Disk Dissipation Timescale of Pre-main Sequence Stars

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Age of PMS stars

Class I
(protostar)

Class II
(Classical T Tauri Star)
1 Myr

Class III
(Weak line T Tauri Star)
10 Myr

Spectral Energy Distribution (SED)

Lada 1987
To discuss the formation and evolution of a PMS star, disk, and planets, a precise age determination of PMS stars is necessary.

Age determination of PMS stars: Mainly estimated by comparing their loci in the HR diagram and the evolutionary models of young stars.

Is the luminosity spread real? Or are these observation uncertainties?
Age of PMS stars in Taurus (Bertout+ 2007)
- Luminosity determinations are based on precise distance estimation
- Lifetime: $4 \times 10^6 (M_{\text{Star}} / M_{\text{Sun}})^{0.75}$ yr
Evolution timescale of the disks of PMS stars

Disk fraction vs. age of star-forming regions

Mamajek 2009
Evolution timescale of disks is estimated by comparing the age of ~25 young clusters and the fraction of stars with disks in each cluster derived from NIR observation.
  e-folding time: 2.5 Myr

Ribas+ 2014
Disk lifetime was estimated by comparing the NIR and MIR excesses of PMS stars (Ribas+ 2014).
  Evolution timescale of
    inner disk: 2-3 Myr
    outer disk: 4-6 Myr
  → inside-out disk clearing
Precise age determination of PMS stars are difficult because of many problems such as:

- Distance uncertainties
- Extinction
- UV and Infrared excesses

The surface gravity determination based on spectroscopy is feasible. Surface gravity of a PMS star increases as they evolve due to the contraction.

Measurement of equivalent width ratio (EWR) of atmospheric absorption lines will allow us to investigate surface gravities of pre-main sequence stars without any corrections of distance, extinction, and veiling.
EWR vs. surface gravity

EWR – surface gravity (log g) relations were estimated by observing field dwarfs and giants with well known surface gravities and nearly equal effective temperatures.

The EWRs used for the surface gravity diagnostic are:

a. Fe and Na lines in the optical I-band for mid-late K type PMS stars

b. Sc and Na lines in the NIR K-band for late K to early M type PMS stars

Typical error of log g: ±0.1-0.2.

Ages of PMS stars age are able to be estimated with factor of 1.5.
Estimating the PMS star age from EWR method

To determine the disk evolution timescale in each star-forming region, we observed PMS stars in Taurus and ρ Ophiuchus star-forming regions.

- Taurus
  • Targets: 10 TTSs
  • Telescopes: Subaru / HDS & IRCS, UKIRT/CGS4, Keck / HIRES
  • Resolution power: 20000 – 60000
  • S/N: ~100

- ρ Oph
  • Targets: 8 TTSs
  • Telescope: Subaru / HDS
  • Resolution power: 60000
  • S/N: ~100
Estimating age with EWR

Taurus

- Average age: 2.1 Myr

- Ages were compared to the NIR color excesses arising from the circumstellar disk.

- Inner disk dissipates gradually with a constant rate.

- The dissipation timescale of the inner disk of Taurus TTSs is ~3 Myr.

  (Takagi+ 2014)
$\rho$ Ophiuchus

- Average age: 0.7 Myr

- As same as Taurus, the disk dissipate constantly with time.

- However, the disk dissipation timescale in $\rho$ Oph is more rapid than Taurus, which is $\sim$1.2 Myr.

(Takagi+ 2015 submitted)
a. Effect of the massive stars

The molecular cloud of \( \rho \) Oph is stripped away by the radiation from the massive stars in Sco-Cen OB associations (e.g. Wilking+ 2005). Did it also strip away the disks?

b. Metallicity dependence

Both observational (Yasui+ 2010) and theoretical studies (Ercolano+ 2010) suggested the metallicity dependence on the disk evolution.

However, the metallicity of both Taurus and \( \rho \) Oph is estimated to be nearly equivalent to the sun (Paddget 1996).

Metallicity investigation with no dependency on veiling may be necessary for further discussions.
To discuss the evolution of the disk of PMS stars, surface gravity is a fine tool for age determination since it is independent of veiling, extinction, and distance uncertainty.

We used the EW ratio of nearby absorption lines obtained from high-resolution spectroscopy. The log $g$ of PMS stars can be estimated with uncertainty of $\pm 0.15$. The age of the YSOs are able to be estimated with a factor of 1.5.

From the spectroscopic age determination, the disk dissipation timescale of PMS stars in the Taurus and $\rho$ Oph are estimated as 3 Myr and 1.2 Myr, respectively.

The disk evolution time depends on the environment of the parent molecular cloud.