Hi this is Steve Nerlich from Cheap Astronomy www.cheapastro.com and this is *Cassini's legacy*

Cassini will die on the 15th of September 2017. There's no *unless* to add onto that, it's a done deal. The spacecraft is running out of fuel and no-one wants it crashing onto Enceladus or Titan or anywhere else it might infect with any Earth germs it has on board. And so, on the 15th of September 2017, it will be directed to plunge into Saturn's atmosphere, broadcasting a few last scraps of science data before it burns up.

Cassini launched nearly 20 years ago, in October 1997, although it took until May 2004 to actually enter Saturn's orbit, because space is really big. Saturn is well over one billion kilometres away from Earth and Cassini didn't fly straight to it – since it needed gravity-assist manoeuvres to increase its velocity and modify its trajectory so as to get to Saturn with minimum fuel consumption. In fact, over its seven year journey to Saturn it covered a distance of around 3 and a half billion kilometres, through doing two gravity-assist manoeuvres past Venus and one past Earth.

Since inserting itself into a Saturnian orbit in May 2004, Cassini's mission has been extended several times. Its prime mission ran from 2004 to 2008, achieving all the imperatives it had been initially funded to achieve. These included sending the Huygens probe to land on Titan in January 2005, as well as managing a detailed study of Saturn's atmosphere, its rings, its moons and its magnetosphere. With the Huygens landing, followed by 75 Saturn orbits and 44 Titan flybys, and the key discovery that the moon Enceladus was spitting out water geysers hundreds of kilometres high, this prime mission was hugely successful. So, it wasn't difficult to gain funding for a mission extension from 2008 to 2010, which was called the Equinox mission, since Saturn's shifting solar orbit would display the planet under new lighting conditions over this period, culminating in a Saturnian equinox in August 2009, when the Sun would be shining directly over Saturn's equator. In the Equinox mission, Cassini continued yet more orbits and undertook yet more investigations of Saturn's atmosphere, its rings and its moons – and we still weren't quite done with its magnetosphere either.

And of course, after the equinox, there was a new opportunity to see Saturn's northern hemisphere being progressively lit up – and so began the Cassini Solstice Mission, planned to proceed until May 2017 when Sun will reach its highest point over Cassini's northern hemisphere. To make sense of the math behind all these mission extensions, Saturn does one solar orbit in a bit under 30 years, so the time from one equinox to one solstice is a quarter of that – that is, a bit over 7 years. So the last equinox was in August 2009 and the subsequent northern solstice will happen in May 2017.

And what's the Solstice mission going to focus on? Yep, the atmosphere, the rings, some moons and the magnetosphere. We just can't get enough of these. At the start of this second mission extension in 2010 the spacecraft only had a quarter of the fuel that it had started its primary mission with, six years earlier in 2004. Nonetheless, it has managed the subsequent seven years of the Solstice mission with just a few prudent rocket burns to reshape its orbit – but now the needle is very close to empty.

To send Cassini on a death spiral into Saturn's atmosphere in September 2017, a bit more fuel efficient orbital shaping is required. In fact, since late 2016 Cassini has been shifting towards a polar orbit – and is now flying quite close in to Saturn, between its F and G rings. In this, its final year, Cassini will do more orbits than it's done in any previous year – 56 in all. In most previous years it's averaged around 20 Saturn orbits. There are so many orbits in this final stage because they are becoming progressively tighter and faster. In its last 22 orbits, Cassini will follow highly elliptical polar orbit which will bring it right in between the planet and the innermost D ring. The spacecraft's rapid speed at its orbital periapsis means in can fly very close in to Saturn, while still retaining enough momentum to pull away again – at least for 21 of those 22 final orbits.

During these final 22 orbits, which called the Grand Finale, the plan is to build a gravity map of Saturn, as well as having one more look at its magnetosphere, from very close up. And then, after a total of 295 orbits around Saturn, in which it took 300,000 photos and sent back data that filled over 3,000 scientific papers – for Cassini, that will be that.

But, just what has Cassini about Saturn, its rings, its magnetosphere and its moons? Although we have learned a lot more about Saturn from Cassini, the origin and age of its rings are still the subject of debate. Some say that the rings have been there since the planet formed. But, much of the material in them appears relatively new – which either means the rings themselves relatively new or it might mean they are relatively old but are continually refreshed with new material. Although the matter is in no way settled, the current weight of opinion slightly favours the rings being as old as Saturn itself, which means they're at least 4 billion years old, but various recycling and refreshing processes keeps them looking young and bright and shiny.

The material in the rings is nearly all water ice – although there are other materials mixed in – which are generally, and unhelpfully, identified as dust and rock. These non-ice components generally have a reddish tinge suggesting the rock is mostly carbonaceous rather than silicaceous – which is not all that surprising since silicon-based rock is mostly found in the inner solar system. The rock and dust that are in the rings may come from meteorites that have struck small moons or just large chunks of water ice found within the rings. And perhaps the water ice has come from passing comets captured by Saturn's gravity, although the outermost E ring appears to be entirely fed by water that has geysered up into space from Enceladus. So, perhaps it's all these processes add new material, while older material is steadily removed from the rings as that old material clumps together into larger and larger chunks, which are orbitally slowed by such clumping collisions and eventually pulled out of the rings altogether by Saturn's gravity.

Anyhow, whatever answer you come up with for why Saturn has such strikingly-huge rings, you are then faced with the question of why the other gas giants don't have them. All the gas giants do have rings of a sort, but apart from Saturn's they are all pretty wimpy and barely visible. So, it may be that Saturn has just the right combination of size, gravity, spin and position within the solar system which is just right for forming really awesome rings.

And what about Saturn and its magnetosphere? Exploration of Saturn and its magnetosphere has given us a bit more insight into the general physics of gas giants. Saturn's atmosphere is less turbulent than Jupiter's, mainly because Jupiter's larger circumference means that Coriolis forces split its atmosphere into turbulent bands. Nonetheless, Saturn does have its own turbulent weather. Cassini witnessed a big planetary storm that wrapped around the whole of the northern hemisphere in 2011, a couple of years after the equinox.

And why the storm? It's been suggested that the ring shadow influences seasonal weather patterns on Saturn. For example, as Saturn's northern hemisphere tilts towards the Sun post equinox, this not only brings more of the Sun's warmth to the north, but also shifts the ring shadow down to the south. Whether these changes, led directly to the 2011 storm is unknown – but the general idea of ring-shadow weather is a pretty nifty idea.

The rings do seem to be largely unaffected by Saturn's magnetosphere – since their primary constituent, water ice, is largely unaffected by magnetic forces. But, it turns out that the intriguing little ring spokes first seen by Voyager 2 in 1981 are dust particles, which are being electrostatically bunched together and lifted away from the ring disk.

As we've also known since the Voyager days, perhaps the most interesting features of any gas giant planet are its moons. Cassini and its Huygen's probe, have confirmed that Titan, the solar system's only moon with a thick atmosphere, has a surface atmospheric pressure of about 1.5 Earth atmospheres and its atmosphere is composed of 98% nitrogen and a bit of methane. A lot of people seem to be excited that this makes it a bit like pre-life Earth – if you ignore that it's minus 200 degrees Celsius.

Anyway, perhaps Cassini's biggest discovery of all was that Enceladus is a water world – although being that far out from the Sun, it's mostly an ice world. Its water geysers are generated by tectonic heating, where Saturn's gravity bends and stretches the little 500 kilometre diameter moon during each of its 33 hour orbits. Of course, if there's warm liquid water, there could be little swimmy-things. The next Saturn mission might fly through one of those geysers and take a sample – although that rather depends upon when the next Saturn mission may be.

Thanks for listening. This is Steve Nerlich from Cheap Astronomy www.cheapastro.com. Cheap Astronomy offers an educational website that tries to gives you a ring sometimes. No ads, no profit, just good science. Bye.