STAR CLUSTERS

There are two main categories of star cluster, and they are distinctly different in origin, form, composition, and longevity:

- Open star clusters
- Globular star clusters.

Globular Cluster - Omega Centauri – NGC 5139

Open Cluster - The Wishing Well – NGC 3532

Definition - Open Star Clusters

Open star clusters are gravitationally loosely bound groups of stars that typically contain a few dozen to a few hundred stars. They are relatively young, often less than a few hundred million years old, and are found in the disc of galaxies, particularly in the spiral arms. Open clusters are irregularly shaped and tend to disperse over time due to gravitational interactions with neighbouring stars.

Definition - Globular Clusters

Globular clusters are tightly packed, spherical collections of thousands to millions of small and very old stars held together by mutual gravitational attraction. They are much older than open clusters, typically 10-13 billion years old, and were found in the halo of stars scattered above and below a galaxy's disc. Globular clusters have a symmetrical (spherical) shape and remain gravitationally bound throughout their existence, which is typically many billions of years.

Open Star Cluster – Formation Process

Open star clusters form from the collapse of giant hydrogen gas clouds within the disc of galaxies. The initial very low-density gas cloud may have a diameter of 15-60 light years. The open star cluster formation process is believed to typically involve:

- Triggering: Shock waves from nearby supernovae, gas cloud collisions, or gravitational interactions can disrupt the equilibrium of the giant cloud. This disruption causes regions of increased gas density, which also increases the gravitational field of that region. The increased gravity then draws in more surrounding gas, further increasing the density and gravitational field. The process continues and accelerates under gravity.
- Collapse and Fragmentation: Due to regions of increasing gravitational field, the collapsing gas cloud fragments into smaller clumps.
- Star Formation: Up to several thousand stars can form within these collapsing regions, initially enshrouded by infrared emitting dust and gas.
- Gas Dispersal: Ultraviolet radiation from the birth of hot, massive stars ionizes the surrounding gas. Stellar winds and radiation pressure drive away the remnant hot ionized gas.

- Cluster Emergence: After a few million years, the first large stars to form may detonate as supernovae, further expelling remnant gas from the young star cluster. Within about 10 million years most of the gas is stripped away revealing the newly formed open cluster of stars. There may be hundreds, or even thousands, of stars in the young cluster.
- Ongoing Evolution: The cluster remains loosely bound by gravity, with stars potentially dispersing over time due to gravitational interactions. The density of star mass within the cluster is not sufficient to generate a gravitational field that retains all the stars withing the cluster. Over time, star drift from the cluster and its shape changes and becomes a less distinct cluster of associated stars.
- New cluster formation: If a galaxy has sufficient hydrogen gas within its disc, countless new open star clusters may be formed during the billions of years the galaxy exists. However, galaxies tend to have less gas available for this process as they age and gas is consumed and expelled. As a result, the rate of new open cluster formation slows with time.

Globular Star Cluster – Formation Process

Globular clusters are much older, having formed in the early universe. Their formation process is less well understood, but likely involved:

- Early Universe Conditions: Globular clusters formed about 8 to 13 billion years ago, when the universe was younger and had different conditions. The critical factor during that ancient era was the much greater availability of hydrogen gas in enormous molecular clouds permeating and surrounding the young galaxies.
- Massive Gas Clouds: Globular clusters likely originated from massive clouds of primordial hydrogen gas in early galaxies or protogalaxies. The initial low-density gas cloud that forms a globular cluster may have had a diameter of 150 to 450 light years.
- Rapid Star Formation: A burst of star formation occurred within these massive gas clouds, creating thousands to millions of stars in a relatively short period. The gas cloud collapse and fragmentation into individual stars was driven by gravity. As a pocket collapsed, its gravitational field increased and thereby drew in more gas. A self-reinforcing process.
- Gravitational Binding: The high density of stars and strong mutual gravitational attraction allowed the stars in these clusters to remain tightly bound. The millions of stars in a typical globular cluster are all bound to a common centre of gravity and slowly orbit around that point. They lack the energy and orbital speed to reach escape velocity. As a result, the tightly bound ball of stars remains in the globular formation, essentially for eternity. They retain the appearance of a globule of tiny stars.
- Lack of Ongoing Star Formation: Unlike open clusters, globular clusters formed their stars in a single burst at the beginning of their existence. The remaining gas was expelled, preventing further star formation.
- Survival and Evolution: Due to their strong gravitational binding, globular clusters have survived for billions of years, orbiting within the galactic halo. The key differences in formation between open and globular clusters lie in their age, location, and the conditions of the early universe versus the present-day galaxy. Open clusters may continue to form in the galactic disk, while globular clusters are relics from the galaxy's early history. Current theory suggests globular clusters are no longer being created.
- Stability: Open clusters disperse over time; globular clusters remain stable globules of many stars.
- Abundance: There are only about 150 known globular clusters in our galaxy. By contrast, the number of open clusters is essentially countless.

Star Density Within Clusters

Stars are much more abundant and densely distributed with globular clusters than open clusters.

Within open clusters: Stars are typically separated by distances ranging from a few light-years to several light-years. For example, in the Trapezium Cluster within the Orion Nebula, stars are about 1.5 light-years apart. Typical open clusters contain hundreds to a few thousand stars spread over a region that can span about 65 light-years across.

Within globular clusters: Within the central core region, the average distance between stars can be as small as 0.03 to 0.16 light-years. Farther out from the core, in less dense regions, the separation distance increases but remains much smaller than in open clusters. Globular clusters are much more densely packed, with thousands to millions of stars

within a radius of about 100 light-years or less. The stellar density in the core can be up to 10,000 times higher than in the neighbourhood of the Sun.

Key Differences Between Open Clusters and Globular Clusters

Density and Distance:

- Open Clusters: Stars are more widely spaced, typically a few light-years apart.
- Globular Clusters: Stars are much closer together, especially in the core, where distances can be as small as 0.03 light-years.

Visual Observation:

- Open Clusters: Individual stars are easily resolved through telescopes due to their wider spacing.
- Globular Clusters: Stars appear as a dense, bright ball of light, with individual stars being harder to distinguish, especially in the core.

Gravitational Binding:

- Open Clusters: Loosely bound by gravity and tend to disperse over time.
- Globular Clusters: Tightly bound and remain gravitationally coherent throughout their lives.

Some Star Cluster Examples

Open Clusters

The Wishing Well Cluster – NGC 3532: https://en.wikipedia.org/wiki/NGC_3532

The Jewel Box Cluster – NGC 4755 https://en.wikipedia.org/wiki/Jewel_Box_(star_cluster)

The Pleiades – Messier 45: https://en.wikipedia.org/wiki/Pleiades

The False Comet Cluster – NGC 6231: https://en.wikipedia.org/wiki/NGC_6231

Globular Clusters

Omega Centauri – NGC 5139: https://en.wikipedia.org/wiki/Omega_Centauri

47 Tucanae – NGC 104: https://en.wikipedia.org/wiki/47_Tucanae

Messier 3: https://en.wikipedia.org/wiki/Messier_3

Messier 13: https://en.wikipedia.org/wiki/Messier_13

Messier 15: https://en.wikipedia.org/wiki/Messier_15