Analysis of The Effect of Accretion Rates and Convection Coefficients on Stellar Evolution in The Pre-Main Sequence for T Tauri-Type Star

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Abstract

T Tauri star (TTS) is one example of a young star still in the pre-main sequence (PMS) phase. Some modeled TTSs are used to trace PMS evolution on the HR diagram and determine the best convection coefficient (α_{MLT}). Using MESA (Modules for Experiments in Stellar Astrophysics) evolution code, we find α_{MLT} = 2 fits the TTSs sample

Introduction

PMS evolution marks the early stage of stellar development. Stars first follow the Hayashi track, dominated by convection and deuterium burning at ~10^6 K, then transition to the Henyey track, where radiative transfer prevails until core nuclear fusion begins.
Convection is modelled using Mixing Length Theory (MLT) (Böhm-Vitense, 1958), where the mixing length is

$$l_m = \alpha_{MLT} H_P$$

with,

$$H_P = \frac{P}{\rho g}$$

and α_{MLT} controlling convective efficiency.

Accretion significantly impacts PMS stars, increasing luminosity, radius, and temperature (Hartmann et al., 2016; Vorobyov et al., 2017). Observations of TTSs — young (<10^6 yr), low-mass (M < 3 $M_\odot$) PMS stars — provide insight into this phase (Appenzeller & Mundt, 1989).

This study models T Tauri evolution using data from Ingleby et al. (2013) and Grankin (2018), estimating α_{mlt} and initial ZAMS mass from HR diagram positions.

Research Method & Result

Modeling Approach (1)
We use the **MESA evolution code** (Paxton et al., 2011–2018) to model PMS evolution for low-mass stars (0.6 – 1.0 $M_\odot$) with accretion rates of 10^{-8} – 10^{-10} $M_\odot$/yr and α_{mlt} = 1 or 2. Convection is defined using Schwarzschild's criterion. Observed TTSs from Ingleby et al. (2013), Grankin (2016), Seiss et al. (2000), and Torres et al. (2010) are compared.

Result: Stars fit better with α_{MLT} **= 2** (see Fig. 1).

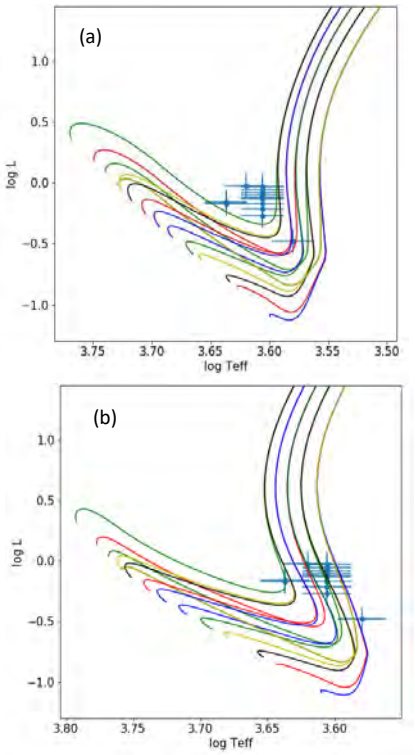


Fig. 1: PMS evolutionary tracks for various masses and accretion rates of modeled TTSs, and position of observed TTSs, for (a) $\alpha_{MLT} = 1$ and (b) $\alpha_{MLT} = 2$.

Modeling Approach (2)
Second, three observed TTSs (Table 1) were modeled on the HR diagram (α_{MLT} = 2; Fig. 2) to estimate their ZAMS masses.

Result: see Table 2.

Table 1: Observed TTSs from references

TTS	Reference Mass ($M_\odot$)	Accretion rate ($M_\odot$/year)
IP Tau	0.54	7.2×10^{-9}
AA Tau	0.77	1.5×10^{-8}
DR Tau	1.1	5.2×10^{-8}

Table 2: Approximate masses of TTSs (Table 1) at ZAMS

TTS	Mass ($M_\odot$)	Luminosity ($L_\odot$)	Temperature (K)
IP Tau	0.89	0.55	5354
AA Tau	1.18	1.71	6082
DR Tau	1.59	7.55	7039

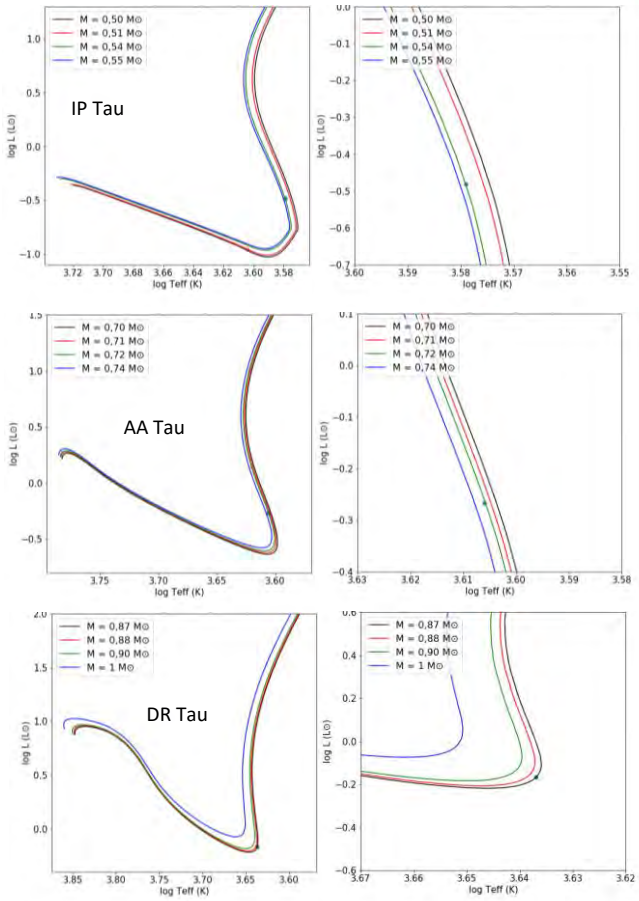


Fig 2: HR diagram for various masses of TTSs from ref.

Conclusion

- Modeling PMS tracks of T Tauri stars on the HR diagram shows that α_{MLT} **= 2** best matches luminosity and temperature data.
- Approximate ZAMS masses for three TTSs were calculated; these results require validation using other references and modeling methods.
- Mass changes occur before reaching ZAMS due to accretion.

References

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