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 carried out surveys extending to 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 $z>7$ 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

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Science Category: Extragalactic: AGN/quasars/radio galaxies
Observing Modes: IRAC Post−Cryo Mapping
Hours Requested: 1,750.0
Proprietary Period(days): 0
premier large area multiwavelength extragalactic region of sky, with already existing deep imaging in the optical (SDSS, CFHTLS), ultraviolet (GALEX), NIR (UKIDSS), radio (VLA), and millimeter (ACT), as well as extensive spectroscopy (SDSS, 2dF). We therefore propose IRAC imaging in Channels 1 and 2, important bands which will greatly enhance the wavelength coverage, providing a wide-area survey of lasting value. At our optimal depth, covering 200 sq. deg. will require 1750 hours. Such a survey will complement existing Spitzer Legacy programs and provide crucial input for future missions such as WISE and 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 Overview and Introduction

It is an exciting time in extragalactic astronomy: studies of the cosmic microwave background (CMB) and galaxies have contributed to an impressively precise and concise model for the structure and geometry of the universe, while observations at low and high redshift have given us enormous insights into the processes of galaxy formation. A wide-field survey with Spitzer at 3.6 and 4.5\(\mu\)m has the potential to make major advances in these areas by greatly improving our census of active galactic nuclei (AGN) and understanding their role in the life-cycle of galaxies, and by allowing us to study the nature of clusters at high redshift and their effect on the CMB. Existing wide-angle Spitzer surveys (SWIRE and Boötes) cover only 58 deg\(^2\) in total and have no high-resolution CMB coverage, making them inadequate for many of these science goals. We propose the Advanced Deep Infrared-Optical Spitzer Survey (ADIOS), a \(\sim 200\) deg\(^2\) survey to SWIRE depths (120s) in IRAC Channels 1 and 2 with which to cement Spitzer’s scientific legacy. 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.

AGN play a key role in galaxy evolution. Central supermassive black holes and spheroids must have co-evolved, given the tight relationship between their properties (e.g., Ferrarese & Merritt 2000; Gebhardt et al. 2000); most massive galaxies hosted an AGN at some time. Feedback from the central AGN, and merger activity related to AGN fueling, are now thought to have played key roles in quenching star formation and creating massive elliptical galaxies (e.g., Croton et al. 2006; Hopkins et al. 2008). But existing surveys of AGN are limited in solid angle, dynamic range in luminosity, and/or completeness to obscured objects. IRAC data coupled with existing data at other wavebands will allow a complete AGN census over a broad range of luminosities from \(z = 0\) to 6. With a survey covering 200 deg\(^2\), we will measure the luminosity function of AGN over a broad dynamic range and the clustering of AGN as a function of luminosity, with errors small enough to break the degeneracy between competing models for AGN fueling and feedback.

On the CMB side, one of the important frontiers is analysis of small-scale (\(\theta < 10'\)) anisotropies, where a host of secondary effects come into play due to the interaction of CMB photons with astrophysical foregrounds. Combining 200 deg\(^2\) of IRAC Channel 1 and 2 data with high-resolution CMB maps from the Atacama Cosmology Telescope (ACT) will allow us to make the first high S/N detection of gravitational lensing of the CMB by foreground structure to find roughly 20 \(z > 1\) clusters of galaxies via the Sunyaev-Zel’dovich effect, and to improve the CMB signal itself by identifying and removing foreground millimeter point sources.

The ADIOS dataset will also enable a very broad range of ancillary science, allowing breakthroughs in areas from high-redshift quasars and the reionization of the universe, to studies of brown dwarfs and white dwarfs. A core goal of our project is to make the fully reduced and cross-linked catalogs public rapidly, building on our experience with the (much larger) SDSS data releases.
1.1.2 Choice of Field

While there are a number of possible areas of sky in which our proposed 200 deg$^2$ warm mission observations could be carried out, our need for complementary, spatially-uniform deep imaging in the optical and millimeter strongly argues for placing our fields in the SDSS “Stripe 82”, on the Celestial Equator centered roughly on zero hours right ascension (Fig. 1). The SDSS has scanned this area of sky up to 100 times over eight years. The resulting coadded photometry goes roughly 2 mag fainter than the SDSS main survey ($g \sim 24.5$, $i \sim 23.3$; 5-$\sigma$ for point sources), while the individual scans give detailed variability information. The data have been exquisitely calibrated, with photometric uncertainties at the 1% level (Ivezić et al. 2007). Extensive spectroscopic followup of stars, galaxies and quasars has been conducted in Stripe 82, using both the SDSS spectrographs (see Adelman-McCarthy et al. 2006) and the 2dF and AAOmega spectrographs (e.g., Croom et al. 2004) and the WiggleZ survey of Glazebrook et al. (2007). Between the SDSS and 2dF datasets alone the spectral density is 300 deg$^{-2}$ in our proposed area.

The deep 5-band SDSS imaging is complemented by GALEX UV coverage to $m_{UV} = 23.75$ (3ks), an ongoing VLA 20 cm program that will cover $\sim 80$ deg$^2$ to 3× deeper than FIRST (Becker et al. 1995), and UKIDSS $YJHK$ coverage to $K_{AB} = 20.1$. We have covered 50 deg$^2$ to $J_{AB} = 22$ using the NEWFIRM camera on the KPNO 4m (with more time allocated), and the VISTA Hemisphere Survey (VHS) will image Stripe 82 to $J_{AB} = 21.2$. Finally, ACT has already covered an appreciable fraction of Stripe 82 and will observe the entire region over the next year at mm wavelengths. Thus, the combination of multi-epoch and multi-wavelength coverage in the proposed field is truly unique. Figure 2 shows these multi-wavelength flux limits as compared to AGN SEDs.

Excluding regions of high Galactic extinction (RA $< -40^\circ$; RA $> +55^\circ$) and low ecliptic latitude ($-10^\circ < RA < +10^\circ$), we propose to carry out IRAC observations as indicated in the top panel of Figure 1. In addition, the CFHTLS survey includes one field, “W4”, which partially overlaps Stripe 82 and also has high-quality optical imaging; we propose to extend our IRAC coverage to this entire field, adding another 12 deg$^2$.

1.1.3 Active Galactic Nuclei

Among our core scientific goals are to measure the luminosity function and clustering properties of a large and complete sample of AGN over a large dynamic range of redshift and luminosity. IRAC data are essential to obtain a complete AGN sample, especially obscured objects, and to refine our photometric redshift estimates.

Selection: Richards et al. (2004) have developed a Bayesian selection method, superior to traditional color cuts (Figure 3, right) to select optically luminous quasars from deep five-band SDSS photometry. We have already cataloged 25,000 unobscured quasars in Stripe 82 with $i < 21.3$ (Richards et al. 2009a) from single-epoch SDSS imaging. Variability selection (Fig. 3, left) using the 8-year SDSS baseline in Stripe 82 will both mitigate and help quantify quasar selection biases based on color. More importantly, including IRAC Channel 1 and 2 data in the Bayesian selection code (Richards et al. 2009b) allows selection of both obscured and unobscured quasars (Fig. 3, right). Figure 2 shows that the coadded SDSS data on Stripe 82 and our proposed IRAC observations are well-matched for both obscured and unobscured quasars at a range of redshifts, and the $[3.6] - [4.5]$ colors of quasars are close to constant with redshift and extinction (Fig. 3, right). Thus the combination of optical and IRAC data allows construction of a clean and complete quasar catalog. We estimate that we will be able
to select > 1000 AGN deg$^{-2}$—hundreds of thousands of quasars in total, far more than will come from the relatively shallow UKIDSS and WISE surveys.

**Photometric Redshifts:** The seven-band SDSS+IRAC photometry improves the accuracy of photometric redshifts and removes denegeracies as compared to photo-$z$'s determined from optical data alone (Richards et al. 2009b). Our photo-$z$’s will be further improved by: (1) Coadding the SDSS images to reduce photometric errors; (2) Incorporating NIR photometry, particularly important as H$\alpha$ passes through the bandpasses, and allowing better template fitting (e.g., Salvato et al. 2008); (3) Incorporating the effects of atmospheric refraction on the band-to-band astrometric shifts (Kaczmarszczik et al. 2007). We estimate that the final redshift errors in ADIOS will be $\Delta z \sim 0.1$ or better with very few catastrophic outliers (Richards et al. 2009b), which is more than adequate for our science goals.

**Obscured Quasars:** The majority of the AGN in the universe are optically obscured (e.g., Brandt & Hasinger 2005; Daddi et al. 2007), 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. 2). The multi-color Bayesian algorithm described above (Fig. 3, right) is effective at selecting obscured quasars; we expect to detect $\geq 1000$ $L_{\text{bol}} > 10^{45}$ erg/s type 2 quasars at redshifts $z < 1.5$ and a further $\geq 400$ objects with $L_{\text{bol}} > 10^{45.5}$ erg/s at $1.5 < z < 2.0$. This represents a 10-fold increase over the number of all $z \simeq 2$ obscured quasars known.

**Quasar Luminosity Function (QLF):** The QLF exhibits a break which evolves with redshift (dotted line in Figure 4 right). Existing optical and mid-IR data fail to probe the QLF below the break luminosity at epochs prior to $z \sim 2.5$ when quasar activity peaked. In models in which quasars are powered by infall triggered by galaxy mergers (e.g., Hopkins et al. 2006), the most luminous quasars are those accreting close to the Eddington limit, while the slope of the QLF below the break luminosity reflects the distribution of Eddington ratios among objects accreting much more slowly. The open squares in Figure 4 (left) indicate the dynamic range and uncertainty ADIOS will obtain in the QLF, adequate to test these models directly in detail. With an appreciably smaller survey (e.g., SWIRE), the correspondingly larger error bars (especially in the highest-redshift bin) would make it impossible to properly distinguish between models.

**Clustering:** Quasar clustering is a function of the mass of their host dark matter halos, and different quasar models make different predictions for the relationship between quasar luminosity and their halo masses. Measuring quasar clustering at $z > 3$, to our proposed flux limit, is a powerful discriminator of feedback models. These models (see Fig. 5) are luminosity-dependent, and are currently degenerate at $z < 2.5$, where existing data (e.g., Shen et al. 2007) have very little dynamic range in luminosity. High-redshift quasars are rare; a statistically significant signal requires large area coverage. A 200 deg$^2$ survey gives enough pairs to distinguish between the models in Figure 5 at $> 2\sigma$ for scales larger than $\sim 3 h^{-1}$ Mpc at $z = 3.5$ and 4.5. IRAC is essential to this endeavor, as 200 deg$^2$ of spectroscopy to the necessary flux limits is infeasible. Further, spectroscopy is unnecessary, as the IR-optical classification and photo-$z$’s obtainable from ADIOS are sufficient. A substantially smaller survey, and/or one with appreciably larger photo-$z$ errors, could not do the job. ADIOS will thus be able to distinguish competing feedback prescriptions for the first time.

**The Highest Redshift Quasars and the Epoch of Reionization.** ADIOS, with deep optical, near-IR and mid-IR imaging, will allow detection of quasar candidates at $z \sim 5 - 9$. 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 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 et al. 2008) to study the history of reionization and metal enrichment.

The luminosity function at these redshifts is wildly uncertain; one of our motivations is to get a proper measurement of it, directly probing the formation and evolution of the earliest supermassive black holes. The Hopkins et al. (2007) model predicts that we will find several hundred $z > 5$ quasars in the ADIOS sample but only 1–3 at $z > 7$, while Jiang et al. (2008), in a small area, found a steeper QLF slope at $z = 6$, predicting $\sim 30$ quasars at $z > 7$ in the ADIOS sample, and $\sim 10$ objects $z > 8$ (Fig. 6, left). The single IR-selected $z > 6$ quasar (Stern et al. 2007) suggests $\sim 0.1–84 z > 6$ quasars in ADIOS and emphasizes the need for more area.

1.1.4 Cosmic Microwave Background and Clusters of Galaxies

The WMAP satellite made precision measurements of fluctuations of the CMB for angular scales larger than 10'. However, there is a great deal of cosmological information that data on smaller scales would give us, including 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 145, 217, 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 about half of our proposed area on Stripe 82 and plans to complete the survey in early 2009 to a point source depth of $2 - 5 \mu K$.

Sunyaev-Zel’dovich Effect and Clusters of Galaxies: The combination of the ADIOS IRAC observations with deep SDSS optical photometry, existing and upcoming GALEX imaging, and near-IR imaging from the ongoing UKIDSS and future VISTA projects over the same region will enable us to probe a wide wavelength range 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. The IRAC Shallow Survey (Brodwin et al. 2006) has already reported 93 cluster candidates at $z > 1$ over a smaller (8 deg$^2$) region with comparable ancillary optical data. With the IRAC bands we will find a large number of clusters in the “cluster desert” which we can use to link the well-known cluster population at $z < 1$ and proto-clusters at $z \sim 2–4$ (Miley et al. 2004).

Through its observations of the Sunyaev-Zel’dovich effect, ACT will carry out a redshift-independent cluster survey mass-limited to $5 \times 10^{14} M_\odot$; we predict of order 60 such clusters over the ADIOS area, perhaps 1/3 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. In addition, 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. Furthermore, the cluster number density with redshift from this complete SZ+IRAC-selected cluster catalog will allow us to put strong constraints on $\sigma_8$ (e.g., Gladders et al. 2007), modified gravity theories (Schaefer & Koyama 2008), and the growth of halos and their occupation with redshift (e.g., Zheng et al. 2007).

\(^1\)http://www.physics.princeton.edu/act/
We will be able to study the luminosity function, the morphology-density relation, and the scaling relations between cluster mass and total number of member galaxies for the blue and red populations separately, with color measured from IRAC-optical colors. At $z > 1$, the red sequence of cluster ellipticals is forming; stellar-mass limited samples of galaxies from IRAC photometry can be compared to their passively evolving counterparts at low redshift.

**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 $\sim 5 \times 10^4 \text{deg}^{-2}$. 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 us to make 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 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 is, and thus the weaker we expect the CMB lensing signal to be. Thus this measurement will constrain the contribution of neutrinos to $\Omega_{DM}$.

**Point Sources and Small-Scale CMB fluctuations:** ACT’s measurement of the power spectrum on small angular scales will be limited by confusion due to sub-mm galaxies (see e.g., Toffolatti et al. 2005), which will not be identifiable as such with only three frequency channels, and not individually resolvable at ACT resolution. The starlight in most of these sub-millimeter galaxies should be detectable in the IRAC bands at 3.6 and 4.5$\mu$m. By cross-correlating the Spitzer catalogs with the ACT maps, we will reduce the contribution of the sources to the power spectrum by roughly an order of magnitude (Figure 7). Removing this dominant source of confusion and systematic error will enable ACT to better constrain 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.

### 1.1.5 Brown Dwarfs and White Dwarfs

ADIOS will measure mid-IR flux densities for the very large number of well-characterized stars in Stripe 82 and will allow the discovery of extremely faint, red objects. Its 4.5$\mu$m imaging will be orders of magnitude more sensitive to Y dwarfs ($T < 500$K) than deep near-infrared surveys such as UKIDSS (Fig. 6, right), and it covers a larger area, with extensive coverage at other wavelengths, than does SWIRE. Thus ADIOS will provide the brighter objects which can be studied in detail in follow-up observations and which will define the properties of new spectral classes. 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 about 150 T dwarfs over the whole sky. This 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.

The SDSS data allow white dwarfs to be selected by color, magnitude and proper motion. The ADIOS data will provide 3.6 and 4.5$\mu$m flux densities for thousands of these stars, which can be used to find possible unresolved cool companions and circumstellar dust, and which complement the targeted Spitzer surveys of these objects (Farihi et al. 2008).
1.2 Technical Plan

1.2.1 Observation Details

**Area:** Our solid angle requirement 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-redshift clusters in IRAC and ACT. Given the rarity of these objects (typical comoving space densities $\sim 10^{-9}\text{Mpc}^{-3}$ for high-z quasars and clusters), we require a survey volume of at least $\sim 10\text{Gpc}^3$ at $z > 1$, or a survey area of $\sim 200\text{deg}^2$.

**Location:** SDSS Stripe 82 provides the best combination of existing, public, deep multi-wavelength data over the required area. Trimming out regions of high stellar density, high optical extinction, and low ecliptic latitude, we cover the region $320^\circ < \alpha < 350^\circ$ and $10^\circ < \alpha < 55^\circ$, for $-1.25^\circ < \delta < +1.25^\circ$. We also observe an additional 12 deg$^2$ at 22 hours ($\alpha = 330^\circ$) to cover the entire CFHTLS W4 field. See the top panel of Figure 1 for a visual summary of our proposed coverage.

**Depth:** We require sufficient depth to 1) measure the QLF below the break luminosity to redshift 5 (Fig 4), 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 happily met both by the depth of our SDSS imaging coadd ($i = 23.3$) and a SWIRE-like depth of $4.25\mu\text{Jy}$ at $3.6\mu\text{m}$ and $7\mu\text{Jy}$ at $4.5\mu\text{m}$ (Figure 2).

**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. 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.

Science productivity in a wide-angle survey roughly goes as the number of total objects detected, which generally favors larger areas over greater depth. Even for the optimal case of a Euclidean distribution (a factor of 4 objects per magnitude of 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. The ADIOS survey balances the competing demands of depth and solid angle while meeting its principal science goals.

For mapping to this depth ($2 \times 2 \times 30 = 120s$), the PET gives estimated 5$\sigma$ depths of 4.25 and $7\mu\text{Jy}$ 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) 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 background), we do not observe within $5^\circ$ of the ecliptic ($350^\circ < \alpha < 10^\circ$) so as to limit our observations to medium background. Our 5$\sigma$ depth estimates above assumed nominal medium background levels of $0.125\text{MJy/sr}$ at $3.6\mu\text{m}$ and $0.366\text{MJy/sr}$ at $4.5\mu\text{m}$. The actual backgrounds over our survey area range between 0.08 and 0.23MJy/sr at $3.6\mu\text{m}$, yielding a S/N at $4.25\mu\text{Jy}$ of 5.6–4.2 for point sources. Furthermore, as the background increases steeply with longer wavelengths, backgrounds should be a minor issue for the warm mission.

**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 (a few tens of pointings).

### 1.2.2 Scheduling Constraints

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 Time</th>
<th>Orientation</th>
<th>Ch1Bkgrnd</th>
<th>Ch1SNR(@4.25μJy)</th>
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<tr>
<td>21h20m+0d Window</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2009Jun16 - 2009Jul27</td>
<td>72-62</td>
<td>0.14-0.11</td>
<td>5.0-5.2</td>
</tr>
<tr>
<td>2009Nov28 - 2010Jan08</td>
<td>259-248</td>
<td>0.08-0.14</td>
<td>5.6-5.0</td>
</tr>
<tr>
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<td>0.13-0.09</td>
<td>5.0-5.2</td>
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<td>259-248</td>
<td>0.08-0.15</td>
<td>5.6-5.0</td>
</tr>
<tr>
<td>23h20m+0d Window</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2009Jul16 - 2009Aug24</td>
<td>66-64</td>
<td>0.18-0.12</td>
<td>4.5-5.0</td>
</tr>
<tr>
<td>2009Dec29 - 2010Feb05</td>
<td>248-246</td>
<td>0.11-0.21</td>
<td>5.2-4.3</td>
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<td>0.18-0.12</td>
<td>4.5-5.0</td>
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<tr>
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<td>0.11-0.21</td>
<td>5.2-4.3</td>
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<tr>
<td>03h20m+0d Window</td>
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<td>5.3-5.8</td>
</tr>
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</table>

Apart from a ~ 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 ~ 12 weeks of total observing could be split into ~ 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 correctly 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 main stripe consists of two sections on either side of the ecliptic plane. 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), and SWIRE (e.g., Surace et al. 2005) 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).

Images will be produced in $2 \times 2.5$ deg$^2$ tiles with $2 \times$ oversampling of the native pixel scale, making them large but manageable. Image generation will be handled at the SSC; this effort will be led by M. Lacy, who is one of the world experts in this processing. Part of our data analysis funds will be used to hire a data analyst at the SSC to undertake the image analysis.

At Drexel, Richards’ group will take these tiles and produce initial catalogs using both APEX and SExtractor (Bertin & Arnouts 1996). With a large Beowulf cluster, 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 1.2Gb of catalogs (about 50,000 sources deg$^{-2}$ at 128 bytes per object). Our planned delivery schedule is as follows:

**Delivery schedule:**
- Observations begin: June 2009
- Observations end: June 2011
- Prelim. delivery of sample data: June 2010
- Delivery of final images: February 2012
- Delivery of single-band catalogues: June 2012
- Delivery of final band-merged IRAC/UKIDSS/SDSS/etc. catalogs: January 2013

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-2010; it may be useful for helping justify a Warm II mission. All of the primary ancillary data sets (SDSS, UKIDSS, GALEX) are or will be public by the time observations begin.
Other data sets (e.g., ACT) will become public over the next few years, thus we have allowed for some extra time in the schedule to produce final multi-wavelength band-merged catalogs.

In addition, 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.

**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, and Bootes 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.

### 1.2.4 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. 1); 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 $> 200 \text{ deg}^2$ to $g \sim 24$; all data public
- SDSS-III imaging over contiguous 2000 deg$^2$ centered on Stripe82; complete by early 2009
- UKIDSS $YJHK$ imaging; DR1 public now; DR4 public Jan. 2010
- NEWFIRM imaging on KPNO 4-m; 50 deg$^2$ to $J_{AB} = 22$ in hand, more time in Jan. 2009
- Deep optical/NIR imaging over 1-10 deg$^2$: CFHTLS W4 field, VVDS 22hr field and UKIDSS DXS field
- SDSS spectroscopy of galaxies, stars, quasar candidates to $i = 19.1$ ($z < 3$) and 20.2 ($z > 3$) over $> 200 \text{ deg}^2$ 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 $i = 19.8$ over 2000 deg$^2$ of Southern Galactic Cap
- Wiggle-Z galaxy spectra (400 deg$^{-2}$) over $\sim 70 \text{ deg}^2$
- ACT to $2 - 5 \mu K$ in 3 mm bands; $\sim 100 \text{ deg}^2$ observed; the remainder done by early 2009
- FIRST (VLA) 20 cm imaging to 1 mJy over entire area
- 3× FIRST depth VLA data at 20 cm over $\sim 80 \text{ deg}^2$
- GALEX two-band UV to 2× MIS depth ($m_{AB} \sim 23.75$), mostly observed

On a longer timescale, additional surveys (Pan-STARRS, LSST, DES [Dark Energy Survey], VHS [VISTA Hemisphere Survey], Subaru Hyper-Suprime Cam) will also cover this region of sky.
Figure 1: 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 $RA \approx -27^\circ$ is not shown). This cut avoids the ecliptic in the middle, high stellar density on the left, and high optical extinction on the right (see Panel g). Panel b: UKIDSS coverage. Black: existing public data (sparse sampled). Grey: DR4 (Jan. 2010). Yellow boxes: existing NEWFIRM coverage. Panel c shows coverage by the Wiggle-z spectroscopic survey (upward hashes), existing ACT coverage (10 < $RA < 90$) (downward hashes), and the CFHTLS W4, VVDS deep fields (boxes near $RA = -30^\circ$). Panel d: VLA coverage at 20 cm to $3 \times$ FIRST depth: x’s mark the region covered to date, and the boxes indicate the area to be covered during the next two VLA semesters (accepted dynamic targets). Panel e: GALEX coverage in the Medium Imaging Survey (blue), regions covered twice as deep (green) and upcoming observations (black). Gaps 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 2: Comparison of AGN 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\(\times\)MIS) 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 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 \(L \simeq 10^{43}\) erg/s type 2 AGN at \(z = 0.5\)).

Figure 3: Left: Optical color-color diagram of point sources in SDSS, coded by the degree of variability. \(\sim\)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). Quasars lie in the large red blob with \(u - g < 0.6\). RR Lyrae stars are the smaller red blob. We are in the process of extending variability selection to high-\(z\). Right: 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.
Figure 4: Left: Predicted QLF and uncertainties for the ADIOS survey (green squares), given its depth and area, following Hopkins, Richards, & Hernquist (2007). For comparison, the blue triangles show data from the much shallower and less complete SDSS survey. The top left panel shows the luminosity function at $z = 2.4$, with three models superposed. The other panels show the results at $z = 0.87$, 2.40, and 4.25, after dividing out a fiducial model to emphasize the model distinctions. Right: $i$-band absolute magnitude for known SDSS quasars (black triangles) and type 1 quasar candidates (grey crosses) in the $\sim 30$ deg$^2$ of overlap between large-area Spitzer fields and SDSS. Quasar candidates are selected using the Bayesian method of Richards et al. (2009b; see Fig. 3). The dashed black line indicates the ADIOS depth ($i \sim 23, f_{3.6} \sim 5\mu m$ at $z = 1$). The dotted black line shows $L^\ast (M^\ast_i)$ for quasars, demonstrating that SDSS only probes the bright end of the QLF, but ADIOS will sample the faint end to nearly $z \sim 4$.

Figure 5: Since quasar clustering is a function of the mass of quasars’ host dark matter halos, different feedback models make different predictions for quasar ”bias”. 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 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 $z = 2$. (Adapted from Hopkins et al. 2007).
Figure 6: **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. (2008), 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 7: **Left:** The effect of point sources on CMB anisotropy measurements. The solid line is the primary CMB power spectrum. The ACT expected bandpower errors (cosmic variance + noise) are shown as bins. Any signal above the error can be measured, and any unsubtracted foreground above this level will introduce systematics in the ACT analysis. The expected point source signal (dark blue band) is well above the experimental errors. The clustering contribution to the point-source signal (dark green, lowest expected level shown) is comparable to the Poisson term (light green, lowest expected level). Both these contributions can be reduced below experimental errors by combining ACT maps with Spitzer observations (blue region). **Right:** The ratio of mm fluxes of dusty galaxies to those at 3.6\( \mu \)m as a function of redshift, calculated using the Arp220 SED for frequencies 353 (green), 270 (red), 217 (blue) and 145 (black) GHz, where we have scaled the mm fluxes by \((\nu/353\text{GHz})^3\) to eliminate the dominant dependence on mm flux. Note the plateau for 0.4 < \( z < 0.7 \), and the exponential rise for 1 < \( z < 3 \). Thus, this flux ratio is a quite effective photometric redshift indicator.
References

Brandt, W. N., & Hasinger, G. 2005, ARAA, 43, 827
Fan, X. et al. 2006a, AJ, 131, 2103
Kaczmarczik, M. C., Richards, G. T., & Schlegel, D. 2007, BAAS, 38, 798
Smith, K. M., Zahn, O., & Doré, O. 2007, PhysRevD, 76, 043510
Surace, J. A., & SWIRE Team 2005, BAAS, 37, 1246
2 Scheduling Profile of the Proposed Program

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 $\sim 200$ 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 - 2009Jul17
  2009Nov28 - 2010Jan08
  2010Jun25 - 2010Aug04
  2010Dec06 - 2011Jan16

- **23h20m+0d Window**
  
  2009Jul16 - 2009Aug24
  2009Dec29 - 2010Feb05
  2010Jul24 - 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

PI: Gordon Richards (Asst. 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: Mark Lacy (PhD, Cambridge 1993) is the Spitzer Archive Scientist at the SSC. His interests include distant galaxies and dust obscured AGN and quasars.

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

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

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: Xiaohui Fan (Assoc. Prof., 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: Gillian Knapp (Professor, Princeton University): leader of SDSS photometric and (part of) spectroscopic pipeline development: papers on SDSS brown and white dwarfs.

Co-I: Eiichi Egami (Associate Astronomer, Steward Observatory, University of Arizona; PhD Univ. of Hawaii 1995); IR/submm extragalactic astronomy both from ground and space

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

Co-I: John Bochanski (Postdoc, MIT; PhD Univ. of Washington); Expert on multi-wavelength survey observations of low-mass stars and brown dwarfs

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: Sudeep Das (Princeton, PhD 2008): member of the ACT team; expert on lensing of CMB and SZ effect.

Co-I: M. Elvis: (SAO, Sr. Astrophysicist; PhD U.Leicester 1978); extensive work on quasars and AGNs, notably SEDs, the Unified Model, and accretion disk winds; PI COSMOS Chandra and Magellan/MMT surveys

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

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

Co-Is: Raul Jimenez (Professor, ICE Barcelona; PhD Niels Bohr Inst. 1995); Extensive expertise on modeling galaxy information and evolution

Co-I: Christopher Kochanek (Professor, OSU); Co-I of Spitzer Deep Wide Field Survey; PI of AGES spectroscopic survey of Bootes IR field

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: Satoshi Miyazaki (Assoc. Professor, NAOJ; PhD Univ. of Tokyo) Instrumentation for the Subaru Telescope (Suprime-Cam; Hyper Suprime-Cam), weak lensing
Co-I: Adam Myers (Research Scientist, Illinois; PhD Durham 2004); pioneering work on clustering of photometric quasars; PI of deep MMT/Hectospec IR/optical quasar survey
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: Licia Verde (Professor, ICE Barcelona, Spain; PhD Univ. of Edinburgh 2001); Extensive expertise in CMB and large scale structure data interpretation.
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 (Institute for Advanced Study; PhD Princeton 2005; Spitzer Fellow 2005-08); selection and multi-wavelength properties of type 2 quasars; AGN demographics

• Anderson, S. F. et al. 2007, “A Large, Uniform Sample of X-ray Emitting AGN from the ROSAT All-Sky and SDSS-DR5 Sample”, AJ, 133, 313
• Lacy, M. et al. 2007, “Optical Spectroscopy and X-ray Detections of Quasars/AGNs Selected in the Mid-IR from Two Spitzer Wide Area Surveys”, AJ, 133, 186
• Richards, G. T., et al. 2006b, “Spectral Energy Distributions and Multiwavelength Selection of Type 1 Quasars”, ApJS, 166, 470
4 Summary of Existing Programs

PI G. Richards is also PI of AR-1 program #3284, AR-3 program #30347, and GO-5 program #50087. 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 79 times and is proving to be quite useful for planning of AGN-related Spitzer proposals. Preliminary results for the cycle 3 program were reported at the Jan. 2008 AAS meeting and a final paper describing our efforts at 8-dimensional selection of quasars from optical+MIR data will be available by the time the TAC meets. The cycle 5 data has just started coming in; Richards’ postdoc Rajesh Deo is leading the data reduction. Richards is also a Co-I on GO-30344 “Decoupling luminosity, evolution and orientation effects in AGN” led by M. Jarvis; the data have been obtained and reduced and the paper is in preparation.

Co-I M. Lacy is PI of, or technical contact on 13 Spitzer proposals (4 DDT, 2GTO, 7GO). Data for 90% of these programs are taken and 70% of it analyzed. Publications: Lacy et al. 2007, ApJL, 669, L61, Lacy et al. 2007, Highlights of Astronomy, 14, 249.

Co-I X. Fan is the PI on five Spitzer projects in previous cycles and CoI on another seven about quasars and brown dwarfs; GO-3198 (PI): One paper published; GO-3221(PI): one paper submitted; GO-30402 (PI): all data analyzed, one paper in preparation; GO-40356 (PI): all data analyzed, one paper in preparation; GO-50390 (PI): 50% data taken and being analyzed.

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.

Co-I E. Egami is the PI of GO programs 20439, 40026, 41011, 50249, 50251, and is the TC for GTO programs 83, 30775, 40409, 40602. Several papers have been published, and more are in preparation.

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 C. Kochanek: Co-I of the Spitzer Deep Wide Field Survey (SDWFS) and the MIPS AGN and Galaxy Evolution Survey (MAGES)

Co-I G. Knapp is a member of the Spitzer-Taurus Legacy Survey Team, PI D.L. Padgett
5 Observation Summary Table

Our Spitzer-IRAC observations will tile \( \sim 200 \text{ deg}^2 \) along the celestial Equator (SDSS Stripe 82) bounded by \(-40^\circ < \text{RA} < -10^\circ \) (21h20m < RA < 23h20m) and \(10^\circ < \text{RA} < 55^\circ \) (00h40m < RA < 03h40m) 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 sticks out of SDSS Stripe 82. See the top panel of Figure 1 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 \(7.0 \mu\text{Jy} \) in channels 1 and 2, respectively.

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<th>Flux Density</th>
<th>AOT/ Int./ AOR</th>
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<td>128</td>
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</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 (a few tens of pointings) 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.