The Nature and Lives of Stars

We are all familiar with the sight of stars in a clear night sky. But what are stars, and how did we come to understand how they tick?

Classifying Stars: Many early peoples thought stars to be "campfires of distant tribes in the sky", too far for mortals to reach and so "in the realm of Gods". Over the centuries superstition gradually gave way to scientific inquiry. Scientists first wanted to classify stars, based on what could be measured for them - their apparent brightness and colours. Colour could be quantified by measuring brightness through two different filters (say, blue and green) and subtracting. We know "white-hot" objects are hotter than "red-hot", and so colour is likely linked with the temperature of a star's surface. After Sir Isaac Newton (1642-1726) showed that sunlight (white to us) passing through a glass prism is spread into a rainbow of colours, it was seen that at particular colours there were "gaps" – these are ***Fraunhofer lines*** and are the fingerprints of chemical elements in the stars (named after Joseph von Fraunhofer who cataloged them). Astronomers soon saw these lines in starlight, too, confirming that stars are like our Sun, only much further away. They invented classes "A", "B", "C" and so on, based on these things, and over time this was revised into the Harvard Stellar Classification System, which goes (from the hottest to coolest stars), "OBAFGKM". This is easily remembered with the mnemonic, "Oh Be A Fine Girl/Guy, Kiss Me!"

To convert apparent brightness into how much light a star really emits (its "luminosity"), you need to know how far away it is. This can be measured with a technique called ***stellar parallax***. To illustrate this, hold up your finger at the end of your outstretched arm and look at a distant building alternately with your left and right eye; your finger shifts, and this shift can be converted into the length of your arm given the distance between your eyes. Similarly, since the Earth orbits the Sun, stellar observations six months apart will show tiny shifts that can also be converted into distances. This was first done in 1838 by Friedrich Bessel for the star 61 Cygni. By the 1900's many stars had both measured spectral types and luminosities. Alpha Centauri (a near-twin of the Sun) is 4.4 "light years" away and the closest star (a light year, "ly", is the distance light travels in a year). It takes 8 minutes for sunlight to reach us. Most stars we see in the night sky are dozens to thousands of ly distant.

The "H-R Diagram": In 1910, astronomers Ejnar Hertzsprung and Henry Norris Russell independently plotted spectral type versus luminosity for all stars then measured. They found that while most stars fell on a broad diagonal band ("the Main Sequence"), others fell into two groups of cool but luminous stars (which were reasoned to be enormous in size), and eventually still others would form a family of very hot stars that were very dim (and hence tiny).

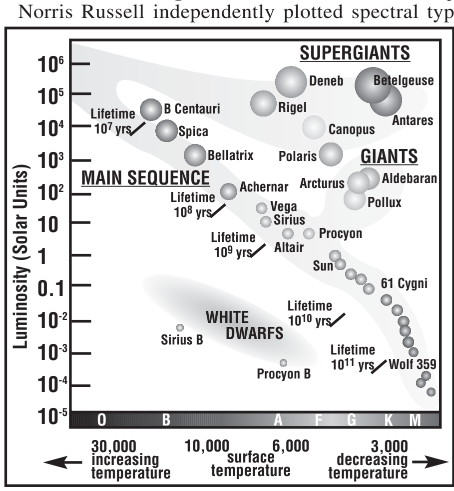


Illustration by: Shawn Martin

The "Hertzsprung-Russell" or ***H-R diagram*** is a basic tool in astronomy, and is useful when tracing how stars live out their lives and die.

The Sun, Our Star: Our Sun is a hot ball of hydrogen gas (with about 10% helium, and <1% other elements like oxygen, carbon and nitrogen), with a diameter of 1,400,000 km. In the early 20th century physicists worked out that ***nuclear fusion***, of hydrogen into helium, must occur in the heart of the Sun to hold itself up against the enormous force of its own gravity. A star is born in a giant interstellar cloud when gravity pulls the gas together in part of the cloud, until fusion "turns on" to stop the collapse. The "main sequence" is where a star lives most of its life burning hydrogen; stars there are called "dwarfs". The Sun is a type G dwarf, and it has a temperature of 5500 Kelvins (a Kelvin is the same size as a degree Celsius, so you could also say "5500 degrees C"). An "M dwarf" (also called a "red dwarf") is cooler (~3000 K), has one fifth the mass of the Sun, emits only a thousandth as much light, and is only a tenth the diameter. On the other end of the scale are supermassive O stars; these can be over 60 times the mass of the Sun, be very hot (~40,000K), emit a million times as much light, and be tens times the diameter of our Sun. The more massive a star, the faster it needs to burn hydrogen to hold itself up – somewhat like some movie stars, the brightest burn out the fastest! An O-star may live only a few million years, but an M-dwarf would take 100's of billions of years to die.

Stellar Life and Death, seen in the Winter Sky: The winter constellation Orion the Hunter is a good place to start when looking for real examples of stars at all stages of life. Below the three "belt stars" is Orion's "sword"; the middle star is fuzzy, and in binoculars or a small telescope is seen to be the "Orion Nebula", an ***emission nebula***. (French astronomer Charles Messier compiled a list of 110 "faint fuzzies" in the mid-19th century, and the Orion Nebula, #42, is also called "Messier 42" or just "M42"). This is a vast stellar nursery where stars are forming, about 1300 ly away. M42 contains hundreds of stars, but only a few truly massive ones, and one (in "The Trapezium") is a young, hot O-star emitting ultraviolet light which causes the whole nebula to fluoresce. Over time the gas in the nebula will be used-up or dispersed, and the stars will wander out of it (perhaps like teenagers). An example of what this might look like shortly after the gas is gone is the Pleiades, an ***open cluster*** (M45, about 440 ly away) west of Orion in Taurus the Bull. It looks like a tiny dipper, but don't confuse it with The Little Dipper constellation! The stars are still in a tight group, and there's still some dust. Another open cluster is the Hyades (150 ly away), a little closer to Orion and marked by bright Aldebaran (which is actually only 65 ly away).

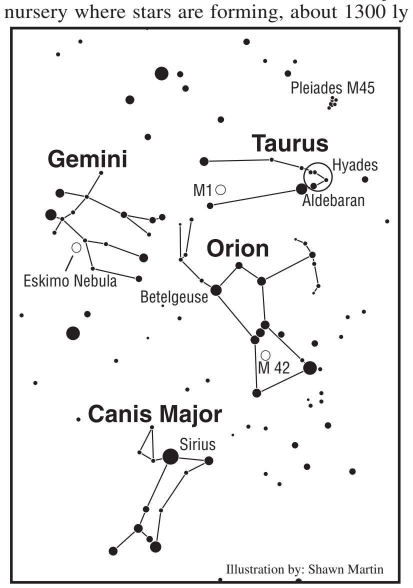


Illustration by: Shawn Martin

So what happens when a star dies? Let's consider the Sun. In about five billion years (thankfully!) its core will run out of hydrogen and start burning helium, and the Sun will expand into a "red giant" the size of the Earth's orbit. Its tenuous outer layers will float away in an expanding shell, while the dying Sun inside will collapse into an Earth-sized, very hot ember of mostly oxygen and carbon called a ***white dwarf***. The white dwarf's ultraviolet light lights up the shell, and someone many light years away would see a ***planetary nebula***. An example is the Eskimo Nebula, in Gemini above and east of Orion's "raised arm".

If a white dwarf is part of a binary and the other star then becomes a red giant, it may suck gas onto itself and increase in mass; when it reaches 1.4 solar masses, it will become unstable and explode as a ***type I supernova***. If you look east of Orion in Canis Major you will see the brightest star visible in the night sky, Sirius. Sirius is a type-A dwarf only 9 ly from us, which is one reason why it looks bright, and it's actually a double-star; the companion is a white dwarf, Sirius B, first directly observed by telescope maker Alvan Clark in 1862. Under excellent conditions and with a larger telescope, you just might be able to spot it, too. Sirius B may explode as a supernova when Sirius A evolves into a red giant, well into the future.

Supernovae are the principal way stars spread the chemical elements they've manufactured during their lives, especially when they occur in more massive stars. For a few days they're so bright we can see them in distant galaxies. A star 10 or more times more massive than the Sun will become a ***red supergiant*** when it starts burning helium, and swell to the size of Mars' orbit. Such a star has a different fate than the Sun. It's gravity can squeeze hard enough to cause fusion reactions making elements all the way up the Period Table to iron, which accumulates in the core. It is impossible to get energy by fusing iron, and when the star has exhausted other fuels and tries, it abruptly collapses in on itself, rebounding outward in a terrific explosion called a ***type II supernova***. The rebound can compress the core into a ***neutron star***. A famous example is "The Crab Nebula" (M1), 6000 ly away in Taurus, right above Orion's "head" about as far as the Belt is below it. A massive O or B stars exploded here about 950 years ago. At M1's centre and lighting it up is a rotating neutron star (a ***pulsar***) about the size of a large city, but 1-2 times the mass of the Sun; your atoms would be crushed into neutrons by its fierce gravity if you attempted to stand on it! The expanding cloud of debris is visible in a small telescope. Betelgeuse, the familiar bright orange star at the left shoulder of Orion, is a 15 solar mass red supergiant 600 ly away poised to explode as a type II supernova, but we hope no time soon! When the very largest stars explode, the remnant core may be too massive for any known force in Nature to hold it up; a ***black hole*** is created.

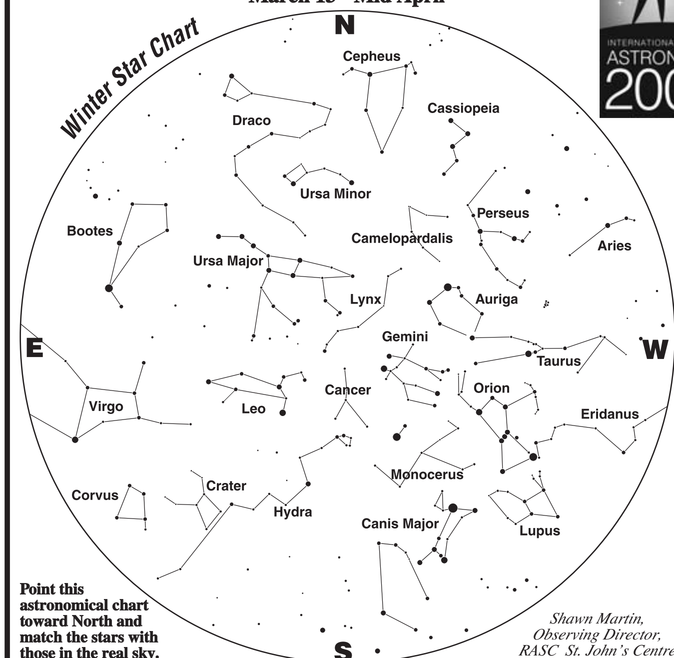
We are all made of elements forged in the nuclear fires of massive stars. It is empowering to be able to look up into the night sky and understand, at least a bit, how stars tick!

Chris Stevenson RASC, St. John's Centre

THE UNIVERSE
YOURS TO DISCOVER
INTERNATIONAL YEAR OF ASTRONOMY 2009

"What's Up"

March 13 - Mid April



Point this astronomical chart toward North and match the stars with those in the real sky.

Shawn Martin, Observing Director, RASC St. John's Centre

Planets

Viewable in a pair of Binoculars or small telescope

Venus (magnitude –4.8) is the dazzling "Evening Star" in the West, during and after twilight. Venus will be visible at both dusk and dawn on the same day for several days before and after March 25. This rare event occurs only once every eight years.

Jupiter, Mercury, and Mars (magnitudes –2.0, –0.2, and +1.2, respectively) are low in the early dawn sky just before sunrise (7:15 a.m.) The visibility of these objects will be during bright twilight; use binoculars for the best views. First spot Jupiter and scan to it's lower left where you will find Mars and Mercury.

Saturn (magnitude +0.5) is rising in the east-southeastern sky, and is well placed for viewing by 9:00 pm in the constellation Leo.

Uranus - is hidden behind the glow of the Sun.

Neptune - is deep in the glow of sunrise.

Pluto (dwarf planet) - is in the southeast before dawn.

Moon

Waxing	First Quarter	Full	Last Quarter	Waning	New
Mar. 31	April 2	April 9	Mar. 18	Mar. 20	Mar. 26

WARNING!" When using a telescope or binoculars, always be sure NEVER TO LOOK AT THE SUN! This can cause serious and permanent eye damage. To be safe, always make sure the Sun is fully set below the horizon before going outside with your telescope or binoculars."

ACTIVITIES

1. The above article contains information on the life cycle of stars. Using The Telegram find similar cycles.

2. The H-R Diagram above categorizes information into classifications. Are there examples of this in The Telegram?

3. Take your binoculars and try to find the objects described in this article. For some a telescope and dark skies outside of town might be better.

For more activities go to **www.thetelegram.com** and click on Our NIE Program