were treated chemically in a way that increased the percentage of mutants resistant to standard antibiotics.

Schuch *et al.* suggest that the absence of the development of resistance to PlyG is due to the fact that any mutational change to the cell-wall structure that prevents binding to PlyG would kill the bacterium. This targeting of phage lysins to an essential bacterial structure gives them an advantage over the small-molecule antibiotics to which bacteria can become resistant rather easily. One drawback, however, shared by many other candidate antibacterial tools, is that PlyG would have to be administered soon after a person became infected, before lethal levels of anthrax toxin could develop. As illustrated by recent human cases, it is often difficult to diagnose anthrax infections early enough for treatment to be effective.

It is here that PlyG has another possible application. Currently, environmental and clinical samples suspected of being contaminated by anthrax are usually sent to specialized labs for culture. One of the tests used at the Centers for Disease Control and Prevention in the United States involves checking cultured bacteria for sensitivity to bacteriophage γ (refs 1, 8, 9). But all culture methods are slow. Efforts are under way to develop quicker tests using, for example, molecular approaches that require DNA extraction and special instrumentation. However, such sophisticated methods are difficult to deploy outside the lab.

Schuch *et al.* have now shown that PlyG can be used in a simple system to rapidly detect *B. anthracis* spores. Spores are resistant to PlyG-induced lysis, so the authors added the amino acid L-alanine to trigger germination, and then treated the emerging bacteria with PlyG, causing lysis and the release of bacterial components. One of these components is ATP, the main cellular energy store, which the authors detected using a luciferase–luciferin system: the luciferase enzyme degrades luciferin in the presence of ATP, producing light, which can be detected with a hand-held luminometer. This type of system would readily lend itself to field detection of spore contamination, because the equipment could be easily incorporated into a relatively small and simple device. One limitation is that it would not distinguish between virulent and non-virulent strains of *B. anthracis*, because PlyG would lyse the bacteria regardless of whether or not they produced the two factors needed for full virulence — anthrax toxin and a polyglutamate capsule. Presumably, however, the test could be used outside the lab as a rapid first indicator of contamination by *B. anthracis*, and further characterization would follow.

There is still much to be done to develop PlyG into an effective drug. For example, it would probably need to be administered intravenously in a formulation that would give adequate concentrations in the blood, because that is where the bacteria grow rapidly during the dangerous final stage of infection. Nonetheless, Schuch *et al.*[1] have introduced a potential treatment for anthrax that might be useful either alone or in combination with other therapies. Similarly, their means of detecting *B. anthracis* spores may prove valuable as the basis for an easily deployable test. Given these promising results, we expect to see rapid moves to test the use of bacteriophage lysins in detecting and treating other bacterial infections. ■

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Atmospheric science

Lasing on a cloudy afternoon

Stephan Borrmann and Joachim Curtius

Brief, high-intensity laser pulses can cause water droplets to emit white light. The technique can potentially be used to analyse the composition of clouds and shed light on how clouds may be affecting climate.

Understanding the role of clouds is one of the major obstacles to successfully modelling Earth's climate. Clouds in the troposphere, the lowest region of Earth's atmosphere, contain water droplets and ice particles ranging in diameter from a few micrometres to tens of millimetres. In *Physical Review Letters*, Catherine Favre and colleagues[1] present a novel way to study small water droplets using powerful lasers. Their technique could be developed into a versatile tool for studying clouds and obtaining information about the size and chemical composition of water droplets.

Droplets in clouds both absorb and scatter radiation from the Sun, and interact with infrared radiation from the Earth. But human activity induces changes in the optical properties of clouds, primarily through the indirect effects of aerosol particles. An increase in anthropogenic aerosol particles, such as soot and sulphate particles, is believed to lead to the formation of clouds consisting of smaller, more numerous droplets, because the same amount of water condenses on a larger number of seed particles. As a result, the cloud appears brighter and scatters solar radiation more efficiently back into space than does a cloud consisting of larger droplets. Anthropogenic aerosols are also thought to influence the lifetimes of clouds and how precipitation develops within them. But to assess these effects quantitatively requires a knowledge of the size distribution and optical properties of cloud droplets.

According to a recent report[2] by the Intergovernmental Panel on Climate Change (IPCC), the indirect effects of aerosols on climate could be as large as the greenhouse effect caused by anthropogenic carbon dioxide emissions, although acting in the opposite direction. But there are large uncertainties in estimating indirect aerosol effects for global climate models, and the IPCC report explicitly states that the level of scientific understanding of the underlying processes is "very low". One reason for this uncertainty is the lack of information on cloud–aerosol interactions, which again depend on the chemical composition of the aerosol particles and cloud droplets. And it doesn't stop there: to properly describe man's impact on Earth's climate, the feedback effects of aerosols and clouds on atmospheric temperature and chemistry, and on wind fields and relative humidity, must all be considered[3].

Favre *et al.*[1] have found that a water droplet 60 μm in diameter can emit white light in response to a laser flash. The droplet acts as a spherical lens, intensifying the incident radiation 100–200-fold until a small region inside the droplet becomes ionized and forms a plasma (Fig. 1). The plasma is so hot that, as electrons and ions recombine, white light is emitted; the spectrum of the emitted light is that expected for a black-body radiator at a temperature of around 7,000 K. This process is not observed in bulk samples of liquid water under comparable experimental conditions.

To ionize water and create a plasma in the droplet, the intensity of the laser pulse — which lasts just 120 femtoseconds (1 fs = 10^{-15} s) — must be high enough to trigger a multi-photon process involving five or more photons[4]. The laser intensity used in the experiments of Favre *et al.* was around 5×10^{12} W cm^{-2}. A three-photon process

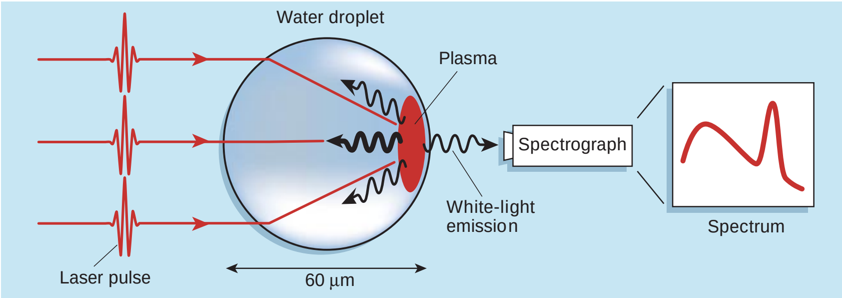

Figure 1 **Reach for the clouds. Favre *et al.*[1] have demonstrated that a water droplet exposed to laser pulses emits white light. The droplet acts as a lens, focusing the laser light into a small region which becomes ionized, creating a plasma. As electrons and ions recombine, white light is emitted from the plasma, its distribution peaking in the backward direction. If the emitted light is subjected to spectral analysis, peaks superimposed on its black-body spectrum provide information about the chemicals present inside the droplet.**

that was also observed in the droplets was insufficient for plasma generation[1,5]. The authors also rule out sonoluminescence and another effect called 'self-phase modulation' as causes of the plasma.

The addition of sodium chloride to the water droplets produces a striking feature: superimposed on the white-light spectrum is the distinctive emission line, called D1–D2, caused by excited sodium atoms. This possibility of identifying the 'finger-prints' of chemical components inside an individual water droplet opens up new avenues in experimental cloud physics and chemistry research.

Furthermore, Favre *et al.*[1] found that white light is emitted from a droplet more strongly in some directions than in others. The favoured emission direction is backwards, towards the laser source; emission is next strongest in the forward direction and there are further emission peaks at 150° to this axis. Theoretical calculations support this angular dependence. They also suggest that droplets as small as 22 μm can emit white light if the incident intensity of the laser beam is sufficiently high. This means that a significant fraction of droplets that occur naturally — in clouds, fog, hazes and smog — could be amenable to this laser-induced spectroscopic technique.

A technique currently used to determine the chemical composition of single particles *in situ* is laser ablation mass spectrometry[6,7]: in this process, particles are transferred into a vacuum and exposed to a powerful, nanosecond-long, ultraviolet laser pulse; this causes the particles to rapidly evaporate, releasing ionized molecular fragments that can be identified by mass spectrometry. However, at present, only particles smaller than around 10 μm can be studied, and although the technique avoids contact with the particles, transfer into the vacuum could change the particle composition. For these reasons, laser ablation mass spectrometry has so far been used mostly to analyse aerosol particles and rarely for larger cloud droplets.

But a hypothetical device designed as a hybrid of a laser ablation mass spectrometer and the femtosecond-laser arrangement used by Favre *et al.*[1] could fill this technological gap and provide information on chemical composition for both large aerosol particles and cloud droplets. Using this device, individual cloud droplets could be sampled and exposed to a femtosecond laser pulse. An appropriate spectrograph could then deliver the chemical-composition information, based on the white-light plasma emission. So far, this has been demonstrated only for sodium dissolved in water droplets, and further studies are needed on different chemical species. However, the limitation of laser ablation mass spectrometry — the fact that only molecular fragments or atoms, rather than whole molecules, can be detected — would still apply to this instrument.

There is another way to use this kind of technique for studying aspects of the atmosphere[1,8]. Because the largest fraction of the emitted white light emerges as a nearly collimated beam in the backward direction, it is conceivable that particle size, phase and chemical composition could be determined by remote sensing, by firing laser pulses up into the atmosphere, in a similar way to lidar (light detection and ranging) measurements. Rairoux *et al.*[8] have already demonstrated the feasibility of plasma analysis for remote gas-phase measurements. The experiments published by Favre *et al.*[1] may well form the cornerstone for the development of innovative instrumentation for cloud and aerosol research. ■

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Cell evolution

Mitochondria in hiding

Andrew J. Roger and Jeffrey D. Silberman

The apparent absence of mitochondria in some microbes contributed to the view that they were early offshoots of the eukaryotic line of descent. New evidence tells a different story.

At some point in the history of life, certain bacteria took up residence in other cells, starting a symbiotic relationship that led to their establishment as the mitochondria found within most eukaryotic cells. Eukaryotes are organisms whose cells contain a nucleus, a cytoskeleton, internal membranes and, typically, mitochondria that generate energy by aerobic respiration. For many years, however, it was thought that certain types of protists — unicellular eukaryotes — lack the mitochondrial organelle, supporting the notion that these organisms were primitive offshoots of the eukaryotic lineage that diverged before the mitochondrial symbiosis developed[1].

This view has been challenged by discoveries of the genetic remnants of mitochondria in the nuclei of mitochondrion-lacking protists (reviewed in ref. 2). On page 865 of this issue[3], Williams and co-workers go further by showing that the apparent absence of mitochondria in one such group, the Microsporidia, was an illusion. Their cells contain minute mitochondrion-derived organelles containing at least one hallmark mitochondrial protein. These curious structures join a growing list of cryptic, mitochondrion-derived organelles found in eukaryotes that no longer need or are capable of aerobic respiration (for example parasites such as Microsporidia, or protists that live in anoxic habitats).

Microsporidia are intracellular parasites that infect many groups of animals and protists. Early evolutionary trees, based on