A Deep Spectroscopic Search for Extreme Emission Line Galaxies: JPAS and MUSE HUDF surveys

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. . .

EXTREME EMISSION LINE GALAXIES – EELG

=> **EELG** galaxies host ***extreme star formation*** (SF) events. (e.g. GPs) -> provide keys for our understanding of early galaxy evolution.

Ly_C photons leakage from EELGs -> expected **main fraction of the budget for re-ionization** of the Universe
(e.g., Erb+ 2016; Yang+; Sobral+ 2018; Naidu+2022; Matthee+ 2022).

=> **EELGs** present intense **emission lines** with **Equivalent Widths EW$_o$ $\geq$ 300** Å

Currently **different selection criteria =>** EELGs include different categories:
Green Peas, Blue berries, Xtreme HII galaxies and BCDs, ELDots / Hα Dots…
(e.g. Cardamone+ 2009, Amorin+ 2010; Yang+ 2017; Terlevich+ 1991; Bekki 2015, Salzer+ 2020)

EELGs -> **large EW$_o$([OIII]+H$_\beta$)** => common **strong *Ly$_\alpha$*** emission	(Tang+2021)
GPs -> ***typical Ly$_C$ leakers*** present also ***high EW$_o$(Ly$_\alpha$)***	(Izotov+ 2016; 2018)

EELG selection -> blind search for emission line targets -> minimise bias (e.g. in BBand samples)
*Important to **increase EELG samples at the lowest mass, lowest metallicity galaxies** populating this ranges in M_* - Metallcity - SFR and M_* - SFR relations (e.g. Indhal+ 2021; Curti+ 2023).*

SEARCHING FOR EELGs

***Currently adopted EELGs selection criteria => a mixed bag of types*:** GPs from broad band photometry (e.g. à la Cardamone+ 2009; van der Well 2011), narrow/medium band imaging (Sobral+ 2014; Lumbreras-Calle+ 2022), spectral targets (e.g. Amorín+ 2015; Maseda+ 2018) . . .

We **propose *a selection of EELGs in wide field emission-line surveys***:
Selecting *galaxies with $EW_o \geq 300$ Å in at last one line* of [OIII]5007, [OII]3727, H_α
(Iglesias-Paramo+ 2022).

SEARCH CONDUCTED with:

1.- **JPAS Survey**: MiniJPAS - AEGIS field (Bonoli+ 2021)
Wide-field spectro-photometry in **56 Narrow Band Filters** (Equiv. R~60) sampling
a strip of 1°□ over the EGS (AEGIS) field (+ SDSS filters).
Search within $0 \leq z \leq 0.8$ (Iglesias-Páramo+ 2022)

Also with:

2.- **DR2 MUSE HUDF Survey**: MOSAIC (9’□) + UDF 10 (1’ □) + MXDF (41”Ø) fields (Bacon+ 2023)
MHUDF survey provides deep spectra + cutouts cubes for each selected candidate

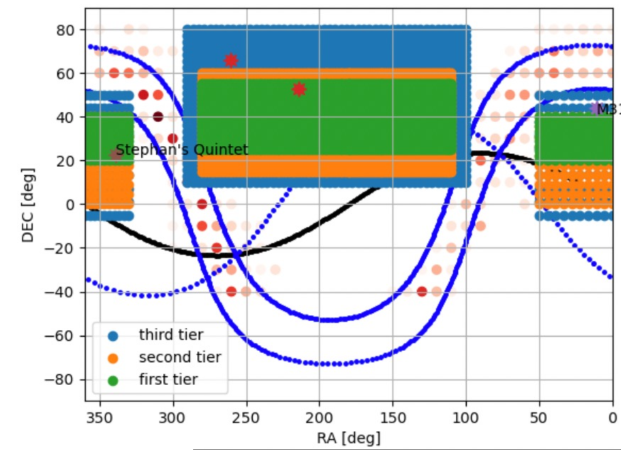
(DR2 -> also incl. catalogue of physical properties for a gal. subsample)

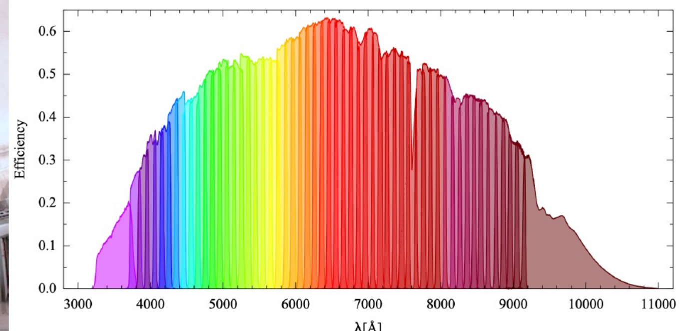
1

J-PAS

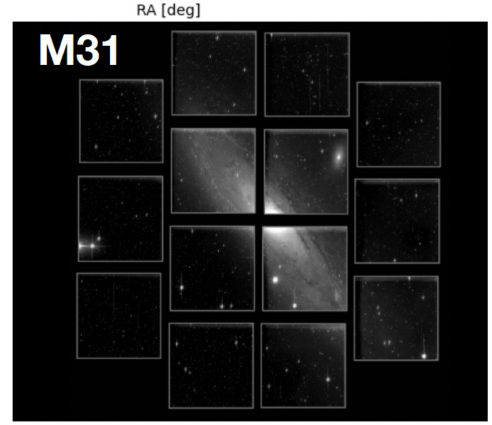
Javalambre Physics of the Accelerating Universe Astrophysical Survey

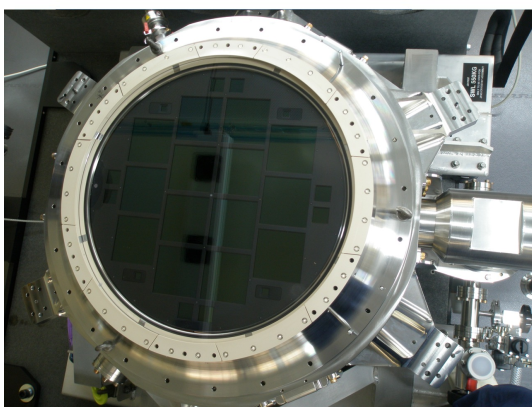
- ✳ >5000 deg^2 in the northern sky
- ✳ 2.5m telescope at OAJ
- ✳ Photometric system: 56 NB; fwhm = 145 Å (R~60)
- ✳ Covering every 100 Å the whole optical range
- ✳ JPCam: 14 CCDs, FoV~4 deg^2; 0.23 arcsec/pixel

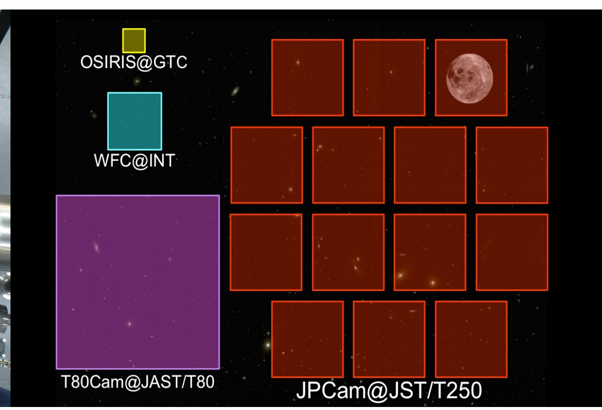




Benítez + 2009; Benítez + 2014
Cenarro + 2014







J-PAS: a survey for Galaxy Evolution

JPCam
O.A. Javalambre

Identification and Characterization of Extreme Emission Line Galaxies-EELGs

A&A 665, A95 (2022)
https://doi.org/10.1051/0004-6361/202243931

Astronomy & Astrophysics

The miniJPAS survey: A search for extreme emission-line galaxies

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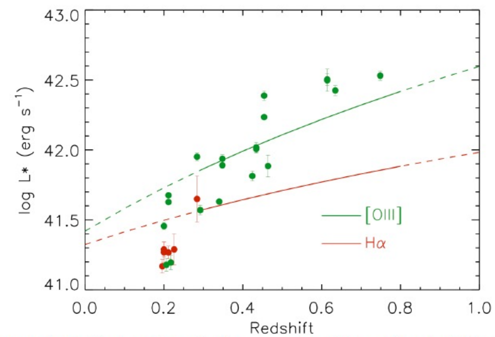


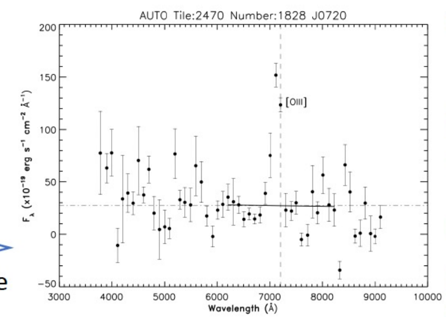
Characteristic luminosity L* as a function of redshift (Comparat+ 2016) for [OIII]λ5007Å (solid green) and Hα (solid red) lines.
Filled points correspond to miniJPAS confirmed EELGs (17), id. color code.

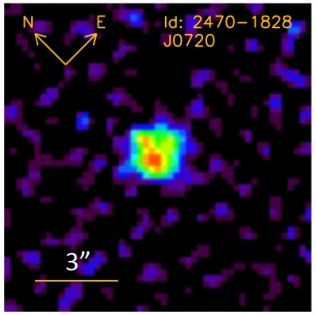
New methodology to obtain a complete census of EELGs with J-PAS over large areas by detection of galaxies with equivalent widths EW ≥ 300 Å in the emission lines: [O II]λλ3727,3729 Å, [O III]λ5007 Å, and Hα

Preparing for the large J-PAS sky coverage

Iglesias-Páramo+ (2022)

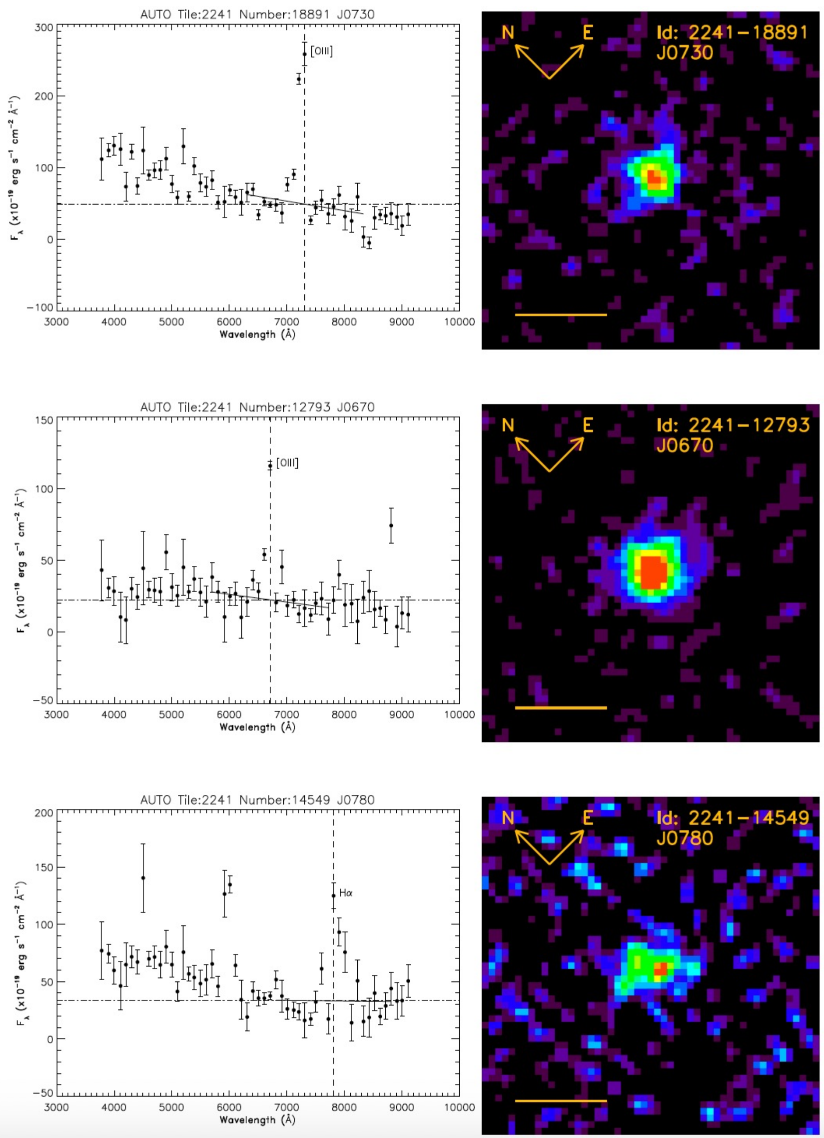
New EELG candidate





RESULTS: **17 EELGs with EW_o [OIII] ≥ 300 Å | 0.196 ≤ z ≤ 0.748 ; 20.5 ≤ r_{SDSS} ≤ 24 mag**

(Examples of) EELG new selections



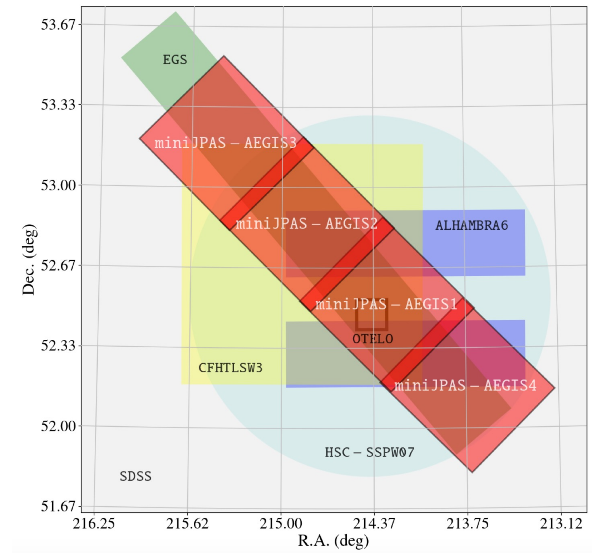
Sample:

17 [OIII] sources peaking

$0.2 \lesssim z \lesssim 0.3$

Highest EW_o[OIII] =1758 Å

$41.17 \lesssim \text{Log}(\text{Lum/erg s}^{-1}) \lesssim 44.25$



EELGs sky density consistent w/ previous work:
Lumbreras-Calle+ 2022 JPLUS (Local EELGs $z \lesssim 0.06$)
Amorin+ 2015 (20k zCosmos bright survey)

JPAS Extreme Emission Line Galaxies properties

Identification and Characterization of Extreme Emission Line Galaxies-EELGs

Multiwavelength exploration of Extreme Emission Line Galaxies detected in miniJPAS survey

Iris Breda[1], José M. Vilchez[1], Enrique Pérez-Montero[1], Carolina Kehrig[1], Jorge Iglesias-Páramo[1], Antonio Arroyo-Polonio[1], Rosa González Delgado[1], Abramo, R.[2], Alcaniz, J.[3], Benítez, N.[1], Bonoli, S.[4,5,6], Cenarro, A. J.[7], Cristóbal-Hornillos, D.[6], Dupke, R.[3], Ederoclite, A.[6], Hernán-Caballero, A.[7], Marín-Franch, A.[7], Mendes de Oliveira, C.[8], Moles, M.[6], Sodré, L.[8], Taylor, K.[9], Varela, J.[7], Vázquez-Ramió, H.[7], and J-PAS team

Submitted to Astronomy & Astrophysics

Multi-wavelength EELGs massive SED fitting pipeline developed

Iris Breda et al.: Multiwavelength exploration of Extreme Emission Line Galaxies detected in miniJPAS survey

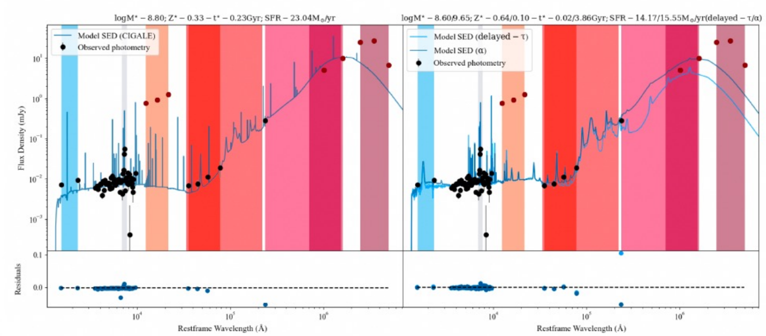
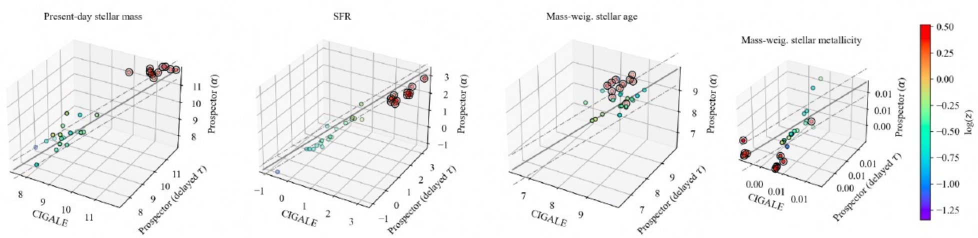


Illustration of the SED fitting results by CIGALE (left-hand side) and Prospector (right-hand side) for the same EELG.
Both, flux density and rest-frame wavelength (Å) are displayed in log scale.

Best-fitting SED models are represented by solid blue lines, observational points are shown by black points and the upper limits by dark red points. The fit residuals are shown in the low panel as well as some derived physical properties presented in the image title.



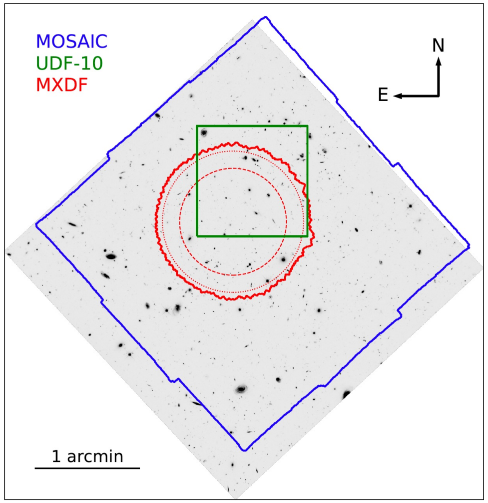
Output: physical characterization of the EELGs miniJPAS sample

2 DR2 MUSE HUDF Survey

FIELDS

1. **MOSAIC** → 3′ × 3′ mosaic 9 MUSE fields at a 10-hour depth
2. **UDF-10** -> a single 1′ × 1′, 31-hour depth field
3. **MXDF** (MUSE eXtremly Deep Field) → depth 141 hours. 1' ϕ

Bacon+ (2023)



SEARCH A

EELGs with $\mathbf{EW_o \geq 300}$ Å in any one of the lines [OIII]5007, [OII]3727, H_α

Results A: **7 EELGs with robust detection** (5 in [OIII] -one of them also in Hα-, + 2 in Hα only)

In this case we have considered and extended sample from an additional Search 2:

SEARCH B (Extended Sample)

EELGs with **200 Å ≤ $\mathbf{EW_o}$ ≤ 300 Å** in any one of the lines [OIII]5007, [OII]3727, H_α

Results B: **+ 6 EELGs with robust [OIII]5007 detection** (of them: 1 also in [OII]3727; 1 in Hα)

Muse ID	ds name	Ra	Dec	z	Line	EWo	EW	F	Log$L$
		(deg)	(deg)			(Å)	(Å)	(10^{-20}erg s^{-1}cm^{-2})	(erg s^{-1})
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
91	MXDF	53.1625	-27.7803	0.719	[OIII]5007	-344.61	-592.38	4098.38	42.82
891	MOSAIC	53.1957	-27.7878	0.2265	Hα	-311.14	-381.62	67945.9	44.04
895	MOSAIC	53.1447	-27.7854	0.2473	[OIII]5007	-362.79	-452.51	92674.08	44.17
					Hα	-331.32	-413.25	57497.73	43.96
2478	MOSAIC	53.1839	-27.7954	0.734	[OIII]4959	-374.78	-649.87	582.64	41.97
					[OIII]5007	-11477.74	-19902.41	2064.91	42.52
2532	MOSAIC	53.1497	-27.8093	0.7525	[OIII]5007	-386.95	-678.12	491.89	41.9
6465	MOSAIC	53.1942	-27.7854	0.7152	[OIII]5007	-362.07	-621.03	668.2	42.03
7373	MXDF	53.1542	-27.7867	0.2759	Hα	-306.61	-391.2	102.29	41.21

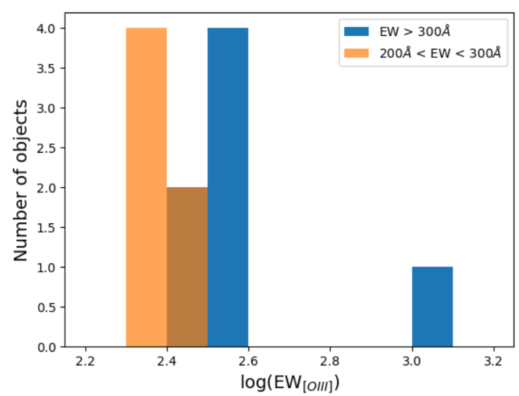
Table 1. Basic properties of the EELG candidates. (1) MUSE source identifier; (2) MUSE data set (MXDF,UDF10 or MOSAIC); (3) Right ascension (J2000.0); (4) Declination (J2000.0); (5) Redshift; (6) Detected emission line with $\geq$ 300 Å; (7) Rest frame equivalent width of the emission feature; (8) Equivalent width of the emission feature; (9) Flux of the emission feature; (10) Luminosity of the emission feature.

1093	MXDF	53.1763	-27.7809	0.5355	[OIII]5007	-235.62	-361.79	5370.59	42.93
1426	MOSAIC	53.1473	-27.8008	0.2799	[OIII]5007	-292.09	-373.84	2485.12	42.6
1561	MOSAIC	53.153	-27.7937	0.7327	[OIII]5007	-253.5	-439.25	1450.04	42.37
1699	MOSAIC	53.154	-27.8052	0.6683	[OIII]5007	-227.63	-379.76	905.36	42.16
6474	MOSAIC	53.1866	-27.7902	0.1239	[OIII]5007	-247.77	-278.47	26043.94	43.62
					Hα	-207.95	-233.72	15342.99	43.39
6865	UDF10	53.1604	-27.7752	0.833	[OIII]5007	-243.93	-447.13	6276.13	43.0
					[OII]3729	-286.38	-694.72	83.74	41.13

Same as Table 1 for the extended sample.

$41.21\ (41.13) \leq$ Log(Lum/erg s^{-1}) $\leq$ 44.17 (43.62)

0.226 (0.1239) $\leq$ z $\leq$ 0.753 (0.833)



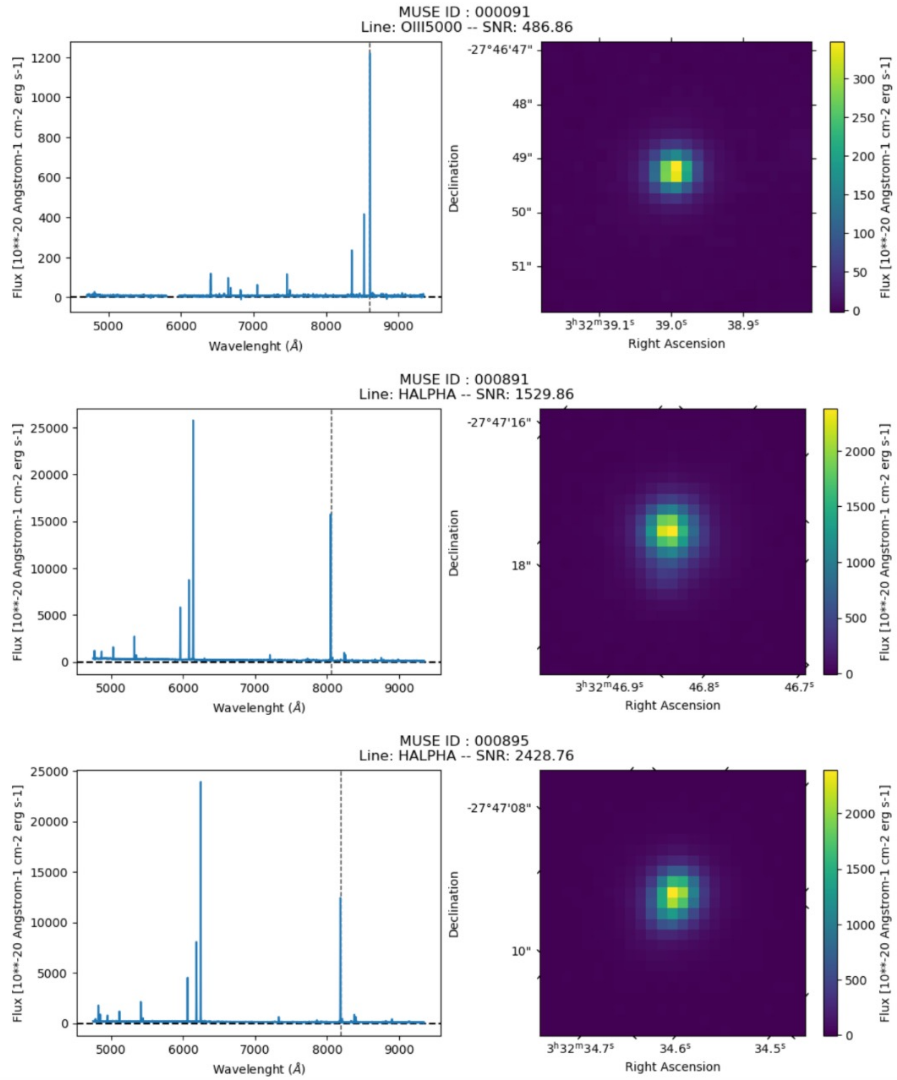


Fig. A.1. Data products from AMUSED for the EELG candidates. *Left:* Spectra using the EMI_ds_id extension. The vertical dashed line indicates the emission line fulfilling our EW0 condition. *Right:* Narrowband source image corresponding to the selection line.

EELGs kinematics from MUSE
cutout cubes

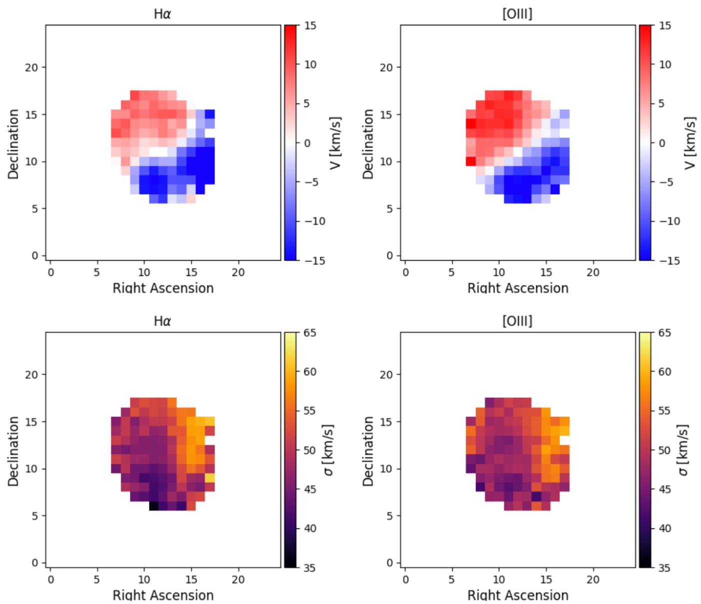


Fig. 1. Kinematics analysis of the Muse ID galaxy 0000891. *Upper left:* Hα rotational velocity. *Upper right:* [OIII] rotational velocity. *Bottom left:* Hα velocity dispersion (σ). *Bottom right:* [OIII] velocity dispersion (σ).

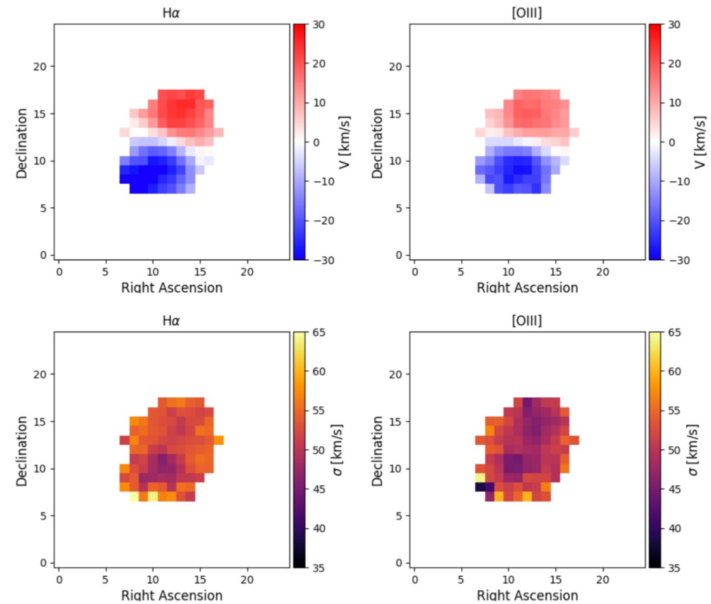
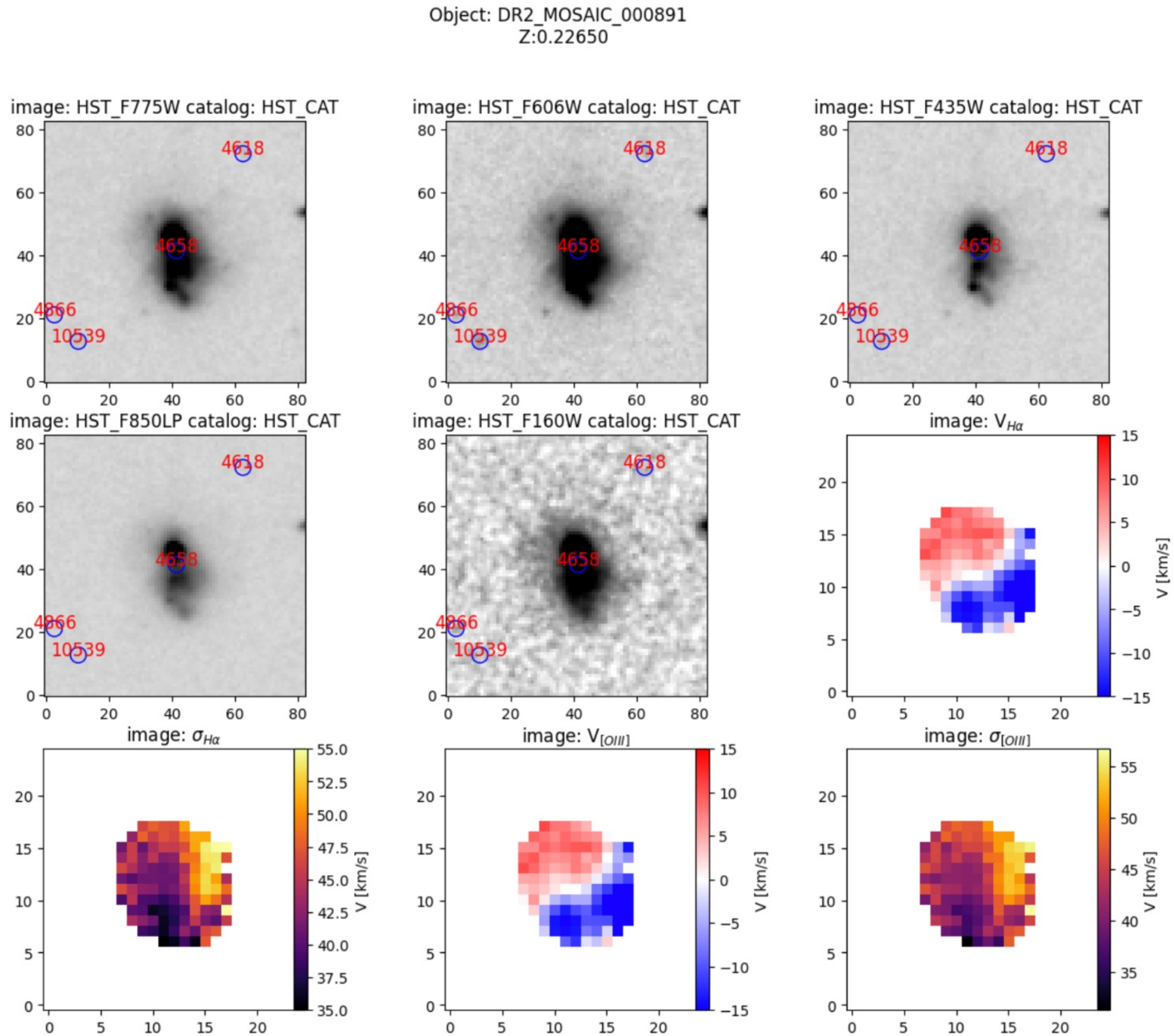


Fig. 2. Same as Fig. 2 for the MUSE ID galaxy 0000895.

Object MOSAIC DR2 ID 000891

Object MOSAIC DR2 ID 000895

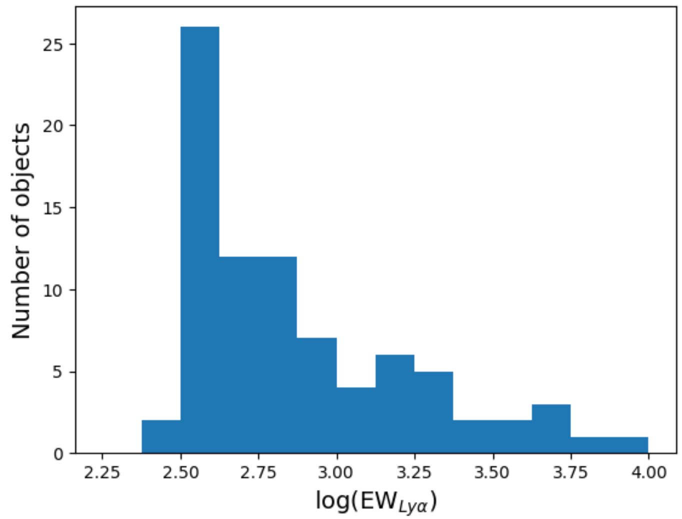
=> Low Mass , low Metallicity (e.g. Pilyugin, Vilchez Contini 2004)

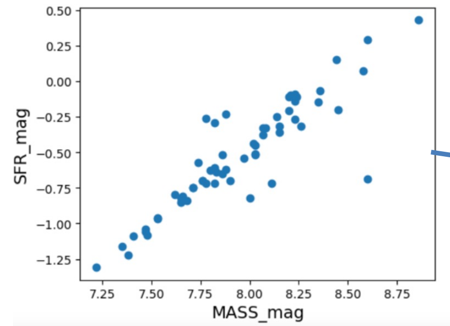


Object: DR2_MOSAIC_000891
Z:0.22650
image: HST_F775W catalog: HST_CAT
image: HST_F606W catalog: HST_CAT
image: HST_F435W catalog: HST_CAT
image: HST_F850LP catalog: HST_CAT
image: HST_F160W catalog: HST_CAT
image: V$_{H\alpha}$
image: $\sigma_{H\alpha}$
image: V$_{[OIII]}$
image: $\sigma_{[OIII]}$
4618
4658
4866
10539
V [km/s]

Fig. 4

EXTRA PRELIM. RESULTS: $EW_o(Ly_\alpha) \geq 300$ Å
Extreme Ly_α galaxies in MHUDF





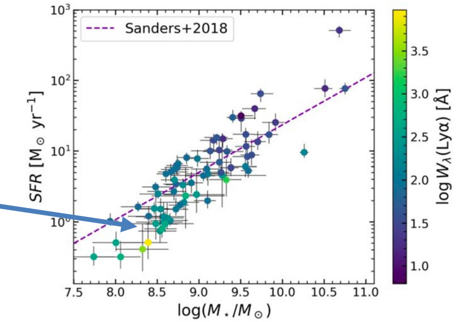
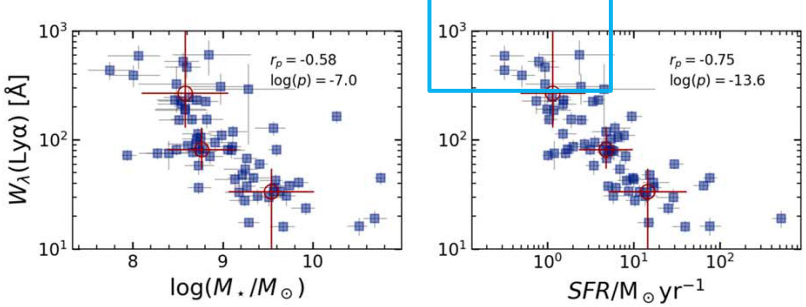
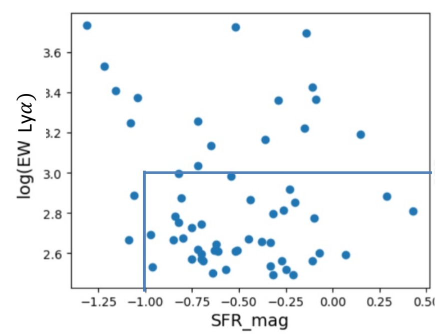


Figure 14. The stellar mass–SFR correlation for LAEs in our sample. The trend fit by Sanders et al. (2018) for $z \sim 2.3$ SFGs is drawn in dashed purple for comparison. LAEs in our sample largely fall on the SFMS, though the lowest-mass sources ($M_\star < 10^9\, M_\odot$) tend to fall below the relation.

SFRs Consistent with Tang+ (2021) for extreme [OIII]+Hb emitters, Ly_α detection and Ly_C leaking.

THE ASTROPHYSICAL JOURNAL, 936:131 (23pp), 2022 September 8





PRELIMINARY RESULTS

(~80 XLAEs)

<EW_o> collected consistent with McCarron+ (2022) HETDEX surv. LAEs in GOODS-N Field

Summary of Results

→ **miniJPAS: 17 EELGs with EW_o [OIII]≥300 Å**

$0.196 \leq z \leq 0.748$ | $20.5 \leq r_{SDSS} \leq 24$ mag | $41.17 \leq \mathrm{Log(Lum/erg\ s^{-1})} \leq 44.25$

→ **MHUDF: 7** *(+6)* **EELGs with EW_o [OIII]≥300 Å** *(200 Å $\leq EW_o \leq$ 300 Å)*

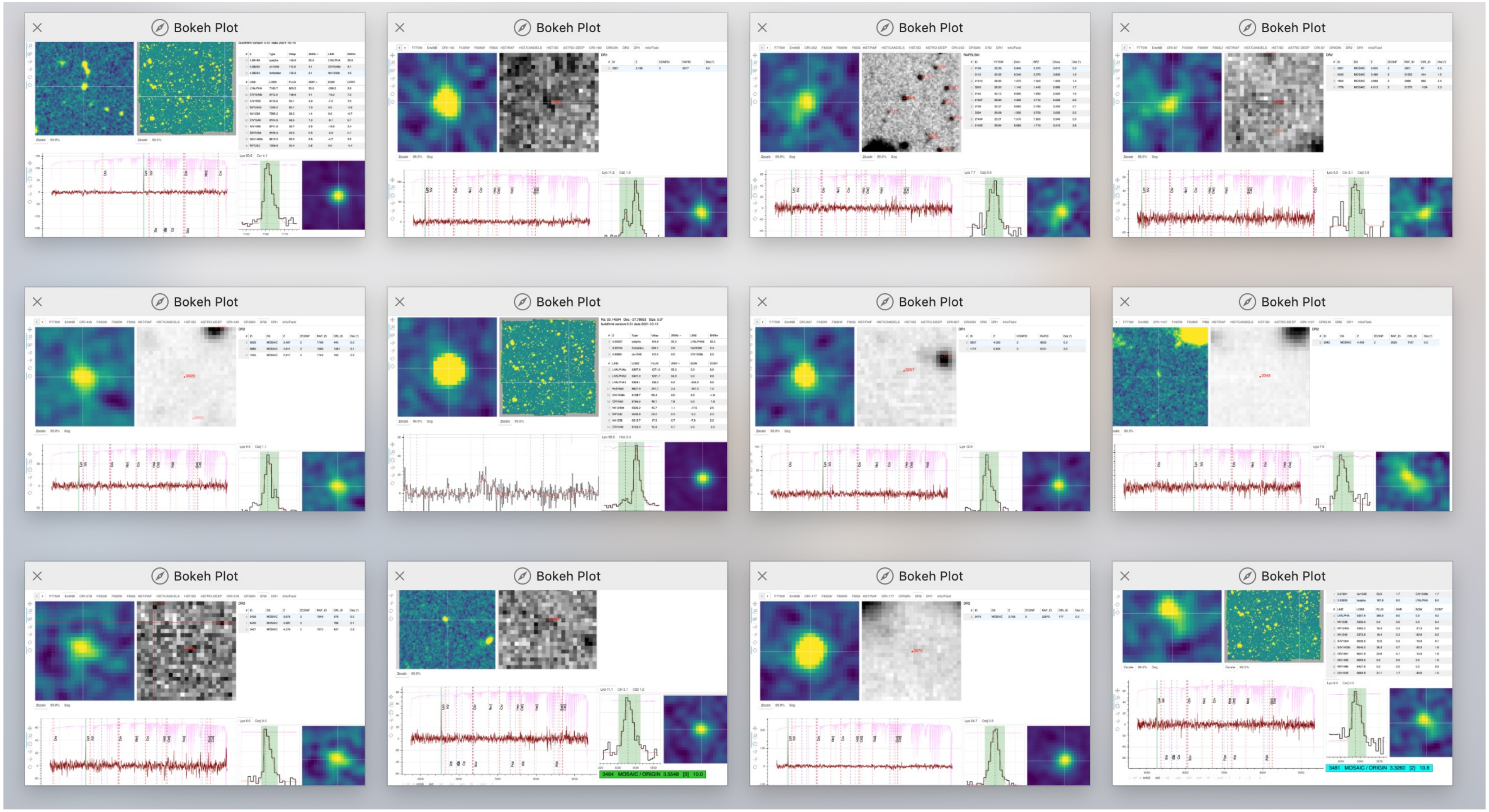
0.226 (0.123) $\leq z \leq$ 0.753 (0.83) | $41.21\ (41.13) \leq \mathrm{Log(Lum/erg\ s^{-1})} \leq 44.17\ (43.62)$

→ **Also: very productive preliminary search for Xtreme Ly_α emitters in MHDF**

→ **Proposal: enlarge statistics for current EELGs/LAEs samples via wide-field emission-ine surveys**

[e.g. JPAS in 2 years could increase EELGs current samples by up to x 1000]


THANKS !
ευχαρίστω !


Bokeh Plot
Bokeh Plot
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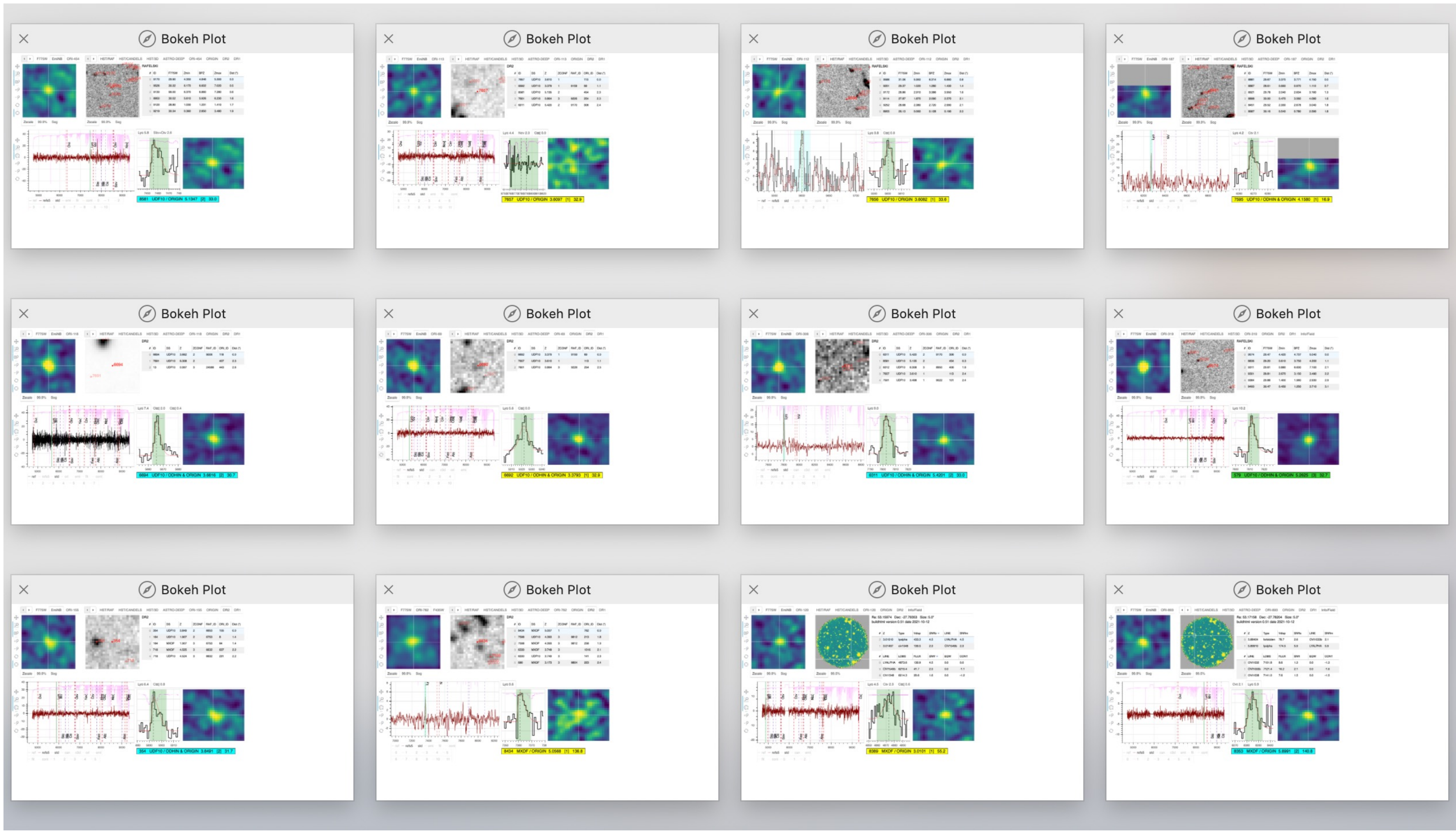
3464 MOSAIC / ORIGIN 3.5548 [3] 10.0
Bokeh Plot
Bokeh Plot
3481 MOSAIC / ORIGIN 3.3260 [2] 10.8


Bokeh Plot
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Preliminary physical Properties of new EELGs MUSE HUDF

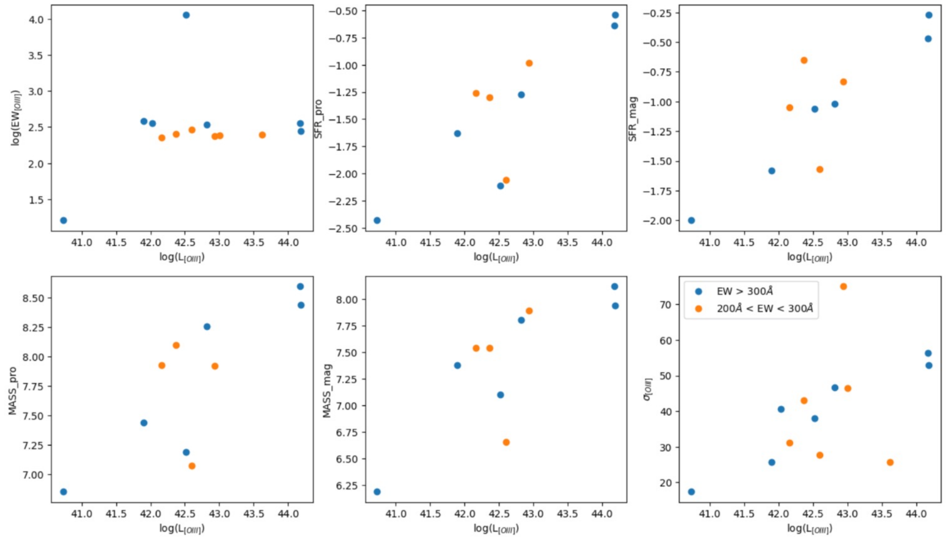


Fig. 5. EW, SFR; MASS and σ VS luminosity

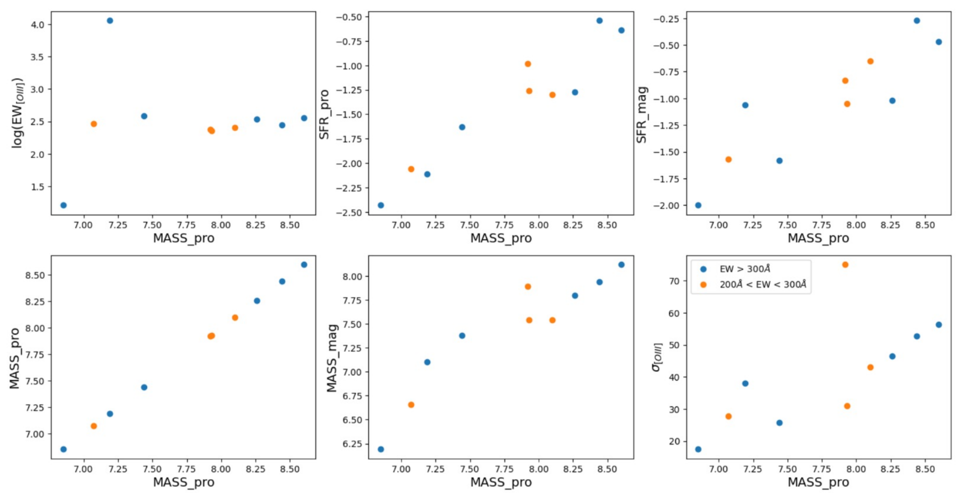
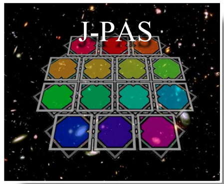


Fig. 6. EW, SFR; MASS and σ VS MASS-mag and MASS-pro

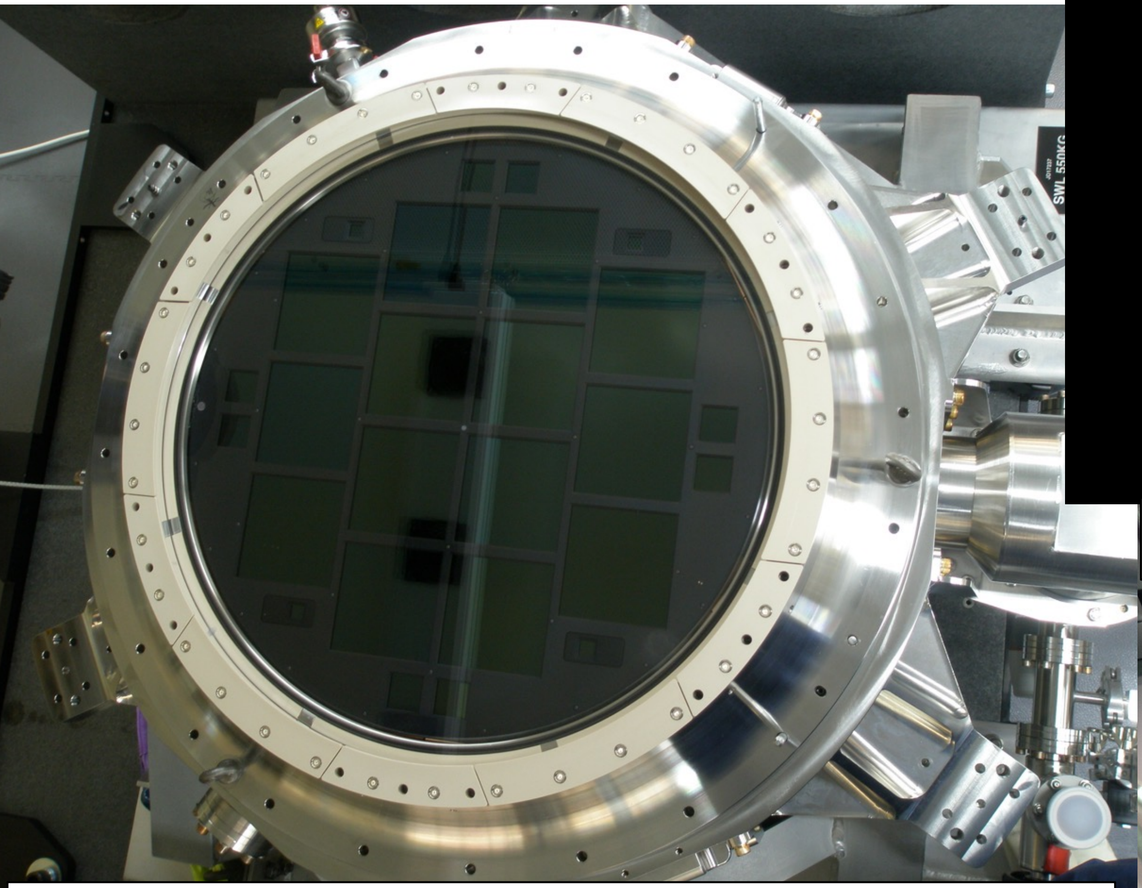
Extragalactic Large Surveys at the IAA: ALHAMBRA, CALIFA and J-PAS



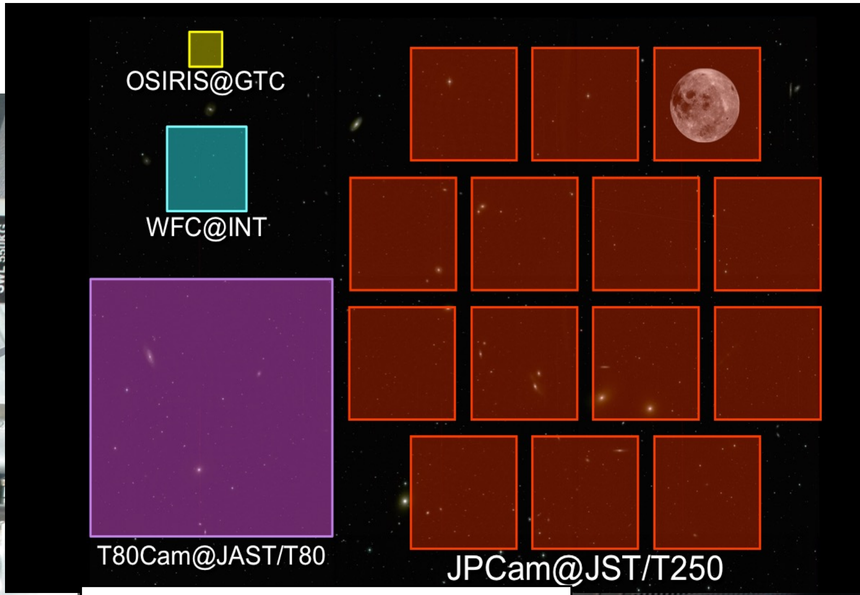
THE JAVALAMBRE PANORAMIC CAMERA – JPCam

1.2 Gpix to conduct J-PAS

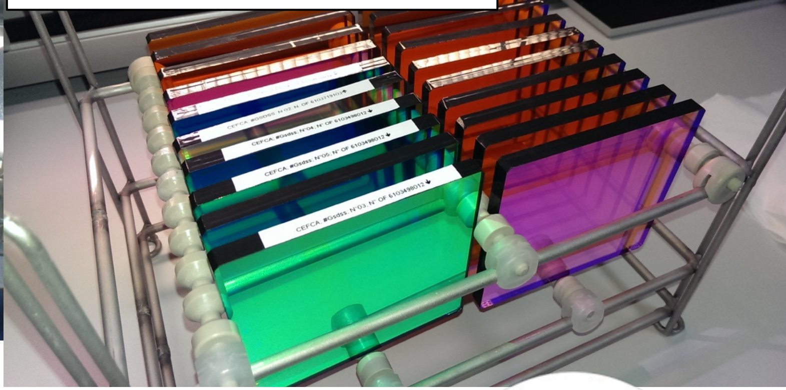
0.22”/pix – 14 CCDs 9.2kx9.2k – 4.5 deg^2



Low RON (< $4e^-$), unique CCDs by e2v for J-PAS

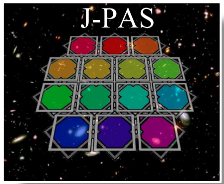


Filters by SCHOTT

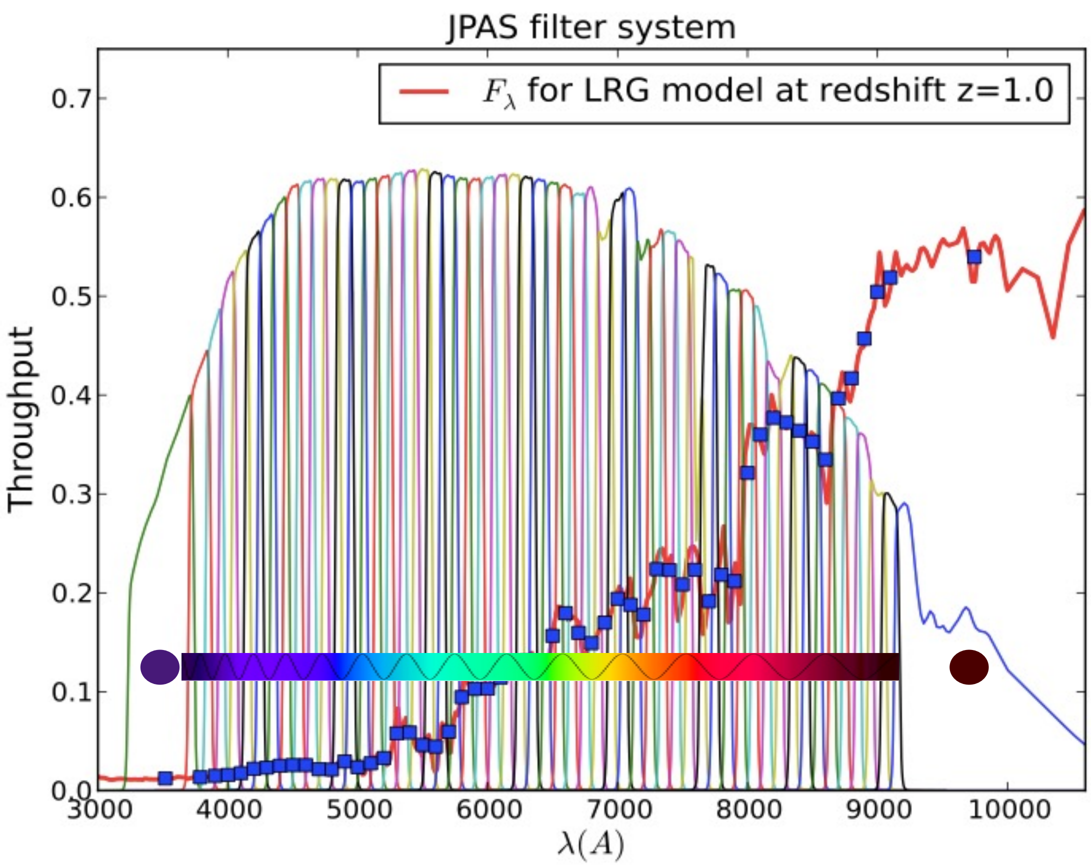


Extragalactic Large Survey

J-PAS



JAVALAMBRE PHYSICS OF THE ACCELERATED UNIVERSE ASTROPHYSICAL SURVEY



Benítez+ (2009; 2014 *Red Book*); *Bonoli+ 2020*

8500 deg^2 (14Gpc^3)

δz / (1+z) < 0.003

- 54 NB Filters (FWHM~14.5nm; $\Delta\lambda$~10nm)
- 1 Blue MB filter (FWHM~260Å; λ_c~3600Å)
- 1 Red BB filter (FWHM~620Å; λ_c~9500Å)
- Broad band filter/s as detection bands

In ~ 5 - 7 years

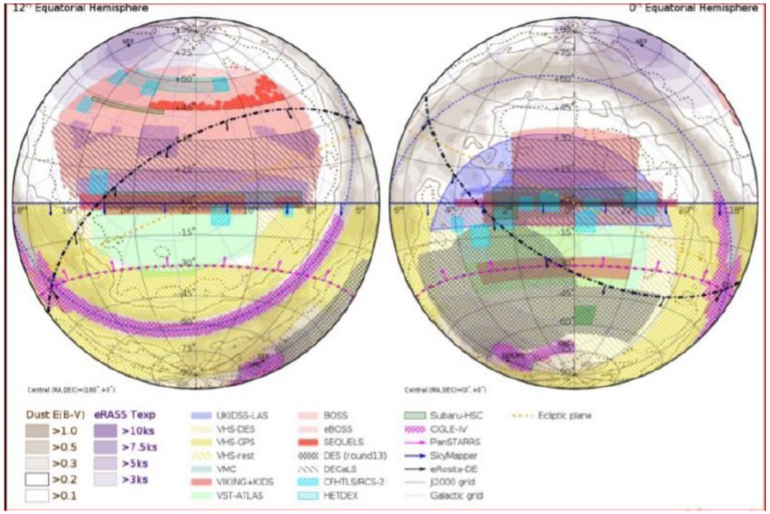
- **BAOs**
- Weak Lensing, Clusters, SNe

JPAS = ALL SKY IFU

Scope of the survey

- **8500 sq.deg. survey with 54 contiguous NB filters, 100A apart 3700A< λ < 9200A + 2 MedB and 3 BB for lensing (u,g,r/i). Full coverage 3300A< λ < 10100A**
- **Dark site with 0.71 arcsec seeing: Javalambre in Teruel, Spain**
- **2.5m tel. + 5 sq.deg. JPCam, 1.2Gpix/shot**
- **It will measure 0.3% photo-z for ~100M galaxies (EType z<1.05 and ELG z<1.4)**
- **~ 400-500 M galaxies with 3% photo-z,**
- **~ few M QSOs with 0.3% photo-z > Measure w all the way to z=3**
- **~ 0.8 arcsec image of the Northern Sky**
- **Extremely mass sensitive optical cluster catalog**
- **Excellent characterization of low-z SN systematics**
- **A few 1000s SNIe survey, no spectroscopy required**
- **Pixel-by-pixel low-res spectrum of the whole northern sky up to m~23/ arcsec^2**
- **It will measure radial BAOs up to z~1.4 ➔ 14 $(Gpc/h)^3$**
- **Clusters (10^5), Weak lensing, SN(10^4), QSOs (several x 10^6), Galaxy evolution (10^8), Stars (10^8), Asteroids, etc**

Synergies with eROSITA, JWST, EUCLID, WEAVE QSO



J-PAS to build strong **synergies**

First Light **March 2020**
Science Commissioning **July 2020**

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