

ADAS Guide to Telescope Instrumentation and Operation

Produced by Members
of the Society, April
2014



Introduction

The ADAS authors hope that this guide will prove useful and ask you to provide a feedback about any features that require further clarification. One final suggestion is do a Google search and with patience you will frequently obtain some answers to your queries, i.e., from Wikipedia, NASA, etc.

Articles on the web

1. Some general notes

- <http://www.astronomynotes.com/nakedeye/s6.htm>

2. University of Nebraska-Lincoln Animations

- <http://astro.unl.edu/naap/motion1/motion1.html>
 - http://astro.unl.edu/naap/motion1/cec_units.html
 - http://astro.unl.edu/naap/motion1/animations/seasons_ecliptic.html
 - http://astro.unl.edu/naap/motion1/cec_both.html
 - http://astro.unl.edu/naap/motion1/orbits_light.html
- 3. Rising, setting and transit times of the sun, planets & major stars**
- <http://aa.usno.navy.mil/data/docs/mrst.php>
- 4. A short guide to star hopping**
- <http://www.astrocentral.co.uk/starting.html>

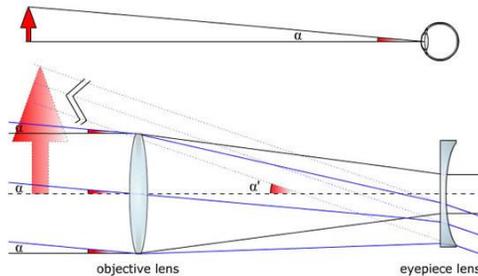
Types of Telescope

1. Refractor (lens) - Galileo, Kepler
2. Reflector (Mirror) - Newton, Cassegrain-Schmidt

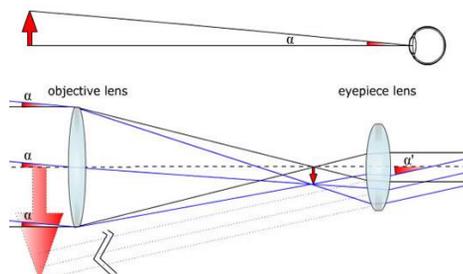
Optics

1. Refractor Telescopes

Galilean The original design Galileo Galilei came up with in 1609 is commonly called a Galilean telescope. It used a convergent (plano-convex) objective lens and a divergent (plano-concave) eyepiece lens (Galileo, 1610). A Galilean telescope, because the design has no intermediary focus, results in an non-inverted and upright image.

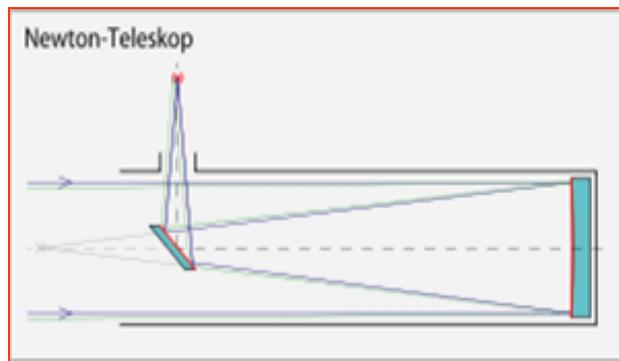


Kepelerian The principle of operation of the Keplerian telescope is relatively simple. The objective forms a real image, diminished in size and upside-down, of the object observed. The eyepiece — which, consisting of a converging lens with short focal length, is actually a magnifying lens — enlarges the image formed by the objective. The image observed is however upside-down, so that the Keplerian telescope, at least for terrestrial use, must be fitted with some kind of erector device which, by inverting the image again, erects it. But this disadvantage is amply compensated for by a much greater and more evenly illuminated field of view than that of the Galilean telescopes.

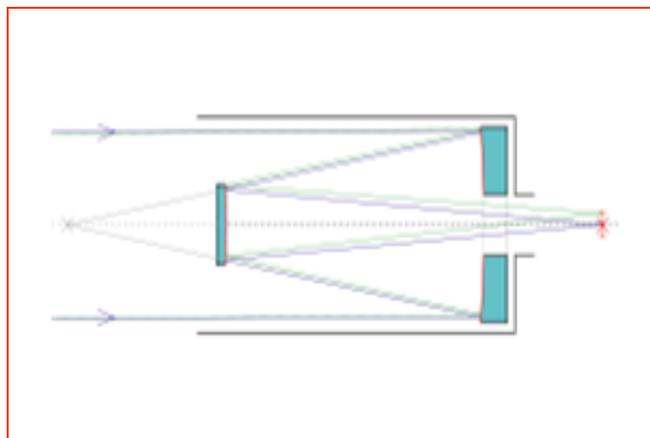


2. Reflector Telescopes

Newtonian The Newtonian telescope was the first successful reflecting telescope, completed by Isaac Newton in 1668. It usually has a paraboloid primary mirror but at focal ratios of $f/8$ or longer a spherical primary mirror can be sufficient for high visual resolution. A flat secondary mirror reflects the light to a focal plane at the side of the top of the telescope tube. It is one of the simplest and least expensive designs for a given size of primary, and is popular with amateur telescope makers as a home-build project.

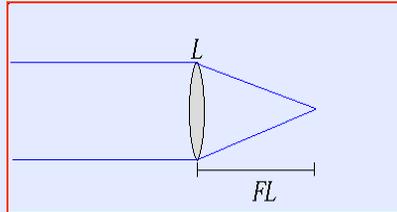


Cassegrain The Cassegrain telescope (sometimes called the "Classic Cassegrain") was first published in an 1672 design attributed to Laurent Cassegrain. It has a parabolic primary mirror, and a hyperbolic secondary mirror that reflects the light back down through a hole in the primary. Folding and diverging effect of the secondary creates a telescope with a long focal length while having a short tube length.



Telescope Optics- Lens System

How The Telescope Objective Works



Above is a simple telescope diagram of how the objective lens of a telescope works. The telescope objective is represented by a simple convex lens. In truth, modern refractors usually have two lenses that make up the objective, and they may be convex (curved out on both sides) or plano-convex (bulged out on one side, flat on the other). The multiple lens setup is used to compensate for chromatic limitations of a simple single lens. The reflector type telescopes use a concave mirror as an objective instead of a lens.

The purpose of the objective is to take incoming light from a distant source and bring it to a focus. In the diagram, light from a desired target enters from the left, and is bent to a focus on the right. An eyepiece placed at the focus will create an image for the observer's eye.

In the case presented, the focal length (FL) of the lens (L) is the distance from the lens to the convergence point. Since telescope_magnification results from the ratio of the objective focal length to the eyepiece focal length, it follows that the longer the focal length of the telescope objective, the more magnification any given eyepiece will provide.

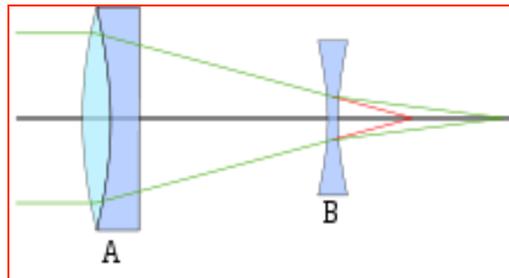
$$\text{Magnification} = \text{Objective FL} / \text{Eyepiece FL.}$$

Magnification increases, therefore, when the focal length of the eyepiece is shorter or the focal length of the objective is longer. For example, a 25 mm eyepiece in a telescope with a 1200 mm focal length would magnify objects 48 times. A 4 mm eyepiece in the same telescope would magnify 300 times.

Telescope Optics

Barlow Lens One easy way to boost magnification is to use a Barlow lens. The image below illustrates what a Barlow lens does when placed in the path of the converging rays of the objective. The initial image shows the same simple lens diagram shown before.

With a Barlow lens between the eyepiece and the telescope objective, the magnification is computed by dividing the effective focal length by the eyepiece focal length. Since the effective focal length is much longer than the objective's inherent focal length, the magnification of any given eyepiece will be much greater. That, in a nutshell is how a Barlow lens increases magnification for any given eyepiece.



**Cone of light behind a doublet object lens (A)
without (red) and with (green) a Barlow lens (B)**

Telescope Mounts

Essentially, there are two types of mounts with a number of variations for Newtonian, Cassegrain or refractor telescopes :

1. *Alt-azimuth (simpler)*
2. *Equatorial (more complex)*

The Alt-azimuth is preferred for large Observatory telescopes and the equatorial by the amateur with small telescopes.



Alt-azimuth Mount
showing elevation and
azimuth
(horizontal axis)



**Dobsonian
Alt-azimuth**



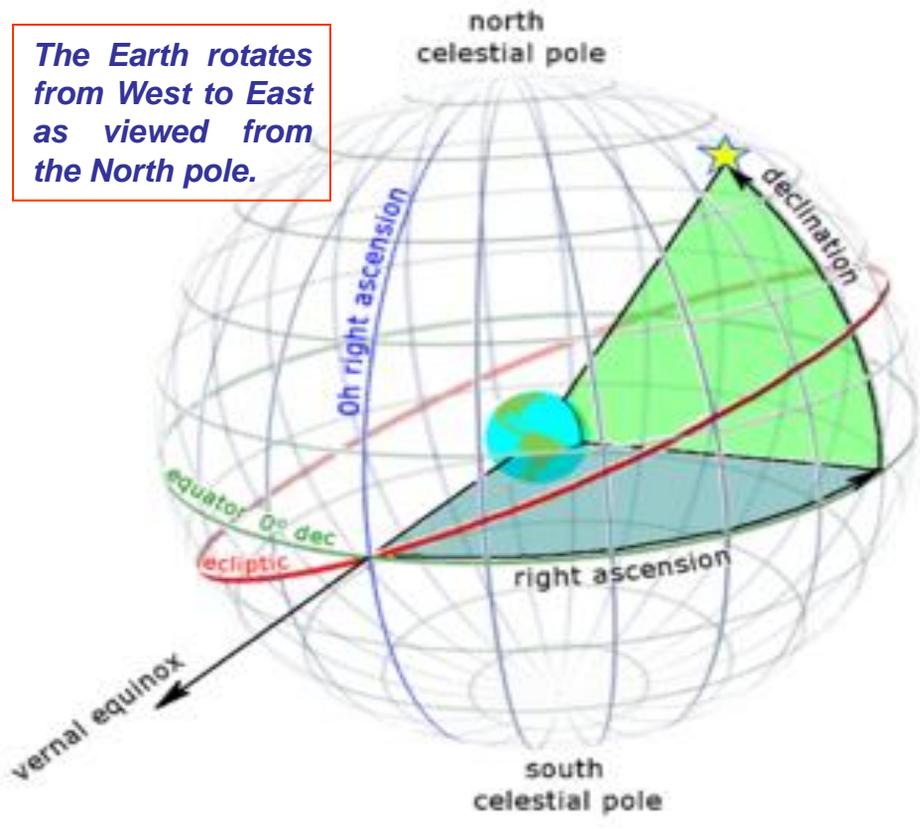
Equatorial Mount
showing angle of latitude,
declination and
polar axes (RA)

The Alt-azimuth mount is certainly simplest, allowing the telescope to be pointed up and down, and around (azimuth-horizontal plane). The various equatorial designs are made to facilitate easier tracking of celestial objects. Each of these come with variations to allow for telescope size and weight, and slow motion or motor control. A few of the most common configurations are shown above.

It is common today for modern telescopes to include not only clock drive mounts, but computerized clock drives that allow the user to simply select objects via computer or hand-held controller. The telescope computer and drive then do the work and locate objects.

The Celestial Sphere, The Ecliptic, Right Ascension & Declination

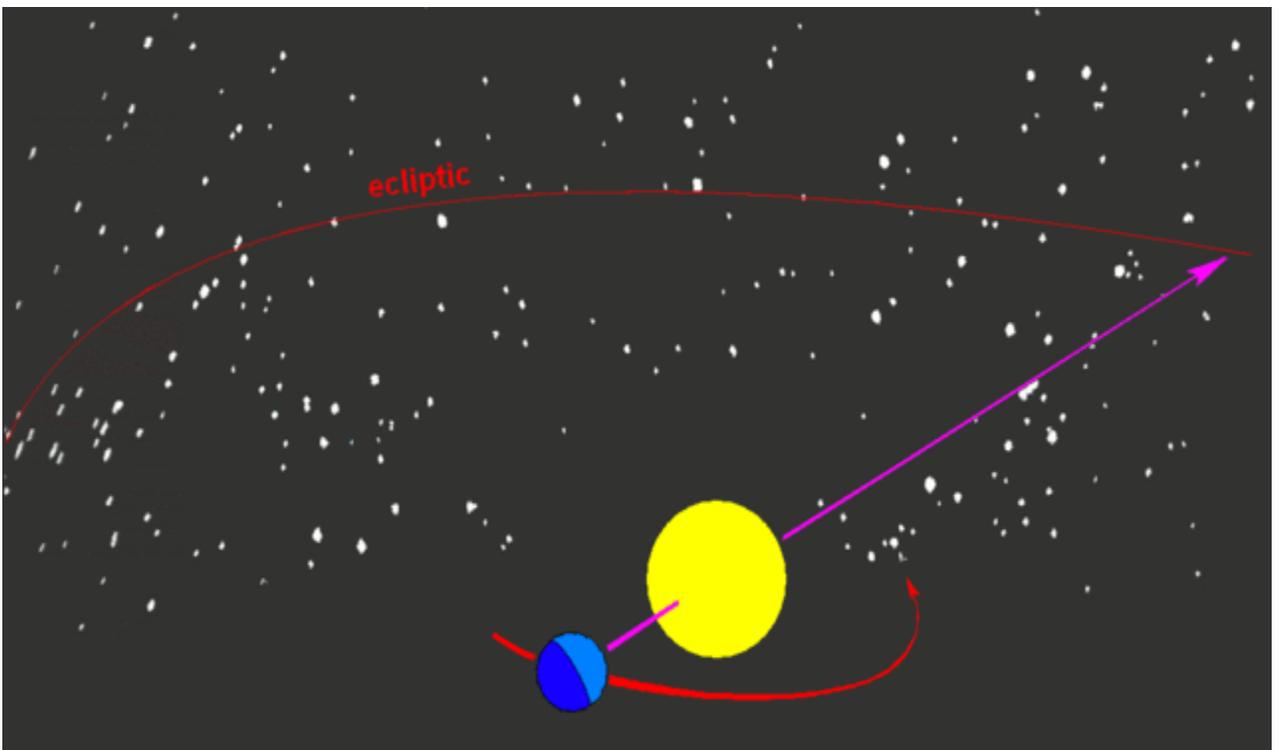
The Earth rotates from West to East as viewed from the North pole.



Key **Celestial equator** ; **ecliptic** ; north and south celestial poles, vernal equinox

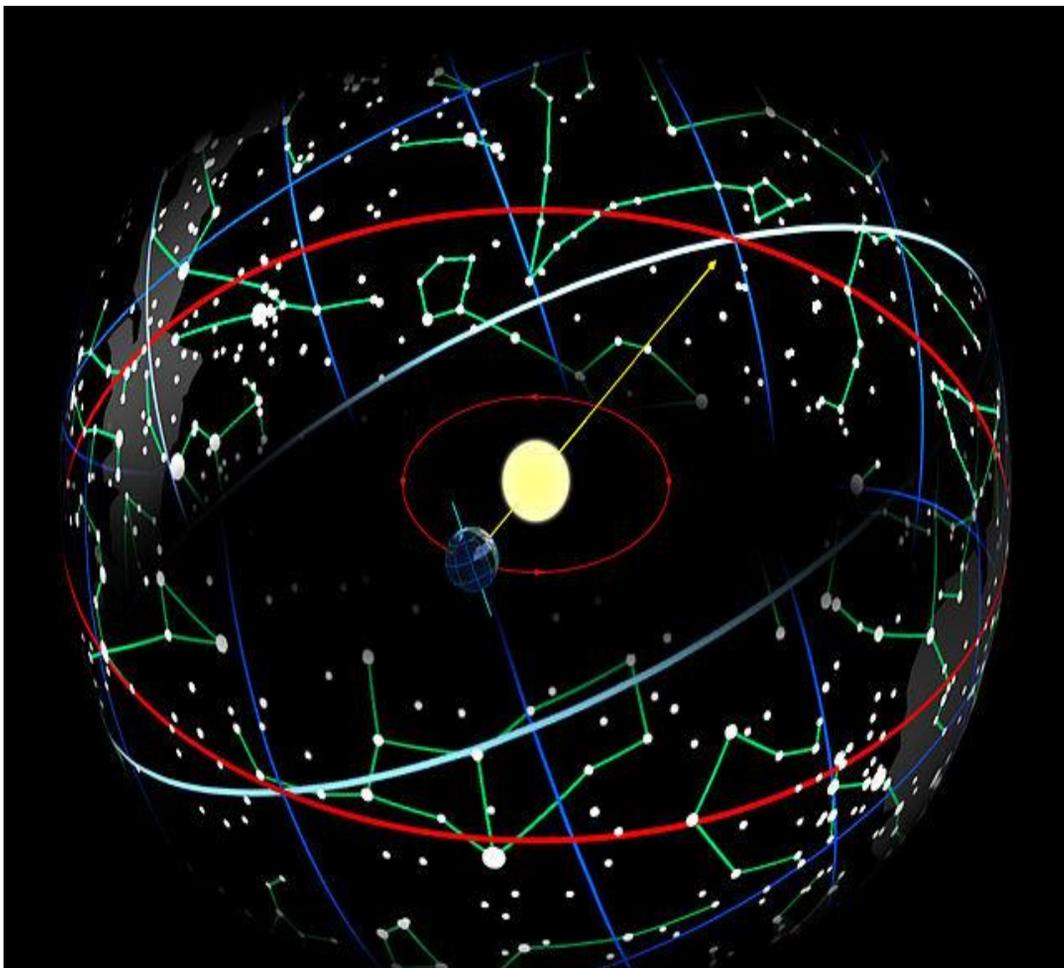
1. **Right Ascension, 0 – 24 hours proceeding, east around the **Celestial Equator****
2. **Vernal or Spring equinox, March 21 (12 hours day and night), where the **ecliptic, path of the sun**, intersects the **Celestial Equator** and **Right Ascension = 0 hours**.**
3. **Declination, 0 degrees at the celestial equator ; 90 degrees at the N & S celestial poles**
4. **The earth is tilted on its axis by 23.5 degrees accounting for the difference between the ecliptic- the path of the sun and the celestial equator**
5. **As a result of the tilt the path of the sun appears to maximise 23.5 degrees north and south of the earth's equator on June 21 and December 21, in summer in the northern and southern hemispheres**
6. **Note the limits of the Tropics of Cancer and Capricorn are 23,5 degrees north and south of the earth's equator, respectively**
7. **The earth rotates on its axis every 24 h (sidereal time- 23h 56m) and scans around the whole northern hemisphere sky in day and night time. Except for the sun, moon (& venus) stars in daylight cannot be not observed.**

As Earth orbits the sun, the sun appears to drift across the background stars. The ecliptic marks the path of the sun. It's the projection of Earth's orbit onto the sky. And it's an essential part of any stargazer's vocabulary.



The plane of the Ecliptic - **red circle**, intersects the plane of the celestial sphere- **blue circle**, twice and represents the path of the sun as the earth orbits the sun – **inner red circle**

The constellations/stars around the ecliptic are shown in green



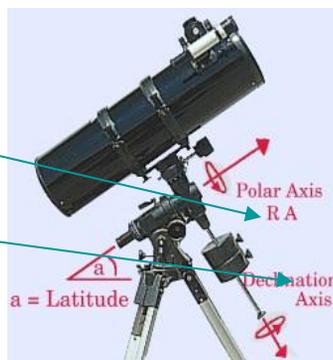
Practical Aspects of Astronomy

Notes on how to set up a telescope for observing

When setting up a telescope for observing the big question is where to start. If the moon is visible then an easy way of commencing observations is by viewing the moon with a 25 mm eyepiece and using a finder scope for a wider field of view. An **alt-azimuth mounted telescope** is easy to rotate and position at the correct angle. However, if there is no clock drive the frustrating feature is that the moon will move out of the field of view and the telescope will require re-positioning.

Although the **equatorial mounted telescope** is more complex in operation, it can be easily fitted with a clock drive, which enables the telescope to rotate to compensate for the rotation of the earth. However, the first step is to angle the telescope parallel to the earth surface at the latitude of the observer which for Manchester is **53.78 degrees north**, **a = latitude** in the diagram below.

Polar axis or Right Ascension, RA and the Declination Axis, DEC, for control of the telescope.



RA is measured in hours and DEC in degrees

The Setting Circles consist of two graduated disks attached to the right ascension (RA) and declination (DEC) axis of an equatorial mount as illustrated above. The right ascension disk is graduated into hours, minutes, and seconds. The declination disk is graduated into degrees, minutes, and seconds. Since right ascension coordinates are fixed to the celestial sphere the RA disk is usually driven by a clock mechanism in sync with sidereal time (23 h 56 m). Locating an object on the celestial sphere with setting circles is similar to finding a location on a terrestrial map using latitude and longitude.

Practical Aspects of Astronomy

Notes on how to set up a telescope for observing

After the telescope has been positioned for the correct latitude on a moonlit night the telescope can be easily directed to observe the moon and the planets, such as, Mars, Jupiter (and Galilean moons) and Saturn (rings with Cassini division). With clock drive the telescope will follow the object (some drift may be experienced)

For rising, setting and transit times of planets & stars refer to

<http://aa.usno.navy.mil/data/docs/mrst.php>

Example for Mars on May 02, 2014

Mars manchester Location: 0°00'00.0", N53°45'00.0", 50m (Longitude referred to Greenwich meridian) Time Zone: Greenwich

Date	Rise Az.	Transit Alt.	Set Az.
2014 May 02 (Fri)	16:13 94	22:00 33S	03:51 266 (hours min degrees)

As mentioned earlier, Right Ascension, RA, is measured in hours around the celestial equator. Since the stars are almost motionless their RAs are the coordinates in time commencing from the zero hour position which is around March 21, the Vernal or Spring equinox (12 hours, equal day and night time), which is when the ecliptic, the path of sun, intersects the celestial equator. This position is known as the first point in Aries in the constellation of Pisces. The RAs are measured east to west, therefore, for example, the Pole star is at an RA 2h 31m east of the RA, at the Vernal Equinox, which is 0 hours, the starting point.

To carry out constellation, star, galaxy, nebula observations, other than the easily observable, and well-known, requires a knowledge of the RA and DEC coordinates for the objects of interest, the date, rising, setting and transit times.

However, two easily identifiable constellations, namely, Ursa Major or the Plough and Orion, can be employed to exemplify how to find well-known stars and features and to use these coordinates.

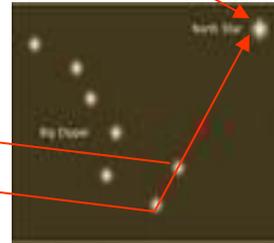
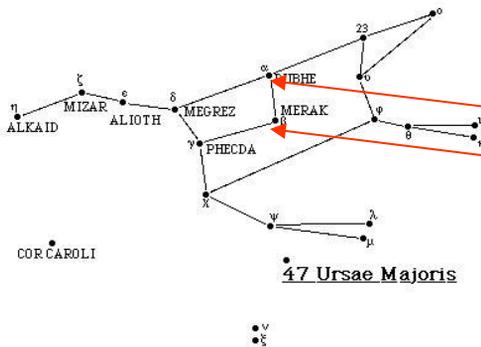
Polaris can be locate using The Plough and the setting circles for its coordinates of this star as described on page 13.

Practical Aspects of Astronomy

Some well-known features of the night sky

The Plough (in Ursa Major) is easily observed and there two stars which act as pointers to **Polaris**, The Pole Star, which is the brightest star in Ursa Minor. This star is virtually motionless at a **DEC** of approx **89 degrees** and **RA 2^h 31^m** and is known by a variety of names, north star, guide star, lodestar ; it is very close to the north celestial pole.

Ursa Major, the Great Bear (The Big Dipper)

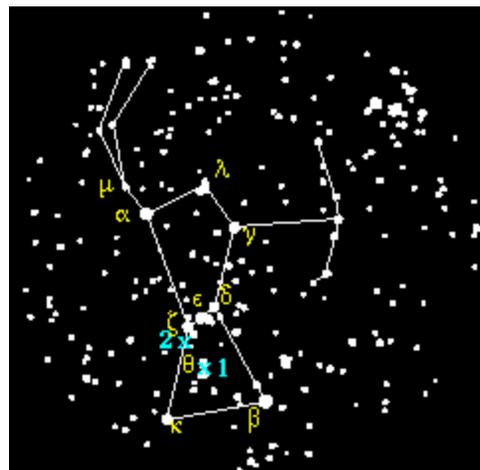


- Right Ascension: 11 hours
- Declination: 50 degrees
- Visible between latitudes 90 and -30 degrees
- Best seen in Spring.

Orion is probably the most easily identifiable and the most prominent constellation. It also has some of the most interesting features, for example, Betelgeuse 300 times brighter than the sun, the Orion nebulae M42 and star clusters in the vicinity, M45, as illustrated on page 14.

Orion

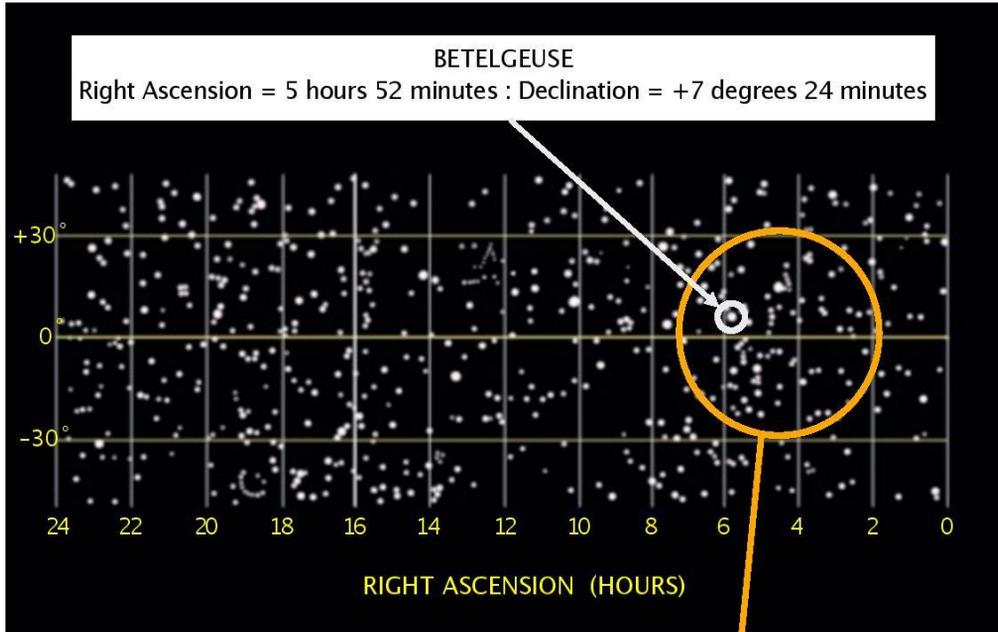
- RA 5 h
- DEC 5 degrees
- Observable between latitudes, +85 and -75
- Best seen in January



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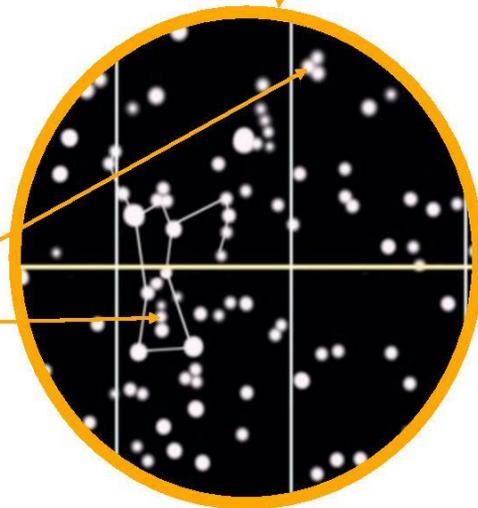
Some well-known features of the night sky

There are many different ways that star maps can be presented. A map may show the stars for a month or over a year. The star map shown below shows the band of stars seen between about dec $+30^\circ$ and -30° .



More detail on star maps shows the constellations like Orion and usually gives information about the locations of other celestial objects found in the region

eg star clusters like (M45) and nebulae (M42)

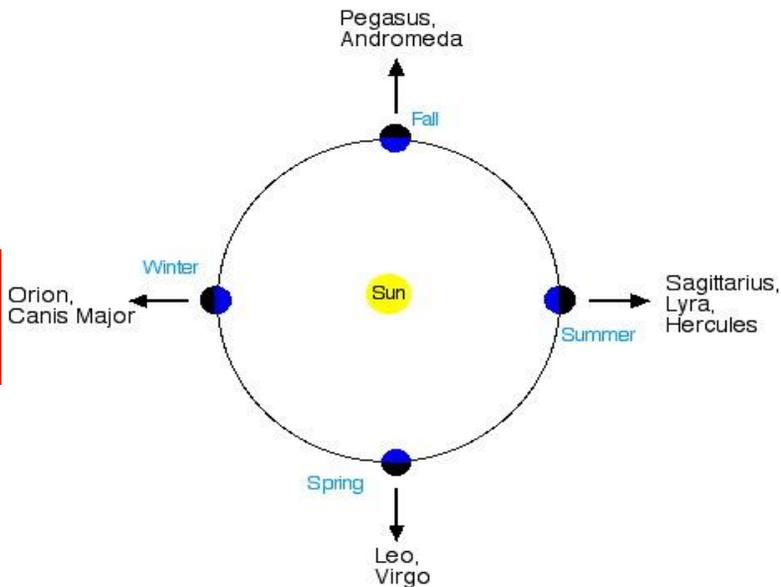


Practical Aspects of Astronomy

Some well-known features of the night sky

Different parts of the sky are observed at night during the seasons of the year as indicated in the diagram below for the northern hemisphere. The sun obscures the constellations as shown and the earth's darkened regions in the different seasons point towards the constellations observed, for example, Orion and Canis Major are Winter features.

RA 22 00 & 01 00 h



**RA 5.52 &
7 00 h**

**RA 19 00 ; 18 36
& 17 00 h**

RA 11 00 & 13 25 h