First Light Lite

February 1, 2021

Jim Lynch – Editor

Message from the CCAS President

Well, looking out the back door at the snow, it's pretty clear that we're in the heart of winter. But, when the weather clears, that means some very good viewing conditions (if cold), and some great winter sky objects to look at! So, all in all, a fair trade!

As previously discussed, CCAS is doing well enough in "virtual land" with our First Thursday meetings and talks, and we are still doing a bit of interfacing with the area schools (more on that to come.) As to star parties, things are a bit slower, and most of us have been restricted to our own personal observing, rather than club activities. (George Silvis' online sessions are an occasional exception to that!)

The emphasis of today's newsletter will be mostly on the future, and what we can do to plan for it while waiting for the pandemic to abate. In-person activities will be far more varied, and we should prepare for them when we are finally cleared to gather again in groups.

Committees

On February 5th, at 7:00 PM Eastern, we will have a 1 ½ hour long meeting of three newly formed CCAS committees: 1) Programs/Content, 2) Membership/Outreach, and 3) Communications. We have a small core group for each committee, but really, *really* could use additional members. This is a once-a-month, half hour Zoom (or GoToMeeting, whatever) session commitment, though with a bit of interesting homework also involved. We sincerely need people to sign on and help with these to get our program(s) back in good order. To do this, just drop me an email at jlynch@whoi.edu saying "I'm interested" or, if you're logged into our meetings, stay around for the club meeting portion and tell me in (virtual) person. I'll send you a link to the CCAS committees meeting as soon as I get an expression of interest!

Upcoming Meeting Talks

The winter, spring, and summer's agenda for talks is again the first item to discuss. The roster has fleshed out since our last announcement, and I think we have some exciting talks to offer to CCAS, the student communities we reach, and even some other astronomy Societies that we have friendly relations with.

First on the agenda, we have Dr. Jim Head of Brown University, http://www.planetary.brown.edu/html_pages/head.htm, who recently gave us a very well received talk on the Apollo Program and US lunar exploration (PPT available upon request). Jim will give another talk on February 4th about the Chinese space program. That program was very much in the recent news with the success of the Chang'e-5 mission, which collected moon rocks and sent them back to earth. His abstract is found below.

China has embarked on an ambitious and fast-paced robotic lunar and planetary exploration program, including the first lander and rover on the farside of the Moon, lunar sample return missions (Chang'e 5 being recently very successful), rovers on the surface of Mars, and missions to many other destinations in the Solar System. Plans also call for Chinese astronauts to explore the Moon by the end of the decade. What is the scope, significance and direction of the Chinese space program and how does it differ from that of the US and other countries? We will put particular emphasis on the recent Chang'e 4 Lunar Farside robotic rover mission, the Change'e 5 lunar sample return mission, and Tianwen-1, the Mars rover mission in transit to Mars.

LATE ARRIVING ADDENDUM!

You could send out the following link to this podcast I recently did for the Watson Institute on the Chinese Space Program. Students and members might find it of interest.

China's Mission to the Moon, and the New Politics of Space Exploration

Between the presidential election, spikes in the coronavirus pandemic, and the beginning of mass vaccination, you might have missed this other world-historical event: China landed on the moon. On this episode, Watson's Director Ed Steinfeld talks about China's lunar mission with Watson Faculty Fellow Jim Head. Jim is a Professor of Geological Sciences at Brown, and a leading expert on interplanetary exploration.

Next up is Dr. Jim Gates, (see link https://www.aps.org/about/governance/leadership/board/president.cfm), who is now the President of the American Physical Society, and is also well known to the public for his Nova and other media appearances. Jim agreed last spring to give us a rain check for the talk that was cancelled on March 16th, 2019. Both he and his co-author, well known writer Ms. Cathie Pelletier, https://en.wikipedia.org/wiki/Cathie_Pelletier will come (virtually) to talk about their book "Proving Einstein Right" to CCAS and the Cape area schools. This talk will be our "First Thursday" talk on March 4th.

Recently, University of Washington astronomer Dr. Emily Levesque also agreed to speak to us, https://www.emlevesque.com/ and will be giving our April 1st talk on her book "The Last Stargazers." Emily having been an MIT undergraduate, and a lover of (and participant in) the pranks ("hacks") MIT undergrads are famous for (read "Nightwork" by MIT press if you are interested) has indicated that, in addition to a great talk, there might be an online hack (of the fun variety) for April Fool's Day. Stay tuned!

In either May or June (TBD), Dr. Daniel Davis, co-author with Brother Guy Consolmagno of "Turn Left at Orion" will speak to us about some amateur astronomy experiments that can easily be done by students and/or beginning amateur astronomers. Information about Dr. Davis can be found at: https://www.stonybrook.edu/commcms/geosciences/people/_faculty/davis.php

Also, Dr. Alyssa Goodman, whose recent work on the "Radcliffe Wave" discovery has been prominent in the news this year, has also agreed to talk to CCAS this summer, hopefully live if /when meeting restrictions are lifted.

One unique thing that will happen this winter/spring is that for each of the four talks that we have scheduled, we will be giving away the author's books to the Cape HS students that attend (and Moon maps for Dr. Head's talk.) This comes at some cost to the CCAS, but is also supported by some donations to CCAS. These hopefully will be good incentives to the students to both listen to some great talks, and also to read some very interesting STEM related material. The logistics of how this will work is being discussed with the area HS teachers.

Welcome to Other Astronomy Clubs

One rather nice thing that has happened during the pandemic is that we have been sharing information with other astronomy clubs and organizations about their upcoming talks and ours. I will post this information in separate emails, and also welcome members of the Phoenix Astronomical Society and the South Shore Astronomical Society to our coming talks!

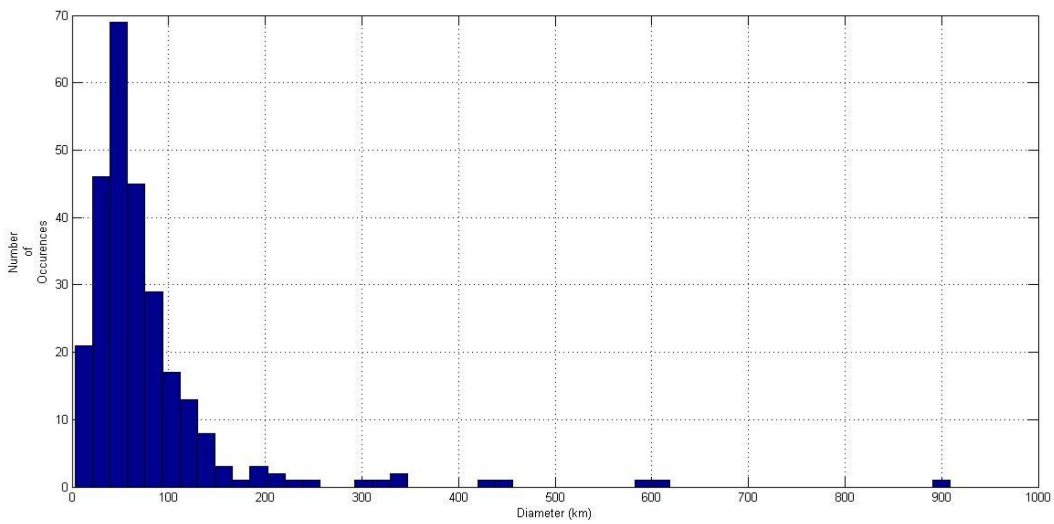
“Backyard Astronomy” projects update

In last month’s newsletter, I described three “mini-projects” you could do with rather basic equipment and promised to show some results in the coming newsletter, i.e. this one. Well, some progress has been made, though (inevitably) more slowly than I had hoped.

The “sunrise position” project is in fact coming nicely, with my second year of data underway. However, I want to get at least one more month of data this year to show the cross comparison with last year, so look for this data next month.

As to the “sky brightness/light pollution” project, I did have to get a bit more sensitive sensor, as the less expensive one I used first hit its limit when it was totally dark, about an hour after sunset. So, my “sunset and light pollution” measurements will be presented next month as well. (One different, additional measurement I did get outside at night was with an infrared camera. I’ll include that photo as well! Very pretty, and very different from the visible band.)

And, as to the Lunar Crater Diameter project, I was disappointed at the small iPhone telescope, which didn’t even focus very well at infinity to see the Moon. (Thankfully, it was inexpensive.) BUT, I always maintain the right to cheat a little (as long as nothing is hurt by doing so), and so I turned to the lunar maps we are giving away, which list about 1000 craters and their diameters. By taking a spare half hour to do some data entry, I listed the diameters of ~250 craters in the southeastern quadrant of the Moon. The (histogram) plot that resulted is shown below.



With apologies that the labels are a bit small, you can see that the craters, which range in size from 3 kilometers to 900 km, have a peak at around 50 km, and then fall off drastically past there. For those who heard Tony Stark's talk "Astronomy Can Save Your Life," you'll recognize that the falloff of the number of craters as one goes to larger and larger sizes is expected from the size distribution of the asteroids that pummel the Earth and Moon, and thus cause the craters. However, why do you see the drop off in number below 50 km?! The best answer wins a Moon map next month!

Last month's speaker

January 7th, 2021

Dr. Jim Lynch, CCAS

"What are Space and Time?"

Precis: As this talk was just intended to fill in a blank spot in our schedule, I was a little self-indulgent about the topic, which is something that I have a personal interest in. Not as a research interest, as this topic is a bit out of my wheelhouse, but as an "educated layman" in the area. My apologies if this writeup is a bit long. I tend to get carried away…

As quoted in an early slide in the talk, “the last thing a fish would notice is water,” and it is the same with us as regards space and time. We are so used to living in these “media,” and familiar with their separate ways, that we rarely think to dig deeper. Indeed, it was only in the 1800’s, when thermodynamics was being developed as a tool to explain the efficiency of steam engines, that “entropy” (colloquially “disorder”) was understood to be “the arrow of time.” While the laws of physics were time-reversible on a small scale, the entropy could only increase with time, and so gave it an unambiguous direction.

While the concept of entropy was originally conceived based upon large scale quantities like heat, energy, and temperature, in the late 1800s Boltzmann and others dug deeper, and showed how it could be derived from the newly minted theory of atoms, though now as a probabilistic quantity. Increasing entropy (time going forward) then becomes identified with seeing the most probable distribution of the atoms’ and molecules’ positions and momenta. In a more usual way of looking at things, consider running a movie of you drinking coffee both backwards and forwards. Both directions are allowable by the laws of physics, but one direction (“undrinking your coffee”) is extremely improbable.

However, being a probability also left the door open for some very weird possibilities, and lively discussions ensued concerning such exotic beasts as Maxwell Demons and Boltzmann Brains. (See Sean Carroll's "From Eternity to Here" for tons of detail.)

At about the same time, space also was getting a look-see. Albert Michelson and Michael Morley devised an ingenious interferometer to test whether light went faster when going with our planets orbital speed than against it, which would be the byproduct of a hypothetical "luminiferous ether." The null result (no ether) forced the first "redefinition" of space - it could now contract along the direction of motion. Absolute, immutable space was dead. Space could now be affected by the state of a particle’s motion. (And a century later, the Michelson/Morley interferometer became the basis of the LIGO interferometer, which first measured gravitational waves.)

Not very long after, the young Einstein appeared on the scene, and in 1905 he showed that not only does space contract, but time also dilates (slows up) for a moving observer/particle, and that the two are connected. Both absolute space and absolute time were gone, and what is more, they were linked into a four-dimensional quantity, spacetime. The absolute quantities that mankind had lived with in our slow speed world had been shown to be mere approximations.

Einstein, being the conceptual wrecking ball that he was, was not content with a theory that just treated velocities, though. To make the story complete, acceleration also had to be considered, which took him another ten years to accomplish. In 1915, he published his famous theory of General Relativity (GR), which showed that matter and energy determine the geometry of spacetime, which in turn produces the gravitational force we feel.

GR is a mathematically formidable theory (using things like non-Euclidean geometry and tensor analysis), and was conceptually weird to people. These factors secured Einstein's public, cult figure reputation as a genius almost immediately after GR was confirmed by astronomers. As history has proven, it was well deserved.

After GR, Einstein contributed two more seminal papers in 1935 on wormholes (called "Einstein-Rosen bridges" in popular jargon) and entanglement (which he called "spooky action at a distance"). Though these were not considered earthshaking by the scientific community at the time, like many of Einstein's theories, these contributions would become important to our spacetime story years later.

The next scientific episode that signaled a real change in the understanding of space was related to black holes, exotic entities which Einstein personally didn't believe in, even though they were well known solutions of his own field equations. As the years wore on, both theory and experiment verified that black holes did indeed exist, and they became a favorite playground for relativity theorists. However, as strange as they were classically, it was when quantum mechanics (actually quantum field theory) was applied to them that things became really strange. Hawking showed that black holes weren't totally black "inbound, one-way streets," but could actually radiate particles outward at some temperature and eventually decay to nothing. And using this temperature, he and Jacob Bekenstein then showed that the entropy of a black hole, which reflects the information content of the stuff that falls into it, is determined by the surface area of the black hole, and not its volume.

If that last sentence sounded vaguely familiar, i.e. a 3-D space's contents being described by a 2-D surface, well, of course it is to a modern person. It is the description of a hologram, a device conceived of only a few short decades ago, but now quite common. This description of the contents of a space by a lower dimensional space is called "the holographic principle," and well-known physicist Leonard Susskind and others have conjectured that it may hold for our entire universe, and not just black holes.

But, if a black hole being some sort of hologram weren't enough, there was some added intrigue. The Hawking radiation is created (simplistically) by particle/antiparticle pairs (which can be created for a short time, thanks to the Uncertainty Principle) at the black hole's event horizon being separated. One goes free with positive energy and the other falls back into the black hole with negative energy. Energy is conserved and all is well, right!? But, no, these are "maximally entangled pairs" which are essentially one system where both particles know all about the other, no matter what their separation. Einstein's spooky action at a distance, to be precise. But, since no information can leave a black hole, it seems this entanglement information the particles shared is destroyed by Hawking radiation...the poor captive particle can't “speak to” its mate!

This was a problem, in that information *should* be conserved. Hawking and a number of other prominent physicists started a betting pool over whether or not it was. These debates became known as the "black hole wars." A seeming solution was put forth by theorist Juan Maldacena, who cryptically wrote to his colleague Leonard Susskind "EPR=EP". This may seem cryptic, but like a good detective story writer, I tried to leave you a clue before. Remember Einstein's two 1935 papers? One was on entanglement (author's initials EPR) and the other on wormholes (ER). The solution being proffered was that the particles could stay entangled via a wormhole, which does not care about the black hole's event horizon! Einstein had struck again. This seemed plausible, and Hawking conceded his bet (which was that information was in fact destroyed). However, the story of how black holes work and communicate with the rest of the universe is still not complete, and for us lay people, Quanta magazine puts out some nice, free, readable articles on where the black hole story currently sits.

As mentioned, Susskind and others have hypothesized that our entire universe may act like this, i.e. our 3-D space may just be a hologram projected from a lower dimensional space. This "holographic principle" for the universe could very possibly be one of the latest twists on spacetime.

But, even at this degree of strangeness from our common reality, there are further shores to visit. Let's proceed.

Superstring theory attempted to explain nature (particularly particle physics) using a ten-dimensional space (9 spatial dimensions, one temporal, with six of the dimensions being small or “compact”) and a new set of “super-symmetric” particles. It let us still have our well-established, four-dimensional spacetime, but now with six new dimensions and another full set of particles riding along as baggage. Encouragingly, superstring theory worked rather well, and hopes were high to discover the supersymmetric particles predicted (thereby knocking off the dark matter mystery as a bonus) and possibly even measure the size of the compact dimensions. But, alas, neither component has been seen to date, despite some very serious efforts, and enthusiasm has damped for superstring theory as a potential TOE (theory of everything.)

However, superstring theory is still very useful and also has a interesting property, called dualities, where one part of the theory corresponds to the "inverse" of another part, allowing it to solve some previously intractable problems. One of the more interesting of these dualities is the "Anti de Sitter/ Conformal Field Theory (AdS/CFT)" duality. (Willem de Sitter was a famous cosmology theorist.) In this duality, a four-dimensional field theory with no gravity corresponds to a five-dimensional superstring universe with gravity present. This is just a higher dimensional version of what we saw for black holes. Despite this being a version of a universe which is definitely not ours, the AdS/CFT universe provides a theoretical playground to explore "holographic universes." And it was this playground that provided what might be the next step in understanding the deeper nature of space and time.

Physicist Mark van Raamsdonk looked at what happened when bits of “entangled information” (due to particles and fields) were placed on the surface of the lower dimensional space, and then mapped to the higher dimensional “bulk” space (e.g. to the AdS space). He conjectured that this quantum entanglement actually *created* the space in the bulk. By “mathematically disentangling” two halves of the boundary of a bulk space, he split the bulk space in two – the surrounding entanglement had indeed created the space! Space now becomes an emergent quantity created by the entanglement of the particles and fields on the lower dimensional boundary! This new view of what space really is comes from “information” and “quantum entanglement,” in a holographic universe. We note that the vocabulary has changed drastically from that describing our previous classical world.

There are just a few more roads to go down, at least for this talk precis. The Planck scale, quantum foam, and the Wheeler-DeWitt equation are our last ports of call in this strange world.

The Planck scale is the scale at which all fundamental constants of nature, i.e. c (the velocity of light in vacuo), $\hbar$ (the reduced Planck's constant), and G (Newton's constant), come together to form units of mass, length, and time. The Planck scale is also the scale at which the quantum mechanical effects of gravity are expected to dominate. This region may be characterized by energies of around 10^{19} GeV, time intervals of around 10^{-43} s and lengths of around 10^{-35} m. (The latter is twenty orders of magnitude smaller than the size of a proton!) The Planck scale is important, because this is where a full theory of quantum gravity is needed to explain what the nature of space and time are there.

One longstanding conjecture about the nature of spacetime at very small scales like the Planck Scale is "quantum foam." Let me be lazy here, and just give a quick Wikipedia quote, which says things succinctly. "With an incomplete theory of quantum gravity, it is impossible to be certain what spacetime would look like at small scales. However, there is no reason that spacetime needs to be fundamentally smooth. It is possible that instead, in a quantum theory of gravity, spacetime would consist of many small, ever-changing regions in which space and time are not definite, but fluctuate in a foam-like manner." In such a region, causality need not apply, as mentioned by Tony Stark after the talk. However, as we look over larger and larger regions, the foaminess should average out to give our usual spacetime as an emergent quantity.

A final look my talk took was at the approach taken by John Wheeler and Bryce deWitt in creating a "wave function for the entire universe," in both space and time. By cutting this wavefunction along "spacelike" contours, one could perhaps create time in the same way that frames of a movie camera do. The degree of correlation of the frames between snapshots might be the same thing as a time interval. Or maybe not – this type of theory has a long way to go.

As you can tell, there's a lot I've missed, or have not plumbed deeply. But that's half the fun of it – there's a lot more here to see. So please add loop quantum gravity, spinfoam theory, causal set theory, twistor theory, and Bohmian approaches to the list, if you're at all interested. This is an area of research that is being actively pursued, but is still in its infancy. We've come a long way from our pre-Industrial Revolution understanding of space and time. But, to use the "long car ride" analogy, we are "not there yet."