LRO Diviner Nonlinear Detector Response Correction

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Background

-Aboard the Lunar Reconnaissance Orbiter (LRO), the Diviner Lunar Radiometer Experiment measures thermal radiation to determine the brightness temperature of the lunar surface.

-Some channels (particularly B3) exhibited unexpectedly high brightness temperatures close to the equator, as well as nonuniformity between the detectors (Figure 1).

-We are investigating the extent to which these issues can be corrected by accounting for the nonlinear response in Diviner's detectors as measured during pre-flight radiometric calibration.

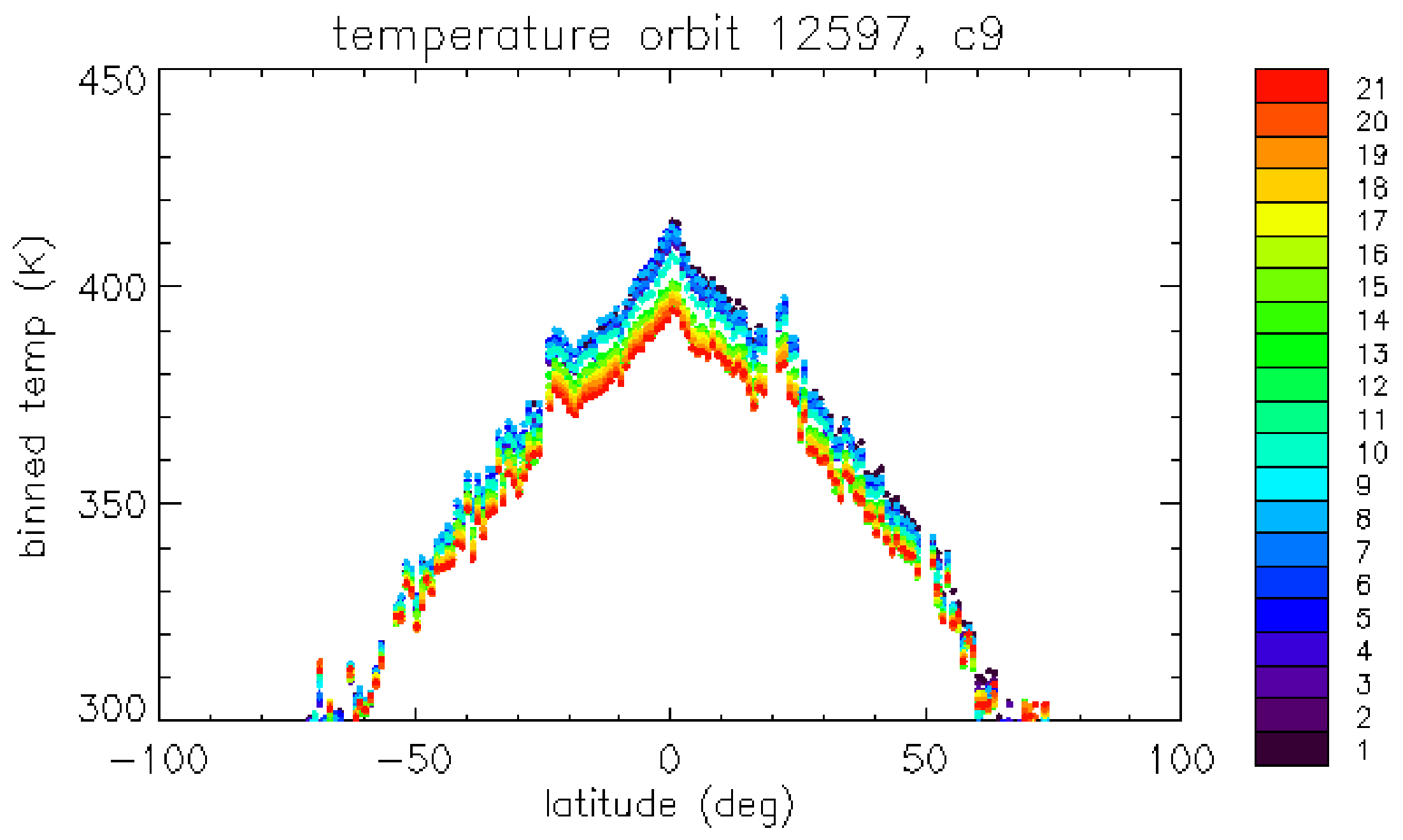

Figure 1: Binned temperature data of a particular LRO orbit. Different colors represent different detectors of channel B3. Note the high brightness temperatures near the equator (0 latitude) and the differences individual detectors.

In-flight Calibration

-Diviner's routine two-point in-flight calibrations use space as a zero reference and the internal blackbody calibration target to calculate signal gain:

$$\text{gain} = \frac{B(T_I)}{C_I - C_S}$$

Where $B(T_I)$ is the calculated radiance as seen by a detector on one of Diviner's channels at the temperature of Diviner's internal blackbody calibration target, and C_I and C_S are the signal counts of the internal blackbody calibration target and space (our zero reference), respectively.

-The signal counts of the moon is subtracted by the zero reference, and this difference is multiplied by the gain to determine the lunar surface's radiance, which can then be referenced to a brightness temperature:

$$\text{gain} * (C_M - C_S) = B_M \rightarrow T_M$$

Where C_M is the signal counts from the moon, B_M is the radiance detected from the moon, and T_M is the brightness temperature of the moon.

Pre-flight Radiometric Cal

-Two external blackbodies were used to simulate space and the lunar surface during Diviner's laboratory radiometric calibration (Figure 2).

-As the variable blackbody temperature was ramped up, the instrument scanned between the two external blackbodies and the internal blackbodies multiple times (Figure 3).

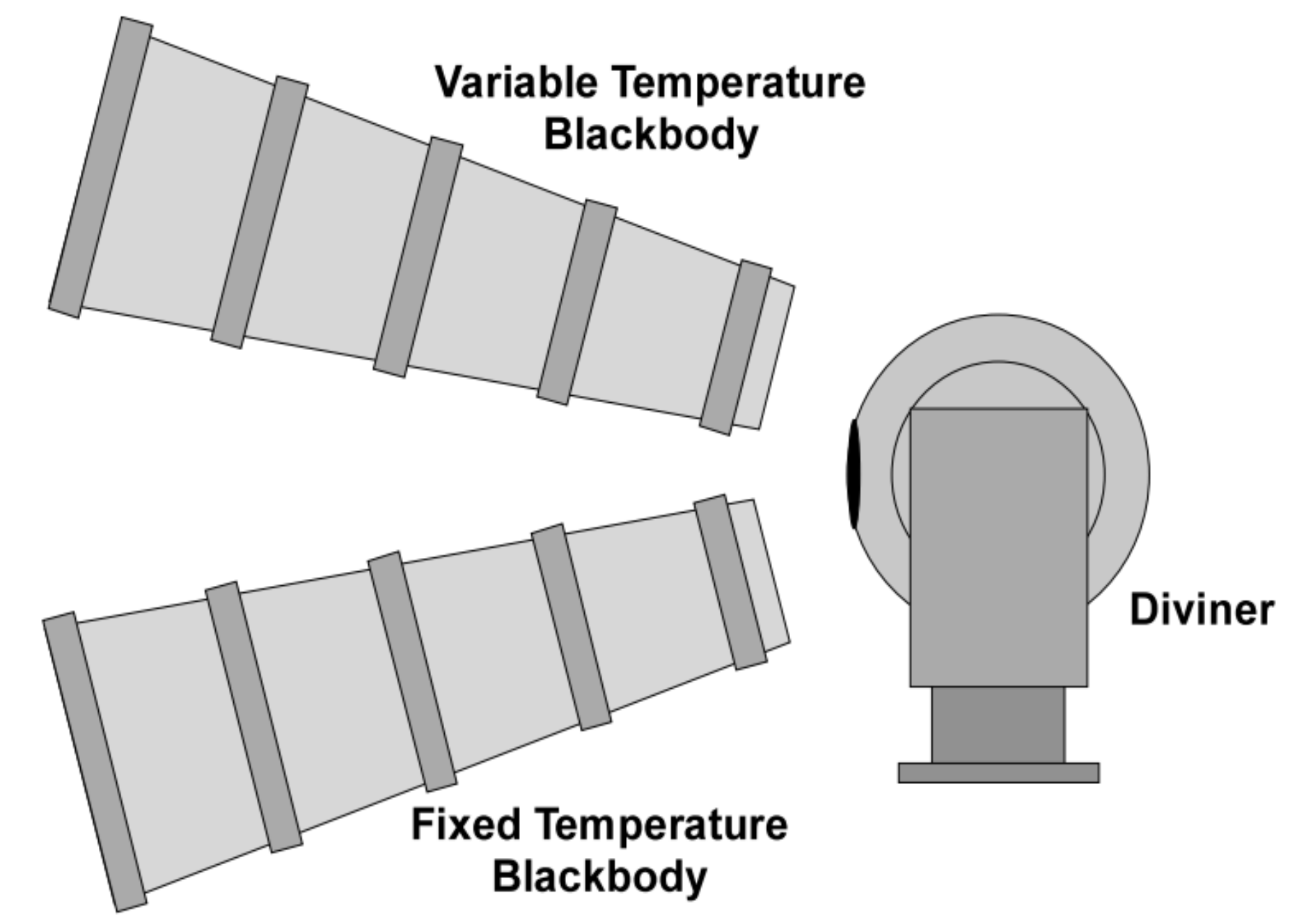

Figure 2: Configuration for pre-flight radiometric calibration. Fixed blackbody was held near 90K, variable blackbody varied in temperature from 20K to 215K.

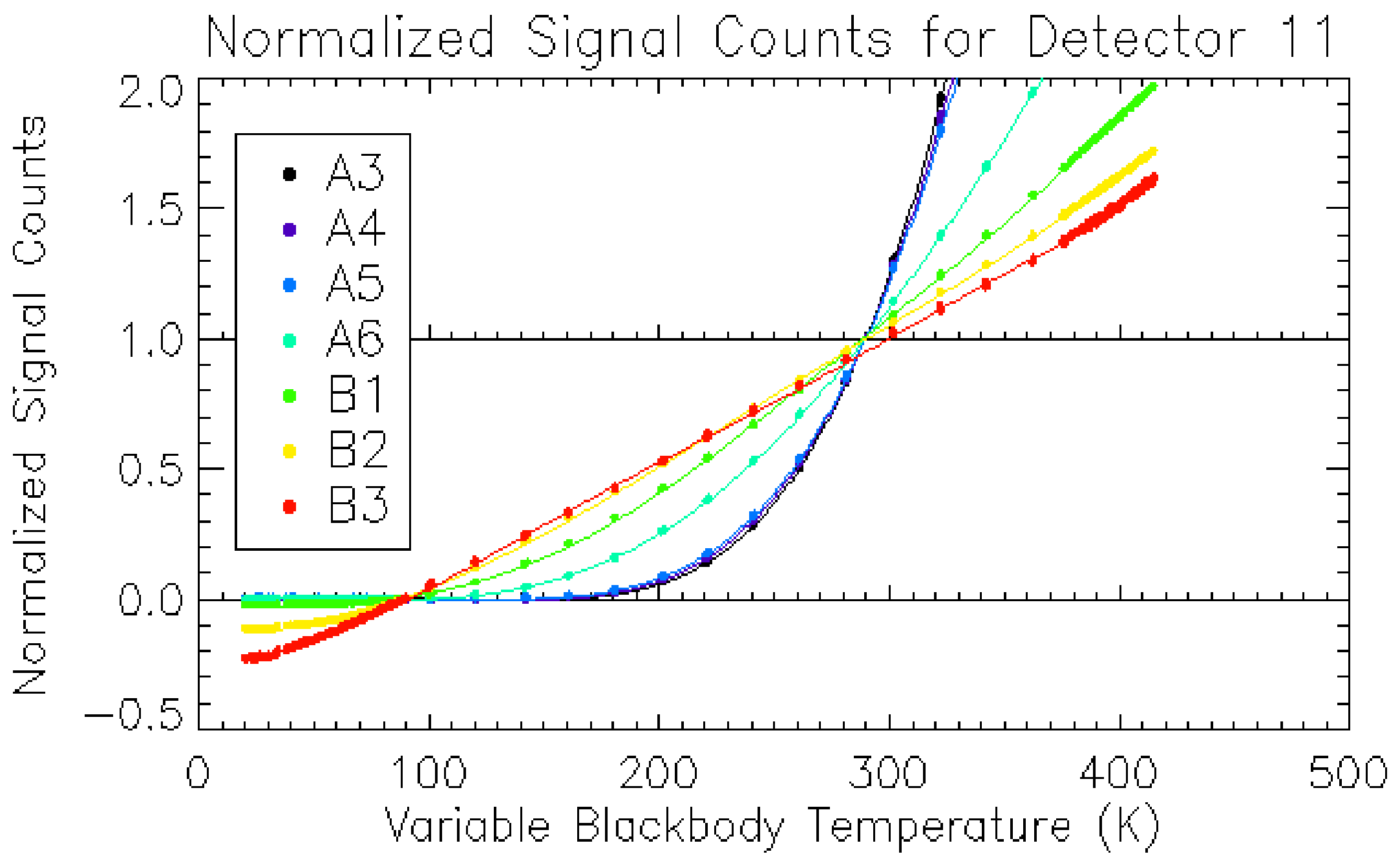

Figure 3: Example of signal counts as observed by detector 11 of each thermal channel at each temperature of the variable blackbody (data points), with a model of this data (lines). Signal counts of the variable blackbody have been normalized by signal counts from the internal blackbody. Counts from both variable and blackbodies have been offset by signal counts from the fixed blackbody.

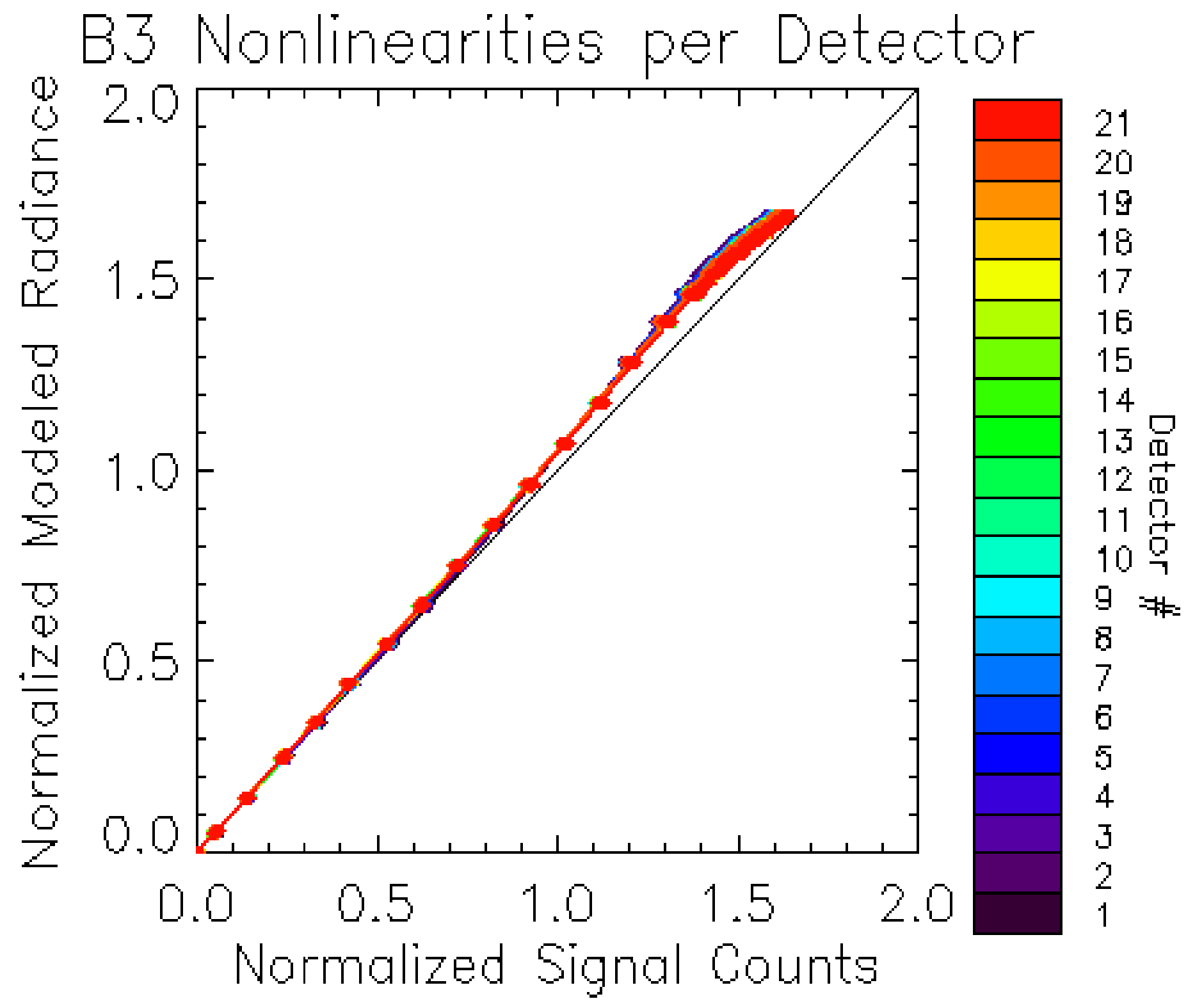

Figure 4: The nonlinear response of all Diviner's channel B3 detectors from lab calibration. Plotted is modeled radiance (derived from the temperature of the variable blackbody and normalized to 289 K) against measured signal counts (also normalized to 289 K). The line fits are polynomial functions that take normalized detected radiance and return normalized corrected radiances, which can then be used to find a corrected brightness temperature.

Determining Nonlinear Response

-Figure 4 shows the nonlinear response for channel B3. The Mars Reconnaissance Orbiter (MRO)'s Mars Climate Sounder (MCS) similarly applies a nonlinearity correction to its detected radiances.

-Further issues are faced, however. Figure 5 exhibits the difference in radiance and temperature from an average detector, as a function of brightness temperature for our pre-flight calibration ramp. Figure 6 exhibits these differences from in-flight data over the course of several orbits.

-Note that although the lab data and orbital data exhibit detector differences of the same order of magnitude, they appear to be differences of opposite signs.

-Thus, a nonlinearity correction derived from lab calibration would not solve the detector discrepancy seen in orbital data (Figure 7).

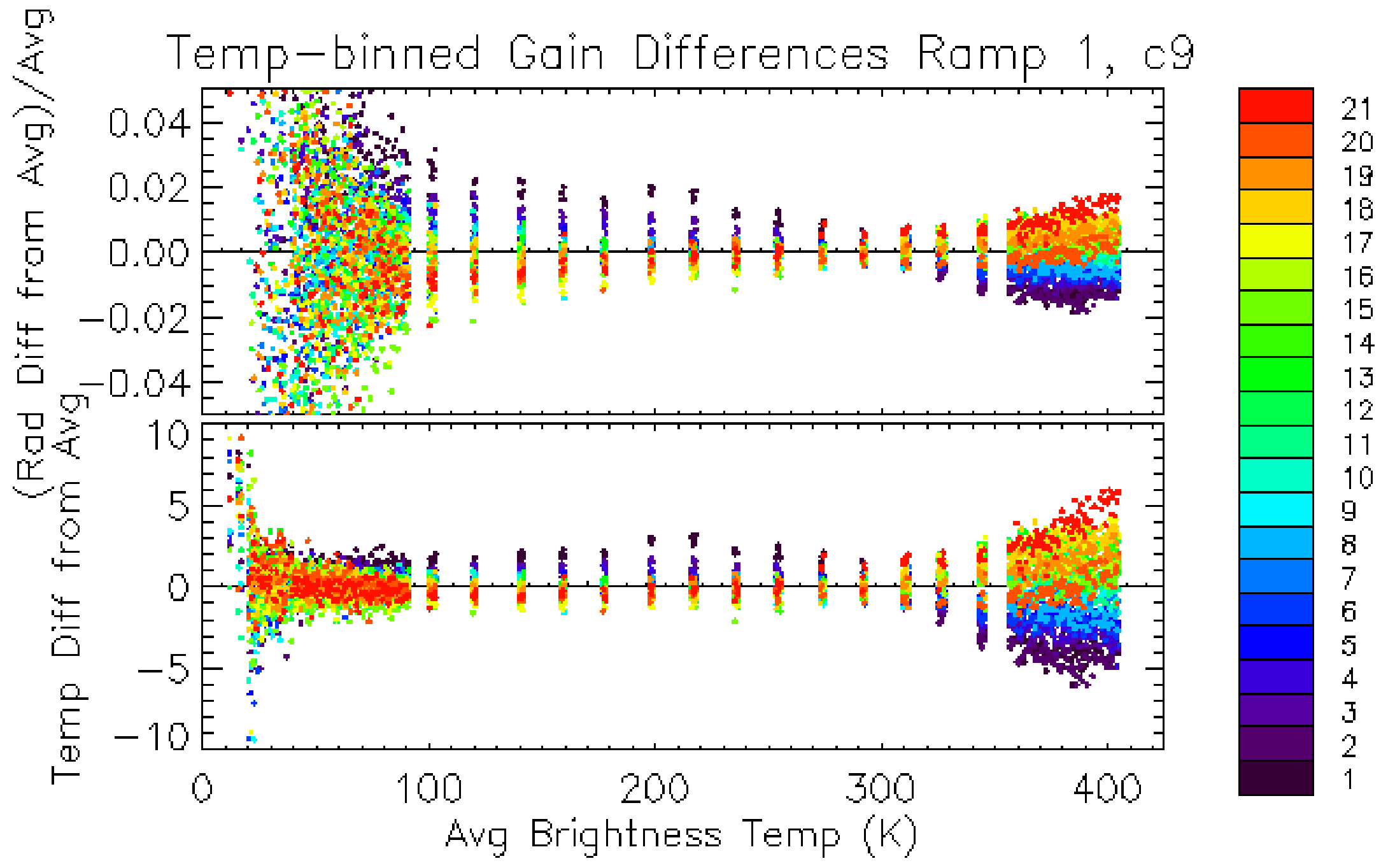

Figure 5: The difference in radiance and temperature of each detector of Channel B3 from the average radiance and average temperature of all channel B3 detectors. This uses data from the pre-flight lab radiometric calibration.

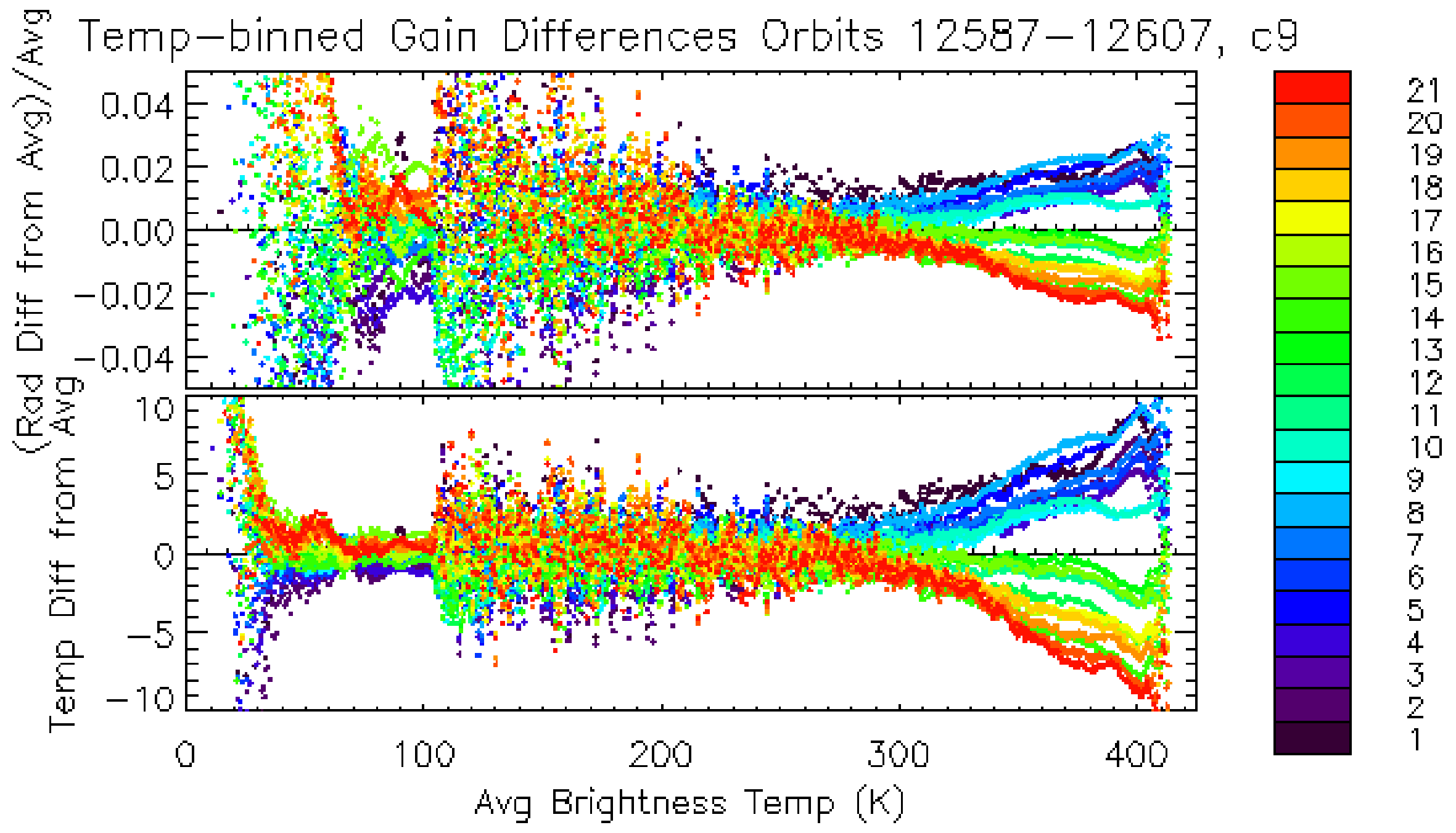

Figure 6: The difference in radiance and temperature of each detector of Channel B3 from the average radiance and average temperature of all channel B3 detectors. This uses data amassed from several orbits.

Preliminary Conclusions

-A simple nonlinearity correction derived from a polynomial fit to the nonlinear response seen during pre-flight radiometric lab calibration will not account for either the discrepancy between detectors, nor fix extreme temperatures seen at the equator.

-This raises the idea that the extreme equatorial temperatures are from another confounding factor.

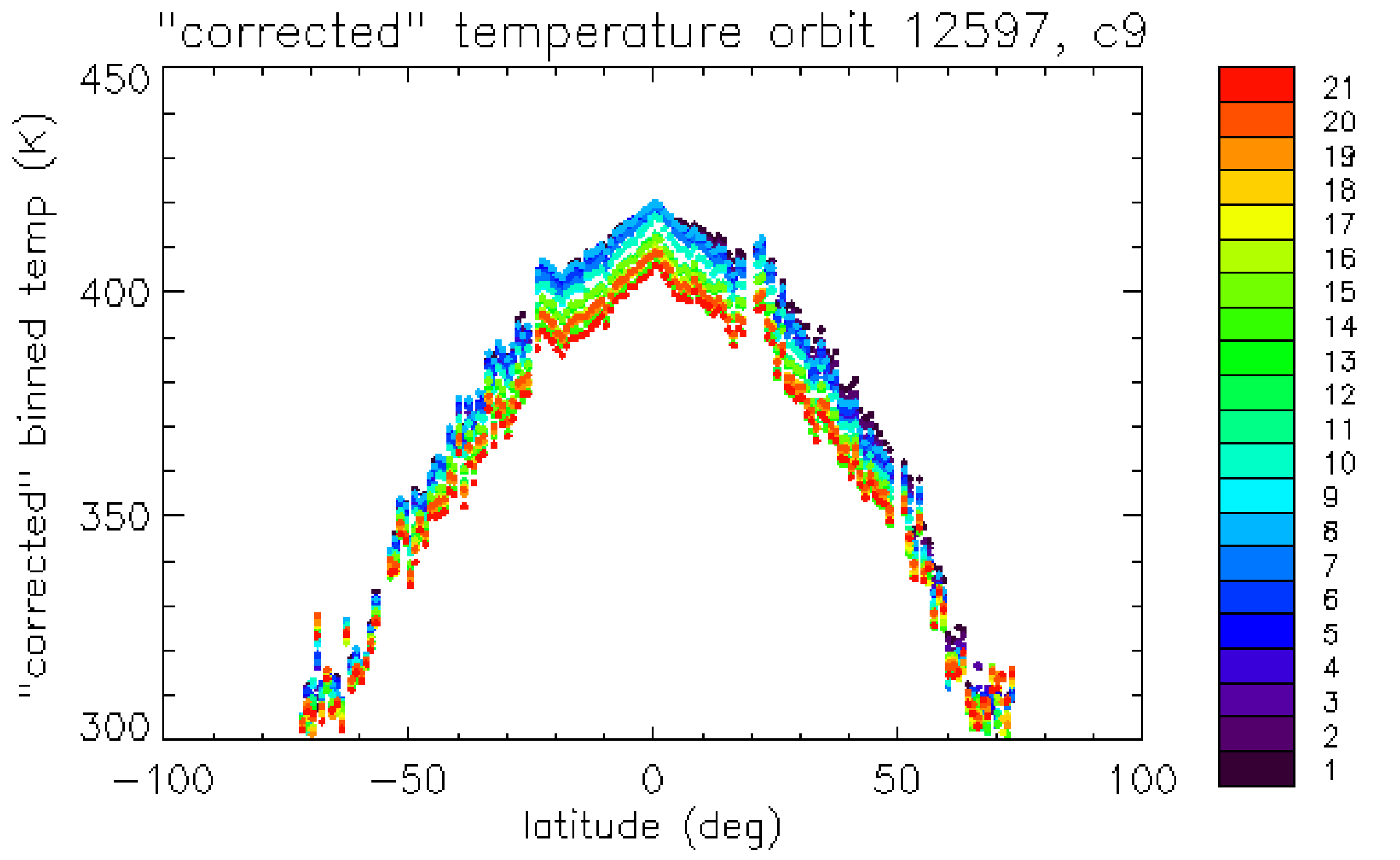

Figure 7: By accounting for the nonlinear response in detectors seen in Figure 4, the data in Figure 1 can be corrected. However, since the disparity seen between the detectors in lab calibration is more or less opposite of that seen in space, the nonlinearity correction does not fix the disparity. The unexpectedly high temperatures at the equator are partially ameliorated by the nonlinearity correction, but not entirely.

Next Steps

-To account for discrepancy between the detectors of any channel, it might be best to empirically fit for the differences exhibited in orbital data. This would, however, not remove the extreme temperatures seen in low-latitudes.

-These extreme temperatures could possibly be from a light-leak, as the brightness temperature in the solar channels (A1 and A2) are extreme at low-latitudes due to a shadow-hiding opposition effect (Figure 8).

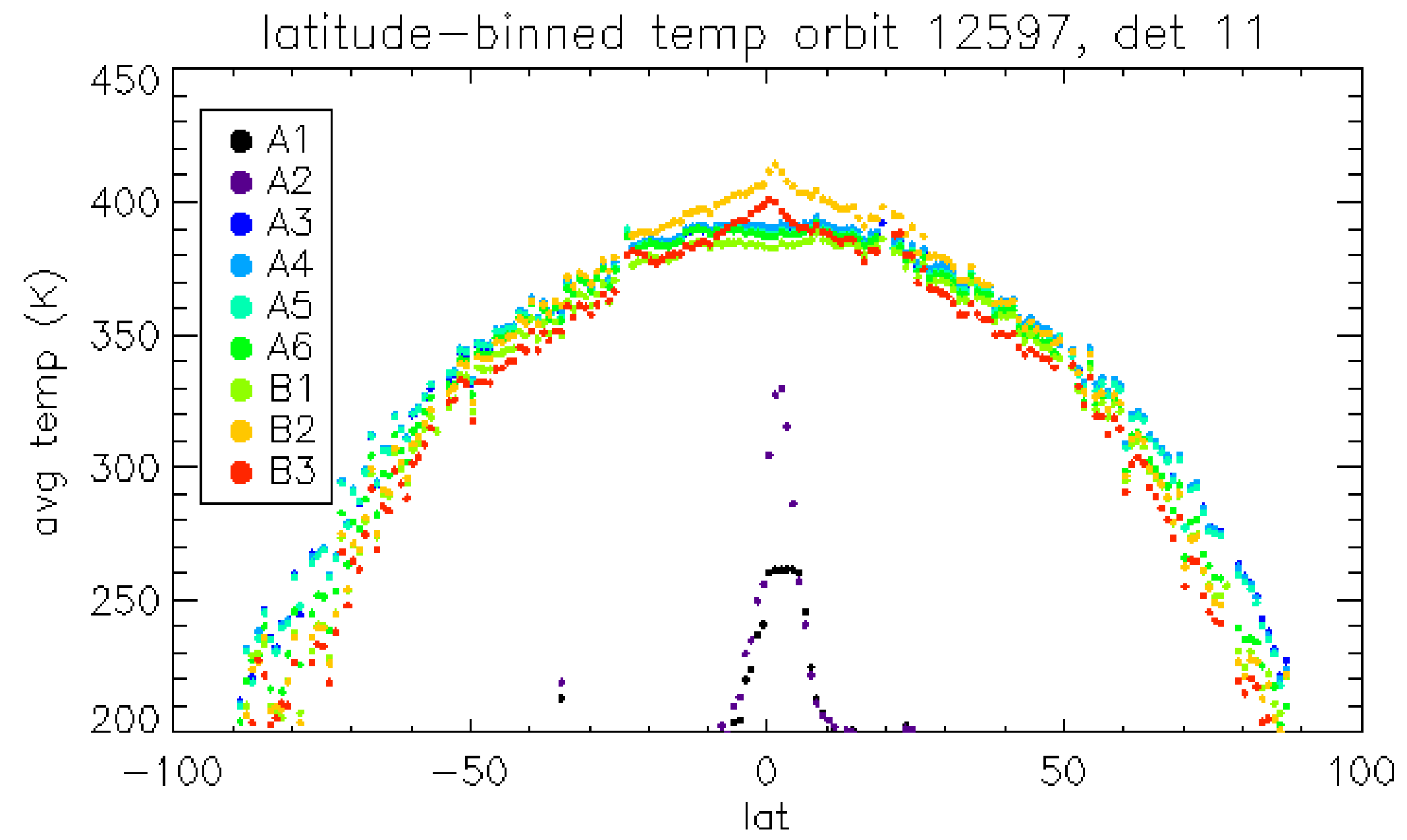

Figure 8: A plot of brightness temperature as seen by detector 11 of each channel,. Note that channels B2 and B3 exhibit extreme temperatures near the equator. There is a possibility this is from a light leak, as channels A1 and A2 (the solar channels) exhibit this same extreme behavior.

Acknowledgements

Szilárd Gyalay would like to thank Professor Dave Paige for his continued support and guidance through every year at UCLA.

References

Paige, D. A. et al. (2009) *Space Sci Rev 150*, 125-160. McCleese, D. J. et al. (2005) *JGR 112*(E5S06), 1-16