The major merger origin of massive early-types since $z \sim 2$

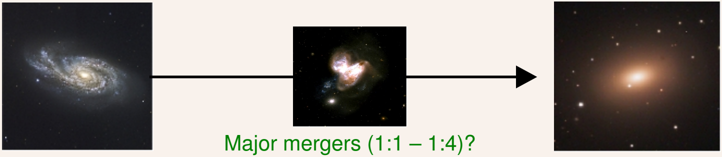
C. López-Sanjuan,
O. Le Fèvre, L. Tasca, L. de Ravel,
and MASSIV + VVDS teams

Centro de Estudio de Física del Cosmos de Aragón

López-Sanjuan+13, A&A, 553, A78

8th July 2013
EWASS 2013 – S04 (Turku, Finland)

The merger origin of early-type galaxies (ETGs)



Major mergers (1:1 – 1:4)?

González-García & Balcells 2005; Naab et al. 2006; Rothberg et al. 2006a,b, 2010; Hopkins et al. 2009

$M_\star \sim 10^{10}\ M_\odot - 10^{11}\ M_\odot$

Major mergers explain $\sim$ 30% of the ETGs' number density evolution since $z \sim 1$. Other processes (e.g., secular evolution, environment) are needed (de Ravel+09, Wild+09 and next talk, López-Sanjuan+10).

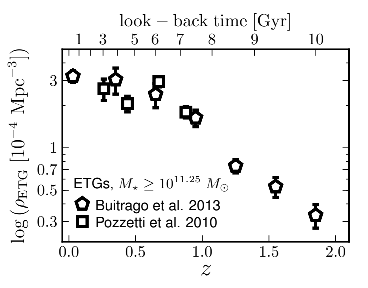
$M_\star \gtrsim 10^{11}\ M_\odot$

Major mergers seem common enough to explain all the ETGs' number density evolution since $z \sim 1$ (e.g., Eliche-Moral+10, Robaina+10, Prieto+13).

Is this the case at $z > 1$?

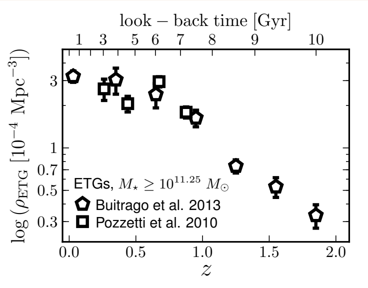
Testing the major merger origin of ETGs

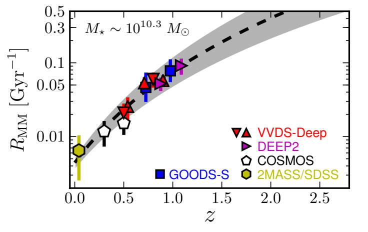
1. The number density evolution of ETGs ($\rho_{\rm ETG}$) since $z \sim 2$. (Buitrago+13, Pozzeti+10).
2. The gas-rich (wet) major merger rate ($R_{\rm MM}$) since $z \sim 2$. At $z > 1$ the merger rates are based on morphology (e.g., Conselice+08) or in photometric pairs (e.g., Ryan+08, Bluck+13). Our first goal is estimate the merger rate up to $z \sim 2$ from spectroscopic close pairs.
3. A model to link $R_{\rm MM}$ and $\rho_{\rm ETG}$.



Testing the major merger origin of ETGs

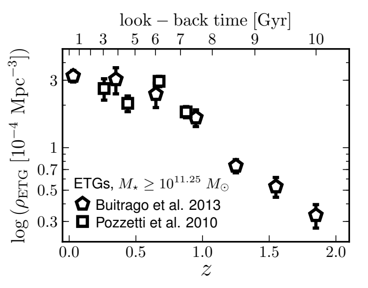
1. The number density evolution of ETGs ($\rho_{\rm ETG}$) since $z \sim 2$. (Buitrago+13, Pozzeti+10). ✓
2. The gas-rich (wet) major merger rate ($R_{\rm MM}$) since $z \sim 2$. ✗
   At $z > 1$ the merger rates are based on morphology (e.g., Conselice+08) or in photometric pairs (e.g., Ryan+08, Bluck+13).
   Our first goal is estimate the merger rate up to $z \sim 2$ from spectroscopic close pairs.
3. A model to link $R_{\rm MM}$ and $\rho_{\rm ETG}$.

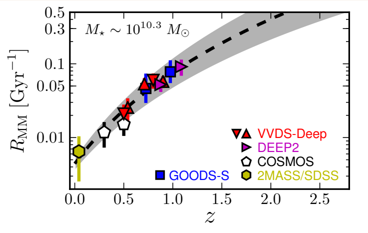




Testing the major merger origin of ETGs

1. The number density evolution of ETGs ($\rho_{\rm ETG}$) since $z \sim 2$. (Buitrago+13, Pozzeti+10). ✓
2. The gas-rich (wet) major merger rate ($R_{\rm MM}$) since $z \sim 2$. ✗
   At $z > 1$ the merger rates are based on morphology (e.g., Conselice+08) or in photometric pairs (e.g., Ryan+08, Bluck+13).
   Our first goal is estimate the merger rate up to $z \sim 2$ from spectroscopic close pairs.
3. A model to link $R_{\rm MM}$ and $\rho_{\rm ETG}$. ✗





VVDS: VIMOS VLT Deep Survey

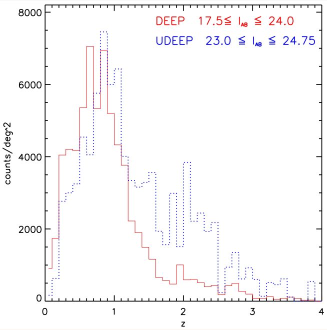
Survey	i (AB)	Area (deg^2)	$N_{\rm spec}$
VVDS-Wide	$i \leq 22.5$	8.10	~ 25800
VVDS-Deep	$i \leq 24.0$	0.74	~ 11500
VVDS-Ultradeep	$i \leq 24.75$	0.14	~ 900

VVDS-Ultradeep

(Le Fèvre+05; Le Fèvre+13, arXiv: 1307.0545): fainter part of the VVDS designed to fill the redshift desert at $z > 1.5$.

We found 9 close pairs at $1.5 < z < 3$ with $r_{\rm p}^{\rm max} = 150h^{-1}$ kpc and $\Delta v \leq 2000$ km s^{-1}.

VVDS-Deep mergers at $z < 1$: de Ravel+09, López-Sanjuan+11

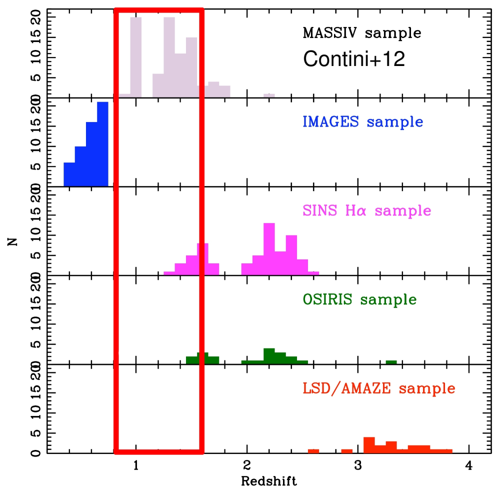


MASSIV : Mass Assembly Survey with SINFONI in VVDS

IFU samples at 0.5 < z <3

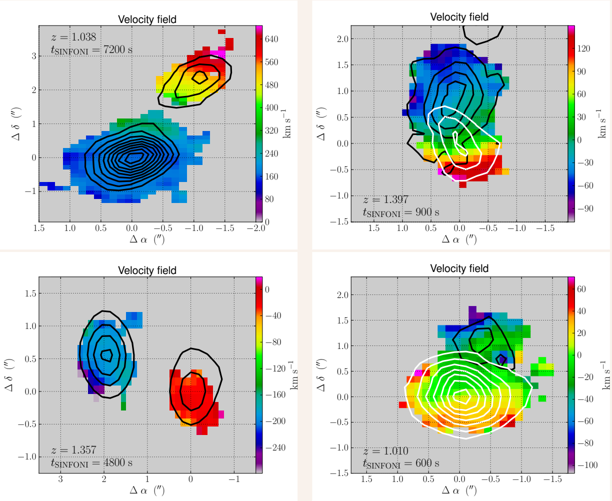
IMAGES 0.4 < z < 0.8
SINS 1.3 < z < 2.7
OSIRIS-Keck 1.5 < z < 2.5
LSD/AMAZE 2.5 < z < 4
MASSIV 0.9 < z < 1.8

MASSIV provides 2D NIR ($J-$ & $H-$band) spectroscopy of 84 star-forming galaxies to study the dynamical support of galaxies at $1 < z < 1.5$ (Epinat+12), fundamental relations (Vergani+12), metallicity gradients (Quyrel+12) and the merger rate from spectroscopic close pairs (López-Sanjuan+13).

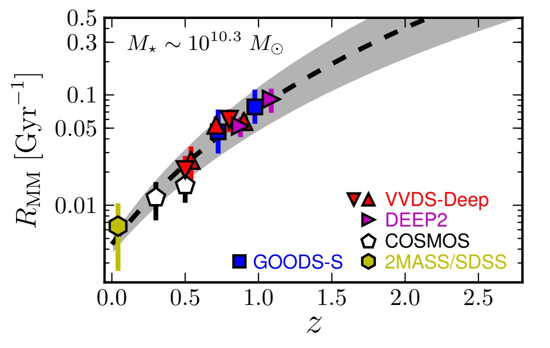


MASSIV : Mass Assembly Survey with SINFONI in VVDS

We found 13 gas-rich major close pairs at $1 < z < 1.8$ with $r_{\rm p}^{\rm max} = 30h^{-1}$ kpc and $\Delta v \leq 500$ km s^{-1}.



The merger rate at $z > 1$ from kinematical close pairs



MASSIV ($1 < z < 2$): the merger rate evolves as $R_{\rm MM} \propto (1+z)^{3.9}$.

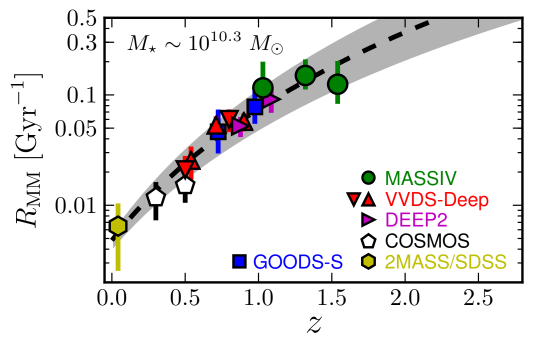
VVDS-Ultradeep ($z = 2.35$)

$R_{\rm MM} \propto (1+z)^{4.5} e^{-0.17z^3}$, with $z_{\rm peak} = 1.8$.

We confirm the tendency from previous work

(e.g., Conselice+08, Ryan+08).

The merger rate at $z > 1$ from kinematical close pairs



MASSIV ($1 < z < 2$): the merger rate evolves as $R_{\rm MM} \propto (1+z)^{3.9}$.

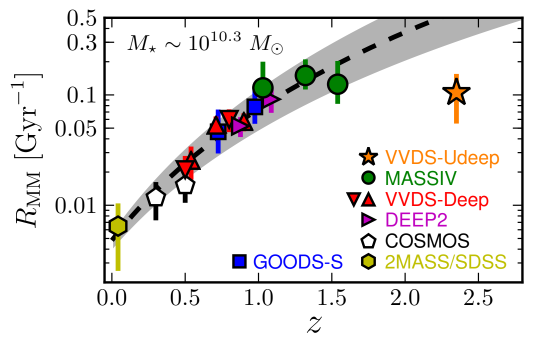
VVDS-Ultradeep ($z = 2.35$)

$R_{\rm MM} \propto (1+z)^{4.5} e^{-0.17 z^3}$, with $z_{\rm peak} = 1.8$.

We confirm the tendency from previous work

(e.g., Conselice+08, Ryan+08).

The merger rate at $z > 1$ from kinematical close pairs



MASSIV ($1 < z < 2$): the merger rate evolves as $R_{\rm MM} \propto (1+z)^{3.9}$.

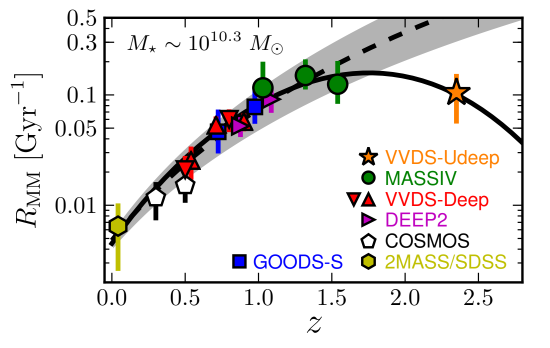
VVDS-Ultradeep ($z = 2.35$)

$R_{\rm MM} \propto (1+z)^{4.5} e^{-0.17z^3}$, with $z_{\rm peak} = 1.8$.

We confirm the tendency from previous work

(e.g., Conselice+08, Ryan+08).

The merger rate at $z > 1$ from kinematical close pairs



MASSIV ($1 < z < 2$): the merger rate evolves as $R_{\rm MM} \propto (1+z)^{3.9}$.

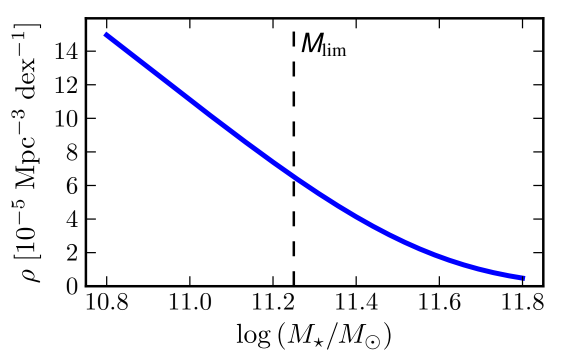
VVDS-Ultradeep ($z = 2.35$)

$R_{\rm MM} \propto (1+z)^{4.5} e^{-0.17z^3}$, with $z_{\rm peak} = 1.8$.

We confirm the tendency from previous work

(e.g., Conselice+08, Ryan+08).

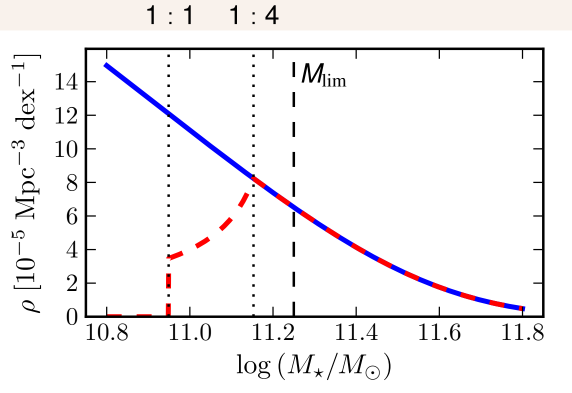
From mergers to ETGs: a toy model



Main assumption: 1 wet major merger = 1 new ETG.

$$\Phi(z, M_\star)R_{\rm MM}(z)$$

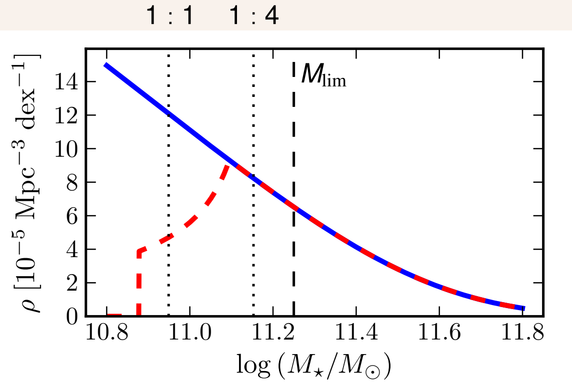
From mergers to ETGs: a toy model



Main assumption: 1 wet major merger = 1 new ETG.

$$\Phi(z, M_\star) R_{\rm MM}(z) E_{\rm MM}(z, M_\star, M_{\rm lim}, \mu_1, \mu_2)$$

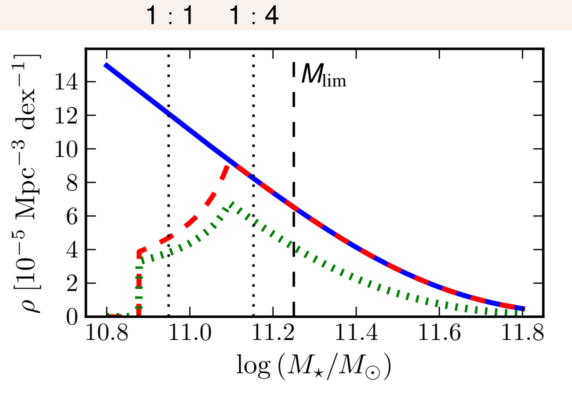
From mergers to ETGs: a toy model



Main assumption: 1 wet major merger = 1 new ETG.

$$\Phi(z, M_\star) R_{\rm MM}(z) E_{\rm MM}(z, M_\star, M_{\rm lim}, \mu_1, \mu_2)$$

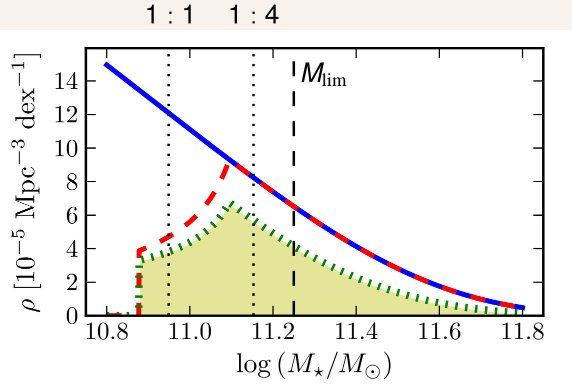
From mergers to ETGs: a toy model



Main assumption: 1 wet major merger = 1 new ETG.

$$\Phi(z, M_\star) R_{\rm MM}(z) E_{\rm MM}(z, M_\star, M_{\rm lim}, \mu_1, \mu_2) f_{\rm LTG}(z, M_\star)$$

From mergers to ETGs: a toy model

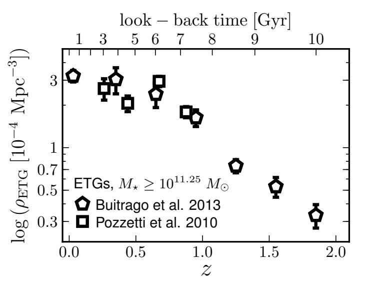


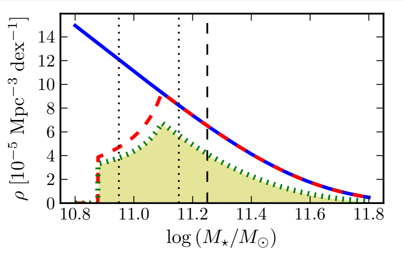
Main assumption: 1 wet major merger = 1 new ETG.

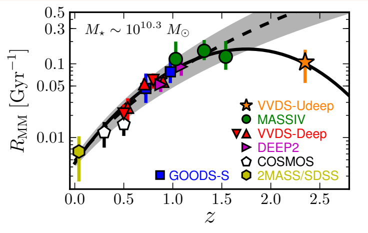
$$\rho_{\rm ETG} = \int\int \Phi(z, M_\star) R_{\rm MM}(z) E_{\rm MM}(z, M_\star, M_{\rm lim}, \mu_1, \mu_2) f_{\rm LTG}(z, M_\star) {\rm d}z{\rm d}M_\star$$

Testing the major merger origin of ETGs

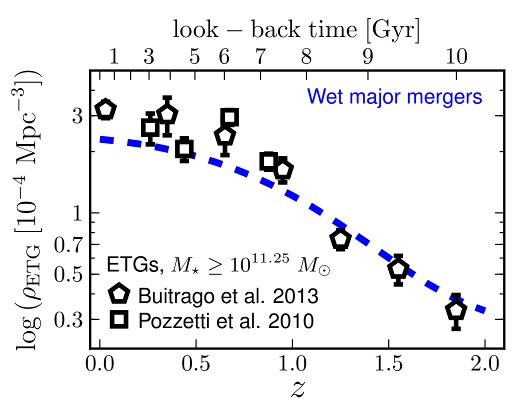
1. The number density evolution of ETGs (ρ_{ETG}) since $z \sim 2$. (Buitrago+13, Pozzeti+10). ✓
2. The gas-rich (wet) major merger rate (R_{MM}) since $z \sim 2$. ✓
3. A model to link R_{MM} and ρ_{ETG}. ✓



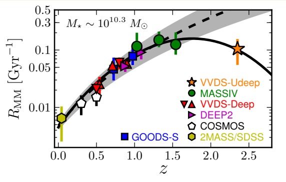




Mergers and ETGs evolution



Wet major merger rate



+ (dry) merger rate of massive ETGs

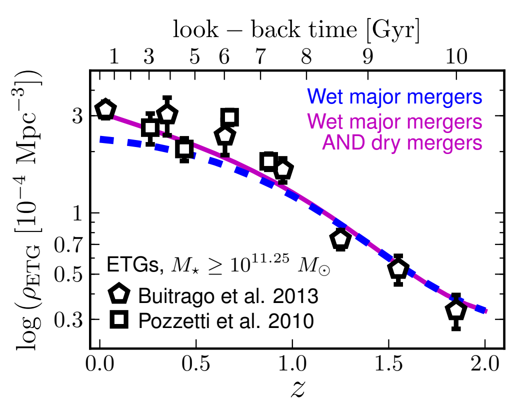
(López-Sanjuan+12, Marmol-Queraltó+12, Newman+12)

If we assume that one gas-rich merger provides a new ETG, we can explain the number density evolution of massive ETGs at $1 < z < 2$.

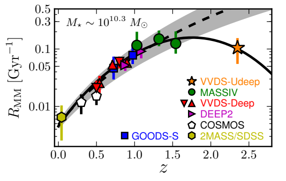
Dry merging becomes important at $z < 1$.

Since $z = 2$, 2/3 of $\rho_{\rm ETG}$ is due to wet mergers and 1/3 to dry mergers.

Mergers and ETGs evolution



Wet major merger rate

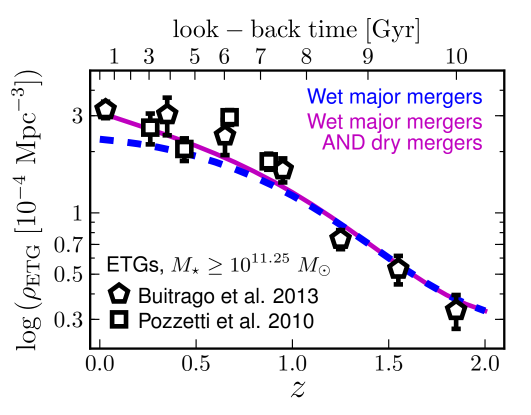


+ (dry) merger rate of massive ETGs

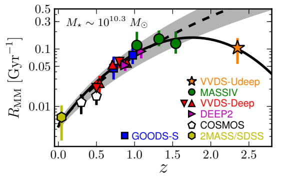
(López-Sanjuan+12, Marmol-Queraltó+12, Newman+12)

If we assume that one gas-rich merger provides a new ETG, we can explain the number density evolution of massive ETGs at $1 < z < 2$.
Dry merging becomes important at $z < 1$.
Since $z = 2$, 2/3 of $\rho_{\rm ETG}$ is due to wet mergers and 1/3 to dry mergers.

Mergers and ETGs evolution



Wet major merger rate

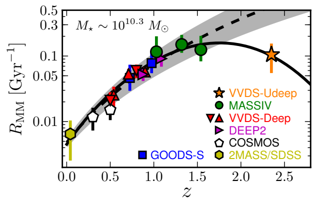


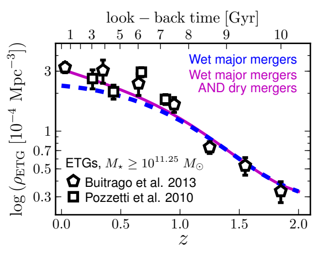
+ (dry) merger rate of massive ETGs

(López-Sanjuan+12, Marmol-Queraltó+12, Newman+12)

If we assume that one gas-rich merger provides a new ETG, we can explain the number density evolution of massive ETGs at $1 < z < 2$.
Dry merging becomes important at $z < 1$.
Since $z = 2$, 2/3 of $\rho_{\rm ETG}$ is due to wet mergers and 1/3 to dry mergers.

Conslusions

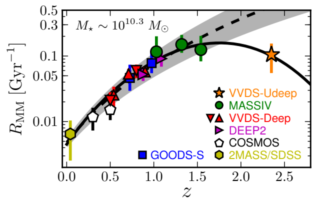


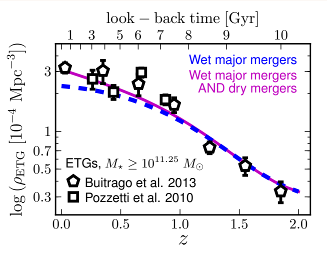


- We measure the merger rate at $z \gtrsim 1$ from spectroscopically confirmed close pairs in MASSIV and VVDS-Udeep. The merger rate evolves as $(1+z)^{3.9}$ up to $z \sim 1.5$, then flattens. **VUDS** (VIMOS Ultra Deep Survey) will provide R_{MM} at $z > 2.5$.
- Since $z = 2$, 2/3 of ρ_{ETG} is due to wet mergers and 1/3 to dry mergers. The evolution at $1 < z < 2$ is fully explained by major wet mergers.

Kiitos!

Conslusions

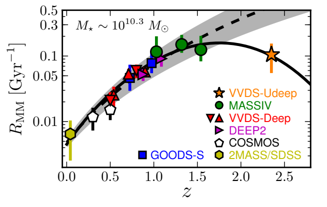


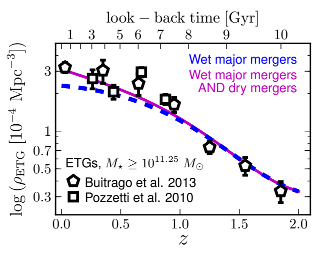


- We measure the merger rate at $z \gtrsim 1$ from spectroscopically confirmed close pairs in MASSIV and VVDS-Udeep. The merger rate evolves as $(1+z)^{3.9}$ up to $z \sim 1.5$, then flattens. **VUDS** (VIMOS Ultra Deep Survey) will provide $R_{\rm MM}$ at $z > 2.5$.
- Since $z = 2$, 2/3 of $\rho_{\rm ETG}$ is due to wet mergers and 1/3 to dry mergers. The evolution at $1 < z < 2$ is fully explained by major wet mergers.

Kiitos!

Conslusions





- We measure the merger rate at $z \gtrsim 1$ from spectroscopically confirmed close pairs in MASSIV and VVDS-Udeep. The merger rate evolves as $(1+z)^{3.9}$ up to $z \sim 1.5$, then flattens. **VUDS** (VIMOS Ultra Deep Survey) will provide $R_{\rm MM}$ at $z > 2.5$.
- Since $z = 2$, 2/3 of $\rho_{\rm ETG}$ is due to wet mergers and 1/3 to dry mergers. The evolution at $1 < z < 2$ is fully explained by major wet mergers.

Kiitos!