STELLAR SURFACE STRUCTURE pdf

1: Star - Stellar structure | www.enganchecubano.com

Our studies provide unique constraints to the theories of stellar magnetism, activity, and structure formation. Time-series spectroscopy and spectropolarimetry. High-resolution spectroscopy and spectropolarimetry are the primary tools for studies of stellar magnetic fields and surface structures.

Unit 49 Stars are basically large balls of hot hydrogen gas, and the macroscopic properties of a hot gas are governed by the Ideal Gas Law of chemistry. An ideal gas is a gas that conforms, in physical behavior, to a particular, idealized relation between pressure, volume, and temperature. Such a relation for a substance is called its equation of state and is sufficient to describe its gross behavior. Although no gas is perfectly described by the above laws, the behavior of real gases is described quite closely by the ideal gas law at sufficiently high temperatures and low pressures such as air pressure at sea level , when relatively large distances between molecules and their high speeds overcome any interaction. A gas does not obey the equation when conditions are such that the gas, or any of the component gases in a mixture, is near its triple point. While all the above conditions are not strictly true, where they breakdown interesting things happen - such as friction in general the behavior of matter is well described by this kinetic theory. Almost all the behavior of normal stars is given by the simple relations of the ideal gas law. For example, as a star shrinks, the volume decreases and the pressure increases. If the equation is confusing, the following summarizes the way the math works: Stars form from clouds of gas and collapse under self-gravity. The collapse is stopped by internal pressure in the core of the star. During the collapse, the potential energy of infalling hydrogen atoms is converted to kinetic energy, heating the core. As the temperature goes up, the pressure goes up to stop the collapse. The heat from the collapse is sufficient for a star to shine, but only for a timescale of 15 million years called the Kelvin-Helmholtz time. Since most stars are over 10 billion years old, then they must be producing its own energy rather than shining on leftover energy from formation. The structure of stars is determined by 5 relations or physical concepts: They are stable in size. Therefore, this fact means that the internal pressure must balance the weight of the material above it self-gravity gravity compression is balanced by pressure outward Greater gravity compresses the gas, making it denser and hotter, so the outward pressure increases thermal equilibrium - the amount of energy generated in the core of a star by thermonuclear fusion must equal the amount radiated away the only place for the energy to go is outward opacity - how fast energy is radiated is determined by the resistance of the stellar envelope to the flow of photons. Conduction, the collisional transfer of energy between atoms, only occurs between solids such as a hot pan and your hand , so is not found in stars. Only convection and radiation transfer are important in stars and the opacity determines which method is used. When the temperature gradient is low and all the atoms are stripped of their electrons, the opacity is low and radiation transfer is dominant. When the temperature drops, and the temerature gradient is high, such as in the outer layers of a stars interior, the protons and electrons recombine to form atoms and the opacity goes up. High opacity slows the transfer of energy by radiation, so bubbles form. These bubbles are hot and low in density, thus starting a convective flow. Whether convection or radiation transport is used depends on the temperature make-up of the stellar interior. When the changes in temperature are sharp, convection is used. Think of the photons as grains of sand on a pile. If the pile is low, radiation is used. If the pile is high, the sand tumbles down, convection is used. This can be either the proton-proton chain or the CNO cycle. These 5 relationships, stated as mathematical formula, show how energy is generated, how that energy effects the structure of stars and how that energy is transported to the surface to make a star shine. A star is divided into six regions based on the physical characteristics of these regions. The boundaries are not sharp, and the regions vary in size from star to star. For example, hot stars have larger radiative zones and smaller convective zones. The reverse is true of cool stars. The stellar equator for a solar mass star completes one rotation in 25 days. The poles complete one rotation in 36 days. The chromosphere is a pinkish atmosphere above a stars surface the photosphere. The most complex and transient stellar phenomena occur in the chromosphere including:

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2: Stellar structure - Wikipedia

Stars of different mass and age have varying internal www.enganchecubano.comr structure models describe the internal structure of a star in detail and make detailed predictions about the luminosity, the color and the future evolution of the star.

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.

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3: Stellar Surface Structures and the Astrometric Serach for Exoplnaets - CORE

The IAU Symposium on `Stellar Surface Structure' consequently focused on spatially resolved stellar observations throughout the H-R diagram, from O- and B-stars to late M-stars. Two further sections in this book summarize the current observational data on surface inhomogeneities in stellar photospheres, chromospheres, and coronae.

Stellar composition Stellar magnetic fields and surface structures Magnetic fields play a key role at many stages of stellar formation and evolution. The fields represent a key ingredient of stellar and planetary system formation processes. They are also responsible for the angular momentum loss in young stars and is the main energy source behind a broad range of dynamic phenomena flares, X-ray emission, star spots occurring at the surface layers of the Sun and other stars. However, magnetic fields are challenging to detect and model directly. We use time-series spectropolarimetric observations and advanced remote sensing algorithms, coupled with detailed theoretical calculations, to detect the feeble signatures of magnetic fields and to study their topologies. Magnetic and star spot maps reconstructed by our group reveal intricate details of the magneto-hydrodynamical processes on the stellar surfaces and in circumstellar environments. Our studies provide unique constraints to the theories of stellar magnetism, activity, and structure formation. Time-series spectroscopy and spectropolarimetry High-resolution spectroscopy and spectropolarimetry are the primary tools for studies of stellar magnetic fields and surface structures. Inhomogeneities on stellar surfaces distort spectral line profile shapes, producing characteristic signatures that can be detected and interpreted. Magnetic fields also give rise to polarisation signatures in spectral lines via the Zeeman effect. This enables detection of stellar magnetic fields and reconstruction of their topologies. Both spectroscopic and spectropolarimetric observations must be obtained repeatedly to resolve the time-dependent phenomena such as pulsations and rotational modulation. We participate in major international projects e. MiMeS and Binamics collaborations aimed at collecting observational data with these instruments. We also provide the community with advanced tools for the spectroscopic and spectropolarimetric data reduction and multi-line analysis. Indirect imaging of stellar surfaces The characteristic distortions produced by magnetic fields and star spots move across Doppler-broadened intensity and polarisation line profiles. This line profile variability provides enough information to reconstruct a two-dimensional map of stellar surface. We have developed and applied to different types of stars a variety of DI codes for the reconstruction of temperature, chemical abundance, and pulsation velocity maps from intensity spectra. We have also developed ZDI inversion codes to recover vector magnetic field maps from spectropolarimetric observations. While most of stellar magnetism studies use only circular polarisation, we have pioneered the use of the full Stokes vector observations for stellar magnetic field mapping. Magnetic fields and star spots across the H-R diagram We use spectropolarimetry and ZDI to detect and reconstruct topologies of surface magnetic fields in stars across the entire Hertzsprung-Russell diagram. These studies provide key constraints to stellar magnetism theories, including stellar dynamos, relaxation of fossil magnetic fields, etc. Our investigations are also relevant in the context of many other astrophysical phenomena where magnetic fields are often invoked but seldom observed directly. Our magnetic maps provide the basis for investigation of magnetospheres surrounding of massive stars. We also reconstruct horizontal and vertical maps of chemical spots. These surface structure studies enable sensitive tests of stellar magneto-hydrodynamic theories. Late-type active stars We study magnetic field geometries of different classes of rapidly rotating, magnetically active late-type stars. Our ZDI studies aim at following evolution of the dynamo-generated magnetic fields through stellar activity cycles. We also carry out detailed modelling of the spectroscopic and spectropolarimetric data with the goal to measure magnetic fields and assess thermodynamic properties of star spots. Young stars This is another type of cool stars displaying conspicuous surface activity related to the presence of strong magnetic fields. We measure magnetic fields though the Zeeman broadening and polarisation and study the field topologies of T Tauri stars of different masses. The general aim of this research is to establish how the field structure and strength change in the course of early stellar evolution. Of special interest are intermediate-mass T Tauri stars which start as cool objects with dynamo fields and then evolve into magnetic A and B stars with fossil fields. Active M dwarfs At the bottom of the main sequence one finds low-mass stars of M spectral classes. Some of these stars possess strong magnetic fields. The nature of these fields and their exact geometries are currently unknown. We study magnetic fields of M dwarfs with near-infrared high-resolution spectra and with optical spectropolarimetry. The focus of this work is to develop self-consistent magnetic topology models capable of explaining all available magnetic observations. The star is shown at two different rotation phases. The surface maps and magnetic field loops are colour coded according to the strength of the radial field component. Chemical star spot maps of the late-A magnetic star HD These chemical distributions were obtained by modelling line profile variations of individual elements with a DI inversion code. Vertical stratification of chemical elements Strong magnetic fields stabilise atmospheres of early-type magnetic stars, facilitating operation of the radiative diffusion process. Under the competing influence of gravity and radiation pressure chemical elements accumulate in distinct layers of under or overabundance in stellar atmospheres. The resulting chemical gradients can reach several orders of magnitude within a thin atmospheric layer. This leads to characteristic anomalies of the spectral line strengths and profile shapes. We have developed and systematically applied inversion methods for reconstruction of the vertical chemical abundance gradients from high-resolution spectroscopic observations. These empirical chemical stratification models, now available for several dozen stars, enable sensitive tests of the theories of hydrodynamic processes atomic diffusion, rotational mixing, weak mass loss operating in stellar atmospheres. Vertical chemical stratification profiles for the cool magnetic A star HD Abundances of different elements are shown as a function of height in the stellar atmosphere. The colour code corresponds to the deviation from solar abundance values expressed in logarithmic units. Pulsational tomography of stellar atmospheres A handful of A-type magnetic stars so-called "rapidly oscillating Ap" or roAp stars pulsate in high-overtone non-radial p-modes, with periods on the order of 10 min. These pulsations, associated with the presence of strong magnetic fields in stellar envelopes, enable asteroseismic analysis that provides useful information about fundamental stellar parameters. Besides the classical asteroseismology high-resolution spectroscopy of roAp pulsations can provide a remarkably detailed view of the propagation of magneto-hydrodynamic waves in stellar atmospheres. Besides the Sun, this is the only class of stars for which such detailed vertical analysis of non-radial pulsations is possible. We have carried out numerous time-resolved spectroscopic studies of roAp stars using spectrographs at large telescopes, such as ESO 3. These investigations led to discoveries of several new roAp stars. We have also reconstructed height dependence of the pulsational amplitude and phase by studying variations of individual chemical elements. In addition to these vertical pulsation tomography studies, we interpreted pulsational line profile variations and developed techniques to map the horizontal structures of non-radial pulsations. These empirical studies were confronted with predictions of theoretical magneto-hydrodynamic models to gain a better insight into the nature of magneto-acoustic pulsations. Typical rapid line profile variations in the time-resolved spectra of a rapidly oscillating Ap star. Pulsations are very weak in the lines of iron-peak elements but reach high amplitudes in rare-earth lines which form in the uppermost atmospheric layers. A gradual increase of the radial velocity amplitude and a change of phase indicate an outward propagating pulsation wave.

4: Stellar Structure

Stellar structure Stellar atmospheres To interpret a stellar spectrum quantitatively, knowledge of the variation in temperature and density with depth in the star's atmosphere is needed.

5: Stellar Surface Structure : Klaus G. Strassmeier :

At a star's surface the energy is released to form the spectrum of the star. energy transport - how energy is transported from the core to the stellar surface determines the surface temperature of a star (its color).

6: Stellar Surface Structure | Strassmeier / Linsky, | Buch | www.enganchecubano.com

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The IAU Symposium No. on the topic "Stellar Surface Structure" was held between October th in Vienna. Five scientific Sessions - Stellar Surface Mapping Techniques, Direct Mapping: The Last Frontier, Photospheric Phenomena: Results, Outer Atmosphere Structures, Next Generation Model Atmospheres with more than participants presenting 55 talks and poster papers cook.

7: [] Limits of ultra-high-precision optical astrometry: Stellar surface structures

K.G. Strassmeier et al.: Doppler imaging of stellar surface structure. X Fig.1a-d. A comparison of observed and synthesized spectra in the CaiA line region.Ëš a A spectrum of HD (thick line) compared.

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