

# Halley as an eclipse pioneer: his maps and observations of the total solar eclipses of 1715 and 1724

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## Abstract

Total solar eclipses crossed England in 1715 and 1724, and Edmond Halley took advantage of the occasions to make broadside maps in order to solicit observations and to summarize the results. His articles in *Philosophical Transactions of the Royal Society* turn out to represent early references to phenomena usually associated with later observers. This article describes reports and maps by Halley and by other scientists of the time, including William Whiston. The Houghton Library of Harvard University and the Royal Astronomical Society of London, between them, own copies of all these maps. The maps drawn by Halley and Whiston for the 1724 eclipse are surprisingly similar to a modern map drawn for the 1999 August 11 total solar eclipse.

**Key words:** *solar eclipses, Edmond Halley, maps, history, England*

## 1 INTRODUCTION

Though principally associated in the public mind with comets (Olson and Pasachoff, 1997), Halley was a polymath with major discoveries in a variety of fields, as described in a major new biography (Cook, 1998). His observations and observations of others that he solicited for the 1715 and 1724 total solar eclipses are still valuable for studies of possible secular changes in size of the Sun, a topic with implications for global warming.

In 1715, ten years after his seminal work on comets, Halley drew a map showing the predicted path of a total solar eclipse. Gingerich (1992) has written that this 1715 map was the first to show the view from above the path of a total eclipse (see also Pasachoff, 1999). Armitage (1997) describes how Halley's maps were a substantial improvement on the crude maps shown earlier that appeared as part of larger maps, and also shows William Whiston's graphical predictions of the same eclipse, which do not show the comparison with a map showing the geography. (Whiston was Newton's successor as Lucasian Professor at Cambridge University.) Armitage also describes a map of this eclipse by Joseph Crosthwait, an assistant of Flamsteed. Dopplemayr (1742) shows two views from above of the path of the 1706 eclipse that crossed Europe, but the date at which these maps were drawn is not clear.

The Houghton Library of rare books at Harvard University has four versions of Halley eclipse maps. The library of the Royal Astronomical Society in London has three of the four maps as well as another map of the 1724 path by William Whiston, a rival of Halley. These maps are broadsides, printed on one side of single sheets of paper. Broadsides survive less often than printed books, since they were not as obviously worthy of preservation. Roberta J M Olson, an art historian, and I (Olson and Pasachoff, 1989) have discussed German broadsides from the two centuries before Halley's, and their use for describing comets.

## 2 THE PREDICTIONS OF 1715

Halley's first map (Figure 1) is headed: "A Description of the Passage of the Shadow of the Moon over England, In the Total Eclipse of the Sun, on the 22<sup>d</sup> Day of April 1715 in the Morning."

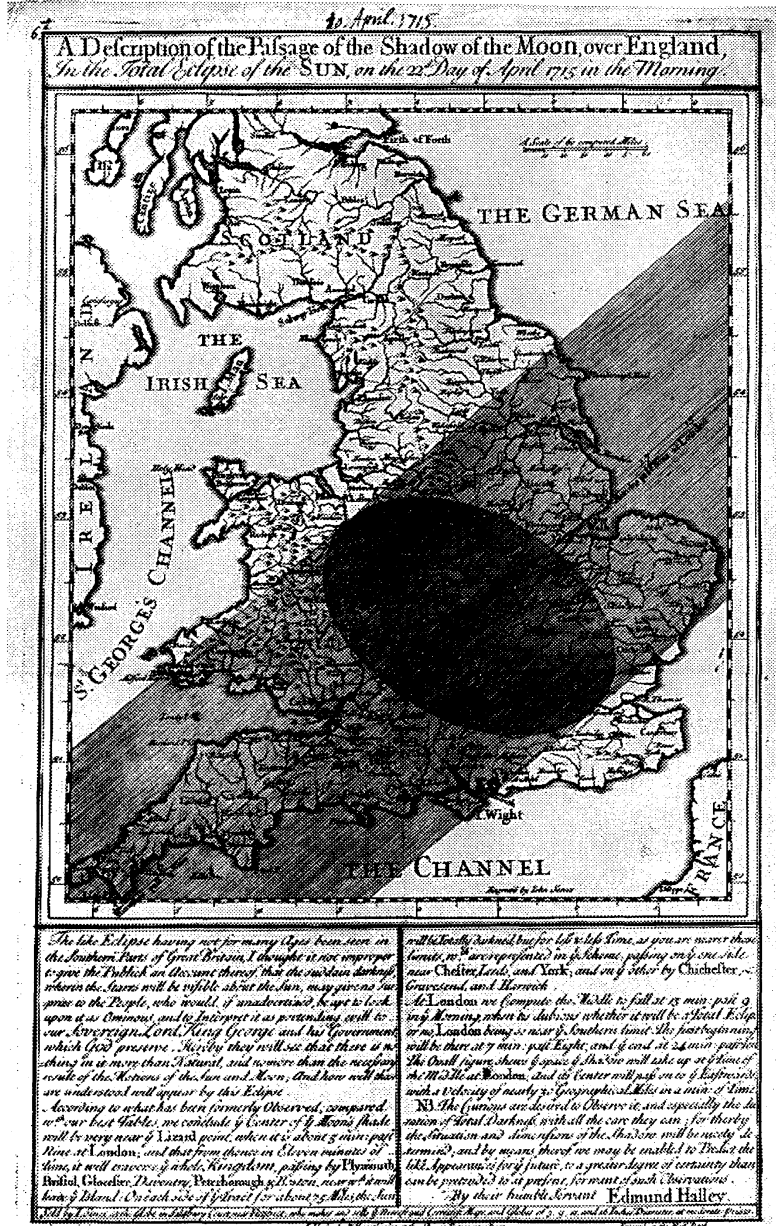


Figure 1. Drawn before the 22 April 1715 total eclipse, the figure shows Halley's predicted path of totality. (With the permission of the Houghton Library, Harvard University. EB7 H1552 715d)

Halley shows the oval shape of totality at a given instant, while also showing the path which that oval traces out. Text below the map describes:

The like Eclipse having not for many Ages been seen in the Southern Parts of Great Britain, I thought it not improper to give the Publick an Account thereof, that the suddain darkness, wherin the Starrs will be visible about the Sun, may give no surprize to the People, who would, if unadvertized, be apt to look upon it as Ominous, and to Interpret it as portending evill to our Sovereign Lord King George and his Government, which God preserve. Hereby they will see that there is nothing in it more than Natural, and no more than the necessary result of the Motions of the Sun and Moon; And how well those are understood will appear by this Eclipse.

According to what has been formerly Observed, compared w<sup>th</sup> our best Tables, we conclude y<sup>e</sup> Center of y<sup>e</sup> Moon's shade will be very near y<sup>e</sup> *Lizard* point, when it is about 5 min: past Nine at *London*; and that from thence in Eleven minutes of Time, it will traverse y<sup>e</sup> whole Kingdom, passing by *Plymouth, Bristol, Gloucester, Daventry, Peterborough, & Boston*, near which it will leave y<sup>e</sup> Island: On each side of y<sup>e</sup> Tract for about 75 Miles, the Sun will be Totally darkned; but for less & less Time, as you are nearer those limits, w<sup>ch</sup> are represented in y<sup>e</sup> Scheme, passing on y<sup>e</sup> one side near *Chester, Leeds, and York*; and on y<sup>e</sup> other by *Chichester, Gravesend, and Harwich*.

At *London* we Compute the Middle to fall at 13 min: past 9 in y<sup>e</sup> Morning, when 'tis dubious whether it will be a Total Eclipse or no, *London* being so near y<sup>e</sup> Southern limit. The first beginning will be there at 7 min: past Eight, and y<sup>e</sup> end at 24 min: past Ten. The Ovall figure shews y<sup>e</sup> space y<sup>e</sup> Shadow will take up at y<sup>e</sup> Time of the Middle at *London*; And its Center will pass on to y<sup>e</sup> Eastwards, with a Velocity of nearly 30 Geographical Miles in a min: of Time.

NB The Curious are desired to Observe it, and especially the duration of Total Darkness, with all the care they can; for therby the Situation and dimensions of the Shadow will be nicely determin'd; and by means therof, we may be enabled to Predict the like Appearances for y<sup>e</sup> future, to a greater degree of certainty than can be pretended to at present, for want of such Observations.

By their humble Servant *Edmund Halley*

The map was engraved and sold by John Senex, whose role as an intermediary between astronomers of that day is described by Armitage (1997). Senex is not only credited at the bottom of the map but also provides purchasing information: "Sold by J. Senex, at the Globe in Salisbury Court, near Fleetstreet; who makes, and sells ye Newest and Correctest Maps, and Globes of 3, 9, 12, and 16 Inches Diameter, at moderate Prises. Sold also by William Taylor at the Ship in Paternoster Row. Entered in the Hall Book."

The Houghton copy of this map is dated 10. April. 1715 and priced at sixpence in a contemporary handwriting, reported by Gingerich (1992:154) to be that of Narcissus Luttrell, an 18th-century collector of ephemera. In Golub and Pasachoff (1997:26), we reproduced the Royal Astronomical Society print of this map.

### 3 HALLEY'S POST-ECLIPSE DESCRIPTIONS

Halley's first article in the *Philosophical Transactions* for later in 1715 (Halley, 1715a) was entitled "*Observations of the late Total Eclipse of the Sun on the 22d of April last past ... With an Account of what has been communicated from abroad concerning the same.*" (See Figure 2.) He wrote,

Though it be certain from the Principles of Astronomy, that there happens necessarily a Central Eclipse of the Sun in some part or other of the Terraqueous Globe, about Twenty Eight times in each Period of Eighteen Years; and that of these no less than Eight do pass over the Parallel of London ... it has so happened that since the 20th of March, Anno Christi 1140, I cannot find that there has been such a thing as a Total Eclipse of the Sun seen at London, though in the mean time the Shade of the Moon has often past over other Parts of Great Britain.

(Williams, 1996, has provided calculations on maps for all such eclipses from the year AD 1 to the present.)

Halley describes his reasoning in printing his map:

The Novelty of the thing being likely to excite a general Curiosity, and having found, by comparing what had been formerly observed of Solar Eclipses, that the whole Shadow would fall upon England, I thought it a very proper opportunity to get the Dimensions of the Shade ascertained by Observation; and accordingly I caused a small Map of England, describing the Track and Bounds thereof, to be dispersed all over the Kingdom, with a Request to the Curious to observe what they could about it, but more especially to note the Time of Continuance of total Darkness, as requiring no other Instrument than a Pendulum Clock with which most Persons are furnish'd, and as being determinable with the utmost Exactness, by reason of the momentaneous Occultation and Emersion of the luminous Edge of the Sun, whose least part makes Day.

III. *Observations of the late Total Eclipse of the Sun on the 22d of April last past, made before the Royal Society at their House in Crane-Court in Fleet-Street, London. By Dr. Edmund Halley, Reg. Soc. Secr. With an Account of what has been communicated from abroad concerning the same.*

THOUGH it be certain from the Principles of Astronomy, that there happens necessarily a Central Eclipse of the Sun in some part or other of the Terraqueous Globe, about Twenty Eight times in each Period of Eighteen Years; and that of these no less than Eight do pass over the Parallel of *London*, Three of which Eight are Total with continuance: yet, from the great Variety of the Elements whereof the *Calculus* of Eclipses consists, it has so happened that since the 20th of *March, Anno Christi 1140*, I cannot find that there has been such a thing as a Total Eclipse of the Sun seen at *London*, though in the mean time the Shade of the Moon has often past over other Parts of *Great Britain*.

The Novelty of the thing being likely to excite a general Curiosity, and having found, by comparing what had been formerly observed of Solar Eclipses, that the whole Shadow would fall upon *England*, I thought it a very proper Opportunity to get the Dimensions of the Shade ascertained by Observation; and accordingly I caused a small Map of *England*, describing the Track and Bounds thereof, to be dispersed all over the Kingdom, with a Request to the Curious to observe what they could

Figure 2. From Halley's article in the *Philosophical Transactions of the Royal Society* (1715a).

Halley continues with a check on his predictions. Note that it is still 43 years before the return, as he predicted ten years before this eclipse paper, of the comet that now bears his name, so it was very valuable to him to have some satisfactory report on the results of his astronomical calculations.

... for the Heavens having proved generally favourable, we have received from so many Places so good Accounts, that they fully answer all our Expectations, and are sufficient to establish several of the Elements of the Calculus of Eclipses, so as for the future we may more securely rely on our Predictions; though it must be granted, that in this our Astronomy has lost no Credit.

Halley's own observations could not have better matched his predictions:

Having computed that the Eclipse would begin at 8h.7', I attended soon after Eight with a very good Telescope of about Six Foot, without stirring my Eye from that part of the Sun whereat the Eclipse was to begin: and at 8h.6'.20". by the Clock, I began to perceive a small Depression made in the Sun's Western Limb, which immediately became more conspicuous; so that I concluded the just Beginning not to have been above five Seconds sooner; that is, exactly at 8<sup>h</sup>.6'00" correct Time.

Just as photographs today do not do justice to the overall feeling of being outdoors during the atmospheric changes during an eclipse, Halley noticed the importance of the colours: "From this time the Eclipse advanced, ... when the Face and Colour of the Sky began to change from perfect serene azure blew, to a more dusky livid Colour having an eye of Purple intermixt, and grew darker and darker till the total Immersion of Sun, which hapened [sic] at 9<sup>h</sup>.9'.17". by the Clock, or 9<sup>h</sup>.9'.3". true time."

Halley wrote,

This Moment was determinable with great nicety, the Sun's light being extinguish'd at once; and yet more so was that of the Emersion, for the Sun came out in an Instant with so much Lustre that it surprized the Beholders, and in a Moment restored the Day ... And as near as I could estimate the Points on the Moon's Limb: where the last Particle of the Sun vanished was about the middle of the South East Quadrant of her Limb, or about 45 Degrees from her Nadir to the Left-Hand: And the first Emersion was about Ten Degrees below the Horizontal Line through the Moon's Center on the West side ...

Halley's comments seem to mark the discovery of what we now know as Baily's beads, here described as "Points on the Moon's Limb"; the first mention of these Baily's beads is generally thought to be later in time (Jones and Boyd, 1971:24; quoted in Golub and Pasachoff, 1997; credit it to Samuel Williams of Harvard, who observed the eclipse from behind the enemy – British – lines at the American eclipse of 1780). Meadows (1970), in his definitive history of solar physics, states that at an annular eclipse in the 1830's, Francis Baily observed "a string of bright points along the limb of the Moon ... This phenomenon, which he attributed to the effect of sunlight shining between lunar mountains is usually referred to as Baily's beads. Although it had been observed before, the earlier accounts had been generally forgotten ..." Such beads were quite visible at the 1999 February 16 99% annular eclipse, as observed from Greenough, Western Australia.

The "last Particle of the Sun" corresponds to what we now call the Diamond Ring effect, first apparently named in 1925. Morris (1999) cites the *The Globe* (Toronto) for January 26, 1925, as reporting:

... said Dr. Russell. 'We astronomers were at fault in failing to emphasize more strongly that the spectator should use his naked eye for seeing the eclipse at totality and a second or so before and after' ... the light comes from a very small point, but the eye exaggerates it into a ball of light. This was spontaneously called 'the diamond ring' by numbers of observers in New York, and this term, hitherto unknown by astronomers, was apparently fixed forever as a technical term in the literature of the subject by Saturday night. 'It is a beautiful and perfect description of the effect,' said Dr. Russell.

*The New York Times* for January 25, 1925, uses a headline stating "Awed by Jewel of Light Hanging from Luminous Ring," and describes "A thin, luminous ring, set with a great gem of soft-burning light, hung in the eastern sky yesterday morning ... For several seconds the jewel sparkled with a pure and mild radiance, then trembled and melted into the circle of the light which rimmed the inky disk of the moon. The total eclipse had come ... The ring, with its gorgeous solitaire ..." But *The New York Times* did not explicitly use the term "diamond ring."

Halley did not know that the Moon has essentially no atmosphere.

... my Eye could not endure the Splendour of the emerging Beams in the Telescope from the first Moment. To this perhaps two Causes concurred; the one, that the Pupil of the Eye did necessarily dilate it self during the Darkness, which before had been much contracted by looking on the Sun. The other, that the Eastern parts of the Moon, having been heated with a Day near as long as Thirty of ours, could not fail of having that part of its Atmosphere replete with Vapours, raised by the so long continued action by the Sun; and by consequence it was more dense near the Moons [sic] Surface, and more capable of obstructing the Lustre of the Sun's Beams. Whereas at the same time the Western Edge of the Moon had suffered as long a Night, during which there might fall in Dews all the Vapours that were raised in the preceeding long Day; and for that reason, that part of its Atmosphere might be seen much more pure and transparent. But from whatever cause it proceeded, the thing it self was very manifest and noted by every one."

Would that we could show Halley the videos from the Apollo moon-landings of 1969-1972, showing the dark, airless sky of the Moon. Halley figured out the cause of the Baily's beads:

About two Minutes before the Total Immersion, the remaining part of the Sun was reduced to a very fine Horn, whose Extremities seemed to lose their Acuteness, and to become round like Stars. And for the Space of about a Quarter of a Minute, a small Piece of the Southern Horn of the Eclipse seemed to be cut off from the rest by a good interval ...: which Appearance could proceed from no other Cause but the Inequalities of the Moon's Surface, there being some elevated parts thereof near the Moon's Southern Pole, by whose Interposition part of that exceedingly fine Filament of Light was intercepted.

Nowadays, we often describe the corona as being "pearly white" in colour. Perhaps that description originated here, with Halley:

A few Seconds before the Sun was all hid, there discovered it self round the Moon a luminous Ring, about a Digit or perhaps a tenth Part of the Moons [sic] Diameter in Breadth. It was of a pale whiteness or rather Pearl colour. seeming to me a little tinged with the Colours of the Iris, and to be concentrick with the Moon, whence I concluded it the Moon's Atmosphere.

So Halley gave reasons for his wrong conclusion about the Moon's atmosphere, even while going on to show that his instincts were correct and that his scientific caution was admirable:

But the great height thereof far exceeding that of our Earth's Atmosphere; and the Observations of some, who found the Breadth of the Ring to encrease on the West Side of the Moon, as the Emersion approached; together with the contrary Sentiments of those whose Judgment I shall always revere, makes me less confident, especially in a Matter whereto, I must confess, I gave not all the Attention requisite.

Halley's description of the corona remains a good one, even for our times.

Whatever it was, this Ring appeared much brighter and whiter near the Body of the Moon than at a Distance from it; and its outward Circumference, which was ill defined, seemed terminated only by the extream Rarity of the Matter it was composed of; and in all Respects resembled the Appearance of an enlightned Atmosphere viewed from far: but whether it belonged to the Sun or Moon I shall not at present undertake to decide.

Halley went on to describe what we now call the solar chromosphere, though following a mention of flashes of light that have no current context:

... I found that there were perpetual Flashes or Coruscations of Light, which seemed for a Moment to dart out from behind the Moon, now here, now there, on all Sides ... And about two or three Seconds before it [the Emersion], on the same Western Side where the Sun was just coming out, a long and very narrow Streak of a dusky but strong Red Light seemed to colour the dark Edge of the Moon; tho' nothing like it had been seen immediately after the Immersion. But this instantly vanished upon the first Appearance of the Sun, as did also the aforesaid luminous Ring.

I have often commented how the appearance of the horizon during a total eclipse looks like a 360 degree sunset, and I see that I was anticipated by Halley, who wrote, "... the under Parts of the Hemisphere, especially in the South East, under the Sun, had a crepuscular brightness: and all round us, so much of the Segment of our Atmosphere as was above the Horizon and was without the Cone of the Moon's Shadow, was more or less enlightened by the Sun's Beams ..." Perhaps Halley felt competition with the Astronomer Royal, a position he was in the future to assume, for he wrote, after describing another person's observations, "The near Agreement of this Observation with our own (the Difference being only what is due to the Difference of our Meridians) makes us the less solicitous for what was noted at the Royal Observatory at Greenwich, from whence we can only learn that the Duration of Total Darkness was 3'.11". Neither was Halley too kind, accurate as his statements may have been, to his colleagues at Oxford and Cambridge:

Our Professors of Astronomy in both Universities were not so fortunate: My worthy Colleague Dr. John Keill by reason of Clouds saw nothing distinctly at Oxford but the End, which he observed at 10<sup>n</sup>.15'.10". As to the total Darkness, he could only estimate it by the sudden Change of the Light of the Sky; and reckoned its Continuance but 3'.30"; which was certainly too little, the Center of the Shadow having without doubt past very near Oxford. And the Reverend Mr. Roger Cotes at Cambridge had the misfortune to be opprest by too much Company, so that, though the Heavens were very favourable, yet he miss'd both the time of the Beginning of the Eclipse and that of total Darkness."

Halley sent a message to us for this summer's eclipse:

As for the Limits of the Shade, both on the North and South side, we have by Enquiry gotten them with all the Exactness the thing is capable of, and we should have been glad the French Astronomers had done the like for the Total Eclipse that past over Languedoc, Provence and Dauphiny on the First of May 1706. But as this is the first Eclipse of this kind that has been observed with the Attention the Dignity of the Phænomenon requires, we hope those which may happen for the future to traverse Europe, may not pass by so little regarded as hitherto.

Halley even described non-astronomical phenomena that are so familiar to eclipse observers: "I forbear to mention the Chill and Damp which attended the Darkness of this Eclipse, of which most Spectators were sensible, and equally Judges. Nor shall I trouble you with the Concern that appear'd in all Sorts of Animals, Birds, Beasts, and Fishes upon the Extinction of the Sun, since our selves could not behold it without some sense of Horror."

A second, shorter eclipse article in *Philosophical Transactions* (Halley, 1715b) provides further information: "Since the Publication of the large Account we gave in Phil. Trans. No. 343 of what was observed in England, and particularly at London, of this Eclipse, we have received from foreign Parts the following Observations; which seem not unworthy the Acceptance of the Curious." Observations follow from at sea near Teneriffe, Nuremburg, Hamburg, Kiel, Berlin, Frankfort, and the Hague. Observations were limited to timing, with no description of the appearance of the sun. Only the conclusion is non-mathematical: "As to the Darkness, it was such that they could scarce distinguish one another: and besides Jupiter, Mercury and Venus; of the Fixt Stars Cassiopea, Capella, Oculus Tauri and Orion (Sirius not being yet risen) were visible."

#### 4 THE ACTUAL ECLIPSE PATH OF 1715

After the eclipse, Halley plotted the actual path on a new engraving (Figure 3). [Williams (1996) draws this actual path as a dotted line on the original map.] Halley discussed his own observations and those of others in the *Philosophical Transactions of the Royal Society* (1715a). He modified the broadside to read, "A Description of the Passage of the Shadow of the Moon over England as it was Observed in the late Total Eclipse of the Sun April 22d: 1715 Manè."

Gingerich (1992) discusses the difference in the actual path from the predictions of Halley and of Whiston. Dunham *et al.* (1980) reported a possible change in the size of the sun based on changes in the widths of eclipse paths between the observations collected by Halley in 1715 and those collected by their group from grazing eclipse paths viewed from the edges of totality and Ribes *et al.* (1987) reported a change based on old observations made at the Paris Observatory. Pasachoff and Nelson (1987), though, found from my timing of the duration of totality at the 1984 eclipse in Hula, Papua New Guinea, that the predictions and timing of the beads are too uncertain to allow the method to be reliably used. Morrison, Stephenson, and Parkinson (1988) used their own observations and also did not confirm that the sun's diameter had changed measurably since 1715.

Notable on the post-eclipse 1715 map is the addition of the predicted path for the forthcoming 1724 eclipse. The new text says,

Since the Publication of our Predictions of this Eclipse has had the desired effect, and many curious Persons have been excited thereby to communicate their Observations from most parts of the Kingdom; we thought it might not be unacceptable to represent after the same manner the passage of the Shade,



as it really happened; whereby it will appear that tho' our Numbers pretend not to be altogether perfect, yet the correction they need is very small.

At London the Eclipse was carefully Observed to begin at 8<sup>h</sup>.6' manè, and to become Total at 9<sup>h</sup>.9'. It continued Total 3'.23", and ended at 10<sup>h</sup>.20'. And by the Accounts we have received from Abroad, the Center of the Shade past nearly over Plymouth, Exeter, Buckingham and Huntingdon, leaving Bath and Lynn a little on the left, and Oxford and Ely on the right. The Southern limit past over Cranbrook in Kent, leaving Newhaven and Canterbury a very little without: And the Northern limit entered on the Coast of Wales in S. Bride's-bay, & left England near Flamborough-head, all which the Map more particularly describes. The greater diameter of y<sup>e</sup> Shade having been 170 Geog:Miles or Minutes, and ye lesser 110.



Figure 3. Drawn soon after the 22 April 1715 total solar eclipse, Halley's map shows the eclipse's actual path. The predicted path of the 1724 eclipse has been added. (With the permission of the Houghton Library, Harvard University. EB7 H1552 715d2)

The Numbers on the middle parallel line, as in our former, denote y<sup>e</sup> place of y<sup>e</sup> Center of y<sup>e</sup> Shade at so many minutes past Nine at *London*. By help of this and of y<sup>e</sup> other diameter of y<sup>e</sup> shaded Oval (conjugate to y<sup>e</sup> on[e] w<sup>th</sup> y<sup>e</sup> Center moved) passing over y<sup>e</sup> places where the greatest Obscurity was at y<sup>e</sup> same instant as at *London*, we may very nearly find y<sup>e</sup> time of y<sup>e</sup> greatest darkness at any other place on y<sup>e</sup> Map. For drawing a line parallel to this conjugate diameter thro' y<sup>e</sup> proposed place, it will cross y<sup>e</sup> way of y<sup>e</sup> Shade at y<sup>e</sup> minute of y<sup>e</sup> greatest Obscurity reckon'd as at *London*, and by allowing y<sup>e</sup> difference of Meridians, at y<sup>e</sup> place itself. Thus for example, the greatest Eclipse will be found at *York* at 9<sup>h</sup>.10', at *Dublin* 8<sup>h</sup>.42' ½, at *Brest* 8<sup>h</sup>.43' ½. After y<sup>e</sup> same manner may y<sup>e</sup> time of Total Darkness be had, by drawing a line parallel to y<sup>e</sup> way of y<sup>e</sup> Shade by y<sup>e</sup> Place propos'd: For as much of that line as falls within y<sup>e</sup> shadowed Oval, measur'd on the Scale of minutes, will shew how long that place continu'd within the true Shade quam proxima.

We give you likewise y<sup>e</sup> Transit of y<sup>e</sup> Shade, as it will pass over y<sup>e</sup> West of *England* in y<sup>e</sup> Eclipse y<sup>t</sup> will be Anno 1724 May 11.P.M. in w<sup>ch</sup> ye Northern limit passes very near *Dublin & Oxford*. But it will scarce reach *London* where it begins at 5<sup>h</sup>.39', is greatest at 6<sup>h</sup>.35' ½, and ends at 7<sup>h</sup>.27' ½ in the Evening.

The credit reads, "Engrav'd and Sold by John Senex at the Globe in Salisbury Court near Fleetstreet."

## 5 PREPARING FOR THE 1724 ECLIPSE

In 1722, Halley (1722) reported, in Latin, timing of a partial eclipse he observed. Observations by others, described in English, followed.

Prior to the 1724 total eclipse, he released another copy of his earlier map (Figure 4). The heading was the only item changed, being transformed to read:

"A Description of the Passage of the Shadow of the Moon over England In the Total Eclipse of the Sun on the 11<sup>th</sup> day of May 1724 in the Evening. Together with the Passage of the Shadow as it was Observ'd in the last Total Eclipse of 1715. By D<sup>r</sup>.E. Halley, R.S.S. Astro<sup>r</sup>:Roy<sup>l</sup>." Halley was Royal Society Secretary (R.S.S.) as well as Astronomer Royal. The credit caption is also slightly different, representing only a change in location of the same publisher: "Engrav'd and Sold by John Senex at the Globe ag<sup>t</sup>. S<sup>t</sup>. Dunstons Church Fleetstreet." The Houghton copy of this map dated, in the same hand as before, "Novemb. 1723." It sold for only fivepence (5<sup>d</sup>).

## 6 PATH OF THE 1724 ECLIPSE

Halley completely redrew his map prior to the 1724 eclipse (Figure 5). London was just north of the path of totality. The new map shows the Continent as far as Venice, which was on the centre line of totality. The ellipse of totality is no longer shown. Gingerich (1992) describes how William Whiston, who had succeeded Isaac Newton in his professorial chair at Cambridge, had made predictions showing the path about 40 km farther north, but how the actual path had gone approximately midway between Halley's and Whiston's predictions.

The text below the map is much shorter, referring to an eclipse that had been visible over the Continent but not the British Isles. (The previous total eclipses visible from parts of England were, barely, in 1652 and, also in the west only, in 1598.) The text stated:

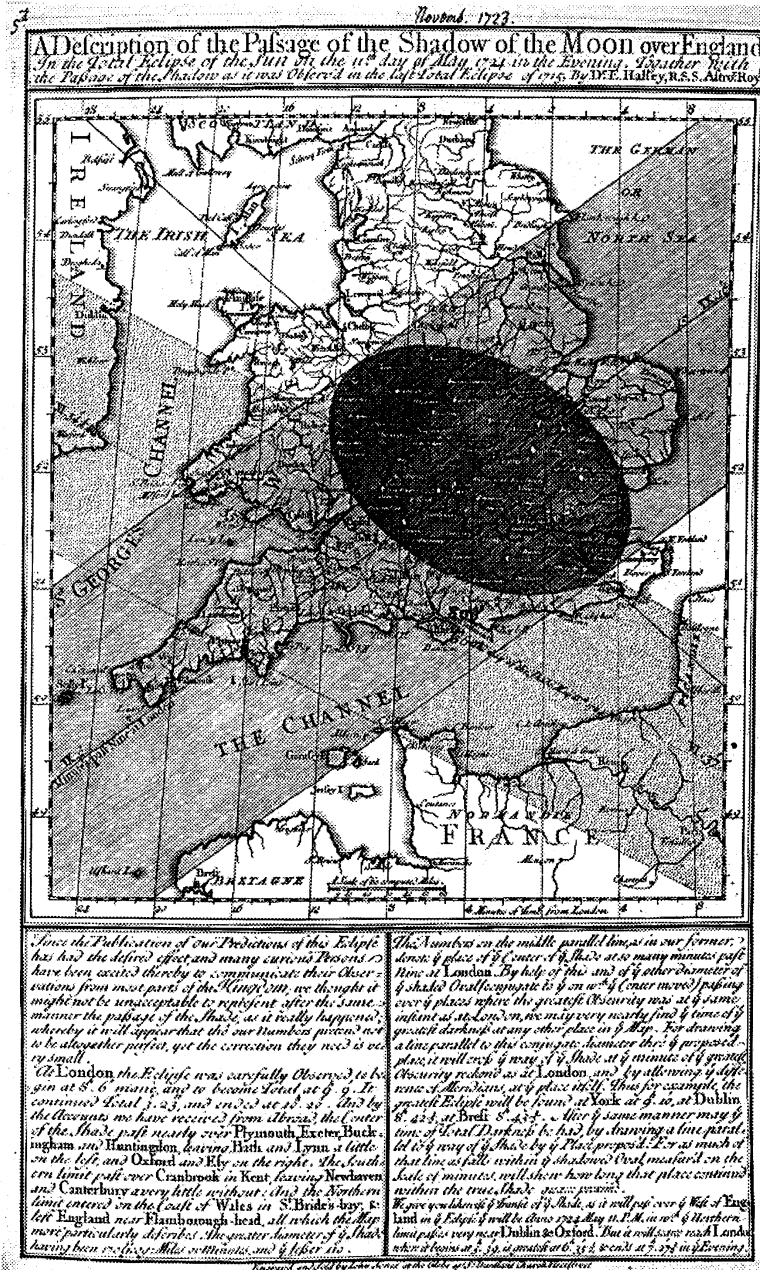


Figure 4. Reprinted shortly before the 1724 eclipse, Halley's map is changed only in the accompanying written text since its 1715 publication. (With the permission of the Houghton Library, Harvard University. EB7 H1552 715d2b)

"This Eclipse being the Return of that wherein the Shadow past over Europe on the first of May 1706, and which was curiously Observed in several Places; we presume the Description we give of it may be very near the Truth, as far at least as the Geographical Mapp may be depended upon. Where it shall be Observed with proper Instruments and due care, we may be assured of the Longitude of those Places; And in order further to perfect our Science, 'tis hoped the Curious that may happen to be near the Limits of the total Shade, where the Sun will be missing but a few Seconds, will be so kind as to transmit their Observations of y<sup>e</sup> continuance of Totality; there being nothing requisite thereto, but to count y<sup>e</sup> Vibrations of y<sup>e</sup> Pendulum Clock, whilst y<sup>e</sup> Sun is absent. The Mapp shows where we expect it, y<sup>e</sup> Northern

edge of y<sup>e</sup> Shade leaving Dublin Oxford & London very little w<sup>h</sup>out it, & y<sup>e</sup> Souther<sup>n</sup> limit including Cork & Kinsale in Ireland, & in England Plymouth & Dartmouth. At London we compute y<sup>e</sup> Beginning at 5<sup>h</sup>.40'.P.M. y<sup>e</sup> Middle when it will be nearly Total at 6<sup>h</sup>.37'. & y<sup>e</sup> End 7<sup>h</sup>.29'. We wish our Astronomical Friends a Clear Sky.

The same publisher did this map from the same address: "Engrav'd and Sold by John Senex at the Globe against S<sup>t</sup>. Dunstons Church in Fleetstreet. Price 1<sup>s</sup>." The Houghton copy is dated in hand about two weeks before the eclipse, and priced at tenpence (10<sup>d</sup>) Since one shilling was 12 pence, perhaps our purchaser of the time was given a slight discount from the list price. One of the pre-eclipse 1715 maps sold at the auction of the Haskell F. Norman Library of Science and Medicine: Part 2, The Age of Reason, at Christie's (1998) in New York on June 15-16, 1998, for a total price of over \$15,000 (Lot 493, 455x285 mm, \$13,800 plus buyer's premium), far exceeding the pre-auction estimate of \$1,500-2,000.

William Whiston's map of the 1724 eclipse (Figure 6) is dated, in the engraving, April 27, 1724. It is labelled "The Transit of the Total Shadow of the Moon over Europe in the Eclipse of the Sun May 11<sup>th</sup>. 1724. in the Evening, described by Will. Whiston M.A." Times of the eclipse for various locations are printed at the bottom of the map, with times of the partial eclipse visible at London printed on the left side.

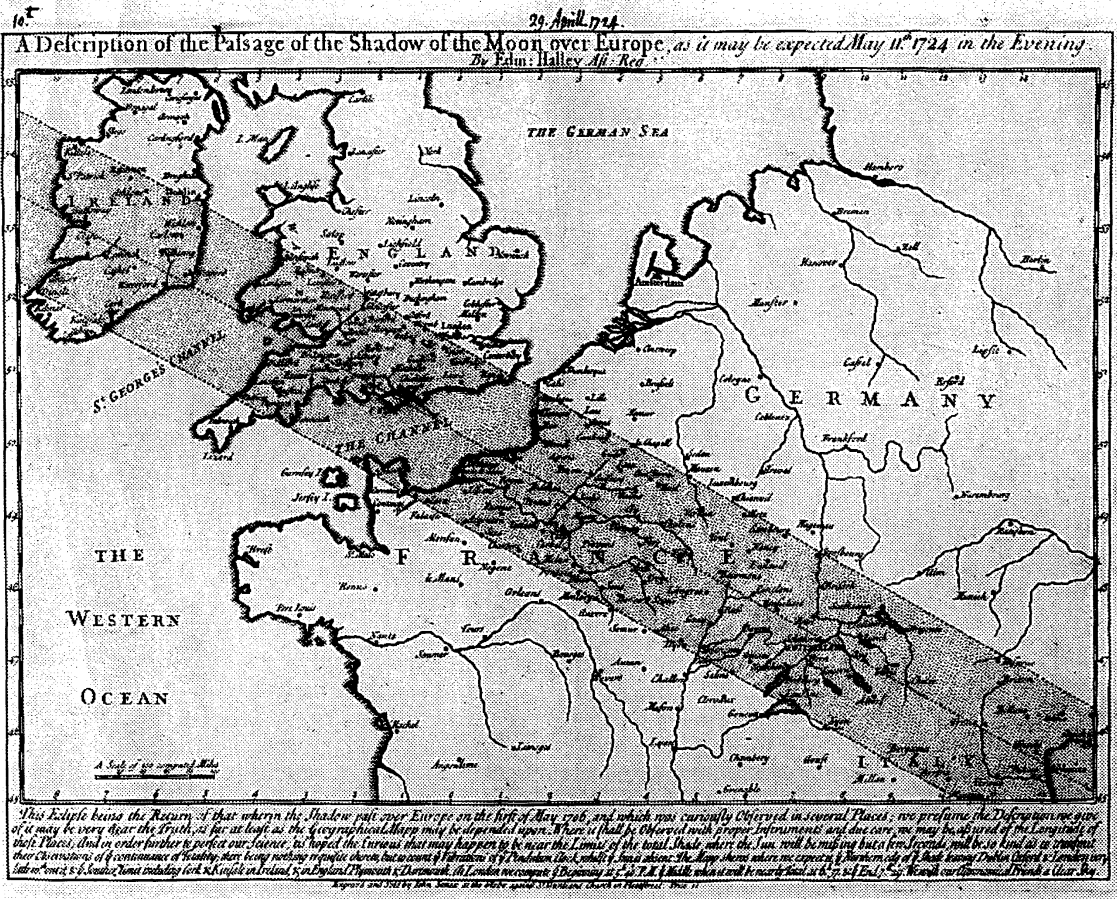


Figure 5. Since the path of totality crossed more of Europe in 1724 than it had in 1715, Halley's map of the predicted path, published closer to the date of the eclipse, showed more of the European Continent. (With the permission of the Houghton Library, Harvard University. EB7 H1552 724d)

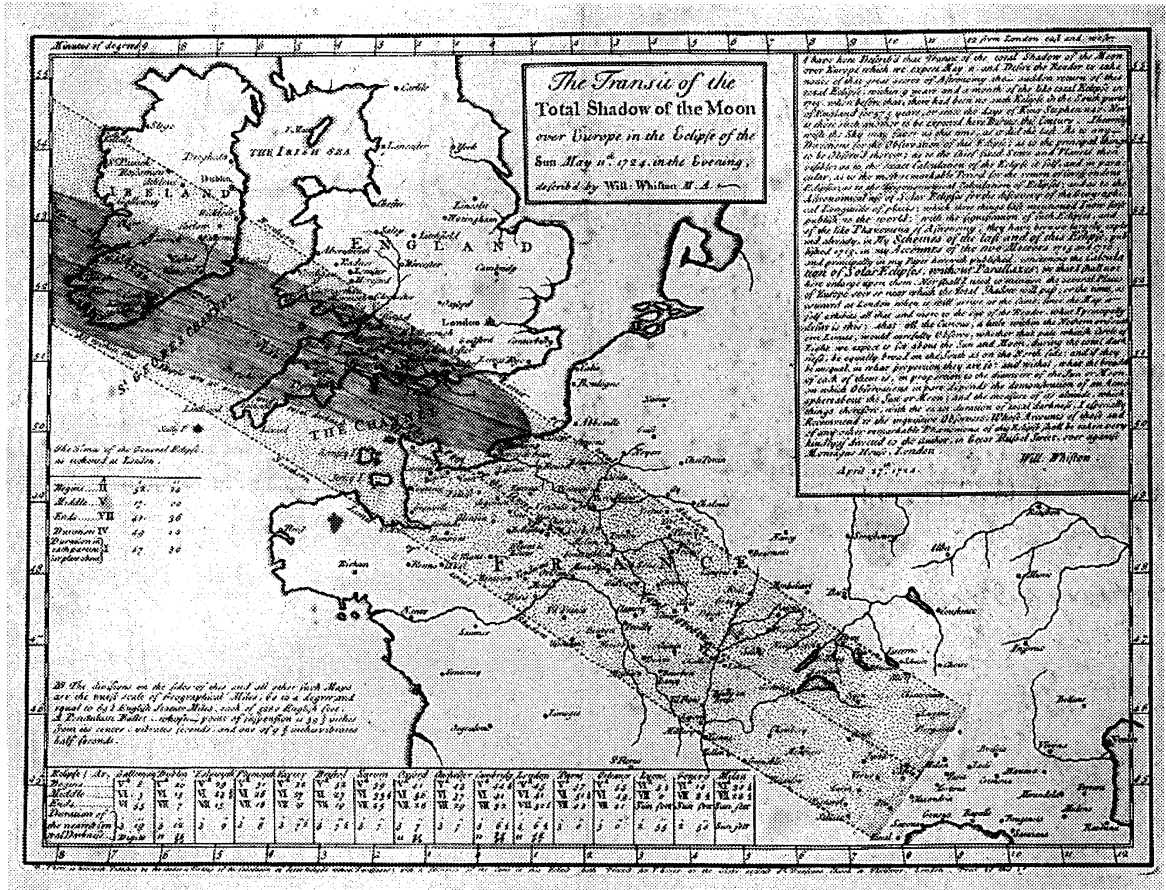


Figure 6. William Whiston's map of the path of the 1724 eclipse. (With the permission of the Royal Astronomical Society)

Armitage (1997) calls it "an obvious and rather crude attempt to copy Halley's successful formula." For the 1724 maps, Halley omitted the shape of the totality oval while Whiston included it, a very extended oval since the end of totality occurred in France and the projection was thus extreme. Armitage (1997 and Gingerich (1992) each report that the actual path was halfway between Halley's and Whiston's predictions, which differed by 25 miles.

**7 THE PATH OF THE 1999 ECLIPSE**

A modern map of the European section of the 1999 total eclipse appears in Espenak and Anderson (1997) (Figure 7). It shows how closely the path of this eclipse corresponds to that shown in Halley's map of 1724. That it resembles Halley's maps so closely is coincidental, as can be seen by the different appearance of the maps we drew of the same eclipse (Pasachoff and Covington, 1993).

Observers were largely successful in viewing the 1715 eclipse but largely foiled by clouds in 1724. One can do no better for the 1999 and future eclipses than to quote Halley's wish from the 1724 map: "We wish our Astronomical Friends a Clear Sky."

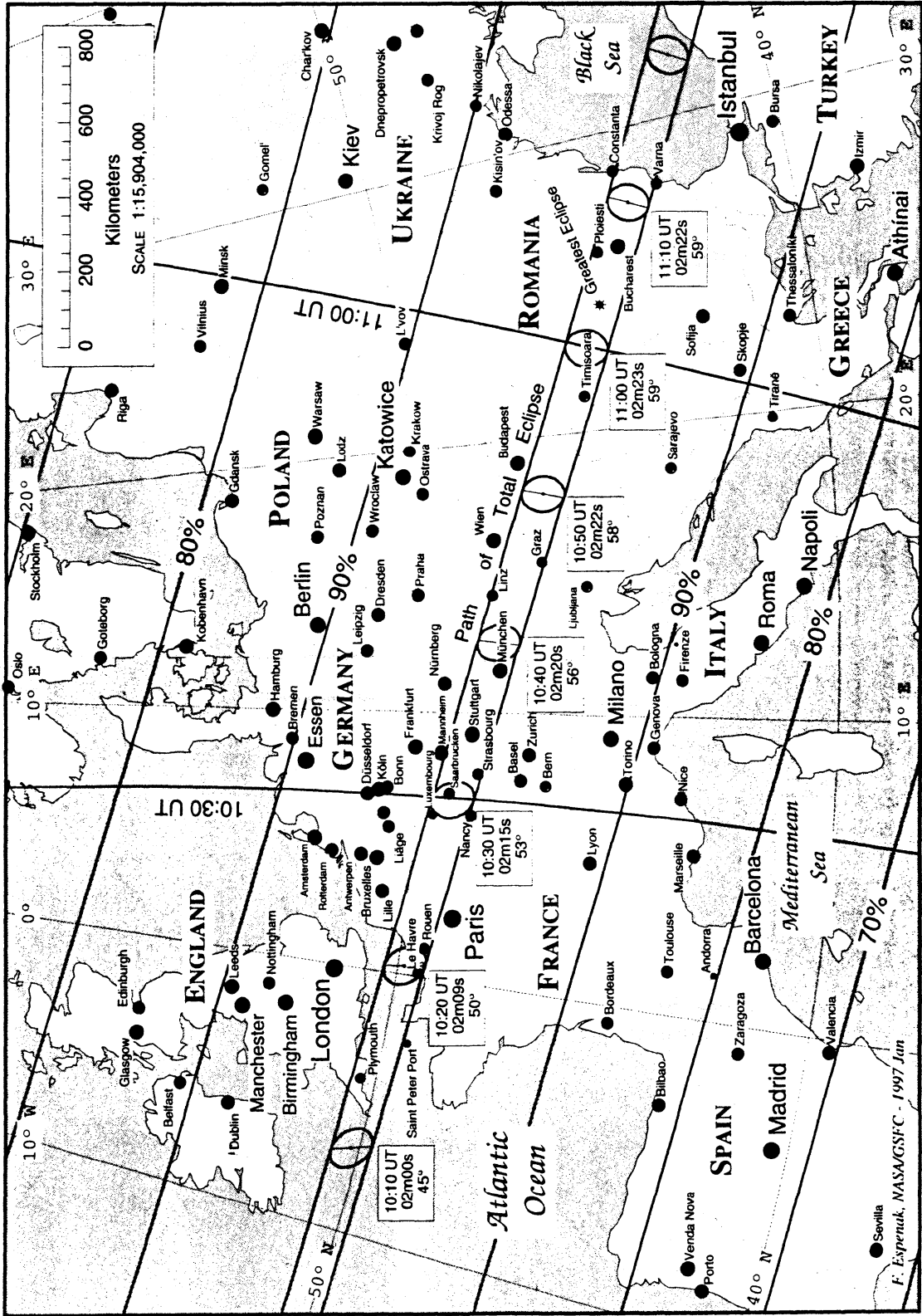


Figure 7. A current map of the predicted path of the 1999 August 11 total solar eclipse, as it appeared in the NASA Reference Publication without knowledge of Halley's older map. (Courtesy of Fred Espenak, NASA Goddard Space Flight Center.)

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Note added in proof:

Alice N. Walters, in "Ephemeral Events: English Broadside of Early Eighteenth-Century Solar Eclipses," *History of Science*, 37:1-43, March 1999, discusses the eclipse maps of Halley and of Whiston, as well as the work of the bookseller and cartographer Senex and the the broadsides of Benjamin Martin.