Report from
the Short Term Mission – STM

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Report:

1. TOPIC

- The stable less abundant isotope of nitrogen, ^{15}N, is enriched in comets and carbonaceous chondrites with respect to the value measured in the Protosolar Nebula (PSN), but the reasons for the ^{15}N-enrichment are still highly uncertain. From an observational point of view, a way to understand why ^{15}N is enriched with respect to ^{14}N is to measure and compare the abundances of molecules through (sub)mm observations of molecular transitions: to do that, radiotelescopes with single-dish antennas and interferometers (which provide higher spatial resolution with respect to single-dish antennas) are needed. In particular we have observations taken at the IRAM-30m Telescope in June 2015: 27 high-mass star forming cores were observed in the receivers at 3 and 2mm, and through the ground state rotational transition of $H^{13}CN$ and $HN^{13}C$ (and ^{15}N-isotopologue) we have measured the $^{14}N/^{15}N$ ratios in order to compare one with each other (Colzi et al., 2018a). We have also other IRAM-30m observations of high-mass star forming cores, for a total sample of 90 sources and we have searched for a Galactocentric trend of the $^{14}N/^{15}N$ ratios, in the same molecules, HCN and HNC (Colzi et al., 2018b, MNRAS in press). Moreover, the most recent and complete gas-phase chemical models (Roueff et al., 2015, Wirström & Charnley, 2018) indicate that ^{15}N should not be enriched in HCN and HNC during the evolution of a star-forming core. In our works on $HCN/HC^{15}N$ (and $HNC/H^{15}NC$), we computed the $^{14}N/^{15}N$ considering the isotopologues $H^{13}CN$ and $HN^{13}C$, which have the advantage of being optically thin with respect to those including the ^{12}C but require to be corrected for the $^{12}C/^{13}C$ ratio. The model of Roueff et al. (2015) considers also the time-dependence of the $^{12}C/^{13}C$ ratio in different molecular species in low-mass cores. It is shown that the $^{12}C/^{13}C$ ratio evolves with time in a different way for each molecule, reaching up to a factor two higher than the local ISM value. In this respect, we decided to start studying C-fractionation in order to constrain, also with grain and gas-grain reactions, N- and C-fractionation results.

2. PROPOSED AND PERFORMED WORK

- I have worked with Prof. Paola Caselli and Dr. Olli Sipilä starting to work with a chemical model in order to understand nitrogen and carbon fractionation in high-mass star forming cores. We started to work implementing his gas-phase and gas-grain model (Sipilä et al., 2015). In particular we have developed new chemical reactions sets including the ^{13}C forms of species with up to five atoms. To study carbon chemistry, we have extended the reaction network to include ^{13}C reactions by running a routine to “clone” chemical reactions involving species with up to 5 atoms. Cloning means in this case that in applicable reactions, ^{13}C is substituted in place of ^{12}C which in many cases produces multiple variants of the original reaction. The rate coefficients of the cloned reactions are assumed to be the same as for the original reaction because laboratory data is only available for a limited number of reactions. After that we have implemented the network with the isotope exchange reactions used by Roueff et al. (2015) and other new ones (Roueff et al., personal communication). To be sure that we did a correct work we started to compare step by step our results, with only gas-phase reactions at works, with the outgoing results from Prof. Evelyne Roueff code, that is collaborating with us. We are now continuing this comparison and then we will include the grain-phase and all the chemistry regarding N-fractionation.
- With the preliminary gas-phase implemented network we also tried to make a preliminary work on which is the impact of cosmic rays on the $^{12}C/^{13}C$ ratio in different physical conditions. We were able to create a grid of models that can constrain the observations and then give an estimate of the cosmic-ray ionization rate.
- We found some differences comparing with Roueff models and then we started a cross check of all the reactions finding some differences on reactions and rate coefficients used. Most of the time these differences are due to the chosen rate coefficient that could be different because of new reactions that are not implemented in the online catalogue that we used (KIDA). We are trying to update every new reaction that we find, but in general our results are almost the same: for example we found the same behavior for $^{12}C/^{13}C$ in many molecules, even if the achieved values are not the same.

3. CROSS-DISCIPLINARITY

- It is well known how in astrochemistry it is important the collaboration of three types of researchers: observers, modelers, and laboratory experts. In our Star Formation Group in the Observatory of Arcetri (Florence) most of the researchers are specialized in the analysis of observations, taken with the best existing radio telescopes (NOEMA, IRAM-30m, ALMA, VLA), as well as with instruments operating at different wavelengths. Therefore, to compare our results with astrochemical models most of the times we have to ask our collaborators in other Institutes, making the process of data analysis less efficient. This part of my PhD thesis in collaboration with the experts in astrochemical models at MPE is an opportunity for me and for all the Arcetri star-formation group to implement the internal knowledges. Moreover, thanks to the link between MPE and Arcetri created by me, in the future new students could start to work in our group (for Master thesis or PhD thesis) and could have the chance to learn something both from an observational point of view and from the models.
- This work will be important also to interpret my observations made in collaboration with part of people working in Arcetri. Moreover will be important to try to explain the link between our Solar System and his origins.

4. IMPACT

- Because transitions of molecules having less abundant isotopes are expected to be fainter, in general, our observations need to have more and more sensitive receivers, and also broader frequency bands. This last requirement is particularly relevant for astrochemical studies because larger receiver bands will provide more molecular transitions in a single spectrum. These reasons lead the industries to produce even more refined radio-receivers for radiotelescopes like IRAM-30m or for the antennas which compose the NOEMA interferometer.

5. PUBLICATIONS

- After we will finish all the implementation of the chemical model we will write the first paper of presentation of the work.
- We have prepared a poster for the conference “Cosmic Rays: the salt of the star formation recipe” held in Florence from 2 to 4 May 2018. The title is: “Carbon isotope chemistry in intermediate and high-mass star-forming cores: the impact of cosmic rays”. The poster will be soon available online on the webpage: https://www.arcetri.astro.it/cosmicrays/