Extreme star formation and feedback in dwarf galaxies.

New insights from GTC-HST-WHT data

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EXTREME STAR FORMATION IN DWARFS

Vigorous starbursts are key stages in the evolution of galaxies

Blue Compact Dwarf (BCD) galaxies are rapidly building-up their stellar component in a nearly galaxy-wide starburst

BCDs are small, gas-rich and dust & metal-poor systems. Host galaxies mostly old

Analogs of high-SSFR galaxies at higher z

TRIGGERING AND REGULATION OF SF

ACCRETION: Feeding star formation with fresh, metal-poor gas (e.g. Elmegreen+2008, Dekel+2009,Davé+12)

- Internal: gravity-driven motions (e.g. Bournaud+09, Elmegreen+12)
- External: interactions and (minor) mergers (e.g. Östlin+01, Kobulnicky & Skillman08)

FEEDBACK: Promotes chemical evolution and favor cessation of the starburst (e.g. Oppenheimer&Davé06)

Energy from SNe, galactic winds by massive stars → removal of enriched gas (e.g. Martin+02,Recchi +07,Tenorio-Tagle+03)

"GREEN PEA" GALAXIES

A SDSS sample of 80 luminous BCDs at z=0.11-0.36 selected using color criteria.

GLOBAL PROPERTIES: Cardamone+(2009); Amorín+(2010, 2012); Izotov+ (2011), Pilyugin+(2012), Hawley (2012), Chakraborti+(2012)

Compact: R_{50} ~ 1-3 kpc

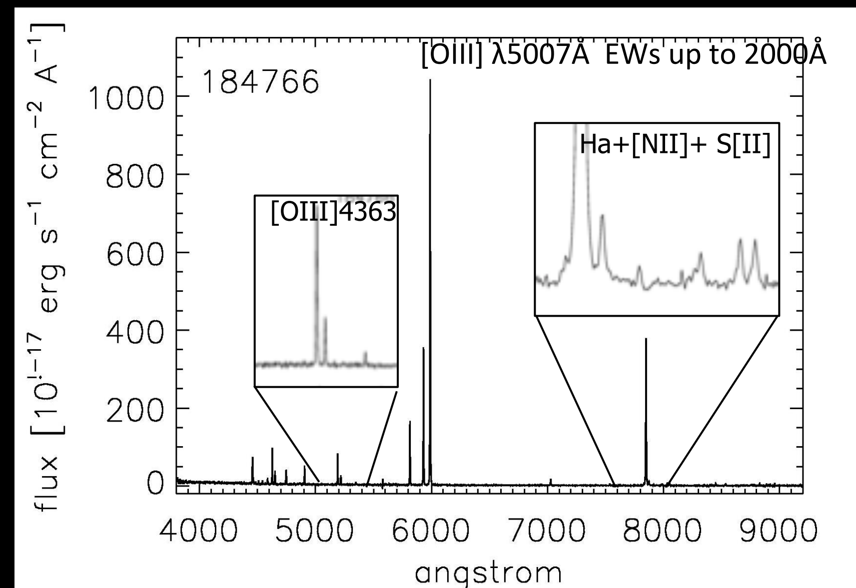
Luminous: $-19 < M_g < -21.5$ $L_{FUV} \sim 3\times10^{10} L_{sol}$

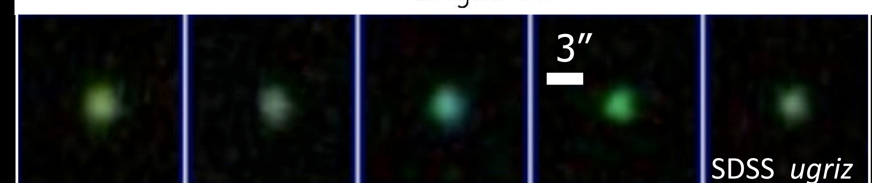
Low stellar mass: $8 < \log(M_*/M_{sol}) < 10$

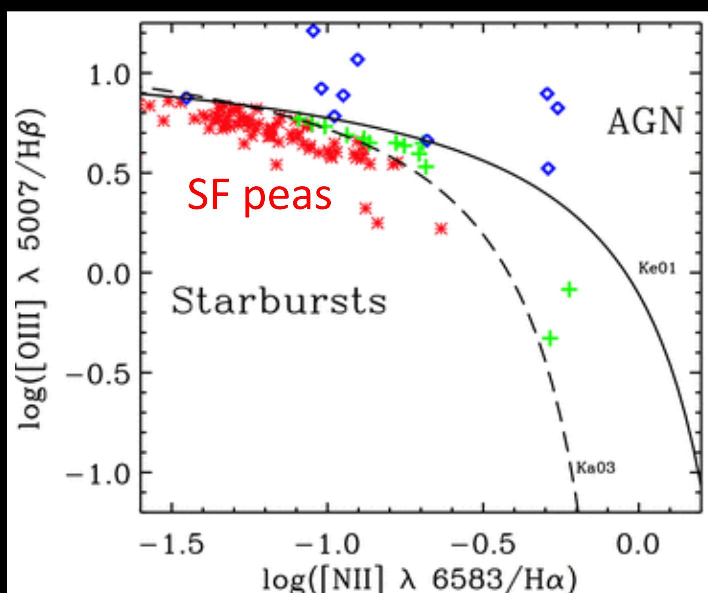
High SFR: $3 < SFR_{H\alpha,FUV}$ [M_* yr^{-1}] < 60

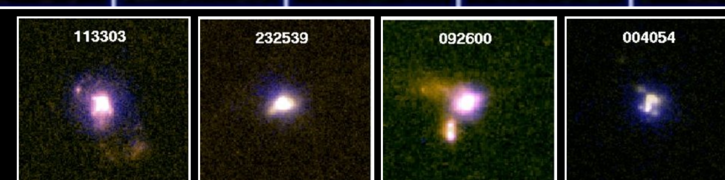
Low metallicity and low extinction:

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









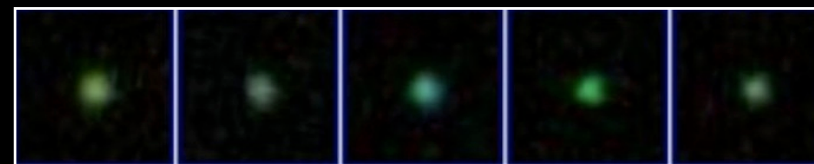
6´´x 6´´ HST (FWHM=0.1´´) blue/purple=FUV; yellow/red=optical.
Overzier et al. (2009)

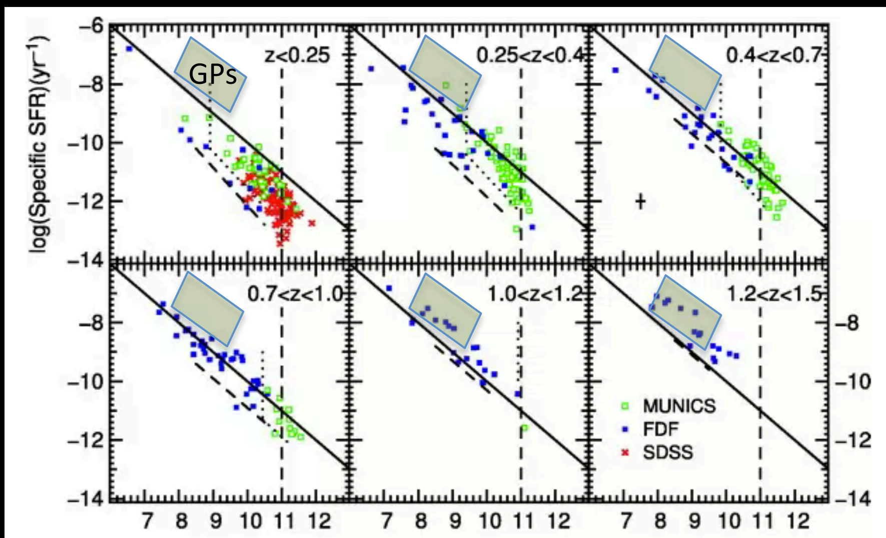
"GREEN PEA" GALAXIES

Peas are rare…rapidly growing systems residing In low density environments

Among the highest SFR/M_* (10^{-7}-10^{-9} yr^{-1}) and Σ_{SFR} in the local Universe (cf e.g. Salim et al. 2007)

Well in the range of values for high-z SF galaxies

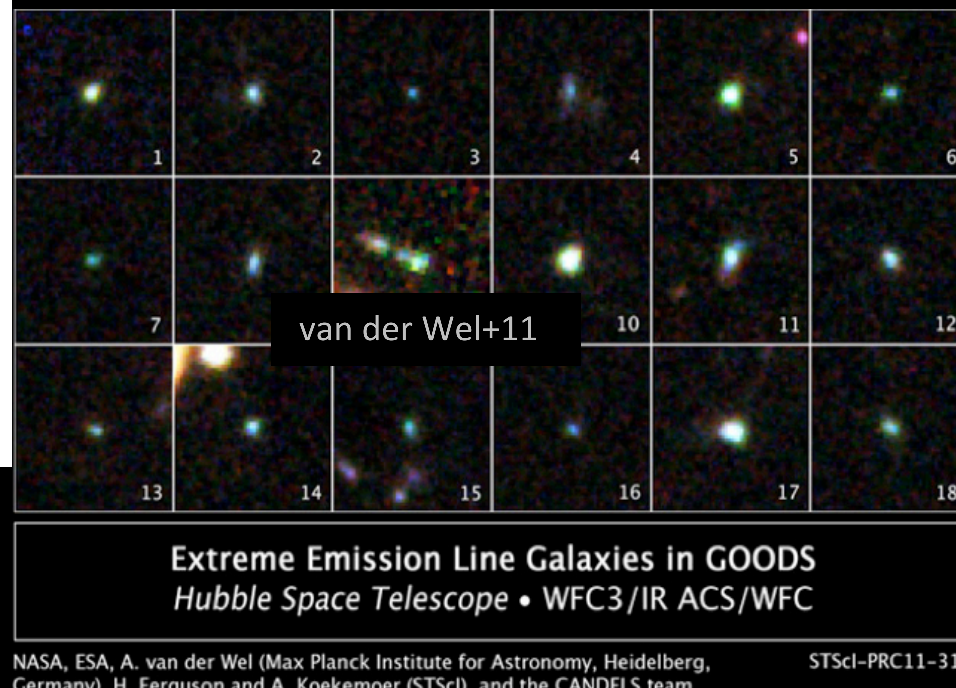




(e.g. Bauer+05)

Convenient laboratories to study SF, feedback, and chemical enrichment under physical conditions approaching those in high redshift galaxies, e.g. LBGs, LAEs

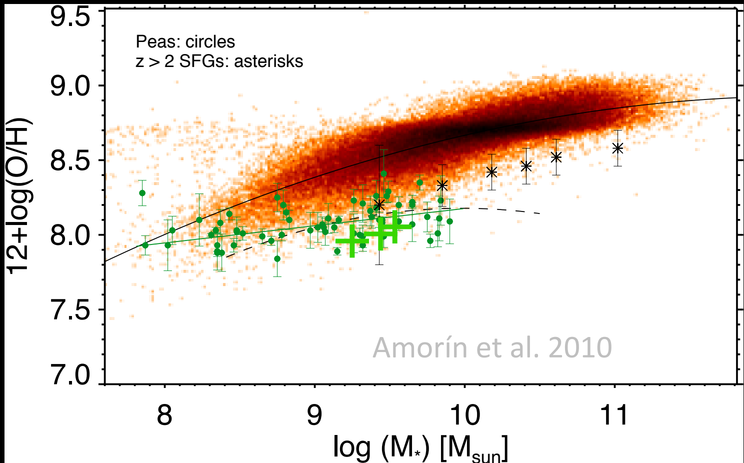
Kakazu+07,Hu+09, Overzier+09,10, Filkenstein+09, van der Wel+11, Xia+12)



van der Wel+11

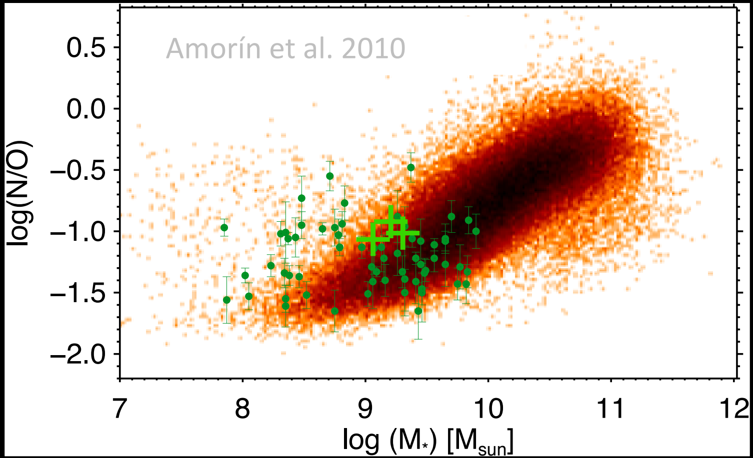
OXYGEN AND NITROGEN ABUNDANCES OF GPs

Amorín, Pérez-Montero & Vílchez (2010)



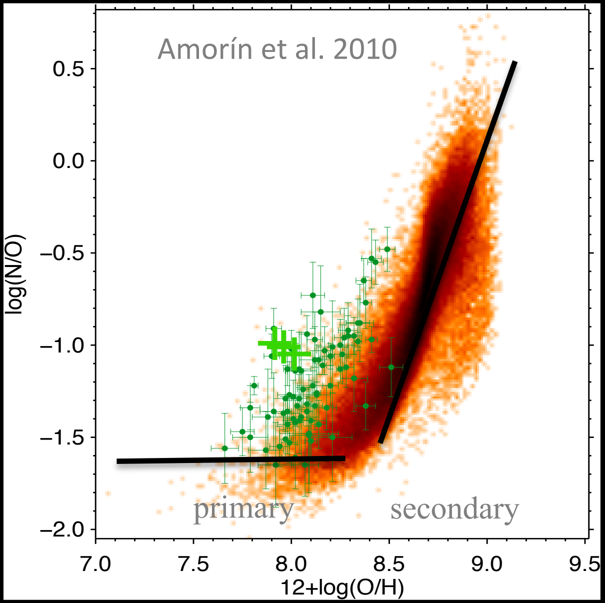
At a fixed stellar mass GPs are more metal-poor than most SFGs in SDSS

However, N/O are not offset from the main trend with mass



The GPs are metal-poor galaxies (Z_{avg}=1/5 solar)

GPs show larger N/O ratios at a given O/H



Favored scenario:

Fast/massive inflow of metal-poor gas

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

Coupled with metal enriched outflows ?

(e.g. van Zee+98)

Other possibilities include:

- pollution by massive stars (Brinchman+08; Monreal-Ibero+10; Pérez-Montero+11)
- peculiar SFH… (Mollá+06; Mallery+07)
- Extra production of primary N by intermediate-mass stars ? (Gavilán+06)
- positive feedback ? (Tenorio-Tagle+06)

GTC-OSIRIS

Amorín, Pérez-Montero, Vílchez ,Papaderos (2012)

SPECTROPHOTOMETRY

Goal: To provide new insights on the nature of the GPs

Pilot study: 3 target galaxies
OSIRIS deep long-slit spectroscopy & optical (z-band) public HST (F606W) imaging

Spectroscopy data:
R1000B & R1000R
(disp. ~ 2.1 & 2.6 A/pix)
Seeing: 0.9”-1.4”
T_{exp}= 3x1200s
S/N (cont) =15-45

Specific objectives:

Detailed analysis of chemical abundances. Detection of faint spectral features

Constrain SFHs from spectral synthesis and surface photometry

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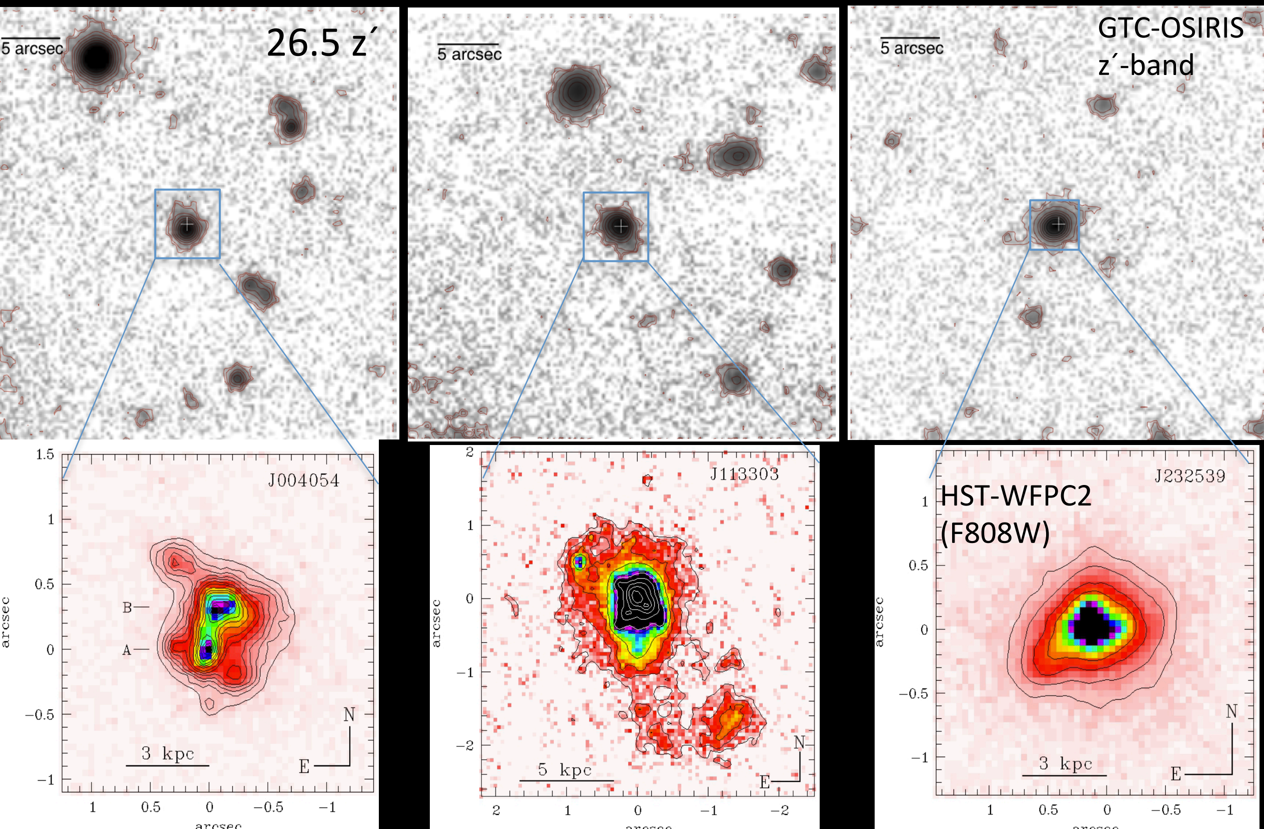
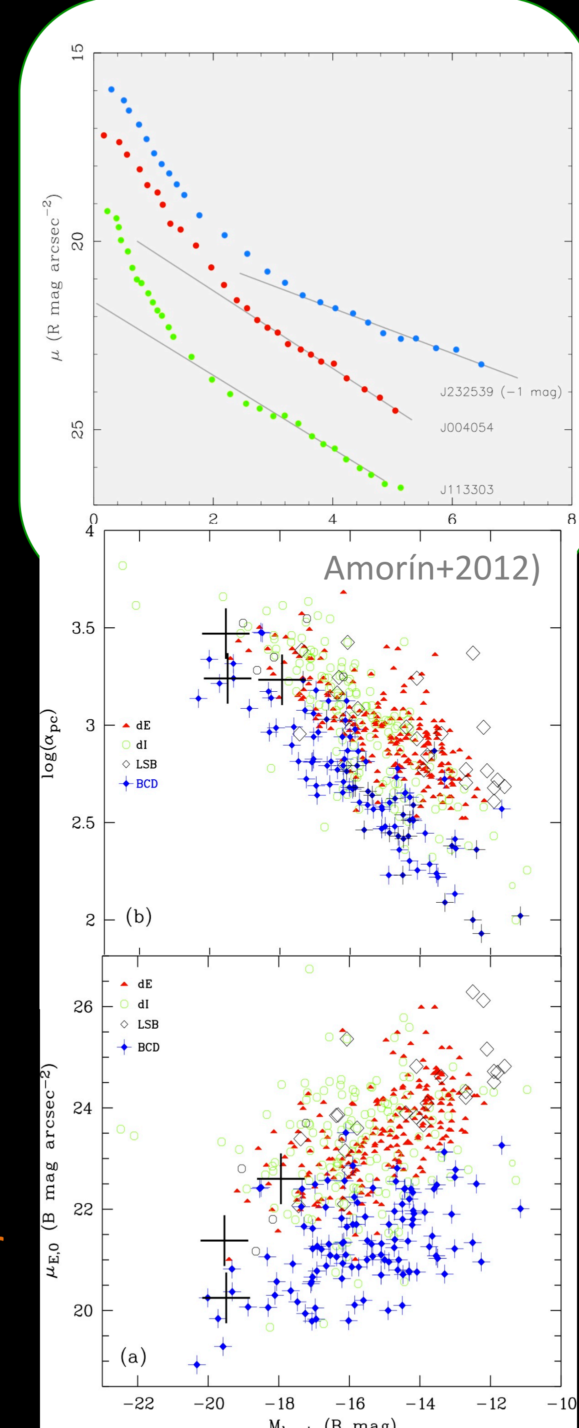
CONSOLIDER - INGENIO
GTC

SURFACE PHOTOMETRY



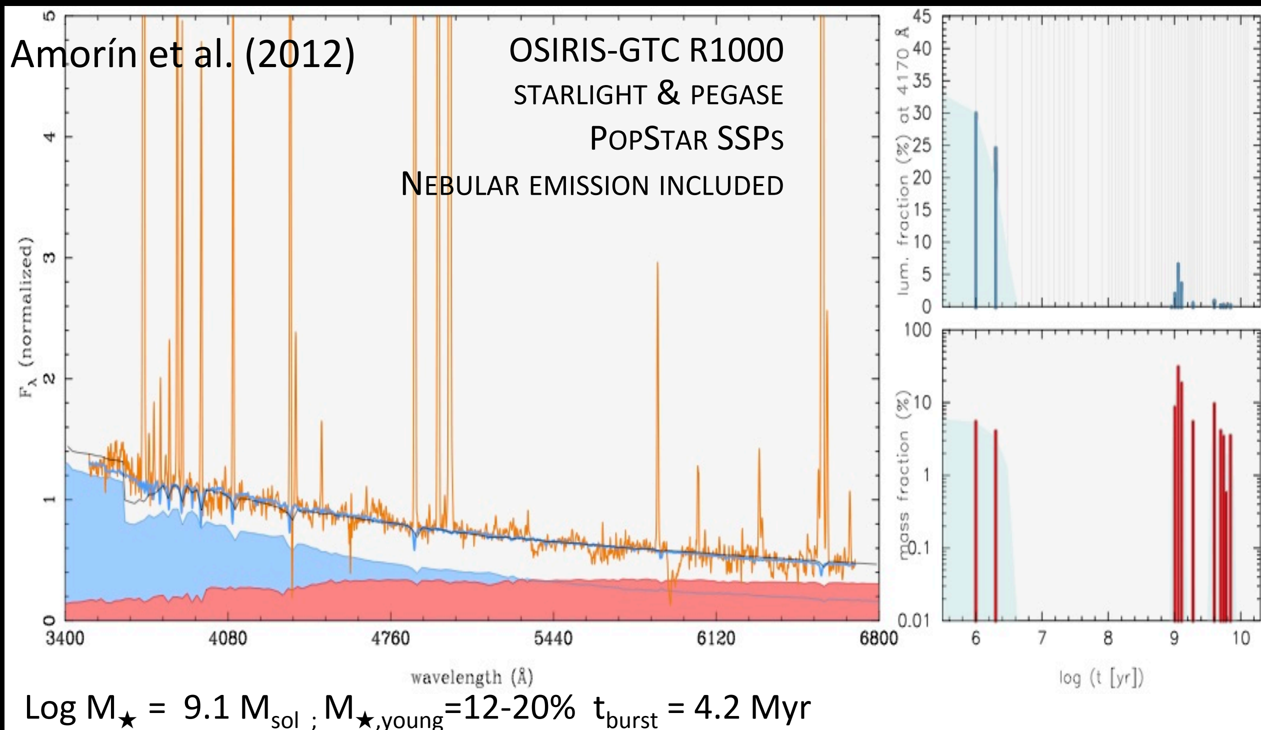


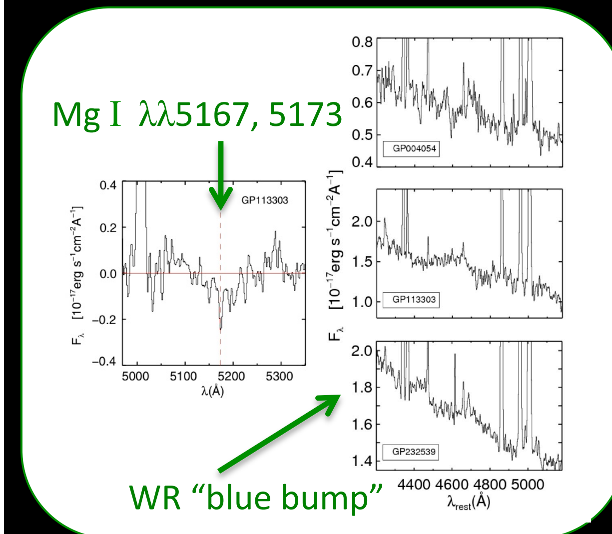
Exponential LSB component in the outer regions.

Be aware of possible biases due to nebular emission (e.g. IZw18, Papaderos+02, Papaderos&Östlin12)

The structural properties of the host galaxies fall in the parameter space populated by luminous BCDs (e.g. Papaderos+1996, Amorín+2009)

Spectral synthesis





Signatures of old stars & very young (WR) stars

The GPs are rapidly forming between 4-20% of their total stellar mass (1.e9 M_{sol}) in an intense starburst, which, as suggested by the presence of WR stars is very recent or still ongoing.

Spectral synthesis, surface photometry, and the detection of Mg I suggest the existence of an evolved stellar component with ages of several Gyr.

CHEMICAL ABUNDANCES

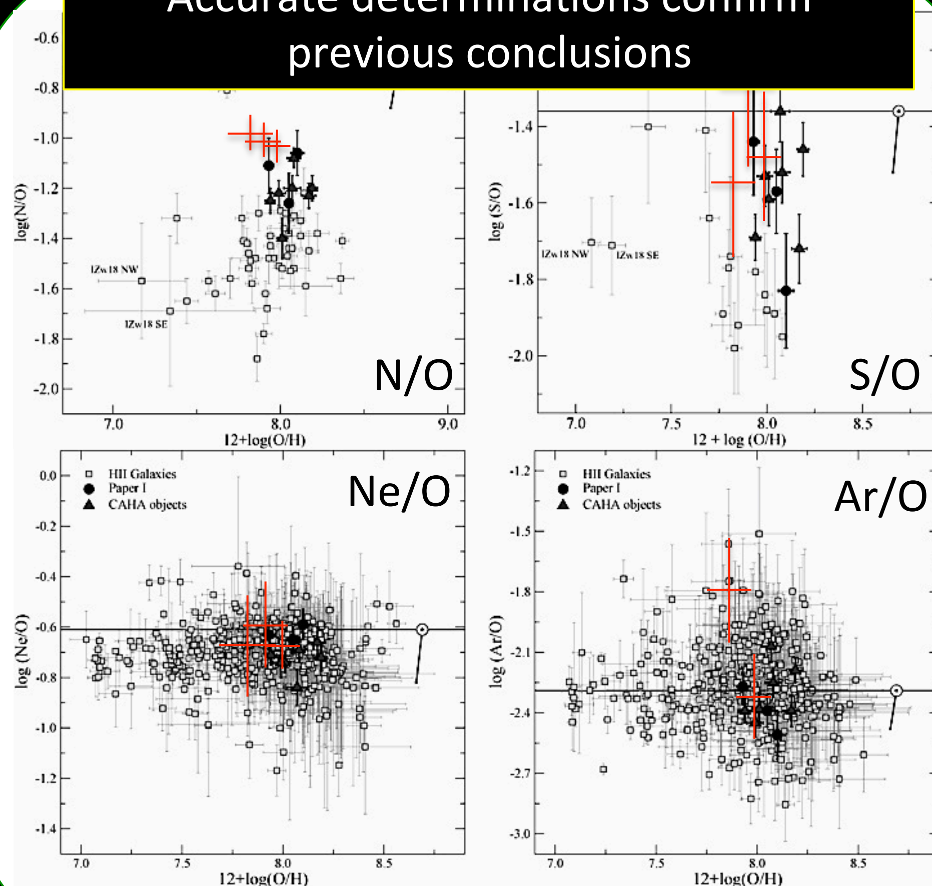
Deriving physical properties and chemical abundances using high S/N spectra

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 galaxies

Pollution by WRs cannot explain N/O ratios
(Similar to results for some "special" nearby BCDs. e.g. B. James & C. Kehrig talks)

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 BCDs
(e.g. Kobulnicky & Skillman 1996; Hägele et al. 2006,2008; Kehrig et al. 2006; Guseva et al. 2011)

Accurate determinations confirm previous conclusions



Comparison with Hägele et al. 2008

COMPREHENSIVE STUDIES OF THE GAS KINEMATICS AND CHEMODYNAMICS IN GPs

GOALS

Unveiling the kinematic structure of the GPs

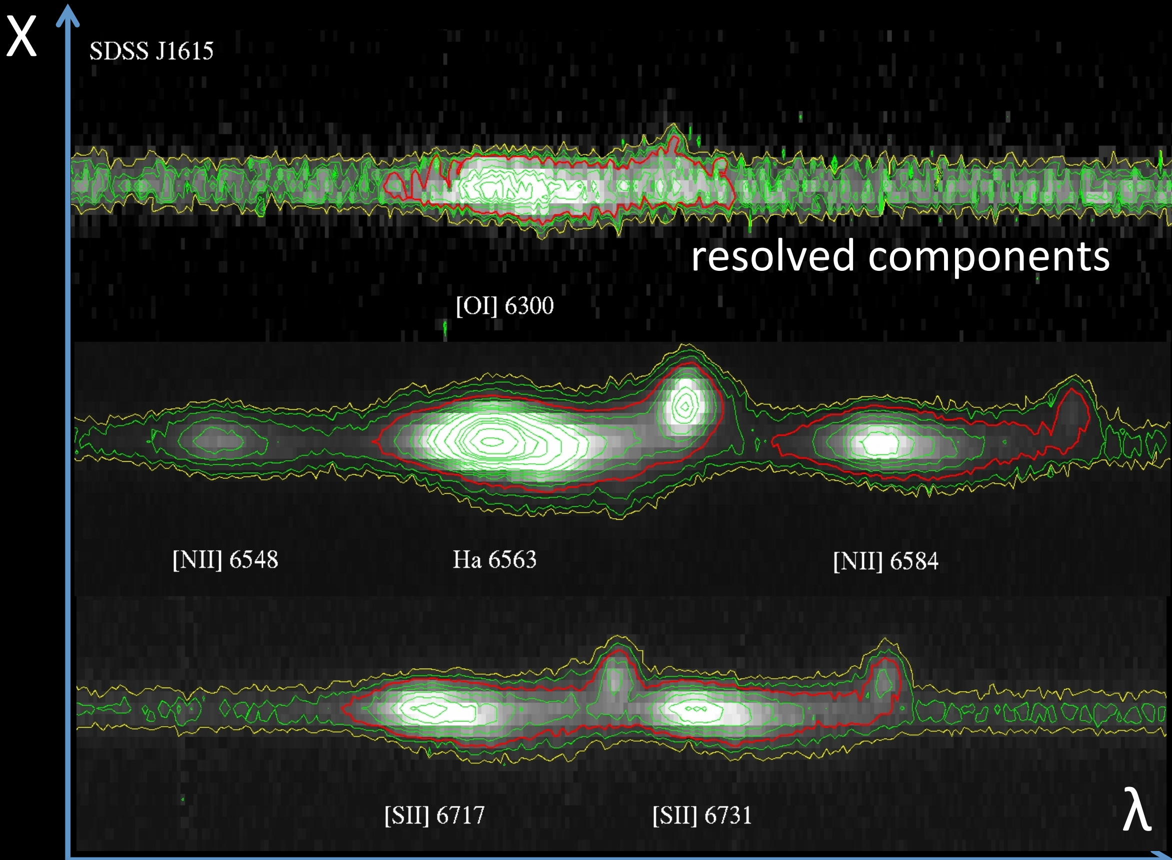
- Physical properties and abundances for individual kinematical components.
- Scaling relations e.g. L-σ
- Observational evidences of strong feedback
- Testing model predictions with observations

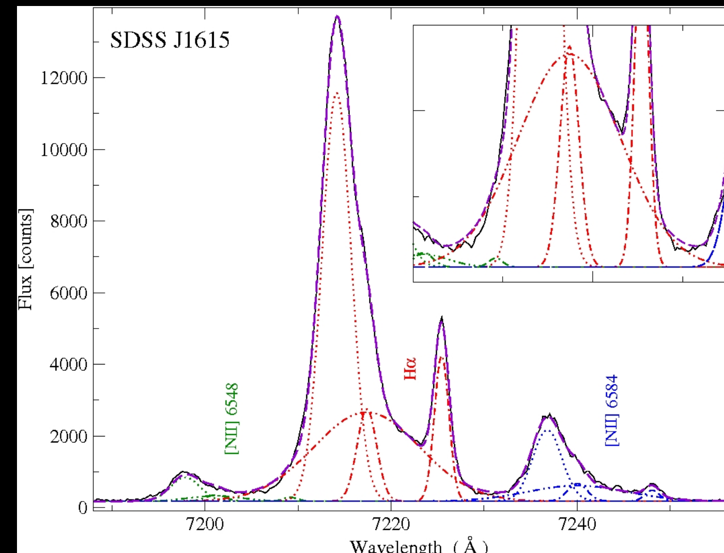
OBSERVATIONS

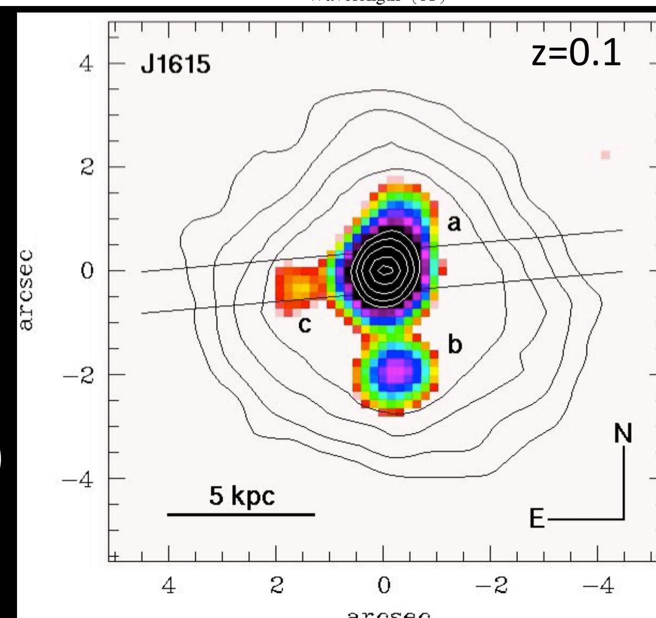
Very deep, high resolution long-slit spectroscopy
ISIS @ 4.2m William Herschel Telescope
Observations for a sample of 14 galaxies.

INSTRUMENTAL SETUP: HR2400, R1200B and R1200R
Spectral dispersion 0.18, 0.23 and 0.26 A/pixel
Slit width 0.9”
FWHM=0.5A & Spatial resolution 0.22”/pixel
Long integration times (~1.5-3.5 hr per setup)

THE SPECTRA: ANALYSIS OF LINE PROFILES







$\sigma^2 = \sigma^2_{Gauss} - (\sigma_i^2 + \sigma_t^2)$

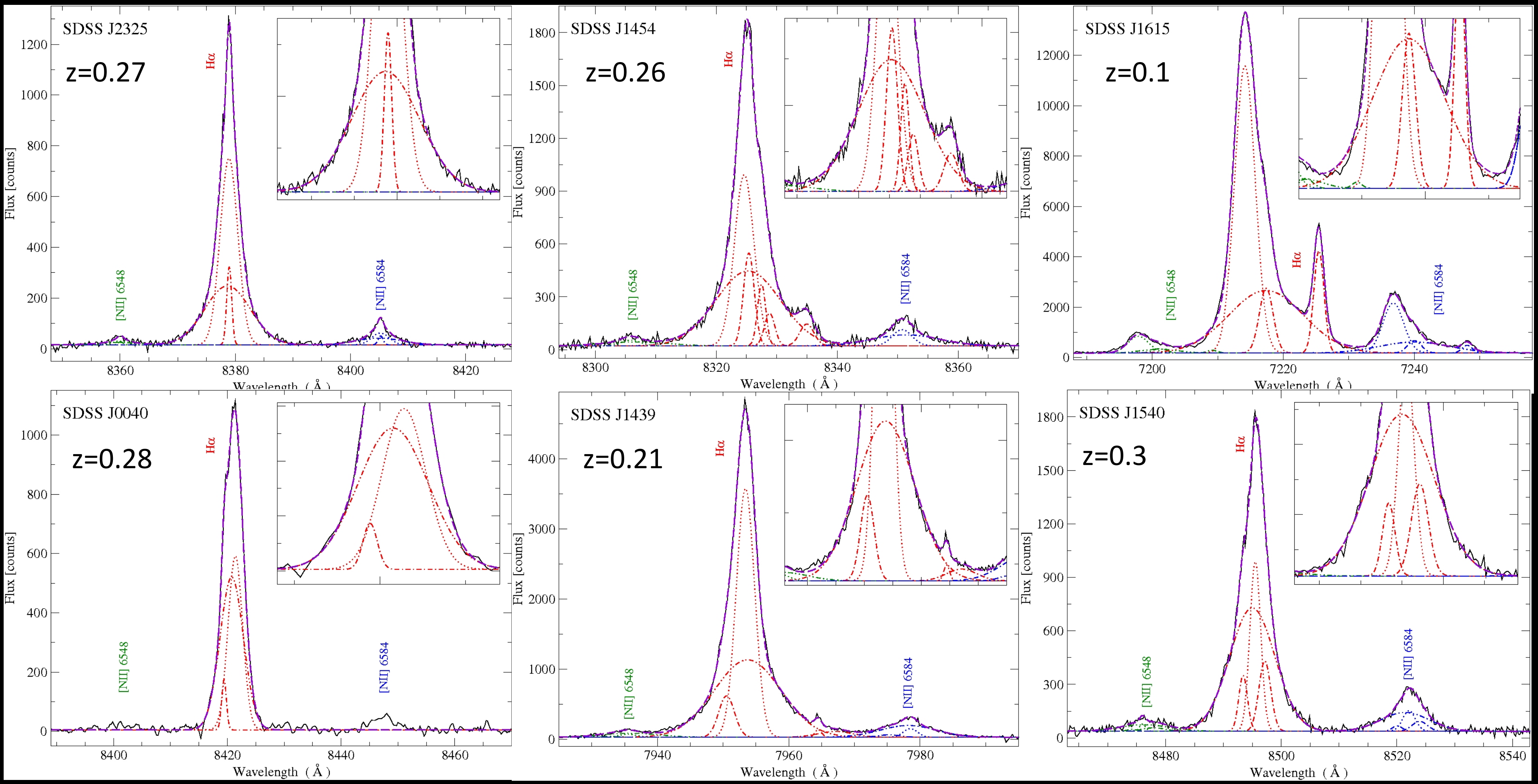
σ_i=10.2 km/s

Iterative multicomponent fitting method based on *NGAUSSFIT* (IRAF)

Firpo+(2010,11) Hägele+(2007,09,10, 12)

RESULTS

Amorín et al. (2012, ApJL, accepted)



RESULTS

NARROWER COMPONENTS

All the observed galaxies show more than one strong narrow components.

Velocity dispersion ranges 30-120 km/s
And luminosities $L_{H\alpha}$~10^{40}-10^{42} erg/s

Several % higher than the average for
Giant HII regions (e.g. Fuentes-Masip+00)
HII galaxies (e.g. Terlevich&Melnick81; Telles+01)
Luminous BCDs (e.g. Östlin+01; Marquart+07)

Blue- and red-shifted components
Δv= 50-500 km/s
In a spatial extent of few kiloparsecs

BROAD COMPONENT

All the observed galaxies show broad emission In Hα and [NII]

Velocity dispersion ranges 100-250 km/s
FWZI ~ 650-1750 km/s

$L_{H\alpha}$~ 10^{41}-10^{42} erg/s
→ 40-60 % of the total $L_{H\alpha}$

Only one galaxy show
broad emission redshifted
from the line centroid Δv ~100 km/s

Amorín et al. (2012, ApJL, accepted)

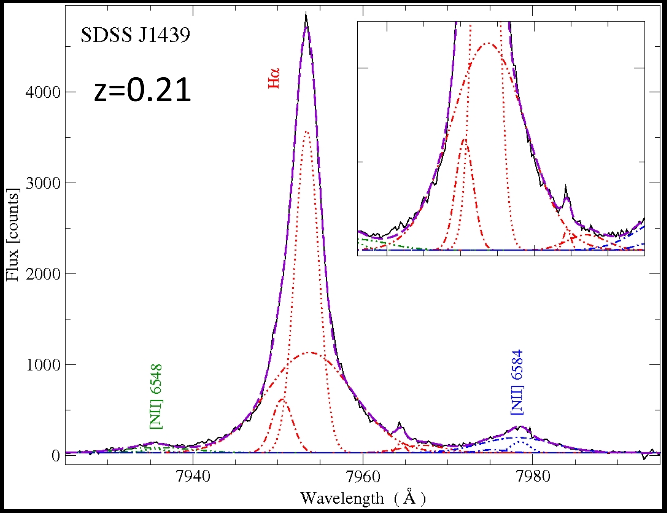
BROAD EMISSION SUGGEST RAPID GAS FLOWS

SF FEEDBACK

Broad emission suggest high velocity gas. Possible mechanisms include:
(e.g. Diaz+87, Castañeda+90, Roy+92, Tenorio-Tagle+93,96,97; Muñoz-Tuñón+96; Izotov+96,07,08; James+09, Binnette+09, among others…)

1.- strong stellar winds by massive stars e.g., WR, Ofp, LBV stars:
→ Supported by previous observational results (Amorin+12,Hewley+12)

2.- propagation of multiple SNe remnants:
→ Supported by their SFHs and 1.4GHz observations
→ (Amorin+12,Chakraborti+12)



Others:
3.- SNe-driven superbubble blow-up: not dominant
4.- effects of turbulent mixing layers: not dominant
5.- AGNs: no evidences…

Broad emission in both Balmer and forbidden lines suggest intense outflows driven by the strong galaxy-wide starburst.

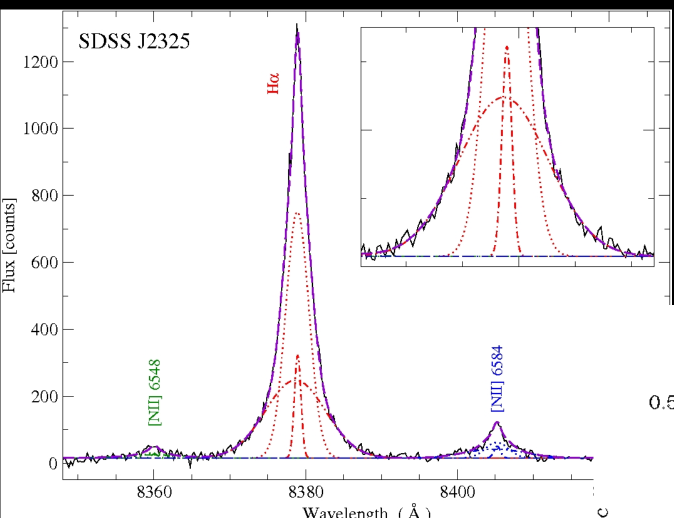
MULTIPLE KINEMATICAL COMPONENTS FROM EMISSION LINE FITTING SUGGEST MULTIPLE STAR-FORMING CLUMPS

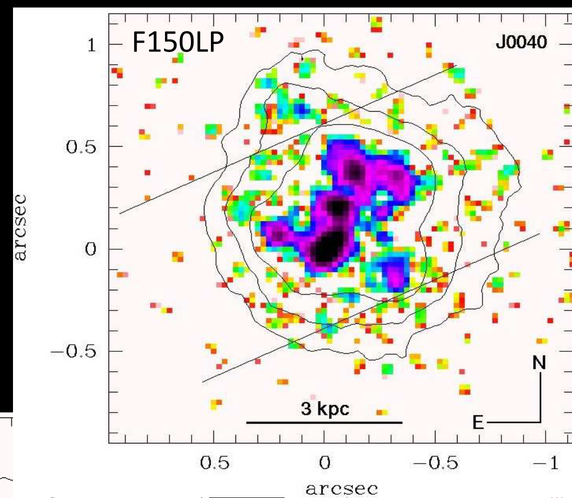
The observed high velocity dispersion suggest disturbed kinematics, likely driven by turbulence rather than rotation (e.g. Marquart+07, Green+10; Goncalves+10)

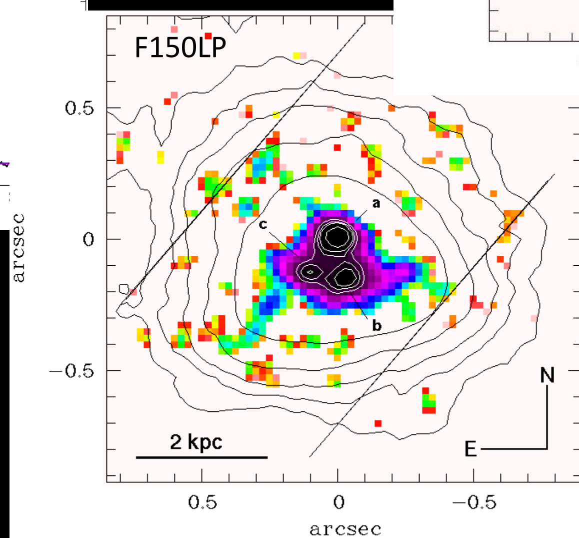
The presence of multiple components may have different interpretations:
(e.g. Östlin+01; Bergvall & Östlin 02; Cairós+10; Pilyugin+12, Elmegreen+05,09,12, Wisnioski+11)

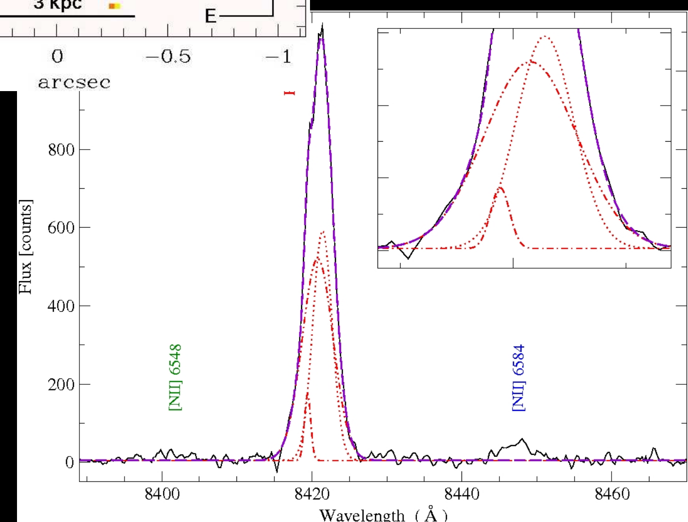
1.- interactions or (minor) mergers

2.- presence of few massive clumps









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well

Overall our first results strongly suggest that all these young starbursts are clumpy and highly turbulent and with strong outflows from SNe feedback. This conclusion highlight analogies between some starbursting dwarfs in the local Universe and clumpy star forming galaxies at z>1-2

What drives up and maintain turbulence in these galaxies ?

- Gravity ? (e.g. Terlevich & Melnick 81)
- Shocks ? (e.g. Tenorio-Tagle+97)
- Accretion ? (e.g. Elmegreen & Burkert 2010)
- Star formation feedback ? (e.g. Lehnert+09)

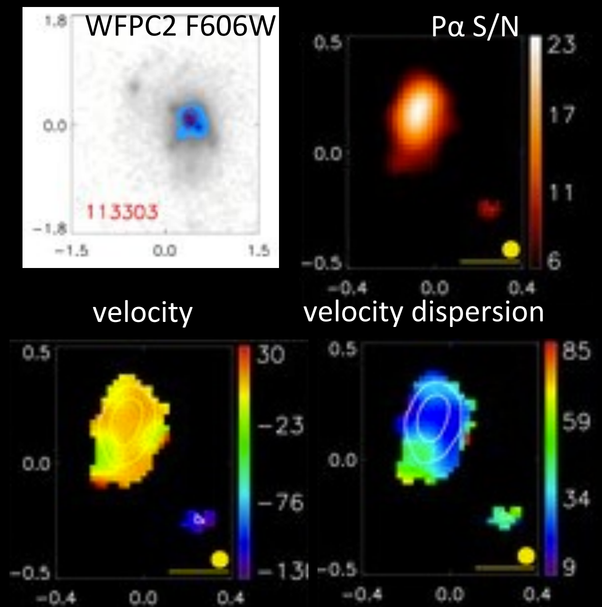
Clues for the main triggering mechanisms?

- External: interactions/mergers (seems clear for the 50%)
- Internal: ?

Ongoing work: Complete the analysis of the whole sample of 14 GPs & Add new observations using IFS

Spatially resolved study: kinematics + SF + chemical abundances in 2D.

(similar to e.g. B. James talk)



OSIRIS Pα +AO @ Keck
Goncalves et al. (2010)

SUMMARY

The properties of the GP galaxies are not common in the local Universe.
They may represent a very short and extreme phase in the evolution of some dwarf galaxies

Deep GTC-OSIRIS + HST observations: new insights on the chemical evolution and SFHs

Evidence of evolved (Gyrs) host galaxy → dominates total stellar mass
Young starburst (WRs). Extremely high SSFR and Σ_{SFR} → forms 4-20% of their total mass
Low-metallicities (15-20% solar) and low extinction. Nitrogen overabundance → gas flows

Deep high resolution WHT-ISIS observations: new insights on the ionized gas kinematics
Complex gas kinematics. Broad + multiple narrower kinematical components on a spatial scale of few kpc. Very high velocity dispersion.
SF proceeds in compact and turbulent clumps with relative velocities of up to 500 km/s.
→ 50% show evidence of interaction/merger & 50% not obvious external effects
Broad emission suggest strong gas flows (FWZI up to 1500 km/s) → strong SF feedback

Our results underline the importance of the GPs for
studying the assembling of low-mass galaxies near and far

MORE ABOUT GREEN PEAS IN:

AMORÍN, PÉREZ-MONTERO & VÍLCHEZ 2010, APJ, 715L, 128
AMORÍN, PÉREZ-MONTERO, VÍLCHEZ & PAPADEROS, 2012, APJ
AMORÍN, VÍLCHEZ, HÄGELE, FIRPO, PEREZ-MONTERO, PAPADEROS, 2012 APJ, SUBMITTED

Thank You !!!

END