Properties and Star Formation Histories of Intermediate Redshift Dwarf Low-Mass Star-Forming Galaxies

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Introduction
The epoch when low-mass star-forming galaxies (LMSFGs) form the bulk of their stellar mass is still uncertain. While some models predict an early formation (e.g., Dekel & Silk, 1986), others favor a delayed scenario until later ages of the Universe (e.g., Kepner+97, Mamon+12). Among dwarfs, LMSFGs turn out to be of special interest for different reasons:
(1) They provide an ideal laboratory for studying star formation (SF) processes, (2) They can be observed at higher redshifts, (3) They resemble the primordial entities in the hierarchical galaxy formation scenario due to their low stellar mass, high gas content, low metallicity, high sSFR, and active SF. The main objective of this work is to shed light on the formation and evolution of dwarf galaxies. We aim at reducing the uncertainties in the formation redshift of dwarf galaxies.

We use two complementary observational approaches: (1) direct observations of galaxies at different redshifts, and (2) SED modeling. Previous studies of low-mass galaxies (e.g., Brinchmann+04; Bauer+05; Salim+07; Amorín+12; Atek+14) have shown that our mass selection criterion includes in the sample galaxies with a wide range of properties.

Spectroscopic Sample
We obtain reliable spectroscopic redshifts and emission lines measurements (e.g., [OIII]λλ5007, Hβ, and [OII]λλ3727,5007) for a representative subsample of 94 galaxies (solid histogram) out of the 327 galaxies observed in (Pacifici+12). Our analysis is limited to these spectroscopically confirmed galaxies. This biases our sample toward star-forming galaxies.

Physical properties (I)
Given the Mass-Excitation diagram (Jumaa+14) of our sample, we can confirm that the nature of the source of the emission lines we identify in our sample is SF rather than AGN activity.

To derive the oxygen abundance we use the R23 method (Péroux+79), and the calibration by Kewley and Dopita (2002) and Kewley and Ellison (2008). We use the method as described in Kewley+06 for low metallicity branch extensions. We obtain 12+log(O/H)=7.16±0.95, i.e., very low metallicity limits: [O/H]<−1.34Z⊙ (solar value by Allende Prieto+01), consistent with high SF as we also find a clear correlation between metallicity and stellar mass.

The Fundamental Metallicity Relation (Mannucci+10; Lara-López+10) is thought to suggest that there is an interplay between SF and gas-phase oxygen abundance. This tool (1) consistently combines photometric (broadband) and spectroscopic (equivalent widths of emission lines) data, and (2) uses physically motivated SFRs with non-uniform variations of the star formation rate (SFR) as a function of time, to provide best estimates and confidence ranges of physical parameters such as:
- [OIII]λ5007
- SFR
- Gas-phase oxygen abundance.

We observe an average sSFR of 30% in the dust.

SED-fitting
We use the Bayesian methodology developed by Pacifici et al. (2012) to obtain SED-fits for 91 galaxies. This tool (1) consistently combines photometric (broadband) and spectroscopic (equivalent widths of emission lines) data, and (2) uses physically motivated SFRs with non-uniform variations of the star formation rate (SFR) as a function of time, to provide best estimates and confidence ranges of physical parameters such as:
- Stellar mass
- SFR
- Gas-phase oxygen abundance
- Total effective V-band absorption optical depth of the dust

We also provide a best-estimate SFR for each galaxy.

Star Formation Histories
Stellar mass assembly milestones:
- L< Lookback time at the onset of SF
- L< Lookback time when a galaxy forms the 50% of the final stellar mass
- L< Lookback time when a galaxy forms the 10% of the current stellar mass

We combine individual SFHs in order to identify general trends:
(1) We normalize the individual SFHs to the median stellar mass of the corresponding subsample. (2) We set each SFH to a common reference system, t=0. (3) We add the individual SFHs and for each step in lookback time we derive median (50%) and confidence ranges (16% and 84%) of the distribution, SFH-P50 and confidence ranges (16% and 84%) of the distribution, SFH-P16 and SFH-P84, respectively) of the SFHs.

We refer to the path defined by the median along the lookback time as SFH-P50. We use SFH-P16 and SFH-P84 for the paths outlined by the percentiles 16th and 84th, respectively. We use a similar approach to obtain the median sSFR history (sSFH). (4) Consecutively, we characterize these composite SFHs using the milestones.

The galaxies in both our final subsamples appear to have formed a large fraction of their stellar mass (90%) recently (a 0.5−1.8 Gyr period prior the observation). This is in agreement with the work by Leitzel+12. Given our reference system t=0, this means that at any redshift low-mass galaxies appear to be intrinsically “young”, objects in agreement with the downsizing cosmological trend (Cowie+96). More massive galaxies tend to present

Conclusions
1) We obtain SFHs and stellar masses consistent with the SF-MS over 2 dex in stellar mass. The large dispersion displayed by our data suggests that our mass selection criterion include samples galaxies with a wide range of properties.
2) Intermediate redshift dwarf SF galaxies present high excited Hα, and low metallicity (∼1−3×Z⊙) resembling the population of galaxies in the primitive universe.
3) The median SFH of our sample of LMSFGs suggests that 90% of the stellar mass observed is formed in a 0.5−1.8 Gyr period prior the observation. Our results reinforce the idea of a recent stellar mass formation for LMSFGs at intermediate redshifts, in agreement with the downsizing cosmological frame (Cowie+96).
4) Despite the fact SFH is predicted to be dominated by stochastic processes, we find an average SFH compatible with delayed decreasing exponentials and incompatible with typical t−models.

References
Allende Prieto+01; Amorín+12; Anf+14; Bauer+13a; Bauer+05; Benítez+06; Cardamone+10; Cardiel, 1999; Cowie+96; Dekel & Silk, 1986; Garavolí+04; Griffith+12; Guseva+15; Henry+13; Hildebrandt+06; Juneau+11, Kartaltepe+14; Kepner+97; Kewley & Dopita, 2002; Kewley & Ellison, 2008; Kohutnický & Kewley, 2004; Koekemoer+11; Leitner,12; Mamon+12; Mannucci+10 (M03); Mamon+12; Mamon+10; Miyazaki+05; Nonino+09; Pacifici+12; Page+79; Phillips+97; Pérez-González+08; Salim+07; Scobie+05; Taylor+09; Whitaker+12 (W12); Whitaker+14 (W14).