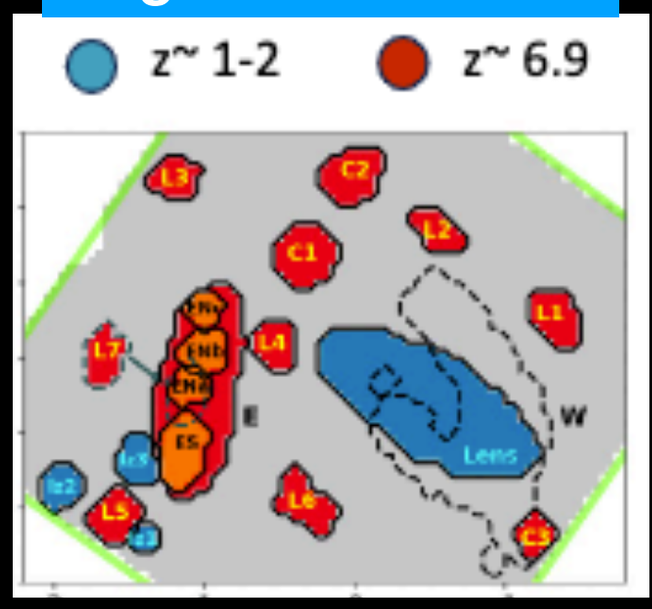
JWST VIEW OF PROTOCLUSTERS GALAXIES

- Identification (z_{phot}, z_{spec}, around QSO or DSFGs, absorption systems)
- Members global properties (SF/Q, AGN)
- Structure dynamical status & z=0 halo mass

SPT0311–58 z=6.9



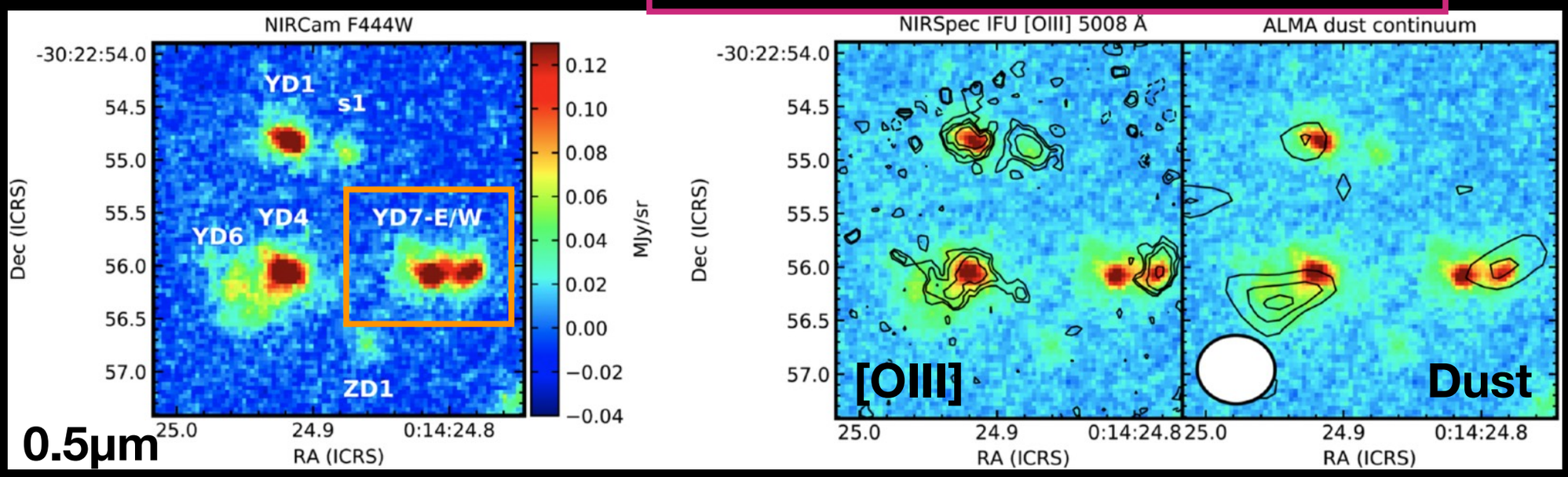
12 galaxies @ z~6.9



Arribas et al. 2024

VESPER IFS: 1.7″ x 1.5″

A2744-z7p9OD (RIOJA) z=7.88

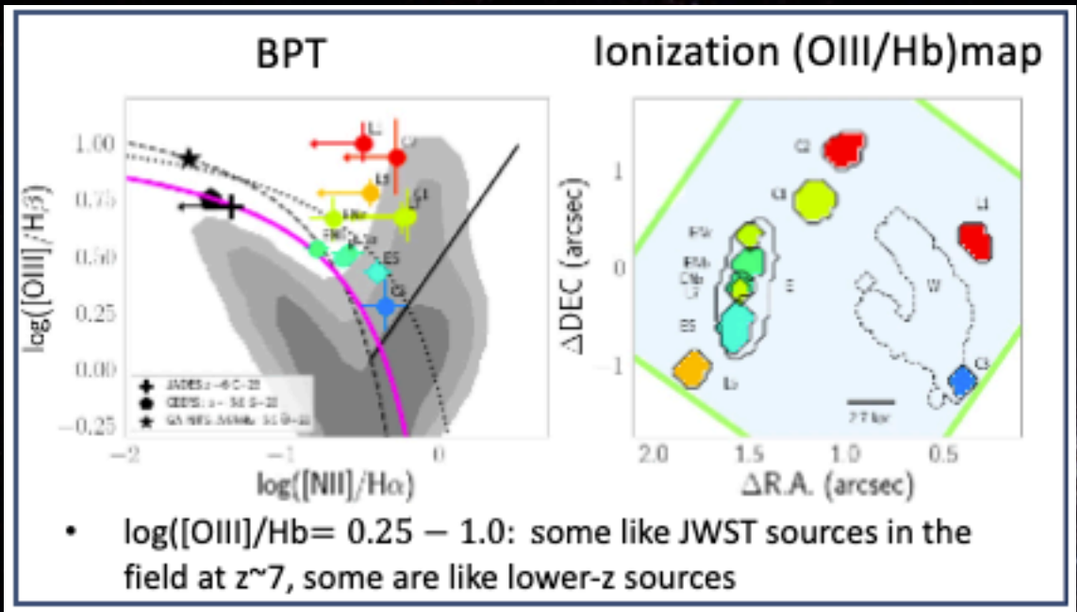


4 galaxies @ z~7.88 in 3″x3″

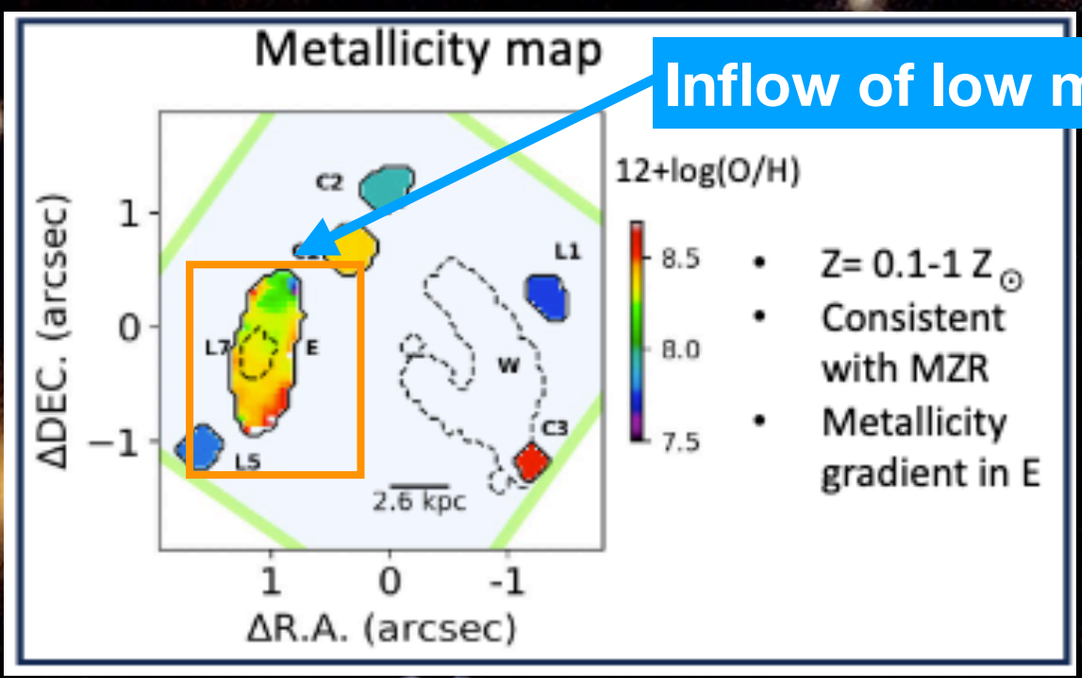
Morishita et al. 2023; Hashimoto et al. 2024

JWST LESSONS ON PROTOCLUSTERS AT Z>5

- Power source (SF vs AGN) and SFR
- Gas kinematics
- Metallicity



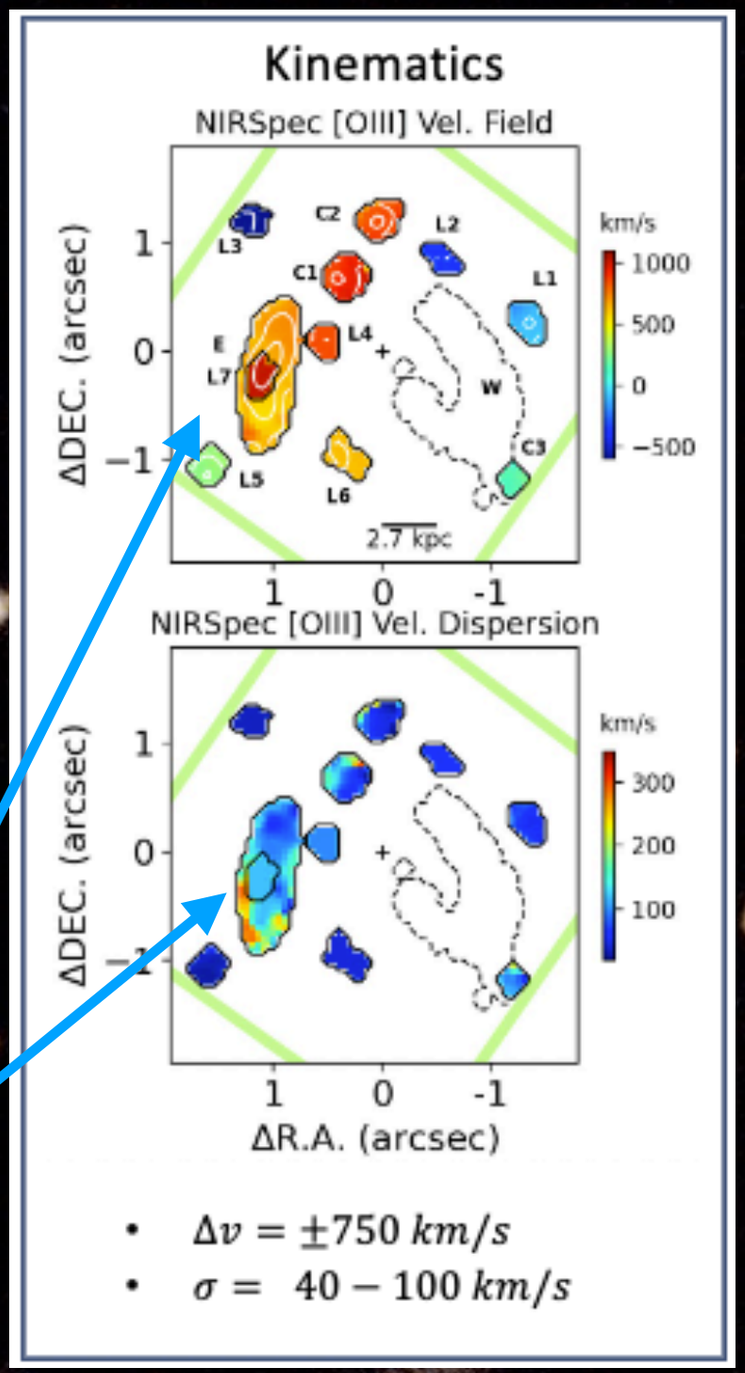
- log([OIII]/Hb= 0.25 − 1.0: some like JWST sources in the field at z~7, some are like lower-z sources



- Z= 0.1-1 $Z_{\odot}$
- Consistent with MZR
- Metallicity gradient in E

Inflow of low metallicity gas

Turbulent disc



- $\Delta v = \pm 750\ km/s$
- $\sigma = \ 40 - 100\ km/s$

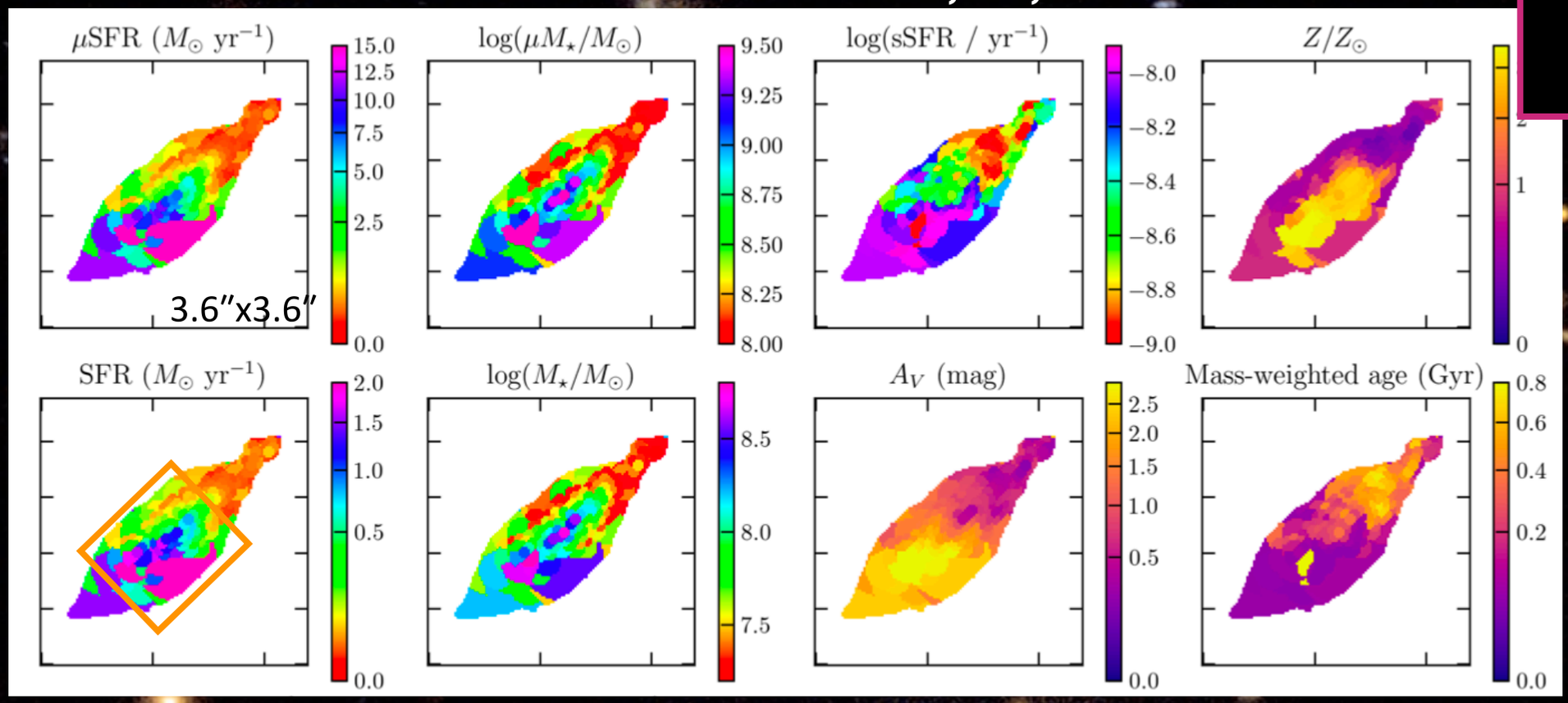
VESPER IFS: 1.7″ x 1.5″

Arribas et al. 2024

JWST STUDIES OF Z~2 PROTOCLUSTER GALAXIES

- Resolved SFR, Av, Mstar

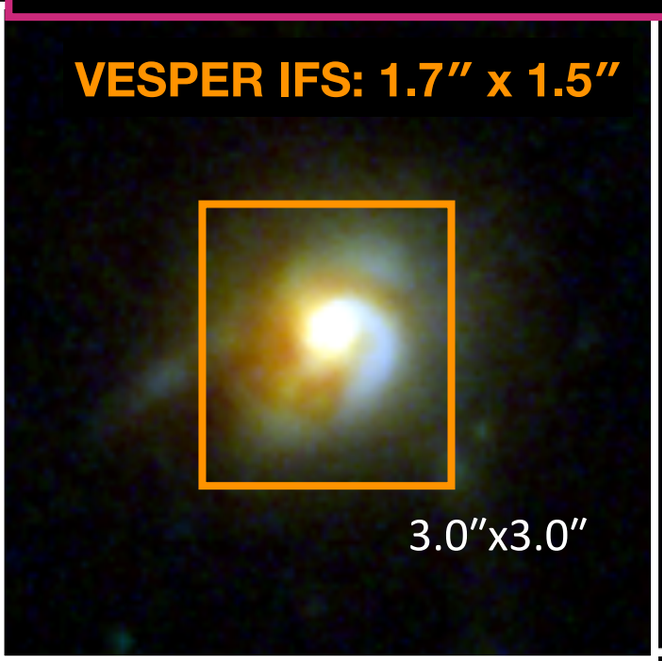
G165 DSFG-1
(Arc-1a) z=2.2

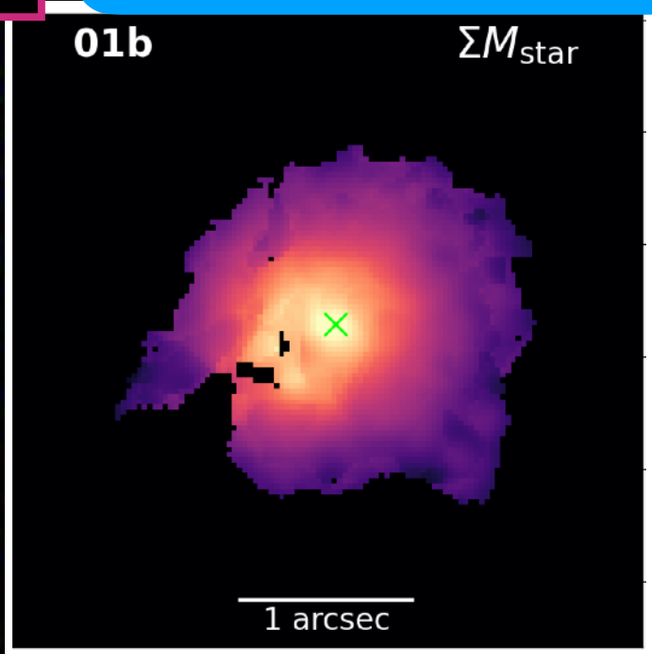


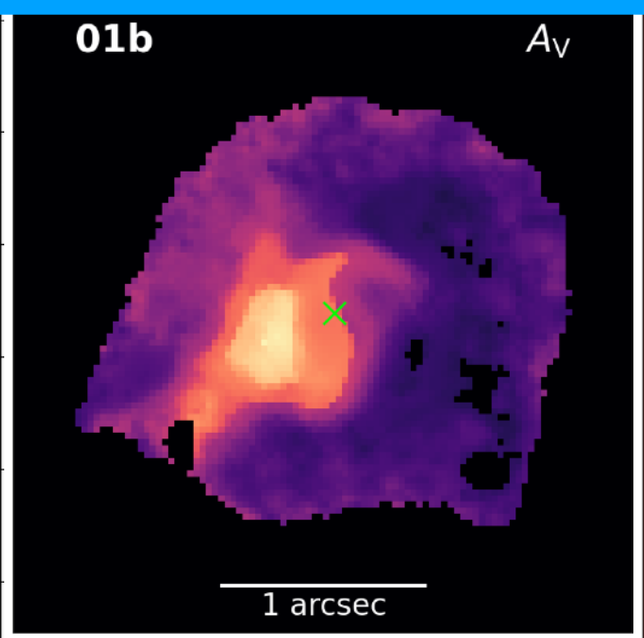
Kamieneskí et al. 2024

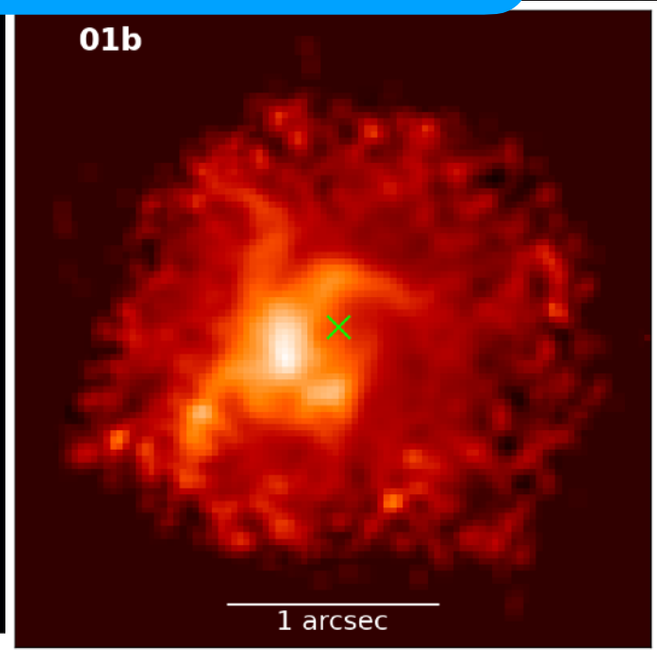
G191 01b z=2.42

Variations of SFR, M_{star}, metallicity, Av and age across galaxies









Polletta et al. 2024

GROUND-BASED STUDIES OF Z~2 GALAXIES

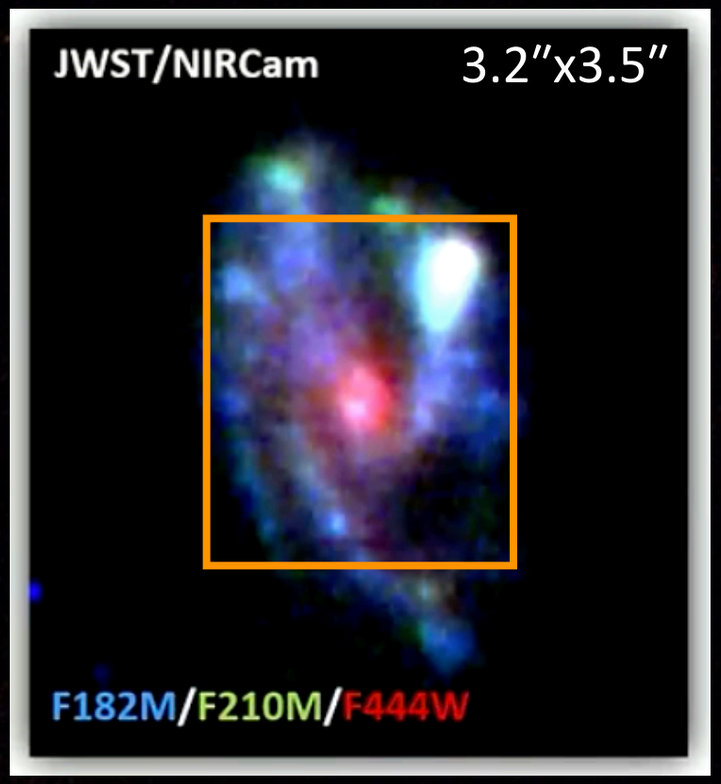
We would like to carry out on protocluster galaxies

K20 ID7 z = 2.225

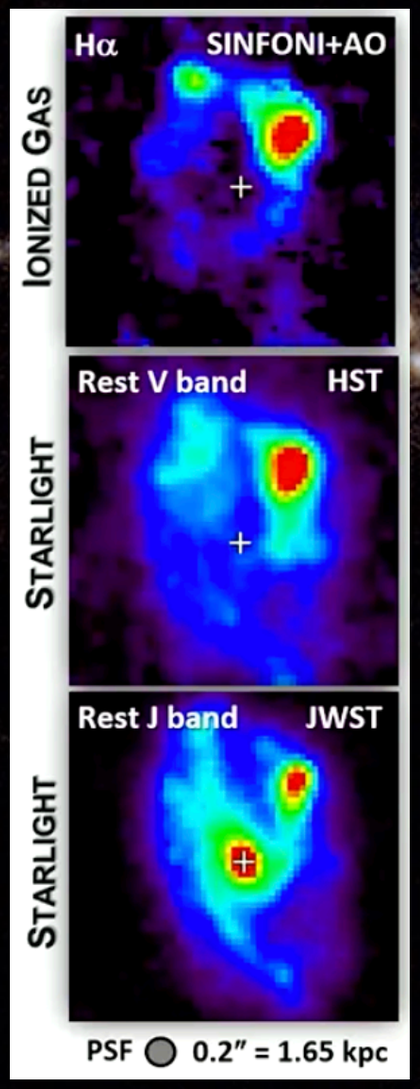
The origin of color gradients

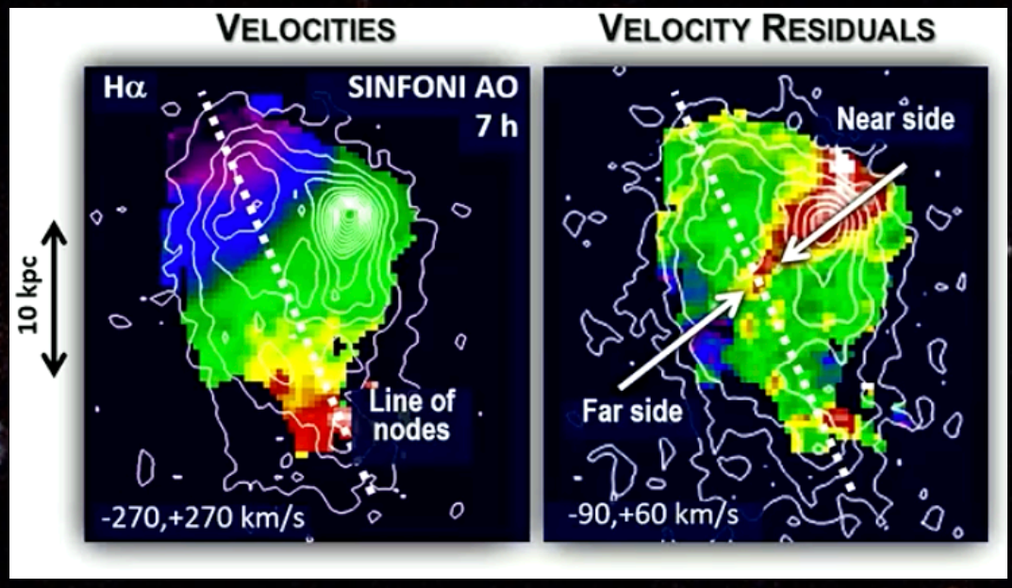
Stars vs gas

Rotation + Inflowing gas



VESPER IFS: 1.7″ x 1.5″

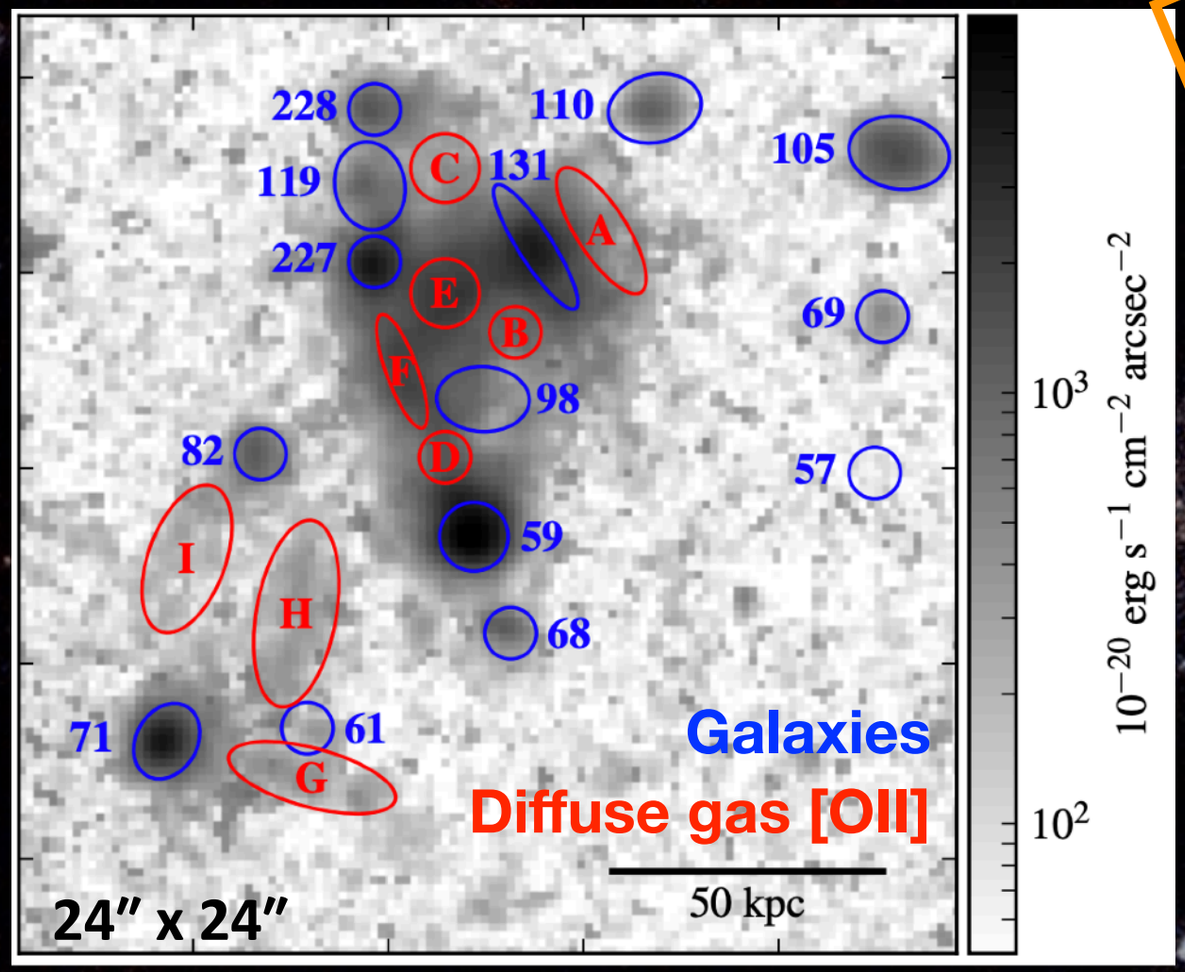




Genzel et al. 2023
Förster Schreiber EAS2024

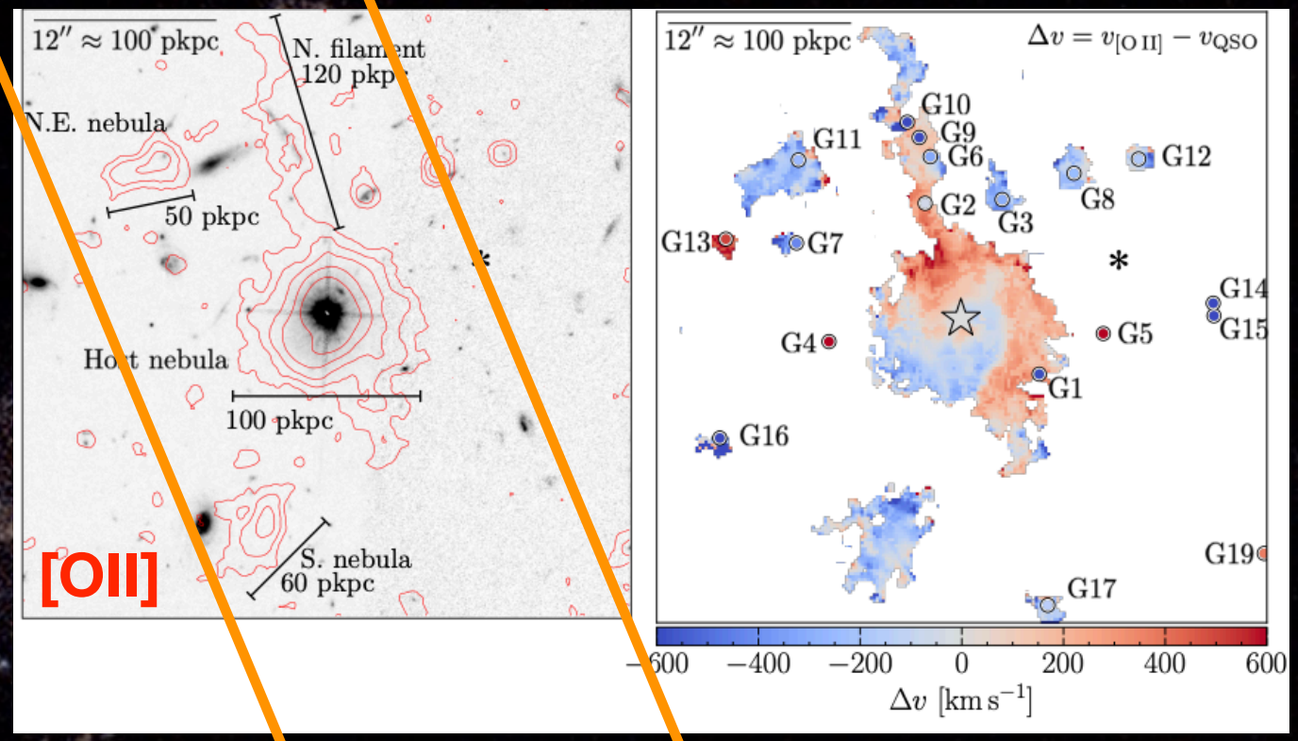
EXTENDED FILAMENTS OF IONIZED GAS IN OVERDENSITIES

Galaxy group COSMOS Gr30 z=0.7



Epinat et al. 2018

QSO TXS 0206−048 z = 1.13



Johnson et al. 2022

VESPER FOV: 24″ x 70″

muse
multi unit spectroscopic explorer

THE SHARP VIEW OF PROTOCLUSTERS

- Goals:
  - Constrain galaxy growth and decline mechanisms in overdensities
  - Explore environmental effects on galaxy formation and evolution
- Targets: galaxy clusters and protocluster cores (1 cMpc) at 1.5<z<4
- Preferentially with ancillary data (optical-NIR imaging & spectroscopy, sub-mm/mm, molecular gas, X-ray, wide-field Lyα)

THE SHARP VIEW OF PROTOCLUSTERS

- Member identification and classification, protocluster dynamical mass

NEXUS

Multiplexing over FOV~Protocluster core ~1 arcmin
Low-moderate spectral resolution

- Resolved kinematical study of stellar and gas components
  - Structural buildup (disks, bulges, spiral arms, clumps)
  - Gas flowing in and out (origin, role)
  - The AGN phase (triggering, fueling and feedback mechanisms)
  - Star formation regulators

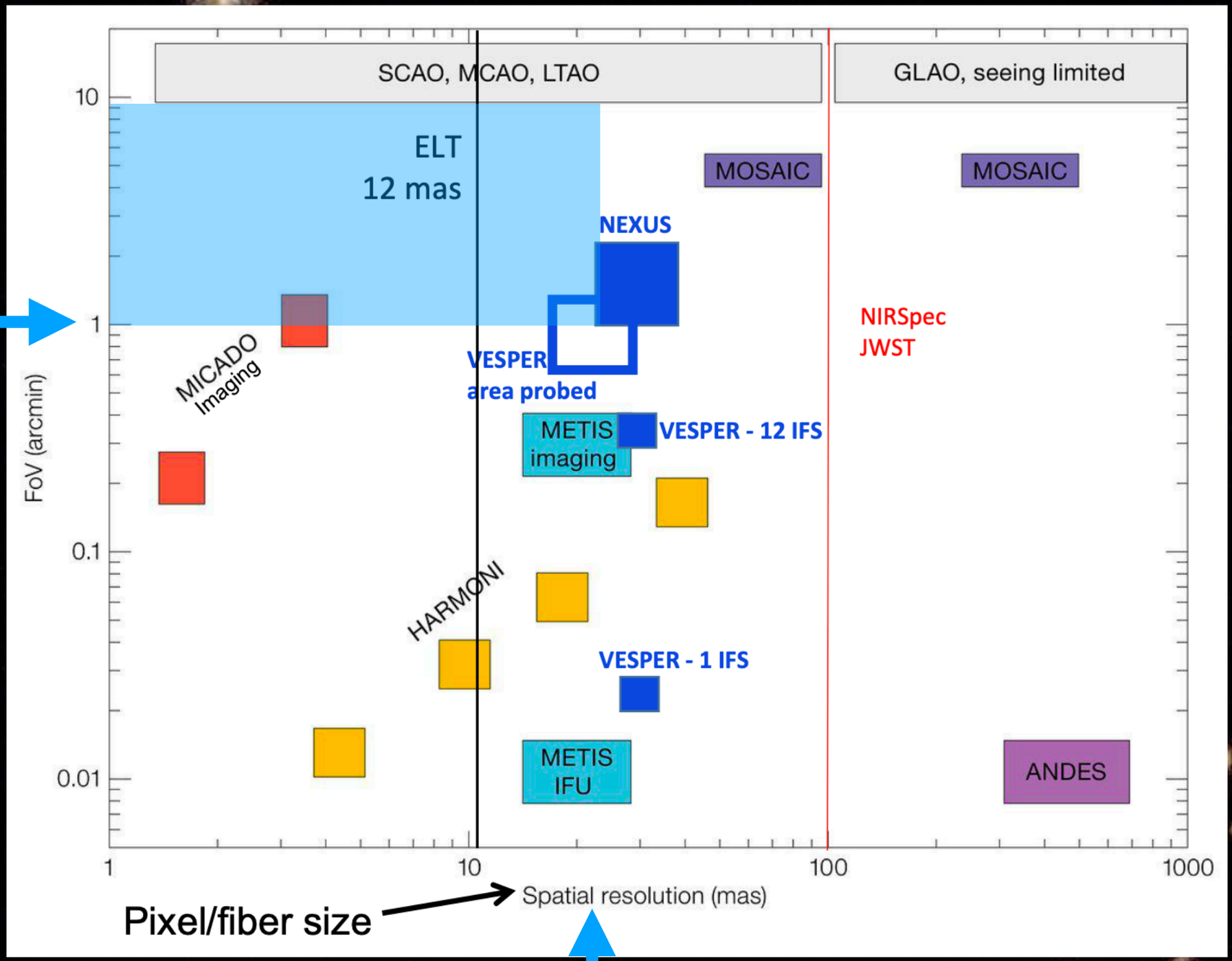
VESPER

Multi-IFU over FOV ~ Protocluster core ~ 1 arcmin
Rest-frame $\lambda \sim 0.3\text{-}0.7\mu m$ for optical absorpton features and emission lines
Sensitivity: $L_{HII}>10^{38}$ erg/s ➞ $F(H_\alpha)>3\times10^{-21}$ erg cm^{-2} s^{-1}
High spectral resolution
Spatial resolution (GMC @ z~2: 200pc~23 mas)

- Diffuse gas (CGM, IGM)
  - The mode of gas accretion
  - Interactions (bridges, tails)
  - ICM buildup

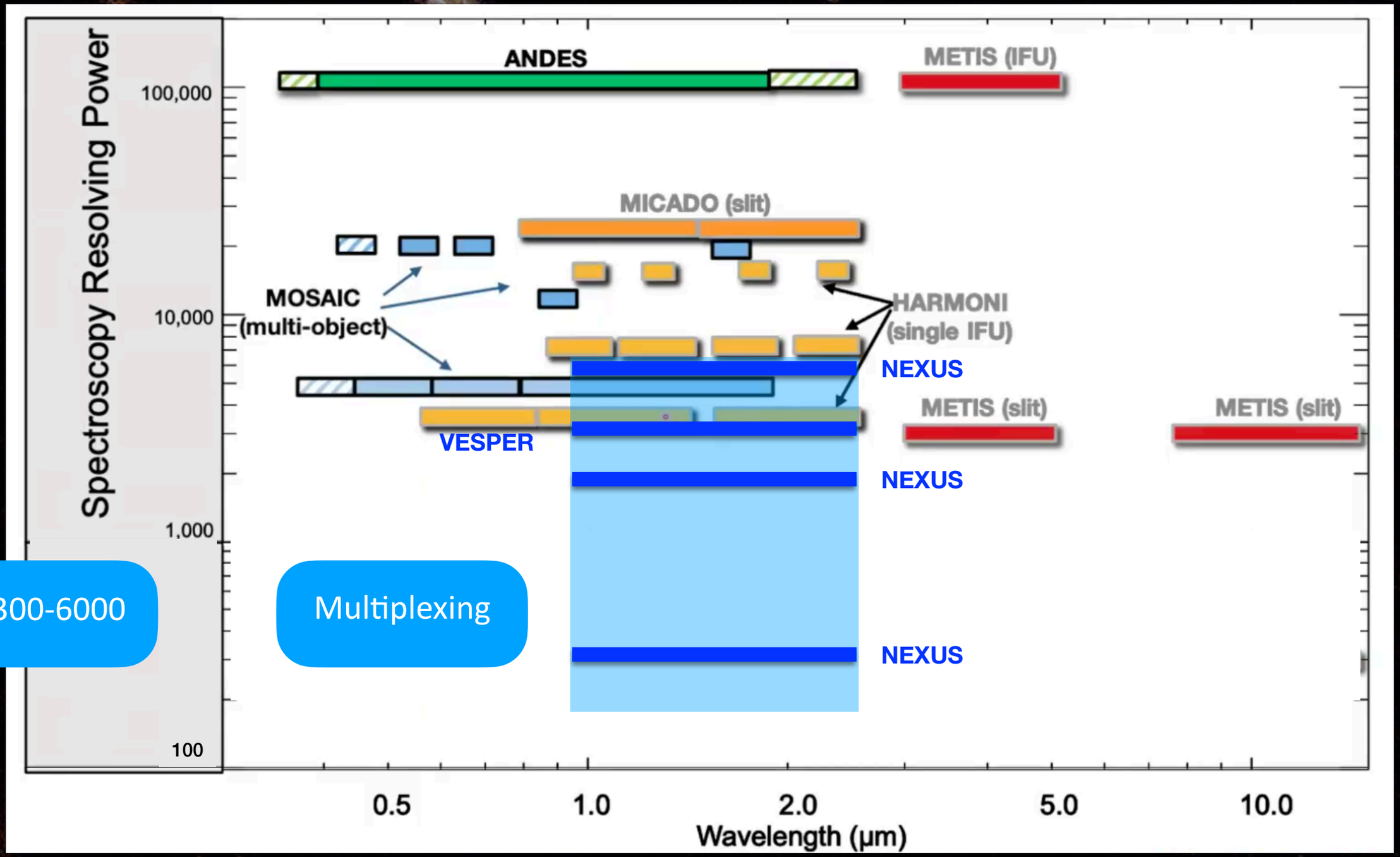
ALTERNATIVE TO SHARP ?

FOV



Spatial resolution

ALTERNATIVE TO SHARP ?



R = 300-6000

Multiplexing

λ^{obs} ~ 0.95-2.45μm

FINAL THOUGHTS

Whether you care about disks
or you dream of AGN winds

whether MPGs are your thing
or IGM, and CGM make you think

to best use SHARP multiplex mode
look at a protocluster core

something you will find
that will amuse your mind.

Mari