On two lost American cometaria

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Introduction:

The loss or destruction of any scientific instrument is always a sad affair. The forces of attrition, however, are probably unstoppable, and it is a fact that once, no doubt, resplendent instruments will fail to be preserved for future generations to study and appreciate. In the course of my investigations of cometaria, devices specifically made to illustrate the motion of a comet around an elliptical track[1], I have come across two particularly interesting accounts of what are now lost machines. The lamentable loss of these cometaria is compounded in the one case by the shear scale of its construction, and in the other by the fact that pieces by the same instrument maker have survived in working order to the modern era.

Gilber Vale's cometarium

It was the anticipated return of Biela's comet in the later part of 1832 that prompted Gilbert Vale (1788 – 1866) to produce a short pamphlet entitled, *Cometarium, the astronomy of comets with a particular account of the comet of 1832* (figure 1). Published in New York on 17 April, 1832 Gale writes "*we propose to furnish the public with the elements of this comet, and to show, in a popular manner, how to obtain from such elements the distance of this comet from the earth. We shall also show how the elements are first obtained, and likewise what is the nature of comets, the cause of their tails, and their connexion with the solar system*"[2]. In addition, as Vale notes in his introduction to the pamphlet, the comet "*will approach nearer the earth than any other was ever known to do*"[3]. Indeed, both public and scientific interest in Biela's comet was riding high in the early 1830s.

Figure 1. Front piece to Vale's *Cometarium*. Reproduced from the pamphlet held in the John Crerar Library collection at the University of Chicago.

In 1832, Gilbert Vale describes himself as a "teacher of mathematics and navigation" (see figure 1). He was, however, much more than a teacher. Born in London, England in 1788, Vale was intended for the church, but in 1829, before taking holy orders, he immigrated to the United States of America where in addition to teaching he became involved in a number of publishing and literary projects[4]. Indeed, it is in his role as editor to the *Sunday Reporter* that we first hear of Vale's plan to produce his *Cometarium* pamphlet. The *Sunday Reporter* was a small circulation newspaper, "devoted to the propagation of political, scientific and moral intelligence"[5]. Vale announced in an advertisement published in the *Working Man's Advocate* (WMA) newspaper for Saturday, April 7th (1832) that advanced copies of his pamphlet could be obtained from the offices of the WMA or directly from the author at 84 Roosevelt Street, price $1.25 a dozen. In the same April 7th issue of the WMA the first two pages of Vale's pamphlet were reproduced. Indeed, further pages from Vale's *Cometarium* were printed in the April 14th, May 19th and May 26th issues of the WMA, but after these insertions we hear no more of his pamphlet. The comet of 1832, however, continued to receive some attention within the *Advocate*. In the June 2nd edition, for example, there is an advertisement for "a large planisphere representation, or map, of the situation and appearance of the approaching comet" as designed by Hezekiah C. Seymour (of New Britain, Connecticut)[6]. The same June 2nd issue of the WMA also carries a long, apocalyptical poem reproduced from the *New England Magazine* called *The Comet*. After the June 2nd issue we do not hear of Comet Biela again until November 17th. This time, however, it is the recovery of the comet that is announced through the reproduction of a letter by astronomer John F. W. Herschel[7] dated "Slough, Monday Sept. 24". The letter was originally published in the *Times of London* newspaper for Wednesday, September 26 (1832, p.2). Interestingly Herschel notes, "it is hardly possible to imagine any more striking event than the reappearance, after a lapse of nearly seven years, of such an all but imperceptible cloud, or wisp of vapour, true, however, to its predicted time and place and obeying the very same laws as those which regulate the movement of the planets". It was presumably felt that this latter point concerning the motion of comets was worth re-iterating even though it had been clearly demonstrated to hold true 74 years earlier through the return of Halley's Comet in 1758. Even though the announcement of the recovery of Biela's comet appeared in the November 17th issue of the WMA, Vale apparently felt no need to (re)advertise his *Cometarium* pamphlet, or to offer any advice on how WMA readers might view the comet. Indeed, the comet had essentially been visible to North American observers for at least a month prior to the reproduction of Herschel's letter in the WMA. Herschel wrote a second letter to the *Times* on September 27th. This letter confirmed the approximate correctness of the predicted position of the comet according to "those computed in the *Nautical Almanack*, by Mr. Henderson, from the elements of M. Darmoiseau". A third, ¾ column length letter concerning Biela's comet appeared in the October 12th issue of the *Times*. This letter, by "John Herapath of Notting-Hill"[8] was concerned with the "apprehension" that the comet had produced. Herapath's letter is mostly concerned with the possible structure of comets, and with the possibility that they might on occasion strike a planet. Indeed, Herapath's letter has an interesting resonance with the poem[9], *The Comet*, published in the 2 June, 1832 issue of WMA. Neither Herschel's second letter nor that by Herapath was reproduced in the WMA, and one can only assume that by late 1832 Vale no longer held much editorial sway at the *Advocate's* office.

Websters Instrument Makers Database[10] identifies Vale as a mathematical instrument maker. This appellation is based upon Vale's design of an astronomical globe patented[11] on 28 October, 1843. In 1846 Vale published an instructional booklet, *Elements of Astronomy and illustrations of G. Vale's Geographical and Astronomical Card*, to describe the many uses of his globe, and there he advertises the price of the instrument as being from "$12 to $150. – size adapted to private and Common Schools, from $24 to $30 – case and packing extra". Vale's Globe was displayed at the 1853 New York Crystal Palace Exhibition, but it received a somewhat muted review from the Franklin Institute's Committee on Science and the Arts[12].

Kile's cometarium for comet Biela

Mr. Kile is a somewhat mysterious figure and essentially nothing is known about his background and location. The only reference to his planetarium, and for that matter to any instrument by Kile, is that contained within Vale's short *Cometarium* pamphlet[13]. Vale praises Kile's work, however, and comments "this instrument exhibits the phenomenon of the earth, moon, and inferior planets, in a greater degree of perfection than any other instrument ever exhibited in America". To this he adds, certainly over stating the case, "to such a degree of accuracy is this instrument brought, that it might be fairly used for the construction of almanacks". The planetarium component of the cometarium is described by Vale as being mechanically driven, but the comet location marker is set manually. A scale drawing of the cometarium showing the Earth's orbit and that of Comet Biela is presented in figure 2. Vale states that the comet moves "in an orbit of sixty feet" which dictates that the diameter of the Earth's orbit in the planetarium component must have been 16-feet (or 4.88-m) across[14]. The scale is truly remarkable. The cometary track was marked, according to Vale's description, so that equal areas are swept out from the Sun in equal intervals of time (as required by Kepler's second law). And, as a final comment, Vale adds that the cometarium was exhibiting at St. John's Hall in Frankfort Street, New York at the time that his pamphlet was being published (April, 1832).

Figure 2: A scale diagram of the orbit of comet Biela and Kile's planetarium. Given the stated scale of the cometary orbit ("60-feet" = 18.29-m) the Earth's orbital track would be 16-feet (4.88-m) across. Biela's comet has an orbital inclination of 12.5 degrees, but no mention is made by Vale as to whether this was incorporated within the cometarium display. Sadly, only the planetarium component of Kile's cometarium is reproduced in Vale's pamphlet.

The cometarium by James Dean

James Dean (1776 – 1849), Professor of Mathematics and Natural Philosophy at the University of Vermont[15], published a description of his new cometarium in 1815. Dean explains in his text that he has "been for some months excessively engaged in a course of experimental lectures", and that he has "constructed an instrument to represent the unequal motion of the planets round the Sun, and the equation of center" [16]. Dean's instrument is therefore clearly intended as a demonstration devise and its novelty, according to Dean, lies in its simplicity of construction. Indeed, in contrast to the elliptical-pulley driven cometaria of Desaguliers, Demainbray and Ferguson[1], Dean's device employs circular gears and the planet/comet motion arm is driven by an off-center circular gearwheel (see figure 3). There is no indication that Dean intended the comet motion arm (wire GEF – see figure 4) to actually drive a comet model around an elliptical track, as was the norm in other cometaria. Rather it appears that it was the variation of the *equation of center* that was his primary interest. The *equation of center* is defined as the difference between the true anomaly and the mean anomaly[17], and as such it describes by how much the motion on an elliptical orbit deviates from that along a circle orbit. Indeed, the greater the orbital eccentricity, so the greater the maximum value of the *equation of center*. One of the key features of Dean's cometarium is that it could illustrate the variation in the *equation of center* for a range of eccentricities. Indeed, the shorter the length of drive arm DE and the greater the distance between centers F and D (see figures 3 and 4), so the greater the modeled eccentricity.

Figure 3: A schematic diagram (plan view) of Dean's cometarium (based upon ref. 16). Both gears A and B are driven at the same rate by pinions attached to the drive axle C. Gear A has a hollow collar at its center so that the wire GEF, which describes the non-constant motion of the comet, can move about center F. The wire GF is driven by the bar DE attached to gear B. The wire is supported in a 'V' shaped grove at E (see figure 4). The center D of gear B is moveable about the center of the drive axle C, while the center F of gear A is fixed relative to the center of the drive axle. By adjusting the length of bar DE and the distance between centers F and D, different orbital eccentricities can be modeled.

Figure 4: A schematic diagram (side view) of Dean's cometarium (based upon ref. 16). A constant motion arm is attached to the hollow collar that turns with gear A (center F). The angle between the constant motion arm and the comet motion arm corresponds to the *equation of center*. The bar DE drives the 'U' shaped wire GEF about the center F at a non-constant rate.

Concerning the advantages of his cometarium design, Dean notes "that toothed wheels are more secure than banded ones; and that circular ones are much more easily formed than elliptical ones"[16]. This is certainly true, and it was a design feature specifically incorporated in to a cometarium built and sold by W. and S. Jones, in London, during the first decade of the nineteenth century – indeed, the fabrication of the Jones cometarium must have taken place at about the same time that Dean was constructing his device[19]. The Jones cometarium (figure 5) incorporates an eccentrically mounted circular gear wheel, anchored to a sliding frame, to produce non-uniform motion; this arrangement is actually equivalent to the sliding wire driven method introduced by Dean. In contrast to the cometarium built by Dean, however, that constructed by W. and S. Jones incorporates a comet model that moves around an elliptical track. While Dean's cometarium is now lost, that by W and S. Jones is on display as one of the King George III Collection of scientific instruments at the Science Museum in London.

Figure 5: Cometarium design by W. Jones. Reproduced from Abraham Rees, *The Cyclopaedia* [vol. 9, plate II (1819)]. The Sun is located at **O** and the comet model is driven around its elliptical track (not shown in this illustration) by arm **I**. The large gear wheel **G** is mounted eccentrically at **H** which slides on plate **D**. The axel **S** drives the constant motion dial.

In his article[16] Dean clearly states that he has constructed the cometarium himself, but Websters Instrument Makers Database[10] records that clock maker Aaron Willard Jr. (1783 – 1864), of Boston Massachusetts, also built a cometarium as "invented by James Dean"[18]. Indeed, in a short 14-page pamphlet[20] published in 1828 by John Locke (1792 – 1856) it is explained that the cometarium built by Willard shows the "equal and unequal motions …. by two indices from the same center, like the two hands of a watch". While a number of clocks and orreries constructed by Aaron Willard Jr. have survived, in working order, to the modern era his cometarium is no longer extant.

Another mechanism capable of illustrating the equation of center[17] "in a lecture-room" is that described by the Reverend William Pearson[21] in Rees's *Cyclopaedia* published in 1820. Pearson's mechanism, presumably built at about the same time that Willard was manufacturing his device, is arguably simpler in construction than the cometarium described by Dean, although it also employs four gearwheels. Two circular gears with equal teeth counts mesh and rotate on their centers to provide the drive for a constant rate, circular motion dial; working from the same axes of rotation as the constant motion gears, two circular and equally toothed, but eccentrically offset gears mesh to provide the drive train for a non-constant motion arm (figure 6). The varying angle between the two arms corresponds to the *equation of center*. The mechanism described by Pearson is less versatile than the cometarium built by Dean in that it can only display the equation of center for a single value of eccentricity. In unison with the cometaria built by Dean and Willard, however, the device constructed by Pearson is also, at least apparently, lost.

Figure 6. Pearson's demonstration device for the *equation of center*. Gearwheels *a* and *b* are equal in diameter and teeth count and drive the constant motion arm *g* attached to the hollow collar centered on *b*. Gearwheels *d* and *c* also have equal diameters and teeth counts, but are mounted eccentrically, with the arbor for gearwheel *d* passing through the hollow collar of gearwheel *b* to drive the eccentric motion arm *i*. The angle between the arms *g* and *i* indicates the *equation of center* according to the eccentricity offset of gears *c* and *d*. Reproduced from Abraham Rees, *The Cyclopaedia* [vol. 9, plate II (1819).

For public consumption

The cometarium designed and built by James Dean (and later reproduced by Aaron Willard Jr.) was an instructional device, neither intended to be a scientific instrument for measurement, nor a toy for simple public enjoyment. Its main function was to illustrate the consequences of Kepler's second law[22], and to specifically make clear the differences between constant motion on a circle and non-constant motion along an elliptical path. The innovation of Dean's cometarium was in its use of circular gears (rather than elliptical ones), and in the 'stripping down' of the visual display to that of two moving arms to describe the *equation of center*. We find, however, that similar such devices were being constructed, on the other side of the Atlantic, at essentially the same time that Dean was developing his simplified mechanism. The cometarium described by Gilbert Vale was also an instructional device, but it was displayed in a manner that made it accessible to a non-technically informed public. Its function was to illustrate to scale the orbit of Comet Biela, an object of great public interest, and to show how the comet moved relative to the planets in the inner solar system. Indeed, while Vale eulogized (perhaps 'exaggerated' is a better word) the quality and accuracy of Kile's planetarium component to the cometarium, this was a mechanical sophistication that was entirely unnecessary to the viewing publics appreciation of the display.

The idea of using a wire-track to illustrate the orbit of a comet within a planetarium display was not new to Vale. Indeed, John Theophilus Desaguliers, who is accredited with the invention of the cometarium[1], described in 1733 a parabolic wire-loop attachment to his new planetarium that could “show the lower part of a comet’s orbit”[23]. Likewise, in America, Bartholemew Burges of Boston advertised[24] in early 1789 the intended exhibition of an astronomical apparatus that would show, with a wire orbit, the path of the comet expected to return later in that year. Unfortunately Burges offers no indication as to the size of the display.

As far as I have been able to ascertain, the cometarium described by Gilbert Vale was the first attempt to illustrate the orbital motion of a comet as part of a display intended for the general public, rather than a paying audience. Indeed, its scale was truly inspiring, and it must surely have enthralled an already interested (and in many cases worried[8, 9, 25]) public. The only other public access cometarium that I am aware of is the recently constructed one at the Armagh Observatory in Northern Ireland[26]. In this latter cometarium the observer actually becomes the comet and can step around the full orbital track of Comet Encke and along part of the orbital track of Comet Halley. Importantly, the distance between each of the steps is spaced according to the dictates of Kepler’s second law.

Notes and references

1. M. Beech. *The mechanics and origin of cometaria*. Jour. Astron. Hist. Heritage. **5** (12), 155 – 163 (2002); M. Beech. *Cometaria and the demonstration of Kepler’s 1st and 2nd laws*. Bulletin Sci. Inst. Soc. No. **82**, 29 – 33 (2004); See also the website: http://hyperion.cc.uregina.ca/~astro/comet/Intro.html.

2. G. Vale. *Cometarium, or The Astronomy of Comets. With a particular account of that comet of 1832 which approaches nearer to the earth than any other comet is known ever to have done*. Evans and Brooks, Printers, New York. 1832. p. 4.
3. Vale actually uses the name Gambart's comet since, as he partially explains in the introduction to his pamphlet, it was the French astronomer J. F. A. Gambart who first calculated the comet's orbit in 1826. In addition, counter to modern practices, Wilhelm von Biela, who swept-up the comet on 27 February 1826, was not the first person to record the comet; it was actually seen during its 1772 and 1805 perihelion returns. Biela did suggest, however, a link between the 1805 comet and the one he found in 1826, but it was Gambart who successfully linked all three apparitions. Biela's comet was observed to split into two fragments during its 1846 apparition and it is now considered to be a lost comet, not having been recovered since 1852.
4. In 1841 Vale published a biography on the radical intellectual and 'father of the American revolution' Thomas Paine (1737 – 1809). He had earlier, in 1839, overseen the construction of a monument (that still stands) to Paine in New Rochelle, New York. Vale also published a number of social commentary texts, including *Fanaticism, its source and influences,* in 1835.
5. From the *Working Man's Advocate* newspaper for Saturday April 14, 1832 (No. 35, vol. III, p.4).
6. This is presumably the same Hezekiah Seymour of Nyack Rockland County, NY, who was elected New York State Engineer and Surveyor, on November 6th 1849. The cost of the planetarium was advertised as one dollar.
7. John F. W. Herschel, son of William and Mary Herschel, was born at Observatory House in Slough on the 7th of March 1792. He followed an illustrious career in astronomy (just as his father had). He was Secretary to the Royal Society (1824 - 1827), a founding member of the Royal Astronomical Society and was made a Knight of the Royal Hanoverian Guelphic Order in 1831. Herschel moved back to his boyhood home in 1832 (following the death of his mother on January 4th of that year). A letter from John Herschel was read to the Fellows of the Royal Astronomical Society on November 9th, 1832 concerning the recovery of Biela's

comet (Monthly Notices, **2**, 141, 1833). Herschel's communication indicates that the comet was swept-up with his "20-feet reflector" telescope on September 22nd.

8. John Herapath (1790 – 1868) pioneered the idea of the kinetic theory of gasses, and he discovered the *Great Comet of 1831* on January 7th, 1831 after it had swung past perihelion. Herapath's letter to the *Times* of 12 October, 1832 argues that the four then known asteroids were produced through the destruction of a small planet following a collision with a comet. He makes it clear in his letter that no collision is going to occur between Biela's comet and the Earth, and he also dismisses the suggestion that the warm summer of 1832 was due to the comet's re-appearance.
9. The third stanza of the poem reads: *And what will happen to the land, / And happen to the sea / If in the bearded devil's path / Our earth should chance to be? / Full hot and high the sea should boil, / Full red the forests gleam - / Me thought I saw and heard it all / In a dyspeptic dream.*
10. See the web link http://www.adlerplanetarium.org/research/collections/websters/index.shtml.
11. The new innovations that Vale claims in his patent are that the Globe has a "movable horizon attached to the meridian [which moves] as the figure representing the traveler moves", and "the application of this instrument as a planetarium, by the introduction of wires representing the orbits of the planets and showing their nodes and inclinations". Vale apparently made no provision to illustrate cometary orbits with detachable wires.
12. Although Vale's patent was awarded in 1843, its announcement in the Journal of the Franklin Institute did not appear until December 1849 [vol. XVIII, (6), 501], and then only a brief account of his claim was given. The Franklin Institute's Committee on Science and the Arts, report number 409 for 13 March 1845, however, noted that "this sphere, because of its price is recommended to teach students the circles of the heavens. Its conversion to a globe with painted gum-taffeta is less satisfactory" [from A. M. McMahon and S. A. Morris, *Technology in Industrial America: the Committee on Science and the Arts of the Franklin Institute 1824 - 1900*. Scholarly Resources Inc., Delaware (1977), p. 50].

Alexander O. Vietor [*Some American Globemakers*, Antiques, January 1943] was much more enthusiastic in his appraisal of Vale's globe and comments that the "apparatus was a unique affair that could well bear production today". This being said, Vietor was not aware of any example of Vale's globe having survived into the mid-twentieth century.

13. Deborah Jean Warner, *The Geophysics of Heaven and Earth: Part 3*. Rittenhouse, **2**(3), 104. There is no mention of Kile in Silvio Bedini's *Early American Scientific Instruments and Their Maker*s (Landmark enterprises, CA, 1986), or in Bedini's *Thinkers and Tinkers – Early American Men of Science* (Charles Scribner's Sons, New York, 1975).
14. The orbital semi-major axis of Biela's comet is a = 3.5253 astronomical units (AU). Given that the major-axis of the cometarium track is 60-feet across then the Earth's orbital semi-major axis will be 1 AU ≡ 60 / 7.0506 = 8.0 feet in scale.
15. The Vermont Historical Magazine for October 1867 records (see, http://www.rockvillemama.com/washington/deanjames.txt) that Dean was Professor of Mathematics and Natural Philosophy at the University of Vermont on two separate occasions between 1809 -1814 and 1822 - 1824. Between 1814 and 1822 Dean apparently "devoted his time to the pursuit of the sciences and benevolent purposes". His second stint as Professor of Mathematics at the University ended when fire destroyed the campus on 27 May, 1824. Dean was a member of the American Peace Society, founded in 1828 (see http://www.swathmore.edu/library/peace/), and he is perhaps best remembered in the modern era for his role in developing the harmonic mean method for allocating seats in the apportionment voting system used in the United States of America (http://www.census.gov/srd/papers/pdf/rr92-6.pdf).
16. J. Dean. *Description of a Cometarium*. Mem. Amer. Acad. Arts and Sci. **3**, 344 – 345 (1815). The gear arrangement for Dean's cometarium is illustrated in figure 6, Plate II of the *Memoirs*.
17. The mean anomaly (M) is defined in terms of the orbital period (P) and it corresponds to the angle swept out by an object moving along a circular orbit; accordingly, $M = (2\pi / P)\, t$, where t is the time. The true anomaly (ν), on the

other hand, is the angle swept out from the Sun focus, measured from perihelion, in time *t* by an object moving along an elliptical path. Kepler's equation provides a relationship between *M* and *v*, and the *equation of center* is expressed as $c = \nu - M$. At perihelion and aphelion $c = 0$.

18. Deborah Jean Warner [*The Geophysics of Heaven and Earth: Part 4*. Rittenhouse, **2**(4), 134] notes that Willard made several types of orrery, and that a number of his so-called portable orrery designs have survived to the present day. Willard also constructed an inclined orrery following the design of John Locke (see 20). Details of the Willard family can be found at the Willard House and Clock Museum web site at http://www.willardhouse.org/. A still working clock built by Aaron Willard Jr. is housed at the South Congregational Church in Kennebunkport, Maine – see http://www.sover.net/~donnl/early1.html.
19. The exact date of manufacture in not known, but H. King and J. R. Millburn [*Geared to the stars*. University of Toronto Press, Toronto (1978), p.208] note that the cometarium was advertised in the Jones catalogue for 1812 – costing five guineas. This catalogue entry indicates that the Jones cometarium was designed and built at about the same time that Dean was constructing his machine.
20. John Locke, *Problems to Illustrate the Most Important Principles of Geography and Astronomy*. Cincinnati: Morgan, Fisher and L'Hommedieu (1828). p. 14.
21. The machine is described under the entry heading *Equation-mechanism* in Abraham Rees, *The Cyclopaedia; or, universal dictionary of the arts, sciences, and literature*. London (1819-20). The diagram that accompanies the text, however, is shown as figure 4 on Plate IV (Planetary Machines), in volume 4 of Rees's plates.
22. Kepler's second law states that a line drawn from the Sun to a planet (comet) will sweep out equal areas in equal intervals of time. The demonstrable upshot of this law is that the planet (comet) will move rapidly when near to perihelion and more slowly when close to aphelion.
23. Desaguliers, J. T. Royal Society Record Book for 1733 (RBC 18.395). Desaguliers indicates that his planetarium can show "the orbits of several comets and the periods of three of them". The latter three comets were presumably those

of 1680, 1661 and 1682 (Halley's Comet), to which Edmund Halley had ascribed periods of 575, 129, and 76 years respectively. In fact, of these three comets only that of 1682 is periodic; the other two are long period comets that have not, to date, returned to perihelion.

24. Bedini, S. A. *Thinkers and Tinkers: early American men of science*. Charles Scribner's Sons, New York (1975). pp. 385-386. The comet that Burges was expecting to return in 1789 never actually appeared. Indeed, the prediction, while widely publicized, was based upon an erroneous linkage (made by Edmund Halley in his *Synopsis Astronomiae Cometicae* published in 1705) between the comets observed in 1532 and 1661. Burges, in fact, provides quite a detailed review of the various ideas relating to cometary structure in his 16 page pamphlet, *A short account of the solar system and of comets in general: together with a particular account of the comet that will appear in 1789* (Printed and sold by B. Edes and Son, Boston. 1789).
25. Although there was some public alarm at the possibility of Comet Biela colliding with the Earth, its closest approach distance, obtained on 24 October 1832, was over 200 times greater than the Moon's orbital separation from the Earth. In fact, the comet passed much closer to the Earth (with a miss-distance of about 14 Moon orbital radii) in December of 1805.
26. M. Bailey, D. Asher and A. Christou. *The Human Orrery: Ground-based astronomy for all*. Astronomy and Geophysics, **46**, 3.21 – 3.35 (2005). See also, M. Beech, *The Living Orrery*. The Observatory Magazine, **127** (1), 60 - 61 (2007).

Figure 1

COMETARIUM,

OR

THE ASTRONOMY OF COMETS.

WITH A PARTICULAR ACCOUNT

OF THAT

COMET OF 1832,

WHICH APPROACHES NEARER TO THE EARTH THAN ANY OTHER COMET IS KNOWN EVER TO HAVE DONE.

BY G. VALE,

Teacher of the Mathematics and Navigation.

TO WHICH IS ADDED

A DESCRIPTION OF

KILE'S PLANETARIUM AND COMETARIUM.

STEREOTYPED, AND COPYRIGHT SECURED.

NEW YORK:
EVANS & BROOKS, PRINTERS.
For sale by the Author, No. 84 Roosevelt Street; and by George H. Evans, at the office of the New York Daily Sentinel, Chatham Square.

1832.

Price 18¾ cents, on fine paper, stitched, with printed covers; or $1 25 per dozen.

Figure 2

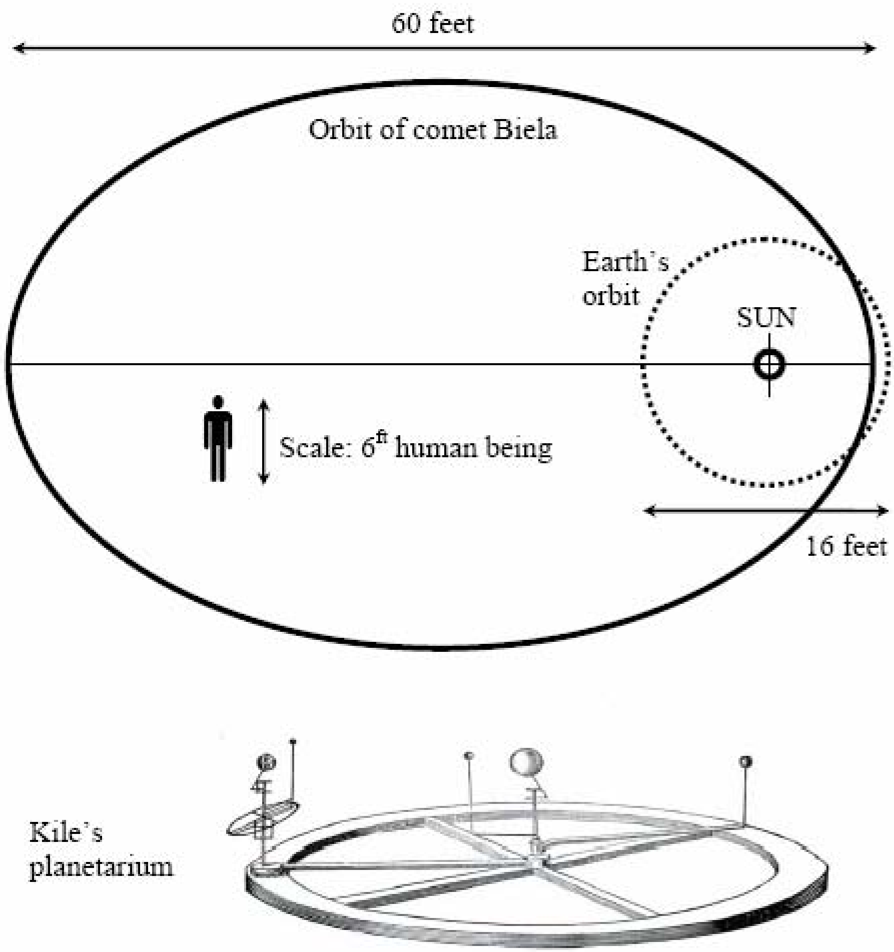
60 feet
Orbit of comet Biela
Earth's
orbit
SUN
Scale: 6ft human being
16 feet
Kile's
planetarium

Figure 3

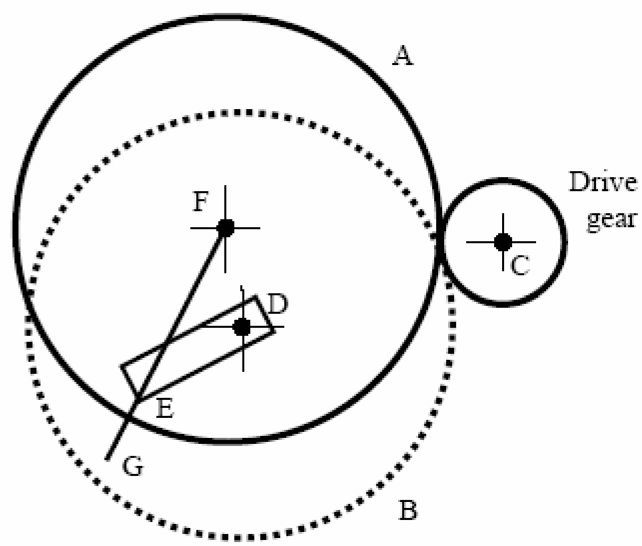

Figure 4:

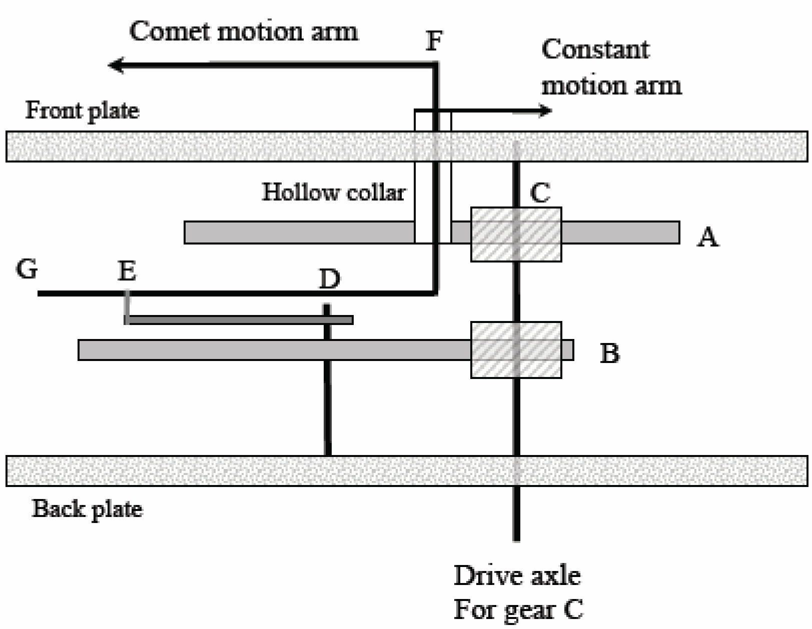

Figure 5

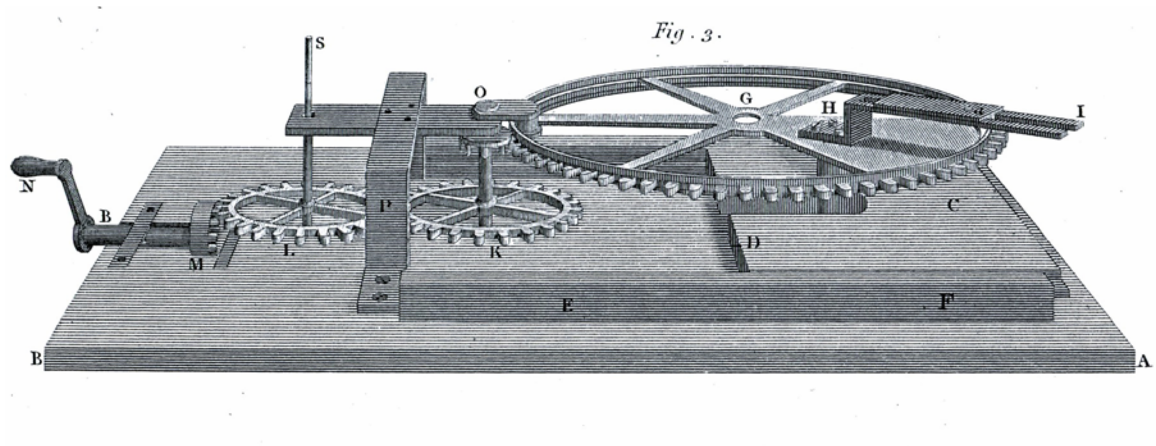

Figure 6