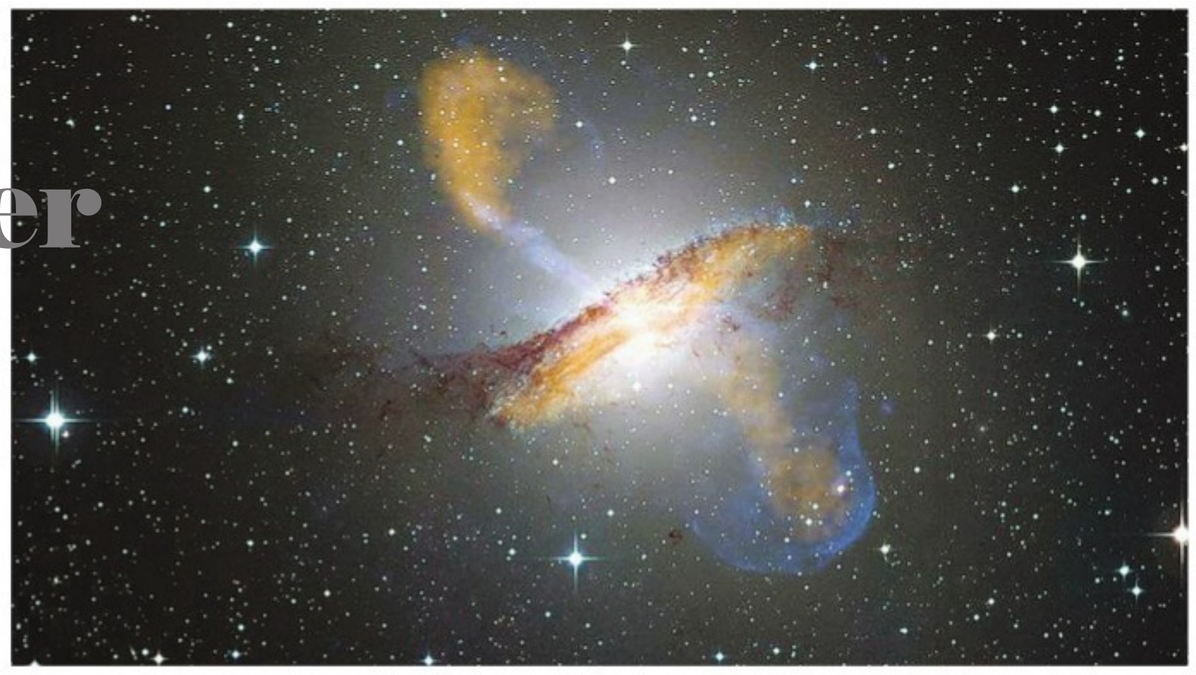
New light on dark matter

A galaxy found to contain no dark matter has put cosmologists in a fix

S ANANTHANARAYANAN



The current view of the universe is that the bulk of its mass is a form of matter that we have not been able to detect. As opposed to matter that we see, this invisible kind is called dark matter. The current understanding is that there is many times more dark matter than ordinary matter.

An apparent contradiction, however, has been reported, in the journal, *Nature*, by a group of cosmologists. Pieter van Dokkum, Shany Danieli, Yotam Cohen, Allison Merritt, Aaron J Romanowsky, Roberto Abraham, Jean Brodie, Charlie Conroy, Deborah Lokhorst, Lamiya Mowla, Ewan O'Sullivan and Jielai Zhang, from the universities at Yale, San Jose and Santa Cruz in California, Toronto, Max Planck Institute in Heidelberg and the Harvard-Smithsonian Centre, Cambridge, report that measurements on a galaxy some 650 million light years away show that it contains almost no dark matter. This is in contrast to galaxies the size of the Milky Way, where dark matter is 30 times the mass of ordinary matter. The ratio is much higher in larger as well as in smaller galaxies — a whole 400 times higher in dwarf galaxies.

Dragonfly Telephoto Array

The idea that there must be unseen matter in the universe is based on features observed in the rotation of galaxies and was formally suggested a century ago. When objects are in orbit, the gravitational attraction towards the centre reduces as the objects move further away. For objects that are in stable orbits, the centrifugal or centre-fleeing tendency is balanced by the force of gravity that draws them to the centre. Objects that are further away, hence, move slower, as it is a weaker gravitational force that their motion needs to balance.

An example is our own Solar System. The inner planets, Mercury, Venus, Earth and Mars are at distances from 57 to 227 million kms from the Sun and the time they take to go once around the Sun ranges from 57 to 887 days. The average speed of motion ranges from 47 km/sec, for Mercury, to 24 km/sec in the case of Mars.

The outer planets, Jupiter, Saturn, Uranus and Neptune are at 780 million to 4.5 billion kms from the Sun and they go around in 11.9 to 165 years. The range of speeds is from 13 km/s, for Jupiter, to 4.3 km/sec for Neptune. We can see that the planets at greater distances from the centre move more slowly.

Surprisingly, this is not what we see in the case of large celestial formations like galaxies. In the case of rotating galaxies, it is found that the portions further away from the centre move at the same or at increasing speeds compared to parts that are closer to the centre. The mass of the galaxy, which can be taken to be at its centre, towards which the extremities are drawn by gravity, can be estimated based on parts of the galaxy that are detectable, visually, by radio telescopes and so on. Given this mass of a rotating galaxy, the force of gravity at the outer reaches can be worked out and hence how fast objects need to be moving. Observation, however, shows that the peripheral objects in galaxies are moving at higher speeds than worked out. In the normal course, these fast moving objects cannot stay in orbit and the galaxy should fly apart. One way of explaining why this does not happen is to propose that the galaxy actually has more mass than we can see.

As early as 1884, Lord Kelvin had suggested that the mass of the Milky Way, as determined from the speeds at which stars in the galaxy moved, appeared to be greater than the total mass of the visible stars. His was perhaps the first proposal that there was an unseen component that made up the mass of the galaxy. Subsequent studies, with superior equipment and instruments, placed the concept of dark matter on a firm footing. Apart from the rotation speed of galaxies, other evidence was the bending of light rays, or gravitational lensing, which brings into view objects that should be hidden behind intervening galaxies. The extent of bending of light could not be explained by the mass of the visible part of the galaxy, and this became a tool to estimate the mass of dark matter that the galaxy contained.

The discovery reported by the group writing in *Nature* is of a galaxy, NGC1052-DF2, which appears to be different from those previously studied. The galaxy was observed using an automated array of multi-lens cameras, the Dragonfly telephoto array, which has been optimised for surveying the extremely low brightness parts of the universe. The case of this galaxy stood out, the group explains, because the Dragonfly image was one of a dim object with some substructure, but a star data base, the Sloan Digital Sky Survey, shows the galaxy as a collection of point-like sources of light.

The group hence collected more data of the spectral structure of the light that came from the galaxy. This data enables estimation of the speeds of motion of the objects from which the light emerges and this in turn, enables an estimate of the mass of matter exerting gravitational forces. The mass of the galaxy, based on the visible matter, they say, is about 200 million times the mass of the Sun, or some 250 times less than the Milky Way. Typically, the mass, as estimated from the rotation speed of the galaxy, is many times the visible mass, on account of dark matter. But in this case, the data of movement speeds of 10 luminous objects in the diffuse galaxy revealed a mass that was practically the same as the visible mass or a zero component of dark matter.

The finding places a large question mark on the concept of dark matter. While dark matter itself has not been detected so far, its supposition is central to explaining the structure of the universe. That dark matter is associated with the existence of ordinary matter, again, is the position that helps understand the distribution of a faint, but pervasive background of microwave radiation, a remnant of the Big Bang, 13 billion years ago.

The present finding, however, is an instance of a large region in space where there is no dark matter. Other findings, as when there are collisions of galaxies, have shown that it is possible for dark matter to move independently of ordinary matter. And as dark matter has not been discovered so far, alternate theories have been proposed to explain the greater gravitational effects within and between galaxies.

A leading alternate theory is the Modified Newtonian Dynamics. This theory suggests that just like relativistic effects kick in when gravitational forces are very strong, there are changes in gravity when the forces become extremely feeble. Working on these lines, one is able explain the anomalies in rotation of galaxies with great accuracy. The same theory, however, needs to fall back on dark matter in some circumstances. The discovery of a galaxy where there is no dark matter would hence embarrass some alternate theories too.

The writer can be contacted at response@simplescience.in

'Crop raiders' of the Amazon

For a year, three researchers studied and photographed animals that cause the most crop damage in the hope of aiding both local farmers and wildlife conservation in the Brazilian rainforest

MARK ILAN ABRAHAMS

Red brocket deer

Rural communities in the Amazon rainforest live alongside an incredibly diverse set of animals. When some of those animals damage and eat farmers' crops ("crop-raiding"), it creates a challenge for conservationists, who need to understand the lives of the people who coexist with that wildlife.

My colleagues and I recently spent a year in the Medio Jurua region of Amazonas, Brazil, using motion-activated camera traps to take photos of the many animals that live on or near Amazonian farms. Along with interviews of farmers, this enabled us to study, which animals cause the most crop damage, how this affects the livelihoods of rural Amazonians and how these communities respond to crop raiders. Our hope was to understand how this issue might affect attempts to preserve wildlife and to offer support to local farmers if they wanted it.

The Medio Jurua region is a vast area of staggeringly biodiverse lowland tropical forest inhabited by river-dwelling communities, who descend from a mix of indigenous Amerindians, European colonists and former slaves from Africa. Our research team (comprising myself, my colleague professor Carlos Peres and Hugo Costa from the State University of Santa Cruz, US) travelled using small boats and dug-out canoes along the sinuous waterways and through the flooded forests. The region experiences a massive 10 metre-high annual flood, which has wide-ranging impacts on the local ecosystems and the livelihoods of the inhabitants.

In the year we spent living and working with the communities of the Jurua, we were fortunate enough to participate in many aspects of life, including learning to harvest the fruit of the acai palm. Many Jurua communities are the descendants of rubber tappers who were drawn to this region during the rubber boom of the late 1800s. Many still depend on the natural resources of the forest and river for their livelihoods. The incredibly hospitable communities of the region frequently hosted and fed us as we travelled.

Most of the carbohydrates in rural Amazonian diets come from manioc (also known as yucca or cassava). This tough plant grows well on infertile tropical soils and has powerful chemical defences that make it pest-resistant. Farmers grow manioc using "slash-and-burn" agriculture in fields called "rocados", which are created by burning down a section of forest. They peel, grind, soak, drain and toast the manioc to remove the toxic cyanide that protects the plant from pests. The result of this process is delicious coarse flour called "farinha", which is commonly eaten with fish soup. Despite high levels of toxins in raw manioc, some wild animals such as large rodents, deer and pig-like peccaries are able to eat it. These crop raiders can have devastating impacts on human livelihoods, destroying an average of about eight per cent of each farmer's crop every year. Farmers estimated that if they did not protect their crops, their losses would be roughly 10 times higher. In other parts of the world, large herbivore crop raiders, such as African and Asian elephants, also endanger the lives of farmers.

Of course, these wild and often endangered species are merely trying to survive in an increasingly human-modified landscape. Poor farmers sometimes resort to killing crop raiders to protect their lives and livelihoods and can end up resenting the conservation organisations who want to protect these species.

To study crop raiding, we set up 132 camera traps in areas next to local rocados, helped by more than 45 people living in the nearby communities. We captured more than 60,000 photographs and detected over 30 species. We detected everything from fearsome predators, such as pumas, to secretive nocturnal giant armadillos, to birds of prey and even primates, such as capuchin monkeys.

One of the most feared predators in the area is the jaguar, locally known as "onca-pintada". We were fortunate to detect this species in several locations. Somewhat unnervingly, we occasionally saw their large fresh prints on the trail as we returned to the community, indicating that we had unwittingly been followed.

Many local residents assured us that this species is "very cunning. They see us, but we don't see them". We were also told a local legend that when a jaguar follows in the tracks of a human, it will sniff their tracks to decide whether or not to attack. We can only presume that we smelled so bad at that point that even our footprints were unappealing.

Collared Peccaries

Capuchin monkey

Agouti

In only one location, our cameras detected a rare red-billed ground cuckoo. This was an unexpected treat. Our colleagues were among the first to photograph this elusive species when they worked along the Xerua River a few years ago.

Some species seemed to rather enjoy the limelight, while others took exception to being monitored. Razor-billed curassows frequently paraded themselves in front of the cameras, whereas a short-eared dog took it upon himself to tear a camera from the tree. Spending long periods hiking through tropical forests surrounded by an exuberance of living things does come with certain drawbacks. For one thing, there is a bewildering array of tiny life-forms for whom humans are mere prey.

We also conducted 157 interviews with local people, who overwhelmingly identified five species as the most burdensome crop raiders. These were, in order of importance, the large rodent agouti, collared peccary, paca (another large rodent), red brocket deer and, to a lesser degree, the spiny rat.

These species were some of the most frequently detected by our camera traps. They were also among the most heavily hunted species. None of these crop raiders are considered highly endangered (though the International Union for the Conservation of Nature doesn't have enough data on red brocket deer to classify them). Other studies have also found that these species can tolerate a moderate level of being hunted for food.

We were encouraged to find that, despite the costs of crop-raiding to rural Amazonian communities, it did not seem to constitute the bitter "human-wildlife conflict" that other researchers have identified. In fact, because the most damaging crop-raiding species are fairly common, crop protection methods, including hunting, may not be a major threat to wildlife in this region.

Rural tropical communities are often encouraged by people from other countries to conserve their biodiverse surroundings and are criticised for hunting that helps them survive. We hope that our study has shed some light on the challenges faced by Amazonian communities who attempt to coexist with wildlife. They could use our results as the basis of a plan to manage the species that they hunt, just as they have implemented plans for sustainable rubber tapping and fishing in partnership with international organisations.

The writer is a lecturer at the University of East Anglia, UK

The independent

PLUS POINTS

Nine novel genes

In the largest study of its kind, nine novel genes for osteoarthritis have been discovered by scientists from the University of Sheffield, UK, and their collaborators. Results of the study, published last week in *Nature Genetics*, could open the door to new targeted therapies for this debilitating disease in the future.

Osteoarthritis is a degenerative disease in which a person's joints become damaged, stop moving freely and become painful. Osteoarthritis is the most prevalent musculoskeletal disease and a leading cause of disability worldwide.

There is no treatment and the disease is managed with pain relief and culminates in joint replacement surgery, which has variable outcomes.

To understand more about the genetic basis of osteoarthritis, the team studied 16.5 million DNA variations from the UK Biobank resource. Following combined analysis in up to 30,727 people with osteoarthritis and nearly 300,000 people without osteoarthritis in total, scientists discovered nine new genes that were associated with osteoarthritis, a significant breakthrough for this disease.

Researchers investigated the role of the nine new genes in osteoarthritis, by studying both normal cartilage and diseased cartilage from individuals who had a joint replacement.

The team looked for genes that were active in the progression of the disease by extracting the relevant cells from healthy and diseased tissue. They examined the DNA signatures, looking for differences between subjects with osteoarthritis to those without. Of the nine genes associated with osteoarthritis, researchers identified five genes in particular that differed significantly in their expression in healthy and diseased tissue. The five genes present novel targets for future research into therapies.

All in the teeth

Researchers from New Zealand's University of Otago are using bottlenose dolphin teeth to help them understand coastal contamination.

Metal contaminants in marine environments are a particular health risk for humans and other animals as they get absorbed into teeth and bones. Carolina Loch from the faculty of dentistry is the principal investigator in the pilot study designed to track metal exposure in marine species to help determine pollution in the ocean.

Similar to humans, bottlenose dolphin teeth are made up of enamel and dentine which grows in layers like the rings in a tree. Each layer corresponds to one year of the life of the animal and using laser spectroscopy, Loch hopes to be able to reveal the toxic metal bioaccumulation.

Dolphin teeth reliably record contamination because toxic metals and trace elements from diet are incorporated into enamel and dentine throughout life.

As dolphins feed from fish and other animals in the ocean they are potentially susceptible to metals like lead or mercury — just as humans are. Humans too eat some of the same seafood as dolphins.

"One of the key issues is that the wastewater from mining and city pollution goes back into the marine environment and it comes back to us when we consume seafood," Loch explains.

Water or seaweed samples can reveal information about contaminants at a certain point in time, but the dolphin's teeth enables the researchers to look at what happened in past times. The teeth are being provided from archival material from Massey University and the South Australian Museum. The bottlenose species have been specifically chosen because these animals do not migrate.