The Odin satellite detects H218O in comet C/2002 C1 (Ikeya-Zhang)

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Observatoire de Paris
Comet C/2002 C1 (Ikeya-Zhang) displayed its beautiful coma and tails in the spring sky. Discovered on February 1st, 2002 by Kaoru Ikeya and Daqing Zhang, the comet could be seen with naked eye in March and April 2002. Reaching its maximum brightness (visual magnitude of 3) on the end of March, it was the brightest comet since comet Hale-Bopp in 1997. Ikeya-Zhang's closest approach to the Sun occurred on March 19, at a distance of 0.507 AU (1 AU = 150 million kilometres). It came near the Earth, on April 29, at a distance of 0.405 AU. These close approaches, as well as abundant productions of dust and gas from its nucleus, were the reasons for its unusual brightness. With a revolution period of about 360 years, comet Ikeya-Zhang certainly visited our environment many times. Comet Ikeya-Zhang is possibly the great comet that appeared in 1661 and was observed by J. Hevelius. Immediately after its discovery, astronomers carried out a number of experiments in order to study dust and gases released by comet Ikeya-Zhang’s nucleus. Comets indeed provide valuable information about the origin and the formation of the Solar System. Mainly made of water (for 80%), cometary ices contain various other molecules that are relics of the primitive nebula at the epoch of formation of planetesimals. Our present knowledge of comets suggests that many of these molecules were produced in the primordial interstellar cloud, before its collapse gave birth to the Solar System. Since comets are variable objects, measurements of the chemical composition, based on observation of species in the comet atmosphere, must be referred to the water production rate from the nucleus. Water in the Universe cannot be easily observed from the ground, because of the water in the terrestrial atmosphere, which absorbs radiation from space. Most often, the water production rate in comets is deduced from observation of 

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The OH radical. The OH radical is produced by the dissociation of the water molecule by solar UV radiation. The observation of OH lines at 18 cm in comets is one of the key programmes of the Nançay radio telescope. Observations by the Odin spacecraft. The Odin satellite is a small spacecraft, orbiting the Earth, designed and built by Sweden, in collaboration with Canada, Finland and France. It was launched in February 2001. Aimed for studying both the Universe (astronomy) and the terrestrial atmosphere (aeronomy), it allows for the observation of a number of molecular lines, at radio (submillimetre range) wavelengths, otherwise not accessible from the ground: in particular the fundamental water line at 556.9 GHz. The Odin radiometer includes a 1.1 m diameter antenna, several receivers covering the 480-580 GHz frequency range and corresponding spectrometers (one acousto-optical and two auto-correlation spectrometers). The acousto-optical spectrometer was developed under the CNES responsibility by three CNRS laboratories: the LAS in Marseille, the CESR in Toulouse and the radio astronomy department (ARPEGES) of the Paris Observatory. Map of the brightness distribution in H$_{2}^{16}$O obtained on April 21 2002. The beam width is 2 arc minutes. The map was obtained in 6 hours integration time with fifty positions in the sky using the acousto-optical spectrometer. The iso-contours correspond to the line intensity integrated over velocity in K km/s.

The study of water vapour in comets is one of the main topics of the Odin observing programme. The sensitivity of the Odin radiometer allows us to detect water in weakly active comets, and its high spectral resolution capability (80 m/s by using the auto-correlators) provides accurate measurement of line profiles. The first comet detected by Odin was C/2001 A2 (LINEAR), observed from end of April until July 2001. Comet Ikeya-Zhang was observed from April 21 to 29, 2002. First, a detailed mapping of the water vapour brightness distribution in the sky was done at 557 GHz. The line intensity at the centre of the map reached 27 K km/s on April 21 (integrated signal over the line profile), then decreased slowly as the comet moved further away from the Sun. The observations provide a first estimate of the water production rate at about 2 10$^{29}$ molecules/s (i.e. about six tons per second). The line profile, very accurately measured, gives information on the velocity of the water molecules and on their radiation mechanism. For example, one could observe that the line is shifted towards positive speed, due to self-absorption effects in the cometary atmosphere. The strong activity of comet Ikeya Zhang and its close approach to Earth, allowed to carry out more challenging observations. Thus, the isotopic variety H$_{2}^{18}$O was searched for and finally successfully detected.

Oxygen exists under three isotopic, stable varieties: 16O, the most abundant isotope, 17O and 18O. In terrestrial water (oceans), the ratios H$_{2}^{16}$O/H$_{2}^{18}$O and H$_{2}^{16}$O/H$_{2}^{17}$O are 499 and 2681, respectively. The H$_{2}^{16}$O/H$_{2}^{18}$O ratio could only be measured by the ESA Giotto spacecraft in comet Halley using mass spectrometers. For the first time, with Odin, was obtained a spectroscopic measurement of this ratio. The H$_{2}^{18}$O line spectrum, at 547.7 GHz, was detected in comet Ikeya-Zhang after 45 hours of Odin observations and an effective integration time, on the comet, of 28 hours. The line was observed in parallel by using two of the four sub-millimetre receivers, centred at 549 and 555 GHz and tuned at the line frequency. The receiver outputs were connected to the high resolution spectrometers and to the acousto-optical spectrometer. The integrated signal was, as expected, very weak (0.24 K km/s). The successful detection demonstrates the excellent capability of the Odin instrumentation, regarding the receiver sensitivity and stability, as well as the spacecraft pointing accuracy. The preliminary measurement of the H$_{2}^{16}$O/H$_{2}^{18}$O ratio in comet Ikeya-Zhang is in agreement with that measured in terrestrial oceans (500), and confirms measurements done in comet Halley. This result is not surprising. With only a very few exceptions, all bodies in the Solar System show a H$_{2}^{16}$O/H$_{2}^{18}$O ratio similar to the terrestrial one. Differences by an amount of 5% at maximum can be observed in some meteorites. Such variations can be explained by slight differences in nucleo-synthesis sources producing 16O (mainly supernovae), nearby the Solar System formation region.

Involved French Scientists

- Alain Lecacheux, LESIA, Observatoire de Paris
- Nicolas Biver, ESA ESTEC
- Jacques Crovisier, LESIA, Observatoire de Paris
- Dominique Bockelée-Morvan, LESIA, Observatoire de Paris

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