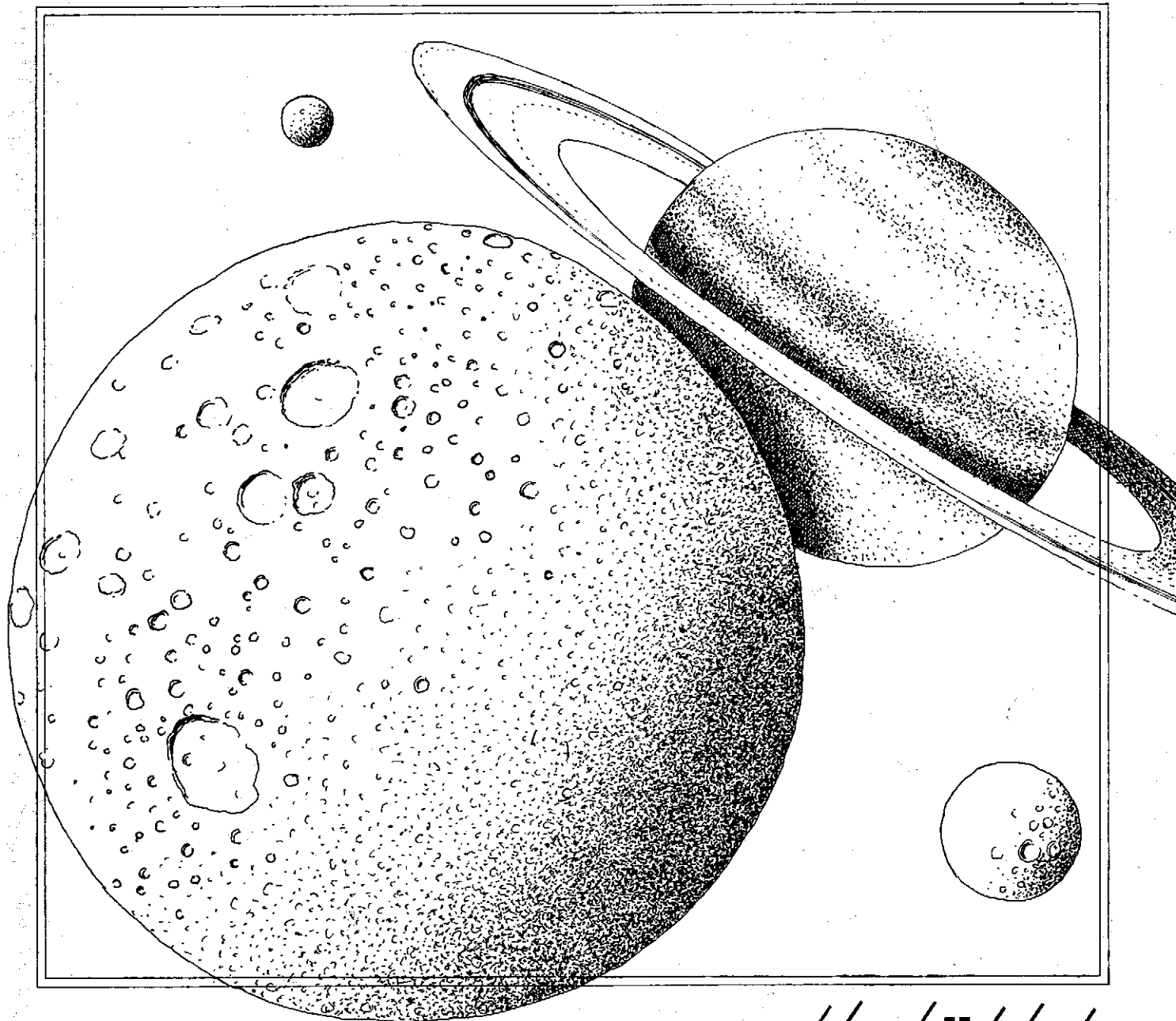


SKY TRAVEL™

An All Encompassing Astronomy Program



microlusions™

SKY TRAVEL™

An All Encompassing Astronomy Program

For The Commodore 64/128



17408 Chatsworth St., Granada Hills, CA 91344

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A WINDOW TO OUR GALAXY

Welcome to Sky Travel!

The magic of microelectronics has made it possible to have an accurate model of the universe in your own home at a modest cost. The awesome computations and enormous amounts of data are handled quickly and efficiently by your Commodore 64 computer. All you have to do is select your exploration commands and **Sky Travel** will return the information in pictorial form, directly on your screen — and in bright colors at that!

Sky Travel is uniquely user friendly and versatile. Special key functions were created to make it easy for you to find your way around the universe. The program also has a time clock so you can observe events as they unfold, without trying your patience. Through the marvels of mathematics, you can even put the clock in reverse and backtrack any event!

This manual first gives you an overview of the planetarium program itself in order to familiarize you with its many features. Next, we take you on a guided tour of the universe — in times past, present, and future. If you are a novice, we have no doubt that you will become so fascinated with the splendors of the universe that you will use the planetarium program again and again as you explore your particular interests on your own. If you are an expert in a given area, we hope to interest you in some new areas. And if you are a teacher, we believe that **Sky Travel** will intrigue your students into more independent work. It will also provide you with a convenient tool for creating lively and instructive classroom demonstrations.

Sky Travel is truly *A Window to our Galaxy* as seen from any place on earth. For general use, the best window for orienting yourself in the

sky is the 72 degree angular view, which corresponds roughly to your normal peripheral vision. The 36 degree angle is often a good compromise for special events such as solar and lunar eclipses, planetary transits and occultations, etc.* For observations requiring maximum magnification such as viewing double stars and satellite galaxies, your window can become a low power telescope by reducing the viewing angle to 18 or even 9 degrees.

The planetarium shows the location of more than 1200 stars, all of the 88 constellations (major ones with optional line drawings), the sun, the moon (with phases), the 8 planets (besides the Earth), a large number of deep-sky objects, and Halley's comet during its appearance in 1985/86. Using a specially developed FIND function, you can locate the sun, the moon, any planet, or any major constellation at the center of your screen. Through a special INFORM function, any object seen can be identified. The program also allows time travel of 10,000 years — both into the past and into the future. If you have a printer, you may make a permanent record of any screen display you create. The planetarium also has a CHART mode showing the sky projected on the celestial sphere with coordinate lines drawn in to make it easy to create, view, and print your own star and planetary charts. The most recent and accurate astronomical data available, from observatories around the world and from the U.S. space program, has been used as a basis for all computations.

Sky Travel design is active rather than stationary. This makes it particularly attractive for instruction since a student can interact with the computer and directly observe the desired phenomena instead of merely having to imagine them from explanations in a book. Furthermore, a student may find answers to test questions by means of the computer, and an instructor may copy printouts of selected screen displays, with certain data blanked out, for

* NOTE: a glossary has been provided to define terms such as these.

written tests. Besides Education in general, the planetarium program is designed for anyone interested in Astronomy (e.g. making stellar and planetary maps, studying eclipses and transits), History and Archaeology (e.g. dating of historical events from astronomical records), Chronology (e.g. synchronizing ancient calendars), Geography (e.g. latitude and longitude, local time and Greenwich Mean Time (GMT), sunrise/sunset vs. latitude and season), and Navigation (e.g. determining position from celestial observations).

Sky Travel actually is designed for anyone who even occasionally looks at the sky and wonders

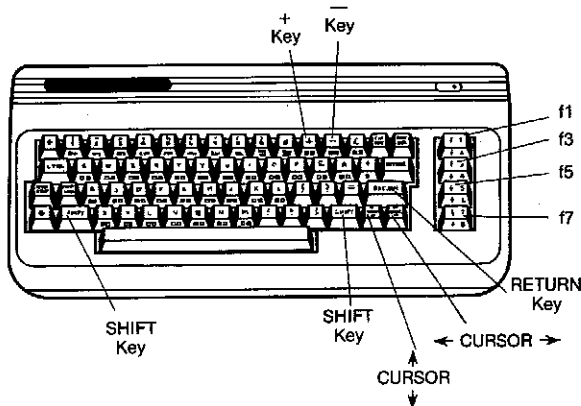
what any particular object might be? This includes the many people who were watching Halley's comet in 1985/86 — which was an opportunity of a lifetime; it will not return for another 75 years!

This manual is intended only to start you on your interesting astronomy study. You will find information in this manual to just spark your interests. We encourage you to enjoy these interests and research them further on your own. A long list of reference materials is provided at the end of the manual to aid you in your research.

GETTING STARTED

Keyboard

Knowing your way around the keyboard is very important. Below is a picture of the Commodore 64 keyboard. The keys necessary to use this program are highlighted.



Power Up Instructions

1. Be sure your Commodore 64 computer is turned **OFF**.
2. Connect your TV or monitor to the Commodore 64 computer.

3. Connect your disk drive to the Commodore 64 computer.
4. Connect your printer (if you have one) to your disk drive.
5. Plug in the TV or monitor, the disk drive, the printer (if you have one), and the Commodore 64 computer.
6. Turn **ON** your TV or monitor.
7. Turn **ON** your disk drive.
8. Turn **ON** your printer.
9. Turn **ON** your Commodore 64 computer.


Loading Instructions

1. Open the disk drive door.
2. Insert the **Sky Travel** disk into the disk drive with the label side up and facing you. Do not touch the exposed, shiny parts of the disk as this may damage it.
3. Close the disk drive door.
4. On the keyboard, type: LOAD "*",8,1 **RETURN** (Note: **RETURN** always means to press the return key.)

The disk drive will get busy for a few minutes and load the program. Upon completion of the loading process, the **Sky Travel** program will automatically start itself, calculate where all the stars and planets are, and draw a picture of the night sky.

If the program or any selection does not load within a few minutes, or if any time the program freezes and will not accept any keys you press, follow these steps:

1. Remove the disk from the drive.
2. Turn **OFF** your Commodore 64 computer, then turn it **ON** again.
3. Put the disk back in the drive.
4. Load the disk again.

On the sky you will see a symbol that looks like this:  p. This is a symbol that always points to the celestial north pole.

A Shortcut for Starting Out

You have just bought an exciting program, and now you have another thick manual to read! Do not despair — although we have tried hard to make the manual interesting and really believe that you will get the most out of *Sky Travel* by going through all of the examples, you can do quite a few things just by knowing how to push a few buttons. So we begin by showing you how to get a display of the sky from where you are right now. We will also show you how to use the program to identify any object you can see in the sky outside, and we will give you a handy table summarizing how to use the various functions (See page 61).

1. Where are You? — Now, the program does not know where you live or even what day it is, so it starts up with some defaults: January 1, 1988 at Washington D.C. But, if it is not New Year's Day 1988 and you do not happen to live in Washington, you'll probably want to change the default setting; whenever any new location is selected from the map that location then becomes the new default location. How do you do this? First, tell the computer where you are. If you knew your latitude and longitude that would help, but most people do not. To find that, you have to use a map. Fortunately, your *Window to our Galaxy* has a built-in map to make it easy.

To get the map, press the **f1** key on the upper right hand corner of your keyboard until the screen display in the lower right corner says "MAP" in reverse field letters. If you press **f1** too many times and go past the map, keep pressing a few more times and it will reappear. Now press **RETURN**. Your disk drive will get busy and paint a Mercator style map of the world on your screen. When it is finished loading, you will find a gold colored cross symbol over Washington D.C. Press one of the cursor keys, or, if you have a joystick, use it. Note that the cross on the screen moves, and some numbers in the data window at the right-hand side of the screen change. These numbers are the LATITUDE and LONGITUDE of the cross shaped symbol. From now on, we will call that symbol "the cursor." You now have two choices. If you happen to know your latitude and longitude, you can move the cursor until the numbers in the data window match those for your location. If you do not know your latitude and longitude, just locate where you are on the map and move the cursor to that point. That is all there is to it!

2. Setting the Date and Time — If the date happens to be January 1, 1988 in the wee hours of the morning, you are done. However, since that is not too likely, you need to tell the computer what date and time it is. To do that, you need to get into the SET mode. Press **f1** again until the screen display says "SET" in reverse field letters. Then press **RETURN**. The map will stay on the screen; however, the data window will change completely. It is now set up for accepting changes in the date and time. All changes can be made using the cursor keys or a joystick, if one is plugged in. Note that the month is highlighted by being displayed in reverse field. Pressing the up/down cursor key or pushing the joystick up or down will change the month. When the month is correct, use the right cursor key or the joystick, pushing it

to the right, to highlight the first digit in the year. The number is then changed by pressing the up/down key or using the joystick. When you get the correct digit for today's date, push the cursor to the right one position and fix the other number. (You can freely go in either direction; the program is smart enough to prevent the cursor from ending up where it should not.) Similarly you can change the day of the month and the time, one digit at a time. Note that we use a 12 hour clock with a little "A" or "P" to the right of the time to indicate whether the time is before or after noon. You can change the A to a P and vice versa using the cursor keys. By the way, the + and - keys do the same thing as the up/down cursor key and the joystick. Use whichever is most comfortable for you.

3. Getting Back the Sky — To return to the SKY mode, go back to our friend the **F1** key and press it until the display shows "SKY" in reverse field. Then press **RETURN**. The computer really gets busy now and calculates where all the planets are on that date and finally, which stars are visible. When all this computation is finished, the sky display will reappear, and it will be correct for where and when you selected.

4. Looking Around — You are now looking south and your window is 72 degrees wide (by default). An easy way to look around is to use the N, E, W, and S keys. These simply direct your point of view to the north, east, west, or south, and they do not affect how high you are looking. Try pressing N. If you told the computer you were anywhere in the northern hemisphere, you are now looking at the familiar circumpolar constellations including the Big Dipper, the Little Dipper (with the North Star at the end of the handle), and the sprawling W shape of Cassiopeia. Their positions in the sky depend on the season and what time of day it is. Looking up or down is easy. Use the up/down cursor key or your joystick to move

the golden cross shaped cursor, which was in the center of the field. Note that you can move it all over the field of view and that the numbers in the data display window at the right of the screen will change. These numbers are the coordinates of your cursor in the sky; you will learn more about them later. Run the cursor all the way to the top of the screen and continue to press the up key. Note that the message "SLEWING" appears in the text window at the bottom of the display. After a few seconds delay, a new view of the sky appears, shifted in the direction which you were moving the cursor and allowing you to see higher up in the sky. You can continue to do this until the center of the screen is the point straight overhead (called the Zenith). At this point, the program refuses to let you look further in that direction and gives you the message "LOOKING STRAIGHT UP". It then begins to rotate the display, exactly as you would if you looked up as high as you could and then turned your body around to see further without falling down! As an exercise, try to look straight down. You are not limited to looking exactly north, south, east, or west. You can use the left/right cursor key or the joystick to slew the field of view also. Just run the cursor into the left or right-hand margin of the screen until the message "SLEWING" appears in the text window, and the field of view will shift in the direction you were trying to move the cursor.

5. Identification — Let us say it is evening, the sun has just set, and you noticed from your back yard that there is a brilliant "star" in the west, just above the horizon and easily seen in the twilight. What is it? **Sky Travel** will tell you. Do steps 1-4 above (if you are just starting up), and press W and the down cursor key until you see the horizon. Compare the display with the sky, and run the cursor over to the object located where your UAO (unidentified astronomical object) is. Then press **F7** key or the

Fire Button on your joystick. The program will now identify the object, and the disk drive will send the computer a text message which will tell you what the object is, how far away it is, and other bits of information. The message will scroll in from the right. Use the cursor keys to read the remainder of long messages. When you have read the message, press **RETURN** to regain control of the SKY mode.

For an enjoyable evening of star watching, set

up your Commodore 64 outside on the patio table, turn down the monitor brightness (to keep your eyes adjusted to the dark), and explore the sky using your computer as a guide.

If you are mainly interested in recognizing the stars outside, the manual gives you some helpful tips starting on page 17.

When you are ready to continue, start reading on!

A GUIDED TOUR OF THE PLANETARIUM

A great deal of flexibility has been built into the **Sky Travel** program to make it both versatile and easy to use. In this section we illustrate how to operate the program and how to choose among the many options, so you can get the optimum output for your particular purpose.

If you are a novice, please do not get discouraged by some of the sketches and explanations. All that is required to operate the program is to follow directions and push buttons. You may therefore safely bypass the descriptions of the various coordinate systems at your first reading. This is not a suggestion to avoid studying the sketches and explanations altogether. If you can balance your checkbook and make a graph of the daily temperature, you have sufficient background to follow everything in this manual — and your efforts will be well rewarded by the additional uses you will find for **Sky Travel**. If you are an expert, you will appreciate the convenience of having your Commodore 64 do your preliminary work before beginning more complicated calculations on larger computers.

The MODE Key **f1**

Sky Travel has four basic modes: MAP, SET, SKY,

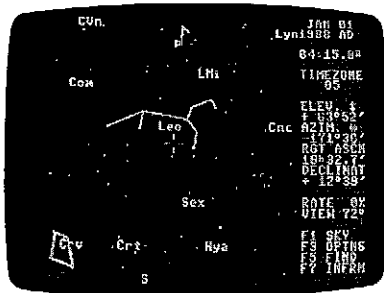
and CHART. The mode you are presently in is displayed in the data window to the right of your screen, in illuminated letters. You can change from mode to mode by tapping the **f1** key. If you choose a new mode, it is shown in the data window in dark letters on an illuminated background (reverse field). You activate the new mode by pressing **RETURN**.

The MAP mode allows you to select your location on the Earth, and the SET mode allows you to choose the month, day, year, and time. The SKY mode is the normal display mode, and here you have a number of options in order to make the sky appear so it best suits your individual purpose. Finally, the CHART mode gives you the opportunity to view the part of the celestial sphere you are pointing at, without obstruction by the horizon and with north always directed upwards for easy orientation. The CHART mode is basically intended for making permanent sky maps of stars and galaxies; for plotting the locations of the sun, moon, or planets during a given period; and for plotting the predicted path for Halley's comet.

When **Sky Travel** first starts up, it goes directly to the SKY mode. We suggest that you accept our preset default selections for location and time the first time around — you will have plenty of opportunity to select your own choices later.

The SKY Mode

After you have started up, **Sky Travel** presents the following screen display:



You are looking out the window early in the morning on January 1, 1988 after celebrating New Year's Eve in Washington D.C. You are looking straight south, and with the help of line diagrams and names magically painted in the sky, you immediately recognize the constellation Leo (the Lion). But your window is controlled by magic also! Use the cursor key on the keyboard to move the cross hair cursor from the center of the screen until it pushes on the right side of your window; your window now moves to the right! Keep pushing until the text line underneath the window shows a W (west), then stop. You are now readily recognize the constellation Gemini (the Twins).

Continue pushing on the right side of the screen until the text line shows an N (north), then stop. You now see these constellations: the Big Dipper, the Little Dipper, and next to the North Pole (which is marked with a small cross) you see Polaris, the Pole Star. Then use the down cursor to move the window downwards until you see the horizon come up; stop when the horizon is about one third up the screen. You now recognize the open W of Cassiopeia about to set below the

horizon in the early morning hours.

Note that **Sky Travel** has a translucent Earth; you can see through it! Therefore, stars and planets, which have already set — or which may be about to rise — can actually be seen through the Earth itself. This, incidentally, is true also of the sun and the moon. Now, use the down cursor to push the window further down; when the cursor no longer moves, you are looking straight down at your own feet!

Now let us push the window upwards as far as it will go using the up cursor key. When you get to the point where you are looking straight up, you cannot go further without losing your balance. So instead, you turn your head. As you turn looking straight up, many of the constellations you saw before now reappear in this overhead view.

This example is merely an illustration of how to operate the basic SKY mode. However, you can change the viewing angle, use an automatic time clock, include deep-sky objects, identify and get information on all visible objects, and even replace the cross hair cursor with a space ship. This will be covered in more detail under the description of the various command keys.

In order to prepare for the next SKY display, tap the **F3** key until the message in the data window shows **LINES**. Then hold down the **SHIFT** key and tap **F3** again; the message now shows **NO LINES** in reverse field. Continue tapping **F3** until it shows **NO SOUND**, then hold down **SHIFT** and tap **F3** changing the message to **SOUND**. Press **RETURN**. We shall now show you how to change your location on Earth; this is done by means of:

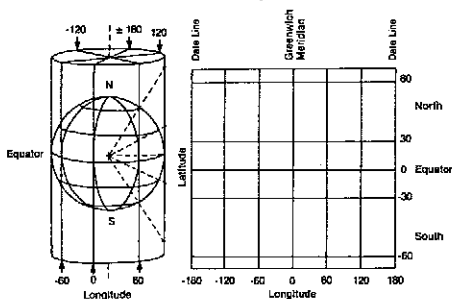
The MAP Mode

Tap the **F1** key until "MAP" shows in

reverse field in the data window, then press **RETURN**. The program now loads a map of the world onto your screen.

The map is a Mercator style projection of the Earth's surface, meaning that the Earth's sphere is projected onto a cylinder which then is unrolled onto a flat map. Each location on Earth is defined by two coordinates: latitude and longitude.

Mercator Projection



7

Latitude is measured in degrees from the equator and goes from 0 degrees at the equator to +90° (degrees) at the North Pole, and to -90° at the South Pole. Note that on a Mercator map you cannot reach the poles. Also, the map reproduces actual distances and areas faithfully only near the equator and stretches everything more and more as you go near the poles. On the other hand, a Mercator projection is ideal for mapping time zones because lines of constant longitude are parallel lines on the map.

Longitude is measured in degrees (or hours) from the so-called Greenwich meridian near London, England and is usually (as in **Sky Travel**) counted positive eastward and negative westward. Each 15° corresponds to an hour of time difference (360 degrees/24 hours = 15 degrees/hour). In Mercator's projection, each hour zone is therefore a 15° wide band parallel to the Greenwich meridian, which goes through the middle of the Greenwich or Zero Time Zone. At 180° east and 180° west, the eastern and

western longitudes superpose as the Date Line.

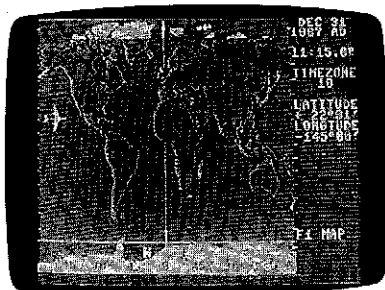
Note that the astronomical time zones may differ from the official time zones because actual zone boundaries are based on political decisions. The official time may also vary during the year due to daylight saving time.

At start-up the cursor was placed over Washington D.C. You can change your location by using the up/down and left/right cursor keys. If you have a joystick, just plug it in at either of the two joystick ports on your Commodore 64 computer. The program will allow you to use either method for moving your cursor; incidentally, this is the case also in the SKY mode. The data window on the right of your screen displays the latitude and longitude as well as the time zone of your cursor location. In cases where great accuracy is needed in pinpointing a location, you should use this numerical display to fine tune the cursor position. The latitudes and longitudes of many strategically located cities and islands are listed in a table at the back of the manual.

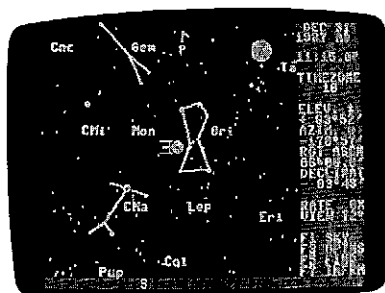
One of the **F3** operations (SOUND), demonstrated before leaving the SKY mode, changed the MAP mode cursor into an airplane and the SKY mode cursor into a space ship. In addition, the cursor movement is now accompanied by sound effects! This option is intended to help you learn concepts such as time zones, the date line, star recognition, etc. while flying around the world. Let us illustrate this by continuing our introductory example:

While you were looking out the window early New Year's morning in Washington D.C., your friend was flying back from a vacation in Hawaii. Since you are now in the MAP mode, use the right/left and up/down cursor keys, or the joystick, to move the airplane to longitude 22° north, latitude 145° west. Being over the Eastern Pacific (Time Zone 10), your friend is five

hours behind Washington D.C. (Time Zone 5), and he is just getting ready to welcome the New Year; the data window shows that his local time is 11:15 P.M. on Dec. 31, 1987.



Now, if you wish to see his view of the southern sky, tap the **f1** key until "SKY" shows in reverse field in the data window. Then press **RETURN**. You are now back in the SKY mode. In order to reduce the VIEWing Angle to 36 degrees, hold down the **SHIFT** key while pressing the **—** key, then press **RETURN**. Press **S** for a southern view. You may now recognize the familiar constellation Orion just to the lower left of the full moon, next to the space ship (the cursor) and the brightest of all stars, Sirius, just to the lower left of Orion in the constellation Canis Major. This is your friend's view as he celebrates New Year.



We now leave your friend to describe how to change to another year, date, and local time. This is done in:

The SET Mode

"When longitude is east
Greenwich time is least
When longitude is west
Greenwich time is best"

In order to get into SET mode, tap **f1** until "SET" is shown in reverse field, then press **RETURN**. This mode allows you to select the time and date. As the SET mode is displayed, a reverse field cursor is shown over the month. Using the **+** and **-** keys, you can change it to any month desired. After changing the month, use the left/right cursor key to move the cursor over any digit of the day display and change it to the desired value using the **+/—** keys. Again, using the right/left cursor key and the **+/—** keys, change the year. Note that the **+/—** keys change any digit by one unit at a time, and that years before 1 A.D. are automatically changed to B.C.

You can now use the left/right cursor key to move the reverse field cursor to the Hour: Minute display. Again, use the **+/—** keys to choose the local time. Note that to the right of the time display, A.M. is indicated as an A and P.M. as a P. For convenience, the **+/—** keys also allow you to change between A.M. and P.M. If you wish to know the corresponding Greenwich Mean Time (GMT), add (with the sign !) the number of hours shown under "Time Zone," to your local zone time. (See the Glossary for a detailed explanation of Greenwich Mean Time.) You can use the little rhyme quoted above to remember this: western time zones are positive numbers so when you add the time zone number to your local time, you get a later hour in GMT. In contrast, eastern time zone numbers are negative so you have to subtract and always get an earlier time for Greenwich than for local eastern times.

The CHART Mode

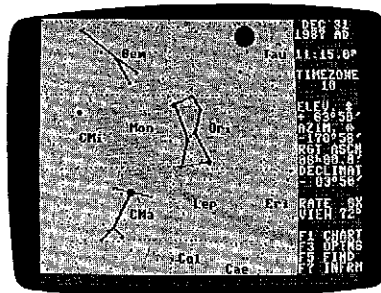
The CHART mode allows you to view and print the section of the celestial sphere corresponding to the view of the sky you selected in the SKY mode. In the CHART mode, the horizon is removed and celestial coordinate lines for Right Ascension and Declination are shown. These lines correspond to longitude and latitude on Earth and help you use the chart for plotting. North is always up on the chart. The CHART mode displays the sky objects in reverse field (that is as dark spots on a light background). The printout is black signatures for the sky objects on a white background, to save your printer ribbon! If you have a printer connected to your Commodore 64, the print command is simply **SHIFT** P. (See page 10 for further instructions.)

The CHART mode can be used for making star maps for any date and location on Earth. The map can be used to locate the planets and any deep-sky object of particular interest. In addition, the movement of the planets, the sun, or the moon for any desired time period can be plotted by hand on the chart. You do this by placing the cursor over the object. Then read the location of these moving sky objects from the Right Ascension/Declination values in the data window for a sequence of times or dates. This is most easily done by using the TRACKing option (more detailed description under Option key **F3**). In general, all of the options available in SKY mode are still available in CHART mode except that you can no longer use the cursor to move your window. To do that, you have to return first to the SKY mode, make the change, and then come back to the CHART mode.

If you wish to know the Declination/Right Ascension values for any object, line, or line intersection on your chart, remember that the coordinates of the cursor position are shown in the data window. All you have to do is move

your cursor to the point in question and read the values off the display. And if you are in doubt as to the identity of any object, just place the cursor over it and use **INFORM** **F7** as we shall discuss below.

*For illustration, tap the **F1** key until "CHART" is shown in reverse field, then press **RETURN**. If you have a printer, connect it and press P while holding down the **SHIFT** key. If you have left the settings (both location and time) unchanged from our earlier example, you will get the CHART mode display of your friend's New Years Eve view, on his flight from Hawaii.*



Now, before we discuss the other function keys (**F3** — **F7**), let us become familiar with the commands assigned to some of the regular keys on the keyboard.

Other COMMAND Keys

The Accelerated Clock (RATE)

In the SKY mode, you can start a clock that updates the display so you can watch, for example, you can see a sunset or an eclipse as it progresses. In the data window to the right, you see a line saying **RATE 0X** — that means that the clock is stopped. To start the clock, you press the + or - keys. 1X is actual time, 2X is twice regular time, and so forth. You can go up to 64X, which means that an hour of real time

only takes about a minute on your computer. Pressing the — key reduces the speed of the clock until you reach 0X — the stopped clock. You can even go backwards in time by continuing to tap the — key up to a maximum rate of — 64X.

It is good practice to stop the clock before you change to another location or date. When your computer is computing, it tells you so in the textline below the screen display. During these times, no new commands are accepted by the computer — it is “busy.” The more you speed up the time factor, the busier the computer gets, and the more difficult it becomes to find a small time window to enter your change command. Therefore, before changing displays, etc., stop the clock!

Sometimes when the clock is set at a RATE of 64X, especially with a wide VIEWing Angle (see below), the computer is so busy that you may have difficulties stopping the clock by tapping the — or + key. In that case, hold the key down steadily. You will eventually catch the brief non-busy moments and manage to stop the clock.

The VIEWING ANGLE

When you are in the SKY mode, the data window just below the clock RATE line, displays the word VIEW. This is the angular section of the sky displayed on the screen, the maximum angle being 72°, the minimum angle being 9°. You change the VIEWing Angle by holding down the **SHIFT** key while tapping the +/- keys. Always start out with the widest angle, making sure that the objects you are interested in are well centered on your screen, before reducing the VIEWing Angle. If you do not do this, you may lose your object outside the screen and have difficulty orienting yourself. For the same reason, it is easiest to decrease the VIEWing Angle in steps!

The DIRECTION Keys

When you are in SKY mode and you want to look in a different direction, you have already seen that you can use the cursor to push the window to either side, as well as up or down. However, there is an easier way. You can use four keys: N (for north), S (for south), and you can guess what directions you get with E and W. North, south, east, and west are known as the cardinal directions.

There is still another direction key: O for Opposition. This key points you in a direction exactly 180° (opposite) from the direction you were looking in. You can use that to see whether any planets are in direct opposition to the sun. Use the FIND key (see page 11) to center the sun on your screen, then press the letter O (not zero) — and abracadabra, there you are!

If you have a joystick, you can use that instead of the direction keys. Just plug it in either of the joystick ports on the side of your Commodore 64. The computer will honor both the keys and the joystick — the latter being most convenient for most people.

By the way, the Fire Button on your joystick functions as your INFORM key in both SKY and CHART modes.

The PRINT Keys

If you have a Commodore printer, you can make a permanent record of any visual screen display you create. You can use either a VIC 1525 printer or a Commodore MPS 801. Just plug it into the serial bus in the back of your Commodore 1541 disk drive, plug in the printer, and turn it on. The printer is activated by holding down the **SHIFT** key while pressing P (for Print).

You will probably be using the printer mostly in connection with the SKY or CHART mode. Therefore carefully study the many choices

you have for changing the screen display by means of the Option key **f3**.

If you try to print when your printer is not hooked up or turned on, the program will show an error message at the bottom of your screen. (IO error, try again!) Simply check your printer to make sure it is hooked up and turned on, and try again.

The OPTION Key **f3**

This key can be used in both SKY and CHART modes and provides a number of choices. By default, **Sky Travel** chooses: LINES, NAMES, SYMBOLS, NO DEEP, NO TRACK, and NO SOUND. (These options are explained below.) The selections which currently are active are shown one at a time in the data window when you tap the **f3** key. If you wish to change any of them, hold down the **SHIFT** key and tap **f3** again; the opposite choice is then shown in reverse field, and you activate it by pressing **RETURN**. Incidentally, you can make all of your choices and then press **RETURN** to activate all of them at once.

LINES mean constellation lines. Simplified line diagrams are available to help locate principal constellations, especially those that are useful for orienting yourself in the sky. NO LINES eliminates these line drawings.

NAMES displays three letter abbreviations next to the constellations appearing on the screen. NO NAMES eliminates them. As with LINES, NAMES is helpful for general orientation, but may be in the way, for example, in trying to identify individual objects.

SYMBOLS refer to the symbols commonly used to identify the planets. For example:

Mercury ☿ Venus ♀ Mars ♂ Jupiter ♃
Saturn ♄ Uranus ♅ Neptune ♆ Pluto ♇

SYMBOLS are generally quite helpful since planets move around and sometimes are difficult to identify by inspection. When not needed or in the way, NO SYMBOLS replaces them with regular starlike patterns.

DEEP-SKY displays several hundred very interesting nebula and galaxies and is essential when you want to study the distant universe. However, they do clutter up the more familiar star patterns and make it difficult to orient yourself, at least in the beginning. NO DEEP turns them off.

TRACK is used in special cases only in combination with the FIND key. If the sun, moon, any of the planets, or Halley's comet has been located under the cursor by means of the FIND function, it is kept there as long as TRACK is active. The principle use is to record Right Ascension and Declination values individually for, say, a planet or the moon over a period of time in order to determine their closest approach. This method is also useful in preparing star charts showing the location of planets over a time period, say, for later outside observation. NO TRACK turns this option off, and this should be the normal position.

SOUND is intended to enhance the learning experience. Aside from a sound effect when the cursor is being moved around, this option simultaneously turns the cross hair cursor into an airplane when in the MAP mode and into a space ship when in the SKY mode. NO SOUND turns these special effects off.

The Find Key **f5**

This key can be used in SKY and CHART modes and enables you to locate the SUN, MOON, any PLANET, any CONSTELLATION, or the COMET (in season) at the center of your screen. Instead of looking around the sky for a specific object, just tap the **f5** key until the desired sky object is shown in the data window, then press **RETURN**. When you ask for a con-

stellation, the screen changes to a display of three letter abbreviations for the 88 constellations. Move the cursor over the desired one and press **RETURN**. If you do not remember the abbreviation, the manual has a listing in the back. By the way, the constellation list also gives you the option to select either the North Pole or the South Pole (lower right on list display). It even gives you the option to get back if you change your mind and do not want to see a constellation after all. The last "constellation" on the display is Oops. When you put the cursor on that and press **RETURN**, you get back to where you were!



The INFORM Key **f7**

INFORM can be used in SKY and CHART modes and is intended to reduce the need for looking in manuals while using **Sky Travel**. Detailed descriptions of the 88 constellations, more than 1200 stars, and 300 deep-sky objects are contained in a disk file which is accessed simply by placing the cursor over the particular sky object and then pressing **f7** (in the case of constellations, the cursor should be placed over the first letter of the abbreviated name). The Fire Button on your joystick may be used instead of **f7**.

The information is displayed on the textline below the screen. You can scroll both forwards and backwards, so in case you mistakenly pass over some important information, you do not have to start all over again. When INFORM is

used the left/right cursor key or your joystick controls the scrolling.

The textline always identifies the object and lists the proper catalog number. For the stars, the HD number (Henry Draper Catalog) is used. For the deep-sky objects, the so-called NGC number (New General Catalog) is shown together with the Messier number. The Messier number is used if the object was originally listed by Charles Messier, a French astronomer and comet hunter who prepared the first catalog (1781 A.D.) of non-stellar sky objects. (e.g. Andromeda galaxy = NGC 224 = M31). These catalog numbers are in universal use and enable you to locate more detailed information about any particular sky object in the literature if you should wish to do so. In addition, the text contains the most important astronomical data including mass and/or dimensions as well as distance in light years.

To get out of INFORM, press **RETURN** or the Fire Button, if you are using the joystick!

12

Program OPERATING HINTS

You will appreciate the many options this program provides as soon as you become familiar with **Sky Travel** and start to use it on your own. However, for general purposes, the following settings are just fine (remember that the Clock RATE, VIEW Angle, and **f3** option changes are made in SKY mode):

Clock RATE: 0X (stopped); VIEWing Angle: 36 degrees is a good choice; DIRECTION keys: a joystick enables you to manipulate the system most easily while you sit back and enjoy it; PRINTER: very helpful if you plan to study the real sky later (constellations, planets, comet); **f3** / LINES: on; **f3** / NAMES: on; **f3** / SYMBOLS: on; **f3** / DEEP-SKY: off; **f3** / TRACKING: off; **f3** / SOUND: off.

For the following purposes, these changes are appropriate:

Star/Constellation recognition: go to VIEW ANGLE 72 degrees.

Studies of galaxies: DEEP-SKY must be on. For faintest stars and galaxies, start with 36 degrees VIEW Angle and lower in steps.

Sunrise/sunset studies: the Clock RATE should be set at 16X to 32X.

Teaching youngsters: turn on SOUND.

For special purposes: consult the discussion in the preceeding section and the examples in this manual.

A GUIDED TOUR OF THE UNIVERSE

In this section we take you on a tour of the universe by way of **Sky Travel** — from many different view points. Human knowledge about the universe has affected most of mankind through the ages — from religion and philosophy to such simple tasks as being able to tell where you are and how to get from one place to another. The understanding of the world we live in has increased perhaps as much in this generation as in all the generations that came before us. Yet, the more we learn, the more amazing the universe becomes!

GEOGRAPHY

The first civilizations all emerged in the valleys of the great rivers: the Nile (Egypt), the Euphrates and the Tigris (Babylonia and Assyria), the Indus and the Ganges (India), and the Yangtze and the Yellow River (China). The fertility of these regions provided a necessary condition for the creation of cities. Some people were freed from laboring solely to provide food. On the other hand, as farming and the raising of animals became more organized, the new societies were affected more by the dangers of nature — such as flooding and droughts. It became essential to know when to plant, when to irrigate, and when to harvest. It also became necessary to understand the seasons.

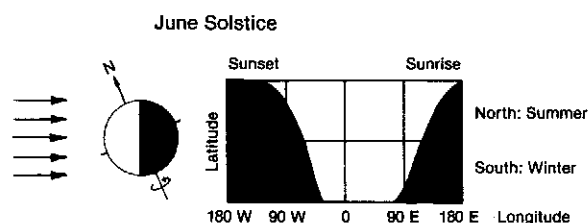
Days, Years, and Seasons

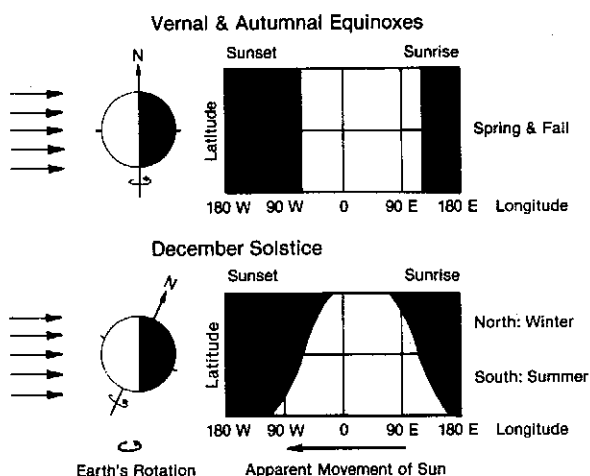
"Time is the dimension that prevents everything from occurring simultaneously"

Anonymous

A solar day is the time it takes the Earth to make one complete turn around its own axis, with relation to the sun. When a given location is facing the sun it is daytime, when that location is covered by the Earth's shadow it is night. The Earth's axis of rotation is tilted $23\frac{1}{2}^\circ$ with respect to the plane of the Earth's orbit. One result of this is that days and nights are not of equal length except at the equator, all year, and at the other locations twice a year [the Vernal (Spring) and Autumnal (Fall) Equinoxes]. This is explained by the sketches below, both in terms of the Earth's shadow on itself during its rotation and varying orbital positions around the sun, as well as in terms of the Earth's shadow on a Mercator map of the Earth.

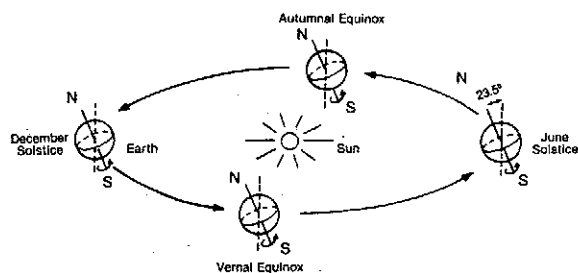
Reasons For The Seasons





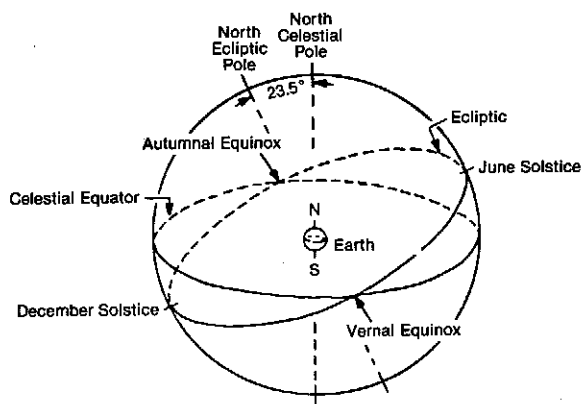
It takes the Earth 365.2422 solar days to complete an orbit around the sun. This is the solar year on which our calendar is based. After that, the cycle of changes in daylight and seasons is repeated. Like the variations in the length of the day, during the year, the seasons are caused by the fact that the Earth's axis of rotation is tilted with respect to the plane of the Earth's orbit. When it is summer on the Northern hemisphere, the Earth's North Pole is tilted towards the sun; when it is winter, the North Pole points away from the sun. Of course, the situation is exactly reversed for the South Pole; therefore, the Southern hemisphere has winter when the Northern hemisphere has summer and vice versa.

Earth's Orbit Around Sun



Let us now translate these motions into the movement of the sun on the celestial sphere, which is the way things actually appear to an observer on the surface of the Earth.

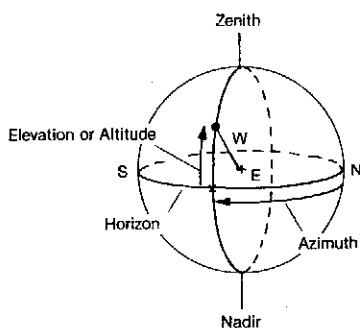
Celestial Sphere and Ecliptic



We see then that the sun appears to travel in a great circle. This circle is called the ecliptic and is tilted $23\frac{1}{2}^\circ$ with respect to the celestial equator. This is the angle the Earth's axis of rotation makes with the Earth's orbit. Ancient astronomers knew the celestial sphere extremely well, including the precise location of the ecliptic; but otherwise, their understanding of the universe was limited. They believed that the Earth was stationary (after all, you cannot feel the rotation), and that it was the center of the universe. Nevertheless, even though we now know much more about the spacial geometry of the universe, the sky still appears to us the same way it did to our forefathers. This "Earth-centered" (geocentric) point of view of the universe is still useful; and in fact, it is the way it is displayed in a planetarium! Before we look at some specific demonstrations, we should mention the meaning of some of the numbers which appear in the data window when we are in SKY mode. The

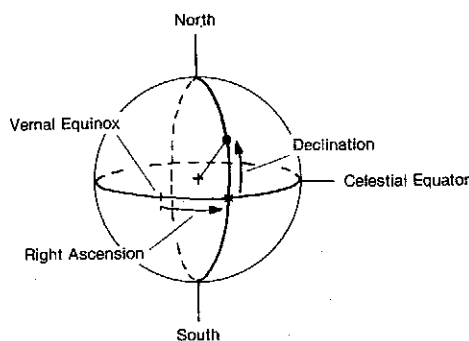
numbers are in all cases the coordinates of the cursor. By placing the cursor over any visible sky object, you can directly read its coordinates. Elevation and Azimuth are the direction coordinates to a point in the sky. It is seen by the observer with reference to the horizon and a meridian (great circle) through the Zenith (the point right overhead). These numbers are convenient to measure but change constantly as the Earth rotates.

Elevation and Azimuth



The other numbers, Declination and Right Ascension, are the position coordinates on the celestial sphere. They correspond to latitude and longitude on Earth. As we shall see later (p. 18), maps for locating stars in the sky are often Mercator style maps.

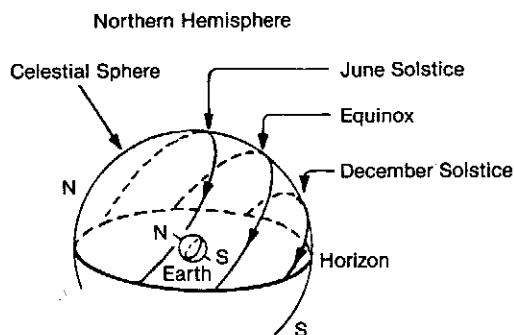
Celestial Sphere



Sunrise and Sunset at Washington D.C.

Sky Travel allows you to observe and study the movements of the sun at different latitudes and times of the year. The following sketch shows how the tilted Earth's axis affects the elevation of the sun on the Northern hemisphere during the year. This is of course quite familiar to people living in North America and Europe.

Apparent Movement of Sun



We shall now use **Sky Travel** to simulate a Northern hemisphere sunrise and sunset:

Tap **f1** and go to MAP mode; press **RETURN**. Set latitude to $38^{\circ} 50' N$ and longitude to $77^{\circ} W$ (Washington D.C.). Tap **f1** and go to SET mode; press **RETURN**. Set the date and time to July 4, 1986 A.D. at 2:45 A.M. Tap **f1** and go to SKY mode; press **RETURN**. Use **OPTION f3** to install the following options: **LINES** on, **SYMBOLS** on, **NAMES** on, **DEEP** off, **TRACK** off, **SOUND** off. Hold down the **SHIFT** key while pressing the **+** key to set the **VIEW** Angle back to 72° . Tap **FIND f5** until "MOON" shows in the data window, then press **RETURN**. You now see that it is night in Washington (black background sky) with a new moon (dotted circle) just above the horizon. Now set the Clock **RATE** to 32X by tapping

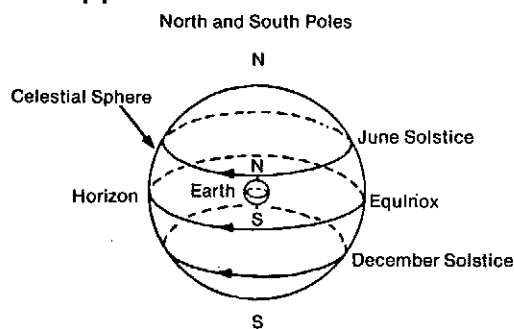
the + key and watch the changing sky colors as the sun rises. Note that the sun at this time of year is in the constellation Gemini, and that Mercury and Venus on this day rise after the sun; hence, they will not be visible until shortly after sunset.

To confirm this, tap **f1** and go to SET mode; press **RETURN**. Set the time to 5:00 P.M. Tap **f1** again until it shows SKY mode; press **RETURN**. Tap FIND until "MOON" shows in data window, then press **RETURN**. Check that the Clock RATE is 32X and watch the setting sun. At about 6:00 P.M. the new moon is setting, at about 7:30 the sun sets with the sky turning blue, then darker blue, and about an hour later, Mercury is setting below the horizon against a purple, twilighted sky. As the sky turns gray and then black, around 9:15 P.M., Venus shines brightly for a short time in the constellation Leo before it sets below the northwestern horizon.

Sun at Equinox Near North Pole

Near the poles, the sun moves parallel to the horizon. The sun is above the horizon all summer and below it all winter. At the equinox it moves along the horizon. On the Northern hemisphere it moves to the right, and on the Southern hemisphere it moves to the left.

Apparent Movement of Sun



We shall now use **Sky Travel** to demonstrate this phenomenon:

Use the **f1** key to select MAP mode; press **RETURN**. Use the cursor keys to set the longitude to 0° (i.e. the Greenwich Meridian which means that the local time is the Greenwich Mean Time = GMT) and move the cursor as far north as it will go. (Note: since this is a Mercator type map, you cannot quite get to the North Pole.) Use the **f1** key to select SET mode. Use the left/right cursor key and +/- keys to set the date and time to March 19, 1984 at 12:00 GMT. Use the **f1** key to select SKY mode, set VIEW to 72° and use the **f5** key (FIND) to locate the sun at the center of the screen. Next, move the sun to the left side of the screen. You do this by moving the cursor to the right side of the screen until the sun is in the proper location. Then set the Clock RATE to 32X using the +/- keys. The sun now moves to the right along the horizon, neither setting nor rising.

Sun at Equinox Near South Pole

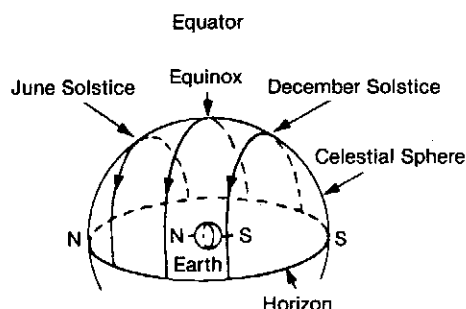
Now we shall show the same near the South Pole, except as we stated, the sun here moves to the left:

Use **f1** to select MAP mode. Keep the latitude at 0° (Greenwich Meridian), but now move the cursor as far south as it will go towards the South Pole. Now use **f1** to select SET mode. Use the cursor keys and the +/- keys to set the date and time to March 22, 1984 at 12:00 GMT. Use **f1** to select SKY mode and use **f5** as before to locate the sun at the center of the screen. Next move the sun to the right of the screen using the cursor. Then set the Clock RATE to 32X using the +/- keys. The sun now moves to the left along the horizon, again neither rising nor setting.

Sunrise and Sunset at Equator

At the equator, the North and South celestial poles lie at the horizon. Both the sun and the stars rise straight up on the east side and settle straight down on the west side of the horizon.

Apparent Movement of Sun



We shall here show both a sunrise and a sunset:

Use **f1** to select MAP mode. Use the cursor keys to set both latitude and longitude to 0° (the Equator at the Greenwich Meridian, GMT = local time). Now use **f1** to select SET mode. Use the left/right cursor key and the +/- keys to set the date and time to December 21, 1983 at 5:00 A.M. Use **f1** to select SKY mode, then use **f5** to center the sun on the screen. Next, set the Clock RATE to 32X using the +/- keys. The sun now rises straight up from the horizon as do the stars. To watch the sun set, use **f1** to go to SET mode, change the time to 5:00 P.M., set the Clock RATE to 32X as before, and watch the sun go straight down followed by the same motion of the stars as the background sky turns black.

ASTRONOMY

As we have seen earlier, just as each location on Earth is defined by two coordinates: latitude and longitude, each location on the celestial

sphere is defined by a similar pair of coordinates: Declination and Right Ascension. An equatorial Sky Orientation Map, (which is a Mercator projection of the celestial sphere), is shown on page 14 together with two special projections of both polar regions. We shall use them later to assist you in finding your way around the sky when you leave **Sky Travel** to go outside to look at the real sky.

Declination is measured in degrees from the celestial equator and goes from 0° at the equator to $+90^\circ$ at the celestial North Pole, and to -90° at the celestial South Pole. Note again (p. 7) that on a Mercator map you cannot reach the pole areas. Also, the map reproduces stellar distances and shapes of constellations faithfully only near the equator but stretches everything more and more as you move closer to the poles. On the other hand, a Mercator projection has the advantage that the circles of constant Declination and Right Ascension, which intersect each other at right angles on the celestial sphere, become sets of parallel lines, which still intersect each other at right angles on the Mercator projection.

Right Ascension is measured in degrees (or hours) from the so-called Vernal Equinox. This is the location of the sun on the first day of spring where day and night are of equal length at all latitudes (p. 18). As was the case for longitudes on Earth, each 15° corresponds to an hour of time difference (360 degrees/24 hours = 15 degrees/hour).

The data window on the right of your screen displays the Declination and Right Ascension of your cursor when you are in the SKY and CHART modes. Hence, if you know these coordinates for any given sky object, you can readily locate it on the map and on your screen. The Declinations and Right Ascensions of the bright stars used in navigation as well as of some other name stars are listed in a table at the back of the manual.

It is no more difficult to locate a star, a planet, or any other sky object in the heavens than it is to locate a city or an island on the surface of the Earth!

Star Recognition/Constellations

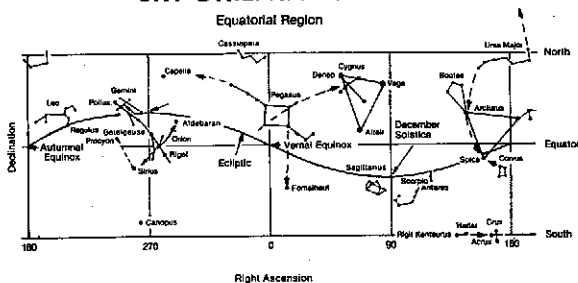
"The Ram, the Bull, the Heavenly Twins
Next the Crab, and the Lion Shines
The Virgin and the Scales
The Scorpion, Archer and Seagoat
The Man that Pours the Water Out
and the Fish with the Glittering Scales"

Old English Nursery Rhyme

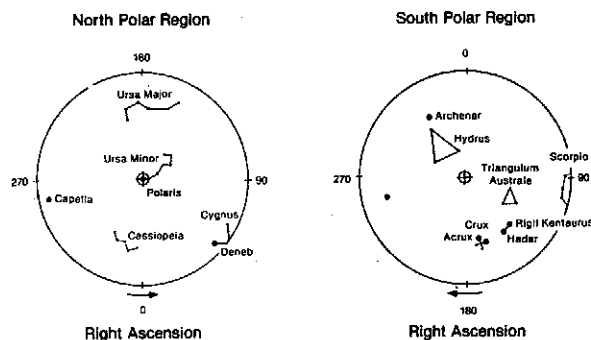
Astrologer-priests in the ancient Assyrian and Babylonian civilizations, during the last two millennia before the birth of Christ, named particular star patterns after their gods, heroes, and animals. The Greeks later changed the names to those of their own gods and heroes, and the Romans — when they adopted the basic Greek mythology — gave most of the constellations the Latin names we still use today.

Constellations have no scientific meaning, yet some are quite useful as signposts when trying to orient oneself in the sky. **Sky Travel** offers simplified line diagrams of the more obvious constellations (**[B]** = LINES) and abbreviated names show next to all constellations (**[B]** = NAMES). When you no longer need these aids, or if you already are an expert star finder, you may prefer to turn these options off. However, if you are a beginner, you will no doubt find these features helpful.

SKY ORIENTATION MAP



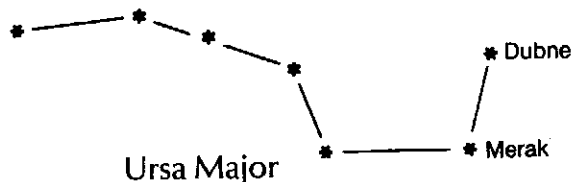
SKY ORIENTATION MAPS



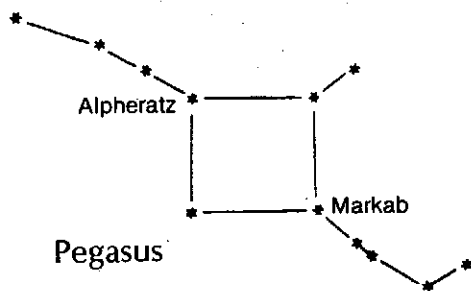
One purpose of **Sky Travel** is to help you become as familiar with the real sky as you already are with the surface of the Earth. If you consider the multitude of stars which are visible on a clear winter night, you may believe that this is quite an undertaking. Fortunately, mariners and navigators, who are depending on their ability to identify specific stars quickly and without hesitation, have identified many easily recognizable star patterns and imaginary connecting lines which make the task easier. The Sky Orientation Maps can teach you some of these "tricks."

You will note first that these maps are uncluttered by showing only the most noticeable stars and constellations. You will note second that certain stars are connected by highlighted lines. Such stars are called "pointer stars" (by drawing imaginary lines through them, you can more easily locate other stars). The most well-known case is that of finding Polaris by means of the Big Dipper (Ursa Major), perhaps the most familiar constellation in the northern sky. For this example, look at the map of the north polar region. Extending a line through the stars Merak and Dubne in the Big Dipper leads directly to Polaris, the North Star. Polaris, in turn, is the last star in the handle of the constellation the Little Dipper (Ursa Minor). Now

look at the equatorial sky map; extending a curved line through the handle of the Big Dipper leads to Arcturus, the bright star at the point of the kite shaped constellation Bootes. Continue further down to the bright star Spica in the constellation Virgo. Spica can be identified further by a line from the small constellation Corvus which mariners often call the Cutter's Main Sail.



Going back briefly to the polar map, note that almost directly opposite the Little Dipper through Polaris we find the constellation Cassiopeia, which is easily recognized by the open W shape. Continuing now again on the equatorial map, further away from Polaris in the same direction we find the readily recognizable "Great Square" of Pegasus with the bright stars Alpheratz and Markab in opposite corners. A line from the latter through the former leads directly to Mirfak in Perseus and to Capella in Auriga. A line through the opposite corners of the square leads to the constellation Cygnus (due to its shape, also called the Northern Cross) and further on to the bright star Vega.



Orion, one of the most beautiful constellations of the northern sky in winter, is another good starting point because of its prominence. A line through the corner stars Rigel and Betelgeuse leads directly to Castor and Pollux, the twin head stars in Gemini. Another line through the stars in Orion's belt lead on the one side to Aldebaran in Taurus, on the other side to Sirius, the brightest star in the sky (in the constellation Canis Major).

Looking now at the map of the south polar region, notice the famous Southern Cross (Crux). This constellation may be located from the bright stars Rigil Kentaurus and Hadar.

Three triangles, which are not constellations, are widely used by navigators because they contain very bright stars and are particularly easy to locate:

Procyon-Betelgeuse-Sirius

Deneb-Vega-Altair

Arcturus-Denebola-Spica

Denebola is the star at the tail of the constellation Leo. These triangles are highlighted on the maps.

Signposts like these will help you locate many less obvious, but nevertheless very interesting, objects in the sky which we shall discuss later. Remember also that you can identify any visible object seen on **Sky Travel** by using the INFORM key **[F7]**. An example is given below:

*Use INFORM to identify the individual stars in the Big Dipper (Ursa Major). In MAP mode, select any location on the Northern hemisphere. In SET mode, select any day and set the time to, say, 11:30 P.M. Go to SKY mode; set the VIEW to 36 degrees, and stop the clock. Use FIND to get the constellation listing; put the cursor on UMa and press **RETURN**. Now place the cross hair cursor over each star in Ursa Major. Press **[F7]** (INFORM) each time and read the information in*

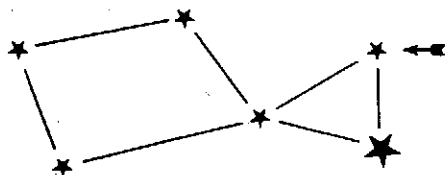
the text line below the screen. When **INFORM** is active, the right/left cursor key or your joystick allows you to scroll the text forward and backward. Before going to the next star, press **RETURN** or the Fire Button on your joystick.

When you are practicing star finding, especially without the **LINES** and **NAMES** options on, **INFORM** is very useful for checking your progress in star identification skills. **INFORM** is also handy if you see a star or planet outside and want to identify it.

Telescope/Stars and Galaxies

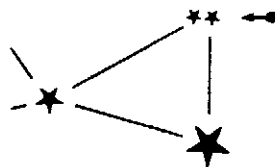
We shall now give two demonstrations of the use of **Sky Travel** as a low power telescope. Many stars which appear as single stars to the naked eye are actually double stars even at relatively low magnification. As an example, take Epsilon-Lyrae:

Go to **MAP** mode; set the latitude to 39°N and the longitude to 94°W (Kansas City). Go to **SET** mode; set the date to August 28, 1985 at 11:00 P.M. local time. Go to **SKY** mode. Make sure **F3** is at **NO DEEP**, and set the **Clock RATE** to **0X** and the **VIEW** to 72 degrees. Use **FIND** to get the Constellation List on your screen. Select **Lyra** and press **RETURN**. The diamond/triangle pattern with the bright star Vega is now in the center of the screen. Look at the rather faint star above Vega.



At this magnification it looks perfectly normal. Now lower the **VIEW** Angle gradually to 36 to 18 and to 9° while keep-

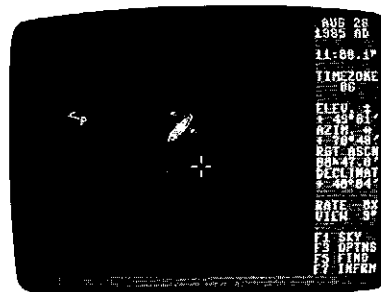
ing Epsilon-Lyrae in the field of view. You should now see two stars.



Place the cross hair cursor in turn over each individual star and press **F7** (**INFORM**) — the stars are Epsilon-1 and Epsilon-2 Lyrae!

Now let us do the same with a galaxy:

Stay in Kansas City, same day, same time. In **SKY** mode, increase the **VIEW** Angle back to 72 degrees. Use **FIND** to get the constellation map and select **And(romeda)**. Press **RETURN**. Now use **F3** to install **DEEP SKY**; press **RETURN**. Use the cursor to place the oval galaxy in the center of the screen. Then gradually lower the **VIEW** Angle as before; you now see two small satellite galaxies next to the Andromeda galaxy. As an exercise, use **INFORM** to identify all three.

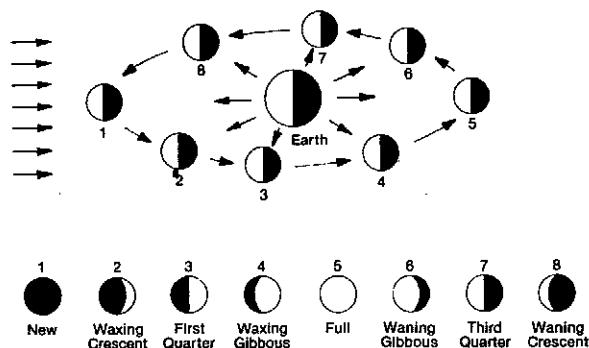


The Phases of the Moon

The phases of the moon are caused by the shadow the moon casts on itself, as seen from Earth, during its orbit around the Earth. This is

illustrated on the sketch below. According to a Latin saying, the moon fools you ("Luna fallit"); when it looks like a C ("crescit" meaning it increases), it is actually decreasing; when it looks like a D ("decrescit" meaning it decreases), it is actually increasing. The sketch shows why the phase sequence actually occurs in the manner stated in the old Latin rule.

Phases of Moon



21

Sky Travel calculates the phases of the moon during its regular updates of the moon's position in the sky. This is illustrated in the following example of the moon's phases as seen from New York City during the month of December, 1983:

Day	NY Time	Moon Phase
4	4:00 P.M.	New
11	4:00 P.M.	1st Quarter
21	7:00 P.M.	Full
26	11:55 P.M.	3rd Quarter

Use **f1** to select MAP mode. Use the cursor keys to set the latitude to 41°N and longitude to 74°W (New York). Use **f1** to select SET mode. Use the cursor and +/- keys to set the date and time to Dec. 4, 1983 A.D. at 4:00 P.M. Use **f1** to select SKY mode and use the FIND key **f5** to locate the moon (New). Now use **f1** to go back

to SET mode, and set the new date and time to Dec. 11, 1983 at 4:00 P.M. Again use **f1** to return to SKY mode. Then use **f5** to locate the moon (1st Quarter). Repeat with Dec. 21, 1983 at 7:00 P.M. (Full Moon) and Dec. 26, 1983 at 11:55 P.M. (Last Quarter).

WARNING

NEVER look directly at the SUN, even during a total eclipse

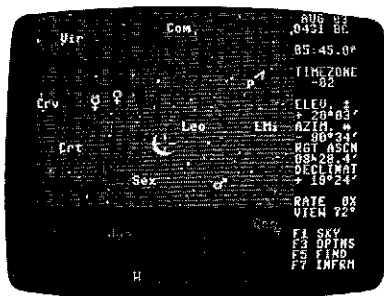
Solar Eclipse

A solar eclipse occurs when the moon blocks the line of sight between some location on Earth and the sun. Although the moon is much smaller than the sun, because the moon is closer to the Earth, the size we see is quite similar. Under optimum conditions, when the moon almost completely covers the solar disk, the eclipse is total.

One of the first reliable records of a solar eclipse is due to the Greek historian Thucydides. He reported an eclipse that occurred in the afternoon on August 3 in the year 431 B.C. The eclipse was not total, but enough of the sun was darkened to make some bright stars appear. The location of the observation was not recorded, but since Thucydides was an Athenian, it is assumed to be Athens. Let us now look at that eclipse with **Sky Travel**:

First use **f1** to go to the MAP mode. Set the latitude to 38° north and the longitude to 24° east (Athens). Then use **f1** to go to SET mode and set the date to Aug. 3, 431 B.C. Set the local time to 4:30 P.M. and use **f1** to go to SKY mode. Set the VIEW Angle to 36°. Then use FIND **f5** to locate the sun on your screen. Next use the cursor to push your window to the right

until the sun is located on the left side of the screen. Change the Clock RATE from 0X to, say, 36X. An eclipse starts before 5 P.M. and is over by 7 P.M. The photograph below is the planetarium screen for 5:45 P.M., local Athens time, showing a crescent sun and the planets Mercury, Venus, and Mars against a twilight sky confirming Thucydides' report.



Next let us consider an eclipse predicted to occur sometime in the future, for example the one on June 30, 1992.

You have decided that the island of Tristan da Cunha might be an interesting place to observe and to photograph this eclipse. So, first you use **f1** to go to the MAP mode and set the latitude to 37°15' south and the longitude to 12°30' west. Then use **f1** to go to SET mode and change the date to Jun. 30, 1992 A.D. Set the local time to 10:30 A.M. and use **f1** to go to SKY mode. If the VIEW Angle is not at 36°, change to this angle. Then use FIND **f5** to center the sun on the screen. Now use the cursor to push the window to the left until the sun is on the right side of the screen. Now set the Clock RATE to, say, 16X and, indeed, you see an eclipse take place.

Now, before you pack your bags for Tristan da Cunha, you realize that total

solar eclipses are extremely location dependent because of the small diameter of the moon's shadow, and under optimum conditions last no more than about 5 minutes! Therefore, you go back to SET mode, change the time back to 10:30 A.M., then use **f1** to get back to SKY mode. Now you tap **f3** until "NO TRACK" is shown in reverse field and press **SHIFT f3** to get into TRACK. Then you tap **f5** (FIND) until it shows "SUN"; then press **RETURN**. Set the Clock RATE to, say 8X or 16X. After that you take a pencil and paper and record Declination and Right Ascension for the sun at the local time shown by the clock during the eclipse. Finally, you repeat the procedure and make a similar recording of the Declination and Right Ascension of the moon and then compare the numbers by plotting the positions on graph paper. The tracking gives you a more accurate determination of the closest approach than you can get by the visual display. Actually, the eclipse is not total at Tristan da Cunha, nor at St. Helena, but you could sail from one island to the other and plan to be, say at 25° south latitude and at the longitude of Tristan da Cunha around 11 A.M. local time, in which case (weather permitting) you should see a total eclipse.

P.S. Remember to tap **f3** and get back out of the TRACK mode when finished; otherwise, you may get some mysterious displays later!

Note: For observations requiring pinpoint accuracy such as total solar eclipses, specialized computer programs are required to determine the precise path of totality. Nevertheless, as you will appreciate increasingly in the following, **Sky Travel** gives a quick and accurate account of the main features of a wide range

of celestial phenomena over large time spans! For a more detailed discussion, see the section on Technical Notes just before the Tables section at the end of the manual.

Lunar Eclipses

A lunar eclipse occurs when the Earth blocks the line of sight between the sun and some location on the moon. If the shadow of the Earth completely covers the moon's surface, the lunar eclipse is total. Hence, while solar eclipses can occur only when the moon is, approximately, new, lunar eclipses can occur only when the moon is, approximately, full. Although total lunar eclipses occur less frequently than solar eclipses, they are much more common from any given location. This is because lunar eclipses are always visible from about half the surface of the Earth while solar eclipses are only visible from within the narrow path of the moon's shadow.

Sky Travel demonstrations are given in a following section on famous historical lunar eclipses.

Transits by Mercury and Venus

The "inferior" planets, Mercury and Venus, are closer to the sun than the Earth is. Therefore, when they block the line of sight from a position on Earth to the sun, a so-called planetary transit occurs.

A planetary transit is thus similar to a solar eclipse, which is caused by the moon blocking the line of sight between some position on the Earth and the Sun. However, planetary transits are much more difficult to observe, in the case of Mercury because of the small size of the planet, and in the case of Venus because of the infrequency of the transits.

Early attempts to observe transits of Mercury, the smallest and the innermost of the two planets, were unreliable due to confusion with sun spots. The first recorded Mercury transit was one predicted by Johannes Kepler to occur

on November 7, 1631. Kepler himself died the year before, but an astronomer in Paris, Pierre Gassendi, observed and recorded the path of the planet across the surface of the sun. A second Mercury transit predicted to occur on May 3, 1661, was observed by the Polish astronomer Johann Hevelius from Gdansk and by the Dutch scientist Christiaan Huygens from London. (Gingerich 1983)

We shall first use **Sky Travel** to verify these transits of Mercury:

Go to MAP mode **[1]**, set latitude to 43°N and longitude to 2°E (Paris). Then go to SET mode and set the date and local time to November 7, 1631 A.D. at 3:00 P.M. Now to SKY mode and make sure Options **[8]** are set at NO NAMES, but SYMBOLS are on. Set VIEW Angle to 36° , use FIND to locate the sun at the middle of the screen, and push the window to the right, using the cursor, so the sun is to the left of the screen. Now use FIND to locate Mercury, then set the Clock RATE to 64X. Note that the symbol for Mercury is made completely invisible by the solar disk; however, as the sun sets, you can see it peek out at the right side of the sun. This was the Mercury transit observed by Gassendi.

Now stop the clock and go back to the MAP mode. Change latitude to $51^{\circ}3'\text{N}$ and longitude to $0^{\circ}1'\text{W}$ (London). Then go to SET mode and change the date and time to May 3, 1661 A.D. at 4:30 A.M. Go to SKY mode keeping the **[8]** selections as before. Use FIND to locate the sun, then MERCURY, next set the Clock RATE to 64X. Note that the symbol for Mercury is invisible because it is right in front of the sun, yet as the sun rises it will peek out at the left side of the solar disk. This was the Mercury transit observed by Huygens.

The first predicted transit of Venus was calculated from Kepler's laws to occur on December 7, 1631, but unfortunately the sun would be below the horizon from Europe at the time so no observations were made. The next transit was predicted to occur on December 4, 1639 and was observed and recorded by the English astronomer and clergyman Jeremiah Horrocks. No Venus transits have occurred during the past 100 years, and the next transits will occur on June 8, 2004 and June 5-6, 2012. (Janiczek & Houchins 1974)

We shall now verify a recorded and a predicted Venus transit:

*First stop the clock. If you are continuing from the previous example, stay in London, otherwise go there by the previous route. Change to SET mode and set the date and time to December 4, 1639 A.D. at 7:45 A.M. Then go to SKY mode with Options **f3** unchanged from before. Use FIND to locate the sun, then Venus. Now increase the Clock RATE to 64X. As the sun rises, you will see the symbol for Venus disappearing into the bright solar disk. This was the Venus transit observed by Horrocks.*

Now stop the clock again. Go to MAP mode and set the latitude to 41°4'N and longitude to 74°W (New York City). Then go to SET mode and change the date and time to June 8, 2004 A.D. at 4 A.M. Go to SKY mode, FIND the sun, then Venus. Change the Clock RATE to 64X. Note the sunrise and the symbol of Venus overlapping the solar disk. This is one of the Venus transits yet to come.

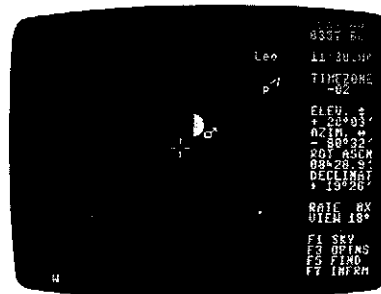
Planetary Occultations

Planetary occultations are eclipses of a planet by another planet or by the moon, as seen from the Earth.

The Greek philosopher Aristotle observed and recorded an occultation of Mars by the half moon on May 4, 357 B.C. He described that Mars disappeared behind the dark side of the moon and then reappeared on the bright side. Aristotle used this observation as proof that the moon is closer to the Earth than Mars and commented that earlier observations by the Egyptians and the Babylonians had proved this to also be the case for the other then known planets. (Richardson & Clark 1978)

The planetarium program recreates this personal observation by Aristotle:

Use **f1** to select MAP mode. Use the cursor keys to set latitude to 38° N and longitude to 24° E (near Athens). Use **f1** to select SET mode. Use the cursor and +/- keys to set the date to May 4, 357 B.C. and the time to 6:00 P.M. Use **f1** to select SKY mode and use FIND **f5** to locate Mars. Use the cursor to push Mars to the upper left of the screen, then use the + key to accelerate the Clock RATE to 16X. Watch from 6 P.M. to about 2 A.M. as the sky changes color due to the sunset. Mars passes behind the dark side of the moon and reappears on the bright side as observed by Aristotle.



As a young man in Tübingen, Germany, Johannes Kepler observed and recorded a rare occultation where Jupiter was eclipsed by

Mars. The event occurred on January 19, 1591 A.D. Because of the distinct, red color of Mars, Kepler was able to see that Mars covered Jupiter rather than the other way around. He therefore concluded — by the Aristotelean argument above — that Mars is closer to the Earth than Jupiter is.

Use **f1** to select MAP mode. Use the cursor keys to set latitude to 48°5'N and longitude to 7°4'E (Tübingen near Stuttgart, West Germany). Use **f1** to select SET mode. Use the cursor and +/- keys to set the date to Jan. 19, 1591 A.D. and the time to 7:00 A.M., local time. Use **f1** to select SKY mode and use FIND **f5** to center Jupiter on the screen. Use FIND to locate Mars, note the close proximity. Using the +/- keys, the Clock RATE may be set at, say, 32X, to illustrate the motion of the two planets. Note also that in a case like this, using the TRACKing option for each planet, and noting Right Ascension and Declination versus the Clock for each planet, allows a more accurate determination of the closest approach.

An occultation of Venus by the Moon on July 17, 1974 is an example of more recent times. The occultation took place in the early morning hours and observations in the U.S. were particularly favorable from Florida. Using the approaches described above, the demonstration of this event is left to you.

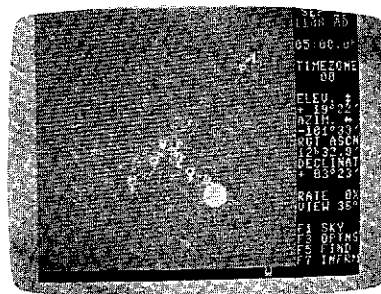
Planetary Alignments and the "Jupiter Effect"

One of the most striking astronomical events occurs when several planets are visible within a narrow field of view. In ancient and medieval times such events were feared as omens of great catastrophies. Even quite recently, predictions of natural disasters have been widely reported. Present day fears are based on concerns that the combined gravitational pulls

of several planets on the Earth might trigger major earthquakes and tidal waves.

On September 15, 1186 A.D., Mercury, Venus, Mars, Jupiter, Saturn, and the moon were all close to the sun and within a narrow viewing angle of 12°. This rare arrangement of planets had been predicted several years in advance by the astrologer John of Toledo. It was taken as an omen of great calamities and earthquakes. Near panic followed, and the location of the planetary clustering in the Zodiac sign of Libra was taken as an omen for high winds. People sought refuge in cellars and caves. In Byzantium the windows of the Imperial Palace were boarded up, and the Archbishop of Canterbury ordered fasting. However, the month of September came and the predicted planetary alignment occurred without consequence on Earth.

The planetarium representation of this planetary alignment is shown below:



You can recreate this view as follows:

In MAP mode, set the latitude to 49° north and the longitude to 5° west. Then go to SET mode and set the date and time to September 15, 1186 A.D. at 5:48 P.M. Now go to SKY mode, set the Clock RATE to 0X and VIEW Angle to 36°. Use FIND to locate, say Saturn, and you will see a display similar to the one in the photograph above.

On February 5, 1524 A.D., another close planetary clustering was predicted, this time in the Aquarius sign of the Zodiac. Serious flooding was feared, another disaster was predicted, and many people took refuge in boats. 1524 A.D. turned out to be an unusually dry year. (Ashbrook 1973)

On March 10, 1982 A.D., the eight planets were almost within the same quadrant of the sky. The event, which scarcely qualified as an "alignment," was nevertheless forecast — by highly unscientific sources — to become the trigger of a major earthquake in California and to result in enhanced solar activity. A so-called "Jupiter Effect" was widely discussed in the news media. For the record, California did not break off at the St. Andreas Fault and slide into the Pacific Ocean in 1982. (Thompson 1981)

On February 26, 1953 B.C. (!), the four planets Mercury, Venus, Jupiter, and Saturn were within a viewing angle of less than four degrees. No historical record exists of this ancient planetary clustering.

The demonstration of the planetary alignments of the latter events will be left to you as practice examples. The last example is particularly striking since the planets can all be viewed within the 9 degree viewing angle of the planetarium!

Precession, Pole Stars, and Zodiac

"This is the Dawning of the Age of Aquarius..."

Song from the Broadway Musical "Hair"

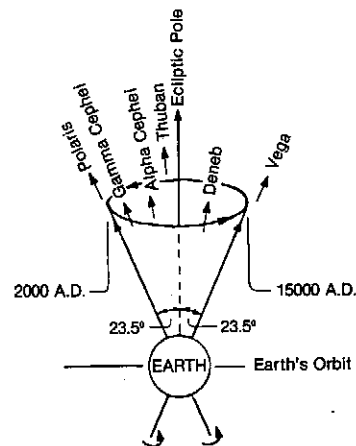
Observers of the northern sky are familiar with the Pole Star (Polaris) or North Star. This star makes it particularly easy to determine the cardinal directions on the Northern hemisphere at night. (There is no similarly easy method on the Southern hemisphere because of the lack of a "South Star.") As we have already seen (p. 19), the North Star is easily

located by extending a line through two "pointer stars" in the constellation the Big Dipper (= Ursa Major = Big Bear). The North Star is more formally known as "alpha Ursae Minoris," which means: the first star of Little Bear. Little Bear is another name for the Little Dipper. However, "alpha Ursae Minoris" has not always been the North Star, nor will it continue to be.

Ancient astronomers and navigators could not have used Polaris as the North Star. We shall see later (p. 36) that the "North Star" at the time the Great Pyramids were built was the star Thuban in the constellation Draco. Polaris is currently 1° from the true pole, and by the year 2102 A.D. it will reach its closest approach to true north of about $\frac{1}{2}^\circ$. The next pole star will be the star "gamma Cephei" in the year 4145 A.D., and the one after that will be the star "alpha Cephei" in the year 7530 A.D. Both stars are in the constellation Cepheus.

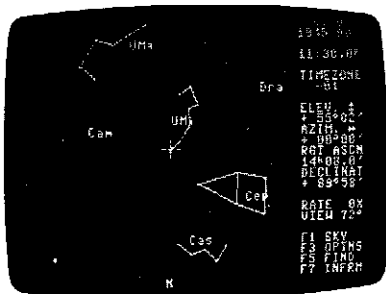
The reason for the changing pole stars is that the Earth's axis wobbles like that of a spinning top. The wobbling (precession) has a time cycle of 26,000 years, after which the sequence of pole stars will repeat itself.

Precession Cone of Earth's Axis



Sky Travel takes the Earth's precession into account; hence, past and future pole star positions mentioned above can be demonstrated. Since we will be showing the position of the pole star at the time of the construction of Cheops' pyramid in another example, we shall here demonstrate the positions far into the future:

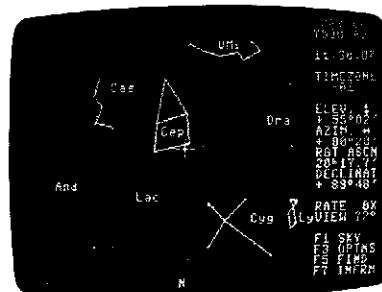
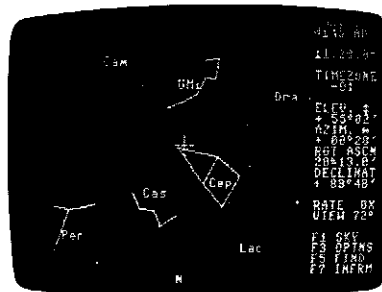
Tap **f1** until "MAP" is shown in reverse field. Use the cursor to go to a position on the Northern hemisphere, say Copenhagen (latitude 55° N, longitude 12° E). Tap **f1** and go to SET mode. Select any date after sunset, for example May 4, 1945 at 11:30 P.M. Tap **f1** again and go to SKY mode. Select the following **OPTIONS** **f3**: SOUND off; LINES off; SYMBOLS off. Now use the FIND key to select CONSTELLATIONS. When the list appears on the screen, put the cursor on the NPole and press **RETURN**. You now see the current Pole Star, Polaris, close to the celestial North Pole as marked by a small cross.



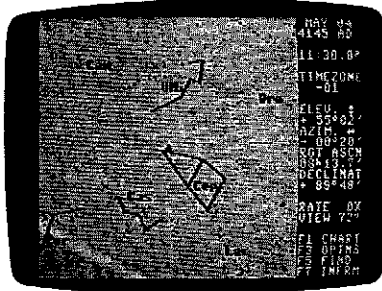
Next use **f1** to go to SET mode and change the year to 4145 A.D. Then use **f1** again to go back to SKY mode. We have previously mentioned that major changes in year settings (> 100 years) cause a delay in getting the screen display of the sky. The reason is that in addition to the usual updating, precession requires recalculation of all star coordinates on

the celestial sphere! While this is happening, the text line shows the message "PRECESSING." Once the SKY mode screen reappears, note the shift in the positions of the stars near the North Pole. Specifically, the pole star is no longer Polaris but gamma Cephei. If you doubt it, put the cursor on top of the new Pole Star and press **INFORM** **f7**.

Now repeat the procedure for the year 7530 A.D.



If you wish to get CHART mode versions of the SKY mode screens, tap **f1** until "CHART" is displayed in the data window. Then press **RETURN**. Two such CHARTs of the SKY displays from the above examples of precession are shown below. If you have a printer connected to your disk drive, you can get a permanent record of either the SKY or the CHART displays by holding down the **SHIFT** key while pressing P.



Earth — including astronomers — the sun and the seasons are more important than the stars for everyday life!

The star background, therefore, changes slowly with respect to the position of the sun. This is most obvious in terms of the so-called Zodiac constellations which are located in a narrow band along the ecliptic. This is also the region in which the planets move, because their orbital planes are tilted only moderately relative to the Earth's orbit. This ecliptic band is thus the region of the sky where all the action is, and it is the region that the astrologer-priests in the Babylonian and Assyrian civilizations paid particular attention to. They divided the ecliptic into twelve, 30°, intervals or "signs" and named them after the principal constellations located in these sections at the time. The Greeks later coined the name "Zodiac" (meaning the circle of animals) for the ecliptic constellations. The Greek astronomer-astrologer Ptolemy of Alexandria, in the second century A.D., described and published illustrations of most of the constellations which still are in use today.

When the Babylonians made their observations around 2000 B.C., the vernal equinox was in the constellation Aries. At the birth of Christ, the vernal equinox was moving into Pisces and today it is approaching Aquarius. In a sense, precession makes the ecliptic into a gigantic clock with a 26,000 year period for a single turn of the “hand” (the vernal equinox). The circular movement of the celestial poles, causing changes in the star which happens to be closest to the North Pole, is just another look at the same clock from a different direction.

Halley's Comet

"Of all the comets in the sky
There's none like comet Halley
We see it with the naked eye
and periodically"

Harold Spencer Jones

Comets are celestial objects which, in spite of a small mass, occupy enormous volumes and have very large and eccentric orbits. When a comet passes close to a large body, such as a large planet, the orbit is changed (perturbed). The path of comets are therefore somewhat changeable. When comets approach the sun, vapor and dust clouds may be created in the form of large tails which often make comets the most striking objects in the sky. For this reason, appearances of comets have been recorded since ancient times.

Halley's comet was first observed in 240 B.C. and subsequent returns have been extensively recorded around the world. A particularly famous appearance is recorded in a segment of the historical Bayeux tapestry, a 239 ft. long embroidery made by medieval ladies in Normandy, depicting the Norman conquest of England. The comet appeared as William the Conqueror set sail for England, and it was taken as an omen for the impending demise of King Harold at the Battle of Hastings in 1066 A.D.



Courtesy: William the Conqueror Center, Bayeux, France

The Latin inscription means "men wondering about the star." Note the messenger bringing the bad news to King Harold and the invasion ships below the king.

The comet is named for the astronomer Halley who in 1704 A.D. calculated the approximate orbit and correctly predicted the subsequent appearances. The cycle of the orbit is about 75

years and the next occurrence is predicted for 2061 at which time additional measurements are scheduled to improve the accuracy of future orbit calculations. (Calder 1980)

Sky Travel contains the predicted path for the 1985/86 passage of Halley's comet. The closest approach to the sun (the perihelion) is expected in early February, 1986. The best time for observation will be from September through December, 1985 (especially on the Northern hemisphere) and from March through July, 1986 (especially on the Southern hemisphere).

Let us illustrate the comet in the following example:

You are watching a movie on a "Red-eye Special" flight over central Australia in the spring of 1986. Tap **F1** for MAP mode; press **RETURN**. Set the latitude to -24° S, longitude to 137° E. Tap **F1** for SET mode; press **RETURN**. Set the date to April 7, 1986 A.D. and the local time to 11:30 P.M. Suddenly, the captain gets excited, interrupts the movie, and suggests that the passengers watch the night sky through the starboard windows of the plane. Tap **F1** for SKY mode; press **RETURN**. Then tap **FIND F5** for the COMET; press **RETURN**. You now all see the captain's reason for interrupting the movie; Halley's comet is visible among the southern constellations.



CHRONOLOGY

Calendars and Astronomical Dates

"Beware the Ides of March"

"Julius Caesar"

William Shakespeare

Sky Travel allows you to go back as well as forward in time by about 10,000 years in either direction. However, in checking astronomical events in the past, care must be taken to assure that the proper calendar date is used, which often is no easy task.

The calendar of Western civilization dates back to the mythical founding of Rome in 753 B.C.)* For many centuries, the Romans dated events by counting from this date and designated the years "ab urbe condita," abbreviated as "A.U.C." (meaning, since the founding of the city.) This is a common inscription on many Roman buildings and monuments. The Roman year originally began in the spring with the month of March and it had only 10 months. We still have a reminder of this in the names of the months September, October, November, and December, which from their Latin origin mean the 7th, 8th, 9th, and 10th month. Later on, the Romans added two more months (January and February) at the beginning of the year which made the months from September through December the 9th through the 12th months as they are today. When the early calendar got too much out of step with the seasons, the Romans occasionally added an extra month. These adjustments were under the jurisdiction of the priests; they were often made randomly and they were not always coordinated within different parts of the Roman empire. Understandably, this became increasingly intolerable to the historians, the scribes, and tax collectors — not to mention the tax payers.

*According to legend, there once was a forger who minted gold and silver coins in an attempt to pass them off as rare, ancient coins. The fraud was soon discovered; however, the years were marked B.C.!

The Julian calendar is named after Julius Caesar. This reformed calendar was based on a solar year of $365\frac{1}{4}$ days, as determined by the Egyptians (a year is actually 365.24220 days long). The calendar was designed so it had three years of 365 days and a fourth year (leap year) of 366 days. Leap years then, as now, were chosen as those evenly divisible by four. The Julian calendar began on January 1, 45 B.C., and in order to offset accumulated errors, corrections are made all at once in the year 46 B.C. which was made 445 days long and is generally referred to as "the year of confusion"!

The Gregorian calendar, which is the one in current use, was formally introduced by Pope Gregory XIII in the year 1582 A.D. The church's main interest in an improved calendar was to assure the proper timing of the holy days of Easter. The Julian calendar year was slightly too long. A correction was made in the Gregorian calendar by requiring that only those centuries evenly divisible by 400 and all other years evenly divisible by 4 be leap years (366 days), while other centuries remain normal years (365 days). The error which had accumulated since the establishment of the Julian calendar was again adjusted in one swoop by eliminating 10 days in the year 1582: October 4th was followed immediately by October 15th!

The Gregorian calendar was not adopted uniformly at that time. For example, England and the American colonies did not adopt the calendar until 1752 A.D. At this time, 11 days had to be eliminated: September 2nd was followed that year immediately by September 14th! One well known historical consequence is George Washington's birthday; according to the Gregorian calendar, as used today, he was born on February 22, 1732, but the calendar in use at his birth showed February the 11th. Russia did not change to the Gregorian calendar until the Bolshevik revolution at which time they had to eliminate 13 days.

After the French revolution, the National Convention in 1795 passed into law a "new" calendar. It was based, in part, on the decimal system. The year started in the fall, at the autumnal equinox, and had 12 months of 30 days each. A month was divided into three 10 day weeks, each day having 10 hours, each hour having 100 minutes, and each minute having 100 seconds. To correct for the fact that a year is longer than 360 days, five or six specially named extra days were added at the end of each year. Actually, this revolutionary calendar was not new at all but a rediscovery of an ancient calendar used in Egypt as early as 3000 B.C. The attempt failed and the law was repealed in 1805; nobody liked a 10 day week!

Astronomical calculations are based on so-called Julian days which, somewhat confusingly, have nothing to do with the Julian calendar. The system was created in 1583 A.D. by the French chronologist and mathematician J.J. Scaliger, who named his invention after his father, who just happened to have the same first name as Julius Caesar. The Julian day system begins at Greenwich noon (GMT) on January 1, 4713 B.C., and a Julian date is simply the number of the day in a continuous count since that day. Dates before 4713 B.C. are counted as negative numbers. The Julian day system offers a simple means of a) determining differences in days by simple subtraction; b) determining days of the week by dividing the Julian date number by seven. The remainder then determines the day of the week (Monday = 0, Tuesday = 1, etc.); c) providing a clear reference for synchronizing dates among a multitude of ancient calendars, etc. (Moyer 1981)

The standard calendar mode of **Sky Travel** is shown as AUTO in the data window when you are in SET mode. The program then converts all entries of dates into Julian day numbers before proceeding with the astronomical

computations. It assumes that all dates before and including October 14, 1582 A.D. are in the Julian calendar, as later modified so that the year count starts with the birth of Christ. On and after October 15, 1582 A.D., the program assumes that the date is in the Gregorian calendar. The Julian calendar has been extended backwards, to avoid the extremely cumbersome calendar systems actually used by the Romans and other peoples during and before antiquity. The program has also been designed so that it does not accept entries of nonexistent dates.

The following examples illustrate how the calendar routines of **Sky Travel** can be used for historical and chronological purposes:

1) Go to the SET mode. Set the year to 1984 A.D., then set the date to February 29. Since 1984 A.D. is a leap year (evenly divisible by 4), February 29 exists. Now change the year to 1985; the date now changes to March 1 since there is no February 29 in a non-leap year! Then change the year to 1900 A.D. and try to set the date to February 29; the program will not let you! Although the year 1900 A.D. is evenly divisible by 4, it is a century not evenly divisible by 400 and by the Gregorian calendar convention, such centuries are not leap years. In contrast, the century 2000 A.D. is evenly divisible by 400; hence, it is a leap year and February 29 exists.

2) Go to the SET mode. Set the year to 1582 A.D., then set the date to October 4. Next advance the date one day at a time and watch the Julian Day number; it also advances one day at a time until you reach October the 15th, then it goes back 10 days to the same Julian day it was showing for October the 5th. You are here seeing the disappearance of the 10

days ordered by Pope Gregory! The program knows that those days do not exist in the Gregorian calendar, so anybody entering them must still be using the Julian calendar! However, on or after October the 15th, the program assumes that the date entry is Gregorian.

3) An example of how **Sky Travel** can be used to determine historical dates with certainty is the rare planetary occultation of Jupiter by Mars presented earlier (page 44). The German astronomer Johannes Kepler reported that the event occurred on January 9, 1591 A.D., yet if you try to repeat the example at that date you will see that no occultation occurred. However, on January 19, 1591 A.D., the date given in our example, there was indeed an occultation. The explanation is unquestionably that in 1591 — only nine years after Pope Gregory had introduced his calendar reform — Johannes Kepler in Germany was still using the Julian calendar!

4) Go to MAP mode. Select the zero longitude (Greenwich Meridian). Now go to SET mode. Local time is now Greenwich Mean Time (GMT). For any day, see that the Julian day number changes at noon rather than at midnight for the calendar day!

You may change the calendar setting from AUTO to JULIAN or GREGORIAN while in the SET mode by the same method of using the cursor and the +/- keys. In general, this is not recommended because the program then no longer protects you from introducing meaningless dates such as Gregorian dates before Pope Gregory, Julian dates in modern times, etc. This option is merely a convenience for users of the program with a need for frequent calendar conversions. Most people should simply ignore this particular feature.

The Star of Bethlehem

"Now when Jesus was born in Bethlehem..., behold, wise men from the East came to Jerusalem saying, 'Where is he who has been born king of the Jews? For we have seen his star in the east and have come to worship him.'"

Matthew 2, 1-2

The Julian calendar was used for many centuries with the year count still beginning at the founding of Rome (A.U.C.), or — rather confusingly — at the reign of various later Roman or non-Roman rulers. However, in the sixth century A.D. (by our present calendar), the monk Exiguus suggested to start the count instead at the birth of Christ, which he calculated to have occurred in the year 754 A.U.C. The proposal was accepted only gradually. For example, in the 9th century A.D., Charlemagne ordered this change in the calendar within his empire. Actually, the custom of counting the years from the birth of Christ did not become common practice in Europe before the 11th century A.D.

There is considerable uncertainty as to the accuracy of Exiguus' calculations. Although Christmas is celebrated on December the 25th, there is uncertainty not only regarding the date, but even as to the actual year. For example, based on what is believed to be reliable historical sources, Herod died in the year 4 B.C. which is in conflict with the statements in both Luke and Matthew that Christ was born during the reign of King Herod.

Astronomical events have often proven to be a means of accurately dating historical events. The brief description of the "Star of Bethlehem" in Matthew might therefore provide a valuable clue. Many attempts were actually made for centuries to identify the nature of the "star" which brought the three magi to Bethlehem at the birth of Christ. It has

been suggested, for example, that the “star” might have been a supernova, but such an event would most likely have been observed and recorded elsewhere; and besides, no supernova remnant has ever been found. Another suggestion was that it might have been a comet. For example, the early Renaissance painter Giotto showed the star as a comet in a well-known 1300 A.D. fresco of the nativity scene located in the Arena Chapel in Padua, Italy. Indeed, later studies have shown that an appearance of Halley’s comet did occur during October in the year 12 B.C. However, the historical records of the reign of King Herod make this appearance too early to be the explanation — although a comet certainly would have alerted astrologers from the east to look for further signs in the sky.

More recently it has been suggested that the “star” actually was an alignment of the planets Jupiter and Saturn. These planets were in close alignment in the year 7 B.C. in the constellation Pisces (The Fish). The conjunction of these particular planets in Pisces at a time when the vernal equinox was moving from the sign of Aries into the sign of Pisces might well have had a special meaning to magi from the Mesopotamian region who were well versed in Babylonian astrology — note also that the fish was used as a secret sign by the early

Christians long before the use of the Cross. Assuming that this suggestion is correct, the most probable date for the birth of Christ has been calculated to be September 15, 7 B.C. (Hughes 1979)

Sky Travel allows you to observe the alignment of Jupiter and Saturn on this night nearly 2000 years ago:

*First select the MAP mode using **F1**. Set the latitude to +32° 30' N and the longitude to 34° E (Bethlehem). Next select the SET mode using **F1**. Set the date to Sept. 15, 7 B.C. and the time to 11:55 P.M., local time. Now select the SKY mode using **F1**. Make sure the Clock RATE is stopped using the +/- keys. Use **F3** to select the following Options: SYMBOLS and NAMES, and set the VIEW Angle to 72 degrees. Use **F5** to FIND Saturn and press **RETURN**. You are now looking at the black midnight sky over Bethlehem: Saturn and Jupiter are seen to be so close that the symbols actually are superposed. Next use **F3** to eliminate the symbols (**SHIFT F3 RETURN**).*

Sky Travel has now recreated the “Star of Bethlehem” as it may have appeared to the magi and the shepherds on the first night of Christmas.

HISTORY/ARCHAEOLOGY

WARNING

**NEVER look directly at the SUN,
even during a total eclipse**

Solar Eclipses in Antiquity

In ancient times, total eclipses were considered to be frightful signs of displeasure by the gods.

Hence, in many instances they influenced human history. Some famous examples are described in a following section on lunar eclipses.

Eclipses are significant to historians for another reason. Because they were widely believed to be warnings of great misfortunes and calamities, they were often recorded if they preceded major historical events. Since present day

calculations can determine the precise date of an eclipse for a given location, such records have proven extremely valuable for synchronizing early calendars and thereby enabling the correlation of the histories of ancient societies.

The Roman statesman Cicero has recorded a solar eclipse that occurred on June 21, 400 B.C. This eclipse attracted special attention because it occurred near Rome shortly after sunset and was very nearly total. The sudden complete darkening of the twilight sky followed by the reappearance of twilight was poetically described at the time as "on the Nones of June, the sun was covered by the moon and night." This particular event is an example of an eclipse that has helped historians settle some difficulties in the early Roman calendar.

The solar eclipse can be verified by **Sky Travel** as follows:

Use **f1** to select MAP mode. Use the cursor keys to set latitude at 42° N and longitude to 14° E (near Rome). Use **f1** to select SET mode. Use the cursor and +/- keys to set the date and time to June 21, 400 B.C. at 6:30 P.M. Use **f1** to select SKY mode and use **FIND f5** to center the sun. Then use the + key to accelerate the Clock RATE to 16X. Watch the eclipse and the sky color changes, due to the eclipse as well as to the setting sun, from 6:30 P.M. to about 8:00 P.M.

Note: Using the TRACKing option for the sun and the moon, and recording the Right Ascension and Declination versus the clock individually for each, allows a more accurate determination of the eclipse.

Lunar Eclipses in Antiquity

Although the loss of the moon's light was less frightening to people in antiquity than the loss

of the sun's light, a lunar eclipse was nevertheless considered an important omen.

The Greek historian Thucydides reported on a famous lunar eclipse during the Peloponnesian War. It occurred on August 27, 413 B.C., the date the Athenian commanders had scheduled to leave Syracuse. However, the eclipse so frightened the Athenian soldiers and sailors that on the counsel of the astrologer-priests, the departure was delayed 27 days. This delay gave the Syracusans the opportunity to regroup, and they destroyed or captured the whole Athenian fleet and army.



Cicero and Livy reported a lunar eclipse that occurred on June 21, 168 B.C. during a war between Rome and Macedonia. The lunar eclipse was interpreted by the soothsayers as an omen for the ruin of the Macedonian king, hence frightening the Macedonians and encouraging the Romans. The eclipse was alleged to have contributed to the Roman victory at the famous battle of Pydna, which ended the Macedonian empire founded by Alexander the Great.

The above reported historical lunar eclipses can be illustrated by **Sky Travel** as follows:

Go to MAP mode. Set the latitude to 37° 30' N and the longitude to 15° E (Syracuse, Sicily). Now go to SET mode and set the date and time to August 27, 413 B.C. at 8:00 P.M. Then go to SKY

mode; set the VIEW Angle to 36 degrees and the Clock RATE to 32X. Use FIND to center the moon on the screen. The Earth's shadow is represented on the same scale as the size of the moon by a circular disk of raster lines. This becomes visible as the Earth's shadow traverses the moon's surface. The eclipse becomes total around 9:15 P.M., and it is over by about 11:30 P.M.

For the other case, first stop the clock. Then go back to MAP mode and set the latitude to 40° 3' N and the longitude to 22° 6' E (ancient city of Pydna near Mt. Olympus in Greece). Now go to SET mode and set the date and time to June 21, 168 B.C. at 7:00 P.M. FIND the moon, set the Clock RATE to 36X, and watch the moon rise, totally eclipsed. By about 9:20 the eclipse is over.

The Great Pyramid at Giza

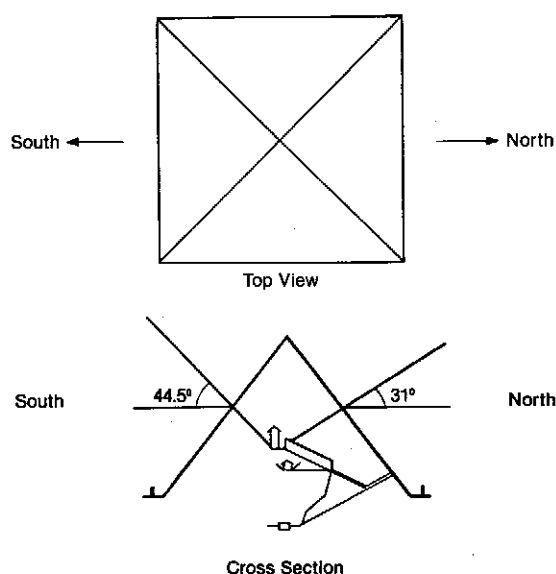
The Great Pyramid at Giza, near Cairo, was built during the reign of Cheops (Khufu), a Pharaoh of the Fourth Dynasty. The dimensions of this, the greatest of the pyramids, are truly impressive; the base is a square measuring 756 ft. on the side, covering over 13 acres, and the original height was 482 ft. Even more impressive is the precision of this large monument; the maximum difference from a true square is less than eight inches, and the base is aligned in the four cardinal directions: north, east, south, and west with a maximum difference of less than 1/10 of a degree. This is a testimony to the skill of the early Egyptians as master builders and surveyors.

The pyramid is a solid building containing over two million limestone blocks weighing on the average of 2½ tons each. The pyramid was originally faced with smooth, well fitted white limestone and capped with a golden "pyramidion." The Greek historian

Herodotus, who visited Giza in the fifth century B.C., reported that Cheops, during his 50 year reign, exchanged 100,000 men every three months to toil at the construction site.

The interior of the pyramid is entered through a single opening, originally covered, on the north face. This entrance is about 55 ft. above ground level. From here a narrow corridor descends at a 26° angle for 355 ft. to an unfinished underground chamber. About 100 ft. from the entrance another corridor, originally blocked off, ascends at a 26° slope from the ceiling of the descending corridor. The ascending corridor ends in a long, tall, and narrow chamber called the "Great Gallery" which is connected to an upper burial chamber, the "King's Chamber." Through a separate corridor, also originally blocked off, is a lower burial chamber, the "Queen's Chamber." The purpose of the complicated network of corridors, no doubt, was to mislead potential grave robbers.

Of special interest are two narrow (9 in × 9 in), precisely aligned shafts, one leading from the upper end of the Gallery and ending on the north face, the other leading from the King's Chamber and ending on the south face of the pyramid. The purpose of these shafts has been the subject of wonder for centuries. An early suggestion that they were intended for ventilation is not logical; the construction of these shafts at precise angles through many courses of limestone blocks must have been such a difficult task that a much better reason must be sought. Considering the importance to the ancient Egyptians of celestial mythology, it is indeed more likely that the astrologer-priests oriented the shafts towards carefully selected regions of the sky.



Cheops' Pyramid

Early estimates place the Fourth Dynasty, the period of the "Great Pyramid Kings," at about 4000-3000 B.C. However, at that time the north shaft would have pointed towards a segment of the sky without any bright stars. In contrast, from 3000-2500 B.C., the bright star Thuban in the constellation Draco was perfectly aligned with the north shaft. Based on this and other evidence, the time of the building of Cheops' pyramid is now believed to be about 2800-2600 B.C. The next question then is: what did the south shaft point towards at that time? Recent studies show that only three bright stars qualify, namely the three stars in what we now call Orion's belt. (Trimble 1964)

It is not likely that the shafts were intended for astronomical observation. First, the shafts were originally covered by the facing stones on the pyramid; second, a slight bend at both ends of the shafts, presumably to prevent accumulation of sand and debris, would have

prevented direct sighting. It is therefore more likely that the purpose was a religious one.

In ancient Egypt, the circumpolar stars, which neither set nor rose, were called "imperishable stars" and represented immortal gods. Pharaoh's soul was believed to ascend to these eternal stars to take its place among the gods in the sky. Thuban, then the Pole Star, would have been the ultimate eternal star. The stars of Orion, in turn, were representative of Osiris, the Egyptian god of transformation and resurrection. The shafts in the pyramid were therefore most likely intended as passageways for Cheops' soul towards its ultimate destination in the sky.

The "Pyramid Kings" of the Fourth Dynasty left no written records and no pictorial descriptions on the walls of their tombs. Yet, in the precise alignment of their pyramids, they revealed an insight into astronomy that has allowed later generations to determine their age.

Sky Travel enables you to recreate the appearance of the ancient sky over Giza as it appeared at the time of the construction of Cheops' pyramid. By setting the elevation and azimuth of the cross hair cursor corresponding to those of the northern and southern shafts, you can see the transits of Thuban and the Orion belt stars, respectively, as Pharaoh's astrologer-priests planned it more than 4500 years ago:

*Go to MAP mode. Set the latitude as close as possible to 29°59' north and the longitude to 31° east (Giza). Go to SET mode. Set date and time to January 1, 2700 B.C. at 10:00 P.M. Go to SKY mode. Stop the clock, then tap **f5** until it shows the constellations. Press **RETURN** and place the cursor on the NPole. Press **RETURN**. Now adjust the cursor elevation as close as possible to 31° north by tapping the up/down cursor key using*

the numerical elevation display in the data window to the right of the screen. The view within the cross hair now corresponds to the view through the north shaft of Cheops' pyramid at the time of its construction. Place the cursor on the Pole Star and press INFORM to verify that the star really is Thuban. Then set the Clock RATE to 64X and watch the stars rotate about Thuban as they did at the time of Cheops.

Now change the setting to show the original view through the south shaft. Again, stop the clock and then press the S key (for South). Using the up/down cursor key, set the cross hair cursor so it has an elevation of $41^{\circ}5'$ as shown in the data window. Set the RATE again to 64X and watch the belt stars in Orion pass through the cross hair.

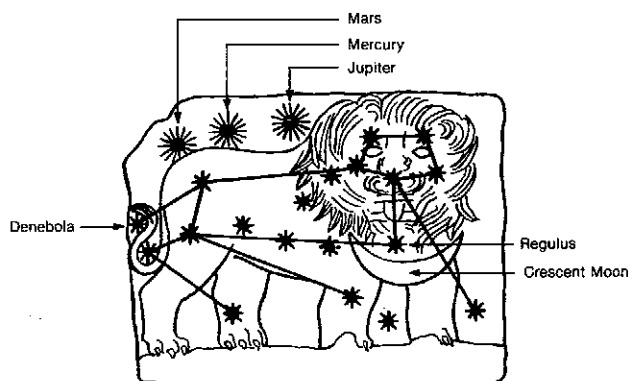
Cheops' pyramid was admired already in antiquity as one of the so-called seven wonders of the world; in fact, it is the only one still standing. However, in terms of its principal function — namely to guarantee the Pharaoh a peaceful resting place surrounded by his signs of power and wealth and protected from grave robbers — it was a monumental failure. Today none of Pharaoh's treasures remain, and even the mummy of Cheops himself vanished long ago — who knows if it was ground up and found in medieval medicines, as happened to so many mummies of lesser distinction.

The Stone Lion of Nimrud Dagħ

In the first century B.C., Antiochus I, of Commagene (Kummuhu), was as obsessed as Cheops had been with preserving his bodily remains and his worldly goods. He may have been more successful, since it appears that to this day nobody has uncovered his burial chamber. Commagene was a land occupying a strategic junction at the inland trade routes between the Greek and Roman empires.

A hundred years ago, German and Turkish archaeologists investigated an open air pantheon of colossal statues on top of the Nimrud Dagħ (Mt. Nimrod), a 7000 ft. mountain south of the Anti-Taurus mountain chain in Turkey and just north of present day Syria. The statues were 25-29 ft. tall and were placed on 20 ft. high platforms on two terraces on the mountain top, one facing east and the other west. The eastern terrace also contained a fire altar for religious ceremonies. The statues were magnificently carved in stone and represented a mixture of Greek and Persian gods — as well as one of the king himself. Between the terraces was a 150 ft. high stone mound believed to contain the remains of King Antioch. (Goell 1961)

Of particular interest was a large stone relief of a lion showing three planets, a crescent moon, and 19 stars on and around the lion's body. A sketch of the stone lion is shown below:



Stone Lion of Nimrud Dagħ

Greek inscriptions identify the three major stars above the lion as the planets Mars, Mercury, and Jupiter. The star pattern is recognizable as the constellation Leo. The star on the lion's chest is no doubt Regulus, also known as Cor Leoins, which means the heart of the lion. The star nearest the tail, in turn,

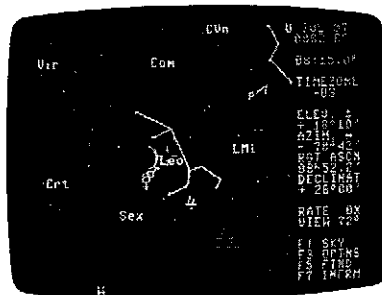
must be Denebola, which means the tail of the lion. The simplified line diagram used in **Sky Travel** for the constellation Leo is highlighted, some additional lines used in the more elaborate classical diagrams are added. The angles in the constellation are a bit distorted. This was caused by the creativity of the unknown sculptor.

The stone lion was the first known Greek horoscope and the configuration of the moon, planets, and stars has been studied in an effort to determine the exact date represented by the horoscope. The only dates in which a crescent moon and the three planets were observable in the sign of Leo during the life of King Antioch were July 6-7, 62 B.C. These dates are in good agreement with the arrival of the Roman consul Pompeius after defeating Mithradates VI and finally joining the Roman guards in Asia Minor. The kingdom of Commagene was a buffer state between the Roman and Parthian Empires, and King Antioch might well have shown his gratitude for the defeat of the Mithradates by erecting this temple and perhaps even counting his actual reign from this date. (Neugebauer & Van Hoesen 1959)

Sky Travel allows you to compare the appearance of the sky over Commagene on the above dates with the planetary and crescent moon configuration shown on the stone lion:

Use **F1** to go to MAP mode. Set the latitude to $37^{\circ}50'N$, longitude to $38^{\circ}7'E$ (Samosata, ancient capital of Commagene,

now village of Samsat in Turkey). Use **F1** to change to SET mode. Set the date and time to July 7, 62 B.C. at 8:15 P.M. Use **F1** to change to SKY mode. When in SKY mode, set the VIEWing Angle first to 72 degrees by means of the **SHIFT** and **+/-** keys. Then tap **F5** (FIND) until the moon is shown, and then press **RETURN**. The VIEWing Angle can be reduced to 36 and 18 degrees for further study of the configuration.



The planetarium program may actually be able to improve on the precision of the dating. As you will note, on the above day, the sun closely preceded the crescent moon and the three planets; hence, the only time that the planets and the crescent moon would have been visible was shortly after sunset and then only for a brief period. If you check both July 6 and July 7, you will see that only the latter day is possible.

NAVIGATION

The art of navigation by the sun and the stars was developed by ancient mariners. The earliest, primitive form of navigation consisted merely of determining the "bearing" (the direction in which you were sailing).

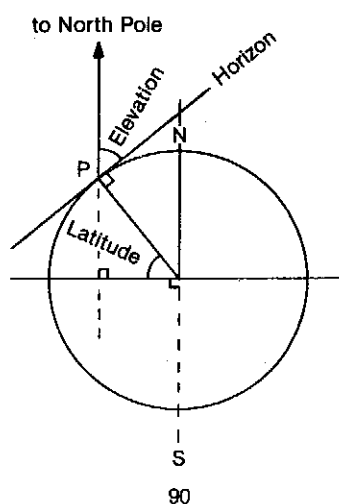
In order to know your position, it is necessary to determine both your latitude and your longitude. Of these, the latitude can be determined solely from celestial observations while longitude requires knowledge of both local time and the time at some longitude, (a time difference from a known longitude).

Although it is always possible to determine local time, it was not before the invention of a reliable, portable chronometer by the British clockmaker John Harrison in 1735 A.D. that it became possible to know a reference time aboard ships. The standard reference time and longitude was and still is that of Greenwich.

Latitude from Polaris

At any point (P) on the Northern hemisphere, the latitude equals the elevation of the North Pole, (see the sketch below). Since stars are so far away that sightings are parallel no matter where on the Earth they are made, the north-south line of the Earth and the sighting line from P are parallel. It follows therefore, from simple geometry, that the angle of P's latitude equals the angle of elevation of the North Pole as sighted from P.

Latitude and Elevation of the Pole



Since Polaris is within about 1° of the North Pole, you can get an immediate, approximate reading of your latitude simply by measuring the elevation of the Pole Star — as long as you are on the Northern hemisphere. Let us give you an example:

You are a merit badge counsellor in astronomy for the Boy Scouts. Your young students want to know whether astronomy "can be used for anything," so you give them a little problem to figure out. You tell them that they have been in a storm on a small boat in the Caribbean, their two-way radio does not work and they are lost. However, they have a small sextant, a small transistor radio, and a map. The sea is now calm and the boat is dead in the water with no current. Just before dawn, there is a break in the clouds and they get to read the elevation of Polaris at 15.5° . Around noon, they sight the sun and find that their wristwatch shows 12:15 P.M. when the sun is at its highest elevation. Afterwards they hear a radio broadcast from Miami stating that it is 12:30 P.M. Eastern Standard Time and they check their watch which shows 12:37 P.M. Where are the boys?

First, their latitude is approximately the same as the elevation of the Pole Star, (15.5° north). Second, the broadcast tells them that their watch is 7 minutes too fast, hence the sun was at Zenith at the boy's location at 12:08 Eastern Standard Time. Third, since Eastern Standard Time is Time Zone 5, the sun would be at Zenith at 12:00 EST at the middle of time zone 5, which is 5 times $15^\circ = 75^\circ$ west of Greenwich. (That is 5 for the number of time zones away from Greenwich and 15° for the number of degrees in each time zone.) Hence, the boys conclude that they are 8 minutes = $15 \times 8 / 60$ degrees = 2° further west than the middle of time zone 5, that is their longitude must be $75 + 2 = 77^\circ$ west. Looking at their map, they see that the nearest major land mass is Jamaica, and that they are about 2.5° (= about 150 nautical miles, see next page)

*directly south of Kingston. So, by setting a course due North, they will surely find the island and be able to get their equipment repaired. You can go to the MAP mode on **Sky Travel**, set the latitude and longitude to these values, go to SET and SKY mode and show the boys that the elevation of Polaris and the local time of noon were as they reported!*

Positional Navigation

Consider the accuracy of position in terms of both degrees and distances. Since the circumference of the Earth is 40,000 km along any great circle (e.g. Equator), 1° of arc corresponds to 111 km (= 69 miles = 60 nautical miles): $(40,000\text{km}/360 \text{ degrees} = 111 \text{ km/degree})$. One minute of arc is 1.9 km (= 1.2 miles = 1 nautical mile) and one second of arc is 31 m (= 116 ft). Hence, if you wish to know your location within 200 m or $1/10$ of a mile, your position in terms of degrees must be determined to within $1/10$ of a minute of arc. For this reason, a number of corrections are required to assure that observation of celestial objects are accurate.

Consider also the accuracy needed of a chronometer for determining longitude. In 1714 the British government posted an award of 20,000 pound sterling for anyone who could design a clock which could be used for determining a ship's longitude within 30 miles after a six week voyage. This translates into an accuracy of better than 3 seconds/day — much better than

even a pendulum clock on land was able to do at that time! The previously mentioned John Harrison won the award, and towards the end of the 18th century, chronometers were in common use aboard ships.

After the invention of the radio by Marconi in 1920, it became very easy to know the Greenwich time anywhere on Earth; hence, longitude became as simple to determine as latitude. Today, pulsed radio and RADAR signals from Earth stations and satellites, combined with on-board computers, have speeded up navigation to match the needs of fast airplanes and space craft. Still, in case of equipment or power failures, the chronometer method is a stand-by technique, especially on small ocean going crafts. Navigation by the stars is, of course, a special subject in the case of space exploration.

We cannot go into the actual techniques used in nautical and air navigation. Due to the accuracy of measurement required, a number of corrections must be made to the readings, for example: for your height over the horizon, for refraction by air, etc. Nevertheless, for instructional purposes **Sky Travel** can replace a Nautical Almanac since the program can calculate the position of the sun, moon, and the navigational stars at any time from any location on Earth. Hence, a student can use the program as a self-contained system for training without the need at this point for sextants, astronomical tables, and clear weather!

SPACE EXPLORATION

"...it would be surprising if life were not abundant in the galaxy. Our problem is to find it."

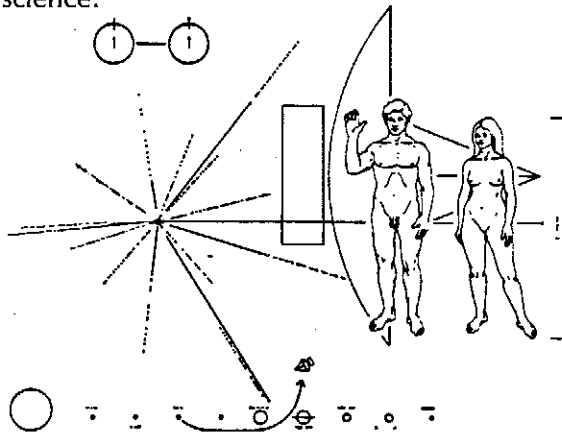
George O. Abell (1976)

In July 1969, American astronauts landed on the moon, the first human beings ever to set

foot on a celestial body other than Earth. The astronauts left a plaque with a message in the English language with the reasonable expectation that other human expeditions to the moon will occur before English — and perhaps mankind — become extinct.

Towards the end of 1973, the unmanned spacecraft Pioneer 10 passed Jupiter on its way

towards the constellations Taurus and Orion, the first man-made object to leave our solar system. This mission also carried a plaque, but since possible intelligent beings in the universe would be unfamiliar with any human language, the message was written in the language of science:



In order to introduce ourselves to extra terrestrials which may have developed along lines very different from ourselves, a male and a female human are shown to the same scale as a sketch of the spacecraft. The symbol at the top refers to Hydrogen, the most abundant element in the universe. In order to identify the launch site, Pioneer 10 is shown leaving the Earth and passing out of our solar system between Saturn and Jupiter. And in order to allow a decoding of the time of the launching, a diagram shows the directions to 14 pulsars as presently seen from our solar system. In a sense, this plaque is a 20th century counterpart to the Stone Lion. (p.36)

The experiment has been compared to throwing a bottle with a note into the sea. However, the ocean of the universe is vast and even though Pioneer 10 travels at 7 miles per second it will not reach a potential planetary system for 10 billion years! (Sagan 1980)

The space program has excited laymen, scientists, and science fiction writers alike, to speculate on the future of humans in space and on the possibilities for finding intelligent lifeforms somewhere in the universe. Through its INFORM function, **Sky Travel** provides general information about all of the celestial bodies and galaxies which are visible on your screen, as well as their distances, if they are known. Hence, you will be able to appreciate both the possibilities and the limitations of the interplanetary and interstellar exploration better and make your own judgements regarding future stories you will see or hear in the news media.

Astronautics

The space program has resulted in a general realization of just how unique the Earth really is and how uninhabitable is the rest of even our own solar system. This does not mean that colonization of space is impossible, but it does mean that it will be difficult — and probably quite some time in coming.

Aside from artificial space stations, the most likely bases for space colonies in our solar system are the moon and perhaps the asteroids between Mars and Jupiter. The asteroids are relatively small, solid bodies ranging from about one mile to five hundred miles in diameter, and they have the distinct advantage that they are already in orbit! Such space stations might some day serve as launch platforms for deeper space probes.

To remind yourself of the nature (size, temperature, composition) of the moon and the planets and to make a list of the distances within our solar system, go to SKY mode, use the FIND key [F5] for each planet and the moon, then press INFORM [F7] sequentially for each. Since the fastest existing spacecraft travels at speeds no more than about 1/10,000 the speed of

light, you can calculate present travel times from the distances given, for example, in light minutes (by multiplying the number of light minutes by 10,000 and converting the minutes to years and months).

For human space travel outside the solar system, the problems are huge. The distance to the nearest bright star (Rigel Kentaurus) is 4.3 light years. Using the same calculation as above, this corresponds to a travel time of 43,000 years!

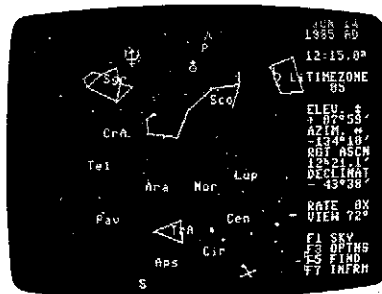
Since the time travel to the nearest star takes so long, it is impractical if not impossible, for humans to travel outside our solar system. An Astronaut's life, so far, cannot be extended long enough for him/her to ever reach another solar system. It is more likely that astronauts could be brought to a state of hibernation to increase their life span, or that later generations born and raised on board might eventually make it to distant places in the universe. Nevertheless, even if they do, this is not exploration in the sense that Earth was explored or that may be possible within the solar system itself. There would be no return tickets for the astronauts! Should they or their descendants ever return to Earth, it would be a very different Earth. If mankind still exists, the differences may be even greater than that between the Stone Age and our age. Such astronauts would literally need an astronomical amount of the "right stuff."

In order to develop an appreciation of the huge size of the universe and the distances even to the closest stars outside our own solar system, use the star and constellation tables in the back of the manual. For example, compare the distance to Sirius in Canis Major versus Deneb in Cygnus! You can locate the selected stars by first using FIND for the corresponding constellation and then

INFORM after placing the cursor over the star. If you do not recognize the star, rather than resorting to trial and error, the Declination and Right Ascension values in the star tables can be used to help place the cursor directly on the star since the coordinates for the cursor are shown in the data window to the right of the screen.

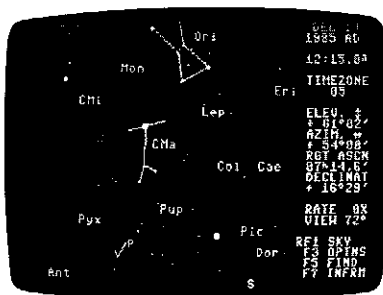
Our galaxy, the Milky Way, is 100,000 light years across. Our sun is about 30,000 light years away from the center. If you look towards Sagittarius, you are looking in the direction of the center of our galaxy:

Go to MAP mode, set the latitude to 0° N, longitude to 77° W. Go to SET mode; select June 14, 1985 A.D. Go to the SKY mode **F1**. Set **F3** to LINES on, NAMES on, SYMBOLS on, DEEP on, TRACK off, SOUND off. Set the VIEW to 72 degrees (**SHIFT** and + key), RATE to 0X (- key). Press the S key for a southern view.



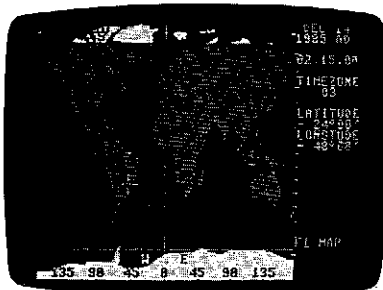
The Milky Way stretches diagonally across the screen. Note the many star clusters. For a good view in the direction of Orion and Canis Major (Sirius), we must go to the winter season.

Keep the above settings, but change the month to December (SET Mode). Go to SKY mode and proceed as before.

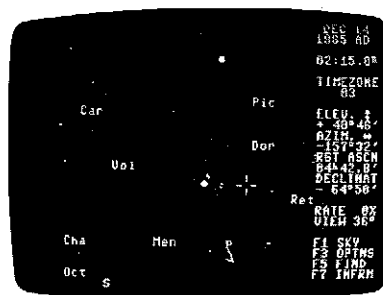


Here a section of the Milky Way covers the whole left half of the screen. Note also the Great Nebula (M 42) in Orion.

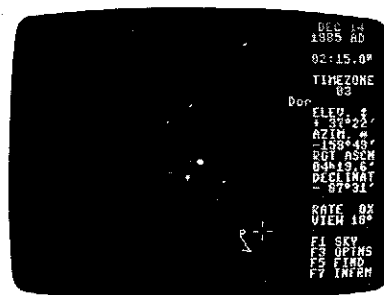
The "closest" galaxies to the Milky Way are the Magellanic Clouds, named after the Portuguese explorer and discoverer of the Magellan Strait, who first noticed these "clouds" in the southern sky. In order to observe them, keep the date and time from the previous example but go to the southern hemisphere, for example latitude 24° south, longitude 49° west.



The easiest way to locate the large Magellanic Cloud is to use **FIND** for the constellation Dor(ado) (**F3** in **SKY** mode) at a 36° **VIEW** Angle (**SHIFT** and +/- keys).



Reducing the **VIEW**ing Angle resolves the cloud further into individual star clusters.



The Magellanic Clouds are satellite galaxies of the Milky Way and are 160 to 180 light years away.

We have earlier (p. 20) observed the Andromeda galaxy which is about 2200 light years away.

The Virgo cluster, which contains thousands of galaxies, belongs to the same super cluster as the Milky Way. It is 50 million light years away.

TECHNICAL NOTES

The following technical details are of particular interest to astronomers.

Stellar Positions

A 2000 A.D. epoch star catalog is used as the basis for all stellar positions. Calculations for other epochs take into account the Earth's precession but not the proper motion of stars.

With the exception of a few of the closest stars which have large proper motions, stellar positions are accurate to within one minute of arc, over the time span from 9999 B.C. to 9999 A.D.

Planetary Positions

The planetary ephemerides used in the program are based upon the method of T. Van Flandern & K.F. Pulkkinen (*The Astro-physical Journal, Supplement Series*, Vol. 41, Nov. 1979, pp. 391-411). Planetary perturbation effects are included. During the period 1700 A.D. through 2300 A.D., planetary position calculations are accurate to within a few minutes of arc. An exception is Pluto, whose orbit is not known accurately enough for position calculations better than about 15 minutes of arc. The utility of the planetary ephemerides has been considerably extended into the past by correcting for the difference between universal time (related to the rotation of the earth) and ephemeris time (related to an absolute atomic clock standard). Calculations for the distant future are less reliable due to the lack of an accurate physical model for the long term variations in the rate of rotation of the Earth.

Solar and Lunar Positions

In addition to the planetary perturbations, this program allows for the long term decelerations of the orbital motions of the Earth and the moon (due to tidal effects). During modern times (1900-2000 A.D.), the solar and lunar positions are accurate to within 1 minute of arc. For

dates earlier than 1000 A.D., time differences of 0.5 to 2 hours may be expected due to uncertainties in the differences between ephemeris time and universal time. These differences are the result of changes in distribution of mass on the Earth (information and melting of icecaps, continental drifts, convection in the mantle, etc.) and may cause corresponding errors in lunar positions ranging from 15 minutes of arc to one degree. In cases where we have had suitable historical data to check against, the accuracy has been well within these limits.

Computer Updating

When the SKY display is driven by the automatic clock, the sky is updated automatically according to the following schedule:

Clock Rate	Display Time Interval Minutes	Real Time Interval Seconds
1X	0.7	42
2X	1.4	42
4X	2.8	42
8X	5.6	42
16X	5.6	21
32X	5.6	10.5
64X	5.6	5.3

The planets in turn are updated at the following intervals:

Mercury: 1 hr, Venus: 2.5 hrs. Mars: 8 hrs, Jupiter: 2 days, Saturn: 5 days, Uranus: 15 days, Neptune: 45 days, Pluto: 61 days.

The sun is updated every 2 hours and the moon every 23 minutes except when an eclipse is in progress, at which time both are updated at 5 minute intervals. However, since periods of totality are of the same order of magnitude, it may occasionally be necessary to repeat an eclipse a second time to achieve a totality display using approximate time estimates from the first trial. (See below under Eclipses.)

The position of Halley's comet during the

1985/86 apparition is updated every 12 hrs.
The anticipated accuracy of the computed trajectory is about 20 minutes of arc.
Automatic updating due to precession occurs every 100 years.

Color Monitor Display

In order to achieve a subjectively pleasing visual display, the sizes of the tokens used to represent the sun and the moon are greatly exaggerated. Since the token sizes are kept constant, the size exaggeration factor varies with the VIEWing Angle as follows for the sun and the moon:

72 degree view: 13.5X, 36 degree view: 6.8X, 18 degree view: 3.4 X, 9 degree view: 1.7X.

The stars and planets are also displayed as enlarged tokens in order to give an impression of their brightness:

Magnitude	Number of Pixels	Pattern
-2 to -1	26	
-1 to 0	16	
0 to 1	8	
1 to 2	4	
2 to 3	2	
3 to 4	2	
4 to 5	1	

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The deep-sky objects are also displayed as tokens having the following pixel patterns:

Deep-Sky Objects	Patterns
Planetary Nebulae	

Deep-Sky Objects

Patterns

Diffuse Nebulae	}			
Star Cluster within Nebulosity				
Globular Star Cluster				
Open Galactic Star Cluster				
Elliptical Galaxy				
Spiral Galaxy (Normal, Barred, or Irregular)				

The Andromeda Galaxy (M 31) has its own token
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Of course, the actual angular sizes of some planets and most of the deep-sky objects are so small that a telescope is necessary for observation. The tokens used in the program are schematic aids for differentiating between celestial objects and for showing their positions. They do not, nor were they intended to, portray the apparent sizes of the objects they represent.

It should also be pointed out that the number of objects which can be displayed on a single monitor screen is limited to 256 objects. While this usually is quite sufficient, it does not allow the display of all the stars and deep-sky objects present in certain highly populated directions in the sky, when both are requested and the widest VIEWing Angle is used. In such cases, the program sorts the display by magnitude and omits the faintest stars and the dimmest deep-sky objects as overflow. However, these faint objects will reappear if the VIEWing Angle is reduced or, in case of faint stars, if the deep-sky display is negated.

Eclipses, Transits, and Occultations

The reasons for using oversized tokens for the various celestial bodies were explained above. One difficulty resulting from this choice is that oversizing may lead to misinterpretations, for example in the case of visual studies of eclipses. In order to overcome this difficulty, the program calculates eclipse graphics based on actual angular sizes rather than the displayed token sizes. As an illustration, the overlapping of the new moon (displayed as a dotted circle) and the sun (displayed as a bright disk) in SKY mode does not constitute an eclipse. When an eclipse actually occurs, the program plots a token for the partially eclipsed solar disk having the correct relative size of the obscuring disk of the moon. This allows the various phases of a solar eclipse from first contact through totality to last contact to be displayed as they would appear in the sky, including the associated sky darkening effects.

The fixed update intervals of 5 minutes for the sun and moon during eclipses is convenient for showing the partial phases; however, totality is usually less than 5 minutes in duration, so it

is quite possible to overshoot totality entirely. If this occurs, the program can be made to show it by the following procedure:

1. estimate the time (from data window) of maximum obscuration of the sun and darkening of the sky by scanning through the eclipse at 8X or 16X Clock RATE.
2. write down the time of the last update prior to the estimated time of totality (this occurs just after the text window shows "Computing Sun").
3. stop the clock; let us call the difference between estimated time of totality and the last update "delta."
4. get in to SET mode; readjust the clock backwards by ten minus delta minutes; go back into SKY mode and restart the clock.

The computer will now recognize that it is more than 5 minutes away from its last update of the sun and will choose the new time as the starting point for the 5 minute updates. One update will now occur near the eclipse maximum. In case of totalities of very short duration, the procedure may have to be repeated.

TABLES

Latitudes and Longitudes

I: North American Cities

Name	Latitude	Longitude	State/Country
	Deg Min NS	Deg Min EW	
Albuquerque	35 05 N	106 38 W	New Mexico, USA
Anchorage	61 10 N	149 53 W	Alaska, USA
Atlanta	33 45 N	84 23 W	Georgia, USA
Baltimore	39 17 N	76 37 W	Maryland, USA
Bangor	44 49 N	68 47 W	Maine, USA
Boise	43 37 N	116 13 W	Idaho, USA
Boston	42 20 N	71 05 W	Massachusetts, USA
Calgary	51 03 N	114 05 W	Alberta, Canada
Chicago	41 59 N	87 38 W	Illinois, USA
Cincinnati	39 06 N	84 31 W	Ohio, USA
Cleveland	41 30 N	81 41 W	Ohio, USA
Dallas	32 47 N	96 48 W	Texas, USA
Denver	39 45 N	105 00 W	Colorado, USA
Des Moines	45 35 N	93 35 W	Iowa, USA
Detroit	42 20 N	83 03 W	Michigan, USA
Edmonton	53 34 N	113 25 W	Alberta, Canada
El Paso	31 45 N	106 29 W	Texas, USA
Fairbanks	64 51 N	147 43 W	Alaska, USA
Halifax	44 38 N	63 35 W	Nova Scotia, Canada
Honolulu	21 19 N	157 52 W	Hawaii, USA
Houston	29 46 N	95 22 W	Texas, USA
Indianapolis	39 46 N	86 09 W	Indiana, USA
Jacksonville	30 20 N	81 40 W	Florida, USA
Kansas City	39 05 N	94 37 W	Kansas/Missouri, USA
Las Vegas	36 11 N	115 08 W	Nevada, USA
Los Angeles	34 00 N	118 15 W	California, USA
Madison	43 04 N	89 22 W	Wisconsin, USA
Mexico City	19 25 N	99 10 W	Mexico; Capital
Miami	25 45 N	80 15 W	Florida, USA
Milwaukee	43 02 N	87 55 W	Wisconsin, USA
Minneapolis	45 00 N	93 15 W	Minnesota, USA
Montreal	45 31 N	73 34 W	Quebec, Canada
New Orleans	30 00 N	90 03 W	Louisiana, USA
New York	40 43 N	74 01 W	New York, USA
Nome	64 30 N	165 30 W	Alaska, USA
Oklahoma City	35 28 N	97 32 W	Oklahoma, USA
Omaha	41 15 N	96 00 W	Nebraska, USA
Ottawa	45 25 N	75 42 W	Ontario, Canada; Capital
Philadelphia	40 00 N	75 10 W	Pennsylvania, USA
Phoenix	33 30 N	112 03 W	Arizona, USA
Pittsburgh	40 26 N	80 00 W	Pennsylvania, USA
Quebec	46 50 N	71 15 W	Quebec, Canada
Salt Lake City	40 45 N	111 55 W	Utah, USA
San Francisco	37 45 N	122 27 W	California, USA
San Juan	18 29 N	66 08 W	Puerto Rico, USA

Seattle	47 36 N	122 20 W	Washington, USA
St. John's	47 34 N	52 41 W	Newfoundland, Canada
St. Louis	38 40 N	90 15 W	Missouri, USA
Toronto	43 39 N	79 23 W	Ontario, Canada
Vancouver	49 13 N	123 06 W	British Columbia, Canada
Washington D.C.	38 55 N	77 00 W	USA; Capital
Winnipeg	49 53 N	97 10 W	Manitoba, Canada

II: Cities Outside NA Continent

Name	Latitude	Longitude	Country/Continent
	Deg Min NS	Deg Min EW	
Accra	5 33 N	0 15 W	Ghana, Africa; Capital
Addis Ababa	9 03 N	38 42 E	Ethiopia, Africa; Capital
Algiers	36 50 N	3 00 E	Algeria, Africa; Capital
Amsterdam	52 21 N	4 54 E	Holland, Europe; Capital
Anadyr	64 55 N	176 05 E	USSR, Asia
Ankara	39 55 N	32 50 E	Turkey, Asia Minor; Capital
Asuncion	25 15 S	57 40 W	Paraguay, S. America; Capital
Athens	38 00 N	23 44 E	Greece, Europe; Capital
Baghdad	33 20 N	44 26 E	Iraq, Middle East; Capital
Bangkok	13 44 N	100 30 E	Thailand, Asia; Capital
Beirut	33 52 N	35 30 E	Lebanon, Middle East; Capital
Belgrade	44 50 N	20 30 E	Yugoslavia, Europe; Capital
Benghazi	32 07 N	20 05 E	Libya, Africa
Berlin	52 32 N	13 25 E	West Germany, Europe
Bern	46 57 N	7 26 E	Switzerland, Europe; Capital
Bogota	4 38 N	74 05 W	Columbia, S. America; Capital
Bombay	18 56 N	72 51 E	India, Asia
Bonn	50 44 N	7 06 E	West Germany, Europe; Capital
Brasilia	15 45 S	47 57 W	Brazil, S. America; Capital
Brussels	50 50 N	4 21 E	Belgium, Europe; Capital
Bucharest	44 25 N	26 07 E	Romania, Europe; Capital
Budapest	47 30 N	19 03 E	Hungary, Europe; Capital
Buenos Aires	34 40 S	58 30 W	Argentina, S. America; Capital
Cairo	30 03 N	31 15 E	Egypt, Africa; Capital
Calcutta	22 30 N	88 20 E	India, Asia
Cape Town	33 56 S	18 28 E	South Africa, Africa
Caracas	10 35 N	66 56 W	Venezuela, S. America; Capital
Casablanca	33 39 N	7 35 W	Morocco, Africa
Colombo	6 55 N	79 52 E	Ceylon-Sri Lanka, Asia; Capital
Copenhagen	55 43 N	12 34 E	Denmark, Europe; Capital
Dacca	23 42 N	90 22 E	Bangladesh, Asia; Capital
Dakar	14 38 N	17 27 W	Senegal, Africa; Capital
Dublin	53 20 N	6 15 W	Ireland, Europe; Capital
Godthaab	64 15 N	51 35 W	Greenland
Hanoi	21 01 N	105 52 E	N. Vietnam, Asia; Capital
Havana	23 07 N	82 25 W	Cuba, Caribbean; Capital
Helsinki	60 08 N	25 00 E	Finland, Europe; Capital
Hiroshima	34 23 N	132 27 E	Japan, Asia
Hong Kong	22 15 N	114 11 E	China, Asia
Istanbul	41 02 N	28 57 E	Turkey, Asia Minor
Jakarta	6 08 S	106 45 E	Indonesia, Asia; Capital

Name	Latitude		Longitude		State/Country
	Deg	Min NS	Deg	Min EW	
Jerusalem	31	47 N	35	13 E	Israel, Middle East
Johannesburg	26	10 N	28	02 E	South Africa, Africa
Kabul	34	30 N	69	10 E	Afghanistan, Asia; Capital
Karachi	24	51 N	67	02 E	Pakistan, Asia
Khartoum	15	33 N	32	32 E	Sudan, Africa; Capital
Kiev	50	26 N	30	31 E	USSR, Europe
Kinshasa	4	18 S	15	18 E	Zaire, Africa; Capital
Kyoto	35	02 N	135	45 E	Japan, Asia
Lagos	6	27 N	3	28 E	Nigeria, Africa; Capital
La Paz	16	30 S	68	10 W	Bolivia, S. America; Capital
Leningrad	59	55 N	30	25 E	USSR, Europe
Lima	12	06 S	77	03 W	Peru, S. America; Capital
Lisbon	38	44 N	9	08 W	Portugal, Europe; Capital
London	51	30 N	0	10 W	England, Europe; Capital
Longyearbyen	78	12 N	15	40 E	Svalbard, Norway, Europe
Madrid	40	25 N	3	43 W	Spain, Europe; Capital
Magadan	59	38 N	150	50 E	USSR, Asia
Manila	14	37 N	120	58 E	Philippines; Capital
Marrakech	31	49 N	8	00 W	Morocco, Africa
Mecca	21	26 N	39	49 E	Saudi Arabia, Middle East
Melbourne	37	45 S	144	58 E	Victoria, Australia
Montevideo	34	55 S	56	10 W	Uruguay, S. America; Capital
Moscow	55	45 N	37	42 E	USSR, Europe; Capital
Murmansk	68	59 N	33	08 E	USSR, Europe
Nagasaki	32	45 N	129	52 E	Japan, Asia
Nairobi	1	17 S	36	50 E	Kenya, Africa; Capital
New Delhi	28	37 N	77	13 E	India, Asia; Capital
Novosibirsk	55	04 N	83	05 E	USSR, Asia
Omsk	55	00 N	73	22 E	USSR, Asia
Oslo	59	56 N	10	45 E	Norway, Europe; Capital
Paris	48	52 N	2	20 E	France, Europe; Capital
Peking	39	55 N	116	26 E	China, Asia; Capital
Perth	31	58 S	115	49 E	West Australia
Prague	50	06 N	14	26 E	Czechoslovakia, Europe; Capital
Quito	0	14 S	78	30 W	Ecuador, S. America; Capital
Rangoon	16	47 N	96	10 E	Burma, Asia; Capital
Reykjavik	64	09 N	21	58 W	Iceland; Capital
Rio de Janeiro	22	53 S	43	17 W	Brazil, S. America
Riyadh	24	39 N	46	46 E	Saudi Arabia, Mid. East; Capital
Rome	41	53 N	12	30 E	Italy, Europe; Capital
Saigon	10	46 N	106	43 E	S. Vietnam, Asia; Capital
Santiago	33	30 S	70	40 W	Chile, S. America; Capital
Sao Paulo	23	33 S	46	39 W	Brazil, S. America
Seoul	37	30 N	127	00 E	Korea, Asia; Capital
Shanghai	31	13 N	121	25 E	China, Asia
Singapore	1	17 N	103	51 E	Malacca, Asia
Sofia	42	40 N	23	18 E	Bulgaria, Europe; Capital
Stockholm	59	20 N	18	05 E	Sweden, Europe; Capital
Sydney	33	55 S	151	10 E	New South Wales, Australia
Taipei	25	05 N	121	32 E	Taiwan, Asia; Capital
Tananarive	18	52 S	47	30 E	Madagascar; Capital

Tashkent	41	16 N	69	13 E	USSR, Asia
Teheran	35	40 N	51	26 E	Iran, Middle East; Capital
Tel Aviv	32	05 N	34	46 E	Israel, Middle East
Thule	77	30 N	69	29 W	Greenland
Timbuktu	16	49 N	2	59 E	Mali, Africa
Tokyo	35	40 N	139	45 E	Japan, Asia; Capital
Tomsk	56	30 N	85	05 E	USSR, Asia
Tripoli	32	58 N	13	12 E	Libya, Africa
Tunis	36	50 N	10	13 E	Tunisia, Africa; Capital
Vienna	48	13 N	16	20 E	Austria, Europe; Capital
Vladivostok	43	09 N	131	53 E	USSR, Asia
Warsaw	52	15 N	21	00 E	Poland, Europe; Capital
Wellington	41	17 S	174	47 E	New Zealand; Capital
Yakutsk	62	10 N	129	50 E	USSR, Asia
Zanzibar	6	10 S	39	11 E	Tanzania, Africa

III: Islands

Name	Latitude		Longitude		Ocean
	Deg	Min NS	Deg	Min EW	
Ascension	7	57 S	14	22 W	Atlantic
Azores	38	30 N	28	00 W	Atlantic
Bermuda	32	20 N	64	45 W	Atlantic
Bouvet	54	26 S	3	24 E	Atlantic
Canary	28	30 N	14	10 W	Atlantic
Cape Verde	16	00 N	24	00 W	Atlantic
Christmas	2	00 N	157	30 W	Pacific
Christmas	10	30 S	105	40 E	Indian
Coco	13	14 N	144	39 E	Pacific
Cocos/Keeling	12	10 S	96	55 E	Indian
Cook	20	00 S	158	00 W	Pacific
Easter	27	07 S	109	22 W	Pacific
Falkland	51	45 S	59	00 W	Atlantic
Fiji	18	00 S	175	00 E	Pacific
Galapagos	0	30 S	90	30 W	Pacific
Gilbert	0	30 S	174	00 E	Pacific
Gough	40	20 S	10	00 W	Atlantic
Guam	13	50 N	144	75 E	Pacific
Jan Mayen	71	00 N	8	20 W	Arctic
Kerguelen	49	15 S	69	10 E	Antarctic
Marquesas	9	00 S	139	30 W	Pacific
Marshall	9	00 N	168	00 E	Pacific
Palmyra	5	52 N	162	05 W	Pacific
Pitcairn	25	04 S	130	06 W	Pacific
Samoa	14	00 S	171	00 W	Pacific
Seychelles	4	35 S	55	40 E	Indian
South Georgia	54	15 S	36	45 W	Antarctic
South Orkney	60	35 S	45	30 W	Antarctic
St. Helena	15	57 S	5	42 W	Atlantic
Tahiti	17	70 S	150	00 W	Pacific
Tonga	20	00 S	175	00 W	Pacific
Tristan da Cunha	37	15 S	12	30 W	Atlantic
Wake	19	17 N	166	36 E	Pacific

Names Stars & Navigational Stars

Name	Declination	Rt. Asc.	Constellation	Comments	Name	Declination	Rt. Asc.	Constellation	Comments
	Deg Min NS	Hrs. Min.				Deg Min NS	Hrs. Min.		
Acamar	40 18 S	2 58.3	Eridanus		Merope	23 57 N	3 46.3	Taurus	
Achernar	57 14 S	1 37.7	Eridanus		Miaplacidus	69 43 S	9 13.2	Carina	
Acrux	63 6 S	12 26.6	Crux		Mira	2 59 S	2 19.3	Cetus	"Disappearing" star, varies during year from very bright to invisible to naked eye
Adhara	28 58 S	6 58.6	Canis Major						
Albireo*)	27 58 N	19 30.7	Cygnus	Blue/yellow double star	Mirfak	49 52 N	3 24.3	Perseus	
Aldebaran	16 31 N	4 35.9	Taurus		Mizar**)	54 56 N	13 23.9	Ursa Major	Double star, observable w/naked eye
Algenib	15 11 N	0 13.2	Pegasus						
Algol	40 57 N	3 8.2	Perseus	3 day cycle double star	Nunki	26 18 S	18 55.3	Sagittarius	
Alioth	56 58 N	12 54.0	Ursa Major		Peacock	56 44 S	20 25.6	Pavo	
Alkaid	49 18 N	13 47.5	Ursa Major		Polaris	89 16 N	2 31.8	Ursa Minor	Pole Star - North Star
Alnilam	1 12 S	5 36.2	Orion		Pollux	28 2 N	7 45.3	Gemini	
Alphard	8 40 S	9 27.6	Hydra		Procyon	5 14 N	7 39.3	Canis Minor	
Alphecca	26 43 N	15 34.7	Corona Borealis		Ras Ethage	12 34 N	17 34.9	Ophiuchus	
Alpheratz	29 5 N	0 8.4	Andromeda		Regulus	11 58 N	10 8.4	Leo	
Altair	8 52 N	19 50.8	Aquila		Rigel	8 12 S	5 14.5	Orion	
Ankaa	42 18 S	0 26.3	Phoenix		Rigel Kentaurus	60 50 S	14 39.6	Centaurus	Third brightest star: closest star to Sun (4.3 light years)
Antares	26 26 S	16 29.4	Scorpio						
Arcturus	19 11 N	14 15.7	Bootes		Sabik	15 44 S	17 10.4	Ophiuchus	
Atria	69 2 S	16 48.7	Triangulum Australe		Saiph	9 40 S	5 47.8	Orion	
Avior	59 31 S	8 22.5	Carina		Schadar	56 32 N	0 40.5	Cassiopeia	
Bellatrix	6 21 N	5 25.1	Orion		Shaula	37 06 S	17 33.6	Scorpio	
Betelgeuse	7 24 N	5 55.2	Orion		Sirius	16 43 S	6 45.1	Canis Major	Brightest star
Canopus	52 42 S	6 24.0	Carina	Second brightest star	Spica	11 10 S	13 25.3	Virgo	
Capella	45 60 N	5 16.7	Auriga		Vega	38 47 N	18 36.9	Lyra	Orbiting infra-red observatory recently discovered solar system in formative state
Caph	59 9 N	0 9.2	Cassiopeia						
Castor	31 53 N	7 34.6	Gemini		Zuben Elgenubi	16 02 S	14 50.9	Libra	
Deneb	45 17 N	20 41.4	Cygnus						
Deneb Kaitos	17 59 S	0 43.6	Cetus						
Denebola	14 34 N	11 49.0	Leo						
Dubhe	61 45 N	11 3.7	Ursa Major						
Elnath	28 36 N	5 26.3	Taurus						
Eltanin	51 29 N	17 56.6	Draco						
Enif	9 52 N	21 44.2	Pegasus						
Fomalhaut	29 37 S	22 57.6	Pisces Austrinus						
Gacrux	57 7 S	12 31.2	Crux						
Gienah	17 32 S	12 15.8	Corvus						
Hadar	60 22 S	14 3.8	Centaurus						
Hamal	23 28 N	2 7.2	Aries						
Kaus Australis	34 23 S	18 24.2	Sagittarius						
Kochab	74 9 N	14 50.7	Ursa Minor						
Markab	15 12 N	23 4.8	Pegasus						
Menkar	4 5 N	3 2.3	Cetus						
Menkent	36 22 S	14 6.7	Centaurus						

*) 30-40 X telescope needed

**) In ancient times, the Arabs used the star Mizar in the Big Dipper for testing vision. If you could see two stars, your eyesight was perfect! Mizar's companion star is Alcor.

Constellations

* Constellations Belong to Zodiac

**Constellations Have Line Diagrams in Planetarium

† Marked Constellations Are Post-Ptolemy (c. 150 A.D.)

Abr.	Latin Name	English Name	Comments	Abr.	Latin Name	English Name	Comments
And	Andromeda	Andromeda	Great Spiral Galaxy (M31), most distant naked eye object (2 million light years)	Lac	†Lacerta	Lizard	
Ant	†Antilia	Air Pump		Leo	***Leo	Lion	
Aps	†Apus	Bird of Paradise		Lep	Lepus	Hare	
Aql	**Aquila	Eagle		Lib	***Libra	Scales	
Aqr	*Aquarius	Water Carrier		LMi	†Leo Minor	Little Lion	
Ara	Ara	Altar		Lup	Lupus	Wolf	
Ari	*Aries	Ram		Lyn	†Lynx	Lynx	
Aur	**Auriga	Charioteer		Lyr	**Lyra	Lyre	Vega (see star table), Ring Nebula (M57)
Boc	**Bootes	Herdsmen		Men	†Mensa	Table Mountain	
Cae	†Caelum	Graving Tool		Mic	†Microscopium	Microscope	
Cam	†Camelopardus	Giraffe		Mon	†Monoceros	Unicorn	
Cap	***Capricorn	Sea Goat		Mus	†Musca	Fly	
Car	†Carina	Keel		Nor	†Norma	Level	
Cas	**Cassiopeia	Cassiopeia		Oct	†Octans	Octant	
Cen	Centaurus	Centaur	Rigel Kentaurus = α-Centauri, this is the closest star (4.3 light years)	Oph	Ophiuchus	Serpent Holder	
Cep	**Cepheus	Cepheus		Ori	**Orion	Orion	Great Nebula (M42)
Cet	Cetus	Whale		Pav	†Pavo	Peacock	
Cha	†Chamaeleon	Chamaeleon		Peg	**Pegasus	Pegasus	
Cir	†Circinus	Compass		Per	**Perseus	Perseus	
CMA	Canis Major	Big Dog		Phe	†Phoenix	Phoenix	
CMi	Canis Minor	Little Dog		Pic	†Pictor	Fasel	
Cnc	*Cancer	Crab	Beehive Cluster = Praesepe Cluster (M44)	PsA	Piscis Austrinus	Southern fish	
Col	†Columba	Dove		Psc	*Pisces	Fishes	
Com	†Coma Berenices	Berenice's Hair		Pup	†Puppis	Stern	
CrA	Corona Australis	Southern Crown		Pyx	†Pyxis	Mariner's Compass	
CrB	**Corona Borealis	Northern Crown		Ret	†Reticulum	Net	
Crt	Crater	Cup		Scl	†Sculptor	Sculptor	
Cru	†Crux	Southern Cross		Sco	**Scorpius	Scorpion	
Crv	Corvus	Crow	Cutter's Mainsail	Sct	†Scutum	Shield	
CVn	†Canis Venaciti	Hunting Dogs		Ser	Serpens Caput	Serpent	
Cyg	**Cygnus	Swan	Northern Cross, CygX-1 may be "Black Hole"	Ser	Serpens Cauda	Serpent	
Del	**Delphinus	Dolphin		Sex	†Sextans	Sextant	
Dor	†Dorado	Goldfish		Sge	Sagitta	Arrow	
Dra	Draco	Dragon		Sgr	***Sagittarius	Archer	Tea Pot, Center of our galaxy (Milky Way)
Equ	Equuleus	Little Horse		Tau	*Taurus	Bull	Crab Nebula (M1) w/pulsar is remnant of 1054 A.D. supernova, Hyades and Pleiades Clusters
Eri	Eridanus	River		Tel	†Telescopium	Telescope	
For	†Fornax	Furnace		TrA	**†Triangulum Australe	Southern Triangle	
Gem	***Gemini	Twins		Tri	Triangulum	Triangle	
Gru	†Grus	Crane		Tuc	†Tucana	Toucan	
Her	**Hercules	Hercules	Great Cluster (M13)	UMa	**Ursa Major	Big Bear	Big Dipper, Exploding galaxy (M82)
Hor	†Horologium	Clock		UMi	**Ursa Minor	Little Bear	Little Dipper, Polaris
Hya	Hydra	Sea Serpent		Vel	†Vela	Sail	
Hys	**†Hydrus	Water Monster		Vir	*Virgo	Virgin	
Ind	†Indus	Indian		Voi	†Volans	Flying Fish	
				Vul	†Vulpecula	Little Fox	

SPECIAL ASTRONOMICAL EVENTS

Total Solar Eclipse

(WARNING — Never look directly at the SUN, even during a total eclipse)

Year	Date	Duration (Min)	Location
1984	Nov. 22	2.1	Indonesia, S. America, Pacific Ocean
1987	Mar. 29	0.3	Equatorial Africa, Atlantic Ocean
1988	Mar. 18	4.0	Philippines, Indonesia, Indian and Pacific Oceans
1990	July 22	2.6	Finland, North Atlantic
1991	July 11	7.1	Hawaii, Brazil, Central America, Pacific Ocean
1992	June 30	5.4	South Atlantic
1994	Nov. 3	4.6	S. America, Pacific Ocean

Year	Date	Duration (Min)	Location
1995	Oct. 24	2.4	S. Asia, Pacific and Indian Oceans
1997	Mar. 9	2.8	Siberia, Arctic
1998	Feb. 26	4.4	Central America, Pacific and Atlantic Oceans
1999	Aug. 11	2.6	Central and Southern Europe, Central Asia

Transits by Venus

2004 June 8
2012 June 5-6

Transits by Mercury*)

1986 Nov. 13
1993 Nov. 6
1999 Nov. 15

*) Telescope needed

Halley's Comet

Best time of observation, Northern Hemisphere: 1985, Sept.-Dec.
Perihelion: 1986, early February
Best time of observation, Southern Hemisphere: 1986, March-July

CONVERSIONS Distance

$$\text{velocity} = \frac{\text{distance}}{\text{time}}$$

e.g. velocity of light = $\frac{186,282 \text{ miles}}{1 \text{ second}} = \frac{299,793 \text{ km}}{1 \text{ second}}$

$$\text{distance} = \text{velocity} * \text{time}$$

e.g. light second
= $186,282 \text{ miles/sec} * 1 \text{ sec} = 186,282 \text{ miles}$
= $299,793 \text{ km/sec} * 1 \text{ sec} = 299,793 \text{ km}$

e.g. light minute
= $186,282 \text{ miles/sec} * 1 \text{ min} * 60 \text{ sec/min}$
= $11,176,945 \text{ miles}$
= $299,793 \text{ km/sec} * 1 \text{ min} * 60 \text{ sec/min}$
= $17,987,550 \text{ km}$

e.g. light hour
= $186,282 \text{ miles/sec} * 1 \text{ hr} * 60 \text{ min/hr} * 60 \text{ sec/min}$
= $670,616,721 \text{ miles}$
= $299,793 \text{ km/sec} * 1 \text{ hr} * 60 \text{ min/hr} * 60 \text{ sec/min}$
= $1,079,253,000 \text{ km}$

e.g. light year
= $186,000 \text{ miles/sec} * 1 * 365.25 * 24 * 60 * 60$
= $5,878,626,175,000 \text{ miles}$
= $299,793 \text{ km/sec} * 1 * 365.25 * 24 * 60 * 60$
= $9,460,731,798,000 \text{ km}$

Another unit of distance is the parsec. It is defined to be the distance at which the orbit of the earth has an apparent radius of 1 sec. of arc. Since the average radius of the earth's orbit is 149,500,000 km, this enormous distance is:

$$\frac{149,500,000 \text{ km}}{1 \text{ sec} / 3600 \text{ sec/deg} / 180 \text{ deg/pi} \cdot \text{radians}} = 3.083659 * 10^{13} \text{ km} = 3.25943 \text{ light years}$$

One light year is therefore 0.306802 parsecs.

Hours and Degrees

$$\text{Hours} \longleftrightarrow \text{Degrees}$$

$$24 \text{ hrs} = 360 \text{ degrees}$$

Hours → Degrees

e.g. Convert 7 hrs 12 min 27 sec to degrees

$$\begin{aligned} 7 \text{ hrs} * 360 \text{ deg/24 hrs} &= 105.0000 \text{ deg} \\ 12 \text{ min} * 1 \text{ hr/60 min} * 360 \text{ deg/24 hrs} &= 3.0000 \text{ deg} \\ 27 \text{ sec} * 1 \text{ hr/3600 sec} * 360 \text{ deg/24 hrs} &= 0.1125 \text{ deg} \\ &= 108.1125 \text{ deg} \end{aligned}$$

i.e.

$$108.1125 \text{ degrees}$$

Degrees → Hours

e.g. Convert 108.1125 deg to hrs:min:sec

$$\begin{aligned} 108.1125 \text{ deg} * 24 \text{ hr/360 deg} &= 7.2075 \text{ hrs} \\ 0.2075 \text{ hrs} * 60 \text{ min/hr} &= 12.450 \text{ min} \\ 0.450 \text{ min} * 60 \text{ sec/min} &= 27.00 \text{ sec} \end{aligned}$$

or

$$7 \text{ hrs } 12 \text{ min } 27 \text{ sec}$$

GLOSSARY

Asteroid:	A rocky object, smaller than a planet, that orbits the sun.	Chronometer:	Instrument used to keep time with great accuracy.
Astronomy:	The branch of science that studies the universe beyond the Earth's atmosphere.	Circumpolar:	Surrounding or found in the vicinity of the Earth's or the sky's poles.
Autumnal Equinox:	The equinox that takes place around Sept. 23.	Cluster:	Groups of thousands to millions of stars that appear to be close together.
Azimuth:	The position of an object above the Earth. The number of degrees east from due north to the object's vertical circle.	Comet:	A bright heavenly body made up of ice, frozen gases, and dust particles that orbits the sun. It has a long tail that points away from the sun.
Cardinal Directions:	North, south, east, or west.	Configuration:	The arrangement of several things.
Celestial Equator:	An imaginary circle on the celestial sphere directly above the Earth's equator.	Conjunction:	The apparent meeting or passing of two or more celestial bodies in the same degree of the zodiac.
Celestial Pole:	Either of the two imaginary points on the celestial sphere directly above the Earth's North and South Poles.	Constellation:	A group of stars forming a pattern that suggests an object, animal, or mythological character. The constellations divide the sky into 88 areas.
Celestial Sphere:	An imaginary sphere surrounding the Earth and representing the entire sky. The stars, planets, and other heavenly bodies appear to be located on the surface of the celestial sphere.	Declination:	The angular distance of a celestial body north or south of the celestial equator.
Chronologist:	A person who studies time and records human history. Orders the time and place of events in the order in which they occurred.	Double Star:	Two stars that appear as one because they are nearly in line with each other, or are close together.

Eclipse:	Total or partial blocking of light from a celestial body caused by its passing into the shadow of another body. Also the hiding of on a celestial body by another.	Horizon:	The line where the sky and the Earth, or sea, meet.
Ecliptic:	The circular path that the sun seems to travel in a year around the sky.	Latitude:	The angular distance north or south of the equator. All points of a given latitude form a circle running east and west. These circles are parallel to the equator.
Elevation:	The angular distance of a celestial body above the horizon.	Light Year:	The distance travelled by light in one solar year. About 5,880,000,000,000 miles.
Equatorial Sky Orientation Map:	Mercator projection of the celestial sphere.	Longitude:	The angular distance east or west of the prime meridian. All points of a given longitude form a circle running north and south through the North and South Poles.
Equinox:	Either of the two times a year when day and night are of equal length all over the Earth. During these two times, the sun is directly above the equator.	Lunar Eclipse:	A partial or total darkening of the moon when the Earth moves between the moon and the sun.
Extraterrestrial:	Originating or existing outside the Earth or its atmosphere.	Mathematician:	An expert in mathematics.
Galaxy:	Any of the huge grouping of stars, dust, and gases scattered throughout the universe. Billions of stars held together by gravitational attraction.	Meridian:	Imaginary great circles on the Earth's surface passing through the North and South Poles. Also known as longitude.
Greenwich Mean Time:	The time at the prime meridian in Greenwich, England. Used as the prime basis of standard time by which the time zones of the world are established.	Messier Number:	Charles Messier was a French astronomer and comet hunter who prepared the first catalog of non-stellar sky objects. He assigned a number to these objects as he encountered them in his comet hunting.

Meteor:	The streak of light caused by a meteoroid that passes through Earth's atmosphere. The burning meteoroid is often called a "shooting star."	Planet:	A rotating body held in orbit by the gravitational attraction of a star. A planet is not self-luminous; it reflects starlight. Its own gravity pulls the planet into its most stable shape, a slightly flattened sphere.
Meteorite:	A meteoroid that survives passage through the Earth's atmosphere and arrives on the Earth's surface without completely burning up.	Planetary Occultations:	The hiding of a star or one planet by another planet.
Meteoroid:	A solid body, smaller than an asteroid, that orbits the sun. Both meteors and meteorites were meteoroids.	Planetary Transit:	The passage of a planet directly between the earth and the sun so that it can be seen as a black dot moving across the disk of the sun.
Millennial:	Of or relating to a thousand years.	Precession:	A slow change in the direction of the tilt of the Earth's axis. This results in an apparent change in the position of the stars. Precession is a wobble in the rotation of the Earth, like a top when it slows down.
Moon:	A natural satellite orbiting a planet.	Prime Meridian:	0° longitude which runs through Greenwich, England. The point from which longitude east and west is measured.
Nebula:	A bright, cloudlike mass composed of stars, or dust, and gases. Visible in the night sky.	Pulsars:	A neutron star that rotates rapidly and emits a beam of radiation. Any number of astronomical objects that send out intense pulses of radiation at short, regular intervals.
Opposition:	A position that is opposite to another.		
Orbital (positions):	Of or relating to the path of a heavenly body as it revolves in a closed curve around another body.		
Parallel:	Going in the same direction and always being the same distance apart at every point, so as never to meet.		
Phases:	The varying shape of the lighted position of a planet or moon, such as full, half, crescent, etc.		

Refraction:	The change in the apparent position of a celestial body due to the bending of the light rays which come from the celestial body.	Solar Year:	The time interval between one vernal equinox and the next. 365 days, 5 hours, 48 minutes, and 46 seconds.
Right Ascension:	The east/west coordinate by which the position of a celestial body is measured.	Stellar:	Resembling a star or stars.
Rotation:	The act or process of turning around an axis. The rotation of the Earth takes 24 hours.	Synchronize:	To happen at the same time.
Sextant:	An instrument for determining the angle between the horizon and a celestial body. Used in navigation of ships and planes to determine latitude.	Trajectory:	The path followed by a meteor, or the like, moving through space.
Slew:	To turn about a fixed point.	Universe:	All that exists including the Earth, heavens, and all of space. The entire physical world.
Solar Day:	The time interval between 2 successive transits by the sun of the meridian directly opposite that of the observer. The 24 hour interval from one midnight to the following.	Vernal Equinox:	The equinox that takes place around March 21.
Solar Eclipse:	The partial or total blocking of the sun's light by the moon as it passes between the sun and the Earth.	Zenith:	The point in the heavens directly above the place where a person stands.
		Zodiac:	An imaginary belt in the heavens approximately 18° wide that the sun, the moon, and all the planets except Pluto appear to follow. The zodiac is divided into 12 parts, called signs, with each part named after a constellation.

SUPPLEMENTARY READING

Books & Articles

Code: E = Elementary
 P = Popular
 A = Advanced
 * = Multi-Authored
 Anon = Anonymous Author

CODE

Astronautics/Xtraterr. Life

Navigation

History/Archaeology

Chronology/Calendars

Astronomy/Deep Sky Objects

Astronomy/General

Astronomy/Star Finding

Geography

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CODE

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Navigation

History/Archaeology

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Astronomy/Deep Sky Objects

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Astronomy/Star Finding

Geography

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Breed, Joseph B. III, <i>Stars for the Space Age</i> , New York, World Publishing/Times Mirror, 1971.	✓								P
Calder, Nigel, <i>The Comet is Coming</i> , New York, Viking Press, 1980.			✓						P
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							✓		P
		✓							A
					✓	✓			P
		✓							P
✓						✓			P
✓					✓	✓			A
								✓	P
					✓				A
					✓	✓			A
			✓		✓	✓			A
							✓		P
			✓						P
	✓								P

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"Astronomy," Astro Media Corporation, Milwaukee, Wisconsin.

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"Scientific American," Scientific American, New York, N.Y.

"Sky and Telescope," Sky Publishing Corporation, Harvard College Observatory, Cambridge, Massachusetts.

COMMAND KEY TABLE

	MAP	SET	SKY	CHART
f1:MODE Select Program Modes	Select location on Earth, Input latitude and longitude.	Select the Date and the time of observation. Select calendar.	Display sky in any direction.	Display sky as a north-is-up astronomical star map.
f3: OPTION Select Sky Display Options	None	None	Cycles through available options. SHIFT f3 turns option on or off. Available: LINES, NAMES, SYMBOLS, DEEP-SKY, TRACK, SOUND. Active in both SKY and CHART.	
f5: FIND Find Major Sky Objects	None	None	Cycles through objects which can be located and brought to the center of the screen: MOON, SUN, individual PLANETS, Halley's COMET, and all CONSTELLATIONS. Active in both SKY and CHART.	
f7: INFORM Identify All Visible Sky Objects	None	None	Identifies all displayed objects with names and catalog numbers. Brief data on distance, size, and object classification.*) Active in both SKY and CHART.	
Up/Down Cursor Control Key	Moves cursor north or south on MAP.*) Displays latitude of cursor position.	Increases/decreases number under reverse field cursor for change of date in data window.	Moves cursor up or down.* Displays coordinates. Slews field when cursor hits edge.	Moves cursor up or down. Displays coordinates. No slewing.
Left/Right Cursor Control Key	Moves cursor east or west on MAP.*) Displays longitude of cursor position.	Advances cursor through month, day, year, hour, and AM & PM positions in data window.	Moves cursor left or right.* Displays coordinates. Slews field when cursor hits edge.	Moves cursor left or right. Displays coordinates. No slewing.
+/- Control Keys	None	Increases/decreases number under reverse field cursor in data window for data changes.	Changes RATE of automatic clock. 0x is stopped clock. Available: 64x, 32x, 16x, 8x, 4x, 2x, 1x, 0x, -1x, -2x, -4x, -16x, -32x, or -64x. Active in both SKY and CHART.	
SHIFT +/- Control Keys	None	None	Changes the VIEWing angle of A Window to Our Galaxy. Available viewing fields: 72, 36, 18, and 9 degrees. Active in both SKY and CHART.	
N, E, W, S Keys	None	None	Points the field of view to north, south, east, or west. Active in both SKY and CHART.	
O (not zero)	None	None	Points the field of view exactly opposite to the current direction. Active in both SKY and CHART.	
SHIFT P	Prints current video display if printer connected. Active in All Modes.			

*)Alternative joystick operation.

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