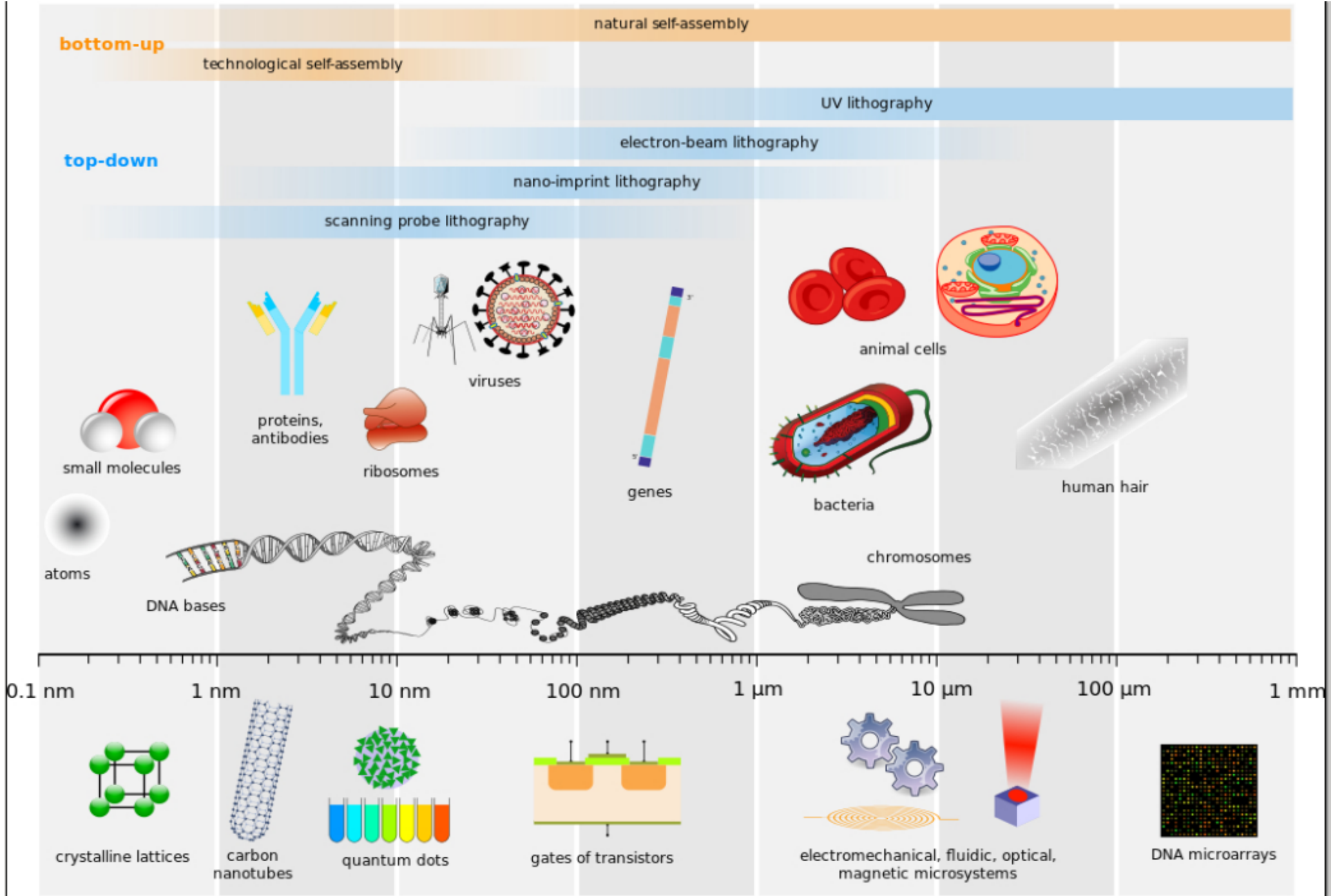


The Origin of Life

Dr. Sudipta Das

Assistant Professor
Department of Mathematics
Banwarilal Bhalotia College
Ushagram, Asansol - 713303

How Small Can It Be?



Plankton Bloom in Black Sea





Realmonte, Sicily





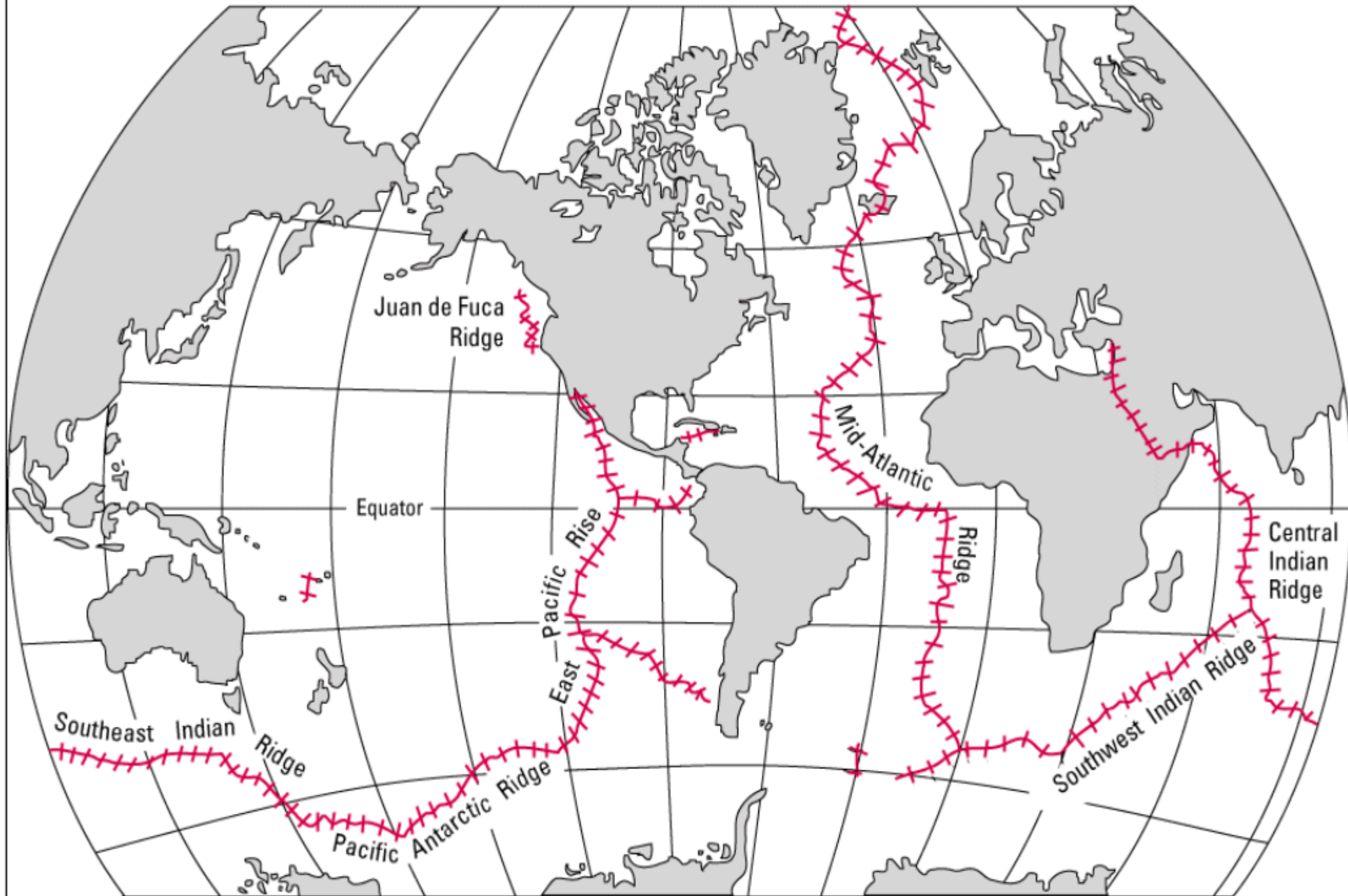




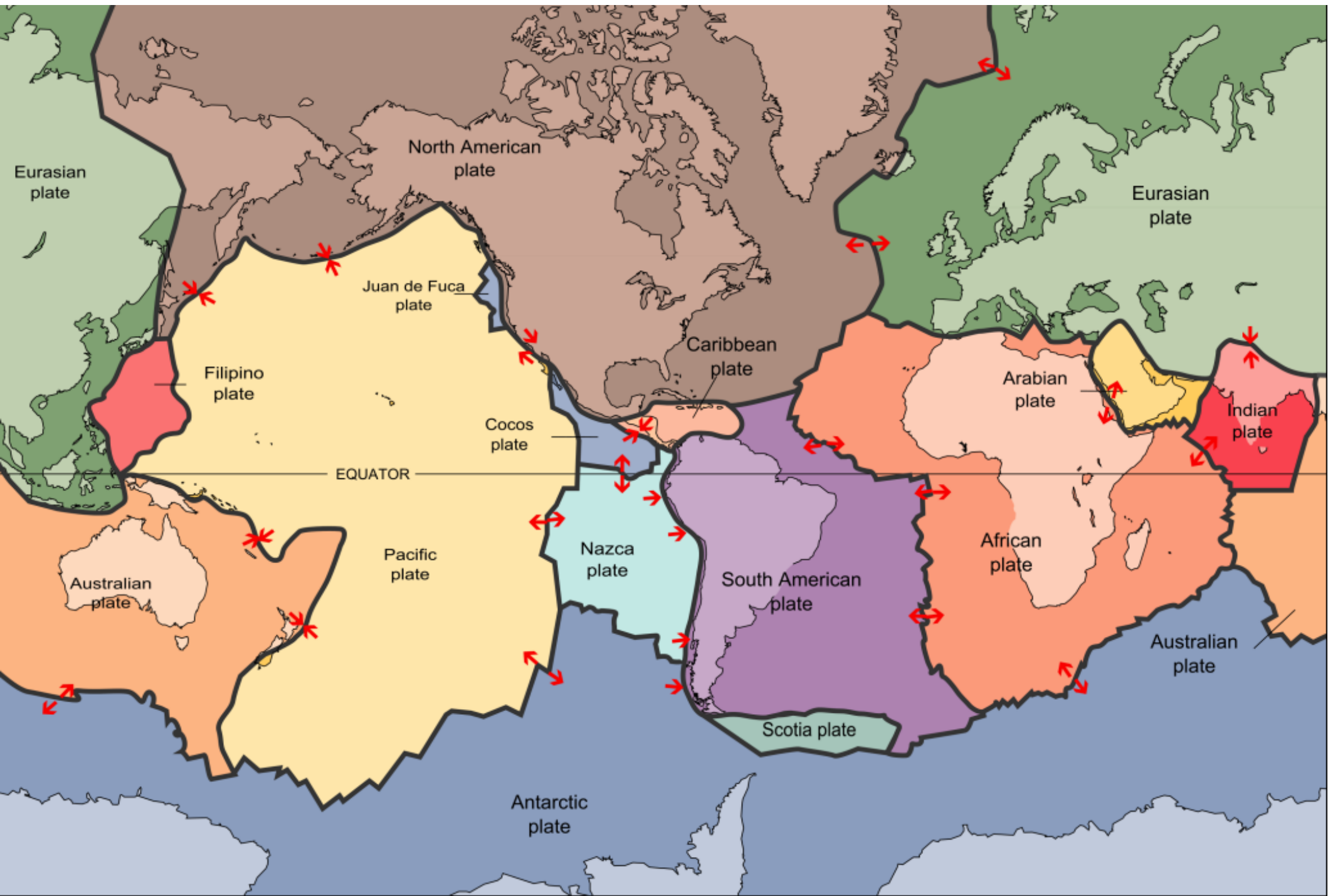
Gypsum Crystals in Naica Mine, Mexico



Map of Oceanic Ridges



Continental Plates



Aurora Borealis



Aurora Borealis



Yosemite Valley



Night Sky



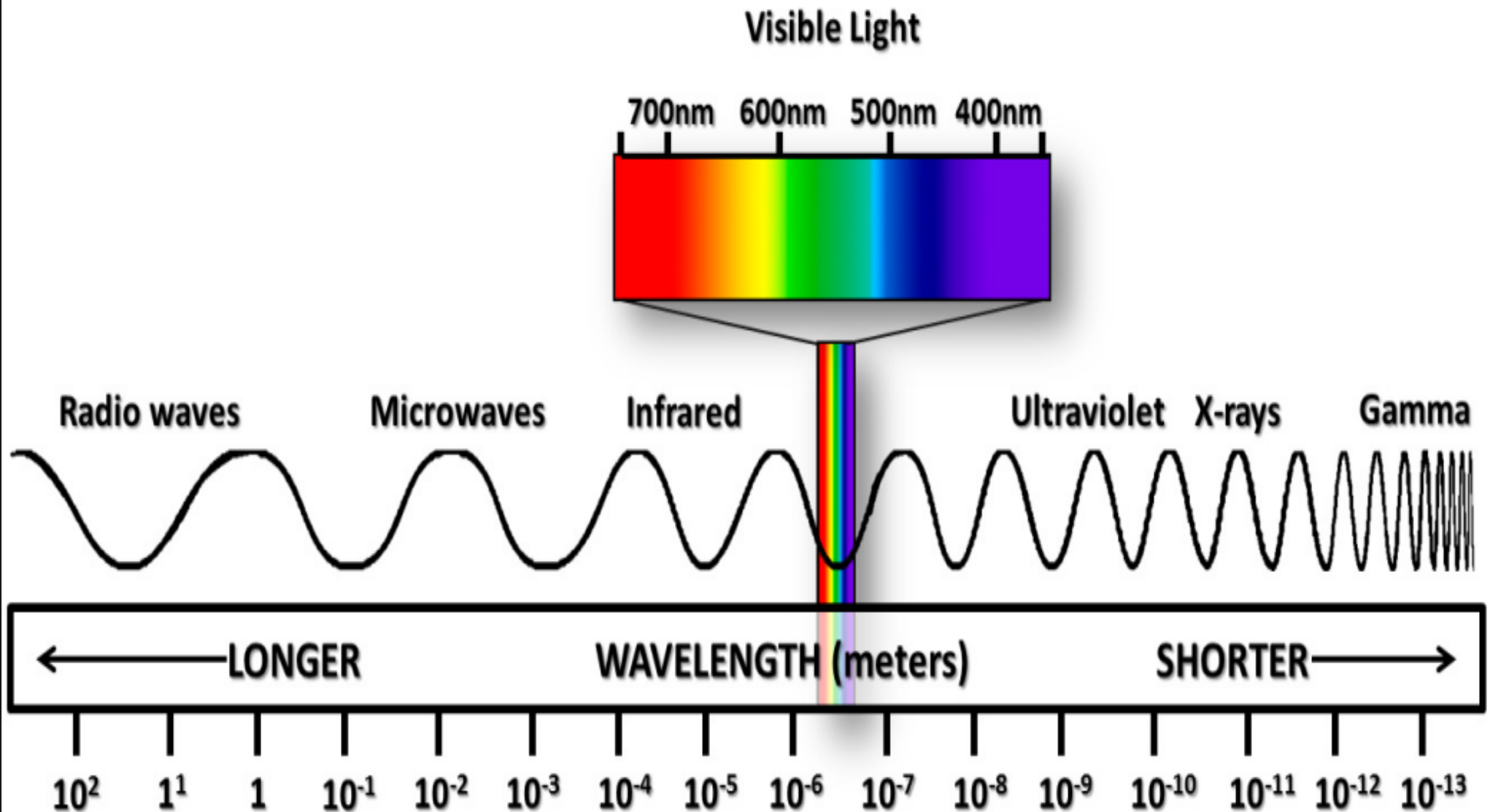
Milky Way



Milky Way



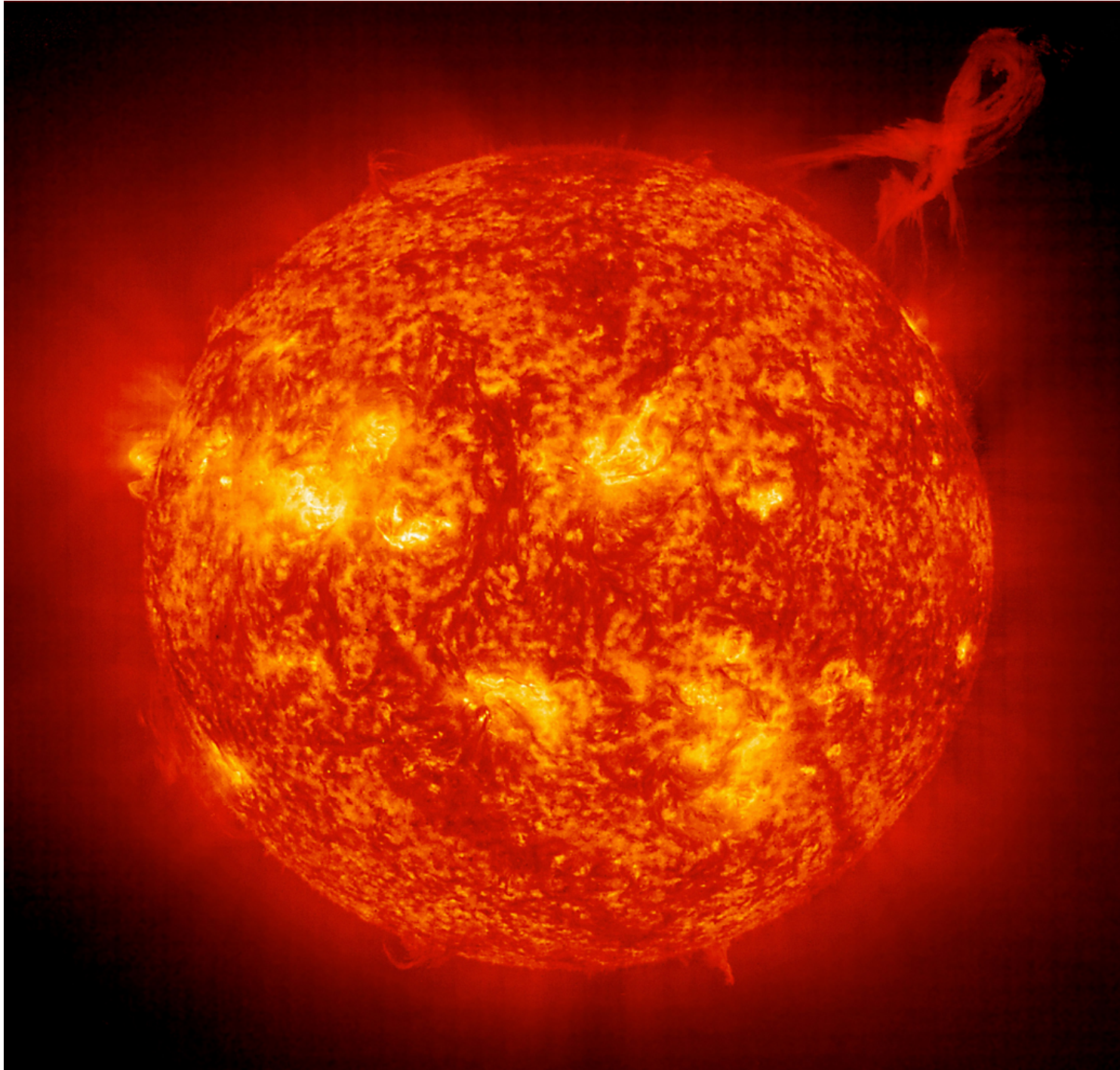
Spectrum of Observation



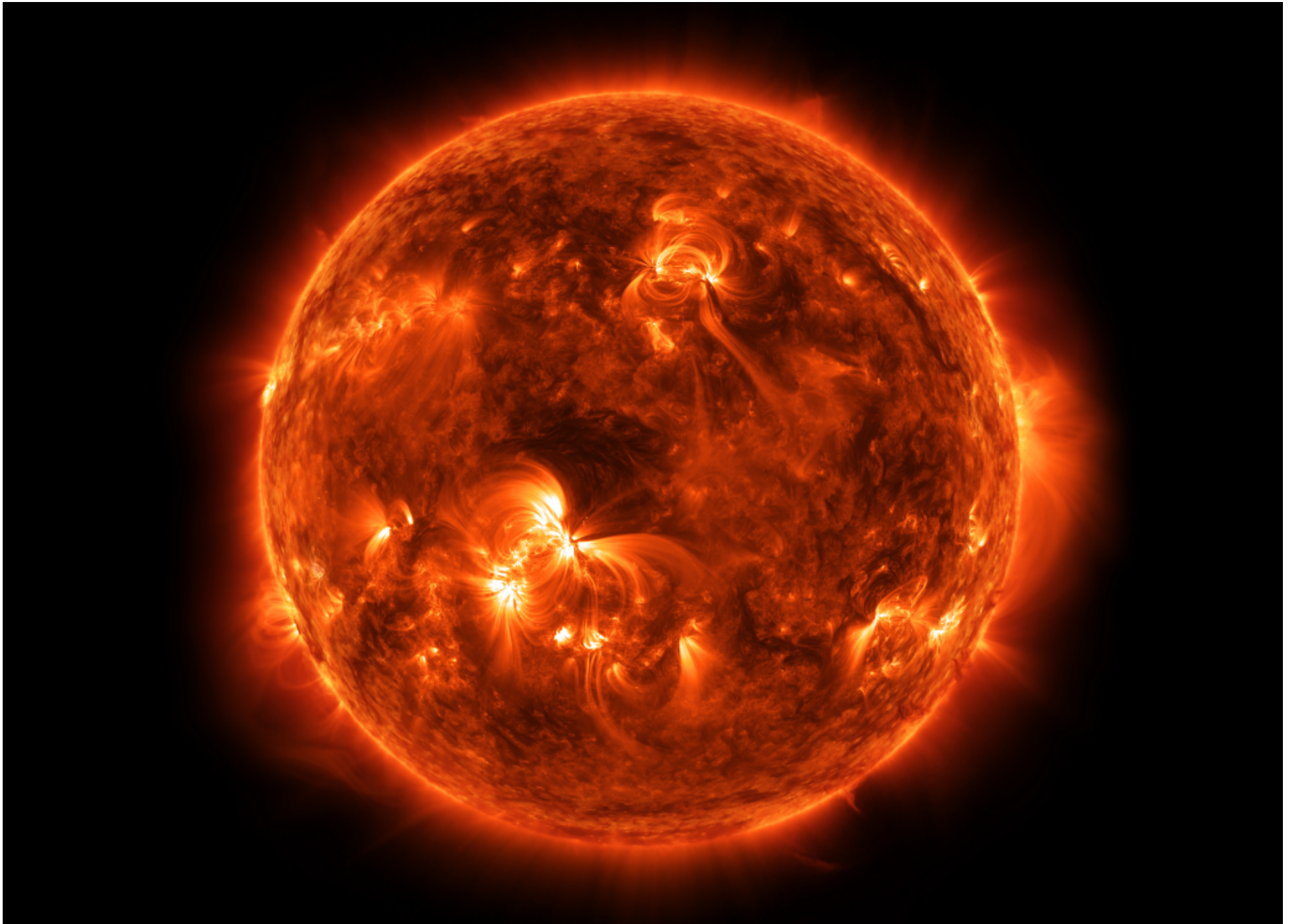
Solar Eclipse & Corona



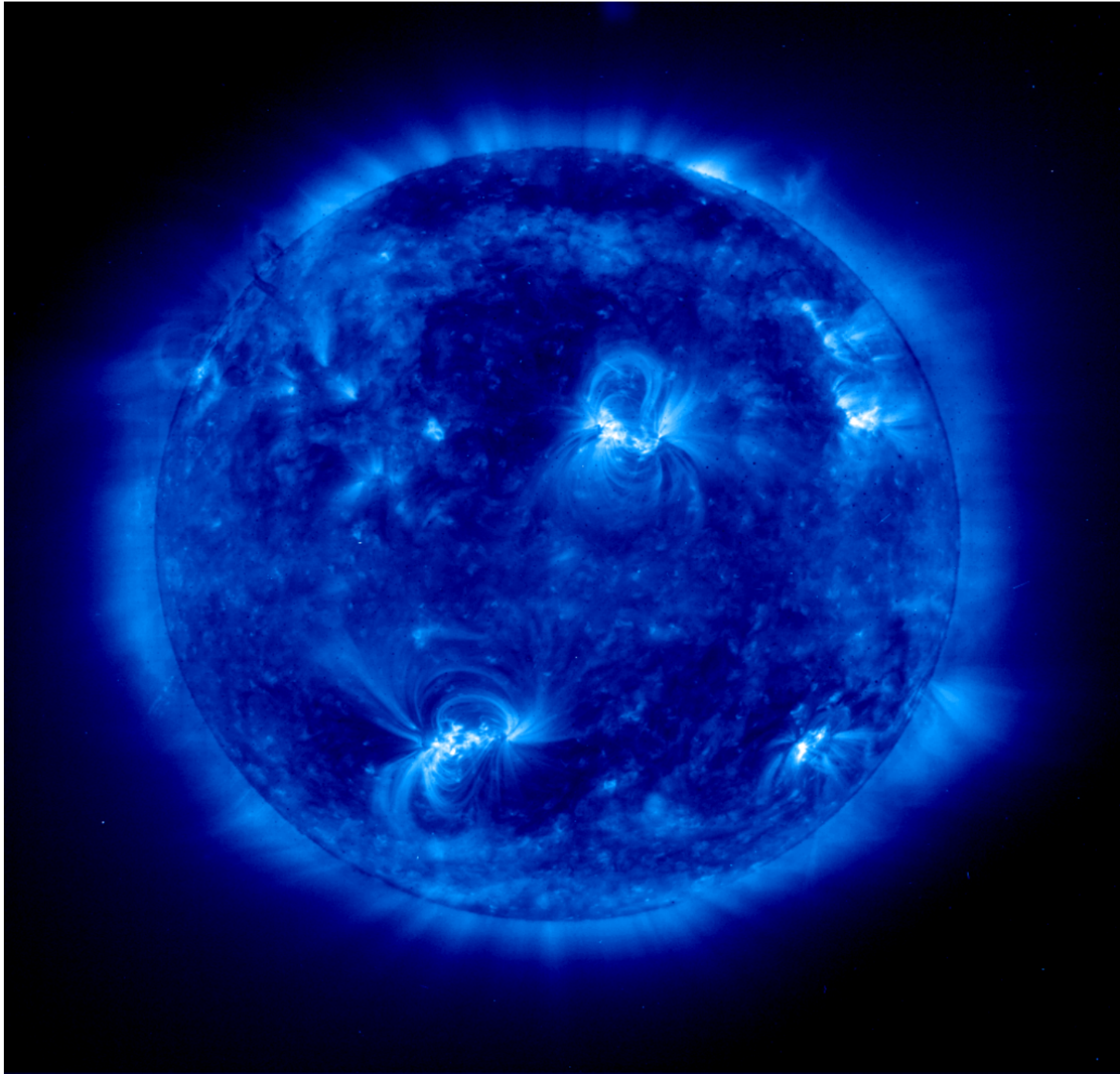
Optical Sun



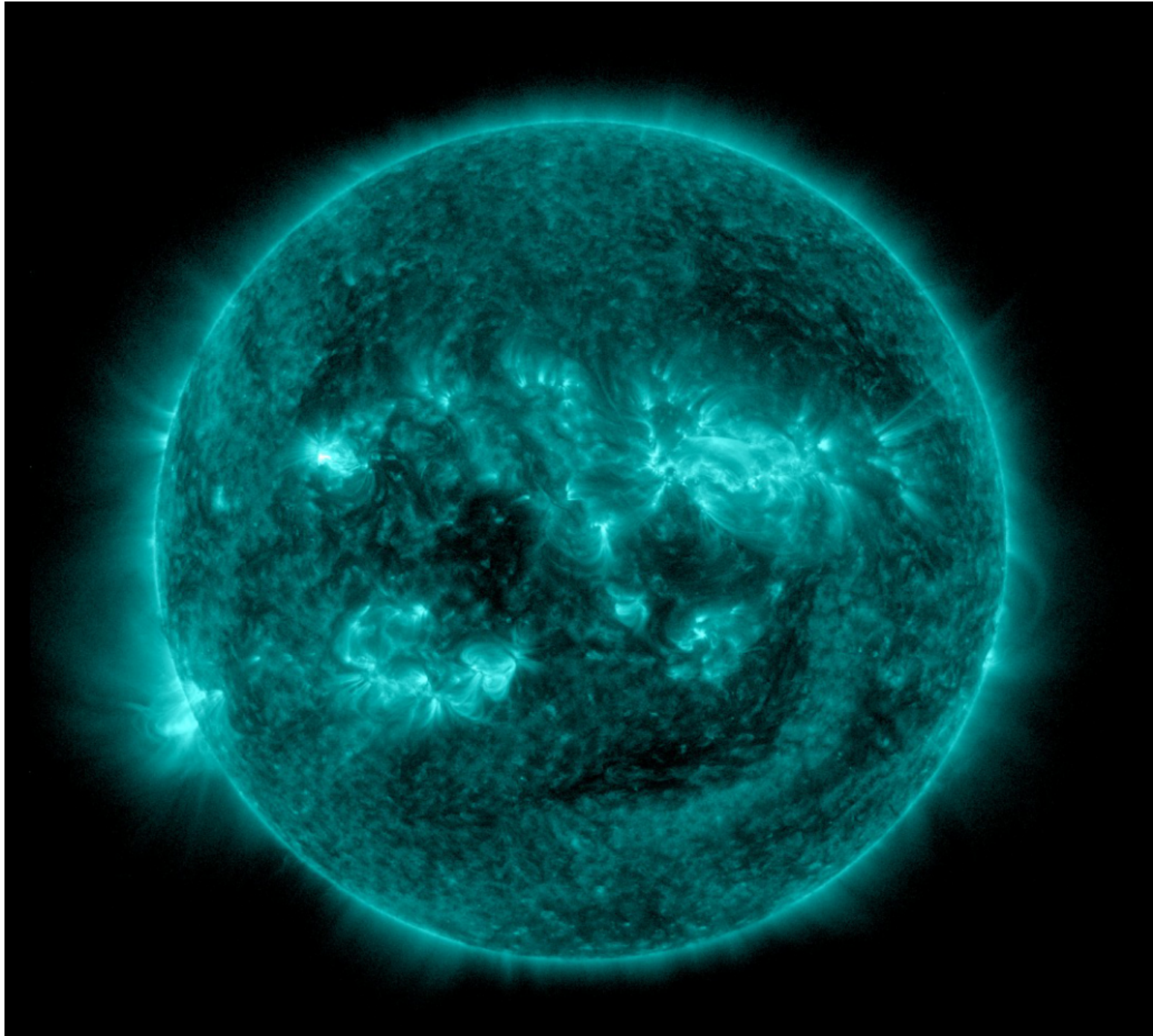
Infrared Sun



Ultraviolet Sun



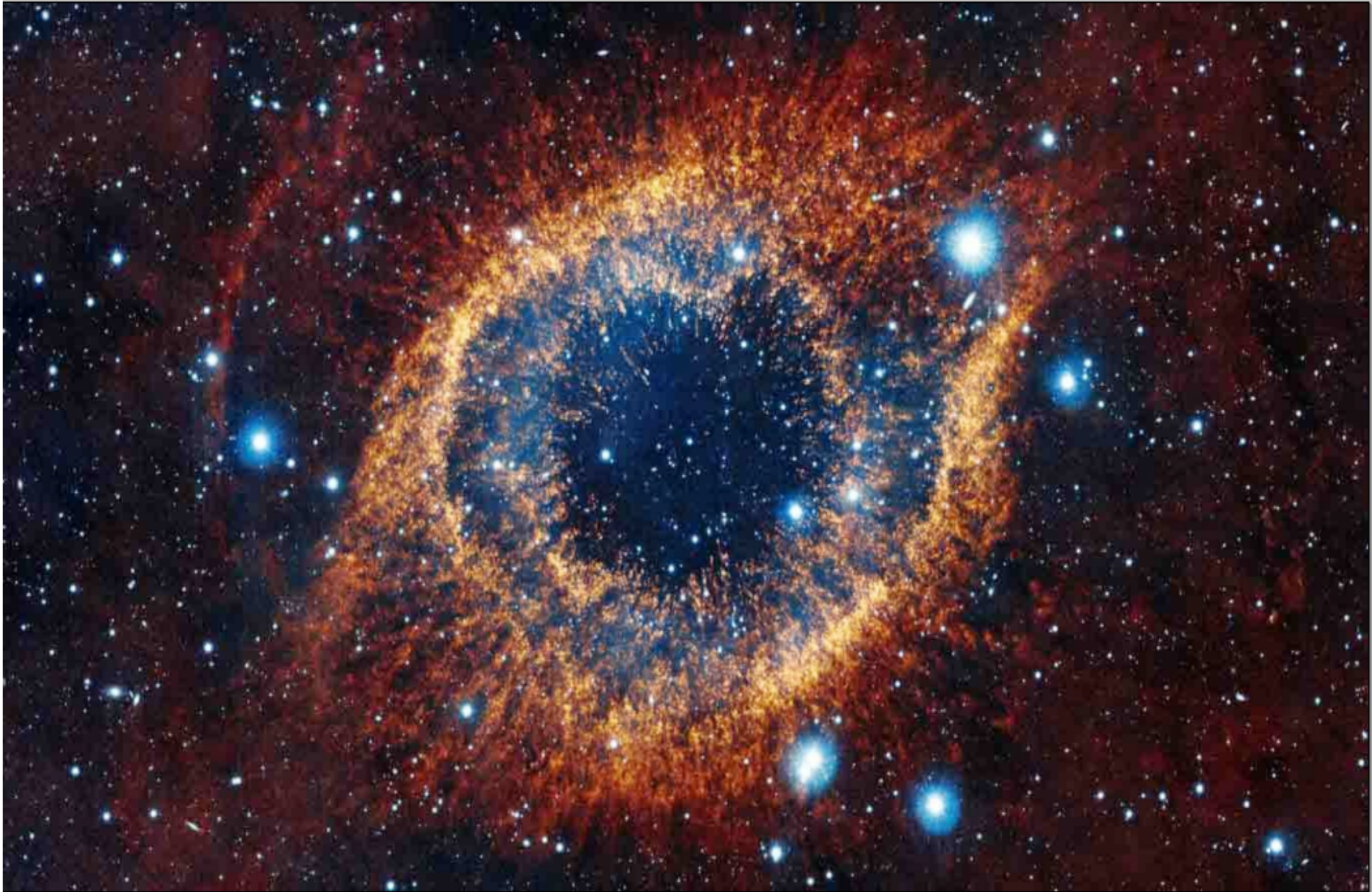
X-Ray Sun

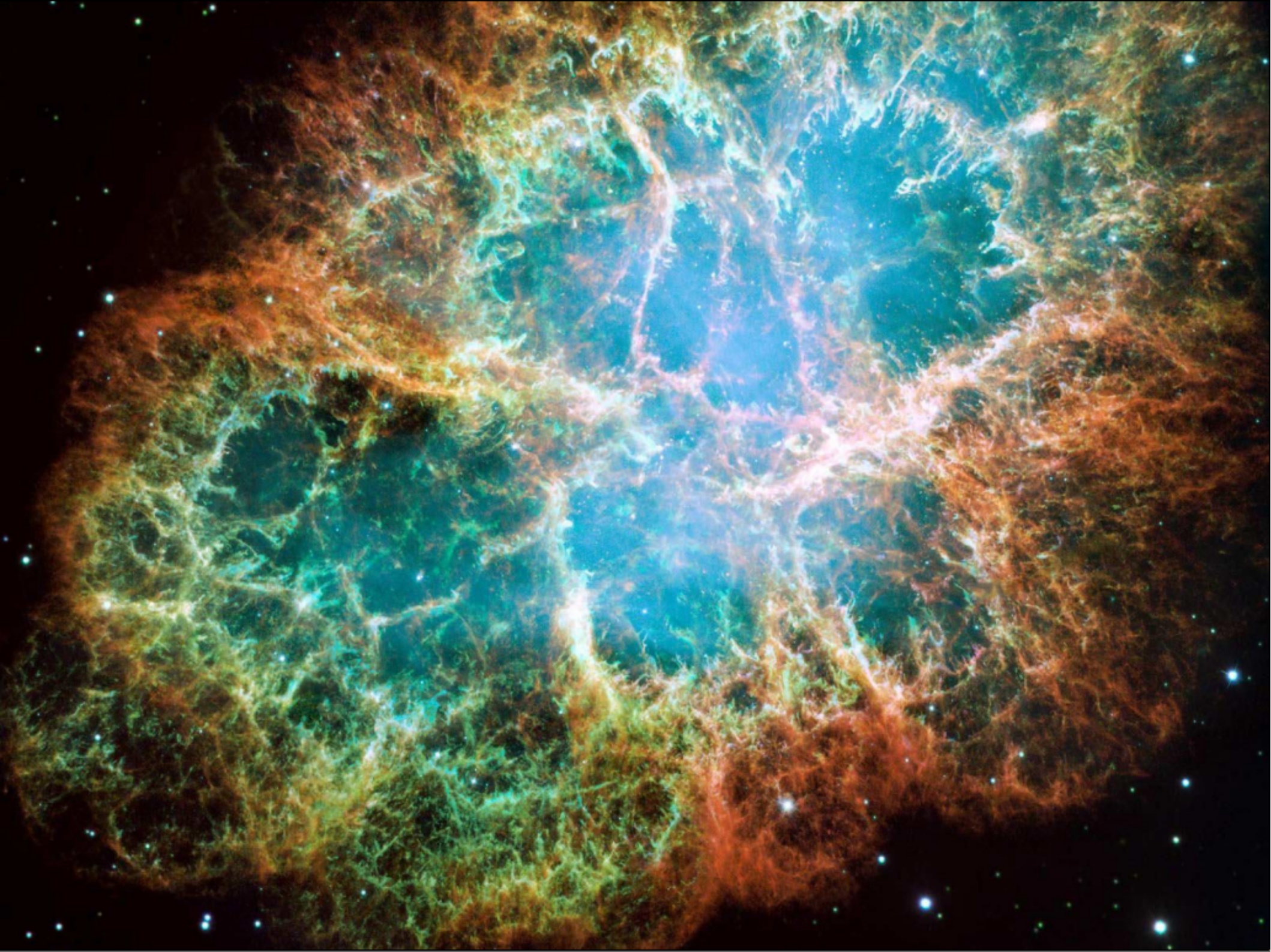


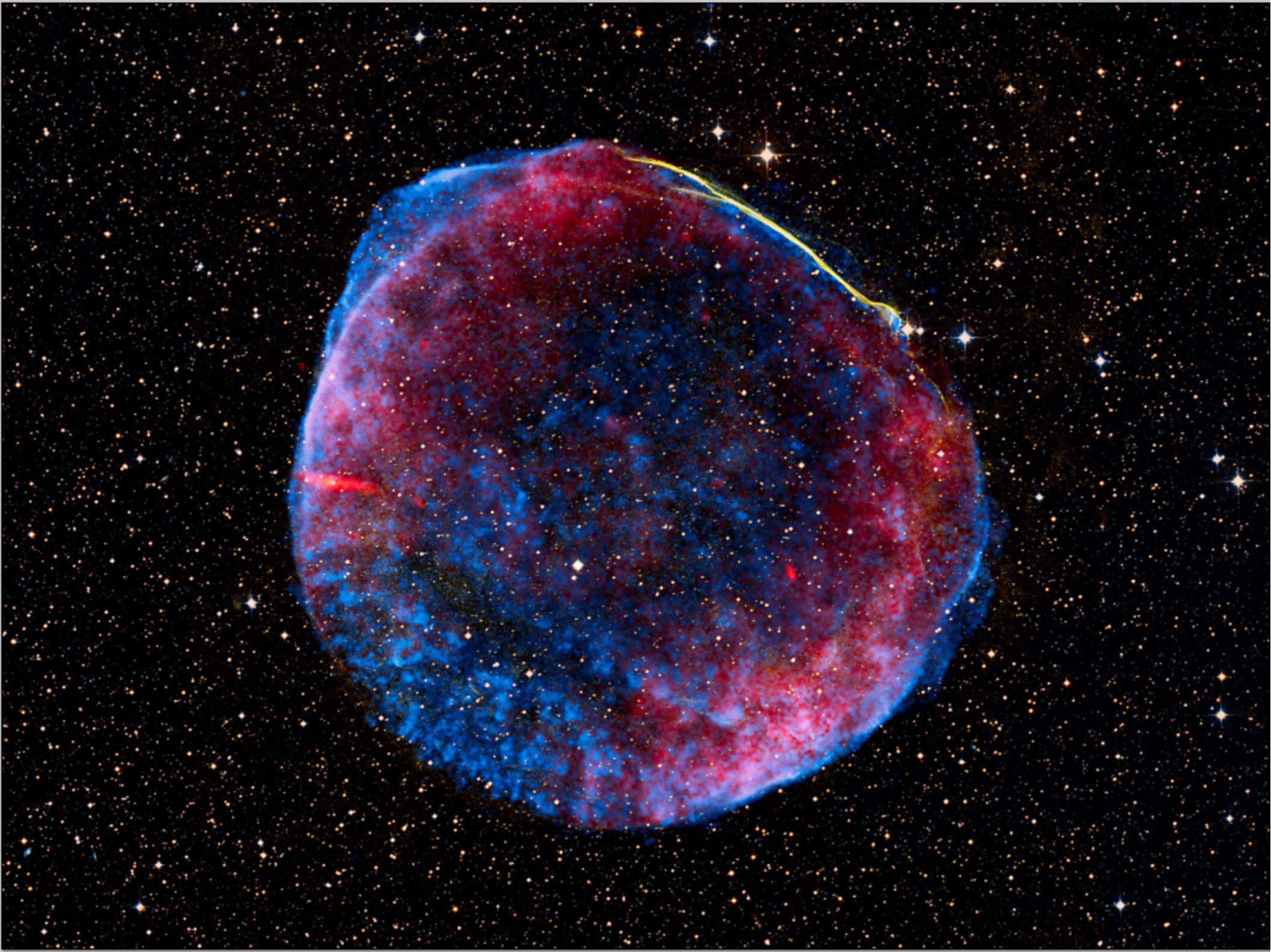
Birth of Stars



Supernova



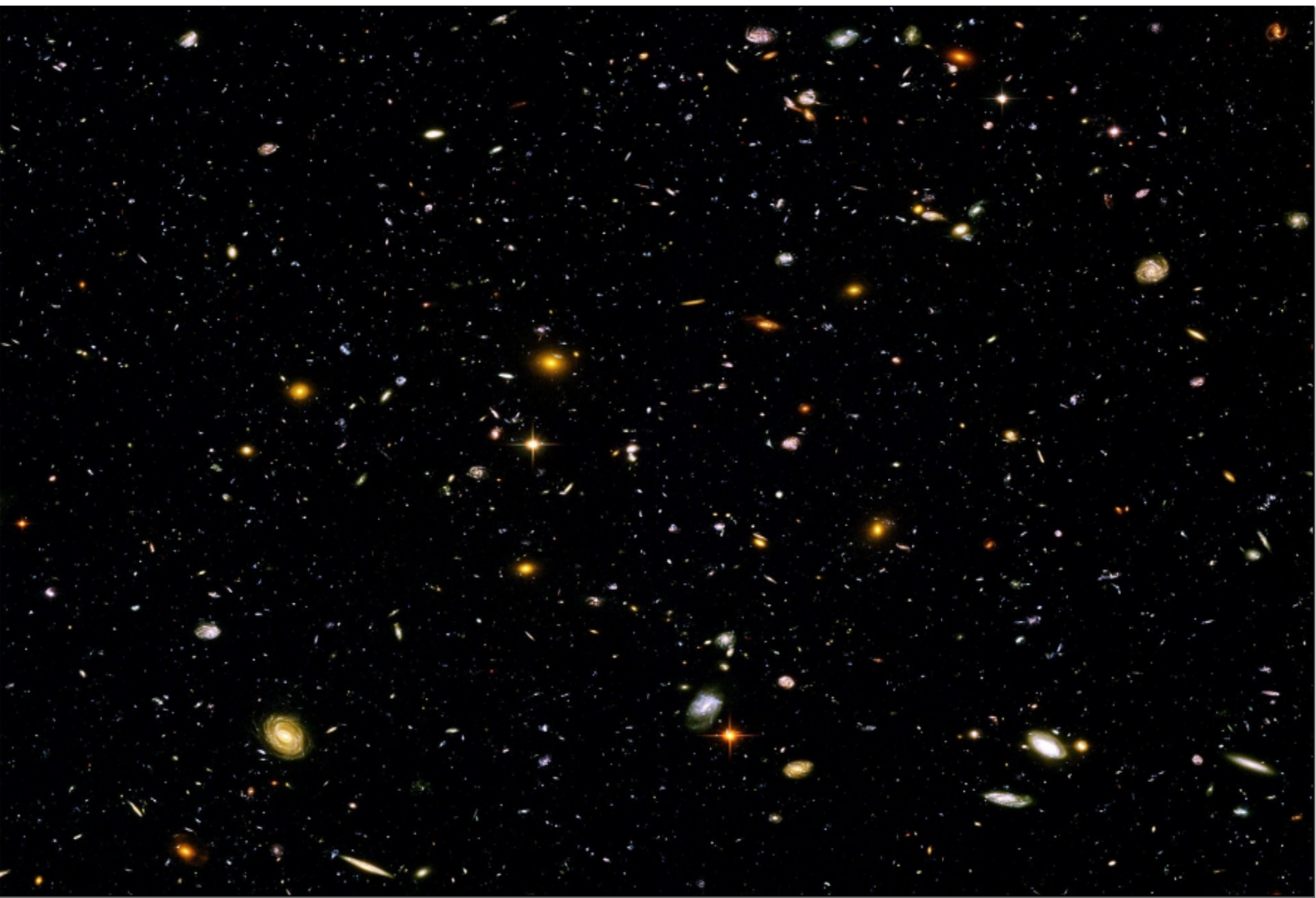




Collision of Two Galaxies



Hubble Ultra Deep Field



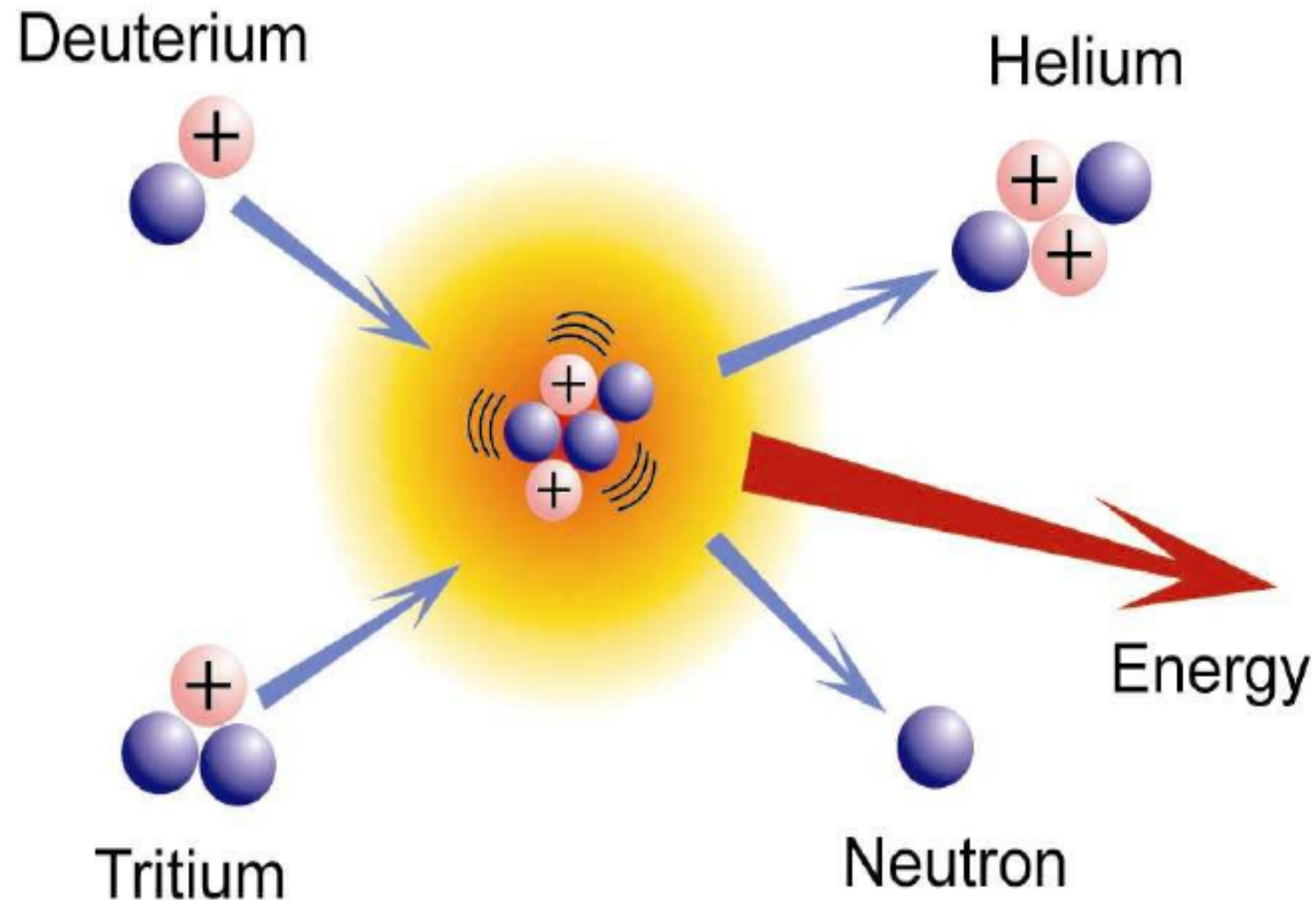
How we came into being?

- What are we made of?
- Sun possesses a fair amount of Oxygen, Carbon, Nitrogen and heavier elements like Iron, Nickel etc.
- It seems that we got these elements from the Sun
- But how did Sun get these elements in the first place?

- How the stars are born?

- (i) There are large clumps of cold Gaseous clouds (mostly Hydrogen)
- (ii) The clumps collapse under gravitational force
- (iii) This collapse heats up the gas and it begins to radiate
- (iv) Stars are formed when a equilibrium is reached, i.e. when inward gravitational pressure = outward radiation pressure
- (v) Stars need to maintain this equilibrium for a steady lifetime; so they use their huge mass as the fuel: $E = Mc^2$

- For stars with Initial mass $< 6M_{Sun}$



- For stars with Initial mass $> 6M_{Sun}$
 - For such massive stars, the **core temperature** can reach up to **150 – 200 million Kelvin** or more due to enormous gravitational pressure
 - At such high temperatures, these stars become able to fuse **Helium** and heavier elements to produce **Carbon, Nitrogen, Oxygen etc.** up to **Iron**
 - Ultimately, in the dying stages of these stars, **all other heavier elements** are produced through violent explosion, named as **Supernovae**

5 Billion Years – 4.5 Billion Years

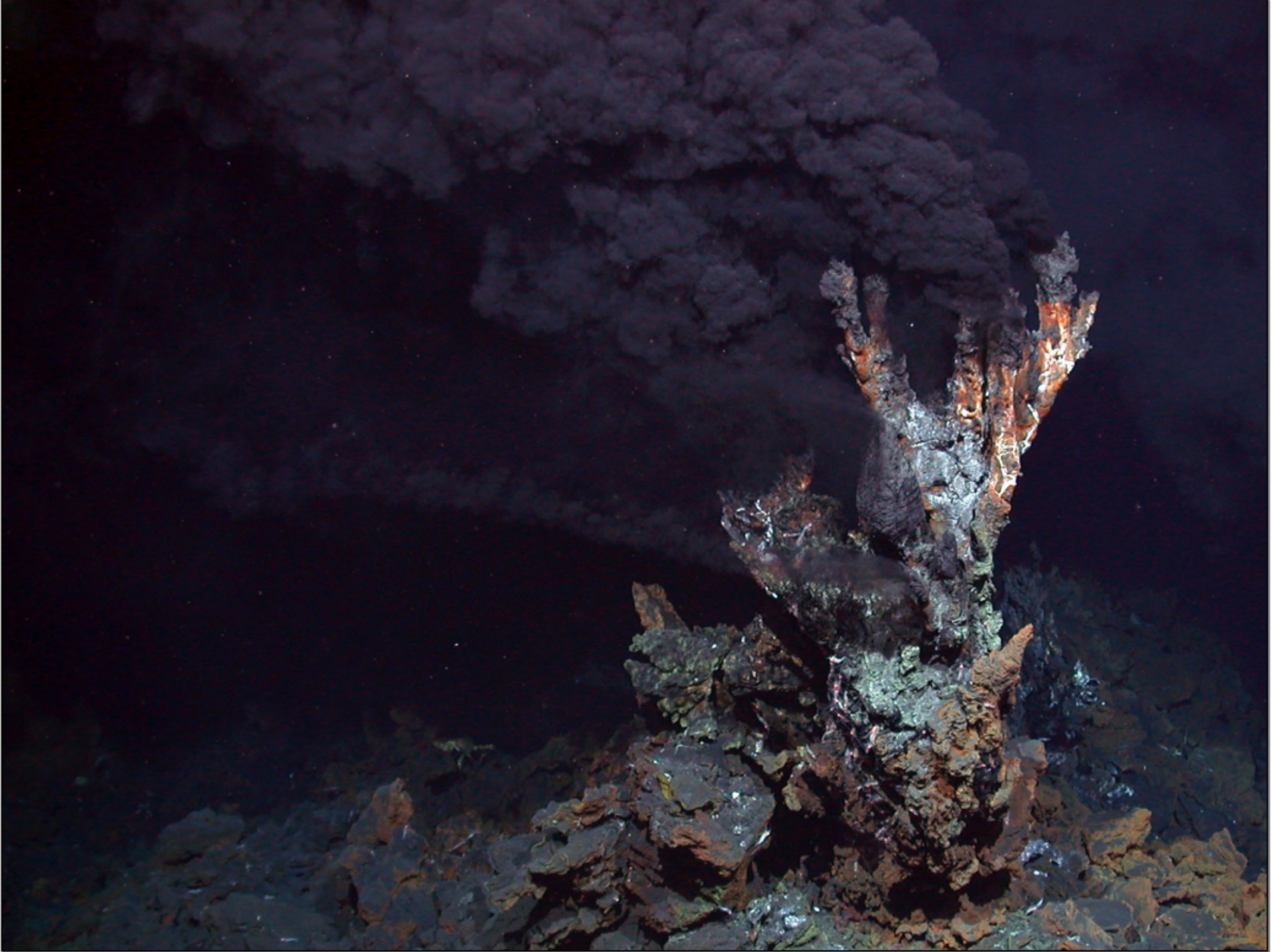
- 5 billion years – Sun formed along with heavy elements
- 4.54 billion years – Earth and other planets formed (primordial)
- 4.5 billion years – Earth collided with another object about size of Mars and the Moon was born
- Earth was a hot mixture of gases and solids; its surface was molten
- Atmosphere emerged from volcanic activity: consists of Methane (CH_4), Hydrogen Sulphide (H_2S), Carbon dioxide (CO_2), Ammonia (NH_3) and water vapour (there was no liquid water)

Lava Lake in Erta Ale, Ethiopia



4.5 Billion Years – 4.1 Billion Years

- Moon was much closer to Earth than today. Its large gravitational pull stabilizes wobble of Earth's axis and hence we have a stable climate (unlike Mars)
- Earth's surface gradually cooled and liquid water was formed through condensation of water vapour (along with many comets) around 4.3 billion years ago (formation of primordial oceans)
- Still too hot and too much Methane, Ammonia, Hydrogen Sulphide and Carbon dioxide
- It was pretty much impossible to form life on Earth's surface (no free Oxygen (O_2) and hence no Ozone (O_3))
- What about deep oceanic hydrothermal vents? Life formed there about 4.1 billion years ago?
- Did life originate from inorganic materials (RNA world hypothesis) as in Miller-Urey Experiment in 1952? Or was it metabolism first?



4.1 Billion Years – 3.8 Billion Years

- **Orbital Migration of Giant Planets** (orbital resonance of gaseous planets like **Jupiter** and **Saturn**)
- **Reshuffling of orbits** of the outer planets and **reformation of the asteroid belts**
- Huge amounts of **asteroids** hit **Earth, Moon** and all other inner **planets** known as **Late Heavy Bombardment (LHB)**
- Evidence found in **3.9 billion years old rock samples** from **Moon** brought by the Apollo Mission
- Finally **life** was able to form **on Earth** after **3.8 billion years**
- Evidence of **biogenic substance** in **graphites** from **Western Australia (4.1 Byrs)** and **Western Greenland (3.7 Byrs)**; **microbial mat fossils** in **Western Australia (3.48 Byrs)**

3.8 Billion Years – 2.4 Billion Years

- Huge number of Cyanobacteria (anaerobic prokaryotes) rapidly grew everywhere on Earth
- 3.5 billion years old fossils are found as Stromatolites
- Cyanobacteria evolved photosynthesis; they used energy for living and produced Oxygen as by-product
- This is known as the Great Oxygenation Event (GOE)
- At first Oxygen reacted with dissolved Iron to form layers of Iron Oxides (banded Iron formation)
- When it got saturated, the excess Oxygen became free to go into the atmosphere (around 2.5 billion years ago)
- But this Oxygen was toxic to the existing anaerobic organisms

Stromatolites, Shark Bay, Western Australia



Cross Section of Stromatolite



Banded Iron Formation



2.4 Billion Years – 750 Million Years

- 2.4 billion years - This atmospheric Oxygen quickly reacted with Methane (strong greenhouse gas) thus drastically reducing global temperature
- This resulted the longest cyclic period of ice age on Earth known as the Huronian Glaciation (from 2.4 Byrs to 2.1 Byrs)
- Volcanoes came to rescue Earth from permanent freezing
- 2.1 Byrs to 1.5 Byrs – Prokaryotes like Cyanobacteria still dominated Earth but Eukaryotes started to appear
- 1.85 billion years – Oldest known fossils of Eukaryotes (cell with a nucleus within)
- 1.5 billion years – Multicellular life forms started to appear
- They evolved and dominated Earth till 750 million years; still no signs of multicellular animals

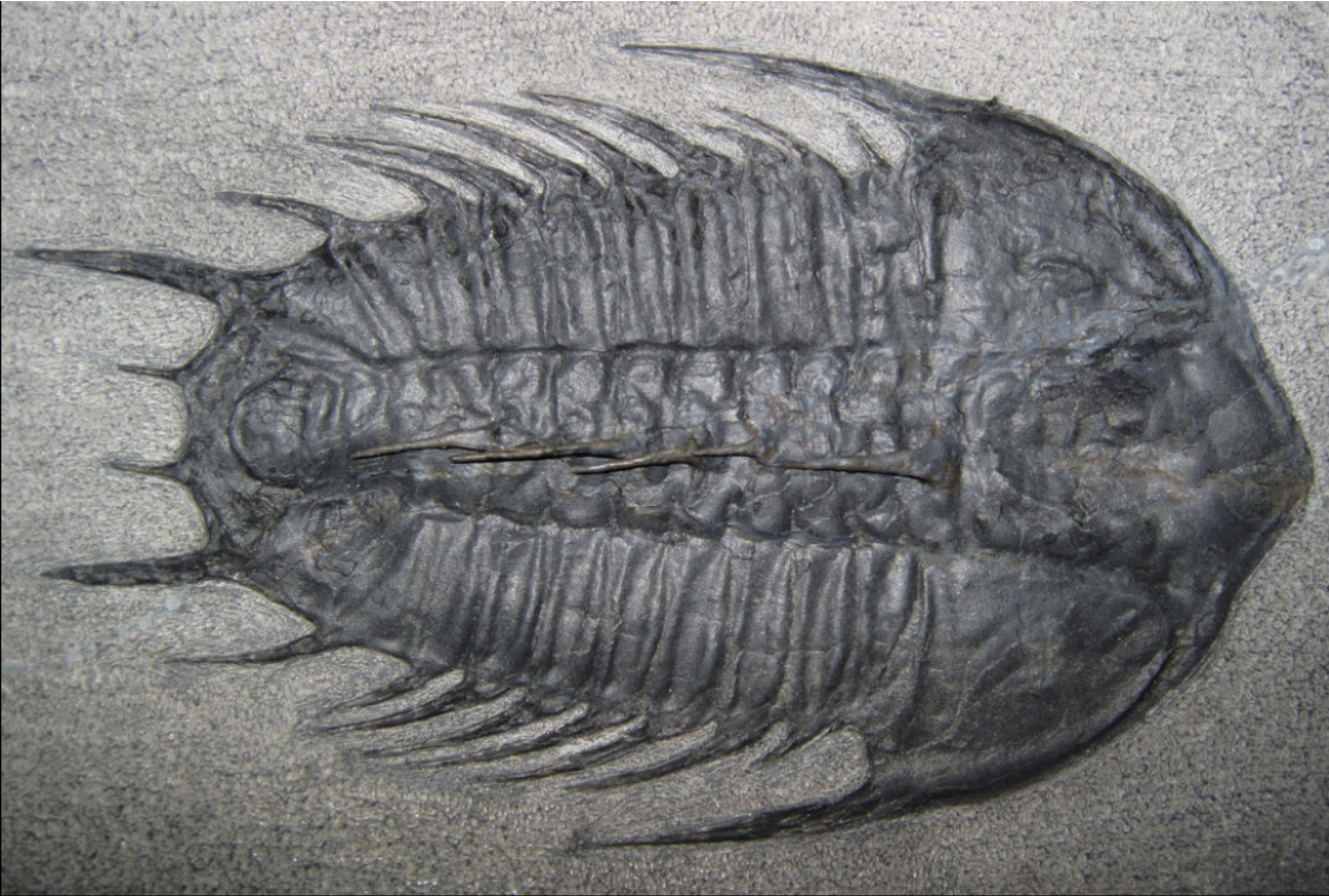
750 Million Years – 600 Million Years

- During this period, Earth was frozen known as Snowball Earth
- Ice advanced even to the tropical regions
- Evidences in glacial sediments all over the world
- High $^{13}\text{C}/^{12}\text{C}$ ratio also indicates sudden absence of life suggesting a global ice age
- Possible causes: Reduction of greenhouse gases, Supercontinent Rodinia, Tilt in Earth's axis, Paleomagnetism
- Volcanoes rescued again by emitting greenhouse gases
- Global ice cover mixed with geothermal heating provided oceans rich ingredients for diverse life
- Snowball Earth acted as a bottleneck for evolution of multicellular animals after 600 million years

600 Million Years – 252 Million Years

- 550 million years – Diverse multicellular complex life forms started to appear and evolution accelerated known as Cambrian Explosion; many fossils are found today
- Possible causes: Completed Ozone layer, Increase in Calcium level, Development of large Planktons (Mesozooplanktons)
- 525 million years – First vertebrates appeared
- 358.9 Myrs to 298.9 Myrs – Carboniferous period; 35% Oxygen Level, Swamp Forests, Mainly Tropical Climate, Mountain Formation (Pangea started to aggregate)
- Huge Animals, Land Vertebrates, Rainforest Collapse due to Climate Change, Formation of Coal Beds
- 298.9 Myrs to 252.2 Myrs – Permian period; Pangea formation completed, The Great Dying (Permian - Triassic mass extinction) about 252 million years ago

Trilobites of Cambrian Era



252 Million Years – 65 Million Years

- 252.2 million years – Largest mass extinction event; over 96% of all marine species and over 70% of all land species were lost
- Possible causes: Siberian Trap, Meteor Impacts, Runaway Greenhouse Effect, Anoxia due to Hydrogen Sulphide
- 252 Myrs to 201 Myrs – Triassic Era; Appearance of Dinosaurs
- 201 million years – Triassic–Jurassic mass extinction event due to massive volcanic eruptions
- 201 Myrs to 145 Myrs – Jurassic Era; Dinosaurs became dominant, first Birds appeared during late Jurassic
- 160 million years – First True Mammal
- 145 Myrs to 66 Myrs – Cretaceous Era; Dinosaurs continued to dominate land, new groups of Mammals and Birds, flowering plants also appeared during this time
- 130 million years - Gondwana began to rip apart

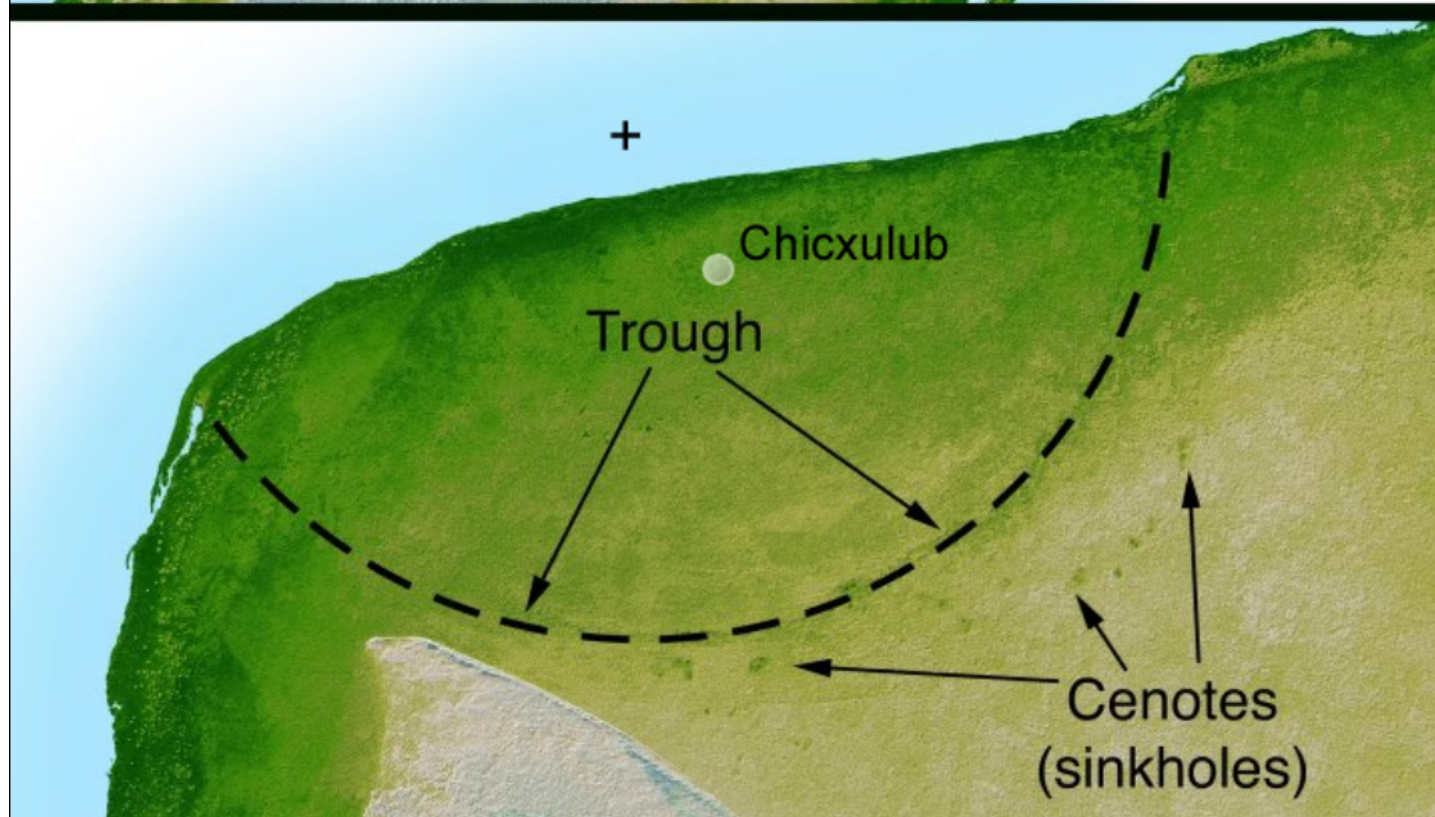
65 Million Years – Present Day

- 65 Million years - Chicxulub meteor (15 km) impact at Yucatan Valley in Mexico with a 200 km crater
- Created a global catastrophe and wiped out the Dinosaurs which kickstarted the reign of the Mammals
- First Primates appeared about 55-60 million years ago
- 45 million years – Indian Plate collided with Asian Plate creating the Himalayas
- Primordial Apes appeared about 15-20 million years ago
- First Gorillas and then Chimpanzees split off from the line of Apes leading to the Humans between 8-4 million years
- 100,000-200,000 years old Fossils of Human Ancestors in Africa; eventually they colonized the whole world
- Agriculture and civilization began only about 10,000 years ago

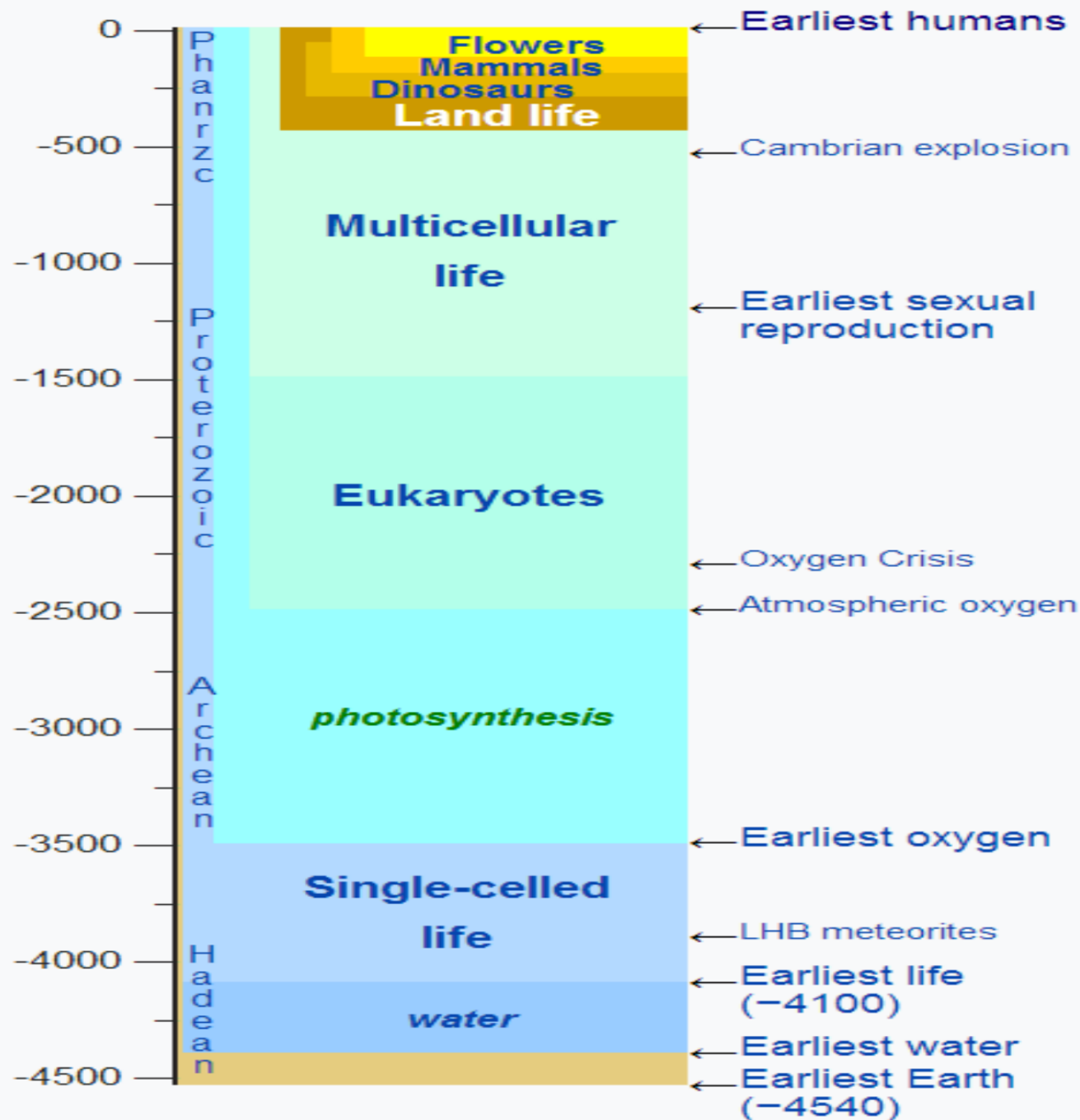
Cenote in Mexico







Life timeline



Axis scale: millions of years.

Also see: *Human timeline* and *Nature timeline*



Miles to go...