large dimensionality allows them to directly verify ETH predictions experimentally. Specifically, Kaufman et al. prepare two copies of the same system, with exactly one boson on every site. After a quantum quench, which allows particles to hop, correlations grow and the system becomes entangled. By performing a many-body interference experiment on the two copies, as suggested in (9) and tested experimentally in (10), the entanglement entropy of different subsystems as well as the entropy of the full state was measured (see the figure). Although the system as a whole remains pure, small subsystems are found to become mixed after a short transient time. Indeed, the reduced density matrices of one- and two-site subsystems become indistinguishable from those of a thermal ensemble. This equivalence is verified by direct observation of the particle occupation distribution and by comparing it with the equilibrium predictions. A recent experiment in a smaller system of three superconducting qubits (11) verified that the full time-averaged density matrix becomes thermal in chaotic regimes; another direct consequence of ETH (8).

Not only does ETH validate the use of statistical mechanics; there are also many important implications of these ideas to future science and technology. Understanding the microscopic structure of complex systems can provide the necessary tools and intuition for designing systems with similar or better performance than those found in nature, which often operate efficiently in far from ideal conditions. Understanding the conditions leading to the breakdown of ETH could be important for developing new technologies not suffering from the usual thermodynamic limitations. Remarkably, what first appeared to be an issue of controversy in quantum mechanics has provided an elegant solution to the problem of thermalization. It is the existence of individual highly entangled eigenstates that allows the somewhat ambiguous coarse-graining required in standard classical arguments to be dropped. Interestingly, ETH can be applied to systems near the classical limit, providing a simple mathematical framework to understand unanswered questions in classical chaotic systems.

REFERENCES


data with labeled patterns, these algorithms can infer an individual subscriber's socioeconomic status directly from his or her history of mobile phone use. The individual predictions can be aggregated into regional measures of wealth that are about as accurate as a 5-year-old household survey (11). Phone-based proxies for wealth are beginning to be used in research, e.g., to understand how new technologies differentially benefit the wealthy and the poor (12) and to assess the creditworthiness of would-be borrowers (13). Although promising, these nontraditional methods have caveats. As Jean et al. show, nightlights data are less effective at differentiating between regions at the bottom end of the income distribution, where satellite images appear uniformly dark. And mobile phone data are owned by mobile phone operators and are generally not available to policy-makers. By contrast, Jean et al. use only publicly available data.

Taking nightlights as their starting point, the authors have devised a clever technique to also extract information from daytime satellite imagery. Daytime imagery is taken at much higher resolution than nighttime imagery. It thus contains visible features—such as paved roads and metal roofs—that make it possible to differentiate between poor and ultrarpoor regions. Jean et al.'s insight was to apply state-of-the-art deep learning algorithms to the daytime imagery to extract these features. When given large quantities of data with labeled patterns, these algorithms...
Satellite images can be used to estimate wealth in remote regions. Predicting poverty, new approaches to program monitoring and impact evaluation will follow.

Considerable validation and calibration are required before proof-of-concept studies such as that of Jean et al. can be used in practice. However, as their study illustrates, there is exciting potential for adapting machine learning to fight poverty. As the economist Sendhil Mullainathan has asked, "Why should the financial services industry, where mere dollars are at stake, be using more advanced technologies than the aid industry, where human life is at stake" (15)?

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CRISTALLOGRAPHY

Now you see me too

Attaching chiral molecules to a chiral framework allows their molecular structures to be determined

By Lars Öhrström

Knowledge of three-dimensional (3D) molecular structures is crucial for scientific advances in fields ranging from materials chemistry to medicine. For solar cell materials, human proteins, or new drugs, the revelation of the exact arrangement of atoms and molecules vastly advances understanding of their properties. On page 808 of this issue, Lee et al. (1) report an approach that allows better structural data to be obtained for large, complex organic molecules that are difficult to crystallize on their own.

The method of choice to obtain structure information is single-crystal X-ray diffraction, a method so important that UNESCO declared 2014 the International Year of Crystallography. However, this method requires not only a pure substance, but also the ability to grow crystals of it—no crystals, no crystal structure data. The main complementary method, nuclear magnetic resonance, mainly provides structures of compounds in solution, often at great detail, but sometimes with inherent uncertainty, especially for chiral (handed) molecules with complicated stereochemistry.

Although long hours in the lab may produce crystals, some substances are notoriously difficult to crystallize or yield crystals with defects and disorder that prevent a complete structure determination. On the other hand, the molecular structures of small solvent molecules, trapped between the larger molecules that are the principal constituents of a specific crystal, are determined over and over again; for example, 1989 molecular structures of pyridine, C_H_N, are reported in the Cambridge Crystallographic Database (2). This occurs because the form and intermolecular interactions of the larger molecules sometimes generate voids in the crystal. Scientists
Fighting poverty with data
Joshua Evan Blumenstock (August 18, 2016)

Editor's Summary

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