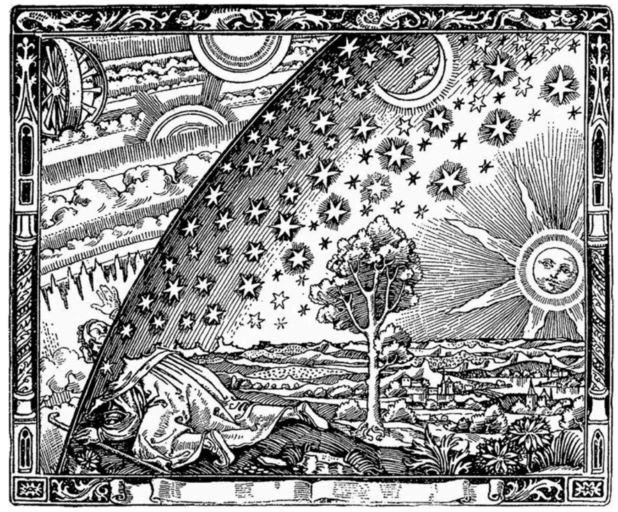
AD ASTRA PER EDUCARE

THE ASTRONOMY MAGAZINE OF NEW HAVEN SCHOOL



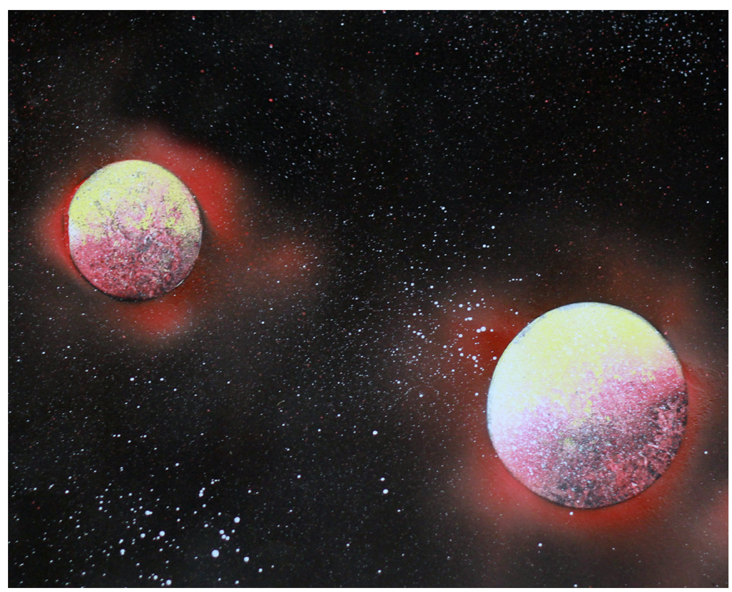
Vol. 2 No. 2 (August, 2021): The Nearby Stars and Exoplanets

I Have Loved the Stars

Editorial by David Black

My first planetarium software was an old black and white program that ran on a Macintosh Classic computer. I have tried to find a reference for it, but can't remember its name. As a physics teacher at Juab High School in the small farming town of Nephi, Utah I had access to a 10" reflecting telescope on a broken down equatorial mount with a burnt out motor. I set up a few evening star parties for students and used the old software to find the locations of the planets and interesting stars and nebulas. We had to move the scope by hand, but it worked all right.

While at Juab High School, as I was working through a unit on astrophysics I came up with a wild idea: to have students create a model of the nearby stars out to 15 light years. I had heard of Alpha Centauri (I grew up watching the original ***Lost in Space***) and had read enough science fiction to know that Tau Ceti and Epsilon Eridani were also nearby stars, but that was about the extent of my knowledge. It became a research quest of mine: to find a table of the nearby stars. I scoured my old college astronomy textbook and it had a table of the brightest stars, but not the closest, although it did list some of them such as Sirius. I looked in university libraries and began to piece a list together. Now this was 1993, and the Internet as we know it now was only beginning. In fact, Tim Berners-Lee developed the World Wide Web system with hypertext about that time, so research had to be done the old way, using the Dewey Decimal System and library index cards.



Twin exoplanets painted by Sammi using spray paint.

I finally put together a moderately complete list and developed my own lesson plan activity. Our first attempt used a large styrofoam ball in the center and the stars were beads glued on wooden skewers poked into the ball. Measuring the right ascension and declination was difficult, and the final model was not very accurate or complete. The next year my lesson improved – we hung the stars from the ceiling with black bulletin board paper behind and strips of tape for the Vernal Equinox and Celestial Equator, using a primitive sextant to get the

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angles and proportional spacing correct. We got the stars mostly hung before I realized we had them backwards, so we tore it down and started over. Right Ascension had to be measured to the left, it turned out. It was a great improvement, but the stars were various sized styrofoam balls and didn't hold up well with repeated use.

Over several decades of teaching and through different schools, I revived the nearby star model every time I taught astronomy. Finding a place to hang it was a challenge. I decided that it would be better to create a hanging platform that could be attached to eyebolts in the ceiling using painted wooden balls on black string and black fabric hung around the model. Much better! I wrote up my lesson plan and submitted it for publication to *The Science Teacher*, and it was accepted with considerable editing and appeared in the Summer 2014 edition. I even taught this lesson plan at the Jet Propulsion Laboratory through my role as the Educator Facilitator for the NASA Explorer Schools program. The original activity expanded into a complete unit on the nearby stars.

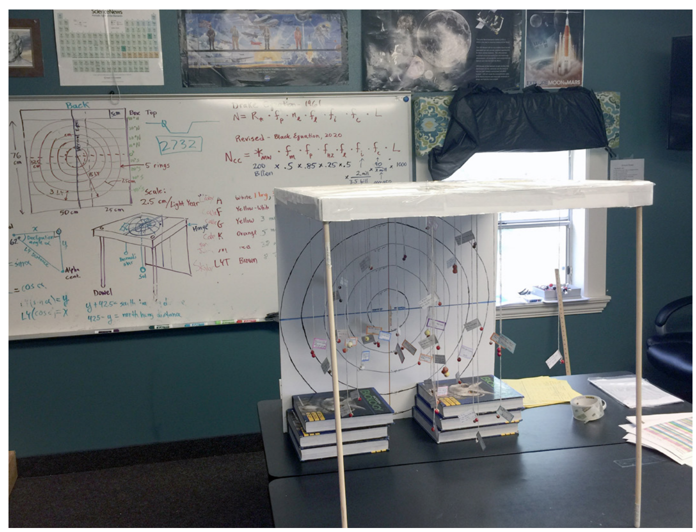
Students in my summer 2020 astrobiology class calculating the proportions for haning the stars in our 3D model of the nearby stars.

Meanwhile, this full-scale hanging platform model was too big to take on the road, so I designed and built my own tabletop model using foamcore as the hanging platform (now actually the lid of a box) and trigonometry to measure the lengths of the strings for the stars to make the final model more accurate. I took this model to several conferences and presented it, but over the years the tape yellowed and lost its adhesion and there were new stars (brown dwarfs) discovered. The positions of all the stars were more accurately measured by the Hipparcos and Gaia space probes, so that my model was falling apart and needed to be upgraded.

This past summer of 2020, my astrobiology class spent a week building a new tabletop model. We used the Wikipedia article on the nearby starts (so much easier than the first time) and teams created a spreadsheet to calculate the scale distances to hang the stars in the model using trig functions. They drew in scales on the model and calculated where to poke the holes in the top foamcore. Other teams measured the strings, or created the labels, or painted the wooden beads. Then teams of three students each came up and hung one star system at a time in the model, starting with Sol and moving outward. We used a scale of one light year equals 2.5 cm. Now I have the model stored in my room and use it for every astronomy class. This summer my astronomy students built scale 3D models of various constellations, which is an easier activity as I only have them hang the most prominent 6-8 stars.

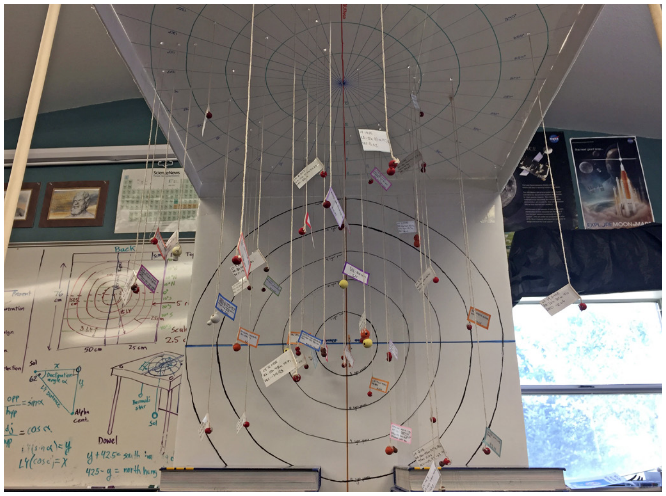
This quest to find out the names and positions of the nearby stars has served me well, as it has led to many opportunities to teach other teachers and students about the night sky. At the time I started this in 1993 no one was really talking about the nearby stars; then the first exoplanets were discovered such as Beta Pictoris b and the 55 Cancri system. Now it has become a hot topic. I have published other lesson plans for how to measure the distances to stars using parallax or my constellation in a box activity.

This third edition of ***Ad Astra*** will feature artices on the nearby stars and exoplanets, including basic information about the more interesting nearby stars as well as shorter articles on such topics as stellar coordinates and how stars are named. My astrobiology students last year wrote most of the articles that are included here. Where articles were not completed or the particular star system was not chosen by a student, I will fill in the gaps.



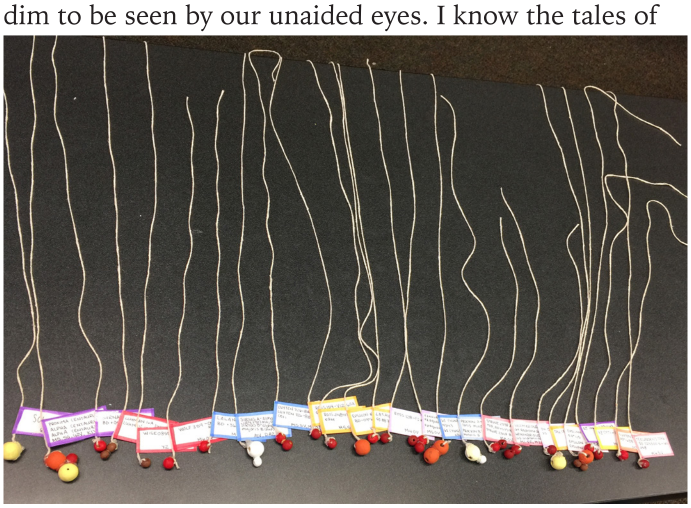
The completed tabletop model of the nearby stars out to 15 light years.

When, as teachers, we get the unavoidable question "Why do we have to learn this stuff?" my answer is always the same: the stars are out there, every night. Students might not be able to see them very well because of light pollution, but I grew up in a dark sky area a long



The completed 3D star model as seen from below.

way from any city in the west desert of Utah. The stars were my friends and I longed to visit them. It would be a shame to go through life without any knowledge of them or how they have influenced humanity from our fundamental mythologies to our current technologies. Ignorance is not bliss. Ignorance is weakness; those that don't know things can be easily controlled by those that do. I can't imagine going through life ignorant of the universe around me. One may say that having a knowledge of the stars detracts from their romance and mystery. On the contrary: the more I learn about the stars, the more fascinating they become. I can look at a star and say that I know exoplanets are orbiting it, some in the habitable zone. There could be life up there. I can say that we can't even see most of the stars (and they don't show up in planetarium software) because they are too small and dim to be seen by our unaided eyes. I know the tales of



The stars, ready to be hung in the model. About half the stars near us are in binary or trinary systems.

the constellations, the ancient myths behind history. I am at home among the stars. "Though my soul may set in darkness, it will rise in perfect light; I have loved the stars too fondly to be fearful of the night" (Sarah Williams, 1936, *The Old Astronomer to His Pupil*).

As a member of a choir at Brigham Young University, I learned the music to Robert Frost's poem "Choose Something Like a Star." The narrator of the poem expresses frustration at how taciturn the star is; it says nothing about what elements it blends, or at what temperature it burns. But Frost was wrong; as much as I like the poem, stars do tell us all about themselves. From their color and spectrum we can tell what elements they blend, what temperature they "burn" (technically fusion), how fast they move, even if they have invisible planets orbiting around them. We have learned to tease a great deal of information out of the light they emit. In the end, the poem comes to peace with the knowledge that the stars are steadfast friends, reliable and ever present, something we can count on. In this world of uncertainty, that means a great deal.

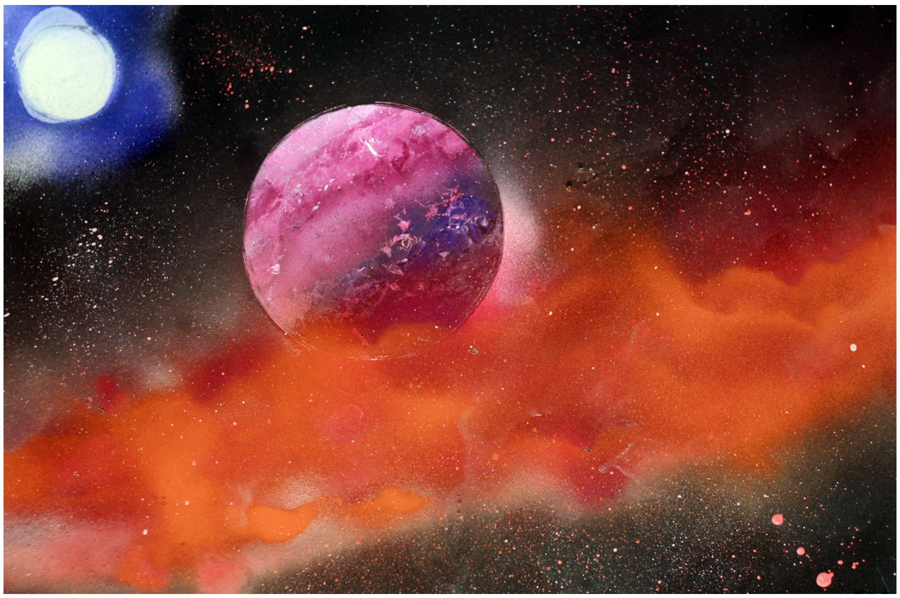
O Star (the fairest one in sight),
We grant your loftiness the right
To some obscurity of cloud—
It will not do to say of night,
Since dark is what brings out your light.
Some mystery becomes the proud.
But to be wholly taciturn
In your reserve is not allowed.
Say something to us we can learn
By heart and when alone repeat.
Say something! And it says, 'I burn.'
But say with what degree of heat.
Talk Fahrenheit, talk Centigrade.
Use language we can comprehend.
Tell us what elements you blend.
It gives us strangely little aid,
But does tell something in the end.
And steadfast as Keats' Eremite,
Not even stooping from its sphere,
It asks a little of us here.
It asks of us a certain height,
So when at times the mob is swayed
To carry praise or blame too far,
We may choose something like a star
To stay our minds on and be staid.

Robert Frost, 1916

Exoplanets and the Habitable Zone

Written by Julia W.

If there is life outside of our solar system, where would we find it? How do we know where to look? The answer relies on exoplanets. As of today, we know of over four thousand confirmed exoplanets. Exoplanets are planets that exist outside our solar system, orbiting stars outside our Sun. The first discovery of an exoplanet was in 1922; however, it was found orbiting a pulsar-- a highly magnetized neutron star, about the size of a small city, that rotates and emits bursts of electromagnetic radiation from its poles. This is unlike our own star, the Sun, which is sometimes called a yellow dwarf. The first exoplanet orbiting a star similar to our Sun was discovered much later, on October 6, 1995. This exoplanet is known as 51 Pegasi b, found orbiting a star in the constellation of Pegasus. It was a monumental discovery, in part due to 51 Pegasi b's size-- it has about half the mass of Jupiter. Now, we know that exoplanets are actually quite common-- NASA speculates that on average, there is at least one planet orbiting every star in the Milky Way. This means that it's possible there are near 200 billion planets in our galaxy alone. Even more fascinating, many of those planets are around Earth-size. Which begs the question-- could any of these planets support life?

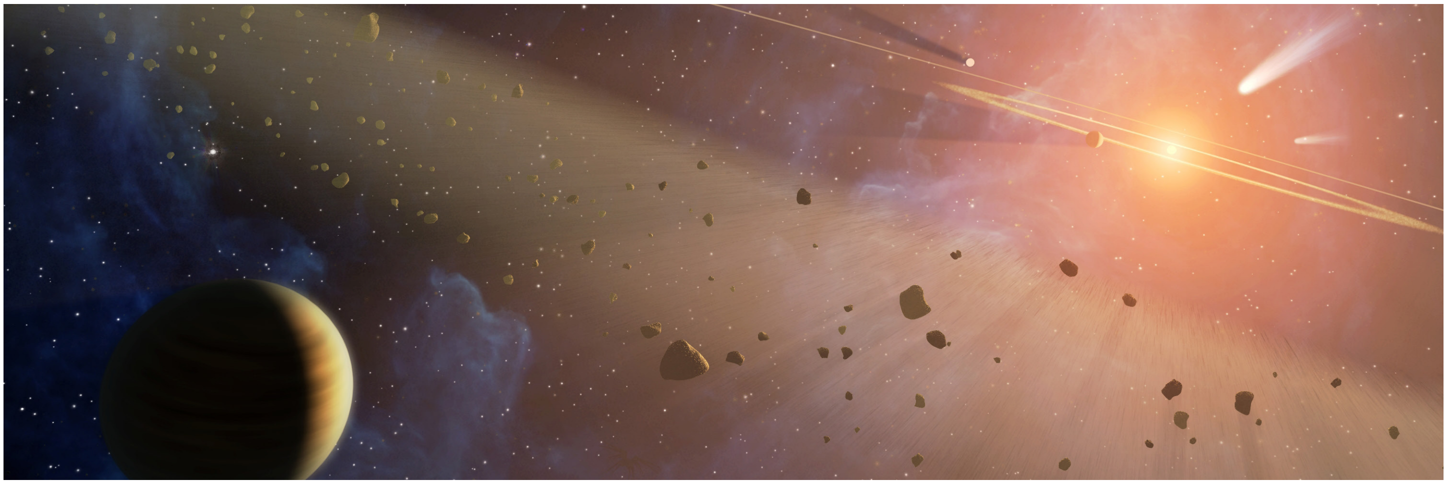


A student painting of exoplanets emerging from a nebula using spray paint.

It depends on where each exoplanet resides in its solar system. Planets that are most likely to support life exist in the habitable zones around their respective stars. The habitable zone is the range of orbits around a star in which a planet could support life. It is sometimes called the Goldilocks zone. Just as Goldilocks wanted pudding that was not too hot, and not too cold, the optimal distance from the star makes it not too hot, and not too cold, on said planet-- but just the right temperature for life to flourish. Where the habitable zone in each solar system is depends on the type of star at the center. Bigger, hotter stars have habitable zones much farther from them then cooler, more compact dwarf stars. The reason habitable planets would need to be in such a specific spot is for the presence of liquid water. Anywhere outside the habitable zone, water would either freeze or evaporate, depending on the planet's proximity to the star. On planets too close to their star, water would evaporate, whereas water would freeze on planets too far away from their star. Of course, this is based off of the assumption that liquid water is necessary for the existence of life-- which may not be true for all life in the universe. Even so, the presence of liquid water provides the best chance we have for finding life on other planets. All in all, terrestrial exoplanets no more than two times Earth size, holding liquid water, and found in the habitable zone of their solar systems, are the best place to search for extraterrestrial life.

However, it is not just the planet that matters. When searching for signs of life elsewhere in the galaxy, or even the universe, it is important to consider all of the variables. It took approximately 3.5 billion years for single-celled life on Earth to emerge, and it wasn't until roughly 600 million years ago that multicellular life came into existence. That was possible due to the size and brightness of the Sun. While the lifespan of our Sun is around ten billion years, those of bigger, brighter stars are much shorter. The biggest and brightest stars can have life spans as short as a few million years, not at all long enough to sustain the development of life, let alone intelligent life. When looking for a planet that life would be most likely to inhabit, the ideal star that said planet would be orbiting is one similar to ours.

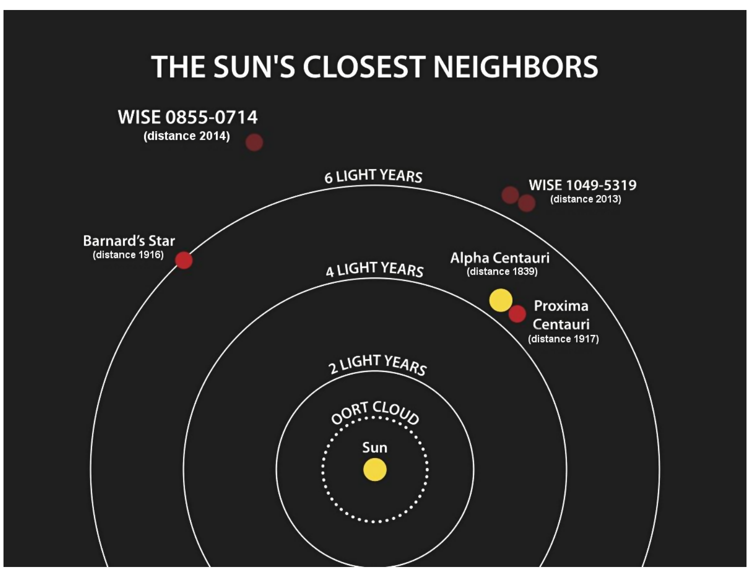
In November of 2013, astronomers reported that there may be as many as eleven billion Earth-like exoplanets orbiting stars similar to the Sun. These planets are light-years away from Earth, making them impossible for us to reach right now, but perhaps not forever. In a few hundred years, humans may have the technology to travel to other habitable planets in our galaxy and establish colonies there. This could possibly involve raising human embryos on an interstellar ship, or sending a group of volunteers into space, knowing that only their great grandchildren would actually see the planet to which they are headed. The possibilities are endless, and as technology advances, we as a species get one step closer to experiencing interstellar travel and inhabiting other planets. The stuff of science fiction might someday become reality. All in all, no matter what the future holds, the discovery of Earth-like exoplanets is a huge step forward-- for us and for generations to come.



The Nearby Stars

In my 2020 astrobiology class, each student chose two star systems to research and report on. For those stars not chosen or written about, I will fill in the gaps and also provide new details on the stars that were written about.

It is surprising how much new information has been found about these stars just in the past year since these articles were written. For example, a new candidate exoplanet in the habitable zone around Alpha Centauri A was reported just this February. Back when I started researching the nearby stars in the early 1990s, this was a somewhat moribund subject without much interest in the astronomy community since no exoplanets had yet been discovered. Now, everyone seems to be getting in on the planet hunting craze and new discoveries are occurring almost weekly. I first wrote a similar article for a project of my media design students back in 2000. So much more has been discovered in the intervening time that this article is now much longer, and far more accurate.



In addition to describing the star systems themselves, the students wrote sidebar articles on star characteristics such as coordinate systems, classification, naming systems, how we find the distances to them, and other

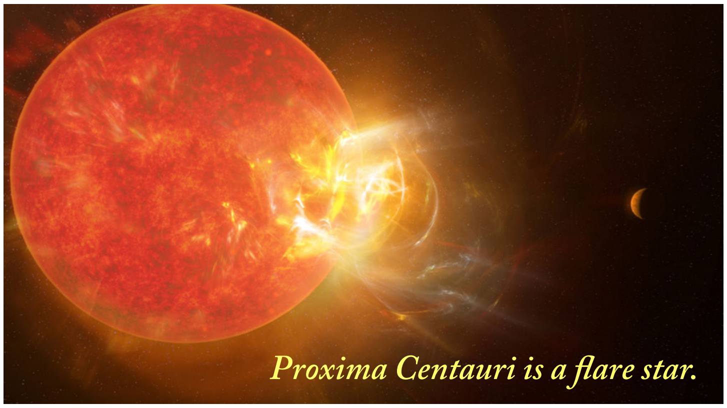
topics. I am including those along the sides of this main article.

The Alpha Centauri System: by Hannah T.

The Alpha Centauri triple star system is the closest star system to us, around 4.37 light years away in the far southern constellation of the Centaur. Alpha Centauri A and B are a pair, also known as AB, that orbit close to each other. Proxima Centauri orbits AB and is the closest known star to earth. The declination of Proxima is –62.68, its apparent magnitude is 11.09 and its absolute magnitude is 15.53.

Proxima Centauri is a small red dwarf star of spectral class M5.5V. It is exactly 4.244 light years away and the right ascension is 14h 29m 43s. This star was discovered by Robert T. A. Innes in 1915. Recently in 2016 an exoplanet was located in the habitable zone of Proxima Centauri using the radial velocity method. It is about the size of Earth but would be most likely tidally locked. Because Proxima is a flare star (V465 Centauri), it is unlikely for life to exist there. Proxima now has two confirmed planets. Proxima Cent c is a super-Earth or sub-Neptune planet seven times more massive than Earth and about 1.49 AU from Proxima. It is therefore too far away to be habitable. There may be a third, sub-Earth sized planet that has not yet been confirmed.

Alpha Centauri A, also known as Rigil Kentaurus ("the Foot of the Centaur") is the largest and brightest



Proxima Centauri is a flare star.

star of this triple star system. It is a spectral type G2V and is just larger and slightly brighter than the sun, with an apparent magnitude of .01 and an absolute magnitude of 4.38 (compared with 4.85 for the Sun). This is the third brightest star visible in the night sky and is 4.365 light years away. Alpha Centauri A has a right ascension of 14h 39m 36.5s and a declination of –60.83. The corona of a star is the aura of plasma surrounding it; Alpha Centauri A shows coronal variability because of star spots. A recent Feb. 2021 paper from the Breakthrough Watch Initiative used a direct imaging technique and found evidence for one planet orbiting around Rigel Kentaurus with a distance of about 1.1 astronomical units (AU or the Sun-Earth distance), putting the planet in the middle of the habitable zone. Called Candidate 1, its mass would be slightly larger than Neptune, so it would be a gas giant. It could have habitable moons. The observation was made using only 100 hours of observing time, so further observations are needed to confirm that this is a true planet and not a dust disk or observational artifact.

Alpha Centauri B, sometimes known as Toliman ("the ostrich"), is an orange dwarf star of spectral class K1V with a mass of .907 that of Sol. This star's apparent magnitude is 1.34, and its absolute magnitude is 5.71. A planet was proposed using radial velocity in 2012 but it has since been refuted as an artifact of data analysis; another candidate planet (Alpha Centauri Bc) was proposed in 2013 using transit data but has yet to be confirmed. It would be slightly smaller than Earth with a 20 day orbit, so not in the habitable zone.

As the closest star system to Earth, Alpha Centauri has figured prominently in science fiction. It was to be the destination of the Robinson family in the ***Lost in Space*** series and movie. The character Zephram Cochran, inventor of the warp drive in the ***Star Trek*** franchise, lived for a time in the Alpha Centauri system before going missing ("Metamorphosis"). Other episodes throughout the ***Star Trek*** universe mention Alpha Centauri. In ***Babylon 5***, an Earth colony is mentioned in the Proxima system and it is the site of a battle between ***Babylon 5*** forces and Earth during the civil war story arc. The planet Polyphemus in the ***Avatar*** movie series, orbited by the moon Pandora where the fictional mineral unobtanium is being mined, is located in the Alpha Centauri system. In literature, Alpha Centauri figures prominently in many science fiction novels including The ***Songs of Distant Earth*** by Arthur C. Clarke, ***Foundation and Earth*** by Isaac Asimov, ***Footfall*** by Larry Niven and Jerry Pournelle, ***Neuromancer*** by William Gibson, and ***The Three-Body Problem*** by Liu CiXin.

Barnard's Star:

The second closest star system to our sun was discovered by E. E. Barnard in 1916 as part of his proper motion studies. It has the fastest known proper motion of any star, at 10.3 arcseconds per year relative to our sun, making it a very close star. Using parallax with refinements by the Hipparcos and Gaia satellites, its distance has been measured at 5.96 light years. It is a small red dwarf with a mass 0.144 times the mass of our sun and a spectral type of M4.0V. It is located in the constellation Ophiucus at 17h 57m 48.5s right ascension and +04° 41m 36.2s declination. It can only be seen with a powerful telescope and has an apparent magnitude of 9.511.

For many years, Peter van de Kamp argued that Barnard's Star had at least one planet based on his astrometry measurements, which involved measuring the changes in the positions of stars on photographic plates as small as one micron. These arguments were largely refuted in the 1970s when it was shown that the perturbations seen in the plates corresponded to maintenance upgrades of the telescope's lens. However, in 2018 a candidate super-Earth was announced from the Red Dots project using highly precise measurements of radial velocity with data from the ESO HARPS (High Accuracy Radial velocity Planet Searcher) spectrograph and other instruments over a 20 year period. It is believed to have a minimum of 3.2 Earth masses and to orbit at 0.4 astronomical units and a period of 233 days, putting it beyond the habitable zone. This planet is also disputed, since star spots might produce a similar radial velocity shift. Barnard's Star is a flare star, as are most red dwarfs, making life on such a planet unlikely.

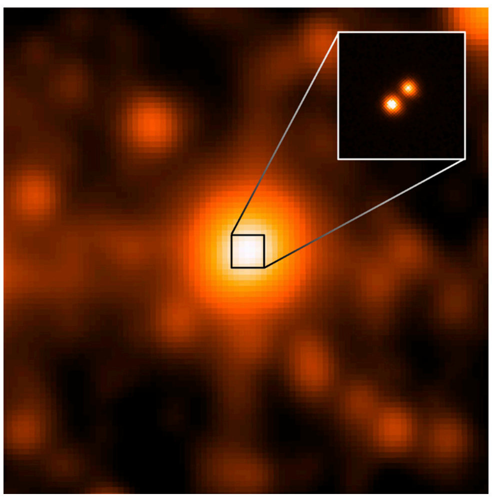
Based on its slow rotational speed and low metallicity, Barnard's Star is estimated to be between 7-12 billion years old, making it much older than the sun. A surprisingly large solar flare was detected in 1998, very unusual for such an old star. Smaller ultraviolet and x-ray flares were detected in 2019.

In the ***Hitchhiker's Guide to the Galaxy*** series by

Douglas Adams, Barnard's Star is said to be the location of an interstellar roundabout used by the Vogon Constructor Fleet. It is also a major part of the novels ***The Garden of Rama*** by Arthur C. Clarke and Gentry Lee and ***Hyperion*** by Dan Simmons.

Luhman 16 A and B: by Navah D.

Luhman 16 is a binary star system with both stars being brown dwarfs orbiting each other at about 3.5 astronomical units (the Earth-Sun distance) and an orbital period of 27 years. The system is actually located in the southern hemisphere in the constellation Vela and is approximately 6.503 light years away from the sun. This very unique star system is also known as WISE 1049-5319 because the stars can only be seen in infrared using data from the WISE telescope. Kevin Luhman, an astronomer with Pennsylvania State University, discovered the stars in 2013. Because they lie close to the galactic plane, where stars are crowded, they eluded discovery until then. They are the nearest known brown dwarfs to the solar system, and the closest system discovered since Barnard's star in 1916. These stars have not been around for a very long time; they are fairly young for stars at about 600-800 million years old.



For Luhman 16 A, the largest of the pair, is classified as an L8 star with .032 times the mass of our sun and 33.5 times the mass of Jupiter. It has a surface temperature of about 1400 K. Luhman 16 B is a T1 star with a mass of .027 Sols or 28.6 Jupiters. Both stars are located at RA 10h 49m 15.57s and declination of -53° 19m 06s. Luhman 16A is suspected of having a planet, Luhman 16Ab, measured through astrometry with the Hubble Space Telescope in 2013. That planet is now considered unlikely based on further measurements of the system.

WISE 0855-0714:

A sub-brown dwarf of classification Y4 in the constellation of Hydra, this smallest of all stars yet known was discovered by Kevin Luhman using data from the WISE infrared telescope in 2013. It is right at the border between planet and star, and would have only fused deuterium for a short time before starting to cool down. Its surface temperature is 225-260 K, making it about the same temperature as Mars and therefore the coldest known star, but also much too warm for it to be a rogue planet; it must have had an internal heat source suggestive of previous deuterium fusion. Yet it only has a mass of 3-10 times the mass of Jupiter, putting it into the planetary mass range. It is 7.43 light years away and has a high proper motion. There is some evidence from the Magellan Baade Telescope that it may have water clouds. If seen up close, it would have a purple to deep magenta color.

The aftermath of the Battle of Wolf 359.

Wolf 359:

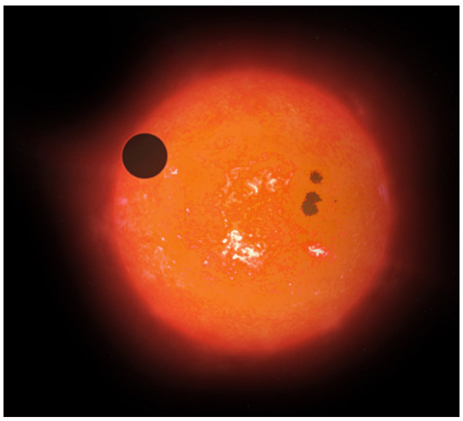
This small red dwarf is located exactly on the ecliptic in the southern part of Leo not far from the star Regulus. It is 7.9 light years away and has a classification of M6.5V and an apparent magnitude of 13.54; it can only be seen with a large telescope. It is far too dim to be seen with the unaided eye. Its surface or photosphere has a temperature of only 2800 K, about half the temperature of our sun. At this temperature, chemical compounds such as titanium (II) oxide and even water can exist in gaseous form. It has a stronger magnetic field than our sun due to the complete circulation of materials inside because of convection currents; as a result of this magnetic field, strong X-ray and gamma ray flares can sometimes be observed. It is less than a billion years old and hasn't had time for these flares to die out as its rotation slows. It is just barely large enough to sustain proton-proton fusion and be considered a red dwarf instead of a brown dwarf, having only 8% of the sun's mass. Because it is able to convect all of its material, it can sustain fusion for eight trillion years. It is just getting started.

Wolf 359 was the 359th star listed by German astronomer Max Wolf in his 1919 catalog. He was cataloguing stars with high proper motion, knowing they were nearby stars. It is known to have at least two planets. Wolf 359 c is a super-Earth with 3.8 Earth masses and near the star, with an orbital period of 2.7 days. It receives three times the energy that Earth does. Wolf 359 b (the first to be discovered) is a Neptune-class planet 44 times the mass of Earth with an orbital period of about 3000 days even though it is only about 2 astronomical units from the star. The low mass of the star allows the planet to have such a slow orbit.

Because of its proximity to Earth, Wolf 359 has been the subject of several important science fiction works.

Most notably, it was the site for a major battle between Federation forces and a Borg cube on its way to Sector 001 (Earth) to assimilate humanity. 40 starships engaged the Borg, but because Captain Picard had been assimilated, they knew all of his tactical knowledge and easily defeated the Federation. Someone in the ***Star Trek*** writers group did their homework and found that Wolf 359 was close to Earth and a likely site for such a battle. However, the Borg are supposed to originate from the Delta Quadrant on the opposite side of the galaxy from our position. Wolf 359 is in Leo, putting it further out from the galactic center than Earth; the Borg would have have had to take a very roundabout route to come at Earth from Leo. "Wolf 359" is also the title of an Outer Limits episode where a scientist creates a simulation of Dundee's Planet in the Wolf 359 system only to see a dangerous life form evolve. In the novel ***Chindi*** by Jack McDevitt, a lost spaceship is found in the Wolf 359 system.

Lalande 21185: by Sarah S.



Another red dwarf located in the southern corner of Ursa Major, this star is 8.31 light years from Earth. With an apparent magnitude of 7.5, it is somewhat brighter and hotter than Wolf 359 and may be as old as 10 billion years. It is also known as BD +36 2147, Gliese 411, and HD 95735. It was first listed in 1801 by Joseph-Jerome de Lalande and its proper motion was first measured by Friedrich Wilhelm Argelander for the Bonner Durchmusterung (BD) or Bonn Star Catalog. It has 38% the mass of Sol and a photospheric temperature of 3828 K. Although listed as a flare star, it is rather quiet as far as red dwarfs go.

Peter van de Kamp claimed in 1951 that Lalande 21185 had a planet based on astrometric measurements using the same photographic plates as for his Barnard's Star planet claim, but those plates were shown to be flawed. George Gatewood made his own astrometric measurements and claimed that there were multiple planets in the system, although his data remains unconfirmed. Using sensitive radial velocity measurements in the 1980s, Geoff Marcy could not find any planets in the system. However, recent measurements by the HIRES system at Keck Observatory supported there being at least one close in planet with a mass of at least 3.8 Earths and a period of 10 days. Further measurements with the SOPHIE echelle spectrograph showed this planet to have a period of 12.95 days and 2.99 Earth masses, which has been confirmed by other measurements. One other planet orbiting at 2806 days and with 14 Earth masses has also been confirmed, with a third planet suspected between them. Thus, van de Kamp and Gatewood's claims have been somewhat vindicated even if these are not the planets they claimed to have found.

In fiction Lalande 21185 is the star of the planet Ormazd in ***Rogue Queen*** by L. Sprague de Camp (1951) and is one of many nearby stars mentioned by Gregory Benford in ***Across the Sea of Suns*** (1983), where it is renamed Ra. In the ***Revelation Space*** stories by Alastair Reynolds, the planet Zion orbits Lalande 21185.

Sirius: by Katie T.

Sirius is the brightest star in the sky seen from earth. The name comes from the Greek word meaning glowing/scorching. Sirius is part of the Canis Majoris constellation, which is also called "The Greater Dog," and can therefore also be called Alpha Canis Majoris. The star lives up to its name; in ancient Greek times a myth was created. Sirius the star was so hot men would feel weaker, plants would fail to grow, and women would become very aroused. Whenever Sirius first made an appearance, it was known as the "Dog Days" to the Egyptians and signaled the beginning of the inundation of the Nile, the beginning of the their calendar year.

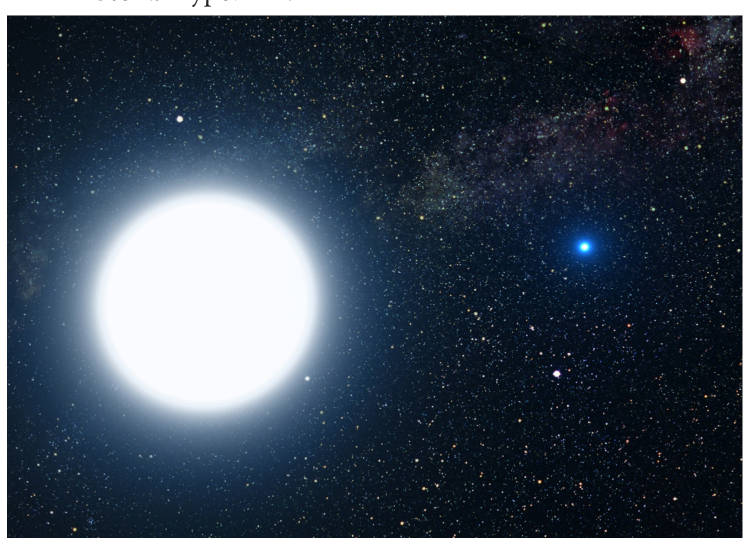
A German astronomer, Friedrich Wilhelm Bessel, predicted Sirius B in 1844. The star is part of a binary star system consisting of two stars orbiting each other, with Sirius B as the closest white dwarf to Earth. Bessel made the assumption there was another star, after observing the motion of Sirius A. Following the information provided by Bessel, an astronomer in 1862 discovered Sirius B (the Pup). Alvan Graham Clark was testing the aperture of the largest telescope in America and came across a smaller star orbiting around Sirius A.

You may not think it, but Sirius is even bigger and hotter than our sun. If you observe the sky on a clear day, you may even be able to catch a sighting of the brightest star, using just the naked eye.

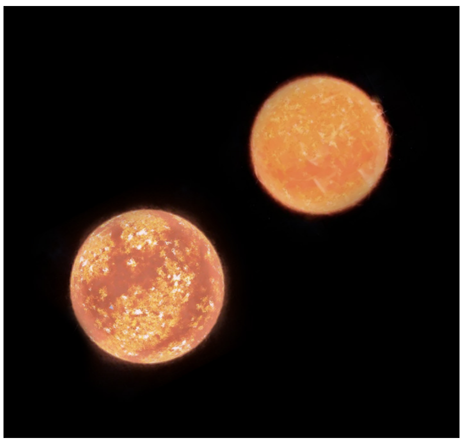
Coordinates: RA: 6h 45m 9s, Dec: -16° 42' 58", Distance: 8.6 light years

Apparent Magnitude: -1.46

Stellar Type: A1V



In fiction, Sirius Black is the name of the godfather of Harry Potter in the series of books by J. K. Rowling, first introduced in the third book, ***The Prisoner of Azkaban*** (although mentioned in the first book as the owner of the motorcycle being used by Hagrid in the first book). He is able to transform into a dog, of course, and he is killed by his cousin, Bellatrix LaStrange, who is also named after a star (meaning "Warrior Woman"). Sirius' brother is named Regulus Arcturus Black, a double star reference. In Homer's ***The Iliad***, Achilles is compared with the brilliance of Sirius. Voltaire's Micromegas describes an alien from a planet orbiting Sirius. In the ***Foundation*** series and the novel ***Pebble in the Sky*** by Isaac Asimov, Earth is considered to be somewhere in the "Sirius Sector." Much of the technology mentioned in Douglas Adam's ***Hitchhiker's Guide to the Galaxy*** series is made by the Sirius Cybernetics Cooperation.



Luyten 726-8:

A binary red dwarf system in the constellation Cetus, it is also known as UV Ceti or Gliese 65. They are 8.7 light years away and considered as prototypes of UV flare stars. They were discovered by Willem Jacob Luyten in 1948, have almost equal brightness and orbit each other every 26.5 years. They may be part of the Hyades open star cluster.

Ross 154:

Another small red dwarf single star located in Sagittarius, it was discovered by Frank Elmore Ross in 1925 as part of his lists of new variable stars and stars with high proper motion. It is a UV Ceti type flare star, with a variable star designation of V1216 Sagittarii and average time between ultraviolet flares of about two days. Using highly precise data from the HARPS spectrograph during the Red Dots campaign, Ross 154 is shown to have a rapid rotation of 2.87 days, which corresponds to a young age of less than one billion years. This was the third star, including Proxima Centauri and Barnard's Star, that was studied in the 2017 Red Dots study. It is of spectral type M3.5Ve and is 9.7 light years distant. It is not known to have any planets, but detecting planets is a challenge because of its rapid rotation and active surface, which produce a great deal of noise in the radial velocity data. In fiction, it is the site of Glory Station in C. J. Cherryh's ***Downbelow Station***.

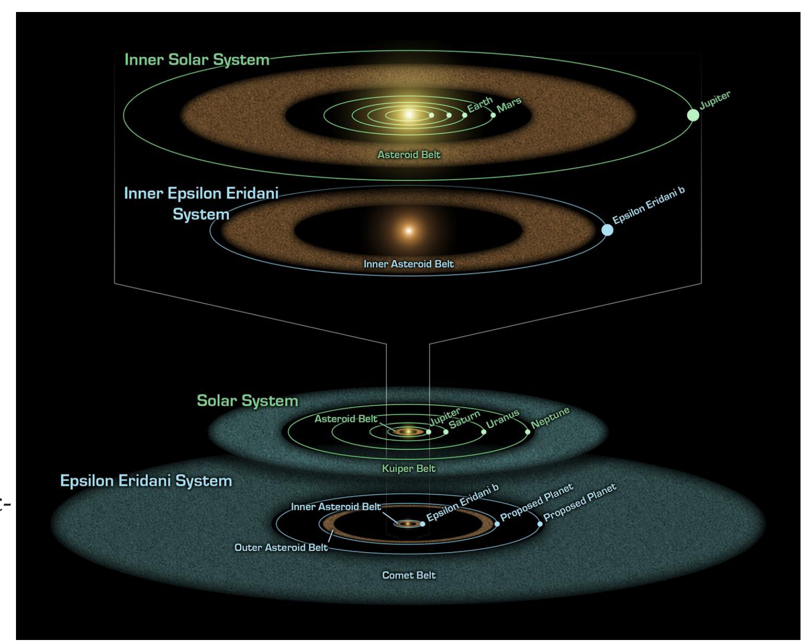
Ross 248:

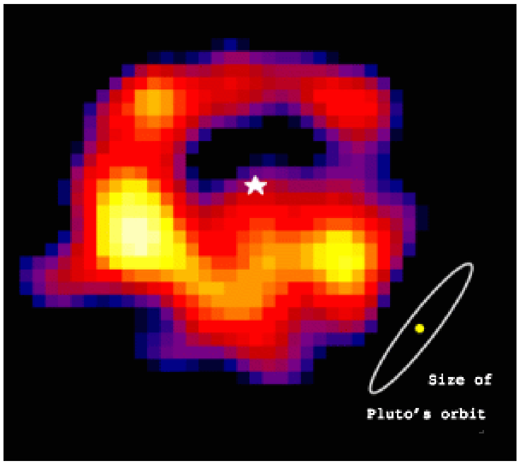
Another unremarkable red dwarf flare star discovered by Frank Ross. It is also known as HH Andromedae or Gliese 905 and is 10.3 light years away, with Right Ascension: 23h 41m 54.7s and Declination: +44.18 °.

Epsilon Eridani:

Also known as Ran (based on a 2015 naming contest by the International Astronomical Union, won by 14-year old James Ott), this is an orange dwarf star slightly smaller and cooler than our sun. It is 10.5 light years away with RA: 3h 32m 55.84s and Dec: -09° 27' 29.73" and spectral class K2V. It has 82% of the sun's mass and is a fairly young star, less than one billion years old and perhaps as young as only 200 million years and still gives off appreciable amounts of ultraviolet radiation.

As a close sun-like star, E. Eridani has been intensely studied for planets. This was another star thought to have had planets by Peter van de Kamp but his measurements were later shown to be caused by defective photographic plates. Measurements by the IRAS infrared satellite showed that it still retains at least two dusty rings containing asteroids, one that is about 4 AU from the star and one at about 20 AU. It also has a Kuiper belt analog or cometary cloud about 30 AU out. Clumping in the dust rings was considered evidence that it may have planets, and at least one large exoplanet perhaps 1.2 times the mass of Jupiter is considered to be confirmed now that the Hubble Space Telescope has shown perturbations in the path of Epsilon Eridani using astrometry. This planet has been given the name Ægir by the IAU and orbits the star every 7.4 years at about 3.4 AU, or just outside the inner asteroid belt. Computer simulations of the clumping of dust particles in the rings suggests their may be a second planet in an eccentric resonance orbit. E. Eridani has slightly less metal than our sun, but enough for rocky planets to exist closer to the star.

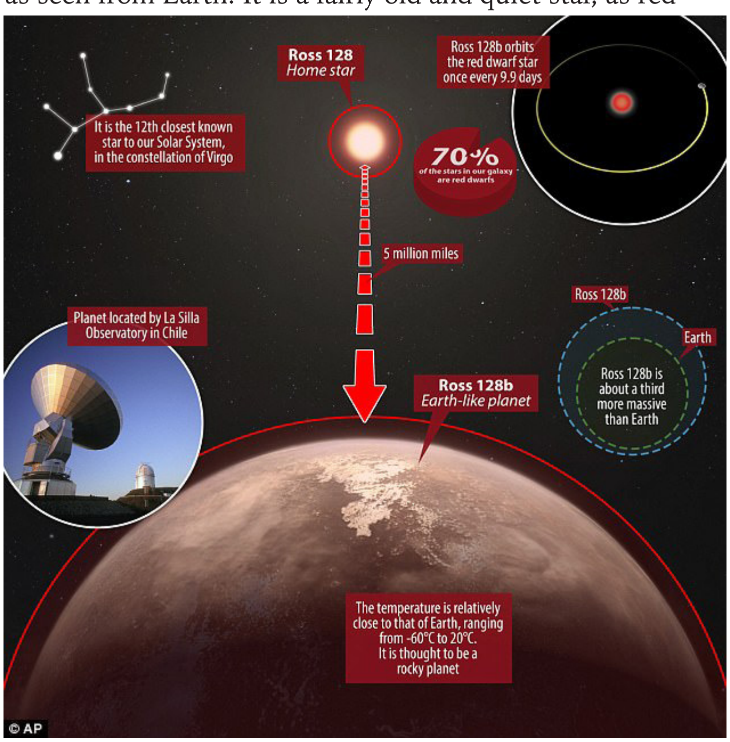




Because of its nearness and similarity to our sun, E. Eridani was one of the two stars first chosen for listening for alien signals by Project Ozma in 1961 by Frank Drake. No signals were detected. Project Daedalus of the British Interplanetary Society has suggested E. Eridani as one of the possible targets for an interstellar space probe. It has been the subject of many science fiction works, including ***Babylon 5***. In the series, the station orbits at the L5 point of Epsilon Eridani III and its moon. The planet is also the site of the Great Machine that figures prominently in several episodes. In ***Star Trek***, Epsilon Eridani is the system of the planet Axanar, where a famous space battle occurred between the Federation and the Klingon Empire prior to the events of the original series and where Garth of Issus became famous for his battle tactics. It is also mentioned in ***Space: Above and Beyond***, ***The Orville***, and ***Space Precinct*** as well as many novels, short stories, and games.

Ross 128: by Julia W.

Ross 128 is a red dwarf star, found in the equatorial zodiac constellation Virgo at RA: 11h 47m 44.4s and Dec: +00° 48' 16.4", not far from the star Beta Virginis as seen from Earth. It is a fairly old and quiet star, as red



dwarfs go, not exhibiting as many flares a seen in other red dwarfs, although a strong flare was noted in 1972 in the UV band. It is 11.13 light years from Earth with a spectral class of M4V and a mass of 15% that of the sun. It was first cataloged in 1926 by Frank Elmore Ross. It is considered to be an old disk star, and recent measurements by the APOGEE instrument indicate is has nearly the same metallicity as Sol. It does not have the infrared excess that would indicate a dust ring. It is a slow rotator, spinning only once every 165.1 days, because of it old age and the gradual slowing or rotation due to magnetic braking.

A great deal of excitement and speculation occurred when an exoplanet, Ross 128 b, was announced orbiting the star in its habitable zone. This planet is slightly larger than Earth at 1.8 Earth masses with about 1.4 times as much energy reaching it than Earth. Although hotter than Earth, its orbit and the quietness of the Ross 128 make this one of the best candidates for life of any exoplanet discovered so far and the second closest habitable zone planet after Proxima b. Ross 128 b orbits every 9.9 days and is close enough to be tidally locked, which, if it has oceans, would make it a candidate as an "eyeball" planet and an Earth-like analog. It is most likely a rocky planet based on its size, orbit, and the parent star's metallicity.

Radio signals were detected in 2017 by the Aricebo observatory that appeared to be coming from the vicinity of Ross 128, but the Allen Array was able to show that these signals were actually from geosynchronous satellites orbiting the Earth; Ross 128 orbits near the celestial equator near the orbits of many communication satellites.

Gregory Benford, in his 1984 novel ***Across the Sea of Suns***, describes an amphibious alien race living below the ice of a Ganymeda-type exomoon orbiting a planet in the Ross 128 system. They are hiding from extinction caused by a Berserker killing machine called a Watcher orbiting the moon. In the TV series ***War of the Worlds*** (2019) Earth is attacked from Ross 128 after picking up a signal.

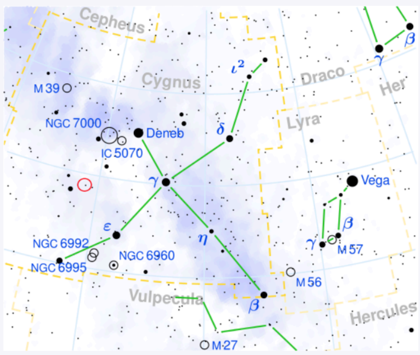
EZ Aquarii: by Lily M.

EZ Aquarii is in the constellation Aquarius and is a triple star system about 11.3 light years away from the Sun and is also known as Luten 789-6 and Glieses 866. Its Right Ascension is 22h 38m 33.4s and its Decl. (deg.) is –15.3. For EZ Aquarii A the stellar type is M5.0V, the other two stars are about the same or slightly smaller. Its magnitude is 12.87. EZ Aquarii may have been found by All of the EZ Aquarii stars A, B, and C are M-typed red dwarf stars and are too faint to be seen by our eyes without help. An interesting fact about EZ Aquarii is that both A and C form a spectroscopic binary that orbit at 3.8 days, with B having an orbit of 823 days. A and B are both flare stars, and the system has no known planets as yet. Its nearest neighbor at this time is Lacaille 9352, which is about 4.1 light years away, making this system rather isolated.

61 Cygni:

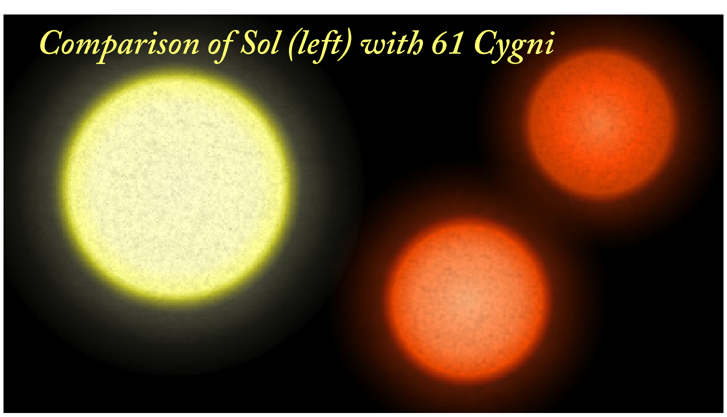
This binary system southeast of Deneb in the summer sky has bright enough stars that they were included in John Flamsteed's star maps and therefore have a Flamsteed designation from his 1712 Historia Coelestis Britannica. Both stars are old K-type orange dwarf stars (K5V and K7V respectively) and can be seen with the naked eye under clear, dark skies or with binoculars in areas of high light pollution. They orbit each other every 659 years at about 44 AU, having a wide separation. In clear skies, the pair of stars can be resolved with a 10x power pair of binoculars. The proper motion of 61 Cygni was measured in 1804 by Giuseppe Piazzi; this is the only visible eye star system that has a high proper motion and was therefore called "Piazzi's Flying Star." In 1834 Friedrich Bessel measured its distance as 10.4 light years using stellar parallax, the first star to ever be measured in this way. Its actual distance is 11.4 light years. There have been claims of a massive planet orbiting one of the two stars which have been controversial. The 2018 data release from the Gaia spacecraft indicates that there are anomalies in the orbits of the stars around each other showing that they are not quite orbiting around their center of mass and that 61 Cygni B is moving too slowly for its mass. This may indicate the presence of an as yet unconfirmed planet around 61 Cygni B. Measurements of the infrared signature of the system show a possible infrared excess suggesting a possible circumstellar dust disc.

61 Cygni



Location of 61 Cygni (circled)

Observation data	
Epoch J2000.0	Equinox J2000.0
Constellation	Cygnus
61 Cygni A	
Right ascension	$21^h 06^m 53.940^s$[1]
Declination	+38° 44′ 57.90″[1]
Apparent magnitude (V)	5.21[1]
61 Cygni B	
Right ascension	$21^h 06^m 55.31^s$[2]
Declination	+38° 44′ 31.4″[1]
Apparent magnitude (V)	6.05[2]



Procyon: by Cate L.

Procyon A is the brightest star in the constellation of Canis Minor, which means "smaller dog" in Latin, the eighth brightest star in our sky, and is a binary star, which indicates that another star orbits around Procyon. The distance of Procyon A and B from our planet Earth is 11.46 light years away. The right ascension for both stars is 7 h 39 m 18.1 s, and the declination of both stars is 5°13 m 30 s. Their stellar types are F5 IV-V, and DQZ. The first one is yellowish-whiteish and the second one is a white dwarf. The temperature for A is 6,530 K, whereas B is 7,740 K. As a white dwarf, B is the core of a star much like our sun that threw off its outer layers leaving a white hot companion to the slightly cooler and more yellowish A star. The two stars orbit a common center of gravity every 40.84 years in moderately eccentric or elliptical orbits.

Procyon was known to the ancients and to all cultures, being one of the brightest stars in the sky. In Greek, its name means "before the dog" referring to it rising before Sirius, the dog star. In other non-Greek cultures, it has been known as Nangar, the Carpenter to the Babylonians. The Latin version of Procyon is Antecanis and Arabic names are Al Shira or Elgomaisa and Turkish Rumeysa, the Bleary-Eyed Woman. To the Hawaians, it was Puana, the Blossom and to the Chinese, Nan He San, the Third Star of South River.

The A star is a late main sequence class F star, and will reach the end of hydrogen fusion in its core within the next 10-100 million years, after which it will swell 80-150 times it current diameter and become a red giant.

Procyon B was first proposed by Friedrich Bessel based on astrometric measurements and it was visually confirmed in 1896 by John Martin Schaeberle at Lick Observatory. It was originally a B-type star about 2.59 times the mass of our sun, which came to an end about 1.19 billion years ago after a main sequence lifetime of about 680 million years, making its remnant an old white dwarf.

Struve 2398:

A binary red dwarf system in the constellation of Draco, these stars were first included in the double star catalog of Friedrich Georg Wilhelm von Struve as system 2398. Also known as Gliese 725, the Greek letter sigma is sometimes used to designate Struve catalog stars. Both stars in the system are x-ray flare stars, as are most red dwarfs, and orbit each other with a period of 295 years. They are 11.6 light years away. The B star in the system has two planets, both of about Neptune's size. One has an orbital period of 91.29 days and the other 192.4 days.

Groombridge 34:

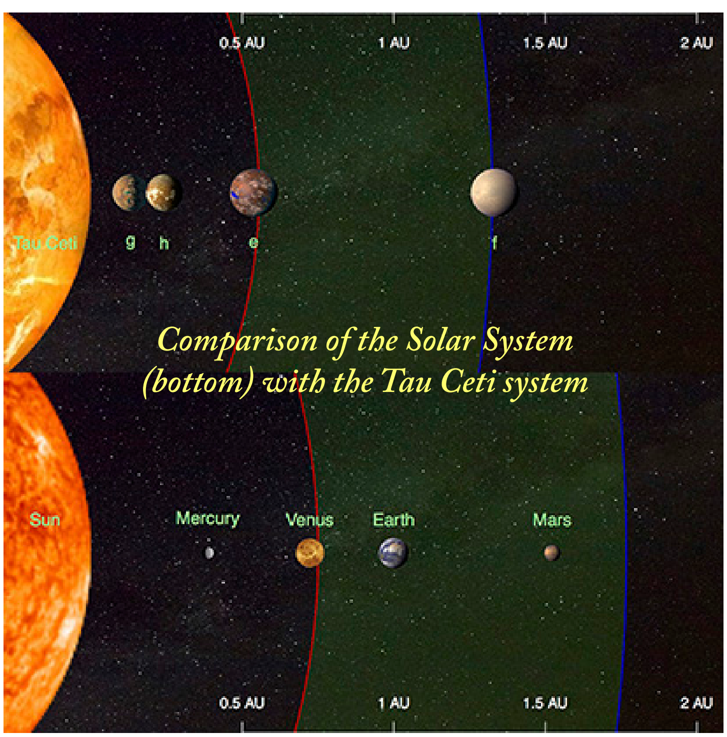
Located in the constellation Andromeda, this pair of binary red dwarf flare stars is ll.618 light years away and was first listed in A Catalogue of Circumpolar Stars by Stephen Groombridge, published posthumously in 1838. They orbit around a common center of gravity in almost circular orbits every 2600 years at about 147 AU. Using radial velocity measurements, two planets have been inferred orbiting around Groombridge 34 A, one a super-earth with 3.03 Earth masses and the other a larger Neptune-class planet with 36 Earth masses.

DX Cancri:

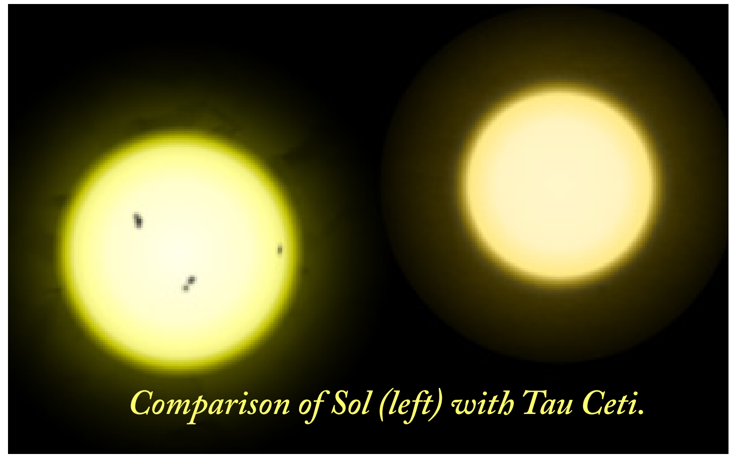
This dim M6.5V red dwarf flare star is in the constellation Cancer and is 11.8 light years away. It is small for a red dwarf, with only 9% of the Sun's mass and a temperature of 2840 K. It is proposed to be part of a group of stars called the Castor moving group that all had a common origin about 200 million years ago in an open cluster and are moving together as a group while gradually spreading apart. It is not known to have planets.

Tau Ceti: by Ruby R.

This is one of the most important stars near us in that it is a G8V star only slightly smaller and cooler than Sol, with 78% of the sun's mass. It has a lower percentage of metals than the sun, and is 11.91 light years away in the constellation of Cetus, the whale. It does not have a Greek common name, and was first listed in western catalogs in 1603 by Johann Bayer in his Uranometria. The Calendarium of Al Achsasi al Mouakket of 1650 lists this star as Thalith al Na'amat, the Third Ostrich. It is the Fifth Star of the Square Celestial Granary in Chinese.



Comparison of the Solar System (bottom) with the Tau Ceti system


Comparison of Sol (left) with Tau Ceti.

Estimates of Tau Ceti's age, based on its metallicity and models of stellar evolution, put it at about one billion years older than our Sun. It is a very stable star, with few if any sunspots and a weak magnetic field.

Because it is the closest single G-type star, it is a Solar analog and has been continually studied for SETI and exoplanet research. It was one of Frank Drake's original stars for Project Ozma in 1961. Four planets are confirmed to orbit Tau Ceti, designated g, h, e, and f. They are all super-Earths. Planet e orbits every 163 days, putting it at the inner edge of Tau Ceti's habitable zone with a radiative flux slightly less than Venus, and Planet f orbits at 636 days, putting it at the outer edge with a solar flux comparable to Mars, but with a thick enough atmosphere could sustain liquid water on the surface. Four other planets are suspected to be in the system but are not yet confirmed, although statistical modeling agrees with the detected radial velocities of Planets b, c, and d. With the possibility of 8 or 9 planets, the Tau Ceti system is similar to our own and one of the best candidates to search for life.

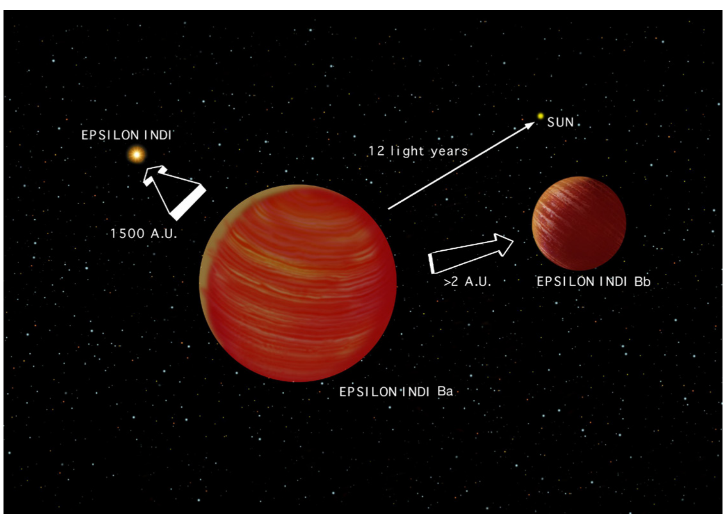
Infrared measurements show that Tau Ceti has a thick debris disc similar to our asteroid belt but ten times more dense, and orbiting roughly in the same area as our Kuiper Belt, which would make collisions with any potentially habitable planets more frequent. If there is a large gas giant, as some have proposed (unconfirmed Planet i) then it might have a similar role to Jupiter in deflecting potential impactors. As dense as this dust disc is, it is only 1/20 as dense as the one around Epsilon Eridani. Such dust discs may be common around sun-like stars and may play a role in planet formation; our solar system may be an exceptionally dustless system that had many of its comets and asteroids cleared out early on by a passing star.

In science fiction, Tau Ceti is the system of the planet Aurora in Isaac Asimov's robot novels as the first settled of the spacer worlds and is the setting of the novel ***The Robots of Dawn***. It is the home world of the roboticist Dr. Han Fastolfe. It is the destination of the torchship Lewis and Clark in Heinlien's novel ***Time for the Stars***. The planets of Tau Ceti are the setting of Ursula LeGuin's ***The Dispossessed***. The ***Downbelow Sation*** of C. J. Cherryh's novel of the same name is located on planet Downbelow orbiting Tau Ceti. ***The Legacy of Heorot*** by Niven, Pournelle, and Barnes takes place on the planet

Avalon (Tau Ceti IV). 100 colonists, sent by sleeper ship, find that ice crystals have built up in their brains while in suspended animation and arrive on Avalon with reduced mental abilities only to be forced to counter the threat of ferocious grendel monsters. In ***Rama Revealed*** by Arthur C. Clarke, a group of colonists travel on the Rama II to a node in the Tau Ceti system. In ***Leviathan Wakes*** in the Expanse series of novels and TV show by James S. A. Corey, the Mormon generation ship *S. S. Nauvoo* is traveling to the Tau Ceti system before being commandeered to crash into Eros.

Epsilon Indi:

This is an unusual trinary system with an orange K-type dwarf star in the far southern constellation Indus orbited by two T-type brown dwarfs that are orbiting each other and designated Epsilon Indi Ba and Bb. The A star has at least one planet called Epsilon Indi Ab and it has a mass of about 3.25 Jupiters, making it the closest Jovian planet to us. It has an orbital period of 45 years compared to about 12 years for Jupiter, putting this planet much further out. Since Epsilon Indi is an orange dwarf star cooler than the sun, this planet is far outside the habitable zone. The two brown dwarfs are about 1460 AU from the main star or over 37 times the distance between our sun and Pluto (which is 39 AU away from Sol). They orbit each other at about 2.1 AU every 15 years. They have the masses of about 47 and 28 times the mass of Jupiter. The complexity of this system makes it ideal for studying the evolution of stellar systems. The size and distance of Epsilon Indi Ab make it a good candidate for direct observation by the James Webb Space Telescope.



Gliese 1061:

Located 11.98 light years from Earth in the constellation Horologium, this small red dwarf was first discovered by Wilhelm Gliese in 1974 when its proper motion was measured, but it was assumed to be much further away at 25 light years. The RECONS satellite was able to measure its parallax much more accurately in 1997 and provide a better estimate of its distance. It is at the lower limit of a red dwarf star at only 11.3% the size of Sol and 0.2% as luminous. Any smaller and it would be a brown dwarf.

In 2019 the Red Dots program announced that the star has three exoplanets: b, c, and d with periods of 3.2, 6.69, and 13.03 days respectively. They are all super-earths with similar masses of 1.38, 1.75, and 1.68 Earth masses. Because of the small size of Gliese 1061, the second planet (Gliese 1061 c) actually orbits just within the inner edge of the star's habitable zone but would have an equilibrium temperature of 307 °K or 93 °F assuming a similar atmosphere to Earth. It receives 34% more radiative flux than Earth but is so close to its parent star that is likely to be tidally locked with one side constantly facing the star. The third planet, Gliese 1061 d, is also possibly in the habitable zone but on the cool side with 40% less stellar flux than Earth, making it more like Mars. Although its close proximity to the star would indicate tidal locking but it has a fairly eccentric orbit at 0.54, which would tend to destabilize the tidal locking and allow for a day-night cycle. This eccentricity would be a challenge for life.

YZ Ceti:

At 12.11 light years from Earth, this red dwarf flare star in the constellation Cetus is unusually close to Tau Ceti at only 1.6 light years and is about 13% of the size of Sol. The YZ designation indicates that this is a variable star with periodic changes in brightness caused by starspots or chromospheric variation as the star rotates every 68.3 days. It also gives off frequent ultraviolet flares.

In 2017 three planets were announced with a possible fourth that still needs confirmation. All three confirmed planets are too close to the star to be inside the habitable zone. Planets b and c are smaller than Earth (0.75 and 0.98 Earth masses) and planet d slightly larger at 1.14 Earth masses.

Luyten's Star:

Also known as BD+05°1668 from the Bonn Star Catalog (Bonner Durchmusterung) or GJ 273, this star is located in Canis Minor at a distance of 12.36 light years. Its proper motion and distance were first measured by Willem Jacob Luyten and Edwin G. Ebbighausen. It is about 35% of Sol's mass and rotates slowly once every 116 days according to variations in surface activity and has a surface temperature of 3150 °K. It is only 1.2 light years from Procyon.

In 2017 two planets were confirmed. GJ 273 b is a super-earth with 2.89 Earth masses at the inner edge of the habitable zone with a radiative flux of 106% that of Earth and a mean equilibrium temperature of 206 to 293 °K depending on the atmosphere's composition, if an atmosphere exists. It is therefore one of the best potential candidates for being similar to Earth and therefore possibly to have life. The inner planet, GJ 273 c, is only 1.18 Earth masses and orbits much closer to the star. In 2019 two more planets were detected using radial velocity but still need confirmation.

Because GJ273 b is one of the closest potentially habitable exoplanets, it was the target for a project in 2019 called Sónar Calling GJ273b, where a series of radio signals containing 33 musical compositions and a decoding tutorial were sent from the Ramfjordmoen radar antenna in Norway toward GJ273b, with more transmitted in 2018. If anyone hears us, we could expect a response no sooner than 2042.

Teegarden's Star:

Located in Ares, this small red dwarf is 12.578 light years distant and was only discovered in 2003 using near-earth asteroid tracking (NEAT) data and is named after the discovery team's leader, Bonnard J. Teegarden. This discovery helps to confirm a hypothesis that many small mass stars have yet to be discovered within 20 light years of Earth. Their low luminosity makes them very difficult to find.

Two planets, both inside the habitable zone, have been confirmed. One orbits at a distance that would put it between Earth and Venus in temperature and the other is cooler, similar to Mars. Both are only slightly larger than Earth at 1.05 and 1.11 Earth masses for Teegarden b and c, respectively. Different studies disagree as to whether these planets could have retained a dense atmosphere.

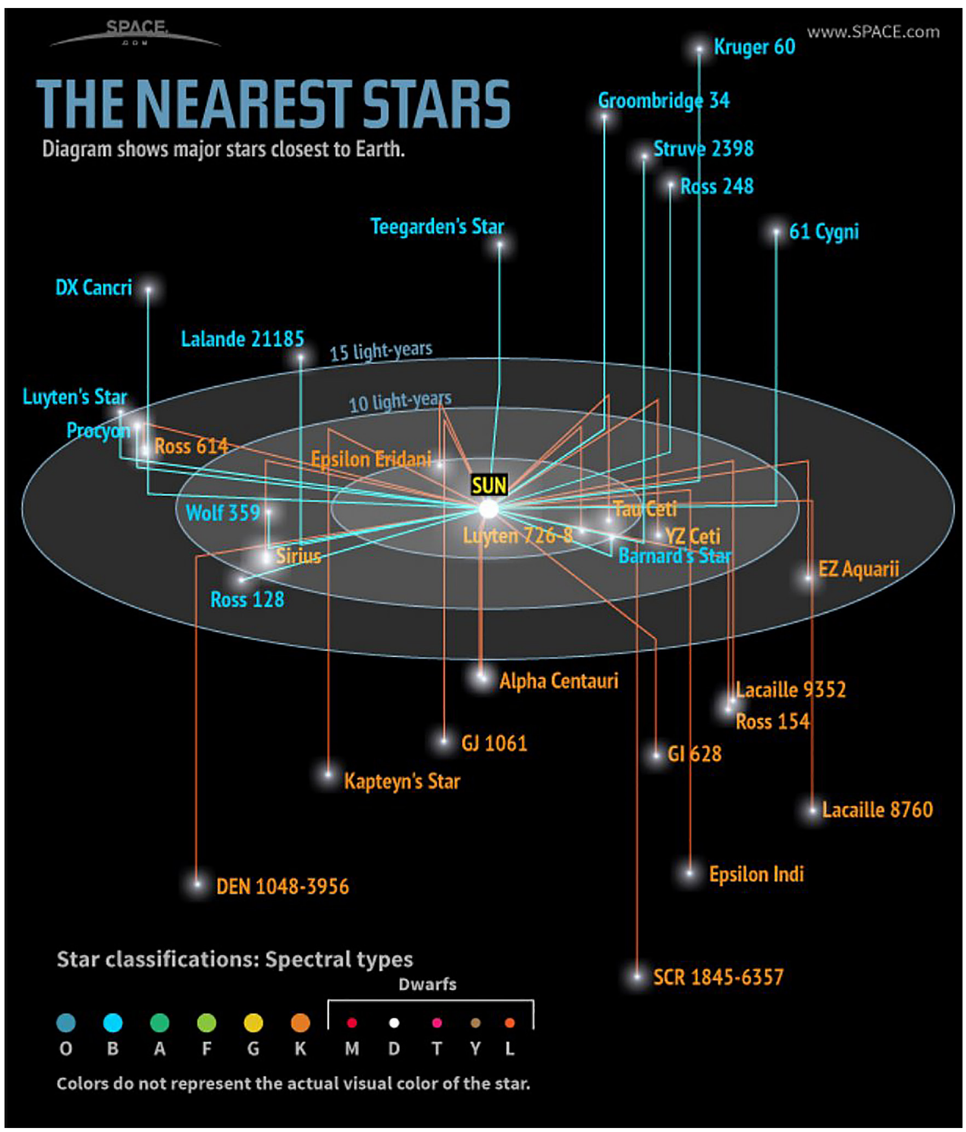
Kapteyn's Star:

Another small red dwarf lies in the southern constellation of Pictor at 12.83 light years distance. It is a bit larger and brighter than some red dwarfs, with a stellar class of M1 instead of usual M3.5-6 of a typical red dwarf. This star may have had an unusual origin, as its motion and elemental abundances indicates it may have been a part of the Omega Centauri globular cluster, a small irregular dwarf galaxy that was absorbed by the Milky Way and produced a stellar stream of which Kapteyn's Star may be a part. Jacobus Cornelius Kapteyn first announced the closeness of the star in 1898. It was listed in the Cape Photographic Durchmusterung as CPD -44° 612 and he noted that it had moved considerably (15 arcseconds) from its originally charted position in 1873. This makes it one of the fastest moving stars in terms of proper motion (sideways motion through the sky). It has fluctuations in its brightness due to starspot activity or chromospheric variation. Because of its high metallicity (14% of Sol) it is considered to be a relatively old star at about 11 billion years.

Two planets were announced in 2014 but their existence has been controversial due to one planet's orbit being a resonance frequency of the star's variation and the other almost identical to the star's rotation, so possibly the planetary induced stellar radial velocity is not due to actual stellar motion but luminosity variations of the surface. If the planets do exist, they would be among the oldest known. Kapteyn b could be potentially habitable, but its atmosphere is likely to have been stripped away over time due to stellar flares and age if it exists at all. In 2014 science fiction author Alastair Reynolds wrote a short story about the proposed planets called "Sad Kapteyn."

Lacaille 8760:

As the last star on this list (but not in our model, which went out to 15.0 light years), this red dwarf is in the southern constellation Microscopium and is 12.9



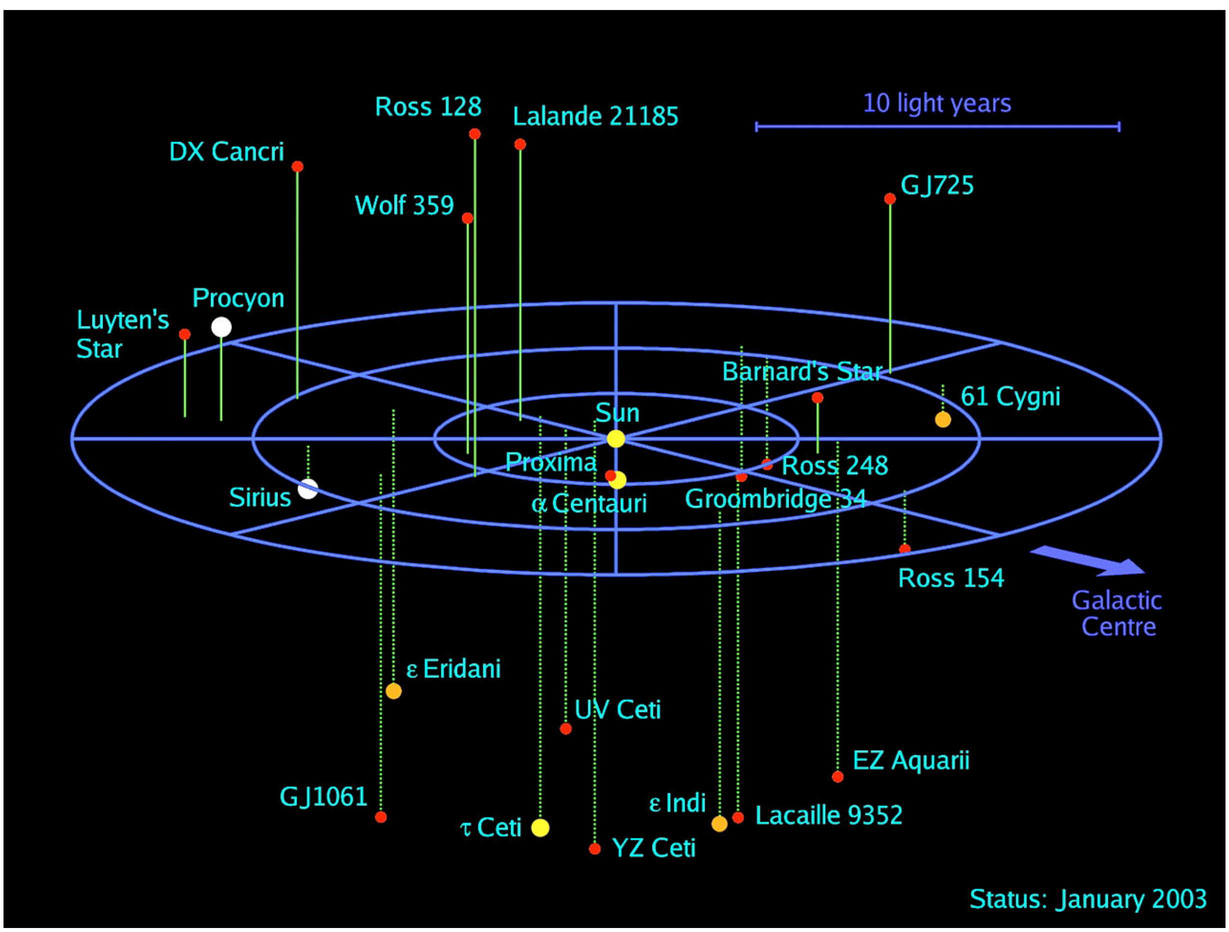
light years away. It is the brightest of the red dwarf stars in our night sky, and may be seen under ideal conditions under very dark and clear skies by the unaided human eye, the only red dwarf to be visible with binoculars or a telescope. It was first listed in 1763 in a posthumous catalog by the Abbé Nicolas Louis de Lacaille and was discovered by him while he worked at an observatory at the Cape of Good Hope. It is a flare star and erupts about once per day. It has 60% of Sol's mass and has been classified anywhere between a K7 to an M2 dwarf star. It is slightly older than Sol at five billion years and rotates only once every 40 days, with a photospheric temperature of 3800 ° K. It is estimated that this star will last about 75 billion years. No planets have been detected around this star.

This is the list of stars within 13.0 light years of Earth. As we go further out, the spherical volume becomes ever larger and a greater number of stars are located within the radial distance. There are 14 more star systems located between 13.0 and 15.0 light years. From our 3D model, it is apparent that the stars are not evenly distributed in our stellar neighborhood. The Alpha Centauri system is located in a region where it is the only star system for many light years in all directions – our solar system is the closest star to it and beyond it there is largely a void with few stars. In other areas the stars are packed more closely, but are still separated by at least a light year. Sol is at the edge of the Orion Branch of the Sagittarius Arm of the Milky Way, so that as we travel beyond the edge of the branch we reach a large gap without stars between the spiral arms.

A quick count of the number of different classes of stars show that red dwarfs far outnumber all other types of stars. It is obvious that small mass stars are like rabbits: they may be dim, but there are a lot of them. Of the 28 star systems within 13 light years (including Sol) there are 21 planetary systems (assuming all the unconfirmed planets are real). That statistic of 3/4 of stars having planets certainly increases the odds of there being life somewhere out there beyond our solar system; quite a few of these planets are within the habitable zone of their stars, but most of these stars are flare stars. This both increases and decreases the odds of life existing on these worlds. We are constraining many of the variables in the Drake Equation and estimates run to as many as 40 billion Earth-like planets in our Milky Way galaxy.

Surely we are not a special case; if life could get started here and chemistry is the same everywhere in the universe, then the factors that led to life here (whatever they were) are likely to occur elsewhere. Life could be abundant in the universe. That isn't to say that intelligent life is abundant; on Earth, conditions may have been just right for us to evolve intelligence (more on this in our next edition). But once life gets started on a planet, according to how tenacious life has been here through six major extinctions, it is likely to hold on; perhaps even in our own solar system, on Mars, or Enceladus, or Europa. If we can get remote instruments out to these 21 star systems, we may very well find life.

I for one hope that some day a form of faster-than-light travel can be realized, perhaps even something like a warp drive in ***Star Trek***. I hope life is as common as science fiction hypothesizes. It would be a wasted universe if we are the only ones out here.



Comparisons between this 2003 map with the more recent one on the previous page show several new additions.

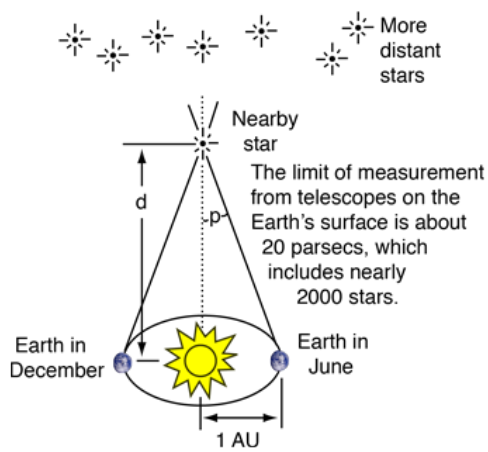
Characteristics of Stars

The following short articles were written by my 2020 astrobiology students as sidebars to the main article above. However, to make layout a bit easier, I am including them here since the main article already has quite a few illustrations.

Determining the Distance to Stars

by Hannah T.

Determining the distance between objects in space is important to set up the cosmic distance ladder and in order to establish relationships between objects and their physical features. Astronomers are able to estimate this distance using stellar parallax or trigonometric parallax. Astronomers measure a star's apparent movement against other background stars as Earth revolves around the sun. This method involves geometry and measures two angles including the triangle formed by the star. Astronomers use the baseline of 1 AU which is the distance between the Earth and the sun, 93 million miles or 150 million km. Arcsecs are tiny fractions of a degree in a night sky. When you divide 1 AU by the tangent of one arcsecond you get 3.26 light years. This is called a parallax second or parsec but even the closest star is farther away than that, or has a parallax angle of less than one arcsecond.



189 B.C is the first time an astronomical method using parallax was recorded. Hipparchus, a Greek astronomer used measures of a solar eclipse from two locations to measure the distance to the moon. Hipparchus found that a total solar eclipse happened in Hellespont, Turkey and Alexandria, Egypt at the same time. Knowing the distance between the two locations, 600 miles, he used the angular displacement of the edge of the moon against the sun and determined that the sun was 350,000 miles away. Later, his mistake was uncovered when the moon was found to be 238,900 miles away and scientists realized he had incorrectly assumed the moon was directly above Greece. Still, it was a remarkable achievement.

F. W. Bessel is the first man to ever successfully measure the distance to a star. In 1838 he measured the distance to the closest star, Proxima Centauri. Since then, thousands of stars have been measured and astronomers continue to explore these distances every day.

Star Types and Classes

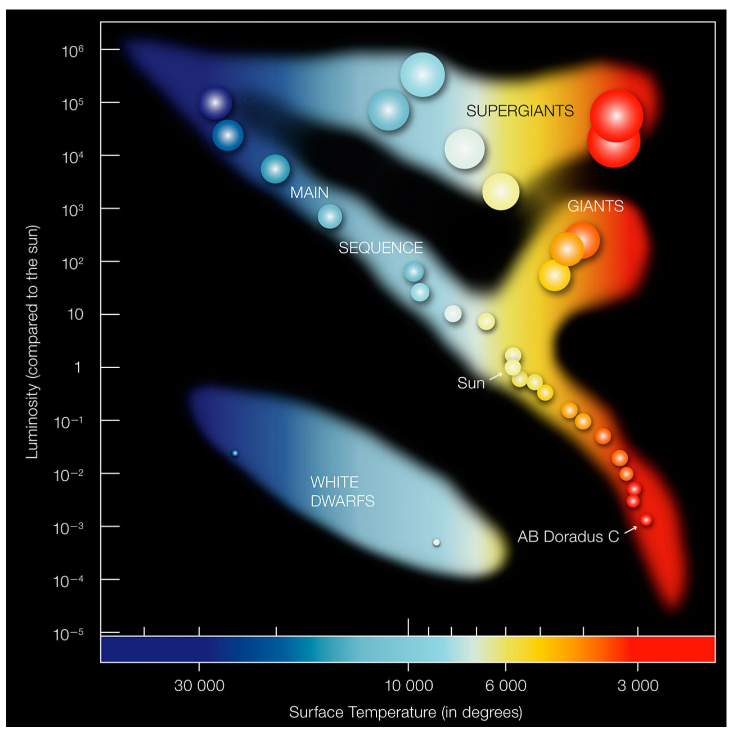
by Vanessa N. and Ruby R.

Stars are classified by their temperature and by the different types of elements found in their coronas as measured by the absorption lines in their spectra. Stars are divided into seven main categories; O, B, A, F, G, K, and M.

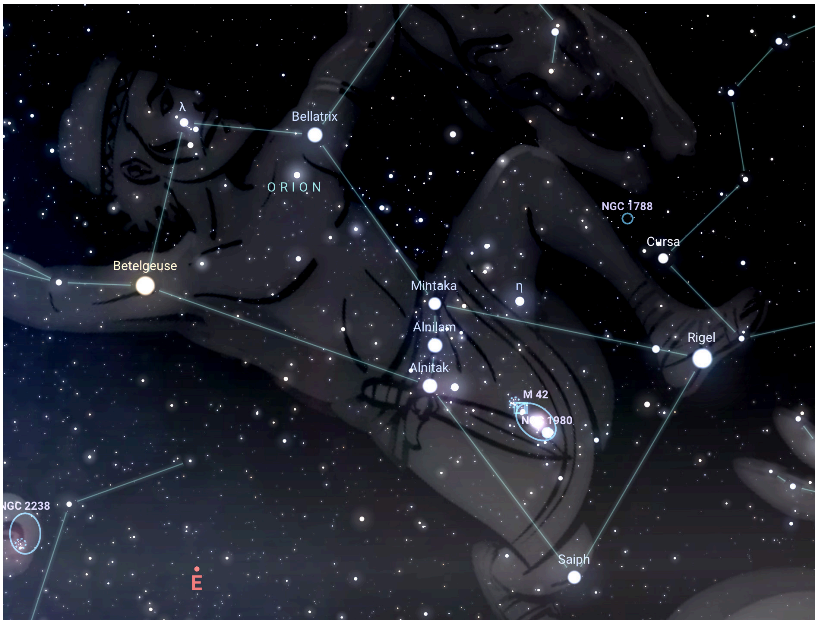
O stars are very blue and bright, they are the hottest types of stars, the outside temperatures for these stars are 25,000-50,000 ° K. B stars are blue white with an outside temperature of 10,000-30,000 ° Kelvin. The A-type stars have a white color; they are 7,400-10,000 ° K. F stars have a yellow white hue and an outside temperature of 6,000-7,400 ° K. G type stars are yellow and have a temperature range of 5,300-6,000 °K, such as our own sun. K type stars have an external temperature of 3,500-5,000 ° K and have an orange color. Lastly the coolest star, the M type star, has an external temperature of 3,000 ° K or less and these stars have a red surface.

The way to distinguish between stars was developed independently in the early 1900s by Ejnar Hertzsprung and Henry Norris Russell. The process includes plotting the temperature of the stars against their luminosity or the color of the stars/spectral type against their absolute magnitude. The temperature and luminosity of each star changes with each evolutionary stage and how it produces energy. New stars produce a great deal of light and heat, then settle down into the middle band of the H-R diagram as they fuse hydrogen to helium. A star that is doing this is said to be on the Main Sequence. Stars in the upper left corner are called Blue Giants. Stars in the middle are yellow dwarfs like our sun. Stars in the bottom right corner are red dwarfs.

As a star evolves it can be seen to move to different regions of the H-R diagram depending on whether it is an orange giant (middle right), a red supergiant (upper



right), or a white dwarf (middle bottom). All of these older stars have used up all the hydrogen in their cores and are beginning to fuse heavier elements. By this process, astronomers can know a star's internal structure, age, and evolutionary stage by charting its position on the H-R diagram.



Star Evolution

by Navah D.

Star evolution, or stellar evolution, is when a star changes over the course of a long period of time. Star evolution usually depends on the initial mass of the star, but a star's lifetime can range from a few million years luminous blue giant stars to even trillions of years for small red dwarf stars.

In the early years of the 20th century, two well-known astronomers, Ejnar Hertzsprung and Henry Norris Russell compared different stars with one another. They compared the surface temperature or color of stars with their luminosity or absolute magnitude to help them determine how star evolution works, as shown above in the H-R Diagram named after them.

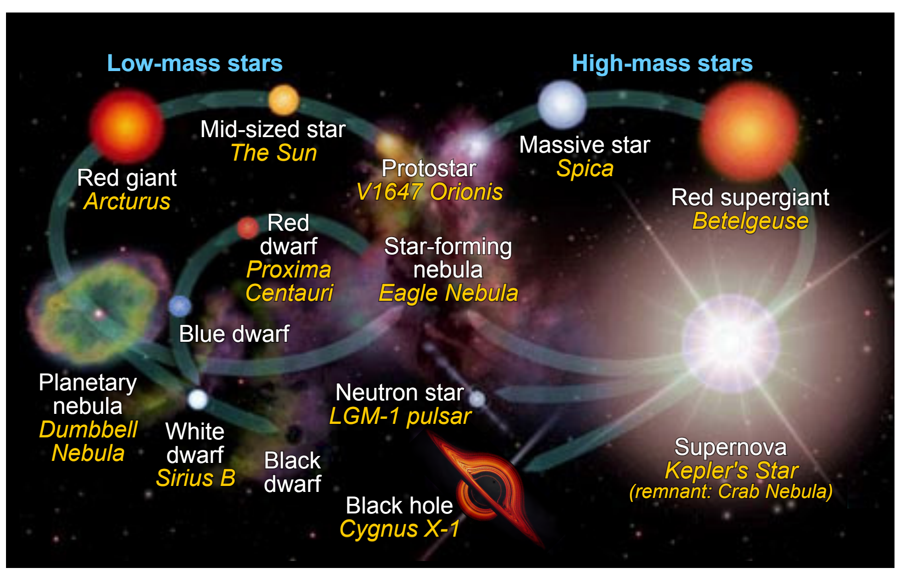
Star evolution starts with the gravitational collapse of a giant molecular cloud or nebula. Most stars begin their lives as a cloud of dust and gas (mainly hydrogen) that gradually collapses to form a protostar, with dust and gas spiralling inward to form a series of rings broken into bands saparated by clumps of matter that will form planets. This entire process is called accretion. Eventually, the central mass of dust and gas becomes so dense from gravity that its center reaches the temperature and density required for nuclear fusion to begin. A star is born.

There are more stars in the universe than there are grains of sand on the earth. An average star like our sun lives to about 10 billion years at least, gradually fusing the hydrogen at their cores to helium. We say that such stars are "main sequence" stars. The outward pressure of the thermonuclear fusion prevents the star from collapsing further. When stars run out of hydrogen they start to collapse again until still heavier elements are formed in a process called nucleosynthesis. All the elements beyond lithium and some beryllium were formed this way, including the carbon, oxygen, nitrogen, phosphorus, and other elements that make up us.

When stars run out of fusable elements, they die. For stars like our sun or smaller, their internal nuclear fires become very unstable; these types of variations cause the star to pulsate and throw off its outer layers which expand outward in a bubble called a planetary nebula, enriching the gas and dust of future nebulas with heavier elements. Whatever happens after that depends on the size of the stars' inner core.

For stars at least 2.5 times the size of our sun (A type stars or hotter), their cores become so dense that they keep fusing elements until they finally reach iron in their cores. Iron is the most stable element and has the lowest nuclear potential energy; it cannot be fused further through normal nucleosynthesis. To make the elements heavier than iron, something truly violent must happen.

Once these stars reach iron and core fusion stops, gravity takes hold and the star collapses, getting denser and denser. The layers outside of the core still contain large amounts of fusable elements, and when they reach a critical density a titanic explosion called a supernova creates a shock wave that implodes the star's core, smashing degenerate electrons onto the protons in the nucleii of atoms to form solid neutronium. The core of the star becomes a neutron star, a corpse of its former glory. Since the original star had rotation, now that it is smaller and denser that rotation speeds up because of conservation of angular momentum. The neutron star may spin as fast as 60 times per second and have the size of a planet. The intense magnetic field surrounding the rapidly rotating neutron star create force the radiation



into tight beams light an airport beacon. We call such stars pulsars.

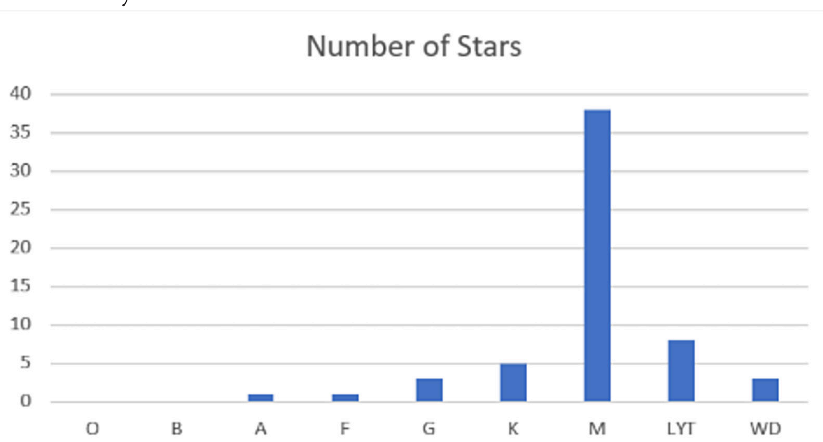
If the star is ten times the size of our sun the collapse does not stop at neutronium; the shockwave compresses the matter in the core of the star into a point of infinite density; it becomes a stellar black hole, distorting space and time so severely that even light cannot escape.

Meanwhile, as the shock wave implodes the core of the star, the outer layers are ripped apart and a violent wave of supernova nucleosynthesis that creates all of the elements heavier than iron. These elements are thrown out into space as a supernova remnant, adding themselves to other nebula and triggering their collapse into future generations of stars.

Our sun has a relatively high abundance of these heavier elements; that they are part of our solar system, our planet, and us testifies that our sun is a second or even third generation star. The elements in us came from an exploding star; it is the only way they can form. We are literally made of stardust.

If we could see one of these brown dwarfs up close, they would give off heat but not much light; they would have a magenta to almost purplish color. Some are cool enough to have clouds, an atmosphere, and perhaps even liquid water on their surfaces yet they would be about the size of Jupiter but many times more dense. You would be crushed by their gravity if you tried to stand on their surfaces.

There are three white dwarfs within 15 light years of us, two of which orbit the biggest stars near us (Sirius and Procyon) and one that is solitary (Van Maanen's star). They are the remnants of stars like our sun. After it throws off its outer layers to form a planetary nebula, our sun's core will remain behind as degenerate matter, a dense white ball about the size of our planet yet many times more massive. A teaspoon full of a white dwarf would way the same as a Boeing 747 jumbo jet. Eventually, after billions of years, the white dwarfs will cool until they are black clinkers in space called black dwarfs.



Frequency of Stars

by David Black and Kate L.

From the chart shown here (created by Kate L.), we can see the relative distribution of star classes in our neighborhood out to 15 light years, based on the 3D model we created in the 2020 astrobiology class.

We do not have any O or B type stars near us. Such stars are rare. Because of their great initial masses, they must form in very dense molecular clouds which collapse quickly. It is much easier for smaller stars to form more slowly and in thinner parts of nebulas. The smaller the stars, the more common they are all the way down to the red dwarf main sequence stars.

One would expect brown dwarfs (classes LYT), which are even smaller, to be even more common than red dwarfs. Yet there are relatively few of them in our model. This is likely because, since they only give off infrared light, they are very hard to find. We probably have a great many more of them near us than have already been discovered. Keep in mind that 20 years ago we did not even know brown dwarfs existed and none had been discovered.

Northern Constellations

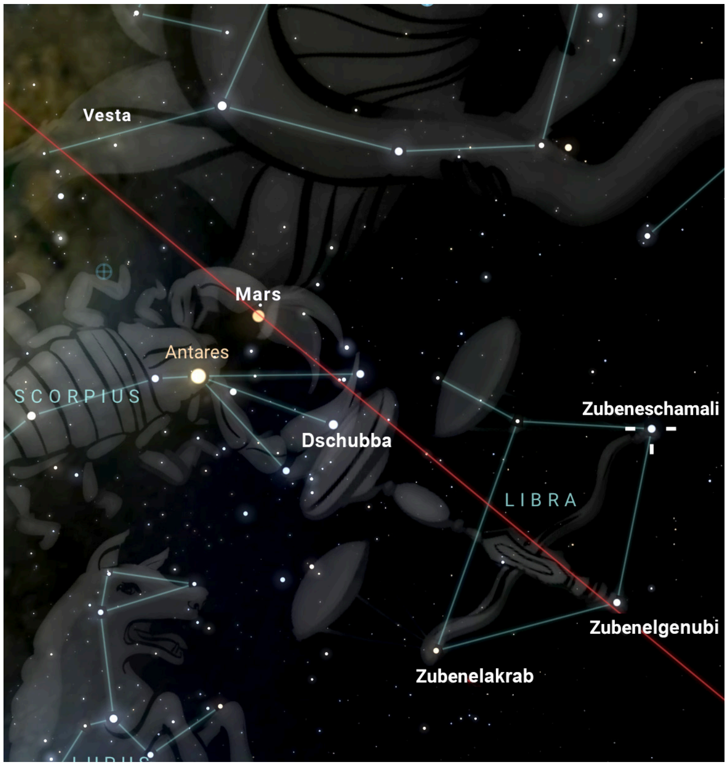
by Katie T.

Constellations are a night attraction to the human eye. The different star designs are like a work of art that surrounds the world. Did you know there are 88 constellations all together? What is a constellation though? How did they come to be named and known around the world?

Constellations aren't actually the grouping of stars. Each pattern of stars is called an asterism. Constellations are only the area of the sky surrounding asterisms. Each constellation has a different name. Many names come from ancient myths, told by ancestors believing in the sky gods and goddesses.

There are many myths created throughout the world. The Greeks believed in Ursa Major ("the great bear"), as a symbol of changing. To the Navajos, a girl seeking revenge turned into a bear and killed her seven brothers, her brothers now are in the sky. The Greeks have Herecles or Hercules to the Romans ("celestial strongman") up in the sky after he protected them and showed his ability to perform heroic labors. Hercules proved to everyone he was a leader by facing obstacles and slaying monsters. He married a woman and she poisoned him, he died and Zeus knew he was worthy and created a constellation in his honor. In Europe the Big Dipper is seen as a plough, instead of a dipper. Each nation has a different story behind their map of stars.

Who would have thought the patterns of the stars was a reminder of myths created long ago? That just the outline of heroic symbols can be filled in with detail and love. Constellations really are an unbelievable creation, that will continue to be studied and admired for years to come.



Naming the Stars

By David Black

Stars get their names from many sources including ancient myths, the patterns or pictures formed by asterisms in the sky, their brightness and position in their constellations, and the names of various astronomers who first catalogued them or by numbers in those catalogs.

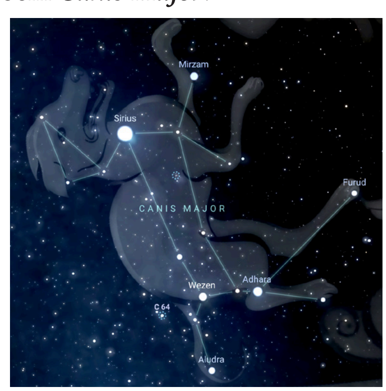
The brighter stars have proper or common names given them by ancient cultures ranging from the Babylonians and Sumerians through the Egyptians, Greeks, and Romans. One of the most ancient star names is Betelgeuse, which means "the home of the giant." Nunki, a Babylonian name that may correspond with the city of Eridu, is one of the oldest star names. Some examples of Greek star names include Antares ("the rival of Ares"), Alcyone (one of the Pleiades sisters), and Procyon ("before the dog"). Egyptian names include Sirius ("the scorcher" which was translated from the original Sopdet through Greek as Sirius), and Latin words include Cor Caroli ("the heart of Charles"), Vindemiatrix ("the grape gatherer"), and Bellatrix ("warrior woman").

Of all the proper names the most common language used is somewhat garbled Arabic, because many of the southern and dimmer stars were first noted by Arabic astronomers on clear desert nights. These include Zubenelgenubi and Zubeneschamali (the southern and northern claws of the Scorpion, now found in Libra). Dschubba is the star in the forehead of the Scorpion, and Zujj al Nushshabah is the tip of Sagitarrius' arrow. Adhafera is "the curl of the lion's mane" in Leo and Ain is the right eye of Taurus the bull whereas Aldebaran is the left and brighter eye which means "the follower" in Arabic. Alathfar in Lyra is "the talons of the swooping eagle" and Alchiba is derived from the Arabic for "the beak of the crow" in Corvus. Zaurak is found in Eridanus, the Greek word for river, and means "the boat' in Arabic. Unukalhai is the "neck of the serpent" in Serpens, and Toliman (Alpha Centaurus B) means "the ostriches." Saiph in Orion means "the sword" and Rigel means "the foot." The belt stars of Orion are Alnitak, Alnilam, and Mintaka and basically are different derivations of "the belt" or "the girdle." There are also stars named Wasat, Wazn, and Wezen, Talitha, Taygeta, and Thuban and many other Arabic derived star names.

Some names have been proposed by various cultures and at least one star was named as a joke. It is Sualocin in Delphinus, which is Nicolaus spelled backward. The International Astronomical Union (IAU) is the official body for naming stars, and several nations have proposed star names including Sterrennacht, a Dutch proposal to the IAU in 2019 to name a star after ***The Starry Night*** painting of Vincent Van Gogh.

Beyond the 800 or so proper names for stars their are many other naming systems. In 1603 the German astronomer Johann Bayer created a beautifully illustrated star atlas called Uranometria where he used a new system for star names based on the apparent brightness of the stars in each constellation. The brightest star was given the designation of Alpha, the second Beta, and so on through the Greek alphabet, with a diminuative form of the constellation name added. Therefore the star properly named Rigel Kent ("the foot of the Centaur" in Arabic) is also called Alpha Centauri by Bayer. Sirius is also called Alpha Canis Majoris, as in the poem ***Canis Major***:

The great Overdog
That heavenly beast
With a star in one eye
Gives a leap in the east.
He dances upright
All the way to the west
And never once drops
On his forefeet to rest.
I'm a poor underog,
But to-night I will bark
With the great Overdog
That romps through the dark.



There were far too many stars to be satisfied with only 24 Greek letters per constellation, especially when the telescope soon revealed vast seas of stars. By 1712 John

Flamsteed, the Royal Astronomer of Great Britain began numbering the stars in their constellations in order from west to east. Such star names as 47 Viriginis, 61 Cygni, and 55 Cancri came from his star catalog. He numbered 2682 stars all told.

Even more names were needed, and soon massive projects were underway to catalog all the visible stars. The first such project was undertaken by Friedrich W. A. Argelander beginning in 1859 from the Bonn Observatory. Called the Bonner Durchmusterung (Bonn Survey or Bonn Star Catalog), it provides star names by declination degree north and south of the celestial equator, then according to right ascension along those declination lines. Therefore Vega has the Bonn catalog number of BD +38°3238. The first survey recorded the northern sky from Polaris south to -2° declination and catalogued 324,188 stars. Other surveys were added for the southern sky, including the Cordoba Durchmusterung (CD) and Cape Photographic Durchmusterung (CPD) with a grand total of 1,071,800 stars. These catalogs became the standard for star positions for 100 years even though the listed magnitudes of the stars were not very reliable.

Other catalogs have been created such as the Henry Draper (HD) catalog from Harvard University compiled by Annie Jump Cannon in the 1910s that included stellar spectra and spectral classes. Not to be outdone, Yale University created the Bright Star Catalogue which is still widely used for its details on naked-eye visible stars.

Variable stars have their own naming conventions, such as Argelander's system of using the letters R through Z (since Bayer had only named stars up to the Greek letter Omega or Q in our alphabet). The first variable star he encountered in a constellation was given the letter R, then S, and so on. Once Z was reached, he started over with RR, then RS, and so on. For example, RR Lyrae is considered a prototype for a particular type of variable star, as is T Tauri. But there were more variable stars than could be named by ZZ, so further variable stars were named using Latin letters starting with A back to AA and so on until all 334 combinations were used. Then they started using numbers. The highest number so far for variable stars is V5112 Sagittarii.

The Smithsonian Astrophysical Observatory created the SAO star catalog in 1966 that has very accurate positions for stars up to 9th magnitude, but it has been outdone by the guide star catalog (GSC) created to provide reference positions for the Hubble Space Telescope for stars dimmer than 9th magnitude. An even more detailed catalog was developed for the Hipparcos satallite tasked with measuring the exact parallax and distances of the brightest million stars. This catalog provides stars with numbers beginning with the HIP designation.

Even more detailed catalogs have been created through the Sloan Digital Sky Survey (SDSS) and the 2-Micron All Sky Survey (2MASS). The US Naval Observatory has created that largest catalog of all (so far) called UCAC.

Some of the stars discussed in our article on the nearby stars are found in specialized catalogs compiled by astronomers interested in high proper motion stars because these are closest to us. These lists have been created by such people as Max Wolf, Nicolas-Louis de Lacaille, Edward Emerson Barnard, the father and son team of Friedrich Georg Wilhelm von Struve and Otto Wilhelm von Struve, Stephen Groombridge, Willem Jacob Luyten, Frank Elmore Ross, Jérome Lalande, Kevin Luhman, Wilhelm Gliese, and Henry Giclas.

One final note. You can't officially have a star named for you or anyone else. The IAU is the only body that can officially name a star and any website that offers to allow you to name a star for your mother or child or girlfriend is just stealing your money. All you will get is a worthless certificate. You might as well print one out yourself, then go outside and call any star you want by the name you choose. It will be just as official and a lot less expensive.

The Crab Nebula, a supernova remnant in Taurus. The light from the explosion that formed this first reached Earth in 1054 CE.