FIR MEASUREMENTS OF Lyα EMITTERS AT $z \lesssim 1.0$: DUST ATTENUATION FROM PACS-HERSCHEL

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ABSTRACT

One remaining open question regarding the physical properties of Lyα emitters (LAEs) is their dust content and evolution with redshift. The variety of results is large and with those reported by now it is difficult to establish clear relations between dust, other fundamental parameters of galaxies (star formation rate, metallicity, or age), and redshift. In this Letter, we report Herschel PACS-100 μm, PACS-160 μm, and Spitzer MIPS-24 μm detections of a sample of spectroscopically GALEX selected LAEs at $z \sim 0.3$ and ∼1.0. Five out of ten and one out of two LAEs are detected in, at least, one PACS band at $z \sim 0.3$ and ∼1.0, respectively. These measurements have a great importance given that they allow us to quantify, for the first time, the dust content in LAEs from direct FIR observations. MIPS-24 μm detections allow us to determine the IR properties of the PACS-undetected LAEs. We obtain that mid-IR/FIR-detected star-forming (SF) LAEs at $z \sim 0.3$ have dust content within 0.75 ≤ $A_{1200\AA}$ ≤ 2.0, with a median value of $A_{1200\AA} \sim 1.1$. This range broadens up to 0.75 ≤ $A_{1200\AA}$ ≤ 2.5 when considering the LAEs at $z \sim 1.0$. Only one SF LAE is undetected both in MIPS-24 μm and PACS, with $A_{1200\AA} \lesssim 0.75$. These results seem to be larger than those reported for high-redshift LAEs and, therefore, although an evolutionary trend is not clearly seen, it could point out that low-redshift LAEs are dustier than high-redshift ones. However, the diverse methods used could introduce a systematic offset in the results.

Key words: galaxies: evolution – galaxies: stellar content – infrared: galaxies – ultraviolet: galaxies

Online-only material: color figures

1. INTRODUCTION

Lyα emitters (LAEs) have been proved to be of great importance in the study of the formation and evolution of galaxies through cosmic time. At $2 \lesssim z \lesssim 7$, a large number of candidates have been found, mainly via the narrow or intermediate band technique in the optical/NIR wavelength range (Ouchi et al. 2008; Cowie & Hu 1998; Gronwall et al. 2007; Guaita et al. 2010; Shioya et al. 2009; Murayama et al. 2007; Nilsson et al. 2009; Fujita et al. 2003; Bongiovanni et al. 2010). At $z \lesssim 2$, the LAEs cataloged up to now have been found by spectroscopic surveys using the Galaxy Evolution Explorer (GALEX; Martin et al. 2005). The selection technique is based on looking for an Lyα line in the UV spectra of objects with a measured UV continuum (Deharveng et al. 2008; Cowie et al. 2010).

Despite a large number of LAE candidates found at different redshifts, their physical properties and evolution with cosmic time are not yet completely understood. Moreover, the relation between LAEs and other kinds of high-redshift galaxies, such as Lyman break galaxies (LBGs) or distant red galaxies (DRGs), remains unclear. Some studies have suggested that the stellar populations of LAEs exhibit a double nature, some being old and massive and other young and less massive (Gawiser et al. 2006; Lai et al. 2008; Ono et al. 2010). However, recent studies have proved that stellar populations of LAEs vary continuously and smoothly over a wide range, confirming a large zoo of galaxies (Oteo et al. 2011; Nilsson et al. 2011).

One remaining open question is whether LAEs are primitive and dust-free objects, evolved and dusty, or present a wide range of dust attenuation. A Lyα line has a resonant nature and, therefore, the probability of being absorbed by the interstellar medium (ISM) even before leaving the host galaxy is quite high. Consequently, it was initially thought that LAEs found via a narrowband technique should be young and dust-free objects, allowing the Lyα line to appear in emission. However, Neufeld (1991) proposed a scenario where the Lyα equivalent width could be enhanced by the presence of dust when it resides in cold and neutral clumps located within an ionized ISM. Actually, some studies (Finkelstein et al. 2009a, 2009c, 2011; Blanc et al. 2010) have observationally confirmed this hypothesis, opening the possibility of finding Lyα emission in non-primordial galaxies at different redshifts. The dust content in LAEs has been studied in a wide range of redshifts and different results have been found, from dust-free objects to low, moderate, and even high dust content. In Table 1, some results
on the study of dust attenuation in LAEs at different redshifts are summarized.

Most previous works have studied the dust attenuation in LAEs by fitting the UV and optical rest-frame spectral energy distribution (SED) with stellar population templates, mainly Bruzual & Charlot (2003, BC03) ones, and assuming the dust attenuation law of Calzetti (1997). However, both dust and old stars can redden the rest-frame-integrated UV continuum, varying the expected colors from the dust-free scenario. UV and optical photons that are absorbed by dust are reemitted in the far-infrared (FIR) region. Therefore, the most accurate way to study the dust properties of high-redshift galaxies is the observation of the dust emission in the FIR. Finkelstein et al. (2009b) and Dayal et al. (2010) studied the expected detection of dust emission from LAEs at $z \geq 4$ and $z \approx 6$, respectively, finding that a large percentage of them should be detected in only a few hours with the Atacama Large Millimeter/submillimeter Array. Finkelstein et al. (2009b) also found that LBGs are 60% more likely to be detected than LAEs, meaning that they are dustier objects and showing a possible difference between the two populations. However, some recent studies did not find FIR counterparts for LBGs, $z \approx 3$, characterizing their FIR SED only with stacked photometry (Magdis et al. 2010; Rigopoulou et al. 2010). For LAEs, Bongiovanni et al. (2010) reported the detection in the FIR of three LAEs at $z \approx 2.3$ selected from the ALHAMBRA survey (Moles et al. 2008), their optical to mid-IR SED being well fitted by the active galactic nucleus (AGN) like templates of Polletta et al. (2007). Oteo et al. (2011) also found FIR counterparts for five spectroscopically confirmed LAEs at $z \approx 2.5$. In this case, according to their optical spectra, only one is an AGN and the other four are star-forming (SF) LAEs. All of these FIR-detected LAEs are (ultra)luminous infrared galaxy (U)LIRG candidates and, therefore, red and dusty objects, despite having the Ly$\alpha$ line in emission and with large equivalent widths. Chapman et al. (2005) also found evidence of the Ly$\alpha$ emission in a sample of submillimeter galaxies detected in 850 $\mu$m, most of them being (U)LIRG candidates too.

Until now, only a few FIR counterparts for LAEs at $z \lesssim 2$ have been reported, and for those LAEs with FIR counterparts, an extensive analysis of their FIR properties has not been done. In this Letter, we report the FIR detections of a sample of LAEs at $z \sim 0.3$ and $z \sim 1.0$ by using data coming from the Photodetector Array Camera and Spectrometer (PACS; Poglitsch et al. 2010) on board Herschel Space Observatory. These FIR measurements, combined with UV information, enable us to determine their dust content in an accurate way without the uncertainties of the optical methods, which do not take into account the dust emission in FIR.

This Letter is organized as follows: in Sections 2 and 3 we present the LAE sample and the FIR data used, respectively. In Section 4 we report the FIR counterparts of our LAEs and in Section 5 we study their dust attenuation, comparing them with previous results. In Section 6, the main conclusions of our work are described.

Throughout this work we assume a flat universe with $(\Omega_m, \Omega_k, h_0) = (0.3, 0.7, 0.7)$, and all magnitudes are listed in the AB system (Oke & Gunn 1983).

### 2. LAE SAMPLE

In our analysis, we use an LAE sample selected from Cowie et al. (2010), where the spectra, taken with GALEX, NUV, and FUV grisms, were selected from the Multimission Archive at STScI (MAST). Cowie et al. (2010) used an automatic search procedure to look for emission lines in the spectra of objects with a measured UV continuum. For each source, a polynomial curve was used for constraining the continuum and a Gaussian profile fit to look for emission lines. Given that the spectra become very noisy at the edges of the spectral range in each channel, only those objects which have the Ly$\alpha$ emission in the wavelength ranges 1452.5–1750 Å and 2006–2735 Å for the FUV and NUV grisms, respectively, were selected. In the redshift space, this means that the sources are located within $z = 0.195–0.44$ ($z \sim 0.3$ sample) and $z = 0.65–1.25$ ($z \sim 1.0$ sample) in the FUV and NUV spectra, respectively. Both samples are

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**Table 1**

Summary of Some Previous Results in Dust Attenuation in LAEs

| Reference | Redshift | Dust Attenuation (mag) | Method |
|-----------|----------|------------------------|--------|
| Finkelstein et al. (2009a) | $\sim 0.3$ | $0.0 \lesssim A_{1200} \lesssim 2.0$ | TF-BC03 |
| Finkelstein et al. (2011) | $\sim 0.3$ | $0.4 \lesssim A_{1200} \lesssim 1.6$ | Spec |
| Nilsson & Moller (2009) | $\sim 0.3$ | $2.0 \lesssim A_{1200} \lesssim 7.5$ | IRAC-8 $\mu$m measurements |
| Cowie et al. (2010) | $\sim 0.3$ | $A_{1200} \approx 2.25$ | UV continuum slope |
| Cowie et al. (2010) | $\sim 0.3$ | $A_{1200} \approx 1.8$ | UV continuum slope |
| Guaita et al. (2011) | $\sim 2.1$ | $0.0 \lesssim A_{1200} \lesssim 2.41$ | TF-BC03 |
| Nilsson et al. (2011) | $\sim 2.3$ | $0.0 \lesssim A_{1200} \lesssim 10.0$ | TF-BC03 |
| Nilsson & Moller (2009) | $\sim 2.3$ | $4.0 \lesssim A_{1200} \lesssim 8.0$ | MIPS-24 $\mu$m measurements |
| Gawiser et al. (2007) | $\sim 3.1$ | $A_{1200} \lesssim 0.5$ | TF-BC03 & Stacked |
| Lai et al. (2008) | $\sim 3.1$ | $A_{1200} \approx 0.0$ | TF-BC03 & Stacked |
| Ono et al. (2010) | $\sim 3.1$ | $A_{1200} \approx 0.25$ | TF-BC03 & Stacked |
| Ono et al. (2010) | $\sim 3.1$ | $0.0 \lesssim A_{1200} \lesssim 5.6$ | TF-BC03 |
| Nilsson et al. (2007) | $\sim 3.15$ | $A_{1200} \approx 0.7$ | TF-BC03 & Stacked |
| Ono et al. (2010) | $\sim 3.7$ | $A_{1200} \approx 1.5$ | TF-BC03 & Stacked |
| Ono et al. (2010) | $\sim 3.7$ | $0.3 \lesssim A_{1200} \lesssim 5.4$ | TF-BC03 |
| Finkelstein et al. (2008) | $\sim 4.4$ | $0.4 \lesssim A_{1200} \lesssim 1.8$ | TF-BC03 |
| Finkelstein et al. (2009c) | $\sim 4.5$ | $0.3 \lesssim A_{1200} \lesssim 4.5$ | TF-BC03 |
| Pirzkal et al. (2007) | $\sim 5.0$ | $0.0 \lesssim A_{1200} \lesssim 1.8$ | TF-BC03 |
| Lai et al. (2007) | $\sim 5.7$ | $1.20 \lesssim A_{1200} \lesssim 1.81$ | TF-BC03 |

**Notes.** Reference, redshift, dust attenuation range, and the method followed to obtain the results are shown: SED fittings with BC03 templates to the individual or stacked observed photometry (TF-BC03 and TF-BC03 & Stacked, respectively), optical spectroscopic analysis (Spec.), UV continuum slope, and mid-IR measurements.
nearly complete to an UVT limiting magnitude of 21.5 and have Lyα luminosity limits of 5 × 10^{41} and 1 × 10^{43} erg cm^{-1} s^{-1} at z ∼ 0.3 and ∼1.0, respectively. LAEs were classified as AGNs or SF galaxies according to the width and shape of the Lyα line and the presence or the absence of AGN ionization lines in the UV spectra. Figure 1 shows the spatial distribution of GALEX-selected LAEs in both COSMOS and GOODS-South fields.

3. FIR DATA

GOODS-South and COSMOS fields have been observed with PACS on board Herschel in the framework of PACS Evolutionary Probe project (PEP; PI: D. Lutz). PEP is the Herschel Guaranteed Time Key-Project to obtain the best profit for studying FIR galaxies’ evolution from Herschel instrumentation (D. Lutz et al. 2011, in preparation). For both fields, PACS-100 μm and PACS-160 μm observations are available, with 3σ limiting fluxes of (1.1, 5.0) in PACS-100 μm and (2.0, 11.0) in PACS-160 μm (GOODS-South, COSMOS). PACS-100 μm and PACS-160 μm bands cover the FIR wavelength ranges 80–130 μm and 130–210 μm, respectively. Two kinds of catalogs have been formed: blind and with position priors. Data reduction, catalog construction, and simulations, aimed at deriving completeness, fraction of spurious sources and photometric reliability, are described in D. Lutz et al. (2011, in preparation).

Figure 1 also shows the PACS-Herschel sources extracted with 24 μm position priors. It can be seen that PACS observations in COSMOS field cover the whole region where GALEX-selected LAEs are located, whereas the surveyed area by PACS in GOODS-South only covers a little portion of GALEX observations. In this sense, 28 and four GALEX-selected LAEs are within the PACS surveyed area in COSMOS and GOODS-South, respectively. Table 2 summarizes the number of GALEX-selected LAEs within the PACS area in both fields.

4. LAEs WITH FIR COUNTERPARTS

In order to find out how many LAEs have FIR counterparts, we performed a match between GALEX LAE coordinates and nearly complete to an UVT limiting magnitude of 21.5 and have Lyα luminosity limits of 5 × 10^{41} and 1 × 10^{43} erg cm^{-1} s^{-1} at z ∼ 0.3 and ∼1.0, respectively. LAEs were classified as AGNs or SF galaxies according to the width and shape of the Lyα line and the presence or the absence of AGN ionization lines in the UV spectra. Figure 1 shows the spatial distribution of GALEX-selected LAEs in both COSMOS and GOODS-South fields.

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4. LAEs WITH FIR COUNTERPARTS

In order to find out how many LAEs have FIR counterparts, we performed a match between GALEX LAE coordinates and PACS catalogs in both fields. We look for a possible FIR detection within a radius of 2″ around the position of each LAE, since it is the astrometric uncertainty in the position of the sources. With this procedure, we find that a noticeable fraction of LAEs, mostly above 30%, have PACS-FIR detections in at least one considered PACS band, considering limiting fluxes shown in Section 3. In Table 2, the number of PACS detection is also shown, separated by field, redshift, and the nature of the object (AGN or SF). The percentages of FIR detections are larger in GOODS-South than in COSMOS because of the depth of the observations. If the PACS observation had been in COSMOS as deep as in GOODS-South, a large number of FIR counterparts would have been expected.

A source confusion analysis is needed to ensure that each FIR detection corresponds to the matched GALEX-selected LAE. We take 30″ optical cutouts around the position of each GALEX-selected LAE and overplot the MIPS-24 μm contours in order to verify if the detections in each band are related or not to the same object. We use the MIPS-24 μm contours given that the PACS catalogs are based on 24 μm position priors, where the point-spread function of the observations is ∼30% narrower than redder bands and, therefore, the accuracy in the positions is better. It can be seen from Figure 2 that each FIR detection reported corresponds to the matched GALEX LAE.

5. DUST ATTENUATION IN STAR-FORMING LAEs

The ratio between the total IR and UV luminosities, L_{IR} and L_{UV}, respectively, is directly related to the dust attenuation in galaxies, and calibrations have already been done (Meurer et al. 1999; Buat et al. 2005, 2007). Since all the PACS-detected SF...
Figure 2. 30″ × 30″ ACS-optical cutouts and MIPS-24 μm flux isocontours. GALEX LAEs are the objects located in the center of each image. Black curves are flux isocontours in the MIPS-24 μm band, linearly scaled to the peak flux.

GALEX LAEs also have UV measurements, we can infer their dust attenuation from direct observations of their FIR SED. We use the NUV band given that, on the one hand, it is not contaminated by the Lyα emission for those GALEX LAEs at z ∼ 0.3 and, on the other hand, it is not affected by the Lyman break for those GALEX LAEs at z ∼ 1.0. L_{UV} can be obtained directly from the observed magnitudes in the NUV band, as in Buat et al. (2005). L_{IR} can be calculated by using the calibrations given in Oteo et al. (2011) between PACS bands and the total infrared luminosities:

\[ \log L_{IR} = 0.99 \log L_{100 \mu m} + (0.44 \pm 0.25) \]  
\[ \log L_{IR} = 0.96 \log L_{160 \mu m} + (0.77 \pm 0.21), \]  

where all the luminosities are in solar units and \( L_{100 \mu m} \) and \( L_{160 \mu m} \) are defined as \( \nu L_\nu \). PACS-detected LAEs have measurements in 100 μm and/or 160 μm. For those detected in both bands, we obtain \( L_{IR} \) by using the calibration in the PACS-160 μm band, since it is the closest one to the dust emission peak at our redshift ranges and, therefore, produces a more accurate result.

We can also obtain the total IR luminosities, i.e., dust content, for those PACS-undetected but MIPS-24 μm-detected SF GALEX LAEs by using the Chary & Elbaz (2001) calibrations between the total IR and 15 μm and 12 μm luminosities for local galaxies. These wavelengths are within the rest-frame ranges sampled through the MIPS-24 μm band for LAEs at z ∼ 0.3 and ∼1.0, respectively. The applicability of these calibrations to high-redshift galaxies is discussed by Elbaz et al. (2010) who found that, below z ∼ 1.5, mid-IR extrapolations to the total IR luminosities are correct for SF galaxies below the (U)LIRG regime. The MIPS-24 μm information was taken from the S-COSMOS survey (Sanders et al. 2007). Only one object is not detected in that band.

In Figure 3, we plot the ratio \( L_{IR}/L_{UV} \) (or, equivalently, dust attenuation) versus \( L_{IR} \) of our mid-IR/FIR-detected GALEX LAEs, besides the corresponding data of Gil de Paz et al. (2007, hereafter G07) for a collection of nearby, SF galaxies. Our LAEs are located in the low-dust regime of the G07 data, indicating that objects exhibiting the Lyα line in emission at low and moderate redshifts should not be as dusty as the whole population of galaxies at the same redshift. The dust attenuation in our mid-IR/FIR-detected LAEs at z ∼ 0.3 ranges within 0.75 mag ≤ A_{1200 Å} ≤ 1.8 mag, with a median value of 1.1 mag. This range broadens up to A_{1200 Å} ≤ 2.5 when considering the z ∼ 1.0 LAEs as well. For the GALEX LAE undetected both in MIPS-24 μm and PACS, we assume an upper limit in its dust attenuation equal to the minimum value obtained for the mid-IR/FIR-detected GALEX LAEs, A_{1200 Å} ≤ 0.75.

Finkelstein et al. (2011) studied the dust content in LAEs at z ∼ 0.3 by using SED fitting and the Balmer decrement. They derived an attenuation in the stellar continuum from the Balmer decrement ranging from A_{1200 Å} ∼ 0 to ∼1.8 with a median value of 0.78 mag. These values are in agreement with those found via SED fitting, most of them being within the combined 1σ uncertainties. Cowie et al. (2010) obtained dust attenuation from the NUV continuum slope and Balmer decrement of their LAEs at z ∼ 0.3, obtaining median values of A_{1200 Å} ∼ 2.25 and ∼1.8, respectively, which are noticeably higher than those reported in Finkelstein et al. (2011). Nilsson & Møller (2009) reported
Figure 3. Ratio between the total infrared and NUV luminosities vs. the total infrared luminosity for star-forming GALEX LAEs. The right vertical axis (dust attenuation) was made by using the calibration of Buat et al. (2005). Black (yellow) dots are data of nearby galaxies taken from Gil de Paz et al. (2007). The dark shaded zone is the average region (±1.5σ) where these objects lie. The light shaded region corresponds to the dust content range of LAEs at z ∼ 0.3 reported by Finkelstein et al. (2009a). Large black dots (red) and black diamonds (blue) are SF LAEs at z ∼ 0.3 and z ∼ 1.0, respectively. Filled symbols are PACS-detected LAEs and open symbols are PACS-undetected LAEs. We do not plot the MIPS-24 μm undetected and PACS-undetected SF-LAE at z ∼ 0.3 (see the text) given that there is no way to obtain its total IR luminosity with the calibrations used.

(A color version of this figure is available in the online journal.)

significantly higher values, most of them being $A_{1200\,\AA} \gtrsim 2.0$ and as large as 7.5 mag. The results derived here are slightly higher than those derived in Finkelstein et al. (2011), similar to Cowie et al. (2010) values, and lower than those in Nilsson & Möller (2009). These discrepancies may be caused by the different methodologies employed, and even when they are same, the results do not agree quite well, likely due to the low number of objects in each sample.

The dust attenuation values reported up to $z \sim 2$ are similar to those obtained in this work. However, at $z \gtrsim 3$, while there are some measurements of high dust attenuation in high-redshift LAEs, the vast majority of the reported extinction measurements are substantially lower than $A_{1200\,\AA} \lesssim 0.75$ and are, in many cases, consistent with essentially no extinction. This could indicate that high-redshift LAEs are less dusty than those at lower redshifts. However, note that, overall at the highest redshifts, the number of the studied LAEs at each redshift is low and, therefore, the results are not statistically significant. Furthermore, it is worth noting that SED fitting estimations (sometimes done with stacking analysis), spectroscopic results, and IR measurements could produce systematic differences. This means that a possible evolution of dust attenuation with redshift should be taken with caution.

6. CONCLUSIONS

In this Letter, we have reported the FIR detections of a sample of GALEX-selected LAEs at $z \sim 0.3$ and $z \sim 1.0$. Our main conclusions are as follows.

1. We find that a large fraction of LAEs at $z \sim 0.3$ and $z \sim 1.0$ are detected in the FIR. In the worst case, the fraction of FIR-detected LAEs is about 15%, although in most cases the fractions are higher than 30%. Therefore, up to $z \sim 1.0$, at least 30% of the LAEs are expected to be detected in the FIR under the depth of the catalogs used. The percentages of MIPS-24 μm detections are even higher, only one object being undetected in that band.

2. Based on direct measurements of the mid-IR/FIR SED, we conclude that the studied SF-LAEs at $z \sim 0.3$ present a wide range of dust attenuation, $0.75 \lesssim A_{1200\,\AA} \lesssim 1.8$, with a median value $A_{1200\,\AA}$ of 1.1. This range broadens up to $0.75 \lesssim A_{1200\,\AA} \lesssim 2.2$ when considering LAEs at $z \sim 1.0$. We only find one object, undetected both in MIPS-24 μm and PACS, whose dust content has an upper limit of $A_{1200\,\AA} \lesssim 0.75$.

3. The dust attenuation values derived here are comparable to those reported in previous works, up to $z \sim 2.0$, pointing out that there is no significant evolution in dust content in that epoch. At $z \gtrsim 3$, although some works showed the existence of dusty LAEs, most of the extinction measurements are lower than those at $z \lesssim 2.0$, which could indicate an evolution with redshift. However, the different methods used to derive the results and the low number of LAEs at certain redshifts make the results statistically insignificant.

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Planck Project team by an industrial consortium under the overall responsibility of the prime contractor Thales Alenia Space (Cannes), and including Astrium (Friedrichshafen) responsible for the payload module and for system testing at spacecraft level, Thales Alenia Space (Turin) responsible for the service module, and Astrium (Toulouse) responsible for the telescope, with in excess of a hundred subcontractors. PACS has been developed by a consortium of institutes led by MPE (Germany) and including UVIE (Austria); KUL, CSL, IMEC (Belgium); CEA, OAMP (France); MPIA (Germany); IFSI, OAP/AOT, OAA/CAISMI, LENS, SISSA (Italy); and IAC (Spain). This development has been supported by the funding agencies BMVIT (Austria), ESA-PRODEX (Belgium), CEA/CNES (France), DLR (Germany), ASI (Italy), and CICYT/MICINN (Spain).

REFERENCES

Blanc, G. A., et al. 2010, arXiv:1011.0430
Bongiovanni, A., et al. 2010, A&A, 519, L4
Bruzual, G., & Charlot, S. 2003, MNRAS, 344, 1000
Buat, V., et al. 2005, ApJ, 619, L51
Buat, V., et al. 2007, ApJS, 173, 404
Calzetti, D. 1997, in AIP Conf. Ser. 408, The Ultraviolet Universe at Low and High Redshift, ed. W. H. Waller (Melville, NY: AIP), 403
Chapman, S. C., Blain, A. W., Smail, I., & Ivison, R. J. 2005, ApJ, 622, 772
Chary, R., & Elbaz, D. 2001, ApJ, 556, 562
Cowie, L. L., Barger, A. J., & Hu, E. M. 2010, ApJ, 711, 928
Cowie, L. L., & Hu, E. M. 1998, AJ, 115, 1319
Dayal, P., Hirashita, H., & Ferrara, A. 2010, MNRAS, 403, 620
Deharveng, J., et al. 2008, ApJ, 680, 1072
Elbaz, D., et al. 2010, A&A, 518, L29
Finkelstein, S. L., Cohen, S. H., Malhotra, S., & Rhoads, J. E. 2009a, ApJ, 700, 276
Finkelstein, S. L., Cohen, S. H., Moustakas, J., Malhotra, S., Rhoads, J. E., & Papovich, C. 2011, ApJ, 733, 117
Finkelstein, S. L., Malhotra, S., Rhoads, J. E., Hathi, N. P., & Pirzkal, N. 2009b, MNRAS, 393, 1174
Finkelstein, S. L., Rhoads, J. E., Malhotra, S., & Grogin, N. 2009c, ApJ, 691, 465
Finkelstein, S. L., Rhoads, J. E., Malhotra, S., Grogin, N., & Wang, J. 2008, ApJ, 678, 655
Fujita, S. S., et al. 2003, ApJ, 125, 13
Gawiser, E., et al. 2006, ApJ, 642, L13
Gawiser, E., et al. 2007, ApJ, 671, 278
Gil de Paz, A., et al. 2007, ApJS, 173, 185
Gronwall, C., et al. 2007, ApJ, 667, 79
Guaita, L., et al. 2010, ApJ, 714, 255
Guaita, L., et al. 2011, ApJ, 733, 114
Lai, K., Huang, J., Fazio, G., Cowie, L. L., Hu, E. M., & Kakazu, Y. 2007, ApJ, 655, 704
Lai, K., et al. 2008, ApJ, 674, 70
Le Floc'h, E., et al. 2009, ApJ, 703, 222
Magdis, G. E., et al. 2010, ApJ, 720, L185
Magnelli, B., Elbaz, D., Chary, R. R., Dickinson, M., Le Borgne, D., Frayer, D. T., & Willmer, C. N. A. 2011, VizieR Online Data Catalog, 352, 89035
Martin, D. C., et al. 2005, ApJ, 619, L1
Meurer, G. R., Heckman, T. M., & Calzetti, D. 1999, ApJ, 521, 64
Moles, M., et al. 2008, AJ, 136, 1325
Murayama, T., et al. 2007, ApJS, 172, 523
Neufeld, D. A. 1991, ApJ, 370, L85
Nilsson, K. K., & Møller, P. 2009, A&A, 508, L21
Nilsson, K. K., Ostlin, G., Møller, P., Möller-Nilsson, O., Tapken, C., Freudling, W., & Fynbo, J. P. U. 2011, A&A, 529, A9
Nilsson, K. K., Tapken, C., Møller, P., Freudling, W., Fynbo, J. P. U., Meisenheimer, K., Laursen, P., & Ostlin, G. 2009, A&A, 498, 13
Nilsson, K. K., et al. 2007, A&A, 471, 71
Oke, J. B., & Gunn, J. E. 1983, ApJ, 266, 713
Ono, Y., et al. 2010, MNRAS, 402, 1580
Oteo, I., et al. 2011, A&A, submitted
Ouchi, M., et al. 2008, ApJS, 176, 301
Poglitsch, A., et al. 2007, ApJ, 667, 49
Polletta, M., et al. 2007, ApJ, 663, 81
Rigopoulou, D., et al. 2010, MNRAS, 409, L7
Sanders, D. B., et al. 2007, ApJS, 172, 86
Shioya, Y., et al. 2009, ApJ, 696, 546