Totality at PARI: campus prepares for total solar eclipse

In addition to the campus preparations, PARI spokesmen have been traveling throughout Western North Carolina helping local groups prepare for the Eclipse. Shown here, representatives from local schools, businesses and organizations gather at the Transylvania County Library, for a workshop sponsored by the TC Tourism Development Authority. PARI representatives presented facts about the eclipse and how to maximize the experience.

PARI will be front and center for the upcoming total solar eclipse, a once-in-a-lifetime celestial event that is bringing national attention to the campus.

The eclipse will traverse the United States August 21, the first total solar eclipse in the continental U.S. in 38 years and the first to cross the entire country in 99 years. PARI will lie in the path of totality, that 70-mile swath that will see the Moon totally block all the Sun’s...
**Totality at PARI (continued)**

rays and reveal the Corona, which is only visible during a total solar eclipse. Totality at PARI will begin at 2:36:44 and last for one minute and 47 seconds.

It will be the first time in history a total solar eclipse has passed over an array of sophisticated radio telescopes like those at PARI: two 26m (85 ft.) instruments, a 12m and a 4.6m radio telescope. Researchers will be using these instruments to conduct scientific studies never before possible. NASA is sending two teams of researchers to PARI. One will collect data from a high altitude balloon and the other will use kites to collect novel meteorological observations.

More than 300 amateur astronomers will be at the site, including 80 from Italy. They will be part of a crowd of up to 1,000 that will include dignitaries, invited guests and news media. Several hundred tickets were made available to the general public via the PARI website and they sold out within weeks.

Totality will be the centerpiece of an all-day festival at PARI. Event activities will include researcher interpretations by NASA and others, meteorite demonstrations, a Moon Tree planting and dedication, project demonstrations, tours, food trucks, merchandise sales, music and entertainment.

**Marketing Director added to PARI staff**

PARI’s growth and expansion plans took a major step forward this spring with the hiring of our first full-time marketing director, Chris Price, shown here examining a mineral case in PARI’s Exhibit Gallery with President Don Cline. Chris is charged with managing PARI’s brand, planning and developing programs to achieve our stated goals, and fostering a marketing-oriented culture among PARI department heads and staff.

The hiring was the result of an intensive search that resulted in 135 applicants for the position. Chris comes to PARI with an extensive marketing background, including recent marketing roles at DEDON Inc. in Greensboro, and Steelcase Inc. in High Point. He has an MBA from Lynn University in Boca Raton, FL, and an undergraduate degree in graphics/commercial design from Marshall University.

Chris has already settled in Brevard with his wife and two daughters.
Redstone rocket engine on display at PARI

One of the newest additions to the PARI campus, and a popular attraction at the recent Space Day, is a Redstone rocket engine donated by the Museum of Life and Science in Durham through the efforts of PARI Board Member Mike Murphy.

The Redstone was NASA’s workhorse in the early days of the U.S. space program and carried our first astronauts into space. The Redstone is also intrinsically linked to the PARI site because many of the satellites it carried into orbit transmitted their signals to the Rosman Research Station, the original occupant of the PARI campus.

SkyTrek explores the night sky

One of PARI’s newest public attractions is rapidly becoming a favorite. Public stargazing programs have been offered on campus periodically over the years and have always been popular, so beginning this winter PARI began offering SkyTrek observing on a regular basis to see if demand would remain constant.

To date, the answer is a resounding YES. SkyTrek sessions are now offered Friday and Saturday the first and third weekends of the month. Overcast skies have caused several cancellations, but for the sessions that took place attendance is averaging more than 30 people per session. SkyTrek is now scheduled through the summer and we anticipate making it a continuing feature of PARI’s public outreach.

Everyone is welcome, so to check the schedule and register (see the Event Calendar on the PARI website).
A group of students visiting PARI from Furman University showed off their creativity by spelling words with their mobile phones and capturing the results with timed-exposure photos.

The students are members of the Furman Astronomy Club and were brought to PARI by Dr. Dave Moffett, Furman Physics Chair and a long-time research associate at PARI. The students spent the night on campus and were treated to a campus tour, demonstrations of the 26m and 12m radio telescopes and celestial observations with PARI’s optical telescopes.

During the visit it was obvious to all that the students also mastered a simple equation: Furman + PARI= fun.

**NC A&T students experience a PARI weekend**

Six students from North Carolina A&T, shown here with PARI Research Director Ben Goldsmith, were treated to a PARI visit as part of a NSF IUSE-funded program at the university.

The students arrived on a Friday afternoon, attended an Evening at PARI program and then went to the optical ridge for an observing session. They stayed overnight on campus then spent Saturday on an instrumentation tour, plus a special AdventureDome presentation.
**PARI profile: Lebby Moran**

In recent months visitors to the PARI campus have been greeted by Lebby Moran at the front desk in the Cline Administration Building. A graduate of George Mason University with an astronomy degree, Lebby is now moving on to her true passion with a promotion to astronomy educator.

During the summer she will be working in the PARI education department with camps and other group visits. In the fall she will be leading new education programs that will be announced at the end of summer.

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**PARI site honored with historical marker**

The North Carolina Department of Cultural Resources recently placed a historical marker on US 64 to honor the historical significance of the Rosman Tracking Station, established by NASA in the pioneering days of the U.S. space program as the primary East Coast satellite tracking facility.

NASA operated the facility until it was transferred to the Department of Defense in 1981. PARI was established as a non-profit science center in 1998 and took occupancy of the 200-acre campus the following year. The new marker is only the second historical marker in the state associated with NASA. The other is near the Morehead Planetarium at UNC-Chapel Hill, and commemorates NASA training.

Shown here during the dedication ceremonies are Ken Steiner and Alex Armstrong from PARI, and Michael Hill representing NC Historic Preservation. The marker is located on US 64, just south of Pickens Road, west of Rosman.
Summertime at PARI is virtually non-stop activity and the upcoming season promises to be our busiest yet.

The anchor program, as it has been for 16 consecutive years, is Duke TIP (Talent Identification Program). This year the campus will host two sessions of Duke TIP’s Summer Field Study in Astronomy, Physics and Astrobiology. In each session, 30 students will spend two weeks at PARI exploring astrophysics, stellar and galactic astronomy, astrobiology and astronomical instrumentation. Students come from across the country to conduct original research under the direction of PARI astronomers and Duke TIP staff.

A teacher development opportunity called Crytoclub will also take center stage at PARI. The National Girls Collaborative and NSF developed Crytoclub and selected PARI and the NC Girls STEM Collaborative as one of nine hub sites in the U.S. PARI’s Christi Whitworth and Tim DeLisle have been certified as trainers for the cryptography and mathematics program and will begin offering training to teachers at PARI in June.

PARI will also be hosting workshops for local educators and businesses planning events for the upcoming total solar eclipse. The workshops will focus on hosting a safe and educational event with tools developed in conjunction with the Morehead Planetarium and Science Center under a grant from NC Space Grant.

Of course, our regular public offerings such as Evening at PARI, SkyTrek and weekly docent-led campus tours will continue all summer. And, there’s more to come: with expanded staff now available, PARI’s education department is planning to host school and camp groups throughout the summer.

For a complete listing of programs, activities, schedules and visitation opportunities, see the Event Calendar on the PARI website.
**Homeschool students learn about the total solar eclipse**

Students being schooled at home were treated to a special day of learning about the upcoming total solar eclipse. The August 21 event is being called by many a “once-in-a-lifetime” experience, so it was a natural fit for PARI’s Spring Homeschool Day.

PARI astronomers and educators designed and taught grade-appropriate (K-2, 3-5, 6-8 and 9-12) modules on the eclipse, explaining the conditions that have to occur and how to safely view an eclipse with glasses and other devices. The Adventure-Dome planetarium was used to demonstrate past eclipses.

PARI conducts Homeschool Days each spring and fall, each time developing a new educational experience.

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**PARI receives Science Museum grant**

PARI has been awarded a $61,913 grant from the N.C. Science Museums Grant Program. The grant program was established by the N.C. legislature to provide funding for the 41 institutions included in the N.C Science Museums Network.

The N.C. Science Museums Network is the successor to the N.C. Grassroots Science Museums Collaborative. PARI was an active member of the Collaborative and is currently engaged in initiatives within the Science Museums Network to encourage collaboration and resource sharing among the museums to promote and advance STEM education.

Shown in this photo, visitors enjoy a trip to the meteorites and minerals section of PARI’s Exhibit Gallery housed in the Cline Administration Building. The Gallery also includes Space Shuttle artifacts, a collection of space program memorabilia and periodic science-related art exhibits.
**Photo exhibit at PARI**

Visitors to PARI’s Exhibit Gallery this spring were treated to a limited-run exhibition of unique nature photographs by Alex Armstrong, professional photographer and long-time PARI volunteer.

Shown here, Alex explains to visitors how he created one of the works in his Ice Worlds series from the Eno River State Park.

Alex’s works are regularly featured at Blue Ridge Parkway Visitor Centers, the Pisgah Conservancy and a number of historic sites in North Carolina. He is also known for his technical archival photography of historical artifacts and has been a multi-level contributor to the Smithsonian Institution (Museum of History, Numismatics, Preservation).

If you missed the exhibit you will find examples of Alex’s work in this newsletter’s **PARI in Pictures** feature.
PARI in Pictures

Friends of PARI Volunteer Alex Armstrong is a professional photographer who graciously provides stunning photos taken at PARI for our literature and public outreach. Here are a few of his recent works.
Since the last newsletter, the PARI research department has kicked off FY-2017 with enthusiasm. Finalizing the 2017 budget was accomplished in early January. We submitted four grants and have been awarded three. PARI President Don Cline and Lead Scientist Mike Castelaz attended the American Astronomical Society (AAS) meeting held in Grapevine, TX in January. Ben Goldsmith attended the Satellite 2017 conference held in Washington DC the first week in March. We have hosted two university groups for weekend workshops.

**Grants**

Dr. Mike Castelaz has been successful in winning three grants for PARI and has submitted another that we feel we are a strong candidate for the award.

Dunham Grant – this grant provides PARI with radio telescope technology that will be fitted on all four of our radio telescopes and will be used to study the sun during the August 21, 2017 total eclipse.

ERGO grant – this grant provides PARI with a cosmic ray sensor and software that connects to an international study to measure the intensity of cosmic rays.

ROVERS – this is a joint grant between PARI and Brevard College to acquire two ground rovers and one submersible rover for studies in the use of remote controllable robots for a number of tasks but primarily in the collection and monitoring of environmental data.

CLIR – this grant has been submitted but not yet awarded. CLIR would provide PARI with money to hire archivists to digitize a collection of 2800 plates in the Nancy Hank Collection in our Astronomical Photographic Data Archive (APDA).

**Instruments and Systems**

**Smiley Radio Telescope**

Smiley motors and drives were ordered and have arrived at PARI. The new Smiley control room has been prepared. Racks and lab benches have been installed, along with power and networking capabilities.

**Programs**

**Astronomical Photographic Data Archive (APDA)**

A new APDA storage area has been completed in the research building basement. This will be the home of the 100,000-plate Yale donation as well as thousands of additional plates.
Meetings

- PARI President, Don Cline and Lead Scientist, Dr. Mike Castelaz attended the AAS meeting in Texas in January.
- Research Director Ben Goldsmith attended the Satellite 2017 conference in Washington.
- The research director and lead scientist are in meetings with a collaboration to include NASA, NOAA, the CDC and other national entities to take the lead on a public service announcement warning the public about the dangers of observing the solar eclipse with the unaided eye.

Accomplishments

- The research department has completed several tasks since the beginning of the year to include:
- Completing the inventory process for thousands of items donated to us by CagleSight and with that done, the fiber optic cable and equipment can be sold.
- Intern announcements and selection – PARI had a tremendous response to our internship announcements this year and we have selected our top picks for the summer.
- Bounded projects – in response to our area university partners, the research department is spearheading an initiative to offer students in the area a set of bounded projects we prefer to call missions, that will give students invaluable hands on experience in a working science and education center.
- Hosted groups from Furman University and NCA&T for weekend workshops and tours.

Total Solar Eclipse

PARI is moving closer to the August eclipse and we will be hosting our research partners in the coming weeks and months for site surveys and rehearsals.

We have just received confirmation that we will have Dr. Elizabeth MacDonald on the campus from NASA to give a presentation on the topic of the eclipse and to be available for media interviews.

Brad McCall of the PARI facilities staff is shown here cleaning the 26 East radio telescope. The reflector will be repainted in preparation for the eclipse.
Future Plans

The research department will move forward in a number of ways to include:

- Acquiring equipment needed for instruments over the summer.
- Getting our interns on board and underway to improve instruments for the solar eclipse, to support education during summer sessions and to work to improve IT.
- Continue planning and testing our observing methods with our optical and radio telescopes for the August solar eclipse.
- Receive research partners for site surveys ahead of the eclipse.
- Continue building collaborations and partnerships with universities and commercial entities.
- Release the bounded project missions to our university partners and make preparations for their students to conduct the missions.
Eclipse of a Lifetime!

The Science of Solar Eclipses

In the previous column on solar eclipses we saw that eclipses are very predictable even in historical times. We looked at the prerequisites for an eclipse to occur and be visible from our observing location:

1. **The phase of the moon must be new.** The moon always has a shadow. (After all, it is a solid body.) But, unless the moon is passing on the line between the sun and earth, its shadow will not touch the earth.

2. **The moon must be near a node of its orbit.** Since the moon’s orbit is tilted about 5° from the plane of the earth’s orbit, called the ecliptic, it spends half of its orbit (half a month) above the plane of the ecliptic and half a month below. Usually, when the moon comes to new moon, it will be above or below the ecliptic and we will have no solar eclipse (since the moon’s shadow will miss the earth above or below).

Here the moon is on line with the sun but it is below the ecliptic. Thus, its shadow will be below the earth and there will be no solar eclipse. Graphic by the author, PARI
The August 21, 2017 Total Solar Eclipse (Continued)

The nodes of the moon's orbit are the points at which the moon's orbit passes through the ecliptic, on one side going up (ascending node) and on the other going down (descending node). Thus, the moon will be in the plane of the ecliptic during a new moon only if the nodes are close to being directly on line with the sun.

What constitutes “close” to being directly on line with the sun? Without getting into the complicated geometry, let me just say “close” is 18°. Since the earth (and, thus, the sun-earth line) moves 1° per day in its orbit, this translates into 18 days. In other words, if the moon comes to new moon within 18 days of passing through a node of its orbit, there will be a solar eclipse somewhere on the earth. Otherwise, its shadow misses the earth and there is no eclipse.

The 36-day period (18 days before and after the node) is called a solar eclipse season. Since it takes the moon 29½ days to go from new moon back to new moon, the moon must pass through new moon sometime within the 36-day eclipse season when it is close enough to a node for a solar eclipse to occur. We must have a solar eclipse, and we could have two, in each eclipse season!

Now, remember there are two nodes, an ascending one and a descending one. They are on the opposite sides of the moon's orbit. As the earth orbits the sun, the line of nodes will line up with the sun twice per year and we have two solar eclipse seasons in a calendar year. Thus, we must have two solar eclipses every calendar year and we could have four.

Now that you have that figured out, here is a complication for which we won’t go into detail. It turns out that the moon’s orbit slips backwards about 19° per year so that the eclipse seasons are not exactly six months apart. We call this the regression of the nodes. This effect causes successive solar eclipse seasons to occur about 9 days less than six months apart. What that means is that in a calendar year we could have two 36-day solar eclipse seasons and one partial eclipse season in a calendar year. It works out that we could have as many as five solar eclipses somewhere on earth in a calendar year. Some may be only partial eclipses that only penguins or polar bears see...but they count. One of those is February 15, 2018. (See Appendix B.)

In 2017 there was an annular solar eclipse on February 26. (Penguins throughout the south Atlantic and Antarctica enjoyed at least the partial phases of that one.) That means there has to be another solar eclipse perhaps a few days less than six months later...Bingo! A total solar eclipse on August 21!

3. The observer must be located on the earth where the moon's shadow will fall. (Obviously, you must be on the side of the earth facing the sun.) This means you can only observe a solar eclipse when it is daytime! You must be at a latitude where the moon’s shadow will touch the earth. This will be determined by how far above or below the ecliptic the moon is. Remember it doesn't have to be exactly at the node of its orbit; it just has to be “close.” Also, the latitude (and longitude) where the shadow touches down will change as a) the earth rotates and b) the moon moves in its orbit.
4. **The weather must be clear!** That’s the big concern for all observers as they consider where to go to observe a given eclipse. Obviously, projections regarding likely weather conditions can be made even years ahead. But, the weather at a given spot on the earth at a given time of the eclipse day has a large amount of luck engrained in it.

So, let’s look at the Eclipse of a Lifetime coming up. Are these conditions going to be satisfied?

On August 21, 2017, the shadow of the moon will hit North America including PARI because . . .

1. New moon is at 2:30 p.m. EDT that day.
2. The moon passes through the ascending node of its orbit at 6:36 a.m. EDT (only 7 hours 54 minutes before new moon).
3. The western hemisphere will be in daytime and the northern hemisphere will be tilted towards the sun it being our summer. At PARI the longitude is 82.88° W and latitude is 35.20° N.
4. The weather will be clear all along the path of totality! (Just hoping!! Average weather in PARI’s area in mid-August is about 54% sunshine. (See Appendix B.)

Now that we’ve established that the conditions are right (except possible the weather, unfortunately) for viewing a total solar eclipse on Monday, August 21, 2017, let’s take a look at what is happening. Remember that there are three things that will determine where the path of totality will be:

- The revolution of the earth around the sun will be the primary motion to determine that the earth is lined up with one of the two nodes of the moon’s orbit and which hemisphere is tilted towards the sun and how much.
- The revolution of the moon around the earth will determine where the moon will be with respect to that node.
- The rotation of the earth on its axis will determine which side of the earth is facing the sun.

The map below shows the complete path of the eclipse. The areas under the dark blue/orange strip are the areas of totality, i.e., where the sun will be completely hidden behind the moon. The lighter bands on either side of the path of totality are the areas where the sun will be partially hidden behind the moon. The closer to the path of totality, the more of the sun that will be hidden.

We can see that the eclipse actually begins in the north Pacific Ocean about 1500 miles west of North America. That happens at 12:49 p.m. EDT.
Then, moving eastward it first touches the coast near Government Point, Oregon at 1:15:56 p.m. EDT (10:15:56 a.m. PDT) where totality will last 1 minute 58.5 seconds.


During its journey across the continental United States, the dark umbra of the moon’s shadow will average 68 miles in diameter. However, at the point of greatest eclipse at latitude 36° 58.0” N and longitude 87° 40.2’ W the width of the shadow will be 71.3 miles across and totality will last 2 minutes 40.1 sec. This is a point about halfway between Paducah and Hopkinsville, KY. There, the shadow of the moon is closest to being in line with the center of the earth and, thus, the earth is deepest within the umbra of the moon’s shadow. However, viewers located a bit to the west of that will actually see totality for a whole tenth of a second longer since that is the location where all those motions mentioned above conspire to slow the motion of the shadow slightly. What is that speed? The moon’s shadow will move an average of 2288 miles per hour along the path of totality.
What about those of us observing from western North Carolina? The map above shows the path of totality through our area. As you can see Brevard is just within the path of totality while Waynesville and Asheville are just outside. The following table gives us the data for points of interest in western North Carolina and South Carolina as calculated by the US Naval Observatory:

<table>
<thead>
<tr>
<th></th>
<th>PARI</th>
<th>Brevard</th>
<th>Asheville</th>
<th>Waynesville</th>
<th>Greenville SC</th>
<th>Charleston SC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eclipse begins (EDT)</td>
<td>1:07:49.5</td>
<td>1:08:06.8</td>
<td>1:08:12.0</td>
<td>1:07:16.8</td>
<td>1:09:14.4</td>
<td>1:16:52.1</td>
</tr>
<tr>
<td>Totality begins (EDT)</td>
<td>2:36:44.0</td>
<td>2:37:14.8</td>
<td>Na</td>
<td>Na</td>
<td>2:38:00.7</td>
<td>2:46:12.0</td>
</tr>
<tr>
<td>Maximum eclipse (EDT)</td>
<td>2:37:36.7</td>
<td>2:37:50.7</td>
<td>2:37:39.9</td>
<td>2:36:52.7</td>
<td>2:39:06.3</td>
<td>2:47:02.4</td>
</tr>
<tr>
<td>Duration of totality</td>
<td>1m 47.0s</td>
<td>1m 13.6s</td>
<td>0m 0s</td>
<td>0m 0s</td>
<td>2m 12.7s</td>
<td>1m 42.5s</td>
</tr>
<tr>
<td>Eclipse ends (EDT)</td>
<td>4:01:35.0</td>
<td>4:01:43.7</td>
<td>4:00:19.8</td>
<td>4:00:47.9</td>
<td>4:02:54.2</td>
<td>4:09:52.9</td>
</tr>
<tr>
<td>Duration of eclipse</td>
<td>2h 53m 45.5s</td>
<td>2h 53m 36.8s</td>
<td>2h 53m 07.8s</td>
<td>2h 53m 31.1s</td>
<td>2h 53m 39.8s</td>
<td>2h 53m 00.8s</td>
</tr>
<tr>
<td>Obscuration</td>
<td>100.0%</td>
<td>100.0%</td>
<td>99.3%</td>
<td>99.8%</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>
The August 21, 2017 Total Solar Eclipse (Continued)

The Progression of the Eclipse

With the above information in mind, let's look at the progression of the eclipse. Put your eclipse glasses on and follow me.

• Eclipse begins: The time at which the observer first notices a dark notch appearing in the western side of the sun. We are looking at the dark side of the moon, of course, so we are seeing a dark moon coming between us and the very bright sun. (Did I remind you to have your eclipse glasses on?) This image is the one on the right above. Gradually more and more of the sun will be obscured by the passing moon. It will get darker and cooler at our observing site. Notice wildlife that might be fooled by this effect; some nocturnal wildlife may come out of their hiding places. Birds may go to nest. Just before totality we may see a ring of bright spots of sunlight shining around the moon. These Bailey’s beads come from sunlight passing through valleys around the edge of the moon. Then, these will disappear and a single point of light may remain on the left/east edge of the moon. This is due to the final piece of the sun shining through a valley on the edge of the moon and, for obvious reasons, it is dubbed the “diamond ring effect.” Very quickly the diamond will disappear (Sorry, Girls!) and . . .

• Totality begins if you are at PARI or in Brevard, Greenville or any place else in the path of totality. You may remove your eclipse glasses until just before the diamond ring appears on the right/west side of the moon signifying that totality is over and you must protect your eyes once again.

• Totality does NOT begin if you are in Asheville, Waynesville or any other place outside the path of totality; you will never enter totality. You will see a maximum obscuration as indicated in the table. Careful! Even though you are seeing less than 1% of the sun’s surface and it doesn’t dazzle you as much as the sun itself, that 1% still has an intensity bright enough to damage your eyes. Keep your eclipse glasses on!

• Totality ends with the reappearance of the sun on the right/west side of the moon. We may or may not see a diamond ring. Eclipse glasses must be used as in the phases leading up to totality. You have now seen the Eclipse of a Lifetime!
**Safety**

There are basically two safe ways of viewing the partial phases of any solar eclipse:

**Solar filters:** The first would be to put a professionally engineered filter between the sun and the retinalae of your eyes. The simplest and cheapest way of doing this is to don a pair of eclipse glasses or use eclipse viewer cards commonly available online or in the giftshops of many museums and other public venues such as PARI. There are three manufacturers who have met international standards for these: Rainbow Symphony, American Paper Optics and Thousand Oaks.

Persons using telescopes will place specially made filters over the objective lens or primary mirror of their telescopes. Use of eyepiece filters that might have come with an older telescope is not recommended as they tend to heat up. However, NASA does endorse use of welder’s glass #14 or darker.

**Projection:** A second way to view the sun safely is to project an image onto a flat light surface. It is perfectly safe to look at the image that way. The most common homemade device for this is a pinhole camera. This can be constructed by taking any flat card and putting a sharp pinhole in it. Usually, this works best by cutting a hole in a piece of cardboard, taping a piece of aluminum foil over the hole, and then poking a neat hole in the foil with a pin or other small sharp object. Then hold the board up so that the sun shines through it onto a smooth light surface such as a piece of white paper. **Caution: DO NOT look through the pinhole at the sun.**

A second way to use projection is to use a small telescope or pair of binoculars to project an image onto a light colored flat screen. Point the telescope at the sun using its shadow to aim it and project the image out of the eyepiece onto the screen. **DO NOT look at the sun through the eyepiece of the telescope.**

In all cases, **watch the children carefully.** Be sure they have their eclipse glasses correctly positioned on their faces. Don’t let them look through the pinhole or the eyepiece—very tempting.
Eclipse Activities

Several phenomena may be observed before, during and after the 1-2 minutes of totality:

- **Stars and Planets:** Perhaps the most fun thing to do during the period of totality (the only time you can remove your eclipse glasses) is to look for planets and bright stars in the vicinity of the totally eclipsed sun.

![Starchart from TheSkyX software program. Copied with permission from Software Bisque. Caveat: You will not see these lines and planet and constellation labels in the sky during totality!](image)

Above is the portion of the sky surrounding the sun at 1:37 p.m. EDT on August 21. You’ll note the sun and moon together (or there wouldn’t be an eclipse) right below the famous “sickle” that forms the head, mane and chest of Leo the lion. It fact, Regulus, the brightest star in Leo is covered by the “Moon” label on this chart and will probably be too close even to the eclipsed sun to be observed.

However, there are four naked-eye planets in the sky during this eclipse. Note Venus, the brightest of all the planets in the eastern edge of Gemini the twins. The two stars above Venus may be visible during totality; they are the twins, Pollux and Castor. Down to the east of Cancer in front of the lion is the red planet Mars. Mars is much fainter than Venus and is closer to the eclipsed sun but may still be visible. Below the sun and moon we may spot the elusive planet Mercury. And, farther to the east in Virgo is the second brightest planet, the giant Jupiter. Just below Jupiter is the bright star Spica, the brightest in Virgo.
The August 21, 2017 Total Solar Eclipse (Continued)

- 3-D Printed Pinhole Cards: NASA has a neat activity designed to personalize this concept for your home state ...

![3-D Printed Pinhole Cards image]

- Tree shadows: A beautiful phenomenon to observe during the partial phases is tree shadows. What is happening here is the gaps among the leaves of a tree are serving as nature’s pin-hole cameras and forming many images of the partially eclipsed sun. Find a place where the shadow of a tree if falling on a smooth piece of ground or on a clean vertical wall and look for these shadows. There are many of these posted YouTube such as https://www.youtube.com/watch?v=i_L1xiy5260. So, if you have a video camera, here’s your chance for fame on YouTube!

- NASA has many other ideas at https://eclipse2017.nasa.gov/citizen-explorers
The August 21, 2017 Total Solar Eclipse (Continued)

The Grand Finality

While people in western North Carolina and upstate South Carolina are beginning to pack up their gear, the eclipse finishes up by visiting the low country of South Carolina and then finishes out in the North Atlantic Ocean. From our table, we see that totality in Charleston ends at 2:48 p.m. EDT after 1 minute 43 seconds of totality. The shadow of the moon leaves the coast a minute later and spends another 75 minutes traveling another 2600 miles before lifting off the surface of the ocean and ending at 4:02 p.m. EDT. Partial phases continue until 4:10 p.m. EDT.

So, look forward to the Eclipse of a Lifetime on the afternoon of August 21 in the Carolinas. Mark your calendars NOW!

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Time and Date:  http://timeanddate.com

The August 21, 2017 Total Solar Eclipse (Continued)

Appendix A: Resources for Eclipse Watchers

http://www.pari.edu/things-to-do/2017-eclipse/ Of course, PARI has a webpage on the upcoming eclipse! And, not to be outdone by NASA, the original owner of PARI’s campus, we’ve got our own countdown clock! PARI’s main eclipse page includes basic information on the eclipse, as seen from PARI and links to PARI’s fact sheet, FAQ’s on the eclipse itself, Science and history of solar eclipses and Safety and security.

https://eclipse2017.nasa.gov NASA’s main page on the eclipse includes links to pages Science, Safety, Public Engagement, Citizen Science, Education and Events. It also includes a countdown clock until first contact in Oregon of the Eclipse of a Lifetime.

https://eclipse.aas.org/ The American Astronomical Society’s Solar Eclipse Across America page includes links to “Eclipse America,” Eye safety, Imaging & video, Resources, FAQ’s, Events & activities, Grants program and other information. Of critical importance is a downloadable one page printable sheet on How to View the 2017 Solar Eclipse Safely, great for teachers and other group leaders:


http://www.mreclipse.com/ The main page of Fred Espenak, a.k.a. Mr. Eclipse. Espenak, a retired NASA astrophysicist, author, photographer, speaker and blogger is undoubtedly recognized as the world’s top expert on eclipses. This main page includes links to just about anything you would want to know about eclipses and especially the Eclipse of a Lifetime.


### The Eclipse of a Lifetime – August 21, 2017

<table>
<thead>
<tr>
<th>Event</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Totality begins in northern Pacific Ocean</td>
<td>12:49 p.m. EDT</td>
</tr>
<tr>
<td>Totality reaches land in Oregon</td>
<td>1:16 p.m. EDT</td>
</tr>
<tr>
<td>New moon</td>
<td>2:30 p.m. EDT</td>
</tr>
<tr>
<td>Totality leaves land in South Carolina</td>
<td>2:49 p.m. EDT</td>
</tr>
<tr>
<td>Number of states with stretches of totality</td>
<td>14</td>
</tr>
<tr>
<td>Number of states with areas of partial eclipse</td>
<td>50</td>
</tr>
<tr>
<td>Totality ends in north Atlantic Ocean</td>
<td>4:02 p.m. EDT</td>
</tr>
<tr>
<td>Average width of the umbra of the moon’s shadow</td>
<td>68 miles</td>
</tr>
<tr>
<td>Average speed of the umbra of the moon’s shadow over the ground</td>
<td>2288 mph</td>
</tr>
<tr>
<td>Asheville Airport: Average cloud cover</td>
<td>61%</td>
</tr>
<tr>
<td>Asheville Airport: Possible sunshine</td>
<td>54%</td>
</tr>
</tbody>
</table>

### Eclipses in General

<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Last total solar eclipse on American soil - Hawaii</td>
<td>July 11, 1991</td>
</tr>
<tr>
<td>Last total solar eclipse on the US mainland</td>
<td>February 26, 1979</td>
</tr>
<tr>
<td>Last total solar eclipse to sweep across the entire US mainland</td>
<td>June 8, 1918</td>
</tr>
<tr>
<td>Next total solar eclipse visible over the continental US</td>
<td>April 8, 2024</td>
</tr>
<tr>
<td>Next solar eclipse (partial over Antarctica)</td>
<td>February 15, 2018</td>
</tr>
<tr>
<td>Next total solar eclipse (over South Pacific, Chile, Argentina)</td>
<td>July 2, 2019</td>
</tr>
<tr>
<td>Minimum number of solar eclipses per calendar year</td>
<td>2</td>
</tr>
<tr>
<td>Maximum number of solar eclipses per calendar year</td>
<td>5</td>
</tr>
</tbody>
</table>

### Eclipse Food for Thought

<table>
<thead>
<tr>
<th>Event</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage of solar eclipses that occur at night</td>
<td>0.000000%</td>
</tr>
<tr>
<td>Most northern latitude from which to observe an eclipse</td>
<td>90°N</td>
</tr>
<tr>
<td>Most southern latitude from which to observe an eclipse</td>
<td>90°S</td>
</tr>
<tr>
<td>Apparent diameter of the sun as seen from the earth’s surface</td>
<td>Approx. ½°</td>
</tr>
<tr>
<td>Apparent diameter of the moon as seen from the earth’s surface</td>
<td>Approx. ½°</td>
</tr>
<tr>
<td>Eclipses 1776 – 2017 observed in front of the Big Dipper</td>
<td>none</td>
</tr>
</tbody>
</table>
Please support the PARI mission!

PARI is a public not-for-profit organization. Financially, we are dependent upon contributions and grants for our educational and research programs, and for the many operating expenses associated with maintaining the campus and our facilities.

If you have recently contributed, we thank you for your support. If not, please support PARI and our mission with a contribution. PARI is a public not-for-profit 501 (c)(3) and all donations are tax deductible to the full amount allowed by law.

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Your generosity in supporting PARI and our mission is appreciated and valued. Your gift will allow PARI to advance STEM learning, empower people of all ages to become more scientifically literate and encourage young learners to consider STEM careers.

Thank you for helping make all of this possible.

Pisgah Astronomical Research Institute
One PARI Drive, Rosman, NC 28772
Phone: (828) 862-5554 Fax: (828) 862-5877 Web: www.pari.edu

Don Cline President dcline@pari.edu
Chris Price Marketing Director cprice@pari.edu
Michael Castelaz, PhD Lead Scientist mcastelaz@pari.edu
Christi Whitworth Director of Learning Experiences cwhitworth@pari.edu
Bob Hayward, PhD Astronomer/Educator rhayward@pari.edu
Lamar Owen Chief Technology Officer lowen@pari.edu
Mark Krochmal IT Support Manager mkrochmal@pari.edu
Ben Goldsmith Research Director bgoldsmih@pari.edu
Thurburn Barker Director of APDA tbarker@pari.edu
John Avant Special Projects Consultant javant@pari.edu
Ann Daves Director of Finance, HR & Development adaves@pari.edu
Sarah Chappell Visitor Support/Volunteers schappell@pari.edu
Chelena Byrthe Visitor Services cbyrthe@pari.edu
Skip Bird Science Educator sbird@pari.edu
Lebby Moran Software Engineering Manager lmanor@pari.edu
Tim DeLisle Facilities Coordinator tdelisle@pari.edu
Donnie Curto Facilities/Security dcurto@pari.edu
Brad McCall Curator of Meteorites and Minerals bmccall@pari.edu
John Sinclair Facilities jsinclair@pari.edu
Timothy Owen Food Service & Housekeeping towen@pari.edu
Laura Owen Special Projects Consultant lauraowen@pari.edu
Ken Steiner Special Projects Consultant ksteiner@pari.edu

The Pisgah Astronomical Research Institute (PARI) is a public not-for-profit 501 (c)(3) organization established in 1998. Located in the Pisgah Forest 30 miles southwest of Asheville, NC, the PARI campus is a dark sky location for astronomy and was selected in 1962 by NASA as the site for one of the first U.S. satellite tracking facilities. Today, the 200 acre campus houses radio and optical telescopes, earth science instruments, 30 buildings, a fulltime staff and all the infrastructure necessary to support STEM (science, technology, engineering and math) education and research. PARI offers educational programs at all levels, from K-12 through post-graduate research. PARI is home to the Astronomical Photographic Data Archive and a member of the NC Grassroots Science Museums Collaborative.

PARI’s Exhibit Gallery displays a collection of rare meteorites as well as NASA Space Shuttle artifacts, many of which have flown in space. For more information about PARI and its programs, visit www.pari.edu. Follow PARI on Twitter at http://twitter.com/Astronomy_PARI. “Like” PARI on Facebook at www.facebook.com/Pisgah.Astronomical.Research.Institute.