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Marginalia

Transits, Travels and Tribulations, II

J. Donald Fernie

My previous column began a series on the transits of Venus, a matter of outstanding importance to 18th-century astronomy. The phrase refers to the rare occasions when Venus comes directly between the earth and the sun, and so is seen transiting across the disk of the sun. Timing such a transit from at least two widely separated places on earth allows astronomers to determine the distance to the sun, a quantity that leads to the scale of the entire solar system. This was poorly known in the early 18th century, and thus the forthcoming transits of 1761 and 1769 were recognized as being well worth the effort of observation, especially since there would be no further transits for more than 100 years. However, travel to remote locations would not be easy, and would certainly be expensive in an age where vast areas of the earth were still unexplored. Moreover, at the time of planning and through the 1761 transit, the western powers were engaged in what was effectively the first global war, the so-called Seven Years War. In particular, Britain and France, the two superpowers of the day with powerful navies, were on opposite sides, making sea travel particularly hazardous as they fought over distant colonies.

The record shows that well over 100 observations of the 1761 transit were made, many by observers other than French or British, but the large majority of them simply observed from their home stations in Europe. And even the French and British planned only very few expeditions to remote places, essential though they would be for obtaining a useful result. Money unquestionably played a role here; it was an age before mass production, and a single good, portable telescope suited to a transit observation cost some £1,400, which probably exceeded the annual salary of the Astronomer Royal by a considerable factor. And more than one telescope per expedition was

needed in case of accidents. Little wonder that the Royal Society of London, which was responsible for the British expeditions, tried borrowing or renting equipment whenever possible.

Given that the first observation of a transit of Venus had been made by an Englishman, Jeremiah Horrocks, and the importance of such transits emphasized by another, Edmond Halley, the British were surprisingly slow in preparing for the June 1761 transit. Only in the summer of 1760 did the Royal Society get down to the details of who would go where, and this in an age when it was hoped that a relatively simple voyage down the Atlantic to the island of St. Helena and back would be completed within a year. Here, however, they were helped in their planning by the French. In charming contrast to our own times, we find that while their governments and associated armies and navies ferociously fought one another, the Royal Society and Académie Royale des Sciences saw no reason not to continue their cordial relations, even if exchanges of documents required more circuitous routes than usual. So both institutions were aware of each other's plans, and, in particular, Joseph-Nicolas Delisle, who had known Halley and taken over his zeal for the transits, communicated to his Royal Society counterparts a lengthy analysis of the situation and French intentions. These included expeditions to Siberia, India and the island of Rodrigues in the southern Indian Ocean.

To complement these, it was desirable to have a station in the southern Atlantic. Initially the British decided on just one expedition, which would go to St. Helena. The expedition would be led by Nevil Maskelyne, later to become Astronomer Royal, accompanied by Charles Mason, an experienced observer and assistant to the current A. R. (The British always sent at least two observers on each expedition in case one should die or be otherwise incapacitated. Indeed, in the light of naval warfare, experts advised that the two should "go in different Ships ... to [avoid] the Risque of both being Embarked on the Same Bottom." Sound advice, but economically unfeasible.)

Later, however, it was decided to extend the longitude range of the sites by having the British send a second expedition to Bencoolen (today's Bengkulu), a small port on the southwest coast of Sumatra. This would be a long voyage, and it being already September of 1760, there was no time to waste. So Charles Mason was abruptly switched to being principal observer for Bencoolen, and an assistant for him was hurriedly found in the person of land surveyor and amateur astronomer Jeremiah Dixon. The Royal Navy was petitioned to provide a ship, which would be faster than scheduled sailings of the East India Company's ships and which would offer better protection against French attack. This was granted, and by early December 1760 Mason and Dixon were aboard HMS *Seahorse* and "waited only for the wind."

Mayhem on the *Seahorse*

Only hours out of Portsmouth, however, *Seahorse* ran into the 34-gun French frigate, *le Grand*. After committing an hour of mayhem on one another, both sides withdrew, and *Seahorse* limped back to port with 11 dead and 37 wounded. Mason and Dixon reconsidered Bencoolen. Although *Seahorse* was being repaired with all haste, and the navy issued assurances that this time she would be escorted through the English Channel by a 70-gun man-of-war, the observers' enthusiasm was on the decline. In fact, Mason wrote to the Royal Society firmly advising that "We will not proceed thither, let the Consequence be what it will."

The Society's reply minced no words. It warned that "their refusal to proceed upon this Voyage, after having so publickly and notoriously ingaged in it ... [would] be a reproach to the Nation in general, to the Royal Society in particular, and more Especially and fatally to themselves.... [It] cannot fail to bring an indelible Scandal upon their Character, and probably end in their utter Ruin." In case this wasn't clear, the Society went on to say it would "with the most inflexible Resentment" take Mason and Dixon to court and prosecute them "with the utmost Severity of the Law."

A curt reply to this on February 3, 1761, announced that “their dutiful servants” would sail that same evening.

The next communiqué came from South Africa, dated May 6, 1761. In it, Mason triumphantly noted the news that Bencoolen had been taken by the French, and that he and Dixon would be staying right where they were in Cape Town to observe the transit. As it turned out, it was just as well. Maskelyne and his assistant were clouded out on St. Helena, and the successful Mason-Dixon data were all that came from the crucially important south Atlantic region. The accuracy of those observations showed the abilities of the team, and so it was that two years later they were chosen to survey the boundary line between Maryland and Pennsylvania, for which their names will forever be inscribed in American history books.

Probably to the surprise of the Royal Society, a third British expedition took place in 1761. This was the work of John Winthrop, professor of mathematics and natural philosophy at Harvard, who petitioned the Province of Massachusetts to provide the means for an expedition to St. John’s, Newfoundland. The 1761 transit did not favor the Americas as observational sites, since much of the transit took place during their night, but at the northeastern location of Newfoundland the egress of Venus potentially would be visible. The Governor, appealing to the House of Representatives that this was a “Phenomenon which has been observed but once before since the Creation of the World,” was successful in acquiring the province’s sloop for the voyage; Harvard provided the necessary observational equipment; and Winthrop and his three assistants sailed from Boston on May 9, 1761. They arrived two weeks later and, given every assistance necessary by the local authorities, began practicing observational procedures “with an assiduity which the infinite swarms of insects, that were in possession of the hill, were not able to abate, tho’ they persecuted us severely and without intermission ... with their venomous stings.” Happily, the sunrise of June 6 was clear and calm and allowed five precise measures of Venus’s path across the sun as well as timing the actual moment of

egress.

Laissez-Passer

By and large, things did not go as well for the French expeditions. Alexandre-Gui Pingré left Paris on November 17, 1760, for his destination of the island of Rodrigues, viewing his forthcoming voyage with foreboding. This despite another remarkable novelty of the times. Although Britain and France were locked in bitter battle, the Académie Royale des Sciences had appealed directly to British authorities to grant Pingré a *laissez-passer*, a letter instructing all British naval and military personnel "not to molest his person or Effects upon any account, but to suffer him to proceed without delay or Interruption." This was indeed granted, although since sea battles tended to exchange gunfire first and civilities later, if at all, Pingré's misgivings were not misplaced.

The transit party sailed on the *Comte d'Argenson*, a warship that found itself with less than half its normal complement of guns in order to extend its cargo capacity to that needed for the expedition. (There had been a heated dockside argument over the baggage, Pingré arguing furiously that seven or eight hundred pounds was not too much for an astronomer!) To the horror of all on board, a group of five British warships was sighted only one day out from port. To allow full play of its remaining guns, the ship's crew tore down the temporary cabins that had been erected for Pingré's companions, the latter and their belongings being flung unceremoniously into Pingré's cabin for the time being. Fortunately, though, a combination of suitable winds, the long winter night, and the captain's skills allowed the *Comte* to slip away unmolested, and everyone settled down to the remaining four months of their voyage.

Methods for determining longitude at sea in the mid-17th century were so poor that an interesting, although friendly, rivalry sprang up between Pingré and the ship's officers as to their location. Each would determine longitude by his preferred method and then compare notes. Thus it was that in late January the ship was bearing down fast on the Cape Verde

islands off West Africa, with Pingré announcing that the ship would pass to the east of the islands and the navigator claiming that passage would be to the west of them. The captain hove to for the night in case the average proved correct. The next morning they sighted the island of Santiago some leagues to the west, although according to their charts and the navigator's latest calculation, they should have been several leagues inland on the island of Bonavista, which, fortunately, was nowhere to be seen.

Compromise

They rounded the southern tip of Africa in April, just two weeks before Mason and Dixon would arrive there, and were looking forward to a comfortable run up the Indian Ocean to Rodrigues Island when they encountered another French ship, *le Lys*. Everyone was delighted, especially since the *Lys* carried fresh supplies of Cape fruit and wine, but delight turned to despair when it turned out that the *Lys* had been severely damaged in an encounter with British ships, and that its captain, superior in rank to the captain of the *Comte*, was demanding that the latter escort the *Lys* at its limping pace to Isle de France (today Mauritius) for repairs. This meant that Pingré would not reach Rodrigues in time for the transit. He was outraged, and a violent exchange of notes ensued. But within a few days he and the captains dined together, digestion being aided by a remarkable flow of wine, and a compromise was reached. The *Comte* would sail ahead to Isle de France. This ended with the astronomers having to transfer to another ship at Isle de France for the final 300-mile run to Rodrigues. Bad weather stretched the journey to 19 days, and then, with the transit only 10 days away, their ship was becalmed for two days within sight of the island. Once ashore, the astronomers rushed to offload their equipment, find a suitable site for observing the transit and set everything up. The instruments were in poor condition after months at sea, but after frantic effort, everything was ready and tested by the evening of June 5, with the transit scheduled to start the next morning and continue through much of the day.

The observers awoke to a steady rain. The moment of the transit's start passed without observations being possible, but later the sky cleared somewhat, and Pingré and his assistant got some measures through passing clouds of Venus's position on the solar disk. They hoped to time the moment of egress, but a solid overcast came back and ruined any such hope. Still, their observations were useful, and, astronomy aside, they had been collecting local flora and fauna to take back to the Académie Royale des Sciences. This continued until the end of June, when a major catastrophe struck with the sudden arrival of a British man-of-war. Its crew captured one of the two French ships in the harbor at the time, burned the other and ransacked the island. Pingré, of course, rushed forward with his letter from the British Admiralty ordering that his expedition not be molested, only to have the British captain ignore it entirely. When the British finally departed, there was little left for Pingré to take home, and indeed he and his companions were reduced to living on rice and flour and "*ignoble de l'eau*" while they waited for another French ship to pick them up on its regular run from Isle de France. Pingré protested vehemently about his treatment in a whole series of letters to the British Admiralty and the Royal Society, but it isn't clear that he ever received any satisfaction.

It was not until the end of May 1762, a year after the transit, that Pingré and his companions once more set foot in Paris, exhausted but happy. And although he was not part of the 1769 transit expeditions, he played a major role in planning them and eventually in analyzing the results of both transits. Astronomer, theologian, classicist, geographer, traveller, he has been described as "one of the most interesting men ever to enter the ranks [of the Académie Royale des Sciences]." It seems fitting that he lived to a fine old age, dying in Paris in 1796 at age 84.

There were two other French expeditions to observe the 1761 transit, one to Siberia and another to India, and both, like Pingré's, were filled with adventure. We shall take them up, along with the 1769 expeditions, in my next column.

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Transits, Travels and Tribulations, V

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It is time to bring to a close this story of the 18th-century transits of Venus and the often amazing expeditions to the ends of the earth that they engendered. The purpose in measuring and timing the passage of Venus across the face of the sun on the very rare occasions it is seen to do this was to establish the scale of the solar system (and eventually the scale of the universe itself). Observers had to be sent to very distant parts of the earth because the longer the baseline between them, the more accurate would be the result, and in the ill-explored world of the 1760s this would cost more than one of them his life. But before we turn to the ultimate results of these undertakings we must look at one more of the expeditions, the most famous of them all, the British expedition to the South Pacific for the 1769 transit.

Early analysis of the 1761 transit observations was not entirely satisfactory, and it was expected that the 1769 transit (the last for more than a century) would offer better results. By 1765 Thomas Hornsby, Savilian Professor of Astronomy at Oxford, was urging the European powers to prepare their expeditions: “Posterity

must reflect with infinite regret their negligence or remissness; because the loss cannot be repaired by the united efforts of industry, genius, or power." Calculation showed that the South Pacific, as yet hardly explored by Europeans, would be a desirable station, and in case science should not prove attraction enough, Hornsby noted that it would be a "worthy object of attention to a commercial nation to make a settlement in the great Pacific Ocean." Thus it was that the British expedition to the Pacific would have far more hopes behind it than merely establishing the scale of the solar system. Commerce, politics and empire were not to be denied. The Royal Society of London's estimate that £4,000 would be needed to mount the expedition met with little argument, and an appeal to the 30-year-old King George III was launched. "The Memorialists, attentive to the true end for which they were founded by Your Majesty's Royal Predecessor ... conceived it to be their duty to lay their sentiments before Your Majesty with all humility, and submit the same to Your Majesty's Royal Consideration." Royal Consideration quickly arrived at acquiescence.

The Society had among its fellows just the man to command such an expedition: Alexander Dalrymple, a former professional sailor with much experience in eastern seas and an adept geographer and navigator. But where to find a ship? Clearly the Royal Navy must be the answer, as it had been for Mason and Dixon years before. And then a major snag. The Admiralty, it seemed, had never forgotten the last time it had allowed an astronomer, Edmond Halley, to command one of its ships on a scientific expedition (see *Marginalia*, January-;February 1986). The result had been mutiny and the

near loss of the ship. The First Lord of the Admiralty, Sir Edward Hawke, rather extravagantly announced he would sooner suffer his right hand to be cut off than sign another such commission. So Dalrymple was out. The Admiralty would find its own man. They picked a junior officer, then doing marine survey work on the St. Lawrence River in Quebec. His name was James Cook, the ship he was to command, the *Endeavour*.

Precious Hardware

The next question was just where in the South Pacific the expedition should go. Such reports of islands in the vast ocean as existed were not entirely reliable as to latitude and longitude, and one would not, as did Le Gentil in 1761, want to find oneself at sea when the crucial moment arrived. But even as the *Endeavour* was being fitted out there arrived back from the Pacific the good ship *Dolphin*. And what news! It had found an island that was a virtual paradise on earth, an island "such as dreams and enchantments are made of...." An island where not only the surroundings were paradisiacal, but where the local culture was also utterly different from that of Europe. In particular, the sailors had discovered, no doubt within minutes of arrival, that the women were extraordinarily free with their sexual favors. The gift of anything metallic would hasten proceedings even further. The captain of the *Dolphin* had feared his ship would sink at her moorings as her crew enthusiastically ripped the nails from her decks. Her navigators had taken particular care in determining the island's latitude and longitude. Its name was Tahiti. The *Endeavour* would sail for Tahiti. Considerable quantities of nails would be among her cargo.

So on August 26, 1768 the *Endeavour* sailed from Plymouth, bearing southwest for Rio, then 'round the horrors of Cape Horn and across some 7,400 kilometers of the Pacific to Tahiti, arriving with almost two months in hand before the transit. Joseph Banks (26, later Sir Joseph, and eventually one of the Royal Society's most colorful presidents), who had joined the expedition as scientific leader and botanist, found previous reports to be accurate.

Soon after my arrival at the tent 3 hansome girls came off in a canoe to see us ... and with very little perswasion agreed to send away their carriage and sleep in [the] tent, a proof of confidence which I have not before met with upon so short an acquaintance.

But cultural differences went well beyond sexual mores. Ownership seemed a very fuzzy concept, and casually stolen goods became a sore point. Particularly when an important astronomical instrument disappeared and had to be hunted down at gunpoint. The English crew set a poor example, as Banks noted in his journal after a near-perfect observation of the transit:

We also heard the melancholy news that a large part of our stock of Nails had been purloind by some of the ships company during the time of the Observation.... This loss is of a very serious nature as these nails if circulated by the people among the Indians will much lessen the value of Iron....

The transit observations concluded, Cook, as per instructions, set off southwestward in search of the great southern continent postulated by philosophers of the day as the counterpart to the great land masses of the northern hemisphere. Instead, he discovered New

Zealand and spent six months charting its coasts. Setting off westward once more, he ran into the east coast of Australia and worked northward, charting 3,000 kilometers of coast as he went. That took them out into the channel between the coast and nearly 2,000 kilometers of the Great Barrier Reef. Despite the crew's desperately careful sailing, the beautiful but treacherous reef claimed the *Endeavour*, and although they eventually got her off they had to beach her for many weeks on the desolate Queensland coast to make repairs.

With supplies running low, the *Endeavour* put in to Batavia (Jakarta) for refreshment and more permanent repairs. So far the crew's health had been fine; indeed, Cook, with his insistence on sauerkraut as a defense against scurvy, was famous for protecting the well-being of his crews, but he had no defense against the malaria and dysentery ("the bloody flux") of tropical Batavia. By the time the ship set off to cross the Indian Ocean, round southern Africa and sail the length of the Atlantic, nearly half the crew had died and most of the remainder were severely stricken. But finally, on July 13, 1771, more than two years after the transit, the survivors, weak and shaken, arrived home. Among those they left behind was Charles Green, the expedition's official astronomer. It was reported that he "had been ill some time ... [and] in a fit of phrensy got up in the night and put his legs out of the portholes, which was the occasion of his death."

It says something of Cook the man that he would undertake two more expeditions to the Pacific despite these previous experiences. It was, of course, to cost him his life.

So another chapter in the history of the transits of Venus was closed. No one alive then would see another. It remained only to determine how well they had done in arriving at their goal of calibrating the astronomical unit, the distance between the earth and the sun.

The Black Drop

Three problems permeated the analysis: first, the curious and unexpected phenomenon called “the black drop”; second, uncertainties in the distances between observers; and third, the problem of how to combine redundant observations.

The black-drop problem surprised observers. They were trying to determine the exact moment when the edge of Venus’s disk was just tangent to the edge of the sun’s disk as Venus began or ended its transit, but what they saw was an elongated black ligament joining the two edges and persisting even when Venus’s disk was clearly within that of the sun. This so surprised and unsettled the observers that even when two of them were standing alongside each other their reported times could be half-a-minute apart, when they were expecting agreement to within a few seconds. As Cook himself reported,

This day prov’d as favourable to our purpose as we could wish, not a Clowd was to be seen the whole day and the Air was perfectly clear ... [yet] we very distinctly saw a ... dusky shade round the body of the Planet which very much disturbed the times of the Contacts.... We differ’d from one another in observeing the times of the contacts much more than could be expected.

Today we understand this as being the result of sunlight refracting through the very dense atmosphere of Venus, but it certainly degraded the timing of the transits.

The accuracy of the final results also depended directly on knowing the length of the baseline between observers--in effect knowing accurately the latitude and longitude of each observer. But since methods for determining longitude in the 1760s were inadequate, to say the least, these baselines were not well determined, and the accuracy of the final results was correspondingly diminished.

The third problem reminds us that although this series of articles has described those few expeditions that went to remote parts of the earth to observe the transits in 1761 and 1769 (and their observations carried the most weight), there were additionally many other observers who saw the transits from home, if home happened to be in the right hemisphere at the right time. The initial analysts of the data faced the problem of getting the best single answer from multiple locations and observations, when in principle only two observations were needed. Methods for combining redundant observations were only in their infancy and would not come to fruition until the work of Legendre, Gauss and Laplace in the early 19th century led to the method of least-squares.

Thus contemporary analyses of the 1760s data yielded a variety of answers. Typical was the analysis of Lalande in 1771, who found values of the earth's mean distance from the sun (the astronomical unit) in the range of 152 to 154 million kilometers (Mkm). But more than a century later in 1891, when locations had been much better determined and mathematical methods improved, Simon Newcomb, dean of late-19th-century American astronomy, from the same data determined a value of

149.7 ± 0.9 Mkm, and when he combined the 1761 and 1769 transits with those of 1874 and 1882, he found an overall transit value of 149.59 ± 0.31 Mkm.

Before we compare this to the latest determination, let it be said we now know that of the methods developed after the last transit of Venus up to the mid-20th century (which included trigonometric parallaxes of asteroids, gravitational perturbations by the sun and improvements in the constant of stellar aberration), none would surpass in accuracy (although often in claimed precision) the results of the transits of Venus.

Modern astronomy has turned back to Venus to calibrate the astronomical unit, but now in quite a different way. Today giant radiotelescopes are used as radar guns, pumping out a tremendously powerful radio signal directed at Venus, and minutes later, switched to receiver mode, detecting the faint echo returning from the planet, the round-trip time being measured by atomic clocks. This interval, together with the speed of electromagnetic waves, yields the distance of Venus at that moment--and thus, through Kepler's third law (see Part I of this series), the value of the astronomical unit. The current value stands at 149,597,870.691 ± 0.030 kilometers. This astonishing result, if taken at its claimed precision, almost defies comprehension. It is the equivalent of measuring the distance between a point in Los Angeles and one in New York with an uncertainty of only 0.7 millimeter!

So when the next transit of Venus finally comes along in about five years (June 8, 2004), we are not likely to expect new exactitude in determining the astronomical unit, but we might give thought to the words of William

Harkness, a key American figure in the 19th-century transits, writing just after those transits:

There will be no other [transit of Venus] till the twenty-first century of our era has dawned upon the earth, and the June flowers are blooming in 2004. When the last [18th century] transit occurred the intellectual world was awakening from the slumber of ages, and that wondrous scientific activity which has led to our present advanced knowledge was just beginning. What will be the state of science when the next transit season arrives God only knows.

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Marginalia

Transits, Travels and Tribulations, III

J. Donald Fernie

Regular readers will recall that we are in the midst of a series of columns on the 18th-century transits of Venus. A transit of Venus is the occasion of that planet coming directly between the earth and the sun, so that we see it as a black blob moving slowly across the face of the sun. As explained in part I, the timing of this event leads eventually to a knowledge of the scale of the solar system, a quantity essential to astronomy but poorly known in the mid-18th century. It was also the case that although there would be transits of Venus in 1761 and 1769, there would be none thereafter for more than 100 years, so it was important to make the most of the opportunity. Thus strenuous efforts were planned by the major scientific bodies of that era to make the necessary observations. The difficulty, though, was twofold. First, adequate precision required that observers doing the timing be as widespread across the earth as possible, even though exploration of distant lands was still decidedly limited. Second, the major powers, particularly the two strongest naval powers, Britain and France, were at war with one another in 1761, making sea travel extremely hazardous.

In my second column on the topic, I described two of the British expeditions to observe the 1761 transit--that of Mason and Dixon to South Africa, and Winthrop's Harvard expedition to Newfoundland. In addition, we looked at the misfortunes of a French expedition, that of Pingré to the island of Rodrigues in the Indian Ocean. Here we deal with the two other French expeditions of 1761, that of Jean Chappe d'Auteroche to Siberia, and of Guillaume-Joseph-Hyacinthe-Jean-Baptiste Le Gentil de la Galaisière to India.

Chappe came from a family of the lower French nobility, but since he was only 31 when he was admitted to the Académie Royale des Sciences in 1759, and since the 1769 transit cost him his life, his career was short-lived and we know little about him. Certainly his early *entrée* to the Académie, and the work he did on his transit expeditions, bespeak a person of talent and determination. Who knows what he might have achieved in a longer life?

Through an invitation from the Russian Imperial Academy of Science, the Académie Royale des Sciences appointed Chappe to observe the transit of June 6, 1761 from Tobolsk, a city in central Siberia some 5,000 kilometers from Paris. This site was chosen because both the start and finish of the transit would be visible from it, granted clear weather. Protocol dictated that Chappe pay his respects to the Russian Academy in St. Petersburg *en route*, and since travel would be slow he would necessarily face a crossing of the Ural mountains and Siberian travel in a Russian winter.

Early Setbacks

Chappe initially hoped to reach St. Petersburg, the halfway mark of his journey, by ship, traveling around the coasts of northwestern Europe. He further hoped to avoid the wretched war between France and Britain by booking passage on a Dutch ship, but a delay in organizing "*un appareil considérable d'Instruments*" made him miss the sailing. He later dryly noted his consolation was that this probably saved his life when the ship ran aground on the coast of Sweden. Travel by land it would have to be, aiming for Strasbourg, Vienna, Warsaw, St. Petersburg, Moscow and then striking out across the Siberian plains and over the Urals for Tobolsk. Chappe's expedition left Paris in late November 1760.

It says something of the times that even within civilized France the journey to Strasbourg, a matter of hours in a car today, took eight days over highways so bad that every thermometer and barometer was broken, and the carriages were damaged beyond repair. What must Chappe have thought, considering that this was only the first small step of his journey and that conditions to come would be much worse? But again in tune with his times, he simply set himself to making a new set of instruments, while new carriages were arranged. He did, however, decide to head first for Ulm and then go by boat down the Danube to Vienna. He was strongly advised against this, since it was the season when heavy river fogs could delay boats for days, but he took to the river nevertheless.

Again one is struck by the "Renaissance Man"nature of these 18th-century

scientific expeditionaries: No lounging around the boat for Chappe. He was busily mapping every turn of the river, since France lacked maps of the upper Danube. When fog on the river left the boat immobile, Chappe was off climbing the surrounding mountains, barometer in hand, to determine their altitudes.

Vienna was reached on the last day of 1760, and after a reception by Maria Theresa, Archduchess of Austria, and her husband, Francis, the Holy Roman Emperor, as well as meetings with local astronomers (comparing barometers, magnetic compasses and the like) Chappe left Vienna on January 8, 1761. It was a cold day, with temperatures around -23 degrees Celsius, and soon Chappe and his men were having to smash their way by foot through half-frozen river crossings. By January 22 they were in Warsaw, where Chappe heard he was awaited in St. Petersburg "with great impatience." Crossing the frozen Vistula, the expedition for the first time transferred to sleds, with Chappe reporting on "the ease of travelling with sledges; we went on with the greatest velocity...."

Tough Sledding

In St. Petersburg he learned that, in light of his delays, the Russian Academy had given up hope of his reaching Tobolsk in time and had sent out expeditions of their own (which seem never to have been heard from) to nearer sites. But Chappe was determined to reach Tobolsk before the transit. Thanks to the Empress, his expedition was equipped with every necessity, from bread to interpreters, and left St. Petersburg in early March on four enclosed sleds, each drawn by five horses running abreast. (One pictures a scene out of *Doctor Zhivago* or something from Tolstoy.) The sleds were smashed beyond repair by the time they reached Moscow, but on March 17 they left that city with new sleds, still with nearly 800 leagues (3,800 kilometers) to go, including crossing the Urals. Paradoxically, while they cursed the bitter cold they prayed for continued cold weather. A thaw would strand them in the Siberian bogs, from which they might never emerge. It took a month (Chappe furiously writing reports on everything he encountered), even though "the surface of the Volga was as smooth as glass ... and the sledges went on with inconceivable swiftness." His retinue chose to desert him in the depths of a Siberian forest, and Chappe had to hunt

them down, pistol in hand, but eventually the expedition found itself in Tobolsk in mid-April, well before the June transit.

Aided by a military party appointed by the local Governor, Chappe soon built a working observatory on a nearby mountain, and began observations to determine his longitude and latitude, essential for the eventual calculations of Venus's distance. However, Tobolsk lies at the confluence of the Irtysh and Tobol rivers, and the thaw that set in with his arrival was unusually rapid, with heavy flooding of the town. To some locals, this was no doubt due to the activities of the foreigner said to be messing with the sun, and mutterings of mob action to deal with him necessitated an increase in Chappe's military guard.

Chappe could sleep only fitfully the night before the transit, even though he reported that "the perfect stillness of the universe completed my satisfaction and added to the serenity of my mind." The day itself proved perfect, and Chappe observed the entire transit. At the start, he says, "I was seized with an universal shivering." But as the hours wore on and success became ever more imminent, "I truly enjoyed [the pleasure of] my observation, and was delighted with the hopes of its being still useful to posterity, when I had quitted this life." Indeed his observations were still prominent in calculating the scale of the solar system more than 100 years later.

Couriers bearing the essential observational data were quickly dispatched to Paris and St. Petersburg, but Chappe himself stayed on making further latitude and longitude observations, not to mention notes on everything that came his way. He eventually made a leisurely return trip through southern Russia, arriving back in Paris almost 18 months after the transit. The only sour note came later when Chappe published his no doubt honest yet excoriating views on Russian backwardness, despite the help he had received from Russians throughout his travels. No less a personage than Catherine II, writing under a pseudonym, undertook a line-by-line rebuttal. No matter. For the next transit Chappe was to abandon the winter wastelands of Russia for the deserts of Mexico.

Endless Journey

The *abbé* Le Gentil was another who would pursue both transits. Indeed, his 11-year odyssey would rank as the longest astronomical expedition in history. Despite a contemporary saying of him that "his face did not prejudice one in his favor," at 28 Le Gentil was a well-trained astronomer. By 1753 he had made his own calculations of the transits and had volunteered to go to Pondichery in India to observe the June 6, 1761 event. He sailed from Brest in a French man-of-war in March 1760, allowing himself plenty of time to sail around southern Africa and across the Indian Ocean. Most of this trip was "uneventful, save for the loss of a fellow passenger by suicide and by the pursuit by an English fleet off the Cape of Good Hope." Arriving at Isle de France (Mauritius) in July 1760, however, he discovered that Pondichery was besieged by the British, and that a French force sent by sea to raise the siege had been all but destroyed by a hurricane while *en route*. A second force arrived after a delay of eight months, and Le Gentil accompanied it on its attempt to relieve the beleaguered Pondichery. Winds were contrary, however ("we wandered around for five weeks in the seas of Africa"), and by the time the fleet arrived off the Malabar Coast only two weeks before the transit, they discovered that the British had captured and consolidated themselves in Pondichery. Le Gentil's ship was lucky to elude the British naval squadrons and immediately headed back the 5,000 kilometers or so to Isle de France. In mid-ocean on June 6, under a cloudless sky, Le Gentil had a perfect view of Venus transiting across the sun's disk. But since precise timing of the event was essential, and his pendulum clocks useless at sea, the view was of no scientific value at all.

Rather than go home empty-handed, Le Gentil wrote to the Académie Royale des Sciences in Paris suggesting that he spend a year or so exploring the islands of the Indian Ocean, carrying out work in natural history, geography, navigation and more or less anything that might be useful. This was agreed to, and soon Le Gentil was busy mapping the east coast of Madagascar. Here he made the mistake of eating the local beef, which though "rich" caused "a sort of violent stroke, of which several copious blood-lettings made immediately on my arm and my foot, and emetic administered twelve hours afterwards, rid me quite quickly." The accompanying double-vision took somewhat longer.

A Second Chance

Time went by. The war with Britain ended. The 1769 transit began to loom, and before long Le Gentil was suggesting that he stay on and try again for observations from this part of the world. His latest calculations suggested that going to Manila in the Philippines would be preferable to Pondichery (now back in French hands), and he even considered heading for the Marianas Islands in the Pacific until he learned that ships only went there every three years. Not waiting for agreement from Paris, he seized the chance of passage on a Spanish ship bound for Manila. It was not until July 1767, a year later, that a reply from the Académie Royale des Sciences caught up with him there. It announced that they would prefer to see him go to Pondichery after all. As it happened, Le Gentil was encountering considerable hostility from the corrupt governor of Manila (soon to be jailed himself), who apparently disliked all French citizens on principle. He claimed Le Gentil's papers must be false, and Le Gentil soon sensed that if he did not soon get away, he would probably find himself in a Spanish jail, if not worse. Clandestinely, he left on a ship bound for Madras in February 1768. It was a nightmare voyage, navigating through the islands and straits of the South China Sea, where the captain and his two pilots argued interminably over which passage to head for. Their arguments were so violent that at times all three would storm off to their cabins and leave the helmsman to his own devices. The captain, noted Le Gentil, "was as little in condition to conduct his vessel as I am to lead an army." On the other hand, the pilots were "two old automatons to whom I would not have entrusted the conduct of a launch." Nevertheless, Le Gentil finally found himself in Pondichery on March 27, 1768, more than a full year ahead of the transit.

Here he was warmly welcomed by the French Governor, Monsieur Law, and an observatory was established for him amid the ruins of a once-palatial estate. In the recent war it had served as a gunpowder magazine. In fact, Le Gentil's observatory was built atop a vault containing "sixty thousand weight of powder." Even so, "this circumstance did not interrupt the course of my observation," said Le Gentil, announcing his pleasure at living and working there. Even the British

sent over an excellent telescope from Madras in case it was needed. Le Gentil settled into regular astronomical work, in particular the all-important determination of his precise longitude and latitude.

Fatal Cloud

1768 gave way to 1769, and the transit date of June 3 approached. At Pondichery only the egress of Venus from the sun would be visible, but the precise timing of that event near 7:00 a.m. local time on Sunday, June 4 would be vital. “During the whole month of May, until the 3rd of June, the mornings were very beautiful.” The evening before was clear and calm. But at 2:00 a.m. Le Gentil was awakened by “the moaning of the sandbar,” implying a change in the wind. Leaping from his bed he “saw with the greatest astonishment that the sky was covered everywhere.... From that moment on I felt doomed, I threw myself on my bed without being able to close my eyes.” A powerful wind brought even heavier cloud, “the sea was white with foam, and the air darkened by sand and dust....” Nothing in the sky was visible at 7:00 a.m., but around 9:00 a.m. the sun came out and “we did not cease to see it all the rest of the day.”

Le Gentil’s journal entry says it all: “That is the fate which often awaits astronomers. I had gone more than ten thousand leagues [50,000 kilometers]; it seemed that I had crossed such a great expanse of seas, exiling myself from my native land, only to be the spectator of a fatal cloud.... I was more than two weeks in singular dejection and almost did not have the courage to take up my pen to continue my journal...,” especially when he later learned that near-perfect conditions had prevailed in Manila.

His one thought now was to return home, and he arranged passage on the first available French ship, due to leave Pondichery in October 1769. But he fell seriously ill with fever and dysentery, and missed the sailing. Indeed, he barely survived, but by March 1770, he was so desperate for home that, although still ill, he took ship for Isle de France as a first step. Here his convalescence continued for seven months, until in November he left on a ship bound for home via the Cape of Good Hope. Only two weeks out, though, an extremely violent storm

almost sank them, and only great good luck brought them back to Isle de France on New Year's Day 1771. Another three months passed ("The sight of [Isle de France] had become unbearable to me"), but in March 1771, Le Gentil was aboard a Spanish warship, which finally returned him to Europe. On October 8, 1771, "at last I set foot on France at nine o'clock in the morning, after eleven years, six months, and thirteen days of absence."

He returned to discover that since no one in Paris had heard from him for so long, he had been presumed dead, and his seat in the Académie Royale des Sciences given to someone else, while his heirs were engaged in dividing up his estate. The latter problem took much expensive and tiresome litigation to correct, but intervention by the King gave him back a seat in the Académie within a few months.

There was a happy ending to his life. He lived another 21 years, married happily and had a daughter who became the delight of his life. He died of a relatively mild sickness at the age of 67 in 1792.

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