DOWNLOAD PDF WHAT DOES AN EXPLODING STAR HAVE TO DO WITH LIFE ON EARTH?

Chapter 1 : How Do Stars Die and How Long Do Stars Live? | Sky & Telescope

When stars go pop, a murderous torrent of energy is released. Life on Earth may have been partly extinguished by just such a violent outburst, but there's little hard evidence yet to justify such.

June 18, The expanding shell is pictured as blue, but gamma rays are actually invisible. The gamma rays initiate changes in the atmosphere that deplete ozone and create a brown smog of NO2. Scientists say that a gamma-ray burst might have caused the Ordovician extinction million years ago. NASA When stars go pop, a murderous torrent of energy is released. A new study plans to fill in the forensic details. The team also will radiate different types of phytoplankton to understand how life would be affected by a stellar blast, since life around the globe is highly dependent on these microscopic plants. The danger from stellar explosions has been considered before, but this will be the first comprehensive study. The usual suspects Stars are generally too far away to be a concern for life on our planet. But certain stellar eruptions have the potential to reach across tens or even thousands of light-years. The most familiar of these is a supernova, which is the curtain call of a massive star with eight or more times the mass of our sun. When the nuclear fuel runs out for such a behemoth, the collapsing core generates an explosion that outshines an entire galaxy-worth of stars while it lasts. A couple supernovae go off in our galaxy every century. But for one of these to have serious consequences for Earth, we would need to be roughly within a 10 light-year radius of the blast. Certain star explosions, called hypernovae, have much greater reach. The number of GRBs is much less than the number of supernovae, but the exact rate in our galaxy is still a matter of debate. A few years ago, a group of astronomers calculated that the likelihood of a GRB going off near us was very low, due to the fact that GRBs tend to arise in young galaxies with less heavy elements than the Milky Way. But Thomas says that subsequent analyses have called this calculation into question, partly because our galaxy has merged in the past with smaller, younger galaxies that could have brought GRB-ticking-time-bombs in with them. He speculates that on average a GRB lights up our galaxy about once every 10 million years. Other possible culprits Long-duration GRBs and supernovae may be the best-understood, but they are not the only super-stellar calamities. Short-duration GRBs do not arise from massive star deaths, but instead are believed to mainly be the merger of two neutron stars. Although less energy is released than in a long-duration GRB, the fraction of high-energy gamma rays is higher. Moreover, short-duration GRBs are more likely to occur in mature galaxies like ours, where neutron stars are more common. Soft gamma-ray repeaters also originate from neutron stars â€" supposedly when the super-dense surface cracks. If one of these happened 10 light-years away, the effects could be dramatic. Nothing was damaged, but the source object was an amazing 50, light-years away. Thomas and his colleagues will be pulling together recent data from the Swift satellite and the Fermi Gamma-Ray Space Telescope to better estimate the rates and radiation output of soft gamma-ray repeaters, GRBs and supernovae. Worldwide ozone hole The other half of the study will look at the possible biological aftermath of an astrophysical firework going off nearby. This molecule destroys ozone in the same way that chlorofluorocarbons CFCs do. By shattering this atmospheric shield, an astrophysical blast could lead to higher rates of DNA and protein damage in organisms from greater sunlight exposure. In contrast, the ozone hole that currently hovers over Antarctica is at most 60 percent depleted but only accounts for a globally-averaged depletion of 3 to 5 percent. Thomas says that the ozone destruction would begin as soon as the radiation hits, and would continue for several years. Fried plankton The loss of ozone would have serious effects on life across the planet. One of the most susceptible organisms would be phytoplankton. These single-celled organisms live at the top of the water column, where UV light is able to reach. They also reproduce quickly, so DNA damage would accumulate over several generations. If phytoplankton began dying off, the effects would ripple throughout the ocean, since these photosynthetic microbes are the base of the marine food chain. The team has selected a couple representative species of phytoplankton to irradiate at different levels, and see how their productivity levels change. The results of the study should give astrobiologists a better sense of how likely it is that our planet or another planet in our galaxy was zapped by a stellar eruption. Possible signs of such astrophysical foul play are seen in the Ordovician extinction , which occurred million years ago and resulted in the loss of 60 percent of marine invertebrates. The fossil record shows that organisms near the top of the water column and at mid-latitudes were hardest hit, as one would expect from a sudden loss of ozone.

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Chapter 2 : Earth's gold came from colliding dead stars

Whenever the Sun and its planets have visited regions of enhanced star formation in the Milky Way Galaxy, where exploding stars are most common, life has prospered. Prof.

The distribution is isotropic , with no concentration towards the plane of the Milky Way, which runs horizontally through the center of the image. Gamma-ray bursts were first observed in the late s by the U. Vela satellites, which were built to detect gamma radiation pulses emitted by nuclear weapons tested in space. On July 2, , at As additional Vela satellites were launched with better instruments, the Los Alamos team continued to find inexplicable gamma-ray bursts in their data. By analyzing the different arrival times of the bursts as detected by different satellites, the team was able to determine rough estimates for the sky positions of sixteen bursts [12] and definitively rule out a terrestrial or solar origin. The discovery was declassified and published in The absence of any such pattern in the case of GRBs provided strong evidence that gamma-ray bursts must come from beyond the Milky Way. The similarities between the two events, in terms of gamma ray , optical and x-ray emissions, as well as to the nature of the associated host galaxies , are "striking", suggesting the two separate events may both be the result of the merger of neutron stars, and both may be a kilonova, which may be more common in the universe than previously understood, according to the researchers. Astronomers considered many distinct classes of objects, including white dwarfs , pulsars , supernovae , globular clusters , quasars , Seyfert galaxies , and BL Lac objects. This suggested an origin of either very faint stars or extremely distant galaxies. Several models for the origin of gamma-ray bursts postulated that the initial burst of gamma rays should be followed by slowly fading emission at longer wavelengths created by collisions between the burst ejecta and interstellar gas. The breakthrough came in February when the satellite BeppoSAX detected a gamma-ray burst GRB [nb 2] and when the X-ray camera was pointed towards the direction from which the burst had originated, it detected fading X-ray emission. The William Herschel Telescope identified a fading optical counterpart 20 hours after the burst. This event was localized within four hours of its discovery, allowing research teams to begin making observations much sooner than any previous burst. GRBs were extragalactic events originating within faint galaxies at enormous distances. The following year, GRB was followed within a day by a bright supernova SN bw , coincident in location, indicating a clear connection between GRBs and the deaths of very massive stars. This burst provided the first strong clue about the nature of the systems that produce GRBs. However, the revolution in the study of gamma-ray bursts motivated the development of a number of additional instruments designed specifically to explore the nature of GRBs, especially in the earliest moments following the explosion. The first such mission, HETE-2 , [34] launched in and functioned until , providing most of the major discoveries during this period. One of the most successful space missions to date, Swift , was launched in and as of is still operational. Meanwhile, on the ground, numerous optical telescopes have been built or modified to incorporate robotic control software that responds immediately to signals sent through the Gamma-ray Burst Coordinates Network. This allows the telescopes to rapidly repoint towards a GRB, often within seconds of receiving the signal and while the gamma-ray emission itself is still ongoing. Classification[edit] Gamma-ray burst light curves The light curves of gamma-ray bursts are extremely diverse and complex. Some bursts are preceded by a "precursor" event, a weak burst that is then followed after seconds to minutes of no emission at all by the much more intense "true" bursting episode. Many classification schemes have been proposed, but these are often based solely on differences in the appearance of light curves and may not always reflect a true physical difference in the progenitors of the explosions. However, plots of the distribution of the observed duration [nb 3] for a large number of gamma-ray bursts show a clear bimodality , suggesting the existence of two separate populations: Additional classes beyond this two-tiered system have been proposed on both observational and theoretical grounds. In addition, there has been no association with supernovae. Such mergers were theorized to produce kilonovae , [58] and evidence for a kilonova associated with GRB B was seen. The observation of minutes to hours of X-ray flashes after a short gamma-ray burst is consistent with small particles of a primary object like a neutron star initially swallowed by a black hole in less than two seconds, followed by some hours of lesser energy events, as remaining fragments of tidally disrupted neutron star material no longer neutronium remain in orbit to spiral into the black hole, over a longer period of time. Because these events constitute the majority of the population and because they tend to have the brightest afterglows, they have been observed in much greater detail than their short counterparts. Almost every well-studied long gamma-ray burst has been linked to a galaxy with rapid star formation, and in many cases to a core-collapse supernova as well, unambiguously associating long GRBs with the deaths of massive stars. They have been proposed to form a separate class, caused by the collapse of a blue supergiant star , [67] a tidal disruption event [68] [69] or a new-born magnetar. Energy from the explosion is beamed into two narrow, oppositely directed jets. Gamma-ray bursts are very bright as observed from Earth despite their typically immense distances. An average long GRB has a bolometric flux comparable to a bright star of our galaxy despite a distance of billions of light years compared to a few tens of light years for most visible stars. Most of this energy is released in gamma rays, although some GRBs have extremely luminous optical counterparts as well. GRB B , for example, was accompanied by an optical counterpart that peaked at a visible magnitude of 5. This combination of brightness and distance implies an extremely energetic source. Assuming the gamma-ray explosion to be spherical, the energy output of GRB B would be within a factor of two of the rest-mass energy of the Sun the energy which would be released were the Sun to be converted entirely into radiation. When a gamma-ray burst is pointed towards Earth, the focusing of its energy along a relatively narrow beam causes the burst to appear much brighter than it would have been were its energy emitted spherically. Very bright supernovae have been observed to accompany several of the nearest GRBs. Wolfâ€"Rayet stars are candidates for being progenitors of long-duration GRBs. Because of the immense distances of most gamma-ray burst sources from Earth, identification of the progenitors, the systems that produce these explosions, is challenging. The association of some long GRBs with supernovae and the fact that their host galaxies are rapidly star-forming offer very strong evidence that long gamma-ray bursts are associated with massive stars. The most widely accepted mechanism for the origin of long-duration GRBs is the collapsar model, [85] in which the core of an extremely massive, low- metallicity , rapidly rotating star collapses into a black hole in the final stages of its evolution. The infall of this material into a black hole drives a pair of relativistic jets out along the rotational axis, which pummel through the stellar envelope and eventually break through the stellar surface and radiate as gamma rays. Some alternative models replace the black hole with a newly formed magnetar , [86] [87] although most other aspects of the model the collapse of the core of a massive star and the formation of relativistic jets are the same. The closest analogs within the Milky Way galaxy of the stars producing long gamma-ray bursts are likely the Wolfâ€"Rayet stars , extremely hot and massive stars, which have shed most or all of their hydrogen to radiation pressure. Eta Carinae and WR have been cited as possible future gamma-ray burst progenitors. There is strong evidence that some short-duration gamma-ray bursts occur in systems with no star formation and no massive stars, such as elliptical galaxies and galaxy halos. According to this model, the two stars in a binary slowly spiral towards each other because gravitational radiation releases energy [90] [91] until tidal forces suddenly rip the neutron stars apart and they collapse into a single black hole. The infall of matter into the new black hole produces an accretion disk and releases a burst of energy, analogous to the collapsar model. Numerous other models have also been proposed to explain short gamma-ray bursts, including the merger of a neutron star and a black hole, the accretion-induced collapse of a neutron star, or the evaporation of primordial black holes. This event had a gamma-ray duration of about 2 days, much longer than even ultra-long GRBs, and was detected in X-rays for many months. There is an ongoing debate as to whether the explosion was the result of stellar collapse or a tidal disruption event accompanied by a relativistic jet, although the latter explanation has become widely favoured. A tidal disruption event of this sort is when a star interacts with a supermassive black hole shredding the star, and in some cases creating a relativistic jet which produces bright emission of gamma ray radiation.

Gamma-ray burst emission mechanisms The means by which gamma-ray bursts convert energy into radiation remains poorly understood, and as of there was still no generally accepted model for how this process occurs. In this model, pre-existing low-energy photons are scattered by relativistic electrons within the explosion, augmenting their energy by a large factor and transforming them into gamma-rays. Any energy released by the explosion not radiated away in the burst itself takes the form of matter or energy moving outward at nearly the speed of light. As this matter collides with the surrounding interstellar gas , it creates a relativistic shock wave that then propagates forward into interstellar space. A second shock wave, the reverse shock, may propagate back into the ejected matter. Extremely energetic electrons within the shock wave are accelerated by strong local magnetic fields and radiate as synchrotron emission across most of the electromagnetic spectrum. Considering the universe as a whole, the safest environments for life similar to that on Earth are the lowest density regions in the outskirts of large galaxies. Furthermore, galaxies with a redshift, z, higher than 0. However, if a GRB were to occur within the Milky Way and its emission were beamed straight towards Earth, the effects could be harmful and potentially devastating for the ecosystems. Currently, orbiting satellites detect on average approximately one GRB per day. Estimates of rate of occurrence of short-duration GRBs are even more uncertain because of the unknown degree of collimation, but are probably comparable. The immediate effect on life on Earth from a GRB within a few parsecs would only be a short increase in ultraviolet radiation at ground level, lasting from less than a second to tens of seconds. This ultraviolet radiation could potentially reach dangerous levels depending on the exact nature and distance of the burst, but it seems unlikely to be able to cause a global catastrophe for life on Earth. Gamma rays cause chemical reactions in the atmosphere involving oxygen and nitrogen molecules , creating first nitrogen oxide then nitrogen dioxide gas. The nitrogen oxides cause dangerous effects on three levels. This reduction is enough to cause a dangerously elevated UV index at the surface. Secondly, the nitrogen oxides cause photochemical smog , which darkens the sky and blocks out parts of the sunlight spectrum. Thirdly, the elevated nitrogen levels in the atmosphere would wash out and produce nitric acid rain. Nitric acid is toxic to a variety of organisms, including amphibian life, but models predict that it would not reach levels that would cause a serious global effect. The nitrates might in fact be of benefit to some plants. Models show that the destructive effects of this increase can cause up to 16 times the normal levels of DNA damage. It has proved difficult to assess a reliable evaluation of the consequences of this on the terrestrial ecosystem, because of the uncertainty in biological field and laboratory data. The late Ordovician species of trilobites that spent portions of their lives in the plankton layer near the ocean surface were much harder hit than deep-water dwellers, which tended to remain within quite restricted areas. This is in contrast to the usual pattern of extinction events, wherein species with more widely spread populations typically fare better. A possible explanation is that trilobites remaining in deep water would be more shielded from the increased UV radiation associated with a GRB. Also supportive of this hypothesis is the fact that during the late Ordovician, burrowing bivalve species were less likely to go extinct than bivalves that lived on the surface. A nearby GRB candidate[edit] Main article: It is expected to explode in a core-collapse-supernova at some point within the next , years and it is possible that this explosion will create a GRB. If that happens, there is a small chance that Earth will be in the path of its gamma ray jet. In light of evolving understanding of gamma-ray bursts and their progenitors, the scientific literature records a growing number of local, past, and future GRB candidates. Long duration GRBs are related to superluminous supernovae, or hypernovae, and most luminous blue variables LBVs , and rapidly spinning Wolfâ€"Rayet stars are thought to end their life cycles in core-collapse supernovae with an associated long-duration GRB.

Chapter 3 : Star - Simple English Wikipedia, the free encyclopedia

The stars in our galactic neighbourhood do have a dynamical, gravitational effect on the inner workings of the solar system. They built the Oort cloud. The Oort cloud is a roughly spherical cloud of icy bodies that is thought to act as a reservoir of long-period comets (and which we speculate exists to explain said comets' existence).

None or luminous supernova? The inner part of the core is compressed into neutrons c , causing infalling material to bounce d and form an outward-propagating shock front red. The shock starts to stall e , but it is re-invigorated by a process that may include neutrino interaction. The surrounding material is blasted away f , leaving only a degenerate remnant. What follows next depends on the mass and structure of the collapsing core, with low mass degenerate cores forming neutron stars, higher mass degenerate cores mostly collapsing completely to black holes, and non-degenerate cores undergoing runaway fusion. The initial collapse of degenerate cores is accelerated by beta decay , photodisintegration and electron capture, which causes a burst of electron neutrinos. As the density increases, neutrino emission is cut off as they become trapped in the core. These thermal neutrinos are several times more abundant than the electron-capture neutrinos. A process that is not clearly understood [update] is necessary to allow the outer layers of the core to reabsorb around joules [85] 1 foe from the neutrino pulse, producing the visible brightness, although there are also other theories on how to power the explosion. This fallback will reduce the kinetic energy created and the mass of expelled radioactive material, but in some situations it may also generate relativistic jets that result in a gamma-ray burst or an exceptionally luminous supernova. Collapse of massive non-degenerate cores will ignite further fusion. When the core collapse is initiated by pair instability, oxygen fusion begins and the collapse may be halted. At the upper end of the mass range, the supernova is unusually luminous and extremely long-lived due to many solar masses of ejected 56Ni. For even larger core masses, the core temperature becomes high enough to allow photodisintegration and the core collapses completely into a black hole. Type II supernova The atypical subluminous Type II SN D Stars with initial masses less than about eight times the sun never develop a core large enough to collapse and they eventually lose their atmospheres to become white dwarfs. These super AGB stars may form the majority of core collapse supernovae, although less luminous and so less commonly observed than those from more massive progenitors. The rate of mass loss for luminous stars depends on the metallicity and luminosity. Extremely luminous stars at near solar metallicity will lose all their hydrogen before they reach core collapse and so will not form a Type II supernova. At low metallicity, all stars will reach core collapse with a hydrogen envelope but sufficiently massive stars collapse directly to a black hole without producing a visible supernova. Stars with an initial mass up to about 90 times the sun, or a little less at high metallicity, are expected to result in a Type II-P supernova which is the most commonly observed type. At moderate to high metallicity, stars near the upper end of that mass range will have lost most of their hydrogen when core collapse occurs and the result will be a Type II-L supernova. Type Ib and Ic[edit] Main article: Type Ib and Ic supernovae SN D, a Type Ib [91] supernova, shown in X-ray left and visible light right at the far upper end of the galaxy [92] These supernovae, like those of Type II, are massive stars that undergo core collapse. However the stars which become Types Ib and Ic supernovae have lost most of their outer hydrogen envelopes due to strong stellar winds or else from interaction with a companion. Binary models provide a better match for the observed supernovae, with the proviso that no suitable binary helium stars have ever been observed. Type Ib supernovae are the more common and result from Wolfâ€”Rayet stars of Type WC which still have helium in their atmospheres. For a narrow range of masses, stars evolve further before reaching core collapse to become WO stars with very little helium remaining and these are the progenitors of Type Ic supernovae. A few percent of the Type Ic supernovae are associated with gamma-ray bursts GRB , though it is also believed that any hydrogen-stripped Type Ib or Ic supernova could produce a GRB, depending on the circumstances of the geometry. The jets would also transfer energy into the expanding outer shell, producing a super-luminous supernova. In the most extreme cases, ultra-stripped supernovae can occur in naked metal cores, barely above the Chandrasekhar mass limit. SN ek [99] might be an observational example of an ultra-stripped supernova, giving rise to a relatively dim and fast decaying light curve. The nature of ultra-stripped supernovae can be both iron core-collapse and electron capture supernovae, depending on the mass of the collapsing core. Failed supernova The core collapse of some massive stars may not result in a visible supernova. The main model for this is a sufficiently massive core that the kinetic energy is insufficient to reverse the infall of the outer layers onto a black hole. These events are difficult to detect, but large surveys have detected possible candidates. Although the energy that disrupts each type of supernovae is delivered promptly, the light curves are mostly dominated by subsequent radioactive heating of the rapidly expanding ejecta. Some have considered rotational energy from the central pulsar. The ejecta gases would dim quickly without some energy input to keep it hot. The intensely radioactive nature of the ejecta gases, which is now known to be correct for most supernovae, was first calculated on sound nucleosynthesis grounds in the late s. Although the luminous emission consists of optical photons, it is the radioactive power absorbed by the ejected gases that keeps the remnant hot enough to radiate light. The radioactive decay of 56 Ni through its daughters 56 Co to 56 Fe produces gamma-ray photons , primarily of keV and keV, that are absorbed and dominate the heating and thus the luminosity of the ejecta at intermediate times several weeks to late times several months. Later measurements by space gamma-ray telescopes of the small fraction of the 56Co and 57Co gamma rays that escaped the SN A remnant without absorption confirmed earlier predictions that those two radioactive nuclei were the power sources. The light curves can be significantly different at other wavelengths. For example, at ultraviolet wavelengths there is an early extremely luminous peak lasting only a few hours corresponding to the breakout of the shock launched by the initial event, but that breakout is hardly detectable optically. The light curves for Type Ia are mostly very uniform, with a consistent maximum absolute magnitude and a relatively steep decline in luminosity. Their optical energy output is driven by radioactive decay of ejected nickel half life 6 days , which then decays to radioactive cobalt half life 77 days. These radioisotopes excite the surrounding material to incandescence. Studies of cosmology today rely on 56 Ni radioactivity providing the energy for the optical brightness of supernovae of Type Ia, which are the "standard candles" of cosmology but whose diagnostic keV and keV gamma rays were first detected only in The light curve continues to decline in the B band while it may show a small shoulder in the visual at about 40 days, but this is only a hint of a secondary maximum that occurs in the infra-red as certain ionised heavy elements recombine to produce infra-red radiation and the ejecta become transparent to it. The visual light curve continues to decline at a rate slightly greater than the decay rate of the radioactive cobalt which has the longer half life and controls the later curve , because the ejected material becomes more diffuse and less able to convert the high energy radiation into visual radiation. After several months, the light curve changes its decline rate again as positron emission becomes dominant from the remaining cobalt, although this portion of the light curve has been little-studied. Type Ib and Ic light curves are basically similar to Type Ia although with a lower average peak luminosity. The visual light output is again due to radioactive decay being converted into visual radiation, but there is a much lower mass of the created nickel The most luminous Type Ic supernovae are referred to as hypernovae and tend to have broadened light curves in addition to the increased peak luminosity. The source of the extra energy is thought to be relativistic jets driven by the formation of a rotating black hole, which also produce gamma-ray bursts. The light curves for Type II supernovae are characterised by a much slower decline than Type I, on the order of 0. The visual light output is dominated by kinetic energy rather than radioactive decay for several months, due primarily to the existence of hydrogen in the ejecta from the atmosphere of the supergiant progenitor star. In the initial destruction this hydrogen becomes heated and ionised. The majority of Type II supernovae show a prolonged plateau in their light curves as this hydrogen recombines, emitting visible light and becoming more transparent. This is then followed by a declining light curve driven by radioactive decay although slower than in Type I supernovae, due to the efficiency of conversion into light by all the hydrogen.

Chapter 4 : gravity - How do stars from far away affect Earth? - Physics Stack Exchange

Astronomers have previously said that any supernova explosion within light-years of Earth would likely be devastating, but beyond light-years, it's not known for sure what the effects.

This spring the attention of astronomers around the world has been focused on a supernova â€" an exploding star â€" that has become visible in one of the companion galaxies that accompany our own Milky Way. Now officially called Supernova A, the explosion in the relatively small irregular galaxy called the Large Magellanic Cloud is the first supernova to be visible to the naked eye since the great astronomer Kepler saw one in The Large Magellanic Cloud is approximately , light years from us, which is an enormous distance in human terms, but really just the local neighborhood on the scale of the universe. It and its nearby companion, the Small Magellanic Cloud, are so named because Magellan and his crew were the first Northern Hemisphere inhabitants to record their existence. They are only visible from the Southern Hemisphere, which means the supernova cannot be observed by students or astronomy buffs in North America. While astronomers detect a number of supernovae in distant galaxies each year, A is the first exploding star in modern times that is close enough, bright enough, and was caught early enough to permit detailed and intense scrutiny. Astronomers from around the world have flown to the Southern Hemisphere or adjusted telescopes aboard Earth-orbiting satellites to observe this long-awaited yet unpredictable event. Even the Voyager 2 spacecraft â€" on its way to a Neptune rendezvous in â€" has been instructed to make some measurements of A. Since this is a rapidly changing story, we cannot cover all the fast-breaking developments about the supernova in a quarterly newsletter like this one. The Resource Corner in this issue does suggest where you can go for current and background information. Instead, we would like to answer the question that many teachers and students are surely asking: Although the behavior of this supernova is already a bit different from what astronomers expected, it appears to be the sort of explosion that ends the life of a single star significantly more massive than our own Sun. Furthermore, we believe the explosions of supernovae have flooded the Galaxy with high-energy radiation that probably contributed to the radiation background that produces mutation and drives the evolution of life on Earth. Also, in recent years, we have found intriguing evidence that the formation of our own solar system may well have been triggered by a nearby supernova more than five billion years ago. Supernova A on February 27, , just four days after It was first seen. The supernova is the brightest star in the picture, just right of center arrow. One of the great questions in modern science has always been the origin of the elements. All our theories about the origin of the universe predict that the cosmos should have begun with only the very simplest atoms. Where, then, did the more complex elements such as carbon? The only sites in the universe where it is hot enough to transform light elements into heavier ones is in the centers of stars. Inside the Sun and other stars the temperatures can reach many millions of degrees. Here is where supernovae come in. Smaller stars like our own Sun live and die in relative peace. Furthermore, the violence of the supernova explosion can produce even heavier elements than the star was able to make during the quieter phases of its life. We believe that the heavier elements we take for granted on Earth â€" elements such as gold, platinum, or uranium â€" are all made during the brief, but intense cataclysm that destroys the most massive stars. Because of the enormous violence of the supernova explosion, the material it produces â€" in the form of individual atomic nuclei â€" can be propelled into space at speeds approaching the speed of light. These particles travel onward and outward and over the eons can spread over vast distances. Before we understood where they came from, physicists gave these particles the somewhat misleading name cosmic rays. Cosmic rays are thought to be â€" along with the radioactive rocks of the Earth â€" a main cause of mutations, the changes in the genetic code in living things that lead to the evolution of the species. By the law of averages, over the five-billion-year history of our solar system, a number of supernovae must have gone off in our Galaxy close enough to our location to flood the Earth with a larger than usual number of cosmic rays and high-energy radiation. The flow of these high-energy particles may well have accelerated the rate of change in living things and helped speed up our advent among the creatures that inhabit our planet. One of the unsolved problems in astronomy is the question of what induces a particular clump of cosmic raw material at some particular time to form a new star and, we believe, sometimes an accompanying planetary system. If this theory is correct, and we can find some of the primordial unchanged material from which our solar system formed, we may be able to find in it traces of the explosion which gave it a push. In the last decade, specialists in extraterrestrial chemistry have made very careful analyses of the composition of ancient meteorites â€” chunks of rock which fall to Earth from space and are thought to have formed at the beginning of our solar system. Much to their surprise, the scientists have found several unusual forms or isotopes of elements that are, in a sense, the fossilized fingerprints of supernova explosions. The abundances of these unusual elements seem to bear silent witness to the fact that a supernova must have gone off quite close to the cloud of raw material from which our solar system originated and only a few million years a very short time in terms of star formation before the cloud began to coalesce. It is interesting to speculate that this explosion may have provided the basic impetus for our Sun and planetary system to form. In any case, it does seem clear that supernovae have an intimate connection with the conditions that led to life on Earth. The intensity with which astronomers are now studying the supernova in the Large Magellanic Cloud reflects more than an abstract interest in cosmic violence. When Earth glides through such a swarm during our yearly path around the Sun, we experience a "meteor shower. As they burn through the thin air, usually 60 to kilometers above the ground, they create luminous streaks that we call meteor. However, when we swing through a stream of comet dust and experience a meteor shower, the average rate of visible meteors can approach one per minute. Instead, the meteors of a shower are generally swift, faint, silent streaks on the sky, lasting only a fraction of a second. All of the bits of debris that make up a meteor shower speed along parallel to one another. In the same way, parallel railroad tracks or a flock of migrating geese appear to emanate from one point on the horizon. Meteor showers are named after the constellation in which this apparent point of origin lies. In general, more meteors in a shower will be visible between midnight and dawn than during the more civilized â€” after sunset â€” hours of the night.

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Chapter 5 : THE ORIGIN OF THE ELEMENTS AND THE LIFE OF A STAR

A near-Earth supernova is a supernova close enough to the Earth to have noticeable effects on its biosphere. Depending upon the type and energy of the supernova, it could be as far as light-years away.

Beth Geiger Feb 28, â€” 9: The nebula here resides 20, light-years away in the constellation Carina. It contains a central cluster of huge, hot stars, called NGC She steps up to the huge telescope and peers into its eyepiece. Suddenly, distant galaxies and stars come into focus. Pilachowski sees dying stars called red giants. She sees supernovas, too â€” the remains of exploded stars. An astronomer at Indiana University in Bloomington, she feels a deep connection to these cosmic objects. Every ingredient in the human body is made from elements forged by stars. So are all of the building blocks of your food, your bike and your electronics. Similarly, every rock, plant, animal, scoop of seawater and breath of air owes its existence to distant suns. All such stars are giant, long-lived furnaces. Their intense heat can cause atoms to collide, creating new elements. Late in life, most stars will explode, shooting the elements they forged out into the far-flung reaches of the universe. New elements also may develop during stellar smash-ups. Astronomers have just witnessed evidence for the creation of gold and more during the distant collision between two dying stars. Shortly after the universe formed, this galaxy churned out stars at an amazing speed. Special star factories like this one might help explain how enough elements built up to create the solar system. Such discoveries are helping scientists better understand where everything in the universe got its start. After the Big Bang Elements are the basic building blocks of our universe. Earth hosts 92 natural elements with names like carbon, oxygen, sodium and gold. Their atoms are the amazingly tiny particles from which all known chemicals are made. Each atom resembles a solar system. A tiny, but commanding structure sits at its center. This nucleus consists of a mix of bound particles known as protons and neutrons. The more particles in a nucleus, the heavier the element. Chemists have compiled charts that place the elements in order based on structural features, such as how many protons they have. Topping their charts is hydrogen. Element one, it has a single proton. Helium, with two protons, comes next. People and other living things are chock full of carbon, element 6. Earthly life also contains plenty of oxygen, element 8. Bones are rich in calcium, element Number 26, iron, makes our blood run red. Scientists have artificially created heavier elements in their laboratories. But these are extremely rare and short-lived. Blast back to the Big Bang, about 14 billion years ago. This set in motion the expansion of the universe, an outward dispersion of mass that continues to this day. The Big Bang was over in a flash. An astrophysicist, Desch studies how stars and planets form. That was just about it. To build those heavier elements, nuclei of lighter atoms had to fuse together. This nuclear fusion requires serious heat and pressure. Indeed, says Desch, it takes stars. Star power For a few hundred million years after the Big Bang, the universe contained only giant gas clouds. These consisted of about 90 percent hydrogen atoms; helium made up the rest. Over time, gravity increasingly pulled the gas molecules toward each other. This increased their density, making the clouds hotter. Like cosmic lint, they began to gather into balls known as protogalaxies. Inside them, material continued to amass into ever-denser clumps. Some of these developed into stars. Stars are still being born this way, even in our Milky Way galaxy. Converting lightweight elements into heavier ones is what stars do. The hotter the star, the heavier the elements it can make. The center of our sun is some 15 million degrees Celsius about 27 million degrees Fahrenheit. That may sound impressive. In fact, they create mainly helium. To forge heavier elements, the furnace must be immensely bigger and hotter than our sun. Stars at least eight times bigger can forge elements up to iron, element To build elements heavier than that, a star must die. In fact, making some of the heaviest metals, like platinum element number 78 and gold number 79 , might require even more extreme celestial violence: And they show that gold formed. Because a similar smash-up probably takes place in a galaxy once every 10, or , years, such crashes could account for all of the gold in the universe, team member Edo Berger told Science News. Death of a star No star lives forever. Gravity is always drawing the components of a star closer together. As long as a star still has fuel, pressure from nuclear fusion pushes outward and counter-balances the force of gravity. But once most of that fuel has burned up, so long star. The age at which a star dies depends on its size. While their core of iron or lighter elements collapses, the rest of the star expands gently, like a cloud. It swells into a huge growing, glowing ball. Along the way, such stars cool and darken. They become what astronomers call red giants. Many atoms in the outer halo surrounding such a star will just drift away into space. Bigger stars come to a very different end. When they use up their fuel, their cores collapse. This leaves them extremely dense and hot. Instantly, that forges elements heavier than iron. The energy released by this atomic fusion triggers the star to expand yet again. At once, the star finds itself without enough fuel to sustain fusion. So the star collapses once again. Its massive density causes it to heat up again â€”after which it now fuses its atoms, creating heavier ones. Amazingly, this all happens within a few seconds. Then, faster than you can say supernova, the star self-destructs in one ginormous explosion. The force of that supernova explosion is what forges elements heavier than iron. Others rocket at warp speed from a supernova. Either way, when a star dies, many of its atoms spew into space. Eventually they become recycled by the processes that form new stars and even planets. Perhaps billions of years. But the universe is in no rush. It does suggest, however, that the longer a galaxy has been around, the more heavy elements it will contain. Blast from the past Consider the Milky Way. When our galaxy was young, 4. Last year, astronomers at the California Institute of Technology, or Caltech, discovered a very faint red dot in the night sky. They named this galaxy HFLS3. Hundreds of stars were forming inside it. Astronomers refer to such celestial bodies, with so many stars springing to life, as starburst galaxies. To study distant stars, astronomers like Bock essentially become time travelers. They must look deep into the past. And that can take months to years â€”sometimes thousands of millennia.

DOWNLOAD PDF WHAT DOES AN EXPLODING STAR HAVE TO DO WITH LIFE ON EARTH?

Chapter 6 : Supernova - Wikipedia

The Star In You. By Peter Tyson; from millions of burning and exploding stars far back in the history of the universe. protons in the atoms created during the star's life collide with.

Space Shuttle Rescue Scenarios 2O that makes up over half your body were born then. Did you have any idea you have atoms in your body that are over 13 billion years old? If you could separate one hydrogen atom from one molecule of water in your body, shrink down to its atomically tiny size like the scientists in Fantastic Voyage , then reverse time and follow it back to through its unimaginable lifetime, you would find yourself in the immediate aftermath of the Big Bang. That very hydrogen atom, an atom now inside you as you read this, has remained unchanged since the beginning of time. Over 13 billion years since the Big Bang, hydrogen and helium still make up most of the visible matter in the universe. Nearly 10, galaxies appear in this Hubble Ultra Deep Field image. But helium is the second most common element after hydrogen. Together they make up more than 98 percent of the matter in the universe. Luminous matter, that is; dark matter is a whole other story. A smattering of lithium element 3 and one or two other of the lightest elements also formed in the Bang, but these were negligible. Everything else, every other chemical element, including carbon, oxygen, nitrogen, and all the other elements essential for your life, is thought to have been fabricated in stars. Table for First, what are we talking about when we talk about an element? A chemical element is a substance that cannot be broken down or changed into another substance using chemical means. It can be changed using nuclear means, which is what happens inside stars. Every second, the sun converts about million tons of hydrogen into helium. As we learn in high school chemistryâ€”and can remind ourselves with a quick glance at the Periodic Table â€”hydrogen, the lightest element, has one proton in its nucleus and thus is given the atomic number 1. Helium has two protons and so is number 2, and so on all the way up to uranium, which, with 92 protons in its nucleus, is the heaviest of the "naturally occurring" elements. Remarkably, all life on Earth, all everything we see around us, consists of various combinations of those 92 elements. There are still heavier elements, ranging from neptunium 93 all the way up to the unofficially named ununoctium , though with the exception of trace amounts of neptunium and plutonium 94 , these are not found naturally on Earth. Stars are born How didâ€”and do, for the process continues todayâ€”all the chemical elements first come into existence? Several hundred million years after the Big Bang, about 13 billion years ago, the hydrogen and helium in the early universe began coalescing into gas clouds, which, in turn, collapsed into the first stars. Gravity, that not-to-be-denied force, caused these newborn stars to contract, heating their cores to temperatures high enough to ignite their hydrogen and trigger its fusion into helium. This is the first link in a chain of thermonuclear reactions that, depending on the size of the star and its fate, bring about the genesis of all the other chemical elements up to about californium, element Heavier elements than that are produced only in particle accelerators, physicists believe. Imagine starting out in your kitchen with just a single natural ingredient and, after baking it in your oven, winding up with all other possible natural ingredients. This is what the universe has done with hydrogen. The burning of H to He is what our star, the sun, does for a living. This is why we wear sunglasses. This will happen in the sun when it becomes a red giant in five billion years. In its fiery core, our star, the sun, produces only a single chemical elementâ€”heliumâ€”over and over again. NASA In very massive stars, those of more than eight solar masses, the force of gravity drives the temperature in the core up so outlandishly high that it triggers thermonuclear reactions that create elements all the way up to iron Iron, alas, marks a major turning point when it comes to fusing ever-heavier elements inside stars. All the way up to iron, every time a new fusion reaction occurs, some heat is released. With iron, no other rearrangement of nuclei can generate any more energy. Two ways to you Stars have one of two ways to produce these heavier-than-iron elementsâ€”and, not incidentally, to get them and all the other elements forged in their nuclear furnaces out into space so they can be incorporated into new stars, planets, and people. Some of that widely dispersed stardust is holding you up right now. The first way occurs in red giants. These are stars that have burned up all the hydrogen in their centers. When that happens, the star becomes, as the astrophysicist Craig Wheeler has put it, somewhat schizophrenic: The core loses energy, contracts, and heats up even as the envelopeâ€”the rest of the star outside the coreâ€—gains energy, expands, and cools and appears redder. The expansion is quite, well, expansive: When our sun becomes a red giant, it will grow so large that it will engulf and evaporate the inner planets, including the Earth. Some red giants last long enough to create elements in their cores heavier than iron through something called the s-process, for slow. Over a time scale of thousands of years, the s-process can result in the manufacture of elements all the way up to bismuth This spectacular false-color image shows Cassiopeia A, the remnant of a supernova. At the center of the image lies the dead star, while surrounding it is the rapidly expanding shell of material blasted away from the star as it died. Krause Steward Observatory A real blast Elements heavier than bismuth only arise through the r-process, for rapid. The r-process is what happens when a star explodes in a supernova. When a red giant gets to the stage of having fused all its lighter elements and is left with an iron core, the star can no longer retain its equilibriumâ€—heat energy pushing out as gravity pulls in. Gravity suddenly gains the upper hand, collapsing the core all at once to billions of times the density of the Earth. The star then blows itself apart in an astronomical cataclysm. For a brief period, it shines as brightly as an entire galaxy and releases as much energy as our sun will in its billion-year lifetime. All these blast out into space at millions of miles an hour, seeding the interstellar medium with the atoms that eventually end up in new stars, new solar systems, and, in your case, you. In this view of the Carina Nebula, the Hubble Space Telescope captured a tumult of star birth and death. In the image, green corresponds to hydrogen, blue to oxygen, and red to sulfurâ€—three of the 92 naturally occurring elements that space has bequeathed to us. And the most abundant elements begin to assemble into molecules, simple ones like water H2O and more complex ones like the sugar glycoaldehyde C2H4O2. Astronomers can identify these compounds, and individual elements, using spectrometers. Eventually, a kind of raw-clay star called a proto-star forms, with a disk of material surrounding it that will eventually beget planets. That process happened in our own solar system about five billion years ago, resulting in the sun, the planets, and, five billion years later, you. Just how those atoms and molecules that ended up on our planet went from non-living to living remains one of the great unanswered questions in science.

DOWNLOAD PDF WHAT DOES AN EXPLODING STAR HAVE TO DO WITH LIFE ON EARTH?

Chapter 7 : Gamma-ray burst - Wikipedia

An explosion of a nearby star might leave Earth and its surface and ocean life relatively intact. But any relatively nearby explosion would still shower us with gamma rays and other high-energy.

Generally, the more massive the star, the faster it burns up its fuel supply, and the shorter its life. The most massive stars can burn out and explode in a supernova after only a few million years of fusion. A star with a mass like the Sun, on the other hand, can continue fusing hydrogen for about 10 billion years. And if the star is very small, with a mass only a tenth that of the Sun, it can keep fusing hydrogen for up to a trillion years, longer than the current age of the universe. Now onto the question: How Do Stars Die? Chandra X-ray photograph of young supernova remnant Cassiopeia A. Answering the question, "How do stars die? The most massive stars quickly exhaust their fuel supply and explode in core-collapse supernovae, some of the most energetic explosions in the universe. The remnant stellar core will form a neutron star or a black hole, depending on how much mass remains. If the core contains between 1. Curious about black holes? As they run out of hydrogen to fuse in their cores, they swell into red giant stars before shedding their outer layers. The remnant left behind in these planetary nebulae is a white dwarf star. Like neutron stars, white dwarfs no longer fuse hydrogen into helium, instead depending on degeneracy pressure for support â€" this time, the electrons are degenerate, packed together and forced into higher energy states, rather than the neutrons. No black dwarfs have been observed yet because a white dwarf takes longer than the current age of the universe to fade away. And if the white dwarf is part of a binary system, it may avoid that fate altogether. By accreting matter from its companion star, the white dwarf can explode in a Type Ia supernova , leaving no remnant behind. The smallest stars in the universe have exceedingly long lives â€" in fact, none have faced their end yet. Red dwarfs, stars with less than 0. Explore single, multiple, and variable stars in the ultimate Sky Atlas

Chapter 8 : ASP: Why Should We Care About Exploding Stars?

The surface of the sun will probably reach the current orbit of Mars - and, while the Earth's orbit may also have expanded outwards slightly, it won't be enough to save it from being dragged.

The energy from the Sun supports almost all life on Earth by providing light for plants. Plants turn the light into energy in a process called photosynthesis. We can see other stars in the night sky when the Sun goes down. Like the Sun, they are made mostly of hydrogen and a little bit of helium plus other elements. Astronomers often compare those other stars to the Sun. For example, their mass is given in solar masses. A small star may be 0. Planets[change change source] The Earth and other planets move around orbit the Sun. The Sun and all things that orbit the Sun are called the Solar System. Many other stars have planets orbiting them: If you were on an exoplanet, our Sun would look like a star in the sky, but you could not see the Earth because it would be too far away. Numbers, distances[change change source] Proxima Centauri is the star that is closest to our Sun. This means that light from Proxima Centauri takes 4. Astronomers think there are a very large number of stars in the Universe. They estimate guess that there are at least 70 sextillion stars. That is 70,,,,,,,, which is over billion times the few hundred billion stars in the Milky Way our galaxy. Most stars are very old. They are usually thought to be between 1 billion and 10 billion years old. The oldest stars are That is as old as the Universe. Some young stars are only a few million years old. Young stars are mostly brighter than old ones. Stars are different sizes. The smallest stars are neutron stars , which are actually dead stars. They are no bigger than a city. The neutron star has a large amount of mass in a very small space. Hypergiant stars are the largest stars in the Universe. They have a diameter over 1, times bigger than the Sun. If the Sun was a hypergiant star, it would reach out to as far as Jupiter. The star Betelgeuse is a red supergiant star. Although these stars are very large, they also have low density. Stars have many sizes. Some stars look brighter than other stars. This difference is measured in terms of apparent magnitude. There are two reasons why stars have different apparent magnitude. If a star is very close to us it will appear much brighter. This is just like a candle. A candle that is close to us appears brighter. The other reason a star can appear brighter is that it is hotter than another cooler star. Stars give off light but also give off a solar wind and neutrinos. These are very small particles of matter. Stars are made of mass and mass makes gravity. Gravity makes planets orbit stars. This is why the Earth orbits the Sun. The gravity of two stars can make them go around each other. Stars that orbit each other are called binary stars. Scientists think there are many binary stars. There are even groups of three or more stars that orbit each other. Proxima Centauri is a small star that orbits other stars. Stars are not spread evenly across all of space. They are grouped into galaxies. A galaxy contains hundreds of billions of stars. History of seeing stars[change change source] People have seen patterns in the stars since long ago. Stars have been part of religious practices. Long ago, people believed that stars could never die. Astronomers organized stars into groups called constellations. They used the constellations to help them see the motion of the planets and to guess the position of the Sun. The calendars were used by farmers to decide when to plant crops and when to harvest them. Stellar evolution Stars are made in nebulae. These are areas that have more gas than normal space. The gas in a nebula is pulled together by gravity. The Orion nebula is an example of a place where gas is coming together to form stars. Stars spend most of their lives combining fusing hydrogen with hydrogen to make energy. When hydrogen is fused it makes helium and it makes a lot of energy. To fuse hydrogen into helium it must be very hot and the pressure must be very high. Fusion happens at the center of stars, called "the core". The smallest stars red dwarfs fuse their hydrogen slowly and live for billion years. Red dwarfs live longer than any other type of star. At the end of their lives, they become dimmer and dimmer. Red dwarfs do not explode. When very heavy stars die, they explode. This explosion is called a supernova. When a supernova happens in a nebula, the explosion pushes the gas in the nebula together. This makes the gas in the nebula very thick dense. Gravity and exploding stars both help to bring the gas together to make new stars in nebulas. Most stars use up the hydrogen at their core. When they do, their core becomes smaller and becomes hotter. It becomes so hot it pushes away the outer part of the star. The outer part expands and it makes a red giant star. Astro-physicists think that in about 5 billion years, the Sun will be a red giant. Our Sun will be so large it will eat the Earth. After our Sun stops using hydrogen to make energy, it will use helium in its very hot core. It will be hotter than when it was fusing hydrogen. Heavy stars will also make elements heavier than helium. As a star makes heavier and heavier elements, it makes less and less energy. Iron is a heavy element made in heavy stars. Our star is an average star. Average stars will push away their outer gases. The gas it pushes away makes a cloud called a planetary nebula. The core part of the star will remain. It will be a ball as big as the Earth and called a white dwarf. It will fade into a black dwarf over a very long time. Later in large stars, heavier elements are made by fusion. Finally the star makes a supernova explosion. Most things happen in the universe so slowly we do not notice. But supernova explosions happen in only seconds. When a supernova explodes its flash is as bright as a billion stars. The dying star is so bright it can be seen during the day. Supernova means "new star" because people used to think it was the beginning of a new star.

Chapter 9 : Are we really all made of stardust?| Explore | theinnatdunvilla.com

When Betelgeuse does blow up, our planet Earth is too far away for this explosion to harm, much less destroy, life on Earth. Astrophysicists say we'd have to be within 50 light-years of a.

Their nuclei can not have a huge age, for if they did, the radioactive nuclei would have already vanished. They could be twice as old as the Earth, for instance, but not ten times as old. Radioactivity has the fascinating property called "half-life". Each radioactive nucleus is characterized by its own half-life. Given an initial number of such nuclei, half of them will change to some other nucleus in a time equal to the half-life. The nuclei themselves do not remember their age. Whatever their age, half will decay to another element within the next half-life, leaving half remaining. The "aging" of radioactive isotope ratios. For example, half of an initial number of uranium nuclei having atomic mass , the uranium isotope that was used to make the atomic bomb and nuclear reactors, will decay to the element lead in 0. After so much history, that uranium isotope is today times less numerous in nature than the more common isotope of uranium having mass When the Earth and planets and Sun were born 4. In such ways one knows the age of the Earth. If the uranium had been created longer ago than actually was the case, we would today have even less of it. Had they been much older, the uranium would have to have been even more abundant initially, so that the element to which it decays, lead, would today be much more abundant than it is demonstrated to be. Figure 1 illustrates this relationship between the two isotopes of uranium and the daughter lead isotopes to which they transmute. These arguments are powerful and persuasive. At least a dozen other nuclei also remain in significant numbers, and by comparing them one can determine that the nuclei began coming into existence about 12 billion years ago and were produced continuously from that time until the present. There seems to exist only one plausible means by which new elements can continuously be born, as required by the radioactivity. That place is within the stars. An illustration of the pressure support of a star against gravity. What is a star? Using the Sun and the laws of physics as a guide, stars are known to be giant balls of gas that are held together by their own weight. To hold up the weight of the overlying gas, the pressure must get larger at increasing depths within a star, just as pressure increases with depth below the top of the atmosphere, or as water pressure increases deeper in a lake. Figure 2 shows how that increasing pressure can just exactly balance the overlying weight, which also increases at greater depth. The star hovers in balance, in equilibrium between these opposing forces. Increasing pressure deeper within is achieved by increasing temperature of the solar gases. Because the sun is hotter within, heat flows outward, for it is one of the fundamental laws that heat flows from hot toward cold. The outflowing heat makes the surface also hot, and that causes the star to shine. By why does it not cool off? How can the sun have continued to shine for its 4. For stars to remain hot even while they lose heat at staggering rates, they must utilize a source of energy within. Some "coal furnace" keeps pouring out the heat at the center, which allows it to flow toward the colder surface and off into space as light. This continues for a very long time without the star cooling off. The laws of nuclear physics confirm that at the fierce temperatures of the stellar centers, the gas particles, which are none other than the nuclei of the atoms, collide with enough speed to cause nuclear reactions to occur. This heating at the solar center sets up another balance, a heat balance. The centers of the stars exist at just the right temperature to cause their reactors to run at the needed rates. Experiments in nuclear physics have made it possible to calculate the rate at which the nuclear reactors generate nuclear power. It is a property of fusion reactors that new, heavier nuclei are fused from the initial lighter ones. This fusion generates the heat, as in nuclear reactors on Earth. But, unavoidably, new chemical elements are brought thereby into being. Study of the light emitted by the hot gases at the surfaces of stars shows that they began their lives as hydrogen and helium, the two lightest elements, and that the nuclear reactors slowly fuse the heavier elements from those initial building blocks. The solar center transforms as much hydrogen as exists in Lake Michigan into helium in every second! This reveals how it is that the stars can be a continuous source of new heavy elements, including the radioactive ones whose lifetimes are so limited. Astronomers not only see stars, they see stars being born from dark clouds of cold gas that hover in the spaces between the stars. Gravity collects that cold gas into dense balls that get hot and turn on. Several new stars are born yearly in the Milky Way. This means that all stars do not have the same birthday. Like people, some are born every year. As a consequence, the stars we see in the sky are of differing ages. Some are old; some are young. A similar spread can be seen in a photograph of all of the people at an Atlanta Braves baseball game. Not only could an alien studying such a photo reason that not all people are the same age, he could even discern that some phases of human life are fast. For example, there are so few small humans with a missing upper front tooth that the life of each human must not long dwell in that condition. Astronomers use that very idea to map out the evolution of the life of a star. Doing so is a careful amalgamation of astronomical observations of many stars with computerized calculations of the fate of hot balls of gas held together by gravity. Those computer models of stars have no choice but to evolve, because the nuclear reactions change the atomic weight of the gas particles in the central regions. As particles fuse into fewer, heavier, particles, the star must lose pressure, whereupon it must shrink. This slow contraction of the center to a denser gaseous state is accompanied by an increase in its temperature. The compression of gas in the cylinder of a diesel engine so heats it that its fuel ignites. It occurs similarly in computer models of the stars. When one nuclear fuel is exhausted, the compression so heats the remaining gas that it ignites a new fuel at higher temperature. This continues until all forms of nuclear fuel are spent. When all nuclear fuel is spent, the core of the star quickly collapses and bounces, causing violent ejection of most of the overlying matter. Astronomers see only about one of these per century in the Milky Way. They are called "supernovae". Each ejects so many new heavy elements, including that suite of radioactive nuclei that are so diagnostic of natural history, that over one hundred million centuries all of the heavy elements contained in all of the stars and in all of the planetary systems within the entire Milky Way galaxy can have been assembled by fusion from initial hydrogen and helium. Many short-lived radioactive nuclei are now extinct but can nonetheless be seen to have existed when the solar system was forming. They leave within solid minerals, after they decay, an anomalously high number of atoms of the daughter nuclear isotope to which the now extinct radioactivity decayed. These telltale markers assert that when the solar system formed, the interstellar gases from which it collected contained radioactivity having half-lives much shorter than that of uranium. Their faster decay rates produce gamma rays more rapidly than can the slowly decaying long living radioactive nuclei. These observations have proven the long held belief that the chemical elements were overwhelmingly created in the supernova explosions that occurred prior to the birth of the sun. Supernova ejecta is profoundly radioactive. The relative natural abundances of isotopes of intermediate atomic weight.. Figure 3 shows the numbers of naturally occurring atoms of the metals between atomic weights 45 and They are dominated, like a mountain, by four abundant isotopes of iron. This is the sort of abundance data that the theory of nucleosynthesis must consider. The scientific method has achieved a great triumph here, from the first argument half a century ago that iron is the natural product of the evolution of the stellar core, to the recent proof by detected gamma rays from supernovae that the iron isotopes were ejected as isotopes of radioactive nickel and cobalt, and in just the ratios found within a common hammer! Stars in the Hertzsprung-Russell Diagram To glimpse all of this, astronomers first had to understand what a star is. That required meaningful photographs of their population. Stars are not all born with the same mass as the Sun, though it is a very common star. Increasingly massive stars are born both more luminous and more blue in color. That trend is called "the main sequence". Their greater mass causes higher central temperature to achieve enough pressure to support the increased overlying weight. That higher temperature causes the nuclear reactions to proceed more rapidly, generating greater power than the Sun. The stars 30 times more massive than the Sun are a staggering , times more luminous owing to this , times more prolific nuclear reactor. This much greater power can be radiated from the surface only if it gets bluer. The blacksmith here in Williamsburg knows well that if the forge gets iron hotter than red-hot, it becomes yellow-hot, and hotter still it become blue-hot. This fundamental truth of thermal physics holds also for stars. And the hotter ones, the bluer ones, radiate heat much more prolifically. It has satisfied generations of astronomers that these basic laws of physics interpret the main sequence so convincingly. An illustration of the main sequence is in Figure 4. But what of the evolution of the star from the main sequence to its final supernova explosion? That evolution occurs so rapidly that, like the toothless child, the condition does not long remain and the fraction of the population in that situation is small. It would be hard to believe all this except that the faithful computer and the laws of physics produce numerical models of stars that do what the real stars are observed to do. As shown in Figure 5, the outer layers get redder and more luminous during the transition from main sequence to presupernova star. Getting more heat from a redder, cooler, star would be impossible except for the huge increase in its surface radiating area as the star expands in size. These are the "red giants". They may live yet only another few million years, even though they were main sequence stars for hundreds of millions of years, or even several billion years like our Sun. The life of a star is not so unknowable after all.