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CN: A Sub-Thermally Excited Molecule Tracing The Atmospheres of Protoplanetary Disks

The formation and subsequent evolution of planetary systems are dictated by the physical structure of their birth environment, the protoplanetary disk. Constraining this structure is therefore of the utmost importance if we are to confront planet formation theories and understand the planet forming potential of the systems we observe. To this end, LTE excitation analyses of simple molecular species have proven fruitful in extracting gas temperatures at a range of radii and heights within the disk, but have provided few constraints on disk density structures.

In addition to its utility as a tracer of magnetic field strengths through Zeeman-splitting, CN is a potential density tracer if it is found to be found in the low density atmospheres of disks as suggested by the modelling of Cazzoletti et al. (2018). Thus far the literature has offered conflicting assessments on the location of CN, however, with studies suggesting that either the CN emission arises from cold gas close to the disk midplane and is in LTE, or arises from warmer gas in the more tenuous atmosphere and suffering from sub-thermal excitation. It is essential for the interpretation of future Zeeman observations to distinguish between these scenarios. In this talk I present a comprehensive non-LTE analysis of 27 resolved hyperfine components of the CN $N=3-2$, $2-1$, and $1-0$ transitions toward TWHya, the closest planet-forming disk. Our analysis provides unambiguous evidence that CN emission is sub-thermally excited and comes from the disk surface. We additionally resolve two hyperfine splittings that had not previously been observed in either the laboratory or space, refining the spectroscopic constants for CN and providing better predictions for future Zeeman studies.