Pre-Main Sequence evolution including intense mass accretion

Masanobu Kunitomo[1], T. Guillot[2], and S. Ida[1]
[1]*Tokyo Tech.*, [2]*Observatoire de la Côte d'Azur*
kunitomo@geo.titech.ac.jp

ABSTRACT

We have studied the evolution of the convective envelope in Pre-Main-Sequence (PMS) stars with the intense disk mass accretion and efficient radiation under a variety of conditions. If the energy loss of the accreting materials by radiation is efficient, the PMS evolution can be different from that in the traditional theory. If a star evolves with the smaller radius and higher center temperature, a radiative core develops and convective envelope shrinks at the earlier stage. We have found that the treatment of the entropy of the accreting material is the important factor for the convective envelope evolution. We also study the effects of the efficiency of the radiation and the mass accretion rate on the convective envelope evolution. With these results, we discuss PMS evolution and connection to planet formation.

1. INTRODUCTION

■classical PMS evolution

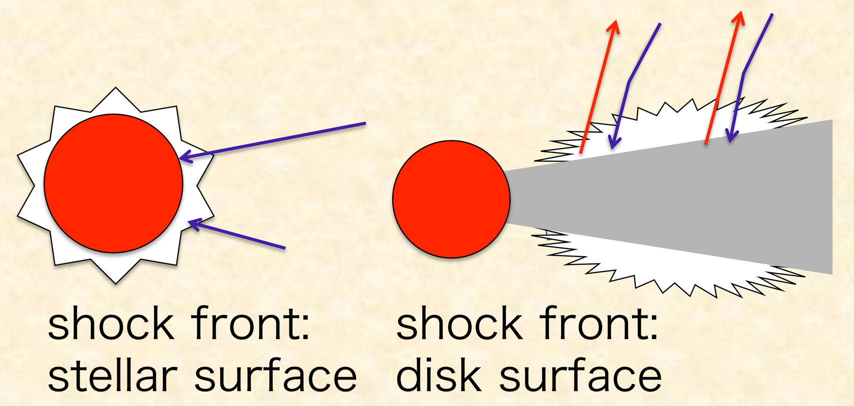
- does not include the accretion
- assumes the initially large entropy, radius and luminosity ("*Hayashi track*")

■recent picture of PMS evolution

(Baraffe+09,12, Baraffe+Chabier10, Hosokawa+11)

protostar's mass ~ M_J→the star is formed by accretion

If the entropy of the accreting material is radiated away efficiently,
then the stellar entropy, radius & luminosity can be much smaller
→the center temperature becomes higher
→ **the convective envelope shrinks at the earlier age**



the accretion through a disk can lose the entropy of the accreting materials

the mass in the convective zone (M_{CZ}) is important for
-the surface composition
-the magnetic field
-the tidal dissipation
but M_{CZ} is investigated under only one condition so far

⇩

Motivation

we investigate the evolution of M_{CZ} under a variety of conditions

2. MODEL & METHOD

■Stellar evolution code

MESA Paxton+11,13

■Input parameters:

M_{ini}=0.01$M_\odot$, M_{fin}=1$M_\odot$, R_{ini}=2.1$R_\odot$, Z=0.02, α_{MLT}=1.89, steady accretion

■heating efficiency of accretion

a fraction (ξ) of the energy of the accreting material is carried into the star

$$L_{add} = \xi GM\dot{M}/R$$

■treatment of the accreting material's entropy

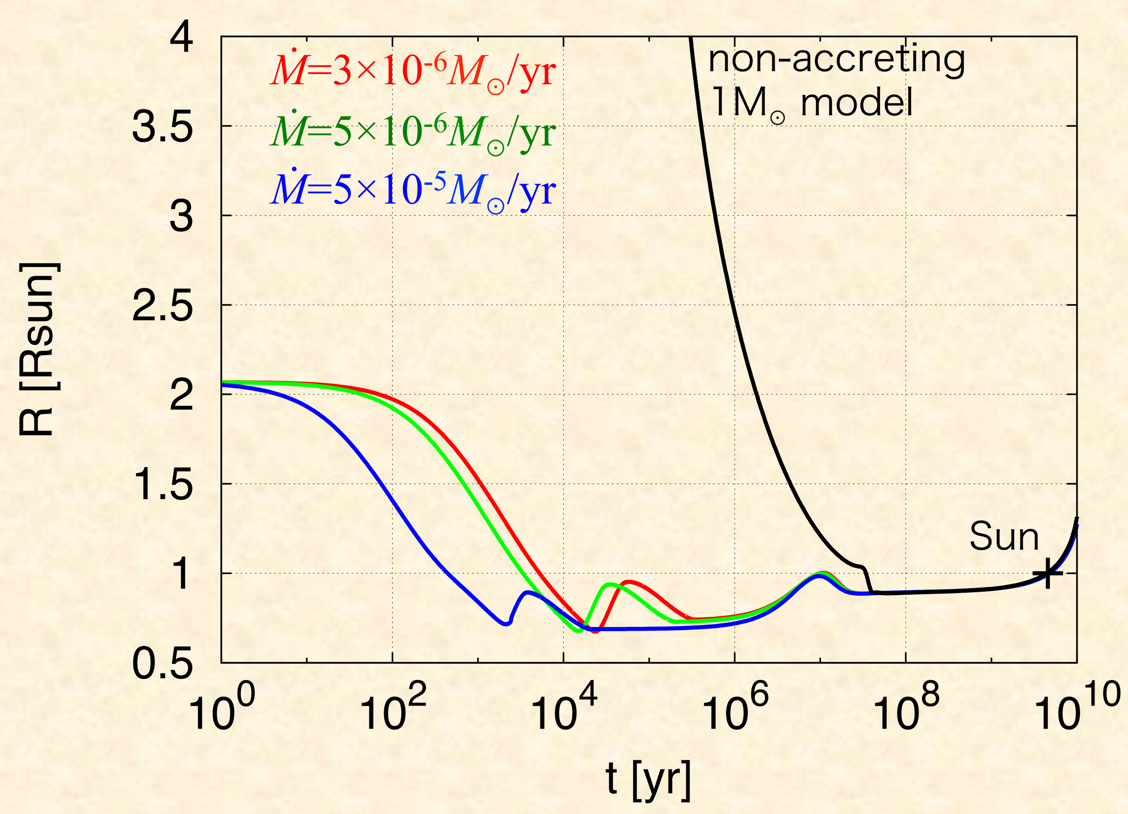
"compressional heating"

Townsley+Bildsten04

3. RESULTS

3.1 "cold accretion" model (ξ=0)

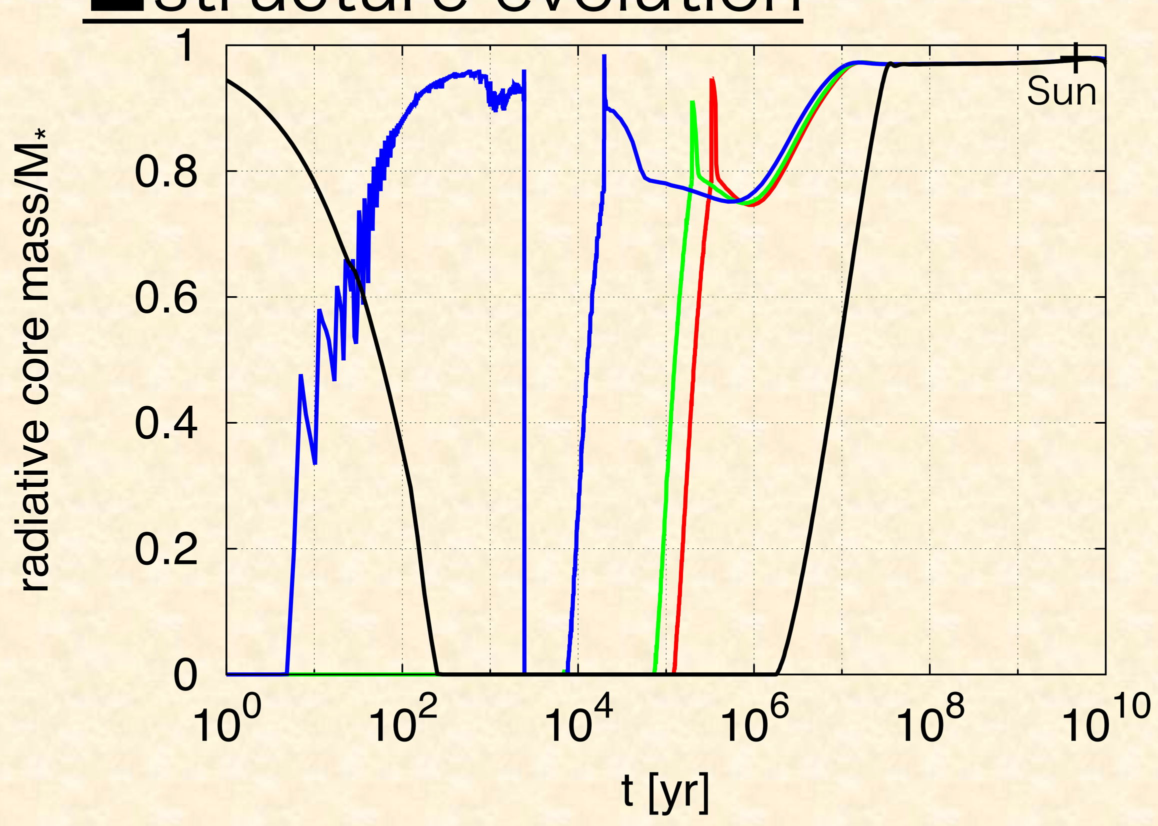
■radius evolution



- converge after accretion
  $\dot{M}$ is not important
- <1$R_\odot$ after accretion
  much smaller than the non-accreting model

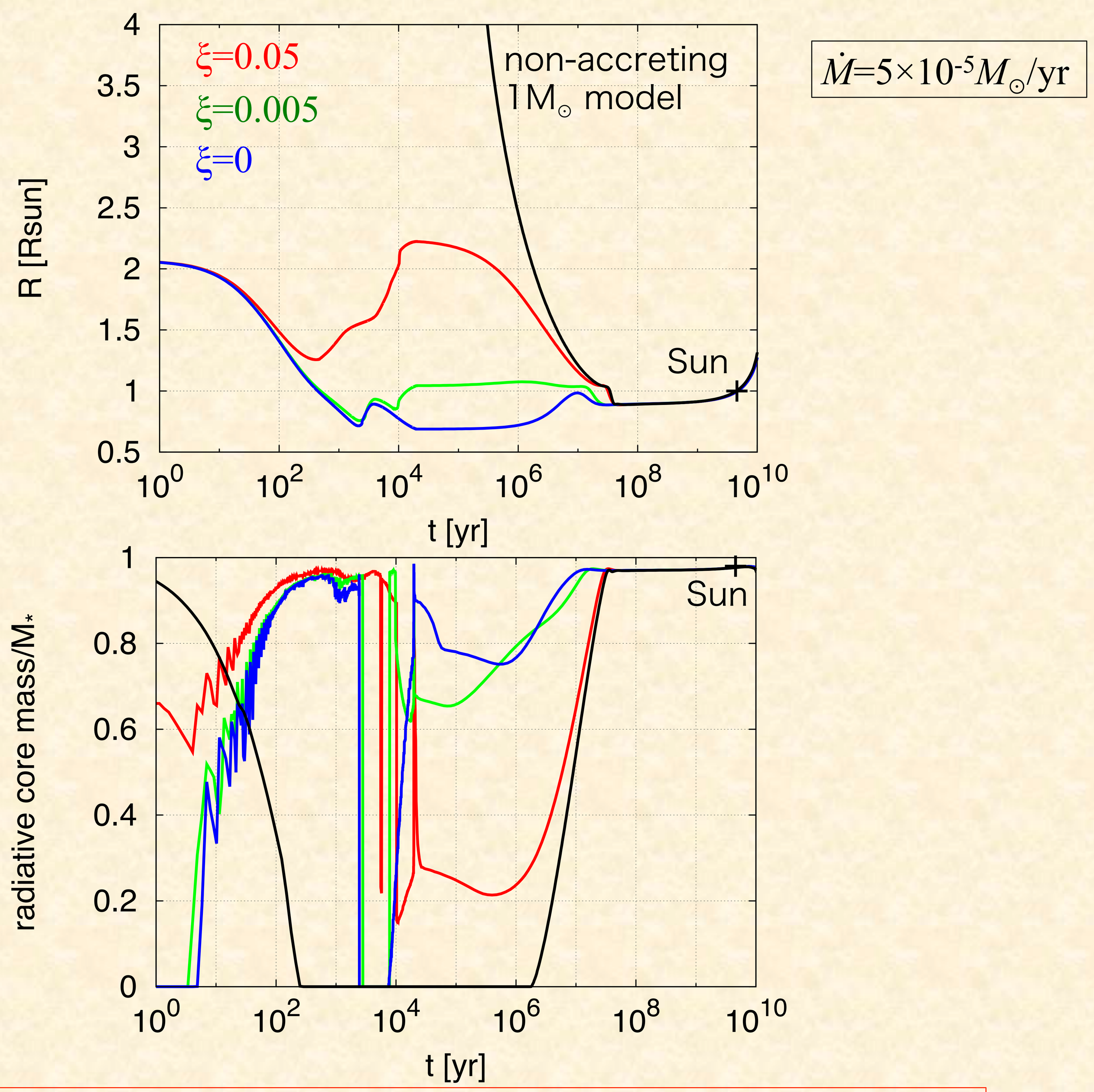
-expansion around 10^4 yrs: D-burning

■structure evolution



- converge after 1Myr
- M_{CZ} < 0.1$M_\odot$ within 5Myr (= within the protoplanetary disk's lifetime)
  much faster than the non-accreting model (25Myr)

3.2 "hot accretion" model (ξ≠0)

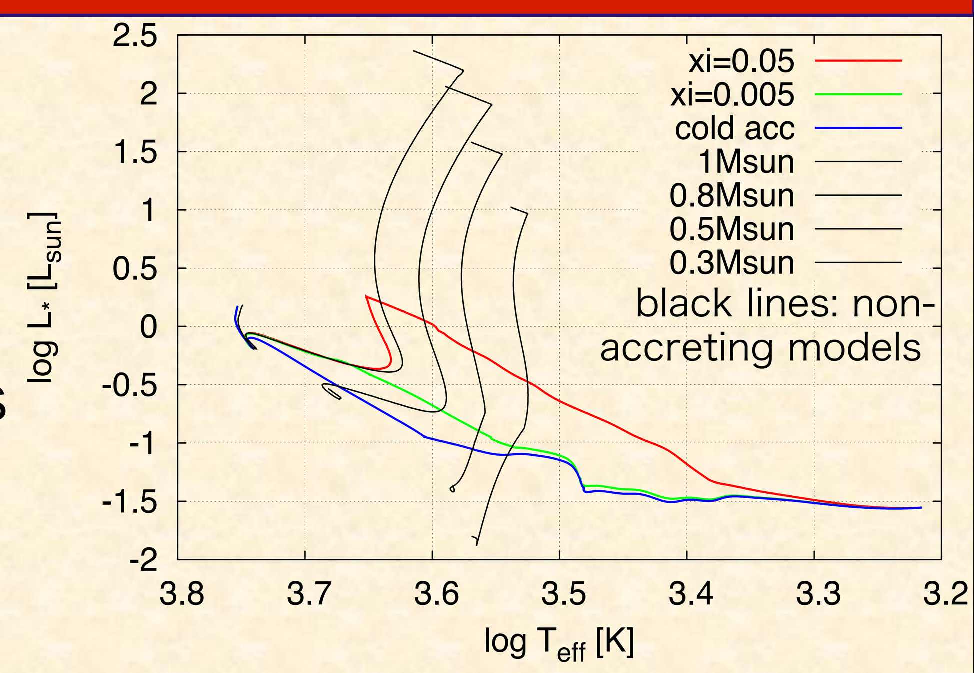


injection of energy →expansion
→similar structure evolution to the non-accreting model

4. DISCUSSION

■ evolution tracks

as found in the previous studies,
the evolution tracks are different from the Hayashi tracks
→this difference leads to the different masses of PMS stars



■ the effect of planet formation

The accreting material can be volatile-rich after the planetesimal formation.
If a volatile-rich material accretes onto the star with a thin convective zone,
the stellar surface becomes volatile-rich

SUMMARY

We calculated the PMS evolution focusing on the convective zone with the efficient entropy loss of the accreting materials. We found that

(1) The convective zone mass can become significantly small within the disk lifetime

(2) The injection of the entropy by accretion makes the evolution similar to the traditional PMS evolution

(3) The difference in the accretion history does not affect the evolution

(4) Planet formation may affect the stellar surface composition