2018 University Of Michigan REU
Report of Summer Research
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A trans-Neptunian object (TNO) is a minor planet orbiting the Sun outside the orbit of Neptune. The first TNO was discovered in 1930 and initially thought to be a planet. Pluto has since been classified as a TNO, alongside over 2000 others[1,2]. There are three prevalent classes of TNO's: Kuiper Belt Objects (KBOs) are remnants of solar system formation with circular orbits close to the ecliptic. KBOs orbit at a distance of 30-50AU. Scattered Disk Objects (SDOs) were scattered out to further distances (>50AU) through gravitational interactions with the large gas giants. SDOs tend to have irregular and non-resonant orbits. Sednoids orbit farthest from the Sun with a semi-major axis greater than 150AU. The origin of these TNOs remains unclear and developing methods to detect TNOs in this population was the goal of my Summer research.

Dr. Gerdes and the TNO group at the University of Michigan use data from the Dark Energy Survey (DES). The DES data pipeline provides difference imaged data - a catalog of transient detections. TNOs in the forefront of DES observations are buried in these catalogs along with thousands of asteroid detections and other sources of noise. It is challenging to detect TNOs in this data due to the contamination of noise and the motion of Earth. Previous detection algorithms succeeded in discovering TNOs when multiple detections at a given opposition were observed. Distant, fainter objects without multiple detections at a given opposition were likely overlooked.

The algorithm for TNO detection I developed over the Summer looked at transient catalogs and de-parallaxed observations at a given distance to a heliocentric frame. Treating each possible pair of detections as a moving body, these algorithms calculated an orbital velocity and direction. 2 dimensional vector representations of tangential velocity and direction were clustered in a 5 dimensional space (2 dimensions of velocity, 2 dimensions of direction, 1 dimension of time). The essence of this clustering was to find multiple detections of an object moving at the same speed, in the same direction, at the same time. Detections with hyper similar features in this space (i.e. clusters) likely represented detections of a physical moving body. Vectors were created only for pairs of observations with orbital velocities reasonable to the de-parallaxed distance, to optimize time efficiency of the algorithm. Clusters of vectors were separated into their corresponding detections (detections with incompatible magnitudes were neglected) and an orbit was fit. Ideally, these algorithms would detect near and distant TNOs without preference.

The algorithms I developed, as well as existing algorithms were applied in search of nearby TNOs in DES fields. The morning of August 9th we discovered a new Centaur (2014 VR39); a subclass of TNOs with orbits that spend time inside the orbit of Neptune. 2014 VR39 was measured to have a semi-major axis of 27.29 ± 0.065 AU, currently at a distance of 20.807 ± 0.003 AU.

Future work involves a collaboration to create a more efficient algorithm by treating velocity as a free parameter. We aim to avoid creating pairs of observations and instead want to scan over not just distance but the tangential components of velocity as well. Our collaborator, Dr. Matthew Holman, plans on repurposing an existing algorithm for linking asteroid tracklets with this goal.

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[1] "List Of Centaurs and Scattered-Disk Objects". *Minor Planet Center*.
[2] "List of Known Trans-Neptunian Objects". *Johnston's Archive*.