Photochemistry of small carbon molecules around evolved stars

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Circumstellar envelopes (CSEs) around Asymptotic Giant Branch (AGB) stars are fascinating regions from a chemical point of view. These environments are the main factories of dust in space, and are also extraordinary chemical laboratories where a large variety of molecules, some of them quite exotic by terrestrial standards, is synthesized. These objects offer a privileged environment where to study how chemistry works in the outer space because, unless other circumstellar and interstellar regions, here the starting conditions and initial chemical composition are relatively well constrained. In these objects chemistry takes place as matter expands nearly isotropically from the hot and dense stellar photosphere, where temperature and abundances are relatively well constrained, out to the outermost interstellar-like regions.

The chemistry in envelopes around AGB stars has been relatively well understood from decades. In the standard scenario, stable molecules are formed in the hot and dense stellar photosphere under chemical equilibrium conditions and are further injected into the expanding wind. At the temperatures and pressures of AGB photospheres, chemical equilibrium imposes a very specific chemical composition in which carbon monoxide (CO) locks most of the carbon in O-rich stars (C/O < 1) and most of the oxygen in C-rich stars (C/O > 1). As matter expands, in the outer circumstellar layers the material starts to be strongly photoprocessed as a consequence of the increasing exposure to the ultraviolet interstellar radiation field. The stable molecules produced in the innermost circumstellar regions are then photodissociated and the newly formed radicals react to form new species. This scenario imposes tight constraints on the types of molecules that can be found in CSEs around AGB stars and on their spatial distribution. With a few exceptions, no C-bearing molecules should be present in O-rich objects and, similarly, there should not be O-bearing molecules in C-rich objects. Moreover, those molecules formed under chemical equilibrium in the innermost regions should display a spatial distribution concentric around the star while those produced by photochemistry in the outer layers should be distributed as a hollow shell located at a specific distance from the star.

This standard scenario provides a resonably good overall description of the circumstellar chemistry and, in general terms, has been validated by extensive observations. There are however a number of observational aspects that do not fit into this scenario, and the number continues to grow as new telescope facilities such as Herschel and ALMA are probing new spectral ranges with unpredecented sensitivity and angular resolution [1]. In this talk I will survey some of the most intriguing chemical mysteries that we do not still understand, and which is leading to a severe revision of the current paradigm on the chemistry of circumstellar envelopes around AGB stars.

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References

[1] Agúndez, M., Cernicharo, J., Quintana-Lacaci, G., et al. 2017, A&A, 601, A4