Knicole D. COLON
Lewis and Clark Fund for Exploration and Field Research in Astrobiology
June 2010

From Hot-Jupiters to Super-Earths: Characterizing Transiting Extrasolar Planets with GTC/OSIRIS

Reports rec'd 8/23/11

Project report

In January and June 2011, I was afforded the opportunity by the Lewis and Clark Fund for Exploration and Field Research to travel to the Canary Islands of Spain to conduct research on extrasolar planets. My primary field work was conducted at the Gran Telescopio Canarias, part of the Observatorio del Roque de Los Muchachos, located at a latitude of 28.7594 degrees North and a longitude of 17.8761 West (on the island of La Palma). The Gran Telescopio Canarias, or GTC, is a 10.4-meter optical telescope, currently the largest single-mirror optical telescope in the world. The primary instrument currently in operation is OSIRIS, which is an imager that I use to observe extrasolar planets as they transit, or cross in front of, their host star.

My specific research projects involve using OSIRIS to observe transiting planets in order to characterize their atmospheres and to also observe super-Earth to Neptune-size planet candidates discovered by the Kepler space mission. In the latter case, the purpose of observing candidate planets is to determine whether or not the candidate is in fact a planet or not, and better characterize the properties of the candidate once its true nature is known. As it were, the first trip I took to the GTC in January was plagued by snow on the mountaintop. This meant that while I was able to travel to the GTC and see the telescope, I was not able to conduct any observations during my time there. However, the second trip in June had excellent weather and allowed for much success. On this trip, I was able to observe two different targets, one of which I intended to characterize the atmosphere of, and the other which is a candidate planet that I intended to determine the true nature of. Overall, the observations were conducted successfully in great weather conditions and with minimal technical issues.

The first target I observed is a previously discovered super-Earth-size planet that orbits a small, M-dwarf star. The planet is known as GJ 1214b. Even though the planet is only ~2.7 times larger than the Earth, it blocks nearly ~1.7% of the light coming from its host star during the transit event because its host star is only two tenths the size of our Sun. The amount of light blocked during transit is therefore quite significant, and it allows for the atmosphere of the planet to be studied relatively easily. Therefore, in order to characterize the atmosphere of this planet, I observed a transit of GJ 1214b at two different but specific wavelengths, with one centered at the wavelength where methane is known to absorb light and one centered at a continuum wavelength (i.e. where methane does not absorb light). By observing the transit at these two wavelengths, I can measure the depth of the transit light curve in each wavelength and compare the depths to each other. If I find that the transit depth is greater at the wavelength where methane absorbs, then that implies that there is methane present in the atmosphere of the extrasolar planet that is absorbing additional light from the host star (compared to the amount of light observed at a continuum wavelength). Finding evidence of methane in the atmosphere of a super-Earth would be a significant step towards characterizing the atmospheres of ever smaller planets. Currently this project is a work in progress, as I am working with collaborators from the Instituto de Astrofisica de Canarias (IAC) located in Tenerife, Spain (as well as from other institutions) on this project. During my time in the Canary Islands in both January and June, I was able to meet with some of my collaborators to discuss this project in more detail. I am currently waiting on all the collaborators to complete their data analysis and then we will push forward with this project. I anticipate meeting with some of my collaborators at the Extreme Solar Systems conference this September and look forward to discussing the results of my observations in more detail as well as eventually publishing them in a refereed journal.

The second target I observed is a super-Earth-size planet candidate discovered by the Kepler mission. It is one of 1235 planet candidates that the Kepler mission has discovered (as of February 2011). Because the Kepler mission has discovered so many planet candidates, it is critical to observe as many as possible using every method available, so we can determine what candidates are not actually planets after all (i.e., false positives). Of the ones that are determined not to be planets, it is useful to determine if they have similar orbital or physical properties. For example, we can determine if it is more likely for candidates with an orbital period of less than three days or a radius of 1.5 times that of Earth to end up being false positives. This is particularly useful for large surveys such as the Kepler mission, because it is difficult to follow up thousands of candidate planets, and if we can vet which candidates are best to follow up, then that can save time and resources in the long run. Therefore, as part of a large program to observe many candidate planets, on my trip to the GTC in June 2011 I observed a candidate planet known as KOI-1187.01. I observed the transit of this target in two bandpasses, chosen so as to cover a large wavelength regime. By observing the transit in multiple wavelengths, the transit depth can be measured at each wavelength, and those measurements can be compared to each other. The technique is similar to that used for GJ 1214b as described above, but in this case, finding a different transit depth in one wavelength compared to the other does not signify absorption due to the planet candidate's atmosphere. Because wider filters that cover a large wavelength regime are used here, a difference in the transit depth instead signifies that the planet candidate is in fact not a planet at all, but instead the transit is caused by some eclipsing star system. In this case, the object that is transiting the target star is a different temperature than the target star, which causes a significant color change during the transit event, equivalent to measuring significantly different transit depths in two widely separated bandpasses such as those used in our observations. What was believed to be a planet candidate may instead be a system composed of one star eclipsing another star, or it could be that the light from a nearby eclipsing star system was blended with the light of the target star, therefore mimicking a transit of a super-Earth-size planet. In the case of KOI-1187.01, I have conducted a preliminary analysis on the data and determined that the transit depth does in fact vary with wavelength, so this candidate is a false positive. I am still determining whether KOI-1187 is an eclipsing star system itself, or if there is a nearby eclipsing star system that was blended with the light from KOI-1187 during our observations. In any case, I have successfully identified a false positive from the candidates discovered by the Kepler mission, and this is just the first step in a large program to observe super-Earth to Neptune-size planet candidates and better characterize their true nature. Furthermore, I was able to meet with some collaborators at the IAC to discuss this project, and we have plans to continue submitting observing proposals to use the GTC for this type of research. Not only is the GTC a world-class telescope to use, but it is ideal for these types of observations, as we can observe in several wavelengths nearly-simultaneously and we can observe relatively faint targets (such as those observed by the Kepler mission and other space missions) and still achieve high precisions.

Knicole D. COLON
Lewis and Clark Fund for Exploration and Field Research in Astrobiology
June 2010

From Hot-Jupiters to Super-Earths: Characterizing Transiting Extrasolar Planets with GTC/OSIRIS

Overall, the GTC/OSIRIS is a fantastic telescope and instrument to use for making the high-precision measurements that are required to study the atmospheres of extrasolar planets and to help vet planet candidates discovered by space missions like Kepler. During my trips to the GTC, I was able to learn more about the process of observing with such a large and unique telescope, and I successfully conducted observations of two different targets. I also was able to meet with several collaborators at the IAC and make progress on various projects that we are working on. I look forward to continuing my work on these projects and working with my collaborators again in the future, and I heartily thank the American Philosophical Society for providing me with the opportunity to conduct hands-on research with one of the largest and most amazing telescopes in the world.