The Universe in a Nutshell

A Very brief and grossly over simplified summary of how it all started and what's out there

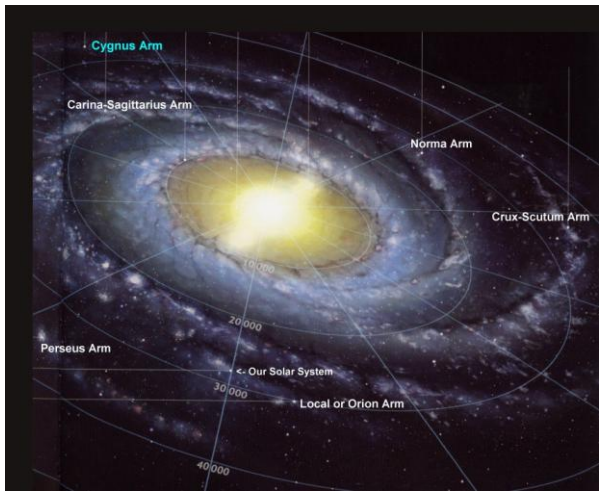
James Yoder

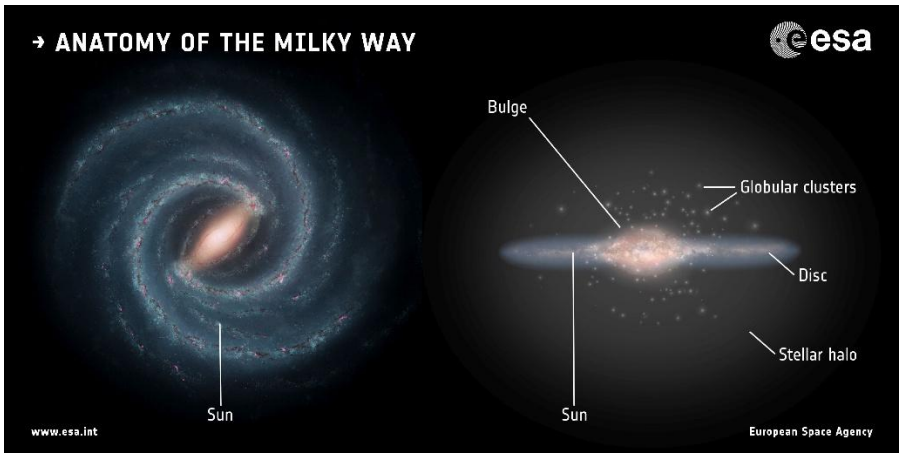
ArtCentrics.com

jty.Astro@ArtCentrics.com

Distances & Time

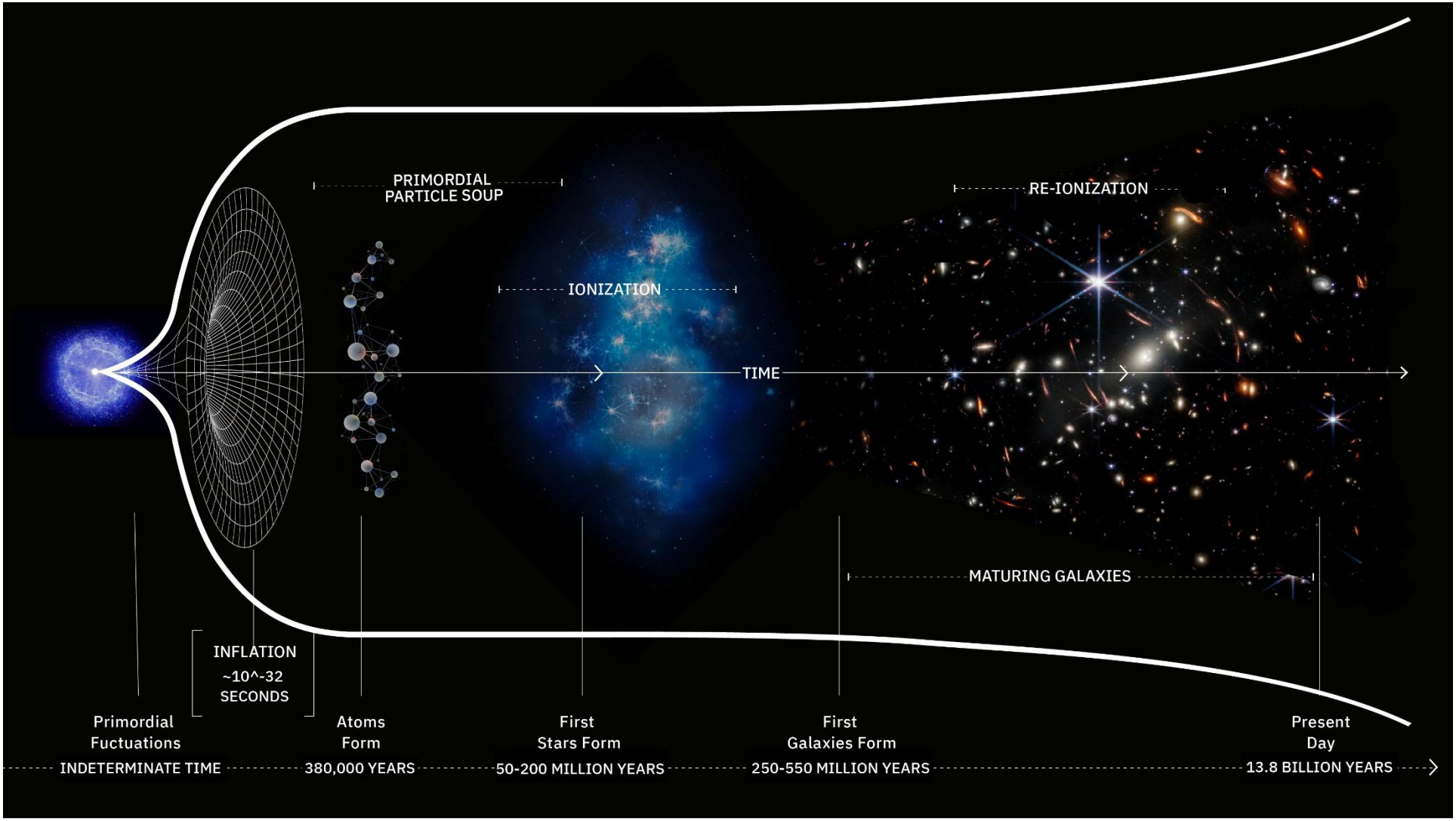
- Speed of light is 186,000 miles per second
- 1 Light Year = 5.88 trillion miles (5.88 x 10^{12}) miles = 5,880 million miles.



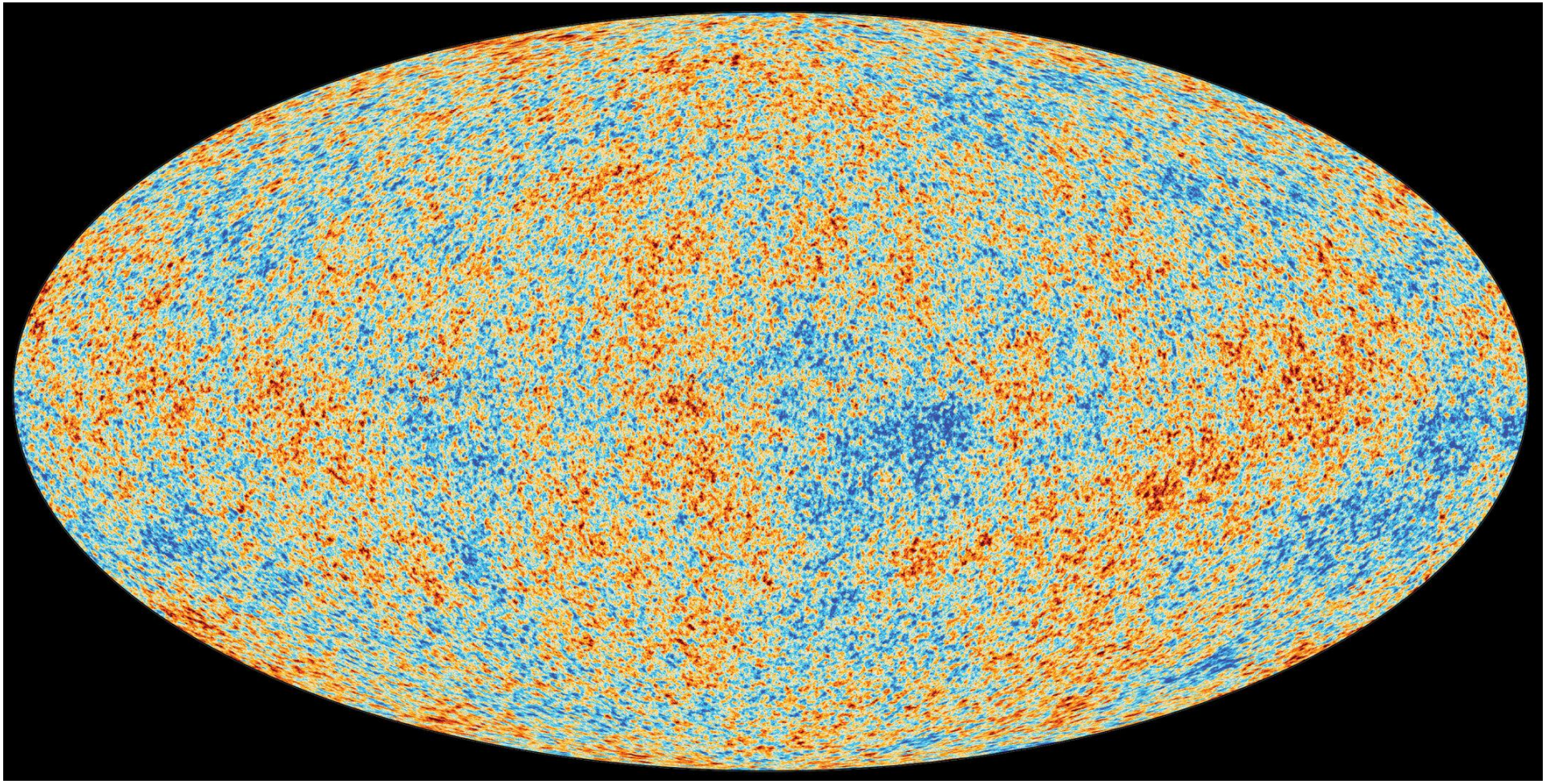


- Time it takes light to travel around the earth at the equator = 0.134 seconds (24,860 miles)
- Moon to earth distance 1.3 light seconds (250,000 miles)
- Earth to Sun 8.3 light minutes
- Sun to Jupiter 43 light minutes
- Sun to Pluto 5.5 light hours
- Sun to the edge of the solar system (9 billion miles) 15 light hours
- Earth to the Andromeda galaxy 2.5 million light years
- Distance to the closest sun (Proxima Centauri) = 4.2 Light Years
- Distance to Orion Nebula = 1,400 LY
- Dimensions of the Milky Way = 100,000 LY x 1,000 LY

The Time Line



Matter Distribution in the Early Universe

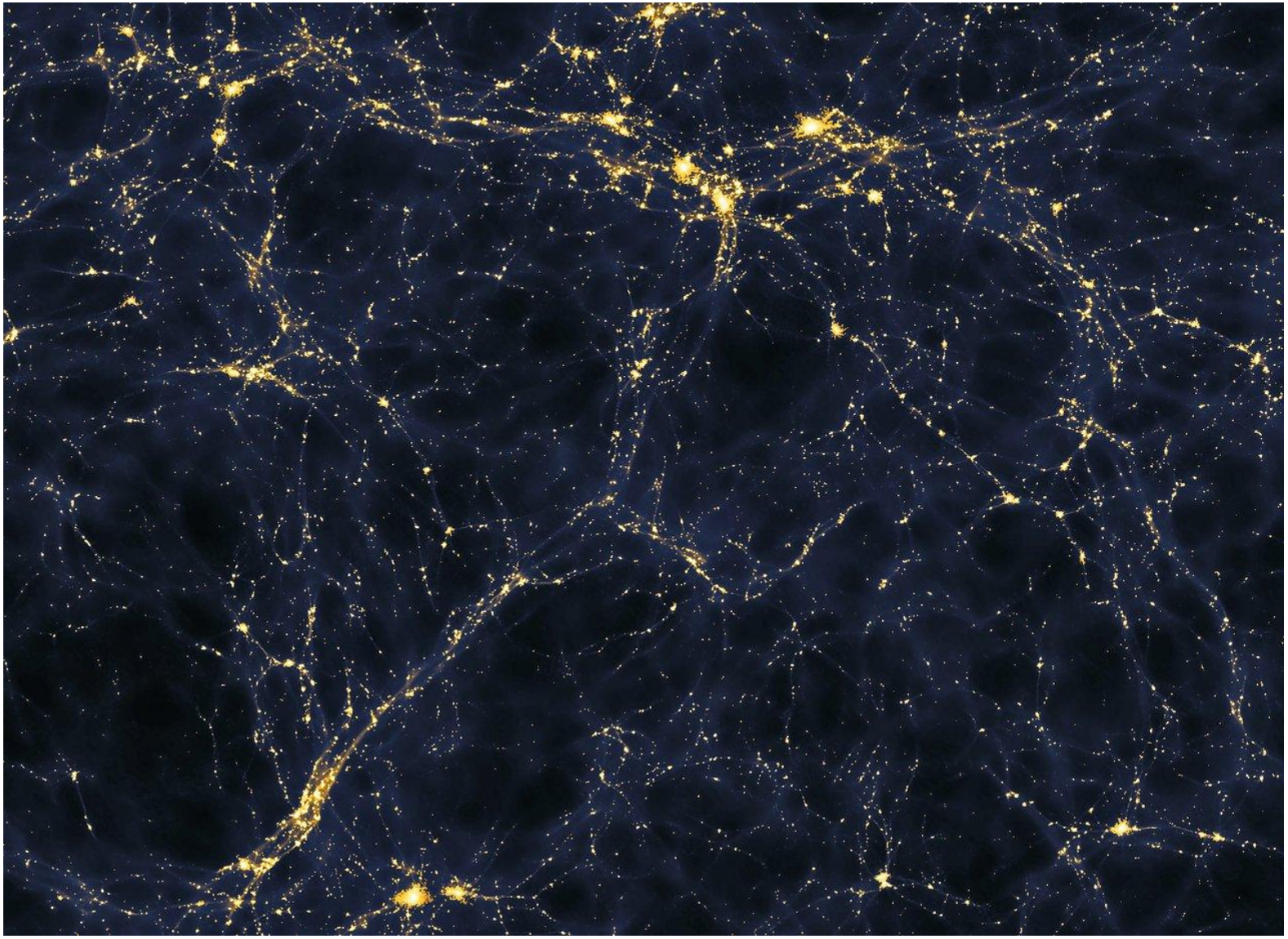


This image is the afterglow of the mass distribution 380,000 years after the big bang when atoms first formed and the universe became transparent. At this point there was Hydrogen, Helium and trace Lithium unevenly distributed giving rise to forming the super structures of our universe once gravity is allowed to work its magic.

Structures in the Universe

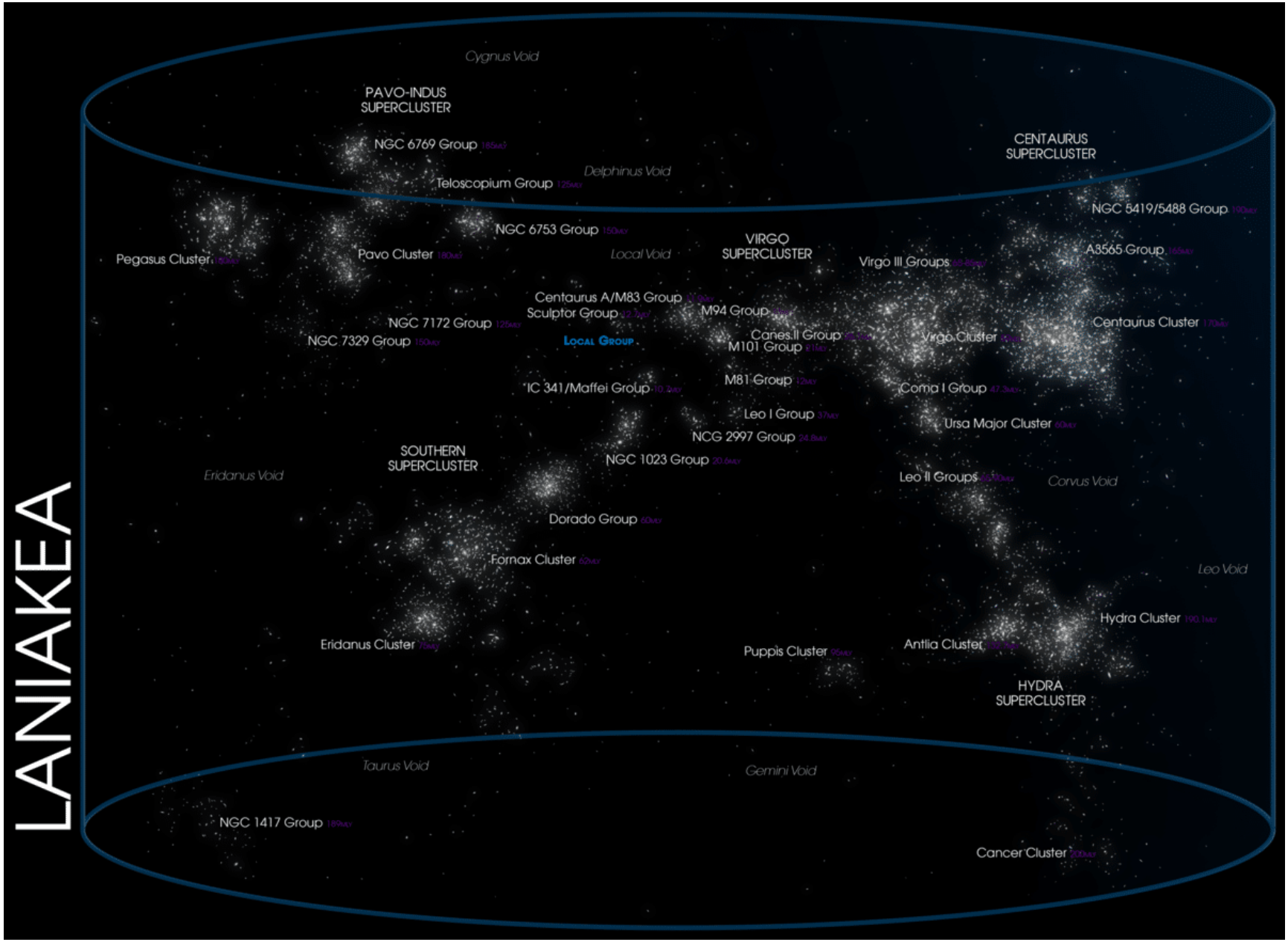
- The Universe
  - Universe 13.8 billion years old
  - Observable universe is 93 billion light years in diameter.
- The Cosmic Web
- Supercluster Cocoon
- Clusters of Galaxies
  - Laniakea Supercluster of galaxies 100,000 (1×10^5) galaxies, 500 million (5×10^8) light years across.
  - The Virgo Super Cluster
    - 1 of million superclusters in the observable universe
    - 47,000 galaxies
    - 100 million light years
  - The Local Group
    - 50 Galaxies (Milky Way, Andromeda, Triangulum)
    - Diameter is 5 million light years
- Our Galaxy
  - Milky Way Galaxy contains 100 to 400 billion stars (1×10^{11}) and is 100 thousand (1×10^8) light years across.

Gravity Forms the Cosmic Web



Computer simulation of a billion-light year cross section of the universe. Dark Matter and Superclusters of galaxies clump together with vast areas of nothing between them.

Laniakea Super Cluster (our supercluster)



Supercluster of Galaxies

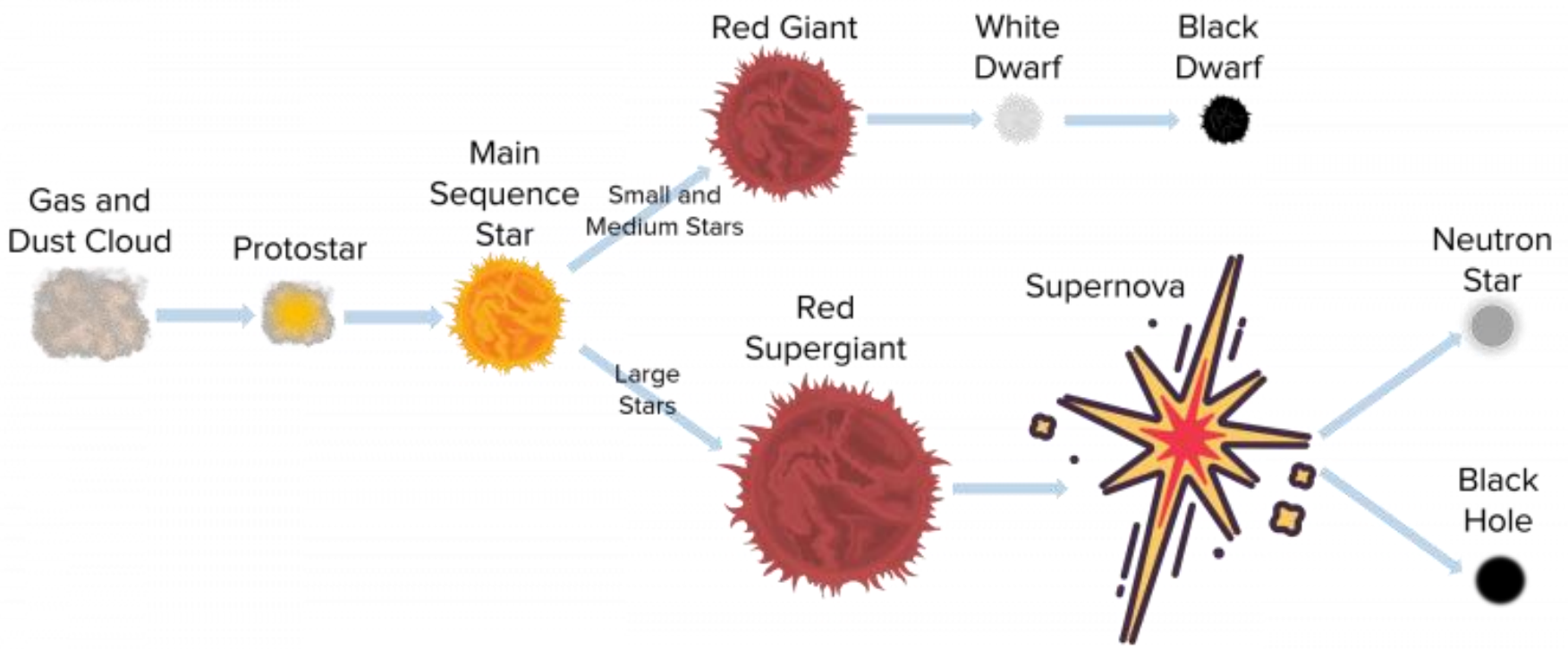
Supercluster “Hyperion” imaged above is an example of a zoom-in of one of the filaments in the cosmic web

Examples: Abell-1656

What is a Galaxy?

A galaxy is a system of stars, stellar remnants, interstellar gas, dust, and dark matter bound together by gravity. Our galaxy, the Milky Way is estimated to have 100 to 400 billion stars.

The Stellar Cycle



Star formation is an ongoing cycle of gas cloud collapse, giving rise to a star that burns through its fuel creating heaver elements, eventually the star dies and the matter created by the star is re-distributed into the universe in the death throes of the sun. What the ultimate fate of the sun's death is dependent on the size of the star.

Objects found in a Galaxy: Birth of a solar system

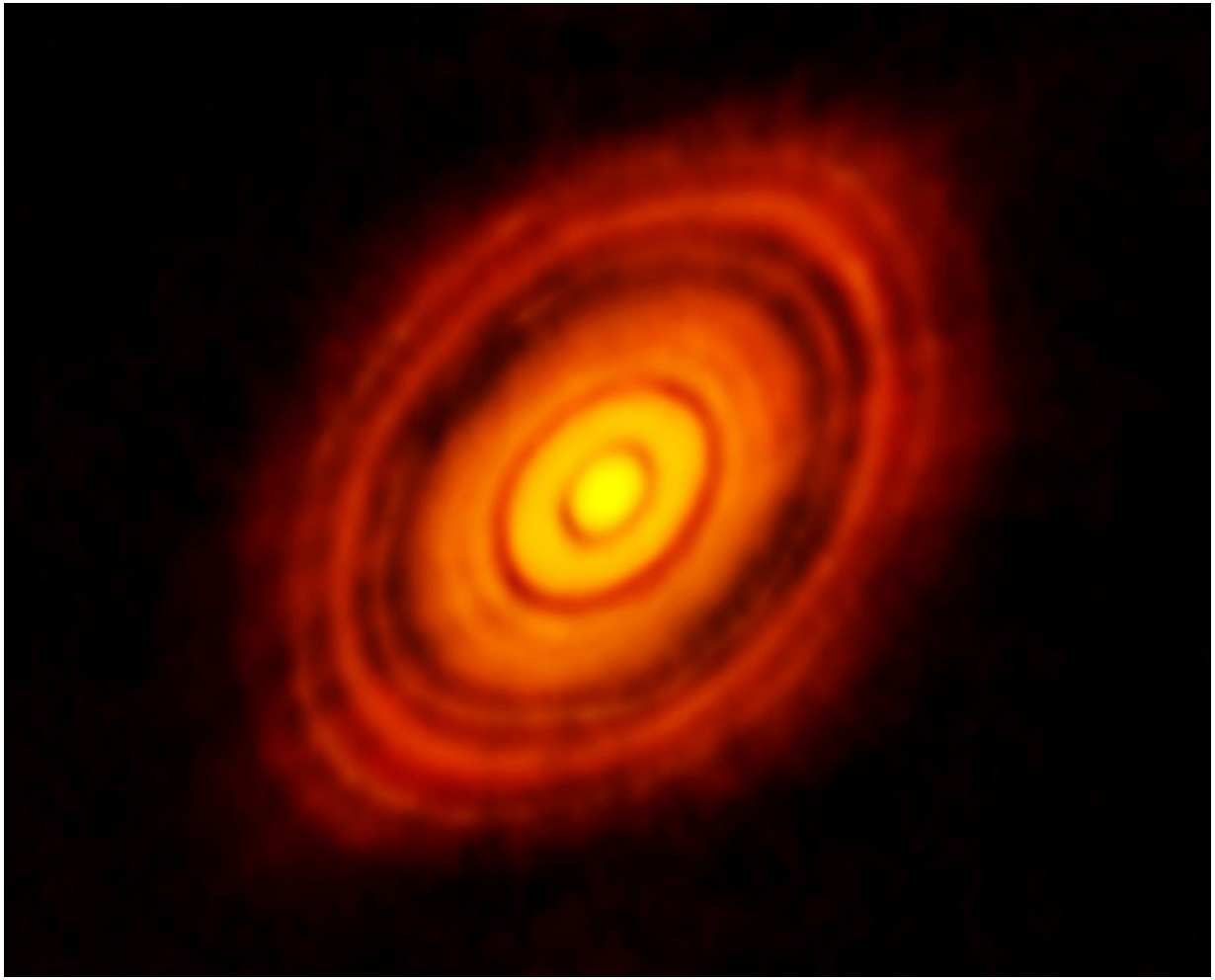


Image of HL Tau taken by Atacama Large Millimeter/submillimeter Array

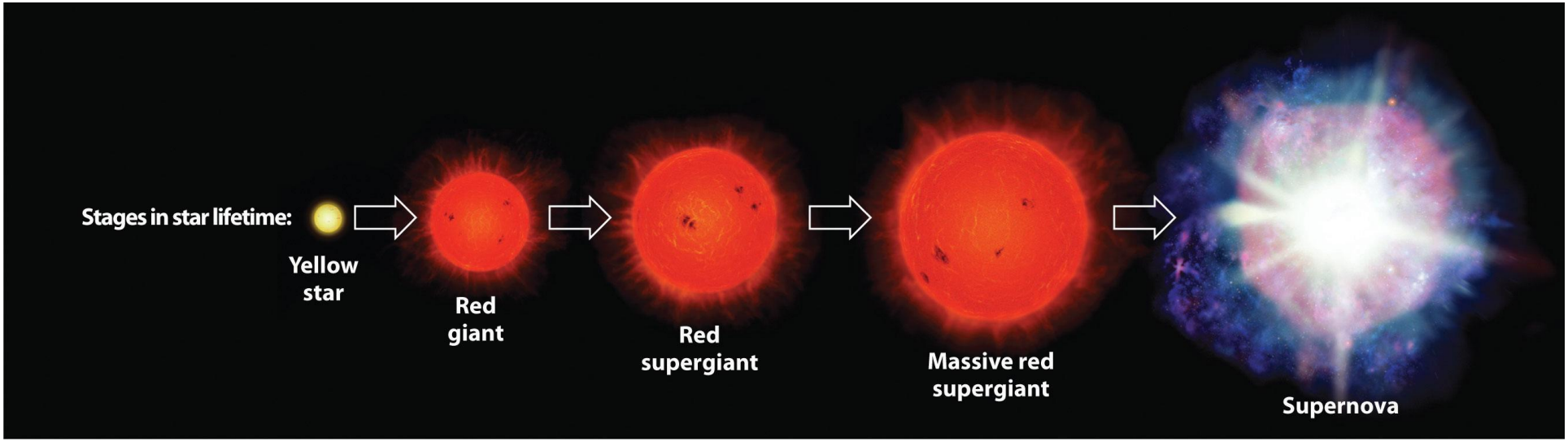
Many times, multiple stars and planets can precipitate out of a cloud system forming multiple star systems where the stars are gravitationally bound to each other (Along with their planets). There have been multiple star systems with up to 8 stars identified, but these are extremely rare.

Objects found in a Galaxy: Death of a Star

The demise of a star is based on the size of the star.

- **Planetary Nebula**: Stars with a mass between 0.8 – 8 solar mass form a Planetary Nebula where their outer shells float away leaving behind dense hot inert core called a white dwarf (Image on left).
- **Neutron Stars**: Stars with a mass between 8 – 20 solar masses will explode leaving behind dense neutrino core called a neutron star where one tablespoon of this star stuff weighs as much as Mount Everest (Image on the right).
- **Black Holes**: Super massive stars with a mass larger than 20 solar masses will blow up leaving behind a black hole

Size of the Star and Elements Created



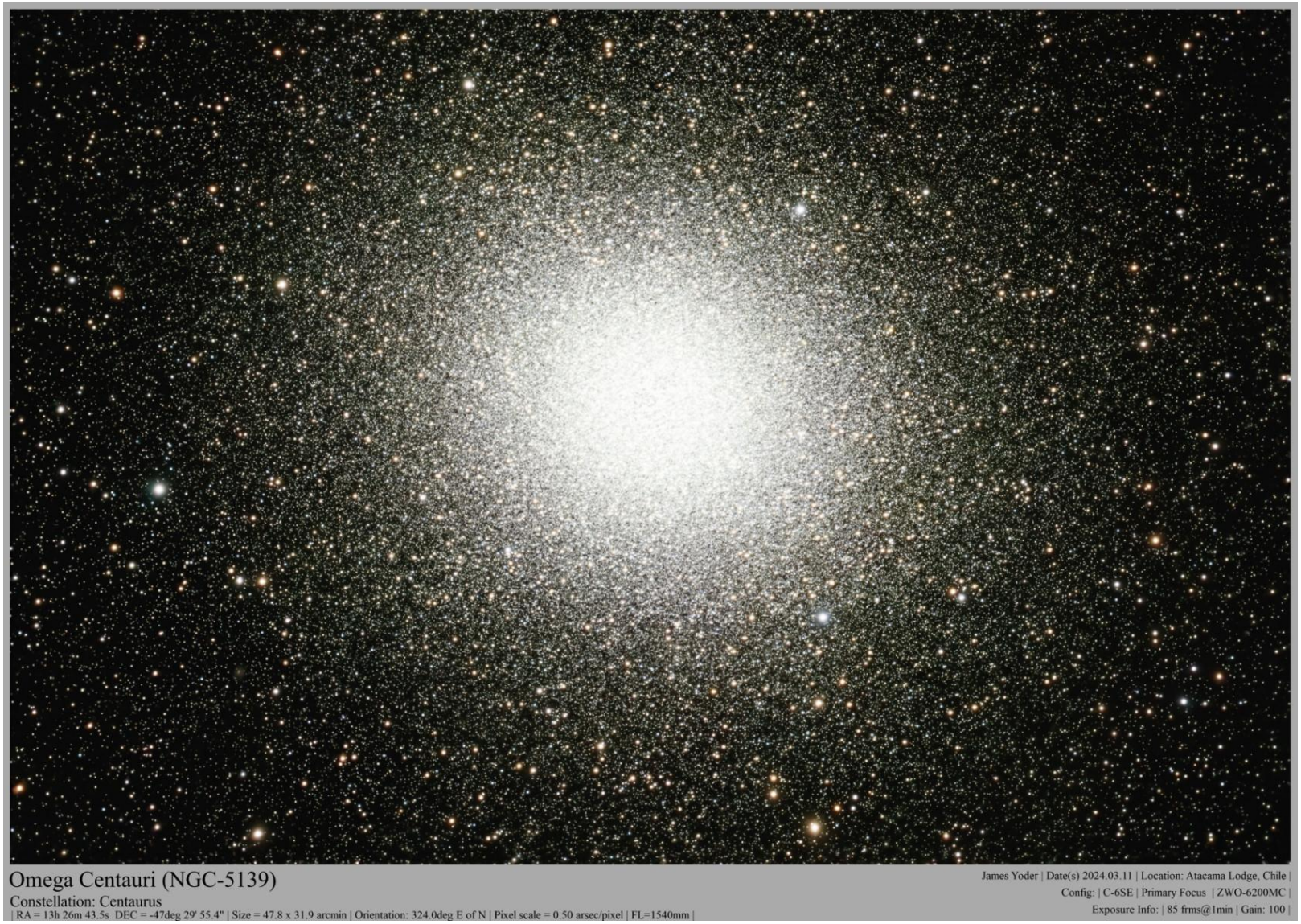
Core Temperature:	1.5×10^7 K	2×10^8 K	7×10^8 K	3×10^9 K	1×10^{11} K
Primary Nuclear Reaction:	^{1}H fusion	^{4}He fusion	$^4\text{He} + {}^{12}\text{C}$ $^{12}\text{C} + {}^{12}\text{C}$ $^{12}\text{C} + {}^{16}\text{O}$	Proton–neutron exchange reactions	Multiple neutron captures
Elements Formed:	He	C, O, Ne, Mg	Na, Si, S, Ar, Ca	Fe, Ni	Elements with $Z > 28$

What elements are formed from a given star is dependent on the size of the star. This is a re-occurring cycle, gas clouds collapse, stars form, they blow up and re-distribute the new elements in the interstellar medium. Gas clouds collapse out of the interstellar medium, form stars and the cycle continue enriching the heaver elements as time goes by. This is how heaver elements are made available to form the planets, comets, meteor, etc.

Objects found in a Galaxy: Dark Nebula

In some areas of space, you can see cold gas and dust clouds that stars may eventually precipitate out of because the block out the light of other stars behind them. These clouds have not collapsed enough to form stars yet.

Objects found in a Galaxy: Globular Clusters



Originally large gas clouds could collapse to form groups of stars known as Globular Clusters. These are balls of stars gravitationally bound to each other orbiting our galaxy. These are Very old structures typically about 10 billion years old, forming about the same time our galaxy formed. This is an image of the Omega Centauri Globular cluster, estimated to contain about 10 million stars

Objects found in a Galaxy: Open Clusters

Now days, large gas clouds collapse to form groups of stars known as Open Clusters. Eventually the remaining gas disperses and the stars disperse throughout the galaxy over a period of time of a few hundred million years to a few billion years. This is an image of the Rosette Nebula that contains about 2,500 “Young” stars, these stars energize the gas they are embedded in so the gas glows like a neon light, the gas cloud is then called an Emission Nebula.

Objects In the Sky

- **Planets**: Venus, Jupiter
- **Globular Clusters**: M-13, M-3, M-92
- Open Clusters: M-44, M-11, M-39, M-29, NGC-6939
- Planetary Nebula: M-57, NGC-3242, M-27, M-97
- Galaxies: M-81, M-82, M-104, M-51
- Multiple Star Systems: Double-Double, Albireo, Polaris
- Carbon Stars: V Hya, Garnet Star

Ring Nebula (M-57)

Hercules Cluster (M-13)