The SPECTROGRAM

Newsletter for the Society of Telescopy, Astronomy, and Radio

VOL 2, No. 6 February, 2002

February's Meeting

The next meeting of S*T*A*R will be Thursday, February 7th, at 8:00 PM. The meeting will be held at the King of Kings Lutheran Church, 250 Harmony Street, Middletown.

This month's meeting will feature a presentation by Dr. Michael Strauss of Princeton University. Dr. Strauss will give a presentation about his research as part of the Sloan Digital Sky Survey.

In this Issue

From the Editor

Thank you to this month's contributors. The Spectrogram is your newsletter and appreciates your support. Articles may be submitted to Greg Cantrell at monthly meetings or electronically at cantrell@optonline.net .

Calendar

September 6, 2001
What I did on my Summer Vacation

October 4, 2001
David Malin's video, "The Man Who Colors Stars".

November 6, 2001
Dr. Edward Collett
STAR Astronomy Club

December 6, 2001
David Britz & Gordon Waite
STAR Astronomy Club

January 3, 2002
Roundtable Discusssion
STAR Astronomy Club

February 7, 2002
Dr. Michael Strauss
Princeton University

March 7, 2002
Dr. Charles Liu,
Hayden Planetarium

April 4, 2002
Dr. Edward Devinney
Rutgers University

May 2, 2002
Dr. Licia Verde
Rutgers University & Princeton University

June 6, 2002
Dr. Tad Pryor
Rutgers University

Ed. Note: The following is taken from the Sloan Digital Sky Survey website, http://www.sdss.org.

What is the Sloan Digital Sky Survey?

Simply put, the Sloan Digital Sky Survey is the most ambitious astronomical survey project ever undertaken. The survey will map in detail one-quarter of the entire sky, determining the positions and absolute brightnesses of more than 100 million celestial objects. It will also measure the distances to more than a million galaxies and quasars. Apache Point Observatory, site of the SDSS telescopes, is operated by the Astrophysical Research Consortium (ARC).

The SDSS addresses fascinating, fundamental questions about the universe. With the survey, astronomers will be able to see the large-scale patterns of galactic sheets and voids in the universe. Scientists have varying ideas about the evolution of the universe, and different patterns of large-scale structure point to different theories of how the universe evolved. The Sloan Digital Sky Survey will tell us which theories are right -- or whether we have to come up with entirely new ideas.

The Sloan Digital Sky Survey (SDSS) is a joint project of The University of Chicago, Fermilab, the Institute for Advanced Study, the Japan Participation Group, The Johns Hopkins University, the Max-Planck-Institute for Astronomy (MPIA), the Max-Planck-Institute for Astrophysics (MPA), New Mexico State University, Princeton University, the United States Naval Observatory, and the University of Washington.

Funding for the project has been provided by the Alfred P. Sloan Foundation, the Participating Institutions, the National Aeronautics and Space Administration, the National Science Foundation, the U.S. Department of Energy, the Japanese Monbukagakusho, and the Max Planck Society.

The Science of the SDSS

The universe today is filled with sheets of galaxies curving through mostly empty space. Like soap bubbles in a sink, they form voids and come together along lines that form dense filaments. Our best model for how the universe began, the Big Bang, gives us a picture of a universe filled with a hot, uniform soup of fundamental particles. Somehow, between the time when the universe began and today, gravity has pulled together the matter into regions of high density, leaving behind empty voids. What triggered this change from uniformity to structure? Understanding the origin of the structure that we see in the universe today is a crucial part of reconstructing our cosmic history.

The quest is made more difficult because the luminous stars and galaxies that we see are only a small part of the total material in the universe. The nature, amount and distribution of the "dark matter" are among the most important questions in astrophysics. How has the gravity from dark matter influenced the visible structures? Or, put another way, by careful mapping of the positions and motions of galaxies, we can reconstruct the distribution of the gravitating mass, and from that find clues about dark matter.

A Map of the Universe

One of the difficulties in studying the entire universe is the problem of getting enough information to assemble a global picture. Astronomers designed the Sloan Digital Sky Survey to address this problem in a direct and ambitious way, by gathering a body of data large and accurate enough to be useful in addressing a broad range of astronomical questions.

The Sky Survey will obtain high-resolution pictures of one quarter of the entire sky in five different colors. From these pictures, advanced image processing software will measure the shape, brightness, and color of hundreds of millions of astronomical objects including stars, galaxies, quasars (compact yet ultraluminous objects thought to be powered by material falling into giant black holes), and an array of other celestial exotica. Selected galaxies and quasars will be observed using an instrument called a spectrograph to determine accurate distances to a million galaxies and 100,000 quasars, and to provide a wealth of information about the individual objects. These data will give the astronomical community one of the things it most needs: a comprehensive catalog of the constituents of a representative part of the universe.

The Sloan Digital Sky Survey will map the three-dimensional distribution of matter through a volume about a hundred times bigger than the volume explored so far. This map will reveal how big the largest structures in our universe are, and what they look like. It will help us understand the mechanisms that converted a uniform "primordial soup" into a frothy network of galaxies.

An Intergalactic Census

The U.S. Census Bureau collects statistical information about how many people live in the U.S., where they live, their race, their family income, and other characteristics. The Census becomes a primary source of information for people trying to understand the nation. In a sort of celestial census, the Sloan Digital Sky Survey will gather information about how many galaxies and quasars there are in the universe, how they are distributed, their individual properties, and how bright they are. Astronomers will use this information to study questions such as why flat spiral galaxies are found in less dense regions of the universe than football-shaped elliptical galaxies, or how the enigmatic quasars have changed during the history of the universe.

The Sky Survey will also collect information about the Milky Way galaxy and even about our own solar system. The wide net cast by the Sky Survey telescope will sweep up as many stars as galaxies, and as many asteroids in our solar system as quasars in the universe. Knowledge of these objects will help us learn how stars are distributed in our galaxy, and where asteroids fit into the history of our solar system.

Needles in a Haystack, Lighthouses in the Fog

Rare objects, almost by definition, are scientifically interesting. By sifting through the several hundred million objects recorded by the Sky Survey, scientists will be able to construct entire catalogs of the most distant quasars, the rarest stars, and the most unusual galaxies. The most unusual objects in the catalog will be about a hundred times rarer than the rarest objects now known. For example, stars with a chemical composition very low in metals like iron are the oldest in the Milky Way. They can therefore tell us about the formation of our galaxy. However, such stars are also extremely rare, and only a wide-field deep sky survey can find enough of them to form a coherent picture.

Because they are so far away, quasars can serve as probes for intergalactic matter throughout the visible universe. In particular, astronomers can identify and study galaxies by the way they block certain wavelengths of light emitted by a quasar. Using the light from quasars, the Sky Survey will detect tens of thousands of galaxies in the initial stages of formation. These galaxies are typically too faint and too diffuse to be detected in their own light by even the largest of telescopes. Quasar probes will also allow scientists to study the evolution of the chemistry of the universe throughout its history.

The Telescope as a Time Machine

Peering into the universe with a telescope allows us to look not only out into space, but also back in time. Imagine intelligent beings in a planetary system around a star 30 light years away. Suppose these beings pick up a stray television transmission from Earth. They would see events now 30 years past on earth, and might, for instance, view a newscast covering the construction of the foundation of the Sears Tower. While today we see the tower as a completed work, they might see workmen pouring the tower's foundation. We think of light as traveling extremely fast, but the universe is a very big place. In fact, astronomers routinely look at quasars that are so far away that it takes billions of years for the light they produce to reach us. When we look at galaxies or quasars that are billions of light-years away, we are seeing them as they were billions of years ago.

By looking at galaxies and quasars at different distances, astronomers can see how their properties change with time. The Sky Survey will measure the "local" distribution of galaxies, allowing comparison with more distant samples now being obtained by the new generation of instruments like the Hubble Space Telescope and the Keck Telescope. Because quasars are very bright, the Sky Survey will allow astronomers to study their evolution through more than 90 percent of the history of the universe.

Measuring Distance and Time: Red Shift

Think of the universe as a loaf of raisin bread rising in an oven. The universe is expanding in the same way as the rising loaf. Now pick any raisin, and imagine it's our own Milky Way galaxy. No matter how you look at it, as the bread rises, all the other raisins are moving away from our raisin. The farther away another raisin is from our raisin, the faster it is moving away. In the same way, all the other galaxies are moving away from ours as the universe expands. And because the universe is uniformly expanding, the farther a galaxy is from Earth, the faster it is receding from us.

The light coming to us from these distant objects is shifted toward the red end of the electromagnetic spectrum, in much the same way the sound of a train whistle changes as a train leaves or approaches a station, compared to the way the pitch is perceived when the train is in the station. The faster a distant object is moving, the more it is red-shifted. Astronomers measure the amount of red shift in the spectrum of a galaxy to figure out how far away it is from us. By measuring the red shift of a million galaxies, the Sloan Digital Sky Survey will provide a three-dimensional picture of our local neighborhood of the universe.

What You Should Know About Large Telescopes

By Ernie Rossi

I am fortunate to have many telescopes of varying sizes. Many people ask me why I have so many. Do I really use all of them? Yes, I do, but of course not all at the same time. I fit the telescope to the occasion. For instance, at a very dark pristine site, I want to have my largest telescope. If I am traveling by plane, I take a compact, high quality, travel scope that I can carry on. For planet observing, I choose my best and sharpest Newtonian or Refractor. For terrestrial viewing I use a 90 MM Maksutov or a 80 MM spotting scope, or simply a good pair of light binoculars. For comets, nebulae, and open clusters, I prefer a large pair of binoculars on a mount, or a short focal length telescope in the 3" to 8" range. Everyone wants a larger telescope to see fainter, dimmer, objects, and to bring out details that can only be realized in a larger aperture. But what many newcomers to astronomy don't know is that larger-aperture telescopes present problems of their own. Consider the following: To transport my 25" telescope that weighs nearly 300 pounds, I have a van, ramps, and move the scope on 10" pneumatic tires attached to wheelbarrow handles not to mention using 6 & 8 foot ladders to reach the eyepiece. Telescopes with solid tubes 15" or more in diameter and at least 6 feet long require at least two people to lift them off and onto a van, truck, or trailer or place it on a mount. If you are thinking about buying a large scope, I urge you to consider the following factors before you decide.

1. Storage: Where are you going to keep the scope?
2. Climatic Acclimation: Temperature variations affect mirrors and lenses.
3. Set up/teardown time.
4. Weight: Can you lift/carry it.
5. Transportation: Do you have a vehicle, or access to one, large enough to transport the scope.
6. Additional, indispensable equipment: Will you need a ladder, a battery, or other equipment to support your telescope.

As you go up in telescope size these questions become very important and can even affect the use of your telescope. The following breakdown separates telescopes into five separate categories according to their aperture and weight including the mounting. I will explain the problems as size and weight increases.

Category 1: Size range 2.4" refractors to 4.5” reflectors no more then 30 pounds including the tripod. Category 2: Size range 3" equatorial refractors to 8" Dobsonian reflectors and 8"

Schmidt Cassegrains weight up to 75 pounds. Category 3: Size range 5" equatorial refractors to 12.5" Dobsonian reflectors 10" and 11" Schmidt Cassegrains. Weight up to 150 pounds. Category 4: Size range 6" equatorial refractors to 20" Dobsonian reflectors. 12" and 14" Schmidt Cassegrains. Weight up to 250 pounds. Category 5: Size range 16" equatorial reflectors to over 25" Dobsonian reflectors. Weight over 250 pounds.

Category 1
A telescope in this category fits in a closet and you should have no problem carrying it up or down a flight of stairs to take it outside and observe. Set up and tear-down should be very easy and quick. Small mirrors and lenses should acclimate to the outside temperature fairly quick under normal conditions. However, even small closed-end scopes like Maksutov Cassegrains and some refractors could take 1 hour in the worst freezing winter, so if you want to use them almost immediately, they should be kept in an unheated place. Even a compact car has room to transport this scope.

Category 2
In this group, the telescopes start to get heavy and bulky. In order to take the telescope up and down stairs, you must take it down in pieces, such as the tripod and tube assembly. Acclimation also takes longer, and a telescope of this size should remain on street level and in an unheated shed or garage. Transporting this size telescope now may require a larger car, large back seat, large trunk, hatchback, station wagon, or small SUV.

Category 3
These scopes with large tube assemblies, such as a 12.5" F/5, are difficult to lift or carry. Heavy and bulky, they should be disassembled and carried in pieces, and then assembled at your observing site. Remember too, that you will most likely be doing this in the dark. This size telescope should be either kept in a garage, or have its own little observatory to avoid acclimation problems. Transporting a scope like this requires a hatchback, station wagon, mini-van, van, SUV, or small truck. You may also need a small ladder to reach the eyepiece and a battery to power your clock drive out in the field.

Category 4
Telescopes of this size really need dark skies to perform optimally. A scope of this size really should have its own observatory. If that is not a possibility, and you plan to use your category 4 telescope to view at home, you will have to move it outdoors from the garage, so it probably needs to be on a dolly or wheels. If you have to transport it to a dark site, you may need help just trying to move and lift it due to its weight and bulk, so you may need a friend. To transport it, you need a pretty large vehicle such as a van or mini-van without a back seat, a large SUV, truck, or trailer and probably ramps. Don't forget a ladder to reach the eyepiece if it's a Newtonian, and a car battery to power a heavy drive system. The scope will have to be assembled and disassembled. You maybe able to do it yourself, or you may need a partner. In any case alignment is very critical, and a partner will come in handy helping you collimate by turning the adjustment screws behind the mirror while you check it from the eyepiece holder with your alignment tools.

Category 5
This category of telescope should be mounted in an observatory on a dark site. However, if it is not permanently installed and you must transport it to a dark site you will need a van, truck or trailer, and ramps. The telescope must be capable of being broken down to a much more manageable form, like a tubular Dobsonian. To move it some type of wheels must be attached, or a dolly placed under the base so the telescope could be rolled off and onto the vehicle. Even then, two or more people may be needed to accomplish this task. Most likely, you will be setting up and tearing down this telescope in the dark. In the winter, you may be doing it with gloves and heavy clothing. With scopes of this size alignment is very critical, and easier to achieve with two people. When you have help, you don't have to keep running back and forth to adjust the collimation. For scopes this size, especially Newtonian of f/5 or f/6 ratio, a 6' - 12' ladder maybe needed. You will also have to transport that to, and don't forget the ramps. One more thing with large scopes, you should have large excellent wide field eyepieces. These are the facts. No matter which scope you buy, if you take the time to consider all the issues involved beforehand, you'll be able to invest wisely and enjoy your

telescope for many years. If you have any questions you can email me EROSSI40@aol.com or via the discussion board

Testing Telescopes: ``Null'' Tests

By Michael Lindner

So far, we've glossed over a number of test methods, all requiring no other optical components other than the mirror under test. All of these tests required some sort of interpretation of the output. For instance, in the star test, the image must be compared to diagrams. In the Ronchi test, the lines must be compared to the ideal lines, In the Foucault test, the numbers must be fed into equations to compute the shape of the surface under test.

A *null test* is a test that needs no interpretation or data reduction. Some of the tests we've discussed can be made into null tests. The knife edge tests, for instance, are null tests for spherical surfaces (unfortunately, Newtonian mirrors must be paraboloids). They are also null tests for a light source infinitely far away (which is hard to produce without using a star, or some other optical components).

But I have yet to explain what a null test really is. Take the Foucault test, on a perfectly spherical mirror. As the knife-edge cuts the return image at exactly the center of curvature, the mirror appears to go completely, uniformly gray. That's it. If the mirror has any spots lighter or darker, it's not spherical. Aside from the fact that the test is easier to interpret, it's also more sensitive than the standard knife-edge tests. It is much easier to see if a surface is uniformly lit than it is to match the brightness of two disjoint areas.

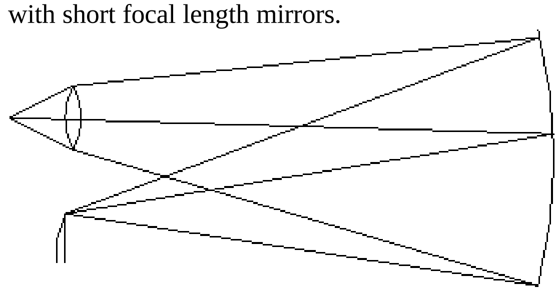
Knife-edge focusers use this fact to assist astrophotographers achieve perfect focus, using a star in the field of view as an infinitely far away light source. In the lab, and during the day, it's difficult to find stars, so we look for alternatives.

One way to make a light source appear infinitely far away is to place it at the focus of a telescope with a known-to-be-near-perfect mirror. Just as the scope brings light from a star to a point at the focal plane, it can be run in reverse to image a point at the focal plane to a position infinitely far away.

Another way to make a test into a null test is to make the parabolic mirror appear to be a sphere, and then test the sphere. A spherical mirror is useless in a telescope because it has "spherical aberration". However, the amount of spherical aberration an optical component has depends on the distance to the light source. That same spherical mirror has no spherical aberration when the source is at its center of curvature. Likewise, a parabolic mirror has spherical aberration when the light source is anywhere but infinitely far away.

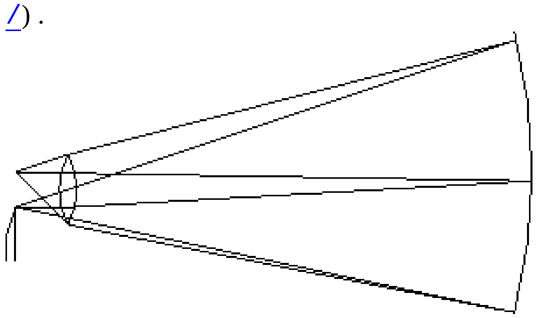
Knowing this, it is possible to design a system where the light source, a parabolic mirror, and a spherical mirror or lens are placed just right so that the spherical aberration introduced by the parabolic mirror is exactly opposite of that introduced by the spherical lens or mirror. When the spherical aberration is canceled this way, any of the knife-edge tests becomes a null test.

Horace Dall devised one such test. In the Dall null test (`http://www.atm-workshop.com/dall-null.html`), light from a pinhole travels through a lens to a parabolic mirror, and a knife-edge is used to examine the returning image. With the correct distance from the pinhole to the lens and from the lens to the mirror, the test is a null test. Of course, the properties of the lens must be known very accurately, and the positions of the optical components must be measured accurately, especially with short focal length mirrors.



Dall Null Test Setup

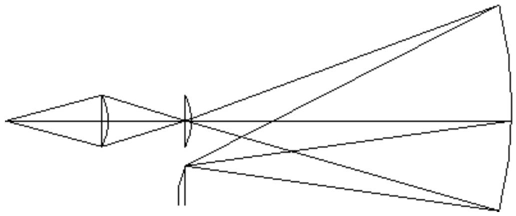
The Ross null test is similar, except the lens is placed in front of both the source and knife-edge. This means the source and knife-edge can be closer, so there is less chance of a problem with the source and image being off-axis. However, since the light travels through the lens twice, any defects in the lens have twice as much effect on the test's accuracy, so the lens must be of very high quality. Steve Swayze, of Swayze Optical (http://home.europa.com/~swayze/) uses the Ross null test for producing some very fine optics. The lens he uses is of very high quality, and was made by Peter Ceravolo of Ceravolo Optical Systems (http://www.cyanogen.com/ceravolo/) .



Ross Null Test Setup

Ross discovered that the best situation for his test involved placing the lens at the surface of the mirror itself. Of course, such a lens would have to be as big as the mirror, which is not generally practical.

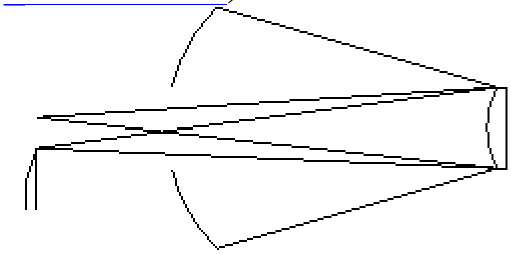
Offner to the rescue. In the Offner test, a small lens forms an image of a point source at the center of curvature of the parabolic mirror under test. A second small lens at the center of curvature of the mirror images the first lens at the mirror. Together they form the equivalent of a single large lens on the mirror.



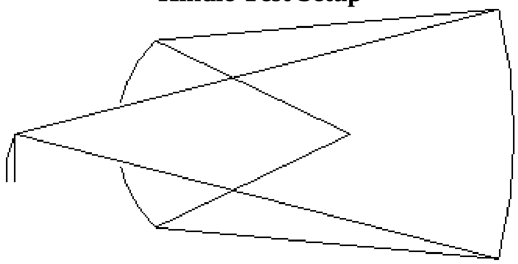
Offner Null Test Setup

The exact placement of the components is rather critical in the Offner test, as Perkin-Elmer found in testing the Hubble Space Telescope's primary mirror. A small error in the test setup led to a large error in the shape of that mirror.

Other null tests include the Hindle test, which uses a large sphere to test the hyperbolic convex secondary mirror of a cassegrain telescope, and the Waineo null test, which uses a spherical mirror instead of a lens to perform the equivalent of a Dall null test (http://zebu.uoregon.edu/~mbartels/dnld/waineo96.html and http://tlepage.home.mindspring.com/Waineo.html).



Hindle Test Setup



Waineo Null Test

Observing in Cold Weather

By Greg Cantrell

Cold weather doesn't only bring clear skies, but also the risk of cold stress. Careful planning and a few simple steps will make your cold weather observing much more enjoyable and safe.

While cold stress, or "hypothermia," can happen at any time during the year, most cases occur while air temperatures are between 30 and 50 degrees Fahrenheit. People who are exposed to these temperatures for long periods of time risk a serious loss of body-heat that could result in brain damage or death.

The effects of cold stress may not be obvious to the victim. The symptoms of hypothermia include:

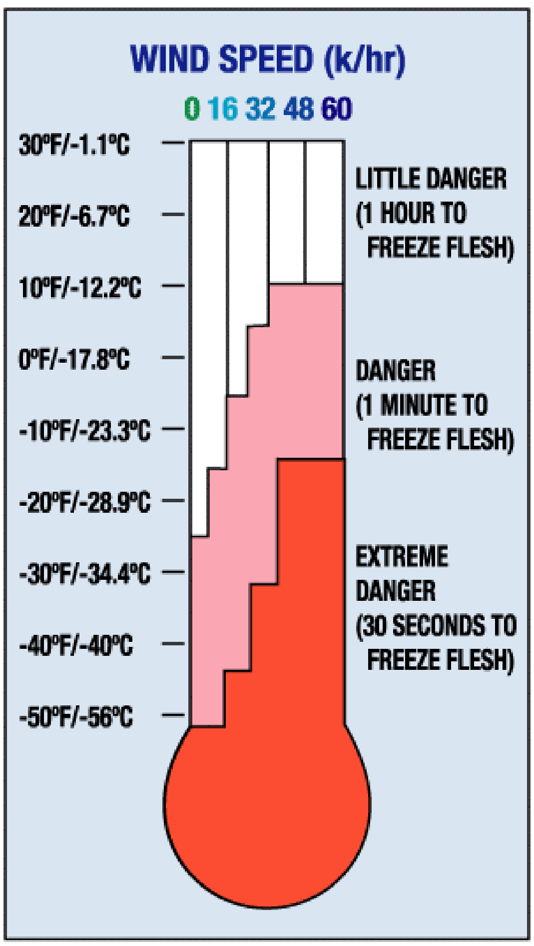
- Uncontrollable shivering and the sensation of coldness

- Slower heartbeat and weak pulse
- Severe shaking or rigid muscles may be evident
- The victim may also have slurred speech, memory lapses, and may become sleepy
- Cool skin, slow, irregular breathing, and exhaustion occur as the body temperature drops even lower.

These symptoms indicate a serious condition that requires immediate medical attention.

You can protect yourself against cold stress by doing the following:

- Instead of a couple of thick layers of clothing, wear several thin layers
- Wear a hat
- Eat and drink hot foods and liquids
- Avoid the consumption of alcohol while working or playing in the cold



Light Pollution Update

By Michael Lindner

New York state has a light pollution bill on the table, so now would be a good time to write Governor Pataki that you support wise lighting and want him to ratify the Grannis/Balboni legislation (A5352/S3386)! You can do so on-line at http://161.11.3.75/, by calling 518-474-8390, or writing to him:

The Honorable George E. Pataki
Governor of New York
State Capitol Bldg.
Albany, NY 12224

and while you're at it, since we have a new governor and new administration, perhaps we can push through the light pollution legislation that Whitman stymied for so long. Governor McGreevy can be contacted on-line at http://www.state.nj.us/governor/govmail.html, by calling 609-292-6000, or writing to him:

The Honorable James E. McGreevey
Governor of New Jersey
PO Box 001
Trenton, NJ 08625

You can also find the address for your NJ state legislators on-line at http://www.njleg.state.nj.us/districts/municipalities.asp . Please let your government officials know that you want them to support light pollution legislation.

Topic #3, Eratosthenes and the Measurement of the Earth's Circumference

By Edward Collett

In Topic #2 the disappearance of a ship below the horizon as it sailed away from an observer showed that this phenomenon could be used to determine the radius (or diameter) of the Earth. In principle, this method could also be used on land but the existence of natural irregularities in the terrain makes this measurement difficult to do. Nevertheless, there is a measurement that can be made on land that allows the Earth's diameter and, hence, its circumference to be measured. This measurement is attributed to Eratosthenes (267- 196 BC) of Alexandria (Egypt) and was made some time around 220 B.C. It is one of the most remarkable measurements ever made in the history of science and geography. It is also a wonderful story because it mixes lots of history with astronomy, geometry, and geography.

Eratosthenes was the chief librarian at the famed Library of Alexandria and in this position, he had access to all the records contained within the Library. He was also a geographer and mathematician; he introduced the word "geography". The city of Alexandria had been selected by Alexander the Great (ca. 330 BC) as a new capital of Egypt (it had been part of the Persian Empire and, *de facto,* then became part of Alexander's Empire after the Persian defeat by Alexander at the Battle of Issus in 333 BC). Alexandria was located on the Mediterranean so that Alexander could have relatively easy access to the mainland of Greece and Macedonia.

The writings of Eratosthenes no longer exist and are only known from the writings of his successors. Egypt as a country extends from the Alexandria in the north on the Mediterranean to the southern most city of Syene on the border with Sudan. According to these reports, Eratosthenes discovered that at noontime on the summer solstice no shadow appeared at the town of Syene (modern day Aswan (Assouan, probably an Arabic variation of "Al Syene")). The writings of his successors claimed that when a person in Syene looked down into a well (of water) one saw that the sun was reflected directly back to the observer. Furthermore, the walls of the well cast no shadow. The "reports" also state that Eratosthenes used a vertical stick to measure the length of the shadow. Before we proceed to describe the measurement, it is worthwhile considering both of these statements because, in my opinion, they are really difficult to believe.

First, let us look at the reflection of the sun from the surface of water. It is very, very difficult to believe that one would look at the sun either directly or reflected from a surface of water. When incident light is normal (perpendicular) to the surface of water, 96% or the light is transmitted and 4% of the light is reflected. Thus, if the brightness of the sun is represented by B_0 then the reflected light B will be

$$B = 0.04B_0 \qquad (1)$$

In term of stellar magnitudes, *m*, the relation between a source brightness *B* and its stellar magnitude is given by

$$B = \frac{B_0}{100^{\left(\frac{m-1}{5}\right)}} \qquad (2)$$

where B_0 is the brightness of the source. In this case, the reflected brightness of the sun, *B*, is then related to the incident brightness, B_0, by

$$B = 0.04B_0 = \frac{B_0}{100^{\left(\frac{m-1}{5}\right)}} \qquad (3)$$

Solving for the magnitude *m* leads to a value of $m = 4.5$ so the sun's apparent magnitude is reduced by this amount. The apparent (visual) magnitude of the sun has been measured to be –26.7 so its observed (reflected) magnitude would be $-26.7 + 4.5 = -22.2$. In comparison to the magnitude of the full moon, which is –11.3, this translates to a brightness difference of around 10,000! Clearly, looking at reflected sunlight is still blinding (this is amply demonstrated when sunlight is reflected from an automobile windshield). Probably, the ancient sources said one could *not* look at reflected sunlight from the well around the summer solstice and along the way, the "*not*" was dropped.

The second statement that a stick was used by Eratosthenes to make the measurements is equally incredulous. This statement is very difficult to believe for the following reasons. Syene was an extremely important place in Egypt because it was the "manufacturing center" for nearly all of the obelisks made in Egypt (The granite is so unique that to this day geologists call the granite quarried at Aswan "syenite.") Syene had still another significance for Egypt. It marked the boundary of Upper Egypt and Sudan and was the last city that, to the Egyptians, marked the end of Egyptian civilization. It also seems reasonable that as the center of the manufacture of obelisks there were several erected in Syene, itself. And almost certainly obelisks were erected in the capital city of Alexandria (Alexandria most probably had obelisks erected in his honor as a “god”; Alexander believed himself to be a god through his mother’s ancestry. Therefore, it is much more believable that obelisks rather than a vertical stick were used in the measurement. If any group of people in the ancient world could erect blocks of granite 60 or more feet with incredible (vertical) alignment it was the ancient Egyptians. It is much more believable that it was the disappearance of any shadows surrounding the obelisks in Syene which was noticed at the summer solstice. In the appendix of this topic, an analysis is given of the accuracy that could be obtained using an obelisk.

Now, on to the measurement of the Earth.

In the following figure, the assumption is made that parallel rays arrive from the sun. We see immediately that on a spherical earth there will be no shadow cast by the obelisk at Syene, **S**, whereas there will be a shadow cast by the obelisk at Alexandria, **A**.

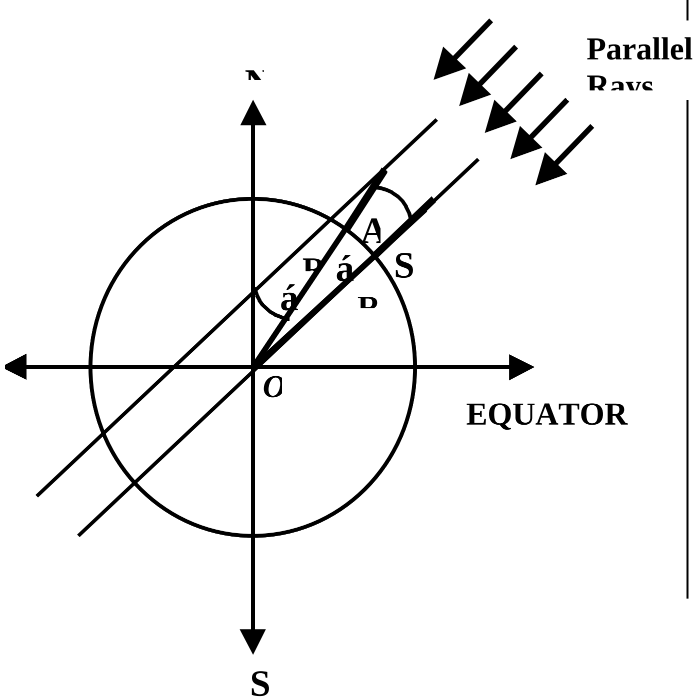


Figure 1. Diagram of the relation of the obelisks at Alexandria (**A**) and Syene (**S**). The radius of the Earth is **R** and α is the angle of the shadow cast by the obelisk at Alexandria.

Eratosthenes discovered, most probably from written records, that a very unusual phenomenon occurred in Syene. It was noticed that at the summer solstice at no shadow was cast by an obelisk – the sun was directly overhead at the zenith. At Alexandria, however, a shadow was cast by an obelisk. Eratosthenes was probably very puzzled by this observation. Why should a shadow be cast at Alexandria but not at Syene? Eventually he realized that this observation could be explained if the Earth was spherical in shape and the Earth was not a flat. Furthermore, the Earth was so far from the sun that the Sun's rays were effectively parallel. From these observations and some simple geometry, he then went on to determine the circumference of the Earth and its radius (and diameter).

We see from **Figure 1** that there is no shadow cast at Syene but there is a shadow cast at Alexandria. The figure shows the interior angles (the interior angles of two parallel lines are equal when cut by a transverse line (in this case the radius, R)). From simple geometry the arc length *s* between **A** and **S** is

$$s = R\alpha \qquad (4)$$

The circumference of the Earth is

$$C = 2\pi R \qquad (5)$$

Dividing eq.(5) by eq.(4) then gives

$$C = \frac{2\pi}{\alpha} s \qquad (6)$$

In order to determine the circumference, *C*, the distance *s* and the angle α must be measured. Egyptian surveyors knew the distance from one end of the kingdom (the Nile delta where Alexandria was located) to the other end (Syene) and *s* was known to be 500 miles. Next, from the shadow cast by the obelisk at Alexandria the angle α could be determined. This relationship is shown in the following figure.

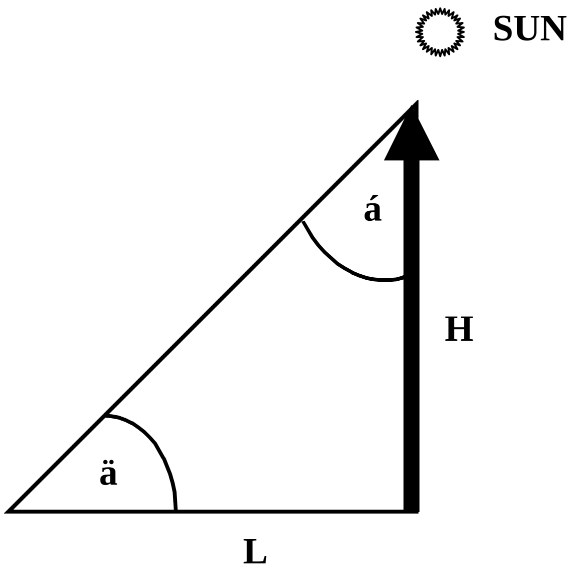


Figure 2. Angular relations between the height of the obelisk, H, the length of the cast shadow, L, and the angle a.

We see from **Figure 2** that

$$\tan a = \frac{L}{H} \qquad (7)$$

The height of an obelisk usually varied from 60 feet to 80 feet. Knowing the height of the obelisk and the length of the shadow, Eratosthenes found that the angle a was 7.2^{o}. In terms of radians this angle is

$$a = 7.2^{o} \times \left(\frac{p}{180^{o}} \right) = 0.1257 \qquad (8)$$

The distance between Alexandria and Syene is, approximately, 500 miles. Substituting the value for a and s into eq.(6) yields a circumference C with a value of

$$C = \frac{2p}{0.1257} \times 500 \text{ miles} = 25,000 \text{ miles} \quad (9)$$

The radius of the earth is then found to be $r = 3{,}979 \text{ miles}$ ($r = 6.404 \times 10^{6}$ meters) . This value is extremely close to the modern value of $r = 6.367 \times 10^{6}$ meters.

Thus, in this exercise of geometry and simple information about the geography of Egypt along with the realization of the significance of the obelisk shadows at Syene and Alexandria, Eratosthenes had determined the circumference and radius of the earth. A truly spectacular measurement. In addition, it was in Alexandria that Euclid later wrote his treatise on geometry, a name derived from the Greek words *geos* and *metros* – earth measurement. As we shall see knowing the radius of the earth is the key to determining the size of the universe.

Accuracy of the Angle used by Eratosthenes

In order to obtain the accuracy of the angle measurement of 7.2^{o} reported by Eratosthenes, a simple calculation shows that it is readily obtained using an obelisk that is 20 meters in height. We have the relation given by eq.(7)

$$L(a) = H \tan a \qquad (10)$$

Consider a measurement between $a = 7.2^{o}$ and $a = 7.3^{o}$. then, the difference in the lengths of a shadow cast by the obelisk at Alexandria would be

$$\Delta L = L(7.3^{o}) - L(7.2^{o}) = 20 \times (\tan 7.3^{o} - \tan 7.2^{o}) = 3.5 \text{ cm} \qquad (11)$$

Thus, the difference in shadow lengths is 3.5 cm, a value that is within easy measurement. Hence, the recorded value of 7.2^{o} certainly could have been done with an accuracy of 1 decimal place.

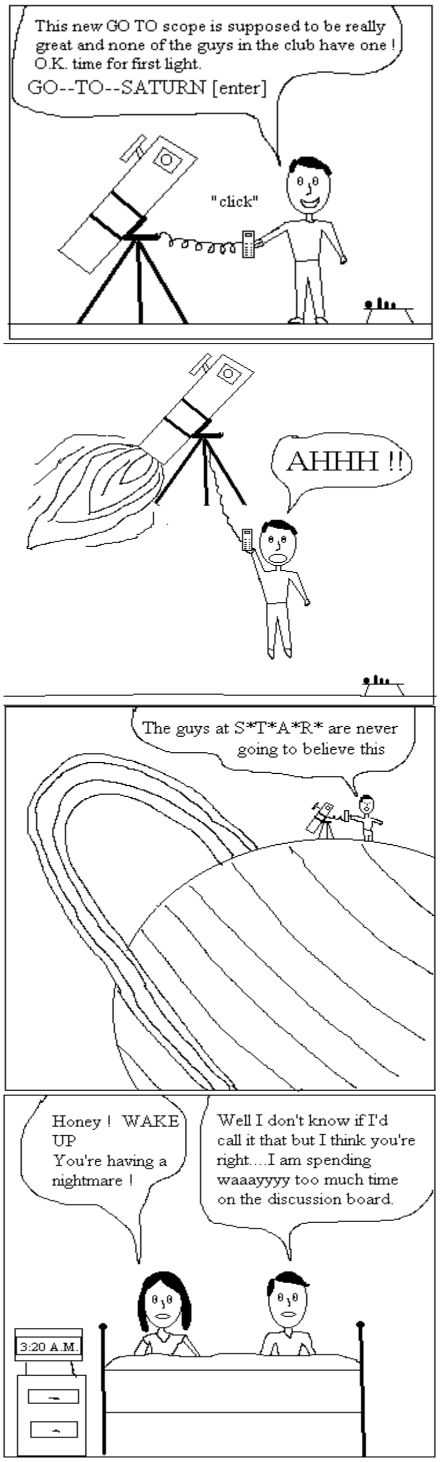
Astronomical Folklore

The following is taken from Thomas Sternberg's "Dialect and Folk-lore of Northamptonshire, 1851"

There is a pretty generally received idea that a new moon on a Sunday will bring a flood before it is out. Thus the proverb "Sunday's moon floods 'fore' tis out."

ScopeToon

By Steve Fedor



Double Star Observing

By Ernie Rossi

Visible double stars are among the easiest of all astronomical objects to observe. We know that about half of all stars are double of multiple star systems. Most of us live in light polluted skies, and we sometimes trek up to a dark remote site for various reasons. In a less then ideal sky we can observe the Sun, Moon, and Planets, but what about double stars. I have a friend who loves to observe and split double/multiple stars, and finds it as fascinating as looking at anything else in the heavens. The double star observer doesn't need a large well-equipped observatory, nor is it necessary to own a large aperture telescope. To define visual double stars to a beginner is looking at "double stars," that is, two or more stars that look as one to the naked eye.

To give the beginner a better understanding of what arc minutes or arc seconds are, let me give you an easy example. Some evening take a look at the star Mizar, the star at the "bend," or sometimes referred to the second star, in the handle of the Big Dipper. Mizar is a second magnitude star, with a fainter fourth magnitude companion, Alcor, 709" (arc seconds) away. Unless you're near city lights, you should be able to see Alcor without much trouble. The distance between two close stars is always expressed in "arc seconds," although the separation of the wider doubles is sometimes given in "arc minutes," where one arc minute is equivalent to 60 arc seconds. In the case of the Mizar-Alcor separation, 709" can alternately expressed as 11.8 (arc minutes). The full moon has a diameter of about 1800", or 30', which is one half of an arc degree?

There are thousands of visual double/multiple stars that are in the range of small telescopes. Amateurs who own small, high quality, high resolution telescopes in the 2" to 7" range will have an abundance of double stars to view. In fact, visual double stars can be easily observed from city locations suffering from moderate light pollution like your own back yard. Of course the very best results are always obtained under clear, dark, and light pollution free skies. However, such sky conditions are seldom realized, and double stars can be observed when deep sky objects are unobservable. The observation of visual double/multiple stars is one of the most neglected areas in both amateur and professional astronomy. Double stars are among the most fascinating objects for viewing in small telescopes, not only are some of them exceptionally pretty (different colors), others are a challenge to observe either because of the closeness of the secondary, or the magnitude difference between the two components. One more important thing I would like to mention, but only briefly cover, is what is the importance of measuring double stars. There are some professionals as well as amateurs astronomers who specialize in getting accurate measurements of double stars. There are over 78,100 pairs of stars listed in the Washington visual double star catalogue and many are still not accurately measured. By taking accurate measurements over time we cannot only calculate the stars orbit, but its mass too. The device previously used to take these measurements of double stars was the Filar Micrometer, but now the more accurate speckle Interferometer has taken its place. Does size matter when it comes to separating two or more stars? The answer is yes. Under ideal conditions the larger aperture telescope will always have greater resolving power. Resolving power means how close two stars can be to each other and still be seen as two distinct stars. To figure this out we have a formula referred to as "Dawes Limit." Resolution (sec of arc) =4.56/diameter of objective (in inches). This formula tells us if we had a 3" telescope we should be able to resolve two stars as close as 1.52", and a 6" would go down to 0.76." Just divide the aperture into Dawes Limit of 4.56. In order to achieve this theoretical limit, everything has to be just so.

1. The two stars should be at the same magnitude.
2. You must have an exceptional good night (very steady) of seeing.
3. Your telescope is optically perfect or very close.
4. You have excellent eyesight.
5. Use the highest magnification without degrading image quality.

Although it's useful to know this limit, in the real world it's difficult to get much below 1" (one-second of arc) consistently (this is due to the unsteadiness of the atmosphere), and the largest telescopes unless equipped with adaptive optics have trouble getting below 0.5" of arc even on the best nights. On most nights a 5-inch unobstructed telescope is the best you will do, and under rare occasions a 10 or 12-inch telescope is possible. Below is a list of some of the best visible double/multiple stars with at least one of its stars 5th magnitude or brighter. Since at least one of the double stars is 5th magnitude or brighter you may even use the sky maps in Sky and Telescope, or Astronomy magazines. However, you may be better off using a regular sky atlas that shows stars dimmer than 5th magnitude such as Sky Atlas 2000. Here are some of the easiest and favorite double/multiple stars of mine. The first word of the star (most of the time) is the Greek Alphabet, followed by the constellation.

Object R.A. DEC MAG SEP
Eta Cassiopeiae 00 49.1 +57 49 3.4, 7.5 12"
Alpha Piscium 02 02.0 +02 46 4.2, 5.1 1.7"
Gamma Andromedae 02 03.9 +42 20 2.3, 5.5 9.8"
Alpha Ursa Minoris 02 31.8 +89 16 2.0, 9.0 18.4"
Gamma Ceti 02 43.3 +03 14 3.5, 7.3 2.8"
Eta Persei 02 50.7 +55 54 3.8, 8.5 28.3"
Beta Orionis(Rigel) 05 14.5 -08 12 0.1, 6.8 9.5"
Delta Orionis 05 32.0 -00 18 2.2, 6.3 52.6"
Lamda Orionis 05 35.1 +09 56 3.6, 5.5 4.4"
Theta Orionis 05 35.3 -05 23 6.7, 7.9, 8.8", 13"
Iota Orionis 05 35.4 -05 55 2.8, 6.9 11.3"
Sigma Orionis 05 35.4 -02 36 4.0, 7.5, 12.9"
Zeta Orionis 05 40.8 -01 57 1.9, 4.0, 2.4"
Gamma Leporis 05 44.5 -22 27 3.7, 6.3 96.0"
Theta Aurigae 05 59.7 +37 13 2.6, 7.1 3.6"
Epsilon Monocerotis 06 23.8 +04 36 4.5, 6.5 13.4"
Beta Monocerotis 06 28.8 -07 02 4.7, 5.2, 7.3"
Epsilon Canis Major 06 58.6 -28 58 1.5, 7.4 5.7"
Delta Geminorum 07 21.1 +21 59 3.5, 8.2 6.8"
Alpha Geminorum 07 34.6 +31 53 1.9, 2.9 2.2"
Kappa Puppis 07 38.8 -26 48 4.5, 4.7 9.9"
Iota Cancri 08 46.7 +28 46 4.2, 6.6 30.0"
Gamma Leonis 10 20.0 +19 51 2.2, 3.5 4.4"
Gamma Virginis 12 41.7 -01 27 3.5, 3.5 3.6"
Zeta Ursa Majoris 13 23.9 +54 56 2.3, 4.0, 14.4"
Kappa Bootis 14 13.5 +51 47 4.6, 6.6 13.4"
Iota Bootis 14 16.2 +51 22 4.9, 7.5 38.0"
Epsilon Bootis 14 45.0 +27 04 2.5, 4.9 2.8"
Beta Scorpii 16 05.4 -19 48 2.6, 4.9 13.6"
Alpha Herculis 17 14.6 +14 23 3.5, 5.4 4.7"
Delta Herculis 17 15.0 +24 50 3.1, 8.2 8.9"

Rho Herculis 17 23.7 +37 09 4.6, 5.6 4.1"
Epsilon Lyrae 18 44.3 +39 40 5.0, 6.1, 208.0"
Beta Lyrae 18 50.1 +33 22 3.4, 8.6 46.0"
Beta Cygni 19 30.7 +27 58 3.1, 5.1 34.4"
Alpha Capricornus 20 18.1 -12 33 3.6, 4.2 378.0"
Gamma Delphinus 20 46.7 +16 07 4.5, 5.5 9.6"
Epsilon Pegasi 21 44.2 +09 52 2.4, 8.4 142.0"

Now even when the moon is up and your sky is not at it's best, you can try observing double stars to test your skills, eyesight, and your telescopes performance.

Word Search - The Pleiades

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S E V E N E U E W I N T E R I
B I A H P Z P C A L L I S T O
U Q S O N O R T R R N O I R O
L Z R T R O L E E E O N X N E
L E U E E A I I T A T B P Y V
M U T P S R S T L S O N S M I
V S P G L S S C C O U P U P F
A T O Y E E Y B T E A L M H Y
R A S M O O I E E R L A C S T
T Y E E N R S A T A I F S N R
C G I E B X T A D A R M E Z O
E E D R O N E A L E C C D R F
L T O P L E I O N E S R A T S
E A N S E M R E H D S W Y S L
S U R U A T N E B U L A H W U
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ALCYONE ARCAS ASTEROPE ATLAS
BEAR BOOTES BULL CALLISTO
CELAENO CLUSTER ELECTRA
FORTYFIVE HERMES HUNTER
HYADES MAIA MEROPE MESSIER
NEBULA NYMPHS ORION PLEIADES
PLEIONE POSEIDON REFLECTION
SEVEN SISTERS SPARTA STAR
TAURUS TAYGETA TROY URSA
WINTER ZEUS
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Upcoming Events

January 26 – The Rutgers University Geology Museum will hold their **34th annual open house** from 9:00 AM to 4:00 PM in Scott Hall room 123. For information contact William Selden, Collections Manager, at (732) 932-7243 or rwselden@rci.rutgers.edu.

February 10-16 – The **Cedar Key Star Party** will be held in Cedar Key, near Chiefland, Florida. For more information, visit http://members.aol.com/bemusabord/cedarkey.html

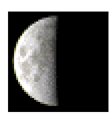
February 11-16 - The 18th annual **Winter Star Party** will be held at the Girl Scout Camp on the Florida Keys. Contact registrars Lucille & Fred Heinrich, e-mail heinrich@atlantic.net.

February 13-17 - The **Orange Blossom Special Star Party** will be sponsored by the St. Petersburg Astronomy Club. For information http://home1.gte.net/hoffmanc/index.html

March 1 – 3 – The **Mid-Atlantic Mirror Making Seminar** will be held by the Delmarva Star Gazers. For information, visit http://www.delmarvastargazers.org/mm2.html

March 14-16 – The **Sugar Hill Star Party & Messier Marathon** will be held by the Sunset Hill House, Sugar Hill, New Hampshire. Visit http://www.sunsethillhouse.com for more information

May 18-19 – The **11th annual Northeast Astronomy Forum (NEAF)** will be held at Rockland Community College in Suffern, New York. For more information, visit http://www.rocklandastronomy.com/neaf.htm.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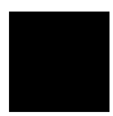
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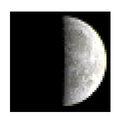
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Feb 27