INFRARED EMISSION FROM THE NEARBY COOL CORE CLUSTER ABELL 2597

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ABSTRACT

We observed the brightest central galaxy (BCG) in the nearby \( z = 0.0821 \) cool core galaxy cluster Abell 2597 with the IRAC and MIPS instruments on board the Spitzer Space Telescope. The BCG was clearly detected in all Spitzer bandpasses, including the 70 and 160 \( \mu \)m wave bands. We report aperture photometry of the BCG. The spectral energy distribution exhibits a clear excess in the far-IR over a Rayleigh-Jeans stellar tail, indicating a star formation rate of \( \sim 4 - 5 \ M_\odot \ yr^{-1} \), consistent with the estimates from the UV and its H\(_\alpha\) luminosity. This large far-IR luminosity is consistent with that of a starburst or a luminous infrared galaxy, but together with a very massive and old population of stars that dominate the energy output of the galaxy. If the dust is at one temperature, the ratio of 70 to 160 \( \mu \)m fluxes indicates that the dust emitting mid-IR in this source is somewhat hotter than the dust emitting mid-IR in two BCGs at higher redshift (\( z \sim 0.2 - 0.3 \)) and higher far-IR luminosities observed earlier by Spitzer in clusters Abell 1835 and Zwicky 3146.

1 INTRODUCTION

The brightest cluster galaxies (BCGs) in the cores of the most X-ray-luminous clusters of galaxies are the most massive galaxies in the universe. Their unusually extended stellar envelopes, high optical luminosities, and red colors pose a challenge to models of galaxy formation, which, conversely, predict that the brightest cluster galaxies should be even more luminous than observed and should be blue, not red (Binney 2004). According to such models, galaxies at the centers of clusters should be highly luminous and blue because supernova feedback is unable to prevent runaway cooling, condensation, and star formation in the gas at the center of a cluster. However, even though the galaxies at the centers of X-ray-luminous clusters are red, Multiband Imaging Photometer for Spitzer (MIPS) imaging of moderate-redshift (\( z \sim 0.2 - 0.3 \)) clusters with cool cores and large H\(_\alpha\) luminosities has revealed that they can still be surprisingly luminous infrared sources, \( \sim 10^{44} - 10^{45} \) ergs s\(^{-1}\) (Egami et al. 2006b). Their mid-infrared luminosity turns out to be \( \sim 0.1\% - 1\% \) times the total X-ray luminosity from the hot intracluster medium (ICM), and puts these galaxies in the same luminosity class as LIRGs (luminous infrared galaxies.)

Historically, clusters in which the central gas radiates enough energy to cool and condense within a Hubble time have been categorized as cooling flow clusters. Such clusters exhibit highly peaked X-ray fluxes and, usually, ICM temperature gradients that decrease into the cluster core. Cool core clusters are rather common at \( z < 0.4 \), accounting for \( \sim 50\% \) of the X-ray-luminous population, indicating that this phase is not short-lived. Yet, the central gas in these clusters does not appear to be cooling and condensing at the rates implied by naive interpretations of X-ray imaging data, which could exceed 100 \( M_\odot \ yr^{-1} \). Central star formation rates are much lower than this, and the central galaxies do not appear to contain the \( \sim 10^{12} \ M_\odot \) of cold gas that should have collected over a Hubble time (e.g., Fabian 1994). This was the notorious “cooling flow” problem: How can these systems be so common, when there is no obvious source of heat to replenish the energy these systems radiate so quickly?

High-resolution X-ray spectroscopy has given the cooling flow problem an additional twist by showing that most of the X-ray gas with a short cooling time does not even cool below 10\(^7\) K (e.g., Peterson et al. 2001). Hot gas is detected at a range of temperatures down to \( \sim \) one-third of the virial temperature but does not appear to emit at lower temperatures. This result confirms that the gas condensation rates in these systems are not very large but does not explain what suppresses cooling. Recent Chandra X-ray observations have suggested that active galactic nucleus (AGN) feedback might be what inhibits cooling in cluster cores, because some (but not all) cooling flow clusters host central AGNs that excavate kiloparsec-scale cavities in the ICM (e.g., McNamara et al. 2001a). Still more clusters exhibit elevated central entropy levels that may have been produced by a now inactive AGN (Donahue et al. 2005, 2006). There is increasing support for the idea that the central AGN is the culprit providing the “extra” heating, not only countering radiative cooling in cluster cores, but also providing a self-regulating feedback mechanism in massive galaxies in general (e.g., Best et al. 2006). These observations and theories have sparked a renewed interest in the role of AGNs in the formation of galaxies, and in particular, their role in heating the ICM and stifling star formation.

Interestingly, the mechanism that counteracts uninhibited radiative cooling in cluster cores does not appear to shut off star formation altogether. Cooler gas is not completely absent in the central galaxies, a few of which have substantial quantities (\( \sim 10^{10} - 10^{11} \ M_\odot \)) of molecular gas at a range of temperatures.
Extended, vibrationally excited H$_2$ 2 $\mu$m emission lines have been detected in these sources (Elston & Maloney 1994; Jaffe et al. 2001; Egami et al. 2006a), and about $10^{10} - 10^{11}$ $M_\odot$ of cold molecular hydrogen has been inferred from CO observations in many of these systems (e.g., Edge 2001a; Edge & Frayer 2003; Salomé et al. 2006). If some of the ICM cools and forms stars, that could explain why most cool core systems exhibit luminous optical emission-line nebulae, which in turn nearly always accompany the presence of molecular gas. Such nebulae produce bright H$_{\alpha}$ and forbidden line emission (Heckman et al. 1989a). Emission-line spectroscopy suggests that at least some of the emission can be explained as the result of photoionization and heating by hot stars (Voit & Donahue 1997a). Tantalizing possible detections by FUSE of million degree gas, via O vi emission, suggest that at least some of the gas does cool below X-ray-emitting temperatures (Oegerle et al. 2001; Bregman et al. 2006). However, the interpretation of such spectra is complicated, sometimes by the presence of a low-luminosity AGN, and possibly by slow shocks or heating by cosmic rays or local X-rays.

In this paper we present Spitzer observations of mid-infrared emission from the BCG in Abell 2597, a nearby cool-core cluster, that address an important question about the cool-core phenomenon: what is the dusty star formation rate in this cluster? These data also stimulate new questions about the star formation in BCGs: (1) Is the infrared emission from a BCG in a cool-core cluster typical of a starburst in a spiral galaxy? (2) Is the dust spectrum characteristic of relatively unprocessed Milky Way-type dust that has been transported to the center of the BCG during a merger, or is it consistent with the dust having been recently exposed to the harsh environment of the intracluster medium? (3) If a modest amount of gas is condensing from the ICM, is the condensation rate consistent with the observed star formation activity and molecular gas content? Our Spitzer observations show that the IR spectrum of this BCG is fairly typical of a normal starburst, with a far-IR peak at $\sim 70$ $\mu$m and a mid-IR excess consistent with emission from polycyclic aromatic hydrocarbons (PAHs). The star formation rate implied by the IR and UV emission from this galaxy are also consistent with observational limits on the cooling and condensation rate of gas from the central ICM. In our analysis we assume $H_\alpha = 70$ km s$^{-1}$ Mpc$^{-1}$, $\Omega_M = 0.3$, and $\Omega_\Lambda = 0.7$ cosmology. At the redshift of the BCG in Abell 2597 ($z = 0.0821 \pm 0.0002$; Voit & Donahue 1997b) the scale is 1.551 kpc arcsec$^{-1}$.

2. THE BRIGHTEST CLUSTER GALAXY IN ABELL 2597

The brightest cluster galaxy in Abell 2597 (Abell richness class 0) contains a well-studied FR I radio source, PKS 2322-12, and is conveniently positioned in region of the sky with very low Galactic extinction ($A_B = 0.131$ mag; Schlegel et al. [1998], confirmed by Barnes & Nulsen [2003]). The optical spectrum of the central galaxy was studied intensively by Voit & Donahue (1997b), who placed the first model-independent reddening, temperature, and metallicity constraints on a cluster emission-line nebula using faint forbidden lines. They also determined that the excitation mechanism of the emission lines could not be shocks. The preferred excitation source was stars, plus an additional, unidentified, source of heat. This conclusion was supported by analysis of the infrared emission line spectrum of Paschen alpha lines and vibrationally excited H$_2$ (Jaffe et al. 2005). One slight difference between these analyses is that the Voit & Donahue (1997b) study also placed limits on the UV spectral shape, from the lack of a measurable He ii recombination line.

Cardiel et al. (1998) found radial gradients in the 4000 Å break and Mg$_2$ indices of Abell 2597’s BCG, indicating recent (0.1 Gyr) star formation. McNamara et al. (1999) found that its U-band light is unlikely to be from scattered AGN light, based on polarization limits on the continuum. Most recently, it has been studied in the far-UV using Hubble Space Telescope STIS observations (O’Dea et al. 2004) and WFPC2 blue and emission-line images (Koekemoer et al. 1999). Vibrationally excited molecular hydrogen was discovered to trace the same features as the optical emission lines by Donahue et al. (2000). The Chandra X-Ray Observatory has revealed two-sided radio bubbles, surrounded by hot ICM (McNamara et al. 2001b). This BCG also has one of the most convincing FUSE detections of O vi (Oegerle et al. 2001). Further, $\sim 4 \times 10^7 M_\odot$ of cold H$_2$ has been inferred from CO detections (Edge 2001b).

The most recent X-ray observations of Abell 2597 are from a 120 ks XMM-Newton observation. Analysis of both EPIC and RGS spectroscopy by Morris & Fabian (2005) suggests a classical cooling flow at the level of $90 \pm 15 M_\odot$ yr$^{-1}$ in the central region, dropping to about $20 M_\odot$ yr$^{-1}$ in the central 40 kpc surrounding the BCG. This result is based on the joint analysis of vanishingly weak ($\sim 1 - 2 \sigma$) Fe xvi features in the RGS and the extremely difficult interpretation of soft X-ray excess in the CCD spectrum. While this result at best is only suggestive of cooling, it makes the BCG in Abell 2597 the only source with published emission-line detections from gas at $10^5 - 10^7$ K, suggesting a possible connection between condensation from the hot gas and star formation.

3. OBSERVATIONS AND DATA REDUCTION

3.1. Infrared Array Camera

The Infrared Array Camera (IRAC) has four wavelength channels, 3.6, 4.5, 5.8, and 8 $\mu$m (Fazio et al. 2004). The Astronomical Observing Request (AOR) number for the IRAC observation was 13372160. The total observing time with all four detectors available for IRAC was 270 minutes. Each frame was 100 s. Thirty-six positions were dithered for a total of 3600 s per bandpass.

We have used the flux-calibrated images from the Spitzer Science Center (SSC) IRAC pipeline (software ver. S14.0.0) for our analysis. The standard pipeline subtracts dark current based on laboratory measurements and a dark-sky frame based on observations of the darkest, star-free parts of the sky. A flat field, based on observations of zodiacal background and cleaned of cosmic rays, is then divided out of the data. Finally, the data are flux calibrated, producing images with flux units of MJy sr$^{-1}$.

See the IRAC data handbook and the IRAC calibration paper of Reach et al. (2005) for more detail.

3.2. Multiband Imaging Photometer

The Multiband Imaging Photometer has three bands, with weighted wavelength averages of 23.68, 71.42, and 155.9 $\mu$m. For convenience, we will refer to these bands as 24, 70, and 160 $\mu$m. The FWHM of the point-spread function in those bands is $6''$, $18''$, and $40''$, respectively. Our total observing time with the MIPS was 36 minutes (total exposure time of 10 s pixel$^{-1}$ at 24 $\mu$m and 15 s pixel$^{-1}$ for 70 and 160 $\mu$m each). The AOR number for the MIPS observation was 13371904.

We used the standard SSC pipeline processing (software version S14.4.0) of the 24, 70, and 160 $\mu$m data. We investigated whether the 70 and 160 $\mu$m data would benefit from additional work. We reprocessed the raw 70 and 160 $\mu$m data with the GeRT software package, following the algorithms derived by the MIPS

9 See http://ssc.spitzer.caltech.edu/irac/dh.
10 GeRT is available from the SSC at http://ssc.spitzer.caltech.edu/mips/gert.
Instrument Team and the MIPS Instrument Support team (Gordon et al. 2005). We time-filtered the resulting 70 μm basic data by subtracting a smoothed version of the signal obtained with a boxcar median filter of 30 frames. This procedure subtracts the residual time-variations of the response. We then used the MOPEX package\textsuperscript{11} to co-add the filtered images. In Figure 1 we show the GeRT-filtered 70 μm image side by side with the standard pipeline image. Here we note that there is some evidence for a faint extended region in the filtered data. However, since this region is aligned with the higher noise streak in the pipeline image, subtracted from the GeRT data, and since a mosaic of the individual pipeline-filtered exposures does not show this feature, we do not make strong claims about its reality.

We reduced the 160 μm data in a very similar way, using GeRT. However, since there are very few pixels and the central source is marginally extended in an odd wedge-shape, additional filtering in the time domain did not result in significantly cleaner 160 μm images. The exclusion of individual images taken directly after the periodic “stim” images had no effect on the final product. The MOPEX package was used to combine the 160 μm basic calibration products.

3.3. Data Analysis

We measured the flux in all seven wave bands within a circular aperture of \( r = 25'' \) (~39 h\textsuperscript{−1} kpc), centered on the coordinates \( \alpha = 351.33199 \) and \( \delta = -12.124612 \) (J2000.0; R.A. = 23\textdegree 25\textquoteright 19.6\arcsec, decl. = -12° 07′ 29″). The background was estimated from pixels in an annulus between 38.5″ and 42.5″ from the center. We also measured the flux in a larger aperture \( (r = 35'') \) for the MIPS 70 and 160 μm images. A histogram of the background values was fit to a Gaussian initially centered on the median background per pixel. The mean background value was subtracted from the aperture flux. The net fluxes were averaged and multiplied by the aperture sky area in steradians to yield the flux in janskys. No aperture correction was required for the IRAC photometry.

Since the MIPS images are nearly point sources, we used the APEX package to fit point response functions (PRFs) and obtain total fluxes for the MIPS. For comparison, we report both the large aperture flux and the PRF flux for each band. We obtain reasonable agreement except in the case of the 160 μm aperture flux, for which the aperture correction, even at \( r = 35'' \) we estimate to be ~1.5, based on the convolution of the standard PRF with the source. The IRAC flux uncertainties are ~5%. The color terms at 3.6 and 4.5 μm are unlikely to be significant; however, if the spectrum is dominated by PAHs at 5.8 and 8 μm, the color-term corrections could be significant, up to ~50%. MIPS absolute flux uncertainties are 10% at 24 μm and 20% at 70 and 160 μm. We report raw and corrected aperture fluxes in Table 1.

We extracted photometry for this galaxy from the Two Micron All Sky Survey (2MASS) extended source catalog (Jarrett et al. 2000)\textsuperscript{12} in \( J, H, \) and \( K \) infrared bands. Absolute photometric

\textsuperscript{11} MOPEX: MOsaicking and Point source EXtraction, available from the SSC at http://ssc.spitzer.caltech.edu/postbcd/download-mopex.html.

\textsuperscript{12} Described in http://spider.ipac.caltech.edu/staff/jarrett/2mass/XSC; query service available through GATOR, http://irsa.ipac.caltech.edu/applications/Gator.
calibration from Cohen et al. (2003) converts the 2MASS magnitudes to janskys. The 2MASS total apertures (the apertures that measured the total light from the extended source) of 25.35 M" were similar to that used for the Spitzer data. We show all images (2MASS and Spitzer) in Figure 2 together with the r = 25'' aperture in the 1–24 μm images and the r = 25'' and 35'' aperture for the 160 μm image, for scale.

4. DISCUSSION

The total amount of far-IR emission from the BGC in Abell 2597 is L_ν ~ 1 × 10^{44} ergs s^{-1}, corresponding to ~4 M_☉ yr^{-1} according to Kennicutt (1998). This far-IR luminosity is as high as that of a LIRG (luminous infrared galaxy), and the broadband spectrum is consistent with that of a starburst. The IR-inferred star formation rate is also consistent with the conclusion of O'Dea et al. (2004) that hot stars, detected in the UV, forming at the rate of a few solar masses per year, are the dominant source of ionization of the optical nebula. The emission we detect with IRAC is extended, but it appears to be mainly associated with the central galaxy. The mid-IR sources, except at 24 μm, are not well fit by point sources, but those too are completely contained within the boundaries of the stellar light of the BCG. Because of Spitzer’s diffraction limit, we cannot say much about its mid-IR morphology. It is also very difficult to place any flux limits on extremely extended emission, beyond the galaxy, such as emission from the cluster ICM itself, due to the nature of mid-IR observations, which require multiple offset exposures to assess the background and the current state of knowledge about absolute Spitzer backgrounds. Because of the positional association of the Spitzer-detected IR emission with the BCG, we suspect that what we detect is entirely interstellar, not intracluster, in nature.

### Table 1

| Band  | Aperture Photometry a (mJy) | Point Response Fit b (mJy) |
|-------|----------------------------|---------------------------|
|       | Flux | Error | Flux | Error |
| 1.235 | 9.7  | 0.6   |      |       |
| 1.662 | 9.3  | 1.1   |      |       |
| 2.159 | 9.64 | 0.96  |      |       |
| 3.6   | 6.0  | 0.8   |      |       |
| 4.5   | 4.0  | 0.2   |      |       |
| 5.8   | 3.1  | 0.2   |      |       |
| 8.0   | 2.7  | 0.01  |      |       |
| 24    | 2.1  | 0.2   | 2.09 | 0.06  |
| 70    | 89   | 4     | 86   | 1     |
| 160   | 35 (52) | 2 (3) | 57.0 | 1.6   |

a Aperture photometry. Cataloged 2MASS total magnitudes were measured with a large aperture r = 25.35''. IRAC and MIPS with 25''. MIPS 160 μm aperture fluxes with r = 35'' aperture are also reported.

b Point response fit (PRF) photometry for MIPS. No aperture correction is needed for the 2MASS or IRAC photometry for this size of aperture and a galaxy of this angular size. To first approximation, the MIPS sources are point-like, so a PRF fit provides a reasonable estimate of the total flux.

c Uncorrected, except in last row. Based on test convolutions with the 160 μm PRF, the aperture correction for a 35'' radius aperture is 1.5; corrected flux shown in parentheses.

d The Spitzer measurement uncertainties quoted here are dominated by background subtraction. IRAC absolute photometry is good to about 3% for point sources (Reach et al. 2005). From the MIPS data handbook, MIPS photometric calibration uncertainties of 10% for 24 μm and 20% for 70 and 160 μm apply.

Fig. 2.—Gray-scale figure shows matched multiwavelength infrared images of the brightest cluster galaxy in Abell 2597. The angular scale of each image is 130'' (horizontal) and 86'' (vertical). North is up, and east is to the left. All subimages have the same angular scale. Left to right, top row: J-band from 2MASS, IRAC 3.6, and 4.5 μm. Second row: IRAC 5.8, 8.0 μm, MIPS 24 μm. Third row: MIPS 70 μm image from the SSC pipeline, the median-sky-subtracted 70 μm image (70F), and the MIPS 160 μm image. An r = 25'' aperture is plotted for scale over each subimage. The 160 μm image also shows an r = 35'' aperture.
is an argument against the dusty gas originating from condensations from the hot ICM.

The 70/160 μm flux ratio is larger than that observed for higher redshift (z = 0.25–0.3) BCGs by Egami et al. (2006a, 2006b). The observed ratios seen for Abell 1835 and Zwicky 3146 by Egami et al. (2006a, 2006b) are 0.4–0.6, corresponding to a rest-frame blackbody temperature of ~35–40 K. The observed ratio for Abell 2597 is ~1.5, corresponding to a rest-frame blackbody temperature of 65–75 K. This finding may mean that the temperature of the hot dust in Abell 2597 is greater than in higher redshift BCGs that are forming stars more quickly than the BCG in Abell 2597. It may seem puzzling that a galaxy with a lower star formation rate (SFR) seems to have hotter dust than larger-SFR galaxies. One possible explanation is that galaxies with very low SFRs may have only cool dust (if any), those with an intermediate SFR may have warmer dust, and perhaps those with a very high SFR may destroy the dust in the star formation regions. The dust in these systems might then be farther from the heat sources, therefore generating a higher IR luminosity, but at a lower dust temperature. Another explanation is suggested by the radiative transfer models presented in Siebenmorgen & Krügel (2007) that indicate that the very luminous (<10^{12.5}L_\odot) sources are cooler because for a given A_V, the dust mass M_d increases like R^2, and the dust temperature scales like L/M_d (Siebenmorgen & Krügel 2007). Also, a large fraction of buried OB stars increases the near-IR flux. Mid-IR spectra of these sources, with more than 2–3 points per spectrum, will provide an interesting discriminant between these model SEDs.

Assuming for the moment that the far-IR peak is indeed from star-forming regions, we can compare the implied star-formation rate with that inferred from the H\alpha emission. The diameter of the H\alpha nebula is about 16′′ (Heckman et al. 1989b), although the high-surface brightness structure visible in the HST image from Donahue et al. (2000) has a similar diameter to that of the radio source (~5′′–6′′). Corrected to H\alpha = 70 km s^{-1} Mpc^{-1}, Heckman et al. (1989b) measure a total H\alpha+[N ii] luminosity of 3.1 × 10^{42} ergs s^{-1}, which is ~(1.3–1.5) × 10^{42} ergs s^{-1} in H\alpha alone. (The ratio of H\alpha/[N ii] 6584 Å varies in this source between 0.8–1.0, and the [N ii]6548 Å line flux is one-third of that of the 6584 Å line.) A reddening analysis of five hydrogen Balmer lines in the spectrum of Abell 2597 by Voit & Donahue (1997a) optical depth at H\beta is about 1.2. The correction to total H\alpha is approximately 25%, corresponding to ~(1.6–1.8) × 10^{42} ergs s^{-1}. Such an analysis is insensitive to absorption by so-called “gray” dust, i.e., a population of large grains whose absorption is independent of wavelength. This luminosity corresponds to a total star formation rate of ~12–14 M_\odot yr^{-1} using the conversion from (Kennicutt 1998). This rate is somewhat larger than the 4 M_\odot yr^{-1} indicated by the far-IR emission but could be an overestimate if any of the H\alpha arises from processes other than star formation (e.g., AGNs, shocks).

The O vi detection reported by Oegerle et al. (2001) suggests a gas cooling rate 20 ± 5 M_\odot yr^{-1} in the central 26 kpc (quantities converted to H\alpha = 70 km s^{-1} Mpc^{-1}). This quantity is higher than the star formation rate inferred from Spitzer data by a factor of ~5 ± 3, but is consistent with the local cooling rate of ~20 M_\odot yr^{-1} inferred from X-ray spectra by Morris & Fabian (2005).

An alternative source of energy for both H\alpha and far-IR emission is conduction (Sparks et al. 1989). If conduction is not completely suppressed by magnetic fields, it must transfer at least some energy from the X-ray gas to the nebula and the cooler dusty gas associated with it. If we assume saturated heat conduction

![Fig. 3.—SED of the central galaxy of Abell 2597. The filled symbols indicate the 2MASS and Spitzer-IRAC and MIPS measurements presented in Table 1. The error bars include systematic uncertainties as described in the text. The solid line is the best-fit two component SED model composed of a giant elliptical SED taken from the template library of the Hyper-z photometric redshift code (Bolzonella et al. 2000; dashed line) and a nuclear starburst SED model (dotted line) from Siebenmorgen & Krügel (2007). The inferred mass of the giant elliptical is ~3.12 × 10^{11} M_\odot. The best-fit component from the Siebenmorgen & Krügel library is indicated with a dotted line, and corresponds to a mid-IR starburst nucleus of r = 0.35 kpc where 60% of the luminosity is from hot spots, dense clouds (n = 10^6 cm^{-3}) around buried OB stars, with a visual extinction A_V = 36 mag. The total luminosity of this component is L_\lambda = 10^{10.9} L_\odot ~ 0.95 × 10^{44} ergs s^{-1}.

Figure 3 compares the broadband spectral energy distribution of this galaxy with the spectrum expected from an old stellar population with zero dust. The near-infrared spectrum is fairly flat, as one would expect from an old stellar population at this redshift, and the stellar mass implied by the near-IR luminosity is ~3.12 × 10^{11} M_\odot. Stellar continuum emission is expected to dominate in the 3.5 and 4.5 μm bands, and the ratio of those two bands to the near-IR emission is consistent with that expectation. Those bands are well fit by a simple giant elliptical spectral template, obtained from the spectral energy distribution (SED) template library of the Hyper-z photometric redshift code (Bolzonella et al. 2000). In the far-IR, one can compare the prominent 70–160 μm peak observed with MIPS. Such a peak is expected from dust in active star-forming regions. Excess emission over an old, dust-free population is also found in the 5.8 μm, and particularly in the 8 μm IRAC bands. The excess at 8 μm is likely due to polycyclic aromatic hydrocarbons (PAHs) transiently heated by UV photons from hot stars. Such emission features are commonly found in the spectra of star-forming galaxies and usually accompany a far-infrared spectral peak at ~70 μm. Adding a nuclear starburst SED model from Siebenmorgen & Krügel (2007) of with a total starburst luminosity of 0.95 × 10^{44} ergs s^{-1} to the emission from old stars yields an adequate fit (solid line) to the combined 2MASS and Spitzer photometry for this galaxy. Note that PAH features are not expected from dust that has been exposed to a harsh X-ray radiation environment, since tiny grains are easily disrupted by X-rays (Voit 1992). This excess, if confirmed to be PAH features,
(Cowie & McKee 1977) from the surrounding $kT = 4 \text{ keV ICM}$ through a spherical surface of radius $r = 10\,r_{50}$ kpc, we obtain a maximum heating rate of a few times $10^{43} r^{2}_0 \text{ ergs s}^{-1}$, which represents a significant fraction of the mid-IR luminosity of $10^{44} \text{ ergs s}^{-1}$. However, many factors could reduce the conductive heating rate, such as suppression of conduction via tangled magnetic fields or the deposition of energy into ionized nebular gas instead of into the grains. Additional theoretical work is needed to explore more quantitatively the effect of the surrounding hot ICM on the dusty clouds responsible for the far-IR emission.

In summary, the UV observations of O'Dea et al. (2004) place a lower limit on the star formation rate because extinction corrections revise the UV rate upward; the H$\alpha$ luminosity provides only an approximate limit since other processes can generate H$\alpha$, and H$\alpha$ can be attenuated by gray absorption. These far-IR infrared observations place the best upper limit on the obscured star formation, because alternative contributions (such as conduction from the ICM) would also revise the inferred star formation rate downward. Because we have estimated above that conduction could in principle provide up to $\sim 50\%$ of the IR luminosity, the uncertainty of the IR-inferred star formation rate is at least a factor of 2, and we require better theoretical models and more detailed spectra to improve our estimates.

5. CONCLUSIONS

We have detected mid-infrared emission from the central galaxy of Abell 2597 with the Spitzer Space Telescope, from 3.6–160 $\mu$m. This galaxy has the luminosity and spectral shape typical of a LIRG embedded in a giant elliptical galaxy. The far-infrared luminosity rivals that of the local X-ray luminosity. We have constructed a broadband spectrum of the galaxy, which is most simply interpreted as a dust-enshrouded stellar population forming stars at a rate $\sim 4 M_{\odot} \text{ yr}^{-1}$ inside the central 35" ($\sim 54 \text{ kpc}$). This estimate is consistent within a factor of 2 of estimates from optical, H$\alpha$, and ultraviolet observations. We cannot, however, rule out additional heating of the dust by electron thermal conduction from the hot gas, and we suggest the development of more quantitative physical models of this process. The presence of UV continuum light argues in favor of a substantial fraction of the mid-IR flux being associated with star formation. The star formation rate inferred from the mid-IR emission is somewhat lower than the cooling rate inferred from O vi and recent X-ray observations, but we cannot rule out the hypothesis that cooling gas may feed the star formation implied by the UV, optical, and mid-IR data.

Finally, we have been able to model the broadband infrared SED of the BCG with a basic giant elliptical template and a standard nuclear starburst model from Siebenmorgen & Krügel (2007) including PAH features. We therefore have no evidence, based on these data, that the dusty gas condensed from the hot ICM. Further spectroscopic detail is required to test the hypothesis that PAHs are responsible for the mid-IR excess.

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