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The Patterns of Stars

Nobody goes out, looks up, and "bingo" identifies a star. People look for a particular pattern of stars on the celestial sphere, and then a particular star in the pattern. The key word is *pattern* ; the key skill is *pattern recognition* — the ability to find (or create) structure in randomness, as in Figure 1-1.

At first glance, Figure 1-1 looks like a random jumble of light and dark blotches, but there is a pattern hidden in the jumble. The word "cow" will bring an image to mind, a mental image that matches the pattern in Figure 1-1. This exercise in perception illustrates what you need to learn the patterns of stars on the celestial sphere: common (recognized by everyone) patterns with common names. The common patterns of stars are called *constellations,* with a total of 88 constellations mapping the entire *celestial sphere.* I your star atlas you'll find a list of the constellation names and their abbreviations.

Figure 1-1

The common names for most of the constellations are pretty uncommon. Most of the names for the ancient constellations originated so long ago that we don't know who invented the names or what patterns they saw on the celestial sphere that inspired the names. All we have are the names and their stories; stories that may tell of great deeds and great heroes, gods and mortals, but not what pattern to look for. The modern constellations, added since the 1700's, mostly to fill in constellations for the southern stars, lack the pedigree of the ancient constellations and bear even less resemblance to their namesakes. Figure 1-2 illustrates the problem of recognizing constellations from their names and illuminates the solution.

The stars in Figure 1-2 compose the ancient constellation *Ursa Major* — the "*Big Bear*". The problem is finding a bear of any size in the pattern of the stars forming *Ursa Major*. What does pop out? The *pattern* of the brighter stars called the "*Big Dipper*." That's the pattern you see in Figure 1-2 ; that's the pattern you'll see at night. Many constellations have such "*nickname*" patterns of their bright stars : Ursa Major the "*Big Dipper," Ursa Minor* the "*Little Dipper*," the "*Teapot* " of *Sagittarius*, and *Cygnus* the "*Northern Cross*." These bright constellations with their recognizable nickname patterns provide the framework for learning the celestial sphere, while faint stars and faint constellations fill out the framework.
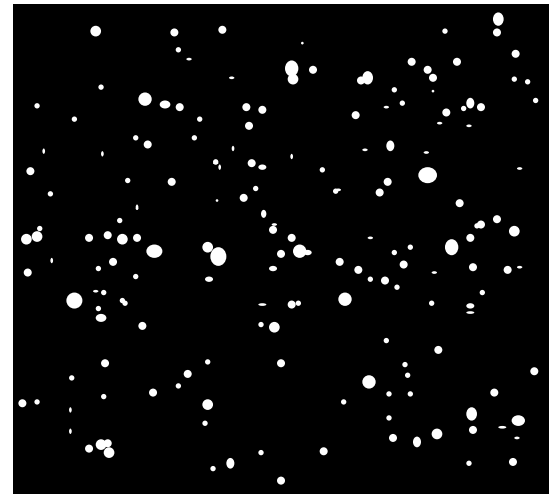
Naming stars is equally hard, there are sooo many of them togive them each an individual name. The astronomer *Johann Bayer* devised a solution in 1603 — make the constellation name a part of a star's name. Bayer assigned the Greek alphabet (α to ω) to the stars he could see in each constellation according from brightest to faintest (there are exceptions — Ursa Major is one he named from one end to the other).

Figure 1-2

As an illustration of Bayer's naming convention, *Vega*, the brightest star in the constellation of *Lyra* is α *Lyrae*, the second brightest star in Lyra is β *Lyrae*, and so on. Unfortunately, most constellations have more stars than there are Greek letters. So when Bayer ran out of Greek letters, he switched to lower case Roman letters (a,b,c ...). When he ran out of those, he switched to upper case Roman letters (A, B, C...). Fortunately, he ran out of stars before he ran out of letters.

In 1725 *John Flamsteed*, another astronomer, devised a similar scheme that avoided the limitations of alphabets by numbering the stars in each constellation from *west* to *east*. For example, the Flamsteed names for *Vega* and β *Lyrae* are 3 *Lyrae* and 10 *Lyrae,* respectively. Although he never ran out of numbers, Flamsteed's names do not carry the brightness information for stars that the Bayer names do, and precession (an effect, due

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to the gravity of the Sun and the Moon on the Earth that causes the north pole to wobble like a top over 26,000 years) has somewhat scrambled the west-to-east ordering over the last 263 years.

Astronomers have since decided to use a mix of the Bayer and Flamsteed names: Bayer names for stars that have Greek letters, and Flamsteed numbers for the rest. That's what you see next to each star in The Trained Eye Star Atlas. Still, these official names are cold — *Algol* "*the demon star*" is more evocative than β *Persei*. So look for the common names for the brighter stars adjacent to the Bayer-Flamsteed names in The Trained Eye Star Atlas.

One last note on names. Look what happens to the word Lyra when we incorporate it into Vega's Bayer-Flamsteed name of α Lyrae. The ending changes to indicate possession; the star α belongs to the constellation Lyra. Similarly, Perseus becomes possessive in β Persei. Possessive forms for the constellation names are given in the Trained Eye Star Atlas.

Now on to the other parameter we need for stars, *apparent visual magnitude.* Such a mysterious phrase. Well, actually only one of the three words is unfamiliar. *Apparent* means what it says, how does it "*appear*" from where you're standing. If you're standing upon the Earth, it will appear quite differently than if you're standing on a planet going round a distant star. "*Visual*" is equally familiar— it means "*as seen with the human eye*." So we are left with the mystery word "*magnitude*". You probably already have some feeling for magnitude's usage, but astronomers use it when talking about *brightness* of stars. *Hipparchus*, an ancient Greek astronomer, devised the original *apparent visual magnitude* scale for stars (back around 120 BC) as an aid in telling stars apart. He assigned *first magnitude* to the *brightest* stars he could see, *sixth magnitude* to the *dimmest*, and magnitudes in between to the stars in between. Astronomers have since revised and refined Hipparchus' original apparent visual magnitude scale and codified the relationship between magnitude and brightness. Still, Hipparchus' apparent visual magnitude scale lives on and has been the seed for other magnitude scales (e.g., *bolometric* and *absolute magnitudes*). Because there are other magnitude scales, we have to be careful in the use of the word magnitude. For now, the word magnitude is used in the context of apparent visual magnitude.

Let's look at the magnitude scale in detail. Reiterating Hipparchus' scheme, the smaller the magnitude, the bigger the brightness of the star. Smaller is bigger? How odd! Not really. Think back to your high school days — what was the brightest student in your class ranked? And the second brightest? And the third brightest? That's the way to think about magnitudes. Figure 1-5 illuminates the magnitude scale and its extension beyond Hipparchus' original 1-to-6 magnitude range.

The circles, representing stars on the maps in The Trained Eye Star Atlas, encode magnitudes in two ways. First, the "*size*" of a circle indicates a star's magnitude. If you compare the visual magnitude of two stars;

The star with the *bigger* circle has the *brighter* magnitude.
The star with the *smaller circle* has the *dimmer* magnitude.

Using circle sizes to represent magnitudes gives the star maps the correct look while the fillings of the circles change every half-magnitude to make reading an individual star's magnitude easier.

Sun = -26
-25
-20
Moon = -16
-15
-10
-5
Sirius = -1.6
0
5
Unaided Eye limit = 6
10
8" Telescope limit = 13.5
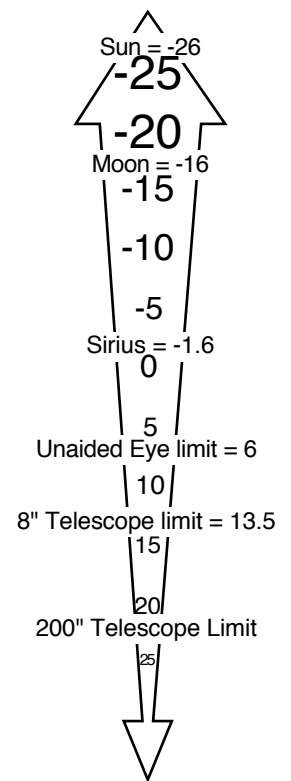15
20
200" Telescope Limit
25

Figure 1-5

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Beyond the Framework of Constellations

The framework of constellations failed at specifying the locations for stars and other celestial objects with the accuracy that civilizations needed to measure time, regulate the calendar, and predict the future. In many ancient civilizations, the astronomers were priests and the planets gods. The stars, fixed to the celestial sphere, provided the backdrop against which the gods/planets danced their passion play. The priest/astronomers discovered that they could predict the movements of the gods/planets in their dance, i.e., predict their future. The predictions weren't perfect at first, but surely that would come with exacting observation and diligent study. The priest/astronomers believed that once they could accurately predict the future for the gods/planets, then predicting the future for mere mortals would be trivial.

This desire to know the future drove the priest/astronomers to find ways of more accurately mapping the celestial sphere than the framework of constellations. The particular priest/astronomers we have to thank were the Babylonians, for it is they who cursed us with 60 seconds to the minute, 60 minutes to the hour, and 24 hours to the day. Why didn't they just count by tens like common folk? Probably because they weren't commoners. These priest/astronomers owed their prestige and livelihoods to their knowledge of the divine heavens. Knowledge that was, and remains, power — not to be given away freely. What better way to protect sacred knowledge from profane minds than a celestial counting ritual mandated by the gods.

Coordinating the Stars

The secret to the celestial sphere that the Babylonian priest/astronomers discovered was powerful in its simplicity — the position of any star could be specified exactly by using just *two coordinates*.   What are *coordinates*? A few commonplace examples of *coordinate systems* give the best definition: chessboards (queen's knight to queen's bishop 4), crossword puzzles (28 across) and the ubiquitous bingo (B 14).   A *coordinate* is just some measure of distance along some *axis* (line) in some direction from some *origin* (starting point). The simplest *coordinate system* imaginable is the one-dimensional "*number axis*" (Figure 1-6). On this *number axis*, the *coordinate* measures the number of units something is left (plus) or right (minus) of the *origin* at zero along the *number axis*. For example, the coordinate of α is 3.5, which tells you α is located 3.5 units to the left of zero.
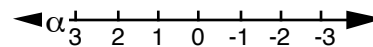
Figure 1-6

A two-dimensional surface (like a sheet of graph paper) requires two number axes (axes is the plural of axis) oriented perpendicular to each other (Figure 1-7). The *coordinates* for any point on the sheet is just an ordered pair of numbers — the horizontal (left/right) coordinate followed by the vertical (up/down) coordinate. On the two-dimensional surface the coordinates for α are (+3.7, -2.5) which means go left 3.7 and down 2.5.
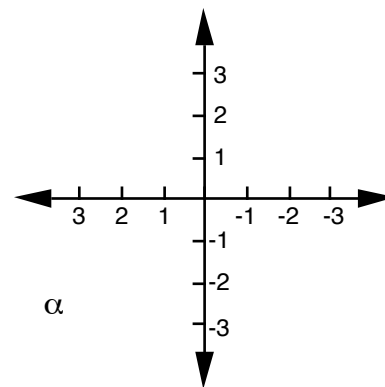
What works for flat surfaces has equivalents for curved surfaces, as the Babylonian priest/astronomers discovered.   Equivalent does not mean identical — you don't just take a sphere and crumple a piece of graph paper around it. The best way to understand the creation of the *celestial coordinate system* is to look at the celestial sphere from the god's-eye perspective — from the outside (Figure 1-8).

Figure 1-7

The first thing to do to create a coordinate system on the celestial sphere is to pick a point. So pick a point and call it the *north celestial pole* — as good a name as you'll see in Chapter 2. Pick another point directly opposite the north celestial pole on the celestial sphere and call it the *south celestial pole*. Then draw a line on the celestial sphere that stays exactly halfway between the north and south celestial poles. This line will circle all the way around the *celestial* sphere and divide it into two *equal* halves, so call it the *celestial equator*. Pick a point on the celestial equator and call it the *origin* by assigning it the coordinate value zero and the name *"first point of*

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Aires" (the origin of this point and its name will be revealed in Chapter 2). Then tick another 23 evenly spaced marks around the celestial equator and number them 1 to 23. The celestial equator now marks *right ascension* one of the two coordinates for the celestial coordinate system. *Right ascension* measures the distance around the celestial equator in units of *hours* (*h*), *minutes* (*m*) and *seconds* (*s*) (thank you, Babylonians), with 24 *hours* equaling a full circle around the celestial equator. Why measure a circle in units of time? The question is backwards — time measures the angular distance around the celestial equator to the Sun, an angle measured in hours, minutes and seconds.

You still need a second coordinate to measure distance *above* and *below* the celestial equator. Here we define the terms *north, south, east* and *west* (Figure 1-9). *East* is the direction of increasing *right ascension*, and *west* is the opposite direction to *east* (in the direction of decreasing *right ascension*). *North* is as shown, and *south* is the opposite direction to *north.*

Now generate the second coordinate by drawing lines due north and south away from the celestial equator at each hour of right ascension. A funny thing happens to the lines drawn to the north — they converge to a point. So do the lines drawn to the south. These are the two points with special names, the *north celestial pole* and the *south celestial pole.*

The second celestial coordinate, *declination*, measures the distance of a star north or south of the celestial equator in *degrees* (°), *arc-minutes* (') and *arc-seconds* (") (thanks again, Babylonians), from zero ° at the celestial equator to +90 ° at the *north celestial pole* or -90 ° at the *south celestial pole*. Notice you can't have a declination greater than +90 ° or less than - 90 °. Once you cross over the north pole you're on the other side and heading south, so declination decreases.

Notice that the key to defining this celestial coordinate system is picking the point for the north celestial pole. It's choice seems arbitrary only because the chooser hasn't been properly introduced (i.e., the *Earth*, Chapter 2). Also, don't confuse arc-second (") and arc-minute (') with second of time (s) and minute of time (m);

an arc-second (") equals	1/60th of an arc-minute (') ,
an arc-minute (') equals	1/60th of a degree (°), and
a degree (°) equals	1/360th of a full circle.

In contrast,

a second (s) equals	1/60th of a minute (m),
a minute (m) equals	1/60th of an hour (h), and
an hour (h) equals	1/24th of a full circle.

Given this difference in encompassing a full circle $\left(\frac{24}{360}\right)$,

an arc-second (") equals	1/15th of a second (s),
an arc-minute (') equals	1/15th of a minute (m) , and
a degree (°) equals	1/15th of an hour (h).

To keep this distinction straight, just use the terms arc-second (") and arc-minute (') with degree (°) and
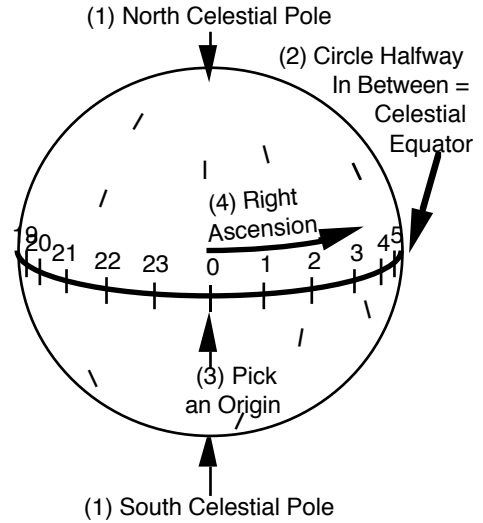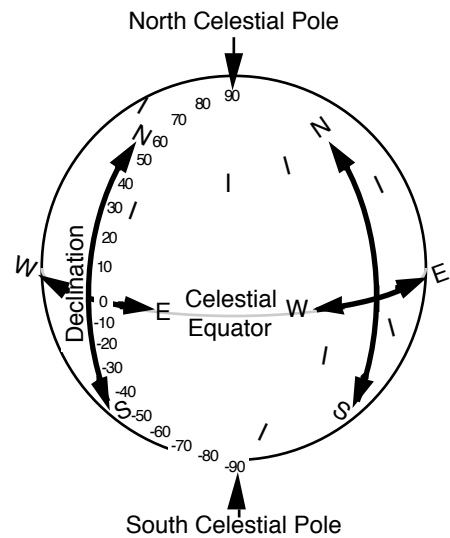

(1) North Celestial Pole
(2) Circle Halfway In Between = Celestial Equator
(4) Right Ascension
(3) Pick an Origin
(1) South Celestial Pole

Figure 1-8

North Celestial Pole
Declination
Celestial Equator
South Celestial Pole

Figure 1-9

second (s) and minute (m) with hour (h). Now its time to see what the celestial coordinate system looks like from the mortal's-eye view — from back inside the celestial sphere.

The Insider's View

 In the Trained Eye Star Atlas, there are two types of maps. Equatorial maps ring the sky around the celestial equator, polar maps show the stars around the north and south poles. Right ascension and declination are encoded on the two types of maps in different ways.

On the equatorial maps, the celestial equator runs across the middle of the maps and the hours of right ascension are labeled at the top and bottom. The 11 tic marks between each hour of right ascension correspond to each 5 minutes of each hour of right ascension. Each 10 ° of declination is printed on the left and right edges of the equatorial maps for the range of -60 to +60 degrees. Each tic mark between the tens of declination corresponds to one degree.   As you hold a equatorial map and look at it, *up* is *north* and *down* is *south* . A point of caution: *up* and *down* on the maps correspond to *north* and *south* on the celestial sphere only because people always hold maps with the *north* side *up.* In the sky, they are definitely not synonymous (as you'll learn in Chapter 2). Right ascension on the equatorial maps increases to the *left*, so *left* is *east* and *right* is *west*. Contrast this to a map of the Earth where east and west are right and left. The difference comes from looking at the Earth from the outside, not from the inside as we do the celestial sphere. Since *left* is *east* (on the maps), each equatorial star map goes to the left of its predecessor (Figure 1-10) and overlaps it by 1 hour of right ascension. This overlap provides continuity for constellations from one map to the next.

The north and south polar maps also encode right ascension and declination but in a strikingly different way. On these maps, right ascension runs around the edge — *clockwise* on the north polar map and *counterclockwise* on the south polar map (an important distinction to keep in mind). Thus, *eastward* is *clockwise* on the north polar map and *counterclockwise* on the south polar map. Declination varies radially inward on the maps from $\pm$50 at the edges to $\pm$90 at the centers. So *northward* is *inward* and *southward* is *outward* on the north polar map, while on the south polar map *northward* is *outward* and *southward* is *inward* (the other way around). The polar maps also overlap the equatorial maps by 10 degrees of declination for continuity.