My research interests focus on how extreme events known as stellar flares shape the mass and chemical compositions of exoplanet atmospheres. Stellar flares are short duration ($\sim$ minutes - hours) bursts of high-energy radiation. In Feinstein et al. (2020a,b), I completed the first large statistical study of 3200 stars with ages < 800 Myr to analyze the evolution of flare rates using publicly available Transiting Exoplanet Survey Satellite (TESS; Ricker et al. 2014) data. I expanded this work to a sample of 200,000 stars to explore flare rates as a function of stellar mass (Feinstein et al. 2022a). Recently, I led a detailed study of far-Ultraviolet (FUV) flares on the 22 Myr M dwarf AU Mic using the Hubble Space Telescope (Feinstein et al. 2022b). I have also presented a potential detection of escaping hydrogen from the atmosphere of a young planet (Feinstein et al. 2021).

As a Simons Fellow, I will expand my research interests to novel observations using the James Webb Space Telescope (JWST) and TESS. First, **I propose to observe young planetary atmospheres in the infrared (IR) to understand their formation history and chemical evolution.** The carbon-to-oxygen (C/O) ratio derived from IR measurements of CO, CH_4, and H_2O yields insight into the formation location transiting planets with respect to the H_2O, CO and CO_2 snowlines. Theory suggests that large gas-rich planets ($\geq 4R_{\mathrm{Earth}}$) which form beyond the aforementioned snowlines and subsequently migrate inwards *after* the disk dissipates will have elevated C/O (> 0.8) and low metal enrichment. Giant planets which form in similar locations, yet migrate *within* the disk will result in a lower C/O (< 0.5) and more metal enrichment (Öberg et al. 2011). These considerations have been crucial for testing whether hot Neptunes and Jupiters ($P < 10$ days), the vast majority of exoplanets found today, formed in situ or experienced inward migration.

However, young planetary atmospheres are challenging to observe due to contamination from stellar activity. My unique interests and experience with stellar flares, starspots, and planetary atmospheres have prepared me for handling such challenges. The goal of this project will be to observe exoplanet atmospheres around $17 - 500$ Myr old stars and compare chemical compositions. This will be achieved via ground-based high-resolution observations using Gemini-S/IGRINS, which I have successfully proposed for in the past (GS-2022A-FT-105), and JWST, which I will apply for this upcoming proposal cycle. Both programs will strive to acquire a sample of 15 young planets to directly measure the H_2O, CO, and CO_2 abundance across time and environments. The IR is the ideal wavelength regime for such observations because it also covers key stellar activity indicators. Now is the opportune time for my proposed observational campaign as many of the young planets were only discovered in the past five years (e.g. Mann et al. 2022), and JWST is operational.

Additionally, I will investigate how the long-term stellar cycles change as a function of age. It is through decades-long monitoring of the Sun which uncovered it goes through solar cycles, or 11-year periods of high and low activity (e.g. more and fewer flares; Schwabe 1844). It is still unclear what drives the length of the solar cycle. **By searching for signatures of stellar cycles on other stars, I hope to not only better understand the timescales of activity for these stars, but also shed light on the mechanisms driving our own Sun.** It is currently believed that the timescale of the solar cycle is proportional to the rotation period of the Sun and inversely proportional to stellar mass (Wright et al. 2011). If stellar cycles are correlated with the rotation period of a given star, then the stellar cycles of young, rapidly rotating stars (Soderblom 2010) should be shorter than the cycle we see for the Sun. For this project, I will search *publicly available* TESS light curves of young stars for signs of flare evolution over a ~ 5 year baseline. This research would yield the first evidence of magnetic activity cycles via flare variations. The results of the project would be used to model long-term evolution of exoplanet atmospheres as well.

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