THE PHYSICAL SCALE OF THE FAR-INFRARED EMISSION IN THE MOST LUMINOUS SUBMILLIMETER GALAXIES

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ABSTRACT

We present high-resolution submillimeter interferometric imaging of two of the brightest high-redshift submillimeter galaxies known: GN 20 and AzTEC1 at 0.8" and 0.3" resolution, respectively. Our data—the highest resolution submillimeter imaging of high-redshift sources accomplished to date—were collected in three different array configurations: compact, extended, and very extended. We derive angular sizes of 0.6" and 1.0" for GN 20 and 0.3" and 0.4" for AzTEC1 from modeling their visibility functions as a Gaussian and an elliptical disk, respectively. Because both sources are B-band dropouts, they likely lie within a relatively narrow redshift window around \( z \approx 4 \), which indicates their angular extent corresponds to physical scales of 4–8 and 1.5–3 kpc, respectively, for the starburst region. By way of a series of simple assumptions, we find preliminary evidence that these hyperluminous starbursts—with star formation rates \( >1000 M_\odot \, \text{yr}^{-1} \)—are radiating at or close to their Eddington limit. Should future high-resolution observations indicate that these two objects are typical of a population of high-redshift Eddington-limited starbursts, this could have important consequences for models of star formation and feedback in extreme environments.

Subject headings: cosmology: observations — galaxies: evolution — galaxies: formation — galaxies: high-redshift — galaxies: starburst

Online material: color figures

1. INTRODUCTION

Wide area surveys at millimeter (e.g., Greve et al. 2004; Bertoldi et al. 2007; Scott et al. 2008) and submillimeter (e.g., Smail et al. 1997; Hughes et al. 1998; Barger et al. 1998; Pope et al. 2006; Coppin et al. 2006) wavelengths have revealed a large population of ultra- and hyperluminous infrared galaxies (ULIRGs and HyLIRGs, respectively) at high redshift (median \( z \approx 2 \)) for a radio-selected sample (Chapman et al. 2005). Since their initial discovery, it has become clear that these “submillimeter galaxies” (SMGs) are likely massive, gas-rich merging systems (Frayer et al. 1998, 1999; Chapman et al. 2003; Greve et al. 2005; Tacconi et al. 2006, 2008) that represent massive galaxies in formation (Scott et al. 2002; Blain et al. 2004). Extremely luminous infrared objects take on increasing cosmological importance at \( z \approx 1 \) (Sanders & Mirabel 1996; Le Floch et al. 2005) and may dominate cosmic star formation for up to the first half of the lifetime of the universe (Blain et al. 1999, 2002).

Despite significant progress over the past decade, a more complete understanding of SMGs has been hampered in part by the relatively poor resolution of submillimeter cameras (\( \sim 10'' \)–18") FWHM). In particular, the size scale of the starburst region [traced by the rest-frame far-infrared (IR)] potentially provides important insights into the nature of the engine driving the tremendous luminosity of these systems. If they are scaled-up versions of local ULIRGs, we would expect far-IR emission on scales of \( \sim 5–10 \) kpc (e.g., Downes & Solomon 1998; Iono et al. 2007 see also D. Iono et al. 2008, in preparation). Hydrodynamic modeling of merger-driven nuclear starbursts (e.g., Mihos & Hernquist 1994) of the kind thought to drive many SMGs (Chapman et al. 2003; Tacconi et al. 2006, 2008) can be somewhat more compact, a result that could have important physical consequences; Eddington arguments suggest a minimum size scale for such regions (Murray et al. 2005; Thompson et al. 2005). Unfortunately, at typical SMG redshifts, all of these size scales are far smaller than the typical angular resolution of submillimeter cameras on single-dish instruments.

The first breakthrough came with deep radio continuum surveys, which leveraged the local far-IR/radio correlation (Condon 1992) in combination with statistical arguments (Ivison et al. 2002, 2007) to associate faint radio counterparts within the submillimeter beam with SMGs. Higher resolution radio imaging of these sources (Chapman et al. 2004; Biggs & Ivison 2008) found a range of source structures with a median source scale of \( \sim 0.5, 1'' \), which for typical SMG redshifts corresponds to extended starbursts on physical scales of \( \sim 5–7 \) kpc. While promising, this technique assumes a spatially resolved far-IR/radio correlation that is not particularly well understood locally (e.g., Hippelein et al. 2003; Murphy 2006; Tabatabaei et al. 2007). As a consequence, these results are not straightforward to interpret.

This motivates high-resolution imaging of the rest-frame far-IR directly, via submillimeter interferometry. The vast majority of previous work was done at resolutions of \( \sim 1'' \)–2" and found that the far-IR continuum in SMGs originates at physical scales of \( \lesssim 4–8 \) kpc (Neri et al. 2003; Greve et al. 2005; Tacconi et al. 2006; Wang et al. 2007; Younger et al. 2007, 2008; Dannerbauer et al. 2008). More recently, very high resolution CO imaging by Tacconi et al. (2008) showed that gas motions in typical SMGs are disordered on scales of \( \sim 1–2 \) kpc, suggesting that they are ongoing major mergers.

In this paper, we present high-resolution (beam size \( \sim 1'' \) 890 \( \mu \)m continuum imaging of two of the brightest SMGs known—GN 20
(Pope et al. 2006; Iono et al. 2006) and AzTEC1 (Younger et al. 2007; Scott et al. 2008)—with the Submillimeter Array (SMA; Ho et al. 2004). By targeting the brightest (and therefore likely the most luminous; Blain & Longair 1993) objects, we constrain the physical scale of the far-IR in extreme conditions. In addition, since these objects are thought to lie at higher redshift than radio-selected samples (Younger et al. 2007), they offer an intriguing probe of the nature of star formation at earlier epochs.

2. OBSERVATIONS AND DATA REDUCTION

The two targets were GN 20, the brightest 850 μm source in the Submillimeter Common User Bolometric Array (SCUBA; Holland et al. 1999) survey of the Hubble Deep Field—North (HDF-N; see Pope et al. 2006), and AzTEC1, the brightest 1.1 mm source in the AzTEC (Wilson et al. 2008) survey of the COSMOS field (Scott et al. 2008). Both were previously detected as single point-sources with flux densities of $F_{850}$ = 22.9 ± 2.8 (Iono et al. 2006) and 15.6 ± 1.1 mJy (Younger et al. 2007), respectively, with the SMA in compact configuration (COM). We have reobserved both these targets with the SMA in extended configuration (EXT), which provides a ~threefold improvement in angular resolution over COM, using the same pointing center as the COM tracks. The EXT tracks (two for GN 20, one for AzTEC1) were taken in excellent weather in 2008 January and February. Since AzTEC1 was unresolved in the EXT track (see §3 and Fig. 3), we reobserved it in very extended configuration (VEX) in 2008 April, which provided a further ~threefold improvement in angular resolution. For details on the tracks, configurations ($u-v$ range, beam size, etc.), and observing conditions, see Figure 1 and Table 1.

The receiver was tuned to 345 GHz in the USB and averaged with the LSB for an effective bandwidth of 4 GHz centered at 340 GHz. For GN 20, passband calibration was done using 3C 273 and 1921−293, and primary flux calibration was done using Titan. The target was observed on a 10 minute cycle (5 minutes on source, 5 minutes on calibrators) with two primary gain calibrators: 1048+717 (~0.3 Jy; 14′ away) and 1153+495 (~0.3 Jy; 14′ away). For AzTEC1, passband calibration was done using 3C 111 and 3C 273, and primary flux calibration was done using Ceres. As with GN 20, the target was observed on a 10 minute cycle with two primary gain calibrators: 1058+015 (~2 Jy; 15′ away) and 0854+201 (~2 Jy; 24′ away). Because Ceres is known to be variable at the ~20%−30% level due to rotation (Altenhoff et al. 1994; Redman et al. 1998; Barrera-Pineda et al. 2005), we confirm this flux scale by checking that the flux density for 0854+201 derived from this track ($F_{340}$ = 2.37 Jy) is consistent to that measured 1 day earlier ($F_{340}$ = 2.29 ± 0.12 Jy) for which Titan was the primary flux calibrator.

In addition to the two primary targets, we observed a nearby test quasar once every 60 minutes throughout the track to empirically verify the phase transfer and inferred source structure and to estimate the systematic positional uncertainty. The test quasars for

![Fig. 1.—The $u-v$ coverage for our high-resolution interferometric imaging of GN 20 (left) and AzTEC1 (right). Included are all tracks in three different SMA configurations: compact (COM: black), extended (EXT: blue), and very extended (VEX: red). For further details, including weather conditions and on-source integration times, see Table 1. [See the electronic edition of the Journal for a color version of this figure.]

| Target     | Configuration | $u-v$ Coverage (kλ) | Beam Size (arcsec) | Date (dd.mm.yy) | $\nu_{\text{center}}$ (GHz) | Obs. Time (hr) | Reference |
|------------|---------------|---------------------|--------------------|-----------------|-----------------------------|----------------|-----------|
| GN 20      | COM           | 15−75               | 2.99 × 2.26        | 20.02.05, 05.03.05 | 0.04, 0.06                 | 10.4           | I06       |
|            | EXT           | 40−200              | 0.81 × 0.75        | 10.02.08, 11.02.08 | 0.04, 0.04                 | 5.3            | This work |
| AzTEC1     | COM           | 20−75               | 2.69 × 2.19        | 17.01.07        | 0.05                       | 5.6            | Y07       |
|            | EXT           | 50−250              | 0.86 × 0.55        | 16.01.08        | 0.03                       | 4.0            | This work |
|            | VEX           | 60−550              | 0.25 × 0.35        | 05.04.08        | 0.03                       | 3.4            | This work |

* Total on-source integration time in that configuration.

b | I06: Iono et al. (2006); Y07: Younger et al. (2007).
GN 20 and AzTEC1 were J1302+578 (~0.1 Jy; 5.5” away) and J1008+063 (~0.2 Jy; 5” away), respectively. Both are included in both the JVAS (Patnaik et al. 1992; Browne et al. 1998) and VLBA Calibrator (Ma et al. 1998; Beasley et al. 2002) surveys of compact, flat-spectrum radio sources, and have absolute positions known to better than 20 mas.

For the VEX track on AzTEC1, time-dependent gain calibration derived from 1058+015 left clear, slow, residual phase variations on 0854+201 (and J1008+063) due to uncertainties in the baseline parameters or other limitations of the SMA interferometer model. To improve the phase transfer and prevent decorrelation, an additional gain calibration was performed using J1008+063, just 4” away from AzTEC1 in declination, since conditions were good enough to yield sufficient signal-to-noise ratio (>10σ) in each of the hourly scans on this source. This additional step minimized the phase errors owing to baseline effects in the calibrated visibilities. Remaining phase fluctuations dominated by the atmospheric effects on short timescales left an effective seeing size scale of ~0.08” in J1008+063 (see § 3 and Fig. 4 for further discussion).

We also make use of extensive multiwavelength data in both fields. For the HDFN, this includes HSTACS B-, V-, i-, and z-band optical (Giavalisco et al. 2004a), IRAC 3.6–8.0 μm and MIPS 24 μm (Dickinson et al. 2003), and VLA 20 cm (Biggs & Ivison 2006) imaging data. For the COSMOS field (see Scoville et al. 2007 for an overview), this includes Subaru ground-based optical (Tanguchi et al. 2007), HSTACS i-band (Koekemoer et al. 2007), IRAC 3.6–8 μm and MIPS 24 μm (Sanders et al. 2007), and VLA 20 cm (Schinnerer et al. 2007) imaging.

3. RESULTS

Both targets were detected at high significance by the SMA in EXT configuration with a ~0.75” beam. The maps, along with overlays on multiwavelength imaging data, are presented in Figure 2. Source structure derived from the calibrated visibilities, which show flux density as a function of decreasing angular scale, and the empirical verification of phase transfer are summarized in Figures 3 and 4 and in Table 2.

GN 20 shows evidence of being partially resolved by the SMA in EXT configuration, with a characteristic angular scale of ~0.5”–1.2” (see Fig. 3 and Table 2) as inferred from modeling its visibility as both a Gaussian and elliptical disk. Its submillimeter position is coincident with a bright IRAC 3.6–8 μm and faint MIPS 24 μm (F_{24 μm} ~ 70 μJy; Pope et al. 2006) source, and a radio source (F_{20 cm} = 57 ± 10 μJy; ~0.5” away). The SMA map is also consistent with the radio morphology, which shows some evidence of being resolved along its major axis with a beam size of 1.5” × 1.5” (Biggs & Ivison 2006). High-resolution (0.08” PSF) ACS imaging shows that the submillimeter detection is not coincident with the nearby optical “smudge.” However, since this source is a B-band dropout, which suggests a redshift range consistent with the observed radio-to-submillimeter (see Carilli & Yun 1999; Yun & Carilli 2002) and 24 μm-to-submillimeter (see Wang et al. 2007; Younger et al. 2007) flux density ratios of GN 20 (see § 4), it is plausible that this object is physically associated with GN 20 and represents a region of lower dust opacity.

AzTEC1 is not resolved by the SMA in EXT configuration; its visibility function is flat out to ~250 kλ, which suggests a characteristic angular scale of ~0.5” (see Fig. 3). The inferred flux density from the EXT track (F_{890 μm} = 13.8 ± 2.3) is furthermore consistent with that from the COM track (F_{890 μm} = 15.6 ± 1.1 mJy; Younger et al. 2007). The EXT detection is coincident with its compact i-band counterpart in ACS imaging, a faint IRAC 3.6–8 μm source (Younger et al. 2007), and roughly so with the radio counterpart (F_{20 cm} = 40 ± 13 μJy; ~0.4” away) to within the uncertainties. Although Figure 2 appears to show a potentially significant offset between the radio and SMA positions, this is roughly with in the total uncertainty in the measurement of...
their relative position.\textsuperscript{6} It is not detected in the deep COSMOS 24 $\mu$m imaging (Younger et al. 2007). The submillimeter size of AzTEC1 is also consistent with its 20 cm counterpart, which is compact compared to the $1.5'' \times 1.4''$ VLA beam. As with GN 20, the optical counterpart is a B-band dropout, which suggests a redshift range consistent with the observed radio-to-submillimeter and 24 $\mu$m-to-submillimeter ratios (Younger et al. 2007).

The visibility functions for AzTEC1 and J1008+063 derived from the VEX track are shown in Figure 4. Some decorrelation on longer baselines (likely the result of residual baseline errors in combination with atmospheric effects) results in artificial structure in the visibility function of J1008+063. A Gaussian fit to this visibility data yields a source size of $(0.09'' \pm 0.02'') \times (0.07'' \pm 0.02'')$, which describes the effective seeing size for the track and thus the minimum source size that is meaningfully probed by these observations. The visibility function for AzTEC1 shows some marginal evidence of being resolved on scales significantly larger than this lower limit; a Gaussian fit to this visibility data yields a total flux of $16.0 \pm 5.0$ mJy (consistent with the COM, EXT, and COM+EXT fits) with a size of $(0.30'' \pm 0.15'') \times (0.20'' \pm 0.10'')$. Fixing the total flux to the value derived from the COM+EXT data marginally improves this size measurement to $(0.29'' \pm 0.13'') \times (0.18'' \pm 0.10'')$. While the statistical uncertainty in the position measurement for AzTEC1 also improves to $\sim 0.04''$ in both $\alpha$ and $\delta$, because we calibrate using J1008+063 to remove baseline errors, it is exactly at the phase center and therefore does not provide an estimate of the systematic positional uncertainty. Therefore, we quote the position and flux derived from the COM+EXT tracks in Table 2.

4. DISCUSSION

The robust result of these observations is that the far-IR emission in both GN 20 and AzTEC1 is small considering the
very high luminosity of these systems but is clearly extended on \( \sim \)kiloparsec scales. This is suggestive of mergers as the physical mechanism driving the bolometric luminosity of these systems (Mihos & Hernquist 1994; Hopkins et al. 2006). However, in general, and in particular for the case of AzTEC1, this does not require that the far-IR luminosity is contributed only by the starburst. Indeed, a significant fraction of the far-IR could arise from a dusty torus associated with an active nucleus, which is generated on significantly smaller scales (e.g., Urry & Padovani 1995). Ideally, one would like significantly improved resolution continuum imaging and resolved gas kinematics via molecular spectroscopy to constrain the structure of these sources and dynamical state of the star-forming gas in detail, measurements that are beyond the capabilities of current facilities (e.g., SMA, CARMA, PdBI) but in the near-term future will likely be accomplished with relative ease by ALMA. Nevertheless, if we assume that GN 20 and AzTEC1 are starburst-dominated (as the typical SMG is thought to be; Alexander et al. 2005, 2008) and make a series of admittedly crude but arguably reasonable assumptions about their morphology and kinematics, we find a preliminary indication that they may be radiating close to or at the Eddington limit of their starburst.

It has been suggested that feedback from ongoing star formation sets a physical limit on the minimum size of a star-forming region (Elmegreen 1999; Murray et al. 2005; Thompson et al. 2005; Socrates et al. 2008). Owing to the significant opacity of dust to the ultraviolet light produced by young stars, radiation pressure from high-luminosity star formation regions can produce strong momentum-driven winds (e.g., Netzer & Elitzur 1993; Elitzur & Ivezić 2001). These winds are confined by the gravitational potential, which for an isothermal sphere scales as \( \Phi \sim f_g \sigma^2 \log D \), where \( f_g \) is the gas fraction, \( \sigma \) is the stellar velocity dispersion, and

### TABLE 2

| Name          | Config. | Model | \( \alpha \) | \( \delta \) | \( \Delta \alpha \) | \( \Delta \beta \) | \( F_{100\mu m} \) | \( \theta_{maj} \) | \( \theta_{min} \) | Position Angle |
|---------------|---------|-------|--------------|-------------|-----------------|-----------------|----------------|----------------|----------------|----------------|
| GN 20         | C       | Point | 12 37 11.920 | +62 22 12.17 | 0.10 e          | 0.10 e          | 22.9 ± 2.8     | ...            | ...            | ...            |
|               | E       | Gaussian | 12 37 11.898 | +62 22 12.14 | 0.06 0.09       | 26.9 ± 5.1     | 0.8 ± 0.2      | 0.5 ± 0.2      | 15             |
|               | C+E     | Gaussian | 12 37 11.903 | +62 22 12.16 | 0.06 0.09       | 23.9 ± 2.6     | 0.8 ± 0.2      | 0.3 ± 0.3      | 35             |
| AzTEC1        | C       | Point | 09 59 42.859 | +02 29 38.21 | 0.11 0.20       | 15.6 ± 1.1     | ...            | ...            | ...            |
|               | E       | Gaussian | 09 59 42.863 | +02 29 38.19 | 0.07 0.07       | 13.8 ± 2.3     | ...            | ...            | ...            |
|               | C+E     | Point | 09 59 42.863 | +02 29 38.19 | 0.05 0.06       | 15.1 ± 1.1     | ...            | ...            | ...            |
|               | V        | Gaussian | 09 59 42.863 | +02 29 38.20 | 0.04 0.06       | 15.1 ± 1.1     | ~0.3           | ~0.4           | 40             |
|               | V        | Disk    | 09 59 42.863 | +02 29 38.20 | 0.04 0.06       | 15.1 ± 1.1     | ~0.3           | ~0.4           | 25             |

Note.—Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds.

\( a \)

Data restricted to this combination of configurations: COM (C), EXT (E), and VEX (V). See Table 1 and Fig. 1 for details.

\( b \)

Combined statistical and systematic uncertainty, where the systematic uncertainty is estimated from the position of the test quasar.

\( c \)

\( \theta_{maj} \) and \( \theta_{min} \) represent the FWHM or diameter of the major and minor axes for the Gaussian and elliptical disk models, respectively.

\( d \)

Position angle.

\( e \)

Since there was no test quasar available for this track, these are just the statistical positional uncertainties from Iono et al. (2006).
For this range, the angular diameter distance is roughly constant both the optical and far-IR SEDs of AzTEC1 independently yield interpretation (Younger et al. 2007). Furthermore, template fitting to similar to Arp 220) are consistent with this higher redshift (arising from redshifted (e.g., Stevens et al. 2005; Huang et al. 2007).

Example, if we assume a Mrk 231 template with significant AGN contribution to the starburst on this scale, with SFR max \( \approx 1 \), the corresponding Eddington limits for each source model are SFR max, G \( \approx 6300 \) and SFR max, D \( \approx 3600 \) M\(_\odot\) yr\(^{-1}\). This very luminous SMG is close to or at the Eddington limit for a starburst on those scales. It is also interesting to note that this size scale is somewhat extended compared to a simple \( R \sim L^{1/2} \) (for a disk geometry) or \( R \sim L^{1/3} \) (for a spherical geometry) scaling of the starburst size of local ULIRGs (e.g., Downes & Solomon 1998; Iono et al. 2007; see also D. Iono et al. 2008, in preparation).

AtzC1 has a far-IR luminosity\(^8\) of \( L_{\text{FIR}}(\text{AtzC1}) \approx 3 \times 10^{13} \) L\(_\odot\) and SFR(AtzC1) \( \approx 5000 \) M\(_\odot\) yr\(^{-1}\) on a characteristic physical scale of \( L_{\text{c}}(\text{AtzC1}) \approx 1.5 \) and \( L_{\text{c}}(\text{AtzC1}) \approx 2.5 \) kpc for a Gaussian and elliptical disk model, respectively. Adopting \( \sigma_{400} = 1 \), this is significantly larger than the Eddington limit for a starburst on this scale, with SFR max, G \( \approx 1350 \) and SFR max, D \( \approx 2250 \) M\(_\odot\) yr\(^{-1}\). Increasing the dust opacity only aggravates the situation. However, some SMGs have been observed with \( \sigma_{400} \sim 1.5-2 \), which could explain the discrepancy. However, under the assumption that the far-IR luminosity is dominated by a starburst component, even at high-velocity dispersion AtzC1 is close to its Eddington limit.

If the volume filling factor of dense molecular gas is close to unity, and therefore the star-forming gas is optically thick, then (again assuming a Salpeter 1955 IMF) the Eddington limit (Murray et al. 2005) on the star formation rate is

\[
SFR_{\text{max, thick}} = \frac{4\pi c^2}{G} \sigma^4 \approx 10^5 \rho_g 0.5 \sigma_{400}^4 M_\odot \text{yr}^{-1},
\]

where \( \rho_g \) is the gas mass fraction in units of 0.5. This is an order of magnitude higher than the SFR of GN 20 and AzTEC1. However, in the optically thick limit, the dust temperature \( T_d \) and brightness temperature \( T_b \) [defined as \( I_v = B_v(T_b) \), where \( I_v \) is the surface brightness and \( B_v \) is the Planck function] are equivalent.

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\(^7\) Using a Kroupa (2001) or Chabrier (2003) IMF will tend to lower SFR max by \( \sim 40\% \) (Kennicutt 1998; Bell 2003; Bell et al. 2005).

\(^8\) The inferred luminosity is known to be uncertain by a factor of \( \sim 2-3 \) due to variations in the dust temperature and emissivity (e.g., Blain et al. 2003).

\(^9\) This differs from the luminosity implied by Fig. 3 of Younger et al. (2007) because it is derived from the far-IR directly, not from the near-infrared.
The implied angular diameter $\theta$ of both GN 20 and AzTEC1 for a given brightness temperature at cosmological redshift $(T_b/(1+z))$ is shown in Figure 5. For GN 20, characteristic angular scale inferred from a Gaussian and disk model yield $T_b \approx 6(1+z)$ and $4(1+z) \, \text{K}$, respectively, which at $z \approx 4$ suggests $T_b \approx 30$ or 20. For AzTEC1, these models yield $T_b \approx 8(1+z)$ and $6(1+z) \, \text{K}$, which at $z \approx 4$ gives $T_b \approx 40$ and 30 $\text{K}$. These are all somewhat lower than would be expected from the temperature-luminosity relation at low (Dunne et al. 2000; Klaas et al. 2001; Yang & Phillips 2007), intermediate (Yang et al. 2007), and high redshift (Blain et al. 2003; Chapman et al. 2005; Kovács et al. 2006).

However, the brightness temperature represents a lower limit, as the inferred dust temperature will increase as the opacity $\tau$ decreases [i.e., $T_d = T_b(1+z)/[(1 - e^{-\tau})]$ or if the volume filling factor of optically thick clouds is less than unity. There is evidence that in the cores of local ULIRGs $\tau(100 \mu \text{m}) \lesssim 1$ for $\lambda \lesssim 100 \mu \text{m}$ (Solomon et al. 1997), and that the volume filling factor of dense molecular gas is $\approx 30\%-70\%$ (Downes et al. 1993). By analogy, it is plausible that GN 20 and AzTEC1 are intermediate between the optically thick and optically thin regimes. Future observations at shorter wavelengths (e.g., at $350 \mu \text{m}$ with SHARC-II; Dowell et al. 2003) could constrain $T_d$ independently and thus help determine the appropriate limit.

Furthermore, our $u-v$ coverage does not exclude a multi-component structure for either GN 20 or AzTEC1, in particular one with two compact point sources. The results of a fit to the calibrated visibilities for this model are summarized in Table 3. These angular offsets correspond to a physical separation of $4$ and $2$ kpc for GN 20 and AzTEC1, respectively, which are consistent with dual nuclear starbursts in a late stage merger (e.g., Mihos & Hernquist 1994; Hopkins et al. 2006). Should higher resolution data from either the SMA or ALMA confirm this interpretation, it is possible that each of these components is at or close to its Eddington limit with $\sigma_{400} \gtrsim 2$.

5. CONCLUSION

We present high-resolution interferometric submillimeter imaging of two of the brightest (and therefore likely most luminous; Blain & Longair 1993) high-redshift starburst galaxies known—GN 20 and AzTEC1. The visibility functions for these sources indicate characteristic angular sizes of $\sim 0.5-1.2$ and $\sim 0.2-0.4''$, respectively. Both are $B$-band dropout optical sources, which indicates a redshift of $3.5 \lesssim z \lesssim 4.5$, and thus these angular size measurement correspond to physical scales of $4-8$ and $1.5-3$ kpc. Assuming a simple morphology and a dynamical state typical of high-redshift SMGs, we find preliminary evidence that GN 20 and AzTEC1 are both close to the limiting luminosity derived via Eddington arguments. If these two sources are indicative of a large population of hyperluminous starbursts at high redshift, this may have important consequences for models of star formation and feedback in extreme environments.

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Facilities: SMA, JCMT, Spitzer (IRAC, MIPS), HST (ACS), Subaru (Suprime-Cam), VLA

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