The likelihood of a species being successful without preadaptation would be even less under these proposed "primitive Earth" conditions than within the limits of modern animal husbandry from which these data were derived. Even here, the sum of edaphic, climatic, microbial, and competitive factors is clearly antagonistic towards the survival of the species involved.

Regarding the question of adaptation vs. preadaptation, the testimony of animal populations is that their existence can best be explained in terms of God's having created them in all their unfathomable intricacy, each kind perfectly fitted by Him at creation to survive the challenges of life on Earth. Perhaps the phrase, "survival of the fittest," should be replaced by "survival of the fitted," and appropriated by creationists?

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Educational Column

THE ROLE OF STELLAR POPULATION TYPES IN THE DISCUSSION OF STELLAR EVOLUTION

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Abstract

Stars can be grouped into two general types called population I and population II. The criteria for classification include space velocity, location in the galaxy, composition, differences in distribution on the Hertzsprung-Russell diagram, integrated color, and the presence of nearby dust and gas. The current evolutionary theory of stellar evolution and galaxy formation succeeds in giving a qualitative explanation for the population types. In establishing a creation model of stellar (and galactic) astronomy, it is important to keep in mind the two different populations. If an alternate model is to be taken seriously, then the observed population types should be explained in a very plausible fashion.

Introduction

In a recent paper Faulkner and DeYoung (1991) briefly surveyed the state of creationist astronomy. It was noted that most work to date has been primarily concerned with the ages of solar system objects or with criticism of the current standard (Big Bang) model of the universe. This trend has overlooked the middle scale of stellar astronomy between these two extremes. For several decades astronomy has been dominated by the concept of stellar evolution which has achieved some success in giving a natural and totally physical explanation for a great number of observed properties of stars. Not much of this has been challenged by creationists and it was the purpose of the paper of Faulkner and DeYoung to call attention to this deficiency and spark discussion on these matters. To this end that paper presented a very brief discussion of stellar structure and its relation to the development of stellar evolution. The Hertzsprung-Russell (H-R) diagram was described, as well as its importance in interpretation of stellar evolution. Several predictions of theoretical stellar evolution and purported observational evidences were presented without comment in that paper as well. This included the coincidence in location and age of planetary nebulae with white dwarfs and the coincidence in location and age of supernova remnants with neutron stars.

In addition the previous paper briefly discussed the differences in observed H-R diagrams of globular and open star clusters. These differences qualitatively agree with the predictions of stellar evolution for young clusters (open clusters) and for old clusters (globular clusters). Armed with the results of stellar evolution it is generally argued that certain features of the H-R diagram, such as the turn off point can be used to determine the age of a particular cluster.

This paper will develop the differences between the two types of clusters further and expand those differences to all stars. The parlance for this is stellar populations, and the two populations will be defined and examined. Very little creationist criticism or commentary will be provided here: the purpose of this paper is to inform readers interested in developing a creationist astronomy of some of the stellar features that should be kept in mind with the goal of explaining them from the creationist perspective.

Stellar Populations

The Milky Way galaxy is believed to be a disk with a fainter, but massive, roughly spherical halo that is concentric with the disk (see Figure 1). The galaxy has a total mass of at least 100 billion, and perhaps as much as 250 billion, times that of the sun. The luminous disk appears to contain most of the brightest stars and is about 100,000 light years across, while it is only a few thousand light years in thickness. There is a thickening of up to perhaps 10,000 light years at the center of the disk, a feature called the nucleus. Most of the hotter and brighter stars in the disk are found in spiral arms that extend from the nucleus, and the Milky Way, along with other similar appearing galaxies, are thus called spiral galaxies. The halo is a fainter, roughly spherical distribution of stars that is concentric with the disk as well. Despite being fainter, the halo does

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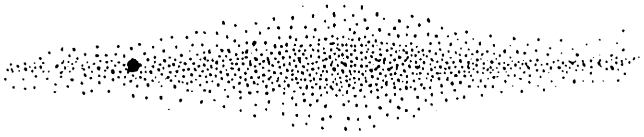
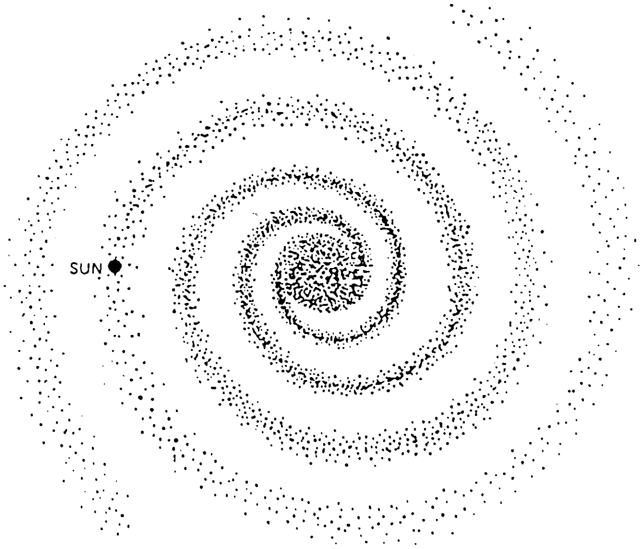


SIDE VIEW



TOP VIEW

Figure 1. Schematic side and top views of the Milky Way galaxy. The diameter of the luminous disk is about 100,000 light years across and a few thousand light years thick. The nuclear bulge is about 10,000 light years across. The sun is located in the disk about half or two thirds the distance out from the center. The halo is a spherical distribution of stars concentric with the disk (DeYoung, 1989, p. 84).

contain a substantial portion of the galaxy's mass. This is particularly indicated from velocity profile studies of the Milky Way and other spiral galaxies. These show that there must be a large amount of mass located beyond where we see most of the stars and other visible mass. Since this inferred additional matter is not visible, it has been termed "dark matter," and though a number of theories have been put forth about its source, its identity is still a mystery.

One of the most important considerations in deducing the structure of the galaxy is the study of stellar kinematics, or the motions of stars. A star's space velocity can be expressed in terms of two component velocities with respect to the the solar system: the radial velocity in the line of sight to the star, and the tangential velocity perpendicular to the radial velocity. The radial velocity is easily measured by using the Doppler shift observed to occur in the spectral lines of stars, and can be determined at any distance, as long as the star is bright enough. Unfortunately the tangential velocity is more difficult to determine. Over time the tangential velocity will cause a gradual change in a star's position in the sky, and generally two photographs made many years apart are carefully measured to determine a star's change in position. The change in position is divided by the time interval to obtain an annual change, which is called the proper motion and is measured in arc seconds per year. Obviously, the proper motion and the tangential velocity are directly related, but the distance is also involved. The three quantities are related to each other by the equation

$$v_T = 4.74\mu d$$

where v_T is the tangential velocity in km / sec, μ is the proper motion and d is the distance in parsecs. The distance can be directly measured by the method of trigonometric parallax, which entails the determination of the annual slight change in the apparent positions of stars that occurs because of the earth's orbital motion around the sun. If π is the parallax, in seconds of arc, then the distance is given by

$$d = 1/\pi,$$

where the distance is measured in parsecs (1 pc = 3.26 light years). It is often stated that this method of distance determination works accurately up to a distance of 100 parsecs (roughly 300 light years). Actually, at 100 parsecs the error in the measurement is equal to the measurement itself, and this method is only reliable (errors within 10 percent) to about 20 parsecs (65 light years) (Mihalas and Routly, 1968; Smart and Green, 1977). Beyond this distance other, indirect, methods must be used.

As would be expected, the nearest stars have the largest proper motions, while distant stars have small proper motions. Since parallax measurements are very difficult and tedious, it is only profitable to attempt measurements of stars which we guess are nearby. Proper motion studies have been conducted for the entire sky, and parallax studies have generally used proper motion surveys to identify candidates for measurement by searching for stars having large proper motions. It is probable that a few faint, nearby stars have been missed this way because they happen to have small proper motions or are very faint, but the sample of nearby stars is otherwise nearly complete.

The space velocity of a star can be determined by knowing its two components, the tangential and radial velocities. It was discovered several decades ago that stellar kinematics naturally divide stars into two classes: those with large space velocities (high velocity stars) and those with small space velocities (low velocity stars). In the original and classic paper on the subject Baade (1944) proposed that there are two types, or populations of stars, population I being the low velocity stars and population II being the high velocity stars. Additional discussion of stellar populations may be found in Mihalas and Routly (1968); Mould (1982); Sandage (1986); Binney and Tremaine (1987). From a creationist perspective Steidl (1979) has briefly described populations as well.

The kinematic differences between the two populations are caused by their different orbits about the galactic center. Space velocities are actually velocities of stars relative to that of the sun. The low velocity or population I stars must then have orbits similar to that of the sun. This suggests that the sun is a population I star, and that population I stars orbit the galactic center in roughly circular orbits confined to the galactic plane. On the other hand, high velocity, or population II, stars must have elliptical orbits that are highly inclined to the galactic plane, while population II stars are found throughout the halo.

There are other differences that Baade noted between the two stellar types. One was the amount of heavier elements present. Chemistry is very simple to astronomers: There is hydrogen, helium, and then there is everything else. Astronomers do, of course, note the complex chemical makeup of interstellar gases and molecules. For stars, however, a gross view may be taken using X, Y, and Z, where X stands for hydrogen abundance, Y for helium abundance, and Z for the abundance of elements above helium. Since many of the other elements are metals, all of these other elements are collectively called "metals," even though some, such as carbon, nitrogen, and oxygen, are not actually metals. The metalicity, Z, is the fraction of mass that is comprised of the metals. Most of the universe and the stars in it are primarily made of hydrogen and helium, with only a few percent of metals. Generally the abundances of the heavier elements increase in about the same proportions to one another, so the measurement of a few elements is sufficient to estimate the abundances of all.

The metalicity can be measured from spectra, but it can be determined more easily and efficiently by using Stromgren (intermediate band) photometry. A good discussion of this technique can be found in Henden and Kaitchuck (1982). Photometry is the precise measurement of star light, and is usually accomplished by using a photosensitive detector with colored filters on a telescope. Each filter has a certain wavelength interval, called the band pass, through which light is transmitted to the detector. The band passes are carefully selected to measure particular spectral features. For example, in the spectra of most stars the near ultraviolet contains numerous absorption lines due to metals. This causes the spectrum to be depressed there, leading to the phenomenon called line blanketing. One of the four filters of the Stromgren system is in this part of the spectrum (the u filter), while a second nearby filter in the violet part of the spectrum (the v filter) does not suffer from line blanketing. The difference in the brightness in the u and v filters is therefore a measurement of the amount of line blanketing present. This measurement also depends upon the stellar temperature, but the temperature can be independently measured by using the two other filters, which are in the blue and yellow (the b and y filters). All of these measurements can be combined in various ways to form several indices, one of which is a metal index. The metal index has been well calibrated with the amount of metals determined from detailed study of stellar spectra. Such studies show that population II stars have a low metal abundance, while population I stars have a high metal abundance. The difference in metalicity between the most metal rich and the most metal poor stars is on the order of about 100.

There is also a difference in the H-R diagrams of typical population I and population II stars as well. Population I stars have an H-R diagram similar to those for open star clusters, while the H-R diagram of population II stars resembles that of globular clusters. More specifically, upper main sequence stars are not found among population II stars, while though they are rare among population I stars, they are among the brightest population I stars. Kinematic and chemical abundance studies of clusters show that the other properties of the two stellar populations are shared with the two types of star clusters. Globular clusters have low metalicity and are found in the halo, and so are considered to be population II. Open star clusters have high metal abundances and are found near the galactic plane, and so are recognized as population I.

Population I stars generally have clouds of dust and gas around and near them, while population II stars generally are found in dust free and gas free environments. This last characteristic is not independent of the others in that most of the gas and dust in the galaxy is found near the galactic plane.

Baade (1944) was working with the most extreme examples of stellar populations, and so it is not surprising that many stars are found somewhere in between the population classifications. It is now recognized that the stellar populations represent a continuum in properties, rather than two distinct bins. Extreme, or halo, population II stars are found high in the halo, possess high velocities, and are very low in metals. Intermediate population II stars are found closer to the galactic plane, have smaller space velocites, and are even higher in metalicity. Old population I stars (in which the sun is included) are found very close to the galactic plane and have high metalicity. Extreme population I stars are the highest in metals and are found in the galactic plane. Extreme population I stars have space velocities that are slightly less than older population I stars. Generally population I stars have a very patchy distribution, being found along the spiral arms in the galactic plane. On the other hand population II stars are found to have a very smooth distribution.

The Evolutionary Explanation for the Stellar Populations

Most current cosmological theories are predicated upon the assumption that the universe began with only the elements hydrogen and helium. All other elements are assumed to have been synthesized in the cores of stars. Certain isotopes up to iron can be synthesized by successive alpha capture by nuclei that results in an energy source for stars. Other isotopes, especially those more massive than iron can be produced by the slow or rapid neutron capture processes. The heavier elements particularly can be synthesized in violent processes such as supernova explosions. Most nucleosynthesis occurs in or around cores of stars, and since convection is usually not present throughout stars, heavier elements that are synthesized remain deep in stellar interiors. Therefore the composition determined from spectral analysis or inferred from photometric measurements must reflect the initial composition of stars.

The cosmology popular today supposes that early in the universe large clouds of gas began to form. These clouds were millions of light years across and slowly condensed to form galaxies. It is recognized that a perfectly smooth Big Bang cannot give rise to these structures, so it has been hypothesized that the early universe contained small inhomogeneities that acted as gravitational seeds to produce the structure in the universe that we see today. The purpose of the COBE satellite has been to look for these inhomogeneities as temperature variations in the background radiation. However, the very subtle and questionable variations recently announced from COBE measurements are far less than had been predicted. Let us set this difficulty aside, and grant that somehow these large clouds, usually termed proto-galaxies, did form. As the Milky Way protogalaxy collapsed, it would have assumed a roughly spherical shape, and parts of the cloud would have subfragmented, and in some locations the density would have increased so that the very first stars would have formed. The process of star formation would have continued as the galaxy collapsed, with most of the leftover gas flattening into a plane. Today virtually all of the remaining gas is confined to the plane. Early in the galaxy's history star formation would have occurred anywhere in the original sphere of gas, but in later times star formation would have only occurred near or in the disk. Since the collisional cross sections of stars are so tremendously small compared to the size of the galaxy, stars would generally continue to follow the orbit about the galactic center that they possessed when they formed.

The first stars to form would consist entirely of hydrogen and helium, with heavier elements being produced in their cores. The more massive stars among the first generation would quickly end their life cycles and explode in violent supernovae that would spew the heavier elements that they synthesized into the gas then present in the galaxy. This would cause the next generation of stars to have a higher metal content. The more massive stars of each generation would repeat the process of synthesizing heavier elements in their cores and then spreading their material into the interstellar medium. Such a process is referred to as chemical enrichment and would cause a gradual increase in the metal content as stars form progressively later.

All together, this theory suggests that the oldest stars generally should be found far from the galactic plane, though a few will be found near the plane if they are in the portion of their orbits where they cross the plane. Such stars would also be expected to be low in metalicity. The youngest stars should be in the galactic plane and have the highest metalicity. There should be stars of intermediate age with intermediate metalicities and locations in the galaxy. Thus the extreme population II stars are identified as the oldest stars while extreme population I stars are the youngest. The differences in the H-R diagram between the two populations discussed earlier are also reflected in the differences of supposed ages as discussed in the previous paper of Faulkner and DeYoung. The properties of the two populations are reiterated in Table I.

Since current cosmological theories demand that the universe began with a composition entirely of hydrogen and helium, it is believed that the very first generation of stars should have had no metals. Such a primordial generation has been dubbed population III, and a vigorous but unsuccessful search for these stars has been conducted. Even though the most extreme population II stars have only one percent of the metal content of population I, the fact that all stars have some metalicity is somewhat embarrassing for the standard theory. There have been several suggested explanations. One is that the Big Bang produced some of the heavier elements, so that even the earliest stars contained some metals. Another is that there was a brief intense period of star formation just before the collapse of the galaxy. These stars are supposed to have been massive, which would have caused them to have synthesized the elements and seeded the interstellar medium very rapidly. Because of the short lifetimes of massive stars, this primordial generation would no longer exist. How or why such a primordial generation would have formed is not known.

Table I. Properties of the Two Stellar Populations.

Property	Population I	Population II
Space velocity	low	high
Location	disk	halo
Metalicity	high	low
Color	blue	red
Dust	yes	no
Supposed age	young	old

Conclusion

The current theories of stellar and galactic evolution can qualitatively explain the differences between the two population types. This agreement has been put forth as evidence of the correctness of the theory. This topic has not been discussed in the creationist literature until now, and it is hoped that this paper will spark interest and discussion of it. The observed differences between the two types is important information that must be considered in developing a comprehensive stellar theory. The evolutionary theory qualitatively explains the types in a plausible and natural way. A creationist alternative must be able to do as good a job in explaining the differences. To that end it is hoped that the previous paper of Faulkner and DeYoung and this paper have provided useful information and direction. The author encourages correspondence with interested parties.

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