Burch Mini-mester: Time, Tides, and the Cosmos in London

Honors Global Education and Fellowships

Title of Program: BFRS 320: Burch Seminar in London:

Time, Tides, and the Measurement of the Cosmos

Faculty Director: Christopher Clemens, Department of Physics and Astronomy

Program Location(s): London, England

Affiliation(s): UNC's Centre for European Studies at Winston House

Total Credit Hours: 3

Proposed Courses: ASTR 105H: Time, Tides, and the Measurement of the Cosmos

Pre-requisites: None

Minimum GPA: 3.0

Contact Hours: 40 hours

BURCH SEMINAR MINI-MESTER PROPOSAL

BFRS 320: Burch Seminar in London
Time, Tides, and the Measurement of the Cosmos

Summer 2018
3 weeks, late June – mid-July

Professor Christopher Clemens
Department of Physics and Astronomy

1. PROGRAM OVERVIEW

The phrase "scientific revolution" refers to a series of radical changes to our view of the cosmos and our methods for learning about it. But were the changes really radical, and is revolution the appropriate word? This class will examine that question beginning in the 13th century, when natural philosophers in Paris began to question the authority of Aristotle in physics, while the Oxford Calculators at Merton College discovered a way to employ the methods of Euclidian geometry to prove theorems of mechanics. Among other things, they developed a proof for the "mean speed theorem" that two centuries later became Galileo's law of falling bodies. Their proof used the "area under a curve" for simple geometric figures, and thereby foresaw part of Newton's calculus. In the same era, compelling arguments were put forth for the rotation of the Earth, but objections were raised over the misalignment between the Earth's center of dimension and its center of gravity which would arise from having heavy continents on one side of the Earth and a lighter element, water, on the other. The Earth would wobble as it rotated and we do not sense this, ergo the Earth is fixed.

In parallel to these developments in the universities, the sailors and navigators of the 15th and 16th centuries developed a practical astronomy that permitted them to predict high tides from the phase of the moon and the "establishment" of each port, which is the time before or after "lunar noon" that the tide reaches its maximum. They could calculate lunar phase for current and future calendar dates on their fingers using the "epact of the hand" and a computation method described by the Venerable Bede in the 8th Century. They reckoned time using a list of stars that are on the horizon at sunset or sunrise. These skills led eventually to the discovery of the continents of the Americas on the other side of the world from Europe, Africa, and Asia. In his work "On the Revolutions of Heavenly Spheres" Copernicus begins with arguments for the Earth's rotation, and invokes America as an answer to the objections about the Earth's wobble raised by his predecessor Jean Buridan 150 years earlier.

This course will examine the critical period from 1277 to 1610 during which the science and practical knowledge of astronomy emerged on separate but interacting tracks, coming together eventually in the application of sophisticated instruments to measure the heavens.

Students will learn about the basic motions of the solar system as viewed from Earth, and how they are reproduced by the Copernican and Ptolemaic models. They will also learn about basic mechanics as taught at Oxford in 1340, and how to reckon time and tides in the Julian Calendar using copies of period tidal calculators like the simple card recovered in the wreck of the Mary Rose in Portsmouth, and more complicated devices found at the National Maritime Museum, Greenwich. They will also learn how to evaluate historical claims by consulting original sources and commentaries of experts. They will develop a richer and more nuanced view of what modern science is and how it emerged in the nexus of intellectual scholasticism and practical seamanship. They will discover that Galileo's main argument for the motion of the Earth in his dialogue concerning two chief world systems was a mechanical argument based on tides that would have been laughable to Michael of Rhodes or any competent seaman of the 15th or 16th century. They will learn to think critically about the popular idea of singular heroes who wrought a scientific revolution, and learn to consider the centuries-long process that started in the medieval universities of the 13th Century and developed into our modern conceptions of science and the Cosmos.

II. ACADEMICS

Students on this 3-week program will be enrolled in the following 3-credit academic course:

- *ASTR 105H: Time, the Tides, and the Measurement of the Cosmos*

This course is a modified and more focused revision of *ASTR 205: The Medieval Foundations of Modern Cosmology*, and is especially designed to take advantage of the opportunities available for enriched learning in England. The course will be problem based, e.g. how did people reckon calendars, time, and tides, both for navigation and daily life, before clocks and the printed word? Some clues to this are scattered around England in the form of sundials, transit circles, tidal calculators, and navigation charts. While it is possible to integrate and assess those clues from Chapel Hill, seeing them first-hand offers a richer experience. My own engagement in many of these topics was initiated by a tour of the Mary Rose exhibit in Portsmouth, and I will share both the process of discovery and the intermediate state of historical research on these subjects with the students. Then the students will construct their own research theses that might bring some key questions to conclusion. Examples of proposed research topics are:

- To what extent did Galileo incorporate Mertonian methods in mechanics into his understanding of falling bodies? What was original with him?
- Did Galileo know the observational facts about tides, available since Bede and known to all mariners? If so did he choose to ignore them? To what extent was his progressive or humanist rejection of Aristotle responsible for his untenable tide theory?
- How widespread was the ability to calculate lunar phases on the fingers? Were the requirements of Charlemagne, reiterated by the Council of Trent, that all clergy be able to perform these calculations taken seriously? Why did Clavius, contemporary of Galileo, write a tract updating the Computus Ecclesiasticus per Digitorum Articulos for the Gregorian Calendar?

If approved, this course will satisfy an elective in science and an elective in world history before 1750. It does not require any language besides English, but students will nonetheless encounter two cultures: that of contemporary England, and that of England in the Middle Ages. Astronomy is a popular subject and this course will combine the best parts of introductory astronomy with the rich scientific (and maritime) history of London, Oxford, and Portsmouth. This program will also target science students who are less likely to study abroad during their time at UNC. In the foreshortened format, it will also be a more affordable study abroad opportunity for students.

Key Readings:

- Selections from Bede, *On the Reckoning of Tim*e *(de Temporum Ratione)*
- Tidal maps and mariner's calendars of Guillaume Brouscon (British Library, London)
- *The Book of Michael of Rhodes*, ed. Long, McGee, and Stahl
- *The Rutters of the Sea*, D. W. Waters
- Chaucer's *Treatise on the Astrolabe*
- Selections from Jean Buridan and Nicole Oresme from *The Science of Mechanics in the Middle Ages* by Marshall Clagett
- Selections from Copernicus, *de Revolutionibus*
- Selections from Galileo, *Dialogue Concerning Two Chief World Systems*
- Selections from Heilbron, *The Sun in the Church*
- Sections of Clavius, *Computus Ecclesiasticus per Digitorum Articulos & Tabulas Traditus,*
- Hoskin, *The History of Astronomy: A Very Short Introduction*

Requirements:

This course will require ten pages of writing (3000 words) exclusive of the in-class tests. These will be satisfied by short written assignments and the final paper. The research projects will be undertaken in teams, but each student will prepare an independent written report.

Learning Objectives:

Level: Remember, understand, apply

Tested by: Exercises and Weekly Tests

- Understand the observed motions of the heavens, as evidenced by the ability to project rough locations of sun, moon, and planets through time from specified starting conditions.
- Understand the connections between the sun and seasons, and the importance of the "obliquity of the ecliptic". Be able to describe methods for measuring the obliquity, and the advantage provided by large, dark places like Cathedrals for taking measurements.

- Understand the ways in which competing celestial models, Ptolemaic, Copernican, and Tychonic, reproduce the motion of the heavens, and their differing predictions for the parallax shift of stars and the size of the solar image throughout the annual orbit.
- Understand how measurements of the solar size functioned as an "experimentum crucis" for establishing the superiority of the Kepler/Copernicus model.
- Understand the connections between the moon and tides, and the relationship to the problem of falling bodies
- Understand Luni-Solar cycles as they form the basis for cyclical calendars.
- Understand the epact, the equinox, and their importance for the calculation of the date of Easter
- Understand the reasons for the Gregorian Calendar reform and how the new calendar differs from the Julian Calendar.
- Be able to calculate the golden number for any year through AD 8900 "memoriter" using the joints of the fingers on the left hand, per Clavius.
- Be able to translate the golden number into a lunar epact "memoriter" using the joints of the left thumb, per Clavius
- Be able to give the age of the "ecclesiastical moon" for any date on the Gregorian Calendar through AD 8900.
- Know how the 32 compass points are named, and how they correspond to time and the age of the moon when the compass face is used as a lunar tidal clock.
- Understand why and how South on a compass is used as a surrogate for lunar noon.
- Understand what is meant by the "establishment" of a port, and how it is denoted in early tidal charts.
- Understand how to get the time of high tide from the establishment + lunar phase using the Mary Rose tidal calculator or our replica of a more recent one housed in the London Maritime Museum.
- Given any day on the calendar and a tidal chart, use your left hand and the tidal calculator to know the time of high tide.
- Understand how Euclid's geometry applies to mechanics through the Merton School's mean speed theorem.
- Understand how Galileo applied the mean speed theorem from the 14th Century to his measurements of falling bodies in the 17th Century.
- Understand how Galileo's conception of motion and gravity differed from or resembled those of Aristotle and the scholastics.
- Be able to derive the mean speed theorem and variants.
- Understand Galileo's tidal theory found in his *Dialogue* and its prediction for tidal periods.

Level: Analyze, evaluate, create

Tested by: In class discussion and report

- Be able to explain why it was so difficult to distinguish between the different models for celestial motions. In retrospect, what ideas would be most useful to introduce into late 16th Century thinking to help resolve the questions.
- Science is (still) divided between a culture of engineering and measurement and a culture of mathematical and algebraic theory. Be able to classify Copernicus, Galileo, Kepler, and Brahe on a scale with experiment at one end and theory at the other, and to justify your classification.
- Analyze the interaction of theory and experiment in Bede, Copernicus, Michael of Rhodes, and Galileo. In what ways does theory inform observation, and vice versa. What are the problems with the notion of an “experimentum crucis”?
- Historically, the humanistic influence confronted the physics and philosophy of Aristotle as practiced in the Medieval Scholastic University. Analyze Galileo’s dialogues for evidence of this conflict. Are there residues of this on the university today? Develop testable hypotheses for how the modern university bears the imprint of its history.
- Assess the skills needed for “computus” with the hand and mind alone and modern computing with calculators and computers. What is lost and gained? Develop testable hypotheses about how pedagogy might change to mitigate losses that arise from automation.
- The historical narrative tells of a conflict between science and religion originating about the time of Galileo, yet all of the essential pieces of modern physics and astronomy were developed within a deeply religious culture that continued into the 20th Century. Be able to analyze and critique the standard narrative. Can you construct a narrative that works better?
- Was there a scientific revolution? Is this different from a technological revolution, if so how? Why do new scientific ideas often occur to several people at the same point in history? Does the historical narrative miss a “conversation of innovation”? Think of ways to apply what we have learned about the process of science to improve discovery and innovation today.
- To what end do we practice science? Most medieval or late modern people would have a deeply held conviction about the answer to this question. Has this changed? In what ways? How would you measure this change?

Exercises (48% of grade): 9-12 short daily exercises, 4-5 points each, to be completed in class or as homework. Some exercises will require free version of Stellarium, available online.

Weekly tests (20% of grade): 3 written exams of 45 minutes each building on the exercises and extending them to new applications

Class Participation (12% of grade): evaluated by attendance, ability to answer direct questions, and probity of questions asked.

Final report (20% of grade, team based): Individual written report with the following elements: 1. Identification of a key problem or question worthy of independent research, 2. Description of a research strategy for addressing the problem or question, 3. Tabulation of resources required, and 4. Preliminary or suggestive results or conclusions based on digital research or London sources.

III. Program Travel

London offers an ideal base for teaching this course. We will have day trips to Merton College, Oxford to see the birthplace of modern mechanics, to Portsmouth to see the recovered wreck of King Henry VIII's ship the Mary Rose. There we will view a primitive wooden tidal calculator and other artifacts that give visceral insight into daily life circa 1450. We will visit the National Maritime Museum in Greenwich and see mechanical tidal calculators and learn about systems of time and navigation. We will hopefully be able to see the beautiful tidal maps of Brouscon housed in the British Library in London. We could also go to the Kew Observatory near London where Molyneux and Bradley first measured the aberration of starlight which proves definitively that the Earth moves. An optional weekend trip to the Bede Museum in Jarrow would also be interesting, though it is quite far away from London.

IV. Program Logistics

a. *Affiliation* – Making use of Winston House, the University of North Carolina's Centre for European Study as a home base in London, classroom space will be made available for the seminar. Additionally, the 2 full-time staff at Winston House support the logistical arrangements for the course including program travel, Oyster Cards for local London travel, risk management support, and on-site orientation.

b. *Student Housing* – Students will be housed with our long-time partner for student housing in London, Acorn of London. Acorn provides a discounted rate to UNC for housing students near to Winston House.

c. *Communications* – Winston House is a primary communication point for the University Program Management. Additionally, we can arrange for the lead faculty to have a cell phone and encourage all students to have a local phone or use their US phone with an added plan with the minimum of a wireless calling app. Internet access is available both in Winston House and in Acorn flats.

d. *Safety and Security* – A safety overview will be provided prior to departure as well as on the ground at Winston House. This usually involves local constabulary advise and local safety procedures as well as the UNC safety protocols enrolling all in HTH Insurance, the

Global Travel Registry, and US Department of State STEP Program. Honors Carolina provides additional stateside support for the program.

e. *Medical care* – Medical care in the UK is easily available and high quality. Using the HTH Insurance, students can use either the website or a mobile application to identify the appropriate medical provider for the situation.

V. Program Itinerary and Class Schedule

Sunday Orientation: London Scavenger Hunt or similar icebreaker with historical, cultural, and social focus

Week One: (9 in-class contact hours, 4 field trip contact hours, 4 available office hours)

Preparation Work: View podcast course overview and end-to-end summary of ideas, concepts, and outstanding mysteries.

Day 1: Morning: Orientation from Winston House staff to acquaint students with Winston House, the surrounding areas, and local context and resources

Lectures, discussion, and practical drills on the celestial motions as viewed from Earth. (2 hours) (resources: Stellarium on student laptops, lecture with projection, written quiz)
Discussion (1 hour). (resources: lecture with projection)

Lunch: Research group formation, discussion of project expectations. (handout and worksheet)

Afternoon: Instructor office hours and work time. Practice time with Stellarium.

Day 2: Morning: Lecture: Bede's view of time and tides (1 hour).
Workshop (1 hour). (resources: facsimile of tidal calculator, maps, Brouscon diagrams)
Lecture: Modern view of tides and seasons (1 hour)

Lunch: Review and practice celestial motions, learn the points of the compass.

Afternoon: Instructor office hours and work time. Free time for reading, research group meetings, preparation for field trip. (resources: Stellarium on student laptops, take home written quiz)

Day 3: All day: Trip to Portsmouth to see the Mary Rose Museum

Day 4: Morning: Lecture: The history of the Calendar I (1 hour).
Reading and Discussion: Michael of Rhodes, Rutters of the Sea, the compass as a clock (1 hour) (resources: Bede, Brouscon diagrams, facsimile of compass dial handout).
Lecture: The history of the Calendar II, with exercises (1 hour)

Lunch: Go over Ecclesiastical Computation with the Finger Joints.

Afternoon: Instructor Office hours and work time. Free time for group exercises, skills practice, and project work (resources: hands, excel on laptops, selected translation of Clavius)

Day 5: Morning: Free time
Instructor office hours and open time for team work
Putting it together
(Students will use the 3-day weekend to work through and practice the method for finding the phase of the moon on any date and then high tide at any place and time with no tools except our memories and our hands and a facsimile of the Mary Rose tidal calculator, and will be as sea-ready as any 15th-16th Century mariner, then will take the weekly test as a take home assignment)

Afternoon: Free time Weekend: Trip to London Library to see Brouscon originals?

Week Two: (10 in-class contact hours, 4 field trip contact hours, 4 available office hours)

Preparation Work: View podcast overview of mathematical deductive proofs, the mean speed theorem, and the Medieval University.

Day 6: Morning: Lecture: Science in the medieval University (1 hour).
Practicum on Mean Speed Theorem. (1 hour) (resources: worksheet, selections from Clagett, quiz)
Lecture: The Merton Calculators and the mean Speed Theorem (1 hour)

Lunch: Discussion of Life in the Medieval University

Afternoon: Instructor office hours and work time. Research group work time (handout and worksheet)

Day 7: Morning: Lecture: Models for Understanding the motions of the Sky I (1 hour).
Workshop: Understanding the predictions of the Ptolemaic model (1 hour) (resources: Stellarium on laptops, lecture with projections)
Lecture: Models for Understanding the motions of the Sky II (1 hour)

Afternoon:	Instructor office hours and work time. Students will have free time to exploring the differences in the predictions of heliocentric and geocentric models or work on projects and take quiz. (resources: Stellarium on student laptops, handouts, written quiz)
	Directed reading, research group meetings, preparation for field trip.
Day 8: All day:	Trip to Oxford to tour Merton College and Library (Travel problem: Explain the design and function of the sundial of Merton College. Resource: Handout on Conic Sections and Sun in Church excerpt).
Day 9: Morning:	Lecture: Kepler's Laws (1 hour). Reading and Discussion: (1 hour). Lecture: Newton's proof of Kepler's Second Law (1 hour)
Afternoon:	Instructor office hours and work time. Project work, directed reading and discussion (resources: written quiz)
Day 10: Morning:	Free time Instructor office hours and open time for team work Putting it together (Students will have the three day weekend to travel, read and digest the predictions of the different world systems, debate the crucial observations required to decide between them, connect this to the post-Galilean Solar Observatories, then take the weekly take home test)
Afternoon:	Free time Trip to Kews?

Week Three: (9 in-class contact hours, 3 overflow hours if necessary, 4 field trip contact hours, 4 available office hours)

Preparation Work:	View podcast of Galilean Mechanics.
Day 11: Morning:	Galileo's Mechanics mysteries of lunar tides (2 hours). Discussion and workshop (1 hour). (resources: lecture with projection)
Lunch:	Research group formation, discussion of project expectations. (handout and worksheet)
Afternoon:	Instructor office hours and work time. Project work, directed reading and discussion (resources: written quiz)
Day 12: Morning:	Lecture: Observations that establish the Earth moves (1 hour).

Workshop (1 hour). (resources: conic sections)
Lecture: The bisection of the eccentricity. (1 hour)

Lunch: Conversation about Greenwich

Afternoon: Instructor office hours and work time. Optional mathematical exercises, project work. (resources: handouts, written quiz), preparation for field trip.

Day 13: All day: Trip to Greenwich and the Maritime Museum

Day 14: Morning: Lecture: Makeup lecture and discussion (1 hour).
Reading and Discussion: Course Summary (1 hour).
Lecture: Course Summary exercises (1 hour)

Afternoon: Project work (resources: written quiz)

Day 15: Morning: Project presentations
(Groups will present their research questions, show the methodology they would use to address them, and give any conclusions they have been able to find, then take the weekly test)

Afternoon: Free time