WHERE EXPLORE

FINDING NEW WORLDS TOGETHER

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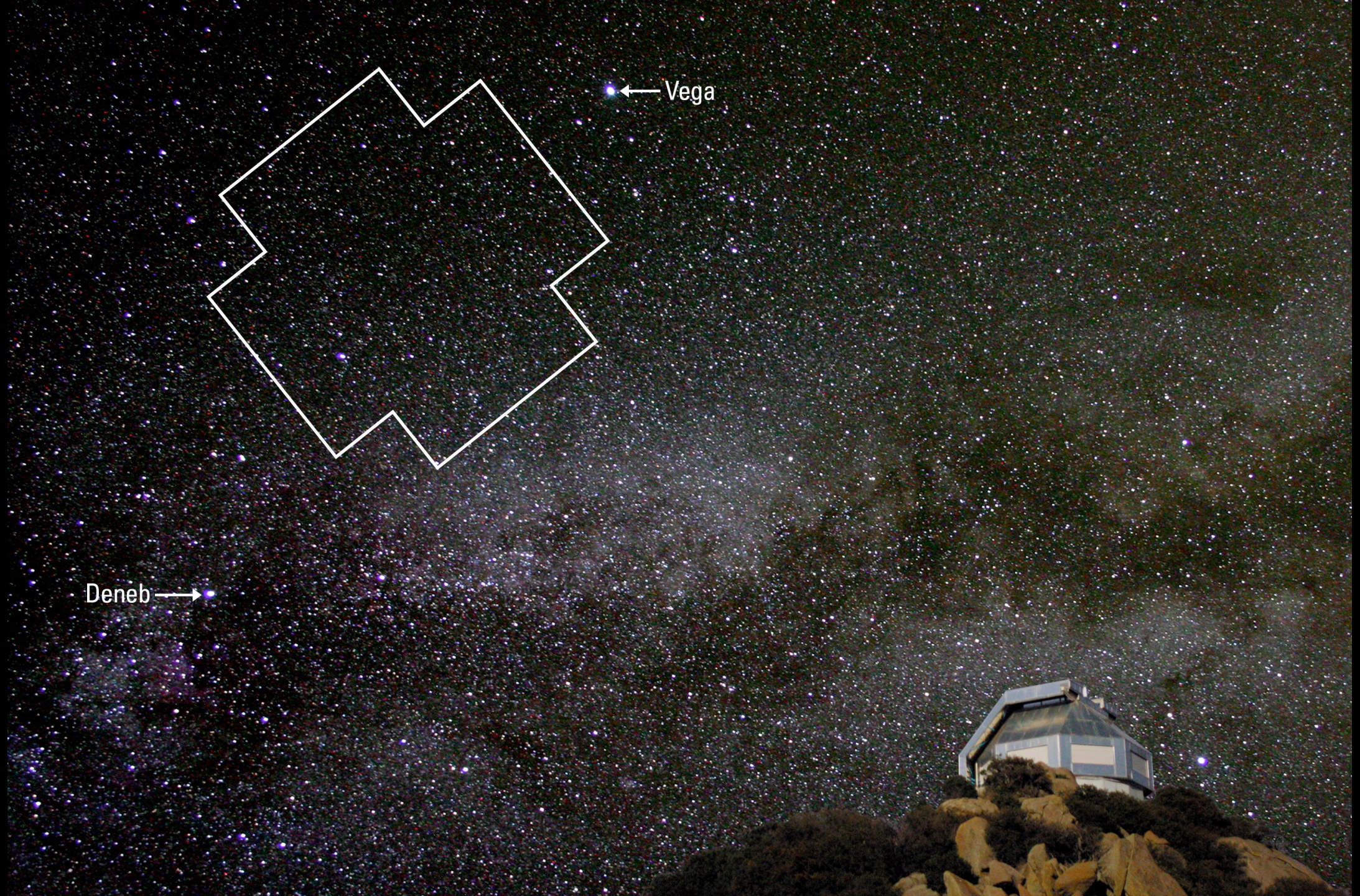
Jet Propulsion Laboratory
California Institute of Technology

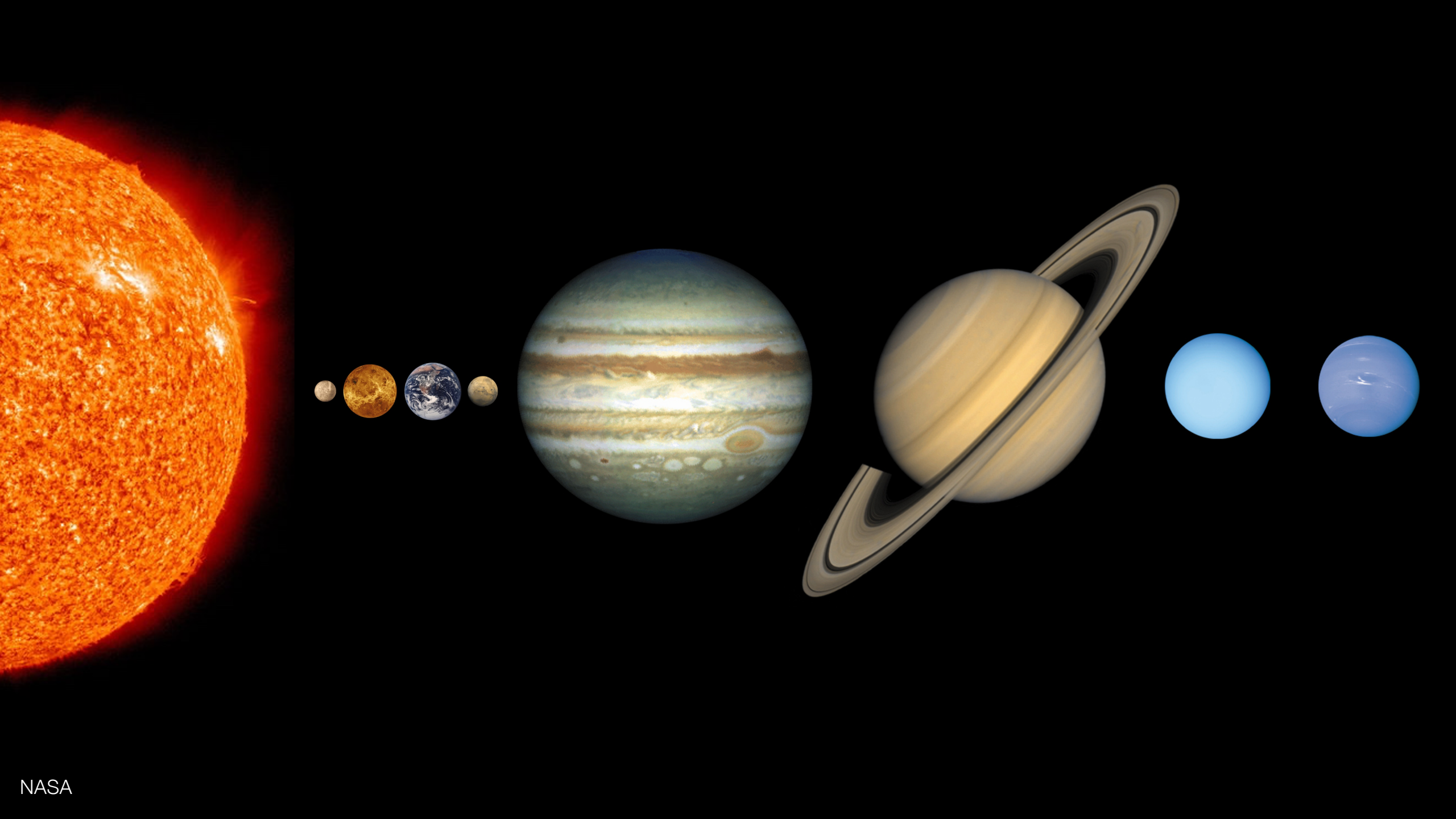
Government sponsorship acknowledged.

Image: NASA Ames/SETI Institute/JPL-Caltech



NOAO


Vega
Deneb
planets are common
and diverse
NOAO/NASA Kepler


NASA

The story of stars

WHERE
EXPLORE

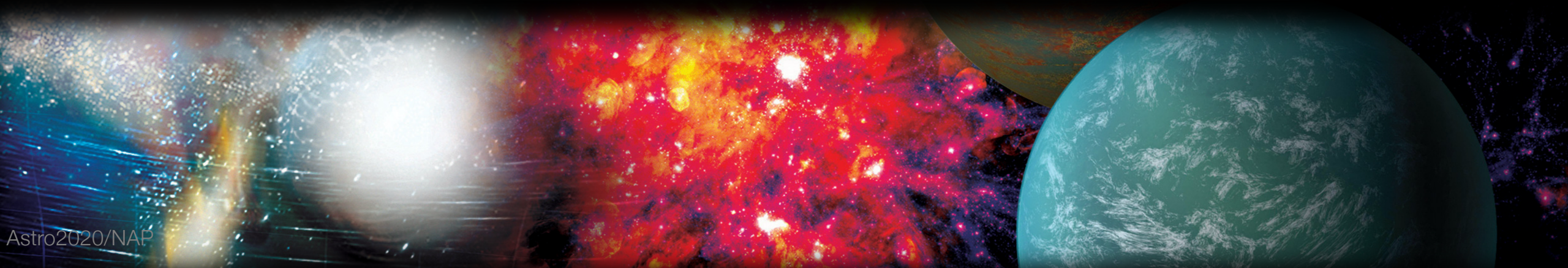
 **Where** Introduce stars as a focal point

 **WE** Highlight the community involved

 **Explore** Share process of discovery

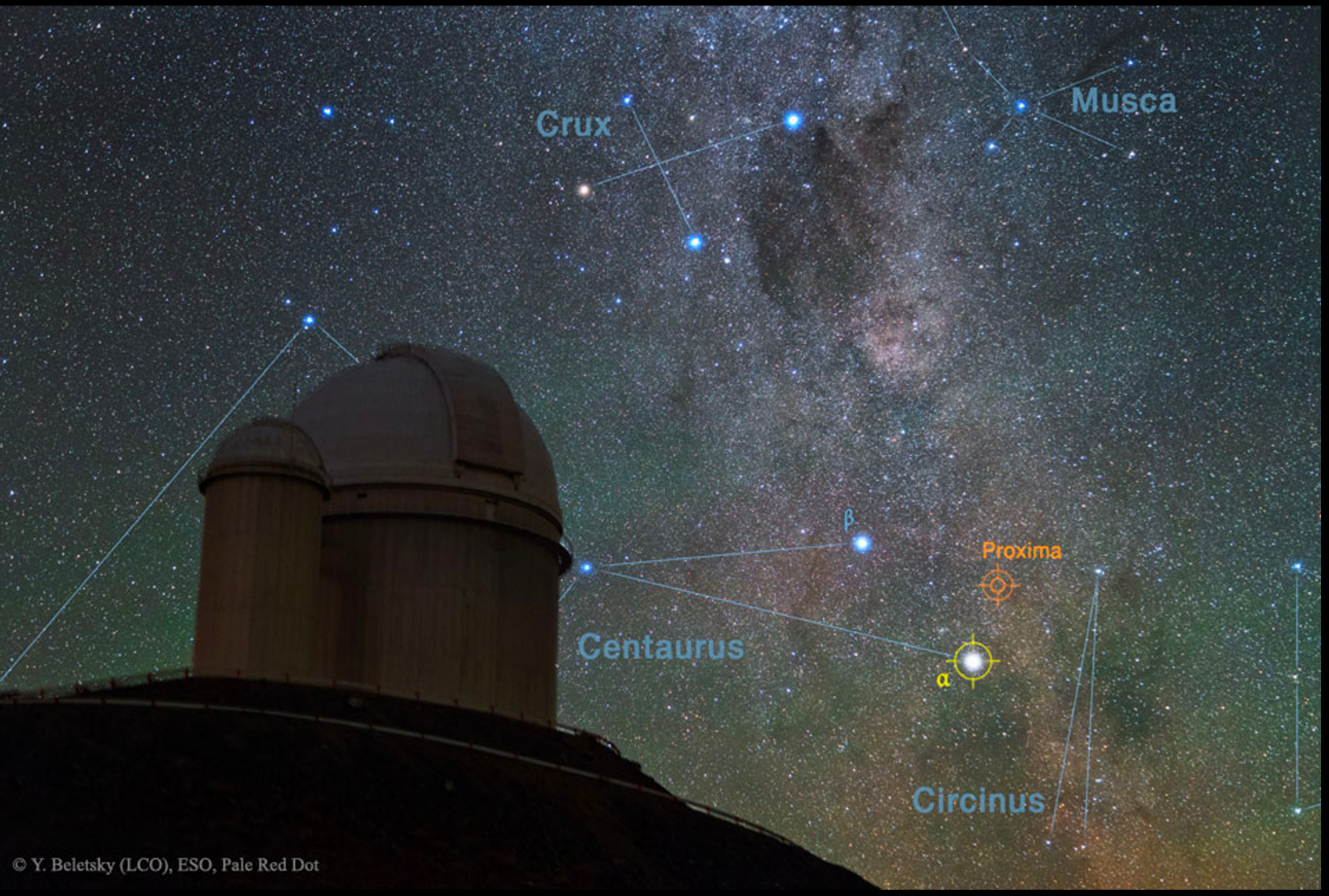
WHERE WE EXPLORE Motivation

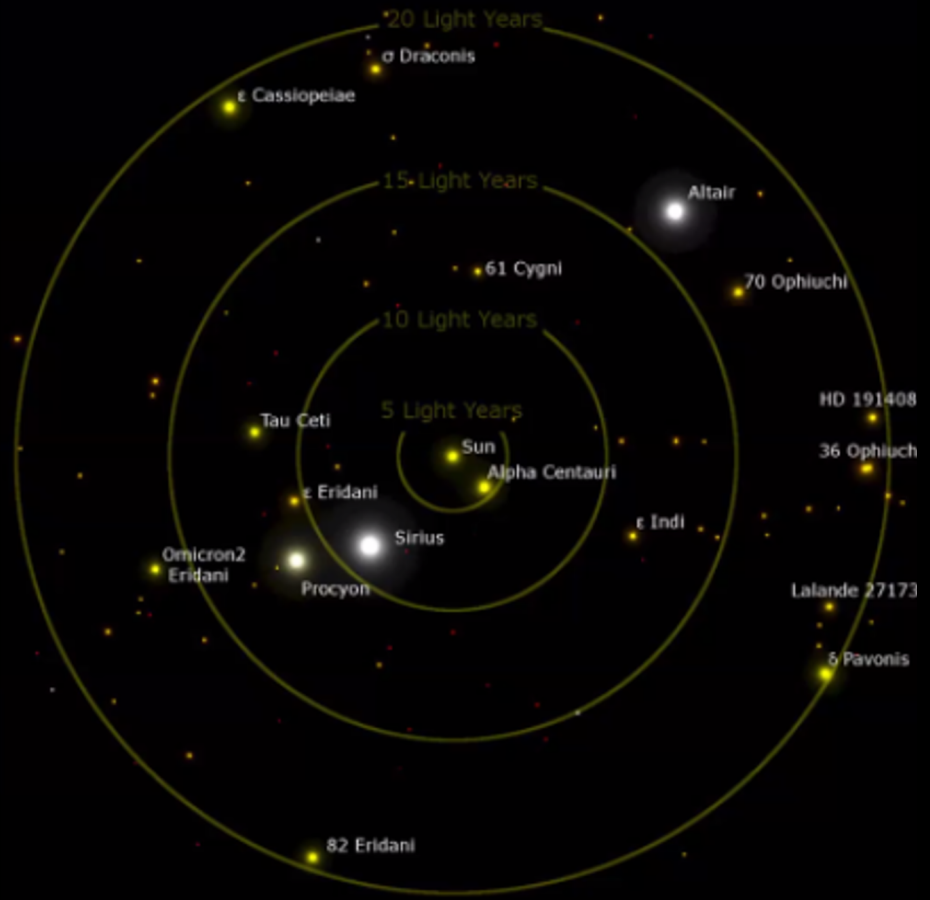
- Expand visibility into the process of exoplanet science
- Prime others about the future of exoplanet exploration
- Broaden representation for the field



WHERE EXPLORE ⭐

Where





WHERE EXPLORE ⭐

Where

Lucasfilm

- Nearby, naked-eye stars
- Best prospects for direct imaging
- Referenced in pop culture

To be featured in a NASA Exoplanet Archive data table

📮 **Upcoming opportunity to comment**

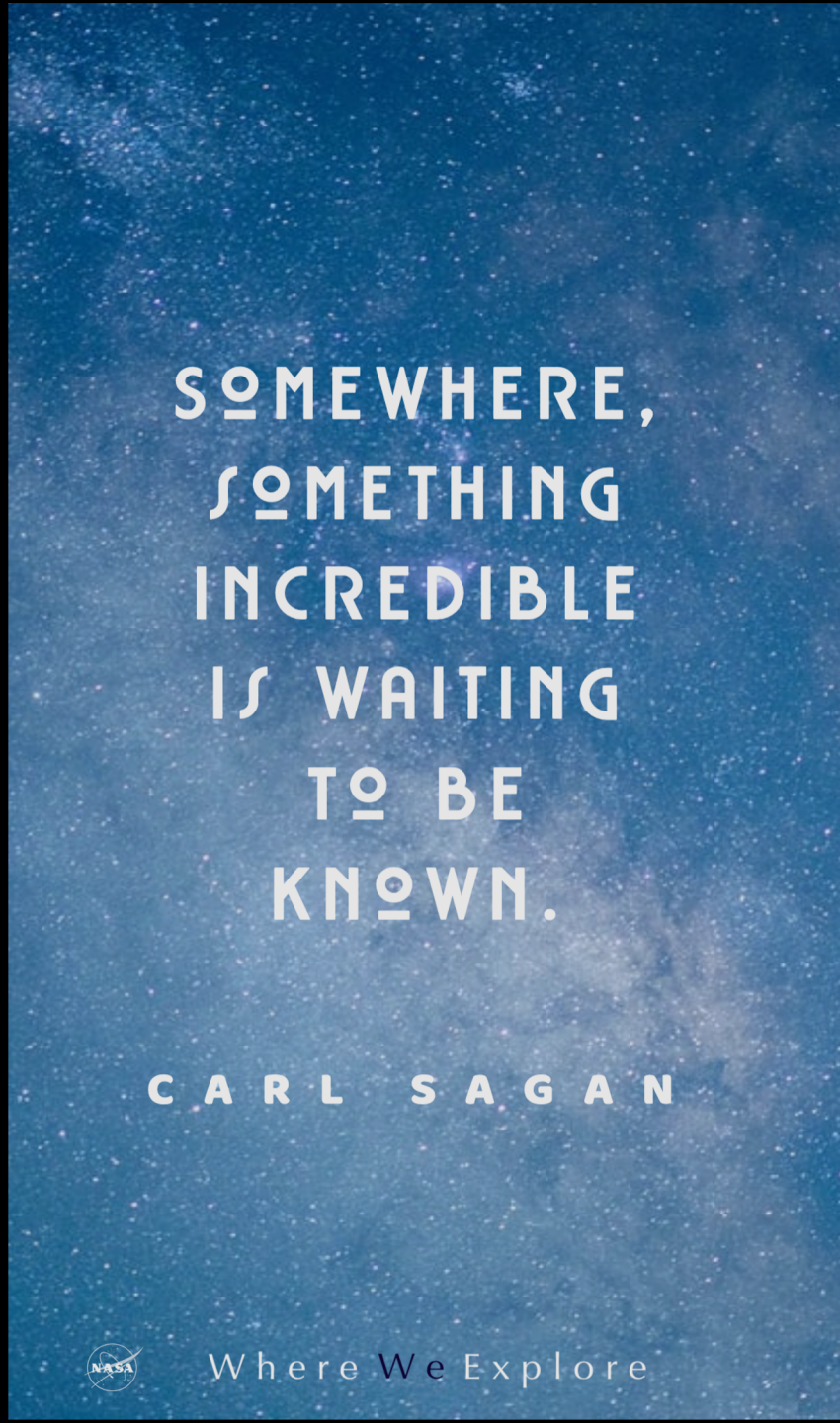
WHERE WE EXPLORE

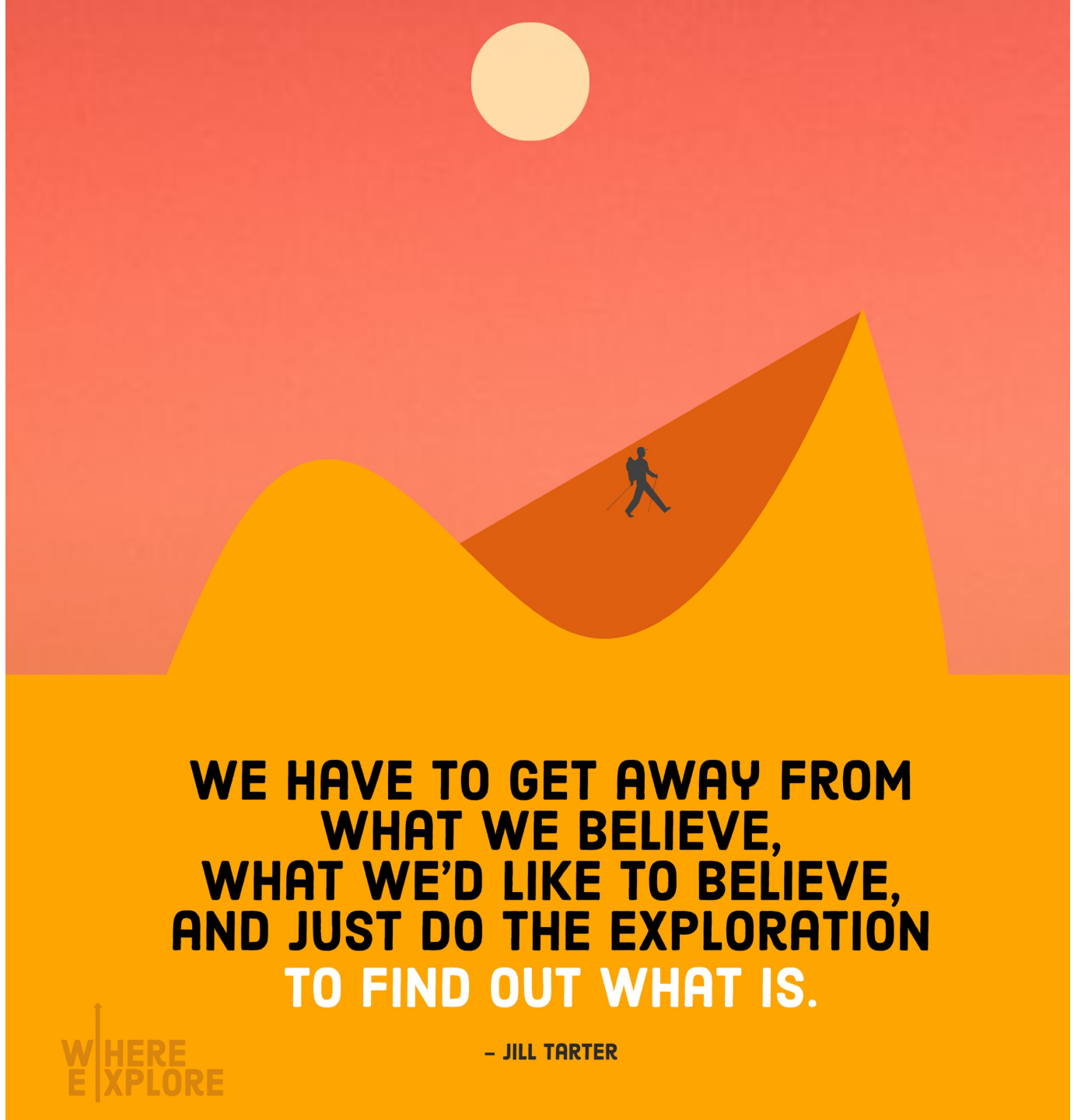
We

- Highlight the exoplanet community
- Amplify underrepresented voices

Create a corpus of inspirational exoplanet & exploration quotes, by featured scientists

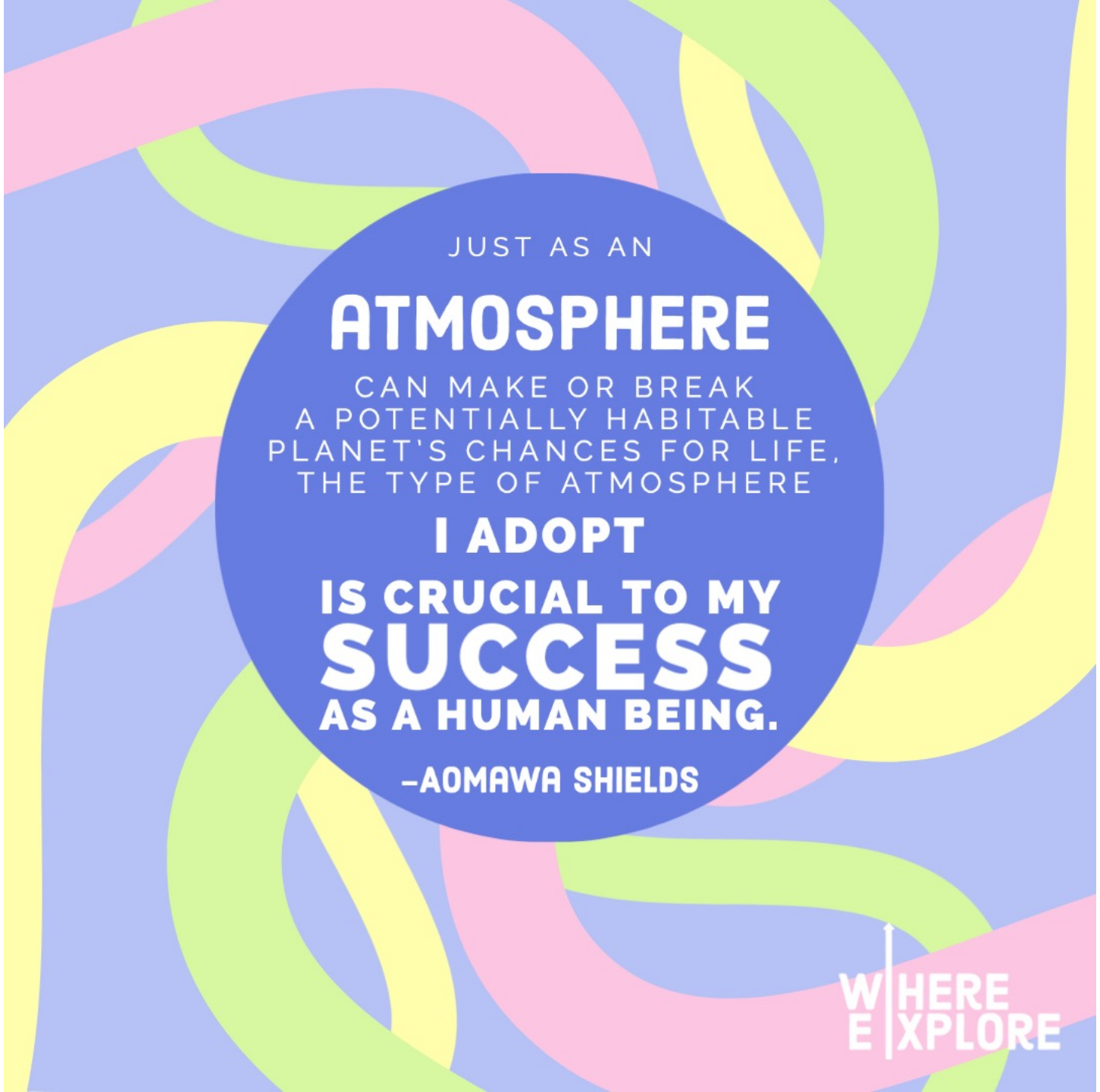
@PersikaDesignCo





Dr. Jill Tarter
is the Chair Emeritus for SETI Research. As an astronomer, Dr. Tarter has worked on the search for extraterrestrial life.

Photo: Cambridge University Press



Dr. Aomawa Shields is an associate professor of physics and astronomy at UC Irvine. Her research focuses on exploring the climate and habitability of small exoplanets.

Photo: TED.com

Opportunity to recommend speakers

WHERE EXPLORE

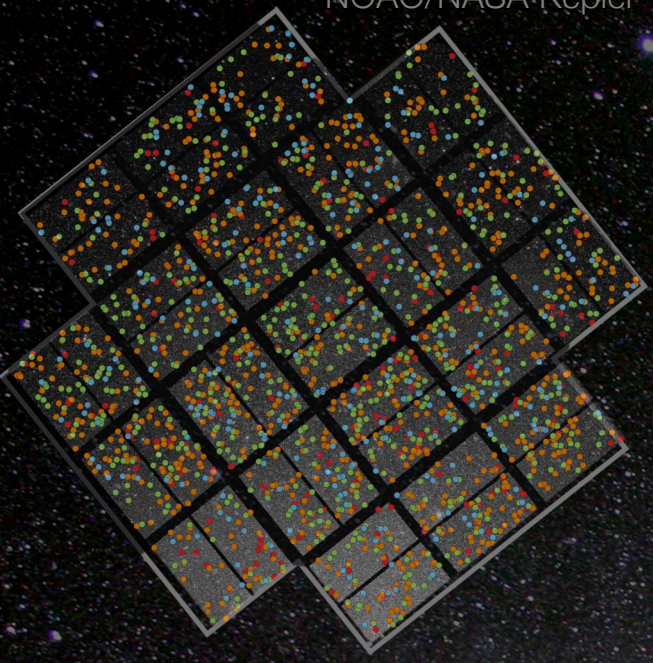
Explore

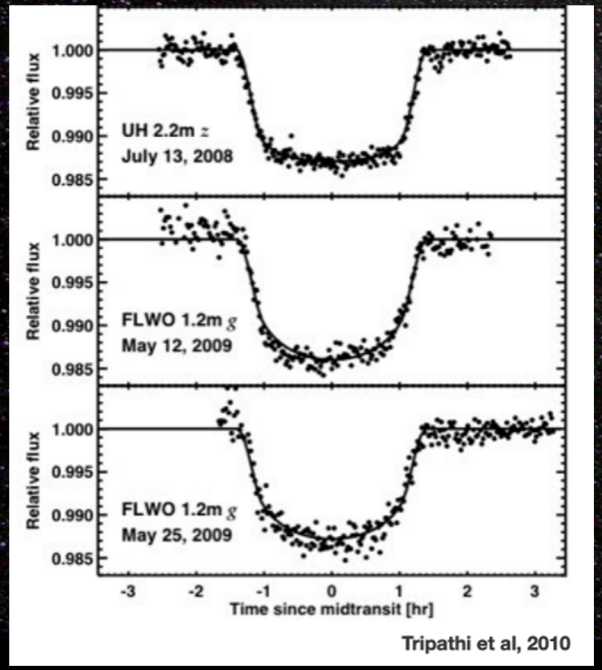
- Discuss the search, not just the results
- Engage and encourage anticipation of future findings
- Teach about direct imaging

Develop public products to highlight the stars and exploration process

Etsy

NOAO/NASA Kepler





Tripathi et al, 2010

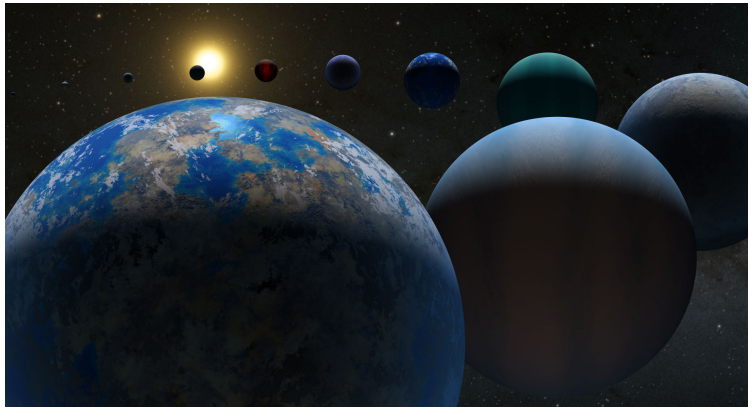
WHERE E XPLORE

Explore

Updated detection techniques lithograph

Pick one up at the booth!

National Aeronautics and Space Administration



The Search for Other Earths

EXPLORING WORLDS BEYOND OUR OWN

Scientists have identified thousands of planets beyond the Solar System. They estimate that there are hundreds of billions more in the Milky Way, which means there are more exoplanets than stars in our galaxy. Many of them may be in Earth's size range. As we imagine these planets and how they might be like our own, scientists are actively searching the sky for stars where we will explore and find exoplanets.

To find and study these distant worlds, astronomers use a variety of methods:

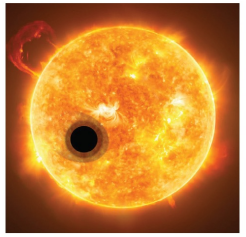
RADIAL VELOCITY: WATCHING STARLIGHT WOBBLE

The radial velocity method was one of the first techniques ever used to find exoplanets. When a planet orbits a star, it exerts a gravitational tug on the star, causing the star to shift position, or wobble. The radial velocity method measures these wobbles, which show up as slight shifts in the wavelength or spectral color of the star's light, to look for planets. Telescopes around the world use this method to detect exoplanets. Often, this method is used to confirm planets found with other methods, including those found with space telescopes using the transit method, and it also provides an estimate of the mass of the planet.

In 1995, the first exoplanet orbiting a star like the Sun was discovered, using the radial velocity technique. Since then, more planets have been found with each of these techniques.

TRANSITS: SEARCHING FOR DIMMING STARS

If a planet passes in between Earth and its host star, it blocks some of the star's light, like an eclipse. For that brief period of time, the star appears dimmer. It's a tiny change, but it's enough to clue astronomers into the presence of an exoplanet around a distant star. By measuring these dips in stellar brightness, the Kepler and the Transiting Exoplanet Survey Satellite (TESS) space telescopes have discovered thousands of exoplanets. This method reveals the radius of the planet and can also be used to study the planet's atmosphere.

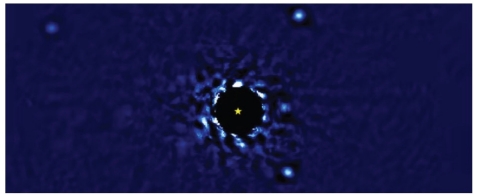


Artist's rendering of a transiting exoplanet.

Transits occur when a planet passes in front of a star, blocking some of the starlight seen. Measuring changes in the starlight during a transit has been used to detect new planets and characterize their atmospheres.

DIRECT IMAGING: TAKING PICTURES OF PLANETS

The only method where planets can be seen directly is direct imaging, or taking pictures of planets. The other techniques look for changes in starlight. Exoplanets are far away, and they are millions of times dimmer than the stars they orbit. So taking pictures of planets is extremely difficult. To see the planet and overcome the challenge of how bright the star is, astronomers use techniques to remove the star's glare. By blocking this starlight, direct imaging has been used to find large planets, far from their host stars. Finding planets that are closer to their bright stars is more challenging, and rapidly advancing technology is working towards this goal. Direct imaging may eventually be used to look at details on planets, such as atmospheres, oceans, and land on the surface.



By blocking light from the star, astronomers are able to directly image planets. This picture shows four planets around the star HR 8799, directly imaged with the Keck telescope. Credit: J. Wang (Caltech)/C. Marois (NRC Herzberg)

ASTROMETRY: MEASURING MINUSCULE MOVEMENTS

Measuring radial velocity isn't the only way astronomers can find stars that are wobbling due to the gravity of their planets. The star's wobble can also be visible as changes in its apparent position in the sky. Astrometry uses precise measurements of a star's movement over time to find planets, and unlike other methods, it can even collect accurate data about a planet's mass and orbit. The star's position on the sky can appear to change by such a small amount that it can be difficult to detect planets with astrometry, especially small ones the size of Earth.

MICROLENSING: FINDING FLASHES OF LENSED LIGHT

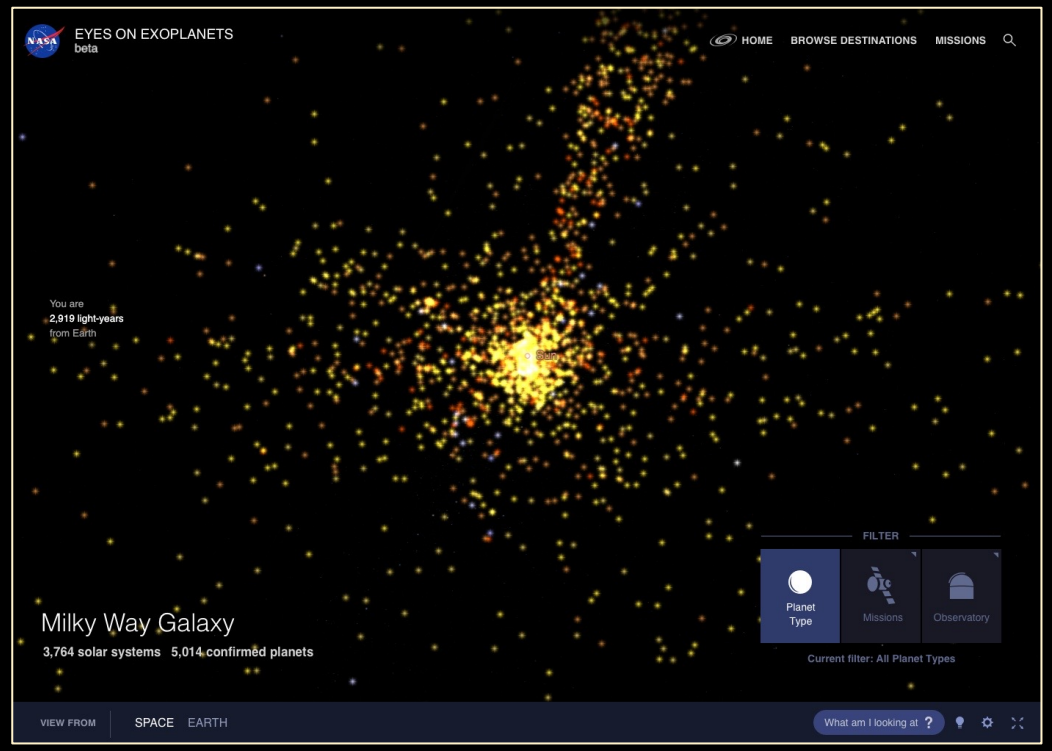
The gravity from heavy objects warps the space around them, so light rays passing nearby will bend. The light behaves as if it were going through the lens of a magnifying glass. This means that when a planet passes in front of a faraway star, the planet's gravity causes lensing and the star temporarily appears brighter. Astronomers search for these fleeting flashes across the sky. Using this method, they have discovered distant and even free-floating planets. Microlensing enables astronomers to estimate the frequency of planets in the outer reaches of exoplanetary systems.

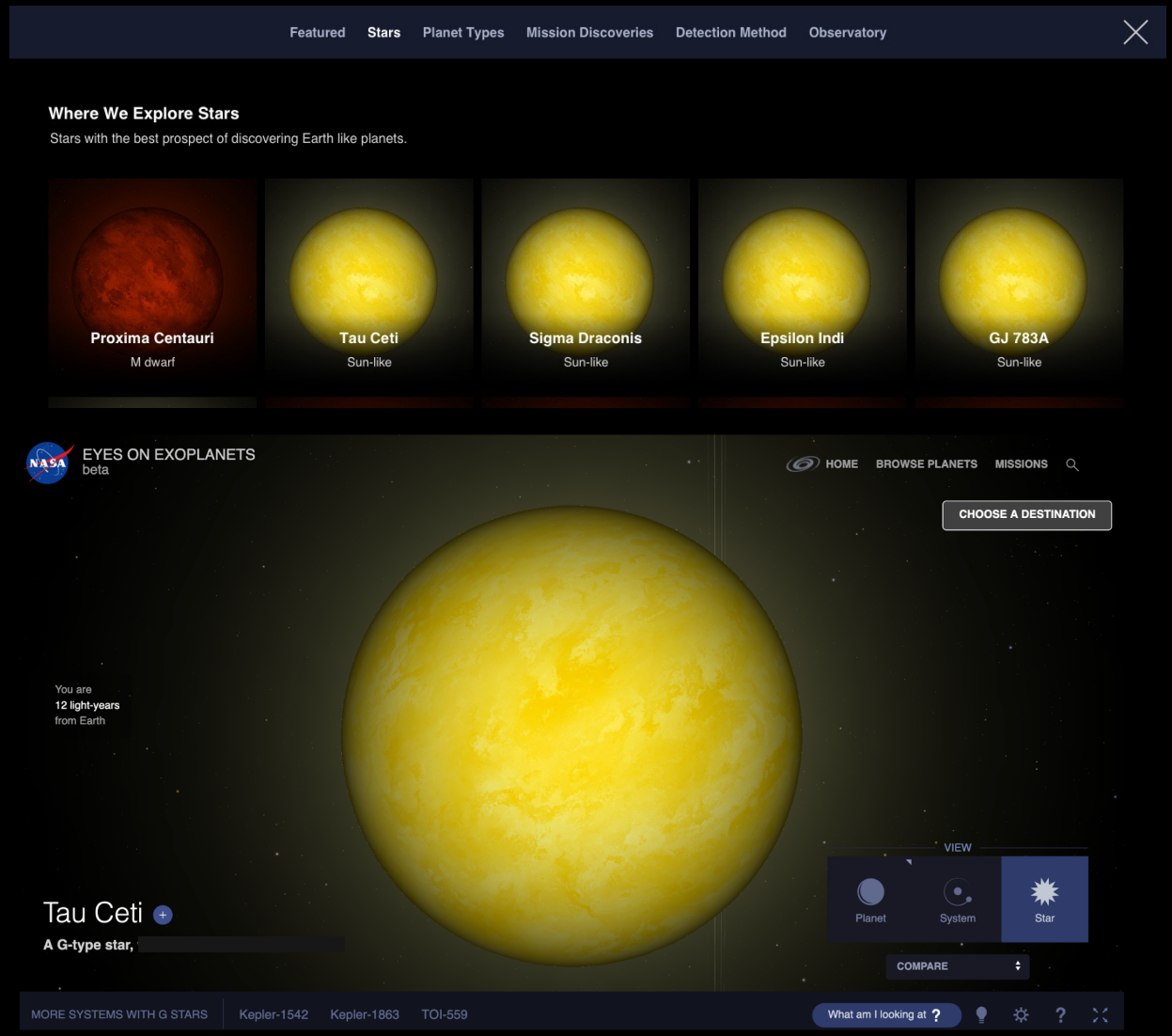
Learn more at exoplanets.nasa.gov

Publication number

WHERE EXPLORE

Eyes on Exoplanets





WE stars coming soon to
exoplanets.nasa.gov/eyes-on-exoplanets

WHERE EXPLORE

Eyes on Exoplanets

STAR TYPE Sun-like

DISTANCE 11.90 light-years away

CONFIRMED PLANETS 2

Tau Ceti (τ Ceti) is the 2nd brightest Sun-like star in the sky. Visible to the naked eye, it is located near the celestial equator, in the constellation Cetus - the sea monster. Compared to the Sun, it has a lower abundance of metals, slower rotation period, and weaker magnetic activity. Around the star, there is a broad, dusty debris disk, which corresponds to Tau Ceti's version of the Kuiper Belt. Smaller and dustier than our own Kuiper Belt, Tau Ceti's disk is inclined roughly 30°. In spite of the disk, Tau Ceti's habitable zone is not very dusty.

Pop Culture

Opportunity to suggest content

As one of the nearest stars, Tau Ceti has been the setting of numerous science fiction novels, from Robert Heinlein's *Time for the Stars* in 1956 to Kim Stanley Robinson's *Aurora* in 2015. These works include Ursula Le Guin's *The Dispossessed*, Isaac Asimov's *The Caves of Steel*, Frank Herbert 's *Destination: Void*, Larry Niven's *A Gift from Earth* and *The Legacy of Heorot*, as well as Arthur C. Clarke's *Rama Revealed*.

STELLAR POWER OUTPUT	STELLAR TEMPERATURE	VISUAL MAGNITUDE
0.51 x Our Sun	5330 K	3.49
Sun: 3.8 x 10^{26} W	Sun: 5772 K	

Star comparison

Tau Ceti Our Sun

MASS 0.94 x Our Sun

RADIUS 0.81 x Our Sun

How to detect a planet in this system?

RADIAL VELOCITY

TRANSIT

IMAGING

MICROLENSING

ASTROMETRY

METHOD

Radial Velocity

PLANETS & PROSPECTS

2 confirmed as of 2017

Good for large planet detection, given that it's a quiet star.

HOW IT WORKS

Orbiting planets cause stars to wobble in space, causing an observable shift in the color of the star's light.

MORE

Radial velocity detections are well suited to quiet stars, like Tau Ceti quisque eleifend sagittis scelerisque. Donec nec est et felis semper molestie sed at enim. Sed eu justo tortor. In in lacus tristique, mollis massa eu, volutpat massa.

E

- ⭐ Introduce stars as a focal point
-  Highlight community & broaden representation
-  Share the process of discovery & a bridge to future observations

WHERE EXPLORE

FINDING NEW WORLDS TOGETHER

Provide community input :

- Share your favorite exoplanet or exploration quotes
- Recommend quotable scientists
- Share pop culture references for naked-eye stars we might miss

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Pick up a quote card or a detection methods litho