Meandering among the stars

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I don't know what you think when you look up at the stars but one of the things I reflect on is how wrong our ancestors were about them. The stars are not all much the same; they are not all the same distance away; they aren't all made of the same stuff. True, hydrogen is the most common element in stars but it is the most common element in whales, men and mice, and they are all very different creatures. Likewise stars are just as diverse as whales, men and mice.

Now we have invented instruments much more sensitive than our eyes to look at stars, we know that the stars we see in the sky are not representative of stars in general. About 80% of all stars are M, L or T class stars, cooler than 4000 K. T class stars are scarcely hotter than the filament of a light bulb. Most of these cool stars we can't see with our naked eyes, which is why the stars in the sky don't represent a cross-section of the stellar population. If we had infra-red vision, like some modern telescopes, then we'd see a lot more of these cool stars. Taking an example at the other end of the temperature scale, less than 1 in a million stars are O type stars, the hottest of all. How many would you expect to see amongst the 2000 or so stars visible on a brilliant starry night? You might have thought 'none', yet there are 9 visible O type stars with magnitude less than 6. The stars we see are not a random sample but a selection biased towards the nearest and brightest.

Our Sun with a surface temperature of 5800 K is not quite an average star either. From the figure given above it's hotter than average. There are plenty of more luminous stars in the sky, though. Some are stunningly more luminous. A star as bright as our Sun wouldn't be seen by naked eyes if it were 100 LY away. A good many stars we see are much further than 100 LY: stars such as Polaris (425 LY), Betelgeuse (450 LY), Antares (620 LY), Rigel (1600 LY); the garnet star (2000 LY), Deneb (~2500 LY) and η Carina (~8000 LY, a phenomenal distance). Some of these are more luminous than the Sun because they are hotter, some because they are much bigger; some are both.

The following list shows way-points on a meander among stars visible in our night sky, with a commentary on why they are different from each other or why they are interesting. You can find a lot of the information that follows in the excellent book by James B. Kaler *The Hundred Greatest Stars* [Copernicus Books, NY 2002, ISBN 0-387-95436-8] which I strongly recommend for the enthusiast. You can follow the trail with a software package like *Stellarium*, freely available from the web, that shows where they are in the night sky or, even better, locate some of them in the real sky. You won't see them all at once in the real sky but thanks to being able to vanish the ground in *Stellarium* and advance time at will then you can see them all on the computer screen in one session.

The trail starts at the pole star, located most easily using the 'pointers' in the Plough.

Polaris – Close to a 2^{nd} magnitude star, notable of course for its position at the moment, about half a degree from the north celestial pole; the nearest and brightest Cepheid variable to us, though surprisingly constant for a variable star. It is at 425 LY and an F5 supergiant. Cepheid variables are a crucial help in sizing the universe out to about 50 MLY. For this method to work we need to know how far nearby Cepheids are as determined by parallax. Thanks to the Hipparcos survey, we know about Polaris.

Mizar & Alcor The Mizar/Alcor visible double may be a line-of-site deception or false double, though both stars are around 80 LY away. Mizar, the brighter, was the first star revealed by telescope to be a double itself, though it looks like a single star to the naked eye. This was in about 1650. Over 300 years later, through the spectroscope, Mizar itself was found to be a double-double of class A dwarfs. One double has a separation of about 1 AU, the second about 0.4 AU and the pair of doubles are about 500 AU apart: two stellar dumbbells rotating around each other.

γ Draconis (Eltanin) - The star James Bradley used to determine *stellar aberration*. It has the same declination as London has latitude, and since it passes directly overhead of London Bradley could plot its position with the least interference from refraction of the Earth's atmosphere, which causes apparent displacement of stars and stellar twinkling. All the stars that have the same declination as your latitude (~ 57°N for Aberdeen) will pass overhead every 24 sidereal hours. During the day you won't see them but at precisely the same time every night the stars on your declination circle will successively come round to the overhead position. It will take a year for you to see them all overhead at one set time; very much less if you watch over a period of hours in the night.

μ Cephei - the "garnet star", so cool at 3500 K you mightn't expect to see it unless it was close to us but it is one of the most distant naked eye visible stars, too far to have its distance measured by parallax. A supergiant star at least as large as the orbit of Jupiter and one of the most luminous stars in the galaxy, with an output of some 350,000 Suns. It would be seen even brighter in the sky in spite of its staggering distance for a naked eye object of around 2000 LY if it weren't for surrounding dust generated by outpourings from the star. This dust will form the stuff of future stars and planets. At some 40 solar masses, this is a star with a fast burn life that is about to end in a supernova explosion, the remnant almost certainly becoming a black-hole.

Algol - β Per, the classic eclipsing binary with a bright B dwarf and a cool K giant orbiting each other every 2.87 days. Algol is the winking eye of Medusa, the Gorgon whose gaze could turn men to stone. Perseus succeeded in slaying Medusa by a ruse and is pictured in the sky holding Medusa's severed head by its dreadlocks. The eye still winks.

Deneb - 1st star of the summer triangle. Fantastically bright star, probably about 2500 LY distant. A class A (~9600K) supergiant, ~ 200 times diameter of the Sun, extending in size beyond the size of the Earth's orbit. ~20 solar masses, a dying star just a few million years from going supernova. To survive a central star like Deneb in its present condition, the Earth would need to be about 400 AU away.

61 Cyg - The faint star pair of 5th and 6th magnitude that Bessel used to measure stellar parallax. The coolest and least luminous binary pair visible to the naked eye. The pair take about 650 years to rotate around each other but what attracted them to Bessel's attention was that they were moving relative to the background stars and therefore he assumed they must be close. We now know that they are moving because they originated in the outer halo of our galaxy and are on an orbit crossing the galactic plane so their high speed of over 100 km s^{-1} is partly a coincidence. We know there are closer stars that aren't moving as quickly.

Albireo - β Cyg – A pretty spectacle. The eye of Cygnus the swan looks like a bright bluish star but is well worth a look through binoculars for you will see it is a binary combination of two stars about half a minute of arc apart, one of which is very clearly blue-hot and the other an orange K star. Their contrasting colours and visible separation emphasise their colours, like topaz and sapphire.

Vega - 2nd star of the summer triangle; an A0 dwarf, apparent magnitude 0, only 25.3 LY, the archetypical white star, surface temp 9600 K; 1.5 solar masses, comparatively young star 385 million years old it is surrounded by a disk of cool dust extending up to 70 AU from the star, about the size of our solar system if you include the inner part of the Kuiper belt.

Altair - 3rd star of the summer triangle, A7, 17 LY, rotating so fast it is conspicuously flattened, though not of course to the naked eye.

Arcturus - α Boö, the brightest star north of the celestial equator, an orange giant 25 times the Sun's diameter it would appear wider than your hand if viewed at the distance Earth is from the Sun. Even through it is 'only' at a temperature of 4300 K, you would still be frazzled at 1 AU because its luminosity is 215 times the Sun's. Instead of about 1400 W m^{-2} of radiation at the distance of the Earth, there would be about 250,000 W m^{-2}, furnace heat. Although it's only 1 billion years old, Arcturus has already used up all its hydrogen, not because it's less massive than the Sun but because it's more massive, about 2 solar masses. It's now converting helium to carbon and oxygen. Although not far from us at 37 LY, it's here by chance because its trajectory and composition put it as a star that originated outside the central galactic disk.

Spica - Archetypical 1st magnitude star, 262 LY, at first sight a close double of B class stars over 20,000 K, class B1 and B4, one of 9 solar masses and the other about 4 solar masses orbiting each other a distance apart equal to the sum of their diameters (0.12 AU, less than one third the distance of Mercury). There are two further B class stars in orbit, one at 4 AU and 40 AU, almost a planetary system except that each of the members is a full star and a hot, bright one at that. Spica lies close to the ecliptic.

Regulus - 78 LY; B7, 4.1 solar masses, 136 times luminosity of Sun. Lies close to the ecliptic too, which in Spring can be tracked between Regulus and Spica.

Procyon - 2nd star of the winter triangle. Unlike the summer triangle, which is composed of A class stars, the winter triangle shines with stars of three different classes; Procyon is an F5 hot star ~6500 K, 11.4 LY and like Sirius with a wobble due to a dim white dwarf companion. The companion is about as massive as the Sun but has a size nearer that of the Earth. As a result it has a density about 1 tonne per cc or a million tonnes m^{-3}. The Sun will end up like this, long after mankind has left the Earth.

Betelgeuse - 3rd star of the winter triangle. α Ori, M1 supergiant, ~450 LY, 650 times Sun's diameter and Betelgeuse would easily engulf the orbits of the Earth, Mars and Jupiter if it were as far away as the Sun. Size makes it luminous. If it were as hot as the Sun then it would be over 400,000 times as luminous but it is 'only' 55,000 times as luminous because it is a comparatively cool 3600 K. It was the first star to have its diameter measured directly and the first to be imaged as a tiny disk by the Hubble Space Telescope. It is one of the really massive stars visible to the naked eye, probably about 15 solar masses, close to the end of its life whereupon it will explode as a supernova, easily visible during the day. We don't really want a supernova much closer than this. The remnant will end up as a neutron star about 20 km across.

Sirius - 1st star of the winter triangle; brightest star in the sky, because it is both 23 times more luminous than the Sun and it is close (8.6 LY). A1 (9400 K), 2 solar masses. Observed to wobble against the background of distant stars because of a companion 10 magnitudes fainter, discovered in 1854. The white dwarf companion, Sirius B, has a surface temperature of 27,000 K but is so dim because its diameter is only about 8000 km (two-thirds of the Earth's).

One feature of the winter triangle is that there are no bright stars within it. Much of the area inside is in the faint constellation of Monoceros (the unicorn). However, hold up even a modest pair of binoculars to the winter triangle and you'll see a host of stars through them. This is because Monoceros includes a section of the Milky Way.

Rigel - B8 supergiant, M= -6.7; 1600 LY, ~60,000 luminosity of the Sun.

The belt of Orion 3 brilliant, young B class stars, very hot (at least 20,000 K), very luminous, stars whose light cuts through the haze and streetlights of a city sky in the winter. All 3 are in the region of 1000 LY distant, an impressive display of luminosity. All are at least 100,000 times as luminous as our Sun but much of their luminosity is in the UV, making them a serious health hazard for any prospective nearby life. They have masses at least 20 times that of the Sun but they'll use up this fuel in a few tens of millions of years. Live fast, die young - they haven't any choice in the matter.

Our meander has taken us around a selection of stars readily visible from our latitude, particularly stars visible in the autumn, winter and spring skies. It's too light in the summer months for real dark-sky viewing. With binoculars you can see some fine open clusters of stars. I'll mention 3, all nicely visible for most of the months of our dark skies. Also, turn your binoculars onto the most clearly visible region of the sky where stars are being born, the Orion Nebula.

M42 (the *Orion* Nebula), not far below the belt of Orion, looking like a distant headlamp in the sky through low power binoculars, a cloud of glowing gas, nursery for new stars, 1500 LY distant.

The **Beehive cluster** in Cancer – An impressive collection of stars appears in the field of view between Gemini and Leo, all about 520 LY distant. Cancer is a constellation with no bright stars.

Aldebaran and the Hyades – a conspicuous V shaped open cluster about 150 LY distant, the brightest member apparently in the cluster being Aldebaran, the eye of the bull Taurus. However, Aldebaran is only 65 LY away, closer than the cluster. It's a large K type cool star, 4100 K, 38 times the diameter of our Sun, 150 times the luminosity of the Sun and the 14^{th} brightest star in the sky.

The Pleiades - one of the most conspicuous sights in the sky. Sometimes called the 7 sisters, a more compact open cluster than the Hyades. The 6 particularly bright stars are blue-white B type stars over twice as hot as our Sun and several hundred times the Sun's luminosity. The whole group is young, about 100 million years, and passing through a dust cloud in our galaxy that is glowing with blue nebulosity, readily visible in a telescope. The Pleiades are 385 LY away.

There are many more interesting stars. With Kaler's book or an astronomy textbook and the *Stellarium* software, you can explore the sky on your own. The journey will last years.

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