ANIMAL MIGRATION

Bird forecasting

P. CHOUI/GETTY

In our restless world, annual bird migrations can provide a transitory opportunity to glimpse beautiful avian visitors (pictured, the migratory Baltimore oriole; *Icterus galbula*). Birds' journeys are influenced by the local daily weather, making it hard to predict when migrating birds will pass through a particular place on their route. Writing in *Science*, Van Doren and Horton report a model that forecasts bird migrations (B. M. Van Doren and K. G. Horton *Science* **361**, 1115–1118; 2018).

They created their model (http://birdcast.info) by analysing bird migrations using 23 years of radar data from 143 locations across the United States, and assessing the data on weather conditions for the migrations. Being able to accurately predict an influx of birds might enable temporary measures to be taken to protect these migrants from hazards: for example, by turning off wind turbines. **Mary Abraham**

METROLOGY

Timing the action of light on matter

Photoemission, the ejection of an electron from a material on the absorption of a photon, is one of the fastest processes in nature. An experiment demonstrates how the dynamics of this process can be captured in real time. SEE LETTER P.374

THOMAS FENNEL

It seems natural that light facilitates photosynthesis, enables visual perception and provides the energy source for solar cells. But the underlying light-absorption process is not fully understood. Energy is transferred from the light to electrons in the irradiated material, which can cause electrons to be ejected — a phenomenon known as photoemission. The dependence of the electron ejection on the frequency of the incident light led to Albert Einstein's discovery[1] that light comes in discrete packets of energy (photons) and sparked the development of quantum mechanics. But how fast can an electron absorb a photon and escape? On page 374, Ossiander *et al.*[2] show how metrology on the attosecond (10^{-18} seconds) timescale can help to answer this fundamental question.

It is only in the past decade or so that flashes of light could be generated that are short enough for researchers to directly track the dynamics of photoemission and to obtain timing information on the ejection of electrons[3,4]. This advance has resulted in a vibrant revival of scientific interest in the fundamental physics of photoemission. The timing information contains valuable details about the electronic structure of the target material, many-body effects (the correlated and collective behaviour of many interacting electrons) and the propagation of the electrons after photon absorption.

One of the key instruments used to carry out photoemission measurements is the attosecond streak camera[5]. In experiments based on this instrument, a material is exposed to an attosecond-duration light pulse that has a frequency corresponding to the extreme-ultraviolet region of the electromagnetic spectrum. Electrons in the material absorb photons from the pulse and are ejected. These electrons are then accelerated by the electric field of a second light pulse — known as the streaking field — and the final energy of the electrons is measured.

Adjusting the time delay between the two light pulses changes the final electron energy in a well-defined way. This relationship enables a reconstruction of either the time evolution of the streaking field[6] or the ejection time of the electrons[3,4], but not both simultaneously. As a result, streaking experiments have been unable to determine absolute photoemission delays — time differences between light absorption and electron ejection. Instead, they have provided

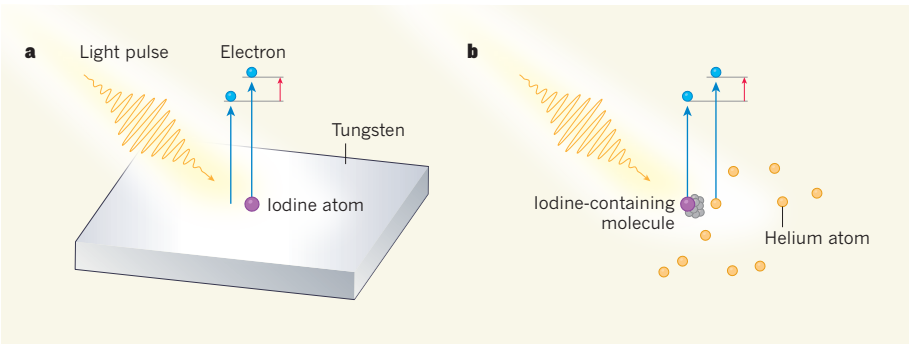

Figure 1 | Measurement of an absolute photoemission delay. Photoemission is the process by which an electron absorbs light and is ejected from a material. Ossiander *et al.*[2] demonstrate a technique for determining absolute photoemission delays — time differences between light absorption and electron ejection. **a**, The authors deposited iodine molecules on a clean tungsten surface (for simplicity, a single iodine atom is shown here) and applied an extreme-ultraviolet light pulse to the material. Electrons were ejected (blue arrows) from both the tungsten surface and the iodine atoms. The authors measured the relative delay (red arrow) between these two ejections. **b**, Ossiander and colleagues then applied the same light pulse to a gaseous mixture of iodine-containing molecules and helium atoms, and measured the relative iodine–helium photoemission delay. Finally, they used the known absolute photoemission delay for helium and the measured relative delays to determine the absolute photoemission delay for the tungsten surface.

measurements of relative delays, such as time differences between ejections of electrons from two different energy levels of the investigated material.

Ossiander and colleagues overcame this limitation using a clever two-stage approach, which they demonstrated by examining photoemission from a clean tungsten surface using an attosecond streak camera. In the first stage of the approach, the authors deposited iodine molecules on the tungsten surface (Fig. 1a). They then applied an attosecond-duration extreme-ultraviolet light pulse to the material and measured the relative delay in photoemission from the tungsten surface and from the atoms in the iodine molecules. In the second stage, the authors applied the same light pulse to a gaseous mixture of small iodine-containing molecules and helium atoms, and measured the relative iodine–helium photoemission delay (Fig. 1b).

Helium atoms are the largest atoms for which streaking experiments can currently be modelled completely by *ab initio* quantum simulations[7]. The absolute photoemission delay for helium is therefore known. Ossiander *et al.* used this result in combination with their measured relative delays to determine absolute photoemission delays for the tungsten surface. Their approach opens the door to measurements of such delays in surface and gas-phase experiments for many other target materials.

However, two central assumptions must be made when using Ossiander and colleagues' technique. First, additional delays caused by interactions between the iodine atoms and the target material must be negligible or known. Second, the iodine atoms must be close enough to the material's surface that spatial variations in the streaking field have only a small effect on the photoemission measurements. In the authors' experiment, the validity of these assumptions was backed up by theory. A closer analysis of the general limits in resolution associated with the technique will be a challenging, but important, task for future work.

The idea of using molecules as a reference to calibrate photoemission timing has previously been applied to streaking experiments on dielectric (insulating) nanoparticles[8]. These experiments suggest that photoemission delays could be used to directly characterize the attosecond-scale collisional dynamics of electrons in dielectric materials. The approach of Ossiander *et al.* is therefore expected to further advance the diagnostic capabilities of photoemission-delay measurements.

Ossiander *et al.* report photoemission delays for several different energy levels of the investigated tungsten surface. Their results imply that electron ejection from the material is more complex than was anticipated from previous measurements of relative delays[3]. The observed absolute delays can be explained only by considering both transport and collisional effects of the electrons during their propagation through the material.

A promising future application of the technique is the characterization of more-complex electronic effects — such as correlation, dissipation and decoherence — using data on absolute photoemission delays. This would provide a key reference for theory. The authors' observation of an extremely short delay (a few attoseconds) from the outermost electron shell of the iodine atoms also highlights application potential for ultrafast switching in electronic devices that operate at extremely high (petahertz; 10^{15} Hz) frequencies. Ossiander and colleagues have therefore provided insights into the dynamics of photoemission that not only advance our understanding of nature but also open routes to new technology. ■

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BIOPHYSICS

Melting sculpts the embryo's body

Collections of cells in the tails of zebrafish embryos have now been found to transition between behaving as solids and fluids. This transition is responsible for the head–to–tail elongation of the embryo. SEE LETTER P.401

PIERRE-FRANÇOIS LENNE & VIKAS TRIVEDI

Understanding how different materials respond to force is central to the field of engineering. For instance, permanent application of force is required to deform a solid-like material, whereas a fluid-like material can be irreversibly deformed by transient forces. Over the past few decades, such concepts have also surfaced in biology. Much like inert materials such as foams and emulsions, collections of cells can switch from solid-like to fluid-like behaviours, depending on cell density and adherence. Processes that coordinate this tissue 'melting' with the application of forces have been shown to locally deform tissues while maintaining their global structure[1]. Mongera *et al.*[2] report on page 401 that the elongation of the head-to-tail axis in zebrafish embryos relies on spatially controlled tissue 'melting'.

Head-to-tail (anterior-to-posterior) axis elongation is a central event in the generation of the animal body plan, and involves large-scale tissue deformation. For example, the posterior tip of a zebrafish embryo doubles in length in about five hours[3]. During this time, cells at the tip — in a region called the mesoderm progenitor zone (MPZ) — differentiate, becoming presomitic mesoderm (PSM) cells as they are left behind when posterior elongation proceeds. Cells of the PSM form structures called somites that will give rise to the animal's vertebrae (Fig. 1).

There are several known modes of tissue elongation. Polarized rearrangement of neighbouring cells can cause elongation in one direction and narrowing along a perpendicular axis[4]. In addition, external boundaries and forces can mediate elongation — neighbouring tissues can constrain, pull[5,6] or compress[7,8] tissues, and differences in the volume and stiffness of the extracellular matrix around cells can also provide guidance[7,9]. But, with a few exceptions[10], we still do not know to what extent the material properties of cells as individuals and collectives control axis elongation *in vivo*, because it is technically challenging to simultaneously measure internal mechanical stresses and changing material properties within elongating tissues at cellular and supracellular scales.

Mongera *et al.* overcame this challenge by inserting magnetically responsive oil microdroplets between cells in the tails of zebrafish embryos undergoing elongation. They used changes in the shape of the microdroplets from spherical to ellipsoid to infer supracellular mechanical stresses, and so to map the spatial distribution of forces along the axis. First, the authors analysed the microdroplets in the absence of a magnetic field, which revealed a gradient of increasing force from the MPZ at the posterior tip of the embryo to the PSM. These supracellular stresses persisted for more than 30 minutes, on a par with the timescale over which PSM maturation leads to the formation of somites.

Second, the researchers applied a magnetic