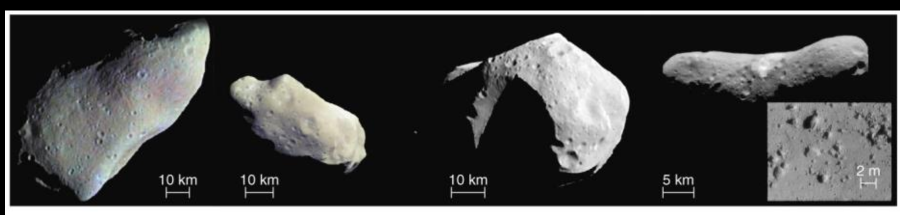
Upcoming Astronomy-themed Talks and Events

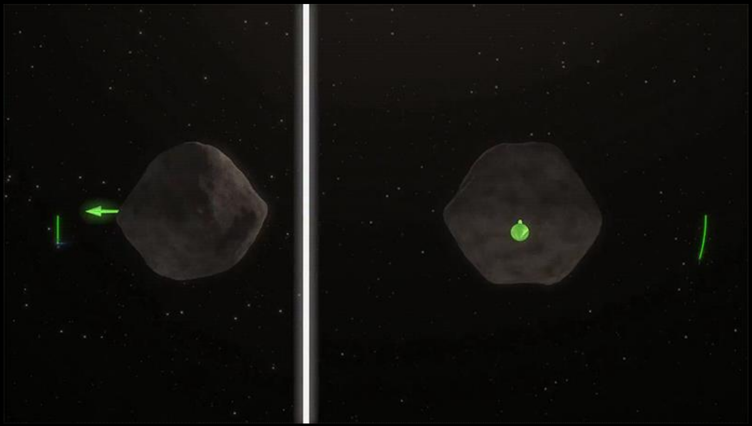
Wednesday, 1/29, 5-6pm – Phys-Astr B360 – League of Astronomers weekly meeting

Thursday, 1/30, 3:45-5:00p Astronomy Colloquium – Phys-Astr A102 – Adrian Liu (McGill) – “The Past, Present, and Future of 21cm Cosmology”.



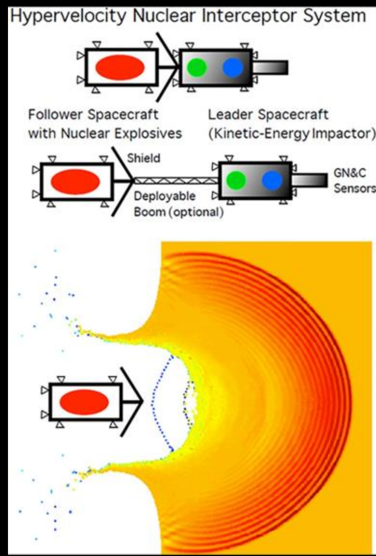
We spent most of last time talking about asteroids and comets – relatively small, rocky and icy bodies leftover from the Solar System’s formation.

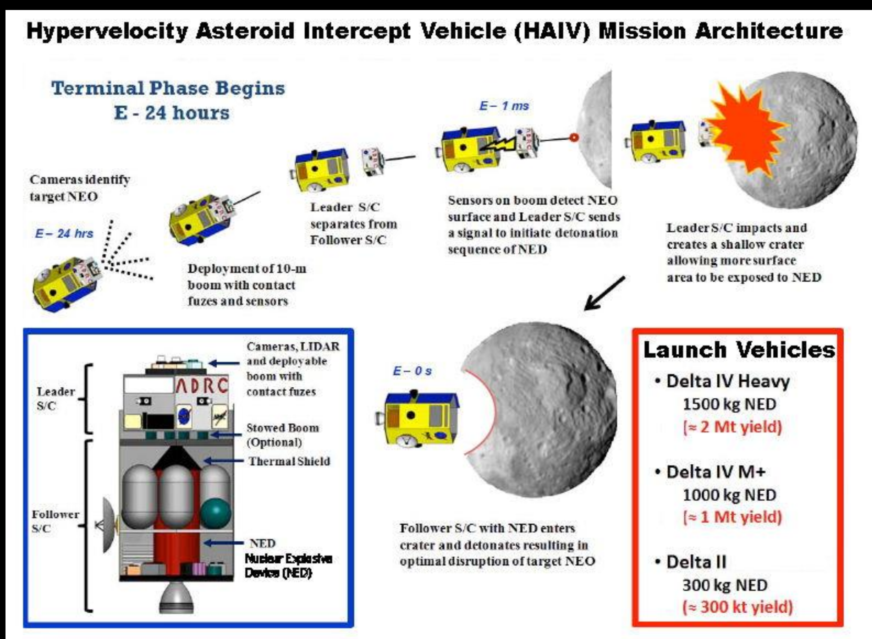
But “small” is a relative concept, and these sorts of objects can nevertheless be very dangerous to us here on Earth – so we also spent time talking about how we might prevent collisions between the Earth and asteroids and comets.



There are many ‘slow push’ methods (like the gravity tractor, shown above) that would work if we had enough lead time – say a few decades or more.

But for more dangerous cases – large asteroids or comets discovered with only months or weeks of notice, the only practical strategies involve the use of nuclear weapons to deflect or destroy the threat entirely.





The Atlantic | Popular | Latest | Sections | Magazine

The Plans to Use Nuclear Weapons to Blow Up Incoming Asteroids

For real.

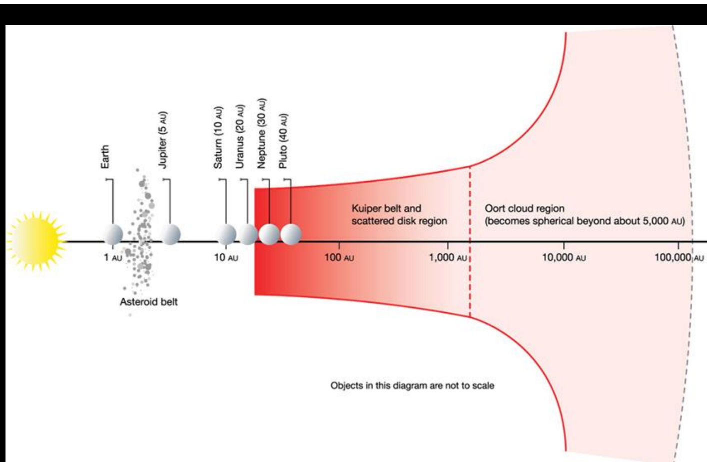
DOUGLAS BIRCH | OCT 16, 2013 | TECHNOLOGY

Many are deeply concerned that even researching this topic is a dangerous move – a form of scientific 'cover' for continuing nuclear weapon development, for example, and a way of 'normalizing' the use of these devices in the public mind.

And frankly, there are meaningful political issues with asteroid deflection in general, nuclear or not. Which way do we move the most likely target location, and who decides that? So many socio-political questions!

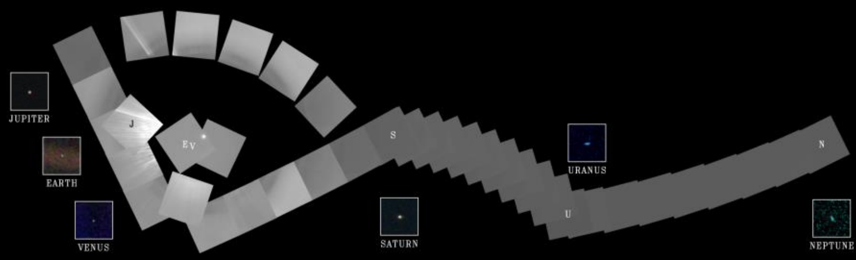
For most cases, changing an asteroid's orbit pulls the impact site to the west.

Asteroids and comets represent the ‘leftover’ bits of the Solar Nebula that remained after the Sun (which had been steadily accreting ***most*** of the material itself!) began to turn into a true “star” – and the energy it produced pushed away the remaining gas in the Solar Nebula, leaving behind only the solid material.

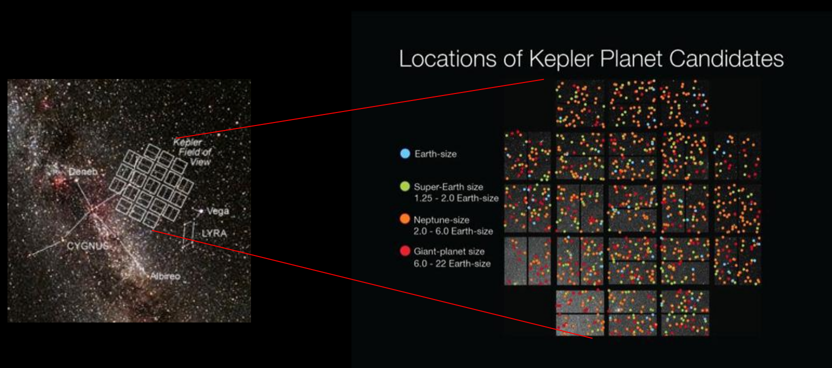


Those particles of rock and ice continued to interact gravitationally with each other and with the planets. Many eventually ‘accreted’ onto the Sun, or more rarely one of those planets, while others were either left in gravitational ‘dead zones’ or ejected to the outskirts of the Solar System.

This take us to the very edge of our Solar System, and we're now in a position to look back and reflect on our home in great detail – and better still, properly ready to look outwards.

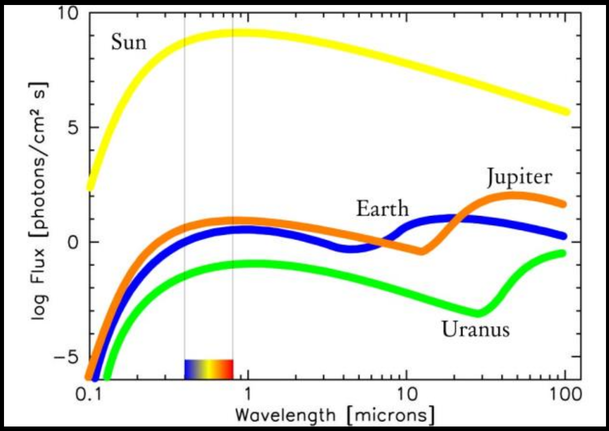


A Family Portrait of the Planets, from Voyager 1

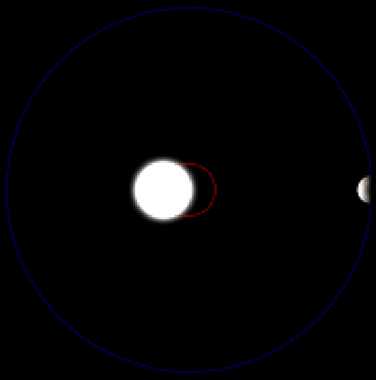


Because our solar system is only one of ***billions*** of such planetary systems in our Galaxy, and we clearly have much more to learn. What do those other planets look like? Can our model of the Solar System's formation – the "Solar Nebula" model – account for what we see in the worlds amongst the distant stars?

Observing such planetary systems is very challenging – for one thing, stars like our Sun are about a billion times brighter in visible light than even the largest of the planets.



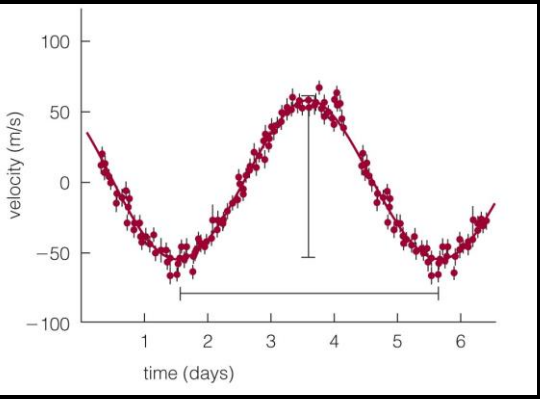
Most planets are in fact found by effects they have on their parent star – such as their (small, but measurable!) gravitational pull.

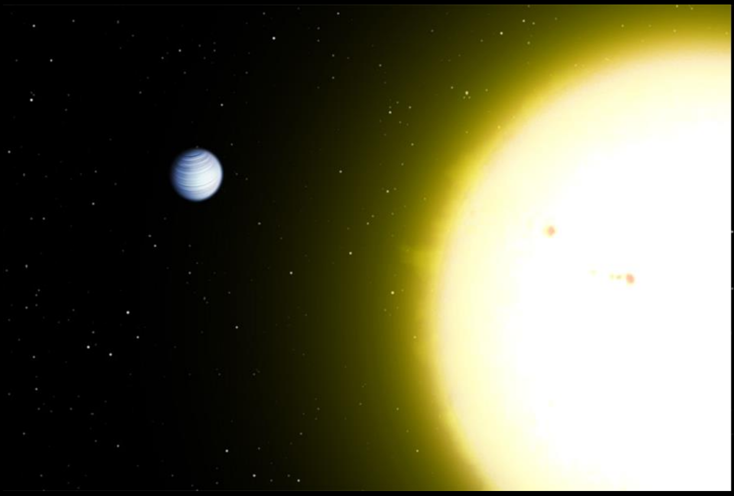


The Sun, for example, is strongly affected by the mass of Jupiter, and "orbits" around the center of mass of the Sun-Jupiter system once every 12 years or so – just like Jupiter does, but in a much smaller ellipse!

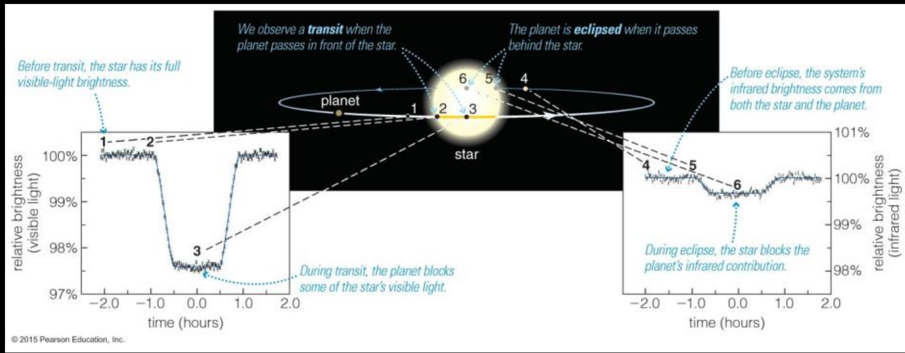
In 1995, such movements of the star 51 Pegasi indirectly revealed a planet with a 4-day orbital period around its parent star.

This short period means that the planet must have a small orbital distance (Mercury orbits the Sun every 88 days!).



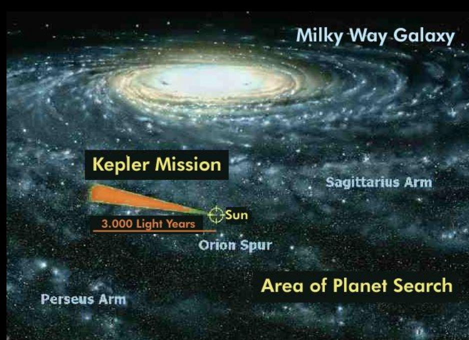


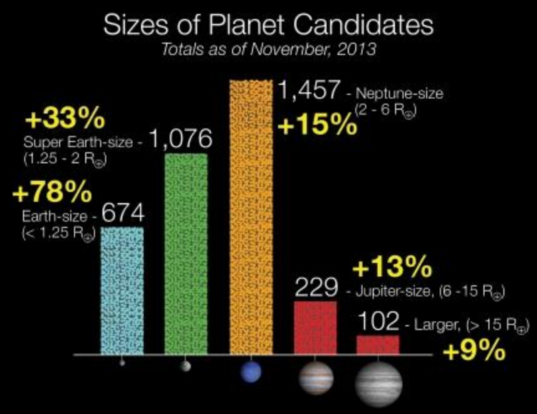
But this is no Mercury – the planet around 51 Pegasi has a mass similar to Jupiter’s, despite its small orbital distance!



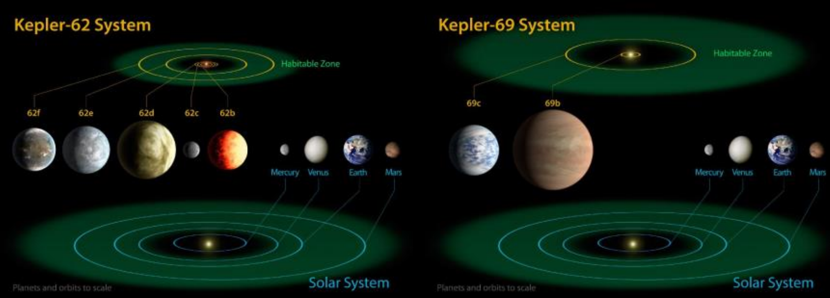
Another method for detecting planets around other stars is the so-called "transit method". If a planet orbiting another star regularly passes directly between us and that star, the result is a small, periodic decrease in the amount of light we see coming from that star.

From 2009-2013, the Kepler spacecraft steadily stared at about 150,000 relatively nearby stars, looking for such cyclic changes in their brightnesses. Because of the large number of stars observed, at least some star-and-planet systems are (by chance!) lined up properly to produce transits as seen from Earth.

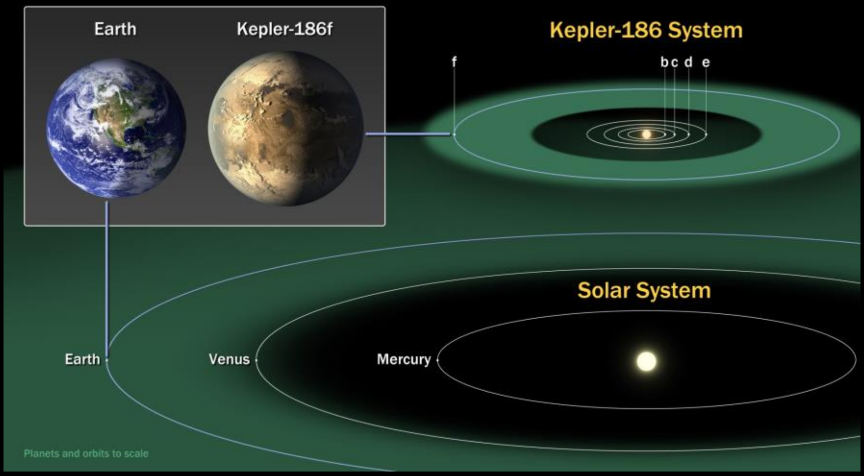




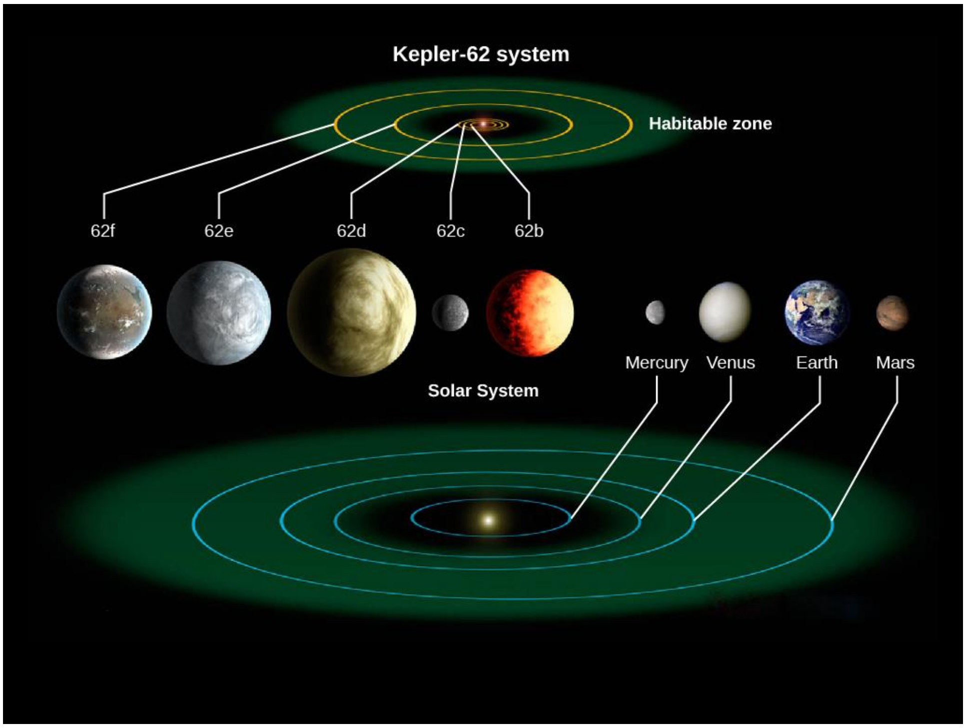
In fact, over 3000 of the stars observed by Kepler show clear signs of planets in orbit – and many have more than one. Thanks to this enormous amount of data, we can now meaningfully assess what is ***common*** about planetary systems!

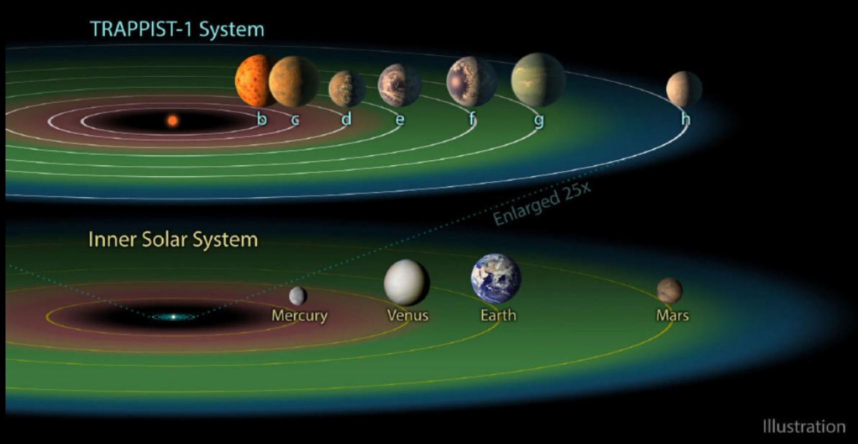


Evidence from both ‘wobble’ and transit methods suggest that planetary systems form around most stars, in flattened, orderly rotating, gravitationally interacting disks of gas and dust. Many multiple-planet systems are seen, as are gas giants, terrestrial worlds, and many transitional worlds – so-called “super-Earths” and “mini-Neptunes”.

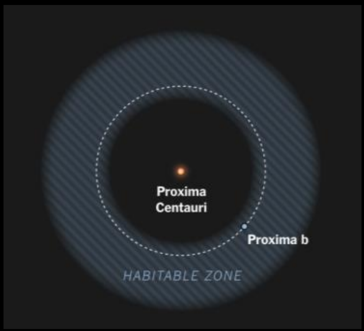


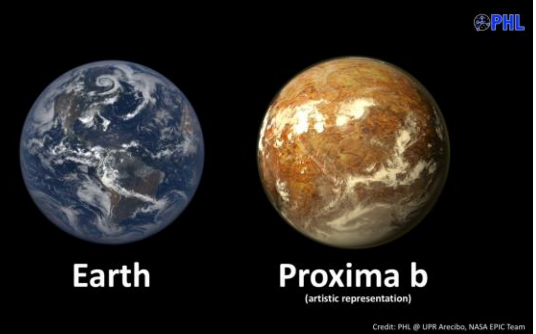
And some systems appear to harbor planets that may be similar in important ways to the Earth!



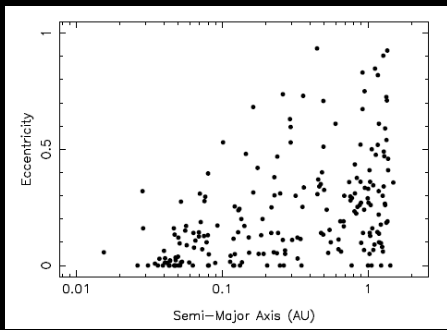


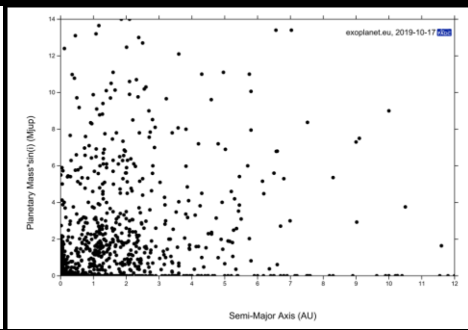
Trappist-1 is yet another example – with multiple planets capable of having liquid water oceans on their surface.





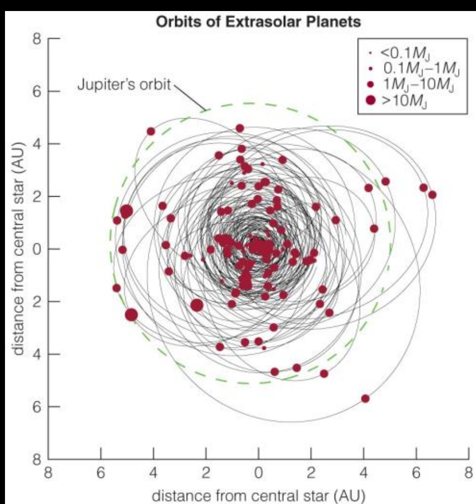
In fact, the very closest star to the Solar System, Proxima Centauri, has an Earth-sized planet warm enough for liquid water – such worlds appear to be very common indeed!



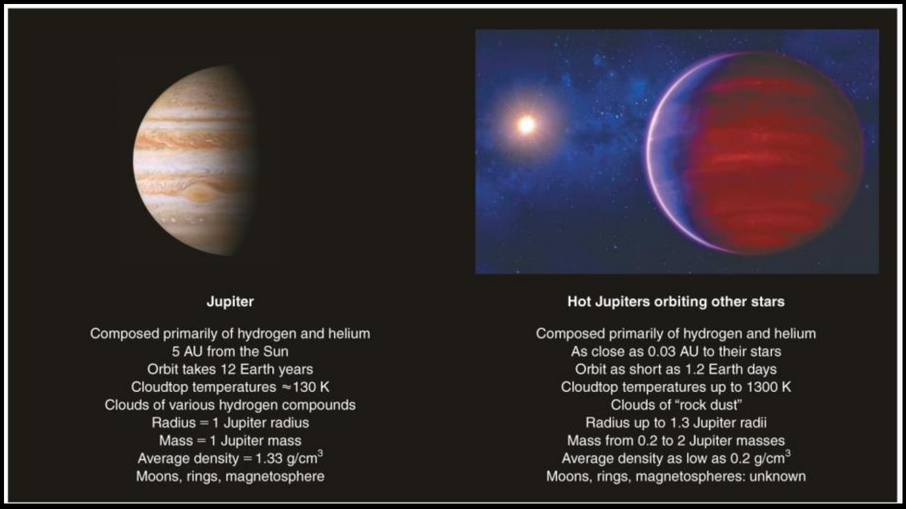


Extrasolar planets data from Kane et al., 2012 (left), and my own work (right) last quarter!

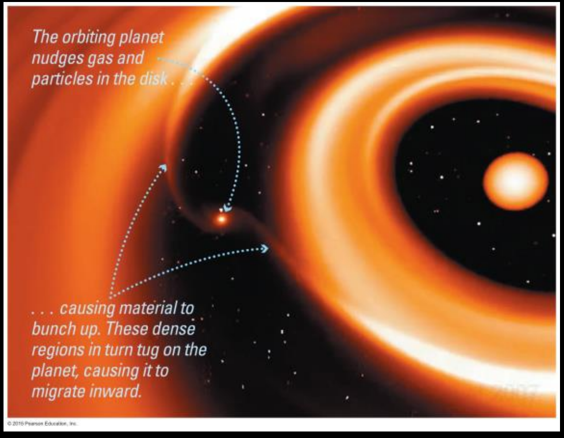
But some characteristics of other systems are quite odd compared to what we see in our Solar System – in particular, many planets with highly elliptical orbits, and those massive planets orbiting extremely closely to their parent star – the so-called “hot Jupiters”.



Both the ‘wobble’ and transit method are biased, of course, to detecting planets with large masses and very small orbits – but they were nevertheless a great surprise at the time of their discovery. Such worlds do not seem to be what we would expect from our model of Jovian vs. terrestrial planet formation.

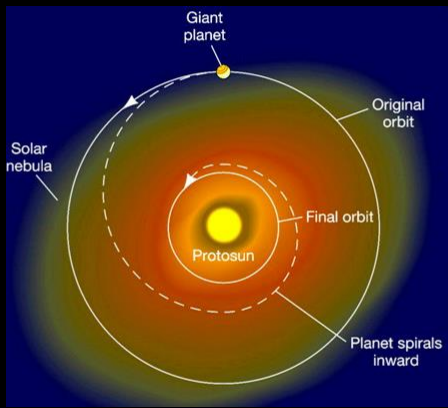


What's going on here? How do these objects form?



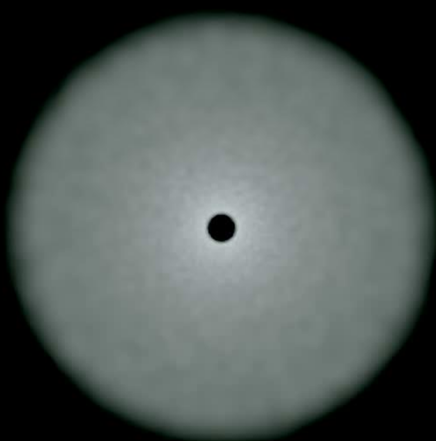
The "density waves" are greatly exaggerated in this image for better visual effect!

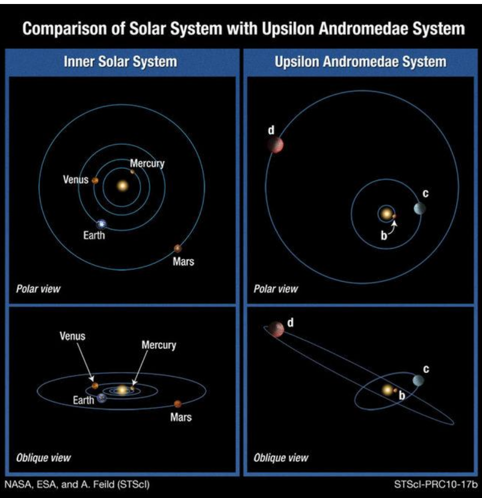
More detailed models of planetary formation have revealed that a forming planet's motion creates waves in the disk of material around (similar to what we see in Saturn's rings, for example). Matter in these waves tugs on a planet, and can cause its orbit to change, or "migrate".



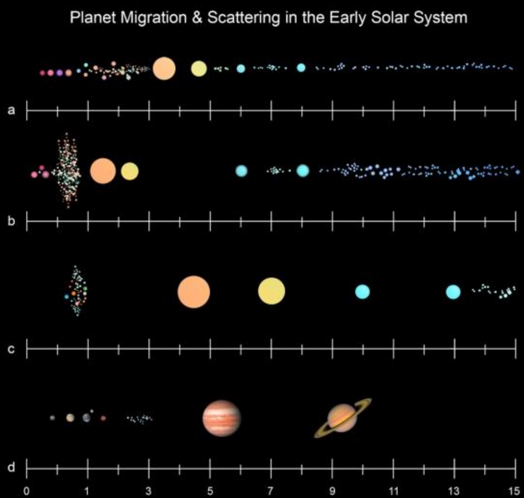
These processes, along with close encounters with other forming planets, can cause giant planets – initially formed beyond the "frost line" – to change their orbits and move closer to their parent star, where our models suggest they could not have formed originally!

In fact, higher resolution models show that gravitational forces can create all sorts of 'chaos', including migration, mergers, and highly eccentric orbits – as seen in this high resolution computer simulation of planetary formation (made by researchers right here at the UW!).

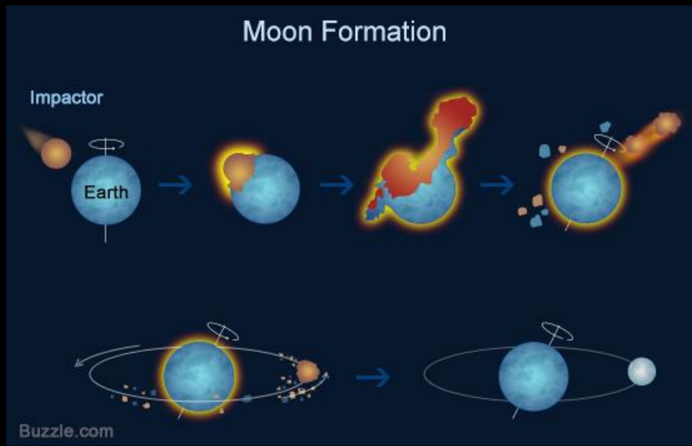




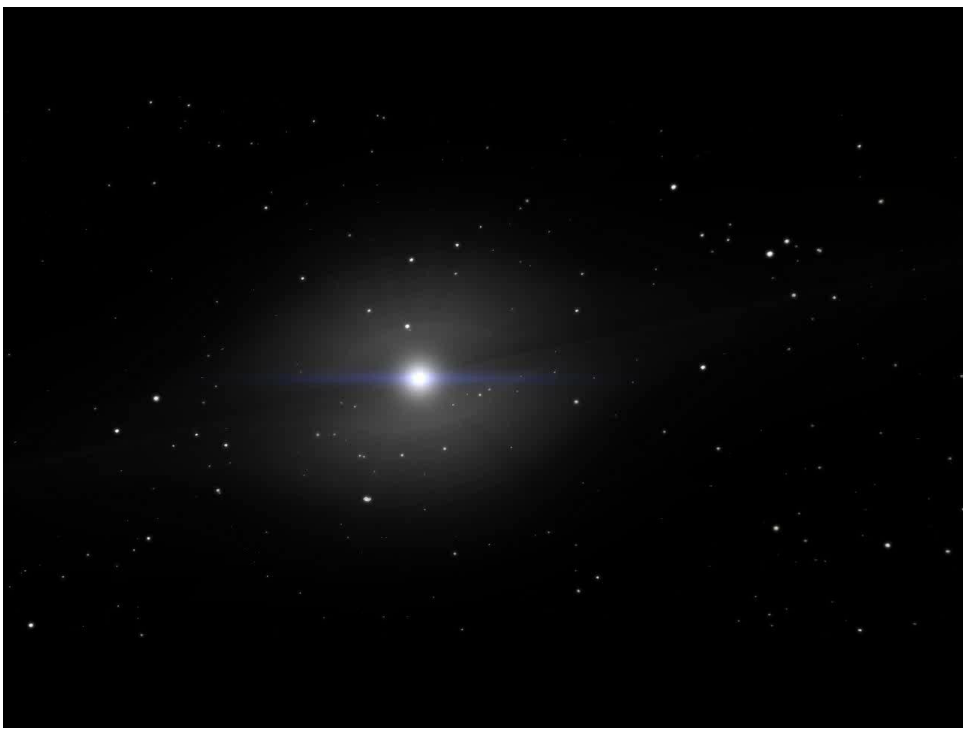
Observations of extrasolar planets have made it clear that the effects of *gravitational encounters* with disk particles and other planets are more important than previously thought, and ***can*** lead to the 'oddities' we see around other stars.

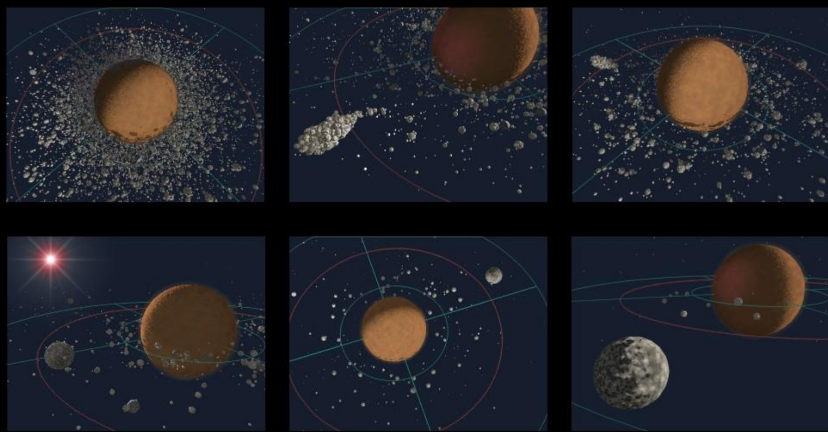


Many astronomers have suggested such orbital changes might have occurred in our Solar System – the Jovian planets, for example, may have moved around quite a bit during their formation, disrupting the inner solar system before 'migrating' back to their current locations!

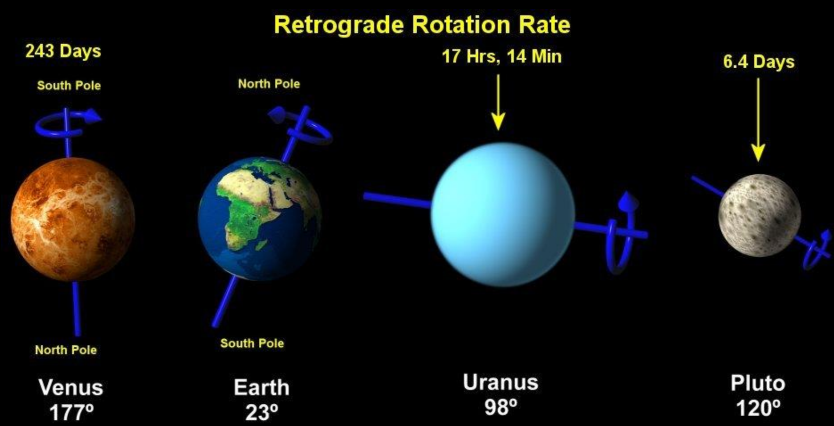


And most agree that gravitational interactions between forming planets seems to have sent a Mars-sized body crashing into the early Earth some 4.6 billion years ago, altering our spin axis and kicking up enough debris to form our Moon!



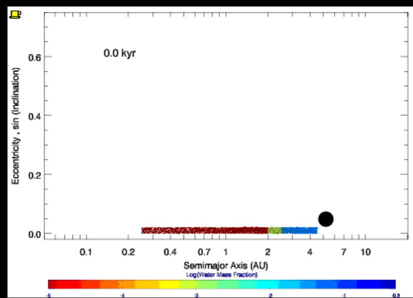


Another set of simulation results, showing the Moon accreting from the debris of the collision (the size of Earth and Moon are not to scale!) – this process takes less than a million years!

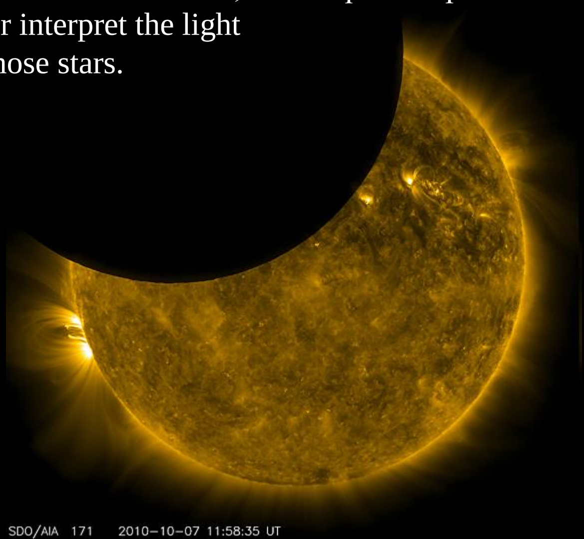


Such collisions are also believed by many to lie behind the unusual rotation of Venus, Uranus, and Kuiper Belt worlds like Pluto – so in fact, there are signs of large-scale gravitational effects throughout the Solar System!

One of the key things we've come to understand from studying extrasolar planets is the key role played by somewhat chaotic gravitational encounters in determining the overall layout and character of the planets in a planetary system. That level of historical contingency is something we simply did not fully appreciate until we looked to the more distant stars!



That's where we'll turn our full attention next time – though we'll need to start closer to home, with a quick exploration of how to better interpret the light coming from those stars.



Read Chapters 5 and 6 for next time!