Jet Propulsion Laboratory
California Institute of Technology

Exoplanets and Excellence
NASA's Search for Life in our Galaxy

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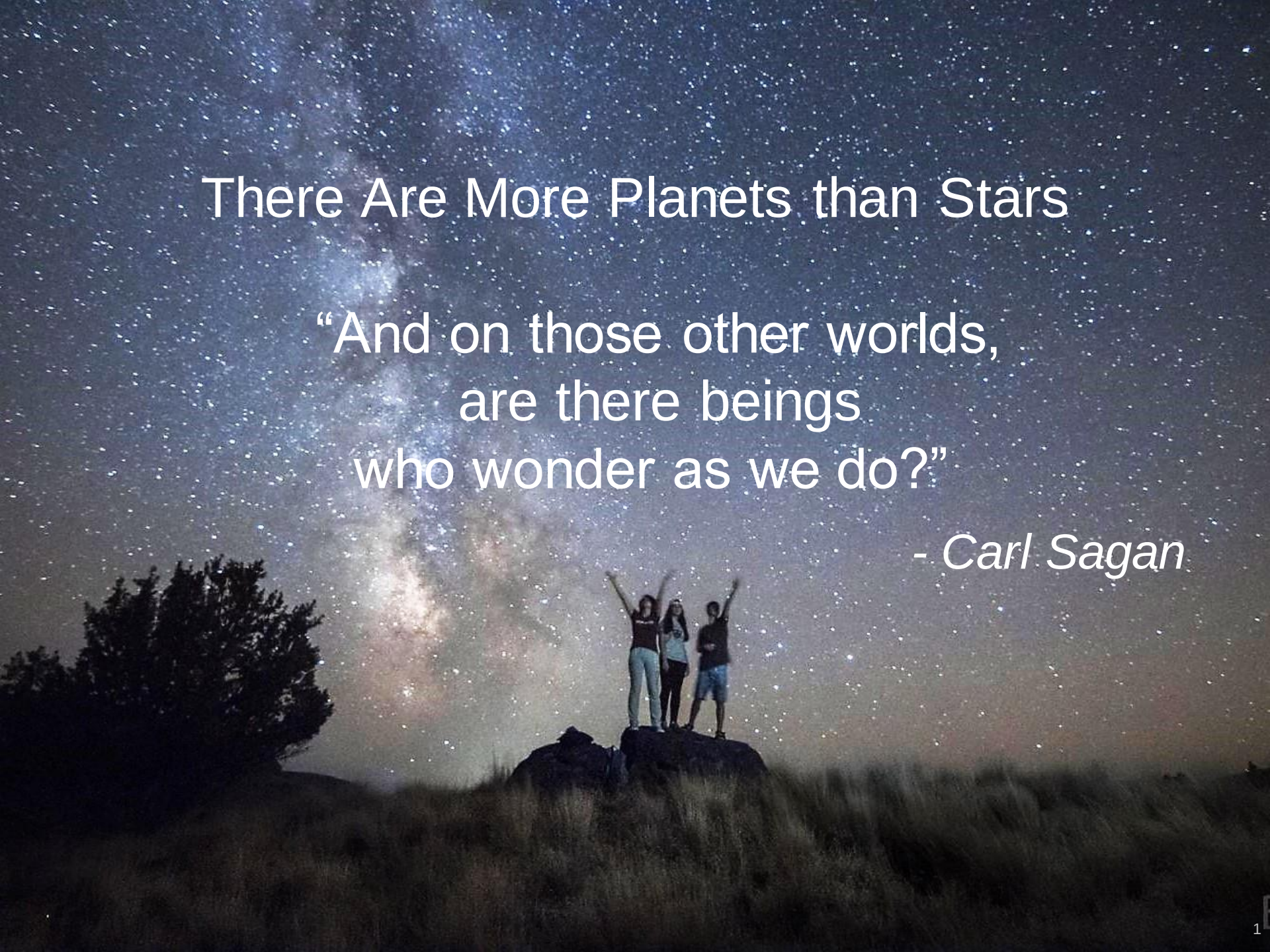
Manager, NASA Exoplanet Exploration Program
Jet Propulsion Laboratory
California Institute of Technology

May 12, 2021
Citi Program Management Awareness Week

URS300140

Artist concept of Kepler-16b


There Are More Planets than Stars
“And on those other worlds,
are there beings
who wonder as we do?”
- Carl Sagan

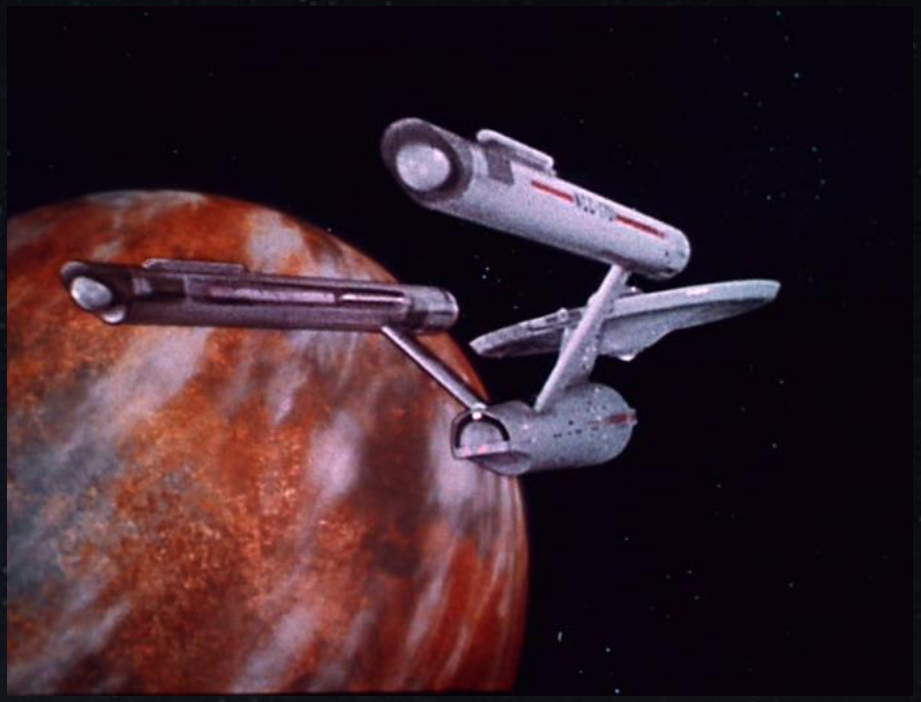
ex·o·plan·et

[ˈeksōˌplanət]

a planet which orbits a star

outside

our solar system



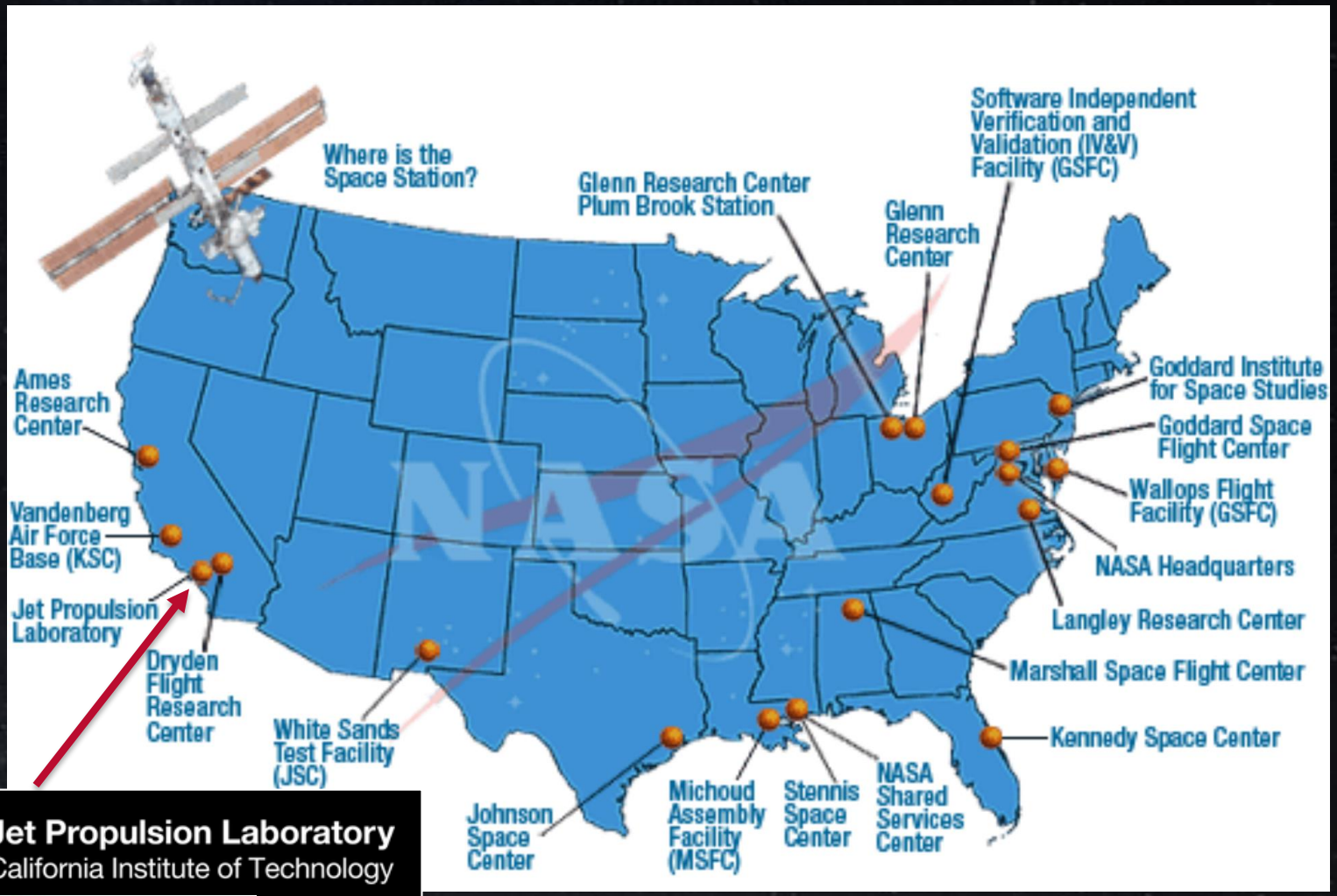
The Search for Life in our Galaxy

Excellence: Explore, Inspire, Aspire !

Planet Earth

NASA Highlights

Where's NASA?



Jet Propulsion Laboratory
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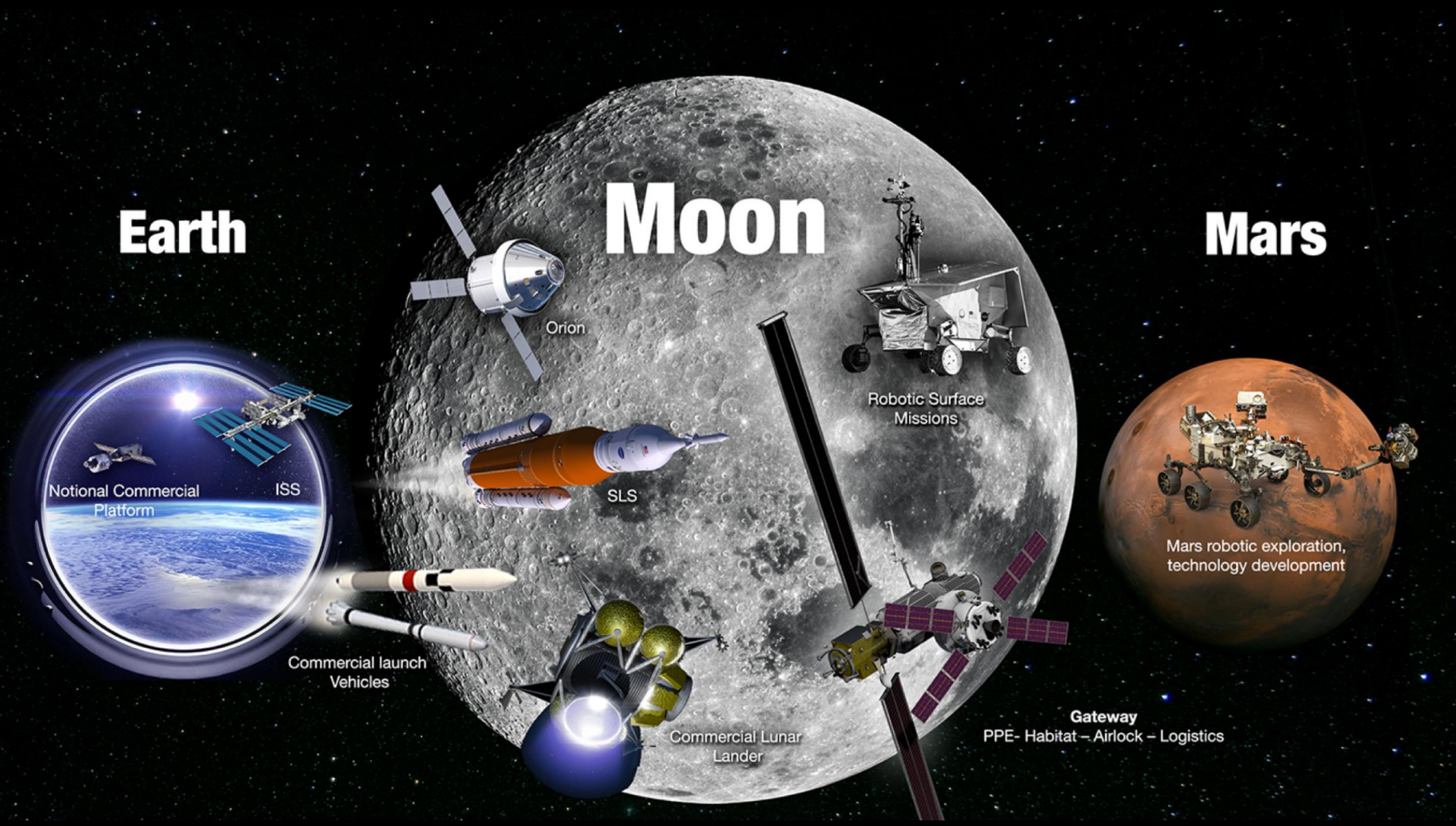
Pasadena, California

How is NASA Organized?

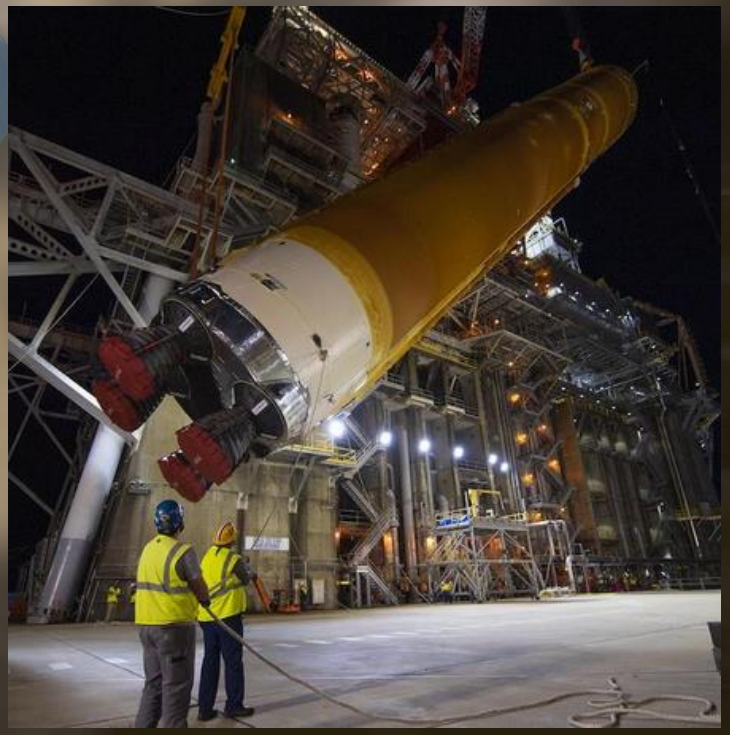
Mission Directorates:

- Human Exploration and Operations
- Science
- Space Technology
- Aeronautics Research

Moon to Mars


Earth
Moon
Mars
Orion
Robotic Surface Missions
Notional Commercial Platform
ISS
SLS
Mars robotic exploration, technology development
Commercial launch Vehicles
Commercial Lunar Lander
Gateway
PPE- Habitat – Airlock – Logistics

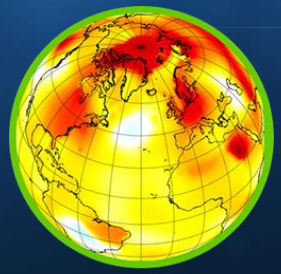
Space Launch System



NASA Key Science Themes

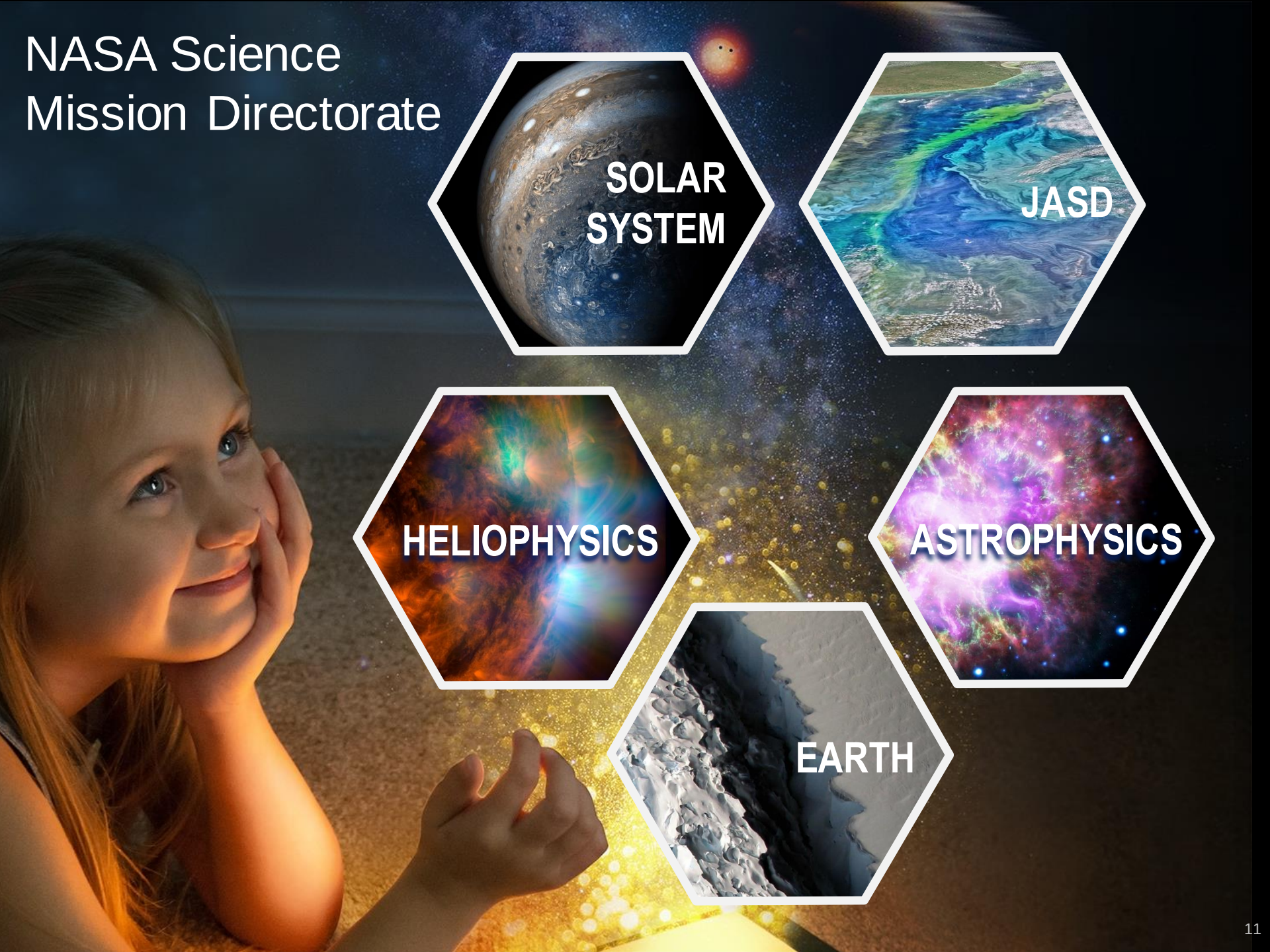
Discovering the Secrets of the Universe

Searching for Life Elsewhere

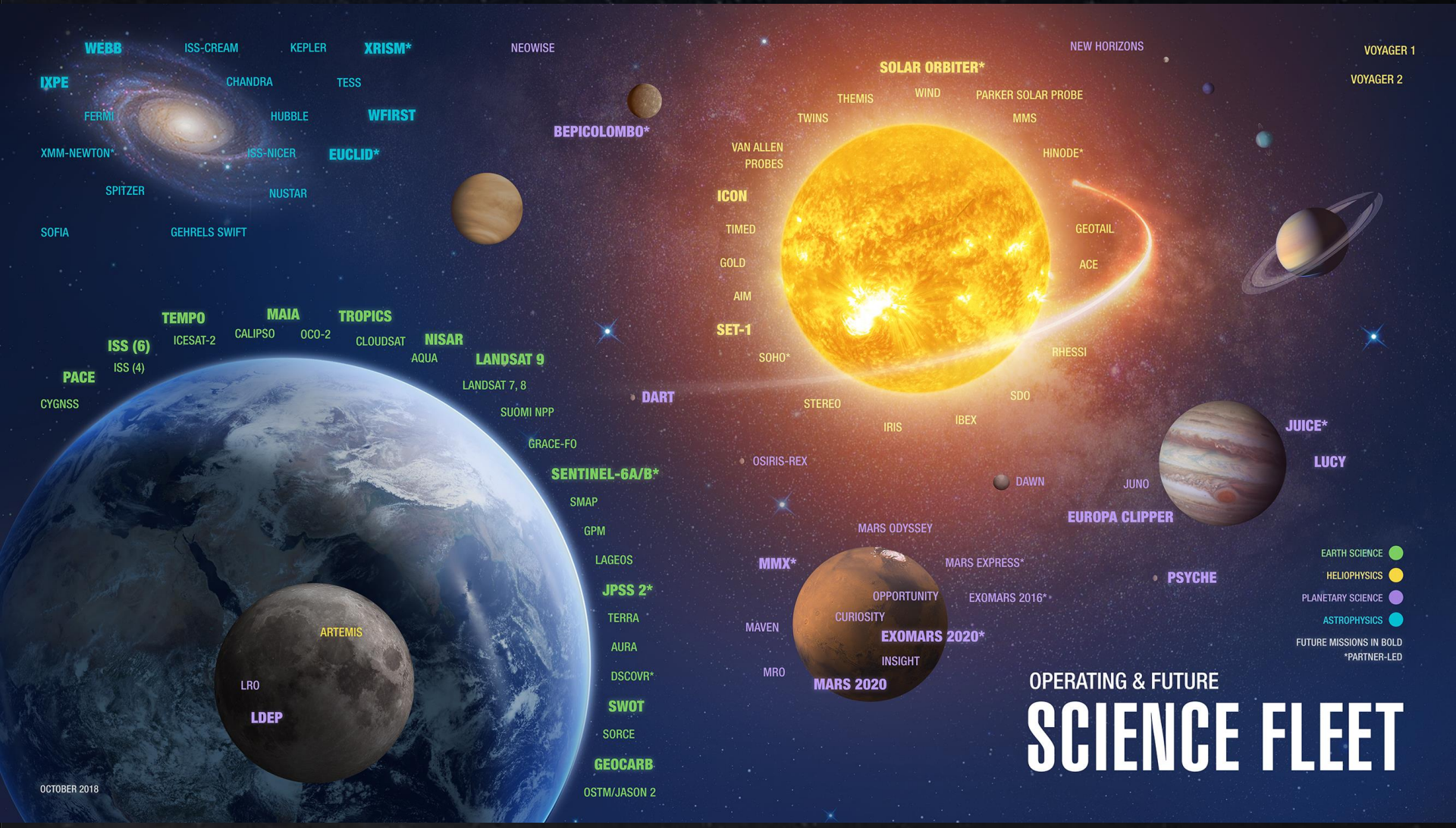


Safeguarding and Improving Life on Earth

NASA Science Mission Directorate

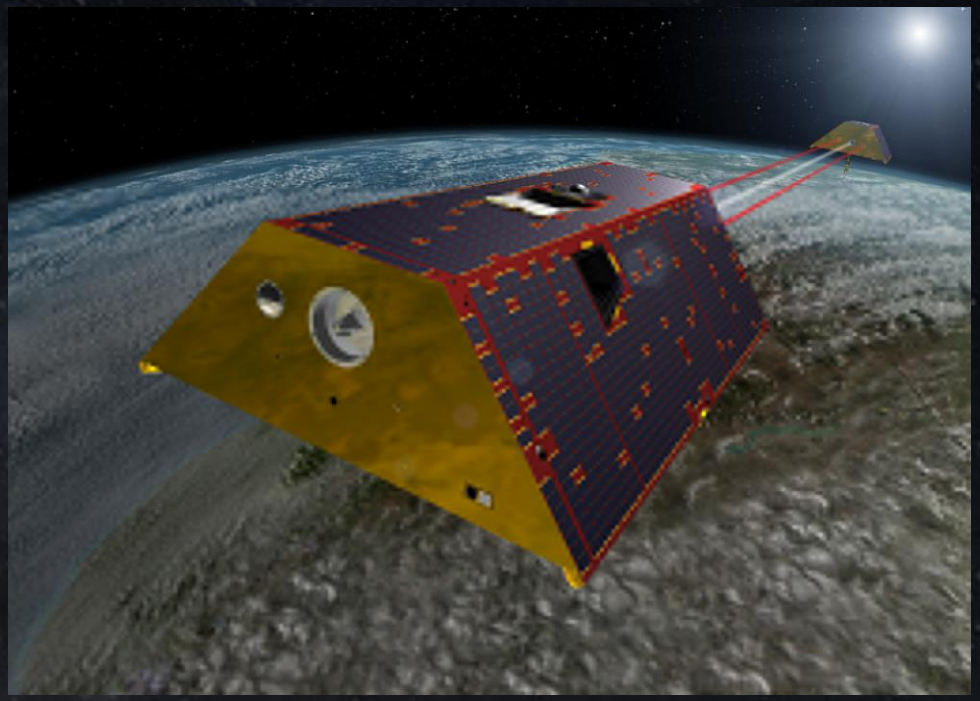


NASA Science Fleet



GRACE Follow-On

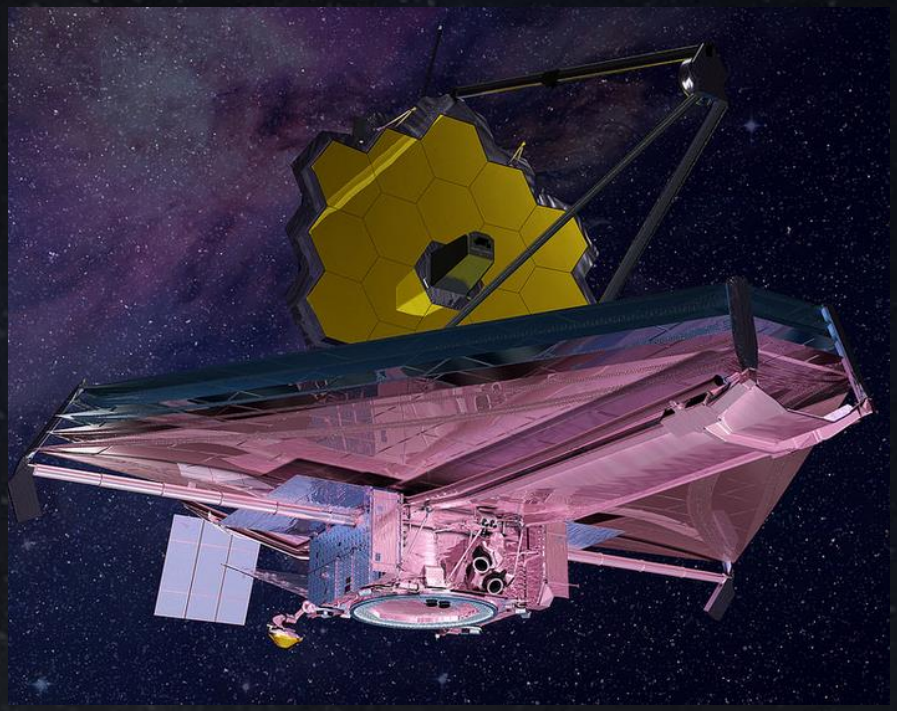
Tracking Earth's Water Movement across the Whole Planet

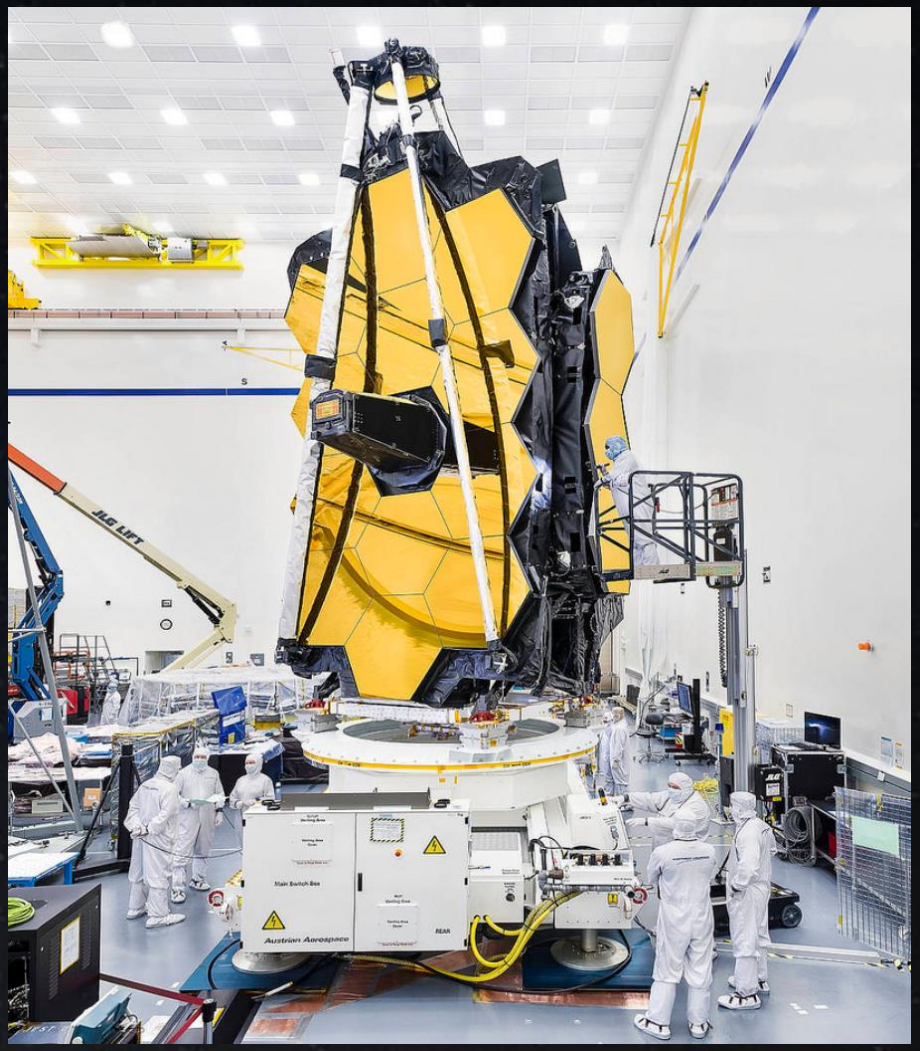


GRACE Data 2002–2017

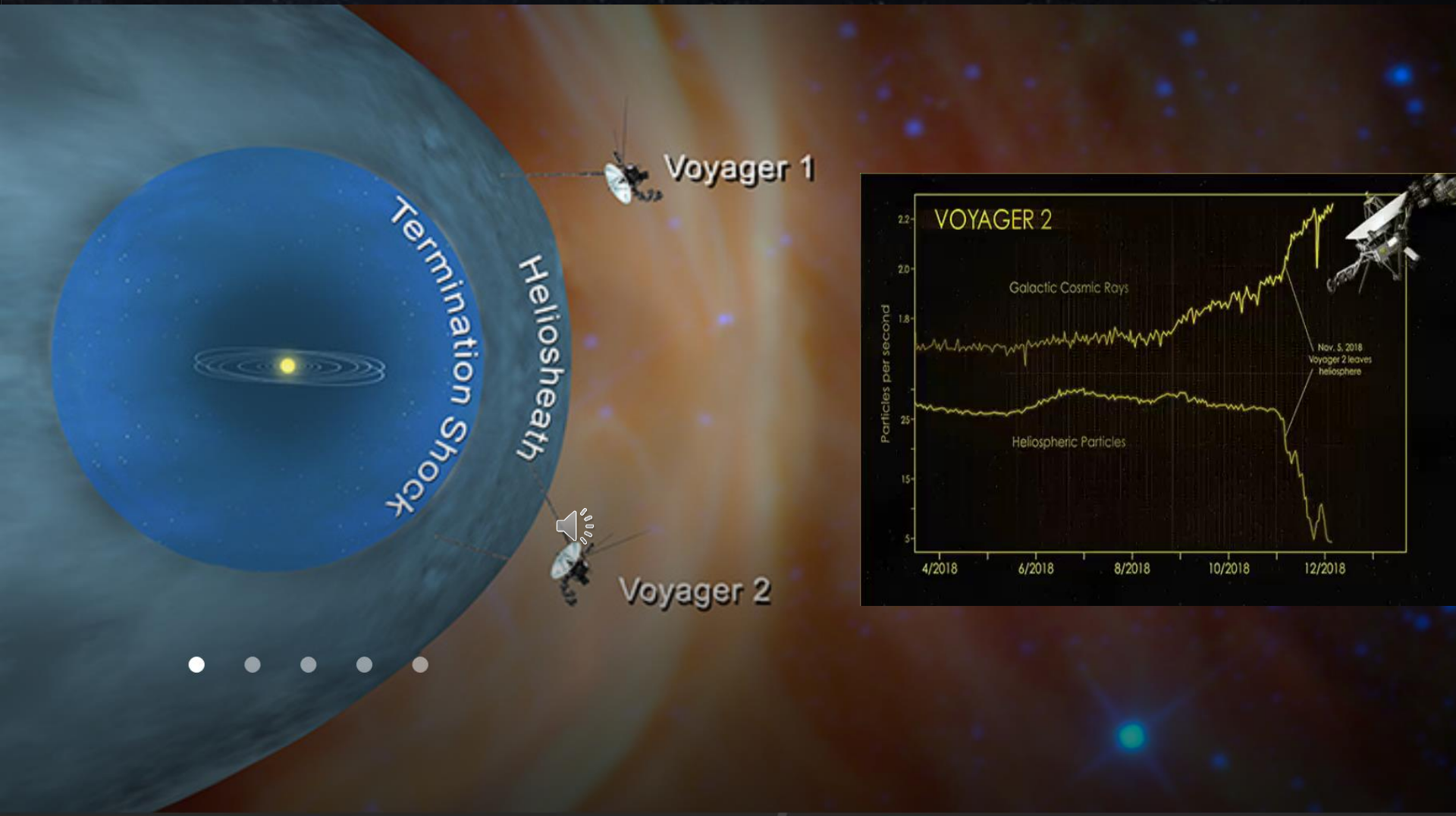
James Webb Space Telescope

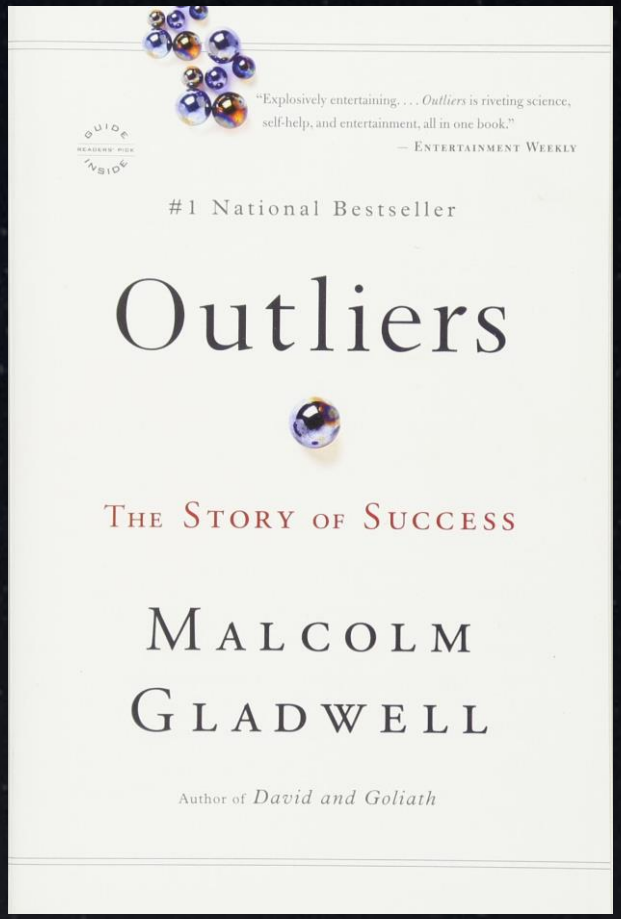
2021 Launch





Voyager 2 Enters Interstellar Space




"Explosively entertaining. . . . Outliers is riveting science, self-help, and entertainment, all in one book."
— Entertainment Weekly
GUIDE
READERS' PICK
INSIDE
#1 National Bestseller
Outliers
The Story of Success
Malcolm Gladwell
Author of David and Goliath

The Search for Life in our Galaxy

Are We Alone?

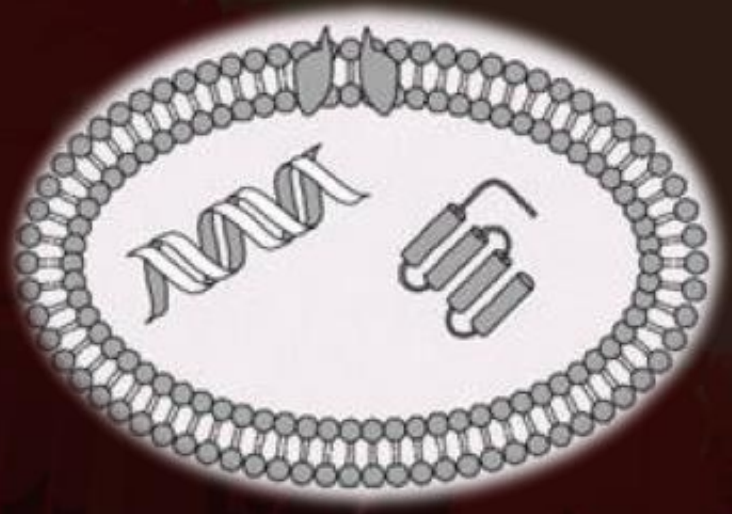
Do We Understand Life?

NASA/Joyce Definition:

"A self-sustaining chemical system capable of Darwinian evolution"

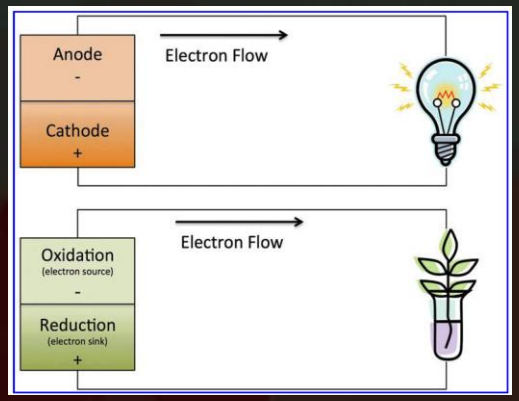
Traits Common to Life on Earth

- Ordered structure
- Reproduction
- Growth and development
- Response to environment
- Homeostatis
- Evolutionary adaptation
- Energy utilization

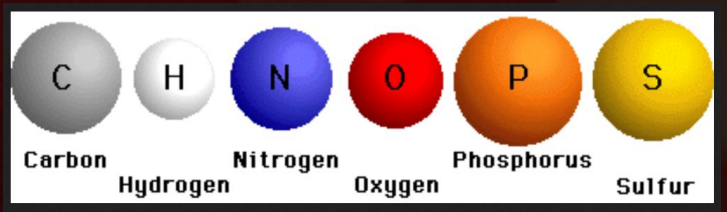


What Is Essential for Life?

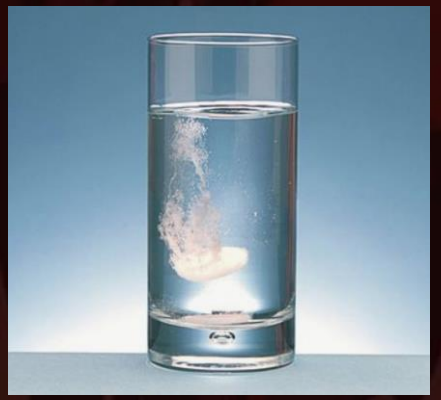
Source of Energy



Essential Elements

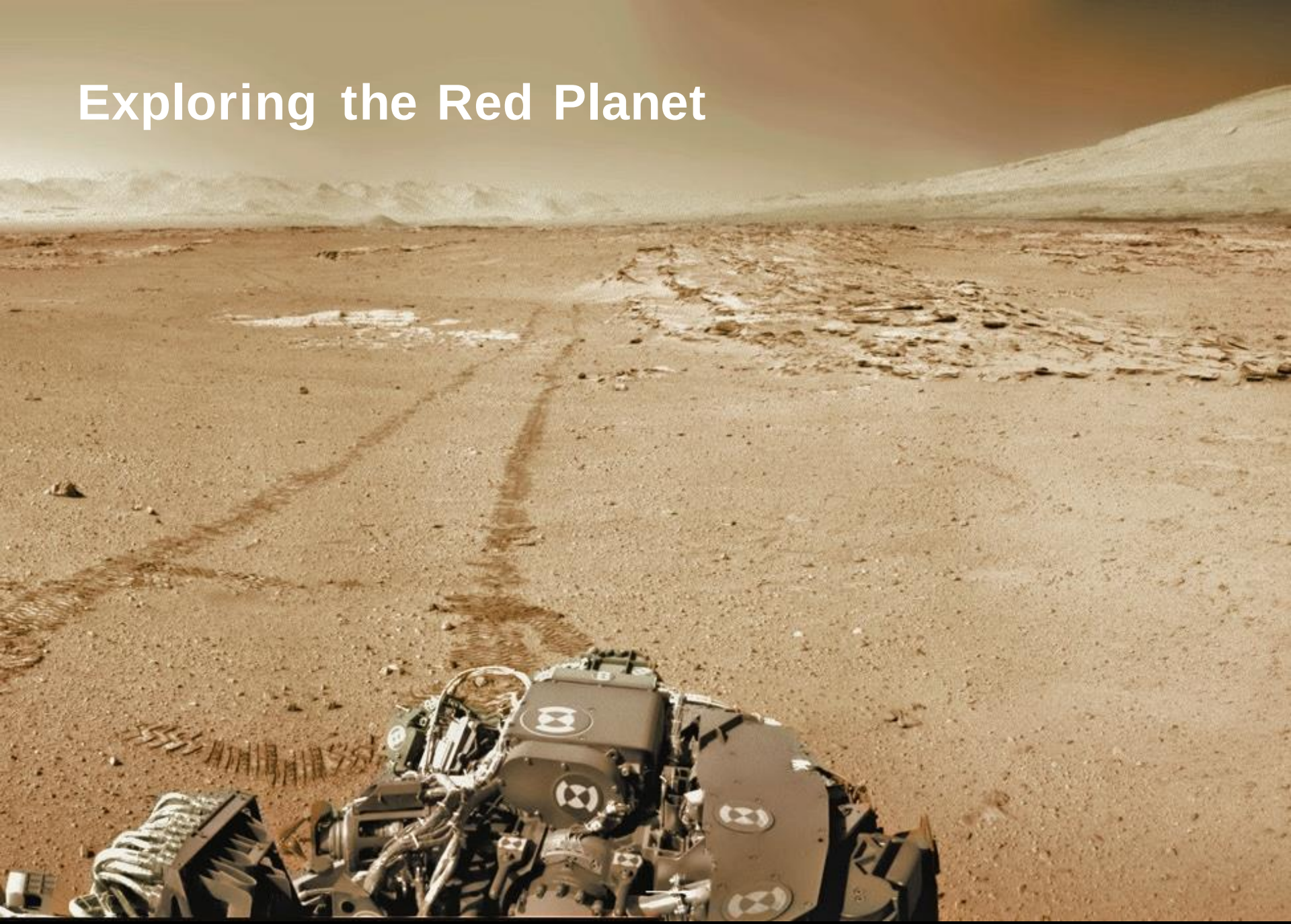


Solvent to Host Chemical Reactions

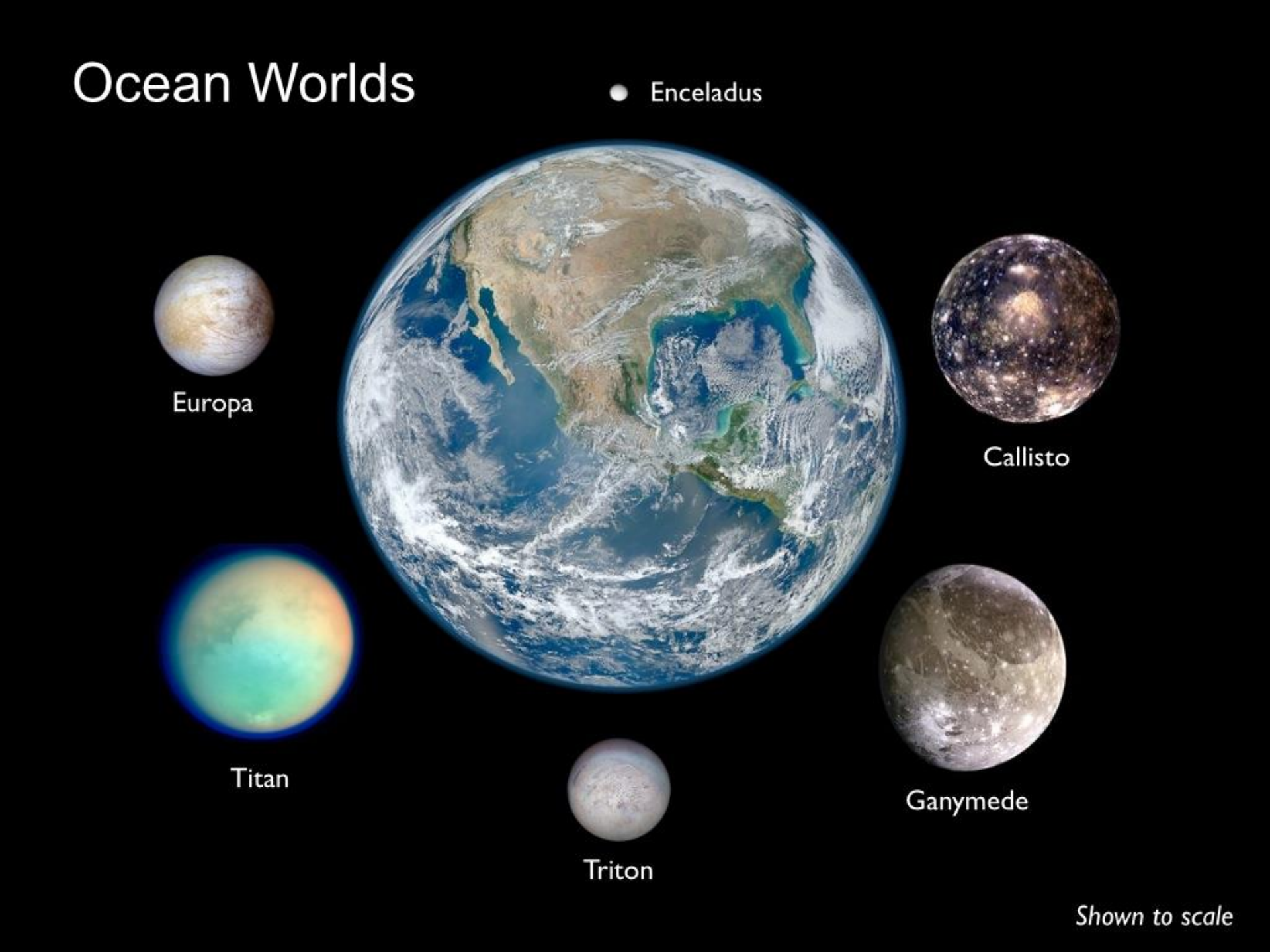


Extreme Environments Support Life

Exploring the Red Planet

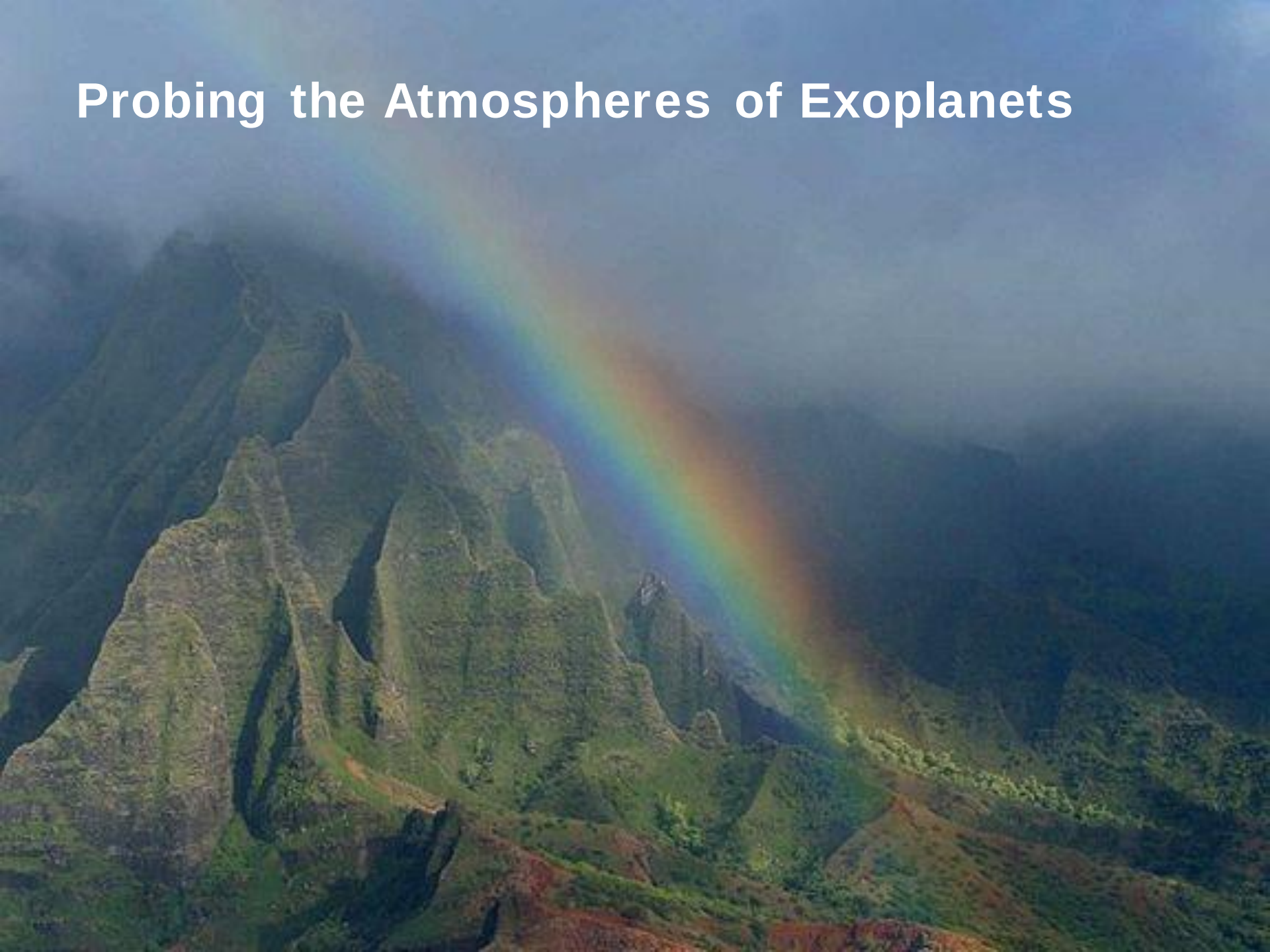


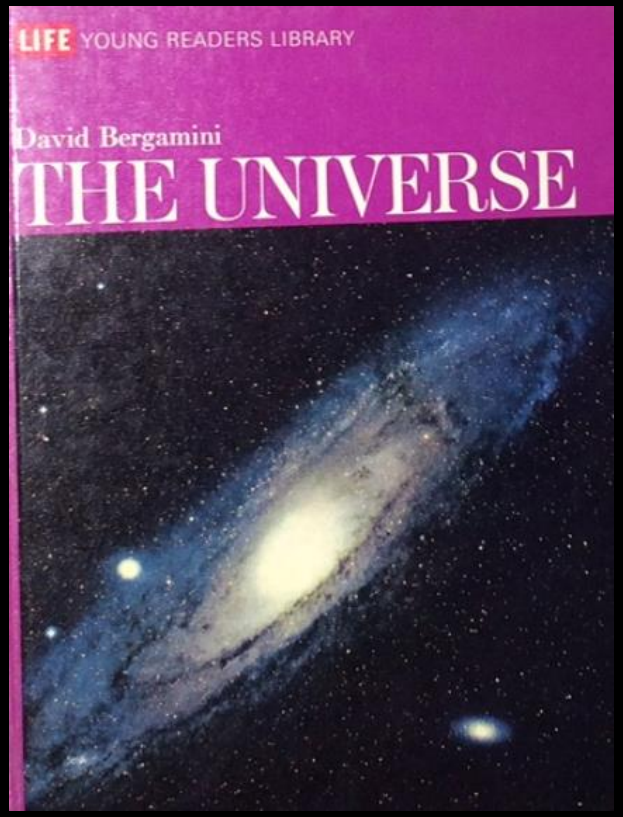
Ocean Worlds




Search for
Technosignatures

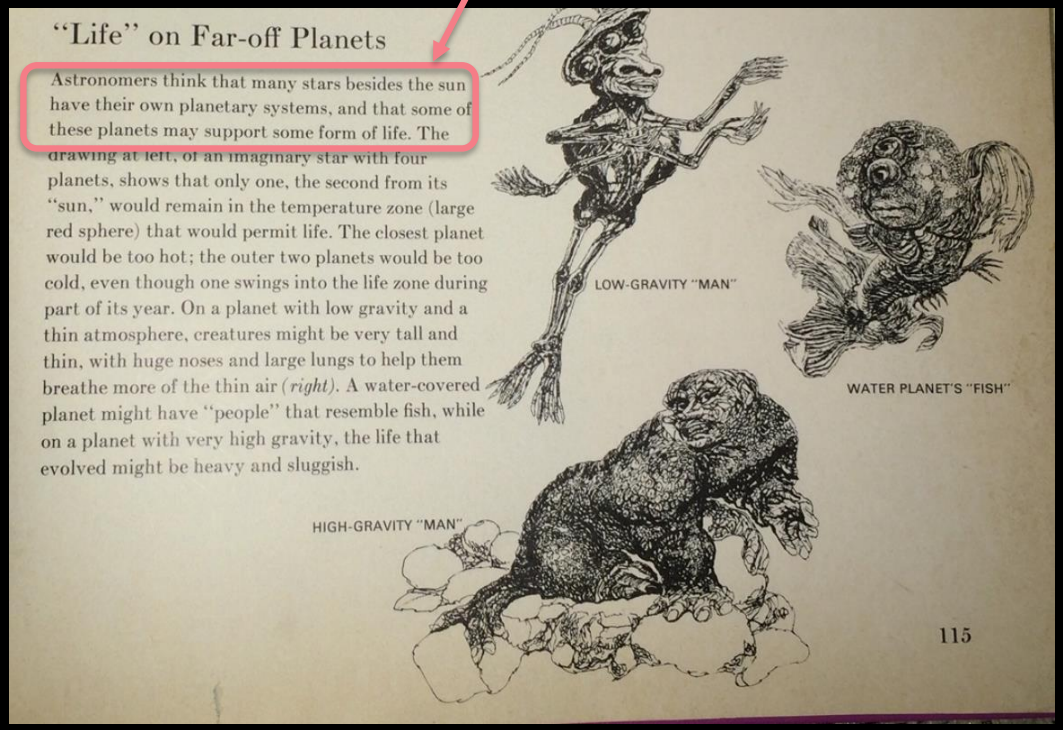
Probing the Atmospheres of Exoplanets





1962

"Astronomers think that many stars besides the sun have their own planetary systems, and that some of these planets may support some form of life"



"Life" on Far-off Planets

Astronomers think that many stars besides the sun have their own planetary systems, and that some of these planets may support some form of life. The drawing at left, of an imaginary star with four planets, shows that only one, the second from its "sun," would remain in the temperature zone (large red sphere) that would permit life. The closest planet would be too hot; the outer two planets would be too cold, even though one swings into the life zone during part of its year. On a planet with low gravity and a thin atmosphere, creatures might be very tall and thin, with huge noses and large lungs to help them breathe more of the thin air (*right*). A water-covered planet might have "people" that resemble fish, while on a planet with very high gravity, the life that evolved might be heavy and sluggish.

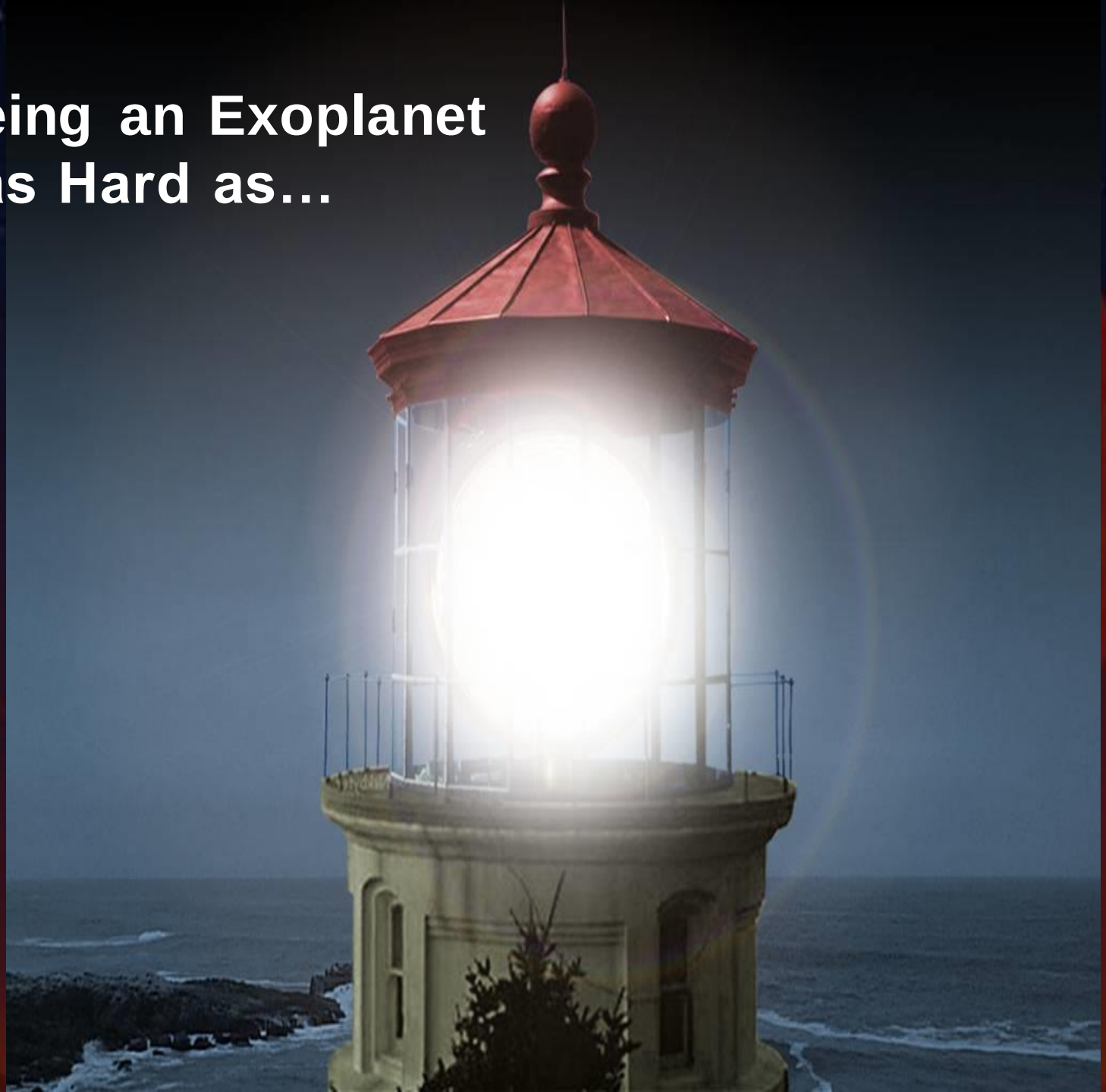
LOW-GRAVITY "MAN"

WATER PLANET'S "FISH"

HIGH-GRAVITY "MAN"

115

Seeing an Exoplanet Is as Hard as…

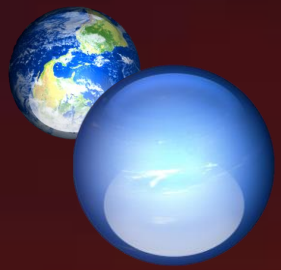


How Are Exoplanets Discovered?

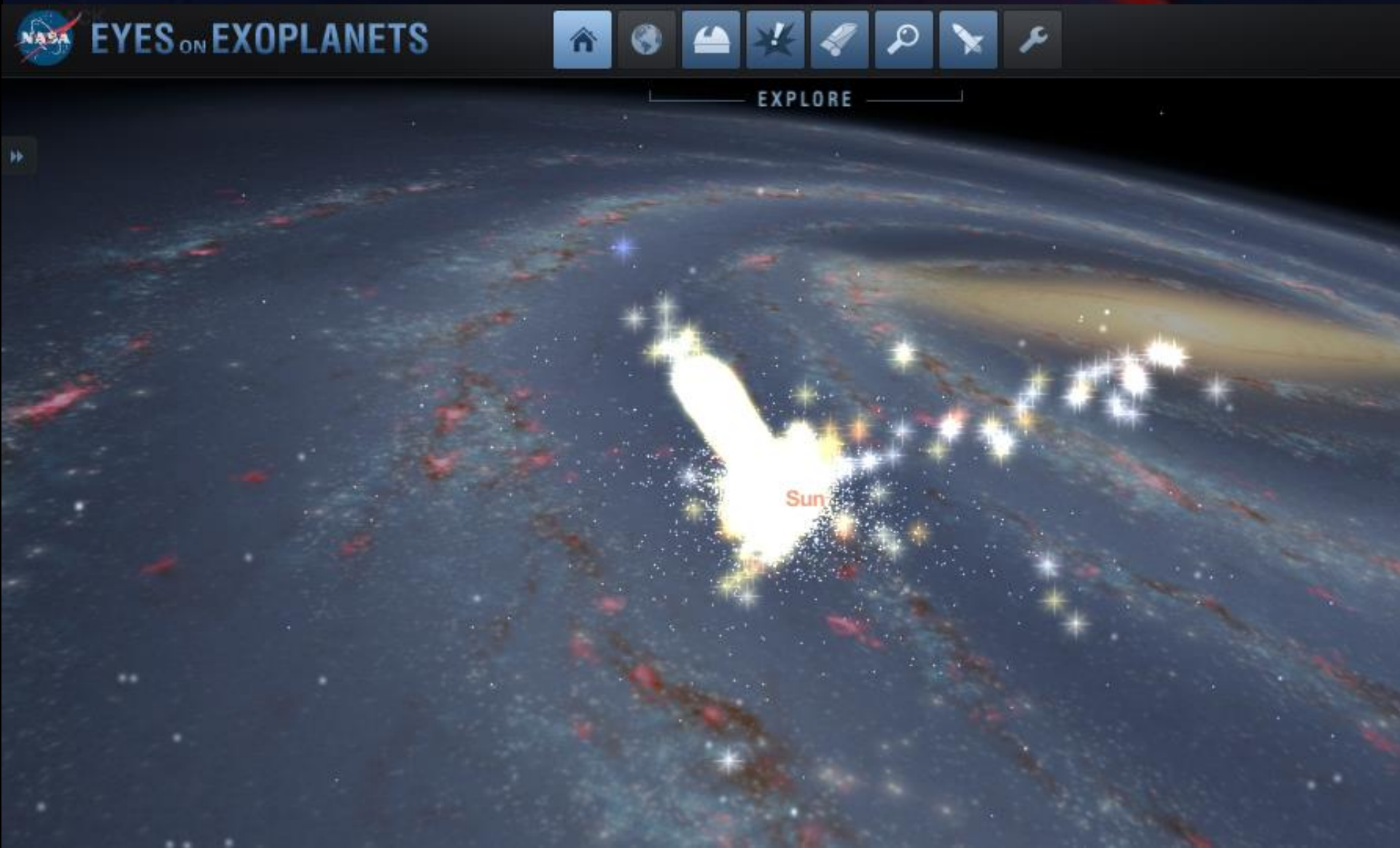
Two Popular Methods

Doppler Spectroscopy
(Radial Velocity)

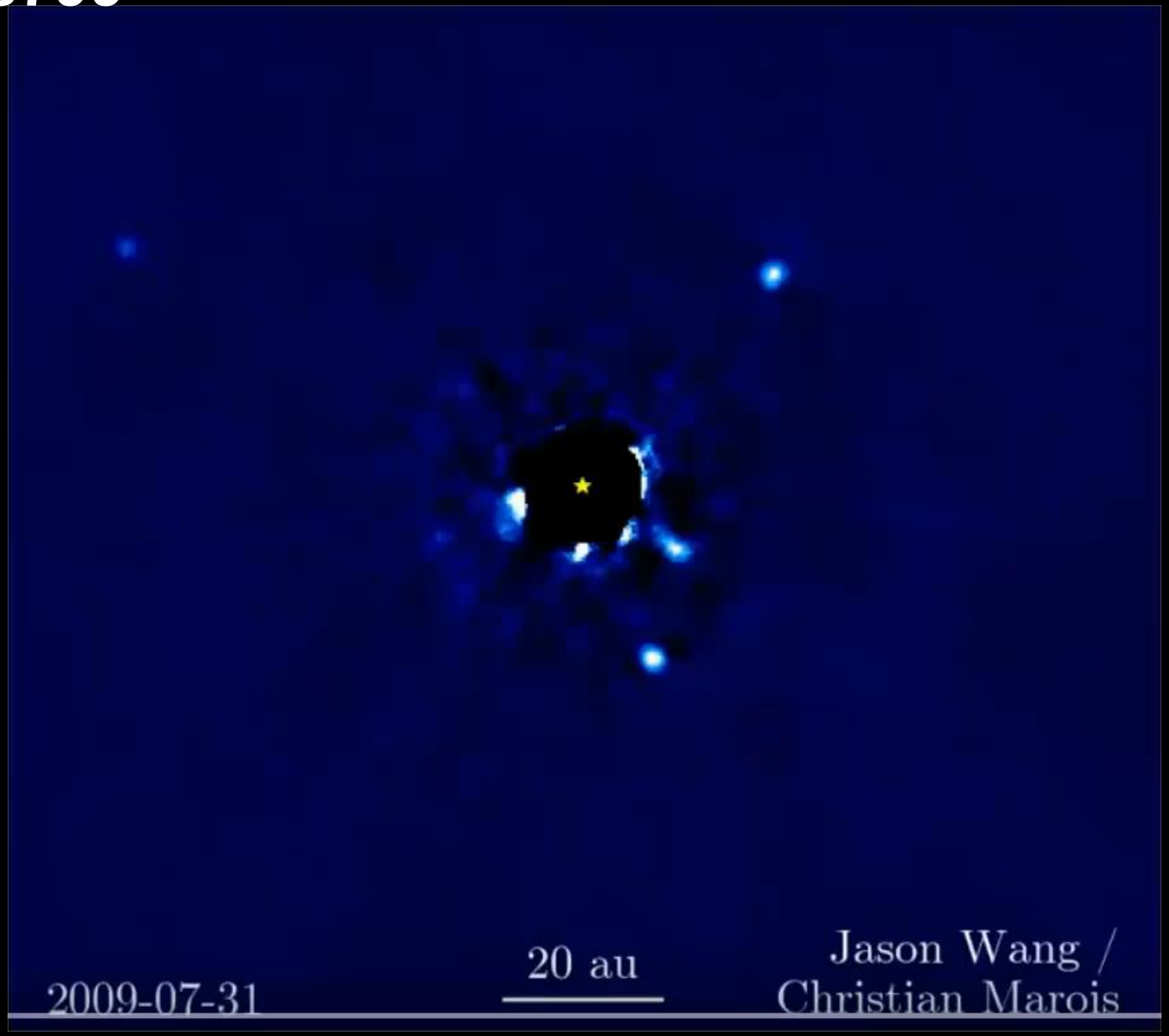
Transit



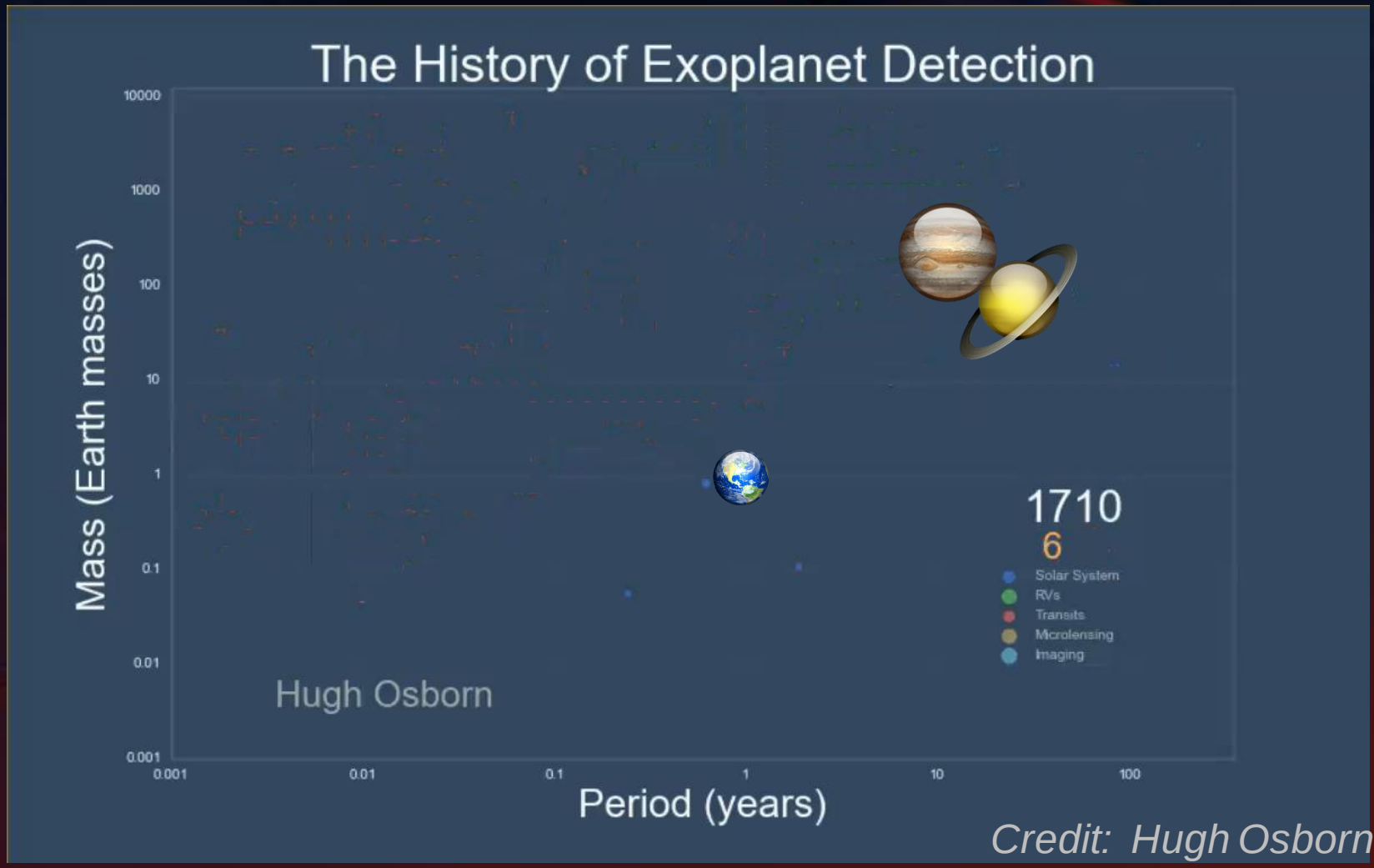
Where Are the Eggsoplanets?



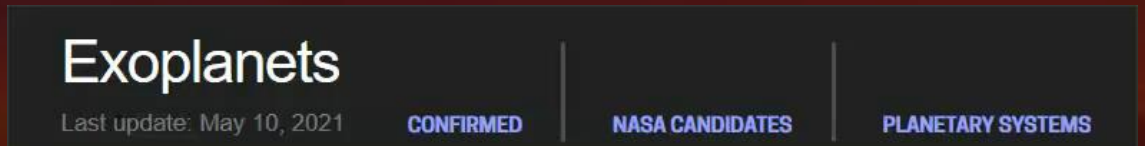
HR 8799



When Were Exoplanets Discovered?



Credit: Hugh Osborn



Kepler Mission: Three Key Results

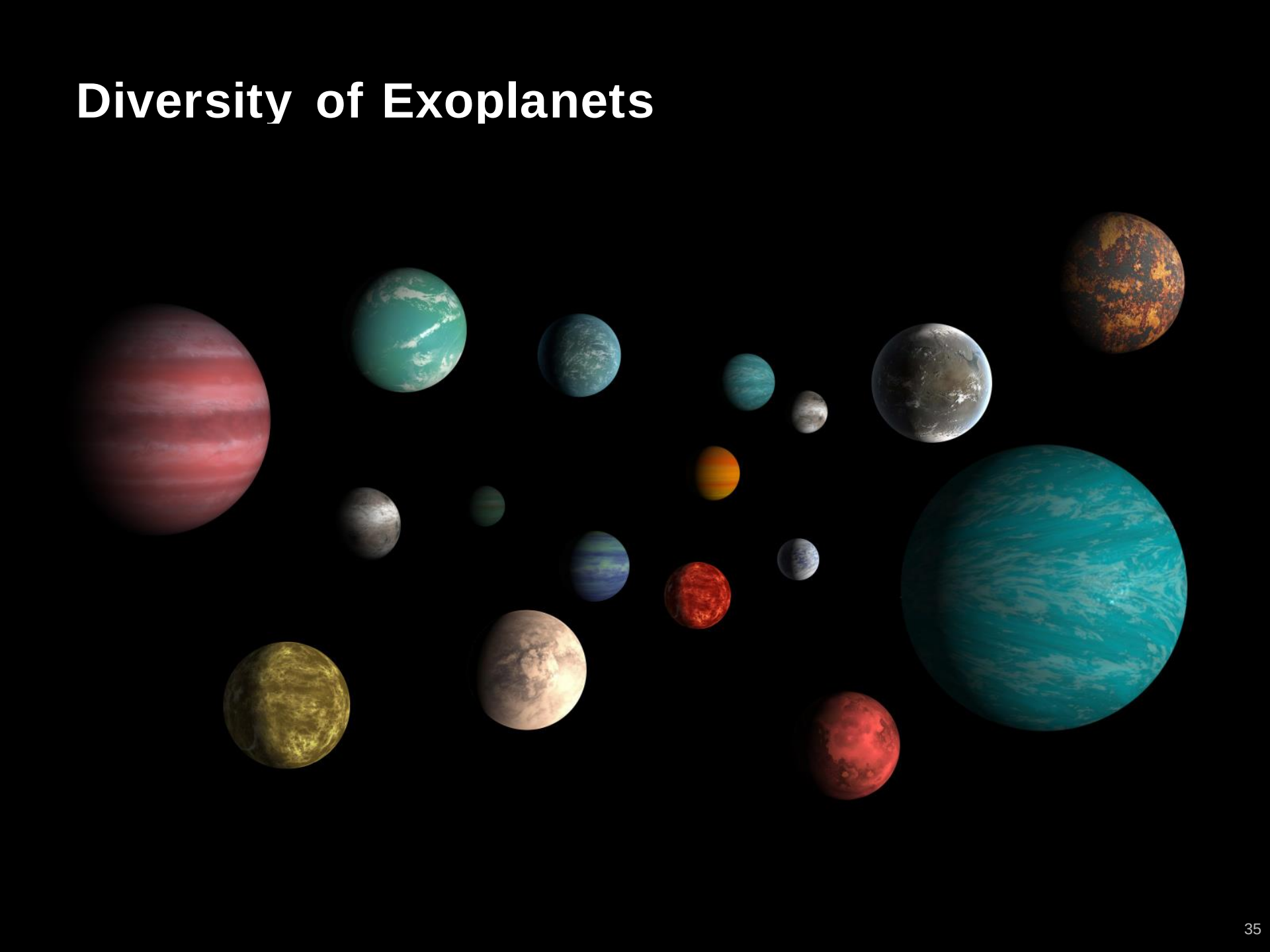
1. There are more planets than stars in the galaxy

2. Small planets are common

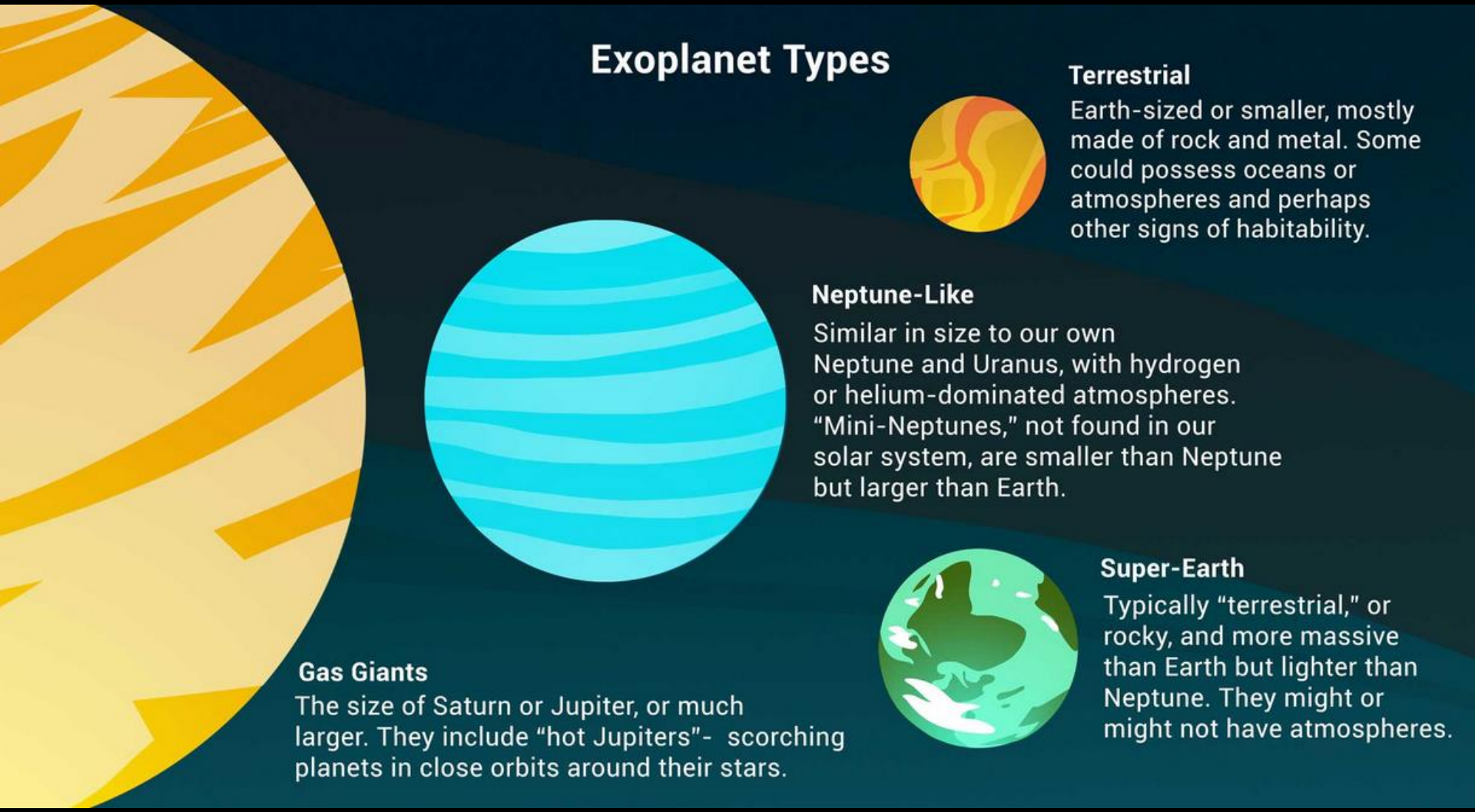
3. Small planets in the Habitable Zone are common

A Familiar Habitable Zone

Diversity of Exoplanets

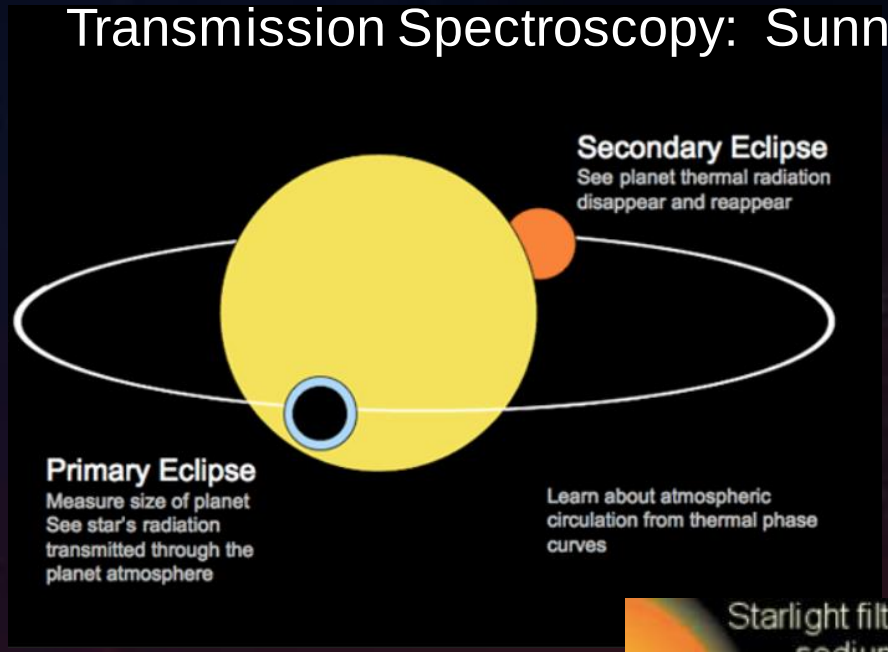


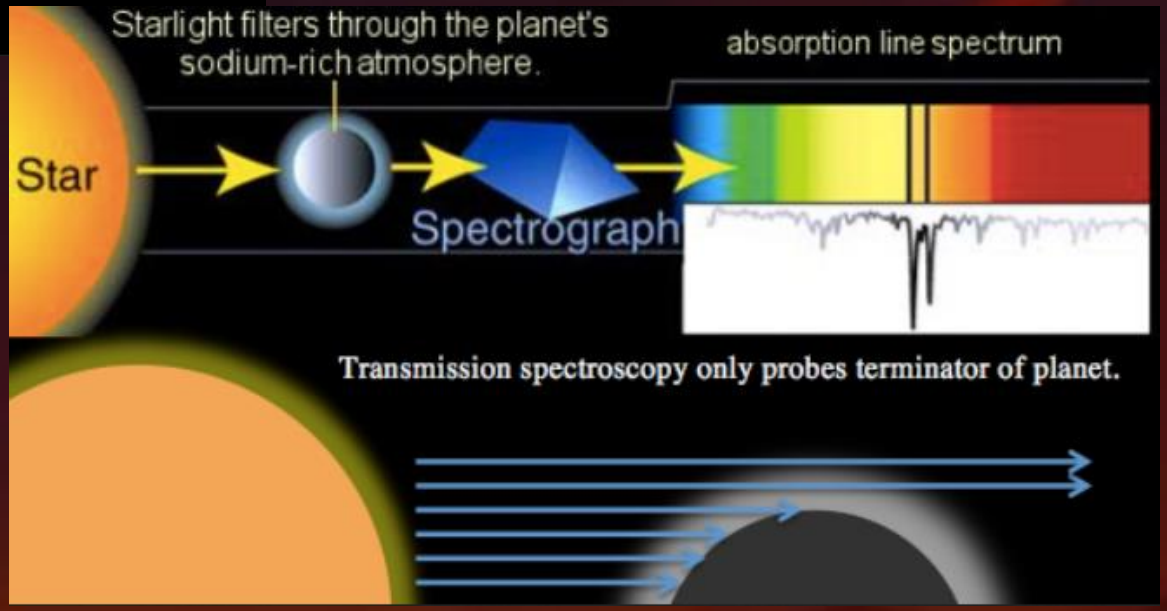
Exoplanet Types



Understanding Exoplanets

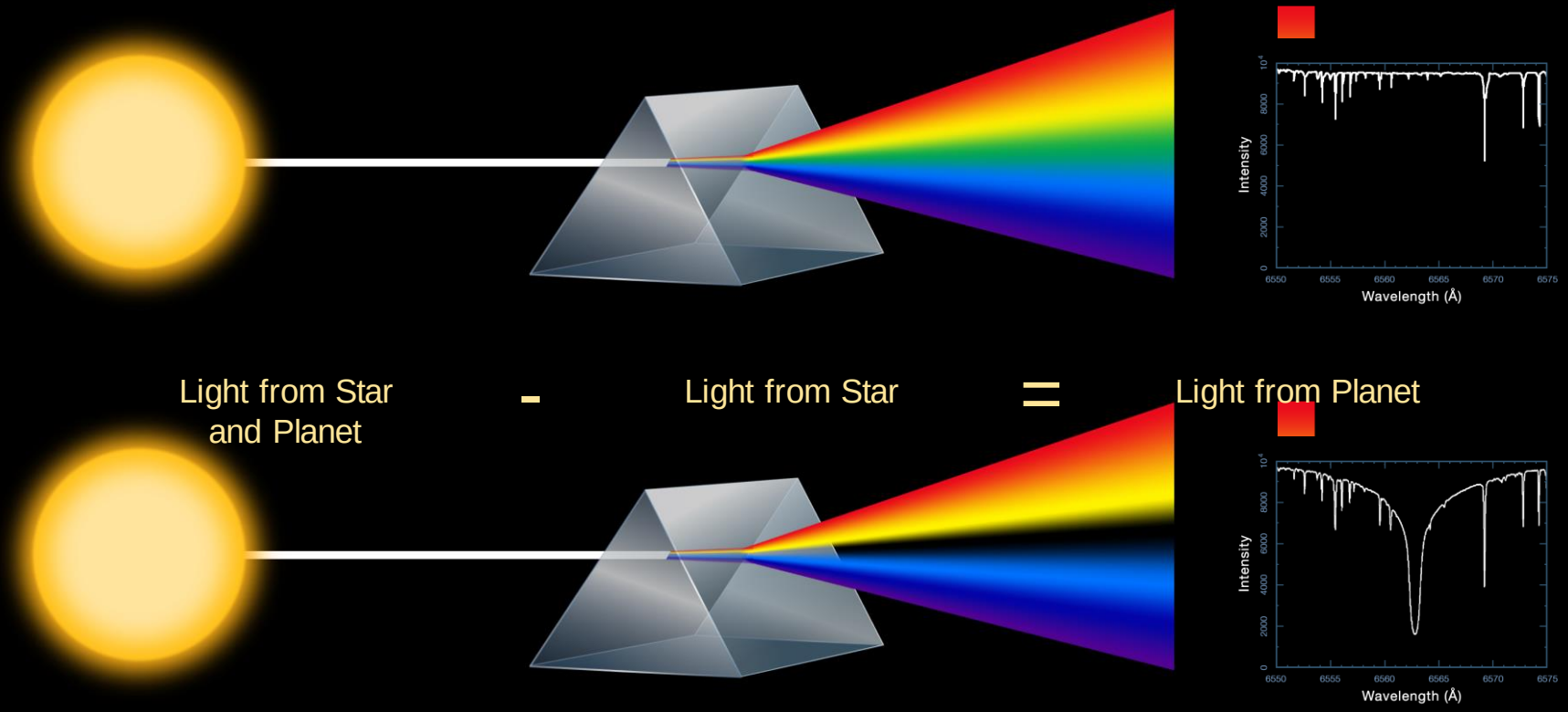
Transmission Spectroscopy: Sunny with a Chance of Clouds



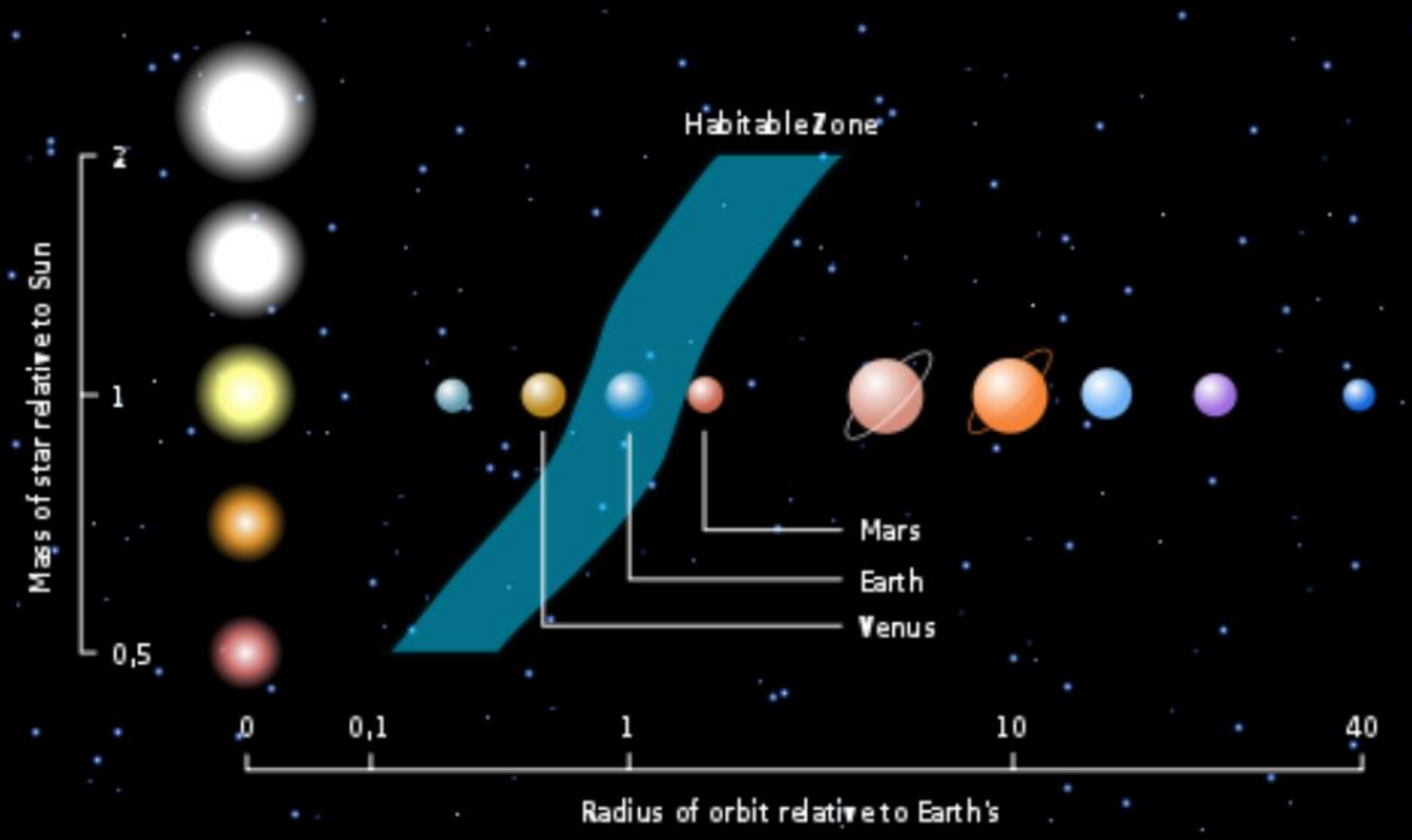


Spectroscopy

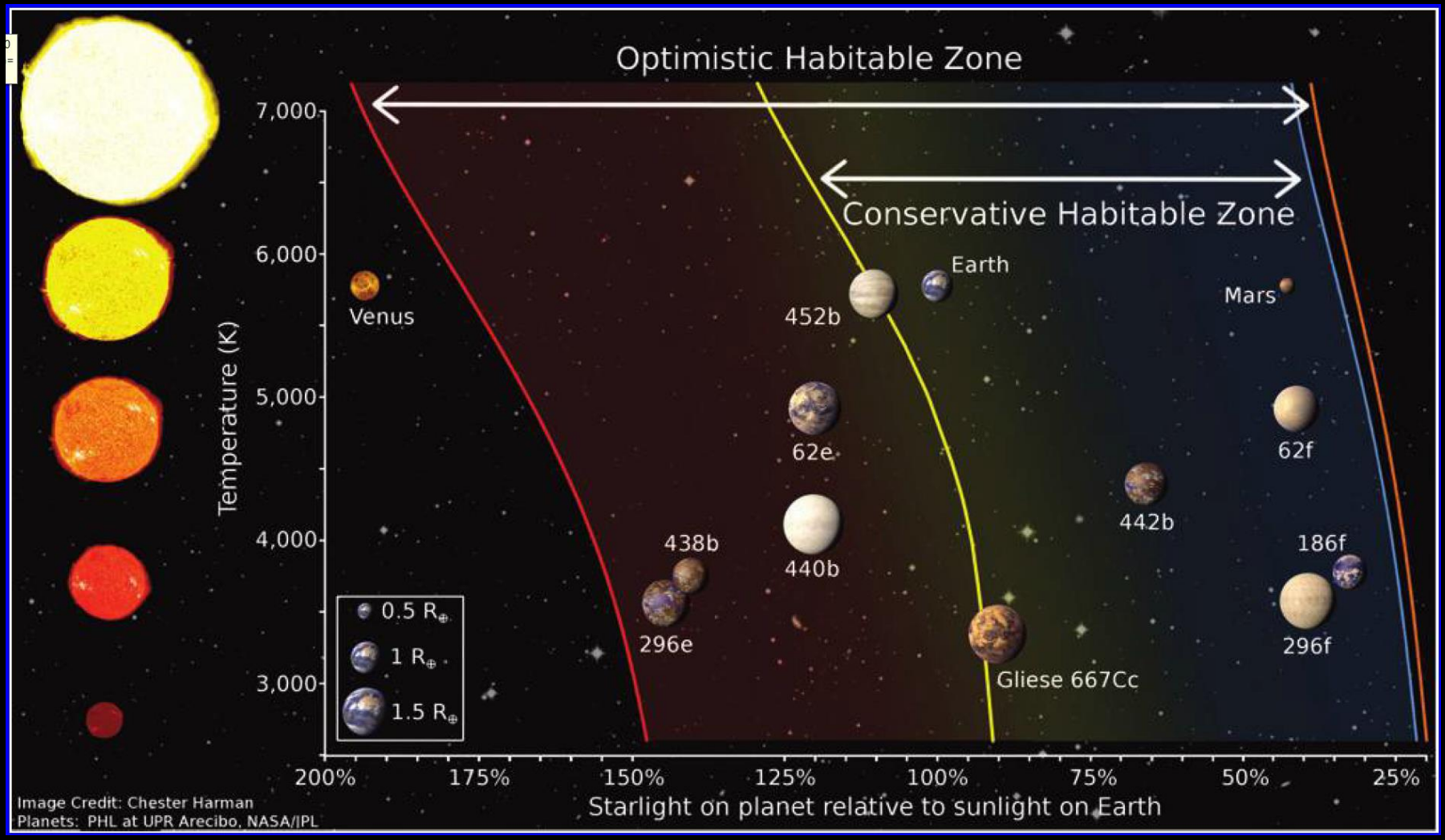
Detection of Biosignatures



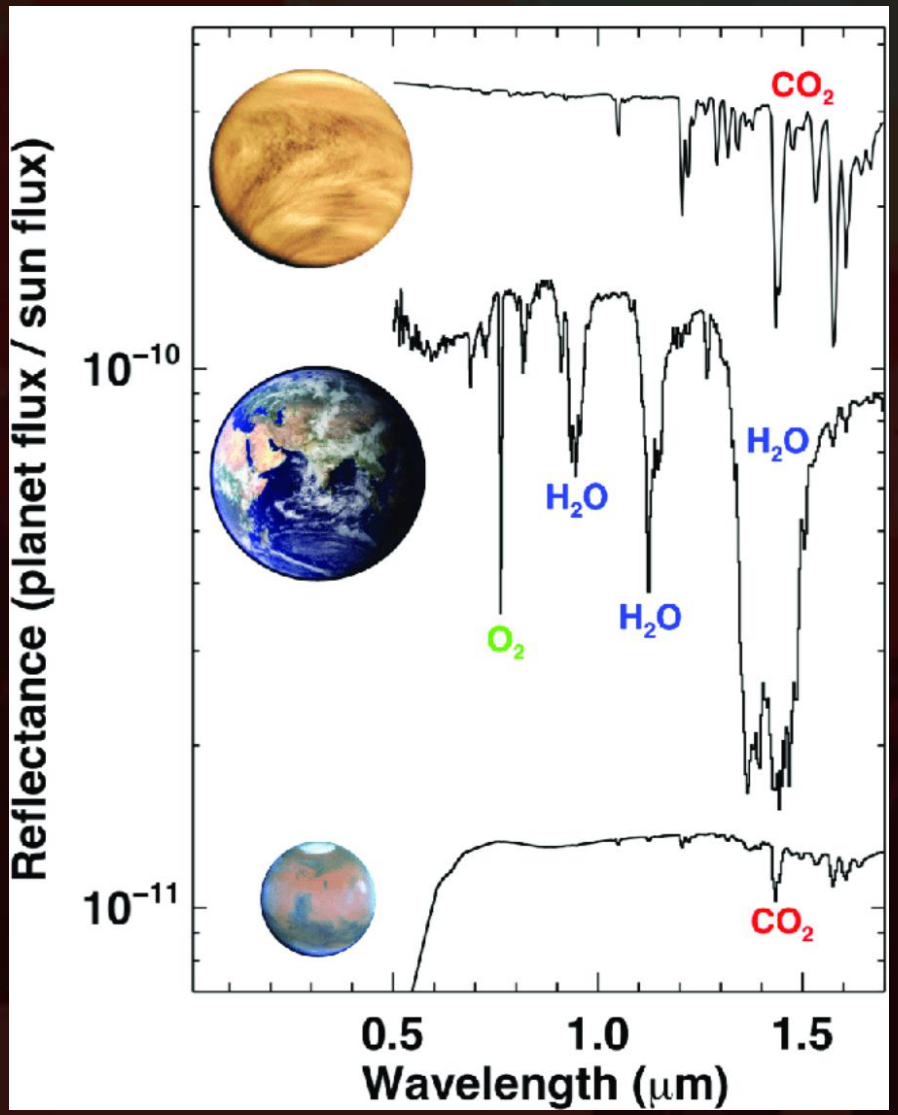
Habitable Zone



Exoplanets in the Habitable Zone



Spectra of Our Solar System Planets



Earth's Spectra

"Blue of the sky" measures total amount of atmosphere

"Vegetation jump" indicates presence of land plants

Carbon dioxide suggests possible volcanic activity

Methane indicates presence of anaerobic bacteria

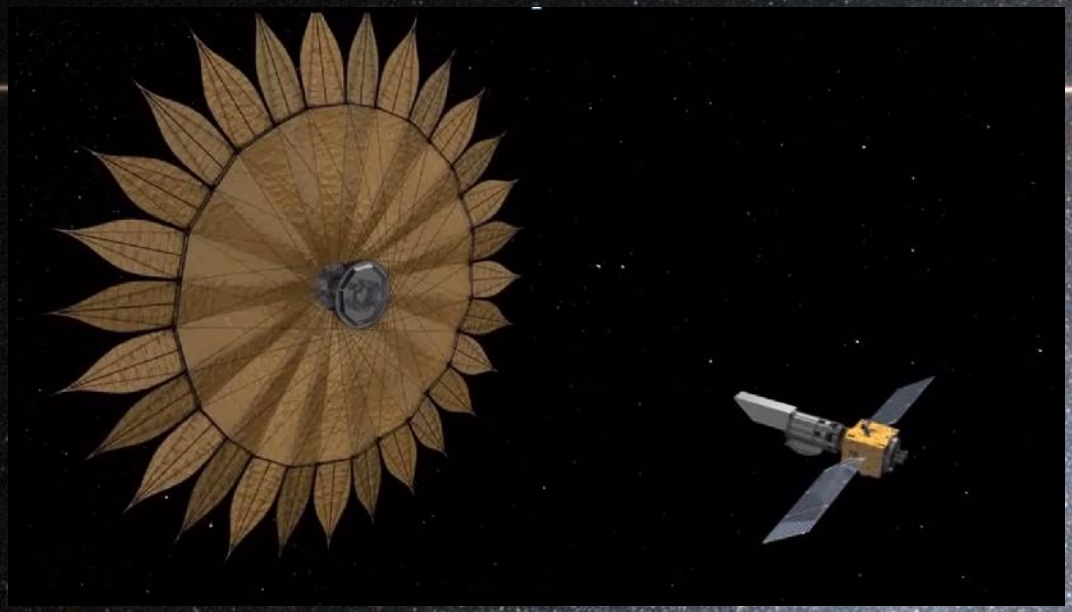
Oxygen and **ozone** were produced by living organisms

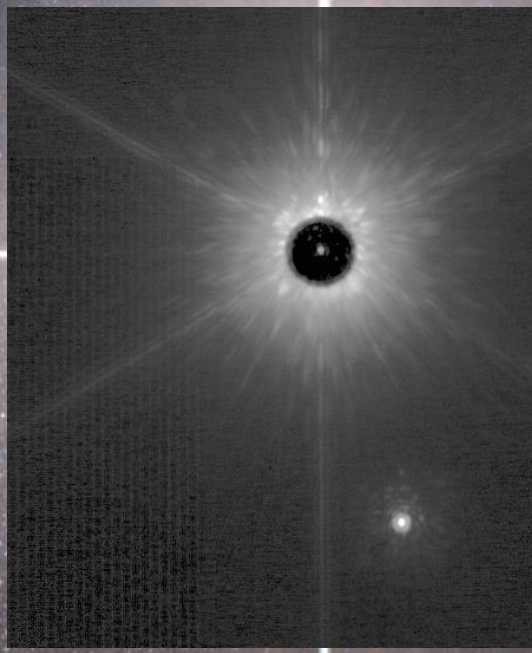
Water vapor suggests habitability

Credit: M. Turnbull

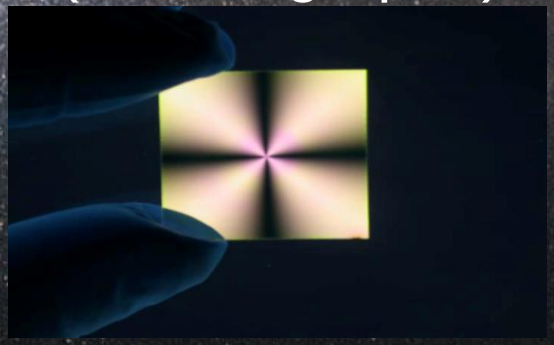
Starlight Suppression

External Occulters
(Starshades)

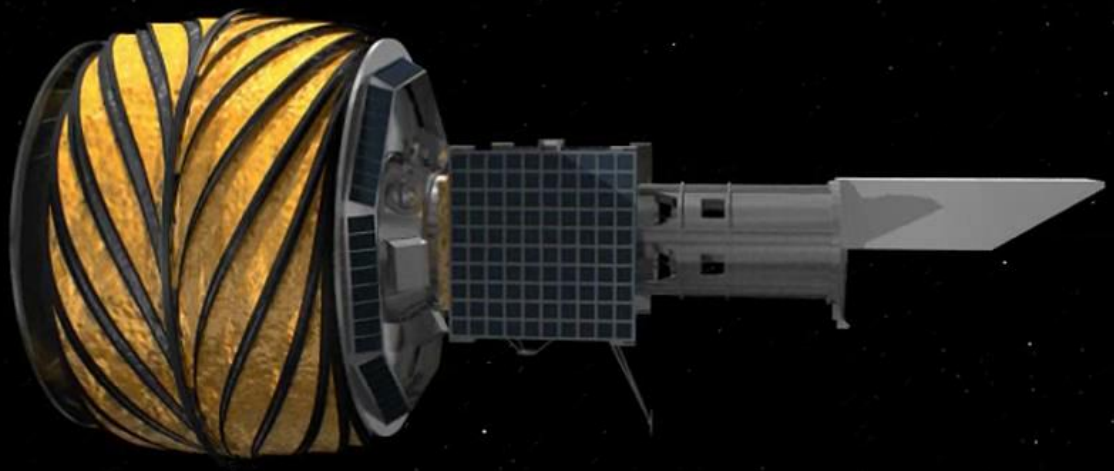


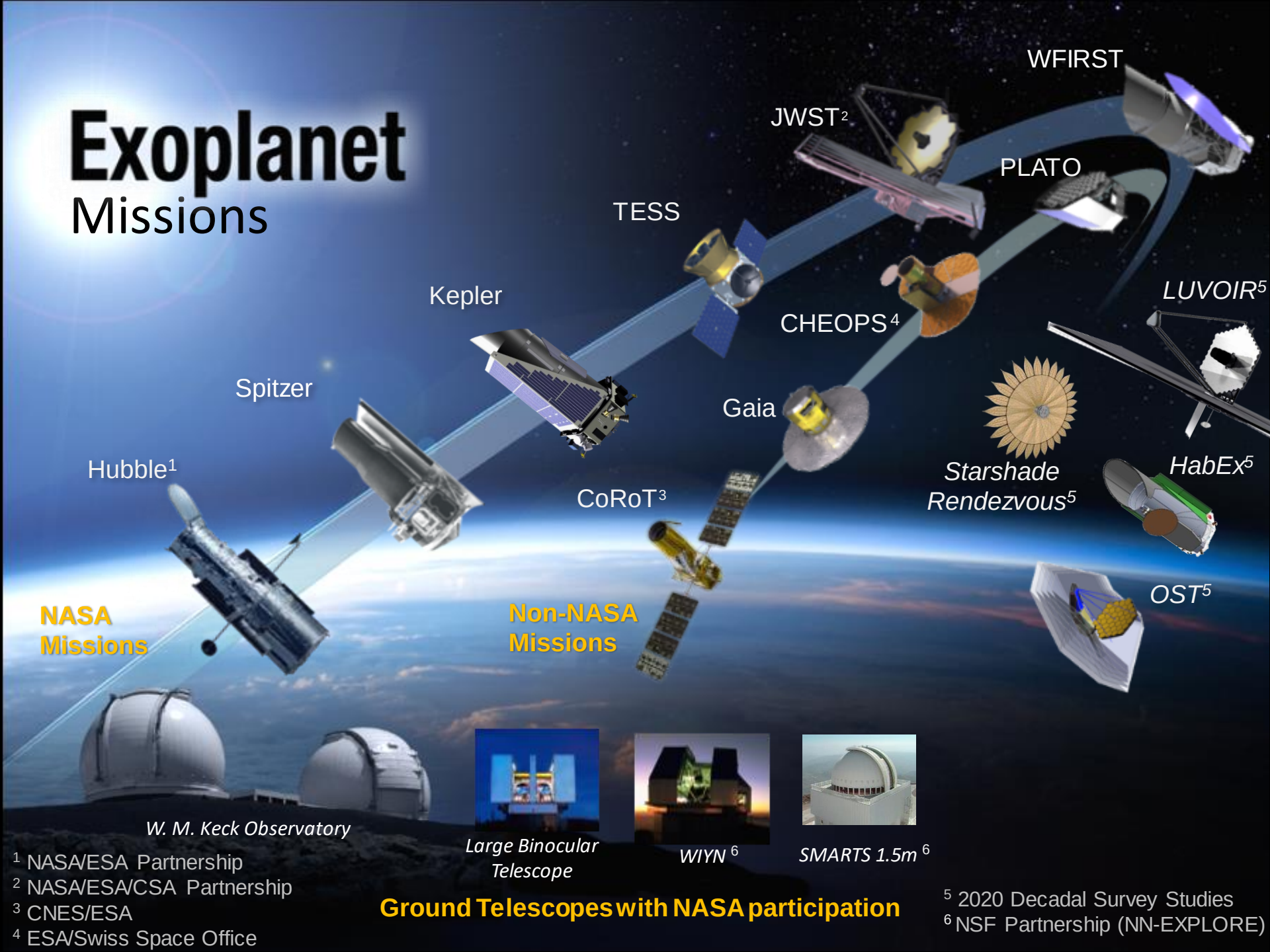


Internal Occulters
(Coronagraphs)



Starshade (External Occulter)





[1] NASA/ESA Partnership
[2] NASA/ESA/CSA Partnership
[3] CNES/ESA
[4] ESA/Swiss Space Office

[5] 2020 Decadal Survey Studies
[6] NSF Partnership (NN-EXPLORE)

Excellence:

Explore, Inspire, Aspire!

Explore: to traverse for the purpose of discovery; to scrutinize, to examine

Inspire: to fill with animating influence; to impel

Aspire: to seek ambitiously, with intent, towards a goal with high value; ascend, soar.

The Search for Life is Aspirational

It Draws us, and Impels us

To Explore and Inspire

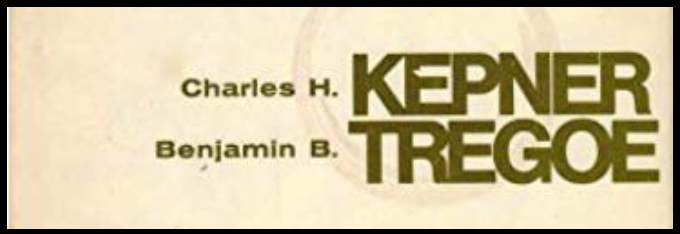
Credit: Nick Siegler


DARE
MIGHTY
THINGS

Ingenuity on Mars

Credit: NASA/JPL-Caltech

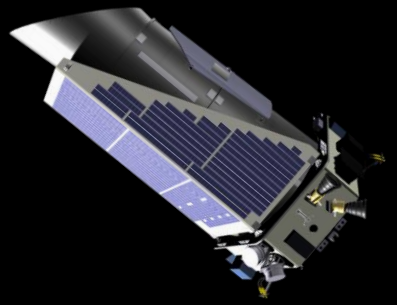
Exploration: Inquiry

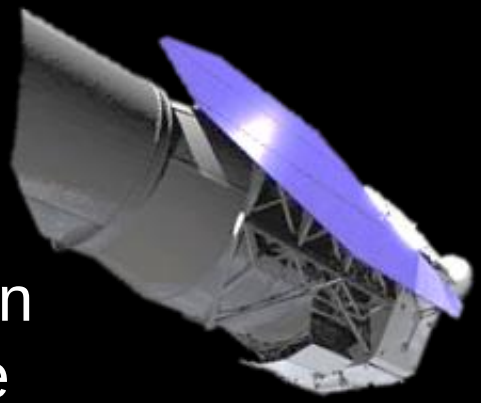


- Prioritization
- Problem Solving
- Decision Making
- Risk Mitigation

- Inclusive
- Transparent

Kepler Mission

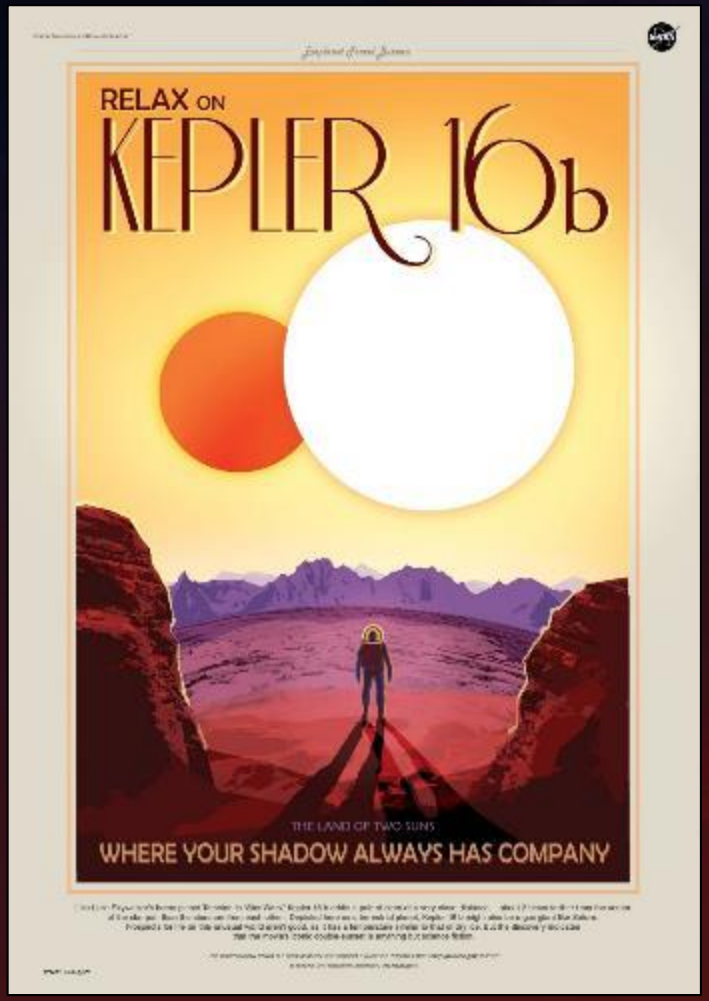




Roman Space Telescope

Inspiration

Exploring a Galaxy of Worlds while Inspiring Our Own



Exoplanet Travel Bureau

"All the News That's Fit to Print"

The New York Times

Late Edition

Today, patchy morning fog, partly sunny, warm, high 64. Tonight, mostly cloudy, mild, low 52. Tomorrow, clouds and sunshine, showers, high 66. Weather map is on Page B8.

VOL. CLXVI ... No. 57,517 © 2017 The New York Times Company NEW YORK, THURSDAY, FEBRUARY 23, 2017 $2.50

A rendering of newly discovered Earth-size planets orbiting a dwarf star named Trappist-1 about 40 light-years from Earth. Some of them could have surface water.

“Exoplanet Earth” Edition

We Are a Leo Sun from Trappist-1

Return to Our Solar System, to Planet Earth


So...
What is a light-year?

Pale Blue Dot

Image by Voyager 1 beyond Neptune

Credit: NASA/JPL-Caltech

Earth and Moon

From Cassini Mission at Saturn

Credit: NASA/JPL-Caltech

Credit: NASA

Credit: NASA/Johnson

Credit: NASA


"All these worlds are yours"
- Arthur C. Clarke
NASA

Jet Propulsion Laboratory
California Institute of Technology

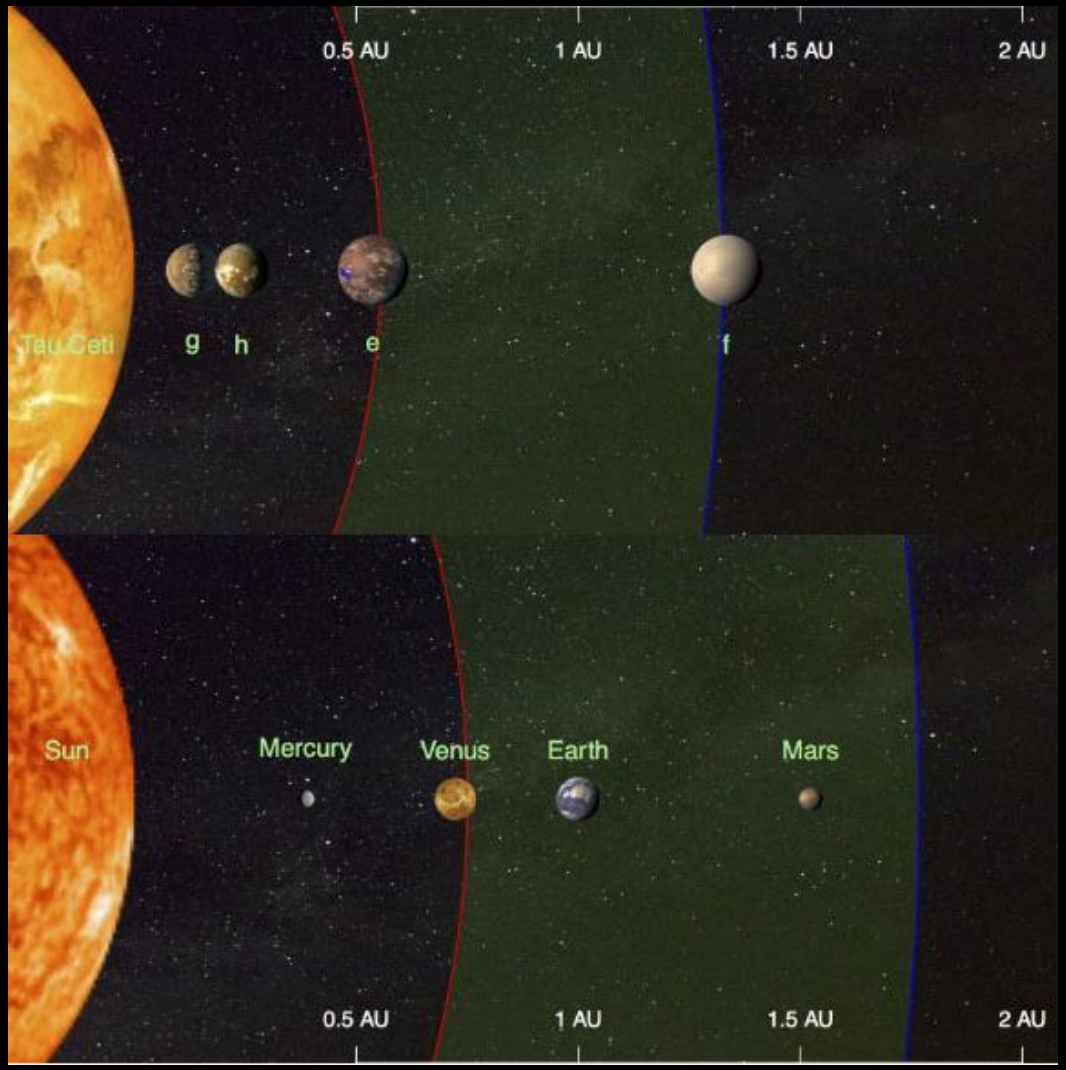
exoplanets.nasa.gov

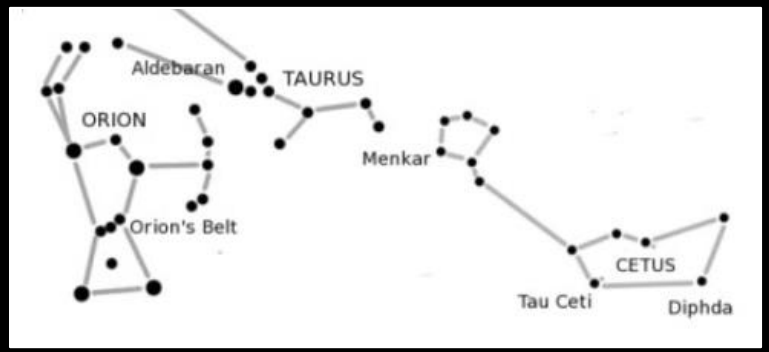
Acknowledgements

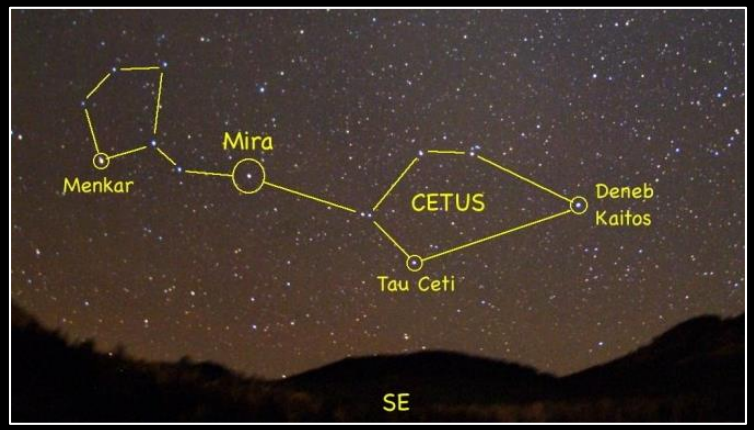
This work was carried out at the Jet Propulsion Laboratory, California Institute of Technology under contract with the National Aeronautics and Space Administration.

Tau Ceti e

Likely Rocky Super-Earth Orbiting a Nearby Sun-like Star







Credit: F. Feng, University of Hertfordshire

Our Place in the Universe