Outer space, or just **space**, is the void that exists between celestial bodies, including Earth.[1] It is not completely empty, but consists of a hard vacuum containing a low density of particles, predominantly a plasma of hydrogen and helium as well as electromagnetic radiation, magnetic fields, neutrinos, dust, and cosmic rays. The baseline temperature, as set by the background radiation from the Big Bang, is 2.7 kelvins (K) (−270.45 °C; −454.81 °F).[2] Plasma with a number density of less than one hydrogen atom per cubic metre and a temperature of millions of kelvins in the space between galaxies accounts for most of the baryonic (ordinary) matter in outer space; local concentrations have condensed into stars and galaxies. In most galaxies, observations provide evidence that 90% of the mass is in an unknown form, called dark matter, which interacts with other matter through gravitational but not electromagnetic forces.[3][4] Data indicates that the majority of the mass-energy in the observable universe is a poorly understood vacuum energy of space which astronomers label dark energy.[5][6] Intergalactic space takes up most of the volume of the Universe, but even galaxies and star systems consist almost entirely of empty space.

There is no firm boundary where outer space starts. However the Kármán line, at an altitude of 100 km (62 mi) above sea level,[7][8] is conventionally used as the start of outer space in space treaties and for aerospace records keeping. The framework for international space law was established by the Outer Space Treaty, which entered into force on 10 October 1967. This treaty precludes any claims of national sovereignty and permits all states to freely explore outer space. Despite the drafting of UN resolutions for the peaceful uses of outer space, anti-satellite weapons have been tested in Earth orbit.

Humans began the physical exploration of space during the 20th century with the advent of high-altitude balloon flights, followed by manned rocket launches. Earth orbit was first achieved by Yuri Gagarin of the Soviet Union in 1961 and unmanned spacecraft have since reached all of the known planets in the Solar System. Due to the high cost of getting into space, manned spaceflight has been limited to low Earth orbit and the Moon.

Outer space represents a challenging environment for human exploration because of the dual hazards of vacuum and radiation. Microgravity also has a negative effect on human physiology that causes both muscle atrophy and bone loss. In addition to these health and environmental issues, the economic cost of putting objects, including humans, into space is very high.

According to the Big Bang theory, the Universe originated in an extremely hot and dense state about 13.8 billion years ago[33] and began expanding rapidly. About 380,000 years later the Universe had cooled sufficiently to allow protons and electrons to combine and form hydrogen—the so-called recombination epoch. When this happened, matter and energy became decoupled, allowing photons to travel freely through space.[34] The matter that remained following the initial expansion has since undergone gravitational collapse to create stars, galaxies and other astronomical objects, leaving behind a deep vacuum that forms what is now called outer space.[35] As light has a finite velocity, this theory also constrains the size of the directly observable universe.[34] This leaves open the question as to whether the Universe is finite or infinite.

The present day shape of the universe has been determined from measurements of the cosmic microwave backgroundusing satellites like the Wilkinson Microwave Anisotropy Probe. These observations indicate that the observable universe is "flat", meaning that photons on parallel paths at one point will remain parallel as they travel through space to the limit of the observable universe, except for local gravity.[36] The flat Universe, combined with the measured mass density of the Universe and the accelerating expansion of the Universe, indicates that space has a non-zero vacuum energy, which is called dark energy.[37]

Estimates put the average energy density of the Universe at the equivalent of 5.9 protons per cubic meter, including dark energy, dark matter, and baryonic matter (ordinary matter composed of atoms). The atoms account for only 4.6% of the total energy density, or a density of one proton per four cubic meters.[38] The density of the Universe, however, is clearly not uniform; it ranges from relatively high density in galaxies—including very high density in structures within galaxies, such as planets, stars, and black holes—to conditions in vast voids that have much lower density, at least in terms of visible matter.[39] Unlike the matter and dark matter, the dark energy seems not to be concentrated in galaxies: although dark energy may account for a majority of the mass-energy in the Universe, dark energy's influence is 5 orders of magnitude smaller than the influence of gravity from matter and dark matter within the Milky Way.[40]

Outer space is the closest known approximation to a perfect vacuum. It has effectively no friction, allowing stars, planets and moons to move freely along their ideal orbits. However, even the deep vacuum of intergalactic space is not devoid of matter, as it contains a few hydrogen atoms per cubic meter.[41] By comparison, the air humans breathe contains about 10^{25} molecules per cubic meter.[42][43] The sparse density of matter in outer space means that electromagnetic radiation can travel great distances without being scattered: the mean free path of a photon in intergalactic space is about 10^{23} km, or 10 billion light years.[44] In spite of this, extinction, which is the absorption and scattering of photons by dust and gas, is an important factor in galactic and intergalactic astronomy.[45]

Stars, planets and moons retain their atmospheres by gravitational attraction. Atmospheres have no clearly delineated boundary: the density of atmospheric gas gradually decreases with distance from the object until it becomes indistinguishable from the surrounding environment.[46]The Earth's atmospheric pressure drops to about 0.032 Pa at 100 kilometres (62 miles) of altitude,[47] compared to 100,000 Pa for the International Union of Pure and Applied Chemistry (IUPAC) definition of standard pressure. Beyond this altitude, isotropic gas pressure rapidly becomes insignificant when compared to radiation pressure from the Sun and the dynamic pressure of the solar wind. The thermosphere in this range has large gradients of pressure, temperature and composition, and varies greatly due to space weather.[48]

The temperature of the vacuum is measured in terms of the kinetic activity of the gas, as it is on Earth. However, the radiation that fills the vacuum has a different temperature than the kinetic temperature of the gas, meaning that the gas and radiation are not in thermodynamic equilibrium.[49][50] All of the observable universe is filled with photons that were created during the

Big Bang, which is known as the cosmic microwave background radiation (CMB). (There is quite likely a correspondingly large number of neutrinos called the cosmic neutrino background.[51]) The current black body temperature of the background radiation is about 3 K (−270 °C; −454 °F).[52] The gas temperatures in outer space are always at least the temperature of the CMB but can be much higher. For example, the corona of the Sun has temperatures which range over 1.2–2.6 million K.[53]

Magnetic fields have been detected in the space around just about every class of celestial object. Star formation in spiral galaxies can generate small-scale dynamos, generating turbulent magnetic field strengths of around 5–10 μG. The Davis–Greenstein effect causes elongated dust grains to align themselves with a galaxy's magnetic field, resulting in weak optical polarization. This has been used to show ordered magnetic fields exist in several nearby galaxies. Magneto-hydrodynamic processes in active elliptical galaxies produce their characteristic jets and radio lobes. Non-thermal radio sources have been detected even among the most distant, high-z sources, indicating the presence of magnetic fields.[54]

Outside a protective atmosphere and magnetic field, there are few obstacles to the passage through space of energetic subatomic particles known as cosmic rays. These particles have energies ranging from about 10^6 eV up to an extreme 10^{20} eV of ultra-high-energy cosmic rays.[55] The peak flux of cosmic rays occurs at energies of about 10^9 eV, with approximately 87% protons, 12% helium nuclei and 1% heavier nuclei. In the high energy range, the flux of electrons is only about 1% of that of protons.[56] Cosmic rays can damage electronic components and pose a health threat to space travelers.[57] According to astronauts, like Don Pettit, space has a burned/metallic odor that clings to their suits and equipment, similar to the scent of an arc welding torch.[58][59]

Despite the harsh environment, several life forms have been found that can withstand extreme space conditions for extended periods. Species of lichen carried on the ESA BIOPANfacility survived exposure for ten days in 2007.[60] Seeds of *Arabidopsis thaliana* and *Nicotiana tabacum* germinated after being exposed to space for 1.5 years.[61] A strain of *bacillus subtilis* has survived 559 days when exposed to low-Earth orbit or a simulated martian environment.[62] The lithopanspermia hypothesis suggests that rocks ejected into outer space from life-harboring planets may successfully transport life forms to another habitable world. A conjecture is that just such a scenario occurred early in the history of the Solar System, with potentially microorganism-bearing rocks being exchanged between Venus, Earth, and Mars.[63]

Effect on human bodies[edit]

See also: Space exposure and Weightlessness

Because of the hazards of a vacuum, astronauts must wear a pressurized space suit while off-Earth and outside their spacecraft.

Even at relatively low altitudes in the atmosphere, conditions are hostile to the human body. The altitude where the atmospheric pressure matches the vapor pressure of water at the temperature of the human body is called the Armstrong line, named after American physician Harry G. Armstrong. It is located at an altitude of around 19.14 km (11.89 mi). At or above the Armstrong line, fluids in the throat and lungs will boil away. More specifically, exposed bodily liquids such as saliva, tears, and the liquids wetting the alveoli within the lungs will boil away. Hence, at this altitude the human body requires a pressure suit, or a pressurized capsule, to survive.[64]

Once in space, sudden exposure of unprotected humans to very low pressure, such as during a rapid decompression, can cause pulmonary barotrauma—a rupture of the lungs, due to the large pressure differential between inside and outside the chest.[65] Even if the subject's airway is fully open, the flow of air through the windpipe may be too slow to prevent the rupture.[66] Rapid decompression can rupture eardrums and sinuses, bruising and blood seep can occur in soft tissues, and shock can cause an increase in oxygen consumption that leads to hypoxia.[65]

As a consequence of rapid decompression, any oxygen dissolved in the blood will empty into the lungs to try to equalize the partial pressuregradient. Once the deoxygenated blood arrives at the brain, humans will lose consciousness after a few seconds and die of hypoxia within minutes.[67] Blood and other body fluids boil when the pressure drops below 6.3 kPa, and this condition is called ebullism.[68] The steam may bloat the body to twice its normal size and slow circulation, but tissues are elastic and porous enough to prevent rupture. Ebullism is slowed by the pressure containment of blood vessels, so some blood remains liquid.[69][70] Swelling and ebullism can be reduced by containment in a pressure suit. The Crew Altitude Protection Suit (CAPS), a fitted elastic garment designed in the 1960s for Shuttle astronauts, prevents ebullism at pressures as low as 2 kPa.[71]Supplemental oxygen is needed at 8 km (5.0 mi) to provide enough oxygen for breathing and to prevent water loss, while above 20 km (12 mi) pressure suits are essential to prevent ebullism.[72] Most space suits use around 30–39 kPa of pure oxygen, about the same as on the Earth's surface. This pressure is high enough to prevent ebullism, but evaporation of nitrogen dissolved in the blood could still cause decompression sickness and gas embolisms if not managed.[73]

Humans evolved for life in Earth gravity, and exposure to weightlessness has been shown to have deleterious effects on the health of the human body. Initially, more than 50% of astronauts experience space motion sickness. This can cause nausea and vomiting, vertigo, headaches, lethargy, and overall malaise. The duration of space sickness varies, but it typically lasts for 1–3 days, after which the body adjusts to the new environment. Longer term exposure to weightlessness results in muscle atrophy and deterioration of the skeleton, or spaceflight osteopenia. These effects can be minimized through a regimen of exercise.[74] Other effects include fluid redistribution, slowing of the cardiovascular system, decreased production of red blood cells, balance disorders, and a weakening of the immune system. Lesser symptoms include loss of body mass, nasal congestion, sleep disturbance, and puffiness of the face.[75]

For long duration space travel, radiation can pose an acute health hazard. Exposure to radiation sources such as high-energy, ionizing cosmic rays can result in fatigue, nausea, vomiting, as well as damage to the immune system and changes to the white blood cell count. Over longer durations, symptoms include an increased risk of cancer, plus damage to the eyes, nervous system, lungs and the gastrointestinal tract.[76] On a round-trip Mars mission lasting three years, nearly the entire body would be traversed by high energy nuclei, each of which can cause ionization damage to cells. Fortunately, most such particles are significantly attenuated by the shielding provided by the aluminium walls of a spacecraft, and can be further diminished by water containers and other barriers. However, the impact of the cosmic rays upon the shielding produces additional radiation that can affect the crew. Further research will be needed to assess the radiation hazards and determine suitable countermeasures.[77]

Boundary[edit]

SpaceShipOne completed the first manned private spaceflight in 2004, reaching an altitude of 100.12 km (62.21 mi).[78]

There is no clear boundary between Earth's atmosphere and space, as the density of the atmosphere gradually decreases as the altitude increases. There are several standard boundary designations, namely:

- The Fédération Aéronautique Internationale has established the Kármán line at an altitude of 100 km (62 mi) as a working definition for the boundary between aeronautics and astronautics. This is used because at an altitude of about 100 km (62 mi), as Theodore von Kármán calculated, a vehicle would have to travel faster than orbital velocity in order to derive sufficient aerodynamic lift from the atmosphere to support itself.[7][8]
- The United States designates people who travel above an altitude of 50 miles (80 km) as astronauts.[79]
- NASA's Space Shuttle used 400,000 feet (76 mi, 122 km) as its re-entry altitude (termed the Entry Interface), which roughly marks the boundary where atmospheric drag becomes noticeable, thus beginning the process of switching from steering with thrusters to maneuvering with air surfaces.[80]

In 2009, scientists at the University of Calgary reported detailed measurements with a Supra-Thermal Ion Imager (an instrument that measures the direction and speed of ions), which allowed them to establish a boundary at 118 km (73 mi) above Earth. The boundary represents the midpoint of a gradual transition over tens of kilometers from the relatively gentle winds of the Earth's atmosphere to the more violent flows of charged particles in space, which can reach speeds well over 268 m/s (600 mph).[81][82]

Space is a partial vacuum: its different regions are defined by the various atmospheres and "winds" that dominate within them, and extend to the point at which those winds give way to those beyond. Geospace extends from Earth's atmosphere to the outer reaches of Earth's magnetic field, whereupon it gives way to the solar wind of interplanetary space.[95]Interplanetary space extends to the heliopause, whereupon the solar wind gives way to the winds of the interstellar medium.[96] Interstellar space then continues to the edges of the galaxy, where it fades into the intergalactic void.[97]

Geospace[edit]

Aurora australis observed from the Space Shuttle *Discovery*, on STS-39, May 1991 (orbital altitude: 260 km)

Geospace is the region of outer space near Earth. Geospace includes the upper region of the atmosphere and the magnetosphere.[95] The Van Allen radiation belt lies within the geospace. The outer boundary of geospace is the magnetopause, which forms an interface between the planet's magnetosphere and the solar wind. The inner boundary is the ionosphere.[98] As the physical properties and behavior of near Earth space is affected by the behavior of the Sun and space weather, the field of geospace is interlinked with heliophysics; the study of the Sun and its impact on the Solar System planets.[99]

The volume of geospace defined by the magnetopause is compacted in the direction of the Sun by the pressure of the solar wind, giving it a typical subsolar distance of 10 Earth radii from the center of the planet. However, the tail can extend outward to more than 100–200 Earth radii.[100] The Moon passes through the geospace tail during roughly four days each month, during which time the surface is shielded from the solar wind.[101]

Geospace is populated by electrically charged particles at very low densities, the motions of which are controlled by the Earth's magnetic field. These plasmas form a medium from which storm-like disturbances powered by the solar wind can drive electrical currents into the Earth's upper atmosphere. During geomagnetic storms two regions of geospace, the radiation belts and the ionosphere, can become strongly disturbed. These storms increase fluxes of energetic electrons that can permanently damage satellite electronics, disrupting telecommunications and GPS technologies, and can also be a hazard to astronauts, even in low Earth orbit. They also create aurorae seen near the magnetic poles.[102]

Although it meets the definition of outer space, the atmospheric density within the first few hundred kilometers above the Kármán line is still sufficient to produce significant drag on satellites.[93] This region contains material left over from previous manned and unmanned launches that are a potential hazard to spacecraft. Some of this debris re-enters Earth's atmosphere periodically.[103]

Cislunar space[edit]

Proposed spacecraft for manned cislunar travel in 2020's

Earth's gravity reaches out far past the Van Allen radiation belt and keeps the Moon in orbit at an average distance of 384,403 km (238,857 mi). The region outside Earth's atmosphere and extending out to just beyond the Moon's orbit, including the Lagrangian points, is sometimes referred to as *cis-lunar space*.[104] By consensus, any region beyond cislunar space is referred to as *deep space*.[105] The region of space where the gravity of the Earth remains dominant against gravitational perturbations from the Sun is called the Hill sphere.[106] This extends well out into translunar space to a distance of roughly 0.01 AU, or 1% of the mean distance from the Earth to the Sun.[107] The night side of Earth's magnetosphere extends into this region, forming a magnetotail that may be up to 1,000 earth radii, or 6.4 million km (4.0 million mi) long.[108]

Interplanetary space[edit]

Main article: Interplanetary medium

The sparse plasma (blue) and dust (white) in the tail of comet Hale–Boppare being shaped by pressure from solar radiation and the solar wind, respectively

Interplanetary space, the space around the Sun and planets of the Solar System, is the region dominated by the interplanetary medium, which extends out to the heliopause where the influence of the galactic environment starts to dominate over the magnetic field and particle flux from the Sun.[96] Interplanetary space is defined by the solar wind, a continuous stream of charged particles emanating from the Sun that creates a very tenuous atmosphere (the heliosphere) for billions of kilometers into space. This wind has a particle density of 5–10 protons/cm^3 and is moving at a velocity of 350–400 km/s (780,000–890,000 mph).[109] The distance and strength of the heliopause varies depending on the activity level of the solar wind.[110] The discovery since 1995 of extrasolar planets means that other stars must possess their own interplanetary media.[111]

The volume of interplanetary space is a nearly total vacuum, with a mean free path of about one astronomical unit at the orbital distance of the Earth. However, this space is not completely empty, and is sparsely filled with cosmic rays, which include ionized atomic nuclei and various subatomic particles. There is also gas, plasma and dust, small meteors, and several dozen types of organic molecules discovered to date by microwave spectroscopy.[112] A cloud of interplanetary dust is visible at night as a faint band called the zodiacal light.[113]

Interplanetary space contains the magnetic field generated by the Sun.[109] There are also magnetospheres generated by planets such as Jupiter, Saturn, Mercury and the Earth that have their own magnetic fields. These are shaped by the influence of the solar wind into the approximation of a teardrop shape, with the long tail extending outward behind the planet. These magnetic fields can trap particles from the solar wind and other sources, creating belts of magnetic particles such as the Van Allen radiation belt. Planets without magnetic fields, such as Mars, have their atmospheres gradually eroded by the solar wind.[114]

Interstellar space[edit]

Main article: Interstellar medium

"Interstellar space" redirects here. For the album, see Interstellar Space.

Bow shock formed by the magnetosphere of the young star LL Orionis (center) as it collides with the Orion Nebula flow

Interstellar space is the physical space within a galaxy beyond the influence of each star on the plasma.[97] The contents of interstellar space are called the interstellar medium. Approximately 70% of the mass of the interstellar medium consists of lone hydrogen atoms; most of the remainder consists of helium atoms. This is enriched with trace amounts of heavier atoms formed through stellar nucleosynthesis. These atoms are ejected into the interstellar medium by stellar winds or when evolved stars begin to shed their outer envelopes such as during the formation of a planetary nebula.[115] The cataclysmic explosion of a supernova will generate an expanding shock wave consisting of ejected materials.[116] The density of matter in the interstellar medium can vary considerably: the average is around 10^6 particles per m^3,[117] but cold molecular clouds can hold 10^8–10^{12} per m^3.[49][115]

A number of molecules exist in interstellar space, as can tiny 0.1 μm dust particles.[118] The tally of molecules discovered through radio astronomy is steadily increasing at the rate of about four new species per year. Large regions of higher density matter known as molecular clouds allow chemical reactions to occur, including the formation of organic polyatomic species. Much of this chemistry is driven by collisions. Energetic cosmic rays penetrate the cold, dense clouds and ionize hydrogen and helium, resulting, for example, in the trihydrogen cation. An ionized helium atom can then split relatively abundant carbon monoxide to produce ionized carbon, which in turn can lead to organic chemical reactions.[119]

The local interstellar medium is a region of space within 100 parsecs (pc) of the Sun, which is of interest both for its proximity and for its interaction with the Solar System. This volume nearly coincides with a region of space known as the Local Bubble, which is characterized by a lack of dense, cold clouds. It forms a cavity in the Orion Arm of the Milky Way galaxy, with dense molecular clouds lying along the borders, such as those in the constellations of Ophiuchus and Taurus. (The actual distance to the border of this cavity varies from 60 to 250 pc or more.) This volume contains about 10^4–10^5 stars and the local interstellar gas counterbalances the astrospheres that surround these stars, with the volume of each sphere varying depending on the local density of the interstellar medium. The Local Bubble contains dozens of warm interstellar clouds with temperatures of up to 7,000 K and radii of 0.5–5 pc.[120]

When stars are moving at sufficiently high peculiar velocities, their astrospheres can generate bow shocks as they collide with the interstellar medium. For decades it was assumed that the Sun had a bow shock. In 2012, data from Interstellar Boundary Explorer (IBEX) and NASA's Voyager probes showed that the Sun's bow shock does not exist. Instead, these authors argue that a subsonic bow wave defines the transition from the solar wind flow to the interstellar medium.[121][122] A bow shock is the third boundary of an astrosphere after the termination shock and the astropause (called the heliopause in the Solar System).[122]

Intergalactic space[edit]

A star forming region in the Large Magellanic Cloud, perhaps the closest Galaxy to Earth's Milky Way

See also: Intracluster medium

Intergalactic space is the physical space between galaxies. Studies of the large scale distribution of galaxies show that the Universe has a foam-like structure, with clusters and groups of galaxies lying along filaments that occupy about a tenth of the total space. The remainder forms huge voids that are mostly empty of galaxies. Typically, a void spans a distance of (10–40) h^{-1} MPc, where h is the Hubble constant in units of 100 km s^{-1} Mpc.[123]

Surrounding and stretching between galaxies, there is a rarefied plasma[124] that is organized in a galactic filamentary structure.[125] This material is called the intergalactic medium (IGM). The density of the IGM is 5–200 times the average density of the Universe.[126] It consists mostly of ionized hydrogen; i.e. a plasma consisting of equal numbers of electrons and protons. As gas falls into the intergalactic medium from the voids, it heats up to temperatures of 10^5 K to 10^7 K,[127] which is high enough so that collisions between atoms have enough energy to cause the bound electrons to escape from the hydrogen nuclei; this is why the IGM is ionized. At these temperatures, it is called the warm–hot intergalactic medium (WHIM). (Although the plasma is very hot by terrestrial standards, 10^5 K is often called "warm" in astrophysics.) Computer simulations and observations indicate that up to half of the atomic matter in the Universe might exist in this warm–hot, rarefied state.[126][128][129] When gas falls from the filamentary structures of the WHIM into the galaxy clusters at the intersections of the cosmic filaments, it can heat up even more, reaching temperatures of 10^8 K and above in the so-called intracluster medium.[130]

Exploration and applications[edit]

Main articles: Space exploration, Space colonization, and Space manufacturing

The first image taken of the entire Earth by astronauts was shot during the Apollo 8 mission

For the majority of human history, space was explored by remote observation; initially with the unaided eye and then with the telescope. Prior to the advent of reliable rocket technology, the closest that humans had come to reaching outer space was through the use of balloon flights. In 1935, the U.S. *Explorer II* manned balloon flight had reached an altitude of 22 km (14 mi).[131] This was greatly exceeded in 1942 when the third launch of the German A-4 rocket climbed to an altitude of about 80 km (50 mi). In 1957, the unmanned satellite *Sputnik 1* was launched by a Russian R-7 rocket, achieving Earth orbit at an altitude of 215–939 kilometres (134–583 mi).[132] This was followed by the first human spaceflight in 1961, when Yuri Gagarin was sent into orbit on Vostok 1. The first humans to escape Earth orbit were Frank Borman, Jim Lovelland William Anders in 1968 on board the U.S. Apollo 8, which achieved lunar orbit[133] and reached a maximum distance of 377,349 km (234,474 mi) from the Earth.[134]

The first spacecraft to reach escape velocity was the Soviet Luna 1, which performed a fly-by of the Moon in 1959.[135] In 1961, Venera 1became the first planetary probe. It revealed the presence of the solar wind and performed the first fly-by of the planet Venus, although contact was lost before reaching Venus. The first successful planetary mission was the Mariner 2 fly-by of Venus in 1962.[136] The first spacecraft to perform a fly-by of Mars was Mariner 4, which reached the planet in 1964. Since that time, unmanned spacecraft have successfully examined each of the Solar System's planets, as well their moons and many minor planets and comets. They remain a fundamental tool for the exploration of outer space, as well as observation of the Earth.[137] In August 2012, Voyager 1 became the first man-made object to leave the Solar System and enter interstellar space.[138]

The absence of air makes outer space an ideal location for astronomy at all wavelengths of the electromagnetic spectrum. This is evidenced by the spectacular pictures sent back by the Hubble Space Telescope, allowing light from more than 13 billion years ago—almost to the time of the Big Bang—to be observed.[139] However, not every location in space is ideal for a telescope. The interplanetary zodiacal dust emits a diffuse near-infrared radiation that can mask the emission of faint sources such as extrasolar planets. Moving an infrared telescope out past the dust will increase the effectiveness of the instrument.[140] Likewise, a site like the Daedalus crater on the far side of the

Moon could shield a radio telescope from the radio frequency interference that hampers Earth-based observations.[141]

Unmanned spacecraft in Earth orbit have become an essential technology of modern civilization. They allow direct monitoring of weather conditions, relay long-range communicationslike television, provide a means of precise navigation, and allow remote sensing of the Earth. The latter role serves a wide variety of purposes, including tracking soil moisture for agriculture, prediction of water outflow from seasonal snow packs, detection of diseases in plants and trees, and surveillance of military activities.[142]

The deep vacuum of space could make it an attractive environment for certain industrial processes, such as those that require ultraclean surfaces.[143] However, like asteroid mining, space manufacturing requires a significant investment with little prospect of an immediate return.[144] An important factor in the total expense is the high cost of placing mass into Earth orbit: $7,000–24,000 per kg in inflation-adjusted dollars, according to a 2006 estimate.[145] Proposed concepts for addressing this issue include non-rocket spacelaunch, momentum exchange tethers, and space elevators.[146]

Space, also known as **outer space**, is the near-vacuum between celestial bodies.[1] It is where everything (all of the planets, stars, galaxiesand other objects) is found.

On Earth, space begins at the Kármán line (100 km above sea level).[2] This is where Earth's atmosphere is said to stop and outer space begins. This is not a natural boundary but is a convention used by scientists and diplomats.

However, the space near Earth is quite crowded by astronomical standards. A list of spaces goes like this:

1. **Geospace** is the region of outer space near Earth. Geospace includes the upper region of the atmosphere and the magnetosphere.[3]The Van Allen radiation belt lies within the geospace. The space inside the magnetosphere is protected from radiation from the Sun. It has a low level of electrically charged particles.
2. **Interplanetary space** is the space around the Sun and planets of the Solar System. It has the solar wind, a continuous stream of charged particles from the Sun. This stream creates a very thin atmosphere (the heliosphere) for billions of miles or kilometers into space.
3. Interplanetary space has the magnetic field generated by the Sun.[4] Planets such as Jupiter, Saturn, Mercury and the Earth also have magnetospheres. These magnetic fields can trap particles from the solar wind and other sources, creating belts of magnetic particles such as the Van Allen radiation belt. Planets without magnetic fields, such as Mars, have their atmospheres gradually stripped off by the solar wind.[5]
4. **Interstellar space** is the physical space within a galaxy not occupied by stars or their planetary systems. It continues to the edges of the galaxy, where it fades into the intergalactic void. Most of the mass in this space is made up of single hydrogen

atoms, fewer helium atoms and a few heavier atoms formed in stars. Supernovae blow some of their atoms huge distances.

5. A number of molecules and tiny 0.1 μm dust particles do exist in interstellar space.[6] About four new types of molecule are discovered each year. Large regions of higher density matter known as molecular clouds allow chemical reactions to occur. This incudes organic polyatomic species. Much of this chemistry is driven by collisions.
6. **Intergalactic space** does have 'cosmic voids' between the large-scale structures of the universe.

A long time ago in a galaxy far away—NGC 4993, to be exact—two neutron stars collided and created a spectacular light show.

After billions of years spent slowly circling each other, in their last moments the two degenerate stars spiraled around each other thousands of times before finally smashing together at a significant fraction of light-speed, likely creating a black hole. The merger was so violent it shook the universe, emitting some 200 million suns' worth of energy as perturbations in the fabric of spacetime called gravitational waves. Those waves propagated out from the merger like ripples on a pond, eventually washing over Earth—and into our planet's premiere gravitational-wave detectors, the U.S.-built LIGO and European-built Virgo observatories.

Yet gravitational waves were not the merger's only products. The event also emitted electromagnetic radiation—that is, light—marking the first time astronomers have managed to capture both gravitational waves and light from a single source. The first light from the merger was a brief, brilliant burst of gamma rays, a probable birth cry of the black hole picked up by NASA's Fermi Gamma-Ray Space Telescope. Hours later astronomers using ground-based telescopes detected more light from the merger—a so-called "kilonova"—produced as debris from the merger expanded and cooled. For weeks much of the world's astronomical community watched the kilonova as it slowly faded from view.
As astronomers studied the merger's aftermath in various wavelengths of light, they saw signs of countless heavy elements forming instantly. Astronomers had long predicted merging neutron stars may be responsible for forming elements such as gold and titanium, neutron-rich metals that are not

known to form in stars. Most everything they saw in the changing light of the merger's kilonova matched those predictions, although no one definitively, directly saw the merger spewing out gold nuggets by any stretch.

Even seen across its estimated 130 million light-year separation from us, the event was big, bright and glorious. Based on the rarity of neutron stars—let alone ones that happen to merge—it is unlikely we will ever see such a display significantly closer to us. But let's imagine if we could—if it happened in the Milky Way or one of its several satellite galaxies. Or, heaven forbid, in our immediate stellar neighborhood. What would we see? What effects would it have on our home world? Would the environment, civilization, even humanity, emerge intact?

INSTANT ACTION

Although LIGO, by design, can "hear" the mergers of massive objects such as neutron stars and black holes, astronomers were still lucky to detect this particular event. According to Gabriela González, a LIGO team member and astrophysicist at Louisiana State University, if the merger had been three to four times farther away, we would not have heard it at all. Ironically, LIGO's exquisite tuning for detecting distant black hole mergers could make it miss big ones occurring around the solar system's nearest neighboring stars. The immense and intense gravitational waves from such a nearby event "would probably be [greater] than the dynamic range of our instrument," Gonzalez says.

Despite being strong enough to shake the universe, the gravitational waves from even a nearby merger of two large black holes would still be scarcely noticeable, because the shaking manifests on microscopic scales. (If gas, dust or any other matter was very close the merging black holes, however, astronomers might see light emitted from that infalling material as it plunges in.) "The amazing thing to me is that you could be so close to black holes colliding, even as close as just outside the solar system, and you wouldn't even notice the stretching of spacetime with your eyes," González says. "You would still need an instrument to see or measure it."

In contrast, a kilonova from a neutron star merger in our galaxy would probably be quite noticeable. Gonzalez says it could suddenly appear as a bright star in the sky, and would be clearly detectable by LIGO, too. Rather than lasting for a matter of seconds, the gravitational waves heard by LIGO would be drawn out over minutes, even hours, as the neutron stars spiraled ever-closer together before their ultimate coalescence. It would be a bit like tuning into a live Grateful Dead jam instead of a studio version. (And yes, let's say the song is "Dark Star" for our purposes.)
Even if LIGO tuned in, however, there are ways we might miss seeing much of the light from a nearby neutron star merger and its subsequent kilonova. Kari Frank, an astronomer at Northwestern University, says such a large, luminous event could end up obscured by dust and other stars—at least at visible and infrared wavelengths. In other words, LIGO and telescopes looking in wavelengths such as radio or x-ray might glimpse a nearby kilonova that optical astronomers would miss. "There have been supernovae—at least ones that we know of in our galaxy in the last 100 years or so—for which we didn't see the explosion at all, we only saw what was left afterward," Frank says. And a kilonova, for all the punch it packs, is only a fraction of the luminosity of a typical supernova.

Still, astronomers' responses to any stellar cataclysm in or around the Milky Way would likely be swift. After all, there's the example of supernova 1987A to consider.

THE BIG BOOM

As its name suggests, supernova 1987A occurred in 1987, unfolding in a dwarf galaxy that orbits the Milky Way called the Large Magellanic Cloud. A star about eight times the sun's mass collapsed in on itself and sent its outer envelope of gas out into interstellar space, forming a nebula of heavy elements and other debris before collapsing into either a neutron star or a black hole. It remains the only nearby supernova astronomers have seen in modern times.

Frank has studied the subsequent global campaign to observe supernova 1987A, focusing on how astronomers organized and executed their observations at a time when the internet was embryonic at best.“Somebody sees something, and they send out notices to everybody,” she says. “The people who first discovered it had to phone whomever they could to tell them that this thing was happening, that they saw this supernova in the sky that was really close by,” Frank says. “They sent these circulars—letters and things to people—and then everyone who could would go to their telescope and point to it.”

For months, astronomers worldwide scrutinized the event, utilizing almost every available telescope. “Everybody wanted to make sure that as many [telescopes] looked at it as possible,” Frank says. Eventually, things settled down, but several researchers—including Frank—are still studying the supernova’s remnants 30 years later.“For some people, it was life-changing, or at least career-changing,” Frank says. “This was *the* thing in astronomy that year.”

Like LIGO, the observation campaign for supernova 1987A involved thousands of collaborators. But not all of them shared in the glory of co-authoring any of the many resulting studies published in the scientific literature. Consequently, there’s no real head count of how many people participated. Counting collaborators working on the recent neutron star merger is much easier—some 3,000 authors across 67 papers, or an estimated 15 percent of the entire field of astrophysics.

The question of how many astrophysicists would receive credit for another event like supernova 1987A depends, in no small part, on just how close the event would be. If supernova 1987A had occurred much, much closer to Earth—around a nearby star, for instance—the key uncertainty could become not how many scientists observed the event, but how many *survived* it.

DEATH FROM ABOVE

According to a 2016 study, supernovae occurring as close as 50 light-years from Earth could pose an imminent danger to Earth's biosphere—humans included. The event would likely shower us in so much high-energy cosmic radiation that it could spark a planetary mass extinction. Researchers have tentatively linked past instances of spiking extinction rates and plummeting biodiversity to postulated astrophysical events, and in at least one case have even found definitive evidence for a nearby supernova as the culprit. Twenty million years ago, a star 325 light-years from Earth exploded, showering the planet in radioactive iron particles thateventually settled in deep-sea sedimentson the ocean floor. That event, researchers speculate, may have triggered ice ages and altered the course of evolution and human history.

The exact details of past (and future) astrophysical cataclysms' impact on Earth's biosphere depend not only on their distance, but also their orientation. A supernova, for instance, can sometimes expel its energy in all directions—meaning it is not always a very targeted phenomenon. Merging black holes are expected to emit scarcely any radiation at all, making them surprisingly benign for any nearby biosphere. A kilonova, however, has different physics at play. Neutron stars are a few dozen kilometers in radius rather than a few million like a typical stars. When these dense objects merge, they tend to produce jets that blast out gamma rays from their poles.

"[W]hat it looks like to us, and the effect it has on us, would depend a lot on whether or not one of the jets was pointed directly at us," Frank says. Based on its distance and orientation to Earth, a kilonova's jets would walk the fine line between a spectacular light show and a catastrophic stripping away of the planet's upper atmosphere. If a jet is pointed directly at us, drastic changes could be in store. And we probably wouldn't see them coming. A kilonova begins with a burst of gamma rays—incredibly energetic photons that, by definition, move at light-speed, the fastest anything can travel through the

universe. Because nothing else can move faster, those photons would strike first, and without warning.
“What [the gamma rays] would do, probably more than anything else, is dissolve the ozone layer,” says Andrew Fruchter, a staff astronomer at the Space Telescope Science Institute. Next, the sky would go blindingly white as the visible light from the kilonova encountered our planet. Trailing far behind the light would be slower-moving material ejected from the kilonova—radioactive particles of heavy elements that, sandblasting the Earth in sufficient numbers, could still pack a lethal punch.

That’s if the kilonova is close, though—within 50 light-years, give or take. At a safer distance, the gamma rays would still singe the ozone layer on the facing hemisphere, but the other side would be shielded by the planet’s bulk. “Most radiation happens very quickly, so half the Earth would be hidden,” Fruchter says. There would still be a momentarily blinding light. For a few weeks, a new star would burn bright in the sky before gradually fading back into obscurity.

IMPROBABILITIES

Don’t let all this keep you up at night. Kilonovae are relatively rare cosmic phenomena, estimated to occur just once every 10,000 years in a galaxy like the Milky Way. That’s because neutron stars, which are produced by supernovae, hardly ever form as pairs. Usually, a neutron star will receive a hefty “kick” from its formative supernova; sometimes these kicks are strong enough to eject a neutron star entirely from its galaxy to hurtle at high speeds indefinitely through the cosmos. “When neutron stars are born, they’re often high-velocity. For them to survive in a binary is nontrivial,” Fruchter says. And the chances of two finding each other and merging after forming independently are, for lack of a better term, astronomically low.

The binary neutron stars we know of in our galaxy are millions or billions of years away from merging. Any local merger of neutron stars at all would take LIGO by surprise, given that the events are so rare, and astronomers might not even see the resulting kilonova at all. But if one did occur—say, in one of the Milky Way's satellite galaxies—it would be a great reason to run to a telescope to witness the flash and fade of a brief, brilliant new "star." The dangers would be nearly nonexistent, but not the payoff: Our generation of astronomers would have their own supernova 1987A to dissect. "This is a once-in-many-lifetimes kind of event," Frank says. Thus, she says, we would need to follow something like it with all the world's astronomical resources. "We have to remember to think beyond the initial explosion," she adds. "Stuff might still happen and we have to keep a watch out for that."

For now astronomers' attentions are still fixated on the kilonova in NGC 4993. The Earth's orbital motion has placed the sun between us and the distant galaxy, however, hiding the kilonova's fading afterglow. When our view clears, in December, many of the world's telescopic eyes will again turn to the small patch of sky containing the merger. In the meantime papers will be penned and published, careers minted, reputations secured. Science will march on, and wait—wait for the next possible glimpse of a kilonova, the whispers of a neutron star merger or, if we're lucky, something new altogether.

The **Universe** is all of space and time (spacetime) and its contents,[12] which includes planets, moons, minor planets, stars, galaxies, the contents of intergalactic space and all matter and energy.[13][14] The size of the entire Universe is still unknown.[6]

The earliest scientific models of the Universe were developed by ancient Greek and Indian philosophers and were geocentric, placing Earth at the centre of the Universe.[15][16] Over the centuries, more precise astronomical observations led Nicolaus Copernicus to develop the heliocentric model with the Sun at the centre of the Solar System. In developing the law of universal gravitation, Sir Isaac Newton built upon Copernicus's work as well as observations by Tycho Brahe and Johannes Kepler's laws of planetary motion.

Further observational improvements led to the realization that our Solar System is located in the Milky Way galaxy, which is one of many galaxies in the Universe. It is assumed that galaxies are distributed uniformly and the same in all directions, meaning that the Universe has neither an edge nor a center. Discoveries in the early 20th century have suggested that the Universe had a beginning and that it is expanding[17] at an increasing rate.[18] The majority of mass in the Universe appears to exist in an unknown form called dark matter.

The Big Bang theory is the prevailing cosmological description of the development of the Universe. Under this theory, space and time emerged together 13.799±0.021 billion years ago[2] with a fixed amount of energy and matter that has become less dense as the Universe has expanded. After the initial expansion, the Universe cooled, allowing the first subatomic particles to form and then simple atoms. Giant clouds later merged through gravity to form galaxies, stars, and everything else seen today. It is possible to see objects that are now further away than 13.799 billion light-years because space itself has expanded. This means that objects which are now 46 billion light years away can still be seen in their distant past, because at that time they were much closer to us.

There are many competing hypotheses about the ultimate fate of the Universe and about what, if anything, preceded the Big Bang, while other physicists and philosophers refuse to speculate, doubting that information about prior states will ever be accessible. Some physicists have suggested various multiverse hypotheses, in which the Universe might be one among many universes that likewise exist.[6][19][20]

The spacetime of the Universe is usually interpreted from a Euclidean perspective, with space as consisting of three dimensions, and time as consisting of one dimension, the "fourth dimension".[39] By combining space and time into a single manifold called Minkowski space, physicists have simplified a large number of physical theories, as well as described in a more uniform way the workings of the Universe at both the supergalactic and subatomic levels.

Spacetime events are not absolutely defined spatially and temporally but rather are known relative to the motion of an observer. Minkowski space approximates the Universe without gravity; the pseudo-Riemannian manifolds of general relativity describe spacetime with matter and gravity. String theory postulates the existence of additional dimensions.

Of the four fundamental interactions, gravitation is dominant at cosmological length scales, including galaxies and larger-scale structures. Gravity's effects are cumulative; by contrast, the effects of positive and negative charges tend to cancel one another, making electromagnetism relatively insignificant on cosmological length scales. The remaining two interactions, the weak and strong nuclear forces, decline very rapidly with distance; their effects are confined mainly to sub-atomic length scales.

The Universe appears to have much more matter than antimatter, an asymmetry possibly related to the observations of CP violation.[40] The Universe also appears to have neither net momentum nor angular momentum. The absence of net charge and momentum would follow from accepted physical laws (Gauss's law and the non-divergence of the stress-energy-momentum pseudotensor, respectively) if the Universe were finite.[41]

In October 2017, scientists reported further evidence that matter and antimatter, equally produced at the Big Bang, are identical, should completely annihilate each other and, as a result, the universe should not exist.[42][43]

General relativity describes how spacetime is curved and bent by mass and energy. The topology or geometry of the Universe includes both local geometry in the observable universe and global geometry. Cosmologists often work with a given space-like slice of spacetime called the comoving coordinates. The section of spacetime which can be observed is the backward light cone, which delimits the cosmological horizon. The cosmological horizon (also called the particle horizon or the light horizon) is the maximum distance from which particles can have traveled to the observer in the age of the Universe. This horizon represents the boundary between the observable and the unobservable regions of the Universe.[44][45] The existence, properties, and significance of a cosmological horizon depend on the particular cosmological model.

An important parameter determining the future evolution of the Universe theory is the density parameter, Omega (Ω), defined as the average matter density of the universe divided by a critical value of that density. This selects one of three possible geometries depending on whether Ω is equal to, less than, or greater than 1. These are called, respectively, the flat, open and closed universes.[46]

Observations, including the Cosmic Background Explorer (COBE), Wilkinson Microwave Anisotropy Probe (WMAP), and Planck maps of the CMB, suggest that the Universe is infinite in extent with a finite age, as described by the Friedmann–Lemaître–Robertson–Walker(FLRW) models.[47][48][49][50] These FLRW models thus support inflationary models and the standard model of cosmology, describing a flat, homogeneous universe presently dominated by dark matter and dark energy.[51][52]

Size and regions

See also: Observable universe and Observational cosmology

The size of the Universe is somewhat difficult to define. According to a restrictive definition, the Universe is everything within our connected spacetime that could have a chance to interact with us and vice versa.[53] According to the general theory of relativity, some regions of space may never interact with ours even in the lifetime of the Universe due to the finite speed of light and the ongoing expansion of space. For example, radio messages sent from Earth may never reach some regions of space, even if the Universe were to exist forever: space may expand faster than light can traverse it.[54]

Distant regions of space are assumed to exist and to be part of reality as much as we are, even though we can never interact with them. The spatial region that we can affect and be affected by is the observable universe. The observable universe depends on the location of the observer. By traveling, an observer can come into contact with a greater region of spacetime than an observer who remains still. Nevertheless, even the most rapid traveler will not be able to interact with all of space. Typically, the observable universe is taken to mean the portion of the Universe that is observable from our vantage point in the Milky Way.

The proper distance—the distance as would be measured at a specific time, including the present—between Earth and the edge of the observable universe is 46 billion light-years (14 billion parsecs), making the diameter of the observable universe about 91 billion light-years (28×10^9 pc). The distance the light from the edge of the observable universe has travelled is very close to the age of the Universe times the speed of light, 13.8 billion light-years (4.2×10^9 pc), but this does not represent the distance at any given time because the edge of the observable universe and the Earth have since moved further apart.[55] For comparison, the diameter of a typical galaxy is 30,000 light-years (9,198 parsecs), and the typical distance between two neighboring galaxies is 3 million light-years (919.8 kiloparsecs).[56] As an example, the Milky Way is roughly 100,000–180,000 light years in diameter,[57][58] and the nearest sister galaxy to the Milky Way, the Andromeda Galaxy, is located roughly 2.5 million light years away.[59] Because we cannot observe space beyond the edge of the observable universe, it is unknown whether the size of the Universe is finite or infinite.[6][60][61]

Age and expansion

Main articles: Age of the universe and Metric expansion of space

Astronomers calculate the age of the Universe by assuming that the Lambda-CDM model accurately describes the evolution of the Universe from a very uniform, hot, dense primordial state to its present state and measuring the cosmological parameters which constitute the model.[*citation needed*] This model is well understood theoretically and supported by recent high-precision astronomical observations such as WMAP and Planck.[*citation needed*] Commonly, the set of observations fitted includes the cosmic microwave backgroundanisotropy, the brightness/redshift relation for Type Ia supernovae, and large-scale galaxy clustering including the baryon acoustic oscillation feature.[*citation needed*] Other observations, such as the Hubble constant, the abundance of galaxy clusters, weak gravitational lensing and globular cluster ages, are generally consistent with these, providing a check of the model, but are less accurately measured at present.[*citation needed*] With the prior that the Lambda-CDM model is correct, the measurements of the parameters using a variety of techniques by numerous experiments yield a best value of the age of the Universe as of 2015 of 13.799 ± 0.021 billion years.[2]

Over time, the Universe and its contents have evolved; for example, the relative population of quasars and galaxies has changed[62] and space itself has expanded. Due to this expansion, scientists on Earth can observe the light from a galaxy 30 billion light years away even though that light has traveled for only 13 billion years; the very space between them has expanded. This expansion is consistent with the observation that the light from distant galaxies has been redshifted; the photons emitted have been stretched to longer wavelengths and lower frequency during their journey. Analyses of Type Ia supernovae indicate that the spatial expansion is accelerating.[63][64]

The more matter there is in the Universe, the stronger the mutual gravitational pull of the matter. If the Universe were *too* dense then it would re-collapse into a gravitational singularity. However, if the Universe contained too *little* matter then the expansion would accelerate too rapidly for planets and planetary systems to form. Since the Big Bang, the universe has expanded monotonically. Perhaps unsurprisingly, our universe has just the right mass density of about 5 protons per cubic meter which has allowed it to expand for the last 13.8 billion years, giving time to form the universe as observed today.[65]

There are dynamical forces acting on the particles in the Universe which affect the expansion rate. Before 1998, it was expected that the rate of increase of the Hubble Constant would be decreasing as time went on due to the influence of gravitational interactions in the Universe, and thus there is an additional observable quantity in the Universe called the deceleration parameter which cosmologists expected to be directly related to the matter density of the Universe. In 1998, the deceleration parameter was measured by two different groups to be consistent with −1 but not zero, which implied that the present-day rate of increase of the Hubble Constant is increasing over time.[18][66]

Spacetime

Main articles: Spacetime and World line

See also: Lorentz transformation

Spacetimes are the arenas in which all physical events take place—an event is a point in spacetime specified by its time and place. The basic elements of spacetime are events. In any given spacetime, an event is a unique position at a unique time. Because events are spacetime points, in classical relativistic physics, the location of an elementary (point-like) particle at a particular time can be written as (x, y, z, t). A spacetime is the union of all events in the same way that a line is the union of all of its points, formally organized into a manifold.[67]

The Universe appears to be a smooth spacetime continuum consisting of three spatial dimensions and one temporal (time) dimension. On the average, space is observed to be very nearly flat (close to zero curvature), meaning that Euclidean geometry is empirically true with high accuracy throughout most of the Universe.[68] Spacetime also appears to have a simply connected topology, in analogy with a sphere, at least on the length-scale of the observable Universe. However, present observations cannot exclude the possibilities that the Universe has more dimensions and that its spacetime may have a multiply connected global topology, in analogy with the cylindrical or toroidal topologies of two-dimensional spaces.[48][69]

Contents

The formation of clusters and large-scale filaments in the cold dark matter model with dark energy. The frames show the evolution of structures in a 43 million parsecs (or 140 million light years) box from redshift of 30 to the present epoch (upper left z=30 to lower right z=0).

See also: Galaxy formation and evolution, Galaxy cluster, Illustris project, and Nebula

The Universe is composed almost completely of dark energy, dark matter, and ordinary matter. Other contents are electromagnetic radiation (estimated to be from 0.005% to close to 0.01%) and antimatter.[70][71][72] The total amount of electromagnetic radiation generated within the universe has decreased by 1/2 in the past 2 billion years.[73][74]

The proportions of all types of matter and energy have changed over the history of the Universe.[75] Today, ordinary matter, which includes atoms, stars, galaxies, and life, accounts for only 4.9% of the contents of the Universe.[10] The present overall density of this type of matter is very low, roughly 4.5 × 10^{-31} grams per cubic centimetre, corresponding to a density of the order of only one proton for every four cubic meters of volume.[8] The nature of both dark energy and dark matter is unknown. Dark matter, a mysterious form of matter that has not yet been identified, accounts for 26.8% of the contents. Dark energy, which is the energy of empty space and is causing the expansion of the Universe to accelerate, accounts for the remaining 68.3% of the contents.[10][76][77]

A map of the superclusters and voidsnearest to Earth

Matter, dark matter, and dark energy are distributed homogeneously throughout the Universe over length scales longer than 300 million light-years or so.[78] However, over shorter length-scales, matter tends to clump hierarchically; many atoms are condensed into stars, most stars into galaxies, most galaxies into clusters, superclusters and, finally, large-scale galactic filaments. The observable Universe contains approximately 300 sextillion (3×10^{23}) stars[79] and more than 100 billion (10^{11}) galaxies.[80] Typical galaxies range from dwarfswith as few as ten million[81] (10^{7}) stars up to giants with one trillion[82] (10^{12}) stars. Between the structures are voids, which are typically 10–150 Mpc (33 million–490 million ly) in diameter. The Milky Way is in the Local Group of galaxies, which in turn is in the Laniakea Supercluster.[83] This supercluster spans over 500 million light years, while the Local Group spans over 10 million light years.[84] The Universe also has vast regions of relative emptiness; the largest known void measures 1.8 billion ly (550 Mpc) across.[85]

Comparison of the contents of the Universe today to 380,000 years after the Big Bang as measured with 5 year WMAP data (from 2008).[86] (Due to rounding errors, the sum of these numbers is not 100%). This reflects the 2008 limits of WMAP's ability to define dark matter and dark energy.

The observable Universe is isotropic on scales significantly larger than superclusters, meaning that the statistical properties of the Universe are the same in all directions as observed from Earth. The Universe is bathed in highly isotropic microwave radiation that corresponds to a thermal equilibrium blackbody spectrum of roughly 2.72548 kelvin.[9] The hypothesis that the large-scale Universe is homogeneous and isotropic is known as the cosmological principle.[87] A Universe that is both homogeneous and isotropic looks the same from all vantage points[88] and has no center.[89]

Dark energy

Main article: Dark energy

An explanation for why the expansion of the Universe is accelerating remains elusive. It is often attributed to "dark energy", an unknown form of energy that is hypothesized to permeate space.[90] On a mass–energy equivalence basis, the density of dark energy (~ 7 × 10^{-30}g/cm^3) is much less than the density of ordinary matter or dark matter within galaxies. However, in the present dark-energy era, it dominates the mass–energy of the universe because it is uniform across space.[91][92]

Two proposed forms for dark energy are the cosmological constant, a *constant* energy density filling space homogeneously,[93] and scalar fields such as quintessence or moduli, *dynamic* quantities whose energy density can vary in time and space. Contributions from scalar fields that are constant in space are usually also included in the cosmological constant. The cosmological constant can be formulated to be equivalent to vacuum energy. Scalar fields having only a slight amount of spatial inhomogeneity would be difficult to distinguish from a cosmological constant.

Dark matter

Main article: Dark matter

Dark matter is a hypothetical kind of matter that is invisible to the entire electromagnetic spectrum, but which accounts for most of the matter in the Universe. The existence and properties of dark matter are inferred from its gravitational effects on visible matter, radiation, and the large-scale structure of the Universe. Other than neutrinos, a form of hot dark matter, dark matter has not been detected directly, making it one of the greatest mysteries in modern astrophysics. Dark matter neither emits nor absorbs light or any other electromagnetic radiation at any significant level. Dark matter is estimated to constitute 26.8% of the total mass–energy and 84.5% of the total matter in the Universe.[76][94]

Ordinary Matter

Main article: Matter

The remaining 4.9% of the mass–energy of the Universe is ordinary matter, that is, atoms, ions, electrons and the objects they form. This matter includes stars, which produce nearly all of the light we see from galaxies, as well as interstellar gas in the interstellar and intergalactic media, planets, and all the objects from everyday life that we can bump into, touch or squeeze.[95] As a matter of fact, the great majority of ordinary matter in the universe is unseen, since visible stars and gas inside galaxies and clusters account for less than 10 per cent of the ordinary matter contribution to the mass-energy density of the universe.[96]

Ordinary matter commonly exists in four states (or phases): solid, liquid, gas, and plasma. However, advances in experimental techniques have revealed other previously theoretical phases, such as Bose–Einstein condensates and fermionic condensates.

Ordinary matter is composed of two types of elementary particles: quarks and leptons.[97] For example, the proton is formed of two up quarks and one down quark; the neutron is formed of two down quarks and one up quark; and the electron is a kind of lepton. An atom consists of an atomic nucleus, made up of protons and neutrons, and electrons that orbit the nucleus. Because most of the mass of an atom is concentrated in its nucleus, which is made up of baryons, astronomers often use the term *baryonic matter* to describe ordinary matter, although a small fraction of this "baryonic matter" is electrons.

Soon after the Big Bang, primordial protons and neutrons formed from the quark–gluon plasma of the early Universe as it cooled below two trillion degrees. A few minutes later, in a process known as Big Bang nucleosynthesis, nuclei formed from the primordial protons and neutrons. This nucleosynthesis formed lighter elements, those with small atomic numbers up to lithium and beryllium, but the abundance of heavier elements dropped off sharply with increasing atomic number. Some boron may have been formed at this time, but the next heavier element, carbon, was not formed in significant amounts. Big Bang nucleosynthesis shut down after about 20 minutes due to the rapid drop in temperature and density of the expanding Universe. Subsequent formation of heavier elements resulted from stellar nucleosynthesis and supernova nucleosynthesis.[98]

Particles

Standard model of elementary particles: the 12 fundamental fermions and 4 fundamental bosons. Brown loops indicate which bosons (red) couple to which fermions (purple and green). Columns are three generations of matter (fermions) and one of forces (bosons). In the first three columns, two rows contain quarks and two leptons. The top two rows' columns contain up (u) and down (d) quarks, charm (c) and strange (s) quarks, top (t) and bottom (b) quarks, and photon (γ) and gluon (g), respectively. The bottom two rows' columns contain electron neutrino (ν_e) and electron (e), muon neutrino (ν_μ) and muon (μ), tau neutrino (ν_τ) and tau (τ), and the Z^0 and $W^\pm$ carriers of the weak force. Mass, charge, and spin are listed for each particle.

Main article: Particle physics

Ordinary matter and the forces that act on matter can be described in terms of elementary particles.[99] These particles are sometimes described as being fundamental, since they have an unknown substructure, and it is unknown whether or not they are composed of smaller and even more fundamental particles.[100][101] Of central importance is the Standard Model, a theory that is concerned with electromagnetic interactions and the weak and strong nuclear interactions.[102] The Standard Model is supported by the experimental confirmation of the existence of particles that compose matter: quarks and leptons, and their corresponding "antimatter" duals, as well as the force particles that mediate interactions: the photon, the W and Z bosons, and the gluon.[100] The Standard Model predicted the existence of the recently discovered Higgs boson, a particle that is a manifestation of a field within the Universe that can endow particles with mass.[103][104] Because of its success in explaining a wide variety of experimental results, the Standard Model is sometimes regarded as a "theory of almost everything".[102] The Standard Model does not, however, accommodate gravity. A true force-particle "theory of everything" has not been attained.[105]

Hadrons

Main article: Hadron

A hadron is a composite particle made of quarks held together by the strong force. Hadrons are categorized into two families: baryons (such as protons and neutrons) made of three quarks, and mesons (such as pions) made of one quark and one antiquark. Of the hadrons, protons are stable, and neutrons bound within atomic nuclei are stable. Other hadrons are unstable under ordinary conditions and are thus insignificant constituents of the modern Universe. From approximately 10^{-6} seconds after the Big Bang, during a period is known as the hadron epoch, the temperature of the universe had fallen sufficiently to allow quarks to bind together into hadrons, and the mass of the Universe was dominated by hadrons. Initially the temperature was high enough to allow the formation of hadron/anti-hadron pairs, which kept matter and antimatter in thermal equilibrium. However, as the temperature of the Universe continued to fall, hadron/anti-hadron pairs were no longer produced. Most of the hadrons and anti-hadrons were then eliminated in particle-antiparticle annihilation reactions, leaving a small residual of hadrons by the time the Universe was about one second old.[106]:244–266

Leptons

Main article: Lepton

A lepton is an elementary, half-integer spin particle that does not undergo strong interactions but is subject to the Pauli exclusion principle; no two leptons of the same species can be in exactly the same state at the same time.[107] Two main classes of leptons exist: charged leptons (also known as the *electron-like* leptons), and neutral leptons (better known as neutrinos). Electrons are stable and the most common charged lepton in the Universe, whereas muons and taus are unstable particle that quickly decay after being produced in high energy collisions, such as those involving cosmic rays or carried out in particle accelerators.[108][109] Charged leptons can combine with other particles to form various composite particles such as atoms and positronium. The electron governs nearly all of chemistry, as it is found in atoms and is directly tied to all chemical properties. Neutrinos rarely interact with anything, and are consequently rarely observed. Neutrinos stream throughout the Universe but rarely interact with normal matter.[110]

The lepton epoch was the period in the evolution of the early Universe in which the leptons dominated the mass of the Universe. It started roughly 1 second after the Big Bang, after the majority of hadrons and anti-hadrons annihilated each other at the end of the hadron epoch. During the lepton epoch the temperature of the Universe was still high enough to create lepton/anti-lepton pairs, so leptons and anti-leptons were in thermal equilibrium. Approximately 10 seconds after the Big Bang, the temperature of the Universe had fallen to the point where lepton/anti-lepton pairs were no longer created.[111] Most leptons and anti-leptons were then eliminated in annihilation reactions, leaving a small residue of leptons. The mass of the Universe was then dominated by photons as it entered the following photon epoch.[112][113]

Photons

Main article: Photon epoch

See also: Photino

A photon is the quantum of light and all other forms of electromagnetic radiation. It is the force carrier for the electromagnetic force, even when static via virtual photons. The effects of this force are easily observable at the microscopic and at the macroscopic level because the photon has zero rest mass; this allows long distance interactions. Like all elementary particles, photons are currently best explained by quantum mechanics and exhibit wave–particle duality, exhibiting properties of waves and of particles.

The photon epoch started after most leptons and anti-leptons were annihilated at the end of the lepton epoch, about 10 seconds after the Big Bang. Atomic nuclei were created in the process of nucleosynthesis which occurred during the first few minutes of the photon epoch. For the remainder of the photon epoch the Universe contained a hot dense plasma of nuclei, electrons and photons. About 380,000 years after the Big Bang, the temperature of the Universe fell to the point where nuclei could combine with electrons to create neutral atoms. As a result, photons no longer interacted frequently with matter and the Universe became transparent. The highly redshifted photons from this period form the cosmic microwave background. Tiny variations in temperature and density detectable in the CMB were the early "seeds" from which all subsequent structure formation took place.[

The universe was born with the Big Bang as an unimaginably hot, dense point. When the universe was just 10^{-34} of a second or so old — that is, a hundredth of a billionth of a trillionth of a trillionth of a second in age — it experienced an incredible burst of expansion known as inflation, in which space itself expanded faster than the speed of light. During this period, the universe doubled in size at least 90 times, going from subatomic-sized to golf-ball-sized almost instantaneously.

The work that goes into understanding the expanding universe comes from a combination of theoretical physics and direct observations by astronomers. However, in some cases astronomers have not been able to see direct evidence — such as the case of gravitational waves associated with the cosmic microwave background, the leftover radiation from the Big Bang. A preliminary announcement about finding these waves in 2014 was quickly retracted, after astronomers found the signal detected could be explained by dust in the Milky Way.

According to NASA, after inflation the growth of the universe continued, but at a slower rate. As space expanded, the universe cooled and matter formed. One second after the

Big Bang, the universe was filled with neutrons, protons, electrons, anti-electrons, photons and neutrinos.

During the first three minutes of the universe, the light elements were born during a process known as Big Bang nucleosynthesis. Temperatures cooled from 100 nonillion (10^{32}) Kelvin to 1 billion (10^{9}) Kelvin, and protons and neutrons collided to make deuterium, an isotope of hydrogen. Most of the deuterium combined to make helium, and trace amounts of lithium were also generated.

For the first 380,000 years or so, the universe was essentially too hot for light to shine, according to France's National Center of Space Research (Centre National d'Etudes Spatiales, or CNES). The heat of creation smashed atoms together with enough force to break them up into a dense plasma, an opaque soup of protons, neutrons and electrons that scattered light like fog.

Roughly 380,000 years after the Big Bang, matter cooled enough for atoms to form during the era of recombination, resulting in a transparent, electrically neutral gas, according to NASA. This set loose the initial flash of light created during the Big Bang, which is detectable today as cosmic microwave background radiation. However, after this point, the universe was plunged into darkness, since no stars or any other bright objects had formed yet.

About 400 million years after the Big Bang, the universe began to emerge from the cosmic dark ages during the epoch of reionization. During this time, which lasted more than a half-billion years, clumps of gas collapsed enough to form the first stars and galaxies, whose energetic ultraviolet light ionized and destroyed most of the neutral hydrogen.

Although the expansion of the universe gradually slowed down as the matter in the universe pulled on itself via gravity, about 5 or 6 billion years after the Big Bang, according to NASA, a mysterious force now called dark energy began speeding up the expansion of the universe again, a phenomenon that continues today.

A little after 9 billion years after the Big Bang, our solar system was born.

The Big Bang

The Big Bang did not occur as an explosion in the usual way one think about such things, despite one might gather from its name. The universe did not expand into space, as space did not exist before the universe, according to NASA Instead, it is better to think of the Big Bang as the simultaneous appearance of space everywhere in the universe. The universe has not expanded from any one spot since the Big Bang — rather, space itself has been stretching, and carrying matter with it.

Since the universe by its definition encompasses all of space and time as we know it, NASA says it is beyond the model of the Big Bang to say what the universe is expanding into or what gave rise to the Big Bang. Although there are models that speculate about these questions, none of them have made realistically testable predictions as of yet.

In 2014, scientists from the Harvard-Smithsonian Center for Astrophysics announced that they had found a faint signal in the cosmic microwave background that could be the first direct evidence of gravitational waves, themselves considered a "smoking gun" for the Big Bang. The findings were hotly debated, and astronomers soon retracted their results when they realized dust in the Milky Way could explain their findings. mysterious ripples

The globular cluster NGC 6397 contains around 400,000 stars and is located about 7,200 light years away in the southern constellation Ara. With an estimated age of 13.5 billion years, it is likely among the first objects of the Galaxy to form after the Big Bang.

Credit: European Southern Observatory

Age

The universe is currently estimated at roughly 13.8 billion years old, give or take 130 million years. In comparison, the solar system is only about 4.6 billion years old.

This estimate came from measuring the composition of matter and energy density in the universe. This allowed researchers to compute how fast the universe expanded in the past. With that knowledge, they could turn the clock back and extrapolate when the Big Bang happened. The time between then and now is the age of the universe.

Structure

Scientists think that in the earliest moments of the universe, there was no structure to it to speak of, with matter and energy distributed nearly uniformly throughout. According to NASA, the gravitational pull of small fluctuations in the density of matter back then gave rise to the vast web-like structure of stars and emptiness seen today. Dense regions pulled in more and more matter through gravity, and the more massive they became, the more matter they could pull in through gravity, forming stars, galaxies and larger structures known as clusters, superclusters, filaments and walls, with "great walls" of thousands of galaxies reaching more than a billion light years in length. Less dense regions did not grow, evolving into area of seemingly empty space called voids.

Content

Until about 30 years ago, astronomers thought that the universe was composed almost entirely of ordinary atoms, or "baryonic matter," According to NASA. However, recently there has been ever more evidence that suggests most of the ingredients making up the universe come in forms that we cannot see.

It turns out that atoms only make up 4.6 percent of the universe. Of the remainder, 23 percent is made up of dark matter, which is likely composed of one or more species of subatomic particles that interact very weakly with ordinary matter, and 72 percent is made of dark energy, which apparently is driving the accelerating expansion of the universe.

When it comes to the atoms we are familiar with, hydrogen makes up about 75 percent, while helium makes up about 25 percent, with heavier elements making up only a tiny fraction of the universe's atoms, according to NASA.

Shape

The shape of the universe and whether or not it is finite or infinite in extent depends on the struggle between the rate of its expansion and the pull of gravity. The strength of the pull in question depends in part on the density of the matter in the universe.

If the density of the universe exceeds a specific critical value, then the universe is "closed" and "positive curved" like the surface of a sphere. This means light beams that are initially parallel will converge slowly, eventually cross and return back to their starting point, if the universe lasts long enough. If so, according to NASA, the universe is not infinite but has no end, just as the area on the surface of a sphere is not infinite but has no beginning or end to speak of. The universe will eventually stop expanding and start collapsing in on itself, the so-called "Big Crunch."

If the density of the universe is less than this critical density, then the geometry of space is "open" and "negatively curved" like the surface of a saddle. If so, the universe has no bounds, and will expand forever.

If the density of the universe exactly equals the critical density, then the geometry of the universe is "flat" with zero curvature like a sheet of paper, according to NASA. If so, the universe has no bounds and will expand forever, but the rate of expansion will gradually approach zero after an infinite amount of time. Recent measurements suggest that the universe is flat with only a 2 percent margin of error.

It is possible that the universe has a more complicated shape overall while seeming to possess a different curvature. For instance, the universe could have the shape of a torus, or doughnut.

Expanding universe

In the 1920s, astronomer Edwin Hubble discovered the universe was not static. Rather, it was expanding; a find that revealed the universe was apparently born in a Big Bang.

After that, it was long thought the gravity of matter in the universe was certain to slow the expansion of the universe. Then, in 1998, the Hubble Space Telescope's observations of very distant supernovae revealed that a long time ago, the universe was expanding more slowly than it is today. In other words, the expansion of the universe was not slowing due to gravity, but instead inexplicably was accelerating. The name for the unknown force driving this accelerating expansion is dark energy, and it remains one of the greatest mysteries in science.

Earth's moon is the brightest object in our night sky and the closest celestial body. Its presence and proximity play a huge role in making life possible here on Earth. The moon's gravitational pull stabilizes Earth's wobble on its axis, leading to a stable climate.

The moon's orbit around Earth is elliptical. At perigee — its closest approach — the moon comes as close as 225,623 miles (363,104 kilometers). At apogee — the farthest away it gets — the moon is 252,088 miles (405,696 km) from Earth. On average, the distance from Earth to the moon is about 238,855 miles (384,400 km). According to NASA, "That means 30 Earth-sized planets could fit in between Earth and the moon."

That wasn't always the case. Scientists think the moon formed when a massive Mars-sized object collided with the young planet. Gravity pulled the debris from the crash together to form the moon. Earth and its newly formed companion were 10 to 20 times closer together at their birth than they are now.

"The moon and Earth loomed large in each others skies when they formed, " Arpita Roy, then a graduate student at Pennsylvania State, said in a statement.

Today, the moon is moving away from Earth at a rate of about 1.5 inches (4 cm) per year.

The moon is in synchronous rotation with Earth. In other words, the moon rotates on its axis in about the same amount of time it takes to revolve around Earth — 27 days 8 hours, which is called sidereal month. So we always see the same side of the moon; there is no "dark side of the moon." Instead, scientists refer to the side of the moon facing away from the planet as the "far side of the moon." The far side can be spotted by missions such as NASA's DSCOVR satellite, which captured a video of the moon "photobombing" Earth.

A lunar month, also called a synodic month, is the time it takes for the moon to complete a lunar cycle — full moon to full moon. A lunar month is about 29 days 13 hours.

How long does it take to get to the moon?

A range of factors determines how long it takes to reach the moon. Human missions, for instance, tend to take longer than passenger-free satellites. Whether or not an object stops at the moon or just zips by also comes into play.

The USSR launched the first mission to the moon, Luna 1, in 1959. With no propulsion system, the sphere-shaped satellite was hurled into space, and took only 34 flight-hours to make the trip. After its flyby, the satellite went into orbit around the sun, between the orbits of Earth and Mars. This remains one of the fastest trips to the moon.

In 2003, the European Space Agency launched SMART-1, the first successful European spacecraft to the moon. Rather than travel a direct path, SMART-1 spiraled around Earth to reach its satellite, arriving more than a year after launch. Instead of propellant, SMART-1 made the first use of an ion engine, in combination with gravity assist maneuvers, to reach the moon making it extremely fuel efficient. The extended path provided significant insight into the Earth-moon system

"Operating SMART-1 has been an extremely complex but rewarding task," Octavio Camino-Ramos, ESA SMART-1 Spacecraft Operations Manager said in a statement.

"The long spiraling trajectory around Earth to test solar electric propulsion (a low-thrust approach), the long exposure to radiation, the strong perturbations of the gravity fields of the Earth-moon system and then the reaching of a lunar orbit optimized for the scientific investigations, have allowed us to gain valuable expertise in navigation techniques for low-thrust propulsion." He called the findings "a remarkable benchmark for the future."

NASA sent eight crewed Apollo missions to the moon, six of which landed successfully. (Apollo 8 was the first mission to orbit another body and Apollo 13's infamous disaster resulted in a journey around the moon rather than a landing on its surface.) Each spent about three days traveling through space.

- MORE

The NASA/NOAA DSCOVR spacecraft captured this view of the moon crossing Earth's face in July 2016.

Credit: NASA/NOAA

Earth's moon is the brightest object in our night sky and the closest celestial body. Its presence and proximity play a huge role in making life possible here on Earth. The moon's gravitational pull stabilizes Earth's wobble on its axis, leading to a stable climate.

The moon's orbit around Earth is elliptical. At perigee — its closest approach — the moon comes as close as 225,623 miles (363,104 kilometers). At apogee — the farthest away it gets — the moon is 252,088 miles (405,696 km) from Earth. On average, the distance from Earth to the moon is about 238,855 miles (384,400 km). According to NASA, "That means 30 Earth-sized planets could fit in between Earth and the moon."

That wasn't always the case. Scientists think the moon formed when a massive Mars-sized object collided with the young planet. Gravity pulled the debris from the crash together to form the moon. Earth and its newly formed companion were 10 to 20 times closer together at their birth than they are now.

"The moon and Earth loomed large in each others skies when they formed, " Arpita Roy, then a graduate student at Pennsylvania State, said in a statement.

Today, the moon is moving away from Earth at a rate of about 1.5 inches (4 cm) per year.

The moon is in synchronous rotation with Earth. In other words, the moon rotates on its axis in about the same amount of time it takes to revolve around Earth — 27 days 8 hours, which is called sidereal month. So we always see the same side of the moon; there is no "dark side of the moon." Instead, scientists refer to the side of the moon facing away from the planet as the "far side of the moon." The far side can be spotted by missions such as NASA's DSCOVR satellite, which captured a video of the moon "photobombing" Earth.

A lunar month, also called a synodic month, is the time it takes for the moon to complete a lunar cycle — full moon to full moon. A lunar month is about 29 days 13 hours.

How long does it take to get to the moon?

A range of factors determines how long it takes to reach the moon. Human missions, for instance, tend to take longer than passenger-free satellites. Whether or not an object stops at the moon or just zips by also comes into play.

The USSR launched the first mission to the moon, Luna 1, in 1959. With no propulsion system, the sphere-shaped satellite was hurled into space, and took only 34 flight-hours to make the trip. After its flyby, the satellite went into orbit around the sun, between the orbits of Earth and Mars. This remains one of the fastest trips to the moon.

In 2003, the European Space Agency launched SMART-1, the first successful European spacecraft to the moon. Rather than travel a direct path, SMART-1 spiraled around Earth to reach its satellite, arriving more than a year after launch. Instead of propellant, SMART-1 made the first use of an ion engine, in combination with gravity assist maneuvers, to reach the moon making it extremely fuel efficient. The extended path provided significant insight into the Earth-moon system

"Operating SMART-1 has been an extremely complex but rewarding task," Octavio Camino-Ramos, ESA SMART-1 Spacecraft Operations Manager said in a statement. "The long spiraling trajectory around Earth to test solar electric propulsion (a low-thrust approach), the long exposure to radiation, the strong perturbations of the gravity fields of the Earth-moon system and then the reaching of a lunar orbit optimized for the scientific investigations, have allowed us to gain valuable expertise in navigation techniques for low-thrust propulsion." He called the findings "a remarkable benchmark for the future."

NASA sent eight crewed Apollo missions to the moon, six of which landed successfully. (Apollo 8 was the first mission to orbit another body and Apollo 13's infamous disaster resulted in a journey around the moon rather than a landing on its surface.) Each spent about three days traveling through space.

Apollo 8 took 69 hours, 8 minutes to enter orbit around the moon. Apollo 11, which placed the first humans on the moon, took 75 hours and 56 minutes to enter orbit around the moon. Long before they entered orbit, however, both spacecraft entered the moon's sphere of influence, a region 33,823 nautical miles (62,630 km) from the moon. For Apollo 11, this occurred after 61 hours and 56 minutes, while for Apollo 8 it took only 55 hours 40 minutes.

But the quickest trip to the moon was the New Horizons probe, which zipped past the moon in just 8 hours 35 minutes. The spacecraft didn't even slow down or approach lunar orbit but instead zipped by on its way to Pluto.

Tidal forces

Tides occur because of the gravitational pull of the moon. The oceans bulge in the direction of the moon. High tide happens when the moon is overhead, but it also happens on the opposite side of the planet because the moon is tugging on Earth as well.

Spring tides — so called because the water "springs up," not because of the season — occur when the moon, the sun and Earth are aligned, during a full moon or new moon.

The moon isn't the only celestial body pulling on Earth's water. "The moon is a major influence on the Earth's tides, but the sun also generates considerable tidal forces," according to the National Oceanic and Atmospheric Administration. "Solar tides are about half as large as lunar tides."

The gravitational forces of the moon and the sun both contribute to these especially strong tides. Neap tides are weak and occur during quarter moons when the forces of the sun and the moon are perpendicular to each other.

Additional reporting by Nola Taylor Redd, Space.com Contributor

"Space-time is not as static as it appears, it's constantly moving," said Wang.

"This is a new idea in a field where there hasn't been a lot of new ideas that try to address this issue," said Bill Unruh, a physics and astronomy professor who supervised Wang's work.

In 1998, astronomers found that our universe is expanding at an ever-increasing rate, implying that space is not empty and is instead filled with dark energy that pushes matter away.

The most natural candidate for dark energy is vacuum energy. When physicists apply the theory of quantum mechanics to vacuum energy, it predicts that there would be an incredibly large density of vacuum energy, far more than the total energy of all the particles in the universe. If this is true, Einstein's theory of general relativity suggests that the energy would have a strong gravitational effect and most physicists think this would cause the universe to explode.

Fortunately, this doesn't happen and the universe expands very slowly. But it is a problem that must be resolved for fundamental physics to progress.

Unlike other scientists who have tried to modify the theories of quantum mechanics or general relativity to resolve the issue, Wang and his colleagues Unruh and Zhen Zhu, also a UBC PhD student, suggest a different approach. They take the large density of vacuum energy predicted by quantum mechanics seriously and find that there is important information about vacuum energy that was missing in previous calculations.

Their calculations provide a completely different physical picture of the universe. In this new picture, the space we live in is fluctuating wildly. At each point, it oscillates between expansion and contraction. As it swings back and forth, the two almost cancel each other but a very small net effect drives the universe to expand slowly at an accelerating rate.

But if space and time are fluctuating, why can't we feel it?

"This happens at very tiny scales, billions and billions times smaller even than an electron," said Wang.

"It's similar to the waves we see on the ocean," said Unruh. "They are not affected by the intense dance of the individual atoms that make up the water on which those waves ride."

Planet Nine is out there, and astronomers are determined to find it, according to a new statement from NASA. In fact, mounting evidence suggests it's hard to imagine our solar system without the unseen world.

The hypothetical planet is believed to be about 10 times more massive than Earth and located in the dark, outer reaches of the solar system, approximately 20 times farther from the sun than Neptune is. While the mysterious world still has yet to be found, astronomers have discovered a number of strange features of our solar system that are best explained by the presence of a ninth planet, according to the NASA statement.

"There are now five different lines of observational evidence pointing to the existence of Planet Nine," Konstantin Batygin, a planetary astrophysicist at the California Institute of Technology (Caltech) in Pasadena, said in the statement. "If you were to remove this explanation and imagine Planet Nine does not exist, then you generate more problems than you solve. All of a sudden, you have five different puzzles, and you must come up with five different theories to explain them." [The Evidence for 'Planet Nine' in Our Solar System (Gallery)]

In 2016, Batygin and co-author Mike Brown, an astronomer at Caltech, published a study that examined the elliptical orbits of six known objects in the Kuiper Belt, a distant region of icy bodies stretching from Neptune outward toward interstellar space. Their findings revealed that all of those Kuiper Belt objects have elliptical orbits that point in the same direction and are tilted about 30 degrees "downward" compared to the plane in which the eight official planets circle the sun, according to the statement.

Using computer simulations of the solar system with a Planet Nine, Batygin and Brown also showed that there should be even more objects tilted a whopping 90 degrees with respect to the solar plane. Further investigation revealed that five such objects were already known to fit these parameters, the researchers said.

Since then, the astronomers have found new evidence that further supports the existence of Planet Nine. With help from Elizabeth Bailey, an astrophysicist and *planetary scientist at Caltech, the team showed that [Planet Nine's influence might have tilted the planets] of our solar system, which would explain why the zone in which the eight major planets orbit the sun is tilted by about 6 degrees compared to the sun's equator.*

"Over long periods of time, Planet Nine will make the entire solar-system plane precess, or wobble, just like a top on a table," Batygin said in the statement.

Finally, the researchers demonstrate how Planet Nine's presence could explain why Kuiper Belt objects orbit in the opposite direction from everything else in the solar system.

"No other model can explain the weirdness of these high-inclination orbits," Batygin said in the statement. "It turns out that Planet Nine provides a natural avenue for their generation. These things have been twisted out of the solar system plane with help from Planet Nine and then scattered inward by Neptune."

Going forward, the researchers plan to use the Subaru Telescope at Mauna Kea Observatory in Hawaii to find Planet Nine, and then deduce [where the mysterious world came from].

The most common type of planets discovered around other stars in our galaxy has been what astronomers call "[super Earths]" — rocky worlds that are larger than Earth but smaller than Neptune. However, no such planet has yet been discovered in our solar system, meaning that Planet Nine could be our missing "super Earth," the researchers said.

A small, recently discovered asteroid - or perhaps a comet - appears to have originated from outside the solar system, coming from somewhere else in our galaxy. If so, it would be the first "interstellar object" to be observed and confirmed by astronomers.
This unusual object - for now designated A/2017 U1 - is less than a quarter-mile (400 meters) in diameter and is moving remarkably fast. Astronomers are urgently working to point telescopes around the world and in space at this notable object. Once these data are obtained and analyzed, astronomers may know more about the origin and possibly the composition of the object.
A/2017 U1 was discovered Oct. 19 by the University of Hawaii's Pan-STARRS 1 telescope on Haleakala during the course of its nightly search for Near-Earth Objects for NASA. Rob Weryk, a postdoctoral researcher at the University of Hawaii Institute for Astronomy (IfA), was first to identify the moving object and submit it to the Minor Planet Center. Weryk subsequently searched the Pan-STARRS image archive and found it was present in images taken the previous night, but was not initially identified by the moving object processing.

Weryk immediately realized this was an unusual object. "Its motion could not be explained using either a normal solar system asteroid or comet orbit," he said. Weryk contacted IfA graduate Marco Micheli, who had the same realization using his own follow-up images taken at the European Space Agency's telescope on Tenerife in the Canary Islands. But with the combined data, everything made sense. Said Weryk, "This object came from outside our solar system."

"This is the most extreme orbit I have ever seen," said Davide Farnocchia, a scientist at NASA's Center for Near-Earth Object Studies (CNEOS) at the agency's Jet Propulsion Laboratory in Pasadena, California. "It is going extremely fast and on such a trajectory that we can say with confidence that this object is on its way out of the solar system and not coming back."

The CNEOS team plotted the object's current trajectory and even looked into its future. A/2017 U1 came from the direction of the constellation Lyra, cruising through interstellar space at a brisk clip of 15.8 miles (25.5 kilometers) per second.

The object approached our solar system from almost directly "above" the ecliptic, the plane in space near where the planets and most asteroids orbit the Sun, so it did not have any close encounters with the eight major planets during its plunge toward the Sun. On Sept. 2, the small body crossed under the ecliptic just inside of Mercury's orbit and then made its closest approach to the Sun on Sept. 9. Pulled by the Sun's gravity, the object made a hairpin turn under our solar system, passing below Earth's orbit on Oct. 14 at a distance of about 15 million miles (24 million kilometers)—about 60 times the distance to the Moon. It has now shot back up above the plane of the planets and, travelling at 27 miles per second (44 kilometers per second) with respect to the Sun, the object is speeding toward the constellation Pegasus.

"We have long suspected that these objects should exist, because during the process of planet formation a lot of material should be ejected from planetary systems. What's most surprising is that we've never seen interstellar objects pass through before," said Karen Meech, an astronomer at the IfA specializing in small bodies and their connection to solar system formation.

The small body has been assigned the temporary designation A/2017 U1 by the Minor Planet Center (MPC) in Cambridge, Massachusetts, where all observations on small bodies in our solar system—and now those just passing through—are collected. Said MPC Director Matt Holman, "This kind of discovery demonstrates the great scientific value of continual wide-field surveys of the sky, coupled with intensive follow-up observations, to find things we wouldn't otherwise know are there."

Since this is the first object of its type ever discovered, rules for naming this type of object will need to be established by the International Astronomical Union.

"We have been waiting for this day for decades," said CNEOS Manager Paul Chodas. "It's long been theorized that such objects exist - asteroids or comets moving around between the stars and occasionally passing through our solar system - but this is the first such detection. So far, everything indicates this is likely an interstellar object, but more data would help to confirm it."

Read more at: https://phys.org/news/2017-10-small-asteroid-comet-solar.html#jCp

New observations carried out by an international team of astronomers have provided important details about an extremely massive galaxy cluster named PLCK G287.0+32.9. The results of these observations, presented October 6 in a paper published on arXiv.org, reveal insights into the structure and mass distribution of this cluster.

PLCK G287.0+32.9 was detected by ESA's Planck telescope in 2011. First observations revealed that it is an extremely massive galaxy cluster at redshift of 0.39 with a mass of approximately 1.57 quadrillion solar masses. Subsequent studies of PLCK G287.0+32.9 found a pair of giant radio relics towards this cluster.

Radio relics are diffuse, elongated radio sources of synchrotron origin. They occur in the form of spectacular single or double symmetric arcs at the peripheries of galaxy clusters. These sources are believed to originate in acceleration and re-acceleration at merger shocks. Thus, in the case of PLCK G287.0+32.9, radio relics confirmed that it is a merging galaxy cluster.

However, the asymmetry of radio relics in PLCK G287.0+32.9 suggests a complex merging scenario. In order to investigate this assumption in detail, dark matter distribution in high resolution was required. Therefore, a team of astronomers led by Kyle Finner of the Yonsei University in Seoul, South Korea, has performed a weak-lensing analysis of the dark matter distribution of this cluster.

Finner and his colleagues employed the 8.2m Subaru Telescope in Hawaii and the Hubble Space Telescope (HST) for their observations. They observed PLCK G287.0+32.9 with the Subaru Telescope on February 26, 2014, and with HST on August 3, 2016 and on February 21, 2017.

"In this study, we present the first constraints on the mass distribution of PLCK G287.0+32.9 from a weak-lensing analysis of Subaru and HST observations. Our analysis with this new data set provides substantial improvements over the previous weak-lensing study of Gruen et al. (2014)," the paper reads.

Subaru and HST observations allowed the researchers to probe the mass distribution of the cluster and to discover its five substructures. PLCK G287.0+32.9 was found to be more massive than previously estimated, as the analysis indicates that it has a mass of approximately 2.04 quadrillion solar masses. The astronomers revealed that the mass of PLCK G287.0+32.9 is dominated by the primary cluster with three of the substructures being about 10 percent of the mass of the primary cluster, while the least massive fifth substructure cannot be considered a galaxy cluster.

"Our analysis shows that the mass distribution features four significant substructures that stretch in a northwest to south-east direction. Of the substructures, the primary cluster dominates the weak-lensing signal. This cluster is likely to be undergoing a merger with one (or more) subcluster whose mass is approximately a factor of 10 lower," the authors wrote in the paper.

The researchers hope

Read more at: https://phys.org/news/2017-10-reveal-insights-nature-extremely-massive.html#jCp

Narrow dense rings of comets are coming together to form planets on the outskirts of at least three distant solar systems, astronomers have found in data from a pair of NASA telescopes.

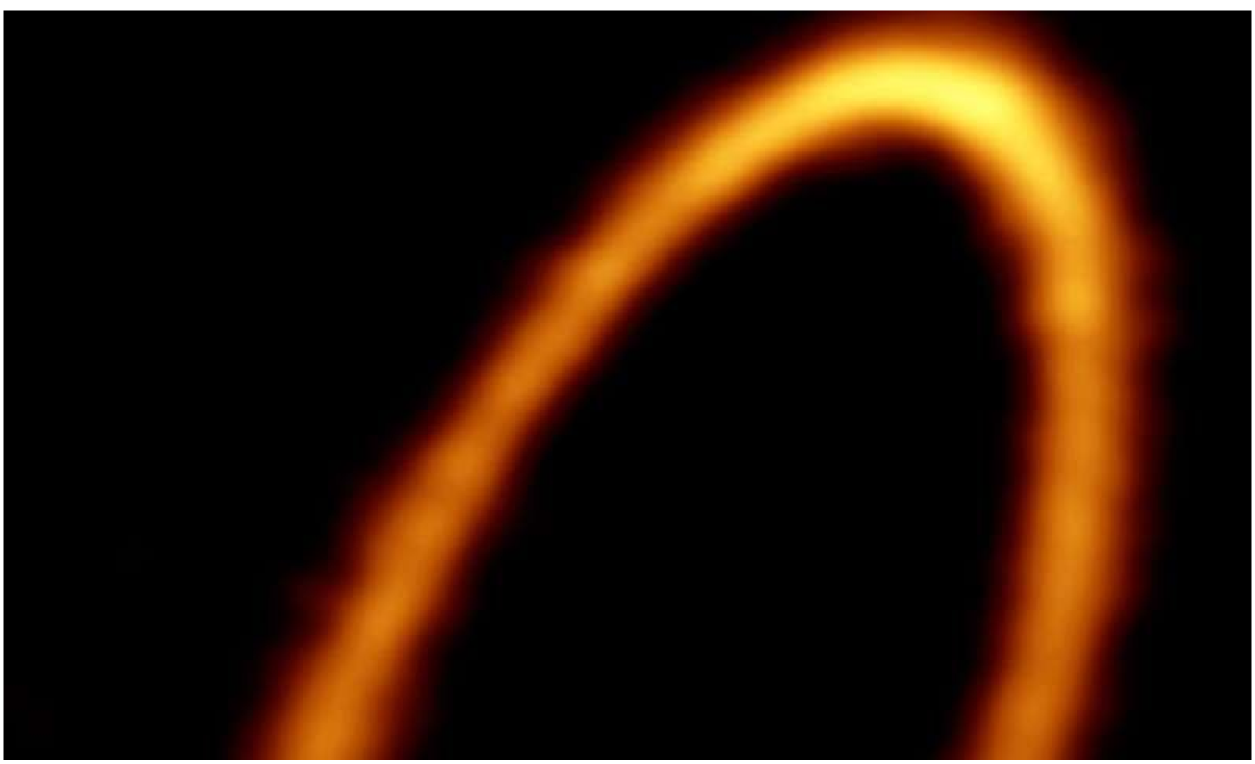
Estimating the mass of these rings from the amount of light they reflect shows that each of these developing [planets](#) is at least the size of a few Earths, according to Carey Lisse, a planetary scientist at the Johns Hopkins University Applied Physics Laboratory (APL) in Laurel, Maryland.

Over the past few decades, using powerful NASA observatories such as the Infrared Telescope Facility in Hawaii and the Spitzer Space Telescope, scientists have found a number of young debris disk systems with thin but bright outer rings composed of comet-like bodies at 75 to 200 astronomical units from their parent stars—about two to seven times the distance of Pluto from our own sun. The composition of the material in these rings varies from ice-rich (seen in the Fomalhaut and HD 32297 systems) to ice-depleted but carbon rich (the HR 4796A system).

Presenting his results today at the American Astronomical Society's Division for Planetary Sciences meeting in Provo, Utah, Lisse said scientists are especially intrigued by the red dust ring surrounding HR 4796A, which shows unusually tight form for an infant solar system.

Lisse traces the extreme red color to the burnt-out rocky organic remains of comets, a result of the system's ring being close enough to the star that they have all boiled off. The researchers don't see red ring dust in Fomalhaut or HD 32297, but instead see normal bluish comet dust containing ices—because these systems' rings are far enough out that their comets are cold and mostly stable.

"The narrow confines of these rings is still a great puzzle—you don't typically see this kind of tight order in such a young system," Lisse said. "Usually, material is moving every which way before an exoplanetary system gets cleaned out and settles down so that planetary bodies rarely cross each other's path, like in our present-day solar system."



ALMA image of the debris disk in the Fomalhaut star system. The ring is approximately 20 billion kilometers (12.4 billion miles) from the central star and about 2 billion kilometers (1.2 billion miles) wide. The central dot is the …more

After eliminating other possibilities due to the lack of primordial circumstellar gas seen in these systems, Lisse and his co-authors have attributed the tight structure to multiple coalescing bodies "shepherding" material through the rings.

"Comets crashing down onto these growing planet surfaces would kick up huge clouds of fast-moving, ejected 'construction dust,' which would spread over the system in huge clouds," Lisse said. "The only apparent solution to these issues is that multiple mini-planets are coalescing in these rings, and these small bodies, with low kick-up velocities, are shepherding the rings into narrow structures—much in the same way many of the narrow rings of Saturn are focused and sharpened."

This is a paradigm shift, he added, because instead of building a planet from one big construction site, it's coming from many small ones, which will eventually merge their work into the final product. Recent studies have yielded similar theories about the formation of the giant gas planets Uranus and Neptune, that each had multiple "subcores" that were eventually covered by thick atmospheres.

In Fomalhaut and HD 32297, researchers expect that millions of comets are contributing to form the cores of ice giant planets like Uranus and Neptune—although without the thick atmospheres enveloping the cores of Uranus and Neptune, since the primordial gas disks that would form such atmospheres are gone. In HR 4796A, with its warmer dust ring, even the ices normally found in the rings' comets evaporated over the last million years or so, leaving behind core building blocks that are rich only in leftover carbon and rocky materials.

"These systems appear to be building planets we don't see in our solar system—large multi-Earth mass ones with variable amounts of ice, rock and refractory organics," Lisse said. "This is very much like the predicted recipe for the super-Earths seen in abundance in the Kepler planet survey."

"Much still has to happen, though, before these rings could become planets the size of the gas giants," he continued. "Why it's taking so long to make outer planets in these systems—after their primordial gas disks have been stripped away—is a big mystery."

Read more at: https://phys.org/news/2017-10-scientist-evidence-planet-formation-narrow.html#jCp

As thousands in the United States (and Canada) get ready to view the Aug. 21 solar eclipse through their special glasses, NASA will be using 11 different spacecraft to study the sun's outer atmosphere during the duration of the eclipse, NASA scientist Dr. Michelle Thaller said.

"The moon is blocking out the main bright disk of the sun. So you can actually see what those levels of solar atmosphere are doing. It's called the corona. It's

spectacular. And actually the way the corona works is still fairly mysterious," Thaller said on Friday.

READ MORE: [What Canadians can expect during the solar eclipse on August 21]

NASA will also fly high-altitude research balloons and airplanes for solar physics and other experiments.

During the eclipse, the moon will pass between the sun and Earth, blocking the face of the sun and leaving only its outer atmosphere, or corona, visible in the sky.

If you're lucky enough the be in the eclipse's direct path — spanning Oregon to South Carolina — you'll get the full show as the sun is completely blocked out, day becomes night, and even the animals and plants around you react.

If you're a bit further north, in Toronto, Vancouver or even St. John's, you'll still be treated to a partial celestial spectacle.

It is the first American coast-to-coast total eclipse since 1918.

Total solar eclipses occur somewhere on Earth every year or so, but most cast their shadow over oceans or remote land. The last total eclipse over part of the contiguous U.S. was in 1979.

Around 130 million years ago, two dead stars violently collided and set off a sequence of events that, over the last two months, have whipped astronomers on Earth into an absolute frenzy.

At press conferences held across continents, scientists today announced the first detection of gravitational waves created by two neutron stars smashing into each other.

First theorized by Albert Einstein in 1916, gravitational waves are kinks or distortions in the fabric of space-time caused by extremely violent cosmic events. Until now, all confirmed detections involved a deadly dance between two black holes, which leave no visible signature on the sky.

0

:

1

8

|

1

:

3

3

GRAVITATIONAL WAVES 101 What are gravitational waves and how are they detected? These ripples in space-time, sometimes caused by neutron stars colliding, were recently recorded in the groundbreaking LIGO-Virgo observation.

But with this latest event, teams using about a hundred instruments at roughly 70 observatories were able to track down and watch the cataclysm in multiple wavelengths of light, allowing astronomers to scrutinize the source of these cosmic ripples for the first time.

"We saw a totally new phenomenon that has never before been seen by humans," says Andy Howell of the University of California, Santa Barbara. "It's an amazing thing that may not be duplicated in our lifetimes."

Unlike colliding black holes, shredded neutron stars expel metallic, radioactive debris that can be seen by telescopes—if you know when and where to look.

"We felt the universe shaking from two neutron stars merging together, and that told us where to go and point our telescopes," says Howell, whose team was among several that chased down the stars tied to the gravitational wave signal.

Theorized by Einstein and confirmed in 2016, gravitational waves have finally been observed from the merger of two neutron stars—ultradense stellar zombies left over from the explosive deaths of gTwo neutron stars rotate around each other; the closer they get, the faster they spin. Eventually, they collide. The energy from their spiraling and merging releases energy in the form of gravitational waves, or ripples in space-time.

The merger most likely resulted in a black hole, although it's also possible it created an abnormally massive neutron star. Regardless, the final object is less massive than the two combined neutron stars. The equivalent mass of 25 Jupiters was converted into gravitational waves. The collision also ejected 50 Jupiters' worth of heavy elements such as gold and silver.

Ultimately, about 3,500 people were involved in the gravitational wave detection and ensuing astrophysical forensics; the results of the massive project are reported today in 40 papers appearing in several scientific journals, including Science and Physical Review Letters.

Together, the observations are helping astronomers verify some long-standing theories in physics and resolve a debate about the origin of gold and other heavy elements in the cosmos—discoveries made possible by the nascent field of gravitational wave astronomy.

"This is the first time that we hear the death spiral of two neutron stars, and we also see the fireworks that came from the final merger," Vicky Kalogera of Northwestern University said today during a press event held in Washington, D.C.

ADVENTURE TIME

The first, though indirect, evidence for the existence of gravitational waves emerged in 1974. But actually snagging the waves proved elusive for decades, because the amount by which they distort space-time on Earth is minuscule—on the order of a fraction of the width of an atomic nucleus. (Find out more about gravitational waves.)

To try and sense these ridiculously small shifts in the cosmos, researchers created the Laser Interferometer Gravitational-wave Observatory, or LIGO. The observatory's twin detectors each use lasers to measure minute changes *in the distance between pairs of mirrors created when gravitational waves wash over Earth; a third detector, run by the European Virgo team, now does the same.*

An all-sky map shows the confirmed detections of gravitational waves to date, and one candidate detection. The bands show where space-time was wrinkled by each event, while the numbers signify the date of detection; the latest event, GW170817, was recorded on August 17, 2017.

ILLUSTRATION BY LIGO/VIRGO/NASA/LEO SINGER/AXEL MELLINGER

In early 2016, scientists at LIGO announced a breakthrough: Their highly sensitive instruments had at last captured their quarry. Since then, LIGO has confirmed three more events, each created by black holes merging, and the team's leaders have been awarded the 2017 Nobel Prize in physics.

But early in the morning of August 17, the LIGO detectors recorded something new. Gravitational waves toggling the distance between those *pairs of mirrors contained telltale clues suggesting their source was not black holes, but merging dead stars.*

Two seconds after those signals shook the LIGO detectors, NASA's orbiting Fermi Gamma-ray Space Telescope caught a flash of gamma-rays coming from the same general region of sky as the LIGO signal. Lasting just under two seconds, the flash looked like a short gamma-ray burst—the type of cosmic explosion thought to be produced by colliding neutron stars.

Coincidence? The LIGO-Virgo team didn't think so. The team sent up the equivalent of an astronomical bat signal, telling observers that if they acted quickly, they could survey the debris left over by the stars' mutual annihilation and, for the first time, watch the aftermath of gravitational waves being born.

That signal triggered follow-up observations by teams around the globe, all of which were clamoring to help put together the pieces of this cosmic puzzle. But first, crucially, the teams needed to know where to point all their fancy hardware.

DANCING WITH THE STARS

Enter Charlie Kilpatrick, a postdoc at the University of California, Santa Cruz. After the gravitational wave and gamma-ray triggers had come in, *Kilpatrick and his colleagues had quickly gotten to work sifting through a pile of galaxies in roughly the same region as the source of the new signals.*

They had under their command a small and unpretentious telescope on the ground in Chile, and as soon as the Chilean sky darkened, they planned to target each of those galaxies and look for signs of activity. But they had to be quick: That portion of the sky would only be visible for an hour or two before slipping below the horizon.

A Hubble Space Telescope image shows the oval galaxy NGC 4993 as it looked four months before the new gravitational wave detection, while a picture from the Swope Telescope in Chile shows where a bright spot appeared in the galaxy in August 2017.

PHOTOGRAPH BY HUBBLE/STSCI (LEFT) AND PHOTOGRAPH BY 1M2H TEAM/UC SANTA CRUZ & CARNEGIE OBSERVATORIES/RYAN FOLEY (RIGHT)

About 10 hours after the LIGO-Virgo alert went out, the fifth galaxy Kilpatrick looked at glittered with a bright spot that hadn't been there before—a very tantalizing sign that something dramatic had happened. The *team sent out a telegram alerting others to the discovery. Within 42 minutes, five other groups, including Howell's, had the galaxy in their crosshairs.*

"It's been sort of slow to dawn on me what a big deal this is," Kilpatrick says.

Over the next several days, a fleet of observatories joined the party. For weeks, the gravitational wave source, near the fringe of an oval-shaped galaxy called NGC 4993, was the most stared-at spot on the sky.

In that region of space, two neutron stars had been spiraling around one another for ages, moving through a breathless dance destined to end in a second, even more violent death. Millions of years in the making, their lethal coda was so furious that it warped and distorted the fabric of space-time, generating the gravitational waves that rippled across the cosmos at the speed of light and eventually alerted us to their demise.

BIG BANG THEORY

Thanks to the quick detective work, scientists were able to study the explosion across the electromagnetic spectrum, in everything from radio waves to gamma-rays.

The merger now resolves a long-standing debate about the origin of heavy elements in the periodic table: precious metals, including gold and platinum, *and things like the neodymium scientists use when building lasers like LIGO's.*

The fabric of space-time distorts as two neutron stars spiral in toward their demise in an illustration.

ILLUSTRATION BY NSF/LIGO/SONOMA STATE UNIVERSITY/A. SIMONNET

For a long time, scientists thought these metals were forged mainly in the bellies of large stars that die explosive deaths. But more recent work suggested that such supernovae didn't eject enough of this stuff into the cosmos to account for what we see.

Building these elements requires an excess of neutrons, one of the particles that make up atomic nuclei; as one might suspect, these are set free in enormous quantities when neutron stars are ripped apart.

By studying the explosion in infrared light, teams determined that the debris contained at least ten thousand Earths worth of precious metals—more than enough to seed the cosmos with the observed amounts.

"These events can actually account for all the gold and all the heavy elements in the universe today," says Enrico Ramirez-Ruiz of the University of

California, Santa Cruz. The observations, he says, are "just breathtaking—the level and quality of the data, it's just beautiful."

However, other parts of the story told by these events are still shrouded in mystery. For starters, it's not exactly clear what was left behind after the two neutron stars collided. All we know is that the remnant of the collision is about 2.6 times as massive as the sun.

Given that mass, and the starting neutron stars, it's almost certainly a black hole, says the University of Arizona's Feryal Ozel. Other less likely possibilities include an anomalously hypermassive neutron star; but that kind of object could break what scientists know about the physics of neutron stars.

STRANGER THINGS

Regardless of its identity, the collision's remnant raises a host of questions about the densest known objects in the universe.

"No one has observed either a neutron star or a black hole with well-measured mass between 2 and about 5 solar masses," says Caltech's Alan Weinstein, a member of the LIGO team.

Using the Swope and Magellan telescopes in Chile, astronomers recorded the neutron star explosion as it suddenly appeared as a bright spot in visible light and then faded. After about seven days, the spot was no longer detected in visible wavelengths.

PHOTOGRAPH BY 1M2H TEAM/UC SANTA CRUZ & CARNEGIE OBSERVATORIES/RYAN FOLEY

Also, the explosion and its aftermath didn't play out exactly as predicted. The gamma-ray burst was relatively wimpy and much fainter than similar events seen before, says Caltech's Mansi Kasliwal. Plus, it took longer than expected for x-rays and radio waves to hit detectors following the blast.

That could mean the jets of high-speed radiation sent out by the explosion were not aimed directly at Earth, and were instead slightly off axis, says Daryl Haggard of McGill University, whose team used the Chandra X-ray Observatoryto spy on the merger.

Or, it could mean something more complex is going on. Perhaps, Kasliwal suggests, a cocoon of energetic debris thrown off by the explosion has choked whatever jet was initially produced. Scientists are hoping that continued observations in radio waves, which should be visible for quite a while longer, will help resolve the issue.

"Even though the radio emission arrived late to the party, it will be the last to leave—and comes bearing gifts!" says Caltech's [Gregg Hallinan].

But further observations will have to wait: The galaxy's position in the sky is so close to the sun right now that it's dangerous for some telescopes to observe it. When it moves slightly farther from our star's glare, telescopes will again swivel to gaze at the last lingering remnants of the blast.

In the meantime, astronomers will no doubt be celebrating their good fortune at seeing the blast in such detail in the first place.

"This thing exploded 130 million years ago," says [Maria Drout], of the Carnegie Observatories. "But if it had happened a month later, we wouldn't have been able to see it at all. The detectors would have been turned off, and it would have been behind the sun."

OLDEST KNOWN PLANETBright-blue Earth looms over the oldest known planet in the Milky Way. The ancient planet is thought to be about 13 billion years old, more than twice as old as Earth and a mere billion years younger than the estimated age of the universe. Its discovery, made using NASA's Hubble Space Telescope, is evidence that planets began forming soon after the big bang and may be very abundant in our galaxy.PHOTOGRAPH COURTESY NASA/BRAD HANSEN (UCLA)/HARVEY RICHER (UBC)/STEINN SIGURDSSON (PENN STATE)/INGRID STAIRS (UBC)/STEPHEN THORSETT (UCSC)

Given the incomprehensible size of space, it can be difficult to sum up some of the latest discoveries and developments in one piece, so we wrote four instead.

For the past four days, Siliconrepublic.com has published an article each day in what we have referred to as Space Week, in an attempt to piece together some of the most out-there areas of space exploration today.
Choosing the topics wasn't easy given the vastness of space and the multitudes of topics that could be written about, but the four chosen really sum up how we are moving into a future that once only existed in science fiction.

Mining its own business

Firstly, we covered the rise of asteroid mining companies like Planetary Resources, which was founded by former NASA flight director Chris Lewicki.

As he explains in the article, the cosmos is full of space debris that might be the remnants of the birth of the universe, and within that could potentially be trillions of dollars of vital resources.

While one single asteroid was recently valued somewhere in the region of $5trn because of its potential platinum deposits, other asteroids could also act as 'gas stations to the stars', providing spacecraft with the necessary water for a long, long journey.

With US President Barack Obama also recently passing a law allowing US companies to mine the contents of space with little-to-no interference, the presumption is that a situation similar to the 19th-century Gold Rush of California is only generations away.

Shot into the dark

But while this resource mining will help us with mining the nearest reaches of our solar system, if we want to go further we have to think of some rather bold and creative ideas.

One such idea is the Starshot programme from Breakthrough Initiatives, which wants to send a series of nanocraft to our nearest star system, Alpha Centauri, within the space of 20 years.

To put the importance of this into context, it would have taken the former NASA Space Shuttle 165,000 years to travel the distance of 4.3 light years.

Having spoken to one of the project leads, Prof Avi Loeb, it seems that it won't be 'plain sailing'.

In Starshot's case, this will be literal sailing, as the technology would power the craft through space using lasers and a sail receiver that would let it reach such high speeds.

If the project proves successful, it could be recruited to analyse a potential Earth 2.0 within the system that was revealed just recently.

Life on Mars, and elsewhere, too

Astrobiologist Prof Penelope Boston told us about her research into how life might exist in the wider universe, from our nearest neighbour Mars to distant exoplanets like the one that could exist in the Alpha Centauri system.

Thankfully, from a scientific perspective, we might not have to look too far to find examples of alien life, with our own planet hosting a number of so-called 'extremophiles' that can withstand the harshest of conditions.

Finally, our understanding of the universe now and in the future will not be simply limited to how far we can travel, as many discoveries could soon be made right here from Earth.

Waves of the future

In February of this year, the Advanced Laser Interferometer Gravitational-Wave Observatory (LIGO) announced the discovery of gravitational waves, describing the moment as a "new era in astronomy and physics".

The man who announced that discovery, Dr David Reitze, spoke with us about his excitement for the years to come following the success of the LISA

Pathfinder satellite, designed to test the potential for an enormous space-based gravitational waves telescope.

With a planned launch in 2034, it will be the largest instrument ever built by humanity and will act as a space-based gravitational wave detector measuring the smallest of space-time distortions.

All-in-all, space is likely to get weirder in the years to come as we attempt to open up a door to a whole new scientific realm.

Starry galaxy image via Shutterstock

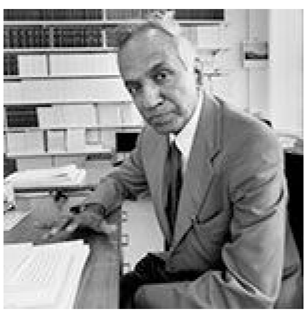
Achieving spaceflight enabled humans to begin to explore the solar system and the rest of the universe, to understand the many objects and phenomena that are better observed from a space perspective, and to use for human benefit the resources and attributes of the space environment. All of these activities—discovery, scientific understanding, and the application of that understanding to serve human purposes—are elements of space exploration. (For a general discussion of spacecraft, launch considerations, flight trajectories, and navigation, docking, and recovery procedures, see spaceflight.)

Overview Of Recent Space Achievements

Motivations for space activity

Although the possibility of exploring space has long excited people in many walks of life, for most of the latter 20th century, only national governments could afford the very high costs of launching people and machines into space. This reality meant that space exploration had to serve very broad interests, and it indeed has done so in a variety of ways. Government space programs have increased knowledge, served as indicators of national prestige and power, enhanced national security and military strength, and provided significant benefits to the general public. In areas where the private sector could profit from activities in space, most notably the use of satellites as telecommunication relays, commercial space activity has flourished without government funding. In the early 21st century, entrepreneurs believed that there were several other areas of commercial potential in space, most notably privately funded space travel.

In the years after World War II, governments assumed a leading role in the support of research that increased fundamental knowledge about nature, a role that earlier had been played by universities, private foundations, and other nongovernmental supporters. This change came for two reasons. First, the need for complex equipment to carry out many scientific experiments and for the large teams of researchers to use that equipment led to costs that only *governments could afford. Second, governments were willing to take on this responsibility because of the belief that fundamental research would produce new knowledge essential to the health, the security, and the quality of life of their citizens. Thus, when scientists sought government support for early space experiments, it was forthcoming. Since the start of space efforts in the United States, the Soviet Union, and Europe, national governments have given high priority to the support of science done in and from space. From modest beginnings, space science has expanded under government support to include multibillion-dollar exploratory missions in the solar system. Examples of such efforts include the development of the Curiosity Mars rover, the Cassini-Huygens mission to Saturn and its moons, and the development of major space-based astronomical observatories such as the Hubble Space Telescope.*

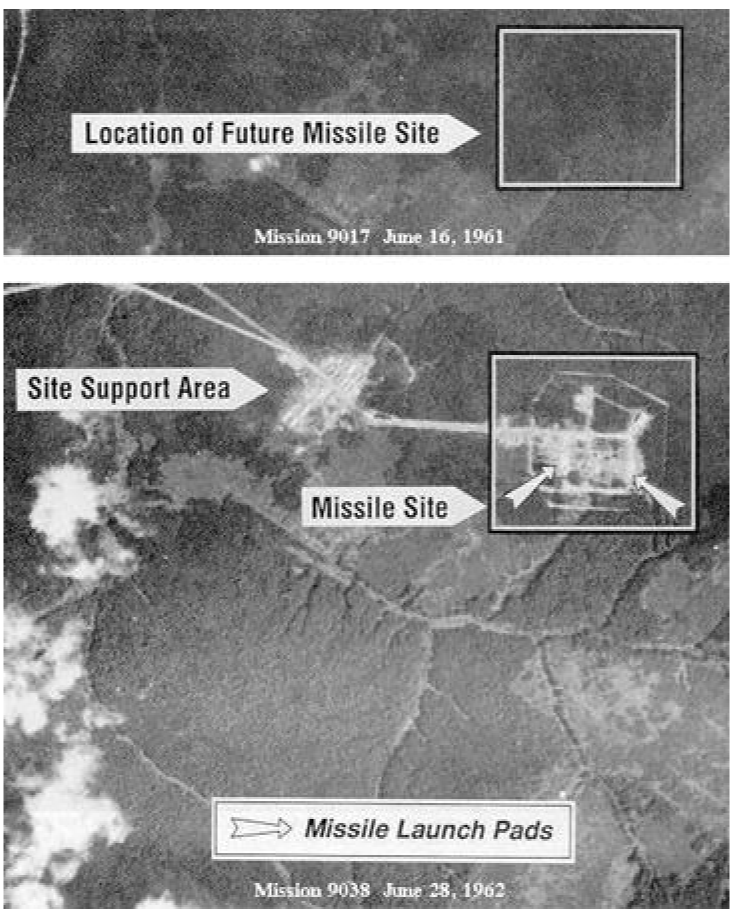
- 
-
- SPOTLIGHT / SCIENCE
- The Fermi Paradox: Where Are All the Aliens?
- 
-
- SPOTLIGHT / SCIENCE
- All About Chandrasekhar
- 
-
- DEMYSTIFIED / SOCIETY
- Why Do We Carve Pumpkins at Halloween?
- 

Soviet leader Nikita Khrushchev in 1957 used the fact that his country had been first to launch a satellite as evidence of the technological power of the Soviet Union and of the superiority of communism. He repeated these claims after Yury Gagarin's orbital flight in 1961. Although U.S. Pres. Dwight D. Eisenhower had decided not to compete for prestige with the Soviet Union in a space race, his successor, John F. Kennedy, had a different view. On April 20, 1961, in the aftermath of the Gagarin flight, he asked his advisers to identify a "space program which promises dramatic results in which we could win." The response came in a May 8, 1961, memorandum recommending that the United States commit to sending people to the Moon, because "dramatic achievements in space…symbolize the technological power and organizing capacity of a nation" and because the ensuing prestige would be "part of the battle along the fluid front of the cold war." From 1961 until the collapse of the Soviet Union in 1991, competition between the United States and the Soviet Union was a major influence on the pace and content of their space programs.

Other countries also viewed having a successful space program as an important indicator of national strength.

TEST YOUR KNOWLEDGE

Even before the first satellite was launched, U.S. leaders recognized that the ability to observe military activities around the world from space would be an asset to national security. Following on the success of its *photoreconnaissance satellites, which began operation in 1960, the United States built increasingly complex observation and electronic-intercept intelligence satellites. The Soviet Union also quickly developed an array of intelligence satellites, and later a few other countries instituted their own satellite observation programs. Intelligence-gathering satellites have been used to verify arms-control agreements, provide warnings of military threats, and identify targets during military operations, among other uses.*

- 

- *Two U.S. Corona reconnaissance satellite images made a year apart—in mid-1961 (top) and …*
  - *National Reconaissance Office*
-

BRITANNICA LISTS & QUIZZES

- 
- *SCIENCE QUIZ*

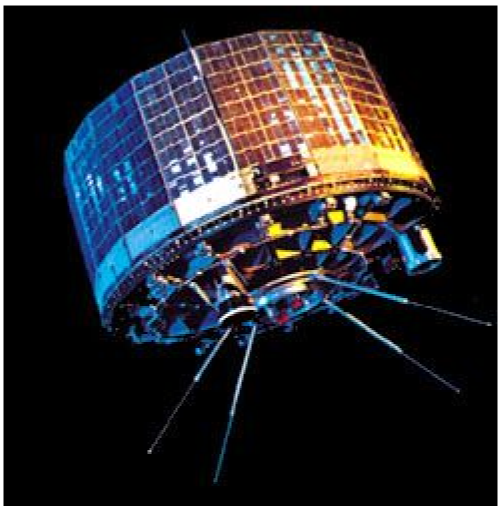
- *Types of Chemical Reactions*
-
- 
- *GEOGRAPHY LIST*
- *How 9 Famous Cities Got Their Nicknames*
-

- 
- *LITERATURE & LANGUAGE QUIZ*
- *Latin American Authors*
-

- 
- POP CULTURE LIST
- 10 of the Best American Sitcoms
-

In addition to providing security benefits, satellites offered military forces the potential for improved communications, weather observation, navigation, timing, and position location. This led to significant government funding for military space programs in the United States and the Soviet Union. Although *the advantages and disadvantages of stationing force-delivery weapons in space have been debated, as of the early 21st century, such weapons had not been deployed, nor had space-based antisatellite systems—that is, systems that can attack or interfere with orbiting satellites. The stationing of weapons of mass destruction in orbit or on celestial bodies is prohibited by international law.*

Governments realized early on that the ability to observe Earth from space could provide significant benefits to the general public apart from security and military uses. The first application to be pursued was the development of satellites for assisting in weather forecasting. A second application involved remote observation of land and sea surfaces to gather imagery and other data of value in crop forecasting, resource management, environmental monitoring, and other applications. The U.S. and Soviet governments also developed their own satellite-based global positioning systems, originally for military purposes, that could pinpoint a user's exact location, help in navigating from one point to another, and provide very precise time signals. These satellites quickly found numerous civilian uses in such areas as personal navigation, surveying and cartography, geology, air-traffic control, and the operation of information-transfer networks. They illustrate a reality that has remained *constant for a half century—as space capabilities are developed, they often can be used for both military and civilian purposes.*

- 
- *TIROS 7 (Television and Infra-Red Observation Satellite 7), launched June 19, 1963. The first …*
  - *NASA*
-

Another space application that began under government sponsorship but quickly moved into the private sector is the relay of voice, video, and data via *orbiting satellites. Satellite telecommunications has developed into a multibillion-dollar business and is the one clearly successful area of commercial space activity. A related, but economically much smaller, commercial space business is the provision of launches for private and government satellites. In 2004 a privately financed venture sent a piloted spacecraft, SpaceShipOne, to the lower edge of space for three brief suborbital flights. Although it was technically a much less challenging achievement than carrying humans into orbit, its success was seen as an important step toward opening up space to commercial travel and eventually to tourism. Nearly a decade after SpaceShipOne reached space, several firms were poised to carry out such suborbital flights. Suggestions have been made that in the future other areas of space activity, including remote sensing of Earth, utilization of resources found on the Moon and near-Earth asteroids, and the capture of solar energy to provide electric power on Earth, could become successful businesses.*

Most space activities have been pursued because they serve some utilitarian purpose, whether increasing knowledge, adding to national power, or making a profit. Nevertheless, there remains a powerful underlying sense that it is important for humans to explore space for its own sake, "to see what is there."

Although the only voyages that humans have made away from the near vicinity of Earth—the Apollo flights to the Moon—were motivated by Cold War competition, there have been recurrent calls for humans to return to the Moon, travel to Mars, and visit other locations in the solar system and beyond. Until humans resume such journeys of exploration, robotic spacecraft will continue to serve in their stead to explore the solar system and probe the mysteries of the universe.