MIPS Radiometric Model Correlation After Campaign D1
MER-IOC-001

G. H. Rieke

September 27, 2003

Summary: First light for the MIPS 24 μm array provided an opportunity to correlate the MIPS radiometric model based on measurements on the sky. The basic input data, measurements, and correlated model outputs are listed in Table 1. All of the instrument models were adjusted to provide equivalently good fits to the data, indicating that the outputs are well constrained and that the models are all valid representations of the instrument.

Table 1. Comparison of Signals and Model Results

Source	Input Flux	Signal	Models
Flat Field	36 MJy/sr + telescope	10,500 e/s	10,350 e/s
Calibration Star Sky	19 MJy/sr + telescope	8800 e/s	8930 e/s
Calibration Star	1.23 Jy star, sky and telescope removed	925,000 e/s	928,000 e/s

The MIPS sensitivity requirements are defined in terms of the one-standard-deviation limits in a 2000 second integration against minimum zodiacal background. A detailed description of the model assumptions is given below, but the values in Table 2 demonstrate that the predictions of the different models do not differ substantially, nor are they substantially affected by assuming a worst-case value for the read noise. A good summary of the predictions is that we expect MIPS to reach one-standard-deviation detection limits of 9 ± 1.5 μJy in 2000 second integrations at minimum zodiacal background.

Table 2. Predicted Sensitivity

	Read Noise = 27 e	Read Noise = 40 e
Model 1	7.6 μJy	7.9 μJy
Model 2	8.5 μJy	8.9 μJy
Model 3	9.9 μJy	10.5 μJy
Model 4	8.9 μJy	9.3 μJy

The observations also allow determination of saturation limits in this band as:

- 7.6 ± 0.5 Jy for first differences
- {[4.0 ± 0.25 - 0.002 X (sky in MJy/sr)]Jy}/(T_{int} - 0.5), where T_{int} is the nominal DCE time.

Discussion

Campaign D1 provided the first opportunity to compare the on-orbit performance of MIPS with the pre-launch predictions, and to correlate the radiometric model to improve its predictive power. At the time, the secondary mirror of the telescope was at 36.65K (average), and we have taken this temperature for the entire telescope in the model since most of the emitting regions are located around the secondary (e.g., the baffles around the mirror, which are viewed by the detector because of the oversized Lyot stops to allow alignment onto the telescope).

Prior to launch, key parameters in the model were as listed in Table 3. All the adjustments made to correlate the model are within plausible ranges for the parameters (see Table 3), except that it is unlikely that the DN conversion is as low as 3 e/DN (this version was created to explore the sensitivity of the conclusions to this parameter). All the models produced equivalently good fits to the input data, shown in Table 1. The actual numbers in Table 1 are for Model 1, and the fits were compared with appropriately modified input values and then normalized to the Model 1 results in judging the equivalence of fit.

Table 3. Key Model Parameters

Parameter	Pre-launch	Correlated Model 1	Correlated Model 2	Correlated Model 3	Correlated Model 4
Emissivity	0.3	0.23	0.23	0.23	0.23
Telescope Throughput	0.88	0.96	0.96	0.96	0.96
Quantum Efficiency	0.6	0.73	0.63	0.51	0.58
Optical Efficiency	0.66	0.71	0.66	0.61	0.66
DN conversion	5 e/DN	5 e/DN	4 e/DN	3 e/DN	4 e/DN
Photoconductive Gain	0.85	0.85	0.85	0.85	0.85
Star Flux Density	1.23 Jy	1.23 Jy	1.23 Jy	1.23 Jy	1.33 Jy

In the case of emissivity and throughput, the model adjustments remove a slight shade of pessimism injected intentionally in the prelaunch numbers and substitute the values that would be expected for an ideal system (the high emissivity is a direct consequence of the 10% oversizing of the cold Lyot stops). Errors of 5 percentage points in the instrument throughput and of 10 percentage points in the focal plane quantum efficiency would also be within expectations. The calibration star observed is not a previously observed infrared standard. The adopted flux density is consistent with shorter wavelength photometry and standard colors, or with a standard spectral energy distribution, and also with the IRAS Band 2 measurement. However, a discrepancy of the order of 0.1 Jy is still conceivable. Although we did not adjust the photoconductive gain in the models (even though the assumed changes in quantum efficiency might suggest small changes in the gain), any changes in this parameter could be compensated by an appropriate change in the DN conversion (so long as we do not enter the regime of gain dispersion greater than one).

However, models outside the range of these three are unlikely, because they would stretch a number of parameters outside the expected error range, and as already mentioned, the model assuming 3 e/DN is already a bit implausible. We have therefore taken these models to define the range of likely instrument performance, and have computed the sensitivity on this basis, as listed in Table 2.

Important assumptions in the radiometric model used for the values in Table 2 include:

- Minimum zodiacal emission defined by 3.5×10^{-14} B(5500) + 2.9×10^{-8} B(278.5) + 1.78×10^{-5} B(24.45). This yields 13 MJy/sr at the MIPS 24 μm band.
- Source extraction by aperture photometry with an aperture diameter of 2.4 λ/D. A 10% penalty in sensitivity has been added to allow for the finite pixel size.
- Flat fielding residual noise of 1 part in 10^4, combined rms with other noise components.
- Cosmic ray hit rate of 0.004/second per pixel
- DCE time of 10 seconds

A further description of the model can be found in the MIPS System Description Document.

Because the signals from the star observed in Campaign D1 are in units of DN, the saturation limits are independent of the various radiometric models and DN conversion factors. We have assumed that 94% of the dynamic range of the A/D converter can be used for the data (that is, that the detector output level is set to 6% above the low-signal rail). We then find that the saturation limits are:

- 7.6 $\pm$ 0.5 Jy for first differences
- {[4.0 $\pm$ 0.25 - 0.002 X (sky in MJy/sr)]Jy}/(T_{int} - 0.5), where T_{int} is the nominal DCE time.

The uncertainties reflect a 0.1 Jy uncertainty in the flux density from the star observed. The sky brightness correction is small, but is included for completeness. The nominal DCE operation includes a reset, and then a second half a second later, after which the integration ramp begins. Therefore, if an observer enters a DCE time of, say, 3 seconds, the instrument will provide an integration of 2.5 seconds, and the saturation limit will be that appropriate to 2.5 seconds. Therefore, the formula above should provide correct estimates independently of T_{int}.