The KStars Handbook

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Abstract

KStars is a graphical desktop planetarium for KDE. It depicts an accurate simulation of the night sky, including stars, constellations, star clusters, nebulae, galaxies, all planets, the Sun, the Moon, comets and asteroids. You can see the sky as it appears from any location on Earth, on any date. The user interface is highly intuitive and flexible; the display can be panned and zoomed with the mouse, and you can easily identify objects, and track their motion across the sky. KStars includes many powerful features, yet the interface is clean and simple, and fun to use.

Chapter 1

Introduction

KStars lets you explore the night sky from the comfort of your computer chair. It provides an accurate graphical representation of the night sky for any date, from any location on Earth. The display includes 126,000 stars to 9th magnitude (well below the naked-eye limit), 13,000 deep-sky objects (Messier, NGC, and IC catalogs), all planets, the Sun and Moon, hundreds of comets and asteroids, the Milky Way, 88 constellations, and guide lines such as the celestial equator, the horizon and the ecliptic.

However, KStars is more than a simple night-sky simulator. The display provides a compelling interface to a number of tools with which you can learn more about astronomy and the night sky. There is a context-sensitive popup menu attached to each displayed object, which displays object-specific information and actions. Hundreds of objects provide links in their popup menus to informative web pages and beautiful images taken by the Hubble Space Telescope and other observatories.

From an object's popup menu, you can open its Detailed Information Window, where you can examine positional data about the object, and query a huge treasury of online databases for professional-grade astronomical data and literature references about the object. You can even attach your own internet links, images and text notes, making KStars a graphical front-end to your observing logs and your personal astronomical notebook.

Our Astrocalculator tool provides direct access to many of the algorithms the program uses behind the scenes, including coordinate converters and time calculators. The AAVSO Lightcurve Generator tool will download a lightcurve for any of the 6000+ variable stars monitored by the American Association of Variable Star Observers (AAVSO). The lightcurves are generated 'on the fly' by querying the AAVSO server directly, ensuring that you have the very latest data points.

You can plan an observing session using our Altitude vs. Time tool, which will plot curves representing the Altitude as a function of time for any group of objects. If that is too much detail, we also provide a What's Up Tonight? tool

that summarizes the objects that you will be able to see from your location on any given night. You can add your favorite objects to the Observing List tool, which provides convenient access to common actions for a list of objects.

KStars also provides a Solar System Viewer, which shows the current configuration of the major planets in our solar system. There is also a Jupiter Moons Tool which shows the positions of Jupiter's four largest moons as a function of time.

Our primary goal is to make KStars an interactive educational tool for learning about astronomy and the night sky. To this end, the KStars Handbook includes the AstroInfo Project, a series of short, hyperlinked articles on astronomical topics that can be explored with KStars. In addition, KStars includes DBUS functions that allow you to write complex scripts, making KStars a powerful "demo engine" for classroom use or general illustration of astronomical topics.

However, KStars is not just for students. You can control telescopes and cameras with KStars, using the elegant and powerful INDI protocol. KStars supports several popular telescopes including Meade's LX200 family and Celestron GPS. Several popular CCD cameras, webcams, and computerized focusers are also supported. Simple slew/track commands are integrated directly into the main window's popup menu, and the INDI Control Panel provides full access to all of your telescope's functions. INDI's Client/Server architecture allows for seamless control of any number of local or remote telescopes using a single KStars session.

We are very interested in your feedback; please report bugs or feature requests to the KStars development mailing list: kstars-devel@kde.org. You can also use the automated bug reporting tool, accessible from the Help menu.

Chapter 2

A Quick Tour of KStars

This chapter presents a guided tour of KStars, introducing many of its important features.
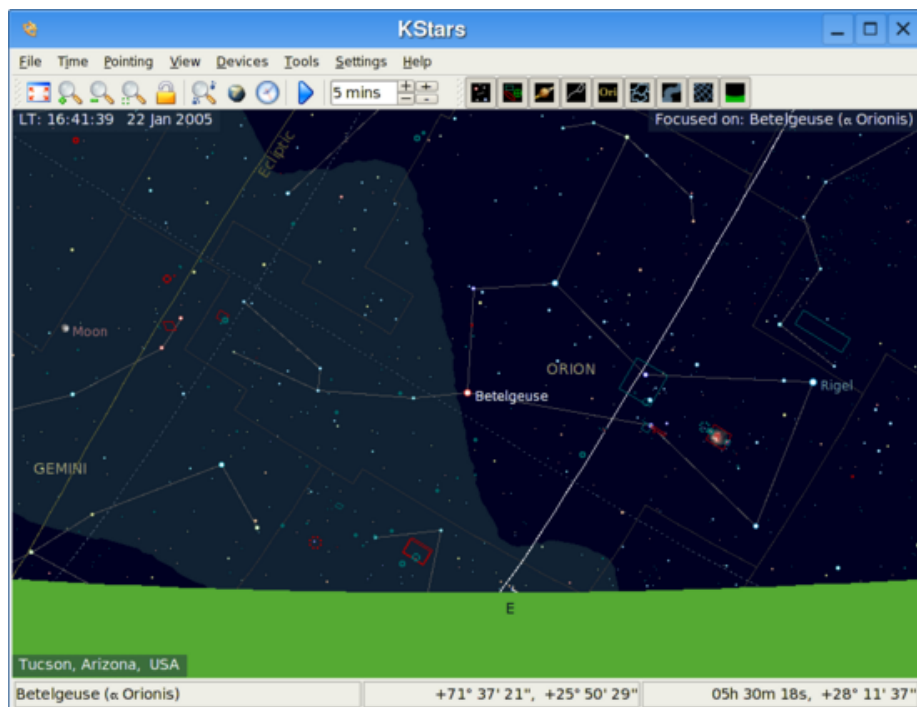
The above screenshot shows a typical view of the KStars program. You can see the sky display centered on Betelgeuse, the brightest star in the constellation Orion. Orion has just risen above the eastern horizon. Stars are displayed with realistic colors and relative brightnesses. In three corners of the sky display, there are on-screen text labels displaying data on the current time ('LT: 16:38:42

23 Jan 2008'), the current Geographic Location ('Tucson, Arizona, USA'), and the current object in the center of the display ('Focused on: Betelgeuse (alpha Orionis)'). Above the sky display, there are two toolbars. The main toolbar contains shortcuts for menu functions, as well as a time-step widget which controls how fast the simulation clock runs. The view toolbar contains buttons that toggle the display of different kinds of objects in the sky. At the bottom of the window, there is a status bar which displays the name of any object you click on, and the sky coordinates (both Right Ascension/Declination and Azimuth/Altitude) of the mouse cursor.

2.1 The Setup Wizard

The first time you run KStars, you will be presented with a Setup Wizard, which allows you to easily set your geographic location and download some extra data files. You can press the Finish button at any time to exit the Setup Wizard.

The first page of the Setup Wizard allows you to choose the starting geographic location, by selecting from the list of the 2500+ known locations on the right side of the window. The list of locations can be filtered to match the text you enter in the City, Province, and Country edit boxes. If your desired location is not present in the list, you can select a nearby city instead for now. Later on, you can add your precise location manually using the Set Geographic Location tool. Once you have selected a starting location, press the Next button.

The second page of the Setup Wizard allows you to download extra data that are not included with the standard distribution of KStars. Simply press the Download Extra Data button to open the Get New Stuff tool. When you are all done, press the Finish button in the Setup Wizard to start exploring KStars.

2.2 Have a Look Around

Now that we have the time and location set, let us have a look around. You can pan the display using the arrow keys. If you hold down the **Shift** key before panning, the scrolling speed is increased. The display can also be panned by clicking and dragging with the mouse. Note that while the display is scrolling, not all objects are displayed. This is done to cut down on the CPU load of recomputing object positions, which makes the scrolling smoother (you can configure what gets hidden while scrolling in the Configure KStars window). There are several ways to change the magnification (or *Zoom level*) of the display:

1. Use the **+** and **-** keys

2. Press the Zoom In/Zoom Out buttons in the toolbar

3. Select Zoom In/Zoom Out from the View menu

4. Select Zoom to Angular Size... from the View menu. This allows you to specify the the field-of-view angle for the display, in degrees.

5. Use the scroll wheel on your mouse

6. Drag the mouse up and down with the middle mouse button pressed.

7. Hold down **Ctrl** while dragging the mouse. This will allow you to define a rectangle in the map. When you release the mouse button, the display will zoom to match the rectangle.

Notice that as you zoom in, you can see fainter stars than at lower zoom settings.

Zoom out until you can see a green curve; this represents your local horizon. If you have not adjusted the default KStars configuration, the display will be solid green below the horizon, representing the solid ground of the Earth. There is also a white curve, which represents the celestial equator, and a brown curve, which represents the Ecliptic, the path that the Sun appears to follow across the sky over the course of a year. The Sun is always found somewhere along the Ecliptic, and the planets are never far from it.

2.3 Objects in the Sky

KStars displays thousands of celestial objects: stars, planets, comets, asteroids, clusters, nebulae and galaxies. You can interact with displayed objects to perform actions on them or obtain more information about them. Clicking on an object will identify it in the status bar, and simply hovering the mouse cursor on an object will label it temporarily in the map. Double-clicking will recenter the display on the object and begin tracking it (so that it will remain centered as time passes). Right clicking an object opens the object's popup menu, which provides more options.

2.3.1 The Popup Menu

Here is an example of the right click popup menu, for the Orion Nebula:

```
                    M 42
                Orion Nebula
               gaseous nebula
                    Orion
              Rise time: 16:01
              Transit time: 21:50
              Set time: 03:37

          Center & Track
          Angular Distance To...          [
          Details
          Attach Label
          Add to List

          Show HST Image
          Show SEDS Image
          Show KPNO AOP Image
          Show NOAO Image
          Show VLT Image
          Show 1st-Gen DSS Image
          Show 2nd-Gen DSS Image

          Wikipedia Page
          SEDS Information Page

          Add Link...
```

The appearance of the popup menu depends somewhat on the kind of object you right-click on, but the basic structure is listed below. You can get more detailed information about the popup menu.

The top section contains some lines of information which are not selectable: the object's names ("M 42"; "Orion Nebula"), object type ("gaseous nebula"), and the constellation which contains the object ("Ori"). The next three lines show the object's rise, set, and transit times. If the rise and set times say "circumpolar", it means that the object is always above the horizon for the present location.

The middle section contains actions which can be performed on the selected object, such as Center and Track, Details..., and Attach Label. See the popup menu description for a full list and description of each action.

The bottom section contains links to images and/or informative webpages

about the selected object. If you know of an additional URL with information or an image of the object, you can add a custom link to the object's popup menu using the Add Link... item.

2.3.2 Finding Objects

You can search for named objects using the Find Object tool, which can be opened by clicking on the search icon in the toolbar, by selecting Find Object... from the Pointing menu, or by pressing Ctrl+F. The Find Object window is shown below:
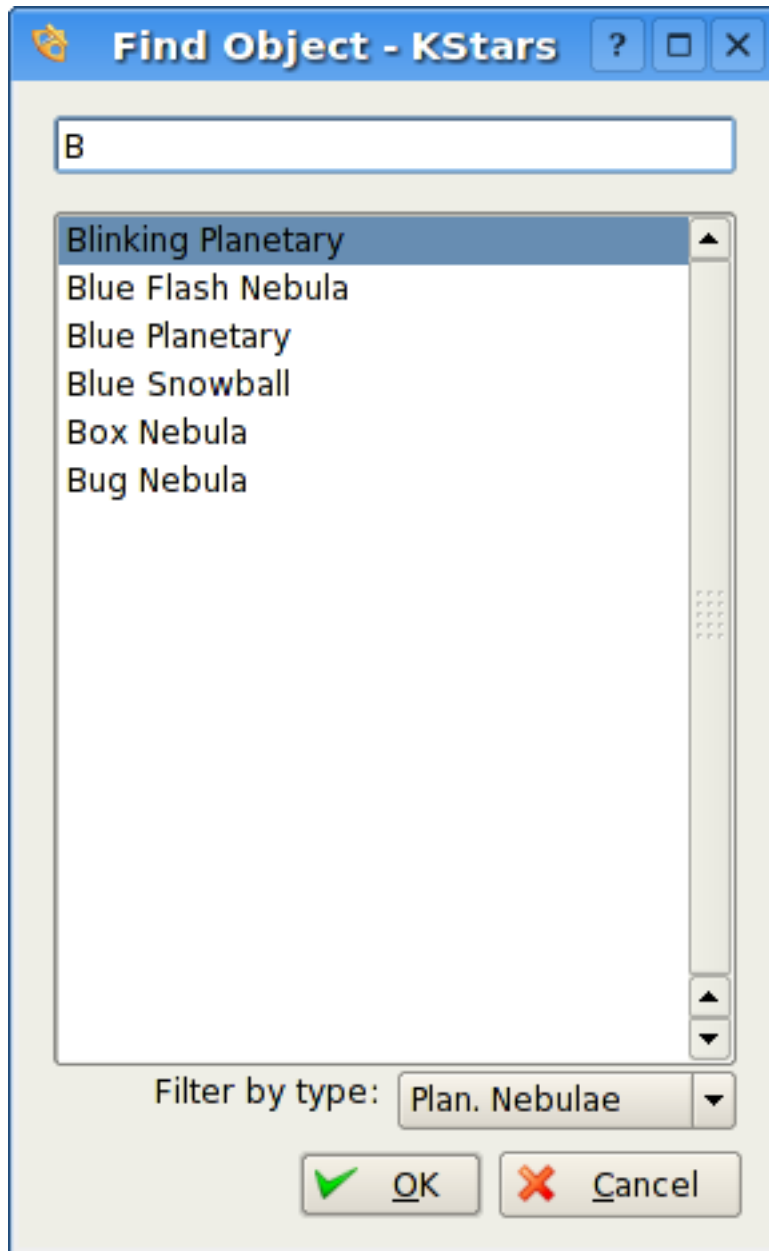
The window contains a list of all the named objects that KStars is aware of. Many of the objects only have a numeric catalog name (for example, NGC 3077), but some objects have a common name as well (for example, Whirlpool Galaxy). You can filter the list by name and by object type. To filter by name, enter a string in the edit box at the top of the window; the list will then only contain names which start with that string. To filter by type, select a type from the combo box at the bottom of the window.

To center the display on an object, highlight the desired object in the list, and press Ok. Note that if the object is below the horizon, the program will warn you that you may not see anything except the ground (you can make the ground invisible in the Display Options window, or by pressing the Ground button in the View toolbar).

2.3.3 Centering and Tracking

KStars will automatically begin tracking on an object whenever one is centered in the display, either by using the Find Object window, by double-clicking on it, or by selecting Center and Track from its right-click popup menu. You can disengage tracking by panning the display, pressing the Lock icon in the Main toolbar, or selecting Track Object from the Pointing menu.

> NOTE
>
> When tracking on a Solar System body, KStars will automatically attach an 'orbit trail', showing the path of the body across the sky. You will likely need to change the clock's timestep to a large value (such as '1 day') to see the trail.

2.3.4 Keyboard Actions

When you click on an object in the map, it becomes the *selected object*, and its name is identified in the statusbar. There are a number of quick key commands available which act on the selected object:

C Center and Track on the selected object

D Show the Details window for the selected object

L Toggle a visible name label on the selected object

O Add the selected object to the Observing List

T Toggle a visible curve on the sky, showing the path of the object across the sky (only applicable to Solar System bodies)

> NOTE
>
> By holding down the **Alt** key, you can perform these actions on the centered object, rather than the selected object.

2.4 End of the Tour

This concludes the tour of KStars, although we have only scratched the surface of the available features. KStars includes many useful astronomy tools, it can directly control your telescope, and it offers a wide variety of configuration and customization options. In addition, this Handbook includes the AstroInfo Project, a series of short, interlinked articles explaining some of the celestial and astrophysical concepts behind KStars.

Chapter 3

Configuring KStars

3.1 Setting the Geographic Location

Here is a screenshot of the Set Geographic Location window:
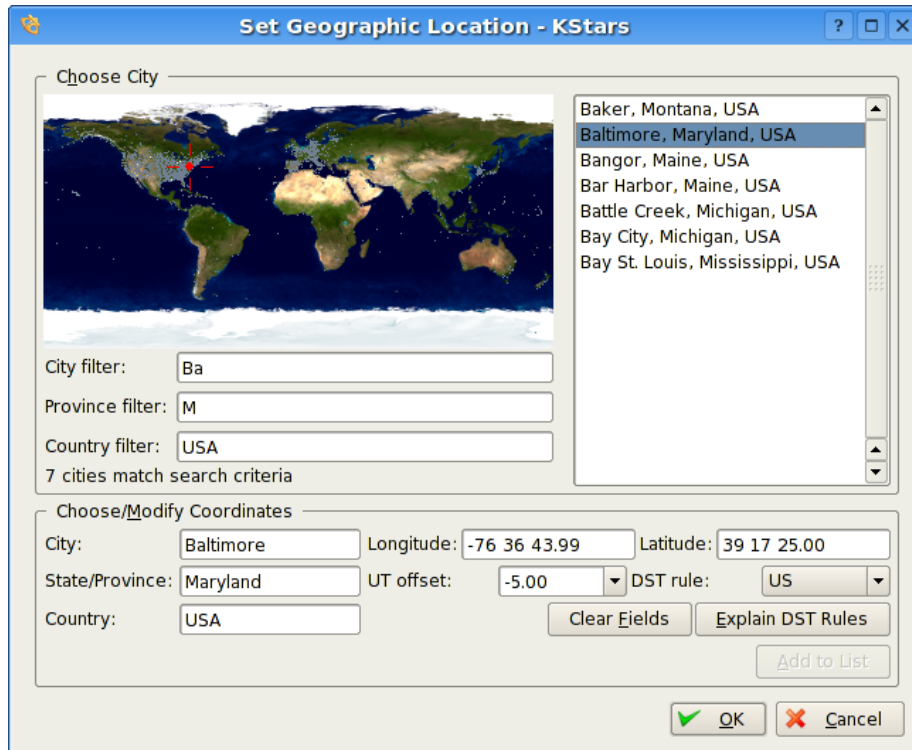
There is a list of over 2500 predefined cities available to choose from. You set your location by highlighting a city from this list. Each city is represented in

the world map as a small dot, and when a city is highlighted in the list, a red crosshairs appears on its location in the map.

It is not practical to scroll through the full list of 2500 locations, looking for a specific city. To make searches easier, the list can be filtered by entering text in the boxes below the map. For example, in the screenshot, the text 'Ba' appears in the City Filter box, while 'M' has been entered in the Province Filter box, and 'USA' is in the Country Filter box. Note that all of the cities displayed in the list have city, province, and country names that begin with the entered filter strings, and that the message below the filter boxes indicates that 7 cities are matched by the filters. Also notice that the dots representing these seven cities in the map have been colored white, while the unmatched cities remain gray.

The list can also be filtered by location in the map. Clicking anywhere in the world map will show only those cities within two degrees of the clicked location. At this time, you can search by name, or by location, but not both at once. In other words, when you click on the map, the name filters are ignored, and vice versa.

The longitude, latitude and time zone information for the currently-selected location are displayed in the boxes at the bottom of the window. If you feel that any of these values are inaccurate, you can modify them and press the Add to List button to record your custom version of the location. You can also define a completely new location by pressing the Clear Fields button, and entering the data for the new location. Note that all fields except the optional State/Province must be filled before the new location can be added to the list. KStars will automatically load your custom locations for all future sessions. Please note, at this point, the only way to remove a custom location is to remove the appropriate line from the file `/.kde/share/apps/kstars/mycities.dat`.

If you add custom locations (or modify existing ones), please send us your `mycities.dat` file so that we can add your locations to the master list.

3.2   Setting the Time

When KStars starts up, the time is set to your computer's system clock, and the KStars clock is running to keep up with the real time. If you want to stop the clock, select Stop Clock from the Time menu, or simply click on the Pause icon in the toolbar. You can make the clock run slower or faster than normal, or even make it run backward, using the time-step spinbox in the toolbar. This spinbox has two sets of up/down buttons. The first one will step through all 83 available time steps, one by one. The second one will skip to the next higher (or lower) unit of time, which allows you to make large timestep changes more quickly.

You can set the time and date by selecting Set Time... from the Time menu, or by pressing the time icon in the toolbar. The Set Time window uses a standard KDE Date Picker widget, coupled with three spinboxes for setting the hours, minutes and seconds. If you want to re-synchronize the simulation clock back to the current CPU time, just select Set Time to Now from the Time menu.

> NOTE
> KStars can accept very remote dates beyond the usual limits imposed by QDate.
> Currently, you can set the date between the years -50000 and +50000. We may
> extend this range even further in future releases. However, please be aware that
> the accuracy of the simulation becomes more and more degraded as more remote
> dates are examined. This is especially true for the positions of solar system bodies.

3.3 The Configure KStars Window

The Configure KStars window allows you to modify a wide range of display
options. You can access the window with the configure toolbar icon, or by
selecting Configure KStars... from the Settings menu. The window is depicted
below:
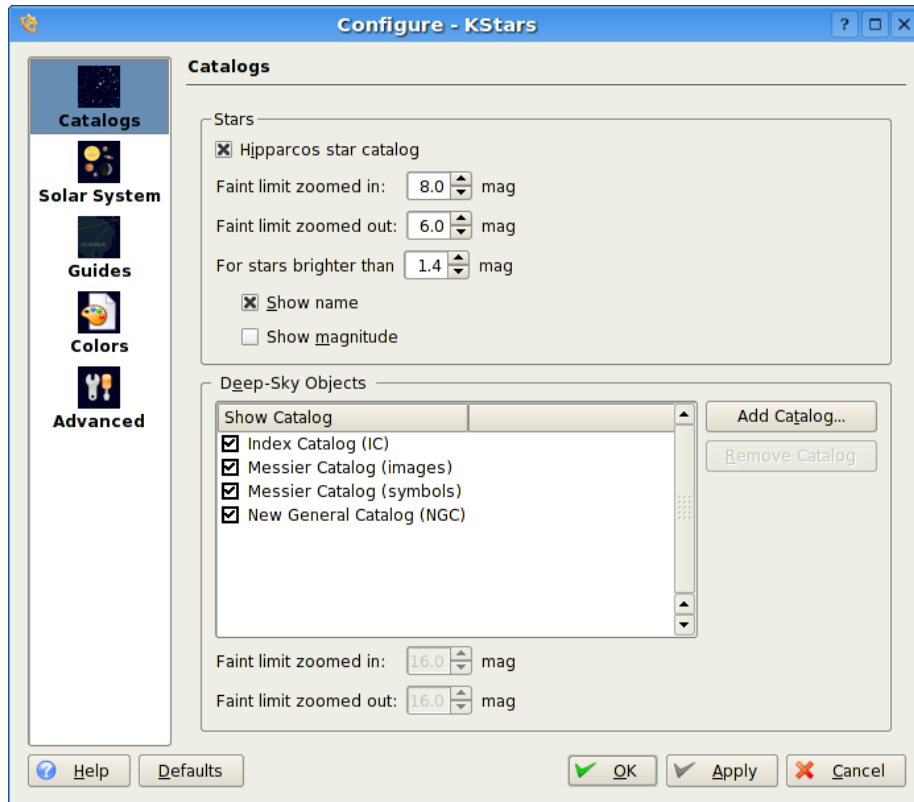
The Configure KStars window is divided into five tabs: Catalogs, Guides, Solar
System, Colors, and Advanced.

In the Catalogs tab, you determine which object catalogs are displayed in the
map. The Stars section also allows you to set the 'faint magnitude limit' for
stars, and the magnitude limit for displaying the names and/or magnitudes of

stars. Below the stars section, the Deep-Sky Objects section controls the display of several non-stellar object catalogs. By default, the list includes the Messier, NGC and IC catalogs. You can add your own custom object catalogs by pressing the Add Custom Catalog button. For detailed instructions on preparing a catalog data file, see the `README.customize` file that ships with KStars.

In the Solar System tab, you can specify whether the Sun, Moon, planets, comets and asteroids are displayed, and whether the major bodies are drawn as colored circles or actual images. You can also toggle whether solar system bodies have name labels attached, and control how many of the comets and asteroids get name labels. There is an option to automatically attach a temporary 'orbit trail' whenever a solar system body is tracked, and another to toggle whether the color of the orbit trail fades into the background sky color.

The Guides tab lets you toggle whether non-objects are displayed (i.e., constellation lines, constellation names, the Milky Way contour, the celestial equator, the ecliptic, the horizon line, and the opaque ground). You can also choose whether you would like to see Latin constellation names, IAU-standard three-letter abbreviations, or constellation names using your local language.

The Colors tab allows you to set the color scheme, and to define custom color schemes. The tab is split into two panels:

The left panel shows a list of all display items with adjustable colors. Click on any item to bring up a color selection window to adjust its color. Below the list is the Star Color Mode selection box. By default, KStars draws stars with a realistic color tint according to the spectral type of the star. However, you may also choose to draw the stars as solid white, black or red circles. If you are using the realistic star colors, you can set the saturation level of the star colors with the Star Color Intensity spinbox.

The right panel lists the defined color schemes. There are four predefined schemes: the Default scheme, Star Chart, which uses black stars on a white background, Night Vision, which uses only shades of red in order to protect dark-adapted vision, and Moonless Night, a more realistic, dark theme. Additionally, you can save the current color settings as a custom scheme by clicking the Save Current Colors button. It will prompt you for a name for the new scheme, and then your scheme will appear in the list in all future KStars sessions. To remove a custom scheme, simply highlight it in the list, and press the Remove Color Scheme button.

The Advanced Tab provides fine-grained control over the more subtle behaviors of KStars.

The Correct for atmospheric refraction checkbox controls whether the positions of objects are corrected for the effects of the atmosphere. Because the atmosphere is a spherical shell, light from outer space is 'bent' as it passes through the atmosphere to our telescopes or eyes on the Earth's surface. The effect is largest for objects near the horizon, and actually changes the predicted rise or set times of objects by a few minutes. In fact, when you 'see' a sunset, the Sun's actual position is already well below the horizon; atmospheric refraction makes it seem as if the Sun is still in the sky. Note that atmospheric refraction is never applied if you are using Equatorial coordinates.

The Use animating slewing checkbox controls how the display changes when a new focus position is selected in the map. By default, you will see the sky drift or 'slew' to the new position; if you uncheck this option, then the display will instead 'snap' immediately to the new focus position.

If the Attach label to centered object checkbox is selected, then a name label will automatically be attached to an object when it is being tracked by the program. The label will be removed when the object is no longer being tracked. Note that you can also manually attach a persistent name label to any object with its popup menu.

There are three situations when KStars must redraw the sky display very rapidly: when a new focus position is selected (and Use animated slewing is checked), when the sky is dragged with the mouse, and when the time step is large. In these situations, the positions of all objects must be recomputed as rapidly as possible, which can put a large load on the CPU. If the CPU cannot keep up with the demand, then the display will seem sluggish or jerky. To mitigate this, KStars will hide certain objects during these rapid-redraw situations, as long as the Hide objects while moving checkbox is selected. The timestep threshold above which objects will be hidden is determined by the Also hide if timescale greater than: timestep-spinbox. You can specify the objects that should be hidden in the Configure Hidden Objects group box.

3.4   Customizing the Display

There are several ways to modify the display to your liking.

- Select a different color scheme in the Settings → Color Schemes menu. There are four predefined color schemes, and you can define your own in the Configure KStars window.

- Toggle whether the Toolbars are drawn in the Settings → Toolbars menu. Like most KDE toolbars, they can also be dragged around and anchored on any window edge, or even detached from the window completely.

- Toggle whether the Info Boxes are drawn in the Settings → Info Boxes menu. In addition, you can manipulate the three Info Boxes with the mouse. Each box has additional lines of data that are hidden by default. You can toggle whether these additional lines are visible by double-clicking a box to 'shade' it. Also, you can reposition a box by dragging it with the mouse. When a box hits a window edge, it will 'stick' to the edge when the window is resized.

- Choose an 'FOV Symbol' using the Settings → FOV Symbols menu. *FOV* is an acronym for 'field-of-view'. An FOV symbol is drawn at the center of the window to indicate where the display is pointing. Different symbols have different angular sizes; you can use a symbol to show what the view through a particular telescope would look like. For example, if you choose the '7x35 Binoculars' FOV symbol, then a circle is drawn on the display that is 9.2 degrees in diameter; this is the field-of-view for 7x35 binoculars.

You can define your own FOV symbols (or modify the existing symbols) using the Edit FOV Symbols... menu item, which launches the FOV Editor:
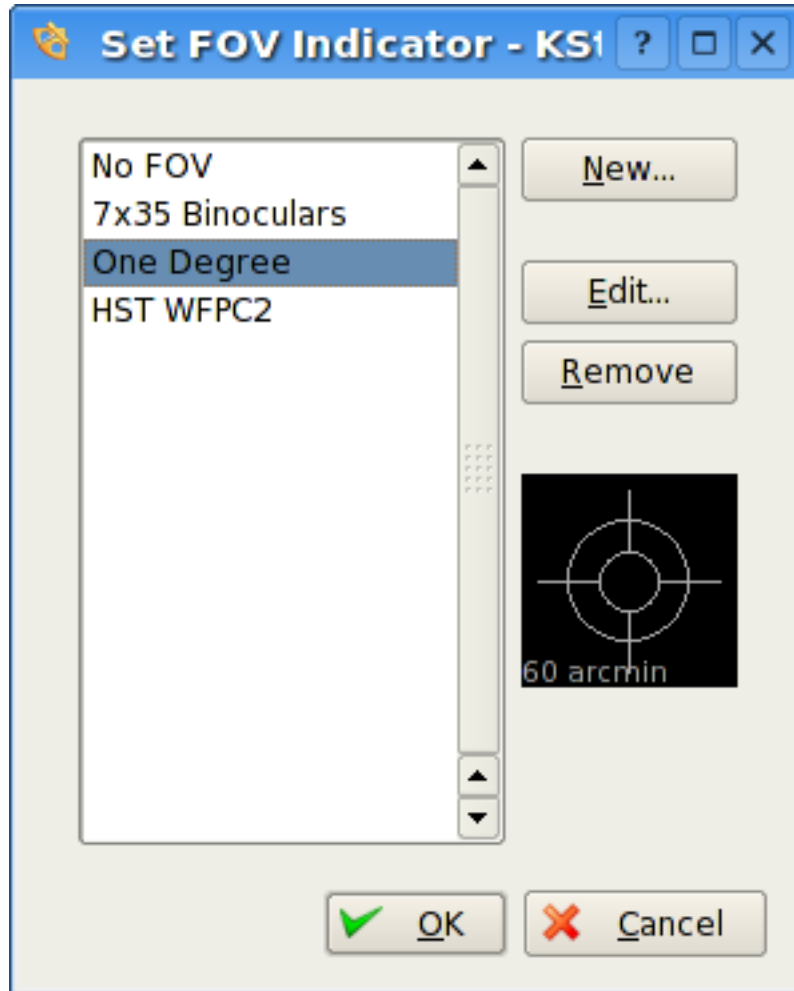
The list of defined FOV symbols is displayed on the left. On the right are buttons for adding a new symbol, editing the highlighted symbol's properties, and removing the highlighted symbol from the list. Note that you can even modify or remove the four predefined symbols (if you remove all symbols, the four defaults will be restored the next time you start KStars). Below these three buttons is a graphical preview display showing the highlighted symbol from the list. When the New... or Edit... button is pressed, the New FOV Symbol window is opened:
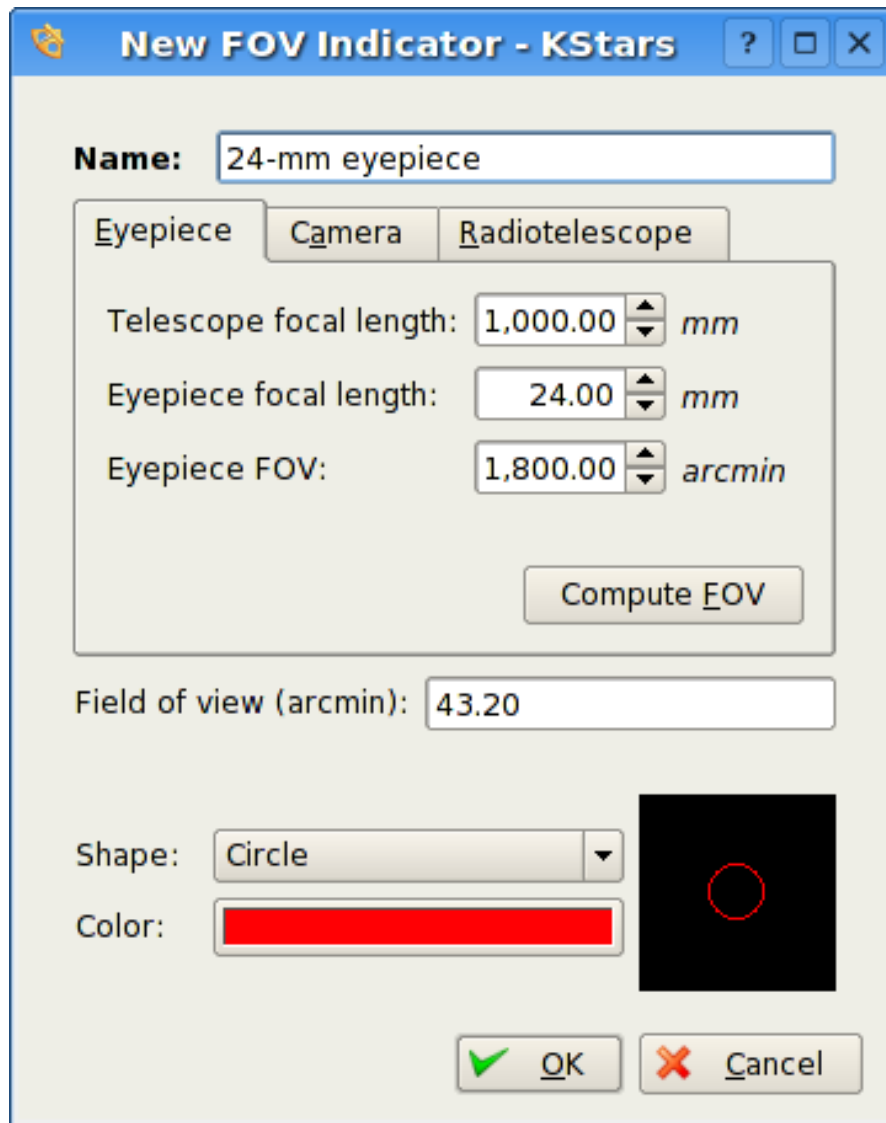
This window lets you modify the four properties that define a FOV symbol: name, size, shape, and color. The angular size for the symbol can either be entered directly in the Field of View edit box, or you can use the Eyepiece/-Camera Tabs to calculate the field-of-view angle, given parameters of your telescope/eyepiece or telescope/camera setup. The four available shapes are: Circle, Square, Crosshairs, and Bullseye. Once you have specified all four parameters, press Ok, and the symbol will appear in the list of defined symbols. It will also be available from the Settings | FOV menu.

Chapter 4

Command Reference

4.1 Menu Commands

4.1.1 File Menu

File → New Window (Ctrl+N) Open another KStars window

File → Close Window (Ctrl+W) Close KStars window

File → Download Data... (Ctrl+D) Open the Download Extra Data tool

File → Open FITS... (Ctrl+O) Open a FITS image in the FITS Viewer tool

File → Save Sky Image... (Ctrl+I) Create image on disk from current display

File → Run Script... (Ctrl+R) Run the specified KStars script

File → Print... (Ctrl+P) Send the current sky map to the printer (or to a PostScript/PDF file)

File → Quit (Ctrl+Q) Quit KStars

4.1.2 Time Menu

Time → Set Time to Now (Ctrl+E) Sync time to system clock

Time → Set Time... (Ctrl+S) Set time and date

Time → Start/Stop Clock Toggle whether time passes

4.1.3 Pointing Menu

Pointing → **Zenith (Z)** Center the display at the Zenith point (straight up)

Pointing → **North (N)** Center the display above the North point on the horizon

Pointing → **East (E)** Center the display above the East point on the horizon

Pointing → **South (S)** Center the display above the South point on the horizon

Pointing → **West (W)** Center the display above the West point on the horizon

Pointing → **Set Focus Manually... (Ctrl+M)** Center the display on specific sky coordinates

Pointing → **Find Object (Ctrl+F)** Locate an object by name using the Find Object Window

Pointing → **Engage/Stop Tracking (Ctrl+T)** Toggle tracking on/off. While tracking, the display will remain centered on the current position or object.

4.1.4 View Menu

View → **Zoom in (+)** Zooms view in

View → **Zoom out (-)** Zooms view out

View → **Default Zoom (Ctrl+Z)** Restore the default Zoom setting

View → **Zoom to Angular Size... (Ctrl+Shift+Z)** Zoom to specified field-of-view angle

View → **Full Screen Mode (Ctrl+Shift+F)** Toggle full-screen mode

View → **Horizontal/Equatorial Coordinates (Space)** Toggle between the Horizontal and Equatorial Coordinate Systems

4.1.5 Devices Menu

Devices → **Telescope Wizard...** Opens the Telescope Wizard, which provides a step-by-step guide to help you connect to your telescope and control it with KStars.

Devices → **Capture Image Sequence...** Acquire images from a CCD camera or webcam device

Devices → **Device Manager** Opens up the device manager, which allows you to start/shutdown device drivers and connect to remote INDI servers.

Devices → **INDI Control Panel** Opens up INDI Control Panel, which allows you to control all the features supported by a device.

Devices → **Configure INDI** Opens up a dialog to configure INDI-related features such as automatic device updates.

4.1.6 Tools Menu

Tools → **Calculator... (Ctrl+C)** Opens the AstroCalculator Tool, which provides full access to many of the mathematical functions used by KStars.

Tools → **AAVSO Light Curves... (Ctrl+V)** Opens the AAVSO Light Curve Generator Tool, which allows you to download a light curve for any variable star from the American Association of Variable Star Observers.

Tools → **Altitude vs. Time... (Ctrl+A)** Opens the Altitude vs. Time Tool, which can plot curves representing the altitude of any object as a function of time. This is useful for planning observing sessions.

Tools → **What's Up Tonight... (Ctrl+U)** Opens the What's Up Tonight Tool, which presents a summary of the objects which are observable from your location on a given date.

Tools → **Script Builder... (Ctrl+B)** Opens the Script Builder Tool, which provides a GUI interface for building KStars DCOP scripts.

Tools → **Solar System... (Ctrl+Y)** Opens the Solar System Viewer, which displays an overhead view of the solar system on the current simulation date.

Tools → **Jupiter's Moons... (Ctrl+J)** Opens the Jupiter Moons Tool, which displays the positions of Jupiter's four brightest moons as a function of time.

4.1.7 Settings Menu

Settings → **Info Boxes** → **Hide/Show Info Boxes** Toggle display of all three Info Boxes

Settings → **Info Boxes** → **Hide/Show Time** Toggle display of the Time Info Box

Settings → **Info Boxes** → **Hide/Show Focus** Toggle display of the Focus Info Box

Settings → **Info Boxes** → **Hide/Show Location** Toggle display of the Location Info Box

Settings → **Toolbars** → **Hide/Show Main Toolbar** Toggle display of the Main Toolbar

Settings → **Toolbars** → **Hide/Show View Toolbar** Toggle display of the View Toolbar

Settings → **Statusbar** → **Hide/Show Statusbar** Toggle display of the Statusbar

Settings → **Statusbar** → **Hide/Show Az/Alt field** Toggle display of the mouse cursor's horizontal coordinates in the statusbar

Settings → **Statusbar** → **Hide/Show RA/Dec field** Toggle display of the mouse cursor's horizontal coordinates in the statusbar

Settings → Color Schemes This submenu contains all of the defined color schemes, including your custom schemes. Select any item to set that color scheme.

Settings → FOV Symbols This submenu lists the available field-of-view (FOV) Symbols. The FOV Symbol is drawn at the center of the display. You may choose from the list of predefined symbols (No symbol, 7x35 Binoculars, One degree, or HST WFPC2), or you may define your own symbols (or modify existing symbols) using the Edit FOV symbols... item.

Settings → Set Geographic Location... (Ctrl+G) Select a new geographic location

Settings → Configure KStars... Modify configuration options

4.1.8 Help Menu

Help → KStars Handbook (F1) Invokes the KDE Help system starting at the KStars help pages. (this document).

Help → What's This? (Shift+F1) Changes the mouse cursor to a combination arrow and question mark. Clicking on items within KStars will open a help window (if one exists for the particular item) explaining the item's function.

Help → Report Bug... Opens the Bug report dialog where you can report a bug or request a 'wishlist' feature.

Help → About KStars This will display version and author information.

Help → About KDE This displays the KDE version and other basic information.

4.1.9 Popup Menu

The right click popup menu is context-sensitive, meaning its content varies depending on what kind of object you click on. We list all possible popup menu items here, with the relevant object type [in brackets].

[All] Identification and type: The top one to three lines are devoted to the name(s) of the object, and its type. For stars, the Spectral Type is also shown here.

[All] Rise, Transit, and Set times for the object on the current simulation date are shown on the next three lines.

[All] Center and Track: Center the display on this location, and engage tracking. Equivalent to double-clicking.

[All] Angular Distance To...: Enter "angular distance mode". In this mode, a dotted line is drawn from the first target object to the current mouse position. When you invoke the popup menu of a second object, this item will read Compute Angular Distance. Selecting this item will display the angular distance between the two objects in the statusbar. You can press the **Esc** key to exit angular distance mode without measuring an angle.

[All] Details: Open the Object Details window for this object.

[All] Attach Label: Attach a permanent name label to the object. If the object already has a label attached, this item will read Remove Label.

[All] Show ... Image: download an image of the object from the internet, and display it in the Image Viewer tool. The "..." text is replaced by a short description of the image's source. An object may have multiple image links available in its popup menu.

[All] ... Page: Display a webpage about the object in your default web browser. The "..." text is replaced by a short description of the page. An object may have multiple web links available in its popup menu.

4.2 Keyboard Commands

4.2.1 Navigation Keys

Arrow Keys Use the arrow keys to pan the display. Holding down the **Shift** key doubles the scrolling speed.

+ / - Zoom In/Out

Ctrl+Z Restore the default Zoom setting

Ctrl+Shift+Z Zoom to specified field-of-view angle

0–9 Center Display on a major Solar System body:

- 0: Sun
- 1: Mercury
- 2: Venus
- 3: Moon
- 4: Mars
- 5: Jupiter
- 6: Saturn
- 7: Uranus
- 8: Neptune
- 9: Pluto

Z Center the display at the Zenith Point (straight up)

N Center the display above the North point on the horizon

E Center the display above the East point on the horizon

S Center the display above the South point on the horizon

W Center the display above the West point on the horizon

Ctrl+T Toggle tracking mode

< Advance the simulation clock backwards by one time step

> Advance the simulation clock forwards by one time step

4.2.2 Menu Shortcuts

Ctrl+N Open a new KStars window

Ctrl+W Close a KStars window

Ctrl+D Download extra data

Ctrl+O Open a FITS image in the FITS Editor

Ctrl+I Export sky image to a file

Ctrl+R Run a KStars DBus script

Ctrl+P Print the current sky map

Ctrl+Q Quit KStars

Ctrl+E Sync the simulation clock with the current system time

Ctrl+S Set the simulation clock to a specified Time and Date

Ctrl+Shift+F Toggle full-screen mode

Space Toggle between the Horizontal and Equatorial Coordinate Systems

F1 Open the KStars Handbook

4.2.3 Actions for the Selected Object

Each of the following keystrokes performs an action on the *selected object*. The selected object is the last object which was clicked on (identified in the status bar). Alternatively, if you hold down the **Shift** key, then the action is performed on the centered object instead.

D Open the Details window for the selected object

L Toggle a name label for the selected object

O Add the selected object to the observing list

P Open the selected object's popup menu

T Toggle a trail on the selected object (solar system bodies only)

4.2.4 Tools Shortcuts

Ctrl+F Open the Find Object window, for specifying a sky object on which to center

Ctrl+M Open the Set Manual Focus tool, for specifying RA/Dec or Az/Alt coordinates on which to center

[/] Start/End an Angular Distance measurement at the current mouse cursor position. The angular distance between start and end points is displayed in the statusbar.

Ctrl+G Open the Set Geographic Location window

Ctrl+C Open the AstroCalculator

Ctrl+V Open the AAVSO Lightcurve Generator

Ctrl+A Open the Altitude vs. Time tool

Ctrl+U Open the What's Up Tonight? tool

Ctrl+B Open the Script Builder tool

Ctrl+Y Open the Solar System Viewer

Ctrl+J Open the Jupiter Moons tool

Ctrl+L Open the Observing List tool

4.3 Mouse Commands

Moving the mouse The sky coordinates (RA/Dec and Az/Alt) of the mouse cursor are updated in the status bar

"Hovering" the mouse A temporary name label is attached to the object nearest to the mouse cursor.

Left-clicking The object nearest the mouse click is identified in the status bar.

Double-clicking Center and track on the location or object nearest the mouse click. Double-clicking on an Info Box will 'shade' it to show/hide extra information.

Right-clicking Open the popup menu for the location or object nearest the mouse cursor.

Scrolling the mouse wheel Zoom the display in or out. If you do not have a mouse wheel, you can hold the middle mouse button and drag vertically.

Click-and-dragging

Dragging the sky map Pan the display, following the drag motion.

Ctrl+dragging the sky map Define a rectangle in the map. When the mouse button is released, the display is zoomed in to match the field-of-view to the bounds of the rectangle.

Dragging an Info Box The Info Box is repositioned in the map. Info Boxes will 'stick' to window edges, so that they remain on the edge when the window is resized.

Chapter 5

The AstroInfo Project

Here you can find a collection of short articles that explain various astronomical concepts used in KStars. From coordinate systems to celestial mechanics, you can find answers to your questions here.

The articles sometimes also contain exercises that you can perform with KStars to illustrate the concept behind the article.

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5.2 Celestial Coordinate Systems

A basic requirement for studying the heavens is determining where in the sky things are. To specify sky positions, astronomers have developed several *coordinate systems*. Each uses a coordinate grid projected on the Celestial Sphere, in analogy to the Geographic coordinate system used on the surface of the Earth. The coordinate systems differ only in their choice of the *fundamental plane*, which divides the sky into two equal hemispheres along a great circle. (the fundamental plane of the geographic system is the Earth's equator). Each coordinate system is named for its choice of fundamental plane.

5.2.1 The Equatorial Coordinate System

The *Equatorial coordinate system* is probably the most widely used celestial coordinate system. It is also the most closely related to the Geographic coordinate system, because they use the same fundamental plane, and the same poles. The projection of the Earth's equator onto the celestial sphere is called the Celestial Equator. Similarly, projecting the geographic Poles onto the celestial sphere defines the North and South Celestial Poles.

However, there is an important difference between the equatorial and geographic coordinate systems: the geographic system is fixed to the Earth; it rotates as the Earth does. The Equatorial system is fixed to the stars[1], so it appears to rotate across the sky with the stars, but of course it is really the Earth rotating under the fixed sky.

The *latitudinal* (latitude-like) angle of the Equatorial system is called *Declination* (Dec for short). It measures the angle of an object above or below the Celestial Equator. The *longitudinal* angle is called the *Right Ascension* (RA for short). It measures the angle of an object East of the Vernal Equinox. Unlike longitude, Right Ascension is usually measured in hours instead of degrees, because the apparent rotation of the Equatorial coordinate system is closely related to Sidereal Time and Hour Angle. Since a full rotation of the sky takes 24 hours to complete, there are (360 degrees / 24 hours) = 15 degrees in one Hour of Right Ascension.

5.2.2 The Horizontal Coordinate System

The Horizontal coordinate system uses the observer's local horizon as the Fundamental Plane. This conveniently divides the sky into the upper hemisphere that you can see, and the lower hemisphere that you can't (because the Earth is in the way). The pole of the upper hemisphere is called the Zenith. The pole of the lower hemisphere is called the *nadir*. The angle of an object above or below the horizon is called the *Altitude* (Alt for short). The angle of an object around the horizon (measured from the North point, toward the East) is called the *Azimuth*. The Horizontal Coordinate System is sometimes also called the Alt/Az Coordinate System.

The Horizontal Coordinate System is fixed to the Earth, not the Stars. Therefore, the Altitude and Azimuth of an object changes with time, as the object appears to drift across the sky. In addition, because the Horizontal system is defined by your local horizon, the same object viewed from different locations on Earth at the same time will have different values of Altitude and Azimuth.

Horizontal coordinates are very useful for determining the Rise and Set times of an object in the sky. When an object has Altitude=0 degrees, it is either Rising (if its Azimuth is < 180 degrees) or Setting (if its Azimuth is > 180 degrees).

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[1]

actually, the equatorial coordinates are not quite fixed to the stars. See precession. Also, if Hour Angle is used in place of Right Ascension, then the Equatorial system is fixed to the Earth, not to the stars.

5.2.3 The Ecliptic Coordinate System

The Ecliptic coordinate system uses the Ecliptic for its Fundamental Plane. The Ecliptic is the path that the Sun appears to follow across the sky over the course of a year. It is also the projection of the Earth's orbital plane onto the Celestial Sphere. The latitudinal angle is called the *Ecliptic Latitude*, and the longitudinal angle is called the *Ecliptic Longitude*. Like Right Ascension in the Equatorial system, the zeropoint of the Ecliptic Longitude is the Vernal Equinox.

What do you think such a coordinate system would be useful for? If you guessed charting solar system objects, you are right! Each of the planets (except Pluto) orbits the Sun in roughly the same plane, so they always appear to be somewhere near the Ecliptic (i.e., they always have small ecliptic latitudes).

5.2.4 The Galactic Coordinate System

The Galactic coordinate system uses the *Milky Way* as its Fundamental Plane. The latitudinal angle is called the *Galactic Latitude*, and the longitudinal angle is called the *Galactic Longitude*. This coordinate system is useful for studying the Galaxy itself. For example, you might want to know how the density of stars changes as a function of Galactic Latitude, to how much the disk of the Milky Way is flattened.

5.3 The Celestial Equator

The *Celestial Equator* is an imaginary great circle on the celestial sphere. The celestial equator is the fundamental plane of the Equatorial Coordinate System, so it is defined as the locus of points with Declination of zero degrees. It is also the projection of the Earth's equator onto the sky.

The Celestial Equator and the Ecliptic are set at an angle of 23.5 degrees in the sky. The points where they intersect are the Vernal and Autumnal Equinoxes.

5.4 The Celestial Poles

The sky appears to drift overhead from east to west, completing a full circuit around the sky in 24 (Sidereal) hours. This phenomenon is due to the spinning of the Earth on its axis. The Earth's spin axis intersects the Celestial Sphere at two points. These points are the *Celestial Poles*. As the Earth spins; they remain fixed in the sky, and all other points seem to rotate around them. The celestial poles are also the poles of the Equatorial Coordinate System, meaning they have *Declinations* of +90 degrees and -90 degrees (for the North and South celestial poles, respectively).

The North Celestial Pole currently has nearly the same coordinates as the bright star *Polaris* (which is Latin for 'Pole Star'). This makes Polaris useful for navigation: not only is it always above the North point of the horizon, but its Altitude angle is always (nearly) equal to the observer's Geographic Latitude (however, Polaris can only be seen from locations in the Northern hemisphere).

The fact that Polaris is near the pole is purely a coincidence. In fact, because of Precession, Polaris is only near the pole for a small fraction of the time.

TIP

Exercises:

Use the Find Object window (Ctrl+F) to locate Polaris. Notice that its Declination is almost (but not exactly) +90 degrees. Compare the Altitude reading when focused on Polaris to your location's geographic latitude. They are always within one degree of each other. They are not exactly the same because Polaris isn't exactly at the Pole. (you can point exactly at the pole by switching to Equatorial coordinates, and pressing the up-arrow key until the sky stops scrolling).

Use the Time Step spinbox in the toolbar to accelerate time to a step of 100 seconds. You can see the entire sky appears to rotate around Polaris, while Polaris itself remains nearly stationary.

We said that the celestial pole is the pole of the Equatorial coordinate system. What do you think is the pole of the horizontal (Altitude/Azimuth) coordinate system? (The Zenith).

5.5 The Celestial Sphere

The celestial sphere is an imaginary sphere of gigantic radius, centered on the Earth. All objects which can be seen in the sky can be thought of as lying on the surface of this sphere.

Of course, we know that the objects in the sky are not on the surface of a sphere centered on the Earth, so why bother with such a construct? Everything we see in the sky is so very far away, that their distances are impossible to gauge just by looking at them. Since their distances are indeterminate, you only need to know the *direction* toward the object to locate it in the sky. In this sense, the celestial sphere model is a very practical model for mapping the sky.

The directions toward various objects in the sky can be quantified by constructing a Celestial Coordinate System.

5.6 The Ecliptic

The ecliptic is an imaginary Great Circle on the Celestial Sphere along which the Sun appears to move over the course of a year. Of course, it is really the

Earth's orbit around the Sun causing the change in the Sun's apparent direction. The ecliptic is inclined from the Celestial Equator by 23.5 degrees. The two points where the Ecliptic crosses the Celestial Equator are known as the Equinoxes.

Since our solar system is relatively flat, the orbits of the planets are also close to the plane of the ecliptic. In addition, the constellations of the zodiac are located along the ecliptic. This makes the ecliptic a very useful line of reference to anyone attempting to locate the planets or the constellations of the zodiac, since they all literally 'follow the Sun'.

Because of the 23.5-degree tilt of the Ecliptic, the *Altitude* of the Sun at noon changes over the course of the year, as it follows the path of the Ecliptic across the sky. This causes the seasons. In the Summer, the Sun is high in the sky at noon, and it remains above the Horizon for more than twelve hours. Whereas, in the winter, the Sun is low in the sky at noon, and remains above the Horizon for less than twelve hours. In addition, sunlight is received at the Earth's surface at a more direct angle in the Summer, which means that a given area at the surface receives more energy per second in the Summer than in Winter. The differences in day duration and in energy received per unit area lead to the differences in temperature we experience in Summer and Winter.

TIP

Exercises:

Make sure your location is set to somewhere that is not very near the equator for these experiments. Open the Configure KStars window, and switch to Horizontal coordinates, with the Opaque Ground shown. Open the Set Time window (Ctrl+S),and change the Date to sometime in the middle of Summer, and the Time to 12:00 Noon. Back in the Main Window, point toward the Southern Horizon (press **S**). Note the height of the Sun above the Horizon at Noon in the Summer. Now, change the Date to something in the middle of Winter (but keep the Time at 12:00 Noon). The Sun is now much lower in the Sky. You will also notice that the day durations are different if you open the What's Up Tonight? tool for each date.

5.7 The Equinoxes

Most people know the Vernal and Autumnal Equinoxes as calendar dates, signifying the beginning of the Northern hemisphere's Spring and Autumn, respectively. Did you know that the equinoxes are also positions in the sky?

The Celestial Equator and the Ecliptic are two Great Circles on the Celestial Sphere, set at an angle of 23.5 degrees. The two points where they intersect are called the *Equinoxes*. The *Vernal Equinox* has coordinates RA=0.0 hours, Dec=0.0 degrees. The *Autumnal Equinox* has coordinates RA=12.0 hours, Dec=0.0 degrees.

The Equinoxes are important for marking the seasons. Because they are on the Ecliptic, the Sun passes through each equinox every year. When the Sun passes

through the Vernal Equinox (usually on March 21st), it crosses the Celestial Equator from South to North, signifying the end of Winter for the Northern hemisphere. Similarly, whenthe Sun passes through the Autumnal Equinox (usually on September 21st), it crosses the Celestial Equator from North to South, signifying the end of Winter for the Southern hemisphere.

5.8 Geographic Coordinates

Locations on Earth can be specified using a spherical coordinate system. The geographic ('earth-mapping') coordinate system is aligned with the spin axis of the Earth. It defines two angles measured from the center of the Earth. One angle, called the *Latitude*, measures the angle between any point and the Equator. The other angle, called the *Longitude*, measures the angle *along* the Equator from an arbitrary point on the Earth (Greenwich, England is the accepted zero-longitude point in most modern societies).

By combining these two angles, any location on Earth can be specified. For example, Baltimore, Maryland (USA) has a latitude of 39.3 degrees North, and a longitude of 76.6 degrees West. So, a vector drawn from the center of the Earth to a point 39.3 degrees above the Equator and 76.6 degrees west of Greenwich, England will pass through Baltimore.

The Equator is obviously an important part of this coordinate system; it represents the *zeropoint* of the latitude angle, and the halfway point between the poles. The Equator is the *Fundamental Plane* of the geographic coordinate system. All Spherical Coordinate Systems define such a Fundamental Plane.

Lines of constant Latitude are called *Parallels*. They trace circles on the surface of the Earth, but the only parallel that is a Great Circle is the Equator (Latitude=0 degrees). Lines of constant Longitude are called *Meridians*. The Meridian passing through Greenwich is the *Prime Meridian* (longitude=0 degrees). Unlike Parallels, all Meridians are great circles, and Meridians are not parallel: they intersect at the north and south poles.

TIP

Exercise:

What is the longitude of the North Pole? Its latitude is 90 degrees North.

This is a trick question. The Longitude is meaningless at the north pole (and the south pole too). It has all longitudes at the same time.

5.9 Great Circles

Consider a sphere, such as the Earth, or the Celestial Sphere. The intersection of any plane with the sphere will result in a circle on the surface of the sphere. If the plane happens to contain the center of the sphere, the intersection circle is

a *Great Circle*. Great circles are the largest circles that can be drawn on a sphere. Also, the shortest path between any two points on a sphere is always along a great circle.

Some examples of great circles on the celestial sphere include: the Horizon, the Celestial Equator, and the Ecliptic.

5.10 The Horizon

The *Horizon* is the line that separates Earth from Sky. More precisely, it is the line that divides all of the directions you can possibly look into two categories: those which intersect the Earth, and those which do not. At many locations, the Horizon is obscured by trees, buildings, mountains, etc.. However, if you are on a ship at sea, the Horizon is strikingly apparent.

The horizon is the *Fundamental Plane* of the Horizontal Coordinate System. In other words, it is the locus of points which have an *Altitude* of zero degrees.

5.11 Hour Angle

As explained in the Sidereal Time article, the *Right Ascension* of an object indicates the Sidereal Time at which it will transit across your Local Meridian. An object's *Hour Angle* is defined as the difference between the current Local Sidereal Time and the Right Ascension of the object:

HA_{obj} = LST - RA_{obj}

Thus, the object's Hour Angle indicates how much Sidereal Time has passed since the object was on the Local Meridian. It is also the angular distance between the object and the meridian, measured in hours (1 hour = 15 degrees). For example, if an object has an hour angle of 2.5 hours, it transited across the Local Meridian 2.5 hours ago, and is currently 37.5 degrees West of the Meridian. Negative Hour Angles indicate the time until the *next* transit across the Local Meridian. Of course, an Hour Angle of zero means the object is currently on the Local Meridian.

5.12 The Local Meridian

The Local Meridian is an imaginary Great Circle on the Celestial Sphere that is perpendicular to the local Horizon. It passes through the North point on the Horizon, through the Celestial Pole, up to the Zenith, and through the South point on the Horizon.

Because it is fixed to the local Horizon, stars will appear to drift past the Local Meridian as the Earth spins. You can use an object's Right Ascension and the Local Sidereal Time to determine when it will cross your Local Meridian (see Hour Angle).

5.13 Precession

Precession is the gradual change in the direction of the Earth's spin axis. The spin axis traces a cone, completing a full circuit in 26,000 years. If you have ever spun a top or a dreidel, the 'wobbling' rotation of the top as it spins is precession.

Because the direction of the Earth's spin axis changes, so does the location of the Celestial Poles.

The reason for the Earth's precession is complicated. The Earth is not a perfect sphere, it is a bit flattened, meaning the Great Circle of the equator is longer than a 'meridonal' great circle that passes through the poles. Also, the Moon and Sun lie outside the Earth's Equatorial plane. As a result, the gravitational pull of the Moon and Sun on the oblate Earth induces a slight *torque* in addition to a linear force. This torque on the spinning body of the Earth leads to the precessional motion.

TIP

Exercise:

Precession is easiest to see by observing the Celestial Pole. To find the pole, first switch to Equatorial Coordinates in the Configure KStars window, and then hold down the **Up arrow** key until the display stops scrolling. The declination displayed in the center of the Info Panel should be +90 degrees, and the bright star Polaris should be nearly at the center of the screen. Try slewing with the left and right arrow keys. Notice that the sky appears to rotate around the Pole.

We will now demonstrate Precession by changing the Date to a very remote year, and observing that the location of the Celestial Pole is no longer near Polaris. Open the Set Time window (Ctrl+S), and set the date to the year 8000 (currently, KStars cannot handle dates much more remote than this, but this date is sufficient for our purposes). Notice that the sky display is now centered at a point between the constellations Cygnus and Cepheus. Verify that this is actually the pole by slewing left and right: the sky rotates about this point; in the year 8000, the North celestial pole will no longer be near Polaris.

5.14 The Zenith

The Zenith is the point in the sky where you are looking when you look 'straight up' from the ground. More precisely, it is the point on the sky with an *Altitude* of +90 Degrees; it is the Pole of the Horizontal Coordinate System. Geometrically, it is the point on the Celestial Sphere intersected by a line drawn from the center of the Earth through your location on the Earth's surface.

The Zenith is, by definition, a point along the Local Meridian.

> TIP
> Exercise:
> You can point to the Zenith by pressing **Z** or by selecting Zenith from the Location menu.

5.15 Julian Day

Julian Days are a way of reckoning the current date by a simple count of the number of days that have passed since some remote, arbitrary date. This number of days is called the *Julian Day*, abbreviated as JD. The starting point, JD=0, is January 1, 4713 BC (or -4712 January 1, since there was no year '0'). Julian Days are very useful because they make it easy to determine the number of days between two events by simply subtracting their Julian Day numbers. Such a calculation is difficult for the standard (Gregorian) calendar, because days are grouped into months, which contain a variable number of days, and there is the added complication of Leap Years.

Converting from the standard (Gregorian) calendar to Julian Days and vice versa is best left to a special program written to do this, such as the KStars Astrocalculator. However, for those interested, here is a simple example of a Gregorian to Julian day converter:

JD = D - 32075 + 1461*(Y + 4800 + (M - 14) / 12) / 4 + 367*(M - 2 - (M - 14) / 12 * 12) / 12 - 3*((Y + 4900 + (M - 14) / 12) / 100) / 4

where D is the day (1-31), M is the Month (1-12), and Y is the year (1801-2099). Note that this formula only works for dates between 1801 and 2099. More remote dates require a more complicated transformation.

An example Julian Day is: JD 2440588, which corresponds to 1 Jan, 1970.

Julian Days can also be used to tell time; the time of day is expressed as a fraction of a full day, with 12:00 noon (not midnight) as the zero point. So, 3:00 pm on 1 Jan 1970 is JD 2440588.125 (since 3:00 pm is 3 hours since noon, and 3/24 = 0.125 day). Note that the Julian Day is always determined from Universal Time, not Local Time.

Astronomers use certain Julian Day values as important reference points, called *Epochs*. One widely-used epoch is called J2000; it is the Julian Day for 1 Jan, 2000 at 12:00 noon = JD 2451545.0.

Much more information on Julian Days is available on the internet. A good starting point is the U.S. Naval Observatory. If that site is not available when you read this, try searching for 'Julian Day' with your favorite search engine.

5.16 Leap Years

The Earth has two major components of motion. First, it spins on its rotational axis; a full spin rotation takes one *Day* to complete. Second, it orbits around the Sun; a full orbital rotation takes one *Year* to complete.

There are normally 365 days in one *calendar* year, but it turns out that a *true* year (i.e., a full orbit of the Earth around the Sun; also called a *tropical year*) is a little bit longer than 365 days. In other words, in the time it takes the Earth to complete one orbital circuit, it completes 365.24219 spin rotations. Do not be too surprised by this; there is no reason to expect the spin and orbital motions of the Earth to be synchronized in any way. However, it does make marking calendar time a bit awkward....

What would happen if we simply ignored the extra 0.24219 rotation at the end of the year, and simply defined a calendar year to always be 365.0 days long? The calendar is basically a charting of the Earth's progress around the Sun. If we ignore the extra bit at the end of each year, then with every passing year, the calendar date lags a little more behind the true position of Earth around the Sun. In just a few decades, the dates of the solstices and equinoxes will have drifted noticeably.

In fact, it used to be that all years *were* defined to have 365.0 days, and the calendar 'drifted' away from the true seasons as a result. In the year 46 BCE, Julius Caeser established the *Julian Calendar*, which implemented the world's first *leap years*: He decreed that every 4th year would be 366 days long, so that a year was 365.25 days long, on average. This basically solved the calendar drift problem.

However, the problem wasn't completely solved by the Julian calendar, because a tropical year isn't 365.25 days long; it's 365.24219 days long. You still have a calendar drift problem, it just takes many centuries to become noticeable. And so, in 1582, Pope Gregory XIII instituted the *Gregorian calendar*, which was largely the same as the Julian Calendar, with one more trick added for leap years: even Century years (those ending with the digits '00') are only leap years if they are divisible by 400. So, the years 1700, 1800, and 1900 were not leap years (though they would have been under the Julian Calendar), whereas the year 2000 *was* a leap year. This change makes the average length of a year 365.2425 days. So, there is still a tiny calendar drift, but it amounts to an error of only 3 days in 10,000 years. The Gregorian calendar is still used as a standard calendar throughout most of the world.

> NOTE
>
> Fun Trivia: When Pope Gregory instituted the Gregorian Calendar, the Julian Calendar had been followed for over 1500 years, and so the calendar date had already drifted by over a week. Pope Gregory re-synchronized the calendar by simply *eliminating* 10 days: in 1582, the day after October 4th was October 15th!

5.17   Sidereal Time

Sidereal Time literally means 'star time'. The time we are used to using in our everyday lives is Solar Time. The fundamental unit of Solar Time is a *Day*: the time it takes the Sun to travel 360 degrees around the sky, due to the rotation of the Earth. Smaller units of Solar Time are just divisions of a Day:

- 1/24 Day = 1 Hour

- 1/60 Hour = 1 Minute

- 1/60 Minute = 1 Second

However, there is a problem with Solar Time. The Earth does not actually spin around 360 degrees in one Solar Day. The Earth is in orbit around the Sun, and over the course of one day, it moves about one Degree along its orbit (360 degrees/365.25 Days for a full orbit = about one Degree per Day). So, in 24 hours, the direction toward the Sun changes by about a Degree. Therefore, the Earth has to spin 361 degrees to make the Sun look like it has traveled 360 degrees around the Sky.

In astronomy, we are concerned with how long it takes the Earth to spin with respect to the 'fixed' stars, not the Sun. So, we would like a timescale that removes the complication of Earth's orbit around the Sun, and just focuses on how long it takes the Earth to spin 360 degrees with respect to the stars. This rotational period is called a *Sidereal Day*. On average, it is 4 minutes shorter than a Solar Day, because of the extra 1 degree the Earth spins in a Solar Day. Rather than defining a Sidereal Day to be 23 hours, 56 minutes, we define Sidereal Hours, Minutes and Seconds that are the same fraction of a Day as their Solar counterparts. Therefore, one Solar Second = 1.00278 Sidereal Seconds.

The Sidereal Time is useful for determining where the stars are at any given time. Sidereal Time divides one full spin of the Earth into 24 Sidereal Hours; similarly, the map of the sky is divided into 24 Hours of *Right Ascension*. This is no coincidence; Local Sidereal Time (LST) indicates the Right Ascension on the sky that is currently crossing the Local Meridian. So, if a star has a Right Ascension of 05h 32m 24s, it will be on your meridian at LST=05:32:24. More generally, the difference between an object's RA and the Local Sidereal Time tells you how far from the Meridian the object is. For example, the same object at LST=06:32:24 (one Sidereal Hour later), will be one Hour of Right Ascension west of your meridian, which is 15 degrees. This angular distance from the meridian is called the object's Hour Angle.

TIP

The Local Sidereal Time is displayed by KStars in the Time Info Box, with the label 'ST' (you have to 'unshade' the box by double-clicking it in order to see the sidereal time). Note that the changing sidereal seconds are not synchronized with the changing Local Time and Universal Time seconds. In fact, if you watch the clocks for a while, you will notice that the Sidereal seconds really are slightly shorter than the LT and UT seconds.

Point to the Zenith (press **Z** or select Zenith from the Location menu). The Zenith is the point on the sky where you are looking 'straight up' from the ground, and it is a point on your Local Meridian. Note the Right Ascension of the Zenith: it is exactly the same as your Local Sidereal Time.

5.18   Time Zones

The Earth is round, and it is always half-illuminated by the Sun. However, because the Earth is spinning, the half that is illuminated is always changing. We experience this as the passing of days wherever we are on the Earth's surface. At any given instant, there are places on the Earth passing from the dark half into the illuminated half (which is seen as *dawn* on the surface). At the same instant, on the opposite side of the Earth, points are passing from the illuminated half into darkness (which is seen as *dusk* at those locations). So, at any given time, different places on Earth are experiencing different parts of the day. Thus, Solar time is defined locally, so that the clock time at any location describes the part of the day consistently.

This localization of time is accomplished by dividing the globe into 24 vertical slices called *Time Zones*. The Local Time is the same within any given zone, but the time in each zone is one Hour *earlier* than the time in the neighboring Zone to the East. Actually, this is a idealized simplification; real Time Zone boundaries are not straight vertical lines, because they often follow national boundaries and other political considerations.

Note that because the Local Time always increases by an hour when moving between Zones to the East, by the time you move through all 24 Time Zones, you are a full day ahead of where you started. We deal with this paradox by defining the *International Date Line*, which is a Time Zone boundary in the Pacific Ocean, between Asia and North America. Points just to the East of this line are 24 hours behind the points just to the West of the line. This leads to some interesting phenomena. A direct flight from Australia to California arrives before it departs. Also, the islands of Fiji straddle the International Date Line, so if you have a bad day on the West side of Fiji, you can go over to the East side of Fiji and have a chance to live the same day all over again.

5.19   Universal Time

The time on our clocks is essentially a measurement of the current position of the Sun in the sky, which is different for places at different Longitudes because the Earth is round (see Time Zones).

However, it is sometimes necessary to define a global time, one that is the same for all places on Earth. One way to do this is to pick a place on the Earth, and adopt the Local Time at that place as the *Universal Time*, abbreviated UT. (The name is a bit of a misnomer, since Universal Time has little to do with the Universe. It would perhaps be better to think of it as *global time*).

The geographic location chosen to represent Universal Time is Greenwich, England. The choice is arbitrary and historical. Universal Time became an important concept when European ships began to sail the wide open seas, far from any known landmarks. A navigator could reckon the ship's longitude by comparing the Local Time (as measured from the Sun's position) to the time back at the home port (as kept by an accurate clock on board the ship). Greenwich was home to England's Royal Observatory, which was charged with keeping

time very accurately, so that ships in port could re-calibrate their clocks before setting sail.

TIP

Exercise:

Set the geographic location to 'Greenwich, England' using the Set Location window (Ctrl+G). Note that the Local Time (LT)and the Universal Time (UT) are now the same.

Further Reading: The history behind the construction of the first clock that was accurate and stable enough to be used on ships to keep Universal Time is a fascinating tale, and one told expertly in the book 'Longitude', by Dava Sobel.

5.20   Blackbody Radiation

A *blackbody* refers to an opaque object that emits *thermal radiation*. A perfect blackbody is one that absorbs all incoming light and does not reflect any. At room temperature, such an object would appear to be perfectly black (hence the term *blackbody*). However, if heated to a high temperature, a blackbody will begin to glow with *thermal radiation*.

In fact, all objects emit thermal radiation (as long as their temperature is above Absolute Zero, or -273.15 degrees Celsius), but no object emits thermal radiation perfectly; rather, they are better at emitting/absorbing some wavelengths of light than others. These uneven efficiencies make it difficult to study the interaction of light, heat and matter using normal objects.

Fortunately, it is possible to construct a nearly-perfect blackbody. Construct a box made of a thermally conductive material, such as metal. The box should be completely closed on all sides, so that the inside forms a cavity that does not receive light from the surroundings. Then, make a small hole somewhere on the box. The light coming out of this hole will almost perfectly resemble the light from an ideal blackbody, for the temperature of the air inside the box.

At the beginning of the 20th century, scientists Lord Rayleigh, and Max Planck (among others) studied the blackbody radiation using such a device. After much work, Planck was able to empirically describe the intensity of light emitted by a blackbody as a function of wavelength. Furthermore, he was able to describe how this spectrum would change as the temperature changed. Planck's work on blackbody radiation is one of the areas of physics that led to the foundation of the wonderful science of Quantum Mechanics, but that is unfortunately beyond the scope of this article.

What Planck and the others found was that as the temperature of a blackbody increases, the total amount of light emitted per second increases, and the wavelength of the spectrum's peak shifts to bluer colors (see Figure 1).
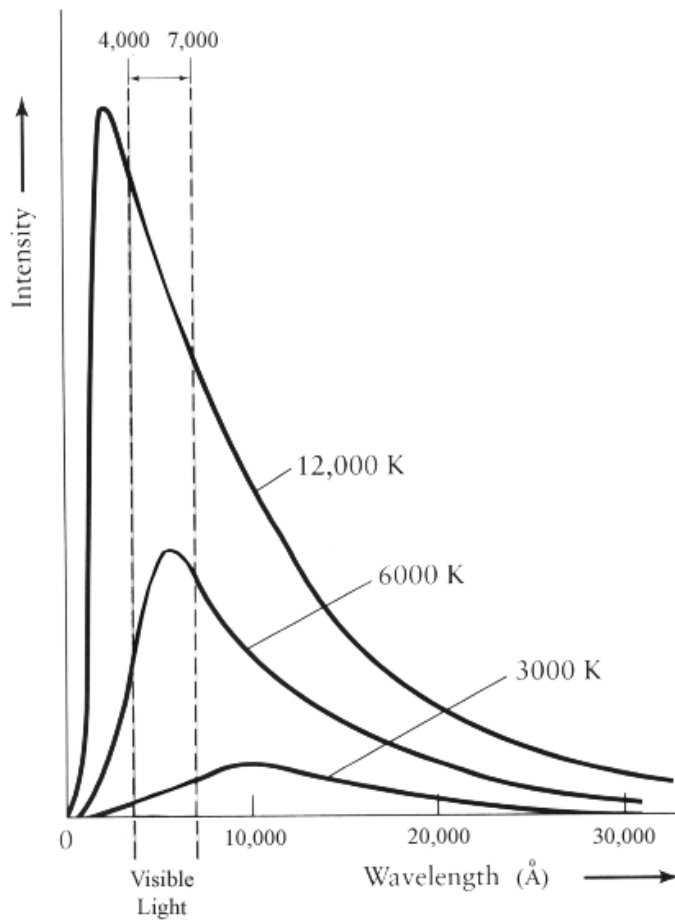
Figure 1

For example, an iron bar becomes orange-red when heated to high temperatures and its color progressively shifts toward blue and white as it is heated further.

In 1893, German physicist Wilhelm Wien quantified the relationship between blackbody temperature and the wavelength of the spectral peak with the following equation:

$$\lambda_{max} \cdot T = 0.29 \ cm \ K$$

where T is the temperature in Kelvin. Wien's law (also known as Wien's displacement law) states that the wavelength of maximum emission from a blackbody is inversely proportional to its temperature. This makes sense; shorter-wavelength (higher-frequency) light corresponds to higher-energy photons, which you would expect from a higher-temperature object.

For example, the sun has an average temperature of 5800 K, so its wavelength

of maximum emission is given by:

$$\lambda_{max} = \frac{0.29\ cm}{5800} = 500\ nm$$

This wavelengths falls in the green region of the visible light spectrum, but the sun's continuum radiates photons both longer and shorter than lambda(max) and the human eyes perceives the sun's color as yellow/white.

In 1879, Austrian physicist Stephan Josef Stefan showed that the luminosity, L, of a black body is proportional to the 4th power of its temperature T.

$$L = A \cdot \alpha \cdot T^4$$

where A is the surface area, alpha is a constant of proportionality, and T is the temperature in Kelvin. That is, if we double the temperature (e.g. 1000 K to 2000 K) then the total energy radiated from a blackbody increase by a factor of 2^4 or 16.

Five years later, Austrian physicist Ludwig Boltzman derived the same equation and is now known as the Stefan-Boltzman law. If we assume a spherical star with radius R, then the luminosity of such a star is

$$L = 4\pi R^2 \cdot \alpha \cdot T^4$$

where R is the star radius in cm, and the alpha is the Stefan-Boltzman constant, which has the value:

$$\alpha = 5.670 \cdot 10^{-5}\ ergs/s/cm^2/K^{-4}$$

5.21 Dark Matter

Scientists are now quite comfortable with the idea that 90% of the mass in the universe is in a form of matter that cannot be seen.

Despite comprehensive maps of the nearby universe that cover the spectrum from radio to gamma rays, we are only able to account of 10% of the mass that must be out there. As Bruce H. Margon, an astronomer at the University of Washington, told the New York Times in 2001: [?].

The term given this 'missing mass' is *Dark Matter*, and those two words pretty well sum up everything we know about it at this point. We know there is 'Matter', because we can see the effects of its gravitational influence. However, the matter emits no detectable electromagnetic radiation at all, hence it is 'Dark'. There exist several theories to account for the missing mass ranging from exotic subatomic particles, to a population of isolated black holes, to less exotic brown and white dwarfs. The term 'missing mass' might be misleading, since the mass itself is not missing, just its light. But what is exactly dark matter and how do we really know it exists, if we cannot see it?

The story began in 1933 when Astronomer Fritz Zwicky was studying the motions of distant and massive clusters of galaxies, specifically the Coma cluster and the Virgo cluster. Zwicky estimated the mass of each galaxy in the cluster based on their luminosity, and added up all of the galaxy masses to get a total cluster mass. He then made a second, independent estimate of the cluster mass, based on measuring the spread in velocities of the individual galaxies in the cluster. To his suprise, this second *dynamical mass* estimate was *400 times* larger than the estimate based on the galaxy light.

Although the evidence was strong at Zwicky's time, it was not until the 1970s that scientists began to explore this discrepancy comprehensively. It was at this time that the existence of Dark Matter began to be taken seriously. The existence of such matter would not only resolve the mass deficit in galaxy clusters; it would also have far more reaching consequences for the evolution and fate of the universe itself.

Another phenomenon that suggested the need for dark matter is the rotational curves of *Spiral Galaxies*. Spiral Galaxies contain a large population of stars that orbit the Galactic center on nearly circular orbits, much like planets orbit a star. Like planetary orbits, stars with larger galactic orbits are expected to have slower orbital speeds (this is just a statement of Kepler's 3rd Law). Actually, Kepler's 3rd Law only applies to stars near the perimeter of a Spiral Galaxy, because it assumes the mass enclosed by the orbit to be constant.

However, astronomers have made observations of the orbital speeds of stars in the outer parts of a large number of spiral galaxies, and none of them follow Kepler's 3rd Law as expected. Instead of falling off at larger radii, the orbital speeds remain remarkably constant. The implication is that the mass enclosed by larger-radius orbits increases, even for stars that are apparently near the edge of the galaxy. While they are near the edge of the luminous part of the galaxy, the galaxy has a mass profile that apparently continues well beyond the regions occupied by stars.

Here is another way to think about it: Consider the stars near the perimeter of a spiral galaxy, with typical observed orbital velocities of 200 kilometers per second. If the galaxy consisted of only the matter that we can see, these stars would very quickly fly off from the galaxy, because their orbital speeds are four times larger than the galaxy's escape velocity. Since galaxies are not seen to be spinning apart, there must be mass in the galaxy that we are not accounting for when we add up all the parts we can see.

Several theories have surfaced in literature to account for the missing mass such as WIMPs (Weakly Interacting Massive Particles), MACHOs (MAssive Compact Halo Objects), primordial black holes, massive neutrinos, and others; each with their pros and cons. No single theory has yet been accepted by the astronomical community, because we so far lack the means to conclusively test one theory against the other.

> TIP
>
> You can see the galaxy clusters that Professor Zwicky studied to discover Dark Matter. Use the KStars Find Object Window (Ctrl+F) to center on 'M 87' to find the Virgo Cluster, and on 'NGC 4884' to find the Coma Cluster. You may have to zoom in to see the galaxies. Note that the Virgo Cluster appears to be much larger on the sky. In reality, Coma is the larger cluster; it only appears smaller because it is further away.

5.22   Flux

The *flux* is the amount of energy that passes through a unit area each second.

Astronomers use flux to denote the apparent brightness of a celestial body. The apparent brightness is defined as the the amount of light received from a star above the earth atmosphere passing through a unit area each second. Therefore, the apparent brightness is simply the flux we receive from a star.

The flux measures the *rate of flow* of energy that passes through each cm^2 (or any unit area) of an object's surface each second. The detected flux depends on the distance from the source that radiates the energy. This is because the energy has to spread over a volume of space before it reaches us. Let us assume that we have an imaginary balloon that encloses a star. Each dot on the balloon represents a unit of energy emitted from the star. Initially, the dots in an area of one cm^2 are in close proximity to each other and the flux (energy emitted per square centimeter per second) is high. After a distance d, the volume and surface area of the balloon increased causing the dots to *spread away* from each. Consequently, the number of dots (or energy) enclosed in one cm^2 has decreased as illustrated in Figure 1.
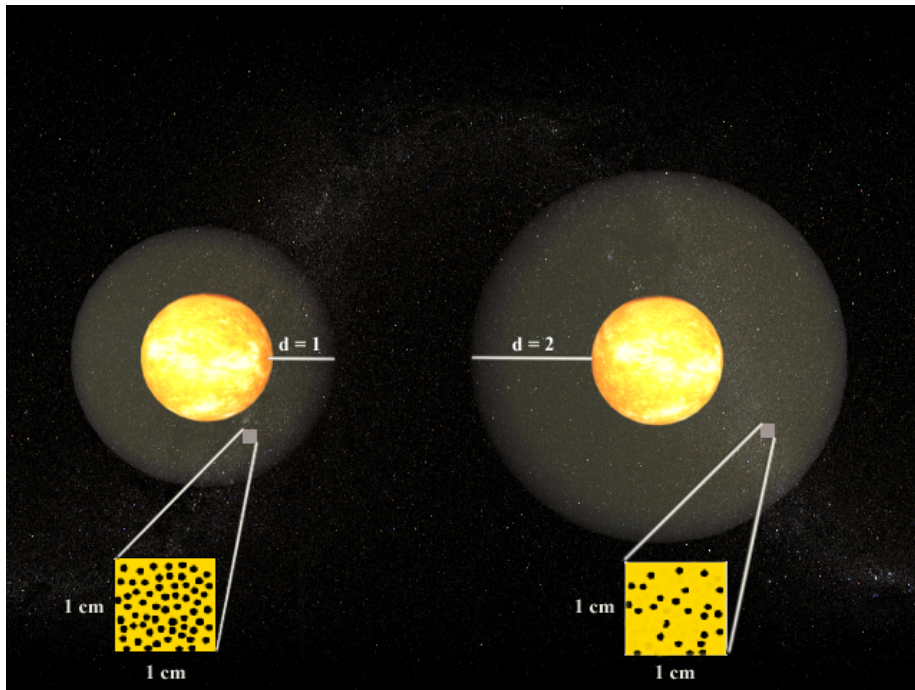
Figure 1

The flux is inversely proportional to distance by a simple r^2 relation. There-fore, if the distance is doubled, we receive 1/2^2 or 1/4th of the original flux. From a fundamental standpoint, the flux is the luminosity per unit area:

$$F = \frac{L}{A} = \frac{L}{4 \cdot \pi \cdot R^2}$$

where (4 * PI * R^2) is the surface area of a sphere (or a balloon!) with a radius R. Flux is measured in Watts/m^2/s or as commonly used by astronomers: Ergs/cm^2/s. For example, the luminosity of the sun is L = 3.90 * 10^26 W. That is, in one second the sun radiates 3.90 * 10^26 joules of energy into space. Thus, the flux we receive passing through one square centimeter from the sun at a distance of one AU (1.496 * 10^13 cm) is:

$$F = \frac{L}{4 \cdot \pi \cdot R^2} = \frac{3.90 \cdot 10^{26}}{4 \cdot \pi \cdot (1.496 \cdot 10^{13})^2} = 0.14 \, joules/cm^2/sec$$

5.23   Luminosity

Luminosity is the amount of energy emitted by a star each second.

All stars radiate light over a broad range of frequencies in the electromagnetic spectrum from the low energy radio waves up to the highly energetic gamma rays. A star that emits predominately in the ultra-violet region of the spectrum produces a total amount of energy magnitudes larger than that produced in a star that emits principally in the infrared. Therefore, luminosity is a measure of energy emitted by a star over all wavelengths. The relationship between wavelength and energy was quantified by Einstein as E = h * v where v is the frequency, h is the Planck constant, and E is the photon energy in joules. That is, shorter wavelengths (and thus higher frequencies) correspond to higher energies.

For example, a wavelength of lambda = 10 meter lies in the radio region of the electromagnetic spectrum and has a frequency of f = c / lambda = 3 * 10^8 m/s / 10 = 30 MHz where c is the speed of light. The energy of this photon is E = h * v = 6.625 * 10^-34 J s * 30 Mhz = 1.988 * 10^-26 joules. On the other hand, visible light has much shorter wavelengths and higher frequencies. A photon that has a wavelength of lambda = 5 * 10^-9 meters (A greenish photon) has an energy E = 3.975 * 10^-17 joules which is over a billion times higher than the energy of a radio photon. Similarly, a photon of red light (wavelength lambda = 700 nm) has less energy than a photon of violet light (wavelength lambda = 400 nm).

Luminosity depends both on temperature and surface area. This makes sense because a burning log radiates more energy than a match, even though both have the same temperature. Similarly, an iron rod heated to 2000 degrees emits more energy than when it is heated to only 200 degrees.

Luminosity is a very fundamental quantity in Astronomy and Astrophysics. Much of what is learnt about celestial objects comes from analyzing their light. This is because the physical processes that occur inside stars gets recorded and transmitted by light. Luminosity is measured in units of energy per second. Astronomers prefer to use Ergs, rather than Watts, when quantifying luminosity.

5.24   Parallax

Parallax is the apparent change of an observed object's position caused by a shift in the observer's position. As an example, hold your hand in front of you at arm's length, and observe an object on the other side of the room behind your hand. Now tilt your head to your right shoulder, and your hand will appear on the left side of the distant object. Tilt your head to your left shoulder, and your hand will appear to shift to the right side of the distant object.

Because the Earth is in orbit around the Sun, we observe the sky from a constantly moving position in space. Therefore, we should expect to see an *annual parallax* effect, in which the positions of nearby objects appear to 'wobble' back and forth in response to our motion around the Sun. This does in fact happen, but the distances to even the nearest stars are so great that you need to make careful observations with a telescope to detect it[2].

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[2]The ancient Greek astronomers knew about parallax; because they could not observe an annual

Modern telescopes allow astronomers to use the annual parallax to measure the distance to nearby stars, using triangulation. The astronomer carefully measures the position of the star on two dates, spaced six months apart. The nearer the star is to the Sun, the larger the apparent shift in its position will be between the two dates.

Over the six-month period, the Earth has moved through half its orbit around the Sun; in this time its position has changed by 2 *Astronomical Units* (abbreviated AU; 1 AU is the distance from the Earth to the Sun, or about 150 million kilometers). This sounds like a really long distance, but even the nearest star to the Sun (alpha Centauri) is about 40 *trillion* kilometers away. Therefore, the annual parallax is very small, typically smaller than one *arcsecond*, which is only 1/3600 of one degree. A convenient distance unit for nearby stars is the *parsec*, which is short for "parallax arcsecond". One parsec is the distance a star would have if its observed parallax angle was one arcsecond. It is equal to 3.26 light-years, or 31 trillion kilometers[3].

5.25 Retrograde Motion

Retrograde Motion is the orbital motion of a body in a direction opposite that which is normal to spatial bodies within a given system.

When we observe the sky, we expect most objects to appear to move in a particular direction with the passing of time. The apparent motion of most bodies in the sky is from east to west. However it is possible to observe a body moving west to east, such as an artificial satellite or space shuttle that is orbiting eastward. This orbit is considered Retrograde Motion.

Retrograde Motion is most often used in reference to the motion of the outer planets (Mars, Jupiter, Saturn, and so forth). Though these planets appear to move from east to west on a nightly basis in response to the spin of the Earth, they are actually drifting slowly eastward with respect to the stationary stars, which can be observed by noting the position of these planets for several nights in a row. This motion is normal for these planets, however, and not considered Retrograde Motion. However, since the Earth completes its orbit in a shorter period of time than these outer planets, we occasionally overtake an outer planet, like a faster car on a multiple-lane highway. When this occurs, the planet we are passing will first appear to stop its eastward drift, and it will then appear to drift back toward the west. This is Retrograde Motion, since it is in a direction opposite that which is typical for planets. Finally, as the Earth swings past the the planet in its orbit, they appear to resume their normal west-to-east drift on successive nights.

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parallax in the positions of stars, they concluded that the Earth could not be in motion around the Sun. What they did not realize was that the stars are millions of times further away than the Sun, so the parallax effect is impossible to see with the unaided eye.

[3]Astronomers like this unit so much that they now use 'kiloparsecs' to measure galaxy-scale distances, and 'Megaparsecs' to measure intergalactic distances, even though these distances are much too large to have an actual, observable parallax. Other methods are required to determine these distances

This Retrograde Motion of the planets puzzled ancient Greek astronomers, and was one reason why they named these bodies 'planets' which in Greek means 'wanderers'.

5.26 Elliptical Galaxies

Elliptical galaxies are spheroidal concentrations of billions of stars that resemble Globular Clusters on a grand scale. They have very little internal structure; the density of stars declines smoothly from the concentrated center to the diffuse edge, and they can have a broad range of ellipticities (or aspect ratios). They typically contain very little interstellar gas and dust, and no young stellar populations (although there are exceptions to these rules). Edwin Hubble referred to Elliptical galaxies as 'early-type' galaxies, because he thought that they evolved to become Spiral Galaxies (which he called 'late-type' galaxies). Astronomers actually now believe the opposite is the case (i.e., that Spiral galaxies can turn into Elliptical galaxies), but Hubble's early- and late-type labels are still used.

Once thought to be a simple galaxy type, ellipticals are now known to be quite complex objects. Part of this complexity is due to their amazing history: ellipticals are thought to be the end product of the merger of two Spiral galaxies. You can view a computer simulation MPEG movie of such a merger at this NASA HST webpage (warning: the file is 3.4 MB).

Elliptical galaxies span a very wide range of sizes and luminosities, from giant Ellipticals hundreds of thousands of light years across and nearly a trillion times brighter than the sun, to dwarf Ellipticals just a bit brighter than the average globular cluster. They are divided to several morphological classes:

cD galaxies: Immense and bright objects that can measure nearly 1 Megaparsec (3 million light years) across. These titans are only found near the centers of large, dense clusters of galaxies, and are likely the result of many galaxy mergers.

Normal Elliptical galaxies Condensed Object with relatively high central surface brightness. They include the giant ellipticals (gE'e), intermediate-luminosity ellipticals (E's), and compact ellipticals.

Dwarf elliptical galaxies (dE's) This class of galaxies is fundamentally different from normal ellipticals. Their diameters on the order of 1 to 10 kiloparsec with surface brightness that is much lower than normal ellipticals, giving them a much more diffuse appearance. They display the same characteristic gradual decline of star density from a relatively dense core out to a diffuse periphery.

Dwarf spheroidal galaxies (dSph's) Extreme low-luminosity, low surface-brightness and have only been observed in the vicinity of the Milky Way, and possibly other very nearby galaxy groups, such as the Leo group. Their absolute magnitudes are only -8 to -15 mag. The Draco dwarf spheroidal

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galaxy has an absolute magnitude of -8.6, making it fainter than the average globular cluster in the Milky Way!

Blue compact dwarf galaxies (BCD's) Small galaxies that are unusually blue. Thehave photometric colors of B-V = 0.0 to 0.30 mag, which is typical for relatively young stars of *spectral type* A. This suggests that BCDs are currently actively forming stars. These systems also have abundant interstellar gas (unlike other Elliptical galaxies).

TIP

You can see examples of Elliptical galaxies in KStars, using the Find Object window (Ctrl+F). Search for NGC 4881, which is the Giant cD galaxy in the Coma cluster of galaxies. M 86 is a normal Elliptical galaxy in the Virgo cluster of galaxies. M 32 is a dwarf Elliptical that is a satellite of our neighbor, the Andromeda galaxy (M 31). M 110 is another satellite of M 31 that is a borderline dwarf spheroidal galaxy ('borderline' because it is somewhat brighter than most other dwarf spheroidals).

5.27 Spiral Galaxies

Spiral galaxies are huge collections of billions of stars, most of which are flattened into a disk shape, with a bright, spherical bulge of stars at its center. Within the disk, there are typically bright arms where the youngest, brightest stars are found. These arms wind out from the center in a spiral pattern, giving the galaxies their name. Spiral galaxies look a bit like hurricanes, or like water flowing down a drain. They are some of the most beautiful objects in the sky.

Galaxies are classified using a 'tuning fork diagram'. The end of the fork classifies elliptical galaxies on a scale from the roundest, which is an E0, to those that appear most flattened, which is rated as E7. The 'tines' of the tuning fork are where the two types of spiral galaxies are classified: normal spirals, and 'barred' spirals. A barred spiral is one whose nuclear bulge is stretched out into a line, so it literally looks like it has a 'bar' of stars in its center.

Both types of spiral galaxies are sub-classified according to the prominence of their central 'bulge' of stars, their overall surface brightness, and how tightly their spiral arms are wound. These characteristics are related, so that an Sa galaxy has a large central bulge, a high surface brightness, and tightly-wound spiral arms. An Sb galaxy has a smaller bulge, a dimmer disk, and looser arms than an Sa, and so on through Sc and Sd. Barred galaxies use the same classification scheme, indicated by types SBa, SBb, SBc, and SBd.

There is another class of galaxy called S0, which is morphologically a transitional type between true spirals and ellipticals. Its spiral arms are so tightly wound as to be indistinguishable; S0 galaxies have disks with a uniform brightness. They also have an extremely dominant bulge.

The Milky Way galaxy, which is home to earth and all of the stars in our sky, is a Spiral Galaxy, and is believed to be a barred spiral. The name 'Milky Way'

refs to a band of very faint stars in the sky. This band is the result of looking in the plane of our galaxy's disk from our perspective inside it.

Spiral galaxies are very dynamic entities. They are hotbeds of star formation, and contain many young stars in their disks. Their central bulges tend to be made of older stars, and their diffuse halos are made of the very oldest stars in the Universe. Star formation is active in the disks because that is where the gas and dust are most concentrated; gas and dust are the building blocks of star formation.

Modern telescopes have revealed that many Spiral galaxies harbor supermassive black holes at their centers, with masses that can exceed that of a billion Suns. Both elliptical and spiral galaxies are known to contain these exotic objects; in fact many astronomers now believe that *all* large galaxies contain a supermassive black hole in their nucleus. Our own Milky Way is known to harbor a black hole in its core with a mass millions of times bigger than a star's mass.

TIP

There are many fine examples of spiral galaxies to be found in KStars, and many have beautiful images available in their popup menu. You can find them by using the Find Object window. Here is a list of some spiral galaxies with nice images available:

- M 64, the Black-Eye Galaxy (type Sa)

- M 31, the Andromeda Galaxy (type Sb)

- M 81, Bode's Galaxy (type Sb)

- M 51, the Whirlpool Galaxy (type Sc)

- NGC 300 (type Sd) [use DSS image link]

- M 83 (type SBa)

- NGC 1530 (type SBb)

- NGC 1073 (type SBc)

5.28 Magnitude Scale

2500 years ago, the ancient Greek astronomer Hipparchus classified the brightnesses of visible stars in the sky on a scale from 1 to 6. He called the very brightest stars in the sky 'first magnitude', and the very faintest stars he could see 'sixth magnitude'. Amazingly, two and a half millenia later, Hipparchus's classification scheme is still widely used by astronomers, although it has since been modernized and quantified.

> **NOTE**
> The magnitude scale runs backwards to what you might expect: brighter stars have *smaller* magnitudes than fainter stars).

The modern magnitude scale is a quantitative measurement of the *flux* of light coming from a star, with a logarithmic scaling:

$m = m_0 - 2.5 \log (F / F_0)$

If you do not understand the math, this just says that the magnitude of a given star (m) is different from that of some standard star (m_0) by 2.5 times the logarithm of their flux ratio. The 2.5 *log factor means that if the flux ratio is 100, the difference in magnitudes is 5 mag. So, a 6th magnitude star is 100 times fainter than a 1st magnitude star. The reason Hipparchus's simple classification translates to a relatively complex function is that the human eye responds logarithmically to light.

There are several different magnitude scales in use, each of which serves a different purpose. The most common is the apparent magnitude scale; this is just the measure of how bright stars (and other objects) look to the human eye. The apparent magnitude scale defines the star Vega to have magnitude 0.0, and assigns magnitudes to all other objects using the above equation, and a measure of the flux ratio of each object to Vega.

It is difficult to understand stars using just the apparent magnitudes. Imagine two stars in the sky with the same apparent magnitude, so they appear to be equally bright. You cannot know just by looking if the two have the same *intrinsic* brightness; it is possible that one star is intrinsically brighter, but further away. If we knew the distances to the stars (see the parallax article), we could account for their distances and assign *Absolute magnitudes* which would reflect their true, intrinsic brightness. The absolute magnitude is defined as the apparent magnitude the star would have if observed from a distance of 10 parsecs (1 parsec is 3.26 light-years, or 3.1 x 10^18 cm). The absolute magnitude (M) can be determined from the apparent magnitude (m) and the distance in parsecs (d) using the formula:

$M = m + 5 - 5 * \log(d)$ (note that M=m when d=10).

The modern magnitude scale is no longer based on the human eye; it is based on photographic plates and photoelectric photometers. With telescopes, we can see objects much fainter than Hipparchus could see with his unaided eyes, so the magnitude scale has been extended beyond 6th magnitude. In fact, the Hubble Space Telescope can image stars nearly as faint as 30th magnitude, which is one *trillion* times fainter than Vega.

A final note: the magnitude is usually measured through a color filter of some kind, and these magnitudes are denoted by a subscript describing the filter (i.e., m_V is the magnitude through a 'visual' filter, which is greenish; m_B is the magnitude through a blue filter; m_{pg} is the photographic plate magnitude, etc.).

5.29   Stars: An Introductory FAQ

1. *What are the stars?*
   Stars are gigantic, self-gravitating spheres of (mostly) Hydrogen gas. Stars are also thermonuclear engines; nuclear fusion takes place deep in the cores of stars, where the density is extreme and the temperature reaches tens of millions of degrees Celsius.

2. *Is the Sun a star?*
   Yes, the Sun is a star. It is the dominant centerpiece of our solar system. Compared to other stars, our Sun is rather ordinary; it appears to be so much bigger and brighter to us because it is millions of times closer than any other star.

3. *Why do stars shine?*

   The short answer is: star shine because they are very hot. It is really no more complicated than that. Any object heated to thousands of degrees will radiate light, just like stars do.

4. *The obvious next question is: why are stars so hot?*

   This is a tougher question. The usual answer is that stars get their heat from the thermonuclear fusion reactions in their cores. However, this cannot be the ultimate cause for the stars' heat, because a star must be hot in the first place for nuclear fusion to be triggered. Fusion can only sustain the hot temperature; it cannot make a star hot. A more correct answer is that stars are hot because they have collapsed. Stars form from diffuse gaseous nebulae; as the nebulous gas condenses to form a star, the gravitational potential energy of the material is released, first as kinetic energy, and ultimately as heat as the density increases.

5. *Are stars all the same?*
   Stars have many things in common: they are all collapsed spheres of hot, dense gas (mostly Hydrogen), and nuclear fusion reactions are occurring at or near the centers of every star in the sky. However, stars also show a great diversity in some properties. The brightest stars shine almost 100 million times as brightly as the faintest stars. Stars range in surface temperature from only a few thousand degrees to almost 50,000 degrees Celsius. These differences are largely due to differences in mass: massive stars are both hotter and brighter than lower-mass stars. The temperature and Luminosity also depend on the *evolutionary state* of the star.

6. *What is the Main Sequence?*
   The main sequence is the evolutionary state of a star when it is fusing Hydrogen in its core. This is the first (and longest) stage of a star's life (not including protostar phases). What happens to a star after it runs out of core Hydrogen is addressed in the stellar evolution article (coming soon).

7. *How long do stars last?*

   The lifetime of a star depends very much on its mass. More massive stars are hotter and shine much more brightly, causing them to consume their nuclear fuel much more rapidly. The largest stars (roughly 100 times as massive as the Sun), will run out of fuel in only a few million years; while the smallest stars (roughly ten percent the mass of the Sun), with their much more frugal consumption rate, will shine on (albeit dimly) for *trillions* of years. Note that this is much longer than the Universe has yet been in existence.

5.30 Star Colors and Temperatures

Stars appear to be exclusively white at first glance. But if we look carefully, we can notice a range of colors: blue, white, red, and even gold. In the winter constellation of Orion, a beautiful contrast is seen between the red Betelgeuse at Orion's "armpit" and the blue Bellatrix at the shoulder. What causes stars to exhibit different colors remained a mystery until two centuries ago, when Physicists gained enough understanding of the nature of light and the properties of matter at immensely high temperatures.

Specifically, it was the physics of blackbody radiation that enabled us to understand the variation of stellar colors. Shortly after blackbody radiation was understood, it was noticed that the spectra of stars look extremely similar to blackbody radiation curves of various temperatures, ranging from a few thousand Kelvin to 50,000 Kelvin. The obvious conclusion is that stars are similar to blackbodies, and that the color variation of stars is a direct consequence of their surface temperatures.

Cool stars (i.e., Spectral Type K and M) radiate most of their energy in the red and infrared region of the electromagnetic spectrum and thus appear red, while hot stars (i.e., Spectral Type O and B) emit mostly at blue and ultra-violet wavelengths, making them appear blue or white.

To estimate the surface temperature of a star, we can use the known relationship between the temperature of a blackbody, and the wavelength of light where its spectrum peaks. That is, as you increase the temperature of a blackbody, the peak of its spectrum moves to shorter (bluer) wavelengths of light. This is illustrated in Figure 1 where the intensity of three hypothetical stars is plotted against wavelength. The "rainbow" indicates the range of wavelengths that are visible to the human eye.
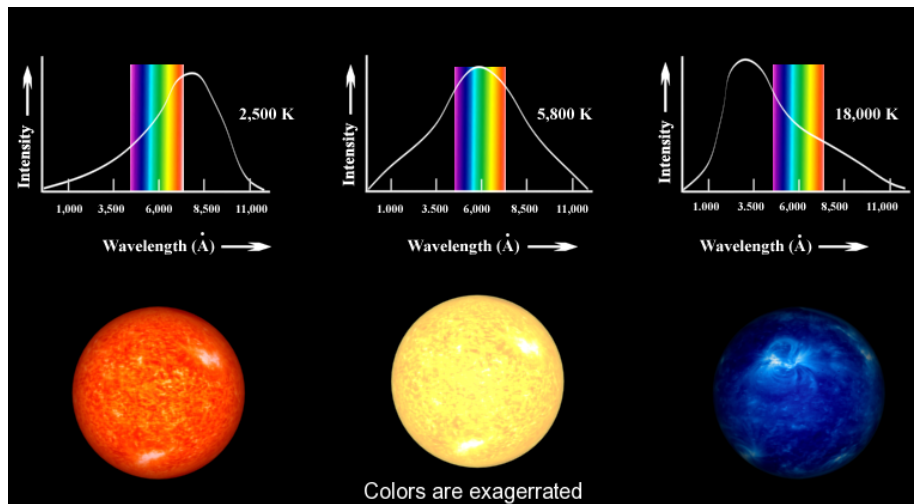
Figure 1

This simple method is conceptually correct, but it cannot be used to obtain stellar temperatures accurately, because stars are *not* perfect blackbodies. The presence of various elements in the star's atmosphere will cause certain wavelengths of light to be absorbed. Because these absorption lines are not uniformly distributed over the spectrum, they can skew the position of the spectral peak. Moreover, obtaining a usable spectrum of a star is a time-intensive process and is prohibitively inefficient for large samples of stars.

An alternative method utilizes photometry to measure the intensity of light passing through different filters. Each filter allows *only* a specific part of the spectrum of light to pass through while rejecting all others. A widely used photometric system is called the *Johnson UBV system*. It employs three bandpass filters: U ("Ultra-violet"), B ("Blue"), and V ("Visible"); each occupying different regions of the electromagnetic spectrum.

The process of UBV photometry involves using light sensitive devices (such as film or CCD cameras) and aiming a telescope at a star to measure the intensity of light that passes through each of the filters individually. This procedure gives three apparent brightnesses or fluxes (amount of energy per cm^2 per second) designated by Fu, Fb, and Fv. The ratio of fluxes Fu/Fb and Fb/Fv is a quantitative measure of the star's "color", and these ratios can be used to establish a temperature scale for stars. Generally speaking, the larger the Fu/Fb and Fb/Fv ratios of a star, the hotter its surface temperature.

For example, the star Bellatrix in Orion has Fb/Fv = 1.22, indicating that it is brighter through the B filter than through the V filter. furthermore, its Fu/Fb ratio is 2.22, so it is brightest through the U filter. This indicates that the star must be very hot indeed, since the position of its spectral peak must be somewhere in the range of the U filter, or at an even shorter wavelength. The surface temperature of Bellatrix (as determined from comparing its spectrum to detailed models that account for its absorption lines) is about 25,000 Kelvin.

We can repeat this analysis for the star Betelgeuse. Its Fb/Fv and Fu/Fb ratios are 0.15 and 0.18, respectively, so it is brightest in V and dimmest in U. So, the spectral peak of Betelgeuse must be somewhere in the range of the V filter, or at an even longer wavelength. The surface temperature of Betelgeuse is only 2,400 Kelvin.

Astronomers prefer to express star colors in terms of a difference in magnitudes, rather than a ratio of fluxes. Therefore, going back to blue Bellatrix we have a color index equal to

B - V = -2.5 log (Fb/Fv) = -2.5 log (1.22) = -0.22,

Similarly, the color index for red Betelgeuse is

B - V = -2.5 log (Fb/Fv) = -2.5 log (0.18) = 1.85

The color indices, like the magnitude scale, run backward. *Hot and blue* stars have *smaller and negative* values of B-V than the cooler and redder stars.

An Astronomer can then use the color indices for a star, after correcting for reddening and interstellar extinction, to obtain an accurate temperature of that star. The relationship between B-V and temperature is illustrated in Figure 2.
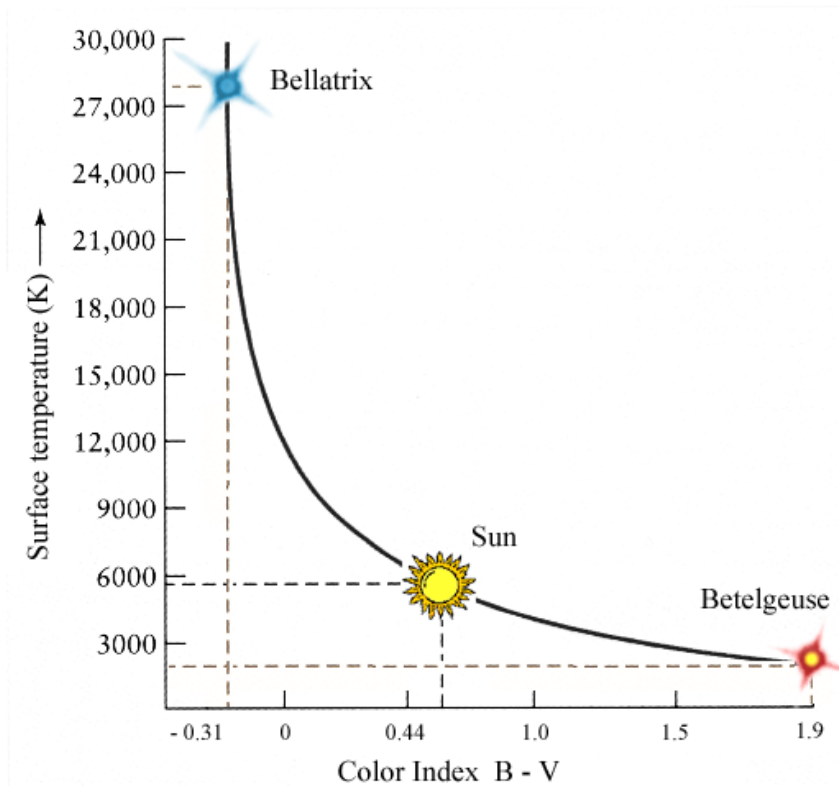
Figure 2

The Sun with surface temperature of 5,800 K has a B-V index of 0.62.

Chapter 6

KStars Tools

KStars comes with a number of tools that allow you to explore some more advanced aspects of astronomy and the night sky.

- Object Details
- Astrocalculator
- AAVSO Lightcurves
- Altitude vs. Time Plotter
- What's Up Tonight?
- Script Builder
- Solar System Viewer
- Jupiter Moons Tool
- Observing List Tool
- FITS Viewer

6.1 Object Details Window
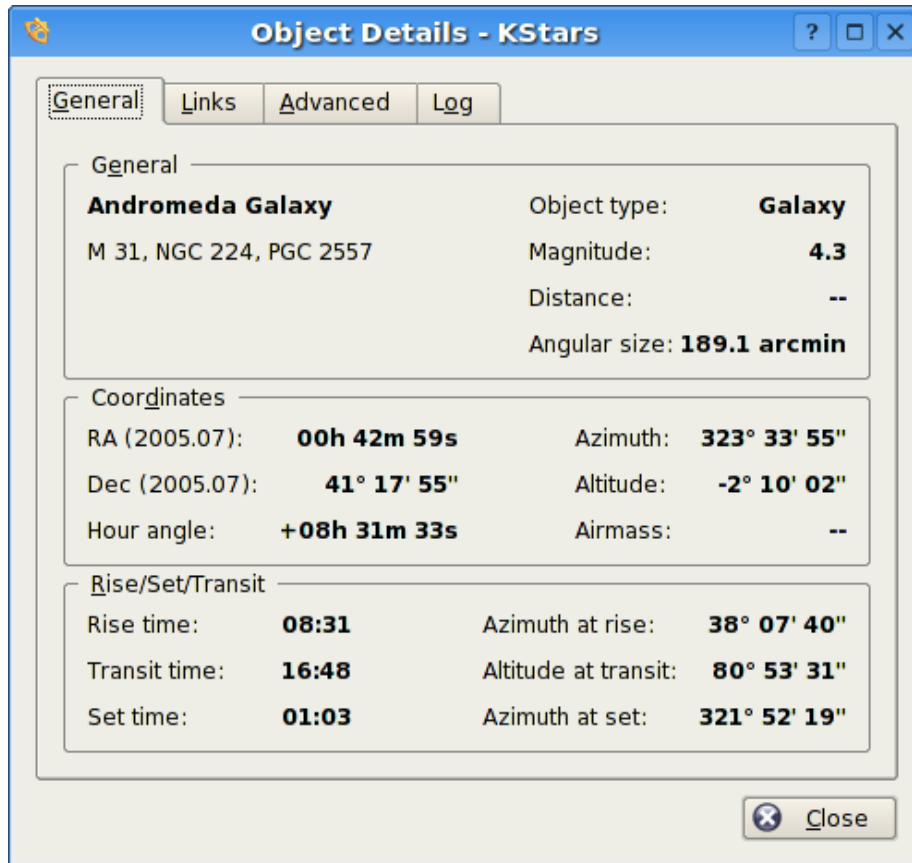
The Object Details Window presents advanced data available about a specific object in the sky. To access this tool, right-click on any object, and select the Details... item from the popup menu.

The window is divided into a number of Tabs. In the General Tab, we present basic data about the current object. This includes names and catalog designations, object type, and magnitude (brightness). Also shown are the object's Equatorial and Horizontal coordinates, as well as its rise, set and transit times.

In the Links tab, you can manage the internet links associated with this object. The Image and Information links associated with the object are listed. These are the links that appear in the popup menu when the object is right-clicked. You can add custom links to the object with the Add Link... button. This will open a window in which you fill in the URL and link text for the new link (you can also test the URL in the web browser from this window). Keep in mind that the custom link can easily point to a file on your local disk, so you can use this feature to index your personal astronomical images or observing logs.

You can also modify or remove any link using the Edit Link... and Remove Link... buttons.

The Advanced Tab allows you to query professional astronomical databases on the internet for information regarding the current object. To use these databases, simply highlight the desired database in the list, and press the View button to see the results of your query in a web browser window. The query is made using the primary name of the object you clicked on to open the Details Dialog. The following databases are available for querying:

- High Energy Astrophysical Archive (HEASARC). Here you can retrieve data about the current object from a number of 'High-energy' observatories, which covers the Ultraviolet, X-ray and Gamma Ray portions of the electromagnetic spectrum.

- Multimission Archive at Space Telescope (MAST). The Space Telescope Science Institute provides access to the entire collection of images and spectra taken with the Hubble Space Telescope, as well as several other space-based observatories.

- NASA Astrophysical Data System (ADS). This incredible bibliographic database encompass the entire body of literature published in international peer-review Journals about astronomy and astrophysics. The database is divided into four general subject areas (Astronomy and Astrophysics, Astrophysics Preprints, Instrumentation, and Physics and Geophysics). Each of these has three subnodes that query the database in different ways. 'Keyword search' will return articles which listed the object's name as a keyword. 'Title word search' will return articles which included the object name in their Title, and the 'Title & Keyword search' uses both options together.

- NASA/IPAC Extragalactic Database (NED). NED provides encapsulated data and bibliographic links about extragalactic objects. You should only use NED if your target is extragalactic; i.e. if it is itself a galaxy.

- Set of Identifications, Measurements, and Bibliography for Astronomical Data (SIMBAD). SIMBAD is similar to NED, except it provides data about all kinds of objects, not just galaxies.

- SkyView provides images from All-Sky surveys that have been performed in dozens of different parts of the spectrum, from Gamma Rays to the Radio. The KStars interface will retrieve an image from any of these surveys, centered on the selected object.

Finally, in the Log Tab, you can type in some text that will remain associated with this object's Details window. You could use this to attach personal observing notes, for example.

6.2 The Astrocalculator

The KStars Astrocalculator provides several modules that give you direct access to algorithms used by the program. The modules are organized by subject:

COORDINATE CONVERTERS

- Angular Distance
- Apparent Coordinates
- Ecliptic Coordinates
- Equatorial/Galactic Coordinates
- Horizontal Coordinates
- Precession

EARTH COORDINATES

- Geodetic Coordinates

SOLAR SYSTEM

- Planets Coordinates
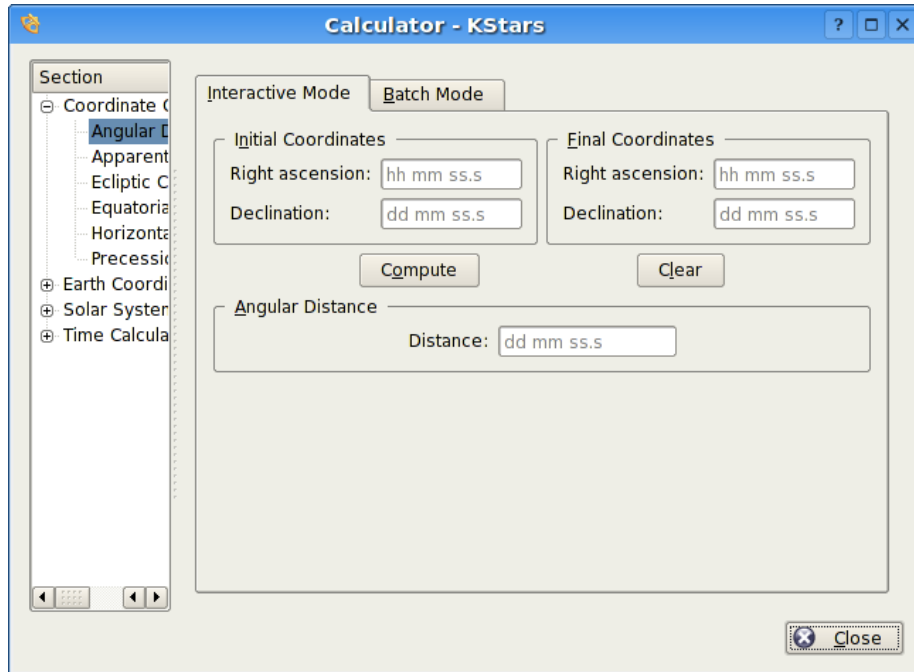
TIME CALCULATORS

- Day Duration
- Equinoxes and Solstices
- Julian Day
- Sidereal Time

6.2.1   Angular Distance module

The Angular Distance tool is used to measure the angle between any two points on the sky. You simply specify the Equatorial coordinates of the desired pair of points, and then press the Compute button to obtain the angle between the two points.

There is also a Batch mode for this module. In batch mode, you specify an input filename which contains four numbers per line: the RA and Dec values for pairs of points. Alternatively, you can specify a single value for any of these four coordinates in the calculator panel (the corresponding values in the input file should be skipped if they are specified in the calculator).

Once you have specified the input filename and an output filename, simply press the Run button to generate the output file.

6.2.2 Apparent Coordinates module
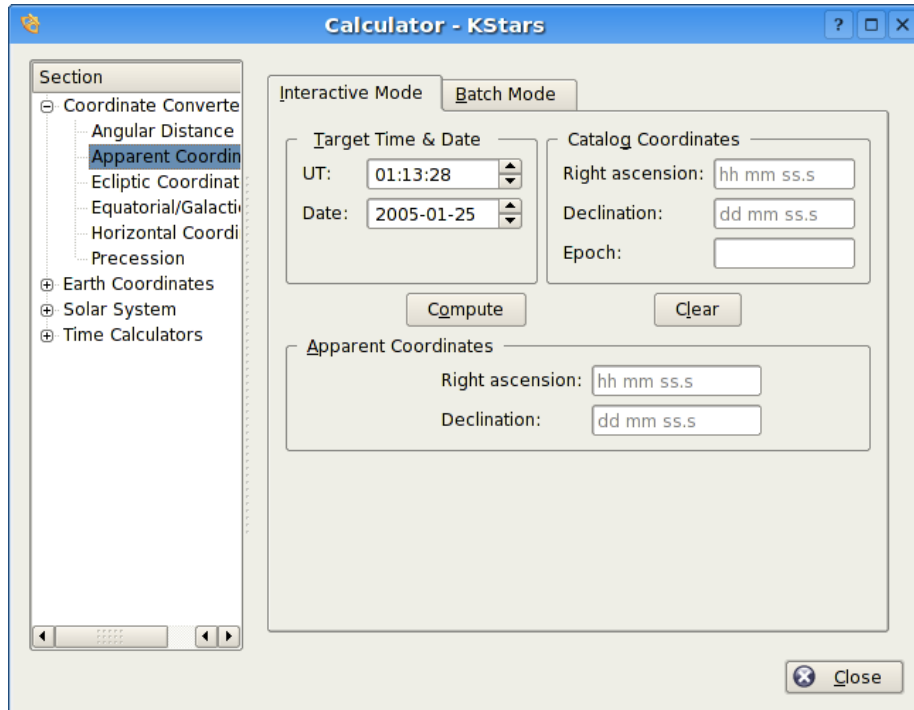
The Apparent Coordinates module converts the *catalog coordinates* of a point in the sky to its *apparent coordinates* for any date. The coordinates of objects in the sky are not fixed, because of precession, nutation and aberration. This module takes these effects into account.

To use the module, first enter the desired target date and time in the Target Time/Date section. Then, enter the catalog coordinates in the Catalog Coordinates section. You can also specify the catalog's epoch here (usually 2000.0 for modern object catalogs). Finally, press the Compute button, and the object's coordinates for the target date will be displayed in the Apparent Coordinates section.

6.2.3 Ecliptic Coordinates module
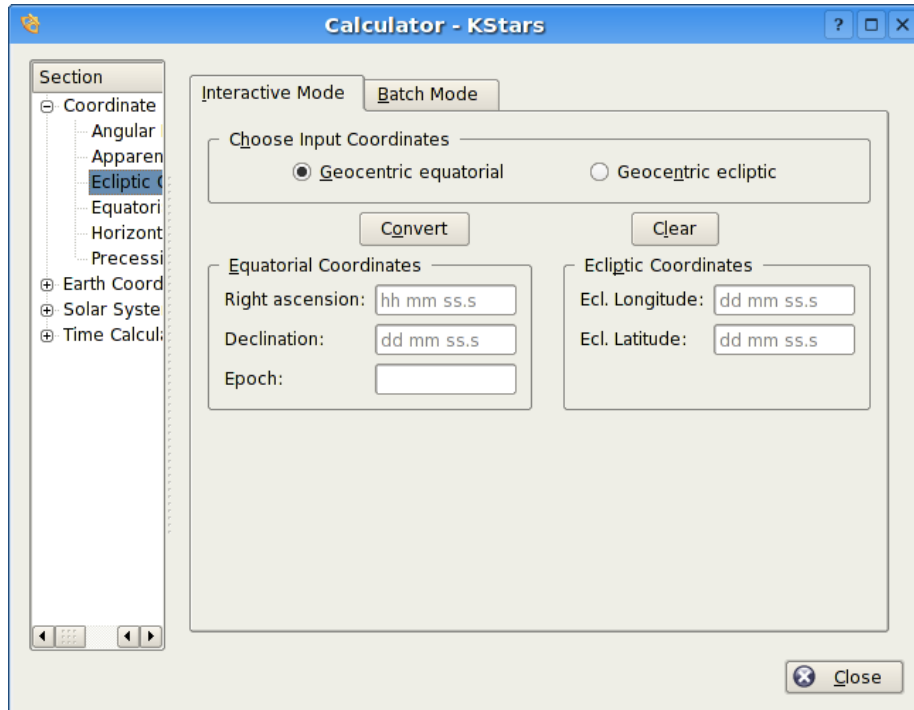
This module converts between Equatorial coordinates and Ecliptic coordinates. First, select which coordinates should be taken as input values in the Choose Input Coordinates section. Then, fill in the corresponding coordinate values in either the Ecliptic coordinates or Equatorial coordinates section. Finally, press the Compute button, and the complementary coordinates will be filled in.

The module contains a batch mode for converting several coordinate pairs at once. You must construct an input file in which each line contains two values: the input coordinate pairs (either Equatorial or Ecliptic). Then specify which coordinates you are using as input, and identify the input and output filenames. Finally, press the Run button to generate the output file, which will contain the converted coordinates (Equatorial or Ecliptic; the complement of what you chose as the input values).

6.2.4 Equatorial/Galactic Coordinates module
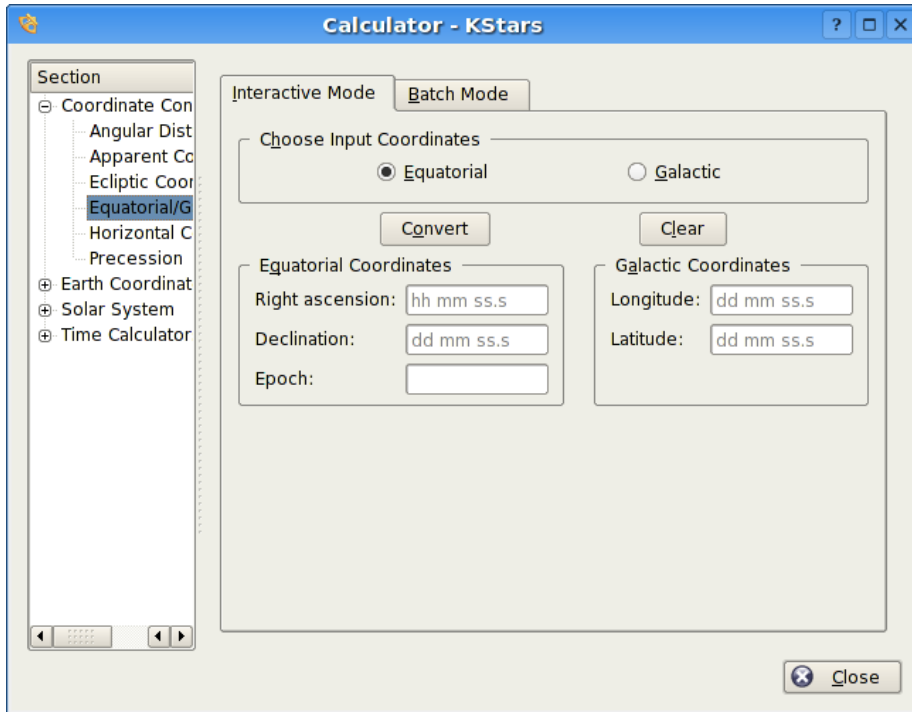
This module converts from Equatorial coordinates to Galactic coordinates, and vice versa. First, select which coordinates should be taken as input values in the Input Selection section. Then, fill in the corresponding coordinate values in either the Galactic coordinates or Equatorial coordinates section. Finally, press the Compute button, and the complementary coordinates will be filled in.

6.2.5 Horizontal Coordinates module
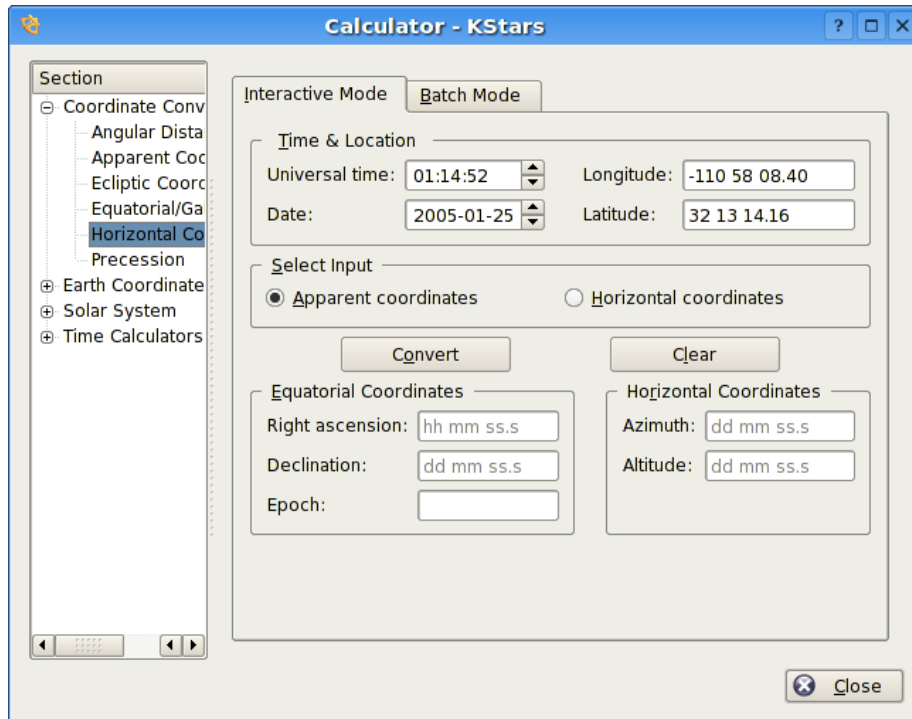
This module converts from Equatorial coordinates to Horizontal coordinates. First, select the date, time, and geographic coordinates for the calculation in the Input Data section. Then, fill in the equatorial coordinates to be converted and their catalog epoch in the Equatorial Coordinates section. When you press the Compute button, the corresponding Horizontal coordinates will be presented in the Horizontal Coordinates section.

6.2.6 Precession module
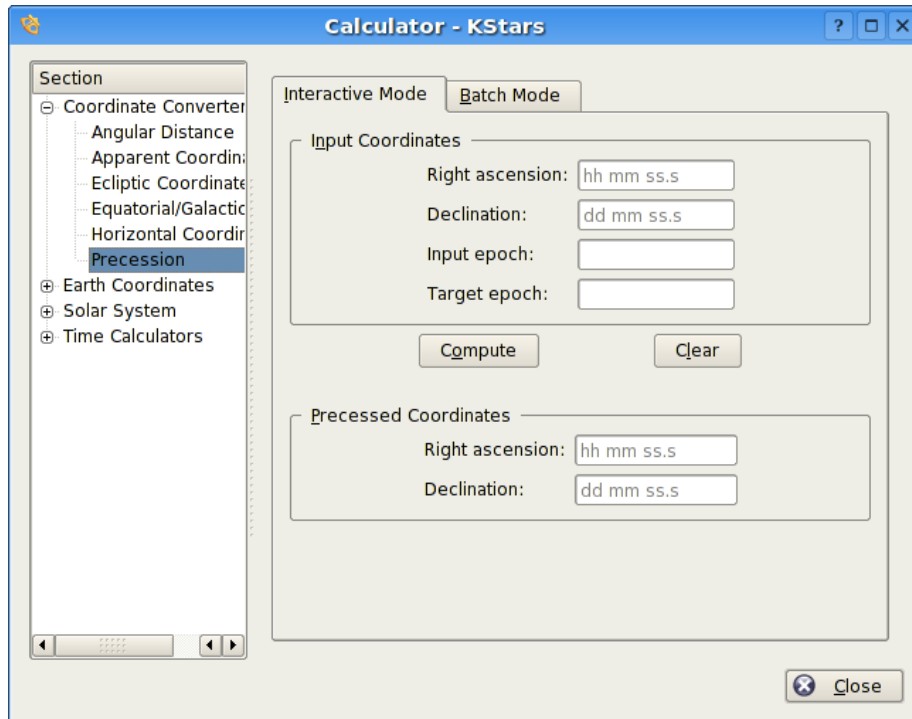
This module is similar to the Apparent Coordinates module, but it only applies the effect of precession, not of nutation or aberration.

To use the module, first enter the input coordinates and their epoch in the Original Coordinates section. You must also fill in the target epoch in the Precessed Coordinates section. Then, press the Compute button, and the object's coordinates, precessed to the target Epoch, are presented in the Precessed Coordinates section.

6.2.7 Geodetic Coordinates module
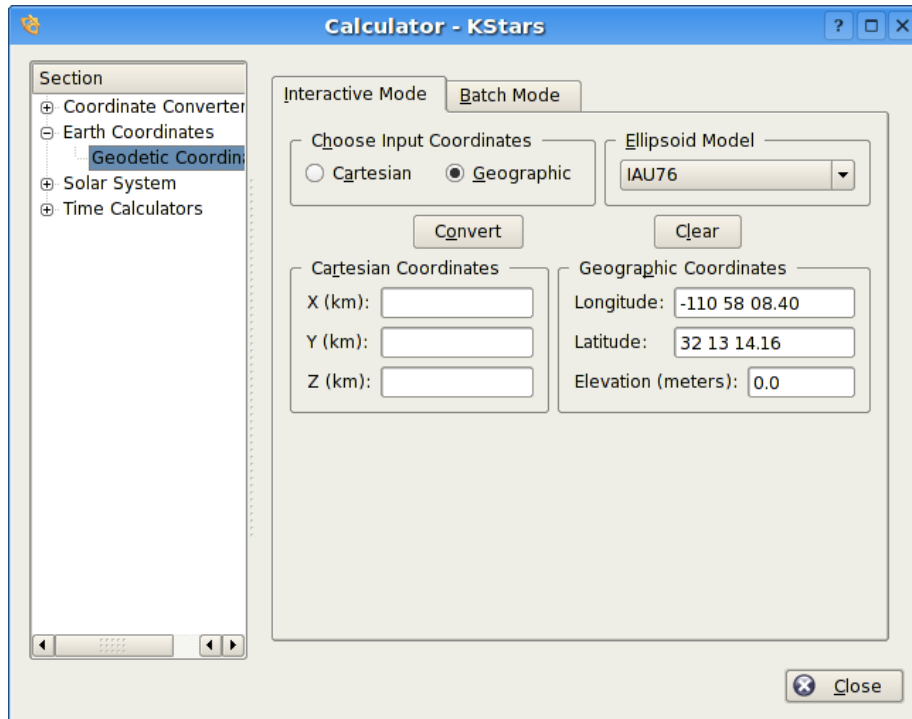
The normal geographic coordinate system assumes that the Earth is a perfect sphere. This is nearly true, so for most purposes geographic coordinates are fine. If very high precision is required, then we must take the true shape of the Earth into account. The Earth is an ellipsoid; the distance around the equator is about 0.3% longer than a Great Circle that passes through the poles. The *Geodetic Coordinate system* takes this ellipsoidal shape into account, and expresses the position on the Earth's surface in Cartesian coordinates (X, Y, and Z).

To use the module, first select which coordinates you will use as input in the Input Selection section. Then, fill in the input coordinates in either the Cartesian Coordinates section or the Geographic Coordinates section. When you press the Compute button, the corresponding coordinates will be filled in.

6.2.8 Planet Coordinates module
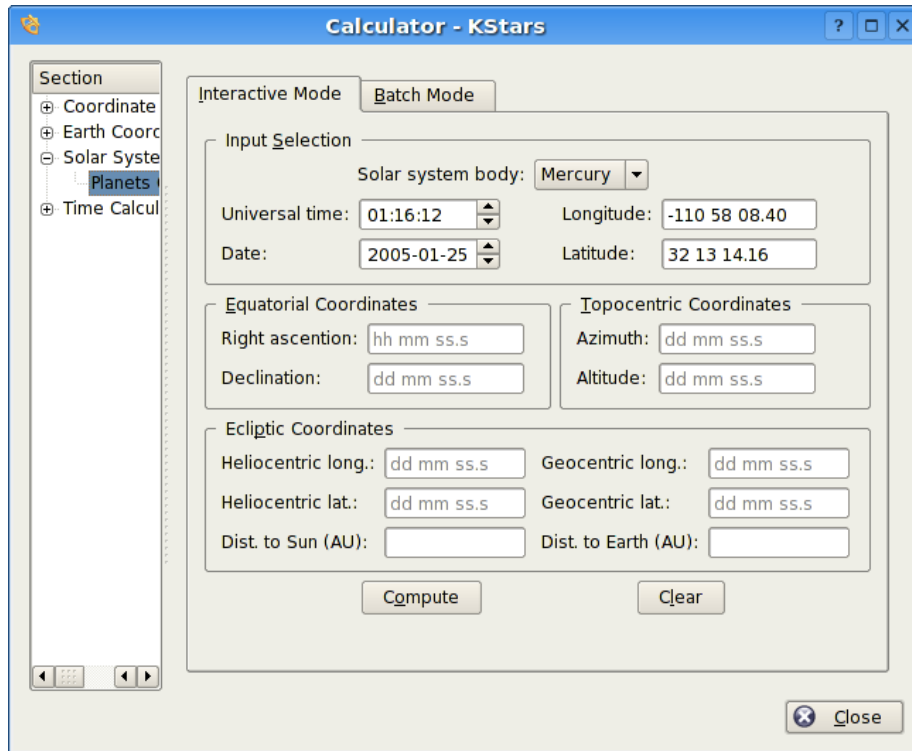
The Planet Coordinates module computes positional data for any major solar system body, for any time and date and any geographic location. Simply select the solar system body from the drop-down list, and specify the desired date, time, and geographic coordinates (these values are preset to the current KStars settings). Then press the Compute button to determine the Equatorial, Horizontal, and Ecliptic coordinates of the body.

There is a batch mode for this module. You must construct an input file in which each line specifies values for the input parameters (solar system body, date, time, longitude, and latitude). You may choose to specify a constant value for some of the parameters in the calculator window (these parameters should be skipped in the input file). You may also specify which of the output parameters (Equatorial, Horizontal, and Ecliptic coordinates) should be calculated. Finally, specify the input and output filenames, and press the Run button to generate the output file with the computed values.

6.2.9 Day Duration module
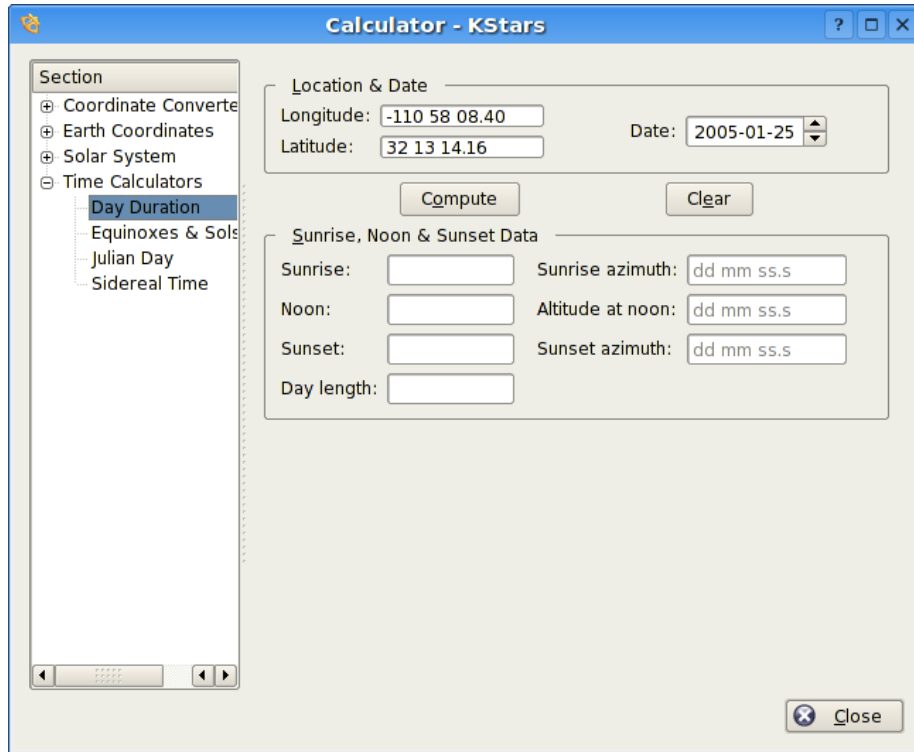
This module computes the length of day as well as sunrise, sun-transit (noon), and sunset times for any calendar date, for any location on Earth. First fill in the desired geographic coordinates and date, then press the Compute button.

6.2.10   Equinoxes and Solstices module
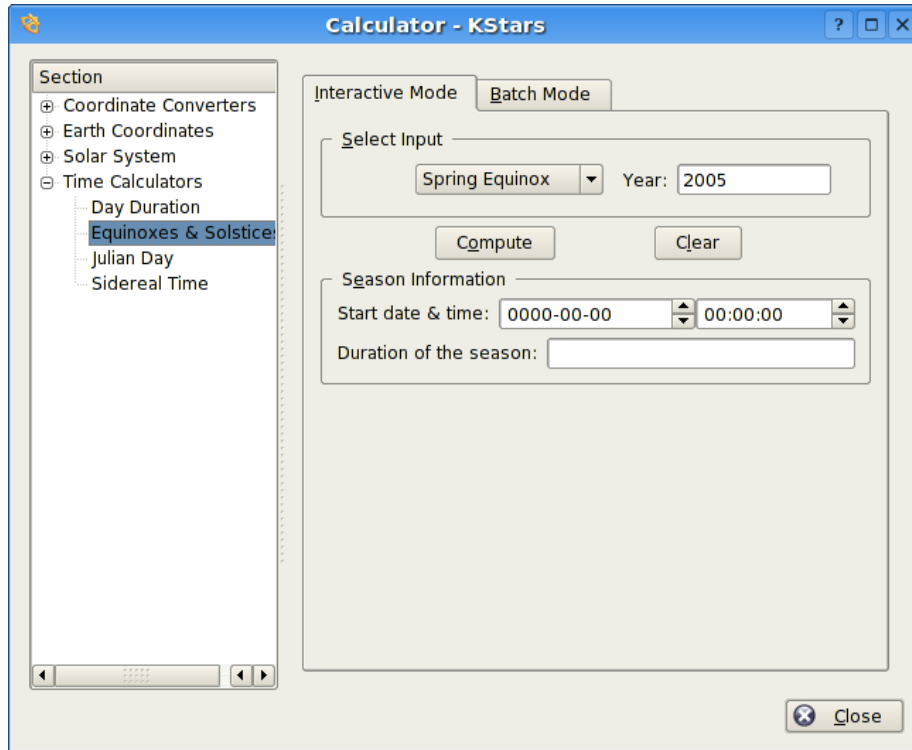
The Equinoxes and Solstices module calculates the date and time of an equinox or solstice for a given year. You specify which event (Spring Equinox, Summer Solstice, Autumn Equinox, or Winter Solstice) should be investigated, and the year. Then press the Compute button to obtain the date and time of the event, and the length of the corresponding season, in days.

There is a batch mode for this module. To use it, simply generate an input file whose lines each contain a year for which the Equinox and Solstice data will be computed. Then specify the input and output filenames, and press the Run button to generate the output file. Each line in the output file contains the input year, the date and time of each event, and the length of each season.

6.2.11 Julian Day module
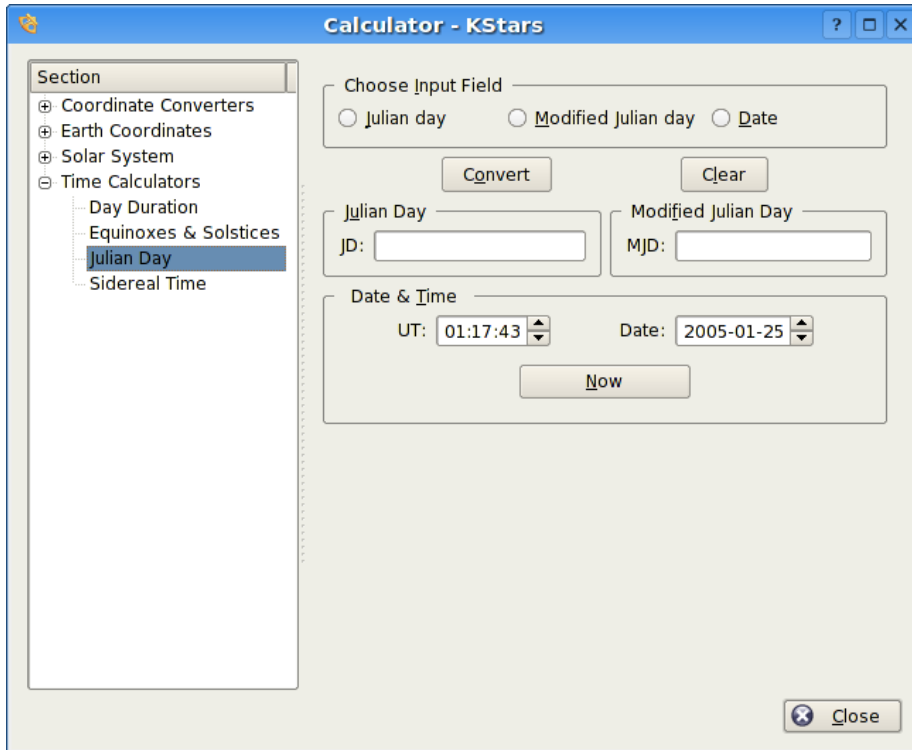
This module converts between the calendar date, the Julian Day, and the *Modified Julian Day*. The Modified Julian Day is simply equal to the Julian Day - 2,400,000.5.

To use the module, select which of the three dates will be the input, and then fill in its value. Then press the Compute button, and the corresponding values for the other two date systems will be displayed.

TIP
Exercise:
What calendar date does MJD = 0.0 correspond to?

6.2.12 Sidereal Time module
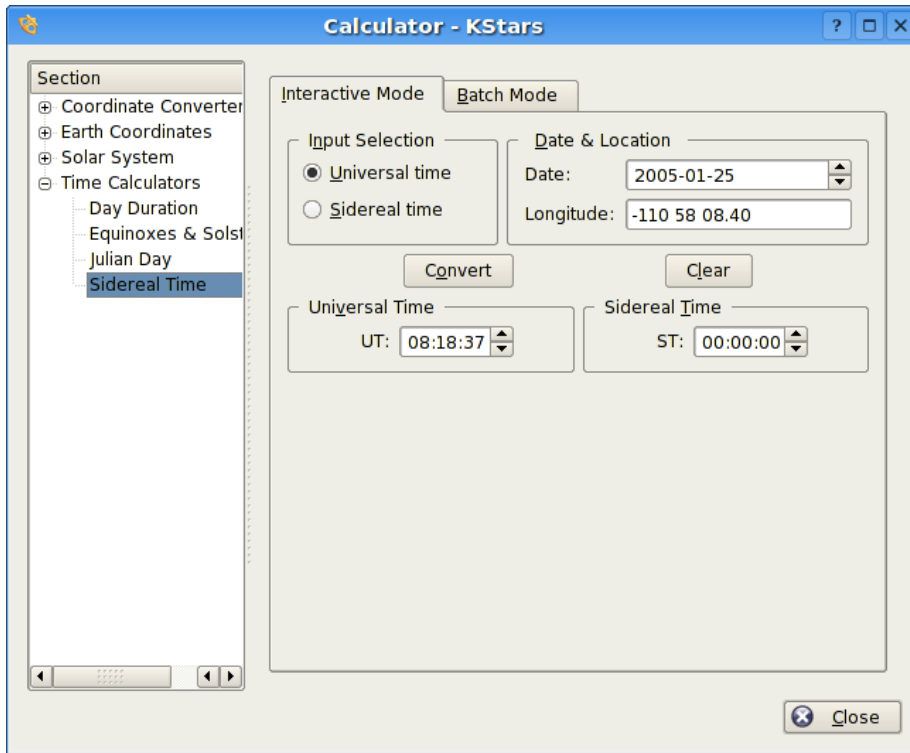
This module converts between Universal Time and Local Sidereal Time. First, select whether you will use Universal Time or Sidereal Time as an input value in the Input Selection section. You must also specify a geographic longitude, and a date for the calculation, in addition to either the Universal Time or the Sidereal Time value. When you press the Compute button, the corresponding value for the other Time will be displayed.

6.3 AAVSO Light Curves
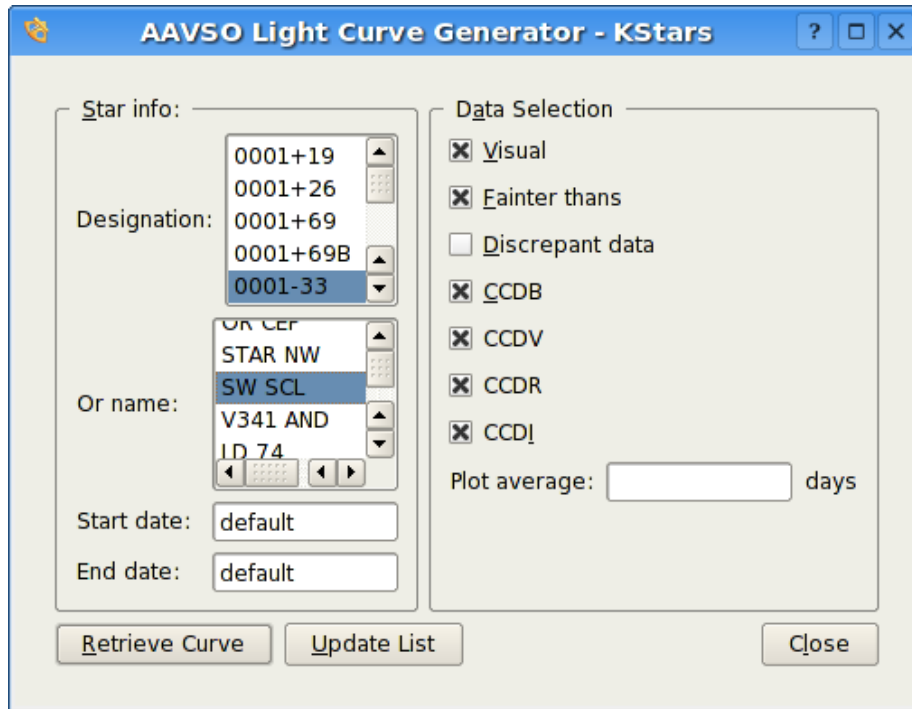
6.3.1 Introduction

KStars can display light curves for variable stars from the observing program of the American Association of Variable Star Observers (AAVSO). This program monitors over 6,000 variable stars and consists of 10 million observations going back almost a century. KStars downloads the very latest data directly from the AAVSO database via the Internet, so a network connection is required to use this tool.

To use the tool, select a variable star either by *designation* or name in the left panel, and set the start and end dates to be plotted. In the right panel, select the type of data that should be plotted (see below). When you have made you selections, press the Retrieve Curve button. KStars will automatically connect to the AAVSO server, which will generate the lightcurve plot and send it to your computer for display. A sample lightcurve plot is shown below:

Light Curve produced by the American Amateur Variable Star Observers
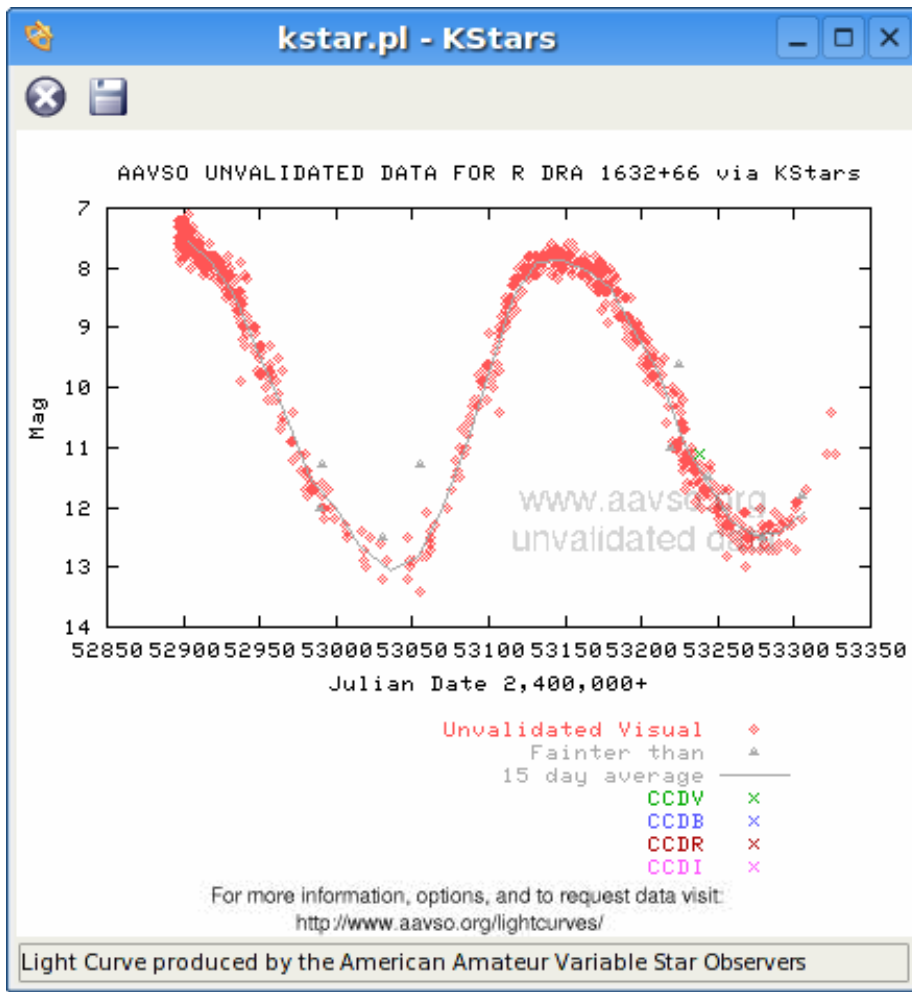
Please not these light curves should *NEVER* be used in research, papers, presentations, publications, etc.. They are only meant to be used as a source of info for KStars. They have not been validated and passed the AAVSO's strict quality control measures. We will be glad to give you good raw data simply by requesting it at http://www.aavso.org/adata/onlinedata/ .

Specific questions about the data in the light curves can be sent to aavso@aavso.org.

6.3.2 About Variable Stars

Variable stars are stars that change in brightness. A *light curve* is a plot of a variable star's brightness over time. By looking at a light curve you can see how the star has behaved in the past and try to predict how it will behave in the future. Astronomers also use this data to model astrophysical processes in the star. This important to help us understand how stars work.

6.3.3 The Data

Here is a summary of the various types of data available in the light curves:

- *Visual Observation*: This is an observation of a variable star by an observer with a regular telescope. It means that an observer saw the star at Y brightness on X date and time.

- *Fainter than*: Sometimes the star is too faint to be seen by the observer. When that happens, the observer reports the faintest star seen in the field. These are called 'fainter thans' because the variable star was fainter than the brightness reported.

- *Average*: This is a computed running average of all the data reported. The *bin* number tells the computer how many days to use in each average calculation. This will need to be adjusted based on the frequency of observations. The error bars represent the 1 sigma standard deviation of error.

- *CCDV*: These are observations reported using a CCD with a Johnson V filter. CCDV observations tend to be more accurate than visual (but not always).

- *CCDB*: CCD observations with a Johnson B filter.

- *CCDI*: CCD observations with a Cousins Ic filter.

- *CCDR*: CCD observations with a Cousins R filter.

- *Discrepant Data*: This is data that has been flagged by an AAVSO staff member as being discrepant following HQ rules for data validation. Contact aavso@aavso.org for more information.

- *Dates*: The observational database the light curves are based on is updated every 10 minutes so you can get data in near real-time. Right now light curve data is only available back to 1961, but this will likely be expanded further back in time in the future.

6.3.4 Updating your local copy of Variable Stars

The AAVSO publishes the full list of variable stars in their monitoring program. This file is updated monthly with newly discovered variable stars. To sync the list that KStars uses with the AAVSO master list, click on the Update List button in the AAVSO dialog. KStars will then attempt to connect to the AAVSO database and download the latest list.

> NOTE
> The customized data stream provided by the AAVSO was implemented for KStars by Aaron Price. Thank you, Aaron!

6.4 Altitude vs. Time Tool
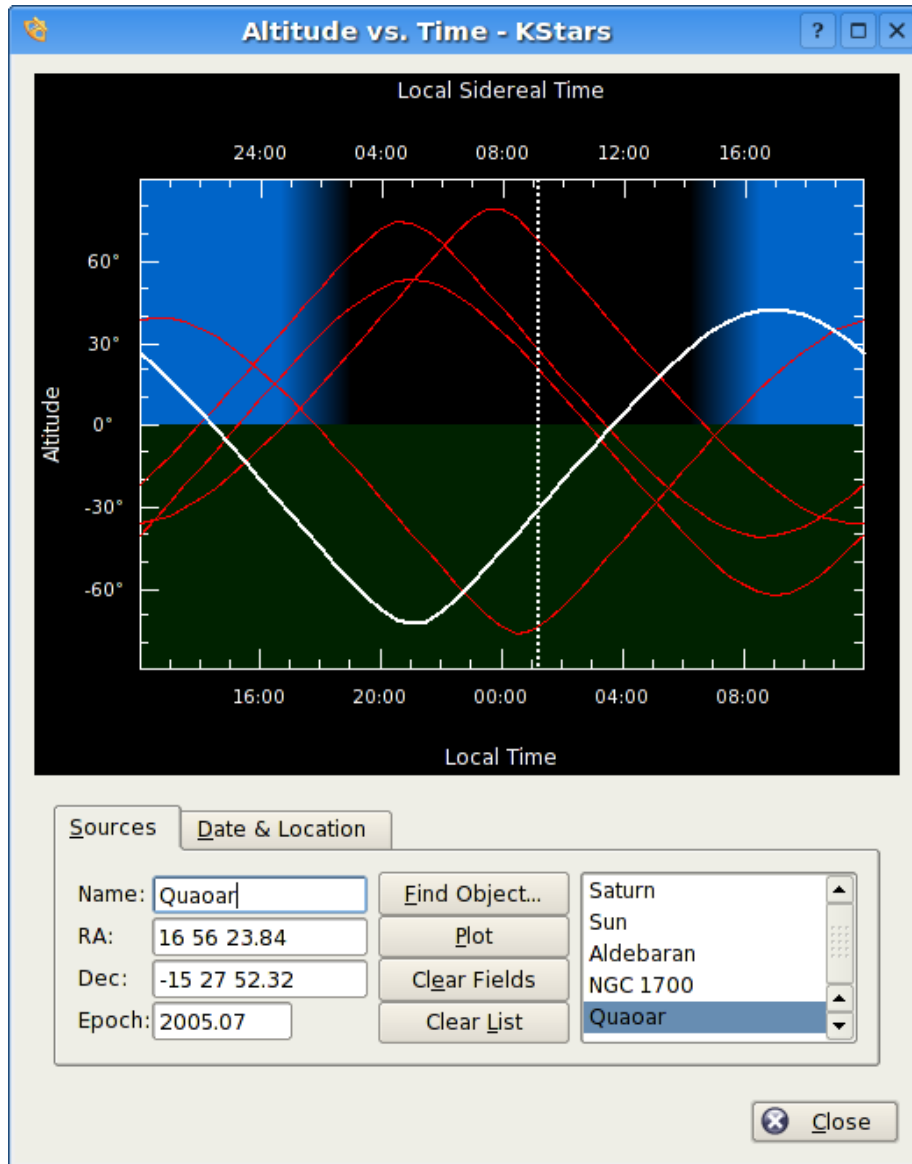
This tool plots the altitude of any objects as a function of time, for any date and location on Earth. The top section is a graphical plot of altitude angle on the vertical axis, and time on the horizontal axis. The time is shown both as standard local time along the bottom, and sidereal time along the top. The bottom half of the graph is shaded green to indicate that points in this region are below the horizon.

There are a few ways to add curves to the plot. The simplest way to add the

curve of an existing object is to simply type its name in the Name input field, and press Enter, or the Plot button. If the text you enter is found in the object database, the object's curve is added to the graph. You can also press the Browse button to open the Find Object Window to select an object from the list of known objects. If you want to add a point that does not exist in the object database, simply enter a name for the point, and then fill in the coordinates in the RA and Dec input fields. Then press the Plot button to add the curve for your custom object to the plot (note that you have to pick a name that does not already exist in the object database for this to work).

When you add an object to the plot, its altitude vs. time curve is plotted with a thick white line, and its name is added to the listbox at the lower right. Any objects that were already present are plotted with a thinner red curve. You can choose which object is plotted with the thick white curve by highlighting its name in the listbox.

These curves show the objects' Altitude (angle above the horizon) as a function of time. When a curve passes from the lower half to the upper half, the object has risen; when it falls back to the lower half, it has set. For example, in the screenshot, the minor planet *Quaoar* is setting at around 15:00 local time, and is rising at about 04:00 local time.

The Altitude of an object depends on both where you are on Earth, and on the Date. By default, the Tool adopts the Location and Date from the current KStars settings. You can change these parameters in the Date & Location Tab. To change the Location, you can press the Choose City... button to open the Set Geographic Location Window, or enter Longitude and Latitude values manually in the input fields, and press the Update button. To change the Date, use the Date picker widget, then press Update. Note that any curves you had already plotted will be automatically updated when you change the Date and/or Location.

TIP

Exercise:

Plot the Sun's Altitude curve. Make sure the geographic location is not near the equator. Change the Date to some time in June, and then again to sometime in January. You can see easily why we have seasons; in the winter, the Sun is above the horizon for less time (the days are shorter), and its altitude is never very high.

6.5 What's Up Tonight? Tool
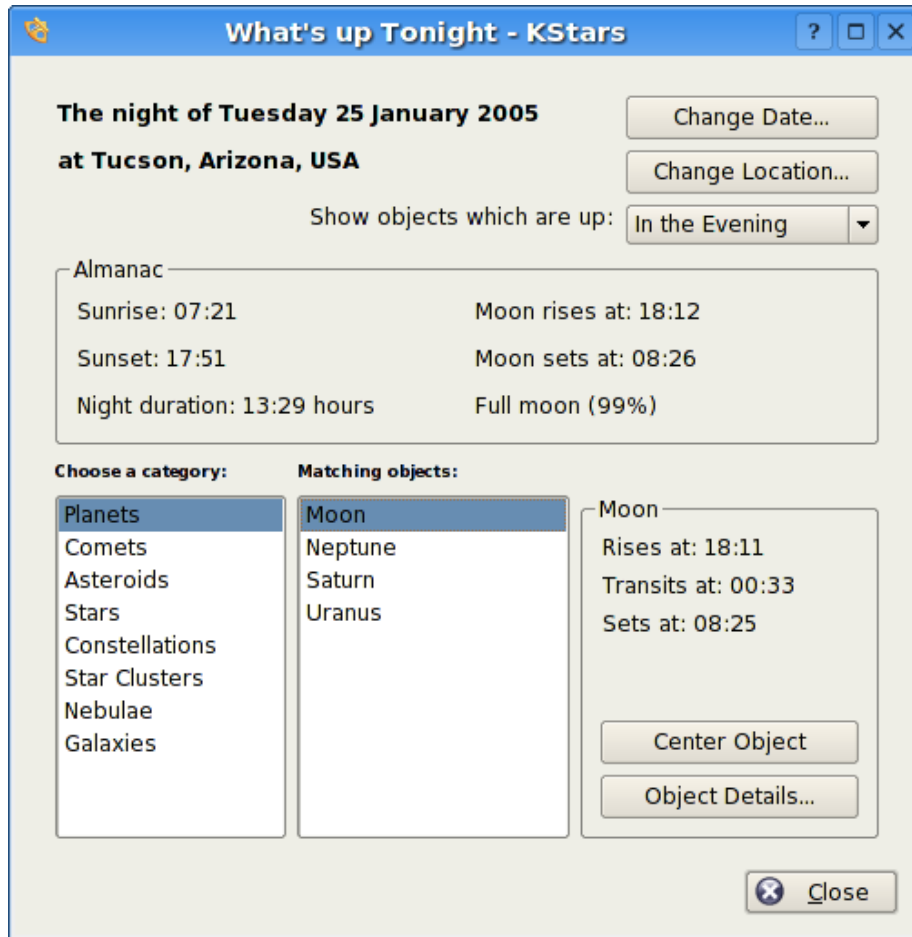
The 'What's Up Tonight?' (WUT) tool displays a list of objects that will be visible at night from any location, on any date. By default, the Date and Location are taken from the current settings in the main window, but you can change either value using the Change Date and Change Location buttons at the top of the WUT window.

The WUT tool also displays a short almanac of data for the selected date: the rise and set times for the Sun and moon, the duration of the night, and the Moon's illumination fraction.

Below the almanac is where the object information is displayed. The objects are organized into type categories. Select an object type in the box labeled Choose a Category, and all objects of that type which are above the horizon on the selected night will be displayed in the box labeled Matching Objects. For example, in the screenshot, the Planets category has been selected, and four planets which are up on the selected night are displayed (Mars, Neptune,

Pluto, and Uranus). When an object in the list is selected, its rise, set and transit times are displayed in the lower-right panel. In addition, you can press the Object Details... button to open the Object Details window for that object.

By default, the WUT will display objects which are above the horizon between sunset and midnight (i.e., 'in the evening'). You can choose to show objects which are up between midnight and dawn ('in the morning'), or between dusk and dawn ('any time tonight') using the combobox near the top of the window.

6.6 The Script Builder Tool

KDE applications can be controlled externally from another program, from a console prompt, or from a shell script using the Inter-process communication protocol (DCOP). KStars takes advantage of this feature to allow rather complex behaviors to be scripted and played back at any time. This can be used, for example, to create a classroom demo to illustrate an astronomical concept.

The problem with DBus scripts is, writing them is a bit like programming, and can seem a daunting task to those who do not have programming experience. The Script Builder Tool provides a GUI point-and-click interface for constructing KStars DCOP scripts, making it very easy to create complex scripts.

6.6.1 Introduction to the Script Builder

Before explaining how to use the Script Builder, I provide a very brief introduction to all of the GUI components; for more infomation, use the "What's This?" function.
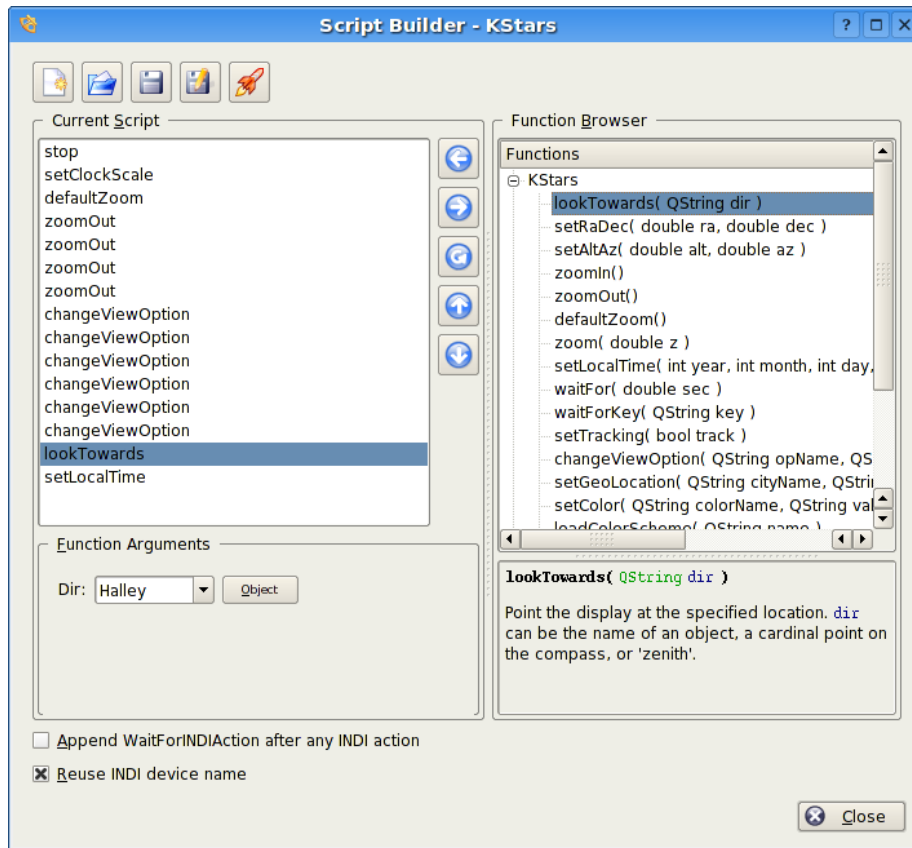
The Script Builder is shown in the above screenshot. The box on the left is the *Current Script box*; it shows the list of commands that comprise the current working script. The box on the right is the *Function Browser*; it displays the list of all available script functions. Below the Function Browser, there is a small panel which will display short documentation about the script function highlighted in the Function Browser. The panel below the Current Script box is the *Function Arguments panel*; when a function is highlighted in the Current Script box, this panel will contain items for specifying values for any arguments that the highlighted function requires.

Along the top of the window, there is a row of buttons which operate on the script as a whole. From left to right, they are: New Script, Open Script, Save Script, Save Script As..., and Test Script. The function of these buttons should be obvious, except perhaps the last button. Pressing Test Script will attempt to run the current script in the main KStars window. You should move the Script Builder window out of the way before pressing this, so you can see the results.

In the center of the window, there is a column of buttons which operate on individual script functions. From top to bottom, they are: Add Function, Remove Function, Copy Function, Move Up, and Move Down. Add Function adds the currently-highlighted function in the Function Browser to the Current Script box (you can also add a function by double-clicking on it). The rest

of the buttons operate on the function highlighted in the Current Script box, either removing it, duplicating it, or changing its position in the current script.

6.6.2 Using the Script Builder

In order to illustrate using the Script Builder, we present a small tutorial example where we make a script that tracks the Moon while the clock runs at an accelerated rate.

If we are going to track the Moon, we will need to point the display at it first. The *lookToward* function is used to do this. Highlight this function in the Function Browser, and note the documentation displayed in the panel below the Browser. Press the Add Function button to add this function to the Current Script box. The Function Arguments panel will now contain a combobox labeled 'dir', short for direction. This is the direction in which the display should be pointed. The combobox contains only the cardinal compass points, not the Moon or any other objects. You can either enter 'Moon' in the box manually, or press the Object button to use the Find Object window to select the Moon from the list of named objects. Note that, as usual, centering on an object automatically engages object-tracking mode, so there is no need to add the *setTracking* function after lookToward.

Now that we have taken care of pointing at the Moon, we next want to make time pass at an accelerated rate. Use the *setClockScale* function for this. Add it to the script by double-clicking on it in the Function Browser. The Function Arguments panel contains a timestep spinbox for setting the desired time step for the simulation clock. Change the timestep to 3 hours.

OK, we have pointed at the Moon and accelerated the clock. Now we just want the script to wait for several seconds while the display tracks on the Moon. Add the *waitFor* function to the script, and use the Function Arguments panel to specify that it should wait for 20 seconds before continuing.

To finish up, let us reset the clock's timestep to the normal value of 1 second. Add another instance of setClockScale, and set its value to 1 sec.

Actually, we are not quite done yet. We should probably make sure that the display is using Equatorial coordinates before the script tracks the Moon with an accelerated time step. Otherwise, if the display is using Horizontal coordinates, it will rotate very quickly through large angles as the Moon rises and sets. This can be very confusing, and is avoided by setting the View Option *UseAltAz* to 'false'. To change any View Option, use the *changeViewOption* function. Add this function to the script, and examine the Function Arguments panel. There is a combobox which contains the list of all options which can be adjusted by changeViewOption. Since we know we want the UseAltAz option, we could simply select it from the combobox. However, the list is quite long, and there is no explanation of what each item is for. It therefore may be easier to press the Browse Tree button, which will open a window containing a tree view of the available options, organized by topic. In addition, each item has a short explanation of what the option does, and the data type of the option's value. We find UseAltAz under the Skymap options category. Just highlight

this item and press OK, and it will be selected in the combobox of the Function Arguments panel. Finally, make its value 'false' or '0'.

One more step: changing UseAltAz at the end of the script does us no good; we need this to be changed before anything else happens. So, make sure this function is highlighted in the Current Script box, and press the Move Up button until it is the first function.

Now that we have finished the script, we should save it to disk. Press the Save Script button. This will first open a window in which you can provide a name for the script, and fill in your name as the author. Enter 'Tracking the Moon' for a name, and your name as the author, and press OK. Next, you will see the standard KDE Save File dialog. Specify a filename for the script and press OK to save the script. Note that if your filename does not end with '.kstars', this suffix will be automatically attached. If you are curious, you can examine the script file with any text editor.

Now that we have a completed script, we can run it in a couple of ways. From a console prompt, you can simply execute the script as long as an instance of KStars is currently running. Alternatively, you can execute the script from within KStars using the Run Script item in the File menu.

6.7 Solar System Viewer
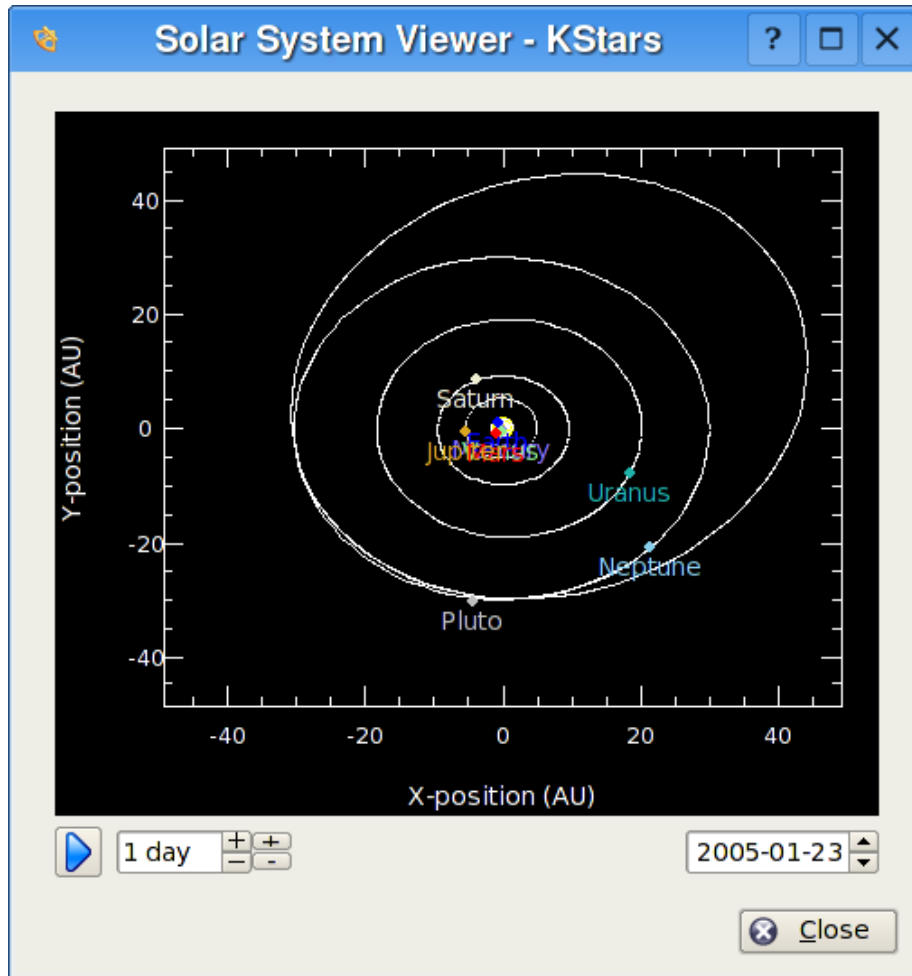
This tool displays a model of our solar system as seen from above. The Sun is drawn as a yellow dot in the center of the plot, and the orbits of the planets are drawn as ellipses with the correct shapes and orientations. The current position of each planet along its orbit is drawn as a colored dot, along with a name label. The display can be zoomed in and out with the **+** and **-** keys, and the display can be recentered with the arrow keys, or by double-clicking anywhere in the window with the mouse. You can also center on a planet with the **0–9** keys (**0** is the Sun; **9** is Pluto). If you center on a planet, it will be tracked as time passes in the tool.

The Solar System Viewer has its own clock, independent of the clock in the main KStars window. There is a timestep control widget here, similar to the one in the main window's toolbar. However, this control defaults to a timestep

of 1 day (so that the motions of the planets can be seen), and it starts out with the clock paused when the tool is opened.

> **NOTE**
> The current model used for Pluto's orbit is only good for dates within about 100 years of the present date. If you let the Solar System clock advance beyond this range, you will see Pluto behave very strangely! We are aware of this issue, and will try to improve Pluto's orbit model soon.

6.8 Jupiter Moons Tool
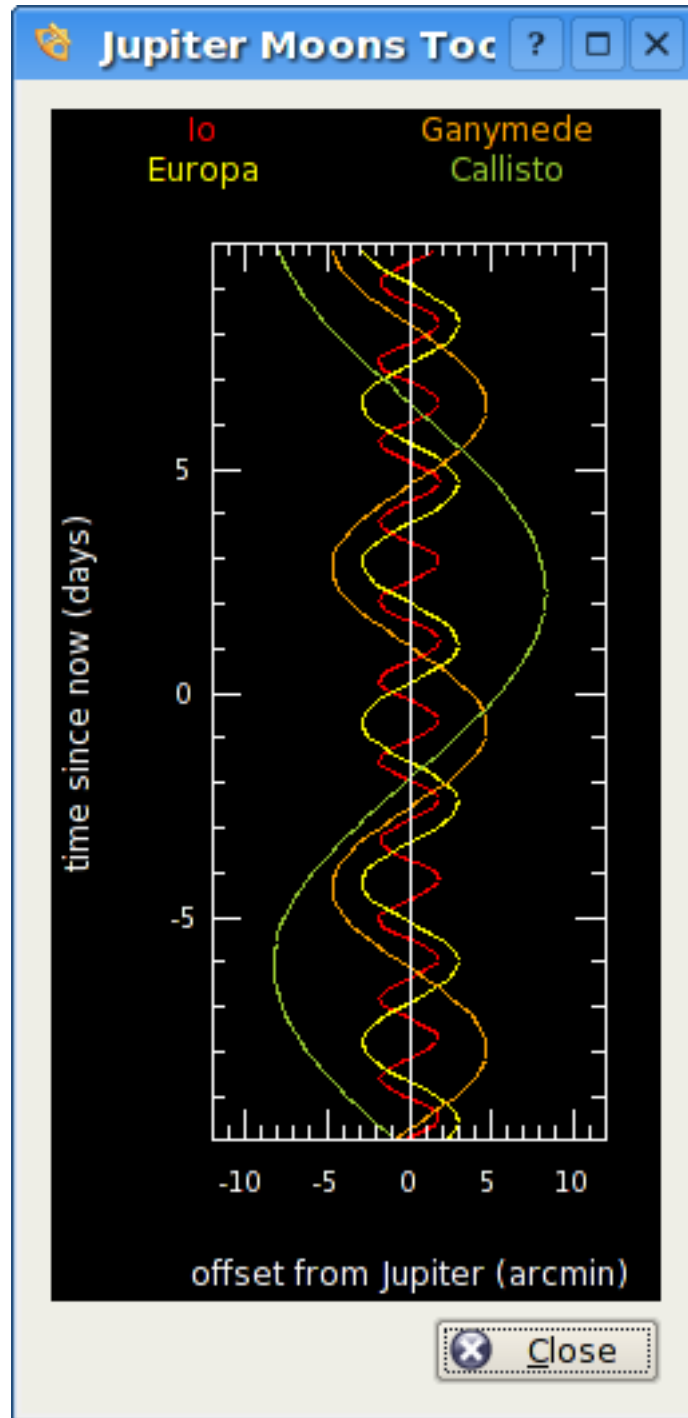
This tool displays the positions of Jupiter's four largest moons (Io, Europa, Ganymede, and Callisto) relative to Jupiter, as a function of time. Time is plotted vertically; the units are days and 'time=0.0' corresponds to the current simulation time. The horizontal axis displays the angular offset from Jupiter's position, in arcminutes. The offset is measured along the direction of Jupiter's equator. Each moon's position as a function of time traces a sinusoidal path in the plot, as the moon orbits around Jupiter. Each track is assigned a different color to distinguish it from the others; the name labels at the top of the window indicate the color used by each moon.

The plot can be manipulated with the keyboard. The time axis can be expanded or compressed using the **+** and **-** keys. The time displayed at the center of the window can be changed with the **[** and **]** keys.

6.9 Observing List Tool
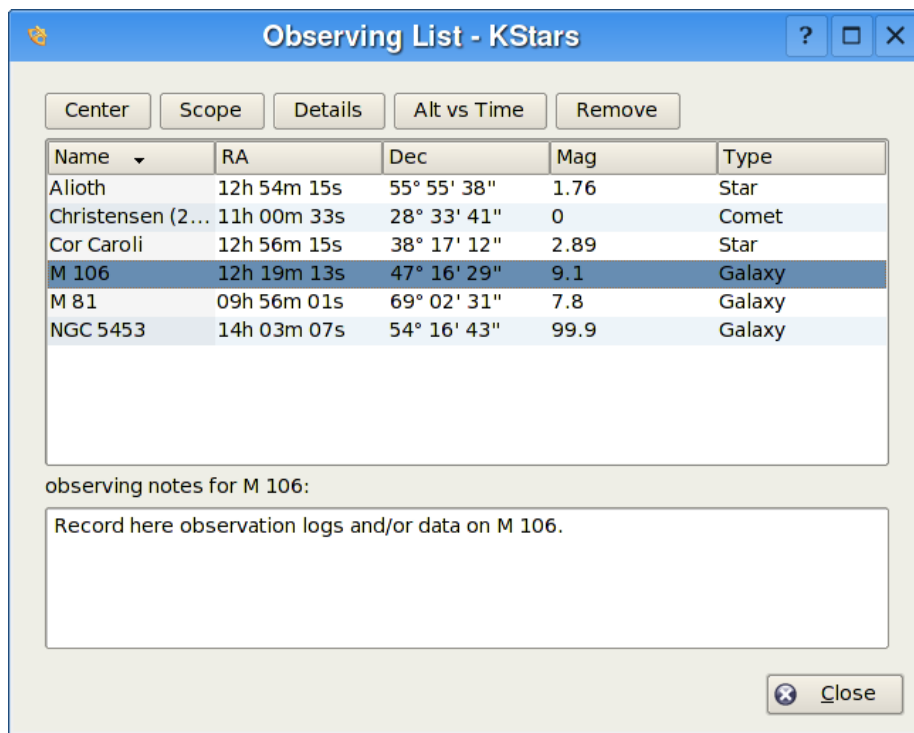
The purpose of the Observing List Tool is to provide convenient access to some common functions for a list of objects chosen by you. Objects are added to the list by using the 'Add to List' action in the popup menu, or by simply pressing the **O** key to add the currently-selected object.

Objects in the list can be sorted by any of the data columns (Name, Right Ascension, Declination, Magnitude, and Type). To perform an action on an object,

highlight it in the list, and then press one of the Action buttons at the top of the window. Some actions can be performed while multiple objects are selected; others only operate when one object is selected. The available actions are:

Center Center the display on the selected object, and begin Tracking it.

Scope Point your telescope at the selected object.

Alt vs. Time Open the Altitude vs. Time Tool, with the selected object(s) preloaded

Details Open the Detailed Information Window for the selected object.

Remove Remove the selected object(s) from the observing list.

NOTE

The Observing List tool is a new feature and is still under development. We are planning to add more features, such as adding objects to the list by selecting a region in the sky, and the ability to save observing lists to disk.

6.10 FITS Viewer Tool

The Flexible Image Transport System (FITS) is the standard format for representing images and data in Astronomy.

The KStars FITS Viewer tool is integrated with the INDI framework for seamless display and manipulation of captured FITS images. To open a FITS file, select Open FITS... from the File menu, or press Ctrl+O.

FITS Viewer features:

- Support for 8, 16, 32, IEEE -32, and IEEE -64 bits formats.

- Histogram with linear, logarithmic, and square-root scales.

- Brightness/Contrast controls.

- Pan and Zoom.

- Auto levels.

- Statistics.

- FITS header query.

- Undo/Redo.
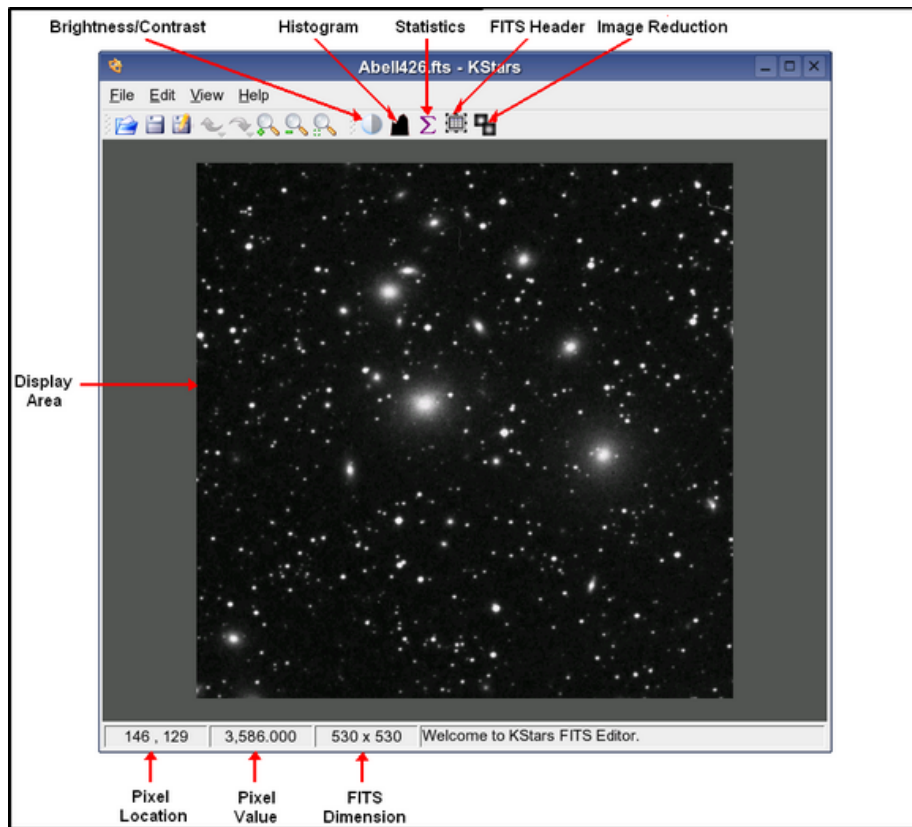
The above diagram illustrates the FITS Viewer work area and window. The tool provides basic functions for image display. FITS data depth is preserved throughout all processing, open, and save functions. While the tool adhere to the FITS standard, it does not support all possible FITS features:

- Support for only *one* image per file.

- Support for only 2D data. 1D and 3D data are discarded.

- No support for WCS (World Coordinate System).

The following is a brief description of the tool's functional units:

- Brightness/Contrast: Adjusts brightness and contrast. The function can be CPU and memory intensive for very large FITS.

- Histogram: Displays one-channel FITS histogram. The user can rescale the image by optionally defining an upper and lower limit for the cutoff region. The rescaling operation (linear, logarithmic, or square-root) may then be applied to the region enclosed by the upper and lower limits.

- Statistics: Provides simple statistics for minimum and maximum pixel values and the their respective locations. FITS depth, dimension, mean, and standard deviation.

- FITS header: Displays FITS header information.

Chapter 7

Command-Line mode for Image Generation

You can use KStars to generate an image of the sky without actually launching the GUI portion of the program. To use this feature, start KStars from a command prompt using arguments to specify the filename for the image, as well as the desired image dimensions:

kstars --dump [--filename *kstars.png*] [--height *640*] [--width *480*] [--script *myscript.kstars*] [--date *"4 July 1976 12:30:00"*]

If no filename is specified, it generates a file named kstars.png. It will attempt to generate an image that matches the extension of your filename. The following extensions are recognized: 'png', 'jpg', 'jpeg', 'gif', 'pnm', and 'bmp'. If the filename extension is not recognized, it defaults to the PNG image type.

Likewise, if the image width and height are not specified, they default to 640 and 480, respectively.

By default, KStars will read in the options values stored in your $KDEHOME-/share/config/kstarsrc file to determine where the image will be centered, and how it is rendered. This means you need to run KStars in normal GUI mode, and exit the program when it is set up with the desired options for the generated images. This is not very flexible, so we also provide the ability to execute a KStars DCOP script to set the scene before generating the image. The filename you specify as the script argument should be a valid KStars DCOP script, such as one created with the Script Builder Tool. The script can be used to set where the image is pointing, set the geographic location, set the time and date, change the Zoom level, and adjust other view options. Some of the DCOP functions make no sense in non-GUI mode (such as waitForKey()); if these functions are encountered while parsing the script, they are simply ignored.

By default, KStars will use the system CPU time and date for generating the image. Alternatively, you may specify a time and date with the '--date' argument. You can also use this argument for specifying the startup date in normal GUI mode.

Chapter 8

Astronomical Device Control with INDI

KStars provides an interface to configure and control astronomical instruments via the INDI protocol.

The INDI protocol supports a variety of astronomical instruments such as CCD cameras and focusers. Currently, KStars supports the following devices:

Telescope	Device driver
LX200 8"-12" Classic	indi_lx200classic
Autostar based telescopes	indi_lx200autostar
LX200 GPS 8"-16"	indi_lx200gps
LX200 Classic 16"	indi_lx200_16
NexStar GPS, CGE, AS-GT	indi_celestrongps
New GT, NexStar 5i/8i	indi_celestrongps
Takahashi Temma	indi_temma
Astro-Electronic FS-2	indi_lx200basic
Argo Navis	indi_lx200basic
Losmandy Gemini	indi_lx200basic
Mel Bartels Controllers	indi_lx200basic
Sky Commander	indi_skycommander
Intelliscope/SkyWizard	indi_intelliscope
Orion Atlas	indi_orion_atlas

Table 8.2: Supported Telescopes

Focuser	Device driver
Meade LX200GPS Microfocuser	indi_lx200gps
Meade 1206 Primary Mirror Focuser	indi_lx200basic
JMI NGF Series	indi_lx200basic
JMI MOTOFOCUS	indi_lx200basic
FLI Precision Focuser	indi_fli_pdf
RoboFocus	indi_robofocus

Table 8.4: Supported Focusers

CCD	Device driver
Finger Lakes Instruments CCDs	indi_fli_ccd
Santa Barbara Instrument CCDs	indi_sbig_ccd
Apogee CCDs	indi_apogee_alta

Table 8.6: Supported CCDs

Filter Wheel	Device driver
FLI Filter Wheels	indi_fli_wheel
True Technology Wheel	indi_trutech_wheel

Table 8.8: Supported Filter Wheels

Webcam	Device driver
Any Video4Linux compatible device	indi_v4l_generic
Philips webcam	indi_v4l_philips
Meade Lunar Planetary Imager	indi_meade_lpi
SBIG STV	indi_sbig_stv

Table 8.10: Supported Webcams

8.1 INDI Setup

KStars can control local and remote devices seamlessly via the INDI server/-
client architecture. INDI devices may be run in three different modes:

1. Local: The local mode is the most common and is used to control local
   device (i.e. a device attached to your machine).

2. Server: The server mode establishes an INDI server for a particular de-
   vice and waits for connections from remote clients. You cannot operate
   server devices, you can only start and shut them down.

3. Client: The client mode is used to connect to remote INDI servers run-
   ning INDI devices. You can control remote devices seamlessly like local
   devices.

You can run local device, establish INDI servers, and connect to remote clients
from the Device Manager in the Devices menu.

Here is a screenshot of the Device Manager window:
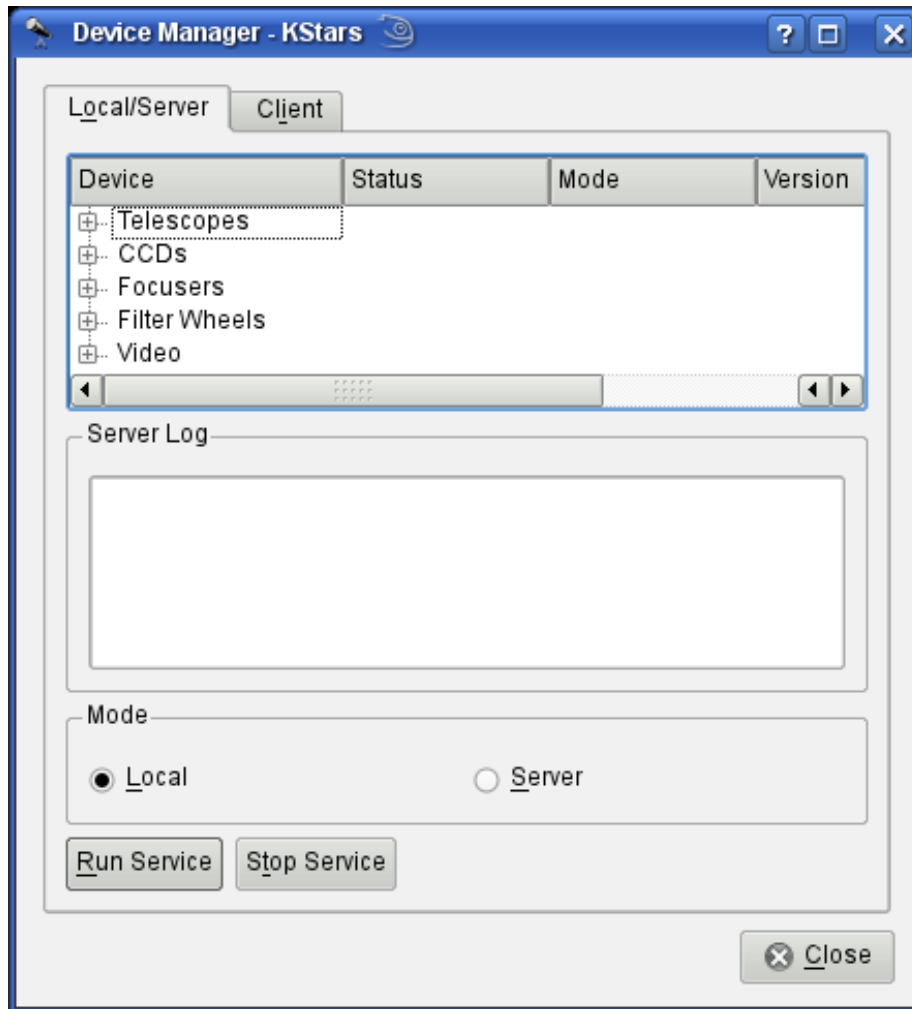
You can run devices by browsing the device tree, selecting a specific device, and then clicking on the Run Service button. You can select the operation mode, either local or server as defined above.

To control remove devices, refer to the remote device control section.

8.2 Telescope Setup

Most telescopes are equipped with RS232 interface for remote control. Connect the RS232 jack in your telescope to your computer's Serial/USB port. Traditionally, the RS232 connects to the serial port of your computer, but since many new laptops abandoned the serial port in favor of USB/FireWire ports, you might need to obtain a Serial to USB adaptor to use with new laptops.

After connecting your telescope to the Serial/USB port, turn your telescope on. It is *highly* recommended that you download and install the latest firmware for your telescope controller.

The telescope needs to be aligned before it can be used properly. Align your telescope (one or two stars alignment) as illustrated in your telescope manual.

KStars needs to verify time and location settings before connecting to the telescope. This insures proper tracking and synchronization between the telescope and KStars. The following steps will enable you to connect to a device that is connected to your computer. To connect and control remote devices, please refer to remote device control section.

You can use the Telescope Setup Wizard and it will verify all the required information in the process. It can automatically scan ports for attached telescopes. You can run the wizard by selecting Telescope Setup Wizard from the Devices menu.

Alternatively, you can connect to a local telescope by performing the following steps:

1. Set your geographical location. Open the Geographic... window by selecting Set Geographic Location... from the Settings menu, or by pressing the Globe icon in the toolbar, or by pressing Ctrl+g.

2. Set your local time and date. You can change to any time or date by selecting Set Time... from the Time menu, or by pressing the time icon in the toolbar. The Set Time window uses a standard KDE Date Picker widget, coupled with three spinboxes for setting the hours, minutes and seconds. If you ever need to reset the clock back to the current time, just select Set Time to Now from the Time menu.

3. Click on the Devices menu and select the Device Manager.

4. Under the Device column, select your telescope model.

5. Right-click on the device and select Run Service.

6. Click Ok to close the Device Manager Dialog.

FREQUENT SETTINGS
You do not need to set the geographic location and time every time you connect to a telescope. Only adjust the settings as needed.

You are now ready to use the device features, KStars conveniently provides two interchangeable GUI interfaces for controlling telescopes:

CONTROLLING YOUR TELESCOPE

1. Sky map Control: For each device you run in the Device Manager, a corresponding entry will show up in popup menu that allows you to control

the properties of the device. You can issue commands like **Slew, Sync,** and **Track** directly from the sky map.

Here is a screenshot of the popup menu with an active LX200 Classic device:
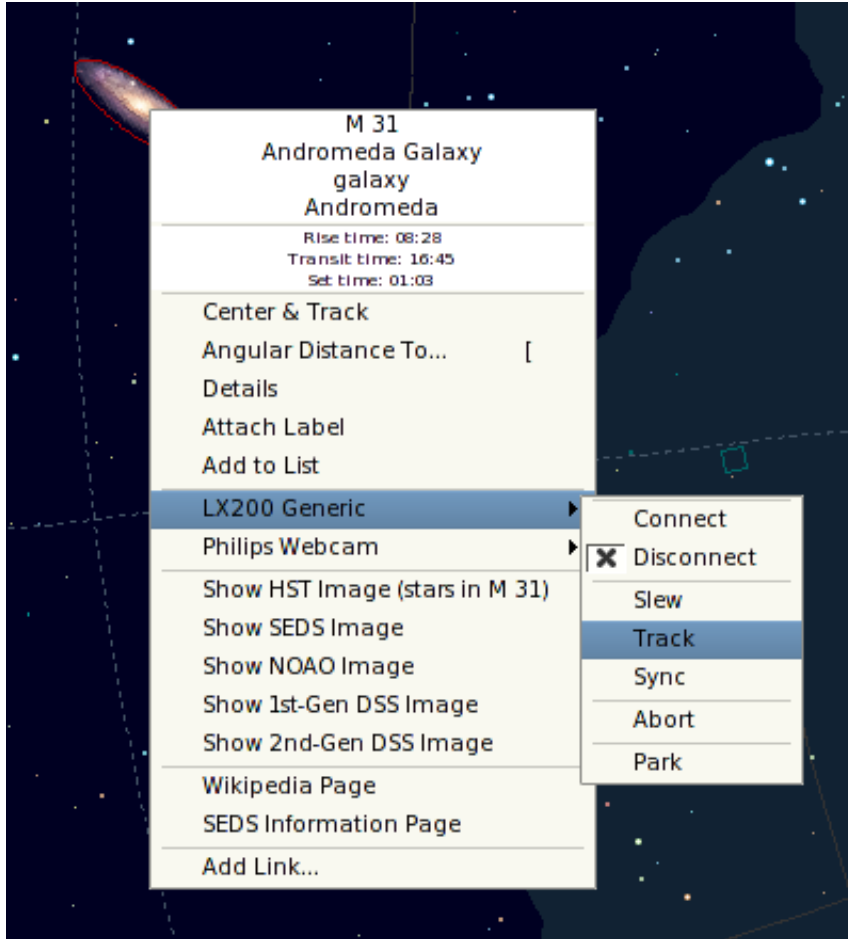

2. INDI Control Panel: The panel offers the user with all the features supported by a device.

The panel is divided into three main sections:

- Device tabs: Each additional active device occupies a tab in the INDI panel. Multiple devices can run simultaneously without affecting the operation of other devices.

- Property view: Properties are the key element in INDI architecture. Each device defines a set of properties to communicate with the client. The current position of the telescope is an example of a property. Semantically similar properties are usually contained in logical blocks or groupings.

- Log viewers: Devices report their status and acknowledge commands by sending INDI messages. Each device has its own log view, and all devices share one generic log viewer. A device usually sends messages to its device driver only, but a device is permitted to send a generic message when appropriate.
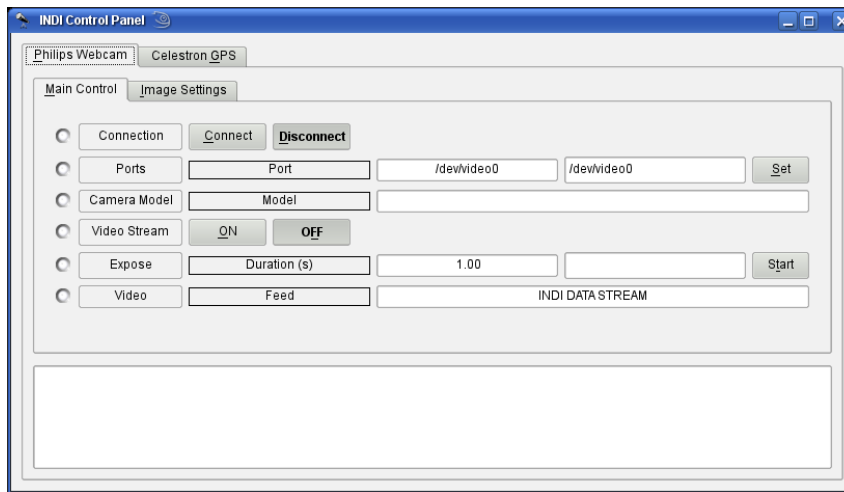
You are not restricted on using one interface over another as they can be both used simultaneously. Actions from the Sky map are automatically reflected in the INDI Control Panel and vice versa.

To connect to your telescope, you can either select Connect from your device popup menu or alternatively, you can press Connect under your device tab in the INDI Control Panel.

> IMPORTANT
> By default, KStars will try to connect to the /dev/ttyS0 port. To change the connection port, select INDI Control Panel from the Devices menu and change the port under your device tab.

KStars automatically updates the telescope's longitude, latitude, and time based on current settings in KStars. You can enable/disable these updates from Configure INDI dialog under the Devices menu.

If KStars communicates successfully with the telescope, it will retrieve the current RA and DEC from the telescope and will display a crosshair on the sky map indicating the telescope position.

SYNCHRONIZING YOUR TELESCOPE

If you aligned your telescope and the last alignment star was, for example, Vega, then the crosshair should be centered around Vega. If the crosshair was off target, then you can right-click Vega from the sky map and select **Sync** from your telescope menu. This action will instruct the telescope to synchronize its internal coordinates to match those of Vega, and the telescope's crosshair should now be centered around Vega.

This is it: your telescope is ready to explore the heavens!

WARNING

Never use the telescope to look at the sun. Looking at the sun might cause irreversible damage to your eyes and your equipment.

8.3 CCD and Video-Capture Setup

KStars supports the following imaging devices:

- Finger Lakes instruments CCDs

- SBIG CCDs: In order to use SBIG CCDs, you must download and install the Universal SBIG Driver library from INDI website.

- Apogee CCDs: Only USB versions are supported. You must have libusb installed.

- Video4Linux compatible devices. Philips webcam extended features are supported as well.

You can run CCD and Video Capture devices from the Device Manager in the Devices menu. Like all INDI devices, some of the device controls will be accessible from the skymap. The device can be controlled fully from the INDI Control Panel.

The standard format for image capture is FITS. Once an image is captured and downloaded, it will be automatically displayed in the KStars FITS Viewer. To capture a sequence of images, use the Capture Image Sequence tool from the Devices menu. This tool is inactive until you establish a connection to an image device.

IMPORTANT

The fli and apogee drivers requires root privileges in order to operate properly. Note that running the driver as root is considered a security risk.

8.4 Capture Image Sequence

The Capture Image Sequence tool can be used to aquire images from cameras and CCDs in interactive and batch modes. Furthermore, you can select which filter, if any, you want to use for your images. The capture tool remains disabled until you establish a connection to an imaging device.
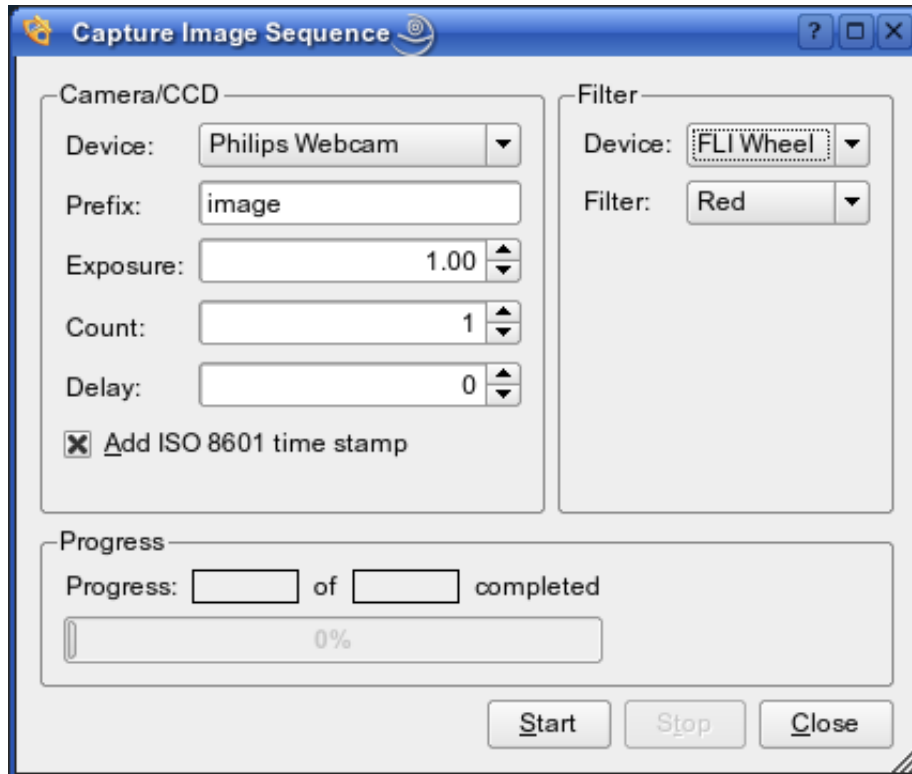
The above screenshot depicts a sample capture session. The tool provides the following options:

- Camera/CCD

    - `Device:` The desired imaging device.
    - `Prefix:` The image prefix which will be prepended to each captured filename.
    - `Exposure:` The number of seconds to expose each frame.
    - `Count:` The number of images to aquire.
    - `Delay:` The delay in seconds between consecutive images.
    - `ISO 8601 time stamp:` Append ISO 8601 time stamp to the filename. (e.g. image_01_20050427T09:48:05).

- Filter

- Device: The desired filter device.
- Filter: The desired filter slot. You can assign color values to slot numbers using the Configure INDI window (e.g. Slot #1 = Red, Slot #2 = Blue..etc).

After you fill in the desired options, you can begin the capture procedure by pressing the Start button. You may cancel at any time using the Stop button. All captured images will be saved to the default FITS directory which can be specified in the Configure INDI window.

If you have more complex capturing requirements and conditions to fulfil, it is recommended to create a script to meet your specific needs using the Script Builder tool in the Tools menu.

8.5 Configure INDI

The Configure INDI window allows you to modify *Client side* INDI specific options. The window is divided into four main categories: General, Automatic device updates, Display, and Filter Wheel:

- General

  - Default FITS directory: Specify the directory where all captured FITS images will be saved to. If no directory is specified, images will be stored in $HOME.
  - Automatic Display of FITS upon capture: When checked, KStars will display captured FITS in KStars FITS Viewer tool. If you use the Capture Image Sequence tool, all captured images will be saved to disk regardless of this option.
  - Telescope port: The default telescope port. When you connect to a local or remote telescope service, KStars will automatically fill the telescope's device port with the specified default port.
  - Video port: The default video port. When you connect to a local or remote video service, KStars will automatically fill the webcam's device port with the specified default port.

- Automatic device updates

  - Time: Update the telescope's date and time, if supported, upon connection.
  - Geographic location: Update the telescope's geographical location information (current longitude and latitude), if supported, upon connection.

- Display

  - Device target crosshair: When checked, KStars displays the telescope's target crosshair on the sky map. The crosshair is displayed upon a successful connection to the telescope and its location is updated periodically. The telescope's name is displayed next to the crosshair. KStars displays

one crosshair per each connected telescope. To change the color of the telescope's crosshair, open the Configure KStars window. Select the Colors tab, and then change the color of the *Target Indicator* item to the desired color.

– `INDI messages in status bar`: When checked, KStars displays INDI status messages in the KStars status bar.

- Filter Wheel: Assign color codes to the filter wheel slots (e.g. Slot #0 Red, Slot #1 Blue..etc). You can assign color codes for up to 10 filter slots (0 to 9). To assign a color code, select a slot number from the drop down combo box, and then type the corresponding color code in the edit field. Repeat the process for all desired slots and then press OK.

8.6 INDI Concepts

The main key concept in INDI is that devices have the ability to describe themselves. This is accomplished by using XML to describe a generic hierarchy that can represent both canonical and non-canonical devices. In INDI, all *devices* may contain one or more *properties*. Any *property* may contain one or more *elements*. There are four types of INDI properties:

- Text property.

- Number property.

- Switch property (Represented in GUI by buttons and checkboxes).

- Light property (Represented in GUI by colored LEDs).

For example, all INDI devices share the CONNECTION standard switch *property*. The CONNECTION property has two elements: CONNECT and DISCONNECT switches. KStars parses the generic XML description of properties and builds a GUI representation suitable for direct human interaction.

The INDI control panel offers many device properties not accessible from the sky map. The properties offered differ from one device to another. Nevertheless, all properties share common features that constrains how they are displayed and used:

- Permission: All properties can either be read-only, write-only, or read and write enabled. An example of a read-write property is the telescope's Right Ascension. You can enter a new Right Ascension and the telescope, based on current settings, will either slew or sync to the new input. Furthermore, when the telescope slews, its Right Ascension gets updated and sent back to the client.

- State: Prefixed to each property is a state indicator (round LED). Each property has a state and an associated color code:

State	Color	Description
Idle	Gray	Device is performing no action with respect to this property
Ok	Green	Last operation performed on this property was successful and active
Busy	Yellow	The property is performing an action
Alert	Red	The property is in critical condition and needs immediate attention

Table 8.12: INDI State color code

The device driver updates the property state in real-time when necessary. For example, if the telescope is in the process of slewing to a target, then the RA/DEC properties will be signaled as Busy. When the slew process is completed successfully, the properties will be signaled as Ok.

- Context: Numerical properties can accept and process numbers in two formats: decimal and sexagesimal. The sexagesimal format is convenient when expressing time or equatorial/geographical coordinates. You can use any format at your convenience. For example, all the following numbers are equal:

  - -156.40
  - -156:24:00
  - -156:24

- Time: The standard time for all INDI-related communications is Universal Time UTC specified as YYYY-MM-DDTHH:MM:SS in accord with ISO 8601. KStars communicates the correct UTC time with device drivers automatically. You can enable/disable automatic time updates from the Configure INDI dialog under the Devices menu.

8.7 Remote Device Control

KStars provides a simple yet powerful layer for remote device control. A detailed description of the layer is described in the INDI white paper.

You need to configure both the server and client machines for remote control:

1. Server: To prepare a device for remote control, follow the same steps in the local/server setup. When you start a device service in the Device Manager, a port number is displayed under the Listening port column. In addition to the port number, you also need the hostname or IP address of your server.

2. Client: Select the Device Manager from the Device menu and click on the Client tab. You can add, modify, or delete hosts under the Client tab. Add a host by clicking on the Add button. Enter the hostname/IP address of the server in the Host field, and enter the port number obtained from the *server* machine in step 1.
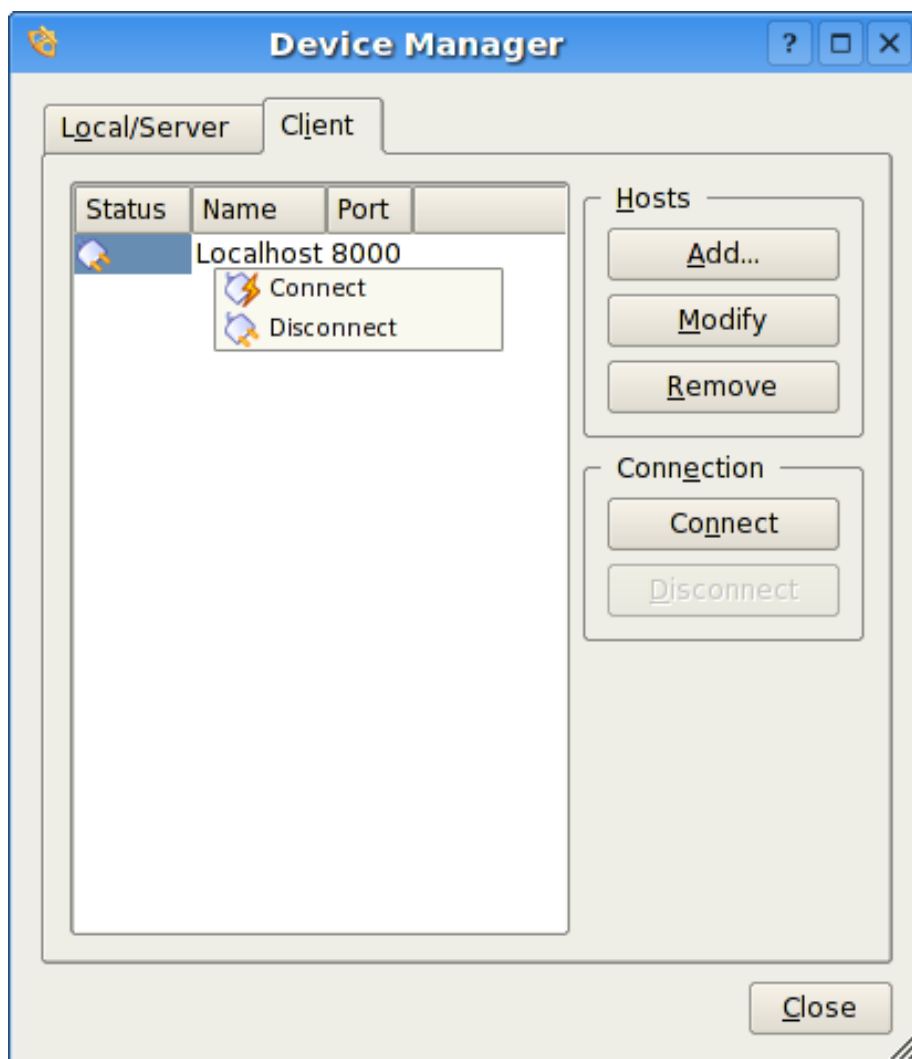
After you add a host, right click on the host to Connect or Disconnect. If a connection is established, you can control the telescope from the Sky map or

INDI Control Panel exactly as described in the local/server section. It is as easy at that.

8.7.1 Running an INDI server from the command line

While KStars allows you to easily deploy an INDI server; you can launch an INDI server from the command line.

Since INDI is an independent backend component, you can run an INDI server on a host without KStars. INDI can be compiled separately to run on remote hosts. Furthermore, device drivers log messages to `stderr` and that can be helpful in a debugging situation. The syntax for INDI server is as following:

$ **indiserver** [options] [`driver ...`]

Options:

-l d : log driver messages to d/YYYY-MM-DD.islog

-m m : kill client if gets more than this many MB behind, default 10

-p p : alternate IP port, default 7624

-v : show key events, no traffic

-vv : -v + key message content

-vvv : -vv + complete xml

driver : executable or device@host[:port]

For example, if you want to start an INDI server running an LX200 GPS driver and listening to connections on port 8000, you would run the following command:

$ **indiserver** -p 8000 `lx200gps`

8.7.2 Secure Remote Operation

Suppose we want to run an indiserver with INDI drivers on a remote host, `remote_host`, and connect them to KStars running on the local machine.

From the local machine log onto the remote host, `remote_host`, by typing:

$ **ssh** -L `local_port:remote_host:remote_port`

This binds the `local_port` on the local machine to the `remote_port` on the `remote_host`. After logging in, run indiserver on the remote host:

$ **indiserver** -p `remote_port` [`driver...`]

Back on the local machine, start KStars then open the Device Manager and add a host under the Client tab. The host should be the local host (usually 127.0.0.1) and the port number should be the `local_port` used in the steps above. Right-click on the host and select Connect from the popup menu. KStars will connect to the remote INDI server securely. The host information will be saved for future sessions.

8.8   INDI Frequently Asked Questions

Q: *What is INDI?*

A: INDI is the Instrument-Neutral-Distributed-Interface control protocol developed by Elwood C. Downey of ClearSky Institute. KStars employs device drivers that are compatible with the INDI protocol. INDI has many advantages including loose coupling between hardware devices and software drivers. Clients that use the device drivers (like KStars) are completely unaware of the device capabilities. In run time, KStars communicates with the device drivers and builds a completely dynamical GUI based on services provided by the device. Therefore, new device drivers can be written or updated and KStars can take full advantage of them without any changes on the client side.

Q: *Do you plan to support more devices?*

A: Yes. We plan to support major CCD cameras and focusers and extend support for more telescopes. If you would like INDI to support a particular device, please send an email to indi-devel@lists.sourceforge.net

Q: *What operations does KStars provide to control the telescope?*

A: It depends on the particular telescope you're running, but the minimum three operations are **Slew**, **Track**, and **Sync**, which you can issue directly from the sky map. Your telescope must be aligned for those operations to perform correctly. Some telescopes offer you more operations like site management, slew modes, focusing, parking, and more. You can access the telescopes extended features from the INDI Control Panel in the Devices Menu.

Q: *What's the difference between **Slew**, **Track**, and **Sync** exactly?*

A: The command **Slew** orders the telescope to move to a particular target, and once the telescope reaches its target, the telescope keeps tracking that target at a *sidereal* rate (i.e. the rate at which stars move across the sky). This works well for stars, Messier objects, and about everything outside our solar system. But solar system objects travel differently across the sky and so the telescope must **Track** the objects as they move. Therefore, you need to issue a track command if you want to track an object with non-sidereal motion. On the other hand, **Sync** is used to synchronize the telescope's internal coordinates with that of an object you select.

Q: *Can I control my telescope remotely?*

A: Yes. You can start an INDI server on the machine connected to your telescope and the server will listen to requests from KStars clients. Once you're connected, you can control your telescope directly from the sky map. This procedure is described in detail in the Remote device control section.

Q: *When I try to Connect, KStars reports that the telescope is not connected to the serial/USB port. What can I do?*

A: This message is triggered when KStars cannot communicate with the telescope. Here are few things you can do:

1. Check that you have both reading and writing permission for the port you are trying to connect to.

2. Check the connection cable, make sure it is in good condition and test it with other applications.

3. Check your telescope power, make sure the power is on and that the telescope is getting enough power.

4. Set the correct port in the INDI Control Panel under the Devices menu. The default device is `/dev/ttyS0`

5. Restart KStars and retry again.

Q: *KStars reports that the telescope is online and ready, but I cannot find the telescope's crosshair, where is it?*

A: KStars retrieves the telescopes RA and DEC coordinates upon connection. If your alignment was performed correctly, then you should see the crosshair around your target in the Sky Map. However, the RA and DEC coordinates provided by the telescope may be incorrect (even below the horizon) and you need to Sync your telescope to your current target. You can use the right-click menu to center and track the telescope crosshair in the sky map.

Q: *The telescope is moving erratically or not moving at all. What can I do?*

A: This behavior is mostly due to incorrect settings, please verify the following check list:

1. Is the telescope aligned?

2. Is the telescope alignment mode correct? Use INDI Control Panel to check and change these settings (`Alt/Az,Polar, Land`).

3. Are the telescope's time and date settings correct?

4. Are the telescope's longitude and latitude settings correct?

5. Is the telescope's UTC offset correct?

6. Are the telescope's RA and DEC axis locked firmly?

7. Is the telescope's N/S switch (when applicable) setup correctly for your hemisphere?

8. Is the cable between the telescope and computer in good condition?

If you think all settings are correct but the telescope still moves erratically or not at all, then please send a report to indi-devel@lists.sourceforge.net

Chapter 9

Questions and Answers

This document may have been updated since your installation. You can find the latest version at http://docs.kde.org/development/en/kdeedu/ .

1. *What is the KStars Icon?*

   The KStars Icon is a sextant, a handheld telescope which was used by navigators on sailing ships back when the stars were important for navigation. By carefully reckoning the positions of the stars, the navigator could get an accurate estimate of the ship's current longitude and latitude.

2. *What do the different symbols for deep-sky objects mean?*

   The symbol indicates the object type:

   - dotted circle: Open Cluster
   - cross-in-circle: Globular Cluster
   - box: Gaseous Nebula
   - diamond: Supernova Remnant
   - circle with outer lines: Planetary Nebula
   - ellipse: Galaxy

3. *What do the different colors of Deep-sky objects mean?*

   Generally, the different colors indicate to which catalog the object belongs (Messier, NGC or IC). However, some objects have a different color which indicates that there are extra images available in the popup menu (the default 'extras' color is red).

4. *Why are there so many more U.S. cities than in other countries?*

   When we started KStars, we were unable to find a longitude/latitude database that covered the globe equitably. However, the KStars community is rapidly overcoming this problem! We have already received city lists from many users around the world. If you can contribute to this effort, please send us your list of cities and coordinates.

5. *I have added a custom location to KStars that I no longer want. How do I remove it from the program?*

   You will have to edit the `/.kde/share/apps/kstars/mycities.dat` file, and remove the location's line from that file.

6. *Why can I not display the ground when using Equatorial Coordinates?*

   The short answer is, this is a temporary limitation. There is a problem when constructing the filled polygon that represents the ground when in Equatorial mode. However, it does not make too much sense to draw the ground in equatorial coordinates, which is why this fix has been given a low priority.

7. *Why do some objects disappear when I am scrolling the display?*

   When the display is in motion, KStars must recompute the screen coordinates of every object in its database, which involves some pretty heavy trigonometry. When scrolling the display (either with the arrow keys or by dragging with the mouse), the display may become slow and jerky, because the computer is having trouble keeping up. By excluding many of the objects, the computational load is greatly reduced, which allows for smoother scrolling. You can turn off this feature in the Configure KStars window, and you can also configure which objects get hidden.

8. *I do not understand all the terms used in KStars. Where can I learn more about the astronomy behind the program?*

   The KStars Handbook includes the AstroInfo Project; a series of short, hyperlinked articles about astronomical topics that can be explored and illustrated with KStars. AstroInfo is a community effort, like GNUpedia or Everything2. If you'd like to contribute to AstroInfo, please join our mailing list: kstars-info@lists.sourceforge.net.

9. *I want KStars to start up with a time and date different from my system CPU clock. Is this possible?*

   Yes; to start kstars with a different time/date, use the '--date' argument, followed by a date string like '4 July 1976 12:30:00'

10. *I want KStars to start up with the simulation clock paused. Is this possible?*

    Yes; to start kstars with the clock paused, simply add the '--paused' argument to the command line.

11. *How accurate/precise is KStars?*

    KStars is pretty accurate, but it is not (yet) as precise as it can possibly be. The problem with high-precision calculations is that you start having to deal with a large number of complicating factors. If you are not a professional astronomer, you will probably never have a problem with its accuracy or precision. Here is a list of some of the complicating factors which limit the program's precision:

    - Planet positions are only accurate for dates within 4000 years or so of the current epoch. The planet positions are predicted using a Fourier-like analysis of their orbits, as observed over the past few centuries. We

learnt in school that planets follow simple elliptical orbits around the Sun, but this is not strictly true. It would be true only if there was only one planet in the Solar system, and if the Sun and the planet were both point masses. As it is, the planets are constantly tugging on each other, perturbing the orbits slightly, and tidal effects also induce precessional wobbling. In fact, recent analysis suggests that the planets' orbits may not even be stable in the long term (i.e., millions or billions of years). As a rule of thumb, you can expect the position of a planet to be accurate to a few arcseconds between the dates -2000 and 6000.

Pluto is the exception to this; its position is perhaps ten times less precise than the positions of the other planets. Still, for dates near the present epoch, its position can be trusted to about an arcsecond.

The moon's position is the most difficult to predict to high precision. This is because its motion is quite perturbed by the Earth. Also, since it is so nearby, even minute effects that would be undetectable in more distant bodies are easily apparent in the moon.

The objects with the worst long-term precision in the program are the comets and asteroids. We use a very simplistic orbital model for the minor planets that does not include third-body perturbations. Therefore, their positions can only be trusted for dates near the present epoch. Even for the present epoch, one can expect positional errors among the minor planets of order 10 arcseconds or more.

12. *Why do I have to download an improved NGC/IC catalog and Messier object images? Why not just include them as part of the KStars distribution?*

The author of the downloadable NGC/IC catalog has released it with the restriction that it may not be used commercially. For most KStars users, this is not a problem. However, it is technically against the KStars license (the GPL) to restrict usage in this way. We removed the Messier object images from the standard distribution for two reasons: to simply reduce the size of KStars, and also because of similar licensing concerns with a couple of the images. The inline images are significantly compressed to a very low quality from their original form, so I doubt there is a real copyright concern, but I did obtain explicit permission from the images' authors to use the few images for which there was any question about it (see `README.images`). Still, just to be absolutely safe, I removed them from the standard distribution, and marked the download archive as being "free for non-commercial use".

13. *I am really enjoying the beautiful images I have downloaded through KStars! I would like to share them with the world; can I publish a calendar featuring these images (or are there any usage restrictions on the images)?*

It depends on the image, but many of the images restrict against commercial usage. The Image Viewer's statusbar will usually contain information about the image's copyright holder, and what usage restrictions apply. As a rule of thumb: anything published by NASA is in the public domain (including all HST images). For everything else, you can pretty safely assume that the images may not be used commercially without permission. When in doubt, contact the image's copyright holder directly.

14. *Can I help contribute to future versions of KStars?*

    Yes, definitely! Introduce yourself on our mailing list: kstars-devel@kde.org.
    If you want to help with the coding, download the latest CVS version of
    the code and dive right in. There are several README files in the distri-
    bution that explain some of the code's subsystems. If you need ideas of
    what to work on, see the TODO file. You can submit patches to kstars-
    devel, and feel free to post any questions you have about the code there
    as well. If you are not into coding, we can still use your help with i18n,
    docs, AstroInfo articles, URL links, bug reports, and feature requests.

Chapter 10

Credits and License

KStars

Program copyright 2001-2003 The KStars Team kstars@30doradus.org

The KStars Team:

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- Mark Hollomon mhh@mindspring.com
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Data Sources:

- Object catalogs and planet position tables: NASA Astronomical Data Center
- Detailed credit information for all of the images used in the program is presented in the file README.images

References:

- 'Practical Astronomy With Your Calculator' by Peter Duffet-Smith
- 'Astronomical Algorithms' by Jean Meeus

Special thanks: To the KDE and Qt^{TM} developers for providing the world with a peerless set of free API libraries. To the KDevelop team, for their excellent IDE, which made developing KStars so much easier and more fun. To everyone on the KDevelop message board, the KDE mailing lists, and on irc.kde.org, for answering our frequent questions. Thank you to Anne-Marie Mahfouf, for inviting KStars to join the KDE-Edu module. Finally, thanks to everyone who has submitted bug reports and other feedback. Thank you, everyone.

Appendix A

Installation

A.1 How to obtain KStars

KStars is distributed with KDE as part of the kdeedu "Edutainment" module.

We also occasionally make an independent release. These independent re-
leases will be available as a gzipped tar archive from the following website:
http://prdownloads.sourceforge.net/kstars/ .

Independent releases are announced through the kstars-announce@lists.sourceforge.net
mailing list. Releases are also posted to the KStars home page, kde-apps.org,
and freshmeat.net.

KStars is been packaged by many Linux/BSD distributions, including Redhat,
Suse, and Mandrake. Some distributions package KStars as a separate applica-
tion, some just provide a kdeedu package, which includes KStars.

If you would like the latest SVN development version of KStars, please follow
these instructions.

A.2 Requirements

In order to successfully run KStars, you need KDE >=4.0 and Qt$^{\text{TM}}$>=4.3.

To compile KStars, you will also have to have the following packages installed:

- kdelibs-devel
- qt-devel
- zlib-devel
- fam-devel

- png-devel

- jpeg-devel

- cmake

On my system, KStars uses about 60 MB of system memory with the default settings. Most of this usage is due to the loaded object databases. You can dramatically reduce the memory footprint by reducing the faint limit for stars in the Configuration Window, or eliminating catalogs of objects (NGC, IC, comets, asteroids, etc.). If KStars is idling, it uses very little CPU; but it will use as much as you have got when panning or zooming.

A.3 Compilation and Installation

In order to compile and install KStars on your system, type the following in the base folder of the unpacked KStars distribution:

```
% ./configure --prefix=$KDEDIR
% make
% make install
```

Please do not forget the prefix argument to configure. If your `KDEDIR` variable is not set, set prefix to whatever folder KDE is installed in: this is usually either `/usr`, `/opt/kde`, or `/opt/kde3`. Also, make sure you do the last step as `root`.

KStars uses **autoconf** and **automake**, so you should not have trouble compiling it. Should you run into problems please report them to the KStars mailing list kstars-devel@kde.org.

A.4 Configuration

At this point, there are no special configuration options or requirements. If KStars complains that there are missing data files, become `root` and manually copy all files in `kstars/data/` to `$(KDEDIR)/apps/kstars/` (If you do not have `root` privileges, copy them to `/.kde/share/apps/kstars/`.)

Appendix B

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