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ISOCAM* Observations of NGC 6946: Mid-IR Structure

S. Malhotra,[1], G. Helou[1], D. Van Buren[1], M. Kong[1], C. A. Beichman[1], H. Dinerstein[2], D. J. Hollenbach[3], D. A. Hunter[4], K. Y. Lo[5], S. D. Lord[1], N. Y. Lu[1], R. H. Rubin[3], G. J. Stacey[6], H. A. Thronson Jr.[7], and M. W. Werner[8]

[1] IPAC, California Institute of Technology, MS 100-22, Pasadena, CA 91125
[2] University of Texas, Astronomy Department, RLM 15.308, Texas, Austin, TX 78712
[3] NASA/Ames Research Center, MS 245-6, Moffett Field, CA 94035
[4] Lowell Observatory, 1400 Mars Hill Rd., Flagstaff, AZ 86001
[5] University of Illinois, Astronomy Department, 1002 W. Green St., Urbana, IL 61801
[6] Cornell University, Astronomy Department, 220 Space Science Building, Ithaca, NY 14853
[7] University of Wyoming, Wyoming Infrared Observatory, Laramie, WY, 82071
[8] Jet Propulsion Laboratory, MS 233-303, 4800 Oak Grove Rd., Pasadena, CA 91109

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Abstract. The nearby spiral galaxy NGC 6946 was observed with ISO-CAM in the mid-infrared, achieving $7''$ resolution and sub-MJy sr^{-1} sensitivity. Images taken with CAM filters LW2 (7μm) and LW3 (15μm) are analysed to determine the morphology of this galaxy and understand better the emission mechanisms. The mid-infrared emission follows an exponential disk with a scale length $75''$. This is 60 % of the scale length in the optical R-band and radio continuum. The nuclear starburst region is too bright for reliable measurement in these images. Its surface brightness exceeds the inner disk by at least a factor of 12. The arms and interarm regions are clearly detected, with each of these components contributing about equally to the disk emission. The arm-interarm contrast is 2-4 in the mid-IR, close to that measured in the visible R band light and lower than the contrast in $H\alpha$, suggesting that non-ionizing radiation contributes significantly to dust heating.

Key words: Infrared:galaxies – Infrared:ISM:continuum – Galaxies:ISM – Galaxies:spiral – Galaxies:structure

1. Introduction

NGC 6946 is a nearby face-on spiral galaxy, a good target for a study of star-formation and related processes in "normal" galaxies. In addition to the well-resolved disk, it has a starburst nucleus (*e.g.* Engelbracht et al. 1996), and a bright northern spiral arm that earned it an entry in the Atlas of Peculiar Galaxies (Arp 1966). NGC 6946 was therefore selected as a focus of the Key Project on the interstellar medium of normal galaxies (Helou et al. 1996) under NASA Guaranteed Time on ISO (Kessler et al. 1996). We report here on the ISO-CAM (Césarsky et al. 1996) maps obtained for this galaxy, revealing for the first time the mid-infrared (mid-IR) morphology at vastly improved resolution and sensitivity.

Mid-IR emission in the 5 to 20 μm range is dominated by very small grains fluctuating to high temperatures and from Poly Aromatic Hydrocarbons (PAH) features. Even though these grains are not in thermal equilibrium, they still convert heating photons (Draine and Anderson 1985), and should therefore trace star-formation, allowing a detailed and un-extincted view of that activity. By studying the distribution of the mid-IR emission with respect to other components of the galaxy, i.e. HI, H_2, ionized gas, and starlight we can also characterize the heating sources for the mid-IR, and better define its diagnostic value.

2. Observations and Data reduction

NGC 6946 was mapped at 7μm (LW2 filter, $\Delta\lambda = 3.5\mu$m) and at 15 μm (LW3 filter, $\Delta\lambda = 6\mu$m), using the raster scan mode to cover roughly $12.5' \times 12.5'$ centered on the nucleus. CAM was set to $6''$/pixel, and the raster was made up of 8×8 pointings separated by $81''$, or 13.5 pixels in each direction, allowing for better spatial sampling. At each pointing in the raster scan we took 8 frames integrating 5 seconds for each at 7 μm, and 10 frames of 2 seconds each at 15 μm. Hα and broad-band imaging

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Send offprint requests to: san@ipac.caltech.edu

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of NGC 6946 was done at Palomar observatory 60-inch telescope.

The first step in reducing the ISO-CAM data was deglitching, done within the ISOCAM Interactive Analysis package using the routine "mr1d_deglitch", found most reliable among the available procedures for removing cosmic ray hits. Detector transients were then removed within the same software package, using the "IPAC" transient removal algorithm, which uses a simplified physical model for each pixel's time dependent behavior. Then a set of eight "local" flat fields were constructed by taking medians of sequential galaxy-free frames and were then used to form interpolated flats for each of the individual frames, by simple linear interpolation for each pixel. The dark-removed, deglitched and transient corrected data were then flattened by dividing each frame by the appropriate interpolated flat field. Using these processed data we then constructed a model for the sky flux distribution in an array with $3'' \times 3''$ pixels. This finer array is required because the raster steps amount to 13.5 of the $6'' \times 6''$ camera pixels. We assume the raster steps correspond exactly to commanded values. A least-squares fit was then made to determine the maximum likelihood value of the sky's average surface brightness in each pixel. This scheme of modelling the sky avoids some of the error propagation problems of the more traditional means of producing mosaiced images (cf Van Buren and Kong, 1996).

The diffraction-limited beam of ISO has a FWHM of $3''$ at 7μm and $6.3''$ at 15μm, but this resolution is not achievable with our observing mode. The $7\,\mu$m image contains foreground stars whose FWHM measures about $7.3''$. At 15μm the stars are very faint, and only one of them has a measurable FWHM of $7.2''$. The noise levels in these images are approximately 0.1 MJy sr^{-1} $\simeq 2\mu$Jy arcsec^{-2}, roughly 3 times lower than the noise in the "Auto-Analysis Results" map (OLP4.0). Features roughly a thousand times brighter are still reliably measured in these maps. The inner $15''$ or so are too bright to measure, and the surface brightness at the nucleus exceeds 300 and 560 MJy sr^{-1} respectively in LW2 and LW3.

These maps result from a preliminary data reduction which could be significantly improved, especially in the areas of transient removal and flat fields.

3. Disk Structure

The ISOCAM maps of NGC 6946 have enough resolution, sensitivity and extent to allow a detailed comparison with the maps at other wavelengths. The mid-IR images at both 7μm and 15μm show a good qualitative similarity to optical, radio and $H\alpha$ images. Diffuse emission from the disk in the interarm regions is clearly detected (Figures 1 and 2) and can be traced out to $\sim 5'$, comparable to the optical size $D_{25} = 10 - 12'$.

Except for the region in the inner $50''$ of the galaxy where oval distortions are present (Zaritsky & Lo 1984),

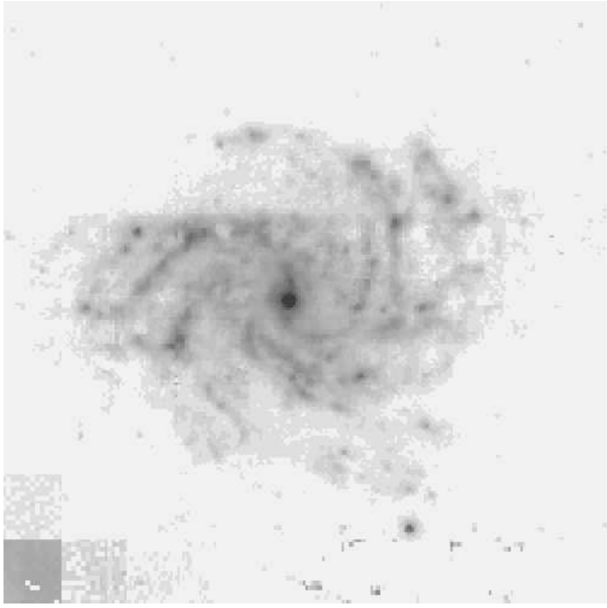

Fig. 1. ISOCAM image of NGC 6946 in the LW2 filter at a wavelength of 7μm, $\Delta\lambda = 3.5\mu$m. This image is a mosaic of 8×8 pointings. Log scale of brightness is used to display the dynamic range of the exponential disk surface brightness. Some Galactic foreground stars are visible to the south and west of NGC 6946. Fortuitous alignment of several features produces what seems to be an "edge" parallel to the major axis in the north. This is at least partly real and visible in optical images, and is exaggerated by residual responsivity drifts unaccounted for by the time-dependent flat field. The image is rotated 21° clockwise w.r. to images showing North at top and east to the left.