Short Lifetime of Protoplanetary Disks in Low-metallicity Environments

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In order to understand protoplanetary disk evolution and planet formation in a wider range of environments than previously studied, we explored the lifetime of protoplanetary disks in the outermost Galaxy ($R_g \gtrsim 15$ kpc), which are known to have a very different metallicity from the solar neighborhood, [M/H] ~ −1 dex.

We obtained the deep near-infrared (NIR) images of six young clusters that are located in the outer Galaxy with known metallicity of [O/H] ≃ −0.7 dex using Subaru 8.2 m telescope[1]. We derived disk fraction for each cluster (Figure 1) and estimated disk lifetime in the environments (Figure 2). As a result, we found that disk fraction of the low-metallicity clusters declines rapidly in < 1 Myr, which is much faster than the ~ 5–7 Myr observed for the solar-metallicity clusters, suggesting that disk lifetime shortens with decreasing metallicity possibly with an ~10^Z dependence[2].

Since the shorter disk lifetime reduces the time available for planet formation, this could be one of the major reasons for the well-known "planet-metallicity correlation", which states that the probability of a star hosting a planet increases steeply with stellar metallicity. The reason for the rapid disk dispersal could be the increase of the mass accretion rate, and/or the effective far-ultraviolet and/or X-ray photoevaporation due to the low extinction; however, another unknown mechanism for the outer Galaxy environment could be contributing significantly. Although more quantitative observational and theoretical assessments are necessary, our results present the first direct observational evidence that can contribute to explaining the planet-metallicity correlation.

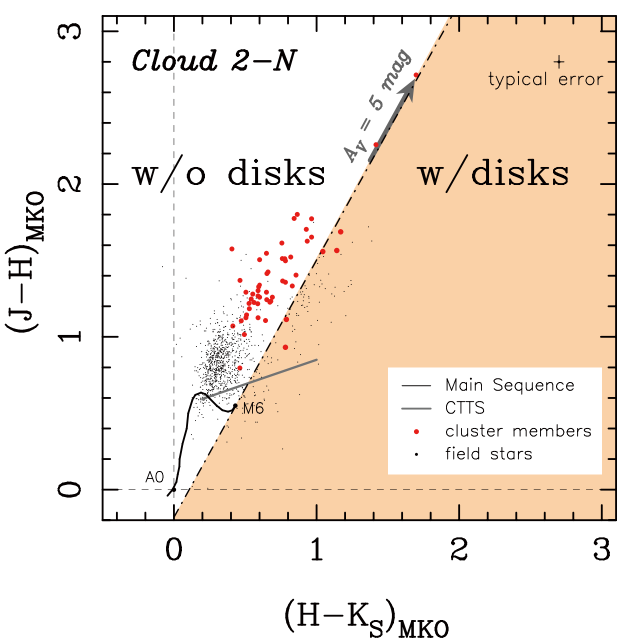

Figure 1: The way of deriving disk fraction for an example cluster, the Cloud 2-N cluster. Disk fraction is defined as the frequency of NIR excess stars (located in orange highlighted region) within a young cluster.

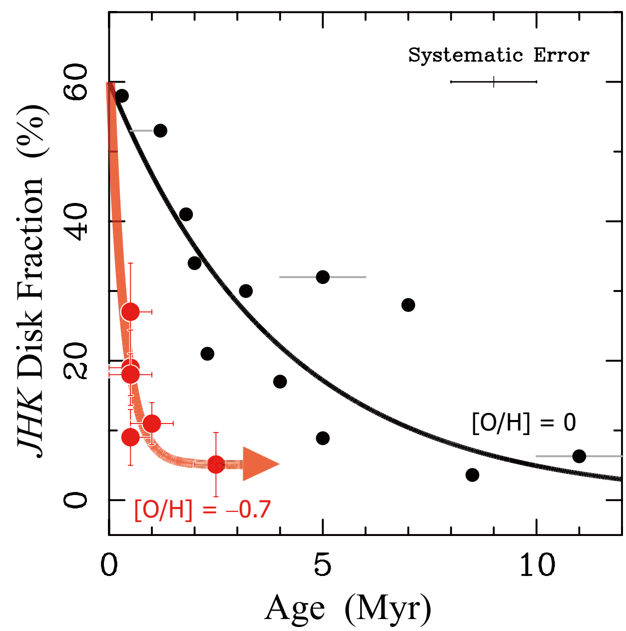

Figure 2: Disk fraction as a function of cluster age. JHK disk fractions of the young clusters with low metallicity are shown by red filled circles, while those of young clusters with solar metallicity are shown by black filled circles. The black line shows the disk fraction evolution under solar metallicity, while the red arrow shows the proposed JHK disk fraction evolution in low-metallicity environments.

References

[1] Yasui, C., et al.: 2009, *ApJ*, **705**, 54.
[2] Yasui, C., et al.: 2010, *ApJ*, **723**, L113.