Parameterization of YSOs using MoogStokes

Matthew N. Jacobs

1. Introduction and Scientific Background

Determining fundamental stellar parameters for pre-main-sequence stars with circumstellar disks is crucial to our understanding of planet formation. However, precise measurements of young stellar object (YSO) parameters are difficult to obtain because of strong magnetic fields, reddening, and continuum veiling. Additionally, YSOs are variable because magnetic fields, spot coverage, and accretion veiling operates on various timescales (e.g. Calvet et al. 1984; Gahm et al. 2008; Gully-Santiago et al. 2017; Sokal et al. 2020;). Recent work by Lopez-Valdivia et al. (2021) obtained YSO stellar parameters by fitting IGRINS spectra with synthetic spectra that had temperature, surface gravity, rotational broadening, veiling, and magnetic field strength as variables. This fitting makes use of the MoogStokes (Deen 2013) to conduct Zeeman polarized radiative transfer and solve for all these parameters in a grid-like fashion.

Lopez-Valdivia et al. (2021) showed a statistically significant difference between the surface gravity (log g) measurements of Class II and Class III YSOs in Taurus-Auriga, suggesting a distinguishable age difference between the classes, as shown in Figure 1. Understanding how YSO disk classifications (which are based on the quantity of dust at larger radii) correlates with the stellar parameters is needed for us to understand the age spreads within star forming regions.

Some Taurus YSOs have had their dynamical masses determined from ALMA observations of the disk kinematics, which are listed in Table 1 (Simon et al. 2017). However, uncertainties in T_{eff}, the magnetic field (B), and other stellar parameters affect the certainty of the mass measurements. We propose to run MoogStokes on TACC's Stampede 2 to parameterize all currently catalogued YSOs in the Taurus and Ophiuchus fields, utlizing high-spectral-resolution IGRINS data is used to simultaneously determine T_{eff}, log g, B, and $v$sini parameters of Class II and Class III YSOs.
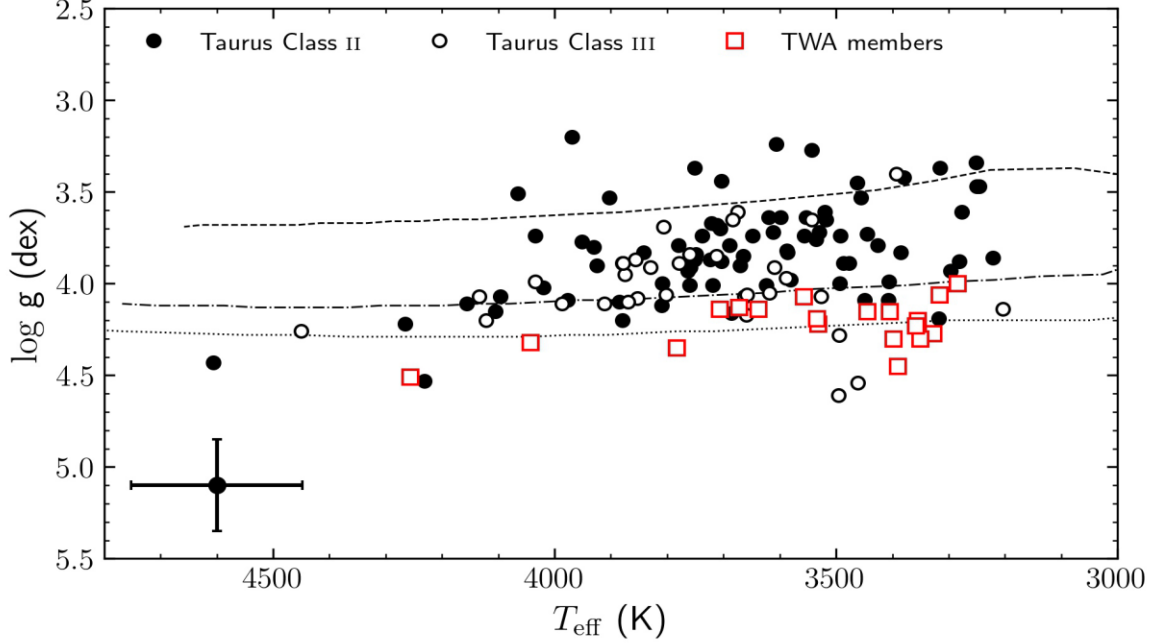
Figure 1: Spectroscopic Hertzsprung-Russell diagram. The isochrones of 1 (dashed line), ~5 (dash-dotted line) and 10 Myr (dotted line) are plotted (Baraffe et al. 2015).

2. Proposed Simulations and Justification of Requested Resources

There are over 400 identified YSOs in Taurus (Luhman et al. 2018) and over 300 YSOs containing circumstellar discs in Ophiuchus (Cánovas et al. 2019). Combining IGRINS database, combined with current and future observations, we can gather the necessary high-resolution spectra in the Near-IR for use with MoogStokes. Each target will have a 4-dimensional grid containing T_{eff}, log, B, and $v\sin i$ and then using the MARCS atmospheric models (Gustafsson et al. 2008), MoogStokes synthesizes a spectrum by stepping through a specified grid of each parameter for each target. The grid ranges are:

$$T_{eff} = [3000:5000], 100\ K\ steps$$
$$\log g = [3.0:5.0], 0.5\ dex\ steps$$
$$B = [0:4], 0.5kG\ steps$$
$$v\sin i = [2:50], 2\ km\ s^{-1}\ steps$$

Which yields grid sizes of:

$$N_{T_{eff}} = 31$$
$$N_{\log g} = 5$$
$$N_B = 9$$
$$N_{v\sin i} = 25$$

For a total number of steps for each target given,

$$N_{steps} = N_{T_{eff}}N_{\log g}N_B N_{v\sin i} = 34875$$

We then have over 700 total targets, giving a combined number of MoogStokes computational steps as:

$$N_{tot} = N_{steps} \times N_{targets} \approx 2.44 \times 10^7$$

In Lopez-Valdivia et al. (2021), the reduction was done on a MacBook Pro and would take approximately 12 hours per target, we can approximate runtime per step

$$R_{single} = \frac{t_{target}}{N_{steps}} = \frac{4.32 \times 10^4}{34875} \approx 1.238 \frac{sec}{step}$$

Giving a total runtime on one CPU for all 700 targets,

$$R_{tot} = R_{single}N_{tot} \approx 3.021 \times 10^7 \; core \; sec$$

We propose using 4096 cores on Stamped 2, so

$$R_{tot} = \frac{3.021 \times 10^7 core \; sec}{4096 \; core} = 7.37 \times 10^3 \; sec \approx 2 \; hour$$

And

$$SUs = R_{tot} \times N_{nodes} \approx 171$$

With $N_{nodes} = \frac{4096 \; cores}{48 \; cores/node} = 853 \; nodes$

So, we propose a total of 2 run time hours, which is approximately 139 node-hours

3. Total Allocation Request

The total request for this project of parameterizing the full Taurus and Ophiuchus catalog of YSOs is:

171 SUs on Stampede2

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