ADIOS: The Advanced Deep Infrared–Optical Spitzer Survey

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Abstract:
The Spitzer Space Telescope has opened up entirely new realms of astronomy, but unlike ground–based optical and NIR surveys, it has not yet performed a survey of hundreds of square degrees, and thus has not been able to carry out wide–angle clustering analyses and searches for rare objects. We propose to remedy this situation by performing a moderately deep Spitzer–IRAC survey of 200 sq. deg. along the Celestial Equator (SDSS "Stripe 82"), complemented with one of the the CFHT Legacy Survey wide fields with which it overlaps. With this dataset, we will 1) identify obscured and unobscured AGNs with a combination of mid–IR, optical, and variability selection, probing quasar clustering and testing "feedback" models of galaxy evolution; 2) measure the gravitational lensing contribution to the Cosmic Microwave Background by cross–correlating the galaxy distribution with data from the Atacama Cosmology Telescope (ACT); 3) identify and determine robust photometric redshifts for $z>1$ galaxy clusters found via the SZ effect; and 4) identify as many as 400 T–dwarfs (and perhaps Y dwarfs) and 30 6$<z<7$ quasars, an important probe of reionization. We show that SWIRE–depth exposures (120s) are an
optimal choice for all of our science applications. Stripe 82 is the premier large area multiwavelength extragalactic region of sky, with deep imaging in the optical (SDSS, CFHT), ultraviolet (GALEX), NIR (UKIDSS), radio (VLA), and millimeter (ACT), as well as extensive spectroscopy (SDSS I–III, 2dF, WiggleZ, DEEP2). We therefore propose Spitzer–IRAC imaging to complete the wavelength coverage there, to provide a wide-area survey of lasting value. At our optimal depth, covering this area (~200 sq. deg.) will require 1720 hours. Such a survey will complement existing Spitzer Legacy programs and provide crucial input for future missions such as JWST. Reduced images and catalogs will be made available to the public using the existing SDSS, NVO, and IRSA database structures.
1 Science Plan

1.1 Scientific Justification

1.1.1 Introduction

A wide-field survey with *Spitzer* at 3.6 and 4.5μm has the potential to make major advances in 1) our understanding of the nature of clusters at high redshift and their effect on the CMB, and 2) our census of active galactic nuclei (AGN) and understanding of their role in the lifecycle of galaxies. Existing wide-area mid-IR surveys with *Spitzer* and *WISE* (see Fig. 1) lack high-resolution CMB coverage and cover insufficient area and/or have insufficient depth for our specific science goals. Given the rarity of high-\(z\) quasars and clusters (typical comoving space densities \(\sim 10^{-9}\) Mpc\(^{-3}\)), we require a survey volume of at least \(\sim 10\) Gpc\(^3\) at \(z > 1\), or a survey area of \(\sim 200\) deg\(^2\). We propose the Advanced Deep Infrared-Optical *Spitzer* Survey (ADIOS), a 200 deg\(^2\) survey to SWIRE depths (120s integration) in IRAC Channels 1 and 2 which will expand *Spitzer*’s scientific legacy into the large-area regime. An unparalleled combination of extensive spectroscopy and deep optical, near-infrared, ultraviolet, X-ray, radio, and millimeter imaging makes the Celestial Equator in the Southern Galactic Cap an ideal location for ADIOS (see § 1.1.2).

On small scales (\(\theta < 10^\prime\)), CMB fluctuations are strongly affected by interactions of the recombinaton photons with hot gas and contamination by astrophysical foregrounds. Combining 200 deg\(^2\) of IRAC data with high-resolution CMB maps from the Atacama Cosmology Telescope (ACT) will improve the CMB signal itself by identifying and removing foreground millimeter point sources, enabling better characterization of the small-scale primordial power spectrum, potential detection of the signal of patchy reionization, and improved measurements of CMB lensing.

AGN appear to play a key role in galaxy evolution through feedback processes (e.g., Hopkins et al. 2008). Existing surveys of AGN are limited in redshift, solid angle, dynamic range in luminosity, and/or completeness to obscured objects, leaving open important questions on black hole growth, the role of feedback and the dark matter halos in which they sit. IRAC data coupled with existing multi-wavelength observations will enable a more complete AGN census over a broad range of luminosities from \(z = 0\) to \(> 6\). Our measurements of the luminosity function and clustering of AGN/quasars (particularly at \(z > 3\)) will have sufficiently small errors to break the degeneracy between competing models for AGN fueling and feedback.

The ADIOS data will also enable a broad range of ancillary science, allowing breakthroughs in areas ranging from high-redshift quasars and the reionization of the universe, to studies of the formation and populations of brown dwarfs. A core goal of our project is to enable community-based science by rapidly making the fully cross-linked catalogs public, building on our experience with the (much larger) SDSS data releases.

1.1.2 Field Selection

While there are a number of possible areas of sky in which a very large-area warm mission survey could be performed, the existence of complementary, spatially-uniform, deep imaging spanning the near-UV through the millimeter (and extensive optical spectroscopy), strongly argues for placing our fields in the SDSS “Stripe 82”, located on the Celestial Equator centered roughly on 0 hrs in RA (Fig. 2). The SDSS imaged this area of sky \(~80\) times over...
eight years. The resulting coadded 5-band photometry reaches roughly 2 mag fainter than the SDSS main survey ($g \sim 24.5$, $i \sim 23.3$; $5\sigma$ for point sources) with combined photometric uncertainties at the 1% level (Ivezić et al. 2007), while the individual scans give detailed variability information. Additional imaging with CFHT exists for 170 deg$^2$ of Stripe 82 to a depth of $i = 23.5$ ($7\sigma$ galaxies) with excellent seeing ($<0.8''$), enabling deep lensing studies. Other multi-wavelength data is summarized in § 1.2.5 and Figure 2, while Figure 3 presents a comparison of SEDs to flux limits. The ACT has surveyed Stripe 82 at mm wavelengths, and a more sensitive survey with the ACTPOL camera will begin in 2012. Extensive spectroscopy of stars, galaxies and quasars has been conducted in Stripe 82 by the SDSS-I/II (Abazajian et al. 2009), SDSS-III/BOSS (Eisenstein et al. 2011), 2dF, 6dF, and AUS (e.g., Croom et al. 2004, 2009), WiggleZ (Glazebrook et al. 2007), VVDS (Le Fèvre et al. 2005), and DEEP2 (Davis et al. 2007) projects. In all, there exist over 125,000 high-quality spectra in Stripe 82 for an average spectral density of over 400 deg$^{-2}$.

Our science goals require 200 deg$^2$, allowing us to choose an optimal region from the 300 deg$^2$ available on Stripe 82. Excluding regions of high stellar density and Galactic extinction, we propose to carry out IRAC observations as indicated in the top panel of Figure 2 ($-35^\circ < RA < 40^\circ$) covering 188 deg$^2$ of Stripe 82, which results in the best use of ancillary imaging/spectroscopic data. As the CFHTLS survey “W4” field overlaps significantly with Stripe 82 and also has similarly high-quality optical imaging, we will extend our IRAC coverage to the rest of the W4 field, filling out the last $\sim 12$ deg$^2$ of our 200 deg$^2$ goal. The Equatorial location also has the advantage of being accessible to all major observatories for ground-based follow-up observations. Other logical choices such as the Herschel-ATLAS/GAMA fields ($\sim 144$ deg$^2$, which currently lacks Stripe 82-depth optical imaging) or the four combined CFHTLS “wide” fields ($\sim 170$ deg$^2$) lack both the area and multi-wavelength depth (especially ACT) required for our science goals.

1.1.3 Science Programs

A. Active Galactic Nuclei

Selection & Photo-z’s: Richards et al. (2004,2009a) have developed a Bayesian AGN selection method from multi-band data, superior to traditional color cuts (Fig. 4, left); combining IRAC Channel 1 and Channel 2 with optical data from SDSS enables robust identification of faint (and obscured) AGNs (Richards et al. 2009b). In the crucial redshift range $3.5 < z < 4.5$, mid-IR selection alone is hampered by the presence of H$\alpha$ in Ch. 1, giving blue [3.6]-[4.5] colors (Stern et al. 2007; Donley et al. 2008; Richards et al. 2009b), but by combining with deep optical data, these important objects can be cleanly selected. Recently-taken IRAC pointings on 300 known $z > 2.2$ SDSS quasars (Fig. 2) provide the necessary training objects that enable us to find fainter high-z quasars in the full ADIOS region (and existing SWIRE fields). Variability selection (Fig. 4, right), using the 8-year SDSS baseline in Stripe 82, will both mitigate and help quantify color selection biases (e.g., MacLeod et al. 2010). Including obscured AGNs, we estimate that we will be able to select $> 1000$ AGN deg$^{-2}$ (as compared to 70 deg$^{-2}$ with WISE; Eisenhardt et al. 2011). In addition to robust selection of AGNs, the deep, seven-band SDSS+IRAC data enables accurate photometric redshifts of AGNs/quasars (e.g., Salvato et al. 2008; Richards et al. 2009b). Optical-only photometry gives photo-z’s accurate to $\Delta z \sim 0.3$, but in ADIOS it will be $\Delta z \sim 0.1$ or better with a much lower rate of catastrophic outliers — more than adequate for our science goals.
Clustering: Feedback models predict how the dark matter halos hosting quasars grow as supermassive black holes evolve; this translates to different predictions for the amplitude of quasar clustering as a function of redshift and luminosity. Current quasar clustering measurements at $z > 3$ (e.g., Shen et al. 2007) fail to constrain feedback models due to a lack of dynamic range in quasar luminosity. Measuring quasar clustering at $z > 3$, to our proposed flux limit, would give sufficient dynamic range, enabling a powerful new discriminator of early feedback (see Fig. 5). The BOSS spectroscopic quasar sample lacks sufficient faint $z > 3$ quasars to perform this measurement (Figure 6, left). However, the deep, multi-wavelength ADIOS imaging provides significantly accurate selection and photometric redshifts to do what a spectroscopic survey cannot. The narrow geometry of the field is not an issue since $2.5^\circ$ is always $> 200 \text{ Mpc/h}$ comoving at $z > 3$. As high-redshift quasars are rare, a significant signal requires a large area to achieve the necessary density of sources. The ADIOS 200 deg$^2$ survey distinguishes the models in Fig. 5 at $> 2 \sigma$ at both $z = 3.5$ and 4.5 (i.e. $> 3 \sigma$ overall).

Quasar Luminosity Function (QLF): In models in which quasars are powered by infall triggered by galaxy mergers (e.g., Hopkins et al. 2006), quasars above the break luminosity (dotted line in Figure 6, left) are those accreting close to the Eddington limit and those below the break luminosity reflect the distribution of Eddington ratios among objects accreting much more slowly. Thus it is essential to sample both populations. Earlier determinations of the QLF do not extend below the break luminosity at epochs prior to $z \sim 2.5–3$ when quasar activity peaked (e.g., Hopkins, Richards, & Hernquist 2007) and do not even approach the break luminosity above $z \sim 3.5$. The open squares in Figure 6 (right) indicate the dynamic range and uncertainty ADIOS will obtain in the QLF—a adequate to test these models directly.

With a smaller survey area, the correspondingly larger error bars (especially in the highest-redshift bin) make it impossible to properly distinguish between models.

The Highest Redshift Quasars: At even higher redshifts ($z \sim 5–9$) the QLF is wildly uncertain (Fig. 7, left); one of the goals of ADIOS is to perform a proper measurement of it, directly probing the formation and evolution of the earliest supermassive black holes. The single IR-selected $z > 6$ quasar (Stern et al. 2007) suggests ADIOS will discover $\sim 0.1–84$ $z > 6$ quasars, and the Willott et al. (2010) results give $\sim 10$ at $6.5 < z < 7.5$. An area of 200 deg$^2$ is needed to pin down the $z > 6$ QLF as Jiang et al. (2008, 2009) predict $\sim 30$ quasars at $6 < z < 7$, and $\sim 1–2$ objects at $z > 8$, while the Hopkins et al. (2007) model predicts several hundred $z > 5$ quasars in the ADIOS sample but only 1–3 at $z > 7$.

These very high-$z$ quasars will be selected as optical and near-IR ($i$ and $z$) dropouts, and will be separated from cool L, T and Y dwarf candidates based on a combination of their blue $J$–$[3.6]$ and red $[3.6]$–$[4.5]$ colors and/or lack of proper motions (Lang et al. 2008). These objects will provide ideal targets for deep near-IR spectroscopy both from the ground and using JWST (e.g., Fan 2009) to study the history of reionization and metal enrichment.

Obscured Quasars: The majority of the AGN in the universe are optically obscured (e.g., Brandt & Hasinger 2005; Daddi et al. 2007; Treister et al. 2009), but only a few dozen obscured quasars are known at the peak of quasar activity at $z \sim 2$. Existing methods for selecting obscured quasars at these redshifts from IR data are limited by their optical faintness; however, the ADIOS depths in the IRAC and SDSS bands are well-matched to the SEDs of obscured quasars (Fig. 3). The multi-color Bayesian algorithm described above (Fig. 4, left) is effective at selecting obscured quasars; we expect to detect more than 1000 $L_{\text{bol}} > 10^{45}$ erg/s type 2 quasars at redshifts $z < 1.5$ and more than 400 objects with $L_{\text{bol}} > 10^{45.5}$ erg/s at $1.5 < z < 2.0$. In short, ADIOS will enable a many-fold increase over the number of all published $z \sim 2$ obscured quasars.
B. Cosmology and the Cosmic Microwave Background

Measurement of CMB fluctuations on scales smaller than WMAP probed will lead to improved measurements of the primordial power spectrum index, constraints on the mass of the neutrino, and secondary effects due to the interaction of CMB photons with foreground objects, in particular gravitational lensing and the Sunyaev-Zel’dovich (1980; SZ) effect. ACT\(^1\) is a millimeter telescope mapping the microwave sky at 148, 218, and 270 GHz (2.1, 1.4, and 1.1 mm) with 1' − 1.7' resolution, designed to address these scientific questions. ACT has already observed the entire ADIOS region down to a noise level of 24\(\mu\)K-arcmin and will begin releasing its maps in 2011. The ACT collaboration is upgrading its camera and will make deeper measurements of temperature and polarization fluctuations across this region starting in 2012.

Sunyaev-Zel’dovich Effect and Clusters of Galaxies: The combination of the ADIOS IRAC observations with extant optical, UV, and near-IR imaging will allow us to secure accurate photometric redshifts of galaxies and reliably select clusters at \(z > 1\). Red galaxy SEDs peak at 3-5\(\mu\)m for \(z > 1\), so clusters stand out particularly well in IRAC data.

Through its observations of the SZ effect, ACT has already performed a cluster survey mass-limited to \(1 \times 10^{15} M_\odot\) via its 2008 data (Marriage et al. 2010). Based on the noise levels in the 2010 maps, we predict of order 50 such clusters over the ADIOS area with masses down to \(5 \times 10^{14} M_\odot\), perhaps 10% of which will be at \(z > 1\). Our ADIOS observations will allow us to determine photometric redshifts and stellar masses for these clusters at all redshifts. We will stack the CMB maps at the positions of the more numerous lower-mass clusters selected from the IRAC data that are not individually detected in SZ, determining their average SZ signal, and allowing us to estimate the mass and pressure in these clusters (e.g., Hand et al. 2010). Furthermore, the cluster number density with redshift from this complete SZ+IRAC-selected massive cluster catalog will place strong constraints on \(\sigma_8\) (e.g., Gladders et al. 2007; Vanderlinde et al. 2010), modified gravity theories (Schaefer & Koyama 2008), and the primordial non-Gaussianity (e.g., Foley et al. 2011).

We will be able to study the luminosity function, the morphology-density relation, and the scaling relations between cluster mass and the number of member galaxies for the blue and red populations separately, with color measured from IRAC-optical colors. At \(z > 1\), the cluster red sequence is forming; stellar-mass limited samples of galaxies from IRAC photometry can be compared to their passively evolving \(z < 1\) counterparts.

Gravitational Lensing of the CMB: The galaxies in the IRAC data will have a median redshift of \(\sim 1\) (Rowan-Robinson et al. 2008) and a surface density of \(\sim 5 \times 10^4\) deg\(^{-2}\). The large-scale structure traced by these galaxies provide the strongest contribution to the CMB gravitational lensing kernel; thus cross-correlating them with the ACT CMB signal will allow a \(\sim 25 \sigma\) measurement of the lensing of the CMB, much better than the \(\sim 3 \sigma\) detection of this effect by Smith et al. (2007). A massive neutrino species represents a relativistic, and therefore unclustered, form of dark matter. The larger the contribution of neutrinos to the dark matter, the weaker the contrast of the clustered component, and thus the weaker we expect the CMB lensing signal to be. Our planned combined measurement will be able to confirm or contradict the recent claims for sterile neutrinos masses of \(\sim 1 eV\) based on reactor and laboratory neutrino oscillation experiments (Mention et al. 2011).

Gravitational Lensing of Galaxies: The excellent quality of the CFHT imaging on Stripe 82 enables galaxy shape measurements for gravitational lensing studies, which can

\(^{1}\text{http://www.physics.princeton.edu/act/}\)
determine the total mass in galaxies and clusters. Combined with stellar masses determined from ADIOS observations, these data will allow a thorough census to be taken of the dark matter and stellar content of galaxies and their halos. Stellar masses can be obtained by fitting the galaxy SEDs to stellar population synthesis models (e.g., Brinchmann & Ellis 2000).

Point Sources and Small-Scale CMB fluctuations: ACT’s power spectrum measurement on small angular scales will be limited by confusion due to sub-mm galaxies (Das et al. 2010). These foregrounds are not individually resolvable at ACT resolution. The starlight in most of these sub-mm galaxies will be detectable in the IRAC bands at 3.6 and 4.5µm. Cross-correlating the ADIOS catalogs with the ACT maps, will reduce the contribution of the sources to the power spectrum by roughly an order of magnitude (Figure 8). Removing this dominant source of confusion and systematic error will produce better constraints on the physics of inflation by measuring the running of the scalar spectral index and to determine the duration of the epoch of reionization by detecting the Ostriker-Vishniac (1986) effect.

SNe Hosts: Stripe 82 formed the basis for the SDSS-II Supernova Survey which resulted in over 500 spectroscopically-confirmed Type Ia supernovae (SNIa) and over 2000 photometrically classified SNIa. Recent research on SNIa indicates a strong correlation between the color and host galaxy properties of SNIa, which, if understood, would improve their effectiveness as “standard candles” in cosmology (e.g., Lampeitl et al. 2010). The addition of IRAC mid-IR data for all the SDSS-II SN host galaxies would greatly improve the stellar population modelling of these galaxies (e.g., break degeneracies in the age, stellar mass, and dust content of these host galaxies), allowing further exploration of correlations with the SN light curve data. Such work would greatly help the next generation of SN surveys (e.g., the Dark Energy Survey, which starts in late 2011, and will target fields within Stripe 82 to find thousands of SNIa’s for cosmology).

C. Brown Dwarfs

As one example of ancillary science, ADIOS will measure mid-IR flux densities for the large number of well-characterized stars in Stripe 82 and enable the discovery of extremely faint, red objects. Its 4.5µm imaging will be orders of magnitude more sensitive to Y dwarfs \((T < 500K)\) than deep near-infrared surveys such as UKIDSS (Fig. 7, right), and ADIOS covers a larger area, with extensive coverage at other wavelengths, than does SWIRE. Based on their Spitzer colors (Patten et al. 2006) and local dwarf density (Burgasser 2007; Metchev et al. 2008), ADIOS should find \(\sim 400\) T dwarfs, including 30 late T dwarfs, and redefine the substellar census, which currently includes \(\sim 200\) T dwarfs over the entire sky. The ADIOS sample will (1) provide the definitive measurement of the mass function and scale height of substellar objects, (2) yield kinematic information via their large proper motions, measured from the SDSS multi-epoch data (see Lang et al. 2008; Scholz et al. 2008), (3) find common-proper-motion faint companions to nearby main sequence stars and white dwarfs, and (4) provide the data to search for Y dwarfs.
1.2 Technical Plan

1.2.1 Observations

**Area:** Our solid angle requirement of 200 deg$^2$ is driven by the need to accurately measure the quasar correlation function on large scales and high redshift, and to obtain a statistically significant sample of high-$z$ clusters in IRAC and ACT. Moreover, science productivity in a wide-angle survey is generally driven by the number of total objects detected, which generally favors larger areas over greater depth for sources like high-$z$ quasars where the number counts rise slowly with depth. In a fixed amount of time the number of objects gained by going deeper does not make up for the area lost by increasing the exposure time.

**Location:** SDSS Stripe 82 provides the best combination of existing, public, deep multi-wavelength data over the required area. Other locations such as the *Herschel*-ATLAS/GAMA fields or the combined CFHTLS W1-4 fields do not cover the full 200 deg$^2$ that we require for our AGN science goals and lack the sensitive ACT coverage needed for our CMB investigations. Trimming out regions of high stellar density, high optical extinction on Stripe 82, we cover the region $325^\circ < \alpha < 40^\circ$, for $-1.25^\circ < \delta < +1.25^\circ$. We also observe an additional $\sim 12$ deg$^2$ at 22 hours ($\alpha = 330^\circ$) to cover the entire CFHTLS W4 field ($\delta \sim +1$). See the top panel of Figure 2 for a visual summary of our proposed coverage. Scanning through the ecliptic allows for significantly more efficient usage of ancillary spectroscopy and multi-wavelength imaging (see Fig. 2 and § 1.2.5). Only 0.2% of the pixels are expected to be affected by asteroids in the ecliptic region. Furthermore, we expect to be able to identify 50–80% of asteroids with known objects.$^2$

**Depth:** We require sufficient depth to 1) measure the QLF below the break luminosity to $z = 4$ (Fig 6), 2) cover sufficient dynamic range to determine the luminosity dependence of quasar clustering as a function of redshift (particularly $z > 3$), and 3) robustly identify AGNs at limits where optical data alone are highly contaminated. These requirements are met both by the depth of our SDSS imaging coadd ($i = 23.3$) and a SWIRE-like depth of 4.25 µJy at 3.6 µm and ~7 µJy at 4.5 µm (Figure 3).

For example: To measure a decade in luminosity above and below the QLF break at $z \sim 2$ requires a magnitude limit $i \sim 23.3/[4.5] \sim 7$ µJy and a volume of $\sim 3$ Gpc$^3$ (to have $\sim 10$ quasars at $M \sim -28$); this volume out to $z \sim 2$ corresponds to 200 deg$^2$. At $z \sim 4$, $i \sim 23.3/[4.5] \sim 7$ µJy reaches $M \sim -24.5$, and in 200 deg$^2$ we will have at least 10 quasars at $M \sim -28.5$, i.e., the proposed survey spans 4 magnitudes with sufficient number of quasars at $z \sim$ to determine the high-luminosity QLF slope well.

**Exposure Time:** Exposure times of less than 30s are inefficient in a large angle survey due to the appreciable overheads. At least two dithered exposures should be taken at each pointing position to account for pixel-to-pixel variations and allow cosmic ray rejection, and at least two epochs separated by a few hours are required to identify and reject asteroids as moving/“variable” objects. This suggests that the SWIRE large-area mapping strategy, namely two epochs at each pointing, each with two dithered exposures of 30 seconds each, is the best for our survey.

For mapping to this depth ($2 \times 2 \times 30 = 120s$), the PET estimates $5\sigma$ depths of 4.25 and 6.3 µJy in channels 1 and 2, respectively, assuming a medium background (see below) and optimal point-source fitting. In practice, e.g., for the XFLS (Lacy et al. 2005), limits tend to be worse than this; however, with newer processing methods (e.g., Hora et al. 2008)

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and considering that most objects will be multiply detected at non-IRAC wavelengths, this estimate should be quite reasonable.

**Background:** While Stripe 82 passes through the ecliptic (and thus the region of highest zodiacal background), backgrounds are a relatively minor issue for the warm mission as the background decreases steeply at these shorter wavelengths. Our $5\sigma$ depth estimates above assumed nominal medium background levels of 0.125 MJy/sr at 3.6$\mu$m and 0.366 MJy/sr at 4.5$\mu$m. The actual backgrounds over our survey area range between 0.08 and 0.23 MJy/sr at 3.6$\mu$m, yielding a S/N at 4.25$\mu$Jy of 5.6–4.2 for point sources.

**Duplications:** There will be some duplication of previous observations, but it is easier for the mapping strategy (and data reduction) to perform the duplicate observations rather than trying to account for the small area of existing data ($\sim 2$ deg$^2$ with both Ch. 1 and Ch. 2 coverage).

### 1.2.2 Scheduling Constraints [GTR: Needs to be updated!!]

We are submitting a full set of AORs for this program. The scheduling constraints are tabulated below in a series of Stripe 82 observing windows, broken into four chunks. For each, we include the range of orientations, backgrounds and PSF S/N for Channel 1.

<table>
<thead>
<tr>
<th>Window</th>
<th>Orientation</th>
<th>Ch1Bkgrnd</th>
<th>Ch1SNR(\text{@}4.25\mu\text{Jy})</th>
</tr>
</thead>
<tbody>
<tr>
<td>21h20m+0d Window</td>
<td>2010Jun25 - 2010Aug04</td>
<td>72-62</td>
<td>0.13-0.09</td>
</tr>
<tr>
<td>2010Dec06 - 2011Jan16</td>
<td>259-248</td>
<td>0.08-0.15</td>
<td>5.6–5.0</td>
</tr>
<tr>
<td>23h20m+0d Window</td>
<td>2010Jul24 - 2010Sep01</td>
<td>66-64</td>
<td>0.18-0.12</td>
</tr>
<tr>
<td>2011Jan06 - 2011Feb14</td>
<td>248-246</td>
<td>0.11-0.21</td>
<td>5.2–4.3</td>
</tr>
<tr>
<td>00h40m+0d Window</td>
<td>2010Aug12 - 2010Sep21</td>
<td>66-69</td>
<td>0.18-0.12</td>
</tr>
<tr>
<td>2011Jan25 - 2011Mar04</td>
<td>243-247</td>
<td>0.12-0.23</td>
<td>5.0–4.2</td>
</tr>
<tr>
<td>03h20m+0d Window</td>
<td>2010Sep21 - 2010Nov02</td>
<td>72-86</td>
<td>0.13-0.10</td>
</tr>
<tr>
<td>2011Mar03 - 2011Apr13</td>
<td>243-257</td>
<td>0.10-0.15</td>
<td>5.3–5.8</td>
</tr>
</tbody>
</table>

Apart from a $\sim 9$ week gap from 2010Apr05 to 2010Jun25, Stripe 82 is visible continuously from the end of June 2009 until the end of the mission. At any epoch, about 1 hour of RA will be visible, so the $\sim 12$ weeks of total observing could be split into $\sim 8$ “mini campaigns” of about 1.5 weeks each. Further subdivision would allow for minimization of PA variation, so more fine-grained splitting could also be considered (e.g., 24 3.5-day campaigns).

Where the background is higher than average, we can follow the practice adopted by the S-COSMOS team of time-constraining our observations to the high solar elongation end of the visibility window to minimize the zodiacal background. We will cooperate with the schedulers to ensure our observations are taken optimally with minimal disruption to the overall telescope schedule. Should such a constraint prove to be too burdensome, it could be lifted without significant loss of data quality.
The AOR details are as follows: Each AOR duration is 24100s (6.7 hours). The area is covered with $8 \times 36$ map with small cycling dither, 2x30s exposures per point and 280'' map offsets. Pairs of AORs, offset by 1/2 array spacing in row and column, are constrained using a “group within” constraint, requiring their execution within an 18 hour window (so the maximum “gap” is $18 - 2 \times 6.7 = 4.6$ hours, enough to slip in downlinks and calibrations, or small program AORs). The CFHTLS W4 requires additional AORs north of Stripe 82, which will use the same strategy as the main Stripe 82 AORs. The northernmost row of W4 AORs have durations of 4.9 hours each, and are constrained to be executed within a 15 hour window. The total AOR durations are 1720 hours; we request another 30 hours for contingency.

1.2.3 Data Analysis Plan

We will follow the data reduction procedures tried and tested on the XFLS (e.g., Lacy et al. 2005), SWIRE (e.g., Surace et al. 2005), and SERVS data sets; see also Hora et al. (2008). As with those surveys, the images will first be pre-processed at the SSC using the IRAC pipeline, which produces the Basic Calibrated Data (BCD) and the corresponding DCE masks. These images will have been corrected for dark current, linearity, flatness, and some image artifacts. In addition to the SSC’s pipeline products, which have been constantly improving, we will use tools developed for the XFLS and SWIRE to fix other data artifacts (e.g., muxstriping), following procedures similar to those detailed in Lacy et al. (2005). [GTR: Update as needed.]

Images will be produced in $2 \times 2.5 \text{deg}^2$ tiles with $2 \times$ oversampling of the native pixel scale, making them large but manageable. Image generation will be handled by a postdoc to be hired that will work under the guidance of PI Richards and Co-I Lacy (who is one of the world experts in this processing).

At Drexel, Richards’ group will use these tiles to produce initial catalogs using both APEX and SExtractor (Bertin & Arnouts 1996). With large Beowulf and GPU clusters, Drexel’s facilities are more than adequate for this task. We will also modify the SDSS imaging pipeline (developed by R. Lupton, a member of our team) to work on the IRAC images, thus taking advantage of the algorithms in that pipeline for PSF fitting and self-consistent deblending across bands. We further plan to improve the algorithms for handling undersampling and intrapixel sensitivity variations in IRAC. The Drexel team will band-merge the IRAC catalogs with data at other wavebands and incorporate the results into the SDSS and NVO database frameworks.

We estimate the data volume to be 27Gb of imaging ($37$ tiles of 5 deg$^2$ at 720Mb each) and 2.6Gb of catalogs (about 50,000 sources deg$^{-2}$ at 256 bytes per object). Our planned delivery schedule is as follows:

**Delivery schedule:**
Observations begin: August 2011
Observations end: September 2012
Prelim. delivery of sample data: August 2012
Delivery of final images: March 2013
Delivery of single-band catalogues: July 2013
Delivery of final band-merged IRAC/UKIDSS/SDSS/etc. catalogs: January 2014

The distribution of IRAC data and catalogs will follow a path similar to that of the Legacy surveys. We will deliver final images and band-merged IRAC catalogs to IRSA’s
Spitzer Legacy repository, and to the SSC directly. The first data will be made public in mid-2012. All of the primary ancillary data sets (SDSS, UKIDSS, GALEX) are already public. Other data sets (e.g., ACT) will soon become public. We have allowed for some extra time in the schedule to produce final multi-wavelength band-merged catalogs.

Band-merged object catalogs will be made available in a VO-compliant format to be served through the NVO. Szalay’s group at JHU and the Drexel team will provide support for this work and for integrating the data into the SDSS database. While the dataset is quite large by Spitzer standards, it is small compared with the total SDSS dataset. Users will be able to access the data through either the SDSS web interface or the NVO web interface. In summary, PI Richards will lead the overall processing, with Co-I Lacy leading the initial data reduction, Co-I Strauss leading SDSS-like processing, and Co-I Szalay leading database distribution. This team has an excellent track record for producing useful public data releases and timely creation of “value-added” catalogs.

1.2.4 Feasibility

Existing observations support the general technical feasibility of our proposed project. SWIRE has demonstrated the limits that our proposed exposures will achieve, and has shown that confusion is not an issue at these limits. The XFLS, SWIRE, Bootes, and SERVS mapping have demonstrated that covering large areas, while challenging, is quite feasible. We are adopting the proven SWIRE mapping strategy of dithering and half-array offsets to minimize problems due to detector artifacts and asteroids. The visibility of our fields has been considered in detail and is supported by the full set of AORs (rather than generic examples that are allowed) that we have submitted with this proposal. Indeed, Co-I Mark Lacy, an IRAC science team member, has been integral to many of these issues at the SSC and has led the feasibility checking of the technical aspects of this proposal.

1.2.5 Provenance/Availability

As this proposal is a survey in a field with existing deep optical data, there are no issues of data provenance in terms of availability of targets. Here we summarize the availability of the ancillary data in our proposed field (Fig. 2); all data we need for our science goals are either already available to us, or will be by the time we need to carry out our science analyses.

- SDSS multi-epoch $ugriz$ imaging over 300 deg$^2$ to $g \sim 24$; all data public
- CFHT imaging to $i = 23.5$ at 0.8" resolution over 140 deg$^2$
- SDSS-III imaging/spectroscopy over contiguous 2000 deg$^2$ centered on Stripe82
- UKIDSS $YJHK$ imaging to $K_{AB} = 20$; DR4 public
- Deep optical/NIR imaging over 1-10 deg$^2$: CFHTLS W4, VVDS 22hr and UKIDSS DXS
- SDSS spectroscopy of galaxies, stars, quasar candidates to $i = 19.1$ ($z < 3$) and 20.2 ($z > 3$) over 300 deg$^2$ plus deeper spectroscopy in places; all public.
- SDSS+2dF spectra of $z < 3$ quasars to $g = 21.85$ and LRGs to $i = 19.8$ over 190 deg$^2$
- SDSS-III spectra of $z \sim 3$ quasars to $g = 22$ and LRGs to $i = 19.8$
- Wiggle-Z spectra (400 deg$^{-2}$) over $\sim 70$ deg$^2$; plus VVDS and DEEP2 spectra
- ACT to 25$\mu$K-arcmin in 2 mm band; ACTPOL data starting in 2012
- FIRST (VLA) 20 cm imaging to 1 mJy over entire area
- 3× FIRST depth VLA data at 20 cm over $\sim 90$ deg$^2$
- GALEX two-band UV to 2× MIS depth ($m_{AB} \sim 23.75$)
- Upcoming XMM observations over 5 deg$^2$ (PI: Meg Urry)
On a longer timescale, additional surveys (Pan-STARRS, LSST, the Dark Energy Survey, the VISTA Hemisphere Survey, Subaru Hyper-Suprime Cam) will also cover this region of sky.
1.3 Figures, Tables & References [5 pages]

References

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Fig. 1: Comparison of deep-wide mid-IR fields. Depths are given as 5-σ, point sources at 4.5 µm according to the PET. These values are deeper than the 80% completeness limit, but provide a level playing field for comparison and are the appropriate numbers for point sources with a priori positions (e.g., quasar candidates). Herschel-ATLAS covers ∼ 600 deg² but at a depth of 67 mJy at 110µm (nearly 1000× brighter than our flux limit at 4.5µm for a type 1 quasar) and a resolution of ∼ 10′′ (Eales et al. 2010). WISE covers the whole sky (41k deg²) but at a 4.6 µm 5-σ point source depth of only 110 µJy and a resolution of ∼ 6″ (Wright et al. 2010).
Figure 2: Multi-wavelength coverage of Stripe 82. Note that the scales on RA (x-axis) and Dec (y-axis) are quite different. Panel a: Every 1000th SDSS source, showing the density of sources with RA. The red boxes outline the proposed 200 deg$^2$ of the ADIOS survey (although the extension to the CFHTW4 field to $\delta \approx 4.5^\circ$ at $\alpha \approx -27^\circ$ is not shown). We avoid the region of high stellar density on the left and high optical extinction on the right (see Panel g). The green box indicates good seeing CFHT imaging and the grey filed boxes indicate DEEP2 spectral coverage. The ecliptic is shown by the dashed blue line. Panel b: IR coverage. Grey: existing public UKIDSS DR4 data (sparse sampled); the dashed box indicates the UKIDSS DXS area. Black: Existing IRAC pointings (covering $\sim 2$ deg$^2$). Panel c shows coverage by the Wiggle-z spectroscopic survey (upward hashes), ACT coverage (downward hashes), and the CFHTLS W4 and VVDS 22hr fields (dotted and dashed boxes near $\alpha = -30^\circ$). Panel d: VLA coverage at 20 cm to 3–5× FIRST depth (FIRST data exist over the whole field). Panel e: GALEX coverage in the Medium Imaging Survey (blue), including regions covered twice as deep (green). Gaps largely indicate regions occupied by bright stars. Panel f: X-ray coverage, by the Chandra (green), XMM (red), and SWIFT (blue) satellites. Panel g: $i$-band Galactic extinction (Schlegel et al. 1998) as a function of RA.
Figure 3: Comparison of SEDs with the multi-wavelength flux limits in Stripe 82, normalized to the ADIOS 4.5\(\mu\)m flux limit. Blue tickmarks indicate the main SDSS depth and the Stripe 82 depth. Cyan indicates the GALEX (2\times M04) depth. Green tick marks show the depth of the existing UKIDSS data and future data from VHS. The brown tick marks show the depth of our proposed IRAC observations. The SED of a \(z = 0.5\) elliptical is shown as a dashed gray line (scaled to our flux limit at 4.5\(\mu\)m). The solid black and grey lines show a type 1 quasar SED at \(z = 4\) and \(z = 1\), respectively, showing good agreement between our proposed IRAC observations and the existing SDSS depth on Stripe 82. We will be able to identify thousands of type 2 AGN to nearly the IRAC limits, because the IR and optical depths are well-matched for a type 2 AGN SED (shown with a dashed red line for a \(L = 10^{48}\) erg/s type 2 AGN at \(z = 0.5\)).

Figure 4: Left: Distribution of point (blue) and extended (red) sources in IRAC (AB mag) and SDSS color space from SWIRE data. Green crosses are known type 1 quasars and open grey squares are known type 2 quasars. Using our multi-color Bayesian selection (Richards et al. 2009b), it is possible to select even those AGNs that are not outliers in this depiction. This selection is both less contaminated and more complete than the standard 2-D MIR-color wedges. T-dwarfs will be identified along with quasars as having red \([3.6] - [4.5]\) colors, but can be distinguished from quasars using the deep optical photometry and astrometry in Stripe 82. Right: Optical color-color diagram of point sources in SDSS, color-coded by the degree of variability. \~90\% of quasars show month-to-year variations at the 0.03 mag level, and more than 60\% are variable at the 0.05 mag level (Sesar et al. 2007). Low-redshift quasars lie in the large red area with \(u - g < 0.6\); RR Lyrae stars are the smaller red area at \(u - g \sim 1.3\).
Figure 5: Different feedback models make different predictions for quasar bias (as a measure of clustering strength). The models predict similar clustering at $z < 2$, as observed (points; see Lidz et al. 2006; Hopkins et al. 2007), but the models diverge at high-$z$. We compare the current SDSS (dotted) and ADIOS (dash-dot) flux limits and an infinitely deep survey (solid). Only a deep spectroscopic survey, or a survey with photometric redshifts comparable to those of ADIOS, across a large range in luminosity, can distinguish competing feedback models. The models are Left: strong feedback, where every high-$z$ quasar is in ‘blowout’ mode, about to shut down for a Hubble time, Center: ‘standard’ feedback, in which the BH and halo are co-eval, and Right: a model in which high-$z$ quasars do not regulate their hosts at all, continuing to grow their BHs rapidly until $z = 2$. (From Hopkins et al. 2007).

Figure 6: Left: Known SDSS (black triangles) and BOSS quasars (light grey points) on Stripe 82 and type 1 quasar candidates (grey crosses) in the $\sim 30 \text{deg}^2$ of overlap between large-area Spitzer fields and SDSS (Richards et al. 2009b, Fig. 4). The dashed black line indicates the ADIOS depth ($i \sim 23, f_{\text{3.6um}} \sim 5 \mu\text{m}$ at $z = 1$). The dotted black line shows $L^* (M_i^*)$ for quasars, illustrating the important parameter space gap that ADIOS will fill. Right: Predicted QLF and uncertainties for the ADIOS survey (green squares) compared to 3 models (black, red, cyan lines), following Hopkins, Richards, & Hernquist (2007). The blue triangles show data from the much shallower and less complete SDSS survey. The top-left panel shows the luminosity function at $z = 2.4$. The other panels show the results at $z = 0.87, 2.40,$ and $4.25$, after normalizing by a fiducial model to emphasize the model distinctions.
Figure 7: **Left:** Predictions of the cumulative number of quasars in the ADIOS area for different high-redshift bins, following models from Hopkins et al. (2007) and Jiang et al. (2009), which represent extrema in predictions for numbers of $z > 6$ quasars. They both involve extrapolations from existing data; their predictions at the ADIOS depth are indicated with a vertical dashed line. **Right:** Volume within which ADIOS, SWIRE and UKIDSS surveys can detect 1 Gyr Y dwarfs between 1 and 25 $M_{\text{Jup}}$. Sensitivity estimates are derived from synthetic photometry of Burrows et al. (2003) model spectra and 5$\sigma$ detection limits at 2.3$\mu$m (UKIDSS) and 4.5$\mu$m (ADIOS & SWIRE). Water, methane, and ammonia absorption shortward of 4.5$\mu$m makes ADIOS 4.5$\mu$m imaging orders of magnitude more sensitive to Y dwarfs than the UKIDSS K band.

Figure 8: The angular auto and cross power spectra measured by ACT at 148GHz and 218GHz (Das et al. 2010), with the theoretical model for CMB, SZ, and point sources best-fit to the three spectra. The lensed CMB dominates at large scales, but falls exponentially due to Silk damping. The majority of power at $l > 3000$ (small scales) comes from extragalactic IR point sources (radio sources are sub-dominant). The infrared source emission, assumed to follow a power law, is dominated by Poisson power at small scale, but about 1/3 of the IR power at $l = 3000$ is attributed to clustered source emission. With ADIOS we will be able to directly detect point sources, and thus subtract the Poisson power on small scales, thus measuring the small-scale CMB much more accurately. (From Dunkley et al. 2010).
2 Scheduling Profile of the Proposed Program [1 page]

[GTR: Update]

SDSS Stripe 82 is a $125^\circ \times 2.5^\circ$ field along the Celestial Equator. The length of the field means that some part of it is nearly always visible to Spitzer. For the $\sim 200 \, \text{deg}^2$ that we propose to cover ($-40^\circ < \text{RA} < -10^\circ$) and ($10^\circ < \text{RA} < 55^\circ$), apart from a $\sim 9$ week gap between from 2010Apr05 to 2010Jun25, our field is visible continuously from the end of June 2009 until the end of this warm mission cycle. At any epoch, about 1 hour of RA will be visible. The $\sim 12$ weeks of total observing could be split into $\sim 8$ “mini campaigns” of $\sim 1.5$ weeks each. Further subdivision could allow for minimization of PA variation (e.g, 24 3.5-day campaigns).

Below we note the windows during which 4 blocks of Stripe 82 are observable during the course of the warm mission.

21h20m+0d Window
2009Jun16 - 2009Jul27
2009Nov28 - 2010Jan08
2010Jun25 - 2010Aug04
2010Dec06 - 2011Jan16

23h20m+0d Window
2009Jul16 - 2009Aug24
2009Dec29 - 2010Feb05
2010Jul124 - 2010Sep01
2011Jan06 - 2011Feb14

00h40m+0d Window
2009Aug04 - 2009Sep12
2010Jan16 - 2010Feb24
2010Aug12 - 2010Sep21
2011Jan25 - 2011Mar04

03h20m+0d Window
2009Sep13 - 2009Oct25
2010Feb23 - 2010Apr05
2010Sep21 - 2010Nov02
2011Mar03 - 2011Apr13
3 Brief Team Resume [2 pages]

PI: Gordon Richards (Assoc. Prof. of Physics, Drexel University; PhD Univ. of Chicago 2000); Alfred P. Sloan Research Fellowship (2007); multiwavelength quasar expert; co-deputy chair of the SDSS Quasar Working Group; PI of 3 Spitzer projects

Co-I: David Spergel (Princeton; Chair of Dept. of Astrophysical Sciences); member of the ACT and WMAP teams; author of the most cited paper in ADS

Co-I: Michael Strauss (Professor, Princeton University; PhD Berkeley 1989); SDSS-III Survey Science Coordinator; author of papers on AGN demographics, type 2 quasars, brown dwarfs, and large-scale structure

Co-I: Mark Lacy (Scientist, NRAO; PhD, Cambridge 1993); former Spitzer Archive Scientist at the SSC. Interests include distant galaxies and dust obscured AGN/QSOs.

Co-I: Scott Anderson (Professor and Assoc. Chair, Astronomy Department, University of Washington; PhD Washington 1985); multiwavelength surveys and quasar studies.

Co-I: Niel Brandt (Professor, Penn State, PhD Cambridge 1996); extensive studies of active galaxies and extragalactic surveys at X-ray and other wavelengths; chair LSST AGN Science Collaboration

Co-I: Xiaohui Fan (Professor, Univ. of Arizona, PhD Princeton, 2000); expert on high-z quasars, cosmic reionization and brown dwarfs; co-deputy chair of the SDSS quasar working group; leads team that has discovered the majority of \( z > 5 \) quasars

Co-I: Karl Forster: (Caltech, GALEX SOC team lead, PhD Columbia 1998); member of the GALEX science team, AGN astrophysics.

Co-I: Philip Hopkins (Miller Fellow, UC Berkeley; PhD Harvard 2008); modeling and numerical simulations of galaxy formation, black hole growth, and AGN feedback

Co-I: Jack Hughes (Professor, Rutgers University); CMB, clusters, SNe

Co-I: Linhua Jiang (Postdoc, Arizona; PhD Arizona 2008); high-z QSOs and galaxies.

Co-I: Gillian Knapp (Professor, Princeton University); leader of SDSS photometric and (part of) spectroscopic pipeline development: papers on SDSS brown and white dwarfs.

Co-I: Robert Lupton (Princeton University): Software algorithms guru for SDSS, ACT, and LSST.

Co-I: Jean-Paul Kneib (Research Scientist, Laboratoire d’Astrophysique de Marseille Observatoire Astronomique de Marseille-Provence); PI of CFHT imaging program on Stripe 82

Co-I: Yen-Ting Lin (Asst. Research Fellow, ASIAA, Taiwan; PhD 2005 Illinois); galaxy formation and evolution, galaxy clusters, radio galaxies

Co-I Peregrine McGehee (Staff Scientist, IPAC; PhD NMSU 2005); Planck Early Release Compact Source Catalog Lead; interstellar medium and galactic star formation.

Co-I: Felipe Menanteau (Research Scientist, Rutgers University; PhD Cambridge 2000); observational cosmology, SZ surveys, clusters of galaxies, formation and evolution of elliptical galaxies

Co-I: Adam Myers (Research Professor, Illinois; PhD Durham 2004); pioneering work on clustering of photometric quasars; SDSS-III/BOSS Architect and External Participant

Co-I: Donald Schneider (Professor, Penn State); Extensive experience in quasar surveys; Chair of SDSS Quasar Working Group; SDSS-III Survey Coordinator; HET Scientist


Co-I: Alex Szalay (Professor, JHU); database guru; NVO Co-PI
Co-I: Paula Szkody (Professor, University of Washington); multi-wavelength observer of cataclysmic variables; Co-I on 3 past Spitzer projects with 3 resulting publications.

Co-I: C. Megan Urry (Prof., Chair, Physics Dept. Yale University); actively accreting supermassive black holes, the co-evolution of AGNs with normal galaxies; PI of XMM Survey on Stripe 82

Co-I: Michael Vogeley (Assoc. Professor, Drexel Univ.; Ph.D. Harvard 1993); cosmology; large-scale structure; environmental dependence of galaxy formation; AGN

Co-Is: Steve Warren (Professor, Imperial College London); Paul Hewett (Professor, IoA, Cambridge); Richard McMahon (Reader, IoA, Cambridge); UKIDSS Survey Scientist and collaborators, bringing significant NIR expertise in addition to being AGN experts

Co-I: Nadia Zakamska (Asst. Prof. JHU; PhD Princeton 2005; Spitzer Fellow 2005-08); selection and multi-wavelength properties of type 2 quasars; AGN demographics

4 Summary of Existing Programs [1 page]

[GR: Update]

PI G. Richards is also PI of AR-1 program #3284, AR-3 program #30347, GO-5 program #50087, and GO-6 program #60139. The cycle-1 program sought to construct mean optical+IR quasar SEDs for SDSS quasars with public *Spitzer*-IRAC photometry. The analysis has been completed and published (Richards, Lacy, et al. 2006, ApJS, 166, 470). This paper has already been cited 182 times and is proving to be quite useful for planning of AGN-related *Spitzer* proposals. Results from the cycle 3 program were published as Richards et al. 2009, AJ, 137, 3884 and have been cited extensively herein. The cycle 5 program results have been presented in Deo et al. 2011, (arXiv:1101.2855) which has just been accepted for publication in ApJ. The cycle 6 program data (on Stripe 82) were being taken until the end of July 2010. The data have all been processed and a preliminary catalog is now available. We are using it to optimize the selection algorithms discussed herein.


Co-I S. Anderson is a co-I on *Spitzer* programs #3221, #3284, and #30476. Publications for #3221 (PI: Fan) and #3284 (PI: Richards) are detailed in this section under entries for X. Fan and G. Richards, respectively. Initial results for #30476 (PI: Shemmer) appear as Lane et al. 2010, BAAS, 42, 372 (“The Optical to Mid-Infrared Spectral Energy distributions of Weak-Emission Line Quasars”; also, paper in prep).

Co-I W. N. Brandt; is a Co-I on 2 previous *Spitzer* proposals. Cycle-2 archival grant (PI: Steffen) was published as “Revealing the unresolved hard cosmic X-ray background using *Spitzer*”. Cycle-3 observing proposal (PI: Shemmer) was published as “Lineless quasars at high redshift: BL Lacs or a new class of unbeamed quasars?”.

Co-I X. Fan is the PI on five Spitzer projects in previous cycles and Co-I on another seven about quasars and brown dwarfs; GO-3198 (PI): all data analyzed and published in Jiang et al. 2007; GO-30402 (PI), GO-40356 (PI), GO-50390 (PI): all data from these programs analyzed and published in Jiang et al. 2010, Nature and featured as a SSC press release. GO-3221 (PI): all data analyzed and published in Diamond-Stanic et al. 2009 and in Lane et al. 2011.

Co-I L. Jiang is PI of GO-70094 (no data taken yet) and TC of another three GO programs 30402, 40356, and 50681 (programs completed, two papers published).

Co-I G. Knapp is a member of the Spitzer-Taurus Legacy Survey Team, PI D.L. Padgett Co-I M. Strauss; GO-3163 (PI: Zakamska, Co-I) “Mid- and Far-Infrared Spectral Energy Distribution of type II Quasars from the Sloan Digital Sky Survey”. All *Spitzer* data reduced and analyzed. Supporting ground-based data obtained, reduced and analyzed. Paper in preparation.

5 Observation Summary Table

Our Spitzer-IRAC observations will tile $\sim 200$ deg$^2$ along the celestial Equator (SDSS Stripe 82) bounded by $-40^\circ < \text{RA} < -10^\circ$ ($21^h20^m < \text{RA} < 23^h20^m$) and $10^\circ < \text{RA} < 55^\circ$ ($00^h40^m < \text{RA} < 03^h40^m$) over $-1.25^\circ < \text{Dec} < 1.25^\circ$. In addition, we will fill in the area covered by the part of the CFHTLS W4 field that extends out of SDSS Stripe 82. See the top panel of Figure 2 for a visual description of the proposed area. We will use half-array offsets between two epochs, with two observations at each epoch for an integration time of 120s, yielding flux density limits of $\sim 4.25$ and $7.0 \mu$Jy in channels 1 and 2, respectively.

<table>
<thead>
<tr>
<th>Target Field</th>
<th>Position (J2000)</th>
<th>Flux Density</th>
<th>AOT/ Int.</th>
<th>AOR Duration</th>
<th># of AORS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stripe 82</td>
<td>21:20:00−01:15:00 to 23:20:00+01:15:00</td>
<td>4.25$\mu$Jy</td>
<td>IRAC</td>
<td>120</td>
<td>24120</td>
</tr>
<tr>
<td>Stripe 82</td>
<td>00:40:00−01:15:00 to 03:40:00+01:15:00</td>
<td>4.25$\mu$Jy</td>
<td>IRAC</td>
<td>120</td>
<td>24120</td>
</tr>
<tr>
<td>CFHT W4</td>
<td>22:13:18 +01:19:00</td>
<td>4.25$\mu$Jy</td>
<td>IRAC</td>
<td>120</td>
<td>24120/17468</td>
</tr>
</tbody>
</table>

There are 1720 hours total in IRAC AORs and we are requesting a total of 1750 hours in order to account for scheduling inefficiencies.

6 Modification of the Proprietary Period

Consistent with the spirit of the Legacy programs in previous cycles, we waive the proprietary period.

7 Summary of Duplicate Observations

Some IRAC observations do exist in our region ($\sim 300$ pointings on known high-$z$ quasars) and thus there will be some duplication. However, they are much smaller than our map sizes, so working around them will be inefficient and discrepant exposure times would pose problems for streamlining the data reduction process. Thus, it is generally better for the mapping strategy to perform the duplicate observations rather than trying to account for the small area of existing data. This is true both in terms of observing strategy and also data reduction (where imaging small areas to a different depth would complicate the reduction pipelines). However, we will work with the schedulers to minimize unnecessary overlap.
8 Summary of Scheduling Constraints/ToOs

Imposing some constraints to minimize zodiacal background (as done by the S-COSMOS team) is desirable and should be possible with minimal disruption of the overall telescope schedule.

AORs are paired with “group within” constraints with 18hr windows to ensure the first epoch follows fairly closely on the second.

There are no ToOs.