Astronomy of the Solar System – Module 1: Science and the Universe Part 1

GEORGIA STATE UNIVERSITY
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Picture of the Hubble Space Telescope in orbit around Earth, taken by astronauts.
Credit: NASA

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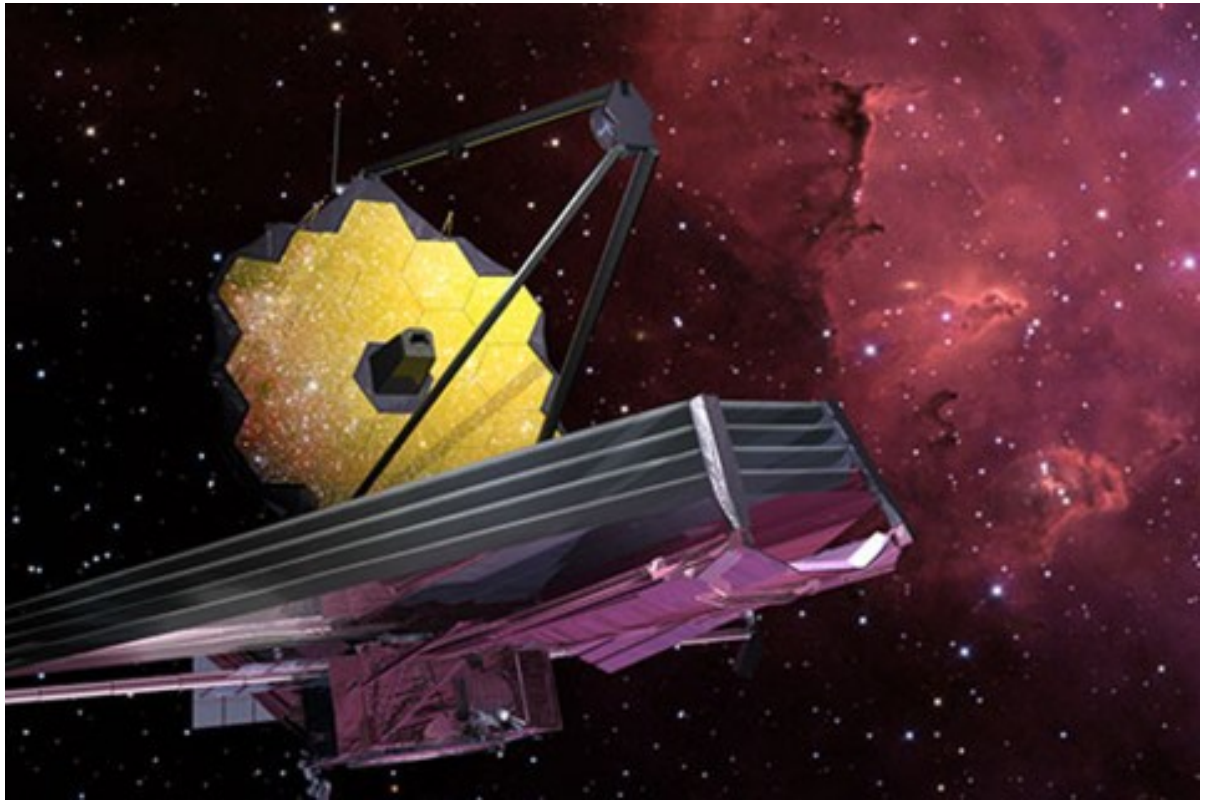
What is “Astronomy”?

OpenStax Astronomy: 1.1

- “**Astronomy**” – scientific study of objects beyond Earth and their interaction
- ***Scientific body of knowledge*** – progress report of current understanding based on current techniques and instruments, constantly tested in nature and updated with new discoveries
- ***Nature is ultimate judge*** on what theories and models are acceptable – must describe all of and nothing but nature

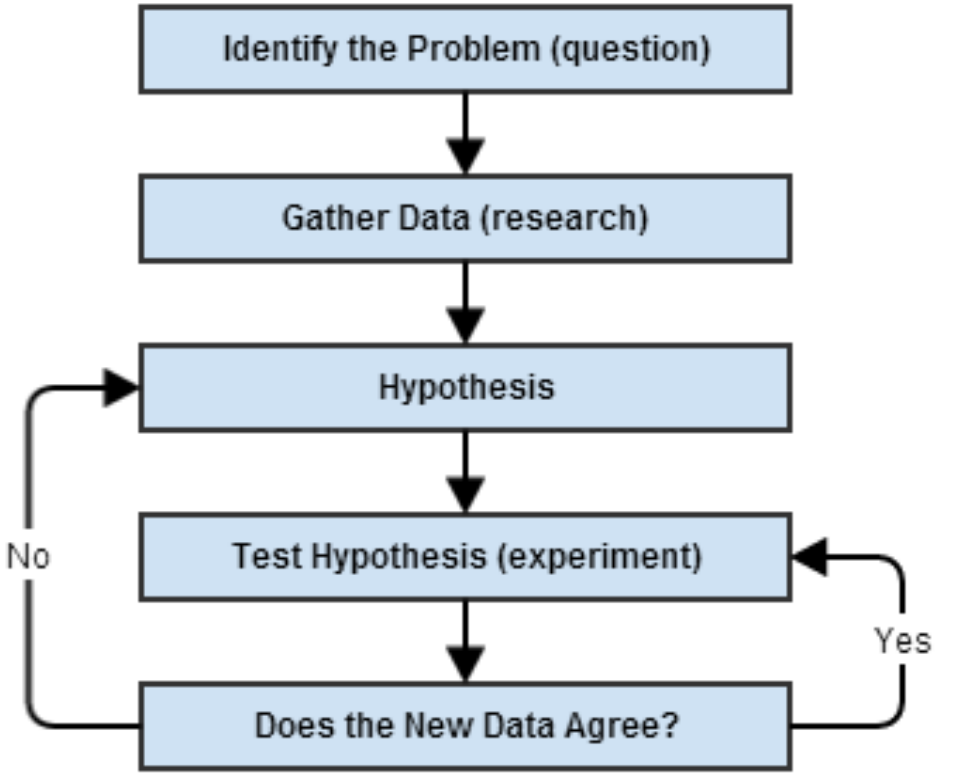


Artist rendition of James Webb Space Telescope, NASA’s most recent flagship mission, launched December 25, 2021. Credit: NASA

What is "Science"?

OpenStax Astronomy: 1.2

- "**Science**" – method to understand nature and its behavior with self-correcting feedback loop of testing against nature
  - Do observation/experimentation
  - Develop "**hypothesis**" – explanation
  - Make prediction based on hypothesis
  - Test prediction with further observation/experimentation
  - Keep hypothesis if successful, modify or discard if not
  - Retest constantly with new techniques and instruments
- "**Theory**" – consistently successfully tested and expanded hypothesis
- "**Model**" – representation of nature according to theory



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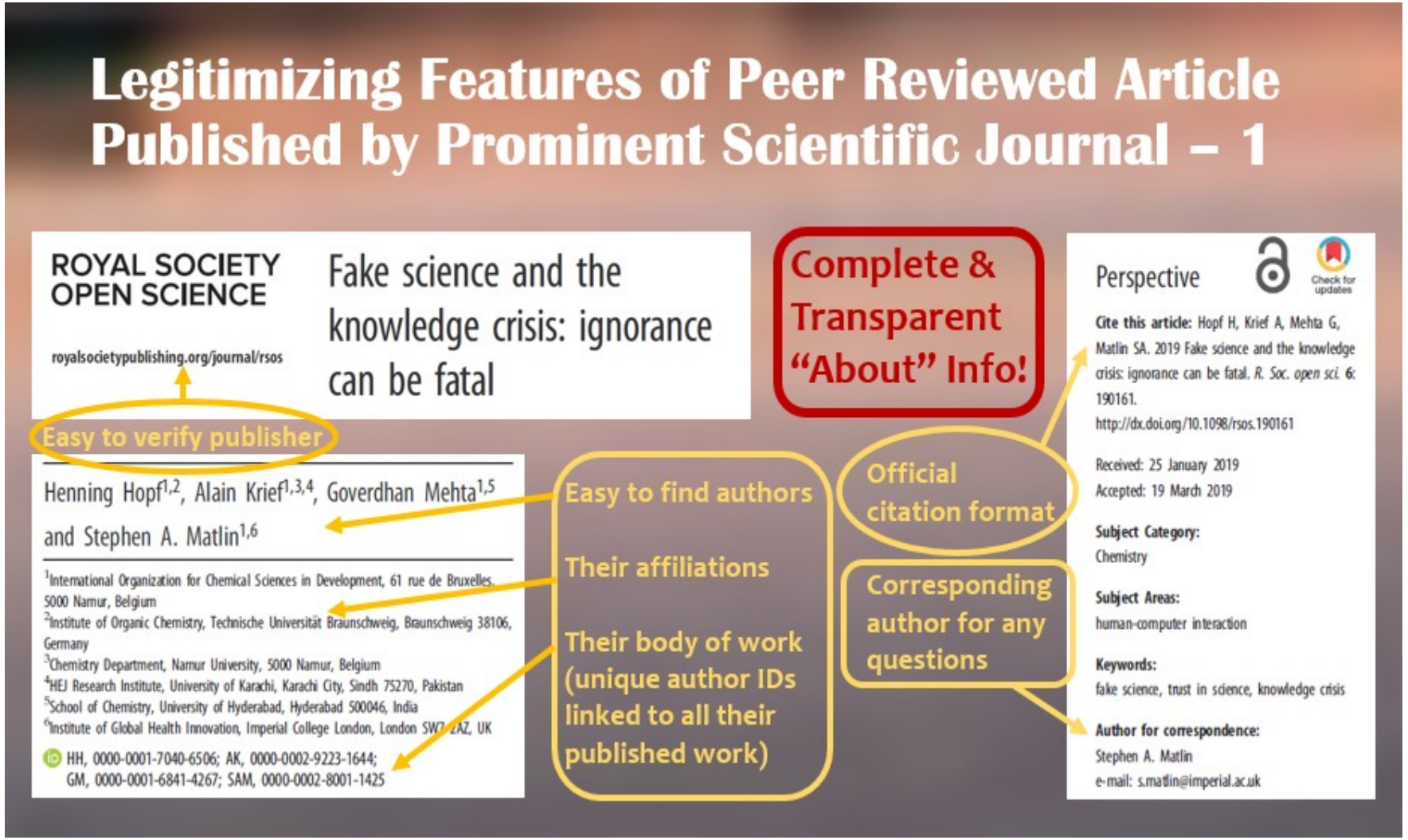
How does this self-correction work? OpenStax Astronomy: 1.2

- "**Peer review**" – quality control of research by scientists in same field before publication (review everything!)
  - Hypothesis must be testable, falsifiable, reproducibly tested
  - Strict research protocols to minimize human error, uncertainties, uncontrolled factors
  - Focus on success with simplest explanations and methods
  - Strong competition among researchers for publication in best journals

A reviewer at the National Institutes of Health evaluates a grant proposal (credit: National Institutes of Health)

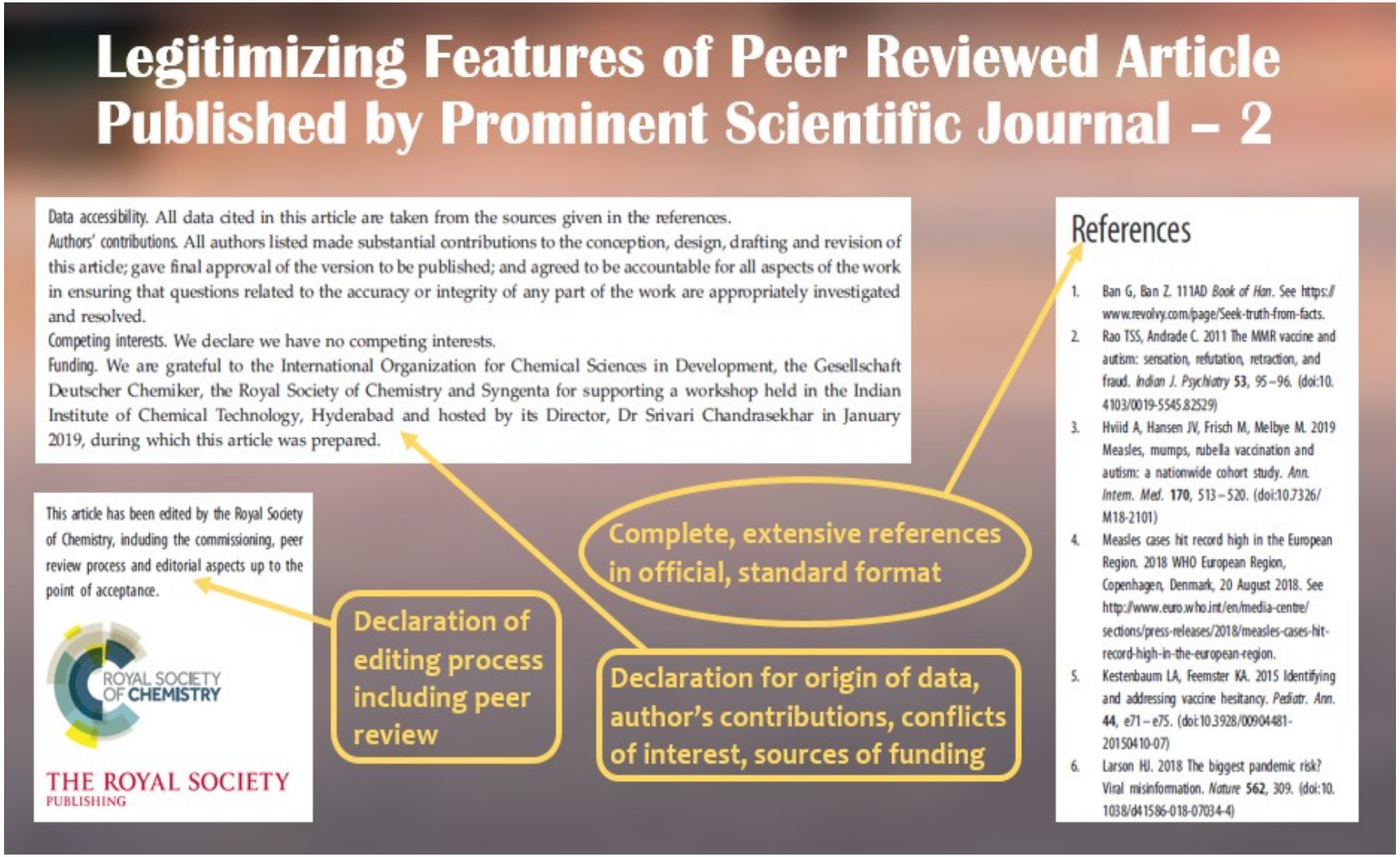
What is the publication format for a peer reviewed article?

Example: The Royal Society Open Science Page 1 of 2



What is the publication format for a peer reviewed article?

Example: The Royal Society Open Science Page 2 of 2



What are "Laws of Nature"?

OpenStax Astronomy: 1.3

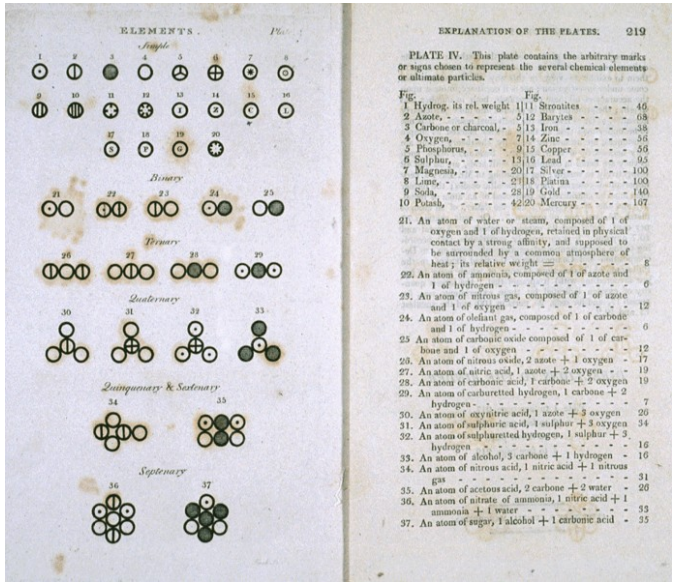
- "**Laws of nature**" or "**scientific laws**" – rules of nature gleaned over centuries of applying the scientific method
  - May change pending future discoveries
- "**Principle of universality**" – laws of nature found to apply everywhere in universe at any time
  - Model universe and its history based on observations/experimentation made on Earth and in Solar System
  - Predict new phenomena testable with future techniques and instrumentation

Thomas Aquinas, a 13th century catholic philosopher, revived and developed the concept of natural law from the ancient Greeks (credit: Wikipedia.org)

Why is there Math in Astronomy?

OpenStax Astronomy: 1.4

- Application of scientific method
  - Numerical measurements of physical properties – *quantitative data*
  - Analysis of data for consistent rules and patterns – *mathematical models*
  - More precise and practical than verbal description
- Astronomy involves extremely large and small numbers
  - Number of stars in our galaxy – 100 billion = 100,000,000,000
  - Size of atomic nucleus – 0.0001 pico meters = 0.000000000000001 m



Atoms and molecules as depicted in John Dalton's A New System of Chemical Philosophy vol. 1 (1808), credit: Wikimedia Commons

How better to handle extreme numbers?

OpenStax Astronomy: 1.4

- "**Scientific Notation**" – two part number
  - Decimal part – meaningful digits
  - Power of 10 part – size (all the zeros)
- From regular to scientific notation
  - ***Factor out powers of 10:*** move decimal point so one digit > 0 in front
  - Keep meaningful digits as decimal x 10^exponent
  - ***Number of exponent:*** how many times decimal point was moved
  - ***Sign of exponent:*** "+" if absolute value of original number > 1, "-" if < 1

Worked Examples

- **Regular number > 1**

  367,000 = 36,700 x 10 = 3,670 x 10 x 10 = 367 x 10 x 10 x 10 = 36.7 x 10 x 10 x 10 x 10 = 3.67 x 10 x 10 x 10 x 10 x 10 =

  367,000. *[5 factors of 10 = moving 5 places]*

  = 3.67 x 10^{5} *["+" exponent, number >1]*

- **Regular number < 1** *[remember 0.1 = 10^{-1}]*

  0.0000367 = 0.000367 x 0.1 = 0.00367 x 10^{-1} x 10^{-1} = 0.0367 x 10^{-1} x 10^{-1} x 10^{-1} = 0.367 x 10^{-1} x 10^{-1} x 10^{-1} x 10^{-1} = 3.67 x 10^{-1} x 10^{-1} x 10^{-1} x 10^{-1} x 10^{-1} = 0.0000367 *[5 of 10^{-1}]*

  = 3.67 x 10^{-5} *["-" exponent, number < 1]*

What is the measure of distances in space? OpenStax Astronomy: 1.4

Examples

Earth-Moon distance and sizes to scale (credit: OpenStax/NASA)

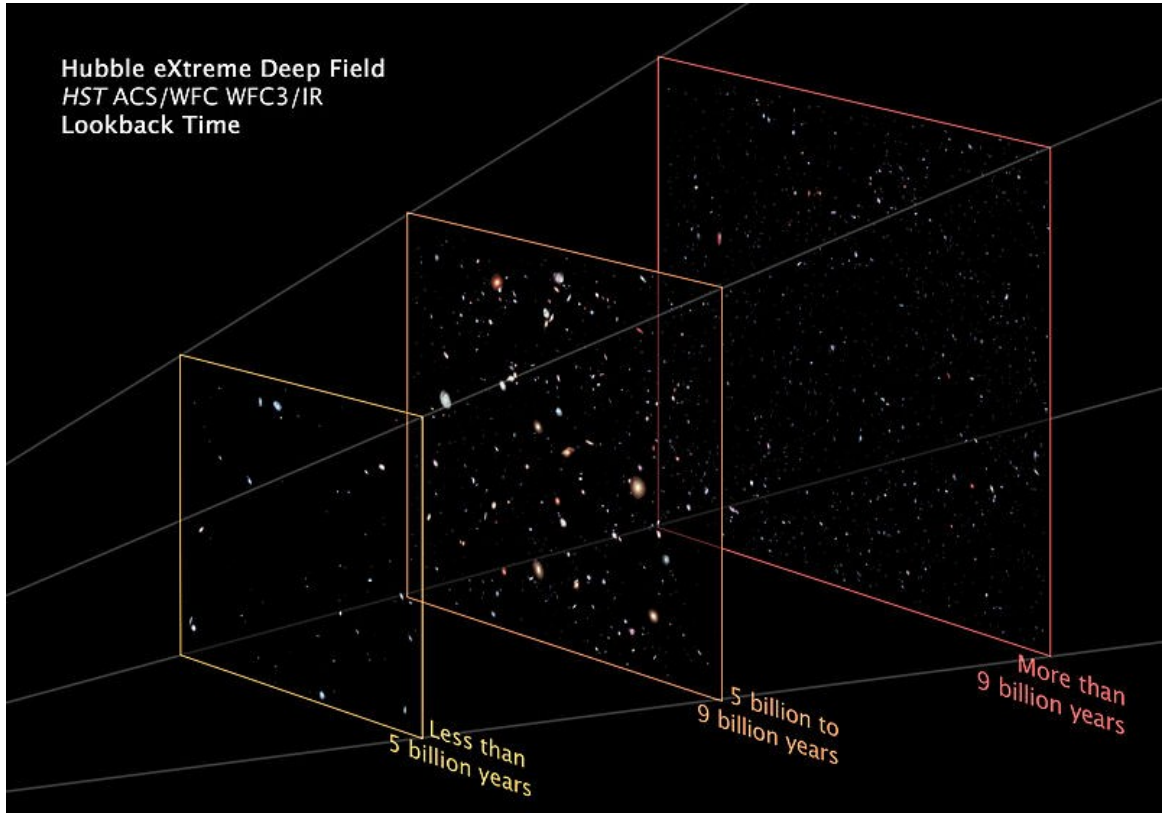
- Distances in space are huge! Large number in units of kilometer (km)
- Larger distance unit – practical numbers
- Ultimate speed limit of universe – **speed of light = 3 x 10^5 km/s** = "**c**" = constant speed at which light travels
- Use ***light travel time as distance unit***
  - 1 light year = distance light travels in one year = 3 x 10^5 km/s x seconds in a year = 9.46 x 10^{12} km
- *Analogy:* GPS assumes constant speed – shows distance as time to get there (unit is "car hours and minutes")

- Some distances in km *(1 mi = 1.6 km)*
  - Earth-Moon: 384,400 km
  - Earth-Sun: 147,450,000 km
  - Earth-Pluto: 3,239,700,000 km
  - Earth-closest star (Alpha Centauri): 40,678,000,000,000 km
- Same distances in light travel time *(divide km by light travel time in sec or min or hrs)*
  - Earth-Moon: 1.28 light seconds
  - Earth-Sun: 8.19 light minutes
  - Earth-Pluto: 3.00 light hours
  - Earth-Alpha Centauri: 4.3 light years

If light takes time to travel, has it aged by arrival? OpenStax Astronomy: 1.5

- Light we receive shows any object the way it was when it left!
  - The further away, the more in the past!
  - We see the Sun from 8.2 minutes ago, Alpha Centauri from 4.3 years ago …
- Study evolution and beginning of universe with more and more sensitive telescopes!

- *Analogy:* You take a picture of a sunset when you leave place A. Then you travel to place B and show it to your friend. By the time your friend sees the picture of the sunset at place A, it is already dark there. Your friend sees into the past by how long ago you took the picture.



Credit: NASA