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Reports by Kate Kennedy

We are Made of Star Stuff

Professor Jocelyn Bell Burnell PRSE

This talk considered the atoms in our bodies and asked where have they come from? What was the Earth made from? What have stars and the Big Bang got to do with our bodies?

The Periodic Table tabulates all the stable chemical elements, laid out in order of density with the columns containing elements of similar chemical properties. Two thirds of the human body is formed of water; the rest largely comprises the five important chemical elements of hydrogen, oxygen, iron, calcium and carbon, alongside smaller amounts of sodium, potassium, lithium, etc. When we are born, we are much smaller and we grow by taking on more atoms through the food that we eat in the form of animal and plant matter. Similarly, the plants that we and other animals eat start small and grow through incorporating atoms from the soil and air. As such, when we eat plants and animals, we are eating atoms from the soil. But where did these atoms originate?

The creation of the Universe started about fourteen billion years ago. Everything within the Universe started in a tiny volume and a rapid expansion, officially named the Big Bang, gave rise to the creation of the elements. Within the first few seconds, a fireball of energy was released which was extremely hot and then expanded and cooled. During this process, some exotic particles were formed and as the cooling commenced, Einstein's equation $E=MC^2$ came into effect; meaning that energy could become matter or mass and vice-versa. As such, solid material began to form in the Universe. In the first instance, this was unrecognisable matter; however, particles continued to combine, producing more recognisable forms such as the nuclei of hydrogen and helium atoms. Thus, within minutes of the Big Bang occurring, the two heaviest elements of the Periodic Table were created; this is known as the Goldilocks Effect, the time within minutes of the Big Bang when conditions in the early Universe were 'just right' for the creation of hydrogen and helium. However, these elements alone are not sufficient to create life.

After the first three minutes, the expansion and cooling continued at such a rate that should have meant that particles were no longer able to meet and combine. Theoretically, the Universe should have been stuck with solely hydrogen and helium forever. This is obviously not the case. Where therefore, did the other elements originate? Dame Jocelyn explained that all the other elements were created in the stars. Stars form in the dark parts of the galaxy, such as the Horsehead Nebula. These areas of the galaxy are dark because they are relatively dense and contain particles of dust and molecules of gas. They are dense enough that they block out light from any other parts of the Universe; like drawing curtains across a window. The stars form in these dark, dense clouds when particles of gas and dust form together in a random knot. The extra gravity of the knot draws in more particles, causing it to grow bigger over millions of years. As the knot grows, its central temperature rises and when it reaches around 10 million degrees, nuclear burning, or fusion, starts and it starts to shine as a star due to hydrogen being converted to helium and energy.

The Sun is burning 600 million tonnes of hydrogen every second. It does not contain enough hydrogen to last forever, but should continue for another five billion years. No stars live forever; they all ultimately run out of hydrogen and become clogged with helium. Once this happens, they can start to burn helium and it is during this stage that carbon is created. For the majority of stars this is the final stage; the star becomes a white dwarf, gradually cools and becomes invisible. Thus, if this happens the carbon is locked up within the star and is not available. A minority of stars, however, such as Betelgeuse or the Pleiades, which are much heavier than the Sun, have several more stages to their life and last an extra 600 years. These are the type of stars we are dependent upon for life, as they create a large nucleus of atoms and are able to burn carbon to form neon, sodium and magnesium. Neon converts to oxygen and silicon is built from oxygen. Silicon also converts to sulphur, argon, calcium, nickel and iron, providing the elements required for life. Eventually, the star explodes; 95% of the star goes out into space and 5% becomes pulsars. This explosion ends the sequence and releases the elements required for life into the Universe. As such, human life is dependent on the life cycle of a star, from its birth to its explosive death.

Unnatural Disasters

Professor Iain Stewart FRSE

Professor Stewart has worked on and researched hazards such as earthquakes, volcanoes and tsunamis for the last thirty years, but states that he never really understood them until the last ten years. This lecture details how television work and meeting real people in real places helped him step outside the academic discipline of geology and develop a true understanding of the impact of natural hazards.

The first disaster area that Professor Stewart visited in its aftermath was the great Sumatran earthquake of 26 December 2004. The subsequent tsunami wrought destruction around the Indian Ocean and was truly a global disaster. The event cost 250,000 lives and huge economic loss, but its reach extended far beyond the country's devastated region, killing large numbers of tourists from distant affluent nations; for example, the disaster is the greatest loss of life of Swedish citizens from a natural event. On somewhat distant coasts, the brunt of the tsunami's impact was borne by coral reefs, coastal dunes and mangrove swamps, though in many places these natural barriers had been removed for tourist developments. In Banda Aceh, Indonesia, however, the presence of such coastal buffers made no difference to the impact of the devastating waves. Nevertheless, throughout southeast Asian shores, deforestation of mangroves for intensive shrimp farming, a lucrative export industry, has reduced livelihood options for local farming and fishing communities. This, together with other forms of chronic degradation (land clearance, coastal erosion, overfishing and coral mining) has significantly reduced the potential for economic recovery from the tsunami, because of the loss of traditional income sources related to diverse coastal ecosystems.

Following the tsunami, Professor Stewart visited the Thai island of Khao Lak, a luxury resort that attracts thousands of tourists each year. Formerly, local people lived in settlements by the coastline built from locally derived materials. The society, predominantly an oral culture where tales of the sea's danger are passed down through generations, are aware that the sea is erratic and variable, a fact borne out through their building of houses on stilts in the water. Tsunamis have affected this coastline before; however, the difference today is that the increase in tourist numbers has required different infrastructure and buildings, such as hotels, formed from different materials, such as concrete, and built in different styles. Thus, Professor Stewart commented, the nature of the physical process of a tsunami has remained the same, but the impact of that process for the people living or staying in the area affected has changed.

In 2005, Professor Stewart visited Mount Merapi in Indonesia, the site of a volcano that experiences lethal pyroclastic flows every few years. The volcano is well monitored and through taking the temperature of the lava and measuring the gases, it is possible to predict a few days, if not a few hours, in advance when it's going to have a volcanic crisis. However, despite the advance warning and mandatory evacuation notices, very few of the communities that live on the top slopes of the volcano leave the mountain. This traditional community believe their ancestors protect them and that leaving the volcano might upset their Gods. However, there are also more economically-grounded reasons for their non-evacuation. The main livelihood on the volcano is milk production and selling. The communities are, in fact, concerned that leaving their cows to potentially die or be stolen, or even having their land stolen if they leave, will result in a higher likelihood of them and their families coming to harm. Rather than a seemingly irrational choice in the face of scientific fact, it is actually a rational decision in terms of human survival.

This is not only the case in developing countries. In La Conchita, California, a mudslide killed nine people. However, people continue to purchase houses in the area which is likely to be affected again; indeed, houses have even gone up in price. Professor Stewart commented that he previously thought his job as a geological scientist was to inform people of where dangers may occur; however, people are repeatedly going against this and making judgement calls and balancing probabilities.

Istanbul has a population of around 50 million people and is one of the best historically recorded cities in the world. It is also a place that has been repeatedly struck by earthquakes. The Hagia Sofia was constructed in 600AD, but within 50 years an earthquake had knocked down part of it. Today, it has a set of stone buttresses built around it and holding it up, offering structural protection. Istanbul is located on the Anatolian Fault and, as such, is almost guaranteed to suffer future earthquakes. The Anatolian plate is gradually being pushed westward by about 2.5–3 cm every year and the strain that builds up along this will, at some point, suddenly release. Ominously, since 1939, there have been seven earthquakes with a magnitude of more than seven on the Richter Scale. All of these have been marching westwards on the Anatolian Fault, towards Istanbul.

Professor Stewart commented that although earthquake science is not as good as volcano science at predictions, understanding the physics of earthquakes means that they can be mapped and patterns identified. An earthquake is the release of a build-up of stress and when this stress is relaxed in one area, it adds stress to another. As such, earthquakes can be predicted and mapped. In terms of Turkey, the 1939 earthquake increased stress at the site of the 1942 earthquake and the 1942 earthquake caused stress at the position of the subsequent earthquake, and so on. Thus, it is possible to determine where the next area of stress is built up and, therefore, where to expect the next large earthquake; in all likelihood, in the industrial heartland of Istanbul.

The major concern for Istanbul is that the city has developed very quickly over the last century. The city is a crowded environment comprising lots of narrow streets and market places and many buildings have been built quickly, using inferior materials and thus, if subjected to any sizeable seismic shake, will be easily destroyed. The city is built on ground comprising lots of soft sediment which turns to 'jelly' when struck by an earthquake. Indeed, Japanese scientists have mapped where they believe there will be high seismic shake in an earthquake and this incorporates most of Istanbul. All major new infrastructure in the city is being engineered to a high standard. However, the problems lie with the older buildings which, over the decades, have been constructed and had storeys added to them; in many cases, unsafely. In the latter part of the 20th Century, realising these buildings would be problematic if struck by an earthquake, the Turkish government legislated that these older buildings should be replaced by new ones built to safe standards. However, this construction was not undertaken using municipal money, but rather through private enterprise, and there is concern that corruption occurs whereby new buildings are signed off as safe when they are not.

Whilst old districts were ripped down and new apartment blocks built, the investment required to make the building worthwhile meant that more people were required to live in the same area. Thus, should an earthquake strike these areas, and the buildings are not built to a safe standard, the death toll will be higher than before. Furthermore, the increased population density has led to a lost sense of community in these areas, something that would be integral to the recovery of a city following a natural disaster. Professor Stewart commented that although it is vital to be able to communicate these hazards to people living in these areas, they are also suspicious of earthquake science, thinking it is just an excuse for a 'land grab' in new areas, with land being bought up and people moved to new areas that are supposedly safer for earthquakes. Furthermore, cities with high levels of corruption also have the highest levels of deaths from earthquakes, as the authorities are not necessarily transparent about their activities. "83% of all deaths from earthquakes in the past 30 years were in low income, corrupt nations".

Professor Stewart concluded by mentioning the destruction of Xinjian Primary School by an earthquake in 2008. Sadly, hundreds of children were crushed by falling bricks and concrete. In contrast, none of the nearby buildings were badly damaged. A separate kindergarten less than 20 feet away survived with barely a crack. An adjacent 10-story hotel stood largely undisturbed. And another local primary school, catering to children of the elite, was in such good condition that local officials were using it as a refugee centre. "This is not a natural disaster," said Ren Yongchang, whose nine-year-old son died inside the destroyed school. This is not good steel. It doesn't meet standards. They stole our children."

Geologists and other physical scientists need to engage with the social aspects of science to understand the real impact of these disasters and the responses to them. Natural hazards have not changed, but what they mean for the communities experiencing them has.

Exploring the Dark Side of the Universe

Professor Martin Hendry FRSE

We live in an extraordinary Cosmos. Less than 100 years after Edwin Hubble discovered that our Universe is expanding, observations of distant supernovae and the afterglow of the Big Bang itself have revealed that the cosmic expansion is speeding up – driven by a mysterious "dark energy", the precise nature of which is one of the biggest puzzles in science. In this lecture, the audience joined University of Glasgow astronomer Martin Hendry on a whistle-stop tour through thirteen billion years of cosmic history: exploding stars, colliding black holes, dark matter, dark energy and the very latest theories for the origin and fate of the Universe.

Cosmology is concerned with the properties of the Universe as a whole, not just individual stars and planets, and its followers and students aim to discover where the Universe came from, how it got there and what it's going to do in the future. Ideas and theories about cosmology have existed for thousands of years and ever since people started stargazing, they have speculated about what is happening in our mysterious skies. Indeed, cultures around the world have interesting stories and ideas that attempt to place humans in the context of the Cosmos. It is all too easy from a 21st-Century perspective, to dismiss some of the earlier ideas (for example, Hindu mythology which suggests the Earth is sitting on the back of a giant tortoise) as nonsense. But how do we actually know that it is not plausible? Some of the modern theories of cosmology, to the uninitiated, are equally bizarre and dumbfounding, even for some scientists. Physicists estimate that we only truly know what 5% of the Universe is made up of. The remaining 95% constitutes the mysterious components of dark matter and dark energy – until recently the stuff of science fiction. Professor Hendry questions "how can you convey to people what they should and shouldn't believe when so much is undiscovered and unknown"? This lecture gave an insight into how we make such judgements and the scientific methods and theories behind the study of cosmology.

2009 was the 400-year anniversary of Galileo first using the telescope, an invention which made a vast difference to the discovery and understanding of the Universe. Telescopes have got much larger since the 17th Century; the four telescopes comprising the *Very Large Telescope Array,* situated in Chile, contain mirrors measuring eight metres across. These larger lenses are better at collecting light and thus observing things located deeper in the Universe, leading to new discoveries. Our galaxy, the Milky Way, is visible to the naked eye and, seen from Chile, resembles a band of stars in which it is almost impossible to make out individual stars. Using his telescope, Galileo discovered that the Milky Way in fact comprises around 100,000 million individual stars. In the early 1900s, this was the sum total of our knowledge about the Universe; it was unknown whether the Milky Way was unique or whether there could be other similar star systems. Astronomers using early telescopes discovered many structures in the night sky which had a likeness to the Milky Way and named them nebulae, due to their cloud-like features. But at this time, stargazers were unable to determine whether they were looking at something small and nearby or something bigger located further away. They were also unable to ascertain whether these nebulae were located within or outwith the Milky Way. Consequently, the early astronomers needed to find a reliable way of measuring the distances to these potential new galaxies.

Astronomical equipment continued to develop and by the 1920s, renowned astronomer Edwin Hubble was working at the Mount Wilson Observatory in Pasadena, using the world's biggest telescope of the time, containing a lens measuring 2.5m. In the 1920s, Pasadena was an ideal location for studying the Universe; the skies were hardly ever cloudy and light pollution was minimal. Hubble used the telescope to observe what we now know as Cepheid stars in the Andromeda Nebula. Professor Hendry explained "In astronomy one needs to be very careful that you have made the right assumption about how bright a star really is, to then deduce how far away it is. This is easier with Cepheid stars as they pulsate. We see a point of light that gets brighter and dimmer in a regular pattern. The Cepheid stars that pulse in and out over a short timescale of a few days are thought to be those that are not as large and bright as those that take longer to complete their pulsation pattern and which are much brighter". There is, therefore, a relationship between length of pulsation and how bright the stars really are. "This is incredibly useful; like knowing you are looking at a 1000-watt light bulb as opposed to a 10-watt light bulb. It is difficult with other types of stars to get an indication of how bright they really are because if the more powerful light bulb was further away its brightness would decrease dramatically and would make it appear similarly bright to the less powerful, but nearer, bulb".

The scientist Henrietta Levett, working prior to Hubble, had already discovered a group of Cepheids and although she didn't know exactly how far away they were, she knew they were approximately the same relative distance from Earth. Therefore, if one appears brighter than another, it is because it truly is brighter and not just further away. Hubble used Levett's discoveries relating to pulsating Cepheid stars in assessing his early measurements of the Universe. He showed through his measurements that the Universe is bigger than originally thought and ascertained that the Andromeda Nebula isn't simply a gas cloud in our galaxy but a whole separate galaxy in its own right; which is actually bigger than the Milky Way. Andromeda is actually about 2.5 million light years from Earth and is the closest galaxy to the Milky Way and the furthest we can see with the naked eye. (A 'light year' is the distance that light would travel in one year and equates to 186,000 miles per second.) Armed with these findings, Hubble began the process of mapping and measuring the scale of the Universe, a process which continues today.

Hubble was also interested in the light coming from the galaxies and studied the colour emitting from them. His experiments utilised the principle that different chemicals produce different patterns of missing lines on a colour chart, known as absorption lines. Professor Hendry explained, "they are missing because the atoms in the atmosphere of, for example, a star located between the light source and Earth have absorbed the light coming from the galaxy and it is no longer available to make its way to us and is, therefore, removed from the colour chart. In recent times, such experiments have been used to detect what planets' atmospheres consist of and could, in future years, be used to detect life on other planets". Hubble, however, used these experiments to work out how and how fast the galaxies were moving, as the absorption lines on the colour charts shift if the galaxy is moving.

A parallel example of this in the study of sound rather than light would be the Doppler Effect, where a sound moving towards us, such as a car horn, changes in pitch the closer it gets. Light does the same and the wavelength affects the colour generated, and can be measured using sensitive equipment known as a spectrometer. Light moving towards us is squashed in wavelength and is blue in colour, whereas, light moving away from us has stretched wavelengths and is red in colour. Hubble discovered that the light from most galaxies is red and as such they appear to be moving away from us. His findings also concluded that galaxies that are further away from us appear to be moving away faster than those which are nearby and, as such, their speed is proportional to their distance away. Professor Hendry described these as "very profound discoveries".

Many of Hubble's conclusions also connect with Einstein's theories relating to gravity. In earlier times, gravity was thought of in terms of "things attracting other things"; Newton stated that the Earth exerts a gravitational force on anything around it. Einstein considered gravity differently; he didn't like the idea of there being a force between things. He thought of gravity as a bending or warping of space itself; "space tells matter how to move and matter tells space how to curve". Professor Hendry explained, "the idea is that all the matter in, for example, the Sun, bends the space around it and causes the Earth to follow those curved contours and this is why the Earth orbits the Sun; it is following the natural shape of space. Thinking of the Universe as a whole, this theory leads to a remarkable conclusion that space should be curved or warped by all the matter and energy present in it and that this would lead to the fact that space should, therefore, be expanding". Professor Hendry described this using a metaphor of the surface of a balloon with yellow dots marked upon it. "As the balloon inflates, the dots stretch further apart; it doesn't matter which dot you chose, it will look to you as if all the other yellow dots are moving away from you. So, in reality, what Hubble discovered was not galaxies moving through space but space between the galaxies stretching and making them appear as if they are receding from us".

The modern era of cosmology began around 1990, when the Hubble telescope was launched. One of its purposes was to look for Cepheid stars in galaxies that were much further away. It was also created with the intention of helping to solve whether the expansion of the Universe would continue forever. The general expectation amongst scientists was that the Universe should be slowing down; but would it slow down enough to start contracting? Theories suggested that if the Universe has more mass than we are aware of, then there may be enough mass to stop the expansion and actually pull it all back together. To try and ascertain if this is possible, physicists needed to find ways to weigh the Universe.

Kepler and Newton had already marked out the orbits of the planets in the solar system and deduced that as the gravitational pull is weaker the further a planet is from the Sun, the longer it takes to orbit the Sun. However, in 1933 Fritz Zwicky, looking at clusters of galaxies, discovered that this orbit distance and speed relationship is not the same in their case; however, his peers at the time paid little attention. In the 1970s, Vera Rubin also discovered that galaxies appear to be spinning faster than our understanding of gravity would predict. She explained this by suggesting galaxies have more potential energy than we realise; more matter than we can see – dark matter. Professor Hendry stated, "We still do not know what dark matter consists of, but we do have a good idea of what it is not; it cannot be made of atoms, it has to be something that doesn't consist of the basic building blocks that we know".

Is the expansion of the Universe slowing down as expected? If not, what is actually happening? Professor Hendry commented, "If you could observe very bright stars known as Type 1 Supernovas (exploding stars) in galaxies much further away, what we would actually be doing would be looking back even further in time. We would be able to see how far away the really distant galaxies are and if they are still obeying the relationship that Hubble established". By 1998, astronomers had become so good at observing these distant supernovae that they were able to collect sufficient data to show that, contrary to expectations, the Universe is actually expanding faster now than it did in the past. At first it was thought this was an error of measurement and was not believed in the scientific community. However, in 2011, following repeats of their experiments resulting in the same conclusions, the scientists who made this discovery were awarded the Nobel Prize, and the theory that the expansion of the Universe is indeed speeding up is now accepted.

Scots & English

Professor Jeremy Smith FRSE

For many, Scots is a language; for others, it is a dialect (or a collection of dialects); for some it is 'slang'. Whatever we call it, the language–variety known as Scots is a complex and dynamic phenomenon with a fascinating history - a history that cannot be separated from the people who spoke (and speak) it. This interactive lecture offered some answers to the question in the title, but also posed some further questions for further pondering.

Professor Smith started by commenting that, as a language historian, people often ask him 'what is Scots?' and this is very difficult to answer and define. No natural languages are pure and all undergo change, adding and losing material throughout time. Indeed, language and how it is currently used can reveal interesting things about its history. One aspect that demonstrates how languages change are place names which can take on their own life and remain in the landscape, even when the people who first used them have long since moved on and the originating language is no longer spoken in a place. Names such as 'Pentland' or 'Pitlochry' are relicts of the Brittonic variety of Celtic that was once spoken over much of Scotland; while names such as Dingwall, Sutherland and Johnshaven are Norse in origin, surviving from the days of Scandinavian settlement. Many others are from the Goidelic branch of Celtic, represented in Scotland by Scottish Gaelic; e.g., Inverness itself, Perth, Balmore. In the south of Scotland, many names derive from the Anglian variety of English; e.g., Ingliston.

Subtle interactions between languages can take place. For example, in Germanic languages, names are usually ordered with the specific element followed by the generic part, as in 'Eye' (specific) 'Mouth' (generic) (*cf*. Eyemouth in the Borders). This is the opposite to Celtic names. For example, Edinburgh was formerly known as the Celtic Dunedin; the 'Dun' referring to 'Castle' and 'Edin' being the specific part, 'Edin's Castle'. In the current Germanic format 'Edin' has been brought to the front and 'Dun' has been replaced with 'Burgh', changing the meaning from 'Castle' to 'Town', or in the German language, 'fortified town'.

Kirkcudbright in southwest Scotland is an excellent illustration of how a place name can incorporate different languages and cultures. 'Cudbright' refers to the Northumbrian saint, Cuthbert; the Northumbrian hegemony spread from the north of England to southern parts of Scotland. 'Kirk' is the Norse for 'church' and therefore, the word Kirkcudbright means the church of Saint Cuthbert. The third interesting cultural element of Kirkcudbright refers to the sequencing of the two words 'Kirk' and 'Cudbright', which is in a Celtic format. Kirkcudbright, therefore, brings together three cultures of the region; it has a Celtic ordering, a Norse generic and includes the name of an Anglo-Saxon saint. Existence of such place names usually indicates an area with a rich history of settlement by different cultures. Professor Smith likened place names to 'fossils' of the people who have lived in a region and commented that other aspects of language have similar 'footprints'. The character and distribution of the languages of present-day Britain derive from their complex histories.

The history of English is typically divided in to four periods: Old English, also known as Anglo-Saxon up to around 1100AD; Middle English, the language of Chaucer; Early Modern English, the language of Shakespeare; and Late Modern English, which continues to this day. Scots and English in Scotland also has a distinct set of periods: Old English up to 1100AD, a particular version of Anglo-Saxon known as Old Northumbrian; Older Scots to about 1375, of which only fragments of information remain; Early Scots from 1375 to 1450; Middle Scots from 1450 to 1700;

and Modern Scots, 1700 to present day. Professor Smith explained that from around the period of Modern Scots, it is also possible to distinguish a form of the language known as Scottish Standard English. People started to write about this in the 18th Century and referred to it as 'Scottish purged of vulgarity'. The Scots language is very closely related to English, but has a complicated relationship with it; some people regard it as a distinct language and others as a dialect or sub-variety of English. A language akin to Scots has been documented since the 14th Century. Professor Smith commented that he is frequently asked whether Scottish Standard English should be considered as an entirely separate language to English or a dialect of English, to which he replies that it is a "very complicated question"!

Languages and their development cannot be formatted into a rigid 'family tree'-style diagram with set boundaries and specific dates when changes occurred. Language development is a more fluid process, with on-going subtle changes, for example, altering vocabulary over time and place. Scots vocabulary is formed from various different sources; for example, the word 'dreich', which many would assume is authentically Scottish, is in fact derived from an Old Norse word meaning tedious or lasting. Words originating from Celtic often relate to cultural objects, animals and topographical features. Other sources include Low German, with words such as 'golf' and 'scone' and, as previously mentioned, Norse words, for example, 'dreich'. There are also words deriving from French, such as 'fash', from the verb 'facher' (to be irritated) and words relating to Latin, which are largely found in Scots Law terminology. Furthermore, there are some Old English words that only survive in Scots, for example, 'gloamin', 'haugh' and 'bannock'. In present-day English, words that originate from old English are often monosyllabic nouns that form the core vocabulary, such as 'hand', 'head' and 'wife'. English also has Norse words, including basic pronouns, and French words that are often used to 'show off'. This relates to the time after the Norman Conquest when people wanted to use French-derived words to indicate their status and intelligence. It is interesting that many of these 'posh' words are not special in French; they are simply the basic word that everyone would use. They do not have any connotations of 'grandeur'; for example, 'regard' from the verb 'regarder' (to look at) and 'commence' from 'commencer' (to begin). There are also many words from Latin and increasingly from other languages, such Urdu and Hindi; for example, 'pyjamas', 'bungalow', 'mulligatawny' and 'shampoo'.

Evidence of the sources of words, can be found in documents, ancient poetry and writing and in inscriptions on material culture. Old English looked very different to the language we read today; it included different letters such as one similar to the Icelandic 'thorn', (Þ, þ), standing for 'f'. There were also letters known as 'Ash', (Æ æ) and 'Eth' (Ð, ð). Professor Smith read a piece of the poem *Beowulf* in Old English pronunciation, commenting that some academics differ on how they believe it was pronounced, but by and large there are accepted ways. On first look, and hearing the Old English text from *Beowulf*, it appears like a foreign language but, on closer study, aspects of current English can be identified. Peculiarities include the fact that Old English had more than one word for 'the' and special endings for 'the' depending on the role it was playing in the sentence. This is common in an inflected language; they have special endings to denote the relationships between words. Old English survives in manuscripts; for example, the *Lindisfarne Gospels* from the 8th Century. This manuscript draws on the Celtic traditions of book illumination and uses the 'diminuendo', whereby the first word of the section starts with a big letter and subsequent letters decrease in size within that word. In this manuscript, there are also 'scribbles' that have been added at a later date. Professor Smith explained that these were added around 1050 by Aldred, who felt the need to gloss the manuscript and added words in between the Latin to help people read it. These scribbles are among the earliest recordings of Old Northumbrian, the ancestor of Scots. The actual words are not very exciting or revealing but their existence is of utmost importance to the history of language.

Over time, the English language developed and changed; for example, the Ellesmere manuscript of Chaucer's *Canterbury Tales* is written in Middle English and looks and sounds more recognisable than the Old English of *Beowulf*. One of the earliest Scots texts to have continually been in print is Barbour's *Bruce*. Originally composed in the 1370s, it was first compiled in a printed edition in 1616, the cover of which makes a claim for authenticity in that it was created from the oldest manuscripts. Professor Smith also showed examples from other early texts, including the first Shakespeare folio, dating from 1623, and written in Early Modern English. In the line from *Macbeth*, "No, this my hand will rather the multitudinous seas incarnadine, making the green one red," the verb incarnadine is an 'inkhorn' term, a 'fancy' word borrowed from another language, in this case Latin, which is deemed to be unnecessary or overly pretentious. Shakespeare uses it here to show an element of 'class'. In some of his other plays, for example, *Love's Labour's Lost*, Shakespeare mocks the use of these words but uses it here as a character trait; Macbeth and his wife often try to hide terrible things using fancy words, for example "the great kwell", an old word for killing. Shakespeare was the first person to use the word incarnadine in English.

Printing started in Scotland in 1508, continued for two years and died out, only reappearing in 1560. An example of an early printed Middle Scots text is Dunbar's *Golden Targe*, in which Dunbar uses something similar to an inkhorn term in the phrase 'golden candle matutine', (golden morning candle), referring to the Sun. Matutine is an 'aureate' term. These date a little earlier than inkhorn terms and are derived from the Roman Catholic liturgy, which is then transferred across to the vernacular. Aureate means gilded or gold; fancy in some way. A final text, Burns' *Tam O'Shanter*, includes elements of Scottish Standard English. The words 'hame' and 'dame' rhyme in Scots but 'storm' rhyming with 'warm' is Scottish Standard English, they do not rhyme in Scots pronunciation. This 'code switching' is the beginning of the phenomenon of language and class; 18th-Century Scotland was beginning to associate some words and pronunciations with particular class groups, something that had been common in English since the 16th Century. Indeed, the 18th Century was a time when much of the Scots language in use today was configured and 'settled down'.

In the question session, Professor Smith encouraged the audience to participate in some interactive exercises devised to show the differences in pronunciation. There are many examples in Scots where the Old English pronunciation has been kept where it has changed in English; for example, 'How now brown cow' is 'Hoo noo broon coo' in Scots. Some sounds have mostly disappeared, even in Scots. The 'gh' in the word 'sight' would originally have had a guttural sound similar to that at the end of 'loch'; this can still be seen in some pronunciations of 'bright' (bricht) and 'might' (micht). Scots pronunciations can still be found in many parts of the world with Scottish connections; for example, Ulster and the Appalachians in the United States. Despite containing identical vowel patterns, the words 'good', 'food' and 'flood' are largely pronounced in different ways in England and Scotland; in Scotland 'good' and 'food' rhyme but do not in England, the vowel is longer in many parts of England and makes an 'oo' sound. However, speakers of English from both countries pronounce flood the same. Why do these words sound different despite the end letters being exactly the same? There have often been suggestions that spelling should change to reflect the differences; however, this ignores the basic function of spelling. Language in its written mode is designed for long distance communication through both time and space. Spelling is a fossil history and contains evidence of how words were pronounced in the past. It can be convenient to have an agreed spelling system that is not dependent upon pronunciation.

Professor Smith commented that a major resource for the study of the history of language, other than inscriptions and text, is the present-day language. Its current format is the result of history and the things people say and write and their accents are receptacles of history. "Just as place names are markers of historical development, so is the speech and writing used by everyone, everyday. The present can explain the past just as the past can explain the present".

Listening to Einstein's Universe: The Discovery of Gravitational Waves

Professor Martin Hendry

Gravitational waves are ripples in the fabric of space and time, predicted by Einstein and produced by the most violent events in the Cosmos: exploding stars; colliding black holes; even the Big Bang itself. Using a global network of giant laser interferometers – amongst the most sensitive scientific instruments ever built – astronomers have succeeded in directly detecting gravitational waves for the very first time. Professor Hendry described the remarkable technology that underpins this exciting new field, and highlighted the fundamental questions – about stars, galaxies, cosmology, perhaps even the nature of space and time – that may be answered as we open this new window on the Universe.

One hundred years ago, Albert Einstein, in his general theory of relativity, predicted the existence of a dark side to the Cosmos. He thought there were invisible "gravitational waves", ripples in space-time produced by some of the most violent events in the Cosmos. For decades, astronomers have gathered strong corroborative evidence of the existence of these waves, but they have never been detected directly – until now. They were the last part of the general theory still to be verified.

Astronomers have used light to study the Universe with optical telescopes for hundreds of years. We have expanded that view hugely since the middle of the 20th Century, by building detectors and instruments sensitive to all the forms of what physicists mean by light: the electromagnetic spectrum, from gamma rays to radio. Yet the discovery of gravitational waves represents our first steps into studying the Universe through the gravitational-wave spectrum, which exists independently from light, probing directly the effects of gravity as it spreads across the Cosmos. It is the first page in a whole new chapter for astronomy, and science.

The first-ever direct detection of gravitational waves took place in September 2015, when two giant measuring devices in different parts of the US called LIGO (Laser Interferometer Gravitational-Wave Observatory) caught a passing gravitational wave from the collision of two massive black holes in a faraway galaxy. LIGO is an interferometer, consisting of two 4km "arms" set at right angles to each other, protected by concrete tubes, and a laser beam which is shone and reflected back and forth by mirrors at each end.

When a gravitational wave passes by, the stretching and squashing of space causes these arms alternately to lengthen and shrink, one getting longer while the other gets shorter and then vice-versa. As the arms change lengths, the laser beams take a different time to travel through them. This means that the two beams are no longer "in step" and an interference pattern is produced – hence the name interferometer.

The changes in the length of the arms are actually tiny – roughly one million millionth the width of a human hair. This is because the signal from a gravitational wave from far out in the Cosmos is mind-bogglingly small by the time it reaches us. As if detecting this were not difficult enough, all manner of local disturbances on Earth make it worse, from the ground shaking to power-grid fluctuations; and instrumental "noises" that could mimic or indeed completely swamp a real signal from the Cosmos.

To achieve the astounding sensitivity required, almost every aspect of the LIGO detectors' design had been upgraded over the period from 2010 to 2015. Scientists at the University of Glasgow led a consortium of UK institutions that played a key role – developing, constructing and installing the sensitive mirror suspensions at the heart of the LIGO detectors that were crucial to this first detection. The technology was based on research carried out with the earlier UK/German GEO600 detector. This turned LIGO into Advanced LIGO, arguably the most sensitive scientific instrument ever, to give us our first direct glimpse of the Dark Universe.

And what a glimpse it was. The two black holes that collided were respectively about 29 times and 36 times the mass of our Sun. It is, incidentally, the first direct evidence that black holes exist, can exist in a pair, and can collide and merge. Comparing this data with Einstein's predictions allowed experts to test whether general relativity correctly describes such a collision – they passed with flying colours.

The merger occurred more than one billion light years from Earth, converting three times the mass of the Sun into gravitational-wave energy. In a fraction of a second, the power radiated through these waves was more than ten times greater than the combined luminosity of every star and galaxy in the observable Universe. This was a truly cataclysmic event a long time ago in a galaxy far, far away. In Star Wars, Darth Vader tells us not to "underestimate the power of the dark side". This amazing discovery shows how right he was. Of course, this discovery wasn't just about checking if Einstein was right. Detecting gravitational waves will help probe the most extreme corners of the Cosmos – the event horizon of a black hole, the innermost heart of a supernova, the internal structure of a neutron star: regions that are completely inaccessible to electromagnetic telescopes.

The LIGO discovery was a huge team effort, however, involving thousands of scientists across the world, working together over many decades to turn what many had considered an impossible dream into the hottest topic in astronomy. But LIGO's first detection of gravitational waves was only the beginning. Since the first detection was announced in February 2016, three further detections of merging black hole binaries have been confirmed, and we are seeing the first hints of how this black hole population fits into the story of how the Universe evolved.

And with the Virgo detector in Italy joining our global network in August 2017, our ability to pinpoint the direction of an incoming gravitational wave has greatly improved – paving the way for the exciting new field of multi-messenger astronomy, where we will combine gravitational waves and light in all its forms, from gamma rays to radio, to probe other extreme objects such as neutron stars or supernovae. Professor Hendry commented "what new science will we discover, as we open this entirely new window on the Universe? Watch this space-time!"

If you would like to read more about the discovery of gravitational waves, and the role of Scottish scientists in that discovery, it is featured in a recent edition of the RSE's *Science Scotland* magazine, available at http://bit.ly/RSEScienceScotland_GravWaves

The Vote of Thanks was offered by Professor Martin Hendry FRSE at the end of all the public talks.