Astronomy Cast Episode 62:
Uranus

Fraser Cain: This week, we're not going to need the pronunciation guides in the same way, but one of the cool things is the planet we're dealing with has many different pronunciations. What are the different ways we can say it, Pamela?

Dr. Pamela Gay: The safest way, the way that's least likely to get us made fun of by any small schoolchildren is to say Uranus, but then there's also the famous ur-ANUS way of saying it.

Fraser: (giggles)

Pamela: Right – get the giggle out. Then there's also URAN-us, as in "to pee on us".

Fraser: Yeah.

Pamela: So, all three are out there, two are embarrassing, and when in doubt don't emphasise anything and just say "Uranus" and run quickly.

Fraser: I think there was a classic segment on the Tonight Show where Carl Sagan admitted to Johnny Carson that with Voyager reaching Uranus, that NASA wanted to sell up the "Uranus" pronunciation, but they're all fine.

Pamela: If you really want to be formally educated about it, from the Latin it's Uranus… but over a couple of hundred years, ur-ANUS has become perfectly acceptable. So yeah – go with it. It's all good.

Fraser: All right, well now that we've got the pronunciation out of the way, let's talk about the planet itself. Give us the intro!

Pamela: It's a little bit different than the previous two gas giants we talked about. It actually has a rocky core that's surrounded by a couple of layers of ice, and its discovery's also a bit different. It is bright enough that you can just barely make it out with your naked eye. It's this pale blue dot at the very edge of human vision.

Even though it had been seen many times, no one actually recognized that it was a planet until 1781. It was William Herschel who finally figured it out – and he thought it was a comet initially. He was going through, plotting the skies, and came across this slightly fuzzier than everything else pale blue dot, and announced that he had found a comet.

As people watched it and looked at it and made calculations about its orbit, they realised this was something that was way faraway, that was moving on a basically circular orbit, and eventually came to realise this was actually a planet.

Fraser: So with nice, dark skies, people a long time ago might have spotted it and known that it was a planet and there would have been another planet in the sky that people were well aware of.

Pamela: the thing is we actually have recorded measurements from much earlier. There were measurements in 1690 by John Flamstead, and there was Pierre Lamonier who saw it in 1750 and 1769 and they made records of this star. The star was 34 Tauri, they mapped it, they named it, they called it a star… and it wasn't a star.

It moves very slowly on the sky. It has an 84-year period around the Sun, which means that in the course of one year, it'll move a little bit more than four degrees across the sky. That's about eight times the width of the moon, but from one night to the next that's very little motion. Your casual person just chewing through the sky isn't going to notice that small amount of motion.

Fraser: But just to be clear, if you went to really, really dark skies, and knew where to look, you could just barely see it with the unaided eye – and with binoculars, no problem.

Pamela: Yeah. It's just right at the edge of vision. It's right around 6 magnitude, which for your standard every day person (there are some insane freaks out there like Steve O'Mira who's a great person but whose eyes are supernatural – he can see things that normal people can't see), this planet is on the edge of normal-person vision, in dark sites. It's really quite cool. It took a long time for people to figure out that the slow moving object wasn't just a star, it was actually another planet.

Fraser: Let's go back to the construction. You said it has a solid core – how do they know that?

Pamela: When we try and sort out how planets are structured, we look at a lot of different things, like how their moons go around them. It basically boils down to figuring out what the mass of the object is, how big the object is in terms of diameter, and then you start figuring out (with mathematical models) how it is that you could get that amount of mass in that size of an area. If you do very careful measurements, you can actually find the moment of inertia. I don't know if we've actually done that with Uranus, but we can figure out the moment of inertia of an object by how that mass is distributed as a function of radius.

So it basically boils down to looking at it, figuring out what its mass is, and then you do a lot of complicated mathematical modelling to fit that amount of mass in that size of a planet.

Fraser: Right, and you can see the outer layers so you know that it should be, say, mostly hydrogen and helium, but since those aren't very dense, something much more dense has got to be going on inside.

Pamela: This is where we get to rocky core surrounded by layers of ices: water ices, carbon dioxide ices… it's really something completely different than Saturn and Jupiter. We call these the ice giants because, just like Neptune, it's this blue colour that comes from having methane in its atmosphere and it's much colder. It's further away from the Sun, and because it's actually lower mass than Neptune, it's even colder than Neptune – it just hasn't held onto its heat, and it doesn't have as much heating from compressing down under its own mass.

So we have this planet that is the fourth largest in terms of mass, and third largest in terms of radius because it just hasn't compressed down very much. It's quite a cold planet, and it has layers and layers of ice beneath its cloudy surface.

Fraser: So does it qualify as a failed star as well, or are we just way too small now?

Pamela: We're getting way too small now. It's something you start talking about in terms of size compared to earth. It's four earth radiuses in size. We're not comparing it any longer to Jupiter: it's 14.5 Earths in terms of its mass. Here we're starting to get to things that aren't even full gas giants. It's an ice giant instead.

Fraser: All right. Now, it's got a few bizarre things about it. First thing is it rotates on its side.

Pamela: Uranus, actually, at different points in its orbit, looks like a target. We see it and there's this big blue part in the centre. If we look carefully in the right wavelengths, we can see its rings wrapping around it saying, "Hey, shoot here with your telescope".

At other points, such as last year, we see it exactly edge on. When it's edge on, it's at its equinox in its orbit – it's at the first day of spring or fall, depending on which hemisphere you're looking at. Here on earth, at winter solstice, the north pole and everything north of the arctic circle doesn't get any sunlight. On Uranus, pretty much everything north of the equator doesn't get much sunlight. It's tilted completely on its side, and this does some really weird things that we're still trying to figure out.

We've only had the ability to get high-resolution images of it for a few tens of years: not even its full orbit. What we're starting to see as it's getting toward its equinox, is clouds that we never saw before. Dark storms are starting to crop up on its polar areas.

We're also seeing neat things like the pole of the planet that's facing the Sun is typically much brighter in colour, much whiter in colour. The pole that's away from the sun is much darker, much greyer in colour. It looks like that colouration, that pattern, isn't associated geographically with the north pole or the south pole, but rather with just facing the Sun.

As Uranus moves out of its equinox, we're actually going to see the colours of the poles change. We're going to see one pole go from bright to dark, and the other go from dark to bright. This is already started. The pole that we've been staring at for the past tens of years now has what appears to be a white collar around it as it starts to darken. There's this white ring of clouds around that darkening pole, and we start to see cloud formations cropping up around the other pole.

It's really quite fascinating to see this seasonal change for the very first time in modern astronomy.

Fraser: It's quite a surprise. Most of the gas giants seem to be having these kinds of seasonal changes. You'd think it's just a great big ball of gas at really frigid temperatures and not much is going to change it. But in fact, all the planets we've talked about already do change quite dramatically, depending on which hemisphere's facing the Sun, and what part of the orbit they're on. So I guess it's quite amazing to watch this because, with Uranus we've never seen this before.

Pamela: This is actually one of the worlds that we know the absolute least about. It has only had one space mission fly anywhere near it, and that was Voyager 2 back in 1986. For the general public, that mission is actually almost completely forgotten. When I looked at the date, I was trying to figure out why I didn't remember this. I remember several of the other Voyager flybys; they're some of my earliest memories.

The Voyager 2 flyby of Uranus happened just 4 days before the Challenger disaster. So in most people's minds, it's been completely forgotten, whereas the memory from that same week of the Challenger stands out firmly. Poor NASA could've had all this huge, wonderful, "here are all of our images of this bright blue planet, with these very beautiful, very thin rings" but instead they were trying to recover from one of NASA's greatest PR and human disasters.

And we haven't sent anything back to it. We don't even actually have any plans to send anything to it anytime in the known future, so we basically have this blue world that we're trying to study from way here on the planet Earth using the Hubble Space Telescope.

Fraser: Let's talk about the rings then. How do these compare to Saturn and Jupiter's rings?

Pamela: They're much darker. They're more like Jupiter's rings than Saturn's rings. They're much thinner in terms of you have these narrow, isolated rings. Uranus' rings are just tens of meters in diameter, they're quite thin, and they're mad up of dark particles. They were actually discovered not by seeing them directly, but because they caused a star in the background to eclipse.

Back in 1977, a group of scientists were trying to study Uranus by watching how it passed in front of a background star, causing that star to eclipse. They watched this and they got a lot of data going into eclipse of this background star. We call these occultations.

As they were reducing their data, they noticed it wasn't just a case of watching the star flicker out as it went behind the planet, but as the star moved away from the planet, it then went out of view five more times, and each of these times the star disappeared it was passing behind a ring. That was how we first found these rings. They're very crisp. You look at pictures of them and you can see the star field behind them – they're just these narrow rings that are very separated, very clean and scientists think they're actually probably quite young. These are very different from what we're used to looking at with Saturn.

Fraser: Do they have ring-tending moons in the same way as Saturn? Are there little moonlets there keeping the rings all nice and organized?

Pamela: There are moons embedded in the rings. We unfortunately don't have quite as good a sense of just how small they get, but at this point we've found twenty-some-odd different moons tending the rings. Some of them are actually starting to creep up in size, but none of them are as big as the ones we saw around Saturn and Jupiter: we don't have ay Ganymede or Titan hanging out being planet-sized. Here we're starting to get moons that are more moon-sized – more the size of our own moon.

They also have neat names. Here we start naming the moons after characters in Shakespeare and Alexander Pope. We have Miranda, Titania and Oberon. Again, like Saturn, these are ice-rock conglomerates. They're about 50-50 in general. We don't have a lot of really high-resolution pictures. We're dealing with just images we got from Voyager 2, but as near as we can tell, they're about 50-50 ice and rock. They also contained some ammonia and carbon dioxide ice mixed in there. They're out tending the rings.

The largest of these, Titania, is actually half the size of our moon. That we can see these at all is kind of incredible. We're looking clear across the solar system, and on a good day with a fair-sized amateur telescope, you can make out the largest of these moons.

Fraser: But if these moons were magically moved into the inner-solar system, we'd have comets right?

Pamela: They're not exactly comets – comets aren't generally 50% rock, but yes, they're more like comets than asteroids.

Fraser: But they're not almost 100% ice like some of Saturn's moons are.

Pamela: Right, so here we're getting a little bit more rocky, though we have a planet that's more icy. It's neat to see how you have the trade-offs between these two worlds. Saturn, itself: not icy. Uranus: icy. Moons of Saturn: much higher in ice. Moons of Uranus: (as near as we can tell) a bit higher on average in the rock content.

Fraser: You brought this up already, which was the Voyager 2 flyby back in 1986. What did Voyager see as it went by? What were some of its discoveries?

Pamela: The main thing it discovered was back then, it was during a period in Uranus' season where it was just this basically featureless blue object. It was mesmerising in how featureless it was. It was just this clear shade of blue and nothing else. No storms, no spots, nothing. Just this vast blueness. That's kind of unusual; everything else we look at we see storms on. Even Neptune, which is very similar, has these big white storms that seem to be fairly persistent. We just happened to catch Uranus during a period of time where its surface was utterly boring. Sometimes boring is remarkable.

Fraser: I know that recent images from Hubble have shown something different.

Pamela: As the seasons have changed, we've started to get banding, we've started to get storms, and we've started to see both white spots and dark spots. There's been what we can only liken to thunderstorms going on as the seasons change.

As you heat one part of the planet that hadn't been heated for a long time, you end up with flows. You end up with currents in the atmosphere that start driving storms that weren't there before, so it seems to be that as we flip which pole is warm and which is cold, we're moving into stormier times that lead to a much more interesting to look at surface of Uranus.

Fraser: So what spacecraft is planned to go back there.

Pamela: None.

Fraser: None.

Pamela: Well, it's one of these things where it's not one of those worlds that's looking to show us a lot of life, a lot of interesting geophysics… you go and visit Saturn's moons and you have titan that has this amazing geology and it has fluvial systems with flowing methane and ethane on its surface, and you have ice volcanoes and all this other really cool stuff going on. You go to Jupiter and you have plasma streams and volcanism and tidally disrupted icy Europa that has liquid water underneath a few kilometres of ice. All these things are really fascinating and you look at Uranus and see: plain, blue, boring world with some fairly boring, mundane moons.

So yeah, it's kind of low on the priority list right now.

Fraser: But why was it on the priority list for Voyager?

Pamela: Because we knew nothing about it. Voyager 2 and Voyager 1 (which were launched in that order, but Voyager 1 escaped the solar system first) were out as our first stab at exploring the solar system. We didn't have Hubble at that point to get high-resolution images. We didn't have Keck and the Very Large Telescope. We didn't have any way of getting detailed images of these distant planets.

Fraser: They were also lined up quite conveniently, right?

Pamela: Everything was lined up perfectly. We couldn't launch those missions today and do the same amount of science they were able to do.

We had this wonderful alignment of planets, we had this opportunity, NASA had good funding… so we set off and took our first space-look at all of these planets. We went, "this one's interesting, this one's interesting," (Saturn and Jupiter), and we sent missions to each of those planets. We got out to Neptune and Uranus and went, "okay, that's kinda cool – move on." And we moved on.

There just aren't the same scientific draws in those two systems. They're intermediate mass. They aren't failed stars, they aren't rocky worlds with the potential for man to go explore on foot, so yeah. They have cool weather, they have moons that are kind of cool to look at… but they're hard to get to, and the science returns aren't what we can get for to easier-to-get-to Jupiter and Saturn.

Fraser: Would you say there are any outstanding mysteries that still need solving?

Pamela: How you tilt a planet on its side. That's always going to be one of those interesting things to think about. If you take a good look at how everything's organized in the solar system, for the most part you get everything orbiting in the same direction, you get everything rotating about their axes in the same direction (there's a couple of exceptions, Venus for instance), but here you have Uranus just totally tipped over.

There are some solar system models that say Saturn, Jupiter, Uranus and Neptune were all gravitationally interacting with each other, and with all of the asteroids and all of the comets… and in the process they were gravitationally torquing and twisting and flinging each other to completely new orbits. It could've been during this period of violence in the solar system that somehow Uranus got spilled over on its side such that it sometimes only shows light to half of the planet, and that's kind of cool to think about, but it's not something we can answer by visiting it. It's something we need to answer by better understanding computer models.

Fraser: Right, I think I've seen that mathematicians are working on various models to figure out what kind of collision or gravitational interaction it would take to turn it over on its side and keep it where it's at instead of tumbling over and over again.

Pamela: One of the things a mission could maybe help sort out is it has this really wonky magnetic field. Its magnetic field is pointed at an angle relative to its tilt, so you have this planet that is almost, but not exactly, tilted over on its side. Relative to that rotation axis, you have the magnetic axis tilted over roughly 60 degrees. That makes the north magnetic pole closer to the equator than to the rotational pole.

It also doesn't go through the centre of the planet. If you draw a line from the north magnetic pole to the south magnetic pole, that line doesn't go through the centre of Uranus, it instead misses by about a third the radius of Uranus, which is just really confusing. We're not quite sure what explains this, but that is something that perhaps could be modelled better if we could go and orbit it with something that could better map out that magnetic field.

Fraser: There you go NASA (or ESA), there's a reason to send a spacecraft.

This transcript is not an exact match to the audio file. It has been edited for clarity.