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Studies of a Population of Stars:

Mapping the Positions of Stars

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Venture out under a clear night sky, in city or country, bright moon or dark moon, and you will see at least a few stars. The brightest stars visible offer, fortunately, a wide variety of characteristics that can be observed or computed easily. With this lesson students have the chance to see these bright stars and learn how the appropriate map tells us about their place in the universe.

The universe is rich with interesting phenomena. Stars, alone, offer many investigations. The results of this activity stand alone, or they may be combined with results from other “Studies of a Population of Stars” activities for more insights.

**OBJECTIVE:** Make observations and use available data and simple calculations to correlate observations and data in the characterization of stars. In this activity, students can discover that the positions of stars in the sky illuminates information about the Milky Way galaxy.

**APPARATUS:**

1. **Scientific calculator or computer spreadsheet** for each student, or small groups of students to share
2. **Data tables** supplied with this lesson
3. **Star charts** supplied with this lesson
4. **Graph paper** measuring 8.5”x11”. For Activity 2, cut the paper in half widthwise and tape it together to make a 5.5”x17” strip for plotting star positions. The length is desirable if the map is to be rolled into a cylinder. Students should start numbering the x-axis from the far *right to the left*, at 0 hours (0h = 0˚), continuing in one hour or 10 or 15 degree intervals to 24 hours (24h = 360˚ = 0˚). Use the same scale for the y-axis. Note that the x-axis should be offset up from the middle of the paper strip since declination spans only +46˚ to -63˚ for the stars being plotted.

 For Activity 3, tape two sheets of graph paper together to construct a base for the map measuring 11”x17”. Students should start numbering the x-axis from the middle of the chart (center of the Milky Way) from *right to left*, at 0˚, continuing in 10 degree intervals to the left margin at 180˚ and then continuing from the right margin from 180˚ to 360˚ = 0˚. Use the same scale for the y-axis, running from 0˚ to +90˚ and from 0˚ to -90˚.

**ACTIVITIES:**

Duplicate and distribute star charts and sets of star information to the students. The specific stellar data tables for the activity’s time of year can be cut/pasted from the full set included with this activity in Appendix 1, based on the calendar-organized table in the DISCUSSION section below. The full set of stars may be analyzed even though not all will be visible at any particular time of year. Measurement units in the activities below are in [brackets]. Explanations of the terminology in the activities is found in the DISCUSSION section below. The phrases in **bold** describe the instructional activity.

1. Students should spend an evening outdoors and **identify the stars** they will be analyzing with the data provided here. They should be encouraged to look for color differences (subtle but visible) and the distribution of the stars in the sky – are they found in all directions or “clumped” together?
2. **Use the ICRF (equatorial) coordinates to plot all the stars in this collection on graph paper showing their positions relative to the projection of Earth’s equator in the sky.** It may help with visualization to make the chart into a cylinder (after plotting) by taping right ascension (RA) 23h59m59s to 0h right ascension. To match the view of the sky, the map should be rolled so it is inside the cylinder.

For convenient plotting, if desired, right ascension can be converted to decimal degrees using equations (2a-c) below or by multiplying hours [h] by 15, minutes [m] by ¼, and seconds [s] by 1/240 and summing.

Decimal degrees = [h of RA] x 15 + [m of RA] x 0.25 + [s of RA]/240 (1)

Is there any obvious grouping in bright star density on the sky?

1. **Use the galactic coordinates to plot all the stars in this collection on graph paper showing their positions relative to the equator of the Milky Way.** It may help with visualization to make the chart into a cylinder (after plotting) by taping galactic longitude 360° to 0°. Is there any increase in bright star density towards the Milky Way? Yes, though with so few stars the effect is not strong and map distortion affects the appearance too.

**Extension:** Make a three dimensional plot or model by including the stars’ distances from the Sun (cf. **Studies of a Population of Stars: Distances and Motions**). Making a scale model will be interesting but finding a scale that will present the full range of distances meaningfully and also fit in a comfortable working space will be challenging.

**THE UNDERLYING PRINCIPLES:**

One fundamental question about stars in the sky is:

Where are they in the sky?

This question can be answered with the data table for each star in the collection.

Astronomers use several coordinate systems for the convenience of analyzing and discussing data. Equatorial coordinates are based on the view from Earth. Right ascension and declination are essentially extensions of Earth’s longitude and latitude into the sky.

Galactic coordinates are designed to describe the positions of objects in the Milky Way galaxy. Their origin is the center of the Milky Way, in the constellation Sagittarius where the Milky Way’s central black hole resides. Note that both of these coordinate systems are two dimensional, in the sensed that positions are measured on the “plane” of the sky (which is a spherical surface). A three dimensional galactic coordinate system would specify a position in two coordinates and distance in a third, from the origin.

**DISCUSSION:**

The stars included in this activity are among the brightest in the sky and are easily visible with the Moon up and in light polluted cities (but not where skyscrapers or trees block the sky!). Use the orientation “rose” in the lower left of the star charts to help with using the charts at night. The stellar data presented here were downloaded from the *SIMBAD* Astronomical Database, <http://simbad.u-strasbg.fr/simbad/> .

The following sets of stars can be used, and viewed, annually from either the northern or southern hemisphere, with considerable geographic and seasonal overlap. Choose the time of year for the students to observe but they will be using all the stars on the list for this activity. Stars with positive declinations will be most easily visible from the northern hemisphere; negative declinations are better seen from the southern hemisphere. (Declination is the celestial equivalent of latitude on Earth; examine the **International Celestial Reference System** coordinates in the tables in Appendix 1, which are explained below.) Some stars at higher positive (north) or negative (south) declinations will not be visible from the opposing hemisphere and others will barely skim the horizon.

The quarters of the year used in the table are based on the assumption that the stars will be observed during evening hours. For viewing, there is considerable overlap of star availability across the quarterly boundaries (as with hemispheres) and they can often be seen for many months before the quarter given if the observer stays up later in the night or looks before dawn. Use a star chart, planisphere (“star wheel”), or planetarium software to determine which stars can be used to match the timing of your lesson plan.

**Bright Evening Stars**

**CONSTELLATION-Hemisphere; Star Name**

|  |  |  |  |
| --- | --- | --- | --- |
| **Jan.-Feb.-Mar.** | **Apr.-May-June** | **July-Aug.-Sep.** | **Oct.-Nov.-Dec.** |
| AURIGA – N Capella | AURIGA – NCapella | AQUILA – N Altair | AQUILA – N Altair |
| CANIS MAJOR – S Sirius | BOOTES – N Arcturus | BOOTES – N Arcturus | AURIGA – N Capella |
| CANIS MINOR – N Procyon | CANIS MINOR – N Procyon | CENTAURUS – SAlpha Centauri | CYGNUS – N Deneb |
| CARINA – SCanopus | CARINA – SCanopus | CENTAURUS – SBeta Centauri | ERIDANUS – SAchernar |
| ERIDANUS – S Achernar | CENTAURUS – SAlpha Centauri  | CRUX – SAcrux | LYRA – NVega |
| GEMINI – NCastor | CENTAURUS – SBeta Centauri | CRUX – SMimosa | PISCIS AUSTRINUS – S Fomalhaut |
| GEMINI – NPollux | CRUX – SAcrux | CRUX – SGacrux | TAURUS – NAldebaran |
| ORION – Equator Betelgeuse | CRUX – SMimosa | CYGNUS – NDeneb |  |
| ORION – EquatorRigel | CRUX – SGacrux | LYRA – NVega |  |
| TAURUS – N Aldebaran | GEMINI – NCastor | PISCIS AUSTRINUS – S Fomalhaut |  |
|  | GEMINI – N Pollux | SCORPIUS – SAntares |  |
|  | LEO – N Regulus |  |  |
|  | VIRGO – EquatorSpica |  |  |

The tables of star data in Appendix 1 are organized alphabetically by CONSTELLATION and then by Star Name. The tables contain a variety of information that can be extracted and used to compare and contrast these bright stars. The text below describes the table entries, and a summary table in the same format as the tables of stars is the first in Appendix 1.

Positions for the stars are given based on the *ICRS*, International Celestial Reference Systemof coordinates. “Right Ascencion” (RA) is the celestial equivalent of longitude on Earth, but is measured in hours, minutes, and seconds. If desired, it can be converted to degrees by first converting to decimal hours, dividing by 24, and multiplying by 360:

[decimal hours] = hours + (minutes/60) + (seconds/3600) (2a)

[decimal days] = (decimal hours/24) (2b)

[degrees of RA] = (decimal days) x 360 (2c)

Declination is the celestial equivalent of latitude on Earth.

*Gal*actic coordinates use the Milky Way center, as seen from Earth, as the origin, with position measured “around” the Milky Way and “above” (north of) or “below” (south of) the plane of the Milky Way. These coordinates are somewhat similar to the system used in *Star Trek*, which might be pedagogically helpful to mention.

**FOR MORE INFORMATION:**

Kelly, P., 2007, *Observer’s Handbook 2008*, Toronto: Royal Astronomical Society of Canada.

*Starry Nights Pro*. (Ver. 3, 1997 was used; Ver. 6 is now available) [Computer software]. New York, New York: Imaginova.

*TheSky6 Professional Edition Version 6 for Windows*. (2004). [Computer software]. Golden, Colorado: Software Bisque.

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**APPENDIX 1: Star Table**

|  |  |
| --- | --- |
| *KEY TO THE STAR INFORMATION TABLES BELOW. THE TABLES ARE ALPHABETIZED BY CONSTELLATION.* |  |
| **CONSTELLATION** |   |
| **Star name** -- Brief description or other designator  |   |
| **International Celestial Reference System** coordinates (epoch=2000 equator=2000) :  | Right Ascension, similar to longitude on Earth, and measured in hours/minutes/seconds *hh mm ss.ssss* Declination, similar to latitude on Earth, and measured in (sign)degrees/minutes/seconds +*dd mm ss.sss* |
| **Galactic** coordinates (epoch=2000 equator=2000) :  | Longitude measured towards celestial east from the center of the Milky Way in Sagittarius, measured in degrees.decimals *ddd.dddd*. Latitude measured North or South (south is negative) from the galactic plane. (sign) degrees.decimals +*dd.dddd* |
|  |  |
|  |  |
| **AQUILA** |   |
| **Altair** -- Variable Star of delta Sct type  |   |
| **ICRS** coord. (ep=2000 eq=2000) : | **19 50 46.9990 +08 52 05.959**  |
| **Gal** coord. (ep=2000 eq=2000) : | **047.7441 -08.9092**  |
|  |  |
| **AURIGA** |   |
| **Capella** -- Variable of RS CVn type  |   |
| **ICRS** coord. (ep=2000 eq=2000) :  | **05 16 41.3591 +45 59 52.768**  |
| **Gal** coord. (ep=2000 eq=2000) :  | **162.5885 +04.5664**  |
|  |  |
| **BOOTES** |   |
| **Arcturus** -- Variable Star  |   |
| **ICRS** coord. (ep=2000 eq=2000) : | **14 15 39.6720 +19 10 56.677**  |
| **Gal** coord. (ep=2000 eq=2000) : | **015.0501 +69.1113**  |
|  |  |
| **CANIS MINOR** |   |
| **Procyon** -- Spectroscopic binary  |   |
| **ICRS** coord. (ep=2000 eq=2000) : | **07 39 18.1183 +05 13 29.975**  |
| **Gal** coord. (ep=2000 eq=2000) : | **213.7022 +13.0194**  |
|  |  |
| **CANIS MAJOR** |   |
| **Sirius** -- Spectroscopic binary  |   |
| **ICRS** coord. (ep=2000 eq=2000) : | **06 45 08.9173 -16 42 58.017**  |
| **Gal** coord. (ep=2000 eq=2000) : | **227.2303 -08.8903**  |
|  |  |
|  |  |
|  |  |
| **CARINA** |   |
| **Canopus** -- Star  |   |
| **ICRS** coord. (ep=2000 eq=2000) : | **06 23 57.1099 -52 41 44.378**  |
| **Gal** coord. (ep=2000 eq=2000) : | **261.2121 -25.2922**  |
|  |  |
| **CENTAURUS** |   |
| **Alpha Centauri** -- Double or multiple star  |   |
| **ICRS** coord. (ep=2000 eq=2000) : | **14 39 36.204 -60 50 08.23**  |
| **Gal** coord. (ep=2000 eq=2000) : | **315.7330 -00.6809**  |
|  |  |
| **CENTAURUS**  |   |
| **Beta Centauri** -- Variable Star of beta Cep type  |   |
| **ICRS** coord. (ep=2000 eq=2000) : | **14 03 49.4045 -60 22 22.942**  |
| **Gal** coord. (ep=2000 eq=2000) : | **311.7670 +01.2511**  |
|  |  |
| **CRUX** |   |
| **Acrux** -- Spectroscopic binary  |   |
| **ICRS** coord. (ep=2000 eq=2000) : | **12 26 35.871 -63 05 56.58**  |
| **Gal** coord. (ep=2000 eq=2000) : | **300.1265 -00.3627**  |
|  |  |
| **CRUX**  |   |
| **Mimosa = Beta Cru** -- Variable Star of beta Cep type  |   |
| **ICRS** coord. (ep=2000 eq=2000) : | **12 47 43.2631 -59 41 19.549**  |
| **Gal** coord. (ep=2000 eq=2000) : | **302.4622 +03.1796**  |
|  |  |
| **CRUX** |   |
| **Gamma Crucis** -- Variable Star  |   |
| **ICRS** coord. (ep=2000 eq=2000) : | **12 31 09.9593 -57 06 47.562**  |
| **Gal** coord. (ep=2000 eq=2000) : | **300.1692 +05.6498**  |
|  |  |
| **CYGNUS** |   |
| **Deneb -- Alpha Cyg** -- Variable Star  |   |
| **ICRS** coord. (ep=2000 eq=2000) : | **20 41 25.9147 +45 16 49.217**  |
| **Gal** coord. (ep=2000 eq=2000) : | **084.2847 +01.9975**  |
|  |  |
| **ERIDANUS** |   |
| **Achernar** -- Be Star  |   |
| **ICRS** coord. (ep=2000 eq=2000) : | **01 37 42.8466 -57 14 12.327**  |
| **Gal** coord. (ep=2000 eq=2000) : | **290.8412 -58.7920**  |
|   |  |
| **GEMINI** |   |
| **Castor -- LTT 12038** -- High proper-motion Star  |   |
| **ICRS** coord. (ep=2000 eq=2000) : | **07 34 35.8628 +31 53 17.795**  |
| **Gal** coord. (ep=2000 eq=2000) : | **187.4410 +22.4792**  |
|  |  |
| **GEMINI** |   |
| **Pollux** -- Variable Star  |   |
| **ICRS** coord. (ep=2000 eq=2000) : | **07 45 18.9503 +28 01 34.315**  |
| **Gal** coord. (ep=2000 eq=2000) : | **192.2293 +23.4063**  |
|  |  |
| **LEO** |   |
| **Regulus** -- Variable Star  |   |
| **ICRS** coord. (ep=2000 eq=2000) : | **10 08 22.3107 +11 58 01.945**  |
| **Gal** coord. (ep=2000 eq=2000) : | **226.4273 +48.9342**  |
|  |  |
| **LYRA** |   |
| **Vega -- Alpha Lyr** -- Variable Star  |   |
| **ICRS** coord. (ep=2000 eq=2000) : | **18 36 56.3364 +38 47 01.291**  |
| **Gal** coord. (ep=2000 eq=2000) : | **067.4482 +19.2373**  |
|  |  |
| **ORION** |   |
| **Betelgeuse --V\* alf Ori** -- Semi-regular pulsating Star  |   |
| **ICRS** coord. (ep=2000 eq=2000) : | **05 55 10.3053 +07 24 25.426**  |
| **Gal** coord. (ep=2000 eq=2000) : | **199.7872 -08.9586**  |
|  |  |
| **ORION** |   |
| **RIGEL** -- Emission-line Star  |   |
| **ICRS** coord. (ep=2000 eq=2000) : | **05 14 32.2723 -08 12 05.906**  |
| **Gal** coord. (ep=2000 eq=2000) : | **209.2412 -25.2454**  |
|  |  |
| **PISCIS AUSTRINUS** |   |
| **Fomalhaut** -- Variable Star  |   |
| **ICRS** coord. (ep=2000 eq=2000) : | **22 57 39.0465 -29 37 20.050**  |
| **Gal** coord. (ep=2000 eq=2000) : | **020.4881 -64.9096**  |
|  |  |
| **SCORPIUS** |   |
| **Antares -- Alpha Sco** -- Semi-regular pulsating Star  |   |
| **ICRS** coord. (ep=2000 eq=2000) : | **16 29 24.4609 -26 25 55.209**  |
| **Gal** coord. (ep=2000 eq=2000) : | **351.9471 +15.0643**  |
|  |  |
| **TAURUS** |   |
| **Aldebaran -- Alpha Tau** -- Variable Star  |   |
| **ICRS** coord. (ep=2000 eq=2000) : | **04 35 55.2387 +16 30 33.485**  |
| **Gal** coord. (ep=2000 eq=2000) : | **180.9719 -20.2483**  |
|  |  |
| **VIRGO** |   |
| **Spica -- 67 Vir** -- Variable Star of beta Cep type  |   |
| **ICRS** coord. (ep=2000 eq=2000) : | **13 25 11.5793 -11 09 40.759**  |
| **Gal** coord. (ep=2000 eq=2000) : | **316.1123 +50.8446**  |

**APPENDIX 2: Star and Constellation Charts**

The following collection of charts is designed to make it easy find and identify bright stars. In the charts, prominent and/or well-known stars or groups of stars, constellations, or super-constellations are used to point to other prominent stars. If desired, once a prominent star is found, other charts can be used to identify other stars in a constellation until the full constellation is recognized.

These charts are useful over large areas of Earth’s northern and southern hemispheres. They place a significant fraction of a celestial hemisphere on a small, flat piece of paper. Use separations between recognized stars (especially those paired to make “pointers” to gauge the distance to the desired target star. In the northern hemisphere, April-June, the ***BIG DIPPER*** asterism (part of the constellation **URSA MAJOR**) visible high in the north is particularly good for learning the sky. **ORION** is good from November-January in the southern hemisphere and January-March in the northern hemisphere. Though the charts are labeled to indicate a hemisphere, many of the stars will be visible from the opposing hemisphere, depending on your latitude.

As a general rule, facing south is best but some neck-craning (and/or facing a different direction and rotating the chart) will be necessary to go from the starting point to the target stars at the ends of the arrows. The font convention for the charts is that **CONSTELLATIONS** are fully capitalized and Star Names are larger and first-letter capitalized. Celestial North and West refer to the direction to those points on the horizon as seen on the sky. (In other words, east and west on the sky and on the charts are reversed compared to maps of features on Earth.) Most important: Pick something familiar and go from there.

At night, some observers find it is easier to use printed star charts with black stars on a white background rather than white stars on a black background. Black on white saves copier toner as well. The charts can be copied from this document and easily reversed with your image viewing and manipulation software if desired. These star charts were generated by TheSky6 © Software Bisque, Inc. All rights reserved. [www.bisque.com](http://www.bisque.com/).











