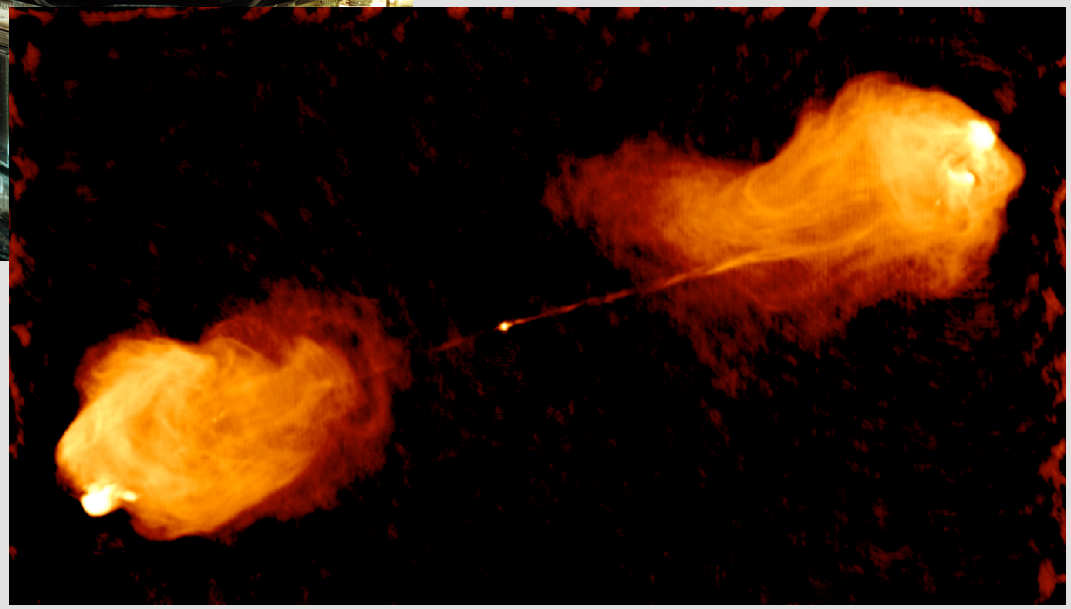
I am Regius Professor of Astronomy.

I work here...



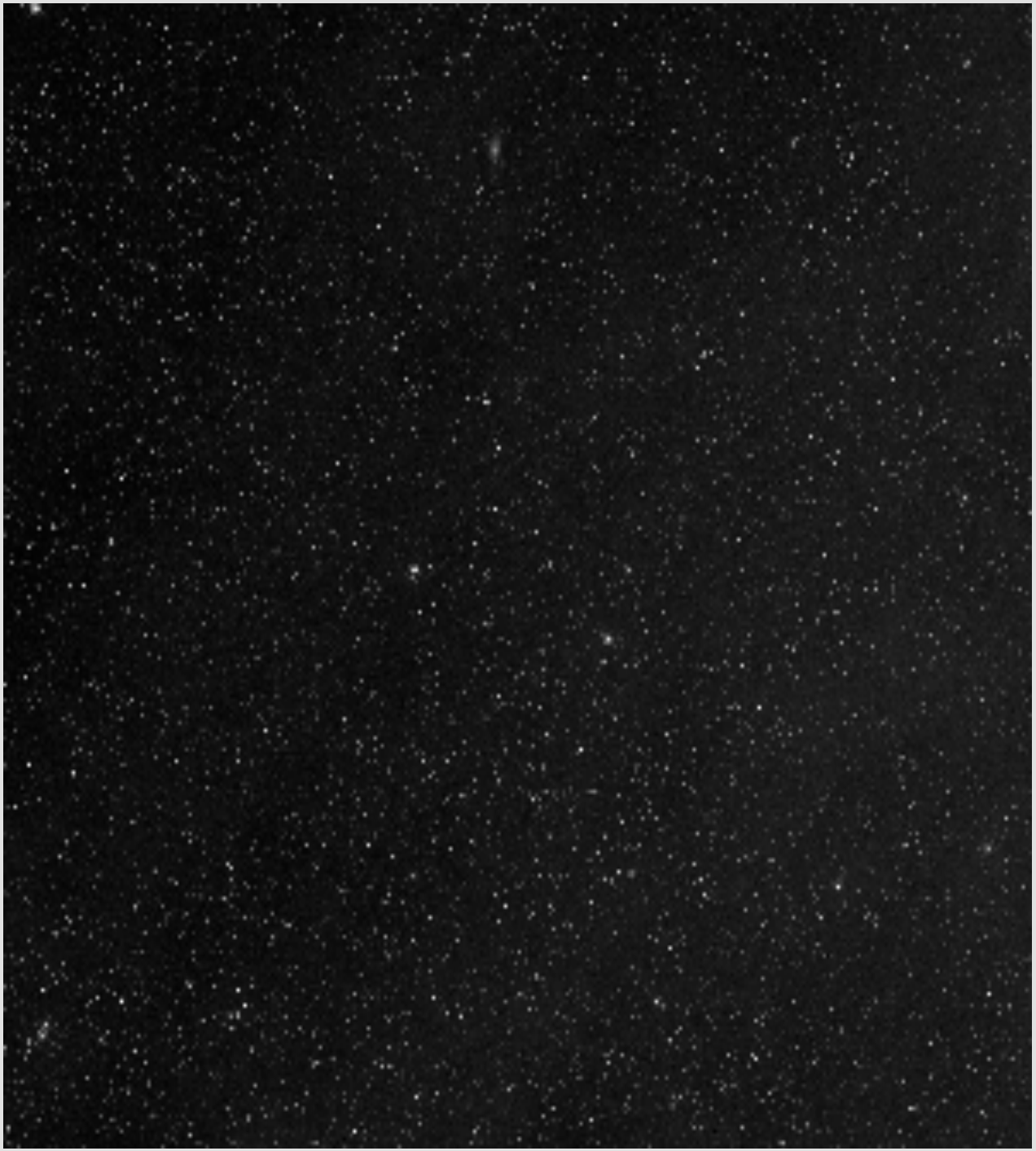
... and I love these !

Hunting the Dragon

The mystery of Active Galactic Nuclei

Andy Lawrence

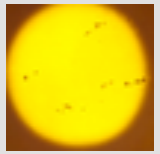

Whats out there ?

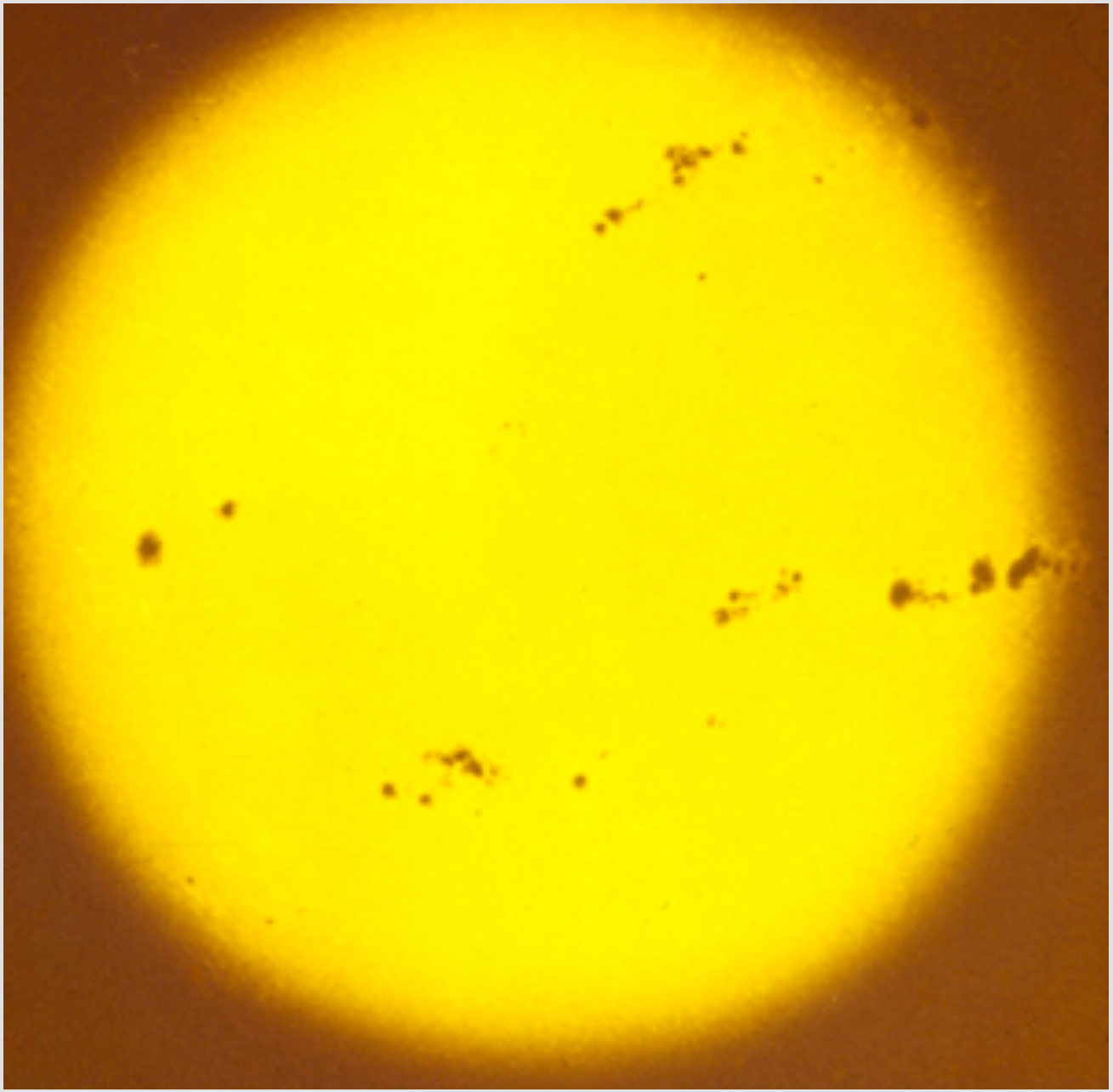


The sky at night...

... lots of stars

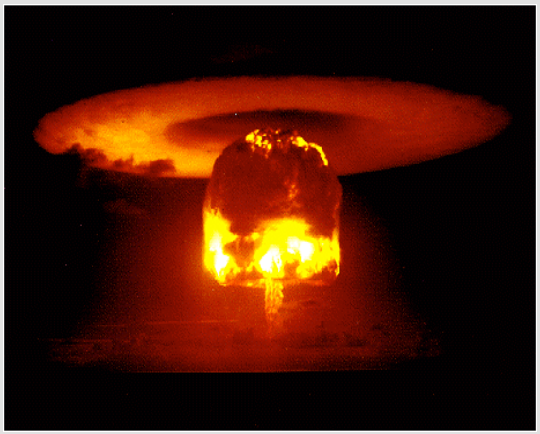
Every star is another Sun





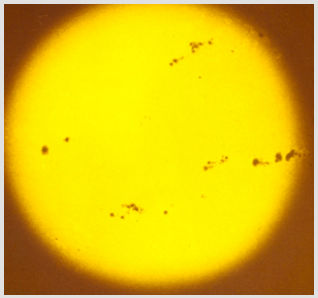
A big burning ball of gas

Ten billion bombs a second



Where does that energy come from ?

Solar energy



Direct source : fusion of atoms – just like H-bomb

But that only works in a VERY hot gas

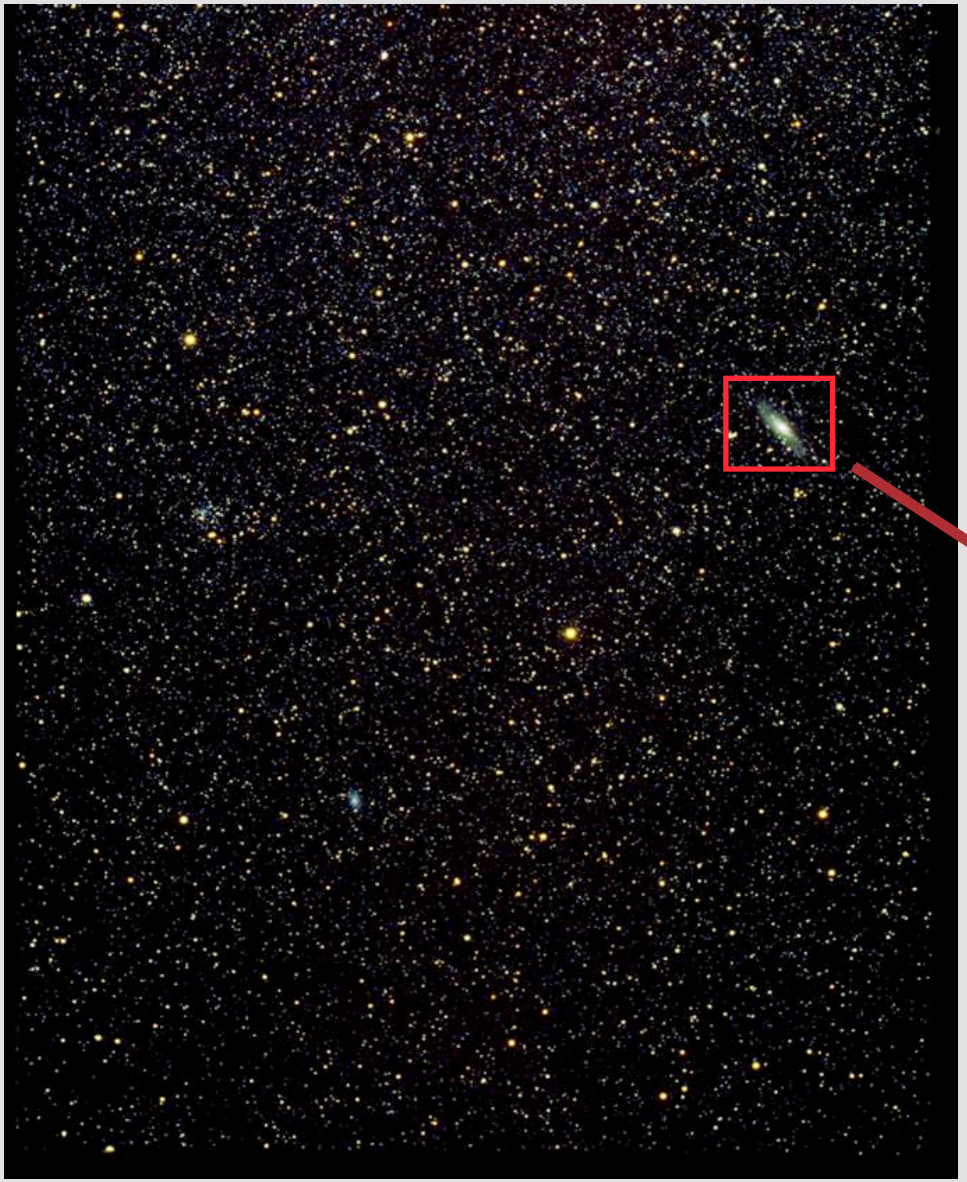
Why is the Sun so hot ?

Fundamental answer : gravity

You can gain energy by dropping things,
or by shrinking things

low-tech demo...

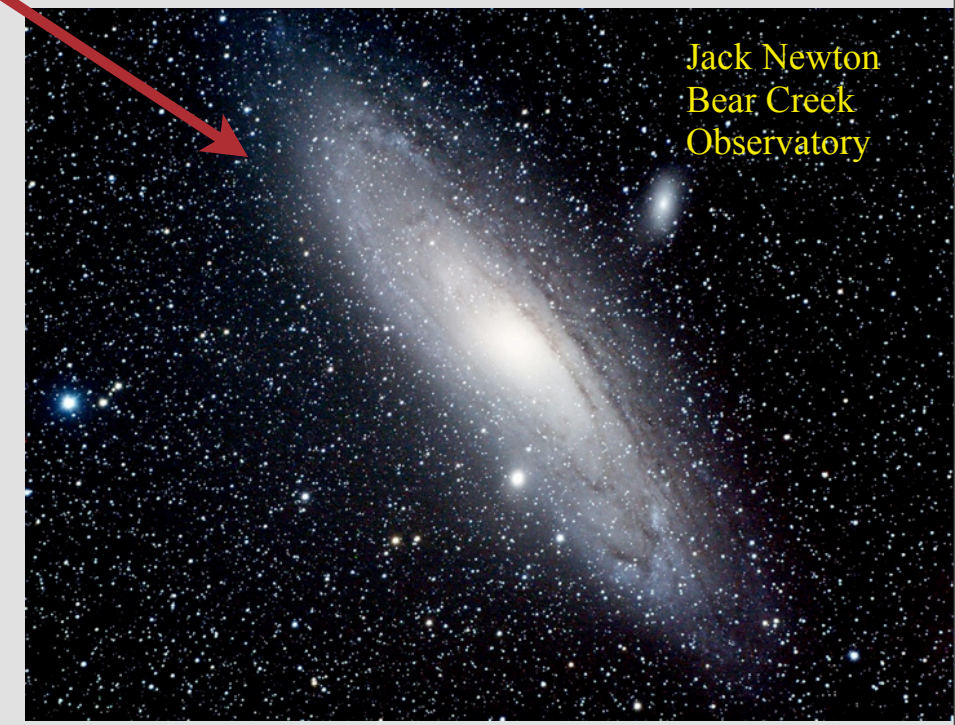
Not everything in the sky is a star ...



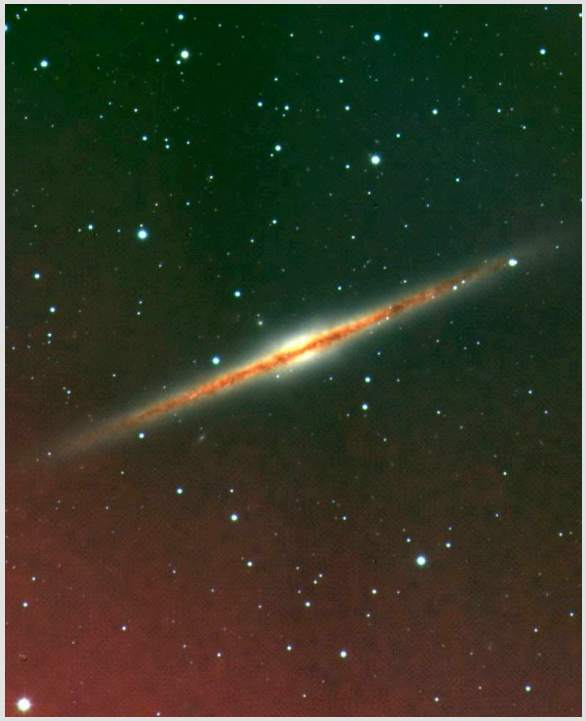
The fuzzy patches are galaxies : cities of stars outside our own

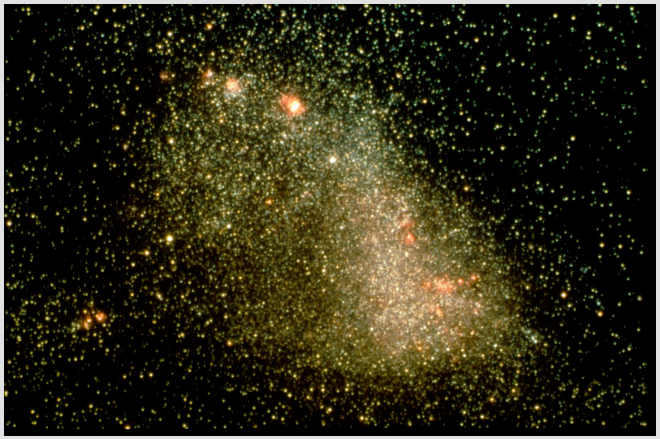
Edwin Hubble

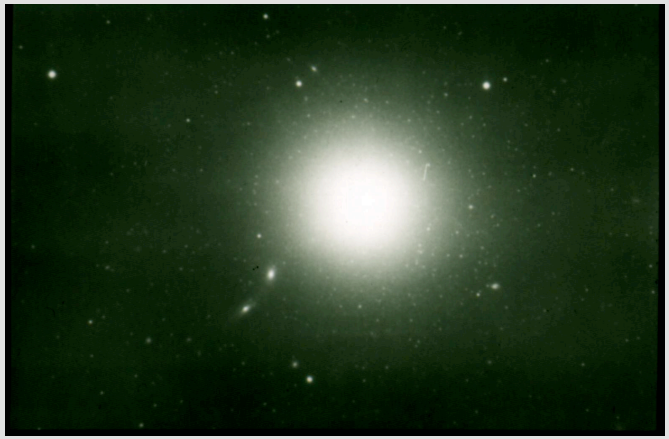
M31 Andromeda Nebula



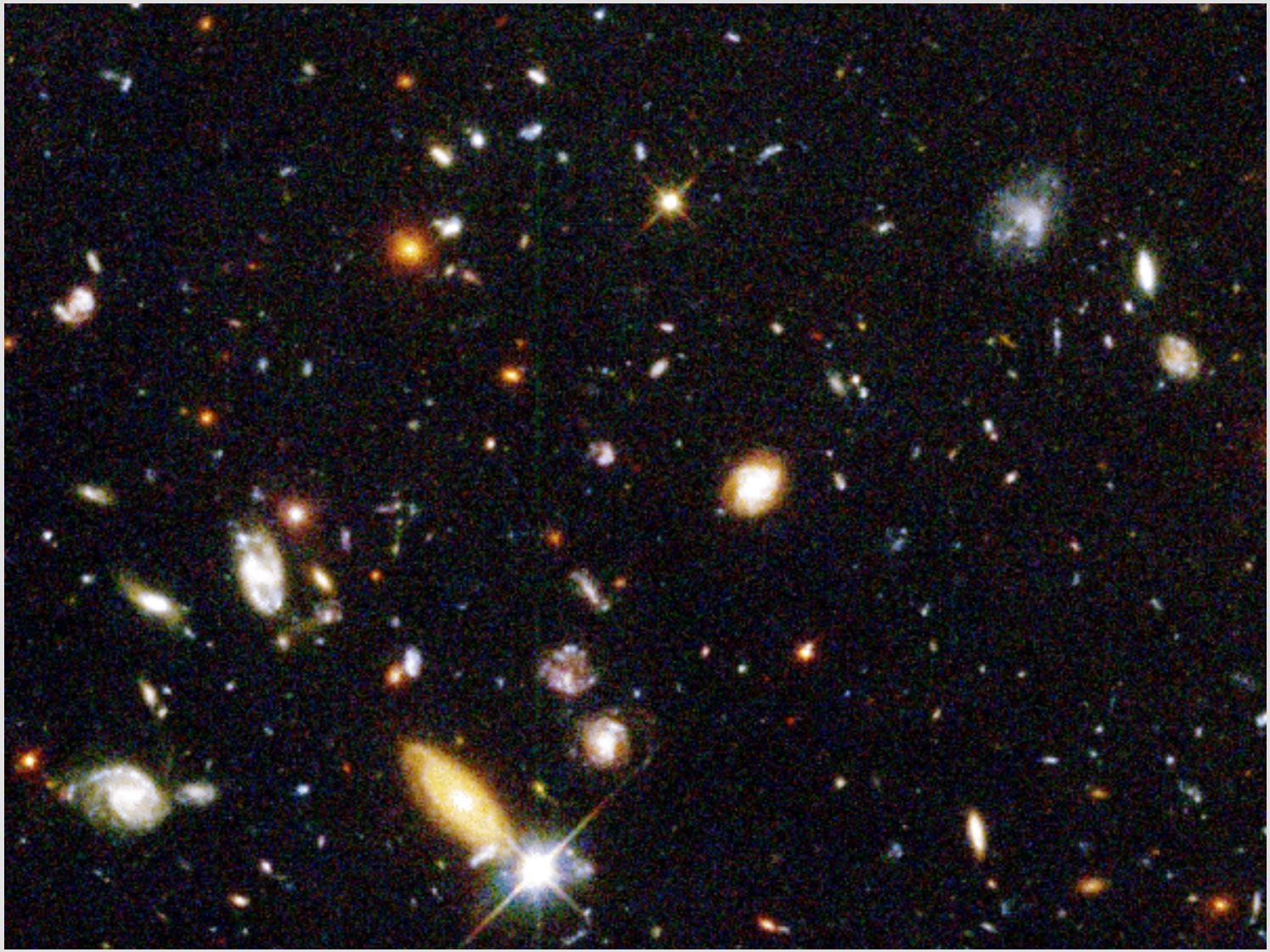
There are lots of galaxies ! They are the basic building block of the Universe.



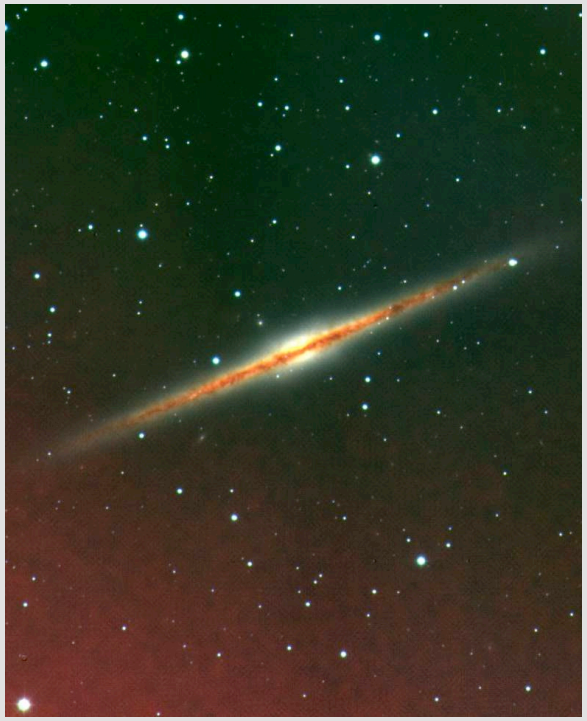


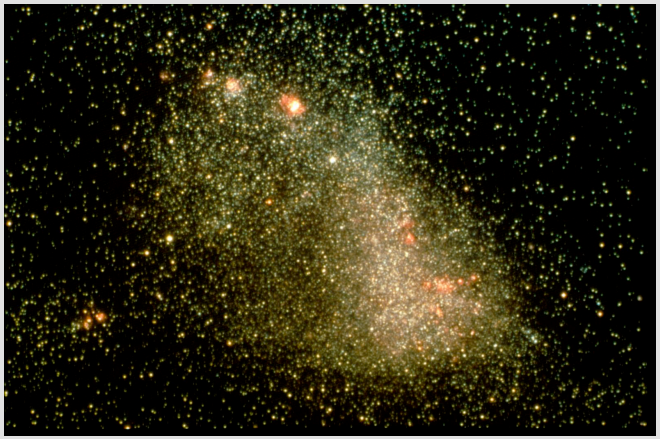


Galaxies as far as we can see

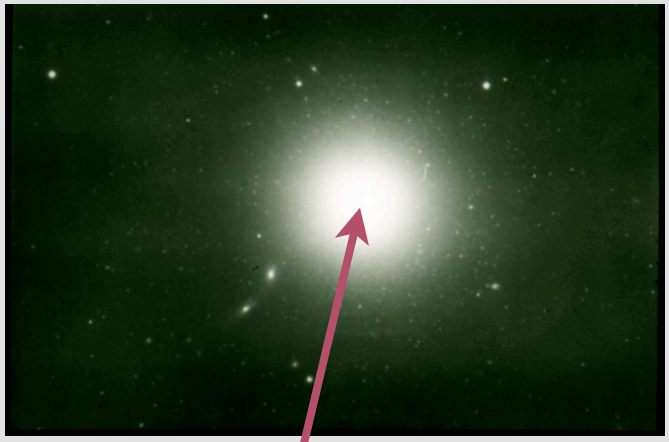


very faint galaxies in the Hubble Deep Field

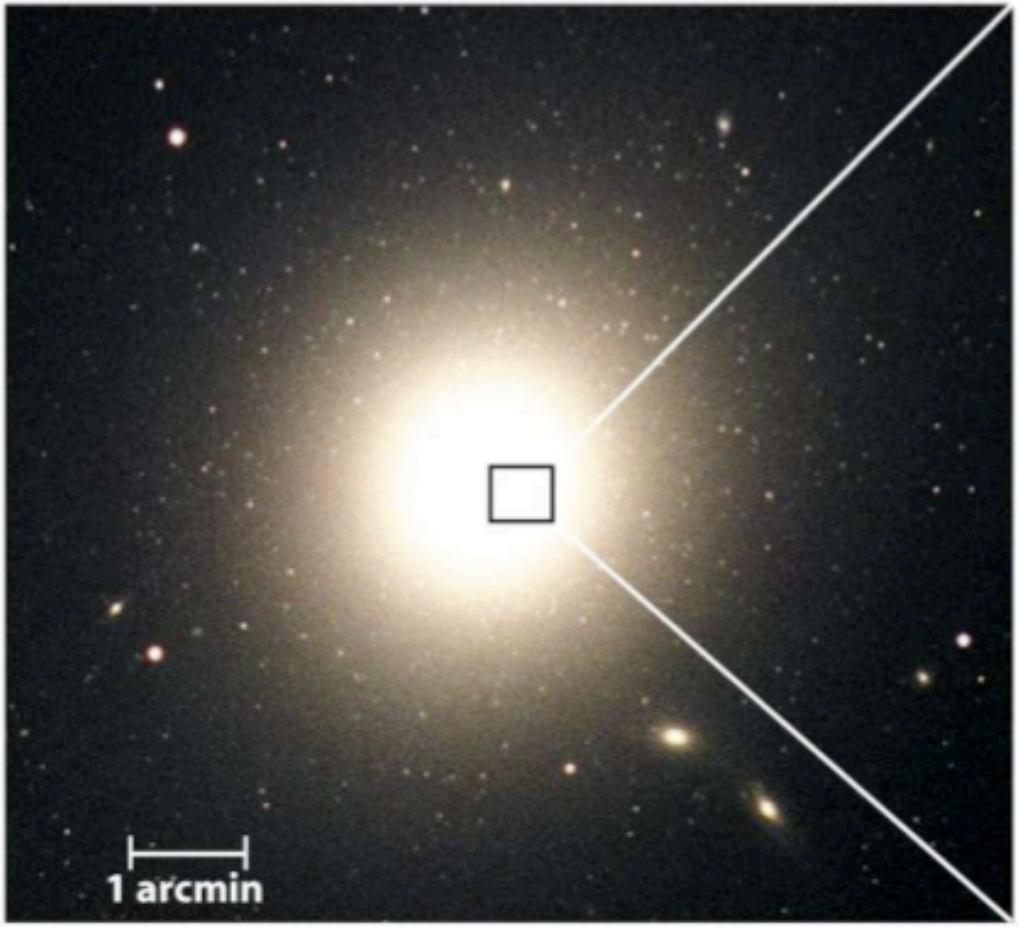




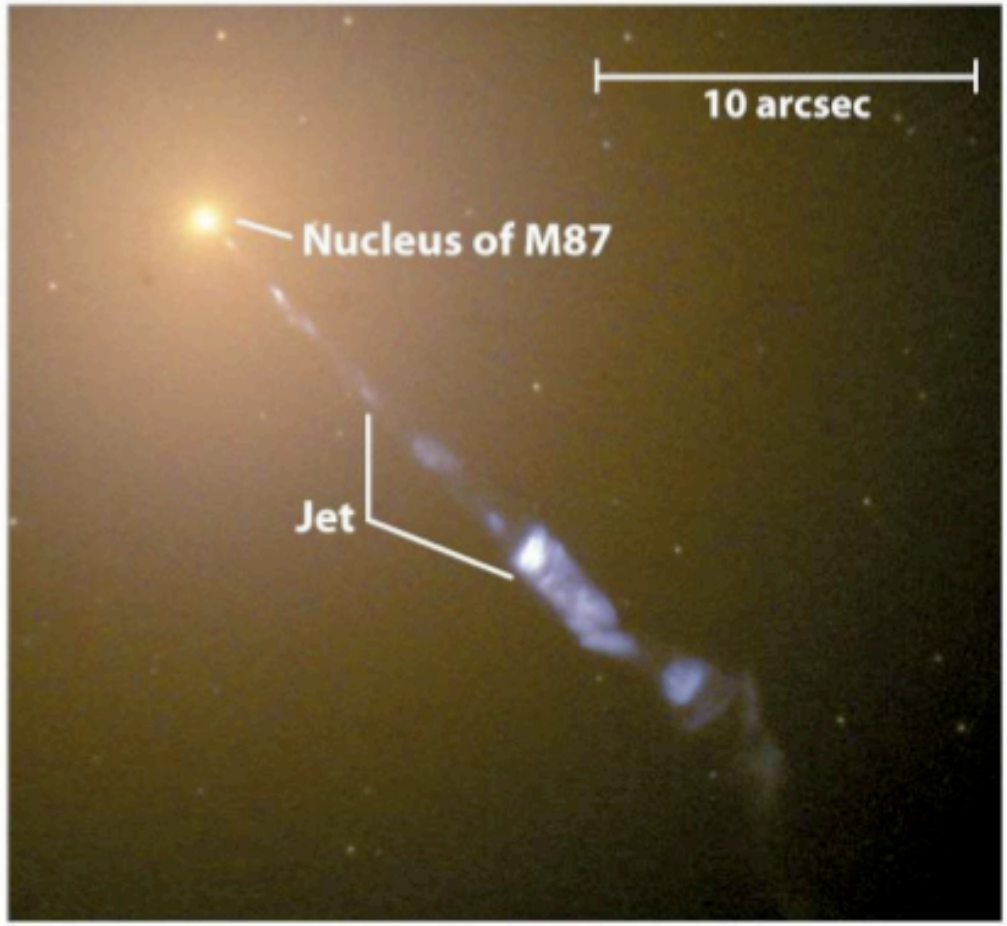
some are irregular



but most have a well defined centre or **nucleus**



(a) The giant elliptical galaxy M87

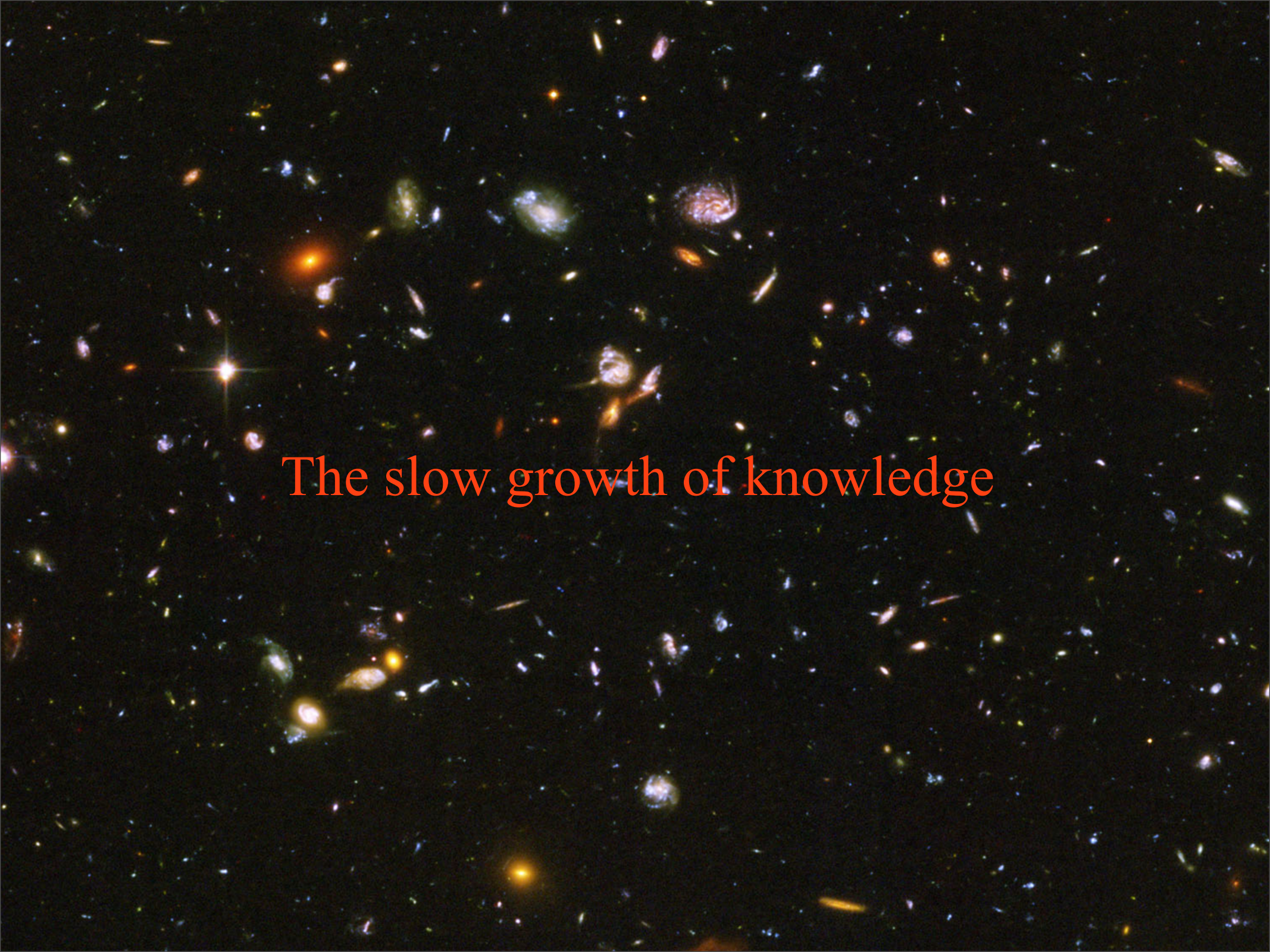


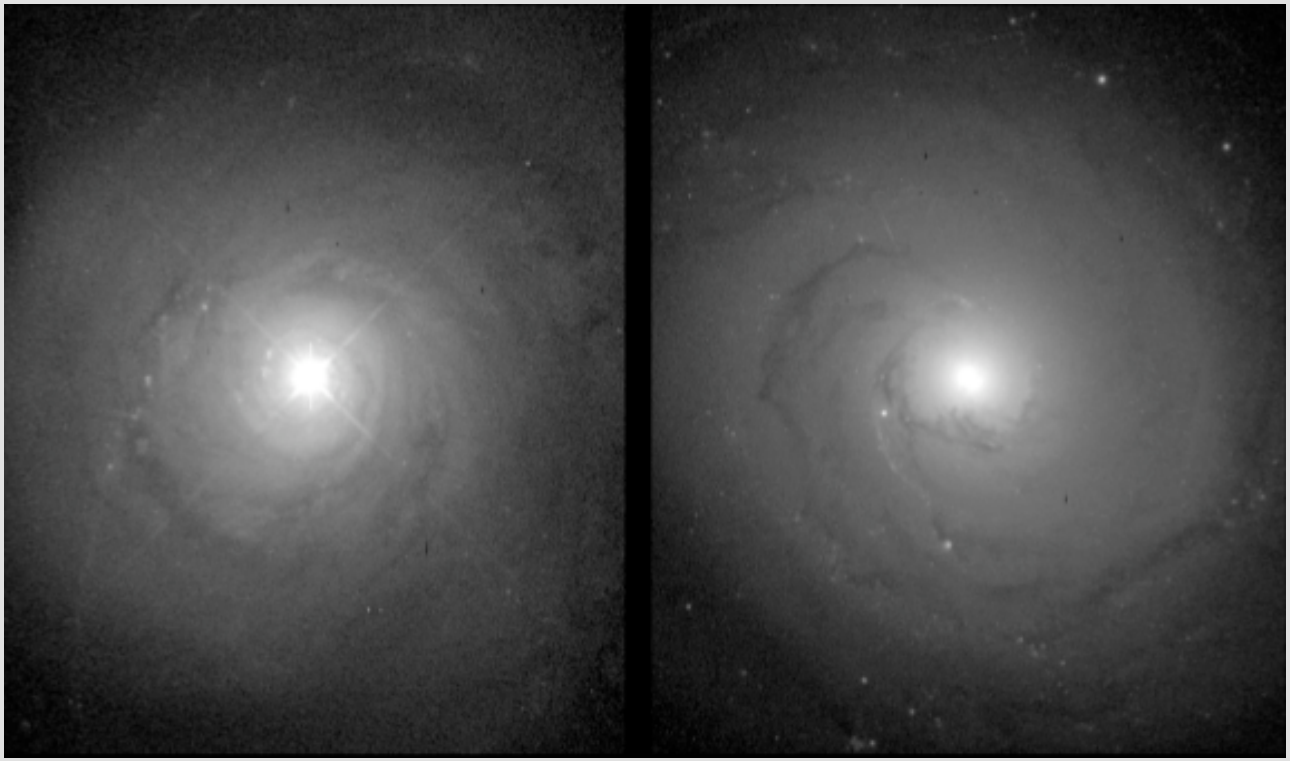
(b) A shorter exposure reveals M87's jet

The nuclei of some galaxies obviously have something strange going on.... first sighted but not understood almost a hundred years ago

1918

Such objects now known as "Active Galactic Nuclei" (AGN)

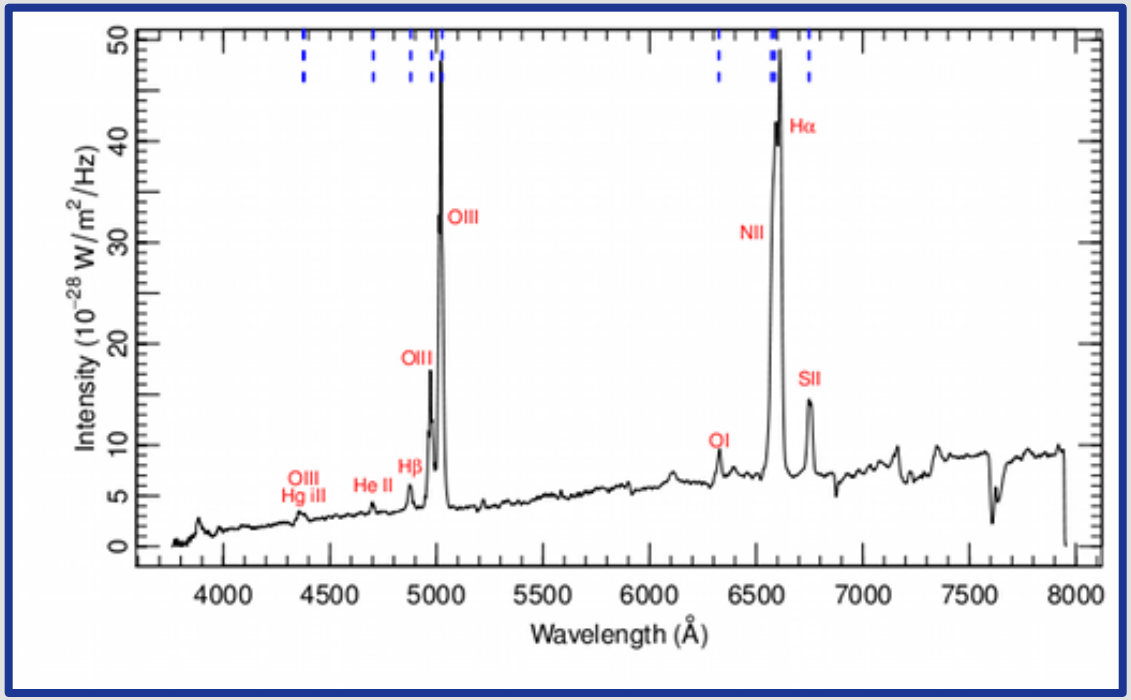

The slow growth of knowledge



Some galactic nuclei are especially bright and starlike

First studied by Carl Seyfert

1940s

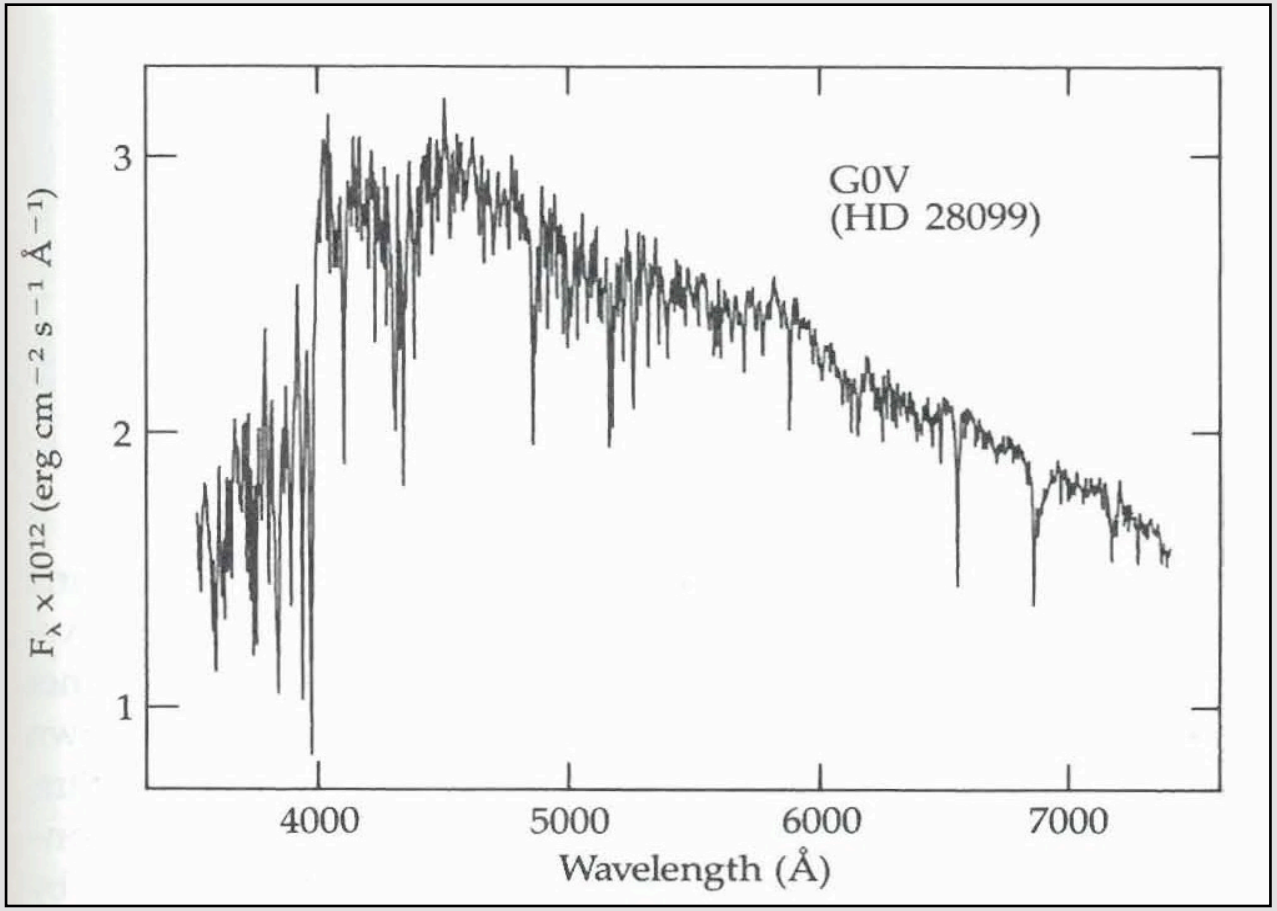


They show "emission lines" in their spectra – whats this all about ?

Time for an explanatory digression....

Techy bit : spectra

Light from a star spread out into a spectrum



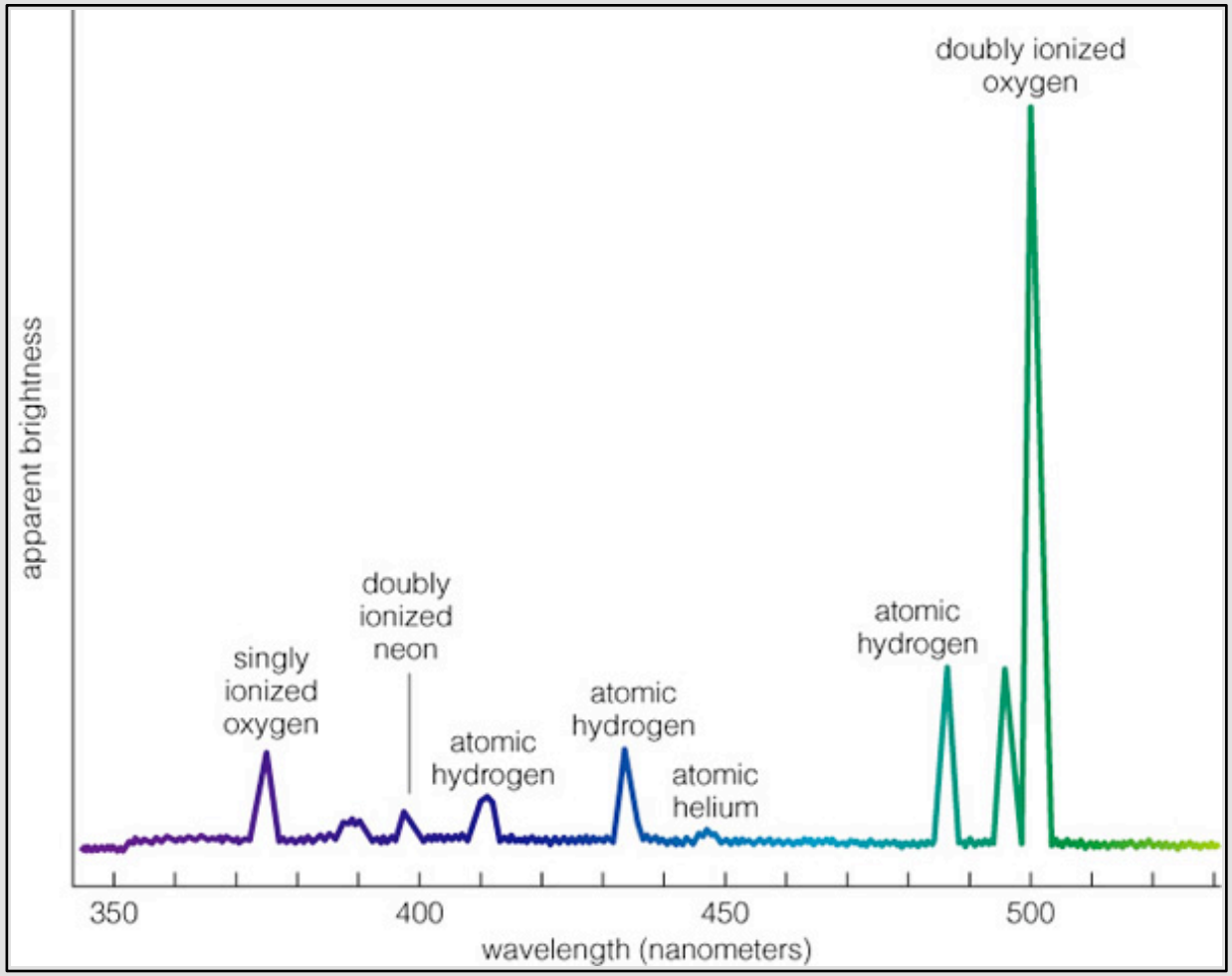
brightness

Graph of the same thing

The dark lines are due to atoms **absorbing** light on the way out of the star

blue ⟷ red

brightness

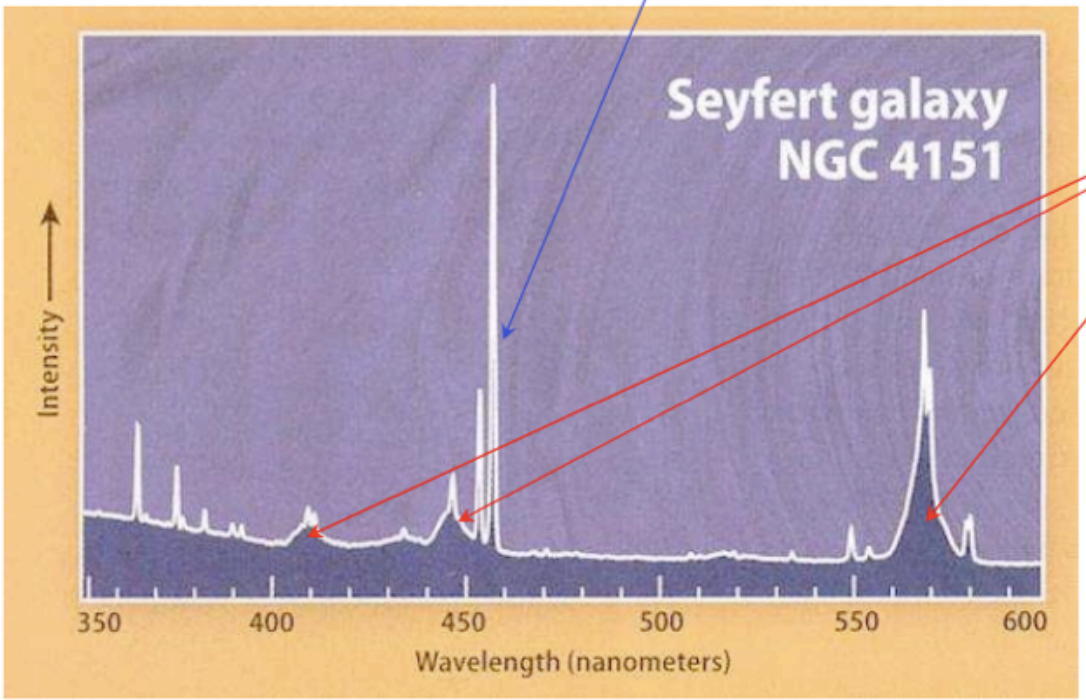


blue ⟷ red

Spectra of some gas clouds (like the Orion Nebula) have **bright lines** where a star would have dark lines

The atoms are excited by UV light from hot new stars in Orion

Narrow lines from further out from the galactic nucleus

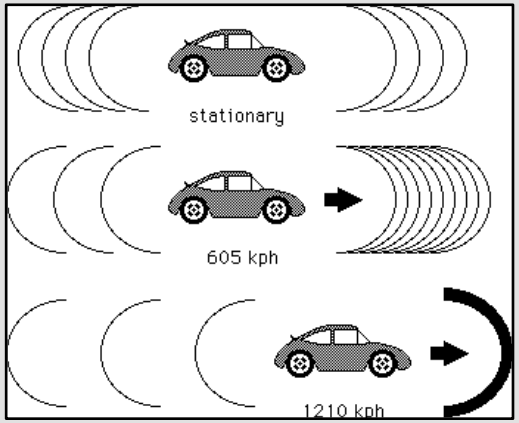


Broad lines from close to the galactic nucleus.

So AGN emission lines show there is gas in the nucleus excited by some bright UV source

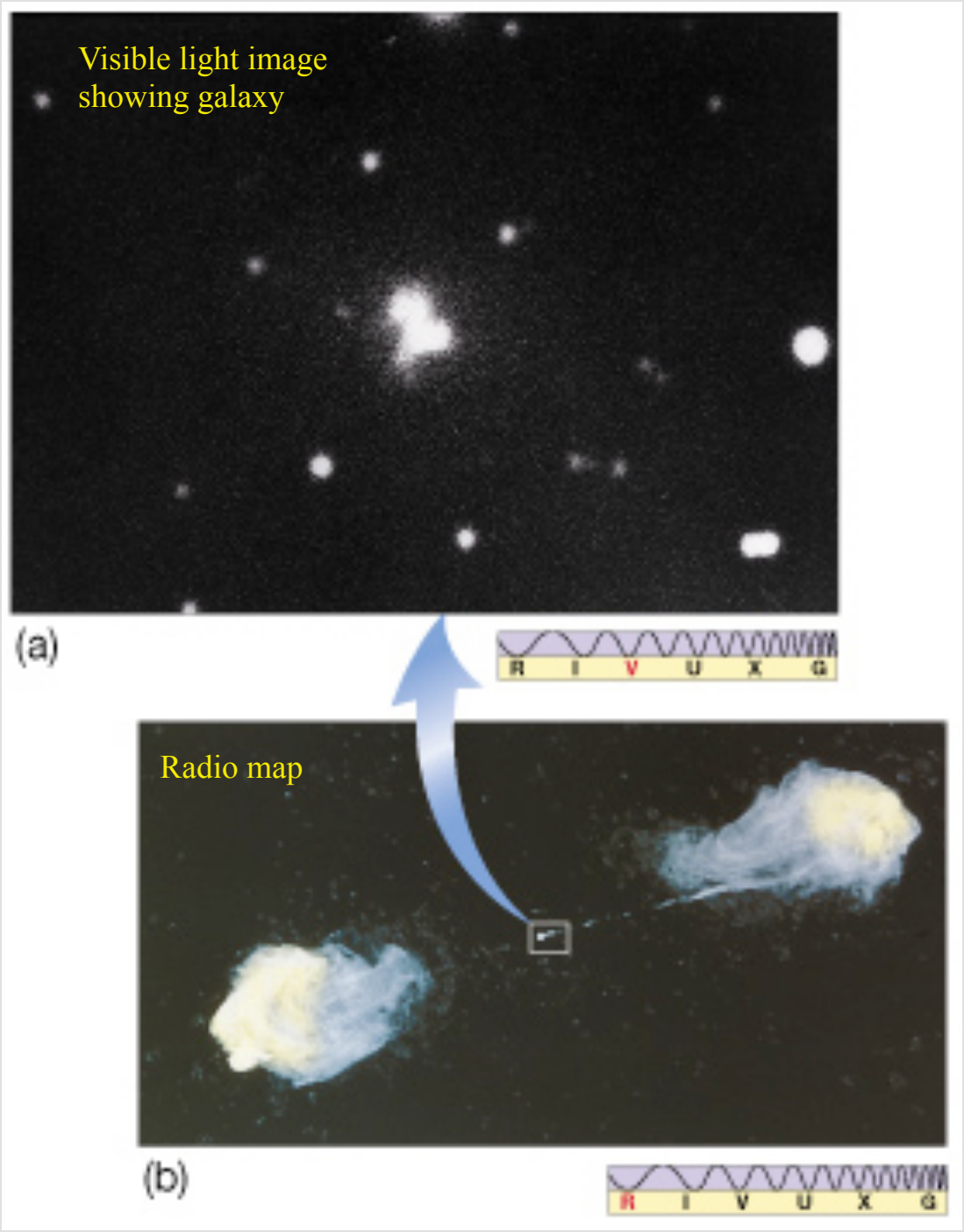
But the lines are **much wider** than the Orion lines. This is caused by the Doppler Effect and shows us the gas clouds are moving **very fast …**

Ten thousand km/sec …

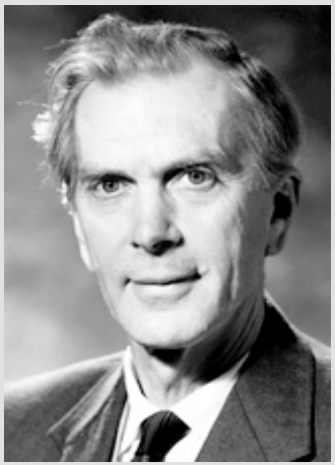


Another low tech demo ...

Radio galaxies



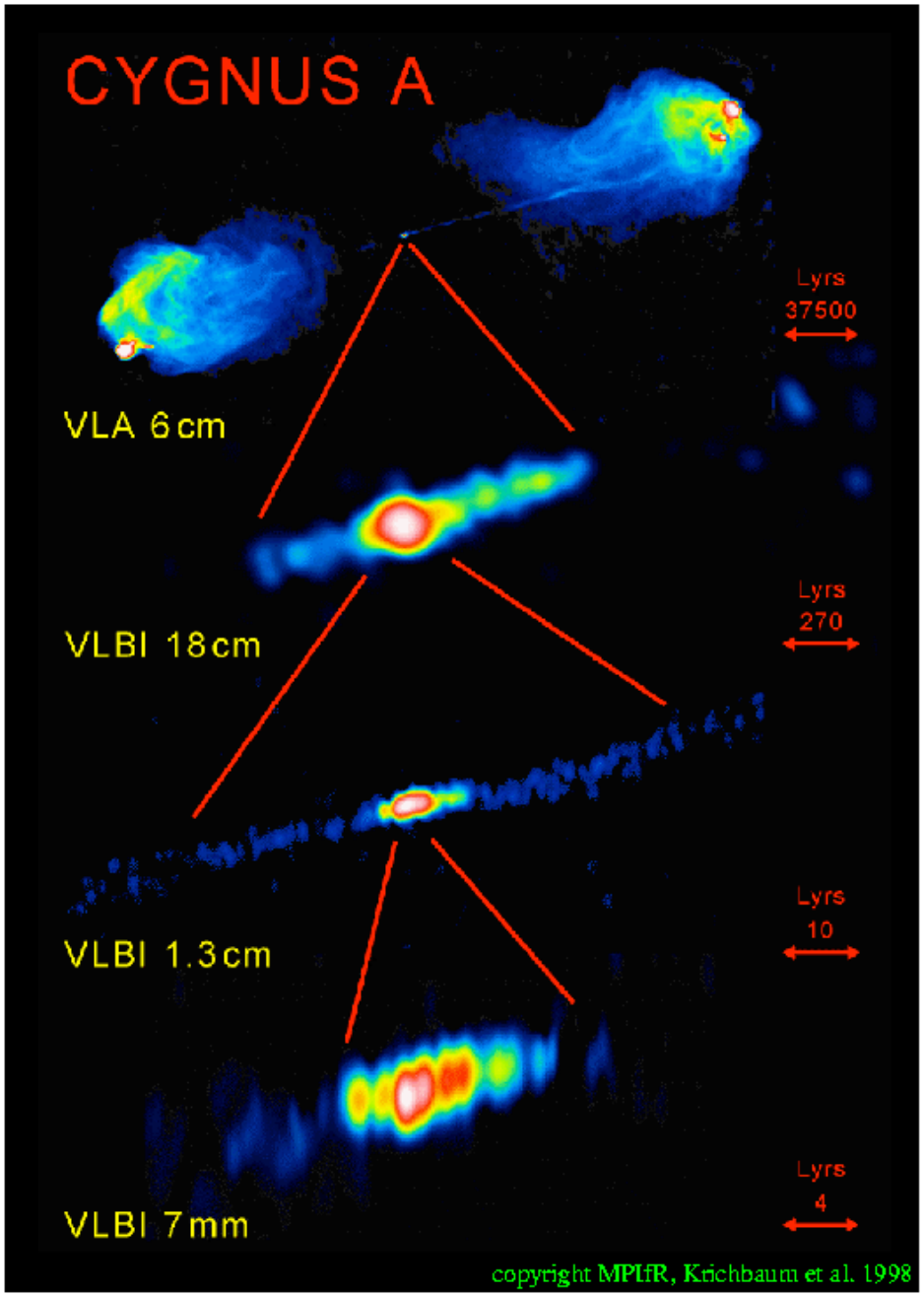
Martin Ryle



Huge radio lobes stretching millions of light years...

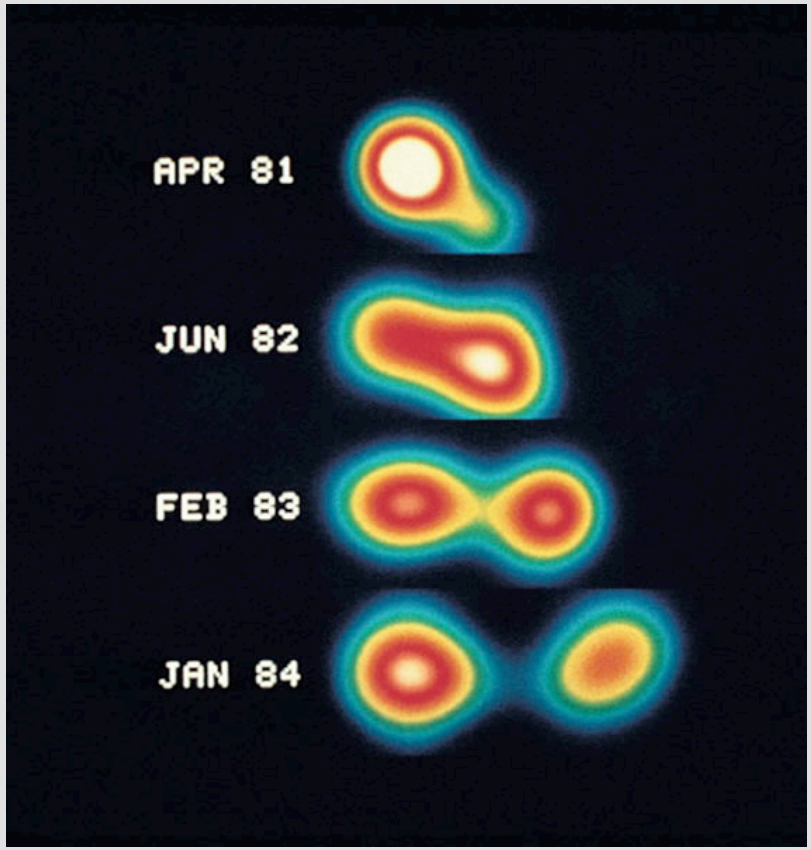
... but narrow "jets" suggesting this has all come from the nucleus

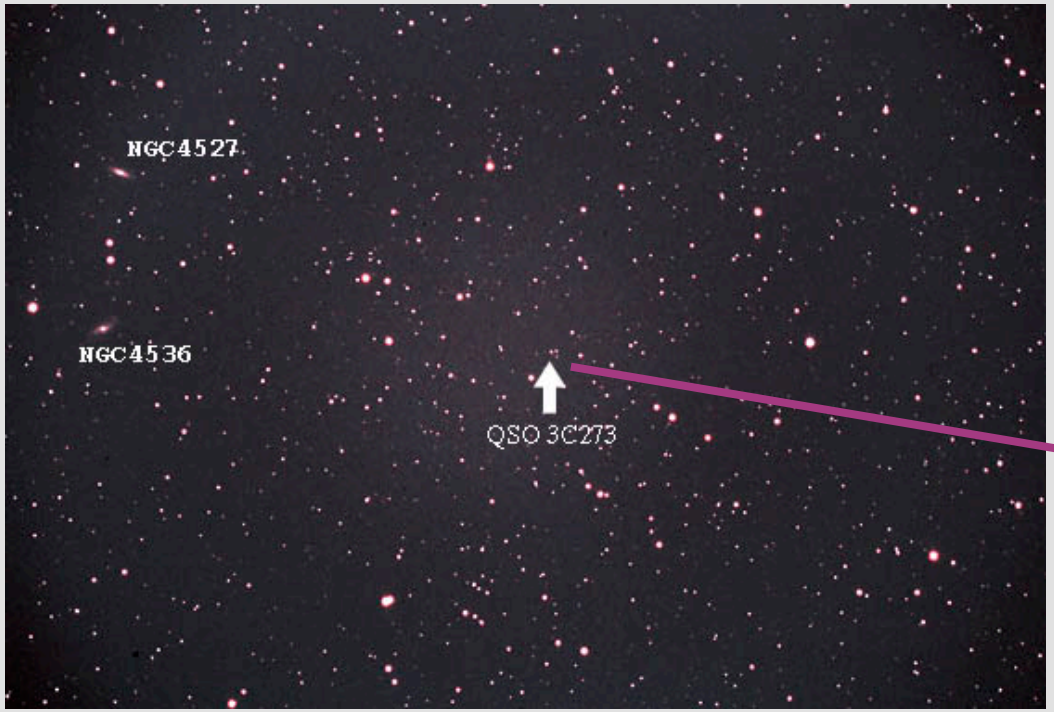
1950s



The radio jets continue all the way to a tiny spot in the nucleus

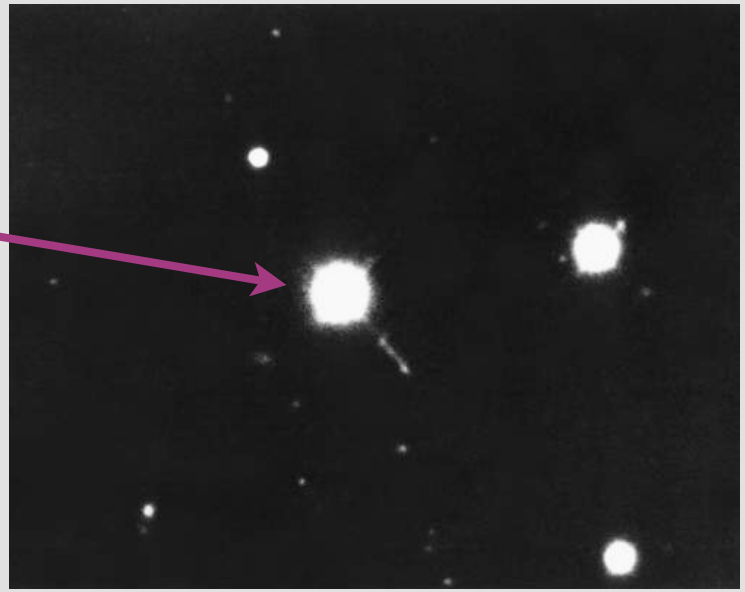
Features in the very nucleus move, showing that the jet is being shot out at 95% of the speed of light !!

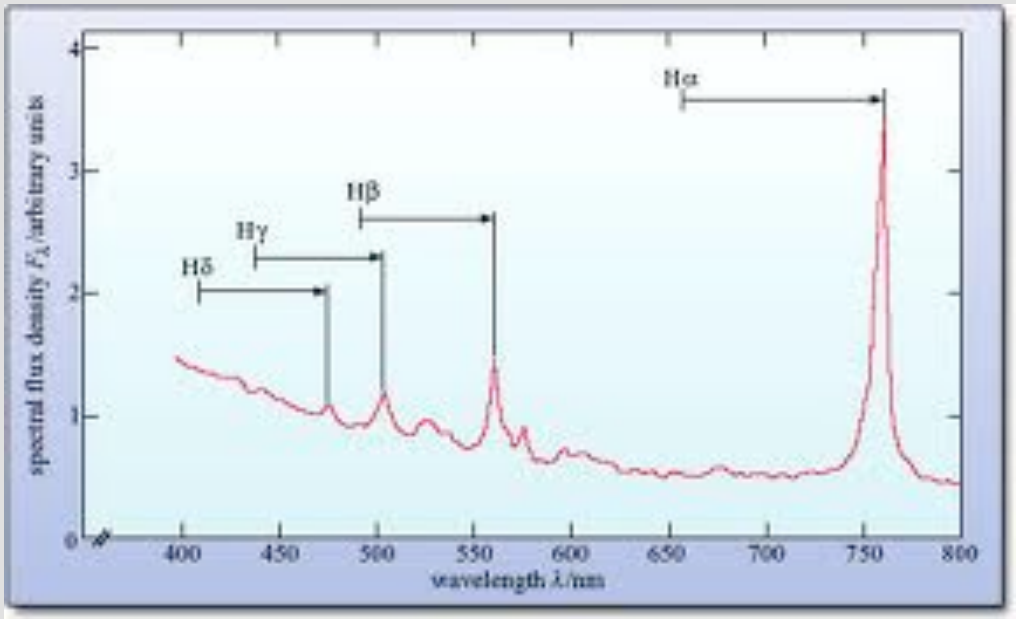




1960s

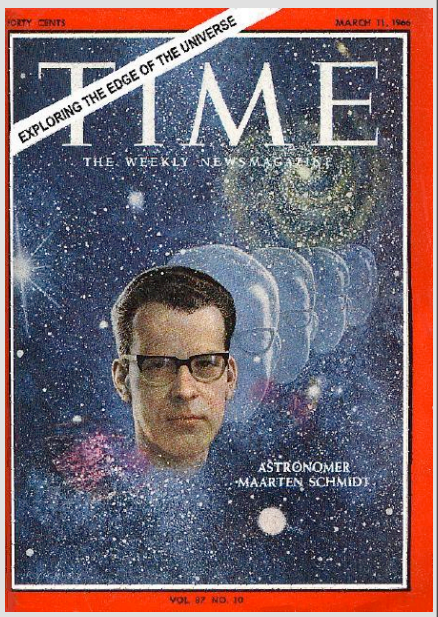
Quasars





Showed a jet like the radio galaxies and a spectrum like the Seyfert galaxies, at high redshift, but was just a star ???

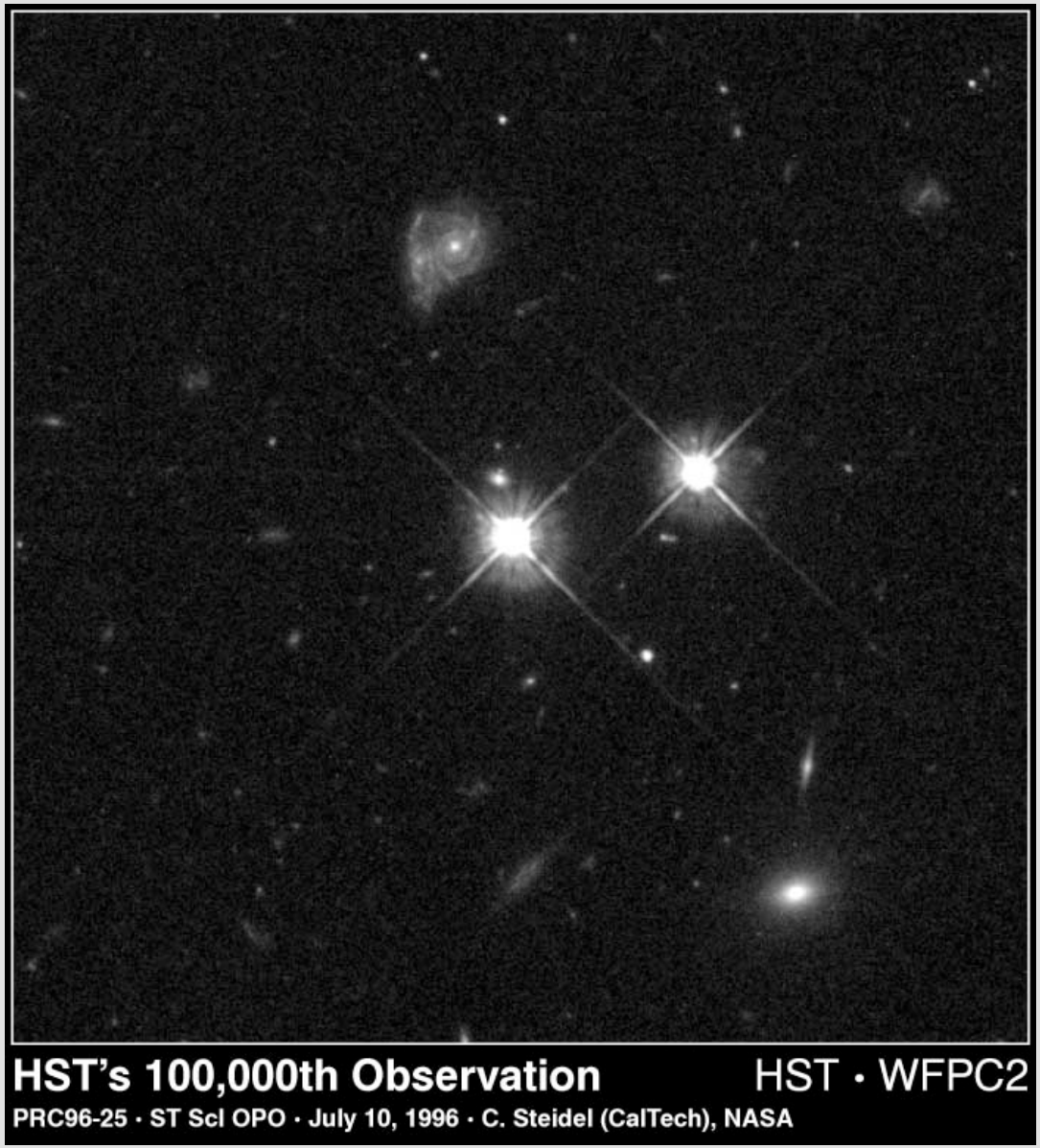
What was going on ?



Maarten Schmidt

Quasar = distant powerful AGN

Cutting a long story short ..



At large distance, the galaxy image is small

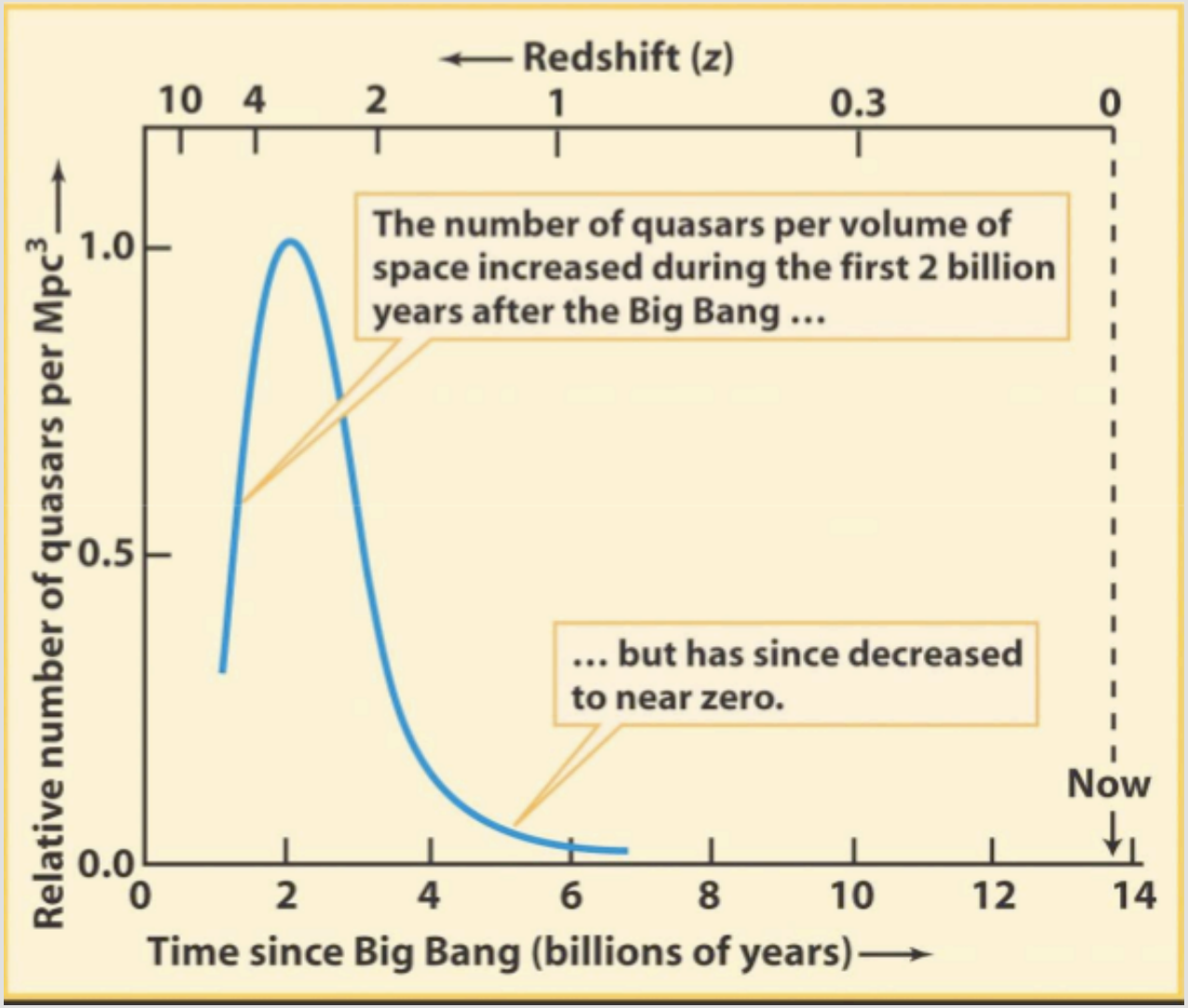
If the active nucleus is very powerful, it can swamp the galaxy image

Sharper modern pictures with HST show "fuzz" around quasars

This is the parent galaxy

Another low-tech demo...

Quasar evolution



Powerful nuclear activity was much more common earlier in the history of the Universe.

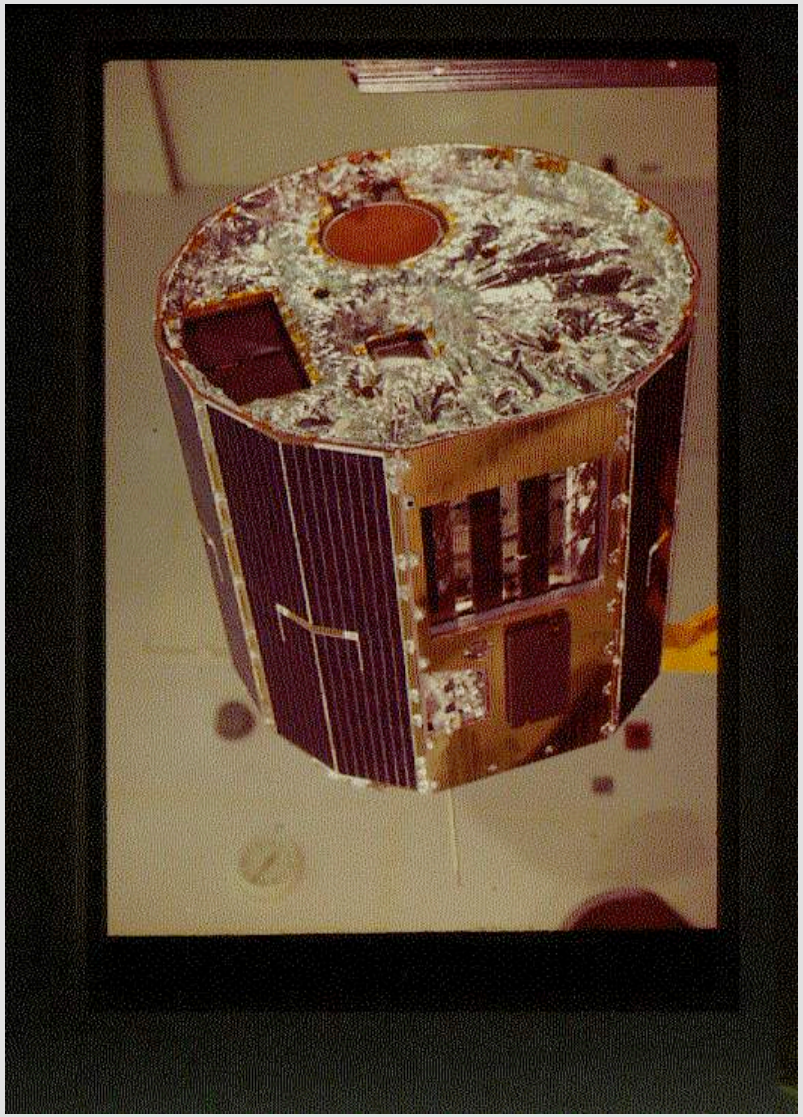
Why ?

1970s – 2000s : the multiwavelength revolution

Some types of light are blocked by the atmosphere...

Have to send telescopes into space

X-ray astronomy



1970s

Ariel V
and Uhuru

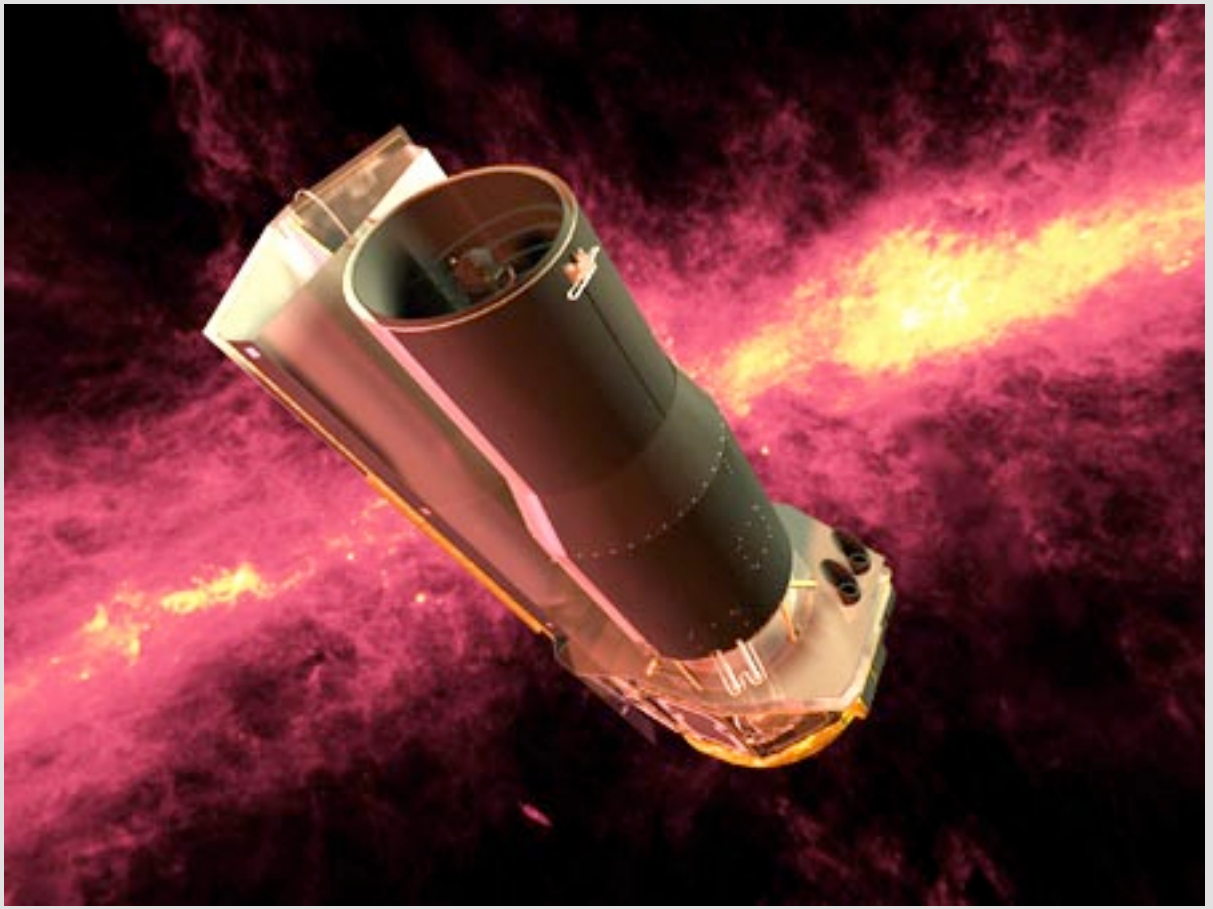
Today

XMM
and Chandra

Infra-red astronomy

1980s

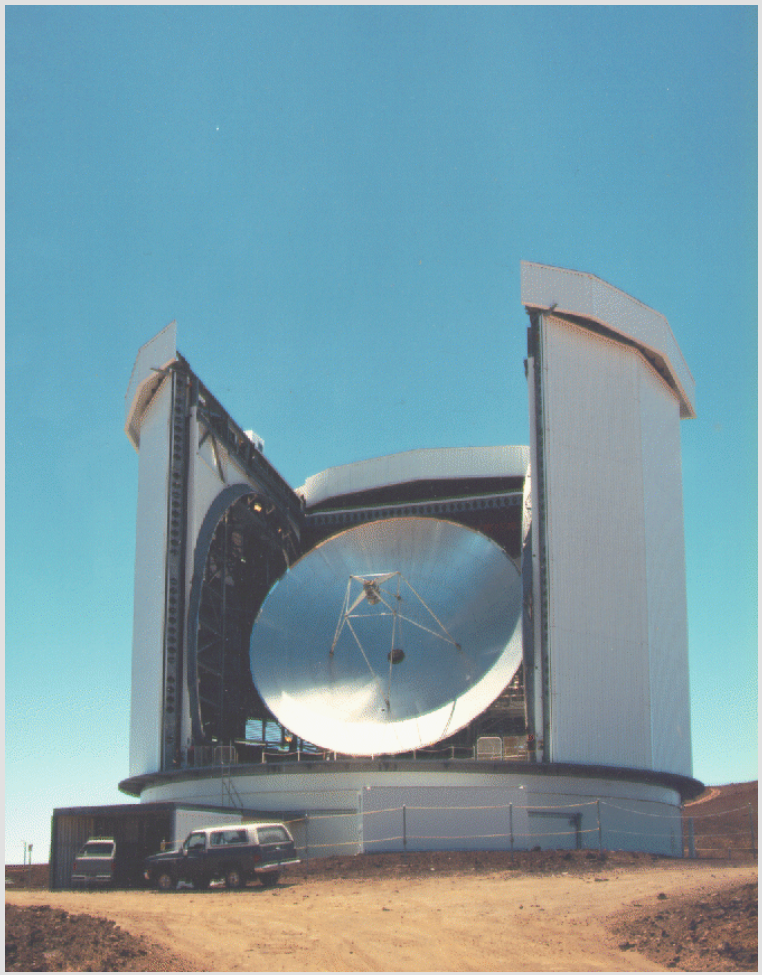
IRAS



Today

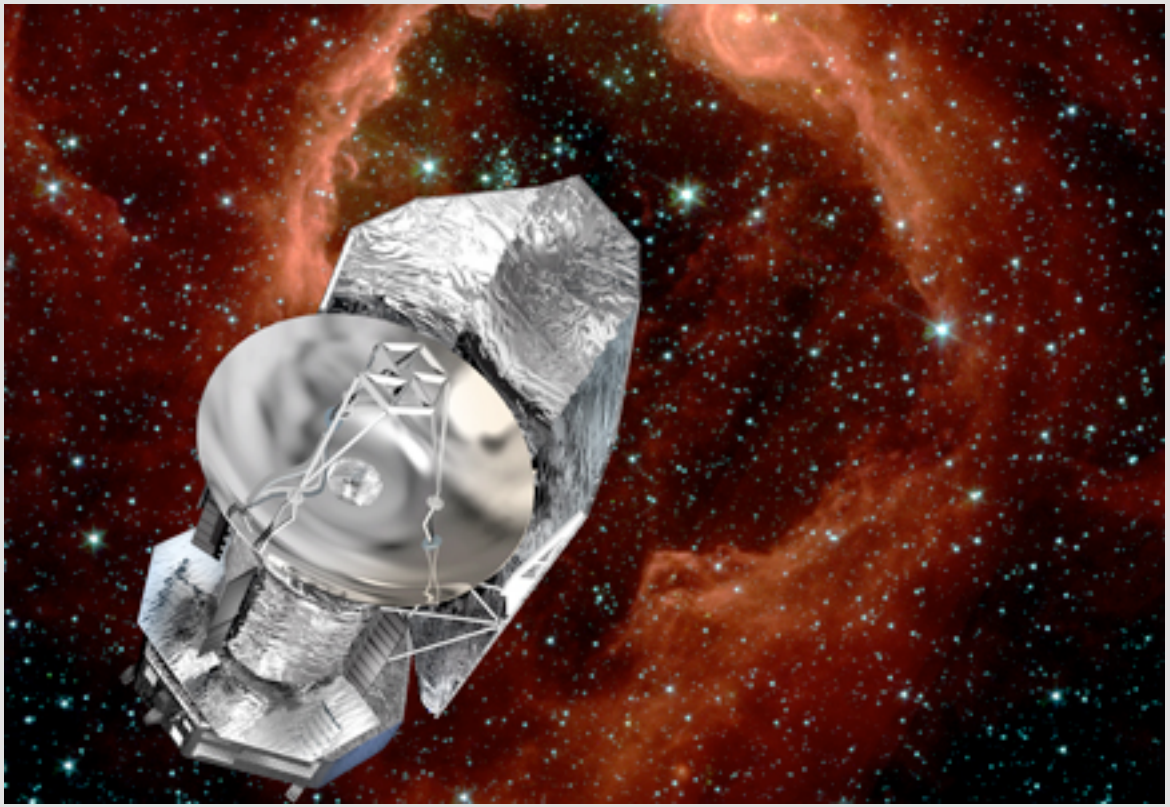
Spitzer

Sub-mm astronomy



1990s

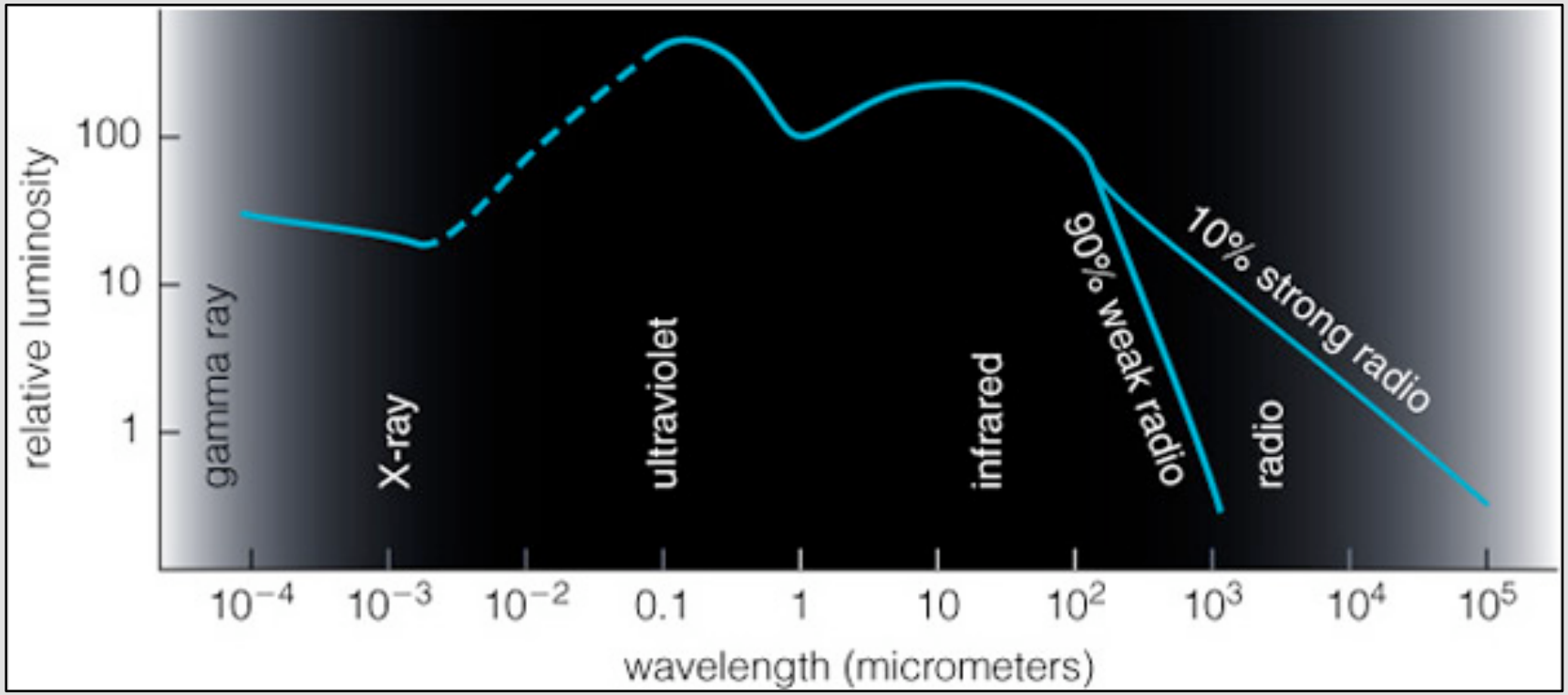
JCMT



Today

Herschel

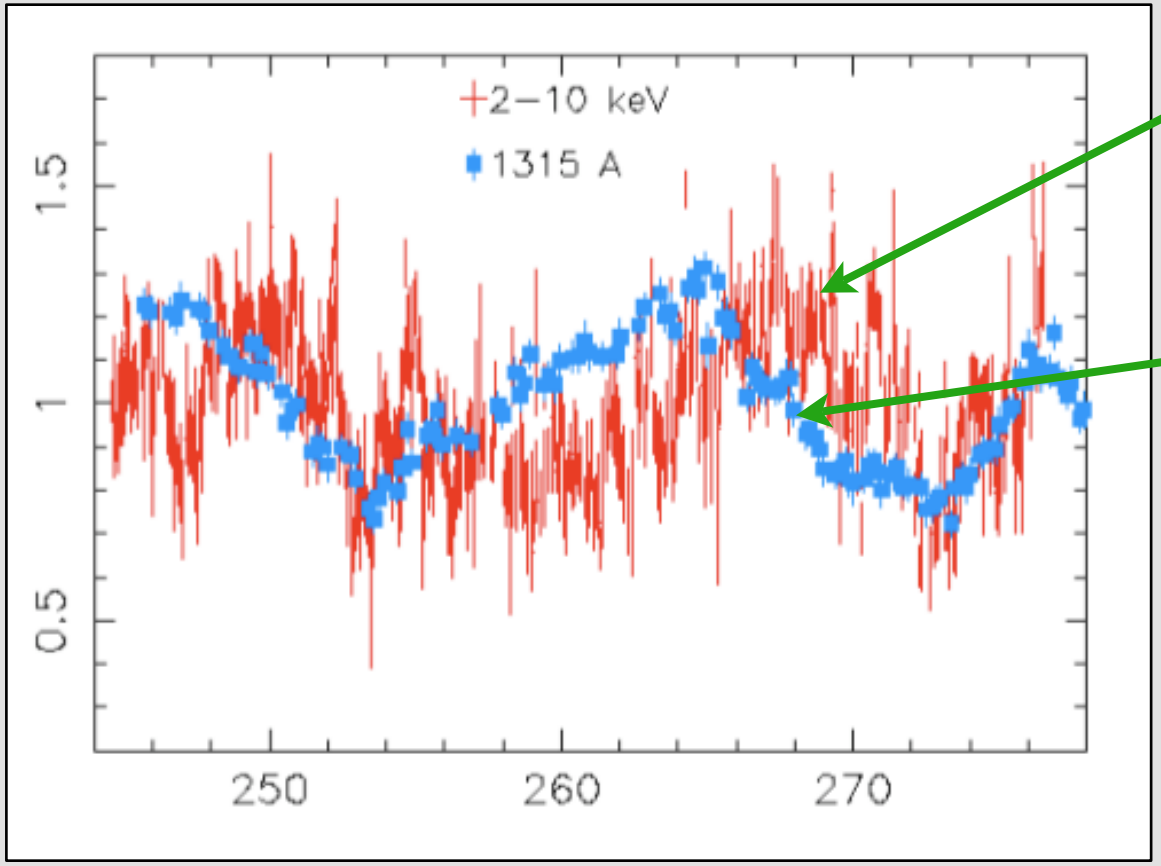
Multi-wavelength radiators



AGN radiate over a huge range of wavelength ... VERY different to stars

Total amount of energy enormous - as much as a **whole galaxy** from a central spot

AGN vary on short timescales



X-rays

Ultraviolet

Big things can't change fast. This AGN must be **smaller than the solar system.**


What does it all mean ?

What we need to explain

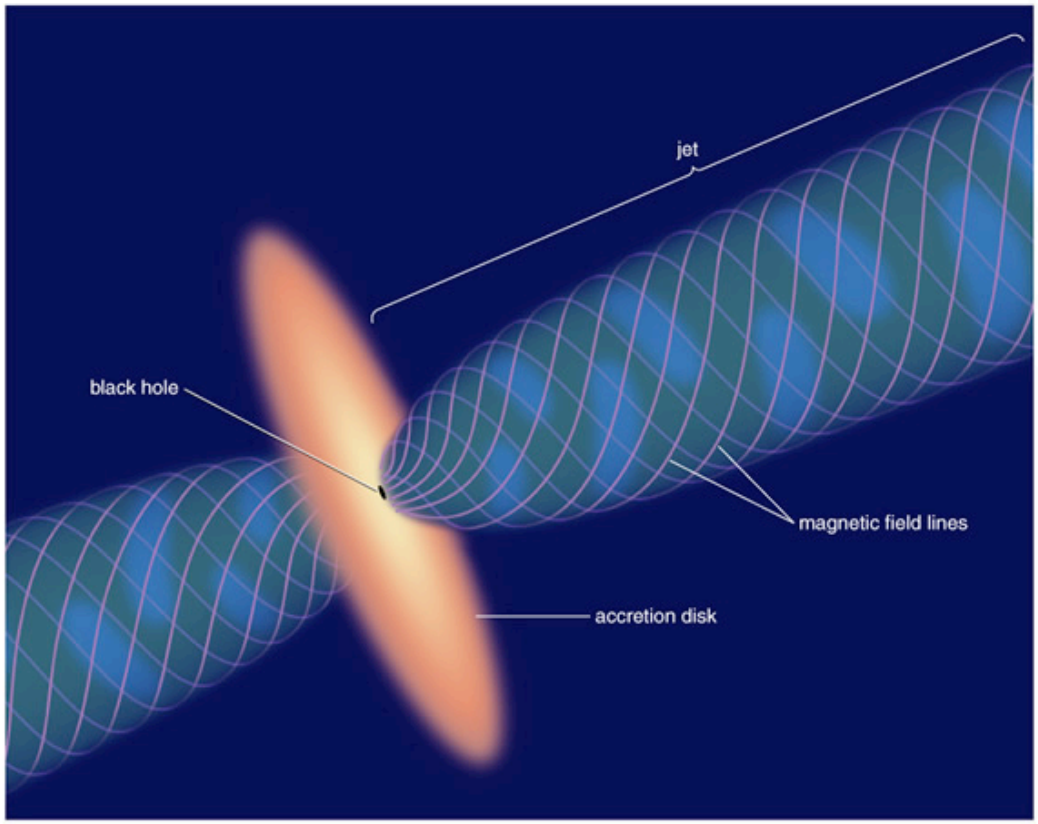
- Radiating huge amounts of luminosity
- From a tiny volume
- Emitting jets at near the speed of light

The answer ?

- Gravity again ...
- but a more extreme version
- ....drop matter onto a black hole

The most efficient energy source we can think of.

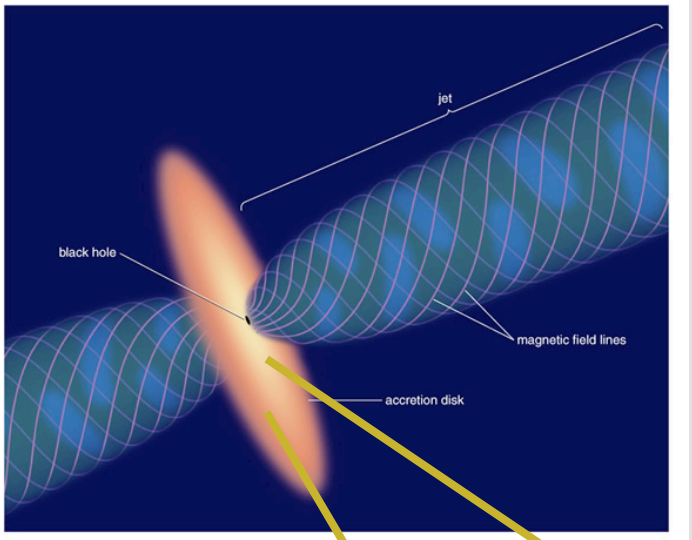
another low-tech demo...

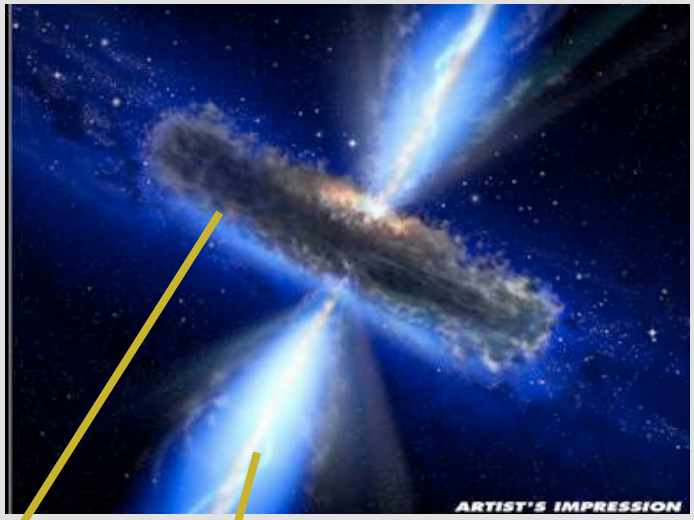


Gas spirals in towards black hole in an "accretion disc", gets very hot, and radiates over a broad range of temperatures

Magnetic field gets stronger and twisted on the way in. Ionised particles get flung out along field lines

Further out, incoming gas and muck absorbs some of the luminosity, and re-radiates in the Infra-red



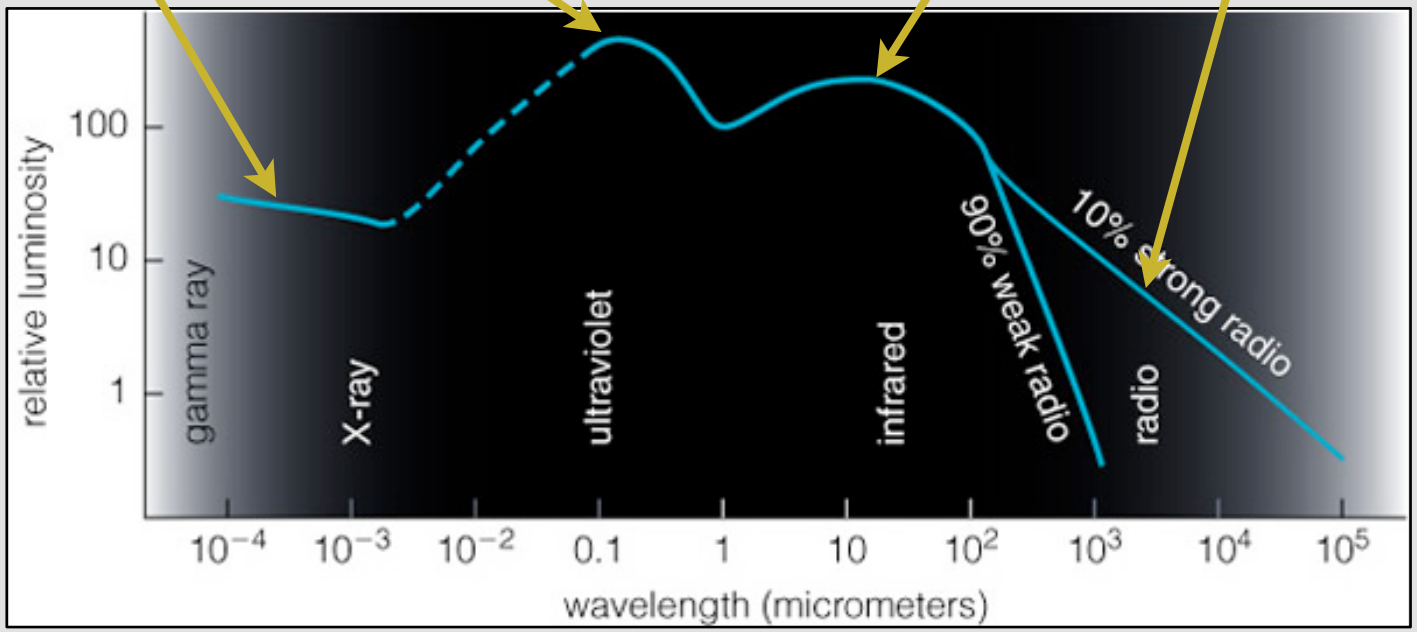


accretion disc corona

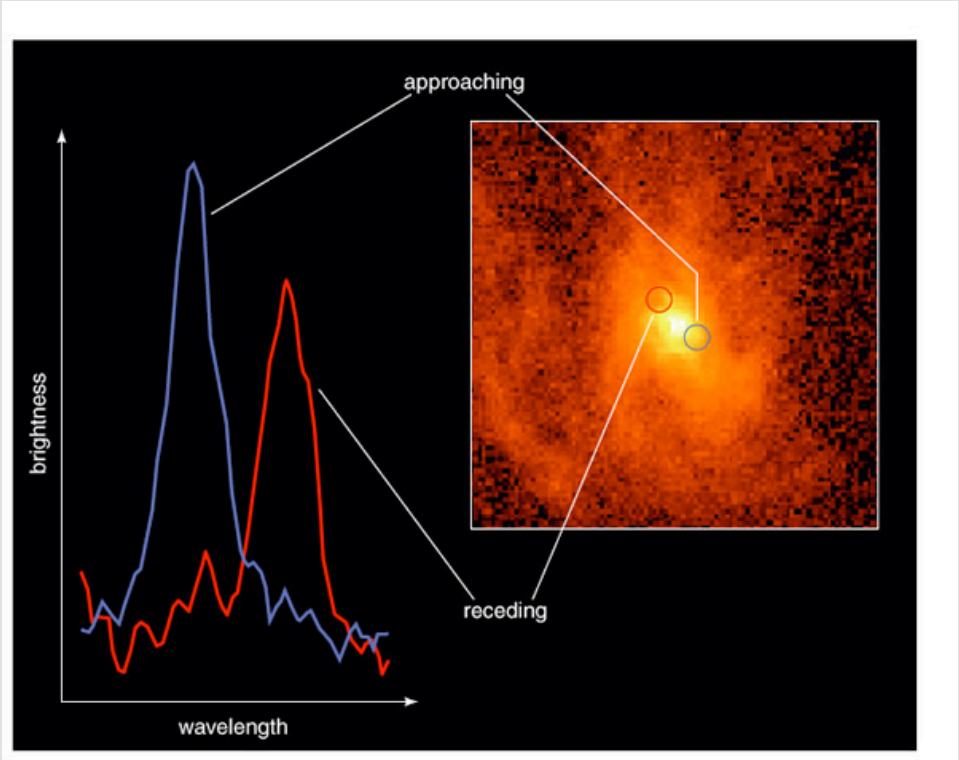
accretion disc

absorbing muck

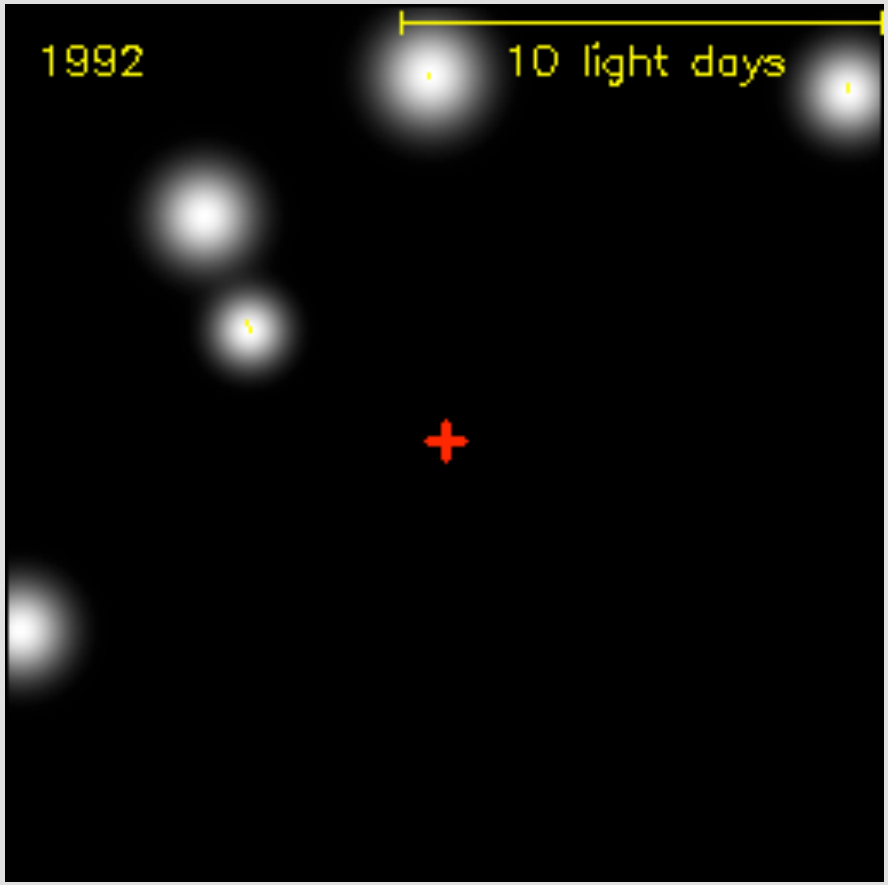
radio jets



Are there really black holes in the middle of galaxies ?



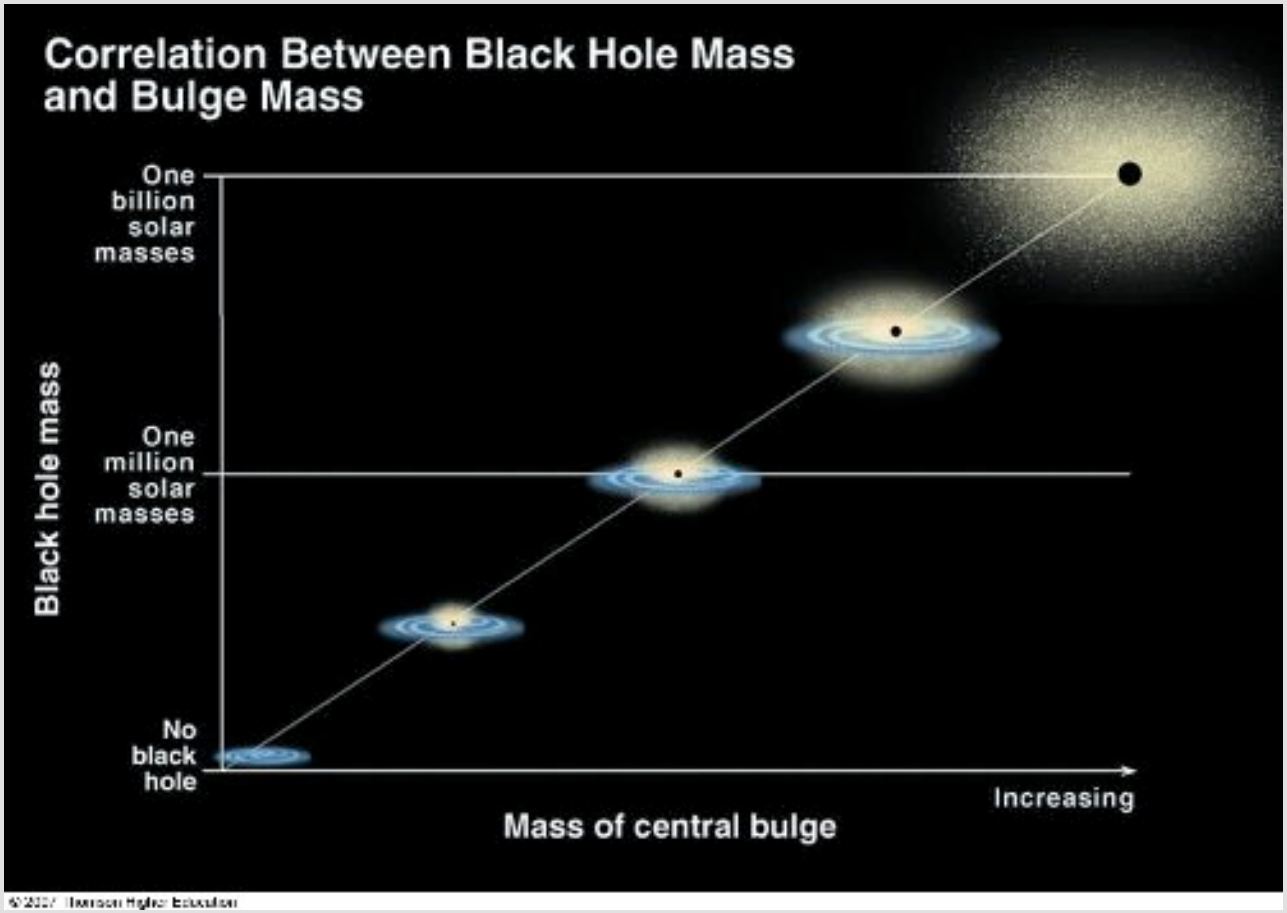
Rotating gas in centre of M87 is orbiting something **dark** with a mass of 3 billion solar masses



Stars in the centre of the Milky Way are orbiting a dark object with a mass of 2 million solar masses.


Black holes everywhere

Ubiqitous black holes ?



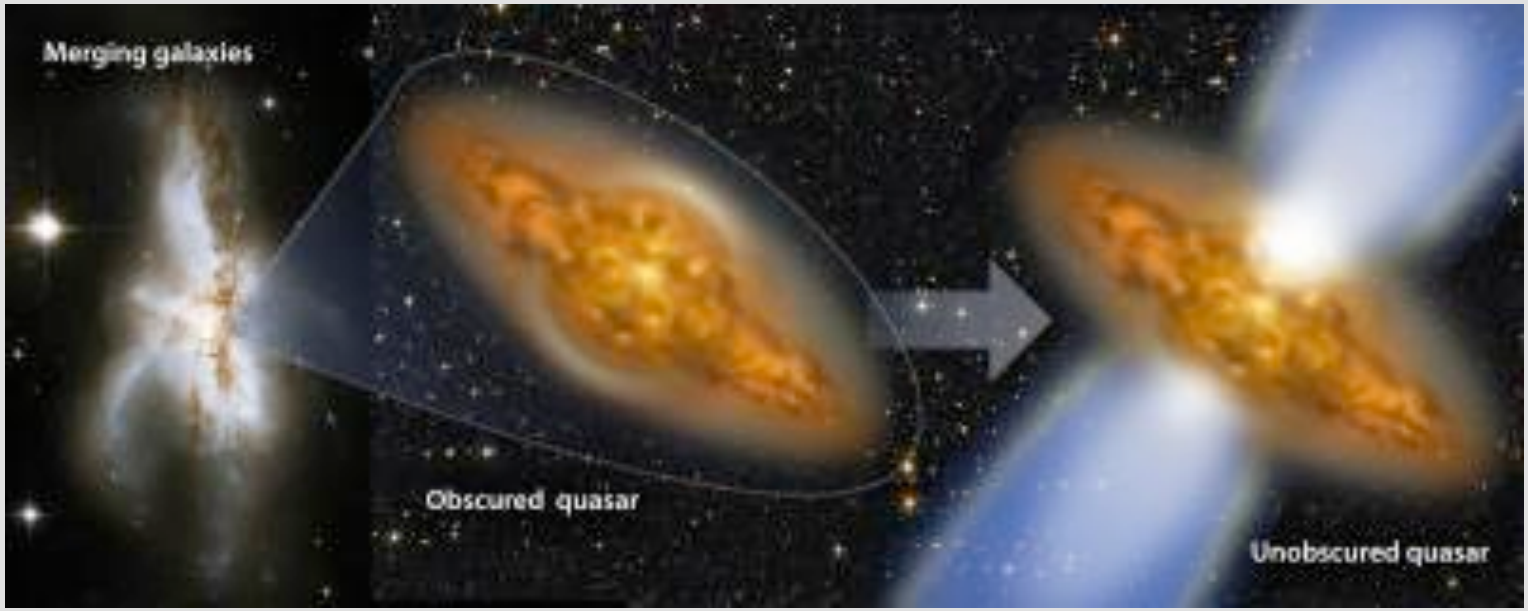
Luminous AGN occur in only a minority of galaxies but the motions of galaxies indicate there is **almost always** a central black hole

The size of the black hole scales with the size of the galaxy.

This may be connected with the **process of galaxy formation**.

Presumably, most of these black holes are not being "fed" so they are not shining ?

Black hole and galaxy growth

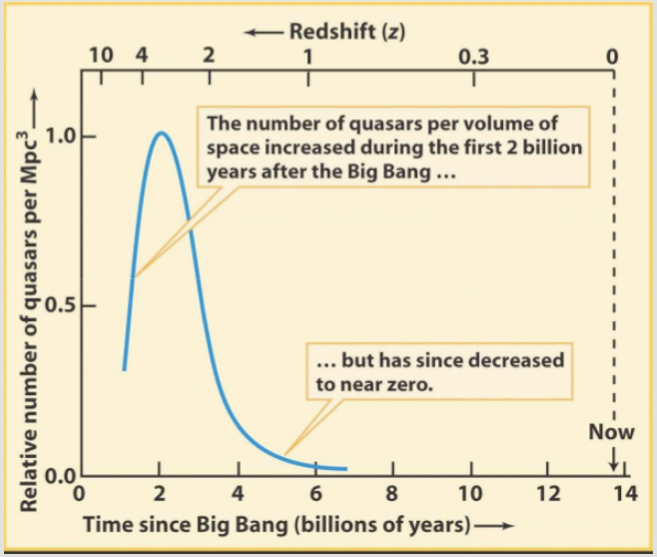


Black holes grow while they are being fed. Feeding may usually be due to galaxy collisions.

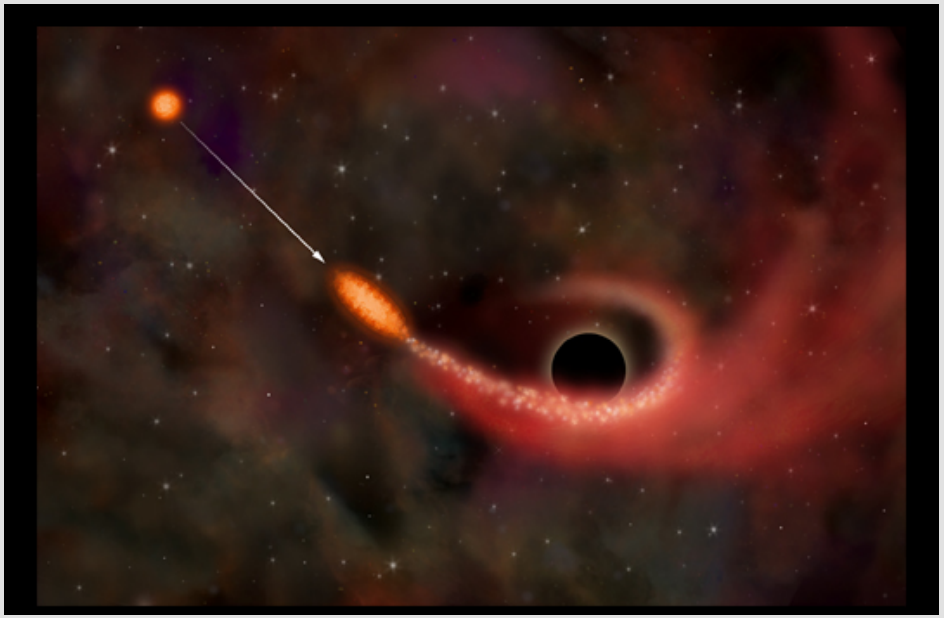
This happens much more in the early universe which is maybe why quasars were more common in past.

Black hole growth and galaxy growth are therefore intimately connected.

When the AGN gets powerful, it could even stop the galaxy growing.



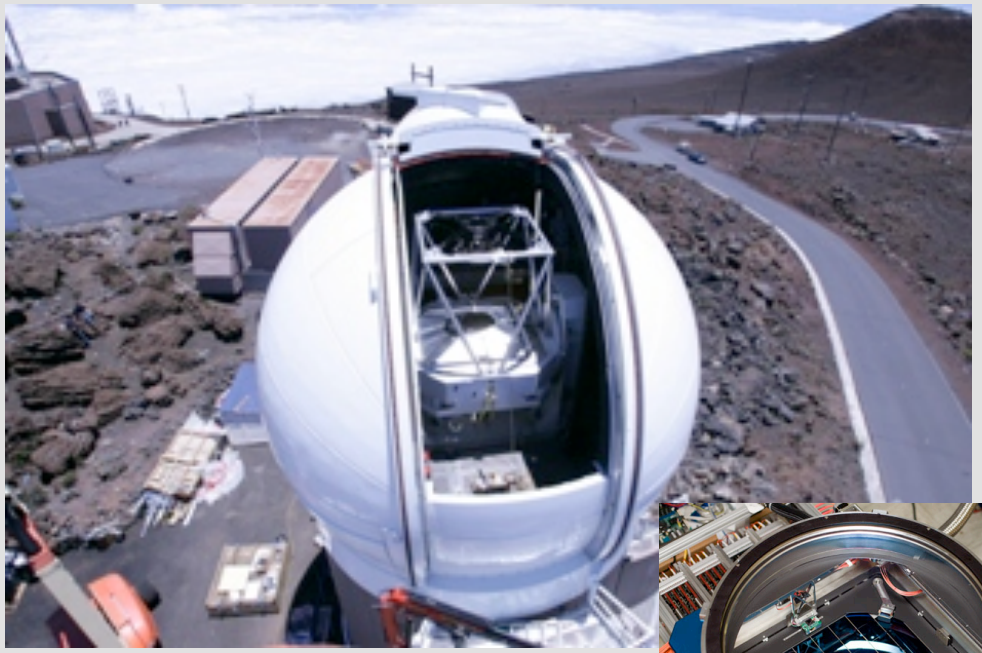
Rejuvenating dormant black holes

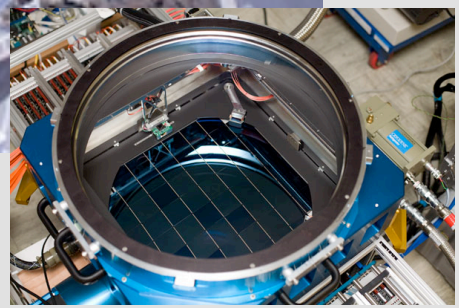


Star passing close to black hole gets shredded and swallowed switching the AGN back on

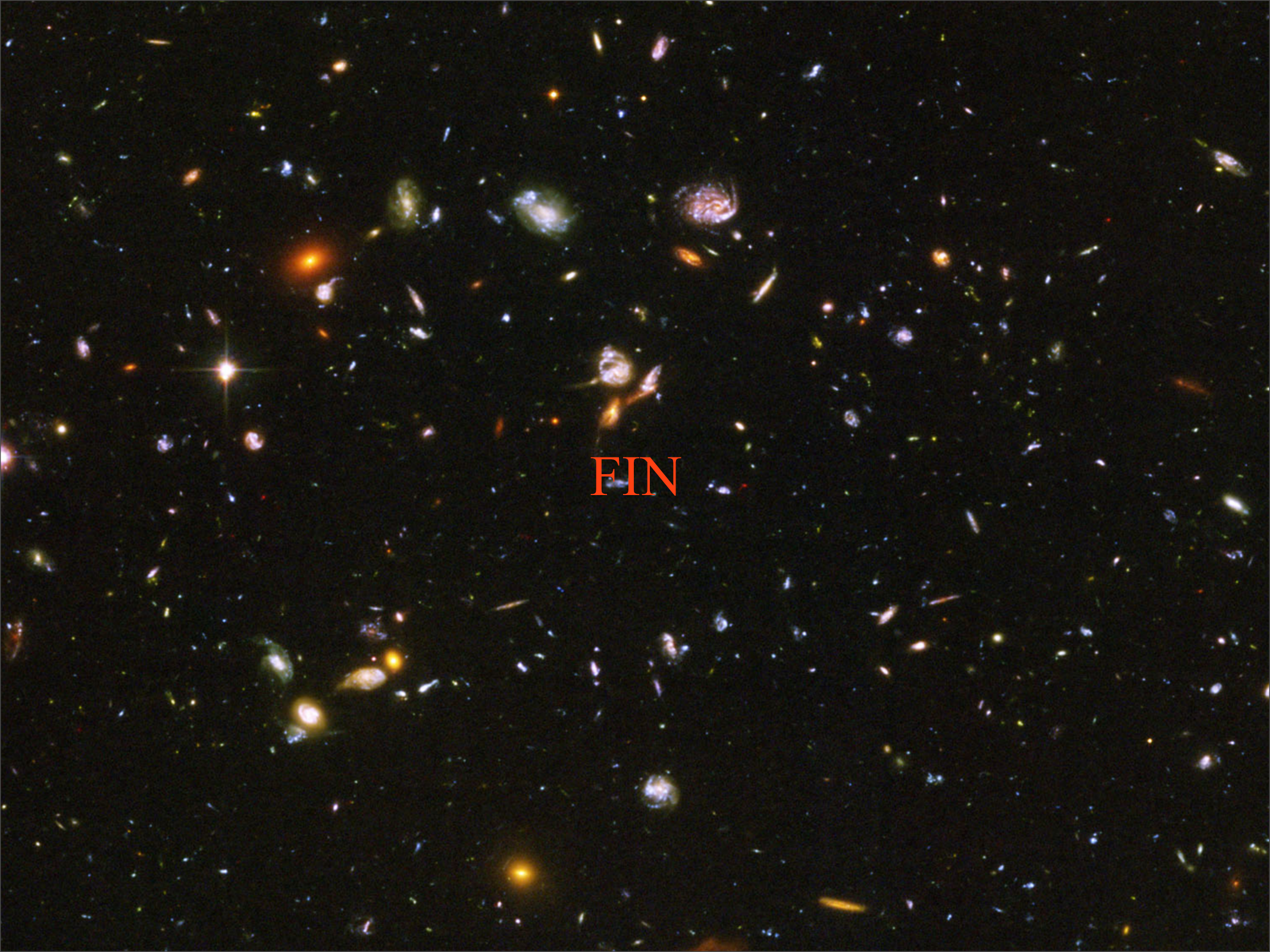
Will happen maybe once every million years...

So have to watch millions of galaxies to catch one !!





PanSTARRS wide field telescope in Hawaii trying this project now ... watch this space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