NEVARC NEWS

VK3ANE

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The monthly magazine of the

North East Victoria Amateur Radio Club www.nevarc.net.au

An affiliated club of the Wireless Institute of Australia

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NO MEETING IN MARCH

Next meeting will be
Sunday 8th April
Details to be advised next newsletter

NEVARC Nets

40M Net

Monday, Wednesday and Fridays
10am Local time (East coast)
7.095 MHz LSB
Hosted by Ron VK3MRH
Using club call VK3ANE

80M Net

Wednesday 20:30 Local time
3.622 MHz LSB
Hosted by Ron VK3MRH
Using the club call VK3ANE

2M Nets

A 2M net will be commenced on the VK3RWO/VK2RWD repeaters
Once they are fully commissioned

NEW QUANTUM PROCESSOR

This week's big news from the ICT industry was Google announcing their new quantum processor - Bristlecone, a new quantum computer chip with the record-setting power of 72 quantum bits (qubits).

Traditional computers perform their calculations in binary, so every bit of data is represented as either a zero or a one. Thanks to the quirky science that is quantum mechanics, a qubit can be in a superposition of both, effectively representing both a zero and a one at the same time. That means the power of a quantum computing system scales exponentially – two qubits can represent four states at once, three qubits represent eight, and so on.

As a result, quantum computers are great at performing simultaneous operations, processing all of these states at the same time where classic computers would have to run through each in turn.

Bristlecone, boasts a staggering 72 qubits. These are arranged in a square array, and get their quantum nature through superconductivity, which allows them to represent multiple states by conducting current in two directions at once.

Qubits are notoriously fragile, and outside fluctuations can introduce memory errors that undermine the whole calculation. To get around that problem, a few years ago the Google Quantum AI Lab developed a quantum error correction (QEC) technique, and demonstrated it in a system with nine qubits.

What does this have to do with radio I hear you ask – well there are many radio applications that use large complex mathematical arrays to calculate say – electromagnetic fields around antennas or fourier transforms for weak signal work. Quantum computing would see the calculation times fall dramatically. Exciting times ahead. *~WIA News*

CIRCUITS SELF-DESTRUCT IN RESPONSE TO RADIO WAVES

Perfect for spies behind enemy lines - an electronic device that can be remotely disabled. That's why scientists from Cornell University and Honeywell Aerospace have developed a method of vaporizing electronic circuits, without laying a hand on the actual device.

The Cornell researchers have created a silicon-dioxide microchip packaged within a polycarbonate shell and in the shell are microscopic cavities filled with rubidium and sodium biflouride.

When exposed to a certain frequency of radio waves, tiny graphene-on-nitride valves between the cavities open, allowing the chemicals to mix and react. The reaction releases heat and hydrofluoric acid to etch away the electronics.

This process does not need water like the previous "transient electronics,".

Possible applications include data protection and environmental sensors that can be remotely vaporized once they're no longer needed. *~WIA News*

ACMA TO AUCTION 3.6GHz

Communications Minister Mitch Fifield has announced an auction process for the 3.6GHz band. Services in the 3.6GHz band will have up to seven years to vacate in regional areas, and only two in most of the nation's capital cities.

Minister Fifield issued declarations for the services to move as part of beginning an auction process for 125MHz of the 3.6GHz spectrum favoured for use by upcoming 5G services.

In its plan put forward in October, the ACMA proposed auctioning off the 3.6GHz band in the second quarter of this year, followed by auctions of 850/900MHz, 26GHz, and 1.5GHz bands in 2019.

The 3.6GHz spectrum band is currently used in Australia for fixed-line and satellite services.

~WIA News

UNAUTHORISED SATELLITES

On the same launch as an Amateur Radio satellite in January from India, some tiny 0.25 U CubeSat's called SpaceBEEs — not to be confused with the fantasy insects in the "Futurama" TV cartoon — also went into space when they apparently should not have.

The US FCC says Swarm Technologies - a communications start-up, launched four tiny internet satellites into space back in January. The FCC didn't approve the project, saying the experimental satellites are dangerous.

If confirmed, it would mark the first known time in history that unauthorised satellites have been placed in space.

The launch occurred on 12 January 2018, the state-owned Indian Space Agency (ISRO) launched its 100th satellite, along with 30 others, four of these 31 satellites probably shouldn't have been packed to the cargo hold of the Polar Satellite Launch Vehicle (PSLV). *~WIA News*

5 MHz BAND ACCESS TRIAL

NZART is pleased to announce that it has negotiated with RSM and the NZ Defence Force to obtain a licence to allow limited operation by ZL amateur operators on 60m on a trial basis.

The purpose of the trial is for RSM, NZART and primary users to investigate the ability for the amateur radio operators to operate on the frequencies of operation on a secondary basis without causing interference to primary users.

Operation centres on 5353 kHz and 5362 - 5364 kHz with a maximum output of 10 dBW e.i.r.p. *~WIA News*

Cool Sun

IT'S producing less sunspots, less magnetism and less ultraviolet radiation. But don't expect this once-in-400-year cooldown by our life-giving Sun to halt climate change.
BY 2050, our Sun is expected to be unusually cool.
It's what scientists have termed a 'grand minimum' — a particularly low point in what is otherwise a steady 11-year cycle.
Over this cycle, the Sun's tumultuous heart races and rests.
At its high point, the nuclear fusion at the Sun's core forces more magnetic loops high into its boiling atmosphere — ejecting more ultraviolet radiation and generating sunspots and flares.
When it's quiet, the Sun's surface goes calm.
It ejects less ultraviolet radiation.
Now scientists have scoured the skies and history for evidence of an even greater cycle amid these cycles.
It appears that every 400 years or so, the Sun goes through a particularly cool cycle.

GRAND MINIMUM

One particularly cool period in the 17th Century guided their research.
An intense cold snap between 1645 and 1715 has been dubbed the "Maunder Minimum".
In England, the Thames river froze over. The Baltic Sea was covered in ice — so much so that the Swedish army was able to march across it to invade Denmark in 1658.
But the cooling was not uniform: Distorted weather patterns warmed up Alaska and Greenland.
These records were combined with 20 years of data collected by the International Ultraviolet Explorer satellite mission, as well as observations of nearby stars similar to the Sun.
Now physicist Dan Lubin at the University of California San Diego has calculated an estimate of how much dimmer the Sun is likely to be when the next such grand minimum takes place.
His team's study, Ultraviolet Flux Decrease Under a Grand Minimum from IUE Short-wavelength Observation of Solar Analogs, has been published in the journal Astrophysical Journal Letters.
It finds the Sun is likely to be 7 per cent cooler than its usual minimum.
And another grand minimum is likely to be just decades away, based on the cooling spiral of recent solar cycles.
While the Sun's 'grand minimum' phase may only cool surface temperatures by a few tenths of a degree, it may have a major impact upon weather patterns. Picture: Sunshine/Fox
While the Sun's 'grand minimum' phase may only cool surface temperatures by a few tenths of a degree, it may have a major impact upon weather patterns. Picture: Sunshine/FoxSource:Supplied

SOLAR FALLOUT

A quiet Sun has a noticeable effect on its planets.
For Earth, Lubin says it first thins the stratospheric ozone layer.
This impacts the insulating effect of the atmosphere, with flow-on effects including major changes to wind and weather patterns.
But it won't stop the current trend of planetary warning, Lubin warns.
"The cooling effect of a grand minimum is only a fraction of the warming effect caused by the increasing concentration of carbon dioxide in the atmosphere," a statement from the research team reads.
"After hundreds of thousands of years of CO_2 levels never exceeding 300 parts per million in air, the concentration of the greenhouse gas is now over 400 parts per million, continuing a rise that began with the Industrial Revolution."
One simulation of a grand minimum on the Earth's current climate anticipates a reduction of Solar warming by 0.25 per cent over a 50-year period between 2020 and 2070.
While the global average surface air temperature appears to cool by "several temths of a degree Celsius" in the initial years, this reduction was rapidly overtaken by ever-increasing trends.
"A future grand solar minimum could slow down but not stop global warming," the study finds.
"Now we have a benchmark from which we can perform better climate model simulations," Lubin says. "We can therefore have a better idea of how changes in solar UV radiation affect climate change."

~Internet

Why the Earth’s magnetic poles could be about to swap places – and how it would affect us

The Earth’s magnetic field surrounds our planet like an invisible force field – protecting life from harmful solar radiation by deflecting charged particles away. Far from being constant, this field is continuously changing. Indeed, our planet’s history includes at least several hundred global magnetic reversals, where north and south magnetic poles swap places. So when’s the next one happening and how will it affect life on Earth?

During a reversal the magnetic field won’t be zero, but will assume a weaker and more complex form. It may fall to 10% of the present-day strength and have magnetic poles at the equator or even the simultaneous existence of multiple “north” and “south” magnetic poles.

Geomagnetic reversals occur a few times every million years on average. However, the interval between reversals is very irregular and can range up to tens of millions of years.

There can also be temporary and incomplete reversals, known as events and excursions, in which the magnetic poles move away from the geographic poles – perhaps even crossing the equator – before returning back to their original locations. The last full reversal, the Brunhes-Matuyama, occurred around 780,000 years ago. A temporary reversal, the Laschamp event, occurred around 41,000 years ago. It lasted less than 1,000 years with the actual change of polarity lasting around 250 years.

Power cut or mass extinction?

The alteration in the magnetic field during a reversal will weaken its shielding effect, allowing heightened levels of radiation on and above the Earth’s surface. Were this to happen today, the increase in charged particles reaching the Earth would result in increased risks for satellites, aviation, and ground-based electrical infrastructure. Geomagnetic storms, driven by the interaction of anomalously large eruptions of solar energy with our magnetic field, give us a foretaste of what we can expect with a weakened magnetic shield.

In 2003, the so-called Halloween storm caused local electricity-grid blackouts in Sweden, required the rerouting of flights to avoid communication blackout and radiation risk, and disrupted satellites and communication systems. But this storm was minor in comparison with other storms of the recent past, such as the 1859 Carrington event, which caused aurorae as far south as the Caribbean.

The impact of a major storm on today’s electronic infrastructure is not fully known. Of course any time spent without electricity, heating, air conditioning, GPS or internet would have a major impact; widespread blackouts could result in economic disruption measuring in tens of billions of dollars a day.

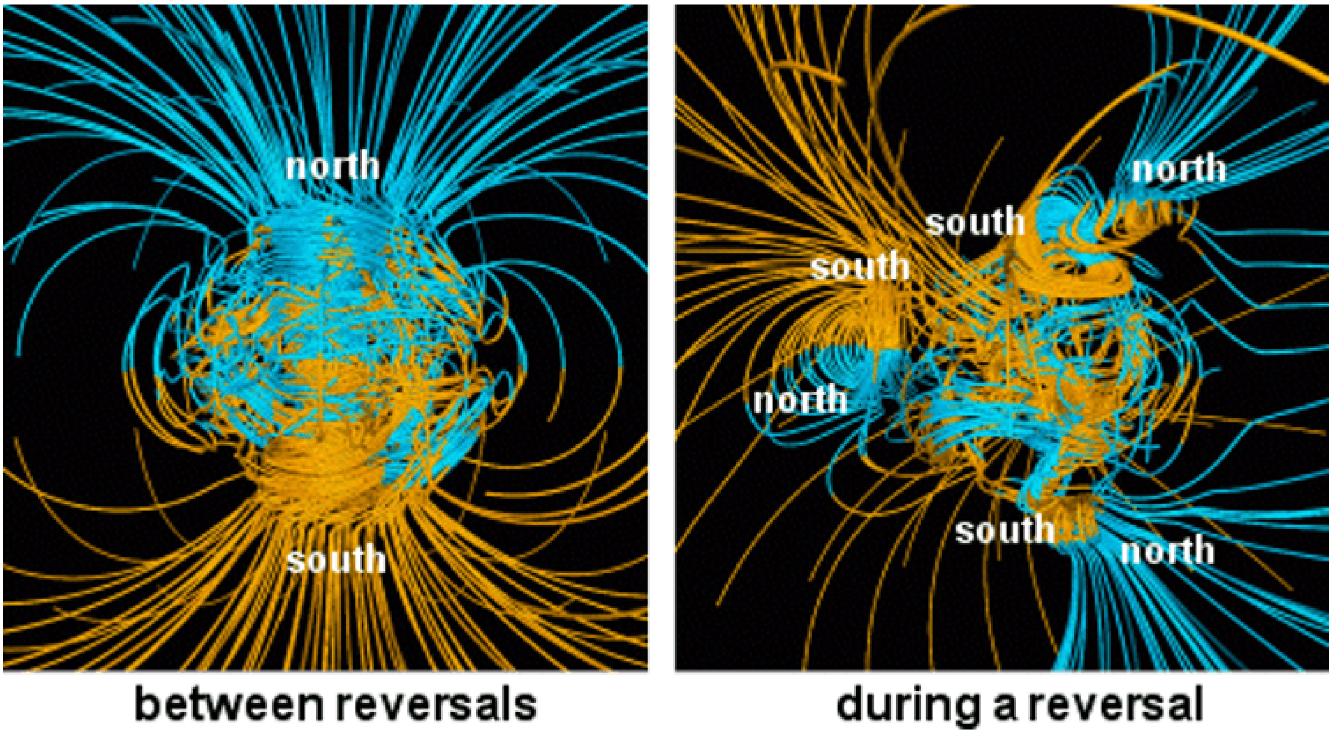
In terms of life on Earth and the direct impact of a reversal on our species we cannot definitively predict what will happen as modern humans did not exist at the time of the last full reversal. Several studies have tried to link past reversals with mass extinctions – suggesting some reversals and episodes of extended volcanism could be driven by a common cause. However, there is no evidence of any impending cataclysmic volcanism and so we would only likely have to contend with the electromagnetic impact if the field does reverse relatively soon.

We do know that many animal species have some form of magnetoreception that enables them to sense the Earth’s magnetic field. They may use this to assist in long-distance navigation during migration. But it is unclear what impact a reversal might have on such species. What is clear is that early humans did manage to live through the Laschamp event and life itself has survived the hundreds of full reversals evidenced in the geologic record.

Can we predict geomagnetic reversals?

The simple fact that we are “overdue” for a full reversal and the fact that the Earth’s field is currently decreasing at a rate of 5% per century, has led to suggestions that the field may reverse within the next 2,000 years. But pinning down an exact date – at least for now – will be difficult.

The Earth’s magnetic field is generated within the liquid core of our planet, by the slow churning of molten iron. Like the atmosphere and oceans, the way in which it moves is governed by the laws of physics. We should therefore be able to predict the “weather of the core” by tracking this movement, just like we can predict real weather by looking at the atmosphere and ocean. A reversal can then be likened to a particular type of storm in the core, where the dynamics – and magnetic field – go haywire (at least for a short while), before settling down again.



The difficulties of predicting the weather beyond a few days are widely known, despite us living within and directly observing the atmosphere. Yet predicting the Earth's core is a far more difficult prospect, principally because it is buried beneath 3,000km of rock such that our observations are scant and indirect. However, we are not completely blind: we know the major composition of the material inside the core and that it is liquid. A global network of ground-based observatories and orbiting satellites also measure how the magnetic field is changing, which gives us insight into how the liquid core is moving.

The recent discovery of a jet-stream within the core highlights our evolving ingenuity and increasing ability to measure and infer the dynamics of the core. Coupled with numerical simulations and laboratory experiments to study the fluid dynamics of the planet's interior, our understanding is developing at a rapid rate. The prospect of being able to forecast the Earth's core is perhaps not too far out of reach.

~Internet

Sunglasses in crackdown on crime, dissent

ORWELL had nothing on this: Chinese police are being issued sunglasses that come complete with facial-recognition features capable of picking a suspect out from a crowd.

GOOGLE's internet-enabled glasses may have bombed. But China's police have turned the concept into a powerful law-enforcement tool.

Facial recognition software is being combined with advanced optics and networking to pinpoint potential suspects — even in crowded subways and shopping malls.

The glasses feed a constant stream of images back to a processor attached to the officer's uniform webbing.

It captures faces as they turn towards the camera, applying a standardised set of measurements to each face before comparing it with a portable database in much the same way fingerprints are assessed.

According to the China News Service, the glasses have already been successfully trialled by four officers on Zhengzhou city's East Railway during the Chinese New Year celebrations.

Authorities say the mobile facial recognition capacity led to the arrest of seven people and the questioning of 26 others believed to have been travelling under a false identity in just its first five days of operation.

The glasses feed a stream of images to a hand-held device which contains a database of suspects. It is able to sort through them at a rate of 10,000 faces in one-tenth of a second.

The facial recognition glasses can process 10,000 faces within one-tenth of a second, its manufacturers claim. The speed of processing and the fact the glasses are being worn by officers gives makes facial recognition a major asset on the police beat, the news service reports.

It says officers are able to respond before suspects are able to blend back into a crowd, helping them to maintain contact in any pursuit.

Security-obsessed China has the largest network of surveillance cameras in the world. It also has assembled biometric data for most of its citizens.

The stated objective of this network is to identify and locate any of its citizens within three seconds.

~Internet

TIME

Physics of Time

Physics is the only science that explicitly studies time, but even physicists agree that time is one of the most difficult properties of our universe to understand. Even in the most modern and complex physical models, though, time is usually considered to be an ontologically “basic” or primary concept, and not made up of, or dependent on, anything else.

In the sciences generally, time is usually defined by its measurement: it is simply what a clock reads. Physics in particular often requires extreme levels of precision in time measurement, which has led to the requirement that time be considered an infinitely divisible linear continuum, and not quantized (i.e. composed of discrete and indivisible units). With modern atomic time standards like TAI and UTC (see the section on Time Standards) and ultra-precise atomic clocks (see the section on Clocks), time can now be measured accurate to about 10−15 seconds, which corresponds to about 1 second error in approximately 30 million years.

But several different conceptions and applications of time have been explored over the centuries in different areas of physics, and we will look at some of these in this section.

In non-relativistic or classical physics, the concept of time generally used is that of absolute time (also called Newtonian time after its most famous proponent), time which is independent of any perceiver, progresses at a consistent pace for everyone everywhere throughout the universe, and is essentially imperceptible and mathematical in nature. This accords with most people’s everyday experience of how time flows.

However, since the advent of relativity in the early 20th Century, relativistic time has become the norm within physics. This takes into account phenomena such as time dilation for fast-moving objects, gravitational time dilation for objects caught in extreme gravitational fields, and the important idea that time is really just one element of four-dimensional space-time.

Relativity also allows for, at least in theory, the prospect of time travel, and there are several scenarios which allow for the theoretical basis of travel in time. There are even theoretical faster-than-light time-travelling particles like tachyons and neutrinos. However, the concept of time travel also brings with it a number of paradoxes, and its likelihood and physical practicality is questioned by many physicists.

Quantum mechanics revolutionized physics in the first half of the 20th Century and it still represents the most complete and accurate model of the universe we have. Time is perhaps not as central a concept in quantum theory as it is in classical physics, and there is really no such thing as “quantum time” as such. For example, time does not appear to be divided up into discrete quanta as are most other aspects of reality. However, the different interpretations of quantum theory (e.g. the Copenhagen interpretation, the many worlds interpretation, etc) do have some potentially important implications for our understanding of time.

Most physicists agree that time had a beginning, and that it is measured from, and indeed came into being with, The Big Bang some 13.8 billion years ago. Whether, how and when time might end in the future is a more open question, depending on different notions of the ultimate fate of the universe and other mind-bending concepts like the multiverse.

The so-called arrow of time refers to the one-way direction or asymmetry of time, which leads to the way we instinctively perceive time as moving forwards from the fixed and immutable past, though the present, towards the unknown and unfixed future. This idea has it roots in physics, particularly in the Second Law of Thermodynamics, although other, often related, arrows of time have also been identified.

Absolute Time

The conception of time as absolute is usually attributed to Sir Isaac Newton and his English contemporaries
The scientific study of time really began in the 16th Century with the work of the Italian physicist and astronomer Galileo Galilei, and continued in 17th Century England with the work of Isaac Barrow and Sir Isaac Newton. In non-relativistic or classical physics (the physics of Galileo, Newton, Maxwell, etc), time has always been considered one of the fundamental scalar quantities, along with length, mass, charge, etc (a scalar quantity is one that can be described by a single real number, usually with measurement units assigned). It was also considered to be absolute and universal, i.e. the same for everyone everywhere in the universe.

Newtonian Time
According to its most famous proponent, Sir Isaac Newton, for example, absolute time (which is also sometimes known as “Newtonian time”) exists independently of any perceiver, progresses at a consistent pace throughout the universe, is measurable but imperceptible, and can only be truly understood mathematically. For Newton, absolute time and space were independent and separate aspects of objective reality, and not dependent on physical events or on each other.

Time, in this conception, was external to the universe, and so must be measured independently of the universe. It would continue even if the universe were completely empty of all matter and objects, and essentially represented a kind of container or stage setting within which physical phenomena occur in a completely deterministic way. In Newton’s own words: “absolute, true and mathematical time, of itself, and from its own nature, flows equably without relation to anything external”.

Newton’s ideas about absolute time were largely borrowed from Isaac Barrow, his predecessor at Cambridge. Barrow himself described time as a mathematical concept, analogous to a line in that it has length, is similar in all its parts, and can be looked on either as a simple addition of continuous instants, or alternatively as the continuous flow on one instant.

Although absolute time is the "real" time in Newton's opinion, he cautioned that we mere mortals are not however capable of perceiving it directly. Instead, we are only capable of perceiving what he called "relative, apparent and common time", which can be observed in the measurement of perceivable objects in motion (like the Moon or Sun) and the ticking of terrestrial clocks, and from which we infer the everyday passage of time. He attributed any discrepancies between absolute and apparent time to such things as irregularities in the motion of the Earth.

The Legacy of Absolute Time
It should be remembered that Newton, perhaps even more than Galileo before him, was a product of his times, and he approached physics from the point of view that God had created the laws of nature, and the job of the scientist was merely to uncover their workings. Newton's conception of time was essentially unchanged from that of Galileo (and, for that matter, everyone else all the way back to Aristotle some 2,000 years earlier). By systematizing and formalizing it, though, Newton was able to formulate his hugely important laws of motion, and to set the stage for other developments to come.

Newton's view of absolute time dominated during the explosion of science in the 18th and 19th Century, despite the objections of relativists like Gottfried Leibniz (who believed that time is essentially derived from events – see the section on Early Modern Philosophy for the details behind this argument). Indeed, it persisted until the revelations of Albert Einstein and his 1905 Theory of Relativity turned our conception of time on its head (see the section on Relativistic Time). Einstein once wrote "Newton, forgive me" in his memoirs.

It should be pointed out, though, that the Newtonian version is still a very good approximation of what time is and how it behaves in the world we actually we live in and experience. As we will see, relativistic time only differs from absolute time to any noticeable degree when travelling at speeds approaching the speed of light or in conditions of extremely high gravity. At everyday speeds, everyday common-sense non-relativistic physics applies.

Relativistic Time

The idea of relativistic time is a direct result of Albert Einstein's Theory of Relativity
Since Albert Einstein published his Theory of Relativity (the Special Theory in 1905, and the General Theory in 1916), our understanding of time has changed dramatically, and the traditional Newtonian idea of absolute time and space has been superseded by the notion of time as one dimension of space-time in special relativity, and of dynamically curved space-time in general relativity.

It was Einstein's genius to realize that the speed of light is absolute, invariable and cannot be exceeded (and indeed that the speed of light is actually more fundamental than either time or space). In relativity, time is certainly an integral part of the very fabric of the universe and cannot exist apart from the universe, but, if the speed of light is invariable and absolute, Einstein realized, both space and time must be flexible and relative to accommodate this.

Although much of Einstein's work is often considered "difficult" or "counter-intuitive", his theories have proved (both in laboratory experiments and in astronomical observations) to be a remarkably accurate model of reality, indeed much more accurate than Newtonian physics, and applicable in a much wider range of circumstances and conditions.

Space-Time
One aspect of Einstein's Special Theory of Relativity is that we now understand that space and time are merged inextricably into four-dimensional space-time, rather than the three dimensions of space and a totally separate time dimension envisaged by Descartes in the 17th Century and taken for granted by all classical physicists after him. With this insight, time effectively becomes just part of a coordinate specifying an object's position in space-time.

It was Hermann Minkowski, Einstein's one-time teacher and colleague, who gave us the classic interpretation of Einstein's Special Theory of Relativity. Minkowski introduced the relativity concept of proper time, the actual elapsed time between two events as measured by a clock that passes through both events. Proper time therefore depends not only on the events themselves but also on the motion of the clock between the events. By contrast, what Minkowski called coordinate time is the apparent time between two events as measured by a distant observer using that observer's own method of assigning a time to an event.

An event is both a place and a time, and can be represented by a particular point in space-time, i.e. a point in space at a particular moment in time. Space-time as a whole can therefore be thought of as a collection of an infinite number of events. The complete history of a particular point in space is represented by a line in space-time (known as a world line), and the past, present and future accessible to a particular object at a particular time can be represented by a three dimensional light cone (or Minkowski space-time diagram), which is defined by the limiting value of the speed of light, which intersects at the here-and-now, and through which the object's world line runs its course.

Modern physicists therefore do not regard time as "passing" or "flowing" in the old-fashioned sense, nor is time just a sequence of events which happen: both the past and the future are simply "there", laid out as part of four-dimensional space-time, some of which we have already visited and some not yet. So, just as we are accustomed to thinking of all parts of space as existing even if we are not there to experience them, all of time (past, present and future) are also constantly in existence even if we are not able to witness them. Time does not "flow", then, it just "is". This view of time is consistent with the philosophical view of eternalism or the block universe theory of time (see the section on Modern Philosophy).

According to relativity, the perception of a "now", and particularly of a "now" that moves along in time so that time appears to “flow”, therefore arises purely as a result of human consciousness and the way our brains are wired, perhaps as an evolutionary tool to help us deal with the world around us, even if it does not actually reflect the reality. As Einstein himself remarked, “People like us, who believe in physics, know that the distinction between past, present, and future is only a stubbornly persistent illusion”.

However, if time is a dimension, it does not appear to be the same kind of dimension as the three dimensions of space. For example, we can choose to move through space or not, but our movement through time is inevitable, and happens whether we like it or not. In fact, we do not really move though time at all, at least not in the same way as we move through space. Also, space does not have any fundamental directionality (i.e. there is no “arrow of space”, other than the downward pull of gravity, which is actually variable in absolute terms, depending on where on Earth we are located, or whether we are out in space with no gravitational effects at all), whereas time clearly does (see the section on The Arrow of Time).

With the General Theory of Relativity, the concept of space-time was further refined, when Einstein realized that perhaps gravity is not a field or force on top of space-time, but a feature of space-time itself. Thus, the space-time continuum is actually warped and curved by mass and energy, a warping that we think of as gravity, resulting in a dynamically curved space-time. In regions of very large masses, such as stars and black holes, space-time is bent or warped substantially by the extreme gravity of the masses, an idea often illustrated by the image of a rubber sheet distorted by the weight of a bowling ball.

Time Dilation
Relativity
Time dilation is just one consequence of the Theory of Relativity and curved space-time
Also as a result of Einstein’s work and his Special Theory of Relativity, we now know that rates of time actually run differently depending on relative motion, so that time effectively passes at different rates for different observers travelling at different speeds, an effect known as time dilation. Thus, two synchronized clocks will not necessarily stay synchronized if they move relative to each other. There is a related effect in the spatial dimensions, known as length contraction, whereby moving bodies are actually foreshortened in the direction of their travel.

Time dilation (as well as the associated length contraction) is negligible and all but imperceptible at everyday speeds in the world around us, although it can be, and has been, measured with very sensitive instruments. However, it becomes much more pronounced as an object’s speed approaches the speed of light (known as relativistic speeds). If a spaceship could travel at, say, 99% of the speed of light, a hypothetical observer looking in would see the ship’s clock moving about twice as slow as normal (i.e. coordinate time is moving twice as slow as proper time), and the astronauts inside moving around apparently in slow-motion. At 99.5% of the speed of light, the observer would see the clock moving about 10 times slower than normal. At 99.9% of the speed of light, the factor becomes about 22 times, at 99.99% 224 times, and at 99.9999% 707 times, increasing exponentially. In the largest particle accelerators currently in use we can make time slow down by 100,000 times. At the speed of light itself, were it actually possible to achieve that, time would stop completely.

Perhaps the easiest way to think of this difficult concept is that, when an object or person moves in space-time, its movement “shares” some of its spatial movement with movement in time, in the same way as some northward movement is shared with westward movement when we travel northwest. What forces this sharing of dimensions is the invariant nature of the speed of light (slightly less than 300,000km/s), which is a fundamental constant of the universe that can never be exceeded. Thus, the slowing of time at relativistic speeds occurs, in a sense, to “protect” the inviolable cosmic speed limit (the speed of light).

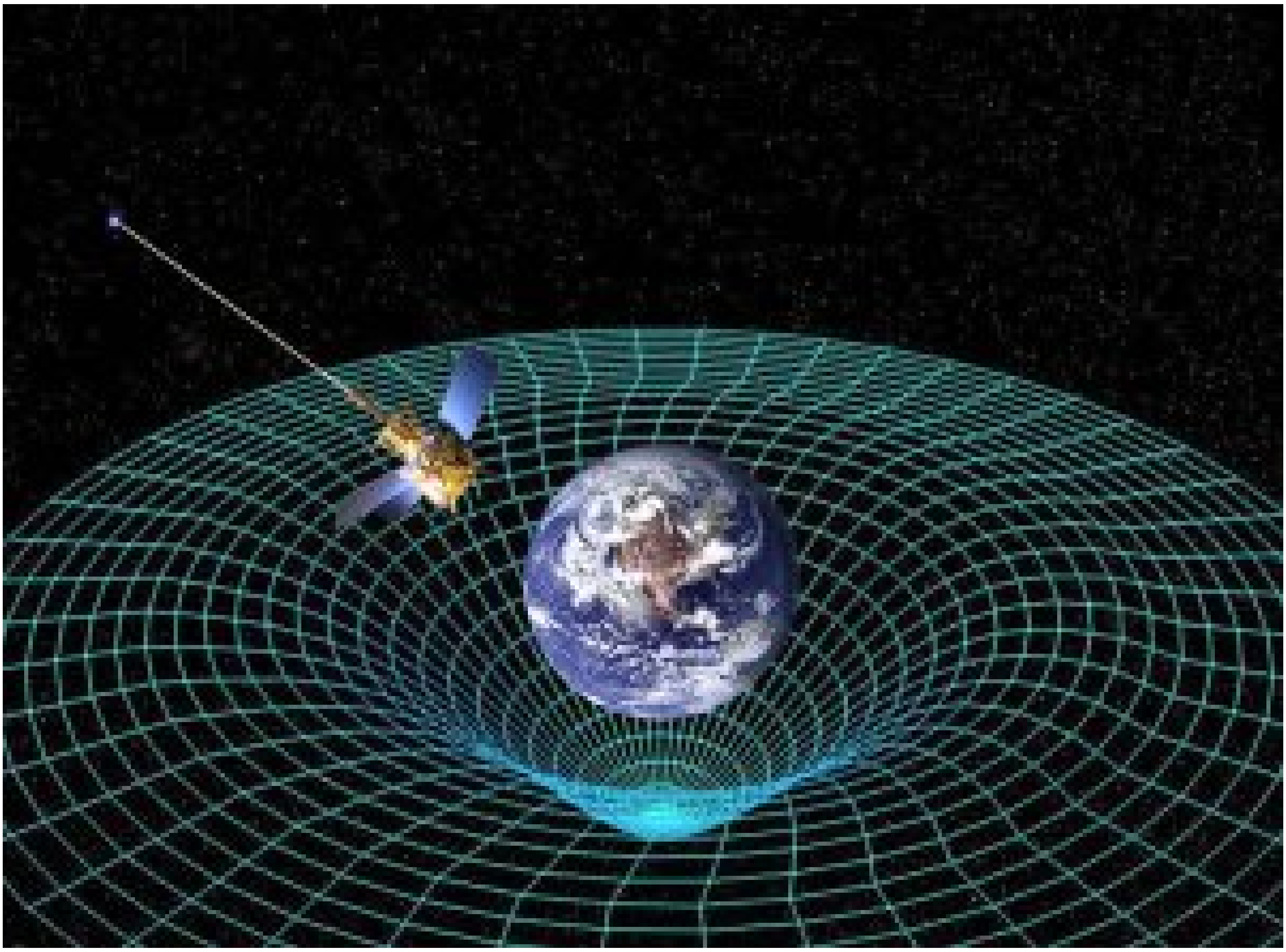
It should be noted that, although a spaceship travelling at close to the speed of light would take 100,000 years to reach a distant star 100,000 light years away as judged by clocks on Earth, the astronaut in the spaceship might hardly age at all as he travels across the galaxy. This characteristic of relativistic time has therefore spawned much discussion of the possibility of time travel (see the separate section on Time Travel).

According to Einstein, then, time is relative to the observer, and more specifically to the motion of that observer. This is not to say that time is in some way capricious or random in nature – it is still governed by the laws of physics and entirely predictable in its manifestations, it is just not absolute and universal as Newton thought (see the section on Absolute Time), and things are not quite as simple and straightforward as he had believed. Some commentators, like the Christian philosopher William Lane Craig, have suggested that there may be a need to distinguish between the reality of time and our measurement of time: according to this line of thinking (which, it should be mentioned, is not a mainstream position in physics), time itself MAY be absolute, but the way we measure it must be relativistic.

One casualty of the Theory of Relativity is the notion of simultaneity, the property of two events happening at the same time in a particular frame of reference. According to relativistic physics, simultaneity is NOT an absolute property between events, as had always been taken for granted up to that point. Thus, what is simultaneous in one frame of reference will not necessarily be simultaneous in another. For objects moving at normal everyday speeds, the effect is small and can generally be ignored (so that simultaneity CAN normally be treated as an absolute property); but when objects approach relativistic speeds (close to the speed of light) with respect to one another, such intuitive relationships can no longer be assumed.

Gravitational Time Dilation
When Einstein extended his Special Theory of Relativity to his General Theory, it became apparent that a similar time dilation effect would also occur in the presence of intense gravity, an effect usually referred to as gravitational time dilation. It is almost as if gravity is somehow pulling or dragging on time, slowing its passage. The closer an object is to another object, the stronger the pull of gravity between them (according to an inverse-square law first identified by Sir Isaac Newton), and thus the more the time drag.

Again, these effects are negligible at the kinds of gravitational differences experienced in everyday life: even though, technically, a person living in a ground floor apartment ages slower than their twin who lives in a top floor apartment of the same building (due to the difference in gravity they experience), the effect might amount to maybe a microsecond over a full lifetime. There is, however, one aspect of modern everyday life where we do experience the effects of gravitational time dilation: it has a noticeable impact on the Global Positioning System (GPS), which many of us now rely on for navigation. The orbiting satellites used by the GPS system experience significantly less gravity than the Earth's surface, and are also moving very fast, so that the time distortion effects of about 38 microseconds a day have to be specifically factored in or GPS would very quickly begin to accumulate errors.



Time dilation is just one consequence of the Theory of Relativity and curved space-time

But, just as with a spaceship travelling at near the speed of light, in the extreme gravity at the edges of a black hole, for example, substantial time differences can become apparent. A black hole spins at close to the speed of light, dragging anything in the vicinity around with it, and the huge gravitational pull of a black hole can bend and warp space-time to a substantial degree. Over the "event horizon" of a black hole – the gravitational point of no return – a hypothetical clock on a spaceship (and indeed the progress of the spaceship itself) would appear from the outside to stop completely due to the infinite time dilation effect. At the gravitational singularity at the centre of a black hole, gravity and density is infinite, and all the normal rules of physics just break down. Time effectively stops, just as there is no time beyond the singularity of the Big Bang (see the section on Time and the Big Bang).

Twins Paradox
The dilation of time also gives rise to the so-called "twins paradox" or "clock paradox", whereby a hypothetical astronaut returns from a near-light speed voyage in space to find his stay-at-home twin many years older than him (as travelling at relativistic high speeds has allowed the astronaut to experience only, say, one year of time, while ten years have elapsed on Earth). Because of the time dilation effect, a clock in the spaceship literally registers a shorter duration for the journey than the clock in mission control on Earth.

The real paradox, though, as Einstein explained it, arises from the fact that (because there is no "preferred" frame of reference in relativity) we could just as easily consider the traveller in the spaceship as the one remaining at rest, while the Earth shoots off and back at close to the speed of light. In that scenario, Einstein argued, one would expect the astronaut to age much more than the inhabitants of the Earth. In fact the "paradox" is explained by Mach's Principle: the spaceship is accelerating away at near-light speed from the bulk of the universe, whereas the Earth is not. Hence, it is the spaceship (and its astronaut) that experiences the relativistic time dilation, not the Earth.

Time Travel

Time travels features extensively in fiction, but there is some theoretical basis to the idea
Arguably, we are always travelling though time, as we move from the past into the future. But time travel usually refers to the possibility of changing the rate at which we travel into the future, or completely reversing it so that we travel into the past. Although a plot device in fiction since the 19th Century (see the section on Time in Literature), time travel has never been practically demonstrated or verified, and may still be impossible.

Time travel is not possible in Newtonian absolute time (we move deterministically and linearly forward into the future). Neither is it possible according to special relativity (we are constrained by our light cones). But general relativity does raises the prospect (at least theoretically) of travel through time, i.e. the possibility of movement backwards and/or forwards in time, independently of the normal flow of time we observe on Earth, in much the same way as we can move between different points in space.

Time travel is usually taken to mean that a person's mind and body remain unchanged, with their memories intact, while their location in time is changed. If the traveller's body and mind reverted its condition at the destination time, then no time travel would be perceptible.

Time Travel Scenarios
Although, in the main, differing fundamentally from the H.G. Wells concept of a physical machine with levers and dials, many different speculative time travel solutions and scenarios have been put forward over the years. However, the actual physical plausibility of these solutions in the real world remains uncertain.

At its simplest, as we have seen in the section on Relativistic Time, if one were to travel from the Earth at relativistic speeds and then return, then more time would have passed on Earth than for the traveller, so the traveller would, from his perspective, effectively have "travelled into the future". This is not to say that the traveller suddenly jumped into the Earth's future, in the way that time travel is often envisioned, but that, as judged by the Earth's external time, the traveller has experienced less passage of time than his twin who remained on Earth. This is not real time travel, though, but more in the nature of "fast-forwarding" through time: it is a one-way journey forwards with no way back.

There does, however, appear to be some scientific basis within the Theory of Relativity for the possibility of real time travel in certain scenarios. Kurt Gödel showed, back in the early days of relativity, that there are some solutions to the field equations of general relativity that describe space-times so warped that they contain "closed time-like curves", where an individual time-cone twists and closes in on itself, allowing a path from the present to the distant future or the past. Gödel's solution was the first challenge in centuries to the dominant idea of linear time on which most of physics rests. Although a special case solution, based on an infinite, rotating universe (not the finite, non-rotating universe we actually find ourselves in), other time travel solution have been identified since then that do not require an infinite, rotating universe, but they remain contentious.

In the 1970s, controversial physicist Frank Tipler published his ideas for a "time machine", using an infinitely long cylinder which spins along its longitudinal axis, which he claimed would allow time travel both forwards and backwards in time without violating the laws of physics, although Stephen Hawking later disproved Tipler's ideas.

In 1994, Miguel Alcubierre proposed a hypothetical system whereby a spacecraft would contract space in front of it and expand space behind it, resulting in effective faster-than-light travel and therefore (potentially) time travel, but again the practicalities of constructing this kind of a "warp drive" remain prohibitive.

Wormhole
A worm hole is a feature of space-time that could theoretically provide a short-cut through time and space
Other theoretical physicists like Kip Thorne and Paul Davies have shown how a wormhole in space-time could theoretically provide an instantaneous gateway to different time periods, in much the same way as general relativity allows the theoretical possibility of instantaneous spatial travel through wormholes. Wormholes are tubes or conduits or short-cuts through space-time, where space-time is so warped that it bends back on itself, another science fiction concept made potential reality by the Theory of Relativity. The drawback is that unimaginable amounts of energy would be required to bring about such a wormhole, although experiments looking into the possibility of creating mini-wormholes and mini-black holes are being carried out at the particle accelerator at CERN in Switzerland. It also seems likely that such a wormhole would collapse instantly into a black hole unless some method of holding it open were devised (possibly so-called "negative energy", which is known to be theoretically possible, but which is not yet practically feasible). Stephen Hawking has suggested that radiation feedback, analogous to feedback in sound, would destroy the wormhole, which would therefore not last long enough to be used as a time machine. Actually controlling where (and when) a wormhole exits is another pitfall.

Another potential time travel possibility, although admittedly something of a long shot, relates to cosmic strings (or quantum strings), long shreds of energy left over after the Big Bang, thinner than an atom but incredibly dense, that weave through the entire universe. Richard Gott has suggested that if two such cosmic strings were to pass close to each other, or even close to a black hole, the resulting warpage of space-time could well be so severe as to create a closed-time-like curve. However, cosmic strings remain speculative and the chances of finding such a phenomenon are vanishingly small (and, even if it were possible, such a loop may well find itself trapped inside a rotating black hole).

Physicist Ron Mallet has been looking into the possibility of using lasers to control extreme levels of gravity, which could then potentially be used to control time. According to Mallet, circulating beams of laser-controlled light could create similar conditions to a rotating black hole, with its frame-dragging and potential time travel properties.

Others are looking to quantum mechanics for a solution to time travel. In quantum physics, proven concepts such as superposition and entanglement effectively mean that a particle can be in two (or more) places at once. One interpretation of this (see the section on Quantum Time) is the "many worlds" view in which all the different quantum states exist simultaneously in multiple parallel universes within an overall multiverse. If we could gain access to these alternative parallel universes, a form of time travel might then be possible.

At the sub-sub-microscopic level – at the level of so-called quantum foam, tiny bubbles of matter a billion-trillion-trillionths of a centimetre in length, perpetually popping into and out of existence – it is speculated that tiny tunnels or short-cuts through space-time are constantly forming, disappearing and reforming. Some scientists believe that it may be possible to capture such a quantum tunnel and enlarge it many trillions of times to the human scale. However, the idea is still at a very speculative stage,

It should be noted that, with all of these schemes and ideas, it does not look to be possible to travel any further back in time that the time at which the travel technology was devised.

Faster-Than-Light Particles

The equations of relativity imply that faster-than-light (superluminal) particles, if they existed, would theoretically travel backwards in time. Therefore, they could, again theoretically, be used to build a kind of "antitelephone" to send signals faster than light, and thus communicate backwards in time. Although the Theory of Relativity disallows particles from accelerating from sub-light speed to the speed of light (among other effects, time would slow right down and effectively stop for such a particle, and its mass would increase to infinity), it does not preclude the possibility of particles that ALWAYS travel faster than light. Therefore, the possibility does still exist in theory for faster-than-light travel in the case of a particle with such properties.

There is a rather strange theoretical particle in physics called the tachyon that routinely travels faster than light, with the corollary that such a particle would naturally travel backwards in time as we know it. So, in theory, one could never see such a particle approaching, only leaving, and the particle could even violate the normal order of cause and effect. For a tachyon, the speed of light is the lower speed limit, while the upper speed limit is infinity, and its speed increases as its energy decreases. Even stranger, the mass of a tachyon would technically be an imaginary number (i.e. the number squared is negative), whatever that might actually mean in practice.

It should be stressed that there is no experimental evidence to suggests that tachyons actually exist, and many physicists deny even the possibility. A tachyon has never been observed or recorded (although the search continues, particularly through analysis of cosmic rays and in particle accelerators), and neither has one ever been created, so they remain hypothetical, although theory strongly supports their existence.

Research using MINOS and OPERA detectors has suggested that tiny particles called neutrinos may travel faster than light. Other more recent research from CERN, however, has put the findings into dispute, and the matter remains inconclusive. Neutrinos are not merely hypothetical particles like tachyons, but a well-known part of modern particle physics. But they are tiny, almost-massless, invisible, electrically neutral, weakly-interacting particles that pass right through normal matter, and consequently are very difficult to measure and deal with (even their mass has never been measured accurately).

Time Travel Paradoxes

The possibility of travel backwards in time is generally considered by scientists to be much more unlikely than travel into the future. The idea of time travel to the past is rife with problems, not least the possibility of temporal paradoxes resulting from the violation of causality (i.e. the possibility that an effect could somehow precede its cause). This is most famously exemplified by the grandfather paradox: if a hypothetical time traveller goes back in time and kills his grandfather, the time traveller himself would never be born when he was meant to be; if he is never born, though, he is unable to travel through time and kill his grandfather, which means that he WOULD be born; etc, etc.

Some have sought to justify the possibility of time travel to the past by the very fact that such paradoxes never actually arise in practice. For example, the simple fact that the time traveller DOES exist at the start of his journey is itself proof that he could not kill his grandfather or change the past in any way, either because free will ceases to exist in the past, or because the outcomes of such decisions are predetermined. Or, alternatively, it is argued, any changes made by a hypothetical future time traveller must already have happened in the traveller's past, resulting in the same reality that the traveller moves from.

Theoretical physicist Stephen Hawking has suggested that the fundamental laws of nature themselves – particularly the idea that causes always precede effects – may prevent time travel in some way. The apparent absence of "tourists from the future" here in our present is another argument, albeit not a rigorous one, that has been put forward against the possibility of time travel, even in a technologically advanced future (the assumption here is that future civilizations, millions of years more technologically advanced than us, should be capable of travel).

Some interpretations of time travel, though, have tried to resolve such potential paradoxes by accepting the possibility of travel between "branch points", parallel realities or parallel universes, so that any new events caused by a time traveller's visit to the past take place in a different reality and so do not impact on the original time stream. The idea of parallel universes, first put forward by Hugh Everett III in his "many worlds" interpretation of quantum theory in the 1950s, is now quite mainstream and accepted by many (although by no means all) physicists

Quantum Time

Max Planck is sometimes considered the father of quantum theory
In the first half of the 20th Century, a whole new theory of physics was developed, which has superseded everything we know about classical physics, and even the Theory of Relativity, which is still a classical model at heart. Quantum theory or quantum mechanics is now recognized as the most correct and accurate model of the universe, particularly at sub-atomic scales, although for large objects classical Newtonian and relativistic physics work adequately.

If the concepts and predictions of relativity (see the section on Relativistic Time) are often considered difficult and counter-intuitive, many of the basic tenets and implications of quantum mechanics may appear absolutely bizarre and inconceivable, but they have been repeatedly proven to be true, and it is now one of the most rigorously tested physical models of all time.

Quanta
One of the implications of quantum mechanics is that certain aspects and properties of the universe are quantized, i.e. they are composed of discrete, indivisible packets or quanta. For instance, the electrons orbiting an atom are found in specific fixed orbits and do not slide nearer or further from the nucleus as their energy levels change, but jump from one discrete quantum state to another. Even light, which we know to be a type of electromagnetic radiation which moves in waves, is also composed of quanta or particles of light called photons, so that light has aspects of both waves AND particles, and sometimes it behaves like a wave and sometimes it behaved like a particle (wave-particle duality).

An obvious question, then, would be: is time divided up into discrete quanta? According to quantum mechanics, the answer appears to be “no”, and time appears to be in fact smooth and continuous (contrary to common belief, not everything in quantum theory is quantized). Tests have been carried out using sophisticated timing equipment and pulsating laser beams to observe chemical changes taking place at very small fractions of a second (down to a femtosecond, or 10−15 seconds) and at that level time certainly appears to be smooth and continuous. However, if time actually is quantized, it is likely to be at the level of Planck time (about 10-43 seconds), the smallest possible length of time according to theoretical physics, and probably forever beyond our practical measurement abilities.

It should be noted that our current knowledge of physics remains incomplete, and, according to some theories that look to combine quantum mechanics and gravity into a single “theory of everything” (often referred to as quantum gravity – see below), there is a possibility that time could in fact be quantized. A hypothetical chronon unit for a proposed discrete quantum of time has been proposed, although it is not clear just how long a chronon should be.

Copenhagen Interpretation
One of the main tenets of quantum theory is that the position of a particle is described by a wave function, which provides the probabilities of finding the particle at any number of different places, or superpositions. It is only when the particle is observed, and the wave function collapses, that the particle is definitively located in one particular place or another. So, in quantum theory, unlike in classical physics, there is a difference between what we see and what actually exists. In fact, the very act of observation affects the observed particle.

Another aspect of quantum theory is the uncertainty principle, which says that the values of certain pairs of variables (such as a particle’s location and its speed or momentum) cannot BOTH be known exactly, so that the more precisely one variable is known, the less precisely the other can be known. This is reflected in the probabilistic approach of quantum mechanics, something very foreign to the deterministic and certain nature of classical physics.

This view of quantum mechanics (developed by two of the originators of quantum theory, Niels Bohr and Werner Heisenberg), is sometimes referred to the Copenhagen interpretation of quantum mechanics. Because the collapse of the wave function cannot be undone, and because all the information associated with the initial possible positions of the particle contained in the wave function is essentially lost as soon as it is observed and collapsed, the process is considered to be time-irreversible, which has implications for the so-called “arrow of time”, the one way direction of time that we observe in daily life (see the section on The Arrow of Time).

Some quantum physicists (e.g. Don Page and William Wootters) have developed a theory that time is actually an emergent phenomenon resulting from a strange quantum concept known as entanglement, in which different quantum particles effectively share an existence, even though physically separated, so that the quantum state of each particle can only be described relative to the other entangled particles. The theory even claims to have experimental proof recently, from experiments by Ekaterina Moreva which show that observers do not detect any change in quantum particles (i.e. time foes not “emerge”) until becoming entangled with another particle.

Many Worlds Interpretation
The Copenhagen interpretation of quantum mechanics, mentioned above, is not however the only way of looking at it. Frustrated by the apparent failure of the Copenhagen interpretation to deal with questions like what counts as an observation, and what is the dividing line between the microscopic quantum world and the macroscopic classical world, other alternative viewpoints have been suggested. One of the leading alternatives is the many worlds interpretation, first put forward by Hugh Everett III back in the late 1950s.

According to the many worlds view, there is no difference between a particle or system before and after it has been observed, and no separate way of evolving. In fact, the observer himself is a quantum system, which interacts with other quantum systems, with different possible versions seeing the particle or object in different positions, for example. These different versions exist concurrently in different alternative or parallel universes. Thus, each time quantum systems interact with each other, the wave function does not collapse but actually splits into alternative versions of reality, all of which are equally real.

This view has the advantage of conserving all the information from wave functions so that each individual universe is completely deterministic, and the wave function can be evolved forwards and backwards. Under this interpretation, quantum mechanics is therefore NOT the underlying reason for the arrow of time.

Quantum Gravity

Quantum gravity, or the quantum theory of gravity, refers to various attempts to combine our two best models of the physics of the universe, quantum mechanics and general relativity, into a workable whole. It looks to describe the force of gravity according to the principles of quantum mechanics, and represents an essential step towards the holy grail of physics, a so-called “theory of everything”. Quantum theory and relativity, while coexisting happily in most respects, appear to be fundamentally incompatible at unapproachable events like the singularities in black holes and the Big Bang itself, and it is believed by many that some synthesis of the two theories is essential in acquiring a real handle on the fundamental nature of time itself.

Many different approaches to the riddle of quantum gravity have been proposed over the years, ranging from string theory and superstring theory to M-theory and brane theory, supergravity, loop quantum gravity, etc. This is the cutting edge of modern physics, and if a breakthrough were to occur it would likely be as revolutionary and paradigm-breaking as relativity was in 1905, and could completely change our understanding of time.

Any theory of quantum gravity has to deal with the inherent incompatibilities of quantum theory and relativity, not the least of which is the so-called “problem of time” – that time is taken to have a different meaning in quantum mechanics and general relativity. This is perhaps best exemplified by the Wheeler-DeWitt equation, devised by John Wheeler and Bruce DeWitt back in the 1970s. Their attempt to unify relativity and quantum mechanics resulted in time essentially disappearing completely from their equations, suggesting that time does not exist at all and that, at its most fundamental level, the universe is timeless. In response to the Wheeler-DeWitt equation, some have concluded that time is a kind of fictitious variable in physics, and that we are perhaps confusing the measurement of different physical variables with the actual existence of something we call time.

Imaginary Time

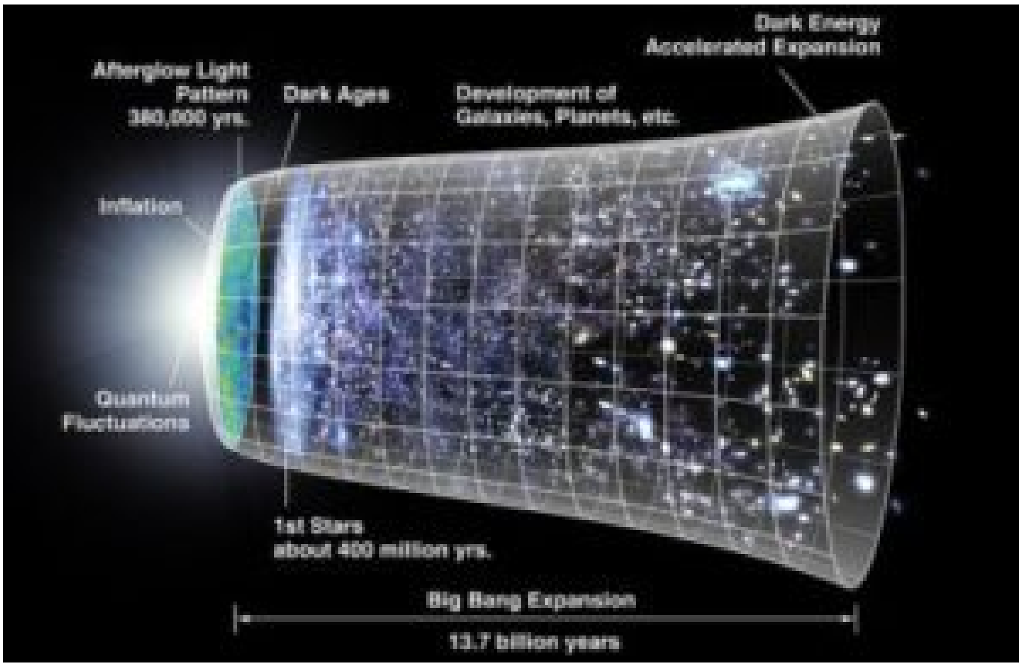
While looking to connect quantum field theory with statistical mechanics, theoretical physicist Stephen Hawking introduced a concept he called imaginary time. Although rather difficult to visualize, imaginary time is not imaginary in the sense of being unreal or made-up. Rather, it bears a similar relationship to normal physical time as the imaginary number scale does to the real numbers in the complex plane, and can perhaps best be portrayed as an axis running perpendicular to that of regular time. It provides a way of looking at the time dimension as if it were a dimension of space, so that it is possible to move forwards and backwards along it, just as one can move right and left or up and down in space.

Despite its rather abstract and counter-intuitive nature, the usefulness of imaginary time arises in its ability to help mathematically to smooth out gravitational singularities in models of the universe. Normally, singularities (like those at the centre of black holes, or the Big Bang itself) pose a problem for physicists, because they are areas where the known physical laws just do not apply. When visualized in imaginary time, however, the singularity is removed and the Big Bang functions like any other point in space-time.

Exactly what such a concept might represent in the real world, though, is unknown, and currently it remains little more than a potentially useful theoretical construct.

Time and the Big Bang

Big Bang



We can model quite accurately the evolution of the universe since the Big Bang 13.8 billion years ago
The general view of physicists is that time started at a specific point about 13.8 billion years ago with the Big Bang, when the entire universe suddenly expanded out of an infinitely hot, infinitely dense singularity, a point where the laws of physics as we understand them simply break down. This can be considered the "birth" of the universe, and the beginning of time as we know it. Before the Big Bang, there just was no space or time, and you cannot go further back in time than the Big Bang, in much the same way as you cannot go any further north than the North Pole.

As theoretical physicist Stephen Hawking notes in his 1988 book A Brief History of Time, even if time did not begin with the Big Bang, and there was another time frame before it, no information is available to us from that earlier time-frame, and any events that occurred then would have no effect on our present time-frame. Any putative events from before the Big Bang can therefore be considered effectively meaningless (or at least the province of philosophical speculation, not physics).

Events after the Big Bang
The universe is expanding, and all the galaxies are moving further and further away from each other. In fact, we now know that this expansion is accelerating faster and faster (largely as a result of the mysterious dark energy that pervades the universe). If we were to play the movie of this expansion in reverse, we would see the universe become smaller and small as we go back in time, until ultimately the matter and energy of the whole universe is concentrated into a microscopic point some 13.8 billion years ago.

We can model this process remarkably closely (at least until the very early nanoseconds or less), and physicists have been able to piece together the major events in the evolution of universe, beginning with the tiniest fractions of a second after the Big Bang:

Planck Epoch (the first 5.39 x 10-44 seconds after the Big Bang) – events (if any) occurring within this time must necessarily remain pure speculation.
Grand Unification Epoch (10-43 to 10-36 seconds) – the force of gravity separates from the other fundamental forces, and the first elementary particles are created.
Inflationary Epoch (10-36 to 10-32 seconds) – the universe undergoes an extremely rapid exponential expansion, known as cosmic inflation, and any existing particles become very thinly distributed.
Electroweak Epoch (10-36 to 10-12 seconds) – the strong nuclear force separates from the other two forces (electromagnetism and gravity), and particle interactions create large numbers of exotic particles, including W and Z bosons and Higgs bosons.
Quark Epoch (10-12 to 10-6 seconds) – the four fundamental forces assume their present forms, and quarks, electrons and neutrinos form in large numbers as the universe cools off to below 10 quadrillion degrees (although most quarks and antiquarks annihilate each other upon contact, a surplus of quarks survives, which will ultimately combine to form matter).
Hadron Epoch (10-6 seconds to 1 second) – the universe cools to about a trillion degrees, allowing quarks to combine to form hadrons like protons and neutrons, and electrons colliding with protons fuse to form neutrons and give off massless neutrinos.
Lepton Epoch (1 to 10 seconds) – most (but not all) hadrons and antihadrons annihilate each other, and leptons such as electrons and positrons dominate the mass of the universe.
Nucleosynthesis (3 minutes to 20 minutes) – the temperature of the universe falls to about a billion degrees, so that atomic nuclei can begin to form as protons and neutrons fuse to form the nuclei of the simple elements of hydrogen, helium and lithium.
Photon Epoch (10 seconds to about 240,000 years) – the universe is filled with plasma, a hot opaque soup of atomic nuclei and electrons, and the energy of the universe is dominated by photons, which continue to interact frequently with the charged protons, electrons and nuclei.
Recombination/Decoupling (about 240,000 to 300,000 years) – the temperature of the universe falls to around 3,000 degrees, and ionized hydrogen and helium atoms capture electrons, neutralizing their electric charge and binding them within atoms; the universe finally becomes transparent to light, making this the earliest epoch potentially observable today.
Dark Age or Era (about 300,000 to 150 million years) – the universe is literally dark, with no stars having formed to give off light; only very diffuse matter remains, and all activity tails off dramatically, with the universe dominated by mysterious "dark matter".
Reionization Epoch (about 150 million to about 1 billion years) – the first quasars form from gravitational collapse, and their intense radiation reionizes the surrounding universe, which goes from being neutral back to being composed of ionized plasma
Star and Galaxy Formation (300 – 500 million years onwards) – small, dense clouds of cosmic gas start to collapse under their own gravity, until they trigger nuclear fusion reactions between hydrogen atoms and create the very first stars, which gradually cluster into galaxies.
Solar System Formation (8.5 – 9 billion years after the Big Bang) – our Sun, a late-generation star incorporating the debris from generations of earlier stars, and the Solar System around it, form roughly 4.5 to 5 billion years ago.
The Ultimate Fate of the Universe
Universe
We can also model, with reasonable confidence, the ultimate fate of the Universe
Our Sun is gradually getting larger, hotter and brighter, and the Earth will probably become uninhabitable within about a billion years from now. In about 5 billion years, our Sun is expected to turn into a red giant star, after which it will gradually shrink and cool into a small, dense white dwarf star, and ultimately into a dark, dead black dwarf star (in about 10 billion years from now). The rest of the universe, though, will continue its expansion and evolution.

There are several possible scenarios in physics for the ultimate fate of the universe, depending on the universe's overall shape or geometry (i.e. whether it is flat, open or closed), on how much dark energy it contains (dark energy is an invisible, hypothetical form of energy with repulsive anti-gravity that permeates all of space, and that may explain recent observations that the universe appears to be expanding at an accelerating rate), and on the so-called "equation of state" (which essentially determines how the density of the dark energy responds to the expansion of the universe). Further advances in fundamental physics may be required before we can make predictions about the future of the universe with any level of certainty, but we can still look at the possibilities.

Without the repulsive effect of dark energy, the effects of gravity will eventually stop the expansion of the universe and it will start to contract until all the matter in the universe collapses to a final singularity, a mirror image of the Big Bang known as the “Big Crunch”. This also offers intriguing possibilities of an oscillating or cyclic universe, or “Big Bounce”, where the Big Crunch is succeeded by the Big Bang of a new universe, and so on, potentially ad infinitum, corresponding to a cyclic view of time.

If the acceleration of the expansion of the universe caused by dark energy increases without limit, one hypothesis is that the dark energy could eventually becoming so strong that it completely overwhelms the effects of the gravitational, electromagnetic and weak nuclear forces. This would result in galaxies, stars and eventually even atoms themselves being literally torn apart, sometimes referred to as the “Big Rip”, with the universe as we know it ending dramatically in an unusual kind of gravitational singularity within the relatively short time horizon of just 35 – 50 billion years. Time under this model would therefore be finite, rather than cyclic or infinite, in nature.

However, the most likely scenario, given our current knowledge of the constantly increasing effects of dark energy, is that the universe will continue expanding forever at an exponentially accelerating rate, ultimately turning space into an almost perfect vacuum as the remaining matter-energy becomes more and more diluted, a scenario sometimes referred to as “Heat Death” or the “Big Freeze“ or the “Big Chill”. Over a time scale of 1014 (a hundred trillion) years or more, the universe would reach a state of maximum entropy and thermal equilibrium at a temperature of very close to absolute zero, where it simply becomes too cold to sustain life or motion of any kind, and all that would remain are burned-out stars, cold dead planets and black holes. Eventually, after an almost unimaginable 10100 (a googol) years, even the black holes will have evaporated away, leaving nothing but random isolated particles floating in emptiness, with little or no prospect of ever interacting with other particles. The implication of this model is that, although time was finite in the past, it will be potentially infinite in the future, although in a scenario like this, where change is practically impossible, the very concept of time becomes effectively meaningless.

The problem with an infinite, eternal universe is that even the most unlikely events will eventually occur (and not only occur, but occur an infinite number of times). In such a scenario, every event would theoretically be equally likely to happen, which effectively undermines the basis for all probabilistic predictions of local experiments. A solution to this problem, according to physicist Raphael Bousso and his collaborators, is to conclude that time WILL eventually end, and he has set about calculating the probability of how and when time will end given five different cut-off measures. Two of these scenarios resulted in time having a 50% chance of ending within 3.7 billion years; in two other scenarios, time has a 50% chance of ending within 3.3 billion years; in the fifth (much less likely) scenario, the time scale is very short and time is overwhelmingly likely to end within the next second. In this hypothetical situation, the end of time is envisioned as similar to an outside observer’s description of a matter system falling into a black hole: everything would gradually slow down and eventually just stop.

Multiverse
An alternative model of the universe sees it as just one of a potentially infinite number of other parallel universes in an overall multiverse (a word actually coined as long ago as 1895 by the American philosopher and psychologist William James). Such a scenario is actually thrown up by many different physical theories, including quantum mechanics, string theory, brane theory, etc, and is increasingly being seen as a real possibility and as a solution to many of the inconsistencies and inexplicabilities in our current theories. It has also been proposed as an explanation for how our universe appears to be so fine-tuned for life as we know it, by calling on the anthropic principle (the idea that the universe is only as it is because we are here to observe this particular version of it).

Parallel universes may physically exist within the same dimensional space as our own universe, but beyond our cosmological horizon; they may exist within black holes; they may exist in other inaccessible dimensions; they may exist very close to our own, or even locked inside or superimposed on it in other dimensions. Some of these parallel universes may even have completely different physical constants and physical laws to ours. By definition, though, we can only ever experience our own universe, and just do not have – and never will have – the ability to see or interact with (or, for that matter, prove the existence of) the rest of the multiverse, and so it remains necessarily hypothetical.

This kind of universe of course also has implications for time, and it may be that what see perceive as time and the arrow of time is only a localized part of an overall concept of time.

The Arrow of Time

The arrow of time refers to the way we always see things progressing in a particular direction,
e.g. eggs may break, but they never spontaneously reform

Time appears to have a direction, to be inherently directional: the past lies behind us and is fixed and immutable, and accessible by memory or written documentation; the future, on the other hand, lies ahead and is not necessarily fixed, and, although we can perhaps predict it to some extent, we have no firm evidence or proof of it. Most of the events we experience are irreversible: for example, it is easy for us to break an egg, and hard, if not impossible, to unbreak an already broken egg. It appears inconceivable to us that that this progression could go in any other direction. This one-way direction or asymmetry of time is often referred to as the arrow of time, and it is what gives us an impression of time passing, of our progressing through different moments. The arrow of time, then, is the uniform and unique direction associated with the apparent inevitable "flow of time" into the future.

The idea of an arrow of time was first explored and developed to any degree by the British astronomer and physicist Sir Arthur Eddington back in 1927, and the origin of the phrase is usually attributed to him. What interested Eddington is that exactly the same arrow of time would apply to an alien race on the other side of the universe as applies to us. It is therefore nothing to do with our biology or psychology, but with the way the universe is. The arrow of time is not the same thing as time itself, but a feature of the universe and its contents and the way it has evolved.

Is the Arrow of Time an Illusion?

As we have seen in the section on Relativistic Time, according to the Theory of Relativity, the reality of the universe can be described by four-dimensional space-time, so that time does not actually "flow", it just "is". The perception of an arrow of time that we have in our everyday life therefore appears to be nothing more than an illusion of consciousness in this model of the universe, an emergent quality that we happen to experience due to our particular kind of existence at this particular point in the evolution of the universe.

Perhaps even more interesting and puzzling is the fact that, although events and processes at the macroscopic level – the behaviour of bulk materials that we experience in everyday life – are quite clearly time-asymmetric (i.e. natural processes DO have a natural temporal order, and there is an obvious forward direction of time), physical processes and laws at the microscopic level, whether classical, relativistic or quantum, are either entirely or mostly time-symmetric. If a physical process is physically possible, then generally speaking so is the same process run backwards, so that, if you were to hypothetically watch a movie of a physical process, you would not be able to tell if it is being played forwards or backwards, as both would be equally plausible.

In theory, therefore, most of the laws of physics do not necessarily specify an arrow of time. There is, however, an important exception: the Second Law of Thermodynamics.

Thermodynamic Arrow of Time

Most of the observed temporal asymmetry at the macroscopic level – the reason we see time as having a forward direction – ultimately comes down to thermodynamics, the science of heat and its relation with mechanical energy or work, and more specifically to the Second Law of Thermodynamics. This law states that, as one goes forward in time, the net entropy (degree of disorder) of any isolated or closed system will always increase (or at least stay the same).

The concept of entropy and the decay of ordered systems was explored and clarified by the German physicist Ludwig Boltzmann in the 1870s, building on earlier ideas of Rudolf Clausius, but it remains a difficult and often misunderstood idea. Entropy can be thought of, in most cases, as meaning that things (matter, energy, etc) have a tendency to disperse. Thus, a hot object always dissipates heat to the atmosphere and cools down, and not vice versa; coffee and milk mix together, but do not then separate; a house left unattended will eventually crumble away, but a pile of bricks never spontaneously forms itself into a house; etc. However, as discussed below, it is not quite as simple as that, and a better way of thinking of it may be as a tendency towards randomness.

It should be noted that, in thermodynamic systems that are NOT closed, it is quite possible that entropy can decrease with time (e.g. the formation of certain crystals; many living systems, which may reduce local entropy at the expense of the surrounding environment, resulting in a net overall increase in entropy; the formation of isolated pockets of gas and dust into stars and planets, even though the entropy of the universe as a whole continues to increase; etc). Any localized or temporary instances of order within the universe are therefore in the nature of epiphenomena within the overall picture of a universe progressing inexorably towards disorder.

It is also perhaps counter-intuitive, but nevertheless true, that overall entropy actually increases even as large-scale structure forms in the universe (e.g. galaxies, clusters, filaments, etc), and that dense and compact black holes have incredibly high entropy, and actually account for the overwhelming majority of the entropy in today's universe. Likewise, the relatively smooth configuration of the very early universe (see the section on Time and the Big Bang) is actually an indication of very low overall entropy (i.e. high entropy does not necessarily imply smoothness: random "lumpiness", like in our current universe, is actually a characteristic of high entropy).

Most of the processes that appear to us to be irreversible in time are those that start out, for whatever reason, in some very special, highly-ordered state. For example, a new deck of cards are in number order, but as soon as we shuffle them they become disordered; an egg is a much more ordered state than a broken or scrambled egg; etc. There is nothing in the laws of physics that prevents the act of shuffling a deck of cards from producing a perfectly ordered set of cards – there is always a chance of that, it is just a vanishingly small chance. To give another example, there are many more possible disordered arrangements of a jigsaw than the one ordered arrangement that makes a complete picture. So, the apparent asymmetry of time is really just an asymmetry of chance – things evolve from order to disorder not because the reverse is impossible, but because it is highly unlikely. The Second Law of Thermodynamics is therefore more a statistical principle than a fundamental law (this was Boltzmann's great insight). But the upshot is that, provided the initial condition of a system is one of relatively high order, then the tendency will almost always be towards disorder.

Thermodynamics, then, appears to be one of the only physical processes that is NOT time-symmetric, and so fundamental and ubiquitous is it in our universe that it may be single-handedly responsible for our perception of time as having a direction. Indeed, several of the other arrows of time noted below (arguably) ultimately come back to the asymmetry of thermodynamics. Indeed, so clear is this law that the measurement of entropy has been put forward a way of distinguishing the past from the future, and the thermodynamic arrow of time has even been put forward as the reason we can remember the past but not the future, due to the fact that the entropy or disorder was lower in the past than in the future.

Cosmological Arrow of Time
It has been argued that the arrow of time points in the direction of the universe's expansion, as the universe continues to grow bigger and bigger since its beginning in the Big Bang (see the section on Time and the Big Bang). It became apparent towards the beginning of the 20th Century, thanks to the work of Edwin Hubble and others, that space is indeed expanding, and the galaxies are moving ever further apart. Logically, therefore, at a much earlier time, the universe was much smaller, and ultimately concentrated in a single point or singularity, which we call the Big Bang. Thus, the universe does seem to have some intrinsic (outward) directionality. In our everyday lives, however, we are not physically conscious of this movement, and it is difficult to see how we can perceive the expansion of the universe as an arrow of time.

The cosmological arrow of time may be linked to, or even dependent on, the thermodynamic arrow, given that, as the universe continues to expand and heads towards an ultimate "Heat Death" or "Big Chill", it is also heading in a direction of increasing entropy, ultimately arriving at a position of maximum entropy, where the amount of usable energy becomes negligible or even zero.
This accords with the Second Law of Thermodynamics in that the overall direction is from the current semi-ordered state, marked by outcroppings of order and structure, towards a completely disordered state of thermal equilibrium. What remains a major unknown in modern physics, though, is exactly why the universe had a very low entropy at its origin, the Big Bang.

It is also possible – although less likely according to the predictions of current physics – that the present expansion phase of the universe could eventually slow, stop, and then reverse itself under gravity. The universe would then contract back to a mirror image of the Big Bang known as the "Big Crunch" (and possibly a subsequent "Big Bounce" in one of a series of cyclic repetitions).
As the universe contracts and collapses, entropy will in theory start to reduce and, presumably, the arrow of time will reverse itself and time will effectively begin to run backwards. In this scenario, then, the arrow of time that we experience is merely a function of our current place in the evolution of the universe and, at some other time, it could conceivably change its direction.
However, there are paradoxes associated with this view because, looked at from a suitably distant and long-term viewpoint, time will continue to progress "forwards" (in some respects at least), even if the universe happens to be in a contraction phase rather than an expansion phase. So, the cosmic asymmetry of time could still continue, even in a "closed" universe of this kind.

Radiative Arrow of Time
Radiating Waves
Waves always radiate away from a source

Waves, like light, radio waves, sound waves, water waves, etc, are always radiative and expand outwards from their sources. While theoretical equations do allow for the opposite (covergent) waves, this is apparently never seen in nature. This asymmetry is regarded by some as a reason for the asymmetry of time.

It is possible that the radiative arrow may also be linked to the thermodynamic arrow, because radiation suggests increased entropy while convergence suggests increased order. This becomes particularly clear when we consider radiation as having a particle aspect (i.e. as consisting of photons) as quantum mechanics suggests.

Quantum Arrow of Time

The whole mechanism of quantum mechanics (or at least the conventional Copenhagen interpretation of it) is based on Schrödinger's Equation and the collapse of wave functions (see the section on Quantum Time), and this appears to be a time-asymmetric phenomenon. For example, the location of a particle is described by a wave function, which essentially gives various probabilities that the particle is in many different possible positions (or superpositions), and the wave function only collapses when the particle is actually observed. At that point, the particle can finally be said to be in one particular position, and all the information from the wave function is then lost and cannot be recreated. In this respect, the process is time-irreversible, and an arrow of time is created.

Some physicists, including the team of Aharonov, Bergmann and Lebowitz in the 1960s, have questioned this finding, though. Their experiments concluded that we only get time-asymmetric answers in quantum mechanics when we ask time-asymmetric questions, and that questions and experiments can be framed in such a way that the results are time-symmetric. Thus, quantum mechanics does not impose time asymmetry on the world; rather, the world imposes time asymmetry on quantum mechanics.

It is not clear how the quantum arrow of time, if indeed it exists at all, is related to the other arrows, but it is possible that it is linked to the thermodynamic arrow, in that nature shows a bias for collapsing wave functions into higher entropy states versus lower ones.

Weak Nuclear Force Arrow of Time

Of the four fundamental forces in physics (gravity, electromagnetism, the strong nuclear force and the weak nuclear force), the weak nuclear force is the only one that does not always manifest complete time symmetry. To some limited extent, therefore, there is a weak force arrow of time, and this is the only arrow of time which appears to be completely unrelated to the thermodynamic arrow.

The weak nuclear force is a very weak interaction in the nucleus of an atom, and is responsible for, among other things, radioactive beta decay and the production of neutrinos. It is perhaps the least understood and strangest of the fundamental forces. In some situations the weak force is time-reversible, e.g. a proton and an electron can smash together to produce a neutron and a neutrino, and a neutron and a neutrino smashed together CAN also produce a proton and an electron (even if the chances of this happening in practice are very small). However, there are examples of the weak interaction that are time-irreversible, for example the case of the oscillation and decay of neutral kaon and anti-kaon particles. Under certain conditions, it has been shown experimentally that kaons and anti-kaons actually decay at different rates, indicating that the weak force is not in fact time-reversible, thereby establishing a kind of arrow of time.

It should be noted, though, that this is not such a strong or fundamental arrow of time as the thermodynamic arrow (the difference is between a process that could go either way but in a slightly different way or at a different rate, and a truly irreversible process – like entropy – that just cannot possibly go both ways). Indeed, it is such a rare occurrence, so small and barely perceivable in its effect, and so divorced from any of the other arrows, that it is usually characterized as an inexplicable anomaly.

Causal Arrow of Time

Although not directly related to physics, causality appears to be intimately bound up with time's arrow. By definition, a cause precedes its effect. Although it is surprisingly difficulty to satisfactorily define cause and effect, the concept is readily apparent in the events of our everyday lives. If we drop a wineglass on a hard floor, it will subsequently shatter, whereas shattered glass on the floor is very unlikely to subsequently result in an unbroken held wine glass. By causing something to happen, we are to some extent controlling the future, whereas whatever might do we cannot change or control the past.

Once again, though, the underlying principle may well come back to the thermodynamic arrow: while disordered shattered glass can easily be made out of a well-ordered wineglass, the reverse is much more difficult and unlikely.

Psychological Arrow of Time

A variant of the causal arrow is sometimes referred to as the psychological or perceptual arrow of time. We appear to have an innate sense that our perception runs from the known past to the unknown future. We anticipate the unknown, and automatically move forward towards it, and, while we are able to remember the past, we do not normally waste time in trying to change the already known and fixed past.

Stephen Hawking has argued that even the psychological arrow of time is ultimately dependent on the thermodynamic arrow, and that we can only remember past things because they form a relatively small set compared to the potentially infinite number of possible disordered future sets.

Anthropic Principle

Some thinkers, including Stephen Hawking again, have pinned the direction of the arrow of time on what is sometimes called the weak anthropic principle, the idea that the laws of physics are as they are solely because those are the laws that allow the development of sentient, questioning beings like ourselves. It is not that the universe is in some way "designed" to allow human beings, merely that we only find ourselves in such a universe because it is as it is, even though the universe could easily have developed in a quite different way with quite different laws.

Thus, Hawking argues, a strong thermodynamic arrow of time is a necessary condition for intelligent life as we know it to develop.

For example, beings like us need to consume food (a relatively ordered form of energy) and convert it into heat (a relatively disordered form of energy), for which a thermodynamic arrow like the one we see around us is necessary.

If the universe were any other way, we would not be here to observe it.

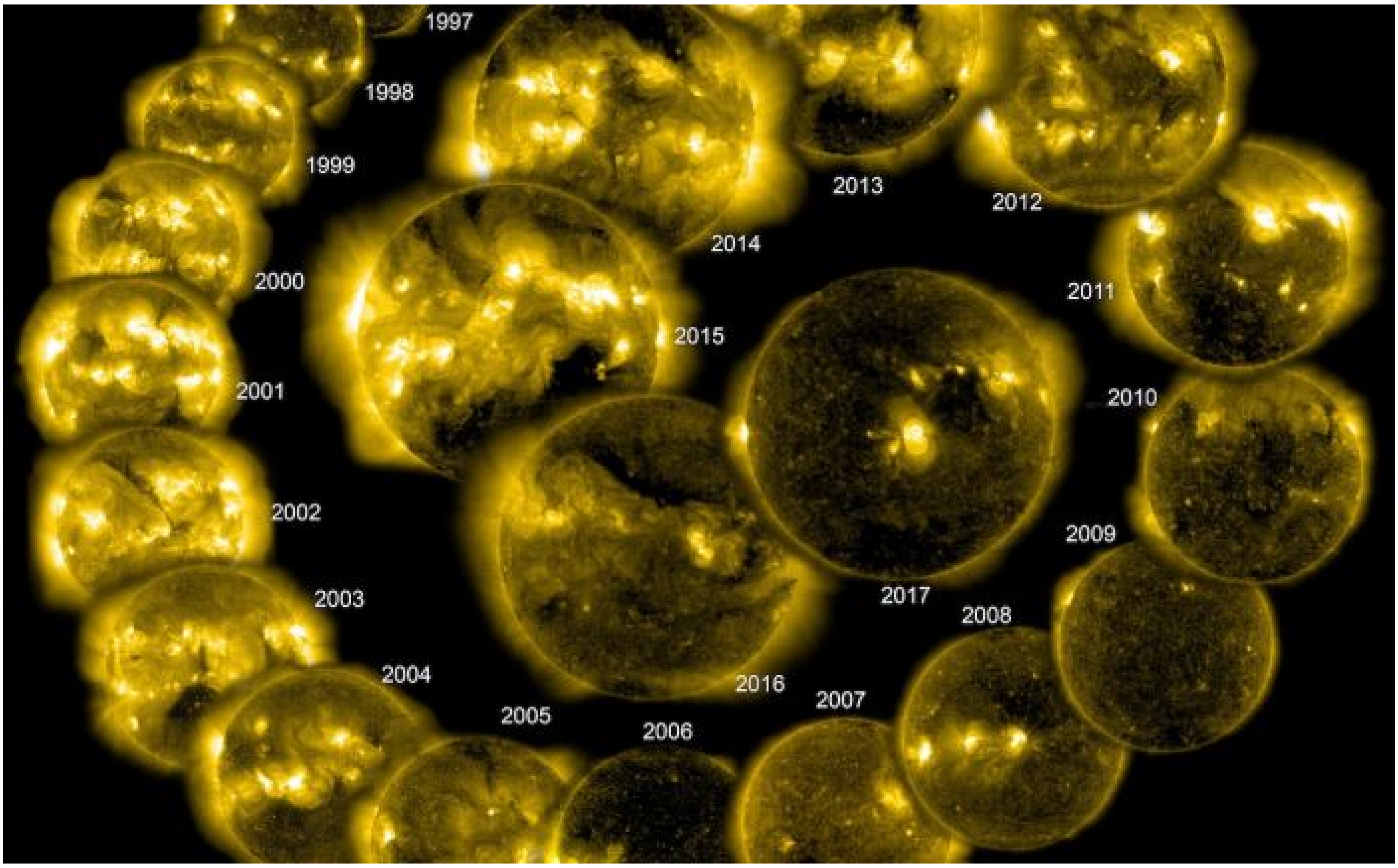
~Internet

22 YEARS OF THE SUN FROM SOHO

The Solar and Heliospheric Observatory (SOHO) is celebrating 22 years of observing the Sun, marking one complete solar magnetic cycle in the life of our star. SOHO is a joint project between NASA and the ESA and its mission is to study the internal structure of the sun, its extensive outer atmosphere, and the origin of the solar wind.

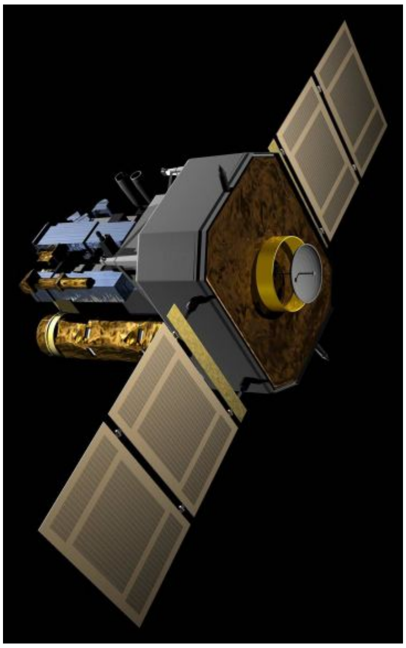
The activity cycle in the life of the Sun is based on the increase and decrease of sunspots. We've been watching this activity for about 250 years, but SOHO has taken that observing to a whole new level.

Though sunspot cycles work on an 11-year period, they're caused by deeper magnetic changes in the Sun. Over the course of 22 years, the Sun's polarity gradually shifts. At the 11 year mark, the orientation of the Sun's magnetic field flips between the northern and southern hemispheres. At the end of the 22 year cycle, the field has shifted back to its original orientation. SOHO has now watched that cycle in its entirety.



The magnetic field of the Sun operates on a 22 year cycle. It takes 11 years for the orientation of the field to flip between the northern and southern hemisphere, and another 11 years to flip back to its original orientation. This composite image is made up of snapshots of the Sun taken with the Extreme ultraviolet Imaging Telescope on SOHO. Image: SOHO (ESA & NASA)

SOHO is a real success story.
It was launched in 1995 and was designed to operate until 1998. But it's been so successful that its mission has been prolonged and extended several times.

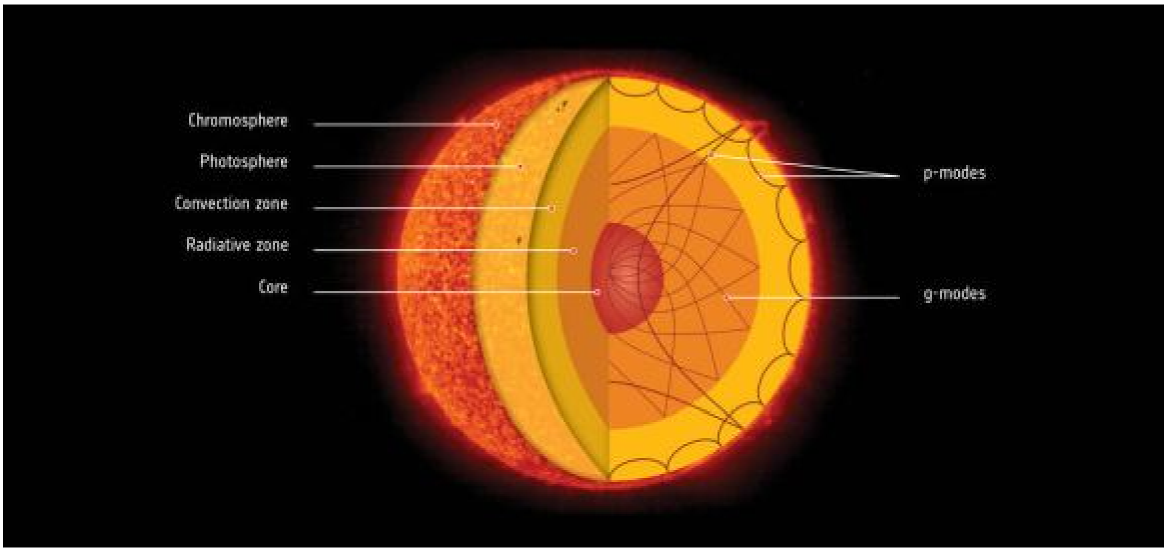


An artist's illustration of the SOHO spacecraft. Image: NASA →

SOHO's 22 years of observation has turbo-charged our space weather forecasting ability. Space weather is heavily influenced by solar activity, mostly in the form of Coronal Mass Ejections (CMEs). SOHO has observed well over 20,000 of these CMEs.

Space weather affects key aspects of our modern technological world. Space-based telecommunications, broadcasting, weather services and navigation are all affected by space weather. So are things like power distribution and terrestrial communications, especially at northern latitudes. Solar weather can also degrade not only the performance, but the lifespan, of communication satellites.

Besides improving our ability to forecast space weather, SOHO has made other important discoveries. After 40 years of searching, it was SOHO that finally found evidence of seismic waves in the Sun. Called g-modes, these waves revealed that the core of the Sun is rotating 4 times faster than the surface. When this discovery came to light, Bernhard Fleck, ESA SOHO project scientist said, "This is certainly the biggest result of SOHO in the last decade, and one of SOHO's all-time top discoveries."



Data from SOHO revealed that the core of the Sun rotates 4 times faster than the surface. Image: ESA

SOHO also has a front row seat for comet viewing. The observatory has witnessed over 3,000 comets as they've sped past the Sun. Though this was never part of SOHO's mandate, its exceptional view of the Sun and its surroundings allows it to excel at comet-finding. It's especially good at finding sun-grazer comets because it's so close to the Sun.

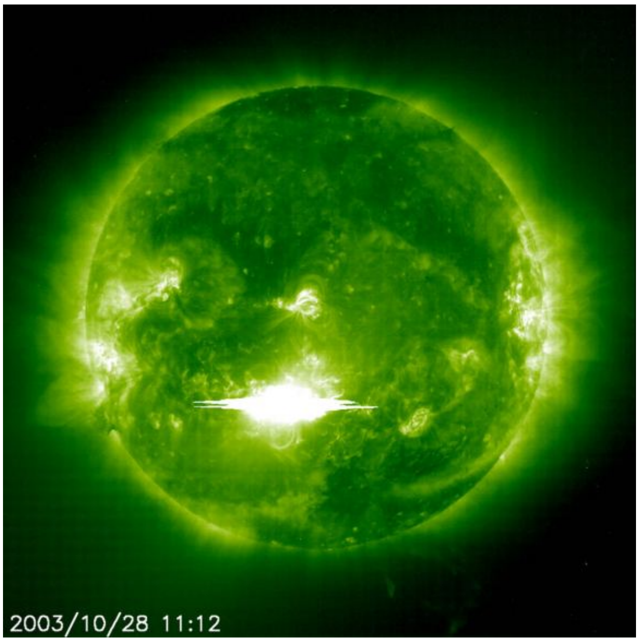
"But nobody dreamed we'd approach 200 (comets) a year." – Joe Gurman, mission scientist for SOHO.

"SOHO has a view of about 12-and-a-half million miles beyond the sun," said Joe Gurman in 2015, mission scientist for SOHO at NASA's Goddard Space Flight Center in Greenbelt, Maryland. "So we expected it might from time to time see a bright comet near the sun. But nobody dreamed we'd approach 200 a year."

A front-row seat for sun-grazing comets allows SOHO to observe other aspects of the Sun's surface. Comets are primitive relics of the early Solar System, and observing them with SOHO can tell scientists quite a bit about where they formed. If a comet has made other trips around the Sun, then scientists can learn something about the far-flung regions of the Solar System that they've traveled through.

Watching these sun-grazers as they pass close to the Sun also teaches scientists about the Sun. The ionized gas in their tails can illuminate the magnetic fields around the Sun. They're like tracers that help observers watch these invisible magnetic fields. Sometimes, the magnetic fields have torn off these tails of ionized gas, and scientists have been able to watch these tails get blown around in the solar wind. This gives them an unprecedented view of the details in the movement of the wind itself.

SOHO is still going strong, and keeping an eye on the Sun from its location about 1.5 million km from Earth. There, it travels in a halo orbit around LaGrange point 1. (It's orbit is adjusted so that it can communicate clearly with Earth without interference from the Sun.) Beyond the important science that SOHO provides, it's also a source of amazing images.



In 2003, SOHO captured this image of a massive solar flare, the third most powerful ever observed in X-ray wavelengths. Very spooky. Image: NASA/ESA/SOHO

~Internet

President, VK2VU, Gary
Vice President, VK3CM, Brenton
Secretary, VK2FKLR, Kathleen
Treasurer, Amy

NEVARC CLUB PROFILE

History

The North East Victoria Amateur Radio Club (NEVARC) formed in 2014.
As of the 7th August 2014, Incorporated, Registered Incorporation number A0061589C.
NEVARC is an affiliated club of the Wireless Institute of Australia.

Meetings

Meetings details are on the club website, check for latest scheduled details.
Meetings held at the Belviour Guides Hall, Silva Drive West Wodonga.

VK3ANE NETS

HF
7.095 MHz Monday, Wednesday, Friday - 10am Local time
3.622 MHz Wednesday - 8.30pm Local time

VHF
VK3RWO Repeater 146.975 MHz – Monday - 8pm Local time
All nets are hosted by Ron Hanel VK3MRH (soon to be VK3ARH) using the club callsign VK3ANE

Benefits

To provide the opportunity for Amateur Radio Operators and Short Wave Listeners to enhance their hobby through interaction with other Amateur Radio Operators and Short Wave Listeners. Free technology and related presentations, sponsored construction activities, discounted (and sometimes free) equipment, network of likeminded radio and electronics enthusiasts. Excellent club facilities and environment, ample car parking.

Website: www.nevarc.net.au

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PO Box 69
Wahgunyah Vic 3683

All editors' comments and other opinions in submitted articles may not always represent the opinions of the committee or the members of NEVARC, but published in spirit, to promote interest and active discussion on club activities and the promotion of Amateur Radio.
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