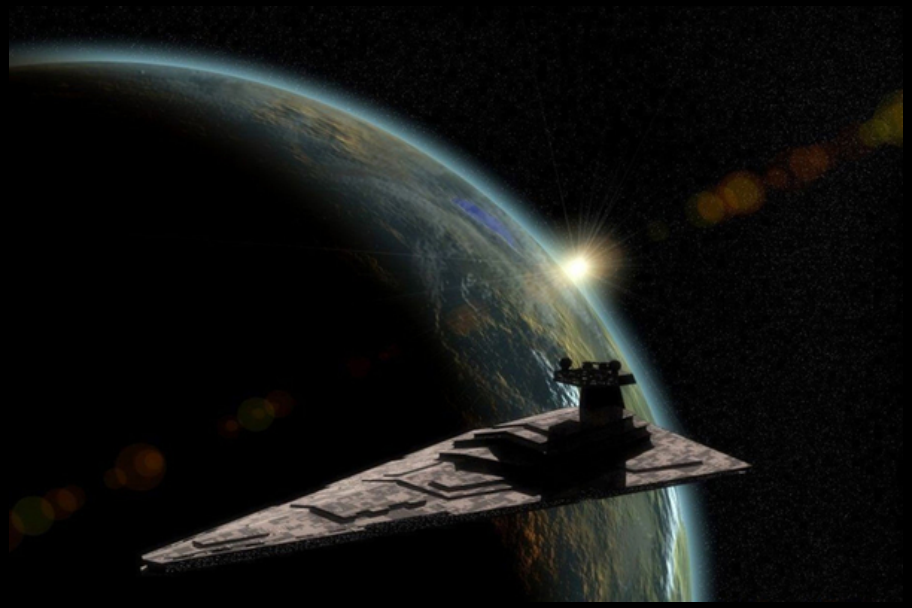
The Search for Other Earths

Class 1: Introduction

Steve Bryson

Planets Around Other Stars?

- Before 1992 we did not know for sure that there were planets orbiting other stars
  - Sure, we expected them, but had not actually found any…

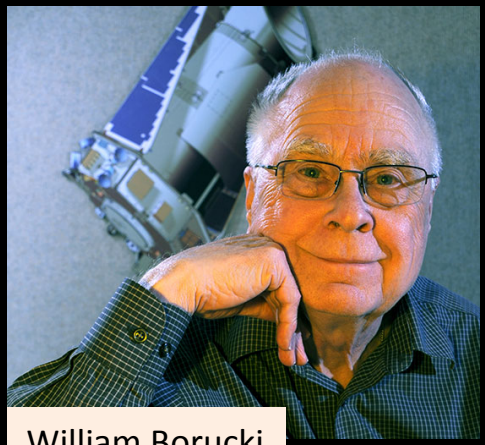


Planets Around Other Stars

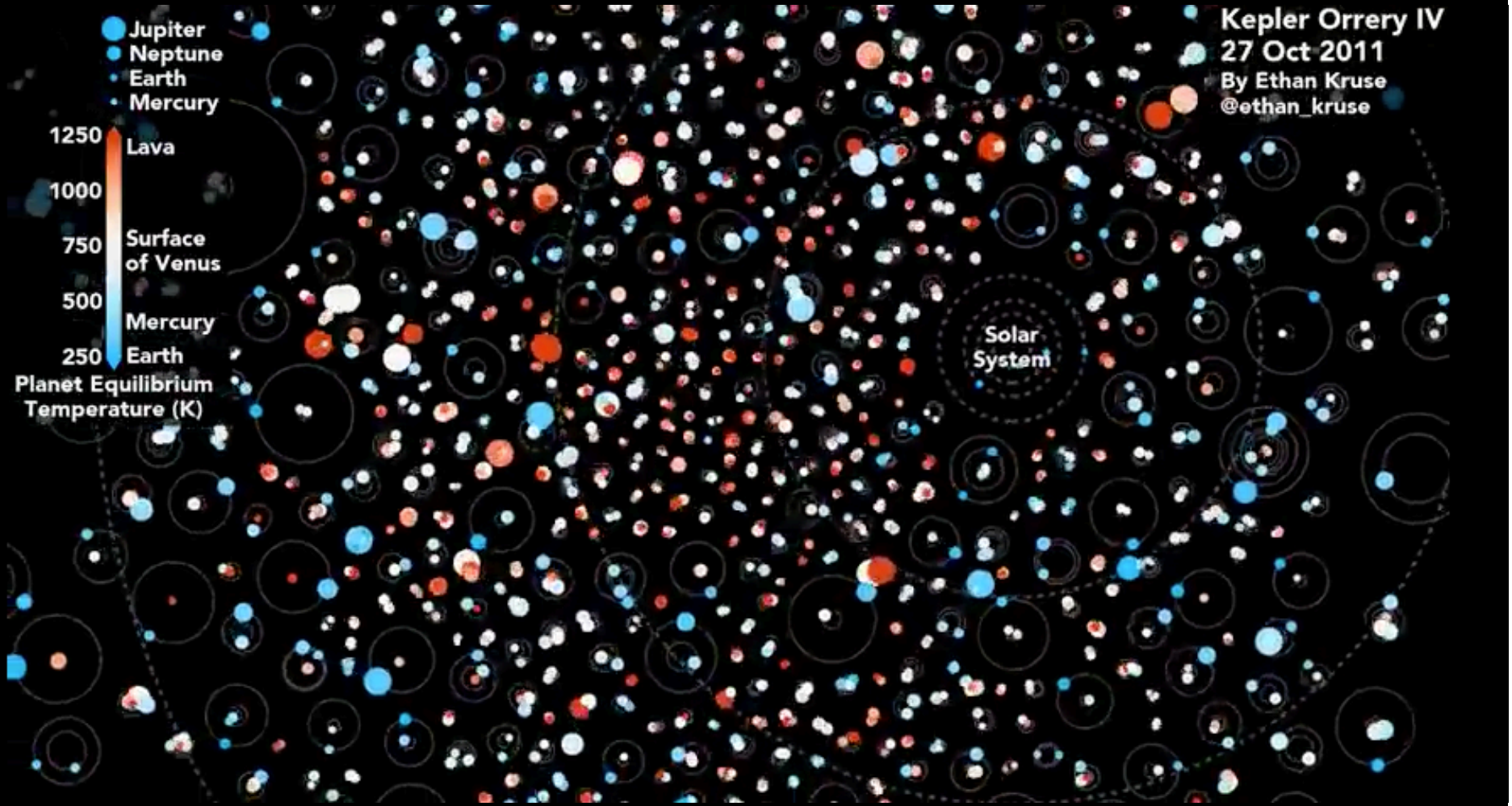
- Since 1992 we've for sure detected 1,959 planets around other stars
  - "confirmed" *Exoplanets*
  - As of Sunday March 20 2016
- We've detected more than 3,699 more exoplanets with less confidence
  - Probably 10% not really planets
- Most exoplanets have a size between Earth and Neptune
  - A planet type that does not exist in our Solar System!


Michel Mayor

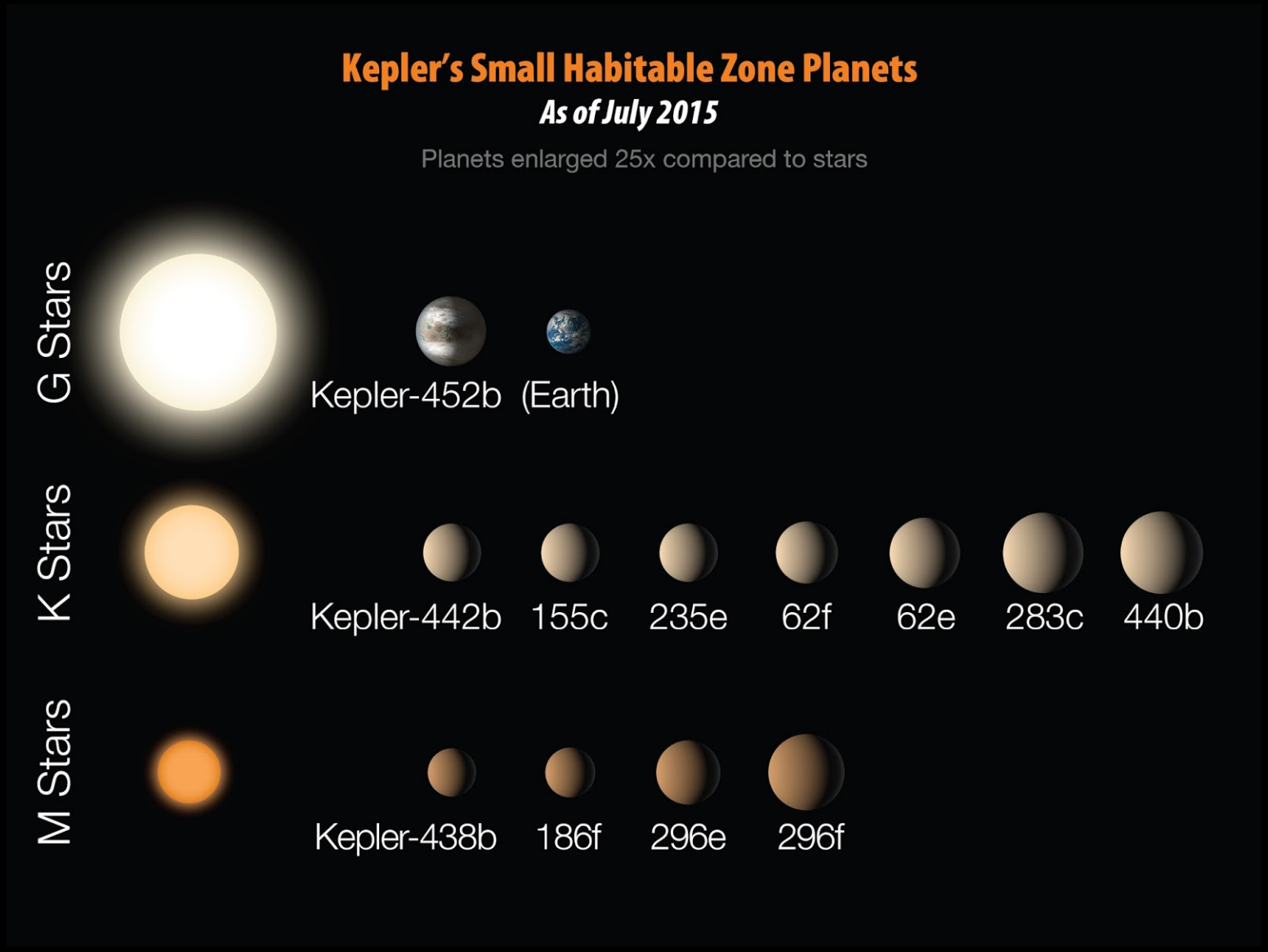

Didier Queloz


William Borucki

Multi-Planet Systems



Possibly Earth-Like Planets?

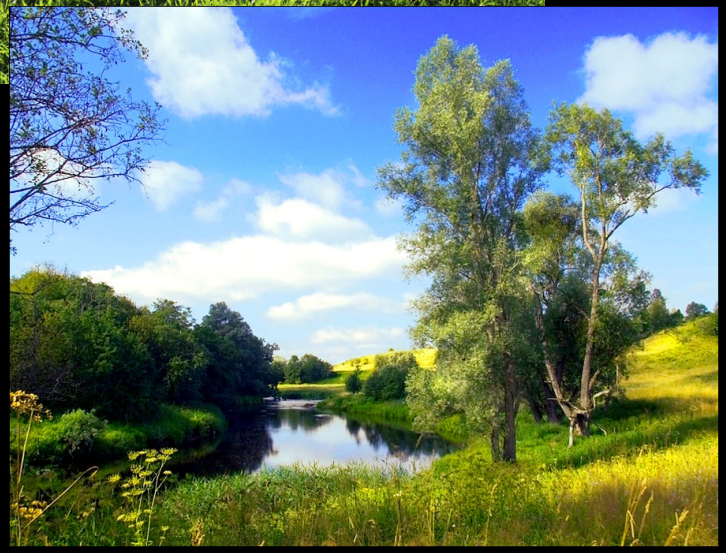


Why Look for Other Earths?

- Helps us understand our Earth and its place in the universe
- Helps us understand how the Earth formed
- Begins to answer the question “Are we alone?”
- A place to dream of going?

Why is Earth Good for Life?

- Solid Surface
- Atmosphere
- Nice temperature
  - Liquid water
- The Right Size
- The Right Ingredients



What is a Planet?

- Planet: A Big Round Thing that orbits a Star
- Star: A Big Round Thing that shines really brightly
  - Or shined sometime in its past or future
  - Shines because of nuclear fusion
- (Moon: A Big Round Thing that orbits another big round thing (planet) that is not a star)
- (We'll ignore the IAU)

Planets in Our Solar System

- Other planets in our Solar System are very different from Earth
  - Terrestrial Planets: Mercury, Venus, Earth, Mars
  - Gas Giant Planets: Jupiter, Saturn
  - Ice Giants: Neptune, Uranus

Notice Their Sizes

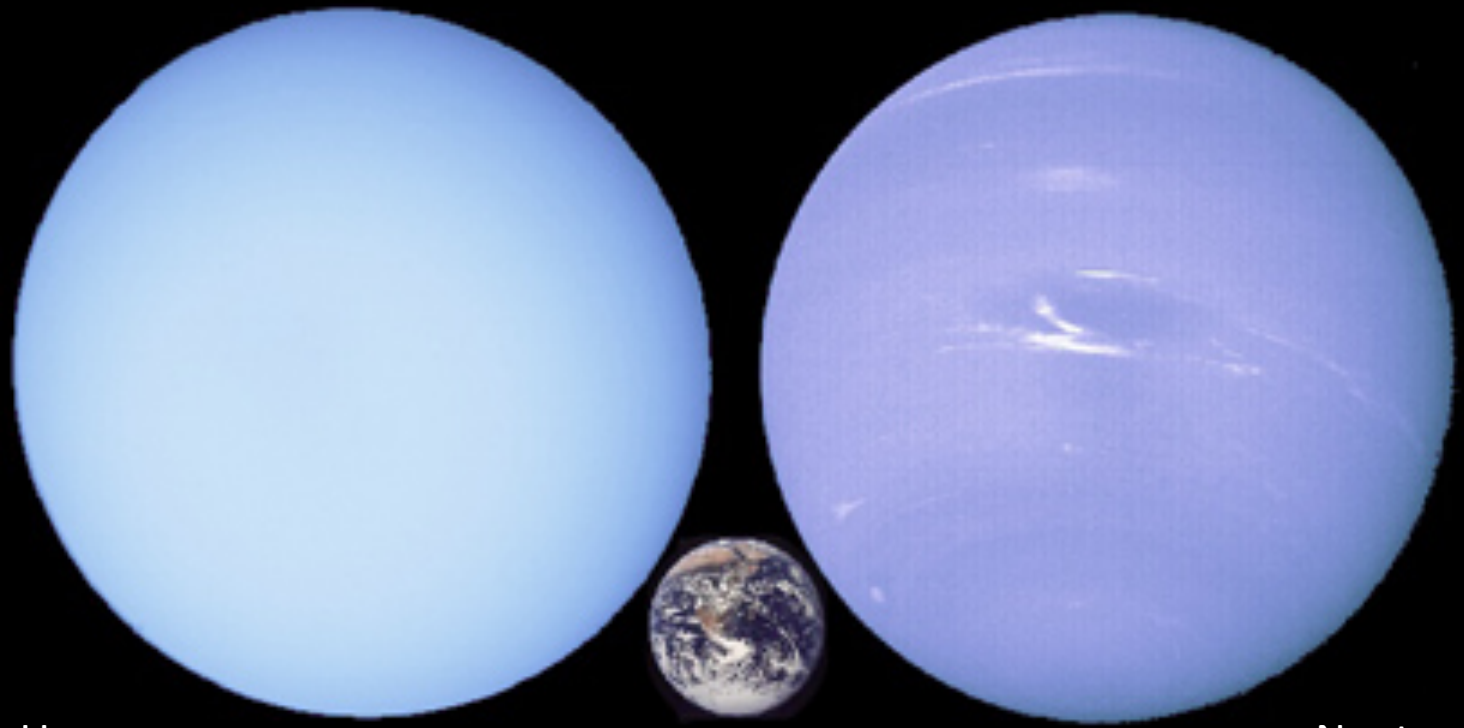
- Terrestrial planets much smaller than gas giants
- Ice giants in between

Terrestrial Planets

- Solid Surface

Ice Giants

- Lots of frozen water, Hydrogen and Helium atmosphere, 4 time radius of Earth

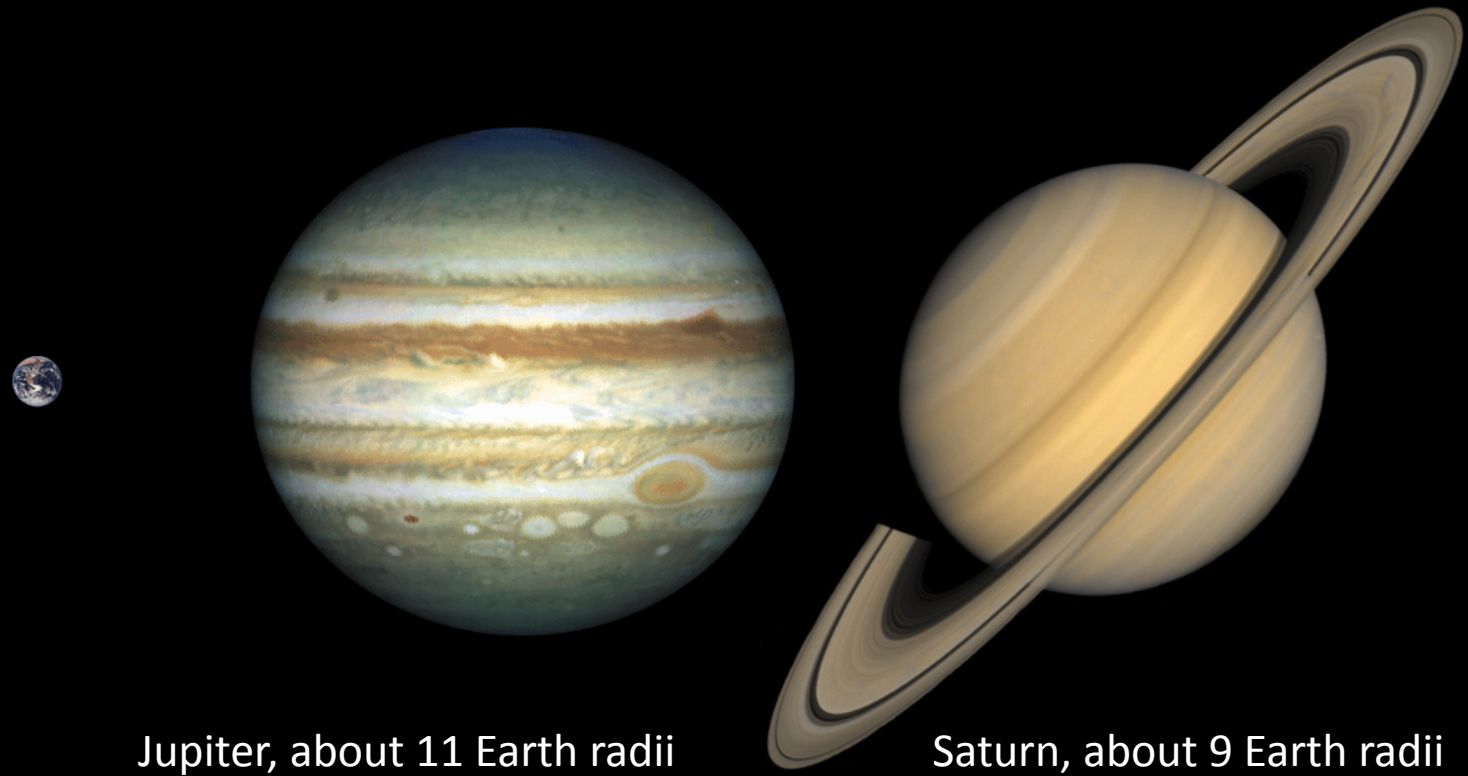


Uranus

Neptune

Gas Giants

- Almost all Hydrogen and Helium, No Surface



Jupiter, about 11 Earth radii

Saturn, about 9 Earth radii

What Planet is Good for Life?

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- Atmosphere
- Nice temperature
  - Liquid water
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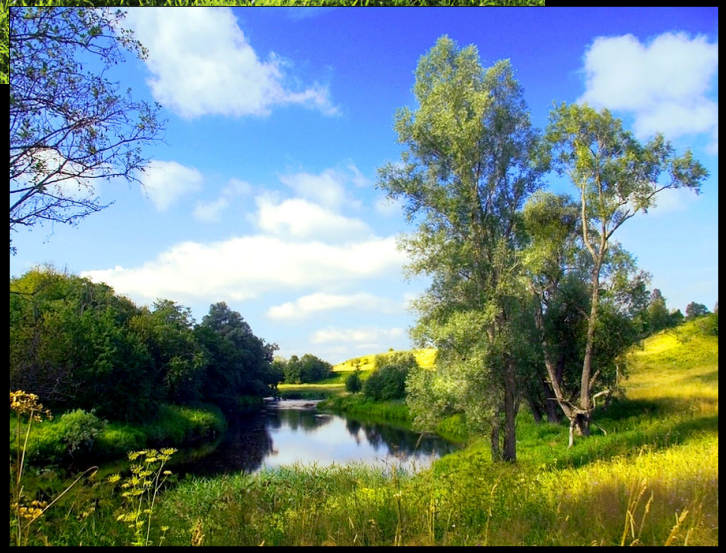
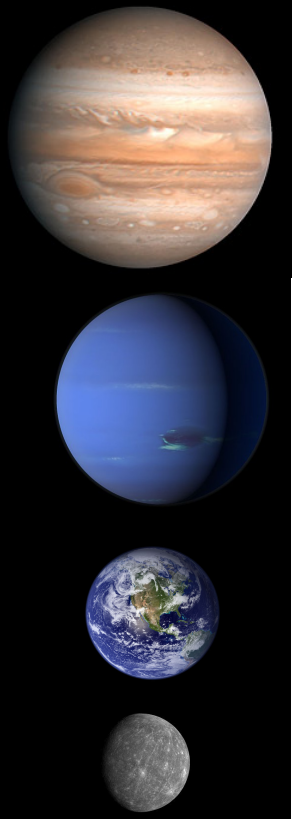


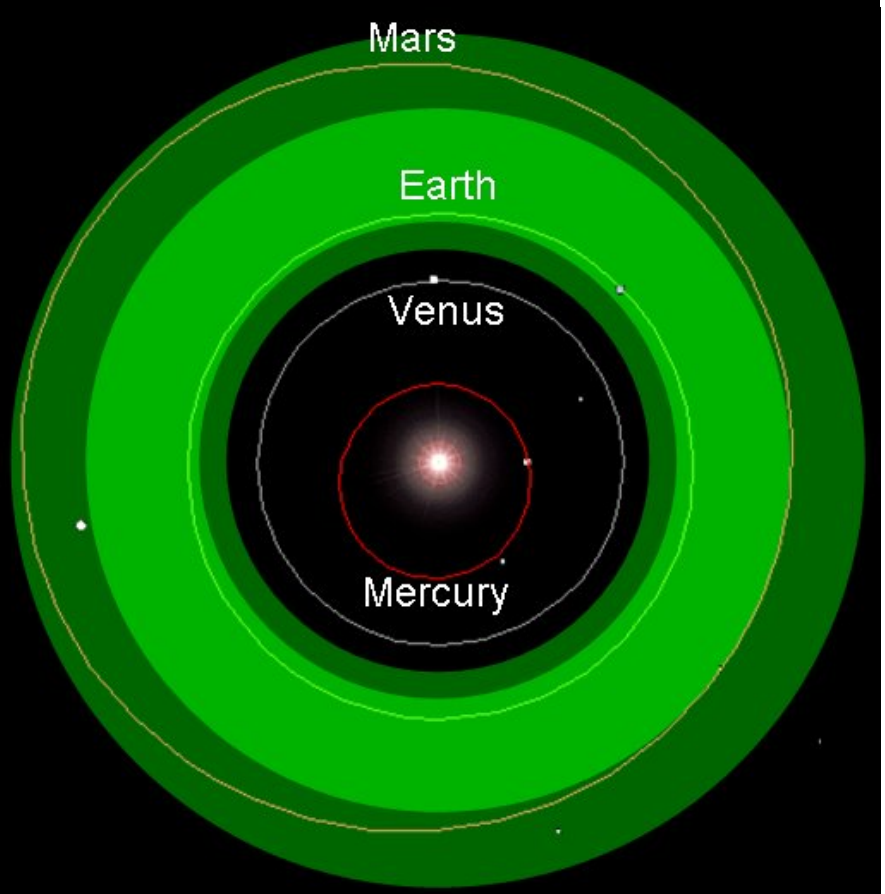
Size Matters

- Determines Mass and therefore gravity
  - Determines whether you have a solid surface
  - Determines composition
- Gas Giant planets have strong gravity
  - Holds everything, especially light elements like Hydrogen and Helium
- Ice Giants have less gravity
  - Loses most light elements, holds onto water and methane
- Terrestrial Planets lose most light elements
  - Keep rock and iron, have a thinner atmosphere
  - But if too small then lose atmosphere



Location, Location, Location

- Distance from the star determines temperature
- The "Habitable Zone" is where temperatures are right for liquid water
  - Depends on details of planet's atmosphere

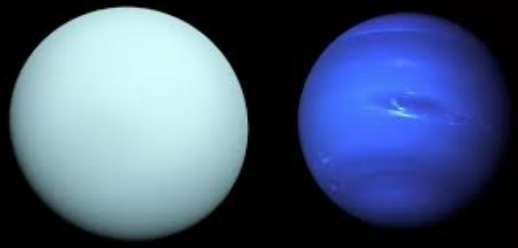


The Right Ingredients

- There is LOTS of water in the Solar System

The moons of Jupiter

The rings of Saturn

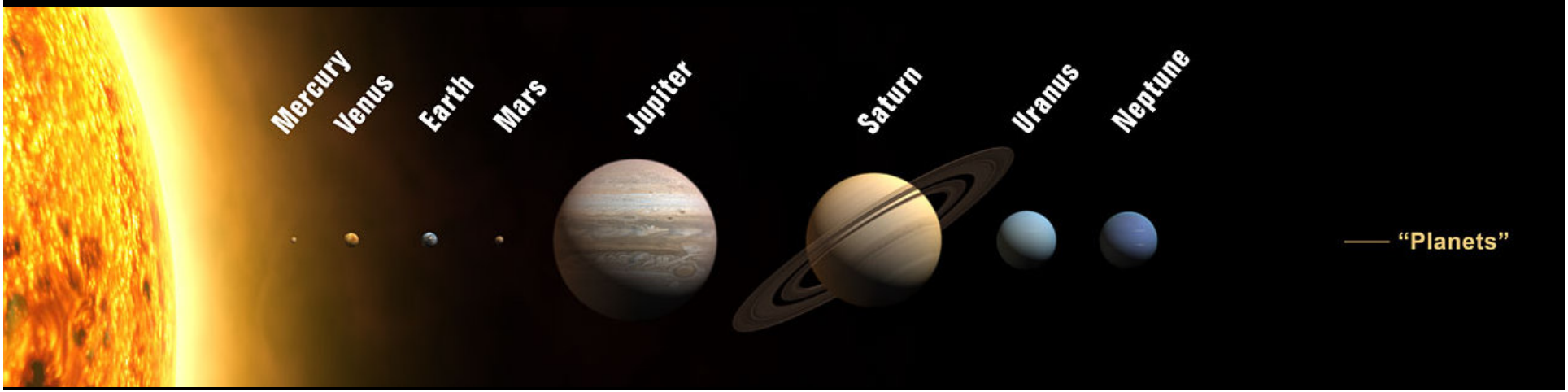


Uranus and Neptune

- By comparison, the Earth is very dry

Several Planets, One Good for Life

- Only Earth is the right size in the right place
  - Marginal possibilities:
    - Mars, but it's too small for life to thrive
    - Moon of Jupiter, under surface where it may be warm
- Gas giants too big: no surface
- Ice giants too cold, too far from Sun

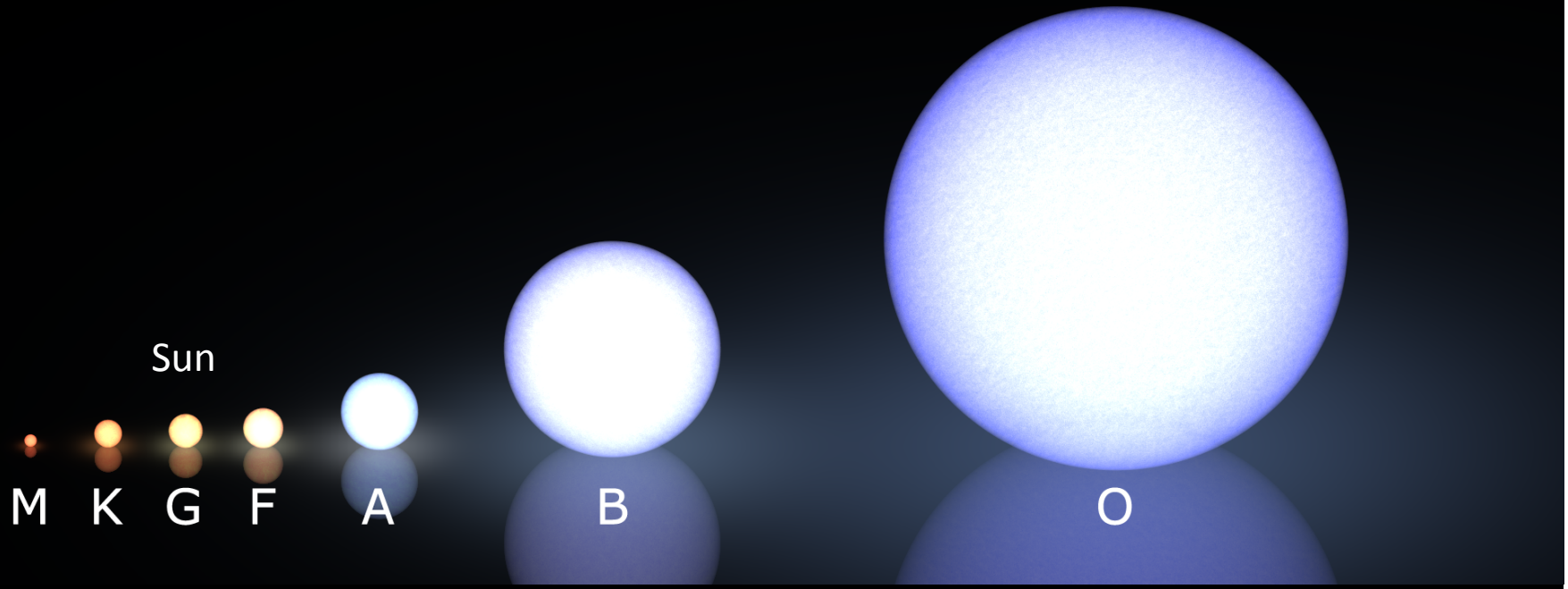


Interlude: Measurement Units

- We're going to talk of really big things, so we need appropriate units
- Distance:
  - 1 Earth Radius = 4,000 miles, used to describe planet sizes
  - 1 Solar Radius = 430,000 miles, about 100 Earth radii, used to describe star sizes
  - 1 AU (astronomical unit): the average distance of the Earth from the Sun = 93 million miles
    - Used for distances within a planetary system
  - 1 Light year: the distance light travels in a year (in vacuum): 5.88 trillion miles = 63,000 AU
    - Used for distances from star to star. Nearest star is 4.3 light years away

What About Other Stars?

- Many stars are like the Sun, but some are hotter and larger while some are cooler and smaller



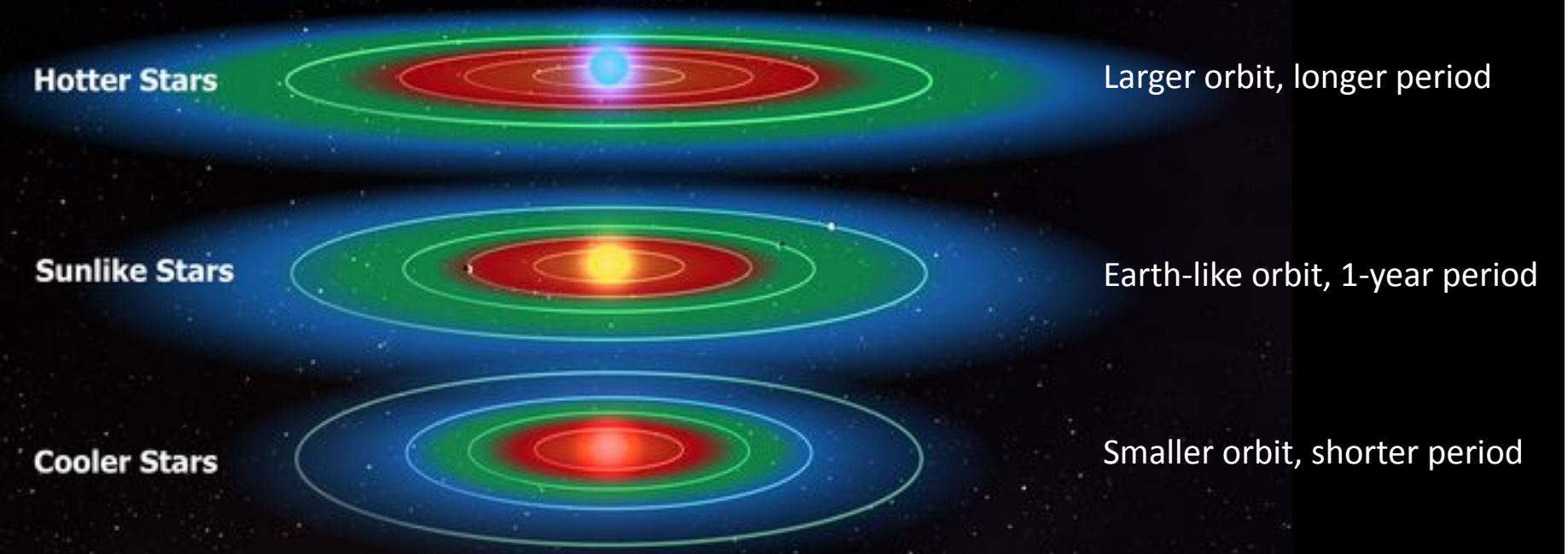

What About Other Stars?


Are there Any Planets in This Picture?


Are there Any Planets in This Picture?
On average, every star has a planet

What We're Looking For

- An Earth-size, rocky planet in the Habitable Zone
  - Not too hot, not too cold for liquid water

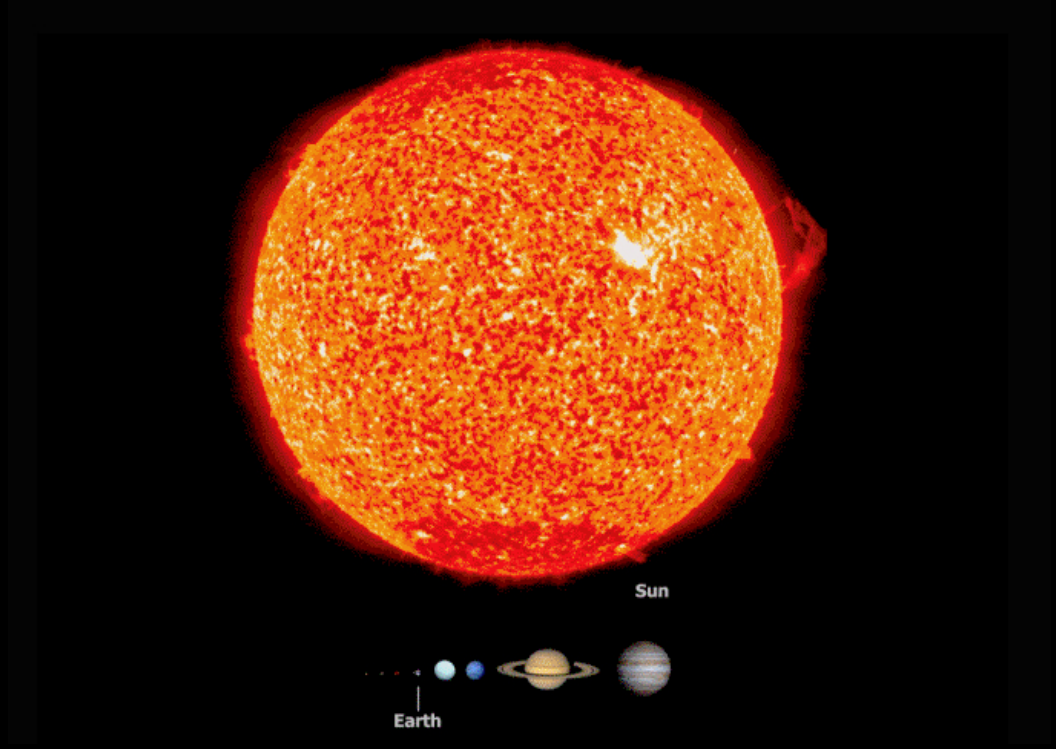


Planets Around Other Stars are Hard to See

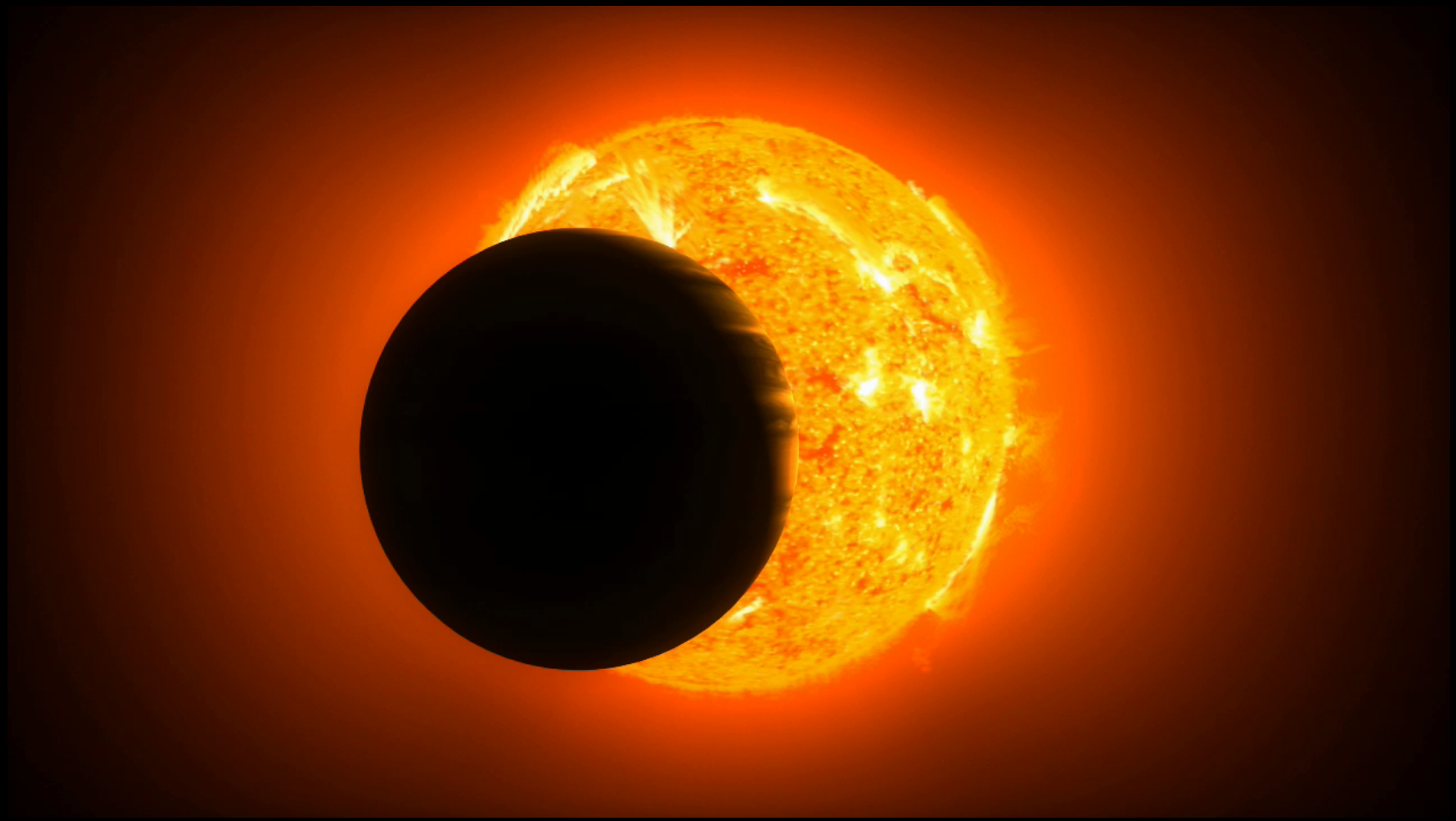
- Stars are big and very very bright
- Planets are dim, reflecting the light from the star
- Stars are very very far away
- So the Planet appears very close to the star from our perspective

Detecting Earth-size planets is difficult

- Earth is very small compared with the Sun
- Light from the star completely overwhelms the reflected light from a small planet

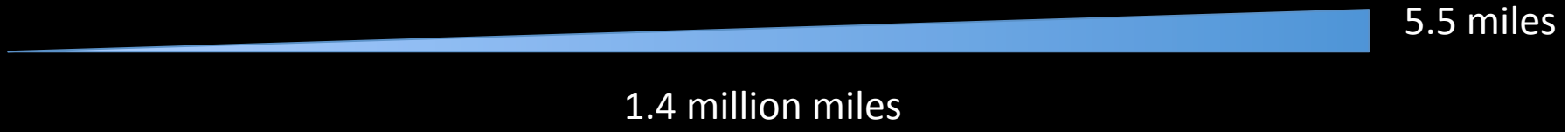


Lost in the Glare



Stars are Really Far Away

- If the Earth were the size of a basketball…
  - The Sun would be 5.5 miles away
  - The nearest star would be 1.4 million miles away
    - 10,000 times the distance to the moon
  - Angle between the Earth and Sun seen from the star: 0.0002 degrees (or 0.8 seconds of arc)
    - Deep in the glare of the Sun

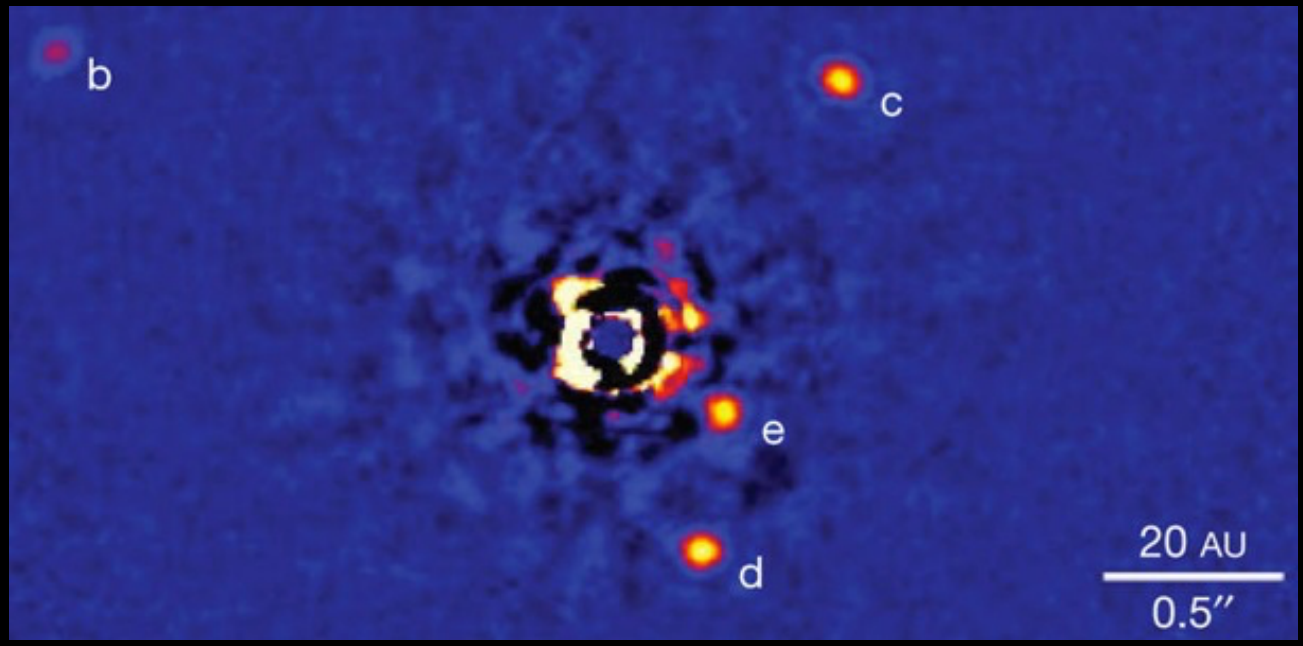


Take a Picture?

- Not of Earth so close to the Sun (yet)
- But if the planet is really big and far from the star…

Light from the Star is (imperfectly) removed

Giant planets around HR8799 in Pegasus, about 129 light years away. We see 4 planets larger than Jupiter, further from the star than Saturn from the Sun



Indirect Detection

- We can't see a planet like the Earth around another star, but we can see the star
- Use starlight in very clever ways to look for
  - Effects of the gravity from the planet
    - Causes the star to move
    - Can magnify the light of the star
  - Effects of the planet on the starlight itself

Move to iPad

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  - Free e-book with animations on iPad in iBooks
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