

A Missile in Your Eye



Patrick L. Barry

Satellite technology designed to catch ballistic missile launches may soon help doctors monitor the health of people's eyes.

For the last 15 years, Greg Bearman and his colleagues at JPL have been working on a novel design for a spectrometer, a special kind of camera often used on satellites and spacecraft. Rather than snapping a simple picture, spectrometers measure the spectrum of wavelengths in the light coming from a scene. From that information, scientists can learn things about the physical properties of objects in the photo, be they stars or distant planets or vegetation on Earth's surface.

In this case, however, the challenge was to capture snapshots of short-lived events—like missile launches! The team of JPL scientists designed the new spectrometer, called a computed tomographic imaging spectrometer (CTIS), in collaboration with the Ballistic Missile Defense Organization as a way to detect missiles by the spectral signatures of their exhaust.

But now the scientists are pointing CTIS at another fast-moving scene: the retina of an eye.

Blood flowing through the retina has a different spectral signature when it is rich in oxygen than when it is oxygen deprived. So eye doctors can use a spectrometer to look for low oxygen in the retina—an indicator of disease. However, because the eye is constantly moving, images produced by conventional spectrometers would have motion blurring that is difficult to correct.

The spectrometer that Bearman helped to develop is different: It can capture the whole retina and its spectral information in a single snapshot as quick as 3 milliseconds. "We needed something fast," says Bearman, and this spectrometer is "missile-quick."

CTIS is even relatively cheap to build, consisting of standard camera lenses and a custom, etched, transparent sheet called a grating. "With the exception of the grating, we bought everything on Amazon," he says.

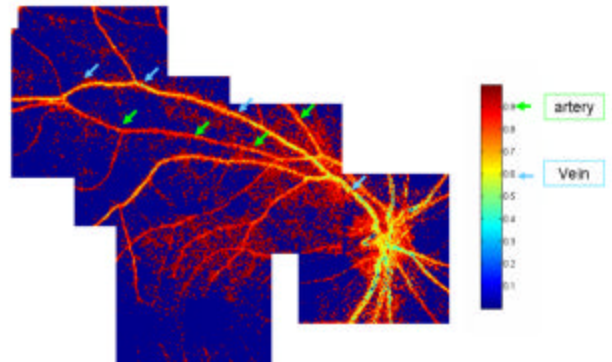
The grating was custom-designed at JPL. It has a pattern of microscopic steps on its surface that split incoming light into 25 separate images arranged in a 5 by 5 grid. The center image in the grid shows the scene undistorted, but colors in the surrounding images are slightly "smeared" apart, as if the light had passed through a prism. This separation of colors reveals the light's spectrum for each pixel in the image.

"We're conducting clinical trials now," says Bearman. If all goes well, anti-missile technology may soon be catching eye problems before they have a chance to get off the ground.

Information about other NASA-developed technologies with spin-off applications can be found at <http://www.sti.nasa.gov/tto>.

This article was provided by the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

This three-color composite image from the computed tomographic imaging spectrometer shows the oxygenation of the blood in the arteries and veins of a human retina. (Arteries appear red, veins appear yellow.)



The Delmarva Stargazers Announces a Writing Contest.

The DMSG will raffle away astronomy gifts to members who submit articles to the Star Gazer News.

How to enter:

- 1 Open to DMSG members.
- 2 Members may submit original articles at least 500 words (1/2 page) for publication in the Star Gazer News.
- 3 Articles **must** be authored by the member.
- 4 Pictures can be included, but they do not count towards word count (1 picture = 1000 words).
- 5 Must be astronomy related. Each article = one chance in the raffle. The drawing will be made at the star parties based on the previous 6 issues – need not attend to win (but it would be nice to see you there). *The editor of the Star Gazer News qualifies articles submitted.*

How to Join the Delmarva Stargazers: Anyone with an interest in any aspect of astronomy is welcome

NAME _____

ADDRESS _____

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Do you need the newsletter snail mailed to you (Y/N)? _____

Please attach a check for \$15 made payable to Delmarva Stargazers and mail to Kathy Sheldon, 20985 Fletown Rd, Lincoln, DE 19960. Call club President Jerry Truitt at 410-885-3327 for more information.

Benjamin Banneker

Free African American, mathematician, astronomer, clockmaker, and publisher

Presented at the September meeting by Jerry Truitt

Banneker' mother was Mary Bannaky (1710-?). Oral tradition states that her mother was a European American named Molly Walsh, who was supposedly accused of stealing a pail of milk and sent from England to the colonies as punishment. The story goes that Molly became the owner of a farm and married one of her slaves named Bannakay, whom she freed. They had four girls and Mary was the oldest. A recent article in the National Genealogical Society Quarterly (Dec. 2006, pp. 305-314) disproves this tradition.

Benjamin's father, Robert Banna Ka, was a former slave who had built a series of dams and watercourses that successfully irrigated the family farm at Ellicott's Mills, where Benjamin lived most of his life.

At 21, Banneker saw a pocket watch/ He was so amazed by it that he spent days taking it apart and reassembling it. Banneker then carved large-scale wooden replicas of each piece, calculating the gear assemblies himself, and used the parts to make a striking clock. This event changed his life, and he became a watch and clock maker. One customer was Joseph Ellicott, a Quaker surveyor, who needed an extremely accurate timepiece to make correct calculations of the locations of stars. Ellicott was so impressed with his work that he lent him books on mathematics and astronomy.

Banneker began his study of astronomy at age 58. He was able to make the calculations to predict solar and lunar eclipses and to compile an ephemeris for the *Benjamin Banneker's Almanac*, which an anti-slavery society published from 1792 through 1797. He became known as the Sable Astronomer.

In early 1791, Joseph Ellicott hired Banneker to assist in a survey of the boundaries of the future 100 square-mile District of Columbia.

Banneker left the boundary survey in April, 1791, and returned to his home at Ellicott Mills to work on his ephemeris.

After departing the federal capital area, Banneker expressed a vision of social justice and equity that he wished to be adhered to in the everyday fabric of American life. He wrote to the Secretary of State and author of the Declaration of Independence, Thomas Jefferson, a plea for justice for African Americans, calling on the colonists' personal experience as "slaves" of Britain and quoting Jefferson's own words. To support his plea, Banneker included a copy of his newly published ephemeris with its astronomical calculations.

Jefferson replied to Banneker less than two weeks later in a series of statements asserting his own interest in the advancement of the equality of America's Black population. Jefferson also forwarded a copy of Banneker's *Almanac* to the French Academy of Sciences in Paris. It was also used in Britain's House of Commons as a testimony to the fact blacks are as intelligent as whites.

In 1792, Banneker included in his *Almanac*, a plan for the creation of a new Department in the American federal government. Several pages of Banneker's *almanac* outlined a Department of Peace, testifying to his ethical positions and to the need to balance a Department of War with a Department of Peace dedicated to promoting the de-escalation of national and international conflict.

Benjamin died on October 9, 1806 at age 74 in his log cabin. He never married.

A small urban park memorializing Benjamin Banneker is located at a prominent overlook (Banneker Circle) at the south end of L'Enfant Promenade in southwest Washington, D.C., a half mile south of the Smithsonian Institution's "Castle" on the National Mall.

The Banneker-Douglass Museum is located in the old Mount Moriah A.M.E. Church at 84 Franklin Street in Annapolis (off Church Circle in the Annapolis historic district)

Ref. Wikipedia



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**The Delmarva Stargazers
are pleased to announce the *No Frills XII* Star Party.
When: Wednesday 12 Noon October 10 through Sunday Morning October 14.
Where: Tuckahoe State Park's Equestrian Center near Queen Anne, MD.**

The registration includes the camping fee for the observing area, campers are permitted to park by their telescopes. FREE ALL NIGHT STARGAZER COFFEE, plus every evening we offer soup or chili except Saturday. Saturday we will host our now famous afternoon fish fry, all included with your registration. Sodas and hot dogs will be available at minimal cost.

**There are no hookups or electricity in the observation area,
but power is available for charging batteries.
Vehicle movement will be restricted in the observing area after dusk
as a courtesy to those who are observing.**

see <http://www.delmarvastargazers.org/archive/nofrills2007/index.html> for more details

We'll see you under the Stars

Observations from bac-o-d-bus and the marsh...

Don Surles

I have been traveling from Smyrna to Wilmington for 27 years...and I drove it for the first 25. Now that I have a reserved seat in da-bac-o-d-bus I am amazed at how often I must have missed so many of the beautiful scenes Mother Nature provides for us along the "scenic" DE #1 - I-95 route.

Yesterday morning just as the sun was peaking over the horizon we passed a section of marsh along I-95 that had a thin layer of wispy fog delicately suspended just above ground level and the sun illuminated that foggy mist into a layer of reflecting jewels just for the pleasure of us folks on the 301 bus. If only I had my camera...but a mile up the road we passed over a bridge...a railroad ran underneath us with a parked train headed east...again Mother Nature provided a beautiful sight as the rising sun's rays reflected off the top of the train. Again I missed that Kodak moment. As we were making our entrance into Wilmington a thin bank of clouds passed in front of the sun ...and again there was a Kodak moment as the clouds dispersed the sun's rays into a beautiful fan shaped spread of sunlight. I am sure that had I been driving...I-95 is bumper to bumper in the morning and afternoon...I would have probably missed these wonders.

Here, at the Delaware latitude, the sunrise can vary approximately 60 degrees along the horizon from summer to winter (Northeast to Southeast). I haven't worked out the math but the speed and distance from Smyrna to Wilmington, along with my departure time, and the sunrise movement along the horizon, allows me to watch the sunrise almost every morning on my commute to Wilmington. In Summer the event takes place shortly after I leave Smyrna. As Fall approaches the sunrise moves northward and is now occurring just south of Wilmington. By the time we reach the end of Daylight Savings Time sunrise happens as I arrive at Rodney Square...looking straight down 10th Street toward the Delaware Bay...beautiful view! And during Winter and the arrival of EST, sunrise stays just south of Wilmington. There are several places along the route where the sunrise can be viewed with a very interesting foregrounds...marshes, refineries, rivers with rowing boats, tall buildings along the Christina River, the Blue Rocks baseball stadium, foggy fields of corn and soybeans. I find these to be pleasing observing alternatives to the nights I once spent peering through the eyepiece and pondering the wonders of the Universe. But, rest assured that once I cease these trips to Wilmington on the 301 bus I will return to the night sky and resume pondering the meaning of the view through the eyepiece in lieu of the 301 bus window.

Observing a sunrise in the marsh east of Smyrna...near Mallard Lodge. Saturday morning, September 8, Doug Norton and I met at 6:00AM for a photography session from the observation tower near Mallard Lodge. When we arrived it was still dark...the waning crescent moon and Venus made a nice picture as they hung over the marsh. There was a small amount of haze but the sky was basically clear. We took several pics of the moon and Venus as we waited for the sunrise. Watching and listening to a marsh awaken is very interesting. There must be a "marsh" routine...certain species of birds fly before the

(See BUS on page 5)

The Solar System in October- You have to come to the star party and see for yourself. Mercury heads to an inferior conjunction by the end of the month. Venus, Saturn, and Regulus form a nice triangle around the 13th. Mars transits just before Sol rises. Jupiter sets in the evening. Saturn rises after 2AM. Uranus is still in Aquarius, and can be seen naked eye if you know where to look. Neptune is 1.3° N of Luna on the 21st. You can find the minor planet Pluto to the right of Scutum. If you're looking for Terra, check under your feet. The largest full moon of 2007 is on the 26th. Zodiacal Light visible in the E before sunrise.

(BUS from page 4)

others. The marsh even smells different in the morning. We noticed a shadow reflecting in the still creek water in front of the tower...the shadow moved and then we could make out a deer on the bank...another shadow on the water and, yes, there was another deer. As the light increased we noticed a mother deer and two young fawns running across the field on the other side of the creek. Dawn was approaching and we turned our attention to the arrival of the sun. It's arrival was worth the wait! The sun was a huge deep red colored ball...we looked at it with naked binos and the view was absolutely amazing. There were several jaggies along the edge caused by layers of atmosphere...it looked like a giant was sitting on it and squishing it into an oval. Time for the cameras! Thanks for digital cameras...push the button and you immediately see if the image needs adjusting (it did...automatic never works in these situations). We filled our cards with images and watched the sunrise high enuf to reflect in the creek...and what a sight! The now orange sun was hanging a few degrees above the horizon with it's reflection in the foreground creek... I wish you could have been there. By 7:15 it was over and we returned to my place for breakfast and coffee. Next time it will be for sunsets!
Don...

Vision

Jerry Truitt

When I started getting really serious about observing one of the first things I realized is that I needed to understand how my eyes work. Now understand I knew the basics but I really wanted to know more. By the way I'm not going to review the basics of vision here, if you need to learn the basics Goggle "How your eyes work" and you'll find a wealth of information or come to one of my out reach events where I go over it in detail.

Very little of the light that enters the eye actually reaches the retina. The light travels through two layers of the retina, a ganglion of nerves, before reaching the photoreceptor cells. The rods and cones shaped cells that are the photoreceptors are on the back of the retina. Yes, not facing the incoming light.

We don't yet really understand this backward arrangement but one possibility is that the position of the light-sensitive cells at the back of the retina allows any stray unabsorbed light to be taken care of by cells immediately behind the retina that contain a black pigment known as melanin. The melanin-containing cells also help to chemically restore the light-sensitive visual pigment in the rods and cones after it has been bleached by light.

About 80% of the data we collect and process from the world around us comes from our eyes. Of the light that hits the retina, only 10% of this light is in focus or responsible for sharp vision. This section is called the Macula and is the area used when you read for example. The rest is responsible for peripheral vision and is basically out of focus.

The ganglion of nerves is actually brain matter and is the only area on our body where doctors can inspect our brain. This brain matter is more than just a transmitter of electrical impulses to the optic nerves and to the brain vision center. Each ganglion processes the electrical impulses creating short clips or movies of the information. Each ganglion create a different type of movie, some are stick figures, some in different colors and some negative images.

These short movies are sent via the optic nerve to the brain's vision center which put all this information together with existing information from past experiences to create what it thinks we are seeing. No, we don't completely understand this process yet, just like space research the more we learn the more questions we have developed.

Now you may know that birds of pray have much sharper vision compared to us humans. A hawk has 120,000 cone cells per square millimeter while humans have a mere 10,000.

However did you know that as sharp as a hawk's vision is it can't see the edges of a dime? Why? Simply put the retina is a two dimensional system. Humans may well be the only creatures on the planet that perceives things in three dimensions.

Our eyes constantly move back and forth in very small motions and very rapidly, so quick and small you can't look at someone's eyes and detect this movement. Scientist think that this motion is used by our brain to create a three dimensional image from a two dimensional optic system.

With recent medical advances, doctors were amazed when they restored the vision of a person in their twenties who had been blind since birth. He could see but he could not make sense of it. It appears we start learning how to see from birth, our brain learns how to process and use the information sent to it. It retains out past experiences to decide what the current information is telling us. Vision is a learned thing as much as it is a physical process.

We are learning more and more about how our vision works. Many of the things we've learned we still don't fully understand but the more we learn the more amazing our ability to see becomes.

Magazine Subscriptions

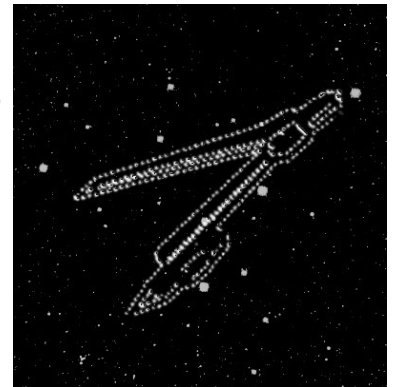
As a paid member of DMSG, you can sign up -or- renew your S&T or Astronomy magazines through the club for a discount over private rate. S&T, reg. \$42.95, is \$32.95 thru DMSG, Astronomy, reg. \$44, is \$34 thru DMSG. See Tony Codella for details.

(Sorties from page 1)

significance to Cepheids is that their period relates to their intrinsic brightness – and if you know how bright an object is you know how far away it lies. (By the way - who first figured out the luminosity - period link? If you think it was Edwin Hubble you may enjoy this [fine article at AAVSO](#) to learn about one of the unsung female astronomers of the 20th century!)

Swinging westward Mu Cephei is the next target, lying along the southern base of the pentagon. At 4th magnitude it is not really naked-eye visible (to me at least) but the distinctive deep orange color makes it obvious when I pan over it. The low power view is really nice - I've certainly seen redder stars than this M2 class sun but it is attractive, glimmering like Arcturus in the 20mm field with about half a dozen field stars littered about. This star is also known as "Herschel's Garnet Star", which at first may seem like yet another example of fanciful color interpretation. But in fairness not all garnets are ruddy in appearance, and [some specimens](#) really do resemble this stellar gem. Like Delta, Mu is also a variable with amplitude of about 1.5 magnitudes, but it does so over a much more leisurely 2-2½ years. In addition to being one of the redder stars one can see naked-eye this member of Cepheus has other notoriety. The relatively common appearance belies the fact that this is a *huge* supergiant, one of the [largest stars](#) that we know of in our galaxy, actually subtending 0.02" in size. If substituted for Sol its surface would lie between the orbits of Jupiter and Saturn! To me this one's a keeper for the yard-sale scope list – easy to target, attractive, and storied.

Continuing to work my way higher in the sky I pan with the binoculars for open cluster M39. I always associate this gem with a vacation we took nearly two decades ago in Maine where all I had were these same binoculars and a couple of cool, crisp summer evenings by the lake and glorious skies. I remember stumbling across this nest of stars and thinking *what is that?* Nothing from my yard resembled this and it was so noticeable! A little chart research soon revealed what it was – the very fine, bright open cluster M39. It's a loose cluster but stands out well enough from the background stars of the Cygnus Milky Way that I'm pretty sure I have it in view – the star hop is more of a broad jump as not even a good 3rd magnitude star is nearby. At about the size of the full moon it's occupying most of the 20mm field. Probably over a dozen stars are seen, contained roughly within a triangle shape, but no color is noted among the members (which is corroborated by spectral studies of the cluster). There's also no misty nebulosity that would imply other unresolved members. The starry pattern that catches my eye is two lines forming an apex – and in unleashing my imagination I think I can fancy the outline of a compass. Anyone for the Cygnus Compass Cluster? Check it yourself and see what you think...

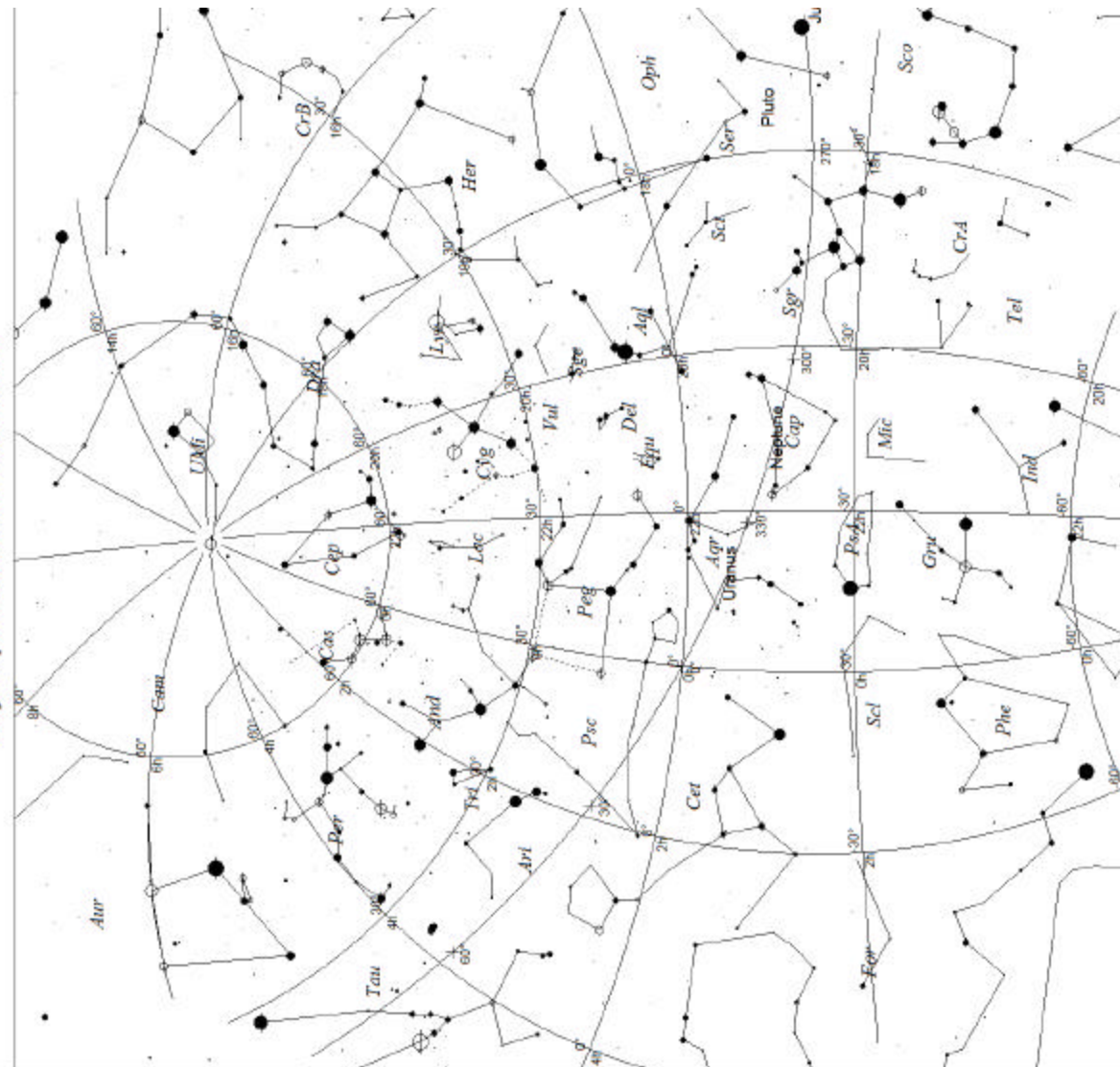


Scooting to the southeast I go in search of easy pickings - M15. This is really a fine globular and a good target for my instrument, a simple sweep northwest of Epsilon Pegasi which is naked eye and I soon have it. The globular is robust enough to take higher (80x) magnification where it appears as a fuzzy globe. Perhaps it's wishful thinking but I believe I can sense it growing brighter at its center, especially when using averted vision. A triangle of reasonably bright field stars encompass it, the brightest (6th magnitude) of which trails the cluster through the field. Its visible size is perhaps 4 arc-minutes, and while not as spectacular as those [Hubble's images](#) that shows it to be one of the densest known globulars at its core (harboring pulsars and perhaps even a black hole), it's still satisfying to view it first hand with even a modest instrument.

It's getting to be a race now as Luna will be cresting in the hill in a little while. The Andromeda galaxy is visible in binoculars as expected, and represents a pretty easy hop. It ends up being a little more challenging than expected – so often things do because of the scope's rather unique method of using a flip-mirror to turn the entire OTA into a rather poor finder. But my delayed gratification is tolerable and soon forgotten as M31 is finally centered. It's by far one of the larger DSO (excluding open clusters) I've seen with this scope. It's an amorphous mass that is a little oblong in shape and perhaps extending 10-15 arc-minutes in the field. Somewhat hard to say if it has much of a nucleus in this little aperture – M15 certainly seemed more definite in that regard. Companion galaxy M32 is hard to distinguish at low power but at 80x it is clearly not a true star, especially when compared to the two nearby field stars of approximately same brightness. M110? Yeah, right...perhaps I'll see it in my dreams but not in suburban Baltimore with 60mm of glass!

The ochre colored gibbous Moon breaks the northeastern horizon by 10:40 pm, a celestial recess bell ruining our game of tag with the deeper universe. One night I'll need to change my perspective and give our natural satellite a little attention – but not this evening While not as beautiful as a good dark sky site I'm pleased to have this venue for its convenience, good horizons, and some improvement in limiting magnitude. Can't wait for No Frills XII – hope to see you there!

Skymap 12 October 2007 10PM



Tuckahoe State Park, MD

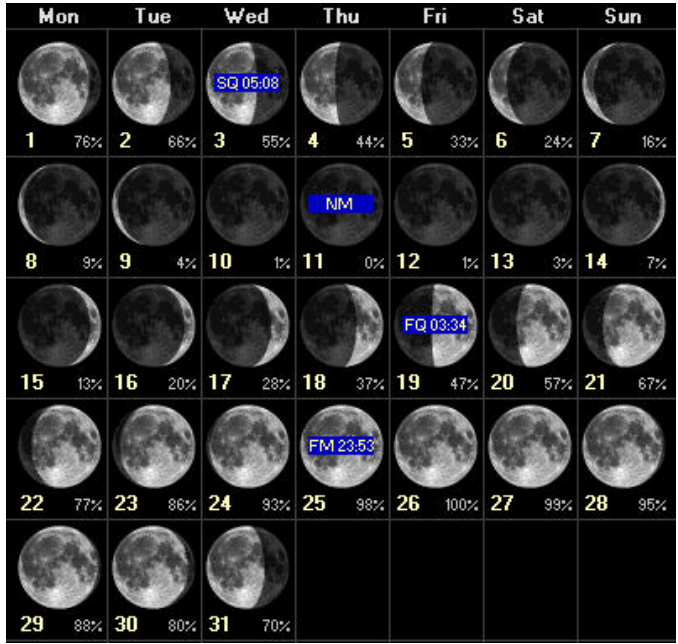
- SYMBOLS**
- Multiple star
 - Variable star
 - ☉ Comet
 - ☼ Galaxy
 - Bright nebula
 - △ Dark nebula
 - ⊕ Globular cluster
 - ⊙ Open cluster
 - ♁ Planetary nebula
 - ⊞ Quasar
 - △ Radio source
 - × X-ray source
 - Other object

- STARS**
- <1
 - 1.5
 - 2
 - 2.5
 - 3
 - 3.5
 - 4
 - 4.5
 - >5

Local Time: 22:00:00 12-Oct-2007
 Location: 38° 58' 0" N 75° 56' 0" W
 UTC: 02:00:00 13-Oct-2007
 RA: 22h21m18s Dec: +23° 57' Field: 180.0°
 Sidereal Time: 22:21:18
 Julian Day: 2454386.6833

Sun and Moon Data for October 2007
 Tuckahoe MD
 38.97°N 75.93°W 5hrW
 Daylight Time Civil Twilight

Date	Twilight	Rise	Sun Transit	Set	Twilight	Rise	Moon Transit	Set	%
10/1/2007	6:33a	6:59a	12:53p	6:47p	7:13p	10:01p	5:00a	1:00p	69
10/2/2007	6:34a	7:00a	12:53p	6:45p	7:12p	11:04p	6:02a	2:04p	58
10/3/2007	6:35a	7:01a	12:53p	6:44p	7:10p	*****	7:03a	2:57p	47
10/4/2007	6:36a	7:02a	12:52p	6:42p	7:09p	12:12a	8:00a	3:39p	37
10/5/2007	6:36a	7:03a	12:52p	6:41p	7:07p	1:21a	8:52a	4:12p	27
10/6/2007	6:37a	7:04a	12:52p	6:39p	7:06p	2:28a	9:40a	4:40p	18
10/7/2007	6:38a	7:05a	12:52p	6:38p	7:04p	3:33a	10:24a	5:03p	11
10/8/2007	6:39a	7:06a	12:51p	6:36p	7:03p	4:35a	11:05a	5:25p	6
10/9/2007	6:40a	7:07a	12:51p	6:34p	7:01p	5:35a	11:45a	5:45p	2
10/10/2007	6:41a	7:08a	12:51p	6:33p	7:00p	6:35a	12:25p	6:06p	0
10/11/2007	6:42a	7:09a	12:51p	6:31p	6:58p	7:34a	1:05p	6:28p	0
10/12/2007	6:43a	7:10a	12:50p	6:30p	6:57p	8:35a	1:48p	6:53p	2
10/13/2007	6:44a	7:11a	12:50p	6:29p	6:55p	9:36a	2:32p	7:22p	6
10/14/2007	6:45a	7:12a	12:50p	6:27p	6:54p	10:38a	3:19p	7:56p	11
10/15/2007	6:46a	7:13a	12:50p	6:26p	6:52p	11:38a	4:09p	8:38p	17
10/16/2007	6:47a	7:14a	12:49p	6:24p	6:51p	12:34p	5:01p	9:27p	25
10/17/2007	6:48a	7:15a	12:49p	6:23p	6:50p	1:26p	5:54p	10:24p	33
10/18/2007	6:49a	7:16a	12:49p	6:21p	6:48p	2:10p	6:46p	11:27p	43
10/19/2007	6:50a	7:17a	12:49p	6:20p	6:47p	2:48p	7:38p	*****	53
10/20/2007	6:51a	7:18a	12:49p	6:19p	6:46p	3:21p	8:26p	12:34a	63
10/21/2007	6:52a	7:19a	12:48p	6:17p	6:44p	3:49p	9:17p	1:44a	74
10/22/2007	6:53a	7:20a	12:48p	6:16p	6:43p	4:16p	10:06p	2:55a	83
10/23/2007	6:54a	7:21a	12:48p	6:15p	6:42p	4:42p	10:55p	4:07a	91
10/24/2007	6:55a	7:22a	12:48p	6:13p	6:40p	5:09p	11:46p	5:21a	96
10/25/2007	6:56a	7:23a	12:48p	6:12p	6:39p	5:38p	*****	6:38a	99
10/26/2007	6:57a	7:24a	12:48p	6:11p	6:38p	6:13p	12:41a	7:58a	100
10/27/2007	6:58a	7:25a	12:48p	6:09p	6:37p	6:56p	1:40a	9:20a	97
10/28/2007	6:59a	7:26a	12:48p	6:08p	6:36p	7:49p	2:43a	10:39a	91
10/29/2007	7:00a	7:27a	12:47p	6:07p	6:34p	8:51p	3:48a	11:50a	83
10/30/2007	7:01a	7:29a	12:47p	6:06p	6:33p	10:00p	4:52a	12:49p	73
10/31/2007	7:02a	7:30a	12:47p	6:05p	6:32p	11:11p	5:52a	1:36p	63



Moondark for October: Space ... the Final Frontier

Doug Miller

With those [unmistakable chimes](#) and Captain Kirk's enduring voice-over, the [Starship Enterprise](#) swooshes across the Universe. Faster-than-light technologies are required to traverse the vast distances between "strange new worlds" all while fitting the storyline within limits of an [hour-long television program](#). Space is a big place, even when you have a warp drive.

Just how big space is is easy to demonstrate by building [a scale model of the solar system](#). You'll need much more room than you'd imagine to accurately model both the relative sizes of the Sun and planets, and the distances between them. Start with a soccer ball for the Sun, Mercury is a pinhead, Venus and Earth are peppercorns. The largest of the planets, Jupiter, is a pecan just shy of an inch across. These relative sizes are comprehensible: the Sun, Jupiter and Earth are about a factor of ten different from one another in size, but the [distance scale is truly amazing](#). Earth is 26 yards away from the Sun, Jupiter 132 yards (a football field and a third) and Pluto over 1000 yards away. Space is ridiculously large, that's why they call it *space*.

Things spread out from there: [to Proxima Centauri](#), the nearest star, is 4000 miles away in this scale model, some 10,000 times the distance from Pluto to the Sun. And the [Andromeda Galaxy](#), also known as M31 and generally considered the farthest thing visible to most people without optical aid, is roughly a million times farther away than that. It's not hard to imagine all the hundreds of billions of the rest of the galaxies spreading ever more thinly in every direction. A big and lonely Universe.

But our intuition and anthropocentric perspective are deceptive at these scales. Remarkably, it turns out that the distances between galaxies are on average only a few tens of times their diameters. For example, the [Milky Way](#) and Andromeda galaxies each span more or less a few 100,000 light years, yet are only approximately ten to twenty times that distance, 3 million light years apart. After all, we do live in the so-called "[Local Group](#)" and many clusters of galaxies are close enough to be readily visible in amateur telescopes. Numerous examples of interacting galaxies are well known, yet when galaxies collide, their stars don't crash into one another. To put it another way, consider this: it is only about 3000 times the distance between here and M31 to the edge of the Universe, about 13 billion light years away. Think about that on the next clear night as the [Andromeda Galaxy](#) rises overhead.

Paradoxically, it's the small scale, solid matter, that is really empty. More than 99% of an atom's mass is contained in the [protons and neutrons of the nucleus](#), all in a diameter 1/100,000 that of the the atom. Repulsion and bonding of the outer [electron shells](#) provide what we feel as the solid structure of matter. The densest matter found on this planet is in fact mostly nothing at all.

So in reality, as well [as on 1960's television](#), the Universe at large isn't such a lonely place. Hollow at the [subatomic dimensions](#), it's almost [cozy at the largest scales](#): galaxies are as close as farm houses in the countryside. And maybe all those stars and planets do harbor life, our galactic neighbors. Perhaps if we can get the dilithium crystal drive to work, space would become a far more familiar, perhaps even welcoming frontier.

In this essay, we've attempted to "boldly go" [over nearly 41 decades of spatial scales](#), a range of 1:100,000,000,000,000,000,000,000,000,000,000,000,000,000 (1 followed by 41 zeros), from an atomic nucleus (femtometers, 10^{-15} m) to the edges of the known Universe ([some \$10^{26}\$ m away](#)). Our perception of time is similarly human-centered. More on this in a chapter entitled "Calibrations" in Natalie Angier's insightful book, [The Canon, A Whirligig Tour of the Beautiful Basics of Science](#) (2007).

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