SkyWAAtch

The Great Red Spot

John Paladini took this image of Jupiter using a Celestron 9.25” SCT and a ZAO color camera. Prominently featured in the image is Jupiter’s Great Red Spot.

The oval-shaped Great Red Spot is a persistent storm (anticyclonic vortex) in Jupiter’s Southern Equatorial Belt about 16,500 km in length. Recent research hypothesizes that the Spot’s color results the reaction of simple chemicals with sunlight in the planet's upper atmosphere.

In This Issue . . .

Events for April 2015

WAA April Lecture

"Astrobiology: the Search for the Conditions to Support Life in the Solar System,"
Friday April 10th, 7:30pm
Lienhard Lecture Hall,
Pace University Pleasantville, NY

Astrobiology is a recent field of study that seeks to look for life outside of the Earth. In a much more practical way, it is a search for conditions that can support life in our Solar System and in other solar systems that have been discovered during the past twenty years. Br. Novak has been collaborating with NASA's Astrobiology Institute located at the Goddard Space Flight Center in Greenbelt Maryland. This research group uses infrared spectrometers on ground-based telescope (NASA-IRTF, Keck II, VLT) to identify organic molecules in comets and the atmosphere of Mars. The talk will discuss these investigations and future plans to continue their "Search for Life."

Br. Robert Novak Ph.D. is a Professor of Physics and Chair of the Physics Department at Iona College. Br. Novak holds degrees in physics from Iona College (B.S., 1972), Stevens Institute of Technology (M.S., 1977), and Columbia University (M.Ph., Ph.D., 1980). Free and open to the public. Directions and Map.

Upcoming Lectures

Lienhard Lecture Hall,
Pace University Pleasantville, NY

Our May 1st speaker will be Dr. David W. Hogg, Professor of Physics and Data Science at New York University. Dr. Hogg's talk is entitled "How Rare are Earth-like Planets?" Free and open to the public.

Starway to Heaven

Saturday April 11th, 7:30 pm.
Ward Pound Ridge Reservation,
Cross River, NY

This is our scheduled Starway to Heaven observing date for April, weather permitting. Free and open to the public. The rain/cloud date is April 18th. **Note**: By attending our star parties you are subject to our rules and expectations as described here. Directions.

New Members. . .

Michael Hajjar - Scarsdale

Renewing Members. . .

Theresa C. Kratschmer - Yorktown Heights
Darryl Ciucci - Greenwich
Everett Dickson - White Plains
Beth Gelles - Scarsdale
John Benfatti - Bronx
Neil Roth - Somers
Jim Cobb - Tarrytown
Jon Gumowitz - White Plains

WAA's own Ann Cefola will present Furious Stardust: Poems of the Night Sky at the new planetarium at the Hudson River Museum on Sunday, April 26th at 3:30 p.m. Ann will read poems from her new book, *Face Painting in the Dark* (Dos Madres Press, 2014) against a spectacular backdrop of astrophotography from our own Doug Baum, the Hubble telescope and others. This unique event celebrates both National Poetry Month and National Astronomy Month. Hope to see you there!

Join WAA at NEAF, April 18-19th
Rockland Community College,
Suffern, NY

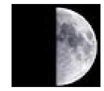
NEAF is one of the largest astronomy shows in the world. Besides the many equipment, book and supply vendors there are lectures and, weather cooperating, the Solar Star Party. WAA will again have a booth at NEAF and we hope you will donate an hour or more of your time to help man the booth. Meet and mingle with fellow WAA members and other astronomy enthusiasts from all over the country, express your enthusiasm for our hobby and have a place to leave your stuff. Put NEAF in your calendar now.

Almanac
For April 2015 by Bob Kelly


Apr 4


Apr 11


Apr 18


Apr 25

As we are well into the Daylight Time season, the dark time of night begins later in the evening hours. But the two brightest planets, from Earth's point of view, give us a head start on night sky watching.

As we learned at the Scarsdale school event in late March, look for Venus blazing in the western sky where the glow of sunset is visible, then look up and back over your left shoulder to find Jupiter, outstanding high in the southeast. They will be our evening partners for the next few months, visible soon after sunset. They may announce their engagement for late June or early July, so mark July 1st on your calendar or smartphone for the big event.

Mars and Mercury are low in the evening twilight later this month. It's almost as if Mercury comes out to escort Mars off the stage following its overextended twelve-month run in the evening sky. You'll need your opera glasses, at least, to see their exit.

Venus spotlights the winter star clusters as they make their exit for the season. Venus politely gives the Pleiades and Hyades clusters some room so as not to overshadow them as it passes by on the 10th-11th and 18th-19th, respectively. This courtesy is contagious as Jupiter pulls up 5 degrees short of the Beehive cluster in Cancer on the 8th, and then respectfully backs away to the east.

Venus is the closest planet to Earth in April, moving closer, getting larger but thinner. This contradiction is apparent in telescopes, as the planet looks larger, but its phase decreases to two-thirds sunlit by the end of April. This is easier to see during twilight, when Venus' glare is offset by the bright sky in front of it.

Jupiter's moons are still doing their amazing tricks, hiding behind each other and casting their shadows on each other and the planet. Two noticeable cover-ups occur on the evenings of the 12th and 18th.

I can't do poetry, so I can't wax poetic about the charms of Saturn. You'll just have to get up a bit earlier in the morning or stay up very late to see for yourself. Saturn tips its rings 25 degrees from our horizontal, as if tipping its hat before our closest approach in late May. Two-faced Iapetus is furthest west from Saturn around the 17th, showing the moon's brighter side at magnitude +10.1; dimming as it moves to the south of Saturn around the 30th.

The third of four total lunar eclipses without a partial eclipse between them starts at 6:16am EDT on the morning of Saturday the 4th. The bad news is the only folks in the USA to see the total eclipse will be in the west since here the Moon will set about 6:38 - four minutes after sunrise. The good news is you can try to make a hand puppet shadow on the Moon at sunrise when our shadow falls on the Moon (although your hands would have to be several hundred miles wide to show up at that distance). People in the Pacific who get to see the total eclipse have to look quickly since the Moon is completely in Earth's shadow only for about 10 minutes. The eclipse should be very colorful, with a large change in brightness across the Moon's disk.

If you are looking for the outer planets - Uranus and Neptune – no luck – they are in the Sun's glare. But you can track Uranus, moving from left to right in the SOHO space solar observatory's C3 camera from March 29th through April 15th. Mercury is easier to find, moving right to left against the starry background from April 2nd through 17th at magnitude minus 2. (See the complete list for 2015 at: http://sungrazer.nrl.navy.mil/index.php?p=transits/transits_2015 .)

The almost-full Moon points out Saturn in the morning on the 8th. There's a photo-op for any camera with the Moon, Venus, the Hyades and Pleiades on the evenings of the 20th and 21st. On the 19th, the 30-hour old Moon is low down with Mercury and Mars right after sunset.

One of our few spring meteor showers occurs before dawn on the 23rd. The Lyrid shower averages only a dozen or so per hour at its peak, but this is useful to know if you see a few more meteors than usual later this month.

Comet Lovejoy continues its encore performance arcing from Cassiopeia toward the North Star in April and May. It's a tiny smudge compared to earlier this year; but still findable as it fades through 8th magnitude.

The International Space Station overflights come to the evening sky from the 2nd through the 24th. On the ISS, Scott Kelly (no relation) begins his Year In Space with cosmonaut Mikhail Kornienko. Data from this rigorous study of long-term effects of space flight on the human body will be useful for surviving your trip to Mars. Figuring out how to stop once you get there will be useful, too. With a surface air pressure only 7% of Earth's, it's hard to use the Martian atmosphere for braking.

Mark your calendars in advance for these events in May:

- 6th: Mercury's best showing in the evening sky this year;
- 22nd: Saturn at opposition, our closest distance for the year;
- 20th, 27th: Shadows of two moons at once on Jupiter.

Earth Eclipse from ISS

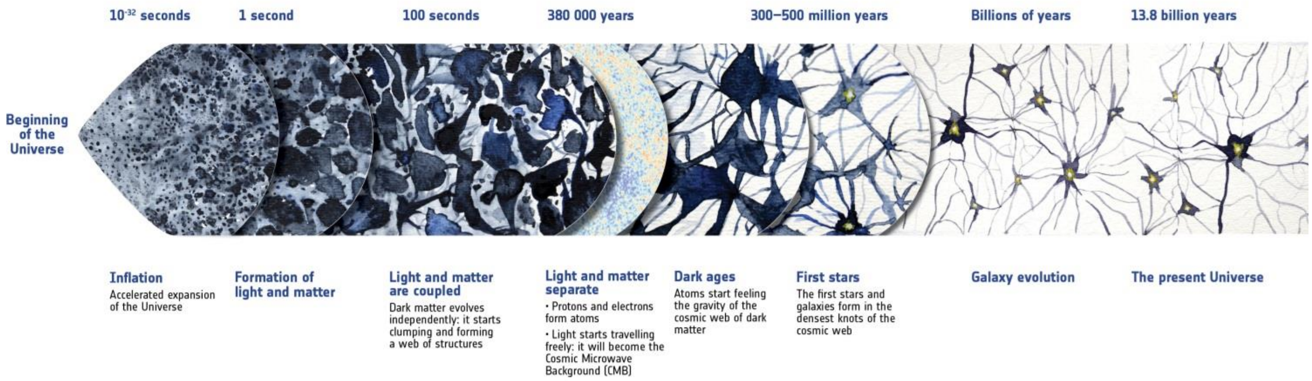
What does the Earth look like during a total solar eclipse? It appears dark in the region where people see the eclipse, because that's where the shadow of the Moon falls. The shadow spot actually shoots across the Earth at nearly 2,000 kilometers per hour, darkening locations in its path for only a few minutes before moving on. The above image shows the Earth during the total solar eclipse of 2006 March, as seen from the International Space Station.

Image Credit: Expedition 12 Crew, NASA

Credit: APOD

Pardon My Dust

Larry Faltz



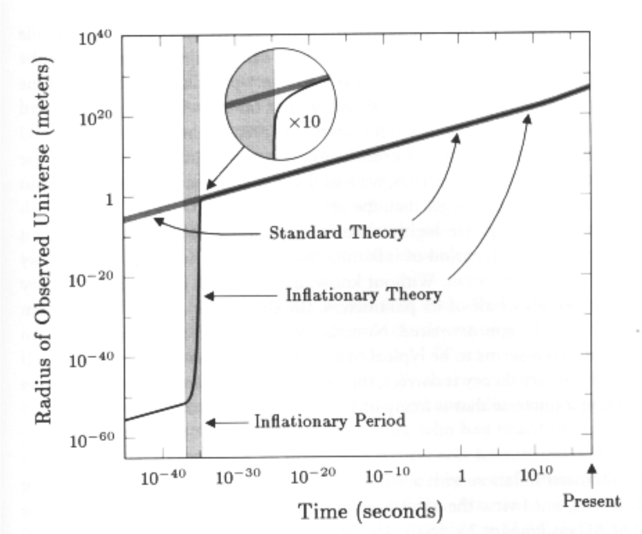
Cosmic History (European Space Agency, 2015)

A year ago, it looked certain that MIT physics professor Alan Guth would be getting an all-expenses-paid trip to Stockholm, a big check and a big gold medal (as well as a smaller version in the form of a lapel pin). I think Nobelists also get a better parking space at their universities, very helpful for Guth since parking is so tough in Cambridge. Provoking vast excitement in the scientific community, the BICEP2 telescope at the South Pole reported in March 2014 to have found evidence of polarization in the cosmic microwave background radiation, providing support for Guth's idea of cosmic inflation, the nearly instantaneous period when the nascent universe expanded at least 10^{25}-fold, perhaps 10^{80}-fold or even more.

Inflation proposes a solution to a problem that had bewildered cosmologists since Isaac Newton first proposed it in the *Principia* in 1687. When we look in any direction, the universe is fundamentally the same, "isotropic" being the term used. It also appears to have the same geometry: it's flat (Euclidean). What about all those stars, galaxies, cosmic filaments and voids, you say? They simply average out over the stupendous volume of the universe. The cosmic microwave background (CMB) radiation is the "cleanest" example of isotropy. The CMB was discovered by Penzias and Wilson in 1965 when they detected a constant hiss in every direction in their hyper-sensitive microwave receiver at a Bell Labs facility in Holmdale, NJ. Detailed mapping of these microwaves, first by balloon and rocket-borne detectors and then by the COBE, WMAP and Planck satellites, showed that there were only miniscule variations in the signal in different points in space, on the order of only a ten-thousandth of a degree. This shouldn't happen. The early universe ought to have been a roiling mess of densities and temperatures that should have persisted even as the cosmos expanded after the Big Bang.

Elyse at the Holmdel Horn, a National Historic Landmark, in 2013. You can visit it, not far from Exit 116 on the Garden State Parkway.

The notion of inflation came to Guth on the night of December 6, 1979 when he was thinking about phase transitions and magnetic monopoles in Grand Unified Theories, which describe the very young, high-energy universe at a time when three of the known forces (electromagnetic, strong and weak) were still a single force, gravity having separated at an even earlier time. In a flash of inspiration around 1 am, Guth realized that there could be an unstable field throughout the new universe (which was then perhaps 10^{-31} cm in diameter, ridiculously smaller than the diameter of a proton) that imparted a form of repulsive energy to space. In less than 10^{-32} seconds, the universe's size increased to about 0.9 mm, the size of a grain of sand. This is an enormous expansion for the amount of time we are talking about, the rate being far faster than the speed of light. In fact, in 10^{-32} seconds light travels merely a ten-thousandth of the diameter of a proton, more or less. By expanding faster than the speed of light, the universe gets much larger than what we can perceive when we see its most distant light (the CMB), and everything within it is stretched to homogeneity and isotropy.



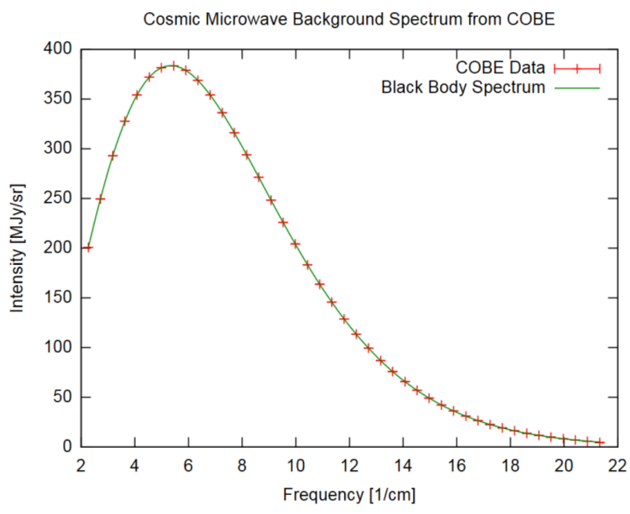
The evolution of the universe (Guth)

Guth's book *The Inflationary Universe* (Helix Books, 1997) tells the story, both personally and scientifically, in comprehensible non-mathematical detail. I recommend it highly. Guth's book was written a year before the accelerated expansion of the universe was discovered, so his discussion of the critical density problem (is there enough matter for the universe to stop expansion and have a "Big Crunch"?) is not exactly correct, but that's not a meaningful defect.

The CMB seemingly has little to do with inflation, having been emitted 380,000 years after the Big Bang, when the universe had expanded and cooled enough for hydrogen atoms to form. Photons were finally free to travel through space rather than just being absorbed and re-emitted by the free protons and electrons created in the Big Bang. The constant signal strength in the CMB across the sky means that the temperature of the surface that emitted the radiation is essentially homogeneous. It has the characteristics of a thermal "blackbody" of about 3,000° Kelvin. Were we there when it began, we would see a diffuse glow in the red and infrared part of the spectrum, receding from us and getting redder over the eons. The expansion of the universe over the next 13.8 billion years redshifted the signal into the microwave region, where it now has spectral characteristics of a blackbody with a temperature of 2.7° Kelvin.

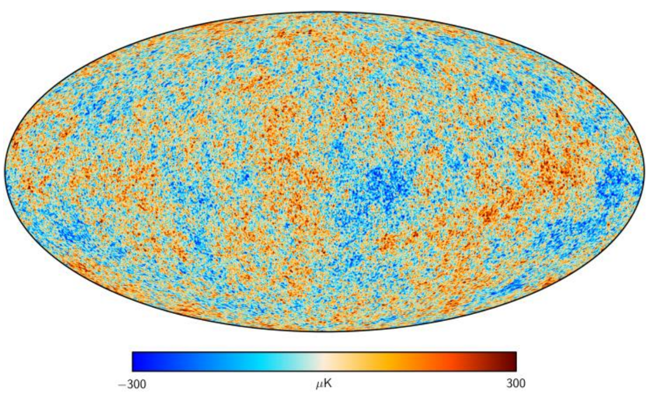
As you look deeper into space, you look back in time. Eight light minutes out, in one particular direction we see the Sun. Two million years out, at RA 00h43m 31.2s Dec +41°20' 57" from our earthly perspective we see the Andromeda Galaxy. At 13.8 billion light years out, we "see" (if we had microwave sensitive eyes, or Geordi LaForge's visor) the inside surface of a sphere radiating microwaves with the CMB spectrum. The CMB appears at the same distance and almost the same temperature, within a fraction of a degree, no matter what direction we look.

Now consider two points on the CMB opposite each other in the sky: they are each 13.8 billion light years from us, but those two points are 27.6 light years apart from each other. They have no right to be in thermal equilibrium because it would have been impossible for light or any other form of energy to have gone from one side of the universe to the other to equilibrate the temperatures, now or at any time in the past up to 10^{-32} seconds after the Big Bang. Light can't go 27.6 billion light years in 13.8 billion years: it would have to travel at 2*c*, but *c* is the limit. No matter how we run the movie backwards and watch the universe shrink back towards the Big Bang, the speed of light is too slow to allow one side of the universe to communicate with the other. To our position, yes, but not from "edge" to "edge" as seen by any observer.



Theory and experiment agree: the microwave background is a thermal blackbody at 2.72548±0.00057° K

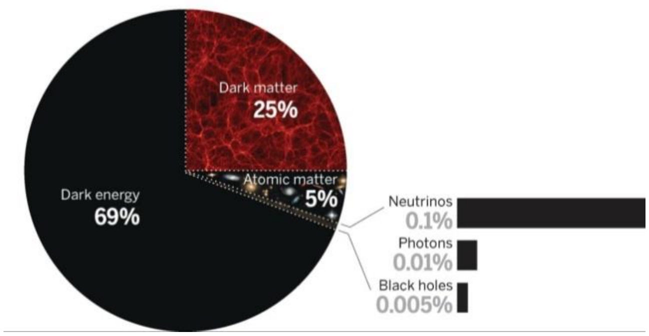
Yet, there it is: the universe is homogeneous and when the universe expanded enough to cool to 3,000° K it was already perhaps 12 million light years across, yet only 380,000 years old. The whole universe is far bigger than the part we can see. The parts outside of our "light cone" are not visible to us, having grown exponentially faster than the speed of light during inflation. If the expansion was slowing down under the influence of the gravitational force from the matter in it (critical density < 1), as was once suspected, our "light cone" might catch up to these unknown areas and over time we would see them. But we now know that expansion is accelerating, so those unknown regions will be forever unknown. In fact, an implication of accelerated cosmic expansion is that in time objects now at cosmological distance will recede faster than that of light and will be lost to us. CMB photons will cool to 10^{-30} degrees Kelvin in a trillion years, a temperature so low that it is doubtful that any technology could detect it. Civilizations in that distant time, if there are any, would not be able to reconstruct cosmological history correctly on their own through observation and experiment.



The Planck image of temperature variances in the cosmic microwave background (2015 data) (ESA)

There has to be a mechanism to achieve universal evenness, and inflation, as first postulated by Guth, seems to be the most viable and generally accepted process. The exponential expansion of space might seem to violate the requirement in our universe for a constant speed of light with a value of 299,792.458 kilometers per second that cannot be exceeded (because inertial mass becomes infinite). But although nothing can go faster than light *in* space, there are no limits to how fast *space itself* can expand.

The details are surprising, a bit complicated and thoroughly explained in Guth's book. Although there are competing theories that try to account for the isotropy and/or expansion of the universe, Guth's inflation is the most favored candidate and is completely consistent with the current ΛCDM (lambda-cold dark matter) theory that says that the universe is composed of familiar matter and energy, dark matter in the form of massive particles that move slowly and mostly don't feel any force except gravity, and dark energy, in the form of the "cosmological constant" Λ, first proposed by Einstein (although for the wrong reason). The cosmological constant seems quite indescribable except for its mathematical formalism. No one can effectively put its nature into words. Not only that, if you try calculate Λ from the rules of the Standard Model of particle physics (which looks to be correct), the result you get differs from what has been measured experimentally by a factor of 10^{123}, which is an insanely big number. But it looks like there really is a cosmological constant, taking the form of repulsive gravity of empty space. It may be something similar to the field that caused inflation but it exerts its influence over eons rather than in a sub-instant of an instant.



Current composition of the universe (Spergel, D, The dark side of cosmology: Dark matter and dark energy, *Science* 2015; 347: 1100-1102)

I have to say I'm fascinated by anything that gives numbers like 10^{-32} and 10^{123}. How small is small, and how big is big? Mathematics has no limits in that regard. Infinity is a well-established concept, but you can always write bigger and bigger numbers that are still less than infinity. It's a fun game to play. For example: let's make up big number with just 10 digits that's insanely big but still less than infinity. It's a finite quantity that you could, by the rules of mathematics, actually count but really can't make anything concrete out of in your mind:

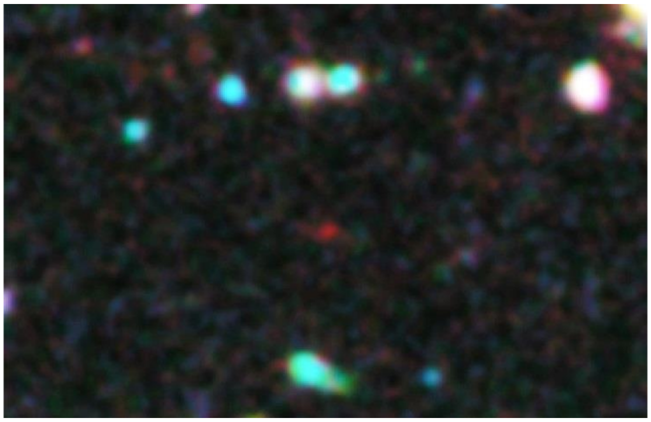
$$10^{10^{10^{10^{10}}}}$$

Now, let's make hugely bigger number just by adding two digits. It's still less than infinity:

$$10^{10^{10^{10^{10^{10}}}}}$$

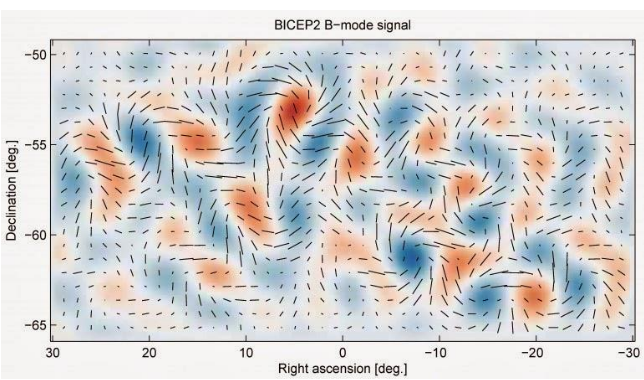
We could go on like this all day, adding exponents, and still not reach infinity. These kinds of numbers boggle the mind. They require a funny and invigorating kind of mental gymnastics. One might understand their significance, if not their actual value. An excellent introduction to the ideas of finiteness and infinity is in the classic *Mathematics and the Imagination* by Kasner and Newman (Simon and Shuster, 1940), a book well worth finding (just about every used book store has one) and reading for the sheer delight of its mathematical concepts and in its clear explanations.

Although the CMB is more homogeneous than it should be under the original Big Bang hypothesis, there are tiny variances that reflect quantum processes in play during inflation. Statistical analysis of the distribution of these variances provides the evidence for the current composition of the universe.



The red mote in the middle is Galaxy UDFj-39546284 with redshift *z*=10 (Hubble Ultra Deep Field image)

Nobel Prizes are not given for theories unless those theories are proven experimentally. While inflation makes sense (once you know the details), we need to actually see it working. We need a corroborative piece of evidence other than the simple end result that the universe is isotropic, not only to prove inflation happened but to rule out a myriad of even wilder (but nevertheless mathematically consistent) ideas.



BICEP2's map of CMB polarization

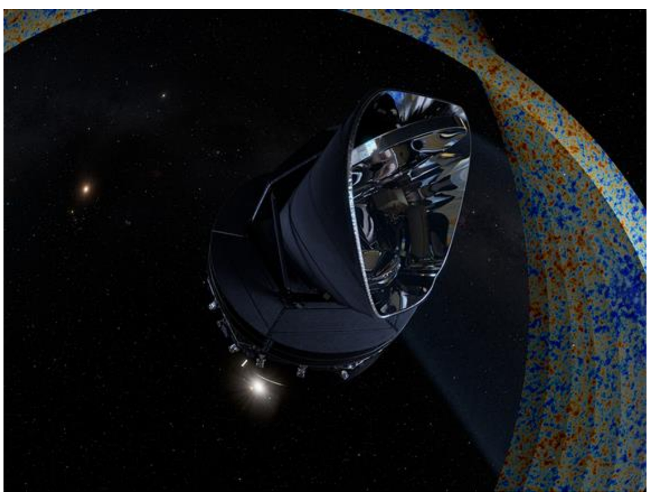
One of the predictions of inflation is that there will be two forms polarization in the CMB, E-modes and B-modes. The E-modes result from scattering of CMB off of atoms throughout the universe, much as blue light from the sun is scattered off of molecules in the atmosphere. The B-mode polarizations can arise from 2 sources. The first comes from galaxy clusters acting as gravitational lenses for the CMB, which is "behind" the galaxies, having arisen much earlier in cosmic history (the earliest galaxies, 12 billion light years distant, have red shifts of around *z*=10 while the CMB has a red shift of *z*=1,096). The second is that gravitational waves rippling through space during the brief era of expansion alternately compressed and expanded space enough to make a permanent imprint on spacetime that imprint polarization on CMB photons 380,000 years later. The E-modes were detected in 2002, but they didn't really prove anything terribly important. B-modes are the key to nailing inflation. Gravitationally lensed B-mode polarization has to be subtracted from the total signal to find residual polarization resulting from gravitational waves.

BICEP (Background Imaging of Cosmic Extragalactic Polarization) at the South Pole

In 2014, scientists working at the South Pole with the BICEP2 telescope claimed that they had found the inflationary B-modes. They published a map of a 15x60-degree segment of the southern sky that made it into newspapers, magazines and web sites all over the world (even the first page of the WAA SkyWAAtch newsletter in April 2014). The measurements were made at one frequency, 150 GHz. Although the announcement of the data took the world by storm, and cameras and microphones were thrust at Guth and Andrei Linde, another pioneer of inflationary theory, the BICEP2 folks did point out limitations in the study: data from a single frequency, the limited patch of sky surveyed and the possibility that a more prosaic explanation could be constructed: dust in the Milky Way has a proclivity to polarize radiation.

The authors noted that the European Space Agency's Planck satellite, which imaged the entire sky at multiple microwave wavelengths and had already yielded a trove of data supporting the ΛCDM theory, would publish its final results in early 2015 and provide more insight into the polarization problem. The two teams agreed to make a joint analysis.

The Planck satellite finished its observations in late 2013, and the full data analyses with the most accurate and detailed information have just begun to be published. The summary article, posted on arXiv in February 5th has 355 authors, evidence of the magnitude of the project, the sophistication of the hardware and software and the massive amount of data analysis required. Another 19 papers with more detail were also published, with 6 more scheduled for March and additional data releases set for the spring and summer. If you want to do your own research, the data is even publicly available on the ESA's web site.



Planck generating its ribbon of data (from the planetarium show *Dark Universe*)

Planck scanned a continuous ribbon of sky for over 4 years (August 2009 to October 2013) from its orbit at the L2 point, 1 million miles outside of the Earth's orbit opposite the sun, uninterruptedly acquiring data for the entire sky. Measuring microwave intensities is not a matter of taking a photograph. Planck has two types of detectors: radiometers and bolometers, tuned to specific frequencies. We may be more familiar with radiometers: some of us used one in science class or received it as a geeky gift. The Crookes radiometer is still sold for $14-15. It's a partially evacuated bulb with a vane made of 4 metal plates, black on one side and white on the other.

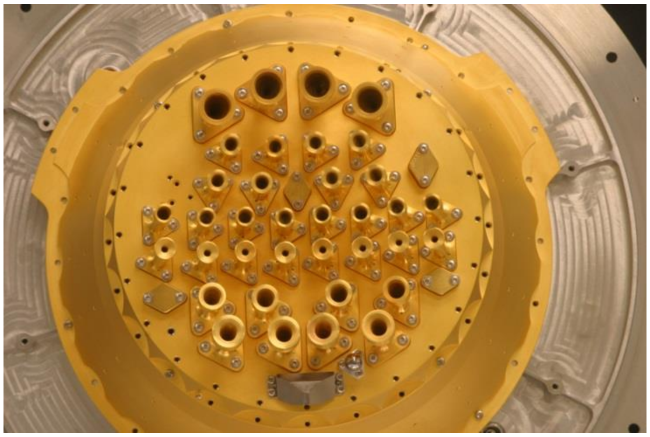
The vanes rotate if light is shined on the vanes, the rotation rate varying with the intensity of the radiation. The mechanism has to do with pressure from heating of gas molecules on the black side of the vanes, not "light pressure" as Crookes originally thought. A Crookes radiometer made with a complete vacuum will not rotate.

A Crookes radiometer

The low-frequency radiometers on Planck are not little windmills, but complex cryogenic "pseudo-correlation continuous comparison receivers" that don't have moving parts. The device looks like a set of small organ pipes. There are 56 of them, operating at 30-100 GHz, cooled to 20° K, with resolution of 10 arc-min and sensitivity of 12 μK.

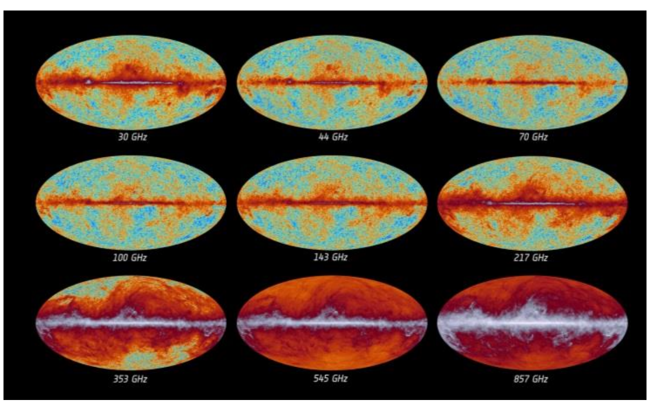
Planck's Low Frequency Instrument, a radiometer.

Higher frequency microwaves are measured by bolometers, which respond to radiation by heating a device containing a temperature dependent electrical resistance. The 56 high-frequency bolometers operate at 100-850 GHz. They are actively cooled to 0.1° K and have angular resolution of 5 arc-min and 5 μK sensitivity. Bolometers can be affected by particles such as cosmic rays, and so the detector in the Planck spacecraft is made like a spider web, allowing the particles to pass through but catching the radio waves.



The outside of the High-Frequency instrument

To make maps of the CMB and check for its polarization, everything in the foreground has to be removed. This is a daunting task, requiring a lot of modelling, statistics and data reduction. As data from each pass was assembled, finer and finer resolution was obtained. In addition to the CMB findings, Planck made catalogs of compact sources (as many as 46,181 objects at 857 Hz), galaxy clusters (1653 objects) and "galactic cold clumps" (13,188 objects plus 54 in the Large and Small Magellanic Clouds). Among other things, Planck made all-sky maps of the Sunyaev-Zel'dovich effect, which results from high-energy electrons boosting the energy of CMB photons by inverse Compton scattering, enhancing the detection of galaxy clusters.



Raw data maps from Planck at each of the detector wavelengths (ESA)

The BICEP2/Planck joint analysis was released in a paper on February 2^{nd}. The polarization detected by BICEP2 is much more likely to be due to dust in the Milky Way than primordial gravitational waves. It's clear that the authors (there are many of them) still hold out some hope that the inflationary B-modes will still be found, stating "The r constraint curve peaks at r = 0.05 but disfavors zero only by a factor of 2.5. This is expected by chance 8% of the time, as confirmed in simulations of a dust-only model. We emphasize that this significance is too low to be interpreted as a detection of primordial B-modes." [r is the amount of power in gravitational waves compared to other density perturbations in the early universe. It was originally calculated at a rather large 0.20. If r is zero, there are no primordial gravitational waves.]

Where does the universe come from? It's hard to believe that there was "nothing" and then there was "something." The first century Roman philosopher Lucretius, in *De Rerum Natura* (On the Nature of Things) explicitly states that "Nothing can come from nothing," which sounds suspiciously like warnings offered by my grandmother. On the other hand, Richard Feynman pointed out that the "equation of the universe" ought to be written as *U=0*. That is, everything cancels out because of conservation laws. Since there was originally nothing, maybe there is still really nothing. We may only temporarily have matter and energy in various forms, but they will have to cancel out. The 69% of everything that is the cosmological constant might just make the balance work. With ultimate expansion of space under the influence of the cosmological constant, eventually there is dissolution of all structure and equilibrium of temperature at absolute zero. This is the "heat death" of the universe, when entropy is maximal and time stops. Is that something, or nothing? Sounds like nothing to me.

If you think that there might have been "something" before the Big Bang, there are a number of theories that have been espoused. Two have been described in recent books by leading cosmologists: Roger Penrose's *Cycles of Time* (Knopf, 2011) and Paul Steinhardt and Neil Turok's *Endless Universe* (Doubleday, 2007). Penrose focuses on thermodynamics and entropy, while Steinhardt and Turok invoke collision of parallel brane-like universes. The mathematics of these theories are advanced and thankfully avoided in the books, but the concepts are still challenging. When the BICEP2 results were first announced, Steinhardt and Turok stated that their theory would definitively fail if primordial gravitational waves were found. The results from Planck mean that Guth's disappointment is their happiness. ■

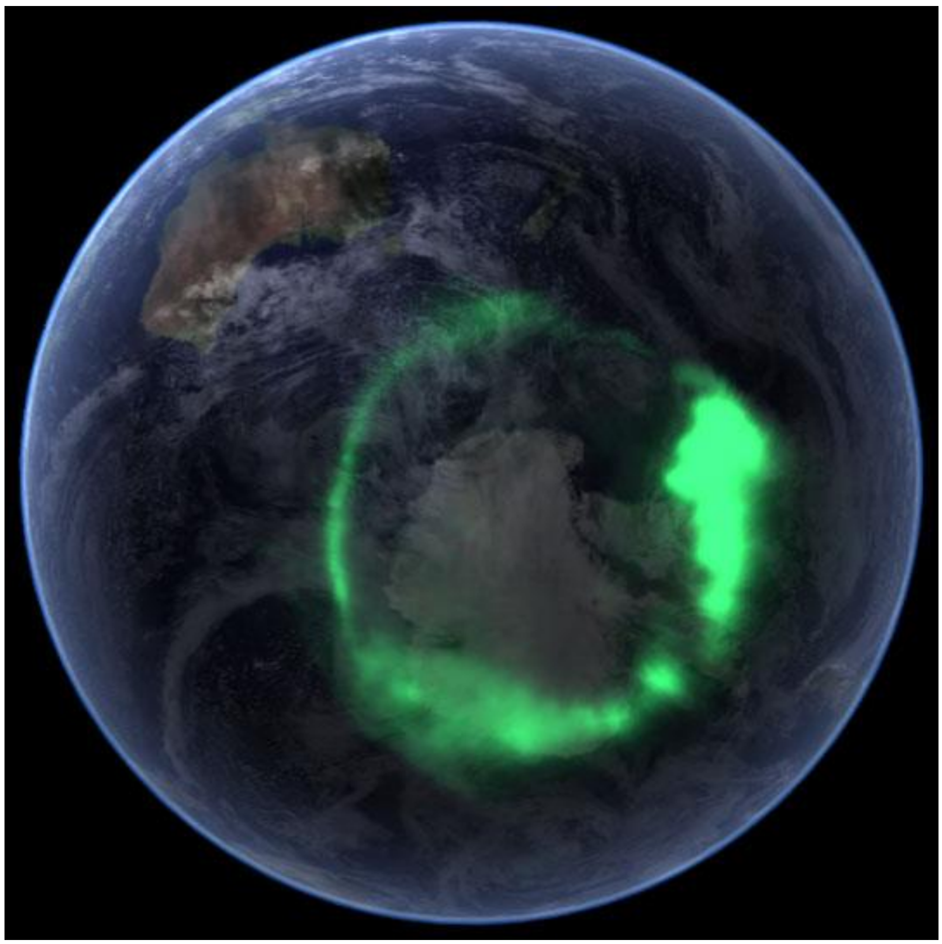
The Cold Never Bothered Me Anyway

By Ethan Siegel

For those of us in the northern hemisphere, winter brings long, cold nights, which are often excellent for sky watchers (so long as there's a way to keep warm!) But there's often an added bonus that comes along when conditions are just right: the polar lights, or the Aurora Borealis around the North Pole. Here on our world, a brilliant green light often appears for observers at high northern latitudes, with occasional, dimmer reds and even blues lighting up a clear night.

We had always assumed that there was some connection between particles emitted from the Sun and the aurorae, as particularly intense displays were observed around three days after a solar storm occurred in the direction of Earth. Presumably, particles originating from the Sun—ionized electrons and atomic nuclei like protons and alpha particles—make up the vast majority of the solar wind and get funneled by the Earth's magnetic field into a circle around its magnetic poles. They're energetic enough to knock electrons off atoms and molecules at various layers in the upper atmosphere—particles like molecular nitrogen, oxygen and atomic hydrogen. And when the electrons fall back either onto the atoms or to lower energy levels, they emit light of varying but particular wavelengths—oxygen producing the most common green signature, with less common states of oxygen and hydrogen producing red and the occasional blue from nitrogen.

But it wasn't until the 2000s that this picture was directly confirmed! NASA's Imager for Magnetopause-to-Aurora Global Exploration (IMAGE) satellite (which ceased operations in December 2005) was able to find out how the magnetosphere responded to solar wind changes, how the plasmas were energized, transported and (in some cases) lost, and many more properties of our magnetosphere. Planets without significant magnetic fields such as Venus and Mars have much smaller, weaker aurorae than we do, and gas giant planets like Saturn have aurorae that primarily shine in the ultraviolet rather than the visible. Nevertheless, the aurorae are a spectacular sight in the evening, particularly for observers in Alaska, Canada and the Scandinavian countries. But when a solar storm comes our way, keep your eyes towards the north at night; the views will be well worth braving the cold!

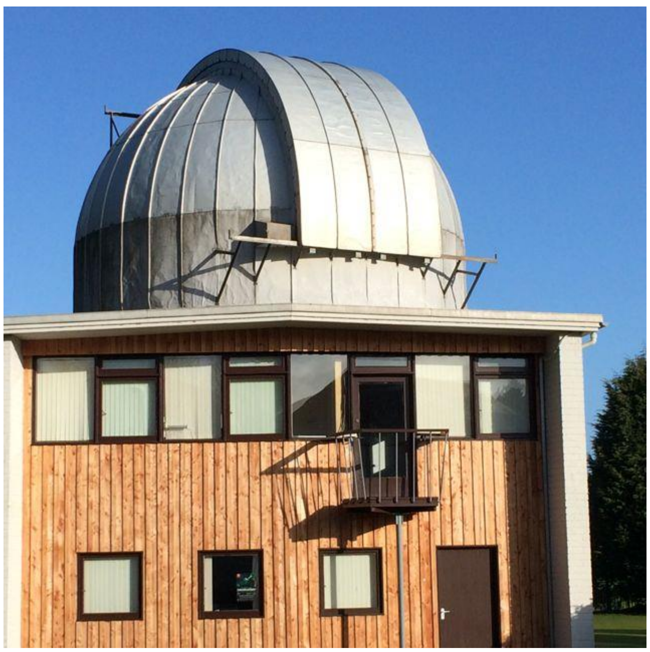


Auroral overlays from the IMAGE spacecraft.

Image credit: NASA Earth Observatory (Goddard Space Flight Center) / Blue Marble team.

Outreach Event

Courtesy of Manos Makrakis is this photo of the WAA outreach event held on March 23rd at the Quaker Ridge School in Scarsdale. Notes Manos: It was my first time attending this event both as a WAA member and a Scarsdale schools parent. It was a definite success as evidenced by the number of participants and attendees in spite of the chilly weather. The weather was very good for observing and the enthusiasm was evident in kids' remarks about the celestial objects they were seeing through members' telescopes.



Telescope Home

Tom Boustead snapped this shot of the building housing the James Gregory Telescope on a recent trip to St. Andrews Scotland (alas no one was home). The JGT is the largest optical telescope in the UK. While named after the famous Scottish mathematician and inventor of the Gregorian telescope, the JGT is a modern 37" Schmidt-Cassegrain. See Observatory website.

Above the Clouds

Bob Kelly took this photo of observatories above the clouds featuring the Mars-like volcanic landscape on Haleakala at 10,000 feet on the Hawaiian Island of Maui. He used his wife's 3mm focal length tablet camera at f/2.5 1/1400 second exposure. See Haleakala Institute for Astronomy.