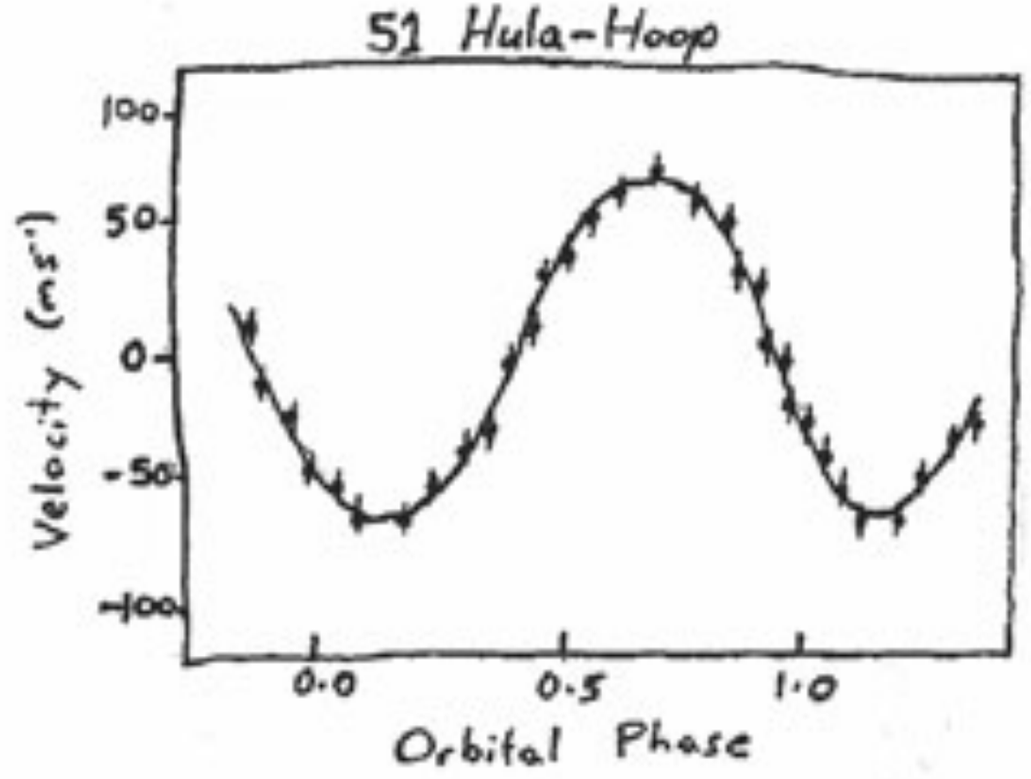
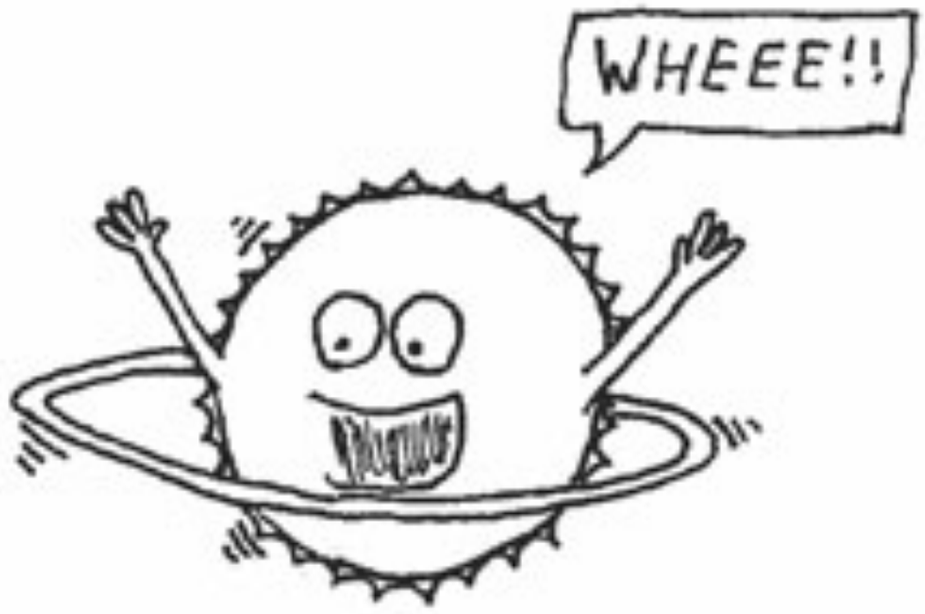
DOPPLER EXOPLANET DETECTION FOR DUMMIES

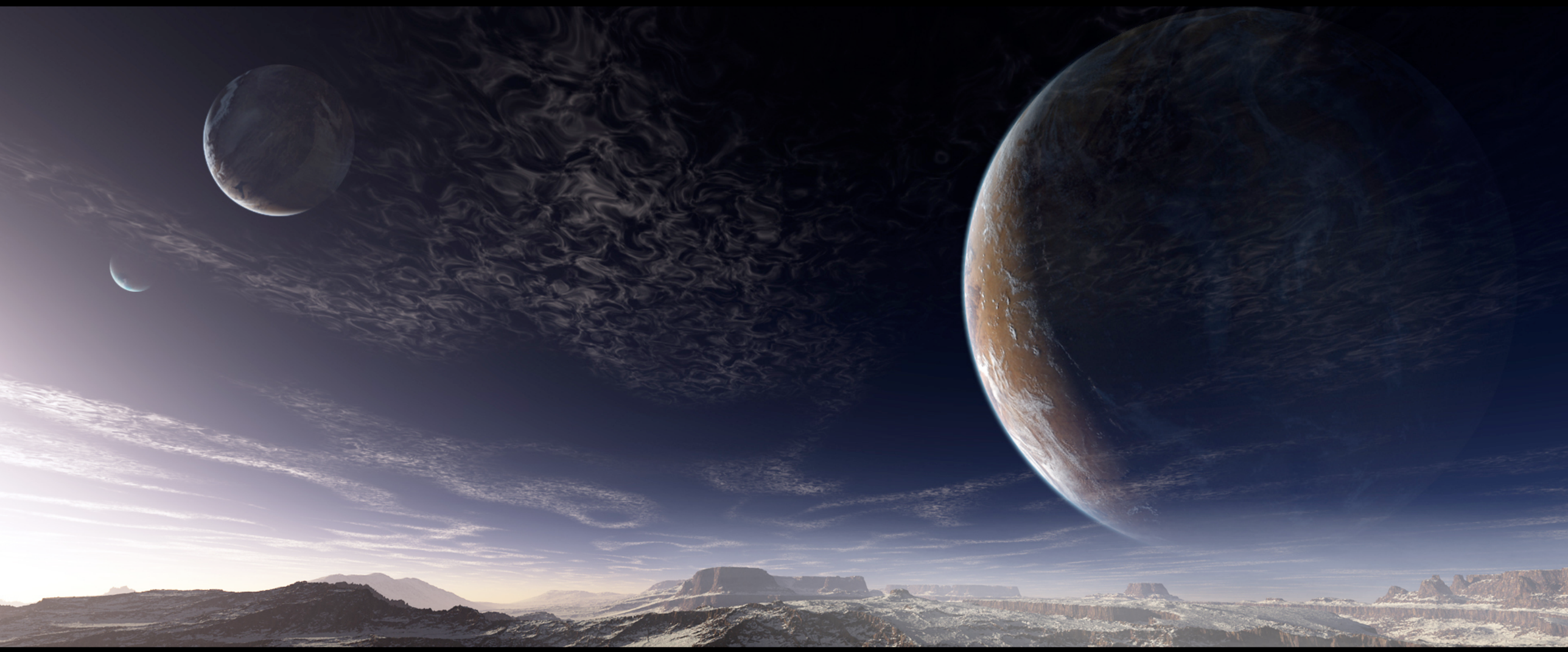
WHAT WE SEE...



WHAT'S ACTUALLY GOING ON...



Exoplanets and Life in the Universe



The Big Questions

- Where did we come from?
- Are we alone?
- How common are other planetary systems?

Stars are a billion times brighter…

...than the planet

...hidden
in the glare. →

Like this firefly.

There were two issues that prevented the discovery of exoplanets until the 1990s:

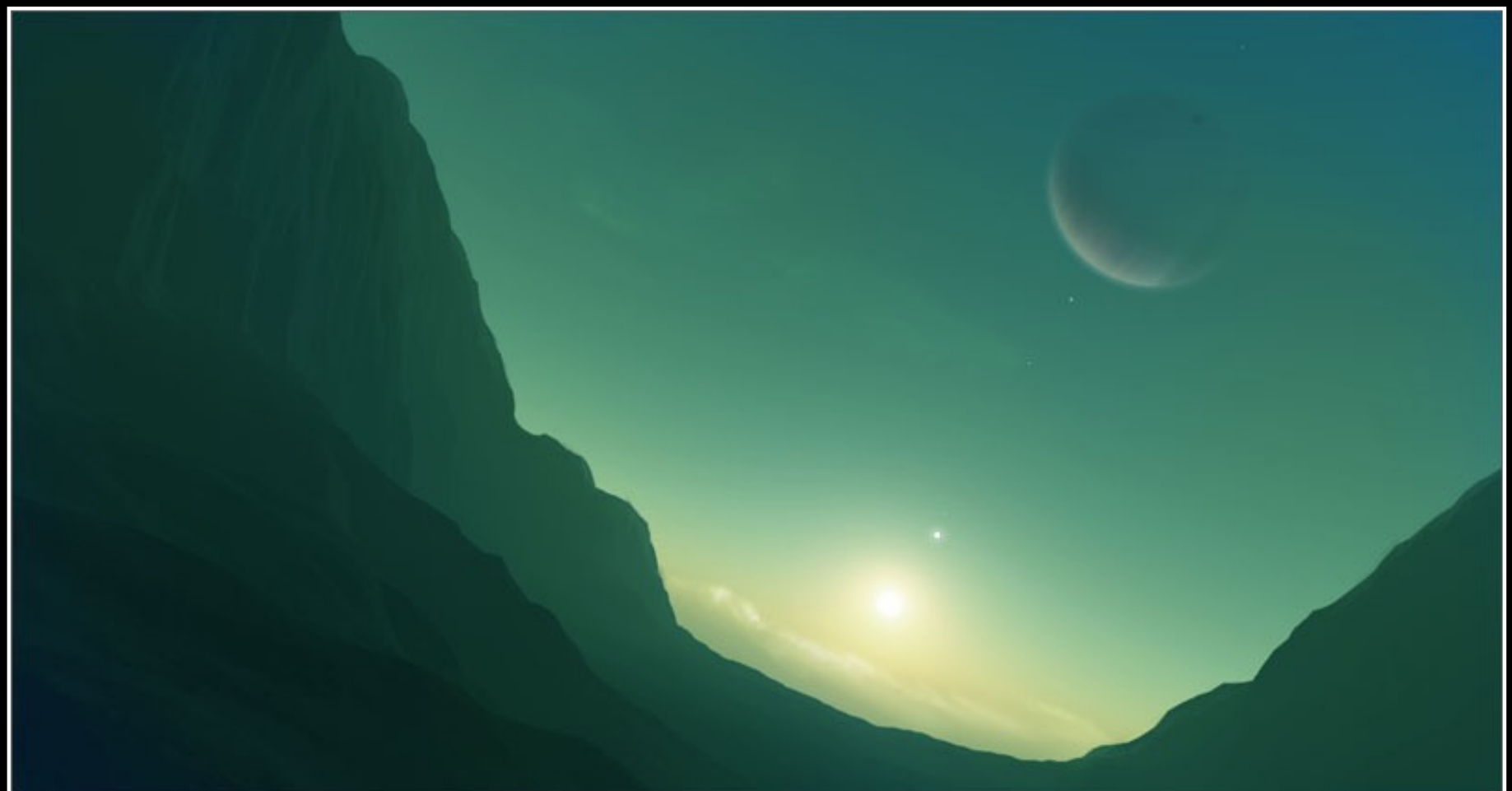
1) Instrument precision

2) The assumption that other solar systems would be like our own

Jupiter has an orbital period of 11.8 years - it also takes a long time to find planets like our own.

A planet orbiting another star is called an extrasolar planet (or exoplanet).

Since 1993, we have over FOUR THOUSAND CONFIRMED extrasolar planetary systems with more coming in every day



How do we find exoplanets??

A. Take pictures of stars and their surroundings
B. Send space missions to nearby stars
C. Monitor the brightness of stars
D. Measure the velocity of stars

How do we find exoplanets??

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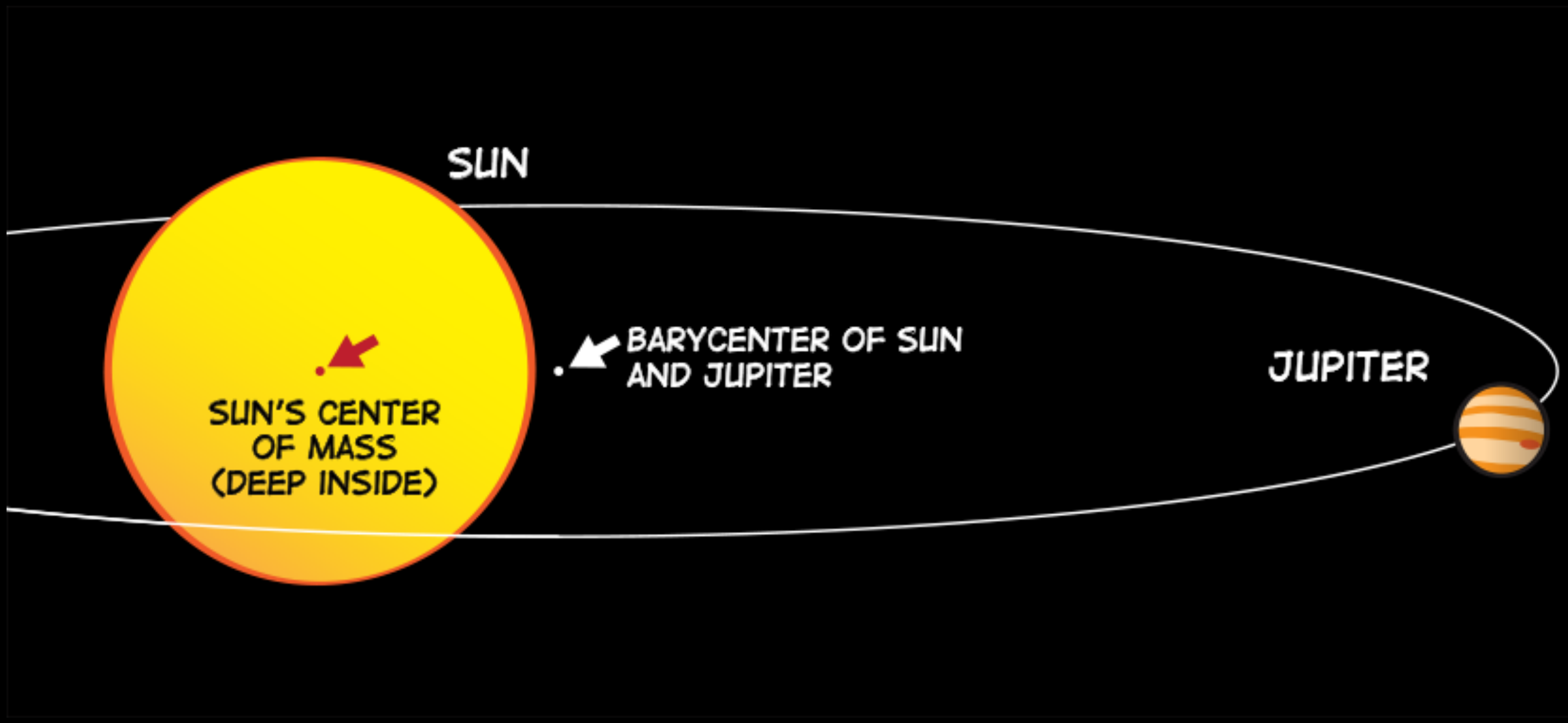
(*Mainly*...)

How do we find exoplanets??

- Measure the velocity of stars

Recall that two objects orbit a center of mass



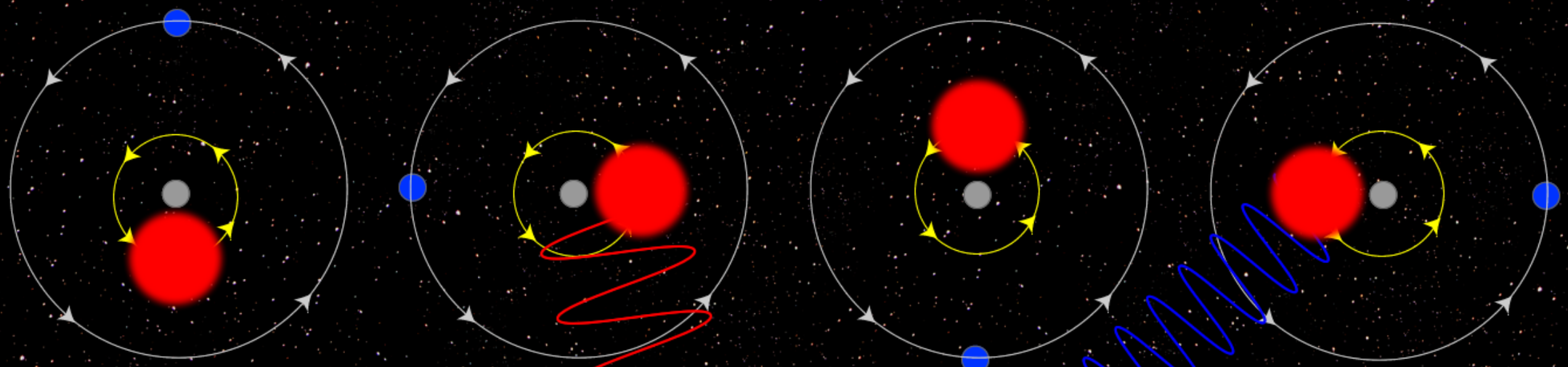
All stars wobble as their planets orbit around them.

Radial Velocity Method

The star and planet orbit their common center of mass.

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.



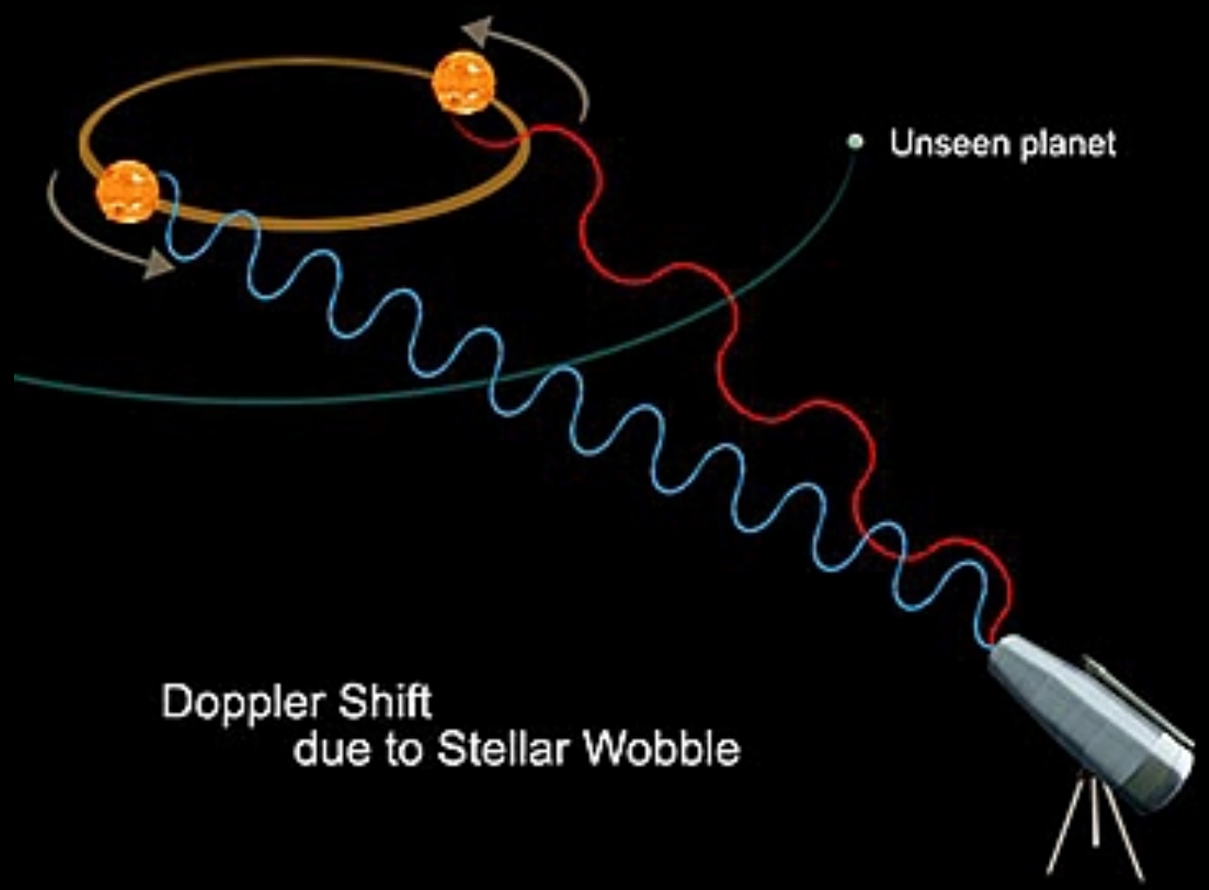
As the star moves away from us, light waves leaving the star are "stretched" and move towards the red end of the spectrum.

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

Many of exoplanet systems were detected from the Doppler shift of the STAR

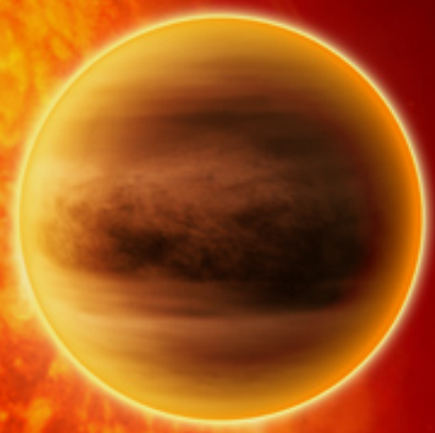


The Doppler method Is limited to finding Jupiter-mass and super-Earth mass planets

artist's concept

THE DISCOVERY THAT CHANGED THE WAY WE SEE OUR UNIVERSE

51 PEGASI b, 1995



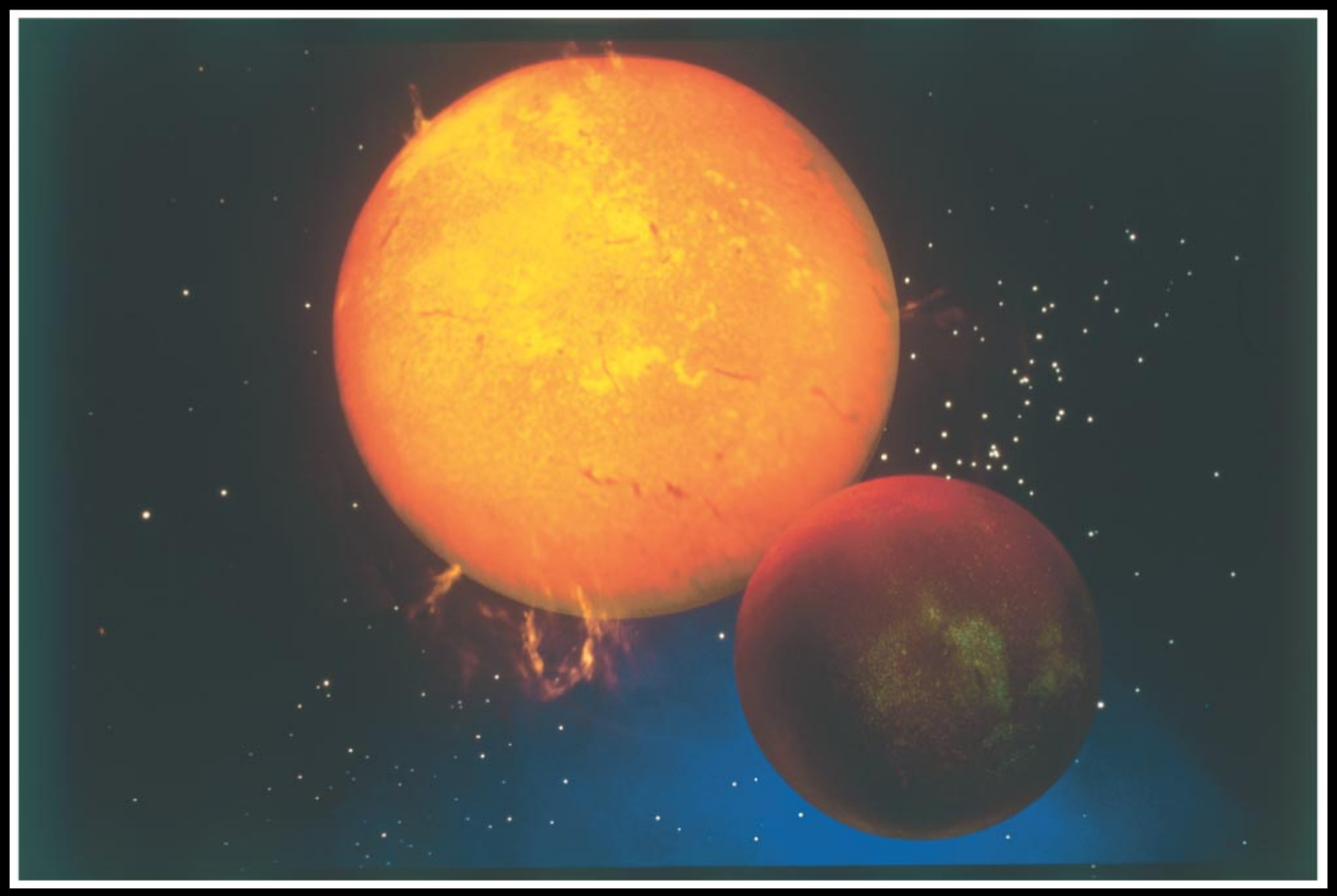
→ 2019 Nobel prize awarded for this discovery!

NASA

WE'RE *OUT* THERE

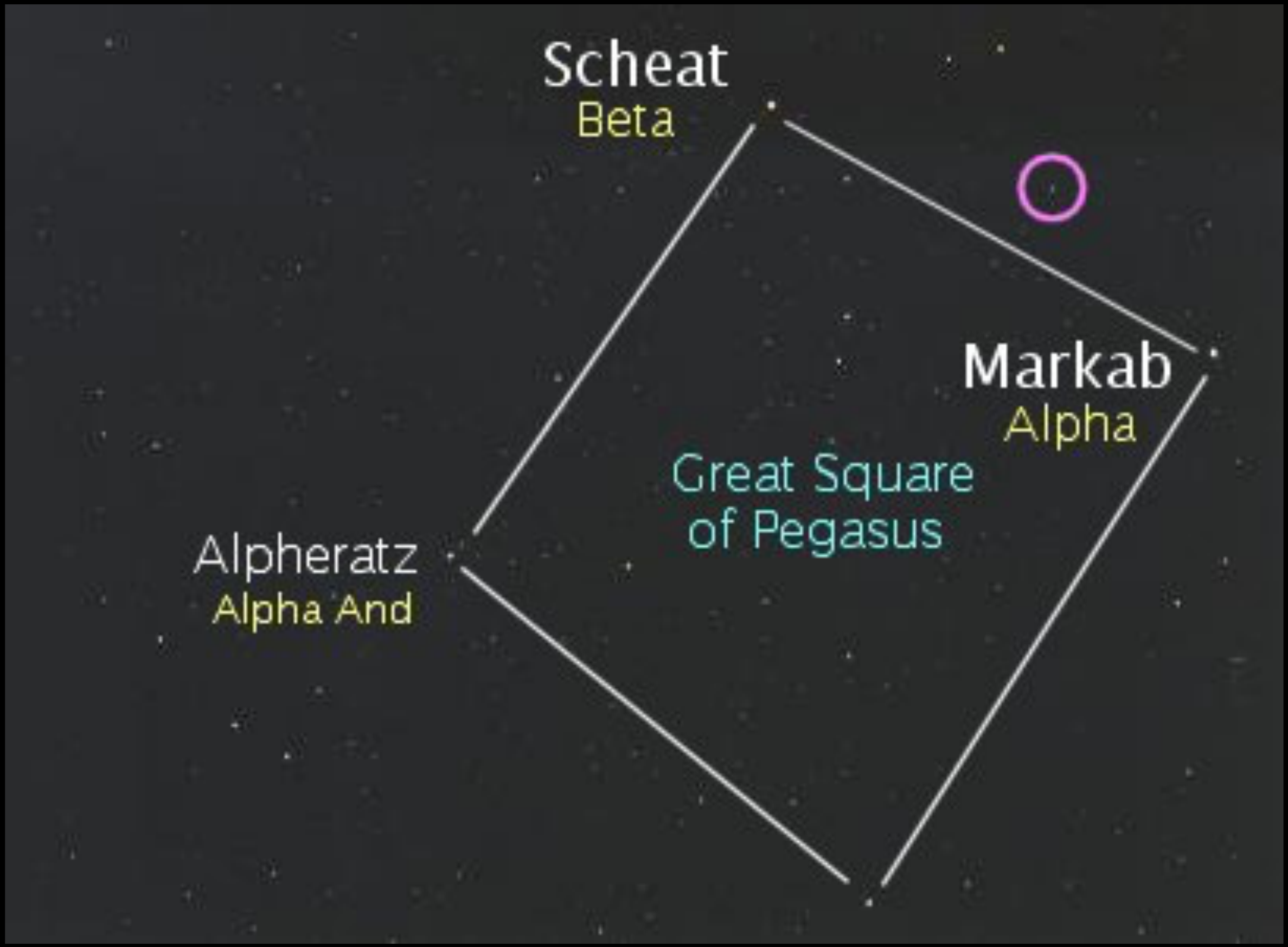
YEARS OF 20 EXOPLANETS

First Doppler Extrasolar Planet



- In 1995, the Doppler shifts of the star 51 Pegasi indirectly revealed a planet with 4-day orbital period.
- This short period means that the planet has a **small** orbital distance.

51 Peg is a “hot” Jupiter


Scheat
Beta
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Alpha
Great Square
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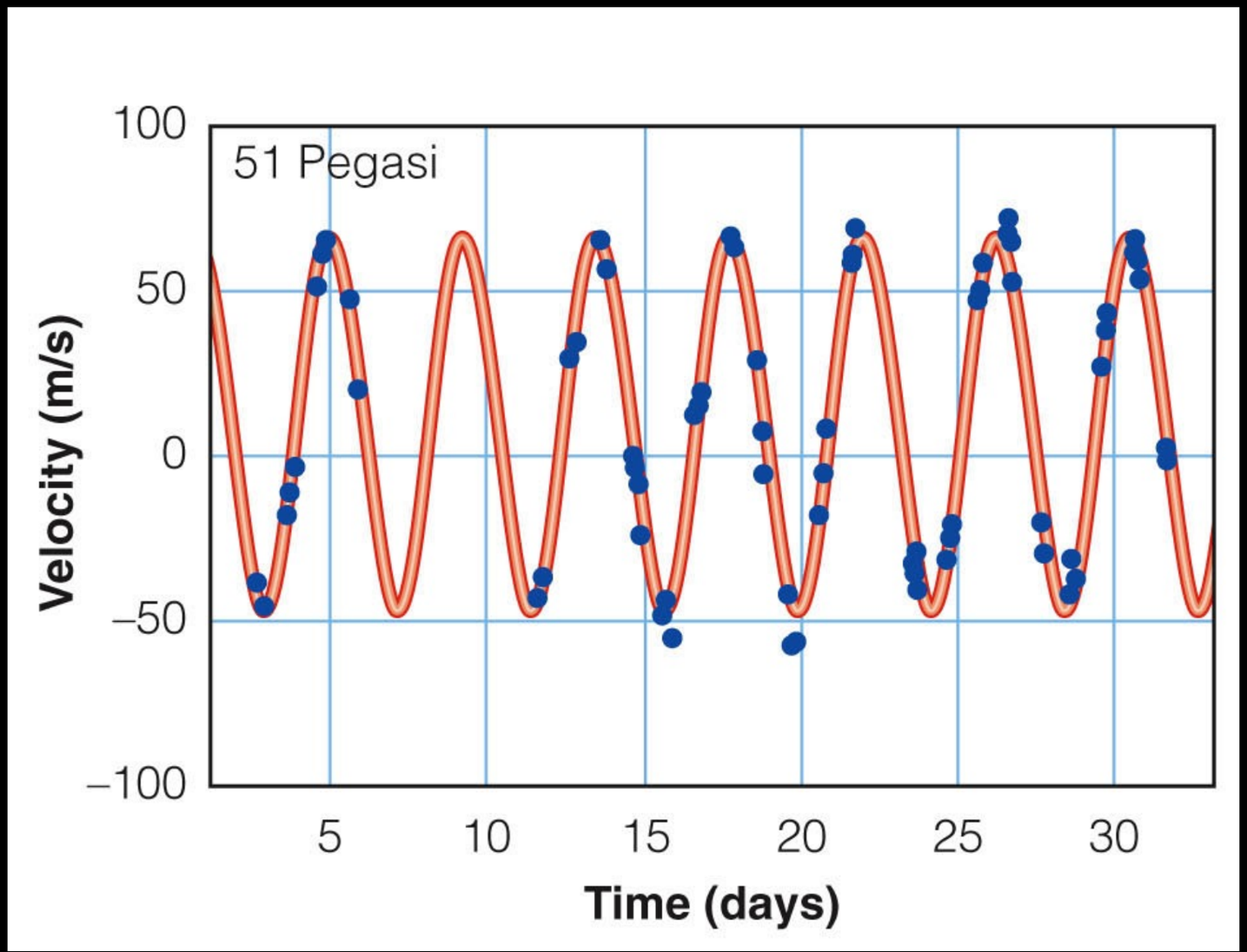
Doppler Data for 51 Peg

From the motion of the star and estimates of the star's mass, astronomers can deduce that the planet has half the mass of Jupiter and orbits only 0.05 AU from the star.

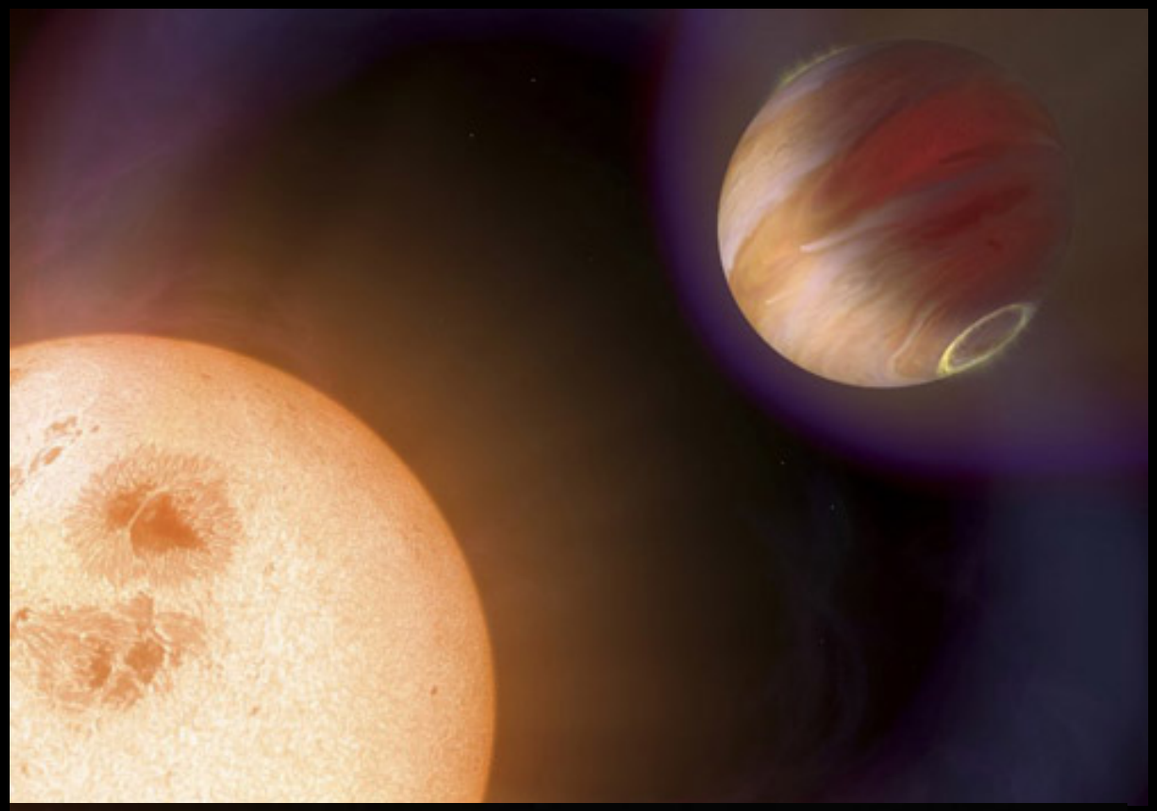


Hot Jupiters were a big surprise

- The planets are the EASIEST planets to detect since they are CLOSER to their star and have periods of only a few days!!!

- 0.05 AU is WAY too close for a planet to form naturally. It too HOT!

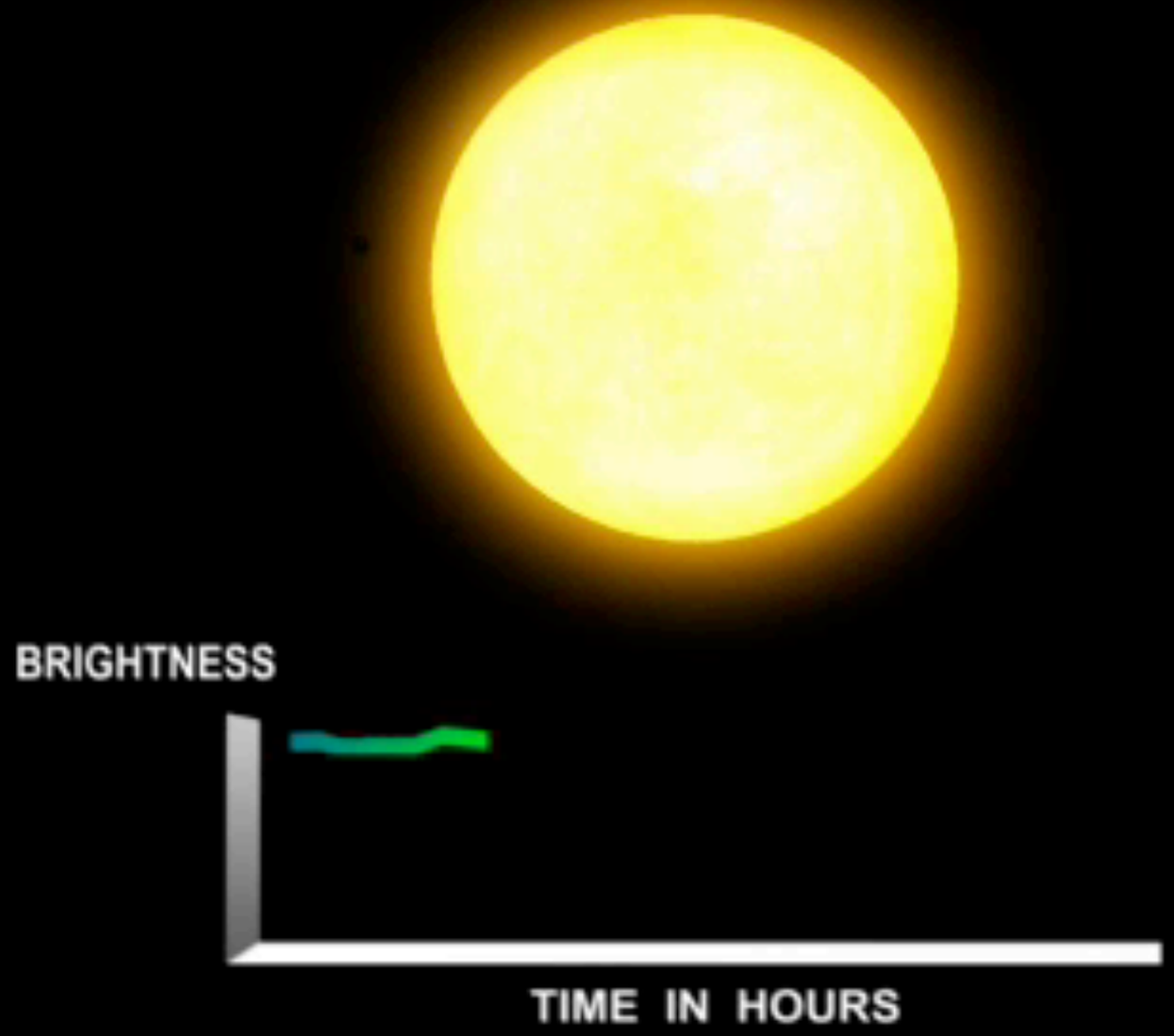
- We think they form at the distance of Jupiter and migrate in toward the star



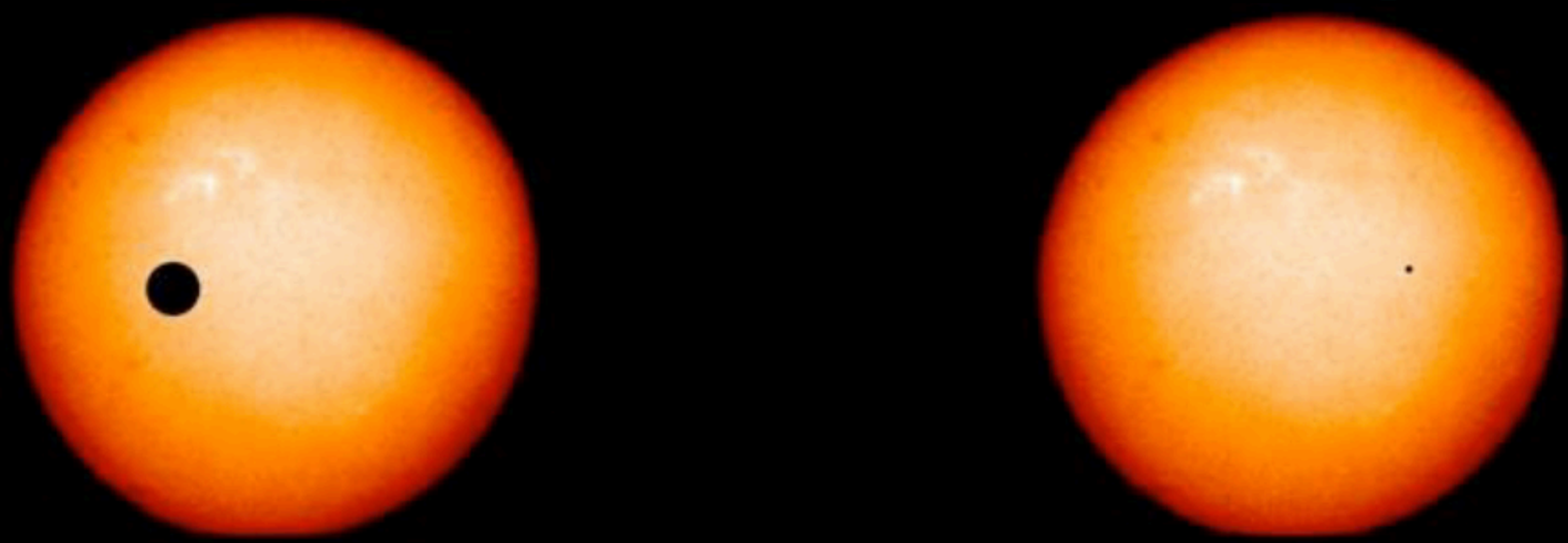
How else do we find exoplanets?

- Monitor the brightness of stars

Transit Method of Exoplanet Detection

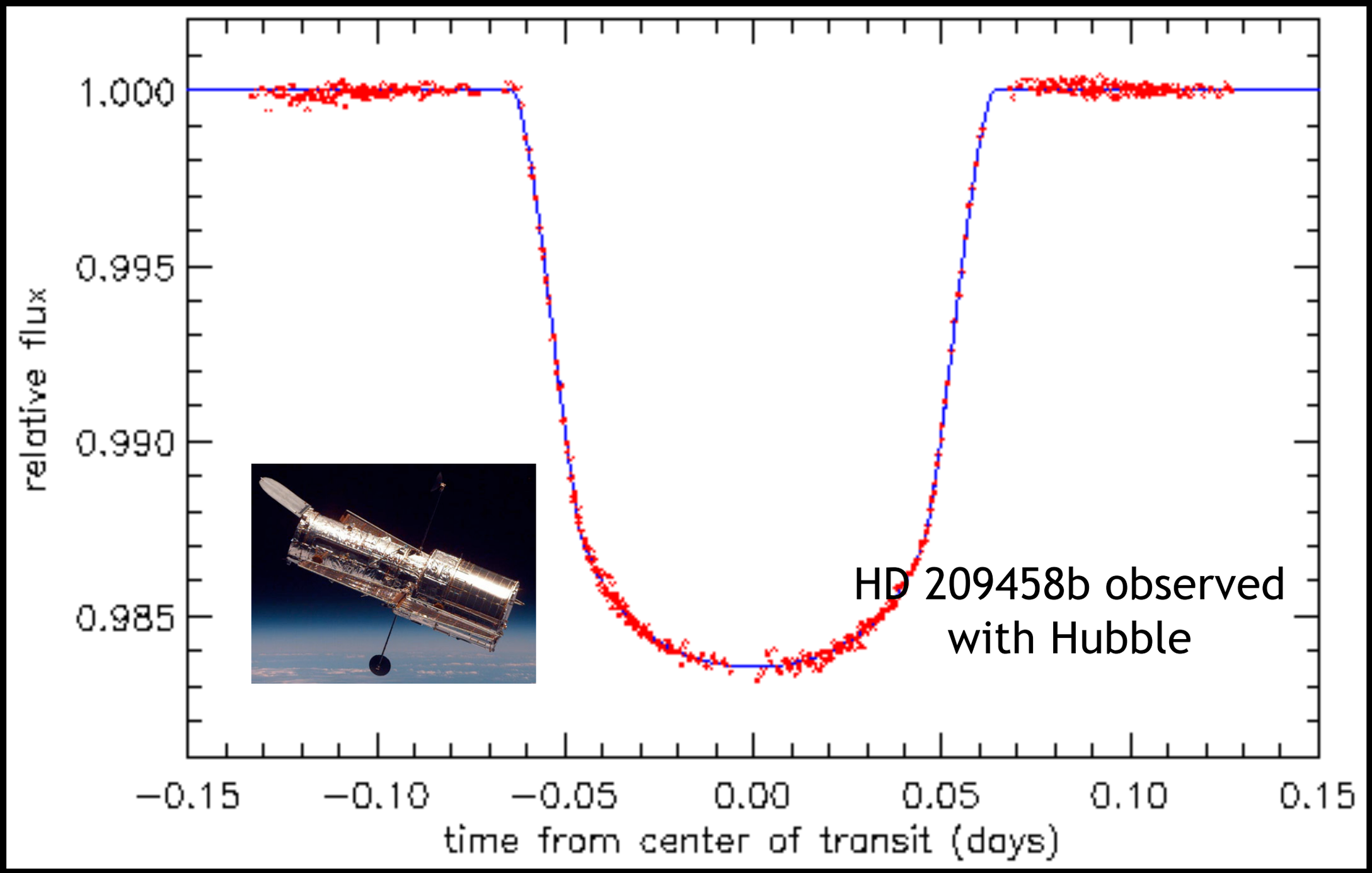


The amount of dimming tells us the size of the exoplanet.



The time it takes to complete an orbit tells us how far away it is from the star.

HD 209458b – the first transiting planet

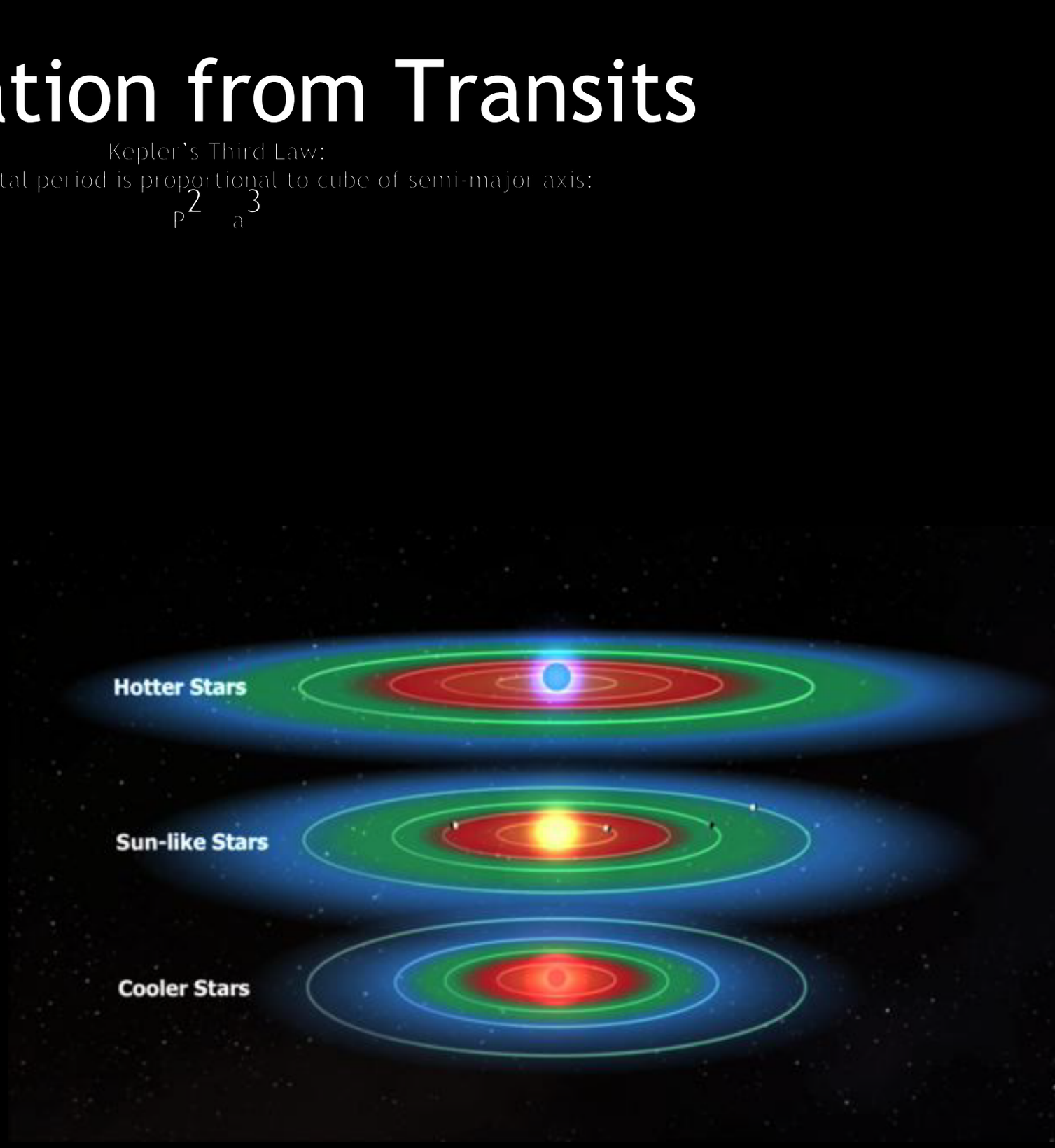


Information from Transits

Kepler's Third Law:
Square of orbital period is proportional to cube of semi-major axis:

$$P^2 \quad a^3$$

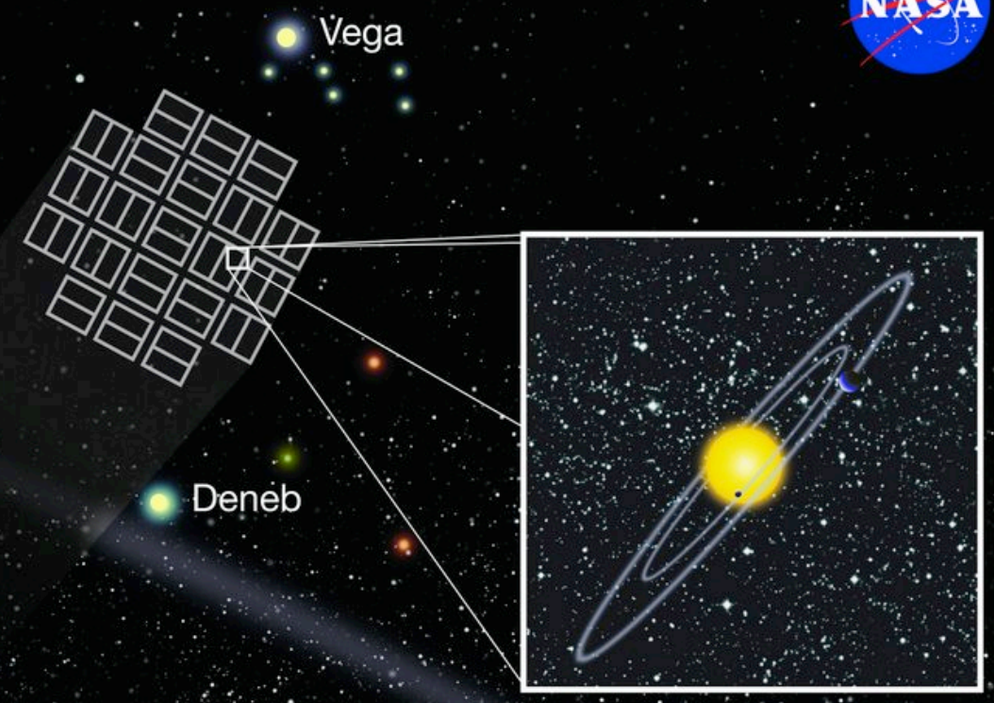
- ✓ **Transit Frequency gives us ORBIT SIZE**
- ✓ **Orbit Size with Star Temperature tells us if planet is in habitable zone.**
- ✓ **Transit duration, depth, gives us PLANET SIZE**
- ✓ **Size and Mass (with a doppler measurement of the "wobble") gives DENSITY**
- ✓ **Density is clue to COMPOSITION.**



National Aeronautics and Space Administration

Kepler

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

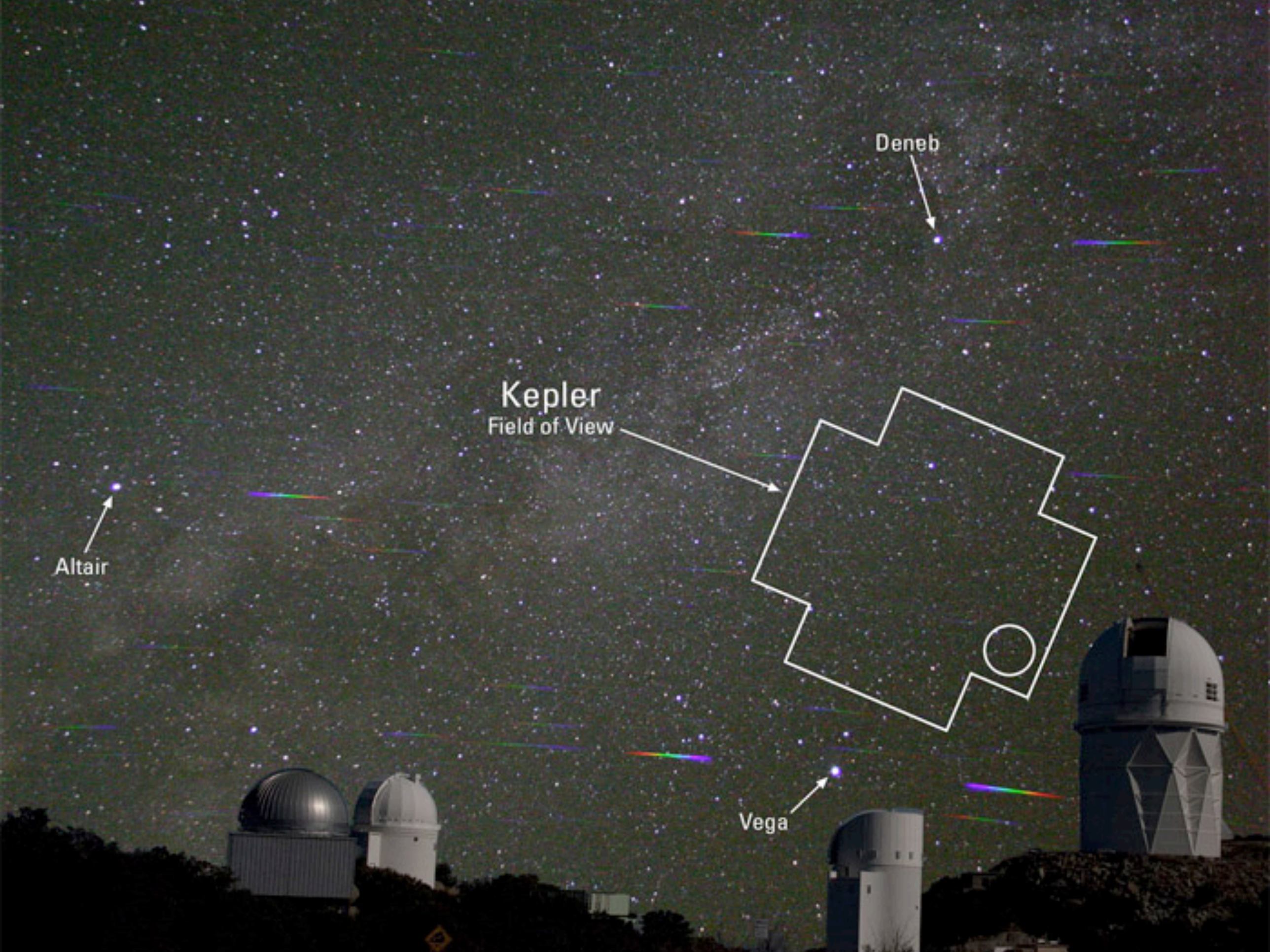


WARNING: OBJECTS IN THIS RENDITION APPEAR LARGER AND CLOSER TOGETHER THAN THEY ARE IN REALITY.

www.nasa.gov

Find educational activities at www.kepler.nasa.gov

March 6, 2009


Deneb
Kepler
Field of View
Altair
Vega

From 2009-2018, Kepler found over 4,000 planets around other stars.