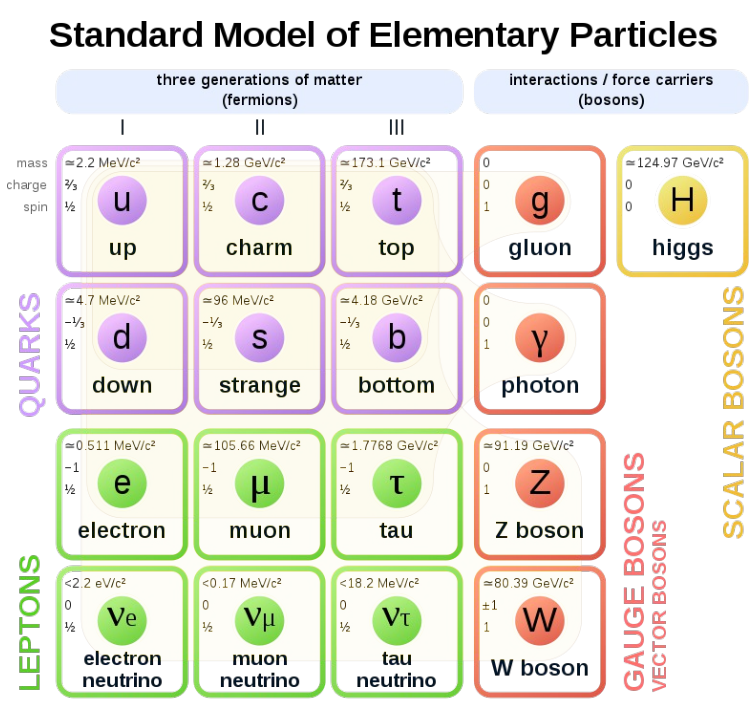
POLARIS

Newsletter of the London Centre, RASC

May 2019

All Things Great and Small Part 1



Astronomers spend a lot of their time studying things that are big, sometimes VERY big. We don't think much about the small stuff, the VERY small stuff. So I thought I'd take this chance to talk about things we know about, but can't see, the fundamental particles that make up everything in our universe.

Necessarily this will be a very short overview but it may serve to whet an appetite.

Everything that we can currently see is made up of a group of particles called the Standard Model. These fall into two broad categories, those that can pile up and those that take up space. The particles that can pile up are called bosons after Satyendra Nath Bose and those that take up space are called fermions after Enrico Fermi.

Each fermion has an anti-particle associated with it. An up quark can have an anti-up quark which has the same mass but all the charges are opposite.

Each has a quantum property called 'spin'. All fermions have what is known as '1/2 integer spin' or, 1/2, 3/2, 5/2 etc. While all bosons display 'integer spin' ie: 0, 1, 2.

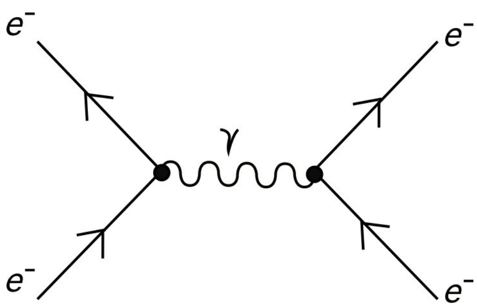
Fermions 'take up space' because they are governed by Pauli's Exclusion Principle which says that two or more of them can't occupy the same quantum state within a quantum system at the same time. Bosons do not and as such any number of them can occupy the same state, like photons in lasers.

Fermions are comprised of quarks and leptons. Quarks make up larger particles such as protons and neutrons and come in three generations. Generation 1 are called 'up' and 'down', generation II are 'charm' and 'strange' while generation III are the 'top' and 'bottom' quarks.

Leptons, from the greek for 'light' also have three generations. In order these are 'electron' and its neutrino, 'muon' and its neutrino and 'tau' and its neutrino. All fermions have mass.

The bosons are the particles that carry forces. Photons carry the electromagnetic force. Gravitons (not yet seen) carry the gravitational force. Gluons carry the nuclear strong force (via colour charge, think positive/negative but there are more of them). The nuclear weak force is mediated by three particles, two W particles (positive and negative) and the Z (neutral). These last three have mass. Photons and gravitons do not but the gluon might. It shows a small experimental mass but zero theoretical mass.

Forces mediated by massless particles act at long distances while those mediated by massive particles are short ranged. Gluons may be an anomaly. They may be massless but are confined within heavy particles such as protons or neutrons. There is one other boson in the Standard Model and that is the Higgs which I'll mention later. Photons, gluons and the W/Z bosons have spin 1. The graviton has spin 2 and the Higgs spin 0. For reasons that take a lot of math bosons with spin 1 are called 'vector' bosons while the Higgs is a 'scalar' boson.

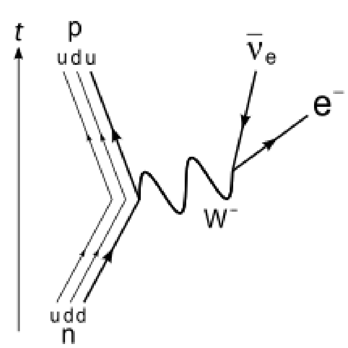


Forces work when two particles exchange bosons. The simplest way to understand them is to look at something called a Feynman diagram. A simple electromagnetic interaction would look like that to the left.

This diagram shows time from bottom to top. An electron (e^-) enters from the left and another enters from the right. The two exchange a photon (wiggly line) and 'recoil'.

Feynman diagrams can be extremely complex and always describe the mathematics of the Standard Model (which we won't get into).

All of the fundamental forces of nature work in similar ways. One particle exchanges a boson (or many) with another particle and actions occur. Feynman diagrams can also describe heavy particles decaying into lighter ones (particles never decay into heavier ones). Consider protons which are formed by two up quarks and a down quark and a neutron which is two down quarks and an up quark. Neutrons, being more massive, can decay into a proton, and do, after several minutes. This means that one up quark must become a down quark and this happens through the weak force (remember W and Z particles). This looks like the following diagram.



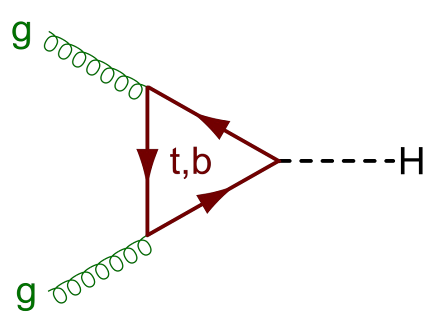
From the diagram we see a neutron entering from the bottom left and a proton exiting from the top left. In the middle a W^- boson is emitted which rapidly decays into an electron (e^-) and an anti-electron neutrino. The boson and two fermions carry away the excess mass/energy and charge is preserved. As an electron is emitted this is known as beta decay.

Why are the W and Z bosons massive while the photon, gluon and graviton aren't? This has to do with the Higgs field and its associated boson (all particles are just vibrations in a field). In the early universe, prior to the electro-weak phase transition (where the weak force and electromagnetic force joined) there were four vector bosons called the W1, W2, W3 and B and four Higgs bosons. When the energy level dropped enough the W1 and W2 'swallowed' two of the Higgs bosons and became the W^- and W^+ while the W3 and B swallowed the third Higgs and became the Z^0. These bosons all inherited mass and the last Higgs was left for us to find.

Finding the Higg's.

A lot has been reported about the Large Hadron Collider finding the Higgs boson so I'll be brief. The LHC fires protons around two 27km rings in opposite directions. At four points around the circuit the rings cross at intersection points inside detectors. At these points the protons can collide and the detectors try to sort out the bits and pieces flying from the collisions. The LHC can accelerate protons to an energy that gives 14 billion electron volts (TeV) at the centre of mass (an electron volt is the energy of an electron acted on by a potential of 1V or ~1.6×10^{-19} joules). The protons are moving at a very large proportion of the speed of light at this point.

We've said that protons consist of three particles, two up quarks and a down quark but this is highly simplistic. These three quarks are known as 'valence' quarks and have a total mass of about 9MeV. A proton has a mass of about 938MeV; so what's up? “When you put three quarks together to create a proton, you end up binding up an enormous energy density in a small region in space,” says John Lajoie, a physicist at Iowa State University.



A proton can be thought of consisting of a 'bag' full of the three valence quarks, a whole bunch of virtual quarks and even more gluons. The rule here is that the 'number of quarks' is the excess of ups and downs in the bag or, 2 up and one down. All the quarks are moving at a very large velocity as they rattle around the bag and these, along with all the gluons flashing between all the quarks, real and virtual, give the proton its mass.

So, when protons collide it's not one proton hitting another, but a bunch of smaller bits in a bag hitting another bunch of smaller bits in another bag (both flattened to be pancakish due to their velocity). The Higgs boson (generally) is created by two gluon fields (particles) causing a vibration in a couple of top or bottom quark fields (like a piano in one room causing a piano in another room to vibrate) which combine to create a vibration in a Higgs field and out pops a 126GeV Higgs boson. There are other mechanisms involving W and Z particles and other top quark mechanisms, but this is close enough.

Why does the Higgs field have a non-zero value at every point in space? Think of a bottle with a dimpled bottom full of liquid. This is how the early universe looks with space being the liquid and the Higgs field 'floating' on top of it. There is no difference between the energy value of the Higgs field and space and everything stays massless. Eventually though, the level of the liquid drops below the dimple at the bottom and starts to show. Now the Higgs can't have any old value but has to drop around the dimple to stay in the lowest erquilibrium state and therefore takes a non-zero value which allows particles to gain mass. How?

Fermions get their mass through their interraction with the Higgs field via the weak force. Thesy have a property called chirality which just means 'handedness'. They either spin clockwise (parallel to momentum or right-handed) or counter-clockwise (anti-parallel to momentum or left-handed) and this spin oscillates back and forth. Having 1/2 integer spin the electron can 'flip' back and forth between 1/2 and -1/2 and this is tied to something called 'weak hypercharge' which turns on and off as the electron's spin flips. When it turns off where does it go? The answer to that is the Higgs field. Having a non-zero value everywhere in space this field is an unlimited source or sink of weak hypercharge. Other fermions react the same and how much mass a fermion has is directly related to how tightly coupled it is to the Higgs field.

I mentioned that particles have chirality. It turns out that the weak interaction only happens to left-handed neutral particles or right-handed neutral anti-particles. So there may be a thing called a 'sterile' or 'inert' neutrino that does NOT feel the weak force, only gravity. Not interacting weakly, the masses of these is unknown. Dark matter? Who knows. They're actively being sought.

RASC London Centre Library

Books of the Month

May 2019

By Robert Duff

As always, these “Books of the Month” are available for loan to members, to be returned at the following monthly meeting. The books for May 2019 are as follows:

The Backyard Astronomer's Guide, by Terence Dickinson & Alan Dyer. Revised Edition. 2002.

Cataclysmic Cosmic Events and How to Observe Them, by Martin Mobberley. c2009. (Astronomers' Observing Guides)

NightWatch: a Practical Guide to Viewing the Universe, by Terence Dickinson. 3rd Edition, Revised and Expanded for Use Through 2010. 1998 (2003 printing).

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Slide Presentation, Thames Valley Science & Engineering Fair, Althouse College, Saturday, April 6th, 2019

Written by Robert Duff, as Reported by Peter Jedicke

RASC London Centre members Peter Jedicke and Mike Roffey made a presentation to 20 high school students at a workshop during the Thames Valley Science and Engineering Fair, held at Althouse

College, Faculty of Education, Western University, Saturday, April 6th, 2019, 11:45 a.m.—12:30 p.m.

The event was held in Althouse College, Room 2038, where the Science and Engineering Fair took place. Peter set up his home-built 40.6cm (16-inch) Truss-Tube Newtonian / Dobsonian and Mike set up his 15cm Celestron NexStar 6SE Schmidt-Cassegrain on a Celestron NexStar Evolution GoTo mount, to demonstrate the 2 different types of telescopes to the students. Peter gave his slide presentation *"Amateur Astronomy Today."*

Cronyn Observatory Public Night, Saturday, May 4th, 2019

By Robert Duff

A mostly cloudy, hazy sky greeted 46 visitors (including 10 youth) to Western University's Cronyn Observatory Summer Public Night, Saturday, May 4th, 2019, 8:30 p.m. Professor Martin Houde made 2 presentations of his digital slide presentation *"Submillimetre Astronomy,"* first at 8:30 p.m. and the second time at 9:45 p.m. There were very good questions from the guests for both presentations and a very good discussion after the first presentation. RASC London member Lynn Jones was the Greeter and counted 46 visitors of which 10 were youth - using 2 hand tally counters, one to count all visitors and one for youth (high school or younger). She directed people into the lecture room for the presentation, upstairs to the dome to view through telescopes or downstairs for demonstrations in the *"Black Room"* and a tour of the historic *"1940s Period Room."*

RASC London Centre was represented by Everett Clark, Lynn Jones, Bob Duff, Mark Tovey and Henry Leparskas, as well as Peter Jedicke who arrived around 9:00 p.m. and listened to the slide presentation. Graduate student Viraja Khatu was telescope operator in the dome and since it was cloudy, directed the big 25.4cm refractor (32mm Erfle eyepiece, 137X) towards the white lights on the communications tower in south London. A wedding party visited the observatory early in the evening for a picture taking session in front of the big telescope—newlyweds under the stars! Since both the bride and groom were Western graduates, they were thrilled with our invitation to have a picture taking session in the Cronyn.

Viraja later redirected the 25.4cm refractor to show visitors the orange giant star Arcturus, faintly visible through hazy clouds. Everett Clark set up the RASC London Centre's 25.4cm Dobsonian (17mm Nagler eyepiece, 66X) and directed it towards some lights in the Engineering building windows. Bob Duff took over the 25.4cm Dobsonian and showed visitors Arcturus when it appeared through the thin hazy clouds. The clouds cleared somewhat overhead and Bob redirected the 25.4cm Dobsonian to show people Mizar and Alcor in the handle of the Big Dipper. Mizar and its fainter companion Alcor are a visual double, 78 and 81 light years away, respectively, and some 3 light years apart, travelling together in space. Mizar itself splits into a double star when viewed through a telescope and is a true binary system. Everett talked to one lady interested in getting a telescope and joining the RASC London Centre. Bob talked to one man, interested in getting a telescope, and showed him the observatory's Meade 20.3cm Schmidt-Cassegrain.

Downstairs in the *"Black Room"* Henry Leparskas did the the *"Transit Demonstration,"* with the *"Transit Demo"* model, showing how the transit detection method worked for finding extra-solar planets, and the *"Spectroscopy Demonstration,"* with the visitors putting on *diffraction grating* glasses to view the spectra of 4 gas discharge lamps, including hydrogen, helium, neon and mercury. Mark Tovey showed visitors the *"1940s Period Room,"* a recreation of Dr. H. R. Kingston's 1940 office, with his brass refractor and the *Sotellunium*—a mechanical eclipse demonstration model built by W. G. Colgrove—on display. The *"1967 Period Room,"* recreating the early control room of the Elginfield Observatory remained closed, while the *"W. G. Colgrove Workshop Period Room"* was open for visitors' inspection. The 3 "*Period Rooms"* were designed by RASC London Centre member Mark Tovey.

The observatory was closed down by around 11:00 p.m. after an enjoyable evening of astronomy for everybody, despite the hazy, cloudy sky.

Polaris On-Line

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