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Chapter 1 : A Stellar Interior (Blog #) | Me and My Therapist

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Some general theoretical principles are outlined here. One way to move energy from the interior of a star to its surface is via radiation ; photons produced in the core are repeatedly absorbed and reemitted by stellar atoms , gradually propagating to the surface. A second way is via convection , which is a nonradiative mechanism involving a physical upwelling of matter much as in a pot of boiling water. For the Sun , at least, there are ways of distinguishing the mechanism of energy transport. The difference in brightness depends on the wavelength of the radiation detected: This limb darkening arises because the Sun becomes hotter toward its core. The planet Mercury can be seen as a small black dot in the lower middle of the solar disk. Mila Zinkova The amount of limb darkening in any star depends on the effective temperature of the star and on the variation in temperature with depth. Limb darkening is occasionally an important factor in the analysis of stellar observations. For example, it must be taken into account to interpret properly the observed light curves of eclipsing binaries , and here again the results suggest transport of energy via radiation. The layers of a normal star are assumed to be in mechanical, or hydrostatic, equilibrium. This means that at each point in the atmosphere, the pressure supports the weight of the overlying layers. In this way, a relation between pressure and density can be found for any given depth. In addition to the temperature and density gradients, the chemical composition of the atmospheric layers as well as the opacity of the material must be known. In the atmospheres of many stars, the extra electrons break loose and recombine with other ions, thereby causing a reemission of energy in the form of light. At visible wavelengths the main contribution to the opacity comes from the destruction of this ion by interaction with a photon the above-cited process is termed photodissociation. In hotter stars, such as Sirius A the temperature of which is about 10, K , atomic hydrogen is the main source of opacity, whereas in cooler stars much of the outgoing energy is often absorbed by molecular bands of titanium oxide, water vapour, and carbon monoxide. Additional sources of opacity are absorption by helium atoms and electron scattering in hotter stars, absorption by hydrogen molecules and molecular ions, absorption by certain abundant metals such as magnesium , and Rayleigh scattering a type of wavelength-dependent scattering of radiation by particles named for the British physicist Lord Rayleigh in cool supergiant stars. At considerable depths in the Sun and similar stars, convection sets in. Photosphere belie this simple picture. Realistic models must allow for rising columns of heated gases in some areas and descent of cooler gases in others. The motions of the radiating gases are especially important when the model is to be used to calculate the anticipated line spectrum of the star. Typical gas velocities are on the order of 2 km 1. The Sun has no distinct solid surface, so the point from which the depth or height is measured is arbitrary. The strata of the solar atmosphere are very opaque compared with the terrestrial atmosphere. For stars other than the Sun, the dependence of temperature on depth cannot be directly determined. Calculations must proceed by a process of successive approximations, during which the flux of energy is taken to be constant with depth. Computations have been undertaken for atmospheres of a variety of stars ranging from dwarfs to supergiants, from cool to hot stars. Considering the known complexities of stellar atmospheres, the results fit the observations remarkably well. Severe deviations exist for stars with extended and expanding atmospheres. Matter flowing outward from a star produces a stellar wind analogous to the solar wind , but one that is often much more extensive and violent. In the spectrum of certain very hot O-type stars e. These absorption features are produced by rapidly outflowing atoms that absorb the radiation from the underlying stellar surface. The observed shifts in frequency correspond to ejection velocities of about km 60 miles per second. Much gentler stellar winds are found in cool M-type supergiants. Since effective gravity is much reduced near the equator, the appropriate description of the atmosphere varies with latitude. Should the star be spinning at speeds near the breakup point, rings or shells may be shed from the equator. Some of the most extreme and interesting cases of rotational effects are found in close binary systems. Interpretations of the light and velocity curves of these objects suggest that the spectroscopic observations cannot be reconciled with simple orderly rotating stars. Instead, emission and absorption lines sometimes overlap in such a way as to suggest streams of gas moving between the stars. For example, Beta Lyrae , an eclipsing binary system, has a period of The brighter member at visible wavelengths is a star of type B6â€"B8; the other member is a larger, early B-type star that is embedded in an accretion disk and is draining matter from the B6â€"B8 star. The spectrum of the B6â€"B8-type component shows the regular velocity changes expected of a binary star , but there is an absorption and associated emission spectrum corresponding to a higher temperature near spectral type B5 and a blue continuum corresponding to a very high-temperature star. The anomalous B5-type spectrum is from the accretion disk and is evidently excited principally by the star within it. This spectrum shows few changes in velocity with time. Supergiant stars have very extended atmospheres that are probably not even approximately in hydrostatic equilibrium. The atmospheres of M-type supergiant stars appear to be slowly expanding outward. Observations of the eclipsing binary 31 Cygni show that the K-type supergiant component has an extremely inhomogeneous, extended atmosphere composed of numerous blobs and filaments. They do not, however. Stellar interiors Models of the internal structure of starsâ€"particularly their temperature , density , and pressure gradients below the surfaceâ€"depend on basic principles explained in this section. Another common assumption is that the interior of a star is in hydrostatic equilibrium. This balance is often expressed as a simple relation between pressure gradient and density. A second relation expresses the continuity of mass; i. Throughout the star the matter is entirely gaseous, and, except in certain highly evolved objects, it obeys closely the perfect gas law. In such neutral gases the molecular weight is 2 for molecular hydrogen, 4 for helium, 56 for iron , and so on. In the interior of a typical star, however, the high temperatures and densities virtually guarantee that nearly all the matter is completely ionized; the gas is said to be a plasma , the fourth state of matter. Under these conditions not only are the hydrogen molecules dissociated into individual atoms, but also the atoms themselves are broken apart ionized into their constituent protons and electrons. As another example, a totally ionized nickel atom contributes a nucleus of mass If the temperature is sufficiently high, the radiation pressure , Pr, must be taken into account in addition to the perfect gas pressure, Pg. The answer is 28 million K, much hotter than the core of the Sun. Consequently, radiation pressure may be neglected for the Sun, but it cannot be ignored for hotter, more massive stars. Radiation pressure may then set an upper limit to stellar luminosity. Certain stars, notably white dwarfs , do not obey the perfect gas law. Instead, the pressure is almost entirely contributed by the electrons, which are said to be particulate members of a degenerate gas see below White dwarfs. The temperature does not enter at all. At still higher densities the equation of state becomes more intricate, but it can be shown that even this complicated equation of state is adequate to calculate the internal structure of the white dwarf stars. As a result, white dwarfs are probably better understood than most other celestial objects. For normal stars such as the Sun, the energy-transport method for the interior must be known. Except in white dwarfs or in the dense cores of evolved stars, thermal conduction is unimportant because the heat conductivity is very low. One significant mode of transport is an actual flow of radiation outward through the star. The rate of flow of radiation is proportional to the thermal gradientâ€"namely, the rate of change of temperature with interior distance. Providing yet another relation of stellar structure, this equation uses the following important quantities: Huge volumes of gas deep within the star become heated, rise to higher layers, and mix with their surroundings, thus releasing great quantities of energy. The extraordinarily complex flow patterns cannot be followed in detail, but when convection occurs, a relatively simple mathematical relation connects density and pressure. Wherever convection does occur, it moves energy much more efficiently than radiative transport. Source of stellar energy The most basic property of stars is that their radiant energy must derive from internal sources. Given the great length of time that stars endure some 10 billion years in the case of the Sun , it can be shown that neither chemical nor gravitational effects could possibly yield the required energies. Instead, the cause must be nuclear events wherein lighter nuclei are fused to create heavier nuclei, an inevitable by-product being energy see nuclear fusion. In the interior of a star, the particles move rapidly in every direction because of the high temperatures present. Every so often a proton moves close enough to a nucleus to be captured, and a nuclear reaction takes place. Only protons of extremely high energy many times the average energy in a star such as the Sun are capable of producing nuclear events of this kind. A minimum temperature required for fusion is roughly 10 million K.

Since the energies of protons are proportional to temperature, the rate of energy production rises steeply as temperature increases. For the Sun and other normal main-sequence stars, the source of energy lies in the conversion of hydrogen to helium. The nuclear reaction thought to occur in the Sun is called the proton-proton cycle. The positron encounters an ordinary negatively charged electron, and the two annihilate each other, with much energy being released. This annihilation energy amounts to 1. Next, a proton collides with the deuteron to form the nucleus of a light helium atom of atomic weight 3, 3He. The most likely event to follow in the chain is a collision of this 3He nucleus with a normal 4He nucleus to form the nucleus of a beryllium atom of weight 7, 7Be, with the emission of another gamma-ray photon. The 7Be nucleus in turn captures a proton to form a boron nucleus of atomic weight 8, 8B, with the liberation of yet another gamma ray. The 8B nucleus, however, is very unstable. It decays almost immediately into beryllium of atomic weight 8, 8Be, with the emission of another positron and a neutrino. The nucleus itself thereafter decays into two helium nuclei, 4He. These nuclear events can be represented by the following equations: In the course of these reactions, four protons are consumed to form one helium nucleus, while two electrons perish. Some of this has been carried away by the elusive neutrinos, but most of it has been converted to radiant energy. In order to keep shining at its present rate, a typical star e. This theory provides a good understanding of solar energy generation, although for decades it suffered from one potential problem. The neutrino flux from the Sun was measured by different experimenters, and only one-third of the flux of electron neutrinos predicted by the theory was detected.

Chapter 2 : Stars - Stellar Interiors and Fusion Processes - Space Art and Astronomical Illustrations

This text, updated and expanded from the first edition, is designed for beginning students of stellar physics, and introduces the fundamentals of stellar structure and evolution.

Stellar Interiors and Fusion Processes Stars are incredibly large matter creating factories. Inside them hydrogen is fused into larger, and larger elements. In fact, all matter that makes up our body, that is heavier than iron, was once produced inside a massive, dying star. Stars are hot on the surface, especially massive blue stars, but inside the star it gets hotter and hotter as you approach the core. In the core of our sun, temperatures are as high as 15 degrees Kelvin, which is enough for fusion between hydrogen atoms to occur. However, in the cores of massive supergiants temperatures can rise up to several billion degrees when heavy atoms are produced. The Interior of Stars On the surface stars can appear to be violent creations of nature, but inside raging powers reside. The closer one gets to the core of the star, the hotter it gets. In the core the main energy in the form of light: This energy is transported to the surface through different methods. In massive stars, energy is mainly transported outside the core by convection. This zone is therefore called the Convective Zone. This energy transport is usually in circular convection currents. Once the energy produced in the core reaches a certain distance and thereby a certain temperature the plasma turns into solid atoms. Therefore energy is now transported through photons colliding with atoms. The powerful gamma ray photons that are produced inside the core take very long to reach the surface because they bounce off of atoms that are in the way. They may take millions of years to reach out into space. Stars smaller than the sun, such as red dwarfs may not even have a radiative zone. Energy is solely transported through convection. This means that the helium that is produced in the center will be mixed up with hydrogen even close to the surface. Because red dwarf stars lack enough mass to produce heavier atoms than helium, they will die only when they have used up all the hydrogen in the star, contrary to other stars. This enables red dwarfs to live for trillions of years! Proton-Proton Chain The Proton-Proton Chain is the primary way to fuse protons to form hydrogen in stars the size of the sun, or smaller. To make them fuse is no easy task, as it requires very high temperatures. The whole sequence takes about years on average to complete. The fact that the sun is still shining brightly is because there are extremely many reactions that are occurring at any given time. The whole chain looks like this: Only one will be mentioned here: The result is 2 gamma rays. Step 3 consists of the deuterium merging with a proton to create a helium isotope and yet another gamma ray. After this has happened the reaction can go in several ways, one way is when two helium isotopes fuse to create one stable helium atom, and two free protons. When a star converts hydrogen into helium it is located on the main sequence on the Hertzsprung-Russell Diagram. As soon as the temperatures inside the core reach about 17 million degrees Kelvin, the CNO-cycle becomes the dominant helium producing reaction, but the cycle starts at a few million degrees less. This is what the reaction looks like: In step 2, the nitrogen atom decomposes into a carbon isotope, a positron and a neutrino. In the next stage, the carbon isotope acquires a second hydrogen atom to create a stable nitrogen atom, and a gamma ray. Later, the nitrogen atom fuses together with a proton. Now we have an oxygen isotope, and a gamma ray. Furthermore, the oxygen isotope decomposes into a nitrogen isotope and thereby releases another set of a positron and a neutrino. In the final stage the nitrogen isotope acquires a hydrogen atom to create one carbon atom, and one helium atom, aka an alpha particle. Triple-Alpha Process Once the hydrogen in the core is used up, the star starts collapsing because no energy is not enough energy produced in the core to counter the gravitaty. As the star starts to collapse, the heat inside the core starts to increase. Once the temperature reaches degrees Kelvin, helium fusion creates carbon. This procedure is simple: In massive stars, a very small fraction of carbon atoms may continue adding helium atoms to create larger, and larger atoms. If the carbon atom continues, then the process is called the Alpha-Process. Other Fusion Reactions How heavy elements that will be created inside the core of a star is entirely dependent on how massive it is. Along with that, temperatures rise in the core. Stars that have less than 3 solar masses stop fusing heavier elements when the helium is digested. If the star is more massive it may start fusing carbon in a process called the Carbon Burning Process, which requires a core temperature of atleast x degrees K. The

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Neon Burning Process requires a core temperature of 1. The Silicon Burning Process starts somewhere between 2. At that point the core fuses silicon Si with helium atoms in the alpha process, until the core consists of nickel, Ni. At this point the fusion in the core stops, because in order to fuse heavier elements, the core must provide each reaction with energy, rather than releasing it. During this process everything is shed into space, except for the core, which collapses into either a neutron star, or a black hole. The matter which is into space may create a planetary nebula , and create new, smaller stars.

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Chapter 6 : Stellar Interiors

Stellar Interiors has 12 ratings and 1 review. Sandu said: Interesting and very educational book. I appreciate the subtle humor going on, which makes it.

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1. Introduction and Fundamental Principles 3 This book is divided into two parts: stellar interiors and stellar atmospheres. While the division between the two is fairly arbitrary, it is a traditional division.

Chapter 8 : E-Design, Online Interior Design Services, E-Decorating

Stellar Interiors -- I. Clusters and Main Sequence Fitting. We mentioned earlier the idea of finding distances to stars using spectroscopic blog.quintoapp.com is a related method for finding the distance to star clusters, which is an extremely important thing to know.

Chapter 9 : Stellar structure - Wikipedia

Physics of Stellar Interiors Rewrite p = mv, which gives n v dv for an ideal gas is the Maxwell Boltzmann distribution. Plugging in an evaluating integral gives, P.