[sci.astro] Stars (Astronomy Frequently Asked Questions) (7/9)

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Subject: Introduction

sci.astro is a newsgroup devoted to the discussion of the science of astronomy. As such its content ranges from the Earth to the farthest reaches of the Universe.

However, certain questions tend to appear fairly regularly. This document attempts to summarize answers to these questions.

This document is posted on the first and third Wednesdays of each month to the newsgroup sci.astro. It is available via anonymous ftp from <URL:ftp://rtfm.mit.edu/pub/usenet/news.answers/astronomy/faq/>, and it is on the World Wide Web at <URL:http://sciastro.astronomy.net/> and <URL:http://www.faqs.org/faqs/astronomy/faq/>. A partial list of worldwide mirrors (both ftp and Web) is maintained at <URL:http://sciastro.astronomy.net/mirrors.html>. (As a general note, many other FAQs are also available from <URL:ftp://rtfm.mit.edu/pub/usenet/news.answers/>.)

Questions/comments/flames should be directed to the FAQ maintainer, Joseph Lazio (jlazio@patriot.net).

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Subject: G.00 Stars

[Dates in brackets are last edit.]

For an overall sense of scale when talking about stars, see the Atlas of the Universe, <URL:http://anzwers.org/free/universe/>.

Subject: G.01.1 What are all those different kinds of stars?
General overview and main sequence stars
Author: Steve Willner <swillner@cfa.harvard.edu>,
Ken Croswell

There are lots of different ways to classify stars. The most important single property of a star is its mass, but alas, stellar masses for most stars are very hard to measure directly. Instead stars are classified by things that are easier to measure, even though they are less fundamental.

There are three separate classification criteria commonly used: surface temperature, surface gravity, and heavy element abundance. The familiar "spectral sequence" OBAFGKM is a _temperature_ sequence from the hottest to the coolest stars. Strictly speaking, the letters describe the appearance of a star's spectrum, but because most stars are made out of the same stuff, temperature has the biggest effect on the spectrum. O stars are hotter than 30000 K and show ionized helium in their spectra. M stars are cooler than 4000 K and show molecular bands of TiO. Others are in between.

The ordinary spectral classes are divided into subclasses denoted by numbers; thus G5 is a medium temperature star a little cooler than G2.

The Sun is generally considered a G2 star. Not all the subclasses are used, or at least generally accepted; G3 and G4 are absent, for example.

For historical reasons, hotter stars are said to have "earlier" spectral types, and cool stars to have "later" spectral types. An "early A" star might mean somewhere between A0 and A3, while "late A" might denote roughly A5−−A8. Or "early type stars" might mean everything from O through A or F. There's nothing terribly wrong with this bit of jargon, but it can be confusing if you haven't seen it before.

There are several spectral types that don't fit the scheme above. One reason is abnormal composition. For example, some stars are cool enough for molecules to form in their atmospheres. The most stable molecule at high temperatures is carbon monoxide. In most stars, oxygen is more abundant than carbon, and if the star is cool enough to form molecules, virtually all the carbon combines with oxygen. Leftover oxygen can form molecules like titanium oxide and vanadium oxide (neither of which is particularly abundant but both of which have prominent spectral bands at visible wavelengths), but no carbon−containing molecules other than CO can form. (This is only approximately true. Weak CN lines can often be seen, for example, and all kinds of stuff will show up if you look hard enough. This article just gives a summary of the big picture.) In a minority of stars, however, the situation is reversed, and there is no (or rather very little) oxygen to form molecules other than CO. These stars show lines of CH, CC, and CN, and they are called (not surprisingly!) "carbon stars." They are nowadays given spectral classifications of C(x,y) where x is a temperature index and y is related to heavy element abundance and surface gravity. These stars were formerly given "R" and "N" spectral types, and you occasionally still see those used. Roughly speaking, R stars have temperatures in the same range as K stars and N stars in the same range as M, though the correspondence is far from exact.

Another interesting group is the S stars. In these, the atmospheric carbon and oxygen abundances are nearly equal, and neither C nor O (or at least not much of either) is available to form other molecules. These stars show zirconium oxide and unusual metal lines such as barium.

There are other stars with unusual abundances: CH, CN, SC, and probably more. They are rare. There are also stars that are peculiar in one way or another and have spectral types followed by "p." The "Ap" stars are one popular class. And finally, some stars have extended atmospheres and show emission lines instead of the normal absorption lines. These get an "e" or "f."

The second major classification is by surface gravity, which is proportional to the stellar mass divided by radius squared. This is useful because spectra can measure the gas pressure in the part of the atmosphere where the spectral lines are formed; this pressure depends closely on surface gravity. But because surface gravity is related to stellar radius, it is also related to the stellar luminosity. Every unit of stellar surface area emits an amount of radiation that mostly depends on the temperature, and for a given temperature the total luminosity thus depends on surface area which is proportional to radius squared hence inversely proportional to surface gravity. The upshot of all this is that we have "dwarf" stars of relatively high surface gravity, small radius, and low luminosity, and "giant" stars of low surface gravity, large radius, and high luminosity _and their spectra look different_. In fact, many "luminosity classes" are identified in spectra. For normal stars, these are designated by Roman numerals and lower case letters following the spectral class in the order: Ia+, Ia, Iab, Ib, II, III, IV, V. Class I stars are also called "supergiants," class II "bright giants," class III "giants," class IV "subgiants," and class V either "dwarfs" or more commonly "main sequence stars." By the way, not all luminosity classes exist for every spectral type.

The importance of all this is that the luminosity classes are closely related to the evolution of the stars. Stars spend most of their lives burning hydrogen in their cores. For stars in this evolutionary stage, the surface temperature and radius, hence spectral type and luminosity class, are determined by stellar mass. If we draw a diagram of temperature or spectral type on one axis and luminosity class on the other and plot each star as a point in the correct position, we find nearly all stars fall very close to a single line; this line is called the "main sequence." (This kind of diagram is called a "Hertzsprung−Russell" or "H−R" diagram after two astronomers who were among the first to use it.) Stars at the low mass end of the main sequence are very cool (spectral type M) and are called "red dwarfs." This term is not very precise and may include K−type stars as well.

As stars age, they expand and cool off; stars in this stage of evolution account for the brighter luminosity classes mentioned above. If they happen to be cool, they are called "red giants" or perhaps "red supergiants." One interesting special case is for the hottest stars, spectral classes O and early B. Normally main sequence stars are hotter if they have more mass, but not once they reach such high temperatures. Instead more massive stars have larger radii but about the same surface temperature, so an O I star is likely more massive but no more evolved than an O V star. These stars are called "blue giants" or "blue supergiants."

After stars finally burn out their nuclear fuel, any of several thing can happen, depending mainly on their initial mass and perhaps on whether they had a nearby companion. Some stars explode and are entirely destroyed, but most leave remnants: white dwarfs, neutron stars, or black holes.

White dwarfs have high density because they are supported by "electron degeneracy pressure." This is a kind of pressure that arises from the Fermi exclusion principle in nuclear physics. A white dwarf has roughly the radius of the Earth but a mass close to that of the Sun. No white dwarf can have a mass greater than the "Chandrasekhar limit," about 1.4 solar masses. White dwarfs are given spectral type designations DA, DB, and DC according to the spectral lines seen. These lines represent the composition of just a thin layer on the star's surface, so the spectral classifications aren't terribly fundamental.

White dwarfs radiate solely by virtue of their stored heat. As they radiate, they cool off, eventually turning into "black dwarfs." Because their radii are so small, though, white dwarfs take billions of years to cool. There may be few or no black dwarfs in our galaxy simply there has not been time for many white dwarfs to cool off. Of course it's not obvious how one would detect black dwarfs if they exist.

Neutron stars are even more compact; the mass of the Sun in a radius of order only 10 km. These stars are supported by "neutron degeneracy pressure," in which Fermi exclusion acts on neutrons. Neutron stars have a maximum mass of around 2 solar masses, although the exact theoretical value depends on properties of the neutron that are not known terribly accurately. Because the radius is so small, these stars don't emit significant visible light from their surfaces. They may emit radio energy as pulsars.

Some properties of black holes are discussed elsewhere in the FAQ.

All types of "compact remnants," white dwarfs, neutron stars, and black holes, may emit energy from an accretion disk around them if a nearby companion is transferring mass to the compact remnant. The emission often comes out at X−ray and ultraviolet wavelengths.

The third classification is by composition and specifically by "heavy element abundance." In astronomy, "heavy elements" or "metals" refers to all elements heavier than helium. Since heavy elements are created in stars, stars formed later in the life of the galaxy have more heavy elements than found in older stars.

The term "subdwarf" or occasionally "luminosity class VI" refers to stars of low metallicity. Because they have so few metals, they look a little hotter than they "ought" to be for their masses or equivalently have lower luminosity than main sequence stars of the same color. Physically, these stars are burning hydrogen in their cores and are similar to main sequence stars except for the lower metallicities. Since all these stars are old, they are of low luminosity. Their higher luminosity counterparts no doubt existed but have long since evolved away, most of them presumably into some form of compact remnant.

The following material is adapted from Ken Croswell's book The Alchemy of the Heavens (Doubleday/Anchor, 1995) and is reprinted here with permission of the author.

The terms "Population I" and "Population II" originated with Baade, who in 1943 divided stars into these two broad groups. Today, we know the Galaxy is considerably more complicated, and we recognize four different stellar populations. To make a long story short, the modern populations are:

THIN DISK metal−rich, various ages
THICK DISK old and somewhat metal−poor
STELLAR HALO old and very metal−poor; home of the subdwarfs
BULGE old and metal−rich

To make a long story longer: as astronomers presently understand the Milky Way, every star falls into one of these four different stellar populations. The brightest is the thin−disk population, to which the Sun and 96 percent of its neighbors belong. Sirius, Vega, Rigel, Betelgeuse, and Alpha Centauri are all members. Stars in the thin disk come in a wide variety of ages, from newborn objects to stars that are 10 billion years old. As its name implies, the thin−disk population clings to the Galactic plane, with a typical member lying within a thousand light−years of it. Kinematically, the stars revolve around the Galaxy fast, having fairly circular orbits and small U, V, W velocities. (These are the intrinsic space velocities with respect to the average of nearby stars. Zero in all components means rotating around the center of the Galaxy at something like 220 km/s but no other motion.) Thin−disk stars are also metal−rich, like the Sun.

The second stellar population in the Galaxy is called the thick disk. It accounts for about 4 percent of all stars near the Sun. Arcturus is a likely member. The thick disk is old and forms a more distended system around the Galactic plane, with a typical star lying several thousand light−years above or below it. The stars have more elliptical orbits, higher U, V, W velocities, and metallicities around 25 percent of the Sun's.

The third stellar population is known as the halo. Halo stars are old and rare, accounting for only 0.1 to 0.2 percent of the stars near the Sun. Kapteyn's Star is the closest halo star to Earth. These stars make up a somewhat spherical system, so most members of the halo lie far above or far below the Galactic plane. Kinematically, halo stars as a group show little if any net rotation around the Galaxy, and a typical member therefore has a very negative V velocity. (This is a reflection of the Sun's motion around the Galactic center in the +V direction.) The halo stars often have extremely elliptical orbits; some of them may lie 100,000 light−years from the Galactic center at apogalacticon but venture within a few thousand at perigalacticon. Metallicities are even lower than in the thick disk, usually between 1 and 10 percent of the Sun's. Subdwarfs are members of this population.

The fourth and final stellar population is the bulge, which lies at the center of the Galaxy. Other galaxies have bulges too; some can be seen in edge−on spiral galaxies as the bump that extends above and below the galaxy's plane at the center. The Galactic bulge is old and metal−rich. Most of its stars lie within a few thousand light−years of the Galactic center, so few if any exist near the Sun. Consequently, the bulge is the least explored stellar population in the Milky Way.

References:

Ken Croswell, _The Alchemy of the Heavens_ (Doubleday/Anchor, 1995)
(See http://www.ccnet.com/~galaxy)

James B. Kaler, _Stars and their Spectra: an Introduction to the
Spectral Sequence (Cambridge U. Press, 1989)

Most any introductory astronomy book.

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Subject: G.01.2 What are all those different kinds of stars?
White Dwarfs How are white dwarfs classified? What
do the spectral types DA, DC, etc. mean?
Author: Mike Dworetsky <mmd@star.ucl.ac.uk>

The MK classification system for the vast majority of stars works remarkably well for one simple reason: most stars in the Galactic disk have surface chemical compositions that are broadly similar to each other and the Sun's composition. They are 71 percent hydrogen, 27 percent helium, and 2 percent "metals" (Li−−U). Thus, the differences in spectral line strengths that give rise to the familiar OBAFGKM sequence are due to their vast range in surface temperature. The MK system can also classify by absolute stellar brightness: the more subtle differences in the strengths of certain lines at various classes, caused by the different surface gravities of main sequence and supergiant stars, for example, are spoken of as luminosity criteria, because they depend on the size of the star (big stars radiate much more energy than small stars, but their atmospheres are much less dense).

The name "white dwarf" for these stars comes from the observed colors of the first examples discovered. They caught the attention of astronomers because they had large masses comparable to the Sun but were hot and very faint, hence extremely small and dense. We now know that there are a few "white dwarfs" that are actually cool enough to look red.

The first spectroscopic investigators of white dwarfs tried to fit them into a descriptive system parallel to the MK classes, using the letter D plus a suffix OBAFGK or M, with the letter C added for the cases when the spectra showed no lines (continuous spectra). The types were sometimes supplemented by cryptic abbreviations like "wk" for weak; "s" for sharp−lined, and so on.

When the spectra of white dwarfs were investigated in more detail, it proved impossible to categorize them neatly for one increasingly apparent reason: the surface compositions of white dwarfs varied enormously from star to star. Astronomers needed a new scheme to reflect this. In the revised classification scheme, white dwarf designations still start with the letter D to indicate dwarf or "degenerate" stellar structure. A second letter indicates the main spectral features visible: C for a continuous spectrum with no lines, A for Balmer lines of hydrogen with nothing else, B for He I (neutral helium) lines, O for He II with or without He I or H, Z for metal lines (often, strong Ca II lines are seen), and Q for atomic or molecular lines of carbon (C is used for continuous spectra; K for Karbon could be confused with the K stars; so try to think of Qarbon!).

These basic types can sometimes mix; DAQ stars are known, for example.

A further suffix can be added: P for magnetic stars with polarized light, H for magnetic stars that do not have polarized light, and V for variable. (There is a class of short−period pulsating white dwarfs, called ZZ Ceti stars.) There may be emission lines (E). And if an unusual star still defies classification, it goes into type X.

Finally, a number is appended that classifies the star according to its effective temperature based on formulae which use the observed colors: the number is 50400/T rounded to the nearest 0.5, i.e., the value of 50400/temperature, rounded. If white dwarfs with T much higher than 50,000 K are ever found, they could have the number 0 or 0.5 appended. The coolest designation is open−ended; there is a star classified as DC13, for example, which is actually rather red, not white.

Thus a hot white dwarf with neutral helium lines might be described as DB2.5; a cooler white dwarf with hydrogen lines, a magnetic field, polarized light, and a trace of carbon might be DAQP6.

This system can provide good summary descriptions of the vast majority of white dwarf stars. However, it is a definite move away from the original concept of spectral classification, because it requires photometry and polarimetry as well as visual inspection of a spectrum, in order to make an assignment. But most leading experts on the subject have agreed it was necessary to move in this direction.

Some references:
Sion, E.M., et al. 1983. Astrophys. J., 269, 253−−257
Greenstein, J. 1986. Astrophys. J., 304, 334−−355
Wesemael, F. et al. 1993. Publ. Astr. Soc. Pacif., 105, 761−−778

(Electronic versions of journal articles can be found on the WWW in postscript and pdf formats via the Astronomical Data Center and its mirrors in Europe, South America and Asia. Start from http://adswww.harvard.edu/ and locate the best mirror for your location.)

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Subject: G.01.3 What are all those different kinds of stars?
Neutron Stars
Author: Joseph Lazio <jlazio@patriot.net>

Neutron stars are the remnants of massive stars. Sufficiently massive stars form iron in their cores during the process of nuclear fusion. Iron proves problematic for the star, though, as iron is among the most tightly bound nuclei. Nuclear fusion involving iron actually requires energy to occur, as opposed to nuclear fusion involving lighter nuclei in which the fusion produces energy. At some point so much iron accumulates in the core of the star that its nuclear reactions do not produce enough heat (i.e., pressure) to counter−balance the force of gravity due to the star's mass. The star implodes in a supernova, blowing off much of its outer layers and leaving an NS as a remnant. A star has to be (roughly) at least 8 times as massive as the Sun and not more than 25−−50 times as massive as the Sun to form an NS. (The upper limit is quite uncertain.)

(There has been a second mechanism postulated as a way to form neutron stars. There is an upper limit to the mass of a white dwarf, 1.4 times the mass of the Sun, called the Chandrasekhar limit after Subrahmanyan Chandrasekhar who first described it. Above this mass the force of gravity overwhelms the internal pressure provided by the electrons in the WD. If one had a WD that was quite close to the Chandrasekhar limit and a small amount of mass was added to it, it might collapse to form an NS. This process is called "accretion−induced collapse." It is not clear if this mechanism actually occurs, however.)

NSs can be divided into three broad classes, rotation−powered pulsars, accretion−powered pulsars, and magnetars.

Rotation−powered pulsars are the kind of pulsars most commonly described and were the first kind of NSs observed. These NSs have powerful magnetic fields and rotate. If the axes of the star's rotation and magnetic field are not aligned, this rotating magnetic field produces an electric field; in the case of NSs, the electric fields are strong enough to rip particles from the crust of the NS and accelerate them. The accelerated particles radiate. The magnetic field collimates the accelerated particles, so the radiation from the NS is emitted in two narrow beams. If one of the beams sweeps across the Earth, we observe a pulsating source−−−a pulsar. Most of the known rotation−powered pulsars are observed in the radio (though the radio emission itself is a usually just a tiny fraction of the rotation energy of the NS).

Rotation−powered pulsars are often further sub−divided into strong−field and recycled pulsars. Strong−field pulsars have magnetic fields of about 10^8 Tesla and observed pulse periods about 1 second. As the pulsars lose energy, their rates of spin slow down. At some point, the rotating magnetic field is no longer produces electric fields strong enough to power the pulsar mechanism, and the pulsar "shuts off." However, if the NS is a member of a binary system, its companion star, during the course of its own evolution, increase in size and start spilling matter onto the NS. As the matter spills onto the NS, if it hits the NS in the same direction that the NS is rotating, it can increase the rate at which the NS is spinning or "spin−up" the NS. If this spin−up process goes on for a long enough period of time, the NS may "turn on" as a pulsar again. The process of matter spilling onto the pulsar tends to suppress the magnetic field, though. With a weaker magnetic field, the spun−up pulsar doesn't spin down as fast as before. So, these recycled pulsars are distinguished by having very slow spin−down rates. As it turns out, they also tend to have very short pulse periods, typically less than 0.1 seconds, with the shortest being 0.00156 seconds.

Accretion−powered pulsars are NSs onto which matter is spilling. The gravity well around an NS is so deep, it is actually fairly difficult for matter to fall onto the NS. Only matter that starts at rest with respect to the NS can fall directly onto its surface. If the matter has any velocity relative to the NS, as it falls toward the NS, it will begin to orbit the NS. (This is the same principle that causes a skater to spin faster as she pulls in her arms.) If a lot of matter is falling toward the NS, a disk is formed around the NS. Due to "frictional" forces within the disk, matter slowly works its way closer to the NS until finally falling a short distance onto its surface. The process of the matter falling onto the NS' surface is known as accretion, so the disk is called an accretion disk. The gravitational potential of a NS is so deep that a lot of energy can be released as the matter forms an accretion disk and spills onto the NS' surface. Consequently, accretion−powered NSs are typically seen as X−ray sources.

Magnetars are a recently recognized class of NSs. It is thought that rotation−powered pulsars only work if the magnetic field is not too strong. If the magnetic field is too strong, it can effectively shut down the process by which the particles are produced. The critical field seems to be about 10^10 Tesla. Only a few examples of magnetars are known. These generally appear as fairly constant X−ray sources, though magnetars have also been suggested to be responsible for sources known as soft−gamma ray repeaters.

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Subject: G.01.4 What are all those different kinds of stars?
Black Holes
Author: Joseph Lazio <jlazio@patriot.net>

A black hole is any object for which its entire mass M is contained within a radius

$$R = \frac{2GM}{c^2}$$

where G is the universal gravitation constant ($G = 6.67 \times 10^{-11}$ $m^3/kg/s^2$) and c is the speed of light. An object this compact will have an escape velocity larger than light so nothing can escape from it. (For an object with the mass of the Sun, this radius is 3 km.)

BHs can be divided into (at least) three classes: primordial, stellar−mass, and supermassive. Primordial BHs, if they exist, were formed during the initial instants of the Big Bang. The initial Universe was not perfectly smooth, there were slight fluctuations in its density. Some of these density fluctuations could have satisfied the above criterion. In that case, BHs would have formed. These primordial BHs could have a range of masses, anywhere from milligrams to 10^{17} times the mass of the Sun. Currently, however, there is little evidence to suggest that any primordial BHs did form. (In fact, the available evidence suggests that no primordial BHs formed.)

Stellar−mass BHs are those with masses of roughly 10 times the mass of the Sun. These are formed from processes involving one or a few stars. For instance, a star more massive than 50 solar masses will also start to form a iron core. Unlike a less massive star that forms an NS during the supernova, though, the iron core becomes so massive that it collapses to form a BH. Another possibility for the formation of a stellar−mass BH is the collision of two stars, such as might happen in the center of dense globular cluster of stars or two orbiting NSs. A Stellar−mass BH is identified typically when it is orbited by a lower mass star. Some of the material from the companion star may be stripped away from it and fall into the BH, producing copious amounts of radio and X−ray emission in the process.

Supermassive BHs are those with masses exceeding roughly 1 million times that of the Sun. These are found at the center of galaxies. It is not clear how these form, but it probably involves the accumulation of many smaller mass BHs, NSs, and perhaps interstellar gas during the formation of galaxies. Recent work shows a correlation between the mass of the central parts of galaxies and the mass of the central BH. This has led to some speculation at to whether the central BHs form first and "seed" the formation of galaxies or if there is a symbotic process in which the central BH and the galaxy are created simultaneously.

There have also been suggestions of "intermediate mass" BHs. These would be objects whose mass is roughly 100−−1000 times that of the Sun. The suggestions that such intermediate mass BHs might exist arise from X−ray observations of other galaxies showing strong X−ray sources not associated with the centers of the galaxies. Certain assumptions must be used in relating the X−ray brightness of the objects to their mass, though, so whether such intermediate mass BHs actually exist is still somewhat controversial.

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Subject: G.02 Are there any green stars?
Author: Paul Schlyter <pausch@electra.saaf.se>,
Steve Willner <swillner@cfa.harvard.edu>

The color vision of our eyes is a pretty complicated matter. The colors we perceive depend not only of the wavelength mix the eye receives at a perticular spot, but also on a number of other factors. For instance the brightness of the light received, the brightness and wavelength mix received simultaneously in other parts of the field of view (sometimes visible as "contrast effects"), and also the brightness/wavelength mix that the eye previously received (sometimes visible as afterimages).

One isolated star, viewed by an eye not subjected to other strong lights just before, and with very little other light sources in the field of view, will virtually never look green. But put the same star (which we can assume to appear white when viewed in isolation) close to another, reddish, star, and that same star may immediately look greenish, due to contrast effects (the eye tries to make the "average" color of the two stars appear white).

Also, stars generally have very weak colors. The only exception is perhaps those cool "carbon" stars with a very low temperature−−−they often look quite red, but still not as red as a stoplight. Very hot stars have a faint bluish tinge, but it's always faint−−−"blue" stars never get as intense in their colors as the reddest stars. Once the temperature of a star exceeds about 20,000 K, its temperature doesn't really matter to the perceived color (assuming blackbody radiation)−−−the star will appear to have the same blue−white color no matter whether the temperature is 20,000, 100,000 or a million degrees K.

Old novae in the "nebular" phase often look green. This is because they are surrounded by a shell of gas that emits spectral lines of doubly ionized oxygen (among other things). Although these object certainly look like green stars in a telescope−−−the gas shell cannot usually be resolved−−−the color isn't coming from a stellar photosphere.

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Subject: G.03 What are the biggest and smallest stars?
Author: Ken Croswell,
John E. Gizis <jeg@pistol.caltech.edu>

[Table reflects most recent distances from Hipparcos.]
The most luminous star within 10 light−years is Sirius.

The most luminous star within 20 light−years is Sirius.
The most luminous star within 30 light−years is Vega.
The most luminous star within 40 light−years is Arcturus.
The most luminous star within 50 light−years is Arcturus.
The most luminous star within 60 light−years is Arcturus.
The most luminous star within 70 light−years is Aldebaran.
The most luminous star within 80 light−years is still Aldebaran.
The most luminous star within 100 light−years is still...Aldebaran.
The most luminous star within 1000 light−years is Rigel.
 (Honorable mentions: Canopus, Hadar, gamma Velae, Antares, and
 Betelgeuse.)
The most luminous star within 2000 light−years is Rigel.
The most luminous star in the whole Galaxy is *drum roll, please*
 .... Cygnus OB2 number 12, with an absolute magnitude around −10.
 (also known as VI Cygni No 12).

A table listing the nearest stars (within 12 light years) may be found at http://www.ccnet.com/~galaxy/tab181.html. The faintest star within that distance is Giclas 51−15 with absolute visual magnitude 16.99 and spectral type M6.5.

Wielen et al. published the following as the local luminosity function (total number of stars within 20 parsecs = 65 lightyears). At the faint end (abs. magnitude >12) this table is bit out of date and the numbers are probably too high. Everything from abs. magnitude 9 to 18 is considered an M dwarf (shows TiO and other molecules) or a white dwarf.

abs. mag	Number
−1	1
0	4
1	14
2	24
3	43
4	78
5	108 Sun is here!
6	121
7	102
8	132
9	159
10	245
11	341
12	512
13	597
14	427
15	427
16	299
17	299
18	>16

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Subject: G.04 What fraction of stars are in multiple systems?
Author: John E. Gizis <jeg@pistol.caltech.edu>

According to the work of A. Duquennoy and M. Mayor, 57% of systems have two or more stars. They were working with a sample of F and G stars, i.e., stars like the Sun. It appears that for the coolest, low−luminosity stars (the M−dwarfs) there are fewer binaries. Fischer and Marcy found that only 42% of M−dwarfs are binaries. Neill Reid and I have used HST images to find that for the coolest stars in the Hyades cluster (absolute magnitude > 12, or mass < 0.3 solar masses) only 30% are binaries.

[There's also the tongue−in−cheek answer that three out of every two stars is in a binary. TJWL]

References:
Gizis, J. & Reid, I. Neill 1995, "Low−Mass Binaries in the Hyades,"
Astronomical Journal, v. 110, p. 1248

Subject: G.05 Where can I get stellar data (especially distances)?
Author: Steve Willner <swillner@cfa.harvard.edu>,
John Ladasky Jr. <ladasky@my−deja.com>

Two key sites for stellar data are the Astronomical Data Center, <URL:http://adc.gsfc.nasa.gov/adc.html>, and the CDS Service for Astronomical Catalogues, <URL:http://cdsweb.u−strasbg.fr/cats/Cats.htx>, both of which maintain large inventories of astronomical catalogs, including star catalogs. Another important site is SIMBAD, <URL:http://simbad.u−strasbg.fr/sim−fid.pl>, as one can use it to find alternate names for a star. (For instance, what is another name for the variable star V* V645 Cen?)

Distances in astronomy are always problematic, and it is important to keep in mind that all astronomical data have uncertainties. It is vital to understand what the uncertainties are. Moreover, if one is interested in constructing 3−D star maps, one should recognize that astronomical data are not stored in XYZ coordinates. Science−fiction writers and people who want to make 3−D maps of local space like them, but astronomers don't use them. Astronomers need polar coordinates (right ascension and declination) centered on Earth, so that they know where to point their telescopes.

Three useful sites for distance data are

* One large (3803 stars) compilation of nearby stars is the "Preliminary Version of the Third Catalogue of Nearby Stars," which aims to catalog all known stars within 25 pc (~ 75 light years) of the Sun. The "ReadMe" file for the catalog is at

<URL:ftp://adc.gsfc.nasa.gov/pub/adc/archives/catalogs/5/5070A/ReadMe>.

* The Internet Stellar Database <URL:http://www.stellar−database.com/> attempts to synthesize information about the nearest stars from various catalogs.

* Recent research on refining astronomical data for the nearby stars can be found at the Research Consortium on Nearby Stars (RECONS), <URL:http://tarkus.pha.jhu.edu/%7Ethenry/RECONS.html>.

(Note that these sites tend to focus on *nearby* stars−−−that's a result of the difficulty of obtaining accurate distances for distant stars.)

If an object is close enough to Earth to have a significant parallax (an apparent yearly wobble in the sky that results from the change in observing position of the Earth), then its distance can be determined by triangulation. With two angles and a distance, you can compute Cartesian coordinates if you want them. If you'd like to use the astronomical data, say, to calculate distances between stars, a useful reference is <URL:http://www.projectrho.com/starmap.html>. (Note that many astronomical catalogs do not include parallax measurements.)

The best parallax data collected thus far comes from the European astrometry satellite, Hipparcos, <URL:http://astro.estec.esa.nl/Hipparcos/>, and it represents a gigantic improvement both in systematic accuracy and in precision over previous catalogs, but it is limited to fairly bright stars (magnitude limit around 11).

Both the CDS and the Hipparcos Web site offer online tools for searching the Hipparcos catalog as well as the full catalog itself. Two important aspects of the Hipparcos catalog are how distances are described and the names given to stars. First, distances are described by the parallax in milliarcseconds. The distance d in parsecs is given by d = 1000/p for a parallax p in milliarcseconds. To obtain a distance in light years, multiply by 3.26. Thus, a star with a parallax of 100 milliarcseconds is at a distance of 10 pc (~ 30 light years).

Second, all of the Hipparcos catalog "names" will be unfamiliar to you, as they are just numbers. One can use SIMBAD to convert from Hipparcos catalog names to more familiar names.

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Subject: G.06 Which nearby stars might become supernovae?
Author: Steve Willner <swillner@cfa.harvard.edu>

Obvious candidates are alpha Orionis (Betelgeuse, M1−2 Ia−Iab), alpha Scorpii (Antares, M1.5 Iab−Ib), and alpha Herculis (Rasalgethi, M5

Ib−II). Spectral types come from the Bright Star Catalog. Although trigonometric parallaxes are listed in the catalog, they will not be very accurate for stars this far away. I derive photometric distances of around 400 light years for the first two and 600 light years for alpha Her. (Anybody have better sources, or do we have to wait for Hipparcos?) Anybody want to suggest more?

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Subject: G.07 What will happen on Earth if a nearby star explodes?

A nice article by Michael Richmond <mwrsps@rit.edu> may be found at <URL:http://a188−L009.rit.edu/richmond/answers/snrisks.txt>. His conclusion is:

"I suspect that a type II explosion must be within a few parsecs of the Earth, certainly less than 10 pc, to pose a danger to life on Earth. I suspect that a type Ia explosion, due to the larger amount of high−energy radiation, could be several times farther away. My guess is that the X−ray and gamma−ray radiation are the most important at large distances."

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Subject: G.08 How are stars named? Can I name/buy one?
Author: Kevin D. Conod <kdconod@delphi.com>

Official names for celestial objects are assigned by the International Astronomical Union. Procedures vary depending on the type of object. Often there is a system for assigning temporary designations as soon as possible after an object is discovered and later on a permanent name. See E.05 of this FAQ.

Some commercial companies purport to allow you to name a star. Typically they send you a nice certificate and a piece of a star atlas showing "your" star. The following statement on star naming was approved by the IPS Council June 30, 1988.

> The International Planetarium Society's Guidelines on Star Naming
>
> SELLING STAR NAMES
>
> The star names recognized and used by scientists are those that have been published by astronomers at credible scientific institutions. The International Astronomical Union, the worldwide federation of astronomical societies, accepts and uses _only_ those names. Such names are never sold.
>
> Private groups in business to make money may claim to "name a star for you or a loved one, providing the perfect gift for many occasions." One organization offers to register that name in a Geneva, Switzerland,

vault and to place that name in their beautiful copyrighted catalog. However official−sounding this procedure may seem, the name and the catalog are not recognized or used by any scientific institution. Further, the official−looking star charts that commonly accompany a "purchased star name" are the Becvar charts excerpted from the _Atlas Coeli 1950.0_. [Other star atlases such as _Atlas Borealis_ may be used instead.] While these are legitimate charts, published by Sky Publishing Corporation, they have been modified by the private "star name" business unofficially. Unfortunately, there are instances of news media describing the purchase of a star name, apparently not realizing that they are promoting a money−making business only and not science. Advertisements and media promotion both seem to increase during holiday periods.

Planetariums and museums occasionally "sell" stars as a way to raise funds for their non−profit institutions. Normally these institutions are extremely careful to explain that they are not officially naming stars and that the "naming" done for a donation is for amusement only.

OFFICIAL STAR−NAMING PROCEDURES

Bright stars from first to third magnitude have proper names that have been in use for hundreds of years. Most of these names are Arabic. Examples are Betelgeuse, the bright orange star in the constellation Orion, and Dubhe, the second−magnitude star at the edge of the Big Dipper's cup (Ursa Major). A few proper star names are not Arabic. One is Polaris, the second−magnitude star at the end of the handle of the Little Dipper (Ursa Minor). Polaris also carries the popular name, the North Star.

A second system for naming bright stars was introduced in 1603 by J. Bayer of Bavaria. In his constellation atlas, Bayer assigned successive letters of the Greek alphabet to the brighter stars of each constellation. Each Bayer designation is the Greek letter with the genitive form of the constellation name. Thus Polaris is Alpha Ursae Minoris. Occasionally Bayer switched brightness order for serial order in assigning Greek letters. An example of this is Dubhe as Alpha Ursae Majoris, with each star along the Big Dipper from the cup to handle having the next Greek letter.

Faint stars are designated in different ways in catalogs prepared and used by astronomers. One is the _Bonner Durchmusterung_, compiled at Bonn Observatory starting in 1837. A third of a million stars to a faintness of ninth magnitude are listed by "BD numbers." The _Smithsonian Astrophysical Observatory (SAO) Catalog_, _The Yale Star Catalog_, and _The Henry Draper Catalog_ published by Harvard College Observatory all are widely used by astronomers. The Supernova of 1987 (Supernova 1987A), one of the major astronomical events of this century, was identified with the star named SK −69 202 in the very specialized catalog, the _Deep Objective Prism Survey of the Large Magellanic Cloud_, published by the Warner and Swasey Observatory.

These procedures and catalogs accepted by the International Astronomical Union are the only means by which stars receive long−lasting names. Be aware that no one can buy immortality for anyone in the form of a star name.

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Subject: Do other stars have planets?
Author: needed

Yes!

This is an active area of research, and since 1992 astronomers have found planets around two pulsars (PSR 1257+12 and 0329+54) and about a half−dozen main−sequence stars.

See
<URL:http://cannon.sfsu.edu/~gmarcy/planetsearch/planetsearch.html>,
<URL:http://www.obspm.fr/planets>,
<URL:http://techinfo.jpl.nasa.gov/WWW/ExNPS/HomePage.html>, and
<URL:http://ast.star.rl.ac.uk/darwin/> for more information.

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Subject: G.10 What happens to the planets when a planetary nebula is formed? Do they get flung out of the solar system?
Author: Joseph Lazio <jlazio@patriot.net>

A couple of possibilities exist. Prior to forming a planetary nebula, a low−mass star (i.e., one with a mass similar to that of the Sun) forms a red giant. Planets close to the star are engulfed in the expanding star, spiral inside it, and are destroyed. In our own solar system, Mercury and Venus are doomed.

As the star expands to form a red giant, it also starts losing mass. All stars lose mass. For instance, the Sun is losing mass. However, at the rate at which the Sun is currently losing mass, it would take over 1 trillion years (i.e., 100 times longer than the age of the Universe) for the Sun to disappear. When a star enters the red giant phase, the rate at which it loses mass can accelerate. The mass of a star determines how far a planet orbits from it. Thus, as the Sun loses mass, the orbits of the other planets will expand. The orbit of Mars will almost certainly expand faster than the Sun does, thus Mars will probably not suffer the same fate as Mercury and Venus. It is currently an open question as to whether the Earth will survive or be engulfed.

The orbits of planets farther out (Jupiter, Saturn, Uranus, Neptune, and Pluto) will also expand. However, they will not expand by much (less than double in size), so they will remain in orbit about the Sun forever, even after it has collapsed to form a white dwarf.

(Any planets around a high−mass star would be less lucky. A high−mass star loses a large fraction of its mass quickly in a massive explosion known as a supernova. So much mass is lost that the planets are no longer bound to the star, and they go flying off into space.)

As for the material in the planetary nebula, it will have little impact on the planets themselves. The outer layers of a red giant are extremely tenuous; by terrestrial standards they are a fairly decent vacuum!

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Subject: G.11 How far away is the farthest star?
Author: Joseph Lazio <jlazio@patriot.net>

This question can have a few answers.

1. The Milky Way galaxy is about 120,000 light years in diameter. We're about 25,000 light years from the center. Thus, the most distant stars that are still in Milky Way galaxy are about 95,000 light years away, on the opposite side of the center from us. Because of absorption by interstellar gas and dust, though, we cannot see any of these stars.

2. The most distant object known has a redshift of just over 5. That means that the light from this object started its journey toward us when the Universe was only 30% of its current age. The exact age of the Universe is not known, but is probably roughly 12 billion years. Thus, the light from this object left it when the Universe was a few billion years old. Its distance is roughly 25 billion light years.

3. Existing observations suggest that the Universe may be infinite in spatial extent. If so, then the farthest star would actually be infinitely far away!

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Subject: G.12 Do star maps (or galaxy maps) correct for the motions of the stars?
Author: Joseph Lazio <jlazio@patriot.net>

In general, no.

The reason is that stellar distances are so large. Over human time spans, the typical velocity of a star is so low that its distance does not change appreciably.

Let's consider a star with a velocity of 10 km/s, typical of most stars. In 1000 yrs, this star moves about 300 billion kilometers (or 3E11 km). Suppose the star is 100 light years (about 1E15 km or 1 quadrillion kilometers) distant. Thus, in 1000 yrs, the star moves about 0.03% of its distance from the Sun. This is such a small change, it's not worth worrying about it.

The situation is even more extreme in the case of galaxies. Typical galaxy velocities might be hundreds to thousands of kilometers per second. However, their distances are measured in the millions to billions of light years.

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Subject: Copyright