The CARMA Survey Toward IR-bright Nearby Galaxies (CARMA STING)

We propose an extragalactic CO survey, the CARMA STING, which will target 27 galaxy disks from a sample designed to span a significant range of star-formation activities, stellar masses, specific star-formation rates (SSFR), and galaxy morphologies. The sample consists of FIR-bright galaxies with a wealth of existing ancillary data (Table 1), selected to fully span the SDSS blue sequence of active star-forming galaxies. The STING will take advantage of the strengths of CARMA — its unique combination of collecting area, field of view, and image fidelity — to deliver excellent images of galactic disks. Unlike previous interferometric surveys, the STING is designed to image these disks out to one-half of their optical radii (R_{25}), thus probing a new and critically important domain by beginning to sample the transition from molecule-dominated to the atomic-dominated galactic regions. This project will take 3 semesters to complete, and we request here time for its first semester.

The power of systematic surveys. Extragalactic CO surveys acutely lag behind optical surveys in their sampling of the universe. Most of the existing CO surveys used single-dish telescopes (e.g., Young et al. 1995 with FCRAO; Elfhag et al. 1996 with SEST; Böker et al. 2003 with IRAM; Kuno et al. 2007 with Nobeyama) with the consequent handicap in angular resolution. Only a handful of sizable CO surveys have used interferometers, chiefly: NUGA targeting 28 nearby AGN nuclei with PdBI (García-Burillo et al. 2003), BIMA SONG imaging of 44 nearby disks (Thornley et al. 1999; Helfer et al. 2001), OVRO MAIN, going after 15 nearby nuclei with different degrees of activity in two transitions (Baker et al. 2003), and the NMA/OVRO survey of the central arcminute of 20 CO-bright galaxies (Sakamoto et al. 1999).

New optical and IR observatories and surveys are producing or will produce a wealth of multiwavelength data on nearby galaxies. The missing datum to put together a complete picture of galaxy evolution is the behavior of the gas reservoir, particularly the molecular gas from which stars form. For example, recent observations in the EGS field show a decline in the co-moving quiescent SFR of star-forming galaxies since $z \sim 1$ (Noeske et al. 2006). This galaxy downsizing (star formation activity progressing from larger to smaller galaxies with decreasing z) may be caused by a progressive scarcity of gas to feed star formation. Understanding the mechanisms by which atomic gas turns into molecular gas and ultimately into stars is clearly crucial to making further progress, and the CARMA STING is designed to move us toward that goal.

CARMA can now start working toward the ultimate goal of comprehensive molecular surveys of the local galaxy population by studying a well-designed local sample of FIR-bright galaxies. Such a sample will be representative of the future molecular detections at cosmological distances, even in the ALMA era.

Sample design. Since the SDSS it has become clear that there is a very well-defined sequence relating stellar mass to star-formation activity (Kauffmann et al. 2003, 2004). Indeed, it appears that star formation rate is primarily dependent on stellar mass or stellar surface density, and only secondarily on morphological type (Boselli et al. 2001). In the SFR vs. M_* plane galaxies separate into two well defined branches: the red branch of "dead" galaxies, prevalent in high density environments and populated mostly by massive galaxies, and the blue branch of "star-forming" galaxies, spanning a range of masses and star-formation activities (Fig. 1). This sequence is at least as fundamental as the original Hubble sequence. Ours is the first CO survey specifically designed to sample the blue galactic sequence in the local universe.

Because obtaining the best science requires a number of ancillary data sets we have stressed in the selection criteria the availability of midIR and FIR photometry, HI data, and SDSS observations. The sample is composed of northern ($\delta > -20°$), moderately inclined ($i < 75$ deg) galaxies from the IRAS Revised Bright Galaxy Sample (RBGS) within 45 Mpc (Sanders et al. 2003). The galaxies were selected to uniformly sample 10 mass bins distributed between $M_* = 10^9$ and 3×10^{11} $M_\odot$. Within each bin the galaxies were ranked according to criteria designed to emphasize the availability of ancillary observations, lower inclinations, and the galaxy size match to the FOV of a 19-point mosaic. The 3 top galaxies per bin were selected where possible (some of the lower mass bins contained fewer than 3 galaxies), thus arriving at the sample size of 27 galaxies. Because of the heterogeneous nature of galaxies and their CO distributions (c.f., Regan et al. 2001), fewer than 10 mass bins and 3 galaxies per bin would result in too coarse a sampling of galaxy properties to yield general conclusions. The resulting sample very uniformly covers a range of stellar masses, star-formation activities, and morphological types (Figs. 1 and 3). We feel that, at this stage in the development of CARMA, selecting from the IRAS RBGS is important to maximize the impact of this study.

Differences and complementarities with other interferometric surveys. Unlike the NMA/ OVRO, NUGA and the MAIN surveys which are directed toward the study of the central region of galaxies (and for the last two, specifically the nuclear activity and feeding processes in AGN), the STING is geared toward the study of molecular disks, their formation and evolution. Therefore, the most directly comparable existing survey is BIMA SONG. SONG, which features several papers that average 12 to 20 citations per year (Regan et al. 2001; Wong & Blitz 2002; Helfer et al. 2003), has become a reference survey and a widely used data set for studies of the distribution of molecular gas in galaxies.

The STING will have substantially better angular resolution ($\sim$ 3") than SONG ($\sim 6-7''$), better to much better sensitivity (depending on when the new 3 mm receivers are available on the 10m dishes), considerably better image fidelity and calibration owing to CARMA's 105 baselines, and far superior galaxy coverage ($\sim$ 30% of the optical disk compared to $\sim$ 6% in SONG; Fig. 3c). With the STING we will sample farther into galaxy disks and cover regions where atomic gas is dominant. These are the key data necessary to discriminate among star-formation recipes.

In order to enlarge the overall sample of galaxies with interferometric CO images, *we have purposefully avoided overlap with SONG.* The SONG sample was constructed by selecting northern nearby spiral galaxies (d < 27 Mpc) with low inclinations and high optical fluxes. Our sample is chosen to span the blue sequence of SFR vs. M_* using nearby FIR-bright galaxies, emphasizing the existence of ancillary data sets. Experience indicates that producing the best science with CO surveys requires a number of ancillary observations, and frequently the science output is slowed down or limited by the acquisition of those data sets. Our sample avoids this pitfall by construction. Figures 2 and 3 graphically describe the sample and compare it to SONG.

CARMA has naturally undertaken deep CO images of some nearby, very extended prototypical galaxies, such as M 51. The detailed study of these flagship galaxies is highly complementary to the information gained from surveys, such as the STING.

Science with the STING. A major goal of the CARMA STING is to help link star formation and the ISM to our understanding of galaxy evolution by asking "What sets the rate of star formation in galaxies?". We will use the STING observations to carry out quantitative tests of a suite of theories about where and under which conditions GMCs and stars form. The resolution of CARMA will allow us to work at sub-kpc scales on a pixel-by-pixel basis (Fig. 3b) . The ancillary data (HI, optical, IR, and UV) will let us construct maps of the star formation rate and the stellar and total gas mass to accompany the CO maps. With rotation curves derived from the CO and HI, and molecular gas surface densities from FIR and CO, we can model the predicted SFR and compare it to observations. In a nutshell, the proposed observations will allow us to:

• Perform resolved studies of the relation between SFR and gas content in galactic disks, addressing the relations between different tracers of SF activity (FIR, Hα, radio continuum) and molecular and atomic gas, and studying the SF efficiency (SFE) in a variety of environments. BIMA SONG, being limited to the inner disk, provided limited constraints on CO radial scale lengths.

• Quantitatively study the distribution of the molecular gas in relation to the stellar and atomic components. We will obtain gas, stellar, and baryonic density profiles, and relate extinction and FIR emission to the gas distribution.

• Perform accurate mass modeling of galaxies, as the STING will yield a wealth of accurate kinematic data. We will use them to study the transport of gas in galaxy disks, and the influence of bars, spiral density waves, and gravothermal instabilities on gas compression and the formation of molecules.

• Clarify how the FIR/radio correlation differs between "normal" and "starburst" galaxies. An FIR-selected survey like the STING probes down to very short star formation timescales (high SSFRs), where deviations from the canonical correlation are most likely. Such deviations will be compared with measurements of gas surface density which, according to some models, should correlate tightly with the magnetic field strength.

• Study the heating and cooling equilibrium of gas in disks, by combining the STING data with spectroscopic FIR observations by Spitzer and Herschel, and planned CO surveys of the 2-1 and 3-2 transitions by the JCMT. We will obtain temperatures in molecular regions and related them to the FIR cooling lines of H_2 and metals.

• Model the FIR dust continuum in relation to the molecular gas distribution, in combination with existing Spitzer data and future Herschel and SCUBA2/LABOCA imaging. We will be able to quantify the fraction of molecular gas traced by CO, study the dust-to-gas ratio, and study the presence of "hidden" molecular gas and the location of ultra-cool dust if present.

What sets the rate of star formation in galaxies? In the last decade, theories consistent with existing data have argued that star formation is regulated by: Coriolis forces and instabilities in gas disks (Martin & Kennicutt 2001); galactic shear (Hunter et al. 1998); cloud-cloud collisions (Tan 2000); the formation of a cold phase above a certain column threshold (Schaye 2004); the ability of stars to bring gas to high densities at the midplane (Regan et al. 2001; Wong & Blitz 2002; Blitz & Rosolowsky 2006); or large scale instabilities in the gas disk driven by stars (Li et al. 2005, 2006; Yang et al. 2007). This striking variety of answers emphasizes the need for a data set designed to test these theories.

It has become increasingly clear that the Schmidt Law as proposed by Kennicutt (1998) is intimately tied to the formation of bound molecular clouds (Wong & Blitz 2002; Krumholz & McKee 2005; Kennicutt et al. 2007). Recent work point to a strong relationship between the conversion of HI to H_2 and the gravitational potential of the stellar disk (Wong & Blitz 2002; Li et al. 2005; Blitz & Rosolowsky 2004, 2006; Leroy et al. 2008; Bigiel et al. 2008). This offers a tantalizing link to the understanding of galaxy evolution offered by the SDSS (e.g., Kauffmann et al. 2003; Salim et al. 2007), in which the stellar mass of a star forming galaxy is a very good indicator of its specific star formation rate (Fig. 1). However, pushing this analysis further has been hindered by the scarcity of CO data, and by the fact that the available observations do not go out far enough in the disk. The STING will provide the data necessary to discriminate among models, by probing the entire SFR range of Kennicutt (1998), and by starting to sample the CO distribution in regions of the disk dominated by atomic gas.

A related question is "What fraction of the molecular gas is traced by CO emission, and what is the proportionality?", particularly relevant in the outer disks of galaxies. Leroy et al. (2007) recently modeled FIR data to explore the relationship between molecular gas and CO in the Small Magellanic Cloud. A similar combined analysis of the STING data together with FIR data sets will definitively provide an answer to this key question.

The CARMA STING will provide a key data set to quantitative explore the relation between the gas reservoirs and the star formation in galaxies, with the ultimate goal of understanding and characterizing the major processes that determine galaxy evolution. This survey takes advantage of the unique capabilities of CARMA.

References

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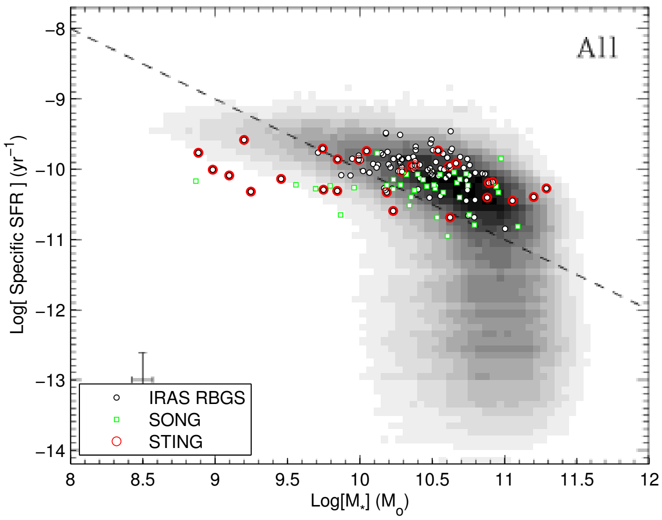

Figure 1: Sampling of the blue sequence of galaxies using the RBGS. The gray scale shows SDSS results for SSFR vs. Galaxy Mass (from Salim et al. 2007). The dashed line shows the locus of SFR= 1 $M_\odot$ yr^{-1}. The horizontal branch corresponds to the sequence of "blue and active" star-forming galaxies. The vertical branch corresponds to the sequence of "red and dead" galaxies. The right panel shows the IRAS RBGS within 45 Mpc, and the targets of the SONG and STING surveys. CARMA STING uniformly covers the blue sequence and samples considerably higher SSFRs than SONG.

Table 1

Name	Morph	RA (h)	Dec (deg)	Dist (Mpc)	Incl (deg)	D_{25} (")	M_* ($M_\odot$)	SFR ($M_\odot$ yr^{-1})	Sl	Sp	He	VLA	Class
NGC 0337	SBcd	1.00	-7.6	21.6	50.6	175	10.0	0.3	N	YY	P	DC	
NGC 0772	Sb	1.99	19.0	28.7	48.5	274	11.1	0.6	N	Y		DC	H:T2
NGC 1156	IB	3.00	25.2	7.0	43.1	173	8.9	-0.9	N	Y		DCB	H
NGC 1569	IB	4.51	64.9	4.6	64.7	238	9.2	-0.4	N	Y	G	DCB	H
NGC 1637	Sc	4.69	-2.9	10.2	31.1	191	9.8	-0.5	N	Y		DC	
NGC 2681	S0-a	8.89	51.3	12.5	15.9	235	10.2	-0.4	Y	Y		B	L1.9
NGC 2782	SABa	9.23	40.1	39.5	45.1	195	10.7	0.7	Y	Y		DCB	H
NGC 3147	Sbc	10.28	73.4	41.4	29.5	243	11.3	1.0	N	Y		DC	S2
NGC 3198	Sc	10.33	45.5	13.8	70.0	388	10.2	-0.1	Y	YY	P	DCB	H
NGC 3486	Sc	11.01	29.0	9.2	46.0	349	9.7	-0.5	Y	Y		DB	S2
NGC 3593	S0-a	11.24	12.8	5.0	74.6	281	9.5	-0.7	Y	Y		DCB	H
NGC 3949	Sbc	11.90	47.9	13.6	56.5	136	9.8	-0.0	Y	Y		B	H
NGC 4151	SABa	12.18	39.4	19.0	21.0	173	10.6	-0.1	Y	Y	G	CB	S1.5
NGC 4214	I	12.26	36.3	3.7	43.7	408	9.0	-1.0	Y	Y	G	DCB	H
NGC 4254	Sc	12.31	14.4	15.3	32.0	302	10.6	0.7	Y	YY	G	DCB	H
NGC 4273	Sc	12.33	5.3	15.3	48.5	131	9.7	0.0	Y	Y		CB	H
NGC 4501	Sb	12.53	14.4	15.3	61.0	519	10.9	0.5	Y	Y	G	C	S2
NGC 4536	SABb	12.57	2.2	14.9	58.9	425	10.4	0.4	Y	YY	G	DCB	H
NGC 4568/7	Sbc	12.61	11.2	15.3	66.0	258	10.4	0.4	Y	Y	G	DCB	H
NGC 4605	SBc	12.67	61.6	3.9	70.4	354	9.1	-1.0	Y	Y		DCB	
NGC 4654	SABcd	12.73	2.2	15.1	56	283	10.3	0.2	Y	Y		DC	H
NGC 4808	Sc	12.93	4.3	19.7	69.2	142	10.0	0.1	Y	Y	G	DCB	
NGC 5371	Sbc	13.93	40.5	41.1	54.0	239	11.2	0.8	Y	Y		DB	L2
NGC 5713	SABb	14.67	-0.3	26.7	48.2	148	10.5	0.8	Y	YY	P	DCB	
NGC 5728	Sa	14.71	-17.3	38.3	59.0	192	10.9	0.7	N	Y		C	
NGC 6503	Sc	17.82	70.1	3.8	73.7	371	9.2	-1.1	N	Y		DCB	T2/S2
NGC 6951	SABb	20.62	66.1	24.0	52.5	193	10.9	0.7	N	Y		DCB	S2

Table of the sample detailing galaxy name, morphology, J2000 coordinates, inclination, major axis extent (D_{25}), log of the stellar mass based on K-band magnitude (M_*), log of the star formation rate based on FIR luminosity (SFR), existing SDSS photometry (Sl), existing Spitzer IRAC *and* MIPS photometry (Sp; YY indicates is part of the SINGS project with a wealth of other ancillary observations), Herschel observations (He, G denotes guarantee time observation, P denotes in PHOENIGS proposal), configurations for archival VLA HI observations, and Ho et al. (1997) nuclear classification (Class; H denotes HII galaxy, T for Transition type, L for Liner, S for Seyfert).

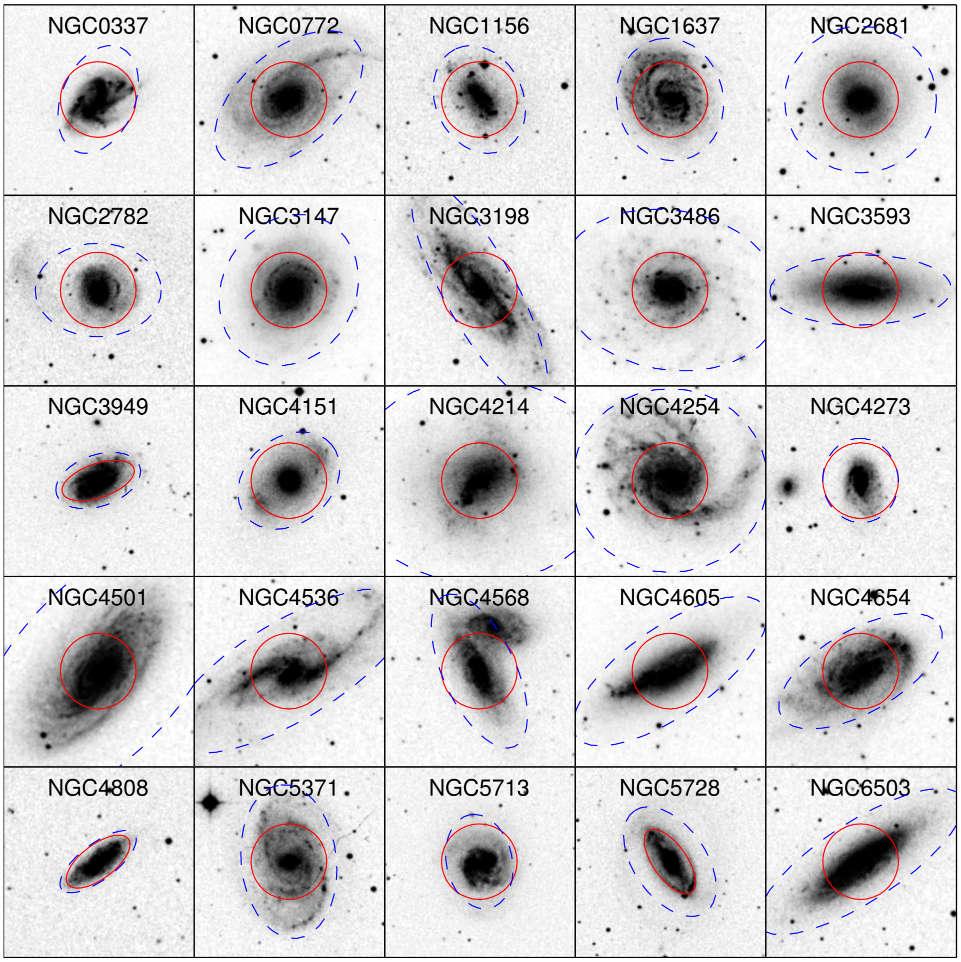

Figure 2: DSS images for 25 of the 27 targets of the STING (NGC 1569 and NGC 6951 excepted, to allow the display in a reasonable size grid). Each panel shows a 5 × 5 arcmin patch of the sky. The red solid line indicates the mosaic coverage in each case. The dashed blue line indicates the approximate location of the 25th magnitude isophote. The CARMA STING observations are designed to go out to at least $0.25R_{25}$, and to $0.5R_{25}$ when possible, in order to image the transition from the molecular to the atomic-dominated regime. These data are key to test the different SFR prescriptions.

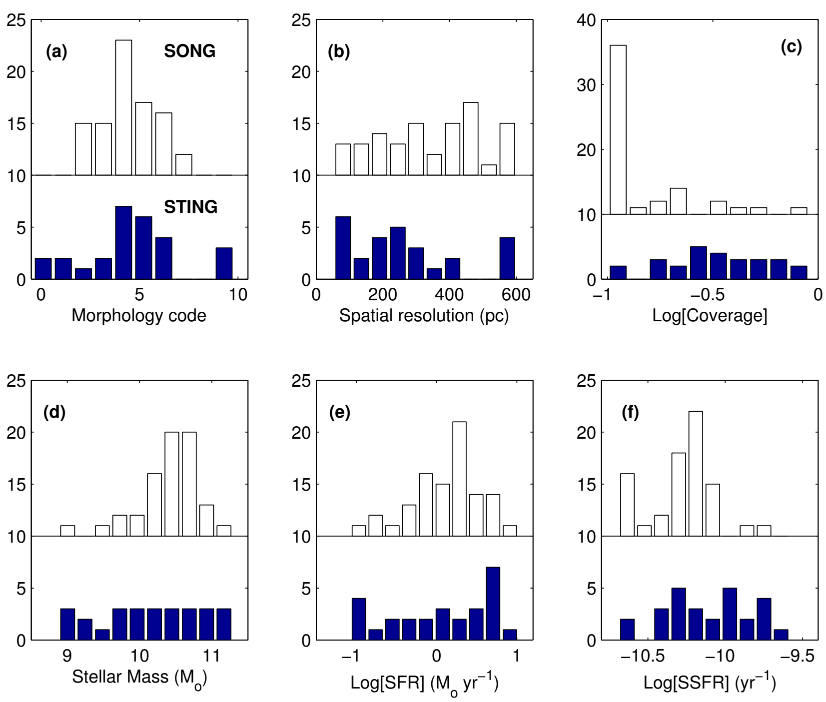

Figure 3: Histograms contrasting the distribution of several parameters for the STING and SONG samples. The panels indicate the distributions of: a) morphological types from LEDA. b) Spatial resolution on source. c) Log of the fraction of the source area (measured by D_{25}) covered. d) Stellar mass, M_*, as measured by K-band light. e) Log of SFR. f) Log of specific SFR, or the inverse time to form M_* at current SFR. The CARMA STING is designed to uniformly sample the stellar mass range of 10^9 to 3×10^{11} $M_\odot$, probing a wider range of SFRs, SSFRs, FIR luminosities, and morphologies than SONG. The STING is also designed to cover a larger fraction of galaxy disks than SONG (median of 30% versus 6%), with no loss of spatial resolution and a factor of two better sensitivity (~ 22 vs. $50 - 60$ mJy beam^{-1}.

Technical Justification and Management Plan

We propose to survey 27 galaxies with spatial resolution of $50 - 600$ pc, covering out to $0.5R_{25}$ in 19-point mosaics, attaining a 3σ point mass sensitivity $\sim 1.5 \times 10^6\ d^2_{15\ \rm Mpc}$ $M_\odot$ in a 10 km s^{-1} channel. One of the galaxies in our sample (NGC 1569) already has most observations obtained by Bolatto and Ott, and we do not anticipate more observations will be necessary. Two more galaxies (NGC 4214 and NGC 4605) have extensive low resolution observations by BIMA and/or OVRO. For each of these we request only two high resolution (C-array) tracks. The remaining 24 galaxies in our sample will be observed with optimally matched mosaic patterns in three tracks over two configurations (D-D-C). To complete this project will require a total of 608 hours of array time, which we request be equally divided over three semesters.

Resolution. Our science goals require ~ 500 pc resolution; this is particularly necessary to carry out local tests of star formation and to resolve spiral arms and bars. A combination of one C array track and two D array tracks will yield a ~ 3" (FWHM) robustly synthesized beam. At the median distance of our sample (~ 15 Mpc) this yields 200 pc spatial resolution — well-suited to make local tests of star formation laws and measure gas kinematics.

Coverage. Mosaicing to half of the optical radius, R_{25}, represents a good compromise between coverage and sensitivity that allows us to probe out to the atomic-dominated regime (the transition from H_2- to HI-dominated usually occurs between ~ 0.25 and $0.5R_{25}$). CO emission in spiral galaxies usually shows a scale length $\sim 0.1 - 0.2$ of R_{25}. The complementary single-dish observations will also allow us to extend our maps beyond the radius visible with the interferometer, with better surface brightness sensitivity but poorer resolution.

The average optical size of a galaxy in our sample is $d_{25} = 240''$. Our default observing mode will be a 19-point mosaic with a width of full sensitivity of ≈ 120", typically covering the target to $0.5R_{25}$ along the major axis. Since there is no advantage to imaging empty sky, in small galaxies with inclinations $i > 55$ deg where mosaics would otherwise spill beyond R_{25} on the minor axes, we will use a redundant elongated 19-point mosaic with 0.45 axis ratio to optimize the mapping. The planned coverage for 25 of the 27 galaxies is shown in Fig. 2.

Sensitivity. We aim for a uniform sensitivity of ≈ 22 mJy beam^{-1} (0.22 K) in a 10 km s^{-1} channel and a $3''$ synthesized beam within the 117" mosaic. This fiducial sensitivity is based on 3 tracks of a 19-point mosaic pattern for the median sample declination of 15° in typical weather, according to the online sensitivity calculator. For the 45% flattened mosaic patterns used in the inclined galaxies we expect a sensitivity of 15 mJy beam^{-1}. These sensitivities will of course improve with the new generation of receivers. By contrast, the interferometric part of the SONG survey achieved typical sensitivities $50 - 60$ mJy beam^{-1} rms (Helfer et al. 2003; Table 2), with beam areas ~ 4 times as large. The STING sensitivity will be substantially better than that of SONG.

Scaling by the median distance of our sample, we expect a 1σ mass sensitivity of $M_{H2} \approx 5.5 \times 10^5\ d^2_{15\ \rm Mpc}$ $M_\odot$ in a 10 km s^{-1} channel assuming the Galactic CO-to-H_2 conversion factor. In surface density terms, this is equivalent to $\Sigma_{H2} \approx 10\ M_\odot\ {\rm pc}^{-2}$. The sensitivity will be about 30% better for the elongated mosaic patterns. Our surface brightness sensitivity to extended emission will be improved by the combination with single-dish data (see below). For a typical line width of 30 km s^{-1}, this point source sensitivity is sufficient to detect large Galactic GMCs or GMAs over a single line of sight. For the purposes of azimuthally averaged profiles (assuming good flux recovery from the deconvolution and the average characteristics of the sample), we expect to be able to average ~ 100 beams at $0.5R_{25}$, yielding an effective sensitivity at that radius a factor of ~ 10 better.

Spectral configuration. We will configure the correlator to observe in 3 partially overlapping 62-MHz windows with 2.5 km s^{-1} resolution. This will provide a total velocity width of 400 km s^{-1}, sufficient to span the CO emission from many of our targets after accounting for overlap between the bands. We will pace our survey to start with the more face-on galaxies until new windows are added to the CARMA correlator in Spring 2008. Our nominal data product will average channels to produce maps with 10 km s^{-1} resolution, but the finer resolution in the raw data will afford more detailed analysis where the signal-to-noise merits.

Zero-spacing single-dish observations. We intend to obtain single-dish (SD) zero-spacing data for this project. The science case presented above does not rely upon the SD data, but the quality of the data set will be improved by including the SD data. In particular, good quality high surface-brightness sensitivity SD data will allow us to probe molecular emission beyond $0.5R_{25}$. This proposal includes co-Is from institutes linked to two major SD telescopes, well placed to lead the effort to obtain observations: co-I Walter is a Senior Staff Scientist in the Max Planck Institute for Astronomy, with access to IRAM (which will have a 3mm focal-plane array in 2 years) and APEX; co-I Calzetti is a Professor at the University of Massachussetts, with access to the LMT.

Team expertise and management plan. The multi-institutional team has proven mm-wave interferometric expertise at the CARMA institutions and abroad. This expertise is complemented by the midIR/FIR contributions by internal and external co-Is.

The following tasks will be pursued by the team of co-Is: Wong, with help from Bolatto, Vogel, Leroy, and Rosolowsky will lead the effort of producing mm-wave cubes from the CARMA observations. Wong and Vogel will also devote a substantial effort to further analysis of the SONG data and improvement of its data products. Bolatto and Wong will set up a website for the distribution of the STING data. Calzetti will lead the effort of producing Spitzer/Herschel images and spectra. Calzetti will also head the single-dish LMT observations. Rosolowsky, who is joining the UBC faculty and will have internal access to the JCMT, will pursue JCMT observations and combine them with CARMA, both for heterodyne and SCUBA2. Walter and Leroy will lead the effort of pursuing IRAM 30m/APEX observations. Ott, with help from Blitz, Walter, and Wong will be in charge of producing the necessary VLA radio continuum and HI cubes from archival data. West will lead the SDSS and GALEX photometry effort. Ancillary optical observations, when necessary, will be pursued by Walter, Vogel, Blitz, and Bolatto using their special institutional access to Calar Alto, KPNO, and Keck/Lick. Blitz will pursue ancillary HI observations of the extended galaxy envelopes with the ATA.

All co-Is and their postdocs and students are invited to participate in all projects, but authorship in publications will be determined on the basis of their individual contributions to the paper by the lead author and the PI. It is expected that these observations will be used in several Ph.D. theses, with the student as the lead author. The following people agree to take the lead on the different science studies that will take place using the STING and ancillary data sets, with the coordination and arbitration of the PI (Bolatto). Wong and Walter will lead the investigations of the FIR-RC correlation and its relation to the CO distribution and SFR. Blitz will head the study of the transport of gas from the outer into the inner disk, and its relation to GMC formation. Leroy and Rosolowsky will lead the studies of the different SFR prescriptions. Bolatto, Calzetti, and Kennicutt will lead the investigations of the relation between the molecular gas and the midIR/FIR emission, the cooling of the gas, and the dust-to-gas ratio and dust properties. Bolatto and Wong will lead the investigation of the molecular, baryonic, and dark mass profiles of these galaxies, with the participation of Wong's thesis student Kijeong Yim. Ott will lead the investigations of the large scale triggering of molecular cloud formation and the impact from stars on the structure and energetics of GMCs. West will lead the joint analysis of the stellar populations from 2D UV-optical-NIR photometry with the gas distribution.

Institutional time charges and scheduling. The entire STING project requires approximately 200 hours per semester during 3 semesters, for a total of $\sim$ 600 hours. *We request here time to complete semester 1 of the project.* If that is granted, we will resubmit for semesters 2 and 3. Six of the STING co-Is are internal and four external. We wish to remark that this is a partnership of equals, and every one of the co-Is is bringing something unique and crucial to the project in expertise and telescope access. The authors wish to break up the hour charge per institution in the following manner:

- Bolatto, Vogel (UMD): 17.5% of the time
- Wong (UIUC): 17.5% of the time
- Blitz, West (UCB): 20% of the time
- Ott (CIT): 15% of the time
- Calzetti, Kennicutt, Walter, Rosolowsky, Leroy (external): 30% of the time