EXTREME EMISSION-LINE GALAXIES IN THE LOCAL UNIVERSE AND BEYOND: POTENTIAL HOSTS OF GRBs

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OUTLINE

- (short) Introduction:

  What are the main properties of extreme emission-line galaxies (XELGs) ?

- The Green Pea galaxies:
  - Physical properties, chemical abundances and star formation histories
  - Insights on the ionized gas kinematics

- Green Pea-like galaxies out to z=1 ?

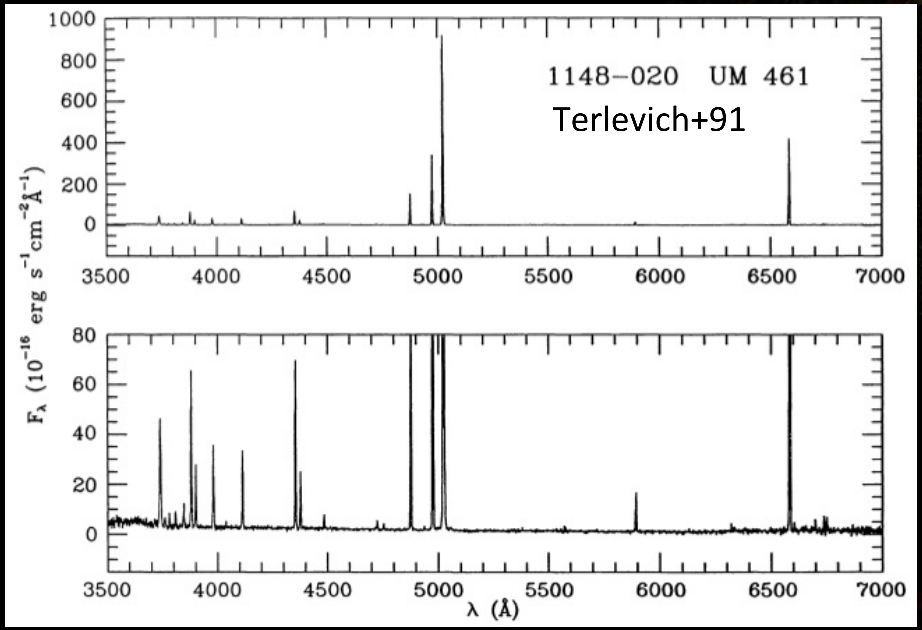
  → Extreme emission-line galaxies in the zCOSMOS-20k survey
  - Characterization and scaling relations

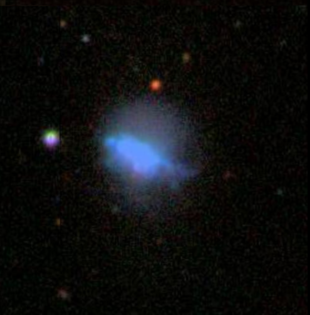
- Conclusions

EXTREME EMISSION-LINE GALAXIES

Low-z Universe (z< 0.1):

HII galaxies and Blue Compact Dwarfs (BCDs) are rapidly building-up their stellar component in a nearly galaxy-wide starburst

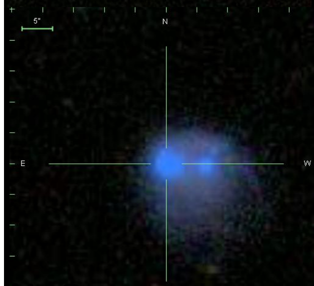




Host galaxies are mostly "old" (few-several Gyr, e.g. Papaderos96, Cairós+01,Amorín+09)

However, they are among the youngest systems that can be studied locally

IZw18



Small, gas-rich, dust-poor & metal-poor galaxies (Review talk by Papaderos)

Includes the most metal-poor galaxies known (<10% solar, Papaderos+08)

XELGs are rare in the local universe (<5% in SDSS, Kniazev+04)

EXTREME EMISSION-LINE GALAXIES

GREEN PEAS: A SDSS sample of 80 luminous compact galaxies at $z=0.11-0.36$

(Galaxy Zoo: morphology + color selection) (Cardamone+09; Amorín+10,12ab; Izotov+11, Pilyugin+12, Hawley12, Chakraborti+12, Jaskot&Oey13)

Compact: $R_{50} \sim$ 1-3 kpc

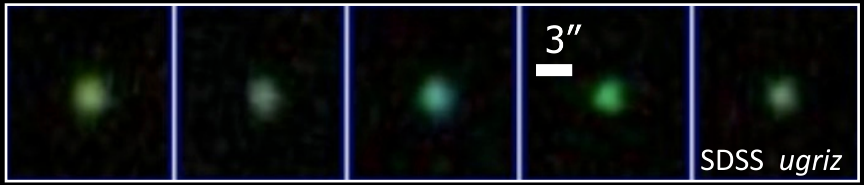
Luminous: $-19 < M_g < -21.5$ $L_{FUV} \sim 3\times10^{10}\,L_{sol}$

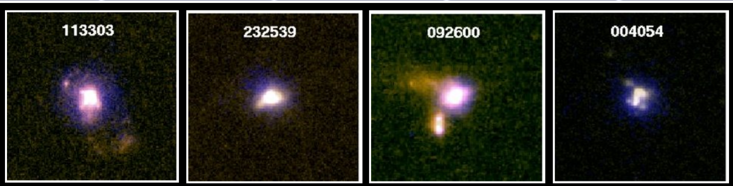
Low stellar mass: $7 < \log(M_*/M_{sol}) < 10$

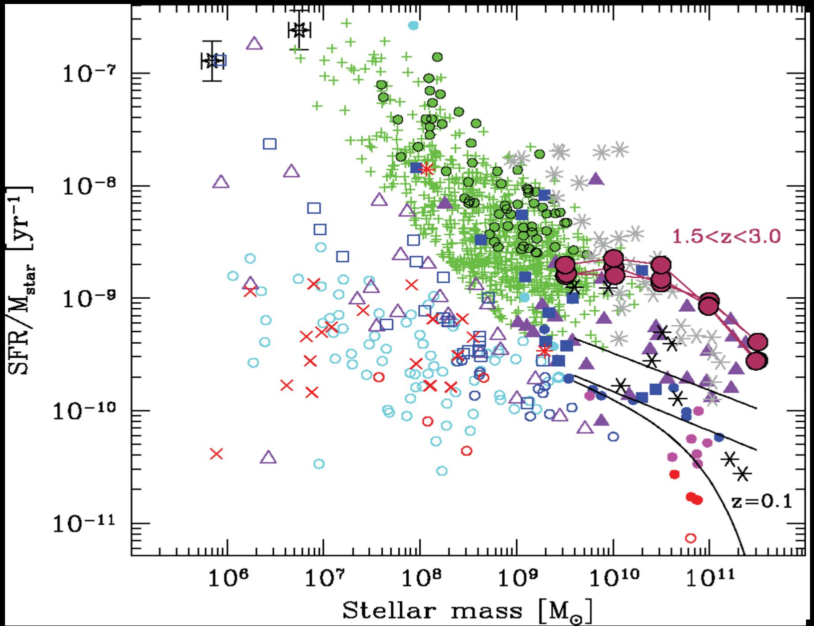
High SFR: $3 < SFR_{H\alpha,FUV}\,[M_*\,yr^{-1}] < 60$

Low metallicity, low extinction and high ionization:

$7.6 < 12+\log(O/H) < 8.5$; $E(B-V) < 0.25$;





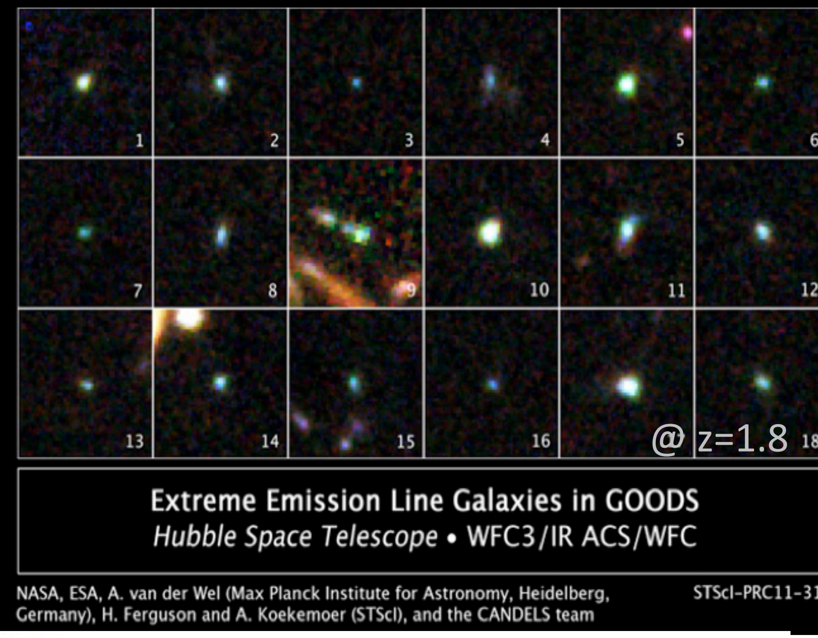


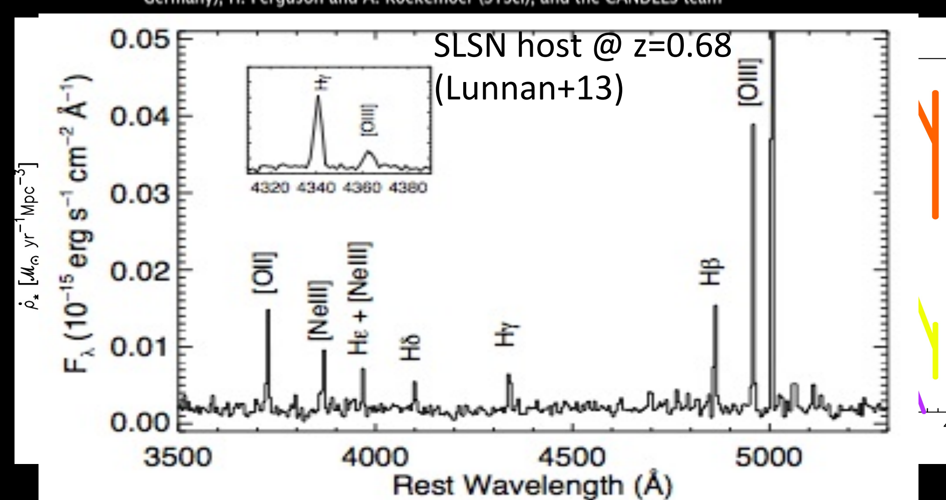
- GPs are rapidly growing systems residing In low density environments.
- GPs are even more rare than local BCDs (2 per deg^2; 0.06% of SDSS)
- The highest SFR/M_* (=100-1 Gyr $^{-1}$) and Σ_{SFR} (=1-10 $M_*\,yr^{-1}\,kpc^{-2}$) in the local Universe (cf e.g. Salim+07)
- SF efficiency, chemical and physical conditions approaching those in high redshift galaxies, e.g. Lyman-break and Lyman-alpha galaxies

Motivations

- Ideal laboratories to study starburst activity, feedback processes, and chemical evolution in low-density environments
- Nearby analogues of low-mass systems in the distant Universe. Clues to the evolution of star formation over cosmic times and downsizing
- Useful probes for observational cosmology: e.g. primordial Helium, cosmological constant, cold-flows, reionization…
- Low-metallicity starbursts are the likely environments to host progenitors of long GRBs and the most luminous supernovae (e.g. Christensen+04, Kewley+07, Thöne+08, Savaglio +09, Guseva+11, Vergani+11, Chen+13, Lunnan+13)

(e.g. talks by Giorgios and Ragnhild)



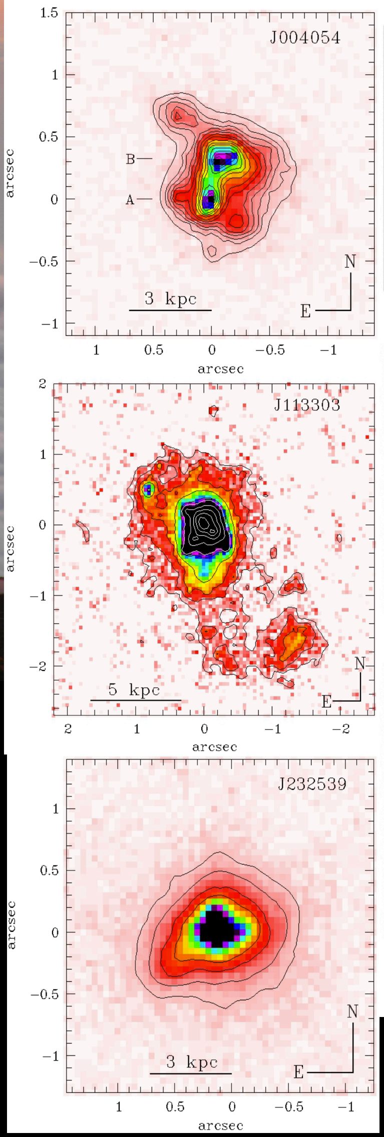


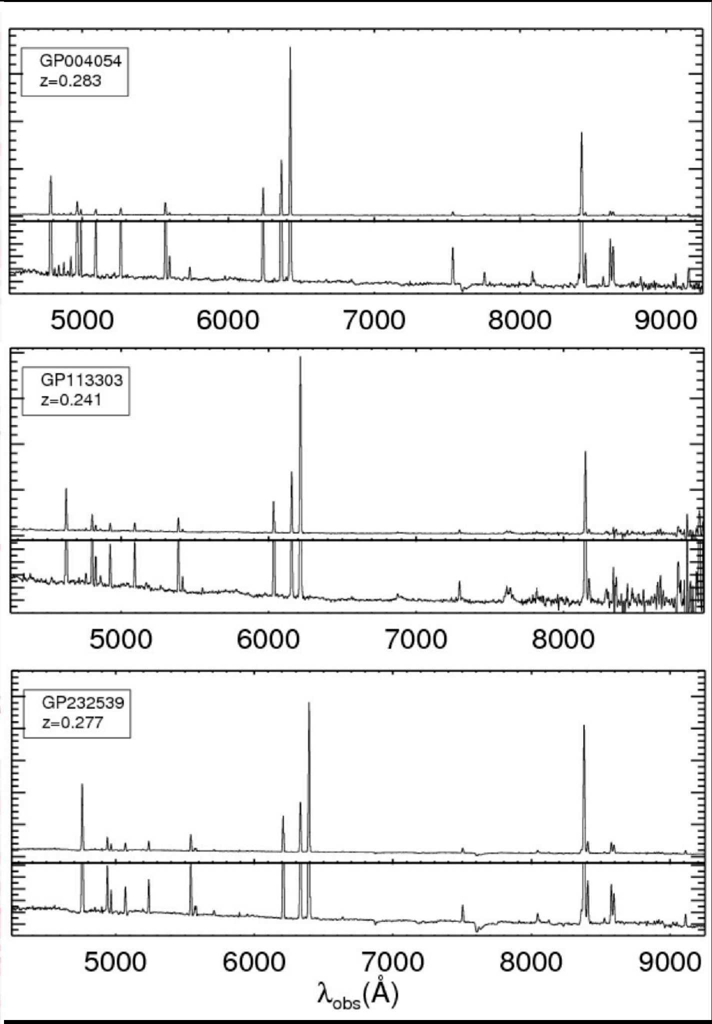
Deep spectroscopy from GTC-OSIRIS

Amorín et al. (2012a, ApJ, 749, 185)

Very deep, mid-res long-slit spectroscopy of Green Peas with HST imaging available

- Detailed analysis of physical properties and chemical abundances
- Detection of faint spectral features
- Star formation histories from spectral synthesis and surface photometry





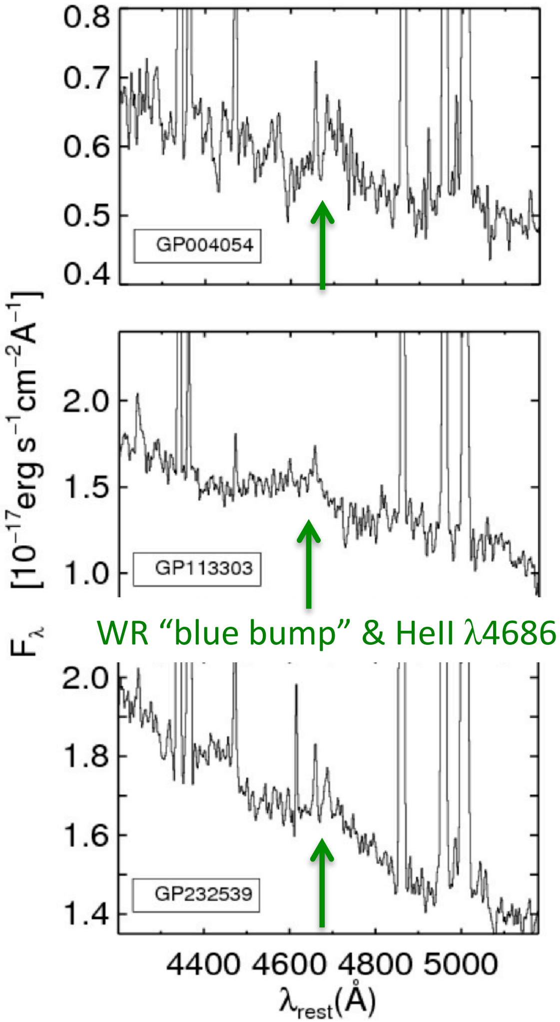
Deep long-slit spectroscopy (R1000 B+R, t=1h, S/N_{cont}=40)
3 target galaxies (m_B=18.5-20) with HST imaging available

Collaborators: E. Pérez-Montero, J. Vílchez (IAA-CSIC, Spain), P. Papaderos (CAUP-Portugal)

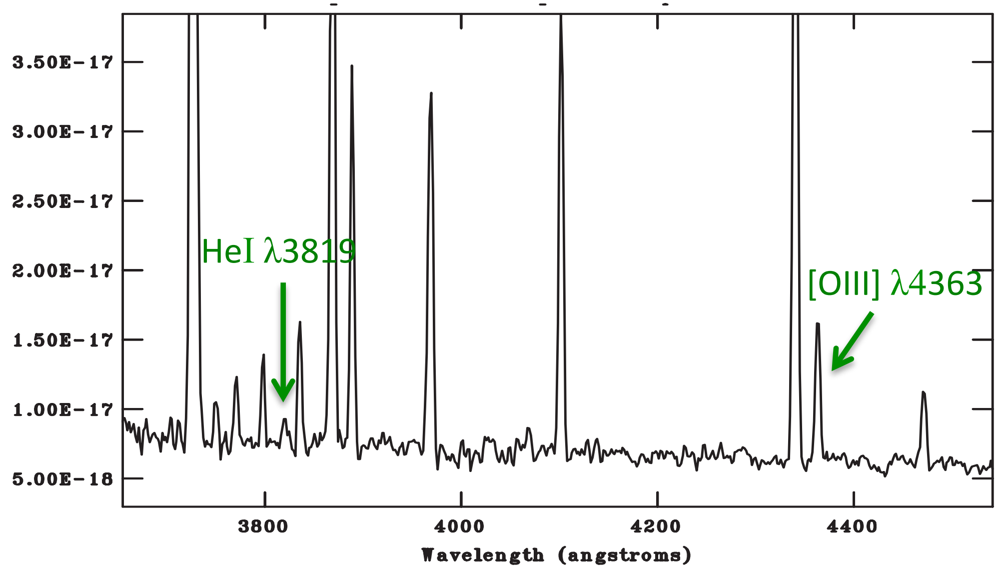
CONSOLIDER - INGENIO GTC ESTALLIDOS

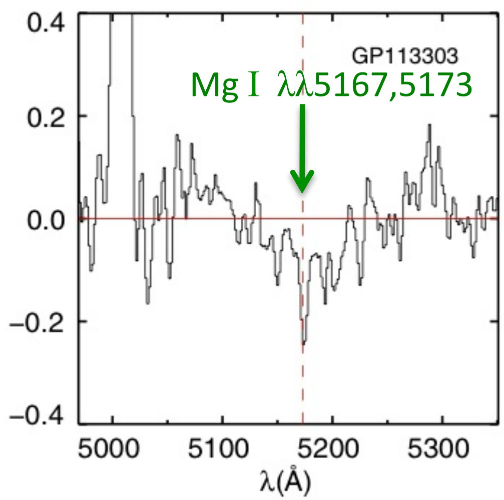
OSIRIS LONG-SLIT SPECTROSCOPY

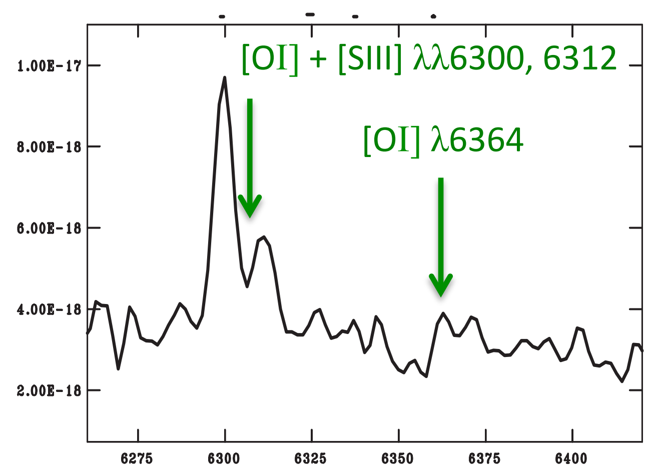
First clear detection of WR stars in Green Peas



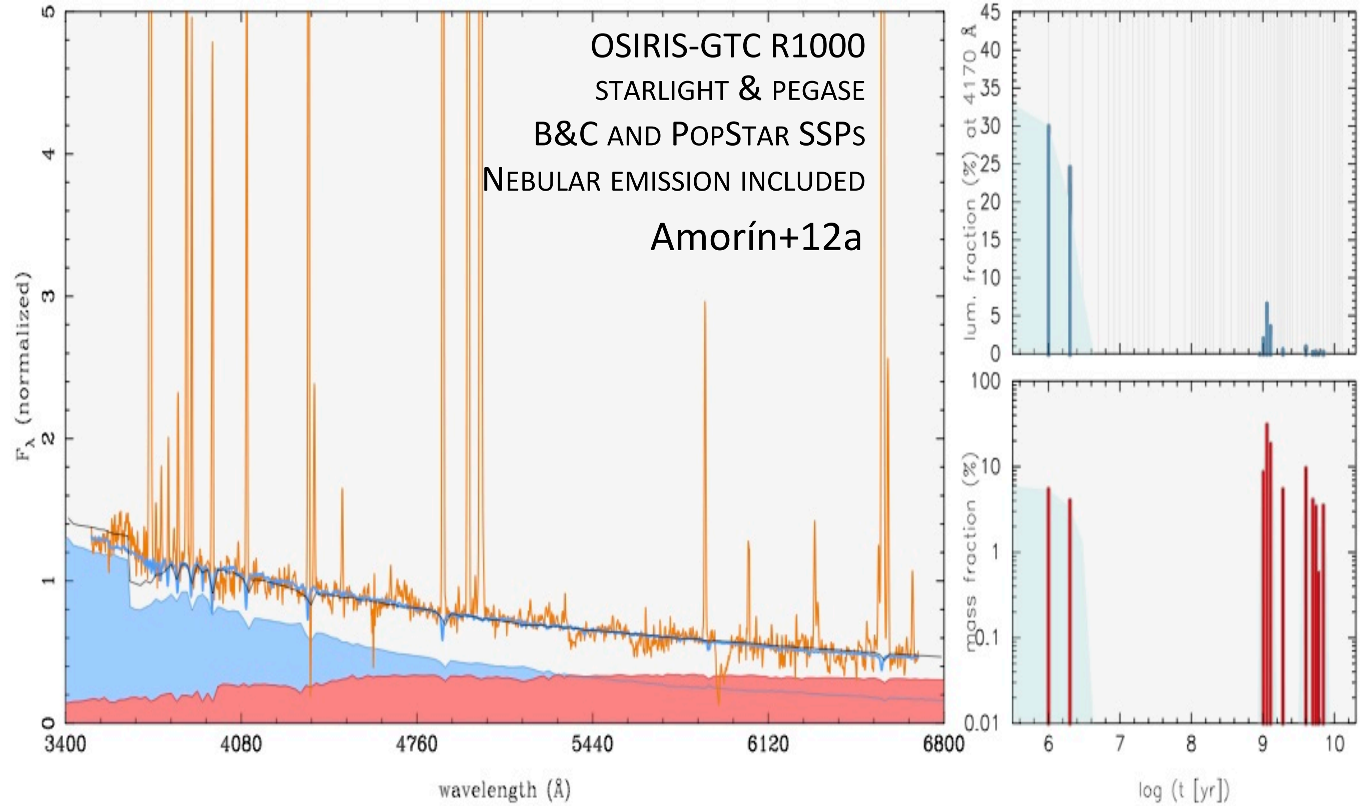
Spectral signatures of old stars & very young stars & shocks







Results from Spectral synthesis



Log $M_\star$ = 9.1 M_{sol} ; $M_{\star,young}$=12-20% t_{burst} = 4.2 Myr

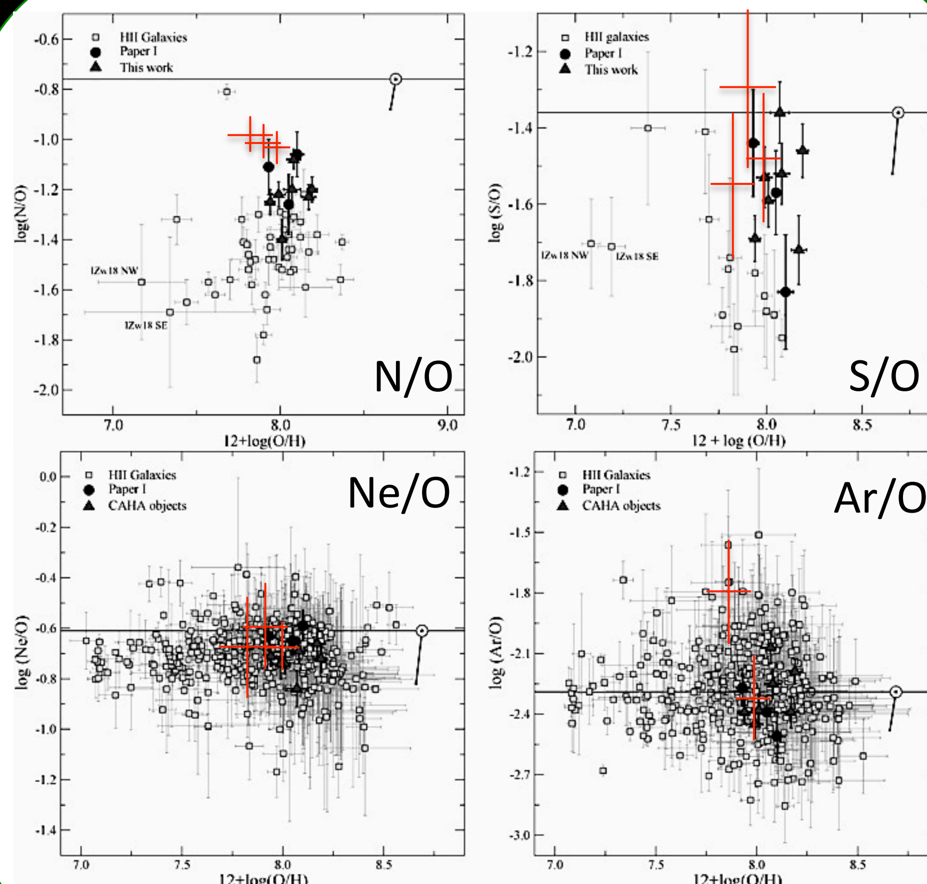
The GPs are rapidly forming ~5-20% of their total stellar mass (10^9 M_{sol}) in an ongoing, intense galaxy-wide starburst. The presence of WR stars also suggest young ages (few Myr)

Spectral synthesis, together with results from surface photometry, and the detection of Mg I consistently suggest the presence of an evolved stellar component, with ages ≥ 1 Gyr.

Physical properties and chemical abundances from GTC

Low extinction c(Hb)=0.2-0.4;
Low oxygen abundances 12+log(O/H) ≈ 8.0
High N/O ratios log (N/O) ≈ -1.0
Are NOT typical for dwarf HII galaxies

The derived physical properties
n_e ([SII]) < 200 cm^{-2}
T_e ([OIII]) ≈ 13400 K – 14600 K
Abundances for Helium (He/H ≈ 0.087)
and heavy elements (Ne, S, Ar and Fe)
are within typical values of those values
for nearby HII galaxies and BCDs
(e.g. Kobulnicky & Skillman 1996; Hägele+06,08; Kehrig+06; Guseva+11)

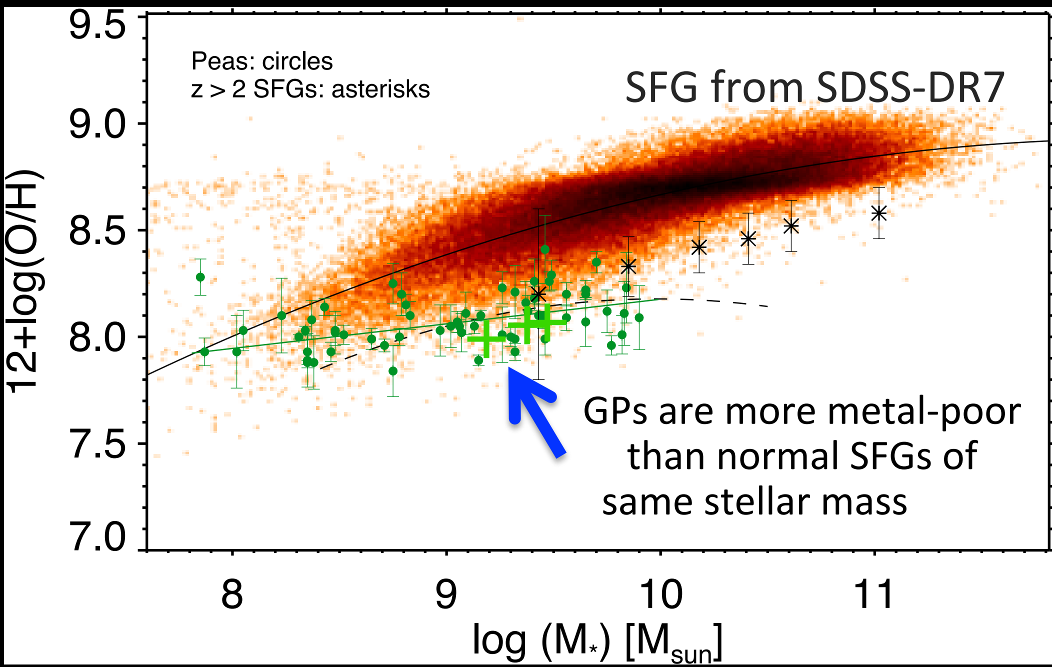


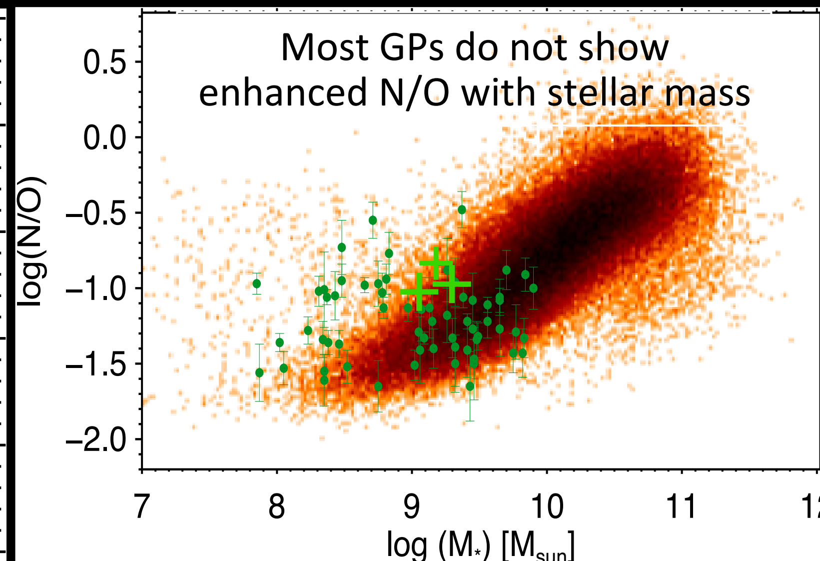
Comparison with HII galaxies (from Hägele+08)

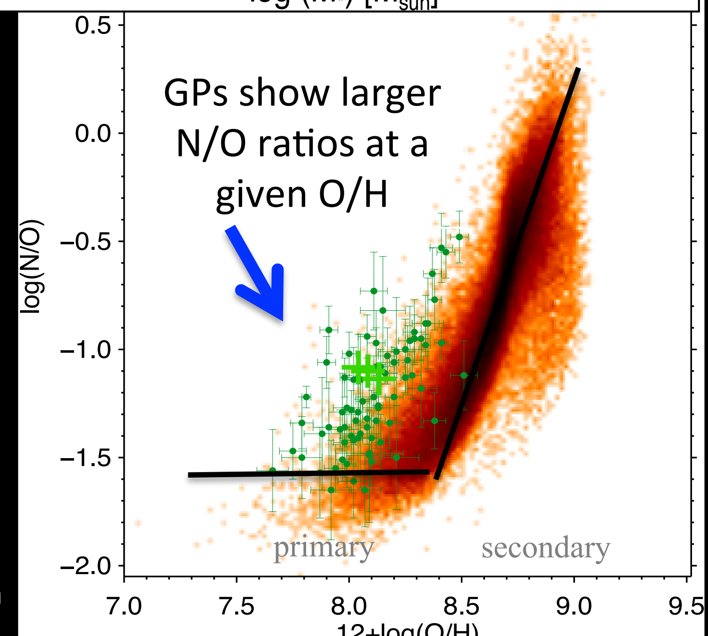
Higher S/N spectra and the direct (T_e) method improve and confirm previous results using SDSS spectra (Amorin+10)

MASS-Z-N/O RELATIONS

Amorín, Pérez-Montero & Vílchez (2010)







Possible interpretations:

- Dilution: fast/massive inflow of metal-poor gas

(cf. e.g. Bergvall & Östlin 2002; Köppen & Hensler 2005)

- Metal enriched outflows? (e.g. van Zee+98)
  - Local pollution by massive stars (Brinchman+08; Pérez-Montero+11)
  - peculiar SFH… (Mollá+06; Mallery+07)
  - Extra production of primary N by intermediate-mass stars ? (Gavilán+06)

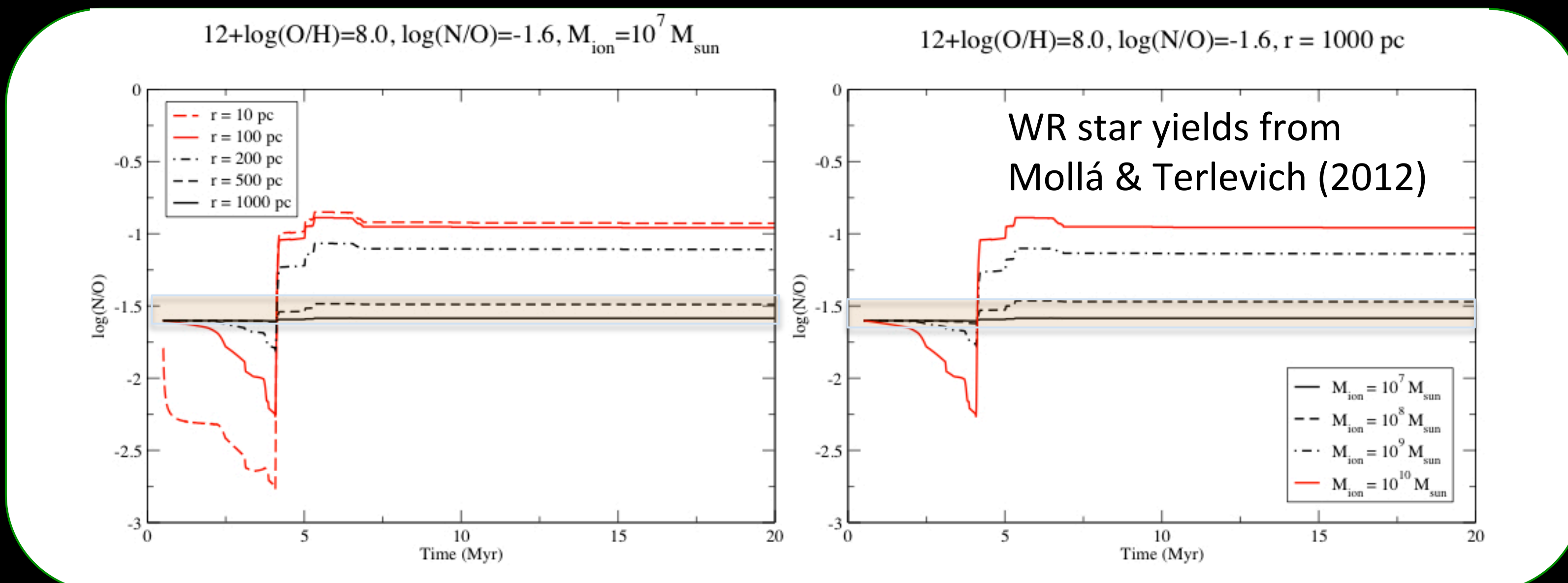
N/O: METAL POLLUTION BY MASSIVE STARS?

Large amounts of WR stars are present in the GPs

N(WR$_\star$)=800-1200 ; N(WR$_\star$/O$_\star$)=0.01-0.03.

According to L(Halpha), cluster masses in GPs are ~ 10^7 solar

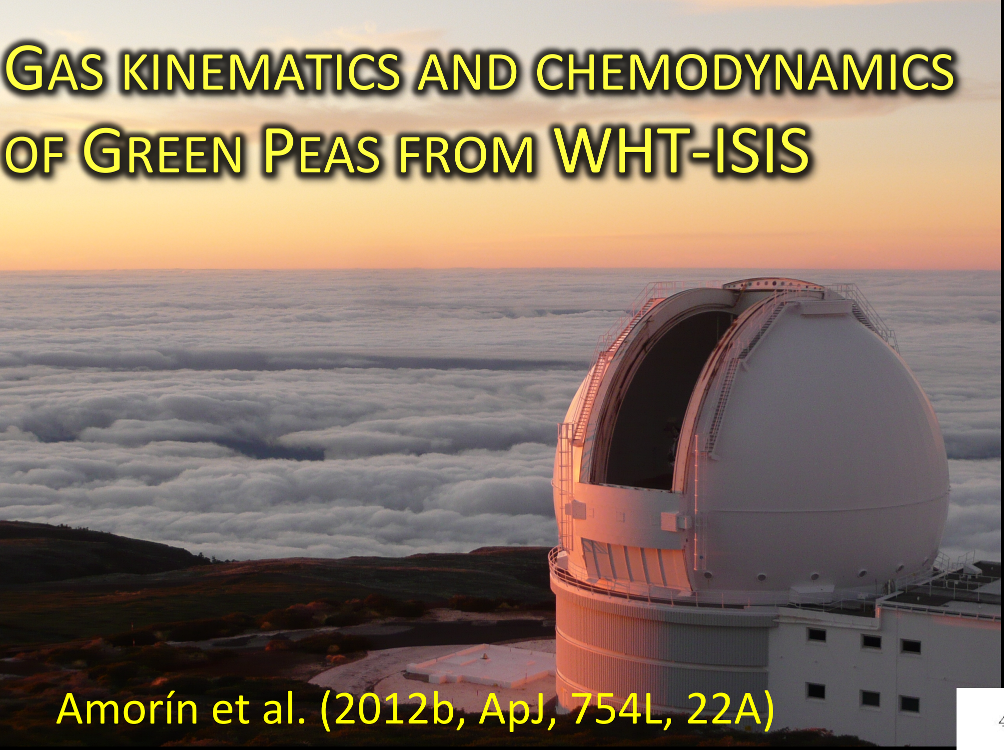
It would be necessary between 2 – 3 orders of magnitude higher in the ionizing cluster mass to reach such degree of pollution in the covered spatial scale (~50% of the galaxy)

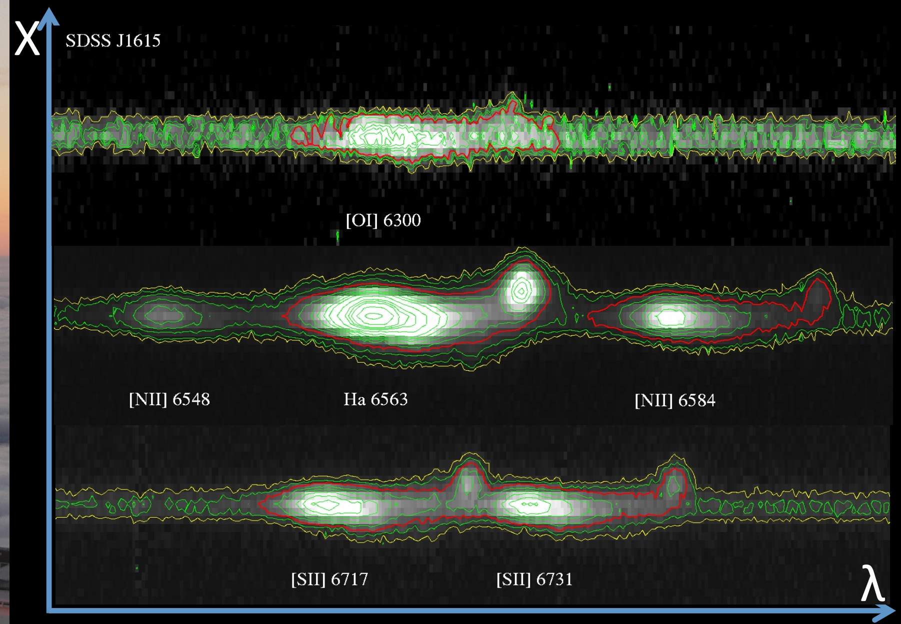


Similarities with some "special" nearby BCDs. e.g. Pérez-Montero+11, Monreal-Ibero+12, Kehrig+12, James+13

CONCLUSION: According to models, pollution by WRs cannot explain the enhanced N/O ratios of GPs

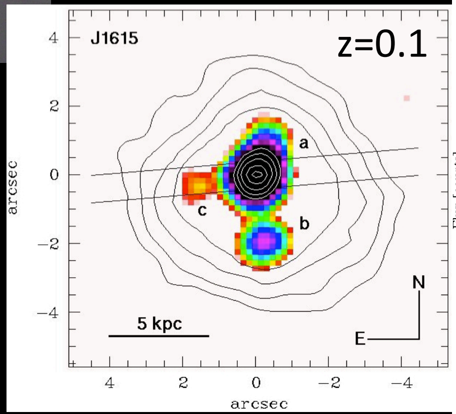
Gas kinematics and chemodynamics of Green Peas from WHT-ISIS

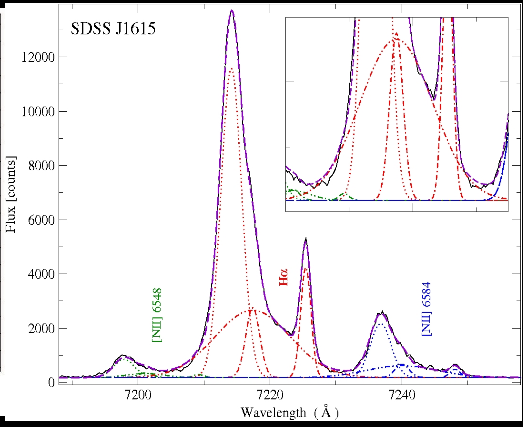




Amorín et al. (2012b, ApJ, 754L, 22A)
Deep, high-res long-slit spectroscopy of Green Peas

- kinematic structure of 14 GPs
- Physical properties and abundances for individual kinematical components.
- Looking for evidences of strong feedback
- Testing model predictions with observations





E. Pérez-Montero, J. Vílchez (IAA-CSIC, Spain), P. Papaderos (CAUP-Portugal)
G. Hägele, V. Firpo, (CONICET, Argentina)

RESULTS FROM HALPHA+[NII] LINE PROFILE FITTING

All the observed galaxies show:

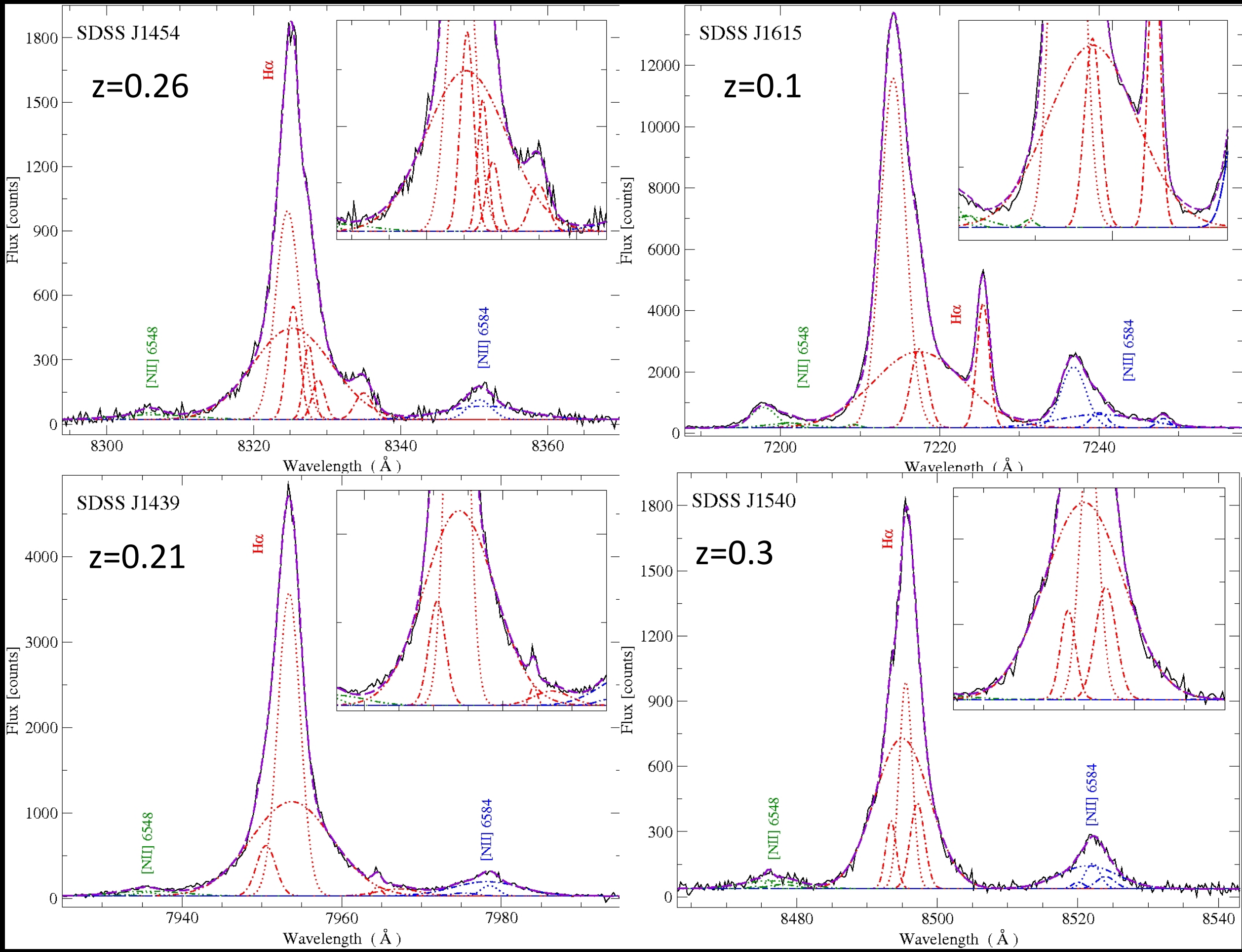
- more than one strong narrow components blue- and red-shifted components Δv= 50-500 km/s in a spatial extent of few kiloparsecs

  σ_{narrow}(Hα)=30-120 km/s
  L_{narrow}(Hα)~10^{40}-10^{42} erg/s

- One broad component in Hα, [NII] and [SII].

  σ_{broad}(Hα)=100-250 km/s
  FWZI ~ 650-1750 km/s

  L_{broad}(Hα)~ 10^{41}-10^{42} erg/s
  → 40-60 % of the total L(Hα)



Iterative multicomponent fitting method based on *NGAUSSFIT*
Details in Firpo+(10,11) Hägele+(07,09,10,12)

Evidence of complex gas kinematics and feedback in Green Peas

The observed high velocity dispersion suggest disturbed kinematics, likely driven by turbulence rather than rotation
(cf e.g. Marquart+07, Green+10; Goncalves+10)

Multiple narrow line components suggests:

- interactions or (minor) mergers
- presence of few massive clumps

(e.g. Östlin+01; Elmegreen+05,09,12, Wisnioski+11)

Clues for the main SF triggering mechanisms?

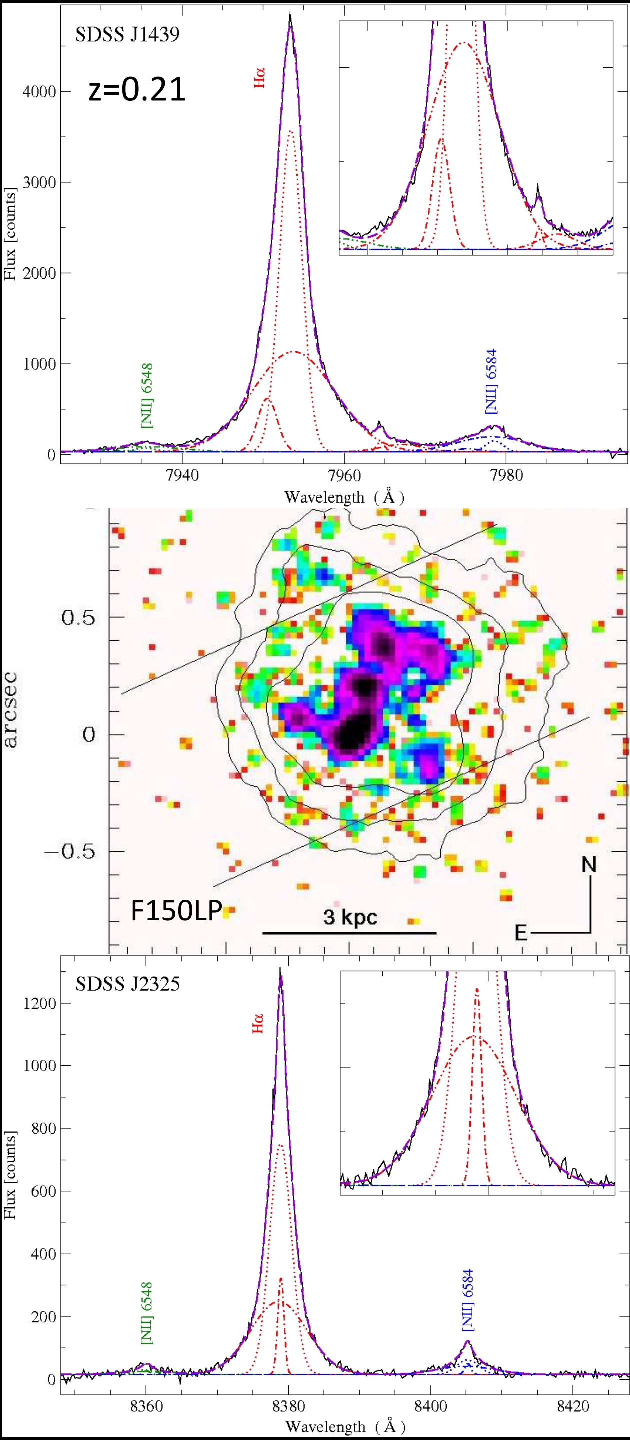
SF in compact and relatively massive (turbulent) clumps

- External: interactions/mergers (not obvious for ~50%)
- Internal: disk instabilities ? Clump-clump coalescence ?

SF Feedback

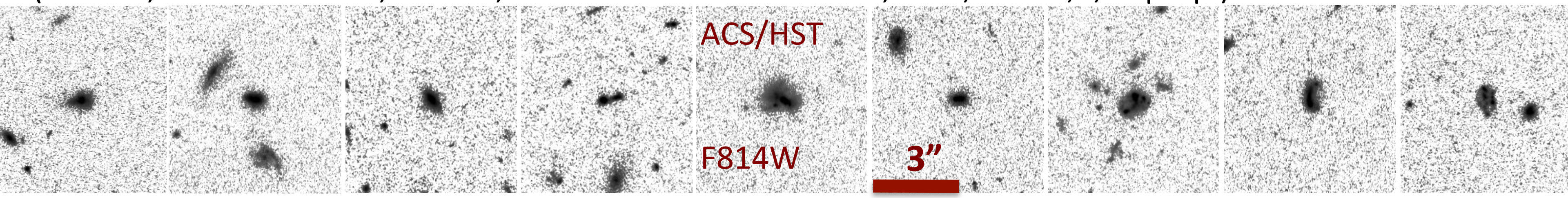
Broad emission in both Balmer and forbidden lines suggest intense gas flows likely driven by the galaxy-wide starburst

- strong stellar winds by massive stars e.g., WR, Ofp, LBV stars
- propagation of multiple SNe remnants



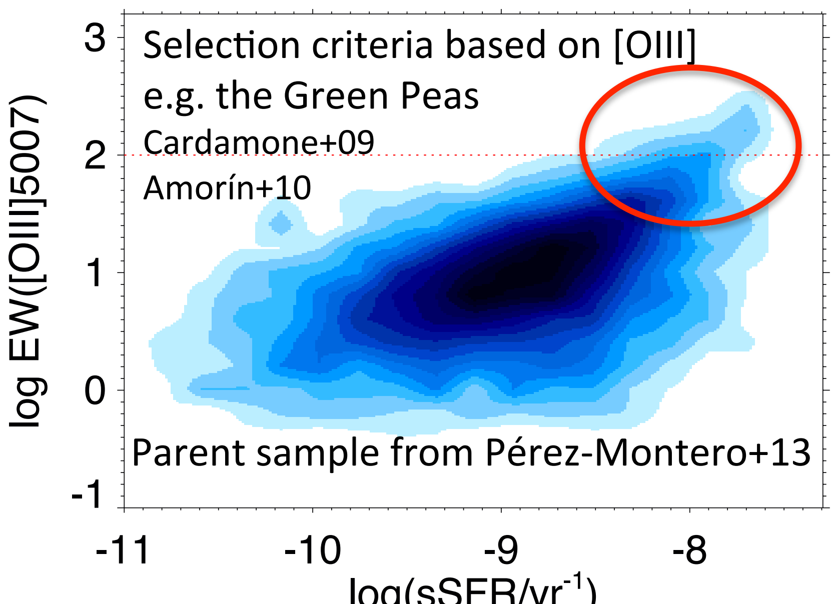
Extreme emission-line galaxies out to z≈1 in zCOSMOS 20k

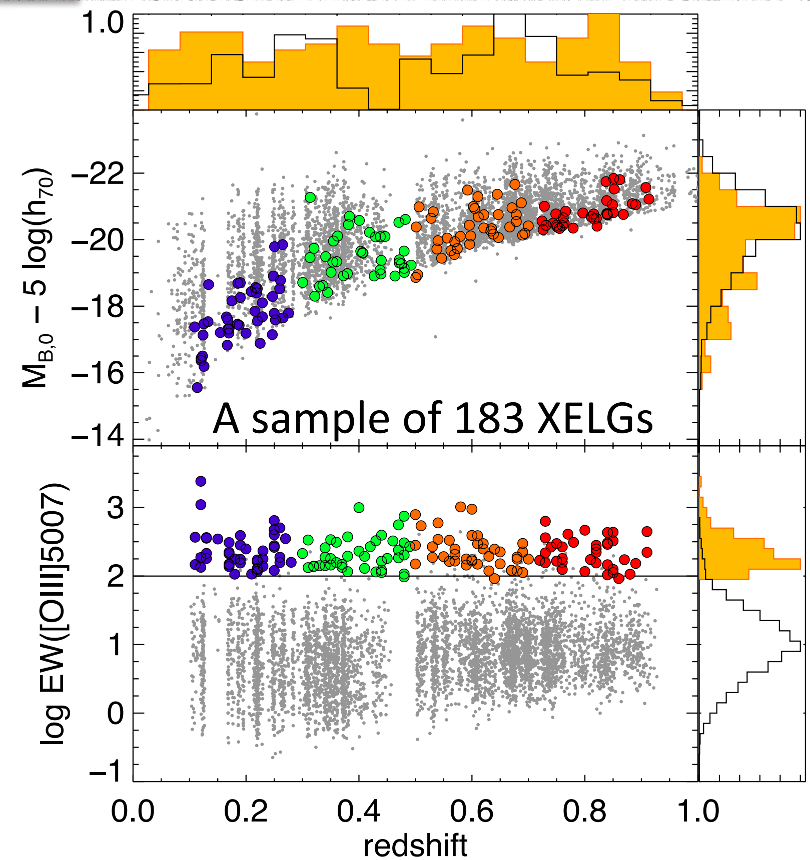
(Amorín, Pérez-Montero, Vílchez, Contini & zCOSMOS team, A&A, 2013a,b, in prep.)



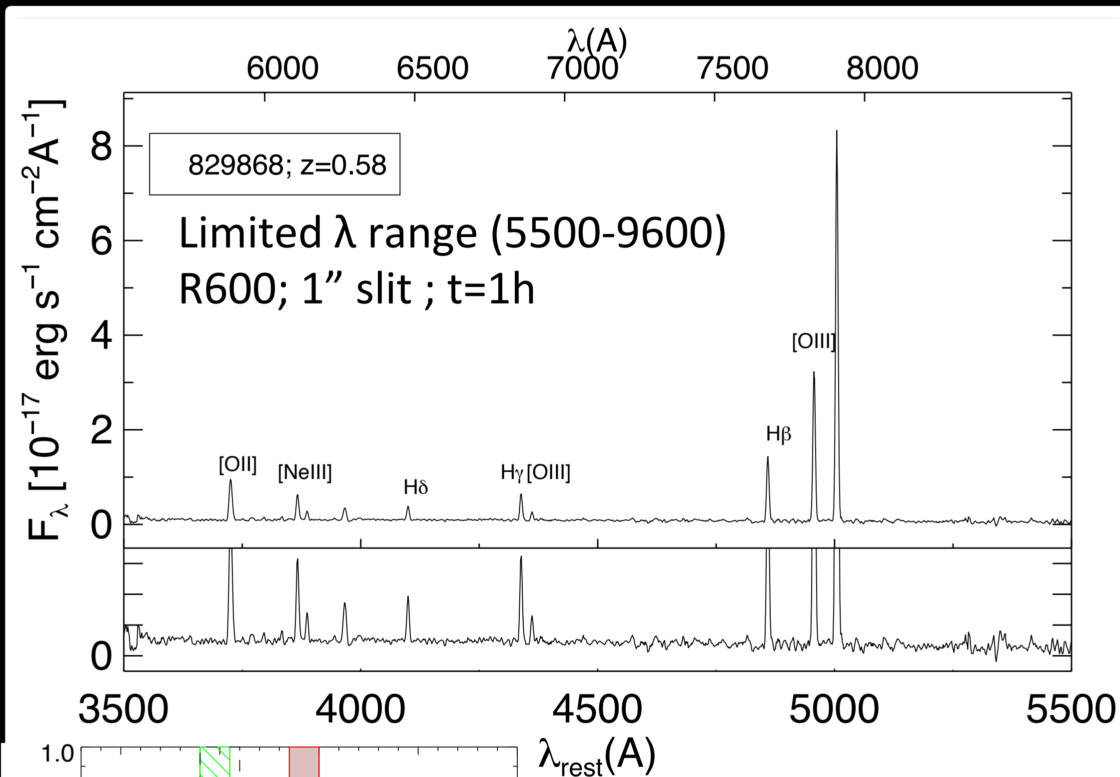
Goals:

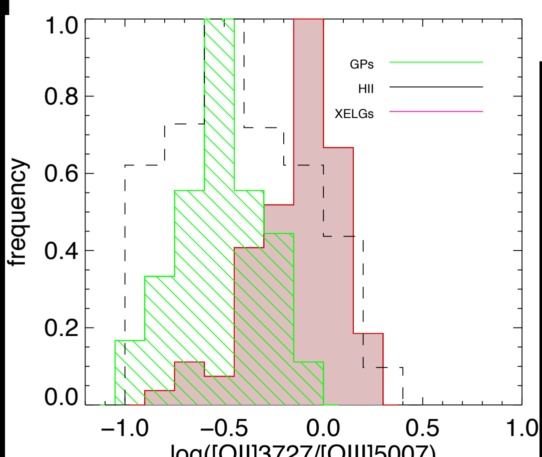
- Characterization of global properties
- Scaling relations between SFR, stellar mass, and metallicity
- Morphology and environment

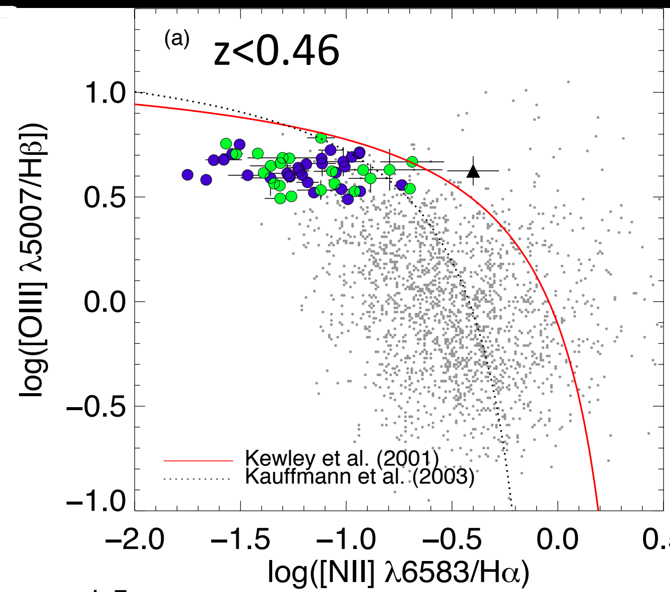


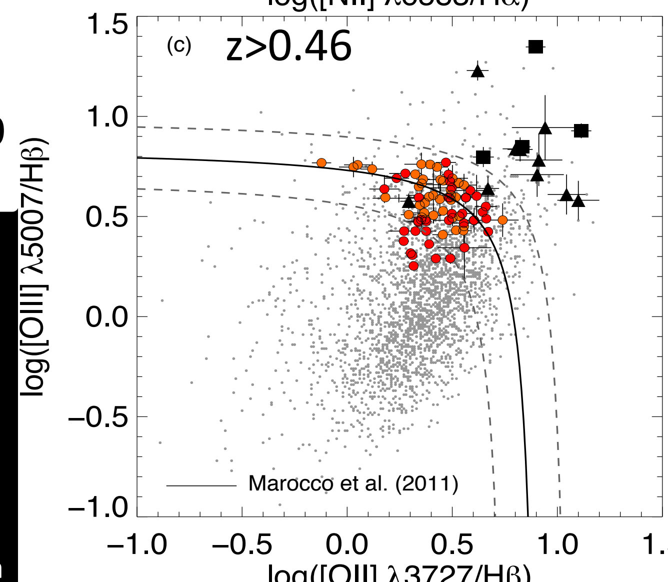


XELGs in zCOSMOS 20k: VIMOS spectra









10% of XELGs are low-mass NL-AGN candidates

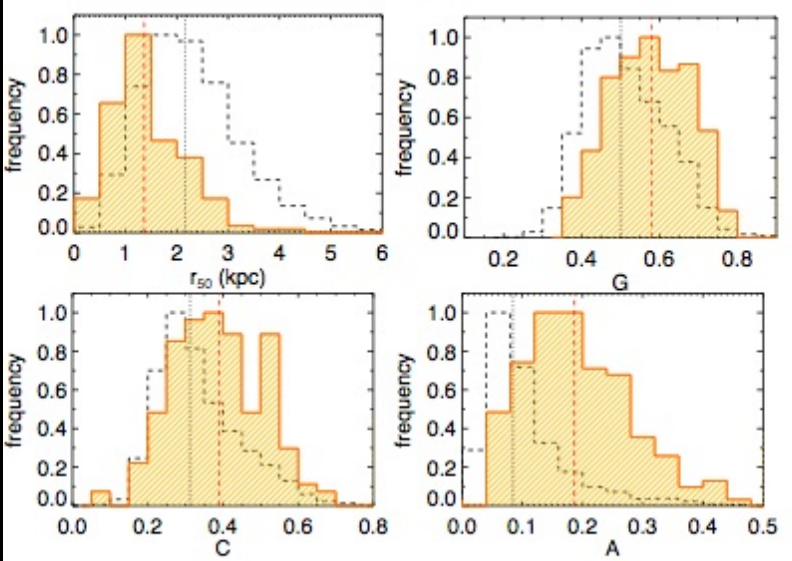
165 pure star-forming galaxies

XELGs show high ionization

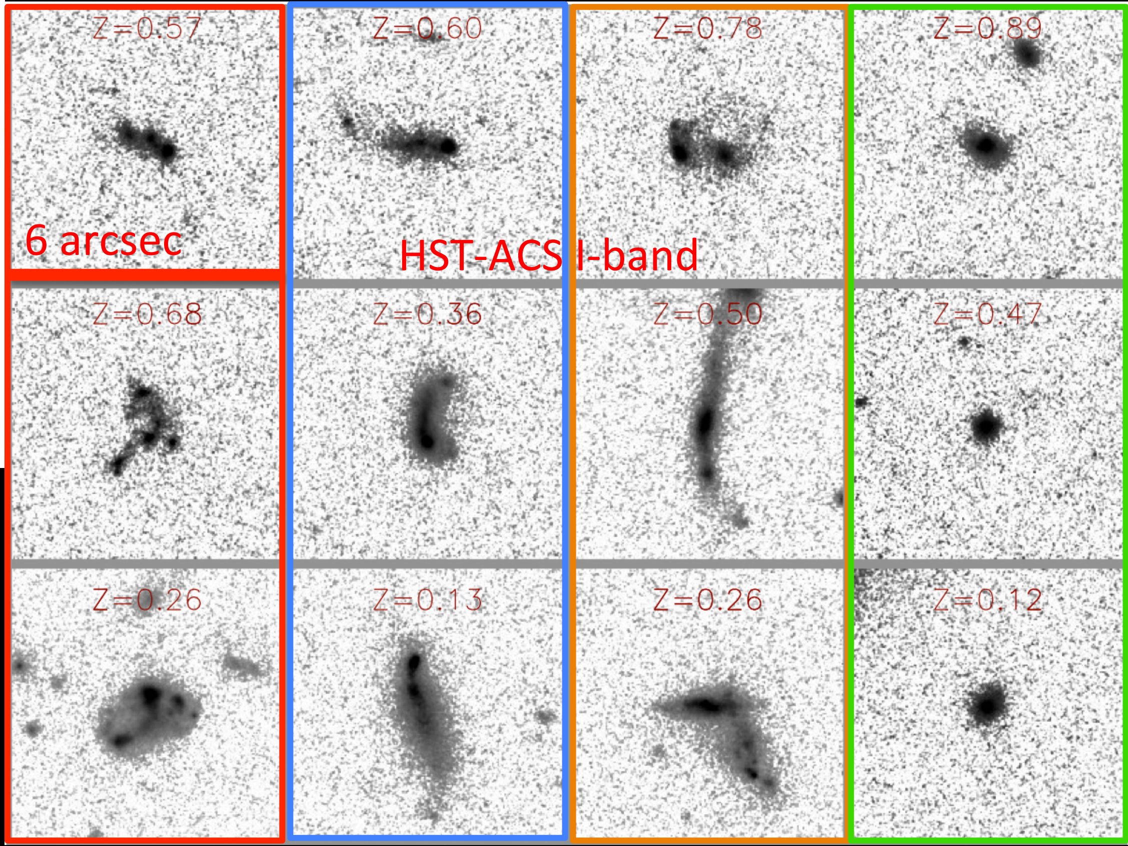
<10% with HeII or [NeV]

HST Morphology

Quantitative morphology (Tasca+09)



XELGs are more compact and asymmetric than normal SFG at z<1



"Eyeball" classification:

I- Regular/Elliptical: (18%)

II-Clumpy/Irregular: (37%)

III- Cometary/Tadpole: (16%)

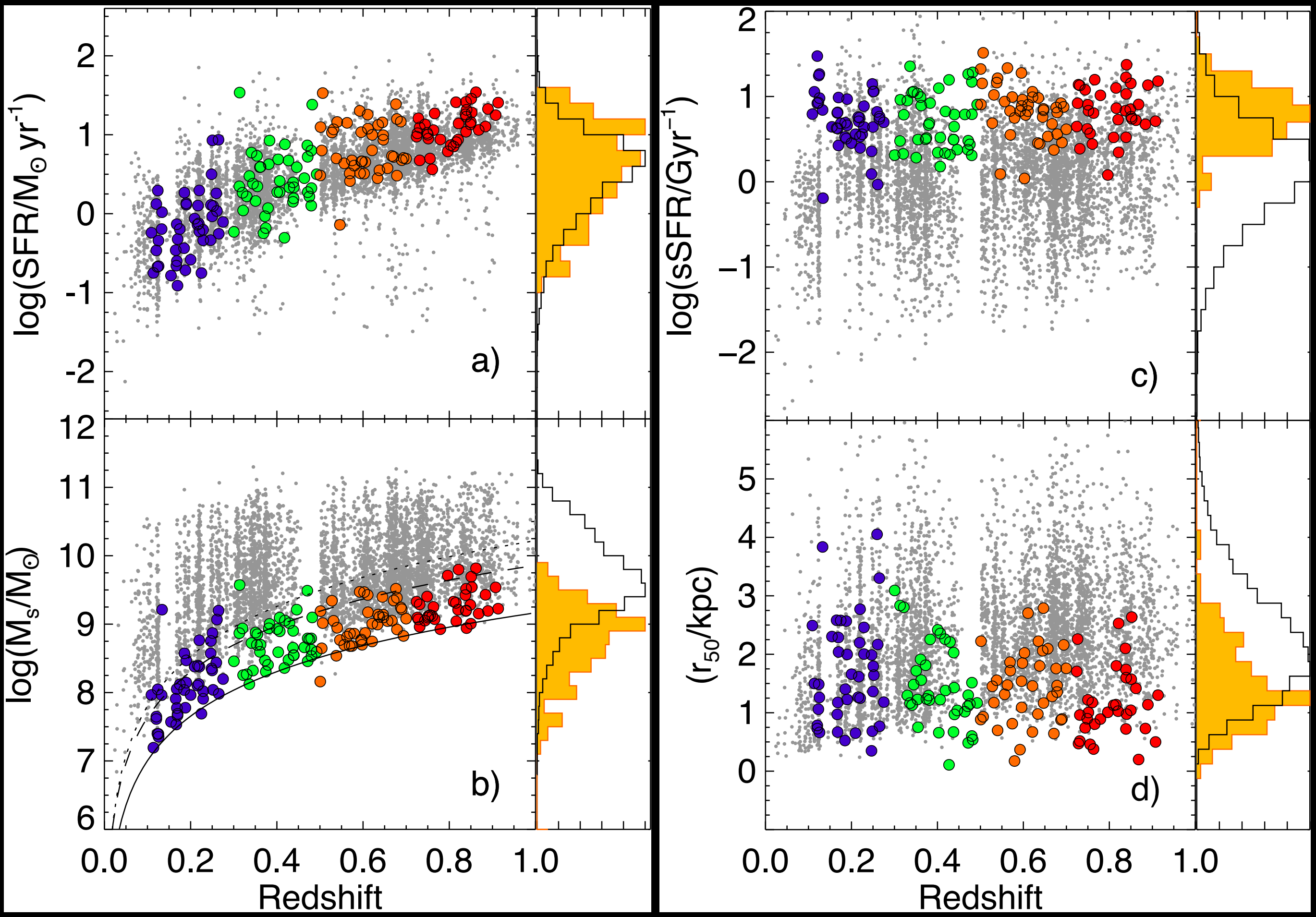
IV- Merger/Interacting: (29%)

Non-axisymmetric morphologies dominate the sample

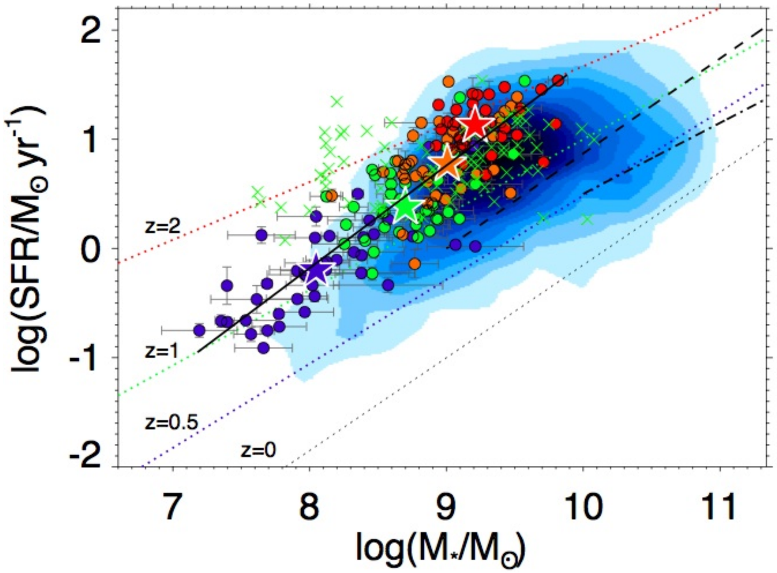
EXTREME EMISSION-LINE GALAXIES IN zCOSMOS 20K: STELLAR MASS, SFR AND SIZE

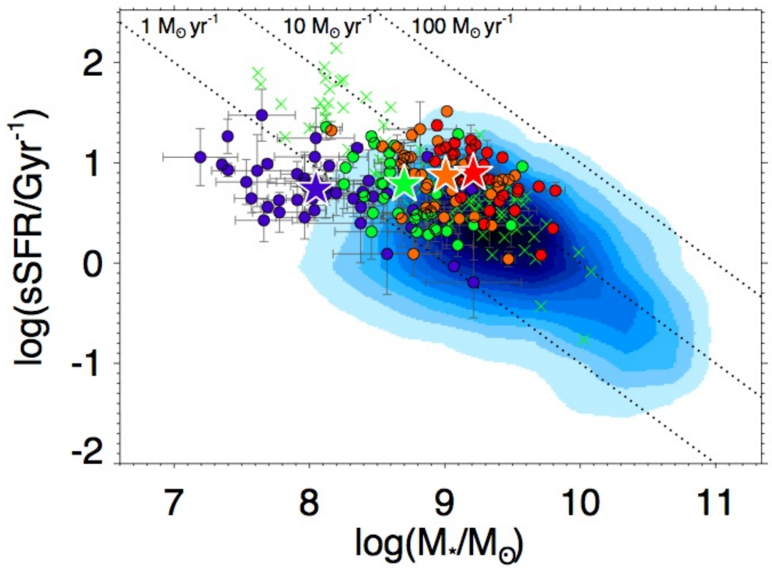
Masses from multi-λ SED fitting after removing nebular emission

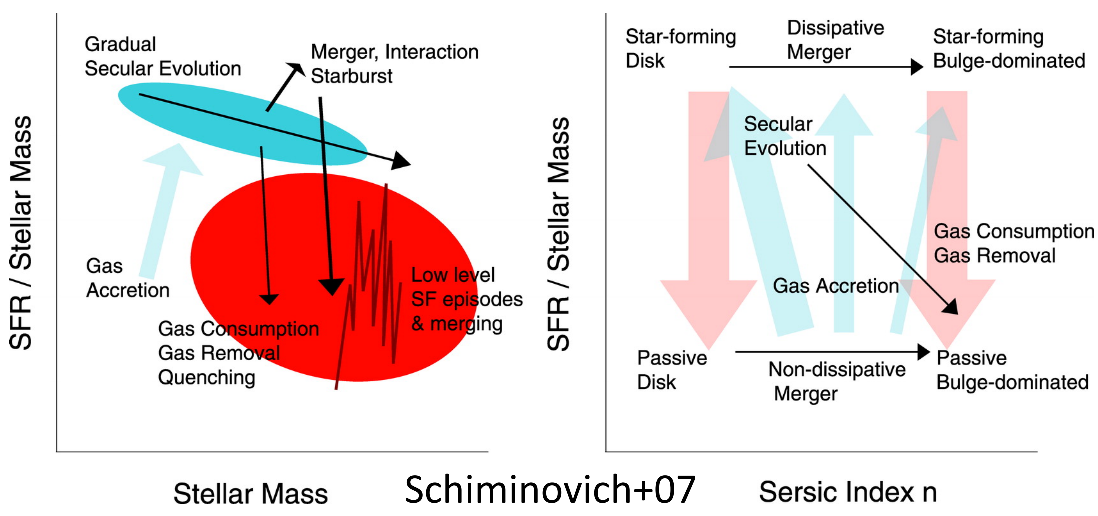
SFR from Hα and Hβ



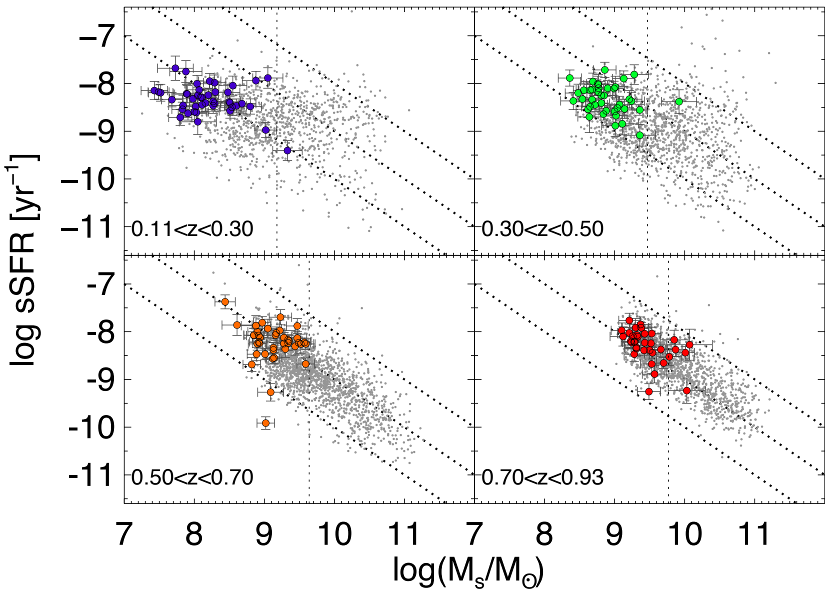
PROBING THE LOW-MASS END OF THE SFR-MASS RELATION OUT TO z~1



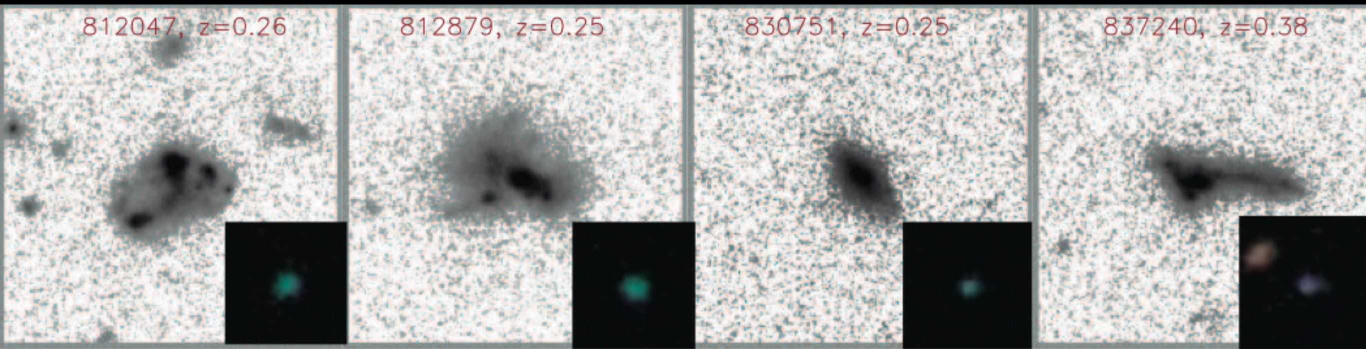




Schiminovich+07

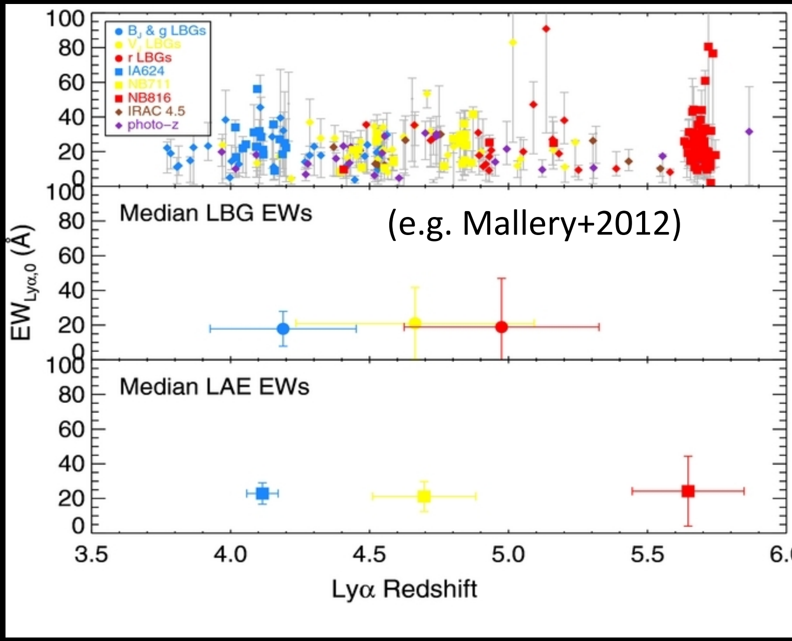


UV PROPERTIES AND THE CONNECTION BETWEEN XELG-LAEs



Four XELGs are confirmed Lyman-α Emitters (LAEs)
Included in the GALEX spectroscopic search by Cowie+2010

Very luminous in the UV continuum: Log(LFUV)=10.5 $L_{\odot}$
Very compact: Log(μFUV)≥ 9 $L_{\odot}$ kpc□
Low extinction: β_{UV} = -1.5
Young Starbursts
Excellent agreement with compact UVLGs
(Heckman+05, Overzier+08 among others)



Local analogs of UV-selected galaxies at high redshift

They show similar rest-frame EW(Lyα)~25-45 Å and Log L(Lyα)~41-42 erg/s as LBG/LAEs at z>4

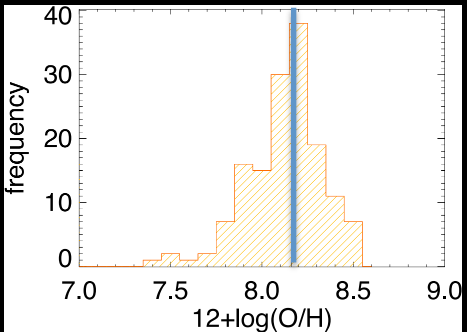
EW(Hα) >200 Å , low dust… suggests **large escape fractions**

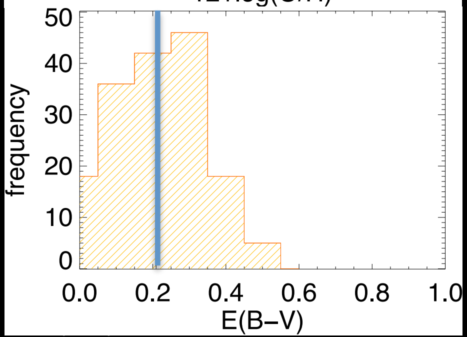
THE LOW METALLICITY OF XELGS

Direct (*Te*) method → 20 XELGs @ z>0.4
Te[OIII]-*Z* calibration → 19 XELGs @ 0.25<z<0.48

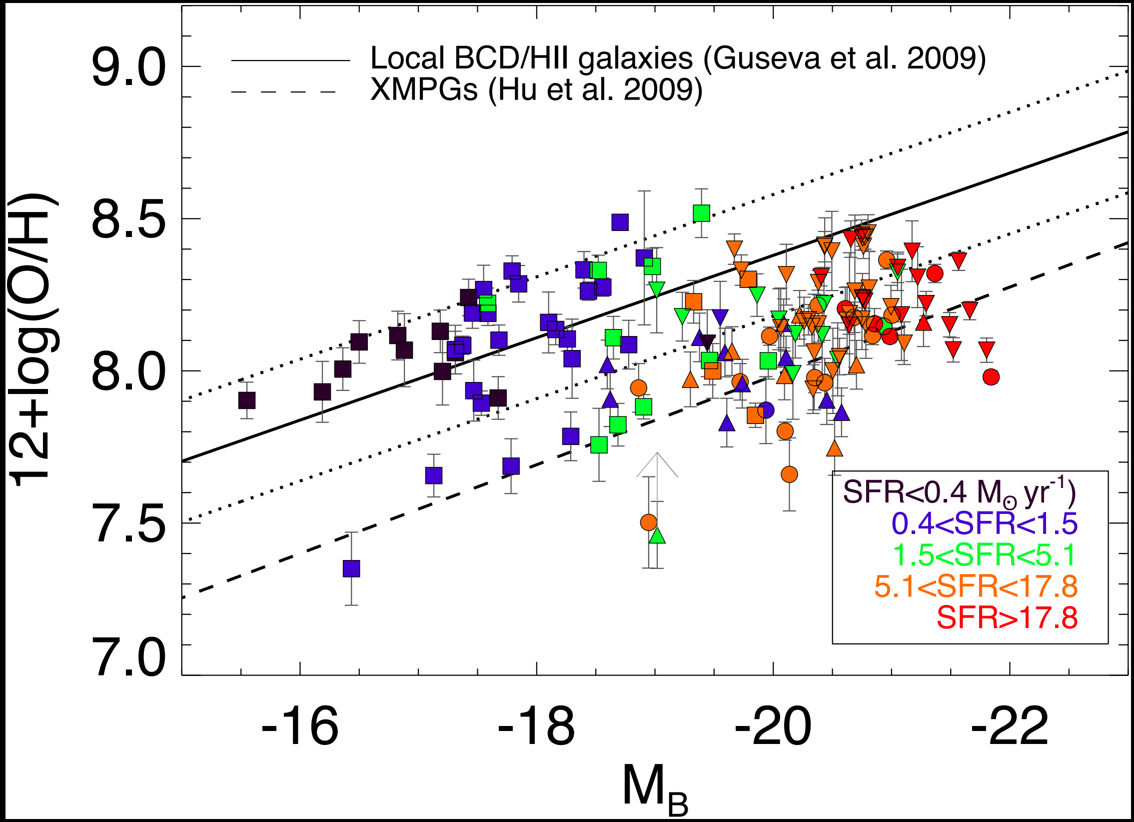
"Strong-line" methods: no [OII] or no [OII]4363
N2 (Pérez-Montero & Contini 2009)
→ 49 XELGs @ z < 0.25 N2 index
→ 59 XELGs @ z>0.48 R23 index

XELGs are metal-poor galaxies

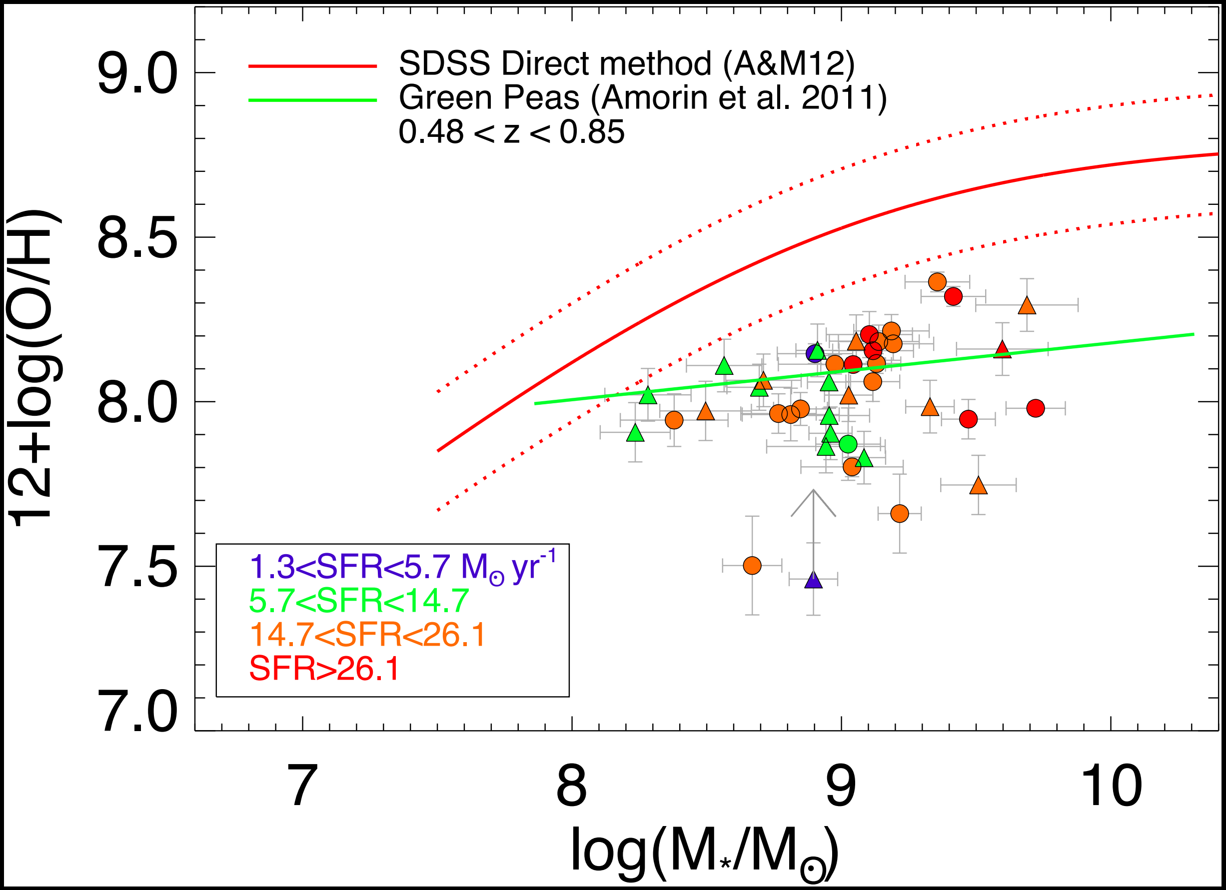




Luminosity-metallicity relation of XELGs



PROBING THE LOW-MASS END OF THE MASS-METALLICITY RELATION OUT TO Z~1



Similarly to what happens for green peas, most zCOSMOS XELGs show an offset (≥0.3dex) from the MZR

CONCLUSIONS

- XELGs (green pea-like galaxies) at 0.1<z<1 are low-mass, metal-poor, and compact objects forming huge numbers of massive stars (e.g. WRs) in a young, galaxy-wide starburst.

- The properties of XELGs are not common at low-z (XELGs are very rare !!)
They closely resemble those found in galaxies at early times (e.g. LBGs,LAEs).
XELGs show us a very short and extreme phase in the evolution of (low-mass) galaxies

- XELGs are likely clumpy and highly turbulent. Coalescence and interactions with faint companions may play a key role in their SF activity

- Massive inflows of metal-poor gas coupled with outflows from SNe, can explain their chemical abundances and high star formation efficiency (mass-metallicity-SFR relations)

- Strong starbursts in XELGs are likely environments to host luminous SNe and LGRBs. Our large XELG samples are an ideal benchmark for comparison studies with LGRB/SNe host galaxies at low and high-z.

Thank you for your attention !!