Atmospheric physics

Natural lasers on Venus and Mars

from F. W. Taylor

THE study of non-equilibrium processes in planetary atmospheres is in vogue at present as interest grows in the stability of our natural environment. It has long been realised that the Earth's upper atmosphere cannot be in thermodynamic equilibrium, and during the last decade astronomers have made telescopic observations[1] of non-equilibrium processes taking place in the upper atmospheres of our Earth-like neighbours, Mars and Venus. A preliminary analysis by Michael Mumma of Goddard Space Flight Centre in Maryland, and his colleagues[2], indicated that processes analogous to optical pumping in laboratory lasers were taking place and led to the coining of the term 'natural lasers'. Now, Deming and colleagues from the Goddard team have taken new observations[3] of emission from Mars and Venus at wavelengths near 10 micrometers, and modelled[4] them to show that stimulated emission — the effect which makes lasers so powerful — accounts for up to seven per cent of the total emission. This is not a large amplification factor by laboratory standards, particularly for a CO_2 laser. But, the authors speculate that the sheer size of the natural lasers could make them useful tools in the future for communicating with distant civilizations far beyond our own planetary system.

Such a far-reaching application is at least conceivable because of the collisions which are constantly taking place between the molecules of the air and infrared radiation. When a molecule absorbs a photon, it stores its energy by making the transition to a higher vibrational or rotational energy state. What happens next involves a web of processes, including natural relaxation to the original state (with re-emission of the photons), relaxation or excitation to a different state (with emission or absorption of a photon of different energy and therefore wavelength), or collisional de-excitation. In the latter case the molecule relaxes by colliding with another and imparting additional kinetic energy to both. In other words, the gas absorbs the radiation and gets warmer, a familiar enough occurrence.

At low pressures, however, such as are found in upper atmospheres where the air is very rarefied (around one millionth of normal surface pressure on Earth for the regions of natural laser emission on Venus and Mars) collisions are relatively rare and the 'thermalization' of photons is relatively infrequent. The molecules thus tend to shuttle the energy from absorbed photons around their myriad energy levels in a very complicated fashion. The process is very difficult to model but is important, not only as basic physics, but because it controls the radiative energy balance of the upper atmosphere and hence its structure and dynamics. Carbon dioxide is the most important molecule in this context and, its behaviour is strongly modified by the availability of collision partners of different types.

Venus and Mars have atmospheres of nearly pure CO_2 and Deming *et al.* believe that the molecules are excited by the absorption of energetic photons from the Sun in the same way as a laboratory laser is pumped by an electrical discharge. Thermally emitted photons from the lower atmosphere on their way to space then can collide with the excited molecules and stimulate the emission of a second identical photon. Since this creates two photons where before there was one, light amplification by the simulated emission of radiation has taken place — laser action. A complication to this simple picture is the fact that most solar photons are so energetic that the absorbing molecules are too highly excited to emit the necessary low-energy ten micro-metre radiation. Deming and Mumma[4] postulate that partial de-excitation takes place by collisions between molecules until energy at the right level can be emitted. They back up their theory with detailed (but still incomplete, because of the state of the art) model calculations which show it to be not only plausible but capable of accounting rather closely for their observations.

Deming and Mumma end with speculations on how the natural laser on Mars might be turned into a man-made one of enormous power by placing large mirrors in orbit, parallel to each other. By passing the photons back and forth, the intrinsic gain of a few percent could be multiplied and an intense beam of infrared radiation, presumably suitably modulated with messages of good will, directed towards neighbouring stellar systems. □

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Ciba Foundation symposium

Human cataract formation

from George Duncan

CATARACT is by far the most common cause of blindness throughout the world. As a result of research efforts on a very broad front, which have been reported at a recent symposium*, we are closer both to understanding the molecular mechanisms involved and to developing preventive drug therapy for certain types of cataract.

Progress in understanding cataract formation has been impeded by our lack of understanding of the physical basis for lens transparency: if the proteins in the lens were simply distributed at random they would make the lens opaque. It appears that a paracrystalline structure is not required for transparency as had previously been believed, but simply a degree of relatively short-range order in the macromolecules making up the lens (see *News and Views* **302**, 383; 1983). Breakdown of this order leads on the macroscopic scale to phase separation with accompanying light scattering so that the lens becomes opaque. Several groups are taking advantage of the natural optical accessibility of the lens and are developing *in vivo* techniques for studying the mechanisms underlying this disorder. Preliminary experiments with a cataract model system examined by X-ray scattering in the rabbit indicate, for example, that changes in protein diffusivity can be detected *in vivo* before opacification occurs. (G. Benedek, Massachusetts Institute of Technology).

It is important to realise that the entire lens is not always involved in the cataract process. Much effort is being devoted to identifying and cataloguing the specific areas affected in different types of cataract (L.T. Chylack, Harvard Medical School). Human lens microdissection techniques, both *in vitro* and, somewhat spectacularly, *in vivo*, are now far advanced (J. Horwitz, Jules Stein Eye Institute, New York) and it is possible to detect specific changes in lens proteins from opaque regions that are not present in neighbouring clear regions. Differences between clear and opaque regions can also be discerned in human lenses using calcium ion-sensitive micro-electrodes. A 10 to 100-fold increase in free calcium occurs in regions with highly localized opacities, while the surrounding clear regions remain at the normal level of less than 10 μM calcium. The rise in free calcium may also be responsible for isolating the affected area, since gap

*The symposium on Human Cataract Formation (Ciba Foundation Symposium 106) was held in London, 25-27 October 1983; the proceedings will be published by Pitman, London, in summer 1984.

0028-0836/83/500640-02$01.00