Volume 49 Number 4 April 2023

The Celestial Mechanic

The Official Newsletter of the Astronomy Associates of Lawrence

Coming Events

Monthly Meeting
April 30, 2022, 7:00PM
Baker Wetlands Discovery Center

Public Observing
April 30, 2022, 8:00PM
Baker Wetlands Discovery Center

Club Officers

President
Rick Heschmeyer email

AICOR
William Winkler email

NSN Coordinator
Howard Edin email

Faculty Advisor
Dr. Jennifer Delgado email.

Newsletter Editor
Chuck Wehner email

Inside This Issue

Report From the Officers

By Rick Heschmeyer

One indication that spring has arrived is cloudy weather. In March, cloudy weather forced the cancellation of our public observing following out monthly club meeting. During that meeting AAL member presented "Twenty Years of Lucky Imaging", chronicling his journey through equipment, software, and imaging results over the years. If you've seen any of David's images on our Facebook page, you know how impressive his planetary and solar imaging is.

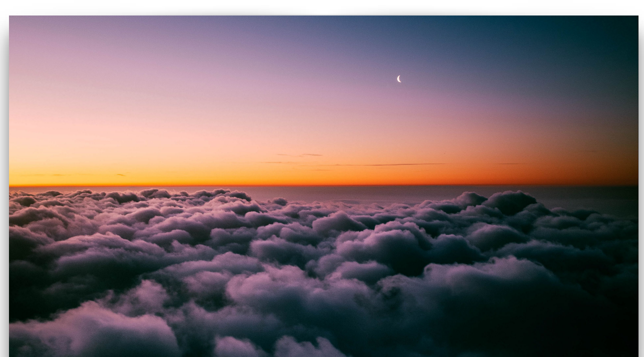
The observing portion of the March Telescope Night at KU was also cancelled due to clouds, but the portable planetarium kept visitors entertained.

We have several events coming up in April. On Monday evening, April 3, PlanetPalooza, a joint AAL/Lawrence Public Library observing event, will take place from 7:30-9:00 PM on the roof of the parking garage next to the library. Please join us and bring a scope if you can. These joint events with LPL have drawn large crowds in the past. Plan on arriving between 6:30 and 7:00 PM to get set up, so that we can avoid vehicle traffic when people start arriving.

On Saturday, April 15 from 9am – noon, AAL will once again be participating in the Baker Wetlands Family Fun Day at the Discovery Center. If clear, we will be conducting solar observing. If not, we will be manning a couple of tables inside, as we did at last year's event.

The next Telescope Night at KU is scheduled for Thursday, April 6. Once the flyer is released, I will forward to everyone and post on our Facebook page.

And finally, our April Club Meeting and Observing will take place on Sunday, April 30. The meeting will start at the usual 7 PM time, followed by public observing, weather permitting. We will be discussing the upcoming 2023 and 2024 Solar Eclipses and begin the planning process for local events to observe both partial eclipses here in Lawrence.

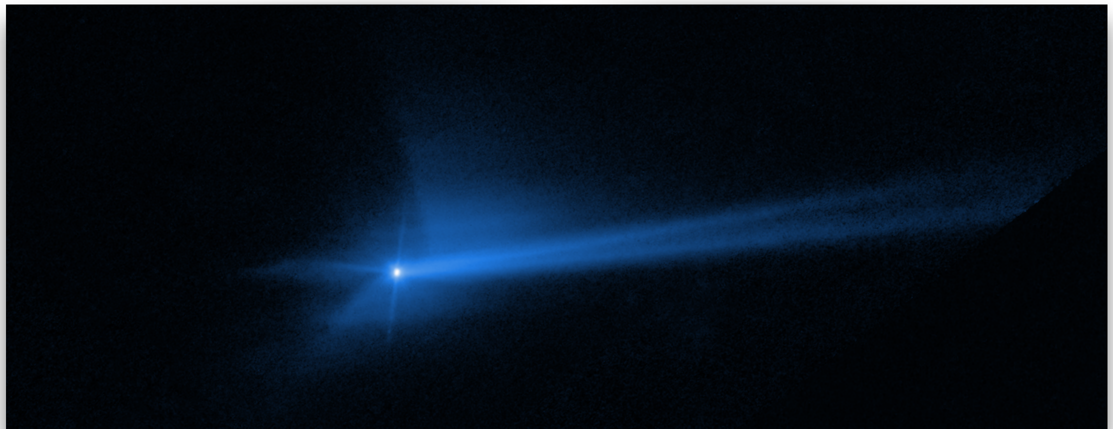


I hope to see you at our upcoming April events, and hope for better cooperation from Mother Nature as well.

HUBBLE CAPTURES MOVIE OF DART ASTEROID IMPACT DEBRIS

Hubblesite, March 1, 2023

NEVER-BEFORE-SEEN SPACECRAFT COLLISION YIELDS UNEXPECTED SURPRISES



In 2022 NASA embarked on a bold experiment to see if they could change an asteroid's velocity by smacking it with a ballistic probe – kind of like hitting it with a hammer. This experiment was to test a potential technique to someday deflect an asteroid on a collision course to Earth. Perhaps, for the first time in the history of the universe, an intelligent planetary species sought ways to avoid its own potential extinction by threats from outer space (something the dinosaurs, who were wiped out 65 million years ago by a rogue asteroid, never evolved to accomplish). Called DART (Double Asteroid Redirection Test), the target was a binary asteroid Didymos/Dimorphos. On September 26, 2022, Dimorphos was hit with the DART spacecraft, which was half the weight of a small car.

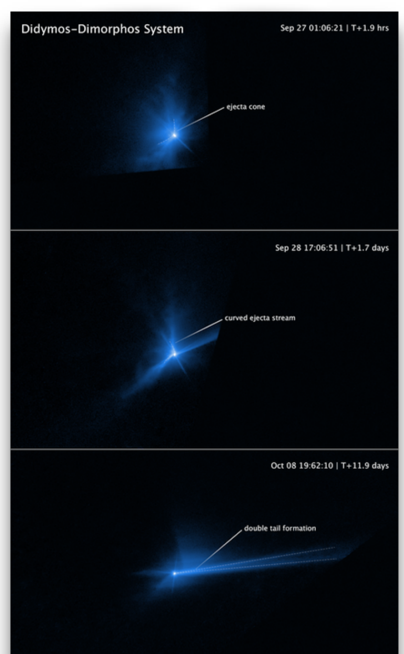
Hubble had a ringside seat to the demolition derby. It fired off a series of snapshots over several days capturing the outflow of tons of dusty debris from the 13,000-miles-per-hour impact. Astronomers didn't know what to expect. They were surprised, delighted, and somewhat mystified by the results. The dust blew off the asteroid into a cone shape, got twisted-up along the asteroid's orbit about its companion, and was then blown into a comet-like tail. Knowing how to steer a rogue asteroid away from a catastrophic collision with Earth might save humanity someday.

Like a sports photographer at an auto-racing event, NASA's Hubble Space Telescope captured a series of photos of asteroid Dimorphos when it was deliberately hit by a 1,200-pound NASA spacecraft called DART on September 26, 2022.

The primary objective of DART, which stands for Double Asteroid Redirection Test, was to test our ability to alter the asteroid's trajectory as it orbits its larger companion asteroid, Didymos. Though neither Didymos nor Dimorphos poses any threat to Earth, data from the mission will help inform researchers how to potentially divert an asteroid's path away from Earth, if ever necessary. The DART experiment also provided fresh insights into planetary collisions that may have been common in the early solar system.

Hubble's time-lapse movie of the aftermath of DART's collision reveals surprising and remarkable, hour-by-hour changes as dust and chunks of debris were flung into space. Smashing head on into the asteroid at 13,000 miles per hour, the DART impactor blasted over 1,000 tons of dust and rock off of the asteroid.

The Hubble movie offers invaluable new clues into how the debris was dispersed into a complex pattern in the days following the impact. This was over a volume of space much larger than could be recorded by the LICIACube cubesat, which flew past the binary asteroid minutes after DART's impact.



"The DART impact happened in a binary asteroid system. We've never witnessed an object collide with an asteroid in a binary asteroid system before in real time, and it's really surprising. I think it's fantastic. Too much stuff is going on here. It's going to take some time to figure out," said Jian-Yang Li of the Planetary Science Institute in Tucson, Arizona. The study, led by Li along with 63 other DART team members, was published on March 1 in the journal Nature.

The movie shows three overlapping stages of the impact aftermath: the formation of an ejecta cone, the spiral swirl of debris caught up along the asteroid's orbit about its companion asteroid, and the tail swept behind the asteroid by the pressure of sunlight (resembling a windsock caught in a breeze).

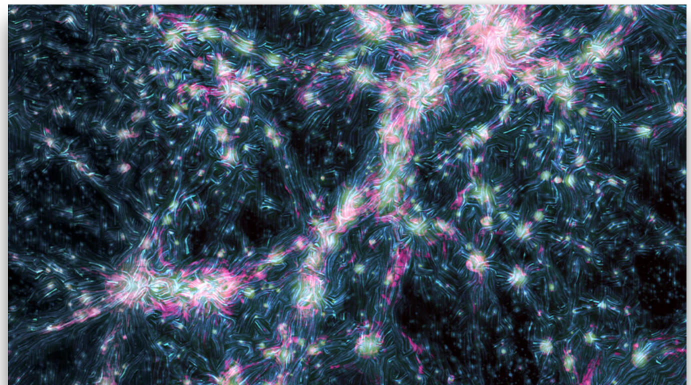
The Hubble movie starts at 1.3 hours before impact. In this view both Didymos and Dimorphos are within the central bright spot; even Hubble can't resolve the two asteroids separately. The thin, straight spikes projecting away from the center (and seen in later images) are artifacts of Hubble's optics. The first post-impact snapshot is 2 hours after the event. Debris flies away from the asteroid, moving with a range of speeds faster than four miles per hour (fast enough to escape the asteroid's gravitational pull, so it does not fall back onto the asteroid). The ejecta forms a largely hollow cone with long, stringy filaments.

At about 17 hours after the impact the debris pattern entered a second stage. The dynamic interaction within the binary system starts to distort the cone shape of the ejecta pattern. The most prominent structures are rotating, pinwheel-shaped features. The pinwheel is tied to the gravitational pull of the companion asteroid, Didymos. "This is really unique for this particular incident," said Li. "When I first saw these images, I couldn't believe these features. I thought maybe the image was smeared or something."

Hubble next captures the debris being swept back into a comet-like tail by the pressure of sunlight on the tiny dust particles. This stretches out into a debris train where the lightest particles travel the fastest and farthest from the asteroid. The mystery is compounded later when Hubble records the tail splitting in two for a few days.

A multitude of other telescopes on Earth and in space, including NASA's James Webb Space Telescope and Lucy spacecraft also observed the DART impact and its outcomes. ☀

Astronomers spotted shock waves shaking the web of the universe for the first time



In this simulation of the cosmic web, shock waves along filaments and around clusters emit radio light (pink) as they ripple through magnetic fields (cyan).

By Elise Cutts
SCIENCENEWS, MARCH 6, 2023

For the first time, astronomers have caught a glimpse of shock waves rippling along strands of the cosmic web — the enormous tangle of galaxies, gas and dark matter that fills the observable universe.

Combining hundreds of thousands of radio telescope images revealed the faint glow cast as shock waves send charged particles flying through the magnetic fields that run along the cosmic web. Spotting these shock waves could give astronomers a better look at these large-scale magnetic fields, whose properties and origins are largely mysterious, researchers report in the Feb. 17 *Science Advances*.

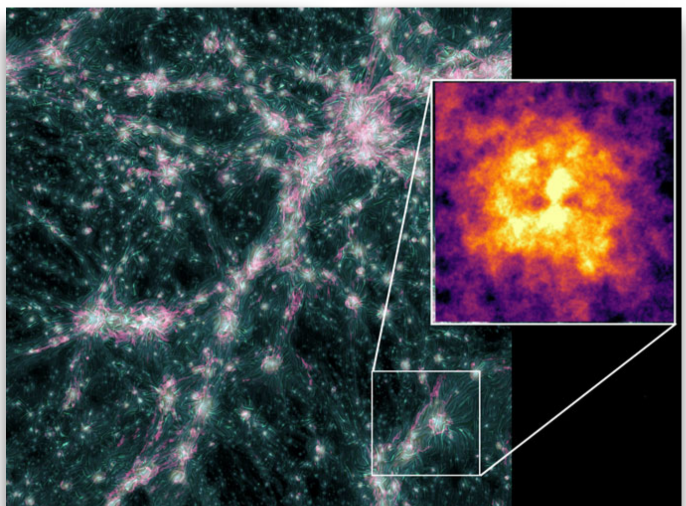
Finally, astronomers "can confirm what so far has only been predicted by simulations — that these shock waves exist," says astrophysicist Marcus Brüggen of the University of Hamburg in Germany, who was not involved in the new study.

At its grandest scale, our universe looks something like Swiss cheese. Galaxies aren't distributed evenly through space but rather are clumped together in enormous clusters connected by ropy filaments of dilute gas, galaxies and dark matter and separated by not-quite-empty voids (*SN: 10/3/19*).

Tugged by gravity, galaxy clusters merge, filaments collide, and gas from the voids falls onto filaments and clusters. In simulations of the cosmic web, all that action consistently sets off enormous shock waves in and along filaments.

Filaments make up most of the cosmic web but are much harder to spot than galaxies (*SN: 1/20/14*). While scientists have observed shock waves around galaxy clusters before, shocks in filaments "have never been really seen," says astronomer Reinout van Weeren of Leiden University in the Netherlands, who was not involved in the study. "But they should be basically all around the cosmic web."

Shock waves around filaments would accelerate charged particles through the magnetic fields that suffuse the cosmic web (*SN: 6/6/19*). When that happens, the particles emit light at wavelengths that radio telescopes can detect — though the signals are very weak.



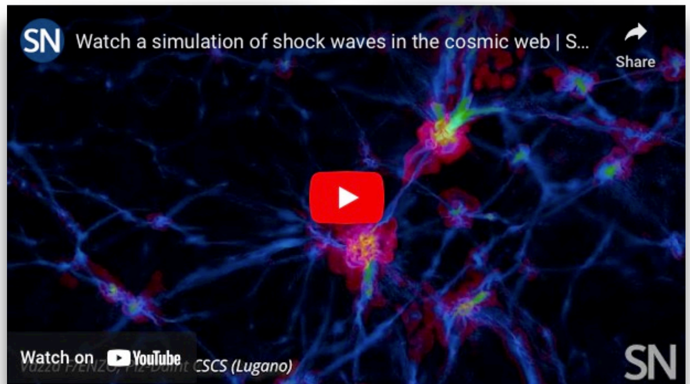
Simulations of the cosmic web and its magnetic field (cyan), like the one pictured here, predict that shockwaves along filaments and around galaxy clusters should emit weak radio signals (pink). The inset shows what combining many radio images of galaxy cluster pairs in the simulated web might look like, with colors representing gas temperature and density (high values are yellow, low values are purple and black).

A single shock wave in a filament "would look like nothing, it'd look like noise," says radio astronomer Tessa Vernstrom of the International Centre for Radio Astronomy Research in Crawley, Australia.

Instead of looking for individual shock waves, Vernstrom and her colleagues combined radio images of more than 600,000 pairs of galaxy clusters close enough to be connected by filaments to create a single "stacked" image. This amplified weak signals and revealed that, on average, there is a faint radio glow from the filaments between clusters.

"When you can dig below the noise and still actually get a result — to me, that's personally exciting," Vernstrom says.

The faint signal is highly polarized, meaning that the radio waves are mostly aligned with one another. Highly polarized light is unusual in the cosmos, but it is expected from radio light cast by shock waves, van Weeren says. "So that's really, I think, very good evidence for the fact that the shocks are likely indeed present."



In this computer simulation, gas falling onto the cosmic web (blue) heats and expands, setting off shockwaves that ripple through the hot, expanded gas (red) and throughout the vast network of galaxy clusters and filaments that fills our universe. These shockwaves interact with magnetic fields (green) in the cosmic web to create radio signals that astronomers can observe.

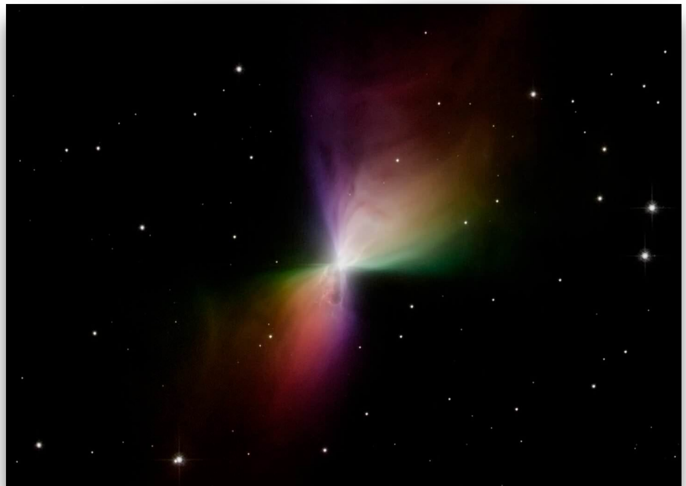
The discovery goes beyond confirming the predictions of cosmic web simulations. The polarized radio emissions also offer a rare peek at the magnetic fields that permeate the cosmic web, if only indirectly.

"These shocks," Brüggen says, "are really able to show that there are large-scale magnetic fields that form [something] like a sheath around these filaments."

He, van Weeren and Vernstrom all note that it's still an open question how cosmic magnetic fields arose in the first place. The role these fields play in shaping the cosmic web is equally mysterious.

"It's one of the four fundamental forces of nature, right? Magnetism," Vernstrom says. "But at least on these large scales, we don't really know how important it is. ☀

How Cold is Space?



Scientists may now know why the Boomerang Nebula, the coldest object in the known Universe. Credit: NASA/ESA/The Hubble Heritage Team

By Paul M. Sutter
UNIVERSETODAY, FEBRUARY 28, 2023

The average temperature of the universe is downright cold – right around 3 degrees above absolute zero.

In order to measure the temperature deep space there must be a substance, because this is how we define temperature. The temperature of the room you're sitting in right now is determined by the average motion of all the air molecules in the room. The more energy they have, the faster they fly around, and the higher the temperature. If you touch a really hot object, its atom and molecules are vibrating furiously, giving it a very high temperature.

There isn't a lot of matter in interstellar space. The average density of the universe is roughly only one hydrogen atom per cubic meter. This makes it very difficult to assign a temperature to the matter of interstellar space. But space itself is soaked in something else, an unending sea of radiation that is very, very cold.

This radiation comes from stars, galaxies and more, but by far the largest source of radiation in the universe is the cosmic microwave background (or CMB). The CMB emerged when the universe was about 380,000 years old. At that time our cosmos was about a million times smaller than it is today and it was in a hot dense plasma state. As the universe expanded and cooled the universe became neutral, releasing radiation that had a temperature of about 10,000 Kelvin, the same temperature as the surface of the Sun.

That radiation accounts for over 99.999% of all the radiation remaining in the cosmos. Since the time it was released, our universe has expanded, which has diluted that same radiation, lowering its temperature. In addition, the cosmic expansion stretches on light itself moving it to longer, cooler wavelengths.

The combined action of this expansion has dropped the temperature of the CMB to right around 3 degrees above absolute zero. That means that if you were to sit in interstellar space, your body would cool and cool and cool towards absolute zero. But it would be prevented from reaching that temperature because the cosmic microwave background radiation would always be hitting you, transferring their energy into your body. So you wouldn't reach absolute zero, but you would come into equilibrium with the CMB, and that's how we determine the (cold) temperature of interstellar space. ☀

Evidence that Venus is volcanically active

SCIENCENEWS, MARCH 15, 2023

Venus appears to have volcanic activity, according to a new research paper that offers strong evidence to answer the lingering question about whether Earth's sister planet currently has eruptions and lava flows.

Venus, although similar to Earth in size and mass, differs markedly in that it does not have plate tectonics. The boundaries of Earth's moving surface plates are the primary locations of volcanic activity.

New research by University of Alaska Fairbanks Geophysical Institute research professor Robert Herrick revealed a nearly 1-square-mile volcanic vent that changed in shape and grew over eight months in 1991. Changes on such a scale on Earth are associated with volcanic activity, whether through an eruption at the vent or movement of magma beneath the vent that causes the vent walls to collapse and the vent to expand.

The research was published today in the journal *Science*.

Herrick studied images taken in the early 1990s during the first two imaging cycles of NASA's Magellan space probe. Until recently, comparing digital images to find new lava flows took too much time, the paper notes. As a result, few scientists have searched Magellan data for feature formation.

"It is really only in the last decade or so that the Magellan data has been available at full resolution, mosaicked and easily manipulable by an investigator with a typical personal workstation," Herrick said.

The new research focused on an area containing two of Venus' largest volcanoes, Ozza and Maat Mons.

"Ozza and Maat Mons are comparable in volume to Earth's largest volcanoes but have lower slopes and thus are more spread out," Herrick said.

Maat Mons contains the expanded vent that indicates volcanic activity.

Herrick compared a Magellan image from mid-February 1991 with a mid-October 1991 image and noticed a change to a vent on the north side of a domed shield volcano that is part of the Maat Mons volcano.

The vent had grown from a circular formation of just under 1 square mile to an irregular shape of about 1.5 square miles.

The later image indicates that the vent's walls became shorter, perhaps only a few hundred feet high, and that the vent was nearly filled to its rim. The researchers speculate that a lava lake formed in the vent during the eight months between the images, though whether the contents were liquid or cooled and solidified isn't known.

The researchers offer one caveat: a nonvolcanic, earthquake-triggered collapse of the vent's walls might have caused the expansion. They note, however, that vent collapses of this scale on Earth's volcanoes have always been accompanied by nearby volcanic eruptions; magma withdraws from beneath the vent because it is going somewhere else.

The surface of Venus is geologically young, especially compared to all the other rocky bodies except Earth and Jupiter's moon Io, Herrick said.

"However, the estimates of how often eruptions might occur on Venus have been speculative, ranging from several large eruptions per year to one such eruption every several or even tens of years," he said.

Herrick contrasts the lack of information about Venusian volcanism with what is known about Jupiter's moon Io and about Mars.

"Io is so active that multiple ongoing eruptions have been imaged every time we've observed it," he said.

On a geological time scale, relatively young lava flows indicate Mars remains volcanically active, Herrick said.

"However, nothing has occurred in the 45 years that we have been observing Mars, and most scientists would say that you'd probably need to watch the surface for a few million years to have a reasonable chance of seeing a new lava flow," he said.

Herrick's research adds Venus to the small pool of volcanically active bodies in our solar system.

"We can now say that Venus is presently volcanically active in the sense that there are at least a few eruptions per year," he said. "We can expect that the upcoming Venus missions will observe new volcanic flows that have occurred since the Magellan mission ended three decades ago, and we should see some activity occurring while the two upcoming orbital missions are collecting images."

Co-author Scott Hensley of NASA's Jet Propulsion Laboratory performed the modeling for the research.

The planet that could end life on Earth

Sciencenews, march 7, 2023

A terrestrial planet hovering between Mars and Jupiter would be able to push Earth out of the solar system and wipe out life on this planet, according to a UC Riverside experiment.

UCR astrophysicist Stephen Kane explained that his experiment was meant to address two notable gaps in planetary science.

The first is the gap in our solar system between the size of terrestrial and giant gas planets. The largest terrestrial planet is Earth, and the smallest gas giant is Neptune, which is four times wider and 17 times more massive than Earth. There is nothing in between.

"In other star systems there are many planets with masses in that gap. We call them super-Earths," Kane said.

The other gap is in location, relative to the sun, between Mars and Jupiter. "Planetary scientists often wish there was something in between those two planets. It seems like wasted real estate," he said.

These gaps could offer important insights into the architecture of our solar system, and into Earth's evolution. To fill them in, Kane ran dynamic computer simulations of a planet between Mars and Jupiter with a range of different masses, and then observed the effects on the orbits of all other planets.

The results, published in the *Planetary Science Journal*, were mostly disastrous for the solar system. "This fictional planet gives a nudge to Jupiter that is just enough to destabilize everything else," Kane said. "Despite many astronomers having wished for this extra planet, it's a good thing we don't have it."

Jupiter is much larger than all the other planets combined; its mass is 318 times that of Earth, so its gravitational influence is profound. If a super-Earth in our solar system, a passing star, or any other celestial object disturbed Jupiter even slightly, all other planets would be profoundly affected.

Depending on the mass and exact location of a super-Earth, its presence could ultimately eject Mercury and Venus as well as Earth from the solar system. It could also destabilize the orbits of Uranus and Neptune, tossing them into outer space as well.

The super-Earth would change the shape of this Earth's orbit, making it far less habitable than it is today, if not ending life entirely.

If Kane made the planet's mass smaller and put it directly in between Mars and Jupiter, he saw it was possible for the planet to remain stable for a long period of time. But small moves in any direction and, "things would go poorly," he said.

The study has implications for the ability of planets in other solar systems to host life. Though Jupiter-like planets, gas giants far from their stars, are only found in about 10% of the time, their presence could decide whether neighboring Earths or super-Earths have stable orbits.

These results gave Kane a renewed respect for the delicate order that holds the planets together around the sun. "Our solar system is more finely tuned than I appreciated before. It all works like intricate clock gears. Throw more gears into the mix and it all breaks," Kane said. ☀

Didymos is Spinning So Quickly That Rocks are Detaching at its Equator and Going Into Orbit

By Scott Johnston

UNIVERSETODAY.COM, MARCH 15, 2023

Last fall, when NASA's DART mission impacted Didymos' moon Dimorphos in a dramatic (and successful) attempt to change the object's orbit, DART got a quick look at the Didymos system before the probe was purposefully smashed to pieces.

Alongside demonstrating the capability to prevent future asteroid strikes on Earth, DART also gathered new information about the dynamics of the pair of asteroids. The data collected suggests that Didymos is actively throwing material out into space, and there are likely millions of other small asteroids doing the same across the Solar System, all the time.

The popular image of an asteroid as an unchanging, solid chuck of rock has evaporated in recent years, as we've come to learn more about these objects. While some asteroids fit this classification, just as many do not. Asteroids are the detritus left over from the formation of the Solar System, and many of them are little more than loose rubble piles, held weakly together by gravity.

Asteroid Bennu, which was visited by NASA's OSIRIS-REx mission in 2020, is a prime example. When OSIRIS-REx touched down to take a sample, it sank

Particles ejected into space from asteroid Bennu, imaged by OSIRIS-REx.

nearly two meters into the loose surface like a child in a ball pit. The spacecraft also unexpectedly photographed material ejecting off the asteroid and into space, indicating that these objects are more active and dynamic than once thought.

Didymos has been under scrutiny for a while now in preparation for DART and the European Space Agency's follow-up mission, Hera. Now that DART has seen the asteroid up close, researchers have a wealth of data about its shape, mass, and rotation.

One thing they've learned is that it's spinning, and quite quickly, completing one full rotation every 2 hours and 16 minutes. At those speeds, Didymos is an asteroid "on the edge of stability," according to a recent preprint published on ArXiv.

At the equator, where the effects of the spin are strongest, rocks and dust are able to lift off the surface, levitating or moving into orbit.

"Massive particles potentially levitate for some time, land on the surface and lift off again, repeating such cycles over and over, or just land at latitudes from which further lift off is not possible," the authors write.

Some of the floating rocks reach orbit, and some of those are likely to be deposited onto the moon, Dimorphos. Smaller particles can even escape the system, blown away forever by the solar wind.

Interestingly, large objects tend to stay afloat longer than small ones. This is because on the day side of the asteroid, solar radiation pressure will quickly push the smaller grains back down to the surface.

The DART spacecraft's final moments as it passes Didymos on the way to impact Dimorphos.

These conclusions are somewhat preliminary, as they are based on best estimates of the asteroid's size, composition, and shape, which the Hera mission should be able to corroborate when it arrives in 2027. But the principle at work applies across the Solar System: if Earth were spinning fast enough (once every 84 minutes), it would be possible to jump from the equator into orbit in the same way these rocks are lifting off fast-spinning asteroids like Didymos.

Asteroid P/2013 R3 disintegrating under the influence of the YORP effect, as seen by Hubble.

The excessively fast rotation of Didymos – and other asteroids like it – is a solar-powered phenomenon.

These asteroids are under the influence of the YORP effect, in which the Sun heats different parts of an asteroid to different temperatures depending on their albedo. That heat is later radiated away, producing thrust. It's a tiny effect, but it builds over time and can eventually push an asteroid around faster and faster like wind turning a windmill.

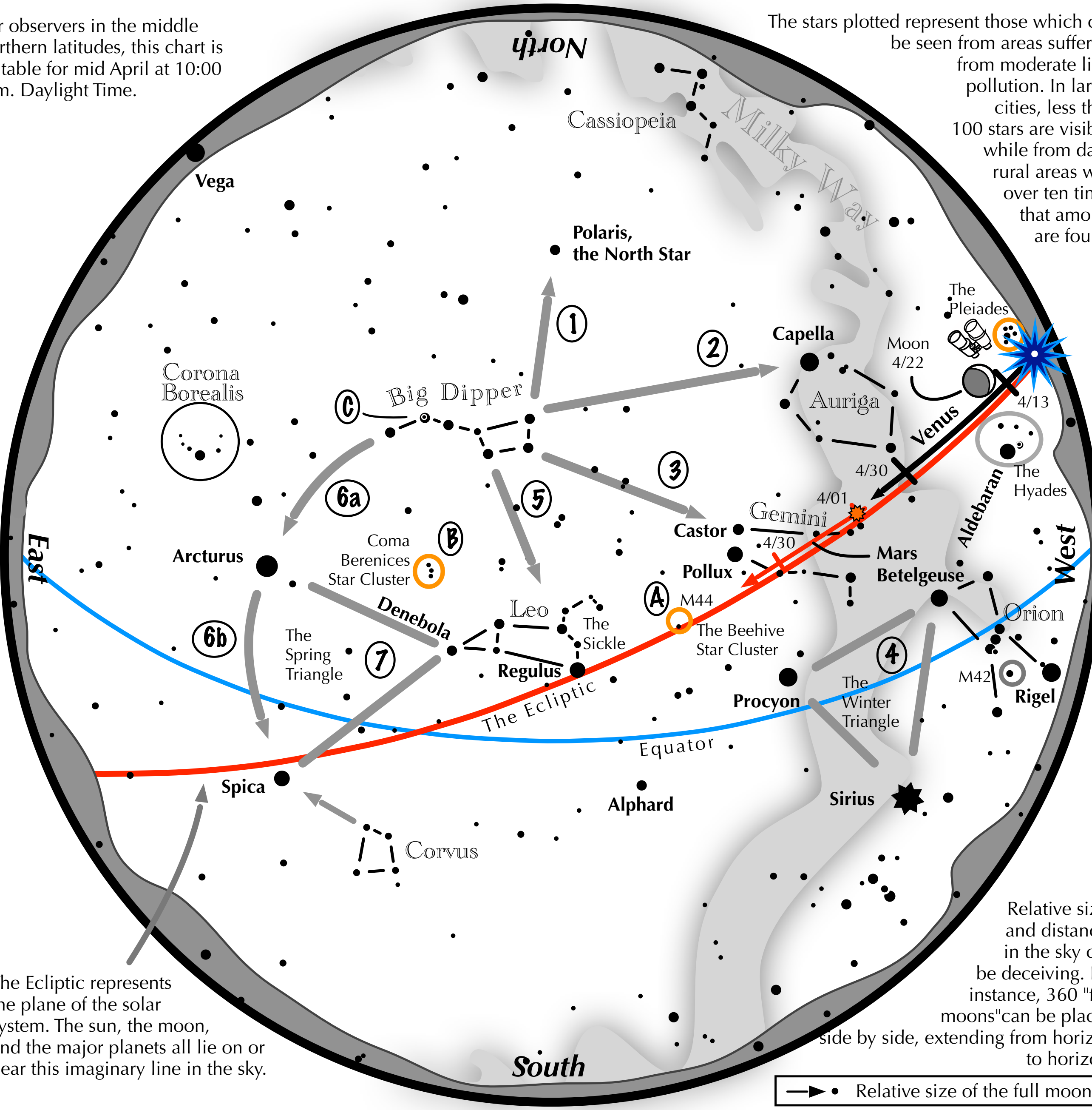
Astronomers have even seen asteroids rip themselves to pieces via the YORP effect, like asteroid P/2013 R3 in 2013.

Didymos is unlikely to see such a dramatic Rapid Unscheduled Disassembly anytime soon. 97% of the particles that lift off the surface land again within 5 hours. But it is something mission planners may have to take into account for future spacecraft that make close approaches to fast-spinning asteroids, if they want to avoid damage to the probe. ☀

Navigating the April Night Sky, Northern Hemisphere

For observers in the middle northern latitudes, this chart is suitable for mid April at 10:00 p.m. Daylight Time.

The stars plotted represent those which can be seen from areas suffering from moderate light pollution. In larger cities, less than 100 stars are visible, while from dark, rural areas well over ten times that amount are found.



The Ecliptic represents the plane of the solar system. The sun, the moon, and the major planets all lie on or near this imaginary line in the sky.

Relative sizes and distances in the sky can be deceiving. For instance, 360 "full moons"can be placed side by side, extending from horizon to horizon.

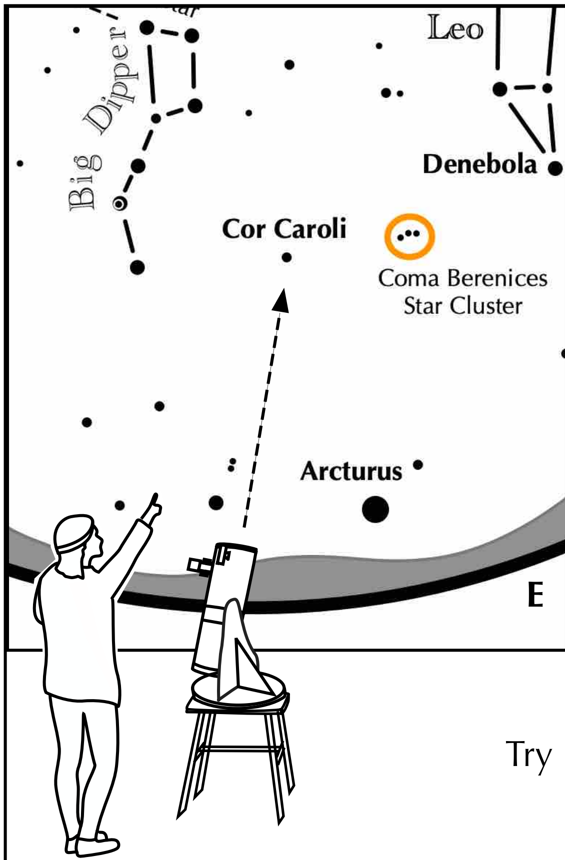
Relative size of the full moon.

Navigating the April night sky: Simply start with what you know or with what you can easily find.

1 Extend an imaginary line north from the two stars at the tip of the Big Dipper's bowl. It passes Polaris, the North Star.
2 Draw another imaginary line west across the top two stars of the Dipper's bowl. It strikes Capella low in the northwest.
3 Through the two diagonal stars of the Dipper's bowl, draw a line pointing to the twin stars of Castor and Pollux in Gemini.
4 Look in the west-southwest for the bright Winter Triangle stars of Sirius, Procyon, and Betelgeuse.
5 Directly below the Dipper's bowl reclines the constellation Leo with its primary star, Regulus.
6 Follow the arc of the Dipper's handle. It first intersects Arcturus, then continues to Spica.
7 Arcturus, Spica, and Denebola form the Spring Triangle, a large equilateral triangle.

Binocular Highlights
A: M44, a star cluster barely visible to the naked eye, lies to the southeast of Pollux.
B: Look nearly overhead for the loose star cluster of Coma Berenices.
C: In the Big Dipper's handle shines Mizar next to a dimmer star, Alcor.

Astronomical League
www.astroleague.org/outreach



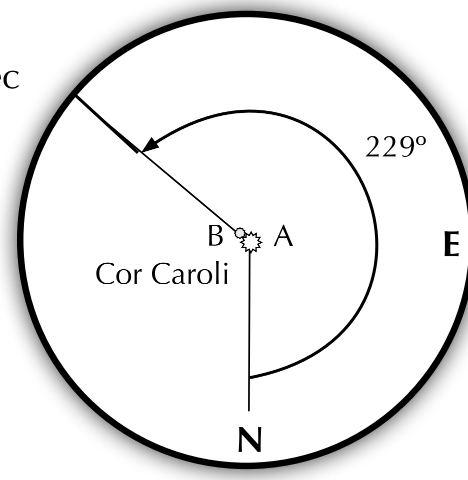
Other Suns: Cor Caroli

How to find Cor Caroli on an April evening

Look northeast toward the Big Dipper. A star, slightly dimmer than the handle stars, is placed near the center of the handle's curvature. That is Cor Caroli.

Suggested magnification: >20x
Suggested aperture: >2 inches

Cor Caroli
A-B separation: 19 sec
A magnitude: 2.9
B magnitude: 5.5
Position Angle: 229º
A color: white
B color: pale blue



Try using steadily held and sharply focused 10x50 binoculars.

About Astronomy Associates

The club is open to all people interested in sharing their love for astronomy. Monthly meetings are typically on the last Sunday of each month and often feature guest speakers, presentations by club members, and a chance to exchange amateur astronomy tips. These meetings and the public observing sessions that follow are scheduled at the Baker Wetlands Discovery Center, south of Lawrence. All events and meetings are free and open to the public. Periodic star parties are scheduled as well.

Because of the flexibility of the schedule due to holidays and alternate events, it is always best to check the Web site for the exact Sundays when events are scheduled.

Copies of the Celestial Mechanic can also be found on the web at newsletter.
Annual Dues for the club are: $12 for regular members; $6 for students Membership forms can be accessed at the club website form.