The SIRTF First Look Survey: Community Workshop Report

J. J. Condon, P. Myers and G. Helou

1. Introduction

A Community Workshop, convened by B.T. Soifer, Director of the SIRTF Science Center (SSC), met on September 15 and 16, 1999 on the Caltech Campus in Pasadena, CA. The purpose of the workshop was to formulate a scientific definition of the SIRTF First Look Survey (FLS), in terms of observational goals and priorities. The Workshop gathered about forty participants, including members of the SSC Oversight Committee, members of the SIRTF Science Users Panel, and potential SIRTF users drawn from the astronomical community at large. Staff scientists from the SSC and from the SIRTF Science office, as well as members of the SIRTF instrument teams also participated, and offered information on technical issues as well as the Guaranteed Time Program. An attendance list is attached at the end of the report.

The Workshop convened in plenary session for half a day, then divided up into two groups, one to consider the needs for extragalactic surveys, moderated by J.J. Condon, and the other to consider the needs within the Milky Way, moderated by P. Myers.

2. The FLS extragalactic component

2.A. Science Goals

The extragalactic working group recommended a FLS program designed to

(1) detect enough extragalactic sources at unexplored sensitivity levels to generate a representative sample and reduce the uncertainties in the source counts,

(2) characterize the dominant source populations with both MIPS and IRAC data from SIRTF plus ancillary surveys at optical, near-infrared, and radio wavelengths, and

(3) explore the cirrus foreground at moderately high |b|, and its

effect on point-source detectability,

all in time to support the first SIRTF science users. Most existing archival data at visible and radio wavelengths are not well matched to supporting the FLS goals. For example, the HDF is too small, and existing all-sky radio surveys are not sufficiently sensitive. New ancillary data obtained well before the (uncertain) SIRTF launch date will significantly enchance the scientific value of the FLS, so most of the extragalactic FLS should be confined to the northern continuous viewing zone (CVZ) with ecliptic latitudes greater than 80 deg.

2.B. Observational Definition

The recommended extragalactic FLS consists of a shallow survey covering 5 square deg of sky and a "confirmation and verification" survey covering about 1/4 square deg with both MIPS and IRAC. In comparison to the shallow survey, the confirmation survey should attempt eight to ten times more integration time per point on the sky. The extensive IRAC surveys improve MIPS source positions (needed for position-coincidence identifications with optical objects as faint as V~25 mag) and aid source classification (e.g., revealing the presence of an AGN, yielding rough redshift estimates, characterizing the stellar populations). No IRS observations are recommended because obtaining spectra for a statistically useful subset of FLS sources would require too much observing time.

The shallow survey is broken up into two areas. The larger covers 4 square degrees in that part of the CVZ with the lowest cirrus background (1 to 2 MJy/sr at 100 microns) near RA=17h, DEC=+61d (J2000), and not containing any strong radio sources (see below). The final square deg is centered on the ELAIS N1 field: RA=16h10m, DEC=+54d30' (J2000). This field is attractive because it has the lowest cirrus background (0.4 MJy/sr at 100 microns) of any region near the northern CVZ, it is continuously visible from the earliest possible SIRTF launch date until September 2002, and it has been covered by a deep ISO survey at 15 and 175 microns. The confirmation survey should be contained within the two shallow survey areas.

Even at 24 microns, the combined surveys are large enough to characterize the extragalactic source populations and determine source counts over 1.5 decades in flux density, after binning sources in six bins of width 0.25 in log flux density.

2.C. Description of Survey

The recommended shallow survey consists of near the minimum coverage one would allow while maintaining reliability and robustness. This conservative approach is best suited for the very early stages of the mission. The MIPS survey consists of freeze-frame scan mapping at the fast speed with 3 seconds of integration time per frame, repeated 5 times. This results in 75 seconds of integration over 15 sightings of each sky pixel at 24 and 70 microns, and 15 seconds of integration during 5 partial sightings at 160 microns. Adding approximate overheads of 30% yields a mapping rate of about 4 hours per square degree. The IRAC shallow survey consists similarly of 5 sightings of the sky at 12 seconds of integration each time, adding up to 60 seconds total integration time. This works out to a mapping rate of about 5 hours per square degree.

The confirmation surveys should cover 3 to 4% of the area covered by the shallow survey, and assuming similar efficiency, i.e. same observing strategy, should require one third as much observing time for 8 to 10 times more integration time. However, these confirming observations may be more effective if the time were spent on fewer sightings with longer integration time in each. The SSC should look into optimizing this choice as part of detailed observation planning for the FLS.

The estimated total time required, depth of integration, and approximate expected source counts are given in table 1. The "nominal sensitivity" corresponds to the limits achievable if all the data were co-added, and sources extracted at the resulting optimal noise levels. Similarly, the confirmation survey would reach an ultimate sensitivity roughly three times deeper (except at 160um where confusion is the limit), assuming all data are co-added optimally, and in quadrature. This ultimate sensitivity will be achieved only after considerable experience with instrument and data characteristics, at least several months into the mission.

The total time required should therefore come up to 45 hours for the shallow survey, and about 15 hours for the confirmation survey, for a grand total of 60 hours.

Table 1. The proposed shallow survey

SHALLOW SURVEY, 5 sq.deg:

Instrument	Survey Time (hr)	Wavelength (microns)	Nominal 5*rms (mJy)	Estimated Number of sources
MIPS	20	24	1.3	400

		70	4.5	1500	
		160	27	2500	Nearly confusion limited
IRAC	25	3.6, 4.5	0.04		
		5.8	0.04		
		8.0	0.06	~750	

2.D. Ancillary Data

Optical, near-infrared, and radio surveys provide essential support for the extragalactic FLS. The principal requirement is for optical identifications, the first step to understanding FLS sources. Deep (e.g., R ~ 25.5 mag) I- or R-band images covering the full 5 sq.deg. survey area should contain the counterparts of most FLS sources, but we note that accurate (~1 arcsec rms) positions are needed for making reliable optical identifications of such faint infrared objects. The KPNO 4 m telescope is equipped with a large-format camera capable of obtaining such data in a few nights of observing. Most of the detected MIPS sources will have flux densities near the 5*rms detection limit, and their rms positional uncertainties owing to noise alone will be about 10% of the half-intensity beamwidths, or 2 arcsec at 70 microns and 5 arcsec at 160 microns. Such sources may first have to be identified with mid-infrared or radio sources having more accurate positions before being optically identified.

The workshop also recommends covering the extragalactic FLS area with deep (K ~ 18 mag) near-IR images which will be useful for distinguishing stars from galaxies and extending the proposed IRAC spectrophotometry. Again, these data are well within existing capabilities at KPNO, or of an enhanced version of the Two-Micron All-Sky Survey (2MASS) project.

Multicolor (three or more bands) of relatively shallow optical images would be useful for redshift estimates and classification of low-redshift galaxies. The SDSS (Sloan Digital Sky Survey) or the KPNO 0.9 meter telescopes would be capable of obtaining such data.

Radio images are scientifically valuable because most far-infrared sources obey the tight FIR/radio flux correlation. Most radio sources fainter than 1 mJy at 1.4 GHz appear to be powered by starbursts and not AGN, so they probably obey the FIR/radio correlation. Thus deep radio surveys and the extragalactic FLS will find similar source populations, and deep radio surveys can provide pre-launch images that will be similar to the FLS images. The resulting radio catalogs can be used to select and identify most FLS sources for further study before launch. FIR/radio flux ratios can later be used to distinguish objects containing radio-loud AGN from

"normal" galaxies. The radio observations should be made with 5 arcsec FWHM resolution (1) to yield sub-arcsec positions for even the faintest detectable sources and (2) to sort out confusion in the larger (20 arcsec at 70 microns, 47 arcsec at 160 microns) MIPS beams.
As a practical matter, only the VLA B-configuration at 1.4 GHz can produce the necessary sky coverage, sensitivity, and resolution. The effective VLA field-of-view is half the beam solid angle, or about 1/7 square deg at 1.4 GHz; thus 35 fields are needed to cover 5 square deg. The 1.4 GHz 5*sigma sensitivities needed to match the FLS shallow survey are listed in Table 3:

Table 2. Radio sensitivities needed to match the shallow FLS

Wavelength (microns)	Sensitivity (mJy)	1.4 GHz sensitivity (microJy)
24	1.3	90
70	4.5	70
160	27	80

These numbers are based on the following assumptions:

(1) In the source frame, <S(60 microns) / S(1.4 GHz)> ~ 140
(2) Radio sources have spectral indices -0.7
(3) Infrared sources have the average spectra of IRAS Bright Galaxy Sample sources
(4) The average redshift of the fainter sources is <z> ~ 1

The VLA can reach the required sensitivity (~15 microJy/beam rms noise) in about 10 hours per field (~350 hours total). In the B configuration, the rms confusion is only about 1 microJy/beam and can be neglected. Fields must be mosaiced in filled hexagonal patterns (seven fields minimum) for uniform sensitivity on the sky, so FLS strips narrower than about 1 deg in either dimension cannot be covered efficiently. Finally, strong sources (1.4 GHz flux densities > several hundred mJy) and low declinations (< +40 deg) must be avoided lest the VLA images be limited by dynamic range, not noise. The VLA will be in the B configuration during the first quarter of 2001.

2.E. FLS Data Products

Finally, the workshop considered which FLS data products would be most useful in an early release for scientists planning to use SIRTF. The recommended wish-list is:

(1) A "high-reliability" source list giving positions, flux densities, and their uncertainties, plus variability indicators and data-quality flags
(2) Band-merging information so that sources in different SIRTF wavebands can be associated with each other and with objects found in the ancillary surveys
(3) individual frames should be available to users, plus
(4) mosaiced, coadded images on a "best effort" basis
(5) tools to view all bands (SIRTF and anciallary) near a given position on the sky

They should be released as soon as possible, even though the calibration may still have large uncertainties and be subject to later revision.

3. The FLS Within-the-Milky-Way component

3.A. Science Goals

The workshop sought to identify observations which would help to characterize the properties of the sky as seen by SIRTF instruments, which would be useful to SIRTF observers. The participants came up with three main science goals:

- Characterize the cirrus and background source counts at low galactic latitudes; this will help guide MIPS and IRAC observers who wish to observe close to the galactic plane.

- Characterize internal cirrus and background source counts toward a molecular cloud; it will be useful to observers of stars and dust in molecular clouds to know how limiting are fluctuations in internal cirrus and extinction, and how well one can distinguish embedded and background populations.

- Characterize the ecliptic plane and zodiacal light for solar system observations, to estimate the possible confusion by moving objects and by zodiacal light.

3.B. Observational Definition and Description of Surveys

To characterize the cirrus and background source counts at low galactic latitudes, the workshop suggested two observations at fixed galactic longitude:

a. A "strip" one footprint (5 arcmin) wide at l=285 deg, -30 deg<=b<=0 deg. This should give a broad range of cirrus intensities and source counts at a longitude close to the inner galaxy. This zone is viewable by SIRTF for many months and so is fairly robust against deviations from launch date. Within this strip, we consider the range -10<=b<=0 to be most important to cover continuously, since it is closest to the plane and can be compared with another strip described in (b) below. The range -30<=b<=-10 could be covered with a lower filling factor, such as 50%. The coverage and integration times are the same as used for the extragalactic shallow survey, again with the assumption that IRAC and MIPS cover the same area. We consider this an important aspect of galactic FLS observations, since IRAC will be much more sensitive than currently available data at IRAC wavelengths. We estimate 6.7 hours for MIPS and 8.5 hours for IRAC to cover a filled strip 5 arcmin wide and 20 deg long.

b. A second strip similar to (a) above, but at a significantly different longitude, l=150 deg, and extending over the latitude range 0deg<=b<=10deg. Strips over this latitude range are viewable for nearly as long as is (a) provided one can shift the longitude slightly. For the same scanning procedure as in (a) and a fully sampled 10 degree strip, we estimate 3.33 hours for MIPS and 4.25h for IRAC.

To characterize internal cirrus and background source counts toward a molecular cloud, the workshop suggested a 2 degree long scan through the Chamaeleon II cloud centered at RA(1950)=12h 50m and Dec(1950)=-77 deg. This should provide approximately equal scan length "off" and "on" the cloud. The cloud was chosen because it has a significant population of embedded T Tauri stars, with substantial cirrus emission, and because its position is fairly robust against launch date variations. It appears from information available at the workshop that this choice probably will not conflict with GTO observations. The same MIPS fast scan as assumed in the galactic scans above, and the same area coverage by IRAC as by MIPS are appropriate, but it is recommended to increase the IRAC integration time by a factor of ten over that assumed above. This increase is necessary because many observers will attempt to detect brown dwarfs with IRAC in clouds such as Chamaeleon II, and it will be useful to learn how limiting the cirrus is at the sensitivity needed to detect brown dwarfs. Accordingly the total time needed for this portion is estimated at 40 minutes for MIPS and 8.3 hours for IRAC.

To characterize the ecliptic plane and zodiacal light for solar system observations, scans are suggested at ecliptic latitudes 0 deg and 15 deg. Each scan would be 5 deg long, with 3 passes by IRAC, each separated from the next by a few hours. This time interval should be enough to allow the

8 micron channel of IRAC to detect moving objects. Each scan would also have 1 pass by MIPS to get the spectral energy distribution of the objects detected by IRAC. For these observations the estimate is 3.3 hours for MIPS and 12.0 hours for IRAC.

Although we do not suggest any specific spectroscopic observations with IRS as part of the FLS, we note that it would be very useful to observers to have "template spectra" of various objects, perhaps as part of the IOC campaign. We suggest that these include objects for which the background or instrument sensitivity may be limiting factors, such as a spectrum of a source in a region of high cirrus background, e.g. 200 MJy/sr at 100 microns, and a spectrum with R ~ 600 of a source at the limit of the IRS sensitivity.

3.C. Ancillary Data

The possibility of ancillary data collection was discussed, and it was considered that this may be highly desirable for followup observations, but is not necessary in advance of the FLS observations.

4. Additional Comments

Workshop participants were also concerned that sufficient resources be devoted to developing software analysis tools for IRS observations, even though for various reasons the FLS Workshop did not recommend FLS observations with the IRS instrument.

5. Summary

The community workshop was able to derive a coherent definition of the SIRTF First Look Survey, which is also quite workable in practice. The total amount of time requested adds up to about 107 hours.

Appendix: Workshop Participants

A. Barger, U. Hawaii
C. Beichman, JPL, MIPS
R. Blandford, Caltech
D. Calzetti, STScI
J. Condon, NRAO
R. Cutri, IPAC

M. Dickinson, STScI
D. Elbaz, Lick Observatory
J. Elliott, MIT
R. Gehrz, U. Minnesota
R. Griffiths, Carnegi-Mellon
B. Januzzi, NOAO,
M. Jura, UCLA
J. Knapp, Princeton
K. Luhman, SAO, IRAC
M. Malkan, UCLA
P. Myers, CfA
D. Schlegel, Princeton
M. Schmidt, Caltech
M. Werner, SIRTF Project Scientist
D. Woodin, NASA-Ames
C. Woodward, U. Wyoming

===================== SSC, SIRTF Scientists =====================
L. Armus
M.D. Bicay
P. Eisenhardt
F. Fang
N. Gautier
C. Grillmair
I. Heinrichsen
G. Helou
J. Keene
W. Latter
C. Lawrence
D. Levine
W. Mahoney
V. Meadows
M. Moshir
A. Noriega-Crespo
D. Padgett
W. Reach
B.T. Soifer
D. Shupe
K. Stapelfeldt
L. Storrie-Lombardi
J. Surace
W. Thaller