= Main sequence =

In astronomy , the main sequence is a continuous and distinctive band of stars that appears on plots of stellar color versus brightness . These color @-@ magnitude plots are known as Hertzsprung ? Russell diagrams after their co @-@ developers , Ejnar Hertzsprung and Henry Norris Russell . Stars on this band are known as main @-@ sequence stars or " dwarf " stars .

After a star has formed , it generates thermal energy in the dense core region through nuclear fusion of hydrogen atoms into helium . During this stage of the star 's lifetime , it is located along the main sequence at a position determined primarily by its mass , but also based upon its chemical composition and other factors . All main @-@ sequence stars are in hydrostatic equilibrium , where outward thermal pressure from the hot core is balanced by the inward pressure of gravitational collapse from the overlying layers . The strong dependence of the rate of energy generation in the core on the temperature and pressure helps to sustain this balance . Energy generated at the core makes its way to the surface and is radiated away at the photosphere . The energy is carried by either radiation or convection , with the latter occurring in regions with steeper temperature gradients , higher opacity or both .

The main sequence is sometimes divided into upper and lower parts , based on the dominant process that a star uses to generate energy . Stars below about 1 @.@ 5 times the mass of the Sun (or 1 @.@ 5 solar masses (M ?)) primarily fuse hydrogen atoms together in a series of stages to form helium , a sequence called the proton ? proton chain . Above this mass , in the upper main sequence , the nuclear fusion process mainly uses atoms of carbon , nitrogen and oxygen as intermediaries in the CNO cycle that produces helium from hydrogen atoms . Main @-@ sequence stars with more than two solar masses undergo convection in their core regions , which acts to stir up the newly created helium and maintain the proportion of fuel needed for fusion to occur . Below this mass , stars have cores that are entirely radiative with convective zones near the surface . With decreasing stellar mass , the proportion of the star forming a convective envelope steadily increases , whereas main @-@ sequence stars below 0 @.@ 4 M ? undergo convection throughout their mass . When core convection does not occur , a helium @-@ rich core develops surrounded by an outer layer of hydrogen .

In general , the more massive a star is , the shorter its lifespan on the main sequence . After the hydrogen fuel at the core has been consumed , the star evolves away from the main sequence on the HR diagram . The behavior of a star now depends on its mass , with stars below 0 @.@ 23 M ? becoming white dwarfs directly , whereas stars with up to ten solar masses pass through a red giant stage . More massive stars can explode as a supernova , or collapse directly into a black hole .

= = History = =

In the early part of the 20th century , information about the types and distances of stars became more readily available . The spectra of stars were shown to have distinctive features , which allowed them to be categorized . Annie Jump Cannon and Edward C. Pickering at Harvard College Observatory developed a method of categorization that became known as the Harvard Classification Scheme , published in the Harvard Annals in 1901 .

In Potsdam in 1906 , the Danish astronomer Ejnar Hertzsprung noticed that the reddest stars ? classified as K and M in the Harvard scheme ? could be divided into two distinct groups . These stars are either much brighter than the Sun , or much fainter . To distinguish these groups , he called them " giant " and " dwarf " stars . The following year he began studying star clusters ; large groupings of stars that are co @-@ located at approximately the same distance . He published the first plots of color versus luminosity for these stars . These plots showed a prominent and continuous sequence of stars , which he named the Main Sequence .

At Princeton University , Henry Norris Russell was following a similar course of research . He was studying the relationship between the spectral classification of stars and their actual brightness as corrected for distance ? their absolute magnitude . For this purpose he used a set of stars that had reliable parallaxes and many of which had been categorized at Harvard . When he plotted the spectral types of these stars against their absolute magnitude , he found that dwarf stars followed a distinct relationship . This allowed the real brightness of a dwarf star to be predicted with reasonable accuracy .

Of the red stars observed by Hertzsprung , the dwarf stars also followed the spectra @-@ luminosity relationship discovered by Russell . However , the giant stars are much brighter than dwarfs and so , do not follow the same relationship . Russell proposed that the " giant stars must have low density or great surface @-@ brightness , and the reverse is true of dwarf stars " . The same curve also showed that there were very few faint white stars .

In 1933 , Bengt Strömgren introduced the term Hertzsprung ? Russell diagram to denote a luminosity @-@ spectral class diagram . This name reflected the parallel development of this technique by both Hertzsprung and Russell earlier in the century .

As evolutionary models of stars were developed during the 1930s , it was shown that , for stars of a uniform chemical composition , a relationship exists between a star 's mass and its luminosity and radius . That is , for a given mass and composition , there is a unique solution for determining the star 's radius and luminosity . This became known as the Vogt @-@ Russell theorem ; named after Heinrich Vogt and Henry Norris Russell . By this theorem , when a star 's chemical composition and its position on the main sequence is known , so too is the star 's mass and radius . (However , it was subsequently discovered that the theorem breaks down somewhat for stars of non @-@ uniform composition .)

A refined scheme for stellar classification was published in 1943 by W. W. Morgan and P. C. Keenan . The MK classification assigned each star a spectral type ? based on the Harvard classification ? and a luminosity class . The Harvard classification had been developed by assigning a different letter to each star based on the strength of the hydrogen spectral line , before the relationship between spectra and temperature was known . When ordered by temperature and when duplicate classes were removed , the spectral types of stars followed , in order of decreasing temperature with colors ranging from blue to red , the sequence O , B , A , F , G , K and M. (A popular mnemonic for memorizing this sequence of stellar classes is " Oh Be A Fine Girl / Guy , Kiss Me " .) The luminosity class ranged from I to V , in order of decreasing luminosity . Stars of luminosity class V belonged to the main sequence .

= = Formation = =

When a protostar is formed from the collapse of a giant molecular cloud of gas and dust in the local interstellar medium , the initial composition is homogeneous throughout , consisting of about 70 % hydrogen , 28 % helium and trace amounts of other elements , by mass . The initial mass of the star depends on the local conditions within the cloud . (The mass distribution of newly formed stars is described empirically by the initial mass function .) During the initial collapse , this pre @-@ main @-@ sequence star generates energy through gravitational contraction . Upon reaching a suitable density , energy generation is begun at the core using an exothermic nuclear fusion process that converts hydrogen into helium .

When nuclear fusion of hydrogen becomes the dominant energy production process and the excess energy gained from gravitational contraction has been lost , the star lies along a curve on the Hertzsprung ? Russell diagram (or HR diagram) called the standard main sequence . Astronomers will sometimes refer to this stage as " zero age main sequence " , or ZAMS . The ZAMS curve can be calculated using computer models of stellar properties at the point when stars begin hydrogen fusion . From this point , the brightness and surface temperature of stars typically increase with age .

A star remains near its initial position on the main sequence until a significant amount of hydrogen in the core has been consumed , then begins to evolve into a more luminous star . (On the HR diagram , the evolving star moves up and to the right of the main sequence .) Thus the main sequence represents the primary hydrogen @-@ burning stage of a star 's lifetime .

= = Properties = =

The majority of stars on a typical HR diagram lie along the main @-@ sequence curve . This line is pronounced because both the spectral type and the luminosity depend only on a star 's mass , at least to zeroth @-@ order approximation , as long as it is fusing hydrogen at its core ? and that is what almost all stars spend most of their " active " lives doing .
The temperature of a star determines its spectral type via its effect on the physical properties of plasma in its photosphere . A star 's energy emission as a function of wavelength is influenced by both its temperature and composition . A key indicator of this energy distribution is given by the color index , B ? V , which measures the star 's magnitude in blue (B) and green @-@ yellow (V) light by means of filters . This difference in magnitude provides a measure of a star 's temperature .

= = Dwarf terminology = =

Main @-@ sequence stars are called dwarf stars , but this terminology is partly historical and can be somewhat confusing . For the cooler stars , dwarfs such as red dwarfs , orange dwarfs , and yellow dwarfs are indeed much smaller and dimmer than other stars of those colors . However , for hotter blue and white stars , the size and brightness difference between so @-@ called dwarf stars that are on the main sequence and the so @-@ called giant stars that are not becomes smaller ; for the hottest stars it is not directly observable . For those stars the terms dwarf and giant refer to differences in spectral lines which indicate if a star is on the main sequence or off it . Nevertheless , very hot main @-@ sequence stars are still sometimes called dwarfs , even though they have roughly the same size and brightness as the " giant " stars of that temperature .
The common use of dwarf to mean main sequence is confusing in another way , because there are dwarf stars which are not main @-@ sequence stars . For example , a white dwarf is the dead core of a star that is left after the star has shed its outer layers , that is much smaller than a main @-@ sequence star- ? roughly the size of Earth . These represent the final evolutionary stage of many main @-@ sequence stars .

= = Parameters = =

By treating the star as an idealized energy radiator known as a black body , the luminosity L and radius R can be related to the effective temperature Teff by the Stefan ? Boltzmann law :