Observational Details and Results

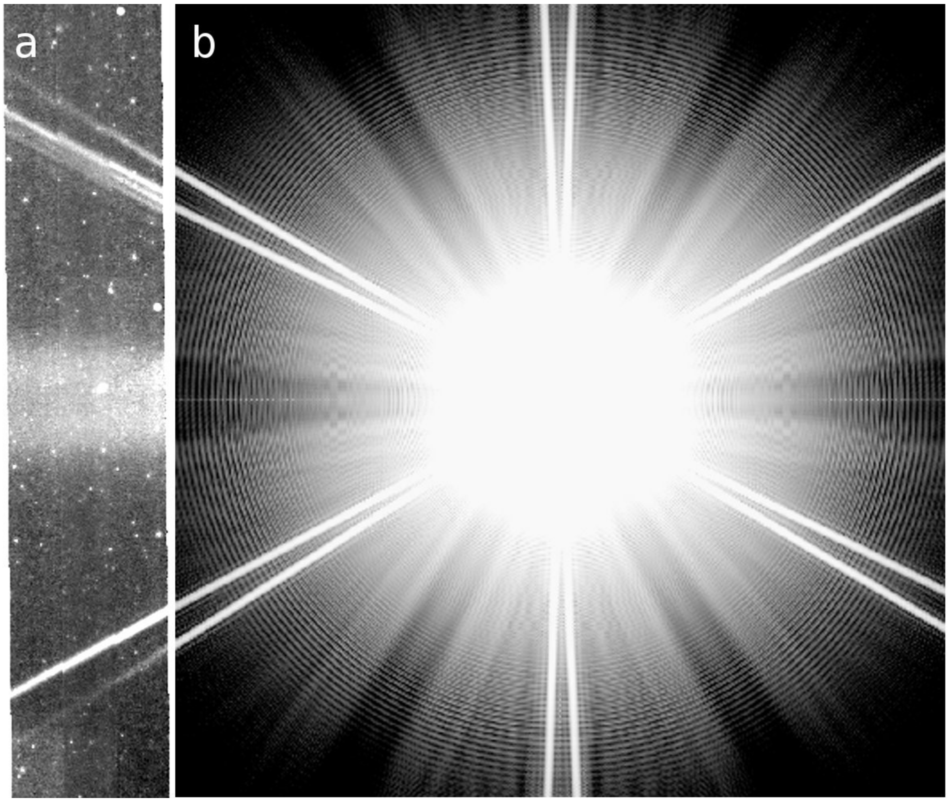
As part of Spitzer Space Telescope Program 40840 (principal investigator A. Verbiscer), on 18 February 2009 the Multiband Imaging Photometer for Spitzer (MIPS) acquired a pair of overlapping slow MIPS scans (with simultaneous imaging at 24 μm and 70 μm) aimed inside the ansa of Phoebe's orbit, passing within 0.40° of Saturn (MIPSON and MIPSON 70 in Fig. 1), spanning the region $128R_S$ to $180R_S$ (where R_S = 60,330 km is the radius of Saturn). The observational program included another similar pair of MIPS scans well outside the orbit of Phoebe passing within 1.0°, or $400R_S$, of Saturn (MIPSOFF in Fig. 1; observed 10 February 2009). Each individual scan collected 178 Basic Calibrated Data (BCD) images which overlap horizontally to form a narrow mosaic 1° in length, centered on and nearly perpendicular to Saturn's orbital plane. The individual frame integration time is 10 seconds; however, the overlap is such that any point on the sky is covered 10 times, resulting in a total integration time of 100 seconds. The two scans overlap by approximately half of the 0.09° (or $34R_S$) field of view. A diffuse, double-peaked band of light appears at the center of both the 24 μm and 70 μm MIPSON mosaics, although the signal-to-noise ratio is substantially lower at 70 μm. The peak intensity at 70 μm, 1.0 +/- 0.5 MJy sr^{-1}, is consistent with a blackbody at 85 K when combined with the detection at 24 μm. No scattered light is visible in the MIPSOFF mosaic, nor is any ring emission evident, as expected, given the large angular separation from Saturn.

The 24 μm 1-σ pixel noise in the MIPSON mosaic is typically 0.06 MJy sr^{-1}. The 0.4 MJy sr^{-1} ring flux amounts to a 7-σ detection in a single pixel. Thousands of pixels comprise the ring image, yielding a statistically robust detection. Uncertainty in the peak ring flux arises from systemmatic uncertainty in the background level and structure underlying the ring. Slices through the ring (Fig. 3) show a 10-20% variation in ring flux increasing toward Saturn. In addition to this probably real variation across the scan direction, the uncertainty in background along the scan could bias these values by 10-20%. The corresponding 70 μm mosaic shows a suggestive, but highly uncertain, detection in the region of the ring. The 1-σ pixel uncertainty in this mosaic is about 0.8 MJy sr^{-1}, nearly equal to the poorly estimated peak flux of the feature of 1.0 MJy sr^{-1}. Background uncertainty dominates any estimate of ring structure on large scales at 70 μm.

Figure 1 includes archival Spitzer MIPS 24 μm photometric images of Kiviuq, Tarvos (Spitzer Program 03582, principal investigator T. Grav), and Phoebe (Spitzer Program 00071, principal investigator J. Houck). Although these these images were not scans like MIPSON and MIPSOFF, they did probe regions at varying radial distances from Saturn along the planet's orbital plane. Ring emission is evident in images acquired near Tarvos (offset by 190R_S; total integration time 1076 seconds) and Kiviuq (offset by 153R_S; total integration time 279 seconds) The bright artifact at the top of the Tarvos image is a calibration bias introduced by the Spitzer scan mirror. The Phoebe images (offset by 219R_S) show little diffuse emission, but here the exposure time was only 37 seconds. Two off-target mosaics, Kiviuq 'off' and Phoebe 'off' with integration times of 1076 and 120 seconds, respectively, illustrate typical background features in the absence of ring flux.

The Kiviuq and Tarvos postage-stamp images in Fig. 1 that show the ring are difficult to analyze quantitatively because of the large biases in the background. These background offsets are characteristic of small 24 μm MIPS images constructed in photometry mode due to the effects of the tilting Spitzer scan mirror. The procedure to remove these biases with a median "delta-flat" would also remove much of the ring emission since the ring fills most of the frame. Measurement of the ring flux in these frames yields levels, although highly uncertain, of 0.2-0.3 MJy sr^{-1}, consistent with the ring emission in the MIPSON mosaic. The frame centered on Phoebe shows little ring flux but is a more shallow exposure with noise levels about twice that of the MIPSON mosaic. Given the background fluctuations, ring structure could be present in this image at the 0.1 MJy sr^{-1} level.

Additional MIPS scans obtained as part of Spitzer Program 50780 (principal investigator A. Verbiscer) on 28 June 2008 offset only 0.11°, or $44R_S$, from Saturn (IAPETUS West and IAPETUS East in Fig. 1) serve to show that the ring emission in MIPSON is not associated with diffracted light from Saturn. The figure below shows the MIPSON mosaic (a) and a simulation (b) of the MIPS 24 μm point spread function (PSF) generated by the Spitzer version of Tiny Tim software for a blackbody at Saturn's temperature (81 K). Both the model PSF and the scan are shown at the same pixel scale with the center of the scan placed $154R_S$ from the center of the simulated PSF. Matched empirically by the patterns in both IAPETUS East and IAPETUS West in Fig. 1, the model PSF shows a null in the direction of the ring emission. If the ring emission were produced by diffracted light from Saturn, bright rays in the direction of the ring emission would appear in (b) below.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