Stars and telescopes: a resource book for teachers of lower school science

Clifton L. Smith


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NEDLANDS COLLEGE of Advanced Education

Stars and Telescopes
STARS

AND

TELESCOPES
STARS AND TELESCOPES

A Resource Book
for Teachers of Lower School Science

by

CLIFTON L. SMITH

Graphics by G. Pollard
Media Services

Nedlands College of Advanced Education
Stirling Highway
NEDLANDS WA 6009

1981
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AIMS AND OBJECTIVES

This resource book has been designed to meet the needs of teachers of lower school science who wish to gain experience in celestial astronomy in order to conduct an observational evening for lower school science students.

The material will be treated at an elementary level, and is intended for teachers who require the acquisition of knowledge, skills and experience in the space sciences.

This resource book will consider:

* Types of star groupings: double stars, binary stars, open star clusters, globular clusters, galaxies, and constellations.

* Types of stars: main sequence stars, red giants, variable stars, white dwarfs, black dwarfs, and neutron stars.

* Types of telescopes: prime focus, newtonian focus, cassegrain focus, coude focus, and Schmidt design telescopes.

* Teaching Aids: planispheres, angle measurers, star maps, celestial sphere, constellation simulator.

Later, we will discuss celestial observations activities suitable for lower school science activity work by;

* Naked eye observations: recognition of prominent constellations and stars, and the measurement of angular distances.
*Binocular observations: gross properties of celestial objects.

*Telescope observations: detailed properties of celestial objects.
STAR GROUPINGS

Stars tend to group in a variety of types of formations. These formations are usually the result of gravitational attraction between the stars.

Some stars are solitary, isolated occupants of space. However, most stars within a galaxy are associated with other stars. Several types of star associations occur, ranging from just several stars in the grouping to extremely large star clusters.

1. Binary Star System

Most stars in our Galaxy are not solitary, but are bound by the force of gravity to one, and sometimes many, companions. About half of all star systems are binary or multiple systems. In binary star systems the two stars move around each other in elliptical orbits.

Example: Alpha Centauri
2. Open Star Cluster

Open star clusters, or galactic clusters, are loose and irregular aggregations of stars containing several hundred to several thousand stars. Individual stars in the open cluster are easily resolved with a telescope, and in some cases can be seen with the naked eye. Open clusters are mainly located close to the galactic plane, which is recognised as the Milky Way in the heavens at night.

Examples: Hyades, Pleiades (Seven Sisters)
3. Globular Cluster

Globular clusters are relatively tightly packed clusters of stars containing hundreds of thousands or millions of stars in spherical symmetry. Globular clusters are symmetrically distributed around the nucleus of the galaxy. Stars in globular clusters are generally older than stars in the galactic arms.

Examples: Omega Centauri and 47 Tucanae.
4. Galaxies

Galaxies are now thought to be the basic unit of the Universe. That is, the Universe contains galaxies. Galaxies are celestial structures with a large number of stars gravitationally held together. Typically about $1 \times 10^{11}$ stars compose a galaxy, with each star possessing a mass comparable to that of our Sun.

Three major types of galaxies are observed.

(a) Elliptical galaxies have stars symmetrically distributed in an ellipsoid, with dimensions differing from galaxy to galaxy.

(b) Spiral galaxies possess the characteristic star spiral arms which sweep out behind the rotating galactic nucleus. Normal spiral galaxies have a central nucleus of stars with radiating spiral arms. Barred spiral galaxies have a distinct "bar" of stars through the nucleus, and from which two spiral arms trail.

(c) Irregular galaxies are generally smaller galaxies which do not possess structure or symmetry. Their shape is probably due to lack of rotation. The Large Magellanic and Small Magellanic Clouds are irregular galaxies close to our galaxy, the Milky Way.
5. Constellations

Constellations are arbitrary patterns of the brighter stars in the heavens. They do not portray real groupings of stars, which may be greatly dispersed at varying distances in space. The ancient mythological names have been retained in Latin form. Each star in the constellation is described by a greek letter of the alphabet, with α designated to the brightest star, β to the next brightest star, etc. For example, α Crux is the brightest star in the Southern Cross.
The famous southern hemisphere constellation of CRUX is composed of stars at varying distances from Earth.

α Crux : 300 light years
β Crux : 490 light years
γ Crux : 200 light years
δ Crux : 590 light years
TYPES OF STARS

Stars are born from interstellar hydrogen gas and dust in the galactic arms. A gravitational collapse of the gas nebula causes the internal pressure and temperature to increase. When the temperature is sufficiently high (6 million K), fusion reactions commence converting hydrogen to helium and releasing enormous quantities of energy. The hydrogen fusion reaction is referred to as hydrogen burning, and the gas cloud is now a protostar.

When the gravitational contraction forces are in equilibrium with the thermal pressure of the gas of the star, the star is then in its stable hydrogen burning phase. Our Sun is undergoing hydrogen burning, and is termed a Main Sequence star.

After about $1 \times 10^{10}$ years, the hydrogen in the core will have been consumed and the fusion reactions cease. Gravitational collapse will recommence, further increasing the stellar central pressure and temperature. At about 30 million K helium fusion reactions begin, again arresting the gravitational collapse and distending the outer gas envelope of the star. This bloated outer envelope of gas will become cooler and hence redder, with an increase in stellar radius by a factor of 1000. The star is now in the Red Giant phase.

Further progressive gravitational collapses occur as core fuel depletes, produces fusion reactions for C, N, O, etc, up to Fe. Iron is the terminating nuclide in the series as it does not undergo fusion reactions. During these phases of the burning reactions the star becomes unstable with its outer gas envelope expanding and contraction. The stellar object is now a Variable Star.
Because of the gross instabilities within the star together with the extremely high temperature and pressure, the thermal pressure of the stellar core "blows" the outer layers of the star outward into space. Large amounts of energy are dissipated in a Nova event. The remnants of the nova is an intensely hot small core of the star and is called a White Dwarf. The white dwarf radiates into space and gradually cools with time to finally become a Black Dwarf.

If the initial main sequence star was large and produced a Super Red Giant, then a Supernova event will remove a major portion of the star. The remnant remaining contracts inwards to form a Neutron Star, which are thought to be composed of incredibly dense matter.

Gravitation is the key to stellar evolution. It is responsible for the initial formation of the nebula, the commencement of fusion reactions within the protostar, the various phases of evolution, and finally the death of the star when debris is flung outwards into space.
TELESCOPES

The function of a telescope is to collect light from a celestial object and to focus this light to an image. Refracting telescopes achieve this outcome by means of a lens, while a reflecting telescope employs a curved mirror.

Reflecting telescopes use a parabolic mirror to minimise spherical aberration. Several optical configurations are possible to achieve the production of an image which can be focussed onto a photographic plate or viewed with an eyepiece.

(a) Prime Focus Telescope

The photographic plate or eyepiece is actually situated in the telescope tube.

(b) Newtonian Focus
The Newtonian focus takes the light beam from the telescope tube by means of a plane mirror. This configuration requires the camera or eyepiece to be near the top end of the telescope tube.

(c) Cassegrain Focus

A second small convex mirror in the field of view focusses the image through a hole in the main reflector. This configuration is very convenient to use, however it reduces the light collecting aperture.

However the insertion of a small plane mirror in front of the primary mirror provides a cassegrain focus configuration with side viewing.
(d) Coudé Focus

An unfocussed image is reflected to a stationary observing station away from the telescope in a separate laboratory. This optical configuration is used with large telescopes and allows the use of heavy analytical equipment.

(e) Schmidt Telescope

The Schmidt telescope design is a relatively new innovation employing a spherical mirror as the primary collector, and having a correcting lens at the front end of the tube to compensate for spherical aberration.
By setting the polar axis of the telescope to the observing latitude on the Earth's surface then the polar axis of the telescope is parallel to the Earth's axis, and hence points to the South Celestial Pole. The latitude of Perth is 31°57'. Thus to compensate for the Earth's rotation during an evening of star viewing, after setting the Declination to that of the star it may be tracked on Right Ascension. The advantage of this type of telescope mounting is that the telescope rotates on one axis only.
A planisphere is a simple device which will allow teachers and students to become familiar with the constellations and stars in the southern sky. It consists of a rotating celestial disc which indicates the relative positions of celestial objects according to the day of the month and the time of the evening.

A variety of planispheres are available. The "Starfinder" planisphere can be obtained from the W.A. Museum at $1.95 each (1981 price).
TO OPERATE "STARFINDER"

The "Starfinder" shows the positions of the Stars and Constellations at any hour throughout the year. To identify any Star or Constellation, rotate disc until the date is in window opposite viewing time. Hold "Starfinder" face downwards with North and South aligned to your North and South. The Star or Constellation is then easily identified, as "Starfinder" shows the stars to 4th Magnitude from the Southern horizon to Declination 30° N. (25° above Northern horizon) usable at that time. Based on Lat. 35° S.

Courtesy of Mr. R.L. Sangster, Astronomical Association of South Australia.
ASTRONOMICAL DATA BOOK

The Astronomical Data Book compiled and printed by the Perth Observatory is an invaluable information source for teachers of astronomy. This book has been prepared for local astronomical sites. Generally, such information is difficult to obtain. However, the Perth Observatory have gathered together much astronomical data of local interest.

A sample of some of the contents:

. Visibility of the Planets
. Time
  The Sun
. Sunrise and Sunset
. Moonrise and Moonset
. Apsides
. The Moon Phases
. Latitudes and Longitudes of W.A. Towns
. Latitudes and Longitudes of W.A. Towns (cont.)
. Eclipses
. The Planets and their Satellites
. The Individual Planets
. Comets
. Lunar occultations
. Variable stars
. Major Southern Meteor Showers
. Some Bright Variable Stars
. Some Bright Double Stars
. Nonstellar Astronomical Objects
. Paths of Uranus and Neptune
. Paths of Mars, Jupiter, and Saturn
A SAMPLE PAGE FROM THE ASTRONOMICAL DATA BOOK

JUPITER 1981

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* INDICATES PLANET SETS ON FOLLOWING DAY

By permission of Dr. I Nikoloff, Government Astronomer, Perth Observatory, Bickley, Western Australia.
ANGLE MEASURERS

(a) CROSS-STAFF

Using the dimensions and shape indicated, cut and fold the stiff cardboard. This will form the masks of the cross-staff. The metrestick which forms the staff must be calibrated. To do this, write "eye" on one end of the staff. From this base, measure off the distance indicated in the chart. Place a mark at each of these distances, and write the corresponding angle on the staff. Note that two scales must be placed on the staff - one scale for using the 20 cm mask to measure large distances between objects, and another scale for using the 10 cm mask to measure smaller distances. Finally, the masks should be placed on the staff so that they will slide with pressure but will not slip out of place.
To use the cross-staff, place the eye end of the staff on one cheekbone and slide the masks back and forth until one of them exactly covers the space between two sky objects. Using the scale on the staff designated for that mask, you can read off the angular distance between the two objects.
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<td>15.5</td>
</tr>
<tr>
<td>76.0</td>
<td>15.0</td>
</tr>
<tr>
<td>78.6</td>
<td>14.5</td>
</tr>
<tr>
<td>81.4</td>
<td>14.0</td>
</tr>
<tr>
<td>84.5</td>
<td>13.5</td>
</tr>
<tr>
<td>87.8</td>
<td>13.0</td>
</tr>
<tr>
<td>91.3</td>
<td>12.5</td>
</tr>
</tbody>
</table>

Angular distance between the two stars.
Table contd

<table>
<thead>
<tr>
<th>Distance eye end (cm)</th>
<th>Angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>63.5</td>
<td>9.0</td>
</tr>
<tr>
<td>67.3</td>
<td>8.5</td>
</tr>
<tr>
<td>71.5</td>
<td>8.0</td>
</tr>
<tr>
<td>76.3</td>
<td>7.5</td>
</tr>
<tr>
<td>81.8</td>
<td>7.0</td>
</tr>
<tr>
<td>88.1</td>
<td>6.5</td>
</tr>
<tr>
<td>95.4</td>
<td>6.0</td>
</tr>
</tbody>
</table>
AN ANGLE MEASURER
(P10, Astronomy Student worksheets, Education Department of W.A.)

An angle measurer is a useful device in the study of Astronomy. You will need an angle measurer in several of the experiments which follow.

![Diagram of angle measurer setup]

Cut out the ruled strip on the opposite page. Glue this on to a piece of cardboard so that it has a firm backing.

Make a hole at the point indicated on the card.

Tie the string through the hole.

Turn up tab on card and measure a distance of 57.5 cm along the string from the card. (Include depth of tab in this measurement.)

Make a knot in the string at this point.

Now you are ready to use your angle measurer.

USE IT TO FIND THE ANGULAR WIDTH OF A WINDOW (OR DOOR, IF YOU PREFER).

This is what you do -

- With one hand, hold the knot of the string up to your cheek.
- With the other hand, hold the ruler so that the string is extended its full distance.
- Now move the measurer in line with the window and count the number of marks which fit across the window.
- The number of degrees in the angular width of the window is the SAME as the number of marks, e.g. 13 marks = 13 degrees.

Write your measurement here:

The angular width of the window = _______ degrees.

By permission of Mr. J. Newby, Superintendent of Curriculum, Education Department of Western Australia.
ESTIMATED ANGULAR DISTANCES BY HANDSPANS

The task of finding particular stars in the sky can be facilitated by using handspans for estimating angular distances between stars.

An average handspan extends about $20^\circ$, but the handspan of many people differs from this. Smaller angular distances can be estimated by using parts of a handspan, as shown in the diagram below.

Here are some angular distances between prominent southern sky stars.

<table>
<thead>
<tr>
<th>Star Pair</th>
<th>Degrees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpha Centauri to Beta Centauri</td>
<td>4.5</td>
</tr>
<tr>
<td>Alpha Crucis to Beta Crucis</td>
<td>6.0</td>
</tr>
<tr>
<td>Alpha Crucis to Beta Centauri</td>
<td>11.8</td>
</tr>
<tr>
<td>Alpha Crucis to Alpha Centauri</td>
<td>15.7</td>
</tr>
<tr>
<td>Canopus to Achernar</td>
<td>39.4</td>
</tr>
<tr>
<td>Canopus to Alpha Centauri</td>
<td>58.0</td>
</tr>
<tr>
<td>Alpha Crucis to Achernar</td>
<td>58.9</td>
</tr>
</tbody>
</table>

contd
<table>
<thead>
<tr>
<th>Star Pair</th>
<th>Degrees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Castor to Pollux</td>
<td>4.5</td>
</tr>
<tr>
<td>Betelgeuse to Rigel</td>
<td>18.6</td>
</tr>
<tr>
<td>Betelgeuse to Aldebaran</td>
<td>21.4</td>
</tr>
<tr>
<td>Rigel to Sirius</td>
<td>23.7</td>
</tr>
<tr>
<td>Betelgeuse to Procyon</td>
<td>26.0</td>
</tr>
<tr>
<td>Spica to Arcturus</td>
<td>32.8</td>
</tr>
<tr>
<td>Altair to Deneb</td>
<td>38.0</td>
</tr>
<tr>
<td>Spica to Antares</td>
<td>45.9</td>
</tr>
<tr>
<td>Altair to Fomalhaut</td>
<td>59.2</td>
</tr>
</tbody>
</table>
**CANIS MAJOR**

The Greater Dog

**CELESTIAL OBJECT**

- **α Canis Majoris (Sirius)**
  - A large hot bright star at a distance of 8.650 L.Y.
  - Brightest star in the sky.

- **β Canis Majoris (Mirzam)**
  - Brighter than Sirius, but at a distance of 650 L.Y.

- **γ Canis Majoris (Muliphein)**
  - A main sequence star at a distance of 325 L.Y.

- **δ Canis Majoris (Wezen)**
  - An extremely bright star at a distance of 1100 L.Y.

- **ε Canis Majoris (Adara)**
  - Red super giant star at a distance of 470 L.Y.
The Centaur

CELESTIAL OBJECT

Toliman (α Centauri)

Proxima Centauri

Agena (β Centauri)

ω Centauri

FEATURES

Double star

Red dwarf associated with α Centauri

4.3 LY from Earth, but not visible to naked eye.

Main sequence giant

Giant globular cluster visible to the unaided eye.

Distance of 5000 parsecs.
**CRUX (SOUTHERN CROSS)**

The Cross

<table>
<thead>
<tr>
<th>CELESTIAL OBJECT</th>
<th>FEATURES</th>
</tr>
</thead>
<tbody>
<tr>
<td>α Crux</td>
<td>Double main sequence stars (blue)</td>
</tr>
<tr>
<td>β Crux</td>
<td>Main sequence star (blue)</td>
</tr>
<tr>
<td>γ Crux</td>
<td>Red giant (red)</td>
</tr>
<tr>
<td>δ Crux</td>
<td>Main sequence star (blue)</td>
</tr>
<tr>
<td>ε Crux</td>
<td>Main sequence star (orange)</td>
</tr>
<tr>
<td>Coal Sack</td>
<td>Dark nebula</td>
</tr>
<tr>
<td>Jewell Casket</td>
<td>Star cluster</td>
</tr>
</tbody>
</table>
**FEATURES**

A white main sequence star at a distance of 91 L.Y.

A red cool surfaced star at a distance of 270 L.Y.

A helium burning star at a distance of 163 L.Y.
**LEO**

**The Lion**

**CELESTIAL OBJECT**

α Leonis (Regulus)  
A helium star of surface temperature 20,000K which lies directly on the ecliptic, and at a distance of 68 L.Y.

β Leonis (Denebola)  
A hot hydrogen burning star at a distance of 42 L.Y.

γ Leonis (Algieba)  
A double system of giant stars, one orange and the other yellow. The sy is 130 L.Y. distant.

Leo contains several bright nebulae: M65, M66, M95 and M96, which lie outside our Galaxy.
CELESTIAL OBJECT

Orion Nebula (M42)
Rigel
Betelgeuse
Bellatrix
Mintaka
Saiph

FEATURES

Stellar birthplace
Five main sequence stars in complex systems
Red giant variable star (red)
Super giant (blue)
Multiple star system of 5 stars with a common centre
Super giant
α Piscis Austrini (Fomalhaut)  
A hot surface main sequence star at a distance of 23 L.Y.

β Piscis Austrini  
Also a hydrogen star at a distance of 220 L.Y.

γ Piscis Austrini  
A red giant star at 180 L.Y. from Earth.
CELESTIAL OBJECT

α Scorpii (Antares)
β Scorpii (Acrab)
δ Scorpii (Dschubba)
λ Scorpii (Shaula)

FEATURES

Red super giant with a diameter 300 times that of the Sun.
Double stars of hot surface temperature.
Sub giant.
A hot distant star with a small companion of period 5.6 days.
CELESTIAL OBJECT | FEATURES
---|---
α Tucanae | A cool main sequence star at a distance of 142 L.Y.
β Tucanae | A binary system, with each component having a surface temperature of 20,000K and at a distance of 148 L.Y.
47 Tucanae | A globular cluster containing in excess of one million stars.
SMC | Small Magellanic Cloud is an irregular galaxy thought to be a companion of our Galaxy.
CELESTIAL OBJECT

y Velorum

A group of four stars, two of which are seen as a double star. These stars are white hot surfaced stars.

e Velorum

A hydrogen star at a distance of 63 L.Y.

λ Velorum (Alsuhaul)

Red super-giant at a distance of 820 L.Y.

w Velorum

Very similar to our Sun, and at a distance of 105 L.Y.
SOUTH CELESTIAL POLE REGION

CELESTIAL OBJECT

Large Magellanic Cloud and Small Magellanic Cloud.

47 Tucanae

FEATURES

Irregular galaxies in the Local Group of galaxies.

Globular cluster
OBSERVATIONAL ACTIVITIES

Teachers of lower school science may engage
in the following activities to become familiar with the observations
of celestial objects. This will allow teachers to design suitable
worksheets for high school students at the appropriate levels of
difficulty.

1. Visual identification of major constellations as indicated
in this manual, or from the planisphere.

For example: Crux
Orion
Centaurus
Vela
Canis Major
Leo


For example: A Crux
α Centauri
Achernar
Canopus
Sirius
Rigel
Betelgeuse
Regulus
Fomalhaut


For example: Hyades
Pleiades
Jewel Casket
Coal Sack
Large Magellanic Cloud
Small Magellanic Cloud
α Centauri binary system
47 Tucanae


Angular distance between sets of prominent stars. Altitude (ele-
vation) of stars above observer's horizon. Colour of stars as
observed through binoculars.
STAR MAPS AND DATA BOOKS

1. Astronomical Data Book        Perth Observatory, W.A.
   Available from Perth Observatory for $1.50 with 45¢ mailing.

   Czechoslovak Academy of Sciences, Praha.

   Czechoslovak Academy of Sciences, Praha.


   George Philip and Son. London.
REFERENCE BOOKS

These books may provide suitable reference materials on stars and telescopes for both teachers and students. However it should be realised that it is not an inclusive list, as many other similar quality books are available.


TEACHING AIDS

Celestial Sphere

A simple working model illustrating the apparent movement of stars can be shown by the rotation of the flask, as shown in the diagram.

The axis of the flask is inclined at an angle equal to the latitude of the location (32° for Perth). The spherical portion of the flask represents the celestial sphere, and the water level represents the horizon as perceived by the observer at the centre.
of the sphere. Constellations of stars may be conveniently marked on the surface of the flask. By rotating the flask in the appropriate direction (clockwise direction), the constellations will be seen to rise, reach its zenith, and then set relative to the surface of the water; the water surface indicating the observers horizon.

An observer at the centre of the celestial sphere looks towards the south and notes that, from his point of view, the stars have a clockwise motion. However, when he turns to face north, the stars have an apparent anticlockwise motion. In the real sky the same sort of movements occur, though they are so slow that more than one observation is required for their detection.

Constellation Simulator

A simulation of bright stars and their movements can be obtained with a simple star demonstration box.
Pinholes are made through one end of a cardboard box to represent a group of stars such as the Southern Cross. These are viewed through a viewing hole about 3 mm diameter made near one corner of the opposite end of the box. For the best effect the star end of the box is pointed towards a bright source of light such as an uncurtained window in daylight. Darkness within the box provides a good contrast to the "stars". A variety of constellations can be constructed, to allow students the opportunity to recognise familiar and prominent star patterns. Rotate the box to illustrate the circular movement of the "stars".
SUGGESTIONS FOR AN OBSERVATIONAL EVENING

The following aspects and equipment should be considered when organising an observational evening for high school students.

Useful Equipment
1. Warm clothing
2. Star map
3. Planisphere
4. Torch
5. Clip board
6. Binoculars
7. Telescope
8. Structured work sheet.

Find Out About
1. Weather conditions
2. Time of Sunset
3. Phase of the moon
4. A suitable site with little ambient light
5. Position of prominent constellations at say 8.00 pm on the chosen evening.
6. Planets suitable for viewing.