Undergrad Research: Formation and Evolution of Planetary Systems Research Group

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Circumstellar Disk Lifetimes vs. Stellar Mass: Constraints on Planet Formation Theory

Description of the Project:

Circumstellar disks around young stars are common, and thought to be a natural outcome of the conservation of angular momentum and the star formation process (e.g. Meyer et al. 2007). These disks provide the initial conditions for, and boundary conditions on, the processes of planet formation. Key properties of these disks are found to depend on stellar mass such as initial mass (Ansdell et al. 2016) and accretion rates of material onto the star (Hartmann et al. 2016). We have recently put forward a theory of gas giant planet formation (Adams, Meyer, and Adams, 2021) which is built in part on these observed properties and explores whether disk lifetimes themselves could be responsible for providing an upper limit to gas giant planet masses. Typical lifetimes of primordial gas rich disks around sun-like stars are about 3 Myr assuming (Mamajek, 2009). There is also evidence that disks around higher mass stars dissipate more quickly than disks around lower mass stars (cf. Yao et al. 2018; Ribas et al. 2015, Yasui et al. 2014; Kennedy & Kenyon, 2009). The work of Adams et al. (2021) depends critically on whether the nature of disk lifetime decay is exponential. Further, the specific predictions of the model as a function of stellar mass depend on how disk lifetimes depend on stellar mass.

Work to be Done:

Using published literature concerning young star cluster and association membership, as well as associated stellar properties, the student will assemble a database. Membership is assessed on the basis of kinematic properties relative to cluster/association distributions, or signatures of youth (Hα emission, Li I absorption, x-ray emission) as well as position in the H-R diagram relative to the main sequence. The student will explore various ways to estimate effective temperature and luminosity for each source in the database. Diverse models of pre-main sequence evolution will be investigated in order to estimate masses and ages for each source. Methods to identify sources with optically-thick, gas-rich, primordial circumstellar disks will be developed based on existing 1-10 micron infrared photometry. The database will be assessed for completeness as a function of mass and age. Where completeness is not possible (most regions), the student will assess the representative nature of the available subsample. For representative samples as a function of mass and age, the student will test different distribution functions as they depend on mass and age and derive a best fit. The likelihood that these data came from the model will be assessed with the goal of identifying the maximum likelihood estimate as well as probability density functions of the fit parameters. A focus will be on remnant circumstellar disk populations at late times (10-30 Myr) to test whether the exponential function is an appropriate description of the data, as well as the implications of the findings for planet formation models (e.g. Adams et al. 2021).

Skills Needed:

Basic programming skills required (e.g. python using Jupyter notebooks). Familiarity with data analysis, statistics, and generating plots helpful (e.g. ASTRO 361 or comparable experience). Ability to critical read literature with guidance.