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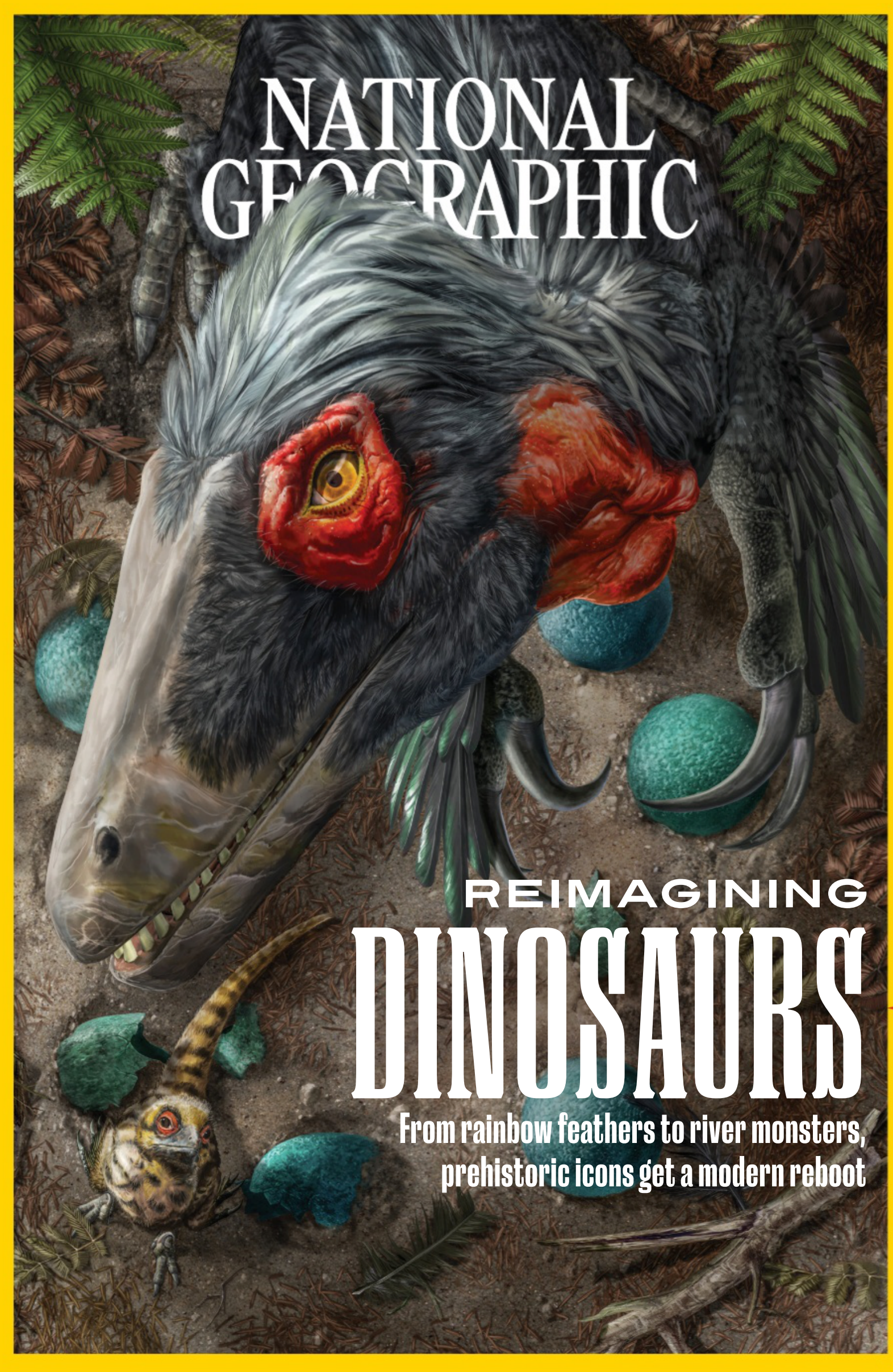

REIMAGINING

DINOSAURS

From rainbow feathers to river monsters, prehistoric icons get a modern reboot

IN THIS SECTION
How Bees Spur Pollen
Healing Coral With Sound
Growing a New Heart
A Shark's-Eye View

ILLUMINATING THE MYSTERIES—AND WONDERS—ALL AROUND US EVERY DAY
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Earth or Bust! A Map for Aliens

THE MAP THAT NASA SENT INTO SPACE IN 1972, OR ITS 2020 REBOOT, COULD LEAD EXTRATERRESTRIALS TO EARTH. IS THAT A GOOD THING?

BY **NADIA DRAKE** AND **SCOTT RANSOM**

A HALF CENTURY AGO astronomers designed a map that would point to Earth from anywhere in the galaxy. Then they sent it into space, reasoning that any aliens smart enough to intercept a spacecraft could decode the map and uncover its origin. Many movies and TV shows have used variations on this theme as a plot point, but we didn't borrow it from science fiction. It's reality.

Truth is, this tale has been part of my family's lore since before I was born. Growing up, I'd heard stories about the map and seen its depiction on multiple interstellar spacecraft, and several years ago, I found the original, penciled-in pathway to Earth where my parents had stashed it. (More on this later.)

That was an exciting find! Then came the buzzkill: This original map won't be good for much longer, cosmically speaking. The signposts it uses will disappear within tens of millions of years, and even if they don't, the map would point toward our home

PHOTO: ORIGINAL BY ROBERT SIMMON, NASA EARTH OBSERVATORY; REBECCA HALE, NGM STAFF

for only a fraction of the 200 to 250 million years it takes the sun and other nearby stars to spin once around the Milky Way.

Sure, the chances of aliens intercepting the map are astronomically improbable—but if that did happen, an outdated map would be useless rather than helpful. And that wasn't the goal.

WHY ON EARTH DOES THIS MAP EVEN EXIST?

It was December 1971, and NASA was getting ready to launch Pioneer 10, a spacecraft that would sweep by Jupiter and make the first reconnaissance of the solar system's biggest planet. More stunningly, though, Pioneer 10's brush by Jupiter would sling it onto an interstellar trajectory, making it the first ever human-made object destined to leave the solar system.

With a little help from his friends, the astronomer Carl Sagan decided that the craft ought to carry a greeting from humanity—a message identifying and commemorating Pioneer's makers that would be interpretable by anyone who found it. NASA agreed and gave Carl less than a month to design the message.

This is when Carl's friend, the astronomer Frank Drake, enters the story. Frank is also my dad, and among other notable accomplishments, he is credited with conducting the first scientific search for noisy aliens and with formalizing a framework for estimating the number of detectable alien civilizations in the Milky Way galaxy.

Carl asked Dad for help crafting the message while the two of them were in San Juan, Puerto Rico, for a meeting of the American Astronomical Society. Dad recalls that, in the lobby of the San Gerónimo Hilton, he and Carl quickly came up with ideas about what to include: line drawings depicting humans, a rendering of the spacecraft—and then, "in the next moment, we hit on the idea of a galactic map that would pinpoint the location of the Earth in space."

Dad designed that map, and in 1972 it flew into space aboard Pioneer 10. The next year Pioneer 11 launched, ultimately carrying the map past Saturn and now on to the stars. Then in 1977 both Voyager spacecraft left Earth carrying Dad's guide to finding our planet, which is etched onto the cover of the "golden record." The way Dad designed the map means that it points back to Earth both in space and in time, making it a galactic positioning system (a different kind of GPS) in four dimensions.

At the time, Dad and Carl didn't really worry that the aliens who found their message in a bottle might be of the more malevolent variety.

HOW THE MAP WAS MADE

Our galactic neighborhood has no obvious street signs, and crafting a map pointing to one planet among the billions (and billions) of worlds populating the Milky Way is no simple feat.

Finding Earth means finding the solar system, and the sun is rather unremarkable. There's really no way to distinguish it from the other several hundred billion stars in the galaxy, each of which is tracing its own path around the galactic center and slowly shifting in location relative to its neighbors. That stellar jostling means the constellations spangling Earth's skies won't be the same in our near future—nor do the stars align in the same recognizable configurations from anywhere other than the solar neighborhood. In fact, in about 2,000 years, Polaris will no longer be the North Star, just as it was not the polestar for ancient Egyptian, Babylonian, and Chinese sky-watchers.

So, what to do? Though normal stars with churning nuclear engines in their cores might not have distinctive fingerprints, Dad realized that pulsars—the corpses of stars that once were much larger than the sun—are potentially uniquely identifiable. Discovered in 1967, pulsars spin very rapidly, often hundreds of times per second. Using powerful radio telescopes, astronomers can measure with extreme precision how quickly pulsars rotate, meaning that each of these spinning stellar relics writes its own signature in space. Dad selected 14 pulsars that could triangulate Earth's position, and he coded information about their rotation rates into the map.

IT'S NOT YOUR TYPICAL MAP

Appropriately, Dad's pulsar map (far right, at top) looks like a fancy asterisk, a radial explosion of hatched lines that intersect at our solar system's location. Briefly, here's how his map works:

Each of the lines connect Earth to a pulsar. The hatch marks are binary numbers that reveal the pulsar's rotation rate (at the time the map was designed), and line lengths are roughly proportional to distance. Some of the pulsars parked on Dad's map—for example, the Crab and Vela—sit in the centers of beautiful nebulae created during the pulsars' violent formations. Presumably, any civilizations sharp enough to detect and snare a quiet interstellar spacecraft would know about pulsars. And by matching the rotation periods on the map with stellar signposts in the sky, aliens could find their way to Earth relatively easily.

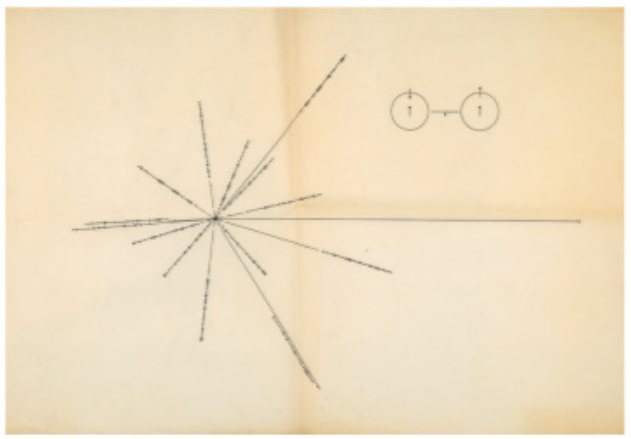
In addition, because the energy we see from pulsars comes from their spin and they slow down over time, Dad's map also points to Earth in the fourth dimension. By calculating the difference between the observed and coded rotation periods—a difference that will be apparent after thousands of years—aliens could figure out how long ago the map was made.

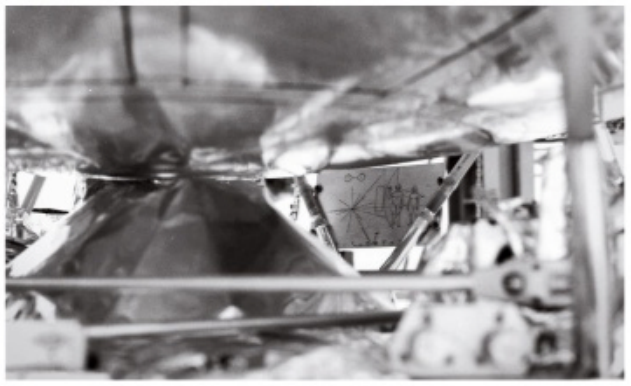
Perhaps somewhat surprisingly, Dad's map became lodged in the popular imagination and is now commonly found on everything from T-shirts to tattoos. I guess there's something captivating about always being able to find your way home, even in the most cosmic sense imaginable.

KEEPING IT IN THE FAMILY: A LOVE STORY

Several years ago, two significant things happened. I found the original, penciled-in pulsar map, folded away and casually tucked into a tomato box in my

PHOTOS (CLOCKWISE, FROM TOP LEFT): F. FERRARO, EUROPEAN





CLOCKWISE, FROM LEFT:

GLOBULAR CLUSTER
A sparkling mass containing at least half a million stars—and some two dozen pulsars—the globular cluster known as 47 Tucanae is one of roughly 150 ancient stellar clumps orbiting the Milky Way galaxy.

PULSAR MAP The original map to Earth, designed by Frank Drake, uses 14 pulsars to point toward home. Until recently, the earliest draft of Drake's map lived in his closet, tucked into a tomato box.

CARL, DAD, AND LINDA
Pictured here in 1972, Carl Sagan (at left, holding son Nick), Linda Salzman Sagan, and Frank Drake designed the plaque that Pioneers 10 and 11 would ferry to interstellar space.

PIONEER 10 Pioneer 10 is carrying a message from humanity into the stars. Etched onto a six-by-nine-inch, gold-anodized aluminum plate, the message commemorates the spacecraft's home world—and tells whoever finds it how to find us.

SOUTHERN OBSERVATORY; COURTESY FRANK DRAKE (MAP AND PORTRAIT); ALAMY STOCK PHOTO

Giving Aliens Our Address

To potentially help extraterrestrials locate Earth, this diagram (below) was first sent into space in 1972 attached to Pioneer 10. That spacecraft is still traveling on to the stars, but time and space are taking a toll on the cosmic coordinates it carries. The map gets increasingly unreliable as the galaxy rotates and our sun and its reference points—pulsars, the spinning cores of collapsed stars—change their relative positions. So one astronomer, Scott Ransom, is proposing a new map (far right) to overcome these weaknesses.

Atomic hydrogen diagram marks a 21-cm distance.

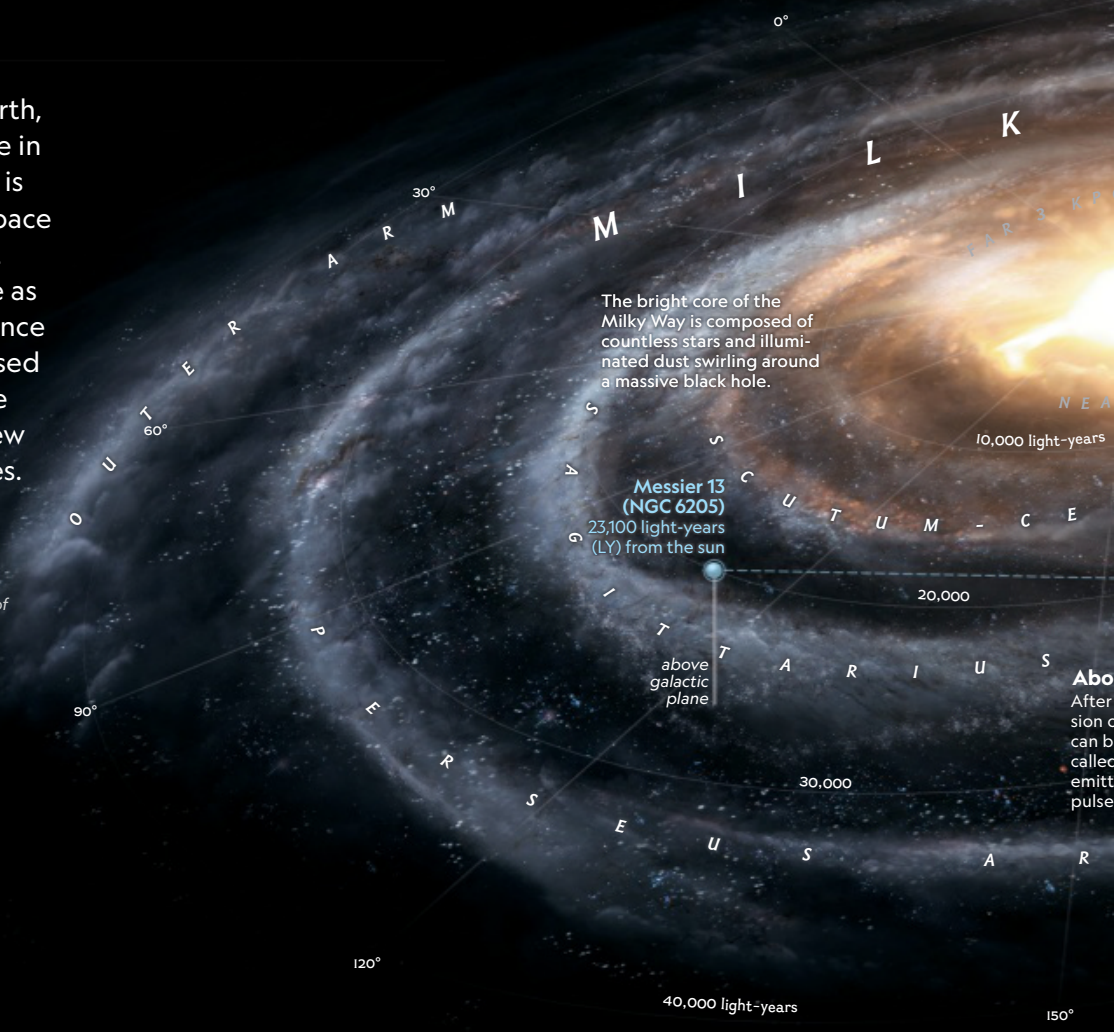
Human figures are shown to scale in front of the Pioneer spacecraft.

Frank Drake's 1972 map

Pioneer's trajectory is shown on this solar system diagram.

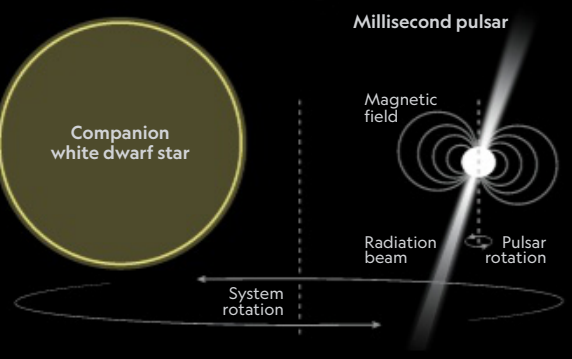
Universal ruler

Our measurements of time and distance would be unfamiliar to aliens. Hydrogen is a good universal alternative. When a hydrogen electron flips the direction of its spin, it emits a radio wave with a wavelength of about 21 centimeters, the distance light travels in just over 0.7 nanoseconds.



Stable signposts

If a small, dense pulsar is paired with another star, it siphons material and energy from its companion, accelerating the pulsar's already rapid rotation. At up to 43,000 rotations per minute, the radiation appears to pulse and acts like a beacon. This system is a reliable signpost for mapping within the Milky Way.



Galactic positioning system

Much like how the Global Positioning System (GPS) works on Earth, these galactic beacons could provide a map to the sun. By identifying these specific pulsars (at right) and how much their spins have changed, you reveal the sun's location—and Earth is right nearby.

MATTHEW W. CHWASTYK, DIANA MARQUES, NGM STAFF; SEAN MCNAUGHTON; NEW P
SOURCES: NASA GODDARD SPACE FLIGHT CENTER; NATIONAL RADIO ASTRONOMY OBS

21.10611405-cm wavelength (actual size)

Light takes 0.704024183 nanoseconds to traverse.

300°

270°

240°

210°

180°

W A Y

Y

C ARM

CORE

Terzan 5
19,200 LY

R 3 KPC ARM

TAURUS ARM

SAGITTARIUS ARM

below galactic plane

47 Tucanae (NGC 104)
14,700 LY

J1614-2230
2,100 LY

WE ARE HERE
SOLAR SYSTEM

SPUR

PERSEUS ARM

NGC 1851
39,500 LY

J2043+1711
4,500 LY

ORION

J0614-3329
2,000 LY

J0218+4232
10,300 LY

Direction of galactic rotation

ut pulsars

a supernova—the titanic explo-
of a massive star—the star's core
ecome incredibly dense. It is
d a "pulsar" if it's set spinning,
ing radio waves that appear to
on and off like a lighthouse.

The new map

These new coordinates might more accurately guide extraterrestrial life to Earth for the next billion years or so. The map encodes how quickly rapidly spinning pulsars rotate (rotational periods) and how quickly star-pulsar systems revolve around each other (orbital periods).

NEAR PULSARS

J1614-2230

J0614-3329

J2043+1711

Binary (I = 1 or - = 0, X=decimal point*) encoding for the rotational period of the pulsar and orbital period of the star pair in units of time based on the hydrogen wavelength*

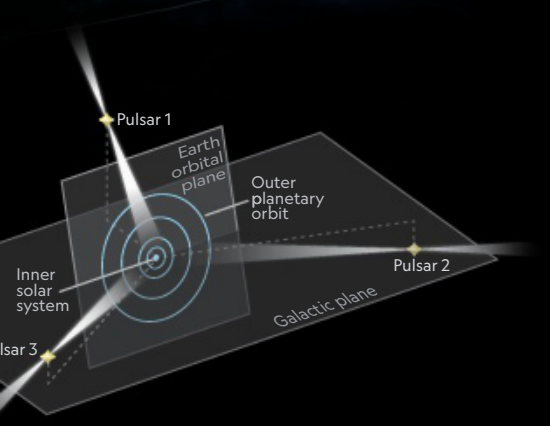
J0218+4232

Our sun is similar to many other stars in the galaxy. To aid in finding it, the new map provides two scales of reference points—one up close (above) and one distant (below).

Millisecond pulsar (pulsar with a rotational period measured in fractions of a second)

Globular cluster containing millisecond pulsar

Globular clusters are dense groups of hundreds of thousands of ancient stars that orbit our galaxy. Their incredible stellar density leads to collisions and interactions over billions of years, which can produce new millisecond pulsar systems.



DISTANT PULSARS

47 Tucanae
(two binary pulsars)

NGC 1851
(one binary pulsar)

Terzan 5
(two binary pulsars)

Near Pulsars

J0218+4232

Messier 13
(two binary pulsars)

ULSAR MAP: SCOTT RANSOM; MILKY WAY: ANTOINE COLLIGNON
SERVATORY; HARVARD-SMITHSONIAN CENTER FOR ASTROPHYSICS

parents' closet. And I linked up with a rock climber named Scott Ransom, one of the world's more prolific pulsar astronomers.

Scott had been thinking about the Voyagers, the "golden record," and the pulsar map since he was a 10-year-old in Mansfield, Ohio, watching Carl's *Cosmos* television show. Some years and an astronomy Ph.D. later, he realized that Dad's map has a near-future expiration date. Its Achilles' heel is the same property that lets it pinpoint Earth in time: Pulsars slow down, and the ones Dad had chosen (from the few known at the time) would fade and disappear within several million years, give or take a few millennia.

Coincidentally, Scott had set out to make a new, more precise, and longer-lived pulsar map even before we moved in together and portmanteau'd ourselves into the Dranksomes. Now I write the words that tell our stories, and Scott does the important cartographic stuff such as choosing pulsars and deriving their binary codes. He occasionally drafts some text passages, but you'll never catch me committing academic acts of astronomy.

A NEWER, BETTER MAP TO EARTH

Scott's new map is a GPS for the ages. It navigates to Earth using pulsars both inside and outside the Milky Way, with a twist.

Instead of the more ordinary pulsars Dad selected, the new map employs millisecond pulsars that spin faster, last longer, and have also-dead orbital companions. These binary pulsars afford a second set of identifiers: the orbital period of the system, which does not change over billions of years. And, crucially, millisecond pulsars age much more slowly than the ones in Dad's map, meaning that it takes thousands of times longer for their spins to become unrecognizable.

In addition, Scott included another layer of signposts: pulsars in globular clusters orbiting the Milky Way. Ancient clumps of stars that predate the Milky Way, globular clusters are gorgeous and mysterious, and they are veritable millisecond pulsar factories.

By including signposts in these hard-to-miss stellar globs outside the galaxy, Scott's map allows Earth to be discoverable for billions of years, even after the Milky Way's stars have trekked around the galactic core multiple times, shuffling their positions and obliterating constellations.

And Dad, for the record, thinks that's spectacular.

HERE'S THE FUNDAMENTAL QUESTION THAT DIDN'T STOP CARL AND DAD: IS IT A GOOD IDEA TO RANDOMLY SEND OUR ADDRESS INTO THE COSMOS?

BUT FIRST, SOMEONE HAS TO READ IT

Dad's map, of course, is still out there—but chances are slim to zero that the Pioneers or Voyagers carrying it will be intercepted. Though all four spacecraft are on interstellar trajectories, space is big, and the next stellar systems on the horizon are many thousands of years away. Plus, the spacecraft are tiny and will be completely quiet within the next couple of decades, making them extremely hard to detect.

As for sending the new map: There's no Voyager-like space probe scheduled for launch anytime soon. But if this map did hitch a ride beyond our solar system, and if it got scooped up by intelligent space aliens, the map should be quite easy for them to read and follow.

That raises all sorts of questions: Would extraterrestrial beings at those distances have the means to reach Earth? If so and they head our way, what if they don't come in peace? What if they're hangry? And what if they're not vegetarians?

Here's the fundamental question that didn't stop Carl and Dad: Is it a good idea to randomly send our address into the cosmos? Today, some folks would have no reservations, given that earthly transmissions already are leaking into space and, traveling at the speed of light, are detectable by anyone with a decent radio telescope living within a hundred light-years of us. Other folks, perhaps more cautiously, would hold off on announcing our presence until we know if ETs have honorable intentions.

As for the Dranksomes: We'd gladly send out the new map to Earth, as a bid to ensure that our presence as a species would live on in some form. If that message in a bottle were finally picked up, after bobbing and drifting through the galactic ocean for millions or billions of years, someone would know that Earthlings did exist—or, with luck, still do. ▯

Bios, verbatim

From **Nadia Drake:** "I'm a contributing writer with *National Geographic* who loves getting lost in Earth's buggy, overgrown jungles (and then finding my way home)." From **Scott Ransom:** "I'm an astronomer at the National Radio Astronomy Observatory and the University of Virginia who loves pulsars, maps, codes, and Nadia."

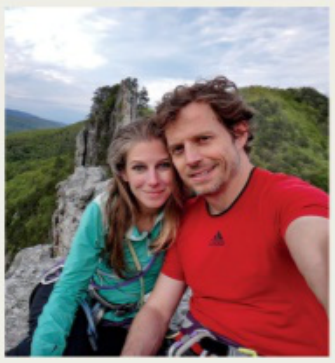


PHOTO: SCOTT RANSOM