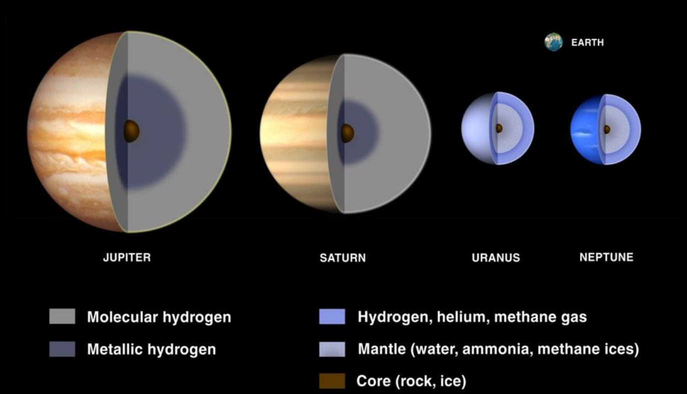
Upcoming Astronomy-themed Talks and Events

Thursday, 10/17, 3:30-5:00p Astronomy Colloquium – Phys-Astr A102 – Tuguldur Sukhbold (OSU) – “Islands of Explosions in a Sea of Implosions”.



We finished our last lecture by examining the “Jovian planets” of the outer Solar System – giant worlds of gas and ice, very different from the small and rocky “terrestrial planets”.

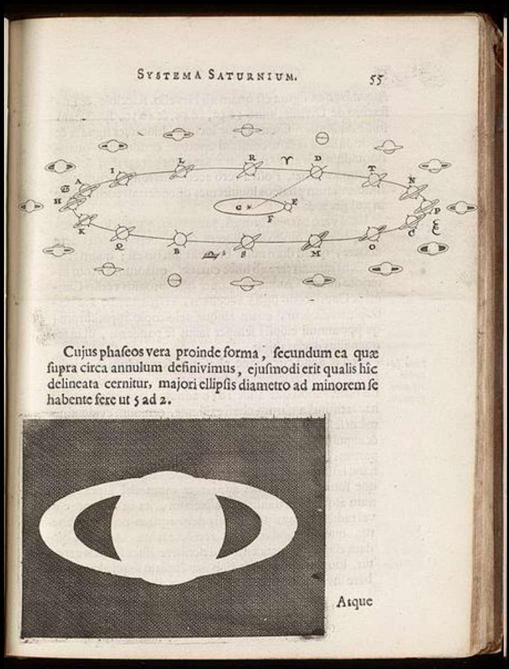
We also noted the large numbers of moons that orbit Jovian planets – many small and irregular worlds, along with dozens of larger, planet-like bodies. The latter include Titan, one of the largest moons in the Solar System, and the only one to possess a thick atmosphere…

…and the "Galilean" moons of Jupiter – Io, Europa, Ganymede, and Callisto. These worlds are roughly the same size as the Earth's Moon, but far more geologically active due to persistent and resonant tidal interactions with their giant host planet.

But a unique feature of the Jovian planets that we *didn't* discuss was their extended systems of rings...

…most familiar and most prominently seen around Saturn.

Saturn's rings were first observed from Earth by Galileo in 1610, but their true nature as distinct "rings", separate from the planet, wasn't made clear until the 1650's, when Christiaan Huygens observed them through a (slightly!) better telescope.

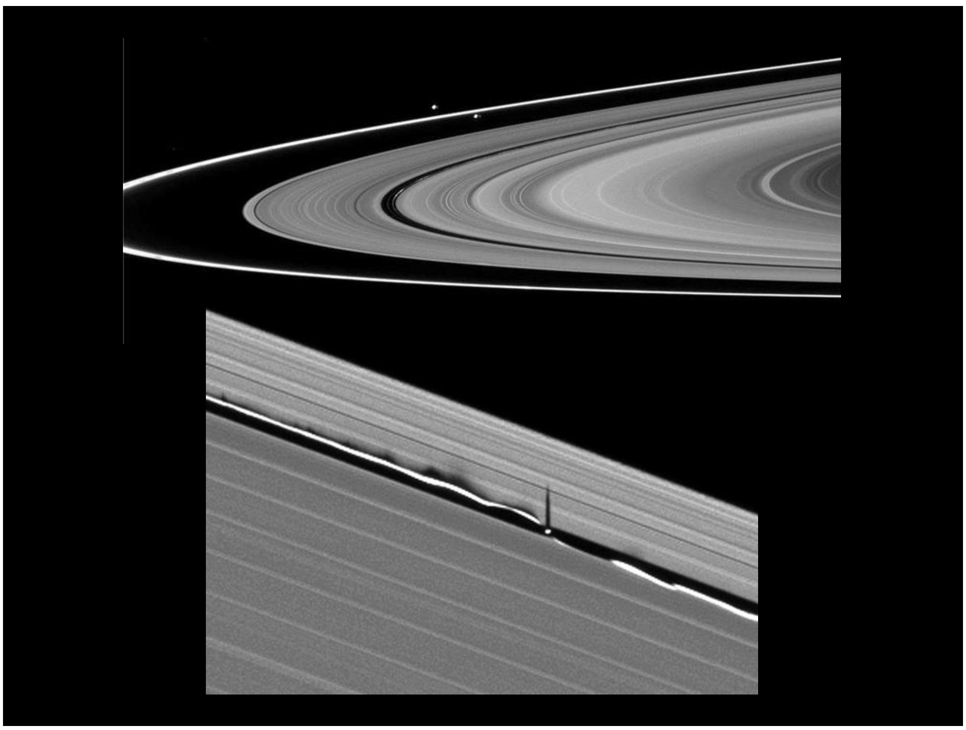


Systema Saturnium. 55

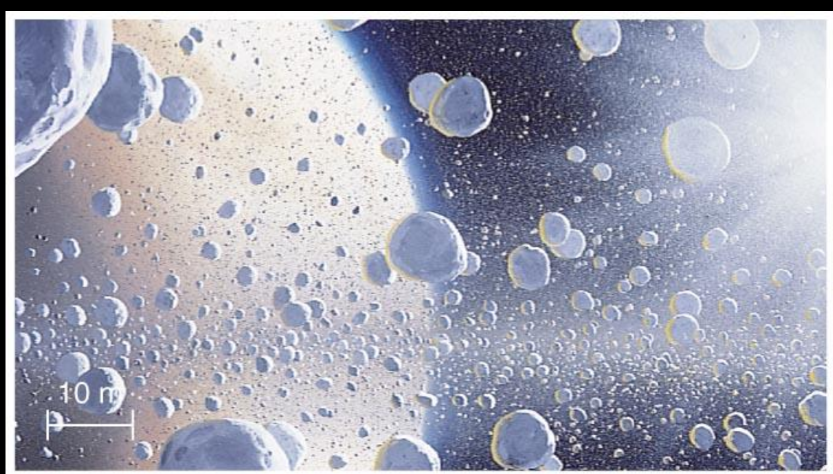
Cujus phaseos vera proinde forma, secundum ea quæ supra circa annulum definivimus, ejusmodi erit qualis hic delineata cernitur, majori ellipsis diametro ad minorem se habente fere ut 5 ad 2.

Atque

Cassini spacecraft view of Saturn’s rings.



The rings are ***very*** thin – less than 100 meters from top to bottom, but over 270,000,000 meters in diameter!



The rings are made up of numerous, tiny, densely packed, particles of rock and ice – most less than a meter across, and only a few meters apart! – that orbit around Saturn's equator.

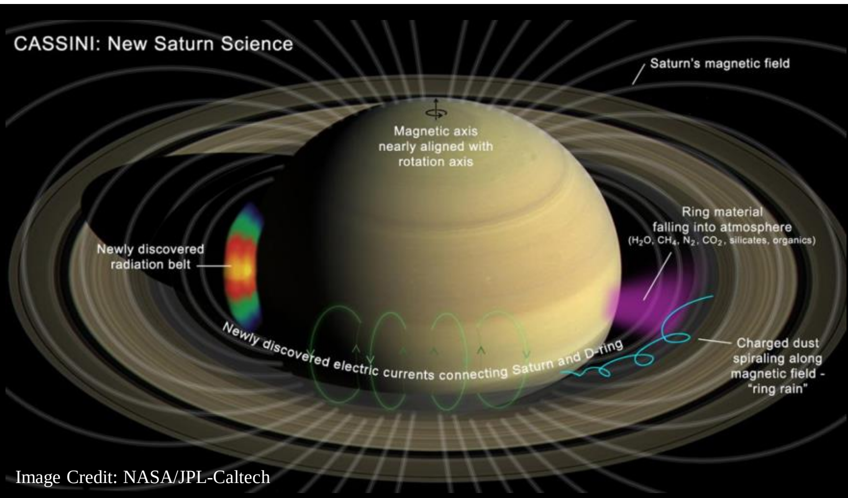
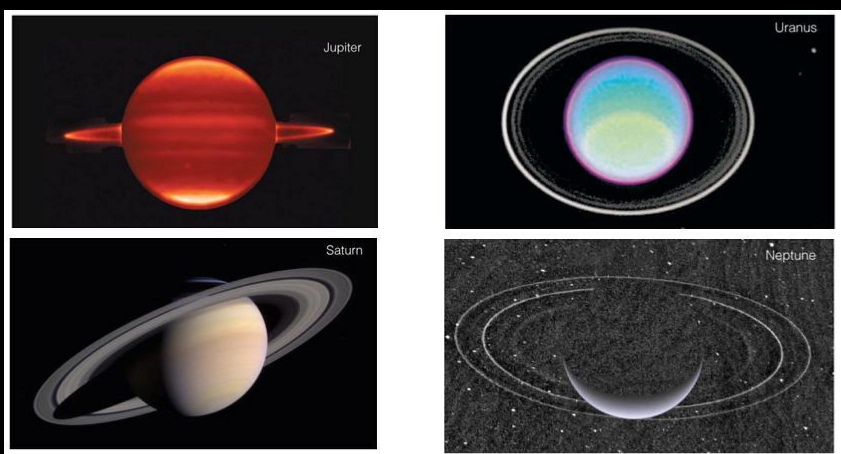
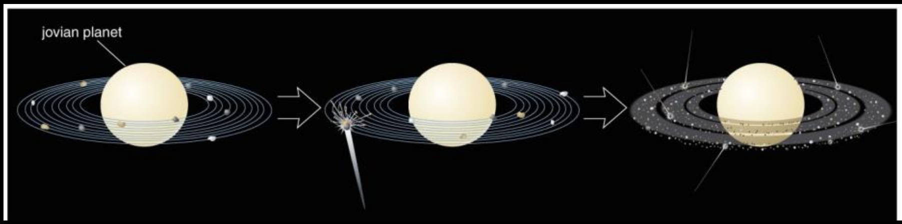


Image Credit: NASA/JPL-Caltech

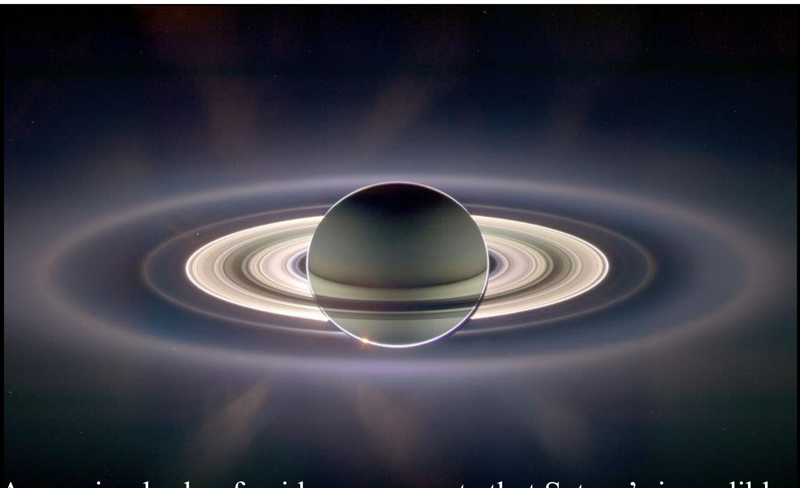
These small ring particles can become charged, and interact strongly with Saturn’s magnetic field, causing them to ‘rain’ down onto Saturn’s atmosphere over time, eroding them steadily away from the inside – suggesting a limited lifetime.



But if you look closely enough, it turns out that ***all*** of the Jovian planets have ring systems – it’s just that the particles in the rings of Jupiter, Uranus, and Neptune are much smaller, darker, and fewer in number than those in the rings around Saturn.

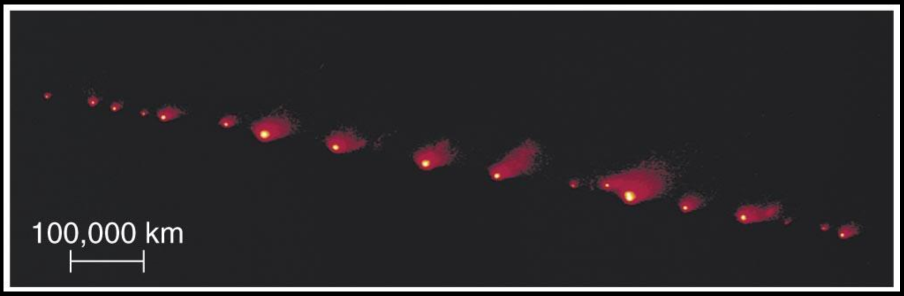


What's going on? We believe Jovian planets have persistent small rings because their moons – and remember, they have ***many*** moons – suffer from frequent collisions with free-floating debris attracted by their planet's immense gravity. These collisions can kick up enough dust and rocks to keep small rings like those around Jupiter, Uranus, and Neptune populated with particles for billions of years.



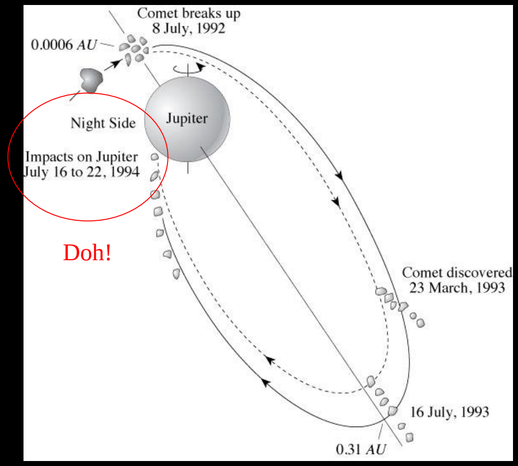
A growing body of evidence suggests that Saturn's incredibly large and prominent rings are from a very recent impact – less than 100 million years ago – though their origin is not entirely clear, like many other details of ring systems.

Do ring-making collisions occur with any real frequency? Do they happen in the present epoch of the Solar System? Indeed they do!

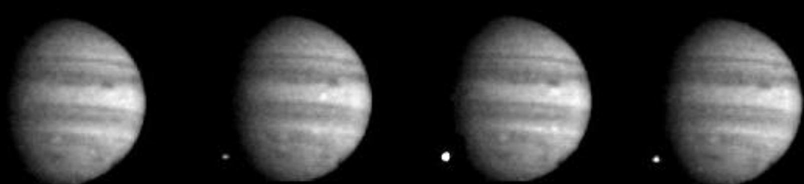


In 1992, Comet Shoemaker-Levy 9 (SL9) passed very close to Jupiter, and tidal forces tore the comet apart, producing a "string" of cometary debris that we first noticed in images like this in 1993.

Based on its orbit, we quickly concluded that SL9 would collide with Jupiter in the very near future – just enough time for us to get ready to watch the show!

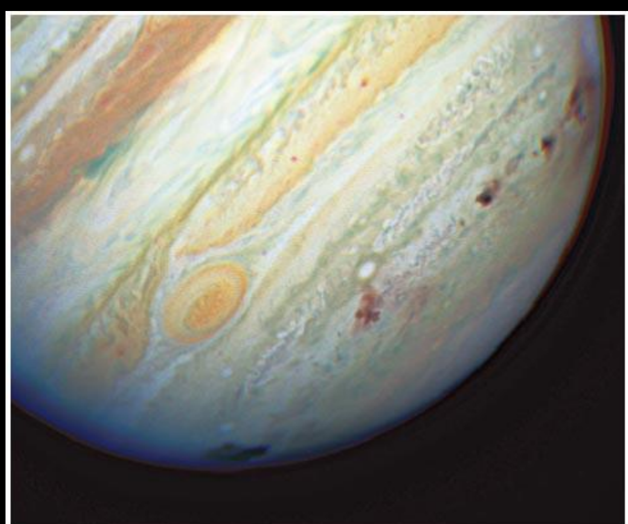


Artist's conception of SL9 impact



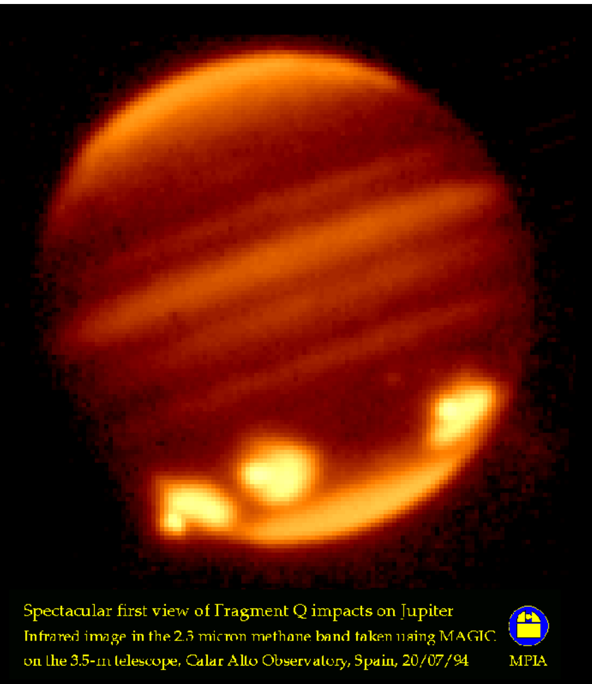
Here's how it looked from the Galileo spacecraft, in orbit around Jupiter at the time.

This series of images from the Hubble Space Telescope shows an impact plume from a fragment of comet SL9 rising thousands of kilometers above Jupiter’s atmosphere.



Debris kicked up from deeper layers reveals multiple impact sites...

…and infrared images revealed the enormous amounts of heat produced – each one of the 21 major impacts released more energy than that of the combined nuclear arsenals of every country on Earth!



Because of its large mass and gravitational attraction, this sort of thing happens with Jupiter all the time – this image shows a smaller impact that happened just a few years ago!

Artist's impression of the Tunguska fireball.

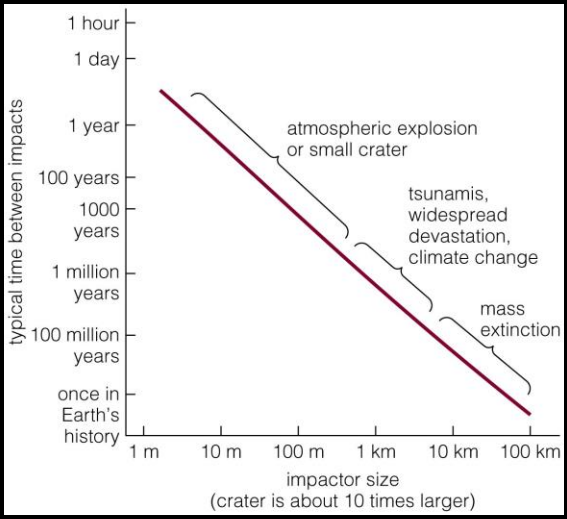
We also see such impacts on Earth – at around 7:15am local time, on June 30, 1908, an object ~ 40 meters across slammed into the Earth's atmosphere above the Tunguska river in Russian Siberia.

Moving at speeds of over 20,000 miles per hour, it became superheated on contact with the troposphere, and its icy interior exploded apart between 5 and 10 km above the surface. The explosion was seen and felt hundreds of miles away, and recorded by seismic stations as far away as London.

More artistry – there were no photographs of the incident!

Due to the remote location, no humans were injured, but over 2000 square kilometers of forest were completely destroyed. The fireball released the equivalent energy of over a thousand Hiroshima-style nuclear weapons.

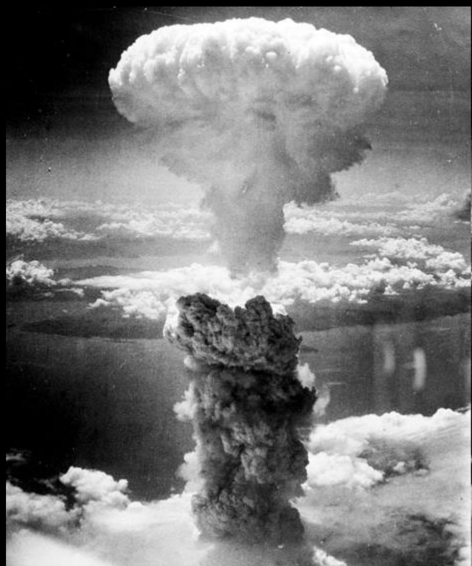
Had the object reached the Earth in space *moments* earlier, its trajectory might have carried it over the city of St. Petersburg – with a population of over 1 million people at the time…



Fortunately, most of the debris that crosses the Earth's orbit is far smaller than the Tunguska body, and truly catastrophic impacts only occur every hundred million years or so on average.

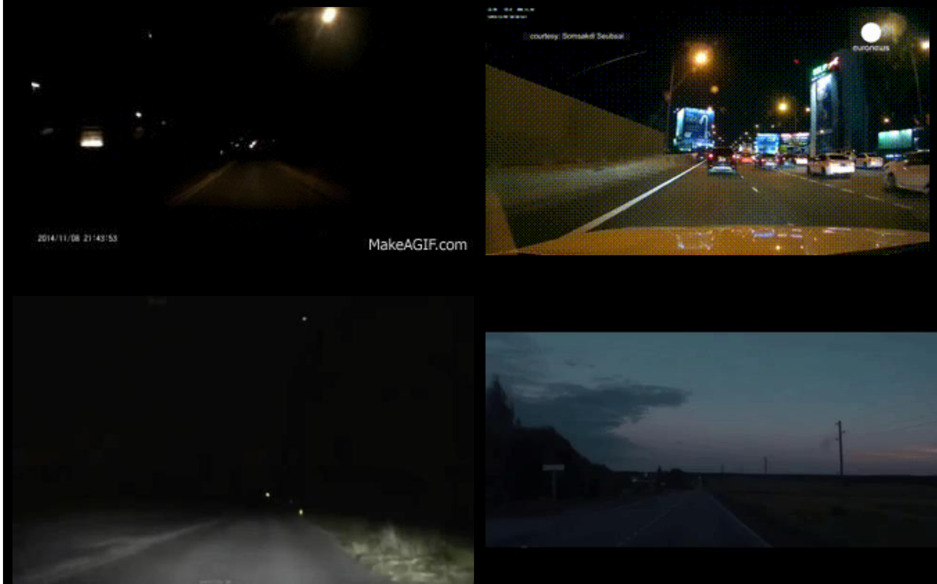
Barringer Crater, *Arizona* – something like this every million years or so!

But thousands of smaller impacts – particles as big as sand grains – happen daily. So-called meteorites strike the Earth every few minutes or so, producing the familiar “shooting stars”.

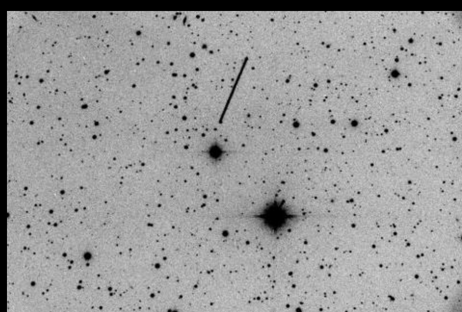


And about once a ***year*** we're struck by an object from space large enough to explode in the Earth's upper atmosphere with the force of a nuclear weapon.

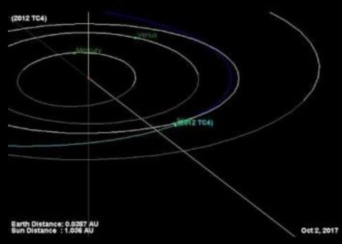
A manmade nuclear 'airburst'



Animated GIFs of the Chelyabinsk Meteor

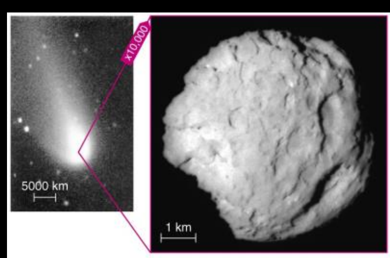


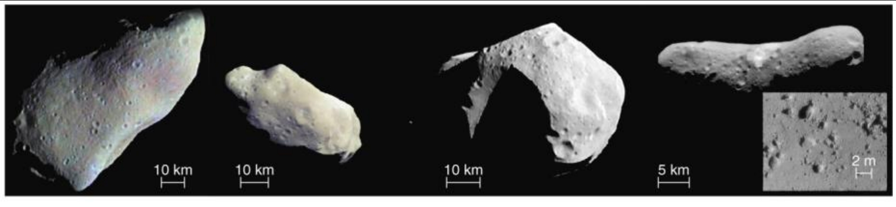
In 2013, just 16 hours after the Chelybinsk impact, asteroid 367943 Duende – almost 30 meters across – passed within 18,000 miles of the Earth, below the orbits of many of our satellites. In both of these cases, we only discovered the object within a few ***days*** of its closest approach!



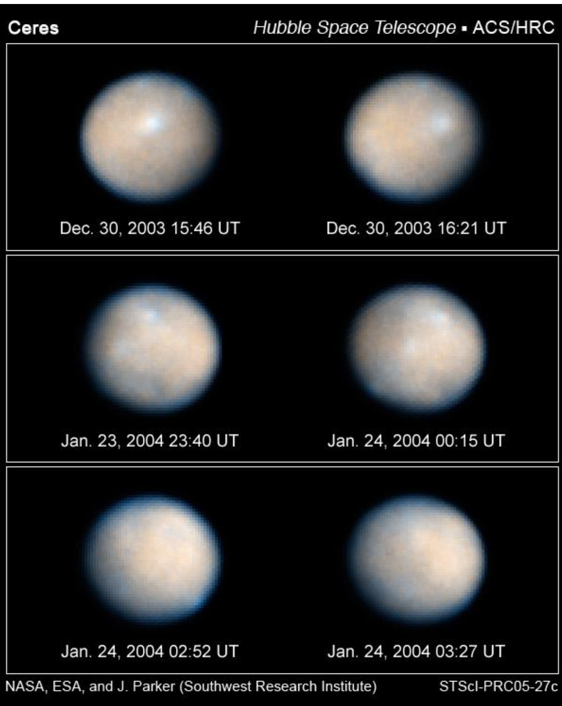
And stay tuned! Asteroid 2012TC4 – some 30m in diameter – made a very close pass on October 12, 2017, coming within 27,300 miles of the Earth – and it'll be back again in 2050 and may even hit us in 2079!

Is it time to panic? Not really – but we definitely need more information about what these objects are, and where they come from if we're going to properly plan for and protect ourselves from impacts with them. Most are shattered bits of the smallest members of the Solar System, ***asteroids*** and ***comets***.



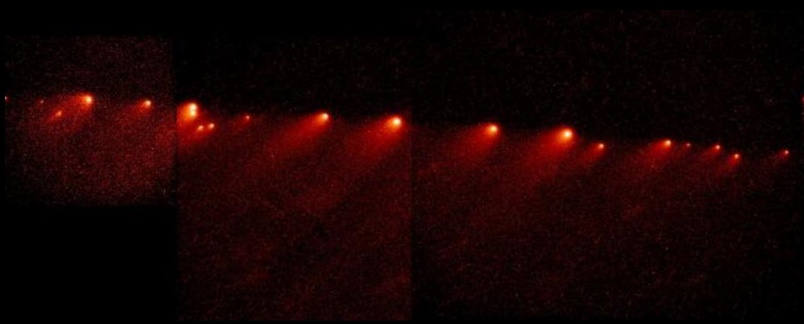


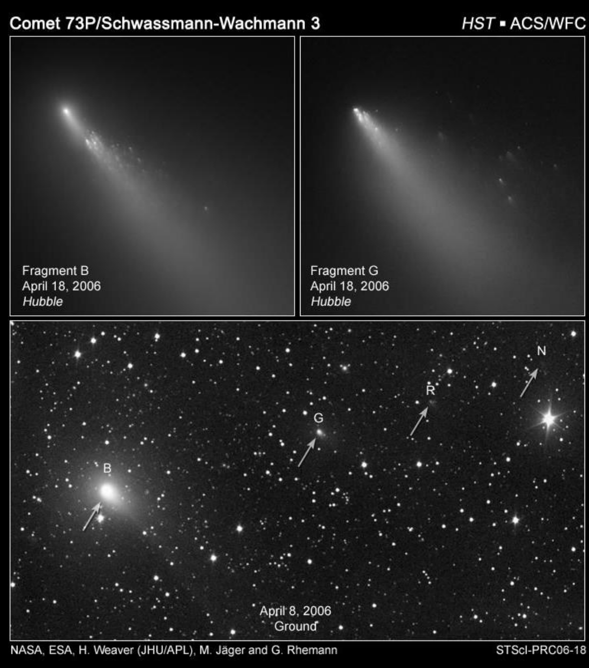
Both asteroids and comets are generally quite small – several kilometers to mere meters across, with far more of the latter – and most are too small for gravity to have forced them into spherical shapes.



Although there are definitely exceptions – Ceres is almost 1000 km across, and is clearly round. In fact, it's so large that it's recently been reclassified as a ***dwarf planet*** – a term we'll come back to later.

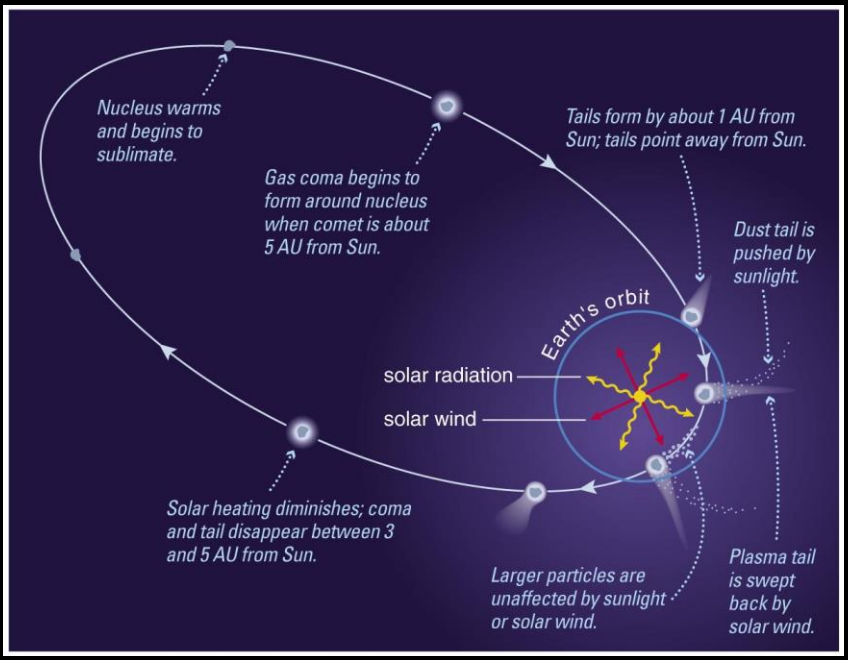
However, the overwhelming majority of asteroids and comets appear to be only loosely held together by gravity, and can be easily disrupted – as we saw with comet Shoemaker-Levy 9 earlier.





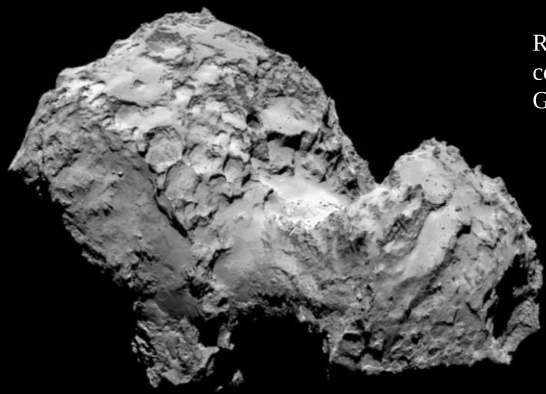
Comets like SL9 break apart easily because they have high concentrations of ***volatile*** materials – generally hydrogen compounds like water, ammonia, and methane ice.

Evaporation of these ices by sunlight is the underlying cause of the bright tails we sometimes see emerging from comets as their orbits bring them closer to the Sun.



Closer views taken by spacecraft – like this image of comet Churyumov-Gerasimenko – reveal the asteroid-like ‘nucleus’ of the comet. You can clearly see jets of material evaporating off of its surface and streaming away into space as they are heated by the Sun.

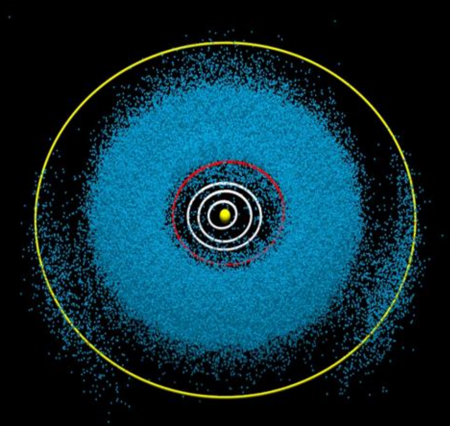
Asteroids are generally made of more rock and iron, and less ices, but they too are often only loosely held together by gravity. Bodies like 25143 Itokawa, above, are often described as “rubble piles” – and are easily broken apart.



Rosetta image of comet Churyumov-Gerasimenko

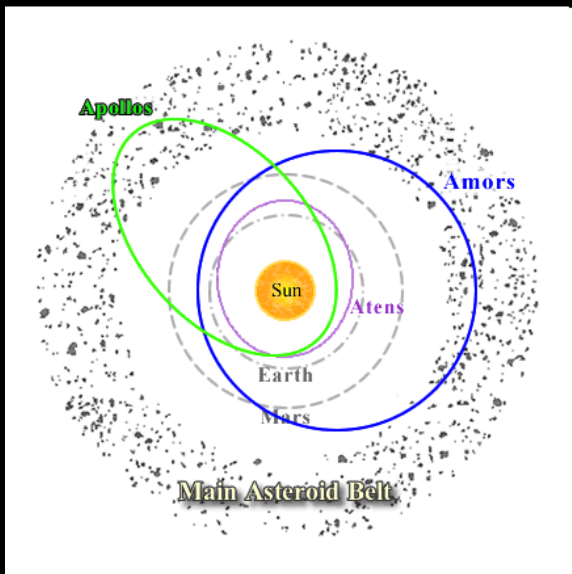
The relatively weak structures of comets and asteroids suggest that great care will be needed in addressing any that are potentially threatening the Earth if we are to prevent them from falling apart and multiplying our problems.

The size of comet Churyumov-Gerasimenko compared to downtown Los Angeles (Matt Wang)

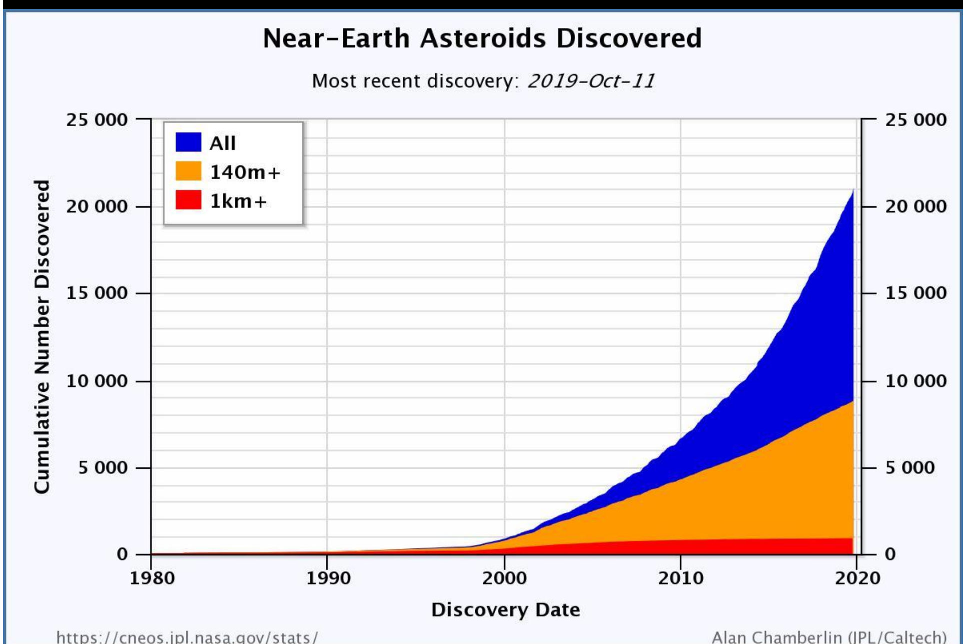


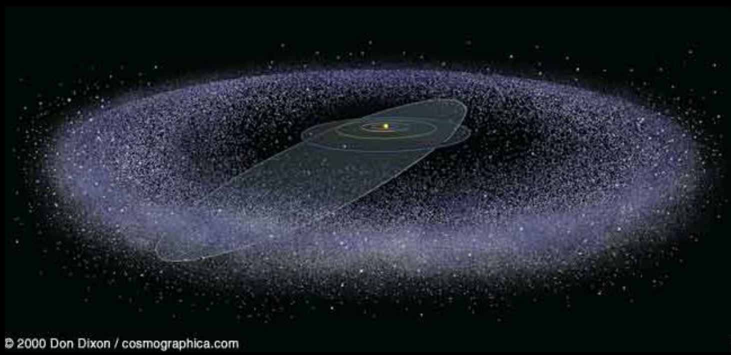
Taking that kind of ‘care’ requires us to find dangerous rocks as early as possible. Asteroids are most concerning because many of them have orbits that lie relatively close to the Earth already. The majority are found in the *asteroid belt* between the orbits of Mars (red) and Jupiter (yellow) – though they are not nearly as closely packed as this graphic would suggest.

So cool, yet so very inaccurate!



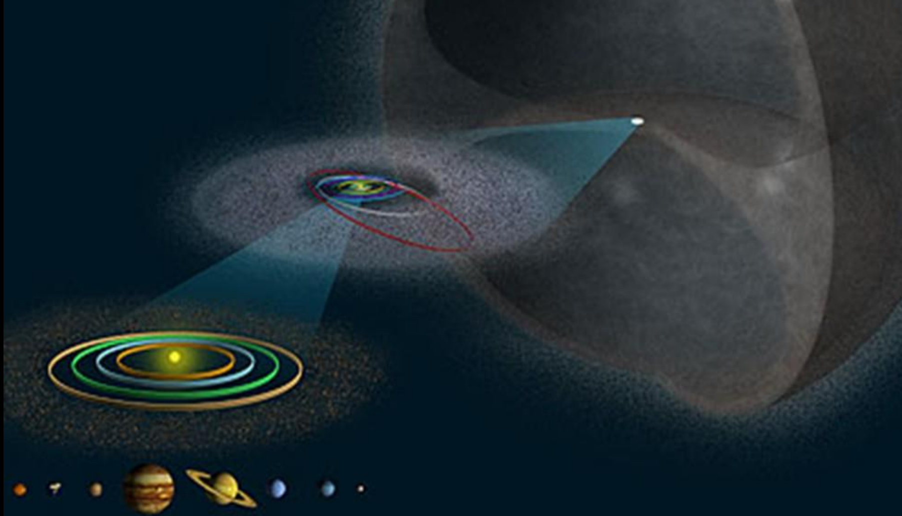
However, some of these asteroids do cross the Earth's orbit – so-called "near Earth asteroids". These are the ones that are most likely to collide with the Earth, and thankfully their study has made great progress in the last few decades.

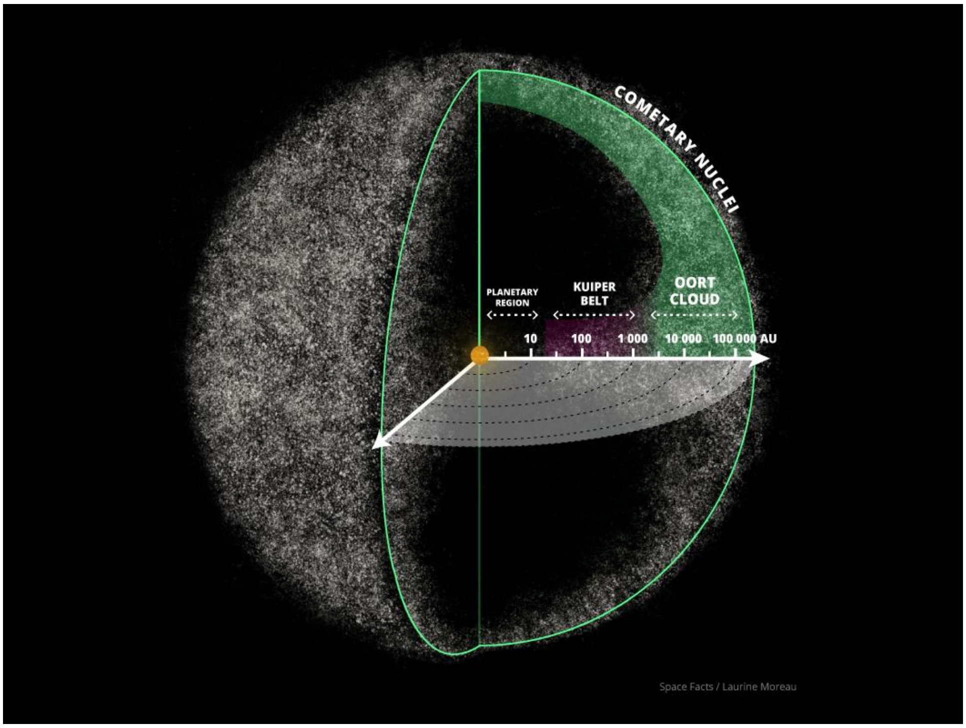


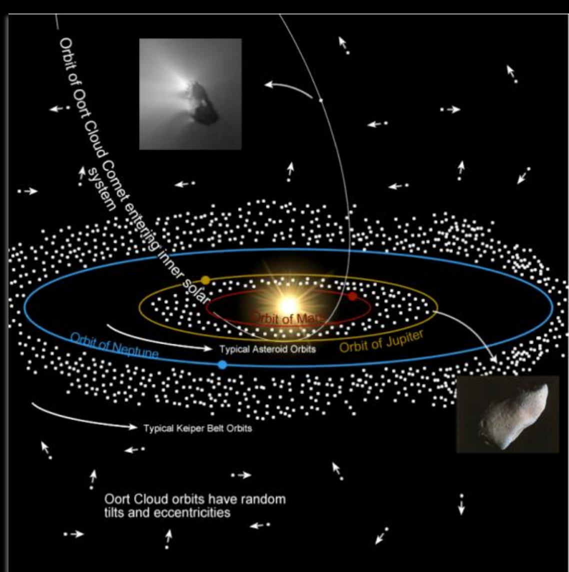


Comets are far less likely to strike the Earth. Only a tiny number of comets ever enter the inner solar system – most are found far from the Sun, in structures like the ***Kuiper Belt***, a band much like the asteroid belt, but beyond the orbit of Neptune…

…or even farther out, in the ***Oort Cloud***, a roughly spherical distribution of comets that stretches almost half way to the nearest star.







Mind you, while comets are generally less likely to strike the Earth because they spend less time in the inner Solar System, that also makes them harder to spot – and collisions harder to predict in advance!

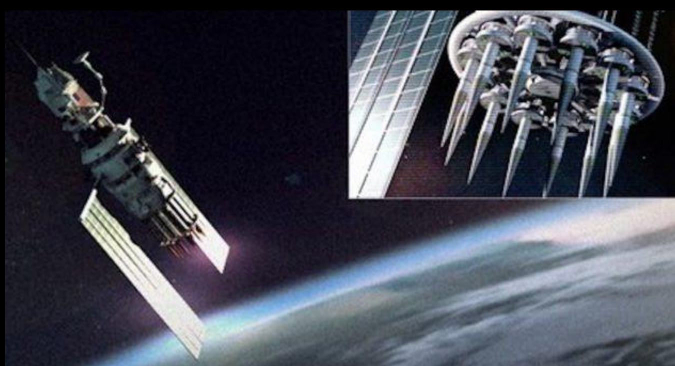
But with enough advance warning, there are options for protecting ourselves. With a few decades of lead time, we could change an asteroid or comet’s orbit with one of many relatively reasonable strategies by just enough to make it miss* the Earth.

Carl Sagan, 1934-1996 – easily the most famous astronomer of his era.

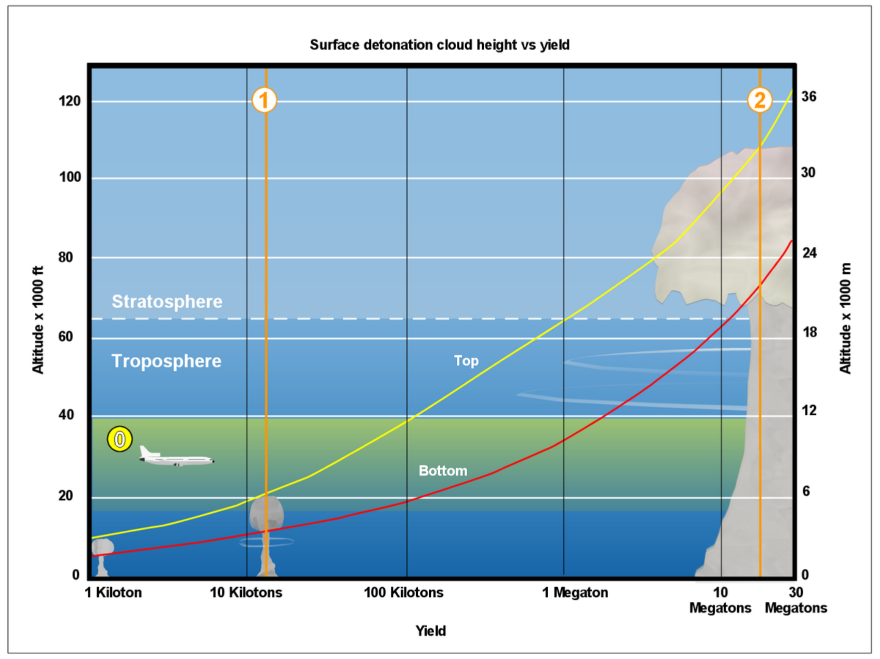
However, many are troubled by the very concept of an effective asteroid ‘steering’ device – which is what these plans we’ve just discussed really produce. They suggest that the probability of the misuse of such a system is far greater than the likelihood of an asteroid or comet impact large enough to demand such a response.

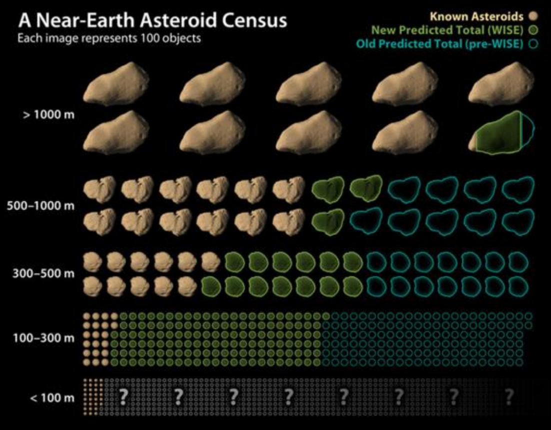
"In our view, development of this asteroid-deflection technology would be premature. Given twentieth-century history and present global politics, it is hard to imagine guarantees against eventual misuse of an asteroid deflection system commensurate with the dangers such a system poses. Those who argue that it would be prudent to prevent catastrophic impacts with annual probabilities of 10^{-5} will surely recognize the prudence of preventing more probable catastrophes of comparable magnitude from misuse of a potentially apocalyptic technology."

– Carl Sagan and Steven Ostro
Nature, 1994

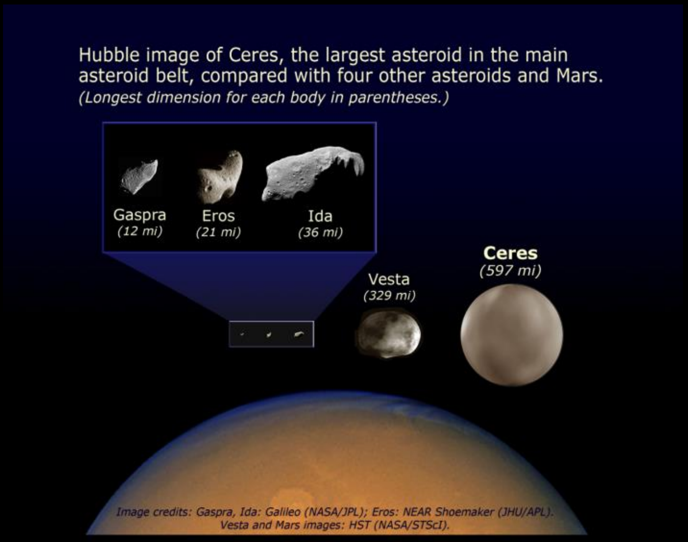


Some of these plans include the development of Gigaton-level nuclear devices – which could destroy asteroids as large as 1km across – and placing these weapons in near-Earth orbit in a 'standby' mode. Potentially concerning? Just a little bit!

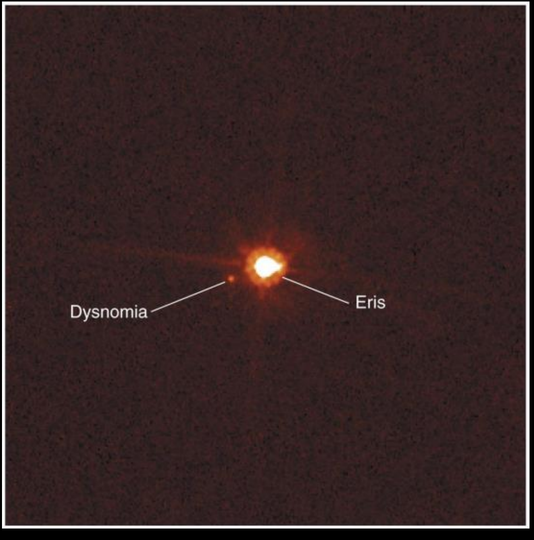




And this is a pressing practical matter – over the next twenty years we will have greatly expanded the number of known asteroids in the 100-500m range, and it's likely we'll have found an asteroid with at least a potentially threatening orbit. How will we respond?

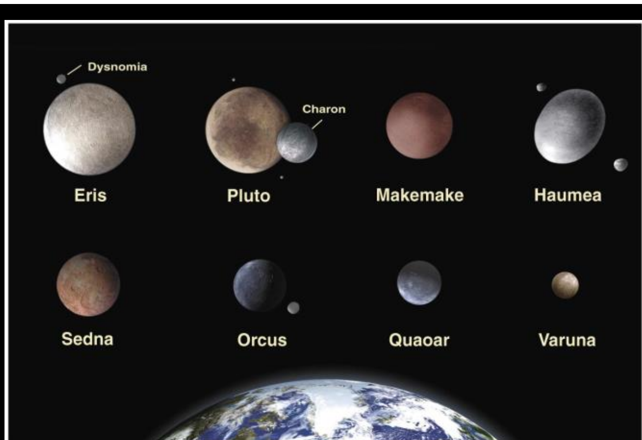


As a final thought, recall that in the asteroid belt most asteroids were quite small, with notably large exceptions – like Ceres.



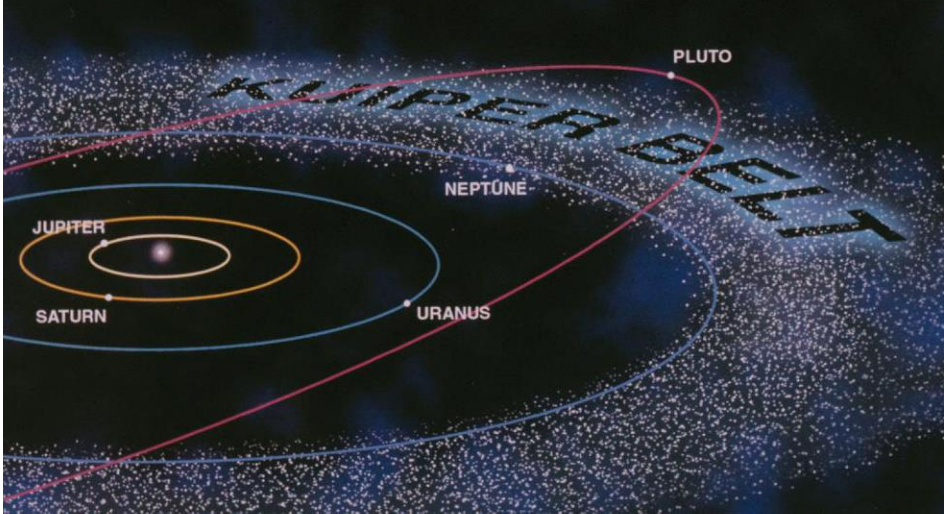
The Kuiper Belt also has some relatively hefty denizens – large, icy objects like Eris and many others that have orbits just like the smaller objects in the Kuiper belt that we think of as “comets”.

Eris (discovered in 2005) is very large indeed – bigger than Pluto, and was definitely marketed by some as the "10th planet" when it was first discovered.



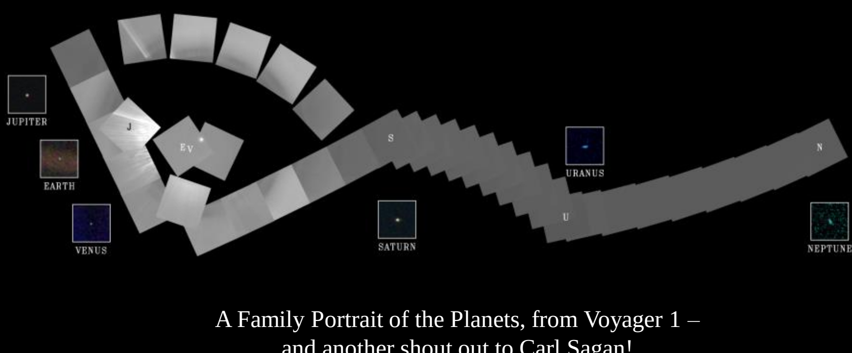
Many other very large Kuiper Belt objects were soon discovered, but because these bodies are so similar to the comets of the Kuiper Belt – and so ***different*** from the terrestrial and Jovian planets – only a few astronomers (mostly those associated with their discovery!) really suggested thinking of them as "planets"..

In fact, the similarities of the orbits of these large KBOs to Pluto eventually led us to reconsider that worlds status as a planet!

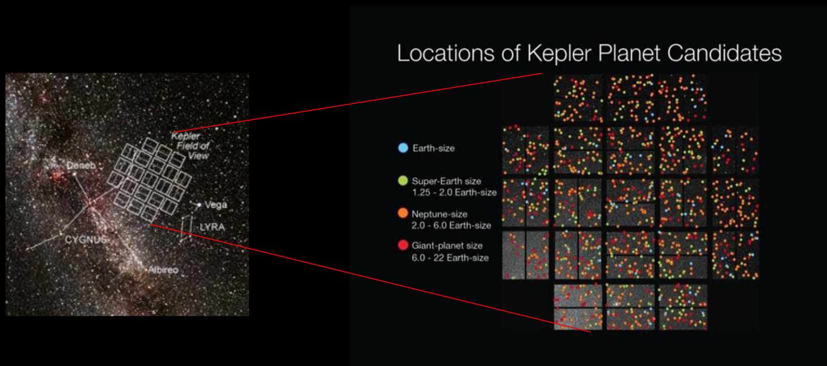


The International Astronomical Union (IAU) , the organization charged with keeping track of the names of things in space eventually created a new class of objects – "dwarf planets" – to categorize bodies like Pluto, Eris, and Ceres. These 'in-between' worlds have many similarities to comets and asteroids, but are so large that they have been rounded by gravity.

Whatever we call those icy worlds, they do represent the last outposts in our Solar System. And now that we've explored them as well, we're in a position to look back on the entire Solar System – from the charred and battered surface of Mercury, to the cold reaches of the Oort cloud – and to know the place in detail.



A Family Portrait of the Planets, from Voyager 1 –
and another shout out to Carl Sagan!



But as always in astronomy – there's far more to see. Our own solar system is only one of ***billions*** of such planetary systems in our Galaxy. 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?

That's where we'll pick up next time!