Name:_____ Collaborators: _____ ASTR51 S2023

Measuring the Mass of Uranus: Analysis

"*It turns out to be the new Planet, which, a decade and a half later, will be known first as the Georgian, and then as Herschel, after its official Discoverer, and more lately as Uranus.*" *- Thomas Pynchon (Mason & Dixon)*

1 Objectives

- Perform astrometric CCD measurements of Uranus and its moons.
- Use those data to determine the orbital parameters of Uranus' main moons.
- Use these parameters and Newton's law of gravity to estimate the mass of Uranus.

2 Data

To work around poor Spring observing conditions, you will be provided with an archive of CCD FITS images taken with the remote Slooh telescopes located in Chile and the Canary Islands. You will use the program DS9 (found on the Mac laptops) to measure and log the RA/Dec positions of Uranus and and its visible moons for each night and time of observation.

3 Analysis

1) Working in groups of 2-3 , first duplicate the *Uranus Template* sheet on the class Q&A journal and rename it with your group name. Next input RA/Dec position for Uranus and its moons into the green cells. You are welcome to make an initial scatter plot in google sheets, but we will copy the data to Logger Pro for fitting.

2) Disentangling the orbits of the different moons can be a little bit tricky but with high quality data taken over short time intervals, you should be able to distinguish the two orbits. This will be an iterative process so be patient.

3) Once you have input all of your data points, copy the data to Logger Pro and consider how to best determine the amplitude and period of your moon orbits. ***Make sure to estimate the fractional uncertainty in your fit parameters.***

4) After you have come up with good fits for all of your moons, use Kepler's third law (below) to compute the mass of Uranus independently using each of the visible moons:

$$\frac{P^2}{a^3} = \frac{4\pi^2}{G(M+m)} \approx \frac{4\pi^2}{GM} = constant$$

where M is the mass of Uranus, m is the mass of the moons, and G is the gravitational constant. You will need to estimate (or look up) the distance to Uranus to convert your angular separations into physical ones. You can use the facts that Uranus has a 19.2 AU semi-major axis, a mean angular separation from the sun of 90 degrees (Jan 26, 2021) and the law of cosines (wolfram.com) to compute its distance from us. This number can be checked online at http://theskylive.com/uranus-info.

5) In a short write-up present a properly labeled moon orbit scatter plot, show your calculations and discuss how consistent your different mass measurements were from moon to moon. Also, discuss whether your measured value was consistent with the known mass of Uranus, within your uncertainties. Finally, discuss any potential systematic errors that may have effected your results and your mass calculations.