



Nearby Stars

{Abstract – In this segment of our video book, we take a look at our stellar neighborhood and how we know how far away these nearby stars are.

We cover the first stellar parallax measurement from the star Cygni 61. This includes the definition of ‘parsec’ and ‘light year’. We then cover the Alpha Centauri system (Proxima Centauri, Alpha Centauri A & B), and use it to show how we calculate the mass of binary star systems. Then we examine our stellar neighborhood including: Barnard’s Star with its Proper Motion, Wolf 359, Lalande 21185, Sirius A & B, 61 Cygni, Altair, Fomalhaut with its planet, and Vega.

A deeper look into what we mean by ‘luminosity’ is outlined. We point out that it is measured in watts just like a light bulb and that its value over distance from a point source follows the ‘inverse square law’. We use our Sun as an example and introduce Einstein’s famous “energy = mass time the speed of light squared” formula.

We then cover some more stars including: Pollux, Arcturus, Capella, and Castor. Having reached the limits of ground based telescopes to measure parallax, we discuss the European Space Agency’s (ESA) Hipparcos satellite and the more distant stars it helped find parallax for including: HD 189733, Aldebaran, Mizar, Spica, Mira, Polaris, and Antares. Along the way, we build the mass vs. luminosity empirical graph.

We then cover the new ESA satellite Gaia that is mapping over a billion stars in the Milky Way and nearby galaxies. We follow that with a look at a few stars too far for Hipparcos but well within the range of Gaia: Betelgeuse, CH Cyg, and Rigel.

We end by pointing out that parallax only takes us to a small percentage of stars in the Milky Way and that we’ll need to know more about light to go any further. }

Introduction

Twinkle twinkle little star. I imagine that hundreds of thousands of generations have wondered what they are.

[Music: “Twinkle twinkle little star”: This children’s music asks the ancient question “what are stars?” This is the very question we will attempt to answer in this video book segment.]

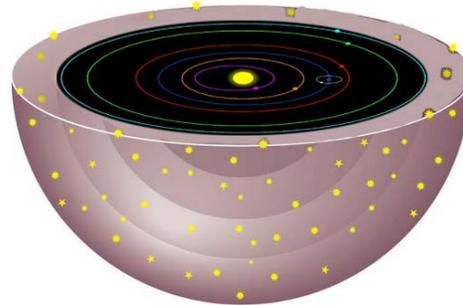
Here I am again in my back yard, looking at the Big Dipper. On a clear dark night, I can see around a thousand stars. For the longest time, it was not known whether stars like these shined by their own light,



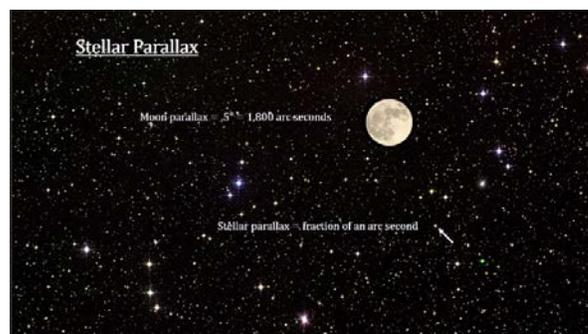
or whether they were reflecting the Sun’s light, as all the planets, moons, comets, and asteroids do. It’s only in the last couple of generations that we have finally reached a point where we know what stars are.



You'll recall that Copernicus first proposed a Sun centric model for the solar system. But you'll note that the outermost celestial sphere did not go away with the Copernican model. Parallax measurements showed us that the Sun was at the center of our planetary system. But no one could find any parallax in the stars – not Tycho Brahe, not Kepler, not Galileo, not even Newton.

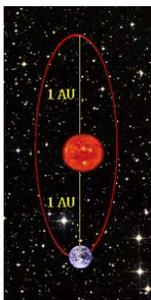


The reason it took so long is that stars are so far away, that parallax angles are just too small for the available instruments. Remember that the moon's parallax was $\frac{1}{2}$ of a degree. But star parallax is measured in fractions of an arc second. [That's why it took over 300 years of trial and error after Copernicus, before it became possible to measure these small angles.]



First Stellar Parallax

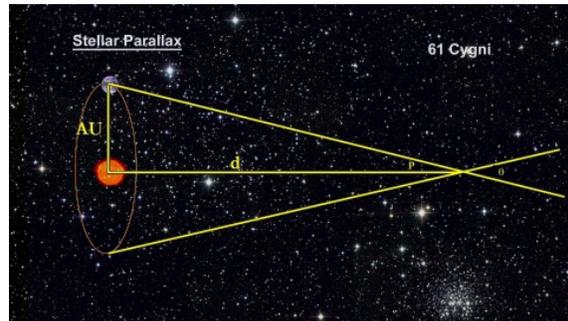
[**Music:** *Tchaikovsky - Symphony No 6, Pathétique IV Finale. Prague Festival Orchestra; from "Must-Have Adagio Masterpieces"*]



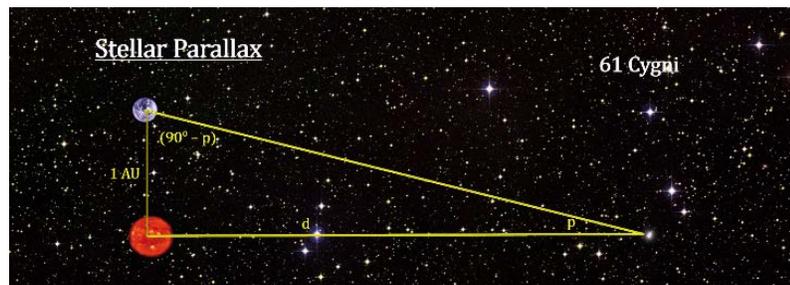
In the 1830s, there was a race to see who could find the first real stellar parallax. The astronomer Fredrich Bessel won. The star was 61 Cygni. Here's how it works. If you recall, the maximum baseline for parallax measurement for planets was the diameter of the Earth. For stellar parallax, we have the diameter of the Earth's orbit around the Sun. That's an increase from around 13 thousand km (or 8 thousand miles) to 300 million km (or 186 million miles). That's 23 thousand times larger.



So from one side of the earth's orbit (say in July) we take a line to the star, and map the positions of the more distant stars. Six months later in January, we repeat the process. This gives us the angle θ . We define stellar parallax as $\frac{1}{2}$ this angle. This would be the angle at the star with the Earth and the Sun marking the other two corners of a right triangle. The math is the same trigonometry we used for finding distances to the rock in my back yard and to the planets in our solar system.



Of course this is an oversimplification. Fredrich Bessel mapped 61 Cygni against the distant star background for 28 years observing the star's ellipses that followed the earth's orbit. In 1838, after thousands of measurements and calculations, he made scientific headlines by announcing that the parallax of 61 Cygni was 0.314 arcseconds. That gives us a distance of 98 trillion km – that's 61 trillion miles. [That's over 6 hundred thousand times further from the sun than we are.] Why too far to be reflecting the Sun's light. So, at this point, in the middle of the 19th century, we knew that stars burned with their own light.



Let

d = distance to 61 Cygni
 p = measured parallax
 = 0.314"
 = 0.0000872 degrees

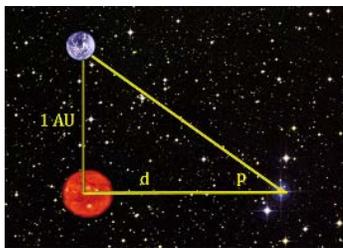
We have

$d = (1 \text{ AU}) \tan(90^\circ - p)$
 $= (150 \times 10^6 \text{ km}) \tan(90 - 0.0000872)$
 $= (150 \times 10^6) (6.57 \times 10^{-5}) \text{ km}$
 $= 98.6 \times 10^{12} \text{ km}$
 $= 61.3 \times 10^{12} \text{ miles}$



Parsec

If we were to move in a little closer to a star that had a parallax of exactly 1 second of arc, we'd find it to be 31 trillion km away (that's 19 trillion miles). This distance is called a Parsec. It gets its name from the first syllable of 'parallax' and the first syllable of 'second'. Astronomers like to use it for measuring distances to stars. If you're a Star Trek fan, you'll hear parsecs used a lot in their distance discussions.



Parsec

Let $p = 1$ second of arc
 $= 0.000278$ degrees

In parsecs

Then $d = (1 \text{ AU}) \tan(90^\circ - p)$
 $= (150 \times 10^6 \text{ km}) \tan(90 - 0.000278)$
 $= (150 \times 10^6) (2.06 \times 10^5) \text{ km}$
 $= 30.9 \times 10^{12} \text{ km}$
 $= 19.2 \times 10^{12} \text{ miles}$
 $= 1 \text{ parsec}$

$$d = 1/p$$

Light Year

As we discussed in our segment on the Solar System, light travels at 300,000 km/s (or 186,000 miles per second).

To calculate how far light travels in a year, we multiply this number by the seconds in a minute; the minutes in an hour; the hours in a day; and the number of days in a year. That totals 9.461 trillion km (or 5.88 trillion miles). We call that 1 light year. So 1 parsec is just over 3 and a quarter light years [equal to 3.26 light years]. I'll use light years throughout this video book, but parsecs will come up from time to time.

Let $c = \text{speed of light}$
 $= 300,000 \text{ km/s}$
 $= 186,000 \text{ miles/s}$

Then $1 \text{ light year} = c \times 60 \times 60 \times 24 \times 365$
 $= 9.461 \text{ trillion km}$
 $= 5.88 \text{ trillion miles}$

And $1 \text{ parsec} = 3.27 \text{ light years}$

Stellar neighborhood

Let's take a look at some of the stars in our neighborhood - out to around 25 light years. That's about as far as stellar parallax measurements from ground based telescopes can take us.



★ Proxima Centauri – $p = 0.768$ (4.25 light-years)

Proxima Centauri is a dim red star. It is the nearest known star to the Sun and thought to be a third member of the Alpha Centauri system. Here's a recent photo of the star taken by Hubble. Although it looks bright through the eye of Hubble, Proxima Centauri is not visible to the naked eye. Its average luminosity is very low, and it is quite small compared to other stars, at only about an eighth of the mass of the Sun. Astronomers predict that this star will remain for another four trillion years, a thousand times longer than our Sun.

[**Note:** However, on occasion, its brightness increases. Proxima is what is known as a “flare star”, meaning that convection processes within the star’s body make it prone to random and dramatic changes in brightness. The convection processes not only trigger brilliant bursts of starlight but, combined with other factors, indicated that Proxima Centauri is in for a very long life.]

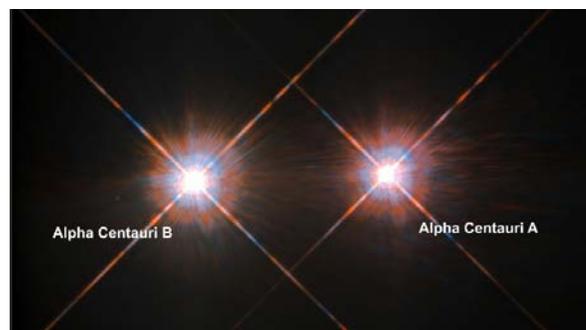


★ Alpha Centauri – $p = 0.755$ (4.37 light-years)

Alpha Centauri A and B form a close binary system that is separated "on average" by a distance slightly greater than the distance between Uranus and the Sun. A, the main star, is bright and yellowish. B is not quite as bright and has an orange tinge.

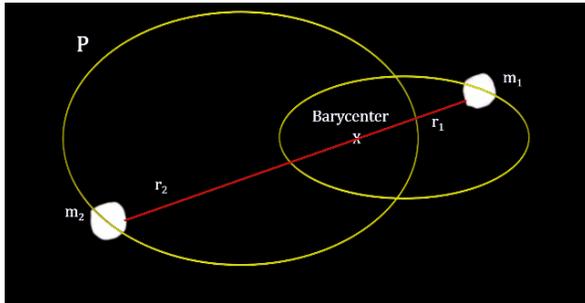
Mass of a star

Here's a recent photograph of the Alpha Centauri binary system take by Hubble. It turns out that half of all stars are actually binary systems like this one. It is the orbital motion of these kinds of stars that enabled us to measure stellar mass - just like we calculated the mass of the Sun by the motion of the planets around it.





These stars orbit the system's center of gravity (called the barycenter). We can observe the distance between the stars and locate the barycenter as the center of their elliptical motion. We can also observe the length of time it takes to make a full orbit (its Period). This, along with Newton's and Kepler's laws is all we need.



Let

P = orbital period

$r = r_1 + r_2$

$m = m_1 + m_2$

G = gravitational constant

We have

$$m = 4\pi^2 r^3 / GT^2$$

$$m_1 = m(r - r_1) / r$$

Careful observations of Alpha Centauri, show that the distance between the two stars is just under 24 times the distance from the Earth to the Sun, with A's distance to the barycenter being a little less than half of that. In addition, we see that the orbital period is almost 80 years. This gives us the mass of A at just over the mass of the Sun, and the mass of B at just under the mass of the sun.

For Alpha Centauri

$P = 79.92$ years

$r = 23.7$ AU

$r_1 = 11.2$ AU

$G = 6.67 \times 10^{-11} \text{ m}^3\text{kg}^{-1}\text{s}^{-2}$

We have

$$m = 4\pi^2 r^3 / GT^2$$

$$= 4.17 \times 10^{30} \text{ kg}$$

$$m_1 = m(r - r_1) / r$$

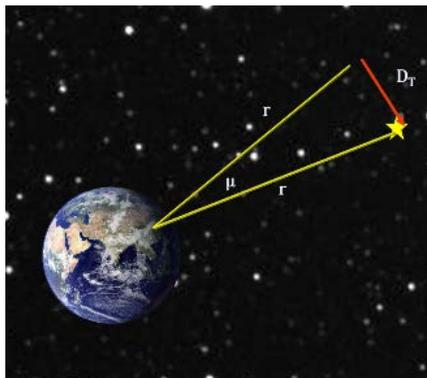
$$= 2.2 \times 10^{30} \text{ kg} = 1.10 M_{\text{sun}}$$

$$m_2 = m - m_1$$

$$= 1.97 \times 10^{30} \text{ kg} = 0.99 M_{\text{sun}}$$

Star Motion

For the most part, the position of stars is virtually identical from century to century. But a very small number of relatively nearby stars show dramatic motion across the sky. This is called **Proper Motion**. Its magnitude can be measured using the number of degrees moved and the distance to the star.



Let

μ = proper motion in arcseconds

p = stars parallax

r = distance to star

D_T = tangential distance traveled

V_T = tangential velocity

t = time

We have

$$\mu / 360^\circ = D_T / 2\pi r$$

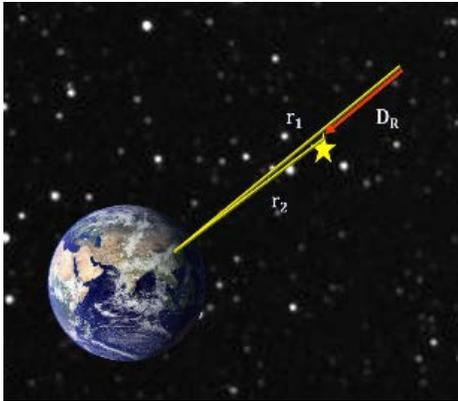
$$D_T = 2\pi r \mu / 360^\circ$$

$$V_T = D_T / t = 2\pi r \mu / (pt 360^\circ)$$

$$V_T = 4.74 \mu / p \text{ in km/s}$$



Motion towards us or away from us is called **radial motion**. We define it as positive if the star is moving away and negative if it is moving closer. For nearby stars this motion can be detected by using parallax techniques.



Let

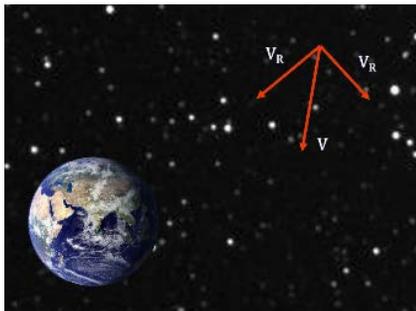
- p_1 = stars parallax at time 1
- p_2 = stars parallax at time 2
- r_1 = distance to star at time 1
- r_2 = distance to star at time 2
- D_R = radial distance traveled
- V_R = radial velocity
- t = time

We have

$$D_R = r_2 - r_1 = 1/p_2 - 1/p_1$$

$$V_R = (r_2 - r_1)/t$$

With these two numbers, the total star motion with respect to the sun can be calculated using the Pythagorean Theorem.



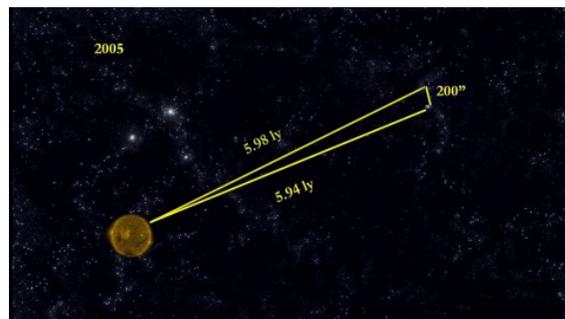
$$V = (V_R^2 + V_R^2)^{1/2}$$



Barnard's Star – Parallax = 0.545 (5.94 light years)

For example, here's Barnard's Star. It's a dim red star with significant proper and radial motion. It's moving so fast that it's called a "runaway" star.

Here's a look at Barnard's Star photographed in 1985. Its parallax measurement indicates that its distance is 5.98 light years. In this second photograph, taken 20 years later in 2005, we see that the star has moved 200 arc seconds across the sky. That's 10" of arch across the sky per year. This is its Proper Motion. Its new distance is 5.94 light years which gives us its radial motion.





Combined, we get the full motion of the star with respect to the Sun. It moves 19.1 billion km each year. (That's 11.9 billion miles). So you can see why it is called a runaway star. In fact, Barnard's Star is approaching us so rapidly that around 11,700 AD, it will be 3.8 light years from the Sun - and that will make **it** the closest star to our own!

<u>Proper Motion</u>	<u>Radial Motion</u>	<u>Star Motion</u>
$V_T = 4.74 \mu/p$ in km/s = $4.74 \times 10 / 0.546$ = 86.8 km/s = 2.74 billion km/year	$V_R = r_1 - r_2 / t$ = 0.04 ly / 20 years = 18.9 billion km/year	$V_{Star} = (V_T^2 + V_R^2)^{1/2}$ = $(2.74^2 + 18.9^2)^{1/2}$ = 19.1 billion km/year = 11.9 billion miles/year

[**Music:** *Mozart -Concerto for 2 pianos & orchestra in E flat major*
 (_Concerto No_ 10_), K_ 365 (K_ 316a) _ 3_ Rondeau_ Allegro; from
 "Amadeus" CD]

 **Wolf 359 - Parallax = 0.415 (7.86 light years)**

Getting back to nearby stars, here's Wolf 359. It is another dim red star. In fact, it's one of the least luminous stars known.

Star Trek fans may recognize Wolf 359 as the scene of a great battle between the Federation and The Borg.

 **Lalande 21185 - Parallax = 0.393 (8.31 light years)**

Lalande 21185 is another dime red star. Recent analysis indicates that it may also be accompanied by at least two orbiting planets. One was confirmed in 2017. The search for planes around other stars (called Exoplanets) is a major focus these days and research is ongoing.

 **Sirius A & B - Parallax = 0.379 (8.60 light-years)**

This Hubble Space Telescope image shows a white Sirius A, the brightest star in our nighttime sky, along with its faint, white tiny stellar companion, Sirius B. The two stars revolve around each other every 50 years.

[**Additional info:** Astronomers overexposed the image of Sirius A so that the dim Sirius B [tiny dot at lower left] could be seen.]



★ 61-Cygni – Parallax = 0.286 (11.4 light years)

Here we have our first parallax star, 61 Cygni again. Modern measurements place the star at 11.36 light-years distant. So Bessel's calculation of 10.4 light years was pretty close. 61 Cygni has another claim to fame in that it was first noted to have a high proper motion as early as 1792, when it got the nickname "Flying Star". To add further to its uniqueness, in 1830 61-Cygni was determined to be a binary star system with two orange stars.

★ Altair - Parallax = 0.295 (16.7 light-years)

Altair is a bright white star. A recent study revealed that Altair is not spherical, but is flattened at the poles due to a very high rate of rotation.

★ Vega - Parallax = 0.130 (25.0 - light-years)

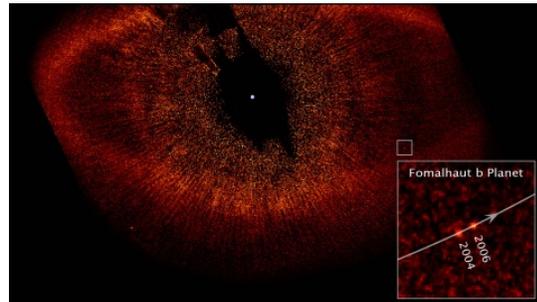
Vega is a bright white star and one of the most luminous stars in the Sun's neighborhood. It has been extensively studied. It was the first star to be photographed by astronomers in 1850.

It was the northern pole star around 12,000 BC and will be so again around AD 13,727.

Fomalhaut - Parallax = 0.130 (25.1 light-years)

This image of Fomalhaut surrounded by a ring of debris was taken by Hubble.

The white dot in the center of the image marks the star's location. It's a bright white star, but the region around it is black because astronomers used the Advanced Camera's capabilities to block out the star's bright glare so that a dim planet called Fomalhaut b could be seen. The small white box, at the lower right, pinpoints the planet's location.



These observations offer insights into our solar system's formative years, when the planets played a game of demolition derby.

Luminosity

So far, we've identified Wolf 359 as one of the least luminous stars in our neighborhood and Vega as one of the most luminous, but we haven't been explicit as to what we mean by luminous.



Stars have a wide range of apparent brightness as measured here on Earth. The variation in apparent star brightness is caused by two things:

- 1) Stars have different intrinsic luminosity.
- 2) Stars are located at different distances from us.

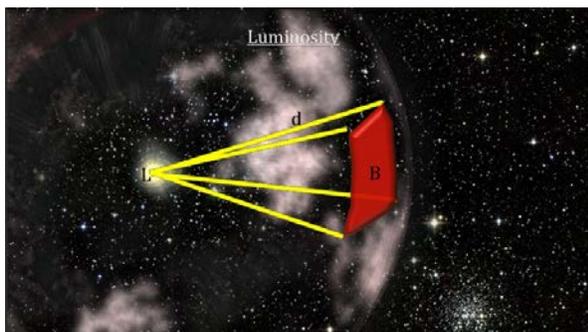
An intrinsically faint, nearby star can appear to be just as bright to us on Earth as an intrinsically luminous, distant star.



Luminosity is what we use to put precise measurements on the idea of brightness. It measures the total amount of electromagnetic energy emitted by a star in watts (just like a light bulb). Apparent brightness is measured in watts/m².

[Additional info: For stars, the area we use is the area of the telescope's lens.]

Because light from stars spreads out over the surface area of a sphere, we can use the inverse square law to categorize luminosity for all the stars that have parallax distance information.



Let

d = distance to the source
 L = luminosity of source in watts
 B = brightness in W/m²

We have

$$L = 4\pi d^2 B$$

Take the Sun for example. The apparent brightness of the Sun, as measured in my back yard, is 1400 watts per square meter. If my backyard solar cells were 100% efficient, that's how much electricity each panel would create. Unfortunately, current technology is only 15% efficient, so I'm only getting around 200 Watts per panel.



Plugging our distance to the sun into the inverse square law, we calculate its total luminosity. Here you can see that the answer is a very big number.



Let

d = distance to the source

L = luminosity of source in watts

B = brightness in W/m^2

We have

$$L = 4\pi d^2 B$$

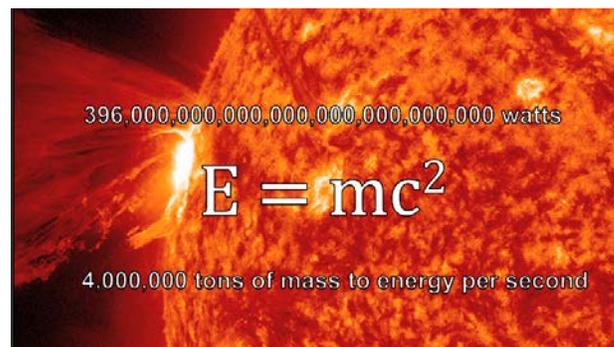
Using Einstein's famous $E = mc^2$, or Energy = mass time the speed of light squared we calculate that the Sun is fusing 600 million tons/sec of Hydrogen in to Helium, and in the process converting 400 million tons/sec of matter into energy.

To put this into perspective, this number is equivalent to around 4 billion Hydrogen bombs exploding per second!

[Additional info: Luckily for us, the Sun has enough mass to keep this process going for another 10 billion years!

The apparent brightness from stars is a tiny fraction of what we get from the Sun. But modern instruments are very good at measuring it very precisely. The equation to determine the intrinsic luminosity is the same. For Vega, the measured luminosity at 25 light years gives us the luminosity for the star at 40 times the Sun's power.

For the Sun and for Vega, and for all the stars we have seen so far, we know the apparent brightness and distance to the star via parallax. The inverse square law gives us the intrinsic luminosity. If we know the intrinsic luminosity and apparent brightness, the same equation gives us the distance. In other words, if we know the luminosity of a star, we can calculate its distance. This is the basic concept around 'Standard Candles'. We'll discuss this a little more in a few minutes.] Astronomers use a more complex set of classifications for calculating brightness called Magnitudes and absolute magnitudes at 10 parsecs. But, for our purposes, we'll stick to Luminosity.





 **Pollux – Parallax = 0.098 – (33.8 light years)**

Getting back to stars, here's Pollux, a bright orange star. In 2006, it was confirmed to have an orbiting planet.

 **Arcturus – Parallax = 0.089 (36.7 light years)**

Arcturus is an even brighter orange star. In fact, it is the fourth most luminous star in the Sun's neighborhood.

 **Capella – Parallax = 0.076 (42.9 light-years)**

Capella has a rich yellow color and is the third brightest star in the northern hemisphere, after Arcturus and Vega. Closer examination finds that Capella is actually four stars organized as two binary systems.

 **GJ1214 – Parallax = 0.069 (47.5 light-years)**

GJ1214 is a dim reddish star. Observations by Hubble in 2009 discovered GJ1214 b, a water-world planet enshrouded by a thick, steamy water rich atmosphere.]

 **Castor – Parallax = 0.064 (51.0 light years)**

Castor is actually three sets of binary systems with some bright yellow and some dim red stars.

Hipparcos

Since 1838, many astronomers have spent decades measuring star parallaxes, but the work is so painstaking that up until 1989, only a few hundred were measured. That's out of a total population of over 1,500 stars within 60 light years from us.

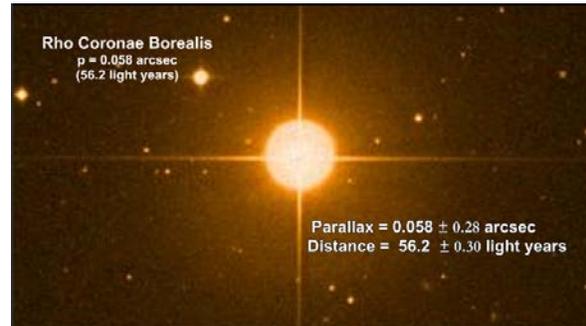
In 1989, however, the European Space Agency launched a spacecraft called **Hipparcos**. It was specially designed to accurately measure parallaxes without all the interference from the Earth's atmosphere. It did so for over 118,000 stars.





Astronomers go to considerable lengths to analyze how much error is introduced into their measurements by the instruments they use. You often see distances followed by a plus and minus error amount like this one for Rho Coronae Borealis 56 light years away. Hipparcos is accurate to within 5% to 10% for stars up to 650 light years away. We'll simply list the baseline distance for each celestial object throughout this video book, but applying an error in this range to each of them should be understood.

Let's take a look at a few of these.



[Music: Puccini - Manon Lescaut - Donna non vidi mai - I have never seen a woman like this; Sofia Philharmonic Orchestra; from album "100 Must-Have Opera Karaoke"]

★ HD 189733 – Parallax = 0.051 (63.4 light years)

HD 189733 is a binary star system with the primary star being a dim orange star and the secondary star being a dim red star. As we zoom into the star, you can see the Dumbbell planetary Nebula. We'll cover these objects in the next section.

Hubble has made the first detection ever of an organic molecule in the atmosphere of a Jupiter-sized planet orbiting this star. The molecule is methane. Under the right circumstances methane can play a key role in prebiotic chemistry — the chemical reactions considered necessary to form life as we know it.

★ Aldebaran – Parallax = 0.050 (65.3 light years)

Aldebaran is a very bright red star. It may have a Brown dwarf companion. A brown dwarf is a star that did not have enough mass to trigger fusion, so it only produces light via conventional means. This makes it very hard to see.

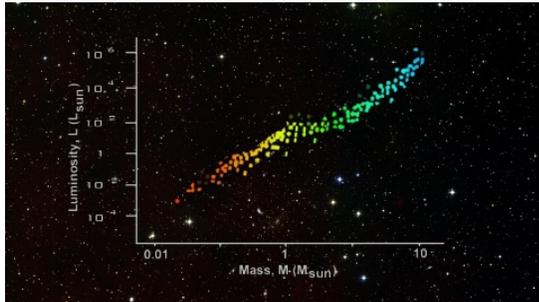
★ Mizar – Parallax = 0.039 (82.9 light years)

Mizar is a bright white star. It is famous for being the first binary star system discovered. Galileo studied it extensively. These two stars take thousands of years to revolve around each other, so they were not seen to be rotating around each other in those days. It wasn't until the early 1800s, that binary stars rotating around each other were seen. This was the first evidence that gravitational influences existed outside our solar system.



Star Mass vs Luminosity

Once the mass of enough binary stars were calculated, it became possible to plot Mass vs. Luminosity on a graph. Here’s what they found.



Instead of having any combination of mass and luminosity, we see that stars fall on a line from low-mass / low-luminosity to high-mass / high luminosity. But it is not linear. Each time the mass is doubled, the luminosity goes up 11 times. This relationship seems to work for most stars that aren’t too massive.

Mass vs. Luminosity

Let: M = Mass of the star
 M_{sun} = Mass of the Sun
 L = Luminosity of the star
 L_{sun} = Luminosity of the Sun

We fit the graph with:

$$L/L_{\text{sun}} = a(M/M_{\text{sun}})^b$$

Where:

$a = .23$ and $b = 2.3$ when $M < .43M_{\text{sun}}$
 $a = 1$ and $b = 4$ when $.43M_{\text{sun}} < M < 2M_{\text{sun}}$
 $a = 1.5$ and $b = 3.5$ when $2M_{\text{sun}} < M < 20M_{\text{sun}}$
 $a = 1$ and $b = 1$ when $20M_{\text{sun}} < M$

Note that this is an empirical relationship. We don’t start with an equation and plot its graph. We observe events to create the graph and then find an equation that would have created a graph that looks the same or ‘fits’ what we observed.

Now back to the stars again.

[Music: Schubert - The Trout from album “A Calendar of Classics - A 12 CD Set Of Romantic Classics For Every Month Of The Yea”]



Spica – Parallax = 0.031 (250 light years)

Spica is a blue star and the 15th brightest star in the nighttime sky. It's a close binary star system whose components orbit each other every four days. They are so close together that they cannot be resolved as individual stars through a telescope.

Mira – Parallax = 0.011 (300 light-years)

Mira is a very high proper motion red star that is shedding an enormous trail of material. The tail stretches a startling 13 light-years across the sky. It has released enough material over the past 30,000 years to seed at least 3,000 Earth-sized planets.



[Additional info: It is zipping along at 468,000 km/hour (291,000 miles per hour). This creates the bow shock, in front of the star. This is similar to the one we saw our Sun creating in our section on the Heliosphere. Mira is also what's called a pulsating variable star. It dims and brightens by a factor of 1,500 every 332 days. Sometimes it is even bright enough to see with the naked eye.]



Polaris Parallax = 0.0075 (433 light years)

Polaris is our current day 'North Star', for it lies less than 1.0° from the north celestial pole. It is a double star system with one being a supergiant. The supergiant is a classic Cepheid variable star. Cepheids are a critically important kind of star for our distance ladder. I'll talk more about them in a minute when we come to Delta Cephei – the first Cepheid star completely analyzed.



Antares Parallax = 0.0059 (550 light years)

Antares is a bright red star - the sixteenth brightest star in the nighttime sky. The size of Antares has been calculated using its parallax and angular diameter. Its radius is 822 times larger than our Sun's.

Gaia

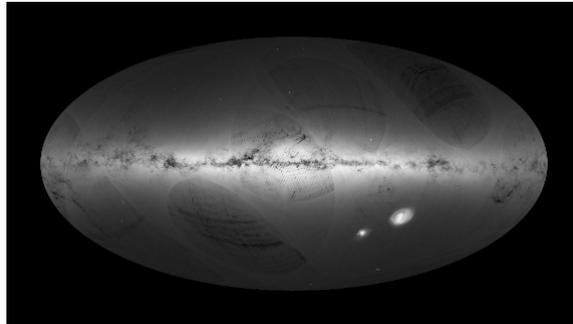
Gaia is an ambitious mission to chart a three-dimensional map of our Galaxy. It will provide unprecedented positional and radial velocity measurements [with the accuracies needed to produce a stereoscopic and kinematic census] for around a billion stars. Hipparcos recorded parallax information for 118,000 stars out to 650 light years. Gaia will do between 10 and 100 times better than that depending on the brightness of the star.

	Hipparcos	Gaia
Orbit	Earth	L2 Lagrange Point
Parallax accurate to	0.005 arcsec	0.00005 arcsec*
Distance	650 ly	650 to 65000 ly*
Number of stars	118,000	1,100,000 to 1 billion

* Better for brighter stars



In 2016, Gaia produced the most detailed 3D map ever made of our Milky Way galaxy. It has pinned down the brightness and precise position on the sky of 1 billion, 142 million stars. This data release also includes the distances and the motions across the sky for more than two million stars. This map shows the density of stars observed by Gaia in each portion of the sky. Brighter regions indicate denser concentrations of stars, while darker regions correspond to patches of the sky where fewer stars are observed. The dark lines are artifacts of the collection process. They will disappear once more data has been collected.



Now, let's take a look at a few stars too far for Hipparcos, but well within the range of Gaia.

★ Betelgeuse – Parallax = 0.0045 (724 light-years)

Betelgeuse is a very rich reddish cool supergiant star. It is also one of the largest and most luminous stars known. If it were at the center of the Solar System, its surface would extend past the orbit of Jupiter.

[**Additional info:** Betelgeuse is also a runaway observed racing through the interstellar medium at a supersonic speed of 30 km/s (18 miles/sec), creating a bow shock over 4 light-years wide. It's expected to end as a supernova within the next million years.]

★ CH Cyg Parallax = 0.0041 (800 light years)

CH Cyg is a "symbiotic" star system in which a white dwarf feeds from the wind of a companion red giant star.

★ Rigel – Parallax = 0.0038 (860 light years)

Rigel is the sixth brightest star in the sky. Since 1943, this star has served as one of the stable anchor points by which other stars are classified.

[**Additional info:** The star is actually a triple star system. The primary star (Rigel A) is a blue-white supergiant around 117,000 times as luminous as our sun. Rigel B is itself a binary system.]

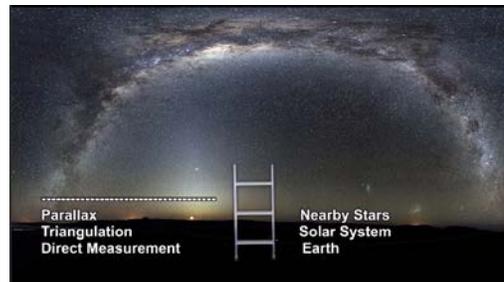


Nearby Stars Summary

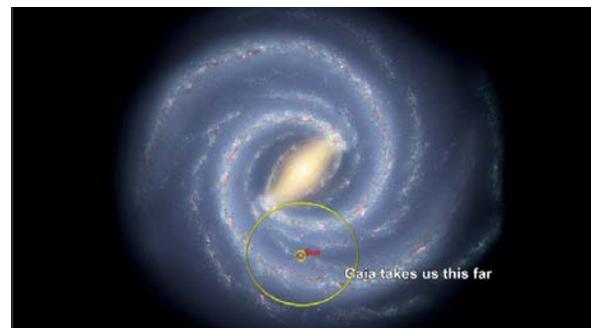
We have now visited a number of stars from our local neighborhood. We started with the nearest stars where parallax measurements from earth bound telescopes were good enough. We then moved out to the further reaches of our neighborhood using Hipparcos based parallax measurements. And we went even further with Gaia.



In our segment on the Solar System, we extended the direct measurement and triangulation to include parallax for the planets. This segment covered how we measured stellar distance, mass, luminosity and motion – all based on parallax techniques – just like we did for the solar system. And thanks to the Hipparcos and Gaia satellites, we know the parallax for hundreds of thousands of stars which are relatively close to the Sun. So we can add stars to the reach of the parallax rung on our cosmic distance ladder.



But, if all we had was parallax, we'd know very little about our galaxy and virtually nothing about the universe beyond. But the only thing we can get from a star is its light.



How Far Away Is It – Nearby Stars



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