Distance to the Stars

The importance of star distances

The distance to the stars is one of the most important elements in the science of astronomy. Just about everything we know (or think we know) about the stars has distance as its foundation. Without a valid yardstick for measuring their remoteness, our knowledge of the universe would be severely limited. In the following I am going to try to convince you that ***everything we thought we knew about star distances is wrong, and that the stars are much nearer than we thought—as near as 0.05 light years for the nearest***. Please read all of it***. You will be amazed—I guarantee it!***

The Magnitude System

Each star observed from the earth has a characteristic brightness related to the amount of light it radiates and its distance. The luminosity of stars is measured in various ways and is classified according to a relative magnitude system.

The apparent magnitude (m) of a star is the observed brightness as measured from photographic plates, by electronic means, or estimated visually by comparison with other stars. The magnitude system is confusing to many, but is simply an ancient convention which has been improved on, but not discarded, in modern times. The original system was devised by the early Greeks as a means of classifying the relative radiance of stars visible to the naked eye. The 20 brightest stars in the sky were classified as first magnitude stars—in the magnitude scale m = 1. Stars about two and a half times fainter were classified as second magnitude, and so on. Stars at the limit of visibility for the naked eye were classified as sixth magnitude (m = 6). There are about six thousand stars visible to the unaided eye in the Northern and Southern hemisphere combined.

With the invention of the telescope, many more stars could be observed and it became necessary to expand the classification to accommodate images fainter than those that could be seen with the naked eye. The Hubble telescope is capable of detecting extremely faint objects with an apparent magnitude of 30 (m =30). The magnitude system was also expanded to include very bright objects, which are assigned negative magnitude values, indicating that they are brighter than the 20 brightest stars. For example, the apparent magnitude of the planet Venus at its brightest is about m = -4.4 and that of the sun m = -27.

The apparent magnitude of stars is a useful tool for cataloging and referencing stars, but by itself is of limited value. Brightness as observed from earth provides only part of the information needed to understand a star. Without more information it is impossible to tell if a star is very dim and very close, or very bright and very far away. If two stars appear to be equally bright, it is impossible to tell from their observed radiance alone if they are indeed equally brilliant, or at different brightnesses but at different distances. So a more valuable classification method would eliminate the effect of distance and allow direct comparison.

Astronomers use a variation of the apparent magnitude system to classify the relative brightness of stars. This classification is absolute magnitude (M). The absolute magnitude of a star is the *apparent* magnitude it would appear to have if it were brought to a standard distance from the earth. This standard distance is 32.6 light years, or 10 parsecs (parallax second). For example, if the sun were 10 parsecs away it would appear to the naked eye to be a fairly dim star with an apparent magnitude of 4.7, and therefore the absolute magnitude of the sun is 4.7. The virtue of this system is that it eliminates the distance factor and can be used for comparison of the actual luminosity of a star with any other star whose absolute magnitude is known.

The inverse square law provides the relationship between apparent magnitude (m), absolute magnitude (M) and distance (D) measured in parsecs as follows:

$$(m - M) = 5 \log D - 5$$

The expression (m – M) is called the distance modulus. If any two variables are known, the third can be determined from the equation. In practice the apparent magnitude can be determined easily from photographs and has been measured accurately for over a million stars. Distance can be determined to calculate the absolute magnitude for any star, or absolute magnitude can be determined to find the distance.

The measurement of absolute magnitude and distance for a large number of stars has been a major effort for astronomers for over a century. The details of this endeavor and the techniques employed are too lengthy to cover here, and may be found in any source book on astronomy. The methods include spectroscopic analysis of stars or star clusters, proper motion studies of star clusters, statistical parallaxes, interstellar absorption, interstellar spectral lines, galactic rotation, nova parallaxes, period/luminosity relationship of Cepheid and RR Lyra variable stars, pulsation parallaxes of Cepheid variables, and calcium emission. The distances and absolute magnitude of thousands of stars have been determined and cataloged by one or more of these procedures.

Calibrating the Measurements

All of the techniques mentioned above have one characteristic in common: they are *indirect* methods of measurements. That is, none directly measures distance or absolute magnitude, but instead obtain data on certain features of stars that can be correlated with one of the variables. To provide meaningful results, each technique must be “calibrated” against the results of some known direct measurement.

The calibration of all these process for determining distance or absolute magnitude has been a lengthy and delicate process, often involving readjustments as refinements were made to one or more methods. In effect, these various measurement tools of the astronomer are a balanced system, finely tuned as a group to give consistent results over a wide range of applications.

The ultimate calibration of these indirect measurement techniques is found in the *direct* measurements which are available. Unfortunately there is only one direct measurement which can be made—trigonometric parallax—the measurement of distances to nearby stars by triangulation.

The Surveyor's Method

Surveyors use a simple method of measuring angles to determine the distance to a point too far away for direct measurement. In this technique, a baseline whose length (d) is accurately known is established. Angular measurements to the object are made and simple equations can then be used to determine the distance (D) to the distant object.

A similar approach forms the basis for the methods used by astronomers to measure the distance to some of the closer stars. Because stars are so far away, the simple procedure used by surveyors must be modified for use in measuring their distances. Instead of measuring two angles, astronomers have found it easier to measure an angle called the parallel angle or the angle from the star to the earth. If this angle is given in seconds of arc, then the distance in light years is simply 3.26 divided by the parallax. To simplify matters even further, distances are often quoted in parsecs, where:

Distance in parsecs = 1/(parallax in arc seconds)

Measurement of Parallax

The principle of parallax measurement is simple in concept. If a nearby star is observed against a background of very distant stars, and photographs are taken from two different points separated by a known distance (a baseline), the position of the nearby star will appear to shift in relation to the background stars. This shift can be used to determine the parallax angle.

Although the principle of measuring the distance of stars has been known for centuries, only within the last 170 years have astronomers been able to measure such an effect. When early attempts to detect parallax failed, it was realized that the stars must be extremely distant. In order to detect parallax, the baseline used must be very large.

The longest baseline available is the earth's orbit around the sun. To take advantage of this baseline, nearby stars are observed at six month intervals. In this time the earth has moved completely around the sun, giving a baseline of 186 million miles. In spite of this long baseline, the parallax angle of even the nearest stars is so small that repeated searches by astronomers of the 18th century were unsuccessful. It was not until 1838 that the first parallax of a star was measured—0.31 arc seconds for the star Cygni 61, giving an estimated distance of 62 trillion miles—the distance traveled by a ray of light in ten and a half years. Although parallax measurements have now been made for thousands of stars, the largest parallax measured for any star is 0.77 arc seconds: thus the distance to the closest star Proxima Centuri is estimated to be 4.3 light years. Since an angle this small is below the threshold of resolution of those early astronomers, it is not surprising that their efforts to observe parallax were futile.

The Difficulties of Parallax Measurements

The measurement of parallax is not quite the same as the simple determination of angles used by the surveyors. Modern parallax data are the result of tedious measurements made from many photographic plates with the aid of a microscope. Because this is very time consuming, parallax studies are generally conducted only for stars suspected to be nearby. The star selection includes the brightest stars, and stars which show appreciable motion over time (proper motion), as determined by comparing photographs of star fields at different epochs with a "blink" comparator. Once a star has been selected for parallax measurements, a series of photographs are taken at regular intervals (such as once a month), usually with a telescope designed specifically for this work. Surrounding the star to be studied are images of many other stars, assumed to be very distant because of their faintness or lack of proper motion. Several of these stars are selected as reference stars, from which all subsequent measurements are made.

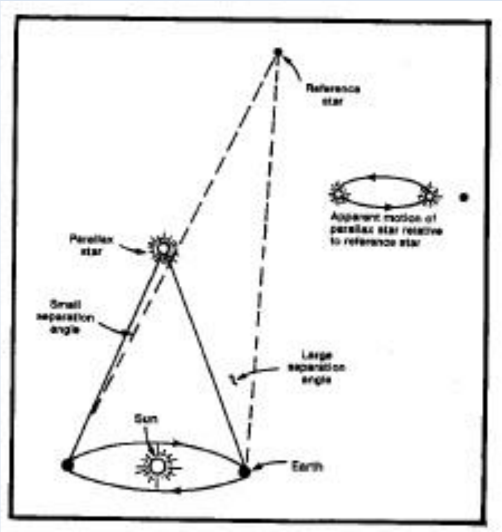
With precise instruments, the distances between the reference stars and the object star are very carefully measured on each plate. Extreme care is taken, because in an interval of six months (for the baseline of the earth's orbit), the shift of the object star position compared to the reference stars is almost negligible—nearly at the limit of measurement error. To increase the accuracy and to reduce the amount of error in the data as much as possible, it is common to make numerous repeat measurements using different observers and to average the results. Recently, computer-controlled measuring machines have taken over some of the more tedious work.

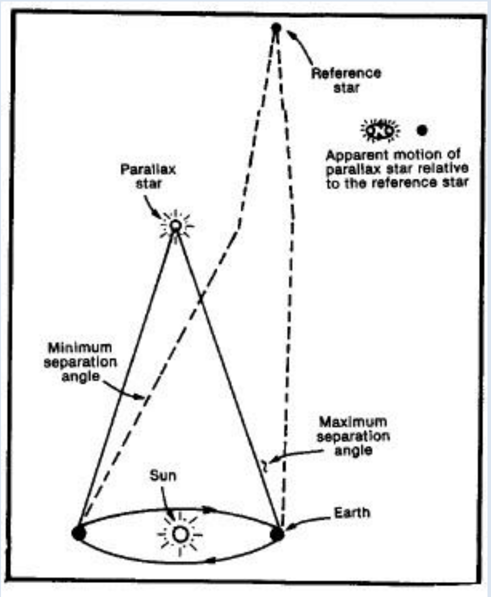
These data are accumulated over a number of years and are subjected to rigorous mathematical analysis. The reasons for this are many. In the first place, the parallax angles for all but a few dozen of the closest stars are barely larger than measurement errors: statistical techniques must be used to separate true parallax from this error. The total parallax typically is less than the dimensions of the star on a single plate. Secondarily, however, there are a number of other factors which cause a star image to move on a series of photographic plates, even if this movement is small. These include proper motion of the object star (actual motion of the star across the heavens relative to the solar system), precession of the earth's axis, proper motion of the solar system through the universe, minor variations in the movement of the object star due to gravitational effects of orbiting bodies (binary stars), plate scale factors, biases in measuring equipment and observers. Typically 30 to 50 plates are used in parallax determination. When the evaluation is completed and all known causes of image motion have been excluded, the final result is selected as the parallax of the star. Because of the many possible sources of error, parallax measurements below 0.02 seconds of arc are usually looked on with reservations. Thus parallax measurements generally are available only for stars closer than 150 light years. The techniques for determining proper motion are similar, and these measurements typically are made from the same plates.

Gravitational Effects on Parallax Measurements

An implicit assumption in the measurement of the parallax of stars is that light follows a straight line, and no corrections are made for gravitational influence on light. But is this valid? Perhaps not. Let us reconsider the techniques used to measure parallax.

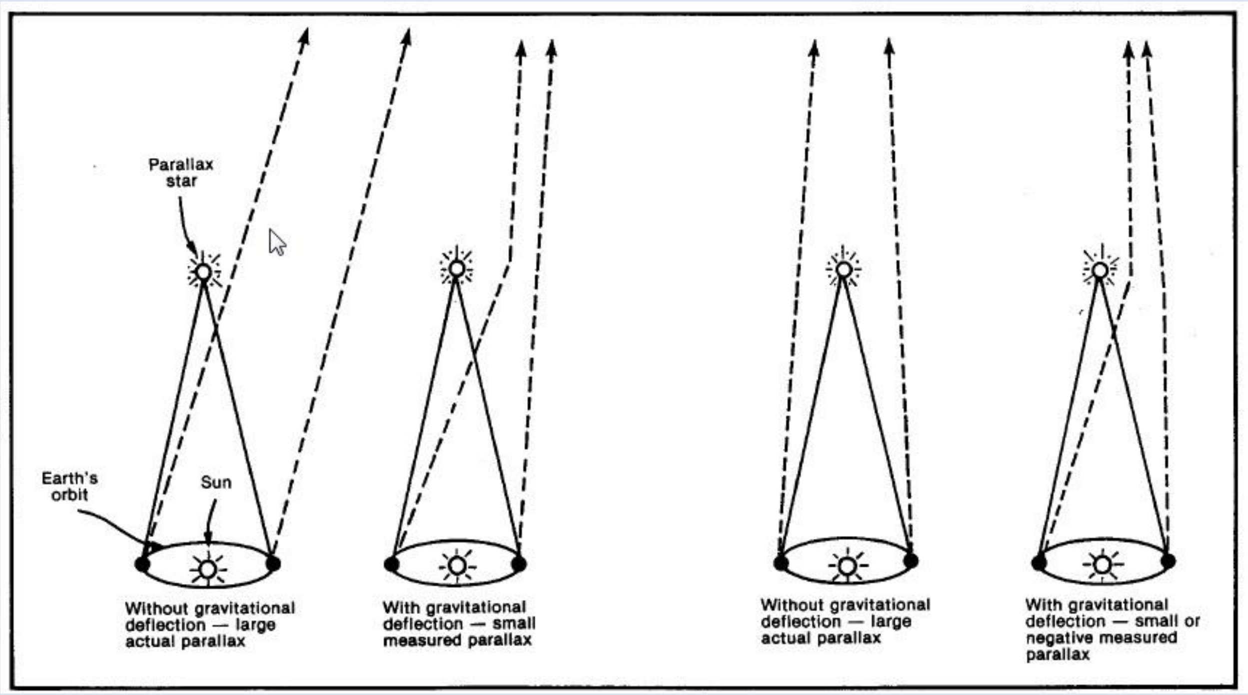
In the following figure, the geometry of a typical parallax measurement is shown. On a series of photographs made over a one year period, the parallax star appears to move in an elliptical path relative to the more distant reference star because of the motion of the earth in orbit around the sun. Measurements of this motion, almost imperceptible on the photographs, provides the parallax, and hence the distance,





But the illustration does not consider the influence of gravity on the light from the distant reference star. This effect, *greatly exaggerated*, is shown in the second figure. Light from the reference star passes near the closest star and is deflected by the gravitational field, resulting in a distortion in the apparent position of the reference star relative to the parallax star. As the earth moves in its orbit around the sun, the relative positions of the reference and parallax stars shift less than they would if light were not deflected by gravity. The net result is that the measured parallax is less than the true parallax of the nearby star. Put another way, the gravitational deflection of light can result in underestimating the parallax and overestimating the distance to the nearby stars.

Several typical examples of this effect are shown in the following illustration. If the parallax star is close enough and deflection due to gravity large enough, image displacement from photographic plates do not relate to actual parallax at all, but to reference star images that have been displaced by the gravitational field of the closer star. The amount of displacement may be large enough to provide very small, or even negative, parallax for very close stars. In other words, close stars may appear to be extremely distant due to errors in parallax measurements—errors introduced by gravitational effects.



Shrinking Star Distances

The effect of gravity on parallax measurements would only be apparent if the amount of deflection were significant. But is it? It is tempting to consider the deflection of light by a star using Einstein's equation for deflection of light by the sun, which is:

$$\text{Angle of Deflection} = 4GM/c^2R$$

Where G is the gravitational constant, M is the mass of the sun, c is the speed of light and R is the distance from the sun. It is well known, however, that this equation has many simplifications meant only to apply to the earth/sun relationship to allow the theory to be tested. It does not apply to distant stars, or different stellar masses. Researchers have found that deflection of light for distant objects is larger than predicted by this equation.

It would seem that the deflection of light by a star's gravitational field may indeed bias parallax measurements. If this is true, the effect would be one of overestimating the distance to the closer stars. As we shall see, there is very convincing evidence that this is the case.

Evidence in Parallax Measurements

Can gravitational effects be seen in parallax measurements? To answer this question, a review of extensive parallax measurements of a large number of faint stars was conducted (*Publications of the United States Naval Observatory, Washington, D.C.*) In this study, 276 stars were photographed at regular intervals over a four–year period in a comprehensive parallax study. These stars were selected because their large proper motions, averaging 0.85 arc seconds per year, indicated they might be close. From 40 to 80 photographs were made for each star. Each plate series had from three to seven reference stars which were used to measure the parallax and proper motion of the selected star. Average angular separation of the reference stars was about five minutes of arc.

The data, some of the most accurate and thorough ever obtained for such a large sample, were subjected to computer analysis, and estimates of parallax and proper motion for each star were derived. As expected, a large number of the selected stars showed appreciable parallax, indicating that they are indeed relatively nearby. Overall, the average parallax measured was 0.47 arc seconds for an average distance of 6.9 light years for this sample.

But do these measurements show the effect of gravitational bending of light? *It seems that they do!*

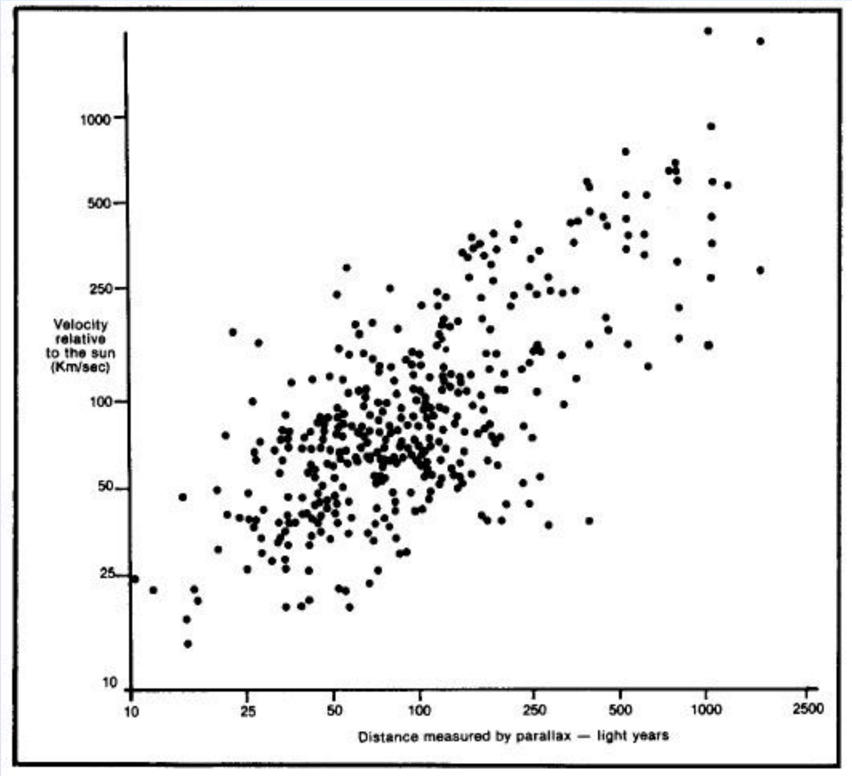
At their best, parallax angles are difficult to determine, and a certain amount of error is always present in the final figures. Strange results are sometimes obtained, and it is comforting for the astronomer to attribute these anomalies to measurement errors. But are they really caused by errors, or they caused in part by the influence of gravity?

For example, nearly 7 percent of the observed stars had *negative* parallax, a recurring phenomenon in parallax work. Such data have no counterpart in the physical concept of parallax—these stars appear to move with the earth in its journey around the sun instead of being semi-fixed at a distance. When negative parallax is measured for a star, the usual assumption made is that the star is extremely distant and that the result is due to random errors. The large proper motion of these stars is difficult to reconcile with great distance, however. Although the negative parallax could perhaps be due to random error, a 7 percent error rate is relatively large, and there are many ways in which the gravitational bending of light can cause such an effect. Negative parallax may actually indicate that a star is very nearby.

Other discrepancies, less easily explained, occur regularly in parallax work. These include major variations in parallax measurements of the same star made by different observers and sometimes between different sets of observations made by the same observers—discrepancies well in excess of the possible error sources. In a few cases these discrepancies can be attributed to systematic errors by one or both observers, undiscovered proper motion of the reference stars and even unnoticed perturbations in the motion of the parallax star due to an orbiting object. However, these differences are more easily explained by the effects of gravitational bending of light from different sets of reference stars, or on different plates. This possibility may also account for the annoying occurrence of apparently legitimate measurements which fall far from the general trend—deviations for which no valid reason can be found. When this occurs, as it does periodically in all parallax work, these spurious measurements are excluded as non-representative. It could be, however, that these inexplicable results occur when a particular alignment of stars is present as the earth moves around the sun in its orbit, accentuating for a brief period the gravitational bending effects. It would be interesting to see if spurious measurements could be repeated under controlled conditions.

Proper Motion and Parallax

Perhaps even more difficult to explain is the incidence of very small (or even negative) parallax for stars with large proper motions—stars which reason indicates are relatively nearby. For example, the sample of stars studied was selected on the basis of large proper motion, characteristic of nearby stars. And yet, 22.5 percent were measured to be at least 300 light years away, with most of these stars showing proper motions similar to that of much closer stars. If the measurement of distance is assumed to be correct, some of these stars have velocities through space relative to earth as much as a hundred times greater than that of the earth around the sun—very fast motion indeed for such massive bodies. In fact, for all the stars studied, there is a very strong correlation between the measured distance to the star and its space velocity relative to the sun (transverse velocity), as illustrated below. In this figure, stars with negative parallax have been excluded (their computed space velocities are even larger than those shown). There is no apparent correlation with direction from the solar system for these stars.



Taken at face value, this figure suggests that the velocity of stars through space increases as their distance from the solar system increases. *But this seems highly unlikely!* A further indication that something is amiss is that many of these stars appear to have transverse velocities in excess of 100 to 200 kilometers per second, and yet the radial velocity of stars (velocities toward or away from the solar system measured by the Doppler principle) rarely exceeds 50 to 60 kilometers per second. This disparity is illustrated in the following table:

Comparision of radial and transverse velocities

Velocity (km/sec)	Radial[1] velocity	Transverse[2] velocity
0-24	77.8%	4.7%
25-49	18.6%	18.5%
50-74	2.4%	21.4%
75-99	0.7%	15.6%
100-124	0.7%	8.0%
over 125	0.0%	31.8%

[1] Based on the Doppler redshift of a large number of stars.

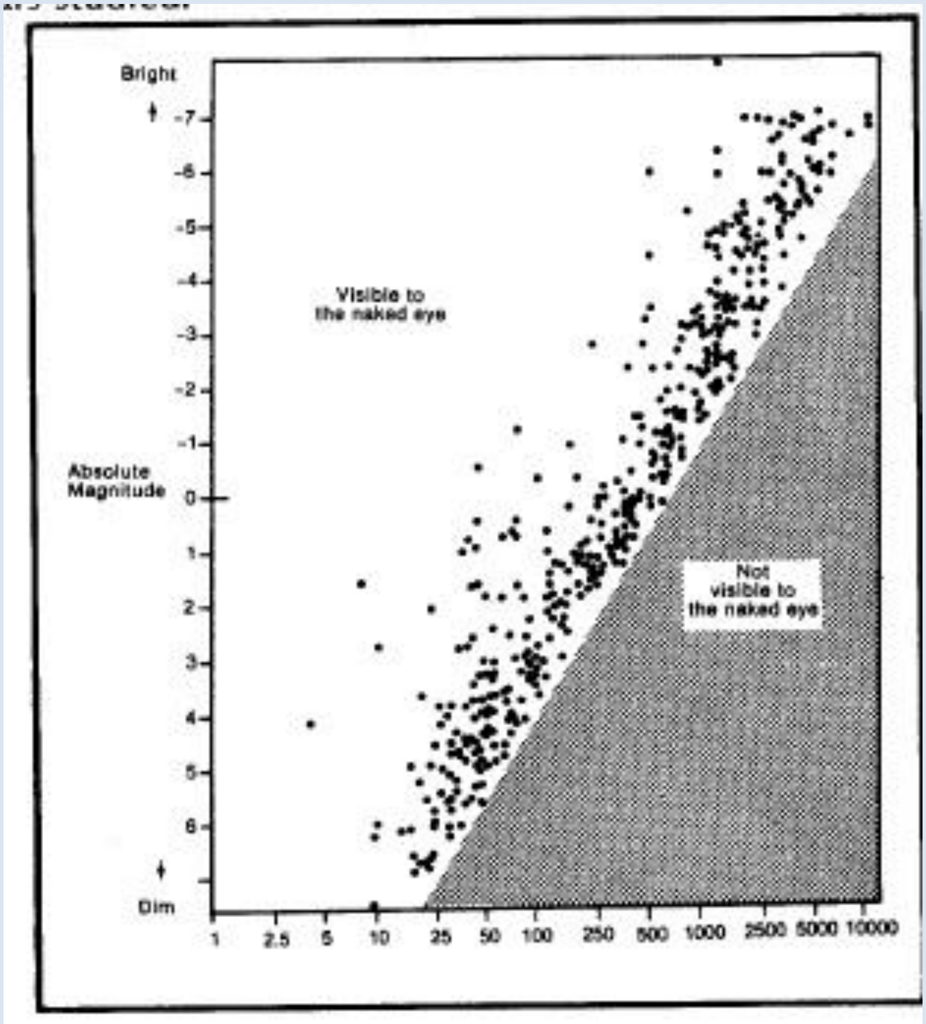
[2] Based on parallax and proper motion measured for 276 faint stars (U.S. Naval Observatory, Washington, DC).

The most reasonable explanation for this difference is that, at least for the sample of stars studied, the distance to many of the stars is ***overestimated!*** That is, there appears to be a systematic error in the measurement of parallax—*exactly the effect that would be expected from the light-bending influence of gravity on parallax measurements*. It would appear that the apparently distant stars (those with very large measured spatial velocities) are, in reality, far closer than indicated by their measured parallax. The seven percent of the sample exhibiting negative parallax may be the nearest of all the stars studied.

Further Evidence

Further evidence that the current distance scale may be erroneous is shown in the following figure. This is a plot of absolute magnitude versus reported distance for a large sample of stars visible to the naked eye. The absolute magnitude of a star, you will recall, is the apparent brightness it would have if brought to the standard distance of 10 parsecs, or 32 light years. Thus absolute magnitude is a normalized brightness, completely independent of the actual distance to the star. And yet this figure seems to show that stars generally are brighter as their distance from the solar system increases—*an unlikely proposition!*

Although this figure is provocative, it must be qualified somewhat. Since the sample of stars is based only on those visible to the naked eye ($m < 6.25$), faint stars are not represented. Furthermore, the density of stars in any given volume of space is not shown, so that a true picture of spatial density of stars of differing absolute magnitude is not apparent. In spite of these limitations, the figure does illustrate that there is a surprising lack of the brighter star types in the close vicinity of the solar system—a deficiency that increases with absolute magnitude. (Note: the absolute magnitudes and distances are from the Sky Catalog 2000.0 and are the officially recognized values).



Since the solar system does not occupy any privileged place in the universe, the brightness of stars would not be expected to increase with distance, as this figure suggests. A more realistic explanation for the apparent correlation between distance and brightness, and one quite consistent with the reasoning presented thus far, is that ***the current distance scale is in error***. The measurement of distance for those stars which appear to be very far away is overestimated, causing an overestimation of their brightness.

Moving Beyond Parallax

Now we have dug ourselves into a hole—a very deep hole. Since parallax is the bottom rung of a large series of steps in determining distances in the universe (including the Hubble Law), if we can't depend on distances determined by parallax, what can we do? Fortunately there is an alternative, but you will be shocked at where it leads!

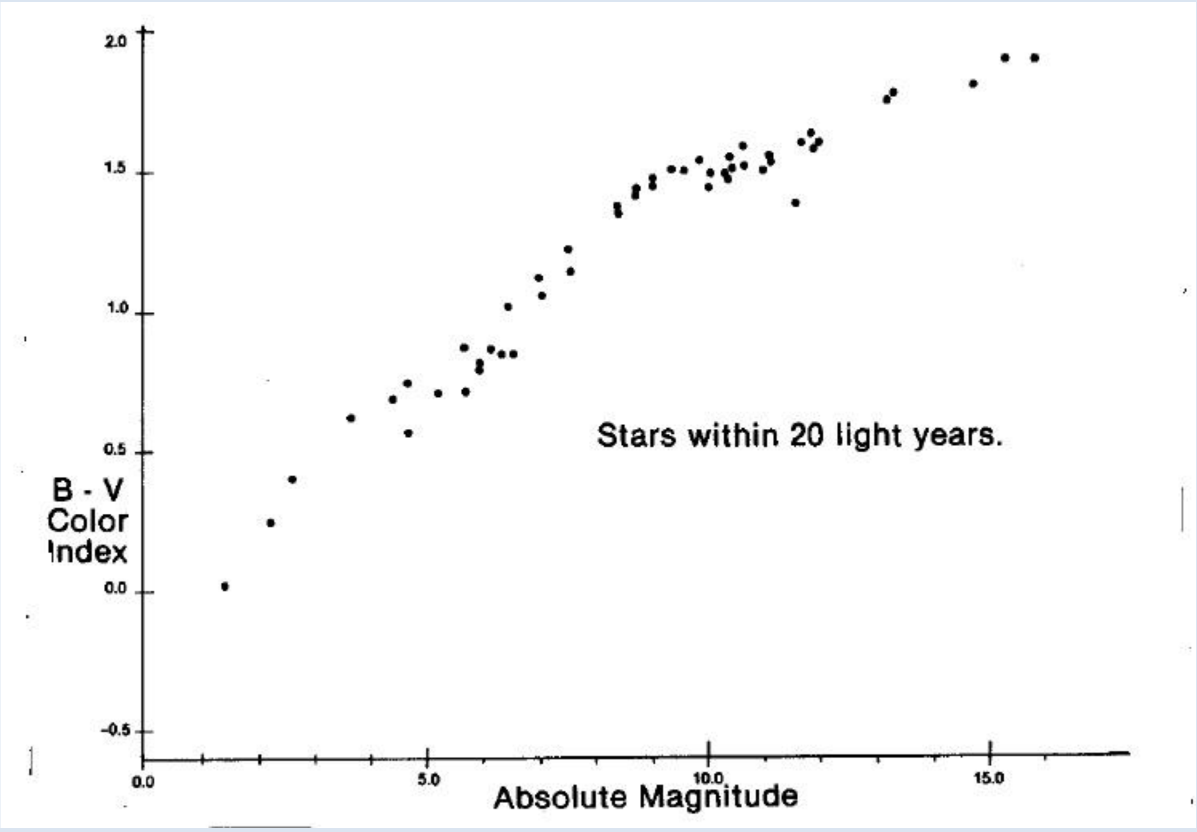
The Color Index

Astronomers study the light from stars and galaxies in different frequencies, such a blue, red, violet, yellow, and in the visible spectrum. By comparing the brightness of a star in each of these colors, a great deal of information about the star can be gleaned, including temperature, allowing each star to be categorized according to type. And surprisingly, *some of this information can be used to determine a star's distance*. The results of studying star colors is summarized in a single diagram called the Hertzsprung-Russell diagram (H/R diagram).

I am not going to go into details about the color index and H/R diagram here, as a simple internet search will provide full information the subject. However I will point out that the H/R diagram, much used by astronomers, is based on stellar distances developed from parallax measurements, and thus may be completely useless and incorrect. There is one color index, however, that is extremely useful. It is the (**B** – **V**) index, or the difference in intensity between the blue and visible spectrum.

The (B – V) Color Index

Simply put, the **B** – **V** index can be used to determine a star's absolute magnitude, and this along with its apparent magnitude, allows the distance to be determined by the formula given below. Although the process is somewhat more complicated than we will give here, the basics are the same. The following figure shows the relationship between the **B** - **V** index and absolute magnitude for the twenty nearest stars.



From this figure it is easy to determine absolute magnitude (M) for a star who's **B** – **V** index is known (nearly all stars). Then using the apparent magnitude (m) of the star and the following equation, the distance can be determined. *And no parallax is used!*

$$(m - M) = 5 \log D - 5$$

The following tables reflect the result of using the **B** – **V** color index instead of parallax to compute the distance to some well-known stars. Note that these tables were taken from my book *The Deceptive Universe,* published in 1982, and may be a little dated, but they illustrate the result. ***(You probably will not find a similar table in all of astronomical research!)***

Brightest Stars

Name		Visual magnitude	Color index	Distance[1] (light years)	Revised[2] distance (light years)
Sirius	α CMa	−1.46	0.01	9	8
Canopus	α Car	−0.72	0.15	1174	10
Arcturus	α Boo	−0.04	1.23	36	1.1
Rigel Kent	α Cen	0.00	0.68	4	5
Vega	α Lyr	0.03	0.00	26	17
Capella	α Aur	0.08	0.80	42	4
Rigel	β Ori	0.12	−0.03	913	19
Procyon	α CMi	0.38	0.42	11	11
Achernar	α Eri	0.46	−0.16	85	25
Betelgeuse	α Ori	0.50	1.85	310	0.05
Hadar	β Cen	0.61	−0.24	456	30
Altair	α Aql	0.77	0.22	17	18
Aldebaran	α Tau	0.85	1.54	68	0.55
Antares	α Sco	0.96	1.83	326	0.08
Spica	α Vir	0.98	−0.23	258	34
Pollux	β Gem	1.14	1.00	36	3.7
Formalhaut	α PsA	1.16	0.09	22	25
Deneb	α Cyg	1.25	0.09	1826	26
Mimosa	β Cru	1.25	−0.23	424	39
Regulus	α Leo	1.35	−0.11	85	37
Acrux	α Cru	1.41	0.10	359	28
Adhara	ε CMa	1.50	−0.21	489	43
Castor	α Gem	1.58	0.04	46	38
Gacrux	γ Cru	1.63	1.59	88	0.55
Shaula	λ Sco	1.63	−0.22	274	44
Bellatrix	γ Ori	1.64	−0.22	359	45
El Nath	β Tau	1.65	−0.13	130	42
Miaplacidus	β Car	1.68	0.00	85	36
Alnilam	ε Ori	1.70	−0.19	1206	45
Al Nair	α Gru	1.74	−0.13	68	44
Alioth	ε UMa	1.77	−0.02	62	40
Dubhe	α UMa	1.79	1.07	75	4.6
Mirfak	α Per	1.80	0.48	619	19
Kans Australis	ε Sgr	1.85	−0.03	85	40
Avior	ε Car	1.86	1.27	202	2.2
Alkaid	η UMa	1.86	−0.19	108	48
Wesen	δ CMa	1.86	0.65	3064	13
Menkalinan	β Aur	1.90	0.03	72	39
Atria	α TrA	1.92	1.44	55	1.4
Alhena	γ Gem	1.93	0.00	85	42

[1] Based on current estimates (*Sky Catalogue 2000.0*, Sky Publishi Corporation, 1982).

[2] Based on color and visual magnitude only, and ignoring paralla

Nearby Bright Stars

Name		Visual magnitude	Color index	Distance[1] (light years)	Revised[2] distance (light years)
Betelgeuse	α Ori	0.50	1.85	310	0.05
Antares	α Sco	0.96	1.83	326	0.08
Aldebaran	α Tau	0.85	1.54	68	0.55
Gacrux	γ Tau	1.63	1.59	88	0.55
Suhail	λ Vel	2.21	1.66	489	0.57
Scheat	β Peg	2.42	1.67	176	0.63
Menkar	α Cet	2.53	1.64	130	0.66
Kornepnoros	β Gru	2.11	1.62	173	0.73
Mirach	β And	2.06	1.58	88	0.80
Arcturus	α Boo	-0.04	1.23	36	1.1
Eltanin	γ Dra	2.23	1.52	101	1.2
Kochab	β UMi	2.08	1.47	95	1.2
Enif	ε Peg	2.38	1.52	522	1.3
Alphard	α Hya	1.98	1.44	85	1.3
Atria	α TrA	1.92	1.44	55	1.4
Avior	ε Car	1.86	1.27	202	2.2
Mira	o Cet	3.04	1.42	95	2.5
	ε Sco	2.29	1.15	65	2.7
Almach	γ And	2.18	1.20	121	3.5
Hamal	α Ari	2.00	1.15	85	3.7
Pollux	β Gem	1.14	1.00	36	3.7
Schedar	α Cas	2.23	1.17	121	4.2
Capella	α Aur	0.08	0.80	42	4.2
Dubhe	α UMa	1.79	1.07	75	4.6
Rigel Kent	α Cen	0.00	0.68	4	5.5
Algeiba	γ Leo	2.28	1.08	104	5.6
Diphda	β Cet	2.04	1.02	68	5.9
Menkent	θ Cen	2.06	1.01	46	6.1
Ankaa	α Phe	2.39	1.09	78	6.2
Gienar	ε Cyg	2.46	1.03	82	6.7

[1] Based on current estimates (*Sky Catalogue 2000.0*, Sky Publishing Corporation, 1982)

[2] Based on color and visual magnitude only, and ignoring parallax.

Amazing – Astounding – Incredible

By ignoring parallax we see an entirely new view of the space surrounding us! Who would have guessed that Betelgeuse was our closest neighbor, just a fraction of a light year away? Who would have guessed how many stars are so close, when parallax measurements put them so far away? While you may have disagreed with some of my conclusions about the problems with parallax, it is hard to dispute that when you ignore parallax altogether, you get some amazing, and hard to disregard, results..

Apparently our nearest companion is the star Betelgeuse, which has been considered a giant star, but may be simply an ordinary star but very nearby. We will investigate Betelgeuse in more detail.

Betelgeuse

Betelgeuse is the only star whose diameter has been measured and studied by speckle interferometry to get a picture of its surface. At its currently estimated distance of 540 light years, it is clearly categorized as a giant, with a mass about twenty times that of the sun. The revised distance by color index Is about 0.05 light years, *or only 250 times the distance from the sun as the planet Saturn!* Using this distance and the measured diameter of 0.45 seconds of arc, the diameter of Betelgeuse can be estimated to be about 70,000 miles, or about 1/13 that of the sun. Betelgeuse has a color index of 1.83, which would classify it as a normal red dwarf. It also has been found to emit radio energy, much as does the sun, and one of the few stars to do so.

Another interesting fact about Betelgeuse is that its diameter has been seen to decrease by 15% since 1993. Astronomers have been puzzled by this, but it is easily explained if Betelgeuse is nearby and moving away from us. In fact, it has a measured redshift of 22 miles per second, or a recessional velocity of 79,000 miles per hour. Using a simple calculator indicates that it has receded around 1.3×10^{10} miles since 1993. *A very simple explanation for the observed reduction in diameter!*

Color Index and Quasars

I have long disputed that the Hubble Law is valid to measure the distance to quasars. This belief is further supported by evidence of proper motion in some quasars, suggesting nearness to the solar system. So can the color index be used to determine the distance to quasars? Maybe so!

To investigate this I selected the quasar 3C 273, the first quasar discovered and still the object of intensive study. This quasar has an apparent magnitude of about 12.7 (m = 12.7) and a **B** – **V** color index of 0.21. Using the (**B** – **V**) / absolute magnitude relationship discussed previously results in an absolute magnitude of about 1.5 (M = 1.5***). By formula, the distance to 3C 273 is then calculated to be 5,668 light years!*** This is compared to the 2.4 *billion* light years estimated with the Hubble Law!

Presumably, a similar analysis can be performed for other quasars, with similar results. Very clearly, quasars are nearby, and not at the billions of light years given by the Hubble law. And since they are nearby, there is no reason to ascribe extraordinary energy to them. Quasars are simply nearby stars with very high redshifts. The cause of this very high redshift is not due to recessional velocity, but will not be discussed here. A small sample of quasar distances recalculated using the **B** – V index is shown below.

Revised Quasar Distances					
name	app mag	redshift	bv color	bv abs mag	bv distance (ly)
IRAS 14167-7236	15.4	0.026	0.7	5.2	3,576
PKS 2153-69	13.79	0.028	0.99	6.5	936
F 357	14.53	0.028	0.7	5.2	2,396
ESO 31-G08	14.98	0.028	0.69	5.2	2,947
ESO 012-G21	14.41	0.033	0.63	5.2	2,267
IRAS 19254-7245	16.37	0.061	1.02	7.0	2,440
H 0355-826	16.44	0.065	0.76	5.5	5,028
IRAS 00521-7054	16.2	0.07	1.02	7.0	2,257
IRAS 00198-7926	16.3	0.073	1.03	7.0	2,363
1H 1836-786	15.55	0.074	0.59	4.7	4,824
UKS 0242-724	15.86	0.102	0.48	2.9	12,748
PKS 0312-77	16.1	0.225	0.16	1.6	25,908
1H 0828-706	16.65	0.239	0.41	2.7	20,111
MC4 0031-70	17.34	0.363	-0.01	1.2	55,135
PKS 2302-713	17.5	0.384	-0.1	0.8	71,356
PKS 0202-76	16.9	0.389	0.05	1.3	42,996
PKS 0858-77	17.57	0.49	0.2	1.9	44,405
PKS 2300-683	16.38	0.516	0.22	2.0	24,515

Summary

Wow! If you have gotten this far you must realize that everything we thought we knew about the universe (or at least have been told) has been challenged! Now it is up to the astronomical community to pick up this information and update our knowledge of the universe. Will they do it? I hope so but I doubt it (*don't bother me with facts—my mind's made up*). But there it is!

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