News from the Society for Astronomical Sciences

Vol. 15 No.2 (April, 2017)

June 2017 Symposium of the Society for Astronomical Sciences, and AAVSO Spring Meeting

You are invited to participate in the premier annual conference devoted to small-telescope astronomical science. This year's gathering will be a joint meeting, combining the SAS Symposium with the AAVSO Spring meeting. There will be Workshops on topics of interest to the small-telescope research community, Technical Papers on research results and project plans, our Sponsors will have new products on display, and participants will be treated to other special features.

The SAS Symposium brings together amateur astronomers who are engaged in scientific research, professional astronomers, and students for in-depth discussions of small-telescope research activities. It is an excellent venue for highlighting results, discussing targets of observational campaigns, developing collaborations, and bringing together the community of practice to share expertise and experience. You do not need be an expert to benefit from participating in the Symposium: both the SAS and the AAVSO strive provide a mentoring environment where all interested people will learn how you can contribute to astronomical science.

Date & Location: The 2017 SAS Symposium + AAVSO Spring Meeting will be held on Thursday-Friday-Saturday, June 15-16-17, 2017 at the Ontario Airport Hotel & Conference Center, Ontario California.

AAVSO Council Meeting will be held on Wednesday and Thursday, June 14-15 at the same venue.

Workshops: Two Educational Workshops will be held on Thursday (June 15). The morning session will be **NASA Needs You! How You Can Help the NASA Kepler and TESS Missions Discover Exoplanets**, presented by Dr Jessie Christiansen. Dr Christiansen is a staff scientist at the NASA Exoplanet Science Institute in the California Institute of Technology. She searches for, studies, and catalogues extrasolar planets – planets orbiting other stars. Her main research focuses on using the thousands of exoplanets found by the NASA Kepler mission to determine how common planets similar to the Earth might be throughout the galaxy.

The afternoon session will be devoted to **Advanced Asteroid Lightcurve Projects**, presented by Brian Warner and Bob Stephens. We'll learn about the importance and challenges of going beyond rotational-lightcurve measurements on asteroids: determining phase curves, shape modelling, sidereal rotation rates, prograde-vs.-retrograde rotation, and detection of non-gravitational torques.

Technical Presentations: Friday and Saturday (June 16-17) will be the Technical Sessions, including both presentations and poster papers. These will span the wide range of topics of interest to the small-telescope research community: solar-system objects, variable-stars, and binary stars; instrumentation for photometry, astrometry and spectroscopy; and related subjects.

Sponsors: SAS Sponsors – developers, suppliers, and retailers of astronomical equipment – will be on hand with displays of their featured products.

Special Features: Our traditional "Evening with the Pro's" will be held on Thursday evening. Our speakers will be Dr. Lance Benner (radar observation of asteroids), and Dr. Joe Patterson (Cataclysmic Variable OV Boo).

Friday evening we will have a special presentation and discussion about the AAVSO-Net. The session will be led by Richard Berry, and will include discussion of how this unique capability can be exploited for variable-star research.

On Saturday morning, we will host the AAVSO Membership meeting.

On Saturday evening, we will have our traditional closing Banquet, featuring a special keynote speaker. Non-astronomer guests are welcome at the banquet, and we strive to have a key-note topic that will be interesting and entertaining for all.

Schedule of Activities

To assist you in planning your travel, here is the "big picture" of the agenda for the joint meeting (SAS Symposium and AAVSO Spring Meeting):

Registration:

On-line Registration is now "live". You can use the link on the SAS website (www.SocAstroSci.org), or go directly to the Registration page at

www.socastrosci.org/StartRegistration.php

You can renew your SAS membership, register for the Symposium, register for the Workshops, and select your menu for the Banquet.

AAVSO members note: For this joint meeting, all AAVSO members receive the "member rate" pricing when you Register.

Hotel Reservations: In addition to Registering for the Symposium, you will need to make travel and lodging arrangements. Our group rate at the Conference hotel is $95/night (plus taxes at 13.95%). You can book at the SAS rate at the website:

http://bookings.ihotelier.com/bookings.jsp?groupID=1754297&hotelID=95765

The hotel has a free shuttle to and from the Ontario CA airport.

Day	slot	Main Conference Room	Sponsor-Vendor room	Breakout Room
Wednesday	all day			AAVSO Council Meeting (all day)
Thursday	morning	Amateur contributions for Kepler & TESS (Christiansen)	Available for set-up Displays + coffee service (all day) (4:30 – 6:30 PM) cocktail hour cash bar	AAVSO Council Meeting (all day)
	lunch			
	afternoon	Advanced Asteroid Lightcurve Projects (Warner, Stephens)		
	evening	"Evening with the Pro's"		
Friday	morning	Technical Paper Presentations	Displays + coffee service (all day) + Posters (4:30 – 6:30 PM) cocktail hour cash bar	
	lunch	Topical discussion: photometry		
	afternoon	Technical Paper Presentations + Sponsor Infomercials		
	evening	AAVSOnet (Richard Berry)		
Saturday	morning	8-9:30 = AAVSO Membership meeting 9:45 = Technical Paper Presentations	Displays + coffee service (all day) + Posters	
	lunch	Topical discussion: spectroscopy		Education & Student Research discussion group
	afternoon	Technical Paper Presentations	tear-down & vacate	
	evening	Banquet		

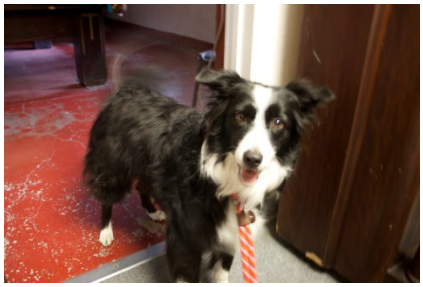
Presenters: Submission of Papers

Presenters are reminded that your paper to be included in the Proceedings is due on April 26, 2017. Papers should be in MS Word (preferred) or plain text, with figures embedded (preferred) or submitted as separate files.

Please submit your paper by e-mail to Bob Buchheim (editor), at Bob@RKBuchheim.org, with a cc to program@SocAstroSci.org.

If you have trouble with the SAS format template, or need other special consideration, contact Bob Buchheim.

Poster Papers are welcomed at the Symposium, and do not need to be pre-reviewed: just bring your poster to the Symposium. Posters can be included in the Symposium Proceedings book, if you provide a formatted version or abstract to Bob@RKBuchheim.org by the Proceedings deadline of April 26.



Reminders to the SAS Membership ...

Membership Renewal: Even if you can't attend the annual Symposium, we value your support of the Society for Astronomical Sciences, and your interest in small-telescope science.

As an SAS member, you will receive a bound copy of the Proceedings even if you cannot come ot the Symposium.

Symposium Proceedings: Published proceedings from all recent Symposia are freely available in PDF format at the PUBLICATIONS tab of the SAS website (www.SocAstroSci.org).

Symposium Videos: If you missed a recent Symposium, you can still watch many of the presentation videos on the SAS website at the PUBLICATIONS tab.

Workshop Videos: Video recordings of most of the Workshops from recent years are available from SAS. If you were registered for the Workshop, then the recording is free. If you were not a registered attendee, then the price is $25 per workshop. Contact Bob Buchheim (*Bob@RKBuchheim.org*) for the details.

Contact Information: If you haven't been receiving e-mail messages about the Newsletter or the SAS Symposium, perhaps it's because you've changed your e-mail address. You can update your contact information on the MEMBERSHIP INFORMATION tab of the SAS website. SAS never sells or shares your name or contact information without your explicit permission.

Keeping in Touch: The SAS Yahoo group ("SocAstroSci") is a good way to keep in touch with the members and participants.

Kudos or Criticisms? We are looking forward to seeing you at SAS-2017! If you have any questions or ideas for the Symposium, or comments related to the 2016 Symposium, please share them with the Program Committee at program@SocAstroSci.org.

We will appreciate your input about the technical sessions, the workshops, the hotel, the banquet, the lunchtime discussions, and anything else that might help us improve the future SAS Symposia.

Also of Interest

In addition to the SAS-2017 Symposium and AAVSO Spring Meeting, there are two Conferences planned for the southern California area that may be of interest to the SAS community:

Remote Telescopes, Student Research, and Education will be held June 19-22, 2017 in San Diego, CA. The conference will focus on the use of remotely-located, relatively small, optical robotic telescopes to drive research by high school and undergraduate students, while also addressing educational outcomes. The three domains of science, technical engineering, and education will be threaded in a complimentary way throughout.

Many of the pioneers and luminaries from the early era of robotic and remote telescopes will be attending this conference to provide their historical outlines and perspectives. Through a variety of presentations, discussion panels and forums, the challenges and pathways for the future will be described and potential solutions outlined.

For more information, see the Conference website at www.rtsre.org.

Fifth International Conference on Binary and Multiple Stars will be held in Irvine, CA on August 4-6, 2017. All types of binary and multiple stars will be covered, including visual binaries, eclipsing binaries, spectroscopic binaries, and gravitationally-bound multiple star systems. As with past conferences, emphasis will be placed on cooperative research by professional and amateur astronomers. In addition, the 2017 conference will explore the role that binary stars play in student research, especially by high school and undergraduate students.

For more information, see the Conference website at www.cui.edu/binary5.

Symposium Sponsors

The Society for Astronomical Sciences thanks the following companies for their participation and financial support. Without them, our Symposium would not be possible. We encourage you to consider their fine products for your astronomical needs.

Sky & Telescope Magazine
The Essential Magazine of Astronomy
http://www.skyandtelescope.com/

DC3 Dreams Software
Developers of ACP Observatory Control Software
http://www.dc3.com/

PlaneWave Instruments
Makers of the CDK line of telescopes
http://www.planewaveinstruments.com/

Woodland Hills Camera & Telescopes
Providing the best prices in astronomical products for more than 50 years
http://www.telescopes.net/

Sierra Remote Observatories
Hosting telescopes for remote imaging and data acquisition
http://www.sierra-remote.com/

About that Solar Eclipse ...

In this Newsletter, we are treated to two wildly innovative perspectives of things to think about, and things to look for on August 17.

In the first article below, Albert DiCanzio describes several interesting observational projects that take advantage of the solar eclipse.

In the second article below, Wayne Green gives some thought to replicating the Eddington observation of gravitational deflection of starlight.

Although independently conceived and written, these two articles turned out to have a coincidental synergy. While Albert calls for measuring "differences of target position from what gravitational lensing theory would predict" in order to detect perturbation by hypothetical dark matter, Wayne presents a wealth of implementation detail aimed at measuring gravitational deflection of starlight that might serve general purposes including addressing the first among Albert's research questions.

North American Solar Eclipses 2017 & 2024:

Criteria of Determination for Metrics Conducive to Sponsorship of Discovery

by Albert DiCanzio

Abstract

This research focuses on harnessing the statistical capacity of many available concurrent observers to advance scientific knowledge. By analogy to some Galilean measurement-experiments in which he used less instrumentation than in others, this researcher will address the question: How might each individual observer, with a suitably chosen common metric and widely available, reasonably affordable equipment, contribute to new knowledge from observing the solar eclipse of 2017? Each observer would report data to an institutional sponsor who would analyze these data statistically toward new knowledge about some question currently unsettled in astronomy or in the target field connected with the question which the chosen metric is targeted to address. A subordinate question will be discussed: As a tradeoff between "best question to answer" and "easiest question for observers' data to answer", is there an event property and related target question that, with high potential utility and low cost, would be measurable by an observer positioned in the path of totality with minimal or inexpensive equipment and training? (And that, as a statistical sample point, might contribute to new knowledge?) In dialog with the audience, the presenter will suggest some measurable research questions which relate to gravitational lensing, solar flares, ground shadow bands, and atmospheric metrics, correlated or not with certain other dependent variables. The independent variable is time in the intervention interval from eclipse contacts 1-4. Because criteria of metrics-determination would include the existence of a data-collection-analysis method, this presentation requires dialogue with a critical mass of audience members who would participate in the consideration of the research objective and of candidate institutional sponsors as a function of candidate target questions.

1. Forenote To The Society For Astronomical Sciences (SAS)

Here is introduced the script I produced as background for an interactive session at the American Astronomical Society (AAS) Spring 2016 Conference where I spoke on the subject of the foregoing abstract. Feedback is invited from SAS astronomers in evaluating the potential for extracting new scientific knowledge from any of research questions proposed here (or any alternatives that may come to be adopted). I plan to identify contributors and implemented contributions to a discussion planned to follow this publication into my acknowledgments when that future discussion is done. Your president Robert Buchheim is already on this list, in gratitude for his arranging some consideration by the SAS of this paper. My AAS 2016 talk began with each arriving visitor or group approximately as follows:

Good afternoon, fellow AAS astronomers. Here you have found not just a presentation; we have more like a workshop. In return for your help in evaluating the potential for new scientific knowledge from research questions I will propose, you will be entered into my acknowledgments when this presentation is published.

Would you like to hear a three minute summary of this workshop so that you can decide whether to stay and participate with me in deciding how the statistical capacity of many users can be harnessed to the objective of deriving new scientific knowledge from observations during the North American eclipses of 2017 and 2024?

2. Aim of the Dialogue

In this presentation, I invite discussion regarding the solar eclipses of 2017 and 2024 whose path of totality will cross territory with a relatively large number of potential observers in North America. The overarching question is this:

Is there an event property and related target question that, with high potential utility and low cost, would be measurable by an observer positioned in the path of totality with minimal or inexpensive equipment and training? (And that, as a statistical sample point, might contribute to new knowledge?)

After elaborating a bit on this question, and then presenting various options, we can have an informal dialogue concerning the criteria of determination and a tradeoff between the best and the easiest questions to answer, and the selection of candidate institutional sponsors. With your permission,

then, any of you who contribute ideas or relevant information will be added to my acknowledgments.

3. Genesis of This Proposed Research

The idea for this project began in 1991 when, as an observer of the solar eclipse from Cabo San Lucas, rather than only to ogle the scene unfolding overhead, I allocated several out of the 6 minutes of totality to take a photograph and to document the exact position, exposure time, and film speed on a 3x5 card. Doing that gave me a false feeling that I had data which might be useful in the pursuit of knowledge about the eclipse. As the feeling gave way to reality, I realized that as an individual observer in one place, I would be unable to generalize on the data. This frustration set me to thinking that if I were ever to witness another eclipse of the sun on North American soil, I would seek out a uniformity of action with other observers, so that some useful knowledge could be derived from it. What kind of knowledge? Most especially, knowledge that would falsify (or require modification of) existing theory in astrophysics or cosmology, which are starved for empirical evidence.

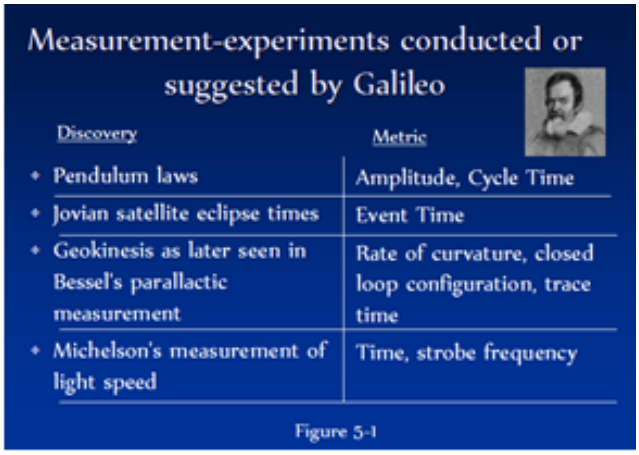
4. Citizen Cate: A Similar, Independently Conceived Project

Then, independently of me, a variation of this idea, requiring more instrumentation than I had in mind, was realized when the National Optical Astronomy Observatory announced the program it called “Citizen Cate”, the Continental America Telescopic Eclipse Experiment. Its plan for the 2017 eclipse is reportedly to utilize observers at 61 locations across the continental USA along the path of totality from Oregon on the U.S. Pacific coast to South Carolina on the Atlantic. Raw data to be collected by the observers would be digital images of the totality phase centered on the Sun. Along with the GPS-location of the site and exposure time, these images would be sent to NSO cloud storage where a single time series would be mathematically constructed. The end result would be the goal of the project: a continuous 90 minute movie of the solar corona during the 2017 total solar eclipse.

5. Measurements Conducted Or Suggested By Galileo

Some of Galileo's discoveries required little in the way of instrumentation. A famous example arises from an event that Galileo described to his student Viviani. At the age of 16, Galileo discovered the isochronism of the pendulum by observing a cathedral lamp that, having been pulled aside to light it, swung in a dampening arc. During the church-service, Galileo used only his pulse to time its period, which did not change measurably as the swing dampened to rest. Future studies of gravity anomalies, using torsion pendula and paraconical pendula during solar eclipses, will build on Galileo’s laws of the pendulum, as well as his law of falling bodies.

After discovering the first four satellites of Jupiter, Galileo recorded the eclipse times of these moons, using a small telescope, as they passed behind and later emerged from the disk of the planet. To obtain accurate observed data, such as the sizes of orbits, he equipped his telescope with an astrometric grid. It was a relatively inexpensive solution that yielded the relationship of orbital period to orbital size, and before Kepler had published his third law of planetary motion.



These two events and their metrics are shown above, along with two more that involved such sophisticated instrumentation that Galileo had to content himself with suggesting experiments that would be carried out later by astronomers with the requisite instrumentation. One of the objections to the Copernican system, which modeled Earth revolving and rotating with a dual motion, was that the orbit it would trace out under that model would be visible in deviations from what would otherwise be the proper motion of a distant star over time, that is, visible in parallax. Galileo's instruments were inadequate to discover parallax; he suggested that later attempts be made at such discovery using future telescopes of higher magnification and resolving power. Indeed, Bessel's detection of parallax in 61 Cygni, announced in 1838, came more than two centuries later.

Galileo had also put forth the idea that light may have a finite speed, and suggested an experiment using light sent and returned by two observers positioned on two Tuscan mountain peaks. The experiment was on the right track, but due to the much faster speed of light than envisioned at the time, could not be carried out if there were any delay of human response in returning the first light beam. It waited until 1926 when Michelson performed the measurement using an octagonal-mirrored stroboscope, equipment unavailable in Galileo's time, between Mount Wilson and Mount San Antonio over a 22 mile path (each way) reportedly surveyed over mountainous terrain to an accuracy less than an inch. Both the equipment and metric technology of that precision were unavailable to Galileo.

In this history, we see that scientific knowledge can be advanced sometimes with little instrumentation (as in the first two cases listed below), and at other times not so (as in the third and fourth cases). In the case of the American eclipses of 2017 and 2024, I seek research questions fitting the former category.

Discovery	Metric
Pendulum laws	Amplitude; Cycle Time
Jovian satellite eclipse time	Event time
Geokinesis as later seen in Bessel's parallactic measurement	Proper motion tracing closed loop; trace time
Michelson's measurement of light speed	Time elapsed and strobe frequency

6. Solar Eclipse Paths 2017 And 2024

On 17 Aug 2017, a total eclipse will enter North America from Pacific coastal waters at Oregon, with a path of totality proceeding southwest through Carbondale, Illinois and exiting to the Atlantic Ocean north of Charleston, S.C. Carbondale is located at 37°44′N 89°13′W. This eclipse offers the longest duration of totality with 2 minutes 41.6 seconds just to the south in Makanda Township. [http://www.greatamericaneclipse.com/]

On 8 Apr 2024, another total eclipse will enter North America crossing central Mexico and then the United States from Texas, through Carbondale, to Maine, then New Brunswick, with longest totality of 4 min, 28.2 sec [http://eclipse.gsfc.nasa.gov].

7. Tradeoff of Knowledge vs. Statistical Capacity

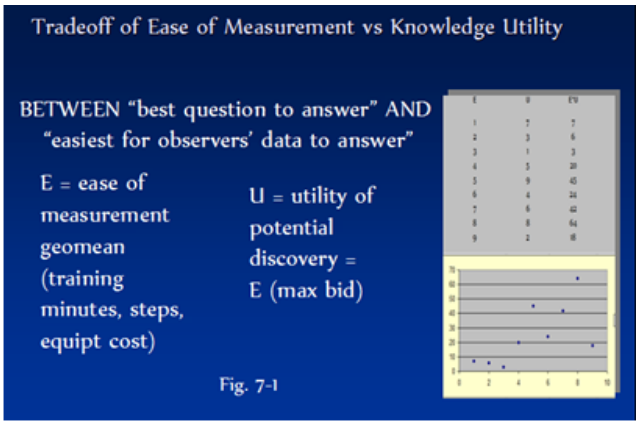
There is a tradeoff between BETWEEN:

"best question to answer" AND *"easiest question for observers' data to answer"*.

Let E = ease of measurement as calculated by the geomean (training minutes, steps, equipment cost)

Let U = utility of potential discovery calculated as the summation over the dollar market value of applications expected from the discovery (Σ app * mkt $ val)

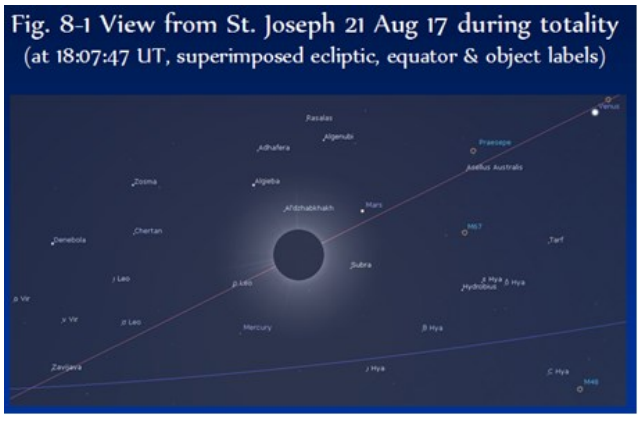
Then, I suggest that we can form the product of E*U and choose the maximum of these product values over the domain, E. I intend later to discuss with expert amateur astronomers the value of E associated with the metric for the ultimately selected research question. Here I am only asking for comments from professional astronomers (or graduate students in astronomy) visiting this presentation regarding seven candidate research questions that I suggest here, which are below numbered RQ X, where X is the question number.



Possible measurables are suggested by such events as solar flares, ground shadow waves, and atmospheric metrics, correlated or not with certain dependent variables; e.g., time-shifted aurorae. Let's elaborate a bit on each of these.

8. View From St. Joseph on 21 Aug 2017 At 18:07:47 Ut

Having constructed a view by the sky-mapping software "Stellarium" for coordinates of St Joseph, Missouri, latitude +39.7421 degrees, longitude -94.8526 degrees (where a duration of 2m 38.3 sec totality is expected at altitude 61.9 and azimuth 172 degrees at 18:06:27.8 through 18:09:06.2 UT on 21 August 2017, with 7 hours offset for local time) I noticed in that view naked-eye visible objects including Algieba and the planet Mars within about half a degree of the sun. Others not human-visible may be picked up by camera with a fairly long exposure time within this interval.



To determine the separation between two celestial objects, let's say, during totality in 2012, Algieba at the 11 o'clock position, and Mars at the 2 o'clock position, it is only neces-

sary to calculate the usual trigonometric function of the right ascension and declination of each object. Given that result, one can operate on it using a normalization function of time and the observer's terrestrial coordinates. The positions can be determined from still photos taken during the eclipse.

In the field of stars proximate to the sun's limb, one would not expect the positions of these objects to be shifted from their pre-eclipse or post-eclipse positions any more or less than gravitational lensing might predict, and likewise for their angular distance from the sun. Therefore, a difference from prediction would be of interest.

E.g., assuming that dark matter exists, might future eclipse photographs from which the bending angle can be accurately re-estimated suggest differences in the distribution of dark matter between the measurements during the eclipse and at other times? The precision required to notice these differences is high; we would be looking for a deviation (between pre-eclipse or post-eclipse positions and positions during totality) in the interval from about 1.55 to 1.75 arcsec depending on the distance of a light ray from the sun [Will, 8]. An assumption that a large number of photographs may reduce error terms that are due to camera construction and optics, even when inexpensive camera equipment is used, seems worth testing. This consideration suggests my first candidate research question:

(RQ1): What are the placement and precision required to detect differences of target position from what gravitational lensing theory would predict? Assuming that dark matter exists, what hypotheses might such distances, measured from eclipse photos, suggest about differences in distribution of hypothesized dark matter between the two eclipses seven years apart?

9. Shadow Bands

In 1991 I experienced shadow bands, just before the eclipse at Cabo San Lucas, as a scintillation caused by seemingly parallel bands of alternating light and dark striations, fast traversing the ground in the direction of the progressing eclipse immediately before and after totality. If the thin slot-like solar crescent is illuminating the Earth's atmosphere at these times, then their motion might be attributed to atmospheric winds [Codona, 483]; and if this explanation, which is consistent with a prevailing theory [Jones], is correct, then I would expect high wind velocities in the troposphere that track the speed of the shadow bands across the ground. I see this condition as making measurements by anemometer during the eclipses useful in confirming or falsifying this explanation of the shadow bands.

In 2008, Stuart Eves offered an alternative explanation that shadow bands might be manifestations of infrasound generated by the shadow of the moon travelling at supersonic speed, which in turn produces a low frequency shockwave that humans cannot hear [Anon., BBC]. If the moving shadow of the moon causes shadow bands by creating a shockwave in front of the shadow, then per Russell, Dugan, and Stewart, this wave moves across the ground toward the observer at the rate of nearly 2100 miles per hour, on average [Russell, Vol. 1, 221].

Barrie Jones stated "The [accepted] theory works; there's no need to seek an alternative". But Stuart Eves argued: "None of the [existing] theories seem to take account of the fact that shadow bands change direction" between the pre-eclipse and post-eclipse directions. Eves also mentioned the unusual behavior of birds and other animals that can be attributed to their ability to hear infrasound. In 1991 I did witness sea animals jumping out of the water as the eclipse approached.

Accordingly, besides the anemometer measurements of wind speed at ground level, a pendulum in motion but isolated from wind might be used to detect disruptive behavior of the pendulum bob. In addition, many small inexpensive cameras or cell phones are capable of taking and storing movies for a minute or two. A movie of the shadow bands may be useful for determining the speed of motion of the bands, by slowing them down by a known factor. In this connection, Codona mentioned the importance of using "... short exposures to freeze the motion of the bands. The bands typically move 1 to 2 feet per second in light wind, so to hold blurring to 10 percent of a typical band's spacing, exposure times must be 1/125 second or less. Use shorter exposures if the wind is blowing harder." [Codona, 486].

There are other simple observations that have been suggested by researchers; e.g., "The easiest observation is to note merely whether [and I would add "when"] shadow bands are present. Also, where are you? What are the weather conditions? Is there any wind? Are trees, buildings, or bodies of water nearby? Note everything and report it." [Codona, 484]. Codona does not say to whom it is best reported; that is one target of the present research.

Probably one of the easiest measurements an untrained observer can make is that of temperature, air pressure, and humidity recorded before totality, during totality, and at 30-sec ivals after totality. In 1991, I recall feeling a temperature drop that I would estimate at about ten degrees Fahrenheit during totality, but I did not take an instrument to measure this change. Presently, there are many inexpensive digital instruments that will measure not only temperature but also pressure and humidity at a given location and time.

(RQ2): Might a sample of measured wind speed, measured band speed (determined from inspection of videorecordings of the bands made by observers just before and after totality), and pendulum bob stability help resolve the Eves-Jones debate on shadow bands?

Conspicuously related to my next research issue was the further mention by Stuart Eves that "long period Foucault pendulums - designed to demonstrate the rotation of the Earth - have been known to swing wildly during eclipses". If this is true, it is not explained by atmospheric winds, while according to Eves "the disruption to pendulums may be caused by infrasound pulses causing the ground to vibrate, disrupting the pendulum's rhythm". Whether due to vibration or other phenomena of nature, shifts in the period and/or oscillation-plane of pendula have been observed by researchers looking for gravity anomalies.

10. Gravity Anomalies

Here and in the following sections on coronal heating and electric sun hypotheses, I present grounds for formulating research questions and constructing metrics to address some additional theoretical controversies which may possi-

bly be able to be informed by solar-eclipse observational data. We might categorize them as "Controversial Theory To Be Considered for 2024." I am attracted to these questions precisely because they involve controversial challenges to the current paradigms in astrophysics. Why? Because my familiarity with the attacks on the arguments and person of Galileo before, during, and after his defense of the Copernican hypothesis, which in the end proved true, have sensitized me to the value of carefully evaluating alternative paradigms -- not just dismissing them out of hand.

Since Galileo discovered laws obeyed by any near-Earth object in free fall in a vacuum, and by a pendulum in oscillation, there is a long history of observations of gravity-related phenomena determined through use of all these laws. They have been used by mechanisms which researchers placed into service during solar eclipses, especially around totality. At least 19 such experiments using the Foucault, paraconical, and torsion pendulum, have been conducted during solar eclipses from 1954 to 2006 [Allais, 72, Table 1] and others more recently. Many of these have observed changes in period, tilt, and plane of oscillation during a solar eclipse.

Through his experiments using the inclined plane, Galileo formulated the basic law that relates speed and distance of fall to time. In a vacuum, the distance through which an object falls is proportional to the square of the time duration of fall and, equivalently, its instantaneous speed of fall is proportional to time. The latter equivalence implies the existence of a constant of proportionality that today goes by the name "acceleration due to gravity" or "g" for short. From many experiments at different locations on Earth, we know that this "constant" varies a bit with the latitude and the terrain, but are there other variable components of g?

In 1954, and again in 1959, Maurice Allais reported observations of strange and unexplained movement during solar eclipses. During the total solar eclipse of 1954, for example, he observed a decrease in the Foucault Effect as seen in the azimuth of the pendulum's plane of oscillation with Earth's rotation. This effect was observed independently by other researchers in 1961 and 1999 [Munera, 191 ff.]. The phenomenon is now called the Allais effect.

Similarly, in 1970, Erwin Saxl and Mildred Allen observed the sudden change in motion of a torsion pendulum; this phenomenon is called the Saxl effect. Dr. Saxl invented the torsion pendulum, patented in 1967, and his patent filing (# 3,357,253) indicated that he did so to find gravitational anomalies including variations in the aforementioned constant g, the acceleration due to gravity [Saxl]. The Saxl Effect is briefly described by him as variations of the oscillation period of the pendulum correlated with the progress of the eclipse [Saxl, 9]. In his discussion of results, he writes: "Since the maximum variation of the acceleration of gravity produced by changes in the positions of the sun and moon is 0.16×10^{-3} cm/sec^2 or 1.6 μm/sec^2 (Heiskanen and Vening Meinesz, 1958) which gives a relative change in g of 1.6×10^{-7} and since the maximum relative change of our observations is of the order of 2×10^{-4}, *the data presented here greatly exceed quantitatively what can be interpreted in terms of Newtonican (sic) mechanics* [Saxl, 11]. (I think he meant to write "Newtonian" and I do NOT think the statement points to a destructive paradigm change in the Kuhnian sense but at most to a refinement in the currently understood laws of mechanics, which may be in order if there shall come to exist significant and sufficient confirmations of the Saxl Effect over time. I might as well confess here that I am a believer in the progress of science by building on the results of earlier innovators and not in a view of progress as one paradigm "destroying" another.)

A recent published observation during the 1997 solar eclipse by Wang et al. [Yang] "suggested a possible gravitational shielding effect, which generated debate. Later in 2002, Yang and Wang published detailed data analysis, which suggested that the phenomenon still remains unexplained." [Anon., Path]

Can the Allais Effect be shown by astronomers without sophisticated equipment to be due to "experimental error", as has been claimed by some? [Anon. Oberlein] If not, then what does it imply for the accuracy of the laws of the pendulum, and can that accuracy be determined by research questions and metrics appropriate to the current project?

For those who may be interested in this challenging study, the best description, known to me, of experimental equipment and procedures for investigating gravity anomalies is contained in Saxl and Allen, supplemented by Munera (See bib.)

11. Coronal Heating Theory Hypothesis

On our planet, we are unaccustomed to an atmosphere that is orders of magnitude hotter than the surface of our planet. By contrast, the sun's surface, its photosphere, may be on the order of 10,000 degrees F. Yet the solar atmosphere, NASA claims, is on the order of 300 times hotter – in the millions of degrees. What heats the atmosphere to such extreme temperatures? NASA has reported [Anon., NASA] that Jim Klimchuk, a solar scientist at the Goddard Space Flight Center, has hypothesized that the new evidence supports a theory that the sun's corona is heated by tiny explosions called nanoflares. These are impulsive heating bursts that individually reach temperatures of some 10 million Kelvins or 18 million degrees Fahrenheit – even greater than the average temperature of the corona – and provide heat to the atmosphere. The research evidence presented by the panel spotted this super hot solar material, called plasma, representative of a nanoflare. "The explosions are called nanoflares because they have one-billionth the energy of a regular flare," said Klimchuk. "Despite being tiny by solar standards, each packs the wallop of a 10 megaton hydrogen bomb. Millions of them are going off every second across the sun, and collectively they heat the corona."

What experiments are the source of this interpretation? The article refers to a sounding rocket mission: "EUNIS flew on a 15-minute flight in Dec 2013 equipped with … a spectrograph. The spectrograph unambiguously spotted this extremely hot material in active regions that visibly appeared to be quiet. … sounding rockets in 2012 and 2013 … imaged soft X-rays from the corona. These results, too, confirmed the presence of … hot plasma on the sun."

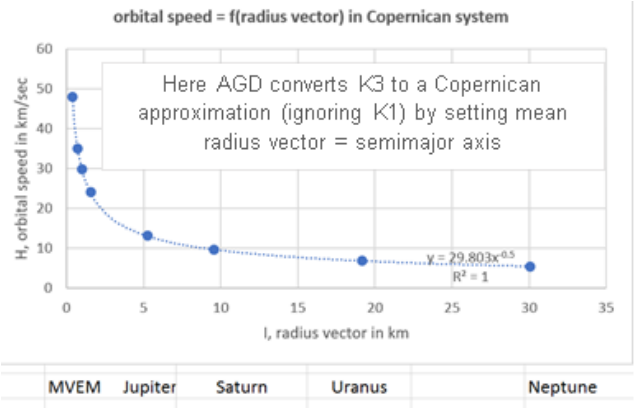
How can amateurs by observing a total eclipse provide data that would either confirm or require modification of NASA's interpretation? The article has given us a likely source: at the April 28, 2015, at the Triennial Earth-Sun Summit, or TESS, meeting in Indianapolis, … "Stephen Bradshaw, a solar astrophysicist at Rice University in Houston, Texas, was the last speaker. … Bradshaw used a sophisticated

computational model to demonstrate why spotting signatures of the nanoflares has been so difficult and how the new evidence will help researchers go forward to improve theories on the details of coronal heating – one day allowing heliophysics researchers to at last solve the coronal heating mystery."

I have early this month sent a missive to professor Bradshaw requesting his opinion on whether a large sample of amateurs, coupled with a suitable sponsoring organization, may be able to provide a data-gathering function to assist in confirming that nanoflares may be a significant causal factor in coronal heating. I await his response and intend to keep SAS informed on this development, particularly as to whether a research question and associated metric that would confirm or require modifications in the nanoflare hypothesis could be formulated for amateur observers.

12. Electric Sun Hypothesis

This hypothesis I cover last (but not least) as controversial theory to be considered for 2024. It is potentially the greatest opportunity for those amateur astronomers, who are used to doing experimental science to aid the progress of astronomy and cosmology. However, the statement of research question is out of scope for this article. Instead, I describe briefly the controversy which is forming around this astronomical-sized topic.



Recently, I entered planetary orbital radii (more accurately, the semimajor axis of each planet's orbit as given by Russell, Dugan, and Stewart [Russell, Vol. 1 Appendix] into an Excel spreadsheet and forced it to calculate and graph orbital speed versus orbital radius by converting Kepler's 3rd Law to a Copernican approximation (ignoring Kepler's 1st Law in simulation of their independence) by setting mean radius vector = semimajor axis.

On seeing the plot and fitting curve, I was immediately struck by an implication embodied in this graph of velocity appearing to vanish asymptotically with distance. Kepler's laws and universal gravitation are, on a cosmic scale, local effects, as it were. That little exercise led me to pay more attention to the electric sun hypothesis.

The "electric sun" hypothesis is related to published theory that views the sun as powered not merely by the radiation emitted in the conversion of hydrogen to helium but also by electric currents, including those in the sun's own ejected plasma and solar wind, that cycle back into the sun. These are known as Birkeland currents.

The way that I choose to introduce this hypothesis is to use the metaphor of a 9-volt battery powering a system or device external to the battery. The flow system consists of two elements: the battery itself and an external device or subsystem, for example, a portable radio. Current flows in a loop, exiting the positive terminal (or cathode) to the device, which it powers, then re-entering the battery at the negative terminal (the anode). If instead we represent the Sun by this battery and the external space by the solar wind interacting with planetary magnetosystems and galactic plasma currents, we have a somewhat analogous situation: first, plasma outflow from the sun, carried by the solar wind out to multiples of the solar system's radius, second, combining with galactic Birkeland currents said to freely flow in our arm of our galaxy, third returning to the sun carried by both gravitational and electrodynamic forces, then the whole process recycling indefinitely.This is by no means a perfect analogy. For example, in the metaphorical example of the portable radio, nothing is added to the current coming out of the battery, whereas in the electric-sun hypothesis, the current is augmented each cycle by currents in the galactic arm.

A summary of related basic ideas is given at http://electric-cosmos.org/sun.htm, where it is stated that the hypothesis is speculative and has been attacked by critics. Such attacks on an innovative hypothesis by defenders of the current paradigm in any science usually capture my attention.

How can observers at centerline provide data bearing on this controversy? As it belongs to the category "Controversial Theory To Be Considered for 2024", I prescind from the question until more is known about the demands of the research and the capabilities of the interested observers. I mention it now in order to indicate that I expect to have more on this issue forthcoming between 2017 and 2024.

Future Direction

When the tradeoff described in section 7 above has been performed, I will have reduced the candidate research questions presented here to a single question. And from that single question a metric can be formulated.

Then when the research question of the study and the associated metric will be known, the following implementation-research question will become:

Based on the research objective (what is to be measured and what question it is expected to address), what are the likely candidate institutional sponsors? In other words, let's identify a sponsor S such that:

S = f(R, M) where R = research question, M= metric

Conclusion

Life may present us occasionally with opportunities to extend the capacity of our work toward a positive future that will survive us. But only occasionally. Two great solar eclipses are visible in our country next year and eight years from now. Let us not lose the opportunity to learn from them

whatever we can about survival on this planet and about our search for the next planetary home.

Thanking you for your attention and your feedback, I acknowledge, in closing, the following individuals whom I consulted prior to and during this conference.

Acknowledgements and References

Buchheim, Robert, Society for Astronomical Sciences

Fetherolf, Tara, University of California, Riverside

Fritzius, Robert G., Shade Tree Physics

Judge, Philip G., National Center for Atmospheric Research

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Mancuso, Salvatore, INAF, Astronomical Observatory of Torino

Morgan, Huw, Independent Researcher

Pasachoff, Jay M., Director, Hopkins Observatory, Williams College

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Contact The Presenter:

Albert DiCanzio

admin@adasi.com

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Gravitational Deflection of Starlight

by Wayne Green

Boulder Astronomy and Space Society

This article considers the planning and observational issues related to attempts to reproduce the famous experiment of measuring the deflection of starlight by gravity, as predicted by Einstein’s theory of general relativity. The next eclipse of interest to US observers is the 21 August, 2017 eclipse. The apparent angular diameter of the Moon will be ≈ 1960 arcsec (32.7 arc-min) and the Sun will be ≈ 1897 arcseconds (31.6 arc-min) in diameter.

Observing stars during the total eclipse of the Sun will be affected by conditions that include aerosols in the atmosphere, seeing, thermal changes to air column during eclipse, solar activity and the brightness of the solar corona; plus optical considerations including focal length and resolution, and sensor type (DSLR vs. CCD vs. film). Secondary conditions include the local refraction of light and mechanical issues like the alignment of the CCD with the optical axis and flexure of the system. The telescope/camera combination will likely suffer from optical distortions that must be carefully cataloged. Observers must account for wind and other local weather conditions. CCD imaging cadence may be an issue as well.

Two periods of observations are needed: one of the field either before or after the eclipse to record the un-deflected apparent location of the stars, and the other period during the eclipse itself. Since it is likely that you will set up your system separately for these two observation sets, it is important to be confident that they are comparable. One way to do this might be to take a calibration image of a target – open clusters are great. Tear down and reassemble the equipment and reproduce the experiment. Compare the results. GAIA astrometry is fresh (less than 1 year out). The PanSTARRs 3π survey is now online and available. These will provide good "truth" astrometry of the stars' initial positions.

Careful planning is required. Figure 1 was made by obtaining the position of the center of the Sun (JPL object 10, not the barycenter with a JPL object 0), for the precise longitude, latitude and altitude of an observer. The apparent diameter is hard to determine for a gas ball; JPL uses two values: Radius (photosphere) = 6.963E5 km, Solar Radius (IAU) = 6.955E5 km. The IAU/JPL definitions include 1 AU= 149597870.700 km, c= 299792.458 km s^{-1}. You can make your own precise predictions using the JPL Horizons database:

http://ssd.jpl.nasa.gov/horizons.cgi

Fill in the form:

Key fields:

2 - Apparent RA & DEC,

4 - Apparent AZ & EL,

13 - Target angular diameter,

20 - Observer range & range-rate.

There is a second table on the main settings page where you may choose sexigesimal or decimal degrees for the positions, range in AU or km (use km), and a few other details.

Example Field, approximately 45 arcminutes on a side. for coordinates:

Lat.: 43.5117 N

Long.: 110.4785 W

for data from JPL Horizons database. (DSS Plate Position 10:03:57.8 +11:52:11.8). The solar position for a location near Casper WY for the time of the eclipse, showing JPL's apparent RA/DEC and the approximate azimuth/elevation for the event.

Figure 1 uses a DSS star field image overlaid with a cartoon of the Sun. Magnitudes are from the UCAC4 V-Band values. Times are UT, referring the NASA/Google URL, puts mid eclipse around 17h43mUT.

Google Maps (™) can provide a decent estimate of the coordinates, including altitude. Obtain the mid- eclipse times with:

https://eclipse.gsfc.nasa.gov/SEgoogle/SEgoogle2001/SE2017Aug21Tgoogle.html

The sun is far enough away, that parallax will not make that much of a difference...

arcsec = earth D/AU17.6 = (12,756/149,597,870.700 for the large FOVs available, path of totality is tiny compared to diameter of the earth.

The gravitational deflection is about 1.8 arc-sec for an object just skimming the solar limb. Ideally (or simplistically), you'd like for your observing system to provide a pixel/plate scale of about 1/2 of that to meet Nyquist criteria (i.e. plate scale ≈ 0.9 arc-sec/pixel). This may not be practical: such a high-resolution system is likely to have a small field-of-view (smaller than the angular diameter of the Sun/Moon). Remember too, short optics tend to have pretty severe optical distortions (something I'm fighting with a project now). If memory serves film has a 'pixel' (grain) size on the order of 1 to few microns, and the QE of film is in the fews of percent, vs approx 60% or better for CCD/CMOS sensors. Bayer masks on DSLRs or color-CCDs will cause their own centroid measurement issues.

Equipment Considerations

First compute the "pixel factor", the fraction of arcseconds per micron (μm) at the focal plane. This uses the focal length (fl) of your scope in microns:

$$pixelfacto\,r = \frac{206264.8}{fl[\mu m]}$$

Multiply that by the "pixel size" in microns of your camera to get arcsec/px.

platescale = pixel factor × pixel size[μm]

Multiply the platescale by the count of pixels to get the FOV, say for a camera with 1,024 by 1,024 pixels:

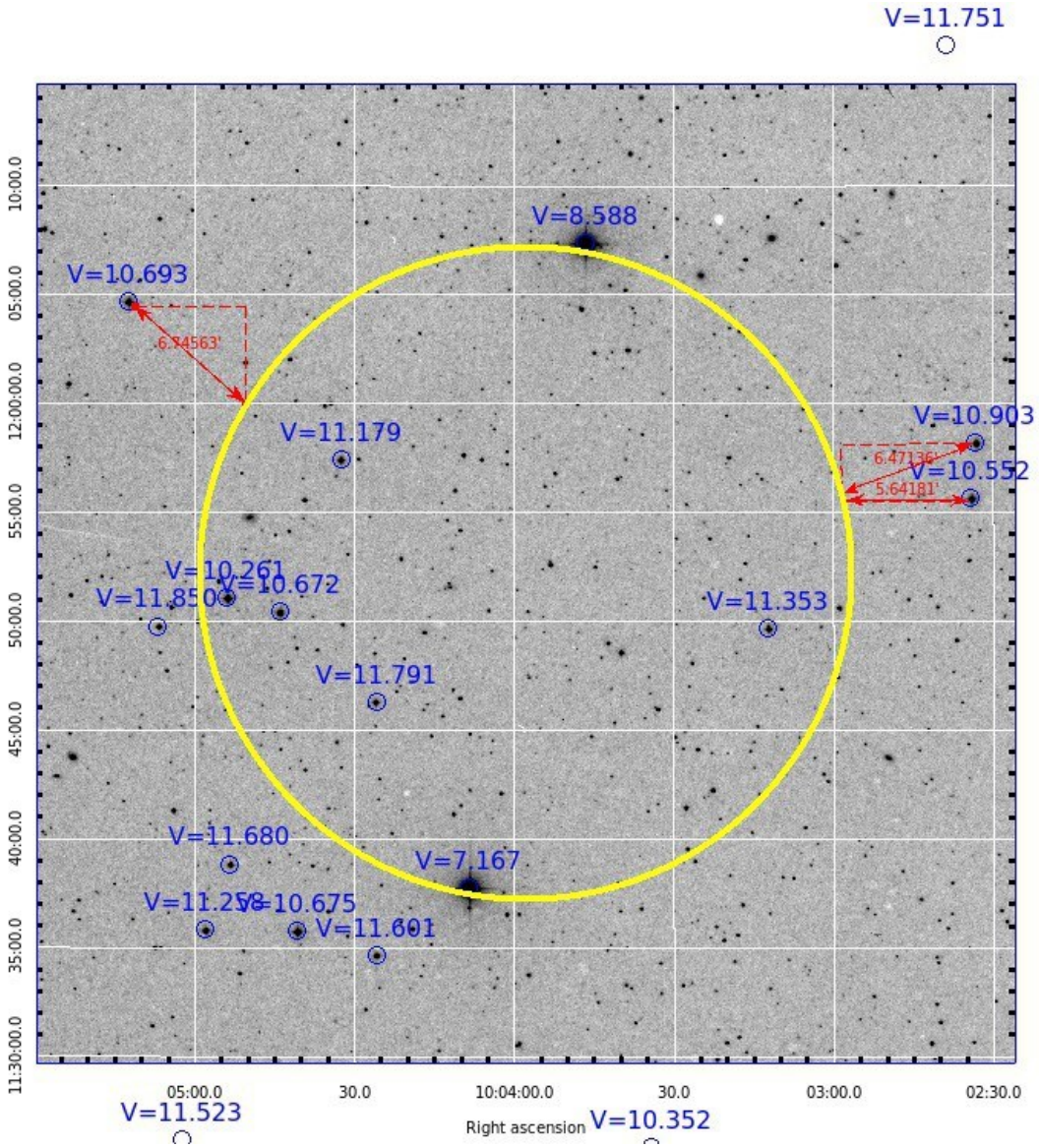
$$FOV = \sqrt{1024^2 + 1024^2} \times platescale$$

There are several things to consider with equipment. The longer the focal length the greater the platescale The longer the focal length, the more disperse the corona's image, and the higher the flux from any star in the field. These two factors make for a better the chance of determining the centroid of any star that is imaged.

I suspect shooting with a red filter may help. If I've had enough coffee this AM, the later the eclipse the more the Sun's disk shifts to the left in the image, making that top star a good candidate.

Example Finder Chart

The Figure below shows an example field (nominal 30-arcseconds), for 21 Aug 2017 eclipse. Brightest Johnson V magnitudes shown (UCAC4). Image prepared with ds9. Ruler distances (in red) are in arc-minutes.



Deflection Table

The complexities of general relativity can be side-stepped with a decent approximation. Here α is the deflection in arcseconds.

For predictions, this equation taken from "Fundamentals of Astronomy", Carlos Barbieri (Taylor & Francis, pub. 2007 pg 126-127) and the chart in figure 2 is good enough for planning.

$$\alpha = \frac{4GM}{Rc^2}$$

The values for constants can be obtained from the tables in sections A and B.

Variable	Value	Units
GM	GM = 1.3271244004193938e11	[km^3/s^2]
M*Sun*	M= ~ 1.988544e30	[kg]
R*Sun*	6.955e5	[km]
c	299792.458	[km s-1]
L (range)	1.5131851440E+08	[km]

Table: JPL Constants and Values

Python Code for Deflection Graph

```
1   import numpy
import matplotlib . pyplot as plt import matplotlib . dates as
mpdate import matplotlib . ticker as mpticker
solarradii = 6.955e5
6   GM = 1.3271244004193938e11
c       = 299792.458
arcfactor = (206264.8 / 60.0 )
sunrange = 1.5131851440E+08
11  x = numpy. arange( solarradii ,3*solarradii , solarradii/100)
y = 4.0 *GM / (c**2) / x
x = (x / sunrange) * 3600
# km into apparent arcminutes
y = y * 206264.8
# radians into arcseconds
fig = plt . figure ( figsize=(8,8))
16  ax = fig . add_subplot(111)
t i t l e = r 'Solar Deflection ' fig . suptitle ( t i t l e )
plt . xlabel ( r 'Distance in arc minutes from limb' )
21 plt . ylabel ( r 'Deflection in arc seconds' )
plt . grid ()
pt = ax. plot (x,y)
plt .show()
```

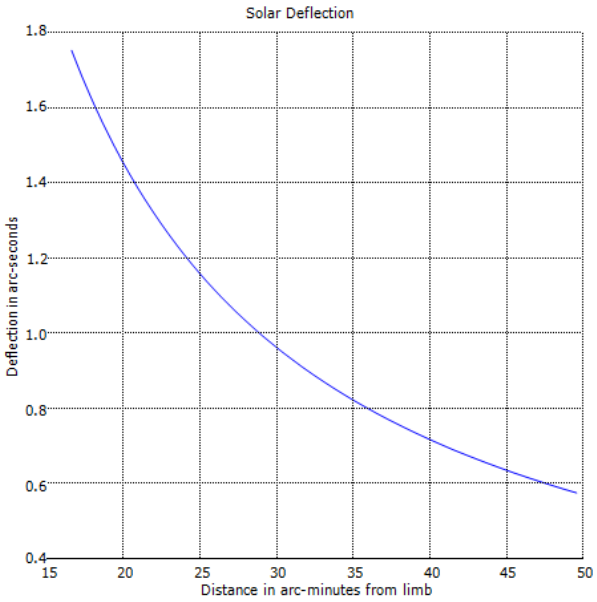


Figure 2: The deflection, in units of arc seconds, for a separation from the limb, given in arc minutes.

Conclusion

An experiment of this time requires careful attention to detail, practice and experience. Good predictions and good data are required to obtain and reduce observations. Good luck!

A. Solar Table for a Wyoming Location

```
Ephemeris Type [change]    :  OBSERVER
Target Body [change]       :  Sun [Sol] [10]
Observer Location [change] :  user defined ( 110Âř28'42.6''W, 43Âř30'42.1''N, 1666 km )
Time Span [change]         :  Start=2017-08-21 17:40, Stop=2017-08-21 17:50, Step=1 m
Table Settings [change]    :  QUANTITIES=2,4,13,20; range units=KM
Display/Output [change]    :  default (formatted HTML)
Object Data Page

 Revised : Jul 31, 2013                 Sun                                  10

 PHYSICAL PROPERTIES (revised Jan 16, 2014):
  GM (10^11 km^3/s^2)   = 1.3271244004193938  Mass (10^30 kg)    ~ 1.988544
  Radius (photosphere)  = 6.963(10^5) km  Angular diam at 1 AU  = 1919.3"
  Solar Radius (IAU)    = 6.955(10^5) km  Mean density          = 1.408 g/cm^3
  Surface gravity       =  274.0 m/s^2    Moment of inertia     = 0.059
  Escape velocity       =  617.7 km/s     Adopted sidereal per  = 25.38 d
  Pole (RA,DEC in deg.) =  286.13,63.87   Obliquity to ecliptic = 7 deg 15'
  Solar constant (1 AU) = 1367.6 W/m^2    Solar lumin.(erg/s)   =  3.846(10^33)
  Mass-energy conv rate = 4.3(10^12 gm/s) Effective temp (K)    =  5778
  Surf. temp (photosphr)= 6600 K (bottom) Surf. temp (photosphr)=  4400 K (top)
  Photospheric depth    = ~400 km         Chromospheric depth   = ~2500 km
  Sunspot cycle         = 11.4 yr         Cycle 22 sunspot min. =  1991 A.D.

  Motn. rel to nrby strs= apex : RA=271 deg; DEC=+30 deg
                          speed: 19.4 km/s = 0.0112 AU/day
  Motn. rel to 2.73K BB = apex : l=264.7+-0.8; b=48.2+-0.5
                          speed: 369 +-11 km/s
Results

*******************************************************************************
Ephemeris / WWW_USER Tue Jan 10 07:19:14 2017 Pasadena, USA      / Horizons
*******************************************************************************
Target body name: Sun (10)                        {source: DE431mx}
Center body name: Earth (399)                     {source: DE431mx}
Center-site name: (user defined site below)
*******************************************************************************
Start time      : A.D. 2017-Aug-21 17:40:00.0000 UT
Stop  time      : A.D. 2017-Aug-21 17:50:00.0000 UT
Step-size       : 1 minutes
*******************************************************************************
Target pole/equ : IAU_SUN                         {East-longitude +}
Target radii    : 696000.0 x 696000.0 x 696000.0 k{Equator, meridian, pole}
Center geodetic : 249.521500,43.5117000,1666.0000 {E-lon(deg),Lat(deg),Alt(km)}
Center cylindric: 249.521500,5841.23694,5515.9501 {E-lon(deg),Dxy(km),Dz(km)}
Center pole/equ : High-precision EOP model        {East-longitude +}
Center radii    : 6378.1 x 6378.1 x 6356.8 km     {Equator, meridian, pole}
Target primary  : Sun
Vis. interferer : MOON (R_eq= 1737.400) km        {source: DE431mx}
Rel. light bend : Sun, EARTH                      {source: DE431mx}
Rel. lght bnd GM: 1.3271E+11, 3.9860E+05 km^3/s^2
Atmos refraction: NO (AIRLESS)
RA format       : HMS
Time format     : CAL
RTS-only print  : NO

EOP file        : eop.170109.p170402
EOP coverage    : DATA-BASED 1962-JAN-20 TO 2017-JAN-09. PREDICTS-> 2017-APR-01
Units conversion: 1 au= 149597870.700 km, c= 299792.458 km/s, 1 day= 86400.0 s
Table cut-offs 1: Elevation (-90.0deg=NO ),Airmass (>38.000=NO), Daylight (NO )
Table cut-offs 2: Solar Elongation (  0.0,180.0=NO ),Local Hour Angle( 0.0=NO )
*******************************************************************************************************
 Date__(UT)__HR:MN     R.A.__(a-apparent)__DEC Azi_(a-appr)_Elev Ang-diam            delta      deldot
*******************************************************************************************************
$$SOE
 2017-Aug-21 17:40 *m  10 03 57.19 +11 52 15.2 136.4593  51.1008 1897.463 1.5131867490E+08  -0.5390384
 2017-Aug-21 17:41 *m  10 03 57.34 +11 52 14.3 136.7954  51.2251 1897.464 1.5131864260E+08  -0.5374152
 2017-Aug-21 17:42 *m  10 03 57.49 +11 52 13.5 137.1331  51.3487 1897.464 1.5131861041E+08  -0.5357886
 2017-Aug-21 17:43 *m  10 03 57.65 +11 52 12.7 137.4725  51.4715 1897.464 1.5131857831E+08  -0.5341586
 2017-Aug-21 17:44 *m  10 03 57.80 +11 52 11.8 137.8135  51.5934 1897.465 1.5131854631E+08  -0.5325251
 2017-Aug-21 17:45 *m  10 03 57.95 +11 52 11.0 138.1561  51.7146 1897.465 1.5131851440E+08  -0.5308882
 2017-Aug-21 17:46 *m  10 03 58.10 +11 52 10.2 138.5005  51.8350 1897.466 1.5131848260E+08  -0.5292480
 2017-Aug-21 17:47 *m  10 03 58.25 +11 52 09.3 138.8465  51.9545 1897.466 1.5131845089E+08  -0.5276045
 2017-Aug-21 17:48 *m  10 03 58.40 +11 52 08.5 139.1941  52.0733 1897.466 1.5131841929E+08  -0.5259577
 2017-Aug-21 17:49 *m  10 03 58.56 +11 52 07.7 139.5435  52.1911 1897.467 1.5131838778E+08  -0.5243077
 2017-Aug-21 17:50 *m  10 03 58.71 +11 52 06.8 139.8945  52.3082 1897.467 1.5131835637E+08  -0.5226544
$$EOE
*******************************************************************************************************
```

B. Lunar Table for a Wyoming Location

```
Ephemeris Type [change]    :  OBSERVER
Target Body [change]       :  Moon [Luna] [301]
Observer Location [change] :  user defined ( 110Âř28'42.6''W, 43Âř30'42.1''N, 1666 km )
Time Span [change]         :  Start=2017-08-21 17:40, Stop=2017-08-21 17:50, Step=1 m
Table Settings [change]    :  QUANTITIES=2,4,13,20; range units=KM
Display/Output [change]    :  default (formatted HTML)
Object Data Page

Revised: Jul 26, 2016             Moon / (Earth)                          301

PHYSICAL PROPERTIES:
 Radius (IAU), km      = 1737.4          Mass, 10^20 kg        =  734.9
 Radius (gravity), km  = 1738.0          Geometric albedo      =    0.12
 Density, gm cm^-3     =    3.3437       GM, km^3/s^2          = 4902.80007
 V(1,0)                =   +0.21         Surface gravity       =    1.62 m s^-2
 Earth/Moon mass ratio = 81.3005691      Farside crust. thick. = ~80 - 90 km
 Nearside crust. thick.= 58+-8 km        Heat flow, Apollo 17  = 2.2+-.5 mW/m^2
 Heat flow, Apollo 15  = 3.1+-.6 mW/m^2  k2                    = 0.024059
 Mean crustal density  = 2.97+-.07g/cm^3 Magnetometer moment   = 435+-15
 Induced magnetic mom. = 4.23x10^22Gcm^3

DYNAMICAL CHARACTERISTICS:
 Mean angular diameter = 31'05.2"        Orbit period          = 27.321582 d
 Obliquity to orbit    = 6.67 deg        Eccentricity          = 0.05490
 Semi-major axis, a    = 384400 km       Inclination           = 5.145 deg
 Mean motion, rad/s    = 2.6616995x10^-6 Nodal period          = 6798.38 d
 Apsidal period        = 3231.50 d       Mom. of inertia C/MR^2= 0.393142

  beta (C-A/B), x10^-4  = 6.310213        gamma (B-A/C), x10^-4 = 2.277317
 Results

 ******************************************************************************
 Ephemeris / WWW_USER Tue Jan 10 07:18:27 2017 Pasadena, USA      / Horizons
 ******************************************************************************
 Target body name: Moon (301)                    {source: DE431mx}
 Center body name: Earth (399)                   {source: DE431mx}
 Center-site name: (user defined site below)
 ******************************************************************************
 Start time      : A.D. 2017-Aug-21 17:40:00.0000 UT
 Stop  time      : A.D. 2017-Aug-21 17:50:00.0000 UT
 Step-size       : 1 minutes
 ******************************************************************************
 Target pole/equ : IAU_MOON                      {East-longitude +}
 Target radii    : 1737.4 x 1737.4 x 1737.4 km   {Equator, meridian, pole}
 Center geodetic : 249.521500,43.5117000,1666.0000 {E-lon(deg),Lat(deg),Alt(km)}
 Center cylindric: 249.521500,5841.23694,5515.9501 {E-lon(deg),Dxy(km),Dz(km)}
 Center pole/equ : High-precision EOP model      {East-longitude +}
 Center radii    : 6378.1 x 6378.1 x 6356.8 km   {Equator, meridian, pole}
 Target primary  : Earth
 Vis. interferer : MOON (R_eq= 1737.400) km      {source: DE431mx}
 Rel. light bend : Sun, EARTH                    {source: DE431mx}
 Rel. lght bnd GM: 1.3271E+11, 3.9860E+05 km^3/s^2
 Atmos refraction: NO (AIRLESS)
 RA format       : HMS
 Time format     : CAL
 RTS-only print  : NO
 EOP file        : eop.170109.p170402
 EOP coverage    : DATA-BASED 1962-JAN-20 TO 2017-JAN-09. PREDICTS-> 2017-APR-01
 Units conversion: 1 au= 149597870.700 km, c= 299792.458 km/s, 1 day= 86400.0 s
 Table cut-offs 1: Elevation (-90.0deg=NO ),Airmass (>38.000=NO), Daylight (NO )
 Table cut-offs 2: Solar Elongation (  0.0,180.0=NO ),Local Hour Angle( 0.0=NO )
 ******************************************************************************************************************
  Date__(UT)__HR:MN     R.A.__(a-apparent)__DEC Azi_(a-appr)_Elev Ang-diam           delta      deldot
 ******************************************************************************************************************
 $$SOE
  2017-Aug-21 17:40 *m  10 04 22.95 +11 43 26.0 136.4350  50.9208 1959.858 3.6570582616E+05  -0.1324607
  2017-Aug-21 17:41 *m  10 04 24.42 +11 43 18.0 136.7641  51.0407 1959.901 3.6569792472E+05  -0.1309203
  2017-Aug-21 17:42 *m  10 04 25.90 +11 43 09.9 137.0949  51.1599 1959.943 3.6569011581E+05  -0.1293766
  2017-Aug-21 17:43 *m  10 04 27.37 +11 43 01.8 137.4271  51.2783 1959.984 3.6568239962E+05  -0.1278296
  2017-Aug-21 17:44 *m  10 04 28.84 +11 42 53.8 137.7610  51.3960 1960.025 3.6567477634E+05  -0.1262794
  2017-Aug-21 17:45 *m  10 04 30.31 +11 42 45.7 138.0964  51.5128 1960.065 3.6566724617E+05  -0.1247260
  2017-Aug-21 17:46 *m  10 04 31.78 +11 42 37.6 138.4334  51.6290 1960.105 3.6565980930E+05  -0.1231693
  2017-Aug-21 17:47 *m  10 04 33.25 +11 42 29.5 138.7720  51.7443 1960.144 3.6565246592E+05  -0.1216096
  2017-Aug-21 17:48 *m  10 04 34.71 +11 42 21.4 139.1121  51.8588 1960.183 3.6564521623E+05  -0.1200466
  2017-Aug-21 17:49 *m  10 04 36.17 +11 42 13.2 139.4539  51.9726 1960.222 3.6563806040E+05  -0.1184806
  2017-Aug-21 17:50 *m  10 04 37.64 +11 42 05.1 139.7972  52.0855 1960.260 3.6563099863E+05  -0.1169115
 $$EOE
 ******************************************************************************************************************
```

```
Column meaning:

TIME

  Prior to 1962, times are UT1. Dates thereafter are UTC. Any 'b' symbol in
the 1st-column denotes a B.C. date. First-column blank (" ") denotes an A.D.
date. Calendar dates prior to 1582-Oct-15 are in the Julian calendar system.
Later calendar dates are in the Gregorian system.

  Time tags refer to the same instant throughout the solar system, regardless
of where the observer is located. For example, if an observation from the
surface of another body has an output time-tag of 12:31:00 UTC, an Earth-based
time-scale, it refers to the instant on that body simultaneous to 12:31:00 UTC
on Earth.

  The Barycentric Dynamical Time scale (TDB) is used internally as defined by
the planetary equations of motion. Conversion between TDB and the selected
non-uniform UT output time-scale has not been determined for UTC times after
the next July or January 1st. The last known leap-second is used as a constant
over future intervals.

  NOTE: "n.a." in output means quantity "not available" at the print-time.

SOLAR PRESENCE (OBSERVING SITE)
  Time tag is followed by a blank, then a solar-presence symbol:

        '*'  Daylight (refracted solar upper-limb on or above apparent horizon)
        'C'  Civil twilight/dawn
        'N'  Nautical twilight/dawn
        'A'  Astronomical twilight/dawn
        ' '  Night OR geocentric ephemeris

LUNAR PRESENCE WITH TARGET RISE/TRANSIT/SET MARKER (OBSERVING SITE)
  The solar-presence symbol is immediately followed by another marker symbol:

        'm'  Refracted upper-limb of Moon on or above apparent horizon
        ' '  Refracted upper-limb of Moon below apparent horizon OR geocentric
        'r'  Rise    (target body on or above cut-off RTS elevation)
        't'  Transit (target body at or past local maximum RTS elevation)
        's'  Set     (target body on or below cut-off RTS elevation)

RTS MARKERS (TVH)
  Rise and set are with respect to the reference ellipsoid true visual horizon
defined by the elevation cut-off angle. Horizon dip and yellow-light refraction
(Earth only) are considered. Accuracy is < or = to twice the requested search
step-size.

 R.A._(a-apparent)__DEC. =
   Airless apparent right ascension and declination of the target center with
respect to the Earth true-equator and the meridian containing the Earth true
equinox of date.  Adjusted for light-time, gravitational deflection of light,
stellar aberration, precession & nutation.
   Units: HMS (HH MM SS.ff) and DMS (DD MM SS.f)

 Azi_(a-appr)_Elev =
   Airless apparent azimuth and elevation of target center. Adjusted for
light-time, the gravitational deflection of light, stellar aberration,
precession and nutation. Azimuth measured North(0) -> East(90) -> South(180) ->
West(270) -> North (360). Elevation is with respect to plane perpendicular
to local zenith direction.  TOPOCENTRIC ONLY. Units: DEGREES

 Ang-diam =
   The equatorial angular width of the target body full disk, if it were
fully visible to the observer.  Units: ARCSECONDS

 delta  deldot =
```

```
   Range ("delta") and range-rate ("delta-dot") of the target center relative
to the observer at the instant light seen by the observer at print-time would
have left the target center (print-time minus down-leg light-time); the
distance traveled by a light ray emanating from the center of the target and
recorded by the observer at print-time. "deldot" is a projection of the
velocity vector along this ray, the light-time-corrected line-of-sight from
the coordinate center, and indicates relative motion. A positive "deldot" means
the target center is moving away from the observer (coordinate center). A
negative "deldot" means the target center is moving toward the observer.
Units: KM and KM/S


 Computations by ...
     Solar System Dynamics Group, Horizons On-Line Ephemeris System
     4800 Oak Grove Drive, Jet Propulsion Laboratory
     Pasadena, CA  91109   USA
     Information: http://ssd.jpl.nasa.gov/
     Connect    : telnet://ssd.jpl.nasa.gov:6775  (via browser)
                  telnet ssd.jpl.nasa.gov 6775    (via command-line)
     Author     : Jon.Giorgini@jpl.nasa.gov

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Dale Mais
Robert Buchheim

Sponsor Liaison:
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SASLiaisons@gmail.com

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SAS Contact Information

9302 Pittsburgh Avenue, Suite 200, Rancho Cucamonga, CA 91730

On the web:
www.SocAstroSci.org

Program Committee:
program@SocAstroSci.org

Membership:
Robert Stephens:
rstephens@socastrosci.com

Newsletter:
dmais@socastrosci.com
Bob@RKBuchheim.org