Galassie Attive e Buchi Neri Supermassivi

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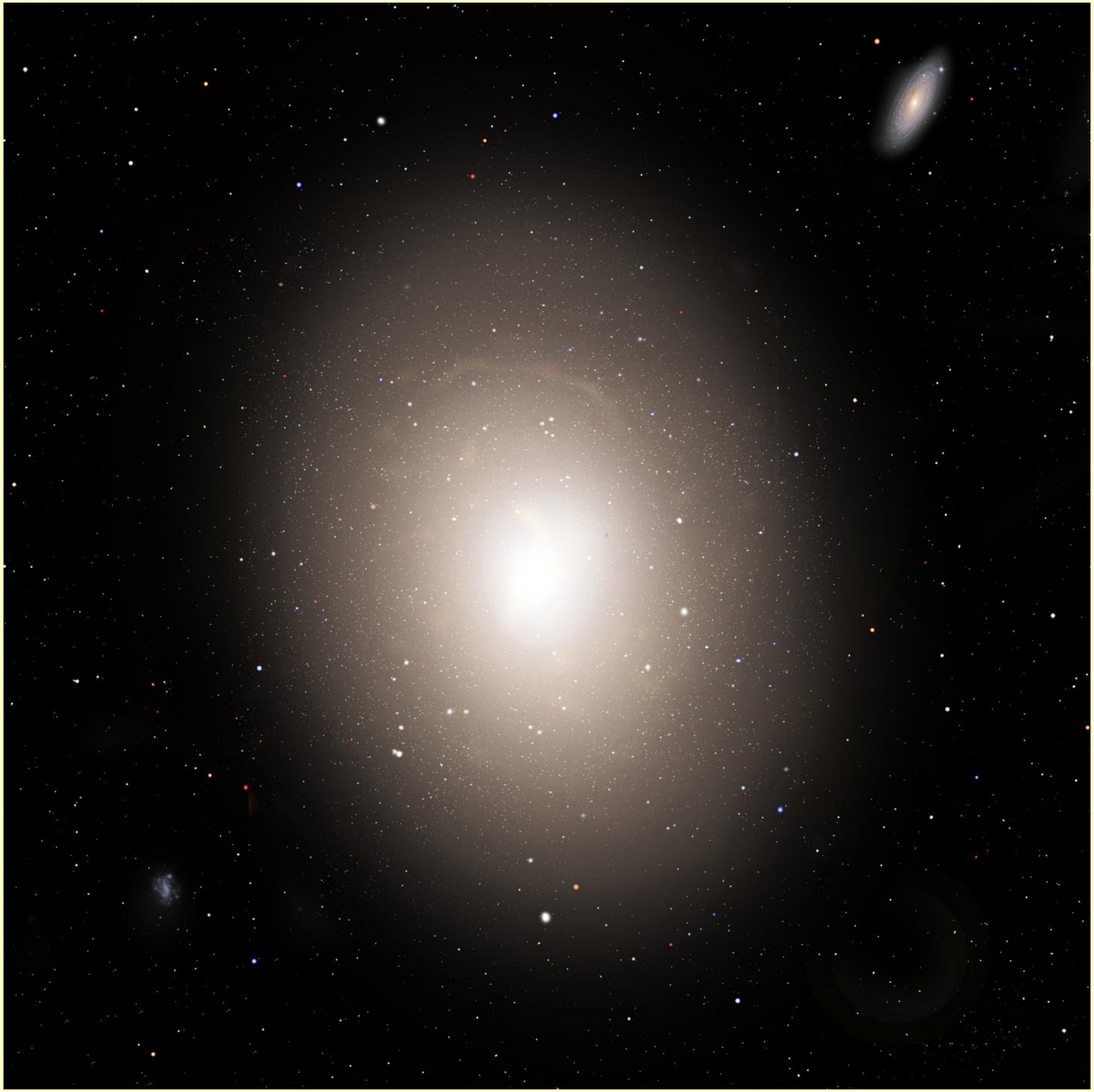
Summary

- Normal and Active galaxies: Observational Properties
- The "Black-Hole Paradigm" for Active Galaxies
- SMBH: Where are, what are and how we find them
- SMBH formation
- Historical notes

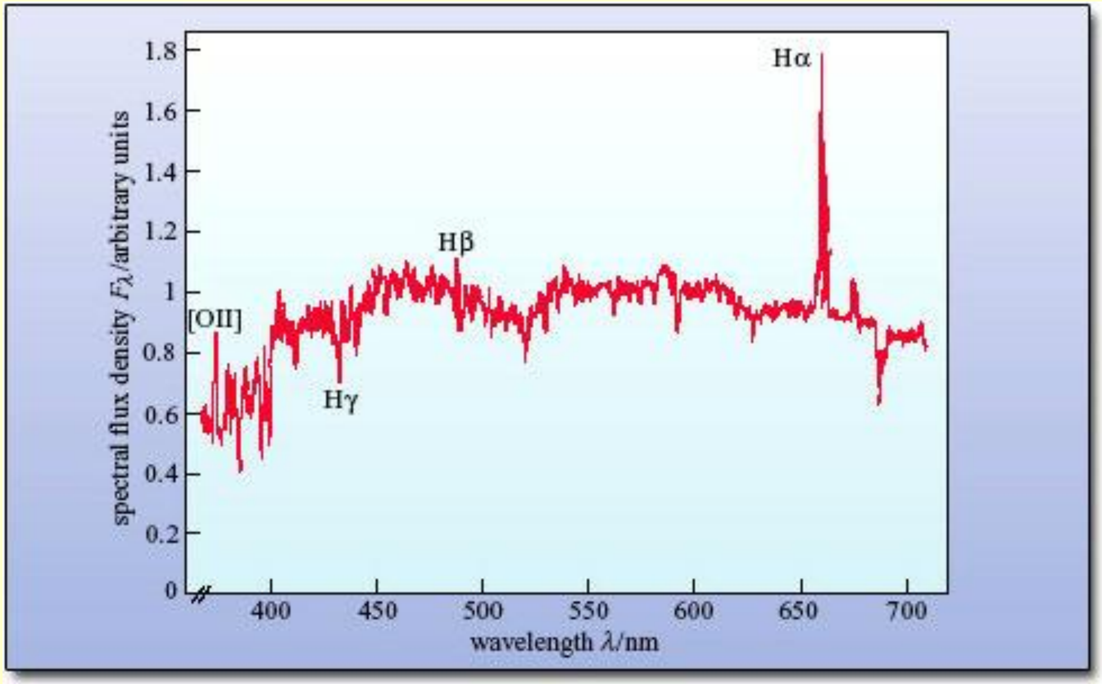
- **Normal and Active galaxies: Observational Properties**

Normal Galaxies



Normal Galaxies

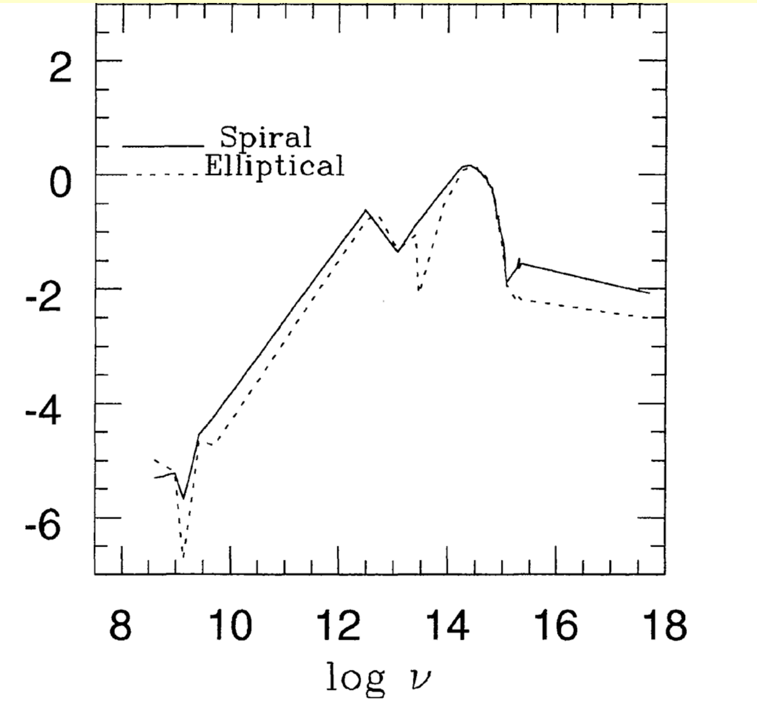
- Stars and interstellar gas contribute to the radiation emission, predominantly in the optical band.
- The spectrum shows absorption lines by stars and emission by HII regions.



NGC 4750
(Kennicut 1992)

Normal Galaxies

- Typically, ~10^{11} stars of a galaxy like the Milky Way emit a luminosity of ~10^{44} ergs s^{-1}
- All but a few percent of the galaxies of the Local Universe are normal galaxies

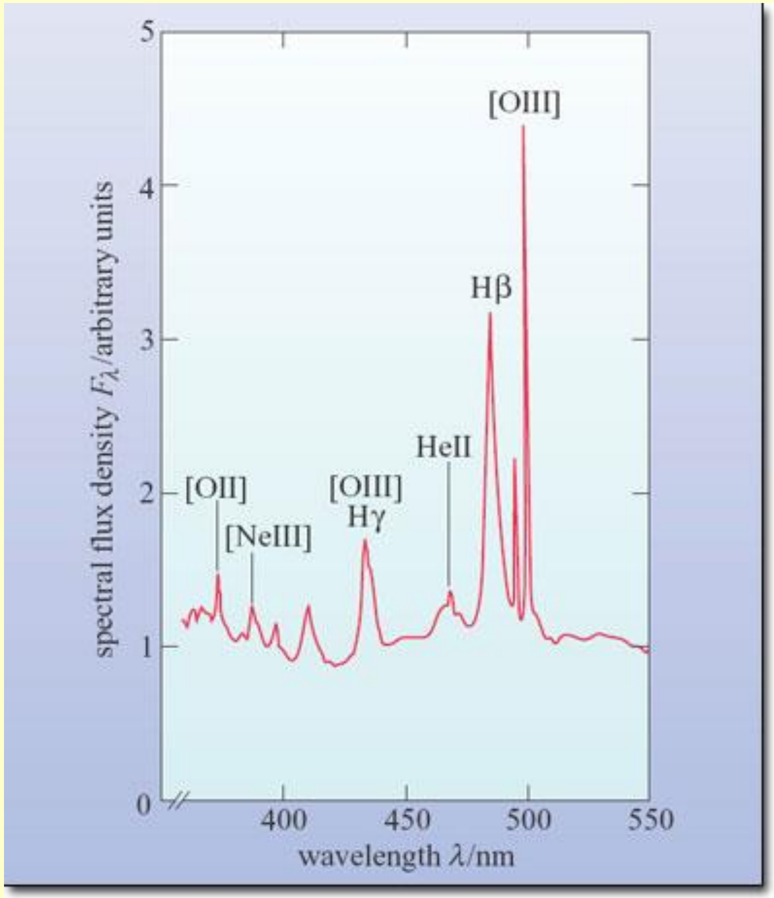


Spectral Energy Distribution (SED) of a normal galaxies

Active Galaxies

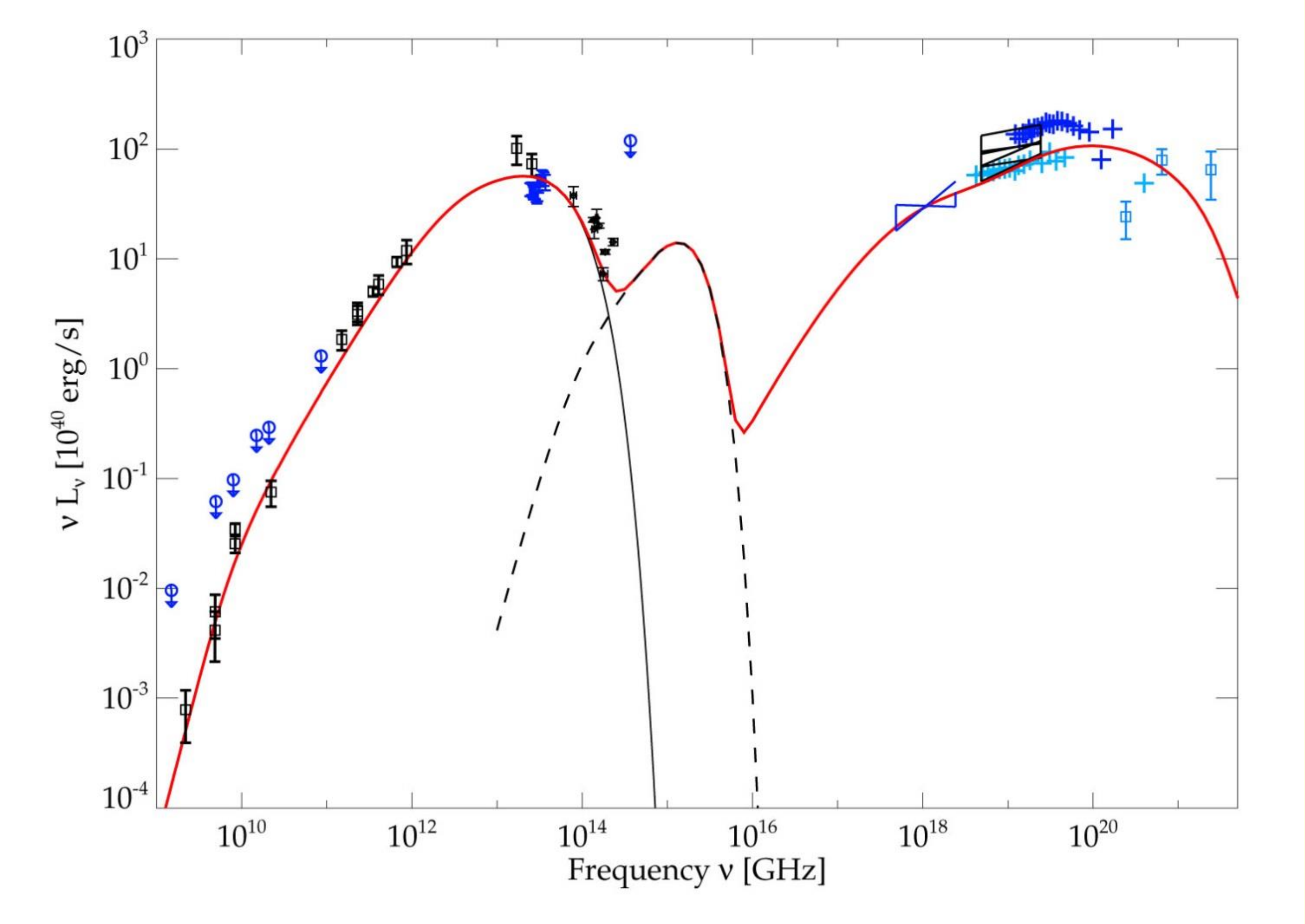
A few percent of the galaxies of the Local Universe show:

- **Strong and broad emission lines, consistent with velocity dispersion of several thousand kilometers per second for the emitting gas**



Active Galaxies

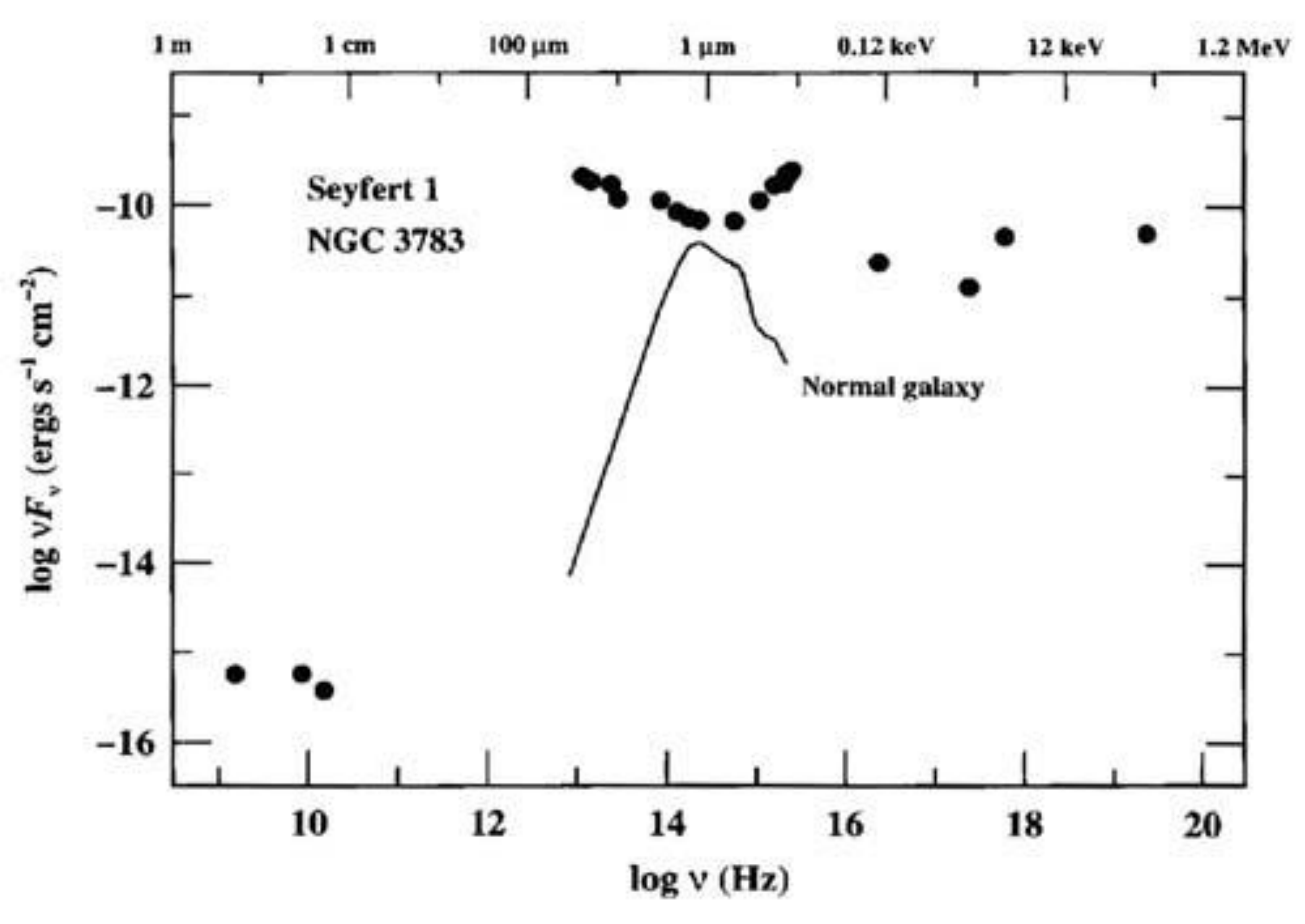
- Non-thermal emission extending from the radio to the X-rays and gamma bands



SED of Cen A
(Prieto et al. 2007)

Normal vs Active Galaxies

Spectral Energy Distributions



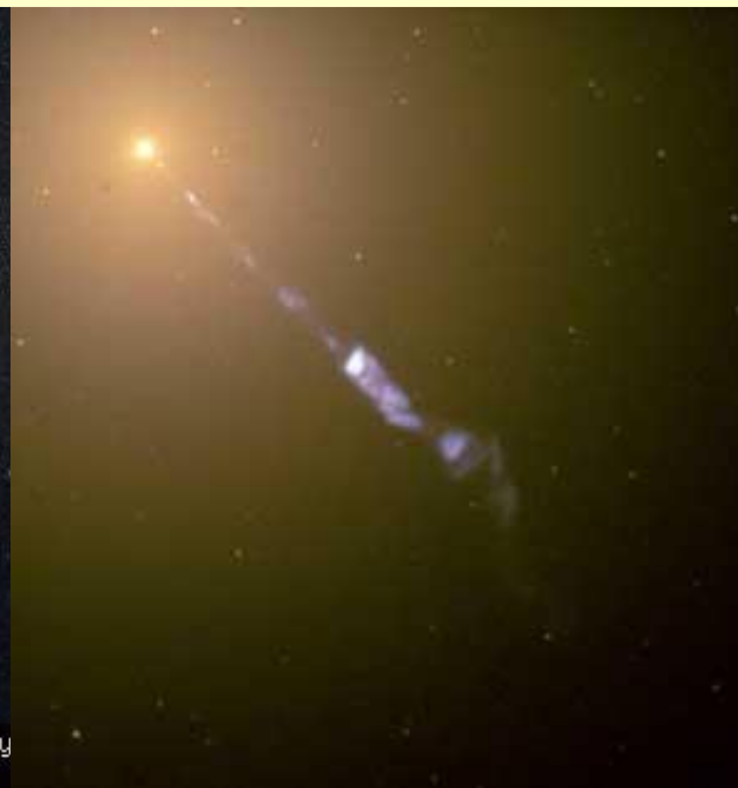
Active Galaxies

The dominant contribution to the total luminosity is not from stars but from an Active Nucleus

M87

R ~ 30 kpc

R ~ 2 kpc

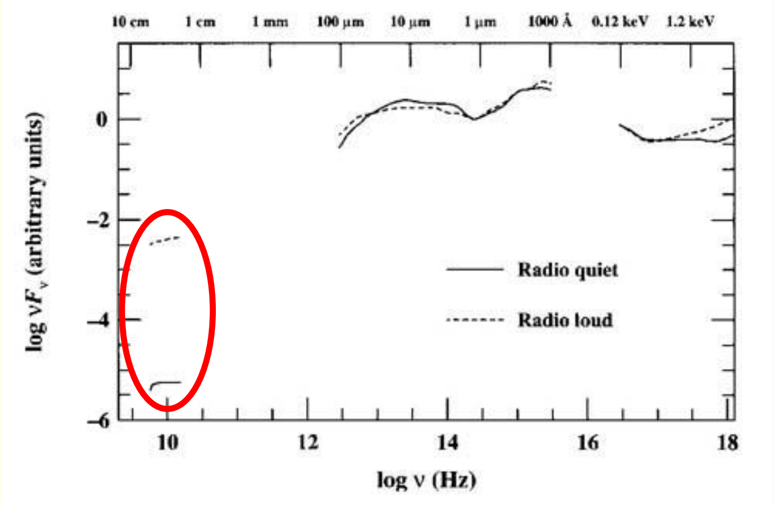


R ~ 10^{-5} kpc

AGN Zoology

”90% Radio quiet AGNs: **No jets**

- Seyfert 1 galaxies (Sey 1) (BLR, ~ 10^4 km/s)
- Seyfert 2 galaxies (Sey 2) (NLR, $\leq 10^3$ km/s)
- Radio Quiet Quasars (QSOs)



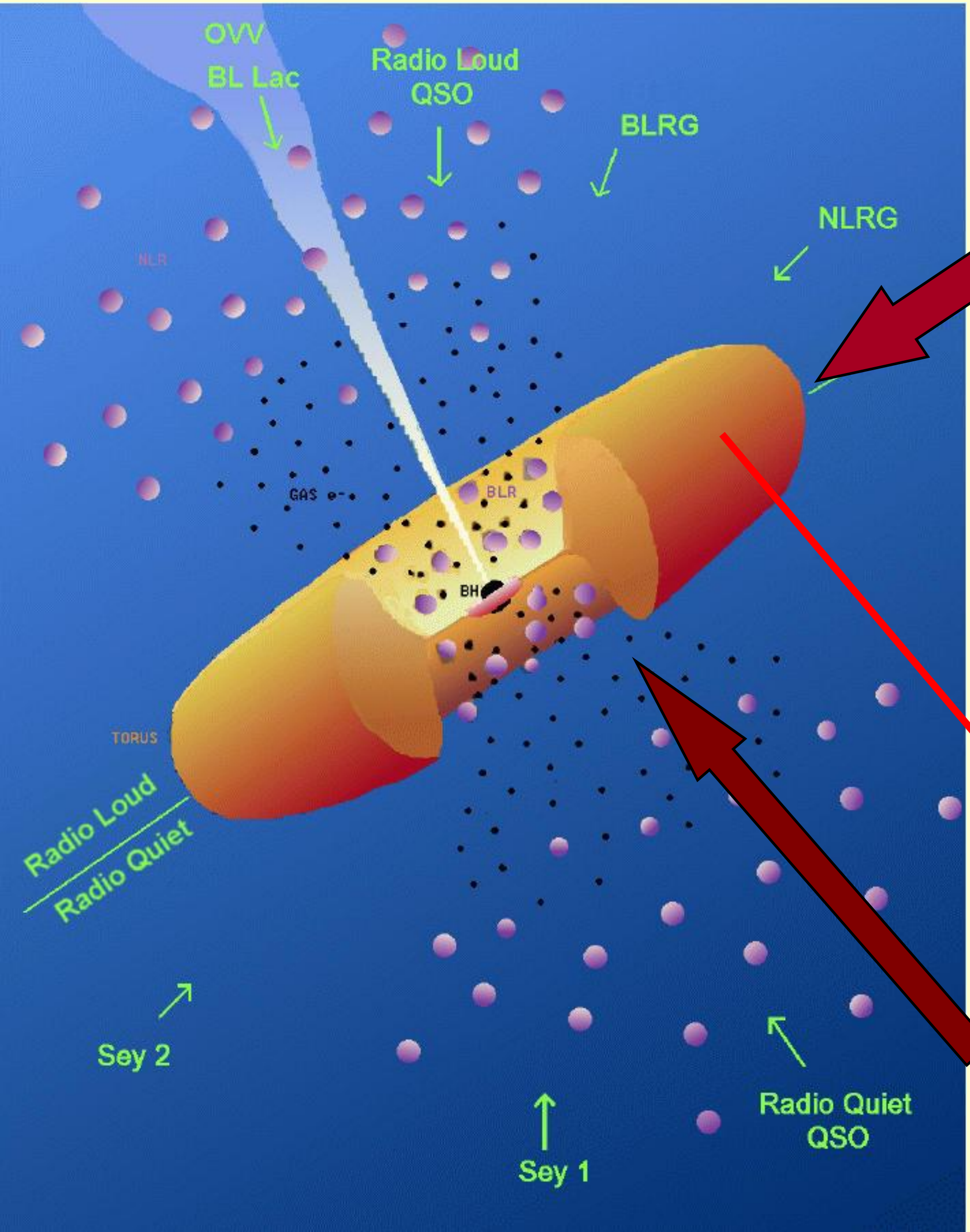
”10% Radio loud AGNs: **Jets**

- Radio galaxies
- Radio Quasars
- BL Lac Objects
- Optically Violent Variables (OVV’s)

Radio loudness parameter: $R = L_{5GHz}/L_{B(nuclear)} > 10$

- **The "Black-Hole Paradigm" for Active Galaxies**

The AGN Unified Model



narrow lines

NLR, L~0.1kpc

Accretion onto a SMBH through an accretion disk, with possible jet ejection seen at differen angles

(Urry & Padovani, 1995)

Obscuring torus

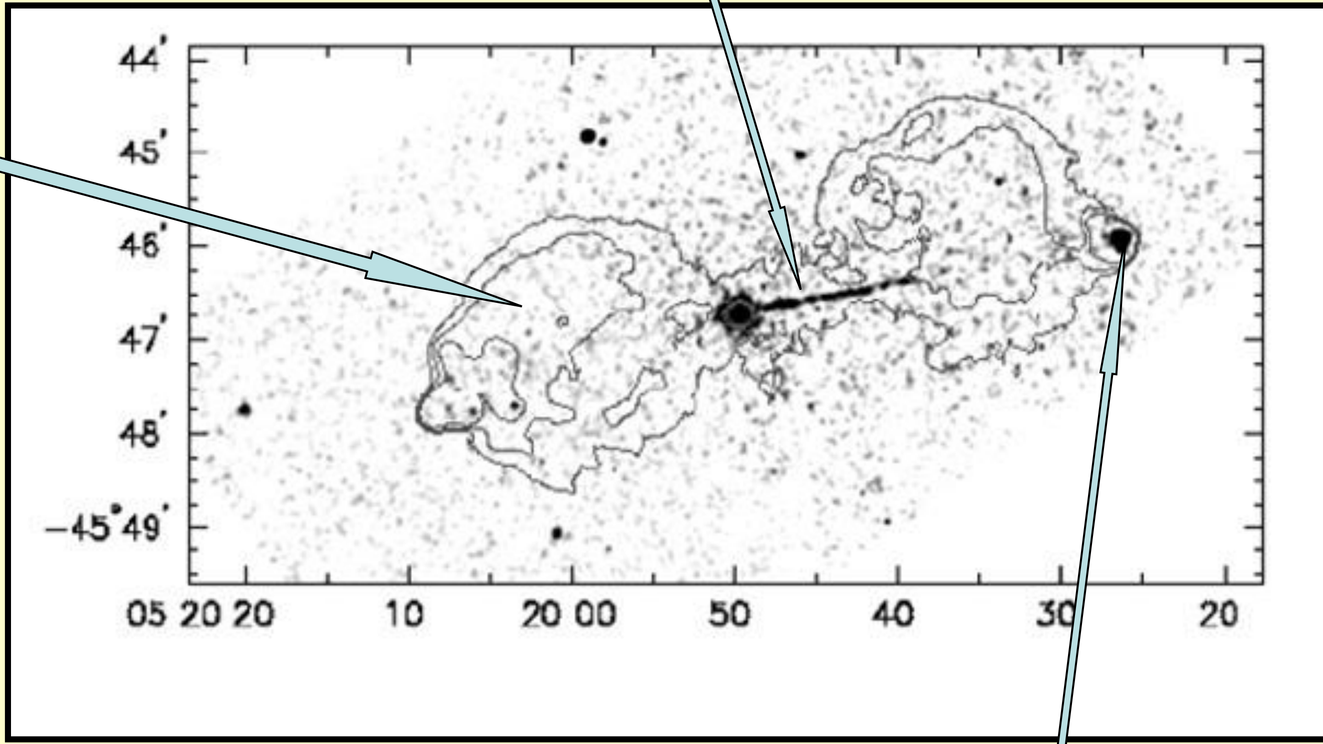
broad lines

About Radio Galaxies and Jets

Synchrotron Radio to X-rays

Radio emission
Synchrotron:
$F(\nu) \propto \nu^{-\alpha}$
$\alpha \sim 0.5$

Electron power law distribution
$n(E) \propto E^{-p}$
$p=2\alpha+1$



Pictor A (z=0.035)
Nucleus to hot-spot ~ 270 kpc
jet ~ 120 kpc

Radio: synchrotron X-rays: synchrotron+SSC

Radio Galaxies: Main facts

What we know:

- Radio luminosity: 10^{41}-10^{44} ergs s^{-1}
- Size: a few kpc – some Mpc
- Morphologies: brightness distributions
- Polarization degree: about 1%-30%

What we derive from hypotheses and models:

- Life timescale: 10^{7}-10^{8} ys
- Magnetic field: 10 – 10^{3} μG
- Kinetic power: 10^{44}-10^{47} ergs s^{-1}
- Jet Mach number: M>1
- Jet velocity: possibly relativistic
- Jet density: 10^{-5}-10^{-4} cm^{-3}

Radio Galaxies: Main facts

Why these uncertainties in constraining the basic parameters?:

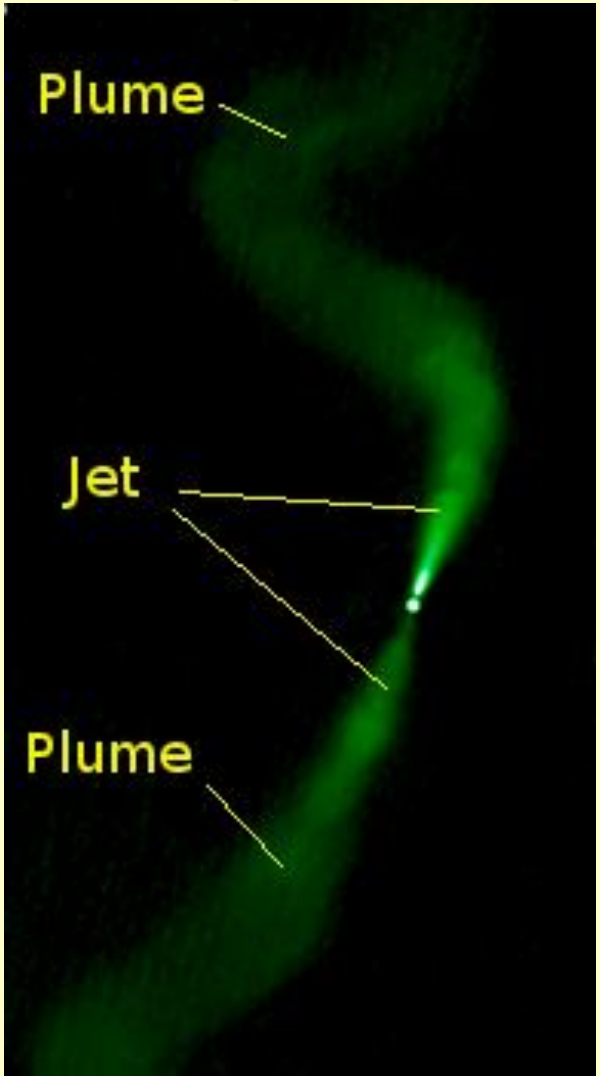
Absence of any line in the radiation spectrum!

Parameters are constrained by indirect means:

- **Magnetic field: by minimum energy condition (equipartition)**
- **Kinetic power: energy requirements**
- **Jet Mach number: indication of shocks**
- **Jet velocity: jet one-sidedness**
- **Jet density: jet numerical modelling**

Observed morphologies:
The Fanaroff-Riley classification

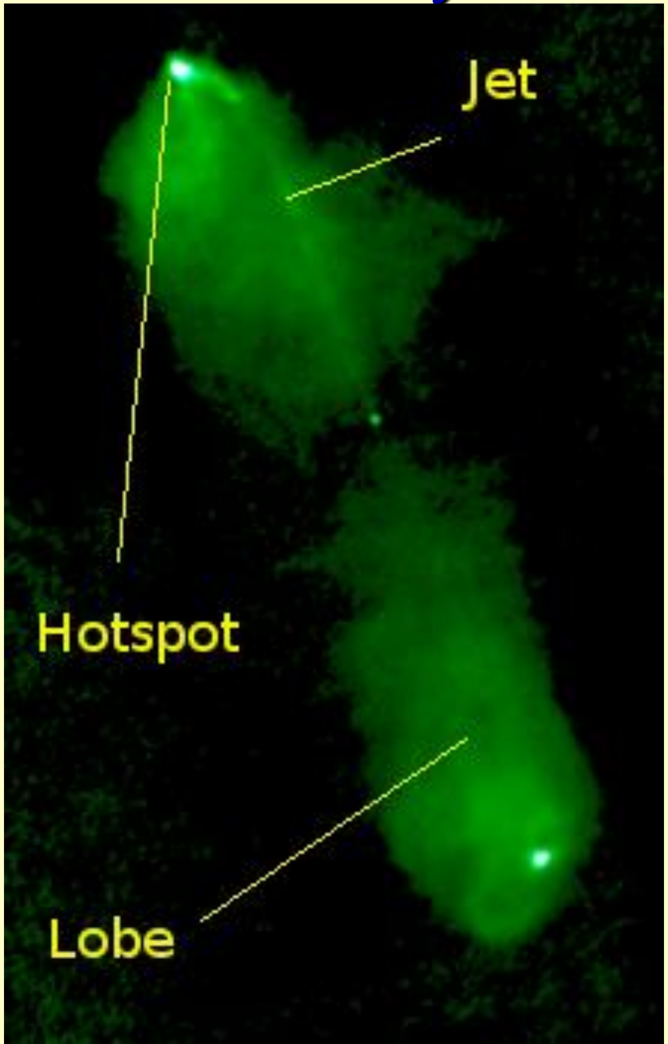
FR I or jet dominated



3C 31
VLA

FR II or lobe dominated (classical doubles)

3C 98
VLA



FR II only have Hot-spots!

- **SMBH: Where are, what are and how we find them**

What is a SMBH?

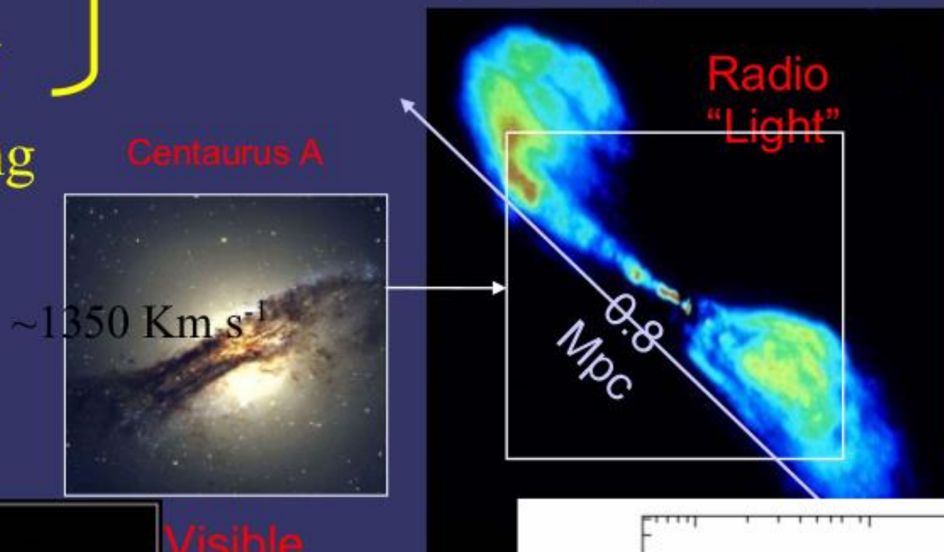
- Mass: 10^{8-9} M_{sun}
- Localisation: Center of galaxies
- Proposed formation mechanisms:

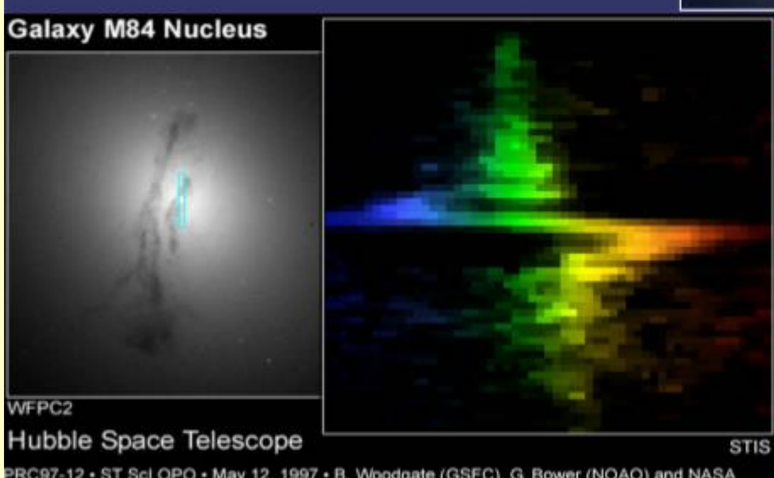
a) Population III stars: accretion, mergers, accretion+mergers
b) Collapse of gas clouds
c) Collapse of stellar clusters

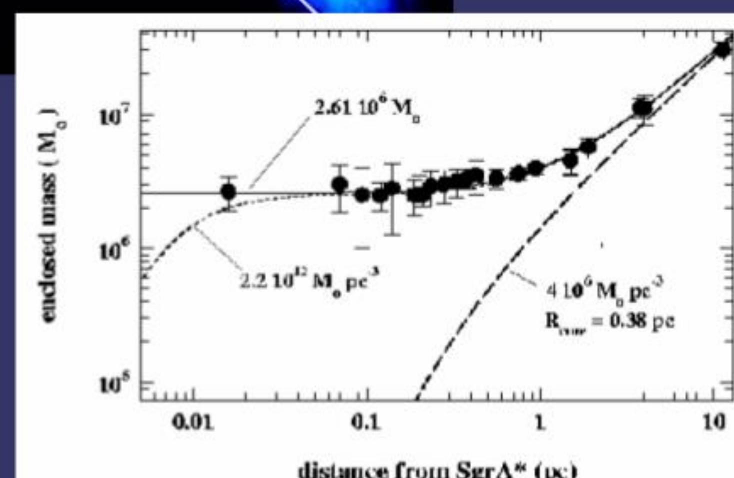
How to find a SMBH?

- X-Ray Emission
- Radial Velocity
- Rotational Velocity
- Gravitational lensing

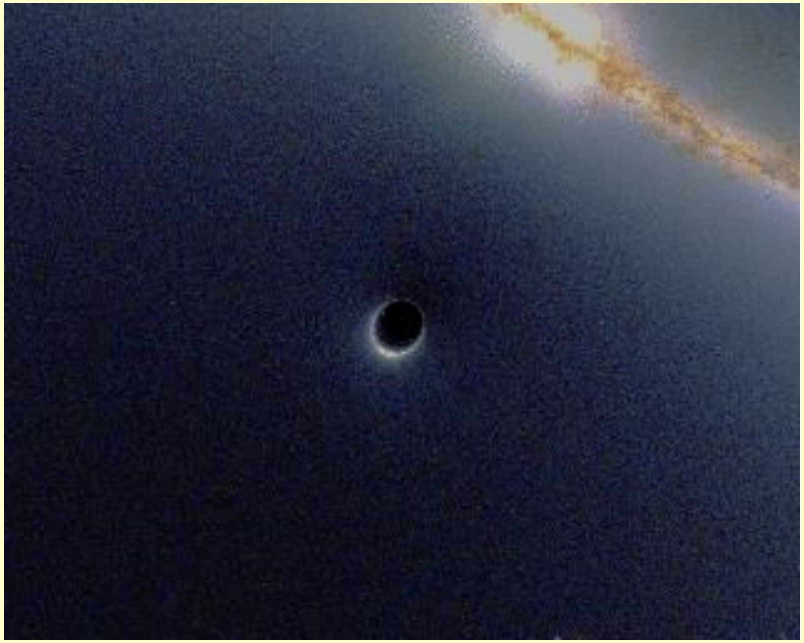
} 10^6 - 10^9 $M_\odot$ ➡ **NO STAR**





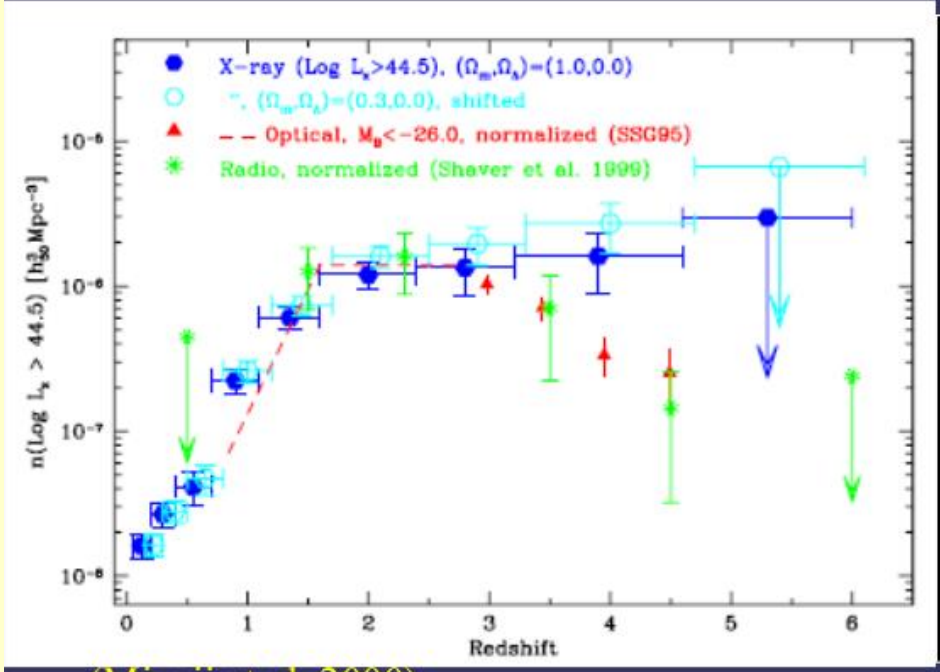


Gravitational Lensing

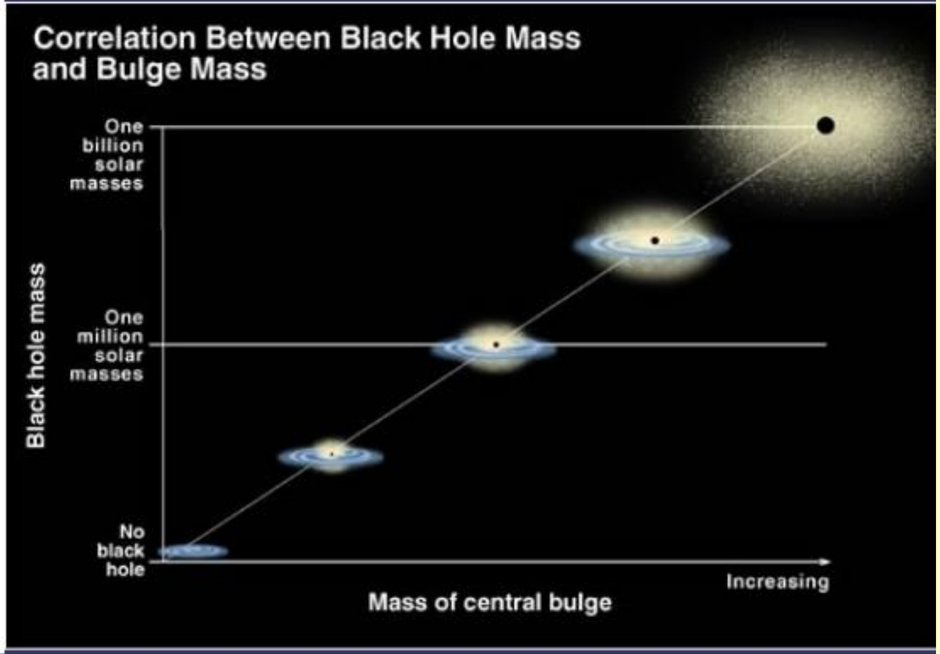


What do we know about SMBH?

- Present in nearly all active and non-active luminous galaxies
- Quasar population
- High z and Low z quasar similar properties – indistinguishable
- Mass proportional to the mass of bulge
- M ~ 0.2% M galaxy



(Miyaji et al. 2000)



Population III stars

- Very low, or zero, metallicity
- Formation within 10^{6-7} yrs from Big Bang
- Stars that no longer exist, but affected the environment of the early Universe
- Form from primordial "molecular" clouds
- Surface temperature ~10^4 K
- Mass up to 1000 M_{sun}

- **SMBH formation**

Pop III stars: Accretion

The process is thought to start with a Population III star as a *seed* in the earlier Universe.
These stars collapse at the end of their lives to form BH's.
These BH's emitting at Eddington luminosity and accreting gas at Eddington limit with a efficiency of 10% would last about 7×10^8 yrs to become a SMBH of mass $10^9\ M_{sun}$.
SMBH at high *z* cannot be explained by this theory.

A plausible explanation for these SMBH's at high *z* is that some period of time they accrete at Super-Eddington rate and the rest of their life at Eddington rate.

Accretion

The Eddington limit:

$$L_{Edd} = \frac{4\pi GM}{\kappa} = 1.25 \times 10^{38} \left(\frac{\mathrm{M}}{\mathrm{M_{sun}}}\right) \boldsymbol{erg/s}$$

Accretion on a BH, luminosity:

$$L_{accretion} = \varepsilon \, \dot{M} \, c^2$$

The emission at the Eddington limit:

$$L_{Edd} = L_{accretion}$$

The accretion at the Eddington limit:

$$\dot{M} = \frac{4\pi G}{\varepsilon \kappa c} M = kM$$

assuming ε=0.1 and κ=0.4 cm^2 g^{-1}

$$k = 7 \times 10^{-16} s^{-1}$$

The accreting object grows as:

$$M = M_0 e^{kt}$$

That is a growth by a factor of *e* in a time scale:

$$\tau = 4.5 \times 10^7 yrs$$

Thus a BH seed of 1,000 M_{sun} will grow up to a SMBH of 10^9 M_{sun} in 7×10^8 yrs
Not at high z(>4) !
Super-Eddington accretion.

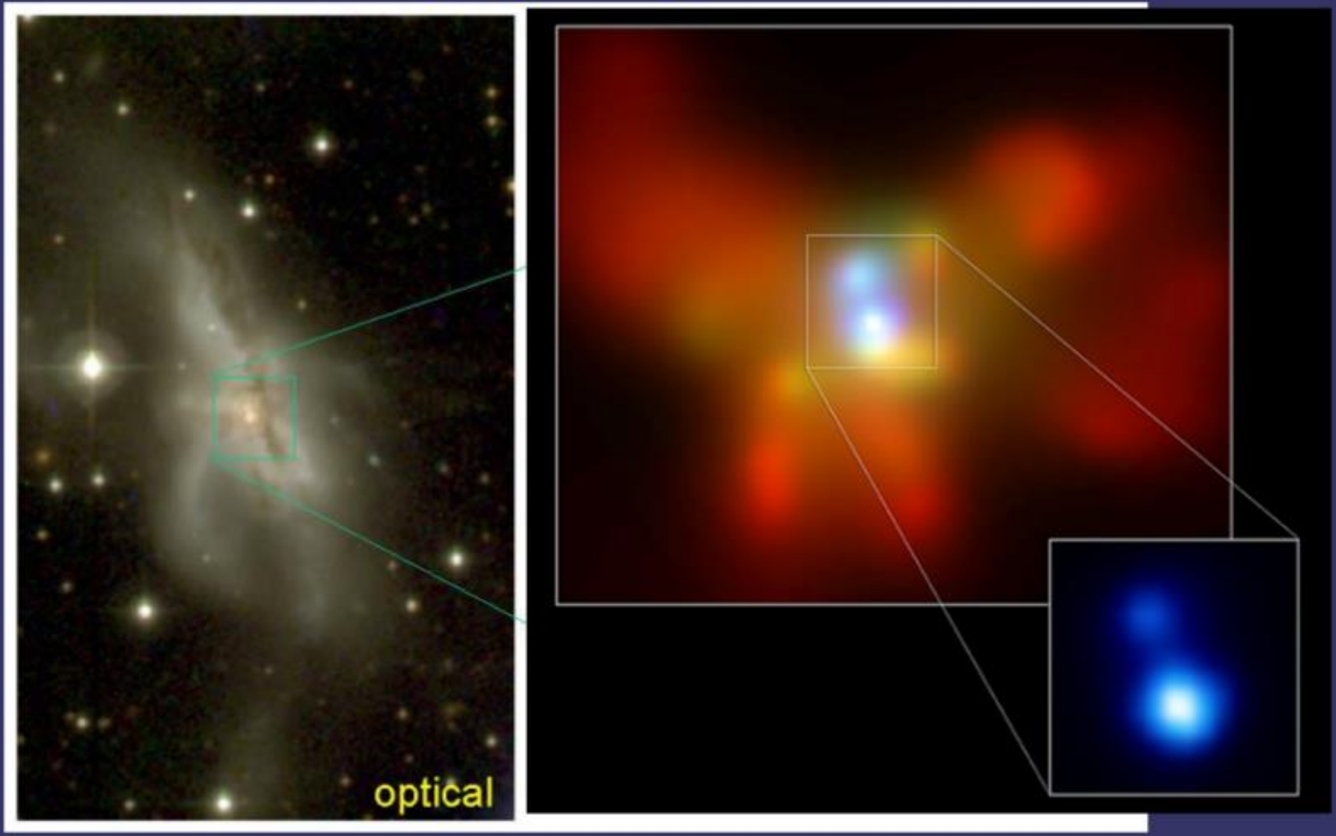
Pop III stars: Mergers

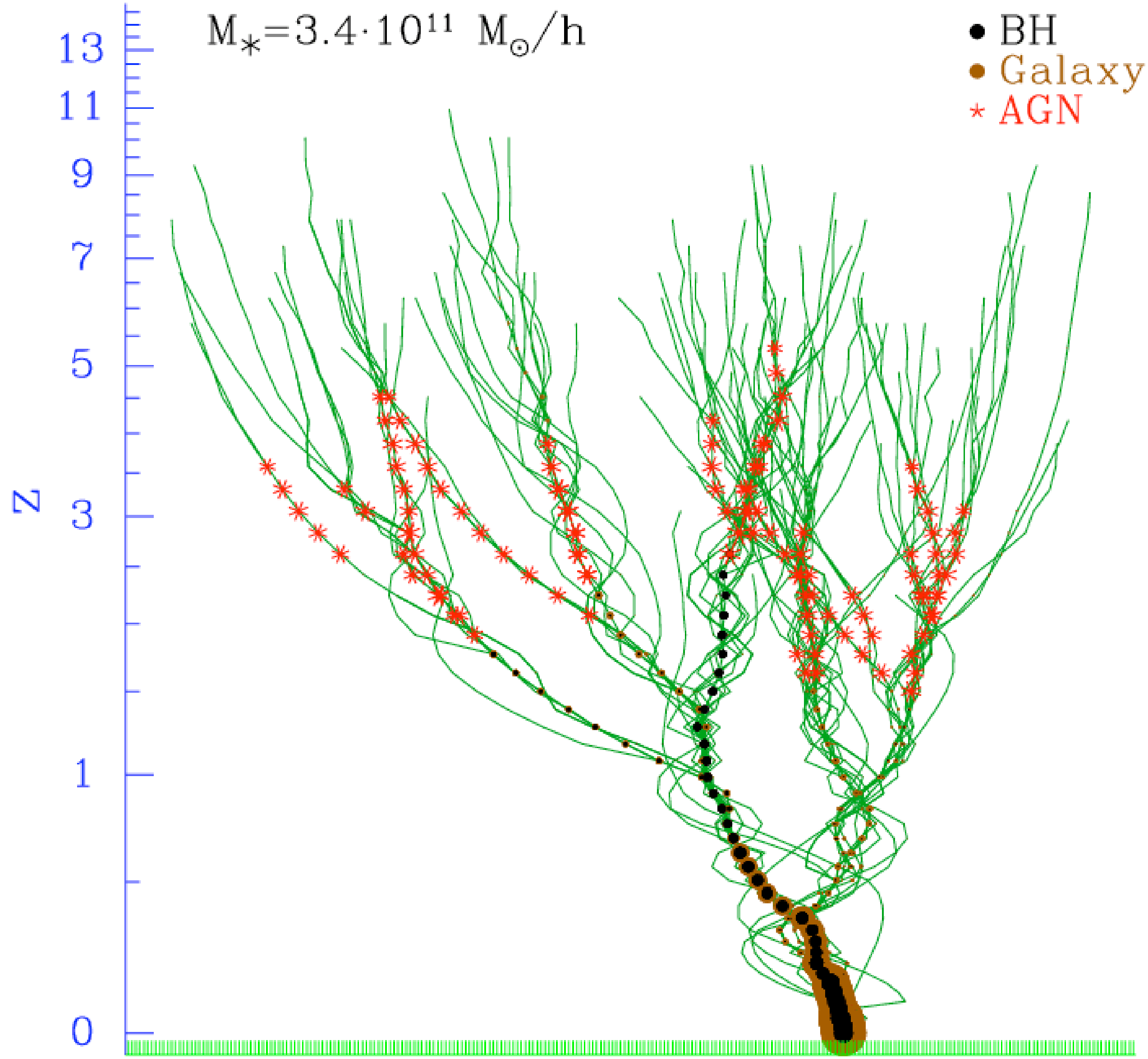
Again the process is thought to star with a Population III star as a *seed* in the earlier Universe which collapse and form a BH. This BH will grow by mergers with others BH and Intermediate BH (IBH). The total number of mergers depends on the mass of Seeds and the mass of Dark Matter Halos.

In a normal case a total of 10^{2-3} dark matter halos are needed to form a SMBH. This big number tells us that the theory is not valid alone.

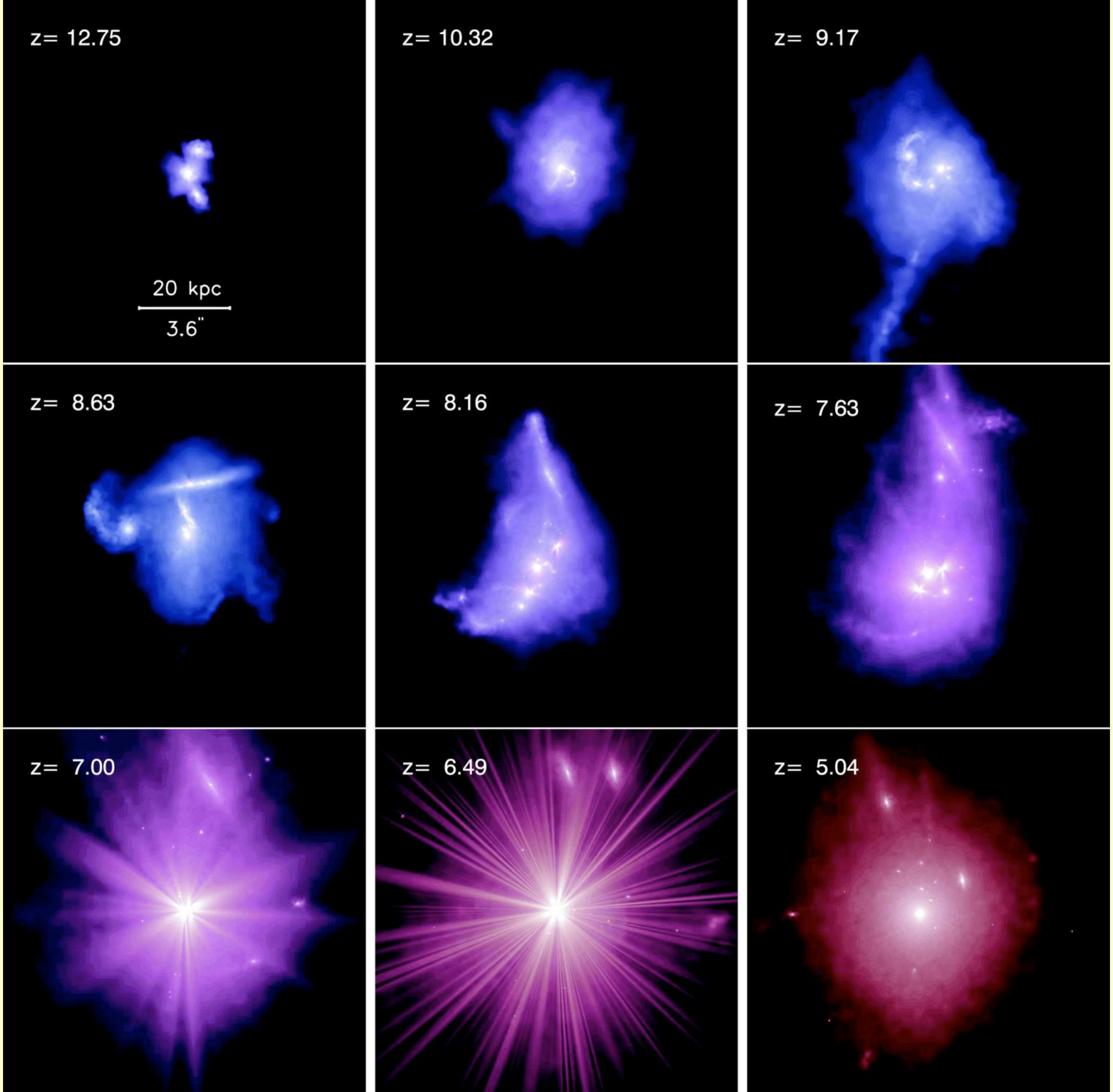
1 - Population III stars: Mergers

- NGC 6240
- First evidence of SMBH Mergers
- 3000 light years apart





$M_* = 3.4 \cdot 10^{11}\ M_\odot/h$
BH
Galaxy
AGN
z
13
11
9
7
5
3
1
0


z= 12.75
20 kpc
3.6"
z= 10.32
z= 9.17
z= 8.63
z= 8.16
z= 7.63
z= 7.00
z= 6.49
z= 5.04

Pop III stars: Accretion+Mergers

The most plausible theory is the combination of Accretion and Mergers. In this case some authors claim that the proportions would be: 10% Mergers + 90% Accretion

Collapse of Gas Clouds

This theory is based in that a gas cloud can collapse to form a SMBH via a supermassive star or via a disk. This theory is only valid if fragmentation of the gas cloud into stars can be avoided.
Conditions necessary to avoid star formation in the gas clouds are given, along with a possible outcome for the formation of the SMBH.

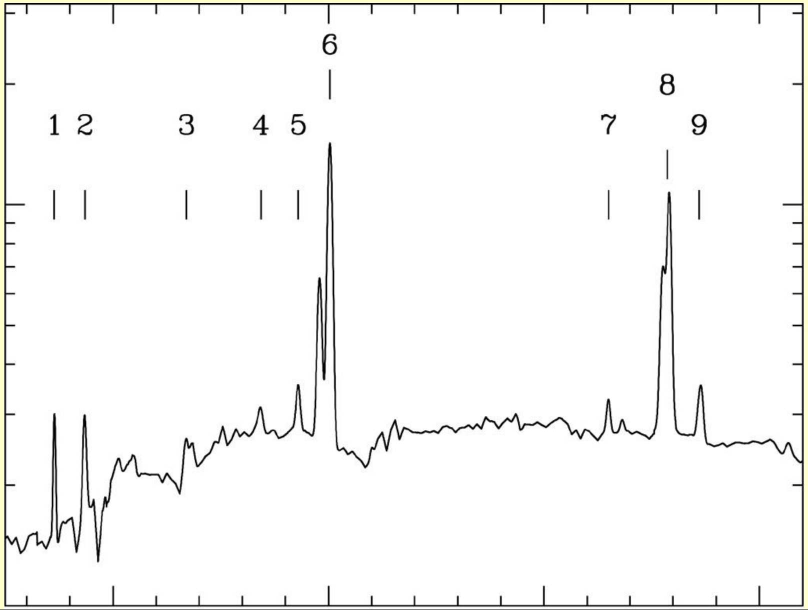
Collapse of Stellar Clusters

This theory is based in the possibility of that a stellar cluster collapse to form a SMBH. Conditions necessary for the collapse are given, so as other possible variation of this theory.

- **Historical Notes**

- E.A. Fath (1908): discovered strong emission lines in the spiral "nebula" (now galaxy) NGC 1068
- C.K. Seyfert (1943, ApJ, 97, 28) obtained high dispersion spectra of 6 spiral galaxies with high excitation nuclear emission lines
  - NGC 1068, 1275, 3516, 4051, 4151, 7469
  - broad emission lines (5000 km/s) attributed to Doppler motions
- Various radio surveys (1950s; 3C, PKS, etc.) discovered sources identified optically as quasi-stellar radio sources
- M. Schmidt (1963) realized that broad lines in the quasar 3C 273 were redshifted nebular lines ($z = 0.158$)
- Eventually, it was realized that quasars (and optically discovered QSOs) are distant, high-luminosity analogs of Seyfert galaxies
- Khachikian and Weedman (1974) defined two types of Seyferts:
  - Seyfert 2s: narrow permitted and forbidden emission lines
  - Seyfert 1: same lines as Seyfert 2s plus broad permitted emission lines

Seyfert 2 NGC 1068



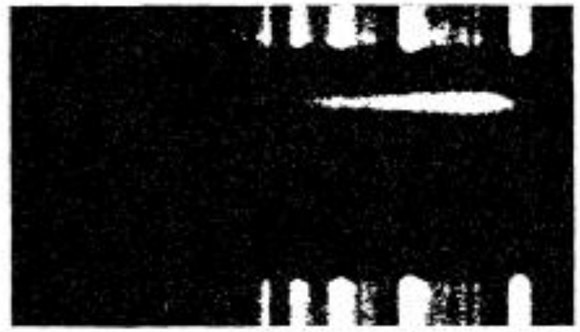


Fig. 3. SPIRAL NEBULA. N. G. C. 1068

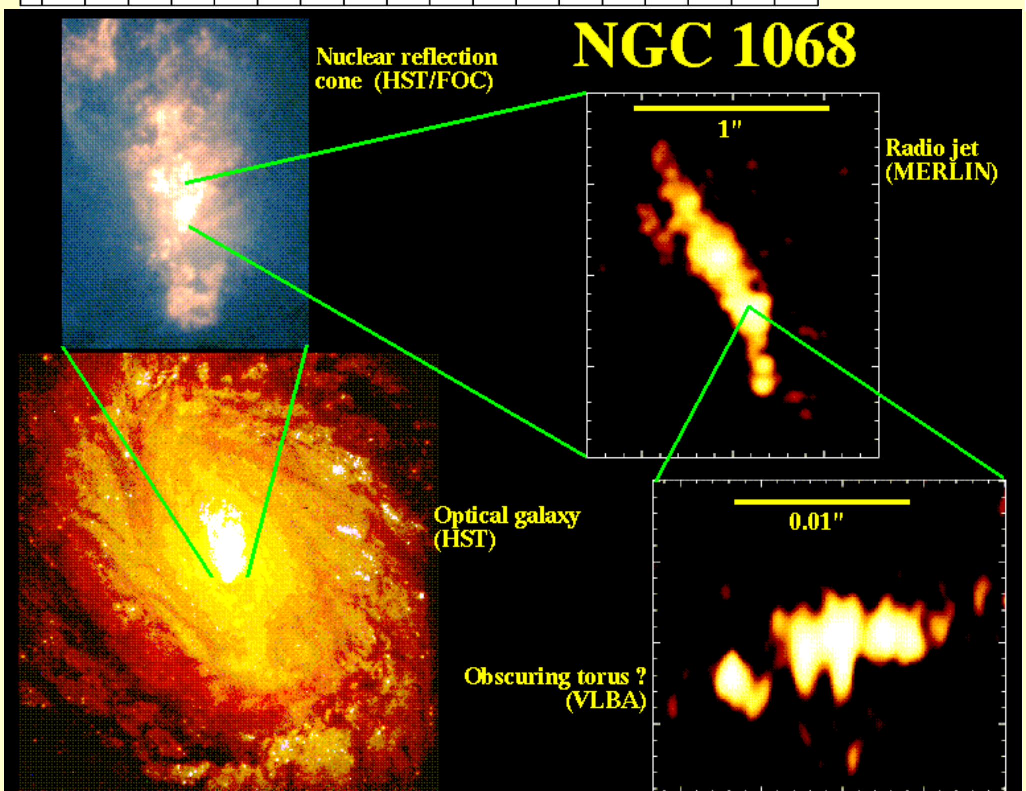
The spectrum is composite, showing both bright and absorption lines. The bright lines are:

λ	Intensity
3733	5
3878	4
4363	3
4959	1
5007	3

'here is a slight indication of bright Hβ. The rption lines are:

λ	Intensity
3845	1
3935	2

'he maximum intensity is at λ 4660.



Grazie per l'attenzione