Introductions and Descriptions

The Uranus ring system has been one of the most interesting yet unknown aspects of our solar system. Studying the ring systems will eventually help us to understand many other interesting phenomena.We study these systems for three key reasons. First, they provide a wealth of information about the history and ongoing evolution of the planetary systems of which they are a part. Second, they are dynamical analogues for protoplanetary disks, exhibiting many of the same processes, but much easier for us to observe. Third, they have many mysterious and unexpected properties, which make them worthy of study in their own right (Showalter 2020). Uranus has 13 different distinct rings with different properties. Uranus has two sets of rings. The inner system of nine rings consists mostly of narrow, dark grey rings. There are two outer rings: the innermost one is a dusty ring. In order of increasing distance from the planet, the rings are called Zeta, 6, 5, 4, Alpha, Beta, Eta, Gamma, Delta, Lambda, Epsilon, Nu, and Mu. With the Epsilon ring being the most physically visible ring, and the Delta ring being the least eccentric (Showalter 2020). As studied in (Molter 2019) previous research it is important and useful to identify these rings and pinpoint their location. So a radial profile would be totally desirable. Hence so far my work addresses a generic way to perform such an operation on all the images taken from the planet Uranus and analyze them to obtain some useful information. In action, the physical limitations will oppose some obstacles in our way. We might as well not be able to get the faintest rings or even capture the closely clustered rings as one ring.
The very final goal of this research is to get accurate brightness measurements of each ring, eventually as a function of phase angle, which tells us about the surface roughness. I see a prospect of 1 more year to complete this research and potentially publish a first author paper.
As demonstrated in (Molter 2019) we also are able to produce Azimuthal ring profiles, which as well could produce useful results for future analysis. Same as the ring profiles, this can also be generalized for all the Keck observatory's data taken from Uranus.
The data is taken of Keck observatory (NIRC2) in Hawaii. In this Description, we use both H (centered on 1.65 um), and K-band (Centered on 2.2 um) for observations of Uranus' rings. With H-band data we generally get fine, reliable data, but the K-band has its very own advantages. At this wavelength, sunlight is absorbed by methane and hydrogen gas in Uranus' atmosphere. This greatly reduces the scattered light from the planet. This phenomenon permits ring material to be traced very close to the planet (de Pater et al. 2006). As you will see, much information is contained in the K-band that is not in the H-band and visa versa. Our goal is to publish a first-author research paper.

Keywords: Aperture Photometry — K-band — H-band — astronomy — Annulus — Uranus' Ring System — Planet — Ring — Flux — Azimuthal Angle — Opening Angle — Rotation Angle — Calibration — Keck Observatory — Epsilon Ring — Delta Ring — Fits file

1. Progress and My Tasks

Over the course of this project, I had many tasks such as aperture photometry, Fits data masking, plotting many ring and azimuthal profile graphs, fitting some of the ring profiles with a Gaussian function, processing images with SAOImageDS9, data analysis, and etc.
So far, my purpose is to provide a generic operation for all the images taken of Uranus by the Keck Observatory. As input we need appropriate required initial parameters such as masking boundaries and 3 points on the Uranus circumference (or equivalently the center of planet on the image). A output we can identify a precise location of up to at least 5 and at max 8 rings of Uranus' ring system! As for my test files, I have tested many different fits files all calibrated and in both h, and k bands. The result shows pinpointed location of each ring. The rings are in the range of 40650 km to 62900 km from the center of the Uranus. These picked rings could be one or multiple rings (multiple rings clustered as on ring) captured from the 13 known rings of the Uranus. The general method in acquiring these information is Aperture Photometry, in which we start with the smallest possible annulus centered at the center of planet on the image, with the same opening and rotation angle. Then increase the radius of annulus gradually to get the largest possible annulus in the image. This yields the radius profile, which is the graph of flux vs distance from the center of planet in kilometers. As a bonus it is also possible to generate the graph of flux vs azimuthal angle for an image given you provide the center of the planet or equivalently three points on circumference of the Uranus.
We also did some masking techniques on the Fits image(a triangular mask!). This type of masking have proved to be extremely effective to fight off the scattered light from the planet. Below, you can see a part of the figures that could describe the process so far. Please refer to fig.2, fig1 and fig.3

2. What to Expect This Semester

In this new semester, our goal is to focus on continuing the paper drafting and completing much more research technicalities such as more line fitting, interpreting the data and plots, and analyzing the generated ring profiles. In particular, There are two tasks that We are planning to do. First off we have to extract each ring's flux by assuming that each ring is infinitely thin and then treat and model that ring as a Dirac delta function and a point spread function (PSF), and then subtract that from the initial ring profiles. This is required to be done on all the detected rings. The same technique was used by (de Pater, 2006) and (Molter, 2019).
Then after that, we should convert our Apperture-sum units (vertical axis of ring profile) from the detector-based unit to a real physical unit. The next most important goal (perhaps we can even call it the very final goal of the research) is to apply this methodology that I have developed so far to a study of ring properties as a function of phase angle

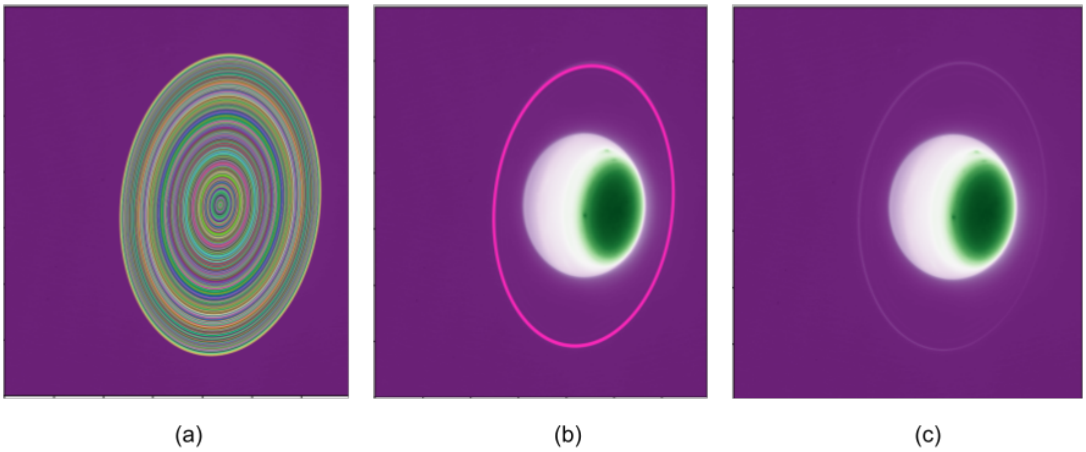

Figure 1: How the Algorithm works:
(a): Creating all the possible specified annuli
(b): the specific annulus of interest which in this case is the Epsilon ring
(c): The original data

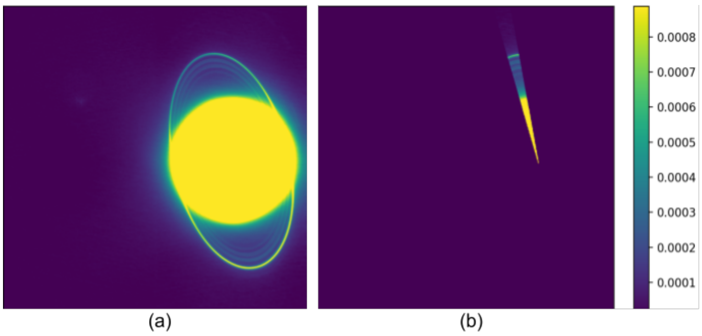

Figure 2: The masking method: The 2015 data is used here to demonstrate how the masking was done in this research. The color bar only indicates the relative flux on the image.
(a): Unmasked
(b): Masked

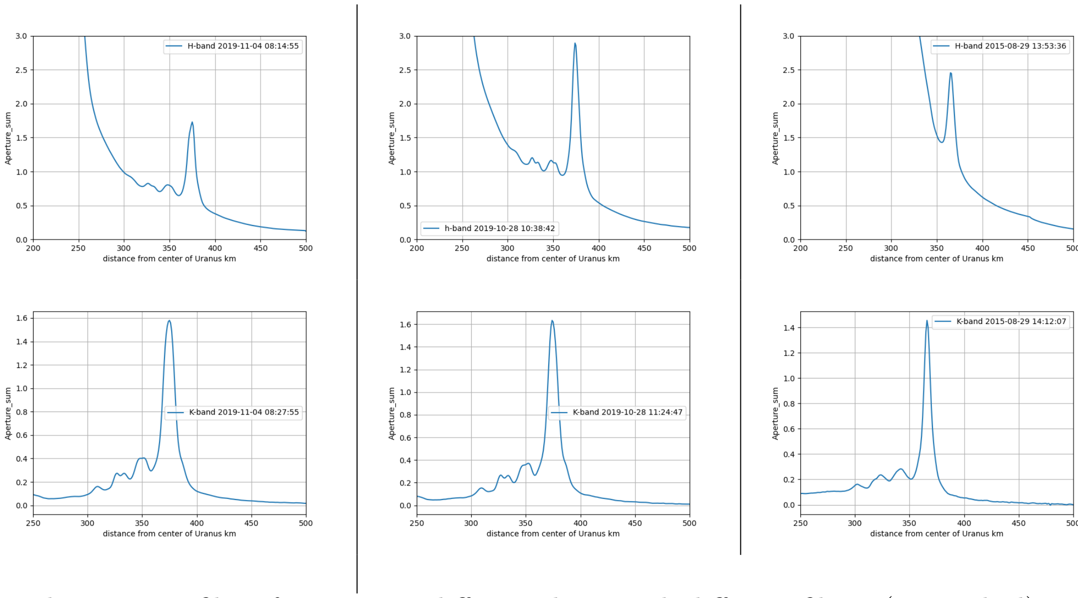

Figure 3: The Ring profiles of Uranus on different dates with different filters (Unmasked)