Comets and Solar Systems

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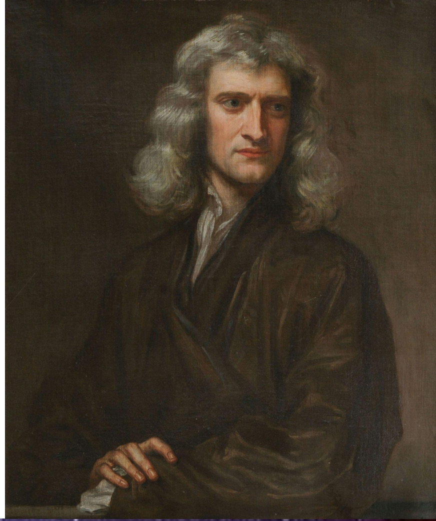
Halley's Comet

Most famous comet

Also the first recognized!

- Aristotle believed comets were disturbances in Earth's atmosphere, bright flashes of light
- In 1577, Tycho Brahe uses parallax angle to approximate distance to previously observed comets→ Aristotle is wrong!
- Believe that comets are astronomical objects whizzing past us on a "straight line"
- Tycho Brahe collects data on anything in the sky, for a very long time

Halley’s Comet



Isaac Newton analyzes Tycho Brahes data, finds patterns! In 1687, Newton publishes “*Philosophiæ Naturalis Principia Mathematica*”, which describes gravity as the same force moving planets and making it hard to jump. Still a little uncertain about how comets work.

- Newton suspects 2 comets seen in 1680 and 1681 are the same object disappearing behind the Sun and coming back (NOT a “straight line”)
- Unlike planets, comets are not usually visible, hard to get consistent data.

Halley's Comet

Newton's editor/friend is Edmund Halley!

In 1705, Halley uses Newton's newly discovered laws of gravity to calculate various properties of cometary motion.

Compiles a list of 24 historical observations of comets.

- 3 of these comets, in 1531, 1607, and 1682 had the same orbital properties
- Halley concludes that this is 3 appearances of the same comet, and that comets do not "pass through" the solar system, but return to it periodically **(usually……)**
    - Halley's comet has period of ~76 years
    - Halley's comet is the only one visible to the naked eye that can be seen twice in one lifetime

Halley’s Comet

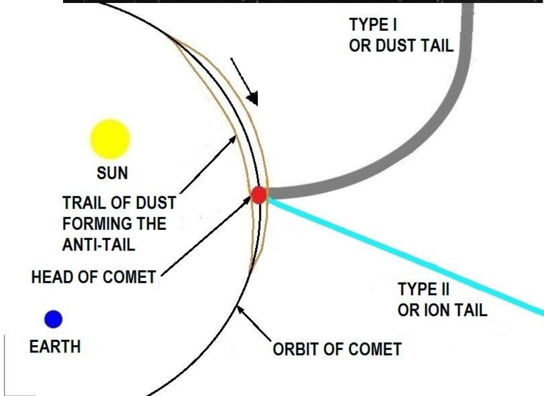
Computers allow us to use modern data to model past behavior of comets

- In 1981, researchers modeled past behavior of halley’s comet and compared it to historical observations
- Around the year 837 AD, Halley’s comet passed very close to Earth, which disturbed the orbit
- To constrain their calculations, researchers relied on very old observations from Chinese astronomers, which describe comets as far back as 600 BC, and are the most accurate available from the time period

What is a comet?

We still glean useful info from Halley's comet today!

- Brightness makes it easier to observe
- Short-ish period and regularity make it easy to prepare for
- In 1986, we observed the comet and discovered/proved:
  - Comets are made of rock, dust, and volatile ices
  - The sublimation of these volatile materials is what gives comets their striking features, such as tails and "coma".
- Tonight we'll observe comet ZTF E3, which also has/had an "anti-tail"!
  - Optical illusion mostly; a thin disk of more massive material surrounds entire comet, but it looks weird in the front
- Green glow caused by diatomic carbon interacting with solar radiation, dissolving



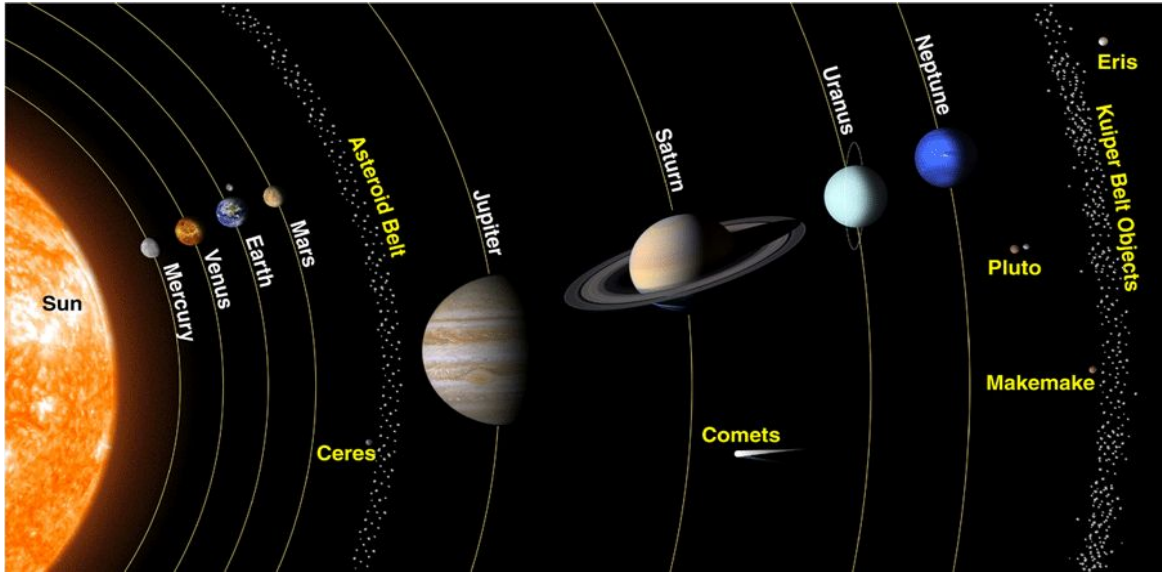
Ok….Then what's an asteroid?

Lots of terms for "space rock":

1. Comet
2. Asteroid
3. Meteor
   a. Meteor
   b. Meteoroid
   c. Meteorite
4. Planetesimal?
5. Planet?
6. Dwarf planet??

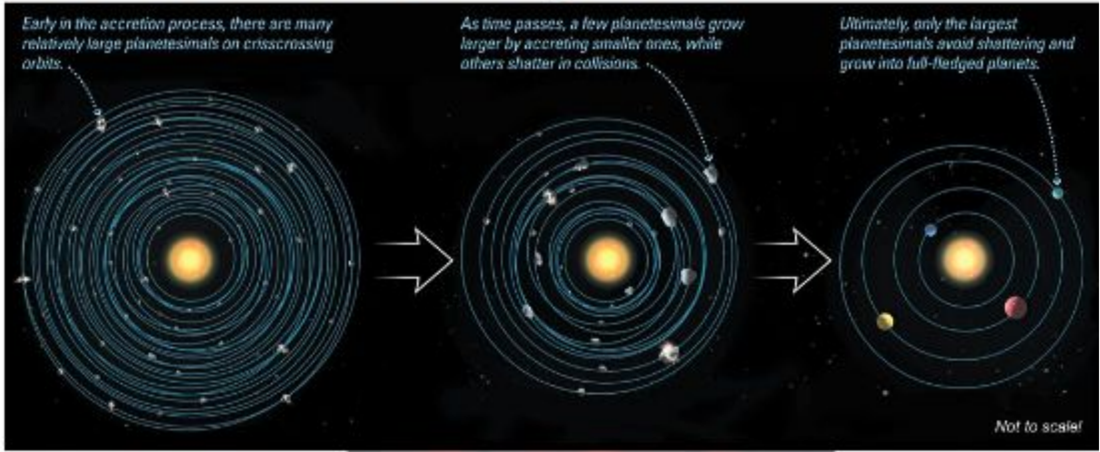
There *are* reasons for all these names! To understand, we need to talk about the formation of our solar system

Anatomy of Our Solar System



Formation of the Solar System

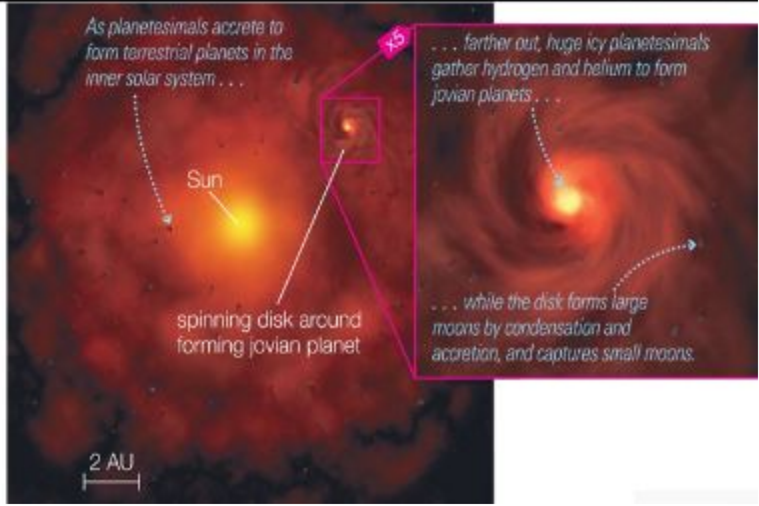
1) Begin with huge cloud of gas, dust
2) Various processes cause cloud to become disk-shaped ("accretion disk"), increase in density
   a) Center extremely dense, hot→ protostar
3) Tiny flecks of dust begin to collide, stick together in disk, forming pebbles→ pebbles to huge rocks→ huge rocks to planetesimals
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

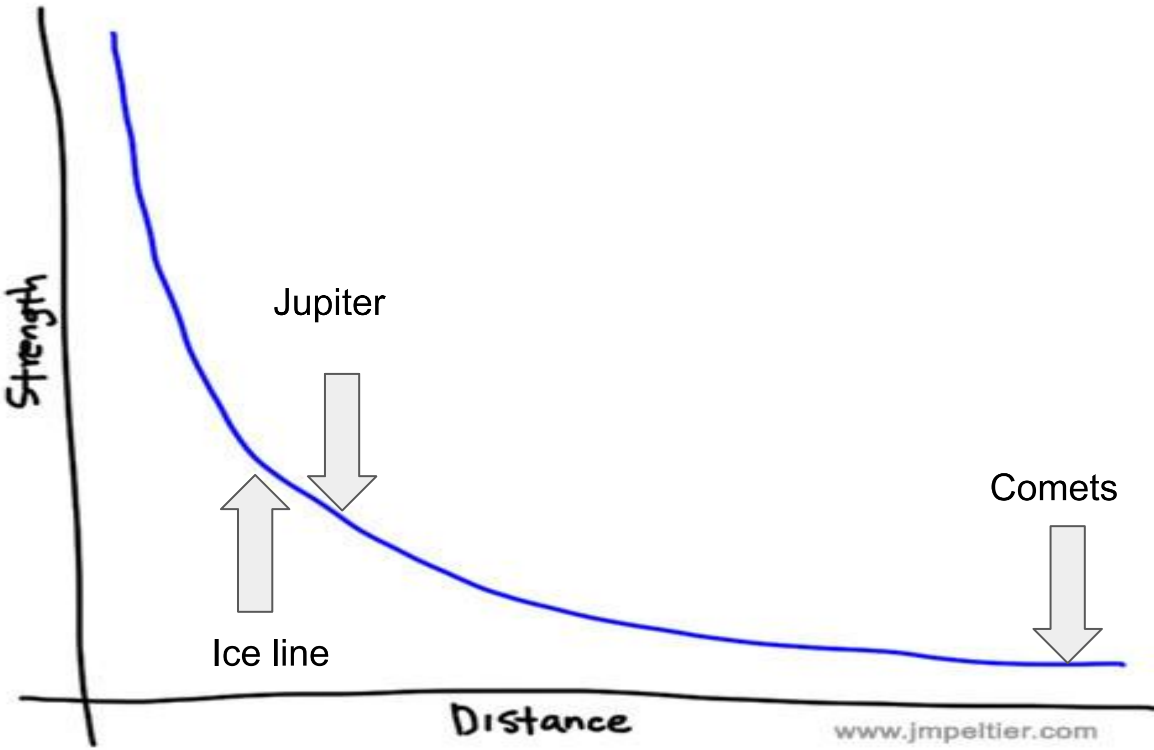
Also Saturn's rings!



Ok….Then what's an asteroid?

Outer planets are larger because they are past the ice-line, so there's more solid material to accrete (which then allows them to retain gasses). But comets tend to be much smaller than asteroids! Why?

Mass availability! Further from the Sun, space is emptier. A higher percentage of material is solid, but there's less material overall. Jupiter is the largest planet, and nearest the ice-line



Ok….Then what's a meteor?

Lots of terms for "space rock":

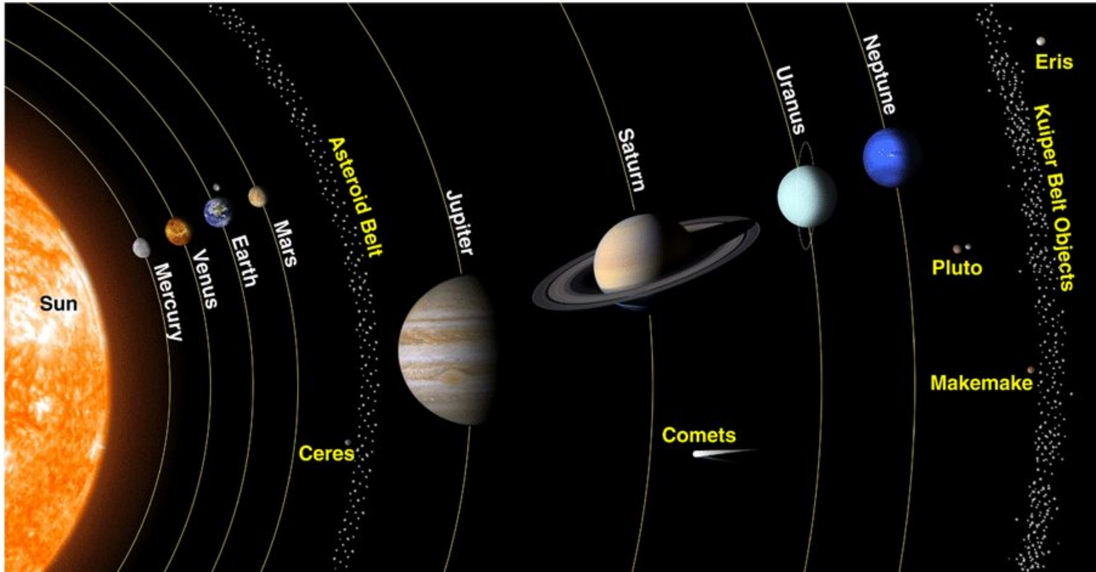
1. Comet→ space rock that comes from region *past* the ice-line, usually Kuiper Belt beyond Neptune. Icy. "Leftover" from formation of outer planets. Smaller.
2. Asteroid→space rock that comes from within the ice-line, usually asteroid belt between Mars, Jupiter. Not icy. "Leftover" from formation of inner planets. Bigger.
3. Meteor
   a. Meteoroid: rocky object from inner solar system– basically smaller asteroids, like grains of sand or rocks
   b. Meteor: Any meteoroid that interacts with Earth's atmosphere. The heat causes them to glow; shooting stars
   c. Meteorite: A meteor that not only interacts with our atmosphere, but actually hits Earth's surface

4. Planetesimal?

5. Planet?

6. Dwarf planet??

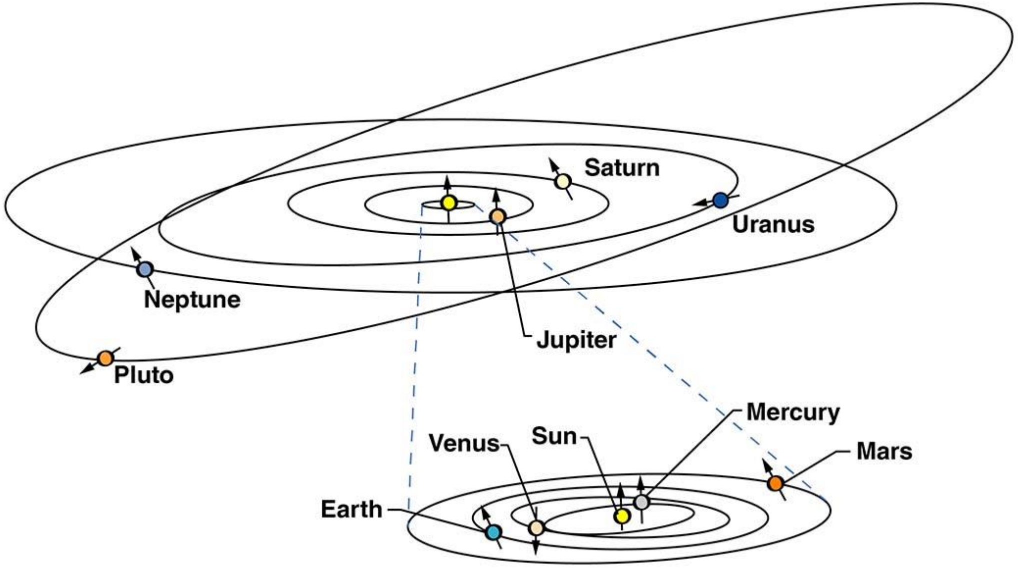
Anatomy of Our Solar System



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!)

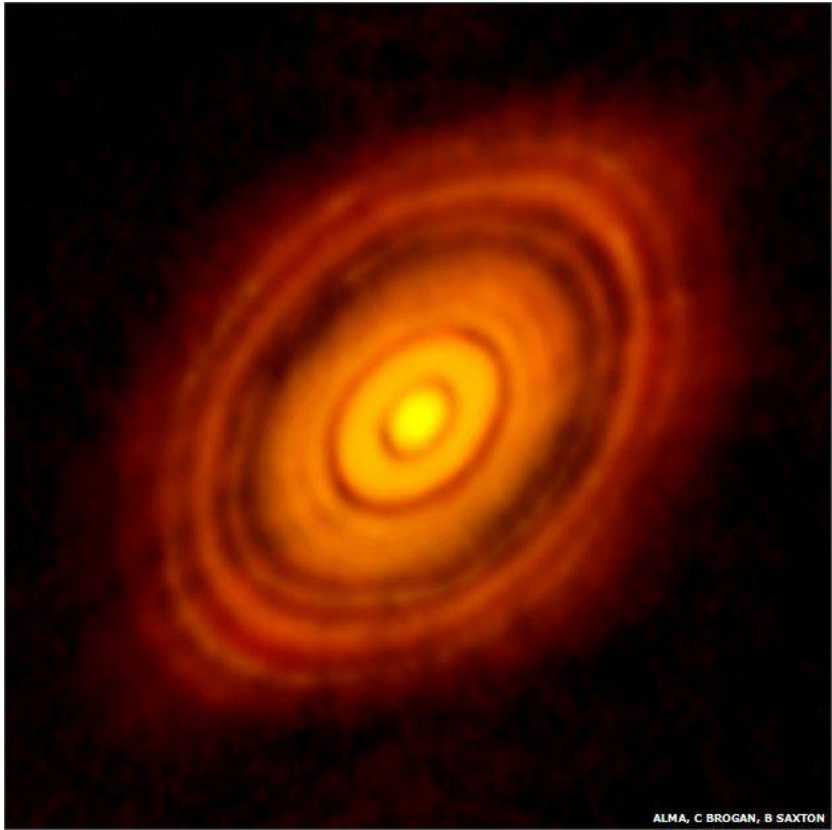


Dwarf Planets

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



Space Rock Definitions

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4. Planetesimal→ What we call the debris that will eventually form planets and dwarf planets

5. Planet→ If all the debris in an orbit is collected into one object with enough gravity to enforce a round shape, we call that a planet

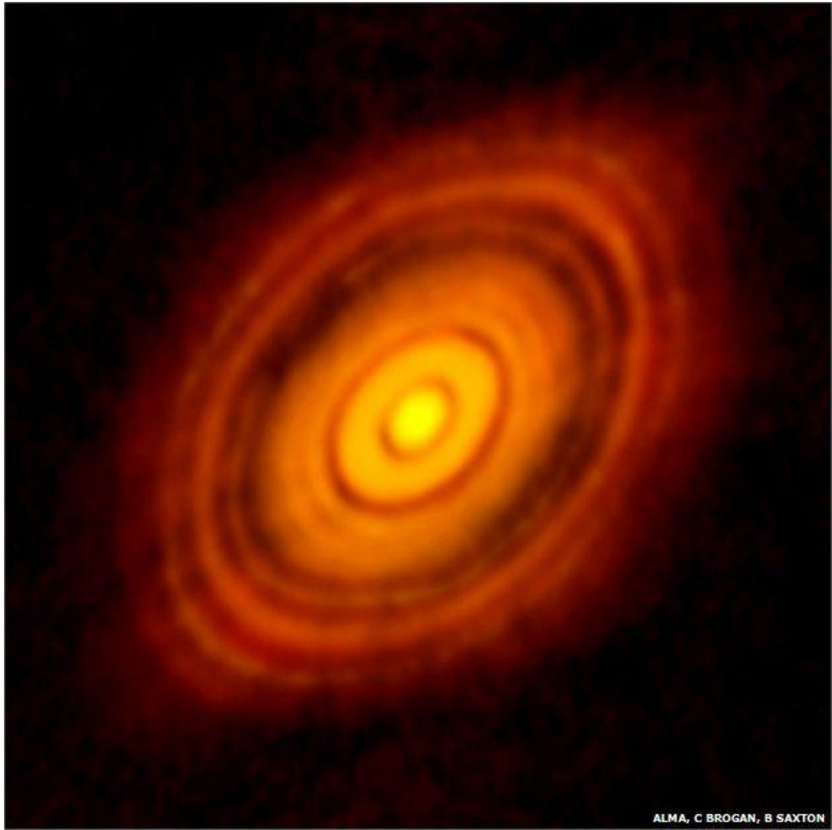
6. Dwarf planet→ If an orbit is not cleared of other debris but an object massive enough to be round is formed, we call that object a dwarf planet

7. Exoplanets????

Other Solar Systems, Exoplanets

Exoplanets are just planets that orbit other stars.

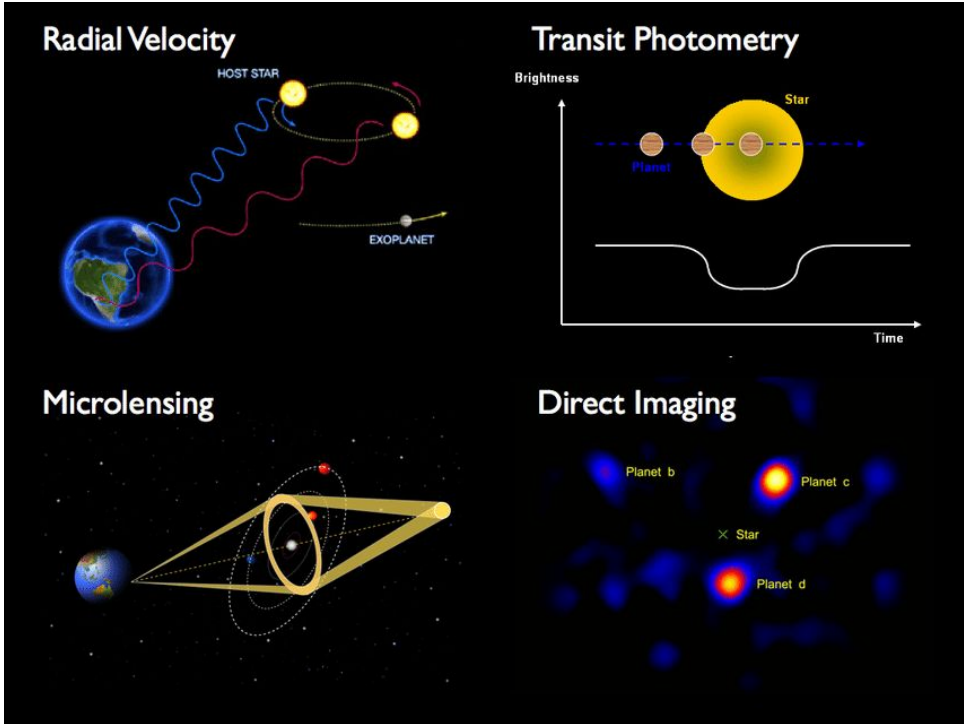
- Not until 1992 did we have proof there were more than 9 planets in the universe. Now we think nearly every star is surrounded by them.
- Since discovering exoplanets, we have also discovered…..exomoons!
    - Exomoons can be huge!
- When new discoveries are made, we learn the limits of our previous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

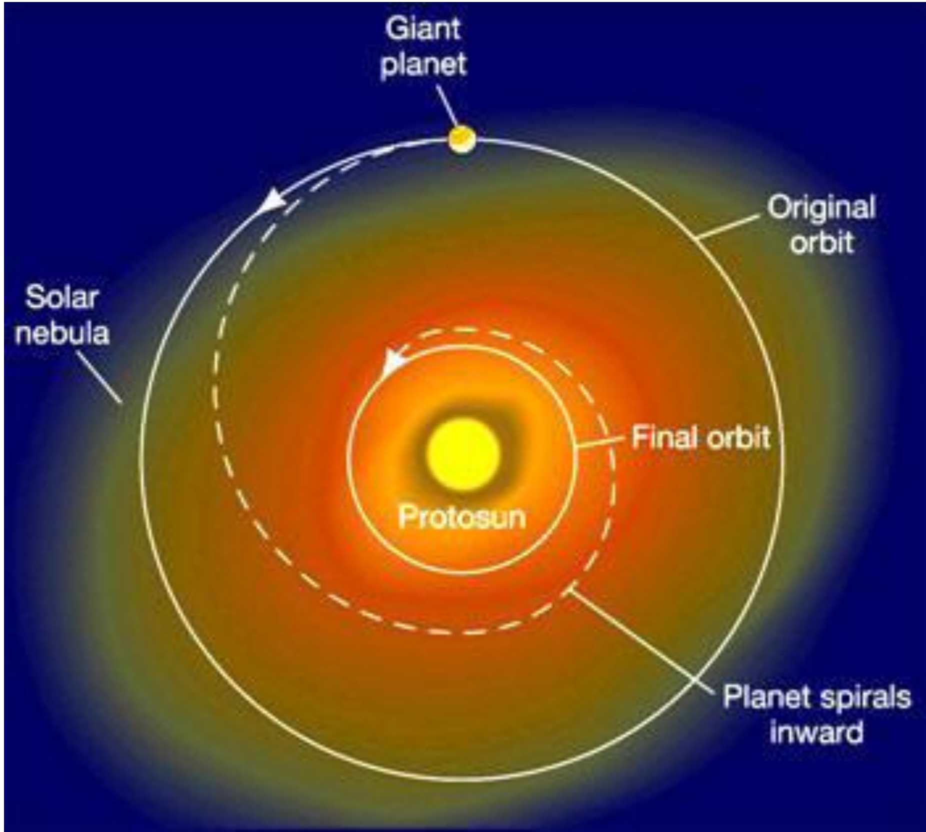
- Recall inner, outer planet differences, formation
- But all of our detection methods work best on planets that are both inner and massive!
- Experts expect to get lucky, catch a few flukes→ instead, discover many systems have planets of similar mass to Jupiter *very* close to their stars



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



ZTF E3

ZTF E3 is coming in from more than 5000 AU to only 0.2!

Just as hot Jupiters were exceptions to our rules about planet formation, the comet ZTF E3 is an exception to some of our descriptions of comets:

1) Unlike most, it doesn’t come from the Kuiper belt, but from the Oort Cloud
2) Whatever bizarre interaction caused the comet to approach so close to the Sun from deep space may have flung it completely out of our solar system; the object will either not return for many millions of years or never at all
3) This makes this passage very special, because we may see an object from the Oort cloud with the naked eye (but binoculars and telescopes are even better!)