Extragalactic Astronomy II

Lecture 11

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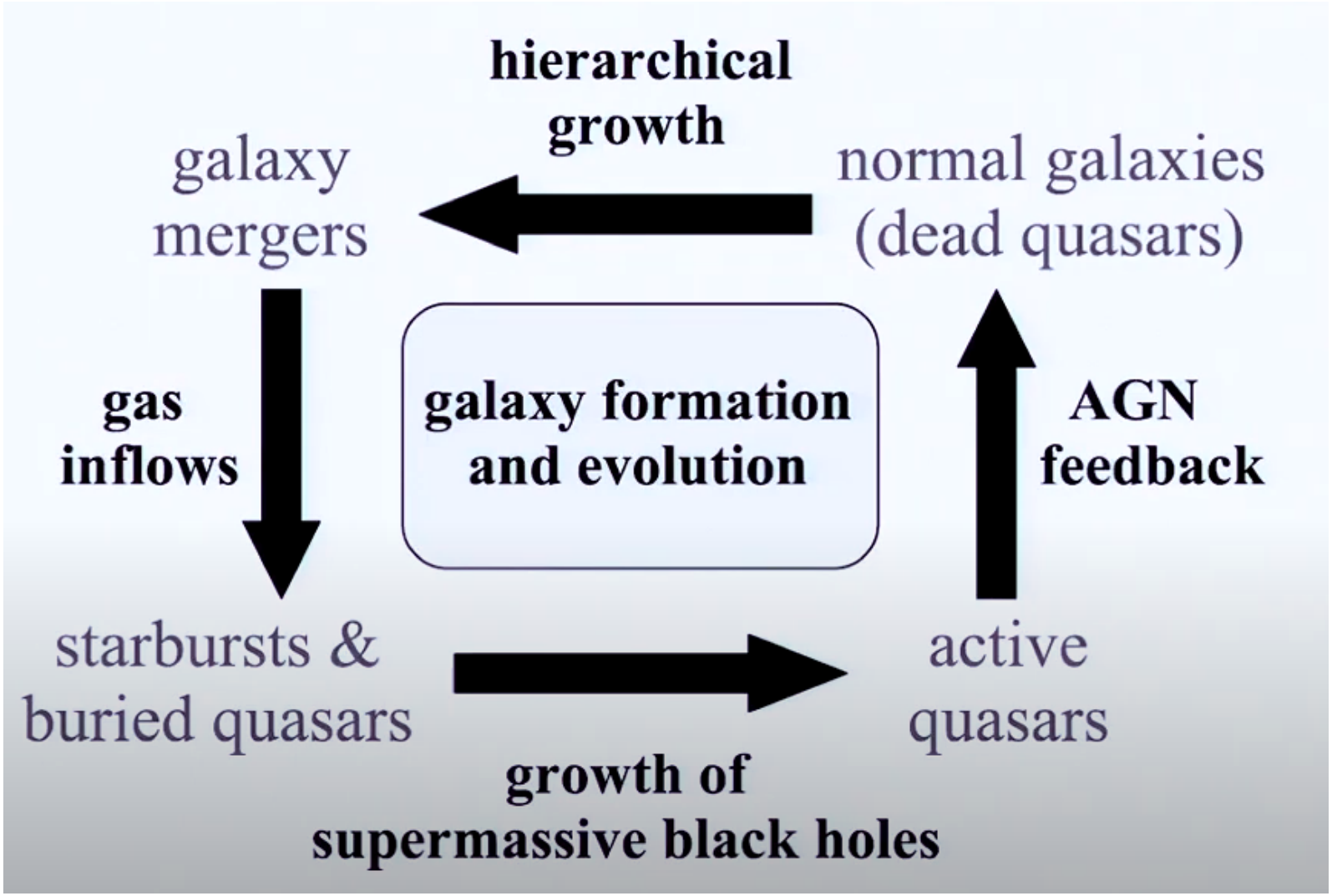
AGN Feedback from jets and galaxy evolution



Credit: Phil Hopkins

Motivation for a dusty torus surrounding the accretion disk

If an AGN consisted solely of the central engine, observers would see X-rays and ultraviolet radiation from the hot accretion disc and, apart from the jets, very little else.
To account for the strong infrared emission from many AGNs, the model includes a **torus of gas and dust** that surrounds the central engine.

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To account for the strong infrared emission from many AGNs, the model includes a **torus of gas and dust** that surrounds the central engine.
The dust particles - which are usually assumed to be grains of graphite - will be heated by the radiation from the engine until they are warm enough to radiate energy at the same rate at which they it receive it.
As dust will vaporise (or sublimate) at temperatures above 2000 K (peak emission at 1.5 micron), the cloud must be cooler than this.
We approximate stellar emission as a blackbody. Can dust be treated as a black body?

Sublimation radius of dust

If the engine has a luminosity L, then the flux at a radius r from the engine will be $L/4\pi r^2$. A dust grain of radius a will intercept the radiation over an area πa^2. Power absorbed will be:
$(\pi a^2)(L/4\pi r^2) = La^2/4r^2$

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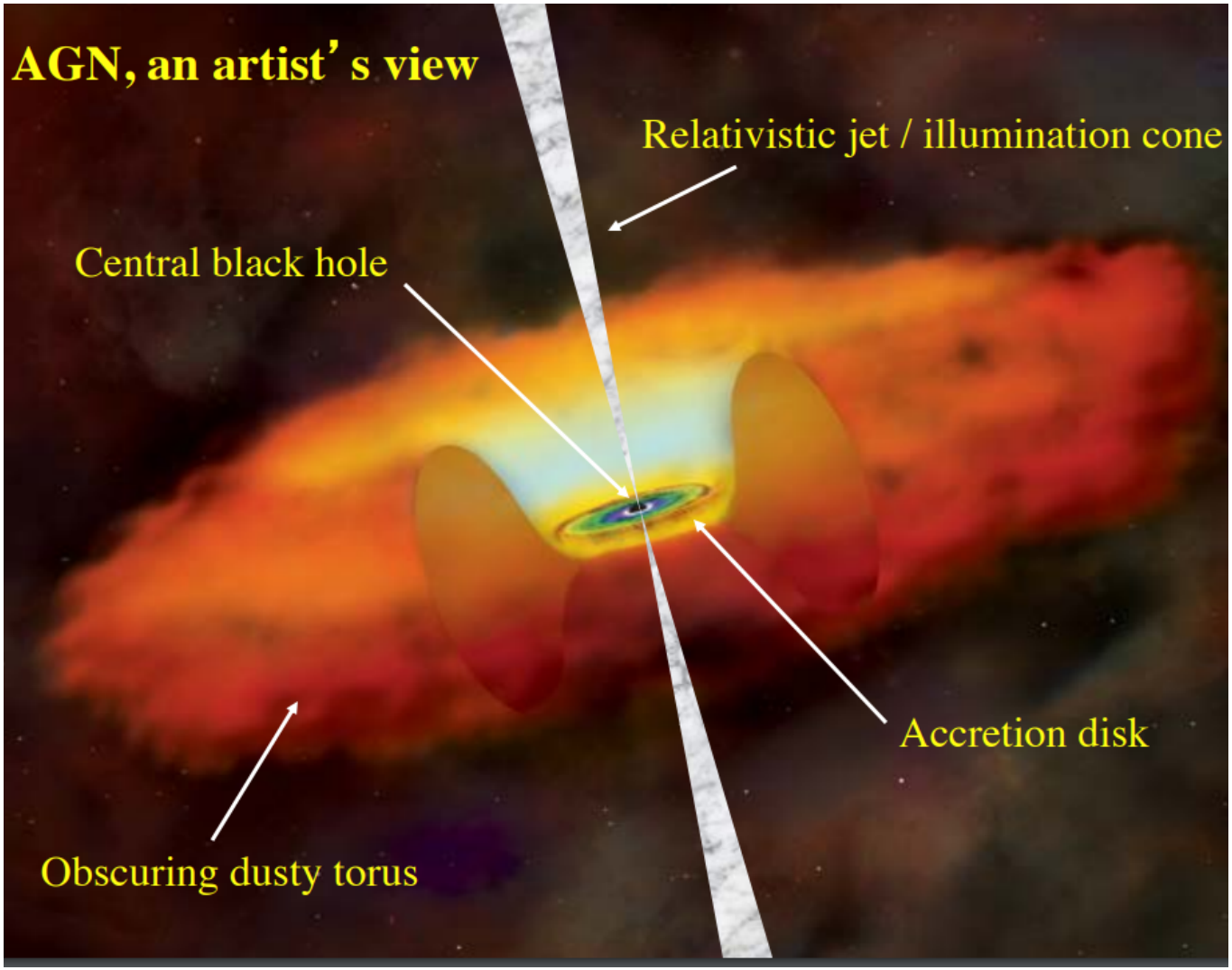
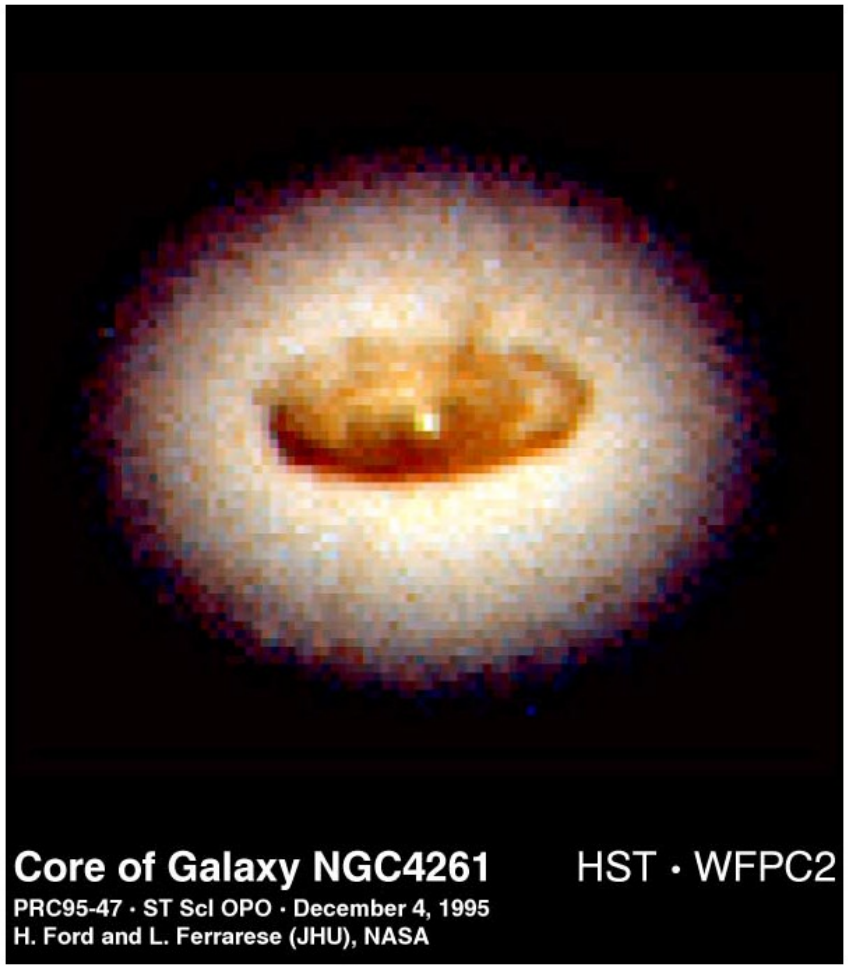
$$\frac{La^2}{4r^2} = 4\pi a^2 \sigma_{SB} T^4 \Rightarrow r = \left(\frac{L}{16\pi \sigma_{SB} T^4} \right)^{1/2}$$

This distance is called the *sublimation radius* for the dust.

A zoomed out view of the SMBH

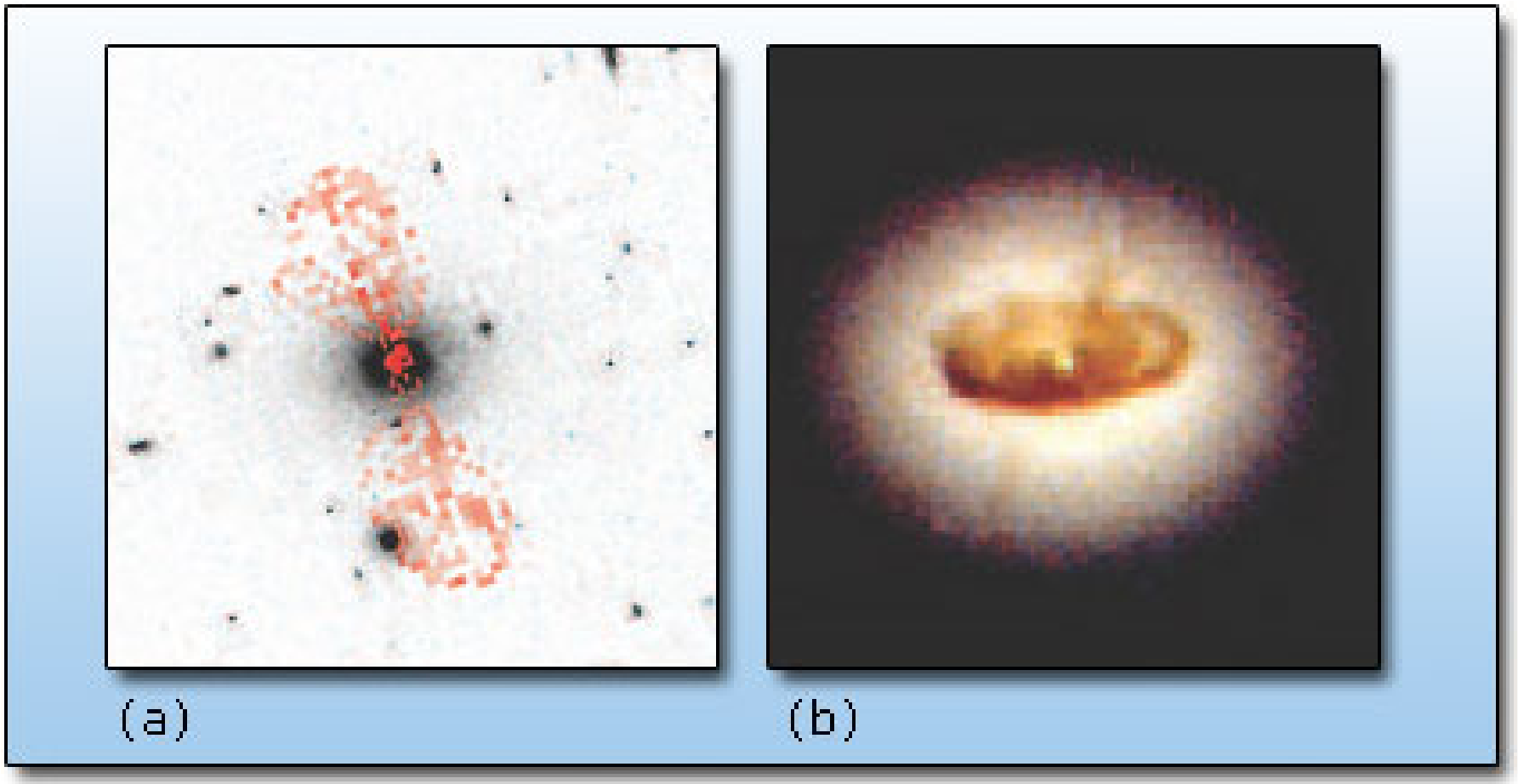


Dusty disk in elliptical (radio) galaxy NGC 4261



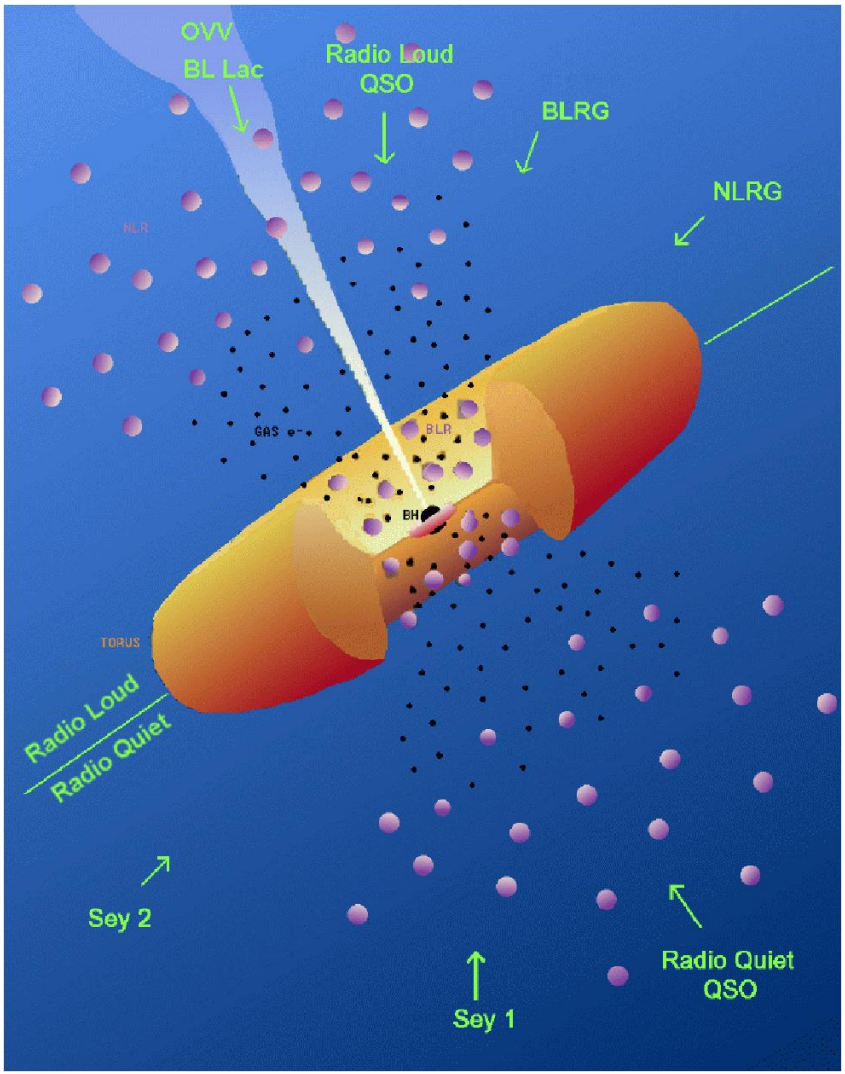
The dust seen has a diameter of 250 pc, much larger than the expected scale of the torus.

The radio structure of NGC 4261



Radio jets seem to be aligned along the rotation axis of the disk.

AGN Unification



How do we detect Type 2 AGN

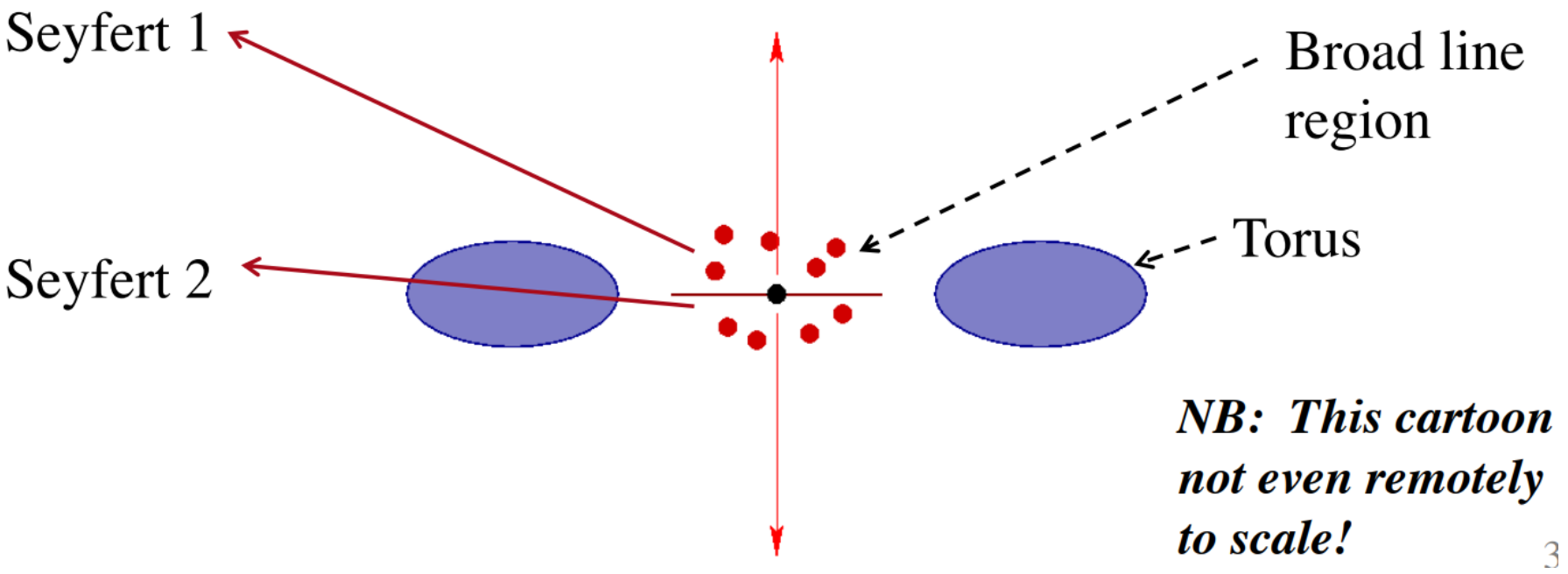
Can we find observational evidence for the existence of Type 2 AGN?

Polarised reflected light

Reflection nebula - Pleides star cluster (M44)

If you took a spectrum of a reflection nebula, what would you expect to see? How is this different from an emission nebula?

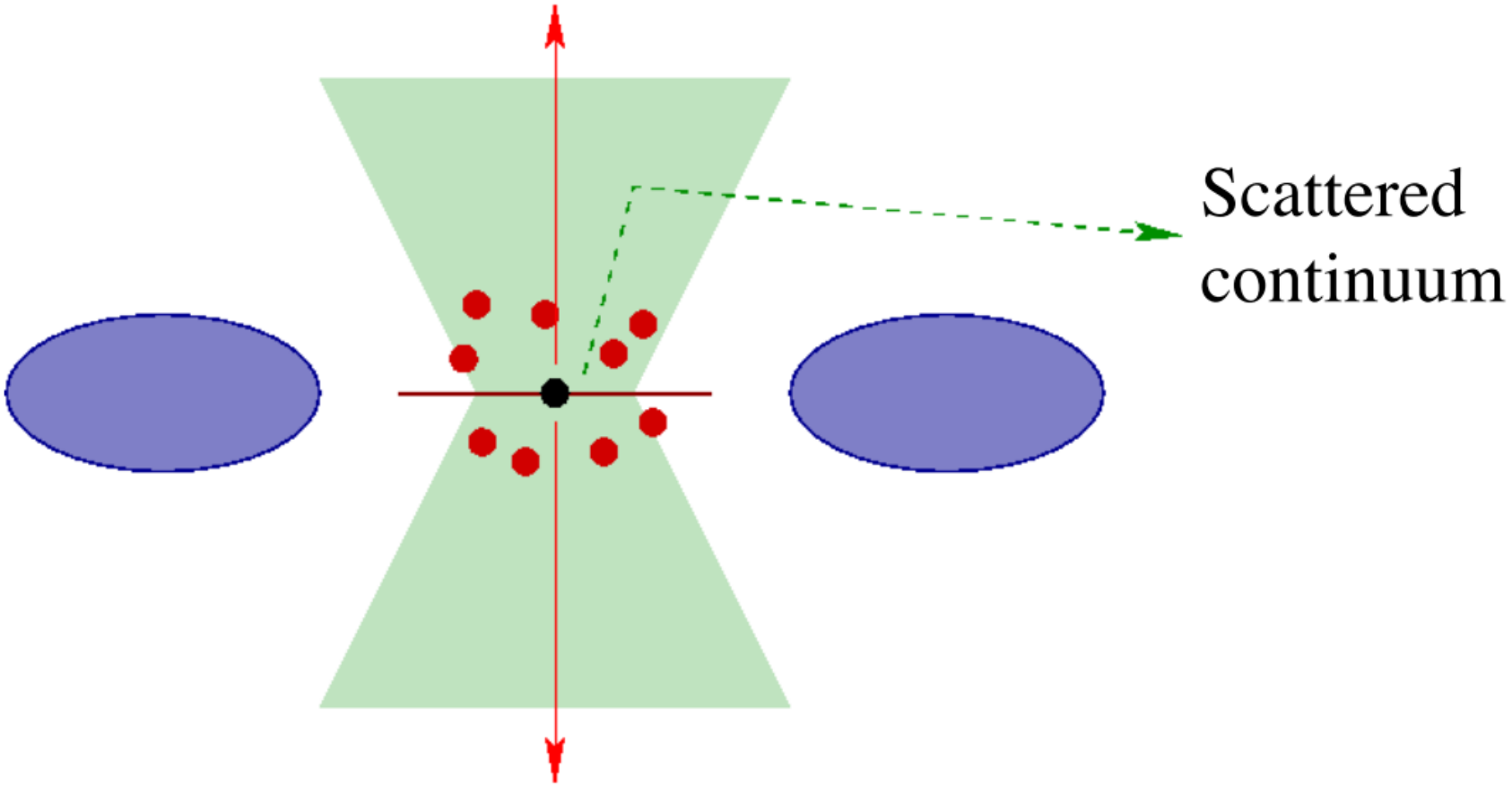
Seyfert 1 and Seyfert 2 Unification



Why do we still see the continuum in Seyfert 2 galaxies?

Credit: S G Djorgovski

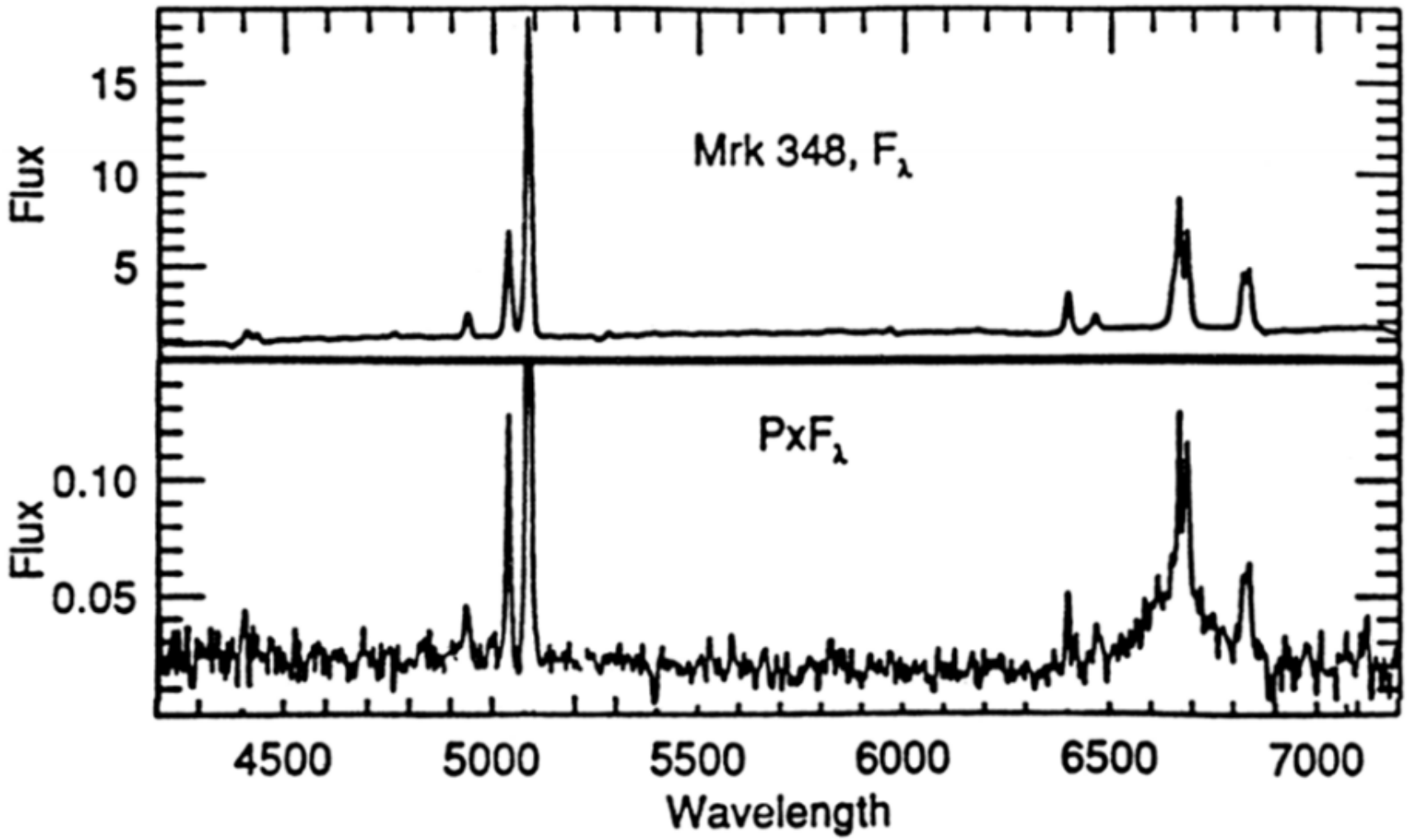
Seyfert 2 continuum



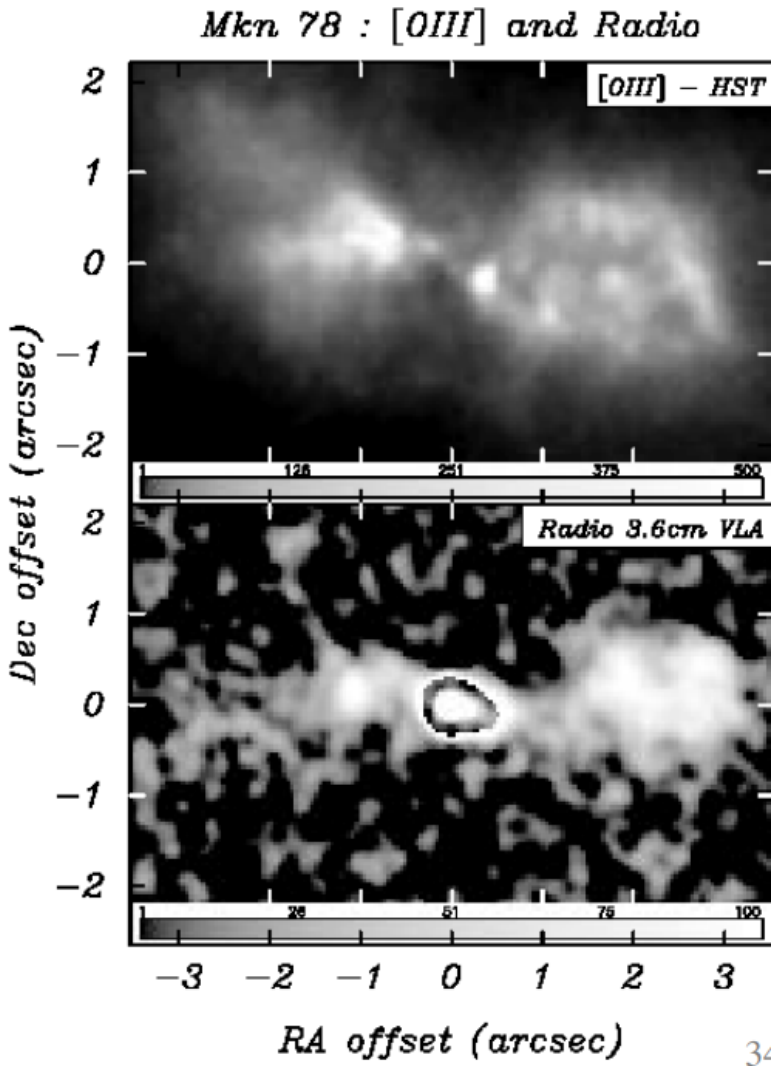
How to verify that this explanation is correct?

Credit: S G Djorgovski

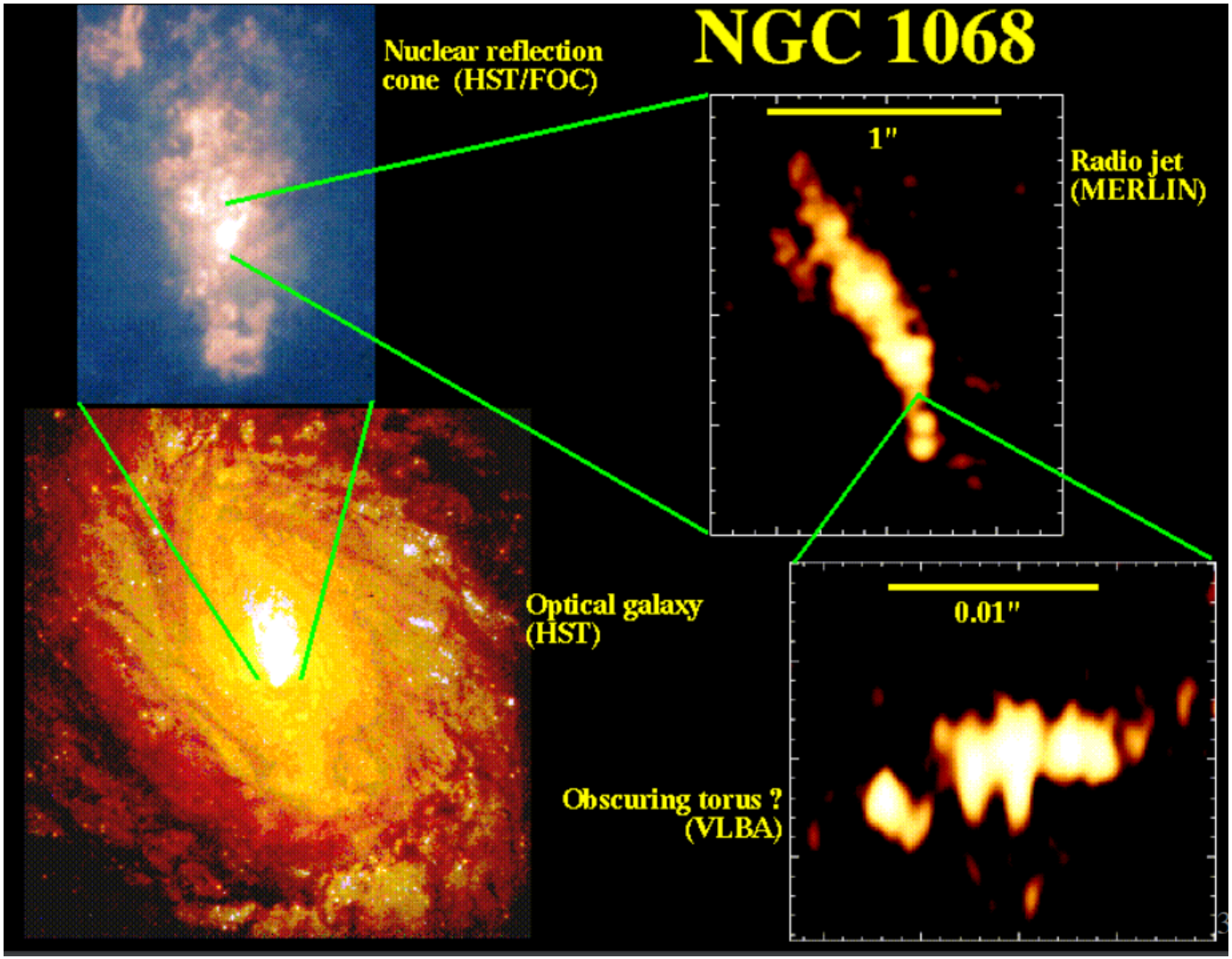
Seyfert 2 in polarised light



Emission cones in narrow lines of Seyfert 2 galaxies



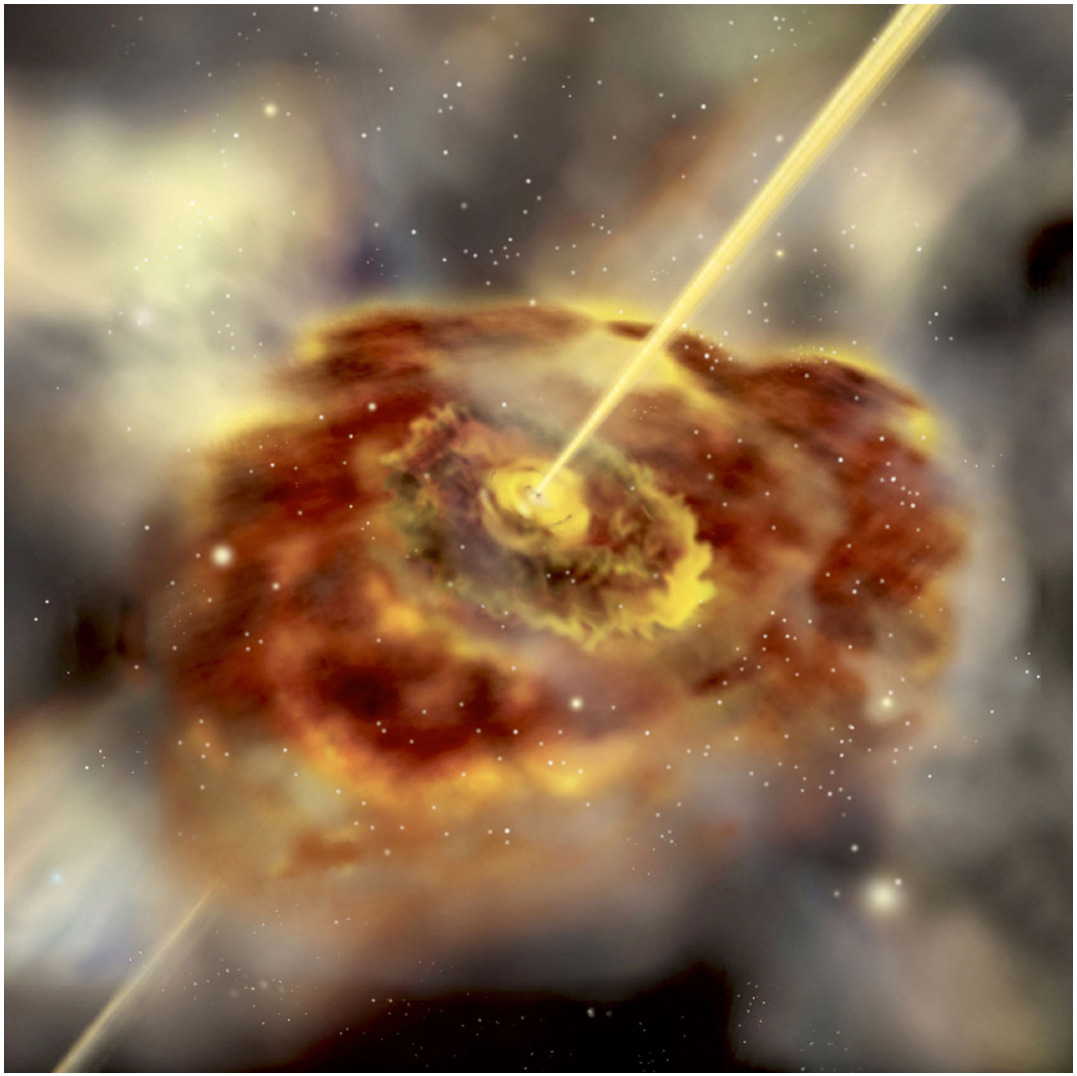
NGC 1068 - M77 - prototypical Seyfert 2 galaxy



Also imaged in mid-infrared with the VLT Interferometer

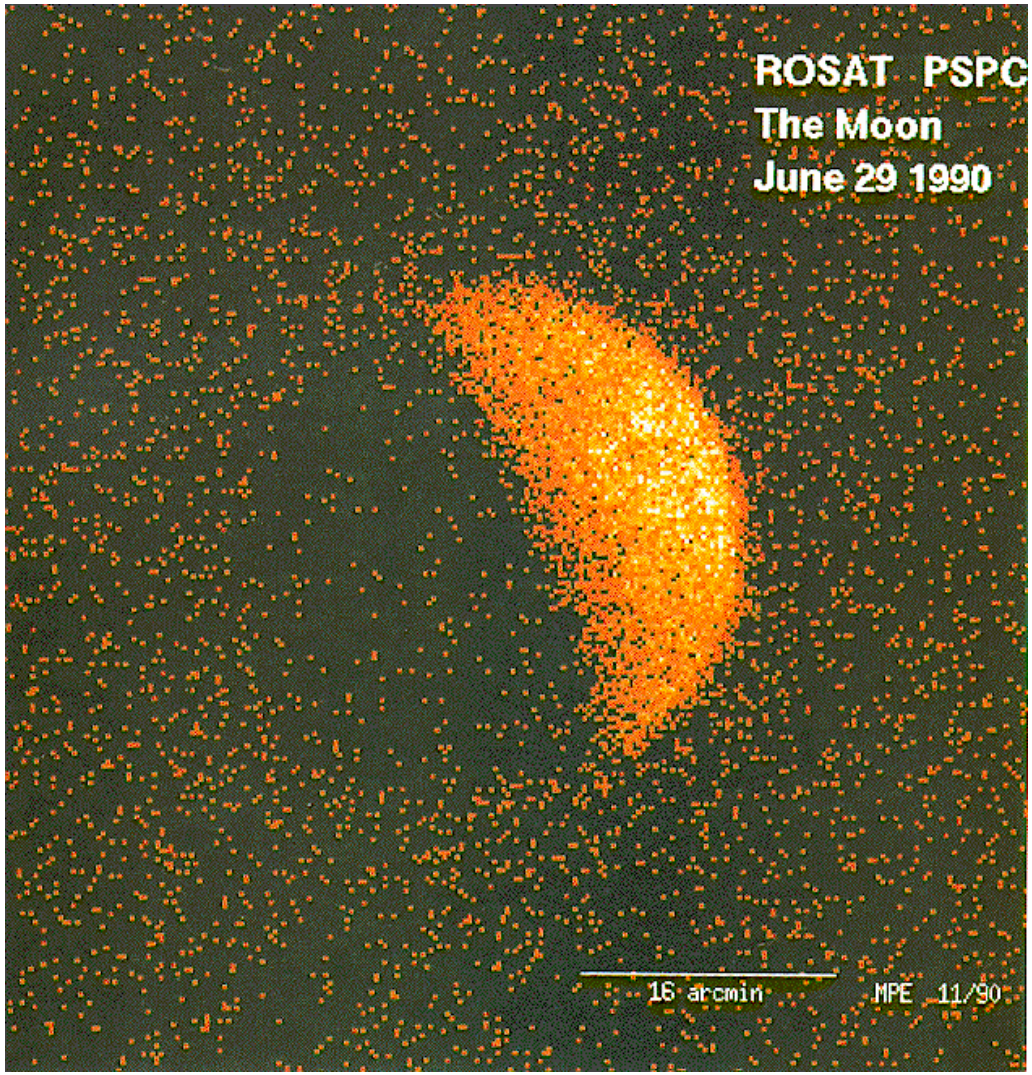
Credit: S G Djorgovski

Artist impression of NGC 1068 core



Credit: ESO

Moon with ROSAT



X-ray background

- A few percent of the energy density of the diffuse optical/IR backgrounds: $u_{XRB} \approx 10^{-17}$ erg/cm ^{3} , $u_{Opt/FIR} \approx 10^{-15}$ erg/cm^3 , $u_{CMB} \approx 10^{-13}$ erg/cm^3
- Now believed to be generated almost entirely by AGN, many of them obscured by dust (hard X-rays go through): the bulk of it is resolved by deep X-ray observations
- The puzzle was to explain the energetics and the spectrum shape at the same time; this required the existence of a substantial obscured (Type 2) AGN population, which has now been found
- The cosmic γ-ray background is mainly due to beamed AGN, but some more exotic components are still possible.

Optical counterparts of X-ray sources