Transit

The Newsletter of Cleveland And Darlington Astronomical Soiety

ARP273 – Hubblesite.org “A Rose” ?

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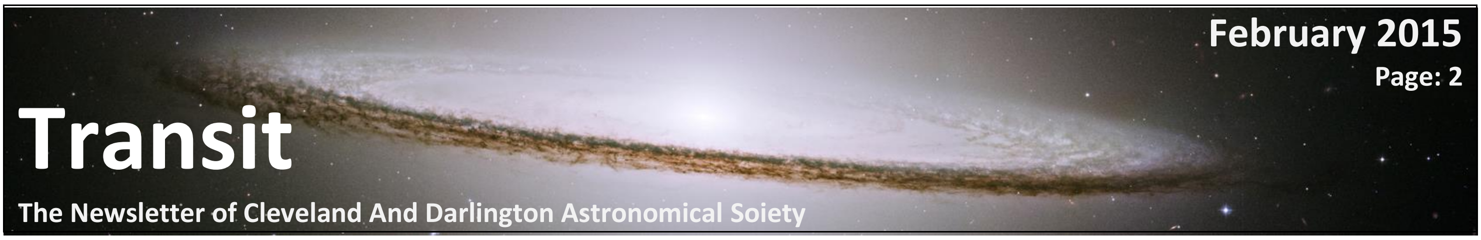


Editorial

Welcome to the February edition of Transit.

I came across this months cover picture while browsing through Hubblesite.org and thought it provided an interesting example of how the objects we see in the sky can combine to give an impression of something familiar, in this case the galaxies UGC1810 and UGC1813. If anyone else has come across other examples like this, it might be interesting to start a collection, and possibly publish some of them in future issues.

This month we have the first part of another great article from one of our regular contributors, Ray Brown on the small particles of nature.

Last months article by Ray Worthy prompted a number of responses from our readers, one of which I have included in this issue (The others having been passed onto Ray). Thanks to those who responded.

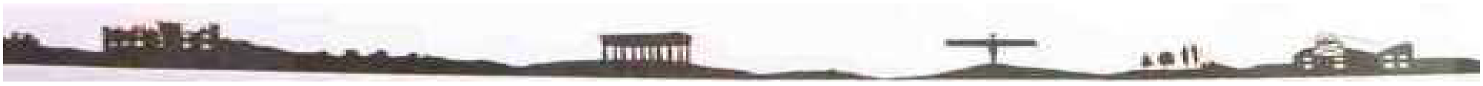
If anyone else has anything they would like to send in, or even just comments, they would be most welcome.

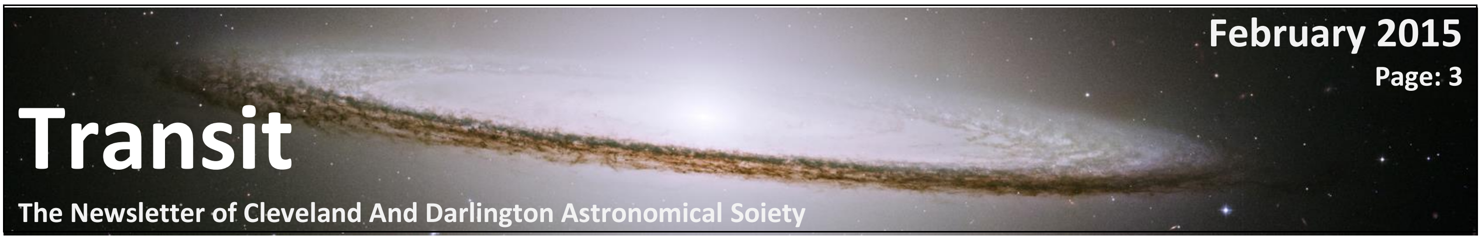
Regards
Jon Mathieson
Address: 12 Rushmere, Marton Middlesbrough, TS8 9XL **Email:** info@cadas-astro.org.uk

Meeting Calendar (2014-2015)

All meetings are held at the Wynyard Planetarium (with the exception of the AGM).
Doors open at 19:15 for a 19:30 start

13th March 2015	Title to be confirmed Gary Fildes of Kielder Observatory
10th April 2015	**One Small Step** **(A Celebration of Apollo)** Neil Haggath, FRAS, CaDAS
8th May 2015	Title to be confirmed Paul Money FRAS, FBIS
12th June 2015	**CaDAS Annual General Meeting and Social Evening** venue to be confirmed





Letters and Notices

Although my poor eyesight precludes my involvement in practical astronomy I have often thought that my CaDAS subscription is justified alone by the enjoyment and education in reading Ray Worthy's articles in Transit. His latest contribution (January 2015) is no exception and I'm sure that editors of other journals, with wider readerships, would be glad to publish his fascinating piece of historical research.

I was especially interested in Ray's description of Wallace's experimental proof of Earth's curvature, as I was familiar with that stretch of the River Nene in the 1990s when my son was an Olympic oarsman; the long straights on the river are ideal for holding racing trials although I recall that a strong crosswind and the reeds along the bank could combine to make a hazard for the single sculler.

The method used by Wallace, as well as proving his argument, could also, thanks to Pythagoras, provide a quantitative value for the radius of the Earth.

To quote from Ray's article

"The judge, looking through the telescope, could see the mark on the barge's upright pole was three feet above the direct line between the telescope and the mark on the six mile bridge."

So using feet as distance units, if R is the radius of Earth then $R^2 = (R-3)^2 + (3 \times 5280)^2$

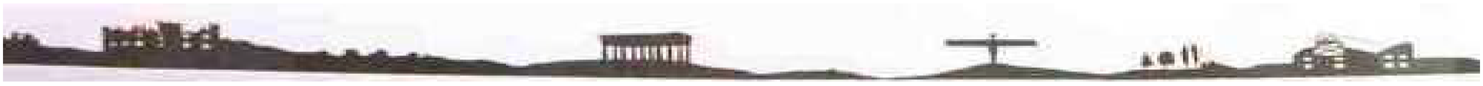
leading to a value $R = 4.182 \times 10^7$

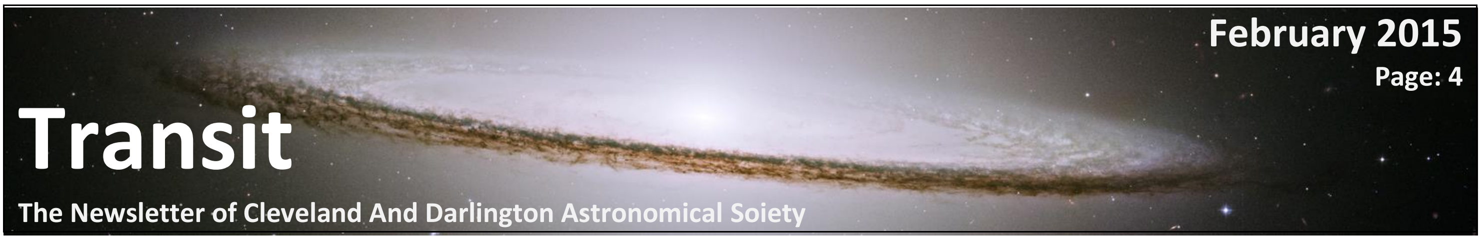
This corresponds to 7920 miles which is the value of Earth's *diameter*, *not its radius* so the mark on Wallace's pole must actually have been 6 feet, not 3 feet, above the direct line of sight.

On the day following the appearance of Ray's article in Transit, the Scientific American web site came up with http://blogs.scientificamerican.com/rosetta-stones/2015/01/12/wallaces-woeful-wager-how-a-founder-of-modern-biology-got-suckered-by-flat-earthers/

which gives a highly detailed account of the dispute between Wallace and the Flat-Earthers. The attitudes and behaviour of the backwoodsmen then was remarkably similar to the intransigence today of Creationists and to the violent tactics of Islamic extremists. In the end Wallace was fortunate not to end up as did the twelve staff of the Charlie Hebdo magazine.

Ray Brown





The Small Particles of Nature (Part 1)

by Ray Brown

Cosmology has one foot in astronomy and the other in particle physics. When my Dad was born in 1895 the largely unchallenged view since Democritus (465 BC) had been that the *atom* was the smallest indivisible unit of matter, so particle physics has come a long way in recent generations. Atoms were not the only particles then known: light rays were supposed to be carried by “corpuscles”, a concept introduced by Isaac Newton and today we believe that all electromagnetic radiations can be regarded as *photon* particles which have defined velocities, highest in a vacuum (c = 2.998 x 10^8 ms^{-1}) but rather lower through other transparent media. Cathode rays had already been discovered but it was only in 1897 that J J Thomson showed them to be particles, each with a mass some 1000 times smaller than that of the hydrogen atom: these were soon to be known as *electrons*. In 1900 Henri Becquerel showed that one of the types of particle emitted in natural radioactivity behaved identically to electrons, showing that electrons are a component of radium, and possibly all atoms.

Characterisation

The two main properties of any particle are the sign and magnitude of its electrical charge and the value of its *proper* mass (i.e. its mass when essentially at rest relative to the observer). The sign of its charge can be obtained from the direction of deflection as the particle passes through either an electric or a magnetic field, applied perpendicular to its direction of movement. Deflections of charged particles were measured in various ways e.g. where they struck a fluorescent screen or they could be tracked in a Wilson cloud chamber or on a photographic plate. Incidentally, before the advent of LCD and LED screens, television receivers used pairs of periodically varying fields to deflect a cathode beam in an evacuated tube, thereby scanning the entire screen from side-to-side and top-to-bottom.

A force qE is exerted on a charge q by an electric field of strength E. A magnetic field of strength B produces a force Bqv where v is the velocity of the particle in a direction perpendicular to the field. According to Newton’s Law (acceleration a = force/mass) heavier particles are deflected less by a given force than are lighter ones as they pass through a field. Faster particles spend less time t within the field and so are deflected less within an electric field. If L is the distance travelled through the electric field then the deflection will be

$$d = \tfrac{1}{2}at^2 = \tfrac{1}{2}(qE/m)(L/v)^2 \qquad (1)$$

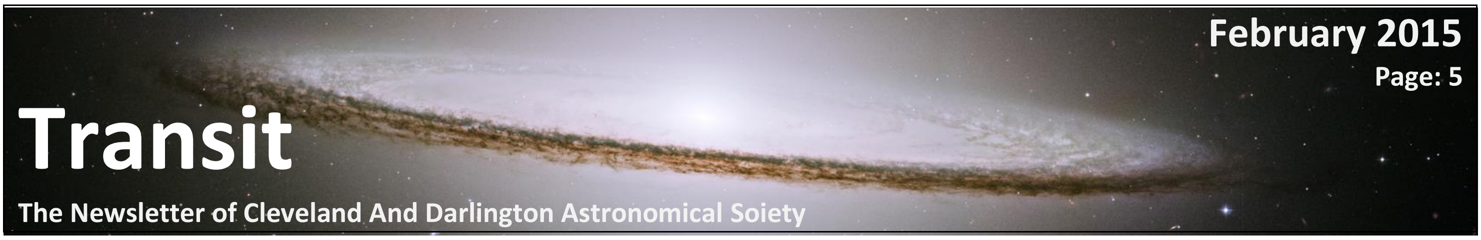
Whereas the force produced by an electric field acts in the direction of the field, a magnetic force acts orthogonal to the plane which contains the vectors of both the magnetic field and the particle velocity. So a charged particle, so long as it stays within a uniform magnetic field, will follow a circular path of radius r. The magnetic force Bqv towards the centre of the circle is the centripetal force mv^2/r so

$$r = mv/qB \qquad (2)$$

Eliminating v from these equations (1) and (2) we obtain

$$q/m = EL^2/2dB^2r^2$$

So, by measuring the deflections of any given type of charged particle both in a magnetic field and in an electric field, early workers were able to obtain the its charge-to-mass quotient quotient; J J Thomson first used the method in 1897 to characterise cathode rays. Soon afterwards Ernest Rutherford applied it to the α-particles formed in decays of natural radioisotopes and showed them to be the nuclei of helium atoms.



The Proton

In 1909 Geiger, Marsden and Rutherford showed experimentally that almost all of the mass of a gold atom (diameter about 3 x 10^{-10} metres) is concentrated in a tiny fraction of the atomic volume (diameter less than 6.8 x 10^{-14} metres), later to be named a *nucleus*, which carried an electrical charge. Consequently in 1911 Rutherford proposed that atoms consist of a dense positively-charged nucleus surrounded by the much lighter negatively-charged electrons which essentially determine the size of the atom. In 1919 after succeeding in producing nuclei of hydrogen, the lightest element, by bombarding nitrogen with helium nuclei (*see later*) he suggested that all atomic nuclei might contain units of the hydrogen nucleus which he subsequently dubbed the *proton*. He realised that the number of protons in an atomic nucleus corresponds to the atomic number of an element (its sequential position in the Periodic Table). However charges of like sign always repel one another, so in order to explain why mutual repulsion between protons does not cause nuclei larger than hydrogen to disintegrate, he believed that some other constituent in these nuclei must bind them together. A clue that this other constituent must possess mass lay in the fact that e.g. the atomic number of oxygen is 8 yet the mass of an oxygen atom is not 8 x greater than the mass of a hydrogen atom with atomic number 1; instead it is about 16 x greater. Compelling support came when the existence of *isotopes* (atoms of the same chemical element possessing different atomic masses), a concept first proposed by Frederick Soddy, was experimentally demonstrated by Francis Aston in 1919.

The Neutron

In 1932 James Chadwick examined the scattering pattern when nitrogen gas was bombarded by unknown particles emitted from a boron target subjected to a stream of α-particles from a radioactive polonium source http://hyperphysics.phy-astr.gsu.edu/hbase/particles/neutrondis.html . He characterised the particles as uncharged with a mass similar to a proton. So the *neutron* was identified as the other *nucleon* (nuclear particle) which contributes to the total masses of all nuclei heavier than common-or-garden hydrogen (*protium*) which has a single proton as its nucleus. So various isotopes of a given element have the same number of positively charged protons (and so the same number of negatively-charged extra-nuclear electrons to confer overall electrical neutrality), but their nuclei include different numbers of electrically neutral neutrons.

As the neutron has almost the same mass as the proton, the nucleus of the predominant oxygen isotope contains 8 protons and 8 neutrons, explaining the atomic number 8 and atomic mass 16. Other isotopes of oxygen have either fewer or more than 8 neutrons; those with 9 or 10 neutrons are rare but further deviations from 8 correspond to increasingly unstable (short-lived) nuclei. With the two exceptions of protium $_1H^1$ and the helium isotope $_2He^3$ which possesses only a single neutron, all stable isotopes have a neutron:proton ratio in the range 1.0 – 1.54; the lower value is commonest in the lightest 20 elements but increasing numbers of protons in a nucleus seem to require additional neutrons to hold them together. No element with an atomic number higher than 83 (bismuth) has a stable isotope. Several heavier elements have isotopes with long half-lives, but none above atomic number 98 (californium) has a half-life exceeding one year. Instability takes the form of decay by the loss of smaller particles. Free neutrons themselves are unstable, fragmenting to an electron and a proton with a half-life about 10 minutes. Electrons and protons are each stable, even when free from atoms.

The Bohr Atom

In 1913 Neils Bohr had proposed a model for the atom in which electrons (each with charge e) are mobile, in circular orbits of radius r around the nucleus much as planets orbit the Sun, thereby explaining why the electrons are able to remain separate from the oppositely-charged protons. The centripetal "force" which prevents the electron from travelling in a straight line and so escaping from the orbit is $m_e r\omega^2$ where m_e is the electron mass and ω is its angular velocity. This force is

provided by the electrostatic attraction of the oppositely-charged nucleus (containing Z protons) whose charge is -*Ze*. So in accordance with Coulomb's inverse square Law (analogous to Newton's Law of gravitational attraction)

$$m_e r\omega^2 = Ze^2/4\pi\varepsilon_0 r^2$$

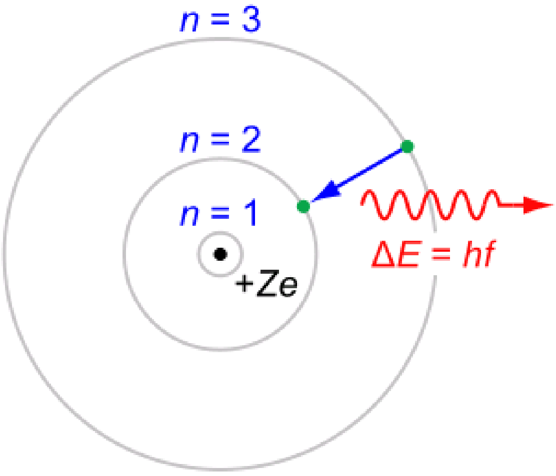
Here ε_0 is a universal physical constant known as the permittivity of free space and has the value 8.85419 x 10^{-12} $C^2J^{-1}m^{-1}$. This argument would have allowed *r* and *ω* (and in consequence the total energy of the electron) to possess any values consistent with this equation. However the infant Quantum Theory of Max Planck required that the angular momentum $m_e\omega$ of the electron could only possess integral multiples ($n \neq 0$) of the quantity $h/2\pi$ where *h* is another universal constant: Planck's constant = 6.62618 x 10^{-34} Js^{-1}. This restriction means that the orbital radius could only have discrete values given by

$$r_n = n^2 \times h^2\varepsilon_0/Z\pi m_e e^2$$

Consequently the energy values for electrons in the permitted orbits are

$$E_n = -(Z^2 m_e e^4/8h^2\varepsilon_0^2) \div n^2$$

Electronic spectra of atoms arise from transitions of electrons between different energy levels; emission spectra when electrons move to a lower radius and absorption spectra when they are promoted to a higher orbit. The frequency *f* of the spectral line is given by $\Delta E/h$ where ΔE is the energy of the photon, being equal to the energy difference between the two levels involved.



Although accounting well for the observed spectral frequencies of the hydrogen atom the Bohr model failed in several other respects and was superseded as a result of the subject of Quantum Mechanics being developed further. In particular Werner Heisenberg in 1926 proved theoretically his Uncertainty Principle: that the precise position and momentum of any particle cannot simultaneously be specified. The extent of the product of the uncertainties in position and velocity increases as the mass of the particle decreases so Bohr's concept of electron orbits around the nucleus needed to be replaced by one of *orbitals*: only the *probability* of an electron being located in any position can be specified. In principle it could be anywhere although the probabilities of it being, even say 10^{-9}m from the nucleus are negligible. Electron densities (probabilities) within orbitals are mathematically defined and surfaces of constant probability (contours) give rise to shapes (not all spherically symmetrical).

Some like the high road, I like the low road
Free from care and strife
Sounds corny and seedy, but yes indeedy
Give me the simple life

Song from the 1946 film "Wake Up and Dream"

That was my state of knowledge (or rather ignorance) of particle physics when in 1956 I went to university to read chemistry, mistakenly and inexcusably believing that sub-atomic particles were then fully understood and that the road ahead lay exclusively with molecules. (Actually from a utilitarian viewpoint I probably guessed correctly).

Knowledge had already advanced on several fronts which should have dispelled any such misconception; my disillusionment was overdue. My initial discomfort, introduced in first-year lectures was the *positron*, the positively-charged antimatter equivalent of the electron. In 1928, Paul Dirac had developed an equation that combined quantum theory and special relativity to describe the behaviour of an electron moving at a relativistic speed. The equation allowed whole atoms to be treated in a manner consistent with Einstein's relativity theory. Just as the equation $x^2=4$ can have two possible solutions ($x = 2$ or $x = -2$), so Dirac's equation could have two solutions, one for an electron with positive energy, and one for an electron with negative energy. Dirac interpreted the equation to mean that for every particle there exists a corresponding antiparticle, exactly matching the particle but with opposite charge. Positrons (anti-electrons) had been first detected in cosmic rays by Carl

Anderson in 1932 and are now familiar among the initial products of many nuclear decay reactions including of some natural isotopes e.g. potassium-40. On encountering their corresponding antiparticle, all particles undergo mutual annihilation being converted to radiation energy. It was not until 1955 that the existence of the negatively-charged *antiproton* had been confirmed by Chamberlain and Segre who used the Berkeley synchrotron to produce collisions between high energy protons.

Of course I already knew about Einstein and his famous equation $E = mc^2$ but the significance of it had passed me by, other than an awareness that a small mass of uranium or plutonium had produced enough energy to level Hiroshima and Nagasaki, that Calder Hall was being commissioned and that the ZETA project was due to start. In fact the UK, already the 3rd member of the atomic bomb club with the USA and USSR, was about to join them in the H-bomb league. All of these were examples of mass being converted into energy.

> *Where ignorance is bliss,*
> *"tis folly to be wise"*
>
> From "Ode on a distant prospect of Eton College" by Thomas Gray

One of the earliest chemistry lessons at school had successfully convinced me of Lavoisier's Law of Conservation of Mass; in any chemical reaction the total mass of all the products must exactly equal the total mass of all the reactants. Many years would pass before it dawned on me that the word "exactly" should, in the 20th century, have been replaced by "for all intents and purposes". In general chemical reactions are accompanied by either the release or absorption of energy, usually mainly in the form of heat. Einstein's equation therefore dictates that the reacting chemical system must respectively either lose mass or gain it. However the energy change is too small to cause a detectable change in the mass of the system. When, for example, 12 grams of graphite C^{12} are burned in air to combine with 32 grams of oxygen O^{16} we know that 393.5 kilojoules of heat energy are released. The CO_2 has a lower mass than the graphite and oxygen from which it formed by the amount

$m = E/c^2 = 3.9351 \times 10^5 / (2.998 \times 10^8)^2 = 4.37 \times 10^{-15}$ kg $= 4.37 \times 10^{-12}$ grams

So the mass of the system changes by only $4.37 \times 10^{-12} \times 100 / 44 = 10^{-11}$ %.

Cosmic Rays

Another subject on which I was lamentably ignorant was cosmic rays. During a balloon flight to an altitude of 5300 metres in 1912, Victor Hess had measured the rate of ionization in the atmosphere and found that it was some three times higher than that at sea level. He concluded that penetrating radiation was entering the atmosphere from above. These high-energy ions are 89% protons, 10% α-particles and 1% heavier ions even as massive as uranium. Only stable particles can survive a long journey through space. Collisions with nuclei present in the upper atmosphere produce unstable secondary particles of which a few can reach the Earth's surface. In 1936 Carl Anderson and Seth Neddermeyer, while studying cosmic radiation, had found particles that curved differently from electrons or other known particles when in a magnetic field. They were negatively charged but they curved less sharply than electrons, but more sharply than protons, for particles of the same velocity. It was assumed that the magnitude of their negative electric charge was equal to that of the electron, so, it was concluded that their mass was greater than an electron but smaller than a proton. These are now known to have been what are today called *muons* μ. In 1947 a team from Bristol University, studying cosmic rays at a high altitude on a mountain discovered another new type of particle, today known as a *pion* or π-*meson*. Later that year a Tynesider, George Rochester, similarly detected the *kaon* or K-*meson*.

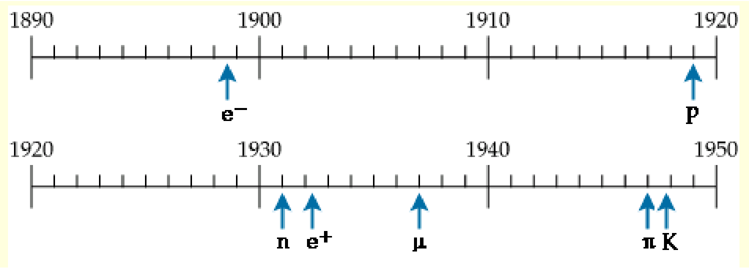
These newly-found particles were of great interest because the question of why atomic nuclei are held together despite the electrostatic repulsion between protons had not been satisfactorily answered simply by the discovery of neutrons. The notion that forces might be carried by messenger particles had been mooted by Coulomb in the 18th century but it was only in the early 1930s that the concept of exchange forces became accepted. In 1935 the theoretical physicist Hideki Yukawa had written “The transition of a heavy particle from neutron state to proton state is not always accompanied by the emission of light particles. The transition is sometimes taken up by another heavy particle."

For this heavy particle he had suggested a mass equivalent to about 100 MeV.

It seems that Yukawa, as Dirac before him, was setting a pattern to be followed by Higgs and many others in particle physics; theory often precedes experiment.

The muon has a mass of 105.7, the π-meson 139.57 and the kaon 497.648 MeV/c^2.

For comparison the proton has a mass of 938.272 MeV/c^2 and the neutron 939.565.



Early timeline for the discovery of subatomic particles

The flyweight electron weighs in at 0.511 MeV/c^2. (Note that the neutron mass exceeds the sum of the proton and electron masses; so decay of a free neutron must be accompanied by a release of energy amounting to 939.565 – 938.272 – 0.511 = 0.782 MeV.)

It was during the 1950s that the field of particle physics started to burgeon both with discoveries, mainly in particle accelerators, of a plethora of new highly unstable particles (the delta Δ, lambda Λ and sigma Σ families) and the development of theories of how they interact and relate to one another. Furthermore the results from electron-scattering experiments indicated that protons have an internal charge distribution. The 1960s followed with discoveries of omega Ω, xi Ξ, chi Χ, phi Φ, eta η and rho ρ particles.

Particle Accelerators

Early in the 20th century physicists became interested in inducing nuclear reactions. The two natural sources of high-energy particles are:

The α-particles, β-rays and γ-rays resulting from radioactive decays and

Cosmic rays but these are generally not available in terrestrial laboratories

Ernest Rutherford, initially a farm boy raised at Brightwater in the South Island of New Zealand but by 1919 a Nobel laureate working at Manchester University, was the first to induce a nuclear reaction when he exposed nitrogen gas to α-particles produced by the radioactive decay of radium. A tiny fraction of collisions between the nitrogen and helium nuclei caused the (α, p) transformation

	$_7N^{14}$	+	$_2He^4$	=	$_8O^{17}$	+	$_1H^1$
Rest mass/GeV c^{-2}	13.04378		3.72840		15.83459		0.938783

The total mass energy of the reactants minus the total mass energy of the products is known as the quantity *Q* which must be positive in order for a nuclear reaction to be possible. But here, when considering only the difference in *rest* masses, *Q* appears to be - 1.2 MeV/c^2. However the kinetic energy of the α-particle emitted by radium was 4.94 MeV/c^2 so *Q* was in fact +3.7 MeV/c^2. Rutherford’s experiment was the first transmutation of an element to be recorded and the first observed creation of mass as well as the discovery of the proton $_1H^1$.

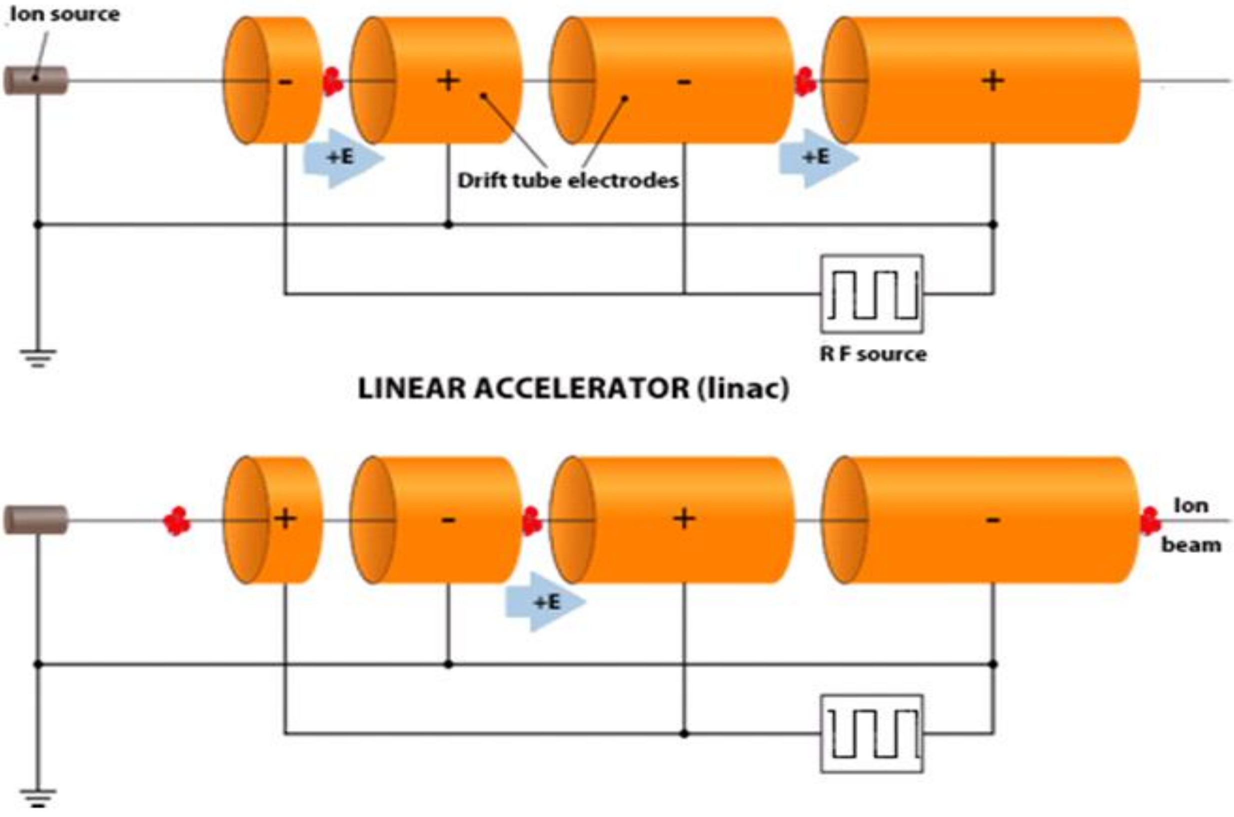
His ambitions were to perform further nuclear transformations but, although he and James Chadwick did achieve several, most would require the kinetic energies of the bombarding particles to be boosted in order to make *Q* positive and indeed sufficiently positive to achieve a detectable rate of formation. Any charged particle (electron, positron or **ion**ised atom) will be accelerated by being subjected to an electric field generated between a pair of electrodes held at different electric potentials. John Cockcroft and Ernest Walton, in 1932,invented a voltage multiplier (a simple but novel network of diodes and capacitors) which they used to bombard lithium with high-energy protons accelerated through 700kV, thereby producing

α-particles in an *exoergic* (energy-releasing) reaction, detected by scintillations on a fluorescent screen.

$${}_3Li^7 + {}_1H^1 = {}_2He^4 + {}_2He^4 + 2 \times 10^7 MeV$$

They measured the speed of the two helium nuclei and found that the net increase in kinetic energies of the particles matched the loss of mass between reactants and products, so their experiment was the first verification of Einstein's law, $E = mc^2$. Several other light elements such as ${}_{11}Na^{23}$, ${}_{13}Al^{27}$ and ${}_{15}P^{31}$ also undergo (p,α) transformations under bombardment with protons with energies below 850keV.

An alternative ultra-high voltage source, the Van der Graaf generator appeared in 1931 but all high voltage sources are restricted to outputs of about 12 megavolts because air between the output terminals breaks down through ionisation if the field exceeds a few thousand volts/cm. Replacing air with SF_6 enables the output to be raised as high as 30MV. The further development of electrostatic accelerators, which accelerate charged particles in a single electric field, would eventually be limited. Instead higher energy particles would be obtained by subjecting ions or electrons to a succession of electric fields in series. The voltages in the linear accelerator (*linac*) had to be applied in sequence as the particles passed through the device, causing them to emerge from it in batches or "bunches". The accelerations took place between neighbouring pairs of cylindrical electrodes, known as drift tubes. Within any tube the velocity was unchanged so speed increased stepwise through the linac.



LINEAR ACCELERATOR (linac)

A single potential difference can be applied simultaneously only to the first, third, fifth etc electrode gaps. Next the accelerating voltage is applied only to the even-numbered gaps before the whole cycle is repeated. This “switching” effect is achieved by using a radio-frequency alternating voltage. Each electrode is longer than the previous one to allow for the facts that the transit time of the particles needs to be the same through each tube whereas their velocities are progressively increasing. Linear accelerators still find use today but the performance is restricted by their length which increases enormously as particle masses become significantly relativistic. The Stanford linac which can accelerate electrons and positrons up to energies of 50 GeV is 2 miles in length.

In practice, further increases in acceleration would demand non-linear i.e circular accelerators. The first cyclotron, devised and built by Ernest Lawrence in 1930 consisted of a pair of D-shaped (near semi-circular) magnets separated by a small gap, amounting to a circle only 4 inches in diameter, with the ion source at its centre. The particles were confined by the magnetic field to a semi-circular path through semicircle A before being accelerated by an electric field across the gap into semicircle B. The increased speed caused the particles to move to a larger radius path through semicircle B. The direction of the electric field was reversed in order to accelerate the particles back into semicircle A. Provided that the particle mass remains essentially constant, the “lap time” is independent of its speed and path radius so the electric field is conveniently switched at the suitable steady frequency. Predictably this simple, but ingenious, arrangement was restricted to producing bombarding ions slow enough to be effectively free of relativistic increases in mass.

The low mass of the electron means that β-particles can only be given high energies by accelerating them to speeds where they would be subject to relativistic increases in mass. So to cope with β-particles the Betatron was developed; in this the electrons were accelerated in an orbit of constant radius by suitable variations in strength and frequency of the alternating magnetic field.

The synchrotron, a later refinement of the circular accelerator still intended for use with stationary targets, employed a series of magnets to confine and accelerate particles as they orbited within a toroid shaped tube. During the 1970s interest moved from particle accelerators to particle colliders.

(Part 2 in Next issue)

The Quiz

This month all of the answer begin with the letter W (apart from no 11 which is X).
As usual, they are in roughly increasing order of difficulty.

1. The common name of M11.

2. The astronaut who made America’s first spacewalk.

3. An 18th Century astronomer from Durham, who was the first to suggest that the Galaxy is disc-shaped.

4. The astronomer who first proposed the “dirty snowball” model of comets.

5. A rare class of very hot and luminous stars, with unusually strong and broad emission lines in their spectra.

6. The author of the 19th Century classic book *Celestial Objects for Common Telescopes.*

7. Two W’s in one here! The town and state where Yerkes Observatory is located.

8. The first comet from which samples of material were returned to Earth.

9. Linear features seen in lunar maria, often associated with buried structures beneath the lava.

10. The fifth nearest star to the Sun - after Proxima Centauri, Alpha Centauri A and B and Barnard’s Star.

And just for the hell of it, here’s a single “X” – albeit a silly one!

11. The musical instrument at which the late Sir Patrick excelled!

Answers to Last Months Quiz

1. Vela, the Sails.

2. The Very Large Array.

3. Viking 1 and 2, which landed in 1976.

4. Vindemiatrix (Epsilon Virginis).

5. Utopia Planitia. (Viking 1 landed in Chryse Planitia.)

6. Uranometria.

7. Uraniborg – “Castle of the Heavens”.

8. Voskhod 1 and 2, in 1964 and 1965.

9. Vulcan, the hypothetical planet which was thought to orbit the Sun closer than Mercury.

10. Uhuru, launched in 1970. It was launched from a sea platform off the coast of Kenya, and on that country’s Independence Day; it s name means “Freedom” in Swahili.

Elaboration of No. 8:

The two Voskhod missions both achieved apparently impressive “firsts”. Voskhod 1 was the first multi-man spacecraft, which carried a crew of three, before the US had launched its two-man Gemini. Voskhod 2 carried a crew of two, and Alexei Leonov performed the first EVA, or spacewalk. At the time, no details of the spacecraft were released to the West – or indeed to the USSR’s own people!

In reality, both were crude and dangerous propaganda stunts, performed for the sole purpose of “beating the Americans to it”. 20 years later, the Russians finally came clean about how the missions had been done. The Voskhod spacecraft were simply modified Vostoks; the “first three-man spacecraft” simply had three men crammed into a capsule built for one – so cramped that they had to fly without spacesuits!

On Voskhod 2, they managed to cram in two cosmonauts in spacesuits. Leonov left and re-entered the capsule through an improvised airlock, consisting of an inflatable canvas tube attached to the outside of the hatch! He had great difficulty getting back in through the contraption, and was very lucky to come back alive.

I’ve seen both actual Voskhod capsules, in the museum of the Energia Rocket and Space Corporation near Moscow. On seeing the Voskhod 2 airlock, you could well believe that it was designed by Heath Robinson!