CHANG'E 5 IS REWRITING LUNAR HISTORY p. 40

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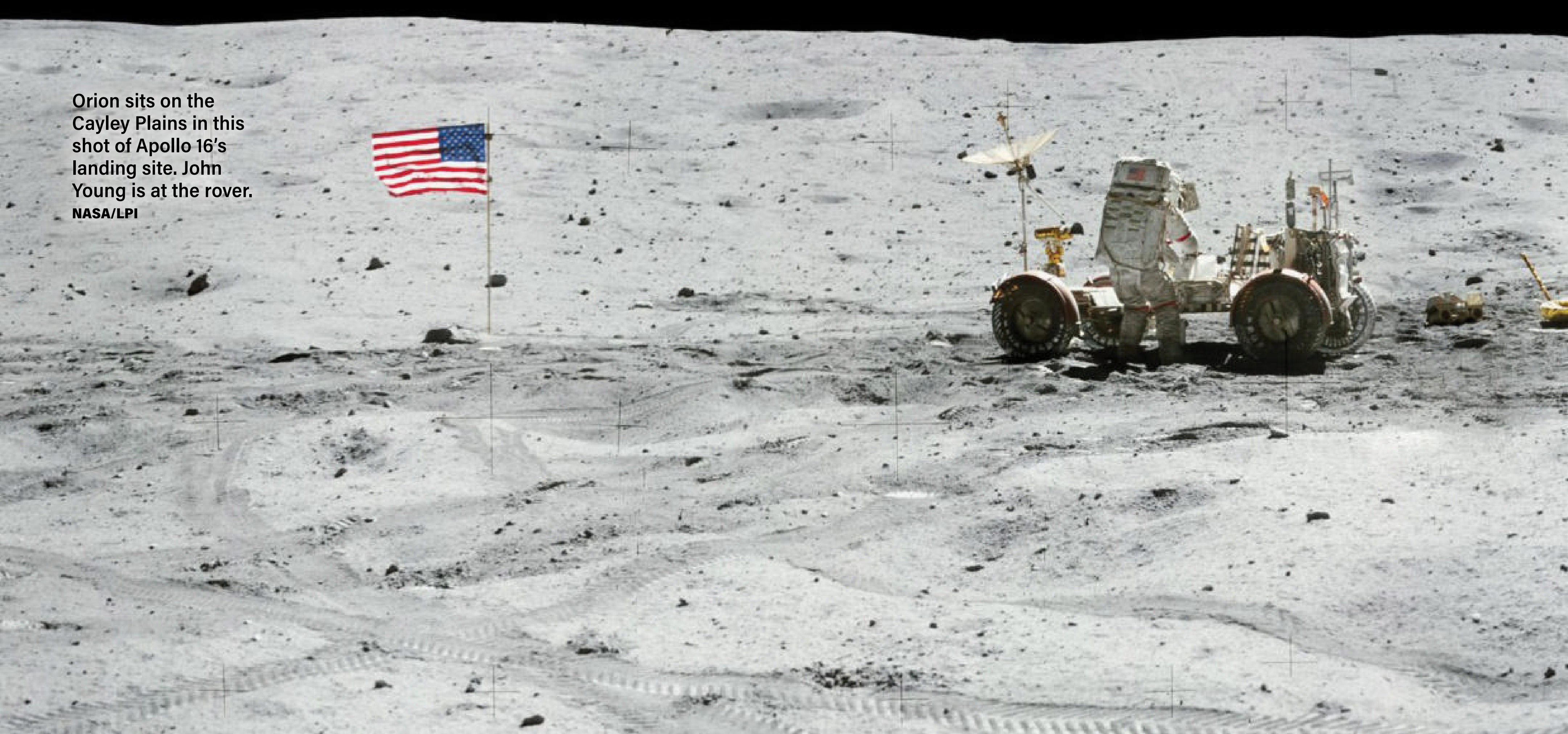
50 YEARS AGO

APOLLO roves the lunar

The fifth crew to land on the Moon took lunar geology to new heights. BY MARK ZASTROW



Orion sits on the Cayley Plains in this shot of Apollo 16's landing site. John Young is at the rover.
NASA/LPI

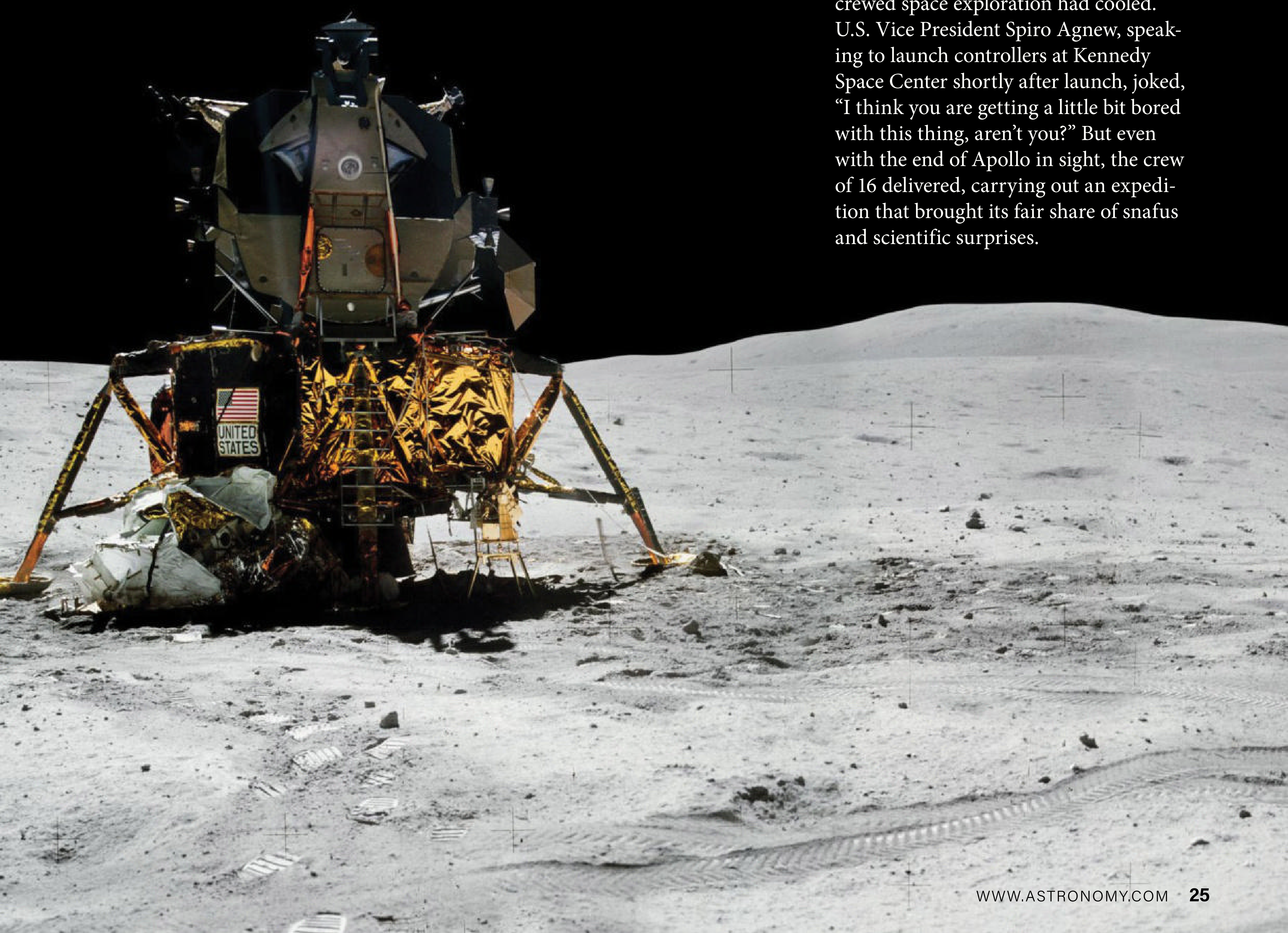
16 highlands

BY THE SPRING OF 1972, traveling to the Moon was, if not routine, at least a more confident affair. When Apollo 16 astronauts John Young and Charlie Duke stepped off the ladder of the Lunar Module (LM) *Orion* onto the lunar surface, "there wasn't any tentative step," Duke later said. "It was just: Jump off and start work."

When Duke and Young hit the regolith, it marked the first time that astronauts had set foot in the rugged lunar highlands. Apollo 16's landing site was Descartes, a region some 7,400 feet (2,250 meters) higher than the Sea of Tranquillity, where Apollo 11 had touched down. Researchers believed the Descartes hills had been formed by lava flows and would yield volcanic material — like igneous rocks — older than the maria where Apollos 11 and 12 had landed.

For the laconic Young, the mission's commander, it was the second trip to the Moon, having orbited it as the Command Module Pilot (CMP) on Apollo 10. He was also a veteran of the Gemini program, having flown on Gemini 3 and commanded Gemini 10. Duke, the mission's Lunar Module Pilot, was an enthusiastic rookie; Apollo 16 would be his first and only spaceflight. Ken Mattingly had been slated to fly as CMP on Apollo 13 but was grounded after being exposed to the measles and shifted to Apollo 16.

All the while, uncertainty hung over the future of NASA. Political support for crewed space exploration had cooled. U.S. Vice President Spiro Agnew, speaking to launch controllers at Kennedy Space Center shortly after launch, joked, "I think you are getting a little bit bored with this thing, aren't you?" But even with the end of Apollo in sight, the crew of 16 delivered, carrying out an expedition that brought its fair share of snafus and scientific surprises.



* * *

Apollo 16 got off to an inauspicious start, with a string of minor glitches. Paint was flaking off the LM's insulation for no apparent reason. The crew discovered a software bug that crashed the guidance system. Upon arriving at the Moon, the LM's communications antenna jammed and its landing radar malfunctioned. Charlie Duke had issues zipping up his spacesuit. And when he finally did, his mic was positioned awkwardly: It tended to bump into his drink tube, spraying the inside of his helmet with an orange-flavored sports drink. (The liquid was laced with potassium to ward off irregular heartbeats that had affected some previous Apollo astronauts.) So, when Young and Duke finally climbed into Orion *and separated from the Command Module (CM)* Casper*, spirits were high. It seemed the mission was back on track.*

YOUNG (TO CM): Boy, Ken, you look great!

MATTINGLY (TO LM): Well —

DUKE (TO CM): You really got a pretty spacecraft!

MATTINGLY (TO LM): Yours is a *[garbled]* pretty one, too.

JIM IRWIN, CAPSULE COMMUNICATOR (CAPCOM): *Orion*, this is Houston. How do you read?

DUKE: Roger. You're five by [five], Jim, and we're sailing free. *[Pause.]* OK, Jim. It was a little rushed, but we got it done. The only bad thing is, I got a hat full of orange juice.

The two craft were in an elliptical orbit that dipped to just 11 miles (18 kilometers) above the lunar surface near the landing site. While on the farside of the Moon and out of contact with Houston, Mattingly in the CM would raise Casper*'s orbit using the Service Module's main engine. It was less than an hour before Young and Duke would begin their descent.*

DUKE (ONBOARD LM): Here we go.

YOUNG (ONBOARD LM): Now, shall we do it?

DUKE (ONBOARD LM): Oh …

YOUNG (ONBOARD LM): Might as well. […]

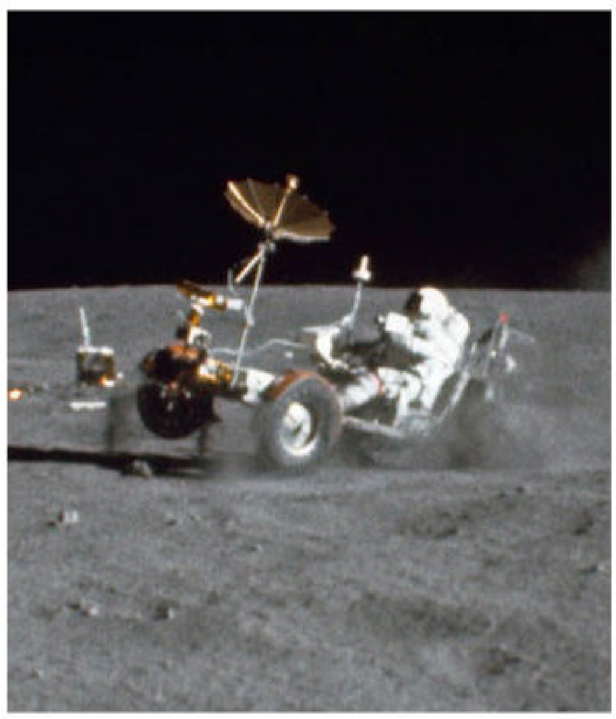
YOUNG: Ken, do you read us on VHF [Very High Frequency radio]? Over.

MATTINGLY: Yes, loud and clear.

YOUNG: You fixing to do the burn, right?

MATTINGLY: Sure am.

Apollo 16 lifted off from Launch Complex 39A at the Kennedy Space Center at 12:55 P.M. EST on April 16, 1972. NASA/KIPP TEAGUE



At the end of the first EVA, Young put the rover through its paces in a test drive dubbed the "Grand Prix," which Duke filmed on a 16mm camera. He enthusiastically reported to Houston: "He's got about two wheels on the ground. There's a big rooster tail out of all four wheels. And as he turns, he skids. The back end breaks loose, just like on snow. […] Man, I'll tell you, Indy's never seen a driver like this." ALL IMAGES BY NASA AND FILM SCANS BY THE JOHNSON SPACE CENTER UNLESS OTHERWISE NOTED

It was then that Apollo 16's most serious problem hit: Before the circularization burn, Mattingly had to run an automated test of all four of the Service Module's engine gimbals, two in the primary system and two in the backup system. These gimbals swiveled the engine to steer its direction of thrust. Mattingly recalled the test in a 2001 NASA oral history: "So you start the little computer program, and it just automatically swings the gimbal up,

John Young works at the rover on the lower slopes of Stone Mountain in the Descartes Highlands, with the Cayley Plains spread out below him.

swings it down, left, right, puts it back in the center, switches over to the other [backup] system, and does the same thing, and you just watch it. It's a little thing that you do, kind of a ritual, happens about 20 seconds before the burn."

While Young and Duke waited for Mattingly to light Casper*'s engine, the pair tried to wipe down Duke's helmet.*

YOUNG (ONBOARD LM): Ain't the clearest in the world, but it's the clearest I could do, Charlie. Honest.

DUKE (ONBOARD LM): It's terrible.

YOUNG (ONBOARD LM): You want to try it yourself? Just doesn't come off. […] OK, we're getting — we're getting behind the timeline probably — maybe.

DUKE (ONBOARD LM): No, we aren't. We're OK.

YOUNG (ONBOARD LM): OK, nothing we can do here, huh?

Onboard Casper*, Mattingly realized he had a problem. In the gimbal test, the second set of yaw gimbals was oscillating violently, causing the entire spacecraft to shake. Not knowing what the issue was, he started to blame himself. In 2001, he recalled: "[I've] practiced this stuff so much, it's like knowing your name. […] We had already done this a couple of times on our way out, so it's not like the first time we'd done this test, only this time the spacecraft was [shaking]. I stopped. [I thought,] 'Oh, God. I've done this a thousand times. How could I screw it up now? I've got to do this again.'"*

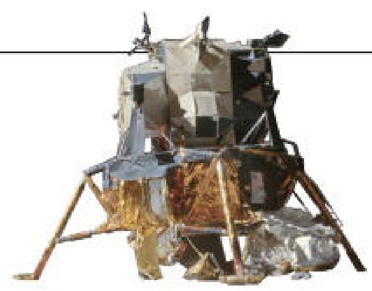
MATTINGLY (TO HIMSELF): *[garbled]* marked. *[garbled] [Long pause.]*

contact with Houston, they got good news: The landing was back on.

IRWIN: We've run exhaustive tests down here, on the West Coast and East Coast on controllability aspects and structural aspects, and everything looks satisfactory. On Apollo 9, we ran — a similar test was run, as you probably remember. […] So we're convinced down here that we have a satisfactory control mode if we have to revert to that one. Over.

In Mission Control, Stuart Roosa, the Command Module Pilot for Apollo 14, took over the CapCom's mic to add more words of reassurance.

ROOSA: You know, Jim was talking



DUKE SAID IN A 1999 NASA ORAL HISTORY, "IF YOUR HEART CAN SINK TO THE BOTTOM OF YOUR BOOTS IN ZERO GRAVITY, OURS DID."

[garbled] yaw. *[garbled] [Pause.] [garbled] [Pause.]* It's not gonna work.

YOUNG (ONBOARD LM): *[sarcastically]* Charlie, this is fun, by golly. *[Laughs.]* It's really — it's really — it's the worst sim I've ever been in.

MATTINGLY (TO HIMSELF): I be a sorry bird.

MATTINGLY: Hey, *Orion*?

YOUNG: Go ahead, Ken.

MATTINGLY: I have an unstable yaw gimbal, no. 2. It's just been oscillating and — oscillates in yaw any time it gets excited.

YOUNG: Oh, boy.

MATTINGLY: You got any quick ideas?

YOUNG: No, I sure don't.

Unless the problem was resolved, mission rules dictated the landing could not continue.

While Mattingly tried to troubleshoot the gimbal problem with Houston, Young and Duke braced themselves for Houston to cancel their landing. "Our hearts sank," Duke said in a 1999 NASA oral history. "If your heart can sink to the bottom of your boots in zero gravity, ours did, because there we were, two years of training, 240,000 miles [386,000 km] away, an hour before the landing, on an orbit you can look down at your landing site, 8 miles [13 km] beneath you, and they're about to tell you to come home."

YOUNG (ONBOARD LM): Man, I'm ready. I'm ready to go down and land. I think that'd really be neat.

DUKE (ONBOARD LM): I bet we dock and come home in about three hours.

The crew spent one more trip around the Moon waiting in agony. When they came around the lunar farside on their 15th lunar orbit and reestablished radio

about the Apollo 9 test, and he said that you really feel it in the spacecraft. But this thing is stable. They've really checked that out, and it'll rattle and roll a little bit if you have to use it, but it's stable.

MATTINGLY: Sounds good. Once again, the ground earns their pay.

From there, the landing was smooth sailing. The site was on the Cayley Plains, nestled between two peaks of the Descartes Highlands — Smoky Mountain to the north and Stone Mountain to the south. Each mountain sported a nearby crater with prominent rays — North Ray and South Ray craters. Geologists hoped these craters would serve as natural drill holes where the crew could find samples of the underlying bedrock. Young and Duke set Orion *down roughly 906 feet (276 m) from their target, near two craters named Double Spot.*

DUKE: Contact. Stop. Boom! PRO. ENGINE ARM. Wow! *[garbled]* man! Look at that! […]

The crew of Apollo 16 (left to right): Command Module Pilot Thomas K. Mattingly, Commander John W. Young, and Lunar Module Pilot Charles M. Duke.

YOUNG: Well, we don't have to walk far to pick up rocks, Houston. We're among them. […]

DUKE: Old *Orion* is finally here, Houston. Fantastic!

IRWIN: Sounds great.

* * *

With the long delay, the crew opted to sleep and push back their first scheduled extravehicular activity (EVA) to the next day. The next morning, as Young clambered down the ladder, Duke couldn't wait to get onto the lunar surface.

DUKE: Hey John, hurry up!

YOUNG: I'm hurrying. OK.

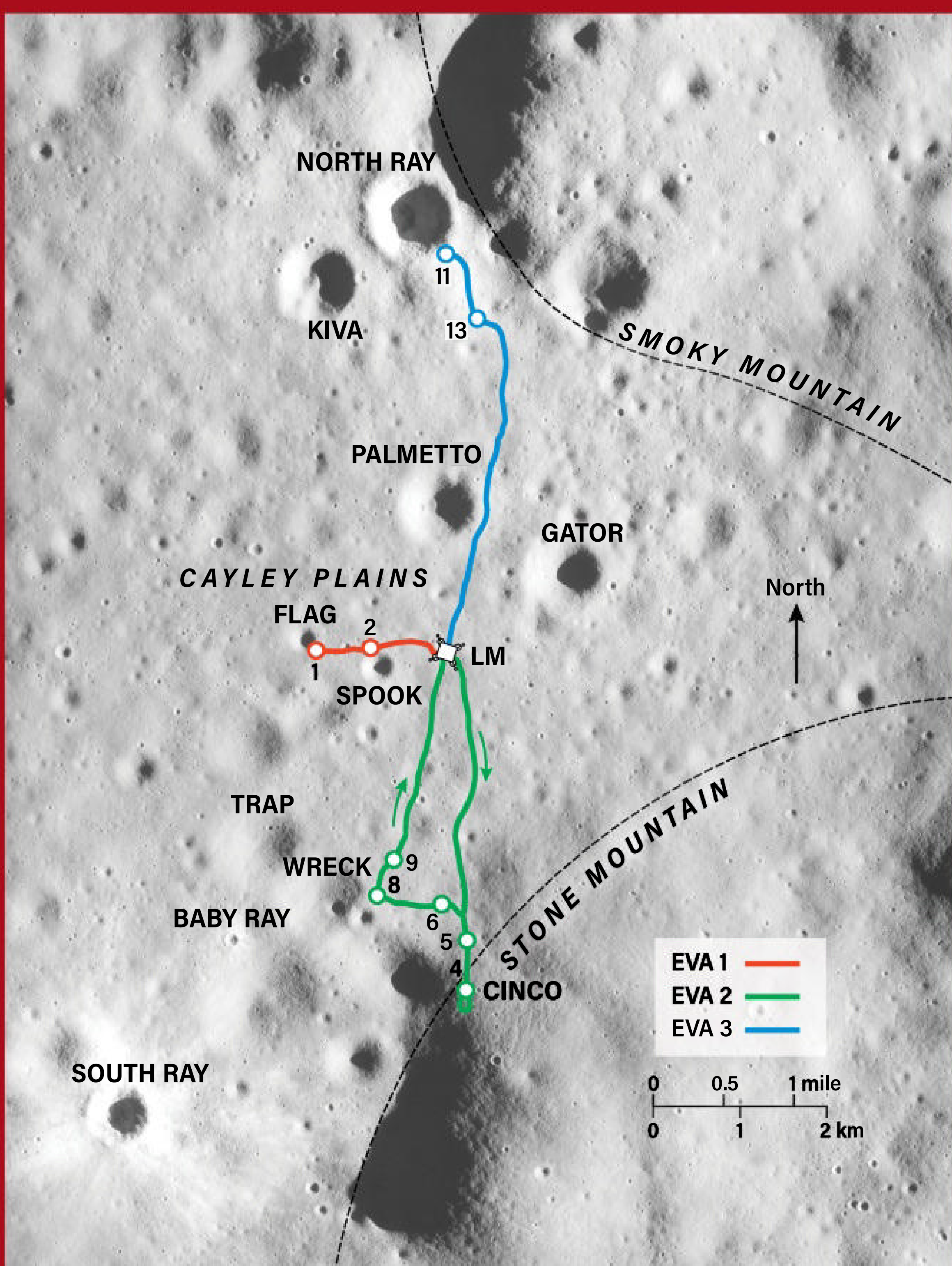
With that, Young stepped onto the Moon.

YOUNG: There you are, our mysterious and unknown Descartes. Highland plains. Apollo 16 is going to change your image.

Duke was next to bound down the ladder.

DUKE: Here I come, babe! […] Hot dog, is this great! […] Fantastic. That's the first foot on the lunar surface. It's super, Tony.

EXPLORING THE HIGHLANDS



The landing site for *Orion* was chosen due to its location at two overlapping geologic formations: the Cayley Formation and the Descartes Formation. Both were thought to be volcanic in nature — but this was quickly disproved by the dearth of volcanic rocks in the area. Instead, scientists suspect, the massive Imbrium impact 3.9 billion years ago blasted ejecta that flowed across the Moon, forming structures at Apollo 16's landing site that resemble volcanic flows. *ASTRONOMY:* ROEN KELLY

ANTHONY ("TONY") ENGLAND (CAPCOM): Sounds great.

Before they began their excursion, the pair set up the Apollo Lunar Surface Experiments Package (ALSEP), a suite of stationary scientific instruments. One highlight was an experiment developed by Columbia University's Marcus ("Mark") Langseth to measure the heat flow within the Moon's interior. It was an upgraded version of a kit that had flown on Apollo 15; on that mission, problems with the drill prevented the heat probes from being planted at their intended depth.

DUKE: OK. Man, you can't believe how happy I am that [the first drill stem] went in there.

YOUNG: Tony, he's very happy.

ENGLAND: Mark's pretty happy, too.

But as Young worked at the ALSEP's central station, with wires tangled at his feet, he accidentally caught his foot on a cable and stumbled.

YOUNG: Charlie …

DUKE: What?

YOUNG: Something happened here.

DUKE: What happened?

YOUNG: I don't know. Here's a line that pulled loose.

DUKE: Uh-oh.

YOUNG: What is that? What line is that?

DUKE: That's the heat flow. You've pulled it off.

YOUNG: I don't know how it happened. Pulled loose from there?

DUKE: Yes.

YOUNG: God almighty. Well, I'm wasting my time. I'm sorry. I didn't even know — I didn't even know it. *[Pause.]* It's sure gone —

ENGLAND: Did the wire or the connector come off?

YOUNG: — our first catastrophe. It broke right at the connector.

DUKE: The wire came off at the connector.

ENGLAND: OK, we copy. OK, I guess we can forget the rest of that heat flow.

DUKE: Now, if I go do the — ah, rats!

YOUNG: I'm sorry, Charlie. You know it.

Young took the mishap hard — he knew how hard Langseth and the other mission scientists had worked on the experiment. But there was nothing to do except carry on.

After deploying the rest of the ALSEP, the pair set out in the rover on their first traverse: a short excursion about 0.9 miles

(1.5 km) west to Flag Crater, a crater nearly 800 feet (240 m) wide. There, they hoped to collect samples representative of the Cayley Formation. One rock caught the eyes of the scientists in the backroom in Mission Control, led by geologist William Muehlberger.

ENGLAND: As you come around there, there is a rock in the near field on this rim that has some white on the top of it. We'd like you to pick it up as a grab sample.

DUKE: This one right here?

ENGLAND: That's it. […]

DUKE: OK, that's a —

YOUNG: That's a football-size rock.

DUKE: It's a "Great Scott" size.

On Apollo 15, Commander David Scott had collected the largest Moon rock to date.

YOUNG: Are you sure you want a rock that big, Houston?

ENGLAND: Yeah, let's go ahead and get it.

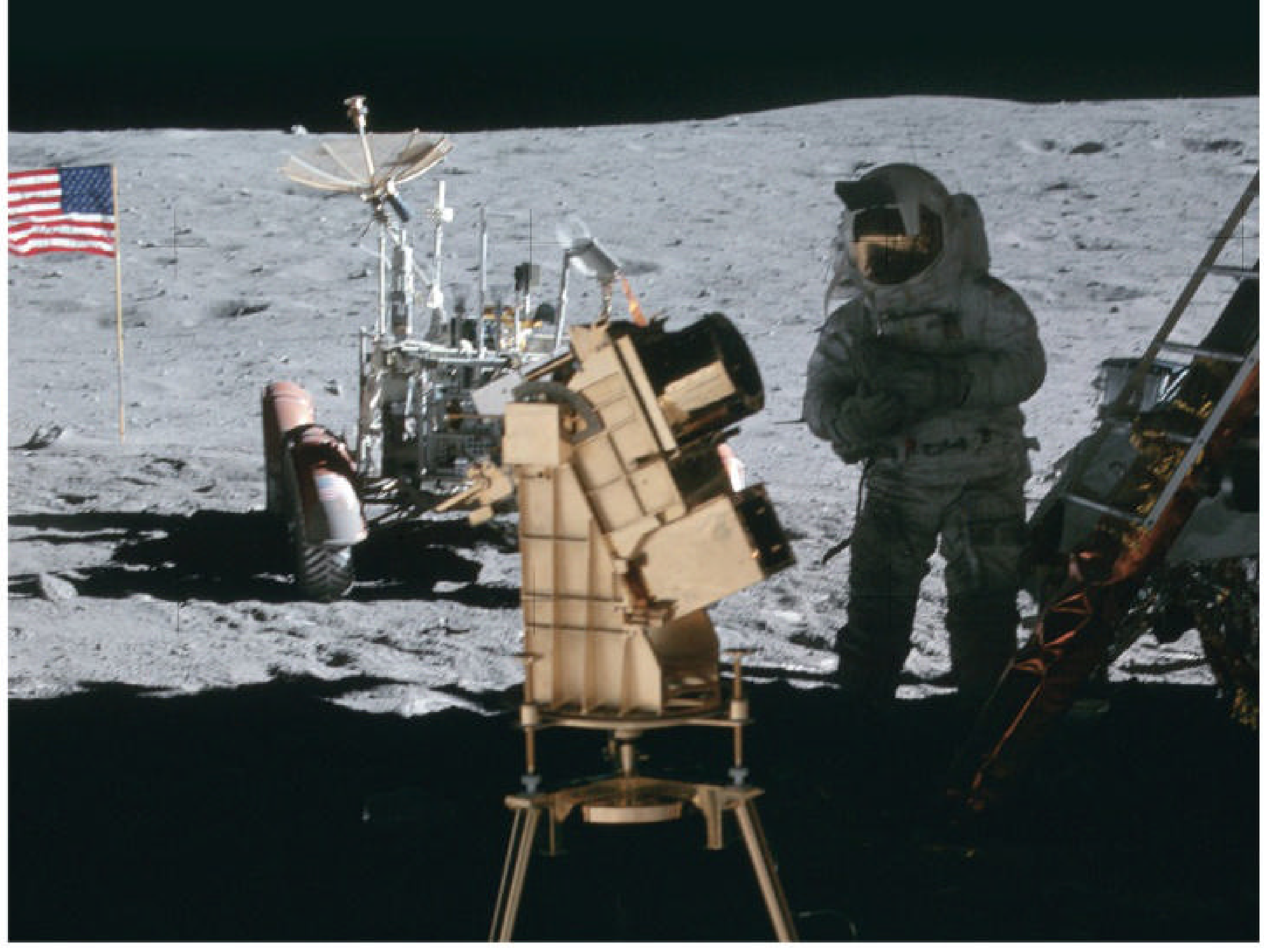
YOUNG: That's 20 pounds [9 kilograms] of rock right there.

DUKE: OK. It has some big clasts in it, John.

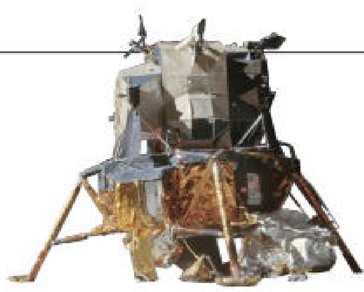
YOUNG: It sure has.

DUKE: If I fall into Plum Crater getting this rock, Muehlberger has had it.

ENGLAND: We agree.



Apollo 16 brought an astronomical telescope (top) to the Moon: a 3-inch, f/1.0 Schmidt far-ultraviolet camera with imaging and spectrographic modes. John Young set up the camera in the LM's shadow to reduce glare and aimed it manually. Objects observed include (bottom row, left to right): the Large Magellanic Cloud, Earth's tropical airglow, and polar aurorae.



UNBEKNOWNST TO YOUNG, HIS RADIO REMAINED OPEN, ALLOWING HOUSTON — AND THE PRESS CORPS — TO EAVESDROP ON A DECIDEDLY PRIVATE CONVERSATION.

DUKE: OK, I've got it. […] Oh, Tony, it's got some beautiful crystals in it though. That was a good guess.

ENGLAND: Good show.

In fact, this rock — dubbed "Big Muley" after Muehlberger — tipped the scales at almost 26 pounds (11.7 kg), setting a lunar sample weight record that has yet to be broken.

As the crew wrapped up their first EVA, the scientists in Mission Control were questioning some of their basic assumptions about Apollo 16's landing site. Perhaps the landscape wasn't as volcanic as they had thought: Nearly all the rocks the crew had found were breccias — cemented piles of smaller rock fragments that are non-volcanic in origin.

CapCom Henry Hartsfield relayed these impressions to Mattingly as he soared over the landing site in Casper.

HARTSFIELD: I guess the big thing, Ken, was they found all breccia. They found only one rock that possibly might be igneous.

MATTINGLY: Is that right? *[Laughs.]*

HARTSFIELD: Yeah. I guess the guys are a little bit surprised by that.

MATTINGLY: […] *[Laughs.]* Well, it's back to the drawing boards, or wherever geologists go.

Inside the LM, as Young and Duke prepared to sleep, Duke paid tribute to the mission geologists who had trained them.

DUKE: Let me say that all our geology training, I think, has really paid off. Our sampling is really — at least, procedurally — has been real team work, and we appreciate everybody's hard work on our sampling training.

ENGLAND: OK. And I sure think it's paying off. You guys do an outstanding job.

YOUNG: Yeah. You noticed how good I carried the bags, huh?

Unbeknownst to Young, his radio remained open, allowing Houston — and the press corps — to eavesdrop on a decidedly private conversation.

YOUNG: I got the farts again. I got 'em again, Charlie. I don't know what the hell gives it to me. Certainly not — I think it's the acid in the stomach. I really do.

DUKE: It probably is.
YOUNG: I mean, I haven't eaten this much citrus fruit in 20 years! And I'll tell you one thing, in another 12 f------ days, I ain't never eating any more! And if they offer to sup[plement] me potassium with my breakfast, I'm going to throw up! *[Pause.]* I like an occasional orange — really do. *[Laughs.]* But I'll be darned if I'm going to be buried in oranges.

After a few more minutes of unguarded conversation, Houston intervened.

JOE ALLEN (CAPCOM): *Orion*, Houston.
YOUNG: Yes, sir.
ENGLAND: OK, uh, John. You — we have a hot mic.
YOUNG: How… How long have we had that?
ENGLAND: OK. It's been on through the debriefing.
YOUNG: How could we be on hot mic with normal voice? […]
ENGLAND: John, would you exercise your push-to-talk button there? It may be stuck.
YOUNG: Yeah, I hit it then.
ENGLAND: John, it doesn't seem to be a hot mic now. Evidently, you got it off.
YOUNG: OK. Fine.

* * *

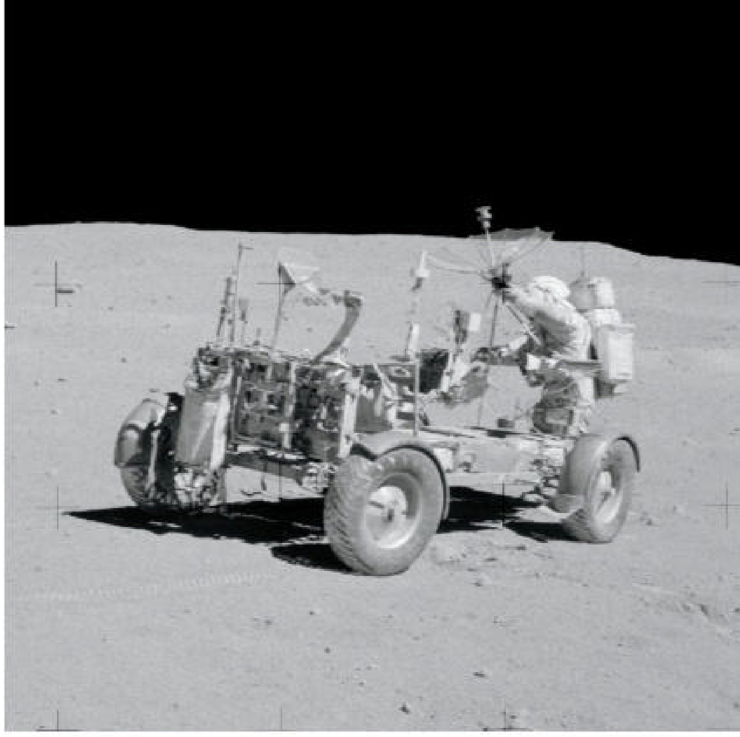
The next day, Young and Duke trekked to the lower slopes of Stone Mountain, 2.4 miles (3.8 km) south. Driving the rover up a 20 percent grade, they reached a cluster of five craters, called the Cincos, 500 feet (150 m) above the Cayley Plains. Their goal was to find chunks of the mountain's bedrock — true samples of the Descartes Highlands. However, this was complicated by the nearby presence of South Ray Crater on the plains below: The crew realized that many of the craters they were seeing were secondary craters formed by flying debris from the South Ray impact.

DUKE: You know, John, with all this — these rocks here, I'm not sure we're getting [samples of] Descartes.
YOUNG: That's right. I'm not either.
DUKE: We ought to go down to a crater without any rocks. […]

As Young and Duke stood at the rim of one secondary crater with a rake for collecting samples, they debated the best spot to sample from.

DUKE: This is steep. OK, where do you want this [rake]?
YOUNG: Well, on the rim, I think, Charlie.
DUKE: Why don't we get outside the rim? That would be definitely Descartes, right down here. OK?
YOUNG: The object is to get the stuff that's been knocked out of the ground [bedrock from the deepest point] and landed on the rim.
DUKE: Yeah, I know it, but I thought that would definitely — we could say that would be definitely — oh, OK, I'll sample right up here.

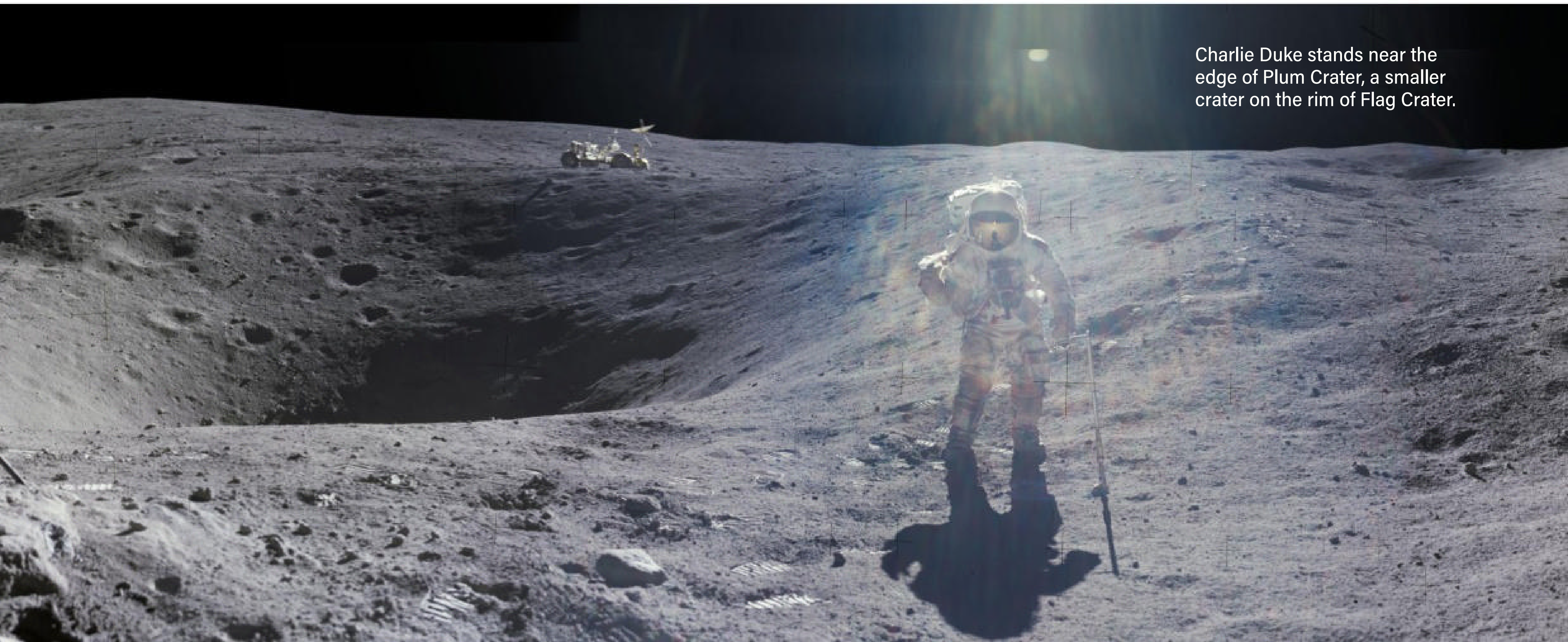
The next day's third and final EVA was originally going to be cancelled due to the landing delay, but it was retained at the insistence of the science team. They argued that EVA 3's main target, North Ray Crater, offered the mission's last, best chance to find Descartes bedrock material.



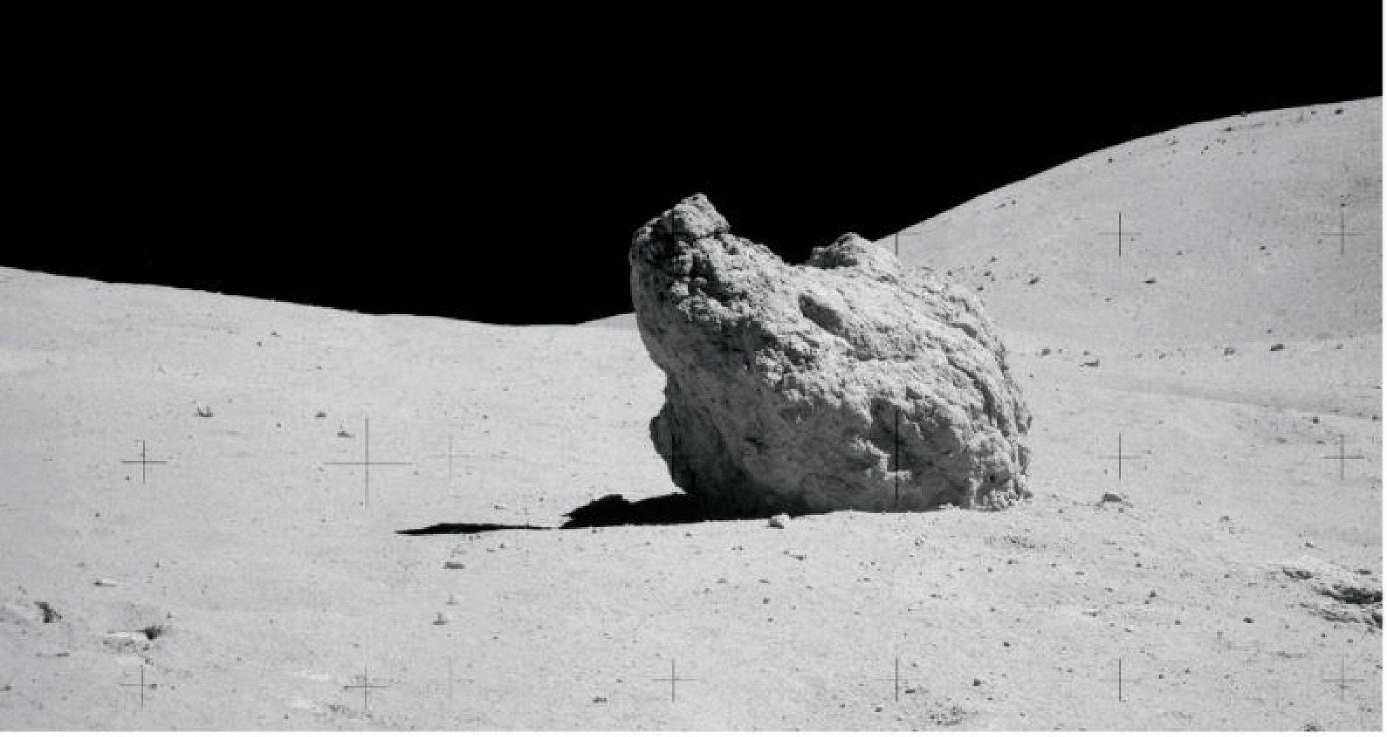
Indeed, North Ray Crater was a crown jewel of the area. At roughly 3,600 feet (1.1 km) in diameter, it was nearly as large as Arizona's Meteor Crater — and with even steeper slopes, as the pair found out.

YOUNG: Man, does this thing have steep walls.
DUKE: They said 60 degrees.
YOUNG: Well, I tell you, I can't see to the bottom of it and I'm as close to the edge as I'm gonna get. That's the truth. […]
ENGLAND: Man, is that a hole in the ground!
DUKE: […] It really is. I see no bedrock, though. All I see is boulders around the crater. There's nothing that reminds me of bedding, just loose boulders.

Though no bedrock seemed available to sample, the crew took the opportunity to scout and sample an enormous boulder several hundred feet in the distance.



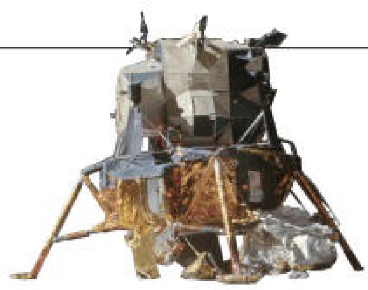
Charlie Duke stands near the edge of Plum Crater, a smaller crater on the rim of Flag Crater.



John Young adjusts the high-gain antenna on the lunar rover at Station 13 so that Houston can receive live images from the rover's TV camera. At right is a boulder named Shadow Rock. The astronauts sampled soil from its its shadow, hoping it was a permanently shadowed area where volatile gases could collect. NASA/LPI

immediately prepared to depart the Moon.

After a successful rendezvous with Casper, *the crew could reflect on what had been, despite all the gremlins, a successful field expedition. Over the course of 20 hours and 14 minutes of EVA, the rover covered 16.6 miles (26.7 km) and Young and Duke collected roughly 209 pounds (95 kg) of samples. The lack of igneous rocks suggested that Apollo 16's landing site had been shaped less by volcanoes and more by impacts and the resulting massive rock flows. It taught geologists an important lesson — that lunar terrain was more complex than it might appear from orbit.*



LOSING HIS BALANCE, DUKE TOPPLED OVER BACKWARD, HIS LEGS FLAILING — AND HIS CRITICAL LIFE SUPPORT SYSTEMS IN HIS BACKPACK ABOUT TO IMPACT THE SURFACE.

DUKE: Look at the size of that biggie!
YOUNG: It is a biggie, isn't it. It may be further away than we think because —
DUKE: No, it's not very far. It was just right beyond you.
YOUNG: Theoretically, huh?

Apollo crews found it notoriously difficult to judge distances on the Moon. The lack of air meant distant terrain never appeared hazy as it would on Earth, robbing astronauts of a helpful distance cue.

DUKE: Look at the size of that rock!
ENGLAND: We can see.
DUKE: The closer I get to it, the bigger it gets.

Appropriately dubbed House Rock for its size, the boulder was one of the most impressive seen on any Apollo mission. Excavated by the North Ray impact, its samples gave scientists one of their best looks at lunar highlands material.

When Young and Duke returned to the LM, they had planned to stage a lighthearted "Lunar Olympics" for the TV camera. After all, 1972 was an Olympic year. But time was running short.

YOUNG: We were gonna do a bunch of exercises that we had made up as the Lunar Olympics to show you what a guy could do on the Moon with a backpack on, but they threw that out.

As Young talked, he decided to show off his high-jump abilities, repeatedly jumping up and down in front of the rover's camera.

ENGLAND: For a 380-pound [172 kg] guy [including the weight of the spacesuit], that's pretty good.

The camera panned over to Duke, who also started jumping up and down.

DUKE: Yeah, jump flat-footed straight in the air, three hundred — about 4 feet [1.2 m]. Wow!

Then, Duke had a brush with disaster. Losing his balance, he toppled over backward, his legs flailing — and his critical life support systems in his backpack about to impact the surface. "That was a moment of panic," he said in 1999. "I really — you know, I was in trouble. You could watch me scrambling like that, trying to get my balance. And my heart was just pounding. You know, the backpack is very fragile. I thought the suit would hold, but the backpack, with the plumbing and connections and all — if that broke, it was just like having a puncture in the suit."

YOUNG: *[disapprovingly]* Charlie!
DUKE: That ain't any fun, is it?
YOUNG: That ain't very smart.
DUKE: That ain't very smart. Well, I'm sorry about that.
YOUNG: Right. Now we do have some work to do.

After returning to the LM and securing their samples, Young and Duke

The next day, the crew lit the Service Module engine once more to begin their journey back to Earth.

On the mission's 11th day, less than 24 hours before Apollo 16 splashed down in the Pacific Ocean, the crew took part in a press conference, answering questions from reporters relayed to them by CapCom Henry Hartsfield. Though the press had many questions for the astronauts about the expedition's numerous technical glitches, the lead topic of that day's news cycle was clear.

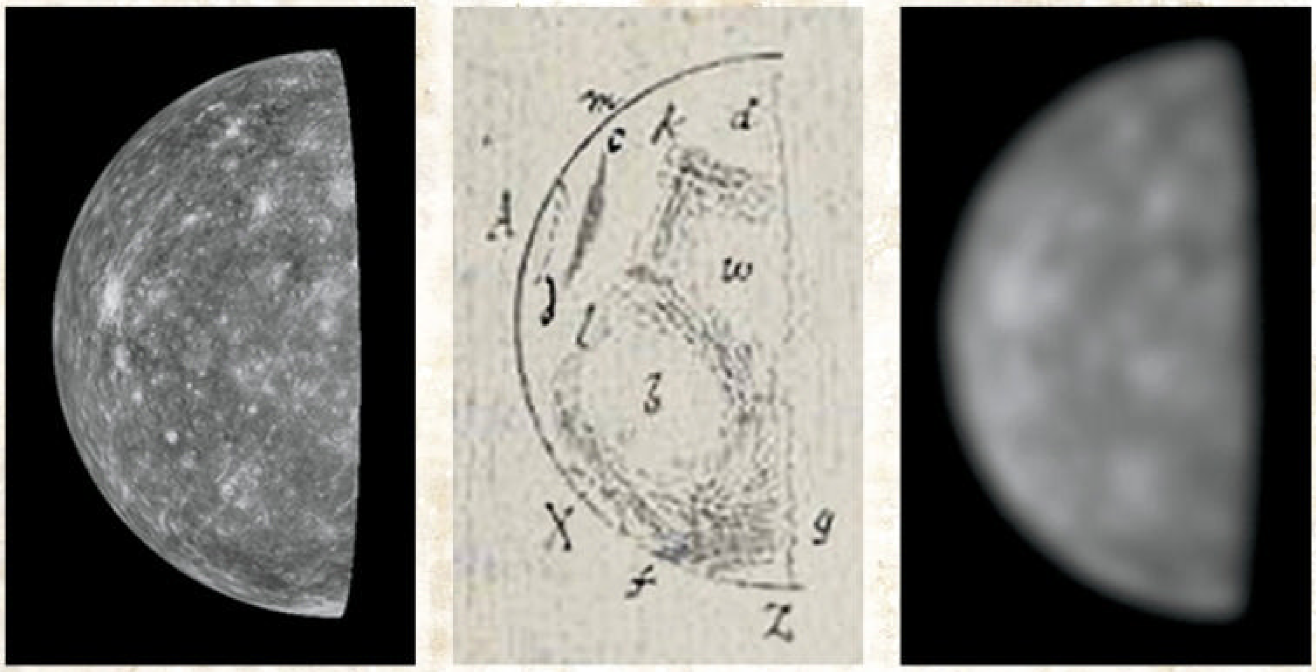
HARTSFIELD: Apollo 16, the questions in this press conference have been prepared by newsmen covering the flight here at the Manned Spacecraft Center. I'm going to read them to you exactly as worded by the newsmen and in a priority specified by them. Question no. 1 for John Young: "A couple of times you were on hot mic and didn't know it, but how could a nice Florida boy like you say what you did about citrus fruit?"
CREW (ONBOARD): *[Laughter.]*
YOUNG: That's a very good question. Wait until you drink it day and night for two weeks and let me know what you think.

Mark Zastrow *is senior editor of* Astronomy.

The strange history of Mercury's spots

WHAT SCHIAPARELLI SAW

Throughout this piece, we have revisited Schiaparelli's historical observations of Mercury by comparing his series of drawings with CCD images and WinJUPOS simulations. As might be expected, there are a lot of figure 5s. Some of Schiaparelli's drawings are quite accurate. But in other cases, there is so little resemblance between modern images and what he described that one has to wonder just what he thought he was seeing. *— W.S.*

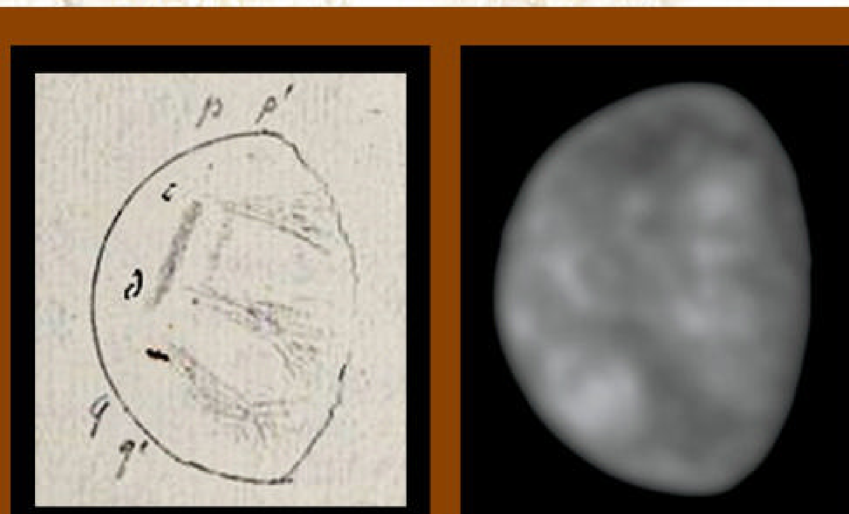


Schiaparelli's view (center) of Mercury on Feb. 6, 1882, with the central meridian (CM) at 85.6°, compared to a WinJUPOS simulation for the same date and CM (left), and a blurred version (right) that better simulates the telescopic view. The figure of 5, which made such an impression on the great Italian astronomer, is clearly evident in the simulation. MIDDLE: BREA OBSERVATORY, MILAN. LEFT AND RIGHT: JOHN BOUDREAU

Schiaparelli targets Mercury

In the early 1880s, when Schiaparelli began his study of Mercury, he was already famous for his work mapping Mars. So, using the 9-inch Merz refractor at Brera Astronomical Observatory in Milan, he decided to extend his survey of the planets inward. Venus, as usual, offered little more than a nearly featureless disk. But Mercury seemed promising.

At the time, the early results of 19th-century German astronomer J.H. Schröter, who utilized a large reflector, still reigned. Noticing a blunting of the southern cusp of Mercury on several nights, Schröter deduced a satisfyingly Earth-like rotation period of about 24 hours. But his observations had been made during the short twilight periods, when he was forced to view the planet through the densest layers of Earth's atmosphere. Schiaparelli's telescope, meanwhile, was equipped with setting circles (by which he could pinpoint objects using their right ascensions and declinations) and a clock drive, allowing him to follow Mercury for hours. He decided to try observing the planet in broad daylight. Because Mercury was higher in the sky then, it would reward sustained inspection.



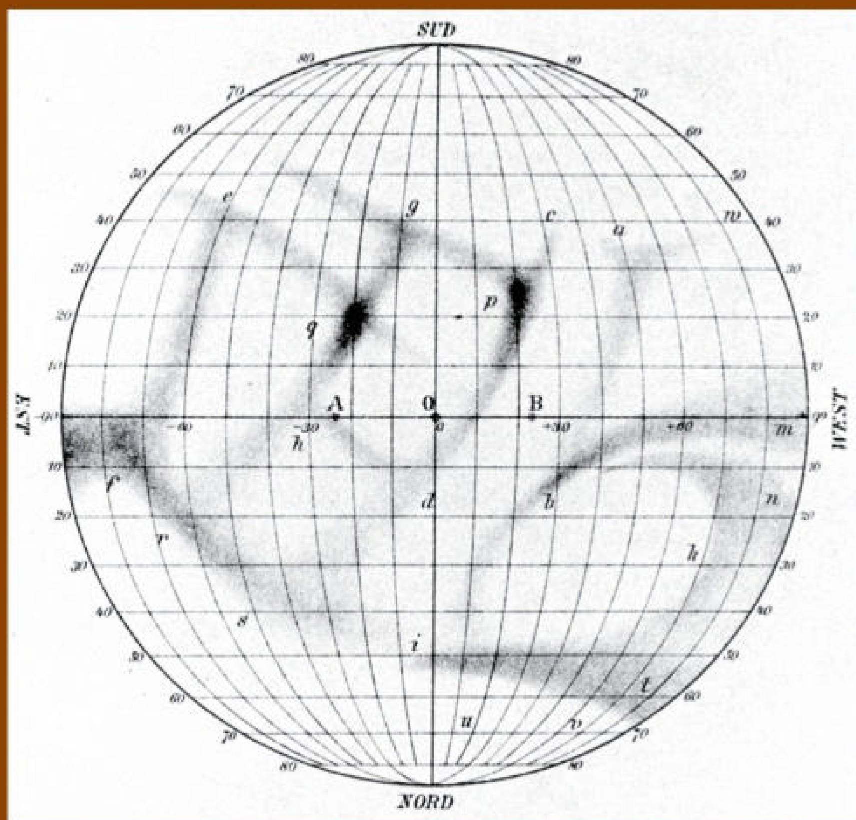
The mesmerizing figure 5 returns — or does it? Compare Schiaparelli's drawing (left) with a blurred WinJUPOS image showing the planet at the same time (May 22, 1882), with the CM at 264.8°. One really has to stare at this to make out anything resembling a 5 — and no wonder! Schiaparelli was actually looking at areas of the planet 170° in longitude apart. LEFT: BRERA OBSERVATORY, MILAN. RIGHT: JOHN BOUDREAU

Schiaparelli's initial tests of his technique in June 1881 were promising. That led to a sustained effort that began at the end of January 1882. Over the course of seven years, Schiaparelli made hundreds of observations of Mercury, as well as 150 drawings, which are preserved in the archives of Brera Observatory.

The air over Milan was turbulent during the summer, but in winter, it was often "pure and calm." That meant observations at any time of day were feasible. With his usual magnification of 200x, Schiaparelli scrutinized the tantalizing pale rose orb, which appeared through his telescope a little smaller than the Moon does with the naked eye. Markings on Mercury were almost always present, in the form of "extremely delicate streaks." But they were of such low contrast that they disappeared whenever haze or a layer of cirrus clouds intervened.

Go figure

Schiaparelli began to observe Mercury around the time of its greatest elongation east of the Sun on Feb. 6, 1882, corresponding to the planet's appearance as an evening star. On that date, he succeeded in making out a "large system of spots" on the nearly dichotomized disk. These spots, he noted, oddly combined to form the shape of the numeral 5. He denoted each part of the number with the letters *w*, *a*, *b*, *k*, and *i*. That figure 5 made a profound impression on Schiaparelli, and it was to haunt him whenever Mercury ran east of the Sun (as it did that May, when he again made out the 5). On the other hand, whenever the planet ran west of the Sun — becoming a morning star — Schiaparelli seemed to see the



Schiaparelli's famous planisphere, based on his belief that Mercury's day was the same as the planet's year, 88 days, was published in 1889.
GIOVANNI SCHIAPARELLI

same prominent dark patch, which he labeled *q*.

He made his bravest series of observations that August, when he followed the planet's tiny gibbous disk to within only 3.5° west of the Sun. This feat of observational daring, he later admitted, proved extremely damaging to his retinas. He found "the planet appears almost perfectly round, with the light only a little less than uniform; but despite the fact that the apparent diameter was reduced to 4" or 5" across, the positions of the observable markings could be judged with greater certainty than at other times." This time, he seemed to recover the dark patch *q*. In September, the next time Mercury ran east of the Sun, he once more discovered the 5. Schiaparelli's ideas were now starting to gel, and he ultimately believed the timely appearances of the observed markings confirmed Mercury's orbital period and rotational period were the same: 88 Earth days.

On Oct. 20, 1882, he wrote to his close friend and confidant François Terby, an amateur astronomer in Louvain, Belgium. Schiaparelli requested that, if he should die before he could publish, Terby should make Schiaparelli's work known "so that this beautiful result will not be lost to science." An avid classicist, Schiaparelli communicated his result to Terby in Latin verses, which read (translated):

> *Cyllenius [Mercury],*
> *turning on its axis*
> *after the manner of*
> *Cynthia [the Moon],*
> *Eternal night sustains,*
> *and also day:*
> *The one face is burned*
> *by perpetual heat,*
> *The other part, hidden,*
> *is deprived of the sun....*

More prosaically stated, one hemisphere of Mercury always faces the Sun, while the other always faces away — just like the Moon with respect to Earth. However, as in the case of the Moon, Mercury would appear to wobble (or librate) around the fixed line between it and the

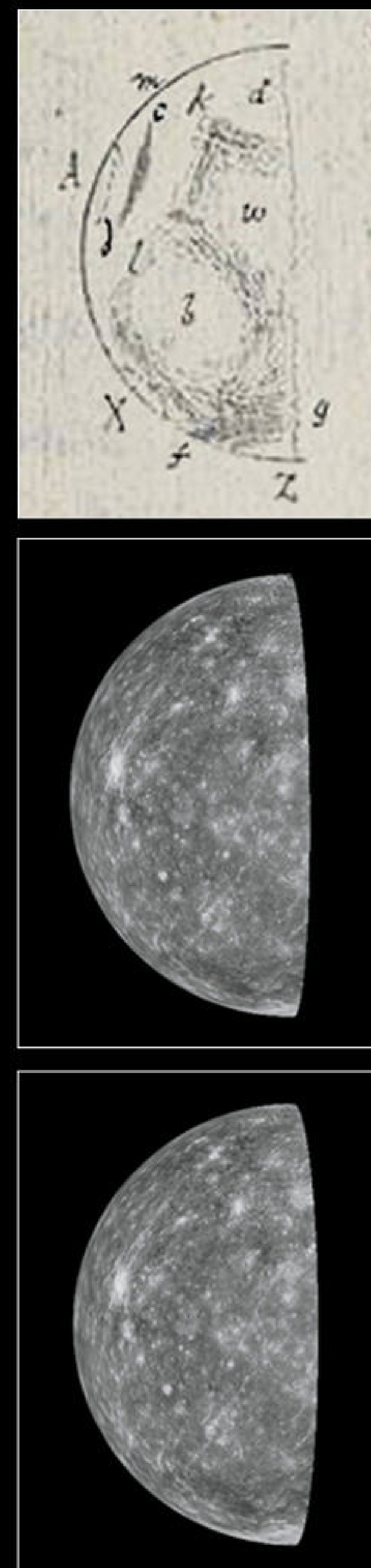
A SCHIAPARELLI CHALLENGE

In April 2022, Mercury comes to its most favorable evening apparition of the year (for Northern Hemisphere observers), advantageously placed for naked-eye and telescopic observers alike. After superior conjunction on April 2, Mercury increases its separation from the Sun, and by mid-April, it is easily visible to the naked eye. The world reaches its greatest elongation east of the Sun on April 29, when it passes only 1.5° south of the Pleiades (M45). On May 2, a thin crescent Moon joins the group. Thereafter, Mercury rapidly drops toward the Sun as it heads toward inferior conjunction on May 21.

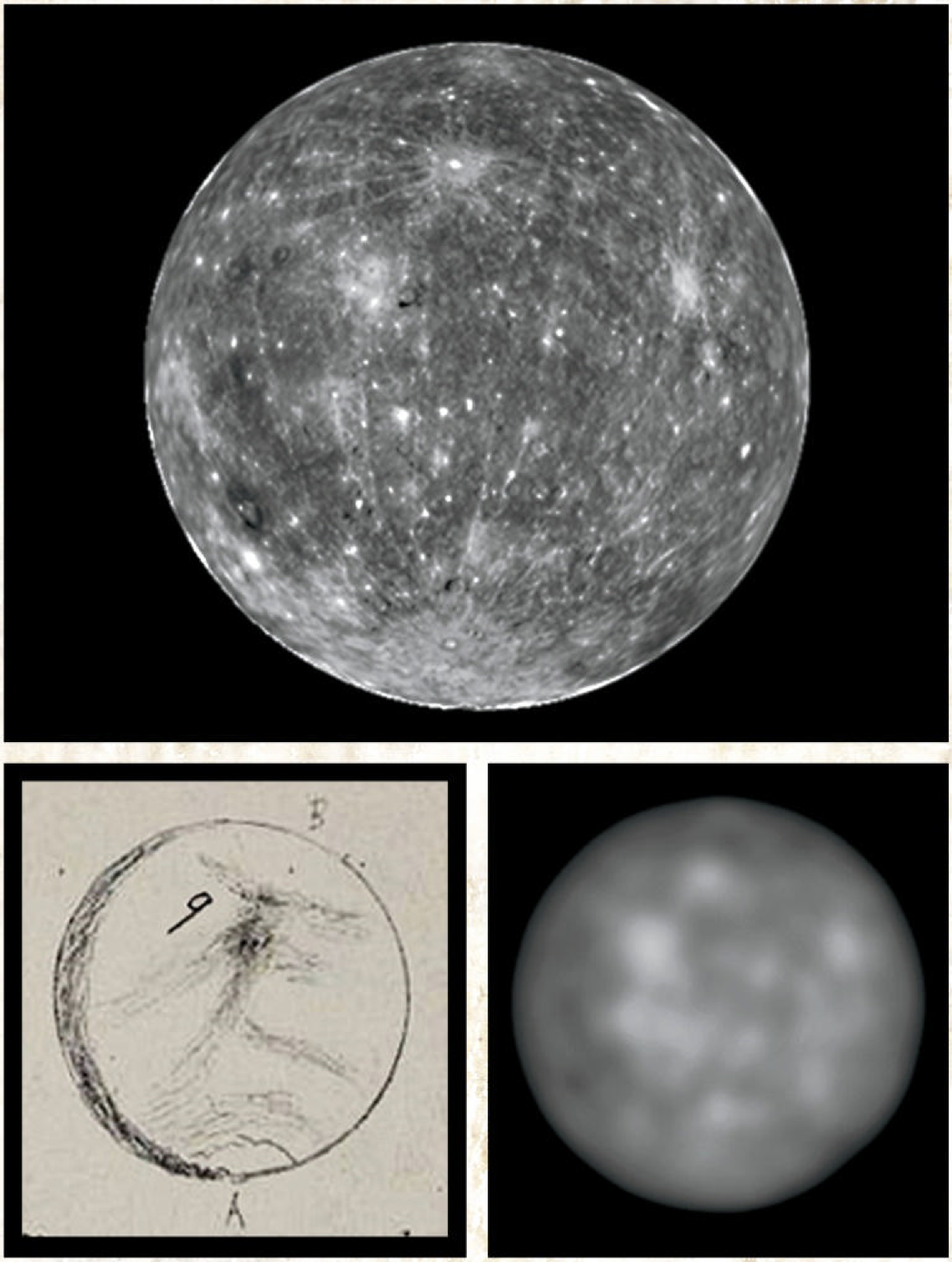
About a week before it reaches greatest elongation, Mercury will present to telescopic observers nearly the same part of the planet that was in view when Schiaparelli began his legendary study of the world in 1882. A potentially perfect night for trying to emulate the great Italian astronomer's view is April 23. At that time, the planet's disk will be 6.8" wide, 56 percent illuminated, and the longitude of the central meridian (CM) will stand at 85° (as compared to 7.0" wide, 53 percent illuminated, and a CM at 86° on Feb. 6, 1882). Observers equipped with telescopes in the 6- to 10-inch range will want to travel back in time and take turns at the eyepiece with Schiaparelli himself in scrutinizing this once-mysterious planet.

In addition to searching for the subtle figure 5, you should also look for the bright spot Kuiper, which pre-spacecraft era observers like Schiaparelli recorded as a brilliant patch and identified as a cloud. During its flyby of Mercury in March 1974, Mariner 10 discovered Kuiper is in reality a fresh, 38.5-mile-wide (62 kilometers) impact crater surrounded by a system of bright ejecta rays.

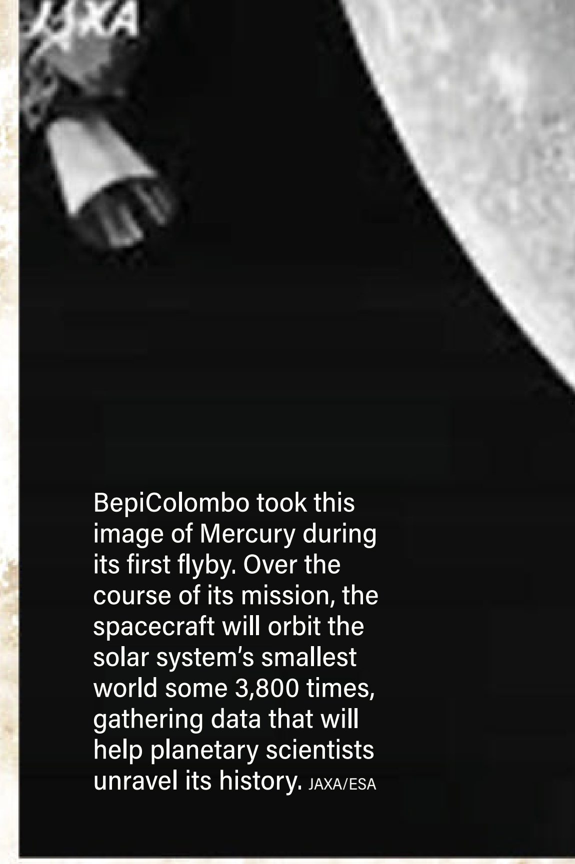
Happy sleuthing! —*Frank Melillo, W.S.*



Schiaparelli's drawing of Feb. 6, 1882 (top), compared with WinJUPOS simulations for that date (center) and April 23, 2022 (bottom). The crater Kuiper is the bright patch left of center. TOP: BRERA OBSERVATORY, MILAN. CENTER AND BOTTOM: JOHN BOUDREAU



Schiaparelli made heroic efforts to follow Mercury to only 3½° west of the Sun, as the planet approached superior conjunction in August 1882 (an endeavor he later admitted was damaging to his eyesight). His sketch (lower left) with CM = 351.9°, was made Aug. 12, and shows a dark patch he called *q* and thought he had recorded at previous elongations west of the Sun. The blurred WinJUPOS image (bottom right) shows the same face of the planet, in which a triad of bright spots can be made out that show up more clearly in the top "Full Moon" of Mercury as the rayed craters Ellington, Debussy, and Kuiper. BOTTOM LEFT: BRERA OBSERVATORY, MILAN. TOP AND LOWER RIGHT: JOHN BOUDREAU



BepiColombo took this image of Mercury during its first flyby. Over the course of its mission, the spacecraft will orbit the solar system's smallest world some 3,800 times, gathering data that will help planetary scientists unravel its history. JAXA/ESA

Sun. This effect was bound to be rather considerable, given the eccentricity of Mercury's orbit, and it provided Schiaparelli with some cover from the fact that he found the positions of his spots were quite variable over time. Yet even libration could not account for all the observed variation. In the end, Schiaparelli was forced to invoke the existence of a substantial atmosphere around the tiny planet, and even sometimes brilliant white clouds.

Despite making up his mind about Mercury's 88-day rotation and revolution period, Schiaparelli still held back from publication until he could confirm his results with a larger telescope. He eventually went on to use a 19-inch Merz-Repshold refractor, which was installed at Brera in 1886. But the observations with this larger scope did not prove decisively better than those made with the smaller Merz. At last, in late 1889, Schiaparelli put forth a memoir, in which he summarized his observations and published his famous planisphere. In December, he made a rare trip outside Milan to lecture at the Quirinal Palace in Rome to a popular audience that included the king and queen of Italy. During the lecture, Schiaparelli provocatively suggested the possibility that liquid water — and life itself — might flourish in the "twilight zone" between the perpetually sunlit and the perpetually night-shaded sides of Mercury.

Schiaparelli lived until 1910, remaining sure of his results to the end. A host of later observers lined up to confirm his results, too. Preeminent above the rest was Greek-French astronomer E.M. Antoniadi, whose long study of Mercury in the 1920s with the 33-inch refractor at Meudon Observatory near Paris seemed to definitively confirm Schiaparelli's map, his rotation period, and his clouds. Researchers came to regard Mercury's 88-day rotation period as one of the best-established facts in all of

During the lecture, Schiaparelli provocatively suggested the possibility that liquid water — and life itself — might flourish in the "twilight zone" between the perpetually sunlit and the perpetually night-shaded sides of Mercury.

planetary science. And yet it was all an illusion.

Dial it back

To astronomers' great surprise — and even consternation — in 1965, radio astronomers established that Mercury's rotation period was really 58.65 days, or two-thirds its orbital period. At once, it was asked how Schiaparelli and his followers could have gotten it so wrong.

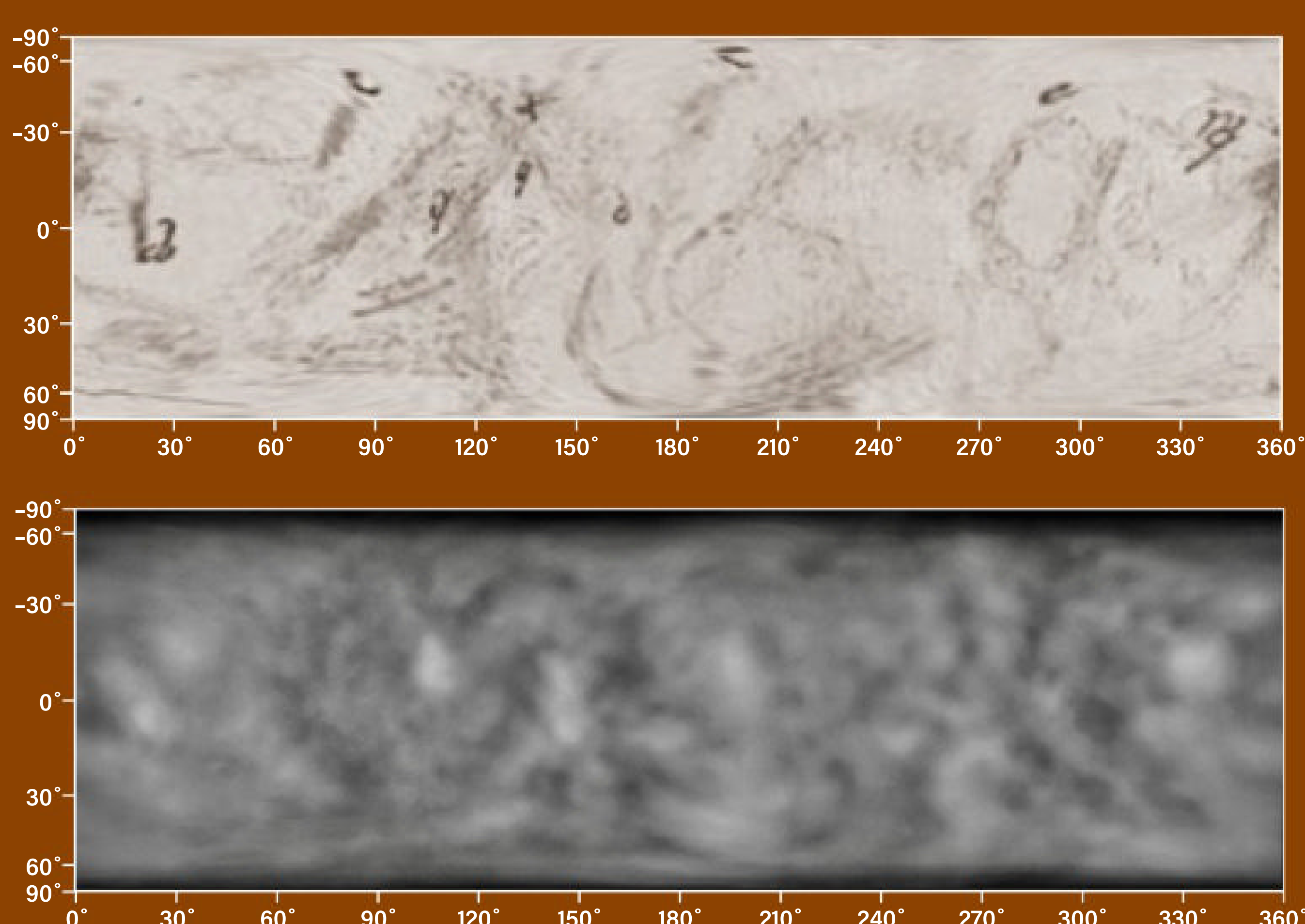
One factor, identified at the time by astronomers Dale P. Cruikshank and Clark R. Chapman, involved a curious "stroboscopic effect." This is where, for several years in succession, the same side of Mercury tends to present itself during the planet's most favorable elongations (in the spring for evening observations and in the autumn for morning observations). This effect causes Mercury's surface features to appear rather static, making it difficult for observers to recognize how the markings change due to rotation. However, because Schiaparelli observed during periods other than spring and autumn, this explanation doesn't completely suffice.

Instead, it seems that because Mercury's markings are so delicate and vague in outline, subjective — that is, perception-based — factors came into play. Once an observer establishes a definite expectation, they become predisposed to seeing the expected result.

This reinforces and refines their expectations until, finally, they see an exact and detailed — but ultimately fictitious — picture. It seems Schiaparelli succumbed to such autosuggestion, falling under the spell of his own preconceptions and unable to help but fixate on Mercury's supposed number 5.

The mental trap that snared Schiaparelli was set with his first drawing of the numeral 5 on Feb. 6, 1882. And here's the pleasant surprise mentioned at the beginning of the article: During this April's favorable evening apparition on the 23rd, Mercury will display almost exactly the same face under conditions nearly identical to those Schiaparelli experienced Feb. 6, 1882.

Be sure to take a look. What do you see?



These cylindrical projections show the albedo markings of Mercury: the top based on Schiaparelli's sketches but reinterpreted using the correct rotation period of 58.65 days, and the bottom based on CCD imagery by John Boudreau using a C-11 between 2007 and 2009. JOHN BOUDREAU

William Sheehan *is author of Mercury (London: Reaktion Books, 2018).* **Frank Melillo** *and* **John Boudreau** *monitor Mercury for the Association of Lunar and Planetary Observers. The WinJUPOs program used to create simulated views of Mercury was written by* **Grischa Hahn**.

Comb through Berenice's Hair

Packed with a veritable smörgåsbord of galaxies, Coma Berenices is on full display this month.

BY MICHAEL E. BAKICH

The constellation Coma Berenices (pronounced KOE-muh-bear-uh-NYE-seez), Berenice's Hair, was envisioned in its current form by Flemish cartographer Gerardus Mercator. To honor Queen Berenice II of Egypt, he placed these stellar locks on a celestial globe he designed in 1551. Unfortunately, Coma Berenices, which contains no bright stars, is not an easy star pattern to find. It's visible only from midwinter through midsummer in the Northern Hemisphere. Its center lies at right ascension 12h45m and declination 23°30'.

Coma Berenices ranks 42nd in size out of the 88 constellations, covering 386.47 square degrees (0.937 percent) of the sky. And while its size is middling, it fares worse (57th) in terms of overall brightness.

24 COMAE BERENICES For a break from galaxies, seek out the double star 24 Comae Berenices. Its components glow at magnitudes 5.2 and 6.7 and are separated by 20". Because people's eyes differ in color acuity, some observers see yellow and blue, others see both as white, and still others see the pair as orange and green. ALAN DYER

NGC 4450 To locate spiral NGC 4450, look just south of the midway point of the line that connects the stars 11 and 25 Comae Berenices. The galaxy is relatively bright (magnitude 10.1) and oval (5.0' by 3.4'). A thick halo surrounds a stretched-out core. ADAM BLOCK (NOAO/AURA/NSF)

M64 The Blackeye Galaxy (M64) got its name after William Herschel discovered its dark dust feature, which he compared to a black eye. That light-obscuring dust lane is prominent, but only when viewed through a 10-inch scope. M64 glows at magnitude 8.5 and measures 9.2' by 4.6'. ALAN DYER

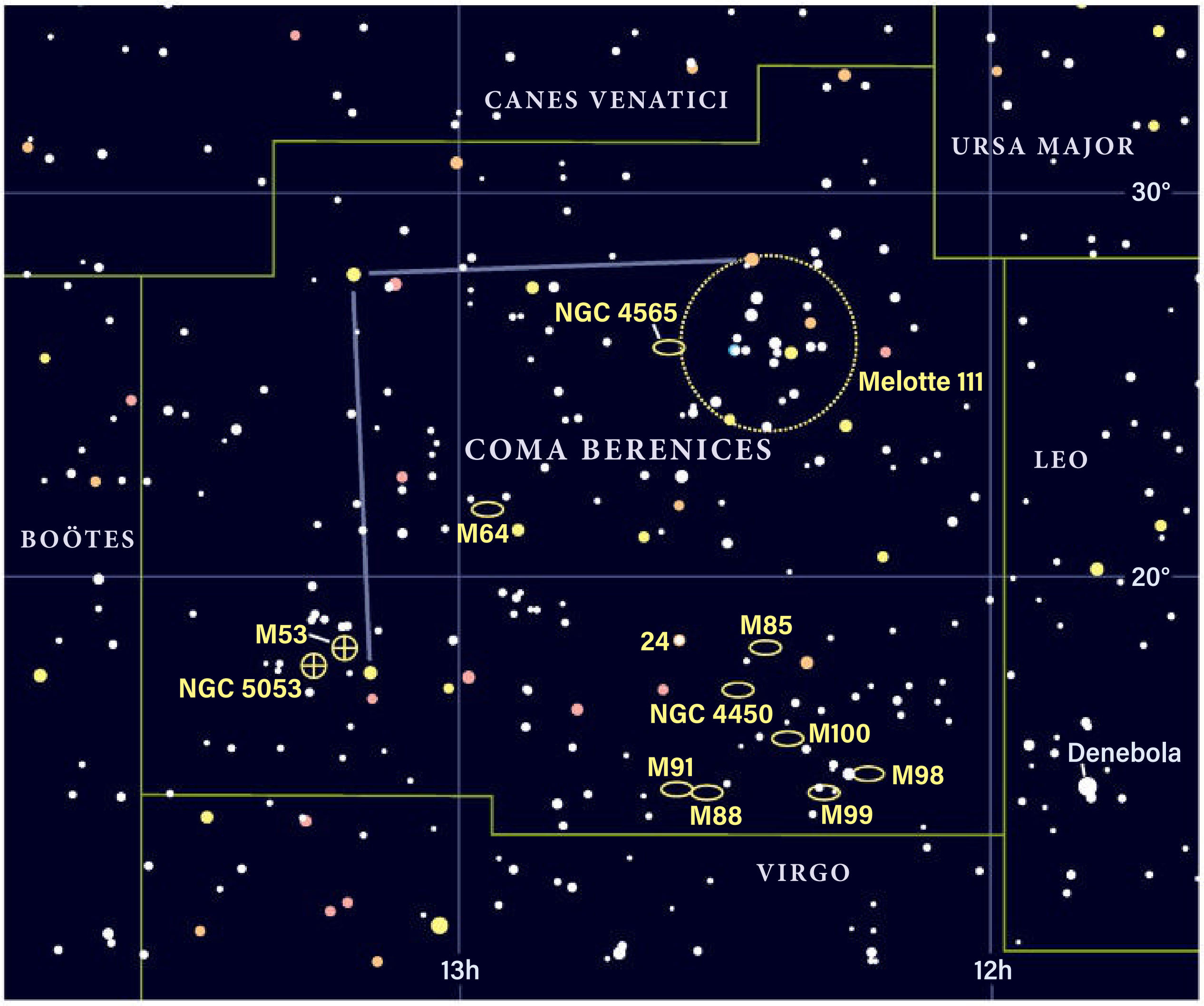
M98 & M99 The magnitude 10.1 spiral galaxy M98 (upper right) measures 9.1' by 2.1'. It lies 7.2° east of Denebola (Beta [β] Leonis). Through an 8-inch scope, its center looks broad and slightly brighter than its arms. And a larger telescope will reveal star-forming regions in those arms. The Pinwheel Nebula (M99) is actually a spiral galaxy sometimes called St. Catherine's Wheel, a rather gruesome comparison considering the purpose of its namesake device. It glows at magnitude 9.9 and spans 5' by 4.6'. Through a 10-inch scope, M99 appears to have only one arm. Go bigger to see the other two. ALAN DYER

M88 & M91 Spiral galaxy M88 (right) resides in a region housing hundreds of other galactic tenants. Fortunately, at magnitude 9.6, it outshines them all. Through a 6-inch telescope, M88 is an oval haze more than twice as long as it is wide (6.1' by 2.8'). A 12-inch scope at 300x will reveal some of the spiral's structure. The easiest way to find the magnitude 10.2 barred spiral M91 (left) is to start at M88 and move 0.8° east. A 6-inch telescope shows a rectangular-shaped object a bit longer than it is wide (5.0' by 4.1'). With a high-power eyepiece in a 12-inch scope, you'll easily see its central bar. ALAN DYER

The best date to see Coma Berenices is April 2, when it stands opposite the Sun in the sky and reaches its highest point at local midnight. The constellation is completely visible from latitudes north of 56° south, and it remains entirely invisible only between latitude 77° south and the South Celestial Pole.

Although this star pattern isn't particularly expansive or bright, it contains no less than eight Messier objects, the third most of any constellation. You'll also find lots of other worthy targets tangled up in Berenice's Hair. Let your telescope adjust to the outside temperature, get comfortable, and spend an enjoyable night combing through the great deep-sky objects in Coma Berenices. Good luck!

Michael E. Bakich *is a contributing editor of* Astronomy *who enjoys slowly moving his telescope through a single constellation.*



ASTRONOMY: RICHARD TALCOTT AND ROEN KELLY

M100 Spiral galaxy M100 ranks as one of the brightest galaxies (magnitude 9.4) in the Coma-Virgo cluster, so it's a great target for amateur scopes. It lies not quite 2° northeast of the star 6 Comae Berenices. Through an 8-inch scope, the arms appear as bright regions to the east and west of the nucleus. BILL SNYDER

NGC 4565 No. 1 on any list of edge-on spirals is the Needle Galaxy (NGC 4565). It glows at magnitude 9.6 and measures 14.0' by 1.8'. An 8-inch telescope reveals a streak roughly 10' long that's oriented northwest to southeast. To see NGC 4565's full extent, move up to a 16-inch scope. ALAN DYER

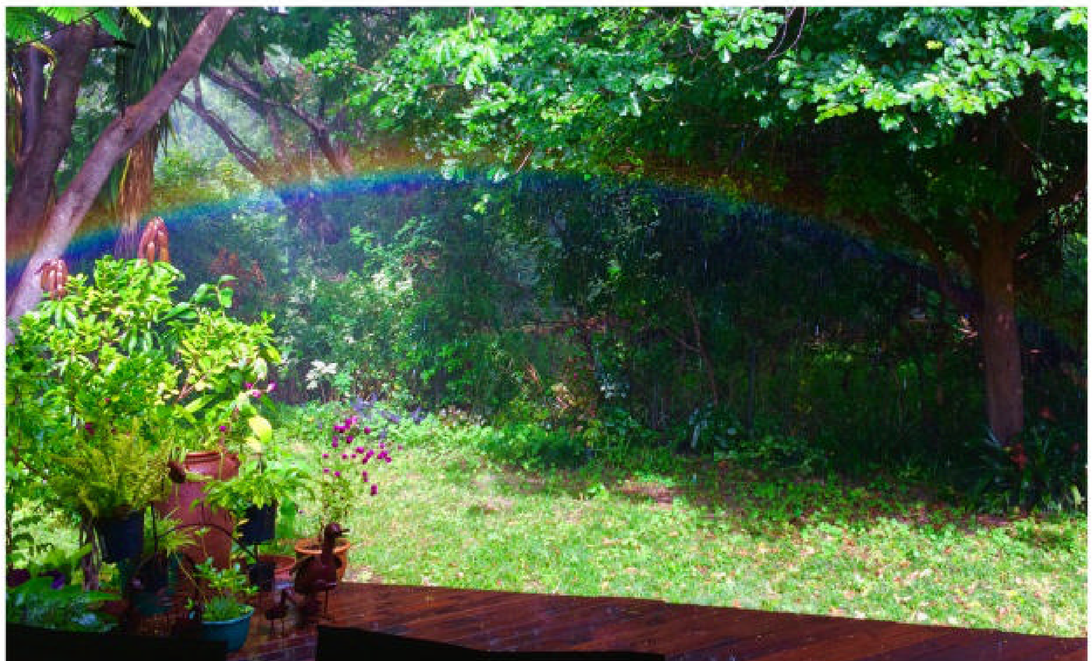
M85 At magnitude 9.1, lenticular galaxy M85 is one of the sky's brightest galaxies. It lies 1.2° east-northeast of 11 Com. A 12-inch scope will reveal the brightness difference as you move out from the core, as well as the galaxy's overall subtle yellow color. The smaller barred spiral galaxy to its left is NGC 4394. LEE BUCK

M53 & NGC 5053 Globular cluster M53 (upper right) lies not quite 1° northeast of Diadem (Alpha [α] Com). It glows at magnitude 7.7, so a 4-inch scope will reveal several dozen of its stars. M53 has a diameter of 12.6'. And because few stars are near the cluster, you'll have no trouble defining its edge. Globular cluster NGC 5053, which looks like an open cluster, lies in the same field as M53. It's a bit smaller (10.5') and, at magnitude 9.9, more than two magnitudes fainter. You'll need an 8-inch telescope to resolve its stars, which form a rough triangle. ALAN DYER

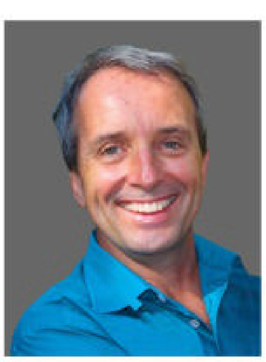
MELOTTE 111 The Coma Berenices star cluster (Melotte 111) contains some 40 stars between magnitudes 5 and 10. Their light combines for a total magnitude of 1.8. Because this object spans more than 4°, start with 50mm or larger binoculars. After that, move to your telescope and select your lowest-power eyepiece. ALAN DYER

The impropriety of rainbows

Rainbows exist at an uneasy nexus of light, shadow, and water.



An "improper" rainbow appeared in the author's garden in Maun, Botswana, during a "monkey's wedding" in March 2021. STEPHEN JAMES O'MEARA



BY STEPHEN JAMES O'MEARA

Stephen is a globe-trotting observer who is always looking for the next great celestial event.

I never thought the day would come when an "improper" natural phenomenon would display itself out in the open air.

I'll explain: I'm talking about rainbows. "Improper" may seem an ill-fitting term, but rainbows have a darker side. After all, rainbows exist when rain and the Sun are juxtaposed in the sky. This makes them a rich topic, scientifically and ethnologically.

For instance, we're used to the sight of a rainbow arc soaring above the horizon. But rainbows can be seen underneath the horizon as well, projected against the ground.

That's because rainbows are centered on the spot in the sky directly opposite the Sun, called the antisolar point, with a radius of 42°. When the Sun is at an altitude of 42°, the tip of the rainbow's arc just touches the horizon. When the Sun is higher, the full arc is seen against the ground.

One can usually see a rainbow underneath the horizon line whenever the Sun shines on, say, the spray of a waterfall, or from a fountain — not to mention from an ordinary garden hose. But in each of these cases, something other than rain generates the phenomenon.

On the afternoon of March 25, 2021, I witnessed for the first time a rainbow that arced below the horizon during a rain. The rainbow formed when the tail-end of a thunderstorm had passed but its strong winds lingered, which shot rain into our garden just as the Sun broke free from an obscuring cloud. The bow was only yards away, arcing beneath the trees.

The rainbow is a universal sign of malevolent spiritual presence.

At first, I thought I was being fooled, reasoning that our plot's gardener must have left a lawn sprinkler on during the storm. But that wasn't the case. Quickly, I realized that I was "a monkey's uncle" — in a state of surprise and disbelief. And therein lies a story.

Umshado wezinkawu

In southern Africa, whenever it rains while the Sun is shining, people say it's a "monkey's wedding." The influential Austronesian linguist Robert Blust, who died Jan. 5, said the expression almost certainly derived from the Zulu expression *umshado wezinkawu*: "a wedding for monkeys." I appreciate the Zulu translation, as it rings familiar. For instance, in English we might say something is "for the birds," or it "has gone to the dogs."

Having lived in southern Africa now for several years, my take on the expression is that a sun-shower represents a union of the Sun and rain that's best fit for monkeys — an animal known in mythology for creating chaos.

The expression fascinates because, while no one knows clearly what it means, it is used in folklore across the globe to describe a sun-shower, albeit with minor twists. For instance, in Japan, and parts of Europe and Asia, a sun-shower is known as the "fox's wedding"; in Lebanon and Syria, it's the "rat's wedding"; in parts of Northern Africa, it's the "hyena's wedding"; and in Afrikaans, it's the "jackal's wedding." One common theme is the clever nature of the selected animal.

In in a 1994 issue of *Anthropos*, Blust wrote, "The essential constellation of features [of the expression] appears to involve animal parturition or conjugal union in connection with sunshowers, or, less often, rainbows."

And what of the rainbow? Despite scattered positive associations, such as in the Judeo-Christian tradition, in the world's preliterate cultures, the rainbow is a universal sign of malevolent spiritual presence, said Blust.

As he explained, "[W]ithin prescientific cultures the natural causality of rainbows is completely obscure, and such a visually stunning and awe-inspiring phenomenon can only be attributed to supernatural agency." In later work, Blust argued that rainbows inspired the varied myths of dragons around the world: In many cultures, rainbows are portrayed as possessive serpents guarding precious fresh water, drinking the rain and causing it to cease.

Some cultures emphasize other supernatural elements in describing a sun-shower: "witches weep"; "the devil fights and gets married"; "fairies comb their hair." Whatever your preference, send your sightings of *rain*-induced earthly bows to sjomeara31@gmail.com.

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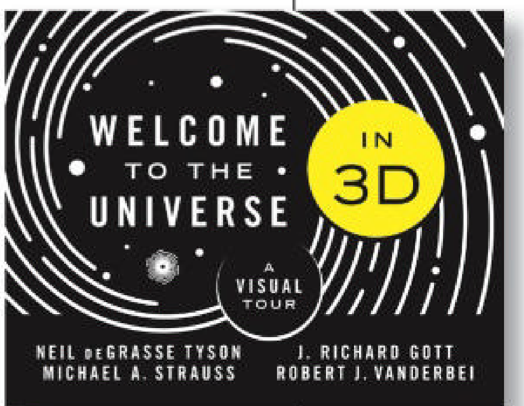

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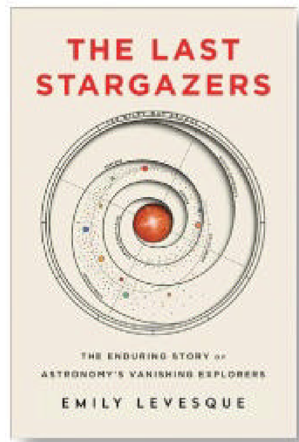

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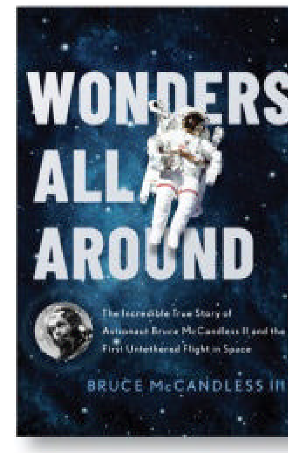

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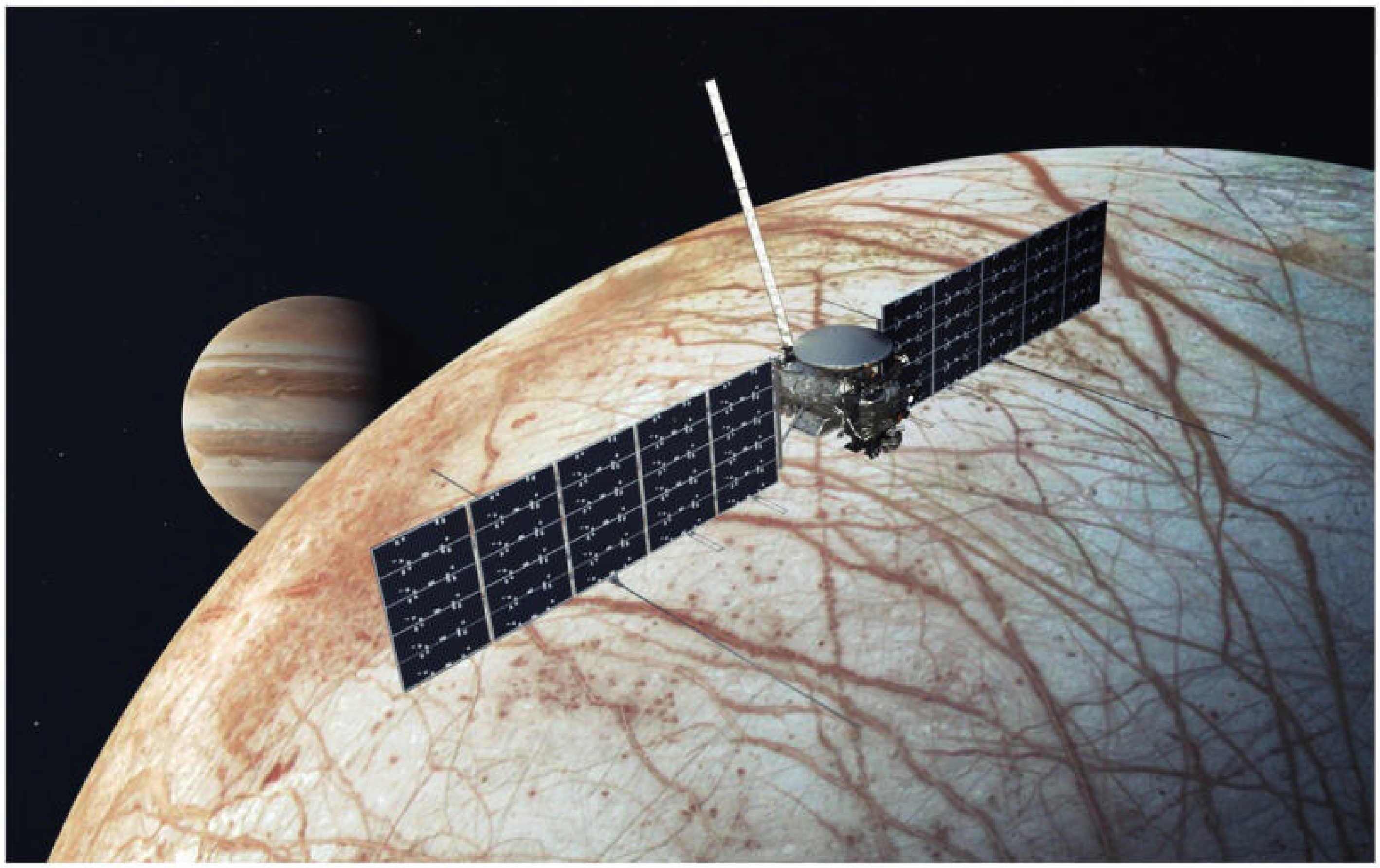


NASA's Europa Clipper performs a flyby of the jovian moon in this artist's concept. NASA/JPL-CALTECH

Safe zone

Q | WHY WILL EUROPA CLIPPER ORBIT JUPITER INSTEAD OF EUROPA?

Gary Duemling
Prescott, Arizona

A | NASA's Europa Clipper spacecraft is scheduled for launch in 2024, carrying 10 instruments that will assess the habitability of Jupiter's moon Europa. The craft will follow up on discoveries by the Galileo mission of the 1990s, which orbited Jupiter and made multiple flybys of both the planet and its major satellites. As you point out, Europa Clipper will orbit Jupiter. However, it will solely focus on Europa, performing some 50 close passes of the ocean-sporting moon during its primary mission.

So why will it orbit Jupiter and not Europa itself? One word: radiation. Jupiter's powerful magnetic field traps and accelerates charged high-energy particles, producing a doughnut-shaped radiation belt that rotates with the planet. Europa orbits Jupiter within this high-radiation zone, and so is continuously exposed to this harsh environment. The radiation belt is damaging to spacecraft and instrument electronics, leading to rapid degradation if unaccounted for.

A 2011 NASA study assessed both a Europa-orbiting spacecraft and a Jupiter-orbiting "Multiple-Flyby Mission" option. Around Europa, an orbiting spacecraft would be limited to a lifetime of a mere one month due to this continuous radiation exposure. In contrast, the highly elliptical orbit of the multiple-flyby Europa Clipper mission means it will spend most of its time outside of the high-radiation zone, only being briefly exposed to it during its quick passes by the moon. As an added bonus, its long elliptical orbit also permits the craft to transmit collected flyby data back to Earth, as well as perform additional functions between Europa encounters (typically two to three weeks apart).

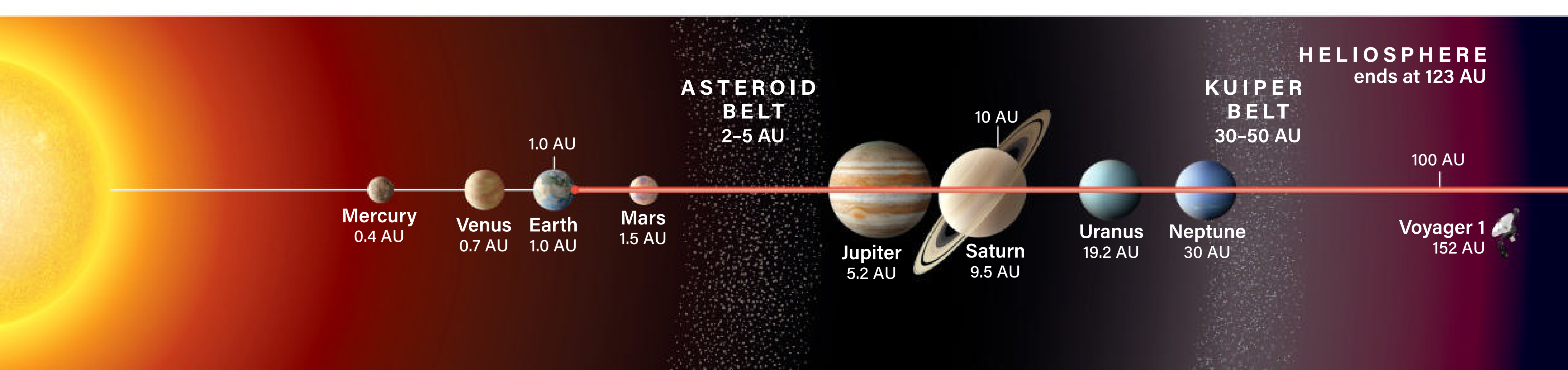
Europa Clipper's multiple-flyby architecture will yield significantly more data than a Europa-orbiting mission, and cleverly designed trajectories will permit near-global high-resolution mapping. As of now, the Europa Clipper spacecraft is taking shape in "shipyard" facilities across the country and overseas. We hope you continue to follow the Europa Clipper mission as we proceed toward unprecedented science!

Cynthia Phillips
Project Staff Scientist, Europa Clipper Mission,
NASA Jet Propulsion Laboratory, Pasadena, California

Q | DOES OUR OORT CLOUD OVERLAP WITH ALPHA CENTAURI'S?

Carles Martinez
Barcelona, Spain

A | About 2,000 to 5,000 astronomical units (AU; where 1 AU is the average distance between Earth and the Sun) from the Sun lies the beginning of the Oort Cloud. For context, the Voyager spacecrafts



The Oort Cloud, a collection of icy bodies left over from the birth of the solar system, lies somewhere between 2,000 to 100,000 astronomical units (AU) from our star. *ASTRONOMY*: ROEN KELLY

— the human-made objects that have traveled farthest from our Sun — will cross this inner edge of our solar system in about 300 years. From there, the Oort Cloud stretches to about 10,000 to 100,000 AU (0.16 to 1.6 light-years), according to NASA. But keep in mind this outer boundary is pretty nebulous, so there is no hard line where the Oort Cloud ends.

All this is to say that it isn't clear how close the Oort Cloud actually gets to the Alpha Centauri system, which is about 4.3 light-years away. Even if the Oort Cloud does stretch halfway to the other system, scientists aren't sure whether it has its own Oort Cloud.

Despite searching, astronomers have seen no direct evidence of extrasolar Oort Clouds (and they've been looking since 1991). Because these clouds would be so far from their stars and aren't very dense, spotting them would be exceedingly difficult.

Our Oort Cloud *is* influenced by other systems. The Oort Cloud is outside of the Sun's heliosphere — the protective magnetic bubble that separates our solar system from interstellar space. The solar system also sits closer to the edge of the Milky Way than the center. This means that one side of the solar system feels a stronger gravitational pull than the other. This gradually jostles the Oort Cloud, sometimes sending long-period comets into the inner solar system. Passing stars and molecular clouds can have similar effects. Likewise, as our nearest celestial neighbor, the Alpha Centauri system likely has some effect, albeit a small one, even at its distance. But Alpha Centauri is actually approaching the Sun. In about 30,000 years, the trio of stars will come within about 2.9 light-years of our star, at which point its influence will be much stronger.

Caitlyn Buongiorno
Associate Editor

Q | HOW FAR AWAY IS THE COSMIC MICROWAVE BACKGROUND?

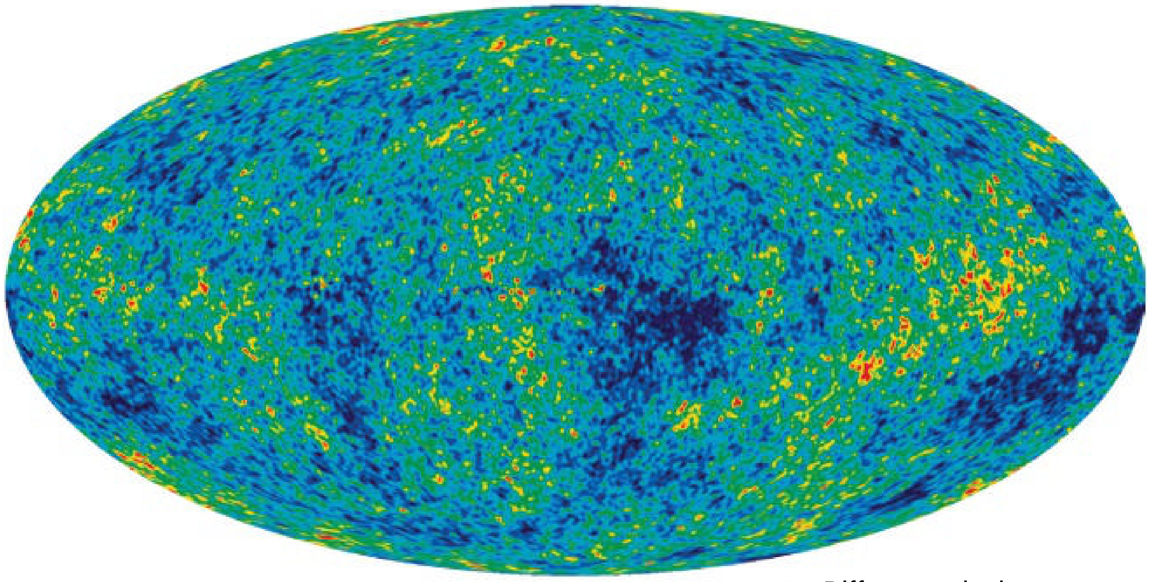
Nick Smith
New Port Richey, Florida

A | The cosmic microwave background (CMB) is the radiation allowed to freely propagate after the universe cooled enough for electrons to combine with atomic nuclei to form neutral atoms some 300,000 years after the Big Bang, or roughly 14 billion years ago. This CMB radiation was mostly in the form of near-infrared light, but the wavelength of the CMB light has been stretched by the expansion of space so much it now falls in the microwave range we see today. This expansion of the universe describes the phenomenon whereby the distance between any two points in space gradually increases over cosmic time. So, the CMB source is 40 billion light-years away and not 14 billion light-years away, as one might expect.

Observations of the CMB convert the light signal into a map of the relative temperature of the radiation. From Earth, we observe slightly hotter and colder spots in the CMB across the sky. We relate these to small (a few parts in a million) differences in the density of matter at that location at the time the CMB formed. Although higher density regions are considered the seeds for large-scale structures like galaxy clusters, individual locations of hot/cold spots in the observed CMB do not tell us anything particularly insightful. Everything we can learn about the CMB is encoded in the distribution of the numbers and sizes of these hot/cold spots.

The cosmological principle postulates that the universe, as a whole, is isotropic and homogeneous. Isotropy means that the universe appears statistically identical in every direction. While the CMB appears different at varying sightlines, the universe evolves in a uniform manner such that the CMB is the same distance in all directions. Homogeneity means that the universe appears statistically identical no matter where you are. The CMB will certainly appear slightly different from any distant galaxy, but the statistical distribution of hot/cold spots (and the cosmological information contained within) should be exactly the same.

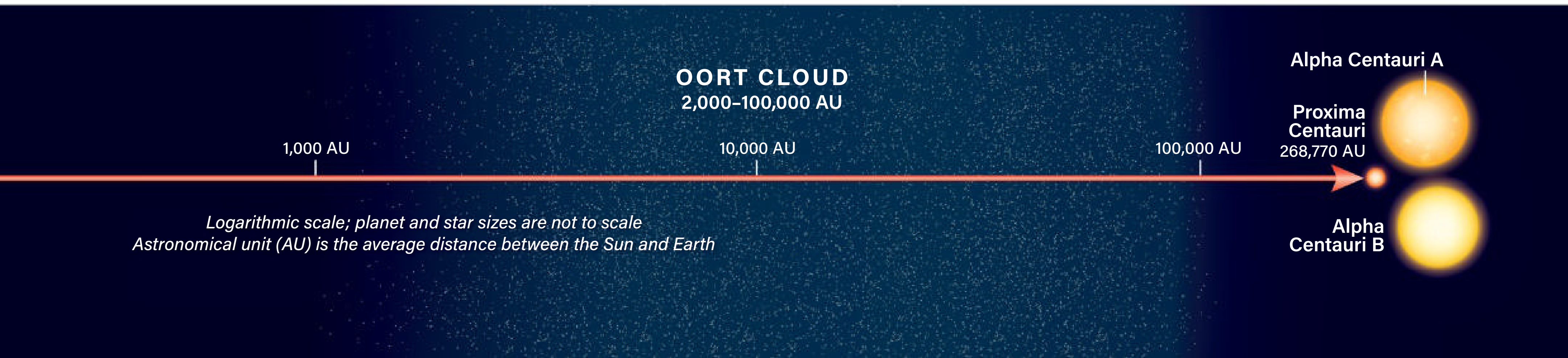
Victor Chan
David A. Dunlap Department of Astronomy & Astrophysics, University of Toronto, Toronto, Canada



Differences in the density of the early universe can be seen in the variations within the cosmic microwave background. These differences are the seeds that eventually grew into clusters of galaxies. NASA/WMAP SCIENCE TEAM

SEND US YOUR QUESTIONS

Send your astronomy questions via email to askastro@astronomy.com, or write to Ask Astro, P.O. Box 1612, Waukesha, WI 53187. Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.



Cosmic portraits


1

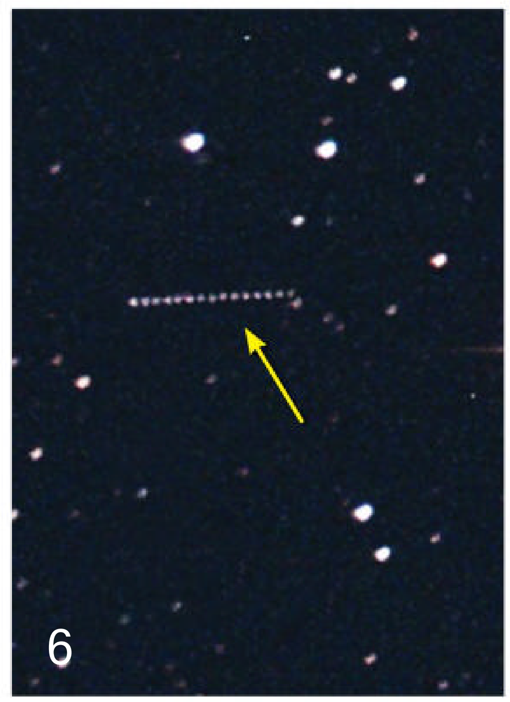

2


3

1. SHELL OF A GALAXY
Arp 227 (upper left) is an interacting pair of galaxies in Pisces roughly 100 million light-years distant. The larger of the two, NGC 474, is an elliptical with multiple shells and tidal tails formed by the influence of neighboring NGC 470. At lower right is elliptical NGC 467, which also shows evidence of interaction. This image was taken with a 4.3-inch scope and 15.3 hours of exposure in LRGB. **▪ *Sergey Trudolyubov***

2. LEONARD ARRIVES
Comet C/2021 A1 (Leonard) closed out 2021 with a spectacular display, brightening into the best comet of the year. On Dec. 3, it passed the 6th-magnitude globular cluster M3 in Canes Venatici. This shot was taken with a 3.2-inch refractor and 81 minutes of exposure. **▪ *Chris Schur***

3. AS CLOSE AS IT GETS
Comet Leonard reached perihelion — its closest approach to the Sun — Jan. 3. This image is a mosaic of two LRGB panels taken that evening with an 8-inch scope and 4.5 minutes of exposure with each filter. **▪ *Gerald Rhemann***



4. ABOVE THE SNOW LINE
The planetary trio of Jupiter, Saturn, and Venus (left to right) shines above Snowdon, the highest mountain in Wales at 3,560 feet (1,087 meters). This shot was taken Dec. 16 from neighboring peak Garnedd Ugain. • ***Kat Lawman***

5. JWST'S JOURNEY
NASA's James Webb Space Telescope rocketed to space Dec. 25 aboard an Ariane 5 launcher. This imager captured the second stage passing the Sculptor Galaxy (NGC 253) from Sukna in West Bengal, India. The image is a series of 40 two-second exposures with a Nikon D5600 and a 135mm f/2 prime lens at ISO 500. • ***Samit Saha/Soumyadeep Mukherjee***

6. ON ITS WAY
Two weeks after launch, JWST was around 650,000 miles (1 million kilometers) from Earth and traveling to the L2 Lagrange point. This image captures the telescope from Yellow Springs, Ohio, the night of Dec. 7, roughly 15 hours before JWST finished deploying its primary mirror. The series comprises one-minute exposures taken every two minutes with a 12-inch scope. • ***John Chumack***

7. LYND'S VESPERS
LBN 587 is an emission region in Cepheus recorded by Beverly Lynds in her 1965 catalog of bright nebulae (a companion to her earlier dark nebulae catalog). This imager used 18 hours and 45 minutes of exposure time with a 4.2-inch scope, rendering the nebulae in the Hubble palette and the star field in LRGB. • ***Emil Andronic***

SEND YOUR IMAGES TO:
Astronomy Reader Gallery, P.O. Box 1612, Waukesha, WI 53187. Please include the date and location of the image and complete photo data: telescope, camera, filters, and exposures. Submit images by email to **readergallery@ astronomy.com.**

SWIMMING WITH THE FISH

Most observers view elliptical galaxies as boring, relatively featureless objects. And at first glance, NGC 474 in Pisces the Fish seems to fit the stereotype. But deep images reveal intricate structures that should put the kibosh on the dull reputation of ellipticals. The outskirts of NGC 474 resolve into multiple shell-like structures and tidal tails containing hundreds of millions of stars. Astronomers suspect these features arise from recent mergers with infalling dwarf galaxies as well as interactions with NGC 470, the spiral companion located to the big galaxy's upper left. NGC 474 spans about 250,000 light-years and lies roughly 100 million light-years from Earth. Scientists took this portrait with the 4-meter Victor M. Blanco Telescope on Cerro Tololo in Chile. DES/DOE/FERMILAB/NCSA & CTIO/NOIRLAB/NSF/AURA

June 2022

The evening sky awakens

Evenings haven't offered much to planet observers in 2022. But the first signs of change arrive in June. **Saturn** pokes above the eastern horizon around 11 P.M. local time as the month opens and rises 30 minutes earlier with each passing week. The planet lies in eastern Capricornus, some 2° north and a little east of the Sea Goat's brightest star, magnitude 2.8 Delta (δ) Capricorni. Saturn shines at magnitude 0.5 and appears eight times brighter than Delta.

It's always worth observing the ringed world with your telescope. Just be sure to wait until it climbs well above the horizon so you can view it through less of Earth's turbulent atmosphere. Even a small scope reveals Saturn's 18"-diameter disk surrounded by a ring system that spans 40" and tilts 12° to our line of sight. Also watch for the planet's brightest moon, 8th-magnitude Titan, which shows up through any instrument.

You'll need to wait a solid three hours after Saturn rises before another planet appears. **Jupiter** comes up around 2 A.M. local time June 1 followed five minutes later by **Mars**. The two worlds stand 1.4° from each other, about twice as far apart as they were when they were in conjunction May 29. The two separate quickly in June, with Jupiter rising nearly two hours earlier by month's end while Mars gains only 15 minutes.

Both planets start the month in Pisces, but the Fish can't hold them. Mars heads eastward quickly, passing into Cetus the Whale on June 3 before returning to Pisces six days later. Jupiter remains in Pisces until it enters the Whale's domain June 25. It may seem strange that these two worlds spend part of the month in Cetus, a non-zodiacal constellation. But the ecliptic passes close to the Pisces-Cetus border, and both planets lie more than 1° south of the ecliptic this month.

Jupiter shines brilliantly at magnitude –2.3 and stands out in this region of relatively unimpressive stars. The giant world appears more than 10 times brighter than ruddy Mars, which still looks quite impressive at magnitude 0.5.

The best telescopic views of these worlds come when they stand high above the horizon an hour or two before twilight begins. Jupiter's disk spans 39" at midmonth and displays a wealth of atmospheric detail. Mars appears 7" across and should show some subtle surface markings during moments of good seeing.

Venus begins June against the backdrop of Aries the Ram before crossing into Taurus the Bull after midmonth. The inner planet shines brilliantly at magnitude –3.9 and dominates this part of the sky. Venus rises nearly three hours before the Sun and makes a spectacular sight well into twilight.

Unfortunately, a telescope doesn't add much to the view. The planet's 13"-diameter disk shows an 82-percent-lit phase in mid-June.

You'll have to search harder to find **Mercury**. The innermost planet hangs low in the east-northeast during morning twilight this month. It reaches greatest elongation June 16, when it lies 23° west of the Sun and 10° above the horizon an hour before sunrise. The magnitude 0.5 world stands out against the background stars of Taurus.

A telescope reveals Mercury's disk, which appears 8" across and about one-third lit at greatest elongation. It looks a bit more impressive around June 8, however, when the world spans 10" and the Sun illuminates 20 percent of its Earth-facing hemisphere.

The starry sky

If you look to the east after darkness falls this month, the spectacular constellation Scorpius the Scorpion dominates the sky. Its bright stars form a pattern that reminds many skygazers of an arachnid, though others think it looks more like the mirror image of a question mark. The Scorpion's head and abnormally short claws lie at the constellation's northwestern edge, to the left as it rises. (The rest of the claws now belong to the neighboring constellation Libra the Scales.)

An event in this part of Scorpius played a significant role in astronomical history. It was here, in 134 B.C., that the great Greek astronomer Hipparchus observed a "new star," or nova. Chinese astronomers also recorded this nova.

The object's appearance had a profound effect on Hipparchus. He wondered how often such novae burst on the scene, and whether individual stars could move. This inspired him to compile a star catalog containing 1,080 entries.

Hipparchus' catalog formed the basis of Ptolemy's masterwork, *Almagest*, compiled nearly three centuries later. Sadly, Hipparchus' original catalog has been lost. But modern researchers have found that the celestial globe forming part of the Roman statue known as the Farnese Atlas has constellation outlines that match their positions in Hipparchus' time. Many scientists think the sculpture was based on the catalog, or on one of Hipparchus' globes.

The catalog's main claim to fame came when Hipparchus compared his star positions with those from an earlier catalog and noticed a systematic shift in star positions. He had discovered precession — the change in the apparent directions of the stars as a result of the gravitational pulls of the Sun and Moon causing Earth's axis to wobble. Precession makes the direction of Earth's axis trace out a circle on the celestial sphere having a diameter of 47° and a period of about 25,800 years. It's a nice tidbit to ponder as you look at the Scorpion this month.

STAR DOME

HOW TO USE THIS MAP

This map portrays the sky as seen near 30° south latitude. Located inside the border are the cardinal directions and their intermediate points. To find stars, hold the map overhead and orient it so one of the labels matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

The all-sky map shows how the sky looks at:

9 P.M. June 1
8 P.M. June 15
7 P.M. June 30

Planets are shown at midmonth

MAP SYMBOLS

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

STAR MAGNITUDES

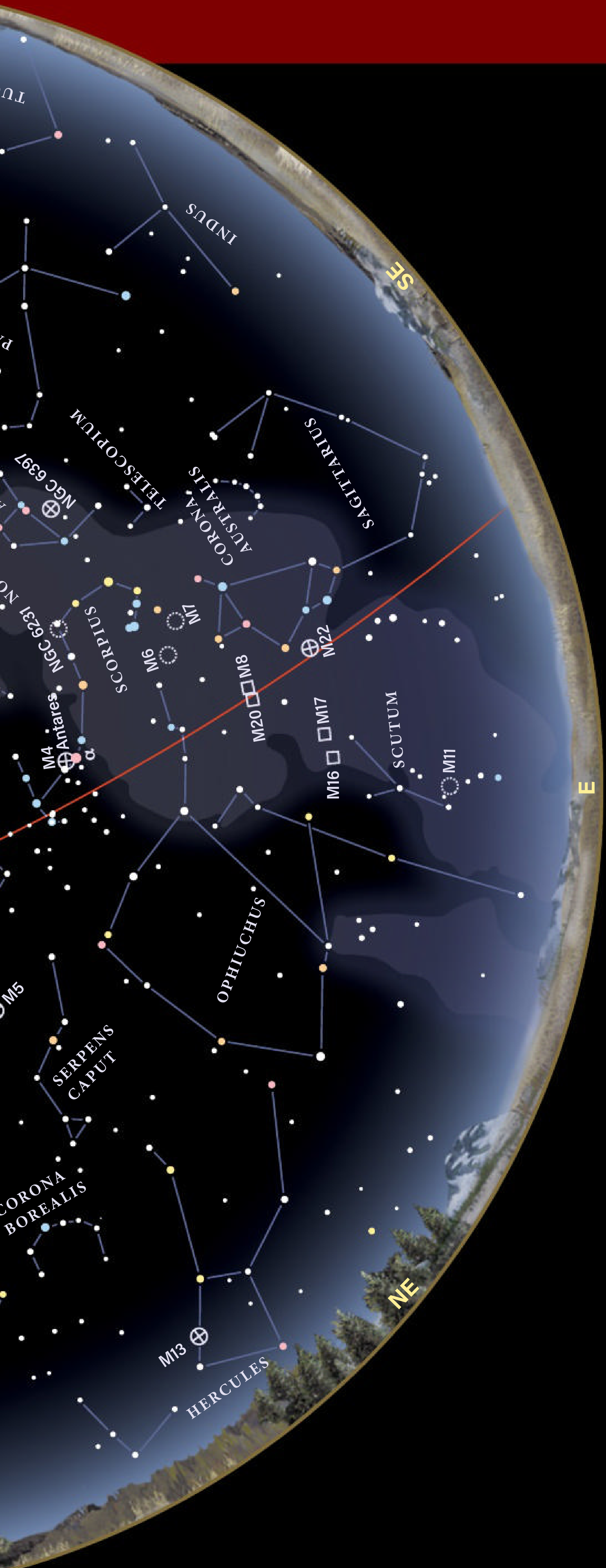
- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

STAR COLORS

A star's color depends on its surface temperature.

- The hottest stars shine blue
- Slightly cooler stars appear white
- Intermediate stars (like the Sun) glow yellow
- Lower-temperature stars appear orange
- The coolest stars glow red
- Fainter stars can't excite our eyes' color receptors, so they appear white unless you use optical aid to gather more light

BEGINNERS: WATCH A VIDEO ABOUT HOW TO READ A STAR CHART AT **www.Astronomy.com/starchart.**



JUNE 2022

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

CALENDAR OF EVENTS

1 The Moon passes 0.1° north of dwarf planet Ceres, 21h UT

2 The Moon is at apogee (406,192 kilometers from Earth), 1h13m UT

3 Mercury is stationary, 0h UT

5 Saturn is stationary, 14h UT

7 First Quarter Moon occurs at 14h48m UT

11 Venus passes 1.6° south of Uranus, 13h UT

14 Full Moon occurs at 11h52m UT

The Moon is at perigee (357,432 kilometers from Earth), 23h23m UT

16 Mercury is at greatest western elongation (23°), 15h UT

18 The Moon passes 4° south of Saturn, 12h UT

19 The Moon passes 0.7° south of asteroid Vesta, 8h UT

20 The Moon passes 4° south of Neptune, 17h UT

21 Last Quarter Moon occurs at 3h11m UT

Winter solstice occurs at 9h14m UT

The Moon passes 3° south of Jupiter, 14h UT

22 The Moon passes 0.9° south of Mars, 18h UT

23 Mercury passes 3° north of Aldebaran, 14h UT

24 The Moon passes 0.05° south of Uranus, 22h UT

26 The Moon passes 3° north of Venus, 8h UT

27 The Moon passes 4° north of Mercury, 8h UT

28 Neptune is stationary, 23h UT

29 New Moon occurs at 2h52m UT

The Moon is at apogee (406,580 kilometers from Earth), 6h08m UT