First Light
Newsletter of the Alachua Astronomy Club

North Central Florida's
Amateur Astronomy Club
29°39' North, 82°21' West

July / August 2009
Issue 83.1/84.1

Member
Astronomical
League

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Dark-Sky Association

A Sweet Way to Measure the Speed of Light in Your Own Kitchen

By Bill Helms, Alachua Astronomy Club President

The velocity of light in a vacuum is perhaps the most fundamental constant of nature. Space and time vary, according to the relative velocities of observers in different reference frames, but they always observe the same velocity for the speed of light in a vacuum. And remember Einstein's famous equation, E = mc^2. The "c" in the equation is the speed of light in a vacuum. A pantheon of illustrious scientists tackled the problem of determining this value over the years, beginning with Galileo. I'm going to share with you a way you can measure it in your own kitchen.

Galileo's idea to measure the speed of light was to station two men within sight of each other on adjacent mountaintops. The first would unmask a lantern, and when the man on the adjacent peak saw the light, he was to unmask his lantern. The first man would note the time delay between his unmasking his lantern and when he saw the lantern of the second man. The distance to the adjacent peak and back divided by that time would give the velocity of light. This didn't work out very well!

Olaf Roemer, the Danish astronomer, used variations in his observed transits of Jupiter's satellite Io as the Earth and Jupiter's distance varied as they both revolved around the sun in their orbits. He computed a speed of about 130,000 miles per second. This was the first proof that the speed of light was not infinite. The French scientist Armand Fizeau used an apparatus of a light bulb, lenses, mirrors, and a spinning toothed wheel to measure a value of about 195,000 miles per second in 1859. French scientist Leon Foucault refined this apparatus by using a spinning mirror in place of the toothed wheel. Albert Michelson, of the U. S. Navel Academy did later experiments, which refined the value to about 186,000 miles per second. The current recognized official value is 299,792,458 meters per second, or about 186,322 miles per second.

We will calculate the speed of light using our kitchen microwave oven and two chocolate bars. Microwaves are electromagnetic waves, no different than radio waves, infrared waves, visible light waves, x-rays and gamma rays, except in frequency, or wavelength, or energy. Microwaves are used in radar sets (the first microwave ovens were called Radar Ranges.), and in telephone transmission. Microwave ovens work by causing water molecules to jiggle. That jiggling is what we call heat. Hot things are hot because their molecules are moving fast, either jiggling back and forth (for solids) or zooming around fast and bumping into each

Continued on page 2

Continued from page 1

other (for liquids and gases). The electric charges of water molecules are not uniformly distributed. They are slightly positive at one end and negative at the other. A changing electromagnetic field can cause them to move. Our microwave oven provides this changing electromagnetic field. Water molecules respond best to fields that change 2.45 billion (2,450,000,000) times a second. So microwave ovens are designed to generate electromagnetic waves that change from positive to negative and back again just that fast. There is a good animation of this at this website:

http://orbitingfrog.com/blog/2008/05/13/measure-the-speed-of-light-using-your-microwave/

The metal walls of the oven reflect the waves and cause standing waves that seem not to move from place to place, but appear to stand in place. See the website animation. The wave actually does travel back and forth, but the maxima and minima of the electric field strength always occur in the same place, and when we visualize that, it looks like a wave that is standing still.

The areas where the wave goes from maximum deflection to minimum, and back again, are the areas where the water molecules in food will be jiggled, or heated, the most, and the null areas between will receive minimum heating. The areas with maximum heating will begin to melt first, and we can see them and mark their location. Then we can use the formula, speed equals distance traveled divided by the time of travel, s = d/t. For waves, the speed is the speed of propagation of the wave. The distance is the wavelength of the wave (length of the full waveform, null to maximum to null to minimum and back to null). The time is the inverse of frequency. If a wave has a frequency of 100 cycles per second, it completes one cycle in 1/100 of a second. For a wave, speed equals wavelength divided by the inverse of frequency, or wavelength multiplied by frequency. So our formula is speed of the wave equals the wavelength times the frequency. We know the frequency, since we know what frequency jiggles water molecules the best, and microwave ovens are built to generate that frequency, 2,450,000,000 cycles per second. We will look for and mark the areas on the chocolate bars that first begin to melt, since these will denote the areas of maximum jiggle, a half-wavelength apart. Mark and measure this distance, multiply by two to get the full wavelength, then multiply that (using the right units) by 2.45 billion cycles per second to get the speed of light in either meters per second or miles per second.

I bought two 7 ounce “Giant” chocolate bars at the grocery store, and put them into the microwave oven long sides adjacent, and smooth side up. I rested them on a paper towel to avoid a potential mess. (If your oven has a carousel, remove it. It’s designed to minimize the hot spots by rotating the food.) I then ran the oven for 22 seconds at a time, and quickly inspected the upper surfaces of the chocolate bars for evidence of melting. After somewhere between one and two minutes, I noticed several oval dimpled areas, giving evidence of local heating. I carefully marked an X in the middle of each with the tip of a knife. I then measured the distance between adjacent marks. They averaged about 66 millimeters, or 0.066 meter. Double that to 0.132 meters for the full wavelength. Then multiply by the frequency, 2,450,000,000 cycles per second. The result is a measurement of 323,000,000 meters per second for the speed of light (about 200,000 miles per second). Dividing that by the accepted value of 299,792,458 meters per second yields an error of eight percent high. Not too shabby. I would consider any error less than fifteen percent quite good, considering the difficulty in accurately determining the center of the melted spots.

Having successfully determined the speed of light, we can sit back, relax, reflect on our cosmic connection with Galileo, Roemer, Fizeau, Foucault, Michelson, and Einstein, and enjoy \ disposing of our experimental supplies. Sweet!

Bill Helms
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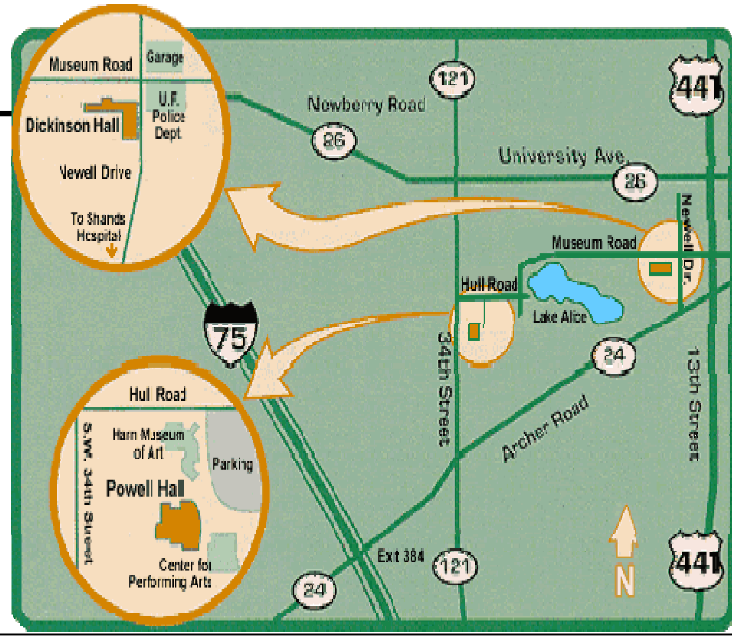
AAC Meeting Location - AAC regular meetings are held on the second Tuesday of each month **at 7:00 p.m.** at the Florida Museum of Natural History, **Powell Hall**, in the Lucille T. Maloney Classroom, on UF campus, unless otherwise announced. All meetings are free and open to the public. Join us for some great discussions and stargazing afterwards. Please visit our website for more information (floridastars.org). There is no monthly meeting in December.



Submitting Articles to FirstLight

The AAC encourages readers to submit articles and letters for inclusion in *FirstLight*. The AAC reserves the right review and edit all articles and letters before publication. Send all materials directly to the *FirstLight* Editor.

Materials must reach the *FirstLight* Editor at least 30 days prior to the publication date.

Submission of articles are accepted **by e-mail or on a CD**. Submit as either a plain text or Microsoft Word file. (In addition, you can also send a copy as a pdf file but you also need to send your text or Word file too.) Send pictures, figures or diagrams as separate gif or jpg file.

Mailing Address for Hard Copies or CDs

Note: Since our mailbox is *not* checked daily, mail materials well before the deadline date. (Hence, submission by e-mail is much preferred!)

c/o FirstLight Editor
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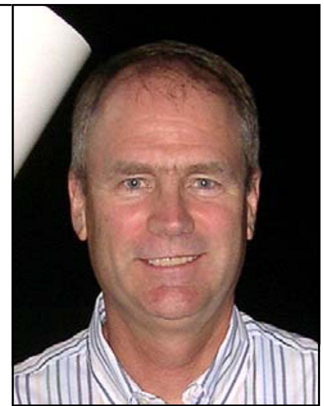
By E-Mail; Send e-mail with your attached files to **FirstLight@floridastars.org**.

July Club Meeting


Dr. Howard Eskildsen

Tuesday, July 14 2009, 7:00 p.m. ET

Speakers: **Dr. Howard Eskildsen**

Title: ***Solar Minimum to the Max***

Location: Powell Hall, Florida Museum of Natural History (*Lucille T. Maloney Classroom*) UF Campus, Gainesville, Florida

Preview: What's with the sun these days? It is common knowledge that sunspots vary in number over a cycle of about 11.1 years. The last solar minimum occurred in mid 1996, so the next solar minimum should have occurred in 2007; only it didn't. In fact the first cycle 24 (new cycle) spot did not appear until January of last year, and 2008 had the lowest sunspot count since 1913. This year is starting off even slower, and some of the old cycle 23 spots still occasionally surface. Carrington rotation 2081, which began in March, had no NOAA numbered spots at all and the Wolf number was zero every day except one during the whole rotation. Are sunspots about to disappear, as some have recently speculated, or are we headed for another Maunder Minimum?

But wait a minute; what's the difference between a cycle 23 and a cycle 24 sunspot? What is a Maunder Minimum, a Carrington rotation or a Wolf number? For that matter what is a sunspot and how does the sun conjure them? What does it all mean or even matter? For answers to this, and even more questions than sane people would care to know about the Sun, attend *Solar Minimum to the Max*. If there is something about the sun that Howard can not explain, before he is done he will make sure that you are just as confused as he is about it.

About the Speaker: AAC member Howard Eskildsen has been interested in the stars, Sun and Moon since childhood. In grade school he learned the stars from star charts in a book and spent hours looking at the sky and watching for meteors. His first telescopic views came from his high school's sadly abused Dynascope, that he restored to working condition. Later he made a 6" reflector and placed it on a pipe fitting mount, per designs by Sam Brown, and used it for observing when time permitted.

In the years that followed, he attended medical school and raised a family, which left little time for stargazing. Finally, after a quarter of a century hiatus, he returned to regular observing in 2002 when his wife, Fairy, purchased him a Meade ETX-125. Since then he has observed the Sun and Moon regularly and anything else in the sky when time permits. He has sent nearly 2,000 observations to the ALPO Solar Section and has written a piece on solar photography for their website. He also provided photos and material for Jamey L. Jenkin's recently released book, *The Sun and How to Observe It*.

Howard also observes the moon and has submitted several hundred lunar photos to the ALPO Lunar Section. He has also written articles for The Strolling Astronomer, Selenology, and The Lunar Observer. In February of this year he presented *Hooked on the Moon, a Lighthearted Look at the Joys of Lunar Observing* at the Winter Star Party. His photos have appeared on spaceweather.com, LPOD, Astronomy Magazine's Photo of the Day and other web sites.

He enjoys looking at the sky and sharing it with others, and especially appreciates the association with other members of the AAC. He hopes that those attending the presentation will find it interesting and informative. Above all he hopes that the attendees will have some fun during the presentation, because he is certainly going to.

Star Party Recap

Unfortunately, there will not be much to recap for star parties on this edition of FirstLight. The Duval party in Chiefland on May 23 was canceled due to poor weather conditions. On June 20, Bob Jacobs hosted AAC for a star party. Though stars could be seen, the "viewing was abysmal". Bob had graciously invited us back for a rain date viewing the following week. The success of this party is unknown at the time of writing.

We will not be having a July star party. Our next party will be hosted by the Loftus residence on August 22. As always, this will be weather pending.

Hopefully, you all have had opportunities around star party dates for some individual observing during our hurricane season.

Hey, at least we've got good beaches.

Thomas Hettinger
Assistant Star Party Coordinator, Alachua Astronomy Club

Book For Gold Head State Park Star Party Now!

Just a friendly reminder, now would be a good time to book your site for the Gold Head State Park star party, October 16 and 17.

As of right now, there are plenty of sites left but all it takes is 1 or 2 large groups to fill it. Last year, the cabins were already booked by this time. Don't delay! Follow the link below to see all the details of this star party. Please read thoroughly since I like to make changes… http://floridastars.org/goldhead.2009.html

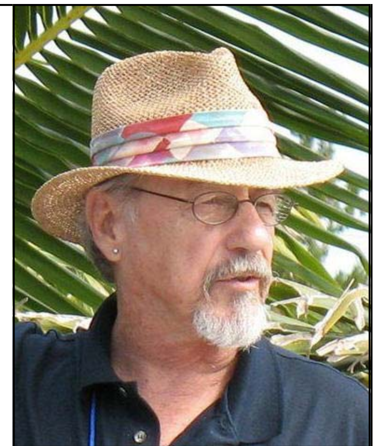
Mike Toomey

***Mike Toomey** has served the AAC in many capacities since 1998, including President, Secretary, FirstLight editor and Star Party Coordinator. He won the AAC's Service Award in 2000. Mike resides in Gainesville with his wife Heidi.*

STAR PARTY / OBSERVATION SCHEDULE: Upcoming Events - 2009

Star Party Event	**Date**	**Location** Check the website for directions and map	**Start/End Time**
AAC July Star Party	NA	No Star Party in July	
AAC August Star Party	August 22nd Saturday	Loftus Family Farm	Sunset approx. 8:20 pm EDT
AAC September Star Party	September 20th, Saturday	Stargate Observatory	Sunset approx. 7:25 pm EDT
Museum Night	Saturday, September 26th	Starry Night at the Florida Museum of Natural History	Sunset approx. 7:25 pm EDT

August Club Meeting



Mr. Tippy D’Auria

Tuesday, August 11 2009, 7:00 p.m. ET

Speaker: **Tippy D’Auria**

Email: mdauria-r@retiree.mdc.edu

Title: *Volcano Suite*

Location: Powell Hall, Florida Museum of Natural History
Lucille T. Maloney Classroom,
UF Campus, Gainesville, Florida

Preview: Go on a fantastic journey, to faraway places, and gather data on erupting volcanoes. Can the moon influence volcanic eruptions? Can eruptions be predicted? Do volcanic eruptions contribute to global warming? Follow the team of "Volcano Watch International" on their quest to answer some of these questions. See and hear the dangers, and life and death struggles of flora and fauna caused by erupting volcanoes. The life, death and rebirth are amazing. Join world renowned astronomer and volcano expert Tippy D'Auria as he leads us on this exciting adventure and spectacular presentation of sight and sound. Experience "Volcano Suite"!

About the Speaker: Tippy D'Auria is a retired Electronics Engineer and has a degree in Electronics Engineering Technology, and a degree in Computer Integrated Manufacturing. He has been an active astronomer since 1980. He is currently a member of the Southern Cross Astronomical Society and has served as a member of the Societies Board of Fellows and was a Vice President of that Society for many years as well. Tippy is also a member of the Local Group of Deep Sky Observers, the Institute for Planetary Research Observatories (IPRO), Association of Lunar and Planetary Observers (ALPO), The Alachua Astronomy Club and the Astronomical League. He is also a founding board member of Astronomy Outreach Network and an advisor for the Meade 4M Community.

Tippy is the founder of the Winter Star Party which is sponsored by the Southern Cross Astronomical Society and has been the Chairman of that Star Party for thirteen of its twenty five years. Tippy D'Auria is an international lecturer and has lectured on Astronomy at many Universities and Astronomy Clubs. He has been a guest speaker at the Winter Star Party on eighteen different occasions and has also been a guest speaker at events such as the Texas Star Party, Mt. Kobau Star Party, Southern Star Conference, Hidden Hollow Astronomy Convention, Peach State Star Gaze, Starfest Convention, Highlands Star Gaze, Nebraska Star Party, Chiefland Star Party, the 4th Annual Congress of Central American Astronomers and many Astronomy Day Conferences.

In 1987 and 1988 he was awarded the Southern Cross Astronomical Societies "Joe T. Doris Service Award for Outstanding Contributions". In 1992 he was honored with a Lifetime Membership to the Southern Cross Astronomical Society for Meritorious Service to that Society. In 2001, Tippy received recognition for his contributions to amateur astronomy, as he was honored by the International Astronomical Union, when an asteroid was given the name "11378 DAuria". He received the 2007 Astronomical League Award for his many contributions to the astronomical community and in 2008 he received the Astronomy Outreach Award in recognition for his contributions for public outreach and education.

In April of 2001, Tippy led an expedition to the Volcanoes of Costa Rica, to film a National Geographic documentary called "The Volcano Hunters". In June of 2001, Tippy joined an elite group of some of the world's best planetary astronomers on a mission to record a predicted flash on the red planet...flashes that may be reflections from ice or other highly reflective land features on Mars in a region called Edom. This is the only existing video sequence of this event which made the IAU circulars and headlines throughout the global astronomy community. He is also the author of numerous articles and papers and co-authored, along with Vic Menard, the definitive book on telescope collimation, "Perspectives on Collimation - Principles and Procedures".

Tippy is also an amateur telescope maker who has several instruments of 2, 4.5, 6, 10, 12, 14, and 18 inch aperture. His main astronomical interests are astrophotography, deep sky observing and solar system observing.

He is also a volcano hunter, and enjoys exploring and photographing active volcanoes, and is a member of the International Volcano Watch team.

Astronomy From Å to ZZ — Howard L. Cohen

A Column for the Beginning Stargazer Introducing New Astronomical Terms

Astronomy is rich with terminology. This column originally began about ten years ago (January 1999). Its intent was to help beginning stargazers ease into the world of astronomy by introducing a new basic astronomical term (word, acronym or abbreviation) each month.

The name of this column, **Å to ZZ**, starts not with the letter A but with **Å**, the symbol for ångström (after Anders J. Ångström), a very small unit of length (0.1 nano meters or 10^{-10} m). Although originally monthly, this feature now appears irregularly. An index of terms that have appeared through 2008 appears in the 2008 Nov/Dec issue of *FirstLight*.

"Astronomy from Å to ZZ" originally started with the letter ***a*** and is alpha-betical using successive letters for each column's entry. The Nov/Dec 2008 column ended with ***n*** (for ***NGC***), just over half way through a second cycle of twenty-six terms. Therefore, our next entry starts with the letter ***o***.

A good choice for this letter is the term ***orbital elements***, a set of numbers describing the unique character of an orbit and its orientation in space. These parameters can be sometimes difficult to explain or understand. However, astronomers use them to predict where observers can see objects on the sky.

Mastering orbital elements can be challenging. Nevertheless, by digesting their meanings, one can better visualize orbit motions and use these elements in software programs to compute where to observe celestial objects.

WORD OF THE MONTH FOR JULY / AUGUST 2009

orbital elements A set of parameters that collectively define the shape, size, orientation in space and timing of a body's orbital motion.

Similar elements are also used to describe planetary and asteroid orbits. With some modification these numbers can also describe satellite orbits and even double star orbits.

Orbital elements typically include at least six numbers (sometimes seven). Five belong to the orbit itself. The remaining numbers pertain to the object's location in its orbit, parameters needed to determine where the planet will be (or was) on any desired date:

Two describe the orbit itself (size and shape).
Three (all angles) describe the orbit's orientation in space.
One (or two) are time elements and describe a position of the object in its orbit.

Various parameters have been historically used to define orbital elements. Here we briefly give common descriptions and some traditional abbreviations but other numerical quantities can substitute for those given here. The following table describes these parameters. Comments about the orbital elements follow Table 1.

Study Figures 1, 2 and 3 along with text for clearer visualization of orbital elements (see pages 10 and 11) **.**

Table 1. The Orbital Elements

ORBITAL ELEMENT	*SYMBOL*	*DEFINES*
Size and Shape of Orbit		
Semimajor Axis	***a***	Size of circular or elliptical
or, if orbit not elliptical		
Periapsis Distance	***q***	“Size” of parabolic or hyperbolic orbits
Eccentricity	***e***	Distance of foci from center for elliptical orbits
Orientation of Orbit in Space		
Inclination	***i***	Angle between orbital plane & a reference plane
Longitude of Ascending Node	$\boldsymbol{\Omega}$	Direction in space of orbit’s line of nodes
Argument of Periapsis	$\boldsymbol{\omega}$	Orientation of orbit relative to a reference plane
or use instead		
Longitude of Periapsis	$\boldsymbol{\varpi}$	Same orientation as $\boldsymbol{\omega}$ where $\boldsymbol{\varpi} = \boldsymbol{\Omega} + \boldsymbol{\omega}$
Position of Object in Orbit		
Time of Periapsis Passage	***T***	When object at specific position in orbit
Orbit Period	***P***	Time to finish one revolution in elliptical orbits

Comments

1. Parabolic and hyperbolic orbits are open curves so size indeterminate (see Figure 1). Therefore, ***q*** used instead of ***a***. However, ***q*** can also be use for all orbits.
2. *Semimajor axis* of ellipse (***a***) also called “mean distance” (see Figure 2). (The semimajor axis not actually the “average distance” but used for convenience.)
3. *Periapsis* refers to point in orbit closest to attracting object (e.g., Sun).
4. *Eccentricity* describes distance of Sun from center of elliptical orbits. For circle, e = 0, a special case of ellipse (e < 1). For a parabola, e =1 and, for hyperbola, e >1.
5. *Line of nodes* is intersection of reference and orbit planes (see Figure 3).
6. *Ascending node* is point in body’s orbit where plane of its orbit intersects a reference. plane (as the *ecliptic*) where object moves from South to North (see Figure 3).
7. The *node angle* (***Ù***) is measured in reference plane from a reference direction to ascending node (see Figure 3).
8. Both ***Ù*** and ***ù*** (including $\boldsymbol{\varpi}$) measured in direction of object’s motion. (Use care to distinguish *argument of periapsis*, $\boldsymbol{\omega}$ from *longitude of periapsis*, .)
9. *Time of periapsis passage* (***T***) defines position of the body in its orbit for some defined *epoch* (a specified date and time). Other parameters sometimes used such as the object’s longitude (***L***), mean (***M***), true (ν) or eccentric (***E***) anomalies at some epoch. (An anomaly angle describes body’s position in its orbit from some reference point.)
10. *Orbit period* (***P***) defines time for body to complete one revolution in closed orbits. Also sometimes omitted for circular or elliptical orbits since we can often compute the orbit period from *Kepler’s Third Law of Motion*.
11. *Kepler’s Third Law of Motion* (“Harmonic Law”), published by Johannes Kepler in 1619, relates the period of an orbiting body to its mean distance from the Sun. Namely, the square of the orbital period is proportional to the cube of the mean distance. This can be written mathematically as $\boldsymbol{P^2 = a^3}$ where P is in years and a is in astronomical units (AUs) where Earth’s mean distance from Sun is one AU.

For Objects Orbiting Sun

1. Both a and q usually measured in AUs (astronomical units).
2. Sun is at one focus of the conic section as in the ellipse (see Figures 2 and 3).

3. Periapsis called *perihelion* (*peri-* for closest + *-helion* for Sun).
4. Reference plane is the *ecliptic plane* (mean plane of Earth's orbit).
5. *Line of nodes* is intersection of ecliptic and orbit planes.
6. Reference direction for line of nodes is direction of *vernal equinox point* (♈).
7. *Vernal equinox* is the intersection of ecliptic plane and celestial equator where Sun crosses from South to North on its apparent annual journey around sky (about March 21).

Thus, from orbital elements we can calculate the position of a body in its orbit (called the *true anomaly* or ν) for any desired date and time. This is the angle in the orbit from the periapsis point to the object itself measured in the direction of motion (see Figure 3).

Viewing the orbit diagrams in Figures 1–3 will help one understand the orbital elements. Table 2 gives some example orbital elements. Can you visualize their orbits?

Table 2. Approximate Mean Orbital Elements for Some Example Objects

Object	***a*** *(or* ***q****)*	***e***	***i***	***Ω***	***ω***	***T***	***P***
Earth	1.00 AU[a]	0.017	0.0°	348.7°	114.2°	2009 Jan 4	1.00 yrs
Venus	0.72 AU	0.007	3.4°	76.7°	54.9°	1998 Sep 7	0.62 yrs
Jupiter	5.20 AU	0.049	1.3°	100.5°	275.1°	1987 Jul 10	11.86 yrs
Pluto	39.48 AU	0.249	17.1°	110.3°	113.8°	1989 Sep 5	248.1 yrs
Comet Halley	17.8 AU	0.967	162.3°[d]	58.9°	111.9°	1986 Jul 28	75.3 yrs
Comet Hale-Bopp	186 AU	0.995	89.4°	282.5°	130.6°	1997 Apr 1	2,553 yrs
Comet Lulin	1.21 AU[b]	1.000[c]	178.4°[d]	338.5°	136.9°	2009 Jan 11	—
Asteroid 1 Ceres	2.77 AU	0.080	10.6°	80.4°	73.2°	1998 Oct 14	4.60 yrs

[a] The *mean distance* (***a***) is usually given in *astronomical units* (AU), the Earth's mean distance from the Sun (about 93 million miles or 150 million kilometers).
[b] For Comet Lulin, the perihelion distance (***q***) is given since orbit is nearly parabolic (see note c below). It also travels nearly along the ecliptic since orbit is tilted only 1.6° (180.0° - 178.4°), but *backwards* (i > 90°)! See comments at end about Comet Lulin, the first bright comet of 2009.
[c] Comet Lulin's eccentricity is very nearly one (***e*** = 0.999982 for the epoch 2009 Jan 9.0).
[d] An *inclination* greater than 90° indicates a *retrograde* orbit—orbital motion appears clockwise as seen from the north side of Earth's orbit.

Finally, the orbits described by these elements are idealistic, a consequence of two isolated bodies each gravitationally acting alone on its companion. However, in reality gravitational *perturbations* (disturbances) by other bodies can sometimes alter the orbits over time. Therefore, designating elements for a specific date is a common practice (called *osculating elements*) as opposed to the *mean elements* of a reference orbit that approximates the actual, perturbed orbit.

An interesting example is Comet Hale-Bopp (C/1995 O1), which had an orbit period of about 4,200 years until this comet passed close to Jupiter in 1996. This encounter shortened the comet's period to about 2,553 years!

Note: The *Observer's Handbook 2009* of the Royal Astronomical Society of Canada gives osculating orbital elements on page 23 for solar system planets and some bright asteroids.

One can obtain many other orbit predictions (*ephemerides*) and orbital elements from sites as the Harvard-Smithsonian Center for Astrophysics at **www.cfa.harvard.edu/iau/Ephemerides**. Here one can also download or copy orbital elements for comets from their web page to use in popular software programs such as SkyMap, TheSky, Starry Night, SkyTools, Voyager II, Deep Space, AutoStar, and more. See **www.cfa.harvard.edu/iau/Ephemerides/Comets/SoftwareComets.html**.

Every year comets come into view. Some have never been seen before. Others have returned one or more times. This coming year will be no different. **In fact, a new comet, discovered in 2007, has been brightening to naked eye visibility.** This object, Comet Lulin (C/2007 N3), moves from *Leo* into *Cancer* during early March. (Elements in Table 2.)

Comet Lulin reached *perigee* (closest to Earth) February 24, 2009 at a distance of 0.41 AUs. Read more about this new comet at *Sky & Telescope's* web site ("Catch Winter's Comet Lulin") at **www.skyandtelescope.com/observing/highlights/35992534.html**. Also see "Green Comet Approaches Earth" from Science@NASA at **science.nasa.gov/headlines/y2009/04feb_greencomet.htm?list94708**.

Understanding orbital elements can help us better appreciate Comet Lulin and others that grace our skies.

¤

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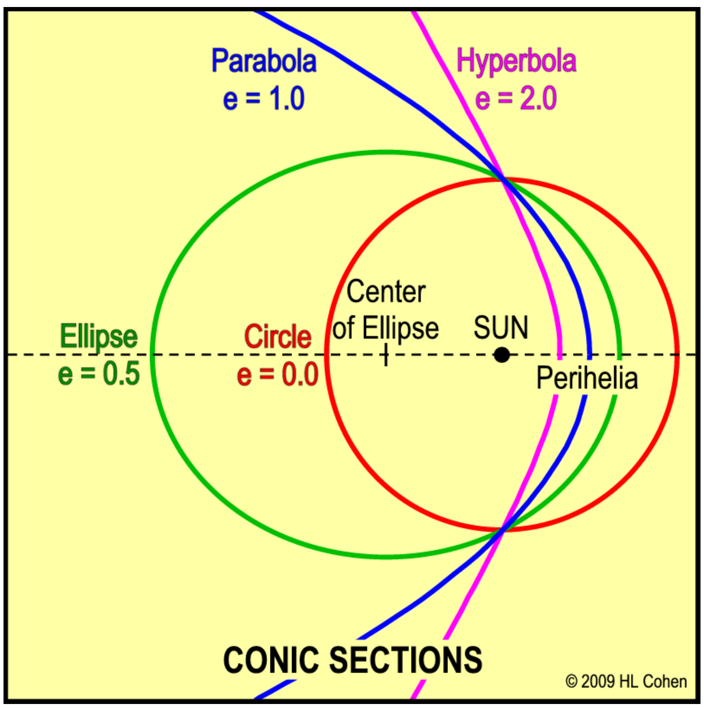
Reference Figures for Orbital Elements

Figure 1. The Conic Sections. These orbits are called conic sections. Circles and ellipses are closed curves while parabolas and hyperbolas are open-ended curves. For circles e = 0 and for ellipses, 0 < e <1. Parabolas have e = 1 and hyperbolas e > 1. The center of attraction in this figure is the Sun so the *perihelia (sing. perihelion) are* the closest points to the Sun.



Reference Figures for Orbital Elements (continued)

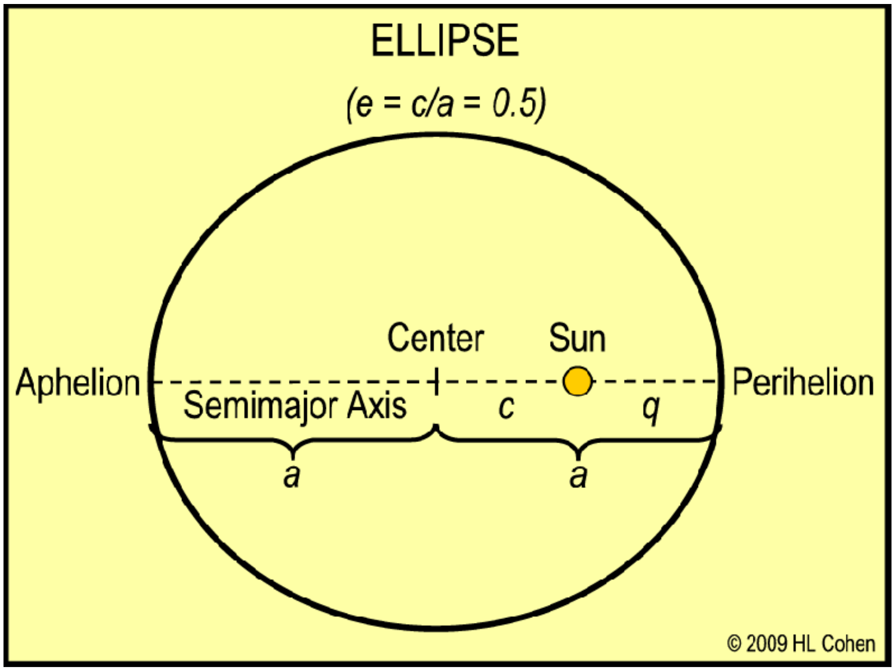
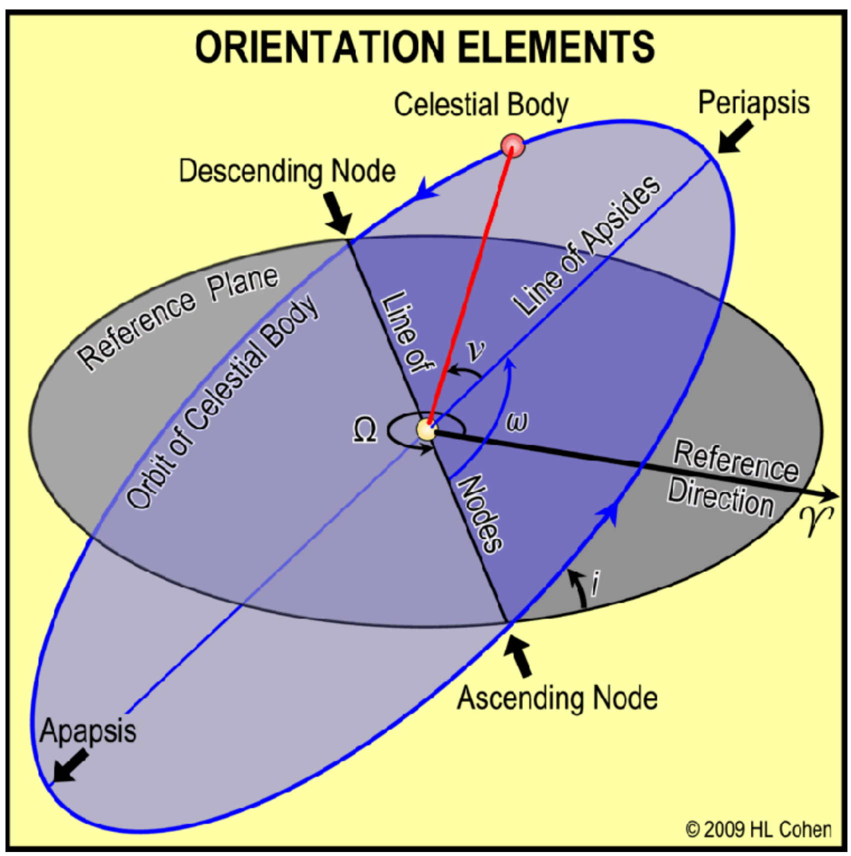


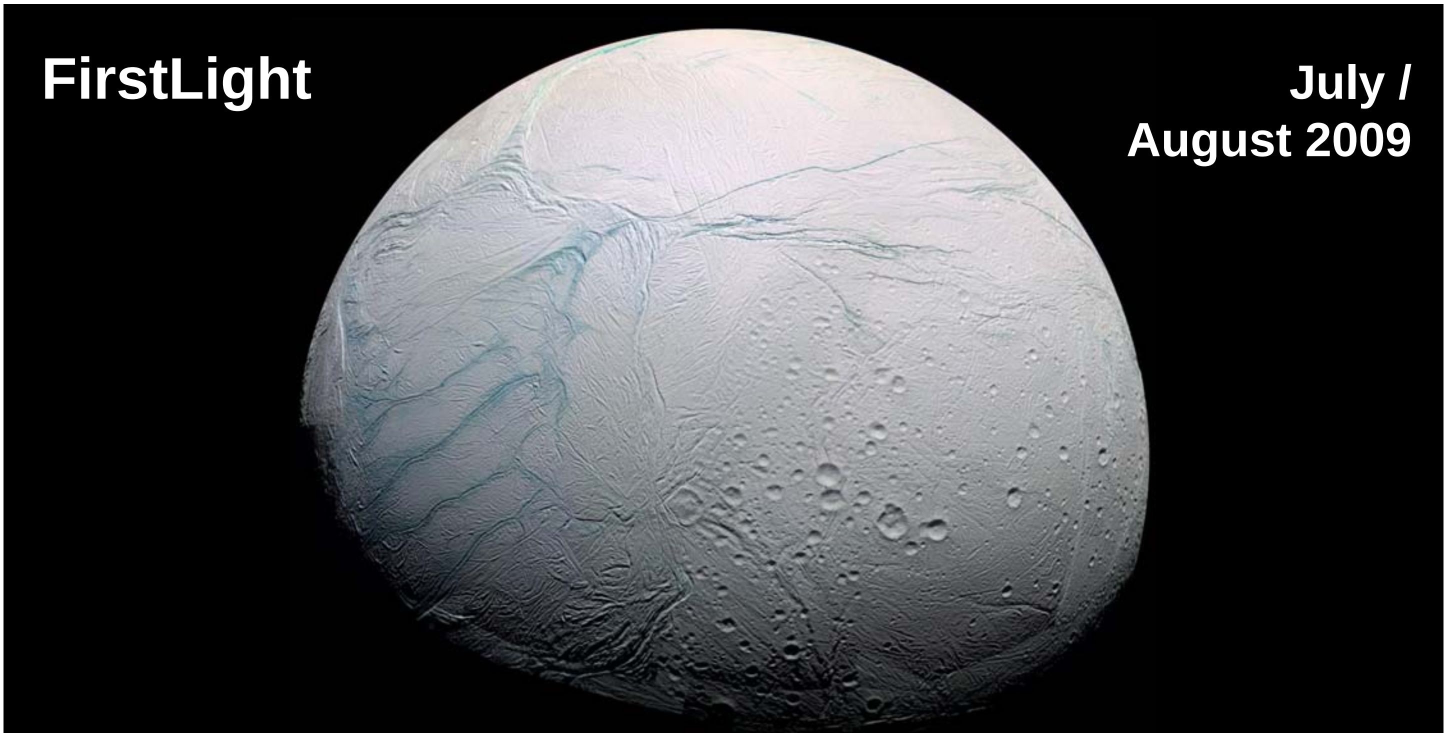
Figure 2. An Elliptical Orbit. This ellipse is drawn for e = 0.5 with the Sun at one focus of the ellipse. Note that the Sun is not at the center of the ellipse. The size of the ellipse is the *semimajor axis*, ***a***, also called the *mean distance* from the Sun. The closest point on the orbit to the Sun is the *perihelion distance*, ***q***. The shape of the ellipse is given by the eccentricity, ***e***. The Sun's distance from the center, ***c***, is given by $c = ae$. Both a and e are the first two orbital elements and describe the size and form of the orbit itself.

Figure 3. The Orientation Elements. These elements show the orbit's orientation in space. The *line of nodes* is the intersection of the object's orbit and a reference plane such as the *ecliptic*. The *inclination*, ***i***, gives the orbit's tilt from the reference plane. The *longitude of the ascending note*, **Ω**, shows which way the orbit faces. This parameter is measured from a reference direction such as the *vernal equinox*, ♈, to the ascending node. The *argument of periapsis*, **ω**, shows the position of the *periapsis* point of the orbit measured from the *ascending node*. Often the *longitude of periapsis*, **ϖ**, substitutes for **ω** where $\varpi = \Omega + \omega$. The *mean anomaly*, ν, shows the object's location in its orbit relative to the *periapsis point*.



FirstLight

July / August 2009



Fresh Tiger Stripes on Saturn's Enceladus **Credit:** Cassini Imaging Team, SSI, JPL, ESA, NASA
Explanation: Do underground oceans vent through the tiger stripes on Saturn's moon Enceladus? Long features dubbed tiger stripes are known to be spewing ice from the moon's icy interior into space, creating a cloud of fine ice particles over the moon's South Pole and creating Saturn's mysterious E-ring. Evidence for this has come from the robot Cassini spacecraft now orbiting Saturn. Pictured above, a high resolution image of Enceladus is shown from a close flyby. The unusual surface features dubbed tiger stripes are visible in false-color blue. Most recently, an analysis of dust captured by Cassini found evidence for sodium as expected in a deep salty ocean. Conversely however, recent Earth-based observations of ice ejected by Enceladus into Saturn's E-Ring showed no evidence of the expected sodium. Such research is particularly interesting since such an ocean would be a candidate to contain life.

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