AirSpace Transcript Season 10, Episode 6: Space Race: The Prequel (Part Two)

Matt: Welcome to AirSpace from the Smithsonian's National Air and Space Museum, I'm Matt

Emily: And I'm Emily. This is part two of our Transits of Venus episode, if you haven't listened yet, scroll down in your feed and listen to Part One first.

Matt: To recap, Astronomers in the 1600s figured out relative distances to the other objects in our solar system and now they're looking to a pair of transits of Venus in the 1760s--when Venus is visible from Earth going across the sun--to give them the exact measure of the distance between the Earth and the Sun.

Emily: Where we left off the colonial powers of the time were sending out ships and astronomers to view and measure the transits. We left a French astronomer in the Indian Ocean, and were about to hear about the discovery of Venus's atmosphere.

That's today on AirSpace, sponsored by Lockheed Martin

AirSpace theme up and out

Matt: In the first episode of this two-parter, we left off with a Russian astronomer who made an observation that it looked like Venus had an atmosphere. But that information wouldn't make it out of Russia for centuries.

Again, Dr. Sam Thompson, Astronomy Curator here at the National Air and Space Museum.

Sam: For the 1761 Transit of Venus, there was a Russian scientist, Mikhail Lomonsov. He observed from St. Petersburg, he used a 4.5 inch refracting telescope, he observed the sun, he was able to observe Venus when it crossed and left the face of the sun, and he recorded what he observed as a thin arc of light around Venus as it first covered the sun and then as it left the sun.

He interpreted this arc to be the result of sunlight being refracted through what must be a very dense atmosphere around Venus. He wrote a paper, this was kind of spread around Russia, but it didn't make it really further than that until about the 1950s, when people discovered this article. This is the problem when we don't have, kind of, widespread access of scholarship. But people discovered it and then kind of retroactively said that he was the discoverer of the atmosphere of Venus.

Matt: The most famous British expedition was made by two men whose last names, at least, will be familiar to a lot of Americans, Charles Mason and Jeremy Dixon. It's actually in part because of the decent job they did on the 1761 transit that they would be asked later to survey the dividing line between the Pennsylvania and Maryland colonies in 1763.[1]

Emily: In 1760, Mason and Dixon left England and they were headed for Sumatra, which is the largest island of Indonesia, but they weren't going to make it very far…

This is Ted Rafferty of the U.S. Naval Observatory.

Ted: Before they got out of the English Channel a French ship attacked them and killed a number of the crew members, uh, on the ship. They had to throw a lot of materials off the ship so they could use their guns. And they were able to defeat the ship. But they were so damaged they had to go back to England to make repairs.

And by the time the ship was repaired and ready to go, Mason realized that there was no way they could make it to Sumatra. And he asked the, the Royal Observatory if he could go somewhere else. And they said no, they wanted him to go to Sumatra.

Matt: Mason and Dixon did not make it to Sumatra, but they did make it to Cape Town in South Africa, which at that time was a Dutch colony. And luckily the Dutch and the English were getting along at the time, and Mason made the decision to stay and get the observations that they could from where they were.

Ted: Cape Town wasn't ideal because they could not see the entire transit. The transit started, uh, before the sun rose.

Emily: So Mason and Dixon did the best they could measuring Venus's distance from the edge of the Sun to the other edge of the Sun as soon as they could see it. But it was essentially an incomplete data set. And so the measurements didn't agree with what other folks were observing during the same transit. So while the measurements that Mason and Dixon made were good, they were also making those measurements in an unideal situation, which meant that their data was not good.

Matt: Yeah, and there was one other complicating factor, which is sort of the human element of is that the observing times that the two of them actually had, didn't agree with each other. This turned out to be a big problem across the board for lots of observers, that two observers in the same place using the same equipment might not see the event quite the same way, at least not in terms of when they see the thing begin and end.

[1] Completed in 1767, this line played an important role in the United States Civil War

Emily: Right, and so what that means is that for the 1761 transit that we've talked about, all these different expeditions heading out to try and observe, none of them really got data that would really help with confirming and coming up with a better, precise measurement of the astronomical unit. Which is a lot, that's a lot of work for a null result.

Sam: So with the 1761 transit, the reason why they didn't get good results was you needed to have observed exactly where Venus was when it crossed the sun the first time. And then when it stopped, when it kind of left the face of the sun, so you had to get two good observations.

In the cases where they were able to observe the transit, they didn't see the whole thing. They only saw half of it, so you don't quite have enough data there to triangulate a position. With the 69 transit, they were able to see the whole thing, which was the crucial component in being able to take the measurements that they needed.

Matt: Even if you put in the work, even if you do everything right, or at least, you know, try to do everything right, a lot of times you don't get the result that you need, or the result that you want. And so, in the case of these transit observations, you just kind of pack up and plan to try again next time you get the opportunity.

Emily: Well, and what I love about us working on this story for this episode is that these fundamental measurements that as scientists we've always just known to exist took a lot of work to get done right. And we kind of take that for granted because of all the technology we have at our fingertips now. But not all is lost, though, Matt. Right? Because we have 1769.

Matt: So astronomers get a second chance in 1769 when the next transit comes around. You get two that are in pretty close proximity to each other, you then have to wait more than a hundred years in between transits.[2]

Emily: So as we approach the 1769 transit, you remember that guy Le Gentil with the really long name? Our fabulous war tossed Frenchman. He's still hanging out in the Indian Ocean. He spent eight years, that eight years between the transits, bopping around the French colonies like Ile de France, Madagascar, the Philippines, and he was doing a lot of land surveying, calculating longitudes.

He was having a great time making all these measurements. I mean, as good of a time as you can have as a colonizer in colonized spaces.

---

[2] https://ras.ac.uk/education-and-careers/for-everyone/125 “First, two transits take place in December (around Dec 8th), 8 years apart. There follows a wait of 121 years, 6 months, after which two June transits occur (around June 7th), again 8 years apart. After 105 years, 6 months, the pattern repeats.”

Matt: And in, in 1951, astronomer Helen Sawyer Hogg recounted Le Gentil's adventures in a serialized column called Out of Old Books in the Journal of the Royal Astronomical Society of Canada.

Helen Hogg (VO)[3]*: "The eleven year voyage of the French Astronomer Le Gentil to the Indian Ocean to observe the transits of Venus in 1761 and 1769 is probably the longest lasting astronomical expedition in history. In fact, it is quite possible that, except for interplanetary travel, there will never be astronomical expeditions to equal in duration and severity those made for that particular pair of transits."*

Emily: It wasn't until 1768 when Le Gentil actually made it to Pondicherry in India, which was back to being a French colony.

From Le Gentils Memoirs (VO): "When we were anchored, a little boat was sent to us from land, in which I embarked with all my possessions and astronomical instruments of which you know. It was therefore on March 27th at nine o'clock in the morning that I saw myself on the land which fate had marked for me."

Emily: Le Gentil was finally where he was meant to be, where it rained during the transit.[4]

From Le Gentil's memoirs (VO): "*I was more than two weeks in a singular dejection and almost did not have the courage to take up my pen to continue my journal; and several times it fell from my hands, when the moment came to report to France the fate of my operations.*"

Emily: Following the transit, Le Gentil gets dysentery, almost dies but does eventually get on a ship to Mauritius which ends up in a hurricane. He survives, ends up on another ship, this time to Spain, which encounters more storms. He says 'the heck with these dang boats[5]' and takes the rest of the trip over land to France.

Where he finds he's been declared dead, his seat in the French academy has been given away, his estate has been stripped by his heirs, and his wife has a new husband.[6]

Matt: Bum bum bum!

---

[3] https://articles.adsabs.harvard.edu//full/1951JRASC..45...37S/0000037.000.html
[4] https://www.sil.si.edu/exhibitions/chasing-venus/measuring.htm
[5] Not a direct quote
[6] https://www.astronomy.ohio-state.edu/pogge.1/Ast161/Unit4/venussun.html

Emily: I mean, I don't know why he didn't just whip out his sat phone, call home, 'hey, everything's fine,' but it also goes to the time period of, ocean travel is hard and dangerous.

Matt: Right, so like, why go home? You might as well stick around for eight years and wait for, you know. *Laughs*

Music button

Matt: In 1769, unlike 1761, this transit of Venus was actually fully visible from parts of the American colonies, and the center of the effort to view and measure the transit is in Pennsylvania with David Rittenhouse, an astronomer and member of the Royal Society.

Emily: So David Rittenhouse[7] built a really cool telescope that allowed him to view the transit really comfortably, kind of like laying down in a lawn chair with the telescope overhead. But he was also in charge of sending teams of astronomers all around so that they could view it too.

Matt: And one of those expeditions that Rittenhouse sent out was Owen Biddle and Joel Bayley to the mouth of Henlopen Bay in Pennsylvania. These are not names that are well known to history, these folks weren't very famous, though their observations were very respectable. But a very famous person wrote up their notes for publication in the Journal of the Royal Society of London. You might've heard of him: Mr. Benjamin Franklin.

Ben Franklin writing for Owen Biddle[8]: "I had left my telescope the minute proceeding the contact, intending to apply myself steadily to it from the next minute until the observation was past. When the 48th second was called I applied myself to the glass and by the time three seconds were elapsed I perceived on the part of the sun's limb where I expected the contact, a small impression which proved to be the limb of Venus in contact with the Sun."

Emily: The article that Ben Franklin wrote, goes on to include the timings during the transit and a lot of the math that Biddle and Bayley did during their observations. And the inclusion of all of this work in the journal is credited by some historians as a key moment that put American science in front of the international community.

---

[7] https://penntoday.upenn.edu/news/stories-penn-scientists-david-rittenhouse

[8] https://www.loc.gov/collections/transit-of-venus-march/articles-and-essays/image-gallery/franklins-royal-society-of-london-article/#slide-2

Matt: Meanwhile, another much more well known agent of the British colonies was taking in the 1769 transit from Tahiti, James Cook[9]. Who's probably best known for claiming Hawaii for the British, also for being killed by Native Hawaiians on a different voyage for trying to kidnap a chief. But for this transit, he was in the Pacific.

Sam: A dark view of that is the story of James Cook, the real purpose was to study and observe the transit of Venus in 1769. That's what was written down on paper. Once he got to sea, he had secret instructions. He had secret instructions on all of his expeditions. And for the first one was basically, 'yes, go study the transit of Venus, but also, whatever land you can take possession of while you're in the Southern Sea, do that also.'

Emily: And perhaps in a bit of foreshadowing, Cook and his crew ran into some problems with indigenous Tahitians.

Sam: One of the issues Cook ran into, their crew had problems keeping the locals away from their scientific equipment. This was incredibly expensive equipment, and they thought the locals were trying to steal them, were trying to take them. It seems like there was just a general interest in what is this and what are you doing type of thing, but they were very protective and people died over trying to protect this scientific equipment.

Emily: One of the many problems of colonialism is folks just showing up like they own the place with deadly consequences often for the people already living there. And so despite all the death and destruction, Cook wasn't even very happy with the data that they'd gathered.

Ted: There were three different observers who, who did the timings of the transit, and their times just did not agree. It would vary between, you know, five and two seconds. Cook was very, very disappointed, actually a little bit upset because he thought that he'd done everything that he could do, finding a good location, being very careful with the observations, and then having these inconsistent results.

Emily: Mason and Dixon were also out in 1769, but not together at this point. They were too valuable to pool together, they were better separate, because they could then distribute their talents to more places.

Mason was sent to Cavan in Ireland to observe, and Dixon went to the Arctic Circle in northern Norway. Mason got good observations, but Dixon got clouded out.[10]

---

[9] https://cudl.lib.cam.ac.uk/collections/tov/1
[10] https://adsabs.harvard.edu/full/1969JBAA...80...52H

Matt: So there were a lot more successful observations in 1769. So astronomers were able to come up with new estimates for the astronomical unit, but with so much variance that they still weren't sure.

Ted: They had better observations from the northern hemisphere and some others in the south, and they were able to narrow the, uh, ballpark estimate for the distance. From the 1769, uh, the distance to the Sun and the Earth ranged from 96.8 million miles to 91.9. The accepted value is essentially 93. So they're in the ballpark.

Emily: One of the things that astronomers couldn't really fully account for at the time of the 1761 or the 1769 transit was Venus's atmosphere. At that point, Lomonsov's observations hadn't made it out of Russia and though several observers noticed that there might have been an atmosphere at Venus, the impact it had on observations was kind of a really big problem.

And the reason for that is because you're trying to make an observation of the time in which the edge of Venus crosses the edge of the sun. And if Venus has an atmosphere, how you define the edge is partially dependent on what your interpretation of the edge is, how good your telescopes are, whether the weather is really good or not, and it adds in an additional level of uncertainty, which nobody needed right now.

Matt: Right, it literally takes what you would hope would be a solid line of demarcation when Venus passes in front and turns it into a blurry line, right? Which then gives you this sort of, you know, problem of subjectivity among observers of when the transit begins.

Emily: And the presence of this atmosphere on Venus creates what's called the black drop effect.

Ted: It looked like there was a dark disc, which was the main part of Venus and that around it was a light halo, which was the Sun shining through the atmosphere.

So when the limbs contacted the limb of the sun, it was hard to tell the two. And then there was a phenomena that called the black drop effect. It looked like as Venus was just starting to go on to the limb of the Sun that it almost like the part of it adhered to the edge of the Sun. So they couldn't tell, you know, when it crossed exactly.

Matt: Basically as Venus crosses onto the Sun and again as it leaves it kind of looks like it sticks to the edge. And the shape of the planet gets distorted. This makes it really hard to tell exactly when the transit started and when it ended.

Emily: So to nobody's surprise, all the data from across the globe of the 1769 transit of Venus was not consistent. Different observers came up with different numbers and all that confusion meant that nobody really trusted the data.

Matt: So, if none of that worked to anybody's satisfaction, how do we now know the distance between the Sun and the Earth? I mean, this is a number that we're very confident in today. Where does that come from?

Emily: There isn't one particular moment in time when we said, 'Aha, we have it!' It was continually building off of previous observations with newer technologies, new information, new knowledge, and even more people working on the problem. This is how science works. This is not a surprise. This is how it worked for the astronomical unit.

So even though the data from 1761 and 1769 transits weren't consistent enough to be trusted at that time, about 100 years later it became an important part of a data set that did yield a number for the Astronomical Unit.

In 1877, Simon Newcomb, who was the director of the Nautical Almanac Office and his assistant, George William Hill, took all the data from all these different transits, including the ones from the 1760s. And they recalculated all these different astronomical constants, including the astronomical unit, hoping that they've amassed enough data over the centuries to come up with a good number.

Matt: Right and they end up with 92.95 +/- .19 million miles as the average distance between the Earth and the Sun.

Emily: In kilometers, that's 149,588,524.8 kilometers. And we should say average because the Earth's orbit around the Sun is not perfectly circular, just mostly circular

Matt: That's right, as Kepler told everybody planetary orbits tend to be elliptical, not perfect circles.

Emily: Simon Newcomb and his assistant George William Hill published their results, including a lot of other measurements, and called it the Tables of the Sun[11]. And these were in regular use until the 1950s. So they either did a really good job, or nobody had done better than they did yet.

Matt: And like anything in science, with more time comes more knowledge and better technologies, or so we like to think. Uh, and so our understanding of the astronomical

---

[11] https://babel.hathitrust.org/cgi/pt?id=uc1.32106005816399&seq=5

unit has only gotten better and more precise with age. We now know it to be 149,597,870.7 kilometers.

So that modern AU is less than 10,000 kilometers different from Newcomb and Hills estimate.

Emily: Which is pretty good when you consider all of the drama in the 1760s, trying to get measurements from those transits. But that data was included in the calculations that Newcomb and Hill were doing, and they did really well. More data's always better[12].

Matt: Spoken like a true scientist.

And, you know, today when we talk about distances between one part of our solar system and another, we refer to that not in miles or kilometers a lot of the time, but in astronomical units, right? How many astronomical units is it from the Sun?

Emily: Yeah. So there we go back to the (*laughing)* rel, the rela the relative numbers. We worked all this time to get an absolute number so we could go back and use relative numbers. But knowing all those distances sure did come in handy 200 years later for the other space race when we were battling the Soviet Union to send the first astronaut the 0.002569 AU to the Moon.

AirSpace theme up then under

Matt: AirSpace is from the Smithsonian's National Air and Space Museum.

AirSpace is produced by Jennifer Weingart and mixed by Tarek Fouda. Hosted by Dr. Emily Martin and me, Dr. Matt Shindell. Our managing producer is Erika Novak. Our production coordinator is Sofia Soto Sugar, and our social media manager is Amy Stamm.

A big thank you to our guests in this episode, Dr. Samantha Thompson from the National Air and Space Museum, and Dr. Ted Rafferty, formerly of the United States Naval Observatory.

Historic text voiceovers in this episode by Jennifer Weingart, Reilly Tifft, and Ben Reyhl.

---

[12] https://phys.org/news/2012-09-iau-votes-redefine-astronomical-constant.html

Additional thanks to Kristen Frederick Frost at the Smithsonian Museum of American History, Morgan Black at the Naval Observatory, And Rachel Poe at the National Air and Space Museum.

Did you know the transcripts of all our episodes include citations and extra fun facts? You can find them linked in the show notes and for additional content, photos and more, follow Airspace Pod on Instagram and X or sign up for our monthly newsletter using the link in the show notes.

AirSpace is sponsored by Lockheed Martin and distributed by PRX.

AirSpace theme up and out