Dust erases evidence for gravity wave detection

An elusive signal from the dawn of the cosmos is officially still elusive.

Galactic dust accounts for much of the signal that researchers originally interpreted as ripples in spacetime imprinted on the universe’s first light, a new analysis confirms. The study, conducted by the BICEP2 team that claimed the discovery and scientists with the Planck space telescope, nullifies a result that would have provided the first direct evidence of cosmological inflation, a brief moment after the Big Bang when the universe rapidly ballooned in size. The new analysis, announced by the European Space Agency on January 30, does not mean that the theory of inflation is wrong or that these primordial ripples, called gravitational waves, don’t exist. In fact, it’s possible that the signature of inflation is subtly embedded in BICEP2’s data. But after properly factoring in the pesky influence of dust, Planck and BICEP2 researchers agree that there is not enough evidence to back up the original extraordinary claim.

“It’s perfectly plausible that there are primordial gravitational waves,” says Raphael Flauger, a cosmologist at Carnegie Mellon University in Pittsburgh. “But experiments right now are just not accurate enough to determine this.”

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The joint analysis provides the latest and most definitive word on a finding that has drawn increasing skepticism since it was announced last March. At the time, BICEP2 researchers proclaimed that their 26-centimeter telescope in Antarctica had detected swirling patterns in the alignment of light waves, known as the cosmic microwave background or CMB, that were emitted 380,000 years after the Big Bang. Those patterns, the researchers said, were imprinted when the fabric of space rapidly stretched during the era of inflation.

Unfortunately for the BICEP2 team, our Milky Way galaxy plays a cruel trick that stamps light with a similar pattern. Shards of carbon and silicon in the Milky Way emit light imprinted with a swirl that is indistinguishable from the signature of primordial gravitational waves. Despite BICEP2 scientists’ insistence that they had accounted for the contribution of this dust, other researchers published multiple independent analyses questioning the discovery.

Seeking to solidify its result, the BICEP2 team joined scientists from Planck, which is mapping the CMB with unprecedented sensitivity, to take a careful look at the slice of sky measured by BICEP2 and another scope called the Keck Array. While BICEP2 measures light at a single frequency, Planck captures a wider spectrum, allowing scientists to isolate the influence of dust, which preferentially emits light at particular frequencies. The detailed survey revealed that BICEP2 underestimated the effect of galactic dust. Once the contribution from dust is removed, the remaining signal is too small to be considered a discovery.

Joanna Dunkley, an astrophysicist at the University of Oxford and coauthor of the new analysis, says the BICEP2 researchers didn’t initially appreciate the uncertainty of dust’s contribution to their measurement. The ballpark figures they used, she adds, “were taken a little too much as gospel truth.”

Despite the dusty disappointment, the new study leaves plenty of wiggle room for future experiments to uncover evidence of inflation. BICEP2’s original measurement of a variable called r, which compares gravitational wave and matter density deviations in the CMB, was considerably higher than most theories predict. The new combined Planck and BICEP2 result pushes down r to a maximum value that is more in line with the simplest inflationary theories, Flauger says. That means any primordial gravitational waves will be harder to detect, but it also gives hope that the signal will eventually shine through as an army of telescopes, including the recently upgraded BICEP3 and Keck, dissect the CMB. Other experiments, including the South Pole Telescope, ACTPol and SPIDER, are also scanning the skies. “We’re still excited about looking for this,” Dunkley says.

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The Planck satellite analyzed the same patch of sky, shown here within the white dots, that the BICEP2 telescope measured in a search for primordial gravitational waves. Yellow and red patches contain the most galactic dust.

and Reid Nelson generated a composite photo showing the object in motion (dashes). They also captured a beautiful shot of Comet Lovejoy (bottom). Second, the KU Marching Band Practice field turned out to be an ideal observing site. So good was the site that we will hold all future public observing sessions there and abandon the Prairie Park Nature Center. Many thanks to those who came out to set up the scopes and keep the public entertained while the asteroid was tracked down. The beautiful views of Orion, Jupiter, the Moon, and the comet were crowd-pleasers, The next session is scheduled for Sunday, March 01, beginning at 8:00 PM. The site map for the Marching Band Practice Field is accessible on the club web site.

Any suggestions for improving the club or the newsletter are always welcome.
Citizen Scientists Lead Astronomers to Mystery Objects in Space

Sometimes it takes a village to find new and unusual objects in space. Volunteers scanning tens of thousands of starry images from NASA's Spitzer Space Telescope, using the Web-based Milky Way Project, recently stumbled upon a new class of curiosities that had gone largely unrecognized before: yellow balls. The rounded features are not actually yellow -- they just appear that way in the infrared, color-assigned Spitzer images.

"The volunteers started chatting about the yellow balls they kept seeing in the images of our galaxy, and this brought the features to our attention," said Grace Wolf-Chase of the Adler Planetarium in Chicago. A colorful, 122-foot (37-meter) Spitzer mosaic of the Milky Way hangs at the planetarium, showcasing our galaxy's bubbling brew of stars. The yellow balls in this mosaic appear small but are actually several hundred to thousands of times the size of our solar system.

"With prompting by the volunteers, we analyzed the yellow balls and figured out that they are a new way to detect the early stages of massive star formation," said Charles Kerton of Iowa State University, Ames. "The simple question of 'Hmm, what's that?' led us to this discovery." Kerton is lead author, and Wolf-Chase a co-author, of a new study on the findings in the Astrophysical Journal.

The Milky Way Project is one of many so-called citizen scientist projects making up the Zooniverse website, which relies on crowdsourcing to help process scientific data. So far, more than 70 scientific papers have resulted from volunteers using Zooniverse, four of which are tied to the Milky Way Project. In 2009, volunteers using a Zooniverse project called Galaxy Zoo began chatting about unusual objects they dubbed "green peas." Their efforts led to the
Minor mergers have massive consequences for black holes

By Dr. Ethan Siegel

When you think of our sun, the nearest star to our world, you think of an isolated entity, with more than four light years separating it from its next nearest neighbor. But it wasn't always so: billions of years ago, when our sun was first created, it very likely formed in concert with thousands of other stars, when a giant molecular cloud containing perhaps a million times the mass of our solar system collapsed. While the vast majority of stars that the universe forms—some ninety-five percent—are the mass of our sun or smaller, a rare but significant fraction are ultra-massive, containing tens or even hundreds of times the mass our star contains. When these stars run out of fuel in their cores, they explode in a fantastic Type II supernova, where the star's core collapses. In the most massive cases, this forms a black hole.

Over time, many generations of stars—and hence, many black holes—form, with the majority eventually migrating towards the centers of their host galaxies and merging together. Our own galaxy, the Milky Way, houses a supermassive black hole that weighs in at about four million solar masses, while our big sister, Andromeda, has one nearly twenty times as massive. But even relatively isolated galaxies didn't simply form from the monolithic collapse of an isolated clump of matter, but by hierarchical mergers of smaller galaxies over tremendous timescales. If galaxies with large amounts of stars all have black holes at their centers, then we should be able to see some fraction of Milky Way-sized galaxies with not just one, but multiple supermassive black holes at their center!

It was only in the early 2000s that NASA's Chandra X-ray Observatory was able to find the first binary supermassive black hole in a galaxy, and that was in an ultra-luminous galaxy with a double core. Many other examples were discovered since, but for a decade they were all in ultra-massive, active galaxies. That all changed in 2011, with the discovery of two active, massive black holes at the center of the regular spiral galaxy NGC 3393, a galaxy that must have undergone only minor mergers no less than a billion years ago, where the black hole pair is separated by only 490 light years! It's only in the cores of active, X-ray emitting galaxies that we can detect binary black holes like this. Examples like NGC 3393 and IC 4970 are not only confirming our picture of galaxy growth and formation, but are teaching us that supermassive relics from ancient, minor mergers might persist as standalone entities for longer than we ever thought!

Images credit: NGC 3393 in the optical (L) by M. Malkan (UCLA), HST, NASA (L); NGC 3393 in the X-ray and optical (R), composite by NASA / CXC / SAO / G. Fabbiano et al. (X-ray) and NASA/STScI (optical).

Check out some cool images and artist reconstructions of black holes from Chandra: http://chandra.harvard.edu/photo/category/blackholes.html

Kids can learn all about Black Holes from this cool animation at NASA’s Space Place: http://spaceplace.nasa.gov/black-holes.
ASTRONOMY ASSOCIATES of LAWRENCE

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Volunteer 'Disk Detectives' Top 1 Million Classifications of Possible Planetary Habitats

A NASA-sponsored website designed to crowdsource analysis of data from the agency's Wide-field Infrared Survey Explorer (WISE) mission has reached an impressive milestone. In less than a year, citizen scientists using DiskDetective.org have logged 1 million classifications of potential debris disks and disks surrounding young stellar objects (YSO). This data will help provide a crucial set of targets for future planet-hunting missions.

"This is absolutely mind-boggling," said Marc Kuchner, an astrophysicist at NASA's Goddard Space Flight Center in Greenbelt, Maryland, and the project's principal investigator. "We've already broken new ground with the data, and we are hugely grateful to everyone who has contributed to Disk Detective so far."

Combing through objects identified by WISE during its infrared survey of the entire sky, Disk Detective aims to find two types of developing planetary environments. The first, known as a YSO disk, typically is less than 5 million years old, contains large quantities of gas, and often is found in or near young star clusters. The second planetary habitat, known as a debris disk, tends to be older than 5 million years, holds little or no gas, and possesses belts of rocky or icy debris that resemble the asteroid and Kuiper belts found in our own solar system. Vega and Fomalhaut, two of the brightest stars in the sky, host debris disks.

Planets form and grow within disks of gas, dust and icy grains surrounding young stars. The particles absorb the star's light and reradiate it as heat, which makes the stars brighter at infrared wavelengths -- in this case, 22 microns -- than they would be without a disk.

Computer searches already have identified some objects seen by the WISE survey as potential dust-rich disks. But software can't distinguish them from other infrared-bright sources, such as galaxies, interstellar dust clouds and asteroids. There may be thousands of potential planetary systems in the WISE data, but the only way to know for sure is to inspect each source by eye.

Kuchner recognized that searching the WISE database for dusty disks was a perfect opportunity for crowdsourcing. He worked with NASA to team up with the Zooniverse, a collaboration of scientists, software developers and educators who collectively develop and manage citizen science projects on the Internet.

At DiskDetective.org, volunteers watch a 10-second "flip book" of a disk candidate shown at several different wavelengths as observed from three different telescopes, including WISE. They then click one or more buttons that best describe the object's appearance. Each classification helps astronomers decide which images may be contaminated by background galaxies, interstellar matter or image artifacts, and which may be real disks that should be studied in more detail.

In March 2014, just two months after Disk Detective launched, Kuchner was amazed to find just how invested in the project some users had become. Volunteers complained about seeing the same object over and over. "We thought at first it was a bug in the system," Kuchner explained, "but it turned out they were seeing repeats because they had already classified every single object that was online at the time."

Some 28,000 visitors around the world have participated in the project to date. What's more, volunteers have translated the site into eight foreign languages, including Romanian, Mandarin and Bahasa, and have produced their own video tutorials on using it.

Many of the project's most active volunteers are now joining in science team discussions, and the researchers encourage all users who have performed more than 300 classifications to contact them and take part.

One of these volunteers is Tadeáš Černohous, a postgraduate student in geodesy and cartography at Brno University of Technology in the Czech Republic. "I barely understood what scientists were looking for when I started participating in Disk Detective, but over the past year I have developed a basic sense of which stars are worthy of further exploration," he said.
Hubble Spies a Loopy Galaxy

At first glance, galaxy NGC 7714 resembles a partial golden ring from an amusement park ride. This unusual structure is a river of Sun-like stars that has been pulled deep into space by the gravitational tug of a bypassing galaxy (not seen in this Hubble Space Telescope photo). Though the universe is full of such colliding galaxies that are distorted in a gravitational taffy-pull, NGC 7714 is particularly striking for the seeming fluidity of the stars along a vast arc. The near-collision between the galaxies happened at least 100 million years ago.

Alissa Bans, a postdoctoral fellow at Adler Planetarium in Chicago and a member of the Disk Detective science team, recalls mentioning that she was searching for candidate YSOs and presented examples of what they might look like on Disk Detective. "In less than 24 hours," she said, "Tadeáš had compiled a list of nearly 100 objects he thought could be YSOs, and he even included notes on each one."

Speaking at a press conference at the American Astronomical Society meeting in Seattle on Tuesday, Kuchner said the project has so far netted 478 objects of interest, which the team is investigating with a variety of ground-based telescopes in Arizona, California, New Mexico, Argentina and Chile. "We now have at least 37 solid new disk candidates, and we haven't even looked at all the new telescope data yet," he said.

Disk Detective currently includes about 278,000 WISE sources. The team expects to wrap up the current project sometime in 2018, with a total of about 3 million classifications and perhaps 1,000 disk candidates. The researchers then plan to add an additional 140,000 targets to the site.

"We've come a long way, but there's still lots and lots more work to do -- so please drop by the site and do a little science with us!" added Kuchner.

WISE has made infrared measurements of more than 745 million objects, compiling the most comprehensive survey of the sky at mid-infrared wavelengths currently available. With its primary mission complete, the satellite was placed in hibernation in 2011. WISE was awoken in September 2013, renamed the Near-Earth Object Wide-field Infrared Survey Explorer (NEOWISE), and given a new mission to assist NASA's efforts in identifying the population of potentially hazardous near-Earth objects (NEOs).
Hubble Discovers that Milky Way Core Drives Wind at 2 Million Miles Per Hour

At a time when our earliest human ancestors had recently mastered walking upright, the heart of our Milky Way galaxy underwent a titanic eruption, driving gases and other material outward at 2 million miles per hour.

Now, at least 2 million years later, astronomers are witnessing the aftermath of the explosion: billowing clouds of gas towering about 30,000 light-years above and below the plane of our galaxy.

The enormous structure was discovered five years ago as a gamma-ray glow on the sky in the direction of the galactic center. The balloon-like features have since been observed in X-rays and radio waves. But astronomers needed NASA’s Hubble Space Telescope to measure for the first time the velocity and composition of the mystery lobes. They now seek to calculate the mass of the material being blown out of our galaxy, which could lead them to determine the outburst’s cause from several competing scenarios.

Astronomers have proposed two possible origins for the bipolar lobes: a firestorm of star birth at the Milky Way’s center or the eruption of its supermassive black hole. Although astronomers have seen gaseous winds, composed of streams of charged particles, emanating from the cores of other galaxies, they are getting a unique, close-up view of our galaxy’s own fireworks.

"When you look at the centers of other galaxies, the outflows appear much smaller because the galaxies are farther away," said Andrew Fox of the Space Telescope Science Institute in Baltimore, Maryland, lead researcher of the study. "But the outflowing clouds we're seeing are only 25,000 light-years away in our galaxy. We have a front-row seat. We can study the details of these structures. We can look at how big the bubbles are and can measure how much of the sky they are covering."

The giant lobes, dubbed Fermi Bubbles, initially were spotted using NASA's Fermi Gamma-ray Space Telescope. The detection of high-energy gamma rays suggested that a violent event in the galaxy's core aggressively launched energized gas into space. To provide more information about the outflows, Fox used Hubble's Cosmic Origins Spectrograph (COS) to probe the ultraviolet light from a distant quasar that lies behind the base of the northern bubble. Imprinted on that light as it travels through the lobe is information about the velocity, composition, and temperature of the expanding gas inside the bubble, which only COS can provide.

Fox's team was able to measure that the gas on the near side of the bubble is moving toward Earth and the gas on the far side is travelling away. COS spectra show that the gas is rushing from the galactic center at roughly 2 million miles an hour (3 million kilometers an hour).

"This is exactly the signature we knew we would get if this was a bipolar outflow," explained Rongmon Bordoloi of the Space Telescope Science Institute, a co-author on the science paper. "This is the closest sightline we have to the galaxy's center where we can see the bubble being blown outward and energized."

The COS observations also measure, for the first time, the composition of the material being swept up.

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Sagittarius A*: NASA’s Chandra Detects Record-Breaking Outburst from Milky Way’s Black Hole

On September 14, 2013, astronomers caught the largest X-ray flare ever detected from the supermassive black hole at the center of the Milky Way, known as Sagittarius A* (Sgr A*). This event, which was captured by NASA’s Chandra X-ray Observatory, was 400 times brighter than the usual X-ray output from Sgr A*. The main portion of this graphic shows the area around Sgr A* in a Chandra image where low, medium, and high-energy X-rays are red, green, and blue respectively. The inset box images shows the giant flare, along with much steadier X-ray emission from a nearby magnetar, to the lower left. A magnetar is a neutron star with a strong magnetic field. A little more than a year later, astronomers saw another flare from Sgr A* that was 200 times brighter than its normal state in October 2014.

Astronomers have two theories about what could be causing these “megaflares” from Sgr A*. The first idea is that the strong gravity around Sgr A* tore apart an asteroid in its vicinity, heating the debris to X-ray emitting temperatures before devouring the remains. Their other proposed explanation involves the strong magnetic fields around the black hole. If the magnetic field lines reconfigured themselves and reconnected, this could also create a large burst of X-rays. Such events are seen regularly on the Sun and the events around Sgr A* appear to have a similar pattern in intensity levels to those.

Sgr A* is about 4.5 million times the mass of our Sun and is located about 26,000 light years from Earth. Researchers have been using Chandra to monitor Sgr A* since the telescope was launched in 1999. Recently, astronomers have been closely watching Sgr A* to see if the black hole would consume parts of a nearby cloud of gas known as G2 and cause flares in X-rays. Due to G2’s distance from Sgr A* at the time of the September 2013 flare, however, researchers do not think the gas cloud was responsible for the spike in X-rays.

In addition to the giant flares, the G2 observing campaign with Chandra also collected more data on the magnetar located close to Sgr A*. This magnetar is undergoing a long X-ray outburst, and the Chandra data are allowing astronomers to better understand this unusual object.
in the gaseous cloud. COS detected silicon, carbon, and aluminum, indicating that the gas is enriched in the heavy elements produced inside stars and represents the fossil remnants of star formation.

COS measured the temperature of the gas at approximately 17,500 degrees Fahrenheit, which is much cooler than most of the super-hot gas in the outflow, thought to be at about 18 million degrees Fahrenheit. “We are seeing cooler gas, perhaps interstellar gas in our galaxy’s disk, being swept up into that hot outflow,” Fox explained.

This is the first result in a survey of 20 faraway quasars whose light passes through gas inside or just outside the Fermi Bubbles — like a needle piercing a balloon. An analysis of the full sample will yield the amount of mass being ejected. The astronomers can then compare the outflow mass with the velocities at various locations in the bubbles to determine the amount of energy needed to drive the outburst and possibly the origin of the explosive event.

One possible cause for the outflows is a star-making frenzy near the galactic center that produces supernovas, which blow out gas. Another scenario is a star or a group of stars falling onto the Milky Way's supermassive black hole. When that happens, gas superheated by the black hole blasts deep into space. Because the bubbles are short-lived compared to the age of our galaxy, it suggests this may be a repeating phenomenon in the Milky Way's history. Whatever the trigger is, it likely occurs episodically, perhaps only when the black hole gobbles up a concentration of material.

“It looks like the outflows are a hiccup,” Fox said. “There may have been repeated ejections of material that have blown up, and we’re catching the latest one. By studying the light from the other quasars in our program, we may be able to detect the fossils of previous outflows.”

Galactic winds are common in star-forming galaxies, such as M82, which is furiously making stars in its core. “It looks like there's a link between the amount of star formation and whether or not these outflows happen,” Fox said. “Although the Milky Way overall currently produces a moderate one to two stars a year, there is a high concentration of star formation close to the core of the galaxy.”

(Continued from page 3)

discovery of a class of compact galaxies that churned out extreme numbers of stars.

In the Milky Way Project, volunteers scan through images that Spitzer took of the thick plane of our galaxy, where newborn stars are igniting in swaths of dust. The infrared wavelengths detected by Spitzer have been assigned visible colors we can see with our eyes. In addition to the yellow balls, there are many green bubbles with red centers, populating a landscape of swirling gas and dust. These bubbles are the result of massive newborn stars blowing out cavities in their surroundings. The green bubble rims are made largely of organic molecules called polycyclic aromatic hydrocarbons (PAHs), cleared away by blasts of radiation and winds from the central star. Dust warmed by the star appears red in the center of the bubbles.

Volunteers have classified more than 5,000 of these green bubbles using the project’s Web-based tools. When they started reporting that they were finding more reoccurring features in the shape of yellow balls, the Spitzer researchers took note and even named the features accordingly. In astronomy and other digital imaging, yellow represents areas where green and red overlap. So what are these yellow balls?

A thorough analysis by the team led to the conclusion that the yellow balls precede the green bubble features, representing a phase of star formation that takes place before the bubbles form.

“The yellow balls are a missing link,” said Wolf-Chase, “between the very young embryonic stars buried in dark filaments and newborn stars blowing the bubbles.”

“If you wind the clock backwards from the bubbles, you get the yellow ball features,” said Kerton.

The researchers explained why the yellow balls appear yellow: The PAHs, which appear green in the Spitzer images, haven’t been cleared away by the winds from massive stars yet, so the green overlaps with the warm dust, colored red, to make yellow. The yellow balls are compact because the harsh effects of the massive star have yet to fully expand into their surroundings.

So far, the volunteers have identified more than 900 of these compact yellow features. The next step for the researchers is to look at their distribution. Many appear to be lining the rims of the bubbles, a clue that perhaps the massive stars are triggering the birth of new stars as they blow the bubbles, a phenomenon known as triggered star formation. If the effect is real, the researchers should find that the yellow balls statistically appear more often with bubble walls.

“These results attest to the importance of citizen scientist programs,” said Wolf-Chase. Kerton added, "There is always the potential for serendipitous discovery that makes citizen science both exciting for the participants and useful to the professional astronomer.”

(Continued from page 8)