

Star formation in dwarf galaxies in the ELAIS N1 field

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Abstract. We estimated several parameters of dwarf galaxies, including their star formation rate and dust mass, and compared them with galaxies with larger stellar masses.

We have chosen dwarf galaxies in the ELAIS N1 field, and fitted their Spectral Energy Distributions (SED) with the SED fitting code CIGALE. We used data from the new Herschel SPIRE and PACS Point Source catalogues, to add data points in the far infrared, so we can constrain the dust emission, and give a better estimation on the star formation rate. Data available in VIZIER from multiple surveys (WISE, SDSS and surveys specific to this region) have also been used. CIGALE can be used in a broad wavelength range, and it is very modular with different modules for the different processes and mediums in galaxies.

With the SED fittings we determined that the star formation rate (SFR), M_* and M_{dust} is one order of magnitude lower in dwarf galaxies compared to galaxies with larger stellar masses. However the starburtiness was higher in the dwarf galaxies. They also had lower redshifts than normal galaxies, so we compared them to a subsample of normal galaxies with lower redshifts. The dust masses and SFRs of the dwarf galaxies were slightly lower, but their starburtiness was higher.

Keywords. galaxies:star formation, galaxies: dwarf

1. Introduction

The European Large Area ISO Survey (ELAIS, Rowan-Robinson et al.(1999)), which was one of the biggest open-time projects of the Infrared Space Observatory (ISO), has covered a total of 12 square degrees on the sky, and measurements were taken in four different bands (in a wavelength range of 6.7-175 μm). The survey consisted of multiple smaller regions, and one of these regions was the ELAIS N1 field. ELAIS N1 became one of the most known regions on the sky thanks to multiple follow up surveys, providing photometric measurements of the region from the optical to the radio.

There are thousands of extragalactic objects in the region, so we collected photometric data and the redshifts of galaxies in this field. We fitted their spectral energy distribution (SED), and derived their physical properties like stellar mass, star formation rate, and dust mass. We divided our sources depending on their stellar mass, and compared the dwarf galaxies to the larger galaxies.

We also compared our sources to the star forming main sequence (MS) of galaxies, to see the mode of star formation in the different samples. The actively star forming galaxies follow a relation between the stellar mass and SFR, with increasing SFR at higher stellar mass. The galaxies below this line are passive objects, with little or no ongoing star formation. The galaxies over the MS are starbursts (Schreiber et al.(2015)).

Another way of examining the activity of star formation is calculating the starburtiness: $R_{\text{SB}} = s\text{SFR}/s\text{SFR}_{\text{MS}}$, where $s\text{SFR}$ is the specific star formation rate. An R_{SB} below 1/4 signals a quiescent galaxy, and values above 4 indicate starbursts. (Rodighiero et al.(2011), Sargent et al.(2012)).

2. Data and SED fitting

We collected photometric data from VIZIER, SDSS (Sloan Digital Sky Survey, Blanton et al.(2017)), WISE (Wide-field Infrared Survey Explorer, Cutri, & et al.(2014)), the ELAIS N1 combined catalogue (Rowan-Robinson et al.(2013)) and the new Herschel Point Source Catalogues (Marton et al.(2017), Schulz et al.(2017)). We only considered sources which have Herschel detections. Including the Herschel far-infrared (FIR) data is important for the estimation of the star formation rate and dust mass. The UV and optical radiation of young stars are absorbed by the dust around them, and then it is re-emitted in FIR by the dust. We also used the AKARI/IRC source catalogues for the ELAIS North field (Davidge et al.(2017)), but it covers only a small region of the ELAIS N1.

We used CIGALE for the SED fitting (Noll et al.(2009), Roehlly et al.(2014)). Different modules can be chosen for the different mediums and processes in galaxies: stellar emission, nebular emission, dust emission and attenuation, and synchrotron emission. We selected a delayed τ model for star formation history, and the Bruzual & Charlot(2003) stellar emission model with Chabrier(2003) Initial Mass Function. Nebular continuum and line emission was also included. We chose a double power law attenuation curve (combining the attenuation caused by the warmer birth clouds and the cold interstellar

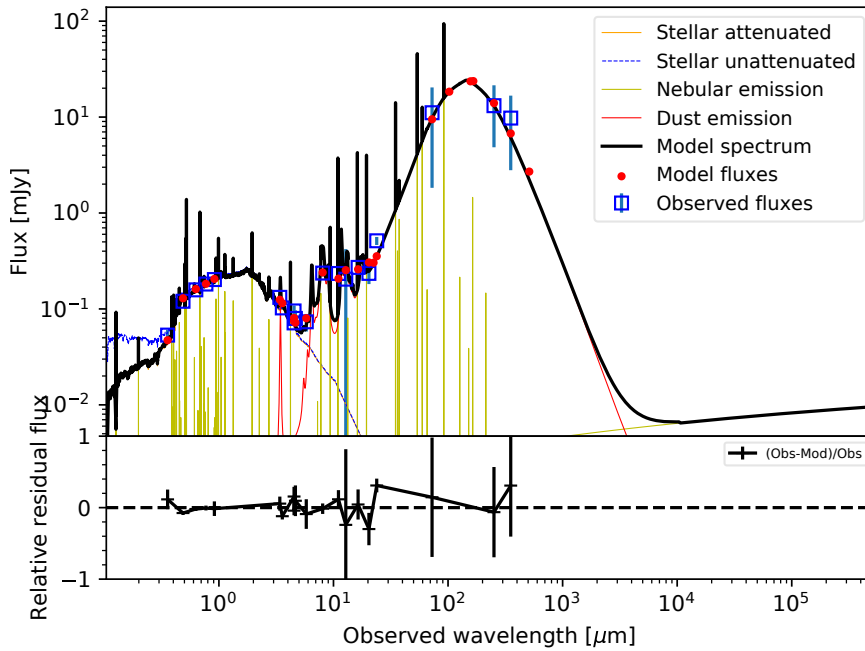


Figure 1. The SED of [RLP2006] EN1-J160844+545846, with a reduced χ^2 of 1.3. The model spectral energy distribution of the whole galaxy is marked by the solid black line. The unattenuated stellar emission is marked by a dashed blue line and the attenuated by an orange solid line. The nebular emission is marked by a yellow, and the dust emission by a red line. The observed fluxes are marked by blue squares, and the fluxes from the model SED by red points.

Table 1. The parameters of the examined dwarf galaxies. The means of the estimated parameters of dwarf and normal galaxies are also given. Redshifts are taken from SDSS (a: photometric, b: spectroscopic).

	z	SFR ($M_{\odot}/\text{yr}$)	log $M_{\star}$ ($M_{\odot}$)	log M_{dust} ($M_{\odot}$)	R_{SB}
[RLP2006] EN1-J160844+545846	0.04 ^a	0.11	8.63	6.47	2.91
[TRG2010] 9	0.13 ^b	3.69	9.54	8.58	9.89
[RLP2006] EN1-J160918+545351	0.11 ^a	0.46	9.56	8.23	1.22
2MASS J16124108+5439566	0.03 ^b	0.32	9.21	6.01	2.22
240.79434 +55.02117	0.05 ^b	0.31	9.44	7.56	1.22
2MASS J16065766+5403231	0.07 ^b	2.38	9.58	7.21	6.55
[VV2003c] J161103.6+535136	0.08 ^b	1.28	9.28	6.85	6.92
Dwarf	0.07	1.07	9.36	7.21	3.87
Normal (All)	0.36	14.45	10.65	8.5	1.25
Normal (local: z<0.14)	0.09	1.23	10.47	7.68	0.59

medium), with the updated Draine & Li(2007) infrared emission model. The results of the SED fittings are summarized in Table 1.

We divided our sources based on the results of the SED fitting (we considered our sources as dwarf galaxies if $\log M_{\star} < 9.7$). Three dwarf galaxy candidates ([RLP2006] EN1-J160844+545846, EN1-J160851+545501, EN1-J160918+545351), and 45 normal galaxies have AKARI detection. There are additional 5 dwarf galaxy candidates, and 81 normal galaxies without AKARI data. So we have 8 dwarf galaxy candidates, and 126 with larger stellar masses in total.

3. Results

Our dwarf galaxy candidates have low redshifts ($z < 0.14$), while the galaxies with higher $\log M_{\star}$ have higher redshifts. The star formation rate, $M_{\star}$ and M_{dust} are one order of magnitude lower in dwarf galaxies. We calculated the starburstiness (R_{SB}), and the dwarf galaxies are above the main sequence of star formation on average (Table 1.). Three of them could be starbursts. However, the R_{SB} is smaller in the normal galaxies on average.

We also compared our dwarf galaxy sample with normal galaxies at lower redshifts ($z < 0.14$, 36 galaxies in total). The properties of these two samples are more similar: while $M_{\star}$ is one order of magnitude lower in dwarf galaxies, M_{dust} is 1/3 of the M_{dust} in galaxies with larger masses. The star formation rate in dwarf galaxies is only slightly lower (87%) compared to normal galaxies, but the R_{SB} is higher on average.

One of the SEDs is shown in Fig. 1.: [RLP2006] EN1-J160844+545846 is a dwarf galaxy with a stellar mass of $\log M_{\star} = 8.6$ according to the SED fitting. Its SFR is 0.11 $M_{\odot}/\text{yr}$, and the dust mass is $\log M_{\text{dust}} = 6.5$. With a starburstiness (R_{SB}) of 2.9 it is above the star forming main sequence of galaxies. Some dwarf galaxy candidates in our sample could even be classified as a starburst ($R_{\text{SB}} > 4$). The optical spectra of 2MASS J16065766+5403231 and [TRG2010] 9 were examined in Toba et al.(2014) and Trichas et al.(2010), and both of them were identified as starforming galaxies, which is consistent with our SED fittings ($R_{\text{SB}} = 6.55, 9.89$). [VV2003c] J161103.6+535136 was identified as a starburst based on its SDSS spectrum, which is also in agreement with our estimated starburstiness ($R_{\text{SB}} = 6.92$).

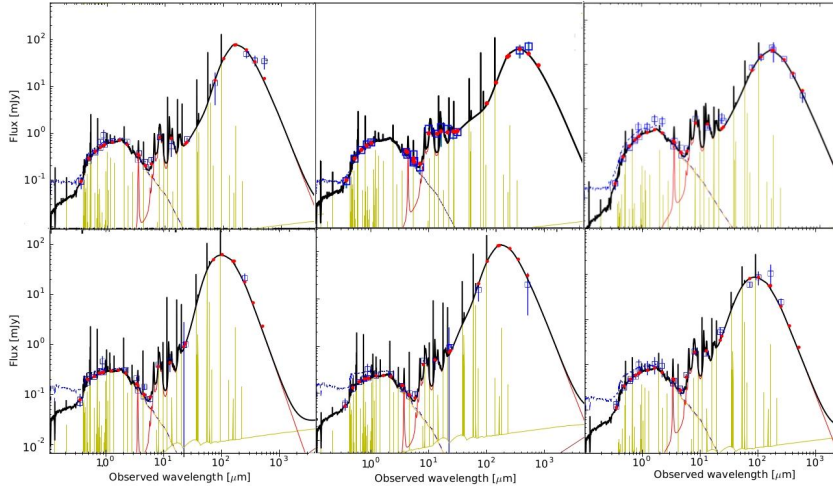


Figure 2. The SEDs of the other dwarf galaxy candidates, the notation is the same as in Fig. 1.

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