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12
Jan 9th 2007
E-SPACE & SCIENCE
THE SCIENTIFIC BULLETIN OF CNES, CENTRE NATIONAL D'ETUDES SPATIALES

Desperately seeking POM

Sources

Heliocentric evolution of the degradation of polyoxymethylène : application to the origin of the formaldehyde (H_2CO) extended source in Comet C/1995 01 (Hale-Bopp),
Nicolas Fray, Yves Benilan, Nicolas Biver, Dominique Bockelée-Morvan, Hervé Cottin, Jacques Crovisier, Marie-Claire Gazeau
Icarus, volume 184, issue 1, september 2006, 239-254,

Notes

Molecular cloud:
Molecular clouds are interstellar clouds whose density and size permits the formation of molecular hydrogen from atomic or ionised hydrogen. Turbulences animate these clouds and create the necessary conditions for the formation of stars.

Sublimation:
The transition of a substance from the solid state to the gaseous state, without passing through the liquid state. This transformation occurs in specific pressure and temperature conditions.

Coma:
The visible envelope around the nucleus of comets developed as they approach the Sun. This sphere is composed of neutral gases and dusts, and is several hundreds of thousands of kilometers in diameter.

Astronomical unit:
Average distance between the Earth and the Sun, i.e. approximately 150 million kilometres.

Comets are one of the most mysterious bodies in the Solar System. They are formed from a material contained in a molecular cloud that collapsed to give birth to our Sun and its trail of planets.


Comète Hale-Bopp en avril 1997 (© Nicolas Biver)

Comets are small bodies that move around the Sun in very elliptic orbits. They consist of a solid nucleus, mainly composed of ices and dust. When they come close to the Sun, their surface heats up, and the ice sublimates causing streams of gas which carry dust and molecules that ionise. This forms the coma, and the two characteristic tails that are sometimes visible to the naked eye. One of the tails is formed by the ions and the other by the dust.

As they are small in size, most comets have probably not undergone any differentiation process. Their out-of-round orbit means they are only occasionally exposed to the sun's rays. The substance of comets has probably not been modified since the formation of our solar system and may therefore have kept traces of the physical and chemical conditions that reigned at the time.

Through Earth-based observation, approximately twenty small molecules have been identified in the coma and in the tails of comets. Water and carbon monoxide and dioxide are the most abundant. Small concentrations of volatile organic compounds such as methane, methanol, hydrocyanic acid and carboxylic acid have also been detected. However, according to the very first analyses done in-situ by the Giotto and Vega probes during the Halley exploration mission in 1986, comets could contain much more complex molecular structures.

For more than ten years, the abundance of formaldehyde (H_2CO) has intrigued observers. The sublimation of frozen formaldehyde from the nucleus does not fully explain the quantities found. It is believed to form gradually inside the actual coma and represents, in comet-speak, an extended source. In cometary conditions, no other transformation of a gaseous compound can explain these observations.

Polyoxymethylene, also known as POM ($-CH_2-O-$)n, has often been raised to explain the origin of the formaldehyde of which it is a polymer. The possibility of it being present in the material of the comet's nucleus cannot be verified for the time being. In fact, the organic matter that exists in a solid

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POM from modeling to measurement

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Differentiation:
During the formation of a planet, differentiation occurs if, under the effect of gravity and internal sources of heat, the matter fluidifies causing the segregation of heavy atoms, like iron and nickel, which sink to the core. Conversely, lighter materials rise to the surface and create the crust. The diameter of the planetary body must be at least five hundred to a thousand kilometres.

Extended source:
The chemical reactions in the coma cause the emission of remotely-detectable molecules. This phenomenon extends over an area of several hundreds of thousands of kilometres in diameter creating an extended source. In contrast, the nucleus is considered to be a point source of a few hundred metres to a few kilometres in diameter.

Polymer:
This is a chain of small repeating molecules. It can form very large molecules which sometimes fold back onto themselves.

Refractory material:
Substance which remains solid at the maximal temperatures that a comet or an asteroid can meet in natural conditions. Refractory is the opposite of volatile.

*by the "Comets" team at the Observatoire de Paris-Meudon.

state in the nucleus can not be detected by remote measurements. This refractory material is only revealed by the volatiles resulting from its degradation under the effect of heat or ultraviolet radiation.

In the lab, the team has developed experimental devices to reproduce conditions similar to those found in the cometary nucleus when it approaches the Sun. They can thus study the products of the thermodegradation or the photodegradation of various solid organic molecules like POM. They compare the results obtained with the observations made on comets and try to determine, indirectly, the nature of the refractory material they contain.

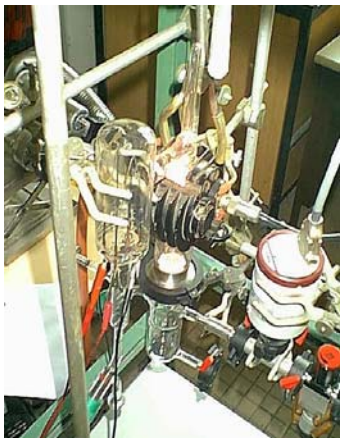

Fig. 1 : Experimental device developed at the LISA to study the photodegradation of molecules of cometary interest. S.E.M.A.PH.OR.E. comet experiment (Simulation Expérimentale et Modélisation Appliquées aux PHénomènes ORganiques dans l'Environnement cométaire – experimental simulation and modelling applied to organic phenomena in the cometary environment).

The Giotto probe measured the distribution of formaldehyde according to the distance from the nucleus in the coma of comet Halley. By adding a small amount of POM in the composition of the cometary grains in the mathematical models computed, results become compatible with these measurements. Furthermore, changes in the production rate of the formaldehyde in relation to distance from the Sun have been estimated* using Earth-based telescopes in the coma of the comet Hale-Bopp. Once again, the results are compatible with the team's hypotheses and with the findings of other laboratories using analogues of cometary ice.

These corroborating results, obtained for two different comets, tend to confirm the hypothesis that POM is present in comets. The matter will most likely be settled thanks to measurements taken by the European probe Rosetta which will arrive, with its lander Philae, near the comet Churyumov-Gerasimenko in 2014.

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Going into (cometary) "coma"

Notes

Thermodegradation:
Degradation of molecules under the effect of heat.

Photodegradation:
Degradation of molecules under the effect of light.

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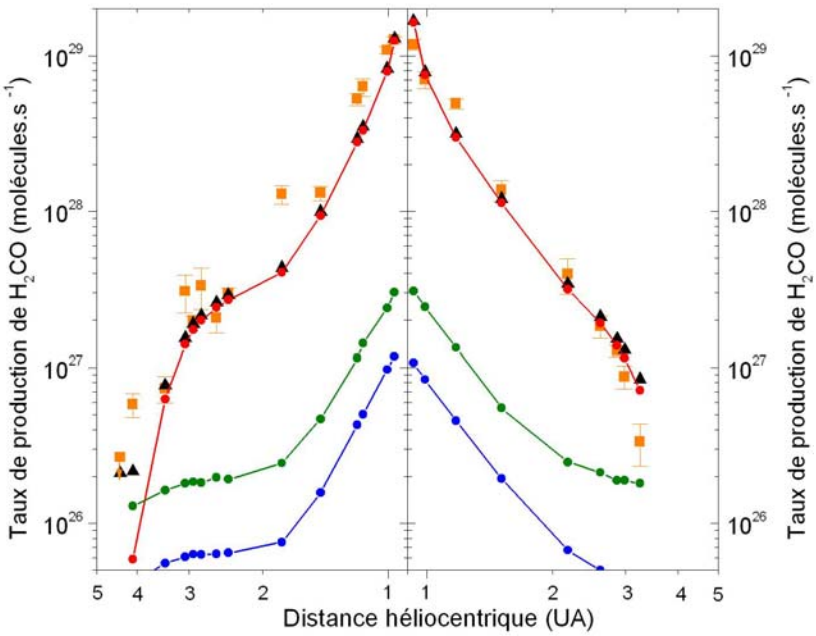

Fig 2 : H_2CO production rates as a function of heliocentric distance in comet Hale-Bopp

- Rates of production of H_2CO observed
- Total rates of production of H_2CO calculated
- Rate of production of H_2CO by thermal degradation of POM (calculation)
- Rate of production of H_2CO by photolytic degradation of POM (calculation)
- Rate of production of H_2CO by sublimation of the ices of the nucleus (calculation)

Careful attention is also paid to other cometary extended sources, i.e. those which respectively produce cyanogen radicals and the carbon monoxide molecule. The organic refractory phase, the dark side of comets, is gradually being discovered through extended sources. Its composition will show the conditions that reigned at the beginning of our Solar System. "Comets are the archives of the solar system and chemistry is the Rosetta stone that will enable us to decipher the message they convey." (*Hervé Cottin*).

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