1 INTRODUCTION

Rest-frame UV selection offers a prime view into populations of star-forming galaxies at z > 1.5. First used to identify z ~ 3 galaxies with sharp breaks in their spectral energy distributions due to absorption below the Lyman limit (Steidel et al. 1996), the Lyman break technique has now been modified and extended to both lower and higher redshift (e.g., Steidel et al. 1999; Lehnert & Bremer 2003; Adelberger et al. 2004). Since the development of the technique in the 1990s, thousands of star-forming galaxies have been spectroscopically confirmed at z ~ 3 (Reddy & Steidel 2004; Reddy et al. 2006b, 2010), resulting in a revolution in our understanding of galaxy formation and evolution. However, these high-redshift galaxies suffer from a fundamental problem: they are typically small and faint, with R_AB ∼ 24 mag, making it impossible to carry out detailed studies of individual objects unless they happen to be strongly lensed. In particular, this limitation applies to observations of UV-bright star-forming systems at the long wavelengths that can trace star formation even in highly obscured regions. While stacking analyses of large samples confirm that UV-selected galaxies at z ~ 2 have substantial fractions of their bolometric luminosities emerging in the far-infrared, with (L_IR/L_{UV}) ∼ 4–5 (Reddy & Steidel 2004; Reddy et al. 2006b, 2010), understanding the parameters of obscured star formation in individual unlensed objects remains out of reach for current facilities.

The first bright lensed Lyman break galaxies, “cB58” (i.e., MS 1512-cB58) and the “Cosmic Eye” (i.e., LBG J213512.73–010143), were discovered serendipitously in the course of a cluster redshift survey (Yee et al. 1996) and a Hubble Space Telescope (HST) snapshot imaging survey of X-ray-bright clusters (Smail et al. 2007), respectively. Since clusters are rich in strong caustics capable of producing fold arcs (like cB58) and in individual galaxies capable of producing nearly complete Einstein rings (like the Cosmic Eye), the circumstances of these discoveries were not surprising. More recently, however, several teams have begun to exploit the enormous footprint of the Sloan Digital Sky Survey (SDSS) to identify UV-bright high-redshift sources that are lensed by individual galaxies in field or group environments. This enterprise kicked off with the serendipitous discovery of the “8 O’Clock Arc” (Allam et al. 2007) and has now spawned a variety of systematic searches within the SDSS object catalog that rely on different selection criteria (e.g., Belokurov et al. 2007; Shin et al. 2008; Hennawi et al. 2008). By focusing on luminous red galaxies with multiple blue neighbors, and on close pairs with characteristic lens+arc morphologies, various authors of this paper have now contributed to the discovery of 11 new spectroscopically confirmed lenses at redshifts 0.4 < z < 2.4 (Kubo et al. 2009; Lin et al. 2009; Diehl et al. 2009).

In this paper, we present Spitzer/IRS spectroscopy of two objects from this new SDSS sample. The first, SDSS J120602.09+514229.5 (aka the “Clone,” hereafter J1206) is a z = 2.00 arc discovered by Lin et al. (2009), who determine a lensing magnification M = 27 ± 1. The second, SDSS J090122.37+181432.3 (hereafter J0901) is a z = 2.26 arc discovered by Diehl et al. (2009); preliminary lens modeling...
implies a magnification $\approx 8$ (A. West et al. 2010, in preparation). Both objects are 20–30 times brighter than galaxies at the knee of the $1.9 \leq z \leq 2.7$ rest-UV luminosity function (Reddy et al. 2008); their estimated intrinsic far-IR luminosities make J1206 a luminous infrared galaxy (LIRG; see Section 3.1) and J0901 an ultraluminous infrared galaxy (ULIRG; see Section 3.2). Here we focus on what can be learned about the conditions in the dusty regions of these galaxies from their integrated mid-infrared emission, based on comparisons with local galaxies, assuming that there is minimal differential lensing across the wavelength ranges of our IRS spectra. We defer to future papers analysis of Spitzer/IRAC and (for J1206) MIPS imaging of these targets in light of more refined $HST$-based lens models, together with detailed comparisons to the source-plane properties of similar lensed star-forming galaxies (Siana et al. 2008, 2009) and high-redshift systems selected through their dust emission rather than rest-UV colors (e.g., Lutz et al. 2005; Weedman et al. 2006; Valiante et al. 2007; Yan et al. 2007; Pope et al. 2008; Menéndez-Delmestre et al. 2009).

2. OBSERVATIONS AND DATA REDUCTION

We used the Infrared Spectrograph (IRS: Houck et al. 2004) on board the Spitzer Space Telescope to obtain 14–38 $\mu$m spectra of both J1206 and J0901 in the instrument’s “long low” mode ($R \sim 57–126$), for which the first (LL1) and second (LL2) orders cover wavelength ranges of 19–38 $\mu$m and 14–21.3 $\mu$m, respectively. In order to ensure optimal signal-to-noise ratios, we followed the recommendations of Teplitz et al. (2007) and mapped the targets at six positions across the slit. Observations of J1206 were taken during Spitzer Cycle 4 (PID 40430; PI S. Allam) on 2007 December 19 and 20, and consisted of 1 $\times$ 6 pointings in LL1 and LL2 for total integration times of 2.1 ks and 2.2 ks, respectively. J0901 was observed on 2009 May 15 during Spitzer Cycle 5 (PID 50086; PI S. Allam) using 2 $\times$ 6 pointings in LL1 totaling 2.2 ks and 2.0 ks, and 1 $\times$ 6 pointings in LL2 totaling 2.3 ks.

Data were obtained under nominal operating conditions, with the exception of the second LL1 Astronomical Observation Request (AOR) for J0901. During this AOR, Spitzer began to warm up due to the depletion of its cryogen. The increased thermal background was marginal, raising data collection event (DCE) values by only 6%. The IRS support team deemed the data nominal, and we reduced them following the same procedures used for our other AORS.

Data reduction relied on standard analysis packages and followed the procedure described by Teplitz et al. (2007). Using IRAF, we removed latent charge in the IRS images row-by-row by fitting the linear background increase over time. Subsequently, we masked “rogue” pixels using the IDL routine IRSCLEAN. After cleaning, we constructed sky images for each target position using the five other pointings from the same mapping AOR. The resulting sky images were subtracted from the corresponding science frames, and the differences were then co-added to produce a final two-dimensional spectrum at each position. We extracted one-dimensional spectra using the SPICE package provided by the Spitzer Science Center, using optimal extraction. We used an extraction aperture half the default size in order to avoid contamination from other sources (see below), but we corrected to full-aperture fluxes using observations of standard stars.

For J0901, extraction of the one-dimensional spectra was complicated by an interloping source, SDSS J090125.59+181427.8 (see Figure 1(a)), lying $\sim 46''$ away from the lens. From its IRS spectrum, this object is likely to be a quasar at $z \sim 1.3$, in agreement with the assessment of its optical colors by Richards et al. (2009). Its spectrum in one pointing often lay on or near the position of a J0901 spectrum in another pointing; combined with the fact that J0901 itself is bright and extended, this situation meant that a given “sky” frame included the true background, light from the interloping source, and residual flux from J0901 at other map positions, leading to oversubtraction in our final two-dimensional spectra (e.g., Figure 1(a)). To
correct for this effect, we extracted one-dimensional spectra of the negative sky echoes at different locations in the two-dimensional spectrum whose combination should have experienced the same oversubtraction as the position in question (e.g., Figure 1(b)). By combining such measurements, we constructed an empirical model for the oversubtraction of each of our target spectra that accounted for both continuum and polycyclic aromatic hydrocarbon (PAH) features. We found that the correction was fairly mild, leading to a ∼10%–25% flux increase over the uncorrected spectrum.

As an alternative to the above procedure, we tried to create sky images using only dithers whose positions were far enough away that no oversubtraction occurred. Doing so meant constructing sky images from many fewer frames, often from only one or two other positions. As a result, we found the reduced (cleaned and sigma-clipped) two-dimensional spectra were affected by rogue pixels whose effects would otherwise have been eliminated. Such pixels not only increased the uncertainty in our final one-dimensional spectrum, but also introduced small-scale features that do not correspond with any known emission features. Given the undesirable effects of this approach to sky subtraction, we opted for the method described above, which uses all of the original frames. We note that the spectra produced via our two sky subtraction procedures yield similar flux densities within the measurement uncertainties.

For both J1206 and J0901, the error spectrum at each position was calculated using SPICE and standard deviation frames constructed in IRAF. The final error spectrum is that of all the positions added in quadrature. For J0901, we include an additional systematic uncertainty associated with our sky correction, raising the final error spectrum by a factor ∼√2.

3. RESULTS

3.1. SDSS J120602.09+514229.5

Figure 2(a) shows the extracted IRS spectra for J1206. On top of a rising continuum, prominent PAH features are present at 6.2, 7.7, and 11.3 μm. In addition, a strong [S iv] feature is present at 10.5 μm. In order to compare the spectrum to those of local starbursting analogs, we fit template Infrared Space Observatory spectra of 30 Doradus, Circinus, M82, NGC 253, and NGC 1068 from Sturm et al. (2000), and the average Spitzer starburst template from Brandl et al. (2006). For the fit we allow a varying contribution from the templates as well as an additional power law continuum (normalized to 6.2 μm):

$$F_{\nu,\text{fit}} = C_1 \times \text{[Template]} + C_2 \times \left(\frac{\lambda}{6.2 \text{ μm}}\right)^{\alpha},$$

where $C_1$ is dimensionless and $C_2$ has units of mJy. The three parameters for the fit were sampled using a standard Metropolis–Hastings Markov chain Monte Carlo (MCMC) algorithm. Figure 2(b) shows two of the template spectra that provide good fits. Table 1 shows the inferred median, 68% confidence limits, and best-fit parameters for the templates that provided reasonable fits. We find that the spectrum is well fit by the M82 template ($\chi^2_{\text{red}} = 0.96$), and marginally fit by the NGC 253 and average
Table 1: Local Starburst Template Fits

| Template | $\log(C_1)$ | $\log(C_2/\text{mJy})$ | $\alpha$ | Fit Type |
|----------|-------------|------------------------|---------|----------|
| J1206    |             |                        |         |          |
| M82      | $-5.063^{+0.004}_{-0.006}$ | $-0.78^{+0.11}_{-0.10}$ | $3.1^{+0.3}_{-0.2}$ | MCMC results |
|          | $-5.06$     | $-0.84$                | $3.1$   | Best fit: $\chi^2_{red} = 0.96$ |
| NGC 253  | $-4.938^{+0.128}_{-0.102}$ | $-0.79^{+0.12}_{-0.14}$ | $3.2^{+0.2}_{-0.2}$ | MCMC results |
|          | $-5.03$     | $-0.86$                | $3.0$   | Best fit: $\chi^2_{red} = 1.20$ |
| Avg. Starburst | $-2.960^{+0.051}_{-0.051}$ | $-0.55^{+0.12}_{-0.22}$ | $3.3^{+0.2}_{-0.2}$ | MCMC results |
|          | $-2.99$     | $-0.72$                | $3.1$   | Best fit: $\chi^2_{red} = 1.14$ |
| J0901    |             |                        |         |          |
| M82      | $-4.557^{+0.061}_{-0.042}$ | $-1.08^{+0.22}_{-0.16}$ | $3.1^{+2.2}_{-2.5}$ | MCMC results |
|          | $-4.52$     | $-1.10$                | $2.6$   | Best fit: $\chi^2_{red} = 0.95$ |
| NGC 253  | $-4.675^{+0.045}_{-0.058}$ | $-0.69^{+0.13}_{-0.18}$ | $3.2^{+0.8}_{-0.6}$ | MCMC results |
|          | $-4.62$     | $-0.56$                | $3.6$   | Best fit: $\chi^2_{red} = 1.42$ |
| Avg. Starburst | $-2.453^{+0.038}_{-0.035}$ | $-6.51^{+0.18}_{-0.13}$ | $0.6^{+0.1}_{-0.1}$ | MCMC results |
|          | $-2.46$     | $-6.42$                | $0.5$   | Best fit: $\chi^2_{red} = 1.26$ |

Notes. $F_{\nu, \text{fit}} = C_1 \times \text{[Template]} + C_2 \times (/2.6 \mu m)^\alpha$. Right-hand column indicates fit type for a given row. “MCMC results” report the median and 68% confidence intervals, inferred using a Monte Carlo Markov Chain method. “Best-fit” values correspond to the highest likelihood fit, derived using optimization techniques.

Table 2: Derived Feature Strengths

| Wavelength | J1206 | J0901 |
|------------|-------|-------|
| $\mu$m     |       |       |
| 6.22 PAH   | 21.7  | 20.2  |
| 6.99 [Ar\text{n}I] | <1.9 | <1.2 |
| 7.42 PAH   |       |       |
| 7.60 PAH   | 24.2  | 20.6  |
| 7.65 [Ne\text{v}II] | <0.8 | <0.10 |
| 7.85 PAH   | 30.9  | 1.55  |
| 8.33 PAH   | 3.1   | 0.6   |
| 8.61 PAH   | 10.2  | 0.51  |
| 8.99 [Ar\text{n}II] | <2.8 | <0.05 |
| 10.51 [S\text{v}II] | 2.1 | <0.10 |
| 11.23 PAH  | 3.7   | 0.11  |
| 11.33 PAH  | 13.2  | 0.61  |
| 11.99 PAH  | 3.2   | 0.78  |
| 15.7 PAH   |       |       |

Notes. Equivalent width values are based on the green dot-dashed lines (power-law continuum fits) in Figures 2(c) and 3(c). Upper limits are based on 3σ uncertainties in the spectra.

equivalent widths (EWs) of the 6.2, 7.7 ($\equiv 7.41 + 7.61 + 7.85$), and 11.3 ($\equiv 11.23 + 11.33$) $\mu$m PAH features to those of local starbursting systems. Comparisons of EWs are known to be sensitive to the details of how authors define the underlying continuum. In particular, continuum levels are often defined by the values of the data seen on either side of emission features (see, e.g., Brandl et al. 2006; Pope et al. 2008). Such definitions result in systematically higher continua and lower PAH EWs than found by comprehensive fits to the spectra (e.g., Siana et al. 2009). To facilitate interpretation of the EW values reported in Table 2, we analyze the average starburst spectrum of Brandl et al. (2006) using the same conventions as for J1206. We find EWs for the average starburst spectrum that are factors $\sim 1-8$ higher than those derived by Brandl et al. (2006) for their own data. Nevertheless, this approach provides a consistent way of measuring and comparing EW values to our data. Relative to the average starburst spectrum, J1206 has EWs that are lower by factors of 1.2, 1.5, and 1.2 for the 6.2, 7.7, and 11.3 $\mu$m PAH features, respectively. This slight deficiency is not surprising, given the additional power-law continuum preferred by our template fitting above.

The two most striking features of the $\sim 4.5-12 \mu$m spectrum of J1206 are its steep underlying continuum and prominent [S\text{iv}] emission. In high-resolution studies of local star-forming galaxies, the latter line is fairly common and appears weakly in starbursts (Bernard-Salas et al. 2009) and ULIRGs (Farrah et al. 2007), but is much stronger in blue compact dwarfs (BCDs; Hao et al. 2009). At lower resolution this line is unresolved, and only the strongest emitters are detected (see, e.g., Brandl et al. 2006; Wu et al. 2006). Comparing the relative strengths of [S\text{iv}] and PAH emission of J1206 to those of local counterparts, we identify the two low-resolution mid-IR spectra of the starburst NGC 1222 (Brandl et al. 2006) and the BCD UGC 4274 (Wu et al. 2006) as close analogs.

Using the optical spectroscopy of Liu & Kennicutt (1995) for NGC 1222 and Ho et al. (1997) for UGC 4274, we calculate the oxygen abundance in each galaxy using the N2 and O3N2 indicators calibrated by Pettini & Pagel (2004). We find $12 + \log(O/H)_{N2} = 8.48, 8.43$ and $12 + \log(O/H)_{O3N2} = 8.38, 8.37$ for NGC 1222 and UGC 4274, respectively. For J1206, Hainline et al. (2009) use near-IR spectroscopy to find
12 + log(O/H)_{N2} = 8.50 \pm 0.18 \text{ and } 12 + log(O/H)_{O3N2} = 8.34 \pm 0.14, \text{ in good agreement with the putative local counterparts. Given the consistency between the spectra and the oxygen abundances, modulo a factor } \sim 2.5 \text{ uncertainty in the calibration of the optical diagnostics}, (\text{Pettini} \text{ & Pagel} \ 2004), \text{ we conclude that NGC 1222 and UGC 4274 have physical conditions similar to those of J1206.}

In addition to oxygen abundances, we can consider the ratios of ionized sulfur and neon lines [S iv] 10.5 \mu m/[S iii] 18.7 \mu m \text{ and [Ne iii] 15.6 \mu m/[Ne ii] 12.8 \mu m for NGC 1222 and UGC 4274. These quantities are well-known proxies for the hardness of the radiation field (see Figure 9 of Hao et al. 2009), which is also a function of metallicity (\text{Wu et al.} \ 2006). The galaxies have similar ratios of [Ne iii]/[Ne ii] \sim 1.30 \text{ and [S iv]/[S iii] } \sim 0.35, \text{ and lie between lower excitation starbursts and higher excitation BCDs on a [S iv]/[S iii] versus [Ne iii]/[Ne ii] excitation diagram (Hao et al. 2009), implying a moderately hard radiation field. Using stellar models, Thornley et al. (2000) estimate the hardness of the radiation in starbursts by relating [Ne iii]/[Ne ii] to the ratio of the infrared and Lyman continuum luminosities (L_{IR}/L_{LYC}). Since NGC 1222 and UGC 4274 have higher [Ne iii]/[Ne ii] ratios than the Thornley et al. sample, we extrapolate their results and find 3 \lesssim L_{IR}/L_{LYC} \lesssim 20 \text{ indicating a somewhat lower range than for their more typical starbursts (4 \lesssim L_{IR}/L_{LYC} \lesssim 30). If present in J1206, such hard radiation would cause significant heating of small dust grains and naturally explain the steep continuum in our IRS spectrum. Unfortunately, [Ne iii], [Ne ii], and [S iii] all lie outside of our spectral coverage, preventing definitive confirmation of this hypothesis.}

In J1206, the apparent consistency between metallicity estimates based on rest-frame optical and (via analogy with NGC 1222 and UGC 4274) infrared observations suggests that we are not seeing discrepancies of the sort seen in the most violent local mergers. For ULIRGs, abundances derived from optical line diagnostics (even after careful extinction corrections) are lower than those derived from mid-infrared spectra, likely because the former are depressed by inflows of metal-poor gas from the outskirts of progenitor disks (\text{Rupke et al.} \ 2008) while the latter reflect rapid local enrichment in the most deeply embedded star-forming regions (\text{Veilleux et al.} \ 2009). Metallicities for J1206 appear internally consistent across both obscured and unobscured regions, suggesting a less traumatic recent history that is consistent with the system’s relatively modest far-IR luminosity.

Our conclusions about the implied metallicity and excitation state of J1206 require a certain degree of caution. While in good agreement with optical measurements, our selection of local infrared analogs for J1206 is based mostly on our detection of a single line, [S iv], whose correlations with PAH strength, metallicity, and spectral hardness may be uncertain by 30% or more (\text{Wu et al.} \ 2006; \text{Hao et al.} \ 2009; \text{Hunt et al.} \ 2010). Further, metallicities derived from the optical emission lines in NGC 1222 and UGC 4274 are themselves uncertain by a factor \sim 2.5 (\text{Pettini} \text{ & Pagel} \ 2004). Nevertheless, the consistency (within the measured uncertainties) between the IR spectra of J1206, NGC 1222, and UGC 4274, as well as the optical and IR properties of NGC 1222 and UGC 4274, is encouraging, indicating that the three objects do manifest similar physical conditions. In the future, more robust estimates of the metallicity and excitation properties of J1206 will be possible with measurements of additional emission lines over a wider spectral range.

We can also consider the absence of other emission lines in our IRS spectrum, which shows no significant ionic or molecular features other than [S iv]. In Table 2, we report 3\sigma upper limits on [Ar ii] at 6.99 \mu m, [Ar iii] at 8.99 \mu m, and [Ne v] at 7.65 \mu m. At first glance, it seems surprising we do not detect [Ar ii], given that it is commonly detected in starburst systems (\text{Brandl et al.} \ 2006), including M82 and NGC 253. As discussed above, however, the presence of a rising continuum and [S iv] emission imply higher excitation in J1206 than in average starbursting systems. Given that the ionization potential of [S iv] at 34.8 eV is a factor \sim 2 greater than [Ar ii] at 15.8 eV, [Ar ii] is likely weak because most of the argon is more highly ionized. This effect is seen in BCD galaxies, which are known to exhibit high excitation states (\text{Hao et al.} \ 2009; \text{Hunt et al.} \ 2010). As a consistency check, we note that our upper limit for [Ar iii] (ionization potential: 27.6 eV) implies a ratio of [Ar iii]/[S iv] that is consistent with values seen in local starbursts and BCDs (\text{Brandl et al.} \ 2006; \text{Wu et al.} \ 2006).

In principle, an alternative explanation for the steep continuum and [S iv] emission in J1206 is the presence of an active galactic nucleus (AGN). Indeed, Seyfert 2 galaxies are known to show PAH and [S iv] features, and exhibit strong, rising continua due to heating of small dust grains. To address this concern, we consider the diagnostics of \text{Laurent et al.} (2000) to disentangle starburst versus AGN energetics. Specifically, we use the flux ratio of 6.2 \mu m PAH to 5.1–6.8 \mu m continuum, which is lower (higher) for a larger (smaller) AGN contribution to the infrared luminosity. For J1206, this ratio is 0.66 \pm 0.08, much larger than the \lesssim 0.3 values of AGN-dominated galaxies like NGC 1068 and similar to results for photodissociation region-dominated systems like M82 and NGC 520, which have \lesssim 5% of the emission contributed by an AGN (see Figures 5 and 6 in \text{Laurent et al.}). Reinforcing this conclusion, Seyferts with similar [S iv] and [Ar ii] strengths have 6.2 \mu m PAH EWs that are >2\sigma lower than for J1206 (\text{Gallimore et al.} \ 2010). Finally, J1206 has a ratio [Ne v]/[S iv] < 0.38 (3\sigma), which is lower than that in any Seyfert for which [S iv] is detected (\text{Sturm et al.} \ 2002). We conclude that nuclear activity plays little role in the mid-IR spectrum of J1206.

3.2. SDSS J090122.37+181432.3

Using the reduction procedure outlined in Section 2, we have derived the final rest-frame spectrum for J0901 that is shown in Figure 3(a). Following the same procedure as above, we fit the same starburst templates to the spectrum as in Section 3.1, with the results shown in Table 1. As for J1206, we find that the spectrum is best fit by a scaled version of M82 (\chi^2_{red} = 0.95), less well by NGC 253 or the average starburst template of \text{Brandl et al.} (2006) (\chi^2_{red} = 1.42, 1.26, respectively), and poorly by the other \text{Sturm et al.} templates (\chi^2_{red} > 20). For the NGC 253 and average starburst fits, the higher \chi^2 values originate from the enhanced 9.7 \mu m silicate absorption in J0901, which is not seen in the templates (see Figure 3(b)). In contrast to J1206, J0901 exhibits only weak evidence for additional power-law emission, with fits favoring a component that is negligible or has highly uncertain parameters. Again (as in Section 3.1) exploiting the similarity to the spectrum of M82, and adopting a lens magnification of M \approx 8 (\text{A. West et al.} \ 2010, in preparation),

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8 While such comparisons involve difficulties in continuum definitions (see above), we note that \text{Laurent et al.} and \text{Gallimore et al.} also use comprehensive fits of all relevant mid-IR features to derive their continua, and therefore should have results similar to ours.
we estimate its intrinsic far-IR luminosity to be $3.8 \times 10^{12} L_\odot$, placing it in the ULIRG regime.

As for J1206, we simultaneously fit the spectrum with a combination of continuum and relevant PAH features and atomic emission lines. We find the degree of inferred silicate absorption is degenerate with the contributions of weak PAH emission features to the spectrum. In general, this degeneracy has little effect on the inferred PAH emission, except in the relative contributions of the 11.23 and 11.33 $\mu$m lines to the 11.3 $\mu$m PAH feature. In fact, the 6.2 $\mu$m and blended 7.7 $\mu$m and 11.3 $\mu$m PAH strengths are essentially unaffected. Ultimately, we have opted to use solutions with higher silicate extinction, in agreement with the template fits above. We present the results of this fit in Table 2 and plot the results in Figure 3(c).

The PAH emission in J0901 is strong relative to local starbursts, with EWs of each feature that are a factor $\sim 1.6$–1.9 times larger than the Brandl et al. (2006) average values. The strengths of the 6.2, 7.7, and 11.3 $\mu$m PAH features serve as common diagnostics of the driving mechanism(s) for infrared emission in infrared-luminous galaxies (e.g., Roche et al. 1991; Genzel et al. 1998; Laurent et al. 2000; Imanishi et al. 2007; Veilleux et al. 2009; Hainline et al. 2010). In particular, suppressed PAH emission (especially at shorter wavelengths) is indicative of a significant AGN contribution to the bolometric infrared luminosity. Given the strength of the observed PAH emission, coupled with the shallow continuum, we conclude that accretion plays a small role in the mid-IR properties of J0901. However, Hainline et al. (2009) examined the optical emission line ratios and found values of [O iii]/H$\beta$ and [N ii]/H$\alpha$ indicative of an AGN, consistent with the significant [N v] and weak [S iv] and [C iv] emission seen in the object’s rest-UV spectrum (Diehl et al. 2009).

To assess this apparent contradiction, we consider the expected flux contribution to our mid-IR spectrum by an AGN whose optical properties resemble those of J0901. Specifically, we treat [O iii] 5007 Å emission as a proxy for AGN strength and scale the ISO template of NGC 1068 by the factor required to reduce the integrated [O iii] flux of NGC 1068 (Moustakas & Kennicutt 2006) to the Hainline et al. value. The dotted line in Figure 3(c) shows the corresponding contribution of the scaled NGC 1068 spectrum: roughly 57% and 35% of the continuum flux at 5 and 10 $\mu$m, respectively. This comparison demonstrates that reliance on rest-frame UV/optical measurements alone may provide a bolometrically unrepresentative picture of the physical properties of high-redshift systems.

Finally, we examine our IRS spectrum of J0901 for ionic and molecular emission. Here J0901 is quite unlike J1206, showing [Ar ii] but no [S iv] emission. The EW of [Ar ii] is similar to that in the average starburst spectrum of Brandl et al. (2006) (see Figure 3(b)). As discussed above, [Ar ii] is weaker for systems with high-excitation interstellar media. Therefore, J0901 must be bathed in a softer radiation field than J1206, reinforcing the conclusion that AGN emission plays little role in the IR properties of the system. With our upper limit on [Ar iii] we find $[\text{Ar iii}] / [\text{Ar ii}] < 0.83$, which when combined with the argon excitation versus abundance relation from Verma et al. (2003)
reveals disparate properties. We summarize our conclusions as
of PAH strengths and emission line and continuum diagnostics
empirical template fits, in which both galaxies are well fit by
strength of the PAH emission implies these objects have prop-
erties in line with those of local starbursting galaxies. We find
this similarity to local starburst galaxies is confirmed by our
empirical template fits, in which both galaxies are well fit by
simple, rescaled versions of M82. In detail, however, analysis
of PAH strengths and emission line and continuum diagnostics
reveals disparate properties. We summarize our conclusions as
following.

4. CONCLUSIONS

We have obtained Spitzer/IRS spectra of two $z \sim 2$ UV-
bright star-forming galaxies, that are magnified by strong grav-
itational lensing. At rest wavelengths of $\sim 5$–$12 \mu m$, the spectra
reveal strong PAH emission at 6.2, 7.7, and 11.3 $\mu m$, indicating
that these objects are undergoing intense star formation. The
strength of the PAH emission implies these objects have prop-
erties with two local galaxies with similar mid-IR spectra,
average.

1. In J1206, we find PAH EWs that are factors 1.6–1.9 times larger than the local
average.

2. We detect significant [S iv] emission in J1206. By analogy
with two local galaxies with similar mid-IR spectra,
NGC 1222 and UGC 4274, we infer a sub-solar metallicities
of $\sim 0.5 Z_\odot$, in agreement with the published optical
measurement (Hainline et al. 2009). The consistency of the
optical and infrared metallicity estimates suggests J1206 has
not undergone a recent violent merger. Considering the
[S iv]/[S iii] and [Ne iii]/[Ne ii] ratios of the local objects,
we argue that J1206 is characterized by a moderately hard
radiation field, which naturally explains the steeply rising
continuum and lack of [Ar ii] emission.

3. In J0901, we detect strong PAH emission but no [S iv]
or significant rising continuum. These results indicate that
the mid-IR properties of J0901 are consistent with purely
starburst-driven energetics. This inference contrasts with
the implications of optical spectroscopy, where emission
line ratios show the presence of an AGN; however, scaling from the [O iii]
flux of a local AGN implies the AGN contributes $<57\%$ of the mid-IR continuum. Thus, from its rest-frame UV through IR properties, J0901 likely hosts a
narrow-line AGN whose IR emission is overwhelmed by that of its surrounding starburst. This analysis highlights
the need for future IR studies of high-redshift objects if we
are to determine their physical properties robustly.

4. With the detection of [Ar ii], we are able to put a lower limit
on the metallicity of J0901. Using the argon abundance and excitation relation of Verma et al. (2003), we find
$Z \gtrsim 1.3 Z_\odot$, similar to many local starbursts.

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