The Star Formation Reference Survey (SFRS): I. Survey Design and Basic Data

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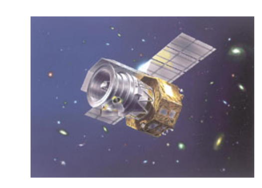
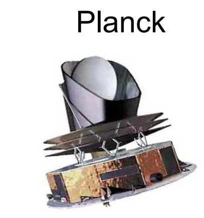
GALEX	SDSS	NAOC 2.16m	2MASS	IRAC	MIPS	IRAS	AKARI	Planck	VLA
									
FUV/NUV	*ugriz*	Hα	*JHKs*	3.6/4.5/5.8/8.0 μm	24	60/100 μm	65/90/140/160 μm	350/550/850 μm	1.4 GHz

Our Goal: observe all kinds of star-forming galaxies in the local Universe with all standard SFR metrics, and thereby better understand their limitations and systematics

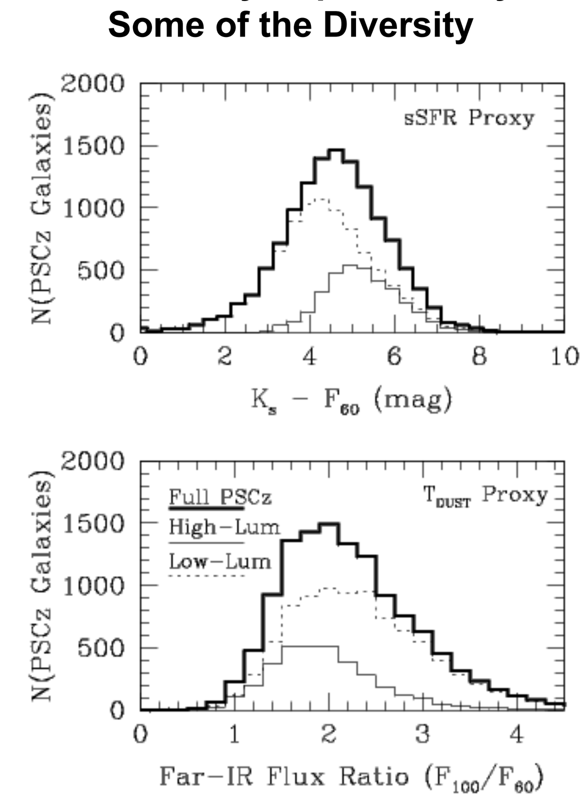
PROJECT OVERVIEW

Star formation has been the single most important physical process since the Big Bang. Stars have created most of the luminous energy in the universe, and have produced the heavy elements needed for planets and life. Stars are the primary reservoir of baryonic matter in galaxies, making star formation and evolution the primary drivers of galaxy formation and evolution.

Over the past decade and more, new observatories and new instruments have led to a new era of precision measurement of star formation in all kinds of environments, not only in the Milky Way but also in external galaxies. These new capabilities present difficulties as well as opportunities. On one hand, they permit quantitative measurements within many more galaxies and at vastly greater distances than had been possible before now, facilitating exploration of much wider ranges of environments and conditions. On the other hand, intercomparison of different techniques reveals the limitations of earlier approaches. Chief among them is that the results depend fundamentally on the wavelength of light being used. In particular, infrared observations tell a very different story than do measurements in the ultraviolet or at visible wavelengths. There are also other complications. We do not yet understand 1) the correlations between the intensity of star formation and the temperature of the associated dust in the interstellar medium, 2) the origin of the scatter in the well-known radio/infrared correlation seen in star-forming galaxies, 3) how emission from quiescent (i.e., old) stellar populations impinge on the standard estimators of star formation, or 4) what factors influence the dependence of star formation on total stellar mass.

Further progress requires a comprehensive approach that brings all available observables to bear on all conditions under which star formation takes place. We began that effort in 2009, collecting photometry from ultraviolet to radio wavelengths for a sample of 369 star-forming galaxies. This is the Star Formation Reference Survey. Much of the basic analysis has now been performed (for example, to evaluate how the ultraviolet and far-infrared bands separately trace star formation). Here, we present our selection technique, introduce the survey, describe the first measurements, and preview some forthcoming papers.

Luminosity Captures Only Some of the Diversity

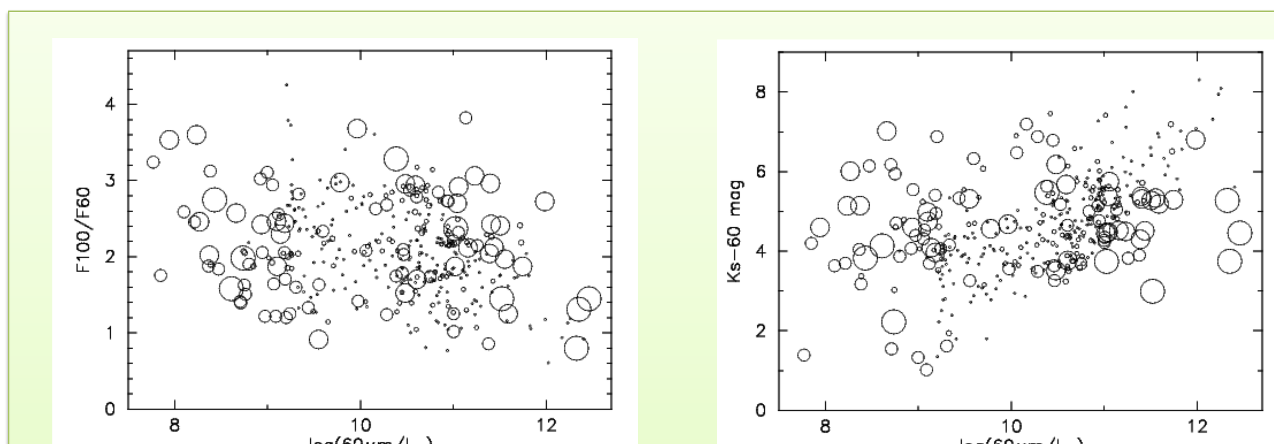


A simple 60 μm luminosity cut at $10^{9.5}$ $L_\odot$ was used to divide the PSCz into high- and low-luminosity subsamples. **Top panel:** Galaxies with lower sSFRs are predominantly low-luminosity objects, but a mix of luminosities are present for high sSFRs. **Bottom panel**: Galaxies with large F_{100}/F_{60} ratios (i.e., cool galaxies) tend to have low luminosities, but warmer galaxies are a mix of both high- and low-luminosity objects.

The Star Formation Reference Survey Includes ALL Kinds of Star-Forming Galaxies

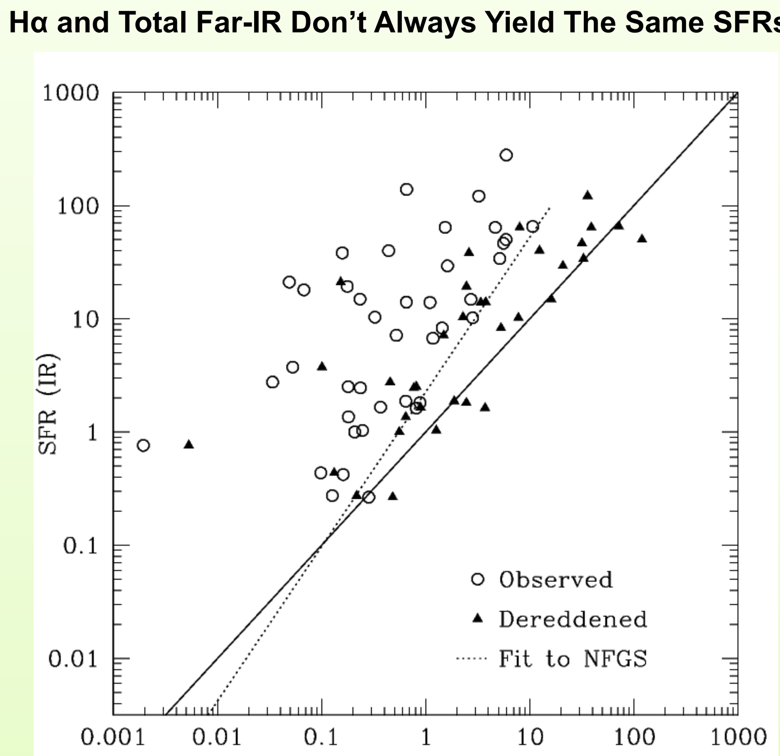
We start with the view that far-infrared flux is an optimal tracer of star formation because it's at the peak of the thermal emission associated with dust-reprocessed radiation from young stars. So, the parent sample is the PSCz catalog (15,000 galaxies detected by IRAS; Saunders etal. 2000).

We created a three-dimensional space to capture all the variation seen in these far-infrared-selected galaxies. We used Ks emission as a proxy for stellar mass, and far-infrared color as proxy for dust (ISM) temperature. The three-dimensional space was then populated with the 15,000 PSCz galaxies and BINNED so that we could extract a representative number of galaxies from each bin. This process sets the sample size (369 galaxies) and guarantees that it includes all existing combinations of star formation rate (SFR), star formation per unit stellar mass (specific SFR), and dust temperature.

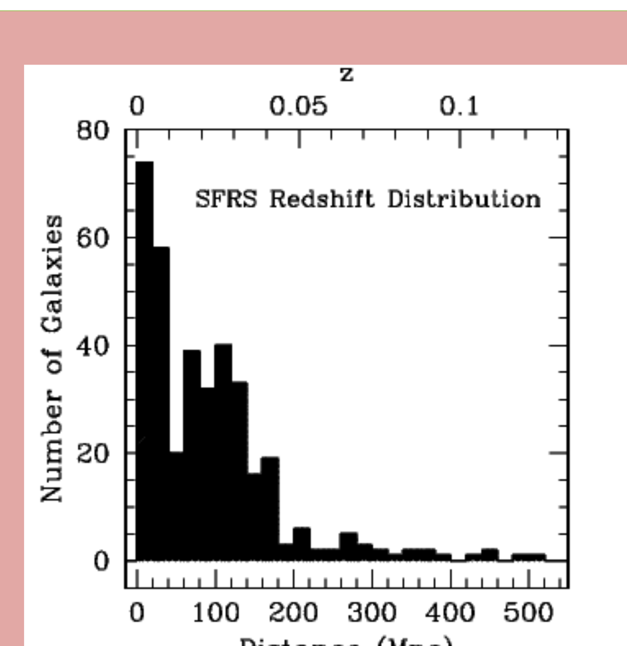


The distributions of the SFRS galaxies projected into two two-dimensional versions of the selection space used to define the sample. The symbols' sizes are inversely proportional to their weight: Large symbols represent relatively rare objects that enlarge the parameter space explored by our survey, and which may be missing from samples selected without regard to specific SFR or ISM temperature.

Hα and Total Far-IR Don't Always Yield The Same SFRs

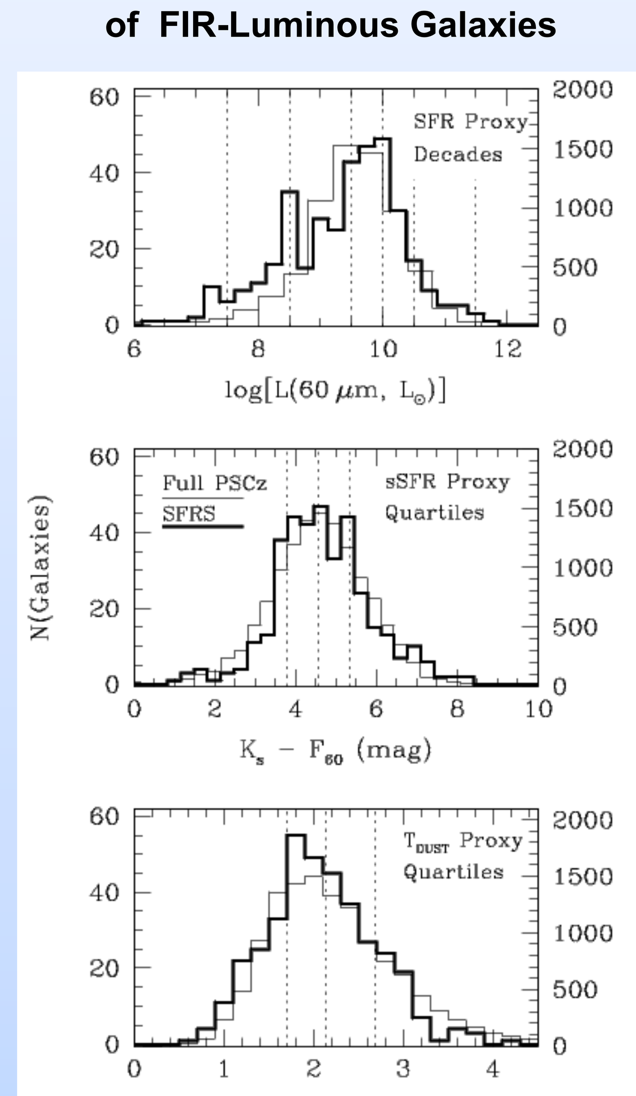


ABOVE LEFT: A comparison of SFR(Hα) derived from the NAOC to SFR(IR) for an unrepresentative subset of the SFRS, following the prescriptions in Kennicutt (1998). The solid line shows where the points would fall if the relations were in agreement. The observed Hα fluxes are indicated with circles. The dashed line indicates the Kewley etal (2002) fit to the corresponding data for a nearby galaxy sample selected at visible wavelengths. The uncorrected SFRS data lie systematically to the left of the fit, suggesting *extinction is systematically greater in SFRS galaxies* than the optically-selected NFGS galaxies. Solid triangles indicate extinction-corrected SFR(Hα), which were calculated using UV-based extinction estimates from GALEX and a Calzetti (2000) dust law. Some SFR(Hα) lie significantly to the left of the line of equality *even when extinction-corrected.*

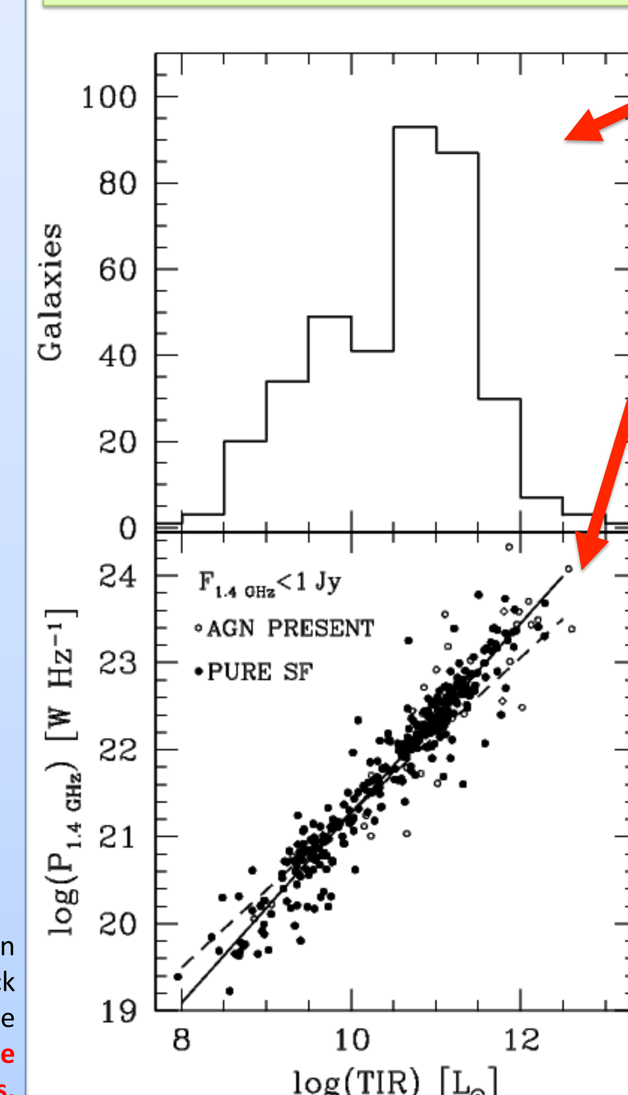


The SFRS Galaxies are NEARBY

The SFRS is REPRESENTATIVE of FIR-Luminous Galaxies

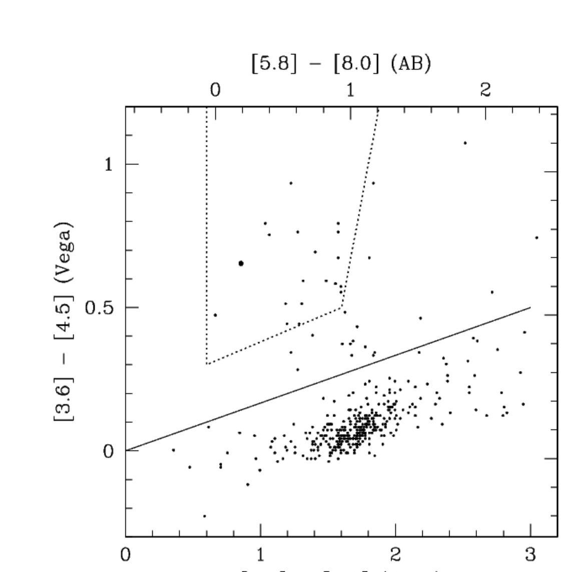


A comparison of the distributions of the PSCz (thin histograms; right-hand axes) and SFRS galaxies (thick histograms; left-hand axes) in each of the three dimensions used to select the SFRS sample. **The distributions are very similar in all three panels.** Vertical dotted lines in each panel indicate the boundaries defining the bins.



Top Panel: the SFRS sample spans four orders of magnitude in L(TIR) (and hence SFR).

Bottom Panel: The FIR-radio correlation. The line is an unweighted least-squares fit to the entire distribution, and has a slope of 1.1. The fit IS UNCHANGED when galaxies hosting AGN are excluded, suggesting the far-IR is relatively unaffected by flux from active nuclei. The scatter seen about the relation is marginally higher (by 0.1 dex) for galaxies with AGN than it is for 'pure' starbursts. The dashed line illustrates a slope of unity.



Some SFRS Galaxies Host an AGN

These related papers will be coming out soon!

Ashby etal (2011, submitted): Survey strategy and basic, data from radio to visible wavelengths
Mahajan etal (2011, in preparation): UV/FIR/Radio/PAH SFRs and extinction in SFRs galaxies
Bonfini etal (2011, in preparation): Structural decomposition of SFRS galaxies w/ PAIRITEL
Zhu etal (2011, in preparation): SFR(Hα) estimates for IR-selected galaxies