# Extragalactic Astronomy II

## Lecture 14

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# AGN properties explained by AGN unification

- Strong UV to X-ray continuum

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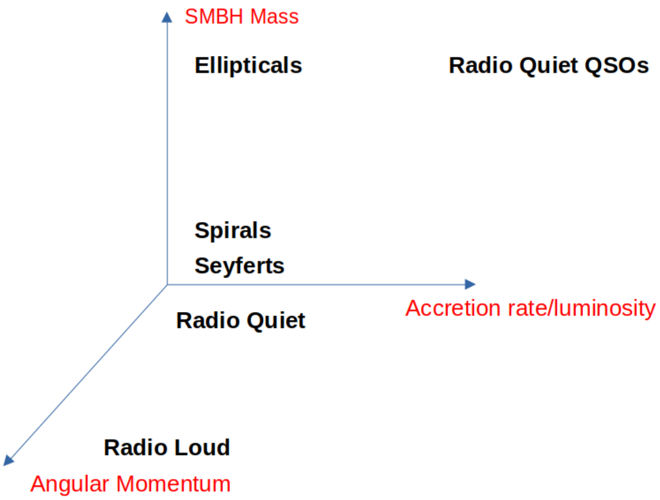
- Strong UV to X-ray continuum $\Rightarrow$ blackbody from accretion disk
- rapid variability in blazars, no emission lines
- gamma ray emission commonly seen in blazars
- Strong broad emission lines
- Strong narrow emission lines
- Strong jet emission in radio
- Steep spectrum emission in radio lobes
- One sided jets in most quasars $\Rightarrow$ Doppler boosting
- Jets aligned on all length scales probed
- AGN are more common at $z \sim 2$
- Superluminal motion
- zero proper motions

# AGN Physical parameters



# AGN Physical parameters - another view

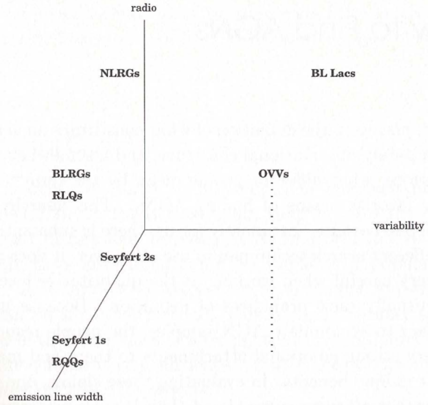



Fig. 1.9 The principal subvarieties of AGNs schematically arranged according to relative power in the radio band, emission line width, and variability. All combinations are possible except that there are no highly variable radio-quiet objects.

Krolik (1999)

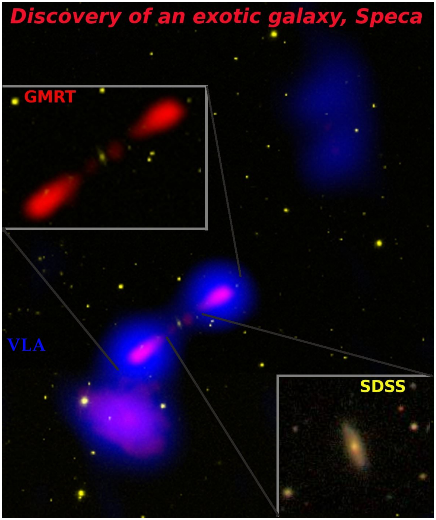
# Radio loud and Radio quiet likely depends on the spin parameter $a = \frac{cJ}{GM^2}$

| | |
|---|---|
| Radio Loud | Radio Quiet |
| High Spin $a \sim 1$ | Low Spin holes |
| Produce jets | No jets |
| Spectrum dominated by non-thermal | Both thermal and non-thermal |

# Question

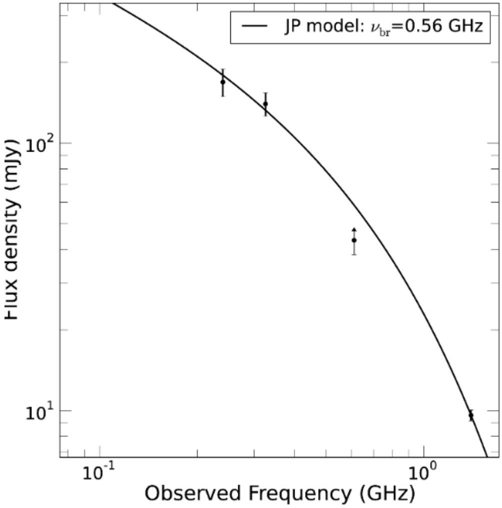
AGNs with large radio structures (kpc scale jets) are invariably hosted in elliptical galaxies. Why should this be the case?

# NGC 3801 Speca



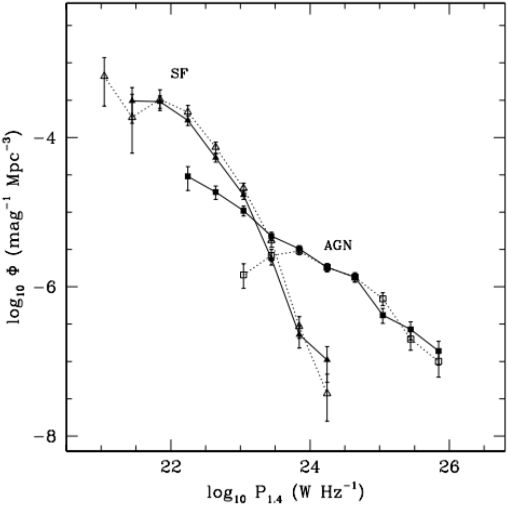

Hota et al. (2012) How do we find more SPECA like galaxies?

# Radio spectrum of radio lobe




How could you use the lobe spectrum to find distant radio galaxies?

# Luminosity function of AGN and SF galaxies




Sadler et al. 2002

# Question?

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- Photometry - Mean Colors, Morphology, Variability
- Astrometry
- X-ray + Radio detections

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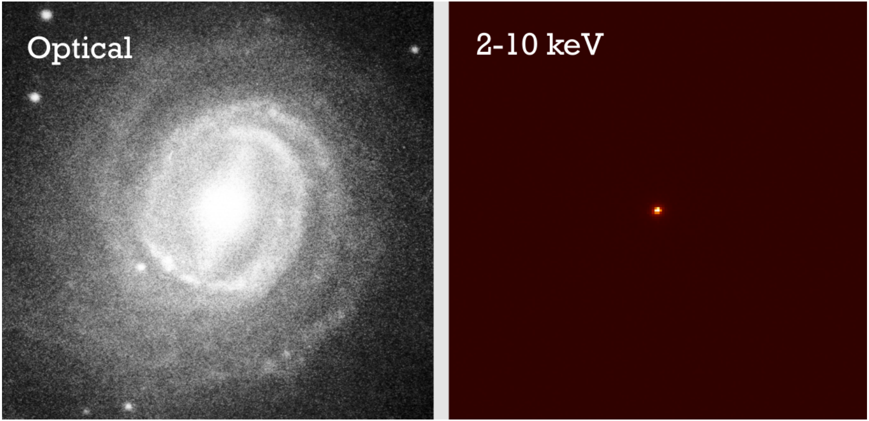
- Optical: **LSST, variability and photometric redshifts**
- Near-IR: Vista Hemisphere Survey (JHK), EUCLID (YJH), WFIRST
- Radio: MeerKAT, ASKAP, SKA (by the end of the decade)
- X-ray detections: eROSITA (expected to detect 3 million AGN during its seven year survey)

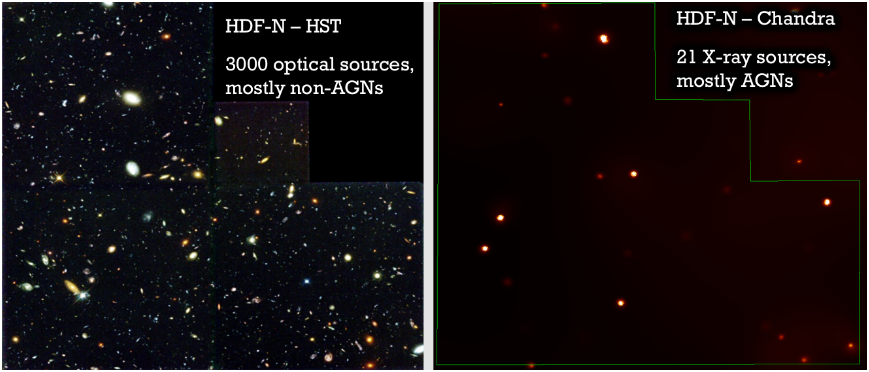
Given the vast data volumes, machine learning based techniques are expected to play an important role.

# Efficient detection of AGN in individual galaxies using X-rays



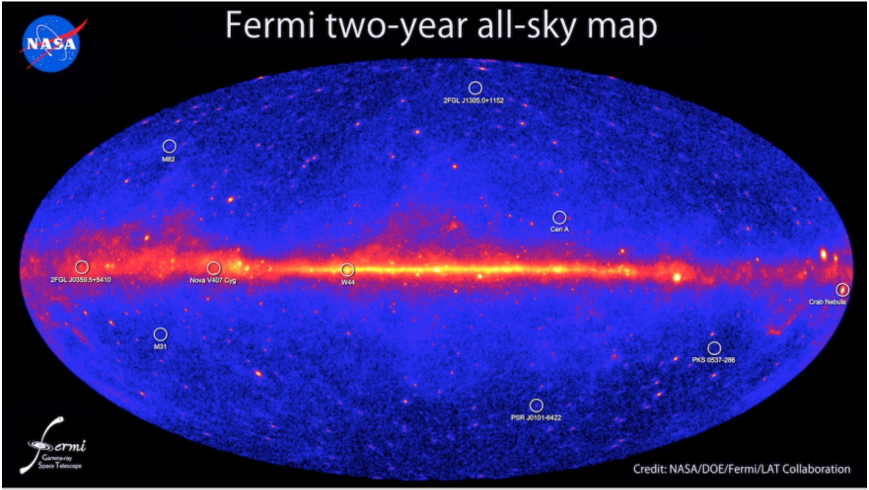

Compton thick AGNs will still be missed by X-ray imaging

# Efficient detection of AGN in deep fields

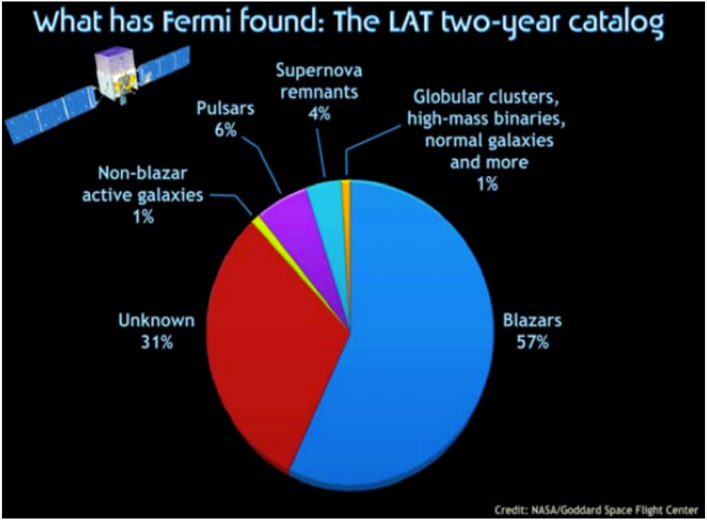



At high redshift, we cannot spatially resolve AGN light from host-galaxy starlight. X-rays enable efficient AGN selection.

# The Gamma ray sky



# What type of sources has Fermi found?



# Gamma ray astronomy from the ground

The high-energy gamma rays from AGN get absorbed in the atmosphere. Upon interaction with the atmosphere, these photons produce electron-positron pairs, leading to a cascade of particles which while moving at very high speed give rise to Cerenkov radiation.

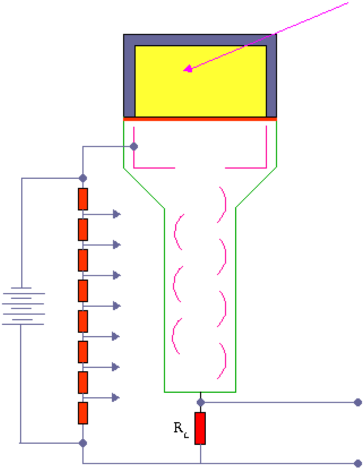
# MACE Telescope, Hanley

Photo: Y. Wadadekar

# GRAPES experiment, Ooty

Photo: Y. Wadadekar

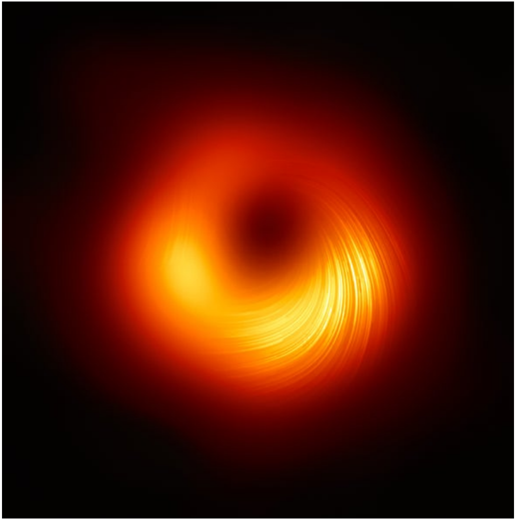
# Scintillation counter



# UHECR - $10^{18}$ eV energy

- highest energy cosmic rays may be iron nuclei rather than protons
- very rare - cause an enormous “air shower” which can be detected with the atmospheric Cerenkov experiments and on ground detectors
- most energetic particles are $> 10^{20}$ eV. equivalent to a cricket ball travelling at 150 kmph from a particle!

# M87 Polarisation map with EHT



Magnetic fields strong enough to push back on the hot gas and help it resist gravity's pull; gas that slips through the field can spiral inwards.

# AGN Bestiary

Table 1.2: The AGN Bestiary

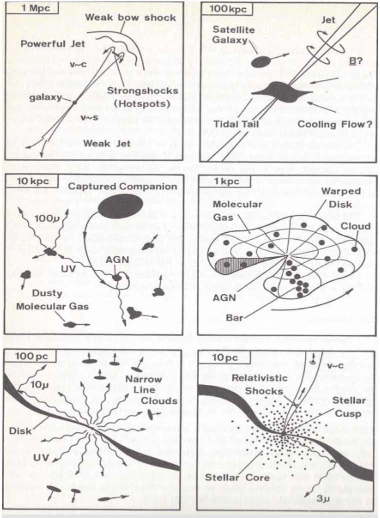
| Beast | Pointlike | Broad-band | Broad Lines | Narrow Lines | Radio | Variable | Polarized |
|---|---|---|---|---|---|---|---|
| Radio-loud quasars | Yes | Yes | Yes | Yes | Yes | Some | Some |
| Radio-quiet quasars | Yes | Yes | Yes | Yes | Weak | Weak | Weak |
| Broad line radio galaxies (FR2 only) | Yes | Yes | Yes | Yes | Yes | Weak | Weak |
| Narrow line radio galaxies (FR1 and FR2) | No | No | No | Yes | Yes | No | No |
| OVV quasars | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| BL Lac objects | Yes | Yes | No | No | Yes | Yes | Yes |
| Seyferts type 1 | Yes | Yes | Yes | Yes | Weak | Some | Weak |
| Seyferts type 2 | No | Yes | No | Yes | Weak | No | Some |
| LINERs | No | No | No | Yes | No | No | No |

Krolik (1999)

# Topics missed out in the course

AGN wind outflows - BAL Quasars - Obscured AGN (Submillimeter studies with ALMA) - high redshift AGN and implications to galaxy evolution - numerical simulations of jets and AGN - evolution of the SMBH mass function.

# AGN Phenomena




Blandford (1990)