Ad astra per aspera, II

Astronomy 101
Syracuse University, Fall 2016
Walter Freeman

December 8, 2016

Announcements

Final projects:

- Before 5PM, Monday December 5: +1 point
- Before 5PM today: +0.5 point
- Before 5PM, Tuesday December 13: graded as normal
- Before 5PM, Thursday December 15: -2 points, -5 if score less than 7/10

Final projects may be turned in:

- In my mailbox in the main office
- In the box I have with me here, or in office hours tomorrow
- See my email for how to turn in fine-art type projects
- Email for submissions of digital projects: `suast101projects@gmail.com`

Preparing for the final exam

- The final exam is next Tuesday, 3PM - 5PM, 13 December
- **Section 1: Grant Auditorium (White Hall)**
- **Section 2: Stolkin Auditorium (here)**
- Exam will be only multiple choice questions
- **Make absolutely sure you have your SUID with you**, since otherwise we can't process grades

Preparing for the final exam: review sessions

- Friday: in the Physics Clinic from 9:30-11:30 and 2-5
- Sunday: here from 6:30-10, weather permitting
- Next Monday: in the Physics Clinic from 12-3
- Next Tuesday: will be in and out of the Physics Clinic from 10AM until your exam starts

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- Study guides posted

Summary

Last time:

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The possibility of life on other worlds...

- What it might look like
- Where it might be hiding, and how we might find it
- How likely this is

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- What it might look like
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- How likely this is

The possibility of extraterrestrial civilizations...

- How we might talk to them
- What *they* might look like
- How likely *they* are: the Drake equation

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...How humans might travel throughout the Solar System...

- More time ("work longer")
- More effort ("work harder")
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- What we might find there

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How we might get to the stars

- The possibility of sending probes to Alpha Centauri
- What we might find there
- How such a mission might look: patience...

Ad astra per aspera: how *we* might become a spacefaring civilization!

- Can we travel to Alpha Centauri?
- ... the technical challenges
- ... the social challenges
- ... the philosophical challenges
- ... and what it would mean: *Homo sapiens celestis...*

Exobiology: life on other worlds

If we're looking for life elsewhere, we should start by looking for Earth-like life:

- Chains of carbon atoms as structural building blocks: `http://bit.ly/2hitrhM`
- Many different chemical pathways to harnessing energy
  - Oxygen: very reactive, very handy, not necessary
  - Light: a great primary energy source, but not necessary!
  - Can also metabolize other things: sulfur, iron, manganese...

Life on Earth is much more resilient than we think!

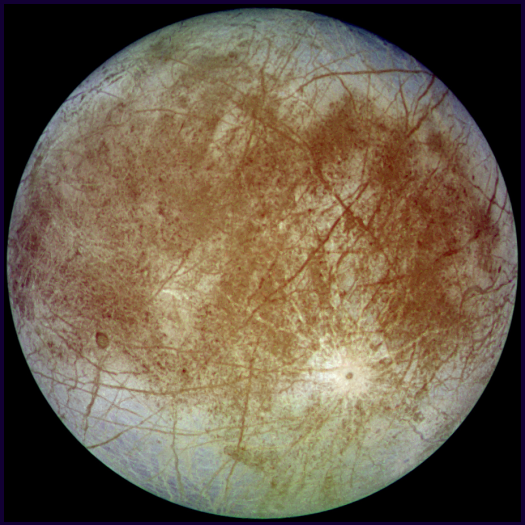
- Above 200F
- Below 0F
- In acid as strong as lemon juice
- Inside the reactors at Chernobyl (!)
- Below the deepest oceans
- On the slopes of Everest

Exobiology: the search for water

Life on Earth needs liquid water; it allows molecules to find each other

Liquid water in the Solar System:

- Need temperatures from 0-c. 100 C
- Earth is perfect (we knew that)
- Young Mars?
- The moons of Jupiter and Saturn...



Europa, from the Galileo *craft (1996)*

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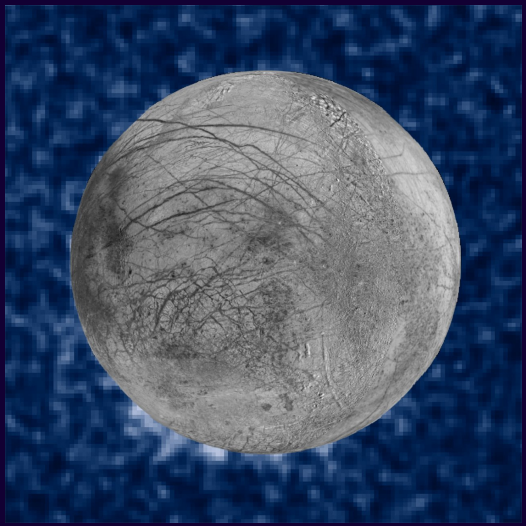
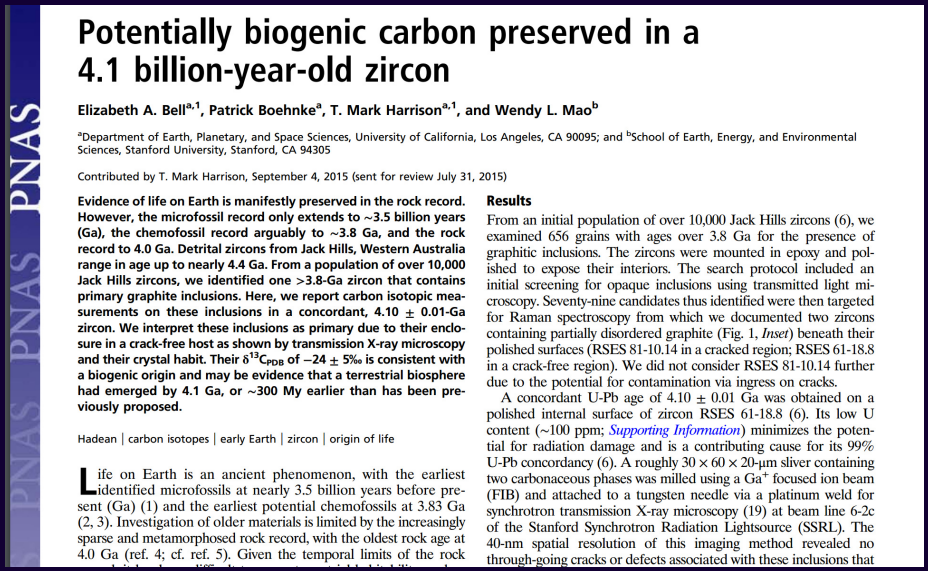
- The moons of Jupiter and Saturn...
- Most exciting near-term astrobiology experiment: send a probe to break through the crust of Europa



Galileo/Voyager/Hubble: ESA (2014)

Exobiology: encouraging signs from Earth

Life evolved on Earth very, very early in its history...



PNAS PNAS PNAS

Potentially biogenic carbon preserved in a 4.1 billion-year-old zircon

Elizabeth A. Bell[a,1], Patrick Boehnke[a], T. Mark Harrison[a,1], and Wendy L. Mao[b]

[a]Department of Earth, Planetary, and Space Sciences, University of California, Los Angeles, CA 90095; and [b]School of Earth, Energy, and Environmental Sciences, Stanford University, Stanford, CA 94305

Contributed by T. Mark Harrison, September 4, 2015 (sent for review July 31, 2015)

Evidence of life on Earth is manifestly preserved in the rock record. However, the microfossil record only extends to ∼3.5 billion years (Ga), the chemofossil record arguably to ∼3.8 Ga, and the rock record to 4.0 Ga. Detrital zircons from Jack Hills, Western Australia range in age up to nearly 4.4 Ga. From a population of over 10,000 Jack Hills zircons, we identified one >3.8-Ga zircon that contains primary graphite inclusions. Here, we report carbon isotopic measurements on these inclusions in a concordant, 4.10 ± 0.01-Ga zircon. We interpret these inclusions as primary due to their enclosure in a crack-free host as shown by transmission X-ray microscopy and their crystal habit. Their $\delta^{13}C_{PDB}$ of −24 ± 5‰ is consistent with a biogenic origin and may be evidence that a terrestrial biosphere had emerged by 4.1 Ga, or ∼300 My earlier than has been previously proposed.

Hadean | carbon isotopes | early Earth | zircon | origin of life

Life on Earth is an ancient phenomenon, with the earliest identified microfossils at nearly 3.5 billion years before present (Ga) (1) and the earliest potential chemofossils at 3.83 Ga (2, 3). Investigation of older materials is limited by the increasingly sparse and metamorphosed rock record, with the oldest rock age at 4.0 Ga (ref. 4; cf. ref. 5). Given the temporal limits of the rock

Results

From an initial population of over 10,000 Jack Hills zircons (6), we examined 656 grains with ages over 3.8 Ga for the presence of graphitic inclusions. The zircons were mounted in epoxy and polished to expose their interiors. The search protocol included an initial screening for opaque inclusions using transmitted light microscopy. Seventy-nine candidates thus identified were then targeted for Raman spectroscopy from which we documented two zircons containing partially disordered graphite (Fig. 1, *Inset*) beneath their polished surfaces (RSES 81-10.14 in a cracked region; RSES 61-18.8 in a crack-free region). We did not consider RSES 81-10.14 further due to the potential for contamination via ingress on cracks.

A concordant U-Pb age of 4.10 ± 0.01 Ga was obtained on a polished internal surface of zircon RSES 61-18.8 (6). Its low U content (∼100 ppm; *Supporting Information*) minimizes the potential for radiation damage and is a contributing cause for its 99% U-Pb concordancy (6). A roughly 30 × 60 × 20-μm sliver containing two carbonaceous phases was milled using a Ga^+ focused ion beam (FIB) and attached to a tungsten needle via a platinum weld for synchrotron transmission X-ray microscopy (19) at beam line 6-2c of the Stanford Synchrotron Radiation Lightsource (SSRL). The 40-nm spatial resolution of this imaging method revealed no through-going cracks or defects associated with these inclusions that

... this suggests that wherever life *can* develop, it will!

Extraterrestrial civilizations: different, but alike

Intelligent life elsewhere has the same resources we do – the same chemical elements and the same physics.

Any intelligent beings in the Universe will come to many of same conclusions we have about Nature.

We'd probably see them in the same way we see everything else: light (radio signals).

Extraterrestrial civilizations: the Drake equation

How many extraterrestrial civilizations might there be? Frank Drake suggested that we multiply...

- The number of stars per year that form
- What fraction of those have planets (we think most of them, now)
- What fraction of those planets could have liquid water and support life
- What fraction of those planets probably *do* develop life
- What fraction of ecologies evolve civilization
- What fraction of civilizations emit strong radio signals (or something else)
- The length of time that they do this (before ... what?)

These quantities are all uncertain, and their product is *very* uncertain!

It's unlikely that we're the only life in the Universe. We might be the only broadcasting civilization in the Galaxy, though...

Extraterrestrial civilizations: the Fermi paradox

"It's likely they're out there, and that they're older than us. Then where are they?"

Lots of answers, all of them speculative, some of them depressing...

- Civilizations tend not to last very long...
- Civilizations are actually pretty rare
- They're there, but aren't very advanced: humans are uniquely intelligent
- They're there, but are *very* advanced and can hide from us
- Nobody thinks we're worth talking to
- ...

Human travel to Mars and beyond

The problem with human travel: humans are fragile. Humans require life-support baggage and want to come home; robots don't.

Going to Mars is just within the reach of current technology (it's an economics problem, not a science one)

- Mission of several years (there and back)
- Providing for food, life support, and radiation shielding would be an engineering challenge, but we can do that
- Would need rockets larger than Saturn V, but not impossibly so
- Several clever ways to use robotics to reduce the size of the rockets needed

Going beyond would likely require substantial improvements in rockets.

Remember: a small improvement in exhaust velocity gives an exponential increase in how fast a rocket can make you go (and where you can go with it)

Robots to the stars (that survive the trip)

Voyager 1 and 2 are headed for the stars, but won't make it near any for tens of thousands of years.

→ Can we send a probe to the stars, like *Viking* or *Spirit*?

The problem here is *time*. We could send a probe to Alpha Centauri now – 4.3 ly (270,000 AU away). Should we?

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Two options:

- A slow probe and patience: centuries or millennia
- Higher exhaust-velocity rockets

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Two options:

- A slow probe and patience: centuries or millennia
- Higher exhaust-velocity rockets
- This would still take decades to a century
- The round-trip communication time would still be eight years!

Improving rockets

Lots of ideas here – some speculative, some tested:

- Scramjets
  - Harvest oxygen from Earth's atmosphere during initial escape-from-Earth rocket burn; it's much heavier than the hydrogen that goes with it
  - Precursor idea already used for Eurofighter's air-to-air missiles (*Meteor*)
- Nuclear rockets
  - A nuclear reactor can heat propellant to a higher temperature than its own chemical energy
  - Probably the most tested of any of these (idea dates to the 1950's)
- Nuclear pulse propulsion
  - Set off nuclear explosives behind the armored rear of a spacecraft
  - Only usable for huge spacecraft without laser fusion
- Ion engines
  - Low thrust per weight, but consumes very little reaction mass (high exhaust velocity)
  - Can't use to escape from Earth, but maybe on a space probe
- Solar sails
  - Sail on the solar wind, or on a laser from Earth or Earth orbit?

Improving humans and changing our outlook

With only a little improvement in rockets, we can conquer space.

Science-fiction authors dream of "faster-than-light travel", but this is likely not possible.

If we take to the stars, humans will be possibly be born, grow, live, love, and die in space. If we stay there long, we will evolve differently: *Homo sapiens celestis...*

There are ways to cheat: cryogenics, freezing embryos and trusting robots to teach babies how to be human...

Even then, a mission to Alpha Centauri is a mission that will outlive those that send it.

The greatest challenge in spacefaring won't be engineering, science, or even economics – it will be *philosophy*.

Improving humans and changing our outlook

We are a young civilization.

Imagine that the distance from San Francisco to Syracuse was the history of Earth: 4500 km to 4.5 billion years.

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- Modern humans evolved at the Hall of Languages (200 m)

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- You were born an inch away, and I was an inch and a half
- Barack Obama was elected the width of a pen in the past
- You started this class only the width of a fingernail ago

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We can conquer space; to become a spacefaring civilization, we will likely need to conquer time as well.

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"I want to build a clock that ticks once a year. The century hand advances once every one hundred years, and the cuckoo comes out on the millennium. I want the cuckoo to come out every millennium for the next 10,000 years. If I hurry I should finish the clock in time to see the cuckoo come out for the first time."

–Danny Hillis, of the Long Now Foundation, 01995

We end where we begun: humility and empowerment

"Consider again that dot. That's here. That's home. That's us. On it everyone you love, everyone you know, everyone you ever heard of, every human being who ever was, lived out their lives. The aggregate of our joy and suffering, thousands of confident religions, ideologies, and economic doctrines, every hunter and forager, every hero and coward, every creator and destroyer of civilization, every king and peasant, every young couple in love, every mother and father, hopeful child, inventor and explorer, every teacher of morals, every corrupt politician, every "superstar", every "supreme leader", every saint and sinner in the history of our species lived there – on a mote of dust suspended in a sunbeam.

The Earth is a very small stage in a vast cosmic arena. Think of the rivers of blood spilled by all those generals and emperors so that, in glory and triumph, they could become the momentary masters of a fraction of a dot. Think of the endless cruelties visited by the inhabitants of one corner of this pixel on the scarcely distinguishable inhabitants of some other corner, how frequent their misunderstandings, how eager they are to kill one another, how fervent their hatreds.

We end where we begun: humility and empowerment

Our posturings, our imagined self-importance, the delusion that we have some privileged position in the Universe, are challenged by this point of pale light. Our planet is a lonely speck in the great enveloping cosmic dark....

The Earth is the only world known so far to harbor life. There is nowhere else, at least in the near future, to which our species could migrate. Visit, yes. Settle, not yet. Like it or not, for the moment the Earth is where we make our stand.

It has been said that astronomy is a humbling and character-building experience. There is perhaps no better demonstration of the folly of human conceits than this distant image of our tiny world. To me, it underscores our responsibility to deal more kindly with one another, and to preserve and cherish the pale blue dot, the only home we've ever known."

–Carl Sagan, *Pale Blue Dot (1994)*

We end where we begun: humility and empowerment

But...

We can look at all of this, here from our little mote of dust...

... we can understand how it works – we, our little carbon-and-water brains, can comprehend the steps in the dance that the Universe is dancing.

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... and it's the same everywhere. We – our star, our planet, and our bodies – are part of it, and we can fathom how it works.

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... and it's the same everywhere. We – our star, our planet, and our bodies – are part of it, and we can fathom how it works.

So, if our bodies and our planet are very small – how much our minds can accomplish!

Course evaluations

You have gotten an email regarding course evaluations for the University.

We take this feedback seriously; I, as a new professor, trying new things, am especially interested in what you have to say.

Thank you for your patience as I've tried different things, seen what you all like, and what you don't.

Please tell me and my supervisors what you think of this course!

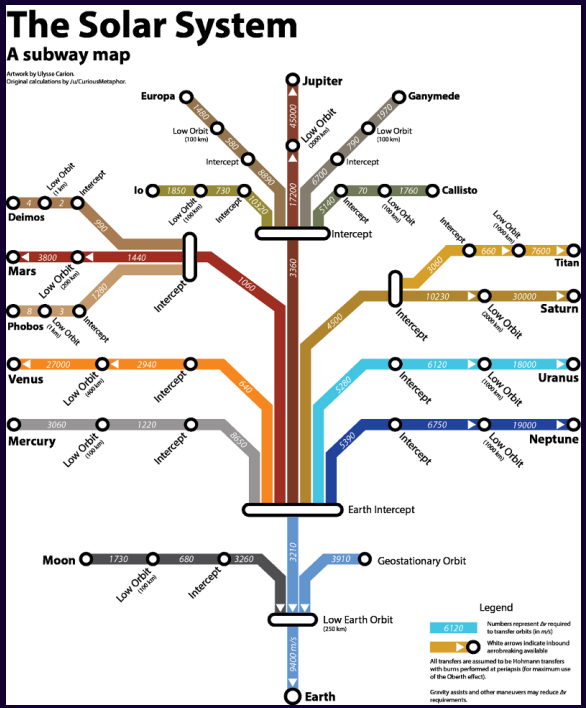
Three last things (1/3): the challenge from Day 1

"With more knowledge comes deeper, more wonderful mystery... with pleasure and confidence we turn over each new stone to find unimagined strangeness leading on to more wonderful questions and mysteries–certainly a grand adventure!

Our poets do not write about [this]; our artists do not try to portray [it]. I don't know why. **Is nobody inspired by our present picture of the universe?** [Science] remains unsung by singers, so you are reduced to hearing not a song or poem, but an evening lecture about it. Is no one inspired by our present picture of the universe? **This is not yet a scientific age.**"

–Richard Feynman, from *The Value of Science* (1955)

A scientific age? You bet.



This was made by a user on the "space" subreddit. (I verified some of the numbers.)

A scientific age? You bet.

... and you can buy a very physically accurate simulation of spaceflight and rocketry on Steam!

A professor's pride (2/3)

Some English faculty doubted you. You proved them wrong.

A professor's pride (2/3)

Some English faculty doubted you. You proved them wrong.

Our lead TA doubted you, at first. He's changed his mind.

I'm immensely proud of your creativity and insight.

Inspiration (3/3)

When I was asked to teach this class, our academic coordinator told me: "These folks aren't here to learn mathematics. They're not here to learn only the laws of physics; they're here to learn what science is about."

In this class I've aimed to both teach you a little astronomy, and how to think scientifically ... but, also, to connect astronomy to the broader story of human thought.

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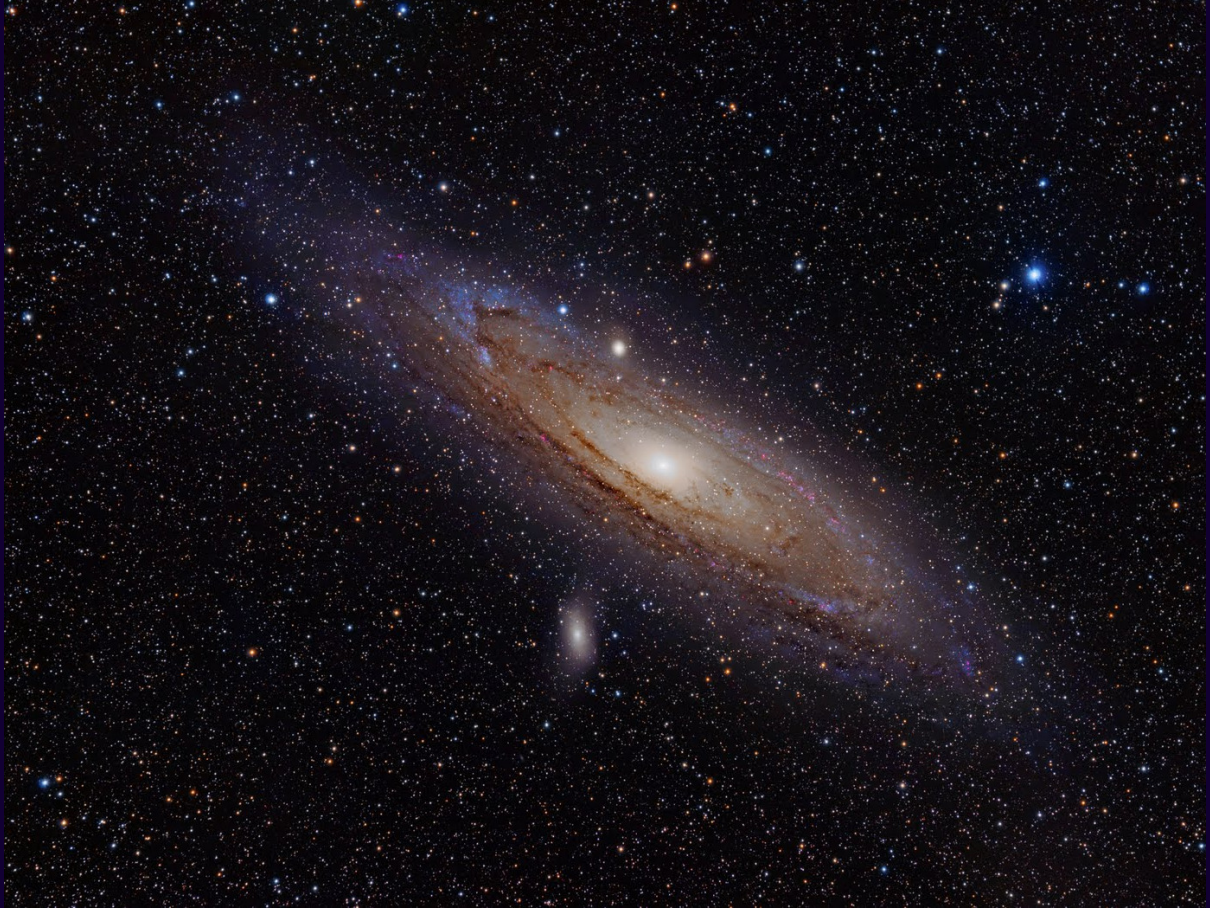
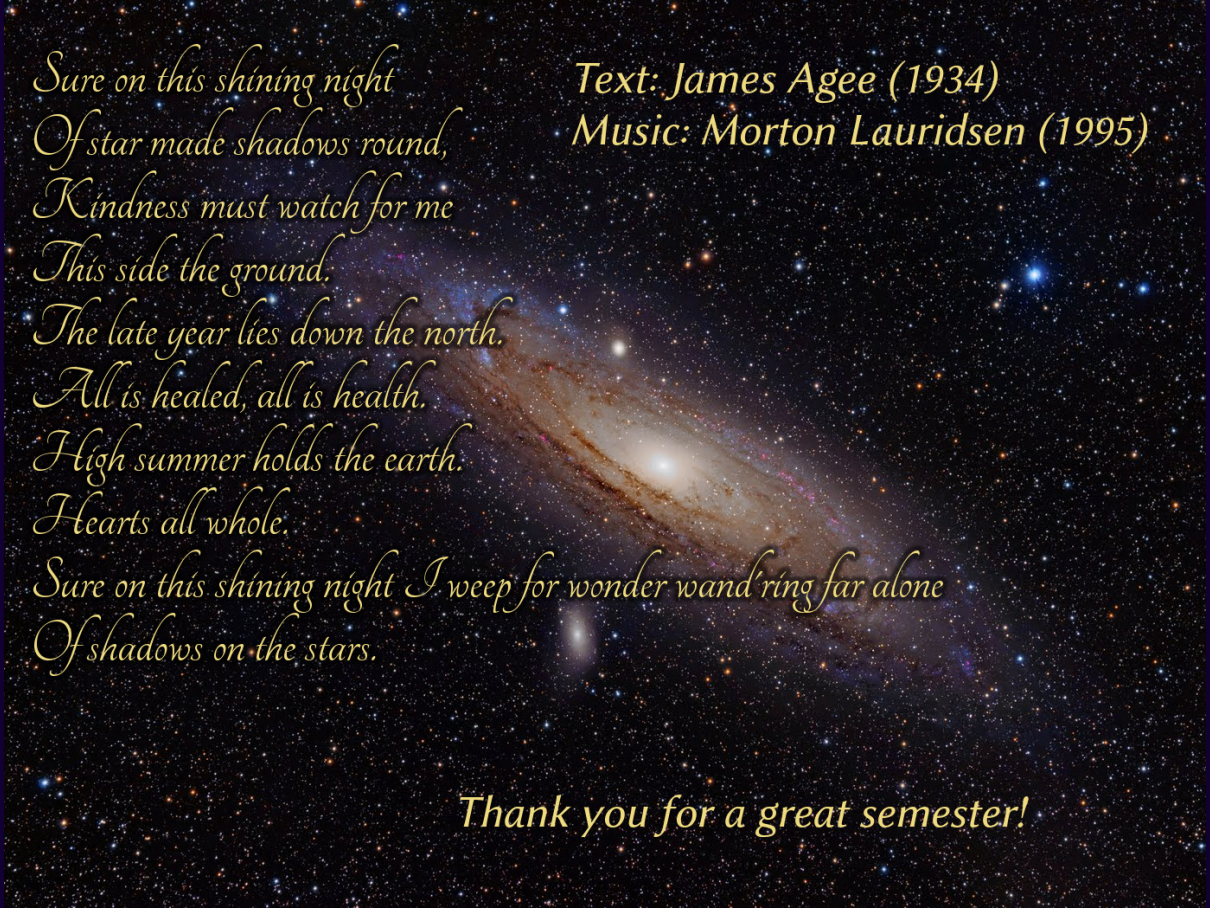
In the end, we look at the sky because it's beautiful.



Sure on this shining night
Of star made shadows round,
Kindness must watch for me
This side the ground.
The late year lies down the north.
All is healed, all is health.
High summer holds the earth.
Hearts all whole.
Sure on this shining night I weep for wonder wand'ring far alone
Of shadows on the stars.

Text: James Agee (1934)
Music: Morton Lauridsen (1995)


Sure on this shining night
Of star made shadows round,
Kindness must watch for me
This side the ground.
The late year lies down the north.
All is healed, all is health.
High summer holds the earth.
Hearts all whole.
Sure on this shining night I weep for wonder wand'ring far alone
Of shadows on the stars.
Text: James Agee (1934)
Music: Morton Lauridsen (1995)
Thank you for a great semester!