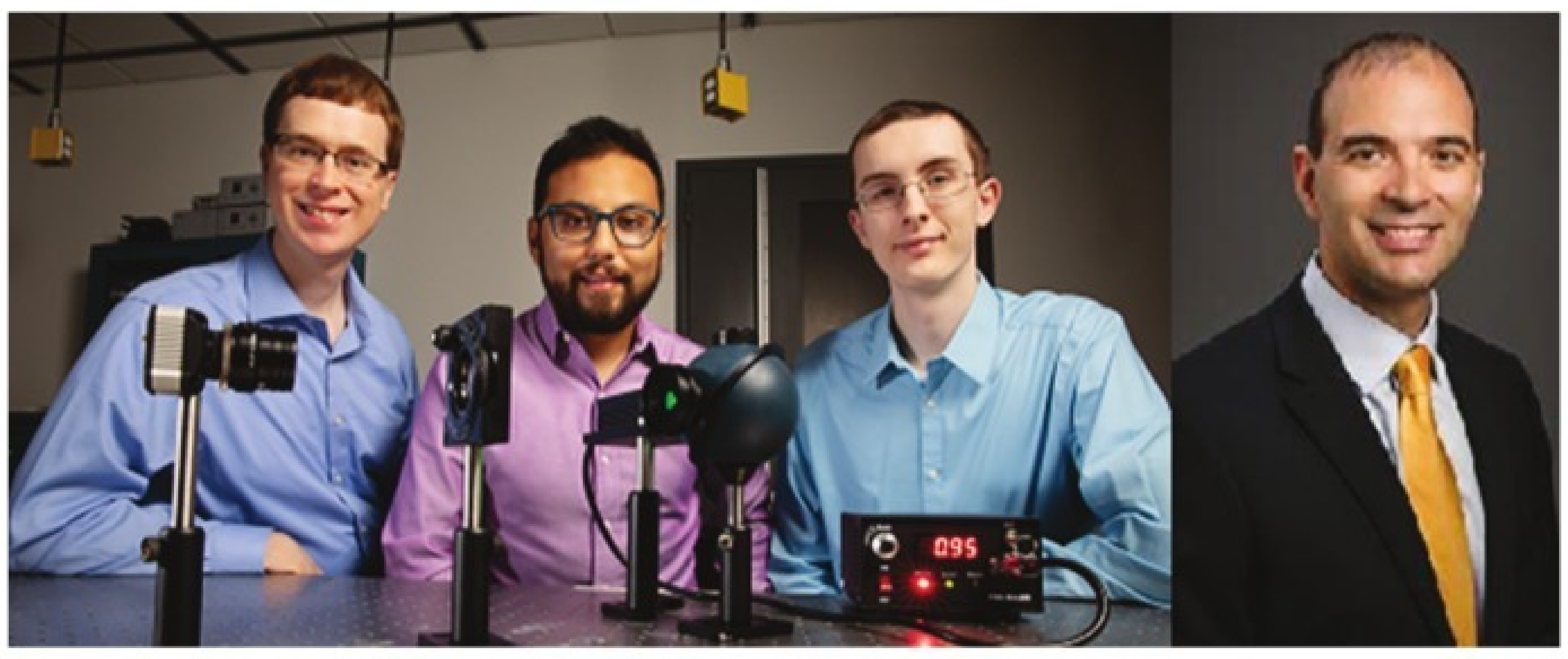
Seeing more with the shrimp

Animal eyes are better models than human ones for devices meant for sensitive imaging



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The photographic camera and now the digital camera have long followed the way the human eye is constructed. The technology has become sophisticated and cameras can send inputs to software that discriminates shapes and generates meaning, like the brain does from the images created by the eye.

The combination of high resolution cameras and computers can resolve the detail to recognise a human face and their speed of action is good enough to support the software that manages a driverless car in busy traffic. In this last application, which needs fail-proof performance, however, the digital camera has been found to have limitations. Missael Garcia, Tyler Davis, Steven Blair, Nan Cui, and Viktor Gruev, from the University of Illinois at Urbana-Champaign and Washington University in St Louis, write in the journal, *Optica*, how eyes in the animal world, adapted for different conditions, show the way digital cameras could use properties of light waves that the human eye cannot.

All that a camera and computer can make out, when an image is scanned, is a sequence of bright and dark spots, or spots of different colours. The translation of the sequence into a meaningful image is brought about by a process of learning, where a large number of sequences are associated with specific images, or not, so that the system, in time, is able to identify a new sequence as belonging to one category or another. Thus, the imaging system can be trained to make out a vehicle, a car or bus or bicycle, for instance, or a pedestrian. Advanced software can then make out one image that is in front of another, and then, movement of objects. In this way, computers have been developed to control a driverless car, by turning the car to the left or right, to speed up and slow down, in the face of a turn in the road or other traffic, obstruction or pedestrians.

With improved optics and electronics, current systems are able to function in ordinary conditions. They run into trouble, however, when there are sudden changes, like when the car moves out of darkness to light, or if an objector obstruction is the same colour as the background, or when it is hazy. It is for these conditions that the team writing in the journal, *Optica*, proposes an alternative system, which uses other properties of light than simply forming geometric images.

The way light affects the eye, or the sensors of the camera, is that it is a wave that carries energy. At the level of cells of the eyes, light behaves like a particle and transfers a packet or lump-sum of energy to the cells. This is the action of light that humans are able to sense and it serves to make out shapes and colours. But, apart from a straight line path and a frequency or colour, the light wave has another dimension, of the plane of vibration of its electromagnetic composition.

We are familiar with waves, or ripples, on water, in which the movement of water is up and down, while the wave moves forward horizontally. Light waves, however, are not restricted to the up-down direction and the vibration can be in any plane. Thus, if a beam of light is moving from left to right parallel to a sheet of paper, the electric vibration is either in and out of the plane of the paper or up and down within the plane of the paper, or in any other plane, so long as the plane is perpendicular to the direction of the beam. Sunlight, which arises from thermal emission of very hot gasses in the sun, consists of waves in all possible planes of vibration.

On reflection, however, there is a selection of the plane of vibration and this is called polarisation of the light. The scattered light from the blue sky and particularly diffused light at sunrise or at dusk is markedly polarised. Different surfaces also impose different modes of polarisation. Light from an object that is before a background of the same colour would hence be distinguishable because of polarisation, even if not by the colour or intensity of light.

As humans have evolved to rely on position and colour for navigation and hunting, and benefit from maximum sensitivity, the cells in the human eye respond equally to light waves of all planes of polarisation. This, however, is not true of some animals, birds or insects, which need to navigate without fixed markers and also to be sensitive to detect prey or food that is not always distinctly visible. Being able to detect the plane of polarisation helps animals know the position of the Sun even when it is hidden behind clouds or to locate specific reflecting surfaces while foraging.

The team writing in *Optica* considered that tapping this property of light may help the electronic camera overcome its limitations, which arose from its being modelled on the human eye, which relies only on the geometric form of optical images. The mantis shrimp, a shellfish found in the sea, is known to have perhaps the most complex visual apparatus of all in the animal kingdom. Each compound eye consists of tens of thousands of clusters of light sensitive cells and the eyes can move independently. The eyes have 16 types of detectors of light, unlike the three types, for the primary colours, that humans have. And they detect not only 16 different shades of colour but also six kinds of polarisation of light, the *Optica* paper says.

Another property of the mantis shrimp's eyes is that they can distinguish a vast range of intensity of light. This range is possible because the sensitivity is not distributed uniformly, from the dimmest to the brightest, but is well separated for dim light and less so for bright light. This is the reason, the paper says, that the mantis shrimp is a deadly predator in dimly lit waters and has inspired several artificial colour and polarisation imaging systems. In order to match the polarisation-resolving quality of photo-detectors with the sensitivity that they have to different colours, the team mimicked the architecture of the eye of the mantis shrimp. The shrimps eye is structured into three parts, the paper says, two peripheral hemispheres and a midband section. The hemispheres have alternate stacks of microscopic projections and respond to light of opposite polarisation. The artificial imager consists of over a hundred and ten thousand pixels, and each has a filter sensitive to one of four kinds of polarised light. And the electronics is arranged to react sensitively to variations in low intensity and more broadly when the intensity rises. This gives the system a wide intensity range, like the eye of the mantis.

The result is a photo-sensor system that works at thirty frames a second, with a huge range of intensity discrimination and exceptional sensitivity, the paper says. The compact size and the low cost of the arrangement make it suitable for use in automobile automation or unmanned, remote sensing equipment, the paper says.

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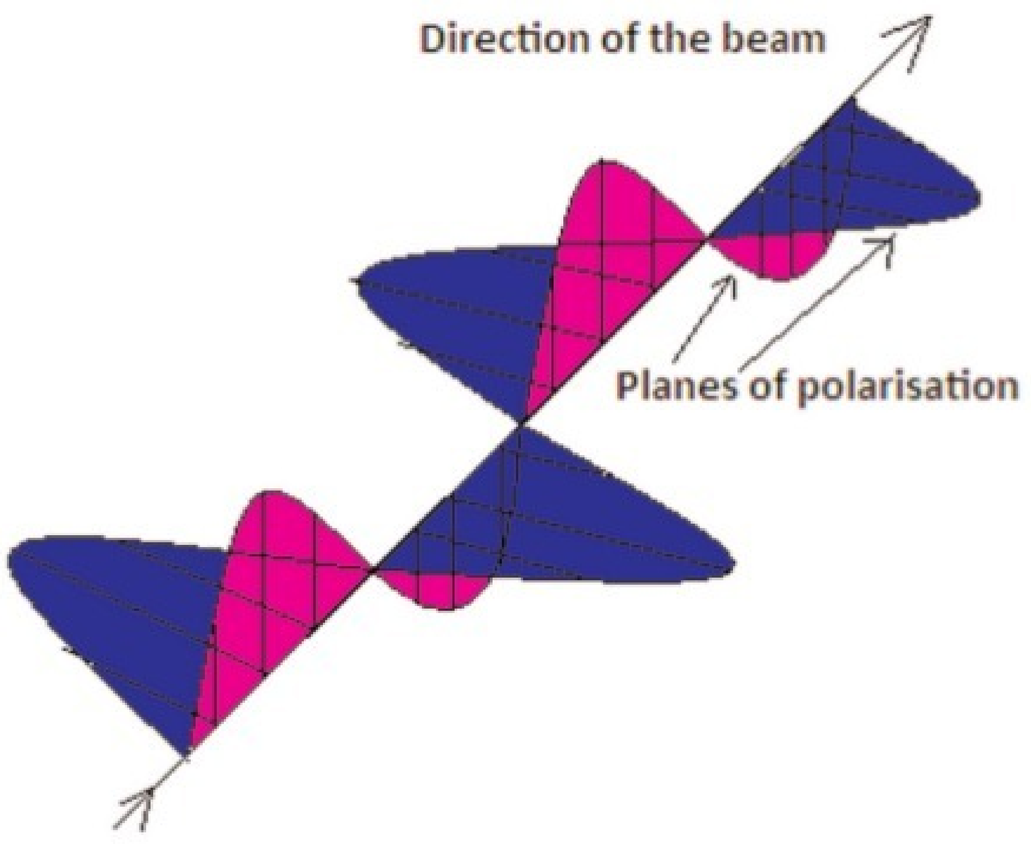


PLUS POINTS

Nothing to eat

Polar bears will be robbed of the food supply that has kept them alive for thousands of years over the next few decades by climate change, a new study has warned. When temperatures have risen in the past and melted Arctic sea ice, scientists believe the creatures survived by scavenging whale carcasses until the ice returned and they could hunt seals again.

However, the Intergovernmental Panel on Climate Change has concluded that ice-free summers could begin occurring again within decades. "If the rate of sea-ice loss and warming continues unmitigated, what is going to happen to polar bear habitat will exceed anything documented over the last million years," said Kristin Laidre, a marine biologist at the University of Washington. "The extremely rapid pace of this change makes it almost impossible for us to use history to predict the future."

Scientists expect there will be a summer in the Arctic without ice by 2040 if warming continues at its current rate.

Polar bears rely on ice because it provides them with a platform from

which to hunt seals. If ice-free summers become a regular occurrence — which is predicted in the IPCC report if warming exceeds 2°C, then Laidre and her colleagues said whale carcasses are unlikely to save the bears.

Firstly, they note that while the Earth has gone through natural cycles of cooling and warming, the current rate of ice loss outstrips anything the bears have experienced before.

This is exacerbated by human intrusion into the Arctic. Centuries of whaling, oil drilling and shipping in the region mean whales are nowhere near as abundant as they were during the last "interglacial" period when temperatures rose. Fewer whales means fewer carcasses to scavenge and this leaves bears vulnerable to severe declines and even extinction as their emergency food supply dries up.

Previous research has already documented polar bears undergoing rapid weight loss as Arctic ice gets thinner. "The environmental changes are too large and the whale carcasses are too few," said Laidre.

The scientists initially set out to understand how bears could have made it through warmer historic periods in the context of a warming climate. They documented their findings in the journal *Frontiers in Ecology and the Environment*.

With a nutritional value equivalent to over 1,000 seals, they found that large whales have the capacity to sustain bears for months or even years — making them perfect for seeing out hot summer seasons.

Their analysis of polar bears diets and whale protein and fat composition suggested that during the summer months a hypothetical population of 1,000 polar bears would need to eat about eight whales.

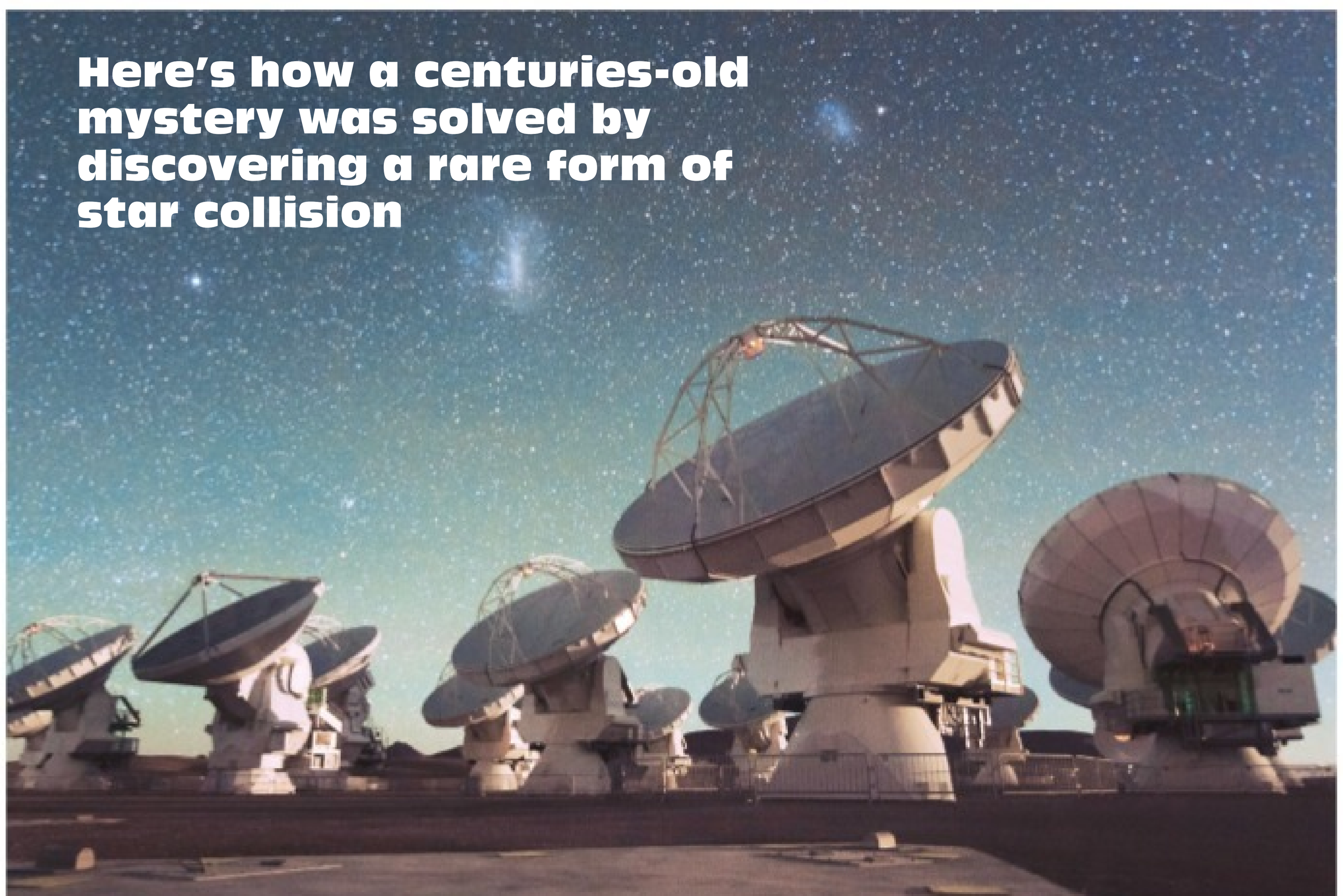
However, particularly in areas where whales are not as common like the island of Svalbard, the scientists predict strandings will not sustain the local bears. "When we look at the situation now, ecologically, with respect to food sources, it's a very different picture," said professor Ian Stirling of the University of Alberta, who has studied polar bears for 45 years. "The potential of whale carcasses to bail bears out may still be important in a few areas but, quite simply, their overall availability is going to be substantially less than before humans invaded the Arctic."

Commenting on the team's findings, WWF chief polar advisor, Rod Downie said, "Polar bears face an uncertain future and we could lose about 30 per cent of the population by the middle of this century.

"That is predicted to happen on our watch. We need to plan for change in the Arctic now. And we need to make deep and rapid cuts to our carbon emissions across the world, in order to secure a future for these icons on ice."

The independent

On a celestial adventure



ALBERT ZIJLSTRA

A bright new star appeared in the sky in June 1670. It was seen by the Carthusian monk Père Dom Anthelme in Dijon, France, and astronomer Johannes Hevelius in Gdansk, Poland. Over the next few months, it slowly faded to invisibility. But in March 1671, it reappeared — now even more luminous and among the 100 brightest stars in the sky. Again it faded, and by the end of the summer it was gone. Then in 1672, it put in a third appearance, now only barely visible to the naked eye. After a few months it was gone again and hasn't been seen since.

This has always seemed to be an odd event. For centuries, astronomers regarded it as the oldest known nova — a type of star explosion. But this explanation became untenable in the 20th century. A nova is a fairly common event, when hydrogen ignites in an otherwise extinct star causing a thermonuclear runaway reaction. Stars can also explode as supernovae, following an implosion of their core. However, we know now that neither would give the kind of repeated appearance seen in this event.

So what was it? Our new research, published in the Monthly Notices of the Royal Astronomical Society, offers a whole new explanation.

In 1982, the American astronomer Mike Shara found a nebula — an interstellar cloud of dust, hydrogen, helium and other gases — at the position of the missing star, which had since acquired the name CK Vulin between. This proved that something had indeed happened here. Astronomers later noted that the nebula was expanding, and that the expansion had started around 300 years ago. But the star itself couldn't be seen.

Things became even stranger when the astronomer Tomasz Kaminski discovered that the nebula contained a most unusual mix of elements, being very abundant in two isotopes (elements with a different number of neutrons in their nucleus compared to the "normal" atom) — a type of nitrogen (15N) and radioactive aluminium (26Al). These require very high temperatures to form. Whatever happened, this had been a high-energy event.

New observations

We observed the location of the star with the ALMA observatory in Chile. This spectacular-looking telescope uses 64 separate dishes, and observes in the microwave region of light. It is particularly good at detecting radiation from molecules in space. What we found is that the debris from the event is visible as two rings of dust, resembling an hourglass. This hourglass is embedded within a larger hourglass seen in previous observations, and itself contains other structures — nested like a Russian doll.

Such hourglass lobes indicate the presence of jets coming from the centre, which blow out the opposing bubbles. But the hourglasses are at slightly different angles. This suggests that the originating structure was spinning, and this requires a protracted process. Whatever happened, it was not just a single explosion. The ejection must have taken some time.

But if it wasn't an explosion, what happened? The alternative to a stellar explosion is a collision between two stars. These are rare events which have caught much attention in recent years. In 2008, a collision was caught near the centre of our galaxy. The colliding stars circled each other closely, before finally merging.

During the event, the stars became 100 times brighter than before, and over the next two years they faded again. A similar event may have happened in the year 2000, when a star called V838 Mon suddenly brightened and then slowly faded.

CK Vul could be the result of a merger between two normal stars. But this didn't seem to fit. Luckily, though, there is a complete zoo of possible collisions, as stars come in many types. We have now worked out that two stars from the opposite side of the stellar spectrum could have produced the pattern seen in the sky.

The main actor would have been a white dwarf — a dense remnant left after a star like the Sun reaches the end of its life. The supporting actor would have been a brown dwarf, an object in the twilight zone between stars and planets — too light to produce the hydrogen fusion, which normally takes place at the centre of a stars, but too heavy to be a planet. They are 10 to 80 times heavier than Jupiter. Brown dwarfs are probably quite common, but they are hard to find because they are so faint.

A collision between a white dwarf and a brown dwarf would be spectacular. The brown dwarf would be shredded by the much heavier and denser white dwarf. Some of the shredded dwarf would rain down on the white dwarf and provide the fuel for a thermonuclear reaction. The rest of the brown dwarf would be swept up in the debris from the outburst.

Unlike a normal star, white dwarfs can be extremely faint, and after the merger and thermonuclear explosion, would eventually have returned to this brightness. The remaining dust shells may also have contributed, making it opaque to visible light. A merger of normal stars would have left a star of normal luminosity, and even if obscured could still have been seen in the infrared. Is this what actually happened? We have made a plausible model but further tests would be required to produce conclusive evidence. For example, would this collision provide the right conditions to form radioactive aluminium? Upcoming observations could look at the details of the innermost region of the hourglass structure to find out.

Our discovery represents the first ever detection of a collision between a white and a brown dwarf. Once confirmed, we can use it to look for other events like it. Astronomy is an adventure — a beautiful mix of physics and discovery. We are still learning.

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