Radio Galaxies

- Galaxy Type : elliptical or giant elliptical

- Radio luminosity / Optical luminosity : 0.001 to 1
A radio galaxy emits more in the radio than normal galaxies.

- Radio source shape : Double - lobed or compact central source.

- Radio waves come from the lobes. Some galaxies have jets aligned with the lobes. Lobes and jets can be enormous. They can extend as much as 5 Mpc from the central galaxy.

- Jets consist of blobs of gas that appear to have been ejected from the galaxy.

- Lobes contain high energy electron - might have been caused by an explosion in the galaxy

- Nature of spectrum :
    - synchrotron radiation produced by high energy e- spiralling in an intense magnetic field. The intensity of radiation is higher at long wavelengths. The radiation is polarized.
    - radiation is due to inverse Compton scattering where energy is transferred from electrons to photons.

- Suggested model for the energy source within these galaxies :
There is an accretion disk around a supermassive black hole (10^6 to 10^8 $M_\odot$). Superheated gas compressed by the imense gravitational field of the black hole escapes along the rotation axes and is channeled into opposing jets.

Seyfert Galaxies

- "Missing link" between ordinary and radio galaxies.

- Usually spiral galaxies with bright blue nucleus. The nucleus is brighter than the rest of the galaxy (i.e. spiral arms).

- Some are radio emitters (synchrotron radiation).

- Radiation from the nucleus in the visible spectrum has broad emission lines.

- Broad emission lines from ionized gas indicates turbulence with velocities of several thousands of km/s.

- Radiation output varies on time period as short as days.

Quasars

- Quasars ≡ quasi-stellar radio source; QSO ≡ quasi-stellar objects

- 3C273 is a typical quasar. It is a bluish star like object with radio emission. It has emission line spectra. The balmer series is shifted to very long wave lengths [z ~ 0.16] corresponding to a velocity of recession of 44,000 km/s.

- Several thousand quasars have been discovered. Highest redshift of z ~ 4.

- If the redshift is doppler then it indicates that quasars have a high recession velocity. From Hubble's law they must be very far away. Hence must be extremely luminous.

- Alternative explanation for redshifts
    1) Gravitational redshift - unlikely - the object would become a black hole or have very broad smeared out spectral lines.
    2) Doppler shift but local objects shot out by our Galaxy. [But why are there no quasars with blue shifts?]

- Properties of quasars
    - Large redshift
    - Compact blue objects with x-ray emission. About 10% are radio sources with radio or optical jets. Emission due to synchrotron radiation.
    - Optical luminosities 100 to 1000 times normal galaxies.
    - Emission lines of highly ionized gas. Some have absorption lines at smaller redshift than emission lines.
        - ejected clouds from the quasar
        - intervening clouds in the line of sight
    - Many are variable in time scales of days or weeks implying a very small region from which the light is emitted.