AirSpace Transcript Season 10, Episode 5: Space Race: The Prequel (Part One)

Emily: Oh, and don't forget your flotation devices. You need those for this!

Matt: We are gonna be traveling a lot by ship.

Emily: right? And you want that PFD to fit.

AirSpace theme in then under

Emily: Welcome to AirSpace from the Smithsonian's National Air And Space Museum. I'm Emily.

Matt: And I'm Matt. It's the 60s, and scientists are looking to the stars to answer a fundamental question about our universe.

Emily: You totally thought he was talking about the 1960s, didn't you? Nope. Today we're talking about the 1760s and two transits of Venus that astronomers hoped would give them the information they needed to figure out just exactly how far the Sun is from the Earth.

Matt: Spoiler alert! Observations of the transits did not actually help conclusively find that elusive number, which you all know as the Astronomical Unit. However, between all the expeditions, new measuring tech, warfare, international cooperation, and non-cooperation, the 18th century transits are a wild ride. So wild that this is only part one of two.

Strap in! This is AirSpace, sponsored by Lockheed Martin.

AirSpace them up and out

Matt: So we've already said the word transit multiple times, and we're going to use it more throughout this episode, so we should probably define what it is?

Emily: Yeah, so it's one of those words that outside of the context, you think public transit or transportation of some kind. I mean, it's a word that doesn't necessarily mean the same astronomically, although it doesn't not not mean that. So a transit in most situations is one astronomical object passing in front of another astronomical object.

And the ones that we spend the most time talking about here on Earth are the ones that we could observe either with the naked eye or with a small telescope. In this particular instance, we're talking about a planet going across the Sun. And what that means is it's kind of like watching a beauty mark on the surface of the Sun traveling from one edge of the Sun to another edge of the Sun.

Matt: Right. And you know, we know that Venus is traveling around the Sun all the time, right? But there's only certain times when it's actually transiting[1] in such a way that we can observe that from Earth.

Emily: So Matt, as the historian, let's put this particular transit of Venus or these transits of Venus in the 1760s into sort of historical astronomical context.

That makes it sound really complicated. But tell us, tell us what's up.

Matt: Yeah, so, you know, as we know, beginning in the early 1600s, the shape of our solar system, or at that time, what was understood to be our entire universe, changed, right? Because people started to understand that the Sun wasn't orbiting the Earth, but rather the earth was one of the planets orbiting the Sun. And with that new understanding, astronomers like Kepler started coming up with new theories of what the actual size of that solar system or universe might be. And one of the issues at stake here is, well, how big are those distances in between? Because Kepler figured them out relatively, but not necessarily being able to put any hard numbers on them about what those distances actually were.

Ted: Back in the early 1600s Johannes Kepler came up with his third law, which gave the relative size of the solar system,

Emily: That's Ted Rafferty.

Ted: I'm Ted Rafferty. I was an astronomer at the U.S. Naval Observatory[2], been retired now for 20 years. Mainly working with positional astronomy and instrumentation.

Emily: So we like to have in physics, in astronomy, in space, in all the physical sciences, we love to name laws after people as if they are these unmovable, unshakable things. And generally speaking, what I love about a lot of these physical laws, in the case of Kepler's third law, is that they apply everywhere at all times, right?

---

[1] https://en.wikipedia.org/wiki/Transit_of_Venus
[2] https://www.cnmoc.usff.navy.mil/usno/

Law of gravity-- how much gravity changes, but gravity[3] always goes down. It's always going to pull you back down to the surface of whatever planetary body you're on. It's always going to behave the same way. Kepler's third law relates how long it takes for a planet to go around its sun to the distance to that sun.

And so that's why it's so important to know the distance between Earth and our Sun. But what's cool about Kepler's third law[4] is a lot of people talk about it relative to planets in our solar system with our Sun. But it behaves the same way and it holds up across all different kinds of solar systems.

Matt: Yeah, and what's really cool about these laws is that people like Kepler came up with them essentially by looking at many, many years, in this case, hundreds of years of observations of the movements of the planets and Kepler derived them from all of these sorts of, you know, records of planetary movements in the sky. It's like, these are all the regularities I see and here's a formula for describing those regularities.

Ted: Because the observations he was using were made from the Earth, all the distances were in terms of the distance between the Earth and the Sun. So for example he calculated that Mercury's orbit is 0.389 times the radius of the Earth's orbit. Mars was 1.524, Saturn was 9.51.

Emily: And as Ted said, these numbers are based on the distance between Earth and the Sun, but because Kepler didn't know the distance between the Earth and the Sun, he was using all of these relative distances, and they needed this one piece of information to kind of plug into the equation to then understand what all of these things meant in absolute distances.

And as we are very likely to do, we love to use our Rolodex to call all the cool kids in who know more about these kinds of things than we do. Matt, you're a historian, but you are not *the* historian of astronomical history. So we had to reach out to friend-of-the-pod, Dr. Sam Thompson, to walk us through this astronomical history.

Sam: I am Samantha Thompson. I am the Phoebe Waterman Haas Astronomy Curator at the National Air and Space Museum. I do all things history of astronomy.

Matt: Yeah, she's really the person you want, not me.

---

3 https://physics.weber.edu/amiri/physics1010online/WSUonline12w/OnLineCourseMovies/CircularMotion&Gravity/reviewofgravity/ReviewofGravity.html

4 https://science.nasa.gov/resource/orbits-and-keplers-laws/#:~:text=Kepler's%20Third%20Law%3A%20the%20squares,the%20radius%20of%20its%20orbit.

Emily: Well, we always want you, Matt, but we also want Sam. Yes, and!

Matt: That's right, *laughs*

Sam: And the idea was that if we could measure one of those distances absolutely, like we knew the exact number, we could then use those proportions to know the distances to other things. So if we could measure the transit of Venus across the Sun, and we could do that from a few different angles, there's some geometry involved[5], but if we could do that from a few different angles, you basically can do some calculations and calculate the distance between the Earth and the Sun.

Matt: In 1672, Giovanni Cassini in Paris and Jean Richer in French Guiana made simultaneous observations of Mars and calculated the very first estimate of the astronomical unit, that distance between the Earth and the Sun.[6]

Emily: I love talking about Cassini[7] because he made some of the first observations of some of the moons of Saturn[8] that I study. But we're going to talk about his other things today, which includes how close he got to making this measurement of the astronomical unit. But because Mars is further away than Venus, the number wasn't precise enough. Precision really matters when it comes astronomy and astronomers weren't satisfied with the number that Cassini came up with[9].

The cool thing about astronomy is that in a lot of ways it can be really predictable. So, astronomers like Kepler are able to make predictions, and in this case, Kepler made predictions about when the next transits of Venus and Mercury were going to be. But it turns out those transits were far enough in the future that Kepler wasn't going to see them.

Matt: Right, but they were far enough in the future as well that people could plan ahead, and they could also refine those measurements so that they knew exactly when and where they needed to be in order to get good observations of those next transits.

---

[5] https://cas.sdss.org/dr2/en/proj/advanced/hr/hipparcos2.asp#:~:text=d%20%3D%201%2Fp%2C,parallax%20angle%20in%20arc%20seconds.

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

[7] Cassini is also the guy NASA named this robotic mission after https://science.nasa.gov/mission/cassini/

[8] https://www.space.com/18902-giovanni-cassini.html

[9] https://skyandtelescope.org/astronomy-news/transits-of-venus-in-history-1631-1716/#:~:text=Astronomer%20Edmond%20Halley%20suggested%20using,Earth's%20distance%20to%20the%20Sun.

Emily: So Jeremiah Horrocks[10] was the one who was able to refine Kepler's measurements and then happened to be alive at the time that those transits were going to be happening. And so Jeremiah Horrocks was able to observe both a transit of Mercury and a transit of Venus in 1639.

Matt: So Horrocks refined those predictions and he was there for the transits, but he wasn't the one who suggested that an accurate observation of the transit would yield a more precise measurement for the absolute distances in our solar system. And that elusive astronomical unit, the AU, it was actually Sir Edmund Halley[11], the one the comet's named after[12].

Sam: It really kicks off with Edmund Halley, and he was the first one to pretty much say, if we can measure this transit and if we can do it from different points on earth, we should be able to calculate the distance between the Earth and the Sun.

Matt: So Transits of Venus happen in pairs eight years apart, then there's more than 100 years before the next pair comes around.[13] Halley was born after the 1631 and 1639 transits, and he knew he wasn't gonna make it to the 1761 for that next opportunity, so he wrote a paper, in Latin, of course, because that was the lingua franca[14] of the time, and he published it in 1716[15], ending it with an impassioned call to action.

Halley (VO): "I recommend it therefore again and again to those curious astronomers who, when I am dead, will have an opportunity of observing these things, that they remember my admonition, and diligently apply themselves with all imaginable success; in the first place, that they may not by the unreasonable obscurity of a cloudy sky be deprived of this most desirable sight, and then, that having ascertained with more exactness the magnitudes of the planetary orbits, it may redound to their immortal glory."

Matt: So by the time 1761 rolled around, the astronomers were ready for it and more than that their sort of countries of origin were ready to send them out on expeditions to view the transit.

---

10 https://www.theguardian.com/science/2023/mar/19/jeremiah-horrocks-the-forgotten-maths-genius-who-laid-the-foundations-for-isaac-newton

11 https://www.space.com/24682-edmond-halley-biography.html

12 https://science.nasa.gov/solar-system/comets/1p-halley/

13 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."

14 From Oxford Languages "a language that is adopted as a common language between speakers whose native languages are different."

15 https://classicalastrologer.com/edmund-halley-admonition-of-1716/

Ted: There were many countries that were interested in the transit of Venus of 1761. The British, the Germans, the French, and you have to have observations made from two widely separate locations. So they wanted to put people in the Northern Hemisphere and in the Southern Hemisphere.

Emily: And this is where our time in global history starts to make this story feel even more interesting because there's a lot of things going on in the 1760s.

Matt: For one thing, this is really deep in the colonial era[16]. The sun that never set on the British Empire, this is that time. And the French, the Dutch, the Portuguese, and the Spanish all have their own major land holdings across the globe, including in the so called "New World," which had been around for quite a while, in fact, and the American colonies there are held by the British through both of these transits.

Sam: A lot of the astronomers involved are British, they're Portuguese, they're Spanish, and they all have colonies around the world. So they do have key places that they can travel to, and they do have ships that they have access to, to make this all happen.

Emily: So within all of this colonialism, we also need to keep in mind that crisscrossing the globe to get to the exact right point on the globe to make these observations was really challenging because the only way to get around was to sail by ship and that's not the fastest way to do that. And it takes months and months for astronomers to get where they need to go

Matt: Right.

Emily: Which means they need megabucks, which I suppose is nothing new, right, Matt? We've talked about it on the podcast before; scientists, historians, to do this kind of research that we're doing, we require funding to do it. And that has not changed.

Matt: That's right. You have to have money to do science. So at this time the governments, the empires that have the money that have the land they're looking to send their astronomers out to where they can see the transit.

And as we said, this has some utilitarian reasoning behind it of knowing the astronomical unit, but there's also a little bit of a national pride dimension to it as well, of kind of like landing the first humans on the moon. Getting this accurate recording of the astronomical unit would be a great feather in the cap of any of these empires if they succeed.

---

[16] https://www.digitalhistory.uh.edu/era.cfm?eraid=2&smtid=1

Emily: So we're going to focus on a few of these expeditions, but first, let's go over how you would actually measure the transit.

Matt: So we already mentioned they're on ships, headed towards different destinations and they're doing this in order to not just observe the transit but to find something called parallax. After they've observed the transit from multiple locations. So the first thing they need to do when they get to their location is to figure out precisely where they are -- the latitude and longitude -- which involves figuring out exactly what time it is.

And once they've observed the transit, those observations get combined with other observations from other places to calculate that parallax. But what is the parallax?

Emily: Well you need parallax in order to calculate the distance between two things, which is what we're doing here right? The astronomical unit.

And the best way to describe parallax if you've never thought about it before, it's how an object shifts given your position, and the best way to think about this is if you put up your pointer finger, and you hold your arm completely straight out so that the pointer finger is out directly in front of your nose, and you close one eye, and then you open that eye, and you quickly close the other eye, and you flick your eyes back and forth, back and forth, and you can see your finger kind of shift back and forth, back and forth.

That's essentially parallax.

So, instead of an astronomer blinking their eyes open and closed, you can imagine that two different astronomers standing at two different points on the surface of the Earth, is effectively you blinking your eyes back and forth, and they're looking at the exact same object at the exact same moment.

Matt: So you can imagine that you need a very accurate clock in order to do this type of work and in 1761 the most accurate clocks were pendulum clocks, which had to be set up and set so that it was accurate to the second and as you can imagine just keeping them on the ship and running while you are actually traveling at sea doesn't really work when you're trying to utilize something that has a pendulum that utilizes gravity and could be set off by the rocking of the ship, right? So they had to actually figure that stuff out when they got to where they were going.

Sam: So to be able to measure both longitude[17] and latitude, latitude's a little bit easier is kind of know where the North Star is where the Sun is at its highest and you can kind of

[17] https://www.sea.museum/en/article/a-beginners-guide-to-longitude

know North-South where you are, but to know how far around you are on the globe East and West you need a working clock. So this was a really crucial part of this.

Emily: And of course the clock was really important for also being able to measure the timing exactly of when the transit was happening. And in this case we're talking about the time in which Venus crossed one side of the sun, and when it crossed the other side of the Sun.

Sam: Otherwise, the other instruments they brought, I mean, anytime you're observing the Sun, you usually have a telescope that's set up to project the sun onto a flat surface so you're not burning your retina[18] out in this process, so you can kind of measure it that way.

Matt: So we mentioned that there's a lot of traveling to colonies to view the transit, while it's going on and that's great until you start warring with someone else whose colonies are changing hands or, you know, the sort of complicated politics of these empires that are stretching around the globe.

Ted: One slight problem in 1761 was that the, the British and the French were at war, the Seven Year War[19]. So the British couldn't go to French colonies or French locations that were controlled by the French and the French couldn't go to ones that were controlled by the British. But the two countries did agree that they would not interfere with any ships going to these different parties.

Emily: So to no one's surprise, the decision to not attack each other's ships wouldn't really hold up very well[20], but we'll get back to that. We'll also get to some more stories of colonialism, because that's a really big part of telling the story of the 1760s transits. But all the transit expeditions were exciting adventures in some ways.

Sam: There's a lot of adventures, especially for this one. There was a group in Russia who kind of had to travel across chilling, icy rivers[21]. They encountered wolves, like it was kind of a trek to get to the city where they were going to observe from. According to the astronomers there, they didn't get a warm reception by the locals when they showed up either. Didn't get great data from that as well. So you have a lot of stories like that.

---

[18] https://airandspace.si.edu/learn/programs/soar-together/total-eclipse
[19] https://history.state.gov/milestones/1750-1775/french-indian-war
[20] https://skyandtelescope.org/astronomy-news/transits-of-venus-in-history-1761/
[21] https://skyandtelescope.org/astronomy-news/transits-of-venus-in-history-1761/#:~:text=Employing%20a%20slightly%20different%20triangulation,required%20protection%20from%20Cossack%20soldiers. The expedition to Tobolsk by Jean-Baptiste Chappe d'Auteroche. Who is going to have an even worse time in 1769…

The same thing kind of happened to the French. They tried to go to an island, but that island was under attack by the British, so they had to go somewhere else.

It was just kind of chaos around the globe and people trying to see something.

Emily: So let's begin with Monsieur Le Gentil. Or, to use his full name, Guillaume Joseph Hyacinthe Jean-Baptiste Le Gentil de la Galaisière. He was a nobleman, French obviously, who got some money to go to Pondicherry[22] in Southeast India, which was when he left France in March 1760, a French colony.

Matt: Le Gentil's ship took the long way around the Cape of Good Hope to the Isle of France, now Mauritius, and then headed north toward Pondicherry, where they encountered a lot of bad weather on the way just to discover that they were no longer welcome at the place that they thought was controlled by their homeland.

From Le Gentil's memoirs (VO)[23]: "We crossed the archipelago of Socotra, at the entrance to the gulf of Arabia. We appeared before Mahé, on the coast of Malabar, the 24th of May; we learned from the ships of this country that this place was in the possession of the English and that Pondicherry no longer existed for us."

Emily: Le Gentil, was running out of time and ended up viewing the transit from the deck of the ship. On a moving vessel, with only the foggiest idea of your longitude, you have to imagine that we also didn't know the correct time very well, and so Le Gentil's observations were pretty much useless.

Matt: And meanwhile, in Russia, an astronomer observed that Venus seemed to have an atmosphere[24].

AirSpace Theme up then under

Emily: There is so much adventure, ship duels, colonialism, and science in this story we had to split it up. We'll pick up with the Russian in Part Two.

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

---

[22] AKA Puducherry https://www.britannica.com/place/Puducherry-union-territory-India
[23] https://adsabs.harvard.edu/full/1951JRASC..45..127S
[24] Did you think this footnote was going to give away the ending? Nope. See part Two :)

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 Ted Rafferty, formerly of the United States Naval Observatory.

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

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