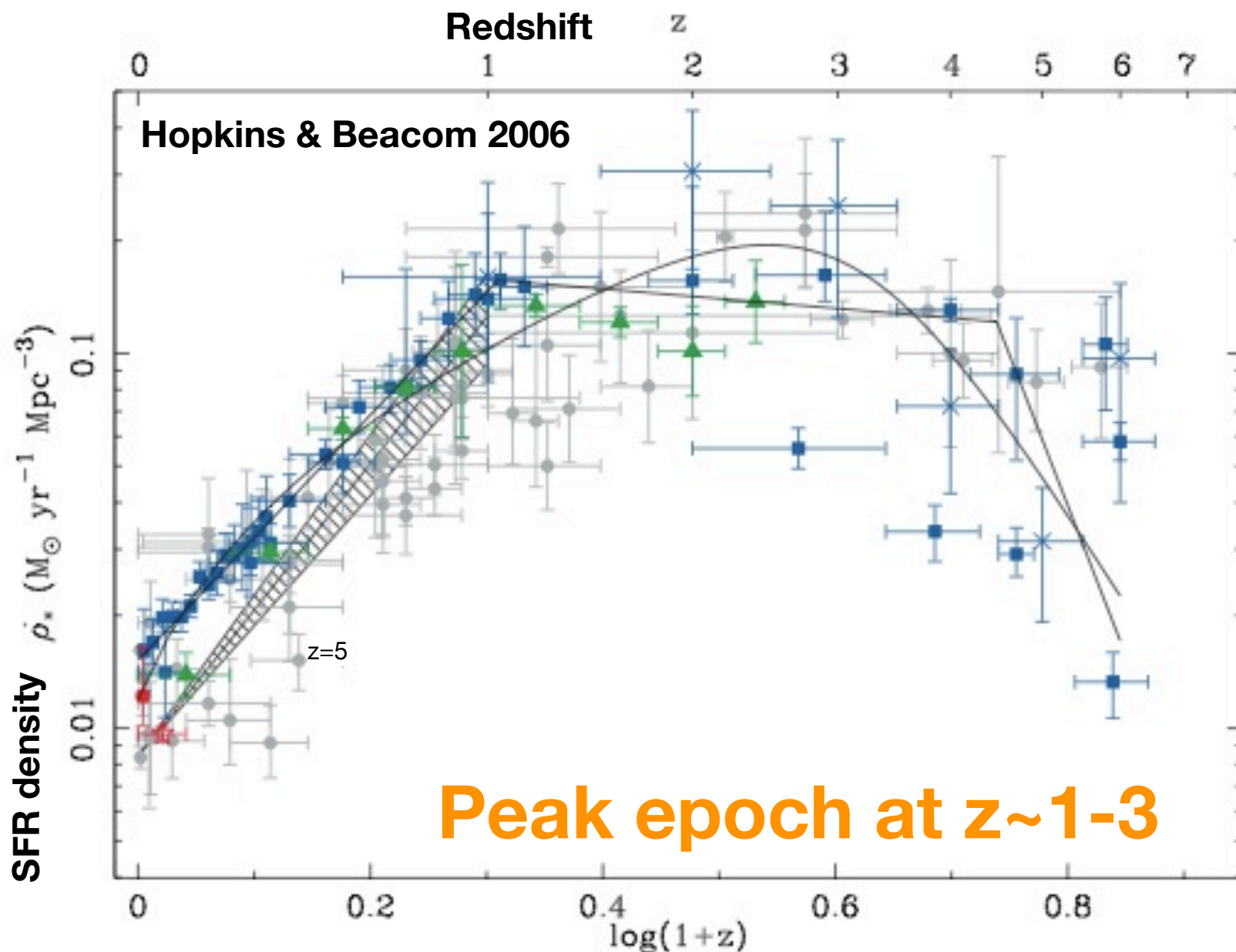


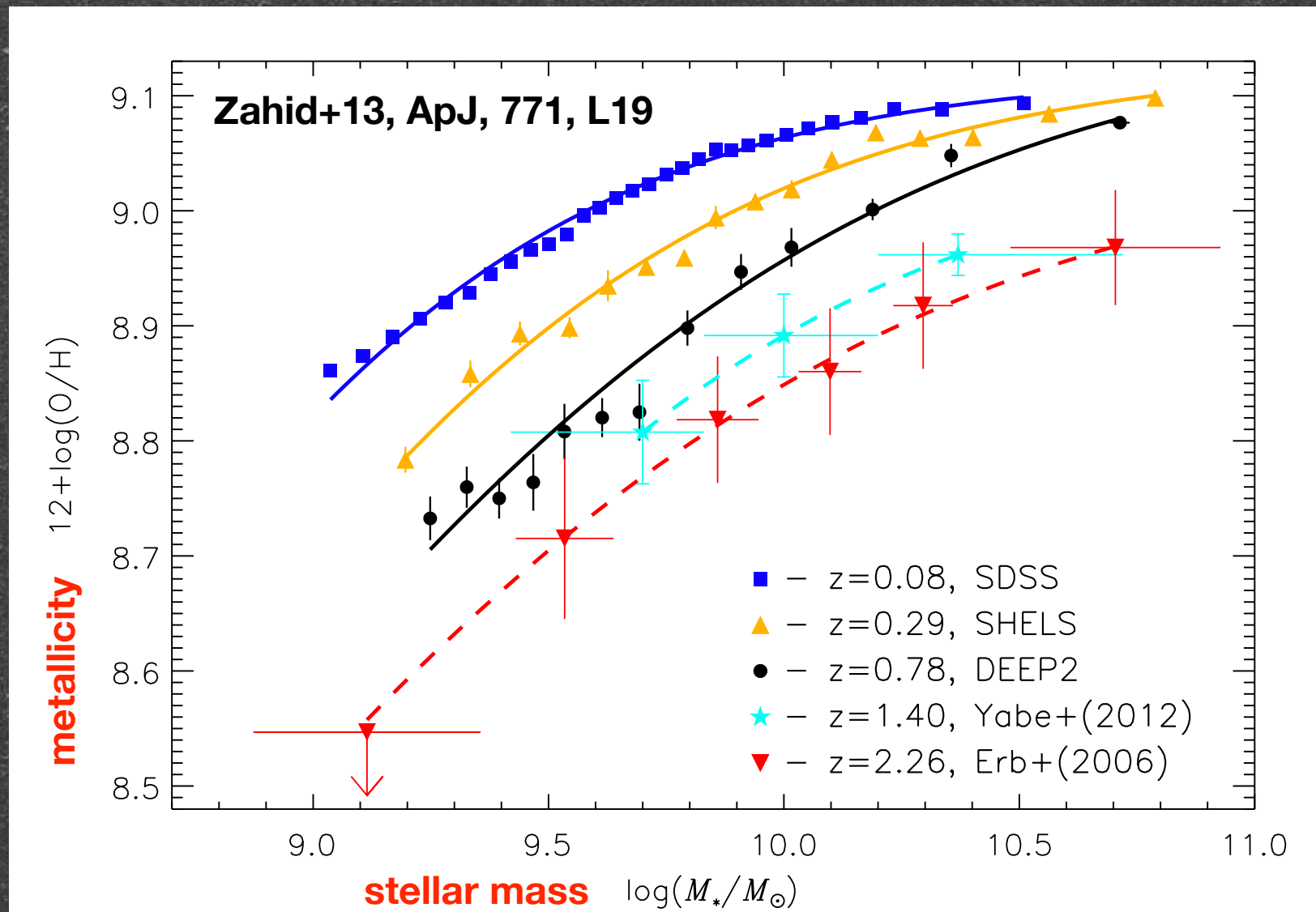
# 高赤方偏移における星形成銀河の微細構造輝線 観測とその理解 (光赤外からのコメント)

矢部清人 (国立天文台)

# Cosmic Star-formation history :

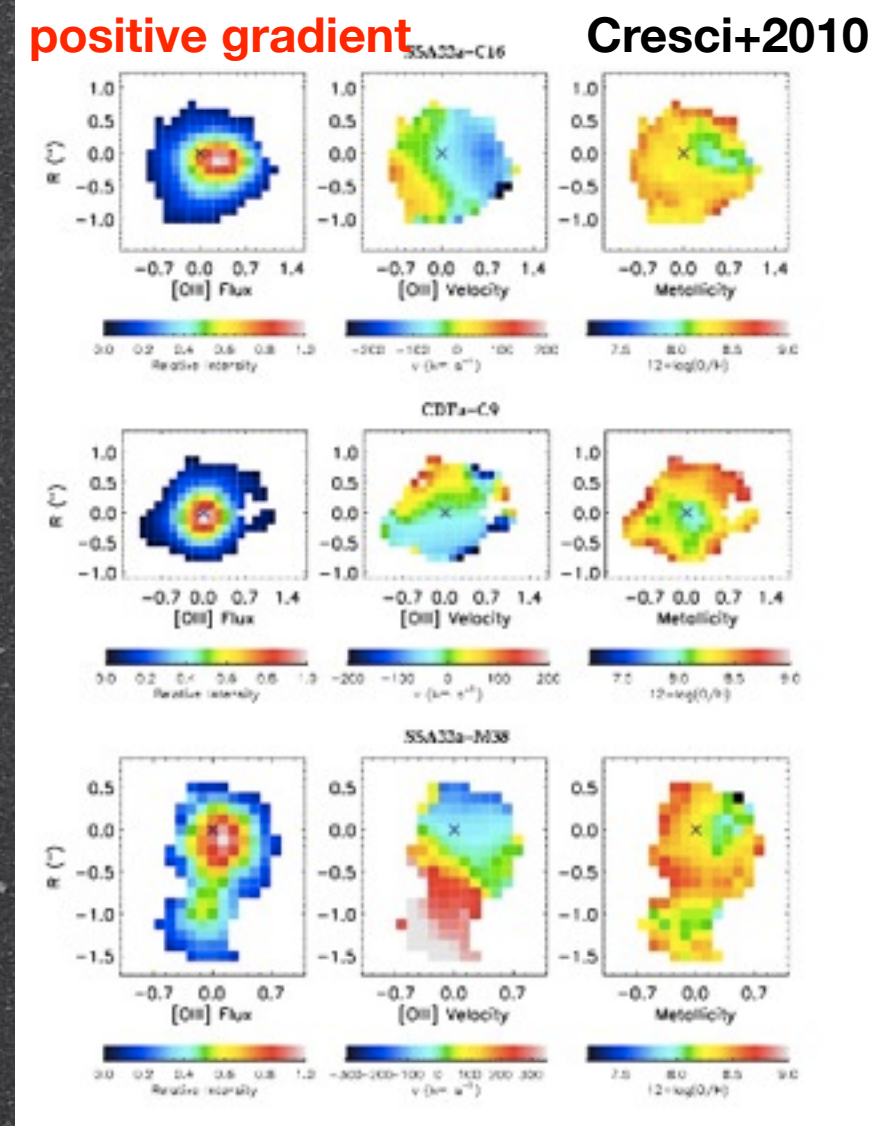
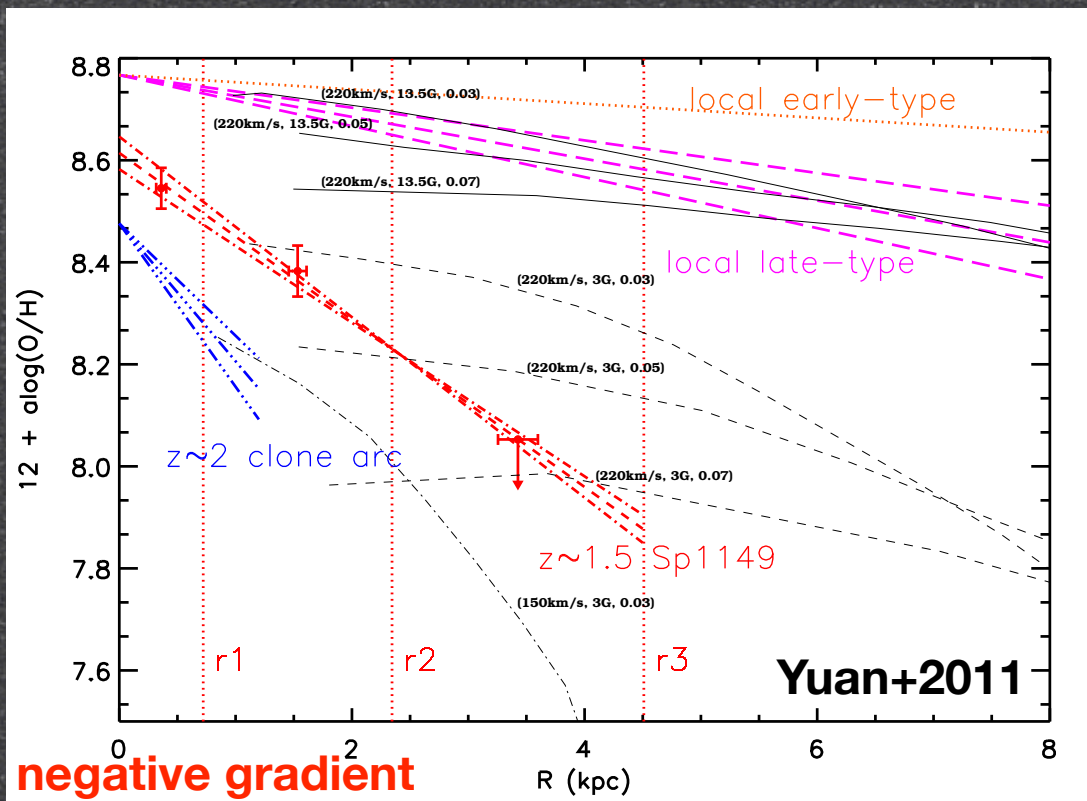


# Metallicity of galaxies at high redshift :



The mass-metallicity relation and its evolution

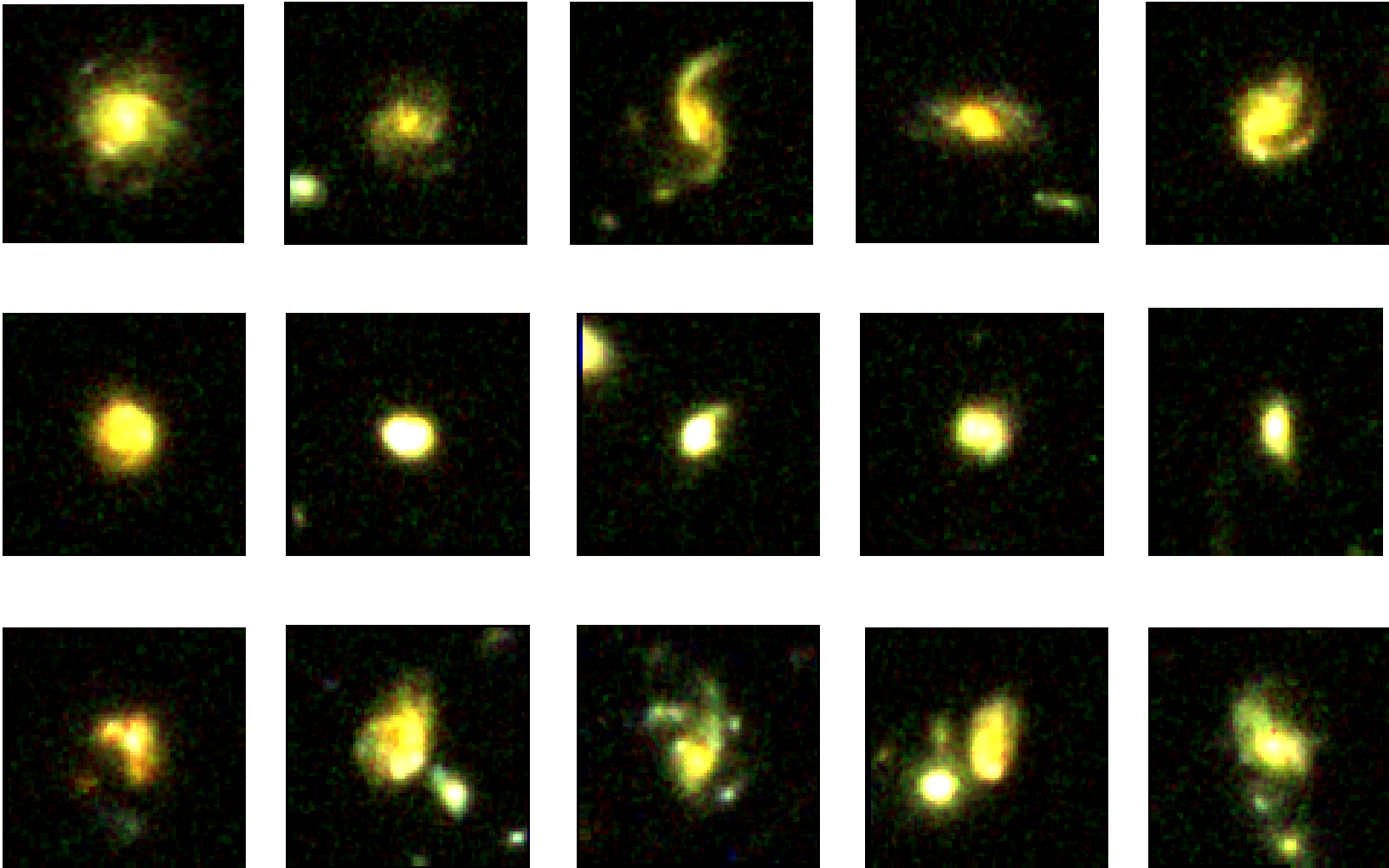
# Metallicity gradient at high redshift :



- Steeper metallicity gradient at high redshift  
→ Inside-out growth?
- Positive gradient  
→ Infall of pristine gas?

# Morphology of galaxies at high redshift :

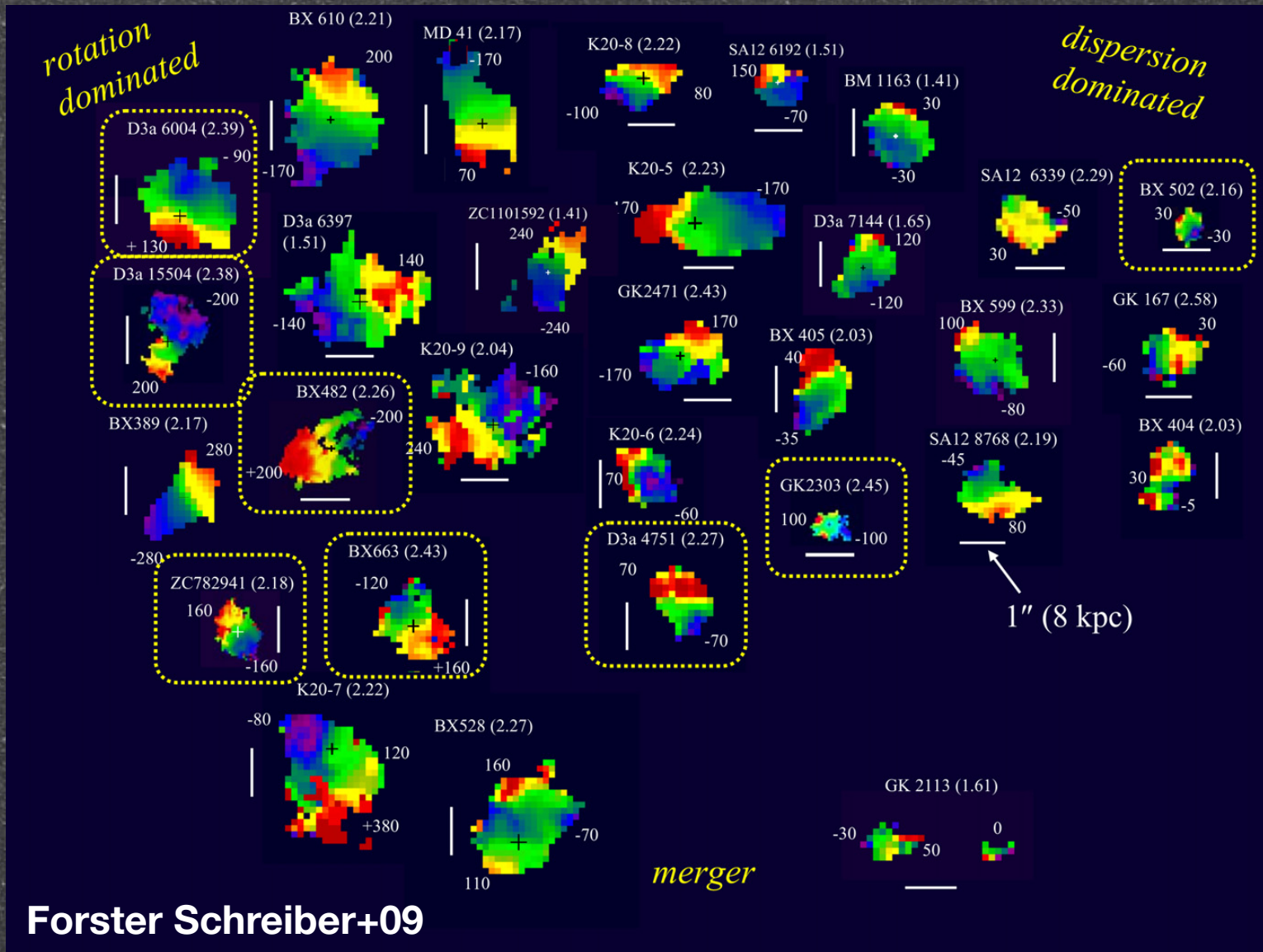
SXDS/CANDELS



Color composites of galaxies at  $z \sim 1.4$  with HST/ACS+WFC3 images

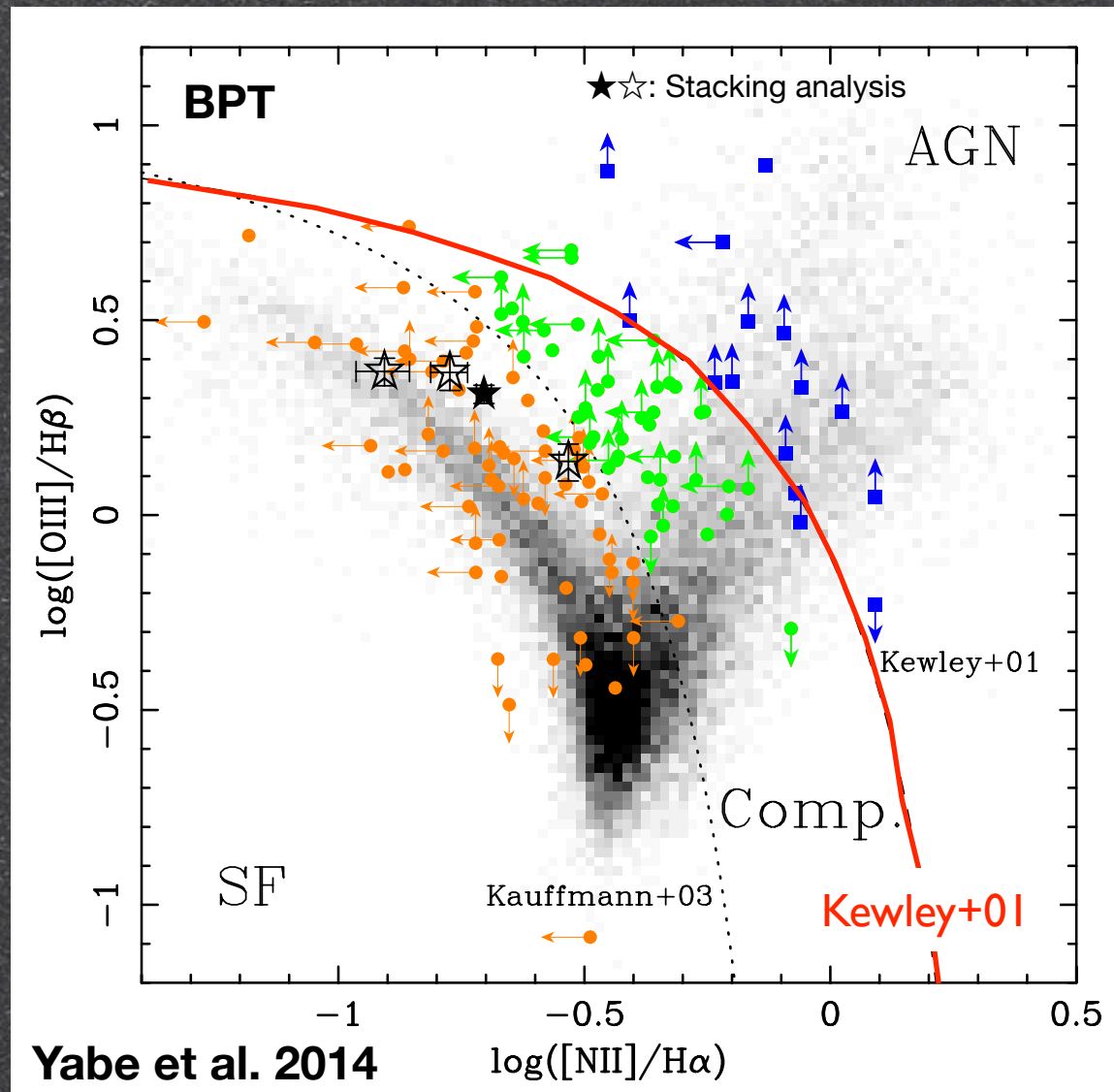
## Large variety of galaxy morphology at $z > 1$

# Kinematics of galaxies at high redshift :



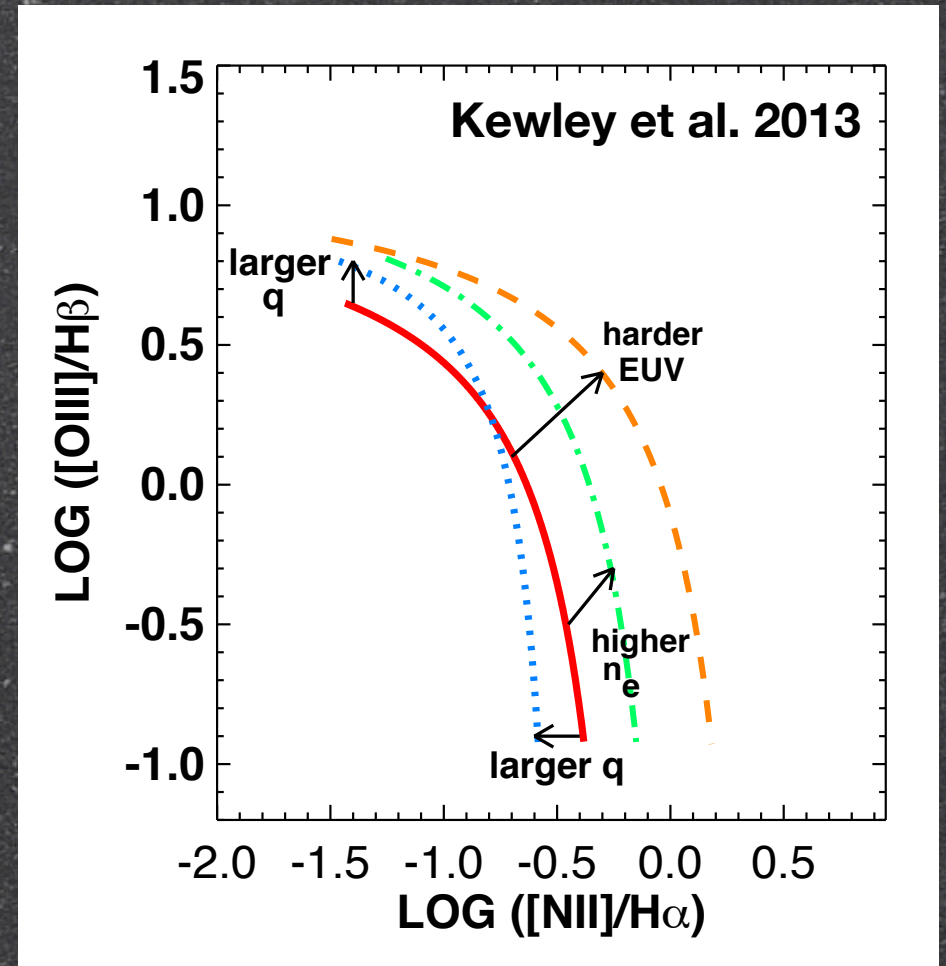
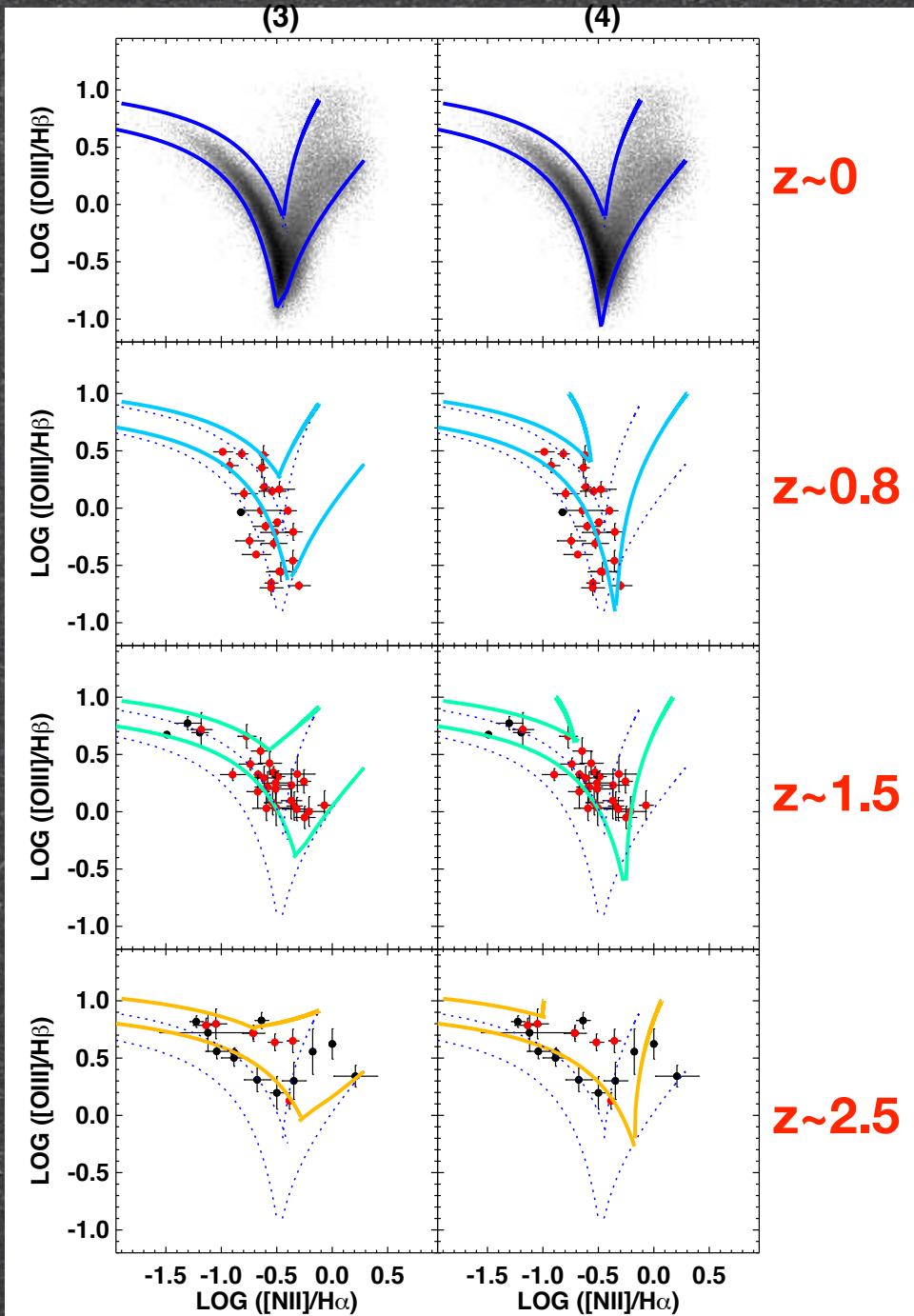
Large variety of galaxy kinematics at  $z \sim 2$

# Connection between galaxies and AGN :



AGN contribution? Different ISM condition?

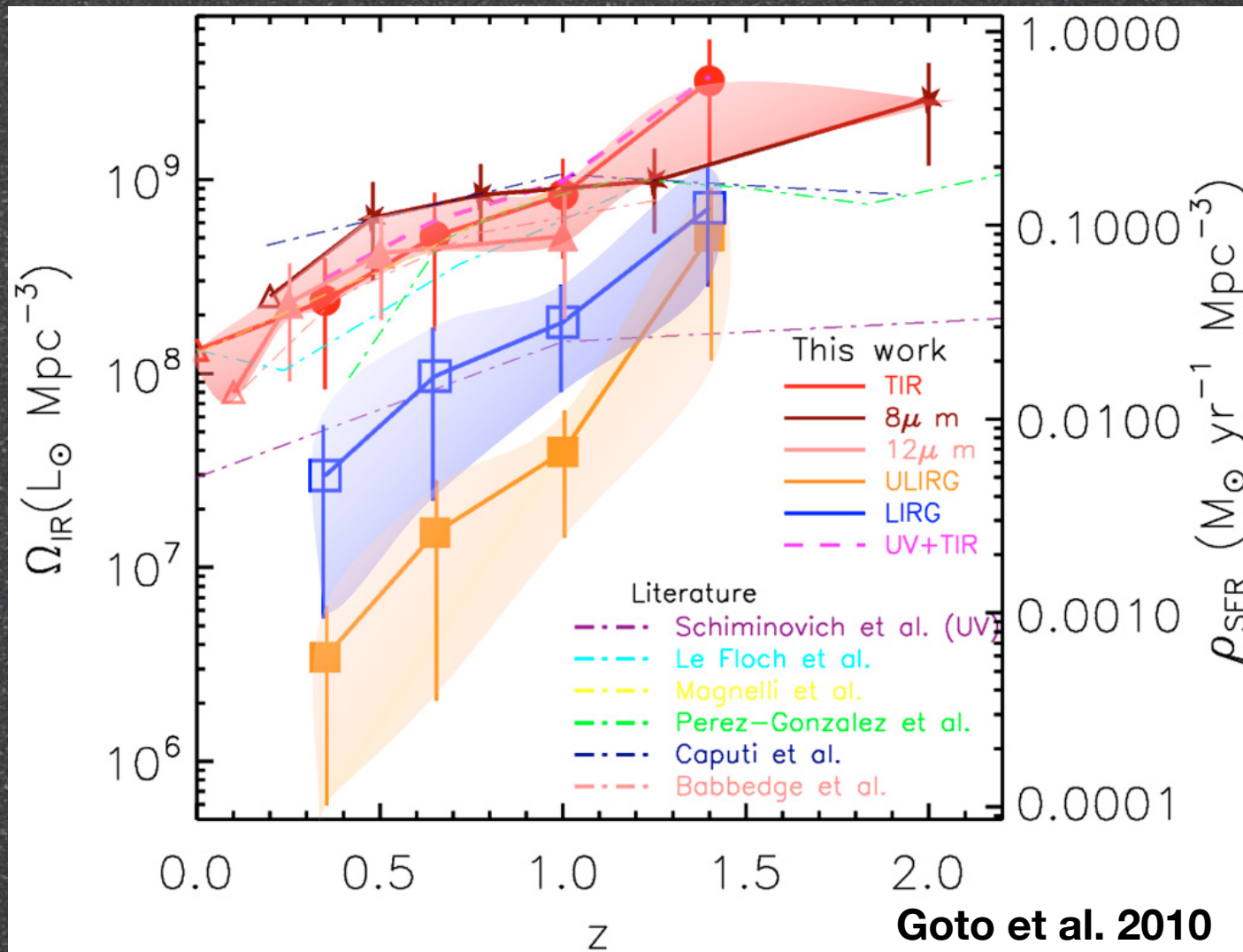
# Connection between galaxies and AGN :



Different ISM condition at high redshift?

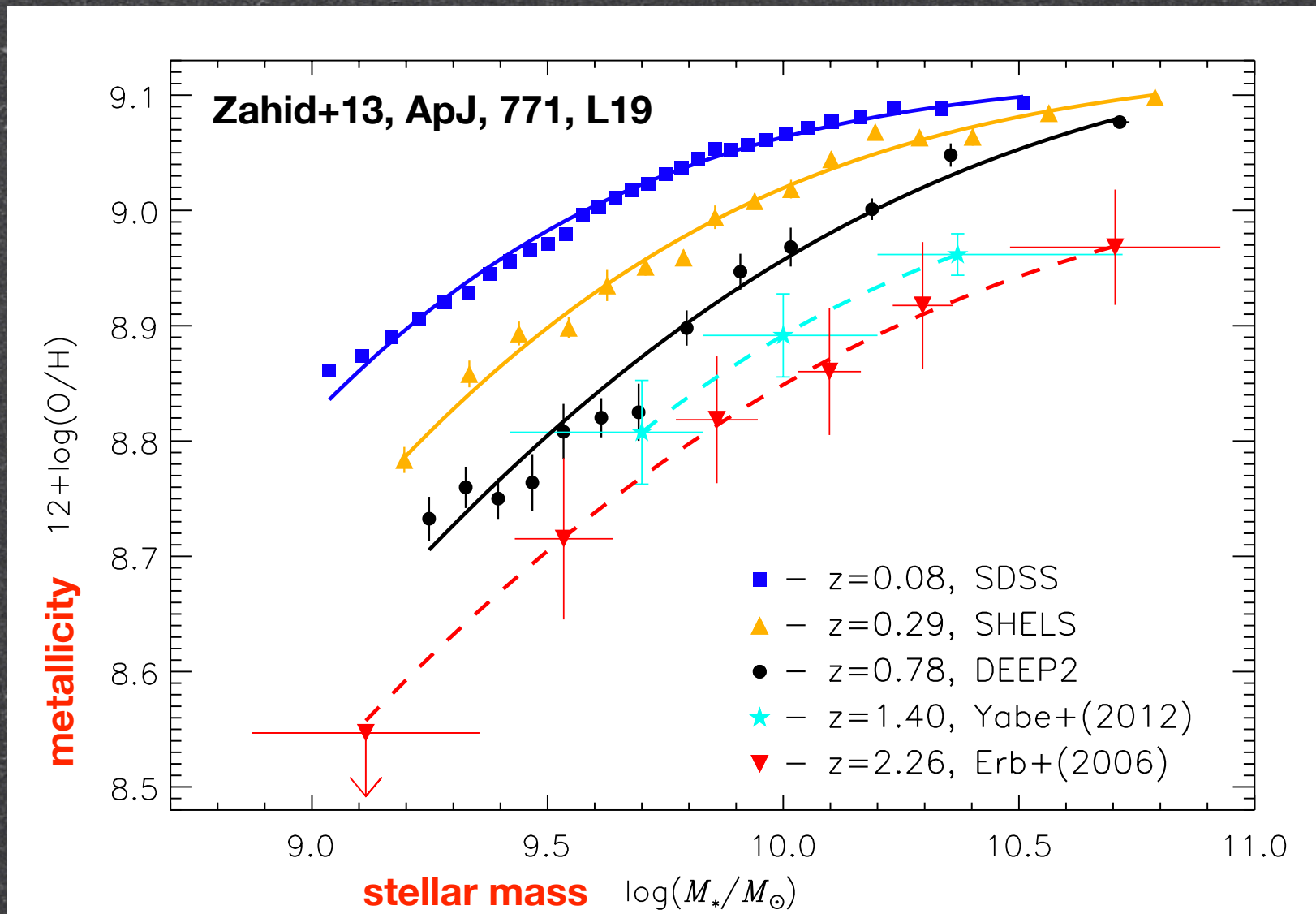


# Galaxies at high-redshift is dusty!! :



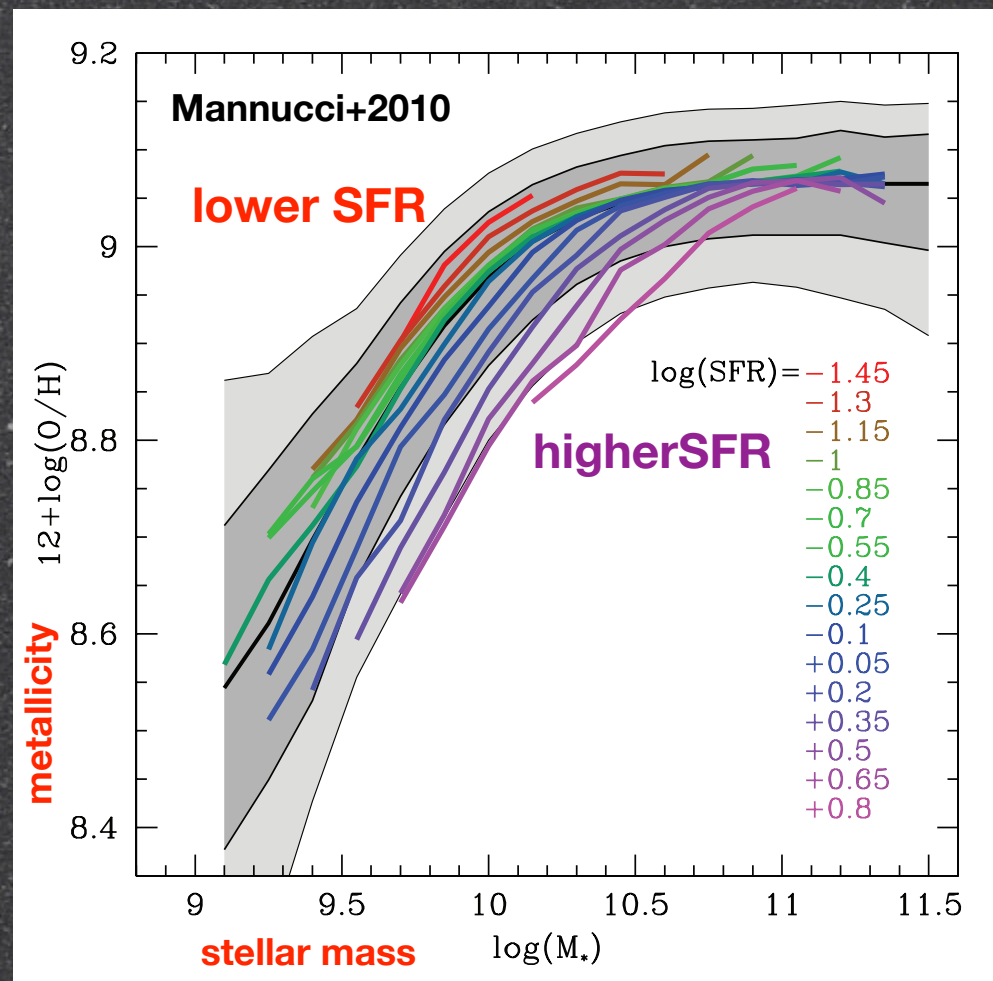
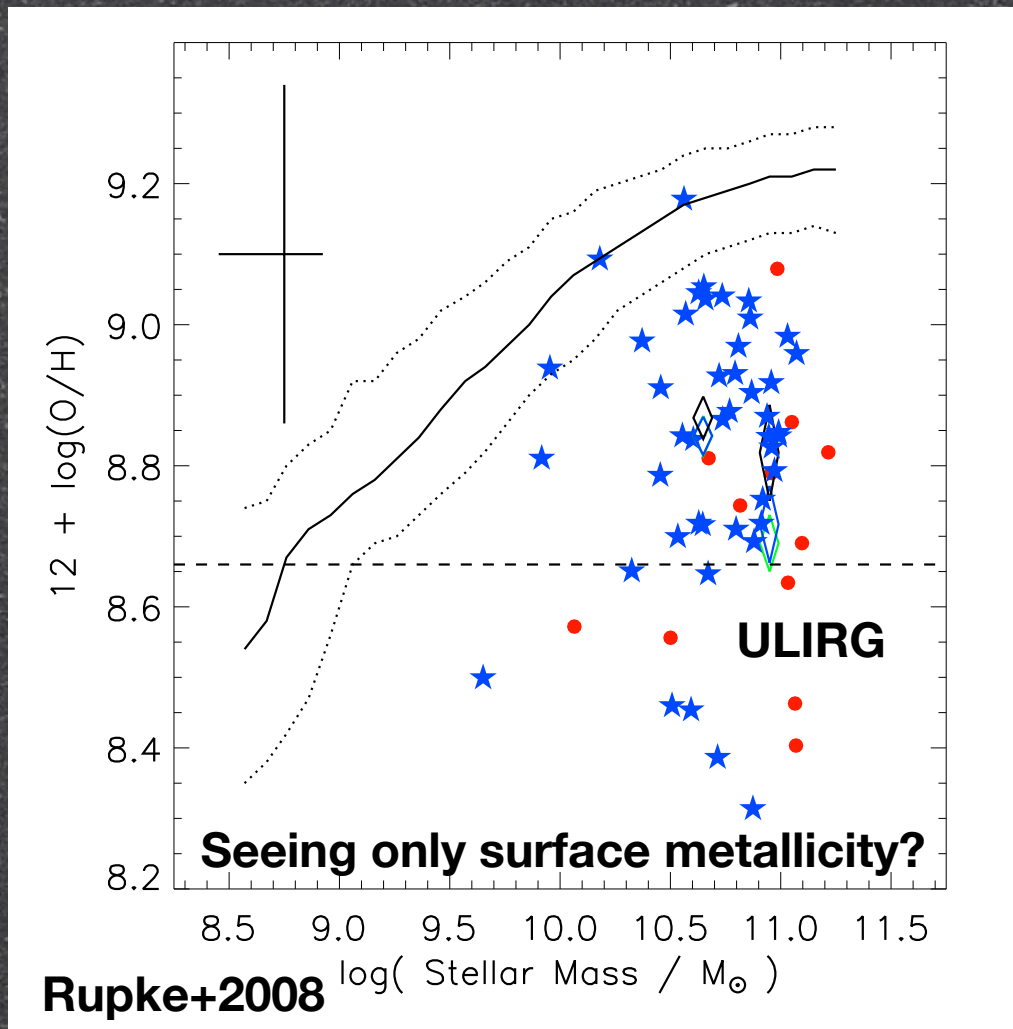
Contribution to SFRD from LIRG/ULIRG increases with increasing redshift

# Metallicity of galaxies at high redshift :



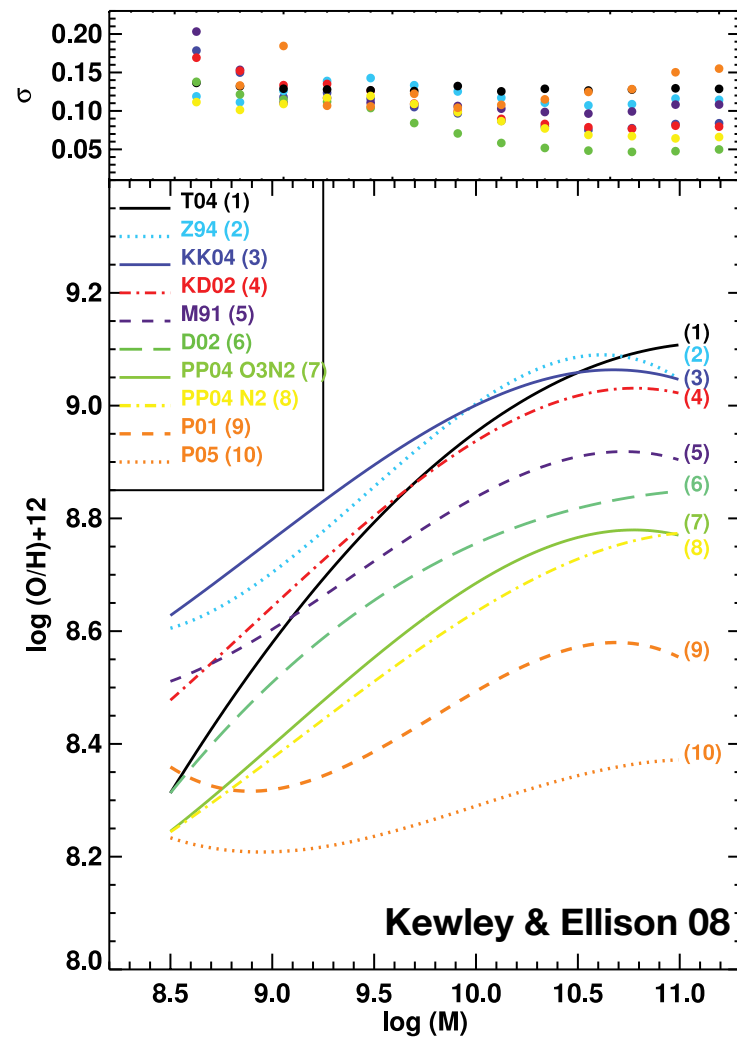
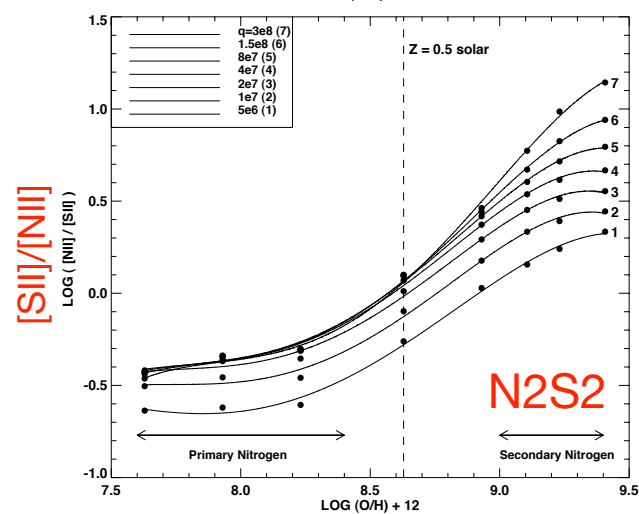
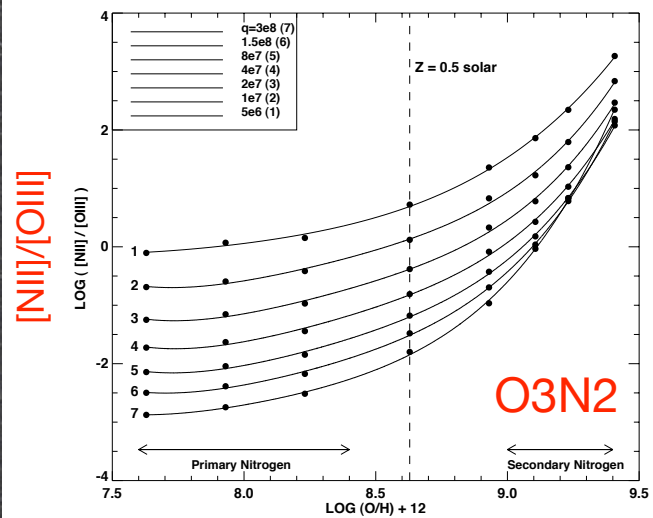
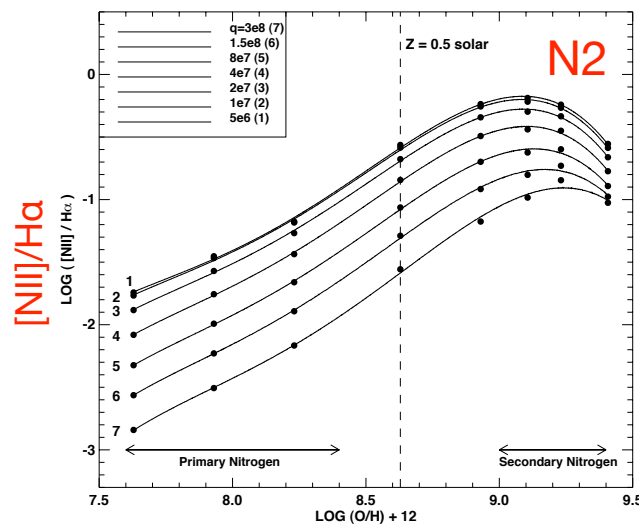
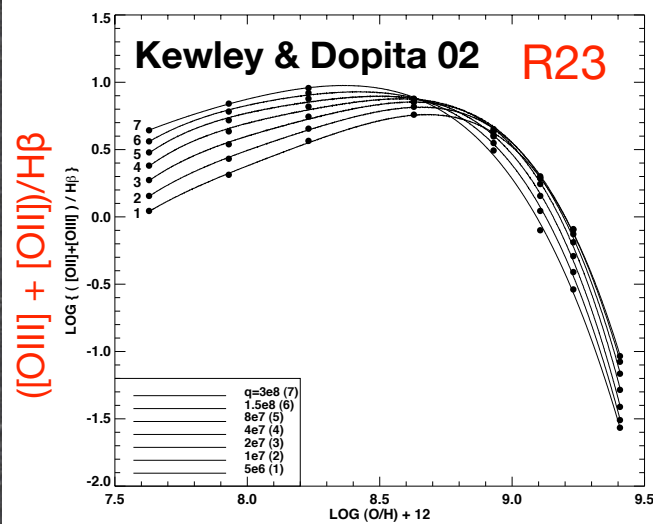
Evolution of mass-metallicity relation is real?

# Metallicity of galaxies at high redshift :



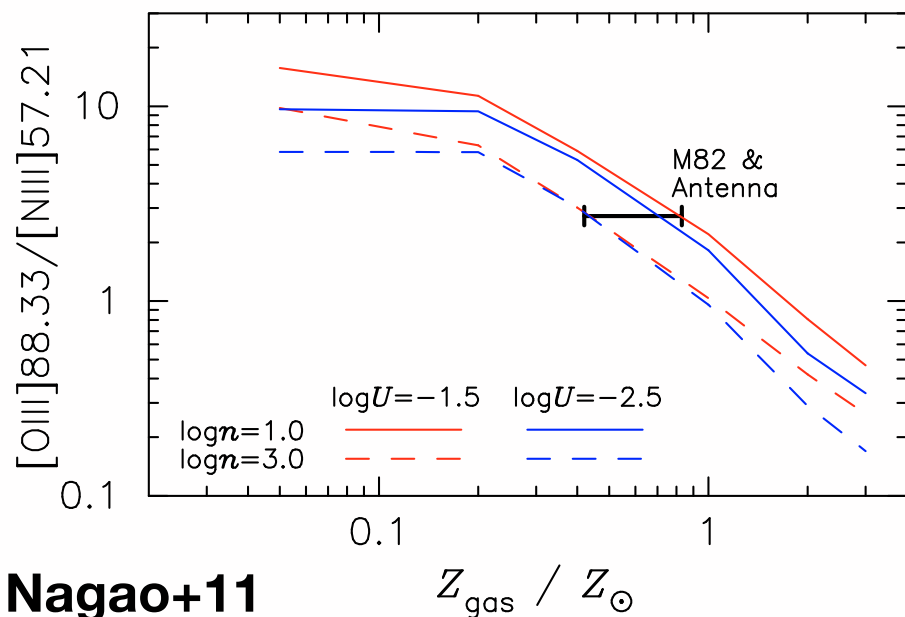
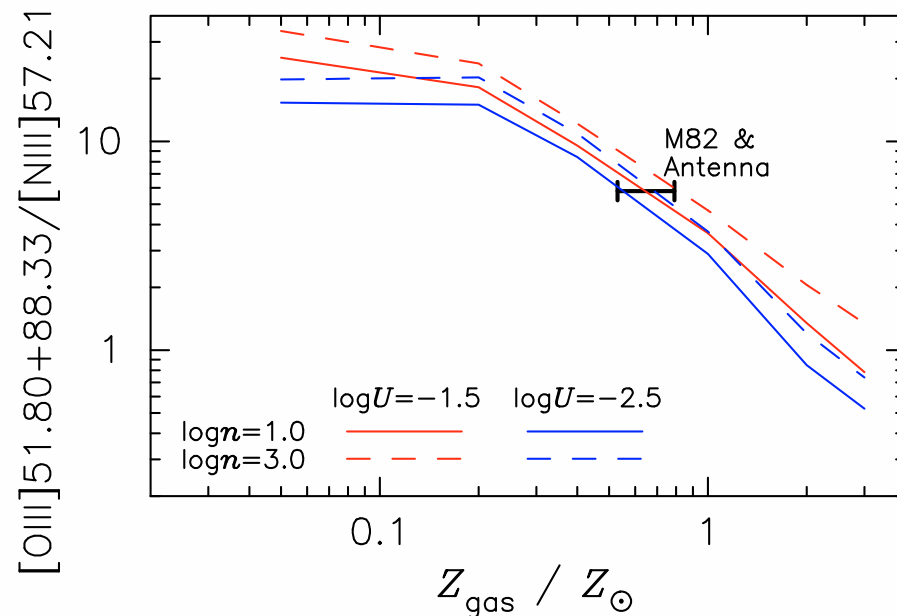
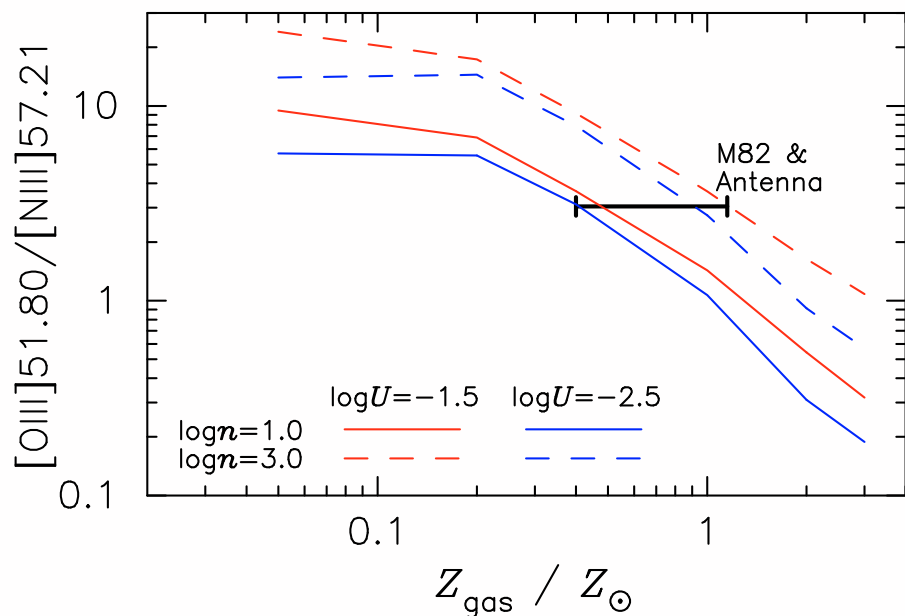
Low metallicity in dusty and high SFR galaxies?

# Metallicity calibration with optical lines :



Empirical/theoretical metallicity calibration by using strong optical lines (note that systematics exist)

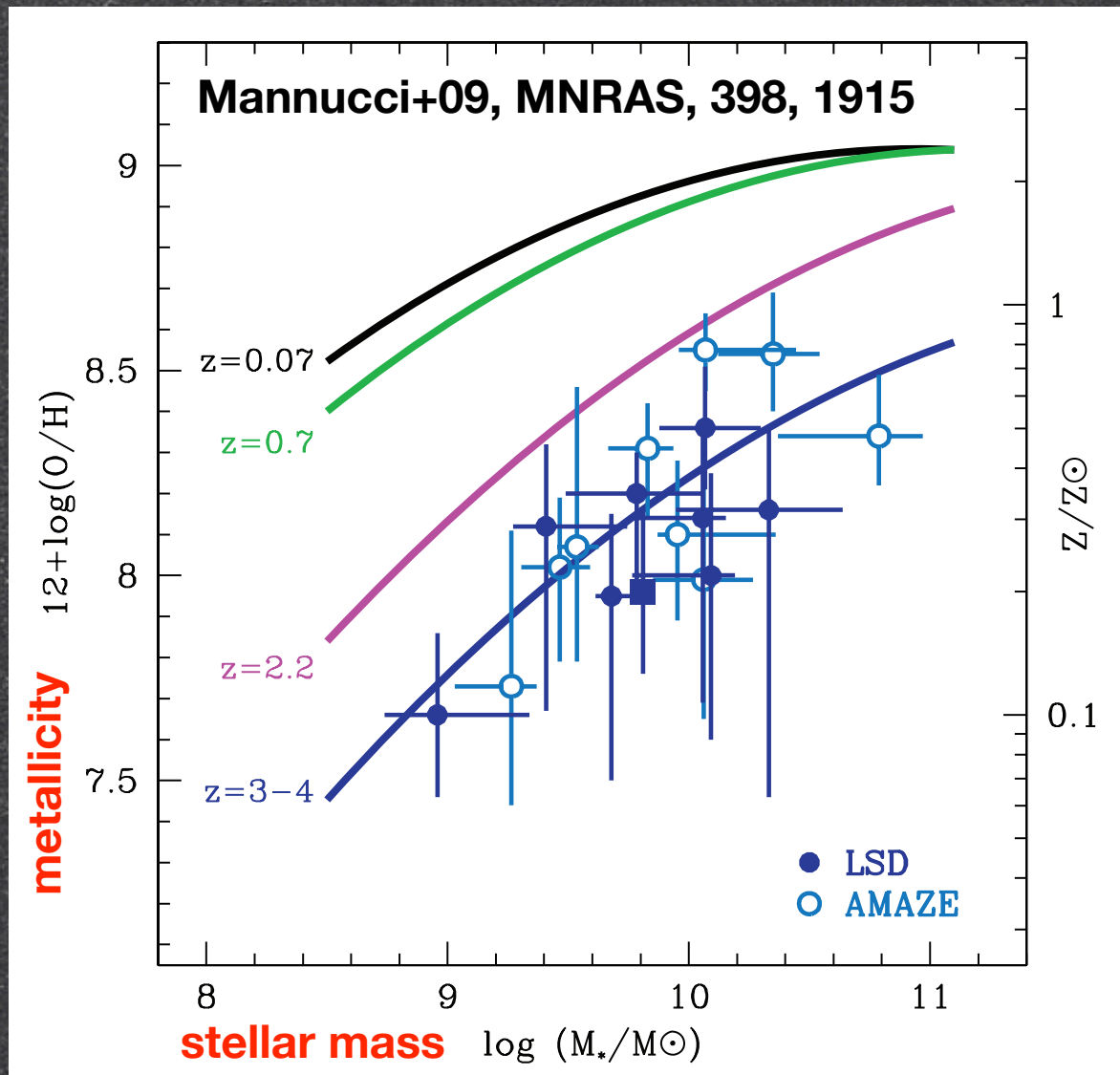
# Metallicity calibration with FIR FSLs :



**Metallicity calibration by using  
FIR [OIII]52 $\mu$ m, [OIII]88 $\mu$ m,  
[NII]57 $\mu$ m**

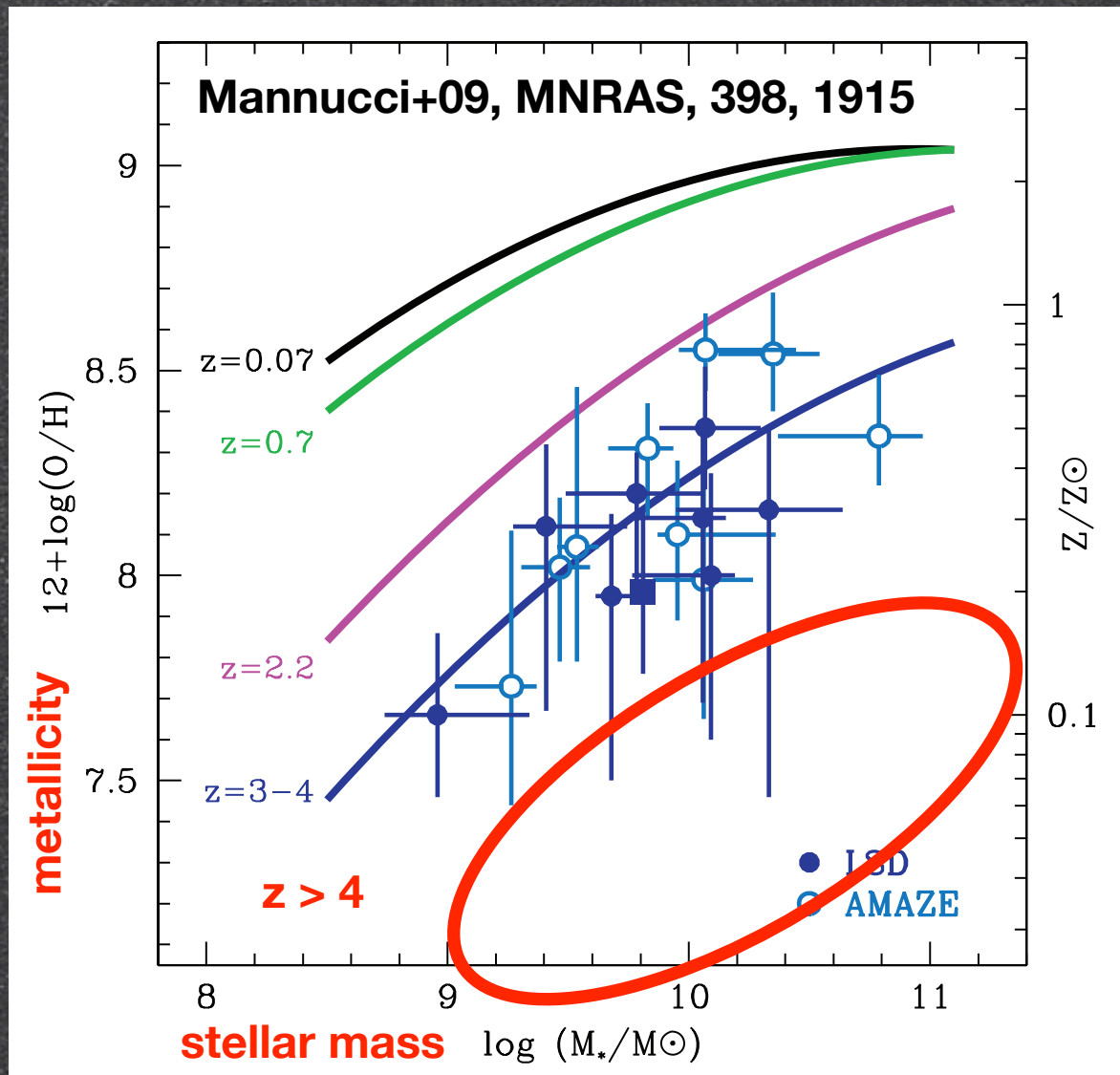
**→ “SPICA” is necessary ! How  
about ALMA?**

# Metallicity of galaxies at high redshift :



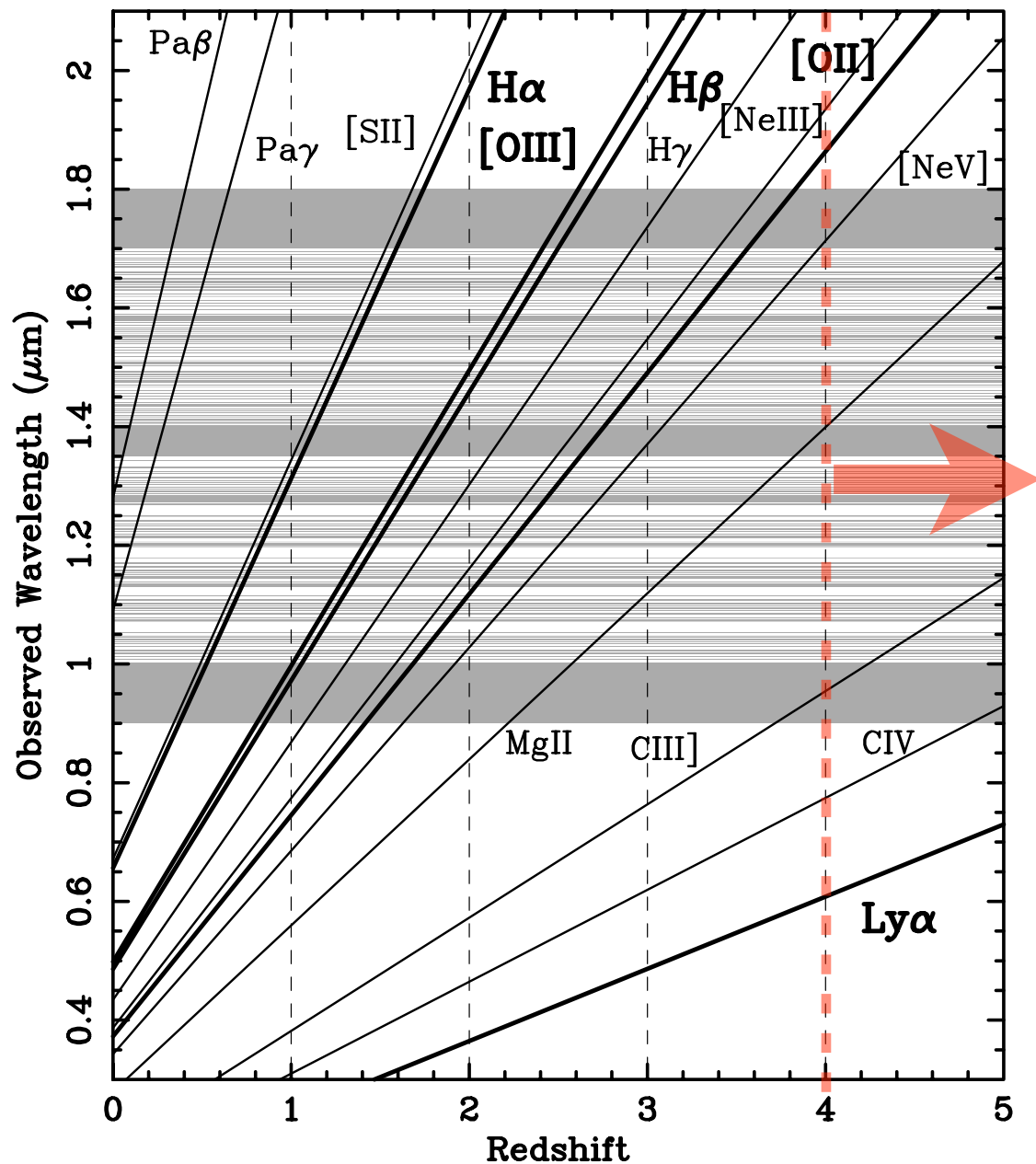
Metallicity measurements are limited up to  $z \sim 3$

# Metallicity of galaxies at high redshift :



Metallicity measurements are limited up to  $z \sim 3$

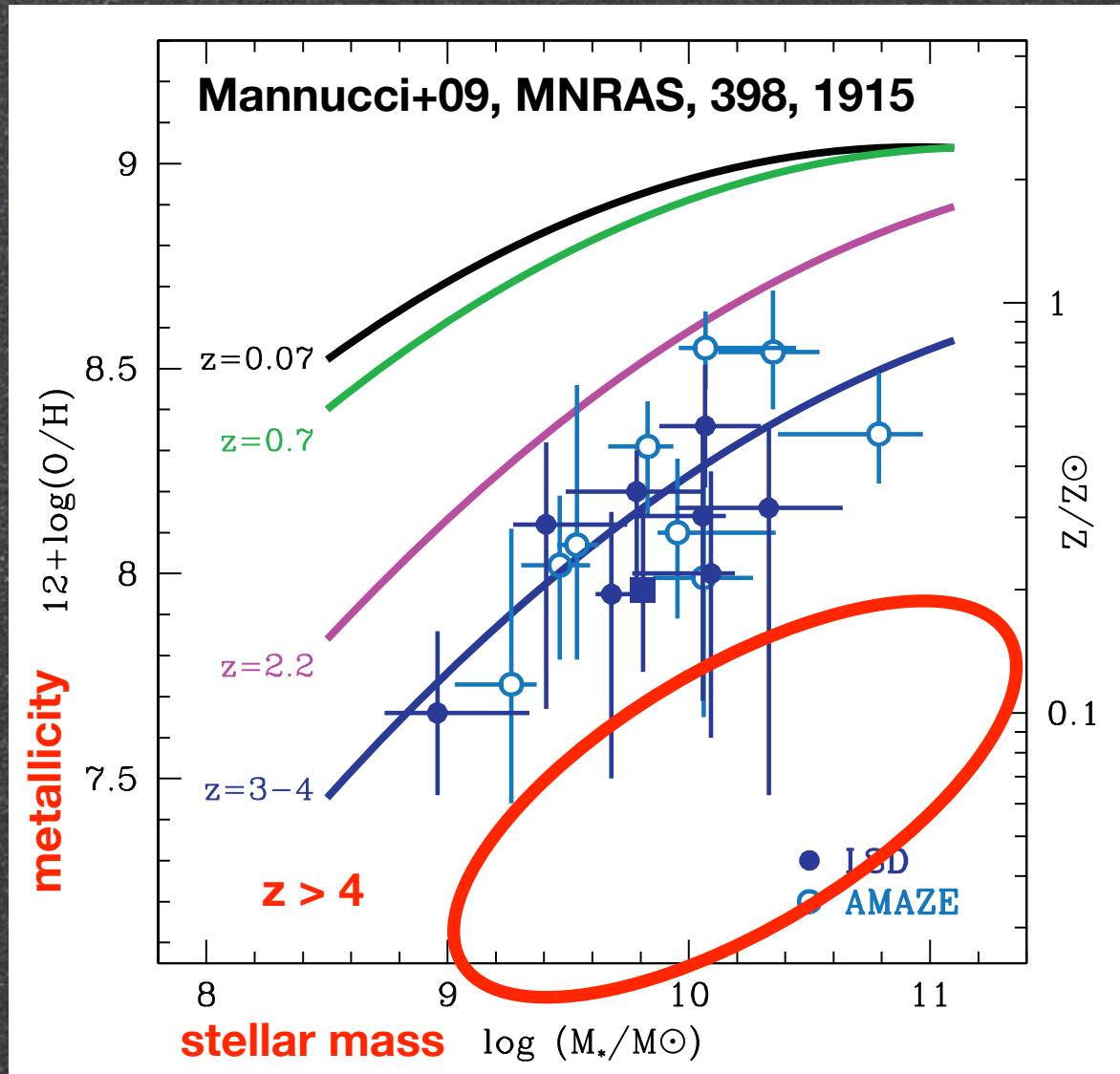
# Metallicity of galaxies at high redshift :



Strong emission lines used to calibrate the metallicity come through the observable wavelength ( $>2.5\mu\text{m}$ )



# Metallicity of galaxies at high redshift :



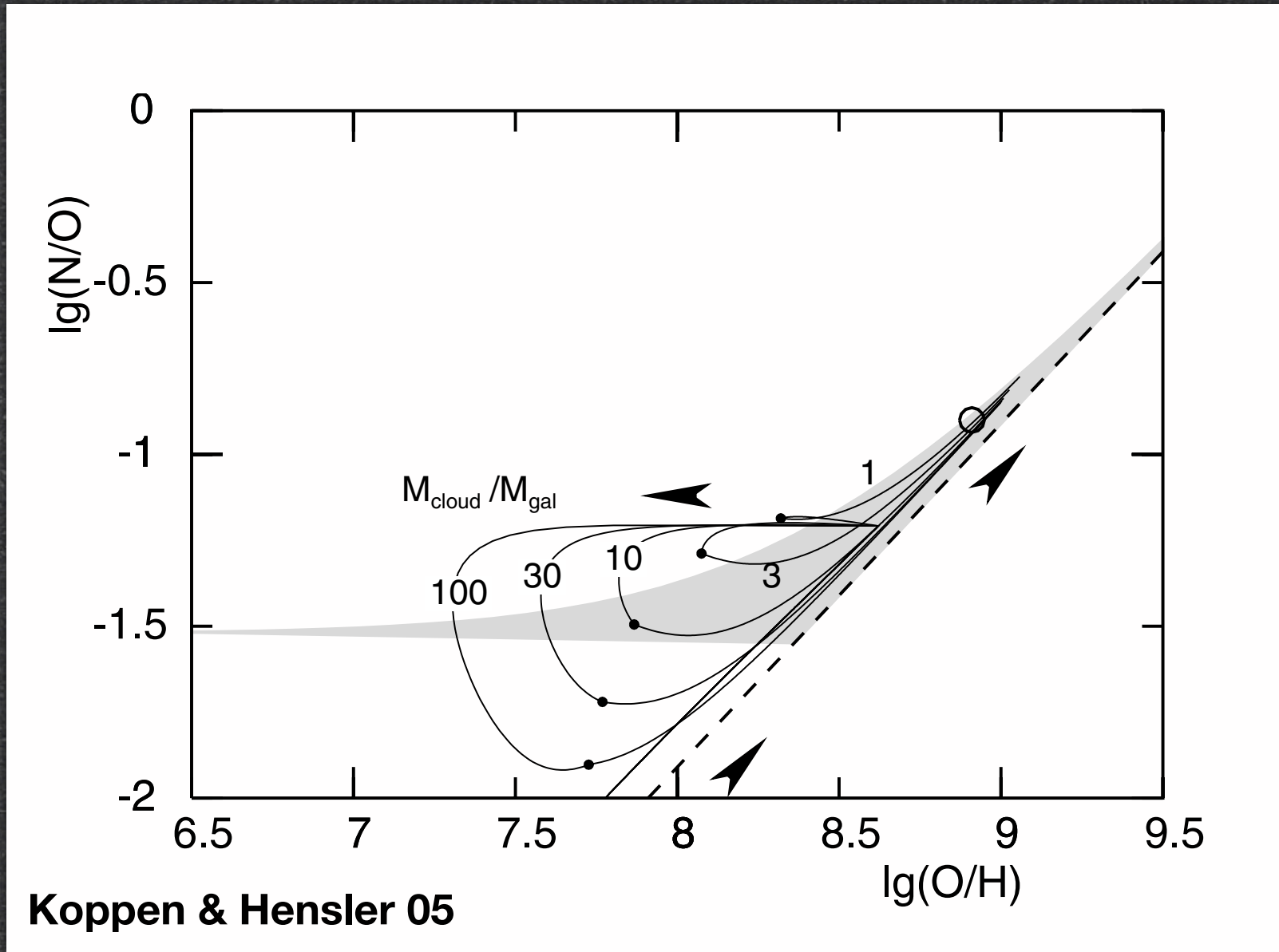
JWST?  
SPICA?

or

ALMA?

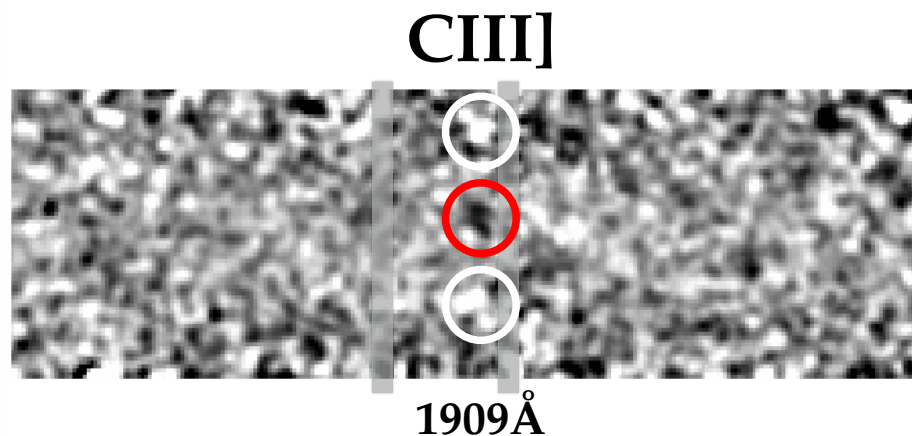
Metallicity measurements are limited up to  $z \sim 3$

# Chemical abundance ratio at high redshift:



Effect of gas inflow on chemical evolution

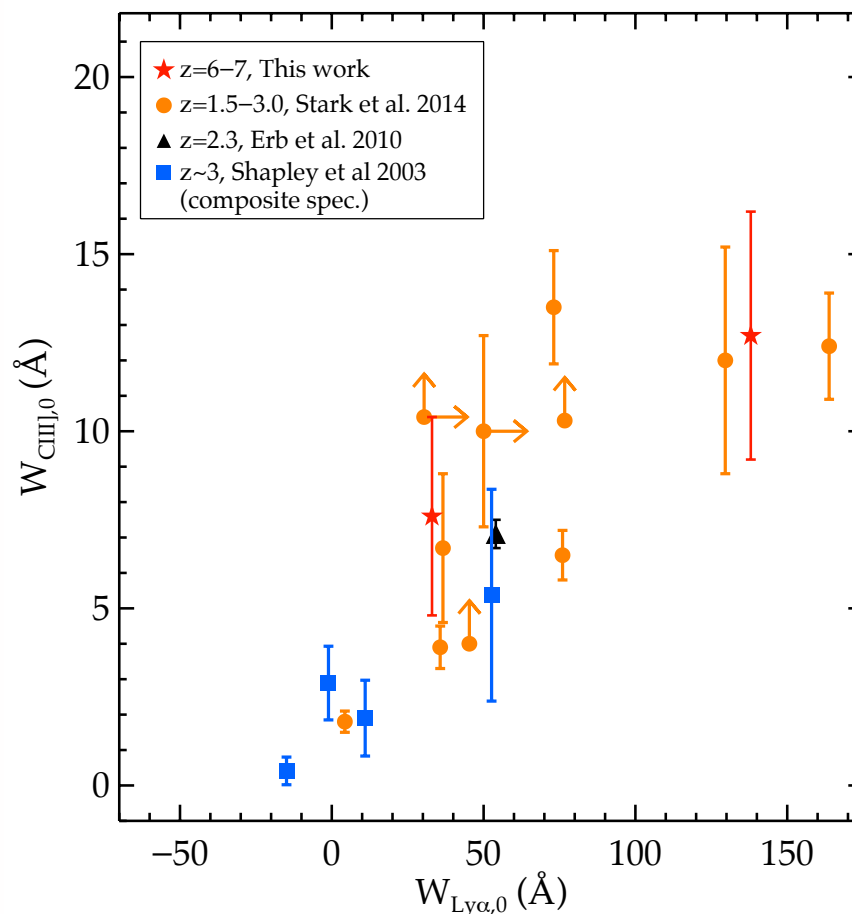
# Chemical abundance ratio at high redshift:



Model fit to A383.5.2

$\log U$	$-1.70^{+0.49}_{-0.64}$
$\log (M_{*,\text{young}}/M_{*,\text{tot}})$	$-2.99^{+0.04}_{-0.03}$
$\log (Z/Z_{\odot})$	$-1.33^{+0.27}_{-0.20}$
$\log(\text{C/O})$	$-0.58^{+0.06}_{-0.06}$
$\log(\text{age/yr})$	$8.72^{+0.10}_{-0.10}$
$\log(M_{*,\text{tot}}/M_{\odot})$	$9.50^{+0.10}_{-0.10}$
$\log(\text{SFR}/M_{\odot}\text{yr}^{-1})$	$0.29^{+0.08}_{-0.08}$
$\hat{\tau}_V$	$0.05^{+0.05}_{-0.05}$

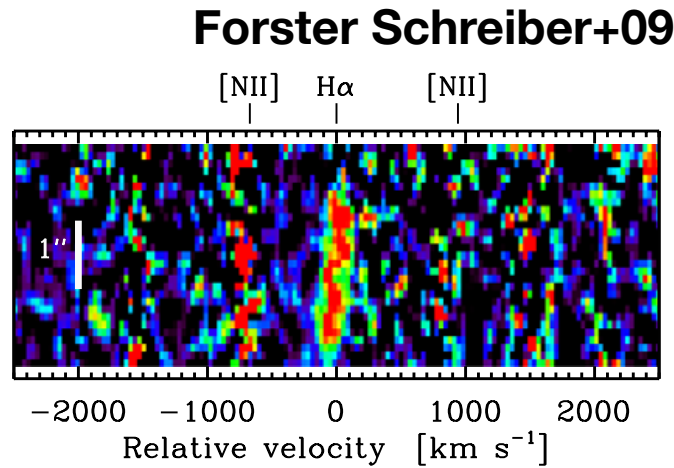
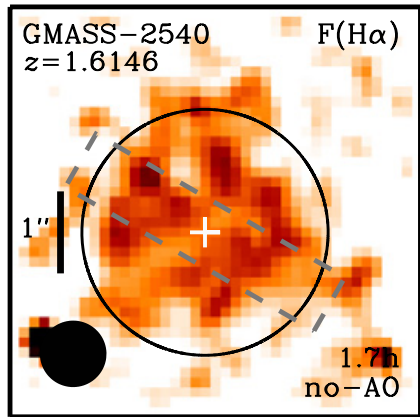
Stark et al. 2014 (arXiv:1408.3649)



Note that they are gravitational lensed objects

## Detection of CIII] $\lambda$ 1909 from galaxies at $z\sim 6$

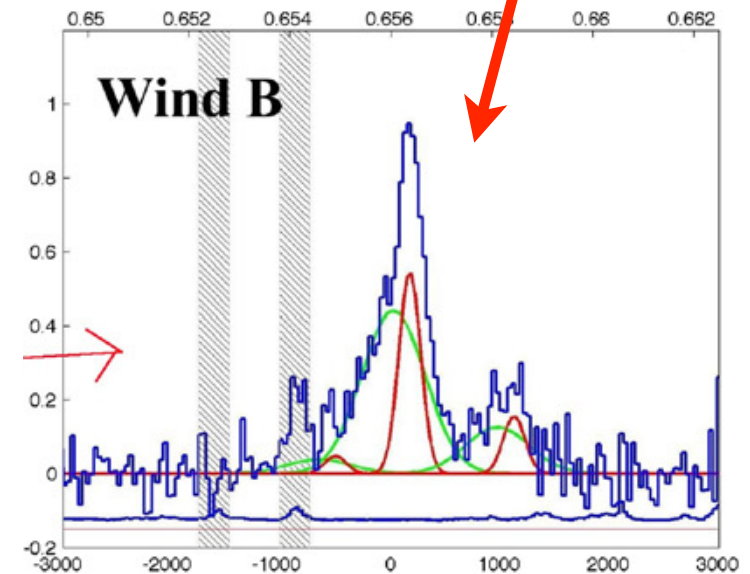
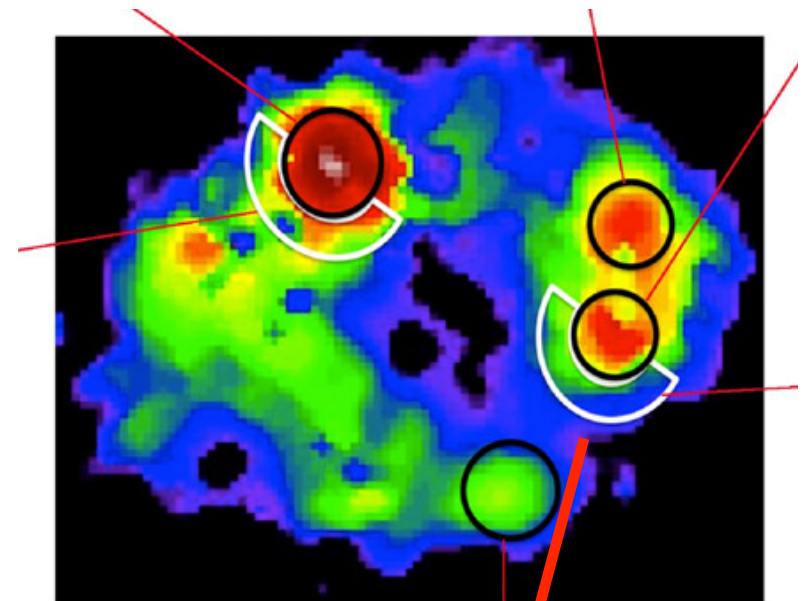
# Morphology and Kinematics at high redshift :



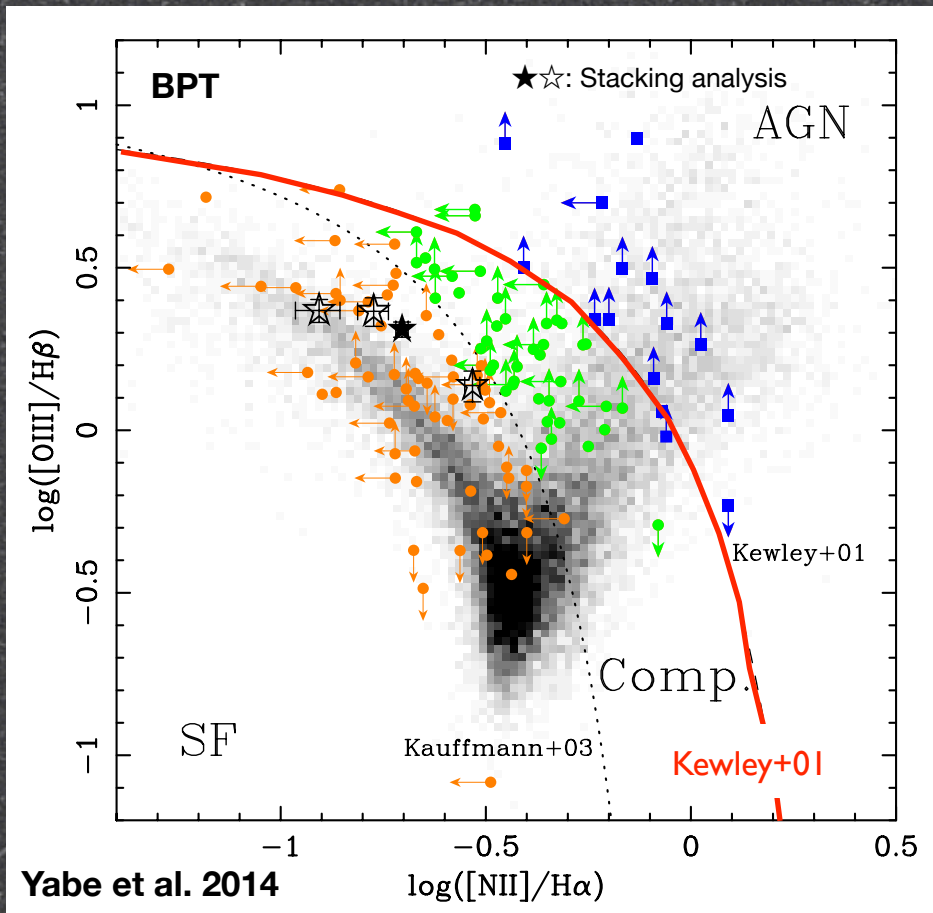
Clumpy structure in high redshift galaxies

Strong Galactic winds in individual clumps of high redshift galaxies

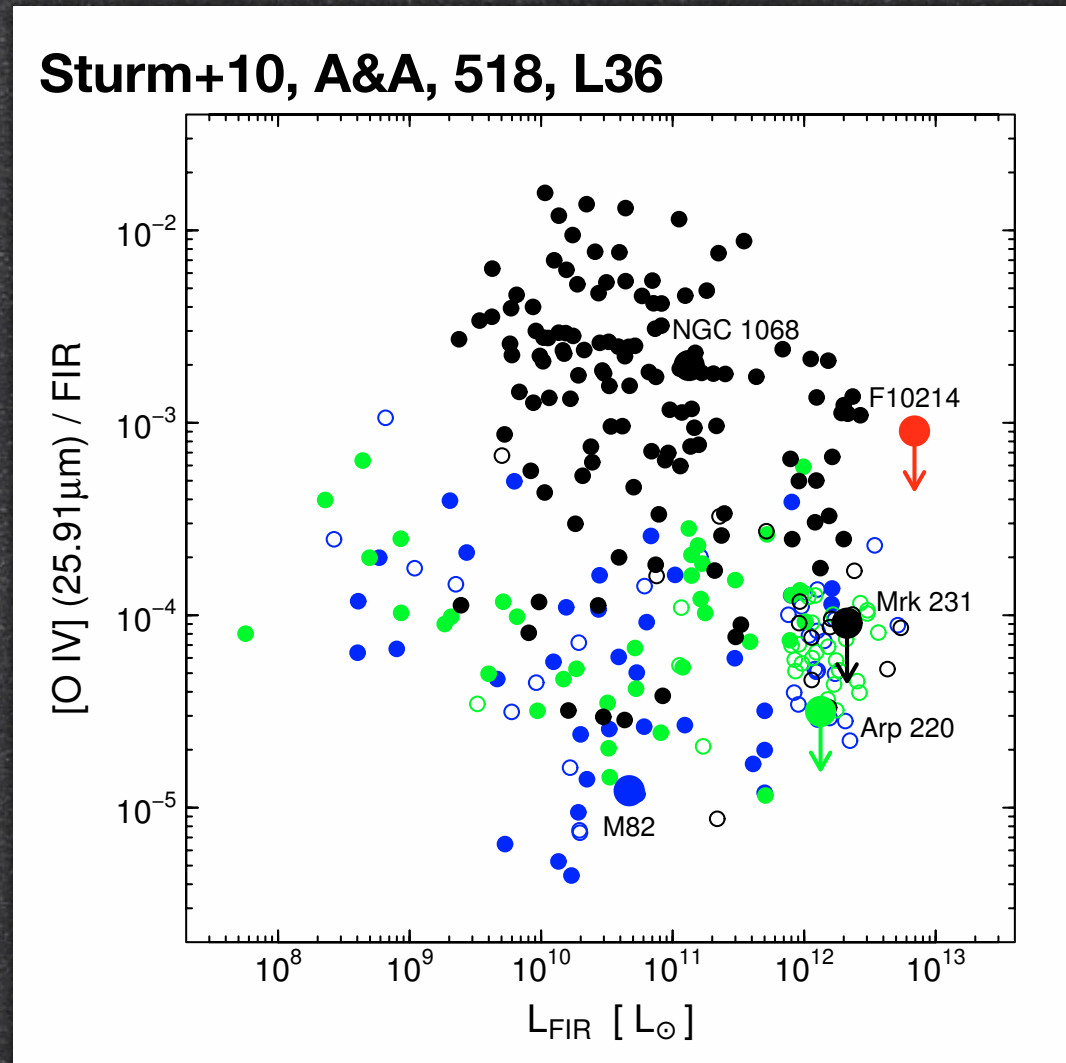
Dust geometry in high redshift galaxies



# Connection between galaxies and AGN :



AGN diagnostics by using FIR fine structure lines ?



# What I want to know :

- **Star formation rate of galaxies**
- **Metallicity of galaxies**
- **Distribution of star-formation**
- **ISM condition / AGN connection**

**... from dust-free observations  
spatially resolved (if possible) ...**