**Astronomy For Science Fiction Writers: Practical Astrogation**
By
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In the last Astronomy for Science Fiction Writers article, we learned that stars come in a variety of sizes and colors, and that they have different properties. For instance, the big blue stars (O, B, and A spectral classes) are powerful beacons that proclaim their presence for thousands and even millions of light years. They are also profligate, spending their energy like a drunken sailor on shore leave. As a result, they are relatively short lived. The big blue stars burn out in a few million years while the smaller, more miserly stars will survive for tens of giga-years.

We learned that the smaller, less spectacular stars (F, G, and K spectral type) are more interesting to humankind. The reason for this is that our own sun is a G2-class dwarf and the yellow and orange stars of F, G, and K are more likely to be benign to our sort of life than are more powerful stars with their high output of ultraviolet rays. The sun is a typical yellow-white star, and at 4.5 billion years old, is just entering middle age.

Then there are the misers of the universe, the red giants of the M, R, and S classes, and the red and white dwarfs, which will probably continue to shine right up to the end of the universe – whatever and whenever that may be.

The variety of stars presents a science fiction writer with a conundrum. Like the seafarers of the Spanish Main, our swashbuckling heroes must sail from island to island in a night-black ocean of stars, periodically putting ashore to save a damsel in distress, fight a dragon (literally), or redress some terrible wrong. And like the Spanish gold galleons or the pirates who preyed on them, we cannot sail interstellar space blindly. We must have maps by which to steer our vessels across this vacuous sea, charts that show us the relative positions of the tiny islands between which we sail.

Unfortunately, the chart makers of our era cannot travel the starlanes themselves. They can only stand on a high cliff and peer off into the distance for as far as their telescopes will penetrate. And though an astronomer's gaze penetrates deeply out into the universe, it is limited by being restricted to only a single perspective. This limited viewpoint causes our ideas of the universe to be largely self-centered, making them congruent with our personalities. And it presents those of us who need to see the universe as it is with a problem.

Open any book on astronomy and you will be treated to very detailed maps of the night sky. Since the days of Tycho Brahe, astronomers have spent uncounted dark nights plotting the positions of every star they can see with ever greater exactitude. Ask an astronomer where any particular star is located, and he can pinpoint it in Earth's sky to within a fraction of an arc-second. Yet, while this angular position data is amazingly precise, ask him how far away a star is and he will probably hem and haw before giving you an answer that isn't even accurate to the first decimal place. For more distant stars, he will probably be unable to pinpoint the distance to within a thousand light years. For when it comes to stars, we lack depth perception.

Astronomy then is not the science of determining where the stars are physically located in the universe. Rather, it is the science of determining where the stars are located with respect to a fixed point in space – *our fixed point*, which we call Earth.

"But the Earth isn't fixed!" you exclaim. "It orbits the sun." True, and for the nearest stars this motion is sufficiently large that we can directly measure their locations using a phenomenon known as parallax. But the more distant stars appear fixed, immobile points of light that refuse to even wriggle during our yearly circuit of the sun.

Thus, our astronomers have a very Earth-centered view of the universe, and while fine for most purposes, this restricted viewpoint is adequate for neither science fiction writers nor starship captains. We aren't interested in where the stars are with respect to the Earth. We want to know *where the stars are with respect to one another!*

Where do you point your ship to get from Polaris to Procyon, or from Tau Ceti to Alpha Centauri? And just exactly where is Antares with respect to the center of the galaxy? Is it close enough that we can stop off for a visit en route from Spica, or is it in the opposite direction altogether? All troubling questions for those who would travel the universe in their imaginations..

That, then, is the purpose of this article: To shake off our provincial view of the vast expanse of vacuum that surrounds us, and to develop a viewpoint more wide ranging and useful to voyagers of the void, real and imagined. The art of steering a starship through the heavens has been dubbed "astrogation," a word construction combining *astro*, or star, and *navigation*. Let us consider for a moment the astrogator's creed: "Never mind the pretty lights. How the hell do we get there?"

**Stellar Coordinate Systems**

One thing we all know, but seldom pay much attention to, is that Earth is a sphere. So, too, is the universe. It is not surprising then that the men and women who plot objects in the sky do so using spherical coordinate systems. The basic coordinate system used by astronomers is the equatorial system, which references stellar observations to the North Star and the plane of Earth's equator. This has the advantage of tradition and aligns well with the way ground-based observers actually see the stars. Because the Earth is tilted on its axis, however, the system has its drawbacks. The sun appears to rise and fall in the sky each season, just as it does here on Earth. Considering that the Earth circles the Sun and not vice versa, this can cause problems for certain observations.

A less terra-centric approach to astronomy is to use the plane of the ecliptic (the plane in which the Earth rotates) as the primary reference rather than the equator. More universal still is the system that uses the plane of the galaxy to orient the stellar coordinate system. Since thinking about coordinate systems is difficult enough (as you will see shortly), we will stick with the traditional method of measuring star positions.

What exactly is a spherical coordinate system, anyway?

The one with which we are most familiar is the coordinate system that sailors have used to navigate the Earth for centuries. This is our system of marking the surface of the planet with lines of latitude and longitude.

When someone specifies a point's longitude, what they are doing is measuring the angle east or west along the equator between location being specified and a reference. By international agreement, the place that acts as the reference is the Royal Observatory at Greenwich, England, an historical oddity for which you can thank the British Navy. To be more technically accurate about it, longitude is the angle between two planes, each of which extends from the center of the Earth, up through the poles, intersecting the surface at the two points of interest – namely, the point being measured and Greenwich.

Latitude is also an angle, but one aligned in a north-south direction. Specifically, a point's latitude is the angle between the plane of the Earth's equator and a line extending from the center of the Earth through the point in question. If one knows a location's longitude (east-west spherical angle) and latitude (north-south spherical angle), one can precisely determine the position of that location on the surface of the globe.

Personally, I spend most of my time at 33 degrees 27 minutes north, 102 degrees, 5 minutes west. This places me approximately one-third of the way around the Earth to the west of Greenwich, England, and slightly more than one-third of the distance between equator and north pole. You, of course, are somewhere else.

By specifying how far north-south, and east-west we are with respect to mutually agreed references on the surface of the globe, we can always locate ourselves. Furthermore, we can always locate any place we wish to go. This ability is quite useful. It allows ships to arrive at their ports of call, airplanes to find cities at night, and ICBMs to make the journey through space to find their targets. Knowing your position is also quite useful if you happen to be shipwrecked, especially if you can communicate this fact to those who would rescue you.

Note that the usual position locating system has only two dimensions: east-west and north-south. Don't we require three dimensions to locate ourselves in 3-D space? Actually, there is a third dimension, but one we seldom use. The reason for that is the third coordinate in a spherical coordinate system is the distance from the object of interest to the center of the reference sphere. That is just a fancy way of saying that the third dimension is the distance between us and the center of the Earth.

We don't use this third coordinate much because almost everyone alive can be found on the surface of the Earth or a few kilometers above it. Yet, even though we take the third coordinate for granted doesn't mean that it doesn't exist. So, my actual position in Earth-centric space is 112°5' W, 33°27' N, 6378 km out from the center of the planet. Your longitude and latitude are different, but your radius (distance from the Earth's center) is almost exactly the same.

What has all of this latitude and longitude have to do with the stars? Simply this: The system for measuring the position of stars is essentially the same, namely one of latitude, longitude, and distance. Of course, it would have been too easy for the astronomers to call their coordinates stellar longitude and latitude. Instead they call them *right ascension* and *declination.* But, to quote Shakespeare: "A rose by any other name would have just as many thorns …" or something like that.

When astronomers transferred longitude and latitude to the heavens, they had to make one basic change to their coordinate system. When measuring things on the surface of this rapidly rotating ball we call Earth, it is important that the coordinates rotate at the same speed as the planet. When looking out into space, however, the coordinate system must be stationary with respect to the stars

So, instead of using Greenwich as the prime meridian in the sky, we use the v*ernal equinox.* The vernal equinox is the point in the sky where the sun is located when it crosses the equator heading north each year; i.e., at noon on the first day of spring in the northern hemisphere. Since the sun is up at noon, you can't see the stars. But if you could, you would notice that the sun is always in the same place each year as it crosses the equator. This is a point in the constellation of Pisces, and it is this point with which we orient stellar longitude, or right ascension.

To locate a star in this east-west plane, we measure the angle around the equator between the vernal equinox and the star. All measurements are to the west, never to the east.

Sky latitude, or declination, is measured by determining the angle between the plane of the Earth's equator and a line drawn between the center of the Earth and the star. Since stars can be either north or south of the equator, declination comes in both plus and minus values. Stars above the northern hemisphere range from 0 to +90° of declination. Stars above the southern hemisphere range from 0 to -90° of declination.

"So," you say, "all I need to know about a star's position is the number of degrees west of the vernal equinox, and the number of degrees above or below the equator?" Well … no! Unfortunately, real life isn't that simple. While declination is measured in plus and minus degrees, right ascension is measured in units of time: minutes, hours, and seconds.

"Huh?" you ask. Strange, but true, I'm afraid.

As previously noted, the Earth spins on its axis once each 24 hours. It is, therefore, an excellent timepiece. In fact, what is a clock other than a mechanical device to mimic the Earth's rotation? The Royal Observatory at Greenwich, along with its US counterpart, the Naval Observatory in Washington, D.C., were both established with something in mind other than astronomy for its own sake. In fact, both organizations are naval observatories, whose primary purpose was to measure the positions of stars so the data could be used to publish navigation tables.

A naval observatory utilizes transit telescopes, optical instruments that are fixed on a precise north-south axis and unable to move except in elevation. To measure the position of a star, an astronomer waits patiently for the Earth's rotation to carry it across the telescope's field of view. When the star crosses a fine line in his lens, the astronomer records the exact time. If he first notes the time a known star transits the crosshairs, and then records the time an unknown star does the same, it is an easy matter to determine right ascension for the second star.

Because all the measurements were initially time based, the astronomers didn't bother to convert them into angular measurements. They just left them in their time units. Thus, right ascension varies from 0hr 0min 0 sec to 23 hr 59min 59 sec, always moving west from the vernal equinox. Please do not be confused, however. Right ascension is a measurement of angular position, not of time. Since the Earth rotates through 360 degrees of angle every 24 hours, one hour of right ascension equals 15 degrees of rotation.

So all an armchair astrogator needs to plot a course between stars is: 1) get the right ascension and declination of two stars, along with their distances from the Earth, 2) visualize the position of each star in their head, and 3) connect the two stars with the line his imaginary ship will take between them. The technical term for this is vector geometry. A vector is like a position arrow pointing out from the Earth to each of the stars in question.

The only problem with this procedure is that I don't know anyone who can do vector geometry in their head, especially in a three dimensional, spherical coordinate system. Frankly, I don't know many people who can do it on paper. The problem is that the spherical coordinate system isn't one we use in our everyday lives, and most people can't think in terms of spherical coordinates. Which is precisely the reason most astronomy books are of limited use to science fiction writers. They tell us where the stars are, but we have difficulty translating that information into something we can visualize. What we need is a more easily understood coordinate system.

**Coordinate System Transformation (Spherical to Cartesian)**

This, then, is the problem I faced when I first became a writer. I searched my various astronomy books for stars that might conceivably support terrestrial planets, then tried to figure out where they were located in space with respect to one another. I found it nearly impossible. Luckily, one of the things they pound into you in engineering school is that one is not stuck with any particular coordinate system. You can always translate from an inconvenient system to one that is more useful.

Though we humans live on the surface of a big sphere, most of us have trouble thinking spherically. That is because we live in square houses (mostly), lay out our cities in rectangular grids (often), and use X-Y coordinate systems to locate things on any scale smaller than global. We even pretend that the surface of our sphere is actually a plane, just to make it easier to think about such things.

The rectangular coordinate system is called Cartesian, and it is the one with which we are most comfortable. We can measure the position of things in a Cartesian coordinate system using three coordinate axes: X, Y, and Z. (If I have lost you, look at any corner in a rectangular room. There you see three planes coming together. Two of these planes are vertical. These are the walls of the room. The third is horizontal. This is either the floor or ceiling, depending on whether you looked up or down to find your corner. Where these planes intersect you can see three lines, each emanating at right angles from the apex formed by the corner. Traditionally we label the horizontal lines as the X and Y axes, and the vertical line as the Z axis.)

If you look in either the *Handbook of Chemistry and Physics,* published by the Chemical Rubber Company, or any number of other reference books, you will find formulas for transforming spherical coordinates into X-Y-Z coordinates. Converting these general formulas for our specific case, we get:

**X = DISTANCE** times **SIN (90-Declination)** times **COS (Right Ascension - in degrees)**

**Y = DISTANCE** times **SIN (90-Declination)** times **SIN (Right Ascension - in degrees)**

**Z = DISTANCE** times **COS (90-Declination)**

With these formulas we can convert our star coordinates from right ascension, declination, and distance into horizontal (X,Y) and vertical (Z) coordinates.

Having run into this problem in 1974 when I first became a writer, I took all of the star coordinates I had collected and converted them into Cartesian coordinates. This allowed me to draw a pseudo-three-dimensional star map that helped me visualize the star positions as they really exist in space. Once I had the positions visualized, I could then imagine a ship traveling from one star to another.

Let's see how one constructs a mechanical aid to visualizing star positions:

## Three Dimensional Star Maps

As an example, let's say that you have a list of all the stars within 15 light-years of Sol. *Note: Although we call our star, "sun," it is likely that the inhabitants of any interstellar colony will also call their star "sun." Science fiction writers therefore give the sun its formal Latin name "Sol" to distinguish it uniquely.*

Table 3 lists the Cartesian coordinates of the stars within the 15 light-years of Sol. If you are very good at visualizing in 3-D, all you need do is read the coordinates and then visualize the structure of local space in your head. If, however, you are like the rest of us, you will need some kind of mechanical aid to visualize where all the stars are located. And unfortunately, we don't yet have any good three dimensional display devices to fall back on.

Several years ago I purchased a book titled *3D Star Maps* that uses the old red-green colored glasses technology to attempt to display the universe in three dimensions. It was a gallant attempt, but not all that successful. For one thing, all the maps are from an Earth-centered viewpoint and for another, there was no way to quantify the third dimension. And finally, the whole thing gives me a headache if I spend too much time looking at the maps.

What I did to solve the problem was to plot each of the stars on a piece of rectangular graph paper using their X and Y coordinates, and then writing the Z coordinate next to the star symbol along with the stellar type and the name. I gave stars north of the plane of Sol positive Z coordinates and those south of Sol's plane, negative Z coordinates. Figure 2 shows such a 3-D star map. By looking at the grid and noting the positive or negative Z coordinates, even someone with moderate powers of visualization can estimate the true position of each star above or below the plane of the paper, thereby figuring out where the stars are with respect to one another. And if you have trouble visualizing, you can use straws or toothpicks of the proper length to find the position of any star in 3-D space.

## Figure 1: The Stars Within 15 Light Years of Sol

| Star No. | Gliese Code | Spectral Type | Lumin-osity | Dist-ance ly | Earth Centered Coordinates X ly | Y ly | Z ly | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1 | Sun | G2V | 1.04713 | 0.00 | 0.00 | 0.00 | 0.00 | Sun |
| 2 | Gl551 | dM5e | 0.00006 | 4.22 | -1.57 | -1.16 | -3.75 | ProximaCen |
| 3 | Gl559A | G2V | 1.61436 | 4.35 | -1.66 | -1.34 | -3.79 | ALFCen |
| 4 | Gl559B | K0V | 0.47424 | 4.35 | -1.66 | -1.34 | -3.79 | ALFCen |
| 5 | Gl699 | M5V | 0.00047 | 5.98 | -0.12 | -5.96 | 0.48 | Barnard'sstar |
| 6 | Gl406 | M6 | 0.00002 | 7.79 | -7.41 | 2.19 | 0.99 | |
| 7 | Gl411 | M2Ve | 0.00586 | 8.21 | -6.39 | 1.70 | 4.86 | |
| 8 | Gl65A | dM5.5e | 0.00006 | 8.56 | 7.43 | 3.32 | -2.68 | |
| 9 | Gl65B | dM5.5e | 0.00005 | 8.56 | 7.43 | 3.32 | -2.68 | |
| 10 | Gl244A | A1V | 23.55049 | 8.57 | -1.53 | 8.07 | -2.45 | ALFCMa |
| 11 | Gl244B | DA2 | 0.00265 | 8.57 | -1.53 | 8.07 | -2.45 | |
| 12 | Gl729 | dM4.5e | 0.00052 | 9.56 | 1.77 | -8.56 | -3.87 | |
| 13 | Gl905 | dM6e | 0.00011 | 10.33 | 7.41 | -0.67 | 7.17 | Ross248 |
| 14 | Gl144 | K2V | 0.31333 | 10.67 | 6.38 | 8.36 | -1.78 | EPSEri |
| 15 | Gl447 | dM4.5 | 0.00036 | 10.83 | -10.80 | 0.70 | 0.21 | Ross128 |
| 16 | Gl866AB | M5e | 0.00009 | 11.08 | 9.96 | -3.83 | -2.98 | |
| 17 | Gl15A | M2V | 0.00637 | 11.26 | 8.12 | 0.55 | 7.78 | GXAnd |
| 18 | Gl15B | M6Ve | 0.00041 | 11.26 | 8.12 | 0.55 | 7.78 | GQAnd |
| 19 | Gl845 | K5Ve | 0.14588 | 11.28 | 5.32 | -3.08 | -9.46 | EPSInd |
| 20 | Gl820A | K5Ve | 0.09036 | 11.29 | 6.37 | -6.12 | 7.03 | 61Cyg |
| 21 | Gl820B | K7Ve | 0.04246 | 11.29 | 6.37 | -6.12 | 7.03 | 61Cyg |
| 22 | Gl725A | dM4 | 0.00308 | 11.39 | 1.06 | -5.68 | 9.82 | |
| 23 | Gl725B | dM5 | 0.00146 | 11.39 | 1.06 | -5.68 | 9.82 | |
| 24 | Gl71 | G8Vp | 0.44875 | 11.40 | 9.88 | 4.70 | -3.18 | TAUCet |
| 25 | Gl280A | F5IV-V | 7.87046 | 11.41 | -4.65 | 10.36 | 1.07 | ALFCmi |
| 26 | Gl280B | DA | 0.00058 | 11.41 | -4.65 | 10.36 | 1.07 | ALFCmi |
| 27 | Gl887 | M2Ve | 0.01306 | 11.47 | 8.97 | -2.29 | -6.76 | PIPsa |
| 28 | GJ1111 | M6.5 | 0.00001 | 11.82 | -6.30 | 8.45 | 5.36 | |
| 29 | Gl54.1 | dM5e | 0.00019 | 12.19 | 11.10 | 3.50 | -3.62 | |
| 30 | Gl273 | M3.5 | 0.0015 | 12.33 | -4.43 | 11.45 | 1.16 | |
| 31 | Gl825 | M0Ve | 0.02938 | 12.61 | 7.34 | -6.47 | -7.94 | |
| 32 | Gl191 | M0V | 0.00394 | 12.62 | 1.94 | 8.71 | -8.92 | |
| 33 | Gl860A | M2V | 0.00164 | 12.94 | 6.39 | -2.77 | 10.91 | |
| 34 | Gl860B | M6V | 0.00044 | 12.94 | 6.39 | -2.77 | 10.91 | |
| 35 | Gl628 | M3.5 | 0.00142 | 13.32 | -5.11 | -11.96 | -2.89 | |
| 36 | Gl234A | M4.5J | 0.00055 | 13.47 | -1.57 | 13.36 | -0.65 | Ross614 |
| 37 | Gl234B | | 0.00002 | 13.47 | -1.57 | 13.36 | -0.65 | |
| 38 | GJ1061 | M4.5 | 0.0001 | 13.99 | 5.91 | 8.01 | -9.84 | |
| 39 | Gl473A | dM5.5eJ | 0.0001 | 14.04 | -13.73 | -1.86 | 2.27 | Wolf424 |
| 40 | Gl473B | M7 | 0.00008 | 14.04 | -13.73 | -1.86 | 2.27 | FLVira |
| 41 | Gl35 | DZ7 | 0.00019 | 14.12 | 13.77 | 2.83 | 1.27 | vanMaanen2 |
| 42 | NN | k | 0.0008 | 14.55 | -10.00 | 10.34 | 2.19 | |
| 43 | Gl83.1 | dM8e | 0.00022 | 14.57 | 12.38 | 6.96 | 3.24 | |
| 44 | NN | m | 0.00005 | 14.63 | -6.70 | 2.35 | -12.79 | |
| 45 | Gl1 | M4V | 0.00711 | 14.70 | 11.64 | 0.12 | -8.97 | |
| 46 | NN | M6.5 | 0.00001 | 14.75 | -13.72 | 4.61 | -2.83 | |
| 47 | Gl674 | M3 | 0.00337 | 14.84 | -1.55 | -10.03 | -10.82 | |
| 48 | Gl440 | DQ6 | 0.00048 | 14.92 | -6.39 | 0.48 | -13.47 | |
| 49 | Gl832 | M1V | 0.00673 | 15.16 | 7.86 | -6.02 | -11.48 | |
| 50 | Gl380 | K2Ve | 0.04656 | 15.29 | -8.74 | 4.63 | 11.66 | |

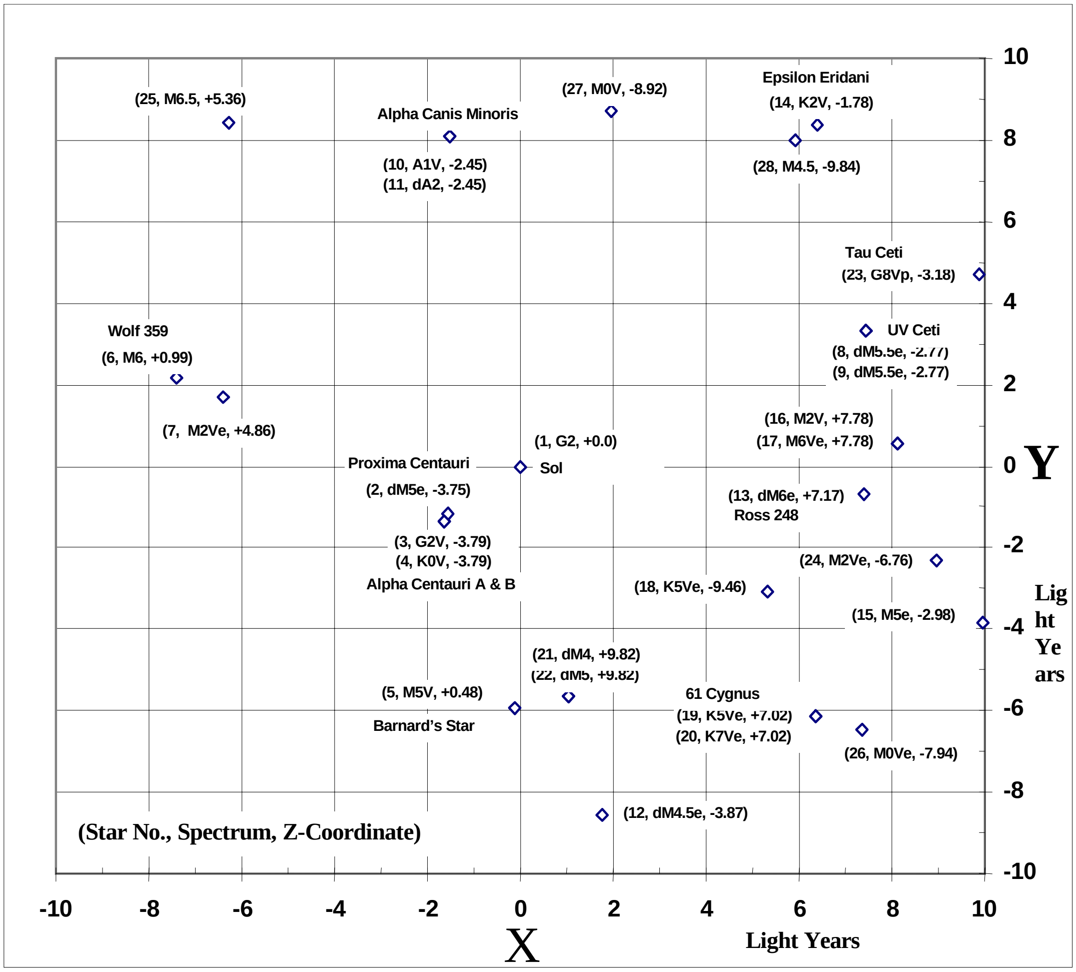


**Figure 2: The Stars within 10 light-years of Sol**

## A More Comprehensive Approach To 3-D Star Maps

While the X-Y grid with annotated Z coordinates is a good tool for visualizing the position of stars, it does have one drawback. There are a lot of stars out there and if you get too many of them on one piece of paper, they start to overlap and the whole map becomes messy. Once your map becomes covered with dots to the point where it is mostly black, it becomes useless. Thus, you either have to selectively leave out stars or else limit the scale of your map.

A more sophisticated method for visualizing star positions involves using several maps to display the universe in slices. In this way, the map that a star appears on also roughly determines its Z-coordinate.

Figure 3 shows how this is accomplished. I have taken the X, Y, Z coordinates of all the stars within 25 light years of Sol and plotted them on five different maps. This forms a cube 50 light years on a side, centered on Sol. The middle map, labeled Map 1, displays all stars out to 25 light years in the X-Y plane, and five light years above and below Sol. The intermediate maps, labeled 2A and 2B, display the layers on either side of the central map. The end maps, labeled 3A and 3B, display the layers of stars at the top and bottom of the 50 light year cube. When coupled with a table of star information, this method makes it easy to visualize where the stars are with respect to one another while keeping the maps readable. And if printed on transparent film such as is used for viewgraph presentations, the charts can be laid one on top of another, eliminating much of the need for visualization.

The same method could be used to plot a 100 light year cube (using 10 layers rather than 5) or any size for which one has data and the patience to do the work.

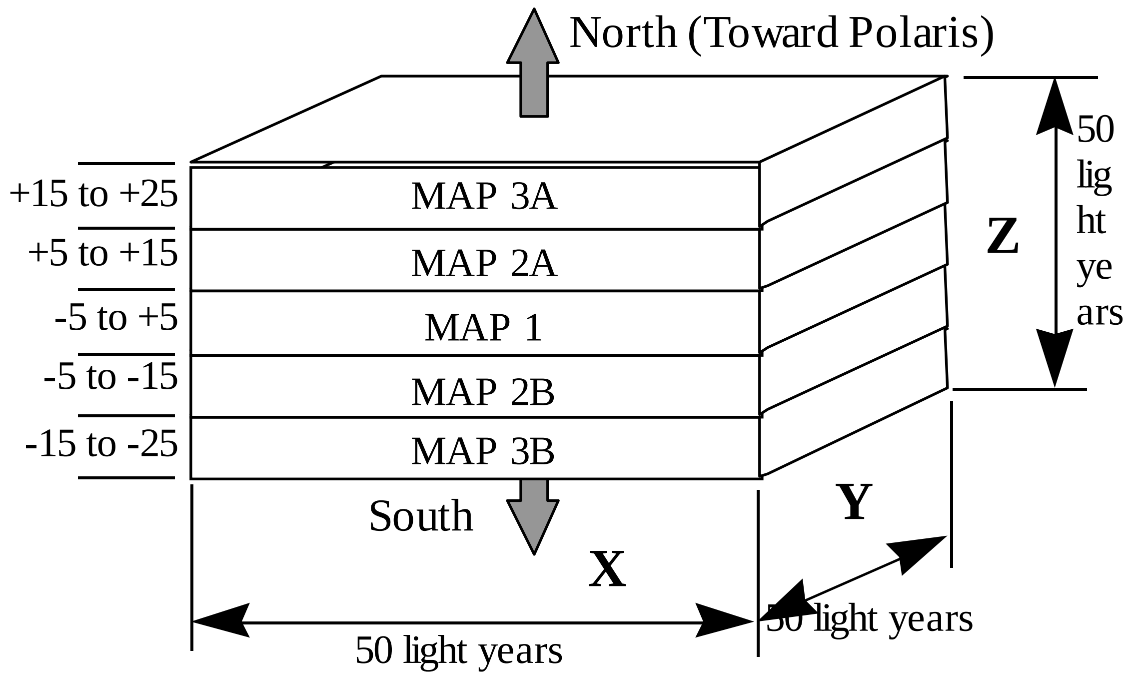


Figure 3: 3-D Layered Star Map

**Sources of Data**

There are a variety of ways to obtain the data needed to do a 3-D star map. One of these is to copy down the position data published in encyclopedias or astronomy books, do the rectangular data transformation, and then plot them by hand. That is precisely what I did in 1974 when I plotted my first 3-D star map. Luckily, in this age of computers and the INTERNET, that isn't necessary.

One excellent source of position data for stars is the Gliese Catalog, which gives the rectangular coordinates for nearly 4000 stars within a few hundred light years of Earth. This represents a considerable advance over the resources of 20 years ago. By utilizing this data and any spreadsheet or curve plotting routine, star maps can be generated fairly quickly.

There are numerous other stellar catalogs available on the INTERNET, some of which have the positions of 400,000 stars. Recognize, however, that the farther away a star is from us, the less accurate we are at measuring its distance. That means 3-D star maps become less accurate as the distance to the star increases. Unless you have an automated method of printing the star labels or Z-coordinates on your maps, you will soon find that annotating a large number of stars is more work than you are probably willing to put out.

There are also several sites on the web that specialize in star catalogs and computer generated star maps. One of the best is Winchell Chung's 3-D Starmap page, **www.clark.net/pub/nyrath/starmap.html,** from which I obtained my Gliese catalog data. You can either copy the address directly or else visit the Link Page at Sci Fi - Arizona. This site has a number of computer programs that plot isometric three dimensional diagrams of star positions, as well as several links to other sites. Mostly these are used by science fiction enthusiasts and people who play strategic games. They use them to set up interstellar empires for their game scenarios. While an isometric view of local space is more intuitive than the layered 3-D star maps discussed in this chapter, I find that if I get too many stars on such a diagram, that the 3-D effect tends to disappear.

So for maps on a scale of 50 to 100 light years, I still recommend the approach discussed in Figure 3.

**Astrogator's Handbook**

If some of the foregoing seemed fairly technical, it can't really be helped. If you are going to write interstellar adventures, it's important that you understand the structure of the universe through which your ships will be traveling. If you put a star in the wrong part of the sky, readers will let you know about it for years afterward. Now that you know how it is done, you can obtain your own star position data and build your own maps from scratch if you like. It's educational, but time consuming. Luckily, there is a better way.

One of the publications available at Sci Fi - Arizona is *The Astrogator's Handbook*. The handbook covers 125,000 cubic light years of space and includes the 275 nearest stars. Included in the handbook are star maps, tables of star data, and summaries of astronomical information to aid you in plotting your stories. With the aid of the layered 3-D star maps you will be able to find your way from Procyon to Tau Ceti to Proxima Centauri without missing a single port of call. And isn't that what's important to a starship captain?

After all, you won't be able to buckle your swash if you can't find the planet where the villain is holding the helpless maiden captive. And we all know how grateful those rescued maidens can be! So, be sure to consult the Sci Fi - Arizona *Astrogator's Handbook* whenever you need to fly between the stars. Don't leave home without it!

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Three hundred years after humanity made its deal with the Life Probe to search out the secret of faster-than-light travel, the descendants of the original expedition return to Earth in a starship. They find a world that has forgotten the ancient contract. No matter. The colonists have overcome far greater obstacles in their single-minded drive to redeem a promise made before any of them were born...

 

**3. Antares Dawn - US$4.50**

When the super giant star Antares exploded in 2512, the human colony on Alta found their pathway to the stars gone, isolating them from the rest of human space for more than a century. Then one day, a powerful warship materialized in the system without warning. Alarmed by the sudden appearance of such a behemoth, the commanders of the Altan Space Navy dispatched one of their most powerful ships to investigate. What ASNS Discovery finds when they finally catch the intruder is a battered hulk manned by a dead crew.

That is disturbing news for the Altans. For the dead battleship could easily have defeated the whole of the Altan navy. If it could find Alta, then so could whomever it was that beat it. Something must be done…

**4. Antares Passage - US$4.50**

After more than a century of isolation, the paths between stars are again open and the people of Alta in contact with their sister colony on Sandar. The opening of the foldlines has not been the unmixed blessing the Altans had supposed, however.

For the reestablishment of interstellar travel has brought with it news of the Ryall, an alien race whose goal is the extermination of humanity. If they are to avoid defeat at the hands of the aliens, Alta must seek out the military might of Earth. However, to reach Earth requires them to dive into the heart of a supernova.

**5. Antares Victory – First Time in Print – US$7.00**

After a century of warfare, humanity finally discovered the Achilles heel of the Ryall, their xenophobic reptilian foe. Spica – Alpha Virginis – is the key star system in enemy space. It is the hub through which all Ryall starships must pass, and if humanity can only capture and hold it, they will strangle the Ryall war machine and end their threat to humankind forever.

It all seemed so simple in the computer simulations: Advance by stealth, attack without warning, strike swiftly with overwhelming power. Unfortunately, conquering the Ryall proves the easy part. With the key to victory in hand, Richard and Bethany Drake discover that they must also conquer human nature if they are to bring down the alien foe …

**6. Thunderstrike! - US$6.00**

The new comet found near Jupiter was an incredible treasure trove of water ice and rock. Immediately, the water-starved Luna Republic and the Sierra Corporation, a leader in asteroid mining, were squabbling over rights to the new resource. However, all thoughts of profit and fame were abandoned when a scientific expedition discovered that the comet's trajectory placed it on a collision course with Earth!

As scientists struggled to find a way to alter the comet's course, world leaders tried desperately to restrain mass panic, and two lovers quarreled over the direction the comet was to take, all Earth waited to see if humanity had any future at all…

**7. The Clouds of Saturn - US$4.50**

When the sun flared out of control and boiled Earth's oceans, humanity took refuge in a place that few would have predicted. In the greatest migration in history, the entire human race took up residence among the towering clouds and deep clear-air canyons of Saturn's upper atmosphere. Having survived the traitor star, they returned to the all-too-human tradition of internecine strife. The new city-states of Saturn began to resemble those of ancient Greece, with one group of cities taking on the role of militaristic Sparta...

**8. The Sails of Tau Ceti – US$4.50**

*Starhopper* was humanity's first interstellar probe. It was designed to search for intelligent life beyond the solar system. Before it could be launched, however, intelligent life found Earth. The discovery of an alien light sail inbound at the edge of the solar system generated considerable excitement in scientific circles. With the interstellar probe nearing completion, it gave scientists the opportunity to launch an expedition to meet the aliens while they were still in space. The second surprise came when *Starhopper's* crew boarded the alien craft. They found beings that, despite their alien physiques, were surprisingly compatible with humans. That two species so similar could have evolved a mere twelve light years from one another seemed too coincidental to be true.

One human being soon discovered that coincidence had nothing to do with it...

**9. Gibraltar Earth – First Time in Print — $6.00**

It is the 24th Century and humanity is just gaining a toehold out among the stars. Stellar Survey Starship *Magellan* is exploring the New Eden system when they encounter two alien spacecraft. When the encounter is over, the score is one human scout ship and one alien aggressor destroyed. In exploring the wreck of the second alien ship, spacers discover a survivor with a fantastic story.

The alien comes from a million-star Galactic Empire ruled over by a mysterious race known as the Broa. These overlords are the masters of this region of the galaxy and they allow no competitors. This news presents Earth's rulers with a problem. As yet, the Broa are ignorant of humanity's existence. Does the human race retreat to its one small world, quaking in fear that the Broa will eventually discover Earth? Or do they take a more aggressive approach?

Whatever they do, they must do it quickly! Time is running out for the human race…

**10. Gibraltar Sun – First Time in Print — $7.00**

The expedition to the Crab Nebula has returned to Earth and the news is not good. Out among the stars, a million systems have fallen under Broan domination, the fate awaiting Earth should the Broa ever learn of its existence. The problem would seem to allow but three responses: submit meekly to slavery, fight and risk extermination, or hide and pray the Broa remain ignorant of humankind for at least a few more generations. Are the hairless apes of Sol III finally faced with a problem for which there is no acceptable solution?

 

While politicians argue, Mark Rykand and Lisa Arden risk everything to spy on the all-powerful enemy that is beginning to wonder at the appearance of mysterious bipeds in their midst…

**11. Gridlock and Other Stories - US$4.50**

Where would you visit if you invented a time machine, but could not steer it? What if you went out for a six-pack of beer and never came back? If you think nuclear power is dangerous, you should try black holes as an energy source — or even scarier, solar energy! Visit the many worlds of Michael McCollum. I guarantee that you will be surprised!

## Non-Fiction Books

**12. The Art of Writing, Volume I - US$10.00**

Have you missed any of the articles in the Art of Writing Series? No problem. The first sixteen articles (October, 1996-December, 1997) have been collected into a book-length work of more than 72,000 words. Now you can learn about character, conflict, plot, pacing, dialogue, and the business of writing, all in one document.

**13. The Art of Writing, Volume II - US$10.00**

This collection covers the Art of Writing articles published during 1998. The book is 62,000 words in length and builds on the foundation of knowledge provided by Volume I of this popular series.

**14. The Art of Science Fiction, Volume I - US$10.00**

Have you missed any of the articles in the Art of Science Fiction Series? No problem. The first sixteen articles (October, 1996-December, 1997) have been collected into a book-length work of more than 70,000 words. Learn about science fiction techniques and technologies, including starships, time machines, and rocket propulsion. Tour the Solar System and learn astronomy from the science fiction writer's viewpoint. We don't care where the stars appear in the terrestrial sky. We want to know their true positions in space. If you are planning to write an interstellar romance, brushing up on your astronomy may be just what you need.

**15. The Art of Science Fiction, Volume II - US$10.00**

This collection covers the *Art of Science Fiction* articles published during 1998. The book is 67,000 words in length and builds on the foundation of knowledge provided by Volume I of this popular series.

**16. The Astrogator's Handbook – Expanded Edition and Deluxe Editions**

The Astrogator's Handbook has been very popular on Sci Fi – Arizona. The handbook has star maps that show science fiction writers where the stars are located in space rather than where they are located in Earth's sky. Because of the popularity, we are expanding the handbook to show nine times as much space and more than ten times as many stars. The expanded handbook includes the positions of 3500 stars as viewed from Polaris on 63 maps. This handbook is a useful resource for every science fiction writer and will appeal to anyone with an interest in astronomy.