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Chemical inventory of Class I protostars with IRAM-30m: A bridge between protostars and planet-forming disks

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Understanding how molecular complexity varies in Sun-like star forming regions is mandatory to comprehend whether the chemical composition of the protostellar stages is inherited by protoplanetary disks and planets. In this perspective, our ambitious overall goal is to follow the chemical evolution from the earliest protostellar stages to the relics of our pristin Solar System, i.e. comets. We investigate the chemical composition of Class I protostars, with a typical age of 10^5 yr. Class I sources represent a bridge between Class 0 protostars (about 10^4 yr), where the bulk of the material that eventually form the protostar is still in the envelope, and the Class II protoplanetary disks (10^6 yr). The importance of the Class I stage has been recently strengthened by recent ALMA images showing that planet formation occurs already in disks with ages < 1 Myr. Unfortunately, only very few Class I sources, e.g. SVS13-A and Ser-17, have been chemically characterized through spectral survey at millimeter wavelengths. Therefore, we are still far to conclude if Class I protostars are also a bridge from a chemical point of view.

In this context, and in the framework of the H2020 MSCA ITN Project AstroChemical Origins (www.aco-itn.org), we present a chemical census of 4 Class I sources: L1551-IRS5, L1489-IRS (in the Taurus star forming region) and B5-IRS1, L1455-IRS1 (in Perseus). We used IRAM 30m single-dish observations at 1.3 mm sampling spatial scales of 1500-2500 au. We detect up to 80 lines (depending on the source) due to 27 species: from simple molecules (e.g. S-bearing: OCS, H_2S, CCS, H_2CS, N-bearing: CN, HNCO, C-chains: c-C_3H_2, c-C_3H, D-species: CCD, DCN, D_2CO, CH_2DOH, ions: N_2D^+, DCO^+) to the so called interstellar Complex Organic Molecules (iCOMs), which can be considered as the bricks of a prebiotic chemistry (H_2CO, H_2CCO, CH_3OH, CH_3CN, CH_3CHO, CH_3CCH, $HCOOCH_3$).

All the sources are associated with high-velocity CO, H_2CO, and SO outflows. In addition, our observations show a chemical differentiation, that can be summarized as follows: (1) we detect hot corino chemistry in one source, L1551 -IRS5, revealed by iCOMs as well as OCS, H_2S, which could be the main S-bearing carriers on icy grains; (2) the envelopes of all the protostars are rich of carbon-chains molecules; (3) we find that the iCOMs of L1551 have similar abundance ratio, within one order of magnitude, as Class 0 and Class I hot corinos previously observed.

We also compare the iCOMs abundance ratios as measured in the Class I source L1551-IRS5 with those measured in comets Hale-Bopp, Lemmon, Lovejoy, and 67P to understand if the cometary composition is inherited from the previous evolutionary stages. We find that the iCOMs abundance ratio (e.g. CH3CHO/HCOOCH3) at the Class 0 and Class I protostellar stages is comparable with that of comets, suggesting that cometary material could be inherited from the early stages of the star forming process leading to a Sun-like star. These results are a basis to future follow-up interferometric observations aimed to obtain a full inventory of the chemistry of Class I sources and to reconstruct the chemical route from Class 0 protostars to protoplanetary disks and planets.