Photograph : Nicolas Biver

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New molecules in comet Hale-Bopp plead for an interstellar origin of the cometary ices Comets are formidable tools for the comprehension of the formation of the Solar system. They were formed 4.5 billion years ago, at the same time as the Sun, in the outer parts of the Primitive Solar Nebula - probably at the distance of Uranus and Neptune -, and are, with the asteroids, the direct descendants of the small bodies whose agglomeration gave rise to planets. Relegated to the borders of the Solar system in a very cold environment, the cometary cores evolved very little since their formation. The study of their chemical composition thus gives us access to the chemical composition of the outer parts of the Solar Nebula such as it was 4.5 billion years ago. It is essential to establish whether this composition reflects the composition of the interstellar protosolar cloud or whether it reveals the chemistry which would have taken place in the Primitive Nebula, like that invoked in the inner parts to explain, for example, the composition of the meteorites. The identification of volatile compounds present in the ices of cometary cores is not easy. The cometary core is too small to be accessible directly, except during space explorations. The compounds are observed in a gaseous state in the cometary atmosphere. Their spectral identification requires millimetric, submillimetric and infrared spectroscopic techniques, and requires bright comets. The passage close to the Sun in April 1997 of comet Hale-Bopp - very exceptional by its activity - made it possible very spectacular improvements of our knowledge of the molecules which compose the cometary ices. Observations of radio spectroscopy at the interferometer and 30m telescope of the Institut de RAdioastronomie Millimetrique (IRAM), and at Caltech Submillimeter Observatory (CSO) led to the identification of 7 new molecules : the sulphur monoxide (SO), the sulphur dioxide (SO 2), formic acid (HCOOH), formamide (NH 2 CHO) cyanoacetylene (HC 3 N), the methyl formate (HCOOCH 3) and the ethanal (CH 3 CHO). These observations also made it possible to confirm the presence of HNCO and OCS, which had been identified one year before in comet Hyakutake. Two dozen molecules are now identified in comets. Several of the cometary molecules were never observed in other objects of the Solar system whereas they are present in the star forming regions of the interstellar medium, more specifically in the molecular hot cores. These dense areas are heated by the radiation of recently formed massive stars. Their composition differs from that of the molecular cold clouds by the presence in abundance of hydrogenated molecules,

such as H2O, NH3, CH3OH and H2S, and of complex organic molecules, in particular those detected in comet Hale-Bopp. A great majority of these molecules were probably synthesized on the surface of the interstellar grains and were released in the gas phase of the molecular hot cores by sublimation. The abundance ratios in the cometary ices present strong similarities with those measured in the molecular hot cores (cf the figure above for the organic molecules). The identification by the infra-red telescope onboard the satellite ISO of some simple compounds constituting the interstellar ices had made it possible to underline analogies of composition between interstellar ices and cometary ices for the major components. The comparison with the molecular hot cores extends this analogy to all molecules detected in comets. This pleads in favour of a formation of the cometary molecules in the protosolar cloud, or in any case by processes very similar to those met in the interstellar medium : ion-molecule reactions and on the grains surface, in opposition to neutral-neutral reactions in the inner Solar Nebula.

Reference :

Bockelée-Morvan, D., Lis, D. C., Wink, J. E., Despois, D., Crovisier, J ., Bachiller, R., Benford, D. J., Biver, N., Colom, P., Davies, J. K., Gérard, E., Ge rmain, B., Houde, M., Mehringer, D., Moreno, R., Paubert, G., Phillips, T. G., Rauer, H. : 2000, New molecules found in comet C/1995 O1 (Hale-Bopp). Investigating the link between cometary and interstellar material. Astronomy and Astroph ysics 353 , 1101 To know more about the observational campaign of comet Hale-Bopp. Contacts : Dominique Bockelée-Morvan, Jacques Crovisier, Observatoire de Paris, ARPEGES

