Analysis of G9.62+0.19 Methanol Maser Spectra

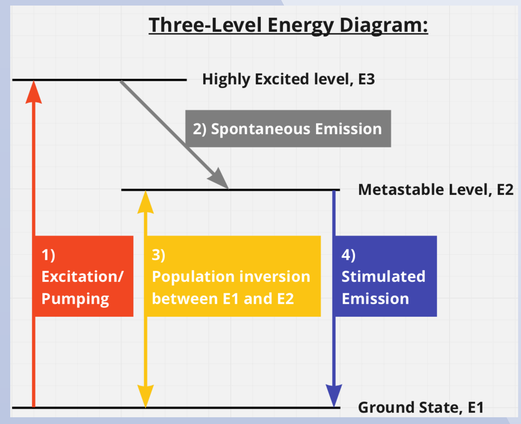
Ander Castelltort Schnaas, AUT

17972849

07/11/2020

INTRODUCTION

The radiation from an astrophysical maser is produced by population inversion of the pertinent transitions and stimulated emission. Identically coherent photons are emitted and have an exponential gain along a path through the gain medium that amplifies the centre of the line feature in the spectra much more than its edges. The resulting narrow spectral line shape is characteristic of the emission spectrum of an astrophysical maser.



A time sequence of observations revealed changes in both frequency and magnitude of these spectral emission peaks.

MATLAB and its Curve Fitting Tool were used to process the maser's data and fit Gaussian curves to model the main features. The centre points of the prominent peaks corresponding to the methanol (CH_3OH) transition were determined and extracted to establish a relative point of reference between the shifted frequencies of each observation.

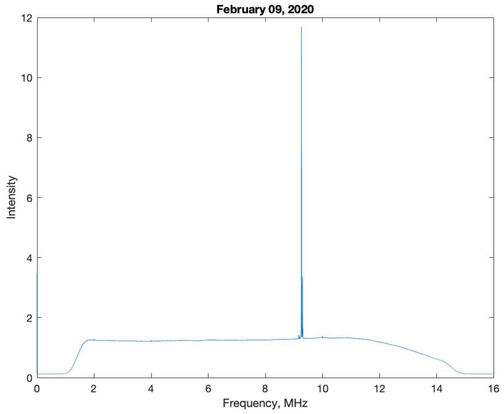
A frequency vs time plot, referred to as a velocity plot, was then constructed from which the change in frequency information was used to substitute into the Doppler equation and prove that the Earth is truly in motion. Thus, providing a different perspective with independent evidence that supports the controversial views of Galileo Galilei in the 17th Century.

OBJECTIVE

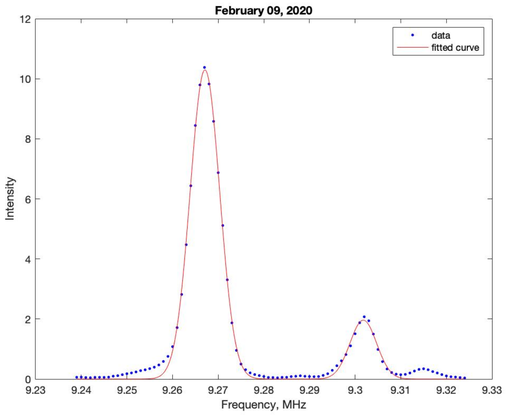
The principal objective of this research project was to conduct a time sequence of observations of the methanol maser G9.62+0.19 and obtain data such that the underlying mechanism which influences said frequency shifts can be shown to be the relative motion of the Earth by the Doppler Effect.

METHOD

1. Conduct observations using the IRASR 30m Radio Telescope based in Warkworth.
2. Implement a code to plot the methanol maser's data on MATLAB.



3. Fit Gaussian curves to the processed data to model the main features of the emission spectrum.

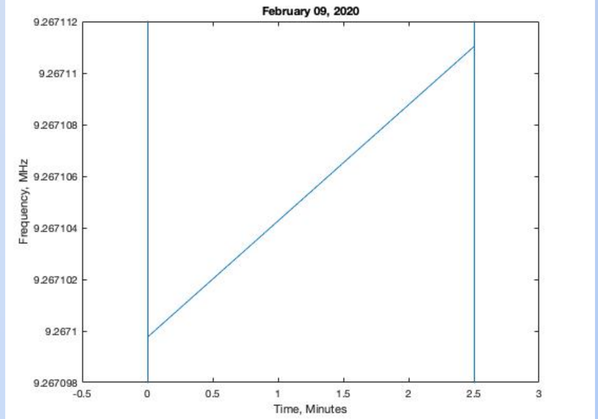


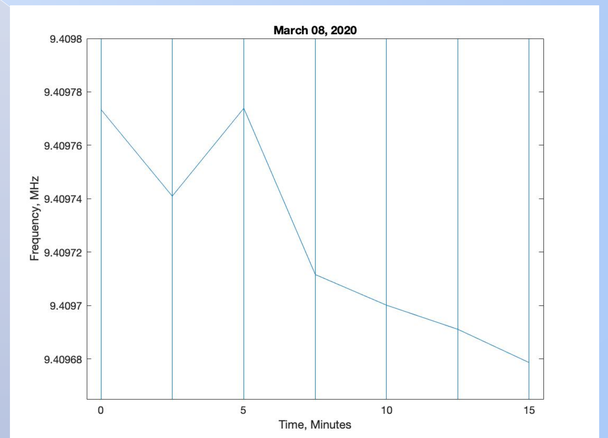
4. Determine and extract centroid points of all peak Gaussian curves and plot them on a velocity plot.
5. Take the difference in frequencies on velocity plots and substitute them accordingly into the Doppler equation to derive the relative motion of the Earth (v_{obs}).

$$f' = \frac{(c + v_{obs})}{(c - v_s)} \cdot f$$

PROCESSED DATA

The following plots show the change in frequency over time of the observed methanol maser G9.62+0.19. Each point is a centroid of a Gaussian curve corresponding to an emission spectrum of a sample from an observation.





Such centroid points have a quantisation error that stems from the IRASR's 30m telescope receiving system metrics and Analogue to Digital Converter (ADC). Consequently, errors bars are much greater in magnitude than the difference in frequency itself and outliers may arise that don't fit the expected behaviour of the frequency shift (see March 08, 2020 velocity plot).

Increasing the sampling rate of the receiver will improve the amount of signal that is sampled and accounted for and hence minimising systematic error. The data used in this project was obtained at a sampling rate of 1 KHz, however, further observations would be conducted at 0.1 KHz to achieve a more accurate value for the centroid point of the Gaussian model.

SIGNIFICANT RESULTS

- Results from all individual velocity plots (except February 09, 2020) show a degressive shift in frequency over a period of 15-20 minutes.
- The overall frequency shift from the first observation to the last (February 09 to March 08, 2020) is incremental and suggests that the Earth must have been in motion towards G9.62+0.19 during this time by the Doppler Effect.
- The magnitude of the change in frequency over the period of all observations correlates well with the hypothesis that it is caused by the relative motion of the Earth, since turbulence in the methanol maser, its own relative motion or other potential mechanisms wouldn't be sufficient to produce such shifts.

The Catholic Church at the time of Galileo Galilei adopted the notion that the Earth was at the centre of the Universe, and therefore, stood still. Galileo's observations of the planets and experiments in Classical Mechanics led him to conclude that the Earth and other celestial bodies moved in orbit around the Sun.

"Eppur si muove." – Galileo Galilei, 1633.

KEY REFERENCES

Elitzur, M. (n.d.). *Masers, Interstellar and Circumstellar, Theory*. NASA/IPAC Extragalactic Database. Retrieved October 22, 2020, from https://ned.ipac.caltech.edu/level5/ESSAYS/Elitzur/elitzur.html

MathWorks. (n.d.). *Gaussian Models*. Retrieved October 4, 2020, from https://au.mathworks.com/help/curvefit/gaussian.html

Wikipedia contributors. (2020, October 10). *Astrophysical maser*. Wikipedia. https://en.wikipedia.org/wiki/Astrophysical_maser

Pestalozzi, M. R., Minier, V., & Booth, R. S. (2005). *A General Catalogue of 6.7GHz Methanol Masers* (J/A+A/432/737) [Dataset]. EDP Sciences. https://doi.org/10.1051/0004-6361:20035855

ACKNOWLEDGEMENTS

This project was supervised by Tim Natusch.

Thank you to Tim Natusch for conducting the project's observations and data collection, as well as the mentoring, it is much appreciated.

Thank you to Sergei Gulyaev and Hannah Mae Wetzel for the advice and support.