Science Last Fortnight

Why only neutron and proton?
Deuterons not the only dibaryon?

Deuteron, the nucleus of hydrogen's heavier isotope, is a stable dibaryon. Can other baryons form such stable coupling, wondered Nilmani Mathur, TIFR Mumbai.

Both neutrons and protons are made up of three quarks each. Can other quark triples come together to form stable dibaryons?

Nilmani and his postdoctoral fellow Parikshit Junnarkar set out to find the answer, using the first principles of quantum chromodynamics.

Quarks interact within a volume of the order of less than a femtometre, one trillionth of a millimetre. So the duo created ensembles of Strange and Charm quarks, the heavier quarks, and Up or Down, the lighter quarks in lattices of about 3 femtometres. Of course, not in the real world where it is impossible to do as an experiment, but on their computer, using simulation.

The interaction had to have exact chiral symmetry within finite lattice spaces. In the simulation, the researchers also took into consideration what is known about the Bottom quark. They tuned the masses of quarks to their known physical values. Taking cues from deuteron, they projected the spin characteristics of the potential dibaryons, to calculate the lowest energy states, the ground state masses of each of the possible dibaryons. Whether they are stable or not can be checked by looking at their relative ground-level energies with respect to the two baryon thresholds: the mass of the dibaryon should be less than that of the two baryons.

It did not take them time to realise that the light quarks, Up and Down, are no help. They create errors that can only be tackled with more computing power. However, combinations of Bottom and Strange quarks, as well as combinations of Bottom and Charm quarks, can produce dibaryons that are stable. 'The heavier the dibaryons, the more stable they seem', says Nilmani Mathur.

'Of course, there is yet another condition for the existence of such dibaryons', he adds. 'The finite volume should also be reasonably small.'

'We are now tackling that problem,' says Parikshit Junnarkar.

In any case, given the mass–energy of the stable baryons, the conditions are ripe for experimental observations to validate or refute the theoretical predictions. This requires heavy ion accelerator facilities with very high energies which are not yet available.

It is quite normal in physics to wait decades for experimental validation of theoretical predictions. This one, let us hope, will materialise sooner.

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Solar Eclipse and Ionosphere
Intensification in E layer

July 2009. Scientists from the Indian Institute of Geomagnetism were preparing to observe the impact of a solar eclipse on the ionosphere. Based on ionisation, the ionosphere is classified into different layers: the D layer, starting from a height of about 60 kilometres, the E layer from about 100 kilometres and the F layer from about 150 kilometres upwards. High frequency radio waves, normally reflected from the F layer, bounce back from the E layer during a solar eclipse, due to the formation of thin intense ionisation clouds in the E layer. So the solar eclipse on 22 July was a great opportunity to investigate the phenomenon called sporadic E.

The scientists started monitoring the ionosphere from the 16th, using a digital ionosonde, a radar that emits specified frequencies and detects the reflected waves – useful for examining the ionosphere from the ground. They set up observations from Allahabad on the path of the moon's shadow. They configured five fixed frequencies from 2.5 MHz to 4.5 MHz for vertical sounding with the ionogram. The ionogram mode was set up to logarithmically sweep 95 frequencies between one and twenty

MHz. Pulses within this range bounce back from 90 to more than 1000 kilometres height.

But there was a technical glitch. They could not take readings from the 18th to the 21st. So they had to be content with examining the top frequencies and the lowest heights from where the signals are reflected, to understand the behaviour of the ionosphere during the solar eclipse.

The eclipse was expected to occur between 5:30 and 7:30 in the morning of the 22nd. The moon's shadow would be about 200 kilometres wide and, since it was early morning, the shadow would be around 1000 kilometres long along the eclipse path and it would travel at a ground speed of nearly nine kilometres per second.

The team kept monitoring the magnetic field with bated breath. If there was a magnetic storm during this time, it could complicate their analysis because magnetic storms also influence ionospheric behaviour. Thankfully, there was no magnetic storm during the eclipse.

Image: Wikimedia Commons

When the researchers compared the top frequencies as well as the lowest heights from where the signals are reflected during the eclipse with those in the morning hours of 16th, 17th and 26th, they found enough data to chew on. Now, nine years later, last fortnight, they reported their results.

Normally, from 5:30 to 8:30 in the morning, frequencies ranging from 4 to 5 MHz come back from about 100 kilometres or from the E layer. But when the eclipse started, the top frequencies reflected from the same

layer went up to about 9 MHz. During the total solar eclipse at about 6:35, there was wave-like behaviour where the frequencies coming back from the E layer played yo-yo and then, after 7 am, the frequencies climbed back to a steady 9 MHz. By about 8 am, again, the top frequencies swung back and forth before going back to 9 MHz.

On analysis, the researchers found dominant harmonics of 4 to 8 minute periodicity in the wave-like behaviour in the E layer during the total solar eclipse and longer duration periodicities in the latter part. The normal behaviour of the E layer returned only after 11 am.

During the main phase of the eclipse, from 6:18 to 6:48, the base of the sporadic E came down from about 104 to 101 kilometres and it took about 20 minutes for it to go back to a height of 104 kilometres. Normally, the sporadic E can be seen over Allahabad till about 9 am. But on the day of the eclipse, the strong blanketing sporadic E continued till about 11.

The moon's supersonic moving shadow perturbs pressure and temperature, creating wind shear conditions, transporting ions and intensifying ionisation, explain the scientists.

A theoretical framework that can predict the behaviour of the ionosphere is still lacking. Building up such data is a first step towards constructing a theory that explains and predicts such phenomena.

Air Pollution
Regional perspective

Almost a quarter of post-harvest crop residue is burned in the open fields of the Indo-Gangetic Plains. Air pollutants from these fires spread in different directions and affect distant places. Though there are many reports on the air pollution in various cities caused by the burning of agricultural residues, a regional scale evaluation has not been done.

So Ravindra Khaiwal from PGIMER, Chandigarh and a team of researchers from five universities and three national labs collaborated to do a sampling of the air at different geo-graphical locations across seven cities in Punjab, Haryana and Chandigarh. Punjab and Haryana are hotspots for the burning of agricultural residue and Chandigarh is mostly urban.

They used the System of Air Quality Forecasting and Research created by the Ministry of Earth Sciences mounted in a mobile van for simultaneous and continuous measurements of air quality and meteorological parameters. From the last week of October to the first week of December, when agricultural residue burning is at its peak, they monitored 16 air pollutants including particulate matter of different dimensions, black carbon, carbon dioxide, carbon monoxide, ozone, oxides of nitrogen and sulphur, ammonia, and many volatile organic compounds. Meteorological parameters that impact the dispersal and accumulation of these pollutants were also monitored.

Particulate matter concentrations were much higher at Amritsar, Sonipat and Bathinda – more than twice the recommended safe limits. It was lowest at Chandigarh. Carbon black was also highest at Amritsar. But Chandigarh took the second place and Rohtak the third. Bathinda had lowest carbon black concentrations. However, Bathinda had highest ozone concentrations whereas with Amritsar it was the other gaseous pollutants. Ozone and oxides of nitrogen were lowest in Sonipat.

Urban locations in Chandigarh had high amounts of benzene while Rohtak had more than a fair share of other volatile pollutants. The rural location of Fatehgarh Sahib had the lowest concentration of all the monitored volatile organic compounds, except toluene. Sonipat had the least amount of toluene.

There was diurnal variation in some of the pollutants. For example, Sonipat showed higher particulate matter in the morning hours due to higher traffic at that time. Pollutants due to agricultural residue burning seemed to peak towards night. Ozone on the other hand increases during the day, positively influenced by temperature and negatively, by relative humidity. Volatile organic compounds were lower during the day in all locations except Rohtak.

The researchers processed the data using principal component analysis to understand the sources of pollution at different locations. The understanding of pollution levels becomes complicated when air movements are also considered. At Chandigarh, the wind direction was mainly southeast. At Fatehgarh Sahib and Amritsar, it was east-southeast and south-southeast. At Bathinda, it was west and east. At Sirsa, the wind blew from the north. At Rohtak, the wind direction varies from northnorthwest to south-southwest. Thus the pollutants do not stay at the location of origin and are dispersed in different directions at different locations.

The findings will be useful to understand the temporal and spatial distribution of air pollutants during crop residue burning. Data collected at regional scales could help plan comprehensive air quality improvement strategies under the National Clean Air Programme.

Remediation of Lead in Soil
Biochar and ash help castor bean

Rapid industrialisation, modern agricultural practices and other human activities often lead to contamination of soil with lead. Among heavy metal soil contaminants, lead leads the way. It is toxic to plants and it can linger in plant and animal bodies for long, leading to biomagnification.

Studies have shown that adding biochar can reduce the uptake of the metal. Similarly, rice husk ash is also reported to ameliorate the effects of metal contamination in soils. But how effective are these treatments on plant growth and productivity?

Boda Ravi Kiran and M. N. V. Prasad from the University of Hyderabad, Telangana decided to check. They prepared biochar from the branches of *Prosopis juliflora* and burned rice husk to ash. To test, they chose castor bean plants grown in soil contaminated with lead.

Castor is a hardy plant resistant to most biotic and abiotic stresses. But when grown in soils with 400 or 800 milligrams of lead per kilogram of

soil, they have reduced amounts of chlorophyll, show signs of oxidative damage and become stunted. The researchers found a higher accumulation of lead in roots than in shoots and leaves.

Castor bean plants. Image: Agri Farming

After treating the soil with biochar or rice husk ash, the researchers added lead nitrate to soil in both groups. The soil was then used to grow castor bean plants in pots for 60 days.

The increased lead concentration reduced the chlorophyll content of the leaves and increased anthocyanin content. The researchers found that oxidative stress parameters such as proline, malondialdehyde and H_2O_2 content had increased but the concentration of proteins had decreased.

The treatment with biochar or with rice husk ash reduced lead accumulation in castor bean, the team reports. Plant height, leaf diameter, and the number of nodes increased in the treated plants. When soil lead content is 800 milligrams per kilogram, treatment with the biochar increased leaf diameter by more than 200%. With rice husk ash, the effects were less dramatic in terms of leaf, but in terms of plant height, the increases were similar in both treatments.

The scientists found that both rice husk ash and biochar increased soil alkalinity, automatically reducing lead uptake. Moreover, rice husk ash adsorbs and precipitates lead. And biochar too adsorbs the metal and the presence of functional groups that form complexes with metals adds to the effect.

Rice husk is a waste, accounting for about one-fifth of the paddy milled. And *Prosopis juliflora* is a tree that grows well even in semi-arid conditions. So there is adequate raw material to combat lead contamination in agricultural soils.

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Cashew – A Cash Crop

Cashew, once a wasteland crop in India, now contributes to foreign exchange. So many industrial units were set up in the last few decades and the capacity of the cashew industry grew beyond the availability of raw nuts. So India has to import raw nuts from Africa and South-East Asia. To sustain the industry, innovative technologies are imperative to improve cashew productivity.

Cashew trees are normally grown at a spacing of 62 trees per acre and nearly 10 lakh hectares are already under cashew. Planting more plants per unit area can improve production. But high density planting can often cause interlocking and over shaded branches, leading to reduced productivity. This necessitates pruning branches to maintain the canopy.

Babli Mog and co-workers from the ICAR Directorate of Cashew Research, Karnataka have now come up with an alternative to pruning. Paclobutrazol is a plant growth retardant that acts by inhibiting the plant hormone, gibberellin. It is widely used for controlling vegetative growth in many fruit crops and trees. So the scientists investigated the effects of paclobutrazol on cashew.

They planted the Ullal-3 cultivar of cashew at their Shantigodu research station in March 2010 with 3 m × 3 m spacing. The canopy of this cultivar normally grows to more than 7 metres.

When the plants were nearly five metres high, they applied paclobutrazol at different concentrations, pouring it into the soil in circular trenches about 2 feet from the cashew tree.

After 10 months, plants treated with 3 grams of paclobutrazol were nearly 30% shorter. Compared to the case with control plants, the ground coverage was reduced by more than 70%. The leaves of the treated plants, though smaller, had intense green leaves, higher concentrations of pigments and increased chloroplast size. Though paclobutrazol treatment reduced the size of the inflorescence and increased the number of hermaphrodite flowers per inflorescence, the mean fruit set per inflorescence increased from a little more than 5 to about 10. The number of nuts was also higher in treated plants, though the dimensions and weight of the nuts were reduced.

The researchers found that all these effects reduced 2 years after application. The leaching and degradation of paclobutrazol would differ from soil to soil, they say.

Till high yielding dwarf varieties of cashew are developed, paclobutrazol might be a good solution for easy crop maintenance in the high density planting of cashew and to improve cashew nut productivity.

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Japanese Encephalitis
Polymorphism predicts predilection

Why is it that some children fall prey to Japanese encephalitis while others in the same locality do not? Can we predict which children are at risk and which are not?

The Japanese encephalitis virus is an RNA virus transmitted by the culex mosquito. Inflammation in the brain is the main cause of morbidity and mortality. The increase in pro-inflammatory mediators and insufficient anti-inflammatory response facilitates the pathology.

The activity of these inflammatory mediators and chemokine receptors are influenced by changes in even a single nucleotide in the genes coding for them. The development of Japanese encephalitis might be associated with single nucleotide polymorphism in the genes coding for inflammatory mediators.

To investigate this possibility, Hirawati Deval and Kalichamy Alagarasu from the ICMR-Regional Medical Research Centre, Gorakhpur and the ICMR-National Institute of Virology, Pune and their research team investigated the association of single nucleotide polymorphisms with Japanese encephalitis.

They took samples from patients with Japanese encephalitis admitted to the BRD Medical College Hospital, Gorakhpur, Uttar Pradesh between July 2017 and December 2018. The team took samples from two controls per case from the same geographical region without any known history of acute encephalitis syndrome. Thus they had samples from a total of 183 Japanese encephalitis cases and 361 healthy controls from the Gorakhpur and Basti division of Uttar Pradesh, where Japanese encephalitis is endemic.

Using two millilitre blood samples from the subjects, the team isolated DNA and did genotyping for single nucleotide polymorphisms in the genes coding for pro- or anti-inflammatory cytokines and other mediators of inflammation.

The team found that Japanese encephalitis is strongly associated with single nucleotide polymorphisms in tumour necrosis factor alpha and C–C chemokine receptor 5 genes. The frequencies of these single nucleotide polymorphisms were lower in children who did not get the disease. Lack of association of single nucleotide polymorphism in three other genes was also identified in such children.

At the rate the genetic studies are progressing, the day is not far when we can target susceptible children for immunisation against Japanese encephalitis

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Packaging Curcumin
Lepidium sativum seed protein

Curcumin, derived from the roots of a medicinal plant, *Curcuma longa* has antioxidant and antimicrobial properties and is known to fight cancer, inflammation, arthritis and gastrointestinal problems. Despite its enormous medicinal potential, poor solubility and bioavailability with rapid degradation limit the health benefits of consuming curcumin.

Last fortnight, researchers from the Institute of Chemical Technology, Mumbai formulated an effective curcumin delivery system by complexing it with the seed protein of *Lepidium sativum*. This herb grows in 7 days. It is a cheap and abundant source of proteins and possesses medicinal uses. The seeds are also used in the production of edible oil.

After extracting the pure protein from *Lepidium sativum* seed cake, the researchers mixed this protein with curcumin and stirred the mixture overnight. This process led to a hydrophobic interaction between curcumin and the *Lepidium sativum* seed protein resulting in the formation of a complex. The complex helped improve curcumin's solubility, stability and bioavailability. Moreover, the antioxidant activity of this complex is much higher than that of the individual compounds.

Turmeric is a traditionally recognised medicine with multiple health benefits. Its benefits are best achieved when combined with agents that increase its bioavailability. And plant-derived proteins as delivery agents are economical.

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Developing Tehri Garhwal
Locating sites for agro-industries

Tehri Garhwal in Uttarakhand is one of the most backward districts in India. Among all the districts in Uttarakhand, Tehri Garhwal has the maximum number of people below the poverty line. Most people here depend on subsistence agriculture and natural resources for livelihood. Funds have, therefore, been allocated to develop agroindustries in the state. But what are the best sites for setting up industries?

Normally, under such situations, decisions are made on *ad-hoc* basis, often biased by political considerations. But now, Sakkeri Ramya and V. Devadas from IIT Roorkee have come up with a more rational method for evidence-based decision making.

While setting up an industry, a number of factors need to be considered: topography, land-use, soil productivity, access to roads, distance from water bodies or ecologically sensitive areas, distance from settlements and so on. The backbone of their strategy was collating available data on a geographic information system.

In consultation with stakeholders, and through public surveys, they organised fifteen relevant parameters in terms of weights to be given while deciding, using an ordered weighted averaging. Analytical Hierarchical Process was then used to calculate the weights of the combined criteria with ordered weighted averaging. And an industrial location suitability map was developed using the geographic information system.

Thus the scientists used the best combination of strengths available in the district – topography, climate, fund availability and niche product development opportunity to come up with development sites that do not tax environmental resources.

The duo found five suitable sites in Tehri Garhwal. Then, using TOPSIS, a method to rank items in a list nearest the ideal situation, they ranked the selected areas for industrial development. Kirtinagar block was ranked highest by the team for industrial development, followed by the Devprayag, Bilangana, Chamba and Jhaknidhar blocks of the district.

Out of 718 districts in India about 250 are considered least developed. The methodology used for Tehri Garhwal can easily be adapted to other districts, enabling evidence-based decision making for sustainable development.

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Reports by: **Subramani Pandian, Sileesh Mullasseri, Ravindra Jadav, Sudhir Verma, G. Sharath Chandra, S. Sheeba** and **Khushbu K. Birawat**