APPLICATION OF MCM IMAGE CONSTRUCTION TO IRAS COMET OBSERVATIONS

MARTIN F. SCHLAPFER AND RUSSELL G. WALKER
Jamieson Science & Engineering, Inc., 5321 Scotts Valley Drive #204, Scotts Valley, CA 95066

ABSTRACT There is a wealth of IRAS comet data, obtained in both the survey and pointed observations modes. However, these measurements have remained largely untouched due to difficulties in removing instrumental effects from the data. We have developed a version of the Maximum Correlation Method for Image Construction algorithm (MCM) (Aumann, Fowler, and Melnyk, 1990, Astron. J. 99, 1674-1681) which operates in the moving coordinate system of the comet and properly treats both real cometary motion and apparent motion due to spacecraft parallax. This algorithm has been implemented on a 486/33 PC in FORTRAN and IDL codes. Preprocessing of the IRAS CRDD includes baseline removal, deglitching, and removal of long tails due to dielectric time constants of the detectors. The resulting images are virtually free from instrumental effects and have the highest possible spatial resolution consistent with the data sampling. We present examples of high resolution IRAS images constructed from survey observations of Comets P/Tempel 1 and P/Tempel 2, and pointed observations of IRAS-Araki-Alcock.

BACKGROUND

The study of comets is of great importance to our understanding of the solar system and its origin, as well as other astrophysical environments such as the interstellar and circumstellar media. Comets are believed to contain the most primitive material in the solar system. Because of their small masses and orbital parameters, comets have probably undergone relatively little processing since their formation (e.g. Weissman and Stern 1990), and thus contain important clues to the conditions in the early solar nebula.

Comets are also known to be a source of interplanetary dust, hence, the determination of their contribution is essential to a detailed modeling of the zodiacal cloud. The understanding of interplanetary dust is relevant not only to solar system studies, but also to studies of most types of astrophysical objects. The proper characterization and subtraction of the foreground light from the zodiacal cloud is a necessary step in many studies of extra-solar system objects ranging from stars to clusters of galaxies.

The detection by the Infrared Astronomical Satellite (IRAS) of comet IRAS-Araki-Alcock on April 26, 1983 marked the first observation from space of a comet in the far-infrared and the first discovery of a comet using a systematic satellite search for fast moving objects. Post mission analysis (Walker et al, 1987) revealed that the IRAS survey produced 122 highly reliable detections of 24 comets. The IRAS observations of comets are by far the largest potential set of infrared comet images ever obtained.

APPROACH

Our method for the production of comet images uses a computer algorithm based on the Maximum Correlation Method (MCM) for Image Construction (Aumann, Fowler, and Melnyk, 1990) and closely parallels the HiRes Processing performed at IPAC (Melnyk and Rice, 1991). The major departure from the IPAC scheme occurs in the Comet Image Preprocessor, where the coordinates of each detector footprint (data sample) are transformed to a moving sun-referenced coordinate system with the comet at the origin.

Preprocessing

A precursor to image construction envolves preprocessing of the IRAS survey or AO CRDD scans. The Comet Image Preprocessor performs three major functions:

1. Remove data artifacts, such as baseline, tails, and radiation hits,
2. Transform the coordinates of the data samples to a coordinate system that moves

S. Terebey and J. Mazzarella (eds.), *Science with High-Spatial Resolution Far Infrared Data*, 173–176, 1994, Jet Propulsion Laboratory, Pasadena, CA.

with the comet, and

3. Associate each data sample with the specific pixels in the map covered by the response function and their weights in the observed response. This information is stored in an array and is later looked up by the Comet Image Processor.

Typical outputs from several stages of the preprocessor are shown in figures 1-4. Figure 5 shows a first iteration 25μm image of P/Tempel 1 with the detailng algorithm turned off. Compare this image with the image in figure 6c.

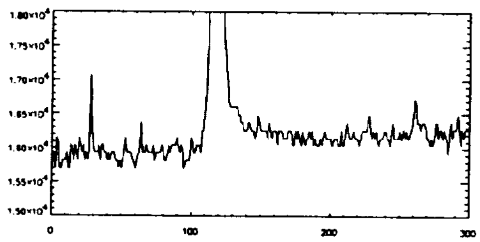

Figure 1. A 20 second snip of a 12μm CRDD survey scan of P/Tempel 2 before any pre-processing.

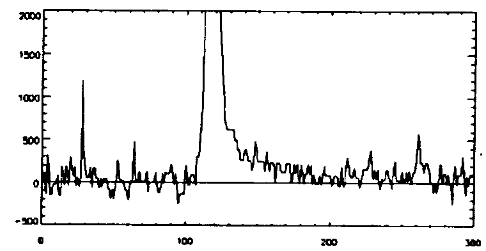

Figure 2. A 20 second snip of a 12μm CRDD survey scan of P/Tempel 2 after baseline removal.

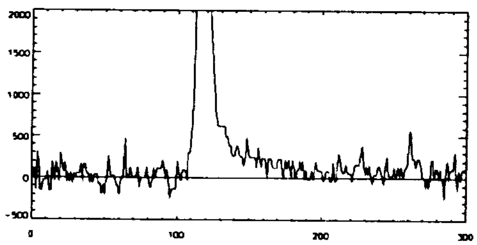

Figure 3. A 20 second snip of a 12μm CRDD survey scan of P/Tempel 2 after noise spike removal (de-glitching).

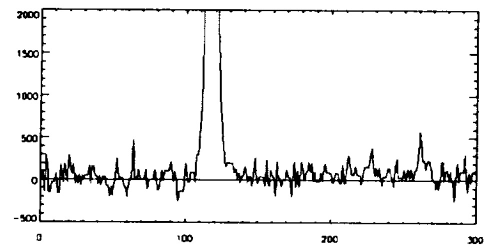

Figure 4. A 20 second snip of a 12μm CRDD survey scan of P/Tempel 2 after detailing.

Image Construction (MCM)

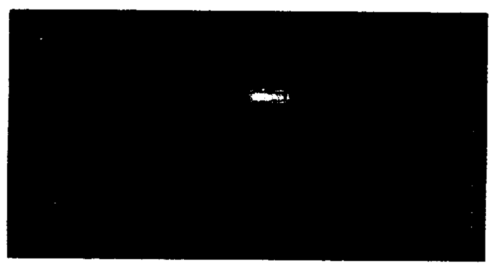

Figure 5. P/Tempel 1 first iteration 25μm image from the Comet Image Processor with the detailing algorithm turned off. Compare this image of P/Tempel 1 with that in figure 6c.

Image construction begins with a map of uniform low level radiance, and builds an image by scanning an analytical version of the IRAS focal plane over the map, simulating the IRAS data taking process. The analytical data samples are compared to the CRDD data samples and pixel correction factors determined. Details of this process are given by Aumann, et al (1990) and Melnyk and Rice (1991). Building the map is an iterative process, wherein each subsequent iteration begins with the most recent estimate of the map radiance. Statistics relating to pixel noise and convergence are generated at each iteration. The actual resolution achieved by the MCM depends upon the density of coverage, the range of scan angles across the field, and the signal to noise ratio of the measured flux. Rice (1993) has successfully used MCM image construction to produce high resolution IRAS maps of nearby galaxies.

Data Products

Intensity Maps

The intensity map is the surface brightness image produced by the Comet Image Processor. Two intensity maps are produced. The first is the map resulting from from the first iteration (equivalent to the IPAC FRESCO image) and the second is the high resolution image produced at the final iteration. Figure 6 shows images of comets IRAS-Araki-Alcock, P/Tempel 1, and P/Tempel 2. The image contours begin at 3σ and each succeeding contour is twice the previous.

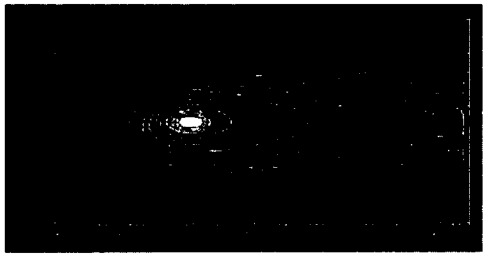

Figure 6a. 60μm first iteration image of IRAS-Araki-Alcock.

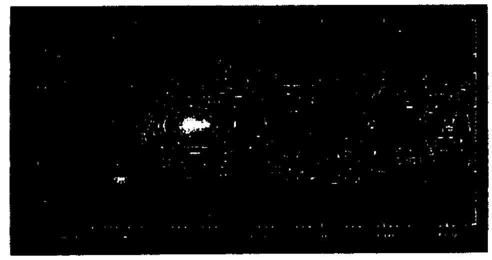

Figure 6b. 60μm tenth iteration image of IRAS-Araki-Alcock.

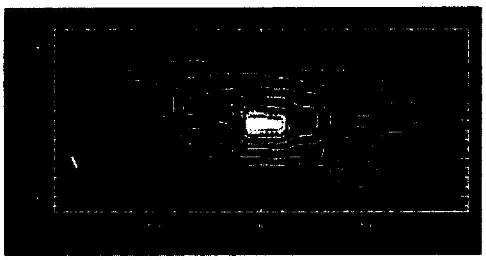

Figure 6c. 25μm first iteration image of P/Tempel 1.

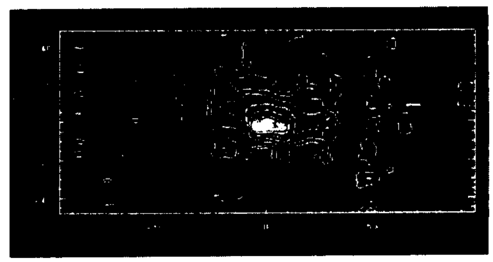

Figure 6d. 25μm 15th iteration image of P/Tempel 1.

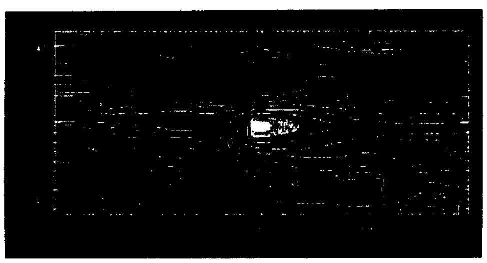

Figure 6e. 12μm first iteration image of P/Tempel 2.

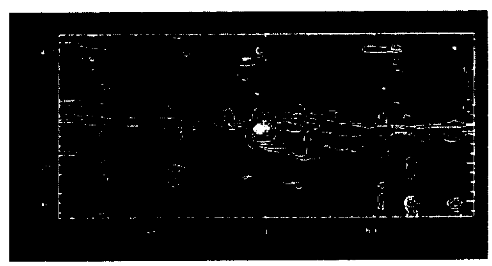

Figure 6f. 12μm 15th iteration image of P/Tempel 2.

The Comet Image Processor also produces several ancilary maps that aid interpretation.

Coverage Map
The coverage map is a measure of the uniformity of coverage of the scanned field. It is computed by summing the relative response of each detector to that pixel for all the times the pixel was sampled. Non-uniformities in coverage are functions of both the detector spatial response and the density of scans. This map is used in an aid to understanding the reliability of features appearing in the intensity maps.

Photometric Noise Map
This is a map of the internal photometric uncertainty of the flux in a pixel as a result of averaging overlapping detector samples. The photometric noise map may be used to estimate the error in aperture photometry of the comet, photometric profiles, and flux ratios.

Resolution Map
The resolution map estimates the spatial resolution and its variation across the field. An array of point sources is constructed along the top and bottom of the field using the analytical model of the IRAS focal plane. Scans of the point sources are summed with CRDD to produce new CRDD that contains all the information and noise of the original plus the array of point sources. This new CRDD is processed by the Comet Imaging Processor to the same number of iterationss that converged the intensity map. The in-scan and cross-scan resolutions are estimated from the widths of the reconstructed point sources.

Convergence Map
This is a map showing which pixels within the image have met the convergence criteria. This map is a simple tool to exclude non-converged, and therefore incorrect, pixel flux

values from further analysis.

Background Map
The true distribution of comet radiance is distorted by the presence of background stars, asteroids, galaxies, and small extended structures. The background map is produced as an aid to estimate the impact of background features on the comet image. This image is built from all the IRAS survey scans that fell within the field of interest during those times when the comet was not present. It is produced in both fixed celestial coordinates, and in the moving comet-referenced system.

PSC 2 and Asteroid Overlay
The PSC 2 and asteroid overlay is produced as a further aid to understanding the features within a comet image. This is the final intensity map overlaid with the positions of all the IRAS PSC 2 sources and numbered asteroids in that field at the time of observation. With the overlay is a listing of the sources and their fluxes on the four spectral bands.

Photometric Profiles
Photometric profiles are generated as an aid to image validation, quality assesment, and image analysis. These include:

1. Aperture photometry centered on the comet and extending to large radii,
2. Intensity profile along the sun-comet direction and passing through the brightest pixel of the intensity map, and
3. Intensity profile normal to the sun-comet direction and passing through the brightest pixel of the intensity map.

REFERENCES

Aumann, H. H., Fowler, J. W., Melnyk, M., 1990, "A Maximum Correlation Method for Image Construction of IRAS Data", Astron. J. 99, 1674-1681.

Melnyk, M., 1990, "Technical Reference to the Full Resolution Survey Coadder (FRESCO):, IPAC User's Guide, Ed. 4, Part V, California Institute of Technology.

Melnyk, M. and Rice, W., 1991, "High Resolution Processing", IPAC User's Guide, Ed. 4, Part VI, Californis Institute of Technology.

Rice, W., 1993, "An Atlas of High-Resolution IRAS Maps of Nearby Galaxies", Astron. J. Vol 105, pp 67-96.

Walker, R. G., Matson, D. L., and Veeder, G. L., 1987, "IRAS Observations of Comets", Advances in Space Research, Vol. 6, no. 57, p. 57.

Weissman, P. R. and Stern, S. A. (1990) Physical Processing of Cometary Nuclei. In Proc. of Workshop on Analysis of Return Comet Nucleus Samples.