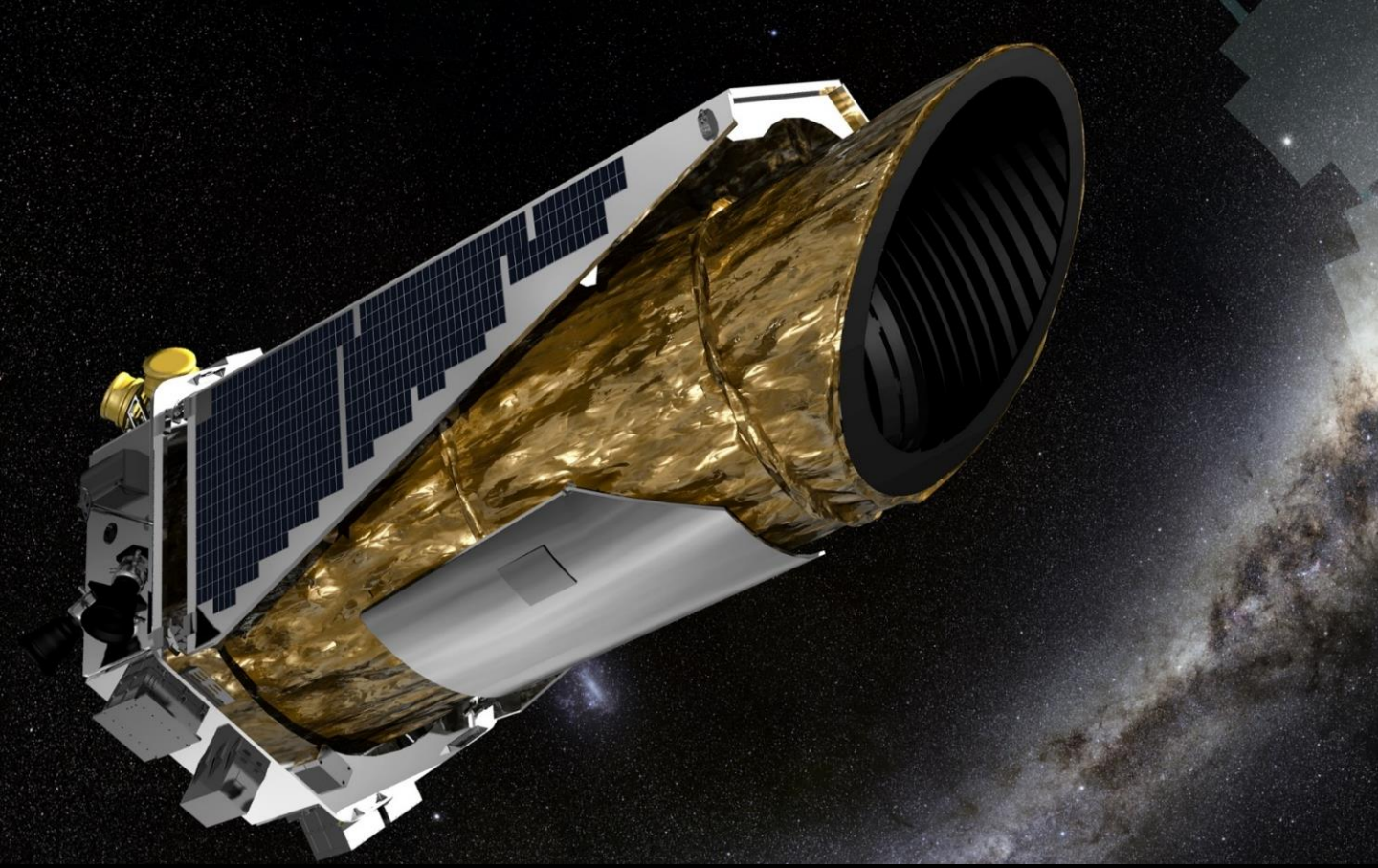
The Search for Life

Finding Earth 2.0

Dr. Jonathan Crass

UNIVERSITY OF NOTRE DAME

Are we alone?



Searching for Exoplanets

Searching for Exoplanets

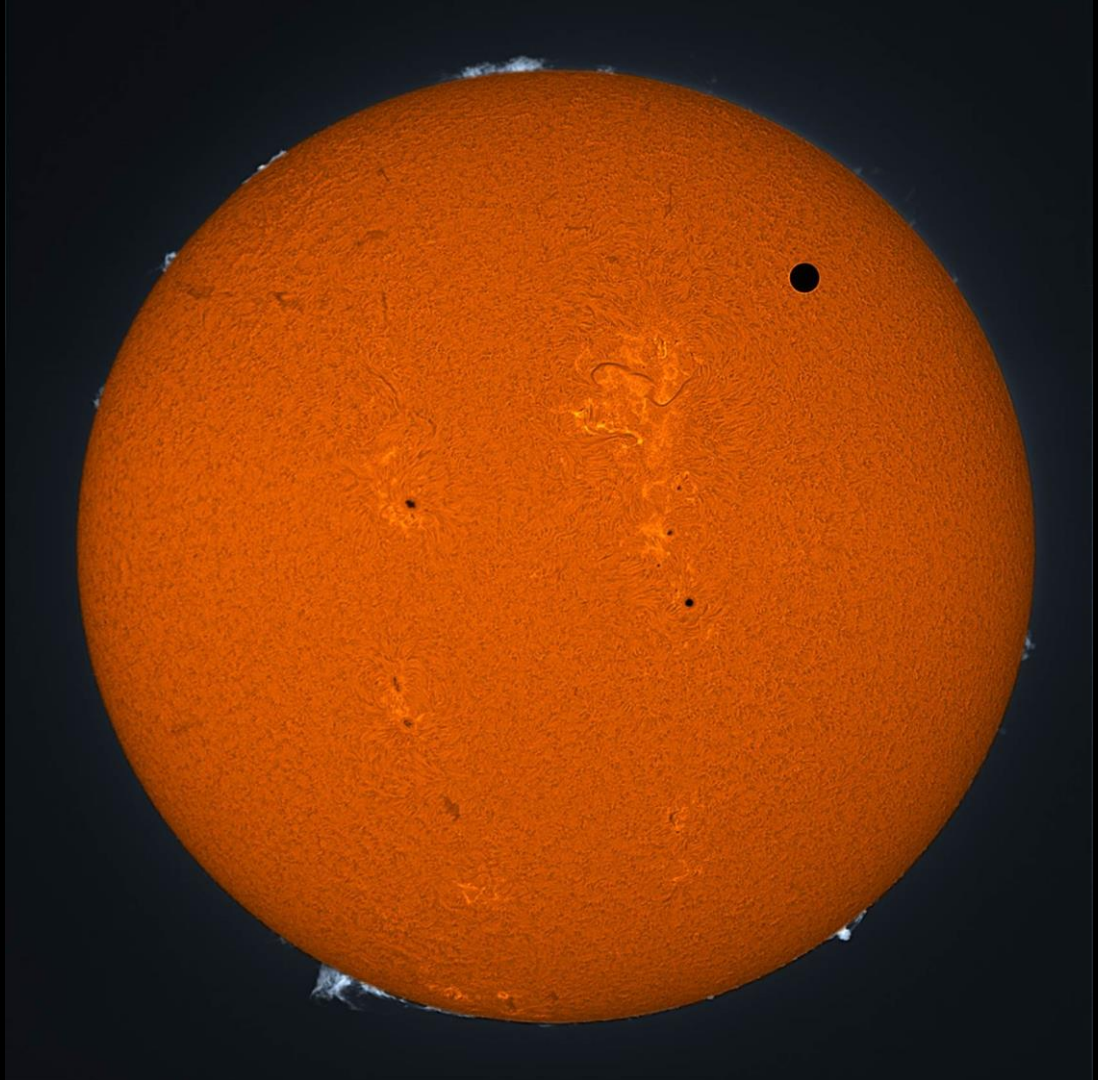
- There are four major techniques for searching for the exoplanets:

Transit Technique

Radial Velocity Technique

Gravitational Microlensing

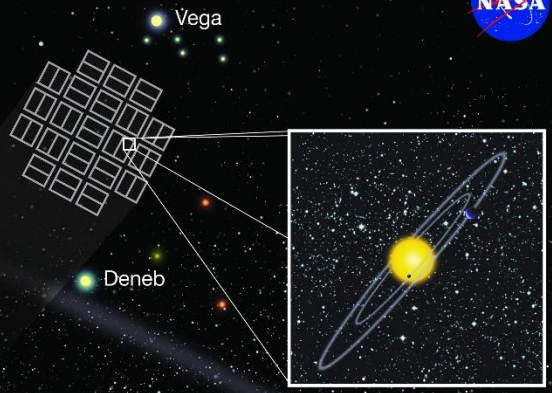
Direct Imaging



National Aeronautics and Space Administration

Kepler

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



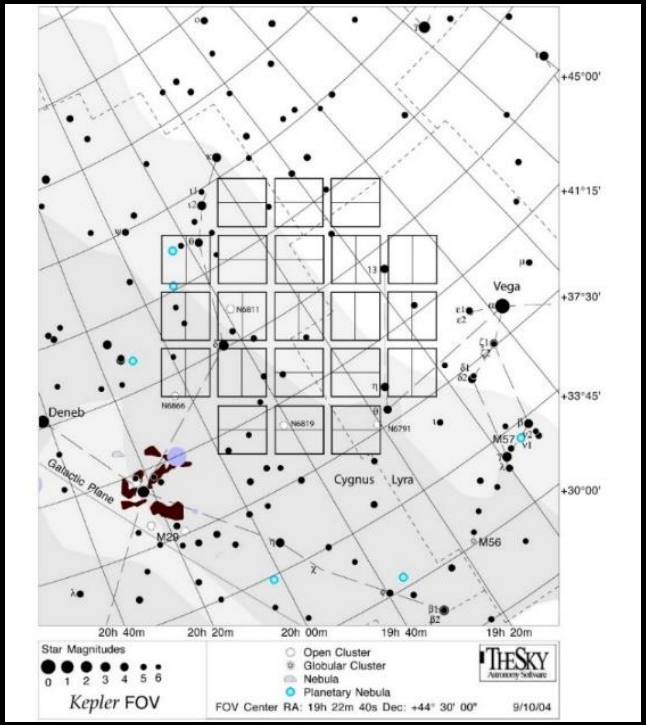
WARNING: OBJECTS IN THIS RENDITION APPEAR LARGER AND CLOSER TOGETHER THAN THEY ARE IN REALITY.

www.nasa.gov

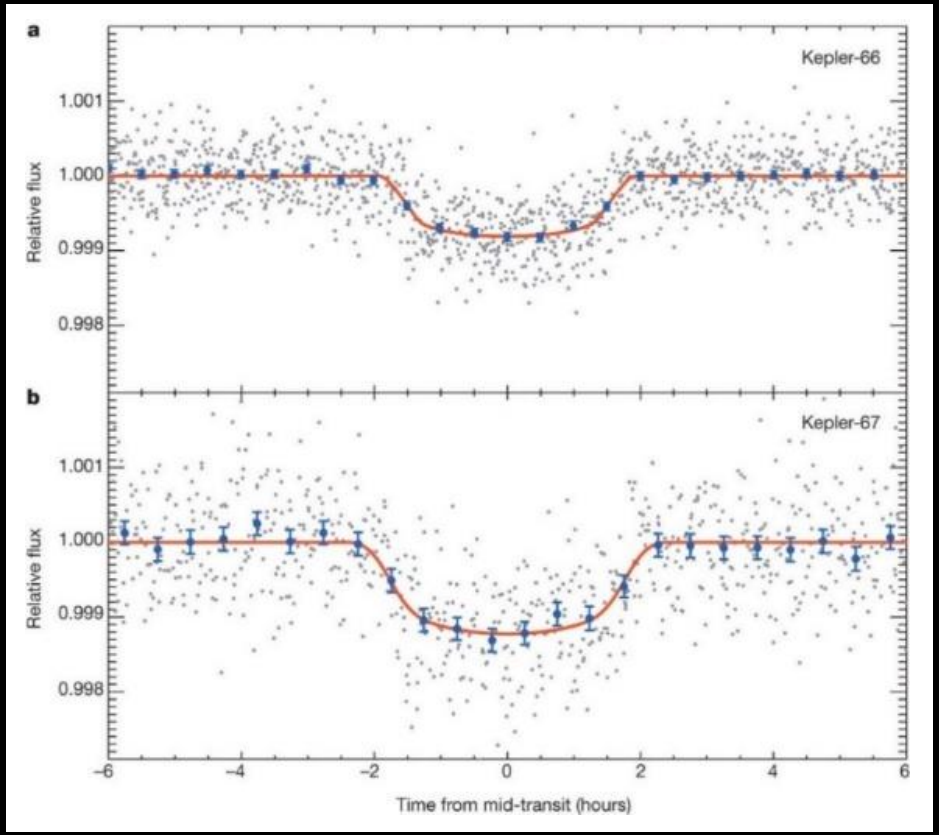
Find educational activities at www.kepler.nasa.gov

The Kepler Mission

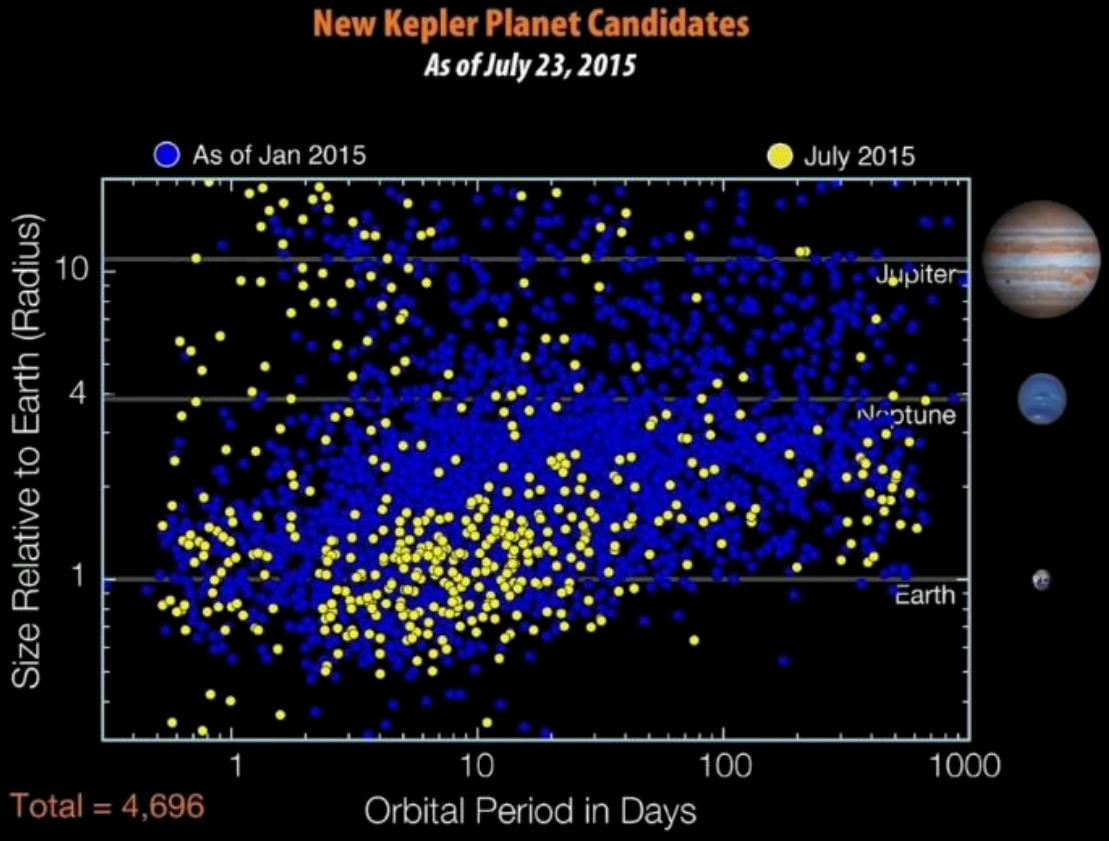
The Kepler Mission

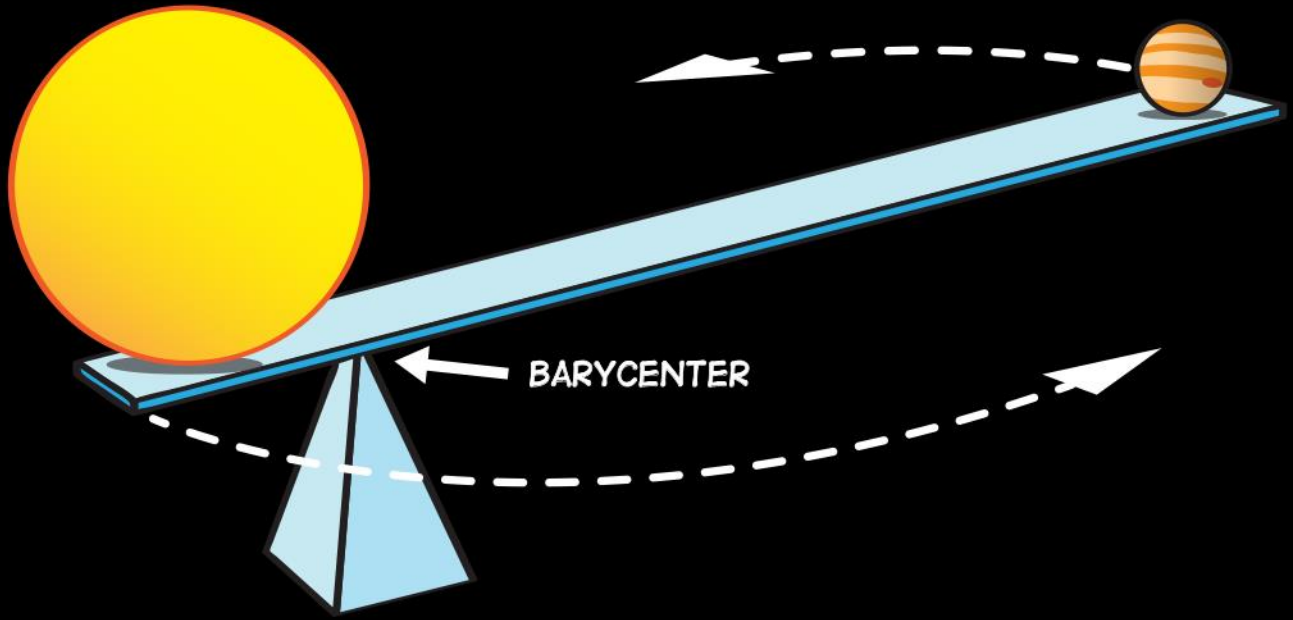


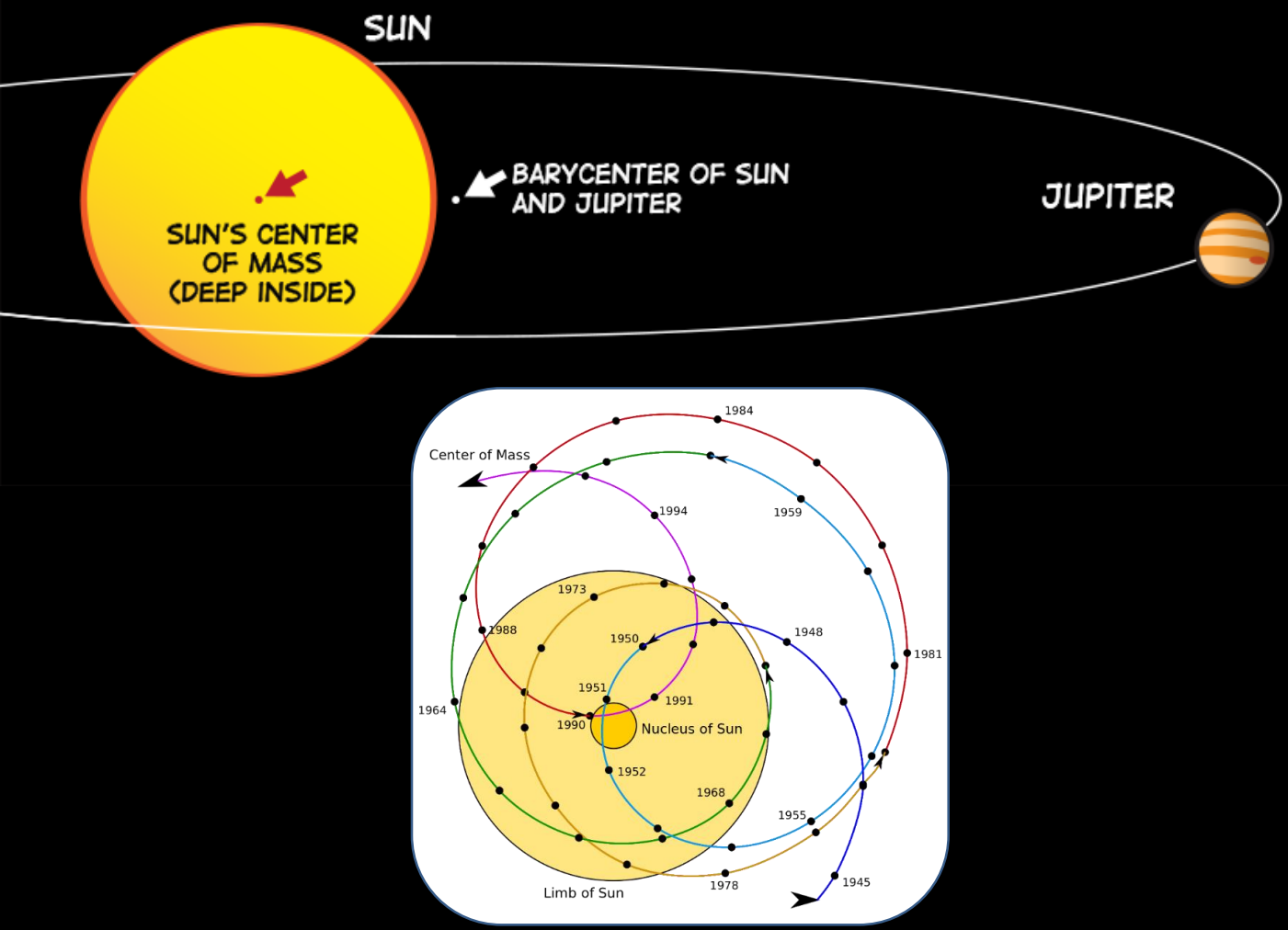
The Kepler Mission

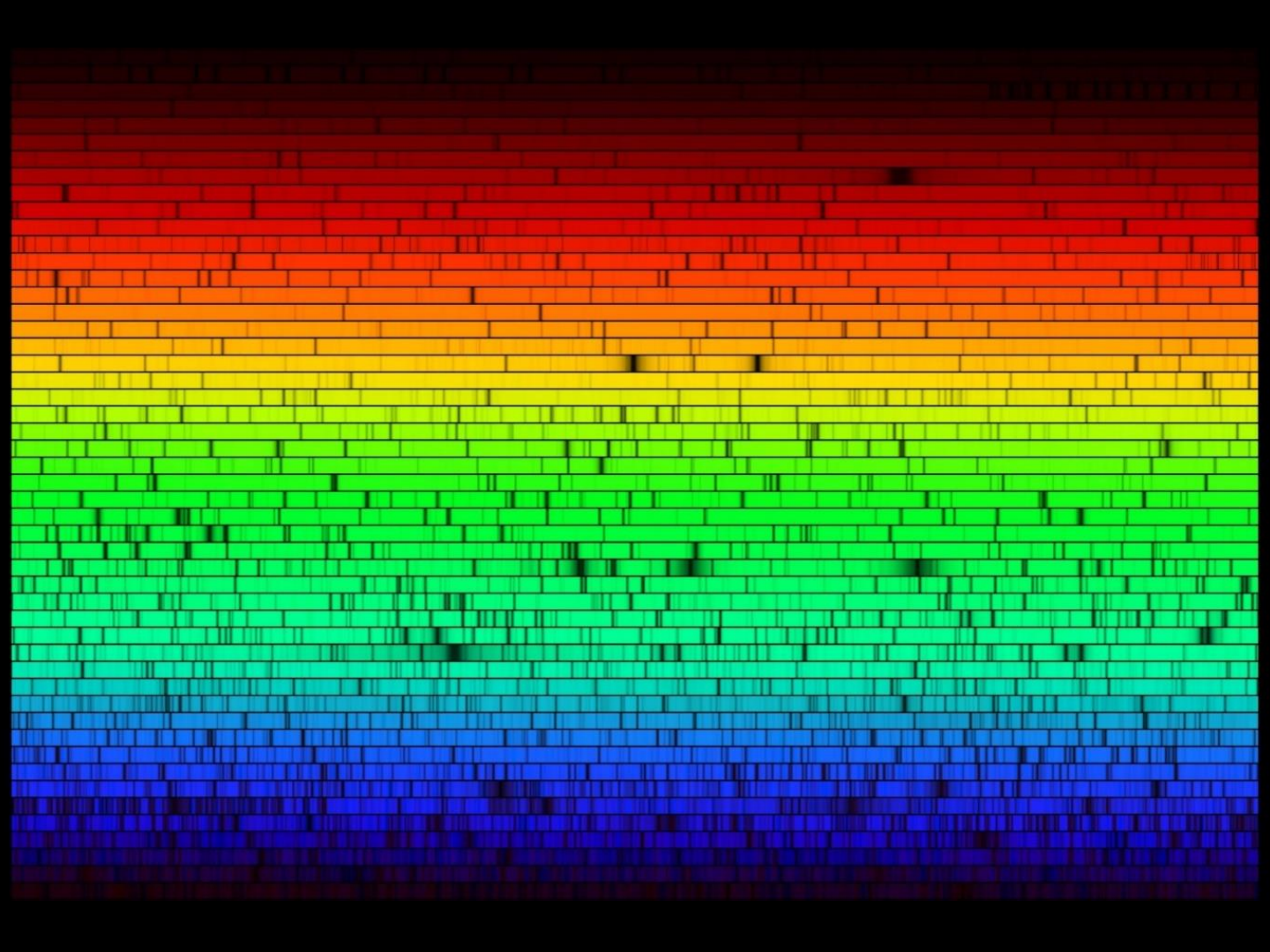


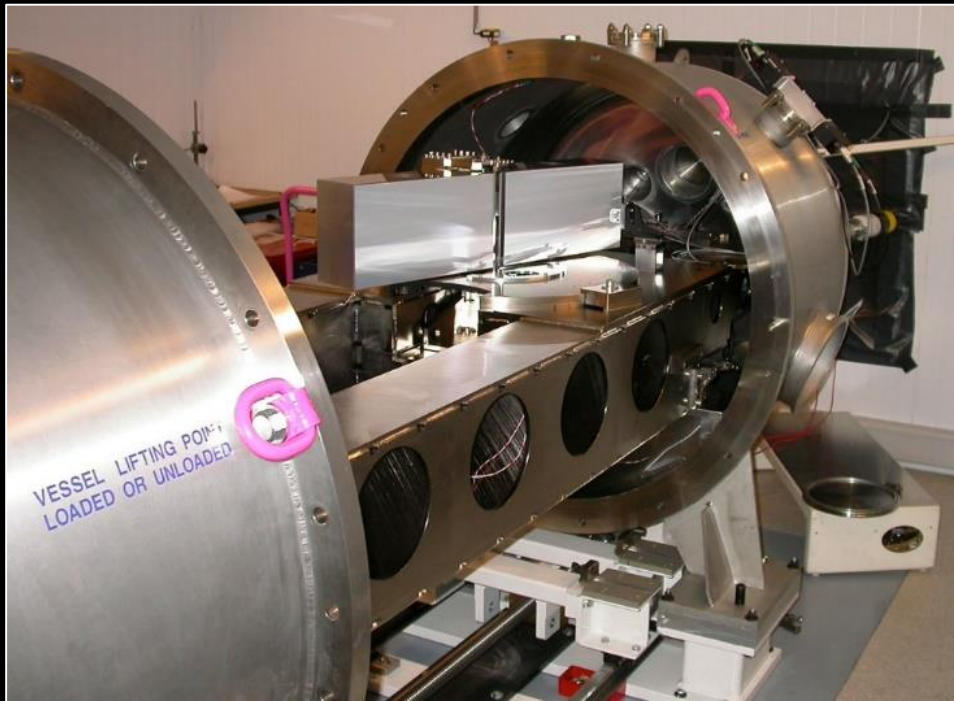
The Kepler Mission

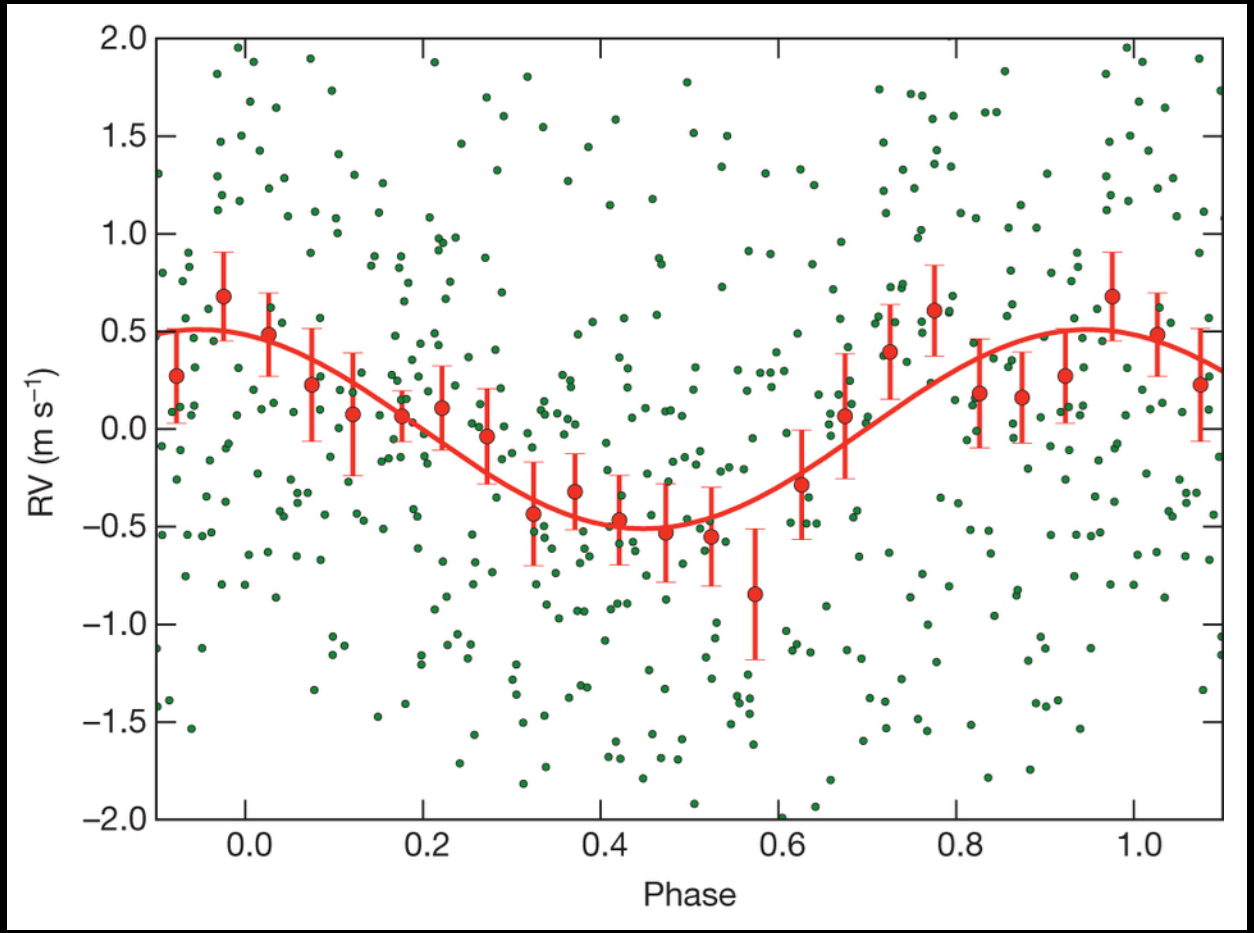



BARYCENTER

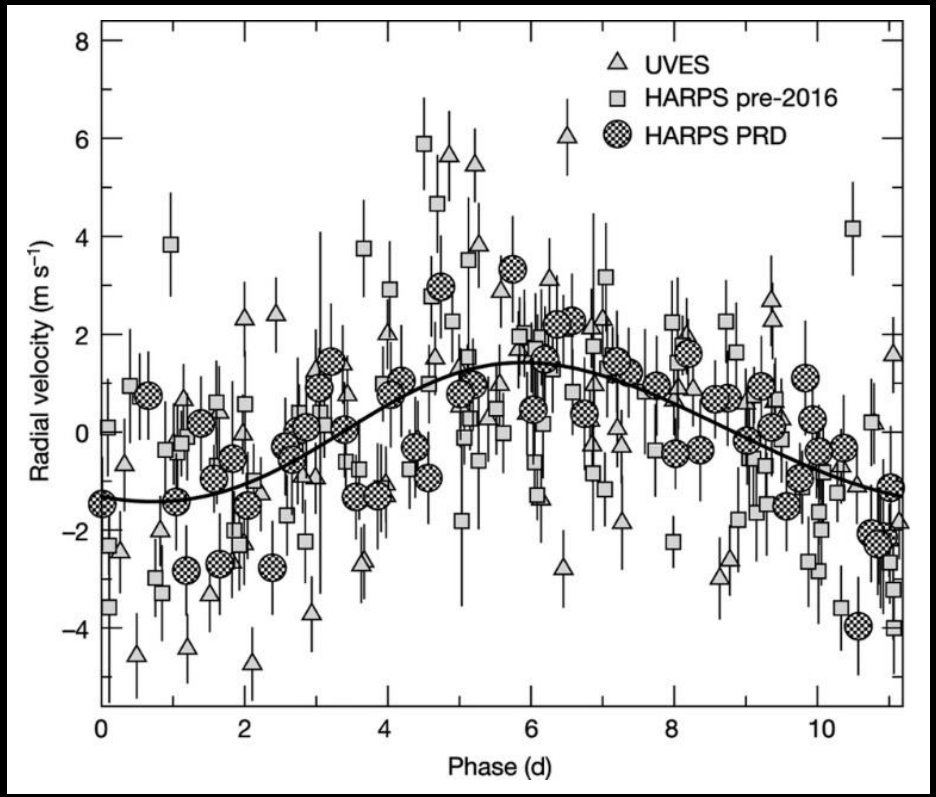

SUN
SUN'S CENTER OF MASS (DEEP INSIDE)
BARYCENTER OF SUN AND JUPITER
JUPITER
Center of Mass
1984
1994
1959
1973
1988
1950
1948
1981
1951
1991
1964
1990
Nucleus of Sun
1952
1968
1955
1978
1945
Limb of Sun



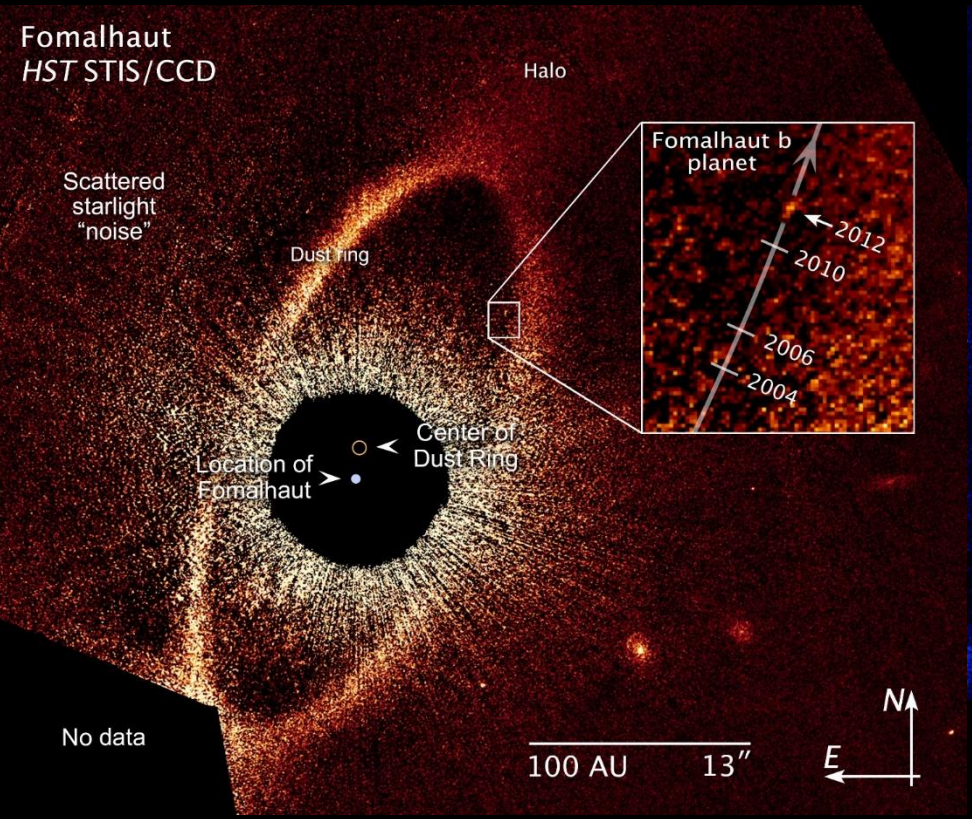

VESSEL LIFTING POI
LOADED OR UNLOADED

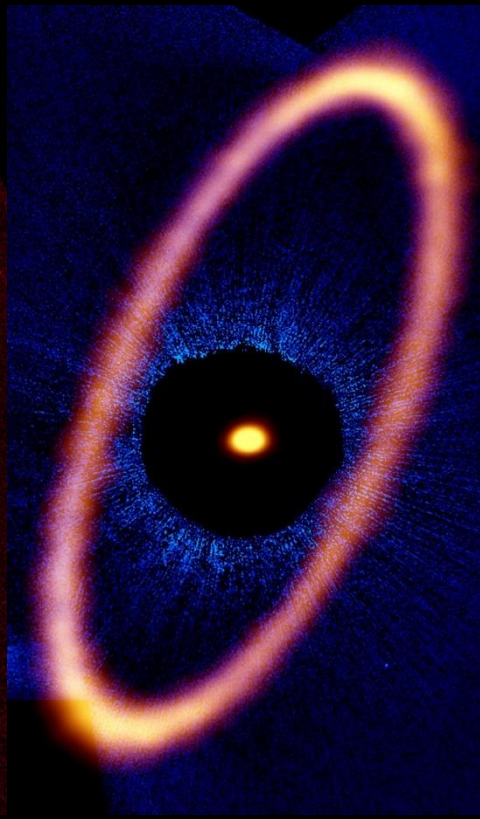

2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
RV (m s−1)
0.0
0.2
0.4
0.6
0.8
1.0
Phase

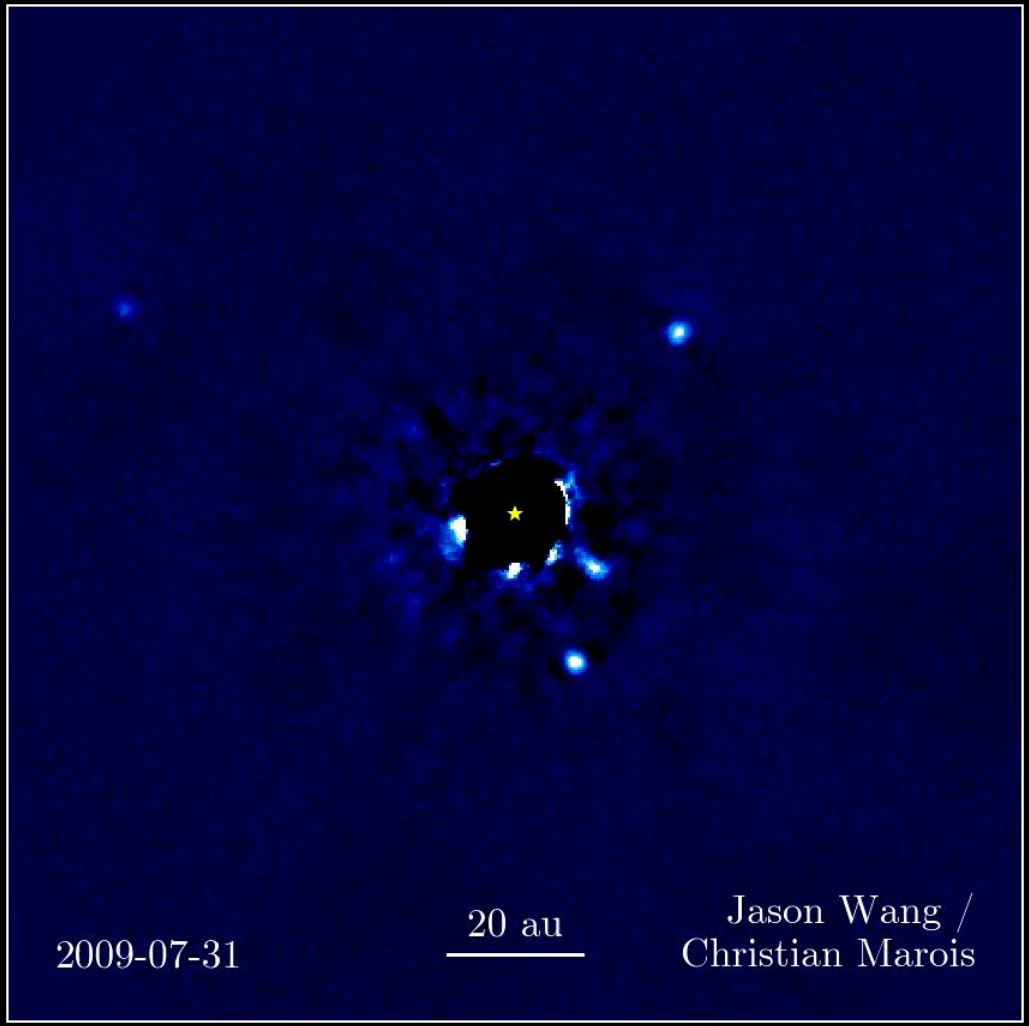
Proxima Centauri b




Brightness


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




2009-07-31
20 au
Jason Wang /
Christian Marois

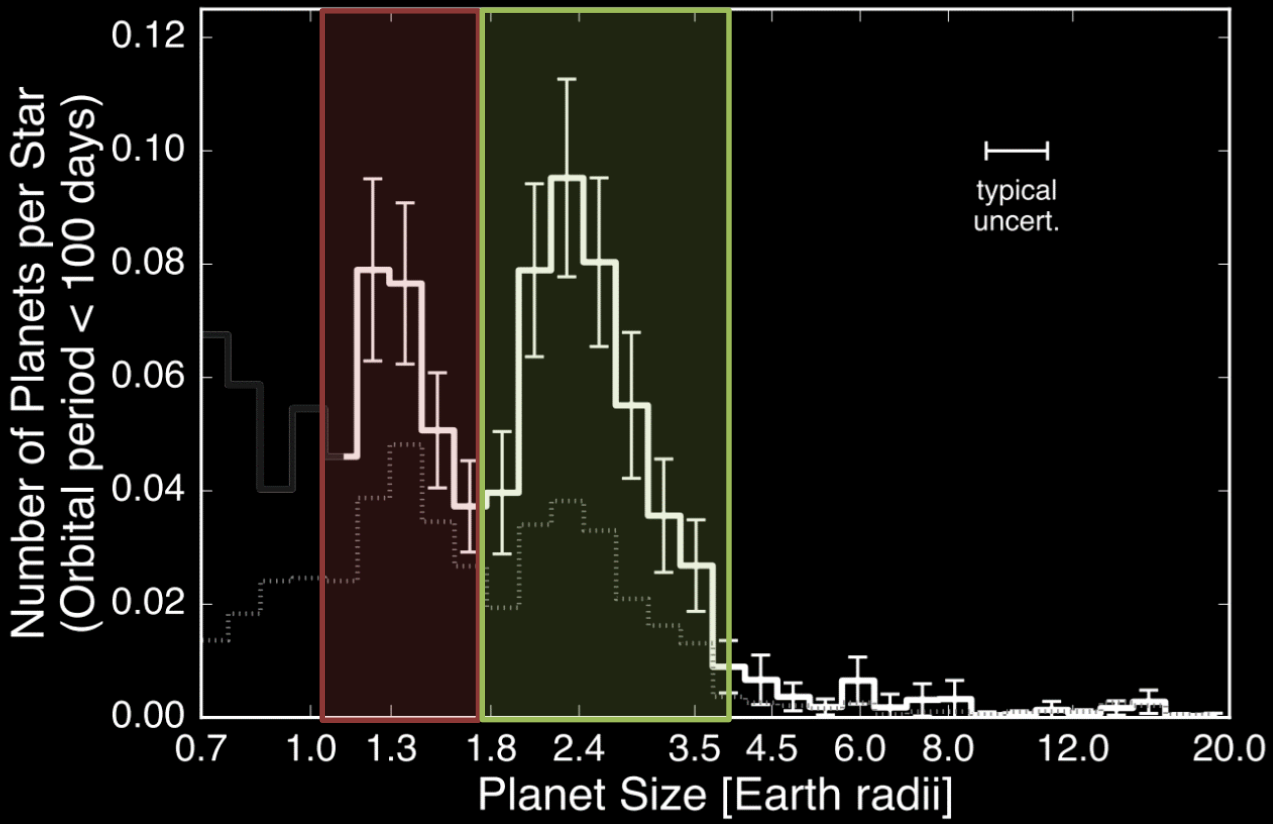
A very new field…

- 1988 - A possible planetary detection…
- 1992 – The discovery of a planet around a Pulsar
- 1995 – The discovery of a planet around the 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

3706
confirmed planets

2,900 discovered by transit method
669 **discovered** by radial velocity
44 discovered by imaging

54 discovered by microlensing
39 discovered using other methods


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]

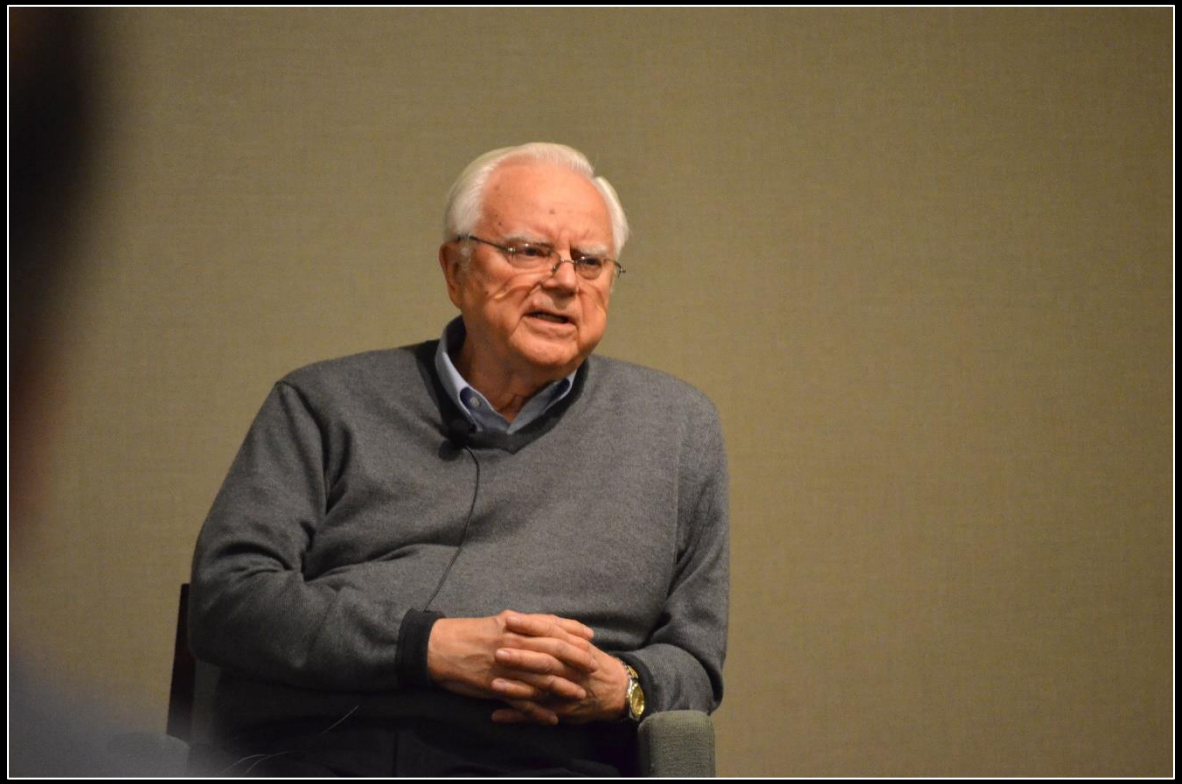

Are we alone?

The ingredients for life

The signatures of life

- "Organic Molecules"
  - Oxygen
  - Methane

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

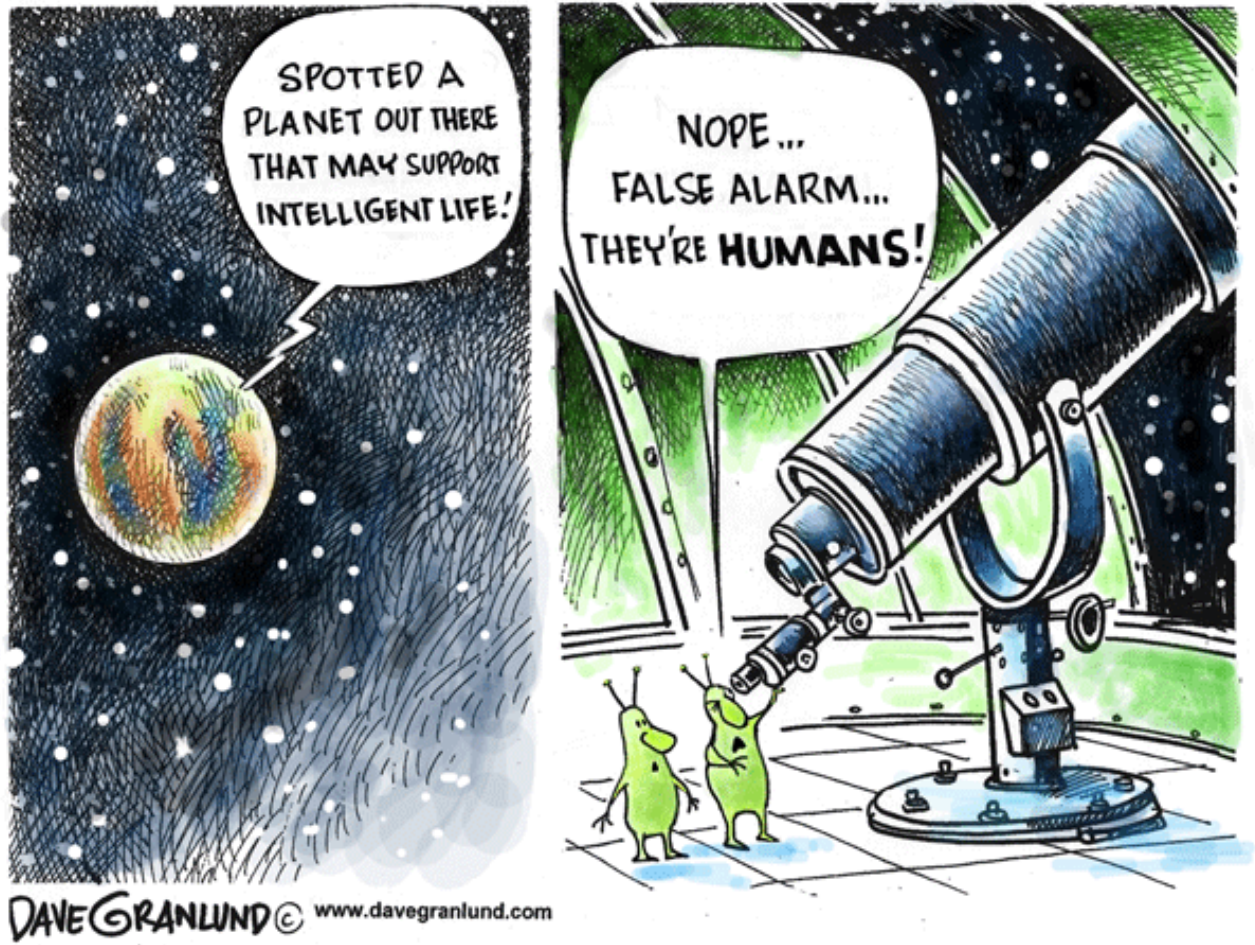
n_e = The number of planets, per solar system, which can support life

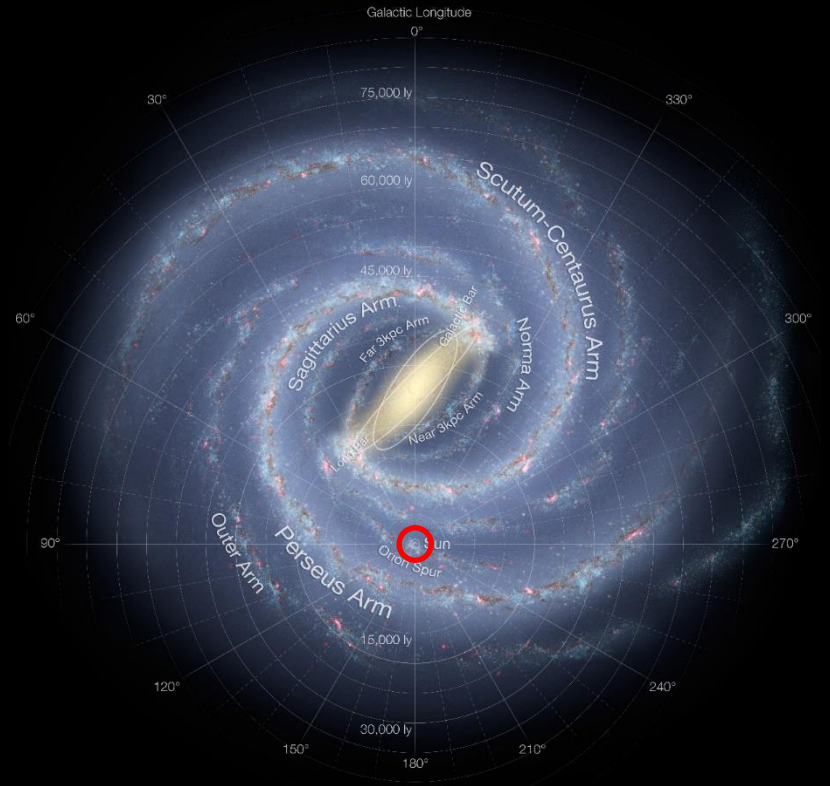
f_l = The fraction of suitable planets on which life actually appears

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

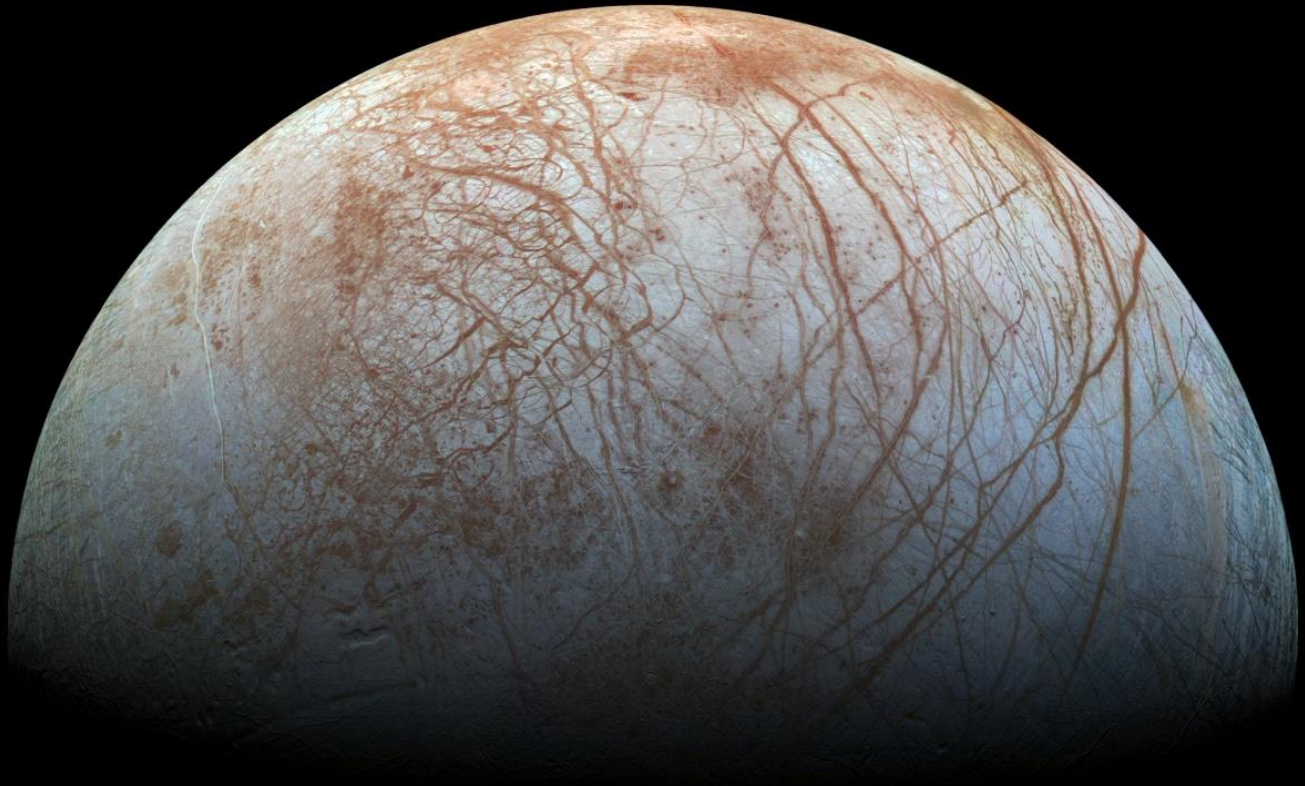
f_c = The fraction of civilizations that develop technology to emit signals into space

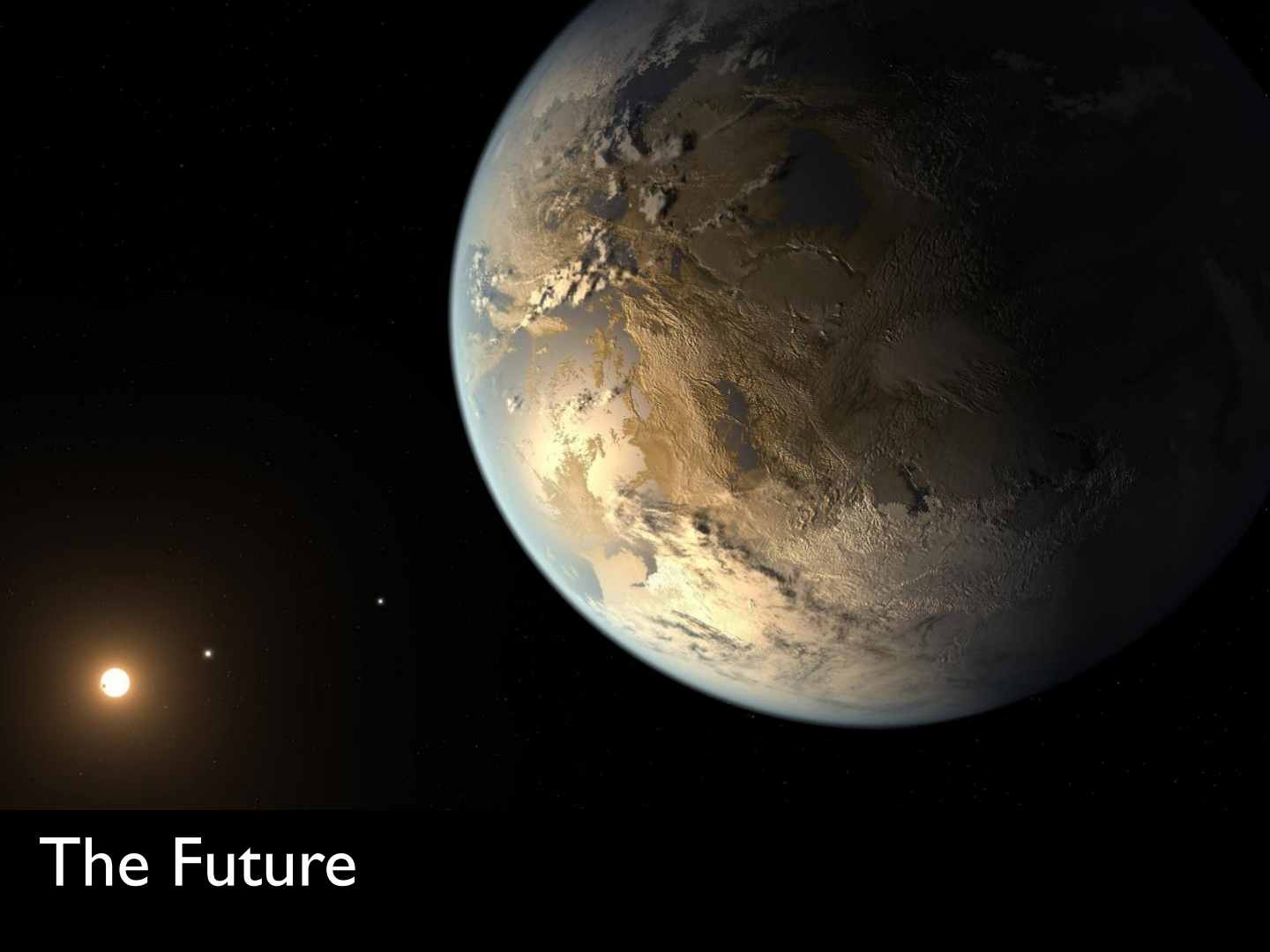
L = The length of time such civilizations release these signals into space


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

Our Own Solar System

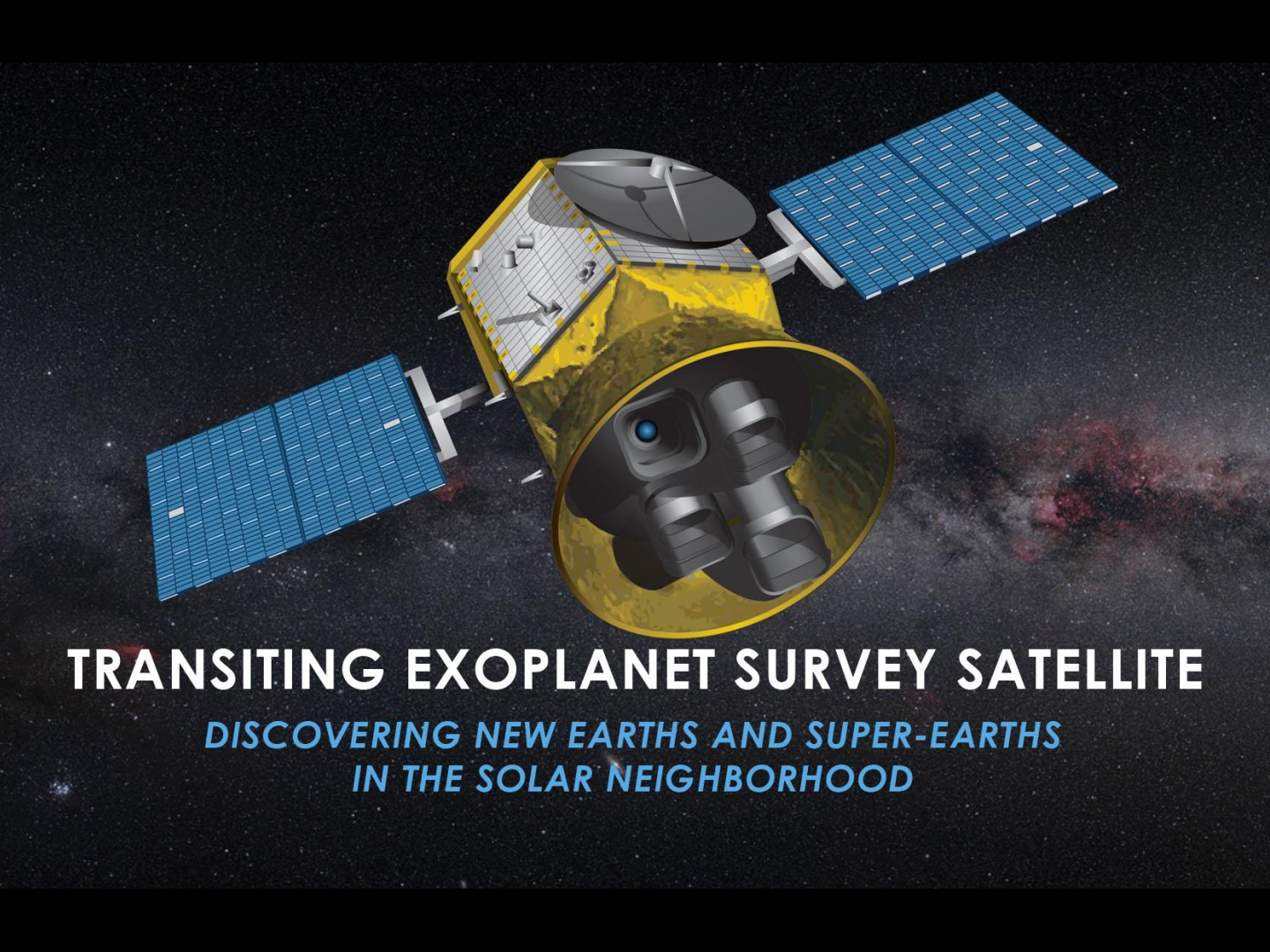


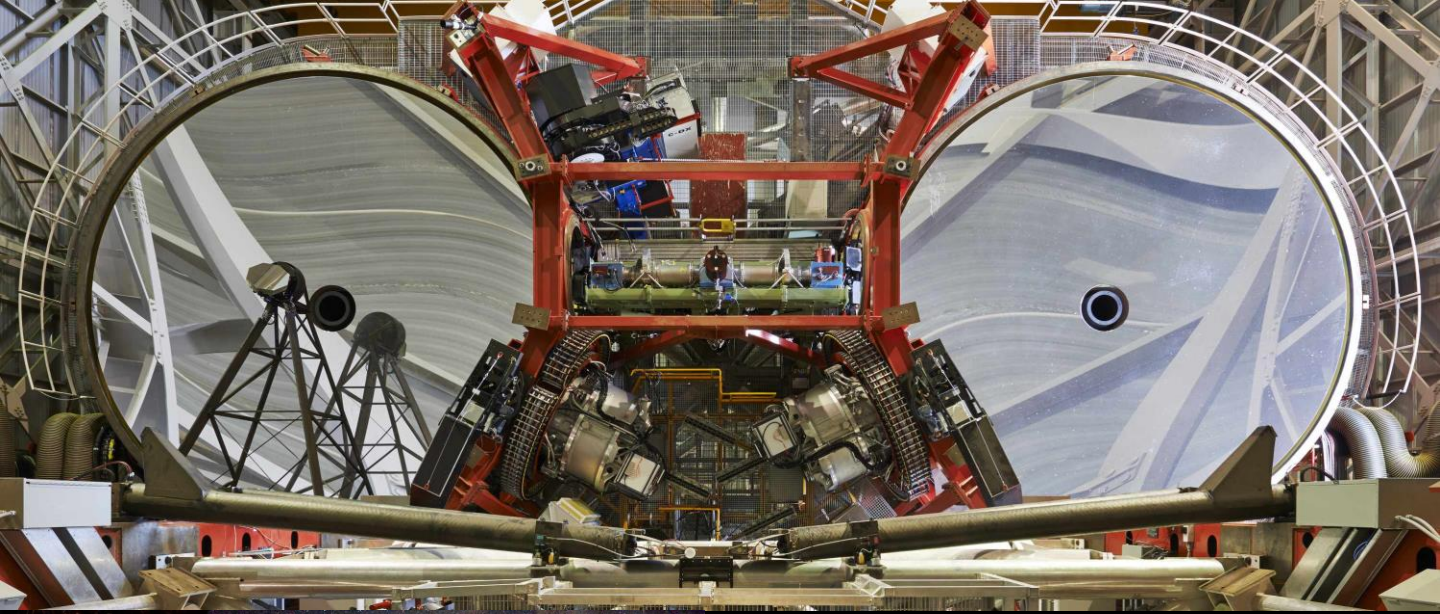


The Future

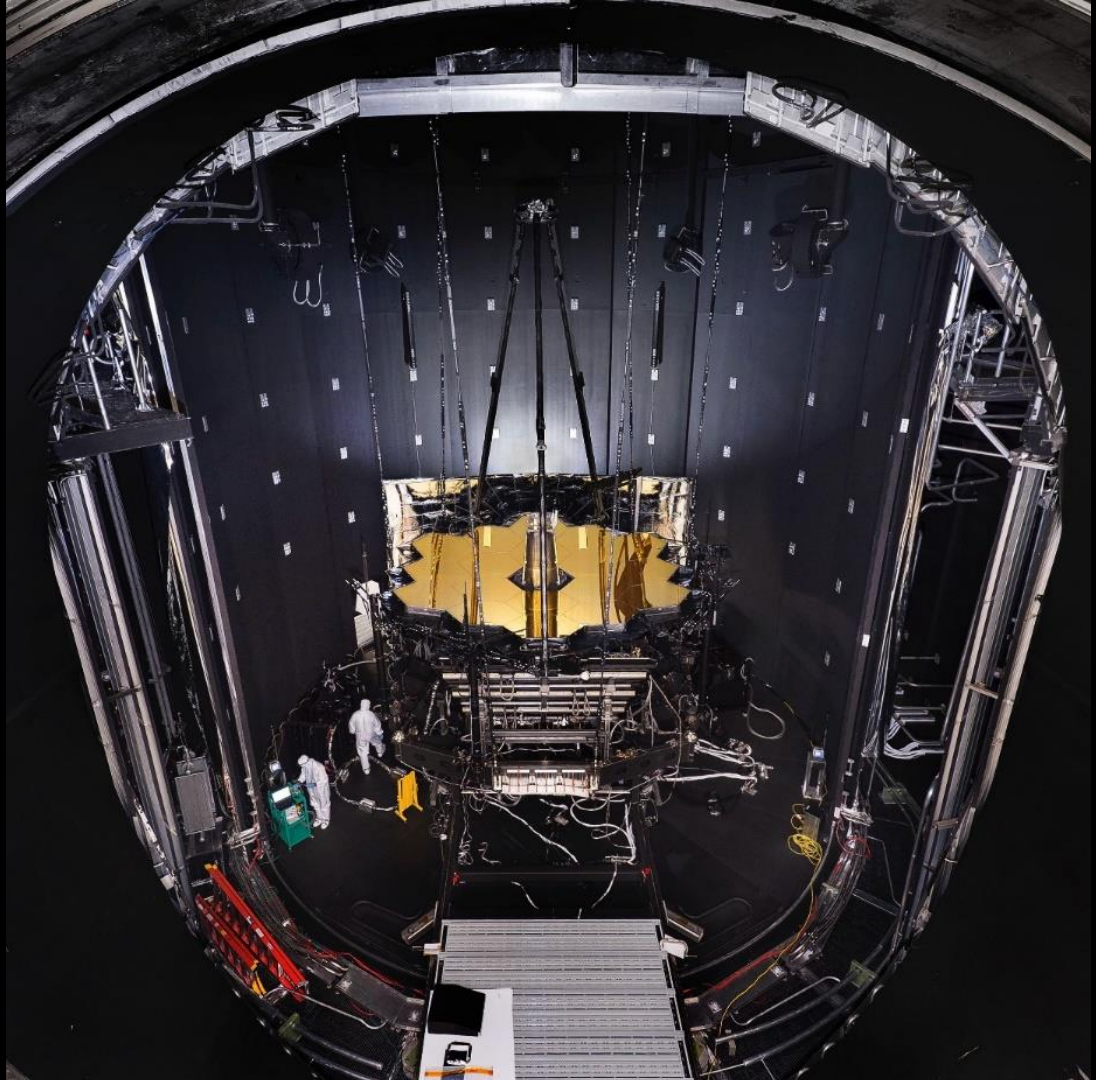
The remaining questions

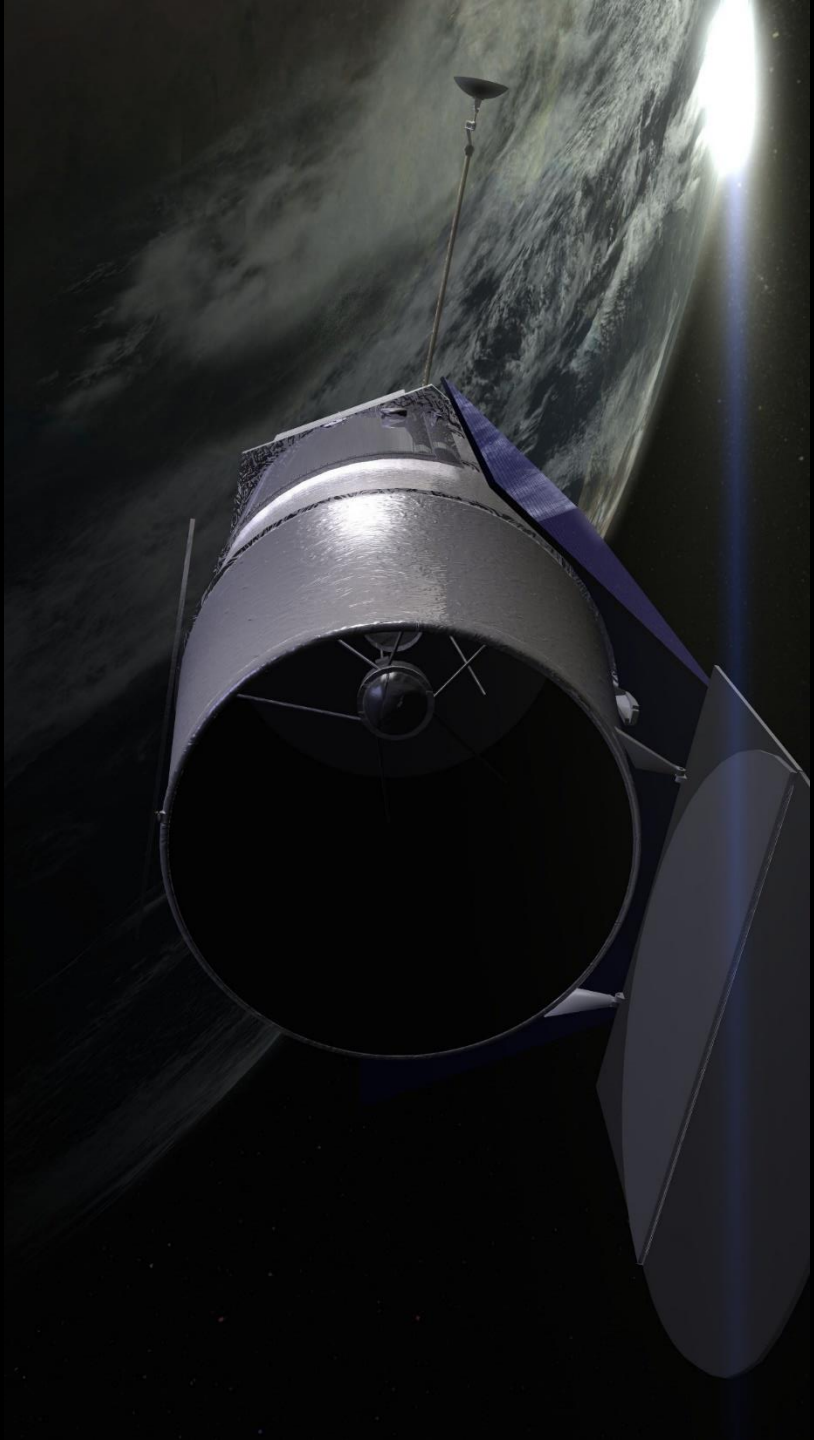
- Is our Solar System special?
- How do exoplanets form?
- What are exoplanets made of?
- Do they show signatures of life?


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



iLocater






Thank you