Probing the radial and vertical structure of an edge-on protoplanetary disk with ALMA and NOEMA

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Understanding how complex molecules evolve and lead to the emergence of life is one of the fundamental questions in astrophysics. A key step toward answering this question is to determine where these molecules form and how they are processed in planet-forming environments. Protoplanetary disks, dense rotating structures of gas and dust surrounding young stars, play a central role in this chemical evolution.

Edge-on disks provide a unique opportunity to directly probe the vertical structure of gas and dust, offering critical insight into molecular stratification and the physical processes governing planet formation. We analyze the disk around Tau042021 using archival ALMA observations of CO isotopologues (^{12}CO, ^{13}CO, $C^{18}O$), N_2H^+, DCO^+, H_2CO, and the continuum, combined with new NOEMA data on HCO^+, HCN, CS, and C_2H. Using a tomographic approach together with the DiskFit radiative transfer model, we derive radial and vertical profiles of gas and dust temperature and density.

Our results reveal a vertically extended gas structure, with clear molecular stratification between a cold mid-plane and a warmer disk atmosphere. Some molecular emission traces material above the disk, possibly linked to a wind, and gas is detected beyond the dust outer radius, indicating that the gaseous component is more extended than the continuum. Overall, these observations provide constraints on the thermal structure and mass distribution of the disk.

These results highlight the power of molecular tomography in constraining the vertical structure of protoplanetary disks. At the same time, they underline the importance of combining multiple molecular tracers to capture the complexity of disk chemistry and to refine thermo-chemical models of planet-forming environments.