HIRES FOR SIRTF EXTRAGALACTIC SURVEYS

Final Report

JPL Task 1039

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A. OBJECTIVES

SIRTF will provide the most sensitive observations at infrared wavelengths to study light from stars and star formation in high-redshift galaxies. However SIRTF (with mirror size 85cm) is resolution-challenged. SIRTF science will greatly benefit from advanced imaging techniques not presently being developed by the project. At JPL, the Center for Long Wavelength Astrophysics is developing a High-Resolution (HIRES) analysis software tool to enhance the angular resolution in the SIRTF images. Preliminary tests show that an increase in the resolution by factors up to two is achievable. Such increase in resolution offers a tremendous increase in the SIRTF science capability. Our goal is to apply HIRES to the simulated SIRTF images of typical extragalactic surveys and validate its potential to enhance SIRTF science capabilities.

B. PROGRESS AND RESULTS

1. Science Data

Nearly half of the bolometric luminosity of the local universe is channeled through the mid- and far-infrared emission of galaxies. This infrared spectral region probes the youngest star-forming regions and their associated interstellar gas and dust. One of SIRTF's Legacy Science Programs (SINGS: The SIRTF Nearby Galaxies Survey) will survey 75 nearby galaxies to characterize their infrared emission properties. This survey will characterize the large-scale infrared properties of galaxies through complete IRAC (3.6 to 8 μm) and MIPS (24 to 160 μm) imaging instruments on SIRTF. The images will be used to further characterize the discrete infrared-emitting components of galaxies. High-angular-resolution imaging is critical to resolve extra-nuclear IR-emitting regions in the galaxies. HIRES offers a unique opportunity to achieve these goals.

The HIRES algorithm was first developed at IPAC for the IRAS infrared data. At JPL, we have successfully implemented this approach to the SIRTF data. HIRES executes a super-resolution algorithm similar to Richardson-Lucy, with added capability of PSF weighted averaging to fold in redundant pixel coverage. Our implementation has added features to speed up its execution by one order of magnitude. Preliminary tests show an increase in the angular resolution by factors up to two is achievable.

To critically evaluate the use of HIRES for this SIRTF survey, we chose one of our nearby galaxies, M100, as the test target. Using the I Band image of M100 (as truth) we simulated the SIRTF imaging for the MIPS (at 24 μm) and IRAC (at 3.6 μm) instruments. We

used the slow scan mode on MIPS to simulate 56 multiple image frames at 24 μm and the 12 position dither pattern to produce 12 image frames of the central region for IRAC at 3.6 μm. The simulated images at each wavelength were combined to produce conventional co-added images, and were also processed using HIRES to produce high-resolution images. The results of the HIRES image enhancement of M100 SIRTF images are shown in Figs 1 and 2. Fig. 3 shows the truth image assumed for the simulations. The application of HIRES to SIRTF imaging of other galaxies in the survey (e.g. the Large and Small Magellanic Clouds) are also being carried out under this task.

2. Other Results

We use the HIRES results of M100 to evaluate the performance of the algorithm as applied to SIRTF data. The degree of resolution enhancement is dependent on the imaging instrument, pixel sizes, and observing scenario (scanning and dithering) to produce redundant sampling of the image pixels. For example, the effect of HIRES is very significant in the case of IRAC 3.6 μm because of the under-sampling in the raw SIRTF images (the IRAC pixel size ($1.2'' \times 1.2''$) is larger than FWHM of the PSF at 3.6μm). Our results show:

a. Enhancement in the angular resolution: From 6″ to 4″ in the case of MIPS 24μm imaging; from 2.4″ to 1″ in the case of IRAC 3.6μm imaging.
b. Fidelity of reconstructed HIRES image is very good. All the features in the truth image are well reproduced in the image reconstruction, as evident from the difference map between the convolved truth and HIRES images..
c. Dynamic range is high, comparable to that in the truth image, except at regions closest to strong point sources.
d. Photometry: HIRES conserves the flux densities in the raw images on all scales, in point sources as well as in extended regions.
e. Artifacts: HIRES images are generally clean except for a low level (few percent) ringing around a strong point source near the Airy lobes. This can be reduced by characterizing the response to a point source in HIRES images.
f. As few as a dozen images obtained by dithering at 12 positions produce good resolution enhancement and high-quality reconstruction.
g. HIRES results can be used to plan SIRTF observations, optimizing for resolution enhancement.
h. HIRES requires some pre-processing of the raw images from SIRTF Science Center (SSC): Flagging bad pixels (cosmic rays) and correcting pointing errors.
i. Knowledge of the PSF is important to HIRES.
j. In this task, we demonstrate that HIRES will be a powerful general-purpose tool for SIRTF science, providing tremendous improvement in the imaging of debris disks, star-formation in galaxies, and forming galaxies. Increased angular resolution at 160 μm reduces the confusion limit, enhancing SIRTF sensitivity.
k. HIRES will be directly applicable to missions beyond SIRTF, including Herschel and SOFIA.

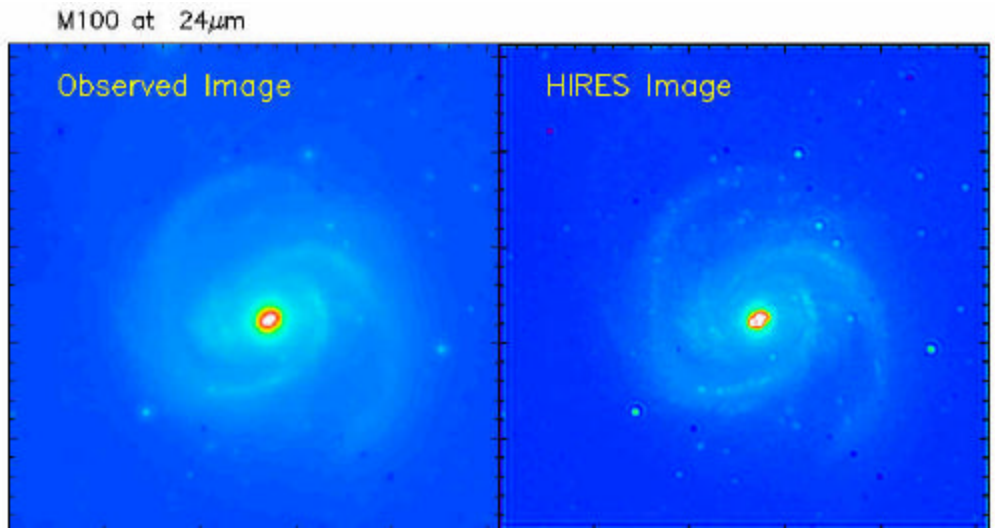

Fig. 1 The 24μm images were obtained from the simulated MIPS frames using the I –band image of M100. A total of 56 SIRTF image frames, obtained in the slow scan mode , were used. Background and noise have been added. The HIRES image shown was obtained after 100 iterations. The observed image is a mosaic of all 56 raw image frames

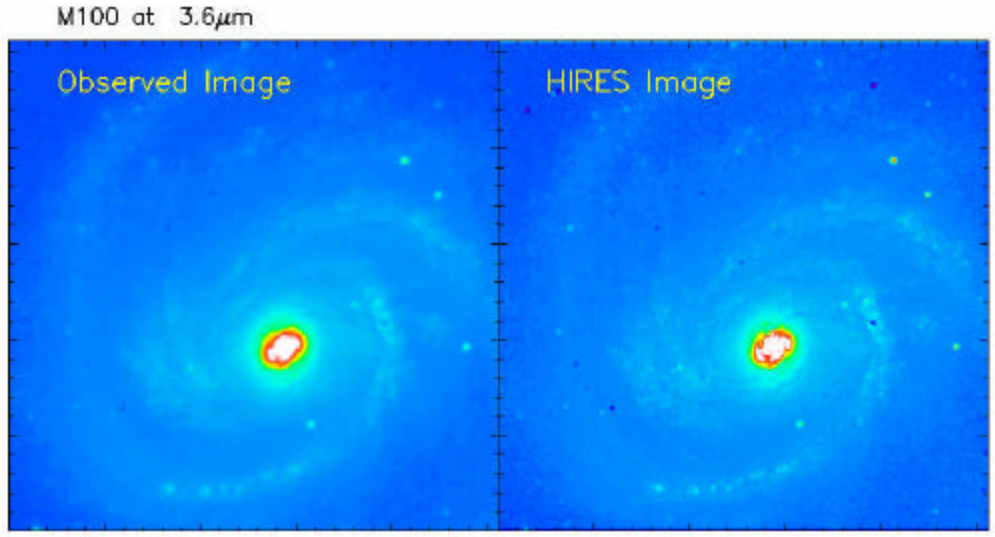

Fig. 2 The 3.6μm images were obtained from the simulated IRAC frames using the I –band image of M100. A total of 12 SIRTF image frames, obtained at 12 dithered positions, were used. Background and noise have been added. The HIRES image shown was obtained after 40 iterations. The observed image is a mosaic of all 12 raw image frames.

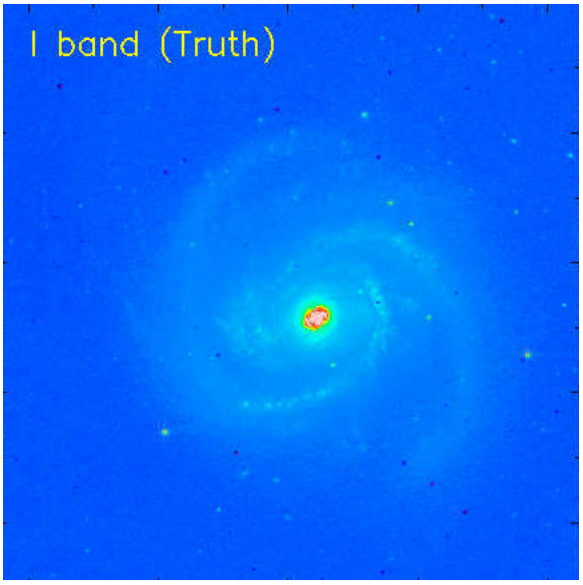

Fig. 3 Truth image used for simulating MIPS and IRAC images: I –band image of M100

C. SIGNIFICANCE OF RESULTS

In this task, we demonstrate that HIRES will be a powerful general-purpose tool for SIRTF science.

The results indicate that application of HIRES to the SIRTF survey of nearby galaxies will provide high-resolution image enhancement to achieve the goals of this survey.

HIRES will be directly applicable to missions beyond SIRTF, including Herschel and SOFIA

D. FINANCIAL STATUS

The total funding for this task was $70,000, of which $46,584 has been expended.

E. PERSONNEL

Timothy Thompson and Charles Backus, both in Astrophysics Element (3262), and Helene Roussel at IPAC were involved.

F. PUBLICATIONS

None.