FRINGE RATE MAPPING OF A 1720MHz MASER

FINAL PROJECT REPORT

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ABSTRACT

In the field of radio astronomy, the study of Magnified Amplitude by Stimulated Emission Radiation (MASERS) provides lots of information that relying on visibility would otherwise miss (Becker 1995). To better understand MASERS this project implements the method of fringe rate mapping to locate the MASER’s celestial coordinate. Python scripting made analyzing the large chunks of MASER detection data from the radio telescopes more manageable. In the end not only were the celestial coordinates for a 1720MHz MASER gathered but also a python script was established that is both reusable for other studies and allows for this one to be recreated.

INTRODUCTION

Astronomy has long fascinated humans, though the majority of the sky is dark leaving us nothing to see. Compared to visual astronomy, radio astronomy is a relatively new field, which has allowed us to understand more of the universe that the visual spectrum of light cannot detect (Becker 1995). Within radio astronomy the study of Magnified Amplitude by Stimulated Emission Radiation (MASER) can tell us about the composition of what is in deep space (Becker 1995). These MASERS are detected by a collection of radio frequencies gathered from an array of antennas. Analysis of the data collected from these arrays confirms MASER detections. A vidal part of this confirmation is a statement of where the MASER is in the sky as “seen” from earth. This project addresses that by posing the research question: How do we confirm the location of a MASER in the sky?

This study will employ the method of Fringe Rate Mapping (FRM), executed by the use of python, to obtain project results. FRM requires a basic understanding of how MASERS work starting with their detection from the antenna arrays.

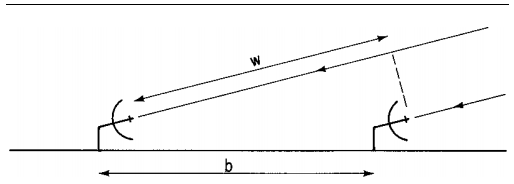
The antennas are spaced at different distances from each other, allowing them to detect only the measurements of the wavelengths that fit between a pair and discriminate against background radiation (Ryle 1946). Depending on the separation of the antennas the detected frequencies create a wavelike fringe pattern (Briggs 1999). The antennas are set to pick up a frequency of interest, which is then passed to a detector, and that data creates a catalogue of the MASER characteristics (Ryle 1946). From such data collected this study works off the detected Amplitude, Phase and Frequency to confirm detection. It is expected that by comparing enough detections at a certain spot, or phase, in the fringe pattern, the celestial coordinates of the source can be confirmed. 

Figure 1. As the earth rotates the apparent separation of the Antennas (noted by the dashed lines) changes, reaching a max separation of b (Briggs 1999).

FRM takes into consideration the movement of the earth and uses this to change the separation distance of the antennas from a celestial perspective (see Figure 1.), whish then changes the amplitude of the fringe pattern (Briggs 1999). For instance when the MASER is just above the horizon the separation of the antennas appears very small, once the earth rotates so that the MASER is directly above the array, the separation of the antennas appears as it’s real distance. The former results in a wide, low amplitude fringe pattern while the later has a narrow, large amplitude fringe pattern (Note: these amplitudes are not the ones listed in the data collected from the antenna which are the amplitude of the radio frequencies in the sky\*).

This study makes use of the varying fringe sizes from a pair of antennas separated by 430m (as measured on earth). The antennas multiple fringe sizes were used to approximate the phase (on the fringe pattern) the MASER detection was made. This is done by eliminating phase points on the fringe patterns from each detection period that don’t align with each other. The hypothesis of this study is that by using FRM implemented by python scripts, the celestial coordinates of a MASER can be obtained.

METHODS

Data for this project is raw data collected over varying time intervals from the antenna array at the Westerbork Synthesis Radio Telescope (WSRT). The data is restricted to a frequency of 1720 MHz, designed to confirm radio emissions from a known MASER. A program called AIPS is used to read in the data from the telescope, the manipulation of the data in this program to get it in a readable state for a python script is beyond the scope of this project. Data analysis for this project is ran by commands found in the project’s main directory README.md page and all code is available on github at <https://github.com/sabdesoto/Sab_Final_Project> .

This project starts with importing the data into python using the pandas library. This alone requires a ‘while’ loop to separate out the 30-minute observation times which each have a chunk of data that needs to be analyzed separately and then compared at the end. Each chunk of data is then assigned to a list, so that each preceding function need only loop through each chunk in the list to create outputs for each observation period.

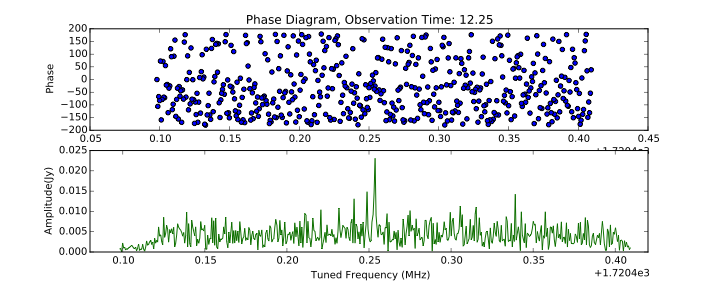
Next phase diagrams for each observation period are created and saved. These diagrams are composed of two subplots stacked on top of each other as they share the same x-axes, frequency (see Figure 2.). They are designed to help visualize the connection between the characteristics of the MASER and help to understand why each of the next analysis steps is done in the order it is. The bottom half of the diagram plots the amplitude vs. the frequency which makes it easy to note a signal from the MASER is present. This signal appears as a large spike in the plot, compared to the many smaller peaks, known as noise surrounding it. If we follow this spike to the top half of the diagram where phase is plotted vs. frequency, there is usually a clump of phase points above the spike that represent the location of the MASER along a fringe pattern. The next step is to then pinpoint what phase the signal was detected at.

Figure 2.) Phase Diagram of the last 30minute observation period. The amplitude spike just to over the 0.25 aligns with a cluster of phase points implying a MASER detection.

To do this a threshold value of amplitude is determined to define any value above it as a signal amplitude. The amplitude data is passed through a loop, which returns a list for each observation period of these specified amplitudes. Next these values are put into a data table that can be used to parse out the phases of the observation period that correspond to larger amplitude and thus a signal detection. Each 30-minute observation time may not return the same amount of signal phases, which is disregarded by taking the average of the phases to get one value for each period. The average phases are saved to a data table along with an additional column that divides them by 360degrees thereby converting them to a point that can be located on the corresponding fringe pattern for the time of day the observation period was. As of now this concludes the analysis done in the python script however to expand on this the fringe pattern itself could be analyzed by python. The start of this work is included in the ipython notebooks in the Bin folder and an overview of this method is below.

To better visualize the MASER location the fringe size for each observation time is also needed. In order to obtain this a bit of calculation regarding the antenna separation, time of day and tuned frequency is needed, the details of which will not be discussed here but can be found with notation in the work notebook and excel data file (in New\_data folder). The fringe pattern is plotted as a sin wave with different amplitudes depending on which detection time it was from and the separation of the antennas at that time.

By matching up each average phase on its’ corresponding fringe size, none-overlapping values can be eliminated, pinpointing where the MASER must be located on the fringe pattern at anytime of day.

RESULTS

The results of this FRM project are two-fold. First there are results created and saved as files from running the python script. Each function within the python script results in an outcome saved with in the project directory. For the load\_data function each chunk of antenna data, separated by observation period, was munged to make future analysis easier. The script saves these chunks of data, individually with in the Data/Analyzed\_data folder. Next the make\_phase\_diagrams functions ploted the phase diagrams for each observation period and separately saved them in the Results folder. Finally the signal\_phase function produces a table of the average signal phase, and that phase converted to a location (on a fringe patter) for each observation period. After running the script this table is also found in the results folder of the project directory.

Secondly, because python scripting was used to carry out the FRM, a step by step record of how to obtain this location is available for recreation. This script is written so that it can be used to parse through any MASER data sets with minimal edits to return a fringe pattern location. Furthermore, the script is modularized into functions that can be referred to for many coding tasks such as: data munging, requiring points over a threshold, multi-panel plotting, separating headed data, ect. .

DISCUSION

The distinct spike in all the phase diagrams makes it clear that there was indeed a MASER detected at the 1720 MHz frequency. For future analysis of the reliability of this detection a statistical analysis could be done for a better fitting threshold value. Next the average phase values with in a range of positive an negative values accurately represents the change in location on a fringe, where negative implies it is located on the downward sloping part of the fringe pattern and the opposite for a positive value. However, the precision of these values is unknown from this study and the reliability of these locations would improve with the inclusion of error bars.

Both the python script and the results it produced may be used as a stepping-stone in future research. Although the product of this work will only visualize one point in the sky, it conveys information of our universe that would otherwise be unknown. Additionally it may be used to inspire continuation of data collection in all wavelengths thus working towards the goal of producing the most comprehensive catalogue of the universe.

REFERENCES

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Ryle, M., & Vonberg, D, D., 1946, Nature, 158

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\*Notice from the phase diagrams that this amplitude is not everywhere other than the MASER detection spike, as would be the case if space were truly empty. Instead these small amplitude fluctuations imply there is background radiation through out the universe. This accidently discover won the Nobel Prize in Physics in 1978 (Penzias 1965).

\*\*The fringe data was created using excel and as noted in the methods of this report the extensive calculations are omitted from this script, but would be useful as a script of there own.