Stellarium User Guide

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Chapter 1

Introduction

Stellarium is a software project that allows people to use their home computer as a virtual planetarium. It will calculate the positions of the Sun and Moon, planets and stars, and draw how the sky would look to an observer depending on their location and the time. It can also draw the constellations and simulate astronomical phenomena such as meteor showers, and solar or lunar eclipses.

Stellarium may be used as an educational tool for teaching about the night sky, as an observational aide for amateur astronomers wishing to plan a night's observing, or simply as a curiosity (it's fun!). Because of the high quality of the graphics that Stellarium produces, it is used in some real planetarium projector products. Some amateur astronomy groups use it to create sky maps for describing regions of the sky in articles for newsletters and magazines.

Stellarium is under fairly rapid development, and by the time you read this guide, a newer version may have been released with even more features that those documented here. Check for updates to Stellarium at the Stellarium webite.

If you have questions and/or comments about this guide, please email the author. For comments about Stellarium itself, visit the Stellarium forums.

Chapter 2

Installation

2.1 System Requirements

- Linux/Unix, Windows 95/98/2000/NT/XP or MacOS X 10.3.x or greater.
- A 3D graphics card with a support for OpenGL. At least a Voodoo3 or a TNT2 is recommended for smooth animation.
- A dark room for realistic rendering - details like the Milky Way or star twinkling can't be seen in a bright room.

2.2 Downloading

You should visit the download page on the Stellarium website. Choose the correct package for your operating system.

2.3 Installation

2.3.1 Windows

1. Double click on the `stellarium-0.7.1.exe` file to run the installer.
2. Following on-screen instructions.

2.3.2 MacOS X

1. Locate the `stellarium-0.7.1.dmg` file in finder and double click on it, or open it using the *disk copy* program.
2. Have a browse of the `readme` file, and drag `Stellarium` to the `Applications` folder (or somewhere else if you prefer).

2.3.3 Linux

Check if your distribution has a package for Stellarium already - if so you're probably best off using it. If not, you can download and build the source. Don't worry - it uses `automake` and `autoconf`, so it's nice and easy. If you're doing it the manual way, dependencies are:

- Some OpenGL implementation, e.g. nvidia GLX

- SDL
- Zlib
- libpng
- SDL-mixer (optional - for audio support)

2.4 Running Stellarium

Windows The Stellarium installer should have put an item in the start menu and/or on your desktop. Select it to run the program.

MacOS X Double click on Stellarium (wherever you put it).

Linux If your distribution had a package you'll probably already have an item in the Gnome or KDE application menus. If not, just use a open a terminal and type `stellarium`.

Chapter 3

Interface Guide

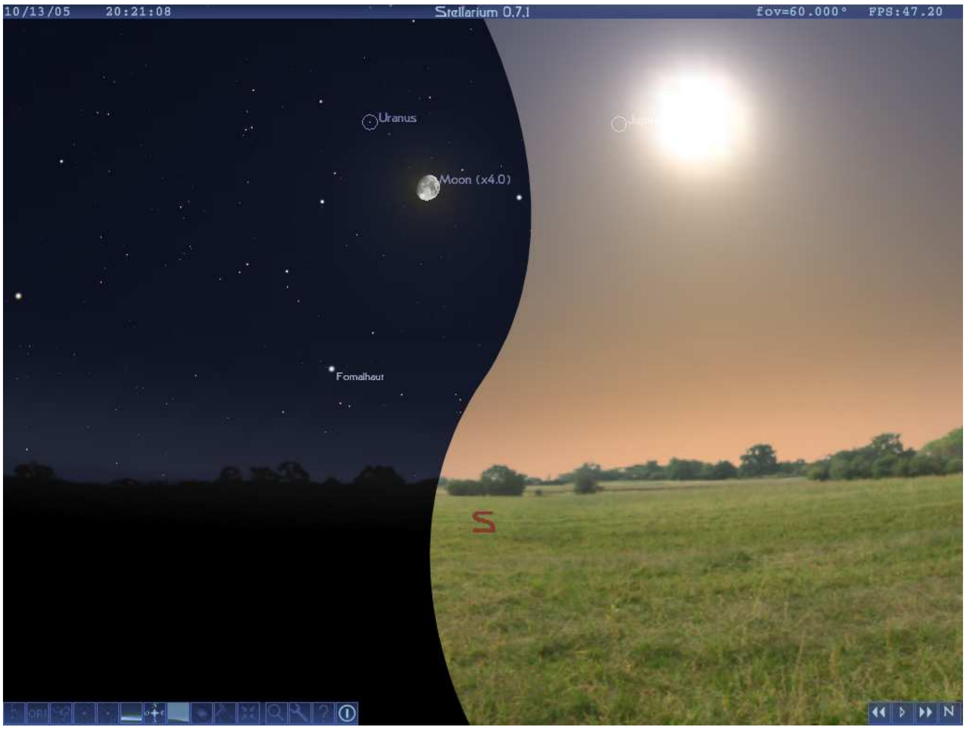

Figure 3.1: A composite screenshot showing Stellarium in both night time (left) and day time (right)

3.1 Tour

After you run Stellarium for the first time, you will see a something like one of the sides of the image shown in Figure 3.1 (depending on the time of day that you start the program).

At the top of the screen you will see: the date, the time, Stellarium's version number, the field of view (fov) and the current frame-rate (FPS). In the bottom-left corner of the screen is the main tool-bar. In the bottom-right corner of the screen is the time tool-bar!. The rest of the screen is a graphical representation of the sky and the ground.

3.1.1 Time Travel

When Stellarium starts up, it sets it's clock to the same time and date as the system clock. However, Stellarium's clock is not fixed to same time and date as the system clock, or indeed to the same speed. We may tell Stellarium to change how fast time should pass, and even make time go backwards! So the first thing we shall do is to travel into the future! Let's take a look at the time tool-bar (table 3.2). If you hover the mouse cursor over the buttons, a short description of the button's purpose and keyboard shortcut will appear.

Button	*Shortcut key*	*Description*
	j	Decrease the rate at which time passes
	k	Make time pass as normal
	l	Increase the rate at which time passes
	8	Return to the current time & date

Table 3.2: Time control tool-bar buttons

OK, so lets go see the future! Click the mouse once on the increase time speed button . Not a whole lot seems to happen. However, take a look at the clock at the top-left of the screen. You should see the time going by faster than a normal clock! Click the button a second time. Now the time is going by faster than before. If it's night time, you might also notice that the stars have started to move slightly across the sky. If it's daytime you might be able to see the sun moving (but it's less visible than the movement of the stars). Increase the rate at which time passes again by clicking on the button a third time. Now time is really flying!

Let time move on at this fast speed for a little while. Notice how the stars move across the sky. If you wait a little while, you'll see the Sun rising and setting. It's a bit like one of those time-lapse movies except there are no clouds. Stellarium not only allows for moving forward through time - you can go backwards too!

Click on the real time speed button . The stars and/or the Sun should stop scooting across the sky. Now press the decrease time speed button  once. Look at the clock. Time has stopped. Click the Decrease time speed button four more times. Now we're falling back through time at quite a rate (about one day every ten seconds!).

Enough time travel for now. Wait until it's night time, and then click the Real time speed button. With a little luck you will now be looking at the night sky.

3.1.2 Moving Around the Sky

Key	*Description*
Cursor keys	Pan the view left, right, up and down
Page up / Page down	Zoom in and out
Backslash (\)	Auto-zoom out to original field of view and viewing direction
Left mouse button	Select an object in the sky
Space	Centre view on selected object
Forward-slash (/)	Auto-zoom in to selected object

Table 3.4: Controls to do with movement

As well as travelling through time, Stellarium lets to look around the sky freely, and zoom in and out. There are several ways to accomplish this listed in table 3.4.

Let's try it. Use the cursors to move around left, right, up and down. Zoom in a little using the Page Up key, and back out again using the Page Down. Press the backslash key and see how Stellarium returns to the original field of view (how "zoomed in" the view is), and direction of view.

It's also possible to move around using the mouse. If you left-click and drag somewhere on the sky, you can pull the view around.

Another method of moving is to select some object in the sky (left-click on the object), and press the Space key to centre the view on that object. Similarly, selecting an object and pressing the forward-slash key will centre on the object and zoom right in on it.

The forward-slash and backslash keys auto-zoom in an out to different levels depending on what is selected. If the object selected is a planet or moon in a *sub-system* with a lot of moons (e.g. Jupiter), the initial zoom in will go to an intermediate level where the whole sub-system should be visible. A second zoom will go to the full zoom level on the selected object. Similarly, if you are fully zoomed in on a moon of Jupiter, the first auto-zoom out will go to the sub-system zoom level. Subsequent auto-zoom out will fully zoom out and return the initial direction of view. For objects that are not part of a sub-system, the initial auto-zoom in will zoom right in on the selected object (the exact field of view depending on the size/type of the selected object), and the initial auto-zoom out will return to the initial FOV and direction of view.

3.1.3 Main Tool-bar

Figure 3.2: Screenshot showing off some of Stellarium's visual effects

Stellarium can do a whole lot more than just draw the stars. Figure 3.2 shows some of Stellarium's visual effects including constellation line drawing, constellation art, planet hint, and atmospheric fogging around the bright Moon. The controls main tool-bar provides a mechanism for turning on and off the visual effects. Table 3.6 describes the operations of buttons on the main tool-bar, and gives their keyboard shortcuts.

Feature	*Tool-bar button*	*Key*	*Description*
Constellations		c	Draws the constellation lines
Constellation Names		v	Draws the name of the constellations
Constellation Art		r	Superimposes artistic representations of the constellations over the stars
Azimuth Grid		z	Draws grid lines for the Alt/Azi coordinate system
Equatorial Grid		e	Draws grid lines for the RA/Dec coordinate system
Toggle Ground		g	Toggles drawing of the ground. Turn this off to see objects that are below the horizon
Toggle Cardinal Points		q	Toggles marking of the North, South, East and West points on the horizon
Toggle Atmosphere		a	Toggles atmospheric effects. Most notably makes the stars visible in the daytime
Nebulae & Galaxies		n	Toggles marking the positions of Nebulae and Galaxies when the FOV is too wide to see them
Coordinate System		Enter	Toggles between Alt/Azi & RA/Dec coordinate systems
Goto		Space	Centres the view on the selected object
Search		CTRL+f	Toggle the display of the object search window
Configuration		1 (digit one)	Toggle the display of the configuration window
Help		h	Toggle the display of the help window
Off		CTRL+q	Close Stellarium

Table 3.6: Main tool-bar buttons

3.1.4 The Object Search Window

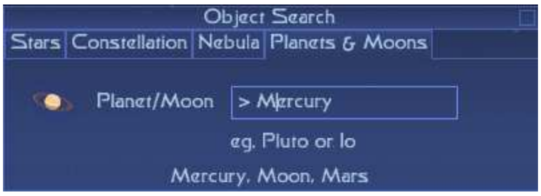

Figure 3.3: The search window

The Object Search window provides a convenient way to locate objects in the sky. There are four tabs, each tab allows you to search for different types of object:

Stars Stars may be searched either by name (for the brighter stars) or by their number in the Hipparcos star catalogue. For example, you might search for "Altair" or 97649.

Constellation Constellations may be searched for by name, for example "Orion" .

Nebula Nebulae may be searched using the Messier catalogue number, e.g. "M31" would search for the Andromeda galaxy.

Planets & Moons This category may be used to locate the major planets (Mercury, Venus, ... Pluto) and their satellites, Earth's Moon and the Sun.

3.1.5 Help Window

Figure 3.4: The help window

The Help window is useful as a quite reference to the key-strokes that may be used to control various aspects of Stellarium. Note that the window doesn't mention all the keys at this time. See table 3.10 in section 3.1.8 for a complete list of key-bindings.

3.1.6 Information Window

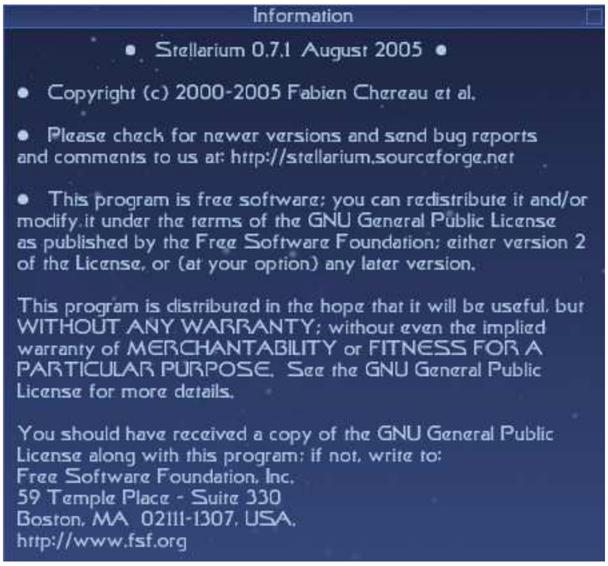

Figure 3.5: The information window

Pressing the 'i' key on the keyboard toggles the display of the information window. This displays the version number of Stellarium and some information about the project.

3.1.7 The Text Menu

As well as the regular key-bindings and the tool-bars, Stellarium has another method for interaction with the user - the Text Menu, or Text User Interface (TUI). The TUI is activated using the 'm' key, and is navigated using the cursor keys. Table 3.8 shows the commands that are available from the TUI menu.

Many of the options in the TUI menu are duplicated elsewhere in the interface. For example, the ability to set the maximum star magnitude to label is also accessible via the configuration window (see section 4.4).

3.1.8 Other Keyboard Commands

As mentioned in section 3.1.5, not all keys are documented in the Help window. Some features of Stellarium are only available via the keyboard, and are not easy to discover! Table 3.10 is a complete listing of key-bindings.

1	Set Location
1.1	Latitude
1.2	Longitude
1.3	Altitude (m)
2	Set Time
2.1	Sky Time
2.2	Set Time Zone
2.3	Preset Sky Time
2.4	Sky Time At Start-up
2.5	Time Display Format
2.6	Date Display Format
3	General
3.1	Sky Culture
3.2	Sky Language
4	Stars
4.1	Show
4.2	Star Magnitude Multiplier
4.3	Maximum Magnitude to Label
4.4	Twinkling
5	Effects
5.1	Landscape
5.2	Manual zoom
5.3	Object Sizing Rule
5.4	Magnitude Sizing Multiplier
5.5	Milky Way intensity
5.6	Zoom Duration
6	Scripts
6.1	Local Script
6.2	CD/DVD Script
7	Administration
7.1	Load Default Configuration
7.2	Save Current Configuration as Default
7.3	Update me via Internet
7.3	Set Locate
7.4	N-S Centering Offset
7.5	E-W Centering Offset

Table 3.8: Text user interface menu

Category	*Key*	*Description*
Movement & object selection	Page up/down	Zoom in/out
	CTRL+up/down cursors	Zoom in/out
	Mouse wheel	Zoom in/out
	Left mouse button	Select object
	Right mouse button	De-select object
	Backslash (\)	Auto-zoom out
	Forward-slash (/)	Auto-zoom in on selected object
	Space	Centre on selected object
Display Options	Enter	Swap between equatorial and azimuthal mount
	F1	Toggle full-screen mode (not available on some architectures)
	c	Toggle drawing of constellations
	v	Toggle drawing of constellation names
	r	Toggle drawing of constellation art
	e	Toggle drawing of RA/Dec grid
	z	Toggle drawing of Alt/Azi grid
	p	Cycle through: no planet labels; planet labels; planet labels with orbits
	g	Toggle drawing of ground
	a	Toggle drawing of atmosphere
	f	Toggle drawing of horizon fog
	q	Toggle drawing of cardinal points (N, S, E, W)
	o	Toggle moon scaling (4x /1x)
	t	Toggle object tracking (moves the view to keep selected object in the centre)
	s	Toggle drawing of stars
	4 or ,	Toggle drawing of ecliptic line
	5 or .	Toggle drawing of equator line
Windows & other controls	CTRL+s	Take a screenshot (will be written to stellarium*.bmp)
	CTRL+r	Toggle script recording
	CTRL+f	Toggle search window
	h	Toggle help window
	i	Toggle information window
	1 (digit one)	Toggle con↓guration window
	m	Toggle text menu
Time & Date	6	Time rate pause (or script pause when a script is running)
	7	Set time rate to zero (time stands still)
	8	Set time to current time
	j	Decrease time rate (or decrease script speed if a script is running)
	k	Set time rate to normal (1 second per second)
	l	Increase time rate (or increase script speed if a script is running)
	-	Move back in time 24 hours
	=	Move forward in time 24 hours
	[	Move back in time 7 days
	]	Move forward in time 7 days
Other	CTRL+c	Stop a running script
	CTRL+q	Quit Stellarium. (command+Q on the Mac)
	9	Cycle through meteor shower rates: low; medium; high; very high

Table 3.10: Key bindings (full list)

Chapter 4

Configuration

Most of Stellarium's configuration is done using the configuration window. To open the configuration window, click the  button on the main tool-bar. You can also press the '1' key (digit one) to open the configuration window. The window has several tabs for configuring various aspects of the program.

In addition to the configuration window, some operations may also be performed using the text menu (see section 3.1.7).

Some options may only be configured by editing the configuration file. See section 5.3 for more details.

4.1 Setting the Date and Time

The first tab in the configuration window is "Date & Time" (figure 4.1). In this tab you will see controls for adjusting the year, month, day, hour, minute and second.

There is also a display of the current time zone setting, and time rate. The time zone setting may be set using the TUI (see section 3.1.7 for more information).

4.2 Setting Your Location

The positions of the stars in the sky is dependent on your location on Earth as well as the time and date. For Stellarium to show accurately what is (or will be/was) in the sky, you must tell it where you are. You only need to do this once - Stellarium saves your location so you won't need to set it again until you move.

To set your location, choose the "Location" tab in the configuration window (figure 4.2). There are then two methods[1] that you may use to select your location:

1. You can set your location by where you live on the map. This is convenient, but it isn't very precise.

2. If you know your longitude and latitude[2], you might want to can set it using the controls at the bottom of the window.

Once you're happy that the location is set correctly, click on the "Save Location" button, and close the configuration window.

[1] Actually there are three methods, you can also edit the configuration file. This is useful if you want to be more precise than is possible with the existing user interface. See section 5.3.1 for more details.

[2] If you don't know your longitude and latitude, you may find this site helpful.

Figure 4.1: Configuration window, date & time tab

Figure 4.2: Configuration window, location tab

Figure 4.3: Configuration window, rendering tab

4.3 Setting the Landscape Graphics

Stellarium has several horizon graphics or "skins". These may be changed by choosing the options under the Landscapes tab in the configuration window.

4.4 Video Mode Settings

The Video tab in the configuration window offers the following setting options:

Fisheye projection mode When this check box is selected Stellarium draws the sky using *angular fish-eye projection*. When the check box is not selected Stellarium uses OpenGL's *perspective projection* to draw the sky. The difference is most obvious when the field of view is wide (i.e. zoomed a long way out). In angular fish-eye projection, straight lines become curves when they appear a large angular distance from the centre of the field of view (like the distortions seen with very wide angle camera lenses).

Disk viewport This check-box, when selected, adds a black circular border around the main view. Using the zoom functions to set the field of view, it's possible to simulate looking through binoculars or a telescope eyepiece - useful if you want to know how much of a constellation you can see at once with a given instrument.

Display resolution You may select what resolution Stellarium runs in using this control. Choose the highest resolution you can, but be aware that the higher the resolution, the slower Stellarium will react. If moving from one object to another isn't a smooth process, try a lower resolution.

4.5 Rendering Options

The Rendering tab (figure 4.3) in the configuration window allows for adjustment of the way Stellarium draws the scene. All the controls are check boxes or numerical spin-buttons. By choosing values and then clicking the button labelled 'Set as default', the user can select what options will be set when the program is started in future. Table 4.2 shows a list of these options and describes what they do.

Control Name	*Action when selected*
Stars	Turns on the drawing of the stars. The drawing of the Sun is not affected
Stars Names Up to mag	Turns on the labelling of named stars. There is a spin box next to this option which controls the brightest magnitude of the stars that are labelled (remember, the lower the number, the brighter the star!)
Star Twinkle Amount	Turns on star twinkles. There is a spin box for setting the amount of twinkle
Constellations	Turns on the drawing of the lines between stars that help to visualise the constellations
Constellations Names	Turns on name labels near the centre of each constellation
Nebulas Names. Up to mag	Turns on the drawing of nebulae and galaxies. A limit may be set as to the magnitude of the objects which will be shown
Planets	Turns on drawing of the planets (Mercury, Venus etc.)
Moon Scale	Magnifies the size of the moon by 4x. People perceive the Moon to have a larger angular size than it actually does. This feature compensates for this illusion (which doesn't apply so much to computer screens as it does in the sky!)
Planets Hints	Draws a small circle around the planets, and labels them with the appropriate name
Equatorial Grid	Draws grid lines for the RA/Dec coordinate system (see section E.2.2)
Equator Line	Draws the celestial equator line
Azimuthal Grid	Draws grid lines for the Altitude/Azimuth coordinate system (see section E.2.1)
Ecliptic Line	Draws the ecliptic line
Ground	Draws the ground. If this option is de-selected, the ground becomes transparent. Note that the daylight effects go a bit weird if you do this, so it's usually a good idea to turn of atmosphere if you turn off ground. It might also be helpful to use the equatorial coordinate system when the ground is turned off
Cardinal Points	Draws markers for North, South, East and West on the horizon
Atmosphere	Draws atmospheric effects. This means the sky brightens when the sun is above the horizon, and that there is a haze around the moon
Fog	Draws a slight fog near to the horizon

Table 4.2: Display options in the configuration window rendering tab

Chapter 5

Advanced Use

5.1 Files and Directories

Stellarium comes with several data and image files. These hold information such as the positions and details of stars, texture files for fonts, landscapes and the Messier objects. These files are gathered into a few sub-directories of a directory called the *config root directory.* The precise location of the config root directory will vary depending on the operating system and installation options that were used:

Windows The config folder is a sub folder of the main Stellarium folder.

MacOS X The config root directory is the Contents/Resources directory inside the Stellarium application bundle.

Linux The config root directory is <prefix>/share/stellarium, where <prefix> is the installation prefix that was chosen when Stellarium was built. This is generally /usr or /usr/local.

5.2 Scripting

Stellarium has the ability to record and play back sequences of commands in much the same way some applications allow the recording and executing of macros.

Using this mechanism it is possible to create presentations of astronomical events using Stellarium. Two scripts come with Stellarium that explore lunar eclipses. More are likely to be included in future versions[1].

At time of writing, this feature is still being developed, and some important components are not yet implemented. Nonetheless, it is still possible (with a little fiddling) to make some useful and visually appealing scripts.

5.2.1 Running Scripts

1. Copy the script file to the <config root>/data/scripts directory.
2. If Stellarium is running, re-start it (there is a bug in version 0.7.1 that means the file names in this directory are only read at start-up).
3. Press the M key to open the text menu. Use the cursor keys to select option 6.1 (local scripts). Press return and the "select and exit to run" text will be highlighted.

[1] A script for seeing a total solar eclipse can be found here. Also search the forums - people often post their latest script creations there.

4. Use the up and down cursors to select your script. Press return and then exit the text menu with ”M” and the script will start to execute.

Note that while scripts are running, some key bindings are altered. Specifically, the time-rate keys J, K and L alter the rate at which the script progresses, and may press control-C to stop the script and result normal operation.

5.2.2 Recording Scripts

Pressing CTRL+r will start and stop script recording. On Linux systems and the Mac script files are created in the user's home directory with the name `stellarium*.sts`, where the `*` is a number. On Windows systems the file is placed in the `My Documents` folder.

5.2.3 Editing Scripts

Manually editing a script file may be done using a simple text editor. To get yourself started, record a quick script - go to a few objects using find and clicking on them, zoom in and out using auto-zoom and see what this generates in the script file. For a complete list of scripting commands see appendix B.

5.2.4 Example script

This example script shows the occultation of Jupiter by the Moon in 2004. Note that the atmosphere and ground rendering is turned off so that they are not in the way if the location of the observer is set such that the event is not in the night time and/or above the horizon. This is a useful technique for scripting to avoid the need to set the location.

```
clear
flag atmosphere off
flag ground off
wait duration 2
date local 2004:12:7T8:39:32
select planet Jupiter pointer off
flag track_object on
zoom fov 0.5
wait duration 2
timerate rate 30
script action end
```

5.2.5 Scripting Hints and Tips

- When writing scripts, it's useful to use the script bar.
- Explicitly set all the display options at the start of each script - you can't guaranteed what state the user's application will have.
- Explicitly set the location and date/time.
- The `clear` command is a useful starting point from which to set the display flags.

5.3 The Main Configuration File

The main configuration file is read each time Stellarium starts up, and settings such as the observer's location and display preferences are taken from it. Ideally this mechanism should be totally transparent to the user - anything that is configurable should be configured "in" the program. However, at time of writing Stellarium isn't quite complete in this respect. Some settings can only be changed by directly editing the configuration file. This section describes some of the settings a user may wish to modify in this way, and how to do it.

If the configuration file does not exist when Stellarium is run (e.g. the first time the user starts the program), one will be created with default values for all settings.

The location of the configuration file varies depending on the OS you're running Stellarium on:

Windows The configuration file, `config.ini`, is in the `config` sub-directory of the main `Stellarium` directory (which one?).

Linux The configuration file is located in the user's home directory, in a sub-directory called `.stellarium` with the filename `config.ini`.

MacOS X The configuration file is located in the `Library/Preferences` sub-directory of the user's home directory. The file name is `Stellarium.ini`.

The configuration file is a regular text file, so all you need to edit it is a text editor like Notepad on Windows, Text Edit on the Mac, or nano or vi on Linux.

The following sub-sections contain details on how to make commonly used modifications to the configuration file. A complete list of configuration file values may be found in appendix A.

5.3.1 Setting Your Location Precisely

The user interface for setting the observer's longitude and latitude isn't very precise. For users with a penchant for accuracy, satisfaction may be achieved by editing the values in the configuration file like this:

```
[init_location]
name = Widdringon
latitude = +55 14'30.00\"
longitude = -01 37'6.00\"
altitude = 53
```

The values for longitude and latitude are positive for North and East, negative for South and West. The format of the number is in degrees minutes and seconds. The value for the altitude is in meters.

5.3.2 Setting the Display Resolution

If your screen resolution is not listed in the video tab of the configuration window, you may edit the configuration file to select it. It is also possible to specify how Stellarium should start - in windowed or full-screen mode:

```
[video] fullscreen = true
screen_w = 1680
screen_h = 1050
```

5.3.3 Enabling the Script Bar

Individual script commands may be entered and executed interactively using a feature called the *script bar*. This feature is not enabled be default, but you can enable it by altering the configuration file:

```
[gui]
flag_show_script_bar = true
```

The script bar appears in the main tool-bar as a long button containing a `>` prompt. Clicking on it with the mouse will give it focus - it will grab keyboard input. After typing a command (e.g. *select planet Mercury*) pressing Enter will execute it. You may also use the up and down cursor keys to navigate through previously executed commands.

5.4 Customising Landscapes

It is possible to create your own landscapes for Stellaium. There are two methods one may use to achieve this:

Single Image Method Using a spherical fish-eye panorama image.

Multiple Image Method Using a series of images split from a 360° "strip" panorama image + a ground image.

For both methods, the difficult part is preparing the image(s). Once this is done, the `<config root>/data/landscapes.ini` file must be modified. The single image method requires less manipulation of `landscapes.ini` than the multiple image method, but may be less memory efficient.

5.4.1 Single Image Method

The *Trees* landscape that is provided with Stellarium is an example of the single image method, and provides a good illustration. The centre of the image is the spot directly above the observer (the zenith). The point below the observer (the nadir) becomes a circle that just touches the edges of the image. The remaining areas of the image (the rounded corners) are not used.

The image file should be saved in PNG format, with an alpha translapency layer. Wherever the image is translapent, that is where Stellarium will render the sky. The image should be saved in the `<config root>/textures/landscapes` directory.

Each single image landscape must have a section in the `<config root>/data/landscapes.ini` file. For example, the Trees landscape which comes with Stellarium is represented by this section:

```
[trees]
name = Trees
type = fisheye
maptex = landscapes/trees_512.png
texturefov = 210
```

Where:

name is what appears in the landscape tab of the configuration dialog.

type identifies the method used for this landscape. Use "fisheye" for the single image method.

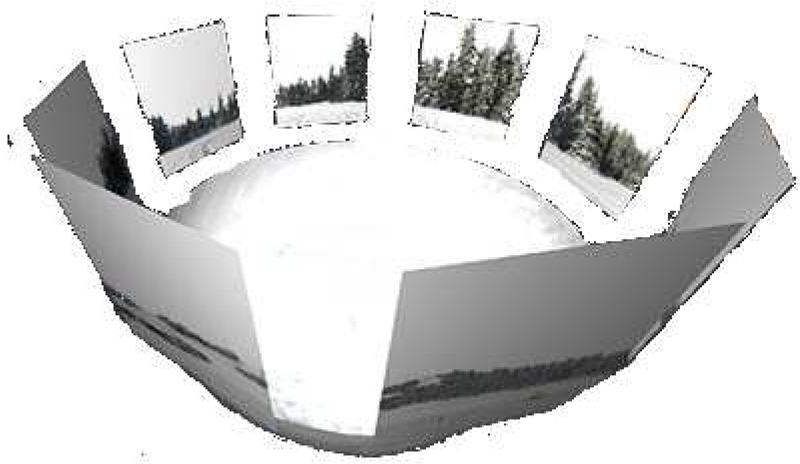

Figure 5.1: Multiple Image Method of making landscapes.

maptex is the path of the image file for this landsape from the `config root` directory.

texturefov is the field of view that the image covers in degrees.

5.4.2 Multiple Image Method

The multiple image method works by having a 360 panorama of the horizon split into a number of smaller "side textures", and a separate "ground texture". This has the advantage over the single image method that the detail level of the horizon can be increased further without ending up with a single very large image file. The ground texture can be a lower resolution than the parorama images. Memory usage may be more efficient because there are no unused texture parts like the corners of the texture file in the single image method.

On the negative side, it is more difficult to create this texture - merging the gound texture with the side textures can prove tricky. The modification of the `<config root>/data/landscapes.ini` file is also somewhat more complicated. Here's an example of the section from `landscape.ini` which describes the Guereins landscape:

```
[Guereins]
name = Guereins
type = old_style
nbsidetex = 8
tex0 = landscapes/guereins4
tex1 = landscapes/guereins5
tex2 = landscapes/guereins6
tex3 = landscapes/guereins7
tex4 = landscapes/guereins8
tex5 = landscapes/guereins1
tex6 = landscapes/guereins2
tex7 = landscapes/guereins3
nbside = 8
side0 = tex0:0:0.005:1:1
side1 = tex1:0:0.005:1:1
side2 = tex2:0:0.005:1:1
```

```
side3 = tex3:0:0.005:1:1
side4 = tex4:0:0.005:1:1
side5 = tex5:0:0.005:1:1
side6 = tex6:0:0.005:1:1
side7 = tex7:0:0.005:1:1
groundtex = landscapes/guereinsb
ground = groundtex:0:0:1:1
fogtex = fog
fog = fogtex:0:0:1:1
nb_decor_repeat = 1
decor_alt_angle = 40
decor_angle_shift = -22
decor_angle_rotatez = 0
ground_angle_shift = -22
ground_angle_rotatez = 45
fog_alt_angle = 20
fog_angle_shift = -3
draw_ground_first = 1
```

Where:

name is the name that will appear in the landscape tab of the configuration window for this landscape

type should be "old_style" for the multiple image method.

nbsidetex is the number of side textures for the landscape.

tex0 ... tex<nbsidetex-1> are the side texture file names. These should exist in the `<config root>/textures/landscapes` directory in PNG format.

nbside is the number of side textures

side0 ... side<nbside-1> are the descriptions of how the side textures should be arranged in the program. Each description contains five fields separated by colon characters (:). The first field is the ID of the texture (e.g. tex0), the remaining fields are the coordinates used to place the texture in the scene.

groundtex is the name of the ground texture file.

ground is the description of the projection of the ground texture in the scene.

fogtex is the name of the texture file for fog in this landscape.

fog is the description of the projection of the fox texture in the scene.

nb_decor_repeat is the number of times to repeat the side textures in the 360 panorama.

decor_alt_angle is the vertical angular size of the textures (i.e. how high they go into the sky).

decor_angle_shift vertical angular offset of the scenery textures, at which height are the side textures placed.

decor_angle_rotatez angular rotation of the scenery around the vertical axis. This is handy for rotating the landscape so North is in the correct direction.

ground_angle_shift vertical angular offset of the ground texture, at which height the ground texture is placed.

ground_angle_rotatez angular rotation of the ground texture around the vertical axis. When the sides are rotated, the ground texturer may beed to me ratated as well to match up with the sides.

fog_alt_angle vertical angular size of the fog texture - how fog looks.

fog_angle_shift vertical angular offset of the fog texture - at what height is it drawn.

draw_ground_first if 1 the ground is drawn in front of the scenery, i.e. the side textures will overlap over the ground texture.

A step-by-step account of the creation of a custom landscape has been contributed by Barry Gerdes. See Appendix D.

5.5 Adding & Modifying Deep Sky Images

Deep sky objects such as galaxies, nebulae and star clusters may have images associated with them. Stellarium version 0.7.1 comes with images of many of the Messier objects. To add new deep sky objects, two tasks need to be performed:

1. Add an entry in the messier.fab file with the details of the object (type, position in sky, name, image filename etc.
2. Create the image and put it in the `textures` directory.

5.5.1 Modifying `messier.fab`

Each deep sky image has one line in the `messier.fab` file in the `data` folder. The file is a plain ASCII file, and may be edited with a normal text editor. Each line contains one record, each record consisting of the following fields, separated by TAB characters:

NGC number NGC catalogue number, e.g. `6523`.

Nebula type Possible values are: `0, EG, GC, LG, N, OC, PN, SG`.

RA hour The right ascension hour of the centre of the image. This is an integer, e.g. `18`.

RA minute Right ascension minutes of the centre of the image. This is the decimal number of minutes, e.g. `3.14`. There is no field for arc-seconds of right ascension - include that value in this field. For example, if you have an object with 20 arc-minutes + 30 arc-seconds, set this value to `20.5`.

DEC degrees Declination degrees of the centre of the image. This value is an integer, e.g. `-24`.

DEC minutes Declination minutes of the centre of the image. This is the decimal number of minutes, e.g. `-23`. There is no field for arc-seconds of declination - include that value in this field. For example, if you have an object with 20 arc-minutes + 30 arc-seconds, set this value to `20.5`.

Magnitude Apparent magnitude of object, e.g. `5` or `6.7`.

Size Angular size in arc-minutes, e.g. `90` or `56.2`.

Rotation The angular rotation of the picture to align if North is not up in degrees, e.g. `45.3`.

Name Nebula name with spaces replaced by underscore character (_), e.g. `M8-Lagoon_Nebula_(diffuse)`.

Texture filename This is the name of the image file (without the filename extension). The file should be in PNG format, without an alpha channel. For example, the filename `m8.png` would be written in this field as `m8`.

Source The source of the picture of image with spaces replaced by underscore characters (_), e.g. `Grasslands_Observatory`.

5.5.1.1 Examples from `messier.fab`

```
7089 GC 21 33.5 0 -49 6.5 12.9 0 M2 M2-globular_cluster m2 Grasslands_Observatory
224 SG 0 42.8 41 16 3.5 147.3 59.73 M31 M31-
Andromeda_Galaxy_(spiral) m31 Herm_Perez
```

5.5.2 Editing Image Files

Images should be copied to the `textures` directory. They should be in PNG format. Images should have an aspect ratio of 1 (i.e. it should be square), and should have a width/height of 2^n pixels, where n is a positive integer (i.e. 2, 4, 8, 16, 32, 64, 128, 256, 512, and so on).

Display of pictures interprets black as 100 % transparent. Looking at the histogram of the picture and making adjustments to the level and stretch can make the lowest level black to great effect.

There is a lot of software that can create / modify PNG images. The author recommends the GNU Image Manipulation Program (GIMP), since it is more than up to the job, and is free software in the same spirit as Stellarium itself.

5.6 Other `.fab` files

In addition to the `messier.fab` file discussed in section 5.5, the `data` directory contains several other files with the name `*.fab`. Many of these files may be edited easily to change what Stellarium will display. Note that * in this context means *something* - it's a wildcard whcih can be replaced with some combination of characters.

File	Purpose
cardinals.<lang>.fab	Each file contains the letters that should be used for the cardinal points. <lang> is the three letter abbreviation of the language name, e.g. the British file is called cardinals.eng.fab, and contains 'N E S W'.
star_names.<lang>.fab	Bright stars frequently have different 'common' names is different languages, as well as catalogue numbers/names. These files defines them for each language. The format of the file is: One star per line. Two fields separated by a pipe character (|). The first field is the Hipparcos catalogue number, the second is the star name, e.g. '32349|Sirius'.
planet_names.<lang>.fab	The names of solar system objects. This file has one record per line with two fields, separated by a TAB character. The first column is the British name of the object, the second field is the name in <lang>, e.g. 'Mercury Merkur'.
skycultures.fab	Describes the sky cultures for which constellations, art etc. may be defined. One record per line, two fields per record, TAB separated. The first field is name of the culture, the second field is the name of the sub-directory in which the sky culture files are stored (sub-directories are found in the data directory), e.g. ' Polynesian polynesian'.
name.fab	This file defines the Flamsteed designation for a star (see section F.2.4.2). Each line of the file contains one record of two fields, separated by the pipe character (|). The firs field is the Hipparcos catalogue number of the star, the second is the Flamsteed designation, e.g. '72370|ALF_Aps'. Note that at time of writing the Greek letters are represented using ASCII letters, e.g. ALF for α.
skylanguages.fab	Contains the list of three letter abbreviations for language names. One record per line, to TAB separated fields. First field is the three letter abbreviation, second field is the name of the language in British, e.g. 'deu German'.

Table 5.2: .fab files

Appendix A

Configuration file

Section	*ID*	*Type*	*Description*
[video]	fullscreen	boolean	if *true*, Stellarium will start up in full-screen mode. If false, Stellarium will start in windowed mode
[video]	screen_w	integer	sets the display width (value in pixels, e.g. *1024*)
[video]	screen_h	integer	sets the display height (value in pixels, e.g. *768*)
[video]	bbp_mode	integer	Sets the number of bits per pixel. Values: *16(?), 24(?), 32*
[video]	horizontal_offset	integer	view-port horizontal offset
[video]	vertical_offset	integer	view-port vertical offset
[projection]	type	string	sets projection mode. Values: *perspective*, *fisheye*
[projection]	viewport	string	how the view-port looks. Values: *maximized*
[localization]	sky_culture	string	sets the sky culture to use. Valid values are defined in the second column of data/skycultures.fab. Values: *western, polynesian, egyptian, chinese.* The sky culture affects the constellations.
[stars]	star_scale	float	multiplies the size of the stars. Typical value: *1.1*
[stars]	star_mag_scale	float	multiplies the magnitude of the stars. Typical value: *1.3*
[stars]	star_twinkle_amount	float	sets the amount of twinkling. Typical value: *0.3*
[stars]	max_mag_star_name	float	sets the magnitude of the stars whose labels will be shown
[stars]	flag_star_twinkle	bool	set to *false* to turn star twinkling off, *true* to allow twinkling.
[stars]	flag_point_star	bool	set to *false* to draw stars at a size that corresponds to their brightness. When set to *true* all stars are drawn at single pixel size.
[gui]	flag_menu	bool	set to *false* to hide the menu

Section	*ID*	*Type*	*Description*
[gui]	flag_help	bool	set to *true* to show help on start-up
[gui]	flag_infos	bool	set to *true* to show info on start-up
[gui]	flag_show_topbar	bool	set to *true* to show the info bar at top of the screen
[gui]	flag_show_time	bool	set to *false* to hide time
[gui]	flag_show_date	bool	set to *false* to hide date
[gui]	flag_show_appname	bool	set to *true* to show the application name in the top bar
[gui]	flag_show_selected_object_info	bool	set to *false* if you don't want info about the selected object
[gui]	gui_base_colour	float R,G,B	these three numbers determine the colour of the interface in RGB values, where *1* is the maximum, e.g. *1.0,1.0,1.0* for white
[gui]	gui_text_colour	float R,G,B	these three numbers determine the colour of the text in RGB values, where *1* is the maximum, e.g. *1.0,1.0,1.0* for white
[gui]	base_font_size	int(?)	sets the font size. Typical value: *15*
[gui]	flag_show_fps	bool	set to *false* if you don't want to see at how many frames per second Stellarium is rendering
[gui]	flag_show_fov	bool	set to *false* if you don't want to see how many degrees your field of view is
[colour]	azimuthal_colour	float R,G,B	sets the colour of the azimuthal grid in RGB values, where *1* is the maximum, e.g. *1.0,1.0,1.0* for white
[colour]	equatorial_colour	float R,G,B	sets the colour of the equatorial grid in RGB values, where *1* is the maximum, e.g. *1.0,1.0,1.0* for white
[colour]	equator_colour	float R,G,B	sets the colour of the equatorial line in RGB values, where *1* is the maximum, e.g. *1.0,1.0,1.0* for white
[colour]	ecliptic_colour	float R,G,B	sets the colour of the ecliptic line in RGB values, where *1* is the maximum, e.g. *1.0,1.0,1.0* for white
[colour]	const_lines_colour	float R,G,B	sets the colour of the constellation lines in RGB values, where *1* is the maximum, e.g. *1.0,1.0,1.0* for white
[colour]	const_names_colour	float R,G,B	sets the colour of the constellation names in RGB values, where *1* is the maximum, e.g. *1.0,1.0,1.0* for white
[colour]	nebula_label_colour	float R,G,B	sets the colour of the nebula labels in RGB values, where "1" is the maximum*1* is the maximum, e.g. *1.0,1.0,1.0* for white
[colour]	nebula_circle_colour	float R,G,B	sets the colour of the circle of the nebula labels in RGB values, where *1* is the maximum, e.g. *1.0,1.0,1.0* for white

Section	*ID*	*Type*	*Description*
[colour]	cardinal_colour	float R,G,B	sets the colour of the cardinal points in RGB values, where *1* is the maximum, e.g. *1.0,1.0,1.0* for white
[colour]	planet_names_colour	float R,G,B	sets the colour of the planet names in RGB values, where *1* is the maximum, e.g. *1.0,1.0,1.0* for white
[colour]	planet_orbits_colour	float R,G,B	sets the colour of the planet orbits in RGB values, where *1* is the maximum, e.g. *1.0,1.0,1.0* for white
[tui]	flag_enable_tui_menu	bool	set to *true* if you want to enable the TUI menu
[tui]	flag_show_gravity_ui	bool	set to *true* if you want to see labels that experience gravity, suited for dome projections.
[tui]	flag_show_tui_datetime	bool	set to *true* if you want to see a date and time label suited for dome projections
[tui]	flag_show_tui_short_obj_info	bool	set to *true* if you want to see object info suited for dome projections.
[navigation]	preset_sky_time	float	preset sky time used by the dome version. Unit is Julian Day. Typical value: *2451514.250011573*
[navigation]	startup_time_mode	string	set the start-up time mode, can be *actual* (start with current real world time), or *Preset* (start at time defined by preset_sky_time)
[navigation]	flag_enable_zoom_keys	bool	set to *false* if you want to disable the zoom keys
[navigation]	flag_enable_move_keys	bool	set to *false* if you want to disable the arrow keys
[navigation]	init_fov	float	initial field of view, in degrees, typical value: *60*
[navigation]	init_view_pos	floats	initial viewing direction. This is a vector with x,y,z-coordinates. x, -1 = look north,+1 = look south y, 0 to â90 E, 0 to 90, deviation W. z, horizon position, 0 to 1 up ,0 to -1 down. Typical value: *1,0.00001,0.2*
[navigation]	auto_move_duration	float	duration for the program to move to point at an object when the space bar is pressed. Typical value: *2.0*
[navigation]	flag_utc_time	bool	set to *true* if you want to display the time in UTC.
[navigation]	viewing_mode	string	if set to *horizon*, the viewing mode simulate an alt/azi mount, if set to *equatorial*, the viewing mode simulates an equatorial mount
[navigation]	flag_manual_zoom	bool	set to *true* if you want to auto-zoom in incrementally.
[landscape]	flag_ground	bool	set to *false* if you don't want to see the ground
[landscape]	flag_horizon	bool	set to *false* if you don't want to see the horizontal part of the landscape

Section	*ID*	*Type*	*Description*
[landscape]	flag_fog	bool	set to *false* if you don't want to see fog on start-up
[landscape]	flag_atmosphere	bool	set to *false* if you don't want to see atmosphere on start-up
[landscape]	atmosphere_fade_duration	float	sets the amount of time the atmosphere takes to fade in or out, in seconds. Typical value *2*
[viewing]	flag_constellation_drawing	bool	set to *true* if you want to see the constellation line drawings on start-up
[viewing]	flag_constellation_name	bool	set to *true* if you want to see the constellation names on start-up
[viewing]	flag_constellation_art	bool	set to *true* if you want to see the constellation art on start-up
[viewing]	flag_constellation_pick	bool	set to *true* if you only want to see the line drawing, art and name of the selected constellation star
[viewing]	flag_azimutal_grid	bool	set to *true* if you want to see the azimuthal grid on start-up
[viewing]	flag_equatorial_grid	bool	set to *true* if you want to see the equatorial grid on start-up
[viewing]	flag_equator_line	bool	set to *true* if you want to see the equator line on start-up
[viewing]	flag_ecliptic_line	bool	set to *true* if you want to see the ecliptic line on start-up
[viewing]	flag_cardinal_points	bool	set to *false* if you don't want to see the cardinal points
[viewing]	flag_gravity_labels	bool	set to *true* if you want labels to undergo gravity. Useful with dome projection.
[viewing]	flag_init_moon_scaled	bool	change to *false* if you want to see the real moon size on start-up
[viewing]	moon_scale	float	sets the moon scale factor, to correlate to our perception of the moon's size. Typical value: *4*
[viewing]	constellation_art_intensity	float	this number multiplies the brightness of the constellation art images. Typical value: *0.5*
[viewing]	constellation_art_fade_duration	float	sets the amount of time the constellation art takes to fade in or out, in seconds. Typical value: 1.5
[astro]	flag_stars	bool	set to *false* to hide the stars on start-up
[astro]	flag_star_name	bool	set to *false* to hide the star labels on start-up
[astro]	flag_planets	bool	set to *false* to hide the planet labels on start-up
[astro]	flag_planets_hints	bool	set to *false* to hide the planet hints on start-up
[astro]	flag_planets_orbits	bool	set to *true* to show the planet orbits on start-up
[astro]	flag_nebula	bool	set to *false* to hide the nebulae on start-up

Section	*ID*	*Type*	*Description*
[astro]	flag_nebula_name	bool	set to *true* to show the nebula labels on start-up
[astro]	flag_milky_way	bool	set to *false* to hide the Milky Way
[astro]	max_mag_nebula_name	float	sets the magnitude of the nebulae whose name is shown. Typical value: *8*
[astro]	flag_bright_nebulae	float	set to *true* to increase nebulae brightness to enhance viewing (less realistic)
[init_location]	name	string	sets your location's name. This is an arbitrary string, For example, *Paris*
[init_location]	latitude	DMS	sets the latitude coordinate of the observer. Value is in degrees, minutes, seconds. Positive degree values mean North / negative South. e.g. *+55 14'30.00"*
[init_location]	longitude	DMS	sets the longitude coordinate of the observer. Value is in degrees, minutes, seconds. Positive degree values mean East / negative West. e.g. *-01 37'6.00"*
[init_location]	altitude	float	observer's altitude above mean sea level in meters, e.g. *53*
[init_location]	landscape_name	string	sets the landscape you see. Other options are *guereins, trees, hurricane, hogerielen*
[init_location]	time_zone	string	sets the time zone. At time of writing, the only valid value is *system_default*
[init_location]	time_display_format	string	set the time display format mode: can be *system_default*, *24h* or *12h*.
[init_location]	date_display_format	string	set the date display format mode: can be *system_default*, *mddyyyy*, *ddmmyyyy* or *yyyymmdd* (ISO8601).

Appendix B

Scripting Commands

Command	*Argument Names*	*Argument Values*	*Notes*
audio	action	pause play sync	
	↓lename	AUDIO_FILENAME	Used with "play" action. Format support depends on your binary. Ogg Vorbis format is recommended. WAV format should work but is discouraged because in this case the audio track will not adjust if the script is fast forwarded. [This is a current limitation of the SDL_Mixer library.]
	loop	on o↑	Used with "play" action. Default is o↑
	output_rate	SAMPLES_PER_SECOND	For example, 44100 is CD quality audio.
	volume	decrement increment VOLUME_LEVEL	VOLUME_LEVEL is between 0 and 1, inclusive.
clear	state	natural	Turn o↑ fog and all labels, lines, and art. Turn planet, star, and nebula rendering on. Deselect any selected objects. Return to initial fov and viewing direction. If state is natural, ground and atmosphere will be turned on, otherwise these will be turned o↑.
con↓guration	action	load reload	Only reload is acceptable from a script. Reloads default settings.
date	local	[[-]YYYY-MM-DD]Thh:mm:ss	Set time to a speci↓ed date and/or time using current timezone. 'T' is literal.
	utc	[-]YYYY-MM-DDThh:mm:ss	Set time to a speci↓ed date and time in UTC time. 'T' is literal.
	relative	DAYS	Change date and time by DAYS (can be fractional).
	load	current	Set date to current date.
deselect			Deselects current object selection, including any constellation selection. See select command.

Command	*Argument Names*	*Argument Values*	*Notes*
'ag	atmosphere azimuthal_grid bright_nebulae cardinal_points constellation_art constellation_drawing constellation_names constellation_pick ecliptic_line enable_move_keys enable_tui_menu enable_zoom_keys equator_line equatorial_grid fog gravity_labels help infos moon_scaled landscape manual_zoom menu meridian_line milky_way nebulae nebula_names object_trails planets planet_names planet_orbits point_star show_appname show_date show_fov show_fps show_gravity_ui show_selected_object_info show_time show_topbar show_tui_datetime show_tui_short_obj_info star_names star_twinkle stars track_object utc_time	on 1 o↑ 0 toggle	Set rendering 'ags. One argument name per command allowed currently. track_object is only useful while an object is selected. The following 'ags are key user settings and are not accessible from scripts: enable_move_keys enable_move_mouse enable_tui_menu enable_zoom_keys gravity_labels help horizon infos menu show_appname show_date show_fov show_fps show_gravity_ui show_time show_topbar utc_time
image	action	load drop	Drop images when no longer needed to improve performance.
	altitude	ALTITUDE_ANGLE	For positioning the center of the image in horizontal coordinates. Zero is at the horizon, 90 is at the zenith.
	azimuth	AZIMUTH_ANGLE	For positioning the center of the image in horizontal coordinates. Zero is North, 90 is East.

Command	*Argument Names*	*Argument Values*	*Notes*
	coordinate_system	viewport horizontal	What coordinate system to use to position the image. Must be defined at image load. Can not be changed later. Default is viewport.
	duration	SECONDS	How long to take to complete the command.
	filename	IMAGE_FILENAME	Path must be relative to script.
	name	IMAGE_NAME	Used to refer to the image in later calls to manipulate the image. Images must be in PNG format. If images do not have dimensions that are powers of 2 (128, 256, etc.) they are re-sized when loaded to meet this requirement.
	alpha	ALPHA	0 is transparent (default), 1 is opaque. ALPHA can be fractional. Note that images are drawn in the order they were loaded.
	scale	SCALE	How large to draw the image. In viewport coordinates, at 1 the image is scaled to fit maximized in the viewport. In horizontal coordinates, this defines the maximum angular width of the image in degrees.
	rotation	DEGREES	Absolute rotation, positive is clockwise.
	xpos	X_POSITION	Where to draw center of image. 0 is center of viewport, 1 is right edge of viewport.
	ypos	Y_POSITION	Where to draw center of image. 0 is center of viewport, 1 is top edge of viewport.
landscape			Load a landscape. Arguments have same names and possible values as in landscapes.ini file except that texture file names need to be specified in full including the path relative to the script. Also add argument "action load"
meteors	zhr	ZENITH_HOURLY_RATE	
moveto	lat	LATITUDE	South is negative
	lon	LONGITUDE	West is negative
	alt	ALTITUDE	In meters
	duration	SECONDS	How long to take to effect this change.
script	action	play end pause resume	Note that pause toggles playback. If a script plays another script, the first will terminate.
	filename	SCRIPT_FILENAME	
select			If no arguments are supplied, deselects current object. (Leaves constellation selection alone.) See deselect command.

Command	*Argument Names*	*Argument Values*	*Notes*
	constellation	CONSTELLATION_SHORT_NAME	3 character abbreviation from constellationship.fab, case insensitive.
	hp	HP_NUMBER	
	nebula	NEBULA_NAME	Name as defined in messier.fab
	planet	PLANET_NAME	Name as defined in ssystem.ini
	pointer	on 1 off 0	Whether to draw the highlighting pointer around the selected object. Default is on.
set	atmosphere_fade_duration	SECONDS	
	auto_move_duration	SECONDS	used for auto zoom
	constellation_art_fade_duration	SECONDS	
	constellation_art_intensity		0-1
	landscape_name		from landscapes.ini
	max_mag_nebula_name		only label nebulas brighter than this
	max_mag_star_name		only label stars brighter than this
	moon_scale		1 is real size
	sky_culture		Directory name from skycultures.fab
	sky_locale		3 letter code. eng, fra, etc.
	star_mag_scale		
	star_scale		
	star_twinkle_amount		0 is no twinkling
	time_zone		System dependent
timerate	rate	SECONDS_PER_SECOND	Set simulation time rate.
wait	duration	SECONDS	Only useful in scripts. SECONDS can be fractional.
zoom	auto	in initial out	"initial" returns to configured initial fov and viewing direction
	fov	FIELD_OF_VIEW	in degrees
	delta_fov	DELTA_DEGREES	
	duration	SECONDS	Not used with delta_fov

Appendix C

Precision

Stellarium uses the VSOP87 method to calculate the variation in position of the planets over time.

As with other methods, the precision of the calulations vary according to the planet and the time for which one makes the calculation. Reasons for these inaccuracies include the fact that the motion of the planet isn't as predictable as Newtonian mechanics would have us believe.

As far as Stellarium is concerned, the user should bear in mind the following properties of the VSOP87 method:

Object(s)	*Method*	*Notes*
Mercury, Venus, Earth-Moon barycenter, Mars		Precision is 1 arc-second from 2000 B.C. - 6000 A.D.
Jupiter, Saturn		Precision is 1 arc-second from 0 A.D. - 4000 A.D.
Uranus, Neptune		Precision is 1 arc-second from 4000 B.C - 8000 A.D.
Pluto		Pluto's position is valid from 1885 A.D. -2099 A.D.
Earth's Moon	ELP2000-82B	Unsure about interval of validity or precision at time of writing. Possibly valid from 1828 A.D. to 2047 A.D.
Galilean satellites	L2	Valid from 500 A.D - 3500 A.D.

Appendix D

Creating a Personalised Landscape for Stellarium

by Barry Gerdes, 2005-12-19

Although this procedure is based on the Microsoft Windows System the basics will apply to any platform that can run the programs mentioned or similar programs on the preferred system.

The first thing needed for a personalised landscape to superimpose on the horizon display is a 360° panorama with a transparent background. To make this you will need the following:

- A digital camera on a tripod or stable platform
- A program to convert the pictures into a 360° panorama
- A program to remove the background and convert the panorama into about 8 square pictures in PNG format for insertion into Stellarium as the sides and if possible a similar square picture of the base you are standing on to form the ground. This last requirement is only really possible if this area is relatively featureless as the problem of knitting a complex base is well nigh impossible.
- Patience. (Maybe a soundproof room so that the swearing wont be heard when you press the wrong key and lose an hours work)

D.0.1 The Camera

Digital cameras are easy and cheaply available these days so whatever you have should do. One mega-pixel resolution is quite sufficient.

The camera needs to be mounted on a tripod so that reasonably orientated pictures can be taken. Select a time of day that is quite bright with a neutral cloudy sky so there will be no shadows and a sky of the same overall texture. This will make it easier to remove later. The pictures were all saved in the JPG format which was used as the common format for all processes up to the removal of the background.

With a camera that takes 4:3 ratio pictures I found 14 evenly spaced pictures gave the best 360° panorama in the program I used to produce it.

Figure D.1: 360° panorama

D.0.2 Processing into a Panorama

This is the most complicated part of the process of generating the panorama. I used two separate programs to do this. Firstly I used Microsoft Paint which is part of the Windows operating system, to cleanup and resize the pictures to 800x600 size and so make them easier to handle in the panorama program.

If you have prominent foreground items like posts wires etc. that occur in adjacent pictures the panorama program will have difficulty in discerning them because of the 3D effect and may give double images. I overcame this by painting out the offending item by cut and paste between the two pictures. Quite easy with a little practice using the zoom in facility and I found the MSpaint program the easiest to do this in.

When I had my 14 processed pictures I inserted them into the panorama program. I used a program called the Panorama Factory. Version 1.6 is a freebee that works well and can be downloaded from the internet - a Google search will find it. I used version 3.4 that is better and cost about $40 off the Internet. This program has many options and can be configured to suit most cameras and can make a seamless 360° panorama in barrel form that will take a highly trained eye to find where the joins occur.

The resulting panorama was then loaded into Paint and trimmed to a suitable size. Mine ended up 4606 x 461 pixels. I stretched the 4606 to 4610 pixels, almost no distortion, that would allow cutting into 10 461x461 pictures at a later date. If the height of the panorama had been greater I could have made fewer pictures and so shown more of the foreground. See figure D.1.

D.0.3 Removing the background to make it transparent

This is the most complex part of the process and requires a program that can produce transparency to parts of your picture, commonly called an alpha channel. Two programs I know of will do this. The very expensive and sophisticated Adobe Photoshop and a freebee called The Gimp.

I used Photoshop to produce the alpha channel because selection of the area for transparency was more positive with the complex skyline I had and I had learnt a little more on how to drive it before I found an executable form of The Gimp. For the rest I used a combination of both programs. I will describe the alpha channel process in detail for Photoshop. A lot of this would be suitable for The Gimp as they are very similar programs but I have only tried the bare essential in The Gimp to prove to myself that it could be done.

1. Load the panorama picture into Photoshop

2. Create an alpha channel using the channel pop up window. This channel was then selected as the only channel visible and it was all black at this stage. It needs to be all white. To edit this took me some time to discover how. What I did was click on Edit in Quick mask mode and then Edit in standard mode. This procedure was the only way I found I could edit. Click on the magic wand and click it on the channel picture. It will put a mask around the whole picture. Next I selected the brush tool and toggled the foreground to white and painted the whole channel white (using a very large brush size 445 pixels).

3. Next I turned the alpha channel off and selected the other channels to get the original picture. I got rid of the full mask that I had forgotten to remove by selecting Step backwards from the edit menu. I first tried the magnetic loop tool to select the sections for a mask but it was too fiddly for me. I then used the magic wand tool to select the sky sections bit by bit (zoom in on the image to see what you are doing) this would have been easy if the sky had been cloudless because colour match does this selection. I cut each selection out. It took about an hour to remove all the sky (because it was cloudy) and leave just the skyline image as a suitable mask. Clicking the magic wand in the sky area when all the sky has been removed will show an outline mask of the removed sky. Zoom in and carefully check the whole area to make sure there is no sky left. Leave this mask there.

4. Re-select the alpha channel and turn the other channels off. The alpha channel will be visible and the mask should be showing. Re-select Edit in Quick mask mode and then Edit in standard mode to edit. Select the brush tool and toggle to the black foreground. Fill in the masked area with a large brush size. The colour (black) will only go into the masked area. It wont spill over so the job is quite easy.

5. When this is done you will have created your alpha layer. Check the size of the image and if it is greater than 5000 pixels wide reduce its size by a fixed percentage till it is under this limit. The limit was necessary for one of the programs I used but may not be always necessary. However any greater resolution will be wasted and the file size will be excessive. Save the whole image in the compressed tiff form or PNG form. The only formats that preserve the alpha channel.

6. This image is the horizon picture. Give it a name .tif or .png, Whichever format you save it in.

   After making the `panorama.tif` I noticed that the trees still had areas of the original sky embedded that werent blanked by the alpha layer. I found that I could add these sections piece by piece to the alpha layer with the magic wand and paint them out. This took some time, as there were a large number to be removed. However the result was worth the effort, as it allows the sky display to be seen through the trees. Especially at high zooms ins.

   Another little trick I discovered was that the panorama could be saved as a JPEG file (no alpha channel) and the alpha channel also saved as a separate JPEG file. This can save space for transmission. And allow manipulation of the original file in another program as long as the skyline is unchanged. At a later date the two files can be re-combined in Photoshop to re-form the TIFF file with alpha channel.

   Using this trick I did a little patching and painting on the original picture in Paint on the original JPEG form. When completed I loaded it into Photoshop and added the blank alpha channel to it. I was then able to paste the previously created alpha layer into the new picture. It worked perfectly.

7. The panorama now needs to be broken up into suitable square images for insertion into a landscape. It took me some time to get the hang of this but the process I found best was in The Gimp. It was the easiest to cut the main panorama into sections as it has a mask scale in the tool bar.

8. Load the panorama file with alpha channel into The Gimp. Then using the mask tool cut out the squares of the predetermined size starting from the left hand side of the picture. I don't think it is necessary to make them exact

squares but I did not experiment with this aspect. The position of the cut will be shown on the lower tool bar. Accuracy is improved if you use the maximum zoom that will fit on the page.

9. Create a new picture from the file menu then select and adjust the size to your predetermined size then select transparent for the background. Because of the alpha channel the transparent section will be automatically clipped of much of the transparent part of the picture. Paste the cutting into the new picture. If it is smaller than your predetermined size it will go to the centre leaving some of the transparent background at the bottom of the picture. Save the file in the PNG format. Moving the picture to the bottom of the window is much easier in Photoshop although quite possible in The Gimp.

10. I repeated steps 8 and 9 till I had all sections of the panorama saved.

11. Next I re-loaded Photoshop and opened the first of the saved pictures. Then from the menu selected the picture with the mask tool and then selected move. Next clicking on the picture will cut it out. The cutting can now be dragged to the bottom of the frame. It will not go any further so there is no trouble aligning. This bottom stop did not work on The Gimp and so it was harder to cut and place the picture section. It is most important to align the pictures to the bottom.

12. Save the picture with the name you intend to call your landscape as `xxxxxx1.png`.

13. Repeat steps 11 and 12 for the rest of the pictures till you have all the elements for your landscape.

14. Place your pictures in the `<config root>/textures/landscapes` folder.

15. Edit the `<config root>/data/landscapes.ini` file (I used wordpad). Select the section [Guereins], copy the section and paste it at the bottom of the file. On your insertion edit the name Guereins in every instance to the name you have given your landscape. Dont forget to make the number of tex entries agree with the number of your pictures. If you havent made a "groundtex" picture use one of the existing ones from the file or make a square blank picture of your own idea. Because I took my pictures from the roof of the house I used an edited picture of the roof of my house from Google Earth. It was pretty cruddy low resolution but served the purpose.

16. Next you need to orientate your picture North with true North. This is done roughly by making the arrangement of "side1" to "side*n*" suit your site as close as possible. Now you need to edit the value of "decor_angle_rotatez" to move your landscape in azimuth. Edit "decor_angle_alt" to move you landscape in altitude to align your visible horizon angle. Edit "ground_angle_rotatez" to align your ground with the rest of the landscape. Leave the other entries they are suitable as is.

Your landscape will now appear on the landscape menu and can be selected as required.

Appendix E

Astronomical Concepts

This section includes some general notes on astronomy in an effort to outline some concepts that are helpful to understand features of Stellarium. Material here is only an overview, and the reader is encouraged to get hold of a couple of good books on the subject. A good place to start is a compact guide and ephemeris such as the National Audubon Society Field Guide to the Night Sky[**?**]. Also recommended is a more complete textbook such as Universe[**?**]. There are also some nice resources on the net, like the Wikibooks Astronomy book[**?**].

E.1 The Celestial Sphere

The *Celestial Sphere* is a concept which helps us think about the positions of objects in the sky. Looking up at the sky, you might imagine that it is a huge dome or top half of a sphere, and the stars are points of light on that sphere. Visualising the sky in such a manner, it appears that the sphere moves, taking all the stars with it—it seems to rotate. If watch the movement of the stars we can see that they seem to rotate around a static point about once a day. Stellarium is the perfect tool to demonstrate this!

1. Open the configuration window, select the location tab. Set the location to be somewhere in mid-Northern latitudes. The United Kingdom is an ideal location for this demonstration.
2. Turn off atmospheric rendering and ensure cardinal points are turned on. This will keep the sky dark so the Sun doesn't prevent us from seeing the motion of the stars when it is above the horizon.
3. Pan round to point North, and make sure the field of view is about 90°.
4. Pan up so the 'N' cardinal point on the horizon is at the bottom of the screen.
5. Now increase the time rate. Press `k`, `l`, `l`, `l`, `l` - this should set the time rate so the stars can be seen to rotate around a point in the sky about once every ten seconds If you watch Stellarium's clock you'll see this is the time it takes for one day to pass as this accelerated rate.

The point which the stars appear to move around is one of the *Celestial Poles*.

The apparent movement of the stars is due to the rotation of the Earth. The location of the observer on the surface of the Earth affects how she perceives the motion of the stars. To an observer standing at Earth's North Pole, the stars all seem to rotate around the *zenith* (the point directly directly upward). As the observer moves South towards the equator, the location of the celestial pole moves down towards the horizon. At the Earth's equator, the North celestial pole appears to be on the Northern horizon.

Similarly, observers in the Southern hemisphere see the Southern celestial pole at the zenith when they are at the South pole, and it moves to the horizon as the observer travels towards the equator.

1. Leave time moving on nice and fast, and open the configuration window. Go to the location tab and click on the map right at the top - i.e. set your location to the North pole. See how the stars rotate around a point right at the top of the screen. With the field of view set to 90° and the horizon at the bottom of the screen, the top of the screen is the zenith.

2. Now click on the map again, this time a little further South, You should see the positions of the stars jump, and the centre of rotation has moved a little further down the screen.

3. Click on the map even further towards and equator. You should see the centre of rotation have moved down again.

To help with the visualisation of the celestial sphere, turn on the equatorial grid by clicking the button on the main tool-bar or pressing the on the 'e' key. Now you can see grid lines drawn on the sky. These lines are like lines of longitude an latitude on the Earth, but drawn for the celestial sphere.

The *Celestial Equator* is the line around the celestial sphere that is half way between the celestial poles - just as the Earth's equator is the line half way between the Earth's poles.

E.2 Coordinate Systems

E.2.1 Altitude/Azimuth Coordinates

The *Altitude/Azimuth* coordinate system can be used to describe a direction of view (the azimuth angle) and a height in the sky (the altitude angle). The azimuth angle is measured clockwise round from due North. Hence North itself is 0°, East 90°, Southwest is 135° and so on. The altitude angle is measured up from the horizon. Looking directly up (at the zenith) would be 90°, half way between the zenith and the horizon is 45° and so on. The point opposite the zenith is called the *nadir*.

The Altitude/Azimuth coordinate system is attractive in that it is intuitive - most people are familiar with azimuth angles from bearings in the context of navigation, and the altitude angle is something most people can visualise pretty easily.

However, the altitude/azimuth coordinate system is not suitable for describing the general position of stars and other objects in the sky - the altitude and azimuth values for an object in the sky change with time and the location of the observer.

Stellarium can draw grid lines for altitude/azimuth coordinates. Use the button on the main tool-bar to activate this grid, or press the 'z' key.

E.2.2 Right Ascension/Declination Coordinates

Like the Altitude/Azimuth system, the *Right Ascension/Declination* (RA/Dec) coordinate system uses two angles to describe positions in the sky. These angles are measured from standard points on the celestial sphere. Right ascension and declination are to the celestial sphere what longitude and latitude are to terrestrial map makers.

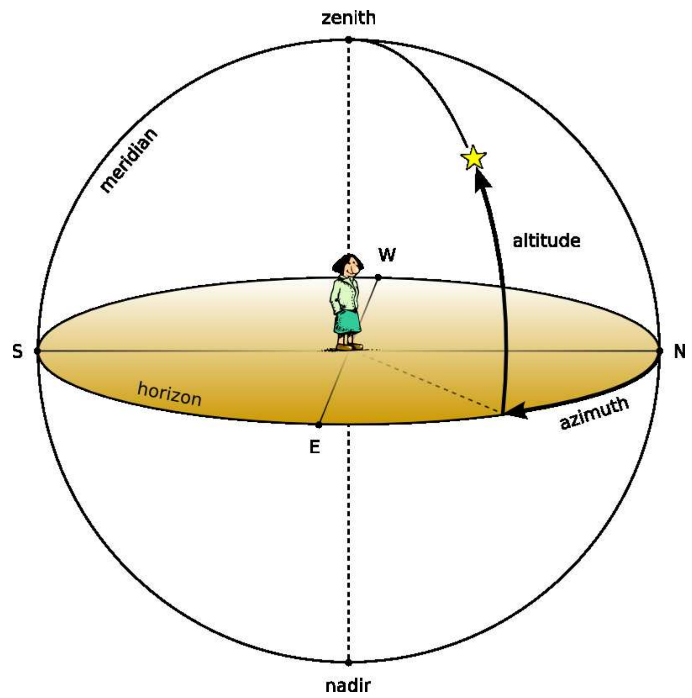

Figure E.1: Altitude & Azimuth

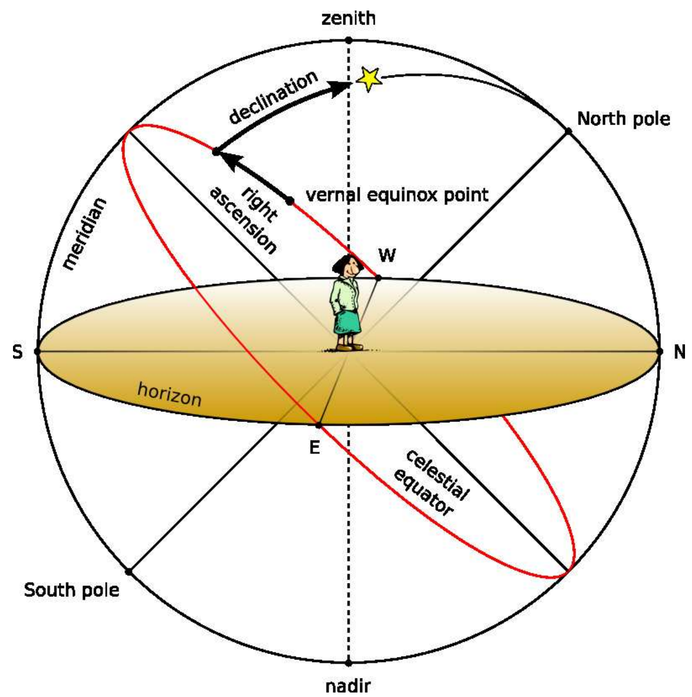

Figure E.2: Right Ascension & Declination

The Northern celestial pole has a declination of 90°, the celestial equator has a declination of 0°, and the Southern celestial pole has a declination of -90°.

Right ascension is measured as an angle round from a point in the sky known as the *first point of Aries*, in the same way that longitude is measured around the Earth from Greenwich. Figure E.2 illustrates RA/Dec coordinates.

Unlike Altitude/Azimuth coordinates, RA/Dec coordinates of a star do not change if the observer changes latitude, and do not change over the course of the day due to the rotation of the Earth (the story is complicated a little by precession and parallax - see sections E.4 and E.5 respectively for details). RA/Dec coordinates are frequently used in star catalogues such as the Hipparcos catalogue.

Stellarium can draw grid lines for RA/Dec coordinates. Use the button on the main tool-bar to activate this grid, or press the 'e' key.

E.3 Units

E.3.1 Distance

As Douglas Adams pointed out in the Hitchhiker's Guide to the Galaxy[**?**],

> Space is big. You just won't believe how vastly, hugely, mind-bogglingly big it is. I mean, you may think it's a long way down the road to the chemist's, but that's just peanuts to space.[**?**]

Astronomers use a variety of units for distance that make sense in the context of the mind-boggling vastness of space.

Astronomical Unit (AU) This is the mean Earth-Sun distance. Roughly 150 million kilometers (1.49598×10^8km). The AU is used mainly when discussing the solar system - for example the distance of various planets from the Sun.

Light year A light year is not, as some people believe, a measure of time. It is the distance that light travels in a year. The speed of light being approximately 300,000 kilometers per second means a light year is a very large distance indeed, working out at about 9.5 trillion kilometers (9.46073×10^{12} km). Light years are most frequently used when describing the distance of stars and galaxies or the sizes of large-scale objects like galaxies, nebulae etc.

Parsec A parsec is defined as the distance of an object that has an annual parallax of 1 second of arc. This equates to 3.26156 light years (3.08568×10^{13} km). Parsecs are most frequently used when describing the distance of stars or the sizes of large-scale objects like galaxies, nebulae etc.

E.3.2 Time

The length of a day is defined as the amount of time that it takes for the Sun to travel from the highest point in the sky at mid-day to the next high-point on the next day. In astronomy this is called a *solar day*. The apparent motion of the Sun is caused by the rotation of the Earth. However, in this time, the Earth not only spins, it also moves slightly round it's orbit. Thus in one solar day the Earth does not spin exactly 360° on it's axis. Another way to measure day length is to consider how long it takes for the Earth to rotate exactly 360°. This is known as one *sidereal day*.

Figure E.3 illustrates the motion of the Earth as seen looking down on the Earth orbiting the Sun.. The red triangle on the Earth represents the location of an observer. The figure shows the Earth at four times:

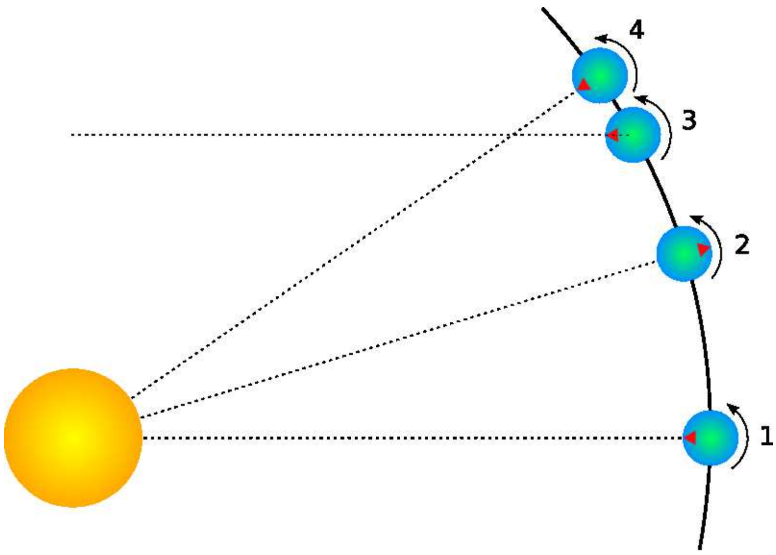

Figure E.3: Solar and Sidereal days

1 The Sun is directly overhead - it is mid-day.

2 Twelve hours have passed since 1. The Earth has rotated round and the observer is on the opposite side of the Earth from the Sun. It is mid-night. The Earth has also moved round in it's orbit a little.

3 The Earth has rotated exactly 360°. Exactly one sidereal day has passed since 1.

4 It is mid-day again - exactly one solar day since 1. Note that the Earth has rotated more than 360° since 1.

It should be noted that in figure E.3 the the sizes of the Sun and Earth and not to scale. More importantly, the distance the Earth moves around it's orbit is much exaggerated. In one real solar day, the Earth takes a year to travel round the Sun - $365\frac{1}{4}$ solar days.

It takes exactly one sidereal day for the celestial sphere to make one revolution in the sky. Astronomers find sidereal time useful when observing. When visiting observatories, look out for doctored alarm clocks that have been set to run in sidereal time!

The Earth spins on it's axis in the same direction that it orbits the Sun. This is called *prograde* motion. When a planet has prograde motion, it's sidereal day is longer than it's solar day. The length of the sidereal day on Earth is three minutes and 56 seconds longer than a solar day.

If the Earth pan on it's axis in the opposite direct to it's orbit (*retrograde* motion), the sidereal day would be shorter than the solar day.

E.3.3 Angles

Astronomers typically use degrees to measure angles. Since many observations require very precise measurement, the degree is subdivided into sixty *minutes or arc* also known as *arc-minutes*. Each minute of arc is further subdivided into sixty *seconds of arc*, or *arc-seconds*. Thus one degree is equal to 3600 seconds of arc. Finer grades of precision are usually expressed using the SI prefixes with arc-seconds, e.g. *milli arc-seconds* (one milli arc-second is one thousandth of an arc-second).

Object	*m*	*M*
The Sun	-27	4.8
Vega	0.05	0.6
Betelgeuse	0.47	-7.2
Sirius (the brightest star)	-1.5	1.4
Venus (at brightest)	-4.4	-
Full Moon (at brightest)	-12.6	-

Table E.2: Magnitudes of well known objects

E.3.3.1 Notation

Degrees are denoted using the ° symbol after a number. Minutes of arc are denoted with a ', and seconds of arc are denoted using ". Angles are frequently given in two formats:

1. DMS format—degrees, minutes and seconds. For example *90° 15'12"*. When more precision is required, the seconds component may include a decimal part, for example *90° 15'12.432"* .

2. Decimal degrees, for example *90.2533°*

E.3.4 The Magnitude Scale

When astronomers talk about magnitude, they are referring to the brightness of an object. How bright an object appears to be depends on how much light it's giving out and how far it is from the observer. Astronomers separate these factors by using two measures: *absolute magnitude (M)* which is a measure of how much light is being given out by an object, and *apparent magnitude (m)* which is how bright something appears to be in the sky.

For example, consider two 100 watt lamps, one which is a few meters away, and one which is a kilometer away. Both give out the same amount of light - they have the same absolute magnitude. However the nearby lamp seems much brighter - it has a much greater apparent magnitude. When astronomers talk about magnitude without specifying whether they mean apparent or absolute magnitude, they are usually referring to apparent magnitude.

The magnitude scale has its roots in antiquity. The Greek astronomer Hipparchus defined the brightest stars in the sky to be *first magnitude*, and the dimmest visible to the naked eye to be *sixth magnitude*. In the 19th century British astronomer Norman Pogson quantified the scale more precisely, defining it as a logarithmic scale where a magnitude 1 object is 100 times as bright as a magnitude 6 object (a difference of five magnitudes). The zero-point of the modern scale was originally defined as the brightness of the star Vega, however this was re-defined more formally in 1982[**?**]. Objects brighter than Vega are given negative magnitudes.

The absolute magnitude of a star is defined as the magnitude a star would appear if it were 10 parsecs from the observer.

Table E.2 lists several objects that may be seen in the sky, their apparent magnitude and their absolute magnitude where applicable (only stars have an absolute magnitude value. The planets and the Moon don't give out light like a star does - they reflect the light from the Sun).

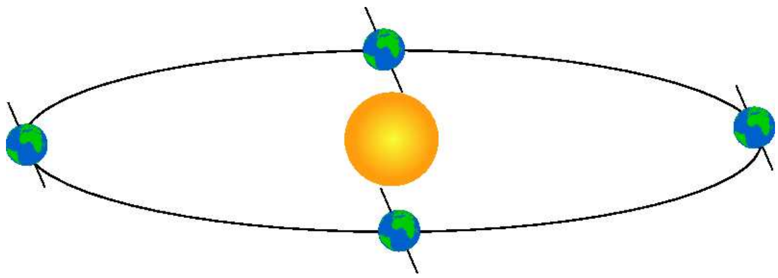

Figure E.4: Obliquity of the Ecliptic

E.3.5 Luminosity

Luminosity is an expression of the total energy radiated by a star. It may be measured in watts, however, astronomers tend to use another expression—*solar luminosities* where an object with twice the Sun's luminosity is considered to have two solar luminosities and so on. Luminosity is related to absolute magnitude.

E.4 Precession

As the Earth orbits the Sun throughout the year, the axis of rotation (the line running through the North and South poles of the Earth) seems to point towards the same position on the celestial sphere, as can be seen in figure E.4. The angle between the axis of rotation and the orbital plane is called the *obliquity of the ecliptic*. It is 23° 27'.

Observed over very long periods of time the direction the axis of rotation points does actually change. The angle between the axis of rotation and the orbital plane stays constant, but the direction the axis points—the position of the celestial pole transcribes a circle on the stars in the celestial sphere. This process is called *precession*. The motion is similar to the way in which a gyroscope slowly twists as figure E.5 illustrates.

Precession is a slow process. The axis of rotation twists through a full 360° about once every 28,000 years.

Precession has some important implications:

1. RA/Dec coordinates change over time, albeit slowly. Measurements of the positions of stars recorded using RA/Dec coordinates must also include a date for those coordinates.

2. Polaris, the pole star won't stay a good indicator of the location of the Northern celestial pole. In 14,000 years time Polaris will be nearly 47° away from the celestial pole!

E.5 Parallax

Parallax is the change of angular position of two stationary points relative to each other as seen by an observer, due to the motion of said observer. Or more simply put, it is the apparent shift of an object against a background due to a change in observer position.

This can be demonstrated by holding ones thumb up at arm's length. Closing one eye, note the position of the thumb against the background. After swapping

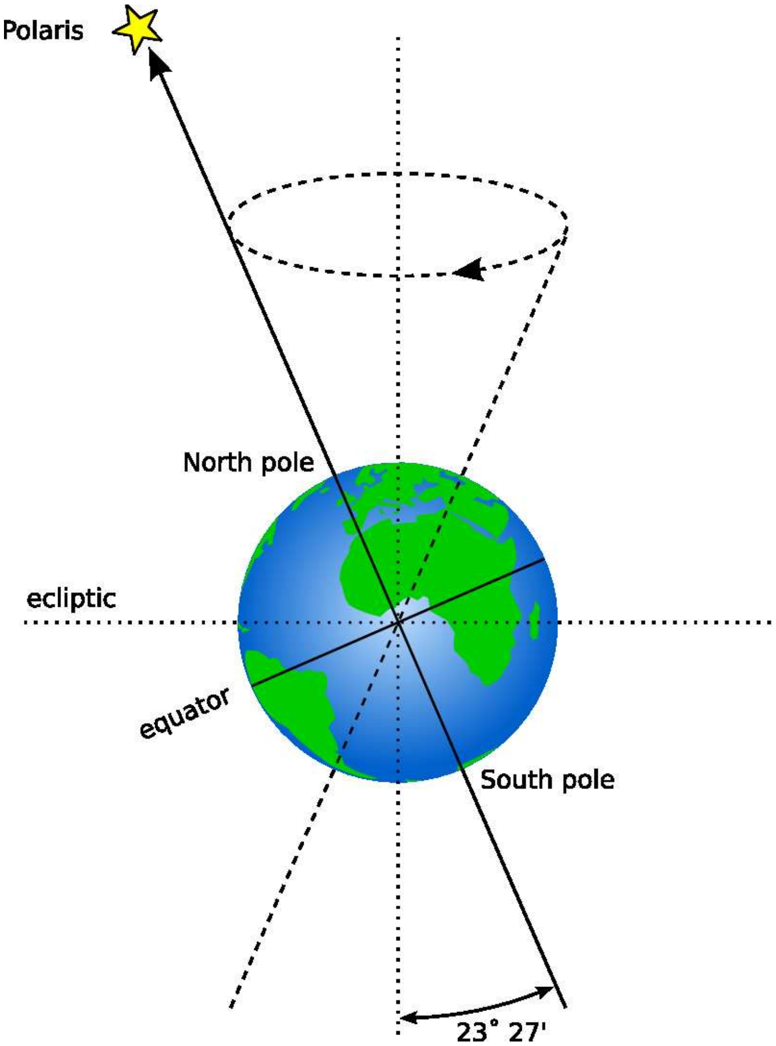

Figure E.5: Precession

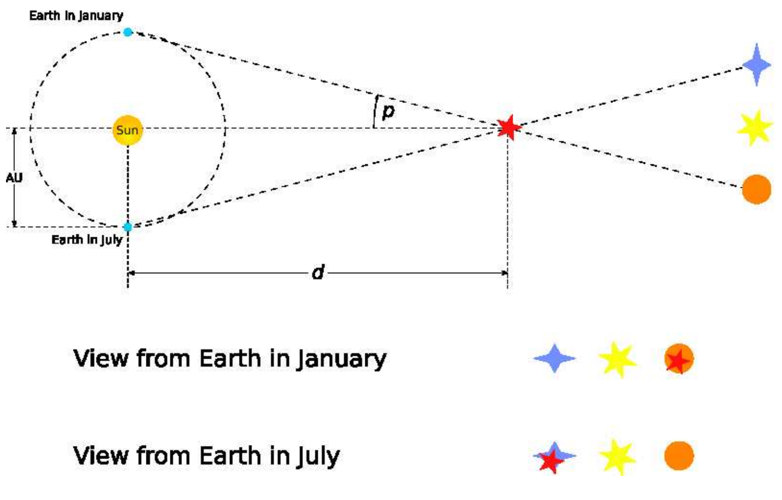

Figure E.6: Apparent motion due to parallax which eye is open (without moving), the thumb appears to be in a different position against the background.

A similar thing happens due to the Earth's motion around the Sun. Nearby stars appear to move against more distant background stars, as illustrated in figure E.6. The movement of nearby stars against the background is called *stellar parallax*, or *annual parallax*.

Since we know the distance the radius of the Earth's orbit around the Sun from other methods, we can use simple geometry to calculate the distance of the nearby star if we measure annual parallax.

In figure E.6 the annual parallax p is half the angular distance between the apparent positions of the nearby star. The distance of the nearby object is d. Astronomers use a unit of distance called the parsec which is defined as the distance at which a nearby star has $p = 1''$.

Even the nearest stars exhibit very small movement due to parallax. The closest star to the Earth other than the Sun is Proxima Centuri. It has an annual parallax of 0.77199", corresponding to a distance of 1.295 parsecs (4.22 light years).

Even with the most sensitive instruments for measuring the positions of the stars it is only possible to use parallax to determine the distance of stars up to about 1,600 light years from the Earth, after which the annual parallax is so small it cannot be measured accurately enough.

Appendix F

Astronomical Phenomena

This chapter focuses on the observational side of astronomy—what we see when we look at the sky.

F.1 The Sun

Without a doubt, the most prominent object in the sky is the Sun. The Sun is so bright that when it is in the sky, it's light is scattered by the atmosphere to such an extent that almost all other objects in the sky are rendered invisible.

The Sun is a star like many others but it is much closer to the Earth at approximately 150 million kilometers. The next nearest star, Proxima Centuri is approximately 260,000 times further away from us than the Sun! The Sun is also known as *Sol*, it's Latin name.

Over the course of a year, the Sun appears to move round the celestial sphere in a great circle known as the *ecliptic.* Stellarium can draw the ecliptic on the sky. To toggle drawing of the ecliptic, press the '4' or ',' key.

WARNING: Looking at the Sun can permanently damage the eye. Never look at the Sun without using the proper filters! By far the safest way to observe the Sun it to look at it on a computer screen, courtesy of Stellarium!

F.2 Stars

The Sun is just one of billions of stars. Even though many stars have a much greater absolute magnitude than the Sun (the give out more light), they have an enormously smaller apparent magnitude due to their large distance. Stars have a variety of forms—different sizes, brightnesses, temperatures, even different colours. Measuring the position, distance and attributes of the stars is known as *astrometry*.

F.2.1 Multiple Star Systems.

Many stars have a stellar companions. As many as six stars can be found orbiting one-another in close association. Such associations are known a *multiple star systems*—*binary systems* being the most common with two stars. Multiple star systems are more common than solitary stars, putting our Sun in the minority group.

Sometimes multiple stars orbit one-another in a way that means one will periodically eclipse the other. These *eclipsing binaries* or *Agol variables*

Figure F.1: The constellation of Ursa Major

F.2.2 Optical Doubles & Optical Multiples

Sometimes two or more stars appear to be very close to one another in the sky, but in fact have great separation, being aligned from the point of view of the observer but of different distances. Such pairings are known as *optical doubles* and *optical multiples*.

F.2.3 Constellations

The constellations are groupings of stars that are visually close to one another in the sky. The actual groupings are fairly arbitrary—different cultures have group stars together into different constellations. In many cultures, the various constellations have been associated with mythological entities. As such people have often projected pictures into the skies as can be seen in figure F.1 which shows the constellation of Ursa Major. On the left is a picture with the image of the mythical Great Bear, on the right only a line-art version is shown. The seven bright stars of Ursa Major are widely recognised, known variously as "the plough", the "pan-handle", and the "big dipper". This sub-grouping is known as an *asterism*—a distinct grouping of stars. On the right, the picture of the bear has been removed and only a constellation diagram remains.

Stellarium can draw both constellation diagrams and artistic representations of the constellations. Multiple sky cultures are supported: Western, Polynesian, Egyptian and Chinese constellations are available, although at time of writing the non-Western constellations are not complete, and as yet there are no artistic representations of these sky-cultures.[1].

Aside from historical and mythological value, to the modern astronomer the constellations provide a way to segment the sky for the purposes of describing locations of objects, indeed one of the first tasks for an amateur observer is *learning the constellations*—the process of becoming familiar with the relative positions of the constellations, at what time of year a constellation is visible, and in which constellations observationally interesting objects reside. Internationally, astronomers have adopted the Western (Greek/Roman) constellations as a common system for segmenting the sky. As such some formalisation has been adopted, each constellation having a *proper name*, which is in Latin, and a three letter abbreviation of that name. For example, Ursa Major has the abbreviation UMa.

[1] Contributions of artwork for these sky cultures would be very welcome - post in the forums if you can help!

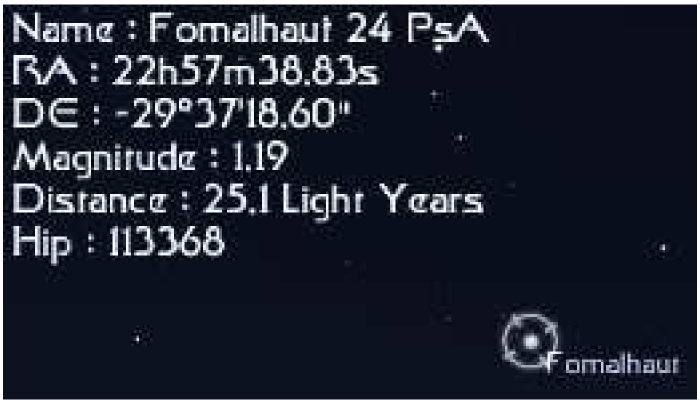

Figure F.2: Stellarium displaying information about a star

F.2.4 Star Names

Stars can have many names. The brighter stars often have *common names* relating to mythical characters from the various traditions. For example the brightest star in the sky, Sirius is also known as The Dog Star (the name Canis Major—the constellation Sirius is found in—is Latin for "The Great Dog").

There are several more formal naming conventions that are in common use.

F.2.4.1 Bayer Designation

German astronomer *Johan Bayer* devised one such system in the 16-17th century. His scheme names the stars according to the constellation in which they lie prefixed by a lower case Greek letter, starting at α for the brightest star in the constellation and proceeding with β, γ, ... in descending order of apparent magnitude. For example, such a *Bayer Designation* for Sirius is "α Canis Majoris" (note that the genitive form of the constellation name is used). There are some exceptions to the descending magnitude ordering, and some multiple stars (both real and optical) are named with a numerical superscript after the Greek letter, e.g.π^1... π^6 Orionis.

F.2.4.2 Flamsteed Designation

English astronomer *John Flamsteed* numbered stars in each constellation in order of increasing right ascension followed by the form of the constellation name, for example "61 Cygni".

F.2.4.3 Catalogues

As described in section F.11, various star catalogues assign numbers to stars, which are often used in addition to other names. Stellarium gets it's star data from the Hipparcos catalogue,and as such stars in Stellarium are generally referred to with their Hipparcos number, e.g. "HP 62223". Figure F.2 shows the information Stellarium displays when a star is selected. At the top, the common name and Flamsteed designation are shown, followed by the RA/Dec coordinates, apparent magnitude, distance and Hipparcos number.

F.2.5 Spectral Type & Luminosity Class

Stars have many different colours. Seen with the naked eye most appear to be white, but this is due to the response of the eye—at low light levels the eye is not sensitive

Spectral Type	Surface Temperature (°K)	Star Colour
O	28,000—50,000	Blue
B	10,000—28,000	Blue-white
A	7,500—10,000	White-blue
F	6,000—7,500	Yellow-white
G	4,900—6,000	Yellow
K	3,500—4,900	Orange
M	2,000—3,500	Red

Table F.1: Spectral Types

to colour. Typically the unaided eye can start to see differences in colour only for stars that have apparent magnitude brighter than 1. Betelgeuse, for example has a distinctly red tinge to it, and Sirius appears to be blue[2].

By splitting the light from a star using a prism attached to a telescope and measuring the relative intensities of the colours of light the star emits—the *spectra*—a great deal of interesting information can be discovered about a star including its surface temperature, and the presence of various elements in its atmosphere.

Astronomers groups stars with similar spectra into *spectral types*, denoted by one of the following letters: O, B, A, F, G, K and M[3]. Type O stars have a high surface temperature (up to around 50,000°K) while the at other end of the scale, the M stars are red and have a much cooler surface temperature, typically 3000°K. The Sun is a type G star with a surface temperature of around 5,500°K. Spectral types may be further sub-divided using a numerical suffixes ranging from 0-9 where 0 is the hottest and 9 is the coolest. Table F.1 shows the details of the various spectral types.

For about 90% of stars, the absolute magnitude increases as the spectral type tends to the O (hot) end of the scale. Thus the whiter, hotter stars tend to have a greater luminosity. These stars are called *main sequence* stars. There are however a number of stars that have spectral type at the M end of the scale, and yet they have a high absolute magnitude. These stars have a very large size, and consequently are known as *giants*, the largest of these known as *supergiantssuper-giants.*

There are also stars whose absolute magnitude is very low regardless of the spectral class. These are known as *dwarf stars*, among them *white dwarfs* and *brown dwarfs*.

A *luminosity class* is an indication of the type of star—whether it is main sequence, a giant or a dwarf. Luminosity classes are denoted by a number in roman numerals, as described in table F.2.

Plotting the luminosity of stars against their spectral type/surface temperature, gives a diagram called a Hertzsprung-Russell diagram (after the two astronomers *Ejnar Hertzsprung* and *Henry Norris Russell* who devised it).

F.2.6 Variables

Most stars are of nearly constant luminosity. The Sun is a good example of one which goes through relatively little variation in brightness (usually about 0.1% over an 11 year solar cycle). Many stars, however, undergo significant variations in luminosity, and these are known as *variable stars*. There are many types of variable stars falling into two categories *intrinsic* and *extrinsic*.

[2]Thousands of years ago Sirius was reported in many account to have a red tinge to it—a good explanation for which is yet to be found.

[3]A common aide to memory for the letters used in spectral types is the mnemonic "Oh Be A Fine Girl, Kiss Me".

Luminosity class	Description
Ia, Ib	Super-giants
II	Bright giants
III	Normal giants
IV	Sub-giants
V	Main sequence
VI	Sub-dwarfs
VII	White-dwarfs

Table F.2: Luminosity Class

Intrinsic variables are stars which have intrinsic variations in brightness, that is the star itself gets brighter and dimmer. There are several types of intrinsic variables, probably the best-known and more important of which is the Cepheid variable whose luminosity is related to the period with which it's brightness varies. Since the luminosity (and therefore absolute magnitude) can be calculated, Cepheid variables may be used to determine the distance of the star when the annual parallax is too small to be a reliable guide.

Extrinsic variables are stars of constant brightness that show changes in brightness as seen from the Earth. These include rotating variables, or stars whose apparent brightness change due to rotation, and eclipsing binaries.

F.3 Our Moon

The Moon is the large satellite which orbits the Earth approximately every 28 days. It is seen as a large bright disc in the early night sky that rises later each day and changes shape into a crescent until it disappears near the Sun. After this it rises during the day then gets larger until it again becomes a large bright disc again.

F.3.1 Phases of the Moon

F.4 The Major Planets

Unlike the stars whose relative positions remain constant, the planets seem to move across the sky over time (the word "planet" comes from the Greek for "wanderer"). The planets are, like the Earth, massive bodies that are in orbit around the Sun. Moving from the Sun outwards, the major planets are: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto[4].

F.4.1 Terrestrial Planets

F.4.2 Jovian Planets

F.4.3 Icy Planets

F.5 The Minor Planets

As well as the Major Planets, the solar system also contains innumerable smaller bodies in orbit around the Sun. These are generally classed as the *minor planets*, or *planetoids*, and include *asteroids*, and [sometimes?] comets.

[4]There is some controversy among astronomers as to whether Pluto should be considered one of the Major planets because of it's small size and eccentric orbit. There is also some controversy as to whether some other Pluto-like bodies should be added to the list.

F.5.1 Asteroids

Asteroids are celestial bodies orbiting the Sun in more or less regular orbits mostly between Mars and Jupiter. They are generally rocky bodies like the inner (terrestrial) planets, but of much smaller size. There are countless in number ranging in size from about ten meters to thousands of kilometres.

Note that are time of writing, Stellarium does not simulate comets.

F.5.2 Comets

A comet is a small body in the solar system that orbits the Sun and (at least occasionally) exhibits a coma (or atmosphere) and/or a tail.

Comets have a very eccentric orbit (very elliptical), and as such spend most of their time a very long way from the Sun. Comets are composed of rock, dust and ices. When they come close to the Sun, the heat evaporates the ices, causing a gaseous release. This gas, and loose material which comes away from the body of the comet is swept away from the Sun by the Solar wind, forming the tail.

Comets whose orbit brings them close to the Sun more frequently than every 200 years are considered to be *short period* comets, the most famous of which is probably Comet Halley, named after the British astronomer Edmund Halley, which has an orbital period of roughly 76 years.

Note that are time of writing, Stellarium does not simulate comets.

F.6 Galaxies

Galaxies are fuzzy blobs in the sky. They represent the light emitted from groups of countless stars too far away to be discernible except in all but the largest of telescopes. Only four are normally visible to the naked eye. The Andromeda galaxy (M31) visible in the Northern hemisphere, the two Magellanic clouds, visible in the Southern hemisphere, and the home galaxy Milky Way, visible in parts from north and south under dark skies.

F.7 The Milky Way

...Is the big fuzzy stripe in the sky.

F.8 Nebulae

Nebulae are also fuzzy blobs in the sky. Nebulae are also fuzzy blobs in the sky. They are mostly glowing clouds of ionized hydrogen or reflections of star light on dust and other gases. They are of immense size that represent the basic atoms of matter from which the universe is constructed. They can also be the remains of exploded stars (novae and supernovae). Some other objects such as un-resolved star clusters and galaxies have also been mistakenly referred to as nebulae.

F.9 Meteors, Meteorites and Meteoroids

These objects are small pieces of space debris left over from the early days of the solar system that orbit the Sun. They may be thought of as the bits that were left over after the Sun and planets were formed. They come in a variety of shapes, sizes an compositions, ranging from microscopic dust particles to about ten meters across.

Sometimes these objects collide with the Earth. The closing speed of these collisions is generally extremely high (tens or kilometers per second). When such an object ploughs through the Earth's atmosphere, a large amount of kinetic energy is converted into heat and light, and a visible flash or streak can often be seen with the naked eye. Even the smallest particles can cause these events which are commonly known as *shooting stars*.

While smaller objects tend to burn up in the atmosphere, larger, denser objects can penetrate the atmosphere and strike the surface, sometimes leaving meteor craters.

Sometimes the angle of the collision means that larger objects pass through the atmosphere but do not strike the Earth. When this happens, spectacular fireballs are sometimes seen.

Meteoroids is the name given to such objects when they are floating in space.

A *Meteor* is the name given to the visible atmospheric phenomenon.

Meteorites is the name given to objects that penetrate the atmosphere and land on the surface.

F.10 Eclipses

Eclipses occur when an apparently large celestial body (planet, moon etc.) moves between the observer (that's you!) and a more distant object.

F.10.1 Solar Eclipses

Solar eclipses occur when our Moon moves between the Earth and the Sun. This happens when the inclined orbit of the Moon causes its path to cross our line of sight to the Sun. In essence it is the observer falling under the shadow of the moon.

There are three types of solar eclipses:

Partial The Moon only covers part of the Sun's surface.

Total The Moon completely obscures the Sun's surface.

Annular The Moon is at aphelion (furthest from Earth in its elliptic orbit) and its disc is too small to completely cover the Sun. In this case most of the Sun's disc is obscured - all except a thin ring around the edge.

F.10.2 Lunar Eclipses

Lunar eclipses occur when the Earth moves between the Sun and the Moon, and the Moon is in the Earth's shadow. They occur under the same basic conditions as the solar eclipse but can occur more often because the Earth's shadow is so much larger than the Moon's.

Total lunar eclipses are more noticeable than partial eclipses because the Moon moves fully into the Earth's shadow and there is very noticeable darkening. However, the Earth's atmosphere refracts light (bends it) in such a way that some sunlight can still fall on the Moon's surface even during total eclipses. In this case there is often a marked reddening of the light as it passes through the atmosphere, and this can make the Moon appear a deep red colour.

F.11 Astronomical Catalogues

F.11.1 Hipparcos

Hipparcos (for High Precision Parallax Collecting Satellite) was an astrometry mission of the European Space Agency (ESA) dedicated to the measurement of stellar parallax and the proper motions of stars. The project was named in honor of the Greek astronomer Hipparchus.

Ideas for such a mission dated from 1967, with the mission accepted by ESA in 1980. The satellite was launched by an Ariane 4 on 8 August 1989. The original goal was to place the satellite in a geostationary orbit above the earth, however a booster rocket failure resulted in a highly elliptical orbit from 315 to 22,300 miles altitude. Despite this difficulty, all of the scientific goals were accomplished. Communications were terminated on 15 August 1993.

The program was divided in two parts: the *Hipparcos experiment* whose goal was to measure the five astrometric parameters of some 120,000 stars to a precision of some 2 to 4 milli arc-seconds and the *Tycho experiment*, whose goal was the measurement of the astrometric and two-colour photometric properties of some 400,000 additional stars to a somewhat lower precision.

The final Hipparcos Catalogue (120,000 stars with 1 milli arc-second level astrometry) and the final Tycho Catalogue (more than one million stars with 20-30 milli arc-second astrometry and two-colour photometry) were completed in August 1996. The catalogues were published by ESA in June 1997. The Hipparcos and Tycho data have been used to create the Millennium Star Atlas: an all-sky atlas of one million stars to visual magnitude 11, from the Hipparcos and Tycho Catalogues and 10,000 non-stellar objects included to complement the catalogue data.

There were questions over whether Hipparcos has a systematic error of about 1 milli arc-second in at least some parts of the sky. The value determined by Hipparcos for the distance to the Pleiades is about 10% less than the value obtained by some other methods. By early 2004, the controversy remained unresolved.

Stellarium uses the Hipparcos Catalogue for star data, as well as having traditional names for many of the brighter stars. The stars tab of the search window allows for searching based on a Hipparcos Catalogue number (as well as traditional names), e.g. the star Sadalmelik in the constellation of Aquarius can be found by searching for the name, or it's Hipparcos number, 109074.

F.11.2 The Messier Objects

The *Messier* objects are a set of astronomical objects catalogued by Charles Messier in his catalogue of *Nebulae and Star Clusters* first published in 1774. The original motivation behind the catalogue was that Messier was a comet hunter, and was frustrated by objects which resembled but were not comets. He therefore compiled a list of these objects.

The first edition covered 45 objects numbered M1 to M45. The total list consists of 110 objects, ranging from M1 to M110. The final catalogue was published in 1781 and printed in the *Connaissance des Temps* in 1784. Many of these objects are still known by their Messier number.

Because the Messier list was compiled by astronomers in the Northern Hemisphere, it contains only objects from the north celestial pole to a celestial latitude of about -35°. Many impressive Southern objects, such as the Large and Small Magellanic Clouds are excluded from the list. Because all of the Messier objects are visible with binoculars or small telescopes (under favorable conditions), they are popular viewing objects for amateur astronomers. In early spring, astronomers sometimes gather for ”Messier Marathons”, when all of the objects can be viewed over a single night.

Stellarium includes images of most Messier objects.

F.12 Observing Hints

When star-gazing, there’s a few little things that make a lot of difference.

Dark skies For many people getting away from light pollution isn’t an easy thing. At best it means a drive away from the towns, and for many the only chance to see a sky without significant glow from street lighting is on vacation. If you can’t get away from the cities easily, make the most of it when you are away.

Wrap up warm The best observing conditions are the same conditions that make for cold nights, even in the summer time. Observing is not a strenuous physical activity, so you will feel a the cold a lot more than if you were walking around. Wear a lot of warm clothing, don’t sit/lie on the floor (at least use a camping mat), and

Dark adaption The true majesty of the night sky only becomes apparent when the eye has had time to become accustomed to the dark. This process, known as dark adaption, can take up to half, and as soon as the observer sees a bright light they must start the process over. Red light doesn’t compromise dark adaption as much as white light, so use a red torch of possible (and one that is as dim as you can manage with). A single red LED light is ideal.

The Moon Unless you’re particularly interested in observing the Moon, it can be a nuisance—it can be so bright as to make observation of dimmer objects such as nebulae impossible. When planning what you want to observe, take the phase and position of the Moon into account. Of course Stellarium is the ideal tool for finding this out!

Averted vision A curious fact about the eye is that it is more sensitive to light towards the edge of the field of view. If an object is just too dim to see directly, looking slightly off to the side but concentrating on the object’s location can often reveal it.

Angular distance Learn how to estimate angular distances. Learn the angular distances described in section F.13. If you have a pair of binoculars, find out the angular distance across the field of view[5] and use this as a standard measure.

F.13 Handy Angles

Being able to estimate angular distance can be very useful when trying to find objects from star maps in the sky. One way to do this with a device called a *crossbow*[6].

[5] Most binoculars state the field of view somewhere on the body of the instrument. Failing that, check the documentation (if you have any) or check with the manufacturer.

[6] A “crossbow” is essentially a stick with a ruler attached to the end. The non-ruler end of the stick is held up to the face and the user sights along the stick towards the object that is being observed. The length of the stick is such that the markings on the ruler are a known angular distance apart (e.g. 1°). The markings on the ruler are often marked with luminescent paint for night-time use. Vanderbilt Universtiy’s site has a nice illustration of the design and use of a “crossbow”. The ruler is held in a curve by a piece of string, giving a better indication of the reason for the name. The curve is there to make all parts of the ruler perpendicular to the line of sight which improves the accuracy of the device.

Crossbows are a nice way get an idea of angular distances, but carrying one about is a little cumbersome. A more convenient alternative is to hold up an object such as a pencil at arm's length. If you know the length of the pencil, d, and the distance of it from your eye, D, you can calculate it's angular size, θ using this formula:

$$\theta = 2 \cdot \arctan(\frac{d}{2D})$$

Another, more handy (ahem!) method is to use the size of your hand at arm's length:

Tip of little finger About 1°

Middle three fingers About 4°

Across the knuckles of the fist About 10°

Open hand About 18°

Using you hand in this way is not very precise, but it's useful enough to give you some way to translate an idea like "Mars will be 45° above the Southeastern horizon at 21:30". Of course, there is variation from person to person, but the variation is compensated for somewhat by the fact that people with long arms tend to have larger hands. In exercise H.2, you will work out your own "handy angles".

Appendix G

Sky Guide

This section lists some astronomical objects that can be located using Stellarium. All of them can be seen with the naked eye or binoculars. Since many astronomical objects have more than one name (often having a 'proper name', a 'common name' and various catalogue numbers), the table lists the name as it appears in Stellarium—use this name when using Stellarium's search function—and any other commonly used names.

The Location Guide column gives brief instructions for finding each object using nearby bright stars or groups of stars when looking at the real sky - a little time spent learning the major constellations visible from your latitude will pay dividends when it comes to locating fainter (and more interesting!) objects. When trying to locate these objects in the night sky, keep in mind that Stellarium displays many stars that are too faint to be visible without optical aid and even bright stars can be dimmed by poor atmospheric conditions and light pollution.

Stellarium Name	*Other Name(s)*	*Type*	*Magnitude*	*Location Guide*	*Description*
Dubhe and Merak	The Pointers	Stars	1.83, 2.36	The two 'rightmost' of the seven stars that form the main shape of 'The Plough' (Ursa Major).	Northern hemisphere observers are very fortunate to have two stars that point towards Polaris which lie very close to the northern celestial pole). Whatever the time of night or season of the year they are always an immediate clue to the location of the pole star.
M31	Messier 31 The Andromeda Galaxy	Spiral Galaxy	3.4	Find the three bright stars that constitute the main part of the constellation of Andromeda. From the middle of these look toward the constellation of Cassiopeia.	M31 is the most distant object visible to the naked eye, and among the few nebulae that can be seen without a telescope or powerful binoculars. Under good conditions it appears as a large fuzzy patch of light. It is a galaxy containing billions of stars whose distance is roughly three million light years from Earth.

Stellarium Name	*Other Name(s)*	*Type*	*Magnitude*	*Location Guide*	*Description*
The Garnet Star	Mu Cephei	Star	4.25 (Variable)	Cephius lies 'above' the W-shape of Cassiopeia. The Garnet Star lies slightly to one side of a point half way between 5 Cephei and 21 Cephei.	A 'supergiant' of spectral class M with a strong red colour. Given it's name by Sir William Herschel in the 18th century, the colour is striking in comparison to it's blue-white neighbours.
4 and 5 Lyrae	Epsilon Lyrae	Double Star	4.7	Look near to Vega (Alpha Lyrae), one of the brightest stars in the sky.	In binoculars epsilon Lyrae is resolved into two separate stars. Remarkably each of these is also a double star (although this will only be seen with a telescope) and all four stars form a physical system.
M13	Hercules Cluster	Globular Cluster	5.8	Located approximately of the way along a line from 40 to 44 Herculis.	This cluster of hundreds of thousands of mature stars that appears as a circular 'cloud' using the naked eye or binoculars (a large telescope is required to resolve individual stars). Oddly the cluster appears to contain one young star and several areas that are almost devoid of stars.
M45	The Pleiades, The Seven Sisters	Open Cluster	1.2 (Avg.)	Lies a little under halfway between Aldebaran in Taurus and Almaak in Andromeda.	Depending upon conditions, six to 9 of the blueish stars in this famous cluster will be visible to someone with average eyesight and in binoculars it is a glorious sight. The cluster has more than 500 members in total, many of which are shown to be surrounded by nebulous material in long exposure photographs.

Stellarium Name	*Other Name(s)*	*Type*	*Magnitude*	*Location Guide*	*Description*
Algol	The Demon Star, Beta Persei	Variable Star	3.0 (Avg.)	Halfway between Aldebaran in Taurus and the middle star of the 'W' of Cassiopeia.	Once every three days or so Algol's brightness changes from 2.1 to 3.4 and back within a matter of hours. The reason for this change is that Algol has a dimmer giant companion star, with an orbital period of about 2.8 days, that causes a regular partial eclipse. Although Algol's 'uctuations in magnitude have been known since at least the 17th century it was the ↓rst to be proved to be due to an eclipsing companion - it is therefore the prototype Eclipsing Variable.
Sirius	Alpha Canis Majoris	Star	-1.47	Sirius is easily found by following the line of three stars in Orion's belt southwards.	Sirius is a white dwarf star at a comparatively close 8.6 light years. This proximity and it's high innate luminance makes it the brightest star in our sky. Sirius is a double star; it's companion is much dimmer but very hot and is believed to be smaller than the earth.
M44	The Beehive, Praesepe	Open Cluster	3.7	Cancer lies about halfway between the twins (Castor & Pollux) in Gemini and Regulus, the brightest star in Leo. The Beehive can be found between Asellus Borealis and Asellus Australis.	There are probably 350 or so stars in this cluster although it appears to the naked eye simply as a misty patch. It contains a mixture of stars from red giants to white dwarf and is estimated to be some 700 million years old.
27 Cephei	Delta Cephei	Variable Star	4.0 (Avg.)	Locate the four stars that form the square of Cepheus. One corner of the square has two other bright stars nearby forming a distinctive triangle - delta is at the head of this triangle in the direction of Cassiopeia.	Delta Cephei gives it's name to a whole class of variables, all of which are pulsating high-mass stars in the later stages of their evolution. Delta Cephei is also a double star with a companion of magnitude 6.3 visible in binoculars.

Stellarium Name	*Other Name(s)*	*Type*	*Magnitude*	*Location Guide*	*Description*
M42	Orion Nebula	Nebula	4	Almost in the middle of the area bounded by Orion's belt and the stars Saiph and Rigel.	The Orion Nebula is the brightest nebula visible in the night sky and lies at about 1,500 light years from earth. It is a truly gigantic gas and dust cloud that extends for several hundred light years, reaching almost halfway across the constellation of Orion. The nebula contains a cluster of hot young stars known as the Trapezium and more stars are believed to be forming within the cloud.
HP 62223	La Superba, Y Canum Venaticorum	Star	5.5 (Avg.)	Forms a neat triangle with Phad and Alkaid in Ursa Major.	La Superba is a 'Carbon Star' - a group of relatively cool gigantic (usually variable) stars that have an outer shell containing high levels of carbon. This shell is very e¡cient at absorbing short wavelength blue light, giving carbon stars a distinctive red or orange tint.
52 & 53 Bootis	Nu Bootis 1 & 2	Double Star	5.02, 5.02	Follow a line from Seginus to Nekkar and then continue for the same distance again to arrive at this double star.	This pair are of di†erent spectral type and 52 Bootis, at approximately 800 light years, is twice as far away as 53.

Appendix H

Exercises

H.1 Find M31 in Binoculars

M31—the Andromeda Galaxy—is the most distant object visible to the naked eye. Finding it in binoculars is a rewarding experience for new-comers to observing.

H.1.1 Simulation

1. Set the location to a mid-Northern latitude if necessary (M31 isn't visible for Southern hemisphere observers). The UK is ideal.

2. Find M31 and set the time so that the sky is dark enough to see it. The best time of year for this at Northern latitudes is Autumn/Winter, although there should be a chance to see it at some time of night throughout the year.

3. Set the field of view to 6° (or the field of view of your binoculars if they're different. 6° is typical for 7x50 bins).

4. Practise finding M31 from the bright stars in Cassiopeia and the constellation of Andromeda.

H.1.2 For Real

This part is not going to be possible for many people. First, you need a good night and a dark sky. In urban areas with a lot of light pollution, it's going to be very hard to see Andromeda.

H.2 Handy Angles

As described in section F.13, your hand at arm's length provides a few useful estimates for angular size. It's useful to know if your handy angles are typical, and if not, what they are. The method here below is just one way to do it—feel free to use another method of your own construction!

Hold your hand at arm's length with your hand open—the tips of your thumb and little finger as far apart as you can comfortably hold them. Get a friend to measure the distance between your thumb and your eye, we'll call this D. There is a tendency to over-stretch the arm when someone is measuring it—try to keep the thumb-eye distance as it would be if you were looking at some distant object.

Without changing the shape of your hand, measure the distance between the tips of your thumb and little finger. It's probably easiest to mark their positions on a piece of paper and measure the distance between the marks, we'll call this d. Using some simple trigonometry, we can estimate the angular distance θ:

Repeat the process for the distance across a closed fist, three fingers and the tip of the little finger.

For example, for the author $D = 72$ cm, $d = 21$ cm, so:

$$\begin{aligned}\theta &= 2 \cdot \arctan(\frac{21}{144}) \\ \theta &\approx 16\frac{1}{2}^{\circ}\end{aligned}$$

Remember that handy angles are not very precise—depending on your posture at a given time the values may vary by a fair bit.

H.3 Find a Lunar Eclipse

H.4 Find a Solar Eclipse

H.5 Apollo 11 Moon

Appendix I

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