Southwest Florida Astronomical Society
SWFAS

The Eyepiece
April 2014

Contents:

A MESSAGE FROM THE PRESIDENT

Spring has finally sprung! (Those up north aren't too sure about this!)
We had a great time at the Hyatt this month for their Jazz Under the Moonlight event. Carol and Dave Stewart and Chris and I were there. Better location and perfect weather. Jupiter put on a great show with a double shadow transit.

We have the showing of 'The Sky Dark' this month on the 19th. This should be an interesting event. We also have a total lunar eclipse on the 15th. It is a later at night event on a weekday, so planning something public may be a bit hard to do.

Astronomy Day is May 10th. Carol is planning on all day shows at the Planetarium.

Brian

In the Sky this Month

Moon: April – 1st Quarter 7th; Full 15th; Last Quarter 22rd; New 29th.
May – 1st Quarter 6th; Full 14th; Last Quarter 21st; New 28th.

The Planets

Jupiter is just past optimum early evening viewing with its magnitude diming from -2.2 to -2.0 by end of month. It is moving eastward relative to its starry background in Gemini. It starts the month east of ε and, moving east, and ends April between ω and ζ.
Mars reaches opposition April 8 and is closest to earth April 14th. It is visible from dusk to dawn with brightness comparable to that of Sirus with -1.5. It is retrograding in Virgo.
Saturn is visible in the east around 10:30 early April and is best viewed after midnight It is in slow retrograde in Libra and shines at magnitude of 0.1.
Venus is low in the SE at dawn at -4.3 magnitude.
Mercury will be in sun's glare this month.

The International Space Station: Best evening viewing times early and late in month:
Apr 3rd at 8:35 pm from S to ESE; max alt 23°; for 3 minutes at -2.1 mag.
Apr 4th at 9:22 pm from WSW to N; max alt 36°; for 3 minutes at -1.8 mag.
Apr 5th at 8:31 pm from SW to NE; max alt 84°; for 7 minutes at -3.3 mag.
Apr 7th at 8:29 pm from W to NNE; max alt 23°; for 5 minutes at -0.8 mag.
Apr 23rd at 9:40 pm from NNW to N; max alt 25°; for 2 minutes at -1.5 mag.
Apr 25th at 9:34 pm from NW to W; max alt 60°; for 3 minutes at -2.9 mag.
Apr 26th at 8:44 pm from NNW to ESE; max alt 50°; for 5 minutes at -3.0 mag.
Apr 28th at 8:38 pm from WNW to SSE; max alt 40°; for 6 minutes at -2.2 mag.

Hubble Space Telescope: Lots of opportunity to see Hubble mid to late in month.
Apr 14th at 9:38 pm from WSW to SW; max alt 43°; for 3 minutes at 1.6 mag.
Apr 15th at 9:31 pm from WSW to SSW; max alt 70°; for 4 minutes at 0.8 mag.
Apr 16th at 9:25 pm from WSW to E; max alt 88°; for 4 minutes at 0.6 mag.
Apr 17th at 9:18 pm from W to ENE; max alt 81°; for 5 minutes at 0.8 mag.
Apr 18th at 9:12 pm from W to ENE; max alt 74°; for 6 minutes at 0.9 mag.
Apr 19th at 9:05 pm from W to ENE; max alt 69°; for 6 minutes at 0.9 mag.
Apr 20th at 8:59 pm from W to ENE; max alt 68°; for 6 minutes at 1.0 mag.
Apr 21st at 8.52 pm from W to E; max alt 69°; for 7 minutes at 0.9 mag.
Apr 22nd at 8:46 pm from W to E; max alt 74°; for 7 minutes at 0.9 mag.
Apr 23rd at 8:39 pm from W to E; max alt 82°; for 7 minutes at 0.8 mag.
Apr 24th at 8:33 pm from W to ESE; max alt 87°; for 8 minutes at 0.8 mag.
Apr 25th at 8:26 pm from W to ESE; max alt 73°; for 8 minutes at 0.9 mag.
Apr 26th at 8:20 pm from W to ESE; max alt 59°; for 8 minutes at 1.1 mag.
Extracted from http://www.heavens-above.com/

Future Events

Upcoming Meetings

Our April meeting will be held on Thursday April 3rd at 7:30 pm at the Calusa Nature Center and Planetarium. Our program will be given by Jack Berninger. His topic will be THEORY OF EVERYTHING.

Star Party and Event Schedule

Date	Event	Location	Time	Info/Contact
Wed Apr 2nd	Library Program	FMB Library		Bruce Dissette
Thurs April 3rd	MonthlyMeeting	Calusa Nature Center Planetarium	7:30 PM	Jack Berninger "Theory of Everything"
Sat April 19th	"The Sky Dark"	Calusa Nature Center Planetarium	Afternoon	Carol Stewart
Thurs May 1st	MonthlyMeeting	Calusa Nature Center Planetarium	7:30 PM	TBD
Sat May 3rd	Star Party	CRP	Dusk	Bruce Dissette
Fri May 9th	School Event	Skyline Elementary Cape Coral	?	Carol Stewart
Sat May 10th	Astronomy Day	Calusa Nature Center Planetarium	All Day	Carol Stewart
Sat May 31st	Star Party	CRP	Dusk	Bruce Dissette
Thurs June 5th	MonthlyMeeting	Calusa Nature Center Planetarium	7:30 PM	TBD
June 28th	Star Party	CRP	Dusk	Bruce Dissette
July 26th	Star Party	CRP	Dusk	Bruce Dissette
August 23rd	Star Party	CRP	Dusk	Bruce Dissette
Sept. 27th	Star Party	CRP	Dusk	Bruce Dissette
October 25th	Star Party	CRP	Dusk	Bruce Dissette
November 22nd	Star Party	CRP	Dusk	Bruce Dissette
December 20th	Star Party	CRP	Dusk	Bruce Dissette

Minutes of SWFAS Meeting – March 6, 2014

Will appear later

Old Tool, New Use: GPS and the Terrestrial Reference Frame

Space Place partners' article March 2014
By Alex H. Kasprak

Flying over 1300 kilometers above Earth, the Jason 2 satellite knows its distance from the ocean down to a matter of centimeters, allowing for the creation of detailed maps of the ocean's surface. This information is invaluable to oceanographers and climate scientists. By understanding the ocean's complex topography—its barely perceptible hills and troughs—these scientists can monitor the pace of sea level rise, unravel the intricacies of ocean currents, and project the effects of future climate change. But these measurements would be useless if there were not some frame of reference to put them in context.

A terrestrial reference frame, ratified by an international group of scientists, serves that purpose. "It's a lot like air," says JPL scientist Jan Weiss. "It's all around us and is vitally important, but people don't really think about it." Creating such a frame of reference is more of a challenge than you might think, though. No point on the surface of Earth is truly fixed.

To create a terrestrial reference frame, you need to know the distance between as many points as possible. Two methods help achieve that goal. Very-long baseline interferometry uses multiple radio antennas to monitor the signal from something very far away in space, like a quasar. The distance between the antennas can be calculated based on tiny changes in the time it takes the signal to reach them. Satellite laser ranging, the second method, bounces lasers off of satellites and measures the two-way travel time to calculate distance between ground stations.

Weiss and his colleagues would like to add a third method into the mix—GPS. At the moment, GPS measurements are used only to tie together the points created by very long baseline interferometry and satellite laser ranging together, not to directly calculate a terrestrial reference frame. "There hasn't been a whole lot of serious effort to include GPS directly," says Weiss. His goal is to show that GPS can be used to create a terrestrial reference frame on its own. "The thing about GPS that's different from very-long baseline interferometry and satellite laser ranging is that you don't need complex and expensive infrastructure and can deploy many stations all around the world."

Feeding GPS data directly into the calculation of a terrestrial reference frame could lead to an even more accurate and cost effective way to reference points geospatially. This could be good news for missions like Jason 2. Slight errors in the terrestrial reference frame can create significant errors where precise measurements are required. GPS stations could prove to be a vital and untapped resource in the quest to create the most accurate terrestrial reference frame possible. "The thing about GPS," says Weiss, "is that you are just so data rich when compared to these other techniques."

You can learn more about NASA's efforts to create an accurate terrestrial reference frame here: http://space-geodesy.nasa.gov/.
Kids can learn all about GPS by visiting http://spaceplace.nasa.gov/gps and watching a fun animation about finding pizza here: http://spaceplace.nasa.gov/gps-pizza.
Artist's interpretation of the Jason 2 satellite. To do its job properly, satellites like Jason 2 require as accurate a terrestrial reference frame as possible. Image courtesy: NASA/JPL-Caltech.
Editors: download photo at

http://www.jpl.nasa.gov/missions/web/ostm.jpg

Zodiacal Light in the Evening

Posted by Tony Flanders, March 4, 2010

Have you ever seen the zodiacal light? This huge pearly pyramid is on its best display in the Northern Hemisphere on moonless evenings from February through April. All you need is a location far from artificial lights (at least 40 miles from a small city and 80 miles from a major metropolis) that also has an unobstructed western horizon.

Doug Zubenel

Go out an hour after sunset and look to the west. Even though the Sun is now far below the horizon, a huge dome of light marks the spot where it disappeared. As this light fades and shrinks down to the horizon, another glow will be unmasked; a tall, leftward-slanting pyramid of light. It follows the path of ecliptic, running left of Aries and then between the Hyades and Pleaides, the sky's most spectacular star clusters.

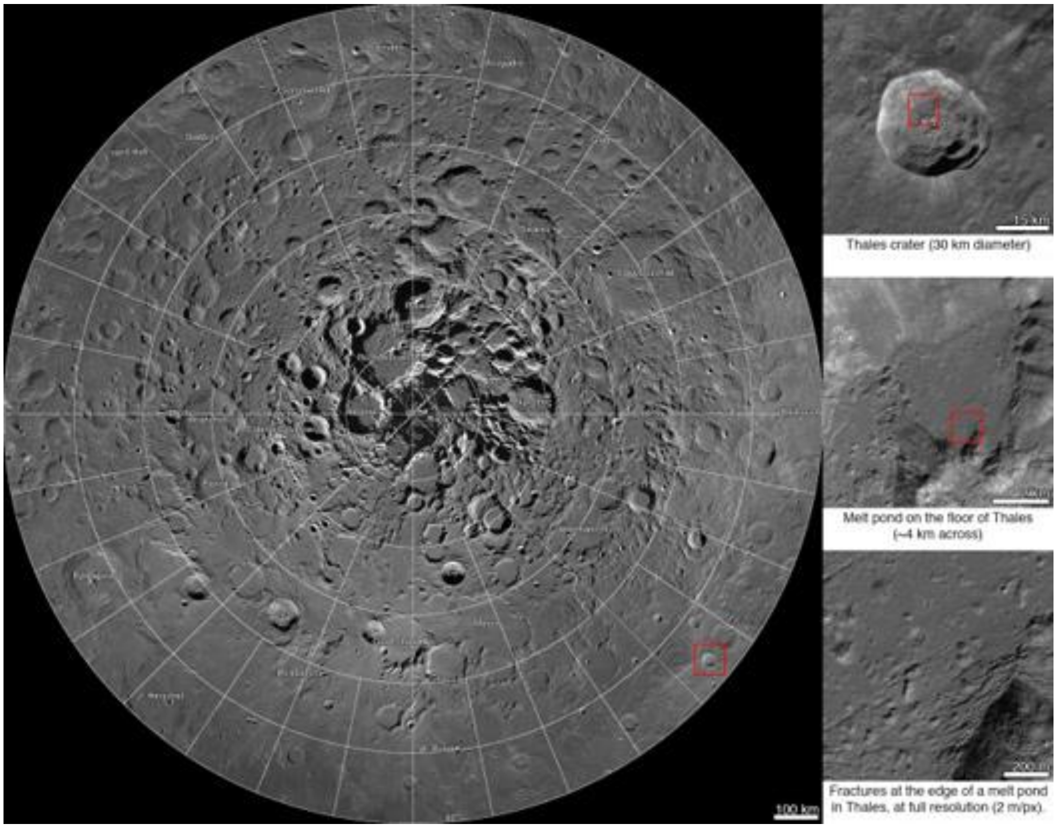
Aside from its shape, you might think it was just part of the twilight, but it will linger long after the rest of the sky is fully dark. The first time I saw the zodiacal light, I thought it was light pollution, but light pollution forms a low band along the horizon. It's amazingly brighter — even brighter than the Milky Way — and once you've seen it, you'll never again have trouble recognizing it.

What are you seeing? The zodiacal light is the combined glow of countless tiny particles (debris from comets and asteroid collisions) that orbit the Sun. See our article Have You Seen the Zodiacal Light? for more information.

First Interactive Mosaic of the Lunar North Pole

With the first interactive lunar north pole mosaic released by the NASA's Lunar Reconnaissance Orbiter Camera team you can explore an area of the Moon's northern hemisphere about the size of Alaska and Texas combined.

Posted by Emily Poore, March 21, 2014



A new mosaic from NASA's Lunar Reconnaissance Orbiter covers the north pole of the moon from 60 to 90 degrees north latitude at a resolution of 6-1/2 feet (2 meters) per pixel. Close-ups of Thales crater (right side) zoom in to reveal increasing levels of detail. [Explore the interactive version here.]() *NASA/Goddard/Arizona State University*

The interactive mosaic consists of 10,581 images collected over four years of observations made by the Lunar Reconnaissance Orbiter (LRO). While the image above is a still, you can explore the interactive version here. The interactive map allows you to zoom in on craters and other features to amazing detail, and a list of notable features allows you to quickly pan and find fresh craters, impact melts, and even the tracks left by a boulder rolling down a crater's central peak.

The LRO launched in June 2009 on a mission to map the surface of the Moon and scout out potential future landing sites and important science targets.

About two years into its mission, LRO changed its orbit from a near-circle to a highly elliptical path that crossed over both poles. The new orbit took the spacecraft closest to the lunar south pole and high above the lunar north pole. At such high altitudes the Lunar Reconnaissance Orbiter Camera (LROC), an instrument with narrow and wide angle cameras, was able to capture images of a vast amount of surface area. This led to a complete mosaic map of the Moon's surface from 60°N to the geographic north pole with a resolution of 2 meters (6.5 feet) per pixel.

This image shows the size of the LROC Northern Polar Mosaic as compared to the continental United States.

NASA/LROC/Arizona State University

To put this in perspective, the area of the Moon that this mosaic allows you to explore is a little bit bigger than the size of Alaska and Texas combined — roughly an area of 2.54 million square kilometers (0.98 million square miles)!

The LRO also released a half-gigabyte view of the moon in February 2011, but the huge interactive LROC Northern Polar Mosaic (LNPM) trumps its coverage by quite a lot.

If the soaring view of the Moon's top half piques your curiosity, S&T has produced a full Moon globe based on 15,000 wide-angle LRO images, with labels for over 850 craters, valleys, lunar landing sites, and more.

Young Stars Lead the Magellanic Stream

Astronomers have discovered hot, young stars in the Leading Arm of the Magellanic Stream, calling the history of the Magellanic Clouds once again into question.

by Shannon Hall, March 18, 2014

In this combined radio and visible-light image, the gaseous stream is shown in pink. The Milky Way is the light blue band in the center of the image. The Magellanic Clouds, satellite galaxies of the Milky Way, are the white regions at the bottom right.

NRAO / AUI / NSF

The Magellanic Stream — a long ribbon of gas stretching nearly half way around the Milky Way and trailing our galaxy's two small companions, the Magellanic Clouds — has a fascinating history. Most of the stream was stripped from the Small Magellanic Cloud some 2 billion years ago, but a small pocket of it was formed more recently from the Large Magellanic Cloud.

Since the stream's discovery in the early 1970s, astronomers have eagerly studied this gaseous filament because it offers the chance to directly probe the nearby result of a powerful tidal interaction. For decades astronomers thought the Magellanic Clouds were old acquaintances with our galaxy, having orbited the Milky Way multiple times over the past several billion years.

Then in 2002 and 2005, astronomers using the Hubble Space Telescope discovered the clouds were moving much faster than anyone had expected. Such rapid movement would make it extremely hard for the clouds to be bound to the Milky Way. Later computer modeling by Gurtina Besla (Columbia University) and colleagues concluded that the clouds have probably never completed an orbit around the Milky Way.

But now an international team of astronomers led by Dana Casetti-Dinescu (Southern Connecticut State University) has for the first time detected young stars in the stream's Leading Arm — a wide and irregular feature at the front end — suggesting once again the stream is an old acquaintance of the Milky Way.

Star formation is a natural consequence of a tidal interaction. As the Leading Arm travels through the Milky Way's halo, the arm's gas feels a headwind, much as a runner feels a wind even on the stillest day, and becomes compressed enough to spark star formation. Note this interaction has to be relatively weak: if the collision is too violent, instead the gas is stripped away and no stars form.

The team observed 42 candidate stars using the 6.5-m Baade Telescope in Chile and verified that 19 are young, massive stars in the Leading Arm. But did they form within the stream itself, or are they runaway stars kicked out of a neighboring galaxy by some dynamic push (say, a supernova's blast or via close passes within a star cluster)?

While it's difficult to rule out these newly identified stars as runaways on a case-by-case basis, the fact that five of them have similar radial velocities argues strongly that they were formed together. It's very unlikely that they were all ejected in the same direction. Additionally, one massive star among the 19 is so young — just 1 or 2 million years old — that it could not have reached its current location from either the Milky Way's disk or from one of the Magellanic Clouds, says coauthor Terrance Girard (Yale University).

Finding embedded stars allows astronomers to determine accurate distances to the Leading Arm. Indeed, these observations show that it's extremely close to the Milky Way's disk — 40,000 light-years closer than current models predict possible.

The presence of hot, young stars so close to the Milky Way suggest the more distant clouds are moving sluggishly. It's simply easier to pull star-forming gas closer if the clouds are moving slower. However, this contradicts previous HST measurements and current models, leading the team to question if the clouds are truly on their first visit, just now "falling in" from elsewhere within the Local Group, or instead have been circling the Milky Way for a long time.

Not all astronomers, however, agree that the infall scenario should be questioned. The stars pose a challenge to "all orbital models of the Magellanic System, not just the first infall scenario," says Besla, who was excited to hear about their discovery.

Casetti-Dinescu stresses that careful modeling is needed to firm up details about the Magellanic Stream's complex history and future. While there is little doubt the clouds will eventually be captured and incorporated into the Milky Way, we're unsure of the timescale at which this will happen.

We also need to find more young stars. "What we have discovered is probably the 'tip of the iceberg' " writes Casetti-Dinescu.

Reference:

D. I. Casetti-Dinescu, et al. "Recent Star Formation in the Leading Arm of the Magellanic Stream" submitted to *Astrophysical Journal Letters*

The Incredible, Shrinking Mercury

As the innermost planet's interior cooled and contracted, its crust buckled and fractured just as much as geologists expected.

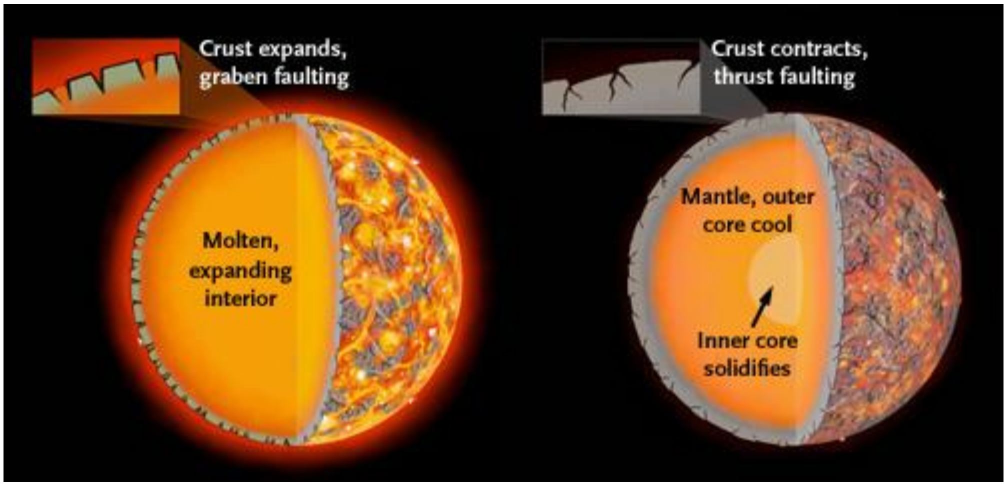
by Kelly Beatty, March 19, 2014

Victoria Rupes is a long scarp that formed when Mercury shrank slightly as its core cooled. "Rupes" on Mercury are named for ships of discovery; this one commemorates one of the ships used by Ferdinand Magellan to circumnavigate Earth in 1519–22. North is to the right, and the scene is about 150 miles (250 km) wide. Click on the image for a larger view. *NASA / JHU-APL / Carnegi Inst. of Washington*

NASA's Mariner 10 spacecraft made three historic flybys of Mercury in 1974–75. Among the mission's many amazing results was the discovery that the innermost planet must have shrunk as it cooled after forming 4½ billion years ago. The evidence for that is a series of ragged thrust faults — places where one giant slab of rock has been pushed on top of another — due to strong compressional stresses within the crust.

Geophysicists quickly realized that Mercury is a "one-plate planet." It lacks the interlocking (and constantly colliding) patchwork of crustal plates found on Earth. Consequently, as Mercury's interior cooled and solidified over billions of years, its total volume shrank a bit. But by then the crust had long since solidifed — it had no "give" to give. So it responded by cracking and crunching, creating the thrust faults and wrinkle ridges seen in Mariner 10's images.

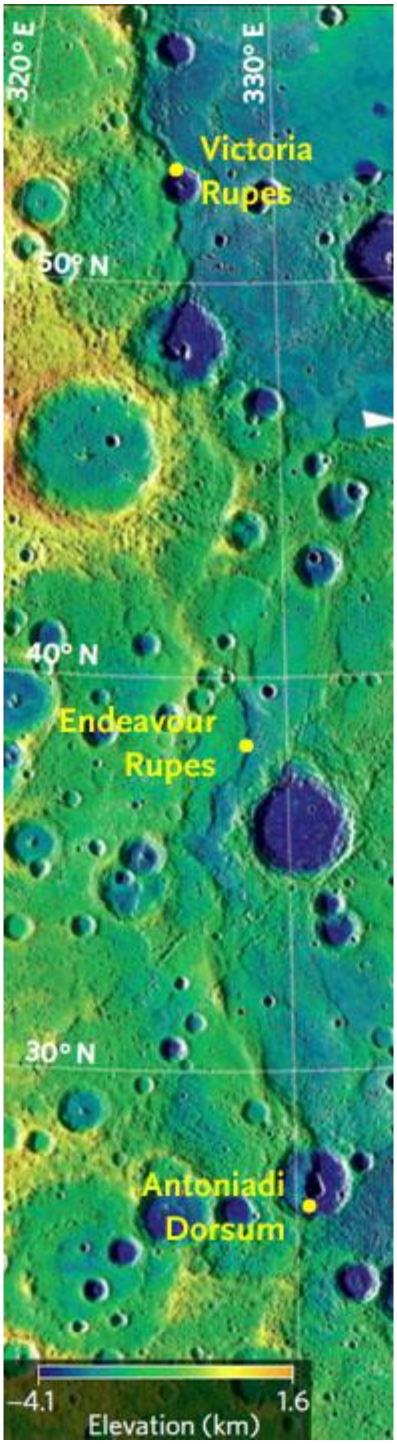
The same thing happens to an apple that's been sitting on the kitchen counter too long: it gets dried out, its volume shrinks, and its skin gets all wrinkly.



Global expansion *(left)* might have occurred early in Mercury's history, creating extensional stress in its crust. But as the planet cooled its entire globe shrunk slightly *(right)*, which compressed the crust and triggered the formation of thrust faults like Victoria Rupes. *Don Davis / The New Solar System*

Due to the peculiar coupling of Mercury's orbital and spin periods, Mariner 10 viewed less than half of the planet despite three passes.at close range. So researchers guesstimated, based on the faulting they could see, that overall the planet's radius had shrunk between 0.8 and 3 km. This result puzzled them, because calculations showed that the contraction should have been several times greater.

Now, thanks to NASA's Messenger spacecraft, geophysicists have global, high-def imagery that allows them to take a fresh look at the problem. In March 16th's issue of *Nature Geoscience,* published online, a team led by Paul Byrne (Carnegie Institution of Washington) reports that Mercury's radius has shrunk up to 7 km, much more in line with the theoretical prediction.



One of the most prominent shrinkage features on Mercury is this 1,700-km-long assemblage of lobate scarps and high-relief ridges. Geologists refer to this as a *fold and thrust belt*. The topographic map has been derived from Messenger's imagery and laser altimetry. *P. Byrne & others / Nature Geoscience*

Byrne and his colleagues measured the crustal shrinkage two ways. First, they kept track of the thrust faults and wrinkle ridges spotted along eight "great circles" around the planet. This yielded a total radial contraction of between 3.7 and 5.5 km. (There's no good way to know at what angles the thrust faults extend down into the crust; shallower angles would cause greater overlap.)

The second method involved taking a complete census of the planet's contraction-induced ridges and fractures — 5,934 in all. After excluding territory covered by the large Caloris and Rembrandt impact basins, which postdate the era when Mercury cooled most rapidly, the team found that the radius had contracted anywhere from 4.7 to 7.1 km, again depending on the thrust-fault angles.

Either way, it's a solid match to the theoretical values. "That we have documented changes in Mercury's radius of up to a factor of seven larger than previous results resolves a nearly four-decades-old paradox," the researchers conclude, adding that "the history of heat production and loss and the accumulated global contraction are now consistent."

Other interesting tidbits emerged from this study. For example, the widespread volcanic plains near Mercury's north pole bear a disproportionate share of the wrinkle ridges and thrust faults. These plains cover only 6% of the planet, yet 28% of the counted features are found there and they account for 19% of the total shrinkage.

Also, because Messenger's laser altimeter has mapped the planet's highs and lows, Byrne's team found several instances where the regional topography slowly undulates, as if the crust has warped and buckled on larger scales.

Historical footnote: back in the 19th century, some scientists speculated that Earth's mountain ranges, tectonic rifts, and fault zones were created by the same kind of global contraction that's evident on Mercury. Now we know that it's all largely the result of plate tectonism, our planet's signature geophysical process.

Still, it's a reasonable scenario for what happens to rocky planets as they evolve. As Byrne and his team point out, "With the increasing number of terrestrial planets identified in extrasolar planetary systems, Mercury may come to serve as a case study with which to understand the global cooling and contractional histories of rocky, one-plate planets in general."

By the way, Mariner 10 will always have a special place in my heart. Its Mercury flybys were the first planetary encounters I covered after joining the staff of *Sky & Telescope.*

Reference:

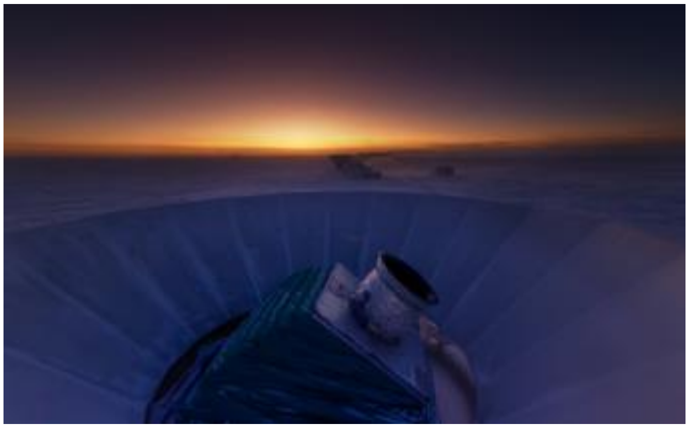
P. Byrne *et al*., "Mercury's global contraction much greater than earlier estimates" *Nature Geoscience,* published online March 16, 2014.

First Direct Evidence of Big Bang Inflation

Researchers with an experiment based at the South Pole have discovered the long-sought "smoking gun" for inflation.

Posted by Camille Carlisle, March 17, 2014

Researchers with the BICEP2 experiment have set the world's cosmologists buzzing with the announcement that they've detected the fingerprints of inflation — the exponential expansion that put the "bang" in the Big Bang.

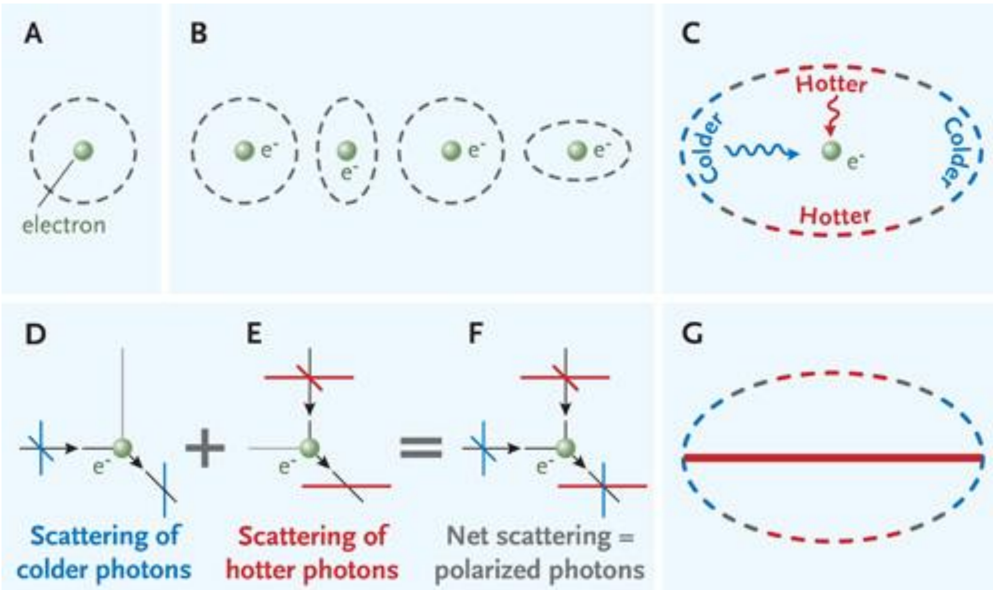


The BICEP2 telescope at twilight, which occurs only twice a year at the South Pole. The MAPO observatory (home of the Keck Array telescope) and the South Pole station can be seen in the background. *Steffen Richter / BICEP Collaboration*

About 10 teams of researchers around the world have been actively looking for this signal, called *primordial B-modes*. But I have to admit that, of all the announcements that might have hit the air waves St. Patrick's Day morning, the discovery of this polarization signal was not at the top of my list. Two teams did reach an important stepping point in this hunt several months ago, by finding another signal that could muck up the primordial data. But from work presented at the American Astronomical Society meeting this past January, I figured astronomers were at least a year away from the announcement made today.

I'm glad to be wrong.

B-modes are a particular pattern of polarization. As a wavelength of polarized light travels through space, it wiggles at a preferred angle to its direction of motion. If inflation happened, it should have sent gravitational waves rippling through spacetime. These waves would have imprinted the B-mode polarization pattern on the cosmic microwave background radiation (CMB).



Gravitational waves created polarization patterns in the cosmic microwave background (CMB) by stretching and squeezing space — and therefore the plasma soup of primordial photons and electrons — as the waves passed through. *(A)* Before a wave hits it from behind, a cross-section of space with an electron in the middle looks normal. But when the wave hits, the cross-section stretches and squeezes one way, then another, in an oscillating pattern *(B)*. Instead of a uniform soup, the electron "sees" around it a universe a bit warmer in the squeezed direction and a bit cooler in the stretched direction *(C)*. Originally, a photon's wave wiggles in all planes perpendicular to the photon's motion *(D and E, incoming crosses)*. When photons scatter off the electron, they become polarized, wiggling in only one plane (outgoing lines). The resulting pattern *(F)* is a sum of the cooler and warmer photons' polarizations. But because photons from warmer regions have more energy, their pattern "wins out," meaning the overall polarization is parallel to the warm regions (G). *S&T: Leah Tiscione*

There's one other way to create a B-mode pattern in the CMB: when the gravity of large-scale cosmic structures works as a lens on the CMB, distorting its polarization pattern. But these *lensed B-modes* exist at an angular scale only one-tenth of the primordial ones. With a lot of careful analysis, researchers can weed these out.

Several projects are currently hunting for the polarization signature of inflation. Shown above are the fields of view for projects active as of fall 2013 (except for Planck, which is all-sky). Fields are approximate and distorted by projection at high declinations. Click to zoom. *S&T / Gregg Dinderman*

The discovery of the primordial B-modes comes from the second round of the Background Imaging of Cosmic Extragalactic Polarization (BICEP) experiment. It's among one of several projects observing the CMB in what's called the Southern Hole, a patch of sky visible from Antarctica that's a direct sightline out of our galaxy and into the cosmic depths. (See the sky map.)

The BICEP2 scope has an aperture of less than 30 centimeters (12 inches), but it doesn't need to be big. Cooled to 4 kelvin, it gazes at a 20° patch of sky 24/7, detecting the CMB's faint microwaves — and, crucially, how they're polarized.

Using 3 years of data, the BICEP2 team meticulously analyzed their polarization measurements. They also compared their data with observations from BICEP1 and from the team's new Keck Array, which is basically like five BICEP2s in one. It was this ability to combine three data sets that ultimately allowed the team to make the discovery.

After a year of intense work — including ruling out more than a dozen alternate explanations — the team is confident that they're seeing the signal of inflation, on a scale of about 2° on the sky. In statistical terms, their signal is better than 5 sigma, which is the gold standard a detection has to meet before physicists accept it as a discovery.

"We are convinced that the signal is really coming from the sky, and that it's coming from the cosmic microwave background," says Clem Pryke (University of Minnesota), who headed up the analysis.

The other researchers present at the technical briefing were also swayed. “This looks as solid as any result that I’ve seen,” says Alan Guth (MIT), co-developer of the inflation paradigm. He and everyone (including the team) want other groups to confirm it, but the signal sure looks like it’s from inflation.

“I am extremely excited,” said gravitational waves physicist Scott Hughes (MIT), beaming. “Of course there are these implications for cosmology and inflation — just as a scientist it’s bloody awesome.”

The “So What?”

Until now, astronomers have really only had one line of evidence to investigate whether inflation happened: the CMB’s speckled pattern of temperature variations. Studies of these patterns — particularly as seen by ESA's Planck satellite — support the simplest version of inflation.

Founding fathers rejoice. Among the many notables who came to be part of Monday's announcement were inflation theory's prime originators, Alan Guth (left) and Andrei Linde. Said Linde, "To see this confirmed within my lifetime — it's so wonderful. I had to get on a plane and fly here." Video of Linde receiving the news. *S&T: Camille Carlisle*

But having B-modes in hand is another ballgame. “This is not something that’s just a home run, but a grand slam,” says Marc Kamionkowski (Johns Hopkins University), one of the theorists who first suggested inflation-triggered B-modes might be detectable in the CMB. “It’s the smoking gun for inflation.”

The B-modes carry with them specific information about the size of the gravitational waves, when inflation happened, and how much energy inflation involved. So having an actual detection in hand shrinks the theoretical playing field — and not just a little, both Kamionkowski and Guth stress.

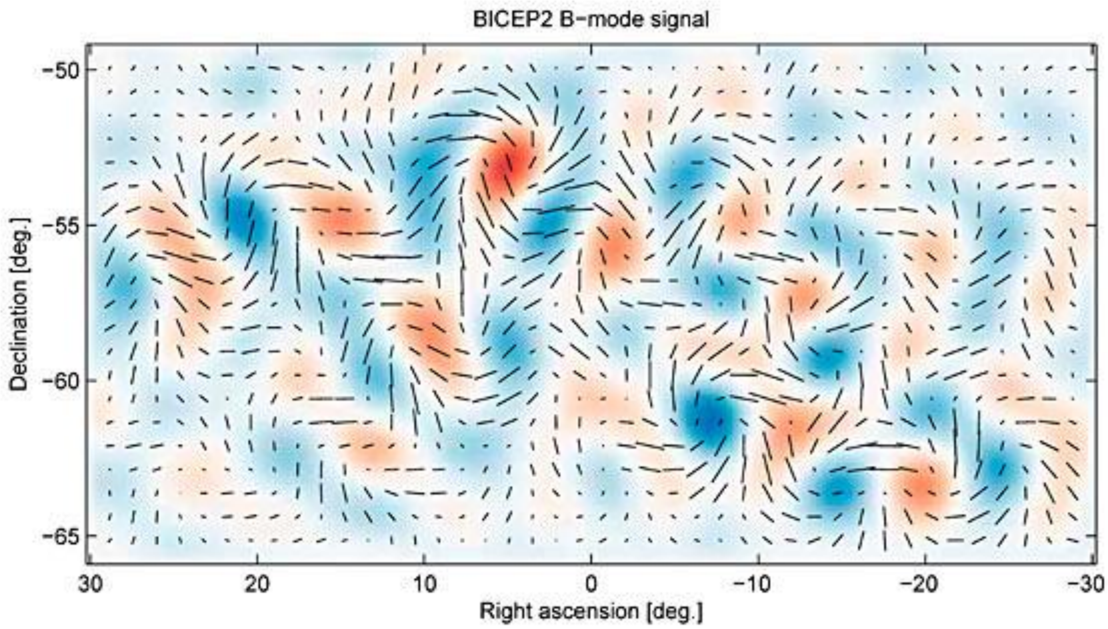
From the BICEP2 results, it looks like inflation happened roughly 0.5×10^{-37} second after the Big Bang, says Kamionkowski — but he cautions that's from a quick calculation he did on a scrap of paper.

The measurement also suggests that inflation might have had something to do with the unification of three of the four fundamental forces of nature — the strong, weak, and electromagnetic. The energy level implied by the BICEP2 data — we're talking 2×10^{16} GeV, according to Guth, or roughly a trillion times the energy of the Large Hadron Collider — matches the energy of grand unified theories, or GUTs. That's an idea theorists have toyed with since the 1970s, but the BICEP2 result is the missing link they've sought for decades.

The data also tell us something about the size of the gravitational waves. This information comes in the form of the ratio of gravitational waves (which are a type of *density perturbation*) to the run-of-the-mill density fluctuations in the CMB. The technical term for this number is the *tensor-to-scalar ratio*, where the gravitational waves are tensors and the "normal" density fluctuations are scalars.

The BICEP2 team came up with a ratio of about 0.2, which means the gravitational waves were "pretty big," Kamionkowski says. (Sorry, I don't have an ironclad number for you.) The Planck team had come up with an upper limit of 0.11 from their data, but Pryke says that, while there's a bit of tension here with his team's result, the discrepancy is not much to worry about. It could be solved by simple extensions to the standard cosmological model, for example. They don't know yet.

The results do *not* tell us what set inflation in motion, only that it happened. Nor do they answer the question of whether inflation is eternal, setting off an endless series of big bangs and creating pocket universes. This cosmological landscape is usually referred to as the *multiverse*. (You can read my in-depth discussion of the search for evidence of multiple universes in the December 2012 *Sky & Telescope*.) However, it's hard to tune inflation such that pocket universes don't happen, Guth points out.



The "curly" B-modes of polarization in the cosmic microwave background. Each line is a measure of polarization at one point on the sky. When the larger E-mode polarization is subtracted, this is what's left. Nearly all of it is the signature of quantum-gravitational chaos in the first instant of the Big Bang. This is an actual map of the sky, about 15° tall, across the southern constellations Phoenix and Tucana. The strongest curl patterns (emphasized with colors) are a couple of degrees wide, roughly the size of your thumb held at arm's length against the sky. *Harvard University / BICEP2 team*

A few “smaller” results that have been lost in the inflation hubbub:

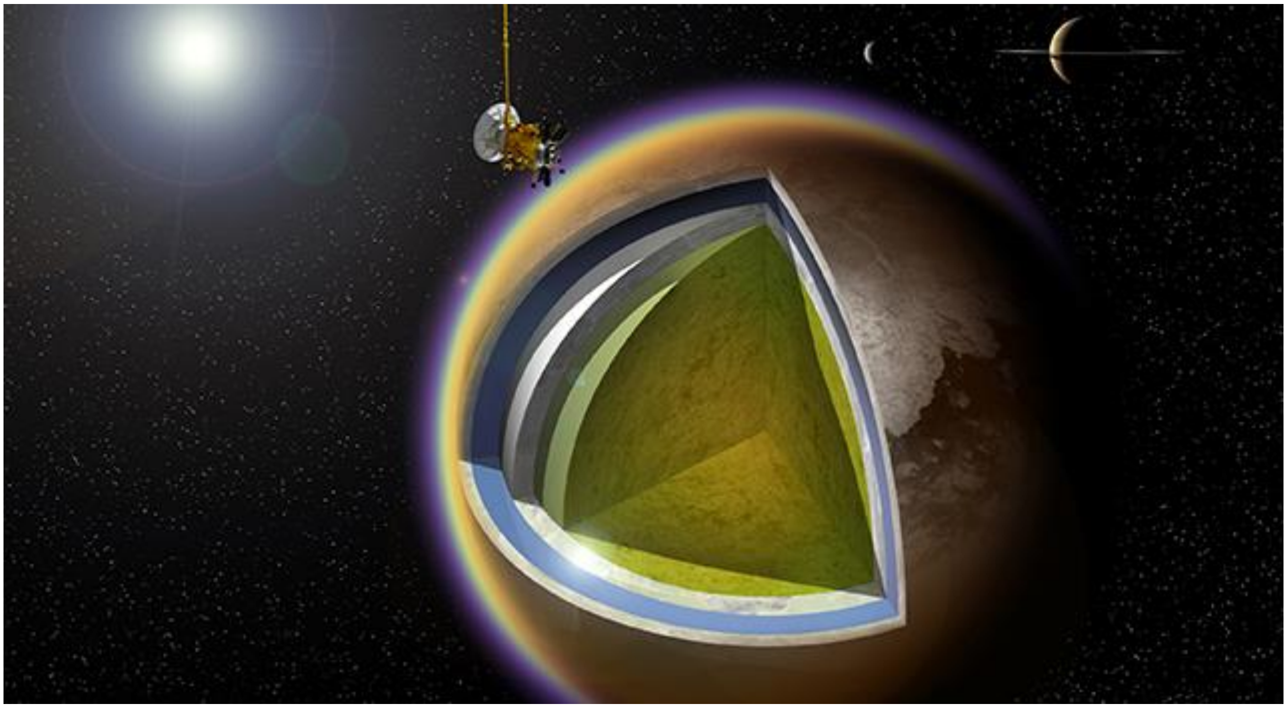
1. This is the first hard evidence that gravity is *quantized*, or comes in discrete packets as light does. The gravitational waves that produced the B-modes were born as quantum fluctuations in gravity itself, then stretched during inflation’s faster-than-light-speed expansion. “I think this is the only observational evidence that we have that actually shows that gravity is quantized,” says cosmologist Ken Olum (Tufts University). “It’s probably the only evidence of this that we will ever have.”
2. This is the first detection of gravitational waves’ action on matter other than their source. Astronomers have observed neutron stars spiraling inward toward each other just as they should if the system was radiating gravitational waves, but they’ve never seen these waves affecting other matter in the cosmos.
3. This is the first detection of Hawking radiation. Hawking radiation is usually associated with the slow evaporation of black holes, as photons emitted from the event horizon. But the observable universe also has a horizon. Hawking radiation should be coming from this horizon, and also from every horizon in the universe — in other words, from every point in the universe, says cosmologist Max Tegmark (MIT). Today the cosmic horizons are huge and their Hawking radiation is utterly insignificant. But in the universe’s first fraction of a second, the horizons were tiny and sharply curved. The gravitational waves announced today are these horizons’ Hawking radiation.

Other teams will be working arduously to confirm the BICEP2 result. Planck's polarization measurements aren't expected until later this year, and the last word from the team was that those results wouldn't include primordial B-mode analysis. But Planck's all-sky coverage might reveal B-modes on larger angular scales than BICEP2 can, and also show something called the "reionization bump," a result of primordial B-modes being rearranged by intervening ionized material, says Planck scientist Charles Lawrence (JPL). Whether Planck can do it at all, though, is for now uncertain.

In the meantime, the excitement is palpable. As Tegmark put it, "I think this is one of the most important discoveries of all time." (See his blog post from the event for why.)

Here is the BICEP team's website for their papers, detailed information about the data, explanations, images, and videos.

Cassini Nears 100th Titan Flyby with a Look Back



This artist's concept shows a possible model of Titan's internal structure that incorporates data from NASA's Cassini spacecraft. Image credit: A. D. Fortes/UCL/STFC
[› Full image and caption]

Ten years ago, we knew Titan as a fuzzy orange ball about the size of Mercury. We knew it had a nitrogen atmosphere -- the only known world with a thick nitrogen atmosphere besides Earth. But what might lie beneath the hazy air was still just a guess.

On March 6, NASA's Cassini spacecraft will swoop down within 933 miles (1,500 kilometers) of Titan to conduct its 100th flyby of the Saturn moon. Each flyby gives us a little more knowledge of Titan and its striking similarities to our world. Even with its cold surface temperatures of minus 290 degrees Fahrenheit (94 kelvins), Titan is like early Earth in a deep freeze.

Since its 2004 arrival at Saturn, Cassini's radar instrument has identified remarkable surface features on Titan. The features include lakes and seas made of liquid methane and ethane, which are larger than North America's Great Lakes, and an extensive layer of liquid water deep beneath the surface. Organic molecules abound in Titan's atmosphere, formed from the breakup of methane by solar radiation.

A recent innovation was the discovery that radar could be used to determine the depth of a Titan sea. "It's something we didn't think we could do before," said Michael Malaska, an affiliate of the Cassini radar team at NASA's Jet Propulsion Laboratory, Pasadena, Calif. "The radar can measure the depth by receiving two different bounces: one from the surface and one from the bottom of the sea. This technique was used to determine that Ligeia Mare, the second largest sea on Titan, is about 160 meters [525 feet] deep. When coupled with some laboratory experiments, it gives us information about the composition of the liquid in Ligeia Mare, too."

As spring turns to summer in Titan's northern hemisphere for the first time since Cassini arrived at Saturn, scientists are looking forward to entering potentially the most exciting time for Titan weather - with waves and winds picking up. With increasing sunlight, the north polar lakes and seas can now be seen in near-infrared images, enabling scientists to learn more about their composition and giving them clues about the surrounding terrain.

"Methane is not only in the atmosphere, but probably in the crust," said Jonathan Lunine, a scientist on the Cassini mission at Cornell University, Ithaca, N.Y. "It's a hint there are organics not only in Titan's air and on the surface, but even in the deep interior, where liquid water exists as well. Organics are the building blocks of life, and if they are in contact with liquid water, there could be a chance of finding some form of life."

Linda Spilker, Cassini project scientist at JPL, speculated on the type of life that could exist. "The astrobiological potential for Titan is two-fold," she said. "Could a unique form of methane-based life exist in Titan's liquid lakes and seas? With a global ocean of liquid water beneath its icy crust, could life exist in Titan's subsurface ocean?"

Although the official Cassini mission name for this flyby is T-99, it is, in fact, the 100th targeted Titan flyby of the mission. Why the discrepancy? An extra flyby was inserted early in the mission, after the Titan flybys had been named.

For additional details on this 100th flyby, visit:
http://saturn.jpl.nasa.gov/mission/flybys/titan20140306/

For more information about Cassini, visit: http://www.nasa.gov/cassini and http://saturn.jpl.nasa.gov

The Cassini-Huygens mission is a cooperative project of NASA, the European Space Agency and the Italian Space Agency. JPL, a division of the California Institute of Technology, Pasadena, manages the mission for NASA's Science Mission Directorate in Washington. Gay Hill
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