Freshmen Seminar FRS 50R: What do you see in the night sky?

Syllabus Fall 2021

Instructor: Prof. Roger R. Fu

Mondays 6 – 8:45 pm in Science Center 804

By the end of this class: You should have (1) become familiar with the stars and planets visible from Cambridge during the fall and early winter, (2) built up knowledge of how celestial objects move across the sky, (3) surveyed how cultures from around the world understand celestial motions and use them for both practical and holy purposes (this is the big one!), (4) thought about how diverse interpretations of the same phenomena arose from necessity and from chance, and (5) appreciated how observations of the night sky directly led to the birth of western science.

Class meetings: Observing the night sky is an integral part of this seminar. We will therefore meet every Monday evening in Science Center 804, which can be accessed by taking the Science Center elevator to the 8th floor. Weather permitting, each class will include stepping outside onto the Science Center 8th floor deck for visual and telescopic observations of the sky.

Class fieldtrips: We have two scheduled evening fieldtrips to Halibut Point State Park. The first will be in mid-September and the second will be shortly before Thanksgiving (dress warm!). Because the State Park is a one-hour drive away, we will meet one hour before sunset and return to Cambridge by 11 pm. The exact date of each trip will be scheduled based on weather. We will make every possible accommodation so that all students can participate in both trips. If that is not possible, each student is expected to participate in at least one trip.

Class assignments: Readings listed under each class are to be completed before class. Please write a short paragraph response to each of the "Questions to consider" to have handy in class. Your answers will not be collected, but will be important for you to prepare your thoughts for discussion. You may be asked to read and discuss your response in class.

Observational project: Students will work in pairs to keep a log of visible star, planet, moon, and sun positions as they change throughout the semester. Each pair is expected to make both daytime and nighttime observations:

<u>Daytime observations:</u>

1. (2x per week) Pick a time that is convenient for you and the shadow of something (could be a building, street sign, etc) and stick with the time and object for the entirety of the semester. Take a photo or make a detailed sketch of the ground near the shadow and annotated it with the position of the shadow each time you make this observation. Record, in millimeters, the distance over which the shadow has moved compared to the first observation.
2. (Once a week) Pick a place with a great horizon view (Science Center 8th floor balcony recommended) and note the position of the sun with respect to visible horizon features at

the moment of sunset. Please make a sketch or a photo of the horizon and annotate it with the sunset position every week. Stick to the same observation point every time. Record the motion of the Sun's setting location in millimeters as measured with a ruler at arm's length. Be sure to record whether it moved left or right and the length of your arm!

<u>Nighttime observations:</u>

1. (2x per week) Choose an observing location and time after dark (Science Center 8th floor balcony recommended). During our first clear sky class meeting, we will pick out between three and four objects for each group to track. Log the altitude (as described in class) of these objects at the same time on clear nights.
2. (whenever Moon is visible during your nighttime observations) If the Moon is visible, record the Moon phase by measuring the width of the illuminated portion parallel to the lunar equator with a millimeter ruler.

We will periodically look at everyone's logs in class to understand what pre-technological observers would have recorded changes in the night sky and how these changes may be used to construct the first calendar systems.

Term paper: You'll write an ethnographic study of the astronomical traditions of an indigenous group… one that you'll invent! This is a chance for you to reflect on everything you've learned during the semester, both the "natural science" aspects including how celestial objects appear and move through the sky and the "social science" aspects that analyze how the needs of the culture influence their perception of the night sky. More details will be forthcoming, but you'll need to think carefully about: (1) Where is your indigenous group located? What star patterns will they see? (2) What are the main activities your group performs for their livelihood? What demands do these activities place on their understanding of celestial motions? (3) Are celestial objects featured in the creation mythology of the group? How about other beliefs? How are these beliefs shaped by the nature of the sky they see? (4) What aids has this indigenous group developed to observe the sky? (5) What calendar(s) has the group developed? (6) What are the main celebrations and rituals and how do they relate to the sky, to their environment, and to their spirituality?

Class dates and topics:

<u>Sep 1, 2021: Introduction to the sky</u>

Activity: Make altitude measurement device. Learn to use planisphere.

Readings (Please take a look before class if at all possible. Because this is the first class, we will not assume that you have read these in detail. You're expected to read ahead of class for all later meetings.):

1. Basic concepts of positional astronomy (14 pp), by C.L.N. Ruggles
2. Origin of the "Western" constellations (17 pp), by R.M. Frank

Questions to consider while reading:

1. Define heliacal rise and acronychal rise. These concepts are unfamiliar to most modern observers, but we will encounter them often in ethnoastronomy. Make a hypothesis as to why that is.
2. The Ruggles article describes the sidereal and synodic cycles of the moon rather academically. As a practical observer, what is the different between the two cycles in terms of what you see?

Sep. 10: Primary date for first Halibut Point State Park fieldtrip

Sep. 11: Rain date #1 for first Halibut Point State Park fieldtrip (no meeting if trip already occurred).

Sep 12: Rain date #2 for first Halibut Point State Park fieldtrip (no meeting if trip already occurred).

<u>Sep. 13: Stars and constellations I:</u>

Activity: Make your own constellations.

Readings:

1. Chinese constellations and star maps (8 pp), by X. Sun
2. *At the crossroads of the earth and the sky*, Chapter 5 (pp 95-112), by G. Urton
3. Inuit astronomy (7 pp), by J. MacDonald
4. Australian aboriginal astronomy and cosmology (8 pp), by P.A. Clarke

Questions to consider while reading:

1. Which star groupings come up repeatedly as significant across different cultures? Why do you think this is? Which attributes of star formations appear to capture peoples' attention?
2. What, if any, where the practical uses of assigning names to stars and groupings? What are the benefits of having many named constellations that cover a sizeable fraction of the sky instead of a small fraction?

<u>Sep. 20: Stars and constellations II</u>

Activity: Hands-on with different types of telescopes and mountings for astronomy (needs clear night)

Readings:

1. *At the crossroads of the earth and the sky*, Chapter 8 (pp 151-168), by G. Urton
2. Stars through the Araucarias: Mapuche-Pewenche ethnoastronomy, Part 1 (pp. 81-90), by R.R. Fu
3. Ethnoastronomy of the Eastern Bororo Indian of Mato Grosso, Brazil, (19 pp), by S.M. Fabian

Questions to consider while reading:

1. In a few sentences, describe the key difference between the star naming system in this week's Urton and Fu readings compared to those of last week.
2. As a Quechua or Mapuche observer at sunset, what practical utility might you derive from the rather peculiar star naming system described here?
3. Should we be surprised that the Bororo constellation Kuddoro, a macaw, corresponds to the western constellation Pavo the peacock? Look up star maps of Pavo. Do you think it was a complete coincidence? Or does that star formation really look like a bird? More generally, list some hypotheses why groupings of stars are sometimes interpreted as figures that bear little resemblance to the star formations themselves. You may want to refer back to the Frank article from week 1 as well.

Sep. 27: Calendarics I: Motion of the Moon

Activity: Geological history of the Moon through a telescope. (Needs clear night)

Readings:
1. Chuquibamba textiles and their interacting systems of notation. The case of multiple exact calendars (pp 251-277), by R. T. Zuidema in *Their way of writing*.
2. Mesopotamian calendars (5 pp), by J.M. Steele.
3. Stars through the Araucarias: Mapuche-Pewenche ethnoastronomy, Part 2 (pp. 90-99), by R.R. Fu

Questions to consider while reading:
1. No one really uses a lunar calendar anymore except to keep track of traditional holidays. Why has it been supplanted and why was it so popular in earlier societies?
2. Why was the sidereal lunar calendar less common than the synodic?
3. What's the great advantage of the sidereal lunar calendar? (Hint: think about matching these months to the solar cycle of 365.25 days).

Oct. 4: Calendarics II: Motion of the sun

Activity: Measuring angles in the classroom.

Readings:
1. Agreeing to disagree: The measurement of duration in a Southwestern Ethiopian community (pp 585-600), by D. Turton and C. Ruggles
2. Ancestors and the sun: astronomy, architecture and culture at Chaco Canyon (10 pp), by A.M. Munro and J. McKim Malville
3. Excerpt from article Archaeoastronomy by A. Aveni: Archaeoastronomy in the Andean world (pp 50-54)
4. Ceque system of Cuzco: A yearly calendar-almanac in space and time (13 pp), by R.T. Zuidema

Questions to consider while reading:
1. By now we have seen some of the observations of the "day observers" in our class and have some idea about the level of accuracy you can get with traditional methods. How

accurately (i.e., how many days from the true solar year) can a solar calendar be if it relies on observing alignments with architecture? And if it relies on horizon observations? Please do a little math and reference the Ruggles article from Class 1 if helpful. Was this adequate for the practical needs of societies?
2. In principle one can identify a number of stars and star grouping and construct a year-round calendar using the helical and acronycal rise of these objects. This calendar will have the advantage of perfectly tracking the Earth's orbit, making it better than lunar calendar in this regard. Why do you think all major calendar systems were lunar- or solar-based despite this?

Oct. 18: The Incan Calendar

Activity: View the Chuquibamba textiles in the Peabody Museum.

Readings:
1. Catachillay: The role of the Pleiades and of the Southern Cross and α and β Centauri in the calendar of the Incas (27 pp), by R.T. Zuidema
2. The archaeoastronomy of the megalithic monuments of Arles–Fontvieille: the equinox, the Pleiades and Orion (10 pp), by M. Saletta
3. *At the crossroads of the earth and the sky*, Chapter 2 (pp 37-65), by G. Urton
4. *At the crossroads of the earth and the sky*, Chapter 9 (pp 169-192), by G. Urton
5. Egyptian "Star Clocks" (6 pp), by S. Symons

Questions to consider while reading:
1. What characteristics make a certain star or group of stars a good basis for a calendar? If you were to choose star formations and use their helical and acronychal rise/set as a calendar, how would you distribute these star formations in right ascension and declination?
2. Our Western astronomy is really very "star-centric". One can argue that it's easier to see shapes in the Milky Way and its dark clouds than in the imaginary lines between bright stars. Why do you think some cultures emphasized patterns in the Milky Way more than others?
3. Go online and look up astrophotos of the Milky Way. How different does it look in the northern and southern hemispheres? In the summer and winter? How do you think these differences are reflected in the interpretations of the various cultures of what they saw?

Oct. 25: The Mayan Calendar

Activity: Read Mayan inscriptions in the Peabody courtyard. Learn to write dates in Mayan glyphs.

Readings:
1. *Cycles of the Sun, Mysteries of the Moon*, Chapters 1, 5, 6, by V.H. Malmstrom
2. Articles Tzolkin, Haab, The Long Count, and The Lunar Series on website http://mayan-calendar.com/ancient.html by E. Barnhart

Questions to consider while reading:

1. Critique the Malmstrom hypothesis for the 260-day calendar. Can you think of any alternative hypotheses for such a cycle length?
2. We have seen throughout the semester that astronomical traditions are motivated by both mundane and spiritual needs. Discuss the various aspects of the Mayan calendar in these terms.

<u>Nov. 1: Meteors, meteorites, and comets</u>

Activity: Hands-on with meteorites and fake meteorites.

Readings:

1. Analysis of historical meteor and meteor shower records: Korea, China and Japan (2 pp), by H.-J. Yang et al.
2. 5,000 years old Egyptian iron beads made from hammered meteoritic iron (8 pp), by T. Rehrens et al.
3. Meteors and meteorites in the ancient Near East (42 pp), J.K. by Bjorkman.

Questions to consider while reading:

1. Rocks falling from the sky! What more proof do you need that the supernatural is real? Reflect on why meteors and meteorites were such an awesome spectacle. After all, ice falls from the sky as well but who writes poetry and makes prophesies based on hail. Is it a question of rarity? Permanence? Utility of the meteorites themselves?
2. In these readings, how (if at all) did the various cultures draw a link between shooting stars and meteorites found on the ground.

<u>Nov. 8. Tour of astronomical exhibits in the Harvard Art Museum and Collection of Historical Scientific Instruments (Note we will meet earlier than usual, probably ~3 pm. We will discuss exact time to accommodate everyone)</u>

Readings: From Heaven's Alarm to Public Appeal: Comets and the Rise of Astronomy at Harvard. By Sara Schechner-Genuth.

Questions to consider while reading:

1. In a few sentences describe the construction and intended use of these objects: Astrolabe, Orrery, Astronomical quadrant, Armillary sphere.
2. Crunch some numbers to understand the impact of the telescope on our knowledge of the universe. The ability of a certain telescope to magnify images of celestial objects is described by its "resolving power," which is the smallest angular separation between two objects that can be seen distinctly through the telescope. An approximate formula for resolving power is known as the Dawes Limit: $R = 11.6/D$, where R is resolving power in arcseconds and D is the diameter of the telescope objective in centimeters. Do some research online and compute the resolving power of (1) your eye, (2) Galileo's original telescope, (3) Newton's reflecting telescope, (4) John Winthrop's Venus transit telescope that we will see in the Harvard collection, (5) the Hubble Space Telescope. (Hint for your search terms: diameter of telescopes is often referred to as "aperture".) Then compute or look up the *angular diameter* of (A) the Moon, (B) the planet Jupiter, (C) the maximum separation between Jupiter and its moon Callisto, (D) the rings of Saturn, (E)

the star Alpha Centauri. You may have to look up the physical diameters of these objects and their distances to Earth to compute the angular diameter. Which objects can be resolved with which telescopes?

Nov. 15: Eclipses

Activity: Build a telescope using Mayan technology.

Readings:

1. Observations of comets and eclipses in the Andes (8 pp), by M. Ziolkowski
2. Eclipses in Australian aboriginal astronomy (35 pp) by D.W. Hamacher and R.P. Norris

Questions to consider while reading:

1. Eclipses are a fully predictable consequence of the Moon and Earth's orbital motion. But they appear to be rather chaotic and unpredictable. For example, the next few total lunar eclipses are in January 2018, July 2018, and January 2019. The last three were in April and September of 2015. This difficulty in prediction certainly contributed to their mystery for early cultures. Given what you know about eclipses and the orbits of the Earth and Moon, why is something that is in theory so predictable so random in practice? By sheer chance sun and moon's disks are roughly the same size when viewed from Earth (about ½°). What would eclipses be like if one were much larger than the other? How do you think the perception of eclipses by early societies would have been different?

Nov. 22: Development of Western astronomy I

Activity: Improve our basic telescope and use it to measure angles. (Needs clear night)

Readings:

1. Chinese calendar and mathematical astronomy (10 pp), by X. Sun
2. Greek mathematical astronomy (6 pp), by A. Jones
3. Babylonian observational and predictive astronomy (8 pp), by J.M. Steele

Questions to consider while reading:

1. The prediction of planetary cycles and even eclipses requires a high level of observational skill and persistence. Exactly how much? Download and install the free planetarium software Stellarium (http://www.stellarium.org). Play with the software by setting your observing location and time to the present and advance the display to show the sky at the same time on successive nights. Focus on Jupiter and its relative position to surrounding stars. How much does it move per night? Given the ancient observational techniques that our "night observers" have been using, how long does it take before the motion of Jupiter is observable?
2. Briefly discuss why each of the three cultures in these readings took the trouble to develop a predictive system for the motion of stars, planets, and eclipses.

Nov. 29: Development of Western astronomy II

Activity: Night skies in other solar systems.

Readings:

1. Reconstructing the Antikythera Mechanism (22 pp), by T. Freeth

(Note, the reading is short but dense! Don't wait until the night before.)

Questions to consider while reading:

1. In your own words, summarize the celestial events and cycles that the Antikythera Mechanism is capable of tracking. How does it perform these functions?
2. It's the end of the semester. Reflect on why, of all the cultures we studied, the Greeks built this extravagantly complex device to describe celestial motion. Were there practical needs driving this?

<u>Dec. 3: Primary date for second Halibut Point State Park fieldtrip</u>

<u>Dec. 4: Rain date #1 for second Halibut Point State Park fieldtrip (no meeting if trip already occurred.</u>

<u>Dec. 5: Rain date #2 for second Halibut Point State Park fieldtrip (no meeting if trip already occurred.</u>