New eye to scan the night sky

After radio waves and UV, it's back to visible light with a cutting-edge telescope in Chile

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The Large Synoptic Survey Telescope, being set up in Chile, South America, is an 8.4 metre-wide reflector that focuses images of a wide swathe of the sky onto a 189 segment, 3,200 megapixel detector. Once in action, it would be able to image a golf ball from 24 kilometres away and its sensitivity would be a 100 million times greater than that of the human eye.

This is a long way from the best optical telescopes that we have made so far. To get the best of both magnification as well as detail, the optical telescope needs lenses of the finest quality and of the largest diameter possible. Deficiencies that are inherent in glass lenses become serious when the lenses become very large. This fact brought in the mirror, or reflecting telescopes, with very large aperture, and faint images were made visible with high-grain photographic film and long exposures.

However, there are limits, both to the detail and the sensitivity, when we use visible light. Detail is limited by the wavelength of visible light, given the dimensions of lenses or mirrors that are practical. And for sensitivity, much of the visible light from distant objects gets scattered before it reaches the Earth. The most distant objects are thus too dim to be seen.

A way to overcome sensitivity was to spot the most distant objects by the radio waves they emit, rather than light. As radio waves have wavelengths thousands of times greater than light, they are scattered much less, and it is by radio telescopes that the farthest objects have been observed. In place of the photographic plate or the eye, the detection of radio images is by an array of radio antennas that is spread over a large area. The timing of the waves that each antenna receives helps work out where the waves would have focused, if there had been a lens, and this helps develop the image.

While the larger wavelength of radio waves helps detect faint signals, the same large wavelength reduces the detail that can be detected. This, however, is compensated by the large area over which signals are collected, which has the effect of a very large lens or mirror, in the visible range.

As for the limit to detail that visible light presents, a way around was by using ultraviolet light, or even X rays. Now, the atmosphere is opaque to UV or X-rays. These telescopes hence had to be stationed outside the atmosphere, which became practical with satellites placed in orbit around the Earth. The celebrated Chandra X ray telescope has been in orbit around the Earth since 1999 and has provided detailed images of high-energy processes, like supernovae and the surroundings of black holes.

The earliest telescopes, naturally, were visible light telescopes where the detector was the human eye. Galileo is credited with the first astronomical observation, using the newly invented device, when he saw the four largest satellites of Jupiter. Telescopes rapidly improved in quality, with lenses that compensated for the splitting of light into component colours, when it passed through glass, as well as the non-uniform magnification, because the lenses were not the ideal, "thin" lenses. The limitations of lenses found an answer in using mirrors in their place and the largest telescopes we have are now the "reflectors".

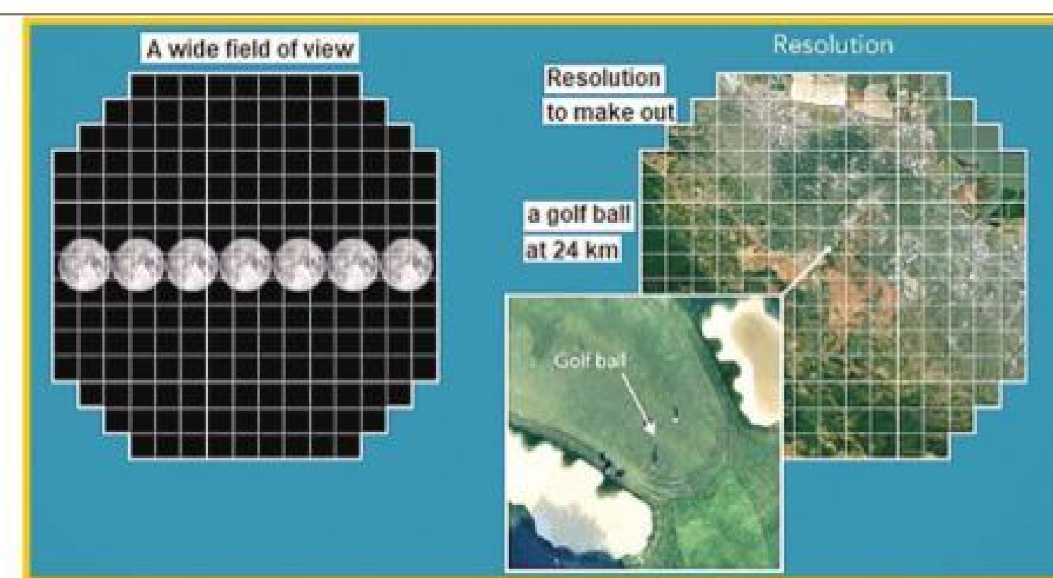
Along with the development of telescopes, was the progress in cameras. Cameras, of course, even when they are used at the focus of a telescope mirror, must use lenses. While the lenses were improved, for larger diameter, or aperture, to admit more light, the quality of the film on which the image was captured was also refined. While we are yet to have a medium that separately captures each photon of light, the grains of chemical, which capture the presence of light, were made finer, to capture more detail. And with long times of exposure, even dim images can be made visible.

The LSST sensor array being assembled - with close-up of broccoli showing, to the right ■ SLAC NATIONAL ACCELERATOR LABORATORY

Photo film has now made way for the array of electronic, light sensitive specks of silicon oxide on a sliver of silicon. In the photo film, the bright spots of an image cause chemical change, and the image is recorded on the film. With the electronic sensor, the bright spots of the image cause build-up of charge, in the specks on the sliver of silicon. These charges are then transferred to a collector, which creates a digital record of how much light fell on each of the specks in the silicon screen. The record can then be used to display the image for the user of the camera to frame the picture, or to save the record, when the picture is clicked.

The resolution, or the detail, in the photo film depended on the fineness of the chemical specks deposited on the film. In the digital camera, the equivalent is the number of light sensors that act to capture the image. If the device has 1,000 rows and 1,000 columns of sensors, there would be a million sensors in all, and we would speak of a megapixel camera. We are familiar with modern mobile phones that sport eight megapixel cameras – their pictures are as good as excellent conventional photographs. The resolution of professional digital cameras goes as high as 50 megapixels.

In the context, the camera of the LSST would take pictures with 3,200 megapixels. The resolution actually works out to 3,024 megapixels, but this is the equivalent of an array with 55,000 pixels in each direction. The imaging is to happen over 189 separate sensors, each capable of 16 megapixels (189x16 = 3,024). While the sensor of a normal digital camera is about 1.4 inches across, the panel of 189 sensors stretches to more than two feet. The sensitivity and detail



then equal what is feasible with much longer and shorter wavelengths – and over a range from the near infra-red to the ultra-violet.

The LSST itself is planned to be in action in 2022, but the sensor array, for the camera, has been assembled and was recently tested. As the sensors are so sensitive, they need to be protected from all kinds of stray radiation, or "noise". To this end, the array is cooled to 100°C below freezing. As the telescope is yet to be built, the camera was tested by taking a picture of a head of broccoli – and the picture it took showed the amazing detail that it is capable of.

From its position in the Vera C Rubin Observatory currently under construction in Chile, the LSST, will survey the entire Southern Hemisphere sky every few days, and go on for the next 10 years. Data amounting to 15 terabytes would be collected every night, and within a month, the LSST would have recorded more detail of the cosmos than all previous astronomical surveys.

The field of astronomy is teeming with puzzling phenomena, like dark matter and dark energy. "With the huge data that would become available with LSST, we could build a 3D of dark matter in the universe, and how it changes with time," said a participant of a round table discussion of the difference the project is going to make.

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Vera C Rubin & dark matter

Vera Florence Cooper Rubin (1928-2016) was an American astronomer who pioneered work on galaxy rotation rates. The periphery of a galaxy is found to move as fast as portions deeper within. This is unlike motion around a gravitational centre (the outer planets of the solar system, for instance, move slower than planets closer to the sun) and more like the movement of a disk. The anomaly is explained by invoking dark matter, as filling the space within the galaxy.

PROMISING DISINFECTANT

Ultraviolet light can make indoor spaces safer during the pandemic – if it's used the right way

KARL LINDEN

Ultraviolet light has a long history as a disinfectant and the Sars-CoV-2 virus, which causes Covid-19, is readily rendered harmless by UV light. The question is how best to harness UV light to fight the spread of the virus and protect human health as people work, study, and shop indoors.

The virus spreads in several ways. The main route of transmission is through person-to-person contact via aerosols and droplets emitted when an infected person breathes, talks, sings or coughs. The virus can also be transmitted when people touch their faces shortly after touching surfaces that have been contaminated by infected individuals. This is of particular concern in health-care settings, retail spaces where people frequently touch counters and merchandise, and in buses, trains and planes.

As an environmental engineer who studies UV light, I've observed that UV can be used to reduce the risk of transmission through both routes. UV lights can be components of mobile machines, whether robotic or human-controlled, that disinfect surfaces. They can also be incorporated in heating, ventilating, and air-conditioning systems or otherwise positioned within airflows to disinfect indoor air. However, UV portals that are meant to disinfect people as they enter indoor spaces are likely ineffective and potentially hazardous.

What is UV light?

Electromagnetic radiation, which includes radio waves, visible light and X-rays, is measured in nanometres, or millionths of a millimetre. UV irradiation consists of wavelengths between 100 and 400 nanometres, which lies just beyond the violet portion of the visible light spectrum and are invisible to the human eye. UV is divided into the UV-A, UV-B and UV-C regions, which are 315-400 nanometres, 280-315 nanometres and 200-280 nanometres, respectively.

The ozone layer in the atmosphere filters out UV wavelengths below 300 nanometres, which blocks UV-C from the Sun before it reaches Earth's surface. I think of UV-A as the suntanning range and UV-B as the sun-burning range. High enough doses of UV-B can cause skin lesions and skin cancer.

UV-C contains the most effective wavelengths for killing pathogens. UV-C is also hazardous to the eyes and skin. Artificial UV light sources designed for disinfection emit light within the UV-C range or a broad spectrum that includes UV-C.

How UV kills pathogens

UV photons between 200 and 300 nanometres are absorbed fairly efficiently by the nucleic acids that make up DNA and RNA, and photons below 240 nanometres are also well absorbed by proteins. These essential biomolecules are damaged by the absorbed energy, rendering the genetic material inside a virus particle or microorganism unable to replicate or cause an infection, inactivating the pathogen.

It typically takes a very low dose of UV light in this germicidal range to inactivate a pathogen. The UV dose is determined by the intensity of the light source and duration of exposure. For a given required dose, higher intensity sources require shorter exposure times, while lower intensity sources require longer exposure times.

Putting UV to work

There is an established market for UV disinfection devices. Hospitals have been using robots that emit UV-C light for years to disinfect patient rooms, operating rooms and other areas where bacterial infection can spread. These robots, which include Tru-D and Xenex, enter empty rooms between patients and roam around remotely emitting high-power UV irradiation to disinfect surfaces. UV light is also used to disinfect medical instruments in special UV exposure boxes.

UV is being used or tested for disinfecting buses, trains and planes. After use, UV robots or human-controlled machines designed to fit in vehicles or planes move through and disinfect surfaces that the light can reach. Businesses are also considering the technology for disinfecting warehouses and retail spaces.

It's also possible to use UV to disinfect air. Indoor spaces like schools, restaurants and shops that have some air flow can install UV-C lamps overhead and aimed at the ceiling to disinfect the air as it circulates. Similarly, HVAC systems can contain UV light sources to disinfect air as it travels through duct work. Airlines could also use UV technology for disinfecting air in planes, or use UV lights in bathrooms between uses.

Far UV-C – safe for humans?

Imagine if everyone could walk around continuously surrounded by UV-C light. It would kill any aerosolised virus that entered the UV zone around you or that exited your nose or mouth if you were infected and shedding the virus. The light would also disinfect your skin before your hand touched your face. This scenario might be possible technologically someday soon, but the health risks are a significant concern.

As UV wavelength decreases, the ability of the photons to penetrate into the skin decreases. These shorter-wavelength photons get absorbed in the top skin layer, which minimises DNA damage to the actively dividing skin cells below. At wavelengths below 225 nanometres – the Far UV-C region – UV appears to be safe for skin exposure at doses below the exposure levels defined by the International Committee on Non-Ionizing Radiation Protection.

Research is confirming these numbers using mouse models. However, less is known about exposure to eyes and injured skin at these Far UV-C wavelengths and people should avoid direct exposure above safe limits.

The promise of Far UV-C for safely disinfecting pathogens opens up many possibilities for UV applications. It's also led to some premature and potentially risky uses.

Some businesses are installing UV portals that irradiate people as they walk through. While this device may not cause much harm or skin damage in the few seconds walking through the portal, the low dose delivered and potential to disinfect clothing would also likely not be effective for stemming any virus transmission.

Most importantly, eye safety and long-term exposure have not been well studied, and these types of devices need to be regulated and validated for effectiveness before being used in public settings. The impact of continuous germicidal irradiation exposure on the overall environmental microbiome also needs to be understood.

As more studies on Far UV-C bear out that exposure to human skin is not dangerous and if studies on eye exposure show no harm, it is possible that validated Far UV-C light systems installed in public places could support attempts at controlling virus transmission for Sars-CoV-2 and other potential airborne viral pathogens, today and into the future.

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PLUS POINTS

Minimising flood risk

Researchers at the Indian Institute of Technology-Madras have studied flooding in and around Chennai and proposed the construction of "straight training walls" at the mouth of Ennore Creek in order to minimise the flood risk significantly on its upstream.

The study focused on extreme storm surge scenarios and high tide levels along with flooding in the river. It found that heavy siltation in the creek mouth and narrow opening in the mouth posed a flood threat to the areas adjoining the river.

The study showed that straight training walls at the creek mouth and some regular de-silting of the river will improve the situation and minimise the flood risk significantly in North Chennai. It also showed that an alternative proposal of curved training walls proposed earlier will worsen the situation, by blocking the free exchange of seawater with the creek, thereby, increasing the flood risk.

The study was commissioned by Kamarajar Port (formerly Ennore Port) in Chennai to propose solutions to reduce flooding around Kosathalaiyar riverbanks. It was undertaken by K Murali, SA Sannasiraj, and V Sundar, faculty in the department of ocean engineering, IIT-Madras.

In the history of flooding in and around Chennai, the three creeks – Adyar, Cooum and Ennore – remain as major bottlenecks due to sand bar formation at their mouths, this results in significant flooding over the settlement along its banks, impact on coastal villages, disruption in fishing activity, industrial network on the upstream, road encroachments and illegal waste disposal.

The comprehensive report by IIT-Madras examined different possibilities of extreme event cases both from the land and the sea. A detailed study for the Adyar and Cooum estuaries will also be taken up for investigation by IIT-Madras.

Lunar commerce

Nasa will pay companies to bring it rocks back from the Moon. The space agency will buy rocks, dirt and other bits of the lunar surface from companies who can make the journey to the Moon and back. The plan is part of Nasa's broader plan to encourage private space exploration, which includes the extraction of materials from objects elsewhere in space.

Nasa administrator Jim Bridenstine wrote in a blog post accompanying the announcement that the plans would not violate a 1967 treaty that holds that celestial bodies and space are exempt from national claims of ownership. The initiative, targeting companies that plan to send robots to mine lunar resources, is part of Nasa's goal of setting what Bridenstine called "norms of behaviour" in space and allowing private mining on the Moon in ways that could help sustain future astronaut missions. Nasa said it views the mined resources as the property of the company, and the materials would become "the sole property of Nasa" after purchase.

Under Nasa's Artemis programme, President Donald Trump's administration envisions a return of American astronauts to the Moon by 2024. Nasa has cast such a mission as a precursor to a future first human voyage to Mars. "The bottom line is we are going to buy some lunar soil for the purpose of it demonstrating that it can be done," Bridenstine said during an event hosted by the Secure World Foundation, a space policy organisation.

Bridenstine said Nasa eventually would buy more types of resources such as ice and other materials that may be discovered on the Moon. Under the initiative disclosed last week, Nasa offered to purchase limited amounts of lunar resources and asked companies to offer proposals. Under contracts whose terms would vary, a company mining on the Moon would collect lunar rocks or dirt to sell to Nasa without having to bring the resources back to Earth.

–The independent