Physical Science | Philip Yock

In defence of the Standard Model's precursor

Since the 1970s, physicists have widely accepted the idea that quarks and gluons are fundamental components of matter, as described by the Standard Model of particle physics. By their very nature, however, these particles can't possibly be isolated or observed in experiments as separate entities. As an alternative, Dr Philip Yock of the University of Auckland, New Zealand, advocates a precursor to the Standard Model, which he first developed early on in his career as a requirement of mathematical self-consistency. Through a future proposed experiment at CERN, the theory could soon be put to the test.

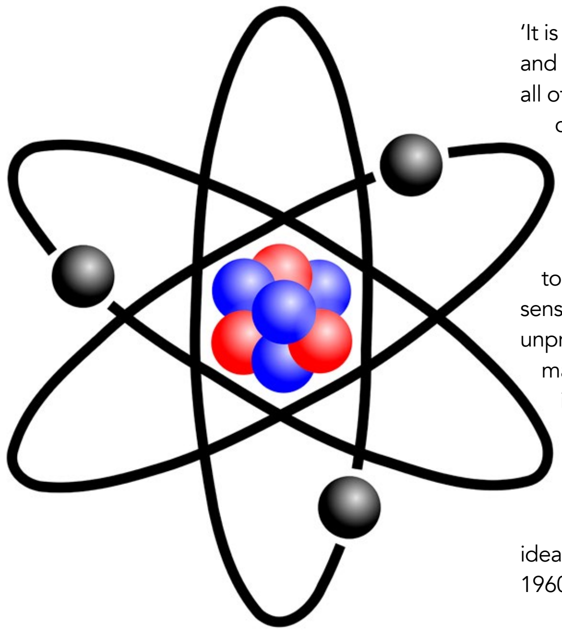

Fig. 1 The Rutherford atom is consistent with Newton's hypotheses on the structure of matter.

Today, the Standard Model is widely seen as one of the greatest achievements ever made in physics. Based on the founding principles of 'quantum field theory', which combines aspects of relativity and quantum mechanics, the model aims to account for three of the four fundamental forces believed to govern all interactions in the universe while also describing the elementary particles believed to make up all observable matter.

Despite its widely acclaimed successes in accounting for observations made in the most cutting-edge experiments to date, a small number of physicists remain sceptical of the Standard Model. According to these researchers, the model is forced to make many ambitious assumptions in order to explain experimental and mathematical results. Yet by their very nature, many of these assumptions can't themselves be studied in experiments.

'It is assumed that the familiar protons and neutrons of atomic nuclei, and all other comparable particles, are composed of smaller particles termed "quarks" and "gluons"', Dr Philip Yock at the University of Auckland, New Zealand, explains. 'But these particles are assumed to be unobservable in the normal sense of the word, and their existence is unprovable.' In addition, some dubious mathematical procedures are followed in the Standard Model, he says. Because of these concerns, Dr Yock has long advocated against a full acceptance of the Standard Model. Instead, he suggests that earlier ideas, which he first developed in the late 1960s, could be closer to reality.

QUARKS AND GLUONS

According to the Standard Model, the quarks which Dr Yock mentions can never exist in a completely isolated state. Instead, they must be grouped together in certain combinations. For example, protons and neutrons each contain different combinations of three 'up' or 'down' quarks. These clumps of particles are then held together by the strongest of the four known fundamental forces, named the 'strong nuclear' force.

Just as the electromagnetic force is conveyed by photons, the strong nuclear force arises as quarks exchange gluons. To make this theory work, quarks are said to possess a property named 'colour charge', which can either be red, green, or blue (in name only), and this colour charge is exchanged between quarks via gluons. Crucially, groups of quarks can never have a collective colour charge: instead, they must exist in 'colour neutral' combinations.

For protons and neutrons, this means that a red, green, and blue quark must always be present at any given time. Ultimately, this cancelling behaviour means that colour charges can never be observed by themselves in experiments. In addition, quarks are said to carry certain fractions of the electrical charge of a proton – which combine in such a way as to cancel each other out within colour-neutral groups of quarks.

'So, the fractional electric charges, like the colour charges, are also rendered unavailable for study in isolation', Dr Yock describes. 'This is in stark contrast to the electric charge of the world's most familiar particle, the electron. Its charge is measured by every student of physics in the undergraduate laboratory.' For Dr Yock, such a clear discrepancy with observable physical theories cannot simply be ignored as an inevitable consequence of the Standard Model.

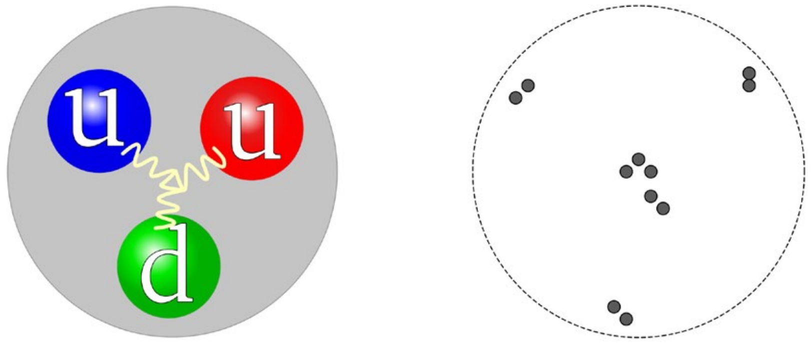

Fig. 2 The proton according to the Standard Model and the alternate model of subnucleons.

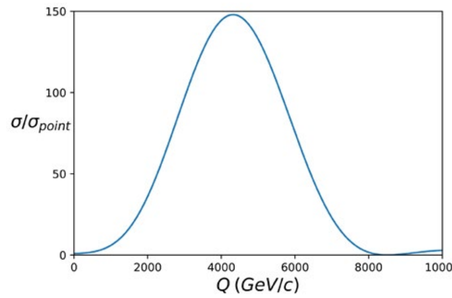

Fig. 3 Form factor effect in electron–proton scattering according to the subnucleon model.

ASSUMPTIONS TO FIT OBSERVATIONS

To bridge the gap between theories and experimental results, physicists have now identified six possible types, or 'flavours' of quark within the Standard Model: each with their own antimatter counterparts. Since each flavour must be able to exist in any of the three possible colour states, the total number of quarks and antiquarks described by the model stands at 36. For a family of particles that has never – and can never – emerge directly through experiments, this value is notably high.

'Added to these quarks are eight gluons: each of which carries a unit of colour charge and a unit of anticolour charge', Dr Yock continues. 'The final number of quarks and gluons in the Standard Model thus rivals the number of chemical elements, but all are unobservable in the normal sense of the word.' Driving this complexity even further, some recent experiments have concluded the existence of particles containing four or even five quarks in order to fit their observations. Such structures would need to contain intricate combinations of quarks and antiquarks to maintain colour neutral charges.

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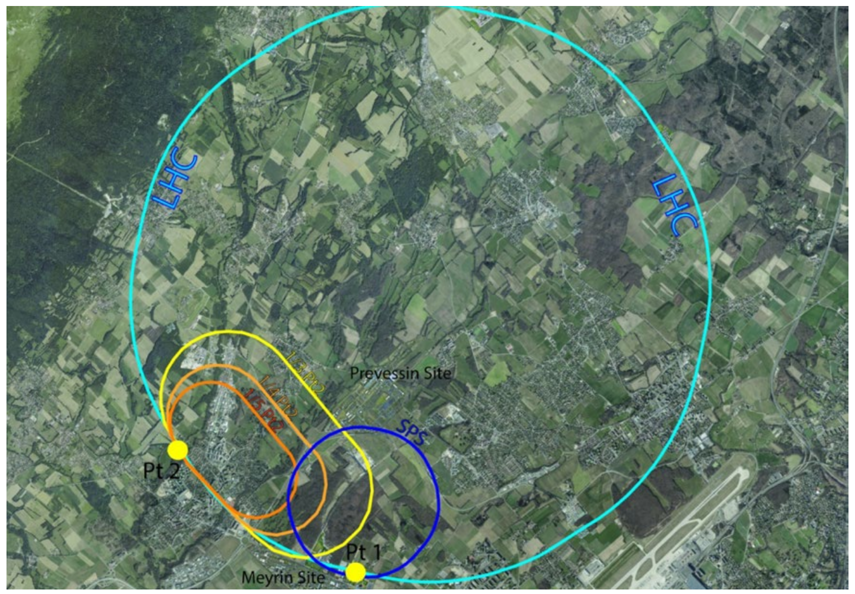


Fig. 4 Schematic of proposed electron-proton collider at CERN with three possible versions of the electron accelerator.

Together, Dr Yock believes that these factors highlight the extensive use of both unproven and unprovable assumptions within the Standard Model – presenting a clear contrast with long-established requirements for robust scientific theories. If this picture is ever going to change, he argues that we may need to turn back the clock to a time before all this complexity first emerged – and when Dr Yock himself was first starting out in his career.

THE STANDARD MODEL'S PRECURSOR

Dr Yock's interest in particle physics arose when he was an MSc student at the University of Auckland in the early 1960s, and he set about teaching himself the intricacies of quantum field theory. He was fortunate to be one of a group of keen students at the university at the time with similar, but not identical, aspirations.

The effort to self-teach rapidly led to confrontation with the so-called 'renormalisation' theory. This aims to describe processes in which a particle such as an electron interacts with itself. Whilst these self-interactions were expected to have small, minor effects on physical processes, the theory actually indicated large, divergent effects. But it was further shown that these divergences could be absorbed into the theory by a re-interpretation of the mathematics. This yielded wonderfully accurate results, while at the same time appearing to be mathematically self-inconsistent.

In 1979 Dr Richard Feynman, a Nobel Laureate in physics, stated in a Robb Lecture at the University of Auckland that 'the shell game we play is technically called "renormalisation". But no matter how clever the word, it is what I call a dippy process. I suspect that

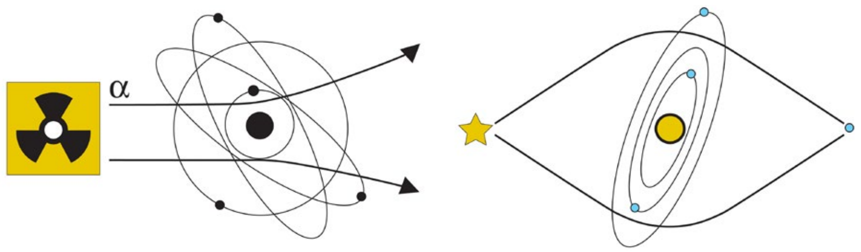


Fig. 5 Rutherford scattering compared to gravitational microlensing.

Subnucleons could show up in LHeC's measurements because of their high charges. If this proves to be the case, it will suggest the need for a profound rethink of the Standard Model.

renormalisation is not mathematically legitimate,' he said.

Dr Yock continued his interest in quantum field theory when he went to MIT to study for his PhD in 1962. There he was fortunate enough to meet a young staff member, Dr Kenneth Johnson, with similar interests, and this eventually led to the formulation of a potentially self-consistent quantum field theory in 1969.

This theory preceded the Standard Model which emerged in 1973, but it shared features with that model. Instead of quarks, however, Dr Yock's theory relied on less exotic fundamental particles, named 'subnucleons'. Rather than carrying some exact fraction of a proton's charge, these particles had very high electrical charges, allowing them to interact via the same mechanisms as the electromagnetic force.

'Gluons were excluded from this model', Dr Yock explains. 'Instead, the humble photon was assumed to do their job.' Rather than being confined within inseparable groups of unobservable particles, interacting subnucleons and their antimatter counterparts existed in tightly bound, neutral clumps. With the right experimental approach, these particles could then be isolated and studied individually.

Dr Yock notes that there are some successful outcomes of the Standard Model which he hasn't yet attempted to incorporate into his own precursor model. Among these are the Higgs boson particle first observed experimentally by physicists at CERN, which is believed to explain why some particles have mass. Yet as technology improves, Dr Yock notes that a new opportunity to test the 1969 theory could soon be on the horizon.

TESTING PREDICTIONS

To study the nature of subatomic particles, physicists today use accelerator facilities such as CERN's Large Hadron Collider (LHC) – which smash larger particles together at the highest possible energies, then analyse the fragments that emerge. As accelerators with ever more sophisticated designs are developed, researchers are now delving ever deeper into the most fundamental aspects of particles. In doing this, they ultimately aim to confirm predictions made through theoretical calculations or to prove them wrong.

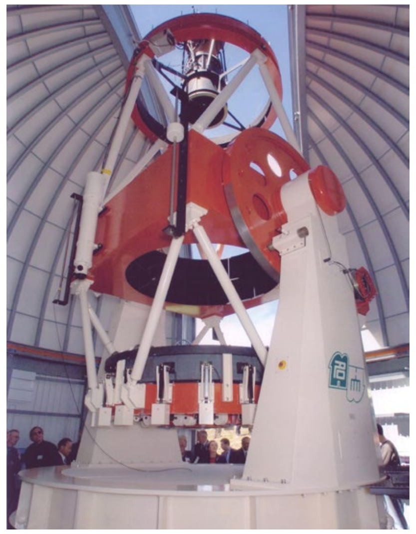


Fig. 6 MOA telescope used to search for exoplanets by gravitational microlensing.

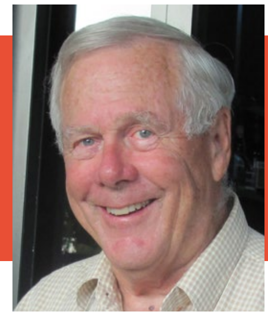
'Recently, an opportunity to test the above prediction of highly charged subnucleons arose through a proposal made at CERN to construct a very high-energy electron-proton collider, known as the 'Large Hadron Electron Collider' (LHeC)', says Dr Yock. 'It would constitute the world's largest electron-microscope, capable of probing structure within the proton with an unprecedented resolution of 10^{-19} metres.'

With this ability to pick out features 10,000 times smaller than the width of an atom's nucleus, Dr Yock believes that subnucleons could show up in LHeC's measurements because of their high charges. If this proves to be the case, it will suggest the need for a profound rethink of the Standard Model, and the theories and experimental methods used to study fundamental physics.

PARALLELS WITH NEWTON

Today, the Standard Model of particle physics is one of the most extensively researched topics in all of science. Over many decades, it has now been scrutinised in extensive detail through thousands of academic papers, although, as Dr Yock notes, none of these papers question the 'dippy' mathematics they implicitly assume. In the face of this expansive but strange body of evidence, Dr Yock ultimately acknowledges that his precursor theory may be a long shot – but all the same, he believes that the reasoning behind his ideas has a deep historical precedent.

'If opinions from the past are permitted, Isaac Newton may provide food for thought', he proposes. '300 years ago, Newton published a series of little-known hypotheses on the structure of matter in his monograph "Opticks" that are in general accord with the now established physics of nuclei, atoms, molecules and macro-molecules.' While remaining consistent with many modern theories, Newton's outcomes seem to lean intriguingly towards Dr Yock's precursor, over the Standard Model itself. Ultimately, Dr Yock hopes that his theories show that a full acceptance of the Standard Model, and the unobservable nature of the particles it describes, shouldn't yet go entirely undisputed.



Behind the Research

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Research Objectives

Dr Yock advocates a precursor to the Standard Model.

Detail

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Bio
New Zealand-born physicist, PhD MIT (1965); FRASNZ; MNZM 2010–2018; precursor proposed to the Standard Model; unified gauge theory of electro-strong interactions; co-founded JANZOS and MOA collaborations with Japan; studied cosmic rays from supernova 1987A; studied extra-solar planets by gravitational microlensing; proposed search for hadronic substructure at CERN with the LHeC collider; noted Newton's hypotheses and Rutherford's experiments on the structure of matter.

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Collaborators
- Prof Max Klein (Liverpool University)
- Dr Oliver Brüning (CERN)

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Personal Response

What major implications could result from observations of highly charged subnucleons at the LHeC?

" Observation of highly charged subnucleons would clearly confirm Feynman's opinion, stated above, that the conventional renormalisation process of quantum field theory is self-inconsistent. It would also lend serious credence to the old hypotheses on the structure of matter enunciated by Isaac Newton in 'Opticks'. Most controversial amongst these might be the role of 'purpose' in science, which is generally seen as irrelevant these days. Another implication that could emerge would be the possible advantage of scientists working solo, or in small, isolated groups, if they are pursuing highly original leads, as discussed in the 2021 paper cited here. "

Professors Roy Sharp and Yasushi Muraki opening the MOA telescope.