Final WriteUp

Andranik Mkrtchyan

May 11, 2019

1 Determining Protostar Mass

1.1 Introduction

We are attempting to find the dynamical mass of multiple protostars with the assistance of Atacama Large Millimeter Array's (ALMA) archive data. Using ALMA's public archive data, it is possible to create moment maps and position-velocity (P-V) diagrams of observed protostars in order to determine source structure and dynamics. Observational data for protostars such as L1527 and BHR71 are available on ALMA in FITS file format and can be processed through a program called ADMIT (ALMA Data Mining Toolkit). Using this code and specifically coding parameters and conditions for each protostar, it is possible to create high order data products to understand large data files more compactly. We describe how the data products can be analyzed to determine the dynamical mass of the protostar.

1.2 Methods and Equations

The objective of this research is to find the mass of protostellar objects due to the nature of them being difficult to measure and therefore few are known. By using ALMA data, each object has its frequency values specifically written because the program cannot automatically figure out where the disk of the object is where researcher has to program it. The importance of the disk is to know the Keplerian velocity of the molecules while using the Kepler and free-fall formulae to find the mass of the protostar.

$$v^2 = \frac{GM}{r} \tag{1}$$

Due to the nature of how this project is being done and how the files are given to us, we need to convert the frequency units given into wavelength so that we can use the Doppler Shift formula to find the velocity.

$$\frac{\lambda - \lambda_0}{\lambda_0} = \frac{v}{c} \tag{2}$$

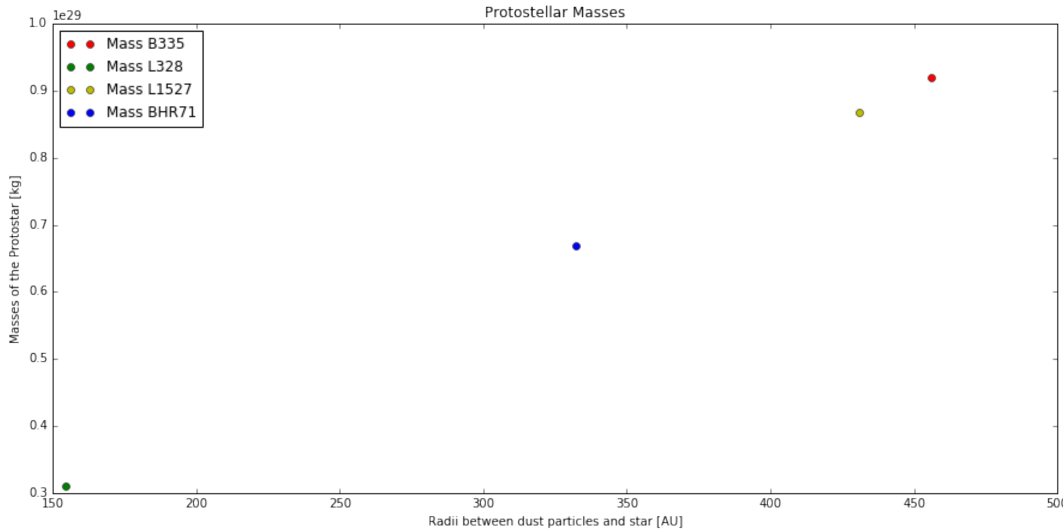

Figure 1: Protostar Masses of 4 Objects

1.3 Conclusion

After plotting our results, we can see that the points plotted are linear enough that we can determine that the radius points determined are precise but not necessarily accurate. Estimated values of protostar masses at the Class 0-I stage is somewhere around 0.1 M_{Sun} to 0.2 M_{Sun} where the values we received are around a factor of ten off from what would be the estimated value.

We can elaborate further on this by saying that our error may be where we determined our disk radius to be or how python decided to do the math involving such large numbers for the frequency where we had to convert it into wavelengths.

2 Differential Equation

2.1 Introduction 2

I used a simplistic Euler equation along with the base code of the zombie assignment I have used in class have set up the code so that it uses the basis of having 1 percent of the S value while having other intial values changed around.

2.2 Equations

The equations are typical Euler equations that don't have any significance in terms of specific equations that represent something in science. The equations that I used are:

$$v' = 3 + (3 + 4t - w)^3 \tag{3}$$

$$w' = 4 + (2 + 3t - w)^4 \tag{4}$$

$$x' = 5 + (1 + 2t - w)^5 \tag{5}$$

These equations each represent a function that uses t time to solve for each numerical method for ODEs. They are also supposed to have linear solutions but the graph that was produced does not necessarily show that.

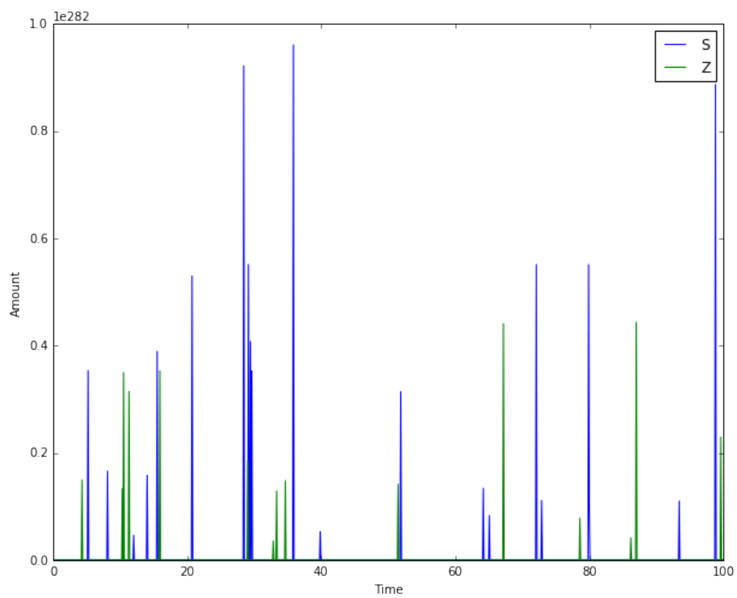

Figure 2: Differential Equation

2.3 Conclusion 2

The sample Euler equation that I used took inspiration from Langtangen's code with respect to the zombie code from Munz et. al to produce the results in the equations section. The actual graphs have sporadic peaks which I am unable to explain as I do not know the equations well enough to answer

References

[1] A. Gusdorf, D. Riquelme, S. Anderl, J. Eislöffel, C. Codella, A. I. Gómez-Ruiz, U. U. Graf, L. E. Kristensen, S. Leurini, B. Parise, M. A. Requena-Torres, O. Ricken, and R. Güsten. Impacts of pure shocks in the BHR71 bipolar outflow. , 575:A98, March 2015.

[2] A. Isella and A. Natta. The shape of the inner rim in proto-planetary disks. , 438:899–907, August 2005.

[3] H. P. Langtangen. ForwardEuler func.py. September 2014.

[4] C. W. Lee, G. Kim, P. C. Myers, M. Saito, S. Kim, W. Kwon, A.-R. Lyo, A. Soam, and M.-R. Kim. High-resolution ALMA Study of the Proto-brown-dwarf Candidate L328-IRS. , 865:131, October 2018.

[5] Philip Munz, Ioan Hudea, Joe Imad, and Robert J Smith. When zombies attack!: mathematical modelling of an outbreak of zombie infection. pages 133–150, 01 2009.

[6] N. Ohashi, K. Saigo, Y. Aso, Y. Aikawa, S. Koyamatsu, M. N. Machida, M. Saito, S. Z. Takahashi, S. Takakuwa, K. Tomida, K. Tomisaka, and H.-W. Yen. Formation of a Keplerian Disk in the Infalling Envelope around L1527 IRS: Transformation from Infalling Motions to Kepler Motions. , 796:131, December 2014.

[7] J. J. Tobin, L. Hartmann, H.-F. Chiang, D. J. Wilner, L. W. Looney, L. Loinard, N. Calvet, and P. D'Alessio. A ˜0.2-solar-mass protostar with a Keplerian disk in the very young L1527 IRS system. , 492:83–85, December 2012.

[8] A. M. Villa, M. A. Trinidad, E. de la Fuente, and T. Rodríguez-Esnard. Proper motions of L1551 IRS 5 binary system using 7 mm VLA observations. , 53:525–531, October 2017.

[9] H.-W. Yen, B. Zhao, P. M. Koch, R. Krasnopolsky, Z.-Y. Li, N. Ohashi, and S. Takakuwa. Constraint on ion-neutral drift velocity in the Class 0 protostar B335 from ALMA observations. , 615:A58, July 2018.