ASTR 3830

Astrophysics 2 -
Galactic and Extragalactic

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Spitzer Space telescope image of M81

Part two of a year-long introduction to astrophysics:

Aim - apply basic physical principles to understand astronomical observations of:

- Galaxies
- Clusters of galaxies
- Structure and evolution of the Universe (**cosmology**)

Overview of the course

1. Stellar phenomena visible at extragalactic distances

Many classes of luminous (massive) stars and stellar remnants are individually detectable in the Local Group and other nearby galaxies:

- X-ray binaries
- Planetary nebula etc…

Most dramatic stellar explosions visible at cosmological distances (i.e. occurred when Universe was significantly younger than today):

- Supernovae
- Gamma-ray bursts (detectable throughout the Universe)

…interesting in their own right and as tools for looking at the distant Universe.

Overview of the course

2. **Normal** galaxies - galaxies whose luminosity is dominated by the total luminosity of the galaxy's stars

Morphological classification into spirals, ellipticals, irregulars by Hubble in *The Realm of the Nebulae (1936)*

Spiral galaxy M51

Contains a disk of stars supported against gravity by ordered rotation

Contains gas… new star formation, spiral arms

May also have a bulge, a halo, a dark matter halo, central black hole

Late type galaxies are common in the field and in small groups

Elliptical galaxy M87

Random motion of the stars dominates over ordered rotation

Smooth, round, featureless at first glance appearance

Generally lacking in cool gas

Early type galaxies are the most common type of galaxy in rich clusters of galaxies

e.g. M87 is in the core of the Virgo cluster

Irregular galaxies

NGC 6822 in Sagittarius

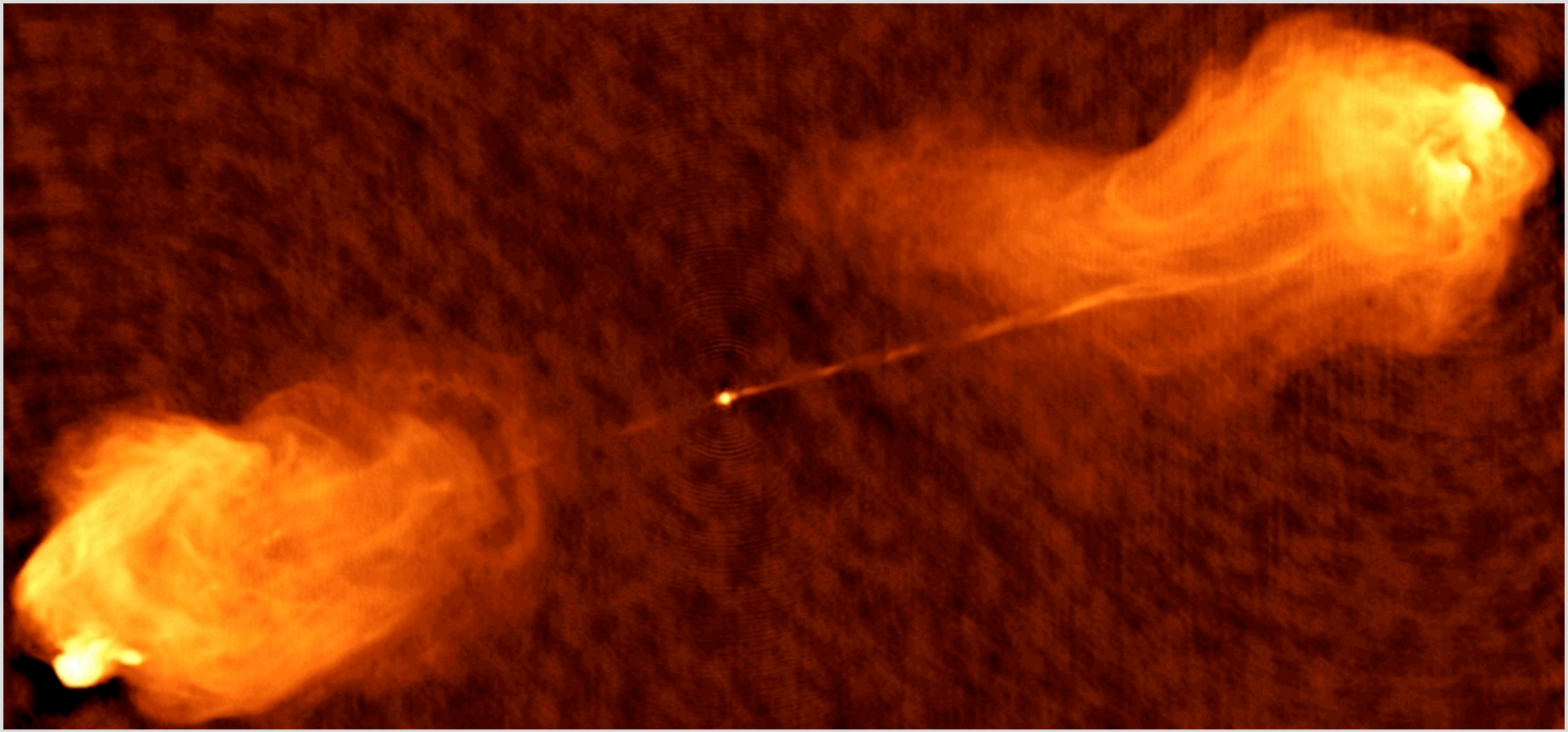
Small blue galaxies which lack any spiral arms or other organized structures

Overview of the course

3. Supermassive black holes and **Active Galaxies** - galaxies with bright nuclei powered by gas accreting onto a central black hole

- Evidence for supermassive black holes in the nuclei of most galaxies, e.g.
  - Milky Way black hole mass few x 10^6 M_{sun}
  - Other galaxies up to 10^9 M_{sun}
- Most nuclei are quiescent - little gas is now flowing into the center
- Small fraction (larger in the past) are actively accreting - **Active Galactic Nuclei (AGN)**. Several types, eg quasars, radio galaxies, Seyferts, blazars…

Phenomena associated with Active Galactic Nuclei

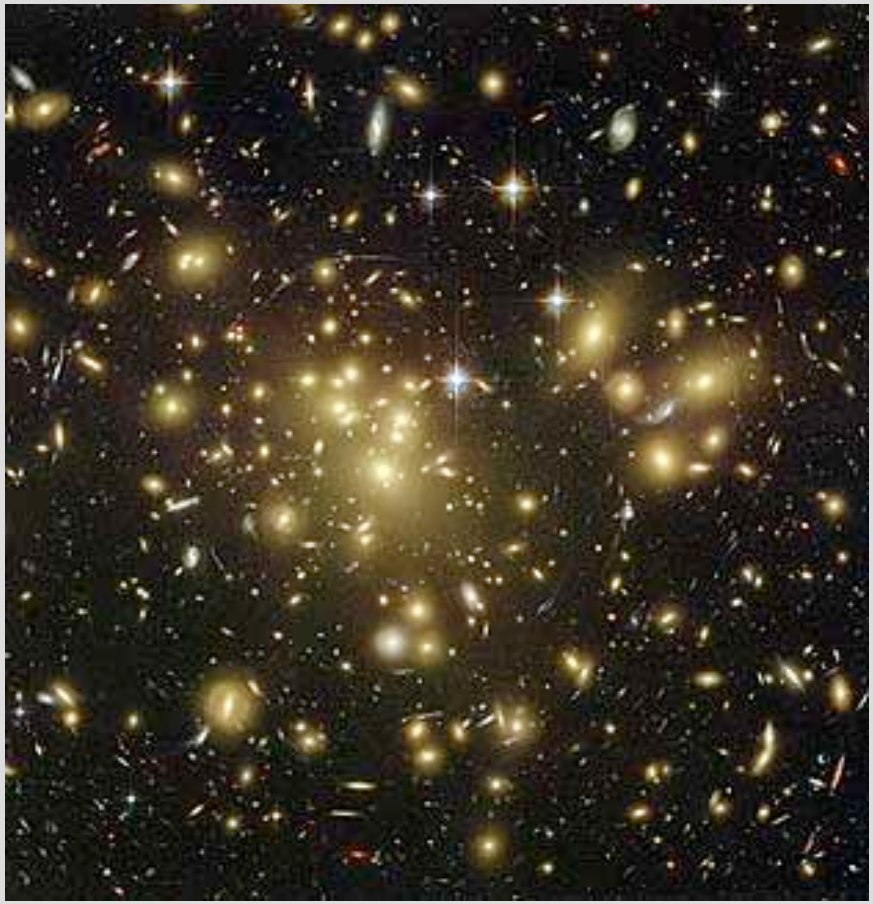


- Relativistic (ie velocity v ~ c) jets
- Strong radio emission
- Here seen in Cygnus A

Overview of the course

4. **Clusters of galaxies**

   Largest gravitationally bound structures in the Universe. Richest examples contain 1000s of galaxies. Nearby examples Virgo and Coma.



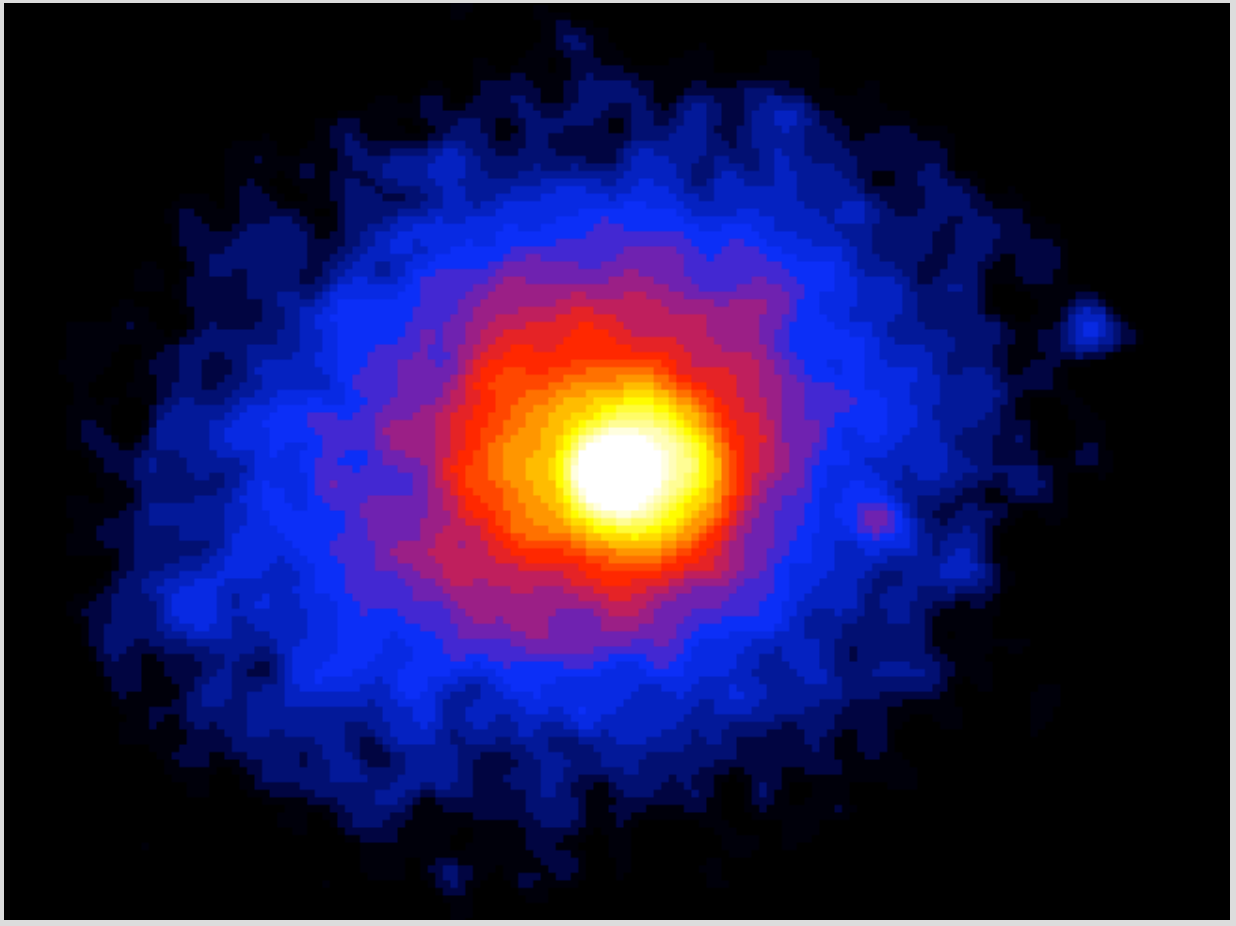
Cluster Abell 1689 observed with Advanced Camera for Surveys on HST

Typical velocities $v \sim 10^3$ km/s

Deep gravitational potential well allows gravitational lensing of background sources

Clusters also contain:

- Hot gas (visible in X-ray observations)
- Dark matter (inferred from gravitational lensing and X-ray studies)



Centaurus cluster seen in the X-ray

Overview of the course

5. **Cosmology** and the origin of **structure** (galaxies, clusters…)

Most `well-understood' observations are consistent with a standard model of cosmology based upon three ideas:

- The Universe expanded from a hot, dense beginning
- Small fluctuations in an almost uniform distribution of matter were amplified by **gravity** to form structure
- Evolution of the Universe now is dominated by **Cold Dark Matter** and **Dark Energy**, neither of which is well understood

Try to justify each of these claims: though not as much detail (especially to do with relativity) as in ASTR 3740…