The Planets

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History of Astronomy

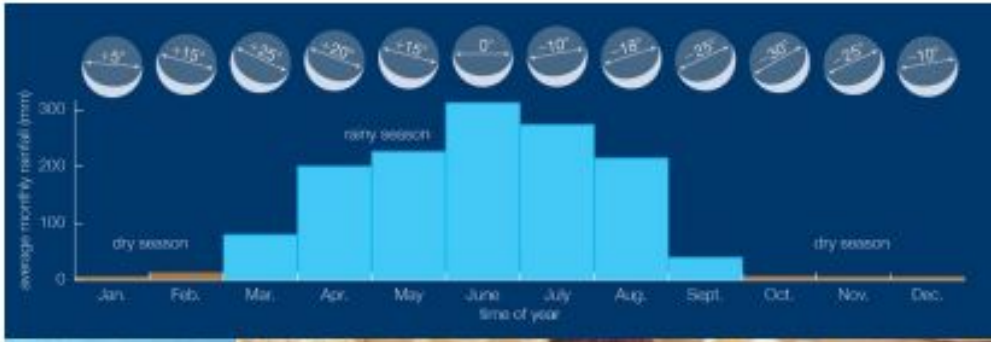
Astronomy was extremely important to ancient humans, mainly for timekeeping:

Month=time for Moon to complete cycle=time for Moon to go around Earth

year=time for seasons to complete cycle=time for Earth to complete revolution around Sun

week=1 day for each of 7 brightest objects in sky (Sun, Moon, 5 planets)

Used for religious and practical purposes.



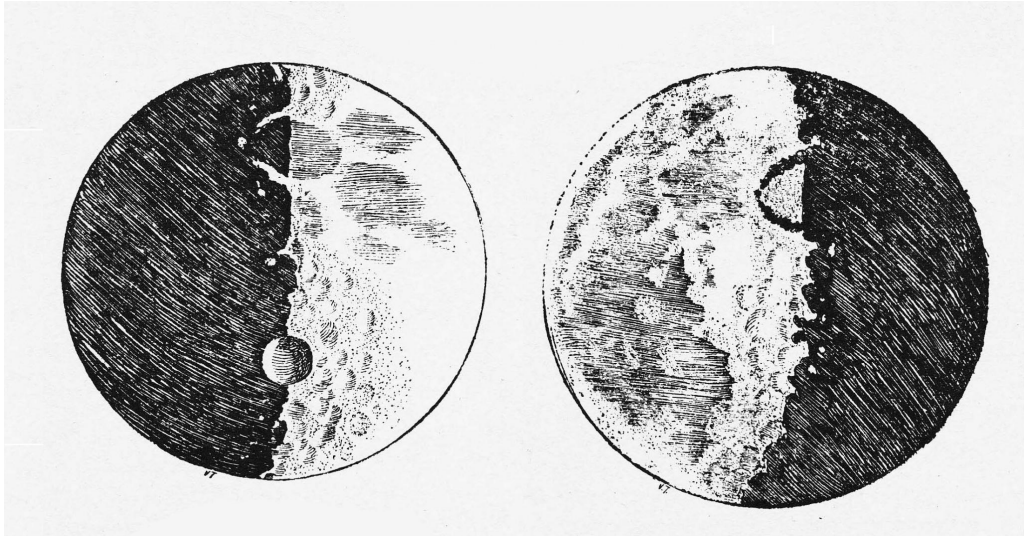
History of Astronomy

Motion of objects in sky due to Earth's rotation→ objects in sky appear as bright, perfect circles moving in perfect circles.

Predictable motion, same direction (east-west), no sign of stopping.

Ancient Greeks believed this perfect east-west circularity and "permanent" motion came from divine nature of sky.
All astronomical objects were then thought to be perfectly smooth spheres which move in circles by default (as things on Earth are stationary by default)

In the early 1600s Galileo began observations of objects in our solar system that would change our understanding of the Universe.

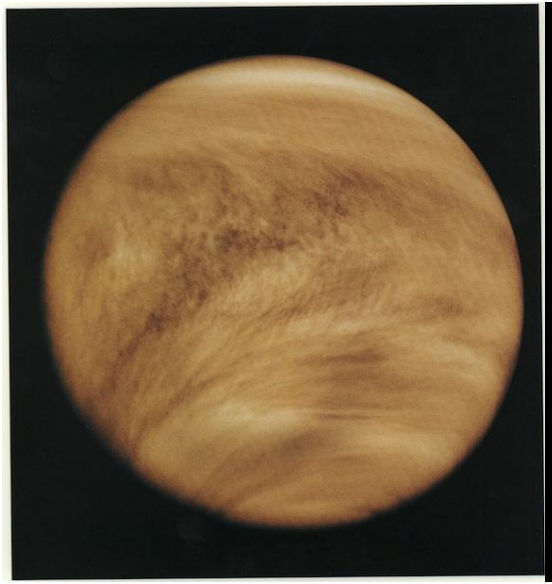


Venus

Inner planet
Distance from Sun: 0.7 AU
Radius: 0.95 R_E
Mass: 0.815 M_E
Temperature: 870 F
Year length: 225 Earth days
Day length: 243 Earth days
Moons: None!

Thick, yellow clouds of sulfuric acid
Volcanos!
Venus has ATMOSPHERE!

It also rotates the wrong way!
Planetary impact?



Scientists used to think Venus would be a paradise; similar to Earth but more tropical and humid.

Why isn’t it?

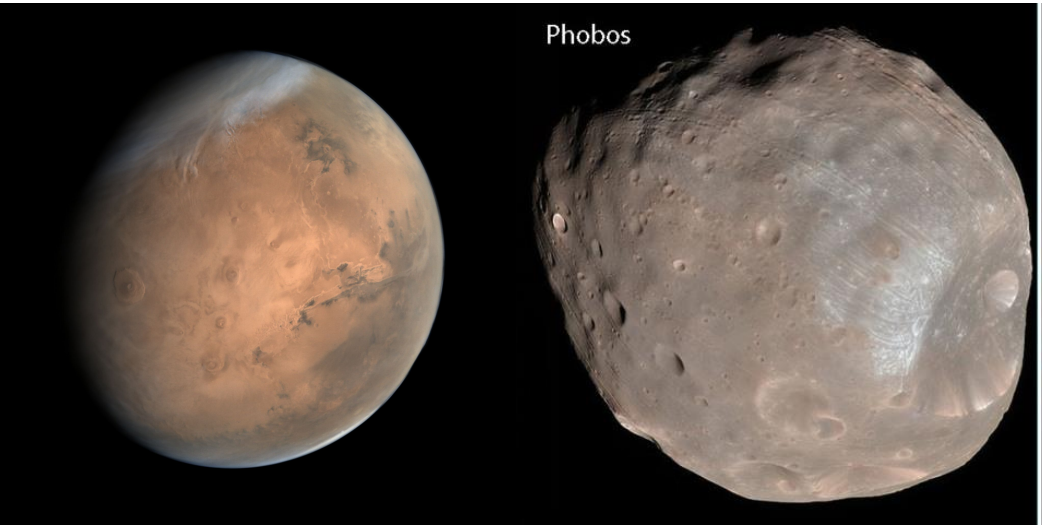
Mars

Inner planet
Distance from Sun: 1.67 AU
Radius: 0.53 R_E
Mass: 0.1 M_E
Temperature: -166 to 95 F
Year length: 687 Earth days
Day length: 1 Earth day+37 minutes
Moons: 2

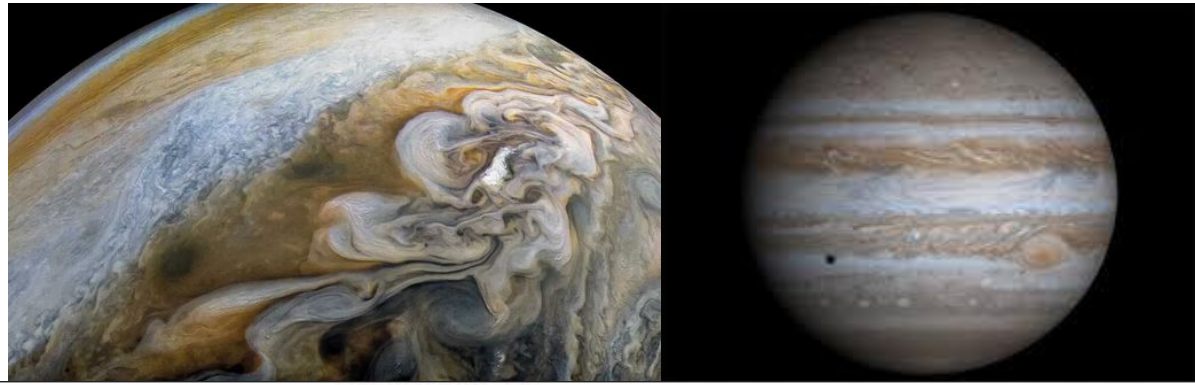
Mars does NOT have atmosphere! Or volcanos!

Earth has two sources of heat; the Sun's rays and internal heat. But Mars' internal heat, magnetic field have dissipated.

Low mass→ low gravitational pull→gasses escape
Low mass→ less internal heat→less volcanic activity→gasses remain trapped under surface



Jupiter



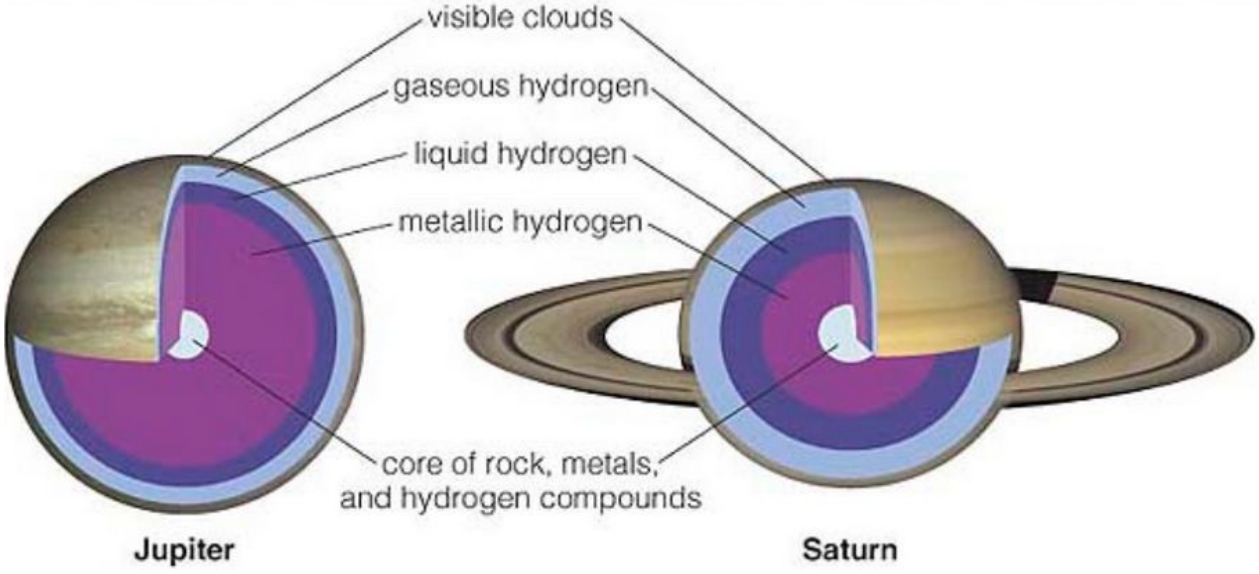
Outer (jovian) planet
Distance from Sun: 4.9-5.4AU
Radius: 10.5-11.2 R_E
Mass: 318 M_E
Temperature: -280 F
Year length: 12 Earth years
Day length: 10 hours
Moons: 76+

At surface of Jupiter, objects are rotating ~(24/10)*11=26 times faster than on Earth!

Venus had atmosphere, Jupiter IS atmosphere!

The outer planets form past the “ice line” and are able to form cores composed of rock and exotic ices such as methane. This allows them to hold onto gas

Liquid metallic hydrogen!

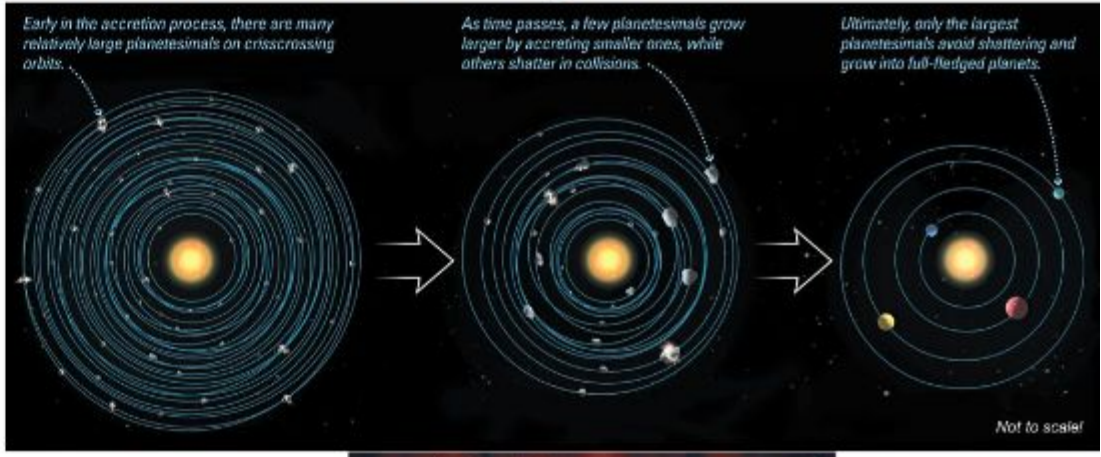


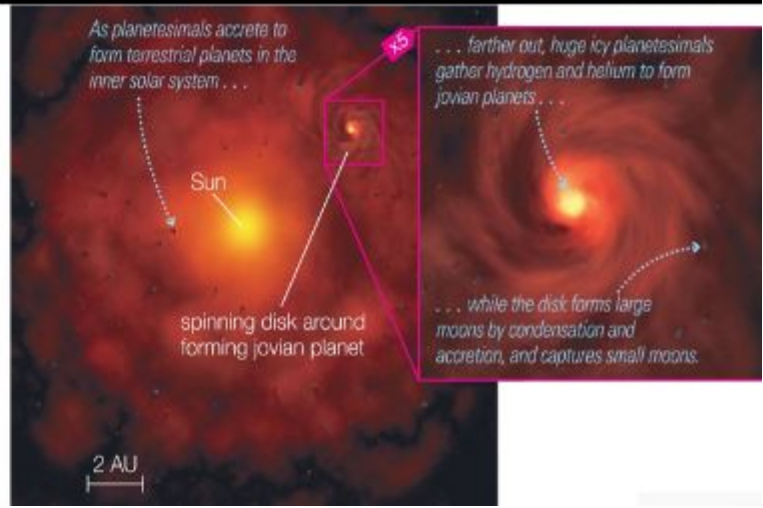
Formation of the Solar System

1) Begin with huge cloud of gas, dust
2) Various processes cause cloud to become disk-shaped ("accretion disk"), increase in density
   a) Center extremely dense, hot→ protostar
3) Tiny flecks of dust begin to collide, stick together in disk, forming pebbles→ pebbles to huge rocks→ huge rocks to planetesimals
4) Almost all material in inner solar system used up to make planets

Inner planet formation basically stops here

5) Further from the protostar/Sun, huge ice crystals form→ outer planets larger
6) Outer planet grows so large, it creates its own accretion disk *within the Sun's*!
7) Just as in larger Sun accretion disk, "moonetesimals" orbit the large planet, colliding with each other
8) Moons in outer planets are leftover accretion disk pieces! Larger planet=larger disk=larger and more moons



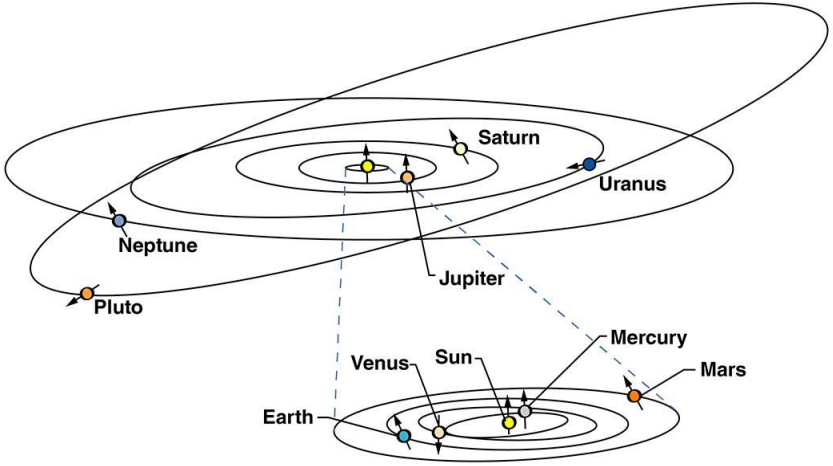


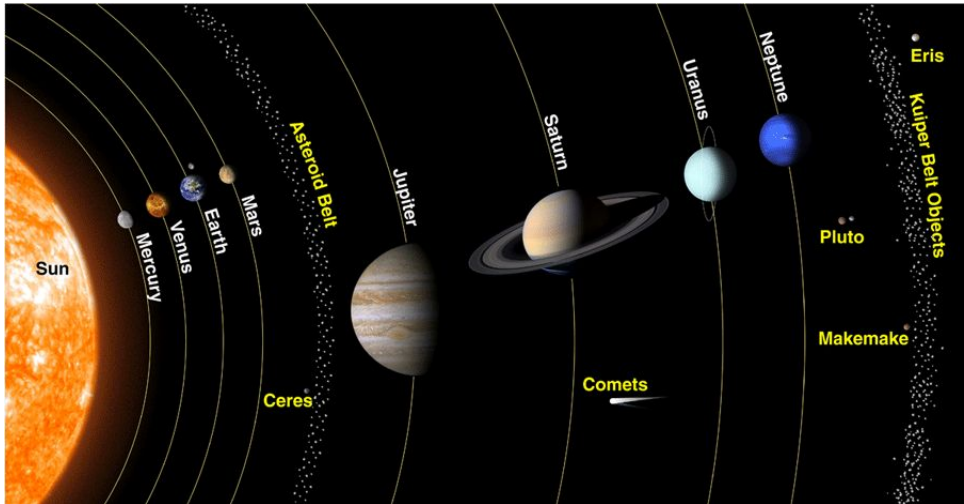
Also Saturn's rings!

Dwarf Planets

We used to have 9 planets, but we removed Pluto. Why? Because language fails to describe the universe

1) We should never have made it a planet in the first place, but we didn't know better
   a) Planets are WAY harder to detect than stars→ only had 9 planet-like objects to study
   b) As time went on, discovered more objects like Pluto
   c) Pluto is not a "weird planet", it's a different type of object, of which there are many in our solar system (CERES!) (ERIS!)



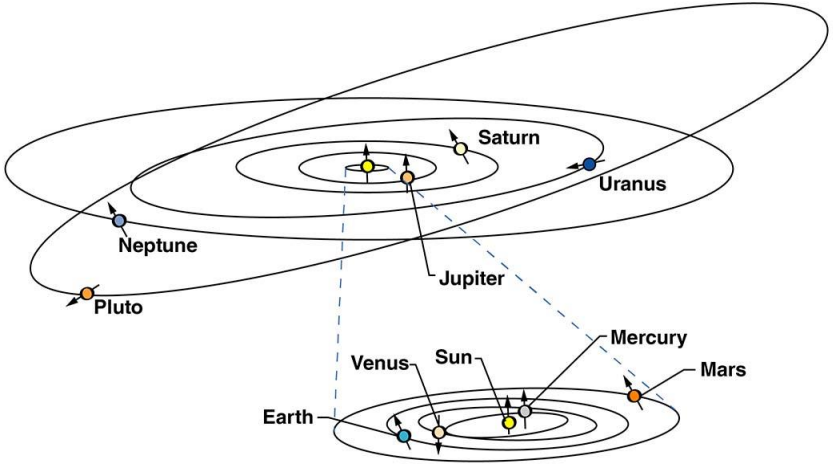


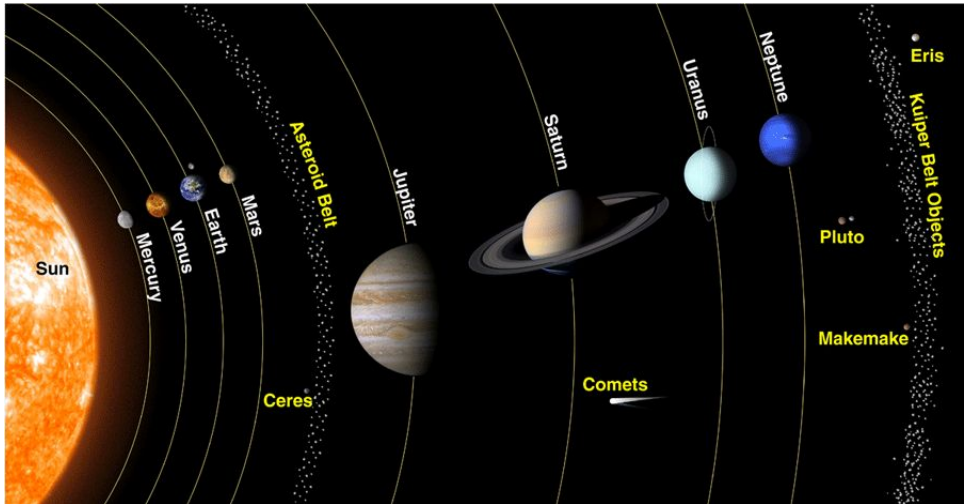
Dwarf Planets

As we discovered more dwarf planets, we understood better what made them different from “regular” planets:

1) Round or nearly round, like regular planets (but unlike asteroids/comets, which are too small to be round)
2) Have not cleared their orbits of debris (unlike regular planets, which are large enough to pull all the debris in)
3) Not a requirement, but dwarf planets tend to have elliptical orbits, and be far from the Sun

Note: ORBITAL PERIODS OF PLUTO, HALLEY’S COMET

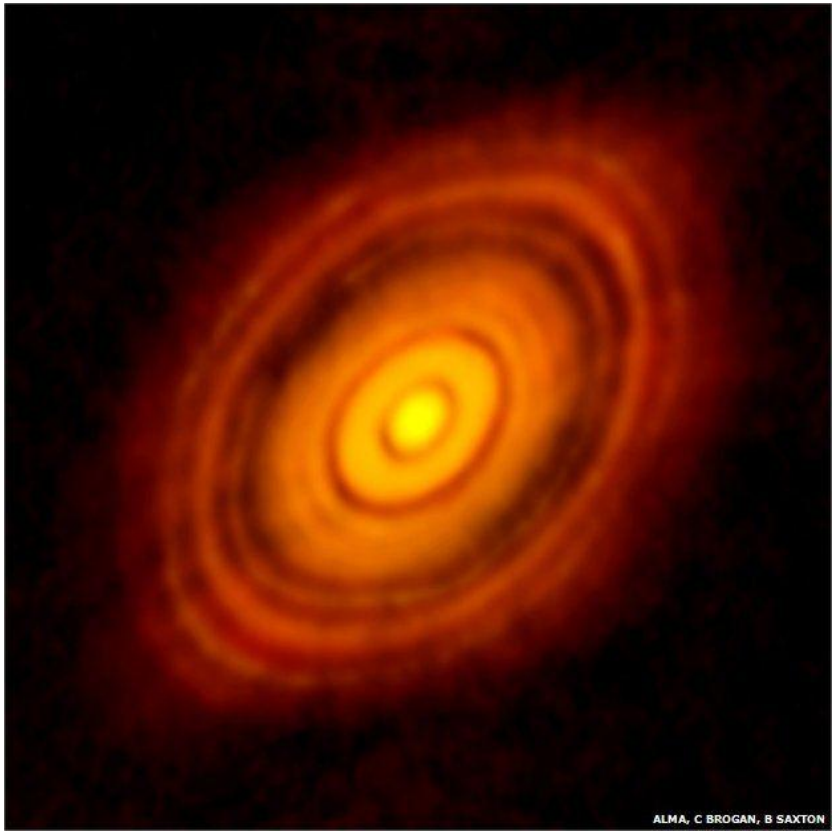




Other Solar Systems, Exoplanets

Exoplanets are just planets that orbit other stars.

- Not until 1992 did we have proof there were more than 9 planets in the universe. Now we think nearly every star is surrounded by them.
- Since discovering exoplanets, we have also discovered…..exomoons!
    - Exomoons can be huge!
- When new discoveries are made, we learn the limits of our previous understanding

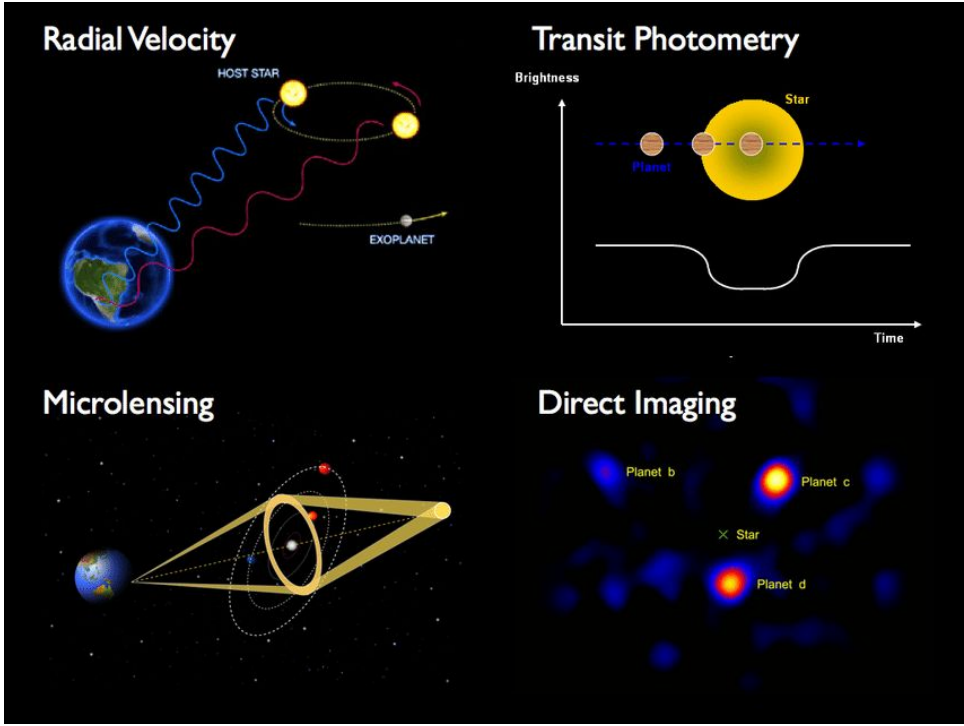


Hot Jupiters

The first exoplanet we found (and most that we've found since) was unlike any of the 8 in our own system

- Recall inner, outer planet differences, formation
- But all of our detection methods work best on planets that are both inner and massive!
- Experts expect to get lucky, catch a few flukes→ instead, discover many systems have planets of similar mass to Jupiter *very* close to their stars

How??



Planetary Migration

- Cannot explain how gas giants form inside of ice-line. Maybe they DONT? Current explanation: hot Jupiters form beyond the ice-line, but move inward after formation!
- Unclear what begins migration, may be variety of factors. Could be a very long very elliptical orbit.
- As the large planet approaches the star it runs into denser and denser debris, and feels stronger gravity.
- These factors turn the elliptical orbit into a more circular one as the planet and star get closer
- Circular orbits are very stable, even the crazy ones we see exoplanets have (<7 days in a year!)
- Migration halts