The existence and universality of the FMR of star-forming galaxies in CLASH clusters at z~0.4

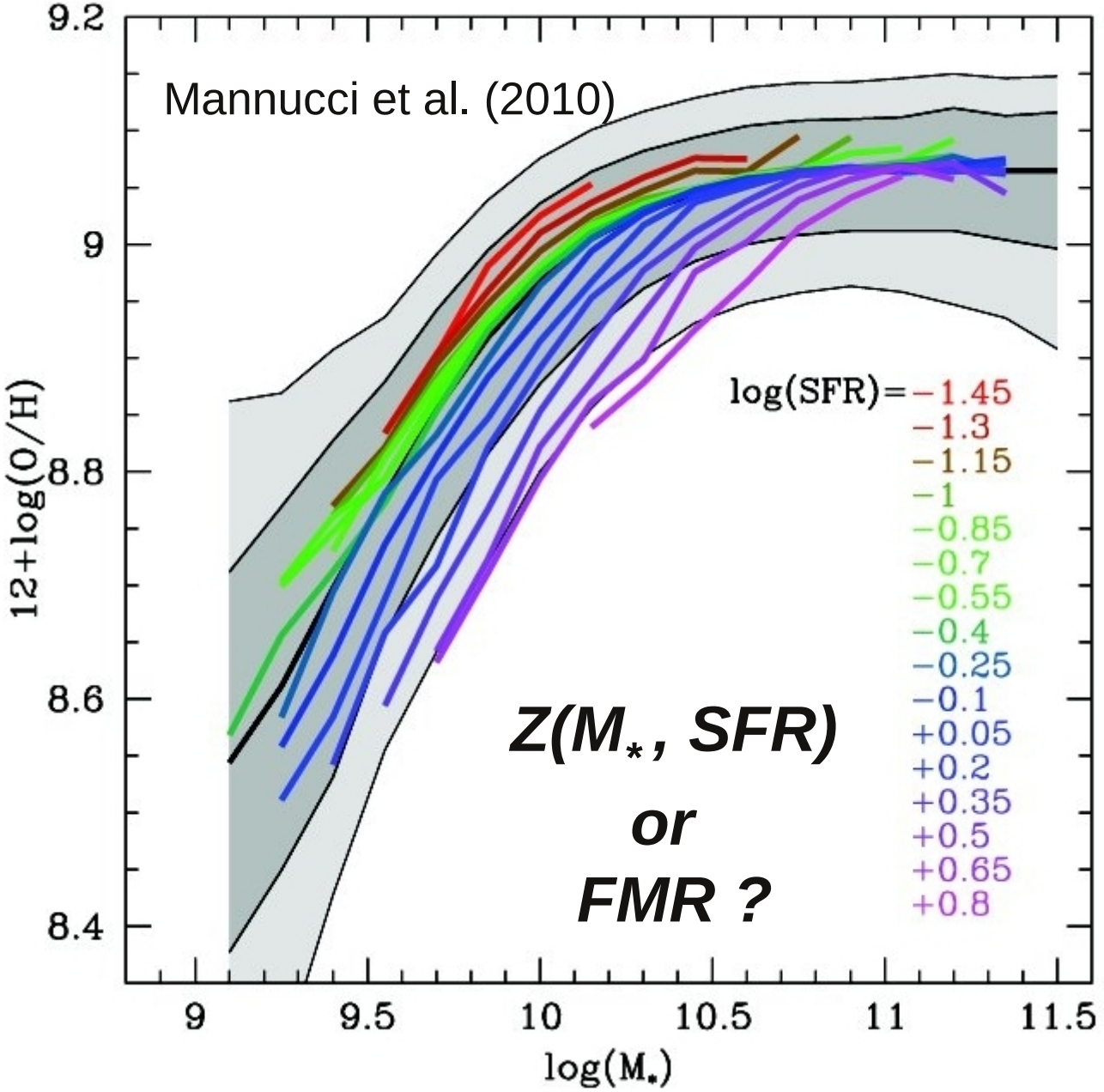
Christian Maier

universität wien

Institut für Astrophysik

& U. Kuchner, B. Ziegler, M. Verdugo
(University of Vienna)

& CLASH Team & CLASH-VLT Team



Empirical dependence: $Z(M_{stellar}, SFR)$ for SDSS galaxies at 0.07<z<0.3: at a given mass, galaxies with higher SFRs have lower metallicities

Z(M,SFR) or Fundamental Metallicity Relation (FMR)?

- **Z(M,SFR) universal (FMR)?**

(see also Maier, Lilly, Ziegler et al. 2014, ApJ, 792, 3 for discussion of the different formulations of the FMR and z>2 observations)

- **Dependence of the mass-metallicity relation (MZR) on SFR:**
  - **Z(M,SFR) exists at higher redshifts? (CLASH z>0.3)**
  - **Z(M,SFR) exists in denser environments? (CLASH clusters)**

Z: metallicity

M: stellar mass of a galaxy

SFR: star formation rate

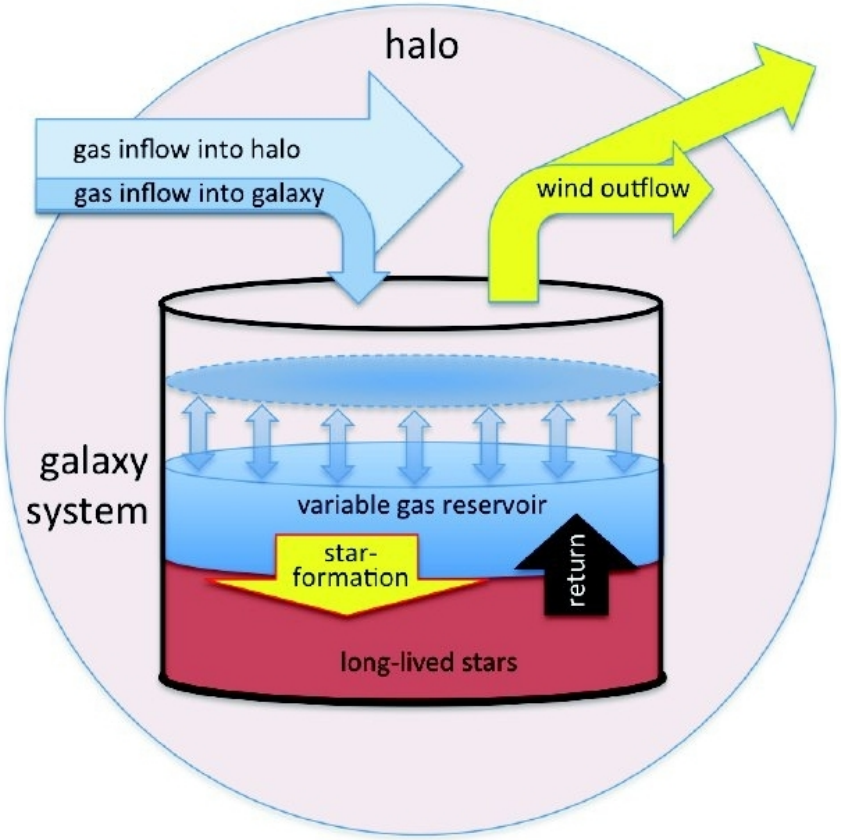
FMR: fundamental metallicity relation

$Z(M_{stellar}, SFR)$ & FMR

- a physically motivated $Z(M_{stellar}, SFR)$, with SFR regulated by the mass of gas
- galaxy evolves in a quasi-equilibrium state

- Z(M,SFR) only evolves to the extent that ε and λ change (at fixed M) with epoch
- if ε and λ do not change, Z(M,SFR) does not –> FMR

- Our aim: compare Z(M,SFR) in CLASH clusters at z~0.4 with model expectations



$$Z_{eq} = Z_0 + \frac{y}{1+\lambda(1-R)^{-1}+\varepsilon^{-1} m_{star}^{-1} \cdot SFR}$$

Z_0: metallicity of the infalling gas

Z_{eq}: equilibrum value for metallicity

y: yield: mass of metals returned to ISM per unit mass locked up in long lived stars

$\varepsilon = SFR/M_{gas}$: star formation efficiency

λ: mass-loading factor (mass loss is λxSFR) of any wind that drives gas out of the system

Lilly et al. (2013)

Observed environmental effects on metallicities

- heterogeneous results in literature

e.g., Mouhcine et al. (2006), Cooper et al. (2006), Ellison et al. (2009), Pasquali et al. (2012)

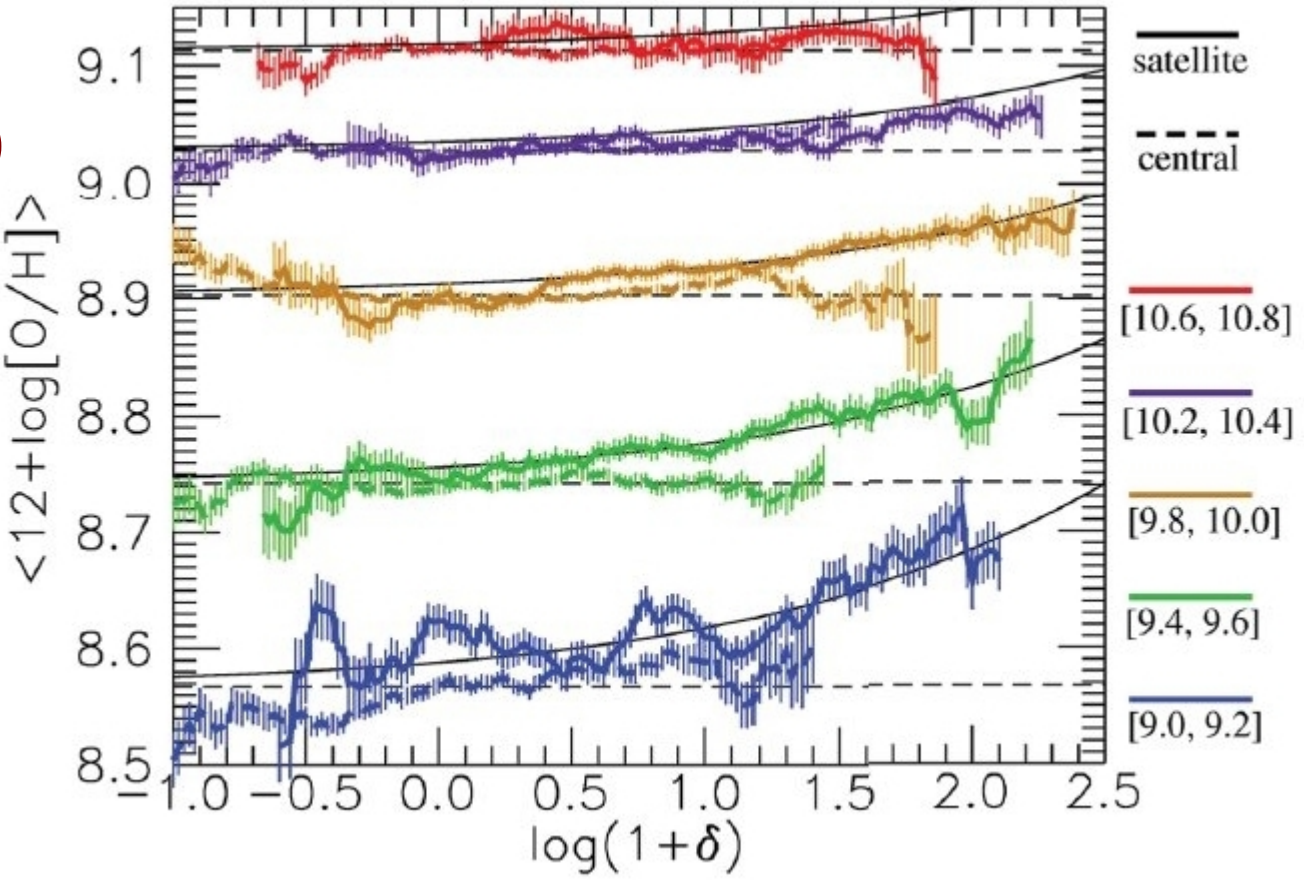
- Peng et al. (2013): used Yang et al. (2007) local (z<0.3) SDSS group catalog
  - strong dependence of metallicity on overdensity for SF satellites, at a given M
  - interpretation: gas inflow progressively metal-enriched in dense regions

Aim of this work:

higher redshifts (z>0.3)

denser environments

CLASH clusters



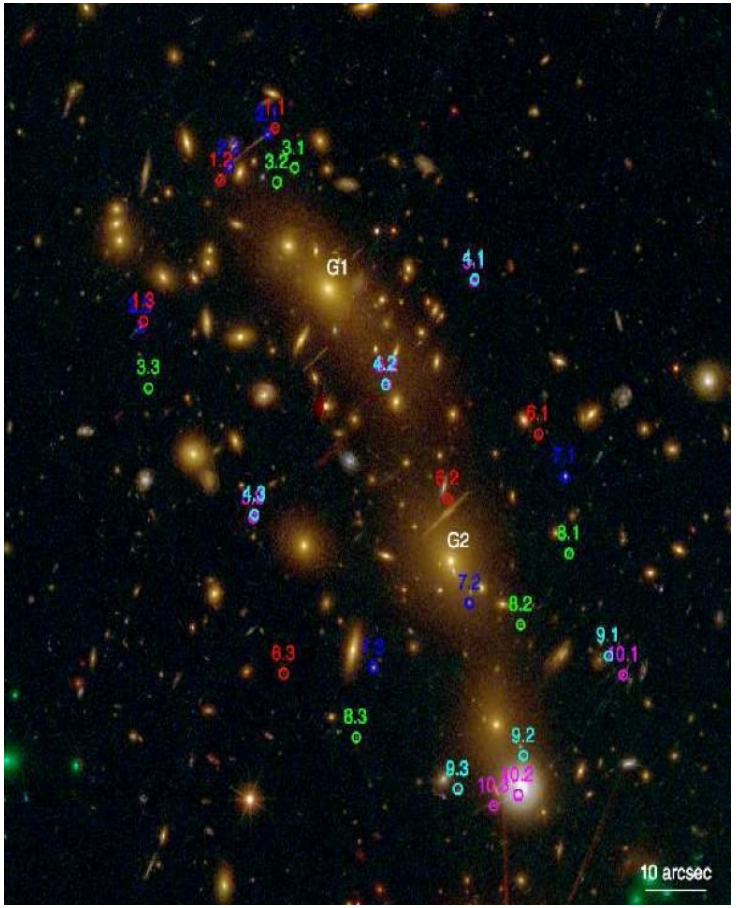
CLASH

Cluster Lensing and Supernova survey with Hubble, Postman et al. (2012)

HST Multi-CycleTreasury Program (530 orbits) – PI: M. Postman

- imaging in 16 filters of 25 massive galaxy clusters at <z>~0.4
- probe dark matter and magnify distant galaxies up to z~12

Cluster MACSJ1206 at z~0.45



Cluster MACSJ0416 at z~0.39

CLASH-VLT

Clash-VLT (PI : P. Rosati):

- 200 hours of VLT-VIMOS (LR-Blue and MR grisms) spectroscopy
- 13 clusters at z=0.3-0.6 from CLASH
- 90% (180 hours) observed

dynamical analysis out to R_{vir} (and beyond)

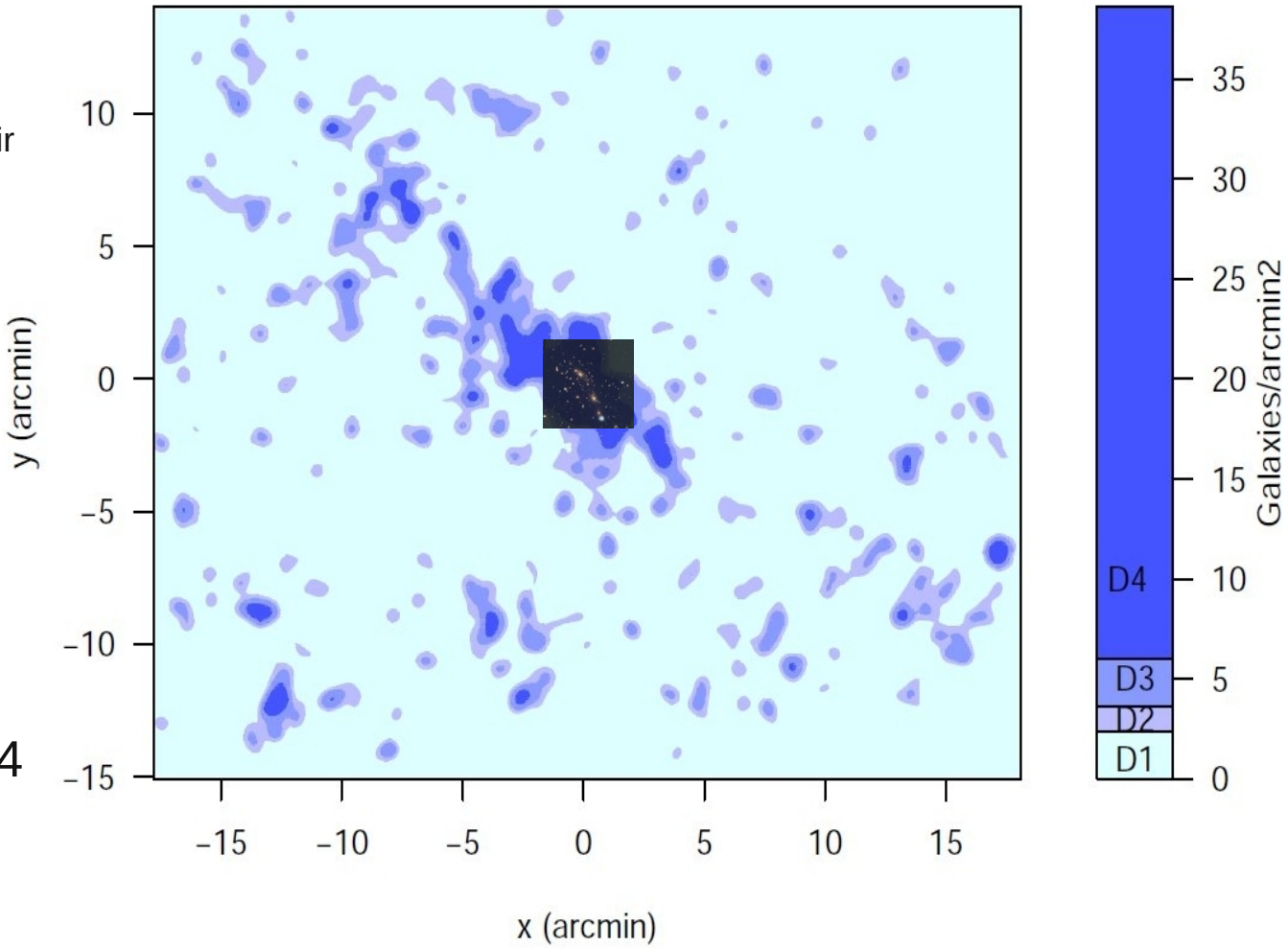
~500 members per cluster

HST area 3.3 x 3.3 arcmin^2

VIMOS spectra over 30x30 arcmin^2 field
Subaru Suprime Cam

different environments D1-D4

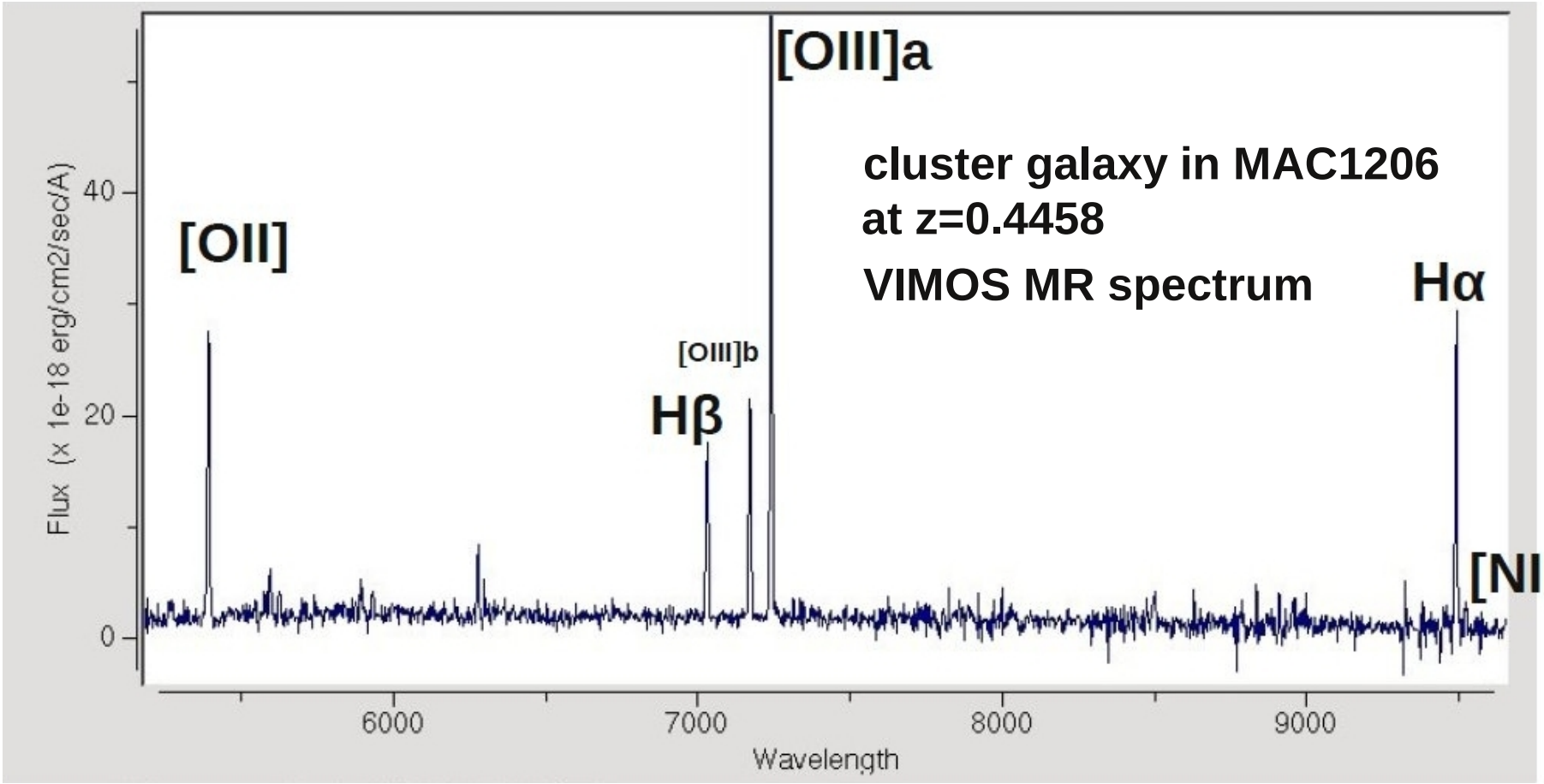
Cluster MACSJ0416 at z~0.39



Gas Metallicities based on 5 lines in CLASH clusters

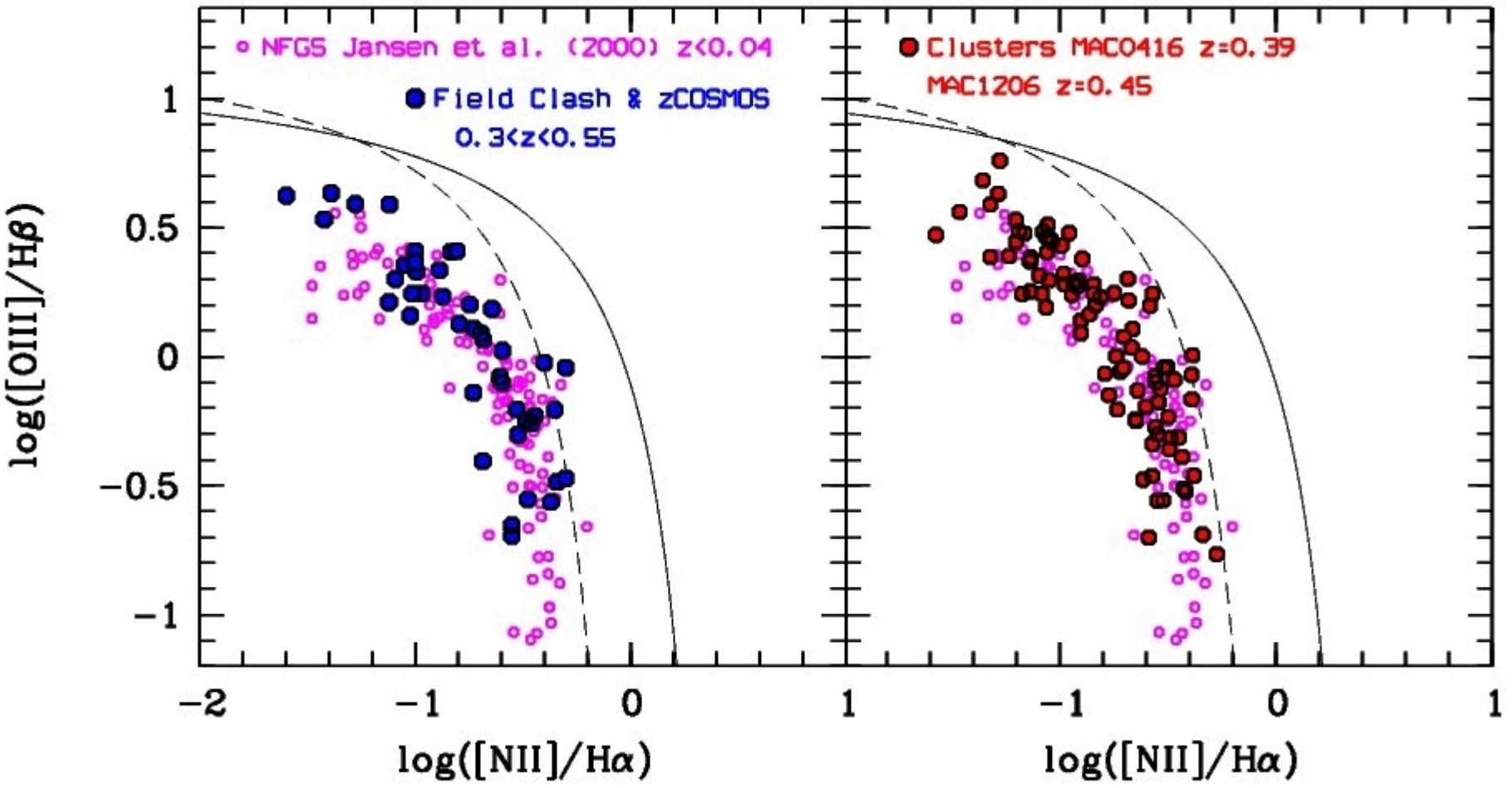
- CLASH MACSJ1206 & MACSJ0416 cluster galaxies at z~0.45 and z~0.39
- all 5 emission lines measured at the same time with VIMOS MR grism
- 91 cluster members and 41 field galaxies at 0.3<z<0.5

with 5 emission lines: [OII]λ3727, Hβ, [OIII]λ5007, Hα, and [NII]λ6584



BPT diagram of cluster galaxies at z~0.4

Field and cluster SF galaxies at z~0.4 are not dominated by type-2 AGNs

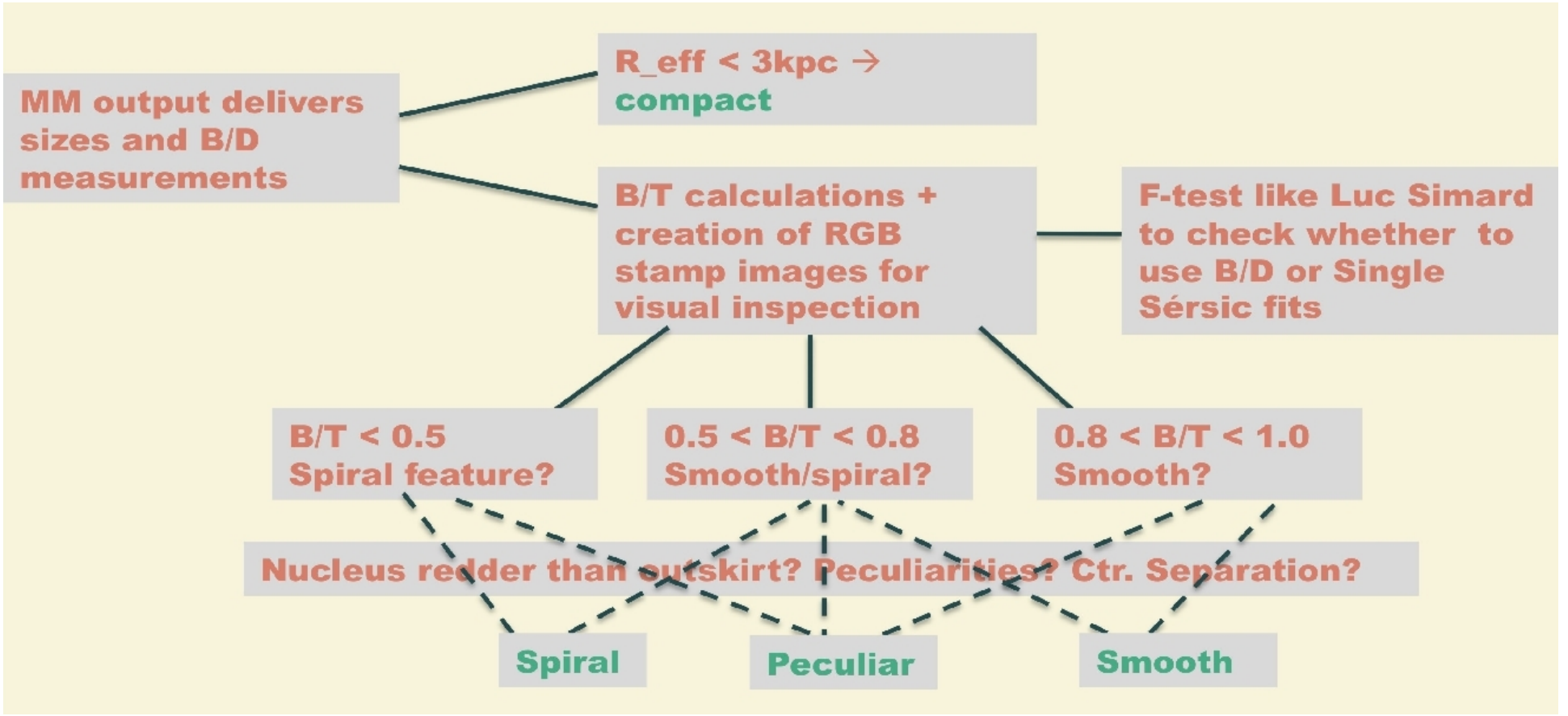


Maier, Kuchner, Ziegler, Verdugo, Rosati et al., in prep.

Determination of morphologies

- U. Kuchner, C. Maier et al. (2014), arXiv:1409.4999: determine morphologies and galaxy sizes using MegaMorph (Häußler et al. 2013) and visual inspection

- Classification scheme based on following decision tree:



Morphologies in field and cluster galaxies

Examples of Subaru Suprime Cam V, R, I color stamps:

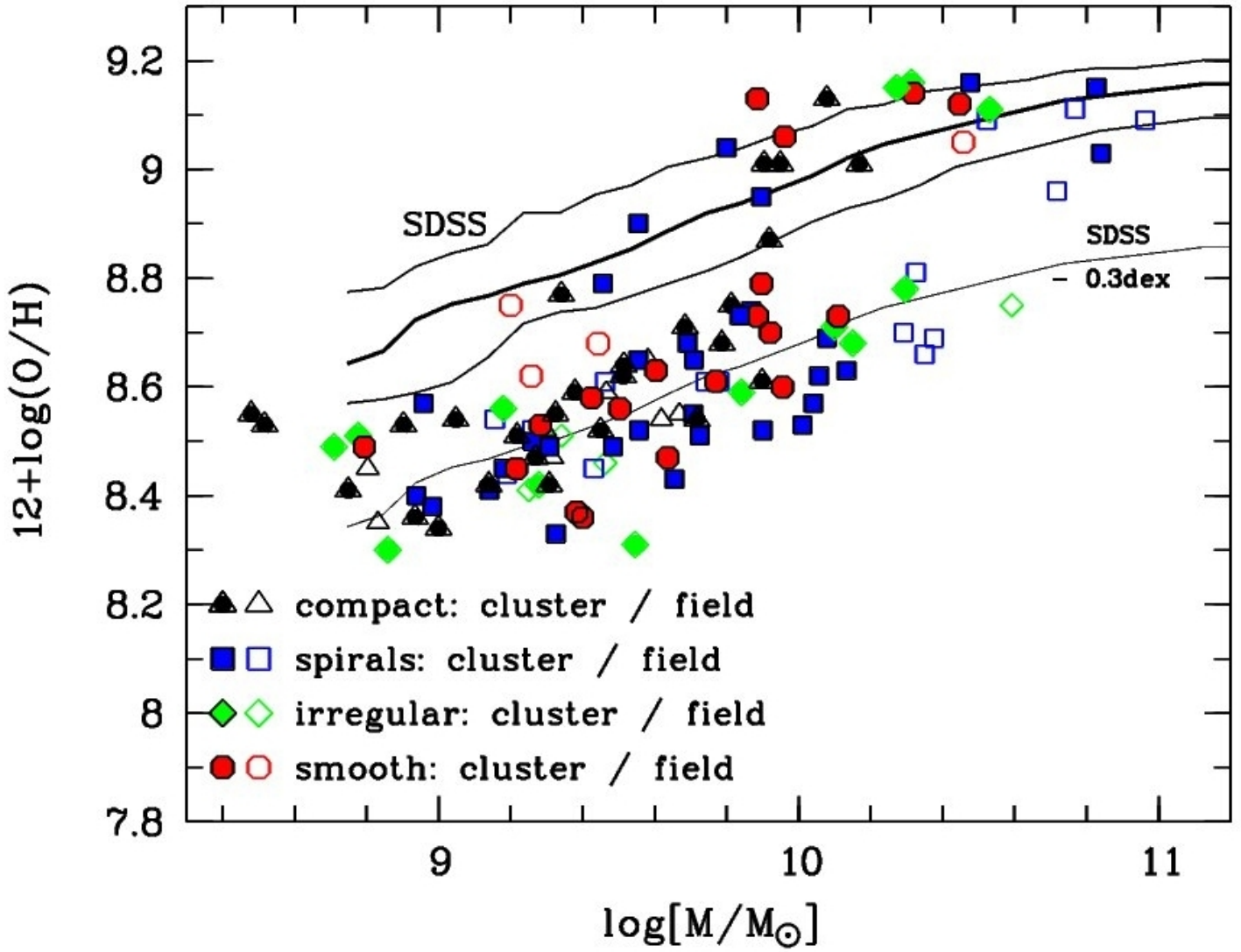
Irregular

Spiral

Smooth

MZR with morphologies of field and cluster galaxies

cluster: filled symbols, field: open symbols



Summary

- gas metallicities based on 5 emission lines ([OII], Hβ, [OIII], Hα, [NII]), in 91 cluster member and 41 field galaxies at z~0.4

- lower mass: cluster and field galaxies occupy similar regions of the MZR diagram

- indication that the Z(M,SFR) exists for star-forming galaxies in clusters at z~0.4, and is independent of environment : FMR

- Z(M,SFR) as a function of morphologies and density field: work in progress