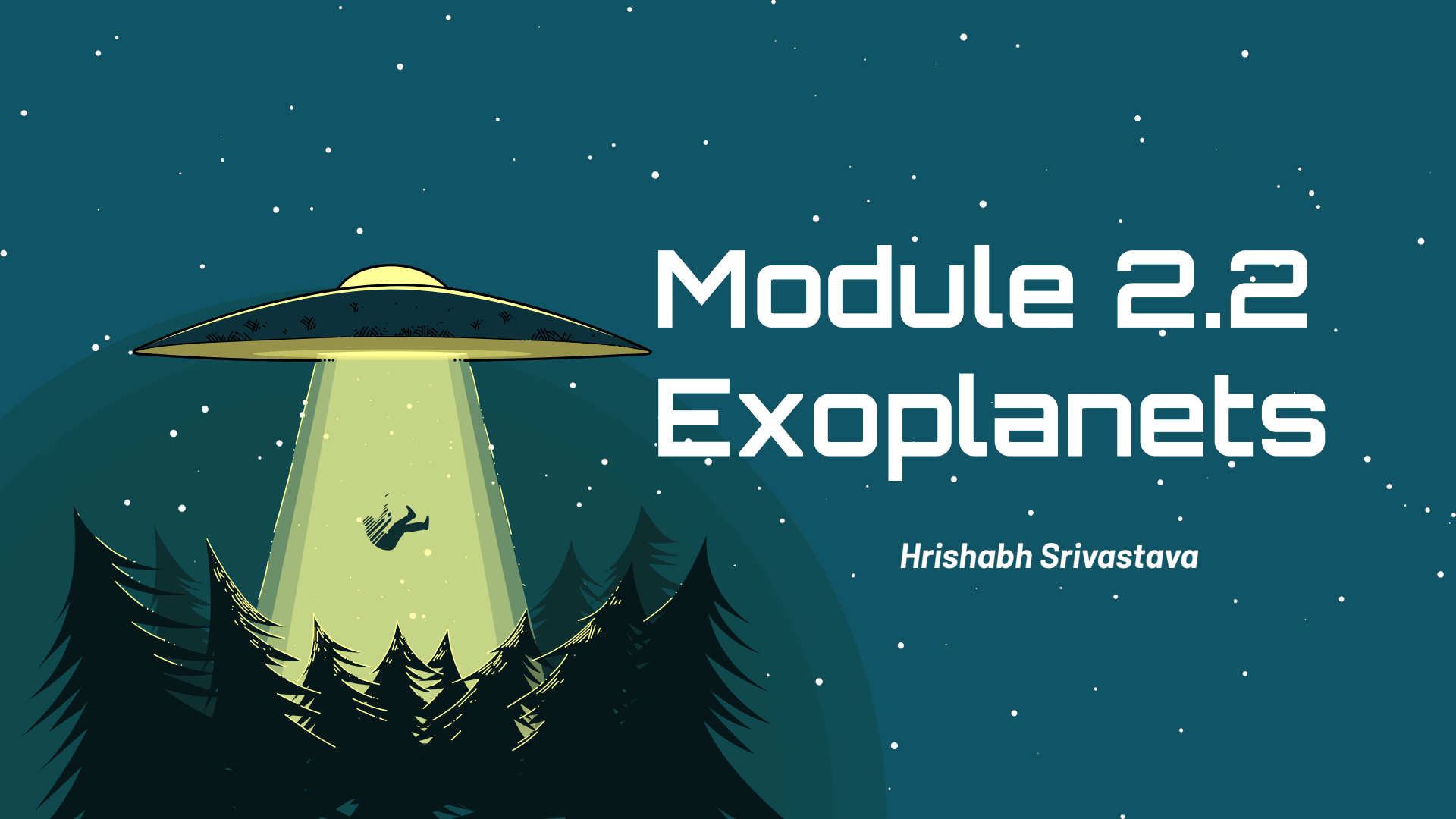


Module 2.2 Exoplanets

Hrishabh Srivastava

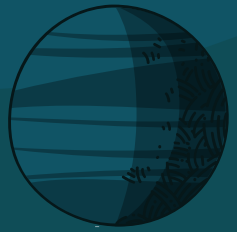
CONTENT OF THIS MODULE

1. What are exoplanets and its types?
2. How do we find exoplanets?
3. Famous exoplanet mission
4. NASA Exoplanet Archive
5. Gaia Data Release

01 Exoplanets and its types

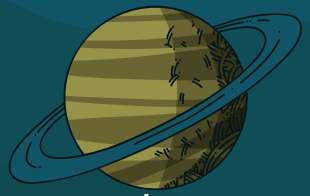
Credits: NASA/JPL-Caltech

MAJOR TYPES

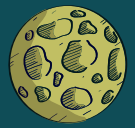


Gas Giants

Super Earth



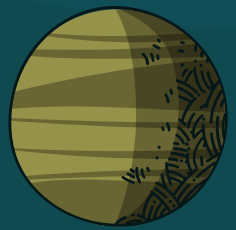
Neptune like

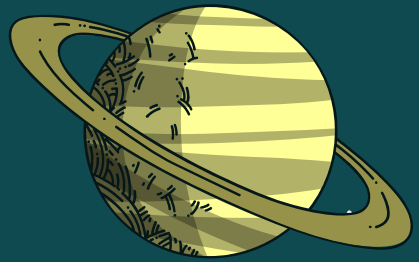


Terrestrial

GAS GIANTS

A gas giant is a large planet mostly composed of helium and/or hydrogen. These planets, like Jupiter and Saturn in our solar system, don't have hard surfaces and instead have swirling gases above a solid core. Gas giant exoplanets can be much larger than Jupiter, and much closer to their stars than anything found in our solar system.





51 Pegasi b

Famous Gas Giant

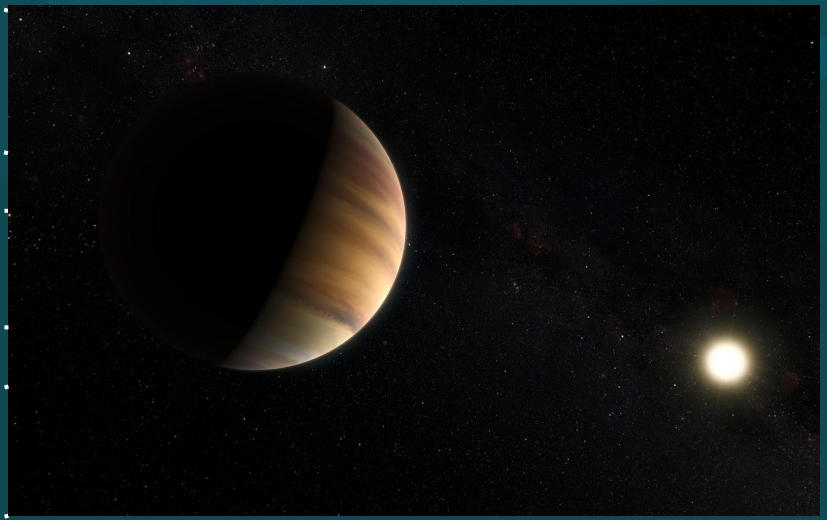
Discovery : 1995

Mass : 0.45 Jupiter Mass

Radius: 1.27 Jupiter Radius

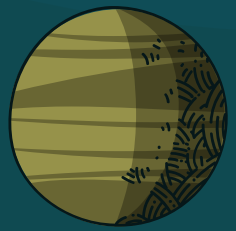
Orbital Period: 4.2 days

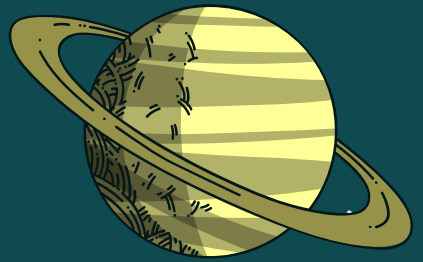
Orbits a G-type star



Super Earths

Super-Earths – a class of planets unlike any in our solar system – are more massive than Earth yet lighter than ice giants like Neptune and Uranus, and can be made of gas, rock or a combination of both. They are between twice the size of Earth and up to 10 times its mass.





Bernard's Star b

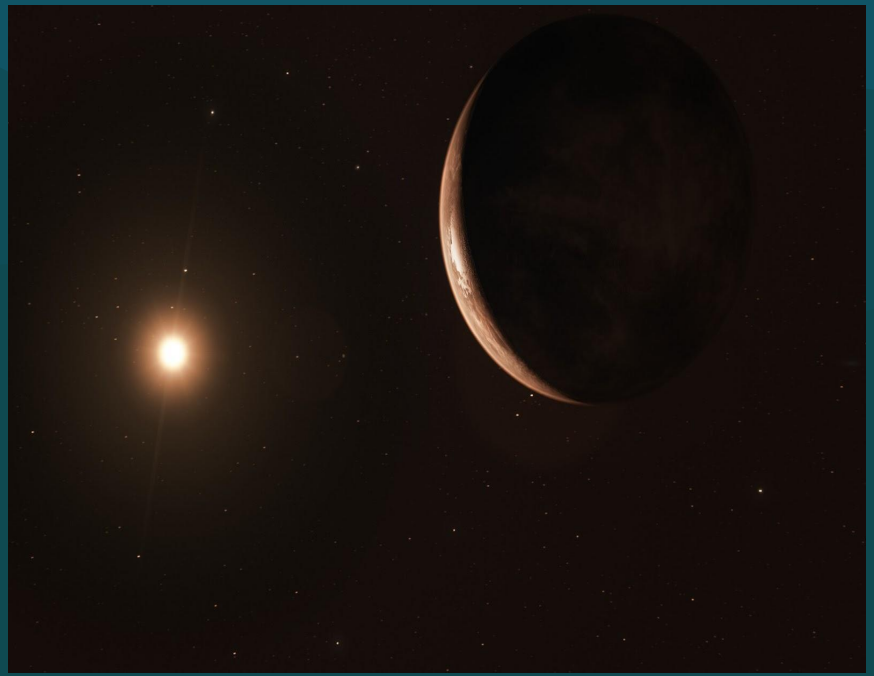
Famous super-earth

Discovered in 2018

Mass : 3.2 Earth Mass

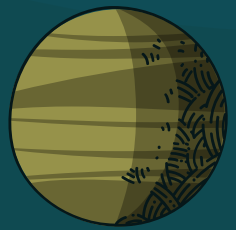
2nd closest exoplanet (6ly away)

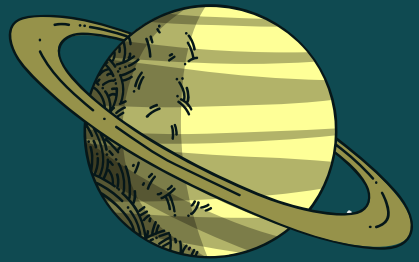
Orbital Period~ 233 days



NEPTUNE-LIKE

Neptunian exoplanets are similar in size to Neptune or Uranus in our solar system. Neptunian planets typically have hydrogen and helium-dominated atmospheres with cores or rock and heavier metals.





Kepler 1655 b

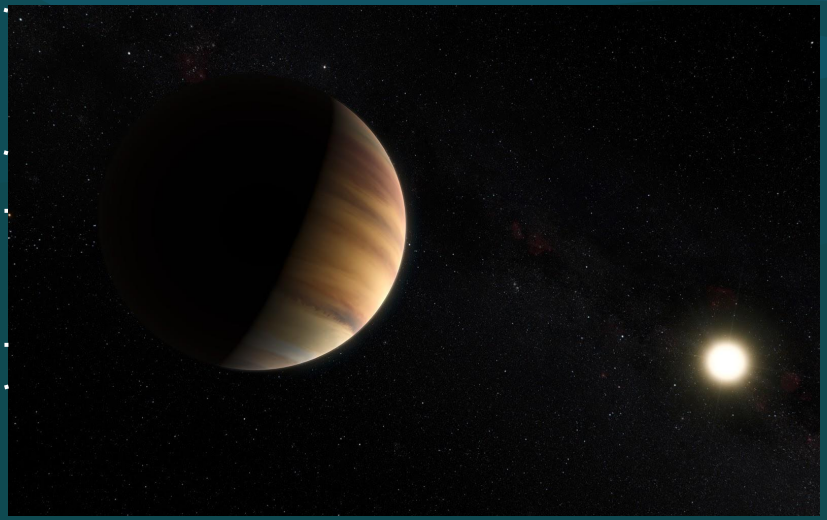
Detection method: Transit

Discovery : 2018

Mass : 5 Sun Mass

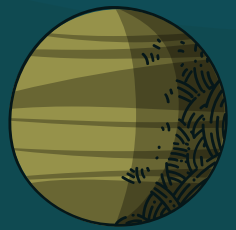
Orbital Radius: 0.103 AU

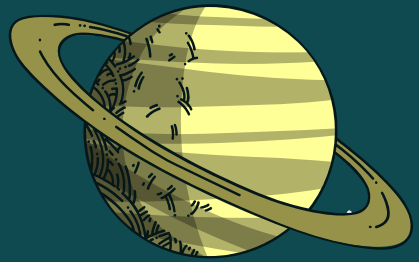
Orbital Period: 11.9 days



Terrestrial

In our solar system, Earth, Mars, Mercury and Venus are terrestrial, or rocky, planets. For planets outside our solar system, those between half of Earth's size to twice its radius are considered terrestrial and others may be even smaller. Exoplanets twice the size of Earth and larger may be rocky as well, but those are considered super-Earths.





Trappist-1e

Famous terrestrial

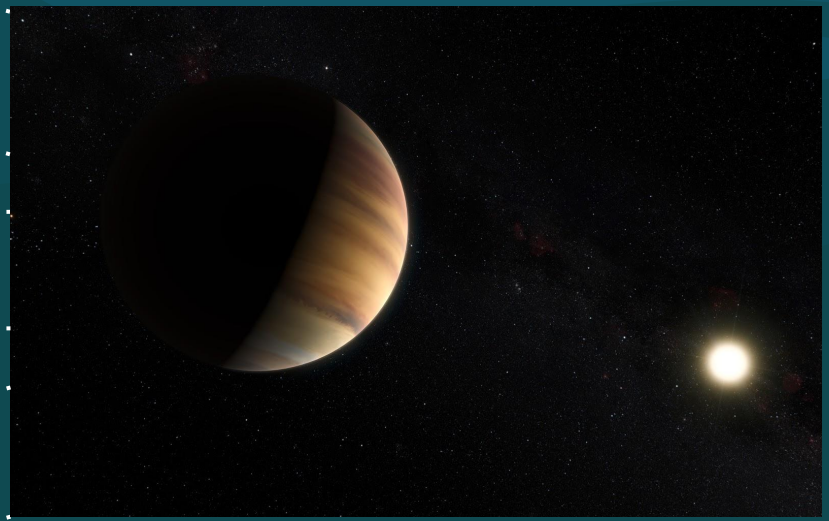
Discovery : 2017

Mass : 0.77 Earth Mass

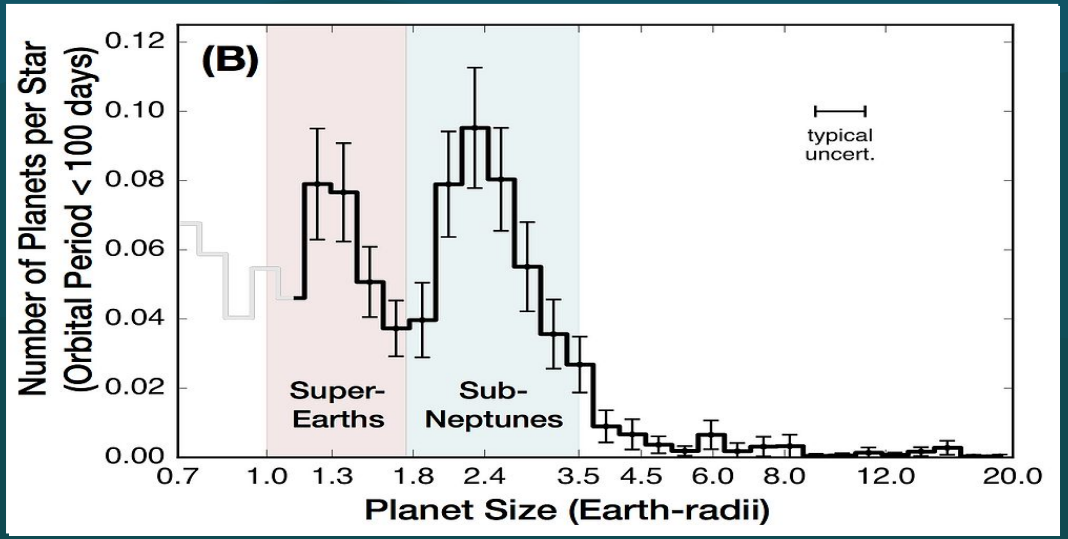
Radius: 0.91 Earth Radius

Orbital Period: 6.10 days

Orbital radius:
0.0293 AU

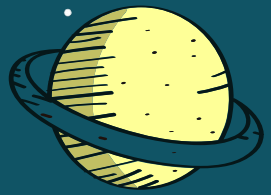


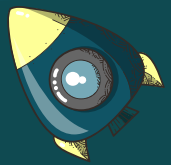
FULTON GAP

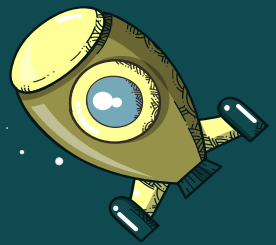

(B)
Number of Planets per Star
(Orbital Period < 100 days)
0.12
0.10
0.08
0.06
0.04
0.02
0.00
typical
uncert.
Super-
Earths
Sub-
Neptunes
0.7
1.0
1.3
1.8
2.4
3.5
4.5
6.0
8.0
12.0
20.0
Planet Size (Earth-radii)

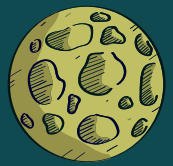
Why Exoplanets?

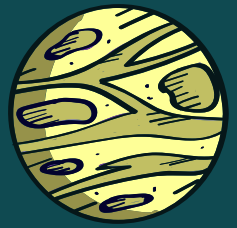
"Somewhere, something incredible is waiting to be known"
-Carl Sagan





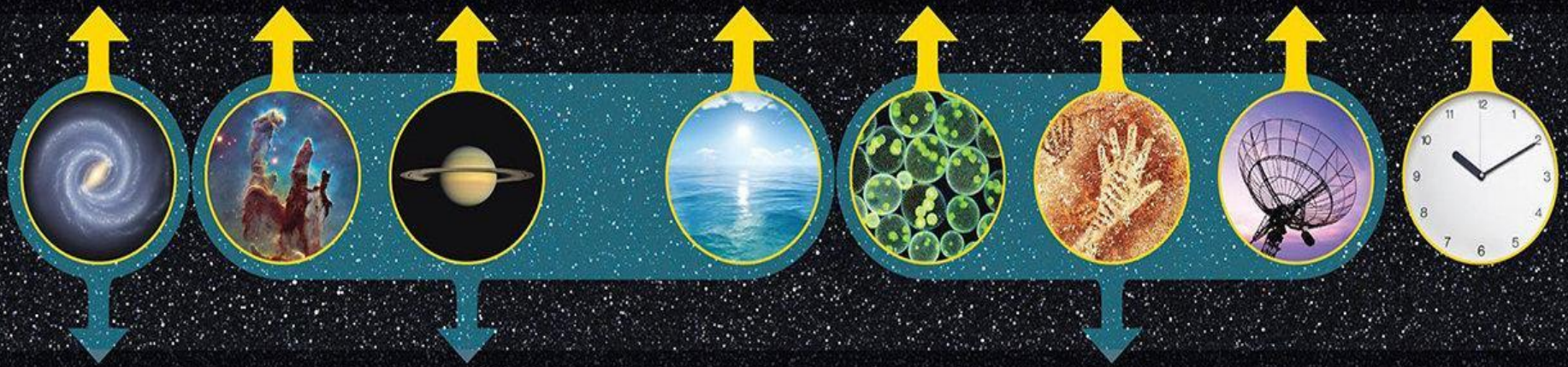






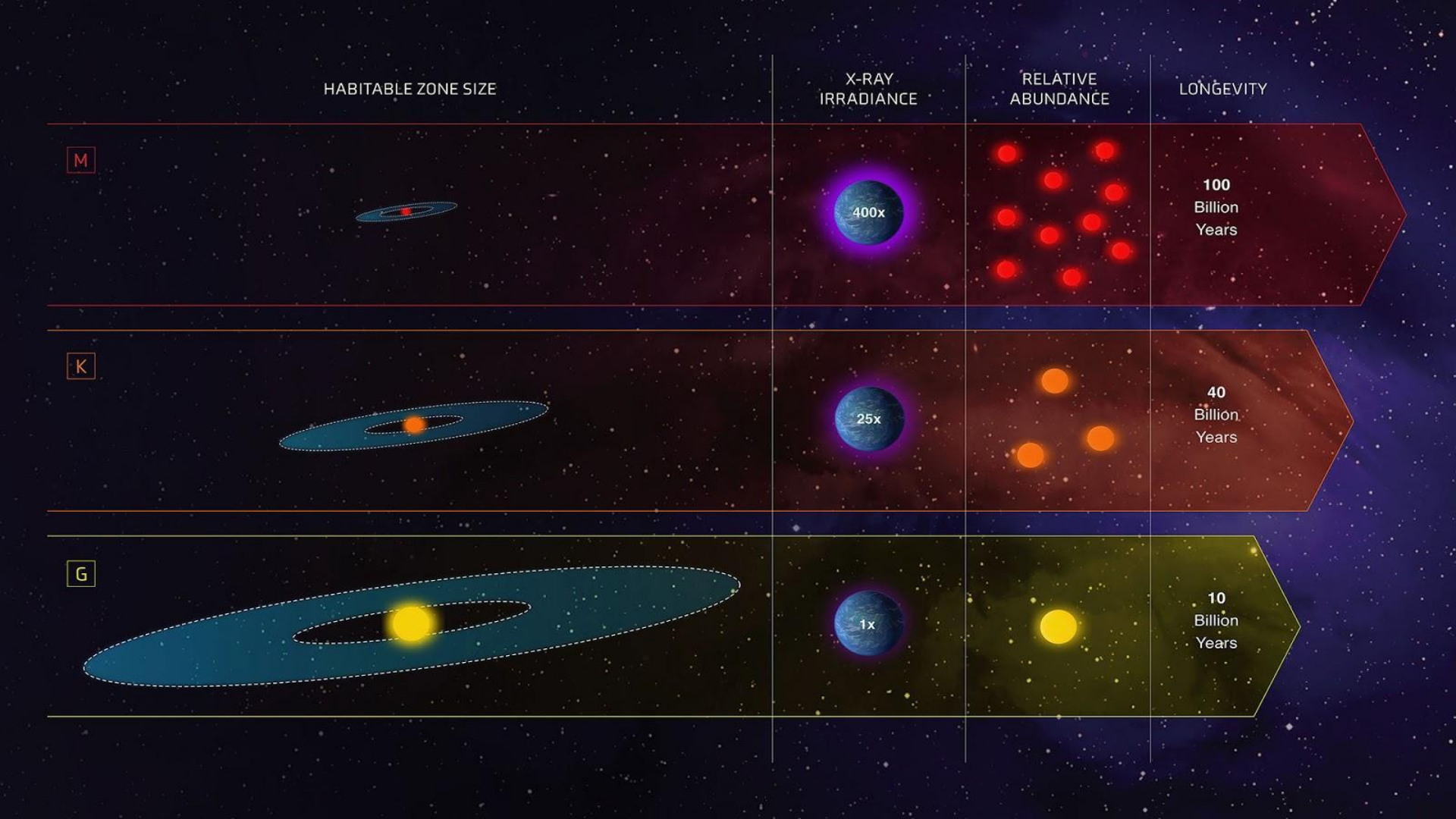
$$N = R_* \times f_p \times n_e \times f_e \times f_i \times f_c \times L$$

- N: The number of technologically advanced civilizations in the Milky Way galaxy
- R_*: The rate of formation of stars in the galaxy
- f_p: The fraction of those stars with planetary systems
- n_e: The number of planets, per solar system, with an environment suitable for life
- f_e: 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 a technology that releases detectable signs of their existence into space
- L: The length of time such civilizations release detectable signals into space



$$A = N_{ast} \times f_{bt}$$

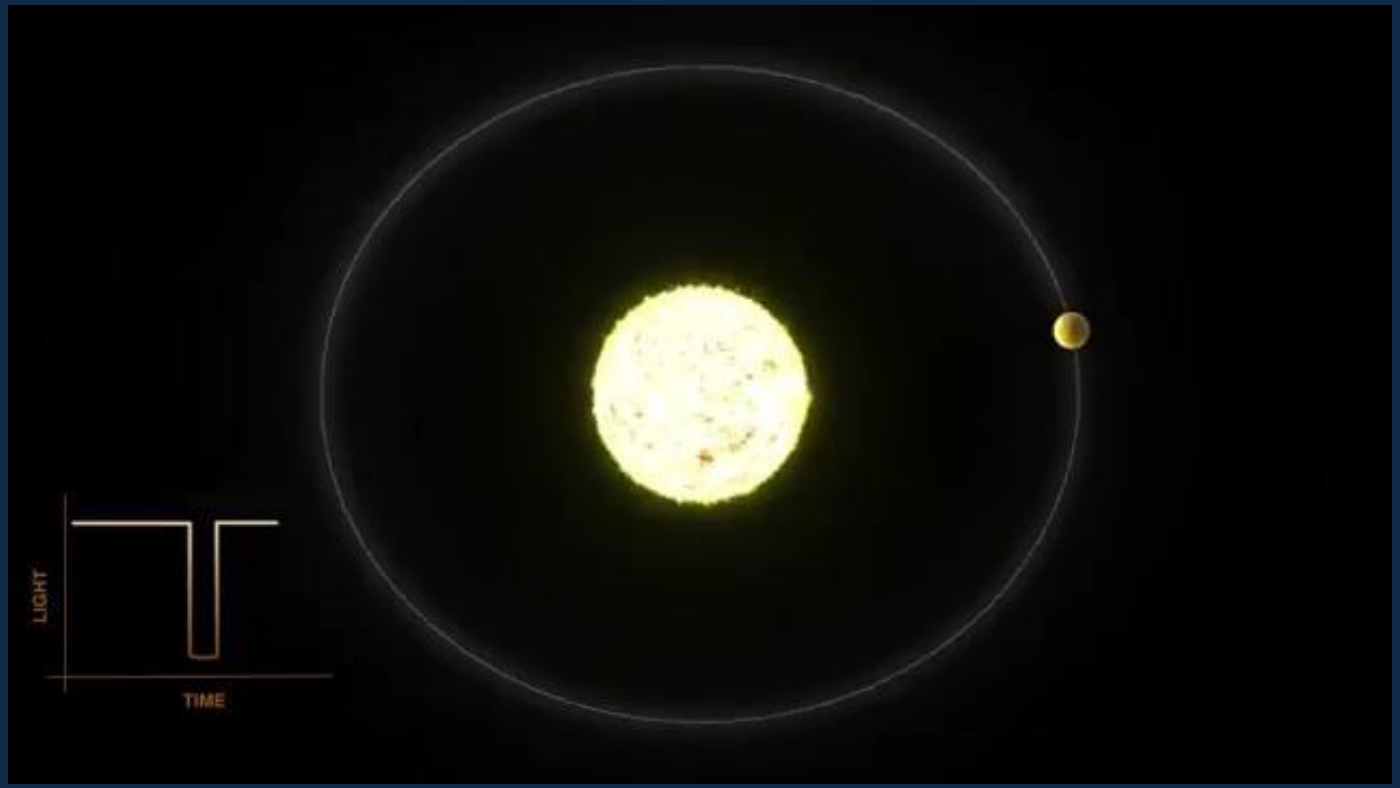
- A: The number of technological species that have formed over the history of the observable universe
- N_{ast}: The number of habitable planets in a given volume of the universe
- f_{bt}: The likelihood of a technological species arising on one of these planets


HABITABLE ZONE SIZE
X-RAY IRRADIANCE
RELATIVE ABUNDANCE
LONGEVITY
M
400x
100 Billion Years
K
25x
40 Billion Years
G
1x
10 Billion Years

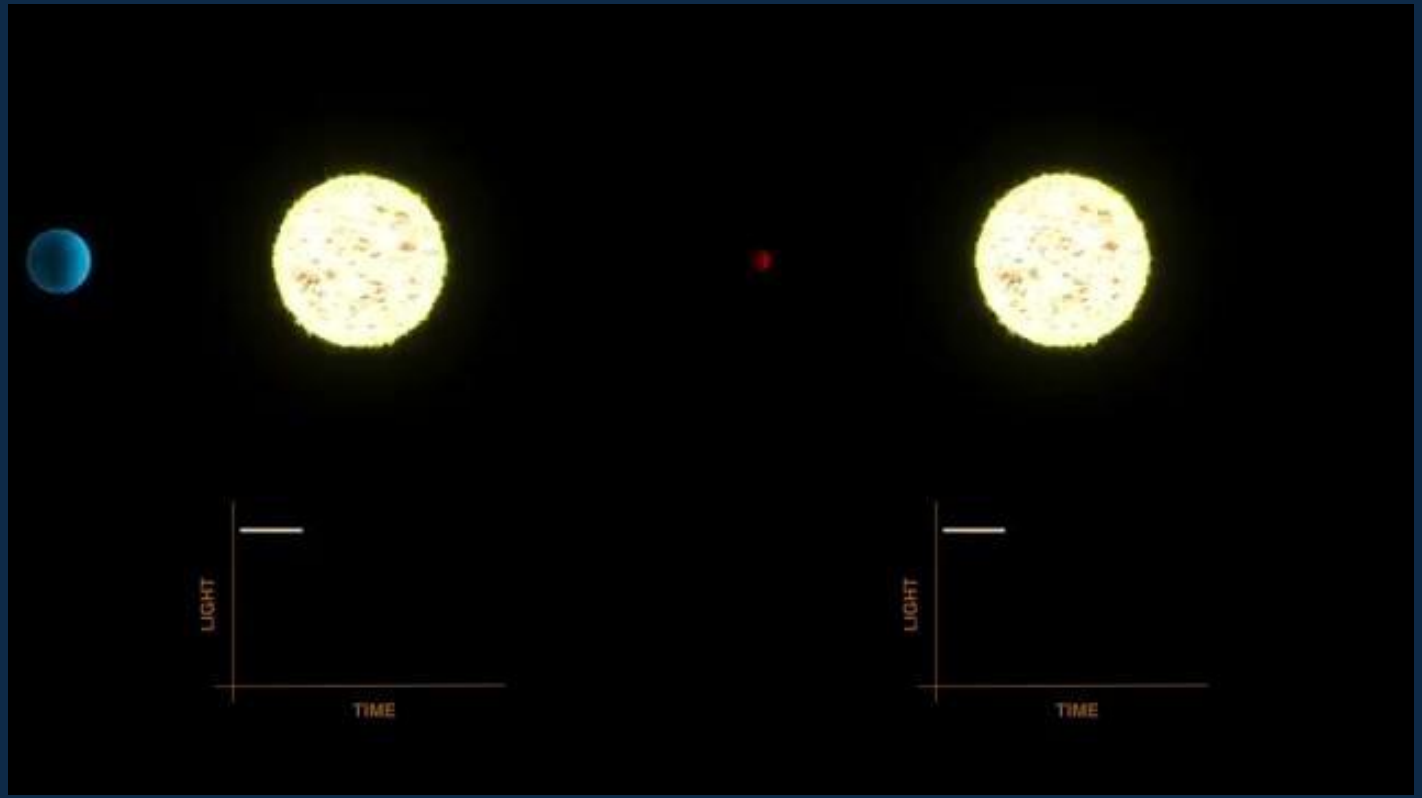
02 EXOPLANET DETECTION

- Transit
- Radial Velocity
- Gravitational Microlensing
- Direct Imaging
- Transit-timing variations
- Eclipse-timing variations
- Pulsar Timing
- Orbital Brightness Modulation
- Pulsation Timing Variation
- Disk Kinematics
- Astrometry

Single-Planet Transit

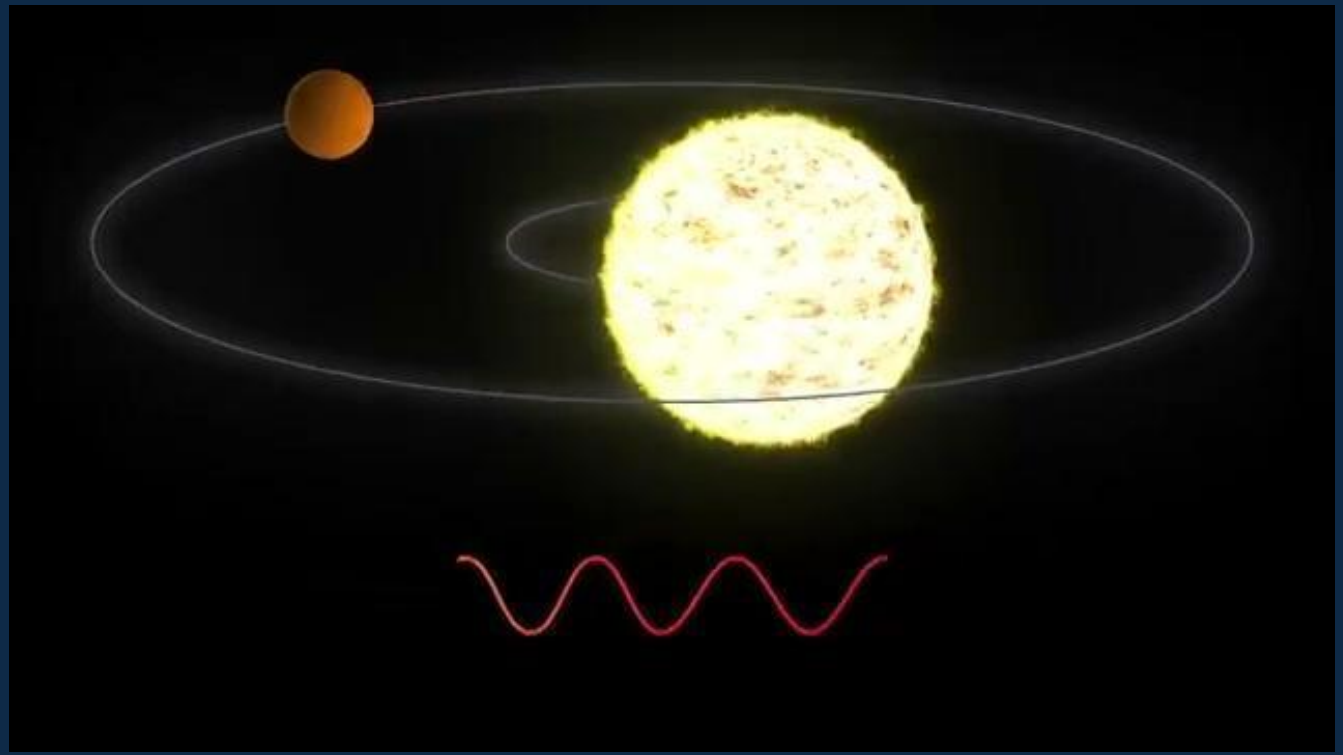


Transit: Different Planet Size

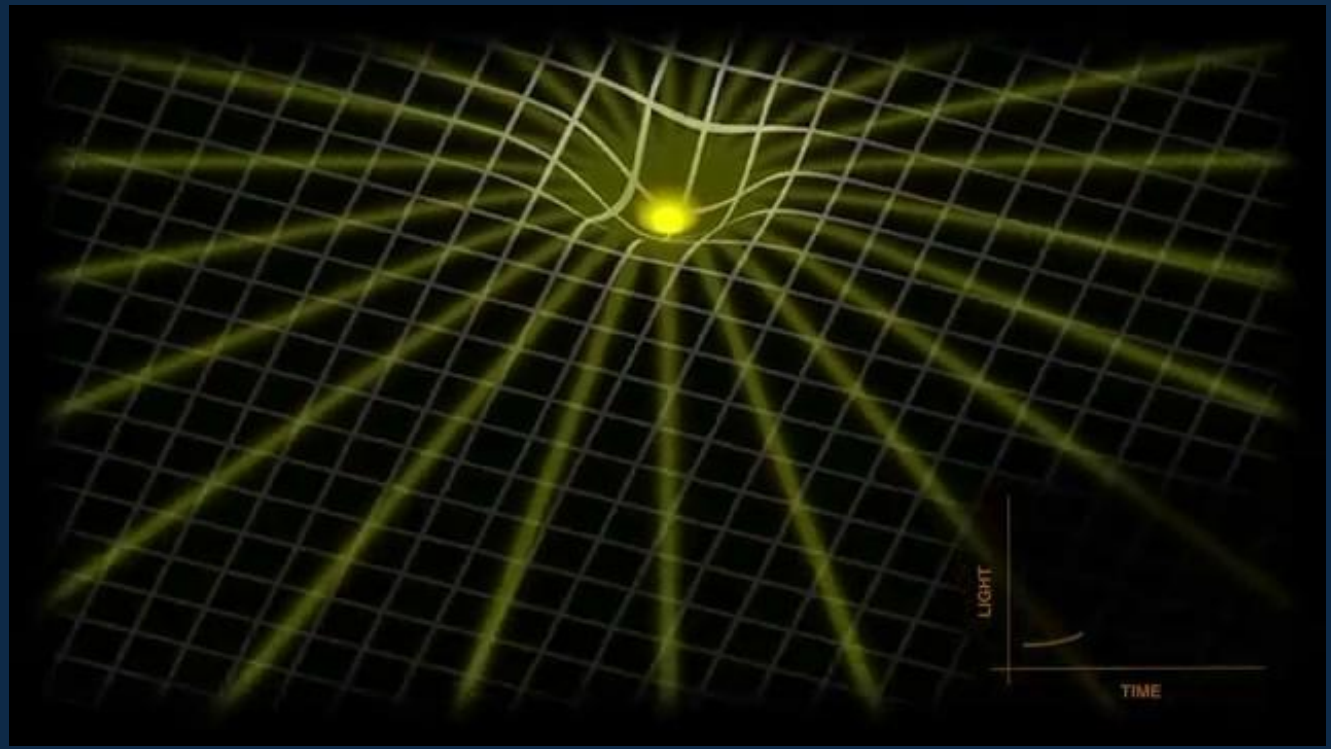


Multiple Planet Transit

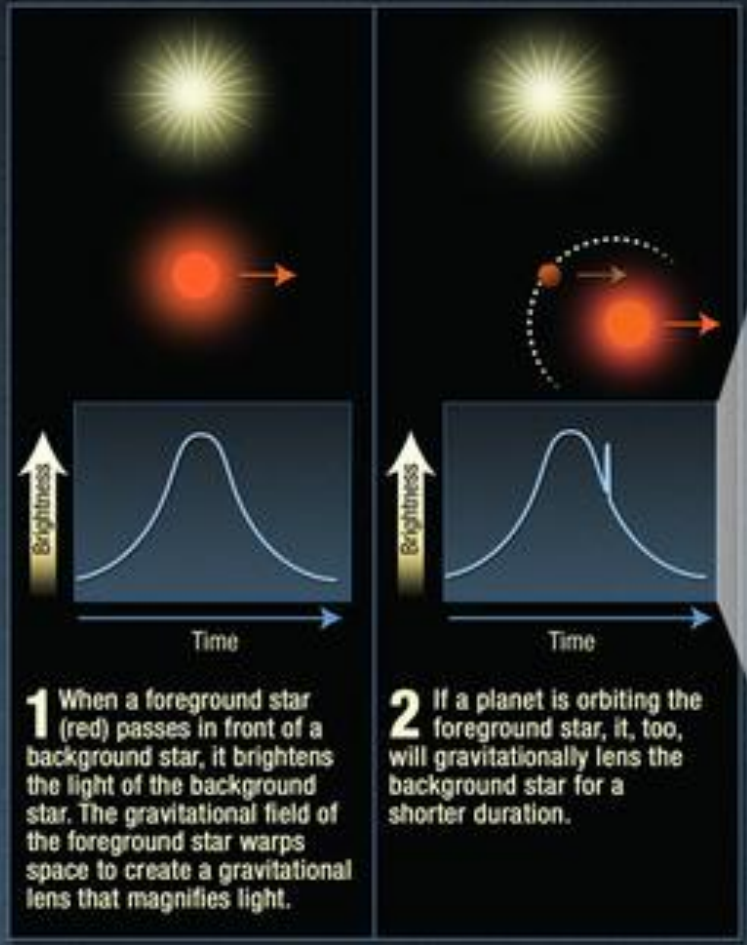
Radial Velocity



Gravitational Microlensing

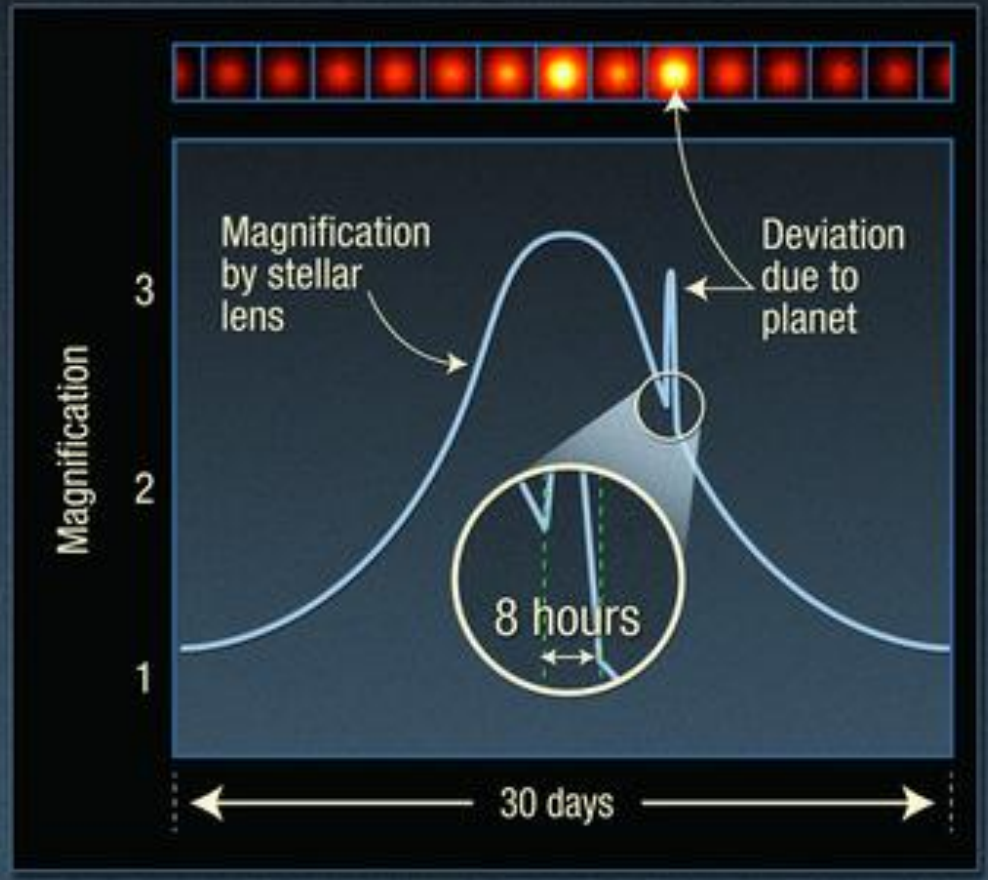


Extrasolar planet detected by gravitational microlensing

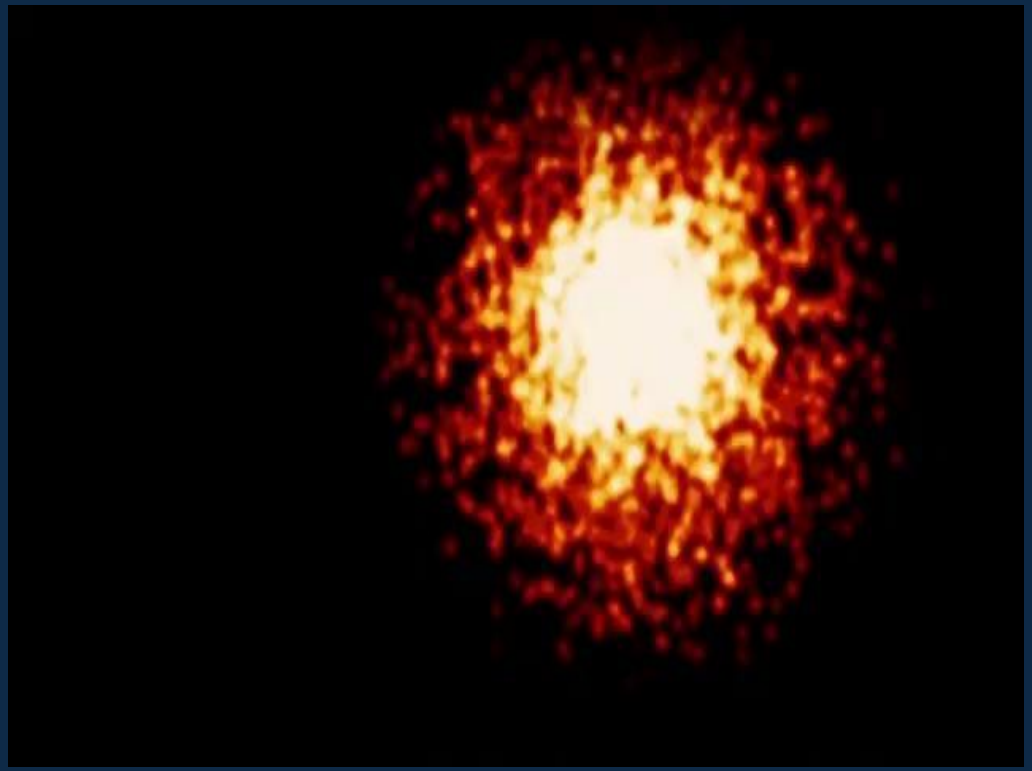


1 When a foreground star (red) passes in front of a background star, it brightens the light of the background star. The gravitational field of the foreground star warps space to create a gravitational lens that magnifies light.

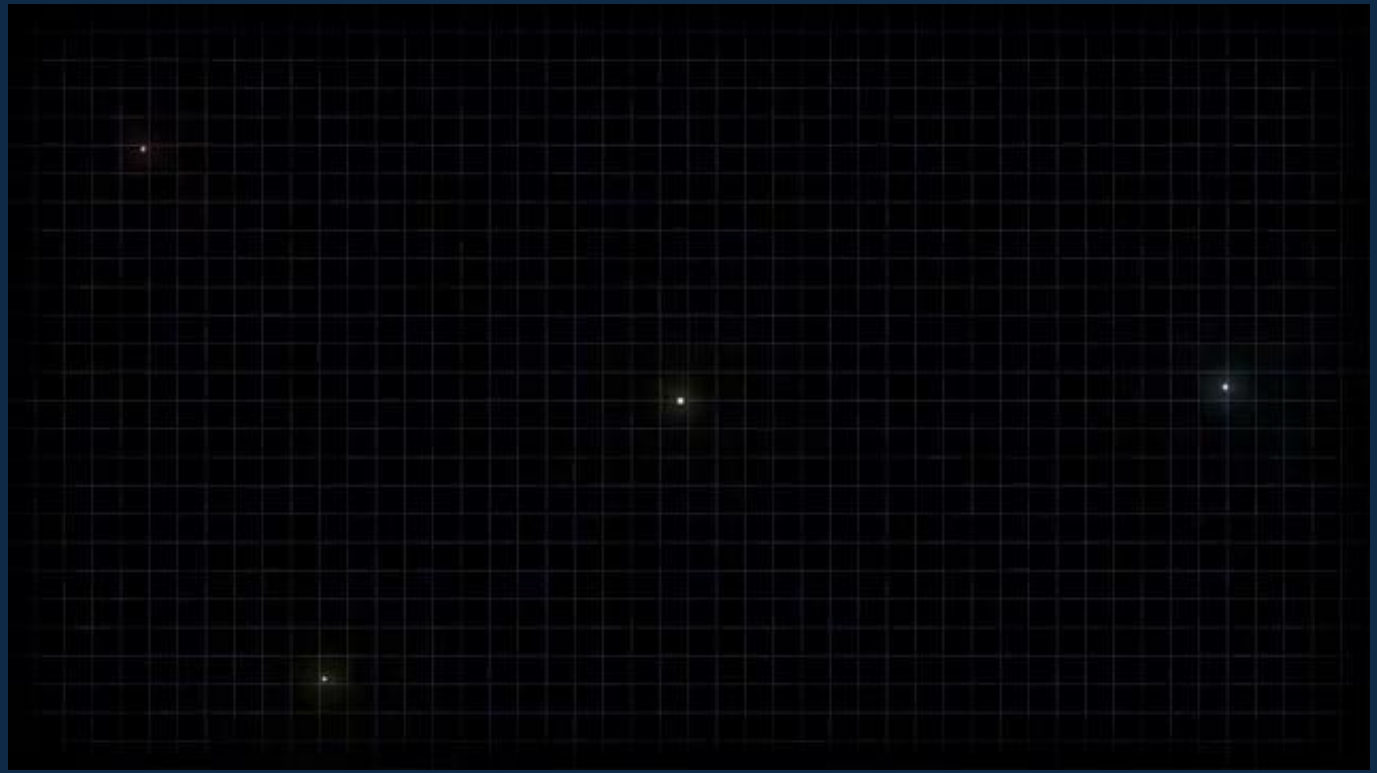
2 If a planet is orbiting the foreground star, it, too, will gravitationally lens the background star for a shorter duration.



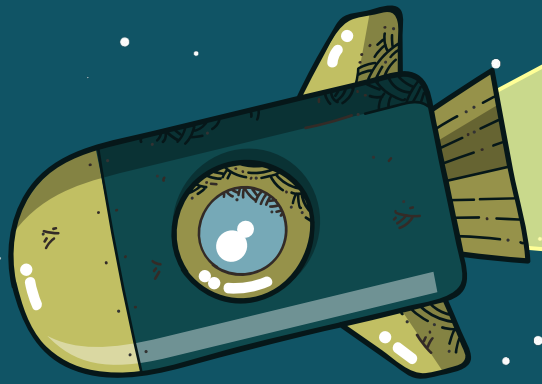
Direct Imaging



Astrometry



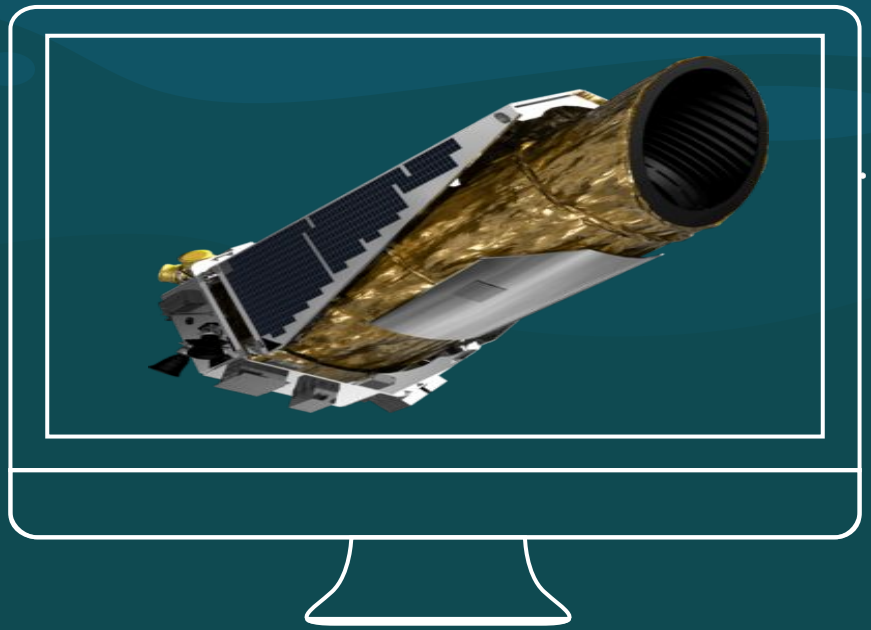
03 FAMOUS EXOPLANET MISSIONS



HUBBLE SPACE TELESCOPE

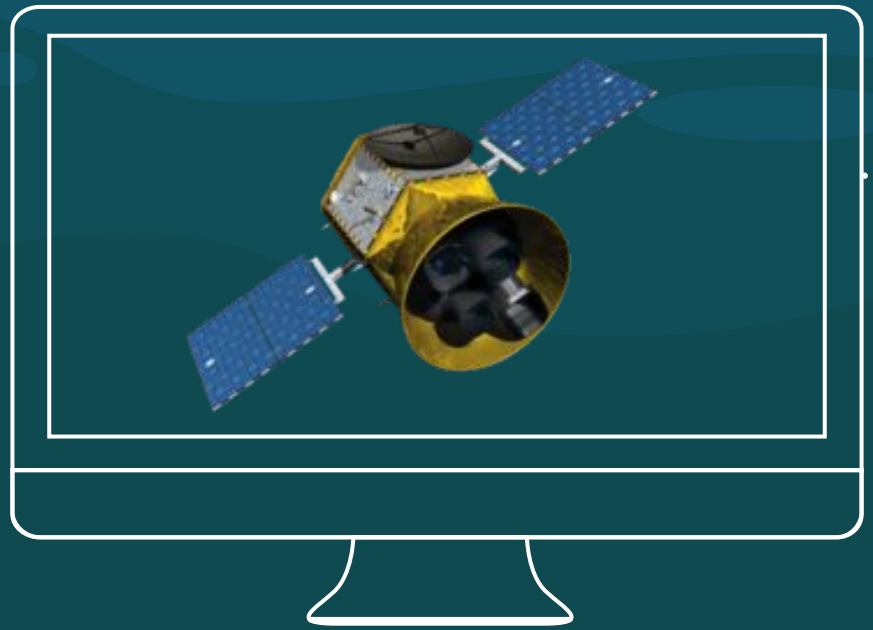
KEPLER MISSION

- Kepler Space Telescope was launched in March 7, 2009 by NASA.
- It surveyed Milky-Way to detend earth-size exoplanets near Goldilocks zone of the star.
- Kepler observed 530,506 stars and discovered 2662 planets
- It got retired on October 30 2018
- The extension of mission was announced on June 2016 beyond the expected exhaustion of fuel



TRANSITING EXOPLANET SURVEY SATELLITE

- Launched in April 18, 2019 by NASA's Falcon 9 rocket
- It covered an area 400 times more than that covered during Kepler mission.
- With TESS it is possible to study the mass, size, density and orbit of large cohort of small planets, including rocky planets in the habitable zone of host stars.
- It was planned for 2 years but is continuing for more than 3 years now.



JAMES WEBB SPACE TELESCOPE

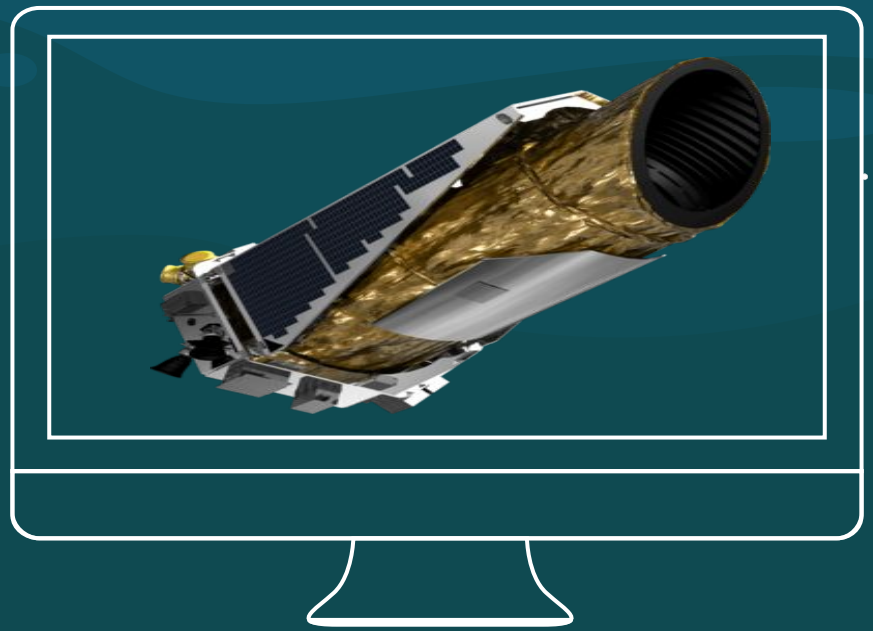
- It is expected to be launch in November 2021 by Ariane 5 rocket.
- Major mission:

  To search for light from first stars and galaxies that formed the Universe after Big Bang

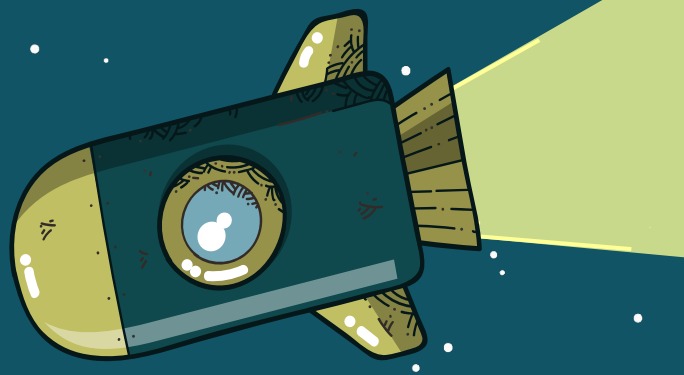
  To study the formation and evolution of galaxy

  To understand the formation of star and planetary system

  To study planetary system and origin of life



SPECIAL THANKS



NASA

SETI INSTITUTE