

AOH Newsletter

Summer 2025



News and Notes

Recent Activities



Zoom Meetings, April, May, and June: Bernie Christen, Pam Cosel, Roger Coy, Rick Gustafson, Brent Howatt, Catrina Howatt, Mary Kaufman, Ann Kilby, Yoon Kim, Jacob Nowatzke, Russ Owsley, Susan Terebey, Allison & Johann Waltberg, Grace Wheeler, Mark Wilson, Ken Yanosko



Kneeland Skycam view of the sunset just after 8 pm on our last scheduled observing session, May 24. The March and April events were no better.

Nothing to see here....

We had a perfect record of being clouded out in March (on both weekends of the Messier Marathon) and on our scheduled observing events in April and May. We will have to do some research on why there is such a good correlation between the Saturday nearest the new moon and the presence of a cloud layer at Kneeland. Does the absence of moonlight make it more likely that clouds will form? Is it a tidal effect? Dark matter? Dark energy? Dementors? Horcruxes? The Grinch? There must be *some* scientific explanation.

Let us know if you can figure it out.



Indoor Event

Allison presented an astronomical slide show for the Eureka Symphony during the April 25 & 26 "Music of the Spheres" Concert, The slides added a visual interest to the Symphony's performance of Gustav Holst's "The Planets."

Upcoming Events

Our summer observing sessions are scheduled for Kneeland Airport on June 28, July 26, August 23, and September 20.

The Albee Creek Star Parties will be on July 5, August 2, and August 30. If you would like to participate contact Brent at brent@astrohum.org. No experience necessary.

We may be doing outreach programs for the Discovery Museum's Pal Camp sometime during the week of July 28 through August 1, and for the Cal Poly Humboldt Natural History Museum Summer Camp sometime during the week of August 4-8. If you would like to participate contact Brent at brent@astrohum.org. No experience necessary.

As always, check the website at <https://www.astrohum.org/upcoming.html> for any additions, cancellations, or modifications to this schedule.

And of course there's the sky. Aurora Season may not be over with (see Grace's article beginning on page 5); Nova T Coronae Borealis is still waiting to happen; and the Summer Perseids are on the schedule for August 12-13.

Keep looking up!

Thanks

Allison, Grace, Mary, and Susan contributed to and/or helped with this issue of the Newsletter.

—Ken



LET'S FIND OUT
WHAT'S REALLY
UP THERE!

JULY 5
8:30pm-10:30pm

ALBEE CREEK STAR PARTY 2025
FREE, FUN, FAMILY-FRIENDLY!

Humboldt Redwoods State Park
Albee Creek Campground
Hwy 101 Exit #663
Head west on Mattole Rd, 5 miles
Follow signs to parking area.

Astronomers of Humboldt
provide telescopes and
expertise and lead
stargazing.



★ Overcast skies cancels ★ Refreshments ★ Bring chair or blanket ★

For more info: 707-946-2263 ★ www.humboldtredwoods.org

The Milky Way

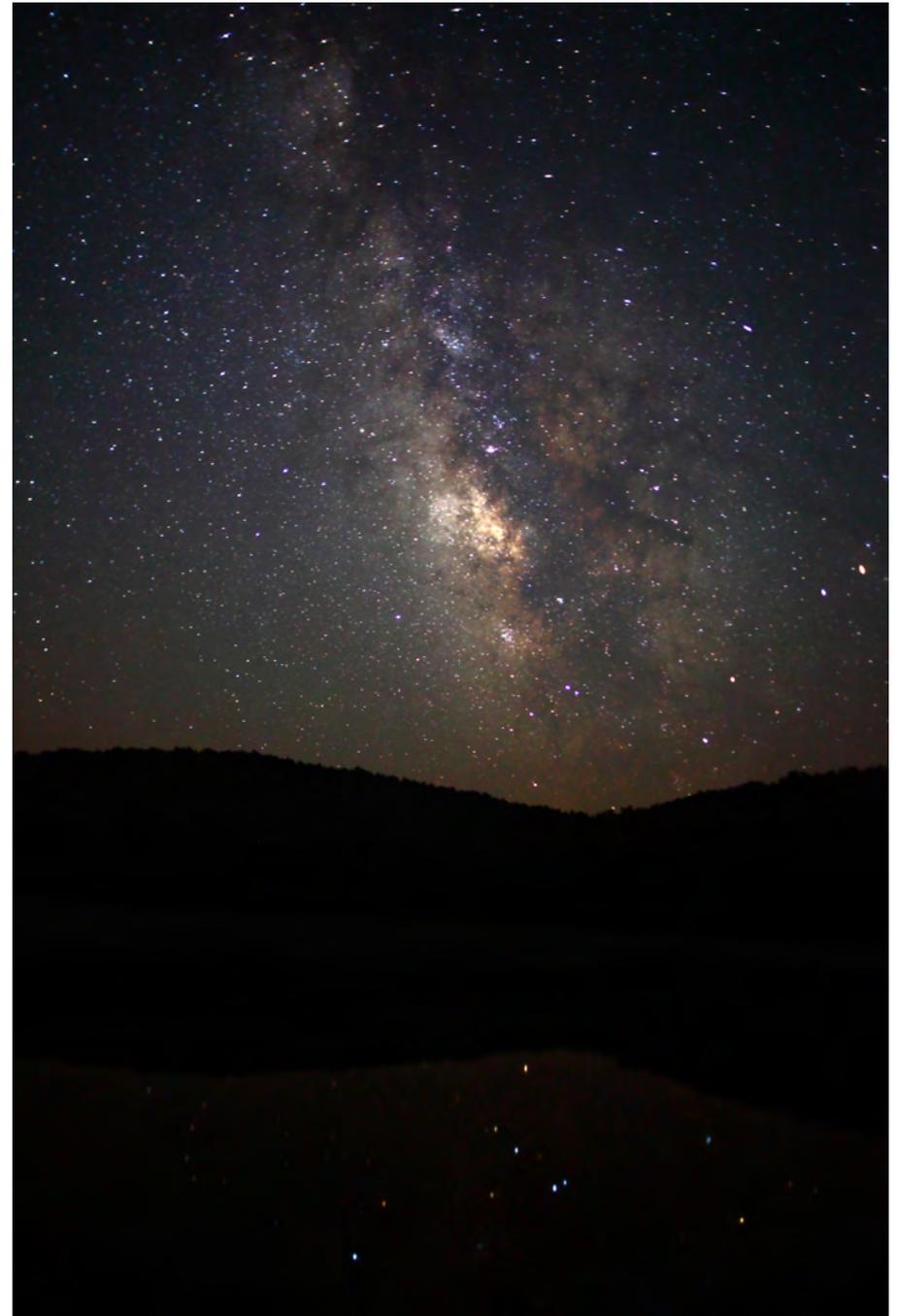
by Allison Waltberg

Summer is Milky Way season! Once it finally gets fully dark – almost 10 PM at this time of year – the hazy band stretches high across the sky, glowing with the collective light of many billions of stars in the galactic plane that are too dim or too distant to resolve individually. Looking south in dark summer skies, the central bulge of the galaxy is easy to see as a hazy glow, veined with shadowy dust lanes referred to as the Great Rift. The brightest region we can see is the Large Sagittarius Star Cloud, which is close to the center of the galaxy. Its light is slightly yellowish (more visible in pictures) because the center of the galaxy is dense with old orangey stars and depleted of gas and dust to form new blue stars.

The Ancient Greeks’ origin story for the Milky Way involves an inauspicious combination of Hera, Hercules, and surprise breastfeeding; it (very predictably) goes poorly and the result was a stream of milk spilled across the sky. This legend led to the name *galaxías kýklos* (“milky circle”), whose base word *gála* (“milk”) is the root of the modern word “galaxy.”

The milk story is but one legend of many; cultures the world over have their own tales that name and explain the origin of the Milky Way’s glow. In these stories it’s usually a river, a road, or a trail, but there are some truly imaginative traditional names and origin myths of our galaxy as it appears in the sky. And while globalization has caused many disparate cultures to adopt a literal translation of “milky” + “way” as their common term for our galaxy, their traditional terms reflect the fascinating poetry and stories behind them.

Naturally, the Greeks’ far-reaching influence across Europe led to an abundance of the standard dairy terminology. From the easily recognized Dutch and Afrikaans *Melkweg* to the Spanish *Vía Láctea* and even the inscrutable Welsh *Ffordd Llaethog*, all literally mean a pathway of milk. The Irish embroider the metaphor with *Bealach na Bó Finne* (“the Way of the White Cow”), referencing a legendary cow with an endless stream of milk.



https://commons.wikimedia.org/wiki/File:Milky-way-galaxy-mountain-sky-lake-reflection_-_West_Virginia_-_ForestWander.jpg CC.

In other regions, straw is spilled rather than milk. The Turkish *Samanyolu* and Croatian *Kumova slama* both mean “Straw Way,” referring to a trail left behind by a running hay thief dropping bits of stolen straw from his arms. Coincidentally, the Cherokee tribe, indigenous to the American Southeast, tell a similar story: a mystical dog stole a mouthful of cornmeal and left a trail behind as it ran into the sky, creating the *Gi li' ut sun stan un' yi* (“the place where the dog ran”).

Another common motif is a river, particularly in East Asian cultures with their intertwined linguistic influences. The Milky Way is *Yínhé* in Chinese and *Ngân hà* in Vietnamese, both of which mean “Silver River.” Japanese *ginga* and Korean *eunha* also mean “silver river,” but can refer to any galaxy. To name the Milky Way specifically, Japanese uses *Amanogawa* (“Heavenly River”), which in Vietnamese is *thiên hà*, their generic word for a galaxy. Several Indian languages derive their term from the Sanskrit *Ākāśagamā* (“Ganges of the Sky”), referring to the major river in India embodied by the sacred mother goddess of the Hindu pantheon. In the Hindi language it is *Akash Ganga*, with the same meaning.

The Baltic states call it “Bird’s Path,” as seen in Finnish *Linnunrata* and Lithuanian *Paukščių Takas*. Their stories connect birds with the souls of the deceased as they journey along the Milky Way to the afterlife; legends vary on whether the birds are spirit guides or the transformed souls themselves. We can imagine them flying alongside Cygnus the swan and Aquila the eagle, following the path of the summer Milky Way into the beyond.

The belief that the Milky Way was the path to the afterlife was shared by many Native American cultures on the other side of the Atlantic. To the Ojibwe it is *Jiibay Ziibi* (“River of Souls”), where a canoe awaited departed souls. The Ojibwe say that the Milky Way was the light of countless campfires of departed souls traveling along the *Wanagi Tacanku* (“Spirit Road”). The Pawnee and Blackfoot tribes saw it as “buffalo dust” kicked up by animals along the path of souls; in southern Africa, the Shona tribe also see dust kicked up by their own traveling megafauna, and call it

Gwara Renzou (“Elephant’s Path”).

Vivid imagery is scattered the world over. Far to the north, it evoked quiet roads covered in white snow with the Swedish *Vintergatan* and Icelandic *Vetrarbrautin* (both “Winter Street”). In Melanesia, they instead allude to the patterns of light and dark of a reef seen through the waves with the term *Saghauru* (“Coral Reef”). A colorful Filipino poet could evoke the light in the sea with the allegorical Tagalog phrase *Dinaanang ng Daong ni Apong Noe* (“the path of Noah’s Ark”). And the Xhosa tribe of South Africa paint a particularly vivid image with *Umnyele wezulu*: commonly translated as “Backbone of the Heavens,” the word *umnyele* specifically refers to the hackles (the raised bristly fur along the spine of an angry dog). Their Milky Way is the sky getting its hackles up.

There are also references to some unique creation myths. The nomadic San people use the Khoekhoe word *Tsaob* (“embers” or “ashes”) to reference a story of a girl who threw embers from the cosmic cookfire into the sky to create the Milky Way, while the Maori speak of *Te Ikaroa* (“the Long Fish”), a mother goddess who gave birth to all the stars in the sky.

Finally, Navajo astronomers noticed that in January, the bright center of the Milky Way rises just before sunrise, and used it as part of their annual calendar cycle. Their term *Yikáisdáhá* means “That Which Awaits the Dawn.”

Luckily, in the summer we don’t have to wait for the early dawn hours to see the Milky Way. In the evenings it rises like steam from the spout of the “teapot” asterism in Sagittarius. If only the Ancient Greeks had invented teapots, today we might instead call our galaxy the Steamy Way!

Allison Waltberg has been a member of AOH since 2023. In that brief time she has become a member of the Board of Directors and our most sought-after star-story-teller.

Aurora Update: Spring 2025

by Grace Wheeler

When I volunteered to provide an update on solar activity and auroras for the upcoming AOH newsletter, I initially thought I wouldn't have much to share. The low to moderate solar activity had resulted in few auroras visible at mid-latitudes. When there was an aurora, bad weather in Humboldt County prevented us from seeing it. However, by the end of May, our luck changed. Significant solar events triggered geomagnetic storms of G3 (strong) and G4 (severe) magnitude. The intensity of these storms pushed the auroras further south, making them visible in Northern California. For once, the night sky was mostly clear.

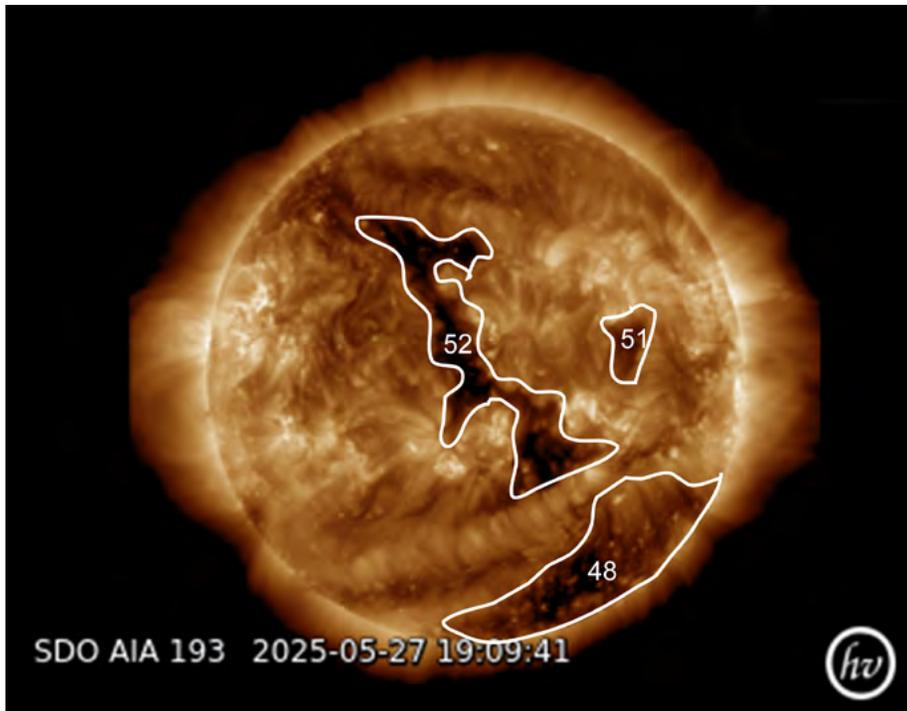


Figure 1. The coronal holes 48, 51, 52 of the sun shown in the SDO AIA 193 channel (extreme UV wavelength). Image credit: Helioviewer.org <https://gs671-suske.ndc.nasa.gov> with modifications by GDW.

May 28: Coronal Hole High Speed Streams.

The first aurora occurred on May 28 and coincided with a G3 geomagnetic storm. The G3 storm was caused by high-speed solar winds emanating from coronal holes 48, 51, and 52 (Figure 1). The G3 magnitude of the storm was surprising as these coronal hole solar winds typically lead to G1 (weak) to G2 (moderate) storms.

Members of the California Aurora Chasing Facebook group reported seeing a brief aurora substorm lasting from 9:50 p.m. to 10 p.m. (Fig. 2.) By the time I arrived in Kneeland at 10:15 p.m., the substorm had subsided. I was able to capture a diffuse purple glow from the aurora using my cell phone camera (Fig. 3.) This was the first aurora that I had seen in several months. Even though the aurora wasn't very intense, and lacked the tell-tale signs of pillars, it was still satisfying to see it with my own eyes, or in this case, through the cell phone camera.



Figure 2. Pillars of an aurora substorm captured on the Big Valley 2 Firecam on May 28, 2025 at 9:58 p.m. The fire cam is located in eastern Lassen County and is part of the Alert California system of cameras. https://cameras.alertcalifornia.org/?pos=41.0700_-121.2200_10&id=Axis-BigValley2



Figure 3. An aurora viewed at the Kneeland Airport on May 28, 2025 at 10:15 p.m. The aurora was the result of a G3 level geomagnetic storm. (Image credit: GDW).

June 1-3: M8 Solar Flare and a large Earth-directed CME

The second aurora I saw was in the early morning of June 1. This aurora was triggered by an M8 solar flare that erupted on May 30 from sunspot AR 4100 (Fig. 4.) The M8 flare was a long-duration event, lasting for two hours, and it produced a massive full-halo coronal mass ejection (CME) directed toward Earth.

Due to the size of the CME, NOAA predicted that Earth would experience a bombardment of solar winds and plasma for three days, thereby increasing the chances of seeing auroras during this period. The forecast indicated that the CME would arrive around midday on June 1 (PDT), with expected G3 and G4 geomagnetic storms occurring

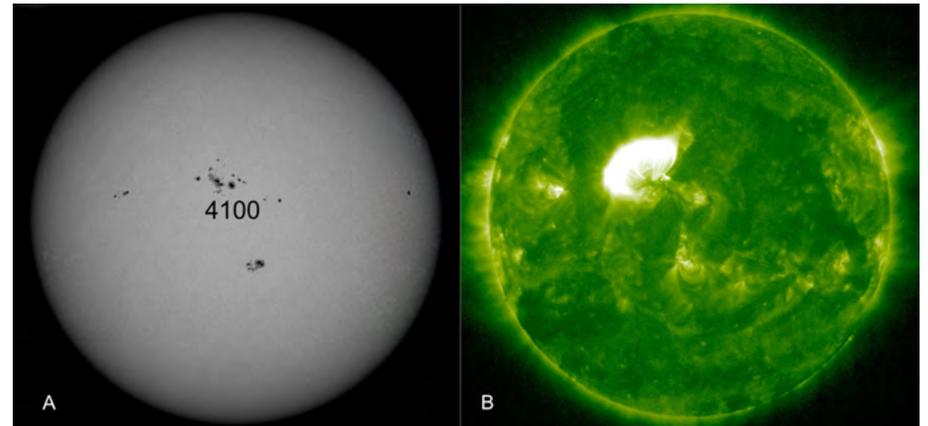


Figure 4. Images of the sun on May 30, 2025. Image (A) is the photosphere showing the sunspots contained in AR 4100. Image (B) is the SDO AIA 094 image of the sun (extreme UV/soft x-rays). This channel is designed to study solar flares. The bright region corresponding to AR 4100 is the long duration flare with a magnitude of M8. Image credit: <https://sdo.gsfc.nasa.gov>

over the next two days. If the predictions were accurate, the first night of aurora watching in North America would begin on the evening of June 1.

However, due to the high speeds of the solar winds, the Coronal Mass Ejection (CME) arrived at 10:30 p.m. (PDT) on May 31, nearly half a day earlier than expected. This led to strong to severe geomagnetic storming levels (ranging from G3 to G4). The first auroras triggered by the CME occurred from the middle of the night to the predawn hours of June 1, rather than in the evening as forecasted

Day 1 of CME Passage

I was fortunate to have my cell phone with me when it pinged with an alert from my Aurora Forecast app at 12:15 a.m. A quick check of the Kneeland Airport Cam (Fig. 5.) confirmed that a substorm was ongoing. This midnight substorm was intense but short and lasted only 30 minutes.



Figure 5. Kneeland Airport Cam: Image and timelapse of the auroral sub-storm from 12:15 to 12:45 a.m. on June 1, 2025. https://www.youtube.com/watch?v=lu7sMasaq_Q
Image and timelapse were provided by Allison Waltberg.

When I arrived in Kneeland at 1:45 a.m., the geomagnetic storm had subsided to G1/G2 levels. Although the aurora was not visible to the naked eye, my cell phone camera was able to capture a diffuse red glow on the northern horizon (Fig. 6A.) For the next two hours, the size of the aurora remained largely unchanged, but it did appear to grow brighter over time (Fig. B.). At 3:45 a.m., the substorm I had been waiting for finally occurred: the aurora was bright and expansive, and featured pillars of light (Fig. 6C.) Later, I learned that this auroral sub-storm coincided with the onset of a G3 storm. Like the first substorm of the night, this intense display was brief, lasting only twenty minutes.

Although strong geomagnetic storming continued into the daylight hours of June 1, by late afternoon the storm had weakened to G1, making conditions unfavorable for viewing the aurora. The much-anticipated aurora on Sunday night did not materialize, except at high latitudes. This was disappointing for aurora chasers who had missed the earlier displays.



Figure 6. Aurora viewed from Kneeland Airport on June 1, 2025. The aurora was imaged at the following times: (A) 2:02 a.m., (B) 3:08 a.m., (C) 3:56 a.m. (Image credit: GDW).

Day 2 of CME passage

In a repeat of the previous day, strong geomagnetic storming (G3) was not observed until the early morning hours of June 2 (day 2). Using the timelapse from Hayfork Fire Cam (Fig. 7.), I noted that the auroral substorm began at 1:50 a.m. and peaked at 3:00 a.m. The aurora was visible across northern and central California. While I slept through this substorm, other dedicated aurora chasers were awake to experience it (Fig. 8.).

By the evening of June 2, the geomagnetic storm had decreased to G2/G1 levels, with occasional spikes reaching G3. This geomagnetic activity pushed the aurora viewing opportunities further south, reaching Northern California, although the auroras were faint and brief. Noticing a substorm captured on the Kneeland Airport camera at 10:49 p.m. (Fig. 9.) I decided it was worth a trip to Kneeland. I met up with Allison and Johann Waltberg, who were also at the airport in search of the elusive aurora. However, when I arrived shortly after midnight, I didn't see any signs of the aurora. If it was present, it was imperceptible to our eyes and



Figure 7. Aurora substorm captured on the Hayfork Divide1 Fire Cam in Trinity County. The 12 hour timelapse shows that the substorm starts at around 2 a.m. and peaks at 3 a.m. https://youtu.be/VaxhMZ_0MHQ

https://cameras.alertcalifornia.org/?pos=40.6244_-123.0393_10&id=Axis-Hayfork



Figure 8. The aurora from Glacier Point in Yosemite National Park on June 2 at 3 a.m. Image courtesy of Phil Anderson.

<https://www.facebook.com/photo?fbid=654016834330891&set=pcb.9397475007020228>

<https://www.facebook.com/reel/1763172377743536>



Figure 9. Aurora substorm captured on the Kneeland Airport Cam on June 2 at 10:49 p.m. https://www.webcamwx.com/details_site022.php

our cellphone cameras. Having the light from the quarter moon didn't help matters.

On the way home, I decided to stop at the Kneeland School bus turnout for one last look. Fortunately, my hunch was correct, and my cellphone camera captured a rose-colored aurora featuring faint pillars of light (Fig. 10). This ended up being a lucky shot; had I arrived just five minutes later, I would have missed it.



*Figure 10. Aurora substorm on July 3 at 12:52 a.m.
Imaged from Kneeland School Bus turnout. (Image credit: GDW)*

I started off May without seeing any auroras for the year. I ended May with seeing three within a week. I had been worried that with what seemed to be a decline in solar activity since the beginning of 2025, my aurora-chasing adventures at mid-latitude were over. This doesn't seem to be the case yet—there has been one mid-latitude aurora (June 12) since I started writing this article. According to NOAA, even though we entered solar maximum in

October 2024, this period can last a year or two, and we can expect heightened solar activity during this time. Let's hope they are right.

Acknowledgments:

Many thanks to Allison Waltberg and Johann Waltberg for aurora scouting on June 1 (early morning) and June 2/3 (late night). I hope that a big aurora is in your future. Thank you to Phil Anderson for allowing me to use his image of the aurora in Yosemite. Phil said that he hoped his photo would spark an interest in auroras for more people.

References and Resources

<https://www.swpc.noaa.gov/news/coronal-hole-high-speed-streams-ch-hss>

<https://www.spaceweatherlive.com>

<https://alertcalifornia.org> (Hayfork Divide, Likely2, Big Valley Cameras)

<https://science.nasa.gov/science-research/heliophysics/nasa-noaa-sun-reaches-maximum-phase-in-11-year-solar-cycle/>

Northern Lights Alert <https://www.facebook.com/groups/154848124616342>

California Aurora Chasers <https://www.facebook.com/groups/539575711835091>

Space Weather by Solar Ham <https://www.facebook.com/SolarHam>

Grace Wheeler has been a member of AOH since 2013. During the day she can be seen capturing solar photons directly, in filtered white, hydrogen- α , or calcium-K light. At night she settles for second-hand photons that the solar wind generates in earth's upper atmosphere.

This is the transcript of a video produced by NASA Science and Jet Propulsion Laboratory, narrated by Jack Elias. <https://science.nasa.gov/resource/orbits-and-keplers-laws/>



Understanding Solar System Dynamics: Orbits and Kepler's Laws

The planets orbit the Sun in a counterclockwise direction as viewed from above the Sun's north pole, and the planets' orbits all are aligned to what astronomers call the ecliptic plane.

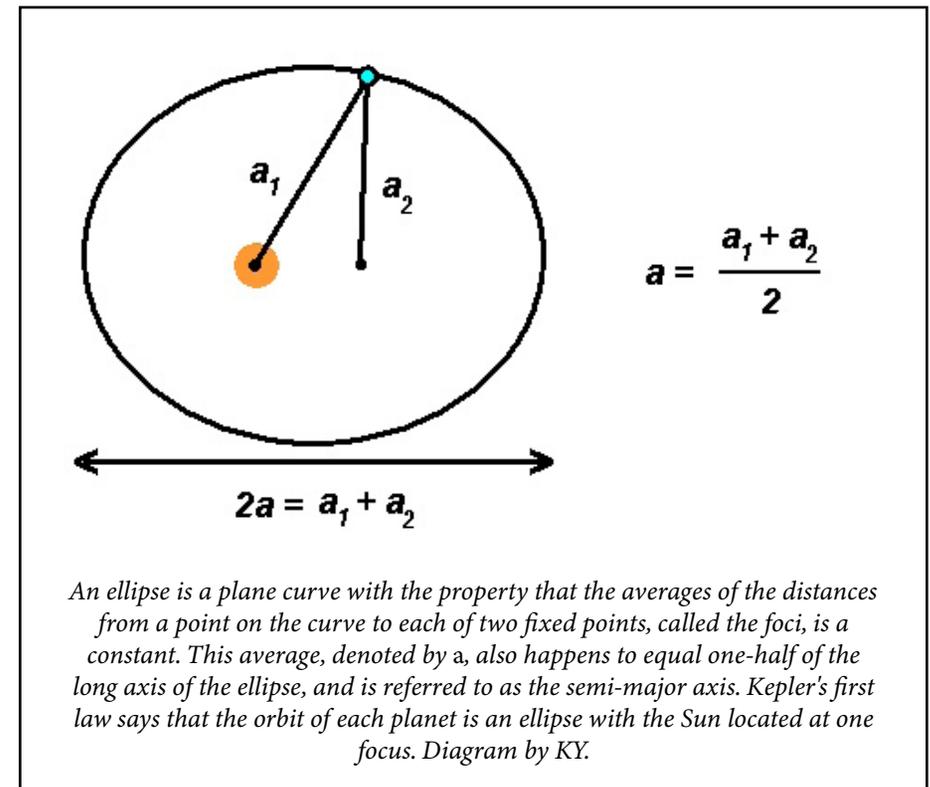
The story of our greater understanding of planetary motion could not be told if it were not for the work of a German mathematician named Johannes Kepler. Kepler lived in Graz, Austria during the tumultuous early 17th century. Due to religious and political difficulties common during that era, Kepler was banished from Graz on August 2nd, 1600.

Fortunately, an opportunity to work as an assistant for the famous astronomer Tycho Brahe presented itself and the young Kepler moved his family from Graz 300 miles across the Danube River to Brahe's home in Prague. Tycho Brahe is credited with the most accurate astronomical observations of his time and was impressed with the studies of Kepler during an earlier meeting. However, Brahe mistrusted Kepler, fearing that his bright young intern might eclipse him as the premier astronomer of his day. He, therefore, led Kepler to see only part of his voluminous planetary data.

He set Kepler the task of understanding the orbit of the planet Mars, the movement of which fit problematically into the universe as described by Aristotle and Ptolemy. It is believed that part of the motivation for giving the Mars problem to Kepler was Brahe's hope that its difficulty would occupy Kepler while Brahe worked to perfect his own theory of the solar system, which was based on a geocentric model,

where the earth is the center of the solar system. Based on this model, the planets Mercury, Venus, Mars, Jupiter, and Saturn all orbit the Sun, which in turn orbits the earth. As it turned out, Kepler, unlike Brahe, believed firmly in the Copernican model of the solar system known as heliocentric, which correctly placed the Sun at its center. But the reason Mars' orbit was problematic was because the Copernican system incorrectly assumed the orbits of the planets to be circular.

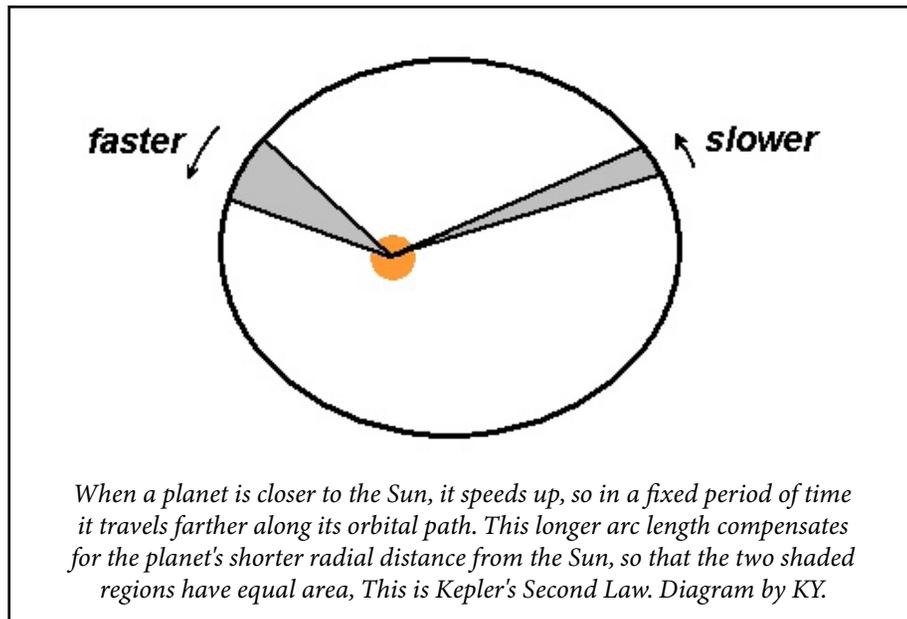
After much struggling, Kepler was forced to an eventual realization that the orbits of the planets are not circles, but were instead the elongated or flattened circles that geometers call ellipses, and the particular difficulties Brahe had with the movement of Mars were due to the fact that its orbit was the most elliptical of the planets for which Brahe had extensive data. Thus, in a twist of irony, Brahe unwittingly gave Kepler the very part of his data that would enable Kepler to formulate the correct theory of the solar system, banishing Brahe's own theory.



Since the orbits of the planets are ellipses, let us review three basic properties of ellipses. The first property of an ellipse: an ellipse is defined by two points, each called a focus, and together called foci. The sum of the distances to the foci from any point on the ellipse is always a constant. The second property of an ellipse: the amount of flattening of the ellipse is called the eccentricity. The flatter the ellipse, the more eccentric it is. Each ellipse has an eccentricity with a value between zero, a circle, and one, essentially a flat line, technically called a parabola.

The third property of an ellipse: the longest axis of the ellipse is called the major axis, while the shortest axis is called the minor axis. Half of the major axis is termed a semi-major axis. Knowing then that the orbits of the planets are elliptical, Johannes Kepler formulated three laws of planetary motion, which accurately described the motion of comets as well.

Kepler's First Law: each planet's orbit about the Sun is an ellipse. The Sun's center is always located at one focus of the orbital ellipse. The Sun is at one focus. The planet follows the ellipse in its orbit, meaning that the planet to Sun distance is constantly changing as the planet goes around its orbit.



Kepler's Second Law: the imaginary line joining a planet and the Sun sweeps equal areas of space during equal time intervals as the planet orbits. Basically, that planets do not move with constant speed along their orbits. Rather, their speed varies so that the line joining the centers of the Sun and the planet sweeps out equal parts of an area in equal times. The point of nearest approach of the planet to the Sun is termed perihelion. The point of greatest separation is aphelion, hence by Kepler's Second Law, a planet is moving fastest when it is at perihelion and slowest at aphelion.

Kepler's Third Law: the squares of the orbital periods of the planets are directly proportional to the cubes of the semi-major axes of their orbits. Kepler's Third Law implies that the period for a planet to orbit the Sun increases rapidly with the radius of its orbit. Thus we find that Mercury, the innermost planet, takes only 88 days to orbit the Sun. The earth takes 365 days, while Saturn requires 10,759 days to do the same. Though Kepler hadn't known about gravitation when he came up with his three laws, they were instrumental in Isaac Newton deriving his theory of universal gravitation, which explains the unknown force behind Kepler's Third Law. Kepler and his theories were crucial in the better understanding of our solar system dynamics and as a springboard to newer theories that more accurately approximate our planetary orbits.

	a	t
Mercury	0.387	0.241
Venus	0.732	0.615
Earth	1.00	1.00
Mars	1.52	1.88
Jupiter	5.20	11.9
Saturn	9.57	29.4

Here is a table of modern measurements for the planets known to Kepler. The semi-major axes a are given in astronomical units, and the orbital periods t are given in Earth years. For each of the planets, the ratios a^3/t^2 are all equal, within roundoff error. This is Kepler's Third Law. Data from NASA.

More on Kepler's Laws

by Ken Yanosko

Galilean Moons

Kepler wasn't taken seriously when he first published his three laws. This was partly because the idea of the Creator using ellipses, which were thought of as being "imperfect circles," to design the solar system was just too much to accept; and partly because Kepler actually published more than just these three laws. These other laws, which nobody ever talks about today, connected the planetary orbits to the regular polyhedra of geometry and to the theory of musical harmonies. But Kepler got some cred when he showed that Galileo's newly discovered Jovian moons also satisfied their own a-cubed t-squared relationship.

	a	t
Io	0.422	1.77
Europa	0.671	3.55
Ganymede	1.07	7.15
Callisto	1.88	16.7

In this table we have modern data: a is in millions of kilometers and t is in Earth days. We get $a^3/t^2 \approx 0.024$ for each moon.

Earth Data

We can do some more Kepler-truthing on our own.

At perihelion (its closest point to the Sun) the Earth is 147.1 million kilometers away, and its orbital velocity is 109,000 kilometers per hour. So in a period of 10 days around perihelion the Earth travels approximately $10 \times 24 \times 109,000 \approx 26.17$ million kilometers along its orbit. The elliptical sector swept out by the Earth-Sun line can be approximated by a circular sector of radius 147.1 and arc length 26.17. The area of the sector is $(1/2) \times 147.1 \times 26.17 \approx 1,925$ in trillions of square kilometers.

On the other hand, at aphelion (its farthest point from the Sun) the Earth is 152.1 million kilometers away, and is traveling at 105,500 kilometers per hour. So over another 10 day period, near aphelion, the Earth travels about 25.32 million kilometers along its orbit and we get a longer but skinnier elliptical sector. The area of this sector is roughly $(1/2) \times 152.1 \times 25.32$ which turns out to be 1,925 in trillions of square kilometers, just as Kepler says it should be.

Artificial Satellites

Here's a little quiz. The ISS has an average altitude of 400 km and orbits the Earth every 93 minutes. So how high are the geostationary satellites?

Kepler gives us the answer.

For ISS, $a = 6800$ km (the 400 altitude plus the 6400 radius of Earth). And for geostationary satellites, $t = 1440$ minutes (they orbit exactly once in 24 hours). So if x is the altitude of geostationary satellites, by Kepler's Third Law we must have

$$\frac{(x + 6400)^3}{1440^2} = \frac{6800^3}{93^2}$$

which gives $x \approx 42,000$ km.

Exoplanets

In 2016 astronomers confirmed the existence of a planet around our neighbor Proxima Centauri with an orbital radius of 7.26 million kilometers and an orbital period of 11.2 Earth days. In 2022 new data suggested that another planet may have an orbital period of 5.12 Earth days. If this new planet is confirmed, how far from its star will it be?

Applying Kepler's Third Law gives

$$\frac{x^3}{5.12^2} = \frac{7.26^3}{11.2^2}$$

and the answer is 4.31 million kilometers.

This article is distributed by the [NASA Night Sky Network](#), a coalition of hundreds of astronomy clubs across the US dedicated to astronomy outreach.



How Do We Find Exoplanets?

by Dave Prosper
updated by Kat Troche

Astronomers have been trying to discover evidence that worlds exist around stars other than our Sun since the 19th century. By the mid-1990s, technology finally caught up with the desire for discovery and led to the first discovery of a planet orbiting another sun-like star, Pegasi 51b. Why did it take so long to discover these distant worlds, and what techniques do astronomers use to find them?

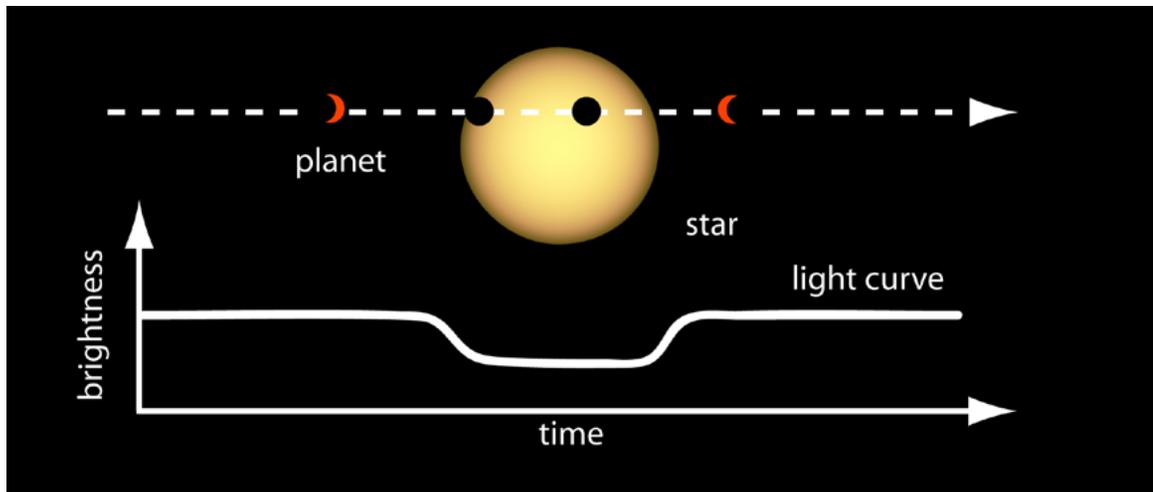
The Transit Method

One of the most famous exoplanet detection methods is the transit method, used by Kepler and other observatories. When a planet

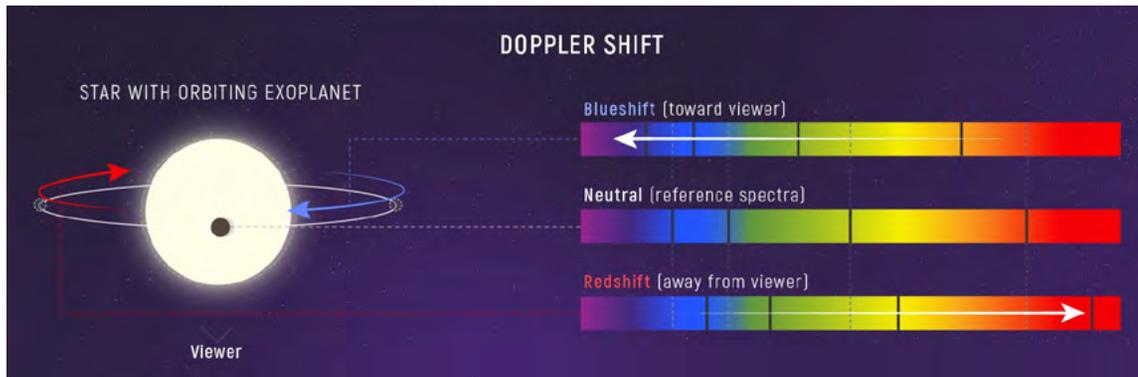
crosses in front of its host star, the light from the star dips slightly in brightness. Scientists can confirm a planet orbits its host star by repeatedly detecting these incredibly tiny dips in brightness using sensitive instruments. If you can imagine trying to detect the dip in light from a massive searchlight when an ant crosses in front of it, at a distance of tens of miles away, you can begin to see how difficult it can be to spot a planet from light-years away! Another drawback to the transit method is that the distant solar system must be at a favorable angle to our point of view here on Earth – if the distant system's angle is just slightly askew, there will be no transits. Even in our solar system, a transit is very rare. For example, there were two transits of Venus visible across our Sun from Earth in this century. But the next time Venus transits the Sun as seen from Earth will be in the year 2117 – more than a century from now, even though Venus will have completed nearly 150 orbits around the Sun by then!

The Wobble Method

Spotting the Doppler shift of a star's spectra was used to find Pegasi 51b, the first planet detected around a Sun-like star. This technique is called the radial velocity or "wobble" method. Astronomers split up the visible light emitted by a star into a rainbow. These spectra, and gaps between the normally smooth bands of light, help determine the elements that make up the star. However, if there is a planet orbiting



A planet passing in front of its parent star creates a drop in the star's apparent brightness, called a transit. Exoplanet Watch participants can look for transits in data from ground-based telescopes, helping scientists refine measurements of the length of a planet's orbit around its star. Credit: NASA's Ames Research Center



As a planet orbits a star, the star wobbles. This causes a change in the appearance of the star's spectrum called Doppler shift. Because the change in wavelength is directly related to relative speed, astronomers can use Doppler shift to calculate exactly how fast an object is moving toward or away from us. Astronomers can also track the Doppler shift of a star over time to estimate the mass of the planet orbiting it. Credit: NASA, ESA, CSA, Leah Hustak (STScI)

the star, it causes the star to wobble ever so slightly back and forth. This will, in turn, cause the lines within the spectra to shift ever so slightly towards the blue and red ends of the spectrum as the star wobbles slightly away and towards us. This is caused by the blue and red shifts of the planet's light. By carefully measuring the amount of shift in the star's spectra, astronomers can determine the size of the object pulling on the host star and if the companion is indeed a planet. By tracking the variation in this periodic shift of the spectra, they can also determine the time it takes the planet to orbit its parent star.

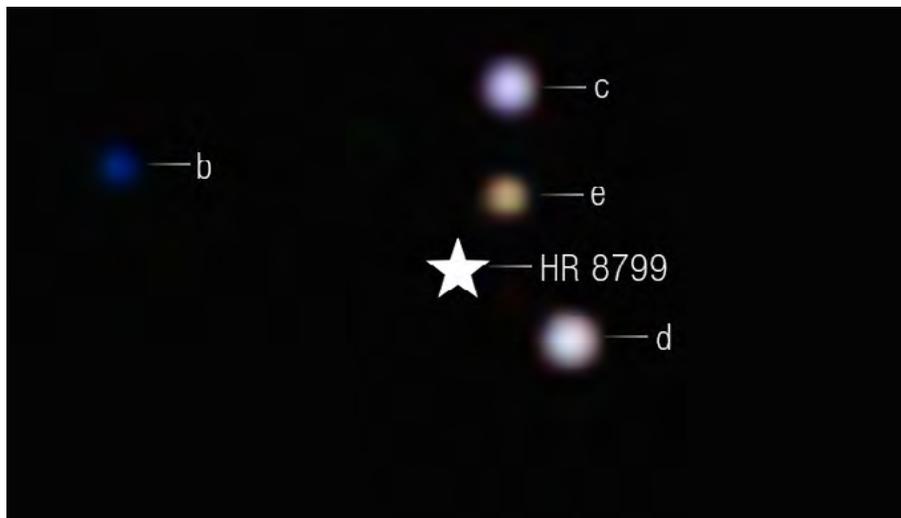


Image taken by the James Webb Space Telescope of four exoplanets orbiting HR 8799. Credit: NASA, ESA, CSA, STScI, Laurent Pueyo (STScI), William Balmer (JHU), Marshall Perrin (STScI)

Direct Imaging

Finally, exoplanets can be revealed by directly imaging them, such as this image of four planets found orbiting the star HR 8799! Space telescopes use instruments called coronagraphs to block the bright light from the host star and capture the dim light from planets. The Hubble Space Telescope has captured images of giant planets orbiting a few nearby systems, and the James Webb Space Telescope has only improved on these observations by uncovering more details, such as the colors and spectra of exoplanet atmospheres, temperatures, detecting potential exomoons, and even scanning atmospheres for potential biosignatures!

You can find more information and activities on [NASA's Exoplanets page](#), such as the [Eyes on Exoplanets](#) browser-based program, [The Exoplaneteers](#), and some of the latest [exoplanet news](#). Lastly, you can find more resources in our [News & Resources](#) section, including a [clever demo](#) on how astronomers use the wobble method to detect planets!

The future of exoplanet discovery is only just beginning, promising rich rewards in humanity's understanding of our place in the Universe, where we are from, and if there is life elsewhere in our cosmos.

Dave Prosper and Katherine "Kat" Troche are the former and current, respectively, Project Coordinator and Night Sky Network Administrator at the Astronomical Society of the Pacific.

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THE CONVERSATION

Dark energy may have once been ‘springier’ than it is today — DESI cosmologists explain what their collaboration’s new measurement says about the universe’s history

by David Weinberg, Ashley Ross, Klaus Honscheid, and Paul Martini

Gravity pulls us to earth, a lesson you learn viscerally the first time you fall. Isaac Newton described gravity as a universal attractive force, one that holds the Moon in orbit around the Earth, the planets in orbit around the Sun, and the Sun in orbit around the center of our galaxy.

In the 1990s, astronomers made the astonishing discovery that the expansion of the universe has sped up over the past 5 billion years, which implies that gravity can push as well as pull.

Einstein’s theory of general relativity explains gravity as a consequence of curved space-time, where it allows for both attraction and repulsion. However, producing gravitational repulsion requires a new form of energy with exotic physical properties, often referred to as “dark energy.”

New results from a large survey of the universe, announced in March 2025, are challenging the conventional picture of dark energy.



The Mayall 4-meter Telescope at the Kitt Peak National Observatory houses the DESI instrument. [KPNO/NOIRLab/NSF/AURA/P. Marenfeld](https://www.kitp.noao.edu/)

Dark energy and cosmic expansion

The simplest explanation for cosmic acceleration assumes a form of energy that fills apparently empty space and stays constant over time, instead of diluting as the universe expands.

In fact, quantum mechanics predicts that “empty” space is filled with particles that flare briefly into and out of existence. At first glance, it seems like this effect could explain a constant dark energy, but no simple estimates of the effect’s magnitude line up with actual observations. Nonetheless, constant dark energy is a simple assumption that has proven successful in explaining many cosmological measurements.

Today’s standard cosmological model incorporates this kind of constant dark energy. It also incorporates atoms and dark matter, which exert the attractive gravity that resists dark energy’s repulsion.

New dark energy measurements

The new measurements from the Dark Energy Spectroscopic Instrument, or DESI, collaboration, which we are affiliated with, pose

the sharpest challenge yet to this standard model.

Relative to the constant dark energy predictions, the new DESI measurements suggest that the universe was expanding slightly faster a few billion years ago—by 1% to 3%—before relaxing to the expansion rate predicted today. One explanation for this temporary speed up is that the “springiness” of dark energy—a combination of energy and pressure that determines its repulsive effect—was higher in the past. The springiness then declined as the universe expanded further.

Astronomers can measure the history of the universe from our vantage point in the present because light travels at a finite speed. So, we see distant objects as they were in the past. Cosmic expansion stretches the wavelength of light—a phenomenon known as redshift. A precise measurement of an object’s light can reveal the size of the universe at the time the light was emitted.

The new DESI results are based on measuring the redshifts of more than 14 million galaxies, creating a three-dimensional map that spans 12 billion years of cosmic history. To determine the distances light traveled across this map, DESI measured a subtle feature imprinted on the clustering of these galaxies by acoustic waves that traveled through the early universe.

An exciting result

DESI’s evidence for evolving dark energy comes from combining its own distance and redshift measurements with other measurements of the average density of matter in the universe. The higher the density of matter, the more strongly it can pull against dark energy’s expansive push. The matter density measurements come from the European-led Planck space mission, which mapped structure in the cosmic microwave background.

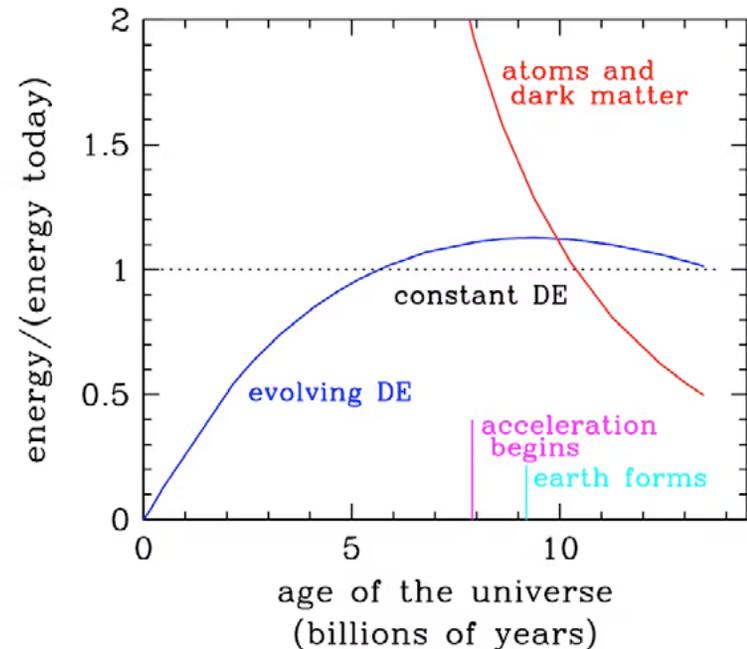
The combination of DESI and Planck data favors evolving dark energy, instead of constant dark energy, with a statistical significance of 3.1 standard deviations. This result has only a 1 in 500 chance of occurring randomly.

Despite the long odds, physicists consider such a finding to be solid but not overwhelming evidence, in part because even the

most careful experimenters may underestimate uncertainties in their measurements.

To strengthen the statistical case, DESI scientists added measurements of cosmic distances made by the Dark Energy Survey collaboration, which applied a different measurement technique based on the brightness of light from supernova explosions.

The combination of DESI, Planck and Dark Energy Survey supernovae favors the evolving dark energy model by odds of 40,000 to 1. However, other supernova surveys give results that agree more with constant dark energy, so most cosmologists aren’t yet ready to abandon the standard cosmological model.



In the model that fits the DESI data, the density of dark energy goes up and then declines, shown as a blue curve, instead of staying constant as assumed in the standard cosmological model, indicated by the horizontal dotted line. In either case, the density of atoms and dark matter dilutes as the universe expands, shown as a red curve, and today it is only about half that of dark energy. The repulsive effect of dark energy began to exceed the attractive effect of matter when the universe was about 8 billion years old, marked as ‘acceleration begins.’ David Weinberg

Even if DESI's findings hold up, they still can't say what dark energy is. But they can provide much stronger clues than cosmologists had before.

The DESI-based model implies that dark energy changed its properties surprisingly quickly. Dark energy began to lose its repulsive strength at about the same time it became the dominant form of energy in the cosmos.

Extrapolating to the past, this model also implies that dark energy once had an extraordinary springiness, at a level that no simple theory of a dark energy field can explain. As future data sharpens these measurements, the findings could point us in a weird new direction—perhaps even challenging Einstein's theory of gravity itself.

An ambitious experiment

DESI is an extremely ambitious undertaking and an example of “big science” at its best. The instrument itself is mounted on the 4-meter Mayall Telescope at the Kitt Peak National Observatory. It uses 5,000 optical fibers mounted on tiny robotic positioners that guide the light



A close-up of the DESI focal plane showing a few of the 5,000 fiber positioners. The white spots inside the bluish circles are the optical fibers that guide the light collected from distant galaxies to the spectrographs about 40 meters away. Dr. Claire Poppett, DESI Collaboration

from individual galaxies to scientific instruments that dissect that light and record the data for measuring redshifts.

Every 15 minutes, the telescope shifts to a new area of the sky, and the robots move the fibers to point to 5,000 new galaxy locations. After five years of design and construction, DESI has operated continuously since 2021.

Led by the Department of Energy's Lawrence Berkeley National Laboratory, DESI is a collaboration of over 900 scientists at 70 institutions around the world. At our university alone, more than 20 faculty, students, postdocs and research staff have worked on DESI over the past decade.

This work includes contributions to building and installing spectrographs, which measure the properties of light, as well as writing software to record data, leading instrument operations, observing and troubleshooting at the telescope, designing galaxy and quasar surveys, creating catalogs for statistical analysis, testing measurement techniques with computer simulations, interpreting results and writing papers—all in tight communication with our collaborators.

If the evidence for evolving dark energy holds up—and despite our instinctive caution, we think it has a good chance of doing so—it will join a list of remarkable 21st-century discoveries achieved with large U.S. national investments.

These discoveries include the first detection of gravitational waves by the National Science Foundation-funded Laser Interferometer Gravitational-Wave Observatory, LIGO, and the spectacular measurements of galaxies and exoplanet atmospheres by NASA's James Webb Space Telescope.

These achievements show what the support of science by U.S. taxpayers and dedicated, creative researchers across the globe can accomplish.

David Weinberg, Professor of Astronomy; Ashley Ross, Research Assistant Professor of Physics; Klaus Honscheid, Professor of Physics; and Paul Martini, Professor of Astronomy and Physics, are all at The Ohio State University.

After Words

"Each of the major sciences has contributed an essential ingredient in our long retreat from an initial belief in our own cosmic importance. Astronomy defined our home as a small planet tucked away in one corner of an average galaxy among millions; biology took away our status as paragons created in the image of God; geology gave us the immensity of time and taught us how little of it our own species has occupied."

—Stephen Jay Gould, *Ever Since Darwin: Reflections in Natural History* (1992)

"We are stardust brought to life, then empowered by the universe to figure itself out—and we have only just begun."

—Neil deGrasse Tyson, *Astrophysics for People in a Hurry* (2017)

"For millions of years, mankind lived just like the animals. Then something happened which unleashed the power of our imagination. We learned to talk and we learned to listen. Speech has allowed the communication of ideas, enabling human beings to work together to build the impossible. Mankind's greatest achievements have come about by talking, and its greatest failures by not talking. It doesn't have to be like this. Our greatest hopes could become reality in the future. With the technology at our disposal, the possibilities are unbounded. All we need to do is make sure we keep talking."

—Stephen Hawking, British Telecom Advertisement (1993)



Randall Munroe, [xkcd](https://xkcd.com), CC.