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Early astronomy in America: the role of The College of William and Mary

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Abstract
During the late eighteenth century, The College of William and Mary in Virginia, led by its president, Bishop James Madison, became a leading institution in the USA for the study of Natural Philosophy, and especially astronomy.

In 1768, the College acquired scientific apparatus that had no equal in the colonies, and among the items in this collection were astronomical instruments that were the finest in America. In 1778, Bishop Madison constructed what was certainly the first observatory at any college in the nation, and possibly the first permanent observatory established anywhere in America. Madison's educational reforms and his personal involvement in the teaching of the natural sciences led to the first complete elective system of college courses in the USA.

Unfortunately the Revolutionary War devastated William and Mary and depleted its resources. Subsequently, the College was never able to achieve the great contributions to astronomy that may otherwise have been possible. Nonetheless, through its teaching programme, William and Mary contributed significantly to the education of many of the nation's early leaders, and it continues today as one of the foremost institutions of higher education in the USA.

Keywords: *The College of William and Mary, Bishop James Madison, early American astronomy, early American observatories, astronomical education*

1 INTRODUCTION

The English colonies in America wished, in many ways, to emulate English society, and to that end the colonists in Virginia petitioned the King and Queen to charter a college in Virginia, which, in 1693, became known as The College of William and Mary. Through many early trials and tribulations, including a disastrous fire that gutted the original main building, the College continued to grow during the eighteenth century.

Located in Williamsburg (for localities mentioned in the text see Figure 1), the College acquired wealth, purchased apparatus for the teaching of Natural Philosophy, and became a University with a complete faculty. A young man, Bishop James Madison (1749-1812), was appointed its President in 1777, and he built an observatory at William and Mary. Together with his friend Thomas Jefferson, he instituted reforms at the College which included the first elective system of study and the first honour system at any educational institution in America.

During the Revolutionary War,[1] the College suffered many major setbacks. The Royal grants of duties were withdrawn, rents for College lands went unpaid, the students left William and Mary to enlist in the army, and several College buildings were damaged or destroyed by occupying armies.

Madison managed to rebuild the College following the war. In doing so, he not only reconstructed most of the buildings that had been damaged, but he also rebuilt the faculty and instituted a complete programme of academic studies. He introduced additional reforms into the curriculum, including the requirement that students have a basic knowledge of astronomy at graduation. Throughout his tenure at the College, Madison maintained a programme of astronomical observations, and a variety of his observations is recorded in letters or other documents.

In the late eighteenth century, astronomy was largely an emerging science in America (e.g. see Bell, 1964; Mitchell, 1942; Milham, 1938; and Williams, 1996). This paper documents the important contributions that The College of William and Mary made to early American astronomy.

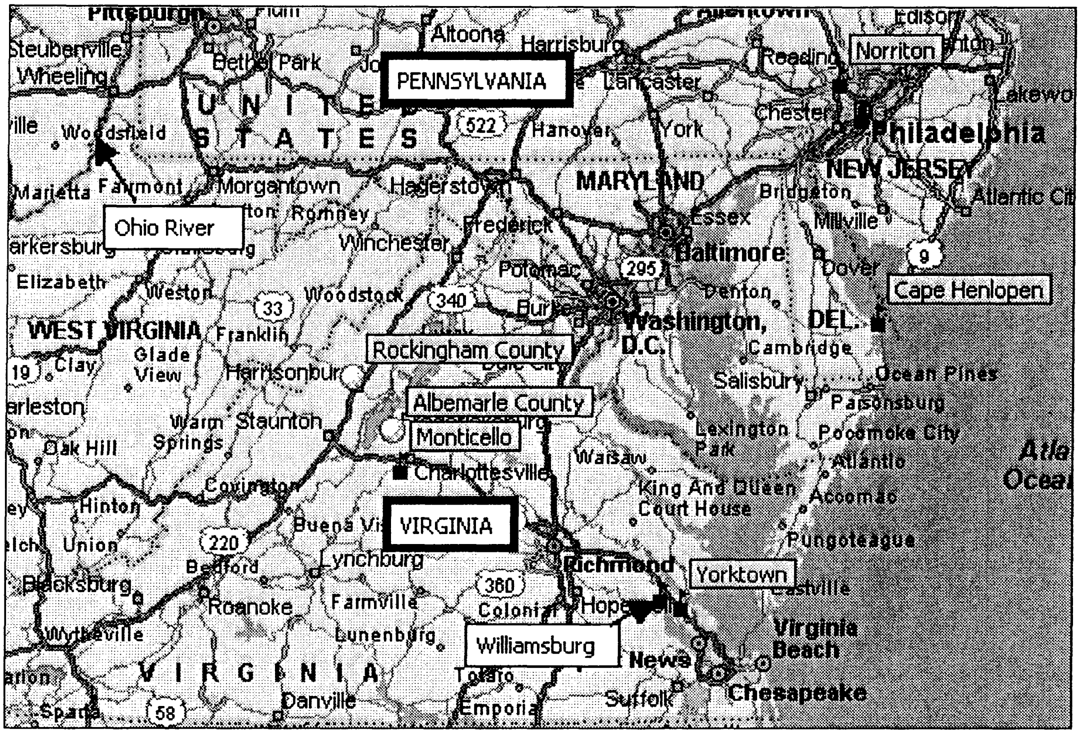

Figure 1: US localities mentioned in the text.

2 BISHOP JAMES MADISON: A BRIEF BIOGRAPHY

A student once said of Bishop James Madison, the eighth President of The College of William and Mary:

> The character of James Madison is an interesting one. In his life and habits he is perfectly systematic and regular; in his disposition, placid and indulgent; in his manner, the perfect gentleman; and in point of scientific knowledge, he is undoubtedly a finished scholar. As a tutor, he certainly stands in the first rank. (Morpurgo, 1976:168).

Bishop James Madison (Figure 2), second cousin of the more famous President James Madison of the United States, served as President of The College of William and Mary longer than any other President save its first, James Blair. Born in rural Rockingham County, Virginia, in 1749, he came to William and Mary in 1768 at the age of nineteen – which at that time was rather old for an entering student. But he excelled academically and was elected to a scholarship in 1770, receiving the Botetourt Medal in 1772 as the outstanding student in his class. Some months before his graduation he was employed by the College as writing master, and began to demonstrate the promise that would later bring him recognition as a scientist. When the Chair of Natural Philosophy was vacated in 1773, Madison was elected to that post. Then at age 28, within five years of his graduation, he became President of William and Mary, and he served in that post from 1777 until his death in 1812.

Unfortunately for Madison (but perhaps fortunately for William and Mary), he acceded to this post at what was to prove the most difficult period in history for the young American colonies. While he was away in London from the spring of 1775 to the fall of 1776, his world was thrown into turmoil when the colonies declared their independence from Great Britain and the United States of America was founded.

During his stay in London, Madison was ordained as an Anglican priest. He also found time to study under Tiberius Cavallo, known for his experiments and investigations of air, electricity, and magnetism, topics which were later to become favourites among students attending Madison's Natural Philosophy lectures (see Sprague, 1859).

Madison gave the first lecture course on political economy in the United States, and in 1774 he became the second professor of chemistry in America (after Dr Benjamin Rush of

Philadelphia). In 1845, the then chairman of the faculty of the University of Virginia, future founder of the Massachusetts Institute of Technology and William and Mary graduate, William Barton Rodgers, noted of William and Mary that "... in her halls were delivered by Bishop Madison the first regular course of lectures on physical science and political economy ever given in the United States." (Tyler, 1905:8). It is said that Madison lectured four to six hours a day (Gill, 1995), and his teaching has been described as part of the "... beginning of Natural History in America." (Goode, 1991:83).

Figure 2. James Madison, 1749-1812 (after Milham, 1938:29).

Madison's favourite topic, and that of his students also, was Natural Philosophy, which was never far from his thoughts. In a letter to another one of his correspondents, Edmund Randolph, he said: "I had a letter ready to acknowledge your favours of the 13th of last Month, which afforded us so much Consolation ... but it would be easy to calculate the time of an Eclipse, as to determine the times ... of one of Clarkson's Riders." (Madison, 1789b).

On 1780 January 27 he was elected to the American Philosophical Society, the same day as his close friend Thomas Jefferson, and some of his astronomical work was later to be published in the *Transations* of the Society.

Madison and Jefferson carried on a lifelong correspondence on all manner of topics, including astronomy. In a remarkable letter written on 1786 March 27, Madison covers a wide range of astronomical topics. This letter was written in response to a 1785 October letter from Jefferson who at the time was in Paris serving as the US diplomatic representative. He thanks Jefferson for information relative to "... ye Planet Herschel..." and relates it to "... that valuable work ye Conn. Des Temps." He mentions that he had not heard "... of the observations of Mr. Piggott ...", who in 1784 had discovered that the star Delta Cephei was variable. A century later, this star would become the prototype of a very important class of variable stars. In his letter, Madison also discusses the history of variable stars and some of the theory behind these objects, and raises several other scientific findings before closing (see Madison, 1786).

During the siege of Yorktown in 1781 the French army occupied the College and used the main building and the President's house as a hospital. Unfortunately, the house burned on the night of 1781 November 22-23 and Madison's personal library and instruments were destroyed. Greatly saddened, he wrote to Yale's President Stiles that he had lost "... every Book and Paper which I had." (Rouse, 1983:82).

After that conflict, Madison worked hard to reform the College, collaborating with Thomas Jefferson on a bill which would have substantially expanded the College's programme. Although the bill was never presented, Madison implemented as many reforms as possible and oversaw the expansion of William and Mary from a college to the first university in the United States. In 1792, he instituted the Statues of the University of William and Mary, which established a set of requirements for graduation that included a basic knowledge of astronomy.

It has often been said that the quality of a teacher may be gauged by the accomplishments of his students. During Madison's tenure at William and Mary, he taught two future Presidents of the United States (James Monroe and John Tyler), one Chief Justice (John Marshall), five Attorneys General of the United States, eight governors, ten United States Senators, sixteen Congressmen (including two Speakers of the House of Representatives), twenty-eight judges, six general officers of the armed services, and innumerable teachers and natural philosophers. All of these were drawn from classes that graduated an average of only fifteen to twenty students per year (Faculty compilation, 1874).

One of Madison's students once penned: "Fish and oysters are very good food at times, but in my opinion not near equal to Mr. Madison's lectures with which I am enamoured, and without which I think no man can boast of a good education." (see Godson *et. al.*, 1993:192). This is high praise indeed.

3 ASTRONOMY AT THE COLLEGE OF WILLIAM AND MARY

3.1 The Place of Natural Philosophy at the College in the early eighteenth Century

The College of William and Mary was founded by Royal charter on 1693 February 8 "... to make, found and establish a certain place of universal study..." (cited in Morpurgo, 1976:1). One President and six Masters or Professors were to be appointed at the establishment of the College. In 1695, the College opened its main academic building; now know as the Wren Building, named after its supposed designer, Sir Christopher Wren. This building became the centrepiece of the College, where its students lived, ate, and studied (see Kale, 1985; Kornwolf, 1989; Sacks, 1984).

Amongst those early areas of study was to be the subject of Natural Philosophy. Bishop Madison defined Natural Philosophy in his lectures as: "... that Science which points out & explains the Laws by which the material universe is governed; & thereby accounts (as far as maybe) for the various Phanomina [sic.] of Nature." (see Watson, 1796).

The young colony was justifiably proud of its College and of the Wren Building, which was even used for meetings of the General Assembly of Virginia from 1700 until 1705 when the building was destroyed by fire. That disastrous fire of 1705 October 29, when everything in the building was lost, including the library and 'philosophical apparatus', was to be the first of three that would strike the Wren Building over the next three centuries.

For the first twenty years or so of its existence, the College was primarily a grammar school. Slowly it began to emerge as a College. The accounts of the first fire, however, do provide us with the evidence that William and Mary, almost from its very beginning, included apparatus necessary for the study of natural philosophy.

In the spring of 1716, Hugh Jones was appointed the first Professor of Natural History and Mathematics. By 1729, a full complement of six professors and a President had been appointed. Once a student had passed his exams in grammar school, he graduated to a study of either Moral or Natural Philosophy. The study of Natural Philosophy included physics, metaphysics, and mathematics. Four years of study were required to obtain a bachelors degree and seven years of study for a Masters Degree. A divinity school was also established (Tyler, 1905).

While these developments were occurring in Williamsburg, Harvard also began to emerge as a College. Harvard had also been founded as a grammar school, and in 1736 Departments of Latin, Greek, Logic, Metaphysics, Mathematics and Natural Philosophy were set up. John Winthrop, often considered America's first astronomer, was appointed to the Chair of Natural Philosophy in 1738, a post that he was to hold for forty years (Brasch, 1916).

In the spring of 1758, William Small came to Virginia and shortly thereafter was appointed to the Chair of Natural Philosophy at The College of William and Mary. Jefferson (1778) said of Small that he, more than any other man, "... fixed the destinies of my life." It was Small who, upon his return to England in 1764, acquired the scientific apparatus mentioned later in this paper which was, by most accounts, the most extensive collection in the colonies at that time. Small also introduced the lecture system to College life and "... left a lasting impression by popularizing the study of Natural Philosophy." (Tyler 1905: 6).

By 1769, the President was being paid £200 sterling and Professors received £80/2/-. The President also received remuneration for his post as Bishop, and therefore was paid a total of around £550 per annum. The entire faculty was also entitled to 10,000 lb. (4536 kg) tobacco per year. According to Tyler (1905:4), at this time the faculty of William and Mary was ".. probably better paid than at any other college in America."

There is little evidence in the College's library collections of any holdings in Natural Science or Mathematics during the early eighteenth century. By contrast, both Harvard and Yale were actively teaching science and conducting scientific research before 1735 and had libraries to support that study. But on 1772 December 8, the College purchased the library of James Horrocks (a former President of William and Mary), which included works in the physical sciences and mathematics that represented most of the significant thinking of the previous one hundred years (Neiman, 1968). Among the books purchased from the Horrocks estate were Newton's *Principia*, two copies of Newton's *Optics*, and Ferguson's *Astronomy Explained*... as well as his *Astronomical Tables and Precepts for Calculating the Times of New and Full Moons, Showing the Method of Projecting Eclipses from the Creation to AD 7800 to which is Prefixed a Short Theory of the Solar and Lunar Motions* (ibid.) Other books utilized by Professors at the College included Lacaille's *Astronomy*, Gregory's *Astronomy*, and Reilo's *Astronomy*.

Madison assumed the Chair of Natural Philosophy in 1773 and in 1777 became the President of William and Mary, which by now had a full, well-paid faculty, a fine collection of scientific apparatus, and a reasonably complete scientific library. It was poised to rival any College in America in its teaching programmes, and especially in the area of Natural Philosophy. Then in 1779, under reforms instituted by Madison and then Governor Thomas Jefferson, William and Mary became the first university in America. The elective system of study was introduced (which initially was roundly criticized in the North), as well as the first honour system.

However, all was not well. Throughout much of its history, the administration and governance of William and Mary had been marked by bickering between its faculty and the Board of Visitors. The Board tended to reflect political tendencies that were in opposition to the Crown, while the faculty possessed more loyalist tendencies which were derived in no small measure from their educational backgrounds in England. The Revolution brought these problems to a head, and within a short time of Madison's ascension to the Presidency, the College and its faculty openly supported the independence movement.

But there was a price to be paid. Whereas there were sixty to seventy students before the Revolutionary War, as the war wore on more and more students left the College to join the campaign, and by 1780 October the campus was largely deserted. Madison wrote to his second cousin and President-to-be, James Madison, that "The University is a Desert. ... We were in a very flourishing way before the first invasion. We are now entirely dispersed. The student is converted to Warrior..." (Madison, 1781a).

Sources of income for the College began to disappear. Duties that had been supplied to the College by the Crown were suspended and the College was forced to subsist on the rent from its lands, and even then it had a very hard time collecting these. According to Zech (2001), income dropped from £3048 per annum prior to the War to a mere £712 in 1777, but in a letter dated 1780 July 12 to President Ezra Stiles of Yale, Madison (1780a) quotes quite different figures: a decrease in revenue from £5000 or £6,000 to only about £500 per annum.

When the Capital was moved to Richmond in 1780 the economy of Williamsburg suffered tremendously as a result. Then in 1781 the French occupied the College's Wren Building, and used it as a hospital. One wing of the Wren Building burned on 1781 November 23 along with the President's House, and several outbuildings were also destroyed during the War. The French eventually agreed to pay £12,000 in damages – which many thought an outrageously low figure – but by 1786 they still owed half that sum (Morpurgo, 1976).

Despite these not inconsiderable 'diversions', Madison managed to resume classes at William and Mary in the fall of 1782. By 1795, there were between fifty and sixty scholars at the grammar school and thirty or forty studying philosophy or law.

In 1803, Samuel Miller wrote that:

> In natural philosophy there is a regular course of Lectures, attended with every necessary experiment. In this course, the works generally referred to, and recommended, are those of Rowning, Helsham, Martin, Desaguliers, Muschenbroeck, Cavallo, Adams, Lavoisier, Chaptal, etc.
>
> The number of Students in this College, in the beginning of the year 1801, was 53. The Library contains about 3000 volumes. The Philosophical Apparatus, when procured in 1768, was well chosen, and tolerably complete. Having been in constant use for more than 30 years, it stands in need of repairs, and is less complete than at first. (Miller, 1803).

The College had managed to withstand the ravages of the Revolution, but barely so. It became the task of Madison and the faculty to begin rebuilding. But the College's undoing came at the hands of the man who had previously been one of its most ardent supporters, Thomas Jefferson.

The reforms that Jefferson desired to propose in 1779 were never considered by the state legislature. Many thought the College ought to move to Richmond. Jefferson began to believe that the best way to serve Virginia's educational needs was to provide for a new university, and in 1800 he said of William and Mary: "We have in [Virginia] a college (Wm. & Mary) just well enough endowed to draw out the miserable existence to which a miserable constitution has doomed it." (cited in Goodwin, 1967:282). He continued to explain that Williamsburg was an unhealthy place and "... we wish to establish in the upper & healthier country, and more centrally for the state, an University..." (ibid.) Of course, the University of which he spoke was to be the University of Virginia, often known as 'Mr. Jefferson's University', located just a few miles from his Albemarle County home, Monticello.

3.2 The Acquisition of Scientific Apparatus

The College had not been without scientific apparatus during the early eighteenth century, although some was lost in the fire of 1705. We do know that Major General Alexander Spotswood bequeathed his 'mathematical instruments' to the College in 1740, and that the College

> ... may have owned a few surveyor's instruments, and navigation instruments, for use in the mathematics course; terrestrial and celestial globes were available; there may have been a telescope; and there were probably a few pieces of "apparatus" available for the study of "fluxions" and "optics" prior to 1767. (Goodwin 1967:61).

Eventually, the Board of Visitors was persuaded to expand the apparatus, and towards that end Professor William Small, holder of the Chair of Natural Philosophy and Mathematics and favourite tutor of Thomas Jefferson, was sent to London to make appropriate purchases.

Small had apparently badgered the Governor, who in turn pressured the House of Burgess for sufficient funding for the apparatus. In 1762 December the Board of Visitors set aside £450 for the purchase "... of a proper Apparatus for the instruction of the Students of the College in Natural and Experimental Philosophy." This was enough to provide for "... the best collection of scientific equipment in America." (Morpurgo, 1976:138).

A fragment of the original list of items purchased by Small survives in The College of William and Mary archives. It is written on a small sheet of paper about 4 inches by 8 inches, folded in half so as to form four pages. Each of those pages lists equipment and associated purchase prices, together with a financial balance brought forward from the previous page. Following is a transcription of these pages; see, also, Figure 3.

The first page:

Balance forwards	£178	10	0
The Fountain Experiment in Vacuo c. in open air with A Bason &c. -	3	3	0
A Lung's Glass -		10	6
The Barometer Exper[t] -		15	0
Wire Cage for breaking Glasses with 6 brass caps with Valves	1	11	6
Plates for Attraction & Cohesion -	0	15	0
A Pendulum to swing in Vacuo -	2	2	0
A Set of Glasses for the Air Pump - - - - - - - - - - - - - - - - - -	3	13	6
6 Pound of Quicksilver -	1	4	0
A Dipping Needle Compass 9 Inches Diam. With Needles for the Dip- -	15	15	0
A Horizon[l] needle with a center Pin Work for it to stand on for the variation - - - - - - - - - - - - - -	0	18	0
	£208	17	6

The second page:

Brought over - - - - - - - -	£208	17	6
E monochord - - - - - - - -	4	4	0
A machine for the Resistance of the Air according to M[r] Robinson	3	13	6
A Standard Barometer -	2	12	6
The 5 Platonic Bodies -	1	5	0
A Cone dissected -	0	12	0
To Packing all the above -	2	0	0
Peter Dolland			
The Arcromatic Telescope with a Triple Object Glass 3 ½ feet focus, two Eye Tubes for Astronomy & one for Day Objects	15	15	0
A best double microscope &c. -	7	7	0
A Solar Microscope with Apparatus - - - - - - - - - - - - - - - - - - -	5	10	0
The Reflecting mirror a true parallel Glass - - - - - - - - - - - - - - -			
	£251	16	6

The third page:

Brought forward - - - - -	£251	16	6
A 12 Inch Concave Mirror, a flat Mirror - - - - - - - - - - - - - - -	4	0	0
A 6 Inch Concave Mirror -		15	0
5 Lenses of different Sorts in Frames - - - - - - - - - - - - - - - - -	3	10	0
A Water Prism -	2	5	0
A Set of small Prisms in e Case -	1	11	6
Two Specule on a Frame to shew a number of Reflexions - - - -	1	5	0
3 Parall: Glasses 2 Inch: Diam. For taking the Sun's Altitude in Mercury	0	6	0
A Square Par: Glass 6 Inch: Diam. In a Frame - - - - - - - - - - -	1	1	0
An Object Glass for shewing the Rings of colors to be us'd With the Plane Glass -	1	11	6
A Square Mahogany Tube with an Object Glass & a Number of Eye Glasses to shew the Direction of the Rays of Light In Eye Glasses -	2	12	6
Packing the above - - - - - - - - - - - - - -	0	5	0
	£273	19	0

The fourth page:

Brought over -------	£273	19	0
An Electrical Machine ----------------------------	10	15	0
A Glass Jarr ------------------------------	2	8	0
5 Glass Syphone ------------------------		7	6
A Model in Gloass to show the manner of Intermitting & Reciprocating Springs ----------------------	2	14	0
17 Capillary Tubes -----------------------------		6	6
2 Glass Models of Pumps ------------------------	4	4	0
2 Glass Parallal Plains ---------------------------		18	0
A Glass Jarr, for the Hydrostatic Balance, the Screw, wheel & Axle Compound & other levers & Weights, Wedges & Weights, Pullies & Weights & y^{e} 6th Mechanic Power, all fix on 2 Brass Pillars	20	7	0
A Brass Circular Carriage ------------------------	3	8	0
A Mahogany inclin'd Plane ^{wth} a Quadr^{t} which sets to any Angle wth Scale & Nest of weights 164 ^{oz} Troy ----	4	16	0
Dr. Barker's Mill -------------------------------	4	4	0
An Instrument to try the Force of falling Bodies ---------	3	17	0
	£332	4	0

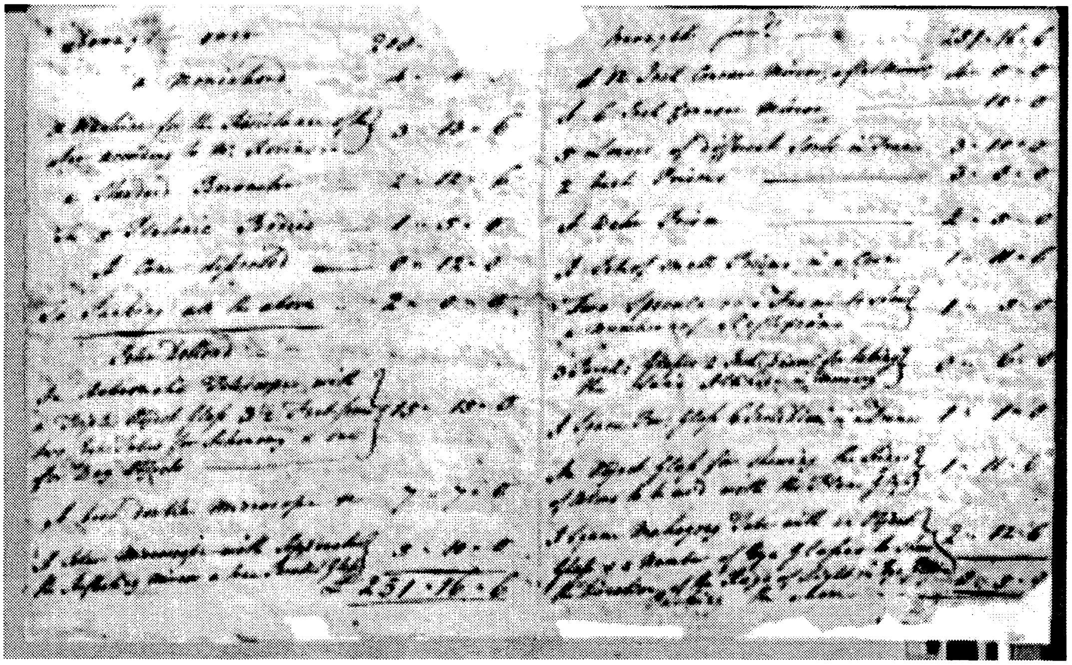

Figure 3: The second and third pages of Small's equipment purchase list (courtesy The College of William and Mary Library).

There are a number of very interesting things to note about this list. Firstly, page one begins by bringing forward a balance of more than £178. One has to wonder what was purchased with these funds and whether they may have related in some way to astronomy. In our discussion of Madison's observations (Section 3.4, below) we shall note that he had access to astronomical instruments not in the above list, including at least one reflecting telescope, an astronomical clock and a transit telescope. At least one of these telescopes was manufactured by James Short (Madison, 1789c), and could have been purchased on this trip.

Secondly, we note that the Board of Visitors set aside £450 for the purchase of apparatus. What became of the remaining £118? Was this money spent elsewhere and accounted for on yet another list? Madison was justifiably proud of the College's collection of scientific instruments, and on 1780 July 12 he advised Ezra Stiles (President of Yale University) that "We have a well chosen Apparatus which cost £500 made by the best Hands in London" (see Goodwin, 1967:237-238). Does this indicate that even more than the allocated £450 was eventually spent on scientific equipment?

Finally, we should note that the above listing includes a 12-inch concave mirror, a 6-inch concave mirror and a flat mirror. Were these purchased for use in the construction of telescopes?

So much equipment was purchased that the College needed to take extraordinary steps to clean and maintain this rapidly-growing collection, and according to the minutes of the faculty on 1772 August 11, the College directed that "Mr. Matthew Davenport be appointed to clean and take care of the College Apparatus, and that he be allow'd a salary of 10£ pAnn." (College ... Faculty minutes, 1729-1784).

Unfortunately, Small was at heart a loyalist and constantly at odds with the other members of the faculty and the Board of Visitors, so he decided to remain in England and never returned to Williamsburg after his London shopping trip. But clearly he had shopped well. Even the American Philosophical Society had to wait twenty years before it would own a telescope of the quality of the Dolland achromatic refractor at William and Mary, and the collection brought considerable prestige to the College (Morpurgo, 1976). In this context, Hornberger (1945:61) notes that at this time "Harvard's greatest rival in Physics was probably William and Mary...", and that it was safe to say that the apparatus at William and Mary "... was comparable to the apparatus at Harvard."

With Small gone there was no one at the College who was qualified to actually put the apparatus to work, and five years after Small "... had shipped to Virginia the superb paraphernalia which should have served to make William and Mary the head and the heart of scientific teaching in America ..." (Morpurgo, 1976: 140) the collection lay in disuse. This situation was roundly criticized by the local newspaper but in the 1771 August 15 issue it noted that Small's successor, Thomas Gwatkin, was willing to make use of some of the apparatus, "... but only if it could be appropriately housed and maintained." (Morpurgo, 1976:162).

Once Madison was appointed to the Chair of Natural Philosophy he began to use the apparatus, and he continued to look for other scientific instruments that would enhance the collection and could be utilized in his teaching. In 1778 Thomas Jefferson and others prepared a "Bill for Amending the Constitution of the College of William and Mary", and this included the following interesting proposal:

> And that this commonwealth may not be without so great an ornament, nor its youth such an help towards attaining astronomical science, as the mechanical representation, or model of the solar system, conceived and executed by that greatest of all astronomers, David Ryttenhouse; Be it further enacted, that the visiters [sic.] ... shall be authorized to engage the said David Ryttenhouse ... To make and erect in the said College of William and Mary, for its use, one of said models ... the cost and expense... be paid by the Treasurer of this commonwealth ... (cited in Goodwin, 1975: 237).

Acquisition of an 'ornament' such as this certainly would have put William and Mary on a par with Princeton in this area, but unfortunately this bill was never put before the House of Delegates.

Other evidence exists of Madison's on-going quest for additional apparatus. In a letter dated 1782 October 3, he asks Colonel Randolph to contact Rittenhouse "... to furnish some electrical apparatus ..." that he has been trying to get built (Madison, 1782b). Madison had apparently been unsuccessful in getting Rittenhouse to work on the apparatus and thought that Randolph might be able to use his influence. No evidence exists that the apparatus was ever obtained.

Madison was highly protective of the instruments in his possession. Upon his appointment to the commission to undertake a survey of the Virginia-Pennsylvania border, Madison received a letter from the Governor of Virginia, Thomas Jefferson, indicating that "... for the Pittsburg observations we must sollicit the proper Instruments from your Corporation [The College of William & Mary] which we will undertake to return in good order, or if injured to replace them. I therefore beg the favor of you to sollicit the Loan of those Instruments..." (Jefferson 1781). In his reply Madison (1781b) insisted that if the College's astronomical clock was damaged then it should be repaired if possible, or else replaced just as soon as peace would allow a replacement to be obtained from London. In this same letter, dated 1781 April 8, he carefully gives instructions for the transportation of the clock: "... if carried in a covered Waggon which shall be provided, well packed, laid on a feather bed ... or otherwise on Straw, or perhaps swung it cannot receive Injury." (ibid.). Madison (1785) later boasted that the College's astronomical clock was more accurate than the one used by the Pennsylvania delegation, which was led by none other than David Rittenhouse.

Madison continued to use the collection of scientific apparatus throughout his tenure at the College, and although "... well chosen and tolerably complete ..." when procured in 1768, by 1803 it was deemed to be "... in need of repairs ... [and] less complete than at first." as a result of constant use over more than 30 years (Miller, 1803). By 1824, when the Commonwealth was studying the possibility of moving the College to the capital in Richmond, a report concluded that it was "... impossible to give a very accurate statement of the philosophical and chemical apparatus. The former was purchased in Europe many years ago. Part of it is very valuable, but it is not extensive." (Report ..., 1824:317).

Disaster again struck the College in 1859. For the second time in its history there was a major fire in the Wren building, and the cabinet containing the collection of scientific instruments was destroyed. This cabinet it said to have contained "... several old instruments valued for their antiquity as the relics of the science of the former ages." (Faculty Minutes ..., 1859:269). Thus the equipment that was purchased with such enthusiasm and promise in 1767 met its end almost one hundred years later in this second conflagration of the Wren Building. A newspaper report published at the time indicated that among the items lost was "... an astronomical clock, of very curious mechanism, and some two or three centuries old." (Faculty compilation, 1874:554). This sounds like the very same clock that Madison expressed such pride in during his work on the Virginia-Pennsylvania boundary.

3.3 Founding of the College Observatory

In *Early American Observatories: Which Was the First Astronomical Observatory in America*? Willis Milham presents a history of observatory building in America. He concludes that the Hopkins Observatory at Williams College is the oldest extant astronomical observatory building in America. But he also acknowledges that "... the reader is left to judge which was the first Astronomical Observatory in America." (Milham, 1938:52).

Milham classifies observatories as (1) temporary observatories, (2) makeshift observatories, (3) mere repositories of apparatus, and (4) regular permanent observatories. He notes that if a telescope were mounted in the open on a pier and then covered in some way so that the instrument did not have to be taken indoors following use, that this might be considered a temporary observatory. If a mere shack or building of temporary construction were used to house an instrument for a few months or even a few years, this still might be appropriately considered temporary. If a telescope were placed in a building in order to view through its windows, this might well be considered a makeshift observatory. If the telescope or other instrument were kept in some other location, then moved to the observatory for use, then the building would be a mere repository of apparatus. But a permanent observatory should have a pier for the mounting of the instrument, some sort of opening rooftop, and be built in such a way to last for a number of years.

It has been generally considered that the first astronomical observatory in America was one constructed for David Rittenhouse. In preparation for the transit of Venus in 1769, the American Philosophical Society arranged to build three temporary observatories in the general area of Philadelphia, one at Cape Henlopen on the Delaware Bay, one in Philadelphia, and one at Norriton. Milham (1938) describes the observatory in Philadelphia as an uncovered raised wooden platform, while others say that it had stone foundations, but was little more than a covered platform above (e.g. see Bell, 1964:7). The Norriton structure was spoken of as a log-observatory (Milham, 1938), and when Rittenhouse moved to Philadelphia in 1770 it was torn down.

Meanwhile, the observatory platform in Philadelphia was used for public rallies, the most memorable of which was the reading of the Declaration of Independence on 1776 July 8. After the evacuation of Philadelphia by the British, the instruments were again brought out for occasional use. However, the observatory was poorly designed for an ongoing observational programme and was razed in 1783. Clearly, the observatories build for the transit were temporary in nature.

Rittenhouse received a grant from the Pennsylvanian legislature, and constructed another observatory in Philadelphia in 1781. This octagonal brick building housed some of his instruments and from it he recorded many observations which were later published. In 1790, Franklin bequeathed his Short reflecting telescope to Rittenhouse. Upon his death in 1796, Rittenhouse was buried beneath this building, and his will stipulated that the observatory be set aside for the use of the American Philosophical Society. In fact, members used it so seldom that the property was returned to the Rittenhouse family in 1810, which effectively marked the end of its use as an observatory.

Back in 1778, Bishop Madison arranged for the erection of an observatory at The College of William and Mary. Humphrey Harwood was retained to build this observatory, and his Account Book survives in the Archives of the Colonial Williamsburg Foundation, and includes the following entries (Harwood, 1778):

May 2^{d}	To 15 bushels of lime @ 1/6. laying floor, & Build^{g} pillers to Observitory 30/	2:12: 6
	To 4 Days labour @ 4/ for M^{r} Madison	:16: -
June 12	To 40 bush^{s} of lime @ 1/6. 3 d^{o} of hair @ 3/9. & Cart^{g} 3 loads of Sand @ 4/.	4: 3: 3
15	To 80 D^{o} @ 1/6, to 5 days work @ 12/. 6 D^{o} @ 8/. & 6 Days labour @ 6/	13:14: -
20	To 11 Days work @ 12/. To 11 D^{o} @ 8/. 11 Days labour @ 6/	14: 6: -
24	To 9 D^{o} of d^{o} @ 12/. To 9 D^{o} @ 8/. & 8 D^{o} labour @ 6/.	11: 8: -

While it is not clear whether the work done during the month of June was for the observatory or some other purpose, it is clear that an observatory was built at the College, under the direction of Bishop Madison, beginning in May of 1778. Harwood's usual practice was to cite the location of the project in the first line detailing billings for that particular project. On June 27 he details repair work in the College laundry and kitchen, so it is quite likely that all the materials and labour documented from June 12 through June 24 related to the observatory.

It is also important to note how the materials that are listed here might have been utilized. The lime and sand would likely have been used to prepare mortar or a paved area. Perhaps the notation on May 2 regarding the laying of a floor amounted to paving the floor with mortar made with the lime and bricks. Meanwhile, the 'pillers' that were mentioned were certainly destined to become piers for a transit instrument, and perhaps for other telescopes. The hair would have been used in plaster. What might all this lime and the 81 man-days of skilled workers and labourers recorded from June 12th have been for? Apart from the observatory, there were no other constructional projects in progress at the College at this time.

The key to the puzzle may lie in the knowledge that the College had its own brick kiln as well as its own access to lumber. Lumber was typically milled on the building site in eighteenth century Virginia. Bricks for College buildings were made on campus from the founding of the College until after the American War of Independence. The likelihood is that the large amounts of lime were used together with bricks made at the College to construct a building. The 80 bushels of lime purchased beyond that used for the floor would probably have been sufficient for the purpose of laying approximately 10,000 bricks, on the basis of the ratio of lime to bricks used in other building projects noted in Harwood's records. Therefore, one might conclude that the observatory project involved a brick structure of 10,000 bricks build with 81 man-days of labour. Unfortunately, there are no archaeological records of brick remains that can, with certainty, be attributed to an observatory, and until such foundations or other archival evidence is identified, the location and construction of the observatory will remain a mystery.

Nor are we certain of the instruments that were housed in the observatory, although a letter that Madison wrote Rittenhouse on 1789 November 5 indicates that a transit instrument was definitely located there: "... the observatory in which the transit instrument had been formally placed, was not, at this time, rebuilt ..." (Madison, 1789c). It is logical to assume that the astronomical clock was located in the transit room at the observatory, and this is most likely the same clock that is referred to in the records of the Virginia-Pennsylvania survey and again in the accounts of the 1859 fire.

We also know from the Small apparatus purchases, that the College had in its possession a fine Dollond 'arcromatic' telescope and, from observational records, an '18-inch' reflecting telescope made by James Short. In astronomical circles, Dollond and Short were well-known names in the eighteenth century. The British father and son pairing of John and Peter Dollond respectively patented and developed the achromatic refracting telescope (see Andrews, 1992; King, 1979), and one of these instruments so impressed the Astronomer Royal that these telescopes were taken on Cook's second and third voyages to the South Seas (see Orchiston, 1998a, 1998b). It is clear that The College of William and Mary also possessed one of these excellent telescopes. Meanwhile, the William and Mary Short telescope also came from a manufacturer with impeccable credentials. Scottish-born James Short was a "... most celebrated personality ... [who] accrued a fortune by supplying excellent instruments (about 1360) to amateurs and professionals." (Andrews, 1996:99). His forté was the Gregorian reflecting telescope, although he occasionally fabricated Cassegrain and Newtonian reflectors. All of his telescopes were known for their optical superiority (see Bryden, 1968; Turner, 1969), and two Short reflectors accompanied the astronomers on Cook first voyage and were used to successfully observe the 1769 transit of Venus from Tahiti. Short's telescopes were generally described in terms of their focal length. Thus, the William and Mary reflector had a focal length of 18 inches (45.7 cm), and the aperture of the mirror would have been about 9 cm.

Although the College's transit telescope was undoubtedly installed in the observatory we cannot be certain that the Dollond and Short telescopes were also housed there, for both were small enough that permanent mountings would not have been necessary for their use.

In addition to its astronomical occupants, it is also possible that the observatory served as a meteorological station. Among the items in Small's list of purchases is "A Standard Barometer", and it is likely that other meteorological instruments were acquired. Madison certainly had an interest in meteorology, and various observations that he made are discussed in a 1779 letter to Rittenhouse, and were subsequently published in the *Transactions of the American Philosophical Society* under the title "Meteorological observations" (see Madison, 1779).

It is not clear when the observatory was destroyed, other than that this event predated 1789 November 5 when Madison (1789c) wrote Rittenhouse. The French occupied the College's main building in 1781, and the Wren Building for use as a hospital. Apparently, more space was needed for that purpose and was requested from the College, and on 1781 October 15, John Blair wrote to George Washington informing him that "... the Commissary has demanded of him the Keys of an out-building called the Granary other Houses near it..." (Blair, 1781). The letter specifically lists items in the buildings that cannot be moved or saved if this action should occur, but no astronomical equipment is mentioned nor is there any reference to the observatory. Washington, however, would not relent and just two days later replied: "... nothing but absolute Necessity could induce me to desire to occupy the College with its adjoin^{g} Buildings for Military Purposes ... [although] many of the Articles are easily removeable [sic]." (Washington, 1781).

Nevertheless, we know that "... some outbuildings were extensively injured ..." (Goodwin, 1967:247), and we can assume that the brick kiln was among the buildings that were destroyed since from that date records show that the College began buying bricks. Subsequently, the College attempted to recover some of the losses suffered during the American War of Independence, and a paper submitted to Congress noted that it was "... unable to complete the repairs of the other buildings rendered necessary by the injury done them whilst in occupation by the French until the year 1788." (Committee ..., 1928:246).

Based on present evidence, all that we can be certain of is that the observatory was constructed in the spring of 1778 and destroyed prior to 1789 November 5, but it is logical to conclude that its destruction was accidental, and occurred during the French occupation of the College. A key question now arises: despite its untimely destruction, was the building erected by Harwood for Madison intended as a 'regular permanent observatory'? If it was – and the evidence tends to support this – then this would have been the first observatory constructed in America that meets the criteria suggested by Milham, and it would almost certainly have been the first documented observatory of any kind associated with an American educational institution. Furthermore, its construction occurred long before 1802 when the observatory at Bogota, Colombia, was built, even though Donnelly (1973:55) regards this as "... the first permanent observatory in the New World ...".

It is interesting to reflect on whether the William and Mary observatory was ever rebuilt. No archival records have been located which document such a reconstruction, but Madison's 1789 November letter to Rittenhouse mentions that the observatory "... was not, at this time, rebuilt ..." (Madison 1789c), which could be seen to imply that a rebuilding was in fact planned. Park Rouse, noted Williamsburg historian, thinks that this did occur. In his book about the President's House he discusses attractions that the College offered its students, noting that: "Some of them were privileged to view the cosmos through Madison's observatory, which he had built in 1778 and reopened after the Revolution." (Rouse, 1983:87). Unfortunately, there is no firm documentation to support Rouse's assertion, and as if only to confuse the issue further, in his 1789 November 5 letter to Rittenhouse, Madison (1789c) reports on that day's transit of Mercury which was observed at William and Mary from two different rooms with two different telescopes but utilizing the same clock for timing. Where were these observations carried out if the observatory had not been rebuilt?

Nothing more is to be found in the College records regarding an observatory until after the fire of 1859 which completely gutted the Wren Building. Following this disaster, a new building was planned utilizing the walls of the original Wren Building but with a façade that included two towers. One of those was for the College bell, and other was to be used as an observatory (Lively, 1859). This new building was completed later in 1859, only to be destroyed in 1862 by yet another accidental fire, during yet another military occupation, this time by the Union Army (see Dearstyne, 1951; Savedge, 1969).

3.4 Madison's Astronomical Observations

No records exist that provide a complete picture of Madison's astronomical observations. However, correspondence and other notes demonstrate that he made many different kinds of observations, and over an extended period.

We have evidence that over the years he used three different telescopes: the Dollond refractor, an 18-in telescope by Short, of unknown origin but possibly also purchased in London by Small; and a transit instrument (that was originally housed in the observatory).

Largely because of losses sustained in the 1781, 1859, and 1862 fires, no observational material in Madison's own hand remains, although original notes of observations that he made with John Page have survived. Other than those notes, all of the information that we have regarding Madison's astronomical observations is derived from letters where he discusses his observations with others. Some of these letters were subsequently published in the *Transactions of the American Philosophical Society*.

In addition to those letters that mention specific observations, Madison refers to many non-specified observations in his letters. For example, on 1789 February 10 he tells Jefferson that he hopes to send him some astronomical observations with his next letter in return for some favours that Jefferson once granted him (Madison, 1789a), and in 1804 he informs Samuel Miller of Williamsburg that he intends sending him some copies of observations (Madison, 1804).

It is interesting to note that the surviving records of Madison's observations begin almost immediately after his return from London in 1776, and that his interest in astronomy continued unabated until the time of his death, as evidenced by the following letter from Jefferson dated 1811 December 29 which Madison would no doubt have read just weeks before his death in 1812:

> I had observed the eclipse of September 17th with a view to calculate from it myself, the longitude of Monticello, but other occupations had prevented it before my journey. The elaborate paper of Mr. Lambert shows me it would have been a more difficult undertaking than

I had foreseen, and that probably I should have foundered in it. I have no telescope equal to the observation of the eclipses of Jupiter's satellites, but as soon as I can fit up a room to fix my instruments in, I propose to amuse myself with further essays of multiplied repetitions and less laborious calculations (Jefferson, 1811).

What follows is a chronological listing of all documented specific astronomical observations made by Bishop James Madison, as well as intended observations which were unsuccessful for a variety of reasons. Throughout we have noted the sources of the documentation, which in many instances are the letters written by Madison to his friends and peers. We have attempted in each case to give some context for Madison's astronomical observations, either through historical references or by attempting to verify the stated observation with a commercial planetarium program such as *SkyMap Pro* or *Starry Night Pro*. We have not, however, attempted to make an accurate conversion of the exact times of each observation, given the differences in timekeeping between the eighteenth century and the present day, but rather we have used these programs to help fill in details of the observation which are lacking in the original documentation.

3.4.1 Observations to Determine the Latitude of Williamsburg in 1776

During his years as a member of the William and Mary faculty, Madison sometimes carried out astronomical observations in collaboration with his friend, John Page. Six years his senior, Page frequently corresponded on many matters, including astronomy. In a letter, to Rev. William Smith written in 1776, Madison relays some observations from Page, as well as some of his own: "... Mr. Page had resolved to send you his Papers upon y$^{\underline{e}}$ last Transit, which he observed at his seat, but y$^{\underline{e}}$ hurry of Business at present prevents him from putting y$^{\underline{e}}$ finishing hand to them." (Madison, 1776). The transit in question was most likely the 1776 November 2 transit of Mercury, which is referred to below.

Madison continues the letter with some personal observations.

I believe there is no doubt of y$^{\underline{e}}$ accuracy of y$^{\underline{e}}$ Observations upon y$^{\underline{e}}$ Longitude & Latitude of y$^{\underline{e}}$ places mentioned. I might add y$^{\underline{e}}$ Longitude of Williamsburg, which I have found by a Mean of several Observations = 5° 6' 22". (ibid.).

Madison apparently was rather proud of his ability to determine the longitude and latitude of a location, and he went on to use these skills for the benefit of his home state during the survey of the Virginia–Pennsylvania border in 1781. Much later, he carefully instructed Jefferson on just how easily latitude could be found using a simple handmade quadrant (see Madison, 1805).

3.4.2 The 1776 November 2 Transit of Mercury

One of Madison's fellow 'philosophers' and observing partners, John Page, kept a memorandum book of some of the observations that he and Madison made. On 1776 November 2 he wrote:

I observe the transit of ☿ at Wm & Mary College with an 18 Inch reflector magnifying about _____ times. Mr. Madison noted down the Time by the Clock (made by Shelton, with Gridinon Pendulum) as corrected by him

external contact 4:12:29
internal contact 4:14:29 (Page, 1762-1797).

The 18-in reflector mentioned here is almost certainly the Short reflector owned by the College. It is interesting to note that Page left the magnification blank as though he intended calculating it at a later date.

The above times agree within minutes of those predicted by *SkyMap Pro*, which also indicates that in Williamsburg the Sun set on this day at 17 h 08 m, within minutes of the end of the transit – making this phase of the event virtually impossible to observe. In this context, note that in the above account Page makes no mention of observing the end of the transit.

3.4.3 The 1778 June 24 Total Eclipse

In a letter to Thomas Jefferson dated 1778 July 26, Madison acknowledges receiving notes on observations from Jefferson. He then proceeds to describe his own observations:

> I was very glad to see your Observations, tho they differ considerably from those we made here. The same Misfortune of a cloudy Morning prevented us from seeing y^{e} Beginning – but we had a very good View of y^{e} End which Mr. Page made at 11^{h} 3' 25" – and myself at 11^{h} 3' 27" – tho I think y^{e} Altitude of y^{e} Sun was such as must render y^{e} Observations uncertain to a few Seconds. The End of total Darkness was at 45'.30" – This was pretty nearly determined, for y^{e} Return of Light was almost instantaneous. There was really something awful in y^{e} Appearance w^{ch} all Nature assumed. You c^{d} not determine your most intimate Acquaintance at 20 yds distance. Lighting Buggs were seen as at Night.
> I began on y^{e} 17th to make corresponding Observations & had y^{e} Time very accurate. Rittenhouse got to Phila Time eno' to make an Observation, but he likewise saw only y^{e} End, and informs that it was at 11. 14' 40" [?] M. [?] Time. The Effect of Parallax will doubtless make a considerable difference. (Madison, 1778).

According to *SkyMap Pro*, a total solar eclipse was visible from Williamsburg on 1778 June 24, and no doubt this is the eclipse discussed in the letter to Jefferson. *SkyMap Pro* indicates that this event began at 08 h 38 m 33 s, reached totality at 09 h 48 m 31 s, which lasted for 3 minutes and 43 seconds, and ended at 11 h 09 m 37 s. Madison's notations about the end of total darkness seem unclear, but his measurement of the ending of the eclipse corresponds reasonably with the time provided by *SkyMap Pro*.

3.4.4 Planned Observations of Jovian Satellites in 1778 October

Madison also notes the upcoming immersion of Jupiter's moons in his 1778 July 26 letter to Jefferson:

> If you sh^{d} be at Home in October you may have an Observation on an Imm. Jup. Sat. on y^{e} 5th at 8^{h} 25' 11" and another y^{e} 12th at 10^{h} 20' 56" for this Planet. They are more to be depended upon than other Observations because ye Theory is better known. (ibid.).

Both of these predictions agree within minutes of those calculated by *SkyMap Pro*. It is interesting to see the teacher in Madison as he explains to Jefferson why he is able to predict so many months in advance the precise times of these events.

3.4.5 The Aurora Borealis in 1779

In a letter written to David Rittenhouse in 1779 November, Madison documents a number of meteorological observations that he had made over the course of the preceding year. Among these are changes in barometric pressure recorded during the observation of an aurora borealis. Madison (1779) also notes that these barometric observations

> ... not only shew us the different states of the atmospheres, but, perhaps, may throw farther light upon the true cause of the Aurora Borealis. That fact is, that a fall of the barometer always succeeds that phenomenon. The frequency of its appearance lately, gave me an opportunity of observing this effect at different times.

In his letter Madison explains that this theory was first proposed by Benjamin Franklin and that the more rarefied air evident during a time of low pressure could lead to auroral displays in the same way that similar displays can be produced in a laboratory by a rarefaction of air and electricity.

Late 1778 and early 1779 marked the peak of the sun-spot cycle, which would certainly have contributed to an increase in auroral displays at this time.

3.4.6 The 1780 October 27 Solar Eclipse

In a letter to David Rittenhouse written in 1780 November Madison discusses, among other things, two failed observations of eclipses: "But a cloudy day, had no other circumstance intervened, effectually prevented all observations. I was attentive to that of May also, the last ... eclipse, and am satisfied it was not visible here. The Reflection magnifying at that time about 130." (Madison, 1780b). From this letter it is not clear what sort of eclipses Madison was trying to view. The more recent observation was prevented by cloudy weather, but no mention is made of bad weather in relation to the earlier eclipse. It appears that he attempted to observe this event with the Short reflecting telescope, but was unable to see an eclipse and concluded that it was not visible from Williamsburg.

In 1779-1780 there were three lunar eclipses that would have been visible from Williamsburg, weather permitting: a total eclipse on 1779 May 30, and partial eclipses on 1780 May 18 and November 12. Interestingly, there was also an annular eclipse of the Sun on 1780 May 4, but it was not visible from Williamsburg. However, there was a total eclipse of the Sun on 1780 October 27, and at mid-eclipse ~75% of the Sun would have been obscured as viewed from Williamsburg.

Although no date is given in the letter for Madison's second attempted observation, it is likely that this occurred in November since he specifically said that he delayed the completion of the letter until this planned observation had taken place. Since he describes the weather during the day and since even a partial solar eclipse would have been a major event, it is reasonable to conclude that he was attempting to view the solar eclipse of 1780 October 27.

The earlier observation is more of a puzzle. It would seem that Madison had accurate enough information to be able to ascertain whether any particular eclipse would be potentially viewable from Williamsburg. The 1780 May annular eclipse was visible only from Africa and the extreme south of South America, and while the partial lunar eclipse in this same month was indeed visible from Williamsburg the Moon was only at an elevation of 15°.9 when it entered the penumbra and at 5°.4 when it entered the umbra. Therefore, it is likely that Madison was asserting that none of the totality (or perhaps any of the eclipse) was observable from Williamsburg.

3.4.7 Observations of Jovian Satellites in 1780

In his 1780 November letter to David Rittenhouse, Madison describes several Jovian satellite observations that he had made the previous May:

> Having made during the summer several observations upon Jupiter's Satellites, I send such as appeared the best.

		Time at Paris	Time here	Difference
May 4th	Em.	2.39.45	9.23.30	5.16.15
May 20th		0.50.10	7.42	5.16.10
	2. lat			
May 30th	2. lat.	0	9.24.51	5.26.9

> The last observation, this upon the 2nd satellite, was much the best, both on account of the remarkable time of the night, and accuracy of the timekeepers, and the addition also of another observation with a very good Refractor, who observerd the emersion the instant almost that I noticed it with our Reflector. (Madison, 1780b).

These observations seem rather sophisticated. Two instruments were used, undoubtedly the Dollond refractor and the Short reflector, and once again Madison relied upon his accurate timekeepers.

SkyMap Pro quite closely matches the May 4 observation, but its time for the May 20 event (which so pleased Madison) differs by about an hour. Meanwhile, this software package does not show any Jovian satellite event that can be associated with Madison's May 30 observation, which may simply reflect a problem in our understanding of the notation that he uses in describing these events.

3.4.8 Aurorae Observed in 1781

According to a letter dated 1782 June 19 sent to President Stiles of Yale, Madison observed "... several Auroras ..." in 1781 and made notes on these. In his letter he explains that he is not able to send details of these observations because the fire which gutted his house on the night of 1781 November 22-23 destroyed all his books and papers (Madison, 1782a). Apparently, in addition to books, at this time Madison lost all his observational notebooks and other records.

Aurorae were relatively rare in Virginia, so perhaps the aurorae referred to in this letter were the same ones he observed in 1779.

3.4.9 The Comet Observation of 1784 January

In a letter to Thomas Jefferson dated 1784 January 22, Madison describes a comet which he assumes Jefferson has also seen:

> You have no doubt observed the Comet w^ch made it's Appearance here last Friday Even^g for y^e first Time. The Cloudiness of y^e Evening prevented observations till last Night y^e Night before. Its Situation is near, I, in y^e Pircis Australis. I shall endeavour to trace its Progress will send you y^e Results. (Madison, 1784).

This object was C/1783 X1, the so-called 'Great Comet of 1784' (Marsden and Williams, 1999), which was discovered in the southern sky by de la Nux on 1783 December 15, observing from Réunion Island (Kronk, 1999). By 1784 January 16, when it became visible from Williamsburg, this comet was already a conspicuous naked eye object with a short tail (see Kronk, 1999 and Vsekhsvyatskii, 1964 for details), and from this date on it would have generated considerable public interest.

3.4.10 Planned Observations of Jovian Satellites in 1784

In 1783 Madison was appointed to lead a commission from the Commonwealth of Virginia for the purpose of fixing the boundary line between Pennsylvania and Virginia. David Rittenhouse was appointed as his counterpart for the state of Pennsylvania. On 1783 October 16 Madison wrote to the Pennsylvania commissioners about the survey, and proposed that the following observations be carried out in 1784:

> ... that the Astronomical Observations on which we are to depend in this Matter must be those of the Emersions and Immersions of Jupiters Satellites, and that an equal Number of them before and after [Jupiter's] oppositions to the Sun should be taken if possible to compensate the Errors that may arise from the different Apertures of the Telescope we may use. This Opposition will be in the month of August; and as every second of time will give an uncertainty of a Quarter of a Mile, a sufficient Number of them must be taken to bring the Decision as near as possible. Six weeks or two Months will then be necessary to be employed in making the observations both before and after the Opposition. (Madison, 1783).

It is interesting to note that Madison believed he had access to more instruments for this survey than might be available to Rittenhouse: "We would be glad to know what Instruments you can furnish, that we may provide the Remainder here. We can furnish two clocks, two equal altitude Instruments and Telescopes for each of our observers ... " (ibid.).

Madison provides a report on the survey in a letter to Thomas Jefferson dated 1785 April 10:

> We were engaged last Year in determining the 5 degrees of longitude claimed by Pennsa. And I believe few Points on the Globe are better ascertained. Our Instruments were good, the Time piece I carried from this Place exceeded even Mr. Rittenhouse's. Our Observations were continued for more than three months. I had some Thoughts at first of sending you the Observations, as they tend not only to establish the Point in Dispute between the two States, but also the Measurement of a greatere, or longer Line upon the Globe that has ever yet been effected, and thus shew with more Certainty the real Length of a Degree of long. In that Lat. It appears to be less than has been hitherto supposed. The Termination of the 50s falls short of the Ohio about 15 or 16 Miles. (Madison, 1785).

This report reveals three very interesting pieces of information. Firstly, given his earlier note to Rittenhouse about equipment and the reference to his time piece in this note to Jefferson, Madison clearly felt that his equipment was superior to that used by Rittenhouse, thereby reinforcing the notion that at this time The College of William and Mary perhaps owned the best astronomical instruments in America. Secondly, through his survey and calculations Madison determined a more accurate way of determining the length of a degree of longitude at a particular latitude. Indeed, he claims that his calculations were more accurate than "... has ever yet been effected." (ibid.). And finally, Madison's letter explains the rather odd configuration of the state of West Virginia (which was part of Virginia at the time of the survey). Apparently, the southern border of Pennsylvania was originally to extend a certain distance, at least to the Ohio River. However, Madison found that the real termination fell some 15-16 miles short of the Ohio River, and as a result Virginia was left with a small finger of land between 3 and 15 miles wide and about 60 miles long extending north between Pennsylvania and Ohio.

3.4.11 The 1789 November 2 Lunar Eclipse

Madison sent David Rittenhouse information about two different observations made in late 1789 that he wanted read before the American Philosophical Society. He began his notes by mentioning that the observatory in which the transit instrument had formerly been placed had not been rebuilt and as a result he was not "... enabled to attend to the going of the time-keeper." He then went to considerable pains to explain how he computed accurate time for the observations by using "... correspondent double altitudes, taken with a sextant."

His observations of this lunar eclipse are as follows:

	App. Tim.		
	H.	'	"
Penumbra–thought to touch the) at	6	8	46
Eclipse begins,	6	21	0
Tycho begins to immerge	6	38	45
Wholly immerged	6	43	"
	Shadow		
Shadow reaches mare nectaris	7	34	0
Tycho begins to emerge,	7	57	44
Wholly emerged,	8	1	26
End of the Eclipse.	8	30	0

> These observations were made with an achromatic telescope, magnifying about 60. – The immersion and emersion of tycho were particularly noted, as those times may be more accurately ascertained, than either the beginning or end of a lunar eclipse – The weather was remarkably favourable for astronomical observations. (Madison, 1789c).

The software package *Starry Night Pro* is able to track this eclipse as it passes over Tycho, and the times shown in this simulation agree with Madison's to within a few minutes.

3.4.12 The 1789 November 5 Transit of Mercury

In the same communication to Rittenhouse reporting the November 2 lunar eclipse, Madison reports observations of a transit of Mercury:

> The 1st internal contact, was not seen. When I first discovered ☿, he was somewhat advanced upon the sun's limb, and had an oval appearance, the longer axis directed towards the body of the sun. – But at $8^h.3'.10''$ The planet suddenly assumed a round figure, and the first internal contact was according noted.
>
> The 2d, internal contact, 12. 53 42.
>
> The 2d, external contact could not be determined with any tolerable accuracy on account of the remarkable undulatory motion which appeared upon the sun's limb, soon after the 2d internal contact. Mercury disappeared to me, at, $12^h\ 55'\ 2''$. I made use of an achromatic, magnifying about 150.
>
> Mr. Andrews, professor of mathematics, with a reflector made by Short, and with a magnifying power of 90-made the following observations.
>
> The 2d internal contact - - $12^h\ 53''\ 48''$
> 2d external contact - 12 55 19
>
> The same undulatory appearance was not seen in the reflector, and therefore the 2d external contact observed by it, may be more relied upon – The times of our observations were taken from the same clock, but noted in different rooms – The day was remarkably favourable, being clear, and sufficiently calm. (ibid.).

This is yet another case where Madison put two instruments to use simultaneously in order to confirm his observations. It is uncertain where these observations took place, but clearly the instruments were indoors at the time, perhaps in Madison's house or in the Wren Building.

Simulations using *SkyMap Pro* and *Starry Night Pro* produced times that were remarkably close to those reported by Madison.

3.4.13 The 1804 January Eclipse of the Moon

Always the teacher, Madison apparently required (or inspired) his students to observe with him. Towards the end of 1804 January, a student named George Blow wrote to his father from Williamsburg:

> Since my arrival here I have been in tolerable good health, at present I am little indisposed owing to my want of sleep. The night before that last I did not go to bed at all being with Mr. Madison at College viewing through the Telescope an Eclipse of the Moon, which, from the commencement of the Penumbra to the termination of the whole eclipse continued from one until ten o'clock in the morning, and last night I was at a ball which kept me up until twelve. (Blow, 1804).

Although there was an eclipse visible from Williamsburg on 1804 January 26, the times in no way match those noted by this student. In fact the eclipse began in the afternoon at 13 h 48 m local time, and ended at 18 h 54 m. The Moon was only at an elevation of 15°.9 at the end of the eclipse, which occurred as the evening began and not in the morning as Mr Blow indicated.

3.4.14 The 1806 June 16 Solar Eclipse

In a letter written to Thomas Jefferson on 1811 November 19, just months before his death, Madison acknowledges Jefferson's observations "... upon the late solar Eclipse." Madison then arranged for Mr W Lambert in Washington to calculate the Longitude of Monticello based upon Jefferson's data. In his letter to Jefferson, Madison also states that:

> By my Observation upon the Solar Eclipse of 1806, the End of which was accurately noted, & the Time well ascertained, Williamsburg is 5^h 17' 4" from Paris 9' 20" Greenwich which compared with the Long. Of Monticello, gives the strait-lined Distance, I believe, very accurately, or rather nearly. (Madison, 1811).

Madison goes on to observe that, based upon his calculations, the time difference between Monticello and Williamsburg is 1 h 39 m10 s.

The total eclipse of 1806 June 16 was visible in Williamsburg, but only 90-95% of the Sun was obscured. It is not clear that this was the same eclipse for which Jefferson supplied notes to Madison. There were two other partial solar eclipses that were visible during this period, on 1809 April 14 and 1811 September 17, and either of these may have been the eclipse noted by Jefferson, but it is less likely that the 1811 eclipse was the one observed since it would have been difficult to get the notes from Jefferson to Lambert and then on to Jefferson in just two months.

3.5 Astronomy in the College Curriculum after the War of Revolution

Following the war, many thought that the College had seen its best days. Jedediah Morse, Noah Webster, and Ezra Stiles, among others, visited Williamsburg and announced that Virginian civilization had vanished and that the College was filled with lazy students and run in a disorganized manner (Morpurgo, 1976).

There can be no doubt that William and Mary was not as regimented as its northern counterparts. But there also can be no doubt that the demands placed upon the students at William and Mary equalled if not exceeded those placed upon students elsewhere, because at William and Mary students were expected to do so much for themselves by the way of regulating their classes and exams. The examination process, in particular, was very rigorous. Jefferson described it as a way of "... raking out the rubbish." (Morpurgo, 1976: 218).

The Statues of 1792 were introduced to provide a new framework for the College. Attendance rules were revised, and a new core curriculum was established:

> For the degree of Batchelor of Arts, the Student must be acquainted with those branches of the Mathematics, both theoretical and practical, which are usually taught as far as Conic Sections, including, viz. The first six books of Euclid, plain Trigonometry, the taking of Heights and Distances, Surveying, Algebra, the 11th and 12th books of Euclid, Spherics, Conic Sections: must have acquired a knowledge of Natural Philosophy as far as it relates to the general principles of Matter, Mechanics, Electricity, Pneumatics, Hydrostatics, Optics, and the first principles of Astronomy ... (cited in Morpurgo, 1976:219).

Thus William and Mary became possibly the first American institution of higher learning that required a basic knowledge of Astronomy for a Bachelor's degree, and Madison liked to include astronomy and examples drawn from astronomy throughout his lectures on Natural Philosophy.

We are fortunate to have in The College of William and Mary Archives, the complete original lecture notes from seven students who attended Madison's classes between 1796 and 1811 (e.g. see Anonymous, 1800-1801; Groghan, 1808; Murchie, 1809; Peachy, 1809-1811). These notes are interesting in that one can see the lectures growing longer year by year as the body of relevant knowledge increases. Perhaps most illuminating is the 'Head' or first lecture, where the content of the course is summarized. After an introduction to and definition of 'Natural Philosophy', Madison briefly speaks of the great Natural Philosophers down through the ages to the end of the eighteenth century. He begins with a discussion of Copernicus and his examination of the 'Ptolemaic system of Astronomy.' This is followed by a brief overview of the work of Tycho Brahe and his view of the cosmos. He then discusses Kepler, his work with Brahe, and his theory of planetary orbits. He then moves to Galileo, noting that "... his knowledge in Astronomy & natural Philosophy was superior to any man of the age." He continues with the work of Bacon, and on to Newton of whom he said "... of the abilities of Newton as Philosopher, it's unnecessary to say any thing." Following his explanation of some of Newton's work, Madison concludes that "... since the time of Newton, so many eminent Philosophers have appeared that it would be doing injustice to point out any [particular] individuals." (Watson, 1796). At the heart of what Madison taught was fundamental knowledge of the cosmos, which he wanted each of his students to understand and to appreciate.

4 DISCUSSION

The research undertaken for this paper has raised some interesting questions. Even with the list of apparatus purchased by Small, we are left wondering what additional items he purchased with the £178 that has not been unaccounted for. Was the Short telescope obtained at that time, and if not, when and from whom was it acquired? What other apparatus was purchased and was any of it used for the study of astronomy? It is unlikely that further research will reveal the missing pages of Small's list, but it may be possible to find references to other instruments that the College had in its possession during this period. A more thorough examination of the apparatus purchased at this time might throw light on the types of demonstrations that various instruments were used for and precisely what was taught to the students. Back in the 1970's some research was carried out in this area by a member of the William and Mary faculty, but follow-up studies are required.

And what became of the observatory? Was it destroyed in the War of Revolution? Was it rebuilt? What did it look like? How large was it? What instruments were housed there? The Colonial Williamsburg Foundation has done a thorough job excavating on the grounds of the colonial campus. However, most of their efforts have centred on the three main buildings: the President's House, the Brafferton building used for an Indian School, and the Wren Building. All of these buildings exist today. A few of the outbuildings have been reconstructed as well, but most have not been. It is possible that more archaeological studies, particularly with the requirements of an observatory in mind, will yield relevant information. It is also possible that more references to the observatory, its use, and its potential repairs exist in archival sources. The College possesses several collections of letters written by individuals associated in one way or another with the College. Perhaps relevant information exists in those letters, or in letters and other documents now in private collections. Further research could throw important new light on what, in Milham's terms, may very well be the first 'regular permanent observatory' build in America.

It is unfortunate that none of Madison's original observational records and associated notes survived the fires in the President's House and the destruction of the observatory. As we have seen, letters in the William and Mary archives, in the Jefferson papers in the Library of Congress, and in the Owens Papers contain many useful references to the observations that he made, and it is likely that additional material exists in private and public collections, and is simply waiting to be discovered.

5 CONCLUSIONS

The study of Natural Philosophy and astronomy had an important place at The College of William and Mary during the second half of the eighteenth century. Its importance accelerated in the mid-eighteenth century under the tutelage of William Small, and expanded still further after the purchase of an impressive collection of scientific instruments, including telescopes, in 1768. But it was the application and determination of Bishop James Madison, first as Professor of Natural Philosophy and later as President of the College, that established William and Mary as one of the foremost astronomical centres in the country and allowed it to play an important role in the development of astronomy in eighteenth century America.

Madison must also be credited with constructing what may very well be the nation's first 'regular permanent observatory', and certainly the first observatory erected at an educational institution in the USA. He also integrated astronomy into the overall educational curriculum, and created an educational system that focussed on the importance of the pupil-teacher relationship and stressed analytical thinking over mere recitation of facts.

It is clear that by the end of 1778 The College of William and Mary was poised to become a major contributor to the study and teaching of natural sciences and astronomy in America. It had an excellent library; arguably the best collection of scientific apparatus in the nation; a transit telescope and excellent astronomical clock; two other telescopes of impressive provenance; and an observatory. It also had an outstanding astronomical role model in the person of Madison, and one of the best-paid faculty of any College in the country. Then the War of Revolution intervened and almost forced the College to close permanently. It was only Madison's drive, his enthusiasm for science, and his love of teaching that helped to keep it open and allowed astronomy to continue and indeed to flourish.

Following Madison's death, the fortunes of the College ebbed and flowed with the currents of history. The Wren Building suffered from further fires in 1859 and 1862, and the College's investments were once again lost as a result of the Civil War. In 1906, William and Mary became a state institution, and it experienced a resurgence of growth and prosperity following the end of the Second World War.

Today, The College of William and Mary has about 5,600 undergraduate students, and is ranked first among American public universities in terms of commitment to undergraduate teaching. It is also the highest ranked small public university in the country, and while it continues to support a strong physics programme, sadly there are only two courses on offer in astronomy.

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Finally, I wish to thank The College of William and Mary for permission to publish Figure 3.

7 NOTES

1 In this paper the term 'War of Revolution' relates to the eighteenth century War of Independence with Great Britain, and not to the American Civil War of 1861.

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