Science Last Fortnight

Charming Beauty of Hadrons
Quirky quarks

Never trust quarks. They make up everything.

You can never detect one alone and cannot observe them directly. They come in six flavours and have bizarre names: up, down, strange, charm, beauty and top. These quarks, when combined in a trifecta, form baryons – distant cousins of protons.

Nilmani Mathur, a particle physicist from TIFR, Mumbai studies the characteristics of baryons. Within the Indian Lattice Gauge Theory Initiative, he, along with his former student, Padmanath, recently determined the ground state mass of charmed-bottom baryons, with unprecedented accuracy.

This is a significant search because these baryons are made from beauty and charmed quarks, which are thousands of times more massive than up and down quarks. Not only do heavy baryons need more energy, they are also rare to find.

Mathur and team used quantum chromodynamics – a set of easy to write but difficult to solve nonlinear equations. Quantum chromodynamics is the theory of strong interactions and can be solved analytically only at very high energies. The solutions to the equations can help describe the strong interactions of our universe.

There is another indirect way to approach the problem: treating space and time as lattices of points. Lattice quantum chromodynamics describes interactions between particles in terms of 'gauge fields', where quarks are treated as points on an imaginary lattice. Mathur and group used this method to make quantitative predictions for subatomic particles.

Until now, such 'bottom charmed' particles were elusive. The work of Mathur and his team marks a new path, where our understanding of heavier subatomic particles is based on lattice quantum chromodynamics. Results from the calculations based on first principles can lead to a better understanding of hadrons, including nucleons, which supply almost all masses of our visible universe. This tandem of theoretical ideas and experimental verifications could yield new pieces to the puzzle of the standard model of particle physics.

DOI: 10.1103/PhysRevLett.121.202002

Bomdila Fault
Moving the mighty river

Strain maps, provided by the US Geological Survey, indicate the existence of tectonic strain in Arunachal Pradesh and Assam, in the Brahmaputra valley – among the most seismically active regions in India. Multiple stages of rock deformations point to faults, in and around Dirang, Arunachal Pradesh. Neotectonic activity, here, is evidenced by recent earthquakes above 5.5 on the Richter scale. The activity fractured the earth's crust and faults created discontinuities in terrestrial structures.

The Bomdila fault is one of the longest – 400 kilometers. The area is wedged between two tectonically active regions: the Himalayan collision arc and the Indo-Burmese subduction arc. To explain geological features around the fault, Jogendra Nath Sarma from the Dibrugarh University and Sangeeta Sharma from the CSIR-North East Institute of Science and Technology used GIS software. They analysed topographical maps of the terrain, stacking and processing satellite images of drainage patterns over 50 years.

The researchers observed that the Dhansiri, a tributary of the Brahmaputra, flowing from the southwest to the northeast, changed its course towards the northwest at Golaghat. The meandering Dhansiri traces a linear course from Golaghat, following the fault, until it joins the Brahmaputra. After the merger, the Brahmaputra turns northwest along the fault for some 25 km before turning southwest again.

The researchers also observed that Mora Dhansiri – the old course of the Dhansiri from east to west – is cut off from the SE–NW trending Dhansiri at Kurabahi. This shift is seen at a 15-metre sloping cliff along the left bank that runs parallel to the river, say the researchers. The Bomdila fault is marked by a stark difference in elevation, overlooking the low-lying eastern side of the river.

The Bargang, another tributary of the Brahmaputra, flowing towards the south-southeast, also changes course and begins to trend southeast at Tengabari. From this point on, until it drains into the northern banks of the Brahmaputra, the river flows more or less parallel to the Dhansiri, along the fault.
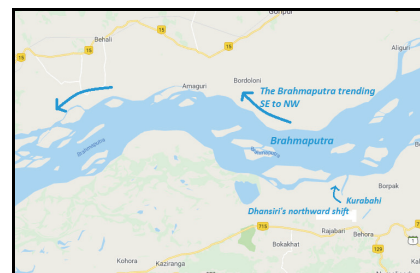
The researchers note that the Naga Thrust shows a sudden change in its trend where it meets the Bomdila fault. A similar change was also observed in the eastern Himalayan Main Boundary Thrust, implying that the fault is influencing the geography of its surroundings.

The alterations in the courses of the Brahmaputra and its tributaries and other topographical changes in the structures suggest that these neotectonic activities are a direct result of the Bomdila fault, say the scientists. The high seismicity of this region poses risks to human settlements along the fault.

DOI: 10.1007/s12040-018-1008-2

Hill Stream Loaches
Fishing for evolutionary clues

Hill stream loaches are small, brightly coloured fish, found in fast-flowing streams. They adapted to the habitat by evolving modified ventral fins that help them adhere to rock surfaces. Many unique and evolutionarily distinct

species of loaches are found in the Western Ghats. What led to this evolution?

Last fortnight, a team of researchers from the Kerala University of Fisheries and Ocean Studies, Kochi, the Nirmalagiri College, Kannur and IISER Pune reported investigating the diversity, distribution and drivers of diversification among hill stream loaches in the Western Ghats.

Image: V. K. Anoop

The southern parts of the Western Ghats have eastward and westward flowing rivers. The team collected samples of the genus Mesonoemacheilus of loaches from both eastward and westward flowing rivers. Only the larger eastward-flowing rivers of the Western Ghats, the Cauvery and the Tambaraparini, they found, are home to the genus. But, loaches inhabit even the small westward-flowing rivers.

The team extracted genetic material from more than sixty samples and measured genetic differences by amplifying and sequencing a mitochondrial DNA gene region. They used various species-delimiting phylogenetic methods to distinguish between species groups among the loaches.

Interestingly, the researchers found seven new species. The widely distributed species group of *M. triangularis* and *M. guentheri* are, in fact, species complexes, they say.

The team discovered that ancient geographical separations contribute significantly to genetic divergence. Two passes, one at Palghat and the other at Shencottah, break the geological barrier posed by the Ghats, but create barriers between north and south. So, the team distinguished between three regions: north of the Palghat Pass, south of the Shencottah Pass and the region in-between.

These barriers also led to differences in species. Species separation also occurred within the same geographic areas.

The team calibrated divergence time on the phylogenetic tree using an algorithm with two runs of ten million generations. 'The Mesonoemacheilus genus evolved less than sixty-six million years ago, in the Palaeogene period, before the Indian continent collided with Eurasia. Diversification seems to have happened much later, in the Neogene and Quaternary periods', says Neelesh Dahanukar, IISER Pune.

'About thirty-nine million years ago, *M. triangularis* formed a separate group. Then, thirty million years ago and again, around twenty-two million years ago, species divergences occurred', says Rajeev Raghavan, KUFOS.

'The *M. triangularis* group evloved differently, north and south of the Palghat Gap, nearly fourteen million years ago,' says Sibi Philip, Nirmalagiri College, Kannur.

'Further separation, across the Shencottah Gap, occurred about six million years ago', says Liji Thomas.

Such evolutionary studies help us understand the magnificence of the Western Ghats as Biodiversity Hotspot. They provide insights into the relationship between the roles of rivers and geographic barriers in speciation.

DOI: 10.1016/j.ympev.2018.08.013

Finfishes of the Poonthura Estuary
Measuring diversity

The Poonthura estuary in Thiruvananthapuram is one of the most polluted estuaries in Kerala. Sewage from adjacent settlements and waste from coir fibre production are destroying flora and fauna and befouling the backwaters.

Recently, researchers from the Kerala University of Fisheries and Ocean studies, Kochi studied the diversity of the finfish population in the Poonthura estuary because finfishes are a prime element in the aquatic habitat. They play a key role in the regional economy.

The scientists travelled in a plank-built boat every month from June 2016 to May 2017, to collect samples with a gill net. They collected water samples also, to analyse seasonal variation in water quality.

The scientists conducted multivariate analyses and measured diversity using different indices. Species abundance data values are significant for comparing the diversity with that of other estuaries and provide reference points for future analyses.

There is more diversity, post-monsoon. 'Higher productivity follows monsoon showers, drainage, and influx from rivers', says Sileesh Mullasseri, KUFOS, Kochi.

The team also observed higher chlorophyll-*a* value in the Poonthura estuary. 'This indicates eutrophication or excessive richness of nutrients, usually caused by run-off from the land, leading to dense growth of plant life', says B. Kiranya, KUFOS, Kochi.

S. Pramila, KUFOS recommends proper management to sustain resources and reduce pollution. Such measures would also improve livelihood opportunities from the estuary.

DOI: 10.1007/s10661-018-7094-4

Changes in Mangrove Cover
A spatio-temporal analysis

Mangroves, versatile and productive wetland ecosystems, stabilise shorelines and provide minor forest products for livelihood. Unfortunately, anthropogenic factors impact mangroves. Periodic studies and surveys monitor changes in local mangrove cover. However, so far, pan-Indian monitoring of mangrove cover has not been done.

Image: S. Suresh Ramanan

A team from the ICAR-Central Institute of Brackishwater Aquaculture, Chennai now provides a detailed analysis of changes in mangrove cover in India. The study included unprotected and protected mangrove forests.

To estimate changes in cover, the researchers took satellite imagery

from the 1989 Landsat 4 Thematic Mapper and the 2013 Landsat 7 Enhanced Thematic mapper. They used Imagine 2014, an earth resource data analysis system, and completed satellite image analysis in ArcGIS Software. The researchers visited selected sites for ground verification.

They report that, in the last twenty-five years, mangrove cover in India increased by 13%, even in some unprotected regions, despite anthropogenic pressures.

The team identified natural factors as responsible for major changes, particularly in the Sundarbans, the largest mangrove forest in India.

Such monitoring of pan-Indian mangrove cover will help formulate appropriate local measures to protect mangrove ecosystems.

DOI: 10.1016/j.ecss.2018.08.016

Electricity from Pine Forests
Needle litter feedstock

A large part of forest cover in Uttarakhand is pine. Pine trees shed needles that resist decomposition. The litter accumulates on the forest floor. Highly inflammable, the litter makes the area prone to fires. Forest fires erupt every year, posing a threat to villages in the area.

Image: Ramwik, via Wikimedia Commons

This threat can easily be converted into an opportunity, point out L. D. Kala and P. M. V. Subbarao, at the IIT Delhi. According to their research, the very pine needle litter that causes damage amounting to millions can, instead, generate 1444 million units of electricity annually! They arrived at this estimate based on the energy content of the litter produced annually.

To calculate the energy content, they adopted two independent approaches.

First, they estimated yield per hectare, multiplying needle yield per tree with average number of trees per

hectare. Multiplying this, in turn, with the area under pine forest cover in the state, they calculated total needle yield. In the second approach, they took an estimate of average needle yield per hectare from earlier studies and multiplied it with the area under pine forest. From both these approaches, they estimated the pine needle yield to be around two million tonnes per year.

The next question was: how much of it is available for energy production? The researchers say that only about 70% is available. The rest is unavailable due to inaccessible terrain, alternative uses, rain wash off or fire. So, the net needle yield for energy production would be about 1.34 million tonnes.

Then, the scientists worked out the primary energy content of the total available needles on the basis of calorific value. They found it to be 25 petajoules – equivalent to the energy produced by burning 600 kilo tonnes of oil.

'But all of this will not be available if we convert the needles into a commercially usable form', say the researchers. 'If we use pine needles as feedstock for steam boilers, the yield is only 17 petajoules of thermal energy'.

Pine needles can also be used to generate electricity locally using a downdraft gasifier. Through this process, Uttarakhand's pine needles can produce nearly one and a half billion units of electricity, annually.

Uttarakhand's pine forests spread over four lakh hectares have potential to generate bio-energy and employment for locals. The process will also reduce fire hazards and biodiversity loss.

DOI: 10.1016/j.renene.2018.05.054

Script Scrutiny
Writer recognition in Gurmukhi

Automated writer identification has evolved to identify duplicates in bank records, handwriting in prescriptions, authorship to allocate historical records and in forensic examination. As yet, however, there is no writer identification system for Gurmukhi, the script in which Punjabi is written.

So, researchers from different universities and institutes in Punjab collaborated to design a framework to identify handwritten Gurmukhi. They collected 31,500 samples from 90 different writers. 22,050 were used as training data set and the remaining for testing the recognition of 35 fundamental Gurmukhi characters.

The selected handwritten samples were scanned, converted into bitmap images and normalised into 100×100 pixels using nearest neighbourhood interpolation. At this stage, the image was transformed into a binary image.

The image was then reduced to its skeleton, retaining points needed for processing. This thinned image of the character was divided into 100 equivalent estimated zones. The researchers considered the features, required to identify the character, and documented them. Besides density and diagonal features, as well as horizontal and vertical transitions, the researchers included a new feature extraction technique, proposed in an earlier work: the peak extent.

Based on the features extracted, writer identification was done using the K-Nearest Neighbours technique where a test character is assigned to a class based on the closest example from the training set. The team mapped examples in space as points, with the help of Support Vector Machine algorithms that use supervised learning. Then, they overlapped test samples to see if they match.

The researchers achieved nearly ninety-five per cent accuracy in identifying Gurmukhi characters. The scientists claim that the framework for writer identification can also be used for other Indian scripts.

DOI: 10.1007/s12046-018-0966-z

Nursing Competence
Midwifery skills

Till 1955, India offered general nursing and midwifery programs as separate courses. Therefore, only aspirant midwives took the midwifery course. Later, the two merged into General Nursing and Midwifery.

According to the WHO, midwives are the primary workforce for maternal

and newborn health. Many countries have invested in midwives with fast reduction in maternal and newborn deaths.

Students with a diploma in General Nursing and Midwifery as well as B Sc Nursing are treated as registered midwives. But how skilled are they to meet the exigencies of supporting mothers and delivering and caring for the new-born?

Bharati Sharma from the Indian Institute of Public Health, Gujarat took a sample of more than 600 students from 25 randomly selected institutions in Gujarat. In collaboration with Swedish researchers, she compared the competence and confidence of final year General Nursing and Midwifery and B Sc Nursing students in attending to birth cases. The participants assessed their confidence on a four-point scale in four domains of midwifery – antepartum, intrapartum, postpartum and new-born care.

The researchers found that attending more than 30 births increased the confidence of the students in managing and supporting women during the three stages of labour. Thus hands-on clinical practice emerged the most important parameter for high confidence amongst students for midwifery skills.

The researchers found that, regardless of the course, half the respondents attended to only about 15 births instead of the INC-recommended 30 births. Only a minority of the General Nursing and Midwifery and B Sc students attended more than the required numbers voluntarily.

Interestingly, General Nursing and Midwifery students had 2–4 times more confidence for antepartum, intrapartum, postpartum and newborn care, compared to B Sc students. The research team attributes this to greater access to clinical practice.

India produces thousands of nurses every year from about 3000 schools and colleges of nursing in the country. Unfortunately, only very few (8%) General Nursing and Midwifery and B Sc students expressed a genuine interest in midwifery. This affects the quality of the midwifery workforce.

The researchers suggest that, for producing quality midwives, the Nursing Council of India should separate the midwifery course rather than integrating it with General Nursing and Midwifery. Many countries have already moved in this direction. The level of education and experience of the teachers as well as first-hand experience received during the course really matter for building up the confidence of midwives to attend births.

Deinked Paper Mill Sludge
Bricks from waste

India is the second largest producer of bricks, making millions each year. To make these bricks, topsoil is destroyed. Scientists at the CSIR-Central Building Research Institute, Roorkee have been searching for alternatives.

Recently, they collaborated with the IIT Roorkee and the IIT Delhi to produce bricks from deinked paper mill sludge. Waste printed paper can be reused as raw material for making paper but, first, it has to be deinked. The waste product, sludge, contains small cellulose fibres which are not so good for paper production.

The team obtained deinked paper mill sludge from Punjab and alluvial soil from Roorkee. Alluvial soil, a mixture of sand, silt, clay and organic matter is considered good for brick making.

The team oven dried the sludge and alluvial soil, a conventional step in brick making. The samples were then ground and sieved for uniform consistency.

The researchers prepared various soil–sludge mixes to make burnt clay bricks. The alluvial soil and sludge were mixed with water and the bricks prepared were dried to remove moisture.

The scientists fired the briquettes at various temperatures and cooled them to room temperature. They found 950°C the best firing temperature, less than the normal firing temperature for bricks.

The researchers evaluated the chemistry and mineralogy of the bricks. The sludge had calcium, titanium, iron, magnesium and potassium oxides – fluxing agents that saved energy during firing.

They determined the porosity and compressive strength of the bricks and observed a reduction in density and compressive strength when sludge is incorporated. The bricks showed higher water absorption and porosity and less thermal conductivity with higher deinked paper mill sludge content.

'A combination of 15% sludge and firing at 950°C firing is optimal for efficient brick manufacture', says S. K. Singh, CBRI, Roorkee.

'Deinked paper mill sludge can make brick manufacturing energy efficient', says Prabhat Vashistha, IIT Roorkee.

'The bricks are lighter, reducing labour and transportation costs', adds Vivek Kumar, IIT Delhi.

'These bricks with low thermal conductivity will be a boon for a tropical country like India', says Shilpa Kulkarni, IIT Roorkee.

Reports by: **Manish Kumar Tekam, S. Badrinarayan, Palatty Allesh Sinu, Kshama Lakshman, Sileesh Mullasseri, S. Suresh Ramanan, Sushmitha Baskar, Anup Raj** and **Pavithra P. Naik**