Search for Building Blocks of the Universe

by Anisur Rahman

SCIENTISTS are spending many a sleepless night to find answer to the ancient and fundamental questions: what is the universe made of and what are the forces that bind its parts together? It is now known that nearly all the matters in the universe, from amoeba to galaxies, as depicted by the Standard Model, which is based on a set of theories that attempt to describe the nature of matter and energy as simply as possible, is composed of just four particles — two quarks, which make up the protons and neutrons in atomic nuclei; electrons, which surround the nuclei; and neutrinos, which are fast moving, virtually massless objects that are shot out of nuclear reactions.

These particles of matter are acted upon by four forces — the strong nuclear force, which binds quarks together in atomic nuclei; the weak nuclear force, that triggers some forms of radioactive decay; electro-magnetism, which builds atoms into molecules and molecules into macroscopic matter, and gravity.

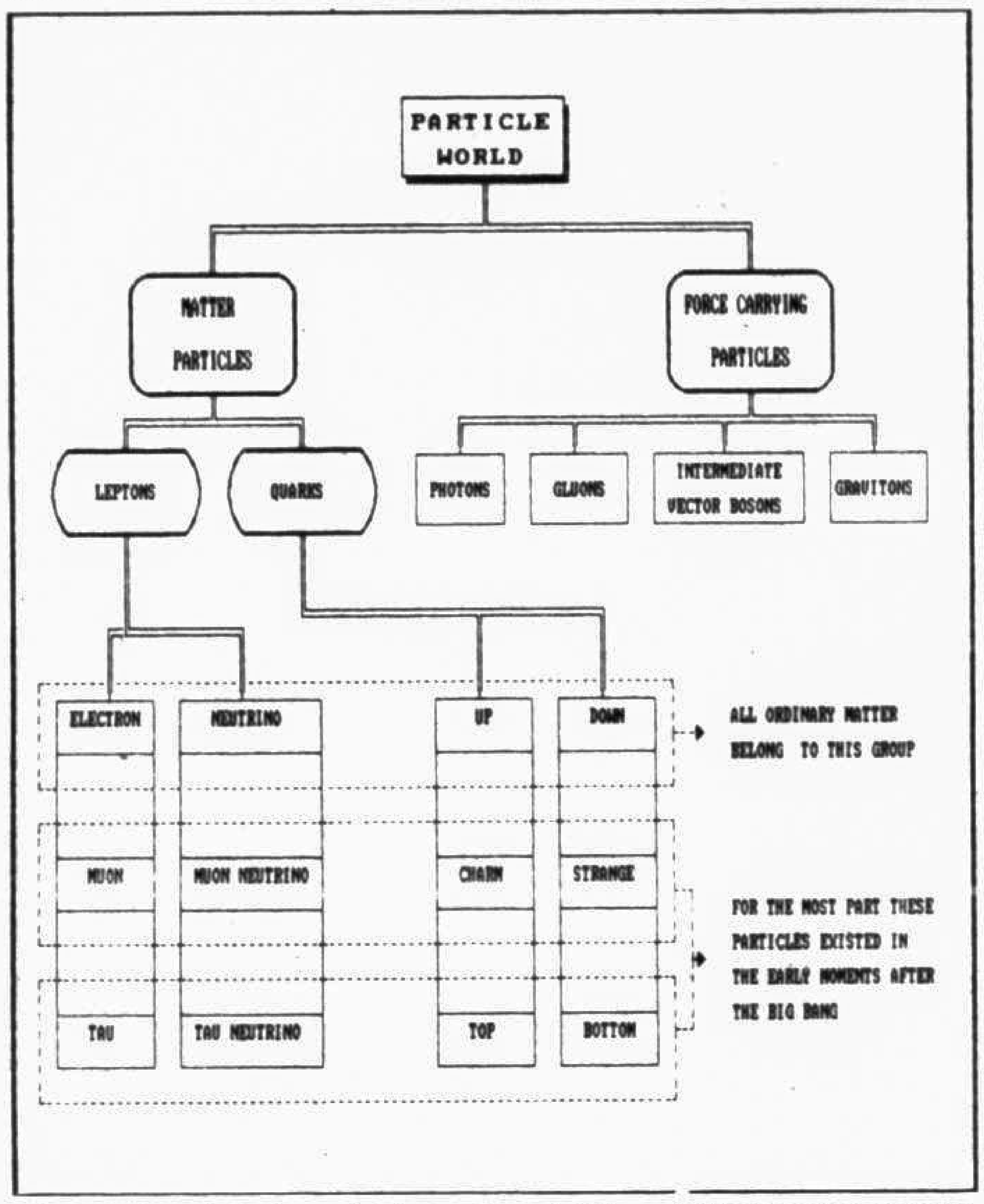
To find a more satisfactory description, physicists have developed just two basic families of particles — three pairs of quarks and three pairs of leptons. Leptons, the elementary particles that can travel on their own, are consisted of two classes — electron and neutrino. The electron itself has two counterparts, the *mu* and *tau* particles, each heavier than an electron. Each of these three particles has an associated type of neutrino, a very light particle with no electric charge that rarely interacts with other matter.

Quarks are trapped inside larger particles, proton and neutron, consisting of two classes — up and down. Up has an electric charge of +2/3, while down has -1/3. Protons are made of 2 ups and 1 down quark, whereas neutrons are made of 1 up and 2 downs. Up has got two heavier forms strange and bottom. Among all these particles *tau* neutrinos and top quarks are not yet discovered, but believed to exist.

An entire separate set of fundamental particles that transmit forces back and forth between particles, people and planets and the universe, are force carrying particles called bosons. They can be grouped in to four categories according to the strength of the force that they carry and the particles with which they interact.

The first category is gluon, the unit of the strong nuclear force that keeps the quarks together in the proton and neutron and holds the protons and neutrons together in the atomic nuclei. The second category is intermediate vector bosons, the carriers of the weak force, which is responsible for some forms of radioactive decay. They come in three forms — w plus (w+), w minus (w-) and z naught (z^0). The third category is photon, the particle that makes light which carries electromagnetic force, the force that interacts with electrically charged particles like electrons and quarks.

The electromagnetic attraction resulting from the exchange of photons between negatively charged electrons and positively charged protons in the nucleus causes the electrons to orbit the nucleus of the atom just as gravitational attraction causes the earth to orbit the sun. The last category is graviton, carrier of the gravitational force, the universal and the weakest of the four forces that every particle feels according to its mass or energy. Our universe is made of all these particles.



This view is however inadequate without the clear understanding of what happened in the big bang, the infinitely hot and dense fireball that gave birth to the universe some 15 billion years ago. Because, at infinite temperature there could have been new sets of particles which may not have existed after a short while, but combined to form particles that, today, we know as elementary particles.

In the 'hot big bang' model of universe, one finds that the universe starts off with unimaginable high temperature and as it expands, any matter or radiation in it gets cooler. This cooling would have a major effect on the matter in it, since temperature is simply a measure of average energy.

At a very high temperature, particles would be moving so fast that they could escape any attraction towards each other due to nuclear or electromagnetic forces. At some very high energy, called the grand unification energy, whose value would probably be of the order of at least a thousand trillion Gev (10^{12} eV) electromagnetic, weak nuclear and strong nuclear forces would all have the same strength and so could just be different aspects of a single force.

Till now, physicists have been able to produce only a few hundred GeV in the laboratory. So the arrays of particles at the earliest moment after the big bang is still an object of mystery.

But one second after the big bang, temperature would have fallen to about ten thousand million degrees — a temperature at which the universe would have contained mostly photons, electrons and neutrinos and their antiparticles (antiparticles are particles that mirror the particles; e.g. positron is the antiparticle of electron, which has the same mass but positive charge), together with the same protons and neutrons.

About one hundred seconds later, temperature would have fallen to one thousand million degrees like that in the hottest star; protons and neutrons would then no longer have sufficient energy to escape the attraction of the strong nuclear force, and would have started to combine together to produce the nuclei of atoms.

When temperature had dropped to a few thousand degrees, electrons and nuclei no longer had enough energy to overcome the electromagnetic attraction between them, they would have started combining to form atoms, then molecules. With expansion and cooling still taking place, molecules would have started to combine giving birth to heavier elements from light ones to form the bodies in the universe.

The formation of the universe at the later parts falls in agreement with all observational evidence. But the story loses the end as one gets more closer to the big bang and scientists also start banging their heads with big bang more rapidly to find the truth.

Many prominent scientists of the day like Stephen W. Hawking, Carlo Rubbia, Burton Ritchter etc. have set sails for the ultimate quest — to get into the big bang. Large accelerometers have been built for the purpose that are designed to recreate the primordial fireball in miniature to unlock nature's secrets.

The basic principal behind its operation is that particles are accelerated to a very high speed, then collided head-on, the collision which releases enormous bursts of energy, giving birth to new arrays of particles which combine as temperature cools down to form new particles and atoms.

Colliders used for the purpose are of different types: in CERN's LEP, an electron-positron collider, operational since 1989 with maximum collision energy 200 billion eV, positrons are created in a linear accelerator and then stored in an accumulator ring. Electrons and positrons are then accelerated in large small syncrotrons, the machines that accelerate charged particles to a very high energy where particles move in an orbit of constant radius guided by a magnetic field; thereby acceleration is provided and sent in through the LEP in opposite directions. LEP is a 27 km circumferential tube with experimental halls in between where particles are collided head-on.

Fermilabs Tevatron with two 6.4km circumferential rings, one placed upon another, are in operation since 1983 producing maximum energy of 2 trillion eV. It is a proton-antiproton collider where protons are created and then accelerated in a small synchrotron; antiprotons are created and then put into another ring where they are accelerated to high energies.

They are then diverted and further accelerated in the Tevatron, a more powerful ring using superconducting magnets installed below the main ring. The counterrotating beams smash together in the detector.

SLAC, operational since 1987 with maximum collision energy 120 eV, uses electron and positron for collision. Here electrons are shot at a target to produce positrons. Positrons and electrons are then collected in dumping rings. The particles are accelerated down a 3-km tunnel.

At the end their paths are bent into a head-on collision course. The energy of collision creates new particles, which are recorded in the detector.

The counterrotating beams will whip around the ring-shaped tunnel 3000 times, producing upto 100 million collisions every second in the experimental halls.

Scientists are expecting much more from the Superconducting Super Collider (SSC) than the contemporary colliders. Apart from setting aside the present theories it may as well prove that the quarks are not fundamental after all, but are themselves made of still more basic building blocks.

Whether SSC confirms the existing theories or unveils a new dimension in the laws of nature, is yet to be seen; but days are not too far for a much more powerful collider to appear in the collision-scene which will provide us with answers for the most fundamental questions regarding the building blocks of the universe.

The Robot Excavator

Digging a hole in the ground may sound easy, but try digging a trench with a precisely measured and graded bottom and you will rapidly discover that it is not only hard work but is a task that requires a great deal of skill and thought. Indeed, the failure to produce properly structured trenches costs the construction industry huge sums of money in time and effort in remedial measures.

Engineers involved in the Construction Robotics Project at Lancaster University in north west England are working on a project that, among other features, knows what depth it has reached and will be able to quickly and automatically produce the required trench profile. In fact, the finished system is intended to enable the excavator to automatically perform many of the routine — and some not so routine — functions of a conventional excavator, freeing the operator to perform other tasks such as quality control.

The hardware and software for the automatic excavator have been developed using a one-fifth scale model of an excavator arm in the laboratories at Lancaster and this has demonstrated the feasibility of achieving functions such as "dig to level" and "teach and repeat" operations together with high level features involving strategic and tactical decision making by the system. Much of the knowledge gained through the use of the one-fifth scale model is now being used to convert a real excavator to automatic excavation for further research.

It is obviously important for automatic operation that the robot excavator, and indeed any other item of plant, is correctly located in relation to its task. The Lancaster team has therefore developed and tested a prototype sensor which will enable the location and motion of the platform deploying the excavator arm, or indeed any other item of plant, using a single laser line as reference.

The research programme into construction systems at Lancaster may well have spin-offs into other areas of technology. for example, it should result in a better understanding of the control and operational requirements of large hydraulic systems and lead to ways of increasing machine life. Also, the greater understanding of the function and use of a wide range of construction plant and machinery that is being developed should result in their more effective operation and use. In particular, the development of expert system based techniques for the control of both tactical and strategic decision making could influence not only the operation of the machines themselves but the whole operation of a construction site.

— London Pictures Service

Solar Energy Can Augment Thermal Power Stations

A new concept of integrating thermal power plants with solar energy may not only save fuel in thermal stations, but also cost only a half of a stand-alone solar plant.

Scientists nowadays are acknowledging that the concept of a power plant operating totally on solar energy, though idealistic, may not be very practical or cost-effective.

Instead, integrating a power plant to a solar energy system may give the desired benefits, says a report by B R Pai, a scientist from the propulsion division of the National Aeronautical Laboratory, Bangalore.

Such a system would utilise the existing equipment and infrastructure as a base load facility and solar energy to reduce the fuel consumption during periods of insolation, the report says.

Large-scale power generation from solar energy is now a reality with recent advances in technology permitting sustained power generation in the range of 5-30 Mega Watts in the United States.

Several solar electric generating systems have already been installed in California about four years ago, and a 30-MWs plant is under construction. Also under operation in California is a 60-MW plant, while a 80-MW plant is being built.

These systems employ large parabolic trough collectors which track the sun and heat a special "heat transfer fluid" to about 330 degrees celsius. This in turn heats water in a solar boiler to generate steam which is expanded in a special steam turbine.

A key element in the set-up is a back-up system which involves an auxillary boiler with a separate fuel, usually natural gas, which provides high-quality steam and ensures a steady power output from the system irrespective of fluctuations in the solar output.

According to Pai, the parabolic trough technology using large collectors constructed from pre-formed mirror segments has matured to a point where it can be considered to be commercially viable.

But there is one major snag. The cost of such a system is exorbitant, working out to Rs 80 million per MW, about thrice the cost incurred in a thermal power plant.

Besides, there is the additional cost of a back-up auxillary boiler needed during cloudy days to supply additional energy to maintain constant output.

Many of these problems would be solved by integrating a solar concentrator field with a conventional thermal power plant, a technology that would have three major benefits, Pai says.

First, the capital cost of the back-up system would be climinated, leaving the basic system cost, involving only retrofitting cost and costs of the collector field and control system.

Second, care could be taken to ensure that the overall thermal efficiency is not affected, by taking into account the temperature and pressure limitations of the collector field.

Third, since only a small fraction of the power plant is affected, the control problem associated with fluctuating solar insolation will be much lower than stand-alone plants.

In a typically reliable and efficient modern thermal power plant, the total steam extraction is about 30 per cent of the boiler flow and is used to heat condensed feed water from about 50 degrees celsius to nearly 238 degrees celsius. This heating in a done is series of six heat exchangers.

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In the new concept, the solar feed water heating system is interspersed between the heat exchangers and additional heat exchangers are provided. Also, the feed water can be heated either by extraction steam or the heat transfer fluid or by both.

During nights and non-insolation periods, the plant operates in the base mode, with normal steam extractions for regenerative heating, and the heat transfer fluid in the solar circuit circulating at a minimum flow rate.

As the sun rises, the solar concentrators start tracking the sun and the temperature of the heat transfer fluid starts rising. At sufficiently high temperatures, the circulation of the heat transfer fluid increases while the steam extraction flows are reduced.

During evening, as solar insolation reduces, the flow rate of the heat transfer fluid is reduced and steam extraction increased. The entire process would be controlled by microprocessors.

Study of a retrofit to a 210-MW coal-fired plant indicates that a saving of fuel up to 24.5 per cent during periods of insolation can be achieved for feed water heating up to 241 degrees celsius.

The annual saving in coal would be around 47,000 tons at an estimated cost of Rs 30 million and a doubling of savings by heating to a higher temperature of 330 degrees celsius is feasible with currently available solar technology.

A major area that needs detailed study is a control system that can provide a smooth interfacing of the solar energy system with power plant operations. Such a control system should allow for fluctuations in the solar energy output.

Scientists believe that the proposed system, where solar energy contributes a small but significant fraction of the total output of the plant, would be easier to control than one where the total energy is provided by solar radiation.

(PTI Science Service)

Advanced Solar Technology promotes power generation

Science Briefs

Swedish Technique to Revolutionise Animated Films

A Swedish company has developed a technique by which the motions performed by human actors are transformed into drawn figures, a process that is expected to revolutionise animated films, reports *New Scandinavian Technology*.

The technique developed by Genimator AB of Sweden saves three quarters of the costs involved in making an animated film in the traditional way. High quality animated films contain enormous amounts of drawings and productions have traditionally required complete staffs of artists and are very expensive.

The group behind Genimator are now hoping for a world market for their technique. The technique developed by Genimator can also used for other applications like various simulation situations, the journal said.

Each individual created figure is drawn in a number old different angles. To ensure the best possible quality, 750 drawings per figure are produced. The motions performed by a human actor are registered by cameras in three dimensions.

Computer simulations of human motions in an natural manner calls for an enormous amount of data-processing capacity. In the Genimator system, however, these needs have been substantially reduced by taking the source information directly from a live actor.

All figures are divided up into segments with defined relations. Position and motional data from the real actor are fed in the computer in real time, whereupon a drawn prestored sequence is generated in the computer. The animator is then able to use a whole box of tools to process these sequences.

The idea of basing drawings on recordings of human motions in not new. The technique called rotoscoping has been used by several animation producers. But in this case the recorded material serves merely as a model for manual drawing work, whereas with the Genimator technique, the motions are transformed directly into drawn forms via the computer. A prototype model based on the Genimator method has been developed, the report said.

Third Generation Anti-Tank Missile

Aerospatiale Bourges in France has began volume production of Eryx, a third generation antitank missile that is expected to equip infantrymen well into the next century.

With a maximum range of 600 metres, it can attack a taken moving 10 to 15 metres per second in under four seconds. Its maximum flight speed is 280 metres per second.

The missile's efficacy and accuracy remains unaffected as the range increases and is thus superior to unguided rockets whose performance diminishes with increasing range.

Its large-diameter explosive charge possesses extremely high penetration power _ over 900 mm of homogeneous steel — and is effective against all current and foreseeable types of armor, the report said.

The missile's unusual architecture, with the propulsion unit at the front and the warhead at the back, results in optimum efficiency of the shaped charge, coupled with compactness and lightness. This low weight (less than 16 kilograms, including the launcher) makes it easy to use by infantrymen.

The guidance concept — vectored thrust applied through the centre of gravity to ensure precise steering even at low speed — makes it possible to fire Eryx with low initial acceleration, making low-observable shoulder firings possible from confined spaces.

Fabrication of the main propulsion unit's structure involves filament wound composite materials: after a thin envelope has been crimped around the propellant grain, it is wound with resin-preimpregnated kevlar filament (for which a special production line has been set up). The structure is then cured in a stove. In order to further reduced the costs and risks, the electric power generators employ the pellet technique, consisting in manufacturing independent multilayer electrochemical elements from compressed powders.

The launch tube is cut by a laser beam from a continuous helically wound carbon fabric tube. The spring-spun gyroscope's components are machined to a tolerance of one micron and are assembled by a robotic system.

Integrated Spindle Motor Improves Lathe Performance

Yamazaki in Britain has introduced a new range of lathes that feature an integral spindle motor which is designed to minimize vibration by elimination the need for belts, pulleys, extra bearings or gears, reports the journal *Engineering*.

The new Super Quick Turn range of lathes will be manufactured at the company's Worcester plant. In the new design, a water-cooled electric motor is wrapped around the spindle, the journal said.

This cuts down the rotating mass of the machine, allows the spindle to move smoothly and quickly, improves acceleration and deceleration, and due to the absence of side loads and reduced vibration improves the surface finish and roundness of components produced on the machines.

The combined spindle and motor was developed in conjunction with Mitsubishi Electric. Yamazaki says it will be fitted to most of its new machine tools.

The Super Quick Turn lathes are sland-bed machines with a spindle speed range of 35 to 6000 revolutions per minute.