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HIGH RESOLUTION IMAGES OF P/TEMPEL 1 AND P/TEMPEL 2 CONSTRUCTED FROM IRAS SURVEY DATA

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ABSTRACT

Infrared images of P/Tempel 1 and P/Tempel 2 have been constructed from IRAS survey data using a computer algorithm based on the Maximum Correlation Method for Image Construction (Aumann et al, 1990). The resulting images are of sufficiently high quality and resolution to delineate coma and tail morphology, and permit accurate photometry of the total dust complex. Comparisons of the infrared colors and photometric profiles of Tempel 1 and Tempel 2 at similar heliocentric distances, show that the grains produced by the two comets are quite similar in radiometric and dynamic properties. Tempel 1 is found to produce about 30% more dust in its coma and tail than Tempel 2. The comae of Tempel 1 and Tempel 2 are expanding with mean velocities of 5.8±.07 and 6.1±.17 m/sec respectively, indicative of the ejection of large grains. The IRAS cataloged infrared fluxes (Walker, 1986) are found to be underestimated by as much as a factor of three for the comets. Therefore, it is essential to create images of the comets to obtain meaningful IRAS photometry.

I. INTRODUCTION

The Infrared Astronomical Satellite (IRAS) sky survey produced 122 highly reliable detections of 24 comets (Walker, et al, 1987). These were the basis for a preliminary estimate of dust production rates for 12 of the comets (Walker and Aumann, 1984), and limited discussion of the physical and thermal properties of their grains (Walker, 1986). It was clear that the survey fluxes were corrupted by the spatial frequency response of the IRAS point source filter. Extended portions of the coma were attenuated, and the response heavily weighted by the intensity gradient in the central region. Thus the observed response was dependent upon the spatial asymmetry of the comet's emission relative to the direction scanned. In addition, it was not possible to obtain reliable infrared colors due to the variation with spectral band of the size of the field viewed. For these reasons we undertook a program to construct comet images from the IRAS survey data that are free from such instrumental effects, and that will permit an accurate measure of the infrared flux, colors, and morphology.

II. THE IMAGES

Infrared images of P/Tempel 1 (T1) and P/Tempel 2 (T2) have been constructed from IRAS survey data using a computer algorithm based on the Maximum Correlation Method for Image Construction (MCM) (Aumann, et al, 1990). Previous images of IRAS comet observations were from raster scans taken in the IRAS "pointed observation" mode (Walker et al, 1984; Walker and Aumann, 1990; Campins, et al, 1990), and motion of the comet during the few minutes required to complete the raster was small compared to the spatial resolution in the image. Image construction from survey data requires the use of scans that span relatively large time intervals (8 to 23 hours for the images of Tempel 1 and Tempel 2) during which the motion of the comet cannot be ignored (10 to 20 resolution elements). Thus our image construction was performed in a moving Sun-referenced coordinate system with the comet at the origin.

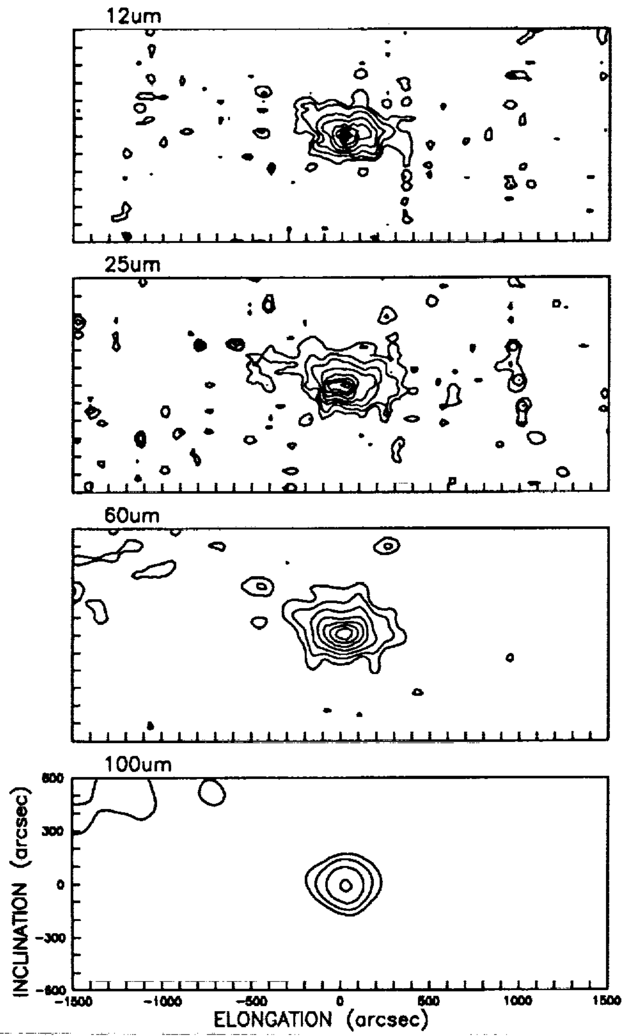

Figure 1. P/Tempel 1

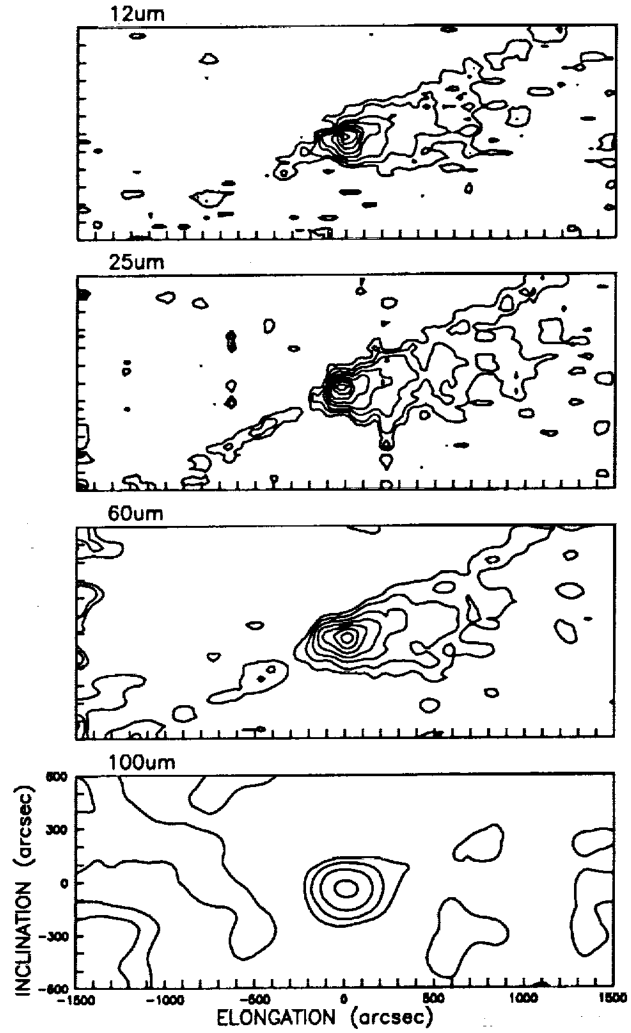

Figure 2. P/Tempel 2

In both figures the field displayed is 20'x50' with a 24" pixel size. Contours start at a signal to noise ratio of 3, and increase in steps of a factor of 2.

Motion of the comet relative to the IRAS survey progression limits the number of scans that cross the comet image, and thus determines the effective spatial resolution achievable by the moving MCM. Typically, 6 to 9 survey scans are used to build each image. The resolution improvement over a single survey scan is a factor of 1.1, 1.1, 1.6, and 2.2 in the in-scan direction, and 6.6, 6.6, 5.0, and 3.7 in the cross-scan direction for the 12, 25, 60, and 100 μm bands respectively. The best spatial resolution achieved in this case was about 41, 41, 57, and 81 arcsec respectively.

Five sets of images were constructed of T1 at 12, 25, 60 and 100 μm. These span the period from 4.6 days to 81 days after perihelion passage. Similarly, four sets of images were produced of T2 that span from 46 to 97 days past perihelion. Figures 1 and 2 show a typical set of images of T1 and T2. The heliocentric and geocentric distances are 1.49 AU and 0.98 AU respectively for T1 and 1.71 AU and 1.01 AU for T2. T1 is 4.5 days past perihelion, while T2 is 97 days past perihelion. The T2 debris trail is prominent is Figure 2.

III. RESULTS

Four sets of T1 and 3 sets of T2 images have been subject to photometry through a series of circular apertures centered on the comet nucleus and extending to 10′ radius. Entries in the first four lines of Table 1 define the circumstances of the observations. ρ is the heliocentric distance, Δ is the geocentric distance, ϕ is the phase angle, and Δt is the time (days) since perihelion passage. R(12) and R(25) are the radii of the apertures (km) that contain 1/2 of the total flux measured at 12μm and 25μm, and are a measure of the radius of the dust coma. A plot of R(12) and R(25) versus Δt yields a linear relation for both comets with a mean expansion velocity of 5.8±.07 m/sec for T1 and 6.1±.17 m/sec for T2.

The total coma fluxes measured in the 12μm band are given by F12. The total flux ratios F12/F25 and F25/F60 do not vary significantly between these comets at comparable heliocentric distances. This indicates that the thermal properties of the grains are similar in both comets. The F60/F100 ratio shows more variation but is a less reliable measure due to the variable infrared background cirrus.

Table 1. A Photometric Comparison of Tempel 1 and Tempel 2.

Parameter	T1	T2	T1	T1	T2	T1	T2	
ρ	1.49	1.47	1.52	1.50	1.51	1.56	1.56	au
Δ	0.98	1.11	1.14	1.06	1.09	1.27	1.06	au
ϕ	42.5	43.7	41.7	42.4	42.2	40.2	39.9	°
Δt	4.49	46.36	29.96	19.16	56.12	45.82	69.44	d
R(12)	55200	54500	63900	55800	62200	75300	70200	km
R(25)	54800	58200	69200	58500	54000	74200	66200	km
F12	28.8	16.4	21.6	24.0	16.9	18.5	19.5	Jy
F12/F25	0.46	0.44	0.48	0.43	0.40	0.43	0.46±.03	
F25/F60	2.67	2.55	2.43	2.67	2.72	----	----±.14	
F60/F100	3.31	(1.7)	2.24	2.43	2.79	----	----±.28	
Δ^2F12	27.7	20.2	28.0	26.9	20.1	29.8	21.9	
Δ^2F25	59.5	46.0	58.4	63.1	50.2	69.4	47.6	
Δ^2F60	22.3	18.0	24.2	23.6	18.4	----	----	

The quantity Δ^2F(band), is measure of the total number of emitting grains in the coma. The number of grains in the coma of T1 is about 1.3 times the number in the coma of T2. This ratio is essentially independent of the wavelength, further indication that the two size distributions are similar.

IV. CONCLUSIONS

Image construction by MCM has proven to be a reliable and effective technique to produce comet images from IRAS survey data. We now have the capability to observe the large scale coma and tail emission using the IRAS survey scans.

Table 2 compares the fluxes derived from the images with the cataloged point source fluxes of the same observation. The cataloged infrared fluxes are underestimated by as much as a factor of three for T1 and T2. These factors could be greater for other comets. It is essential to create images of the comets to obtain a meaningful measure of their infrared properties.

The infrared flux ratios are similar for the two comets indicating that the grain composition and size distribution are also similar for the two. The F(12)/F(25) flux ratios are only slightly greater than those expected for a blackbody at the same heliocentric distance, while the F(25)/F(60) ratios are significantly larger. This indicates that the infrared emission from the dust coma is dominated by grains smaller than 60 μm, and smaller than those observed in the debris trail of either comet (Sykes and Walker, 1991). This result is in apparent conflict with the low velocities found for the coma expansion, which are characteristic of large particles (on the order of 1 cm radius, assuming a density of 1 g/cm^3). Possible mechanisms to resolve this apparent conflict include fragmentation of grains in the coma and/or the existence of fluffy grains that can behave thermally as small particles.

Table 2. Ratio of the Total Flux in the Image to the Cataloged Point Source Flux (Obs. is an image identifier).

Tempel 1					Tempel 2				
Obs.	12μm	25μm	60μm	100μm	Obs.	12μm	25μm	60μm	100μm
339	2.39	2.91	1.50	0.99	346	1.53	1.89	1.48	1.60
368	2.52	3.19	1.68	1.56	365	1.68	2.29	1.43	1.15
389	2.74	3.00	1.99	2.06	392	2.58	2.56	----	----
421	3.03	3.58	----	----	448	3.63	3.54	2.29	2.61
Mean	2.67	3.17	1.72	1.54	Mean	2.36	2.57	1.73	1.79

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