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This article is about the scientific study of celestial objects and is not to be confused with Astrology, a divinatory pseudoscience. For other uses, see Astronomy (disambiguation). Astronomy is a natural science that studies celestial objects and the phenomena that occur in the cosmos. It uses mathematics, physics, and chemistry in order to explain their origin and their overall evolution. Objects of interest include planets, moons, stars, nebulae, galaxies, meteoroids, asteroids, and comets. Relevant phenomena include supernova explosions, gamma ray bursts, quasars, blazars, pulsars, and cosmic microwave background radiation. More generally, astronomy studies everything that originates beyond Earth's atmosphere. Cosmology is a branch of astronomy that studies the universe as a whole. The Paranal Observatory of European Southern Observatory shooting a laser guide star to the Galactic Center Astronomy is one of the oldest natural sciences. The early civilizations in recorded history made methodical observations of the night sky. These include the Egyptians, Babylonians, Greeks, Indians, Chinese, Maya, and many ancient indigenous peoples of the Americas. In the past, astronomy included disciplines as diverse as astrometry, celestial navigation, observational astronomy, and the making of calendars. Professional astronomy is split into observational and theoretical branches. Observational astronomy is focused on acquiring data from observations of astronomical objects. This data is then analyzed using basic principles of physics. Theoretical astronomy is oriented toward the development of computer or analytical models to describe astronomical objects and phenomena. These two fields complement each other. Theoretical astronomy seeks to explain observational results and observations are used to confirm theoretical results. Astronomy is one of the few sciences in which amateurs play an active role. This is especially true for the discovery and observation of transient events. Amateur astronomers have helped with many important discoveries, such as finding new comets. Astronomy (from the Greek ἀστρονομία from ἄστρον astron, "star" and -νομία -nomia from νόμος nomos, "law" or "culture") means "law of the stars" (or "culture of the stars" depending on the translation). Astronomy should not be confused with astrology, the belief system which claims that human affairs are correlated with the positions of celestial objects.[1] Although the two fields share a common origin, they are now entirely distinct.[2] "Astronomy" and "astrophysics" are synonyms.[3][4][5] Based on strict dictionary definitions, "astronomy" refers to "the study of objects and matter outside the Earth's atmosphere and of their physical and chemical properties",[6] while "astrophysics" refers to the branch of astronomy dealing with "the behavior, physical properties, and dynamic processes of celestial objects and phenomena".[7] In some cases, as in the introduction of the introductory textbook The Physical Universe by Frank Shu, "astronomy" may be used to describe the qualitative study of the subject, whereas "astrophysics" is used to describe the physics-oriented version of the subject.[8] However, since most modern astronomical research deals with subjects related to physics, modern astronomy could actually be called astrophysics.[3] Some fields, such as astrometry, are purely astronomy rather than also astrophysics. Various departments in which scientists carry out research on this subject may use "astronomy" and "astrophysics", partly depending on whether the department is historically affiliated with a physics department,[4] and many professional astronomers have physics rather than astronomy degrees.[5] Some titles of the leading scientific journals in this field include The Astronomical Journal, The Astrophysical Journal, and Astronomy & Astrophysics.[citation needed] Main article: History of astronomy For a chronological guide, see Timeline of astronomy. Further information: Archaeoastronomy and List of astronomers The Nebra sky disc (c. 1800–1600 BCE), found near a possibly astronomical complex, most likely depicting the Sun or full Moon, the Moon as a crescent, the Pleiades and the summer and winter solstices as strips of gold on the side of the disc,[9][10] with the top representing the horizon[11] and north. In early historic times, astronomy only consisted of the observation and predictions of the motions of objects visible to the naked eye. In some locations, early cultures assembled massive artifacts that may have had some astronomical purpose. In addition to their ceremonial uses, these observatories could be employed to determine the seasons, an important factor in knowing when to plant crops and in understanding the length of the year.[12] A Babylonian planisphere (7th century BCE). Babylonian astronomy made early advances in astronomy. Its use of sexagesimals (e.g. 12, 24, 60, 360) is still being used today through having been broadly adopted for timekeeping and astrometry.[13] As civilizations developed, most notably in Egypt, Mesopotamia, Greece, Persia, India, China, and Central America, astronomical observatories were assembled and ideas on the nature of the Universe began to develop. Most early astronomy consisted of mapping the positions of the stars and planets, a science now referred to as astrometry. From these observations, early ideas about the motions of the planets were formed, and the nature of the Sun, Moon and the Earth in the Universe were explored philosophically.[citation needed] Mesopotamia is worldwide the place of the earliest known astronomer and poet by name: Enheduanna, Akkadian high priestess to the lunar deity Nanna/Sin and princess, daughter of Sargon the Great (c. 2334 – c. 2279 BCE). She had the Moon tracked in her chambers and wrote poems about her divine Moon.[14] A particularly important early development was the beginning of mathematical and scientific astronomy, which began among the Babylonians, who laid the foundations for the later astronomical traditions that developed in many other civilizations.[15] The Babylonians discovered that lunar eclipses recurred in a repeating cycle known as a saros.[16] Following the Babylonians, significant advances in astronomy were made in ancient Greece and the Hellenistic world. Greek astronomy is characterized from the start by seeking a rational, physical explanation for celestial phenomena.[17] In the 3rd century BC, Aristarchus of Samos estimated the size and distance of the Moon and Sun, and he proposed a model of the Solar System where the Earth and planets rotated around the Sun, now called the heliocentric model.[18] In the 2nd century BC, Hipparchus discovered precession, calculated the size and distance of the Moon and invented the earliest known astronomical devices such as the astrolabe.[19] Hipparchus also created a comprehensive catalog of 1020 stars, and most of the constellations of the northern hemisphere derive from Greek astronomy.[20] The Antikythera mechanism (c. 150–80 BC) was an early analog computer designed to calculate the location of the Sun, Moon, and planets for a given date. Technological artifacts of similar complexity did not reappear until the 14th century, when mechanical astronomical clocks appeared in Europe.[21] The Earth was believed to be the center of the Universe with the Sun, the Moon and the stars rotating around it. This is known as the geocentric model of the Universe, or the Ptolemaic system, named after Ptolemy.[22] Portrait of Alfraganus in the Compilatio astronomica, 1493. Islamic astronomers began just before the 9th century to collect and translate Indian, Persian and Greek astronomical texts, adding their own astronomy and enabling later, particularly European astronomy to build on.[23] Astronomy flourished in the Islamic world and other parts of the world. This led to the emergence of the first astronomical observatories in the Muslim world by the early 9th century.[24][25][26] In 964, the Andromeda Galaxy, the largest galaxy in the Local Group, was described by the Persian Muslim astronomer Abd al-Rahman al-Sufi in his Book of Fixed Stars.[27] The SN 1006 supernova, the brightest apparent magnitude stellar event in recorded history, was observed by the Egyptian Arabic astronomer Ali ibn Ridwan and Chinese astronomers in 1006. Iranian scholar Al-Biruni observed that, contrary to Ptolemy, the Sun's apogee (highest point in the heavens) was mobile, not fixed.[28] Some of the prominent Islamic (mostly Persian and Arab) astronomers who made significant contributions to the science include Al-Battani, Thebit, Abd al-Rahman al-Sufi, Biruni, Abū Isḥāq Ibrāhīm al-Zarqālī, Al-Birjandi, and the astronomers of the Maragheh and Samarkand observatories. Astronomers during that time introduced many Arabic names now used for individual stars.[29][30] It is also believed that the ruins at Great Zimbabwe and Timbuktu[31] may have housed astronomical observatories.[32] In Post-classical West Africa, Astronomers studied the movement of stars and relation to seasons, crafting charts of the heavens as well as precise diagrams of orbits of the other planets based on complex mathematical calculations. Songhai historian Mahmud Kati documented a meteor shower in August 1583.[33][34] Europeans had previously believed that there had been no astronomical observation in sub-Saharan Africa during the pre-colonial Middle Ages, but modern discoveries show otherwise.[35][36][37][38] For over six centuries (from the recovery of ancient learning during the late Middle Ages into the Enlightenment), the Roman Catholic Church gave more financial and social support to the study of astronomy than probably all other institutions. Among the Church's motives was finding the date for Easter.[39] Medieval Europe housed a number of important astronomers. Richard of Wallingford (1292–1336) made major contributions to astronomy and horology, including the invention of the first astronomical clock, the Rectangulus which allowed for the measurement of angles between planets and other astronomical bodies, as well as an equatorium called the Albion which could be used for astronomical calculations such as lunar, solar and planetary longitudes and could predict eclipses. Nicole Oresme (1320–1382) and Jean Buridan (1300–1361) first discussed evidence for the rotation of the Earth, furthermore, Buridan also developed the theory of impetus (predecessor of the modern scientific theory of inertia) which was able to show planets were capable of motion without the intervention of angels.[40] Georg von Peuerbach (1423–1461) and Regiomontanus (1436–1476) helped make astronomical progress instrumental to Copernicus's development of the heliocentric model decades later.[citation needed] The first sketches of the Moon's topography, from Galileo's ground-breaking Sidereus Nuncius (1610), publishing his findings from the first telescopic astronomical observations. During the Renaissance, Nicolaus Copernicus proposed a heliocentric model of the solar system. His work was defended by Galileo Galilei and expanded upon by Johannes Kepler. Kepler was the first to devise a system that correctly described the details of the motion of the planets around the Sun. However, Kepler did not succeed in formulating a theory behind the laws he wrote down.[41] It was Isaac Newton, with his invention of celestial dynamics and his law of gravitation, who finally explained the motions of the planets. Newton also developed the reflecting telescope.[42] Improvements in the size and quality of the telescope led to further discoveries. The English astronomer John Flamsteed catalogued over 3000 stars.[43] More extensive star catalogues were produced by Nicolas Louis de Lacaille. The astronomer William Herschel made a detailed catalog of nebulosity and clusters, and in 1781 discovered the planet Uranus, the first new planet found.[44] During the 18–19th centuries, the study of the three-body problem by Leonhard Euler, Alexis Claude Clairaut, and Jean le Rond d'Alembert led to more accurate predictions about the motions of the Moon and planets. This work was further refined by Joseph-Louis Lagrange and Pierre Simon Laplace, allowing the masses of the planets and moons to be estimated from their perturbations.[45] Significant advances in astronomy came about with the introduction of new technology, including the spectroscope and photography. Joseph von Fraunhofer discovered about 600 bands in the spectrum of the Sun in 1814–15, which, in 1859, Gustav Kirchhoff ascribed to the presence of different elements. Stars were proven to be similar to the Earth's own Sun, but with a wide range of temperatures, masses, and sizes.[29] The earliest known photograph of the Great Andromeda "Nebula", by Isaac Roberts from 29 December 1888. With the calculation of its distance in 1923 intergalactic space was proven, allowing the calculation of the age and expanse of the Universe. The existence of the Earth's galaxy, the Milky Way, as its own group of stars was only proven in the 20th century, along with the existence of "external" galaxies. The observed recession of those galaxies led to the discovery of the expansion of the Universe.[46] In 1919, when the Hooker Telescope was completed, the prevailing view was that the universe consisted entirely of the Milky Way Galaxy. Using the Hooker Telescope, Edwin Hubble identified Cepheid variables in several spiral nebulae and in 1922–1923 proved conclusively that Andromeda Nebula and Triangulum among others, were entire galaxies outside our own, thus proving that the universe consists of a multitude of galaxies.[47] With this Hubble formulated the Hubble constant, which allowed for the first time a calculation of the age of the Universe and size of the Observable Universe, which became increasingly precise with better measurements, starting at 2 billion years and 280 million light-years, until 2006 when data of the Hubble Space Telescope allowed a very accurate calculation of the age of the Universe and size of the Observable Universe.[48] First ever direct image of a (supermassive) black hole, taken 2019 in radio wavelength, located at the core of Messier 87. Theoretical astronomy led to speculations on the existence of objects such as black holes and neutron stars, which have been used to explain such observed phenomena as quasars, pulsars, blazars, and radio galaxies. Physical cosmology made huge advances during the 20th century. In the early 1900s the model of the Big Bang theory was formulated, heavily evidenced by cosmic microwave background radiation, Hubble's law, and the cosmological abundances of elements. Space telescopes have enabled measurements in parts of the electromagnetic spectrum normally blocked or blurred by the atmosphere.[49] In February 2016, it was revealed that the LIGO project had detected evidence of gravitational waves in the previous September.[50][51] Main article: Observational astronomy Overview of types of observational astronomy by observed wavelengths and their observability The main source of information about celestial bodies and other objects is visible light, or more generally electromagnetic radiation.[52] Observational astronomy may be categorized according to the corresponding region of the electromagnetic spectrum on which the observations are made. Some parts of the spectrum can be observed from the Earth's surface, while other parts are only observable from either high altitudes or outside the Earth's atmosphere. Specific information on these subfields is given below. The Very Large Array in New Mexico, an example of a radio telescope Main article: Radio astronomy Radio astronomy uses radiation with wavelengths greater than approximately one millimeter, outside the visible range.[53] Radio astronomy is different from most other forms of observational astronomy in that the observed radio waves can be treated as waves rather than as discrete photons. Hence, it is relatively easier to measure both the amplitude and phase of radio waves, whereas this is not as easily done at shorter wavelengths.[53] Although some radio waves are emitted directly by astronomical objects, a product of thermal emission, most of the radio emission that is observed is the result of synchrotron radiation, which is produced when electrons orbit magnetic fields.[53] Additionally, a number of spectral lines produced by interstellar gas, notably the hydrogen spectral line at 21 cm, are observable at radio wavelengths.[8][53] A wide variety of other objects are observable at radio wavelengths, including supernovae, interstellar gas, pulsars, and active galactic nuclei.[8][53] ALMA Observatory is one of the highest observatory sites on Earth. Atacama, Chile.[54] Main article: Infrared astronomy Infrared astronomy is founded on the detection and analysis of infrared radiation, wavelengths longer than red light and outside the range of our vision. The infrared spectrum is useful for studying objects that are too cold to radiate visible light, such as planets, circumstellar disks or nebulae whose light is blocked by dust. The longer wavelengths of infrared can penetrate clouds of dust that block visible light, allowing the observation of young stars embedded in molecular clouds and the cores of galaxies. Observations from the Wide-field Infrared Survey Explorer (WISE) have been particularly effective at unveiling numerous galactic protostars and their host star clusters.[55][56] With the exception of infrared wavelengths close to visible light, such radiation is heavily absorbed by the atmosphere, or masked, as the atmosphere itself produces significant infrared emission. Consequently, infrared observatories have to be located in high, dry places on Earth or in space.[57] Some molecules radiate strongly in the infrared. This allows the study of the chemistry of space; more specifically it can detect water in comets.[58] The Subaru Telescope (left) and Keck Observatory (center) on Mauna Kea, both examples of an observatory that operates at near-infrared and visible wavelengths. The NASA Infrared Telescope Facility (right) is an example of a telescope that operates only at near-infrared wavelengths. Main article: Optical astronomy Historically, optical astronomy, which has been also called visible light astronomy, is the oldest form of astronomy.[59] Images of observations were originally drawn by hand. In the late 19th century and most of the 20th century, images were made using photographic equipment. Modern images are made using digital detectors, particularly using charge-coupled devices (CCDs) and recorded on modern medium. Although visible light itself extends from approximately 4000 Å to 7000 Å (400 nm to 700 nm),[59] that same equipment can be used to observe some near-ultraviolet and near-infrared radiation.[citation needed] Main article: Ultraviolet astronomy Ultraviolet astronomy employs ultraviolet wavelengths between approximately 100 and 3200 Å (10 to 320 nm).[53] Light at those wavelengths is absorbed by the Earth's atmosphere, requiring observations at these wavelengths to be performed from the upper atmosphere or from space. Ultraviolet astronomy is best suited to the study of thermal radiation and spectral emission lines from hot blue stars (OB stars) that are very bright in this wave band. This includes the blue stars in other galaxies, which have been the targets of several ultraviolet surveys. Other objects commonly observed in ultraviolet light include planetary nebulae, supernova remnants, and active galactic nuclei.[53] However, as ultraviolet light is easily absorbed by interstellar dust, an adjustment of ultraviolet measurements is necessary.[53] Main article: X-ray astronomy X-ray jet made from a supermassive black hole found by NASA's Chandra X-ray Observatory, made visible by light from the early Universe X-ray astronomy uses X-ray wavelengths. Typically, X-ray radiation is produced by synchrotron emission (the result of electrons orbiting magnetic field lines), thermal emission from thin gases above 107 (10 million) kelvins, and thermal emission from thick gases above 107 Kelvin.[53] Since X-rays are absorbed by the Earth's atmosphere, all X-ray observations must be performed from high-altitude balloons, rockets, or X-ray astronomy satellites. Notable X-ray sources include X-ray binaries, pulsars, supernova remnants, elliptical galaxies, clusters of galaxies, and active galactic nuclei.[53] Main article: Gamma ray astronomy Gamma ray astronomy observes astronomical objects at the shortest wavelengths of the electromagnetic spectrum. Gamma rays may be observed directly by satellites such as the Compton Gamma Ray Observatory or by specialized telescopes called atmospheric Cherenkov telescopes.[53] The Cherenkov telescopes do not detect the gamma rays directly but instead detect the flashes of visible light produced when gamma rays are absorbed by the Earth's atmosphere.[60] Most gamma-ray emitting sources are actually gamma-ray bursts, objects which only produce gamma radiation for a few milliseconds to thousands of seconds before fading away. Only 10% of gamma-ray sources are non-transient sources. These steady gamma-ray emitters include pulsars, neutron stars, and black hole candidates such as active galactic nuclei.[53] In addition to electromagnetic radiation, a few other events originating from great distances may be observed from the Earth.[citation needed] In neutrino astronomy, astronomers use heavily shielded underground facilities such as SAGE, GALLEX, and Kamioka II/III for the detection of neutrinos. The vast majority of the neutrinos streaming through the Earth originate from the Sun, but 24 neutrinos were also detected from supernova 1987A.[53] Cosmic rays, which consist of very high energy particles (atomic nuclei) that can decay or be absorbed when they enter the Earth's atmosphere, result in a cascade of secondary particles which can be detected by current observatories.[61] Some future neutrino detectors may also be sensitive to the particles produced when cosmic rays hit the Earth's atmosphere.[53] Gravitational-wave astronomy is an emerging field of astronomy that employs gravitational-wave detectors to collect observational data about distant massive objects. A few observatories have been constructed, such as the Laser Interferometer Gravitational Observatory LIGO. LIGO made its first detection on 14 September 2015, observing gravitational waves from a binary black hole.[62] A second gravitational wave was detected on 26 December 2015 and additional observations should continue but gravitational waves require extremely sensitive instruments.[63][64] The combination of observations made using electromagnetic radiation, neutrinos or gravitational waves and other complementary information, is known as multi-messenger astronomy.[65][66] Main articles: Astrometry and Celestial mechanics Star cluster Pismis 24 with a nebula One of the oldest fields in astronomy, and in all of science, is the measurement of the positions of celestial objects. Historically, accurate knowledge of the positions of the Sun, Moon, planets and stars has been essential in celestial navigation (the use of celestial objects to guide navigation) and in the making of calendars.[67]:39 Careful measurement of the positions of the planets has led to a solid understanding of gravitational perturbations, and an ability to determine past and future positions of the planets with great accuracy, a field known as celestial mechanics. More recently the tracking of near-Earth objects will allow for predictions of close encounters or potential collisions of the Earth with those objects.[68] The measurement of stellar parallax of nearby stars provides a fundamental baseline in the cosmic distance ladder that is used to measure the scale of the Universe. Parallax measurements of nearby stars provide an absolute baseline for the properties of more distant stars, as their properties can be compared. Measurements of the radial velocity and proper motion of stars allow astronomers to plot the movement of these systems through the Milky Way galaxy. Astrometric results are the basis used to calculate the distribution of speculated dark matter in the galaxy.[69] During the 1990s, the measurement of the stellar wobble of nearby stars was used to detect large extrasolar planets orbiting those stars.[70] Main article: Theoretical astronomy Theoretical astronomers use several tools including analytical models and computational numerical simulations; each has its particular advantages. Analytical models of a process are better for giving broader insight into the heart of what is going on. Numerical models reveal the existence of phenomena and effects otherwise unobserved.[71][72] Theorists in astronomy endeavor to create theoretical models that are based on existing observations and known physics, and to predict observational consequences of those models. The observation of phenomena predicted by a model allows astronomers to select between several alternative or conflicting models. Theorists also modify existing models to take into account new observations. In some cases, a large amount of observational data that is inconsistent with a model may lead to abandoning it largely or completely, as for geocentric theory, the existence of luminiferous aether, and the steady-state model of cosmic evolution.[citation needed] Phenomena modeled by theoretical astronomers include: stellar dynamics and evolution galaxy formation large-scale distribution of matter in the Universe the origin of cosmic rays general relativity and physical cosmology, including string cosmology and astroparticle physics. Modern theoretical astronomy reflects dramatic advances in observation since the 1990s, including studies of the cosmic microwave background, distant supernovae and galaxy redshifts, which have led to the development of a standard model of cosmology. This model requires the universe to contain large amounts of dark matter and dark energy whose nature is currently not well understood, but the model gives detailed predictions that are in excellent agreement with many diverse observations.[73] Main article: Astrophysics Astrophysics applies physics and chemistry to understand the measurements made by astronomy. Representation of the Observable Universe that includes images from Hubble and other telescopes. Astrophysics is the branch of astronomy that employs the principles of physics and chemistry "to ascertain the nature of the astronomical objects, rather than their positions or motions in space".[74][75] Among the objects studied are the Sun, other stars, galaxies, extrasolar planets, the interstellar medium and the cosmic microwave background.[76][77] Their emissions are examined across all parts of the electromagnetic spectrum, and the properties examined include luminosity, density, temperature, and chemical composition. Because astrophysics is a very broad subject, astrophysicists typically apply many disciplines of physics, including mechanics, electromagnetism, statistical mechanics, thermodynamics, quantum mechanics, relativity, nuclear and particle physics, and atomic and molecular physics.[citation needed] In practice, modern astronomical research often involves a substantial amount of work in the realms of theoretical and observational physics. Some areas of study for astrophysicists include their attempts to determine the properties of dark matter, dark energy, and black holes; whether or not time travel is possible, wormholes can form, or the multiverse exists; and the origin and ultimate fate of the universe.[76] Topics also studied by theoretical astrophysicists include Solar System formation and evolution; stellar dynamics and evolution; galaxy formation and evolution; magnetohydrodynamics; large-scale structure of matter in the universe; origin of cosmic rays; general relativity and physical cosmology, including string cosmology and astroparticle physics.[citation needed] Main article: Astrochemistry Astrochemistry is the study of the abundance and reactions of molecules in the Universe, and their interaction with radiation. The discipline is an overlap of astronomy and chemistry. The word "astrochemistry" may be applied to both the Solar System and the interstellar medium. The study of the abundance of elements and isotope ratios in Solar System objects, such as meteorites, is also called cosmochemistry, while the study of interstellar atoms and molecules and their interaction with radiation is sometimes called molecular astrophysics. The formation, atomic and chemical composition, evolution and fate of molecular gas clouds is of special interest, because it is from these clouds that solar systems form. Studies in this field contribute to the understanding of the formation of the Solar System, Earth's origin and geology, abiogenesis, and the origin of climate and oceans.[78] Main article: Astrobiology Astrobiology is an interdisciplinary scientific field concerned with the origins, early evolution, distribution, and future of life in the universe. Astrobiology considers the question of whether extraterrestrial life exists, and how humans can detect it if it does.[79] The term exobiology is similar.[80] Astrobiology makes use of molecular biology, biophysics, biochemistry, chemistry, astronomy, physical cosmology, exoplanetology and geology to investigate the possibility of life on other worlds and help recognize biospheres that might be different from that on Earth.[81] The origin and early evolution of life is an inseparable part of the discipline of astrobiology.[82] Astrobiology concerns itself with interpretation of existing scientific data, and although speculation is entertained to give context, astrobiology concerns itself primarily with hypotheses that fit firmly into existing scientific theories.[citation needed] This interdisciplinary field encompasses research on the origin of planetary systems, origins of organic compounds in space, rock-water-carbon interactions, abiogenesis on Earth, planetary habitability, research on biosignatures for life detection, and studies on the potential for life to adapt to challenges on Earth and in outer space.[83][84][85] Main article: Physical cosmology Cosmology (from the Greek κόσμος (kosmos) "world, universe" and λόγος (logos) "word, study" or literally "logic") could be considered the study of the Universe as a whole.[citation needed] Hubble Extreme Deep Field Observations of the large-scale structure of the Universe, a branch known as physical cosmology, have provided a deep understanding of the formation and evolution of the cosmos. Fundamental to modern cosmology is the well-accepted theory of the Big Bang, wherein our Universe began at a single point in time, and thereafter expanded over the course of 13.8 billion years[86] to its present condition.[87] The concept of the Big Bang can be traced back to the discovery of the microwave background radiation in 1965.[87] In the course of this expansion, the Universe underwent several evolutionary stages. In the very early moments, it is theorized that the Universe experienced a very rapid cosmic inflation, which homogenized the starting conditions. Thereafter, nucleosynthesis produced the elemental abundance of the early Universe.[87] (See also nucleocosmochronology.)[citation needed] When the first neutral atoms formed from a sea of primordial ions, space became transparent to radiation, releasing the energy viewed today as the microwave background radiation. The expanding Universe then underwent a Dark Age due to the lack of stellar energy sources.[88] A hierarchical structure of matter began to form from minute variations in the mass density of space. Matter accumulated in the densest regions, forming clouds of gas and the earliest stars, the Population III stars. These massive stars triggered the reionization process and are believed to have created many of the heavy elements in the early Universe, which, through nuclear decay, create lighter elements, allowing the cycle of nucleosynthesis to continue longer.[89] Gravitational aggregations clustered into filaments, leaving voids in the gaps. Gradually, organizations of gas and dust merged to form the first primitive galaxies. Over time, these pulled in more matter, and were often organized into groups and clusters of galaxies, then into larger-scale superclusters.[90] Fundamental to the structure of the Universe is the existence of dark matter and dark energy. These are now thought to be its dominant components, forming 96% of the mass of the Universe. For this reason, much effort is expended in trying to understand the physics of these components.[91] This image shows several blue, loop-shaped objects that are multiple images of the same galaxy, duplicated by the gravitational lens effect of the cluster of yellow galaxies near the middle of the photograph. The lens is produced by the cluster's gravitational field that bends light to magnify and distort the image of a more distant object. Main article: Extragalactic astronomy The study of objects outside our galaxy is a branch of astronomy concerned with the formation and evolution of galaxies, their morphology (description) and classification, the observation of active galaxies, and at a larger scale, the groups and clusters of galaxies. Finally, the latter is important for the understanding of the large-scale structure of the cosmos.[67] Most galaxies are organized into distinct shapes that allow for classification schemes. They are commonly divided into spiral, elliptical and Irregular galaxies.[92] As the name suggests, an elliptical galaxy has the cross-sectional shape of an ellipse. The stars move along random orbits with no preferred direction. These galaxies contain little or no interstellar dust, few star-forming regions, and older stars.[67]:877–878 Elliptical galaxies may have been formed by other galaxies merging.[67]:939 A spiral galaxy is organized into a flat, rotating disk, usually with a prominent bulge or bar at the center, and trailing bright arms that spiral outward. The arms are dusty regions of star formation within which massive young stars produce a blue tint. Spiral galaxies are typically surrounded by a halo of older stars. Both the Milky Way and one of our nearest galaxy neighbors, the Andromeda Galaxy, are spiral galaxies.[67]:875 Irregular galaxies are chaotic in appearance, and are neither spiral nor elliptical.[67]:879 About a quarter of all galaxies are irregular, and the peculiar shapes of such galaxies may be the result of gravitational interaction.[93] An active galaxy is a formation that emits a significant amount of its energy from a source other than its stars, dust and gas. It is powered by a compact region at the core, thought to be a supermassive black hole that is emitting radiation from in-falling material.[67]:907 A radio galaxy is an active galaxy that is very luminous in the radio portion of the spectrum, and is emitting immense plumes or lobes of gas. Active galaxies that emit shorter frequency, high-energy radiation include Seyfert galaxies, quasars, and blazars. Quasars are believed to be the most consistently luminous objects in the known universe.[94] The large-scale structure of the cosmos is represented by groups and clusters of galaxies. This structure is organized into a hierarchy of groupings, with the largest being the superclusters. The collective matter is formed into filaments and walls, leaving large voids between.[95] A diagram of the Sun's location in the Milky Way, the angles represent longitudes in the galactic coordinate system Main article: Galactic astronomy The Solar System orbits within the Milky Way, a barred spiral galaxy that is a prominent member of the Local Group of galaxies. It is a rotating mass of gas, dust, stars and other objects, held together by mutual gravitational attraction. As the Earth is located within the dusty outer arms, there are large portions of the Milky Way that are obscured from view.[67]:837–842,944 In the center of the Milky Way is the core, a bar-shaped bulge with what is believed to be a supermassive black hole at its center. This is surrounded by four primary arms that spiral from the core. This is a region of active star formation that contains many younger, population I stars. The disk is surrounded by a spheroid halo of older, population II stars, as well as relatively dense concentrations of stars known as globular clusters.[96] Between the stars lies the interstellar medium, a region of sparse matter. In the densest regions, molecular clouds of molecular hydrogen and other elements create star-forming regions. These begin as a compact pre-stellar core or dark nebulae, which concentrate and collapse (in volumes determined by the Jeans length) to form compact protostars.[97] As the more massive stars appear, they transform the cloud into an H II region (ionized atomic hydrogen) of glowing gas and plasma. The stellar wind and supernova explosions from these stars eventually cause the cloud to disperse, often leaving behind one or more young open clusters of stars. These clusters gradually disperse, and the stars join the population of the Milky Way.[98] Kinematic studies of matter in the Milky Way and other galaxies have demonstrated that there is more mass than can be accounted for by visible matter. A dark matter halo appears to dominate the mass, although the nature of this dark matter remains undetermined.[99] Mz 3, often referred to as the Ant planetary nebula. Ejecting gas from the dying central star shows symmetrical patterns unlike the chaotic patterns of ordinary explosions. Main article: Star See also: Solar astronomy The study of stars and stellar evolution is fundamental to our understanding of the Universe. The astrophysics of stars has been determined through observation and theoretical understanding; and from computer simulations of the interior.[100] Star formation occurs in dense regions of dust and gas, known as giant molecular clouds. When destabilized, cloud fragments can collapse under the influence of gravity, to form a protostar. A sufficiently dense, and hot, core region will trigger nuclear fusion, thus creating a main-sequence star.[97] Almost all elements heavier than hydrogen and helium were created inside the cores of stars.[100] The characteristics of the resulting star depend primarily upon its starting mass. The more massive the star, the greater its luminosity, and the more rapidly it fuses its hydrogen fuel into helium in its core. Over time, this hydrogen fuel is completely converted into helium, and the star begins to evolve. The fusion of helium requires a higher core temperature. A star with a high enough core temperature will push its outer layers outward while increasing its core density. The resulting red giant formed by the expanding outer layers enjoys a brief life span, before the helium fuel in the core is in turn consumed. Very massive stars can also undergo a series of evolutionary phases, as they fuse increasingly heavier elements.[101] The final fate of the star depends on its mass, with stars of mass greater than about eight times the Sun becoming core collapse supernovae;[102] while smaller stars blow off their outer layers and leave behind the inert core in the form of a white dwarf. The ejection of the outer layers forms a planetary nebula.[103] The remnant of a supernova is a dense neutron star, or, if the stellar mass was at least three times that of the Sun, a black hole.[104] Closely orbiting binary stars can follow more complex evolutionary paths, such as mass transfer onto a white dwarf companion that can potentially cause a supernova.[105] Planetary nebulae and supernovae distribute the "metals" produced in the star by fusion to the interstellar medium; without them, all new stars (and their planetary systems) would be formed from hydrogen and helium alone.[106] An ultraviolet image of the Sun's active photosphere as viewed by the NASA's TRACE space telescope. Solar observatory Lomnický štít (Slovakia) built in 1962 See also: Solar telescope At a distance of about eight light-minutes, the most frequently studied star is the Sun, a typical main-sequence dwarf star of stellar class G2 V, and about 4.6 billion years (Gyr) old. The Sun is not considered a variable star, but it does undergo periodic changes in activity known as the sunspot cycle. This is an 11-year oscillation in sunspot number. Sunspots are regions of lower-than-average temperatures that are associated with intense magnetic activity.[107] The Sun has steadily increased in luminosity by 40% since it first became a main-sequence star. The Sun has also undergone periodic changes in luminosity that can have a significant impact on the Earth.[108] The Maunder minimum, for example, is believed to have caused the Little Ice Age phenomenon during the Middle Ages.[109] At the center of the Sun is the core region, a volume of sufficient temperature and pressure for nuclear fusion to occur. Above the core is the radiation zone, where the plasma conveys the energy flux by means of radiation. Above that is the convection zone where the gas material transports energy primarily through physical displacement of the gas known as convection. It is believed that the movement of mass within the convection zone creates the magnetic activity that generates sunspots.[107] The visible outer surface of the Sun is called the photosphere. Above this layer is a thin region known as the chromosphere. This is surrounded by a transition region of rapidly increasing temperatures, and finally by the super-heated corona.[67]:498–502 A solar wind of plasma particles constantly streams outward from the Sun until, at the outermost limit of the Solar System, it reaches the heliopause. As the solar wind passes the Earth, it interacts with the Earth's magnetic field (magnetosphere) and deflects the solar wind, but traps some creating the Van Allen radiation belts that envelop the Earth. The aurora are created when solar wind particles are guided by the magnetic flux lines into the Earth's polar regions where the lines then descend into the atmosphere.[110] The black spot at the top is a dust devil climbing a crater wall on Mars. This moving, swirling column of Martian atmosphere (comparable to a terrestrial tornado) created the long, dark streak. Main articles: Planetary science and Planetary geology Planetary science is the study of the assemblage of planets, moons, dwarf planets, comets, asteroids, and other bodies orbiting the Sun, as well as extrasolar planets. The Solar System has been relatively well-studied, initially through telescopes and then later by spacecraft. This has provided a good overall understanding of the formation and evolution of the Sun's planetary system, although many new discoveries are still being made.[111] The Solar System is divided into the inner Solar System (subdivided into the inner planets and the asteroid belt), the outer Solar System (subdivided into the outer planets and centaurs), comets, the trans-Neptunian region (subdivided into the Kuiper belt, and the scattered disc) and the farthest regions (e.g., boundaries of the heliosphere, and the Oort Cloud, which may extend as far as a light-year). The inner terrestrial planets consist of Mercury, Venus, Earth, and Mars. The outer giant planets are the gas giants (Jupiter and Saturn) and the ice giants (Uranus and Neptune).[112] The planets were formed 4.6 billion years ago in the protoplanetary disk that surrounded the early Sun. Through a process that included gravitational attraction, collision, and accretion, the disk formed clumps of matter that, with time, became protoplanets. The radiation pressure of the solar wind then expelled most of the unaccreted matter, and only those planets with sufficient mass retained their gaseous atmosphere. The planets continued to sweep up, or eject, the remaining matter during a period of intense bombardment, evidenced by the many impact craters on the Moon. During this period, some of the protoplanets may have collided and one such collision may have formed the Moon.[113] Once a planet reaches sufficient mass, the materials of different densities segregate within, during planetary differentiation. This process can form a stony or metallic core, surrounded by a mantle and an outer crust. The core may include solid and liquid regions, and some planetary cores generate their own magnetic field, which can protect their atmospheres from solar wind stripping.[114] A planet or moon's interior heat is produced from the collisions that created the body, by the decay of radioactive materials (e.g. uranium, thorium, and 26Al), or tidal heating caused by interactions with other bodies. Some planets and moons accumulate enough heat to drive geologic processes such as volcanism and tectonics. Those that accumulate or retain an atmosphere can also undergo surface erosion from wind or water. Smaller bodies, without tidal heating, cool more quickly; and their geological activity ceases with the exception of impact cratering.[115] Astronomy and astrophysics have developed significant interdisciplinary links with other major scientific fields. Archaeoastronomy is the study of ancient or traditional astronomies in their cultural context, utilizing archaeological and anthropological evidence. Astrobiology is the study of the advent and evolution of biological systems in the Universe, with particular emphasis on the possibility of non-terrestrial life. Astrostatistics is the application of statistics to astrophysics to the analysis of a vast amount of observational astrophysical data.[116] The study of chemicals found in space, including their formation, interaction and destruction, is called astrochemistry. These substances are usually found in molecular clouds, although they may also appear in low-temperature stars, brown dwarfs and planets. Cosmochemistry is the study of the chemicals found within the Solar System, including the origins of the elements and variations in the isotope ratios. Both of these fields represent an overlap of the disciplines of astronomy and chemistry. As "forensic astronomy", finally, methods from astronomy have been used to solve problems of art history[117][118] and occasionally of law.[119] Amateur astronomers can build their own equipment, and hold star parties and gatherings, such as Stellafane. Main article: Amateur astronomy Astronomy is one of the sciences to which amateurs can contribute the most.[120] Collectively, amateur astronomers observe a variety of celestial objects and phenomena sometimes with consumer-level equipment or equipment that they build themselves. Common targets of amateur astronomers include the Sun, the Moon, planets, stars, comets, meteor showers, and a variety of deep-sky objects such as star clusters, galaxies, and nebulae. Astronomy clubs are located throughout the world and many have programs to help their members set up and complete observational programs including those to observe all the objects in the Messier (110 objects) or Herschel 400 catalogues of points of interest in the night sky. One branch of amateur astronomy, astrophotography, involves the taking of photos of the night sky. Many amateurs like to specialize in the observation of particular objects, types of objects, or types of events that interest them.[121][122] Most amateurs work at visible wavelengths, but many experiment with wavelengths outside the visible spectrum. This includes the use of infrared filters on conventional telescopes, and also the use of radio telescopes. The pioneer of amateur radio astronomy was Karl Jansky, who started observing the sky at radio wavelengths in the 1930s. A number of amateur astronomers use either homemade telescopes or use radio telescopes which were originally built for astronomy research but which are now available to amateurs (e.g. the One-Mile Telescope).[123][124] Amateur astronomers continue to make scientific contributions to the field of astronomy and it is one of the few scientific disciplines where amateurs can still make significant contributions. Amateurs can make occultation measurements that are used to refine the orbits of minor planets. They can also discover comets, and perform regular observations of variable stars. Improvements in digital technology have allowed amateurs to make impressive advances in the field of astrophotography.[125][126][127] Main article: List of unsolved problems in astronomy In the 21st century there remain important unanswered questions in astronomy. Some are cosmic in scope: for example, what are dark matter and dark energy? These dominate the evolution and fate of the cosmos, yet their true nature remains unknown.[128] What will be the ultimate fate of the universe?[129] Why is the abundance of lithium in the cosmos four times lower than predicted by the standard Big Bang model?[130] Others pertain to more specific classes of phenomena. For example, is the Solar System normal or atypical?[131] What is the origin of the stellar mass spectrum? That is, why do astronomers observe the same distribution of stellar masses—the initial mass function—apparently regardless of the initial conditions?[132] Likewise, questions remain about the formation of the first galaxies,[133] the origin of supermassive black holes,[134] the source of ultra-high-energy cosmic rays,[135] and more. Is there other life in the Universe? Especially, is there other intelligent life? If so, what is the explanation for the Fermi paradox? The existence of life elsewhere has important scientific and philosophical implications.[136][137] Cosmogony – Theory or model concerning the origin of the universe Outline of astronomy – Overview of the scientific field of astronomy Outline of space science – Overview of and topical guide to space science Space exploration – Exploration of space, planets, and moons Glossary of astronomy List of astronomical instruments – Devices for observing, measuring or recording astronomical data List of astronomical observatories List of astronomy acronyms List of astronomical societies List of software for astronomy research and education ^ Losev, Alexandre (2012). "'Astronomy' or 'astrology': A brief history of an apparent confusion". Journal of Astronomical History and Heritage. 15 (1): 42–46. arXiv:1006.5209. Bibcode:2012JAHH...15...42L. doi:10.3724/SP.J.1440-2807.2012.01.05. ISSN 1440-2807. S2CID 51802196. ^ Unsöld, Albrecht; Baschek, Bodo (2001). 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Wikimedia Commons has media related to Astronomy. Wikibooks has more on the topic of: Astronomy NASA/IPAC Extragalactic Database (NED) (NED-Distances) Core books and Core journals in Astronomy, from the Smithsonian/NASA Astrophysics Data System Portals: Astronomy Stars Spaceflight Outer space Solar System Retrieved from " 2 Aluminium-26 (26Al, Al-26) is a radioactive isotope of the chemical element aluminium, decaying by either positron emission or electron capture to stable magnesium-26. The half-life of 26Al is 717,000 years. This is far too short for the isotope to survive as a primordial nuclide, but a small amount of it is produced by collisions of atoms with cosmic ray protons.[1] Aluminium-26GeneralSymbol26AlNamesaluminium-26Protons (Z)13Neutrons (N)13Nuclide dataNatural abundancetrace (cosmogenic)Half-life (t1/2)7.17×105 yearsSpin5+Decay modesDecay modeDecay energy (MeV)β+4.00414ε4.00414Isotopes of aluminium Complete table of nuclides Decay of aluminium-26 also produces gamma rays and x-rays.[2] The x-rays and Auger electrons are emitted by the excited atomic shell of the daughter 26Mg after the electron capture which typically leaves a hole in one of the lower sub-shells. Because it is radioactive, it is typically stored behind at least 5 centimetres (2 in) of lead. Contact with 26Al may result in radiological contamination. This necessitates special tools for transfer, use, and storage.[3] Aluminium-26 can be used to calculate the terrestrial age of meteorites and comets. It is produced in significant quantities in extraterrestrial objects via spallation of silicon alongside beryllium-10, though after falling to Earth, 26Al production ceases and its abundance relative to other cosmogenic nuclides decreases. Absence of aluminium-26 sources on Earth is a consequence of Earth's atmosphere obstructing silicon on the surface and low troposphere from interaction with cosmic rays. Consequently, the amount of 26Al in the sample can be used to calculate the date the meteorite fell to Earth.[1] The distribution of 26Al in Milky Way The gamma ray emission from the decay of aluminium-26 at 1809 keV was the first observed gamma emission from the Galactic Center. The observation was made by the HEAO-3 satellite in 1984.[4][5] 26Al is mainly produced in supernovae ejecting many radioactive nuclides in the interstellar medium. The isotope is believed to be crucial for the evolution of planetary objects, providing enough heat to melt and differentiate accreting planetesimals. This is known to have happened during the early history of the asteroids 1 Ceres and 4 Vesta.[6][7][8] 26Al has been hypothesized to have played a role in the unusual shape of Saturn's moon Iapetus. Iapetus is noticeably flattened and oblate, indicating that it rotated significantly faster early in its history, with a rotation period possibly as short as 17 hours. Heating from 26Al could have provided enough heat in Iapetus to allow it to conform to this rapid rotation period, before the moon cooled and became too rigid to relax back into hydrostatic equilibrium.[9] The presence of aluminium monofluoride molecule as the 26Al isotopologue in CK Vulpeculae, which is an unknown type of nova, constitutes the first solid evidence of an extrasolar radioactive molecule.[10] In considering the known melting of small planetary bodies in the early Solar System, H. C. Urey noted that the naturally occurring long-lived radioactive nuclei (40K, 238U, 235U and 232Th) were insufficient heat sources. He proposed that the heat sources from short lived nuclei from newly formed stars might be the source and identified 26Al as the most likely choice.[11][12] This proposal was made well before the general problems of stellar nucleosynthesis of the nuclei were known or understood. This conjecture was based on the discovery of 26Al in a Mg target by Simanton, Rightmire, Long & Kohman.[13] Their search was undertaken because hitherto there was no known radioactive isotope of Al that might be useful as a tracer. Theoretical considerations suggested that a state of 26Al should exist. The life time of 26Al was not then known; it was only estimated between 104 and 106 years. The search for 26Al took place over many years, long after the discovery of the extinct radionuclide 129I which showed that contribution from stellar sources formed ~108 years before the Sun had contributed[how?] to the Solar System mix. The asteroidal materials that provide meteorite samples were long known to be from the early Solar System.[14] The Allende meteorite, which fell in 1969, contained abundant calcium–aluminium-rich inclusions (CAIs). These are very refractory materials and were interpreted as being condensates from a hot solar nebula.[15][16] then discovered that the oxygen in these objects was enhanced in 16O by ~5% while the 17O/18O was the same as terrestrial. This clearly showed a large effect in an abundant element that might be nuclear, possibly from a stellar source. These objects were then found to contain strontium with very low 87Sr/86Sr indicating that they were a few million years older than previously analyzed meteoritic material and that this type of material would merit a search for 26Al.[17] 26Al is only present today in the Solar System materials as the result of cosmic reactions on unshielded materials at an extremely[quantify] low level. Thus, any original 26Al in the early Solar System is now extinct. To establish the presence of 26Al in very ancient materials requires demonstrating that samples must contain clear excesses of 26Mg/24Mg which correlates with the ratio of 27Al/24Mg. The stable 27Al is then a surrogate for extinct 26Al. The different 27Al/24Mg ratios are coupled to different chemical phases in a sample and are the result of normal chemical separation processes associated with the growth of the crystals in the CAIs. Clear evidence of the presence of 26Al at an abundance ratio of 5×10−5 was shown by Lee et al.[18][19] The value (26Al/27Al ~ 5×10−5) has now been generally established as the high value in early Solar System samples and has been generally used as a refined time scale chronometer for the early Solar System. Lower values imply a more recent time of formation. If this 26Al is the result of pre-solar stellar sources, then this implies a close connection in time between the formation of the Solar System and the production in some exploding star. Many materials which had been presumed to be very early (e.g. chondrules) appear to have formed a few million years later.[20] Other extinct radioactive nuclei, which clearly had a stellar origin, were then being discovered.[21] That 26Al was present in the interstellar medium as a major gamma ray source was not explored until the development of the high-energy astronomical observatory program. The HEAO-3 spacecraft with cooled Ge detectors allowed the clear detection of 1.808 MeV gamma lines from the central part of the galaxy from a distributed 26Al source.[4] This represents a quasi steady state inventory corresponding to two solar masses of 26Al was distributed.[clarification needed] This discovery was greatly expanded on by observations from the Compton Gamma Ray Observatory using the COMPTEL telescope in the galaxy.[22] Subsequently, the 60Fe lines (1.173 MeV and 1.333 Mev) were also detected showing the relative rates of decays from 60Fe to 26Al to be 60Fe/26Al ~ 0.11.[23] In pursuit of the carriers of 22Ne in the sludge produced by chemical destruction of some meteorites, carrier grains in micron size, acid-resistant ultra-refractory materials (e.g. C, SiC) were found by E. Anders & the Chicago group. The carrier grains were clearly shown to be circumstellar condensates from earlier stars and often contained very large enhancements in 26Mg/24Mg from the decay of 26Al with 26Al/27Al sometimes approaching 0.2.[24][25] These studies on micron scale grains were possible as a result of the development of surface ion mass spectrometry at high mass resolution with a focused beam developed by G. Slodzian & R. Castaing with the CAMECA Co. The production of 26Al by cosmic ray interactions in unshielded materials is used as a monitor of the time of exposure to cosmic rays. The amounts are far below the initial inventory that is found in very early solar system debris. Before 1954, the half-life of aluminium-26m was measured to be 6.3 seconds.[26] After it was theorized that this could be the half-life of a metastable state (isomer) of aluminium-26, the ground state was produced by bombardment of magnesium-26 and magnesium-25 with deuterons in the cyclotron of the University of Pittsburgh.[13] The first half-life was determined to be in the range of 106 years. The Fermi beta decay half-life of the aluminium-26 metastable state is of interest in the experimental testing of two components of the Standard Model, namely, the conserved-vector-current hypothesis and the required unitarity of the Cabibbo–Kobayashi–Maskawa matrix.[27] The decay is superallowed. The 2011 measurement of the half life of 26mAl is 6346.54 ± 0.46(statistical) ± 0.60(system) milliseconds.[28] Isotopes of aluminium Radiometric dating § The 26Al – 26Mg chronometer Surface exposure dating ^ a b Barbuzano, Javier (2020). "Radioactive Aluminum Sheds Light On Solar System History". 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Until the invention of the telescope and the discovery of the laws of motion and gravity in the 17th century, astronomy was primarily concerned with noting and predicting the positions of the Sun, Moon, and planets, originally for calendrical and astrological purposes and later for navigational uses and scientific interest. The catalog of objects now studied is much broader and includes, in order of increasing distance, the solar system, the stars that make up the Milky Way Galaxy, and other, more distant galaxies. With the advent of scientific space probes, Earth also has come to be studied as one of the planets, though its more-detailed investigation remains the domain of the Earth sciences. Brian May: Queen guitarist and astrophysicistMany consider Brian May to be the greatest guitarist of all time. He's also an astrophysicist.See all videos for this articleSince the late 19th century, astronomy has expanded to include astrophysics, the application of physical and chemical knowledge to an understanding of the nature of celestial objects and the physical processes that control their formation, evolution, and emission of radiation. In addition, the gases and dust particles around and between the stars have become the subjects of much research. Study of the nuclear reactions that provide the energy radiated by stars has shown how the diversity of atoms found in nature can be derived from a universe that, following the first few minutes of its existence, consisted only of hydrogen, helium, and a trace of lithium. Concerned with phenomena on the largest scale is cosmology, the study of the evolution of the universe. Astrophysics has transformed cosmology from a purely speculative activity to a modern science capable of predictions that can be tested. Its great advances notwithstanding, astronomy is still subject to a major constraint: it is inherently an observational rather than an experimental science. Almost all measurements must be performed at great distances from the objects of interest, with no control over such quantities as their temperature, pressure, or chemical composition. There are a few exceptions to this limitation—namely, meteorites (most of which are from the asteroid belt, though some are from the Moon or Mars), rock and soil samples brought back from the Moon, samples of comet and asteroid dust returned by robotic spacecraft, and interplanetary dust particles collected in or above the stratosphere. These can be examined with laboratory techniques to provide information that cannot be obtained in any other way. In the future, space missions may return surface materials from Mars, or other objects, but much of astronomy appears otherwise confined to Earth-based observations augmented by observations from orbiting satellites and long-range space probes and supplemented by theory. stellar distancesCalculating stellar distances.A central undertaking in astronomy is the determination of distances. Without a knowledge of astronomical distances, the size of an observed object in space would remain nothing more than an angular diameter and the brightness of a star could not be converted into its true radiated power, or luminosity. Astronomical distance measurement began with a knowledge of Earth's diameter, which provided a base for triangulation. Within the inner solar system, some distances can now be better determined through the timing of radar reflections or, in the case of the Moon, through laser ranging. For the outer planets, triangulation is still used. Beyond the solar system, distances to the closest stars are determined through triangulation, in which the diameter of Earth's orbit serves as the baseline and shifts in stellar parallax are the measured quantities. Stellar distances are commonly expressed by astronomers in parsecs (pc), kiloparsecs, or megaparsecs. (1 pc = 3.086 × 1018 cm, or about 3.26 light-years [1.92 × 1013 miles].) Distances can be measured out to around a kiloparsec by trigonometric parallax (see star: Determining stellar distances). The accuracy of measurements made from Earth's surface is limited by atmospheric effects, but measurements made from the Hipparcos satellite in the 1990s extended the scale to stars as far as 650 parsecs, with an accuracy of about a thousandth of an arc second. The Gaia satellite is expected to measure stars as far away as 10 kiloparsecs to an accuracy of 20 percent. Less-direct measurements must be used for more-distant stars and for galaxies. Two general methods for determining galactic distances are described here. In the first, a clearly identifiable type of star is used as a reference standard because its luminosity has been well determined. This requires observation of such stars that are close enough to Earth that their distances and luminosities have been reliably measured. Such a star is termed a “standard candle.” Examples are Cepheid variables, whose brightness varies periodically in well-documented ways, and certain types of supernova explosions that have enormous brilliance and can thus be seen out to very great distances. Once the luminosities of such nearer standard candles have been calibrated, the distance to a farther standard candle can be calculated from its calibrated luminosity and its actual measured intensity. (The measured intensity [I] is related to the luminosity [L] and distance [d] by the formula I = L/4πd2.) A standard candle can be identified by means of its spectrum or the pattern of regular variations in brightness. (Corrections may have to be made for the absorption of starlight by interstellar gas and dust over great distances.) This method forms the basis of measurements of distances to the closest galaxies. Constellations of the Zodiac and Their Signs Quiz The second method for galactic distance measurements makes use of the observation that the distances to galaxies generally correlate with the speeds with which those galaxies are receding from Earth (as determined from the Doppler shift in the wavelengths of their emitted light). This correlation is expressed in the Hubble law: velocity = H × distance, in which H denotes Hubble's constant, which must be determined from observations of the rate at which the galaxies are receding. There is widespread agreement that H lies between 67 and 73 kilometres per second per megaparsec (km/sec/Mpc). H has been used to determine distances to remote galaxies in which standard candles have not been found. (For additional discussion of the recession of galaxies, the Hubble law, and galactic distance determination, see physical science: Astronomy.) Astronomy is one of the oldest scientific disciplines that has evolved from the humble beginnings of counting stars and charting constellations with the naked eye to the impressive showcase of humankind's technological capabilities that we see today. Despite the progress astronomy has made over millennia, astronomers are still working hard to understand the nature of the universe and humankind's place in it. That question has only gotten more complex as our understanding of the universe grew with our expanding technical capabilities. As the depths of the sky opened in front of our increasingly sophisticated telescopes, and sensitive detectors enabled us to spot the weirdest types of signals, the star-studded sky that our ancestors gazed at turned into a zoo of mind-boggling objects including black holes, white dwarfs, neutron stars and supernovas. You may like Related: Famous astronomers: How these scientists shaped astronomyAt the same time, the two-dimensional constellations that inspired the imagination of early sky-watchers were reduced to an optical illusion, behind which the swirling of galaxies hurtling through spacetime reveals a story that began with the Big Bang some 13.8 billion years ago. Here is how the story of astronomy and our understanding of the universe evolved. Astronomy FAQsAstronomy uses mathematics, physics and chemistry to study celestial objects and phenomena. Astronomy cannot be divided solely into four types. It is a broad discipline encompassing many subfields including observational astronomy, theoretical astronomy, planetary science, astrophysics, cosmology and astrobiology.Those who study astronomy explore the structure and origin of the universe including the stars, planets, galaxies and black holes that reside in it. Astronomers aim to answer fundamental questions about our universe through theory and observation. Astrology is widely considered to be a pseudoscience that attempts to explain how the position and motion of celestial objects such as planets affect people and events on Earth. Astronomy is the scientific study of the universe using mathematics, physics, and chemistry.History of astronomy: The beginningsMost of today's citizens of planet Earth live surrounded by the inescapable glow of modern urban lighting and can hardly imagine the awe-inspiring presence of the pristine star-studded sky that illuminated the nights for ancient tribes and early civilizations. We can guess how drawn our ancestors were to that overwhelming sight from the role that sky-watching played in their lives. Ancient monuments, such as the 5,000 years old Stonehenge in the U.K., were built to reflect the journey of the sun in the sky, which helped keep track of time and organize life in an age that solely depended on seasons. Art pieces depicting the moon and stars were discovered dating back several thousand years, such as the "world's oldest star map," the bronze-age Nebra disk.Ancient Assyro-Babylonians around 1,000 B.C. systematically observed and recorded periodical motions of celestial bodies, according to the European Space Agency (ESA), and similar records exist also from early China. In fact, according to the University of Oregon, astronomy can be considered the first science as it's the one for which the oldest written records exist.Ancient Greeks elevated sky-watching to a new level. Aristarchus of Samos made the first (highly inaccurate) attempt to calculate the distance of Earth to the sun and moon, and Hipparchus sometimes considered the father of empirical astronomy, cataloged the positions of over 800 stars using just the naked eye. He also developed the brightness scale that is still in use today, according to ESA. The Nebra Disc, estimated to be 3,600 years old, is one of the oldest known artefacts depicting the night sky. (Image credit: Frank Vincentz)History of astronomy: The arrival of the telescopeDuring the Middle Ages, the science of astronomy continued to advance in Asia and the Islamic world. Islamic scholars kept building on the knowledge of the Ancient Greeks, expanding the catalog introduced by Hipparchus. They also developed new tools for measuring the positions of objects in the sky such as the quadrant and the sextant, according to ESA.The first true breakthrough in humankind's exploration of the universe, however, arrived with the invention of the telescope in the 17th century. Italian astronomer Galileo Galilei was an early adopter and developer of the technology, which enabled him to make major strides in the understanding of our solar system. Called "the father of modern science" by no other than the great Albert Einstein, Galileo was able to sketch the surface of the moon, discover the main moons of Jupiter, find sunspots on the sun, and much more, thanks to the telescope.The invention of the telescope supercharged astronomy. Despite the objections of the Catholic Church, the notion that Earth wasn't the center of the universe but orbited the sun together with other planets and their moons could no longer be denied. Astronomy at that time played a key role in helping seafarers and travelers navigate the globe, and so, first, government-funded observatories, the Paris Observatory and the Royal Greenwich Observatory were established in 1667 and 1675 respectively with the goal of building more accurate stellar maps. In the 18th century, astronomers for the first time managed to calculate the distance of a nearby star, adding a third dimension to stellar catalogs. The advent of photography in the 19th century simplified the charting of the night sky and the stellar position catalogs quickly grew from a few thousand to tens of thousands of stars, according to ESA. The first photographs of the moon and sun were published in the 1840s followed by the images of the first star, Vega, about a decade later.The discovery of spectroscopy, a discipline analyzing the ability of matter to split light into different wavelengths depending on its chemical composition, opened new and completely unexpected avenues of astronomical research in the second half of the 19th century. With spectroscopy, astronomers could study the chemical composition of celestial objects, first of those nearby, such as the moon and the sun, and later the more distant ones, including other stars and even galaxies. Suddenly, astronomy was not only about where things were located in the universe but also about what they were made of.Famous astronomer Galileo Galilei showing off his telescope in Venice in a historical engraving. (Image credit: Welcome Images)History of astronomy: The boom of the modern eraHand in hand with the overall rocket-speed technological progress that the world has witnessed since the beginning of the 20th century grew the ability of astronomers to see farther and analyze more precisely.In the early 20th century, fast improvements in telescope technologies led astronomers for the first time to question whether the Milky Way was synonymous with the universe or only one of many starry universes scattered in space. American astronomer Edwin Hubble solved this question in the 1920s when he managed first to distinguish individual stars in the Andromeda nebula, today known as the Andromeda galaxy, and eventually calculate their distances from Earth. These stars were so much farther away than anything else in our galaxy that Hubble concluded that Andromeda is its own Milky Way. A new, much deeper universe suddenly unfolded in front of astronomers' eyes. Other "nebulas" were soon confirmed as galaxies. Within a decade, astronomers realized that these nebulas were speeding away from Earth the faster the farther away they were, according to Science News. This discovery led to the idea that the universe was expanding probably from the time of a giant explosion that had created it in the most distant past. The Big Bang theory was born.The Second World War sped up technological progress even further, ushering in the era of spaceflight and exploration of the universe from space. What only a few decades prior would have been the stuff of science fiction was quickly becoming reality. In 1957, the U.S.S.R launched the first-ever satellite, Sputnik. From then on, more and more complex scientific instruments would be installed on satellites and the picture of the orbital environment around Earth would start to emerge. In 1962, NASA's Mariner 2 became the first spacecraft to visit another planet, Venus, and in 1964, the first radio astronomy satellite, the U.K.'s Ariel 2, made it into orbit.The space race of the 1960s culminated with the successful moon landings of the Apollo program. Scientists on Earth could, for the first time, hold in their hands' pristine pieces of rock from another celestial body. The U.S.S.R celebrated its own successes with the lunar rover Lunokhod, which analyzed 25 lunar soil samples with its onboard instruments. In 1968, NASA launched the Orbiting Astronomical Observatory 2, nicknamed Stargazer, the first attempt to study the wider universe from space, according to USA. Today. Only a year later, plans for the Hubble Space Telescope started to shape up, although it would take more than two decades to get the grand telescope off the ground.Since then, dozens of probes have been sent to study bodies in the solar system including planets, comets, moons and asteroids. Space telescopes, together with ever more powerful ground-based telescopes have revealed the star-studded sky in detail that the ancient tribesmen would never be able to even imagine. The James Webb Space Telescope, launched on Christmas Day 2021, represents the pinnacle of this eternal endeavor that started thousands of years ago and grew from humble beginnings. Yet, the more astronomers see, the more questions are arising and the answers to the grand questions of the nature of the universe and our place in it remain elusive. The Hubble Space Telescope, launched in 1991, supercharged astronomical research. (Image credit: NASA)Types of astronomyIn the past century or so, astronomy has been broadly split into two camps — observational astronomy (using telescopes and cameras to collect data about the night sky) and theoretical astronomy (using that data to analyze, model and theorize about how objects and phenomena work). They complement each other, yet within these two broad categories, modern astronomy includes many subsets, from astrometry to exoplanetology, that intrinsically overlap yet help explain the many things astronomers do. Here's what they all mean: Astrometry: This ancient branch of astronomy concerns precise calculations of the motions of the sun, the moon and the planets. It includes predictions of solar and lunar eclipses and meteor showers. It also includes exoplanetology, a relatively new and very exciting field that concerns itself with the discovery and characterization of planets outside of the solar system. Planetary astronomy: How did the solar system come to be? This is the central question penetrating planetary astronomy, which focuses on the formation, evolution and death of planets, moons and other objects in the solar system, it also includes planetary geology. Astrophysics: Astrophysicists apply the laws and theories of physics to astronomical observations. It's an attempt to understand the mechanism behind how the universe was created and how it has and will evolve.Astrochemistry: Astrochemists study the composition and reactions of atoms, molecules and ions in space. Astrobiology: This emerging and, for now, largely theoretical field of astronomy is the study of life beyond Earth. Stellar astronomy: The study of the life cycle and structure of the sun and the stars, stellar astronomy concerns the classification of stars, and populations of stars. Galactic astronomy: astronomers study our galaxy, the Milky Way, while extragalactic astronomers peer outside of it to determine how these groups of stars form, change and die. Cosmology: Although it's sometimes used to mean astronomy, strictly speaking, cosmology refers to the science of the origin and nature of the universe. The key concept in cosmology is the Big Bang Theory, the most widely accepted explanation of how the universe began. Cosmology also includes purely theoretical subjects including string theory, dark matter and dark energy, and the notion of multiple universes.The iconic Pillars of Creation. The Hubble Space Telescope's view on the left, the new James Webb Space Telescope photo on the right. (Image credit: NASA, ESA, CSA, STScI; Joseph DePasquale (STScI), Anton M. Koekemoer (STScI), Alyssa Pagan (STScI).)What are optical, infrared and radio astronomy? All astronomy is the study of different wavelengths of the electromagnetic spectrum, which comprises radio, microwave, infrared, visible, ultraviolet, X-ray and gamma rays. To get the full picture of what's out there astronomers need to study various wavelengths of light. Optical astronomy is the study of celestial objects using telescopes that observe visible light. Infrared light can be detected outside of the Earth's atmosphere, so by space-based observatories like the Hubble Space Telescope and the James Webb Space Telescope. Radio astronomy is the study of the sky in radio frequencies; radio telescopes detect and amplify radio waves from space.The Square Kilometer Array's site in Australia will rely on 130,000 Christmas-tree like dipole antennas to listen to radio waves emitted by objects in the most distant universe. (Image credit: SKAO)The problem with astronomyHowever they observe the universe, astronomers only ever get a snapshot of the planets, stars and galaxies they study. So although there are dozens of different branches of astronomy, in practice many of them must overlap for an astronomer to get as full a picture as possible of objects that exist for millions to billions of years. We're on the cusp of some tremendously exciting new technology that looks set to revolutionize astronomy. In addition to the James Webb Space Telescope a range of ground-breaking Earth-based telescopes is set to come online within this decade including the Vera Rubin Observatory all-sky survey, the Extremely Large Telescope and the Square Kilometre Array, the world's largest radio telescope.Astronomers are about to see deeper into space to observe regions and objects never seen before. The difference between astronomy and astrologyAstrology and astronomy have the same origin but over the past centuries diverged onto irreconcilable paths. (Image credit: Public Domain Pictures/Andrea Stöckel)Astronomy and astrology have grown from the same roots. Ancient civilizations and early tribesmen believed that the sky held power over their lives and that by observing the motions of celestial bodies, one could learn about the future. The close bond between the two disciplines survived millennia. During the renaissance period, astronomers were frequently hired as personal advisers to monarchs to advise on decisions based on the positions of stars and planets, according to Astronomica.But as the scientific method grew in strength over the subsequent centuries, astronomy and astrology have grown apart. While astronomy has become the domain of no-nonsense data-driven observations and verifiable predictions relying on the most cutting-edge technology, astrology was reduced to the realm of new-age superstition where considerably less educated future predictors use glass crystals and simplistic star charts to predict the path of a person's life. In fact, astronomers point out, that due to the irregularity of Earth's orbit, the position of the sun within the zodiac signs, which form the backbone of western astrology and which were identified centuries ago, no longer matches the actual position of the sun. So while you may have been told you were born in Taurus, you actually could have been born in Aries.Jobs in astronomyIf star-gazing is your calling and you think of making it your life's path, you can find some useful insights about what it takes to be an astronomer on the website of the International Astronomical Union. The Royal Astronomical Society also has many useful resources in its Careers section.If you are already further down the path and looking for a suitable opening based on your qualifications, the American Astronomical Society lists all kinds of openings all over the world on its jobs register site.If you wonder how much you'd earn in an astronomy-related career, the SciJournal lists ten highest paying astronomy jobs.Additional resourcesRead this detailed three-part series by the European Space Agency about the history of astrometry from the earliest times, to the emergence of telescopes to modern space-based observations. This ScienceNews feature tells the story of the major leaps in astronomers' understanding of the universe in the first half of the 20th century. This article by the Royal Society provides a detailed overview of the evolution of astronomy in the post-war era. To learn more about the early days of the telescope and the role of Galileo Galileo in shaping modern astronomy, check this article by the Library of Congress.BibliographyEuropean Space Agency, A history of astrometry - Part I - Mapping the sky from ancient to modern times, September 1, 2019 Space Agency, A history of astrometry - Part II - Telescopes ignites the race to measure stellar distances, September 1, 2019 Space Agency, A history of astrometry - Part III - Astrometry moves to space: The mapmakers guide to the galaxy Royal Society, A brief history of astronomy, astrophysics and cosmology 1945-2000, June 9, 2022 In 20th century, astronomers opened their minds to gazillions of galaxies, February 2, 2017 of Congress, Galileo and the Telescope, Welcome to Astronomy Online A legally blind photographer/astronomer on disability so I use this site to contribute to society. Last Updated: added graphics for the 88 constellations under Observation/The Night Sky. This site is a testament that even though I have a physical disability - legally blind - I can still do things that helps other people. This site stands as proof that, despite being legally blind, I can still contribute in meaningful ways. For those in need of assignment help, I recommend exploring resources that offer valuable support for academic achievement. Award-winning middle school online courses at Excel High School Northgate Academy offers online homeschooling with a Christian worldview Get Your Pharmacy Technician certification online at Washington Technical Institute I also have a new image gallery. I call it Second Site Image Gallery. Real-World Applications of Advanced Tools in Ocean Research www.deep.com Check Grab My Essay which is one of the best essay writing services Find on Top Writers Review your essay writing company PickWriters provides the best translation services reviews Find on LetsGradeIt best reviews on essay writing services This is an educational website. It's never too late to learn astronomy, even for those who have not completed their primary (High School) education. A GED can get you in the door to college level courses. Affordable academic writing company CheapWritingHelp.com provides students with unique astronomy research papers and science essays. A-Writer essay writing service with the best PhD writers on Astronomy. Stargazing to Star Charts: Engaging Students in the Wonders of Astronomy How Video Chat Platforms Bring Astronomy Enthusiasts Closer APOD:Lunar Farside Image Credit: NASA / GSFC / Arizona State Univ. / Lunar Reconnaissance Orbiter Explanation: Tidally locked in synchronous rotation, the Moon always presents its familiar nearside to denizens of planet Earth. From lunar orbit, the Moon's farside can become familiar, though. In fact this sharp picture, a mosaic from the Lunar Reconnaissance Orbiter's wide angle camera, is centered on the lunar farside. Part of a global mosaic of over 15,000 images acquired between November 2009 and February 2011, the highest resolution version shows features at a scale of 100 meters per pixel. Surprisingly, the rough and battered surface of the farside looks very different from the nearside covered with smooth dark lunar maria. A likely explanation is that the farside crust is thicker, making it harder for molten material from the interior to flow to the surface and form dark, smooth maria. A Student's Guide on How to Tackle Complex Astronomy Assignments Discover the World of Document Editing with the Top PDF Editor The Gig Economy and Student Employment: Exploring Opportunities and Challenges Navigating the Final Frontier: Understanding Space Law in the Age of Commercial Space Flight APOD:The Seagull Nebula Image Credit & Copyright: Timothy Martin Explanation: An interstellar expanse of glowing gas and obscuring dust presents a bird-like visage to astronomers from planet Earth, suggesting its popular moniker, the Seagull Nebula. This broadband portrait of the cosmic bird covers a 3.5-degree wide swath across the plane of the Milky Way, in the direction of Sirius, alpha star of the constellation of the Big Dog (Canis Major). The bright head of the Seagull Nebula is cataloged as IC 2177, a compact, dusty emission and reflection nebula with embedded massive star HD 53367. The larger emission region, encompassing objects with other catalog designations, is Likely part of an extensive shell structure swept up by successive supernova explosions. The notable bluish arc below and right of center is a bow shock from runaway star FN Canis Majoris. Dominated by the reddish glow of atomic hydrogen, this complex of interstellar gas and dust clouds with other stars of the Canis Majoris OB1 association spans over 200 light-years at the Seagull Nebula's estimated 3,800 light-year distance. Astronomy in the Classroom: Engaging Students In Interesting Lessons Leveraging Your Passion for Space in Job Applications APOD:W5: Pillars of Star Formation Image Credit: NASA, WISE, IRSA; Processing & Copyright : Francesco Antonucci Explanation: How do stars form? Images of the star forming region W5 like those in the infrared by NASA's Wide Field Infrared Survey Explorer (WISE, later NEOWISE) satellite provide clear clues with indications that massive stars near the center of empty cavities are older than stars near the edges. A likely reason for this is that the older stars in the center are actually triggering the formation of the younger edge stars. The triggered star formation occurs when hot outflowing gas compresses cooler gas into knots dense enough to gravitationally contract into stars. In the featured scientifically colored infrared image, spectacular pillars left slowly evaporating from the hot outflowing gas provide further visual clues. W5 is also known as Westerhout 5 (W5) and IC 1848. Together with IC 1805, the nebulas form a complex region of star formation popularly dubbed the Heart and Soul Nebulas. The featured image highlights a part of W5 spanning about 2,000 light years that is rich in star forming pillars. W5 lies about 6,500 light years away toward the constellation of Cassiopeia. How the Website is Organized: Advertising within text will be in italics with a link to the ad source. Observation - This section includes information on coordinate systems, constellations, objects visible in the night sky, and some images of the night sky of the northern and southern hemispheres. Science - This section includes information on some of the basic science used in astronomy. There is information on the variety of tools used (like telescopes) as well as methods of using them. There is a mathematics primer, introduction to some physical processes, formulas used in astronomy, and information on computer use in Astronomy. Solar System - As indicated, this section covers our Solar System and everything in it. It covers the Sun, planets, their moons, asteroids, comets and exotic objects like TNO's and Kuiper Belt Objects. Stars - This section covers stars in our own galaxy. It covers the variety of stellar evolution paths. It also covers supernova, black holes, and some of the radiative processes in the interstellar medium. Our Galaxy - This section covers our galaxy as well as some of the nearby galaxies in our own Local Group. It also covers galaxy evolution. Cosmology - This section covers other galaxies and galaxies clusters. It also covers the big bang, relativity and dark matter. Astrobiology - This section covers the relatively new field in astronomy - the possibility of life in our Solar System and the Universe. There is also information on some of the projects dealing with this - like SETI. Exoplanets - This section covers the study of planets known to exist around other stars. It covers both amateur and professional involvement and shows you how you can get involved with the search as well. Astrophotography - This section covers the fastest growing hobby of astrophotography. This section offers information and tips on photography and also features and Image Gallery. Back to Top