**Final Project Report**

Title: Fringe Rate Mapping of a 1720MHz Maser

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 recreatable.

-there are MASERS and data collected for their detection

-python script created to do fringe-rate mapping

-mapping returns coordinate of MASER location for further research

Introduction:

-Why study space

-how to study space: MASERS?

-What are MASERS

-RESEARCH QUESTION: how to we locate them, fringe rate mapping

-HYPOTHESIS: get coordinates by fringe rate mapping

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 their detection. This confirmation is however lacking a statement of where the MASER is in the sky as “seen” on 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.

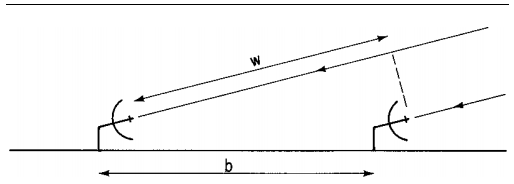
The antennas are spaced at different distances from each other, allowing them to discriminate against background radiation and detect measurements of only the wavelengths that fit between a pair (Ryle 1946). Depending on the separation of the antennas the detected frequencies create a wavelike fringe 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 certain spots 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.) (Briggs 1999). For instance at 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.

This study makes use of the fringe sizes from this separation to zero in on the phase the detection was made by eliminating possibilities from each detection period that don’t match up. The hypothesis of this study is that by using FRM implemented by python scripts, the celestial coordinates of a MASER can be obtain.

Methods:

-collect data and organize using AIPS

-load data separating into chunks by observation periods(op)

-create phase diagram for each op and store in file \*include example pic

-useful to visualize/define signal

-get signal phase from data for each op

-get ampl > threshold set (how to set?)

-get phases for these signal ampl

-average these phases for one value

-get fringe size for each op

-use constant 1720 freq

-calculate antenna separation as a function of time

-make a table of op, average phase, fringe size

-GET COORDINATE?

METHODS

Data for this project is raw data collected over varying time intervals from the Westerbork Synthesis Radio Telescope (WSRT). The data is restricted to a frequency of 1720 MHz, designed to confirm radio emissions from known MASERS. 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. 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 a table, **so that when completely each step of analysis the loop just runs through each table?**

Next phase diagrams for each observation period are created and saved to separate file. These diagrams are composed of two subplots stacked ontop of eachother as they share the same x-axes, frequency. They are designed to help visualize the connection between the data and help to understand why each of the next analysis steps is done in the order it is. The bottom half of the diagrams 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 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 signal. The next step is to then pinpoint what phase the signal was detected at.

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 return a list for each observation period of these specified amplitudes. Next these values are put into a data table that can be used to signal 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 detection times and average phases are saved to a data table.

The fringe size for each observation time is also needed to decipher the MASER location. 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. Once the fringe size for each 30-minutes it is included in the signal detection table.

By matching up each average phase in it’s known fringe size, none-overlapping values can be eliminated, pinpointing one option for MASER detection on the fringe. **And then…?**

Results:

The results of this fringe mapping project are two-fold. First, the desired coordinates of the MASER are **obtained….**

Secondly, because python scripting was used to carry out the fringe mapping a step by step record of how to obtain these coordinates 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 celestial coordinate. Furthermore, functions from the script can be separated or referred to for any data munging, requiring points over a threshold, multi-panel plotting, separating headed data, creating new dataframes, ect.

-Where is the coordinate

-how sure about this being a MASER (amp. Threshold to be a signal)?

-methods can be repeated for any MASER data set

Discussion:

-CONCLUSION found coordinate by fringe rate mapping

-improvements on methods of finding

-what this could be used for

-how precise is this

OUTCOMES

The final product of this project will be the coordinates of MASER(s) responsible for the radio emissions over the chosen data collection time frame. These points will not only be an accurate condensed interpretation of the many detections recorded but are useful by noting of the location of that which is invisible. Many important discoveries of the universe from its matter composition to its large-scale structure have come from comparing data across the electromagnetic radiation spectra not just that in the visible part (Becker 1995). Although the product of this work will only visualize a point of the sky, it can be used with other sky maps to analyze larger areas. Additionally it should inspire its viewers to continue data collection in all wavelengths working towards the goal of producing the most comprehensive catalogue of the universe possible.

References:

REFERENCES

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