Planets Everywhere!

Learners @ Wind Crest
February 2020

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Overview

- Are we alone? Is there life elsewhere in the universe?
- Spoiler: I have no idea. Well, I have ideas, but can’t promise they’re correct.
- What is life, anyway?
- What about intelligent life?
- Life as we know it needs a world to stand on (swim in, etc.). There are now (5 Feb ’20) 4176 known planets around other stars. Not to mention 8 planets and dozens of moons in our own solar system.

Course Outline

- Factoring our ignorance: the Drake Equation
- Planets: a look at our own solar system
    - How special is the Earth?
    - Mars… like dry valleys in Antarctica. Possible underground microbes.
    - Ocean moons: Europa, Enceledus, … Could have environments like earthly mid-ocean ridges

Planets elsewhere

- How can we possibly know anything at all?
- Detection methods:
  - Radial velocity
  - Transiting planets and timing
  - Gravitational micro-lensing
  - Direct imaging

What to expect from this course

- We’ll have a mix of pictures with descriptive information, and more quantitative things.
- I’d like to save time in each lecture for questions about anything astronomical and/or scientific.
- This is my first Learners class, please be gentle.
- Course materials, links, and further info will be on my website: RichardJEdgar.github.io

Who am I anyway?

- BA, math/physics, CU-Boulder
- 4 years instructor at USN Nuclear Power School
- MS, PhD, Physics, U. Wisconsin-Madison
- 8 years @ UW working on the Diffuse X-ray Spectrometer; flew on the space shuttle in 1993.
- 24 years @ SAO working on the Chandra X-ray Observatory, a Hubble-class satellite launched in 1999 that does x-ray observations instead of optical light like the Hubble.
- SAO = Smithsonian Astrophysical Observatory, under contract with NASA. SAO shares facilities with the Harvard Astronomy Dept.
- Retired 2019, moved to Wind Crest.
- Other interests: vocal music, writing (speculative fiction)

The advertisement:

Necessary Lies

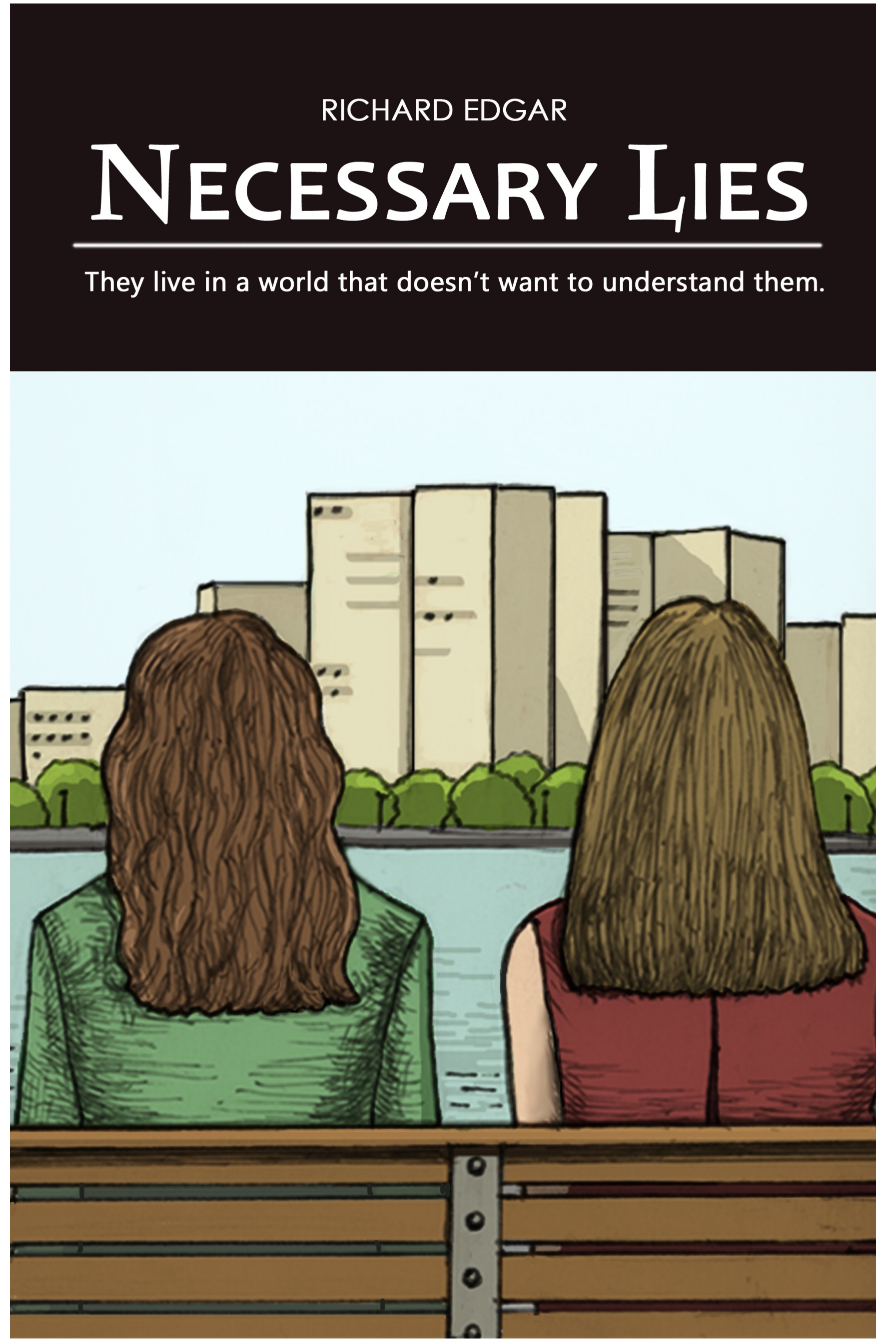
Richard Edgar

What if they told you you could never have children… but maybe there's a way?

What if your marriage is only valid on one side of the river, and the kid is in an accident on the other side?

Work hard, do your homework, cheat a little when you have to.

Available now on Amazon.



Some useful stuff

- How big are things? A few minutes about numbers large and small, sizes of things, how long things take.
- Electromagnetic radiation (i.e. light, infrared, ultraviolet, radio, x-rays, etc.). Wavelengths, frequencies.
- Interaction of light with matter: How we know most of what we know about the cosmos beyond the earth.

Numbers large and small

- Numbers get cumbersome when they're very large or very small compared to one.
- *Scientific Notation* writes them as something between 1 and 10, times some number of factors of 10, like this:
- Avogadro's number is 6.02×10^{23}, in other words 6 followed by twenty-three zeroes. It's how many protons there are in a gram. 12 grams of carbon have this many atoms.
- The radius of a hydrogen atom is 5.3×10^{-11} meters, or about half an Angstrom unit. Move the decimal point eleven places to the left, making an extremely small number.
- Powers of Ten: the movie. Shown in class, or you can find it online here: https://www.youtube.com/watch?v=0fKBhvDjuy0

Units of measure

- We'll mostly use the metric system: meters for length, seconds for time, kilograms for mass. Prefixes help manage the very big and very small numbers.
- We'll also use some astronomical-size units:
  - Astronomical Unit, AU = 150 million km, distance from earth to sun.
  - Light year, 10^{16} meters, distance light travels in a year. Parsec (3.26 light years, 3×10^{16} meters)
  - Mass of sun (2×10^{30} kg), earth (6×10^{24} kg), Jupiter (2×10^{27} kg or one milli-sun)
  - Radius of sun (6.9×10^{8} m), earth (6378 km), Jupiter (71,300 km)
  - year, 3.16×10^{7} seconds (remember as pi times 10^{7}).

Angular units

- Angles are typically measured in degrees, with 360^o in a full circle.
- A right angle is 90^o.
- A degree is subdivided into 60 minutes of arc, (60’), each of which is equal to 60 seconds of arc (60”), which makes 3600”=1^o.
- For historical reasons, the longitude coordinate in the sky, called Right Ascension, is measured in time units, tied to the rotation of the earth. One hour of Right Ascension is 15^o.
- For example, Proxima Centauri, the closest star, has celestial coordinates Right Ascension 14^h 29^m 42.9^s, declination -62^o 40’ 46”.
- Occasionally people use radians, there are 2π radians in a circle. Each radian is about 57.3^o.
- One arc second is typical “seeing”: the sharpest images that can be made without major technology from the ground with an optical telescope.

Let there be Light

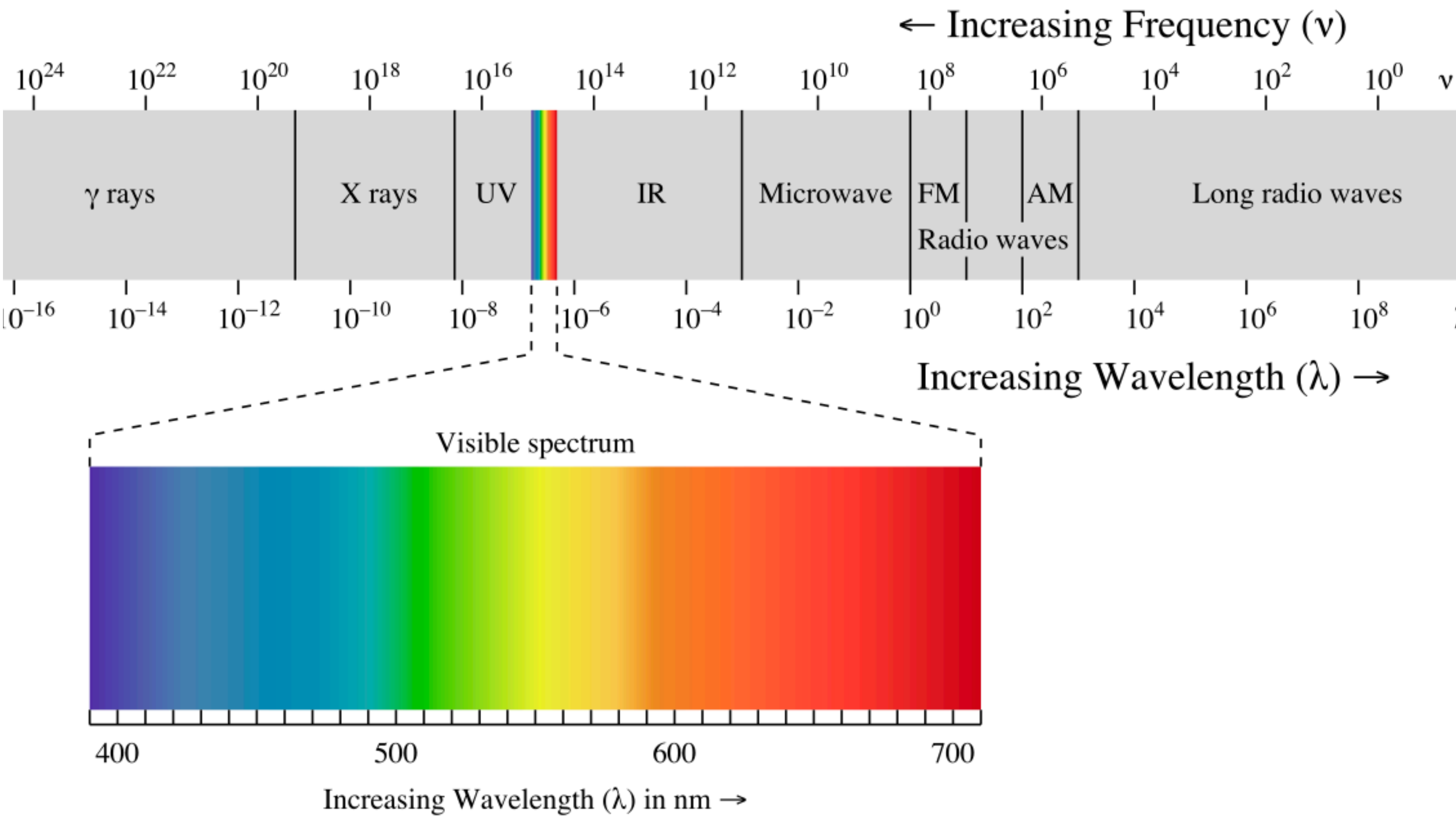
- Light is a wave in the electric and magnetic fields. These waves travel (in vacuum) at 3×10^8 meters per second. (186,000 miles per second, or about a billion feet per second).

- Visible light has waves of length between 400 and 700 nanometers, or 4 and 7×10^{-7} meters.

- This is just one octave (factor of two) in a very very long piano keyboard.

- Wavelength (meters per wave) times frequency (waves per second passing by) gives the speed of light.

- Light sometimes acts like a stream of particles, each with an energy given by a constant (Planck's constant) times the frequency of the wave.



Regions of the spectrum, by wavelength (in m, left to right) or frequency (in cycles/sec, right to left).
UV = Ultraviolet; IR = Infrared

Light, continued

- Every kind of atom, molecule, or ion has favorite wavelengths of light it likes to absorb or emit. We can exploit this to find out what astronomical objects are made of.

- The Döppler Effect (or Döppler shift) alters the wavelengths of light due to relative motion of the sender and receiver, by a factor of about v/c. We can use this to measure velocities of astronomical objects.

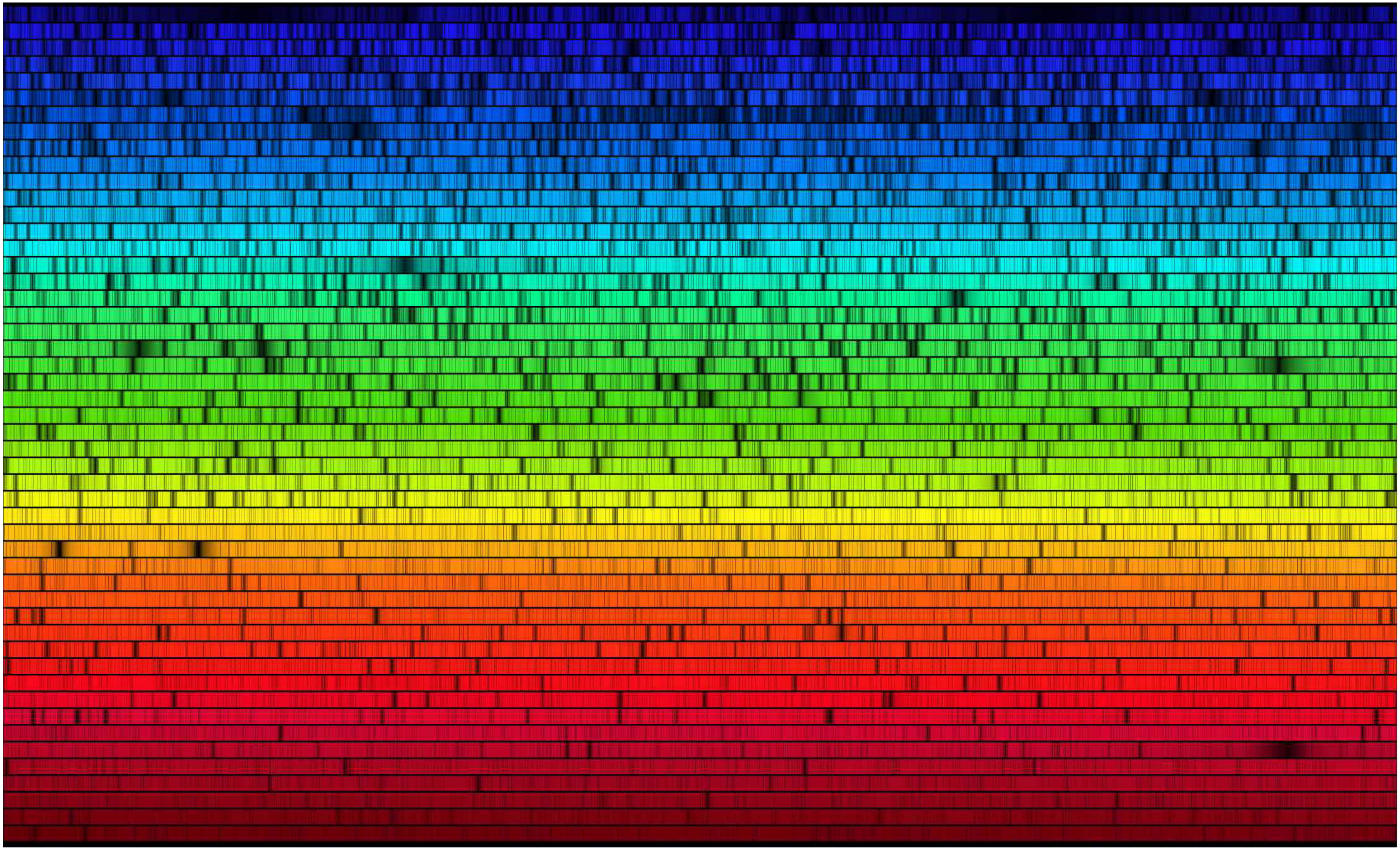
- The wave nature of light means it spreads out if you force it through an aperture. This “diffraction” limits the sharpness of the image you can make with a telescope.

- A great deal can be learned by sorting incoming light according to its wavelength, into a *Spectrum* using instruments called *Spectrographs.*

- Composition: what elements, what ionization states (how many electrons have been lost from the atoms), molecules

- Physical conditions such as temperature, density, etc.

- Velocity of the object toward or away from the observer.



A spectrum of the sun. The dark smudges are *Spectral Lines*, each one due to one kind of atom in the solar atmosphere. Wavelength increases left to right, and top to bottom, from about 400 to 700 nanometers. (Kurucz, SAO)