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Nailing fingerprints in the stars

Laboratory-based experiments are sorely needed to complement the rapidly proliferating spectral data originating from observations by the latest space telescopes.

What are stars made of? After astronomers detected a bright-yellow, unknown spectral line in sunlight in 1868, they named the new element helium after the Greek Sun god Helios. But it was some 30 years before physicists on Earth managed to detect — and so confirm the discovery of — helium in a laboratory.

It is a pattern that has been repeated many times since: the indirect detection of elements and molecules through spectral signatures in space has come ahead of detailed study on the ground. Lab spectroscopy has long lagged behind telescope observations, but it is striking just how wide the gap has now grown.

A cutting-edge infrared spectrograph, for example, installed in 2011 on the Sloan Digital Sky Survey (SDSS) telescope in Sunspot, New Mexico, records the spectra of 1,800 stars per night, most located in the bulge of the Milky Way galaxy, where dust prevents visible wavelengths of light from reaching Earth. The result is the detection of thousands of unidentified spectral lines — dips or peaks of electromagnetic waves at specific energies, caused by absorption of the light by gas on the way to Earth or emission by gas on stars.

Some physicists are now pointing out the irony that multimillion-dollar projects such as the SDSS are producing data that cannot be analysed because of a failure to support much cheaper lab work on the ground. They have a point, and support for lab-based research that can decipher such spectra should be increased. A good rule of thumb is that agencies funding telescope projects that are doing cutting-edge spectroscopy should spend a small fraction, maybe a few per cent, of the money on associated lab spectroscopy.

Lab-based measurements are less glamorous, but big questions about the evolution of galaxies will be solved by understanding small but important details about the physics and chemistry of millions of stars as revealed by spectra. For example, spectra could give clues to whether stars in the Galactic bulge formed there or migrated to it later. Spectra can also shed light on the amount of dark matter near a star, by revealing information about the star's motion, which shifts its spectral lines.

A good example of the benefits of such work comes from a November paper in *The Astrophysical Journal* by atomic physicists at Imperial College London, the National Institute of Standards and Technology in Gaithersburg, Maryland, and the Astrophysical Institute of the Canary Islands in Tenerife, Spain (M. P. Ruffoni *et al. Astrophys. J.* **779,** 17; 2013). They report 28 probabilities of electron transitions between sets of energy levels for the element iron. These can now be used in combination with spectra to estimate the abundance of iron in stars in the Galactic bulge — a step towards determining their ages and where they formed. None had previously been measured in the laboratory.

Such research is necessary because, to identify and quantify elements in space from spectra, astronomers must know the probability that electrons in the elements' atoms will move between energy levels. For light elements with few electrons, such as hydrogen and helium, the probabilities of transitions can be calculated using the rules of quantum mechanics. But heavier elements have many electrons that can participate in transitions — iron has 26, making the probabilities of possible transitions between levels too complex to calculate accurately. Measuring emissions in the lab is the only alternative. Physicists can use tunable lasers to excite electrons into more levels and measure further transitions. This information can then feed back to the astronomical observations. Extra funds would significantly improve this capacity, giving better access to powerful lasers and detectors.

Even as experimentalists face challenges taking lab spectra, there is an astronomical spectroscopy boom. Aside from the infrared instrument taking data on the US$55-million SDSS, astronomers are planning to build gigantic 30–50-metre telescopes, such as the €1-billion (US$1.3-billion) European Extremely Large Telescope, to be based near Cerro Paranal, Chile, which will take hundreds of thousands of stellar spectra. Furthermore, NASA's planned $8.8-billion James Webb Space Telescope, which like the Sloan instrument uses cutting-edge mercury cadmium telluride infrared detectors, will look at stars and, it is hoped, at the atmospheres of planets outside the Solar System. Although the spectra can be used to estimate the amounts of different elements in the atmospheres of stars or planets, a particular area of interest is in identifying molecules, which also emit characteristic spectral lines when they transition between different states.

"Measuring emissions in the lab is the only alternative."

Other lab-based experiments might even solve one of the longest-standing questions in astronomy: the origin of the diffuse interstellar bands — dips in the spectra of stars caused by diffuse matter spread between the stars and Earth. They are thought to be due to unstable hydrocarbon radicals, the exact mix of which has yet to be made in the laboratory, and they have puzzled astronomers for almost 100 years. How long do researchers want to wait? ■

The DIY dilemma

Misconceptions about do-it-yourself biology mean that opportunities are being missed.

The do-it-yourself-biology movement has an image problem. More commonly called DIYbio, it tends to conjure up pictures of T-shirt-clad misfits marshalling limited scientific skill in their basements as they try to make cool-but-fringe things such as glow-in-the-dark plants. Policy-makers take an opposite view: instead of wayward amateurs, they see twisted experts hellbent on harm, engineering pathogens in their garages to unleash upon the world. A survey of DIY biologists released on 19 November by the Woodrow Wilson International Center for Scholars in Washington DC reveals, unsurprisingly, that neither caricature is accurate, and that the DIYbio movement is more nuanced than it would seem to those looking in from the outside (see go.nature.com/nj9xk6).

The movement is made up of enthusiasts with a range of backgrounds and interests in biology, who work in wet-lab spaces not affiliated with traditional science centres such as universities. The survey found that 92% of DIY biologists work at least some of the time in communal spaces rather than in their garages or basements; that they are mostly young (36% under 35, 78% under 45); that they are more educated than the general population; and that many are still learning the basics of biotechnology. Only 6% of people surveyed said their experiments were of the kind that would require the safety conditions for work that might cause human disease.

It is interesting to note that 28% of people who responded to the survey said that they already do some or all of their work in academic, corporate or government labs, and that 19% have obtained a doctorate-level degree. So at least some DIY biologists are peers of — or indeed themselves — readers of this journal, and are within the mainstream scientific community.

This undercuts the notion that all DIY biologists are inexperienced if enthusiastic amateurs. And the report argues that this expertise and access to sophisticated lab facilities mean that the DIY community has the potential to generate products that will benefit society. As a result, it recommends that the US government should fund networks of community lab spaces.

Examples of the positive impact DIYbio can have already exist: its practitioners have produced a cheap alternative to commercial machines for the polymerase chain reaction, and they have come up with an inexpensive diagnostics device for malaria. Yet so far, the projects that have garnered the most attention have been essentially frivolous, such as the project to create a glowing plant, which collected US$500,000 in public crowdsourced funds last year — ten times as much as the malaria tool earned in seed funding.

This highlights the key problem. There is no government granting agency judging which DIY project is worthwhile, so DIY biologists can do what they like, as long as it's legal. Although this is an intrinsic part of the thrill of being in the movement, it is also a factor that keeps legitimate funders away, and some community labs are threatened with closure as a result. Governments would gain much by supporting the DIYbio movement; it would give them more access to and potentially more control over the work that goes on in labs that they fund.

"DIY biologists can do what they like, as long as it's legal."

But the report also notes that most DIY biologists do not favour government regulation, now or in the future. Governments, of course, cannot become more involved in supporting this movement without taking a more proactive role towards regulation. Is this apparent impasse permanent? Perhaps not. The report notes that a sizeable minority — 43% — of DIY biologists do favour some kind of regulation in the future, and this may grow as the movement matures.

The report's authors anticipate such a change. They suggest benchmarks and timelines to address regulation — a time in the future, for instance, when people outside companies and sophisticated labs will be able to synthesize long stretches of DNA. Still, rather than risk being overrun by events, the DIY-biology community and regulators should start to talk about how to anticipate such developments, rather than merely respond to them.

The security and stability of government funds would safeguard the future of the DIYbio movement; the issue is whether the movement would accept the trade-offs that such stability would bring. If you are reading, then do please tell. ■

Enemy of the good

Universities need to counter pressures that undermine support for younger researchers.

Who are the outstanding mentors of young researchers? Since 2005, *Nature* has awarded an annual prize for scientific mentoring, rotating through a variety of countries. Over the years it has become clear that, regardless of the country and scientific discipline, there are some consistent key characteristics of lab heads that bode particularly well for young scientists under their leadership. Outstanding mentors tend to have a thorough command of their research field. They are highly accessible to the members of their lab. They can relate to individuals in a way that is specific to each person's characteristics. And they know how to balance support with the nurturing of independent creativity, problem-solving, integrity and initiative (see *Nature* **447,** 791–797; 2007).

This year's winners are no exception. The competition was held in Italy, and the awards went to neurobiologist Michela Matteoli, theoretical physicist Giorgio Parisi and chemist Vincenzo Balzani (see pages 443 and 559). All received glowing testimonials from their past trainees. For example, the success of one mentor was ascribed to "complete emotional and scientific investment" in mentees, who in turn "dedicate themselves to work at their best to pay back that faith".

That degree of mentoring commitment is unusual. All too often one meets young researchers who, despite working in prestigious institutions, have had no such experience. Yes, the 'sink or swim' approach can breed resilience, but proper mentoring can safeguard scientific integrity in the full sense of the word. It enables young researchers to develop a critical approach to their own ideas and data, and to maintain professionalism by using robust techniques and analyses. Mentoring also helps to engender a culture of transparency in allowing others access to raw data, gives a sense that one's leader has one's interests at heart, and can moderate the pressure to publish. Universities have a duty to ensure that this culture prevails, not least to ensure that public and private money is not squandered on sloppy, amateurish research.

But especially now, the pressures on young lab leaders are huge. Encounters with early-career principal investigators all too often indicate how narrow their focus must be to survive. They might be adding to those pressures because of hyper-competitiveness or anticipated demands from university and funding-agency committees. Typically, principal investigators are well-intentioned towards their younger colleagues, but feel an obligation to produce strong results in the first few years of their labs, to get funding or tenure. They may often feel that they do not have enough time to invest in mentoring their teams. Or they may well judge that they simply cannot tolerate people in their labs who are underperforming.

Such a lack of attention to nurturing individuals could exacerbate another damaging trend. With more people seeking alternative careers during their PhDs because of the ever tougher prospects in academia, those graduate students might lose motivation to go the extra mile to fulfil their research potential. And yet the principal investigator needs the papers generated by the students' work to get tenure.

These problems can be addressed in two ways: from the bottom up, by a sheer determination of younger lab heads to be responsible leaders; and more importantly, from the top down, by heads of universities and departments providing incentives for great leadership. Such heads should look at the winners of the *Nature* mentoring awards and ask: 'Does my institution cultivate such behaviour or hinder it?' ■

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