

Use all available information to determine answers relating to **quasars, AGNs, galaxy clusters, and groups of galaxies**, including star formation, massive and **supermassive** black holes, galactic structure, globular clusters, Type Ia and Type II supernovae, eclipsing binaries and X-ray binaries.

1 Galaxies

1.1 History

derived from the Greek *galaxias*, meaning milky.

1.2 Galaxy Morphological Classification

astronomers divide galaxies into groups based on their visual appearance. the most often used is the **Hubble sequence**, invented by Edwin Hubble in 1926.

1.2.1 Elliptical Galaxies

General Characteristics	<ul style="list-style-type: none"> • smooth, featureless image comprised of ovoid masses of stars attached by the gravitational attraction b/w them • no rotational axis — stars show wide range of orbital paths around center, primarily radial motion; slight uniformity is what determines overall shape of the galaxy
Stars	<ul style="list-style-type: none"> • ellipticals contain mostly old stars <ul style="list-style-type: none"> – more red in color – very little gas and dust hampers formation of new stars
Shapes and Sizes	<ul style="list-style-type: none"> • highest variability of all galaxy types: <ul style="list-style-type: none"> – wide range of masses — 10^5 to 10^{13} solar masses – wide range of sizes — observations showing that objects can have diameters of between 1 and 100 kiloparsecs (or 3260 to 326,000 light years) – wide range of brightnesses — some can be up to 10 times brighter than the brightest spirals. At the other end of the scale, the faintest ellipticals can be 1000 times less luminous than the faintest spirals • The Hubble classification of elliptical galaxies contains an integer, n that describes how elongated the galaxy image is. The classification is determined by the ratio of the major (a) to the minor (b) axes of the galaxy's isophotes: $10 \times (1 - \frac{b}{a})$ • thus, a given elliptical galaxy can be classified as E_n, where an E_0 galaxy is spherical, and an E_7 galaxy is flat. this classification is dependent on the angle from which the galaxy is viewed and thus does not affect its physical properties, but is useful for describing how a galaxy appears through a telescope.

Evolution	<ul style="list-style-type: none"> • astronomers believe that elliptical galaxies form earlier than spiral galaxies, but they can still have quantities of gas and dust, and can still be very noisy in the radio spectrum. evidence has shown that a reasonable proportion (25%) of early-type (E, ES and S0) galaxies have residual gas reservoirs and low level star-formation. • evolve from the fusion of smaller, gravitationally bound galaxies which are of similar size • more commonly found around clusters and groups of galaxies due to forming from fusion. They are less frequently spotted in the early universe, which supports the idea that they evolved from the collisions that came later in the life of a galaxy. • A supermassive black hole is thought to lie at the center of these ancient galaxies. These gluttonous giants consume gas and dust, and may play a role in the slower growth of elliptical galaxies.
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