ANDREA WULF

CHASING VENUS

The Race to Measure the Heavens

'Nail-biting thriller ... don't miss this wonderful book'
Daily Mail

Contents

About the Book

On two days in 1761 and 1769, astronomers cast their eyes to the skies to witness a rare sight: Venus travelling across the face of the sun. The two transits were to become the most significant astronomical events in scientific history, as by recording the path of Venus and comparing results, these men hoped to calculate the dimensions of our solar system – one of the most pressing quests of the Enlightenment. For the first time, scientists from across the globe came together – despite wars, savage weather and bitter rivalries – to measure the universe.

Chasing Venus recounts the extraordinary expeditions that set off on a race around the world to observe the transits, and the triumphs and misfortunes that befell them. Overcoming enormous obstacles to make their observations, these astronomers were pioneers: helping to discover new lands, animal and plant species, and to map the world as we know it today.

Featuring a cast of some of the most recognisable names in world history – Edmond Halley, Benjamin Frankin, James Cook, Mason and Dixon, and Catherine the Great, among others – *Chasing Venus* is a thrilling adventure story, a tale of obsession and personal tragedy, and an inspiring account of Enlightenment science and discovery.

About the Author

ANDREA WULF was born in India and moved to Germany as a child. She trained as a design historian at the Royal College of Art and is the author of *The Brother Gardeners* (longlisted for the 2008 Samuel Johnson prize and winner of the 2010 American Horticultural Society Book Award) and *The Founding Gardeners,* and is the co-author of *This Other Eden: Seven Great Gardens and 300 Years of English History* (with Emma Gieben-Gamal). She has written for the *New York Times,* the *Guardian,* the *Wall Street Journal,* the *Los Angeles Times* and many others. She lives in London.

Also by Andrea Wulf

The Founding Gardeners:
How the Revolutionary Generation
Created an American Eden

The Brother Gardeners:
Botany, Empire and the Birth of an Obsession

This Other Eden: Seven Great Gardens and
300 Years of English History
(with Emma Gieben-Gamal)

ANDREA WULF

CHASING VENUS

THE RACE TO
MEASURE THE HEAVENS

WINDMILL BOOKS

To Regan

‘*The planet Venus drawn from her seclusion, modestly delineating on the sun, without disguise, her real magnitude, whilst her disc, at other times SO lovely, is here obscured in melancholy gloom*’

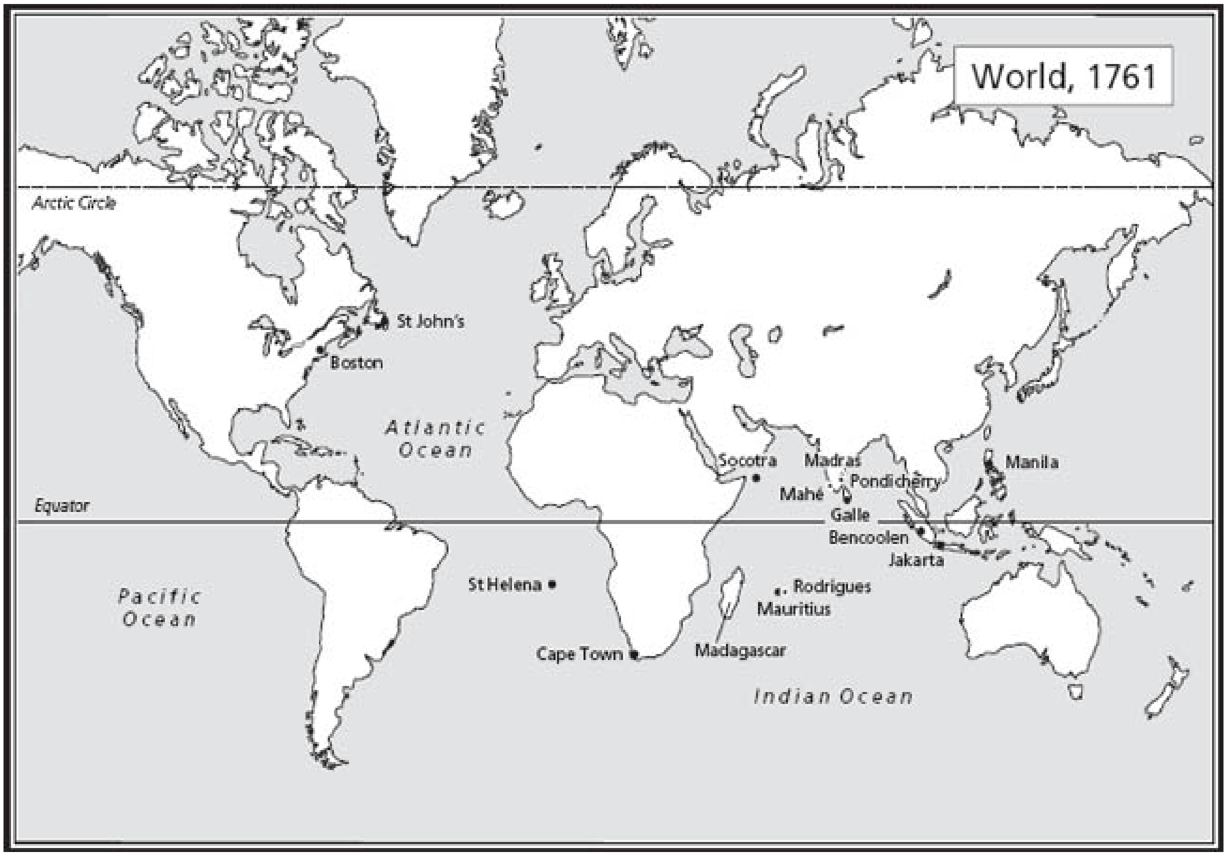
Jeremiah Horrocks

‘*We must show that we are better, and that science has done more to humankind than divine or sufficient grace*’

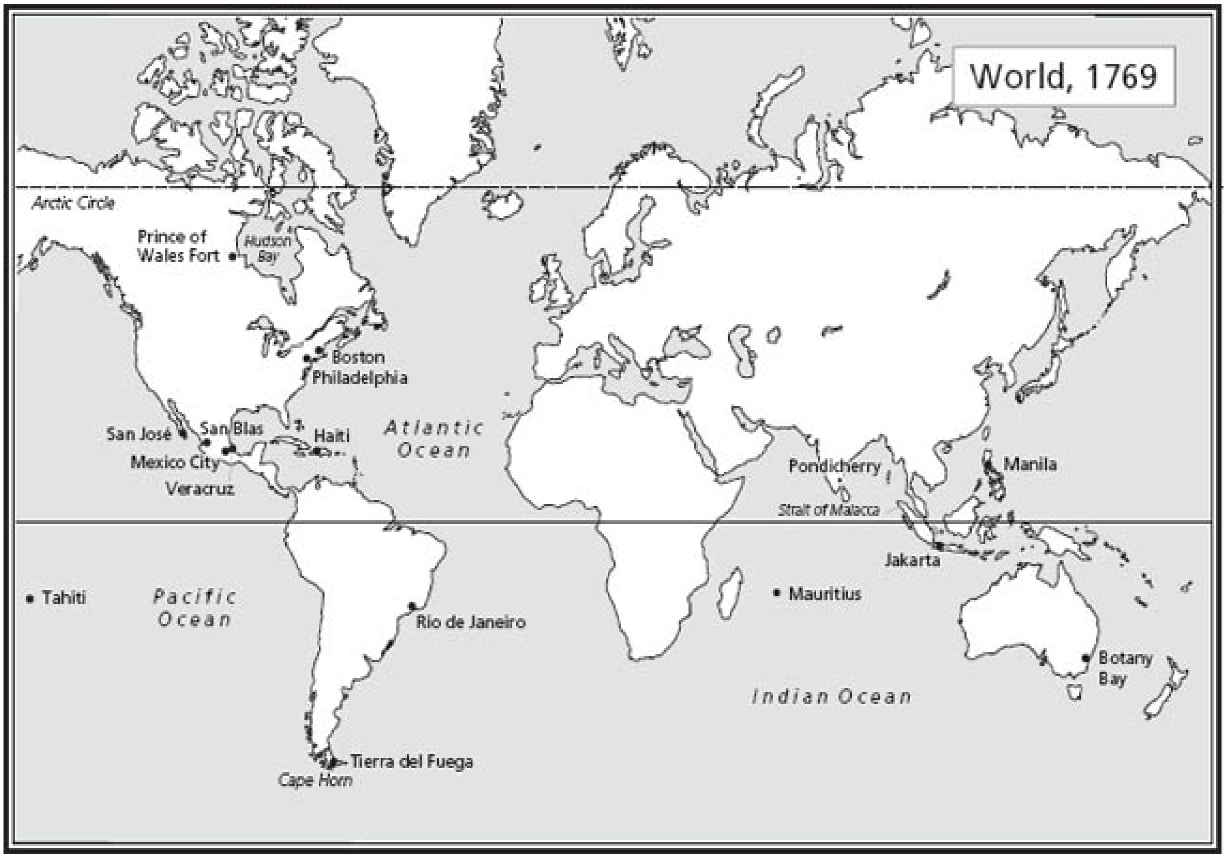
Denis Diderot

Author’s Note

In the interests of clarity and consistency I have retained in the maps and in the text certain place names of the viewing stations as the transit astronomers referred to them in the eighteenth century. Instead of the modern ‘Puducherry’, for example, I have used ‘Pondicherry’; ‘Bencoolen’ instead of ‘Bengkulu’; ‘Madras’ instead of ‘Chennai’; ‘Constantinople’ instead of ‘Istanbul’. In some rare cases where the old names have fallen completely out of use, I have taken the modern name: ‘Jakarta’ instead of ‘Batavia’, for example. Please refer to the ‘List of Observers’ for a full list of the historic and contemporary names.


World, 1761
Arctic Circle
Equator
St John's
Boston
Atlantic Ocean
Pacific Ocean
Socotra
Madras
Pondicherry
Mahé
Galle
Bencoolen
Jakarta
Manila
St Helena
Rodrigues
Mauritius
Madagascar
Cape Town
Indian Ocean

Europe and Russia, 1761
Norwegian Sea
North Sea
Tornea
Kajana
Gulf of Bothnia
Åbo
Uppsala
Stockholm
St Petersburg
RUSSIA
Tobolsk
GREAT BRITAIN
Copenhagen
Lake Baikal
Irkutsk
Nerchinsk
Selenginsk
London
Leiden
Warsaw
Portsmouth
Brest
Strasbourg
Vienna
Paris
Lorient
FRANCE
Black Sea
Rome
SPAIN
Madrid
Lisbon
Caspian Sea
Mediterranean Sea


World, 1769
Arctic Circle
Prince of Wales Fort
Hudson Bay
Boston
Philadelphia
San José
San Blas
Haiti
Mexico City
Veracruz
Atlantic Ocean
Pondicherry
Manila
Strait of Malacca
Jakarta
Tahiti
Pacific Ocean
Mauritius
Rio de Janeiro
Botany Bay
Indian Ocean
Tierra del Fuega
Cape Horn

Europe and Russia, 1769
North Cape
Hammerfest
Vardø
Kildin
Barents Sea
Norwegian Sea
Kola
Umba
Ponoy
Pello
Torneå
Kajana
Trondheim
Gulf of Bothnia
Öregrund
Uppsala
Oslo
Stockholm
St Petersburg
North Sea
RUSSIA
Yakutsk
GREAT BRITAIN
Copenhagen
Moscow
Lake Baikal
Lübeck
London
Leiden
Göttingen
Orenburg
Orsk
Plymouth
Le Havre
Paris
Vienna
Guryev
Geneva
FRANCE
Rome
Black Sea
SPAIN
Caspian Sea
Cadiz
Mediterranean Sea

Dramatis Personae

Transit 1761

Britain
Nevil Maskelyne: St Helena
Charles Mason and Jeremiah Dixon: Cape of Good Hope

France
Joseph-Nicolas Delisle: Académie des Sciences, Paris
Guillaume Le Gentil: Pondicherry, India
Alexandre-Gui Pingré: Rodrigues
Jean-Baptiste Chappe d'Auteroche: Tobolsk, Siberia
Jérôme Lalande: Académie des Sciences, Paris

Sweden
Pehr Wilhelm Wargentin: Royal Academy of Sciences, Stockholm
Anders Planman: Kajana, Finland

Russia
Mikhail Lomonosov: Imperial Academy of Sciences, St Petersburg
Franz Aepinus: Imperial Academy of Sciences, St Petersburg

America
John Winthrop: St John's, Newfoundland

Transit 1769

Britain
Nevil Maskelyne: Royal Society, London
William Wales: Prince of Wales Fort, Hudson Bay
James Cook and Charles Green: Tahiti
Jeremiah Dixon: Hammerfest, Norway
William Bayley: North Cape, Norway

France
Guillaume Le Gentil: Pondicherry, India
Jean-Baptiste Chappe d’Auteroche: Baja California, Mexico
Alexandre-Gui Pingré: Haiti
Jérôme Lalande: Académie des Sciences, Paris

Sweden
Pehr Wilhelm Wargentin: Royal Academy of Sciences, Stockholm
Anders Planman: Kajana, Finland
Fredrik Mallet: Pello, Lapland

Russia
Catherine the Great: Imperial Academy of Sciences, St Petersburg
Georg Moritz Lowitz: Guryev, Russia

America
Benjamin Franklin: Royal Society, London
David Rittenhouse: American Philosophical Society, Norriton, Pennsylvania
John Winthrop: Cambridge, Massachusetts

Denmark
Maximilian Hell: Vardø, Norway

Prologue

The Gauntlet

The Ancient Babylonians called her Ishtar, to the Greeks she was Aphrodite and to the Romans Venus – goddess of love, fertility, and beauty. She is the brightest star in the night sky and visible even on a clear day. Some saw her as the harbinger of morning and evening, of new seasons or portentous times. She reigns as the ‘Morning Star’ or the ‘Bringer of Light’ for 260 days, and then disappears to rise again as the ‘Evening Star’ and the ‘Bringer of Dawn’.

Venus has inspired people for centuries, but in the 1760s astronomers believed that the planet held the answer to one of the biggest questions in science – she was the key to understanding the size of the solar system.

In 1716 British astronomer Edmond Halley published a ten-page essay[1] which called upon scientists to unite in a project spanning the entire globe – one that would change the world of science forever. On 6 June 1761, Halley predicted, Venus would traverse the face of the sun – for a few hours the bright star would appear as a perfectly black circle. He believed that measuring the exact time and duration of this rare celestial encounter would provide the data that astronomers needed in order to calculate the distance between the earth and the sun.

The only problem was that the so-called transit of Venus is one of the rarest predictable astronomical events.

Transits always arrive in pairs – eight years apart – but with an interval of more than a century before they are then seen again.[fn1] Only once before, Halley said, in 1639, had an astronomer called Jeremiah Horrocks observed the event. The next pair would occur in 1761 and 1769 – and then again in 1874 and 1882.

Halley was sixty years old when he wrote his essay and knew that he would not live to see the transit (unless he reached the age of 104), but he wanted to ensure that the next generation would be fully prepared. Writing in the journal of the Royal Society, the most important scientific institution in Britain, Halley explained exactly why the event was so important, what these ‘young Astronomers’[2] had to do, and where they should view it. By choosing to write in Latin, the international language of science, he hoped to increase the chances of astronomers from across Europe acting upon his idea. The more people he reached, the greater the chance of success. It was essential, Halley explained, that several people at different locations across the globe should measure the rare heavenly rendezvous at the same time. It was not enough to see Venus’s march from Europe alone; astronomers would have to travel to remote locations in both the northern and southern hemispheres to be as far apart as possible. And only if they combined these results – the northern viewings being the counterpart to the southern observations – could they achieve what had hitherto been almost unimaginable: a precise mathematical understanding of the dimensions of the solar system, the holy grail of astronomy.

Halley’s request would be answered when hundreds of astronomers joined in the transit project. They came together in the spirit of the Enlightenment. The race to observe and measure the transit of Venus was a pivotal moment in a new era – one in which man tried to understand nature through the application of reason.

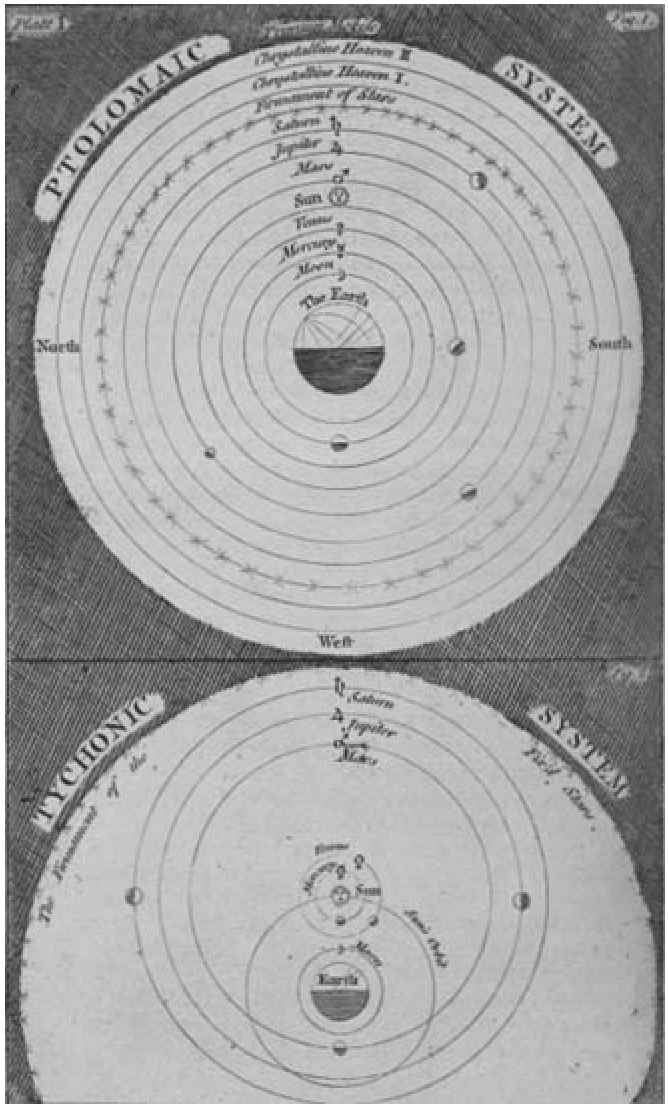
This was a century in which science was worshipped, and myth at last conquered by rational thought. Man began to order the world according to these new principles. The Frenchman Denis Diderot, for example, was amassing all available knowledge for his monumental *Encyclopédie*. The Swedish botanist Carl Linnaeus classified plants according to their sexual organs, and in 1751 Samuel Johnson imposed order upon language when he had compiled the first English dictionary. As new inventions such as microscopes and telescopes opened up previously unknown worlds, scientists were able to zoom in on the minutiae of life and gaze into infinity. Robert Hooke had peered through his microscope to produce detailed engravings of magnified seeds, fleas and worms – he was the first to call the basic unit of biological life a 'cell'. In the North American colonies Benjamin Franklin was experimenting with electricity and lightning rods, controlling what until then had been regarded as manifestations of divine fury. Slowly the workings of nature became clearer. Comets were no longer viewed as portents of God's wrath but, as Halley had shown, predictable celestial occurrences. In 1755 the German philosopher Immanuel Kant suggested that the universe was much larger than his contemporaries believed and that it consisted of uncountable and gigantic '*Welteninseln*'[3] – 'cosmic islands', or galaxies.

Humankind believed it was marching along a trajectory of progress. Scientific societies were founded in London, Paris, Stockholm, St Petersburg, and in the North American colonies in Philadelphia, to explore and exchange this new-found knowledge. Observation, enquiry and experimentation were the building blocks of this new understanding of the world. With progress as the leading light of the century, every generation envied the next. Whereas the Renaissance had looked back upon the past as the Golden Age, the Enlightenment looked firmly to the future.

Halley's idea of using the transit of Venus as a tool to measure the heavens was born out of developments in astronomy over the previous century. Until the early seventeenth century man had observed the sky with his naked eye, but technology was slowly catching up with the reach of his ambitions and theories. Astronomy had changed from a science which mapped stars to one which sought to understand the motion of planetary bodies. In the early sixteenth century Nicolaus Copernicus had proposed the revolutionary idea of the solar system with the sun rather than the earth at the centre, and the other planets moving around it – a model that had been expanded and verified by Galileo Galilei and Johannes Kepler in the early seventeenth century. But it was Isaac Newton's groundbreaking *Principia*, in 1687, which had defined the underlying universal laws of motion and gravity that ruled all and everything. As astronomers gazed at the stars, they were no longer in search of God but of the laws governing the universe.

By the time Halley called upon his fellow astronomers to view the transit of Venus, the universe was regarded as running like a divinely created clockwork according to laws which humankind had only to comprehend and compute. The position and movements of planets were no longer seen as ordained arbitrarily by God but as ordered and predictable, and based on natural laws. But man still lacked the knowledge of the actual size of the solar system – an essential piece of the celestial jigsaw puzzle.

Understanding the dimensions of the heavens had 'always been a principle[4] object of astronomical inquiry', the American astronomer and Harvard professor John Winthrop said in the transit decade. Already in the early seventeenth century Kepler had discovered that by knowing how long it took for a planet to orbit the sun, the relative distance between the sun and the planet could be calculated (the longer it took a planet to orbit the sun, the further away it was).[fn2] From this he had been able to work out the distance between the earth and the sun relative to the other planets – a unit of measurement that became the basis for calculating comparative distances in the universe.[fn3] Astronomers knew, for example, that the distance between the earth and Jupiter was five times that of the distance between the earth and the sun. The only problem was that no one had as yet been able to quantify that distance in more specific terms.



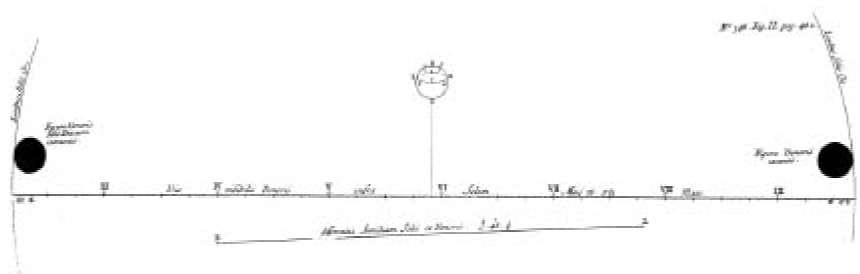
A 1759 depiction of the Ptolemaic and Tychonic planetary systems

Eighteenth-century astronomers had a map of the solar system, but no idea of its true size. Without knowing how far the earth really was from the sun, such a map was all but useless. Venus, so Halley believed, was the key to unlocking this secret. As the brightest star in the sky, Venus became the perfect metaphor for the light of reason that would illuminate this new world and extinguish the last vestiges of the Dark Ages.

Unlike most astronomers whose lives were ruled by the repetitive labour of their nightly observations, Halley had embarked on a far more exciting career – which was probably why he could envisage a global army of swashbuckling astronomers. Not only had he spent one and a half hours in a diving bell[5] submerged almost twenty metres deep in the Thames, he had also undertaken three expeditions[6] to the South Atlantic as the first European to map the southern night sky with a telescope. Halley 'talks, swears, and drinks[7] brandy like a sea captain', a colleague said, but he was also one of the most inspired scientists of his age. He had predicted the return of the eponymous Halley's Comet, produced a map of the southern stars and convinced Isaac Newton[8] to publish his *Principia*.

Knowing that he would not be alive to orchestrate the global cooperation to view Venus's transit – a fact that Halley lamented 'even on his death-bed'[9] whilst holding a glass of wine[10] in his hand – all he could do was to place his trust in future generations and hope that they would remember his instructions half a century hence. 'Indeed I could wish[11] that many observations of this same phenomenon might be taken by different persons at separate places', he wrote. 'I recommend it therefore[12], again and again, to those curious Astronomers who (when I am dead) will have an opportunity of observing these things'.

Halley was asking his future disciples to embark on a project that was bigger and more visionary than any scientific endeavour previously undertaken. The dangerous voyages to remote outposts would take many months, possibly even years. Astronomers would be risking their lives for a celestial event that would last just six hours and be visible only if weather conditions permitted it. The transit would be so short that even the brief appearance of clouds or rain would make accurate observations difficult or even impossible.



Edmond Halley’s drawing of Venus entering and exiting the sun during the transit

In preparation for it, scientists would need to secure funding for the best telescopes and instruments as well as for travel, accommodation and salaries. They would have to convince their respective monarchs and governments to support their individual efforts and would have to coordinate their own observations with those from other countries. Nations locked in battle would have to work together in the name of science for the first time ever. From many dozens of locations, hundreds of astronomers would have to point their telescopes to the sky at exactly the same moment in order to see Venus’s progress across the burning disc of the sun.

And perhaps even more challenging still – though less exhilarating – they must then share their findings. Each observer would have to add his or her observations to the pool of international data. No single result would be of any use without the others. In order to calculate the distance between the sun and the earth, astronomers would have to compare the figures and consolidate the different data into one definitive result. Timings obtained across the world using a disparate range of clocks and telescopes would somehow have to be standardised and made comparable.

The transit of Venus observations were to be the most ambitious scientific project that had ever been planned – an extraordinary undertaking in an era when a letter posted in Philadelphia took two to three months to reach London, and when the journey from London to Newcastle[13] was six days. It took a great leap of the imagination to propose that astronomers should travel thousands of miles into the wildernesses far north and south, laden with instruments weighing more than half a ton.

Their idea of calculating exact distances in space was a bold concept too, considering that clocks were still not accurate enough to measure longitude precisely, and there was as yet no standardised measurement on Earth: an English mile was a different length from a mile in German-speaking countries – which also varied between northern Germany and Austria. A '*mil*' in Sweden was more than ten kilometres, in Norway more than eleven, while a French league could be three kilometres but also as much as four and a half. In France alone there were 2,000 different units of measurement[14] – which varied even between neighbouring villages. In light of this, the idea of merging hundreds of observations taken by astronomers across the world to find one common value seemed outrageously ambitious.

The scientists, who were to leave their observatories in the learned centres of Europe to view Venus from remote outposts of the known world, made for strange adventurers too. At first sight they might not have looked like heroic explorers, but as they chased Venus across the globe they did so with extraordinary intrepidity, bravery and ingenuity. On 6 June 1761 and again on 3 June 1769, several hundred astronomers all over the world pointed their telescopes towards the sky to see Venus travel across the sun. They ignored religious, national and economic differences to unite in what was the first global scientific project. This is their story.

[fn1] Because the orbits of Venus and earth have different inclinations, Venus usually passes above or below the sun (and therefore cannot be seen from the earth). The periods between the pairs of transits alternate between 105 and 122 years. The first transit of Venus observed by an astronomer was on 4 December 1639. The next transits were on 6 June 1761, 3 June 1769, 9

December 1874 and 6 December 1882. There was no transit in the twentieth century but two in the twenty-first – on 8 June 2004 and 6 June 2012. It will be another 105 years until the transit of 11 December 2117.

[fn2] This was Kepler's third law which said that 'the square of the orbital period of a planet is directly proportional to the cube of the semi-major axis of its orbit'. In simpler terms it means that Kepler had provided a mathematical formula which could be used to calculate the relative distances in the solar system by using the radius of a planet and the time it took to orbit the sun.

[fn3] The distance between the earth and the sun became the base unit for measuring distances in the universe – it is 1 AU (1 Astronomical Unit). As such the distance between Jupiter and the sun was 5 AU and between Earth and Venus 0.28 AU.

Part 1

Transit 1761

1
Call to Action

BY THE MID-EIGHTEENTH century, at the beginning of the transit decade, the commercial empires of the European countries stretched across the globe. International travel was possible along the established trade routes to distant destinations in the East and West Indies,[fn1] Africa and Brazil. Britain controlled much of the eastern seaboard of the North American continent as well as parts of India, some Caribbean islands and Sumatra in Indonesia. France counted among her possessions Canada and Louisiana as well as plantations in India, sugar-producing colonies such as Haiti and St Lucia, and some islands in the Indian Ocean, while the Dutch organised much of their East India trade from Jakarta and ports at Galle in Sri Lanka and the Cape of Good Hope in South Africa.

But voyagers would also face great dangers: since 1756 much of Europe had been embroiled in the Seven Years' War. The political conditions made the transit expeditions perilous enterprises. As scientists from France, Britain, Sweden, Germany, Russia and elsewhere were planning their international cooperation, their armies were fighting bloody battles against each other in the forests of Saxony, on the coast of the Baltic Sea, in the wilderness of the Ohio valley and in India. Rival fleets criss-crossed the oceans from Guadeloupe to Mauritius, engaging in attacks as far away as Pondicherry and Manila but also closer to home in the Mediterranean and the Atlantic.

The war had its origins in the old European conflicts between the Hohenzollerns in Prussia and the Habsburgs in Austria, and in the ongoing imperial contest between Britain and the House of Bourbon which ruled France and Spain. Britain and Prussia were fighting against France who was allied with Russia, Austria and Sweden. Not only political power was at stake, but also trading and commercial ventures: possession of the North American colonies, of India, the slave trade in West Africa and the valuable sugar-producing islands of the West Indies. As Europeans expanded their world, so did their warfare. It was the first global war – tearing apart Europe and its colonial outposts across the world. It was amid these turbulent times that the astronomers would have to travel on their ambitious quest.

On 30 April 1760, seventy-two-year-old Joseph-Nicolas Delisle, the official astronomer to the French Navy,[fn2] walked to a meeting of the Académie[1] des Sciences in Paris. Every Wednesday, academicians who studied in the fields of mathematics and astronomy assembled there to discuss experiments, projects and current research. Delisle only had a short distance to travel. The Académie's rooms were in the Louvre, about a mile across the Seine from his small observatory at the Hôtel de Cluny, the administrative centre of the Royal Navy. The streets were narrow but, as Benjamin Franklin remarked a few years later, 'fit to walk'[2] and kept clean by daily sweeping. They were lined with large houses and busy with people on foot and in coaches. Men and women hawked their wares from stalls – everything from brooms to oysters and from eggs to cheese and fruit. Cobblers, knife grinders and pedlars shouted at the passers-by, offering their services. People 'of all sorts[3] & condition' mingled here, one traveller noted in surprise –

from pickpockets to a ‘Prince of Blood[4]’. It was, Franklin said, ‘a prodigious Mixture[5] of Magnificence and Negligence’ – others were harsher and called it the ‘ugliest, beastly town[6] in the universe’.

Delisle crossed the river by the Pont Neuf, a sturdy stone bridge famed as the haunt of performers, quacks and tooth-pullers. The bridge was to the city, one Parisian said, ‘what the heart[7] was to the body: the centre of movement and circulation’. Turning left, Delisle faced the imposing facade of the Louvre at the next corner.

France at that time was ruled by Louis XV, a king who had succeeded to the throne in 1715 at the age of five. He adored astronomy, and regularly attended scientific demonstrations in Versailles, even allowing himself to become electrically charged. His great-grandfather Louis XIV had founded the Académie des Sciences[8] in Paris in the previous century to promote science (and its practical uses) and the glory of his reign. Over the past century, academicians had met there to discuss a wide range of scientific subjects, from the study of insects and comets to practical inventions such as hydraulics to power the fountains in Versailles or pumps to clean harbours. The Académie was the most important scientific institution in the country and its members were the best scientists – to be elected as a ‘membre de l’Académie’[9] was the greatest scientific honour and the academicians wore their title proudly like a badge of nobility.

The paper that Delisle was about to present would place the academicians at the nexus of the greatest scientific project that had ever been planned. He was going to ask his colleagues to take up the gauntlet thrown down by Edmond Halley forty-four years previously: to set in motion an international collaboration to observe the transit of Venus due to occur one year later, on 6 June 1761.

Halley[10] had propounded the revolutionary idea that Venus’s transit could be used as a natural astronomical