Temperature map of the galactic plane based on infrared wavelength intensity across 5 bands

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ABSTRACT
The Hi-GAL dataset includes data for 5 different infrared wavelengths (70, 160, 250, 350, and 500 micron). By analyzing the differences in intensity in these wavelengths, we aim to create a temperature map of the galactic plane.

CCS Concepts
• Applied computing → Physical sciences and engineering → Astronomy

Keywords
Galactic plane temperature; Hi-GAL; Herschel; galactic temperature map

1. INTRODUCTION
Blackbody radiation, such as that from interstellar dust clouds, can be used to determine an approximate temperature of the emitting body using Wien's Law (Fritzsche, 2016). This radiation is emitted at varying wavelengths, with the peak wavelength being the wavelength at which the most light is emitted. It is this peak wavelength that can be converted to an approximate temperature using Wien's Law. For each data point, we will attempt to match the intensities of each of the 5 different wavelengths to a normal blackbody radiation curve to determine the peak wavelength (and its corresponding temperature) for that data point. We will then be able to assemble a temperature map based on the calculated temperature for each data point.

2. MOTIVATION
The Hi-GAL dataset is relatively new and holds a great deal of promise in areas of research including star formation and molecular dust cloud structure. A temperature map of the galactic plane would provide a basis to perform deeper analysis and be very useful in identifying areas of further research.

3. LITERATURE
There have been numerous analyses involving the Hi-GAL dataset, but relatively fewer dealing with creating a temperature map of the galactic plane. Here are a few of the most pertinent:

3.1 Dust temperature maps of the Galactic plane by Zhu J. and Huang M.
This study used both the radiative transfer code, Cloudy, and the DustEM dust model, to analyze the dust continuum emission in two Hi-GAL science-demonstration phase (SDP) fields to explore the effect of radiative transfer on dust temperature. The authors were able to derive dust temperature maps of the two SDP fields by comparing the observation with the Cloudy and DustEM model predictions. They concluded that the FIR SED of the SDP fields is affected by the radiative transfer, resulting in a higher temperature distribution than the dust-only fit. They also confirmed that the star formation field has a higher temperature than the non-star formation field. (Zhu, 2014).

This study is similar to what we propose in that they performed some temperature mapping, but different because they were specifically looking at the effect of radiative transfer on dust temperature. Our work is focused on the map making itself.

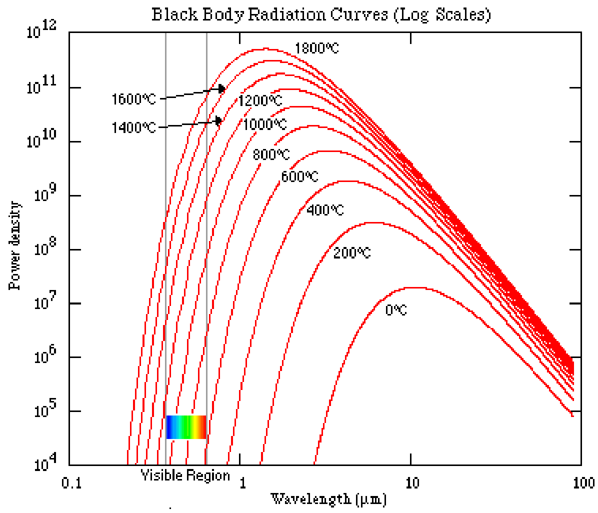
3.2 Mapping the column density and dust temperature structure of IRDCs with Herschel by Peretto N., Fuller G. A., Plume R., et al.
This study uses the first Herschel data from the Hi-GAL galactic plane survey to map dust temperature and column density of Infrared Dark Clouds (IRDCs). The authors used a gray-body function to analyze a sample of 22 IRDCs and found that dust temperatures decrease significantly within those IRDCs, and that those decreased temperatures corresponded with areas of dense stellar dust, indicating possible massive prestellar core candidates.

This study is also similar to what we propose in that they performed some temperature mapping. This study is different in that they also looked at dust could density and possible prestellar core candiate areas. Our work will be focused on making the temperature maps. (Peretto, 2010).

3.3 Temperature as a third dimension in column-density mapping of dusty astrophysical structures associated with star formation by Marsh K. A., Whitworth A. P., and Lomax O.
This study produces resolution-enhanced image cubes of differential column density as a function of dust temperature and position using images of dust continuum emission at multiple wavelengths. (Marsh, 2015).

Again, this is similar to what we propose in that they performed some temperature mapping, but different that they also looked at dust could density. Our work is focused on the map making itself

4. PROPOSED WORK
We aim to create a temperature map of the galactic plane using the Herschel Hi-GAL dataset. Details on the data itself can be found in the Data section below. We plan on using pattern matching to match each data point to a corresponding black body radiation curve. The black body radiation curve will give us a peak wavelength, which can then be converted to a temperature value to be used for map generation. Below is an example of black body radiation curves (source: http://www.capgo.com/Resources/Temperature/NonContact/NonContact.html):



We will be focused on the lower curves that correspond to the very low-end temperatures shown on this graph.

4.1 Data

The portion of the higal data set that we will be using consists of 760 .fits files (152 per wavelength- 70um, 160um, 250um, 350um, and 500um). Each .fits file contains two sections: a header and data. The header includes many useful bits of information about the data, including coordinates of the data, the size of any given image (in pixels), and other attributes that are necessary to process and analyze the data. The data section contains an array of data points, each with an x and y coordinate, and an intensity value. With five sets, each pixel is essentially given a 'wavelength' attribute as well. It is this wavelength attribute that we will be using to determine a corresponding temperature.

This data contains information about the front 120 degrees of the galactic plane; from galactic longitude ~66, through the center of the galaxy, to galactic longitude ~290, and from galactic latitude +2 to galactic latitude -2. Essentially we are looking at the most active part of the Milky Way.

4.2 Subtasks / Milestones

4.2.1 Mosaic existing data

Using Montage to mosaic the data we will be able to consolidate our data into 5 larger files which will be easier to work with and is basically doing some data preprocessing for us. Various Montage modules also ensure that our data is well calibrated and background intensity levels are consistent. A mosaic of the data has the added benefit of allowing us to visualize our data which could alert us to potential patterns of interest or even data inconsistencies.

4.2.2 Method of pattern matching

We will need to derive a way of matching a set of data points to a black body radiation curve. Once we have the curve, we can translate that into a peak wavelength and it's corresponding temperature. We will have only 5 data points (one for each wavelength of light in our dataset) that we will need to match to a black body curve, so we will need to determine a reliable and accurate method for doing this.

4.2.3 Code for pattern matching

We will need to write code that will take our data as input and output a corresponding temperature for each data point based on our method of pattern matching determined above.

5. EVALUATION

We plan on cross-referencing our findings with those from other related scientific research papers. We will also use the most precise method possible to draw conclusions about our data, including known accurate formulas and acceptable-value thresholds. Similar research has been performed on data from a very small subset of the region of space that we will be analyzing, and that research will be very useful for checking the validity of our results.

6. PROJECT CHECKPOINT

6.1 Review of proposed work

We plan on extracting data from the Herschel Hi-GAL dataset in order to make a temperature map of the galactic plane. We want to match each data point to a corresponding black body radiation curve. The black body radiation curve will give us a peak wavelength, which can then be converted to a temperature value to be used for map generation. Our subtasks are to: mosaic the existing data, determine our method of pattern matching, and develop code to convert the data into their corresponding temperature values. Our final task will be to use the temperature values to create the temperature map.

6.2 Accomplishments so far

6.2.1 Mosaicked existing data

We have mosaicked the data using Caltech's Montage software for all 5 wavelengths.

6.2.2 Determined method of pattern matching

We are going to use SciPy's curve_fit function to match the data points (wavelengths and intensities) to a blackbody radiation curve. The curve_fit function will output a corresponding temperature value based on the data. The black body radiation function we will be using is:

$$E(\lambda, \mathrm{T}) = \frac{2hc^2}{\lambda^5} \cdot \frac{1}{e^{hc/\lambda kT} - 1}$$

Where h is Planck's constant, c is the speed of light, k is Boltzmann's constant, E(λ, T) is the intensity as a function of wavelength λ and temperature T. The intensity and wavelength values will be obtained from the data set and fed into the curve_fit function to generate a corresponding temperature.

6.2.3 Started writing code for the pattern matching

We have started writing the code for pattern matching using the curve_fit function as described above.

6.3 Key results, lessons, any changes

One result of mosaicking the data is that we found the 160 band contains one flawed image. The Montage package includes a module that we should be able to use to fix the data, however at the time of discovery the module was not working properly. We've been in touch with Montage's senior software engineer and he has made changes to the module and believes it to be working properly now.

We've also become aware of a potential hurdle in working with our data. The data has different resolutions for each the different wavelengths, making it more difficult to make sure we are comparing the same galactic coordinates across the dataset. We have come up with a few methods of dealing with this issue, and we are currently deciding which will be the best to use in our situation.

Another lesson learned is that we might not be able to use data points that don't contain a peak wavelength inside of our wavelength range. We are still working on this issue, and may be able to still fit the data using the SciPy curve_fit function, but it will come down to how accurate the results are. If needed, we may need to throw away data points that don't contain a peak wavelength.

6.4 Remaining tasks

- Fix the 160 micron mosaic
- Choose and implement method for dealing with the different resolutions to achieve galactic coordinate consistency across the dataset
- Finish the code for the pattern matching
- Test our method with small medium dataset first
- Generate the temperature map based on the temperature values obtained

7. REFERENCES

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