User Manual: B_{LOS} Mapping Code

Terminology

- B_{LOS}: Line-of-sight component of magnetic field
- ROI: Region of Interest
- RM: Rotation Measure
- Reference Point: Points representing "off positions"

1 Introduction

This code determines the line-of-sight component of magnetic fields (B_{LOS}) associated with molecular clouds using the technique described in Tahani et al. (2018).

1.1 Overview of Steps

The B_{LOS} Mapping method is conducted over 7 total steps, as detailed in Tahani et al. (2018).

Step 1: Preparation: The necessary output folders and sub-folders are created.

Step 2: Rotation Measure-Extinction Matching: (2a): The rotation measure points are read from the Taylor et al. (2009) catalog and matched to visual extinction values using a map of the region of interest. (2b): Optionally, the rotation measure points can be plotted over a map of the region of interest in order to get a sense of the rotation measure coverage.

Step 3: The reference points are chosen. These points represent "off positions" on the cloud, as defined in Tahani et al. (2018). (3a): First, candidate reference points are identified, and filtered for disqualifying features. (3b): Next, the remaining points are sorted between off positions and cloud envelope according to a stability heuristic, and to ensure even sampling of the cloud's surroundings. (3c): Optionally, the results of this stage may be plotted for information on the decision making process conducted by the script.

Step 4: The B_{LOS} directions and values are determined and calculated for the rotation measure points in the region of interest using the reference points found in step 3.

Steps 5 & 6: The B_{LOS} uncertainties that result from using different density (step 5) and temperature (step 6) values as input parameters to the chemical code are determined.

Step 7: The total uncertainty in B_{LOS} values is calculated (resulted from RM, RM_{off}, extinction values, and input parameters to the chemical code).

2 Installation and Configuration

2.1 Minimum Python Version

The minimum Python version is 3.6.1.

2.2 Quick Setup and Installation

Once Python has been installed, the rest of the code's dependencies may be quickly installed via running the Initialize.py script. A more detailed description of the code's dependencies may be found in the following sections.

2.3 Required Modules

The following packages must be installed:

- astropy
- adjustText
- matplotlib
- numpy
- pandas
- scipy
- requests

2.4 Obtaining the Data

In order for the analysis to be conducted on a given region, three pieces of data must be obtained.

Rotation Measure Catalog: A rotation measure catalog must be obtained and placed in the Data/RMCatalog directory, with the appropriate format as specified by the example in the file RMCatalogue-Header.csv. The catalog must cover the region or cloud you are interested in, or else there will be nothing to analyze.

Region Fits File: A fits file, either Extinction or Hydrogen Column Density, which has information for the region or cloud you are interested in. Place these files inside the Data directory.

Cloud Parameters: A .ini configuration file, which specifies information about the region of interest, including its distance from Earth, its chemical code parameters, the rotation measure catalog's area of coverage, and image subsections of the fits file. This file ties all the data together. Place these files in Data/CloudParameters. Examples can be seen inside that directory. A template is automatically generated as part of initialization.

The initialization script downloads the Taylor et al. (2009) catalog, as well as the Hydrogen Column Density fits files for a large number of regions. Default clouds with their parameters are provided in the Data directory under the Cloud Parameters directory.

2.5 Configuration

Configuration files control the operation of the scripts, and are the primary means by which user input or decision-making is taken into account before the analysis is conducted. They are as follows.

configStartSettings: This file contains a list of parameters involving human judgment or stylistic choices. In particular, parameters related to: Which cloud to analyze, what points to quality/disqualify as potential reference points, and plotting and logging styles are set here. This is the primary configuration file to be adjusted before each analysis.

configDirectoryAndNames: This file contains the names of directories and files utilized and produced by the scripts as part of their analysis.

configConstants: This file contains the values of constants utilized in the calculations performed by the scripts. It is recommended that you verify that they are correct before proceeding.

3 Conducting the analysis

3.1 Setting Up

Once the files have been installed and configured, we can begin to prepare for conducting the analysis.

1. Run Initialize.py, if it has not already been run.
2. Check that the constants defined in the 'configConstants.ini' file are correct.
3. Check that the directory file naming scheme is to your satisfaction in the 'configDirectoryAndNames.ini' file.
4. Check that the various starting settings and judgment parameters are to your satisfaction in 'configStartSettings.ini'.

The following will need to be done for every given region of interest.

- Check that your region of interest is correctly defined in its 'Region.ini' file (located in Data/CloudParameters).
  - If your region of interest is not defined, create a new region.ini data file. Then place it in the Data/CloudParameters folder.
  - An example template has been placed in the folder for you. It is called '0 - template.ini'

3.2 Running the analysis

Each step of the analysis corresponds to the scripts numbered accordingly, and they are meant to be run one at a time in the order indicated by their name. Run-all scripts are further provided, which automate the process of running each of the scripts in order.
Before conducting the analysis, user input is obtained via the configuration settings of configStartSettings.ini. Please review these settings before conducting the analysis. Different quick run scripts are provided Further details on the run-all scripts are as follows:

Run.py: Standard Run-all script which runs each of the seven steps of the analysis in sequence, utilizing the default configuration files. It can be run directly, or through the terminal via: python Run.py

RunCloud.py: Meant to be run through the terminal only, and clouds to be analyzed are specified afterwards. Any number of clouds can be specified, so long as the data is available, separated by a space. Ex. python RunCloud.py Oriona Orionb California Taurus

RunConfigCloud.py: In the event the user wishes to run the analysis on an alternatively specified starting configuration file, they can do so utilizing this script, by specifying the starting configuration file first in the terminal. It must be of the exact same format as the regular starting settings configuration file. Once it finishes, it will rename the output folder with the config file's name, to keep track of what information the output folder contains. Ex. python RunParamCloud.py altStartConfig.ini Oriona Orionb Taurus California Perseus

Each step of the analysis will produce output either in the form of a figure or a table of data. Output will be saved to a folder with the same name as the region of interest. It is strongly recommended that the output be critically examined after each analysis, and starting configuration parameters adjusted accordingly.

3.3 A note on Step 3

Step 3 requires the most input from the starting configuration file, as this is the step in which reference points are chosen. Reference points are meant to sample "off positions" around the cloud in order to estimate the Galactic contribution to the observed rotation measure.

The primary criterion for determining reference points is visual extinction. The program will list all points with extinction less than a specified threshold value, numbered in order of increasing extinction, as "potential reference points". Depending on the distance (and location) of the cloud,

this threshold value should be modified. The map of these points should be reviewed to ensure that all sides of the cloud are sampled properly by their selected reference points.

The program will then recommend an optimal number of points to take as reference points using a trend stability analysis. Afterwards, it will ensure that sufficient points have been sampled from around the cloud. The reference points chosen after these two steps will go on to form the reference values for the off positions.

The program will also flag and remove points that are too close to the cloud, and points that have odd anomalous rotation measure values. The program can also flag and remove points which are too far from the cloud to be considered to be sampling its background. Points with these properties may require additional consideration from the user as to whether they are suitable reference points. Figures displaying the location of these points, and their relevant data, are produced for user review, in case parameters need to be changed for the next analysis.

References

Tahani, M., Plume, R., Brown, J. C., & Kainulainen, J. 2018, A&A, 614, A100

Taylor, A. R., Stil, J. M., & Sunstrum, C. 2009, ApJ, 702, 1230