Statement of Research Interests for Pennsylvania State University

My goal is to become a tenure-track professor of astronomy and the leading researcher of young planets in the world. My research interests include testing planet formation and migration theories by conducting radial velocity (RV) searches for new planets, assessing planet detection prospects at young ages, and developing techniques to distinguish Doppler signatures of planets from stellar variability. My current dissertation project focuses on the two youngest (43-52 Myr) closest (~150 pc) open clusters, IC 2602 and IC 2391. Given their close proximities and young well-determined ages, they are important benchmarks for testing star and planet evolution theories, both structural and dynamical. By the time I defend my dissertation and graduate (est. April 2022), I will have published two research papers to the Astrophysical Journal (ApJ).

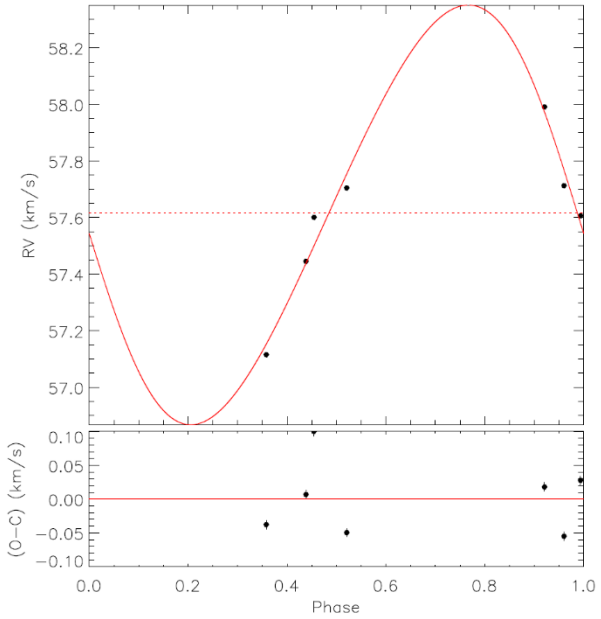
In the first part of my dissertation project, I mapped out the stellar populations of these clusters and discovered hundreds of new candidate members using precise new astrometric data from *Gaia DR2*. I confirmed the brightest of these new members using high-resolution spectroscopy on the high-dispersion optical echelle spectrographs, CHIRON and GOODMAN, to measure signatures of youth (lithium absorption, Hα emission) and stellar properties (RV, $v\sin i$, Teff, log(g), [Fe/H]), which are reported for the first time in the literature for these stars. In the larger picture, by extending the known populations of these clusters and refining their membership lists, the ages of the stars and planets in these clusters can be more accurately determined to place observational constraints on theories. I present the results of this investigation in my 1st paper submitted to ApJ entitled, "Mapping out the Stellar Populations of IC 2602 and IC 2391."

In the second part of my dissertation project, I monitor the RVs for 30 slowly-rotating ($v\sin i$ < 30 km/s or period > 3 days, if known) Sun-like (F5-K0) single stars in IC 2602 and IC 2391, including some from the 45-Myr stellar association Tucana-Horologium, using CHIRON (R~79,000 and ~7.5 m/s RV precision) on the SMARTS 1.5-m telescope through National Optical Astronomy Observatory (NOAO). The purpose of this survey is to (1) potentially discover new planets in IC 2602 and IC 2391, which would be the youngest RV-detected cluster planets known and the first ones discovered in the southern hemisphere, and to (2) directly measure the stellar jitter, noise in RV measurements due to star spots, at ~50 Myr. Determining the structural and orbital properties of planets discovered in these clusters will allow us to distinguish between competing theories of giant planet formation and dynamical evolution. Our stellar jitter measurements will allow us to better understand the magnitude and age-dependence of stellar jitter in the age range of 10-100 Myr, which is largely unknown. I monitor line bisector spans to assess whether RV variations are primarily induced by reflex motion of a companion or stellar variability. Thus far, I have identified 8 candidate hot Jupiter planets and I am currently obtaining follow-up observations to confirm the origins of their RV variability. Even if new planets are not detected, the stellar jitter measurements can be used to establish detection limits and will be vital for confirming new young planet candidates identified by NASA's TESS and K2 missions. The results of my completed investigation will be presented in my 2nd paper.

As a postdoctoral researcher of Penn State University, I will utilize the expertise and resources from the Center for Exoplanets and Habitable Worlds (CEHW) and address the next set of research questions in topics related to the detection, formation, and dynamical evolution of exoplanets, as well as variability and properties of host stars. My work will greatly benefit from the expertise

provided by collaborations in CEHW with faculty from the Departments of Astronomy and Astrophysics and Geophysics, and as part of the Consortium for Planetary Science and Technology. The Habitable Zone Planet Finder (HZPF; R~55,000) on the 10-m Hobby Eberly telescope with a 1-3 m/s RV precision and NEID (R~60,000-90,000) on the WIYN 3.5-m telescope with < 50 cm/s RV precision will enable new science in exciting fields stemming from my work. The higher RV precision and larger-aperture telescopes for these spectrographs compared with CHIRON will allow me to detect smaller planets, as well as access the Sun-like populations of more distant star clusters and map out the evolution of planetary systems and stellar jitter more completely. Moreover, due to the HPZF's focus on the near-infrared (NIR; 810-1280 nm), I will observe exoplanet host stars at spectral ranges where stellar jitter is predicted to be less prohibitive for planet detection. My observational program will bring us a long way in improving our capacity to discover the most Earth-like planets, reduce the effects of stellar jitter, inform our understanding of how the gas giant planets in our Solar System came to be, and use the architecture of planetary systems to assess overall habitability. I would be extremely excited to work on these stimulating projects with scientists such as Eric Ford, Suvrath Mahadevan, Larry Ramsey, Jason Wright, Rebekah Dawson, and Steinn Sigurdsson. If I discover planetary systems from these surveys, I will collaborate with researchers at Penn State's Astrobiology Research Center and Planetary System Science Center to investigate the atmospheres of discovered planets and propose a search for biosignatures, such as green colors indicative of chlorophyll, as well as Penn State's Extraterrestrial Intelligence Center to identify candidate technosignatures and listen for radio signals from promising habitable planets.

As a graduate student of Georgia State University, I have been afforded many opportunities to pursue independent research, as well as contribute to teams of students and Ph. D. researchers. As an active member of the SMARTS consortium, I give observational advice, assist in scheduling observations, help manage the automated data reduction pipelines, and troubleshoot problems for more than a dozen research groups at a time that rely on CHIRON for their science. By taking on this support role, I have gotten to know lots of researchers and the details of the science they do. I have also been active in public outreach efforts by arranging public observing sessions to share the wonder and awe of the cosmos, giving presentations, and developing astronomy game shows to incite enthusiasm for science in elementary and middle school students. As a Muslim-American first-generation immigrant, I also seek to combat the strong underrepresentation of Muslims in science, who make up 1% of the world's scientists but 20% of the world's population, through my research career in astrophysics that will encourage Muslim-Americans to participate in and bring unique perspectives to science. Nothing is more deeply fulfilling to me than conducting ground-breaking research independently and in collaboration, writing papers on new discoveries that expand the frontiers of human knowledge, and inspiring the next generations of scientists with teaching and outreach. As a postdoctoral researcher of Penn State University, I will continue to carry this energy to contribute to the scientific and public outreach efforts of the department.



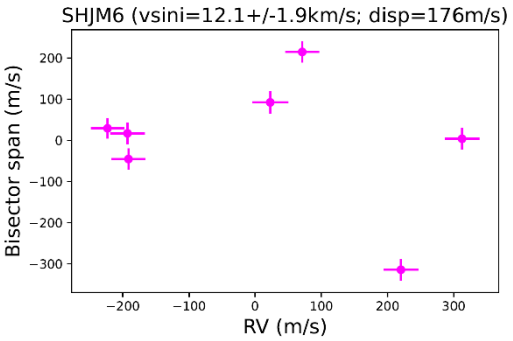


Fig. 1: A preliminary orbit fit (left panel) and the plot of bisector span versus RV (right panel) is shown for the IC 2391 star, SHJM6. Given the lack of correlation between spans and RVs but the large variations in spans, are the RV variations dominated by reflex motion of a hot Jupiter planet or stellar noise? It could very well be a mix of both!