ASTRO 5: LIFE IN THE UNIVERSE – HIGHLIGHTS OF THE COURSE: SPRING ‘21

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CHAPTER 0: PRINCIPLES OF CLEAR THINKING AND SCIENTIFIC METHOD

KEY IDEAS FROM CHAPTER 0

- the mind WORKS! (given proper operator attention), because it's our chief tool of survival and advantage. Natural Selection; If it didn't work we wouldn't be here
- The "light bulb", when new information is integrated with pre-existing knowledge w/o contradiction
- The brain is a pattern-making machine. Sometimes leaps to conclusions. A good scientist will tug back on the leash and regard as tentative until stronger evidence confirms. Average people often don't
- Mental health requires energy and effort. Anxiety signals inadequate awareness.
- There is only ONE Reality, by definition. Mental health and self confidence require our conclusions have as large an overlap with actual reality as we can muster.

MORE CHAPTER 0 - KEY IDEAS…

- “I just want to know the truth” – practice repeating this whenever conflicted, as a clarifying guide to the best path to a good relationship with Life and others.
- “Amplifying feedbacks” apply not just to climate but psychologically. Refusal to face difficult truths leads to further repressions, so avoid painful admissions. Must reverse this through act of will, early in the process.
- Percepts integrated into concepts, into ideas, ideas integrated into principles – and along this maturity process, always checking for errors along the way.
- A healthy mind loves to be used, experiences strong curiosity, and the pleasure of successful thinking. In contrast, an orientation towards dogmatism leads to an attitude which desires avoidance of thought, fear of thinking, and should be interpreted as a signal you need to question your mental methods.

NATURE GAVE US REWARDS FOR ENGAGING IN THE ENERGY-CONSUMPTIVE ACTIVITY OF THINKING

- 1st: curiosity to get us started
- 2nd: the “light bulb” experience, the “ah ha!” moment of pleasure at reaching a non-contradictory integration of new knowledge
- 3rd: the reward of a more successful coping with life, from using those new conclusions

PSEUDO-SCIENCES

- Arise not from evidence and a desire for the Truth above all else, but instead out of more questionable desires.
- Defensiveness in these areas is a sign – truth is not what is motivating, instead, it's wishful thinking, or tribal alliances, or other pathologies.
- Curiosity thrives in people who've genuinely made sacred the desire to know what is real and valid and true above ALL else. Chronic lack of curiosity is a sign mental habits need an upgrade.
- These issues could arise in your response to the question: "Is there Life elsewhere in the Galaxy?" as well. Too strong a desire for the answer to be "yes" or "no" could drive so called "motivated reasoning" (a euphemism for fooling yourself and others!)
- Stay open-minded, and realize that "truthiness" is - for us imperfect observers of Reality - a probability function and not a black-and-white thing. Learn to judge how light or dark gray a "truth" is. Somethings are black and some are white, but objective scientific conclusions are usually some shade of gray, because of limited technology and limited knowledge.

BIASED TEACHING

- Biased teaching – when an instructor does not strive to convey accurately the best “weight of evidence” supporting an idea. Strongly supported ideas SHOULD be taught as strongly supported, that is NOT “biased teaching”.
- Giving equal weight to all ideas can, rather than be “unbiased”, a way to promote an idea only supported by wishful thinking and not evidence.
- Or it can be outright timidity in the face of authoritarian enforced “political correctness”.
- Unbiased teaching – is conveying to students what is the “weight of evidence” for the validity of an idea

SCIENTIFIC METHOD – PROCEDURE WE'VE FOUND IS THE MOST EFFICIENT WAY TO GET TO "THE LIGHT BULB" EXPERIENCE OF NON-CONTRADICTORY IDENTIFICATION

- *"Science is what we do to keep from fooling ourselves"* – Richard Feynman
- 1st step: Observations relevant for a phenomenon
- 2nd step: Form a hypothesis, a mechanism which makes a cause-and-effect reasonable, explaining what the phenomenon is about
- 3rd step: Test your hypothesis: "IF hypothesis X is true, then by logic I ought to be able to see Y if I design an experiment to do so"
- If Y, and later predictions based on the hypothesis, survive tests, your hypothesis graduates to being called a "Theory". It's on the 'short list' for being true!
- If they fail, we reject the hypothesis as false and seek a new hypothesis

2. WHAT IS LIFE?

KEY IDEAS:

- All laws of physics are identical and true throughout our Galaxy and the entire observable universe
- The same chemical elements, the same chemistry, the same laws of gravity and thermodynamics and the rest, hold true identically everywhere in our Universe.
- This critically limits the options for Life

WE ARGUED…

- To be a living thing, this thing must…
- Be able to reproduce
- Be able to take in energy and material from its environment to sustain itself and reproduce
- Be able to compete for matter and energy resources
- Be able to evolve to sustain that ability to successfully compete
- All of these actions require COMPLEXITY
- **Life is Complex. Even the simplest life, is not simple!**

CARBON IS THE ONLY CHEMICAL ELEMENT FROM WHICH COMPLEX MOLECULES AND STRUCTURES CAN BE BUILT

- Has 4 bonding sites, permitting chains, loops, and 3D structures, with available bonds for attaching other chemical elements, permitting very complex shapes and valence geometries to catalyze wide variety of functions and chemistry
- Silicon has 4 bonds as well, but much too strong an affinity for oxygen, so that silicon will not, so far as we can deduce, naturally form complex structures we could call “living”
- Leaves open the idea that carbon-based life could at some point design silicon-based life.

FINDING E.T. LIFE THEN MEANS FINDING CARBON-LIFE FRIENDLY PLANETS

- “The Habitable Zone” = the range of distances from a star such that, given a suitable atmosphere with the right greenhouse gases, there could be liquid water on the surface
- Habitable zone planets are NOT necessarily inhabited.
- Likely only a tiny minority are inhabited by any life.

HOW MANY ROCKY PLANETS IN HABITABLE ZONE AROUND SUN-LIKE STARS, IN THE GALAXY?

- Kepler Mission – found thousands of planetary systems, enough to combine with selection effects to give good estimates of how many rocky planets there are around G and K Main Sequence stars in our Galaxy.
- Last estimate (Bryson 2020) is 300 million

HOW TO ASSESS SUCH PLANETS?

- Transit method: Use “transmission spectra” to look for signature of molecules in planetary atmospheres
- Water should be a common molecule, since oxygen is nuclear fusion’d by medium and high mass stars
- “Flower Power” telescope to use giant “flower” shield to occult parent star and allow clearer detection of only the light from the surrounding planets, for assessing their chemical composition
- Methane and oxygen both together in good quantities in a planet atmosphere is strong sign of photosynthetic life

THE ULTIMATE PLANETARY REQUIREMENT FOR A COMPLEX LIVING PLANET….?

- Stability of climate!
- Climate can and even should change some, to stimulate evolution.
- But it cannot change too quickly and it cannot change too much or it violates the requirements of life
- Too cold – you're frozen and can't do anything. Too hot, and your complexity breaks up into simple atoms, and you're not alive.
- All stars get more and more luminous and deliver more and more heat to their planets as they age. This is a fundamental problem which all long-lived planets must cope successfully.

WE HAD A LECTURE ON CURRENT CLIMATE CHANGE ON EARTH

- And showed that there are key dangerous elements in this system.
- 1. Climate is dominated by amplying feedbacks, such that a hotter climate just gets hotter still, and at a faster rate. Equibrium Climate Sensitivity (ECS) now known to be higher in hotter climates. Fewer low (cooling) clouds in hotter climate. Albedo of icesheets reduces and speeds heating further. Methane escapes from bio systems much faster with hotter climate – a powerful GHG. And many more.
- 2. Humans – Natural Selection bred us to outcompete other species and even each other in a race to dominate and leave more genes. That succeeds spectacularly, until ultimate spectacular failure when the limited sustainability of your planet is exceeded. Good analogy, mold in a Petrie dish grows exponentially, then dies suddenly when the edge of the dish is reached. That's us. Today. Now. Will we rise to the occasion? So far, no.

LIFE IS ENERGY. LIFE IS NETWORKS. NETWORKS POWERED BY ENERGY. PLANETS ARE FINITE: GROWTH MUST END. LIFE IS NOT GENETICALLY PROGRAMMED TO DO SO.

- The Garrett Relation: is the observed proportionality of current global energy consumption rate and the sum total of all economic spending ever done. Wealth is not "stuff", it's networks of connections, powered by energy. When energy stops, EVERYTHING withers and dies, not just this year's created wealth, but ALL wealth ever created.
- Geoffrey West's insights, showing that yes – Malthus and Paul Ehrlich ("The Population Bomb") were both wrong, because they didn't include innovation, but so are the *Economic Growth Uber Alles* advocates that claim technological innovation will always save us. They're both wrong.
- Innovation only leads to faster growth, and new innovation requires ever newer innovation, all of which history shows have finite time singularities built in, so that the end result of innovation is only a delay in reaching the "singularity", not avoidance.

THE FERMI PARADOX -

- If there are so many life-promising planets, and if intelligence is so successful a strategy for coping, why isn't the Galaxy teeming with civilizations?
- If there are so many civilizations, why is there no evidence any have visited us, and (now) why are they not making it easy for us to discover their communications?
- **Basically – "Where IS everyone??" is the "Fermi Paradox", voiced by 20th century physicist Enrico Fermi**

GAIA *VS.* MEDEA: DOES LIFE GUIDE A PLANET'S EVOLUTION IN ORDER TO FAVOR LIFE? OR INSTEAD DOES LIFE TEND TO BE SUICIDAL?

- James Lovelock proposed the Gaia Hypothesis
- Paleontologist Peter Ward, being "cheeky", gave the name "Medea Hypothesis" to reasonings that life has a very difficult path to succeed and should be very rare, and that too much success in competition leads to ultimate death and failure.
- In the end, we concluded the evidence much more favors "Medea," and "Gaia" has fallen steadily out of favor. It's always been rather sparsely supported by scientists, and its popularity is mostly cultural.

EVIDENCE THAT IS PRO-GAIA…

- Oxygen content of our atmosphere. If it were too high, wildfires would lower plant abundance and thence reduce oxygen. (but, what if it were too low, as it was for billions of years??)
- The Walker-Alley mechanism preventing “snowball Earth” from being permanent – volcanic CO2 shutoff from ocean absorption by frozen oceans means it builds up in atmosphere -> Greenhouse heating thaws oceans, sending CO2 out of atmosphere. Except – this is not LIFE that is helping its environment, it’s geology – so not truly GAIA.

ANTI-GAIA EVIDENCE

- Climate change has mostly amplifying feedbacks, making climate change worse.
- Earth has had 5 major mass extinctions killing most life and most species on the planet each time.
- We're in the 6th Great Mass Extinction right now, many biologists argue.
- Oxygen is toxic to primitive life, but an oxygen atmosphere is essential to block out solar UV, which kills all life on land. Very tough to get around this, only with complex cell walls, Prokaryotic life.
- This took billions of years to happen, and may have required some lucky accidents to happen at all.

LIFE AS A THERMODYNAMIC PROCESS

- We showed that only chemical processes which are thermodynamically allowed (i.e. they increase entropy, and/or they liberate energy), can happen spontaneously.
- The 2nd Law of Thermodynamics. Disorder (entropy) always increases in a closed system
- The processes which allow life to make complexity out of simplicity are processes going UPHILL, against the normal entropy-increasing (disordering) processes which we see all around us (only succeed by making even greater INCREASES in entropy in their surroundings.
- These are themselves very complex and require all steps to happen in precisely the right order (the Krebs cycle) to generate the basic molecules around which all life consists.
- Nature had to find a way to do this, and it took a billions of years before it happened. Dr. Eric Smith argues these points in linked YouTube lecture.

ALL ADVANCED LIFE USES OXYGEN-BASED METABOLISMS

- Since oxygen is so chemically reactive, it is toxic to simple life
- Advanced life could only survive on land after Ozone Layer established.
- All intelligent life is land-based life, we argue, because only then do we have the vision and the environment for advancing technology and tool-making at the levels necessary
- And oxygen did not dominate the atmosphere until just 2 billion .

THE ORIGIN OF LIFE

- Amino acids are the basic building blocks of all proteins
- Proteins are the molecules which are complex enough to perform the thousands or millions of different chemical functions and catalysts life requires.
- Amino acids form easily, even in interstellar clouds
- Early hopes that the later steps to life would then follow easily too, were dashed when we realized the rest of the steps to complex biochemistry are UPHILL thermodynamically, and so require rare or poorly understood mechanisms.

ERIC SMITH ARGUES LIFE FIRST AROSE ON EARTH AT THE DEEP SEA VENTS

- Earlier hypothesis that perhaps in hot springs on land not likely because solar UV would sterilize the land effectively
- Need protection from solar UV to get things going
- Smith also points out the strong temperature gradient at deep sea vents promotes the thermodynamic “uphill” battle can be won there, making biochemistry impossible in milder places.
- I find his reasoning solid and agree. This idea has gained a lot of support over the years.

THIS ARGUES THAT PERHAPS ON ALL PLANETS, LIFE MAY REQUIRE DEEP OCEANS AND PLATE TECTONICS IN ORDER FOR ANY LIFE TO ARISE

- Long lived stars which are hot enough to not require a planet to be so close as to be tidally locked (bad!), are hot enough to be emitting plenty of killer UV light, from which life needs protection.
- Key realization too – just because life has invaded every nook and cranny on Earth today, does NOT mean life can be created in every nook and cranny!
- Highly likely and supported that life needs a very special environment to be created, and then once complexity and adaptability and versatility has gotten to an advance point, can evolve to live in more challenging places.

ALL CELLULAR LIFE REQUIRES THESE 5 ESSENTIAL CATEGORIES…

- **Fatty acids** – essential to build cell walls and boundaries within cell structures
- **Amino Acids** – all proteins, which are the myriad blocks out of which all larger functions are done, are built of the 20 essential amino acids
- **Sugars** – for energy storage, and also for cell structures
- **Co-Factors** – a group of about 2 dozen small molecules that are the basis for functions like carrying oxygen in blood, and chlorophyll to do photosynthesis
- **Nucleic Acids** – RNA, DNA, maybe TNA in the past, for cell reproduction
- ALL are built from the KREBS CYCLE requiring delicate thermodynamic process to proceed and create.

EVERY MOLECULE IN EVERY LIVING THING, FOR ALL OF TIME, HAS BEEN SYNTHESIZED FROM ONE OF THESE 11 MOLECULES IN THE KREBS CYCLE

- This is more basic, more fundamental, and more important than the other use of these molecules - in the Krebs Cycle which eukaryotes (cell-walled modern cells) use to generate the energy that powers their life.
- **If we want to understand the origin of life here, and perhaps everywhere in the Galaxy, this is a fundamental fact which should be appreciated. Is <u>all</u> life impossible without these?**

ADVANCED LIFE ALSO MAY REQUIRE, OR AT LEAST IS HIGHLY FAVORED BY, SEXUAL REPRODUCTION

- Life requires adaptation and therefore Imperfect reproduction.
- PERFECT reproduction means eternal sameness and inflexibility when climate changes even a little
- Need “errors” but not big ones and not too often.
- Sex is GREAT! What I mean is, it takes two already successful mature adult organisms, demonstrated “fit”, and then combines their genetic properties in ways that are mostly going to be good, yet different and therefore MUCH more likely to be favorable fitness errors of copying.
- Alternative sources of copying errors – cosmic rays arriving at ~the speed of light wreck havoc on DNA, radioactivity from natural radon, uranium, etc. DNA is delicate, when you just randomly whack it, you are usually going to make it go bad and life gets messed up, not improved.
- But sex is complicated. How long before Nature figured out how to arrange it? Not clear, may argue that complex life is RARE.

LIFE ON EARTH BEGAN EARLY

- ~3.8 billion years ago, evidence of fossil deep sea vent life
- Perhaps even 4.1 billion years ago, from organic ratio of C13/C12 found in zircon crystals this old (not super strong evidence for life, but intriguing)
- Early atmosphere likely heavy in ammonia, CO2, perhaps methane. Necessary to explain liquid ocean 4.2 billion years ago when sun was 25% - 30% less luminous than today, yet our orbit was ~same.
- Nitrogen atmosphere of today likely from NH3 (ammonia) atmosphere early on. Ammonia is a greenhouse gas. N2 atmosphere of today is not – nice!

“RARE EARTH” POINTS OUT HOW MUCH HAD TO GO RIGHT FOR LIFE TO EXIST ON EARTH FOR BILLIONS OF YEAR

- Need major planetesimal impact to create our Moon, to stabilize our rotation axis, to give us fast (mild day/night climate) rotation, and add heat to interior to favor plate tectonics
- Plate tectonics essential to life: 1. cycles carbon out of the atmosphere into the mantel and into limestone rock, reducing GHG’s as sun brightens over cosmic time. 2. Provide deep sea heat source for life’s thermodynamics to happen. 3. brings heavy rare chemical elements necessary for life (like molybdenum, iron, many others) up to the surface instead of sinking to the core. 4. Provides mountain and continent building, giving dry land for complex life to evolve to intelligence
- Earth is the only planet we know of with plate tectonics, although Mars may still have a bit of gurgling volcanism not yet total dead.

NEED THE ASTRONOMY TO BE RIGHT, TOO…

- No binary stars
- need circular stable orbits,
- need no resonances with giant planets,
- need some but not too many impacts or else planet is regularly sterilized.
- Need strong magnetic field to hold on to atmosphere
- Need oxygen creation for ozone layer to block out star’s UV light
- Need to stay out of spiral arms, (dangerous nearby supernovae too common) requires being in rare co-rotation resonance within the Galaxy to do that and stay there
- Need to be in the habitable zone of the Galaxy, midway out, not in Central Bulge, and not out where there’s no metals

THE MODERN DRAKE EQUATION MAKES USE OF THESE INSIGHTS FROM THE "RARE EARTH" UNDERSTANDINGS…

- We put reasonable numbers on these and some others
- We assumed our intelligent life (Homo Sapiens) was midway during its existence as a species, for lack of any better motivating numericals.
- We then arrived at a final number for the number of interstellar communication capable civilizations in the Milky Way Galaxy today…
- That number was….. 1/3 ! In other words, just US!

BUT LEAVES OPEN THE QUESTION…

- Carbon based life will advance only at the pace dictated by the time span of many generations, for genetic changes of significance to arise and propagate through the gene pool
- What if this is hopelessly too slow to deal with the problems created by their own speeding technology (such as we're facing)?
- Is it inevitable they will turn to creating AGI (Artificial General Intelligence), basically a new species… **Robo Sapiens**
- Will versions of Robo Sapiens be who we should look for, and who will survive long term?

OUMUAMUA – GHOST SPACE CRAFT FROM ANOTHER CIVILIZATION?

- Tumbling: argues it's very stiff, made of ice or metal or solid rock
- No outgasing at all, no dust at all, very unlike comet
- Clearly interstellar origin, not of this Solar System
- Finding it so soon after PanSTARRS telescope survey began, indicates ~1016 of these per stellar system.
- If nitrogen ice, indicates several Earth masses of such is created and ejected per stellar system, which is surprisingly large
- Jackson and Desch (2021) find odds that our first interstellar visitor would be solid nitrogen ice only 4%
- Other theories much less favored
- Interstellar space sail craft remains credible, but still need to create, launch these about once per decade at Earth, for millions of years, to account for its discovery. Are we THAT special a target? Not unreasonable, actually.

THE MOST UNKNOWN TERM IN THE DRAKE EQUATION…. "L". HOW LONG DOES AN INTERSTELLAR COMMUNICATING CIVILIZATION LAST?

- Astronomical tragedy only comes along once every ~hundred million years.
- But if civilizations lasted this long, the Galaxy should be full of civilizations, but then we're back to the Fermi Paradox
- Perhaps civilizations kill themselves as soon as they reach the technological means to do so?

MEDEA HYPOTHESIS TO THE MAX?!

- Not so unreasonable
- Natural Selection on all planets will favor successful competition for resources and maximum genetic propogation: GROWTH.
- GROWTH clearly is the winner… until it's the ultimate Loser.
- *"When you're a species as powerful as Homo Sapiens, the tragedy is not when you LOSE the Darwinian competition, the tragedy is when you WIN. Because then ALL other species lose, and then you lose too" – R Nolthenius*

OR DO ONLY THE HOPELESSLY IMMATURE CARBON-BASED LIFE FORMS DIE?

- … but not before they invent ***Robo Sapiens.***
- *Robo Sapiens* may grow in knowledge and wisdom so fast, they tire of their hormonally challenged and glacially slow-to-evolve parents.
- Do they "terminate" us, as a danger to our own Planet?
- Do they instead, out of benevolence, create and inject us into "The Matrix" where we can live blissfully, while not cluttering up the Real World with our poor decisions,
- Or prior to that, do we lose The **War Against the Machines**, as *Robo Sapiens* decide we will destroy the Earth if given the power we had once before The Machines took over? Is this a generic process we should expect to happen nearly always in the Galaxy?
- Or does Carbon-based life generally "grow up" in time to mend its ways, before it is too late? The answer to this is very unclear.

THE KEY QUESTION TO ALLOW US TO FIND OUT THE KEY ANSWER TO - WHAT IS "L"?

- Do civilizations universally achieve the technological ability to kill their planet ("planetary cancer cells") before they achieve the ability to control their genetic impulses to growth?
- Do they terminate their fatal genetic inherited characteristic of Growth Uber Alles before they achieve the technological ability for that growth to kill their planet
- Those two forces: The Dark Side Darth Vader, and the plucky Luke Skywalker of Jedi wisdom and maturity…. Are running to the finish line for the one and only intelligent species we know of in the Universe. They coming down to the wire, the finish line, THIS century. So far, Darth Vader is ahead. Will Luke dig deep and find a way to pull victory out of apparent defeat?
- We don't know.
- It's the young, the Greta Thuneburg's of Earth who will decide that.