The Search for Life

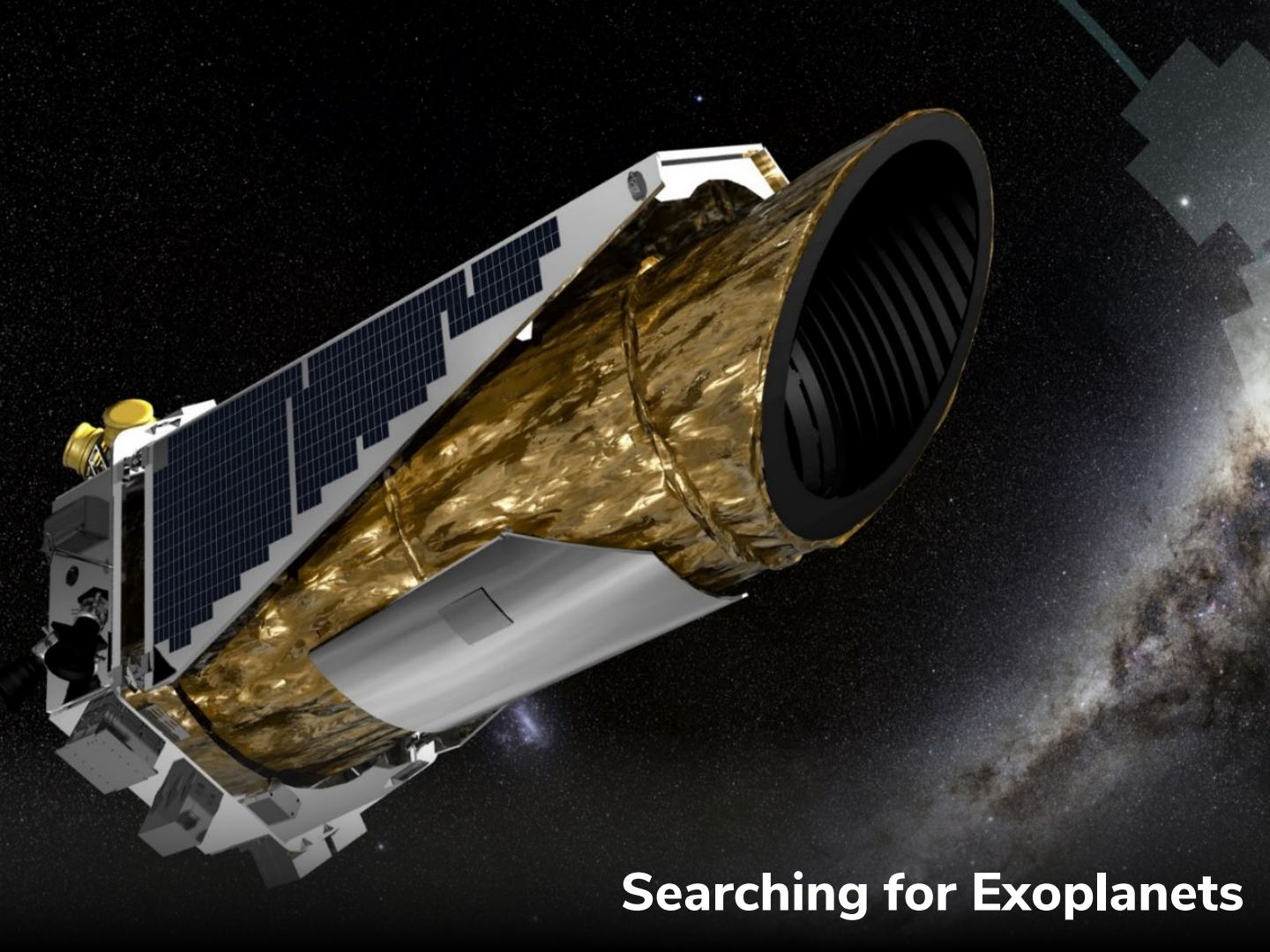
Finding Earth 2.0

Dr Jonathan Crass

The Ohio State University

Royal Astronomical Society

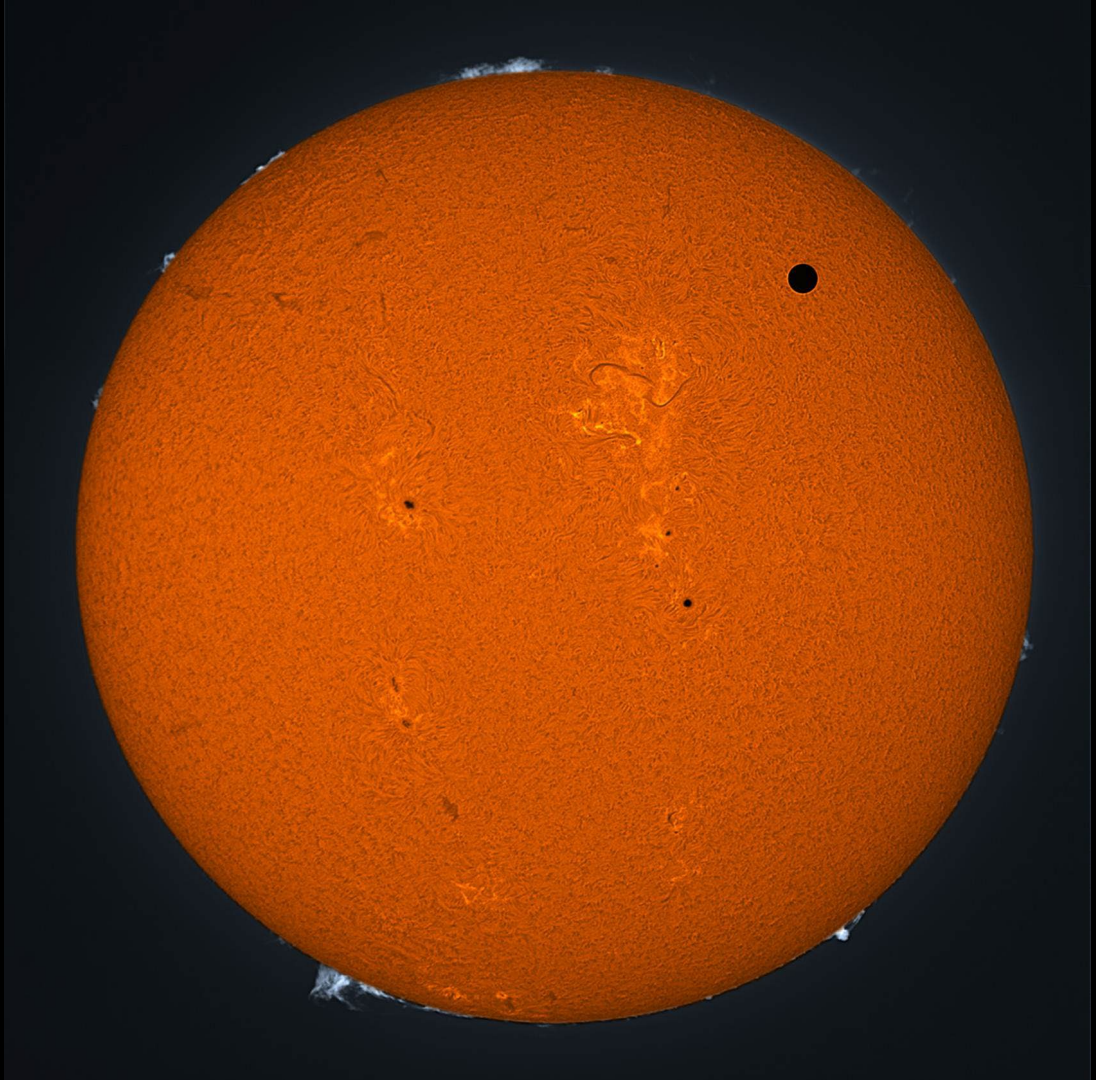
Are we alone?


Searching for Exoplanets

Searching for Exoplanets

There are four major techniques we use to search for exoplanets:

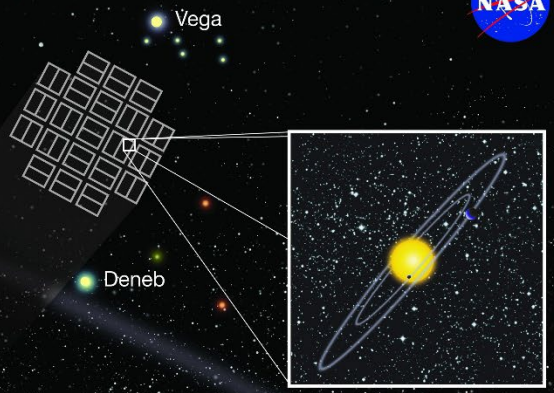
- Transit Technique
- Radial Velocity Technique
- Gravitational Microlensing
- Direct Imaging



National Aeronautics and Space Administration

Kepler

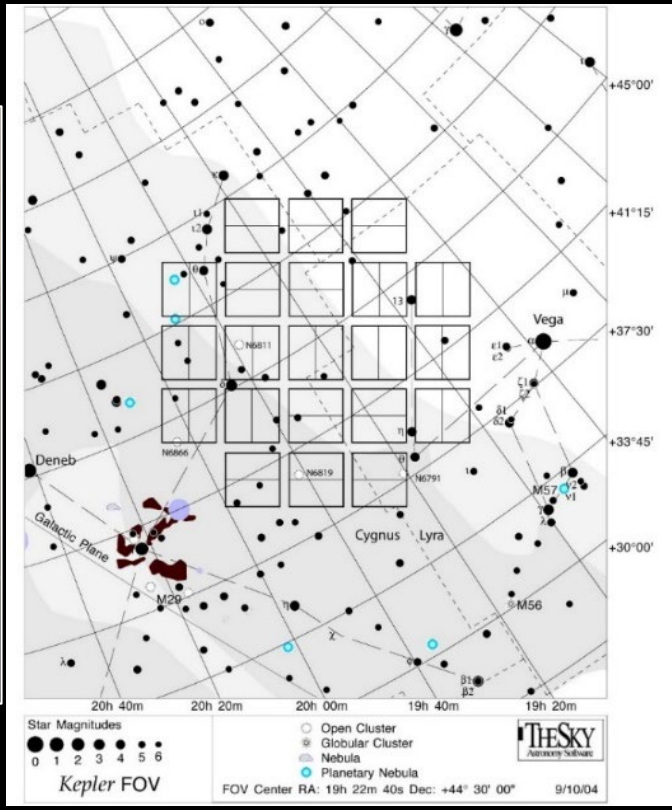
NASA's First Mission Capable of Finding Earth-size & Smaller Planets

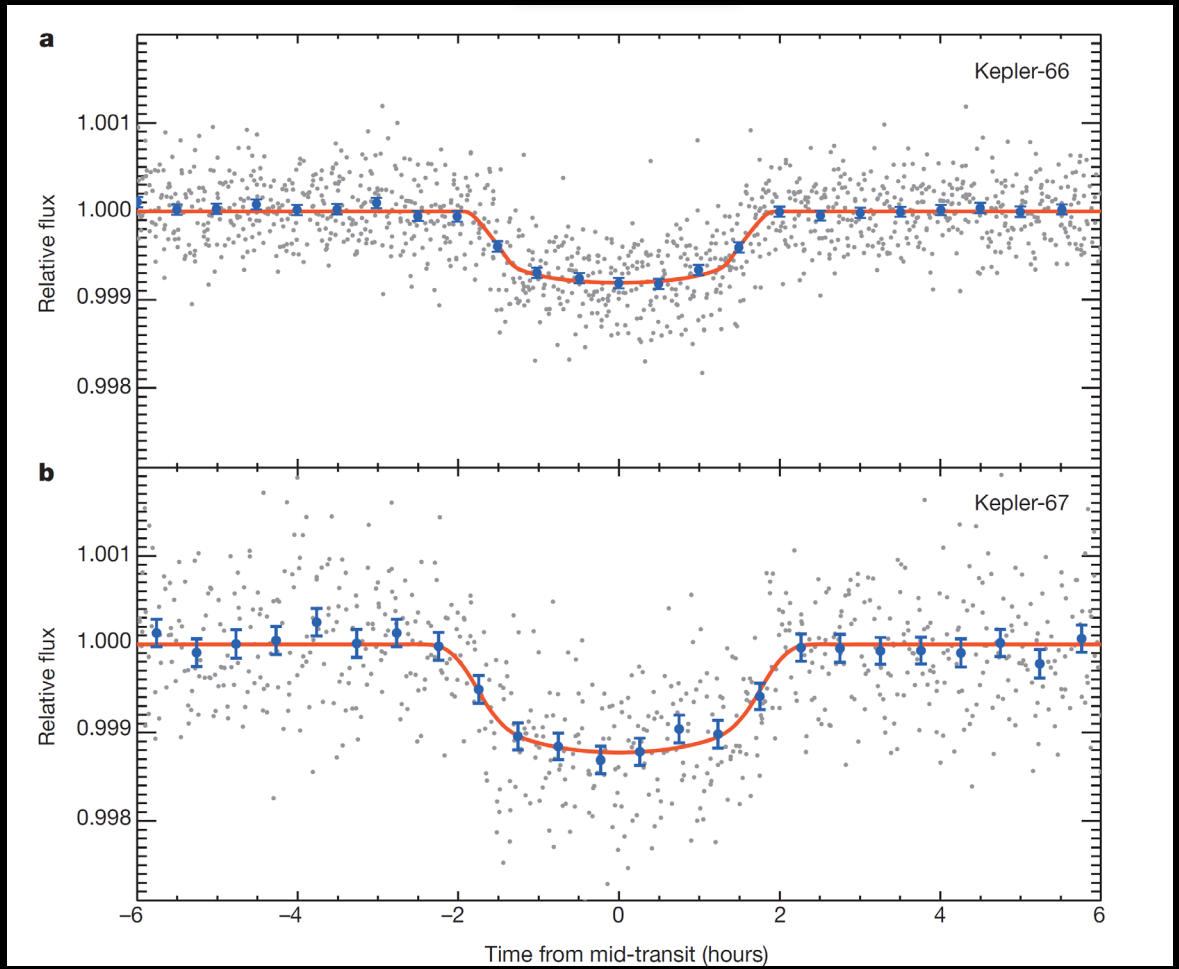


WARNING: OBJECTS IN THIS RENDITION APPEAR LARGER AND CLOSER TOGETHER THAN THEY ARE IN REALITY.

WARNING: OBJECTS IN THIS RENDITION APPEAR LARGER AND CLOSER TOGETHER THAN THEY ARE IN REALITY.

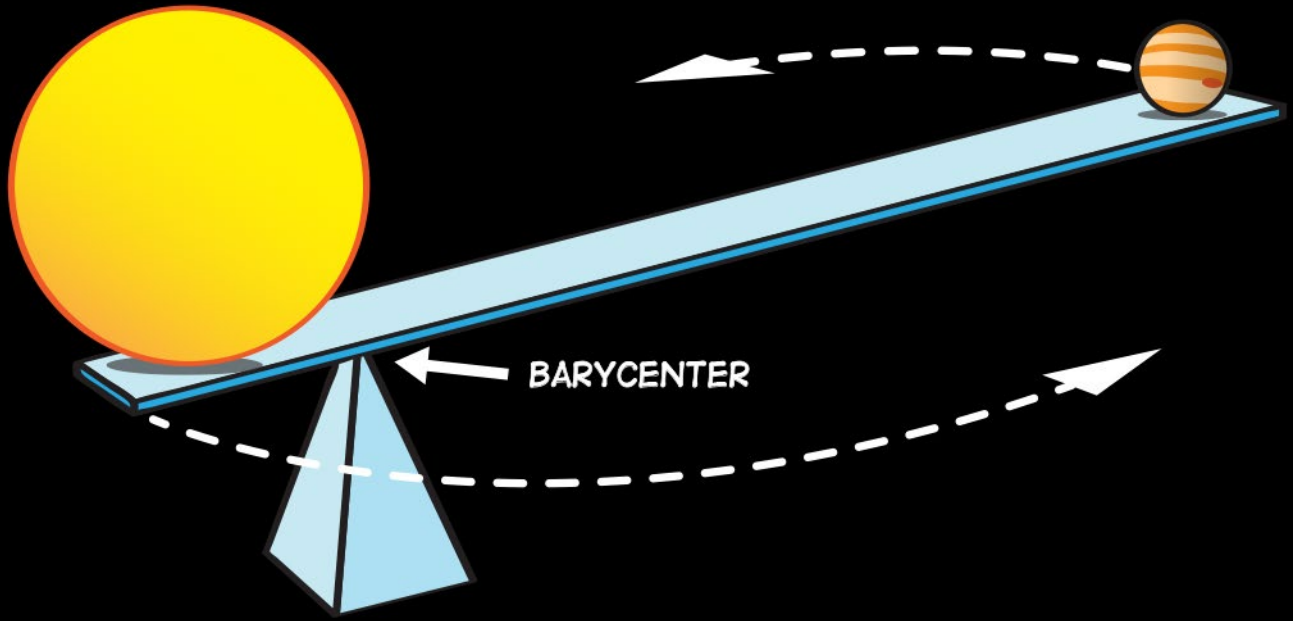

The Kepler Mission

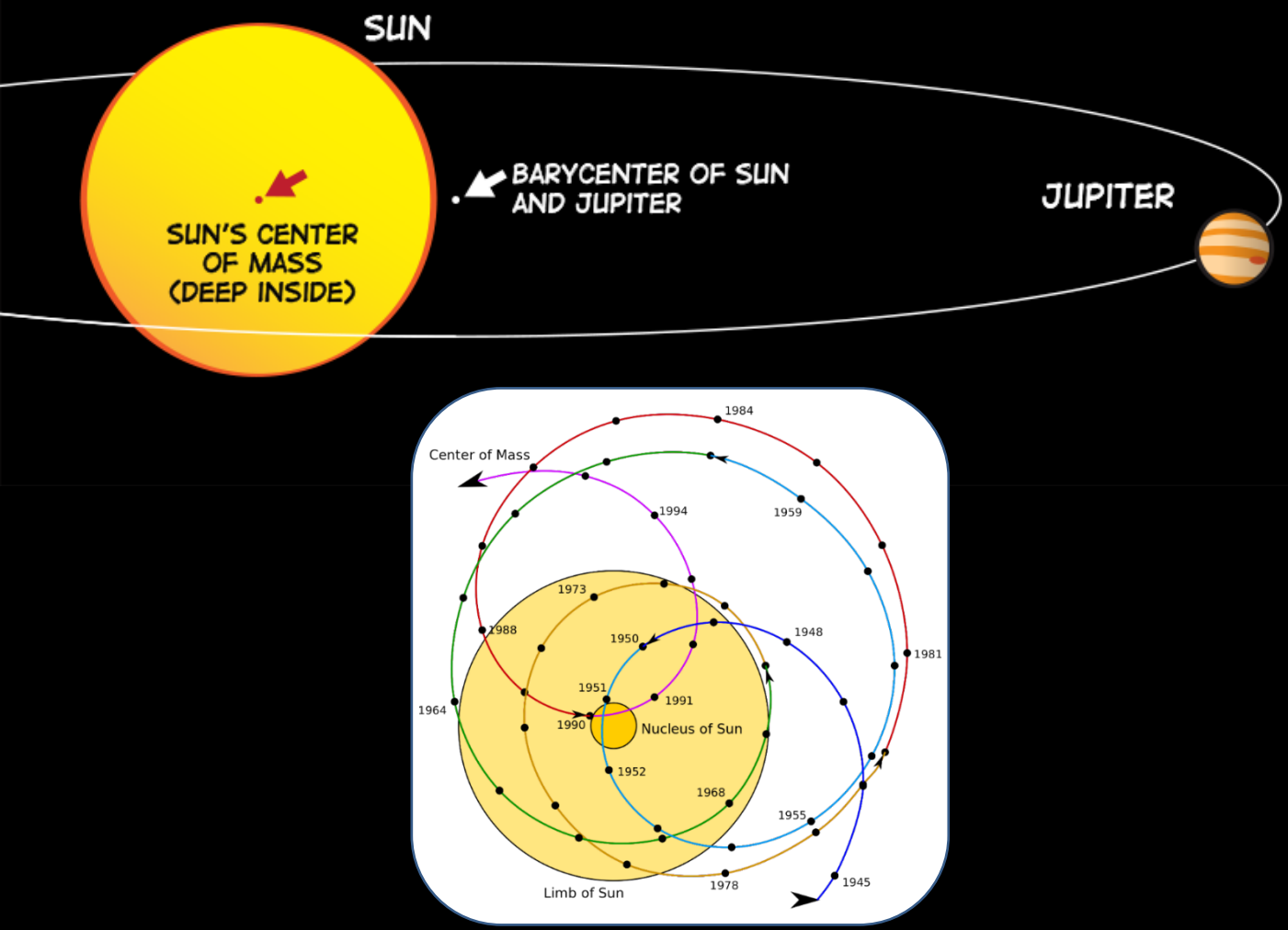

+45°00'
+41°15'
+37°30'
+33°45'
+30°00'
Vega
Deneb
Cygnus
Lyra
Galactic Plane
M29
M56
M57
N6811
N6866
N6819
N6791
20h 40m
20h 20m
20h 00m
19h 40m
19h 20m
Star Magnitudes
0 1 2 3 4 5 6
Kepler FOV
Open Cluster
Globular Cluster
Nebula
Planetary Nebula
FOV Center RA: 19h 22m 40s Dec: +44° 30' 00"
9/10/04
TheSky
Astronomy Software

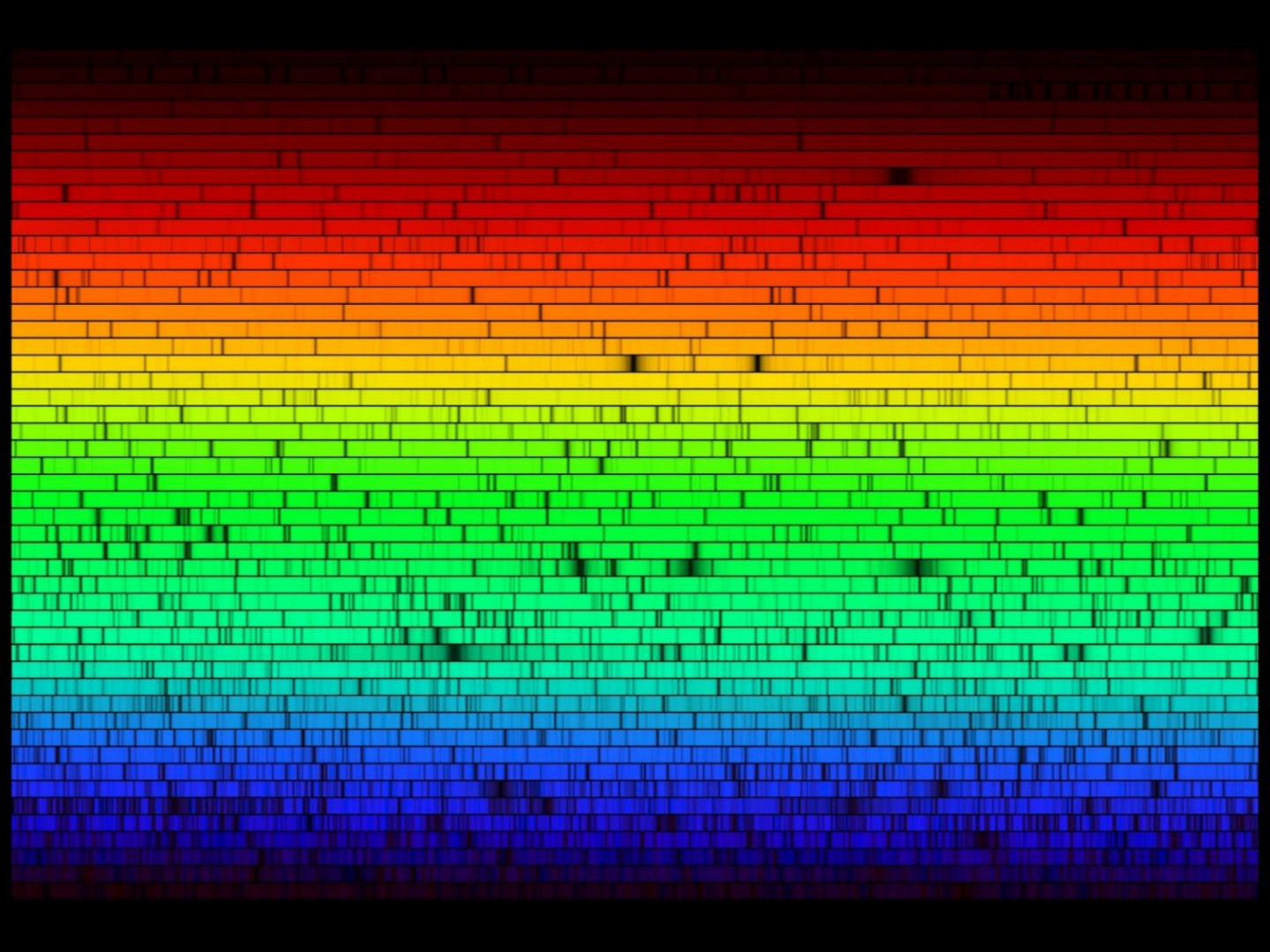

a
Kepler-66
1.001
1.000
0.999
0.998
Relative flux
b
Kepler-67
1.001
1.000
0.999
0.998
Relative flux
−6
−4
−2
0
2
4
6
Time from mid-transit (hours)

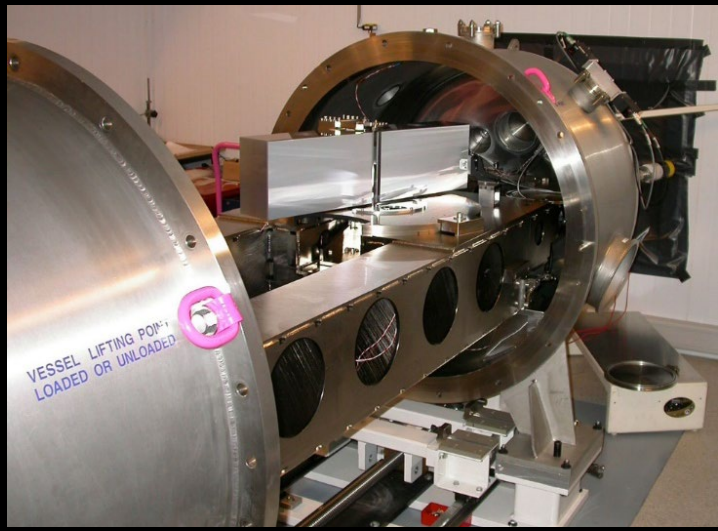

Solar
System

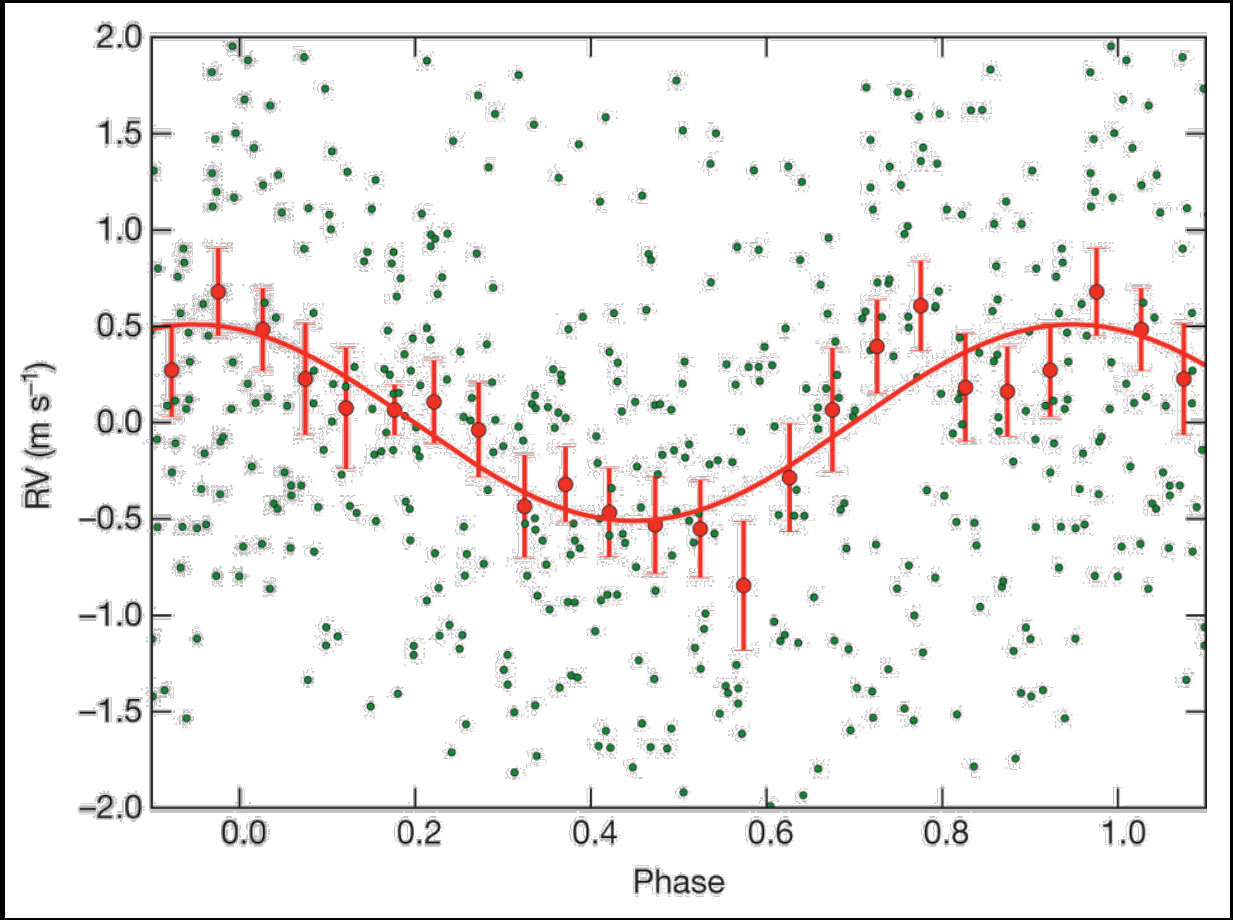

TRANSITING EXOPLANET SURVEY SATELLITE
DISCOVERING NEW EARTHS AND SUPER-EARTHS
IN THE SOLAR NEIGHBORHOOD


BARYCENTER

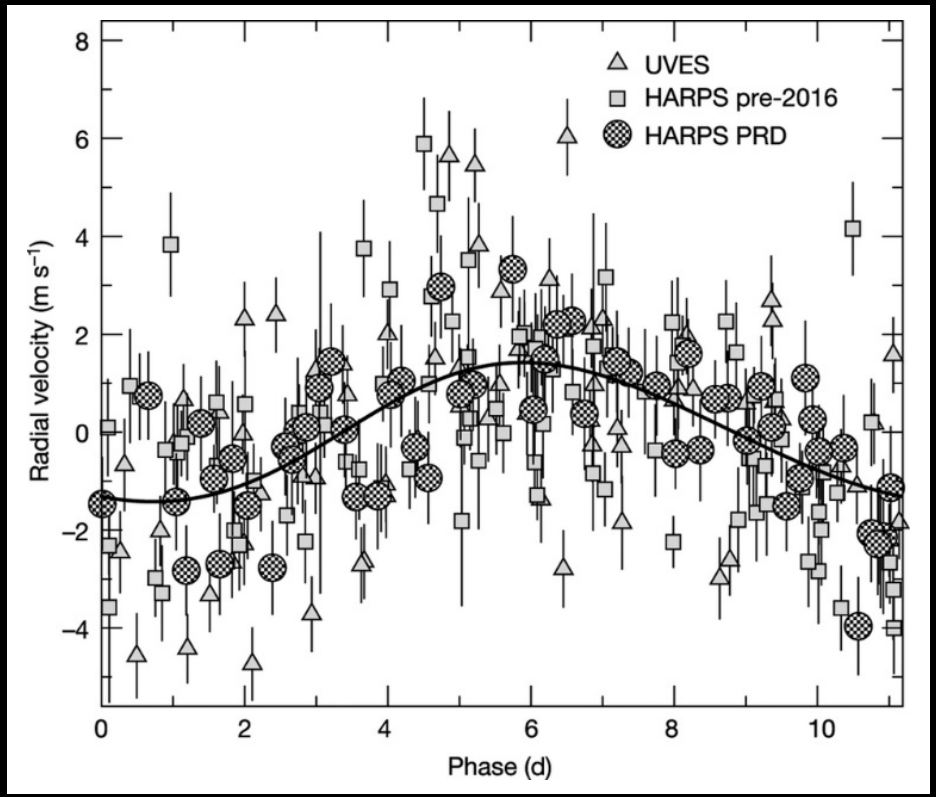

SUN
SUN'S CENTER OF MASS (DEEP INSIDE)
BARYCENTER OF SUN AND JUPITER
JUPITER
Center of Mass
1984
1994
1959
1973
1988
1950
1948
1981
1951
1991
1964
1990
Nucleus of Sun
1952
1968
1955
1978
1945
Limb of Sun




VESSEL LIFTING POI
LOADED OR UNLOADED

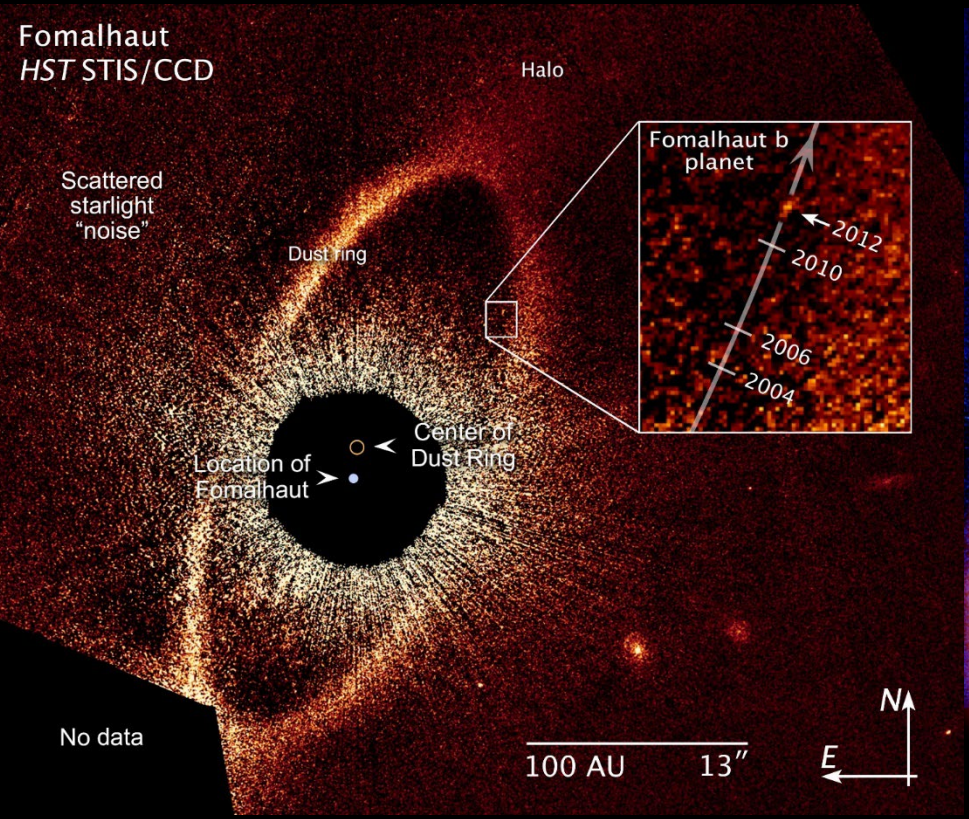

2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
RV (m s−1)
0.0
0.2
0.4
0.6
0.8
1.0
Phase

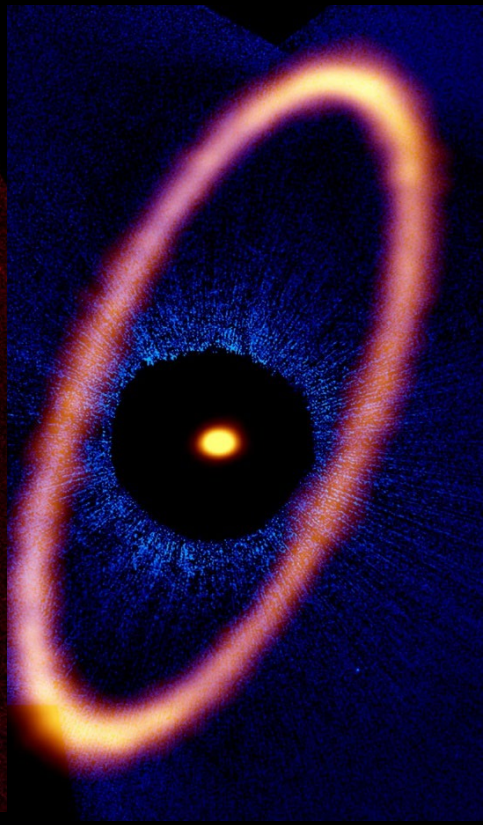
Proxima Centauri b

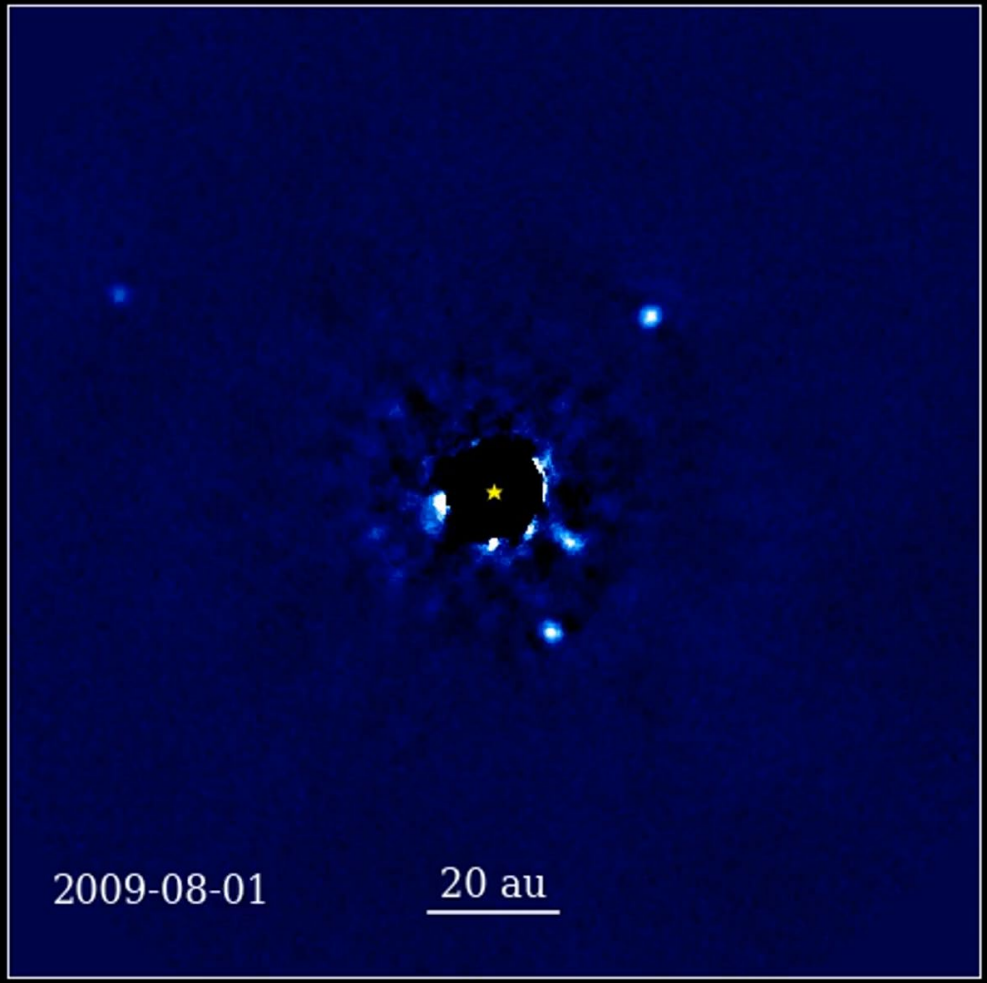



Brightness


NOT A STEP

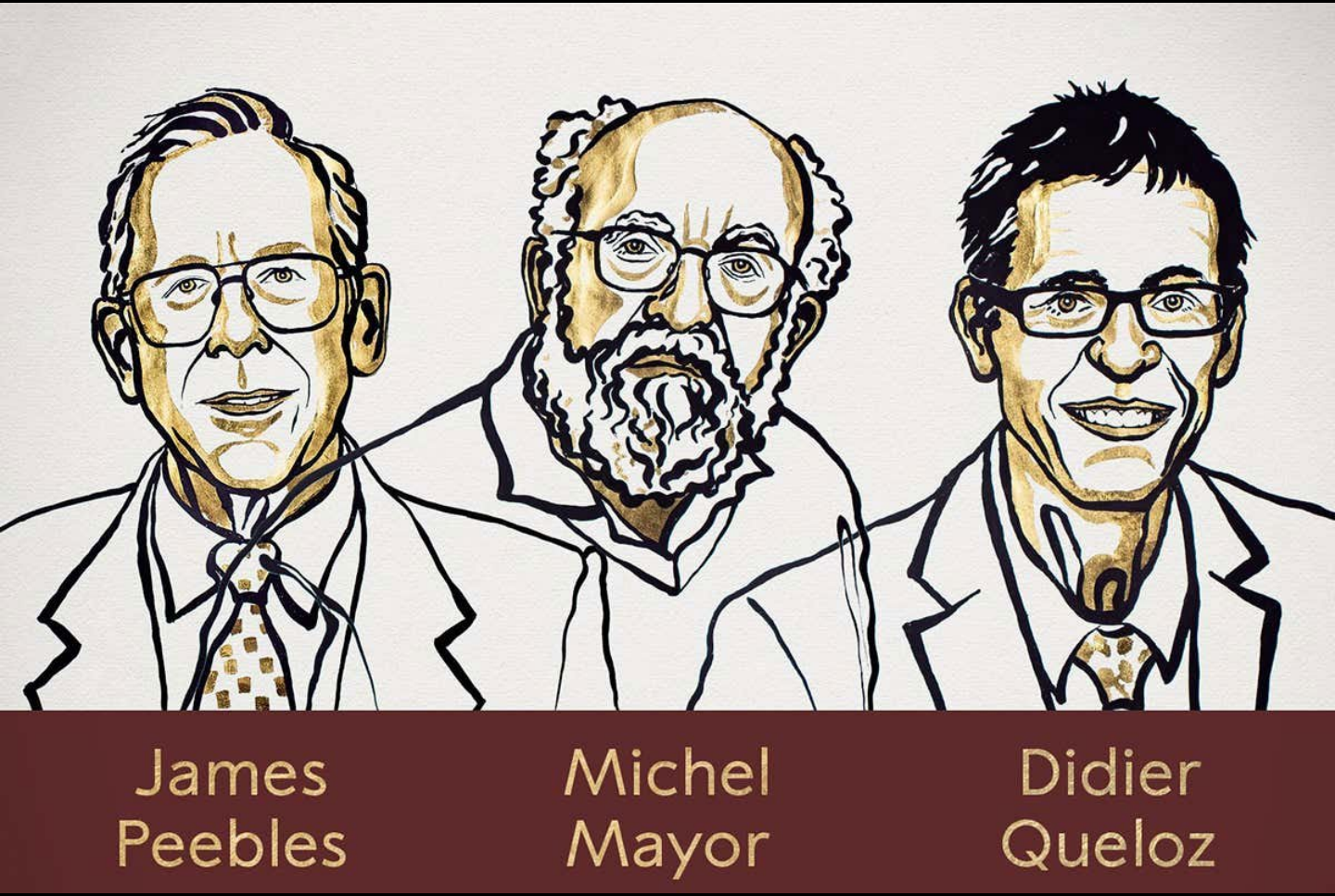

Fomalhaut
HST STIS/CCD
Halo
Scattered
starlight
"noise"
Dust ring
Fomalhaut b
planet
2012
2010
2006
2004
Center of
Dust Ring
Location of
Fomalhaut
No data
100 AU
13″
N
E




2009-08-01
20 au

A very new field…

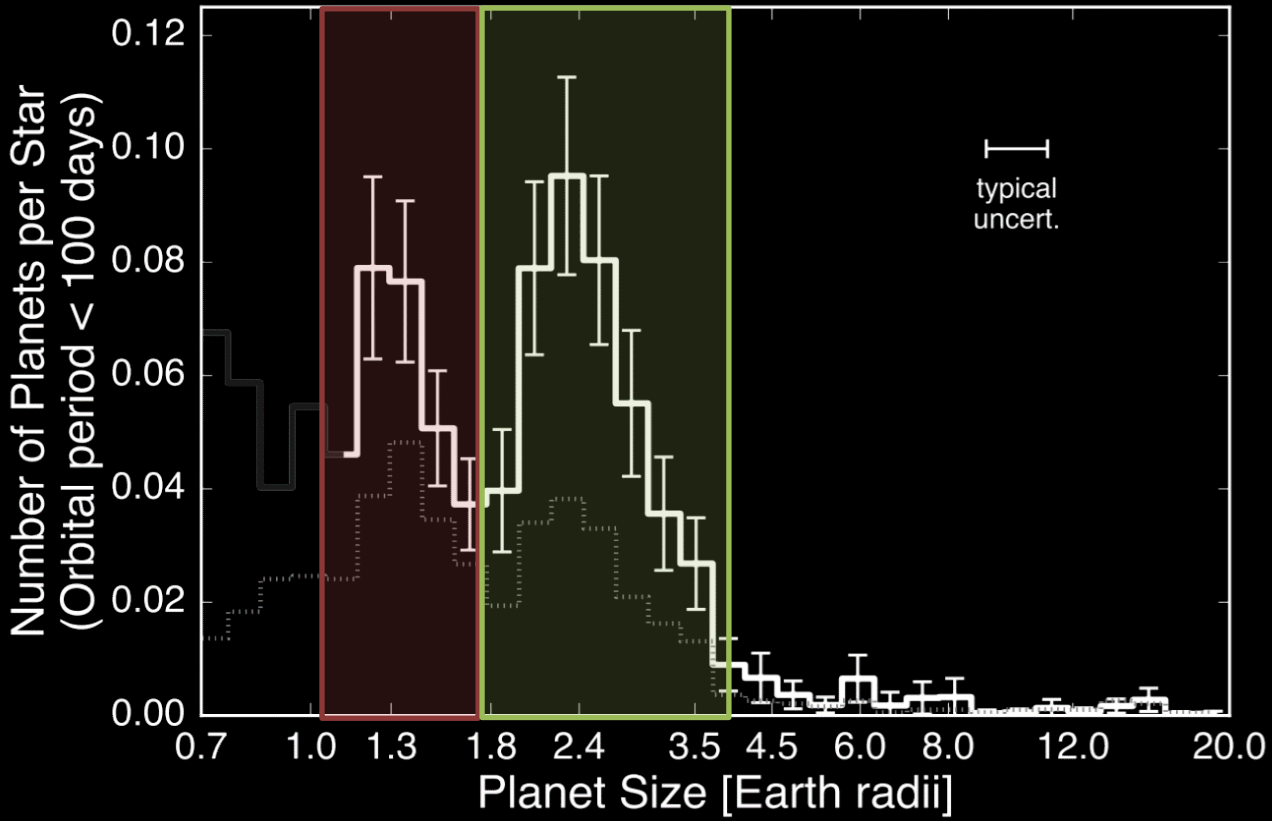
- 1988 - A possible planetary detection…
- 1992 – The discovery of a planet around a Pulsar
- 1995 – The discovery of a planet around a Sun-like star: 51 Pegasi
- 2016 - Earth-Size Planet in Habitable Zone: Proxima Centauri
- 2017 – 7 Earth-Size Planets around a single star: TRAPPIST-1


James Peebles
Michel Mayor
Didier Queloz

5811
CONFIRMED EXOPLANETS

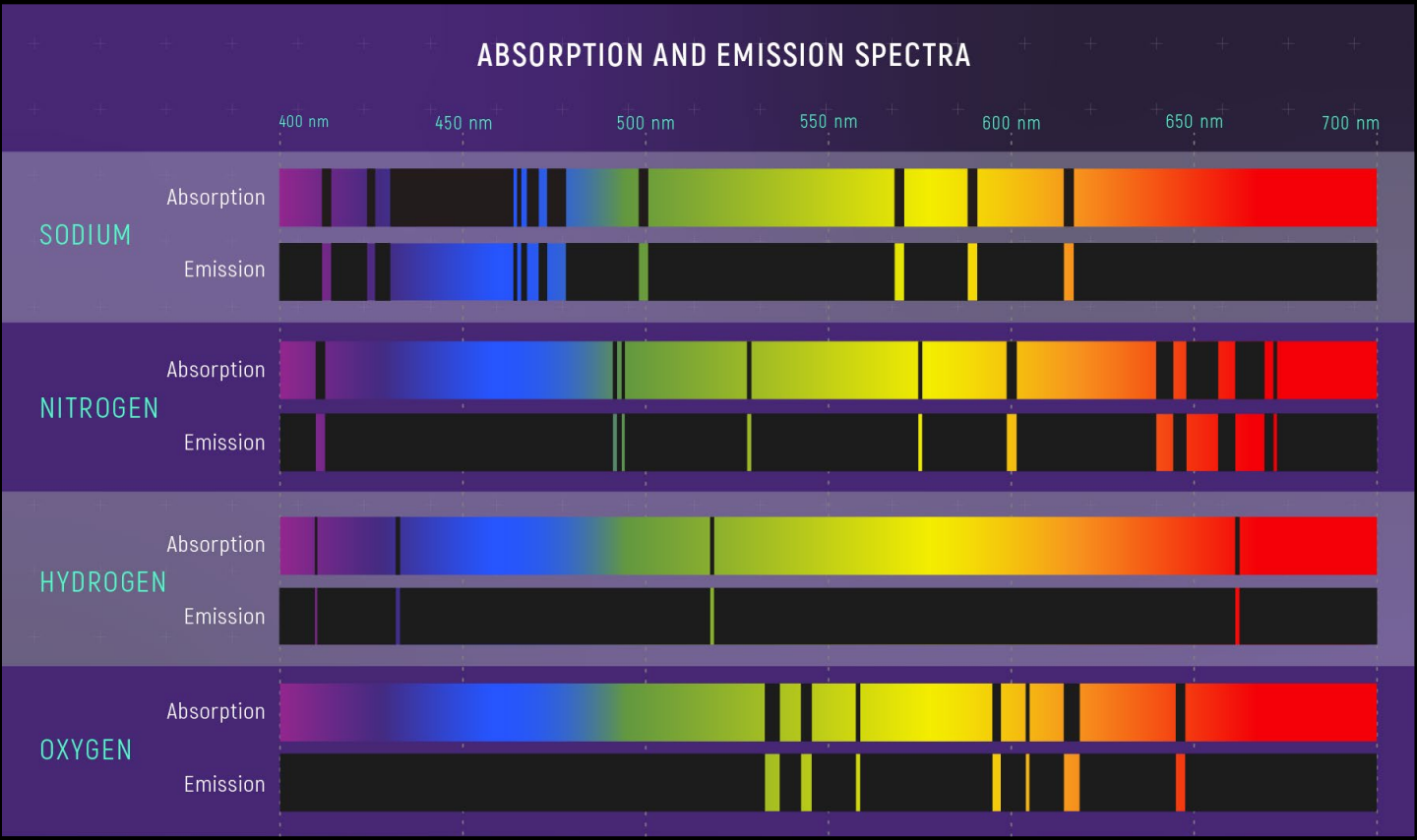
Detection Method	Number of planets	Detection Method	Number of planets
Astrometry	3	Imaging	82
Radial Velocity	1096	Transit	4329
Transit Timing	32	Eclipse Timing	17
Microlensing	232	Pulsar Timing	8
Orbital Brightness Modulation	9	Other	3

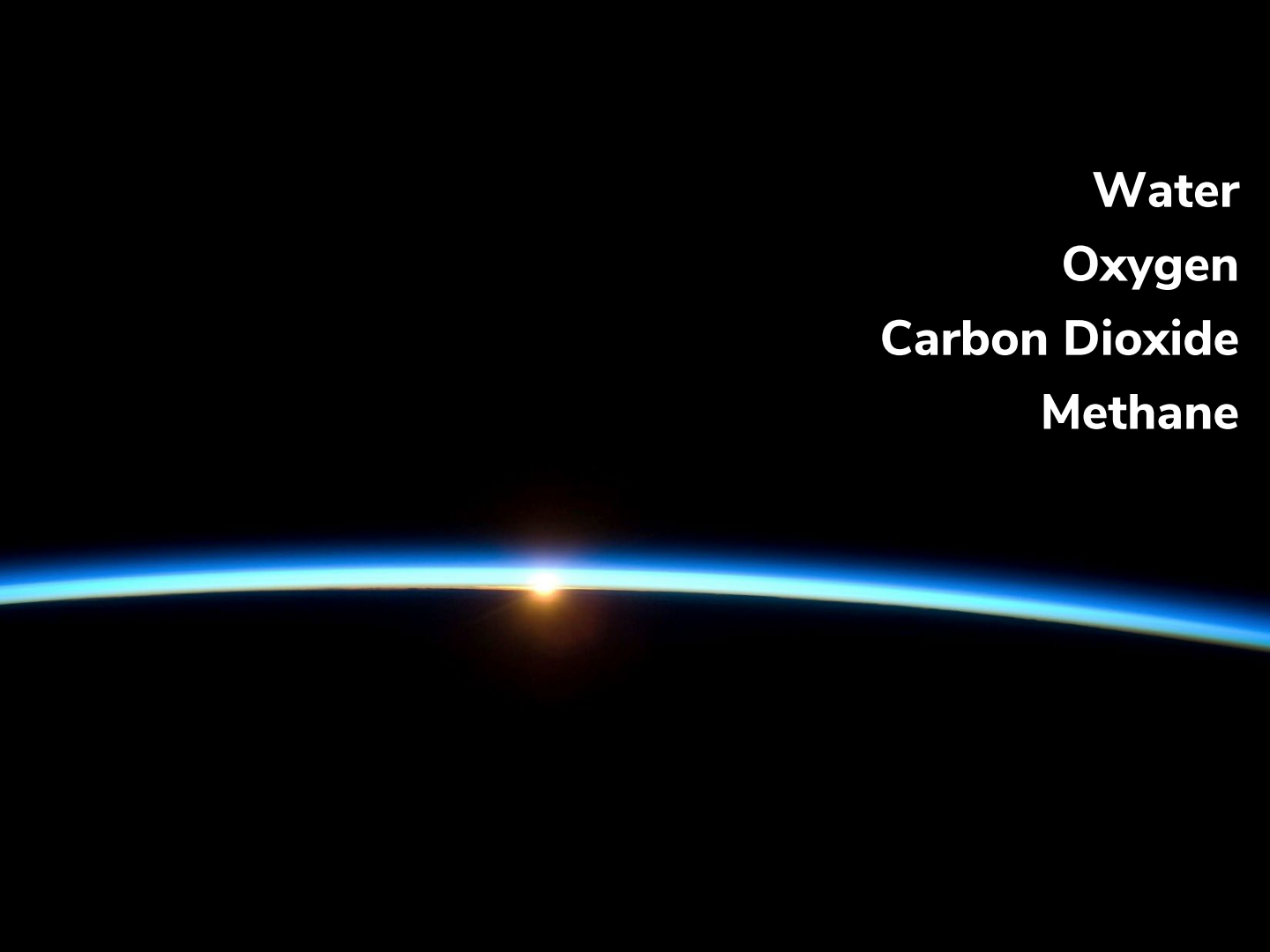
Data from NASA Exoplanet Archive. Image credits: ESO & NASA


Number of Planets per Star
(Orbital period < 100 days)
0.12
0.10
0.08
0.06
0.04
0.02
0.00
typical
uncert.
0.7
1.0
1.3
1.8
2.4
3.5
4.5
6.0
8.0
12.0
20.0
Planet Size [Earth radii]


Are we alone?

The signatures of life



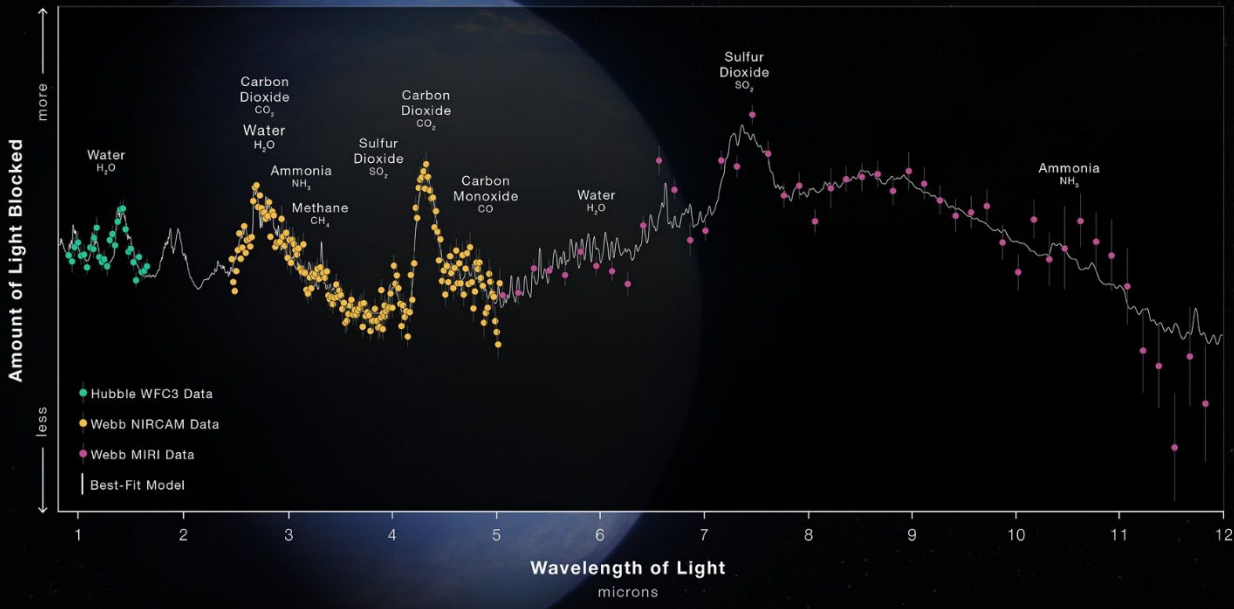

Water
Oxygen
Carbon Dioxide
Methane


NORTHROP
GRUMMAN

GAS-GIANT EXOPLANET WASP-107 b

TRANSMISSION SPECTRUM

Hubble WFC3	Grism Spectroscopy
Webb NIRCam	Grism Spectroscopy
Webb MIRI	Low-Resolution Spectroscopy

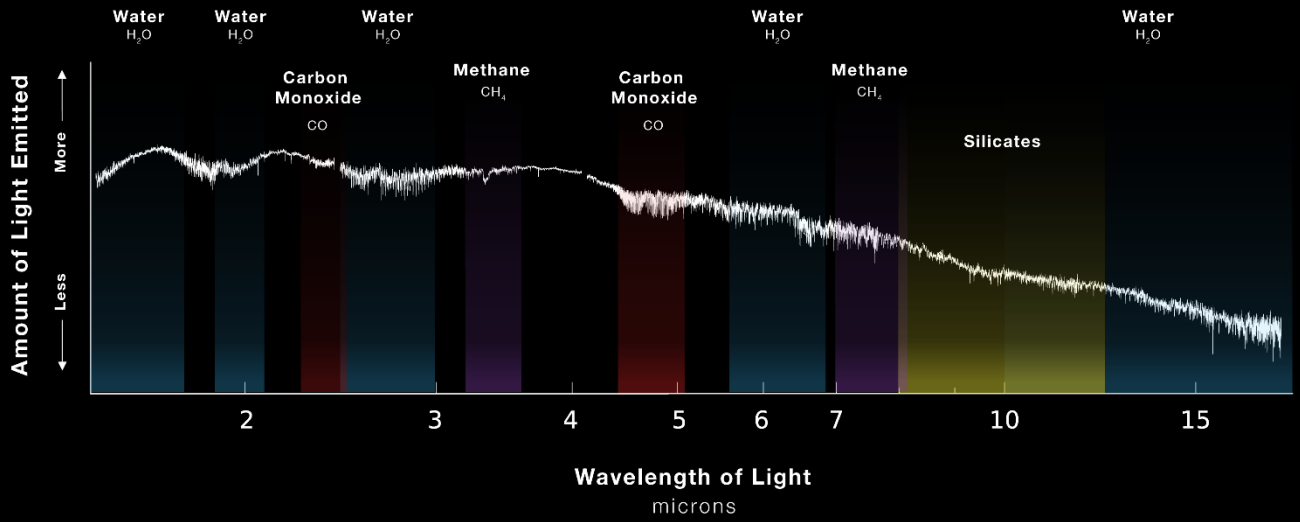


WEBB
SPACE TELESCOPE

EXOPLANET VHS 1256 b

EMISSION SPECTRUM

NIRSpec and MIRI | IFU Medium-Resolution Spectroscopy

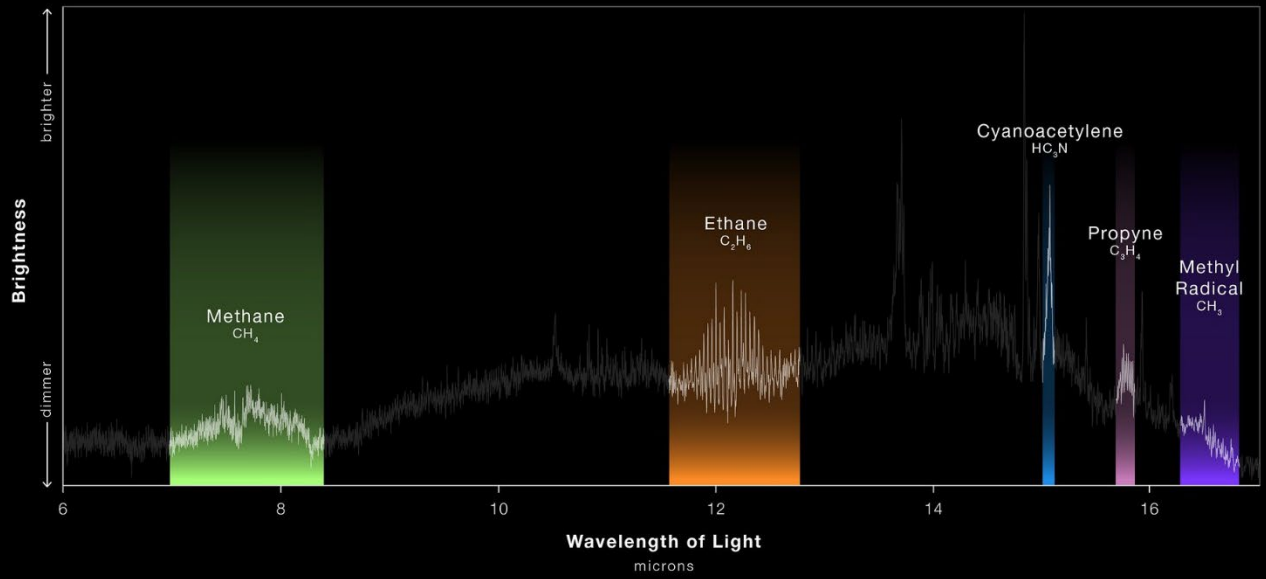


WEBB
SPACE TELESCOPE

VERY LOW-MASS STAR : ISO-CHAI 147

HYDROCARBONS IN PROTOPLANETARY DISK

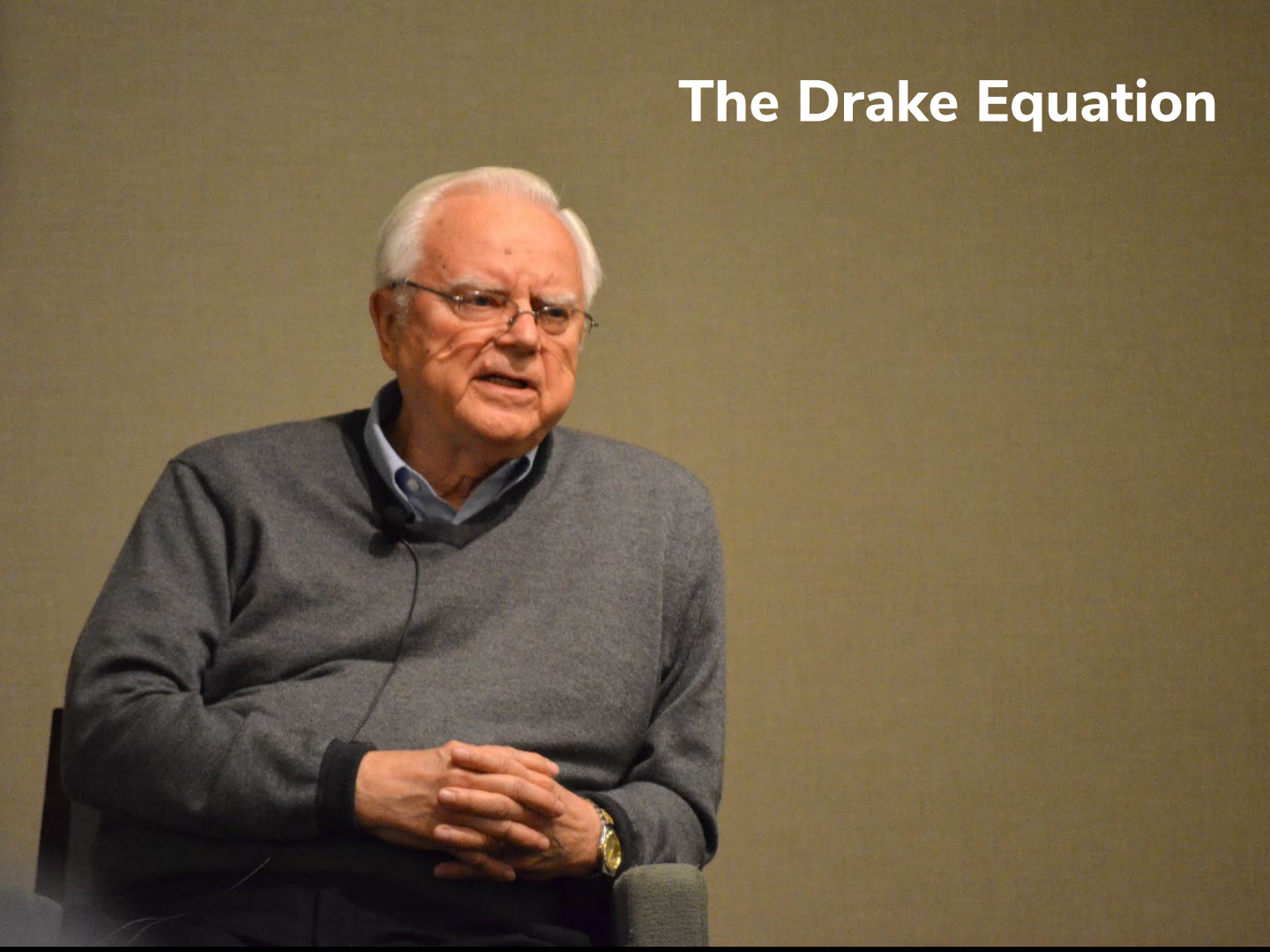
MIRI | Medium Resolution Spectroscopy



WEBB SPACE TELESCOPE


Life in our Galaxy

The Drake Equation



The Drake Equation

$$N = R^* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

N = The number of civilizations in The Milky Way Galaxy

R* = The rate of formation of stars

f_p = The fraction of those stars with planetary systems

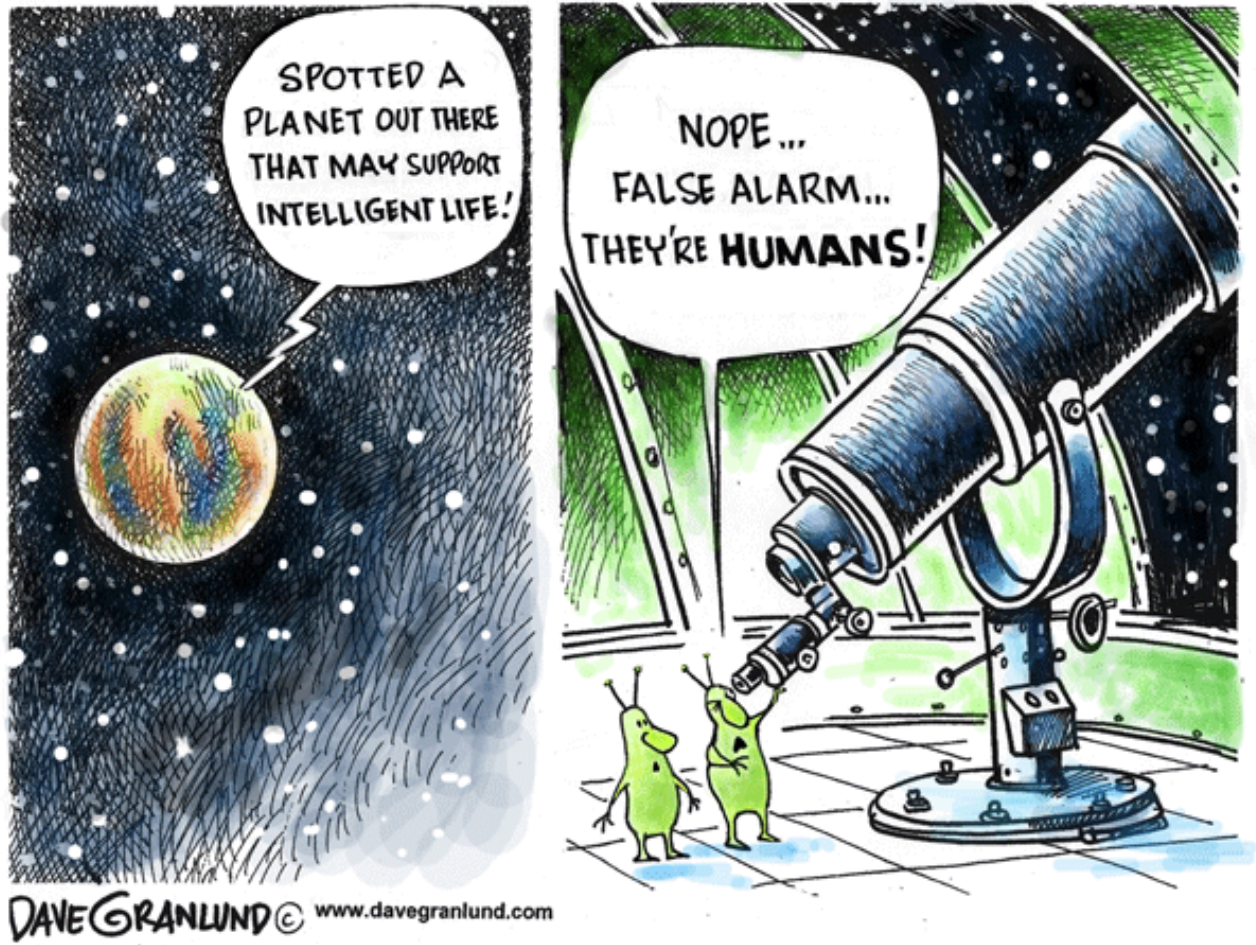
n_e = The number of planets, per solar system, which can support life

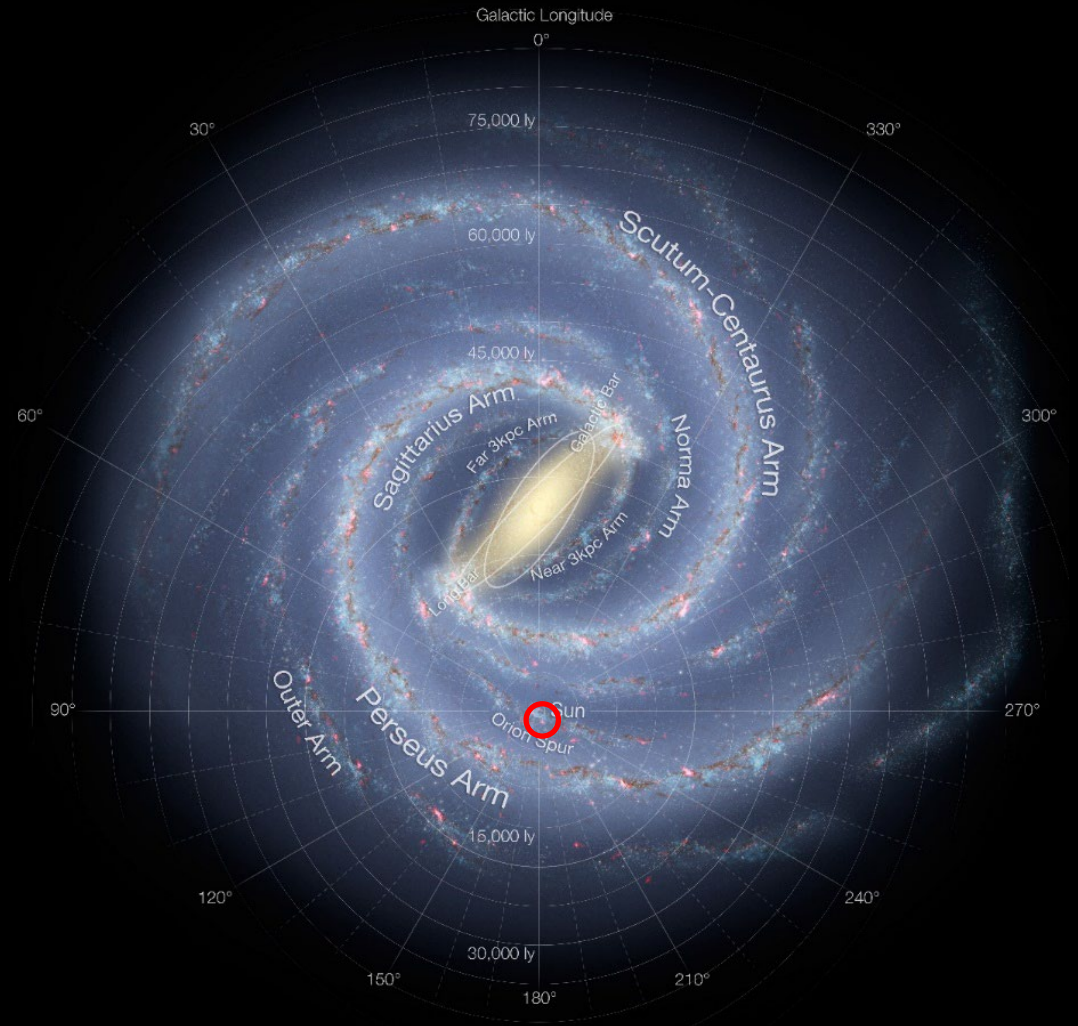
f_l = The fraction of suitable planets on which life actually appears

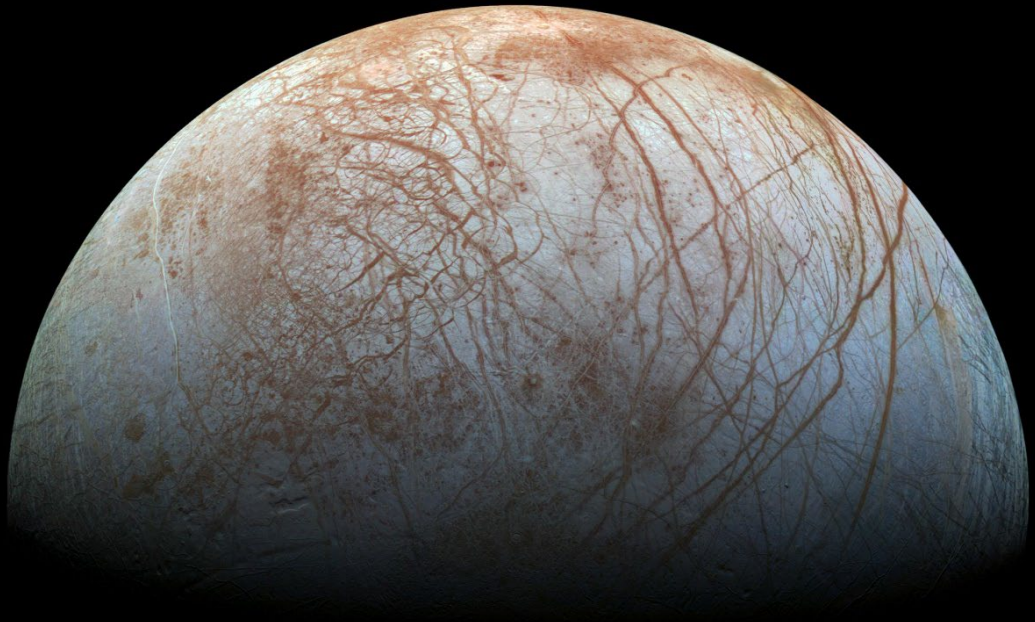
f_i = The fraction of life bearing planets on which intelligent life emerges

f_c = The fraction of civilizations that develop technology to emit signals into space

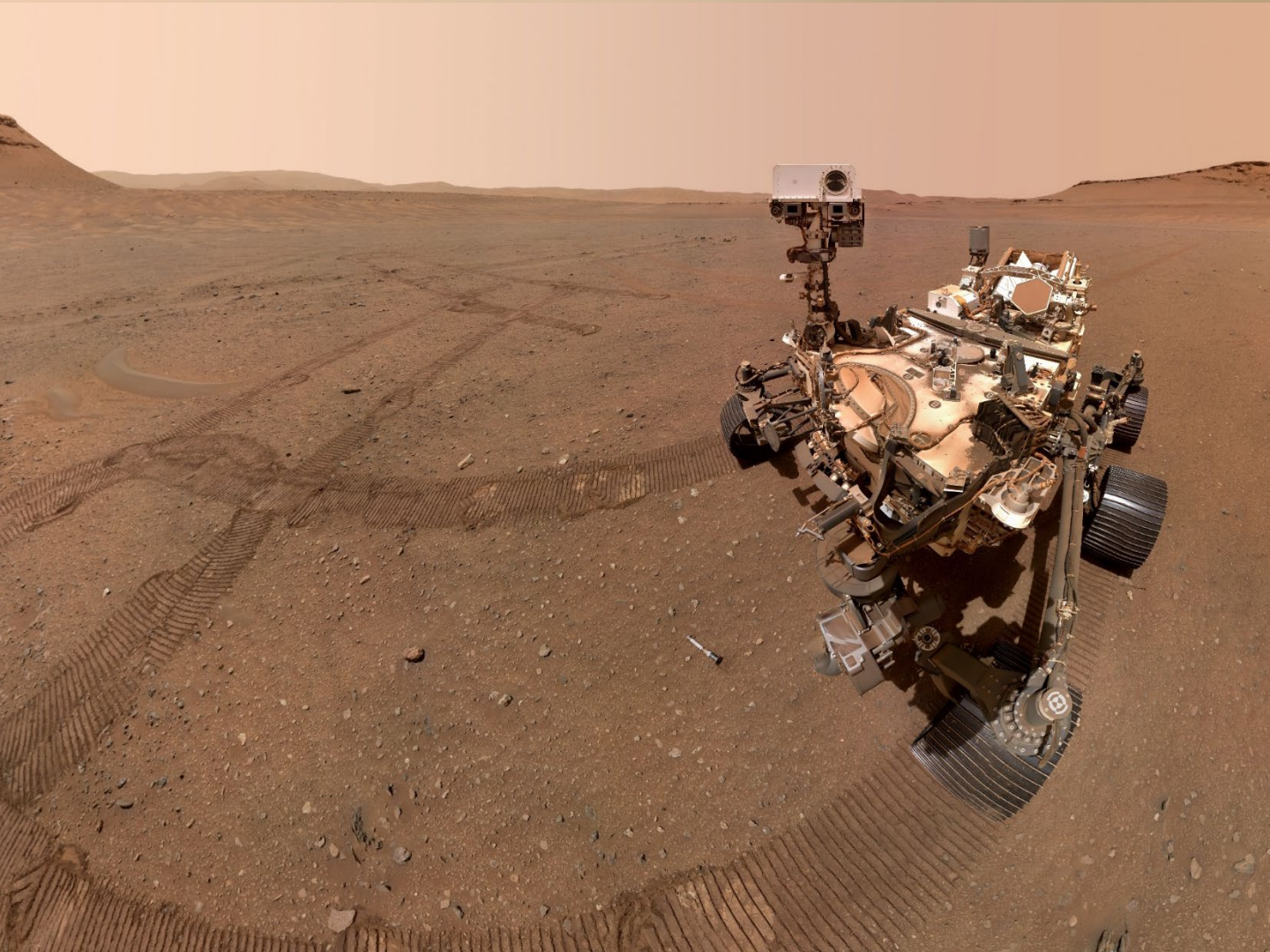
L = The length of time such civilizations release these signals into space

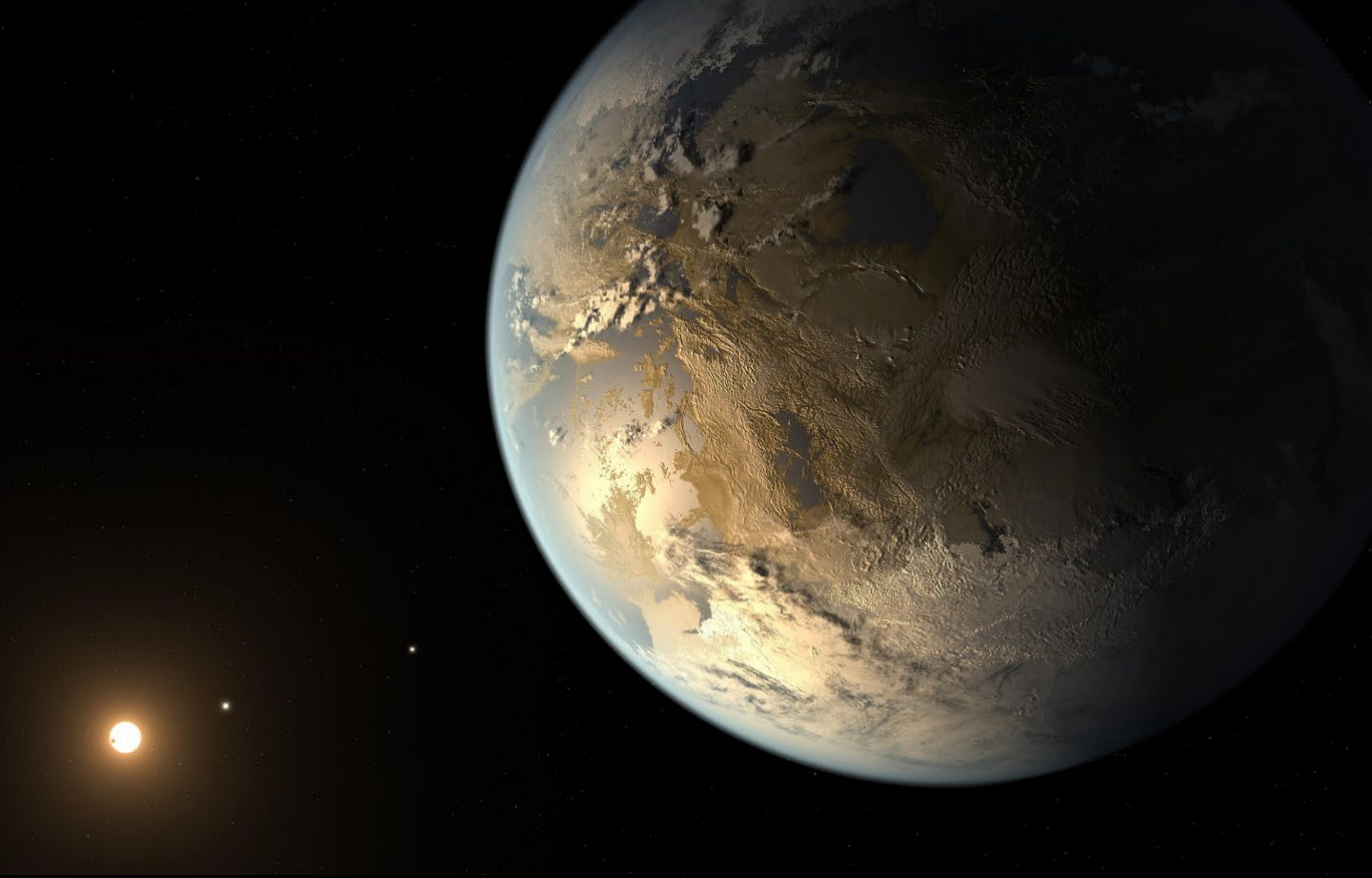

SPOTTED A PLANET OUT THERE THAT MAY SUPPORT INTELLIGENT LIFE!
NOPE... FALSE ALARM... THEY'RE HUMANS!
DAVE GRANLUND ©
www.davegranlund.com


Galactic Longitude
0°
30°
330°
75,000 ly
60,000 ly
45,000 ly
60°
300°
Scutum-Centaurus Arm
Sagittarius Arm
Far 3kpc Arm
Galactic Bar
Norma Arm
Near 3kpc Arm
Long Bar
90°
270°
Outer Arm
Perseus Arm
Sun
Orion Spur
15,000 ly
120°
240°
30,000 ly
150°
210°
180°



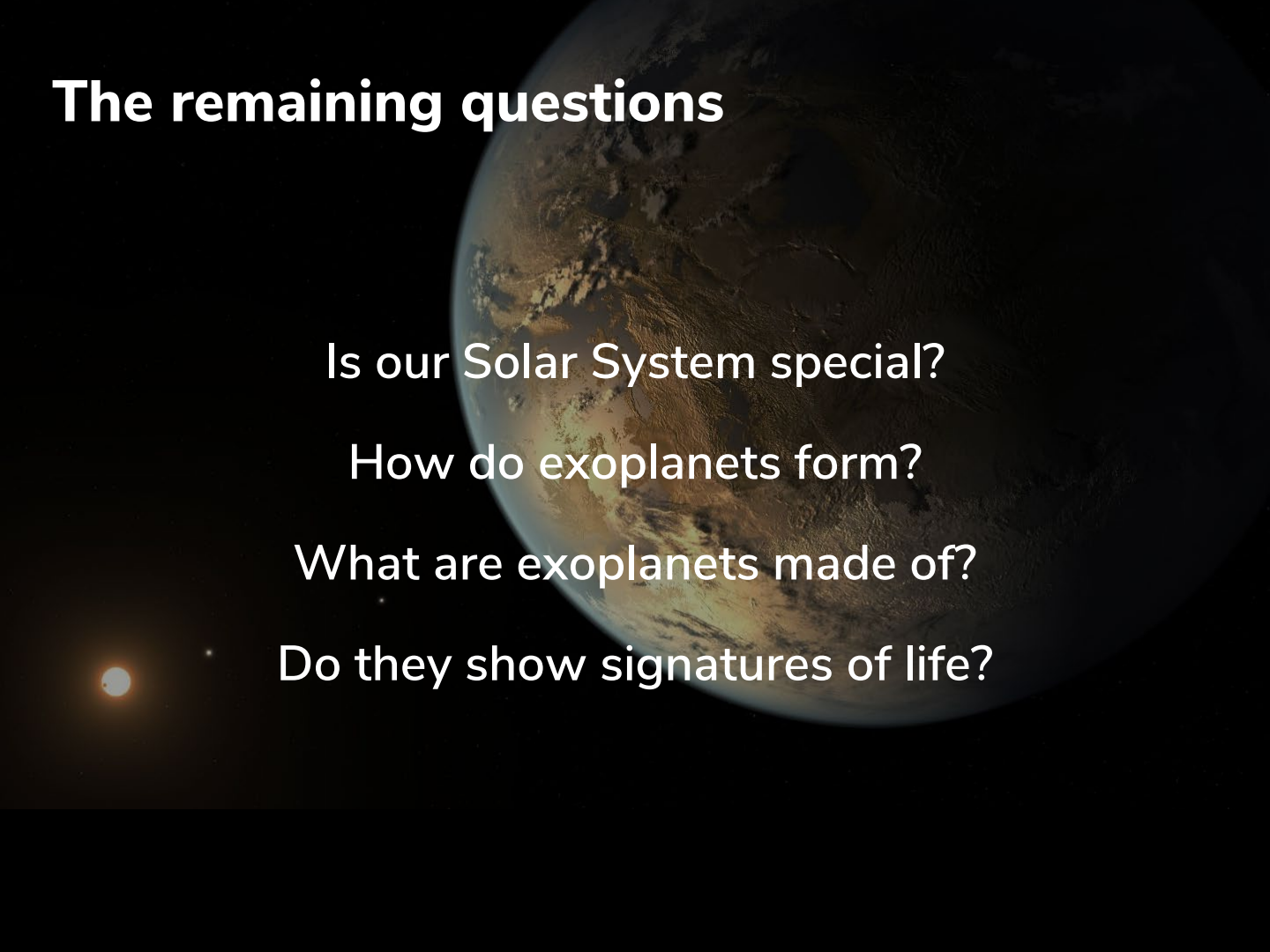
Life in our own Solar System





The Future

The remaining questions

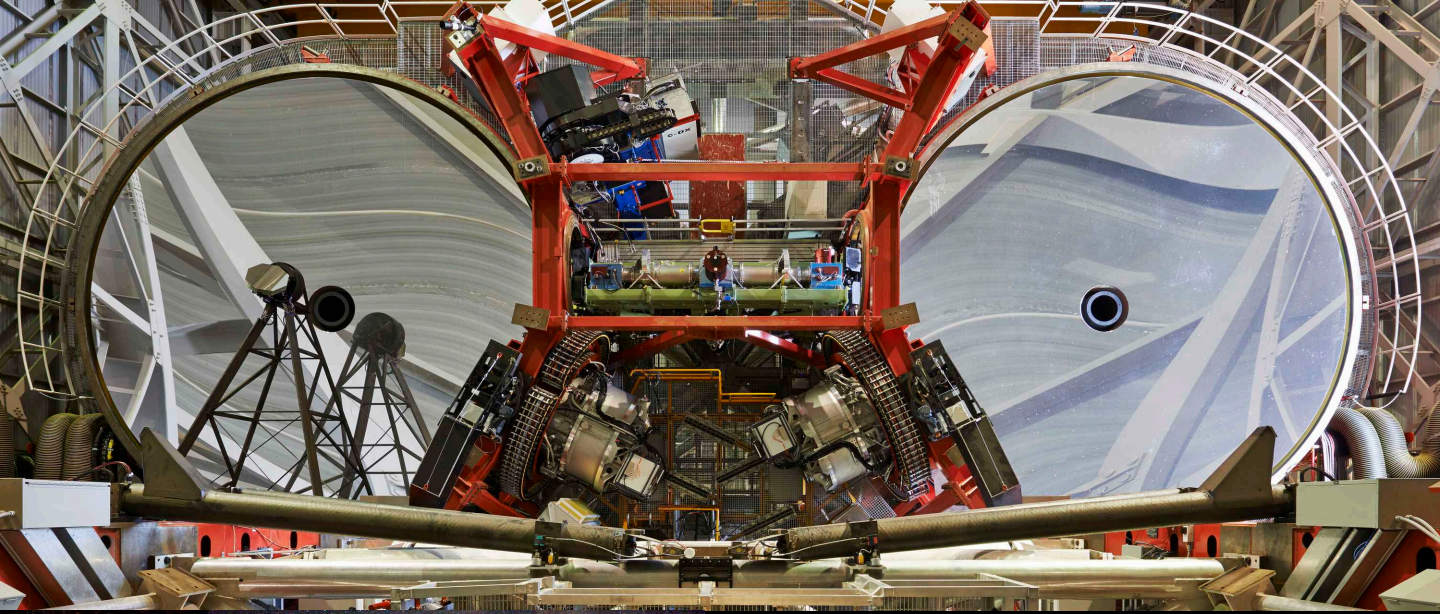


Is our Solar System special?

How do exoplanets form?

What are exoplanets made of?

Do they show signatures of life?



iLocater

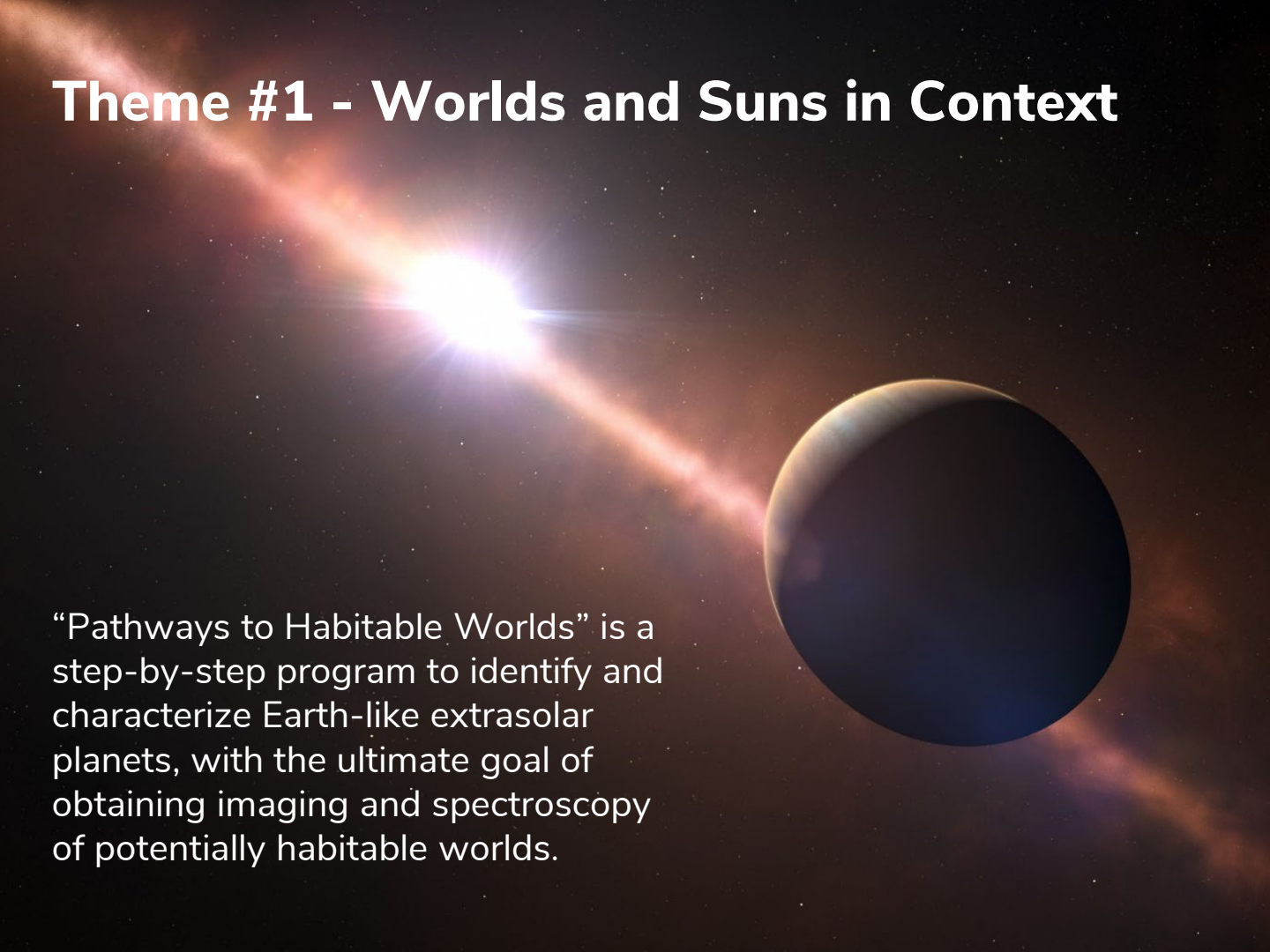

NASA
Goddard
SPACE FLIGHT CENTER
SKYJACK
SKYJACK
SKYJACK

The National Academies of
SCIENCES · ENGINEERING · MEDICINE

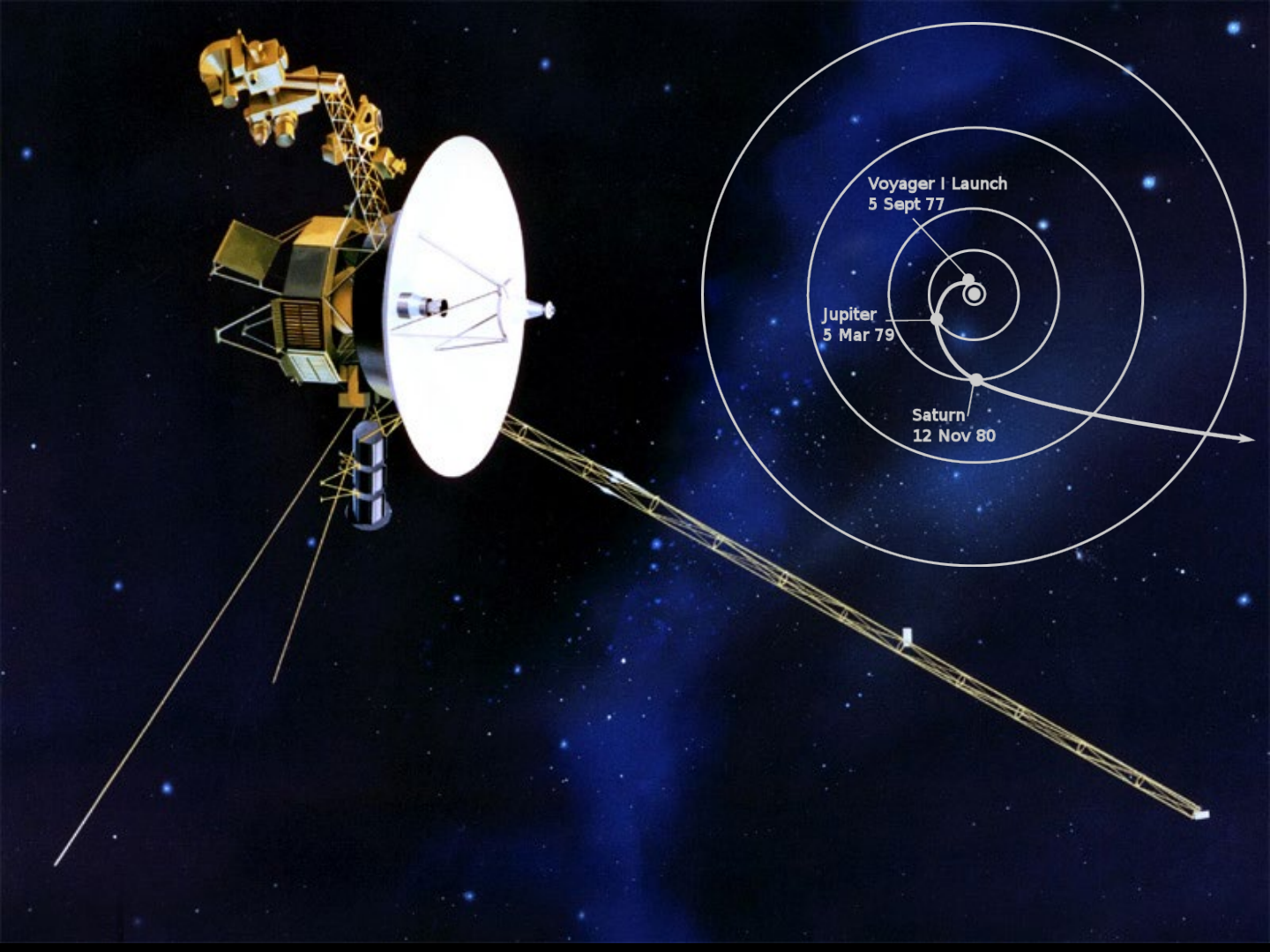
Pathways to Discovery in Astronomy and Astrophysics for the 2020s

nap.edu/astro2020

Theme #1 - Worlds and Suns in Context



“Pathways to Habitable Worlds” is a step-by-step program to identify and characterize Earth-like extrasolar planets, with the ultimate goal of obtaining imaging and spectroscopy of potentially habitable worlds.


Voyager I Launch
5 Sept 77
Jupiter
5 Mar 79
Saturn
12 Nov 80