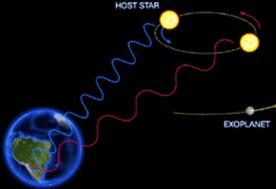


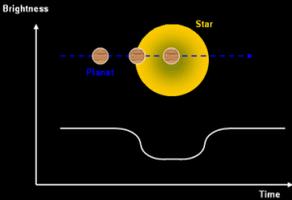
Exoplanets

Radial Velocity



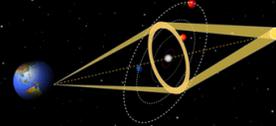
HOST STAR
EXOPLANET

Transit Photometry

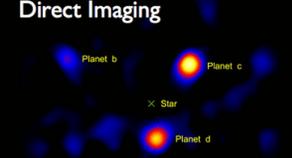


Brightness
Star
Planet
Time

Microlensing



Direct Imaging

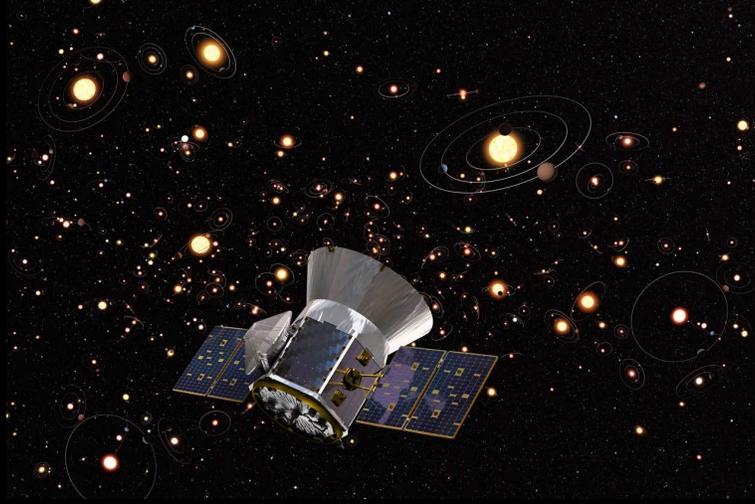


Planet b
Planet c
Star
Planet d

**Peterborough Astronomical Association
Novice Astronomy Class # 22
May 3, 2024
Brett Hardy**

What is an Exoplanet?

- Planet in orbit around another Star
- 51 Pegasi b
- > 4,000



ESA, M. Kornmesser (ESO), Aaron E. Lepsch (ADNET Systems Inc.), Britt Griswold (Maslow Media Group), NASA's Goddard Space Flight Center and Cornell University

Types of Exoplanets

- Hot Jupiters
- Ice Giants
- Super Earths
- Terrestrial



National Aeronautics and Space Administration

What's Out There? Exoplanet Types

Gas Giant
Similar to Jupiter or Saturn

Neptune-Like
Similar to Uranus or Neptune

Super Earth
More massive than Earth, lighter than Neptune

Terrestrial
Rocky, in Earth's size range

www.nasa.gov For more information, please visit: exoplanets.nasa.gov

Radial Velocity Method

The star and planet orbit their common center of mass.

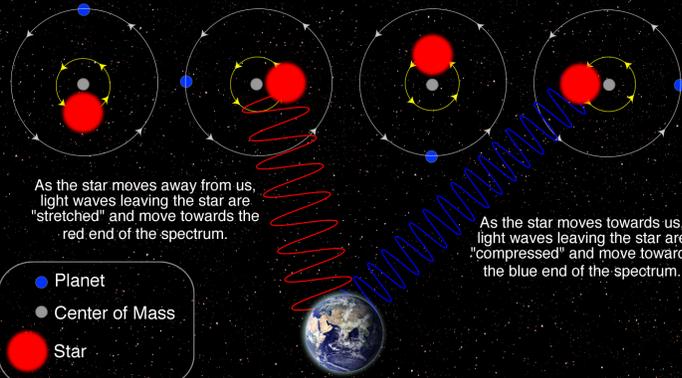
- Wobble effects light frequency
- Biased toward detecting large planets
- Effective up to 100 ly
- 820 planets

Spectral lines move towards the red as the star travels away from us.



Spectral lines move towards the blue as the star travels towards us.





As the star moves away from us, light waves leaving the star are "stretched" and move towards the red end of the spectrum.

As the star moves towards us, light waves leaving the star are "compressed" and move towards the blue end of the spectrum.

- Planet
- Center of Mass
- Star

Not to scale

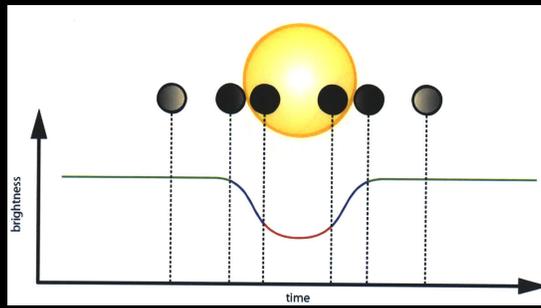
Las Cumbres Observatory

Transit Method

- Transiting planet blocks small portion of light
- Directly indicates exoplanet size and distance
- Atmosphere detection
- Effective for hundreds of ly
- 3,261 planets
- Kepler Space Telescope
- Transiting Exoplanet Survey Satellite - TESS

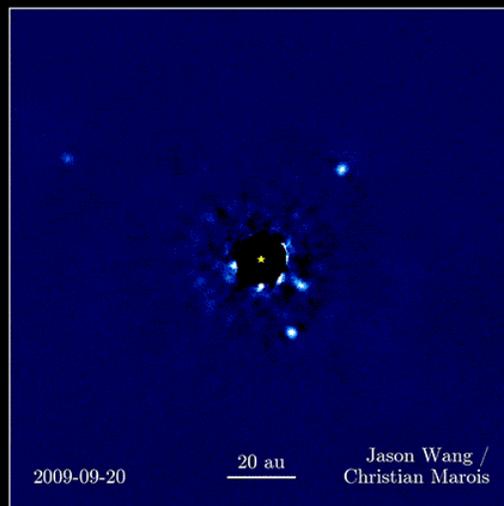


NASA



Direct Imaging

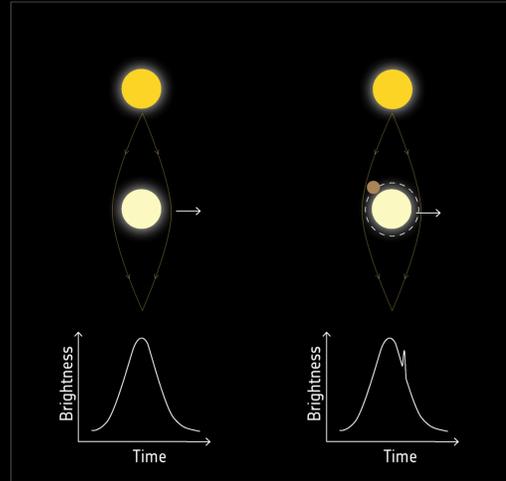
- Coronagraph
- HR8799 in Pegasus
- 129 ly away
- 30 million years old
- 4 visible planets
- All larger than Jupiter
- Orbit from 40-400 years
- Keck Telescope
- 7 images from 2009 - 2016
- 51 planets



Gravitational Microlensing

- Capable of finding the smallest & farthest exoplanets
- Passage of one star in front of another distant star
- “Rogue” planets
- Effective for thousands of ly
- Optical Gravitational Lensing Experiment (OGLE)
- 98 planets

Microlensing

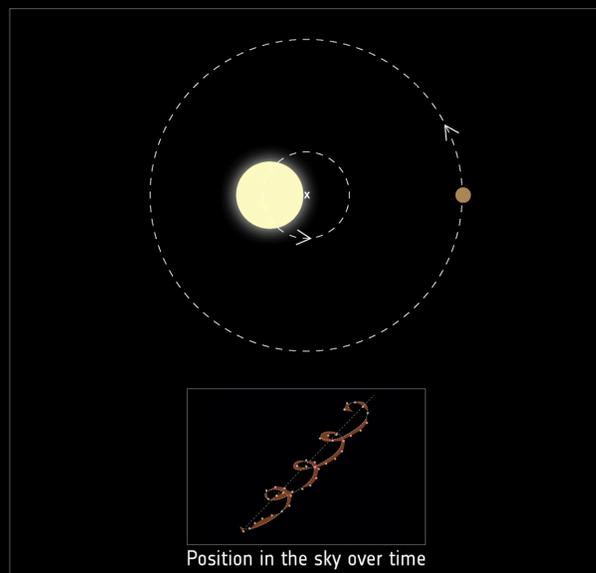


ESA

Astrometry

- Measuring Star positions to detect exoplanets
- Extremely challenging method
- 1 planet

Astrometry



Position in the sky over time

ESA

Characterizing Exoplanets

- Size
- Orbital period
- Mass
- Density
- Distance from Star

Exoplanet Missions

NASA Missions

ESA/European Missions

Ground Telescopes with NASA participation

W. M. Keck Observatory
Large Binocular Telescope Interferometer
NN-EXPLORE

¹ NASA/ESA Partnership
² NASA/ESA/CSA Partnership
³ CNES/ESA

Characterizing Exoplanets

- Planetary atmospheres
- Transit Method & Direct Imaging

atmosphere spectrum

Na K

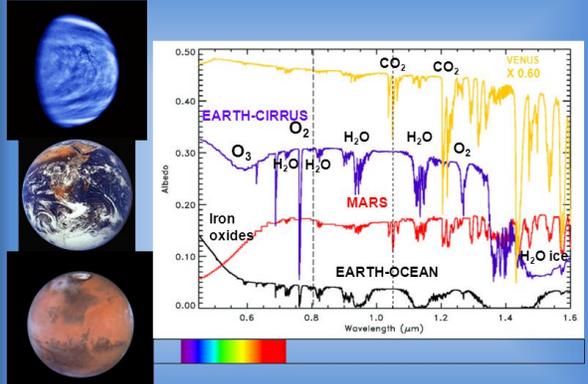
Exoplanet Transit Event → Towards Earth

European Southern Observatory

Characterizing Exoplanets

- Biomarkers
- Must be in a gaseous state
- Biotic VS abiotic formation

Spectroscopy: detecting biomarkers



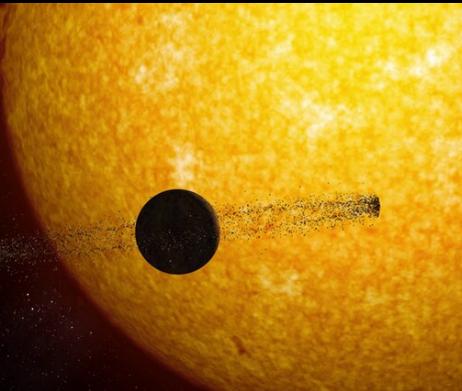
Detecting atmospheric oxygen and water likely indicates life

(because very few non-biological processes can sustain an oxygen atmosphere)

Ref: R. Hanel, GSF

Characterizing Exoplanets

- Technomarkers
- Current detection technology is limited
- Radio message
- Clarke Exobelt
- Dyson Sphere



Hector Socas-Navarro

Potentially Habitable Exoplanets

- Habitable Zone
- Stellar Type

Potentially Habitable Exoplanets

Ranked by Distance from Earth (light years)

Distance (ly)	Exoplanet Name
[4.2 ly]	Proxima Cen b
[12 ly]	tau Cet e
[12 ly]	GJ 1061 c
[12 ly]	GJ 1061 d
[12 ly]	GJ 273 b
[12 ly]	Teegarden's Star b
[12 ly]	Teegarden's Star c
[14 ly]	Wolf 1061 c
[17 ly]	GJ 3323 b
[22 ly]	GJ 667 C c
[22 ly]	GJ 667 C e
[22 ly]	GJ 667 C f
[41 ly]	TRAPPIST-1 d
[41 ly]	TRAPPIST-1 e
[41 ly]	TRAPPIST-1 f
[41 ly]	TRAPPIST-1 g
[217 ly]	K2-72 e
[561 ly]	Kepler-186 f
[770 ly]	Kepler-1229 b
[1115 ly]	Kepler-442 b
[1200 ly]	Kepler-62 f

Artistic representations. Earth, Mars, Jupiter, and Neptune for scale. Distance from Earth is between brackets.

PHL UNIVERSITY OF PUERTO RICO AT ARECIBO

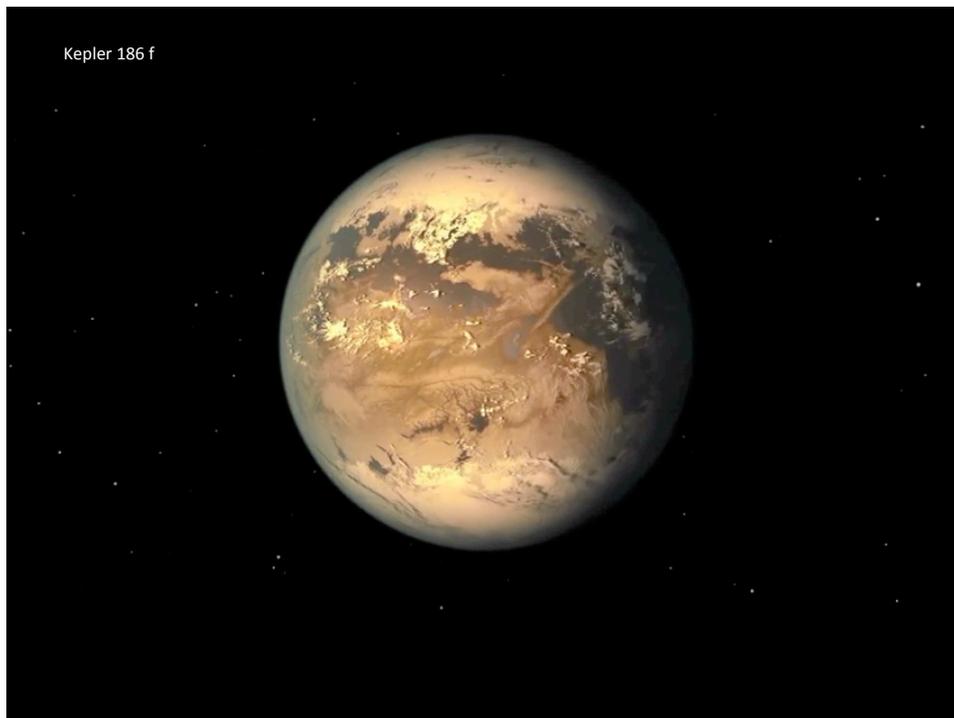
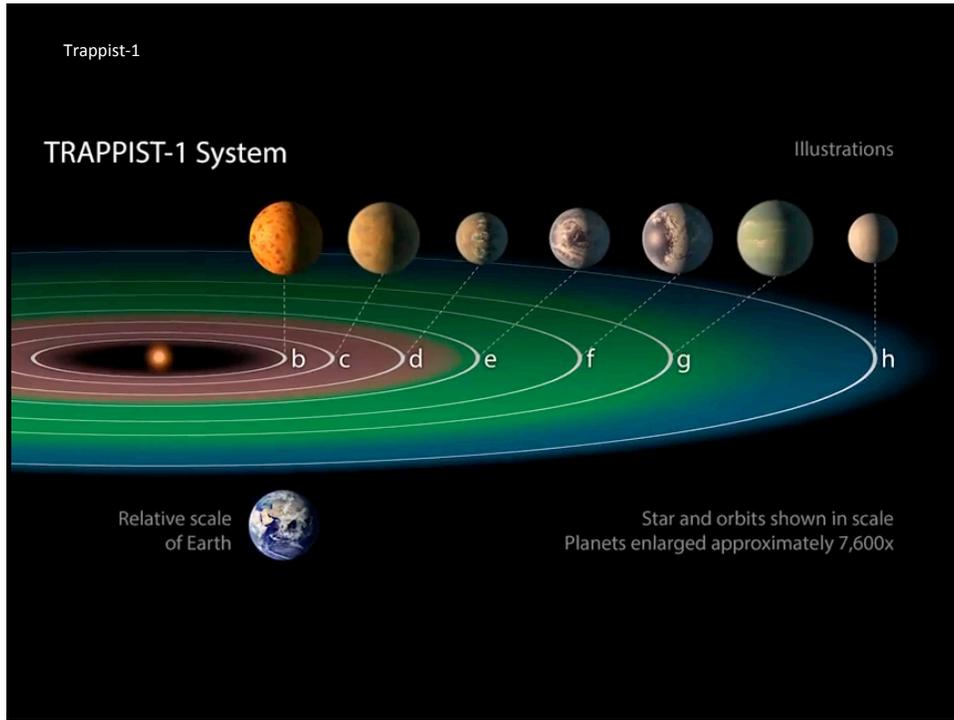
CREDIT: PHL @ UPR Areibo (phl.upr.edu) Sep 4, 2019

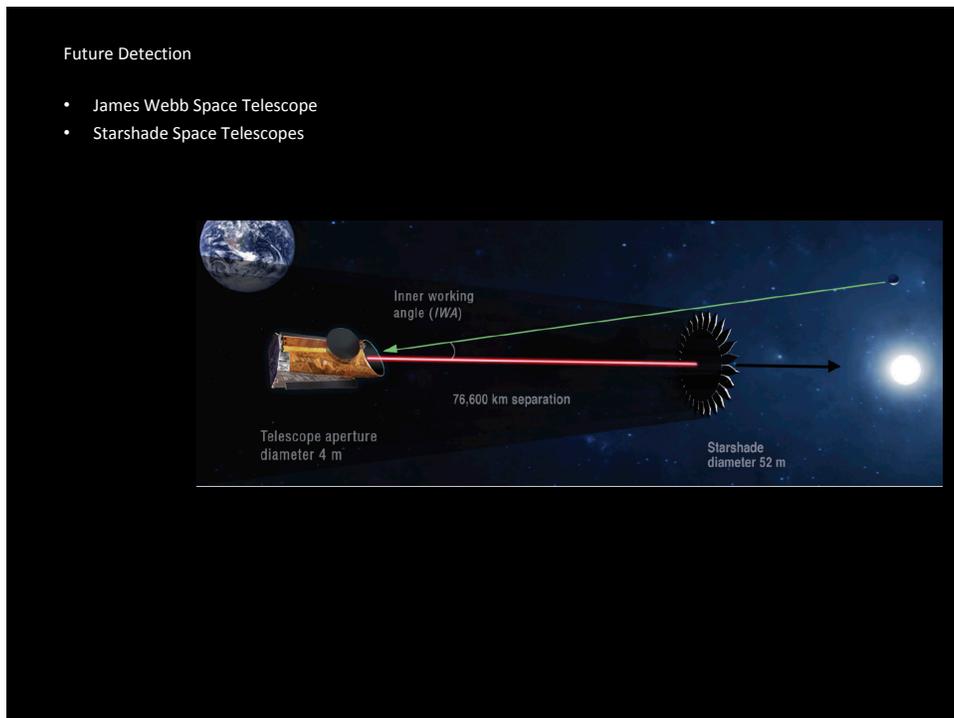
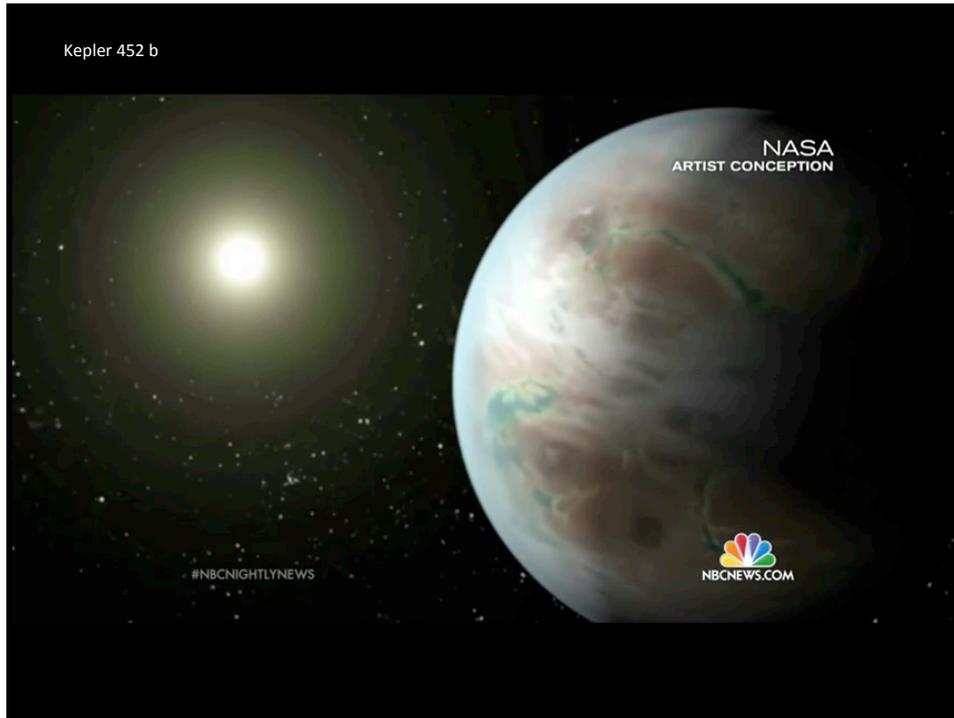
Proxima b

Proxima b

artistic representation

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Next Month Novice Class # 23

Mobile Apps, Computer Software
&
Observing Techniques
June 7, 2024

