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JWST TECHNICAL REPORT

Title: Monitoring MIRI Imager backgrounds	Doc #: JWST-STScI-008928, SM-12 Date: 10 February 2025 Rev: -
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1 Abstract

The Near and Mid-Infrared backgrounds observed by JWST are made up of several components. The longest wavelengths, which are only observed by MIRI, are dominated by thermal components. Since any changes in these wavelengths could indicate changes in the thermal properties of JWST, the MIRI team started using all science observations observed with MIRI to track the level of observed background at each filter over time. The purpose of this report is to describe the methodology for obtaining the trending data with which further analysis can be performed. With a more in-depth analysis (described in a later report), a seasonal fluctuation was observed for most wavelengths, and a rise in backgrounds at the three longest wavelengths, F1800W, F2100W and F2550W was also observed. The possible causes of this rise in backgrounds are currently being explored.

2 Introduction

The background observed by JWST is a combination of several components. For MIRI, the zodiacal light dominates shorter wavelengths, while thermal telescope components dominate the longer wavelengths. In order to determine how well the observations match the background model, and whether there are any observable changes in this background over time, the MIRI team began monitoring the backgrounds of science observations on a monthly basis. Every month, the team downloads any new data, finds the median over the Imager field of view, and creates plots to view any trends based on time, galactic altitude, and other desired parameters. The resulting plots showed that the background does seem to be increasing at the longest wavelengths of the MIRI imager. Any rise at the longer wavelengths could indicate changes in the thermal properties of JWST, so are of great interest.

The JWST Backgrounds Tool (JBT) can show, for each day of the year, what the expected backgrounds components are. An example of this plot, for day of the year 268 is shown in Figure 1 below.

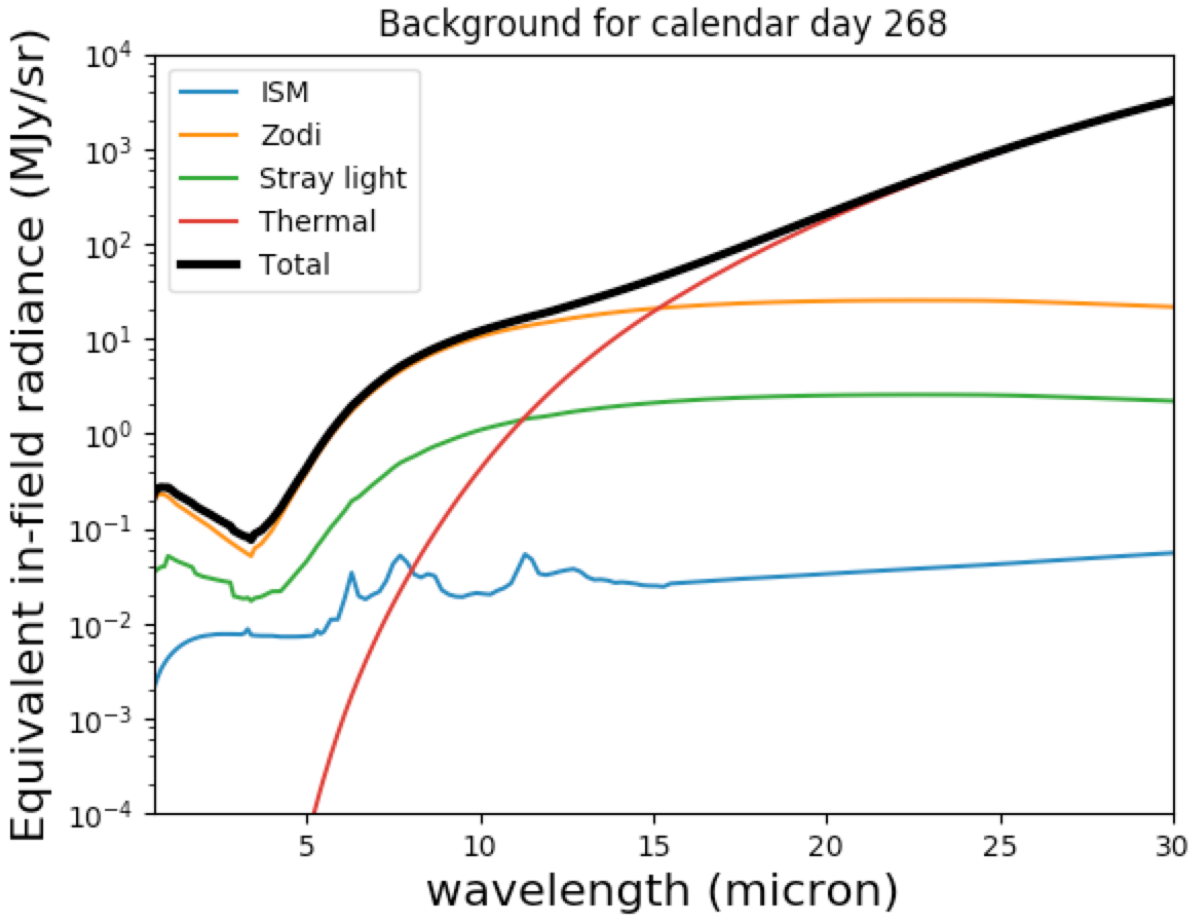

Figure 1: Example plot from the JWST Backgrounds Tool showing the expected contributions to the background for day of the year 268.

3 Analysis and plots

3.1 Procedure for analysis

The analysis is performed on calibrated data (cal.fits files from calwebb_image2) for all FULL frame images for each filter. Each month, all new cal files are downloaded and the analysis is run on all data per filter. In the fall of 2023, a time-dependence was found in the photon count rate and the derived flux for MIRI data at the longest wavelengths. This effect was found to be at 3% for F1280W and F1500W, 8% for F1800W, 12% for F2100W and 18% for F2550W. In December of 2023, the pipeline was updated to apply coefficients to correct for this time-dependence to the scalar conversion factor in the photom step in calwebb_image2. All of the cal images used in this report have had this time-dependent correction applied.

Since the data is usually downloaded a month at a time rather than starting over from scratch and re-downloading all the data each month, this can result in a mix of different pipeline versions and different reference files being used. When there are any major reference file or pipeline updates that would have a large impact on the data, the previous repository of data is deleted and the files are all downloaded at the same time to ensure a consistent set of data is being used. At the end of 2024, this syncing of data was done, so that the plots shown in this

report use a consistent pipeline build and set of reference files. The pipeline version used is 1.15.1.

Once all of the data is downloaded, the data is analyzed by taking pre-defined regions of the image, calculating the median pixel value for those regions, and saving a file for each filter that contains header keywords from each file, as well as all of the calculated region medians and a standard deviation of all of the median values across the regions, or 'quad_scatter' in the output file. Figure 2 shows the regions used in the analysis. Each of the 10 smaller boxes (3x3 grid plus the Lyot region) are 256 by 256 pixels, and the larger 'imager_cal' region is 512 by 768 pixels.

Each output file has the column names as listed in Table 1. Those column names have information taken from the header values of the fits files. Then there are a list of regions names that contain the median pixel value for each region and a standard deviation across the regions. Figure 2 shows where these regions are on the Imager detector.

Table 1: Header values in output file

Column name	Description of column name
cal	Path to file+ file name
pid	Program id
obsid	Observation id
visid	Visit id
gsaid	Visit group + sequence id + act id
expid	Exposure id
exptime	Exposure time
mjd	Date in MJD
cal_ver	Version of pipeline used to process data
crds_ctx	pmap version used for crds
attitude	Separation angle between the spacecraft v1 optical axis and the sun vector
targ_ra	Target Right Ascension (RA)
targ_dec	Target Declination (DEC)
bkgstep	Was the background step performed in the pipeline (True or False)

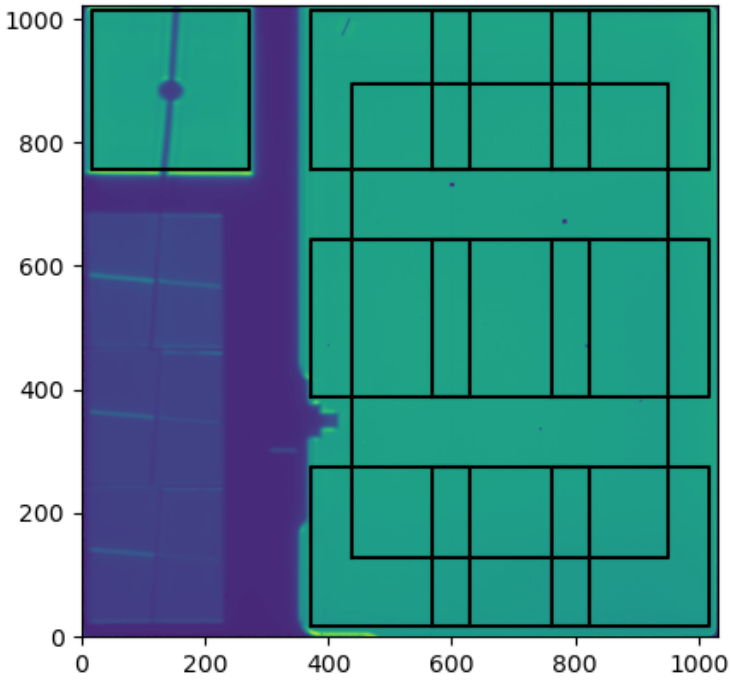

Figure 2: Regions used in background analysis. Each of the boxes in the figure show a region for which the median values are recorded. The large box in the middle is the 'imager_cal' region which is used for most of the monitoring plots. The smaller regions are used to determine if there are spatial differences across the imager, which might indicate that more work is needed to create better flat fields.

Using the information in this file, plots are generated to show if the background varies over time. Since we are using all of the science data, and the images could contain bright or extended sources that would not be representative of the true background, a filter is applied to the data before any plots are created. Any data that had been background subtracted by the pipeline or has a 'quad_scatter', or standard deviation across all region medians more than 10 percent of the median background in the imager region is rejected.

We also compare our calculated background to the model background obtained from the JWST Background Tool (JBT). For each data point in an output file that passed the previously stated filter, the background tool is provided with the RA, Dec, MJD date and filter wavelength. The tool then provides the following values, in MJy/sr: total background, straylight , zodi, non-zodi and thermal components of the background. We then save a file that contains the columns listed in Table 1, as well as the median region values, the various components of the background as provided by the background tool, and a column for the data minus the total expected background from the model.

These files are then provided to Goddard and other team members as desired, and used as the basis for all plots.

3.2 Resulting plots

The plots here show data from the start of commissioning up through December of 2024. For any plot that utilized the JBT, the thermal curve in use is thermal_curve_jwst_jrigby_v4.0.csv, which was updated to predict the expected background at the end of cycle 4 based on the MIRI imaging results and the observed rise in background at the longest wavelengths. The solid green line in the plots is the median value across all data points, and the dotted green lines above and below are 10% above and below the median value. Data points in black squares are from a background monitoring calibration program (PID 6616) that started in the summer of 2024, intended to get a more consistent set of data on darker sky regions for the three longest wavelengths.

The error bars are calculated as the standard deviation of the median values in the various regions over the imager as shown in Figure 2.

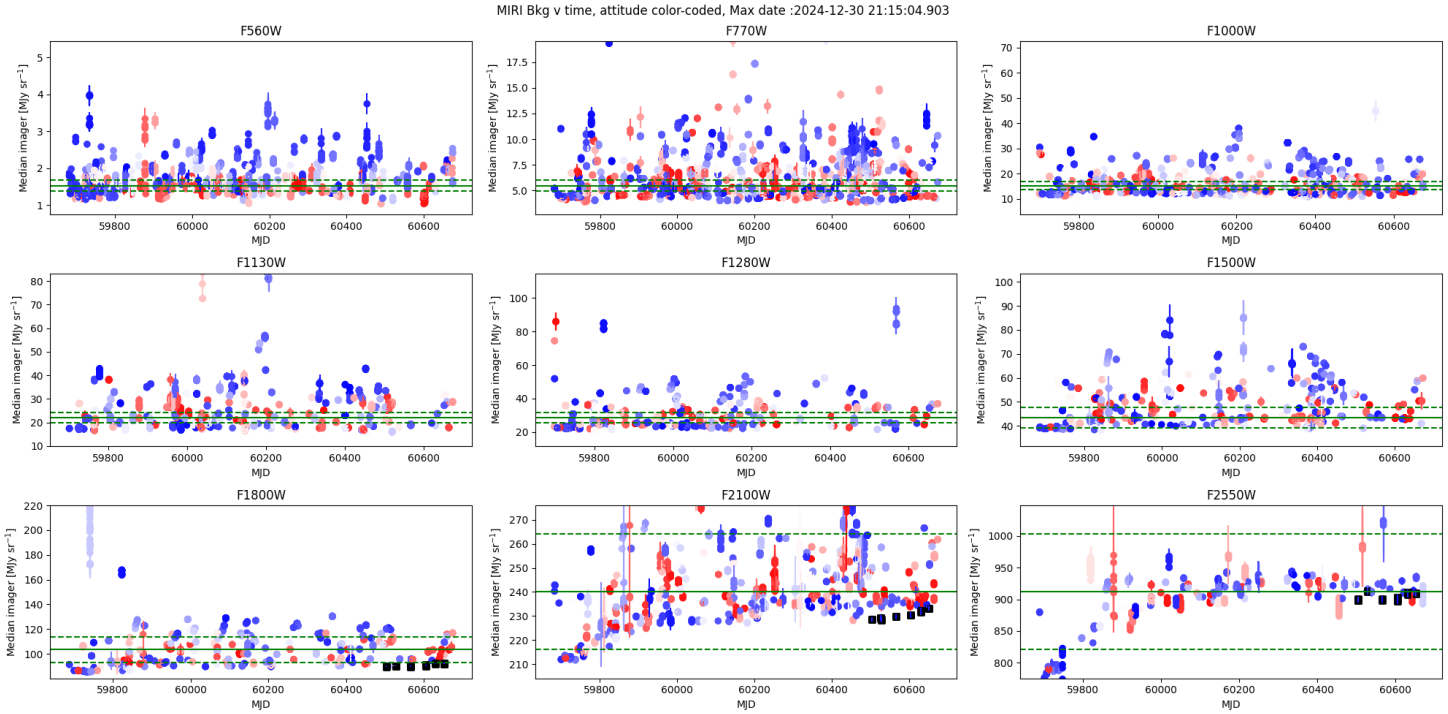

Figure 3: Plots of median background values in MJ/str versus MJD date. All data in FULL frame cal files for each filter, color coded by attitude with darker blue at the low end of attitude values, and darker red at the higher values.

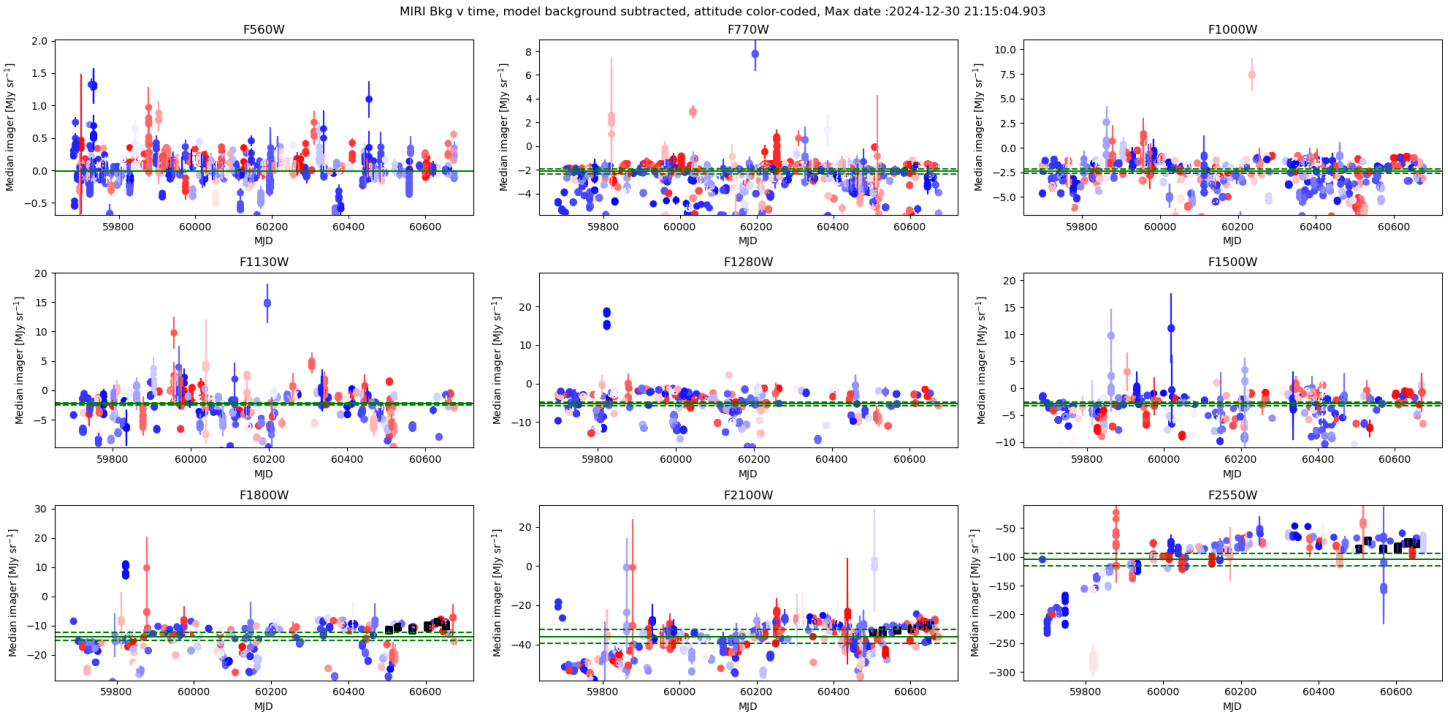

Figure 4: Background minus model background vs. MJD date. These plots show the median background for each filter minus the total background from the JBT in MJ/str.

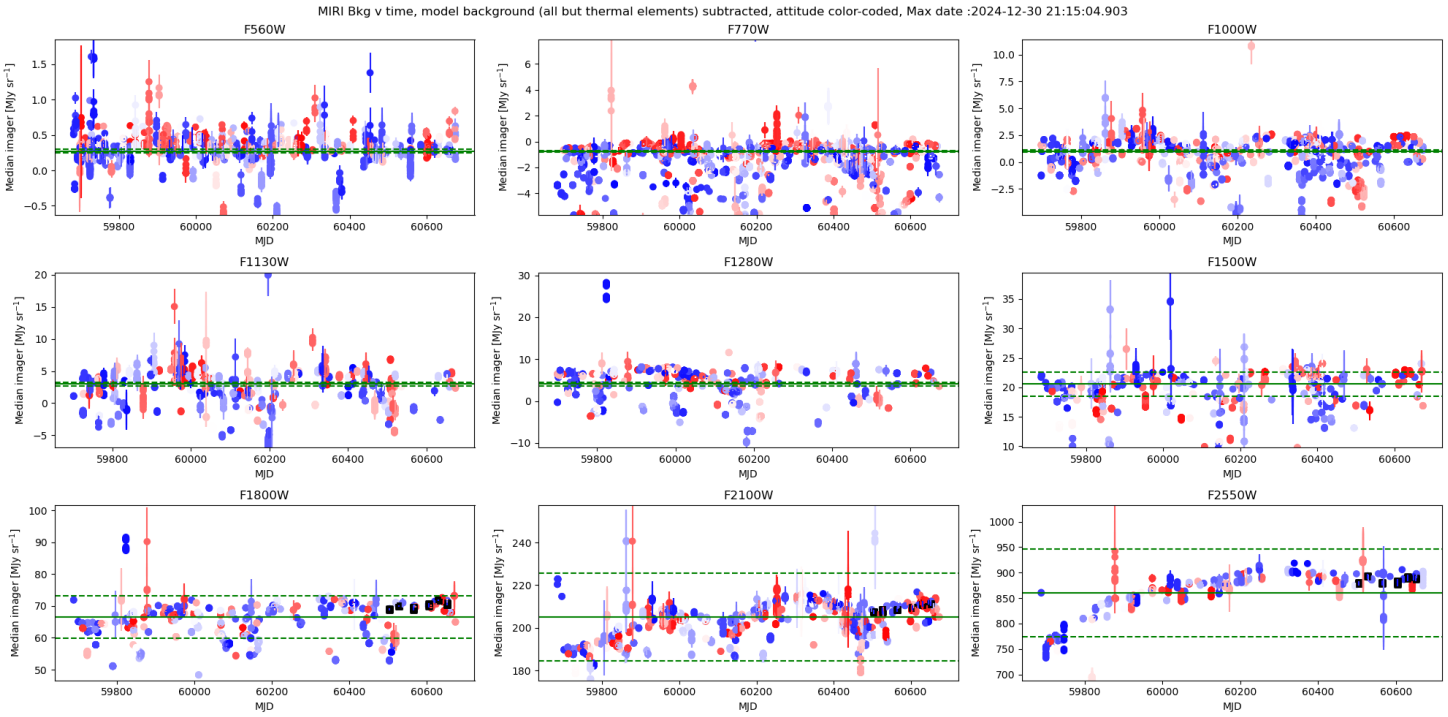

Figure 5: Background minus non-thermal background model vs. MJD date. This version of the plot subtracted all of the non-thermal components of the model background. Background values in MJ/str.

In order to determine whether there are any patterns according to position, Figure 6 plots the position of each observed field in Galactic coordinates, with the color coding indicating the level of median background in the imager.

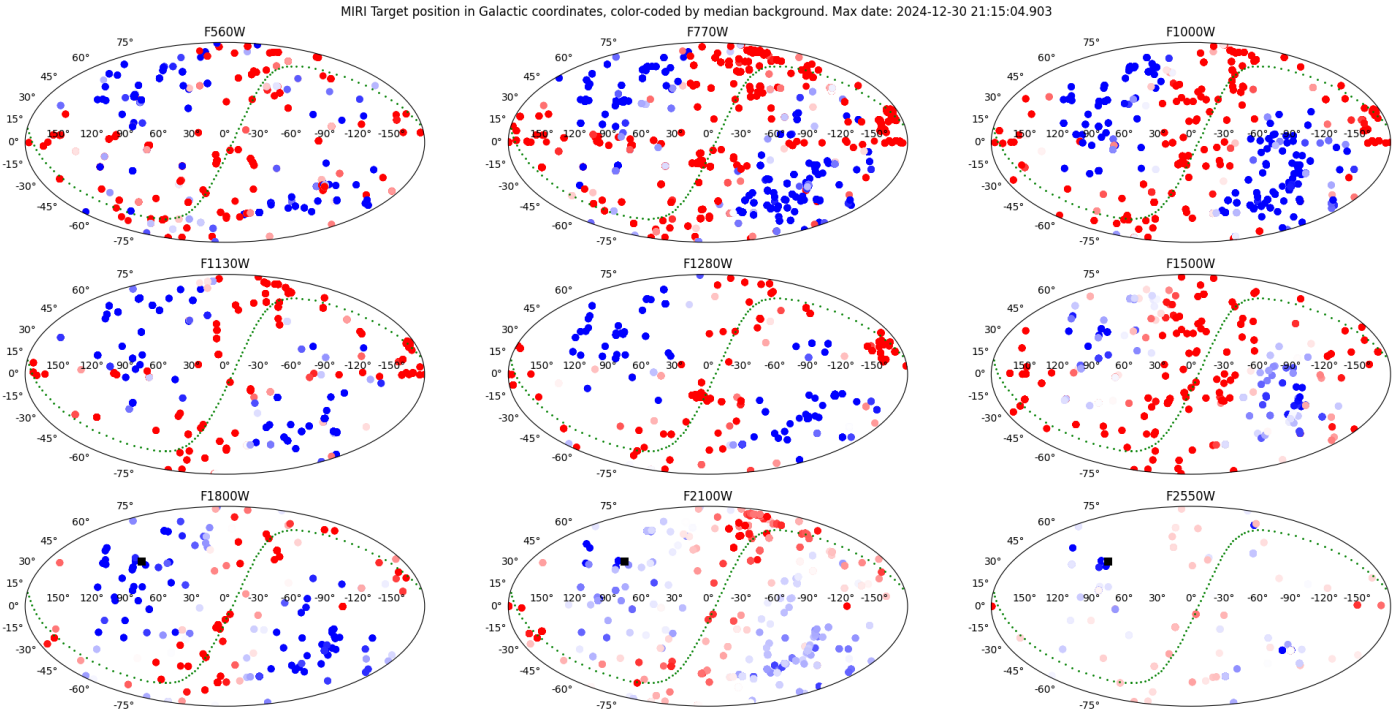

Figure 6: Positions of all observations in Galactic coordinates, color coded by median background level in the imager_cal region. Dark blue is the lowest background level and dark red is the highest background level. It can be seen that the higher backgrounds can be found along the ecliptic (dotted green line). Black squares are the background monitoring program data, intended to look at 'darker' regions to obtain better background observations.

4 Conclusions

Examination of the plots (Figures 3-5) show a seasonal sinusoid, which is not accounted for in the model, but even after the sinusoid is accounted for, there is still a noticeable rise in background for the longest wavelength filters, F1800W, F2100W and F2550W. This rise was factored into the JWST Background Tool with the thermal curve v4.0 and included in the ETC for cycle 4. Discussions among members of STScI and Goddard are continuing to determine why the background might be increasing over time.

5 References

Rigby, J., Pontoppidan, K., Kinzel, W., et al., 2022, JWST Backgrounds Tool: v1.2.0, https://github.com/spacetelescope/jwst_backgrounds