

Extreme Emission Line Galaxies at $z < 0.05$ with S-PLUS

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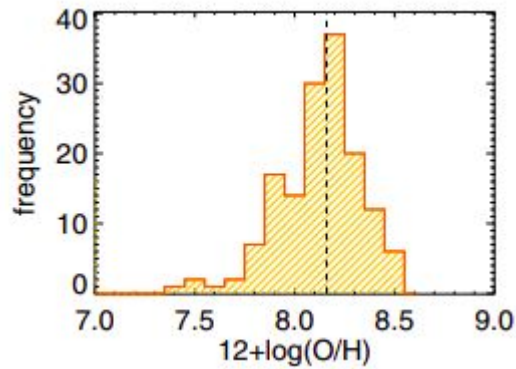
16th Collaboration S-PLUS Meeting
December/2021



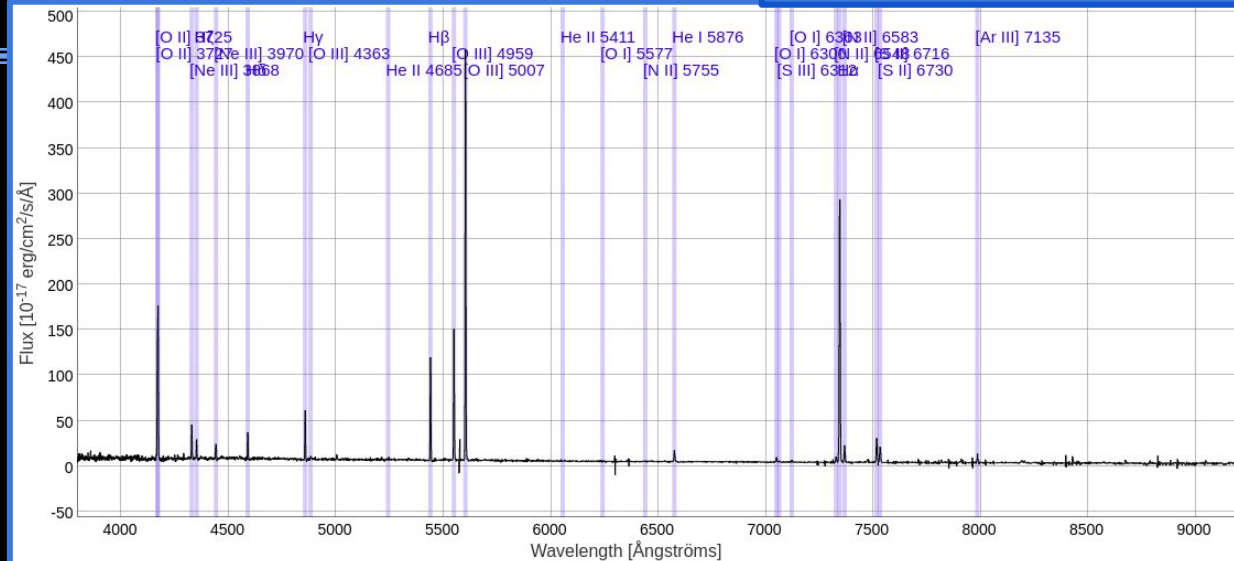
Extreme emission line galaxies (EELGs)

- Spectra characterized by strong emission lines, i.e. $EW([OIII]) > 200\text{\AA}$ ou $EW(H\alpha) > 200\text{\AA}$.
- Low mass galaxies
- Low metallicity
- High specific star formation rate ($sSFR = SFR/M \sim 10^{-7} \text{ yr}$)
- Compact objects

SDSS J214459.58-001140.2

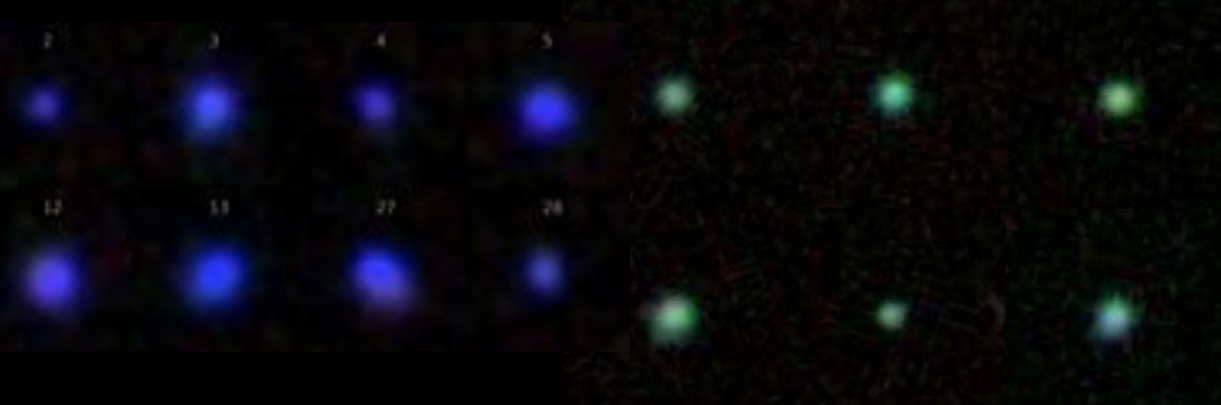


Amorín et al. (2015)



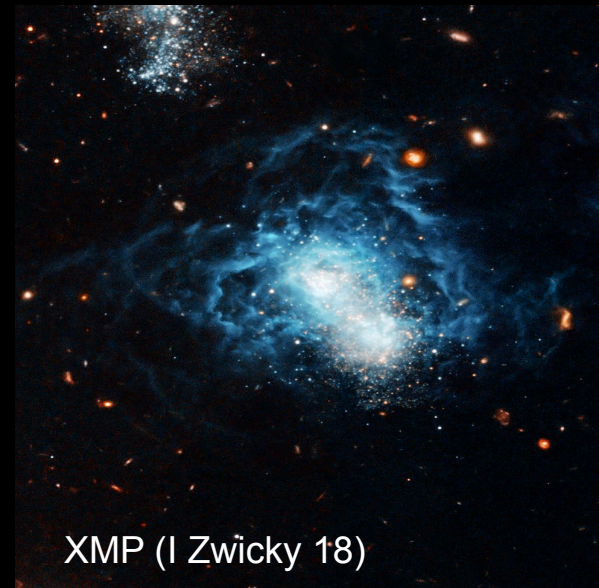
Local Analogs of high-z galaxies

- Low metallicity
- High specific star formation rate (sSFR = SFR/M $\sim 10^{-7}$ yr)
- High ionization
- Simplest starbursts in local in galactic scale with the highest SF efficiencies



Blueberries
(Yang et al. 2017)

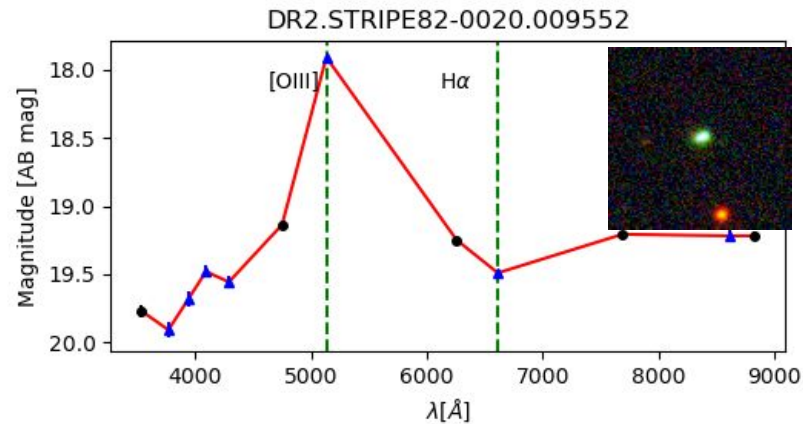
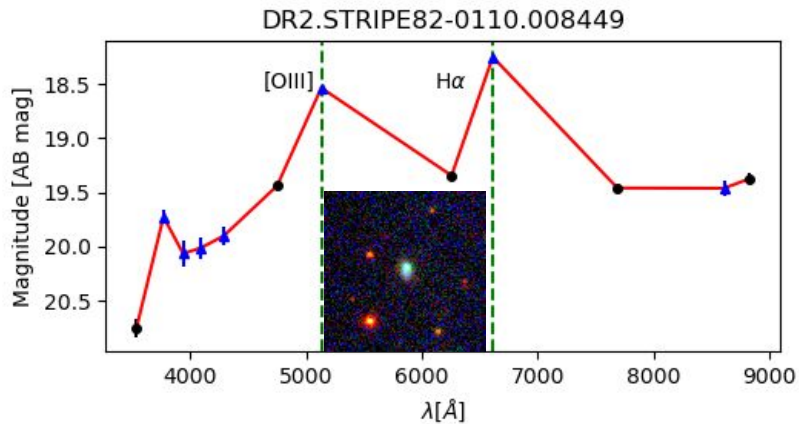
Green Peas
(Cardamone et al. 2009)



XMP (I Zwicky 18)

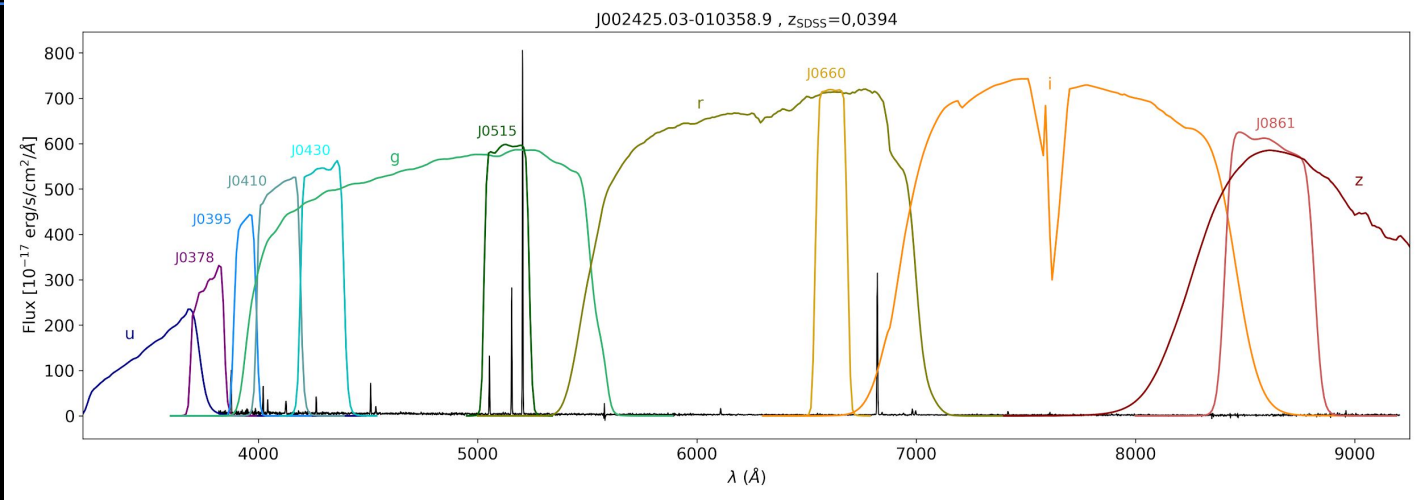
Project goals

- Select EELG candidates at different z-ranges
 - + $H\alpha$ at J0660 ($z < 0.016$), J0861 ($0.285 < z < 0.36$)
 - + $[OIII]$ at J0515 ($0.008 < z < 0.05$), J0660 ($0.323 < z < 0.332$)



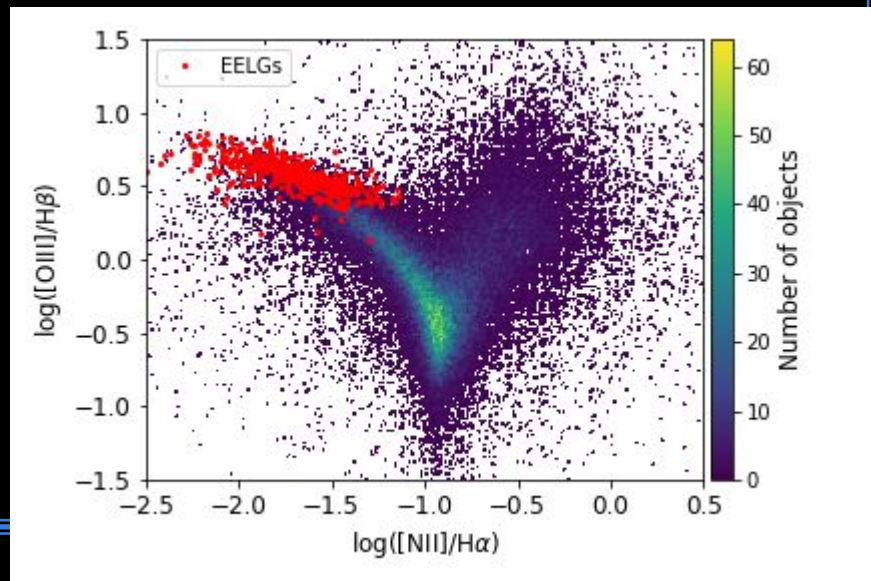
How to identify EELGs?

- Excess in a narrow band indicate the presence of a emission line
- Locate using color-color plots to detect the presence of emission line:
 - + $H\alpha$ em $z < 0.019$: $(J0660-i) < 0$
 - + $[OIII]$ em $0.008 < z < 0.05$: $(J0515-r) < 0$



How to identify EELGs?

- SDSS DR16 spectroscopic sample:
 - + emissionLinePort + galSpecLine tables
 - + Cross-match with SPLUS DR2 + PhotoFlag<4: 77210
- From known [OIII] EELGs:
 - + eliminate subclass=AGN
 - + $z > 0.005$
 - + $EW(H\beta) > 30\text{\AA}$
 - + $EW([OIII]) > 100\text{\AA}$
 - + $EW(H\alpha) > 100\text{\AA}$
 - + $0 < \log([OIII]/H\beta) < 1.2$
 - + $-2.5 < \log([NII]/H\alpha) < 0.8$
 - + Total of 427 galaxies



EELGs selection

Removing stars and QSOs:

- S-PLUS classification based on machine learning (random forest technique, Nakazono et al. 2021)
- For the known EELGs:
 - + 88% galaxies
 - + 3% stars
 - + 9% QSOs
- In $z < 0.05$: 96% of EELGs are properly classified.

First condition: **PROB_GAL > 0.5**

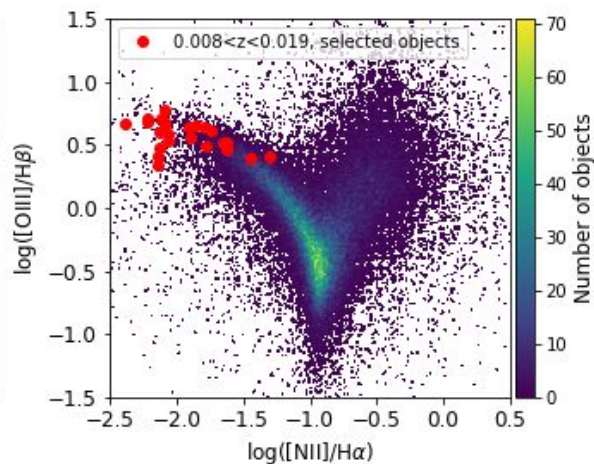
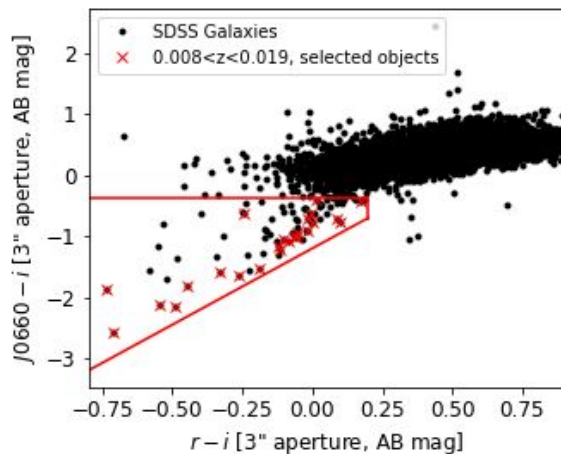
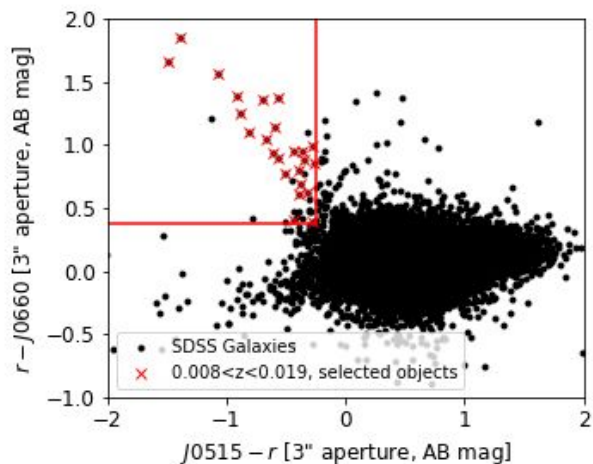
- Additional quality of conditions:
 - + APER_3 magnitude (recovers 77% of EELGs)
 - + **S/N > 3** in the detection bands
 - + **$r_{\text{AUTO}} < 22$**

EELGs selection

- EELGs em $0.008 < z < 0.019$:

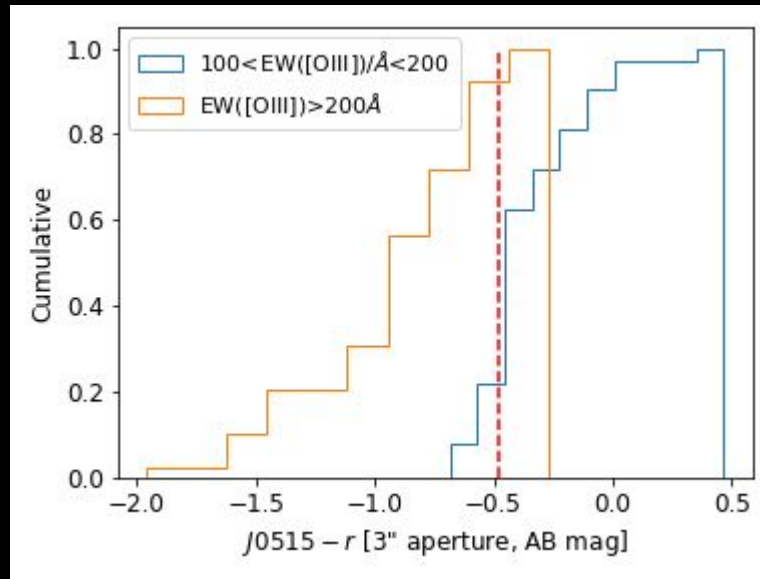
$$+ (r - J0660) > 0.38 \quad ; \quad (J0660 - i) < -0.38 \quad ; \quad (J0515 - r) < -0.25$$

$$+ (r - i) < 0.2 \quad ; \quad (J0660 - i) > 2.5 (r - i) - 1.2$$



EELGs selection

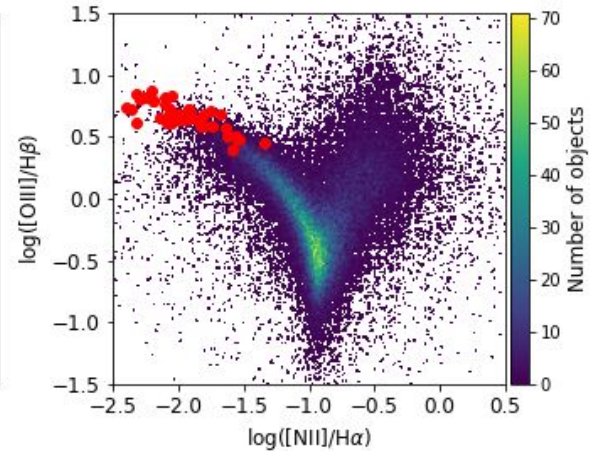
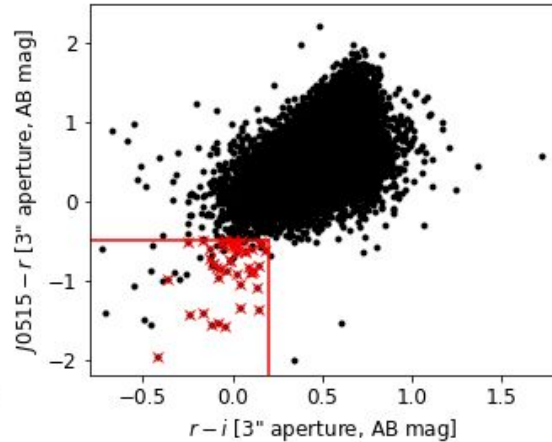
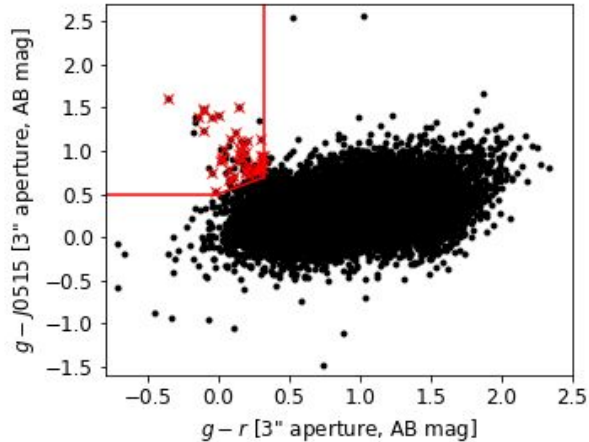
- EELGs at $0.019 < z < 0.05$:
 - + only [OIII] emission in J0515
 - + optimize for $EW([\text{OIII}]) > 200 \text{ \AA}$



EELGs selection

- EELGs em $0.019 < z < 0.05$:

$$\begin{aligned} &+ (J0515-r) < -0.48 \quad ; \quad (g-J0515) > 0.5 \quad ; \quad (J0660-i) > -0.38 \\ &+ (r-i) < 0.2 \quad ; \quad (g-r) < 0.32 \quad ; \quad (g-J0515) > 0.6 \quad (g-r) + 0.5 \end{aligned}$$



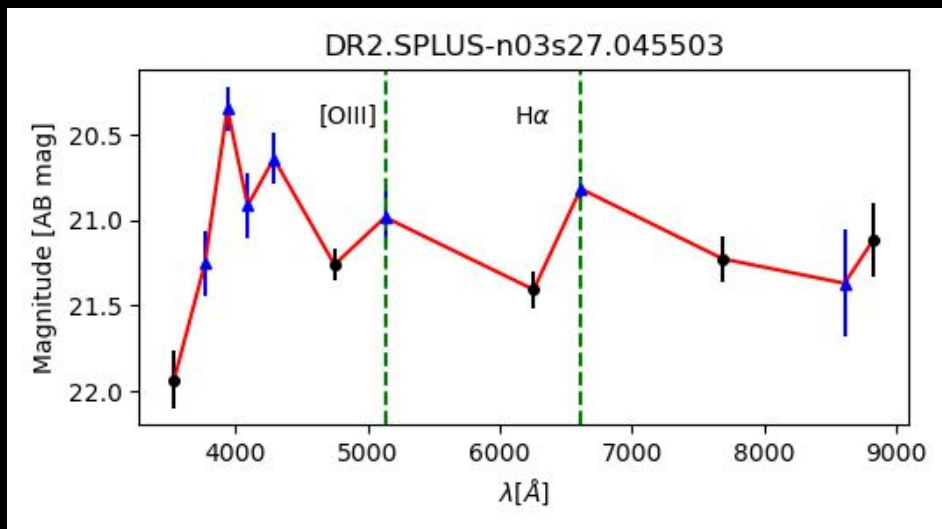
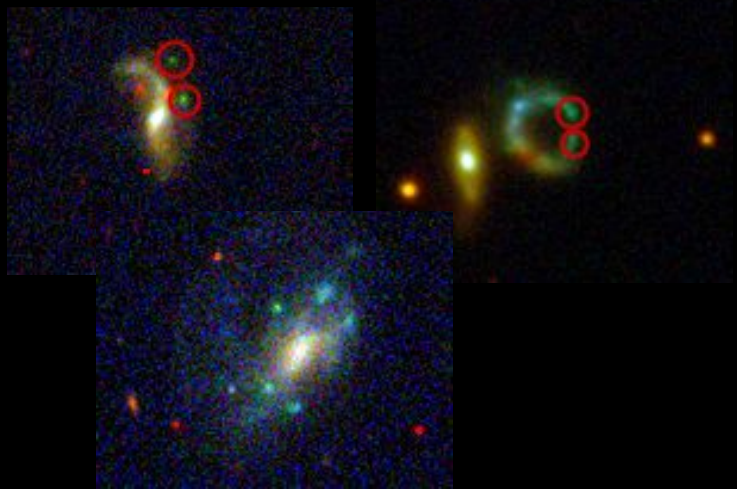
EELGs selection results

- S-PLUS DR2 (PhotoFlag<4 + PROB_GAL>0.5) : 11395120
- EELG candidates at $0.008 < z < 0.019$: 541
 - + (r-J0660)>0.38 ; (J0660-i)<-0.38 ; (J0515-r)<-0.25
 - + (r-i)<0.2 ; (J0660-i) > 2.5 (r-i) -1.2
- EELG candidates at $0.019 < z < 0.05$: 482
 - + (J0515-r)<-0.48 ; (g-J0515)>0.5 ; (J0660-i)>-0.38
 - + (r-i)<0.2 ; (g-r)<0.32 ; (g-J0515)>0.6 (g-r)+0.5
- After removing saturated and duplicated objects:
 - + EELG candidates at $0.008 < z < 0.019$: 292
 - + EELG candidates at $0.019 < z < 0.05$: 224

Removing additional contaminants

Possible contaminants:

- HII regions
- Excess in J0515 due to different emission lines at different z :
 - + Mg II at $z\sim 0.8$; C III] at $z\sim 1.7$; C IV at $z\sim 2.3$; Ly α at $z\sim 3.2$
 - + Sinal de CIV 1549 no filtro J0430



EELG result samples

Table 3. EELG samples based on $H\alpha$ and [OIII] emission using S-PLUS.

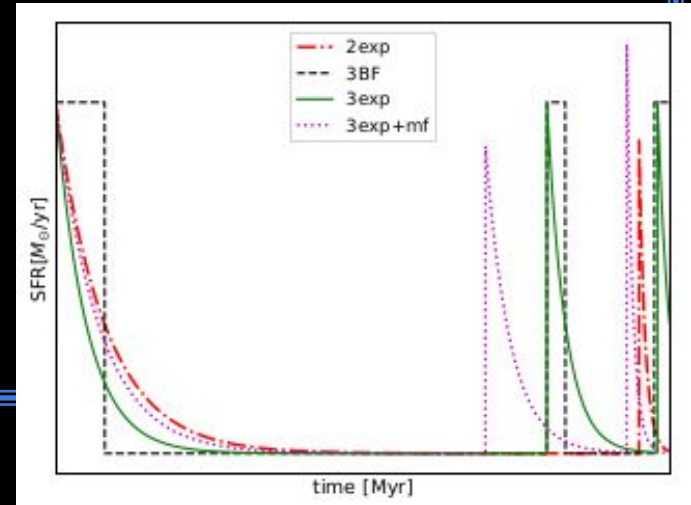
Sample definition	z range	# of galaxies	# of HII regions	# of QSOs
$H\alpha$	$0.008 < z < 0.019$	123	167	2
[OIII]	$0.019 < z < 0.05$	126	86	–

Total of 248 EELGs



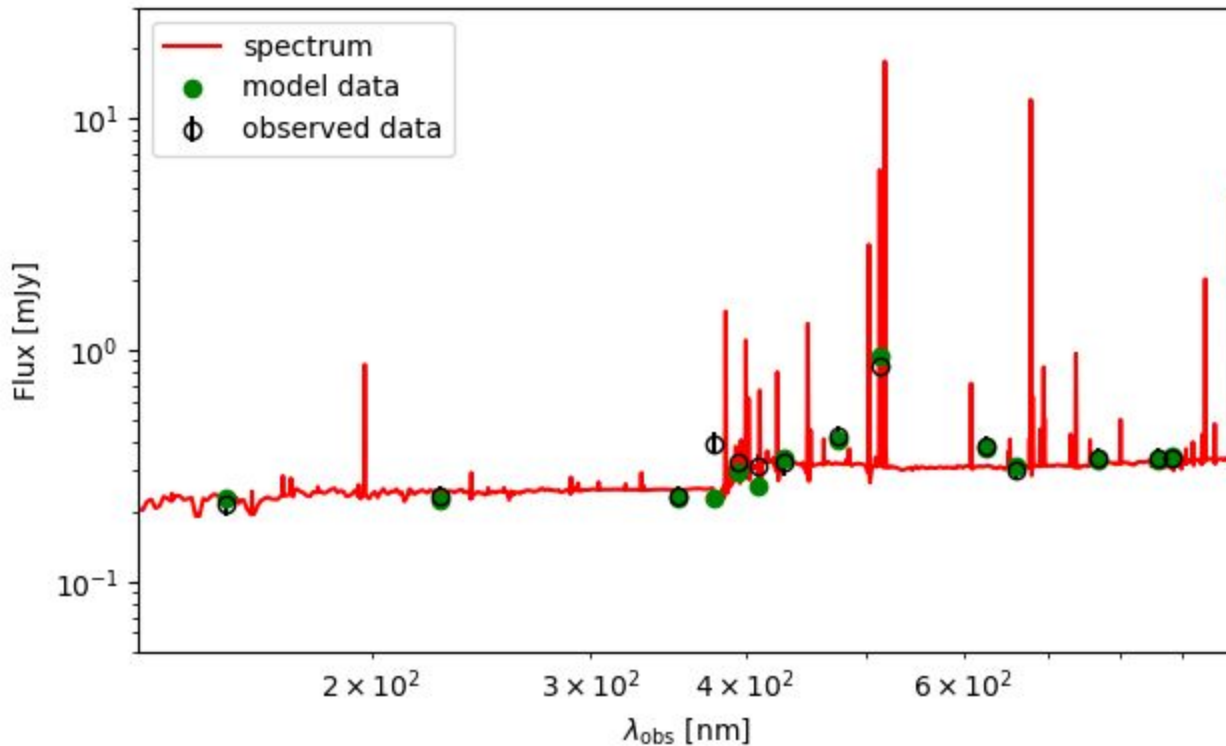
SED-fitting for EELGs

- Crossmatch to GALEX GR6 :
 - + 131 galaxies found from 248
- CIGALE (Code Investigating GALaxy Emission, Boquien et al. 2019)
 - + Bruzual & Charlot (2003) models
 - + Chabrier (2003) IMF
 - + Metallicity [Z] : [0.0001, 0.0004, 0.004, 0.008, 0.02]
 - + Calzetti (2000):
 - $E(B-V) = [0., 0.05, 0.1, 0.15, 0.2, 0.25, 0.3, 0.35, 0.4, 0.45]$
 - + 3BF SFH (Lopes et al. 2021)

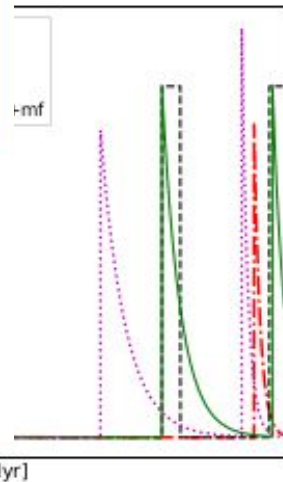


SED-fitting for EELGs

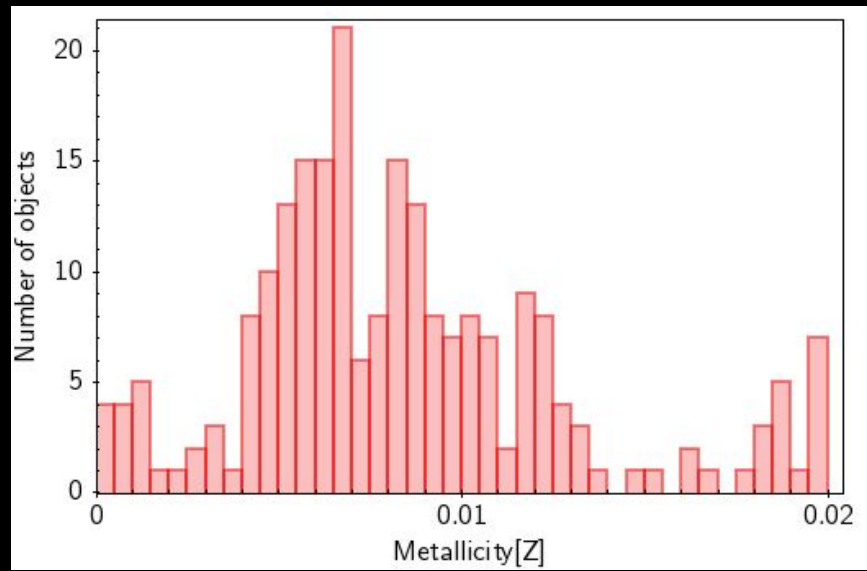
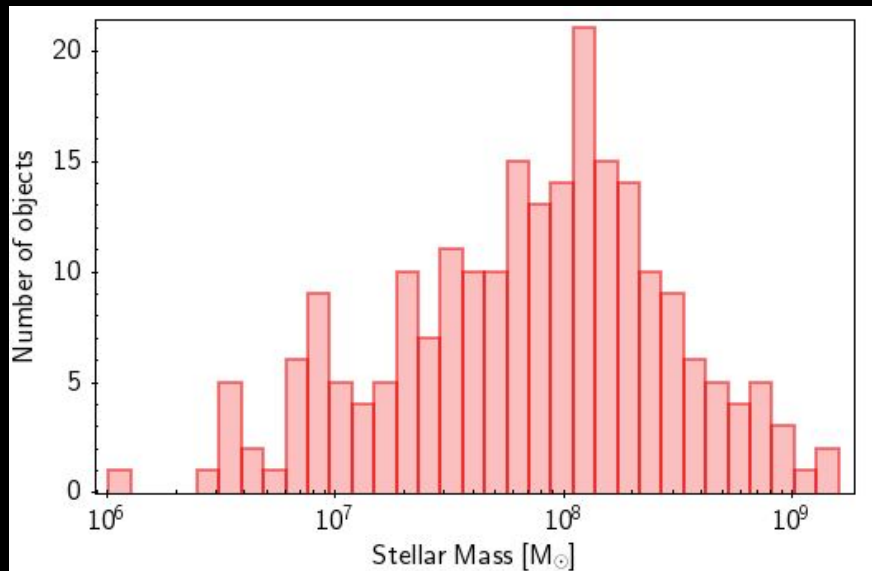
- Cross
- + 13
- CIGAL
- + Bru
- + Ch
- + Me
- + Ca
- $E(B-V) =$
- + 3B



(I. 2019)



SED-fitting for our sample of EELGs



Line emission flux estimates

- Three filter method (Pascual et al. 2007, Vilella-Rojo et al. 2015):

$$F_{\text{line}} = \frac{(f_{\text{obs}}^{\text{BBC}} - f_{\text{obs}}^{\text{BBU}}) + \left(\frac{\alpha_{\text{BBU}} - \alpha_{\text{BBC}}}{\alpha_{\text{NB}} - \alpha_{\text{BBU}}} \right) (f_{\text{obs}}^{\text{NB}} - f_{\text{obs}}^{\text{BBU}})}{\beta_{\text{NB}} \left(\frac{\alpha_{\text{BBU}} - \alpha_{\text{BBC}}}{\alpha_{\text{NB}} - \alpha_{\text{BBU}}} \right) + \beta_{\text{BBC}}}$$

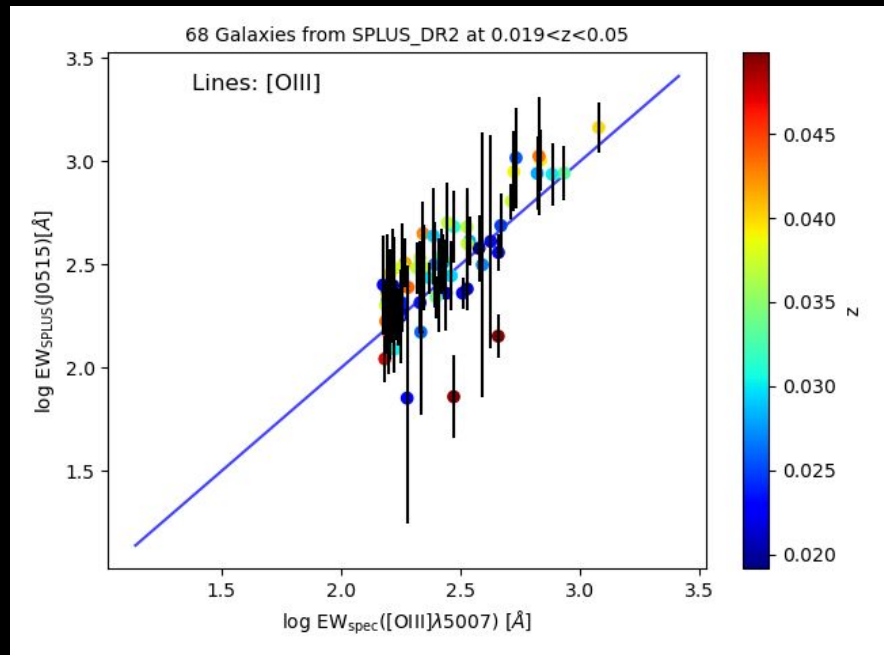
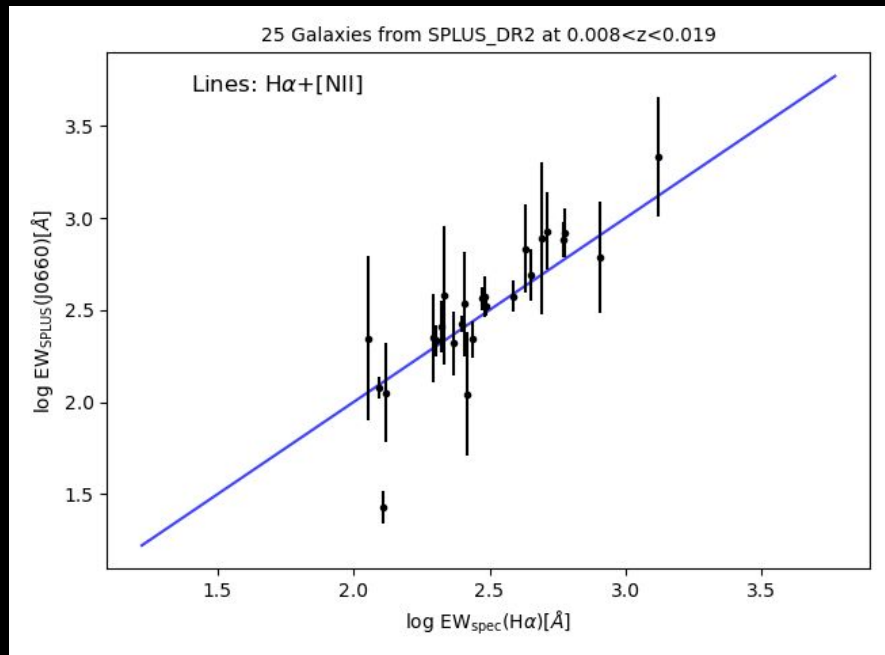
where: $\alpha_{\text{band}} = \frac{\int \lambda^2 T_{\text{band}}(\lambda) d\lambda}{\int T_{\text{band}}(\lambda) \lambda d\lambda}$ and $\beta_{\text{band}} = \frac{\lambda_{\text{EL}} T_{\text{band}}(\lambda_{\text{EL}})}{\int T_{\text{band}}(\lambda) \lambda d\lambda}$

Equivalent width: $\text{EW} = F_{\text{line}} / F_{\text{cont}}$ with $F_{\text{cont}} = A\lambda + B$

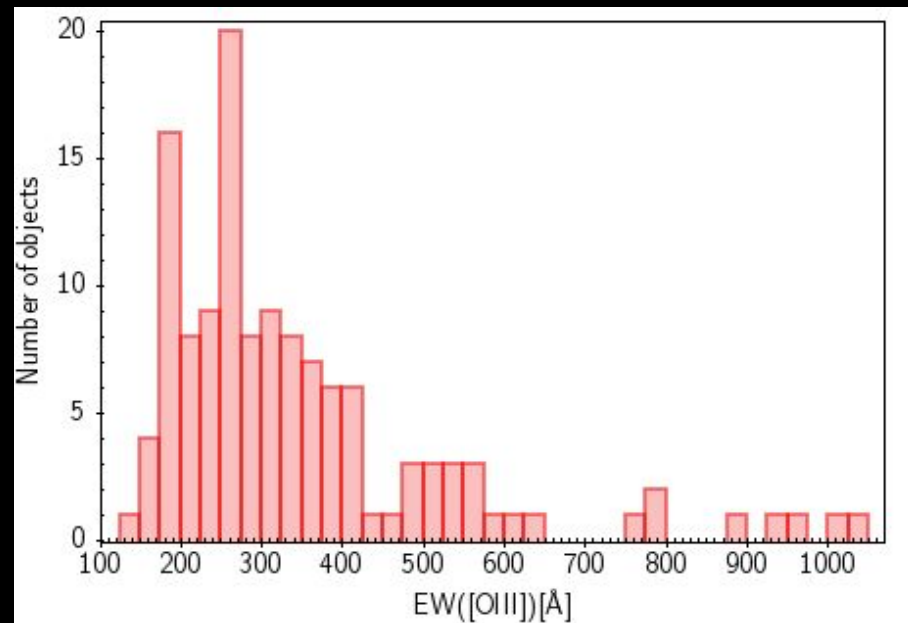
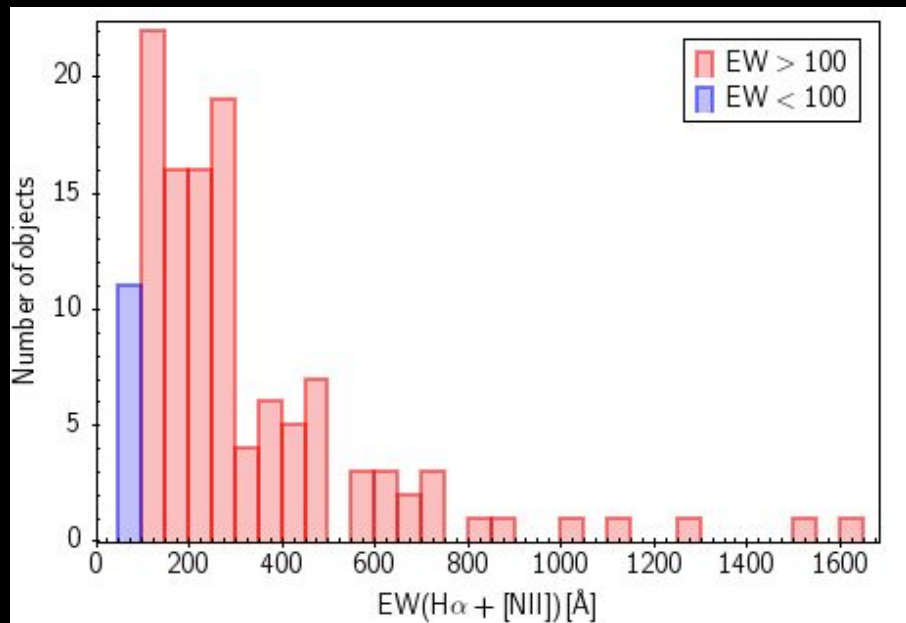
$$A = \frac{(f_{\text{obs}}^{\text{NB}} - f_{\text{obs}}^{\text{BBU}}) - \frac{\beta_{\text{NB}}}{\beta_{\text{BBC}}} (f_{\text{obs}}^{\text{BBC}} - f_{\text{obs}}^{\text{BBU}})}{\alpha_{\text{NB}} - \alpha_{\text{BBU}} - \frac{\beta_{\text{NB}}}{\beta_{\text{BBC}}} (\alpha_{\text{BBC}} - \alpha_{\text{BBU}})}$$

and $B = f_{\text{obs}}^{\text{BBU}} - \alpha_{\text{BBU}} A$

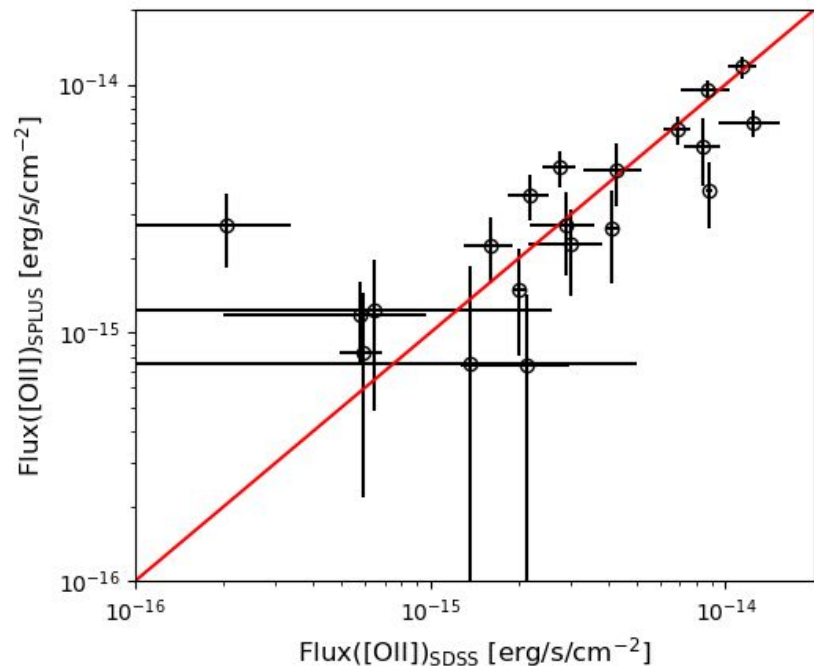
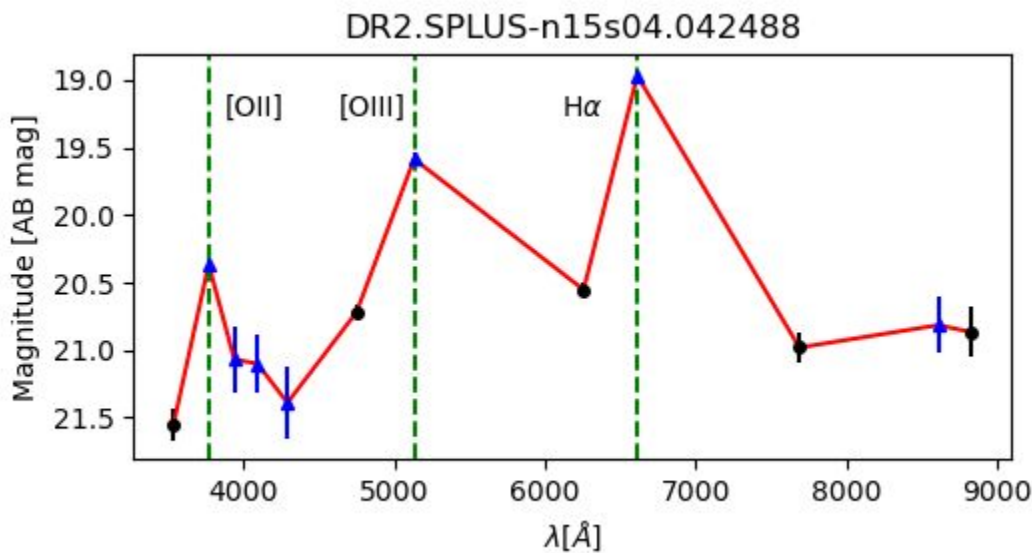
Test results from line emission flux and EW



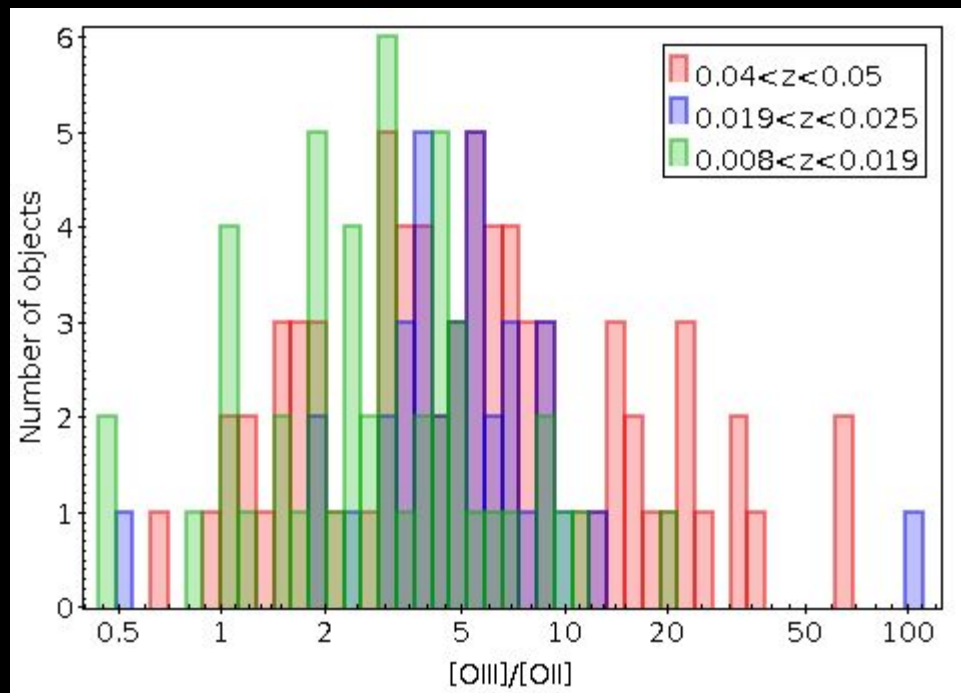
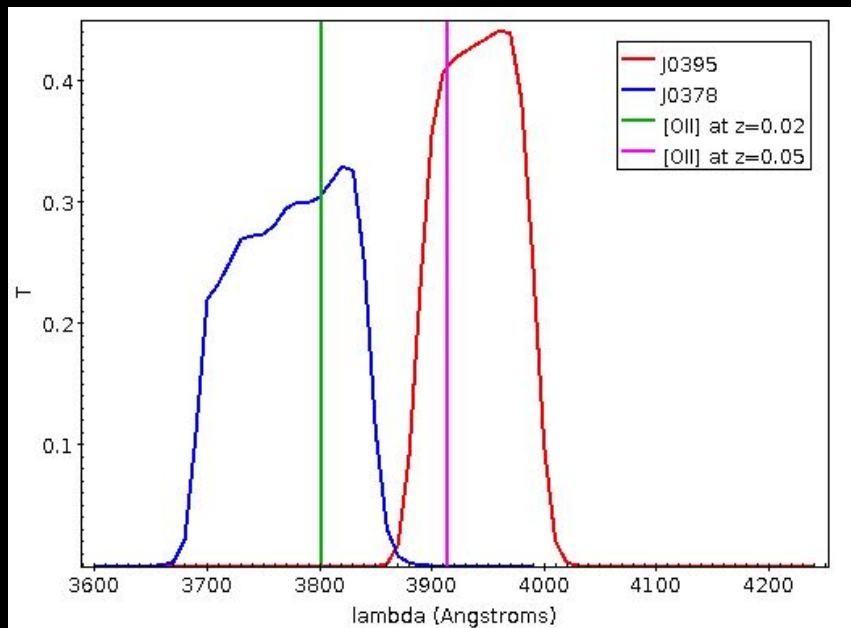
Equivalent Width estimates for our sample of EELGs



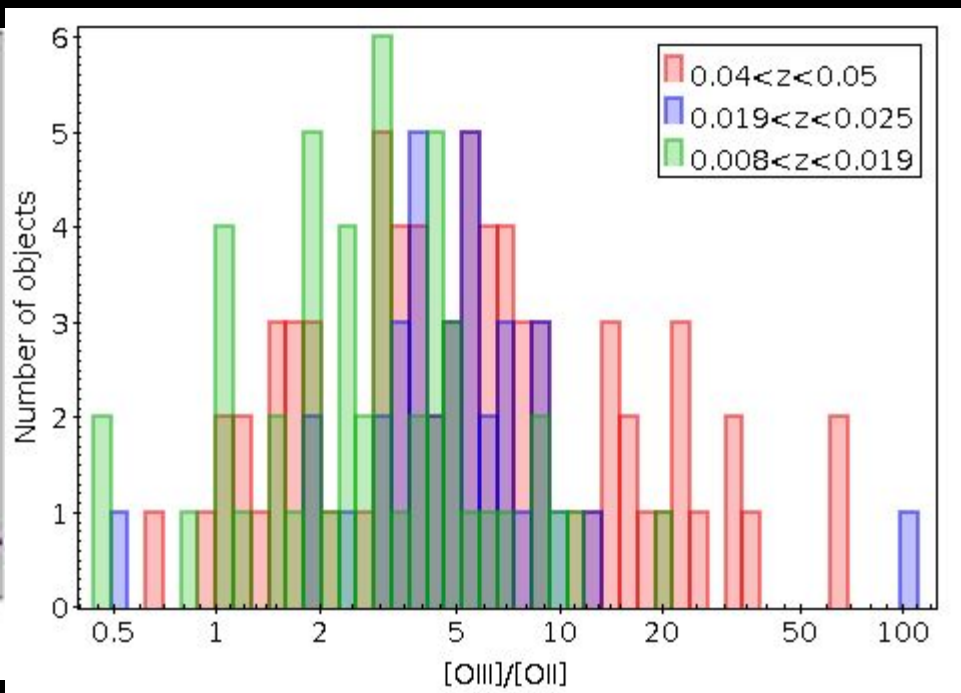
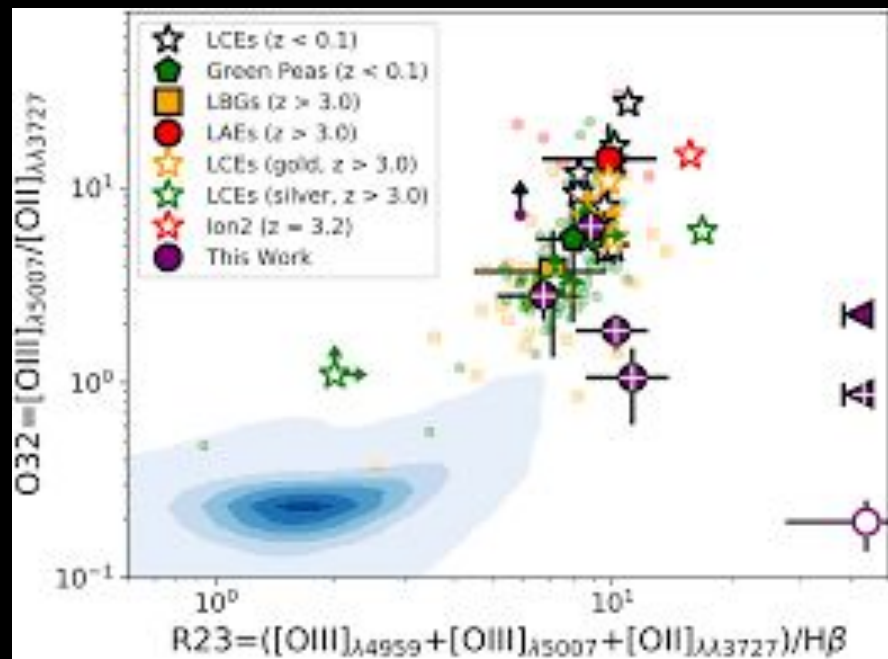
[OIII]/[OII] ratio



[OIII]/[OII] ratio



[OIII]/[OII] ratio



Bassett et al. (2019)

Conclusions and perspectives

- We selected 248 EELG, following color cuts derived from a sample of known EELGs from SDSS.
- The SED-fitting results confirms: low mass, low metallicity objects
- 3 Filter method: $EW(H\alpha) \gtrsim 100\text{\AA}$, $EW([OIII]) \gtrsim 200\text{\AA}$, $0.5 < [OIII]/[OII] < 100$

- Compare available photo-z with derived photo-z from SED-fitting
- Search for [OIII] EELGs at $z \sim 0.3$

- Any comments, suggestions or questions:
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**Brainstorming session about
Emission Line galaxies
Friday afternoon!**