Chemical Evolution in Turbulent Disks: Stochastic Effect by UV photons

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Whether the complex organic molecules (COMs) detected within the disk are inherited directly from the protostellar stage or are chemically processed within the disk itself remains a topic of debate. Our research aims to shed light on this debate by studying the chemical evolution of COMs in these dynamic environments. First, we trace the grain motion (advection, turbulent diffusion, radial drift, and vertical settling) of individual dust particles for 10^6 yrs on a physical structure model of a protoplanetary disk[1]. Next, we solve a gas-ice chemical reaction network along the trajectories and obtain the temporal evolution of molecular abundances.

Our findings underscore the pivotal role of UV flux in the formation of COMs within turbulent disks. The journey of each grain particle, marked by its unique thermal and UV exposures, results in diverse chemical evolutionary among grains even if the cumulative UV dose is same. Contrary to the hypotheses of past research[1], there is not a direct proportionality between the abundance of COMs and cumulative UV exposure. High UV exposure convert oxygen into CO_2, diminishing the abundances of oxygen-bearing COMs. Nitrogen, however, is not locked into certain species, leading to the high abundances of COMs, even under intense UV exposure. Notably, a threshold UV fluence of around 500 [G_0 * years] signals the decline of COMs with oxygen, mirroring the reduction trend of the major source of radical, i.e. CH_3OH. Since COM abundances depend on the stochastic evolution of physical parameters, grains ended up in a similar disk radius will show significant diversity of COM composition.

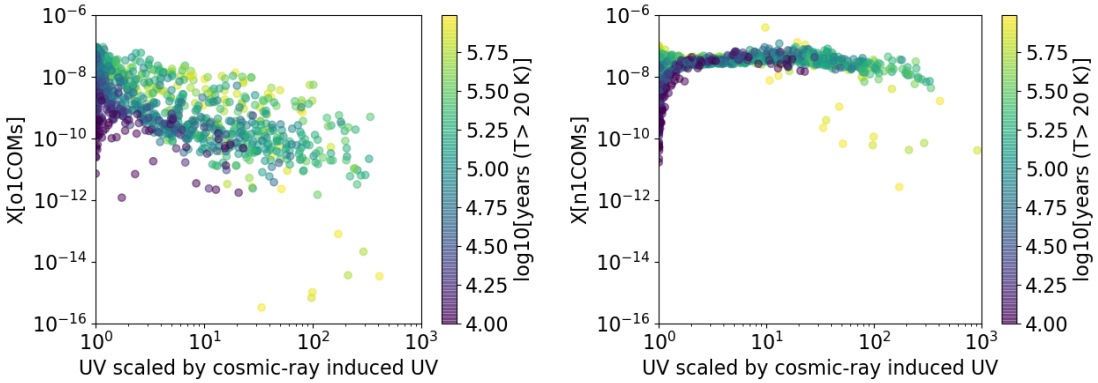

Figure 1: Abundance of COMs containing at least one O (excluding CH_3OH) and COMs containing at least one N, after 10^6 years of turbulent motion. The horizontal axis represents cumulative UV exposure.

References

[1] Ciesla, F. J., & Sandford, S. A. 2012, Science, 336, 452