Relativistic Jets From Supermassive Black Holes

(Radio Galaxies : One kind of exotic objects in the sky)

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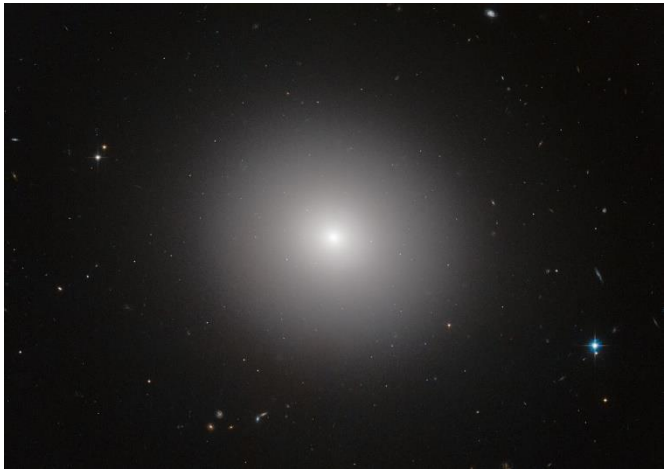
May 13, 2018

Galaxies

M102

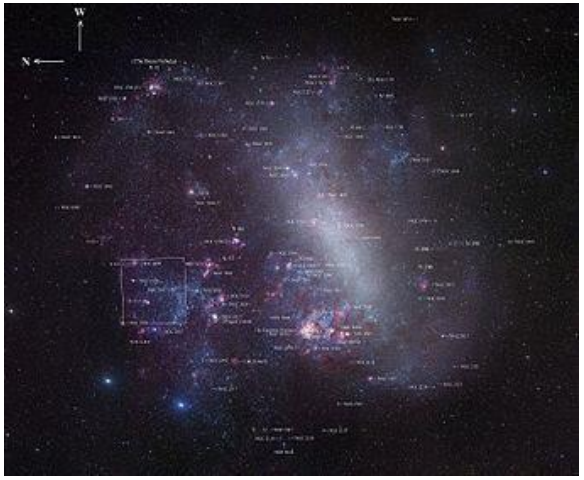
(The image was obtained by Chris & Dawn Schur from Payson, Arizona at 5150 feet elevation with an amateur telescope)

IC2006



From google image

Large Magellamic Cloud



Wikipedia

Galaxies and their morphological classification

There are three morphological types of galaxies:

a) spiral galaxies, b) elliptical galaxies and c) irregular galaxies

We live in a galaxy called the Milkyway Galaxy. This is a spiral galaxy.

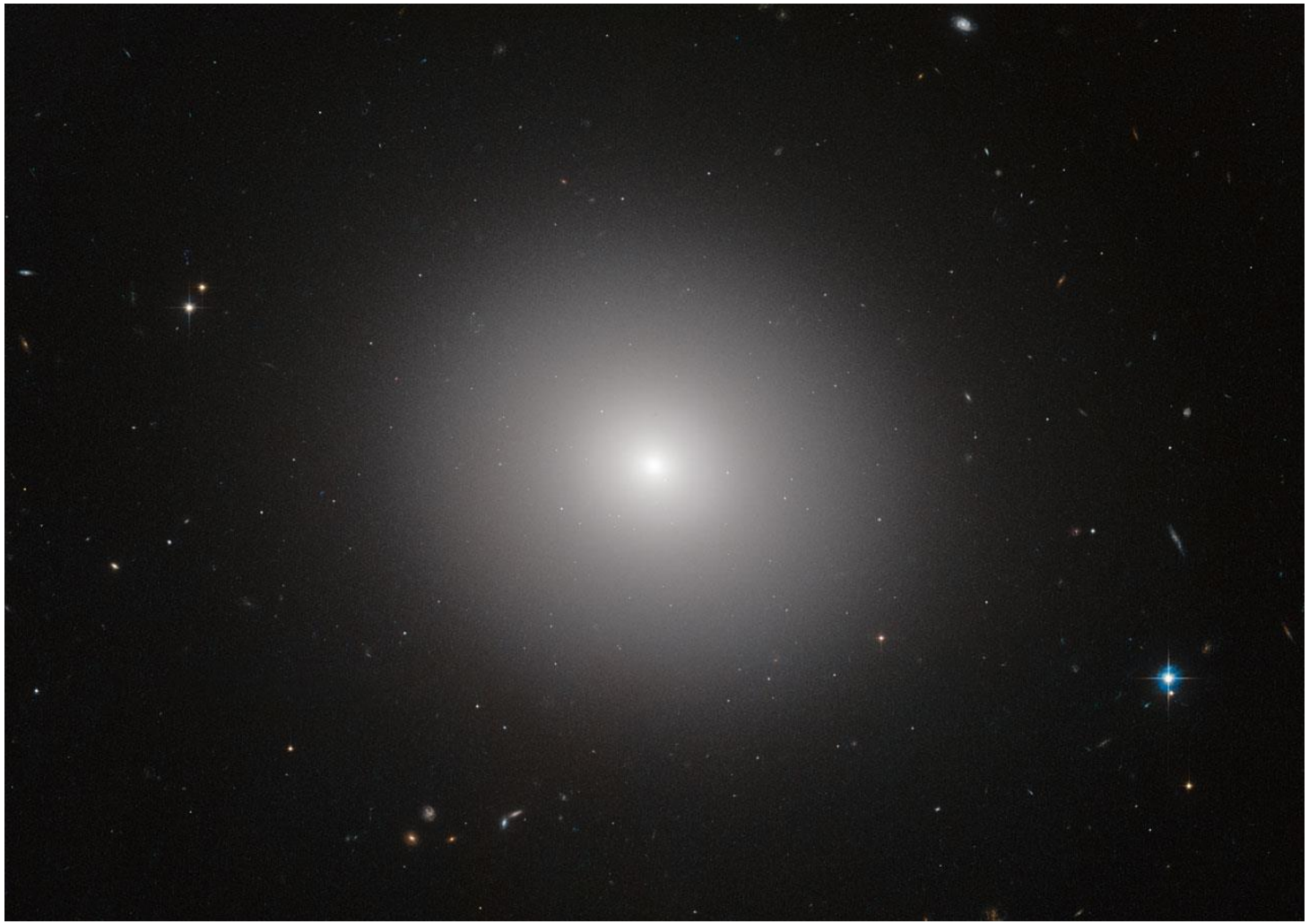
All massive galaxies have a SuperMassive Black Hole (SMBH).

Our galaxy Milkyway has a SMBH of mass ~ 4 x 10^6 M_sun

Spiral galaxy M102

(The image was obtained by Chris & Dawn Schur from Payson, Arizona at 5150 feet elevation with an amateur telescope)

Elliptical IC 2006



Source: Google

Consequences of the presence of SMBH at then centre

A black hole attracts gaseous matter.

So accretion is an inevitable process in presence of a black hole.

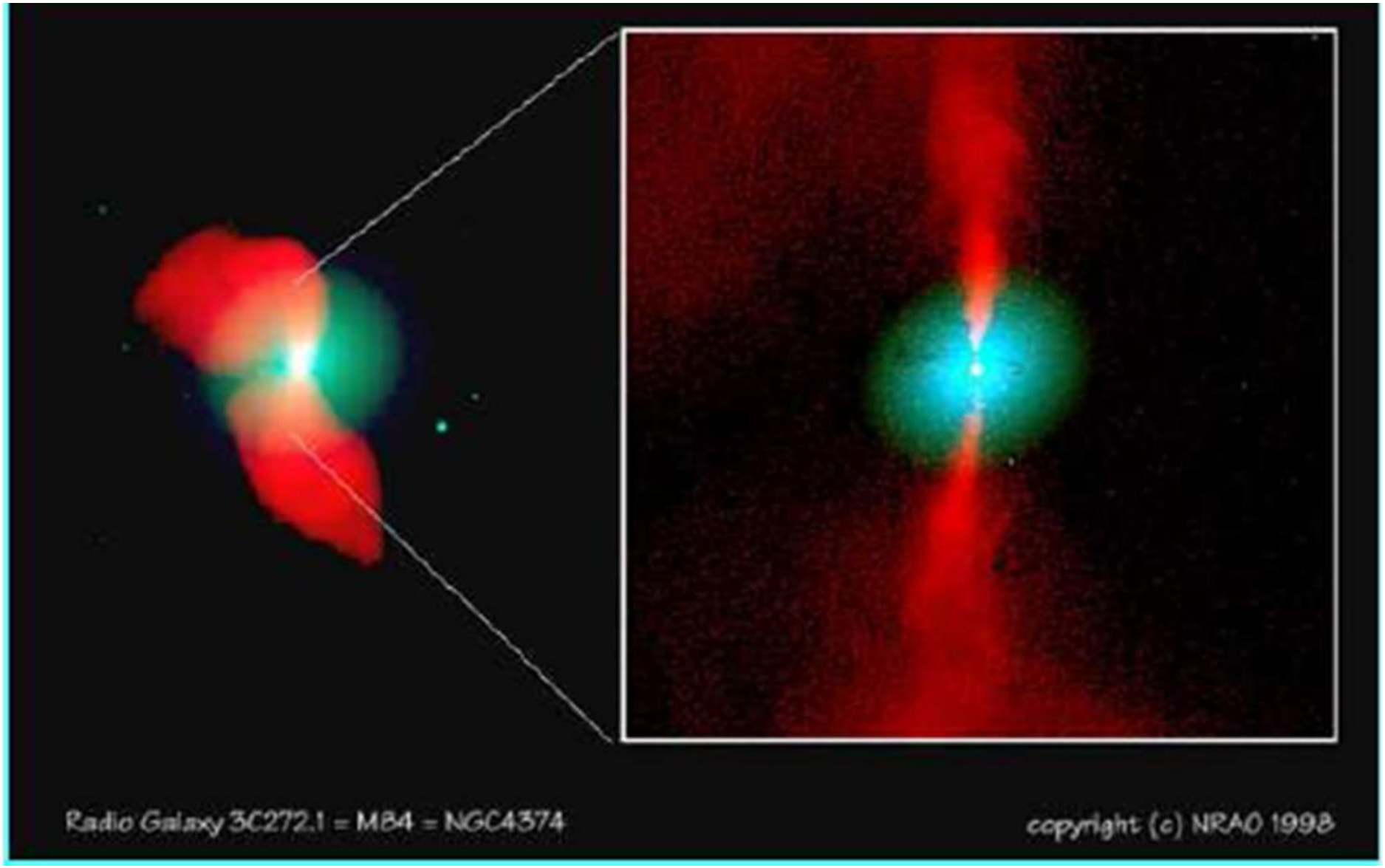
The matter spiral around and form a disk ---accretion disk.

Since there is differential rotation, heat is generate and the accretion disk radiates.

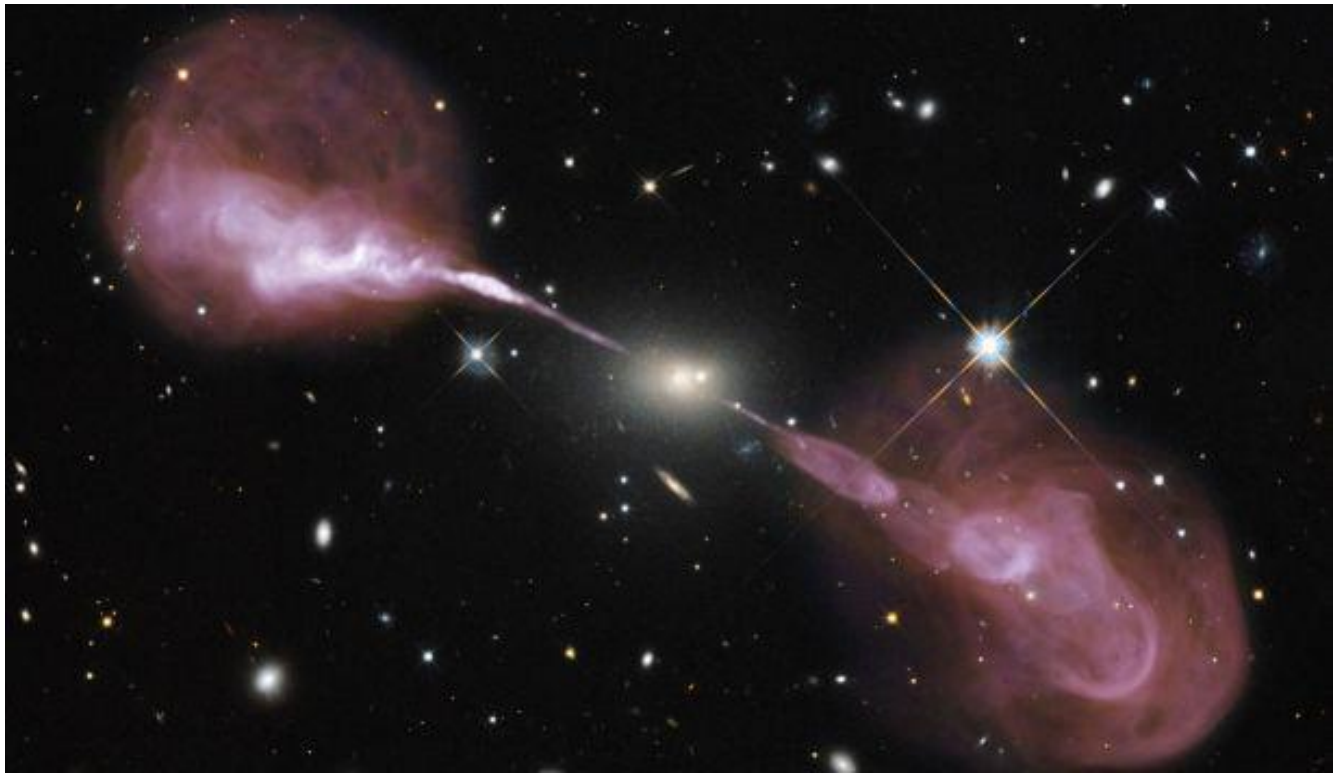
When accretion is in efficient mode, these galaxies are called active galaxies

Some of the active galaxies launch jets and form what are called radio galaxies.

Most of the radio galaxies are hosted by elliptical galaxies

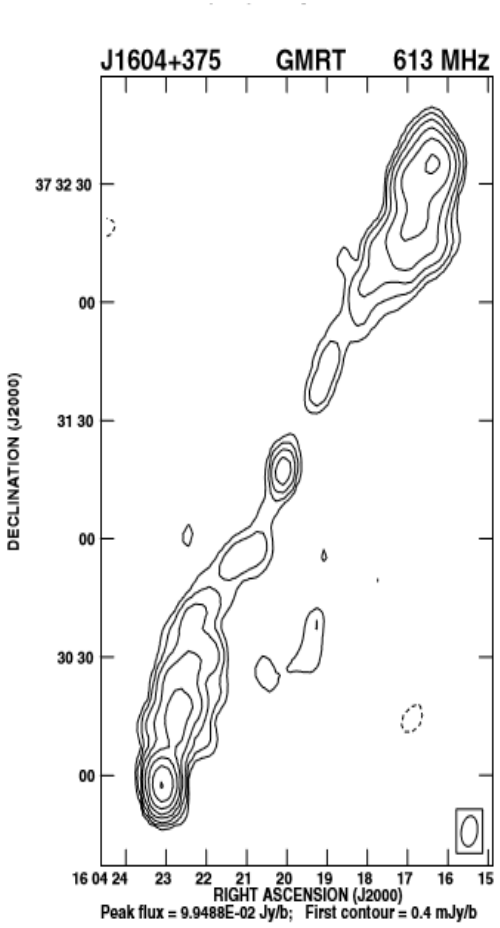


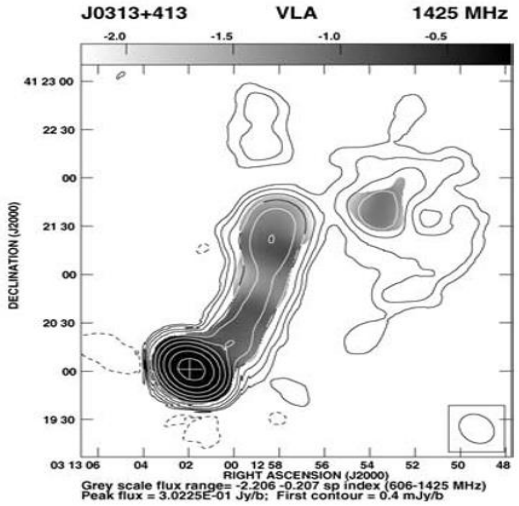
Hercules A

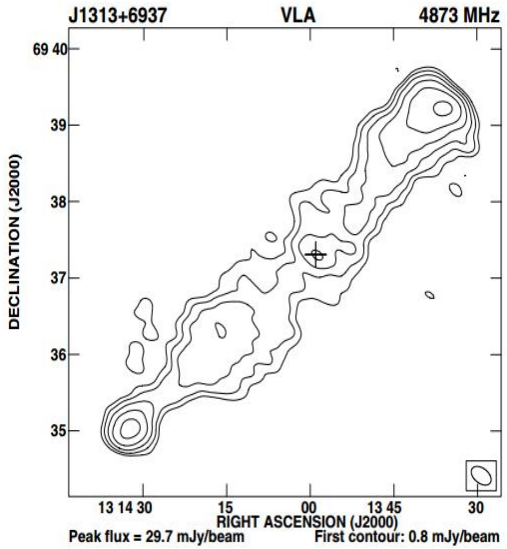


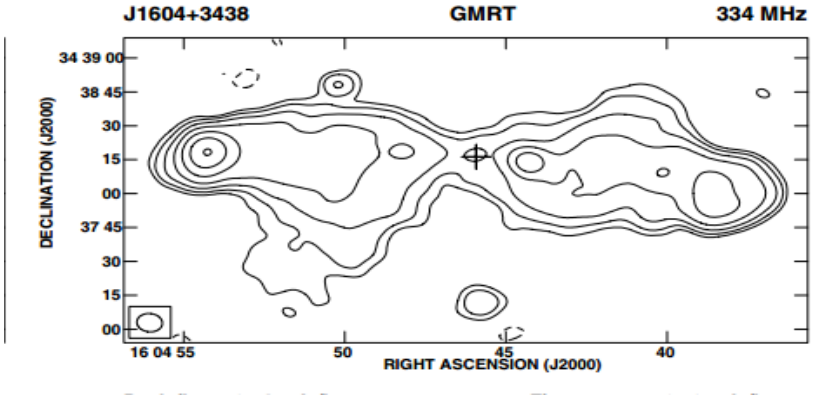
(Credit: NASA, ESA, S. Baum and C. O'Dea [RIT], R. Perley and W. Cotton [NRAO/AUI/NSF], and the Hubble Heritage Team [STScI/AURA])
(https://public.nrao.edu/mediause)

GMRT images of various giant radio galaxies





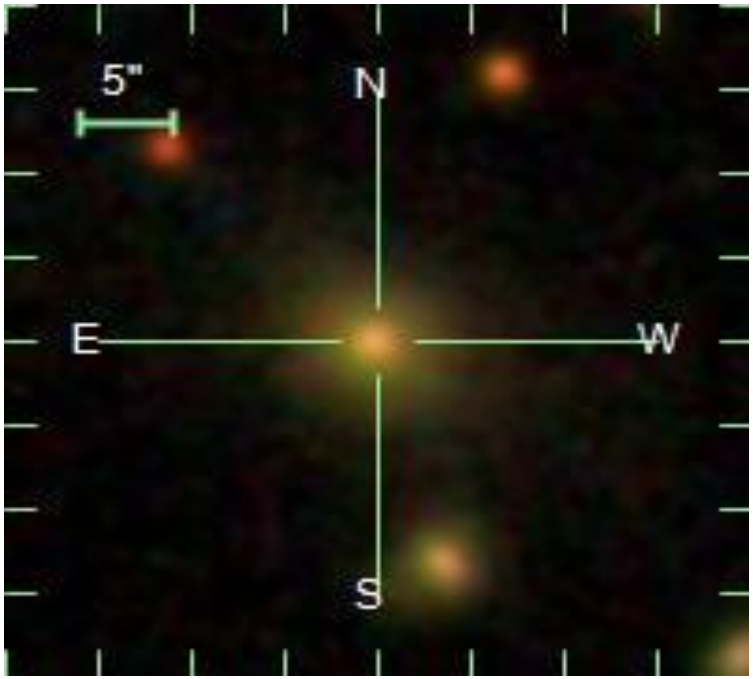




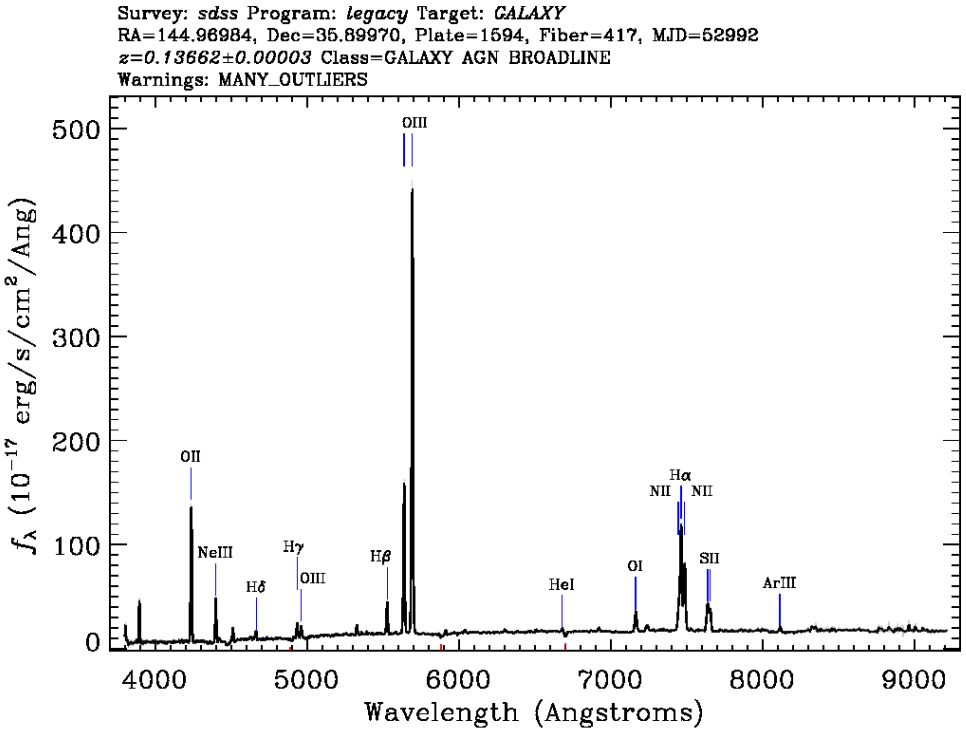
Large size is not due to large nuclear power, but due to large age of the sources

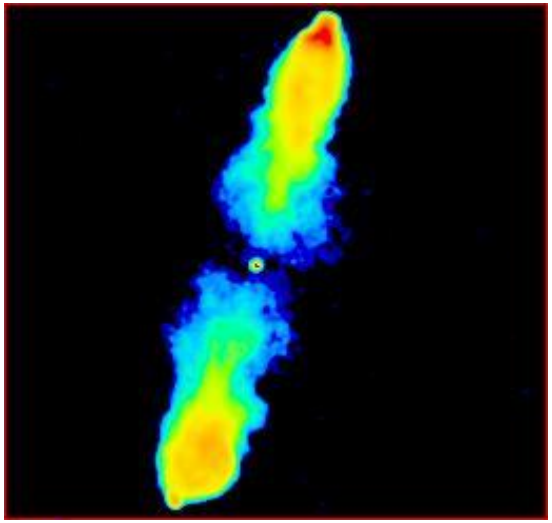
Konar et al., 2004, 2008

SDSS image of 3C 223



SDSS spectra of 3C223





J. P. Leahy

3CR 457: GMRT 605 MHz contour overlaid with X-ray image in grey scale

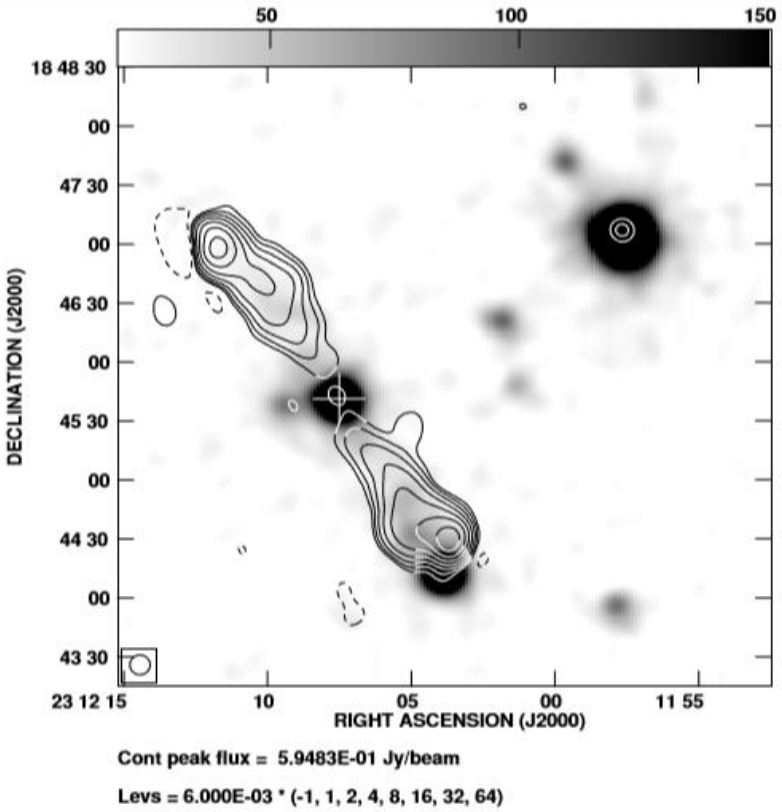


Figure 3. A 10 arcsec Gaussian smoothed image of 3CR457 and its field in the energy range 0.3 to 10 keV has been displayed in grey scale. Overlaid on top of this is the GMRT 605 MHz map with a resolution 10″ in contours. A few more AGNs are visible in the field.

Konar et al. 2009

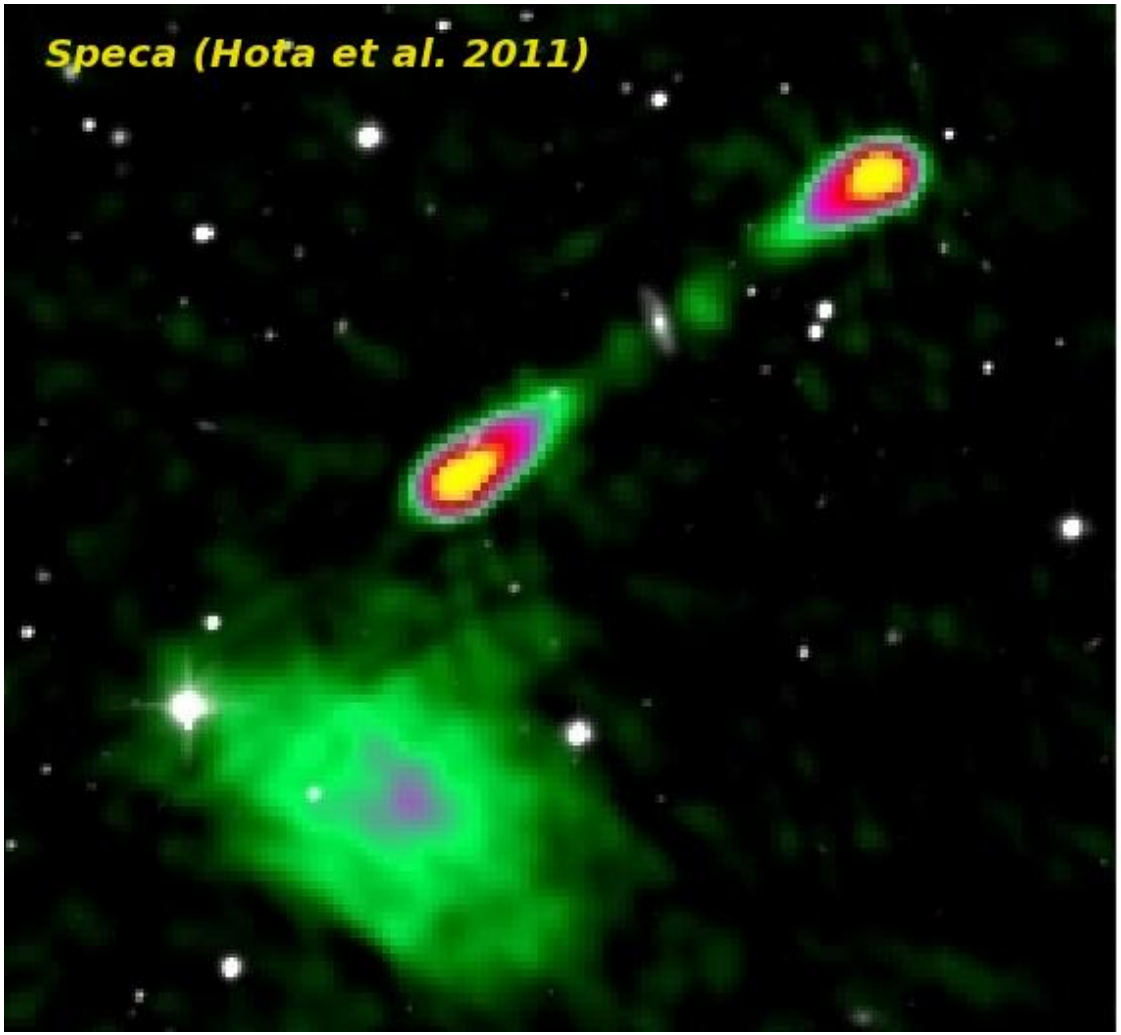
Who launches jets, ellipticals or spirals?

1. Initially we knew that only ellipticals launches radio jets and lobes

2. Ledlow, Owen, Keel (1998), then Hota, Syrothia, Ohyama, Konar et al. (2011) showed that even spirals creates radio galaxy. (Subsequently, Bagchi et al., Mao et al. have shown the same thing.)

They are relatively rare. Why? Need more investigation.

Radio galaxy created by a spiral (disk) galaxy discovered by Hota, Sirothia, Ohyama, Konar et al. (2011)



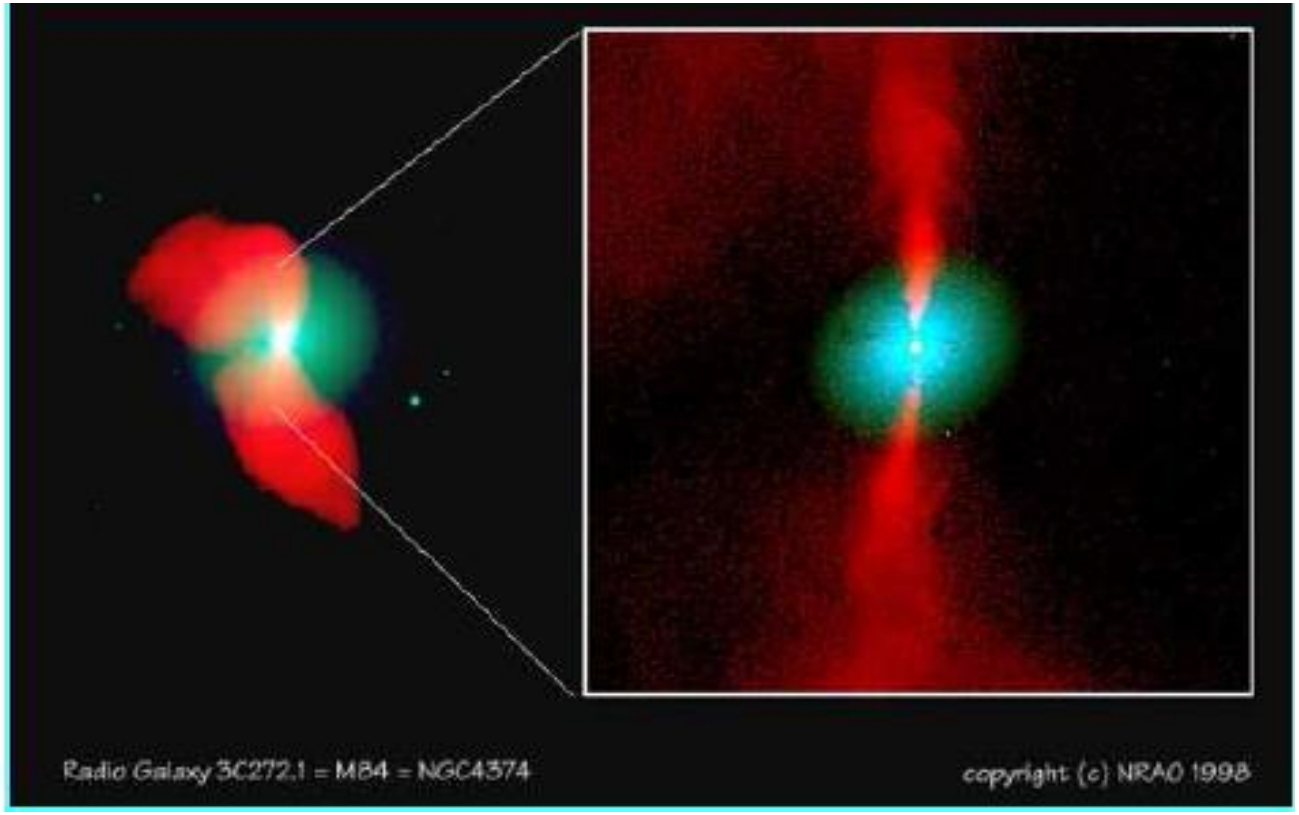
Spiral host radio galaxy: SPECA

What is basically a radio galaxy?

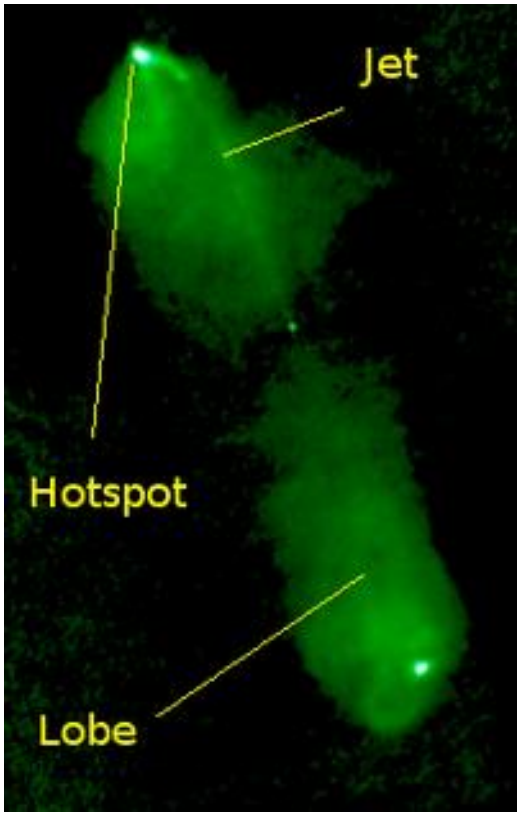
When

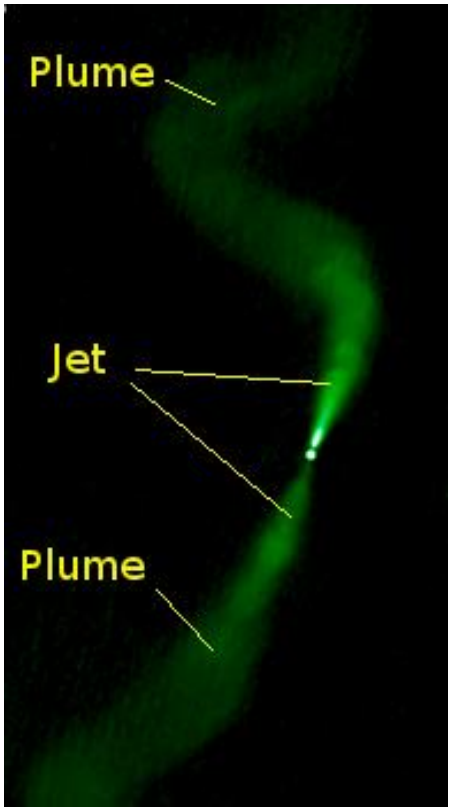
- the accretion is in suitable mode (as all AGNs don't form RGs)
- M● >= 10^8 M⊙ (Chiaberge & Marconi, 2011)
- the SMBH perhaps has the right amount of spin: ??

SMBH in ellipticals launches 100-kpc scale jets.



Radio galaxies: two types depending upon the collimation and the speed of the jets



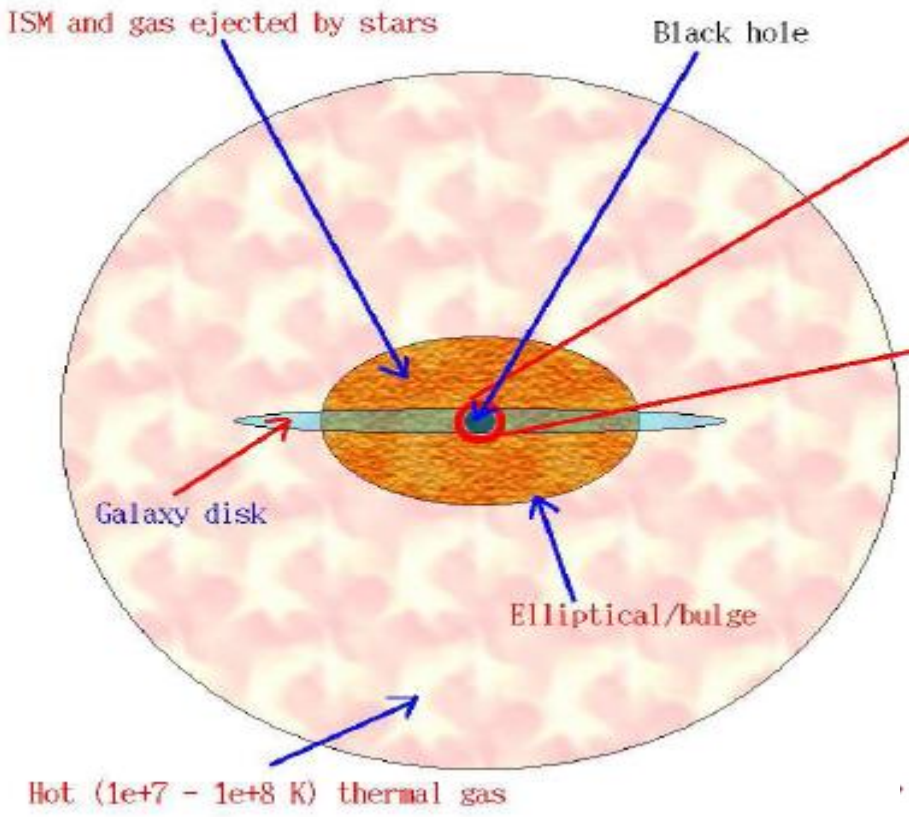


3C 98 (FR-II RG) **3C 31 (FR-I RG)**

(Image courtesy: M.J. Hardcastle)

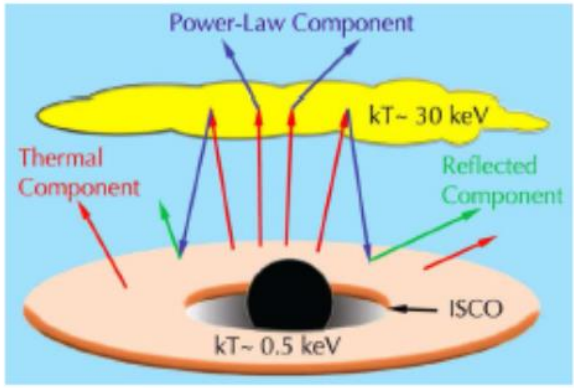
1. Hotspots are jet termination shocks
2. No such shocks in FR-I
3. Jet Lorentz factor is up to 10 (speed is close to c)
4. Core is the base of the jet
5. Lobe/plumes consists of electron-positron plasma. There are some protons that goes into plumes/lobes from the environment

The Central Engine System



$\beta-$model amb medium:

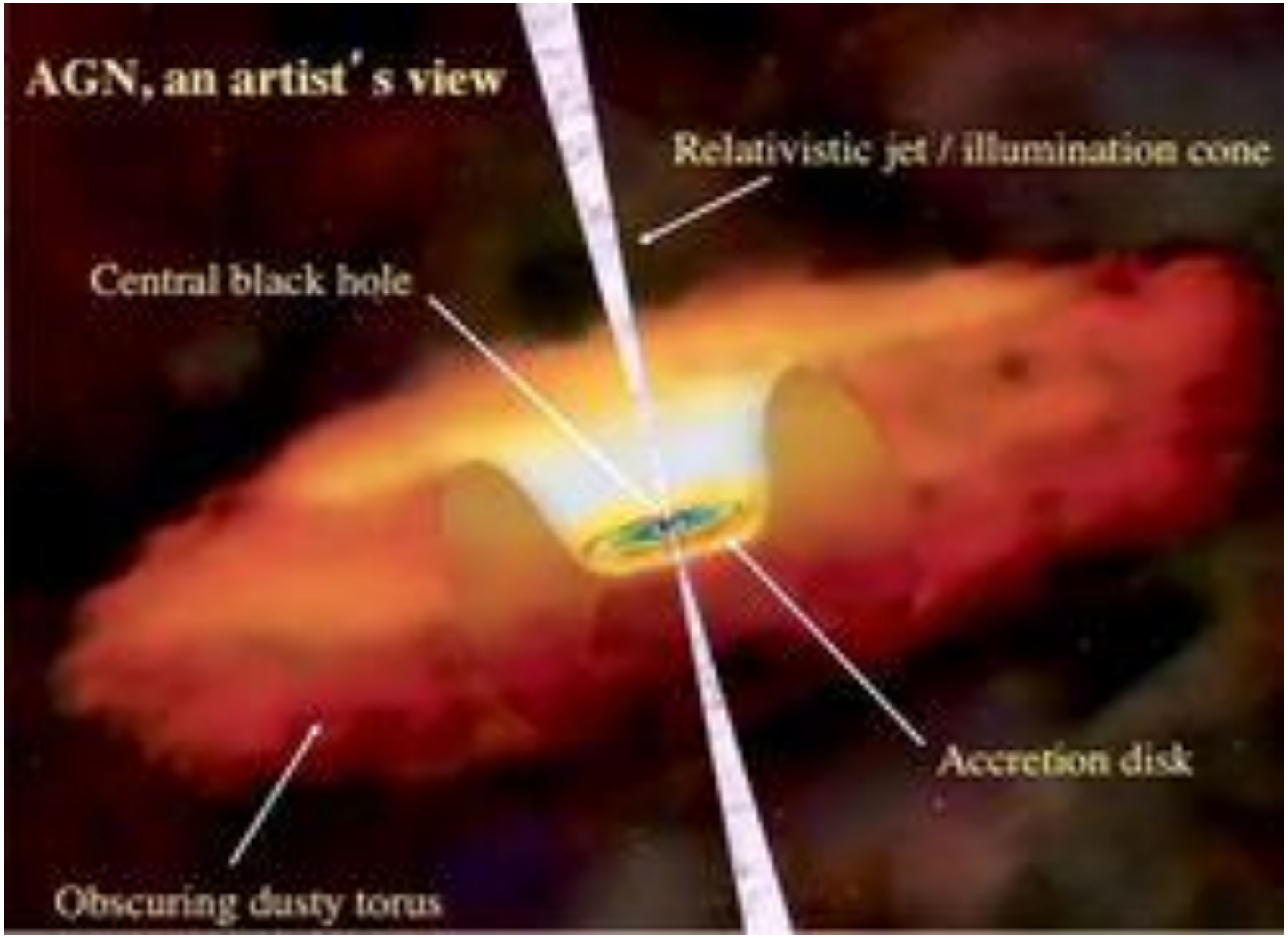
$$n_{\rm p}(r) = (1+\frac{r^2}{r_c^2})^{-\frac{3\beta}{2}}$$



Keplerian motion: standard disk

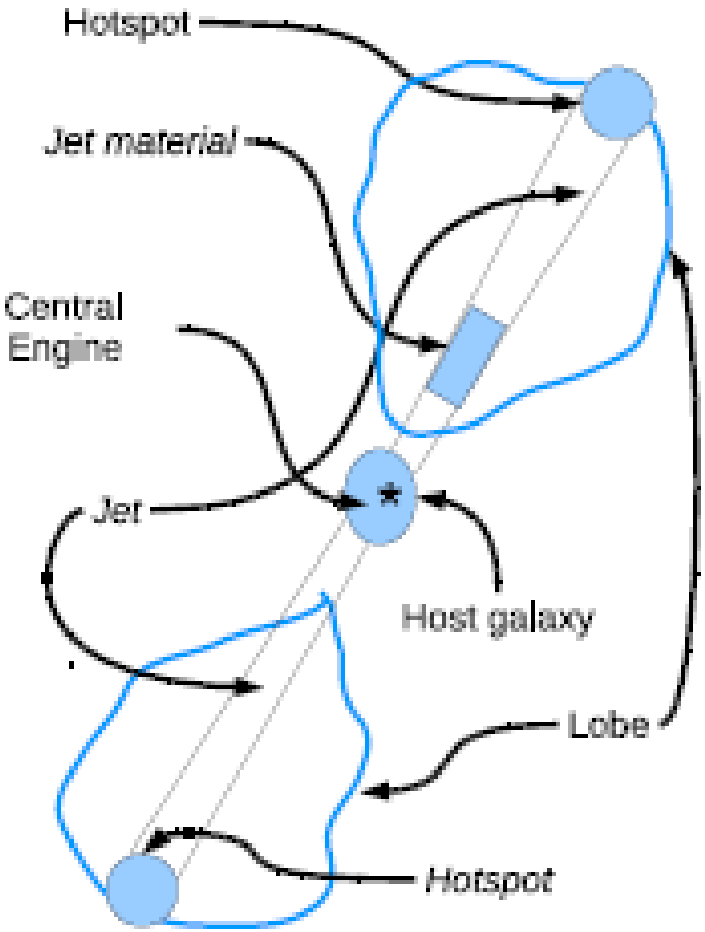
At the centre, there is (1) molecular torus, (2) Accretion disk and (3) SMBH

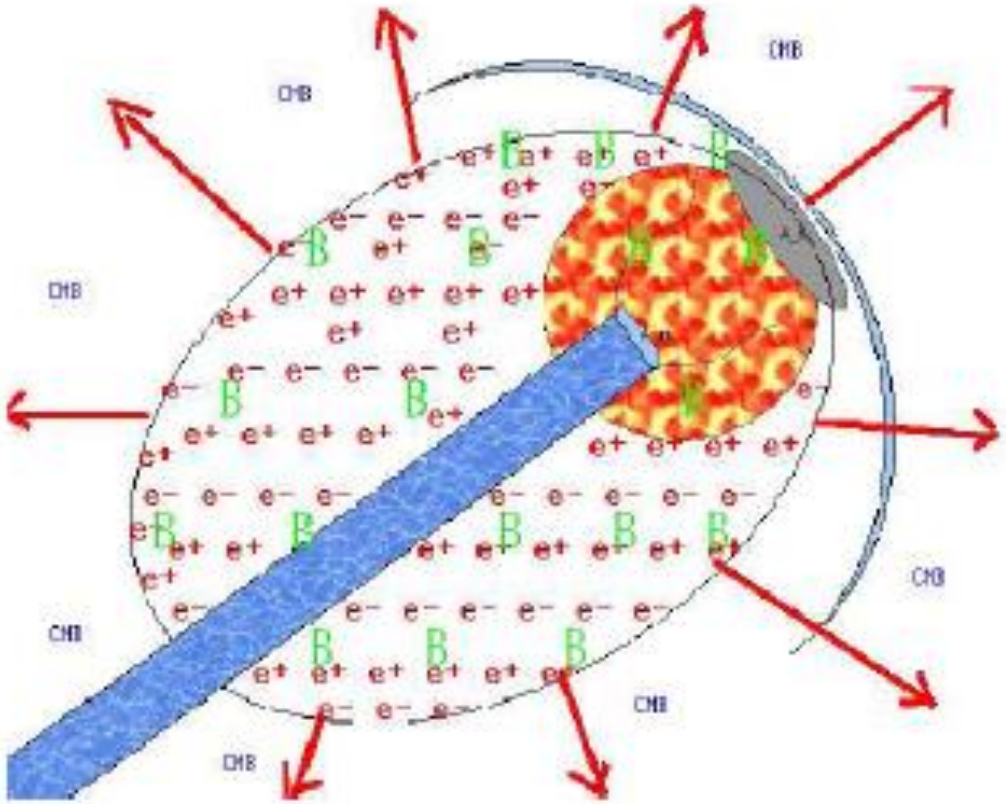
Schematic Picture of Central Engine of Radio Galaxies



Source: Google

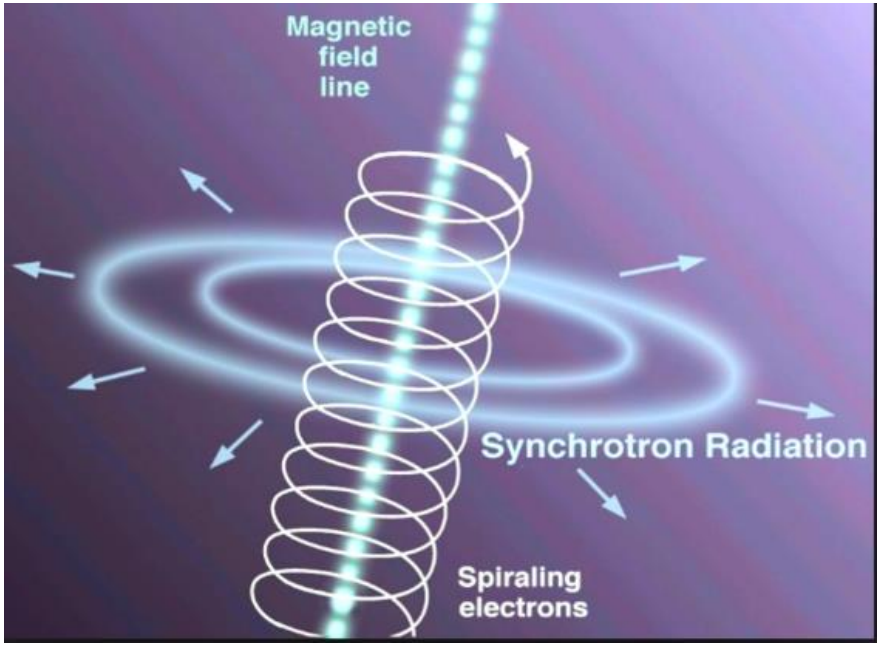
Components and radiations

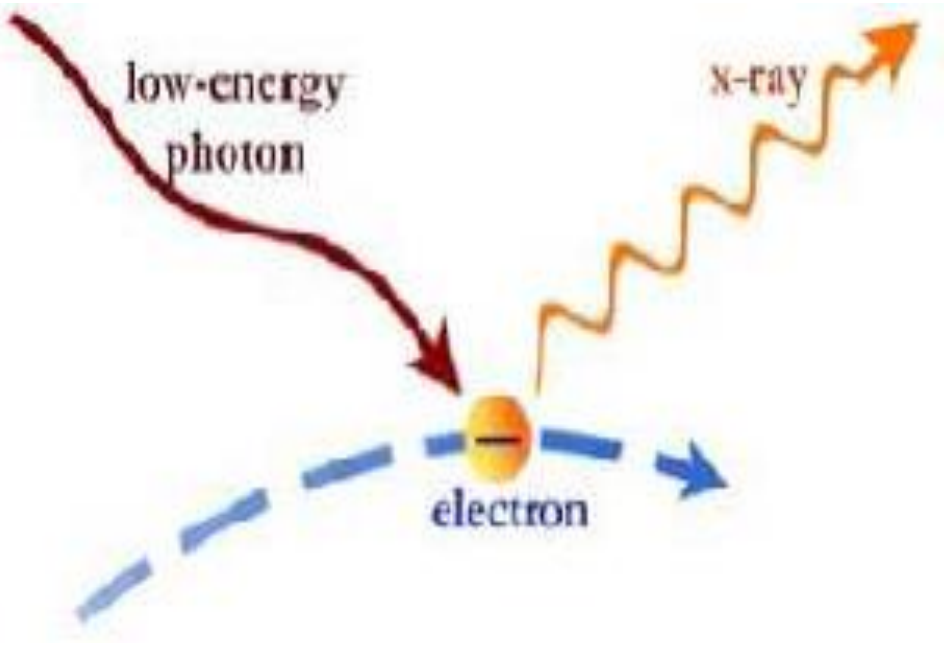




$$J_{\nu,\mathrm{syn}} = J_{\nu}(n_0, U_B) \qquad J_{\nu,\mathrm{IC}} = J_{\nu,\mathrm{IC}}(n_0, U_{CMB})$$

Lobes are in Equipartition condition





Source of the diagrams: Google

In Lobes

Particles are electron-positron:(e.g., Konar & Hardcastle 2013)

Typical no. density of particle = 10^{-4} - 10^{-10} cm^{-3}

N(E)dE = N_0 E^{-p} dE → power law distribution

The particles are not in equilibrium. We cannot define temperature in thermodynamic sense. However, energy density can be determined.

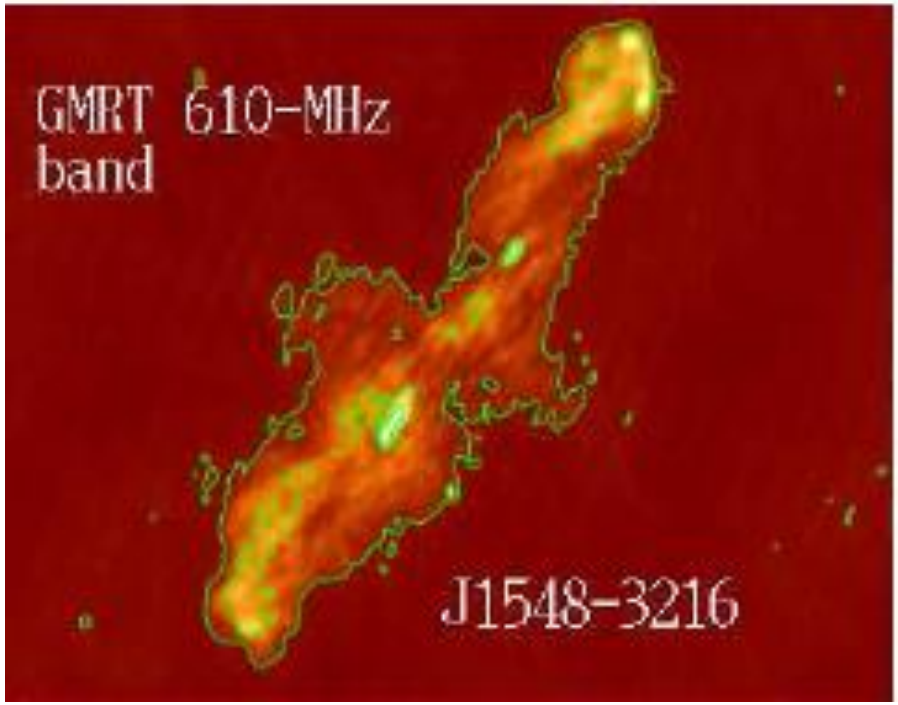
u = 10^{-8}- 10^{-10} erg cm^{-3} , Age = 10 – 100 Myr

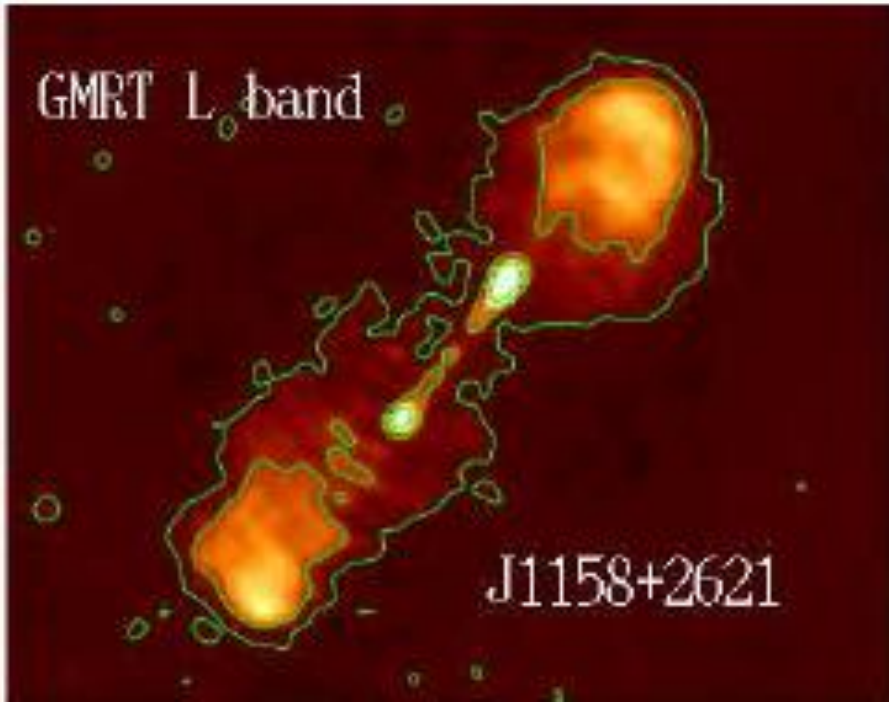
P_J = 10^{44}- 10^{46} erg/s ,

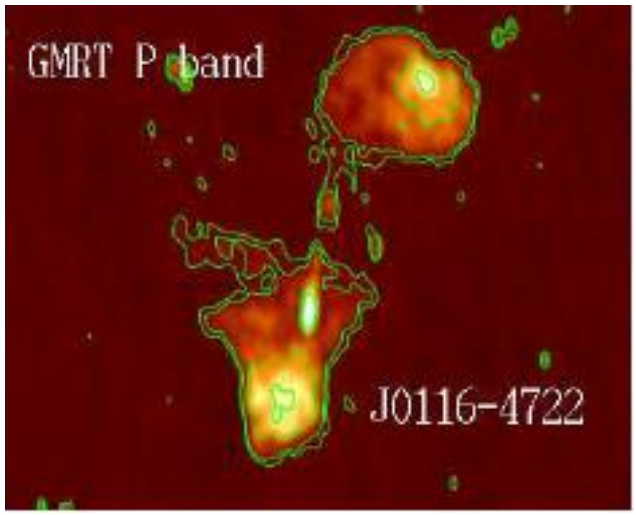
Lorentz factor_jet = 10-20 → (Konar & Hardcastle, 2013)

The jet formation from the SMBHs is episodic in nature

These are called DDRGs or Episodic Radio Galaxies







There are Triple Double Radio Galaxies also. That Means there are three episodes of jet activity.

Jet powers in two episodes are same

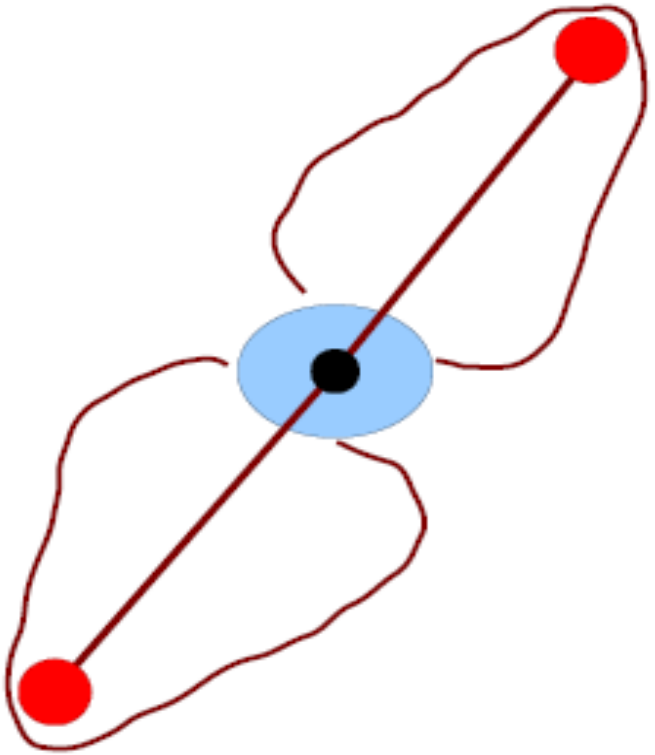
Konar et al., 2013

How Episodic Radio Galaxies form

- A massive galaxy with SMBH

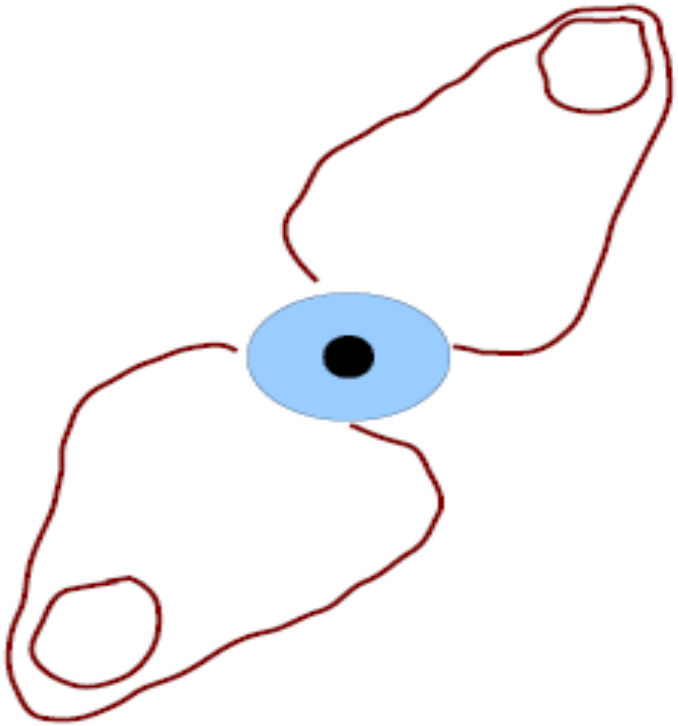
How Episodic Radio Galaxies form

- A massive galaxy with SMBH
- Launches kpc-Mpc scale jets



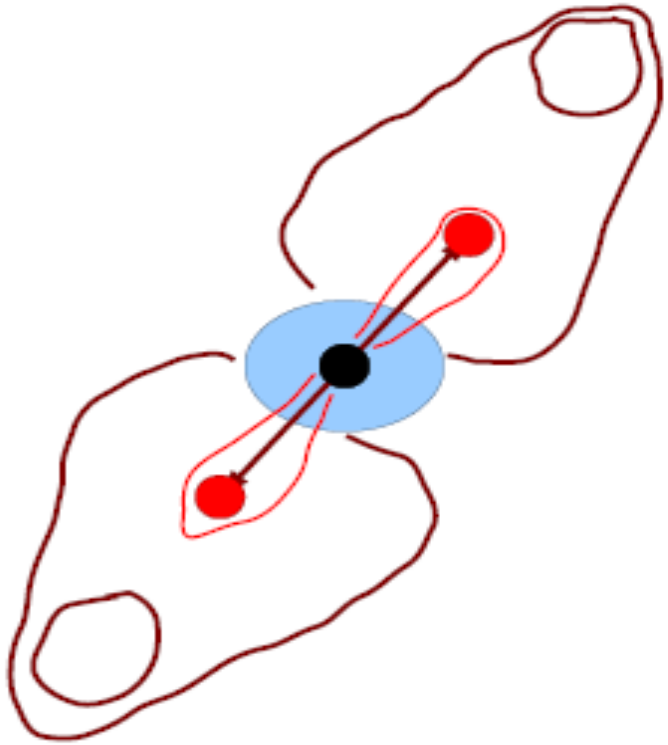
How Episodic Radio Galaxies form

- A massive galaxy with SMBH
- Launches kpc-Mpc scale jets
- Jet switches off, HS–>WS



How Episodic Radio Galaxies form

- A massive galaxy with SMBH.
- Launches kpc-Mpc scale jets.
- Jet switches off, HS–>WS.
- New jets starts, propagates thru cocoon matter of outer lobes.
- new jets forms JTS inspite of the tenuous ambient medium.
- Inner lobes seems to have back flow.



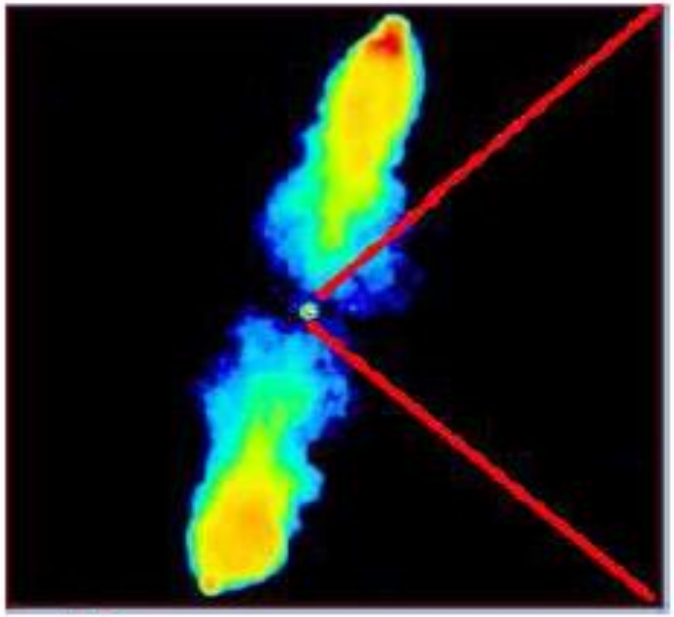
Mode of accretion in radio galaxies

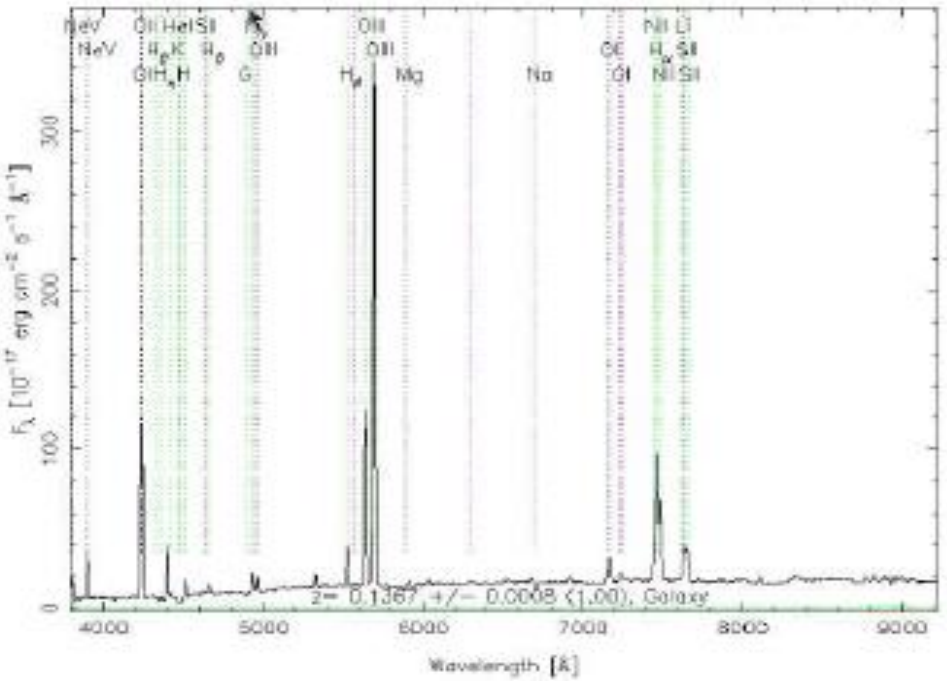
(See Hardcastle+, 2006, 2007; Allen+, 2006)

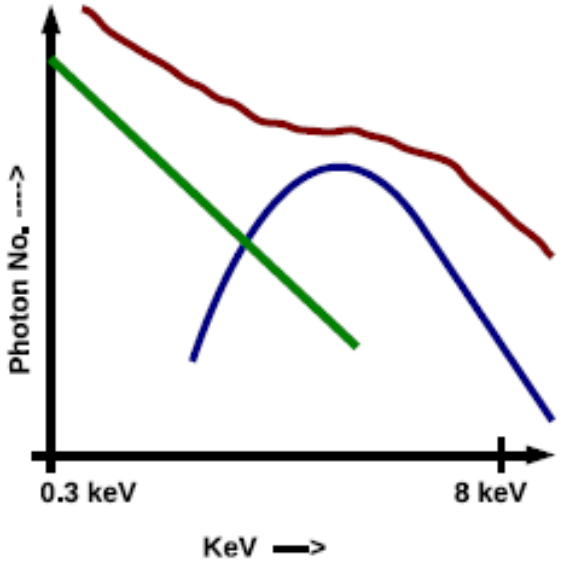
Two types of Radio Galaxies in terms of mode accretion:

1) HERG : High Excitation Radio Galaxy
2) LERG : Low Excitation Radio Galaxy

HERG: cold mode accretion



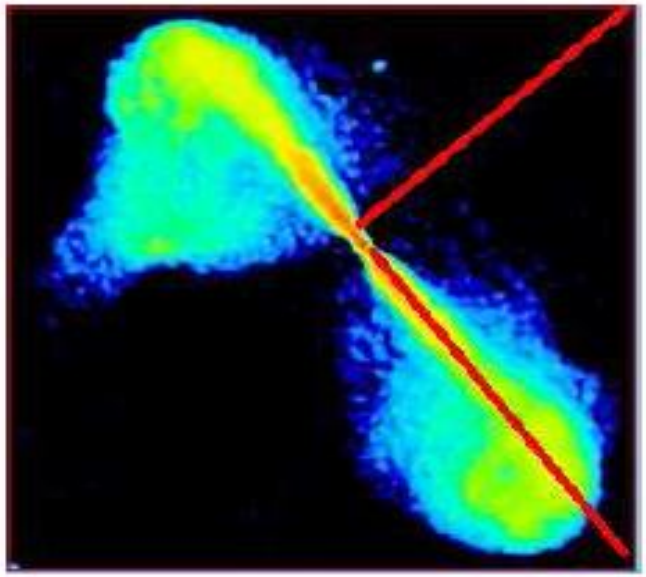


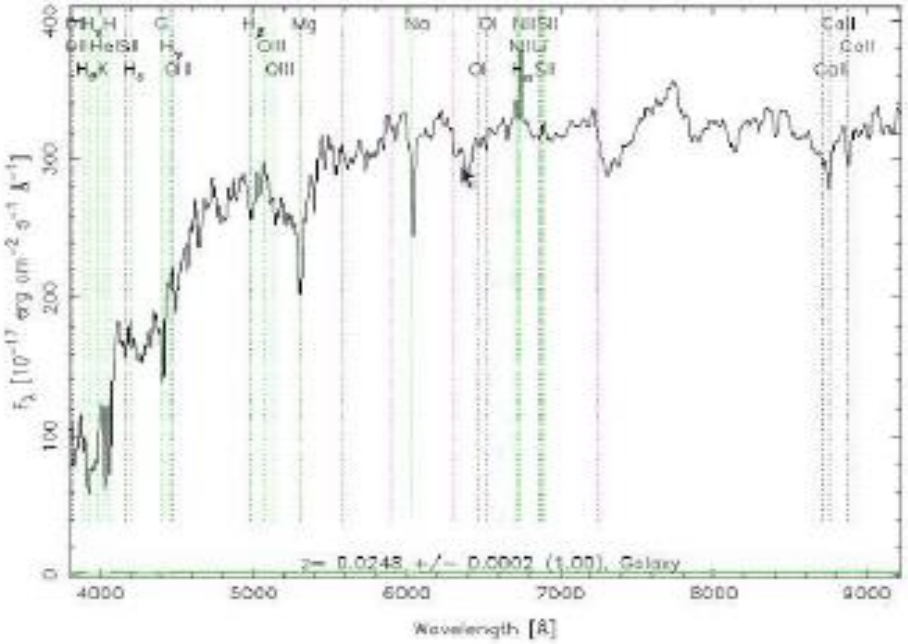


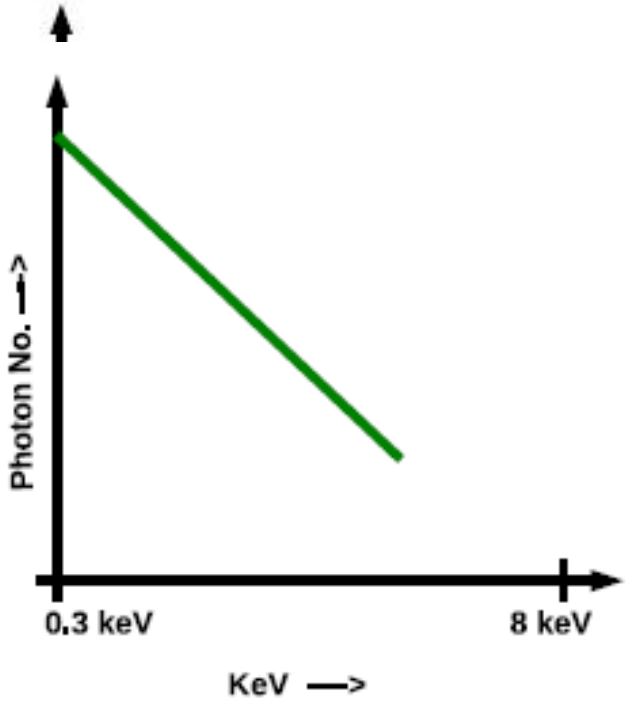
←-Source: Google

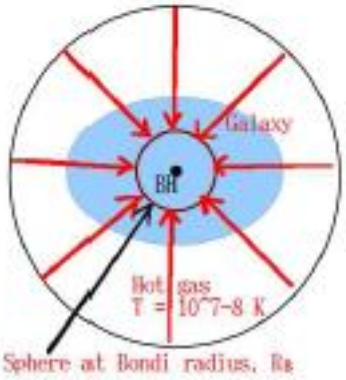
Keplerian motion: standard disk

LERG: hot mode accretion









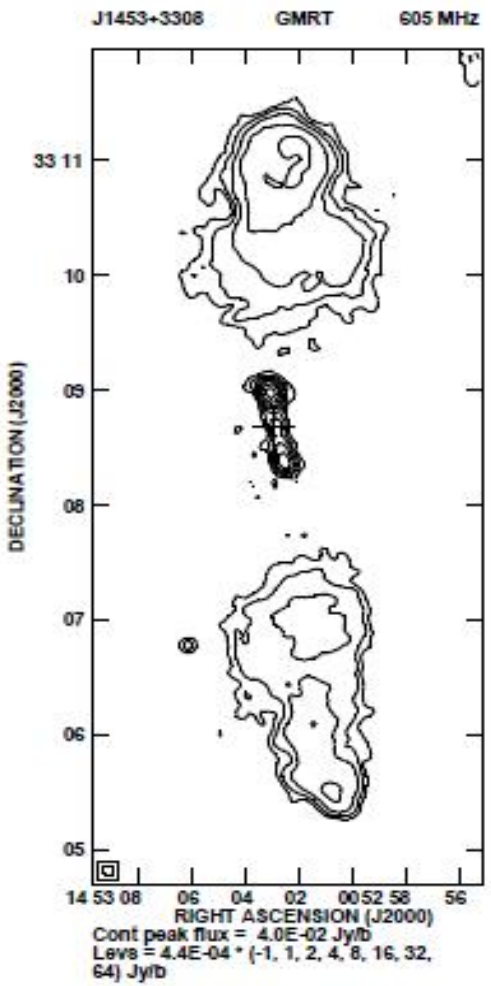
$R_B = 2GM_\bullet/C_s^2$

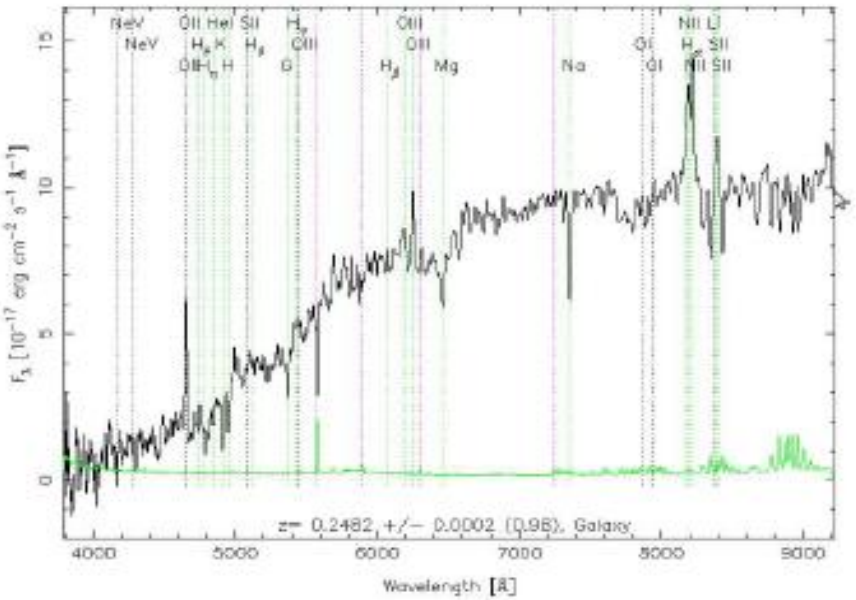
$$\frac{dM_B}{dt} = \frac{4\pi G^2 M_\bullet^2}{C_s^3}$$

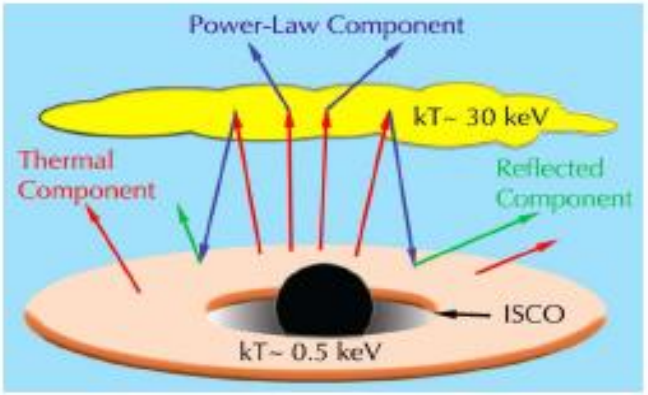
Sub Keplerian accrn flow: RIAF

Episodic Radio Galaxies show both the modes of accretion

Episodic HERG

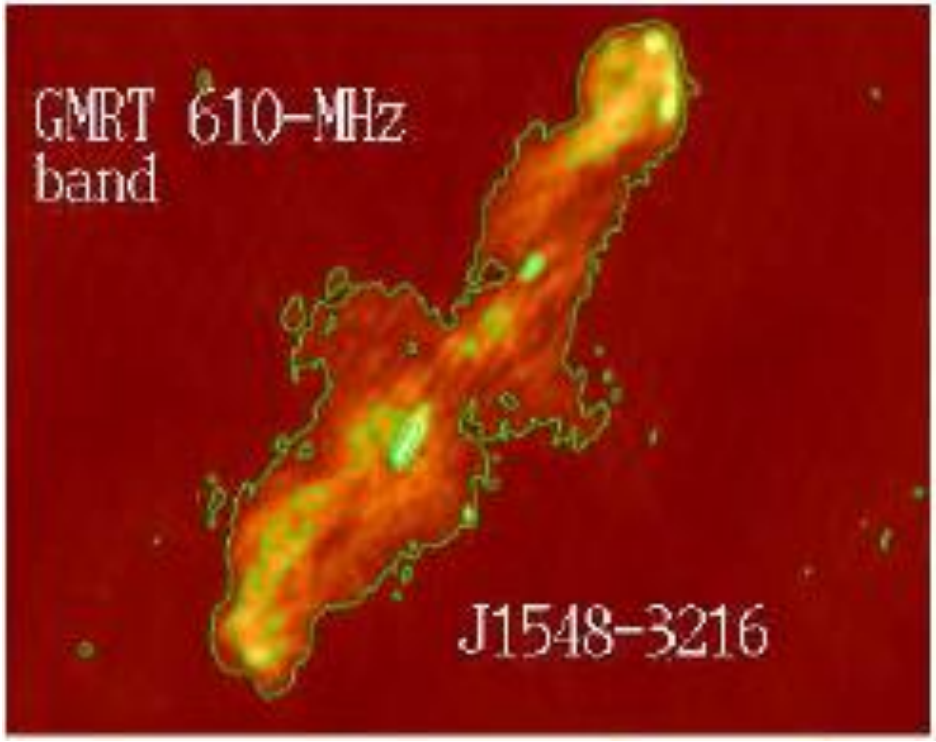


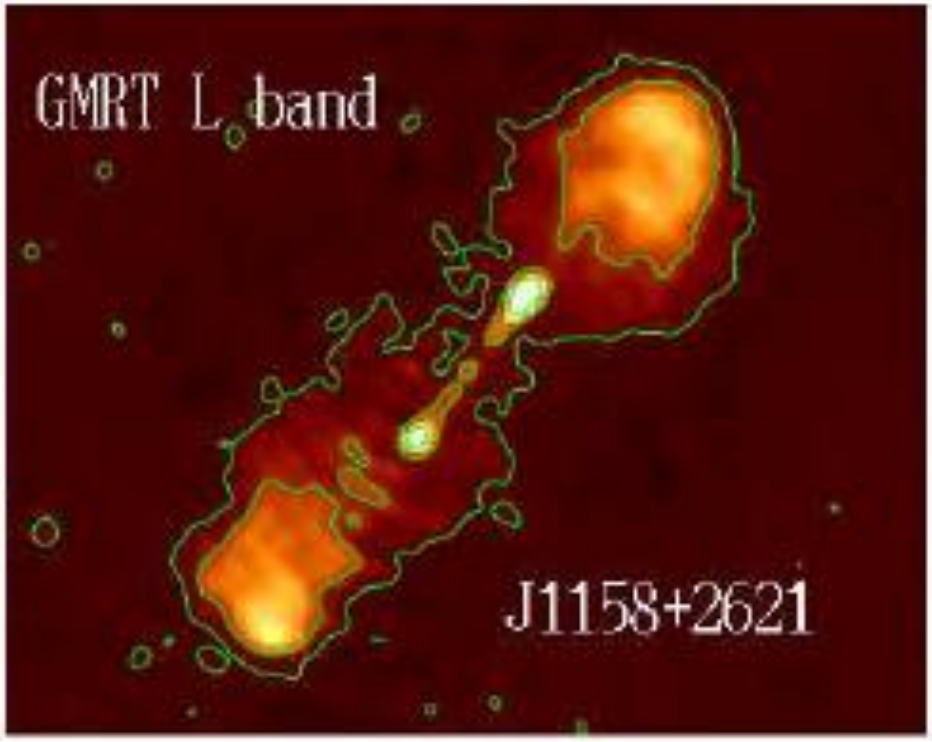


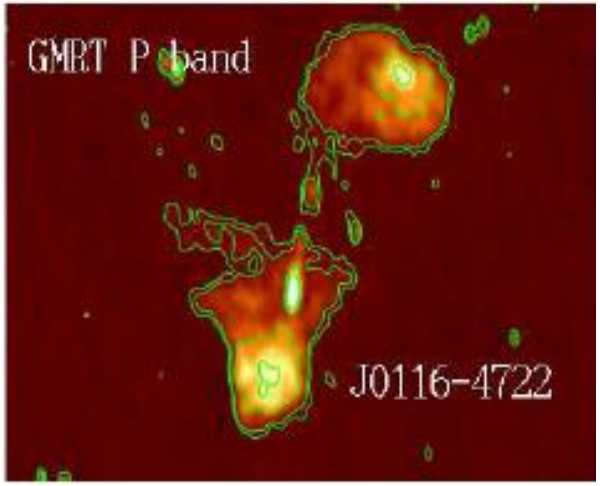


Keplerian motion: standard disk

Episodic LERG

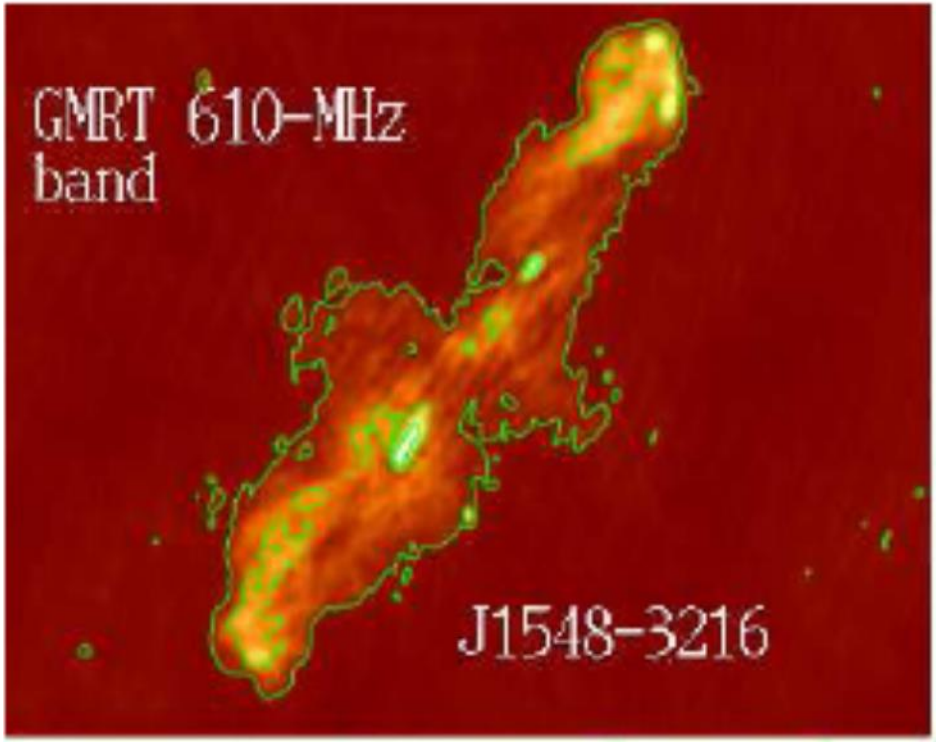


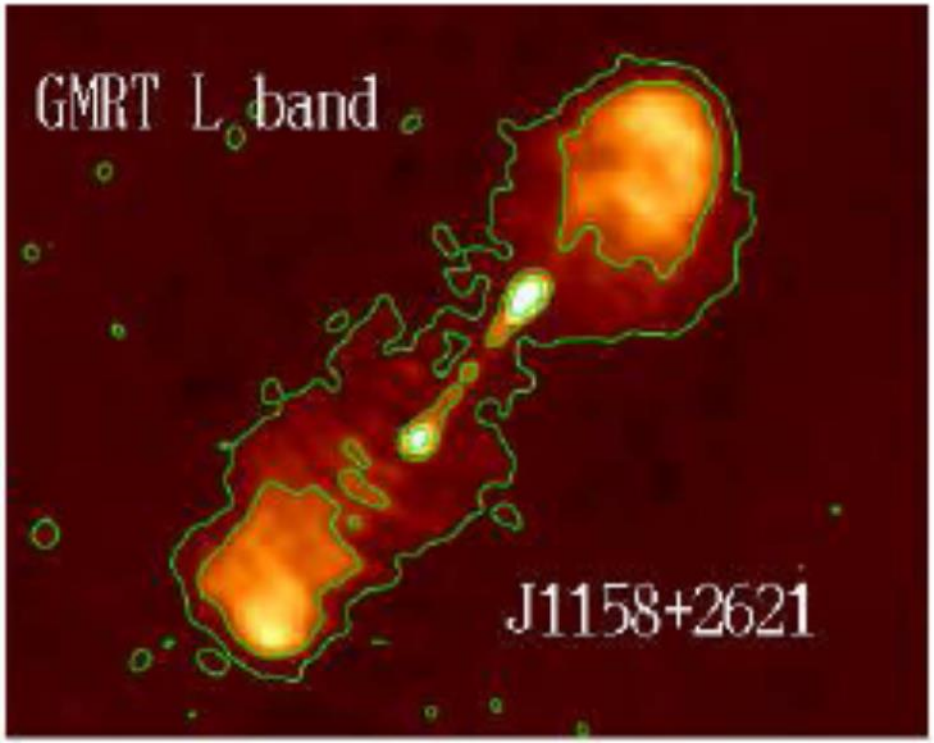




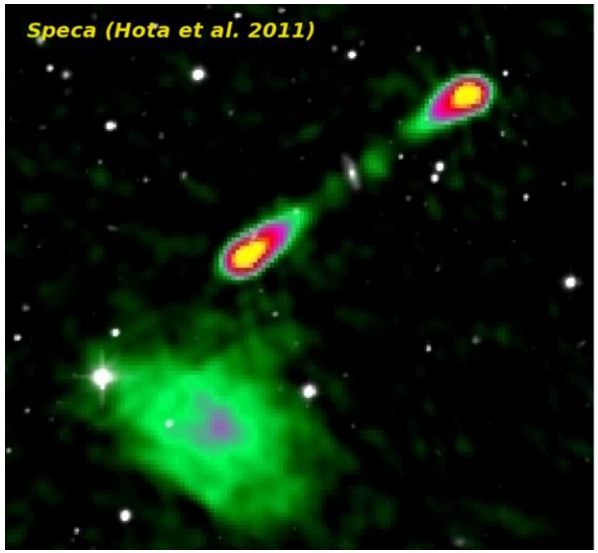
(Z=0.1082, 0.1121, 0.1461)
No [OIII] lines, no hard power laws
Konar+, 2018, submitted.

Our objective is to discover DDRGs, relic radio sources, cluster halos etc. from TGSS and other surveys, then follow up with the GMRT to understand the physics of them with the help of citizen scientists.

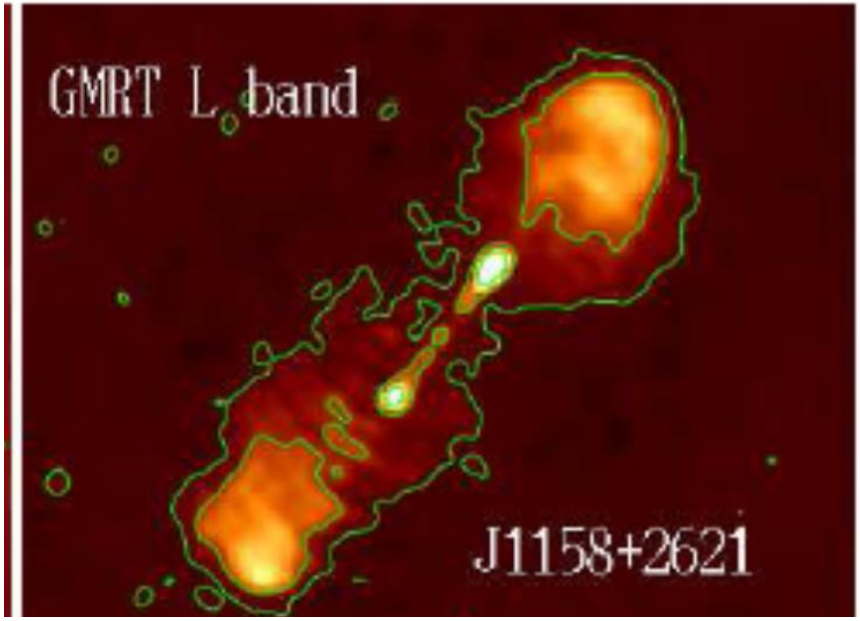




Two of our main discoveries



→ **Spiral host radio galaxy**



→ **Jet powers in two episodes are same**

SUMMARY

1) Morphologically 3 types of galaxies: Ellipticals, spirals, irregulars

2) All massive galaxies are found to have evidence of BHs at their centres.

3) Mostly elliptical galaxies host radio galaxies, though a few spirals have been discovered to host radio galaxies.

4) Radio galaxies can be of two types in terms of morphology (FR-I & FR-II).

5) Radio galaxies can be of two types in terms of mode of accretion at the central engine (HERGs & LERGs)

6) Radio galaxies can be episodic in nature (DDRGs & TDRGs).

7) Episodic RGs can also be classified as FR-I/FR-II and HERG/LERG.

8) Discovery of Spiral Host Radio Galaxy

9) Jet powers in two episodes are same

THANKS