INFRARED ASTRONOMY

The real water-bearer

Sun Kwok

THE Infrared Space Observatory (ISO), launched by ESA last November, has detected water in the planetary nebula NGC7027. Given that water is widely present on Earth, it would seem that it is a natural molecule to be found in the interstellar medium. In fact, the ISO discovery is the first success after many years of searching, and a major step in solving a long-standing puzzle of interstellar chemistry — the missing oxygen problem.

It is generally accepted from solar observations that oxygen is the third most abundant element (after hydrogen and helium) in the Universe. In fact there is believed to be more oxygen than all the other elements combined. It has been detected in various forms in the interstellar medium — the strong green lines in the spectra of gaseous nebulae are from doubly-ionized oxygen, and infrared spectroscopy has seen oxygen in solid form (as ice, for example, or as part of the sand-like silicate compounds commonly seen around cool stars and dark clouds). It is also seen in molecules such as carbon monoxide, which has been widely detected in the interstellar medium. However, only about half of the oxygen implied by solar abundances is accounted for, and the rest remains 'missing'.

Theoretical chemical models imply that most of the oxygen should be in the form of water and O_2 molecules, but the detection of these molecules has proved elusive. Because of the pressure-broadened absorption lines of the same molecules in Earth's atmosphere, most of the line emissions from celestial sources don't reach the ground. Balloon experiments have searched for oxygen, but so far without success.

Although water has been detected in various lines from natural masers, reliable abundances cannot be derived from these observations[1]. The water molecule, being asymmetric, has a complicated spectrum. It is difficult to translate the maser intensity arising from a highly excited state into a total molecular abundance. The most straightforward way to determine abundance is to measure radiation from the ground-state transition.

Attempts have been made to find molecules containing different isotopes of oxygen and hydrogen, which would radiate at frequencies less affected by atmospheric absorption. Astronomers have also tried to use the fact that molecular lines from distant galaxies are redshifted, and so could pass through spectral windows in the atmosphere. All results to date have been negative[2,3].

The most extensive effort has been made by the Cosmic Background Explorer satellite (COBE), which carried a spectrometer capable of measurements in the 100 μm to 1 cm wavelength range. There are a number of important atomic and molecular transitions in this range that are difficult to observe from the ground. With a wide 7-degree beam, COBE was successful in mapping the Galactic plane, and detected emission lines from carbon and nitrogen. COBE found that the 157 μm line from Galactic C II (singly ionized carbon) radiates as much energy alone as 100 million Suns[4].

This radiation escapes into the intergalactic medium, so atomic and molecular lines are powerful agents in the cooling of the Galaxy. However, COBE was only able to put upper limits on water and oxygen abundances. As they are not widely distributed in the Galactic plane, they must be much less abundant than we thought, or they are only concentrated in small volumes. COBE, with its wide beam, will fail to detect signals from small sources. This has brought home the need for a large antenna (therefore a narrow beam) to search for possible locations of oxygen and water molecules, such as stellar envelopes or cores of star-forming regions.

The ISO results are not only a positive step in the solution of the missing oxygen mystery, they also pose some new questions. The object in which water was detected (NGC7027) is a very young planetary nebula with a massive envelope of dust and molecular gas left over from its progenitor, a giant star whose stellar wind formed the nebula. Many molecular species have been seen in this object. However, it is carbon rich, and in traditional chemical models most of the oxygen gets tied up in CO in such an environment, and not much water is expected. This observational discovery therefore poses new challenges to our understanding of interstellar chemistry, and a new network of reactions may have to be developed to account for this surprising result.

The water transition detected by ISO is the 179.5 μm rotational line. When the flux of this line has been absolutely calibrated, reliable abundances of water can be derived. A different line at 539 μm from the ground-state transition of water is the target of two upcoming space missions, SWAS and Odin. The ISO results have raised high hopes that these missions will bring in enough new data finally to identify the whereabouts of the Universe's oxygen. □

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BLOOD

Taking the pressure off

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THE identification of the endothelial relaxing factor with nitric oxide (NO•), an unstable and highly toxic radical, has been one of the most astonishing discoveries in physiology[1–3]. The ramifications have been seemingly endless — only last week, for instance, this journal carried a report[4] of endothelial damage caused by superoxide radicals generated by β-amyloid, which inactivate nitric oxide.

One remaining puzzle is that the haem iron in haemoglobin has an affinity for NO• at least ten thousand times greater than for oxygen. In the walls of our blood vessels, NO• is generated from arginine by the haem-enzyme nitric oxide synthase[3]. Why is NO• liberated there not instantly sequestered and inactivated by the erythrocytes?

On page 221 of this issue[5] Stamler and his colleagues demonstrate the existence of an equilibrium between erythrocytic NO• bound to the haem iron and the reactive thiol groups of haemoglobin on the one hand, and NO• bound to glutathione and other small molecular erythrocytic thiols on the other hand. They also show that these thiols can transfer NO• from erythrocytes to endothelial receptors and relax vascular tension.

This work is the continuation of research made possible by the use of a highly sensitive chemiluminescence method for the quantitative determination of nanomolar concentrations of nitrosothiols in biological systems[6], in a prolonged study of the interaction of NO• with thiol groups in peptides and proteins *in vitro* and *in vivo*. The results showed that glutathione is abundant in human lung alveoli; that *in vivo* NO• reacts with it, forming *S*-nitroso (SNO)-glutathione which has a half-life of several hours compared to that of a few seconds of NO• *in vivo*; and that SNO-glutathione reduces the toxicity of NO• and relaxes smooth muscle in human airways. The studies also showed that SNO-cysteine is a more potent vasorelaxant than SNO-glutathione and more potent even than the classical relaxant nitroglycerine, probably because it