But a team led by Endy and BIOFAB co-director Adam Arkin, of Lawrence Berkeley National Laboratory in Berkeley, California, has found that the activities of those sequences are far from predictable. In two papers published online this week in *Nature Methods*[1,2], the team reports inserting many different combinations of promoters and RBS sequences in front of genes encoding fluorescent proteins, and then measuring the level of protein that was made. "It was a bloody mess," says Arkin, with each promoter–RBS combination having varying effects depending on the gene.

He and Endy also cite an earlier finding that a scientist hoping to express a protein at a particular level has just a 50% chance of producing the required amount within a factor of two. Such hit-or-miss expression poses a major challenge to synthetic biologists who would like to create genetic circuits involving dozens of genes.

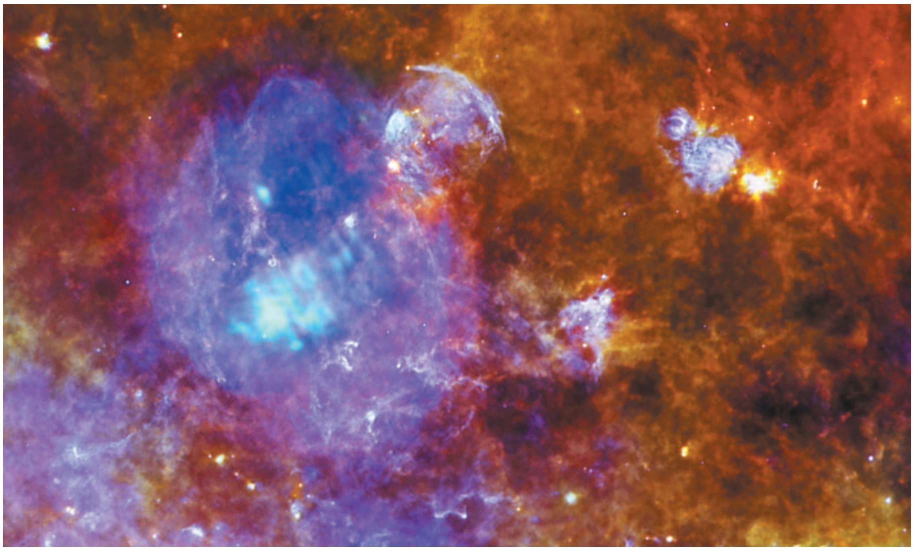
As a solution, the BIOFAB team designed promoter and RBS sequences for *E. coli* that do not interfere with downstream DNA, so that their effects are independent of the specific gene they are paired with. The sequences should provide scientists with a much tighter grip on gene expression, offering around a 93% chance of hitting a desired level of expression within a factor of two[2]. Researchers can obtain the sequences for free online (see http://www.biofab.org/data), and Arkin says that some of his colleagues are already finding them useful.

Endy and Arkin's team also devised a statistical method[1] to measure the variability in the performance of their promoter and RBS sequences, and indeed any genetic part to be used in synthetic-biology applications. The method should allow researchers to create a kind of specification sheet for each biological part, making it easier for scientists to develop and share their work.

Randy Rettberg, a synthetic biologist at the non-profit organization the iGEM Foundation in Cambridge, Massachusetts, who has worked with Endy on similar projects, says that more labs should follow BIOFAB's lead and industrialize the production of biological parts. And synthetic biologist Alistair Elfick of the University of Edinburgh, UK, says that the BIOFAB products should help synthetic biologists to design bigger and more complicated circuits.

"I think the community is very aware that we've got a long way to go before we can fulfil our dream of *in silico* design of genetic circuits we can just pop into a cell and run like an app," Elfick says. ■

1. Mutalik, V. K. *et al. Nature Meth.* http://dx.doi.org/10.1038/nmeth.2403 (2013).
2. Mutalik, V. K. *et al. Nature Meth.* http://dx.doi.org/10.1038/nmeth.2404 (2013).



HERSCHEL: Q. NGUYEN LUONG/F. MOTTE/HOBYS KEY PROGRAM CONSORTIUM/HERSCHEL SPIRE/PACS/ESA CONSORTIA. XMM-NEWTON: ESA/XMM-NEWTON

Herschel captured the shells of dust (orange) generated in supernovae (blue, from an X-ray image).

ASTRONOMY

Cold telescope faces hot death

Herschel space observatory nears its end after unravelling star formation and tracking dust from supernovae.

BY GEOFF BRUMFIEL

After more than three years of observations, astronomy's premier infrared space telescope is about to catch a fever and die. Later this month, Europe's Herschel space observatory, which has helped astronomers to revise theories about the birth and death of stars, will exhaust its stores of liquid-helium coolant, and its instruments will begin to heat up. At that point, "all the scientific instruments will shut down within hours", says Göran Pilbratt, the mission's project scientist at the European Space Research and Technology Centre in Noordwijk, the Netherlands.

Astronomers are hailing the legacy of the €1.1-billion (US$1.4-billion) mission, which has made some 22,000 hours of observations in the far infrared and submillimetre wavelengths, a part of the electromagnetic spectrum blocked by Earth's atmosphere. In an era when scientific spacecraft are increasingly specialized, the 3.5-metre Herschel telescope was a rare general-purpose observatory, used by more than 2,500 astronomers. "Anyone you ask who's been involved with Herschel has their own favourite results," says Matthew Griffin, an astronomer at Cardiff University, UK. "There's something for everybody."

Herschel orbits the L2 point, 1.5 million kilometres away in the cold shadow of Earth, where the combined gravity of the planet and the Sun create a 'gravitational well'. This shady perch, together with 2,300 litres of liquid helium, allowed Herschel to cool its instruments to a chilly 2.2 kelvin. At that temperature, the spacecraft could observe the low-temperature glow of gas and dust in stellar nurseries and in the shells of supernovae.

The cold Universe has held surprises. For example, astronomers thought that young stars form from long filaments of gas that collapse smoothly under their own gravity. Herschel painted a more complicated picture. When it looked at star-forming regions, it saw swirling, churning flows of gas driven by turbulent winds. Researchers now think that turbulence, rather than gravity, creates dense patches in the filaments that eventually collapse into stars, says Griffin. "That's a challenge for theoreticians."

The deaths of stars yielded other revelations. Astronomers had thought that most of the dust in the Galaxy forms in red giants, which puff it into space as they shrink in their waning years. Instead, Herschel detected massive amounts of dust ▶

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To see some images from Herschel, visit: go.nature.com/aiylqs

in the shock waves around supernovae, says Alexander Tielens, an astrophysicist at Leiden University in the Netherlands. "I think Herschel really nailed that supernovae make a lot of dust."

Outside the Milky Way, Herschel enabled observations of dusty galaxies from 10 billion years ago — when most of the Universe's stars were forming. The data show that stars tended to form evenly across these early galaxies, rather than being spurred by galactic mergers, says Gordon Stacey, an astronomer at Cornell University in Ithaca, New York. They also show that some giant black holes at the centre of galaxies, known as active galactic nuclei, hurl out jets of gas so powerful that they may prevent stars from forming in the vicinity. "It's pretty exciting to actually see these processes in action," says Phil Appleton, head of the NASA Herschel Science Center at the California Institute of Technology in Pasadena.

Herschel also allowed astronomers to look at a range of molecules in the Milky Way. Hydrogen fluoride worked as a tracer to reveal larger clouds of hydrogen gas, the building blocks of star formation. And water vapour turned up sometimes in unexpected places: stars made mainly of carbon and Jupiter's atmosphere, to name but two.

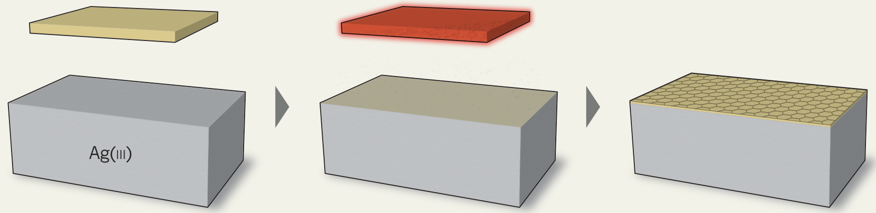
A new generation of instruments will follow up on Herschel's discoveries. From a perch in the Chilean Andes high enough to observe in the far-infrared, the Atacama Large Millimeter/submillimeter Array (ALMA) will point its dishes at distant galaxies first catalogued by Herschel (see page 156). The Stratospheric Observatory For Infrared Astronomy (SOFIA), a telescope carried by a high-flying 747 jet, will also be able to build on Herschel's observations. So will NASA's James Webb Space Telescope, scheduled for launch in 2018.

But "without Herschel there will certainly be a gap", says Stacey. Infrared astronomers want another space telescope that could make the same ultra-cold observations as Herschel, but with the sensitivity to reach farther into the Universe. To that end, the European Space Agency, which built Herschel, now hopes to collaborate with Japan to build the Space Infrared Telescope for Cosmology and Astrophysics (SPICA), a 3-metre-class telescope that would chill its mirror as well as its instruments. If the project wins funding, it could be launched sometime in the 2020s, says Pilbratt.

In May, after it shuts down, Herschel will be shunted to an orbit around the Sun to eliminate the risk of it falling back to Earth (an alternative plan to send it crashing into the Moon was abandoned owing to cost). But the observatory's public data archive will continue to lead to discoveries for years to come. "This is not the end of the mission," says Pilbratt. "This is the end of observing." ■

MAKING SILICENE

Atom-thick sheets of silicon — silicene — were first produced in 2010 but researchers have yet to grow the material on an insulating surface to test some of its predicted properties.



Step 1: Place silicon wafer above crystalline silver (Ag) in a vacuum.

Step 2: Heat the silicon until it begins to sublimate.

Step 3: Silicon atoms spontaneously organize on the silver surface as silicene.

MATERIALS SCIENCE

Sticky problem snares wonder material

Graphene-like form of silicon proves hard to handle.

BY GEOFF BRUMFIEL

In 2011, physicist Guy Le Lay stood before a half-filled room on the last day of the American Physical Society's March meeting in Dallas, Texas, and presented data on a new form of silicon. In his laboratory at Aix-Marseille University in France, Le Lay had grown sheets of honeycombed silicon with layers just one atom thick. He had only preliminary evidence that was unpublished at the time. "It was a risk, you know?" he says now of his decision to present the data.

At this year's meeting, on 18–22 March in Baltimore, Maryland, scientists will deliver about two dozen talks on silicene (see 'Speaking of silicene'), the material that Le Lay tentatively described two years ago.

The name recalls graphene, the current darling of the materials-science world — and the flurry of interest suggests that silicene could be the next one. But for that to happen, Le Lay and others will have to overcome silicene's unfortunate tendency to stick to practically everything it touches.

Structurally, silicene looks a lot like graphene, which is also a honeycombed sheet, but of carbon atoms rather than silicon. Silicene's two-dimensional structure should lead to strange quantum effects and allow electrons to streak across it at incredible speed — properties that, in graphene, have entranced physicists and builders of electronic devices since it was first characterized in 2004. In 2010, work on graphene won a Nobel prize, and earlier this year, graphene research was selected by the European Commission as one of its billion-euro flagship projects (see *Nature* **493,** 585–586; 2013).

Silicene could even have some extra attractions. It is predicted to have characteristics similar to topological insulators — materials that conduct electrons only on their outer surfaces — another trendy area of research.

Above all, silicene is made of silicon, the same material that drives the modern electronics industry. Bringing it all together could lead to "a new era" in silicon electronics, says Kehui Wu, a physicist at the Chinese Academy of Sciences' Institute of Physics in Beijing.

There's just one problem: silicene is super sticky. "Graphene is a very stable material," says François Peeters, a condensed-matter theorist at the University of Antwerp in Belgium. But silicene reacts easily with the environment — oxidizing in the air and bonding chemically with other materials. And unlike graphene, which lies flat, silicene crinkles into bumps and ridges as a result of the way neighbouring silicon atoms bond with each other. That makes it more likely to stick to surfaces.

SPEAKING OF SILICENE

The number of times that silicene is mentioned in abstract titles for the American Physical Society's March meetings has shot up this year.