Just waiting to be found from Teruel: extreme emission line galaxies in J-PLUS

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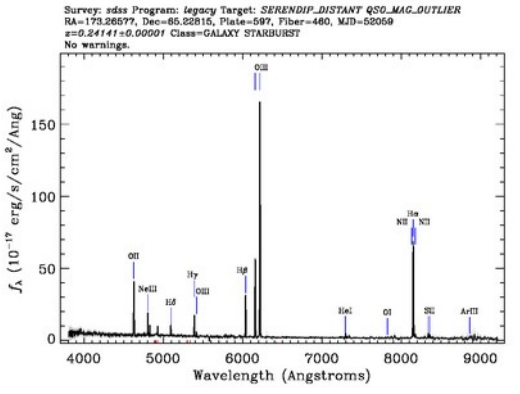
Alejandro Lumbreras Calle – CEFCA
alumbrerascalle@gmail.com - @alumbrerasc
Carlos López Sanjuan – CEFCA
and many more! D. Sobral (Lancaster U.), CEFCA colleagues (J.A. Fernández-Ontiveros, A. Hernán-Caballero, M. Akhlaghi) and the IAA group (J.M. Vílchez, C. Kehrig, J. Iglesias-Páramo, A. Arroyo Polonio)

Summary

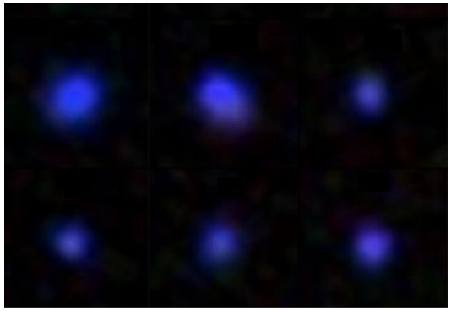
- Extreme emission line galaxies (EELGs) are rare but very interesting objects
  - Challenging the limits of our understanding of SF
  - Analogs at low-z of the first galaxies in the Universe
- Wide, medium-narrowband surveys are great tools to select EELGs in complete, unbiased ways
  - Best done from Teruel: J-PLUS and J-PAS
  - Obatining great targets for follow-up observations

Introduction

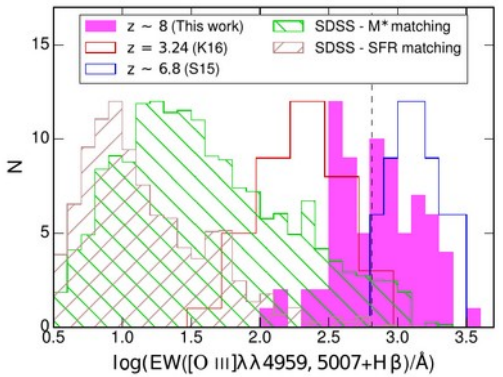
- From the 1960s, many surveys have uncovered compact, strongly star-forming galaxies in the nearby Universe
  - HII galaxies, BCDs, Green Peas, Luminous compact galaxies, Blueberry galaxies, emission line / Halpha dots, extreme emission line galaxies (EELGs)
- Different observational approaches have been taken
  - Objective prism, multiband surveys (broad and mediumband filters), narrow band surveys, multiobject spectroscopy
- Similarities between reionization-era galaxies and some local starburst galaxies
  - Low masses, high sSFR, low metallicity
  - Lyman continuum leakage
- **Analyzing this rare local starbursts helps uncover the nature of the first galaxies in the the Universe and the limits of SF processes**



Green pea galaxy (Cardamone et al. 2009)



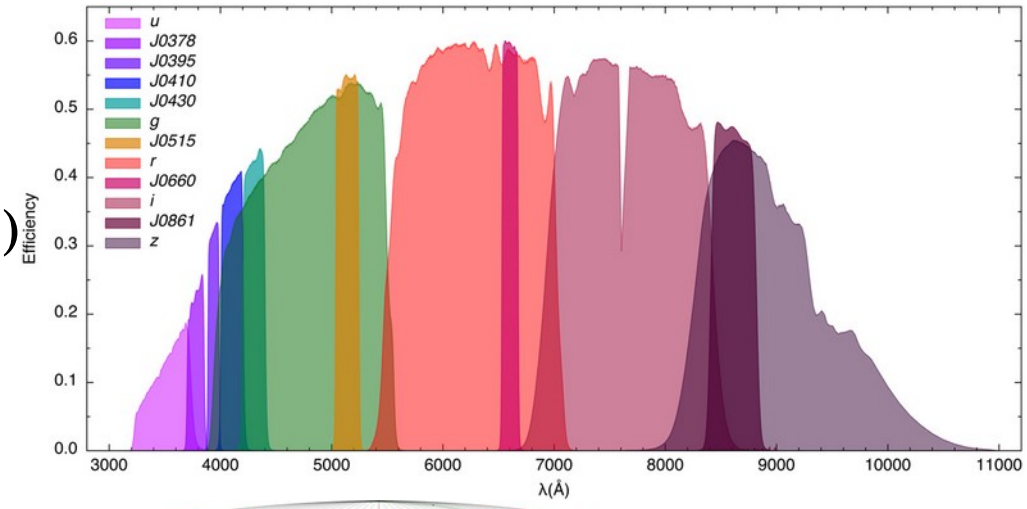
Blueberries (Yang et al. 2017)

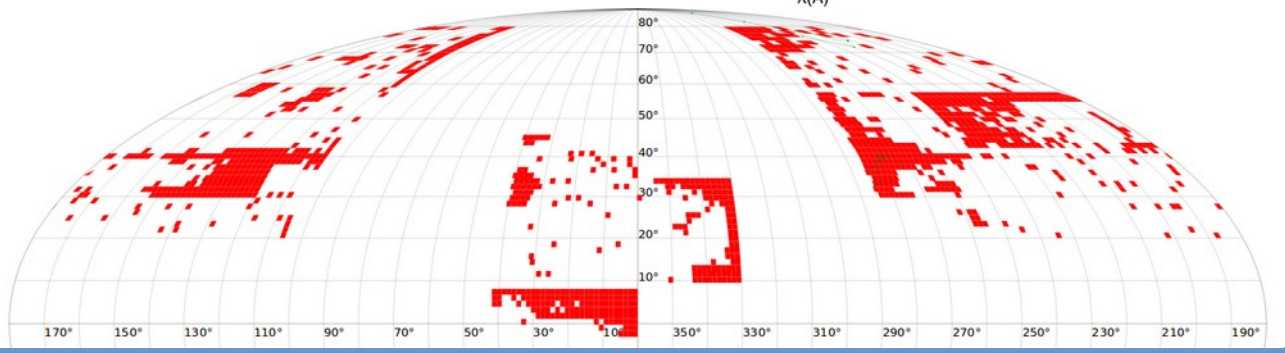


De Barros et al. (2018)

J-PLUS

- T80 at Observatorio de Javalambre
- Wide, multiband photometric survey
  - DR2: 2000 deg²
  - 12 filters (7 narrow-medium, 5 broad)
- Depth: 5σ 20.3 – 21.75
- S-PLUS (south), J-PAS
  - 56 narrow-band filters, T250
- Previous work on local SF galaxies (Logroño-Garcia+19, Vilella-Rojo+21) and extreme quasars (Spinoso+21)
- Open access, ADQL query, VO tools www.j-plus.es
- S-PLUS (south9)
- J-PLUS DR3 (3200 deg²)
  - Public during SEA 2022!





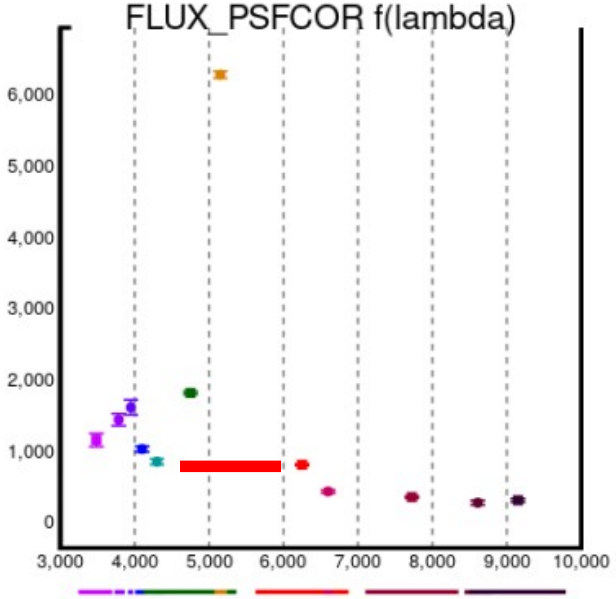
Cenarro et al. 2019

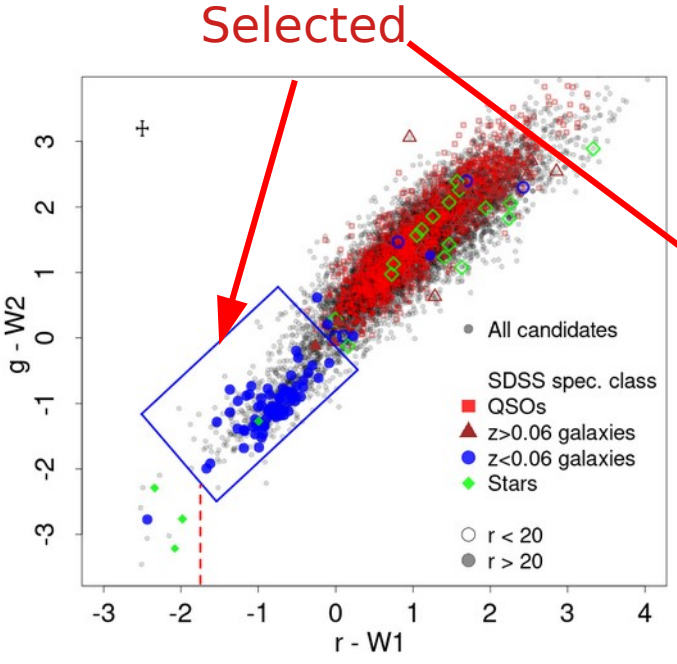
Sample selection - WISE

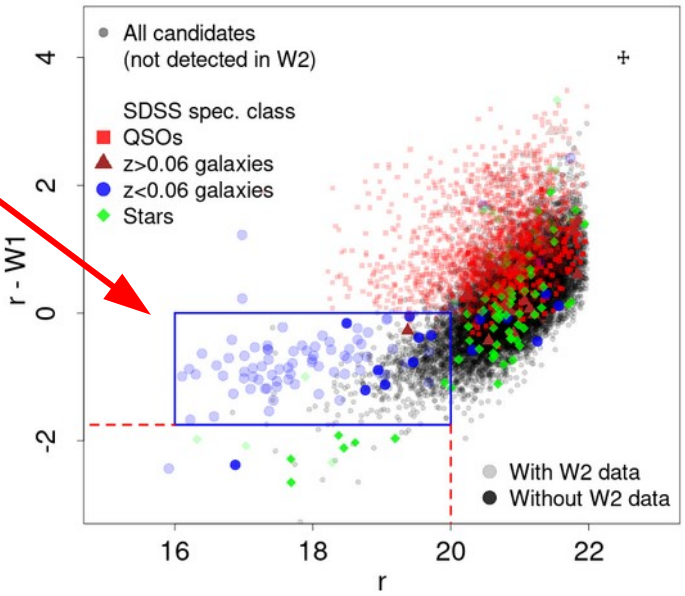
- Selecting galaxies that show excess of flux in the J0515 filter compared to rSDSS
  - J0515: $\lambda_{central}$ ~ 5140 Å. Width ~ 200 Å
    - [OIII] 5007+4959 at 0.015<z<0.055
  - $(F_\lambda[J0515]-F_\lambda[rSDSS])/F_\lambda[rSDSS] > 1$

    EW ~200 Å
    - 30336 objects

- The optical-IR colour allows us to separate QSOs and EELGs
  - *unWISE* catalog W1 - 3.4 μm, W2 - 4.6 μm
- rSDSS<20 to ensure clear separation
- Separation QSO/Galaxy in the g-W2 vs. r-W1 and r-W1 vs. R diagrams
  - Spectroscopically confirmed objects:
    - >90% purity, >90% completeness
- **Sample of 1493 galaxies**



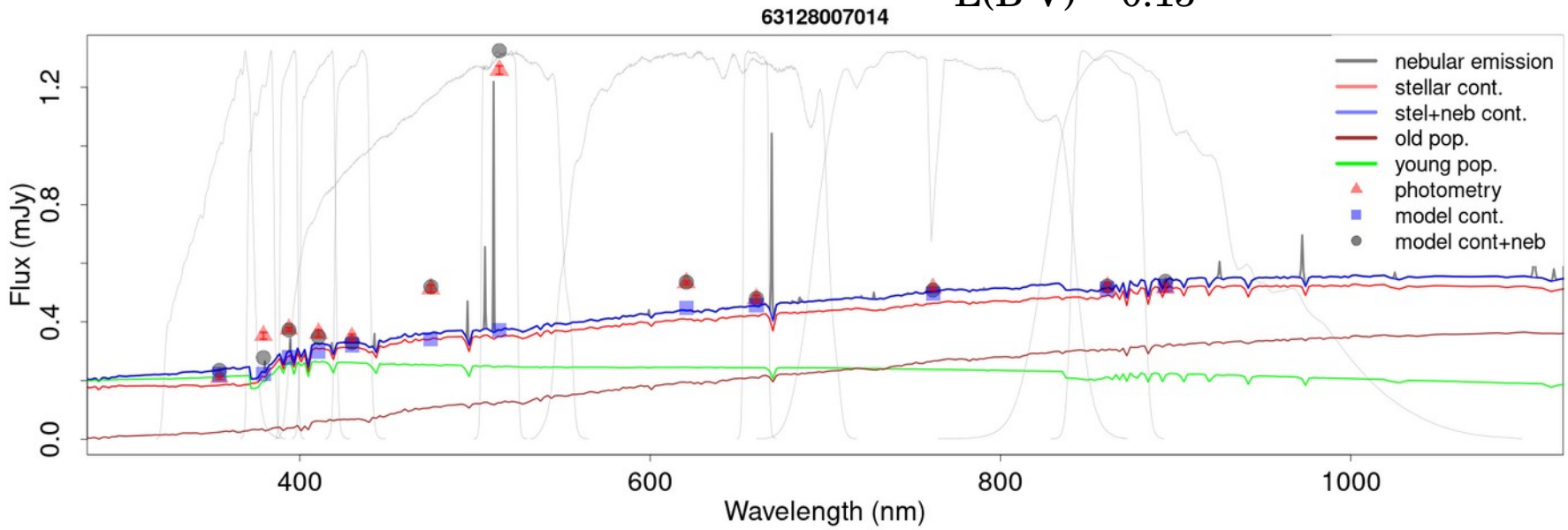




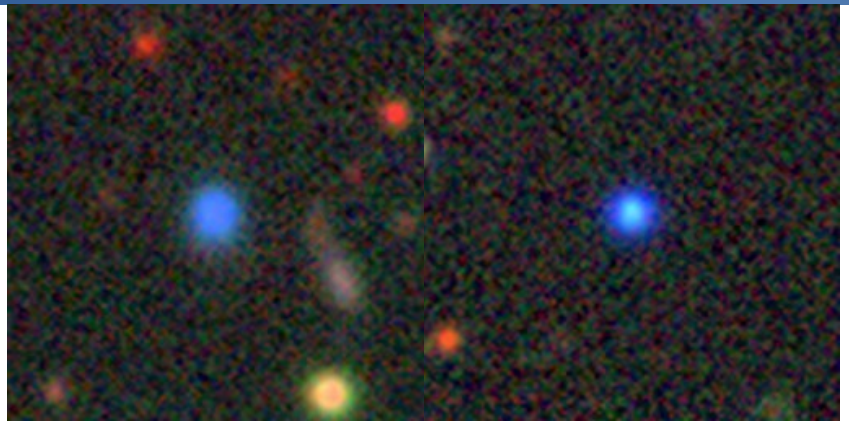
SED fitting

- SED fitting to extract physical information
  - CIGALE (Boquien et al. 2019)
  - Nebular emission (Inoue et al. 2011)
- Parameters
  - Two stellar populations (BC03)
  - “Instant” bursts, old population parameters fixed

- **466 galaxies with EW([OIII])>300 Å**
  - **410 of them previously unknown**
  - **EW threshold to ensure completeness**
- Very young burst (<=6 Myr)
- Low-mass galaxies
  - Median value ~ 10^8 $M_\odot$
- Old population ~100 times more massive than burst
- Low dust extinction
  - E(B-V) ~ 0.15



Results: Morphologies



Compact

(majority of the sample)

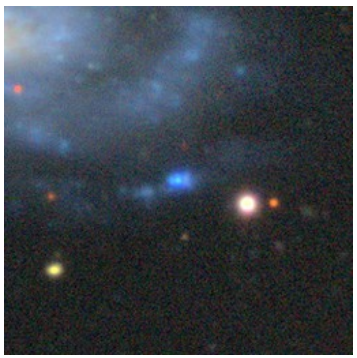
- Compact - 43 %
- Semi-compact - 38 %
- Extended -19 %

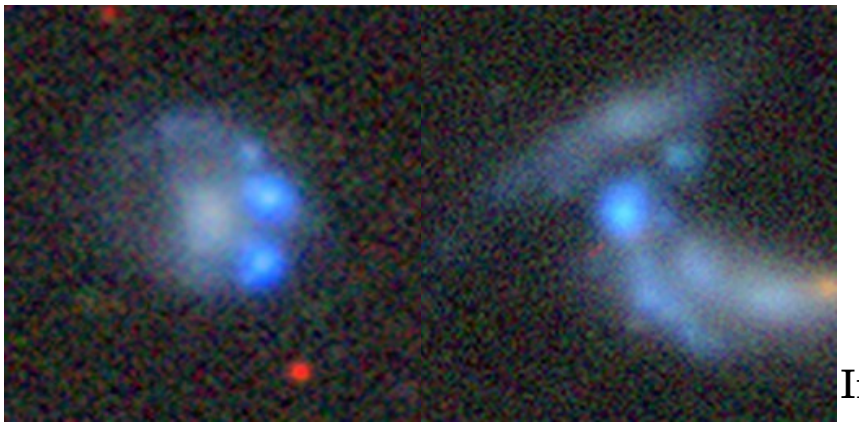
- Extended objects are slightly more massive ($10^{8.32}$ $M_\odot$ vs. $10^{8.04}$ $M_\odot$ in compact or $10^{8.15}$ $M_\odot$ in semi-compact galaxies)
- Extended show slightly lower EW (397 Å vs. 466 Å and 445 Å respectively)

Semi-compact

(tadpole, SF region + diffuse area, etc.)

Rejected: SF regions in large-scale spirals



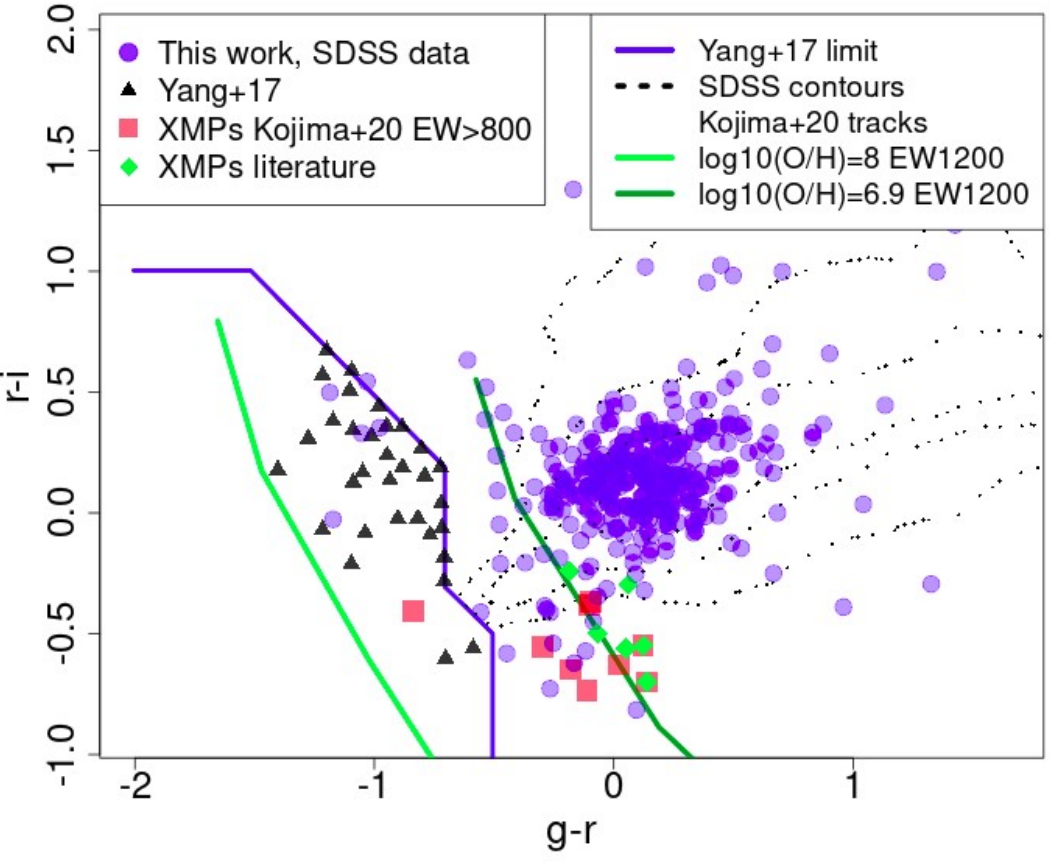


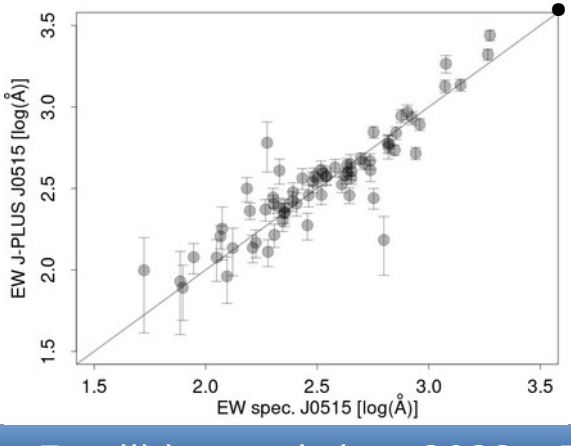
Complex morphology

(multiple SF regions, mergers, etc.)

Images from the Legacy Survey viewer www.legacysurvey.com/viewer

Comparison with previous work



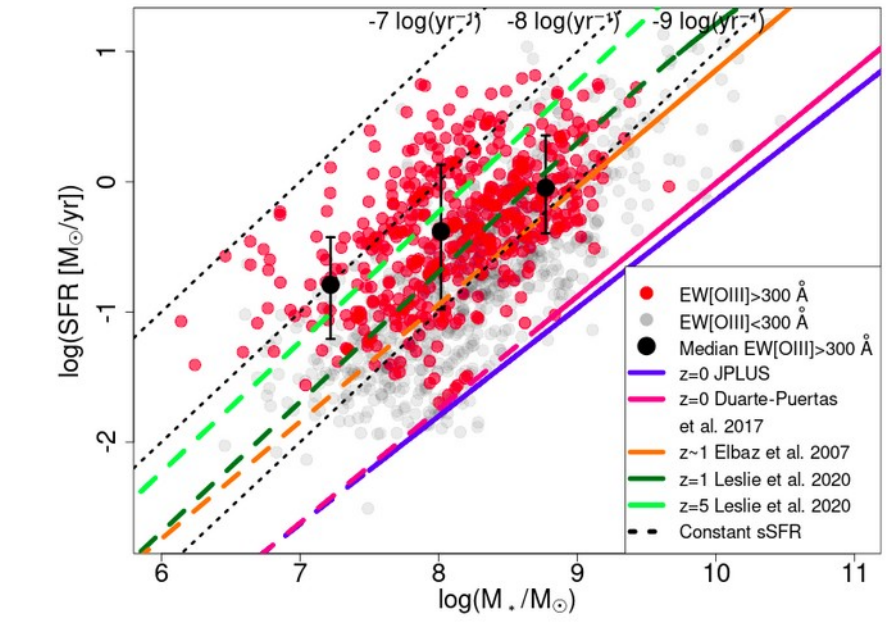


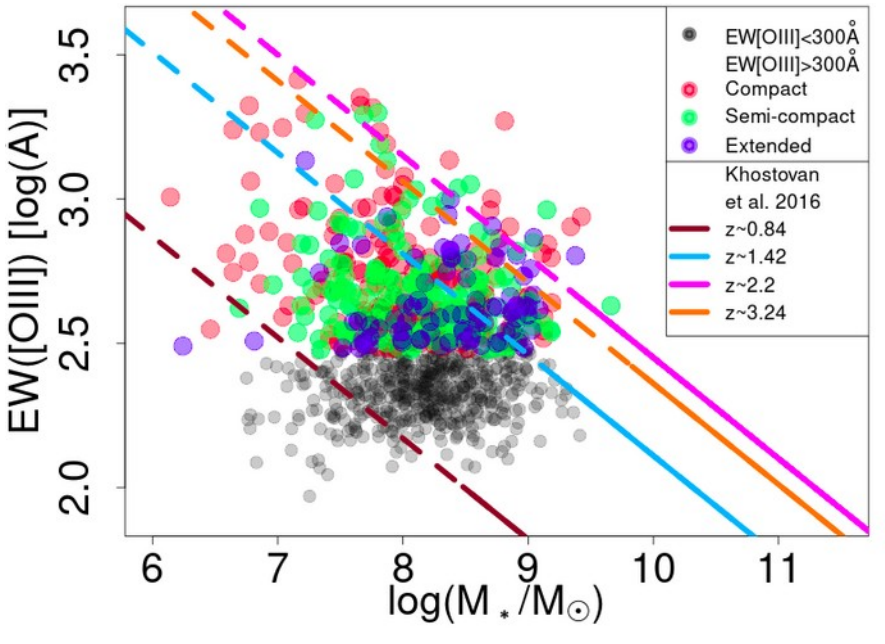
- Comparison with spectroscopic data
  - Very good agreement in line fluxes and EW
    - 0.15 dex scatter
  - Very good agreement in redshift

- More precise selection than broadband surveys
  - **20 – 50 times more density of objects than broadband selection (GPs, blueberries)**
- Going deeper than wide spectroscopic surveys
- As efficient in detection as magnitude limited spectroscopic or narrowband surveys
- Almost no selection bias

Results: SFR and EW vs Mass

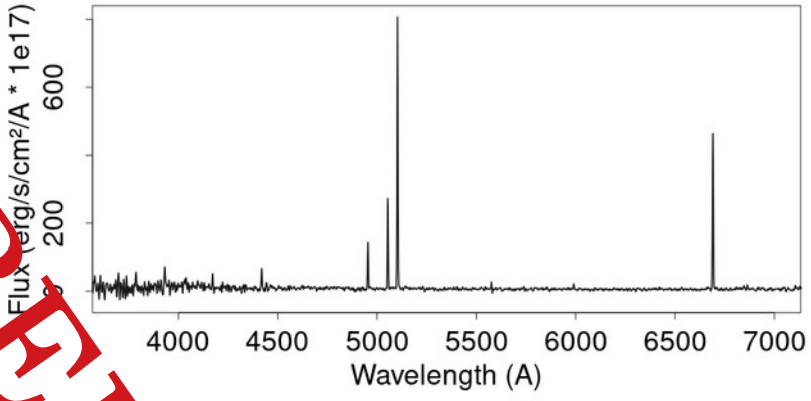
- SFR estimation using Hα (Kennicutt+98)
  - Typically low extinction (median E(B-V)=0.15)
- Depletion time as low as ~ 10 Myr
- Typical galaxy in our EW>300Å sample: SFR 1.2 dex above local Main Sequence
  - Similar sSFR as typical galaxies at z~3-5
- The sample reaches very high EW([OIII])
  - Comparable to the expectations for typical low mass high-redshift galaxies

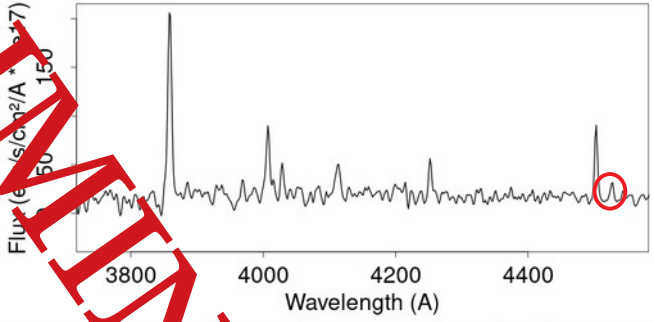




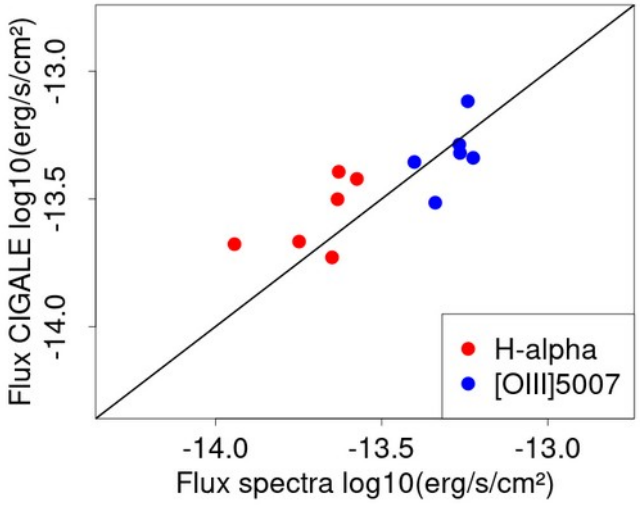
Follow-up longslit spectra (INT)

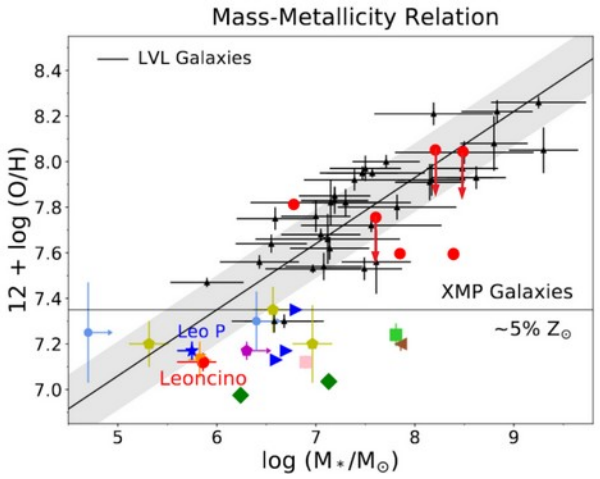
- IDS@INT at ORM (La Palma)
  - 3500 Å - 7000 Å, R ~ 400
  - 33 galaxies observed, ALL
    - ALL are low redshift EELGs with strong emission lines
  - Preliminary reduction
    - Good agreement in line fluxes with J-PLUS photometry
    - ~ half show significant [OIII]4363, Only a few show [NII]6583
  - Metallicity estimations
    - HII-CHI-mistry (Pérez-Montero+14), N2 upper limits
    - Filling the gap at log(M)~8 and 12+log(O/H) ~ 7.6?
  - Extreme [OIII]/[OII] ratios
    - High ionization parameter, leakeage?

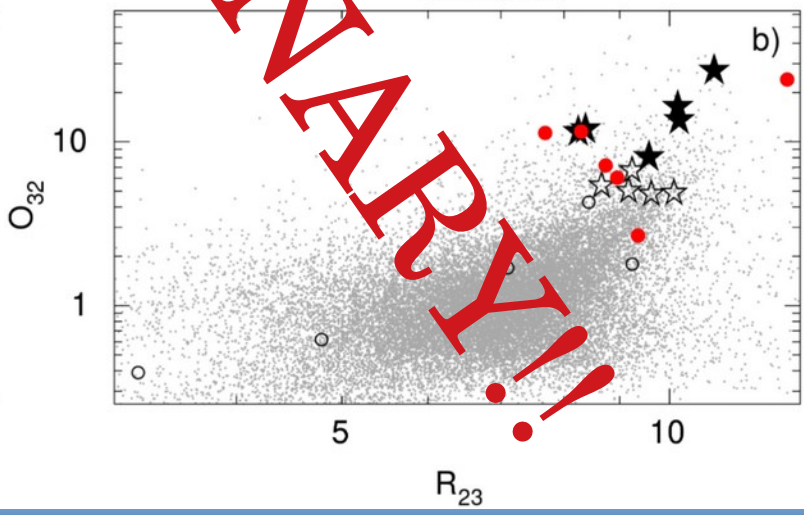




PRELIMINARY!!

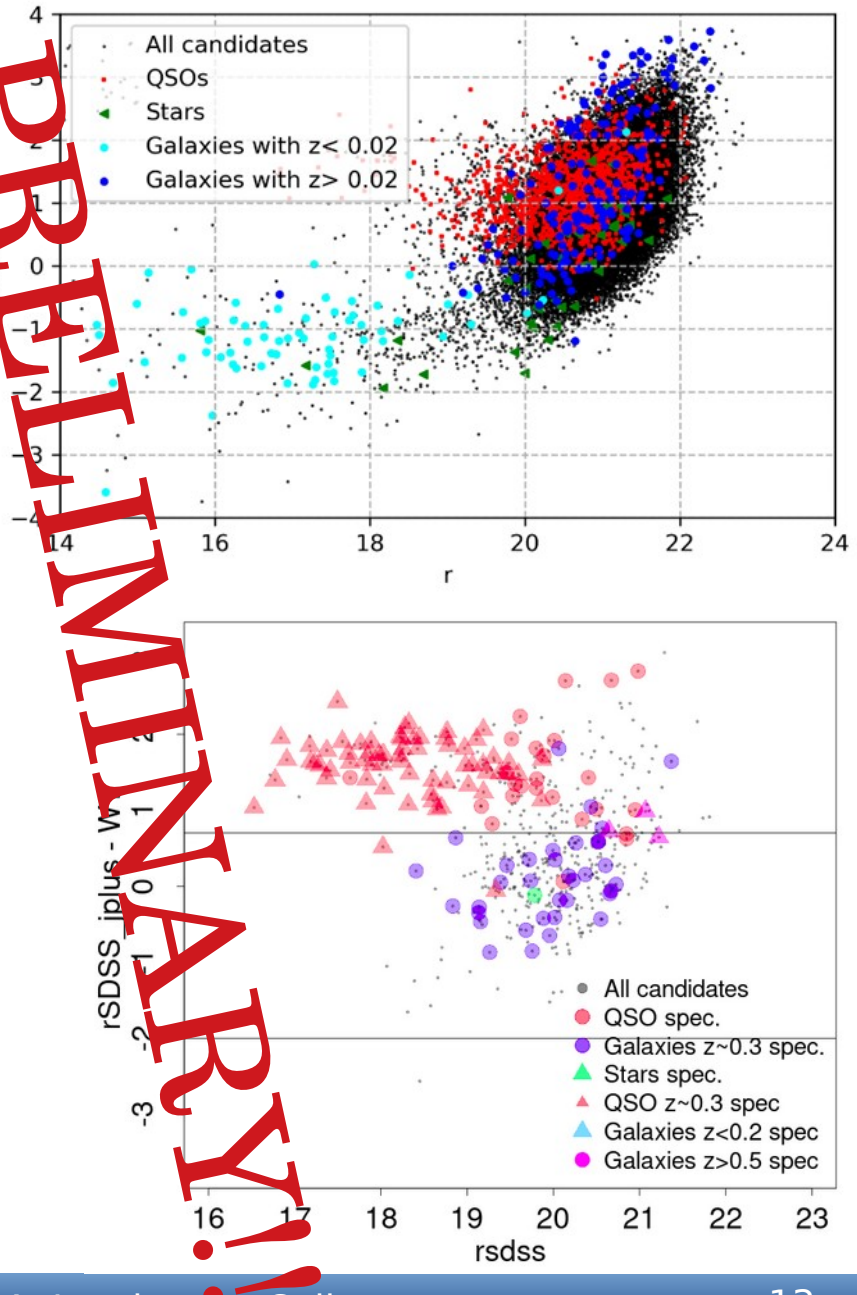






EELGs at different redshifts

- Extreme Hα emitters in the nearby Universe (J0660 filter)
  - Master thesis by Luis Soliveres Higuera (VIU)
  - Hundreds of objects fulfilling criteria, but further cleaning necessary
- Extreme Hα emitters in at z~0.3 (J0861 filter)
  - The “red” Green Pea galaxies
    - Hα selection vs. [OIII] sel.
  - More than a hundred new Gps!
  - ~90% completeness/purity
  - More diverse morphology (not all are compact)



Summary and future work

- Using the J0515 J-PLUS filter, we compile the largest sample (466) of extreme emission line galaxies (EW([OIII])>300Å) in the local Universe (z<0.06) after SDSS spectra
  - 410 previously unclassified as EELGs
  - Very efficient, unbiased selection of EELGs
  - High purity (>95%), high completeness (>90%)
- SED fitting reveals very young, low mass galaxies with little dust extinction
- SFR and EW comparable to high-redshift (z ~ 3-5) systems
- Follow-up observations
  - INT spectra: Analyzing a full sample
    - Metallicities, extreme [OIII]/[OII] ratios
    - Potential identification of XMPs and candidates to have Lyman continuum leakage
- Future work:
  - Higher/lower redshift EELGs (>100 new Green Peas, 100s of low-z candidates)

Lumbreras-Calle et al. 2022 - arxiv:2112.06938