Disk Dissipation Timescale of Pre-main Sequence Stars

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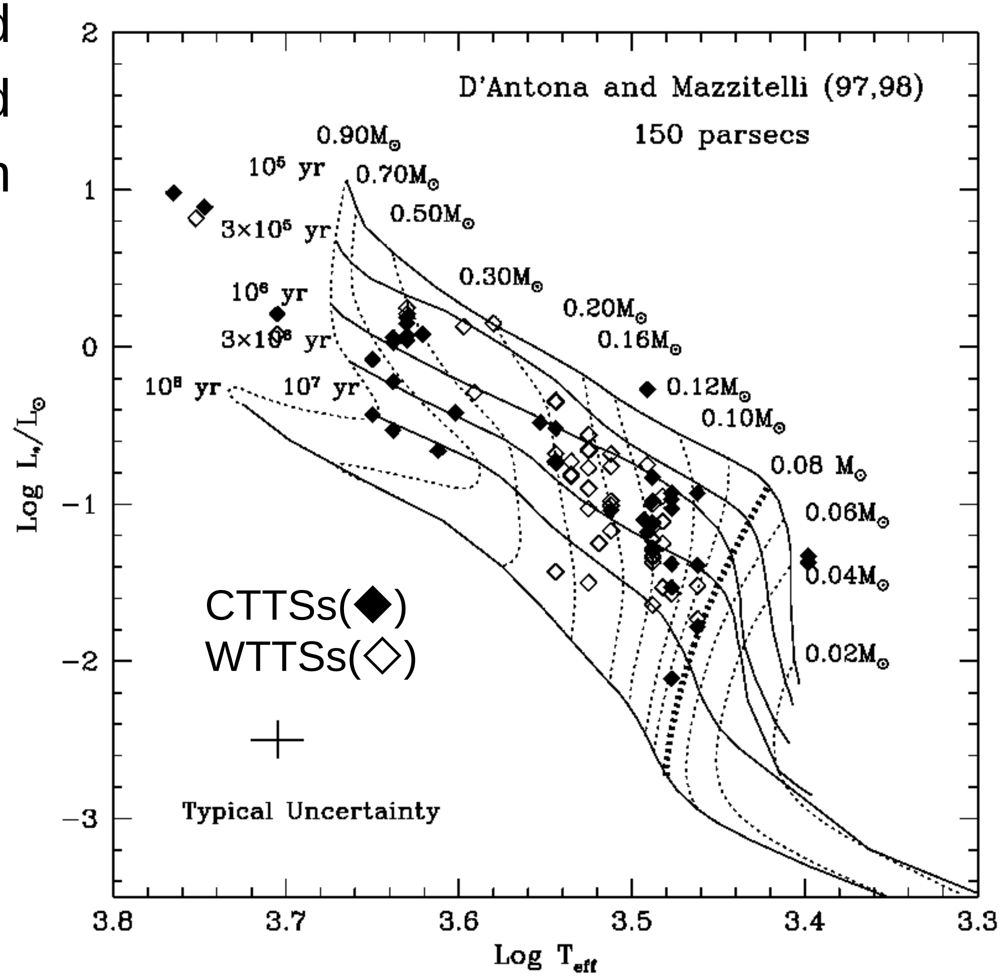
Age of PMS stars

To discuss the formation and evolution of 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.



Ophiuchus
Wilking+ 2005

Is the luminosity spread real?
Otherwise observation uncertainties?

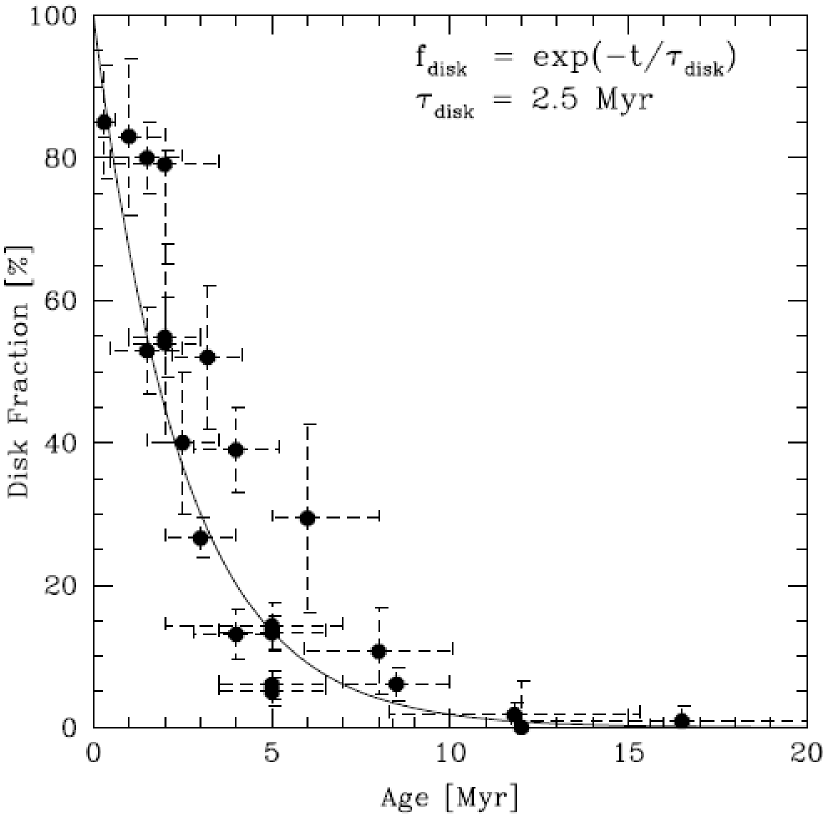
Evolution timescale of the disks

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.

<u>e-folding time: 2.5 Myr</u>



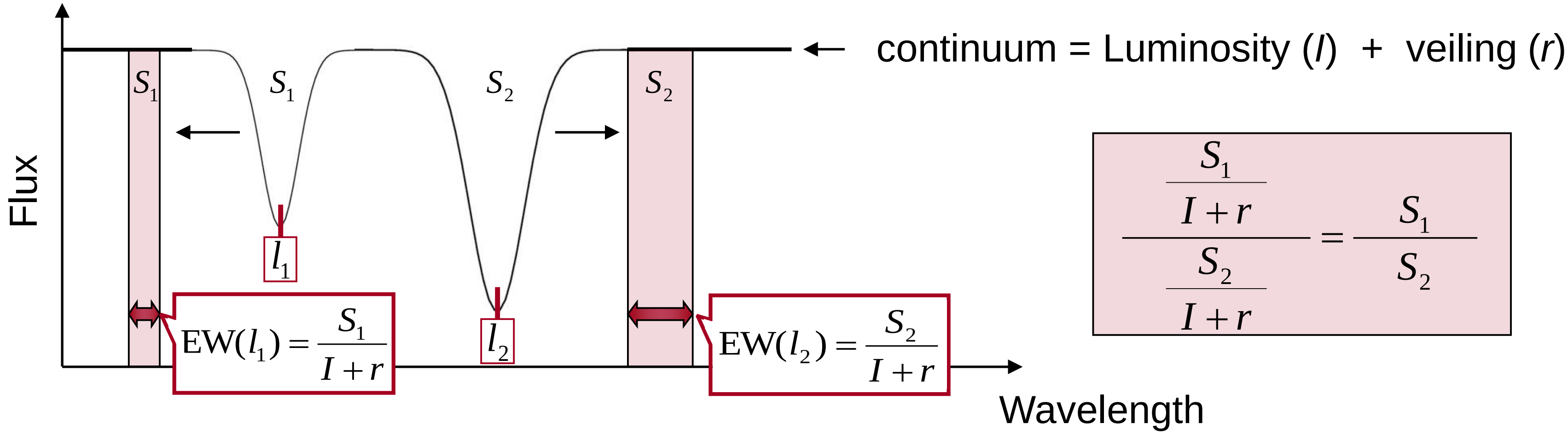
Age estimation by spectroscopy

Precise age determination of PMS stars suffers from the uncertainties of

- Distance - 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 continuum veiling.

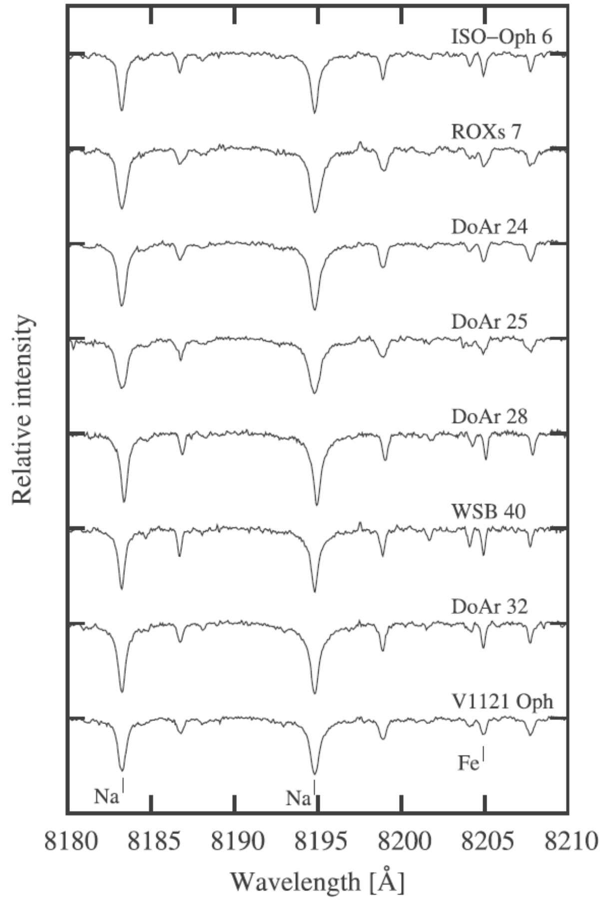


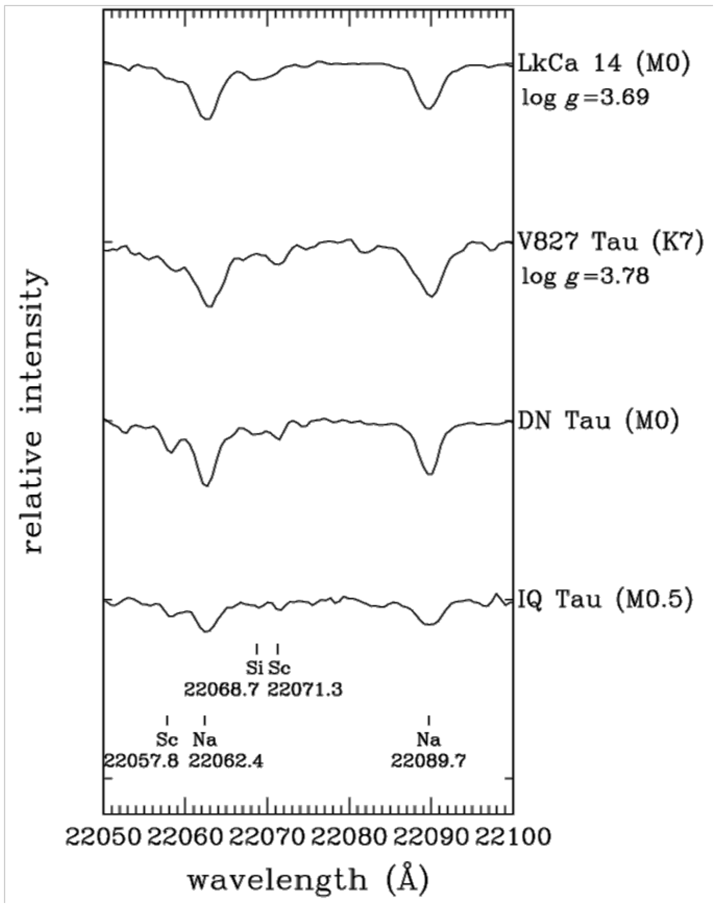
EWR vs. surface gravity

The EWRs used for the surface gravity diagnostic

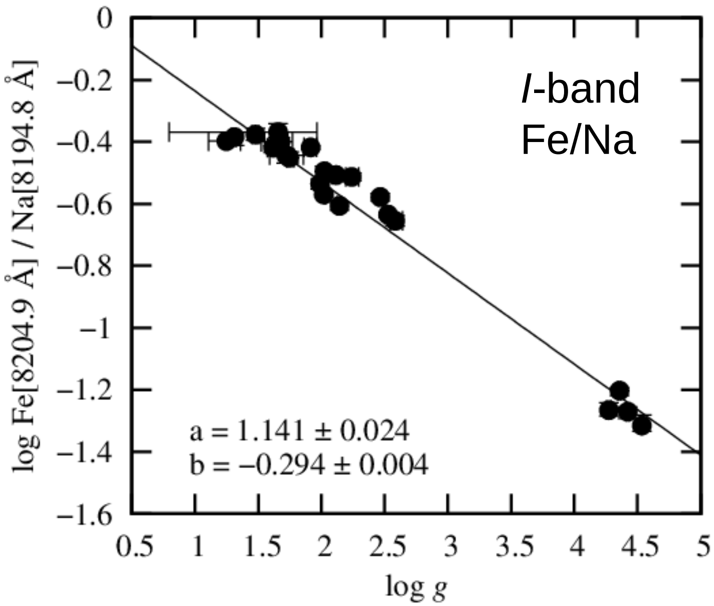
a. Fe and Na lines in the *I*-band for mid-late K type PMS stars

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

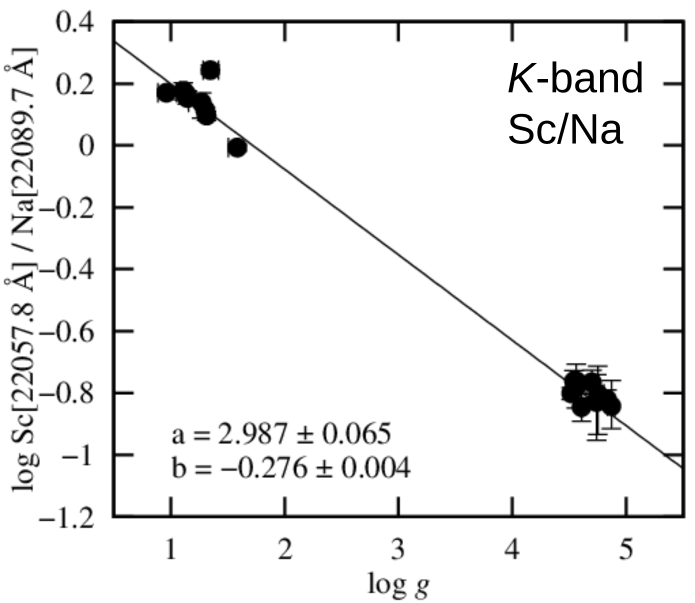




EWR vs. surface gravity



EWR - log *g* relations were estimated by observing field dwarfs and giants with well known surface gravities and nearly equal effective temperatures.



Typical error of log *g* : ±0.1-0.2.

Ages of PMS stars age are able to be estimated with factor of 1.5.

PMS star age determination with EWR

- Observation details

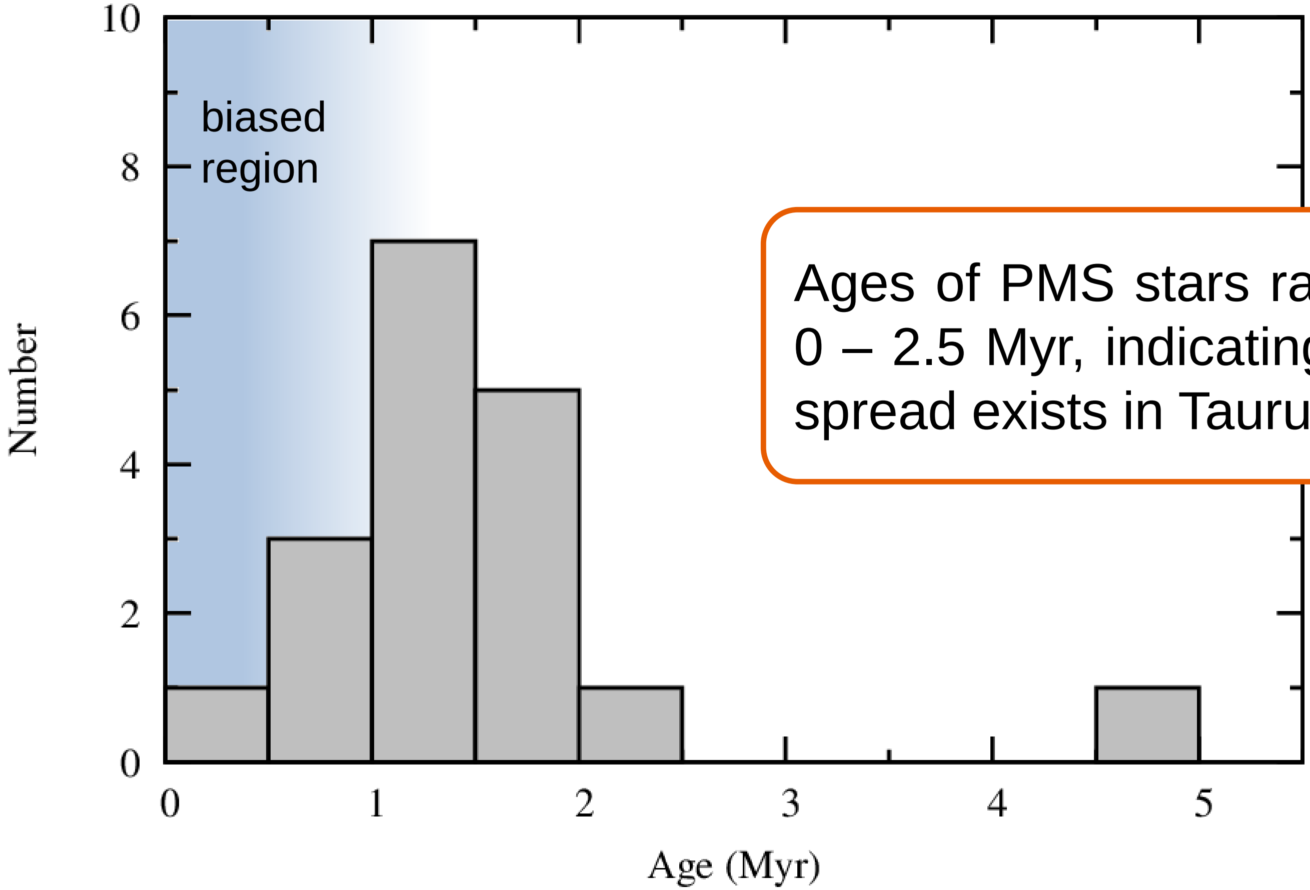
  - Taurus cloud
    - Targets: 18 TTSs
      8 CTTSs, 3 transitional disk objects, and 7 WTTSs
    - Telescopes / Instruments
      Subaru / HDS, IRCS, UKIRT/CGS4,
      Keck / HIRES (archive data)
    - Resolution power : 20000 – 60000
    - S/N : ~100

  - Ophiuchus cloud
    - Targets: 8 TTSs
      (6 CTTSs, 1 transitional disk object, and 1 WTTS)
    - Telescope: Subaru / HDS
    - Resolution power : 60000
    - S/N : ~100

PMS star age determination with EWR

- Taurus
  Average age of 18 PMS stars: 1.4 Myr

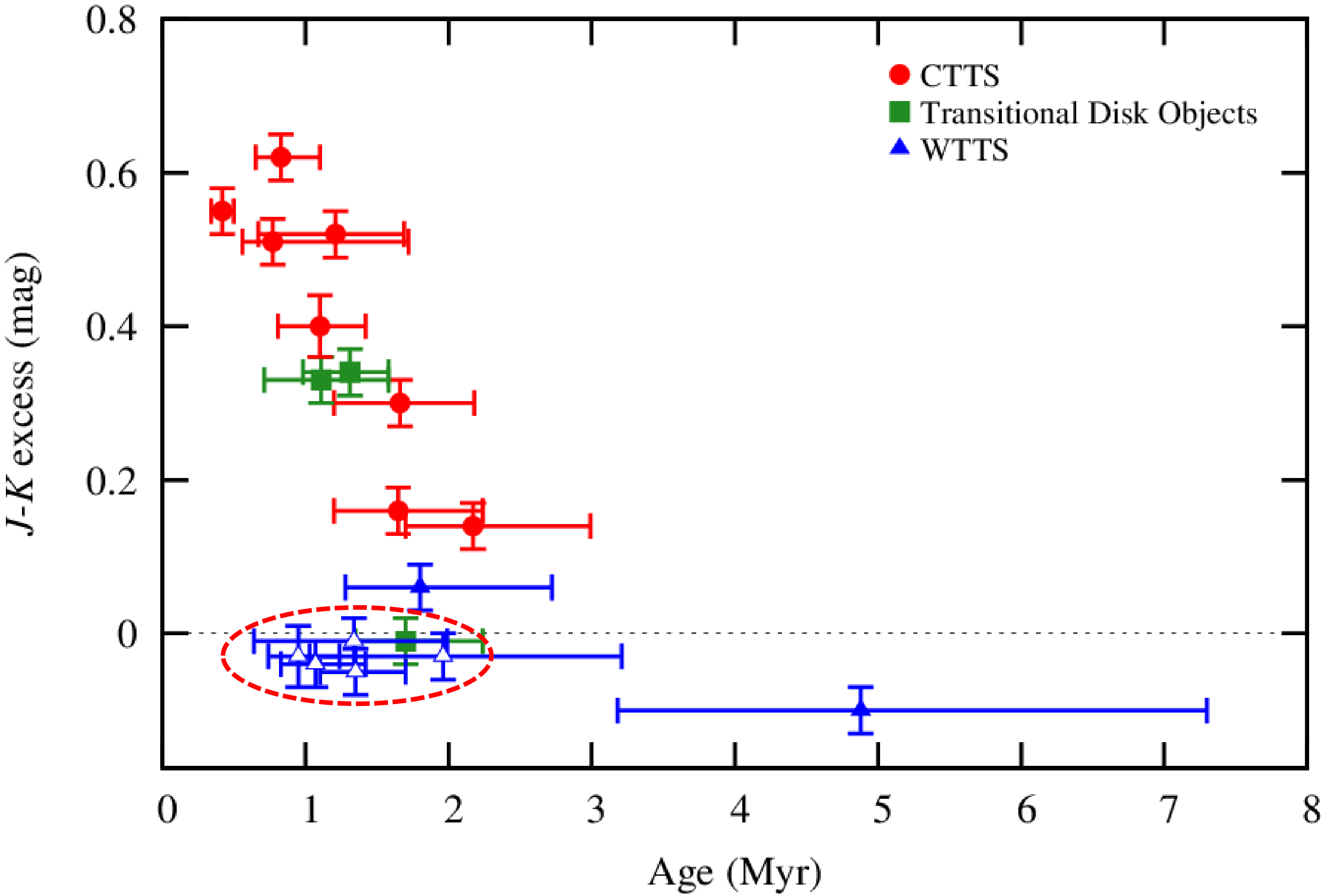
- Age distribution



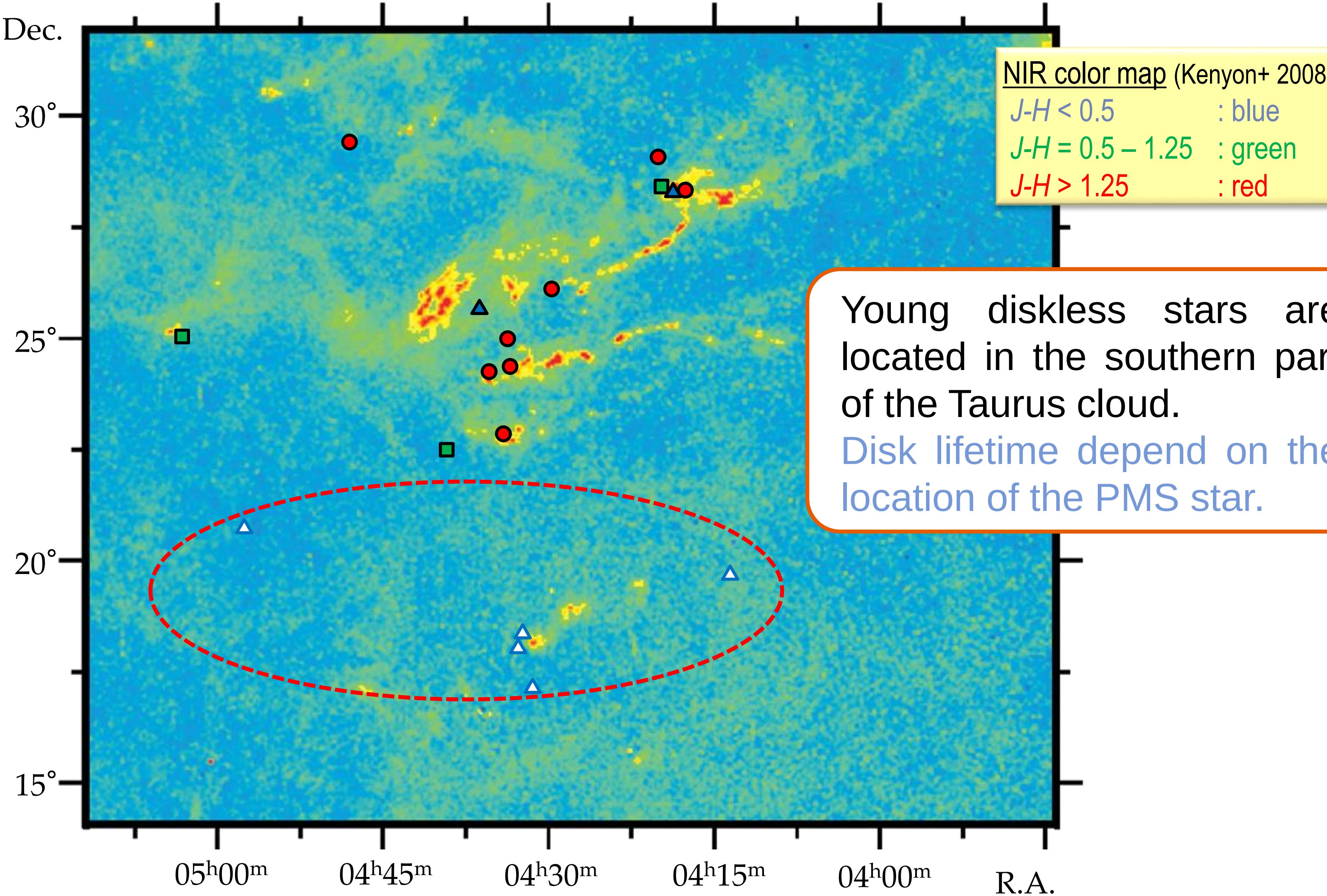
Ages of PMS stars range from 0 – 2.5 Myr, indicating the age spread exists in Taurus.

PMS star age determination with EWR

- Age – near infrared excess relation



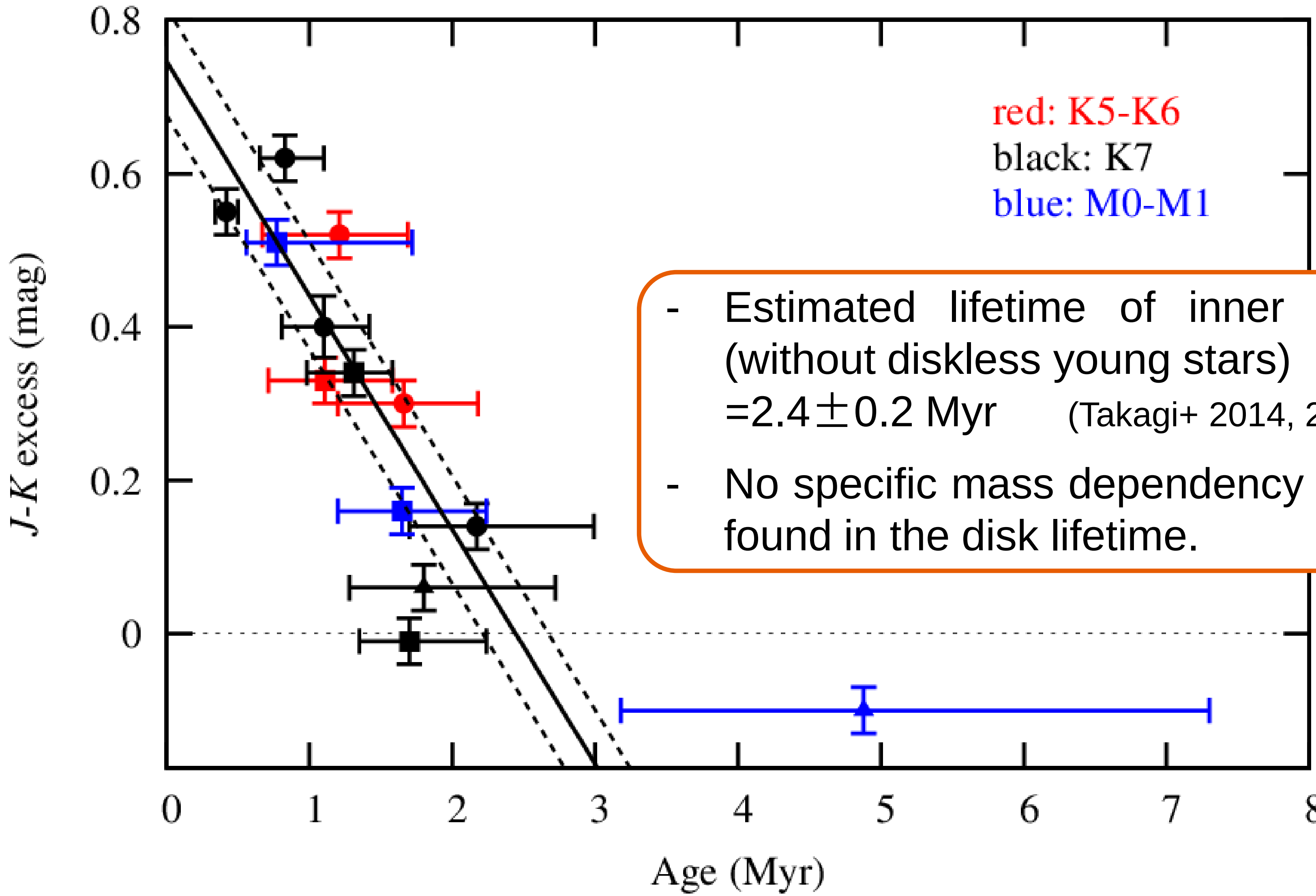
PMS star age determination with EWR



Young diskless stars are located in the southern part of the Taurus cloud.
Disk lifetime depend on the location of the PMS star.

PMS star age determination with EWR

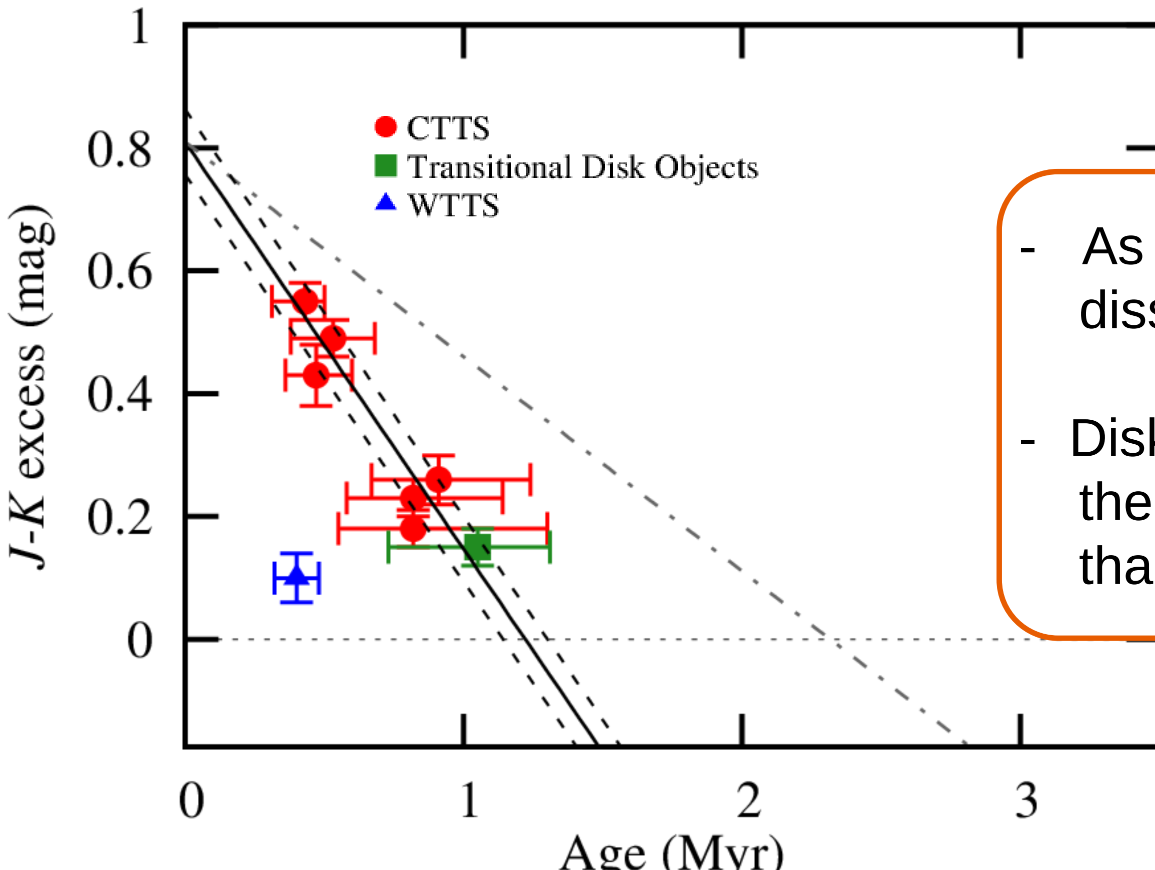
- Disk lifetime in the Taurus



- Estimated lifetime of inner disk (without diskless young stars) =2.4±0.2 Myr (Takagi+ 2014, 2015)
- No specific mass dependency was found in the disk lifetime.

PMS star age determination with EWR

- Disk lifetime in the Ophiuchus



- As same as Taurus, the disk dissipate with time.
- Disk dissipation timescale in the Ophiuchus is more rapid than Taurus, which is 1.2 Myr.

What causes the difference of disk lifetime?

a. Effect of the environment of the molecular cloud

- The molecular cloud of Ophiuchus is stripped away by the radiation from the massive stars in Sco-Cen OB associations (e.g. Wilking+ 2005). Did it also ripped up the disks? (even the inner part of the disk?)
- The environment of the Taurus cloud could be different in the northern and southern part. (Strength of the disk wind (e.g. Suzuki+ 2010) ?)

b. Metallicity dependence

- Metallicity dependence is discussed both in the theoretical (Ercolano+ 2010) and observational studies (Yasui+ 2010).
- However, the metallicity of both Taurus and Ophiuchus is estimated as solar abundance (Fukagawa-san's talk).

→ Metallicity investigation with no dependency on veiling is necessary for accurate discussions.

Summary

To discuss the evolution of the PMS stars and disks, we used the EWRs for a surface gravity indicator. EWR is a fine tool for surface gravity and age determination since it is independent of veiling, extinction, and distance uncertainty.

The log *g* of PMS stars can be estimated with uncertainty of ± 0.15. The age of the PMS stars are able to be estimated with a factor of 1.5.

From the EWR method, we confirmed a spread in the age of the PMS stars in the Taurus. Some young WTTSs with no *J-K* excess are located in the southern part of the cloud, which implies that the disk lifetime depends on the location of the star.

The disk dissipation timescale of PMS stars in the Taurus and Ophiuchus are estimated as 2.4 Myr and 1.2 Myr, respectively, which also indicates that the disk lifetime is different between the star-forming regions.

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