Active Versus Normal Galaxies

- M33 – Normal Galaxy
- M100 – Normal Galaxy
- 3C273 – Active Galaxy
- PKS 2349–014 – Active Galaxy
Optical Spectrum of a Typical Active Galaxy

Optical spectrum of the Seyfert–type active galaxy RX J 2256.6+0525
Optical Spectra of Active Galaxies

BL Lac object
0814+425

Mean quasar

Seyfert 1
NGC 4151

Seyfert 2
NGC 4941

LINER
NGC 4579

Normal galaxy
NGC 3368

BLRG
3C 390.3

NLRG
Cygnus A
X-ray Emission from an Active Galactic Nucleus

NGC 4051 X-ray Chandra
Broad-Band Spectrum of an Active Galaxy

Markarian 421 – broad-band spectrum
Variability of Active Galaxies

IRAS 13225–3809

Bl Lacertae

NGC 5546 emission lines

NGC 5548 UV continuum
Rapid X-ray Variability of Active Galaxies

X-ray light curve of the active galaxy 1H0707–495
Evidence for Relativistic Motions from X-ray Spectroscopy

Broad iron K line from the active galaxy MCG–6–30–15

Energy (keV)

Line flux $F_L$ (keV cm$^{-2}$ s$^{-1}$ keV$^{-1}$)
Particle Jets from Active Galaxies

Radio galaxy 3C353
VLA multi-band image (c) NRAO 1995

Optical and Radio Views of Radio Galaxy 3C219 Montage (c) NRAO 1994
Particle Jets from NGC 6251

Notice the collimation on a huge range of size scales.
The Particle Jet from M87

Gas Disk in Nucleus of Active Galaxy M87

Hubble Space Telescope Wide Field Planetary Camera 2
## Historical Overview of Early Active Galaxy Studies

### Some early events in the history of active galaxy studies

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
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<tbody>
<tr>
<td>1908</td>
<td>Edward Fath notices strong emission lines from hydrogen, oxygen and neon in the nuclear spectrum of NGC 1068</td>
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<td>1924-1929</td>
<td>General realization that galaxies are extragalactic - led by Edwin Hubble</td>
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<tr>
<td>1926</td>
<td>Edwin Hubble notices the nuclear emission line spectra of NGC 1068, NGC 4051 and NGC 4151</td>
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<td>1939</td>
<td>Grote Reber discovers the radio source Cygnus A</td>
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<td>1943</td>
<td>C.K. Seyfert shows that a fraction of galaxies have strong, broad emission lines and that these galaxies are especially luminous</td>
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<td>1954</td>
<td>Walter Baade and Rudolph Minkowski find the counterpart to Cygnus A at $z = 0.057$</td>
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<tr>
<td>1963</td>
<td>Maarten Schmidt discovers 3C273 to have $z = 0.158$</td>
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<tr>
<td>1964</td>
<td>Zeldovich and Salpeter speculate about black holes powering quasars</td>
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<td>1967</td>
<td>The term 'black hole' is coined by John Wheeler</td>
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<td>1969 onward</td>
<td>Serious research on the black hole plus accretion disk model</td>
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<tr>
<td>1971-1974</td>
<td>Identification and study of the first stellar mass black hole in our Galaxy (Cygnus X-1)</td>
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Artist’s Impression of the Black-Hole + Accretion-Disk Model
Innermost Part of the Accretion Disk
Model for Jet Formation

Formation of extragalactic jets from black hole accretion disk

- Extragalactic jet
- Magnetic field lines
- Black hole
- Accretion disk
Active Galaxies are Common

The Chandra Deep Field-North

ACIS-I
1.95 Ms over 2.3 yr

Red: 0.5–2 keV
Green: 2–4 keV
Blue: 4–8 keV

448 arcmin²
(~ 60% Moon)

~ 582 point sources
~ 6–7 extended sources
Posns. good to 0.3–0.8 arcsec
Cosmic Evolution of Luminous Quasars

The diagram shows the relative number of quasars per Mpc$^3$ as a function of time since the Big Bang (billions of years) and redshift ($z$). The graph indicates a peak in the relative number of quasars at some point in time, after which the number decreases rapidly.
Lack of Spectral Evolution

- Optical spectra do not evolve significantly
- X-ray-to-optical flux ratio does not evolve significantly
Some Active Galaxy Researchers
A Supermassive Black Hole in Hibernation at the Center of Our Galaxy
Hibernating Supermassive Black Holes in Most Galaxies

This strong relation suggests a link between galaxy formation and the growth of supermassive black holes.
Feedback from Active Galaxy Winds?
Feedback from Active Galaxy Winds?