Nitrile chemistry in a disk structure around the G24.78+0.08 hyper-compact H_{II} region

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Complex nitrile species, such as CH_3CN and HC_3N, have been usually detected in disks around T Tauri stars and Herbig Ae stars (e.g., [1]). The Molecules with ALMA at Planet-forming Scale (MAPS) [2] Large Program reveals that CH_3CN and HC_3N trace different layers of these disks; HC_3N traces upper and warmer layers compared to CH_3CN [3]. Thus, it is useful for investigating physical conditions of disks to observe different nitrile species. However, only CH_3CN lines have been used as typical disk tracers around massive stars (M > 8 M_{sun}) so far, and the nitrile chemistry in disks around such massive stars is still unrevealed yet.

We have analyzed Atacama Large Millimeter/submillimeter Array (ALMA) Cycle 6 Band 6 data toward the hyper-compact H_{II} region G24.78+0.08 A1 (hereafter G24 HC H_{II} region). A current protostellar mass is derived to be ~20 M_{sun} by the SED fitting. Two vibrationally-excited lines of HC_3N (v_7=2, J=24-23, l=0 and l=2e) have been detected from this HC H_{II} region. The spatial distribution and position-velocity (P-V) diagram of the HC_3N line (l=2e) are similar to those of the vibrationally-excited CH_3CN line (v_8=1, $J_{K,l}$ =$12_{6,1}$-$11_{6,1}$). The CH_3CN lines were confirmed to trace the molecular disk in the G24 HC H_{II} region [4]. These results suggest that the HC_3N emission traces the molecular disk around the G24 HC H_{II} region previously identified by CH_3CN.

Using the $^{13}CH_3CN$ (J=13_K-12_K, K=0-6) and $HC^{13}CCN$ (J=26-25) lines, we have derived the $N(^{13}CH_3CN)/N(HC^{13}CCN)$ column density ratios at the two positions around the G24 HC H_{II} region, which we name "HC H_{II} region" and "Molecular Peak", respectively. The $N(^{13}CH_3CN)/N(HC^{13}CCN)$ ratios are derived to be ~3.0-3.5. If there are no effects of the ^{13}C isotopic fractionation in each molecule (e.g., [5]) and the selective photodissociation of $^{13}CH_3CN$ and $HC^{13}CCN$, the $N(^{13}CH_3CN)/N(HC^{13}CCN)$ ratio is expected to reflect the CH_3CN/HC_3N abundance ratio. We compare these $N(^{13}CH_3CN)/N(HC^{13}CCN)$ ratios to the CH_3CN/HC_3N abundance ratio in disks around T Tauri stars and Herbig Ae stars [3], as shown in Figure 1. The $N(^{13}CH_3CN)/N(HC^{13}CCN)$ ratios around the G24 HC H_{II} region are more than an order of magnitude higher than the CH_3CN/HC_3N abundance ratios in the other disks (~0.03-0.11). The higher $N(^{13}CH_3CN)/N(HC^{13}CCN)$ ratios around G24 suggest that the CH_3CN/HC_3N abundance ratios in the disk around the massive star are higher than those around the other disks.

Another possible interpretation of the much high $N(^{13}CH_3CN)/N(HC^{13}CCN)$ ratios around the G24 HC H_{II} region is that the column density ratios do not reflect the CH_3CN/HC_3N abundance ratios. In fact, the integrated-intensity ratios of the vibrationally-excited lines of CH_3CN and HC_3N, which have almost same upper-state energies (~770 K), are derived to be ~ 0.5-1.5 around the G24 HC H_{II} region. These integrated-intensity ratios are still higher than the abundance ratios in disks around T Tauri stars and Herbig Ae stars. Thus, it is most likely that the CH_3CN/HC_3N abundance ratios around the G24 HC H_{II} region are higher than those in the other disks around the lower-mass stars.

The high CH_3CN/HC_3N ratios around the G24 HC H_{II} region imply the thermal desorption of CH_3CN in the hot dense region, and efficient destruction of HC_3N by the UV radiation and reactions with ions (e.g., H_3^+) in the ionized region. The former is supported by the fact that the derived excitation temperatures of CH_3CN (~ 330 K) around the G24 HC H_{II} region are much higher than its sublimation temperature. This is different from a suggestion that the photo-evaporation is important in disks around T Tauri stars and Herbig Ae stars. The higher UV photodissociation rate of HC_3N compared to CH_3CN [6] can destroy both HC_3N and $HC^{13}CCN$ efficiently, which should increase the CH_3CN/HC_3N abundance ratios and the $N(^{13}CH_3CN)/N(HC^{13}CCN)$ ratios. In summary, the nitrile chemistry around the massive star is likely different from that in the disks around T Tauri stars and Herbig Ae stars.

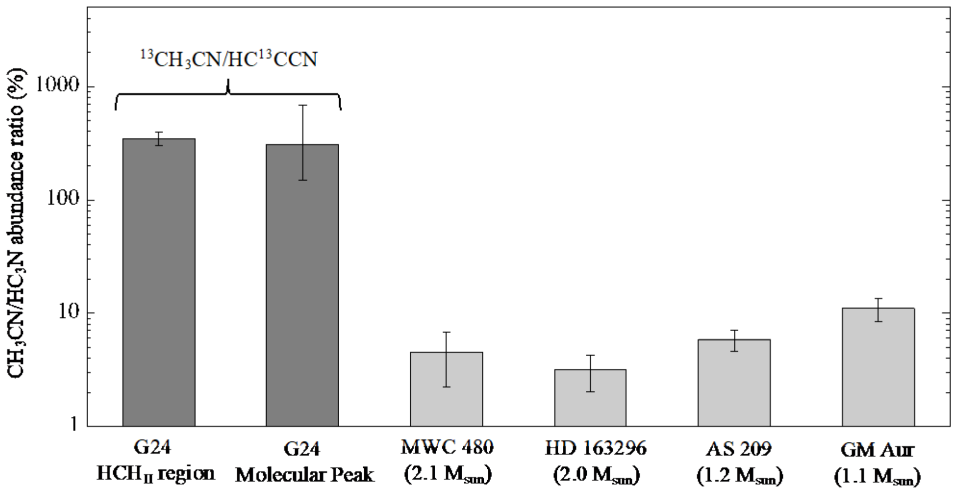

Figure 1: Comparisons of the CH_3CN/HC_3N abundance ratio among disks with different stellar masses.

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