Einführung in die Astronomie II

Teil 14

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13. August 2019

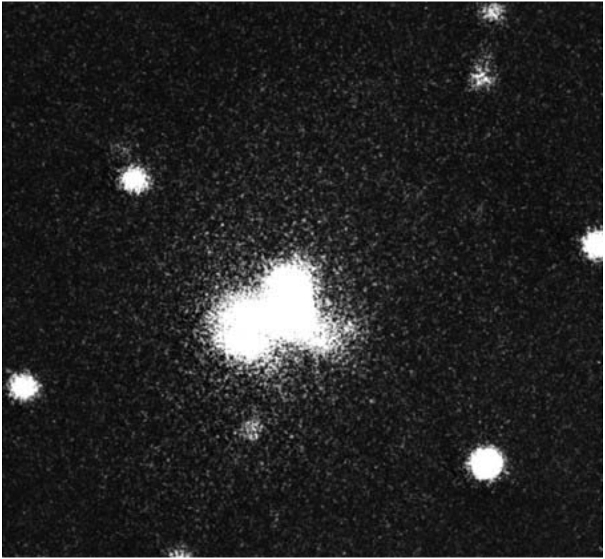
Overview part 14

- active galaxies & quasars

Quasars

- first radio surveys of the sky:
- discovered 2 strong galactic radio sources: Cas A, Sgr A
- 3rd strongest source: Cyg A
- radio interferometry (1951) $\rightarrow$ extra-galactic
- optical observations $\rightarrow$ strange galaxy
- has *emission spectrum* (usually absorption spectrum!)

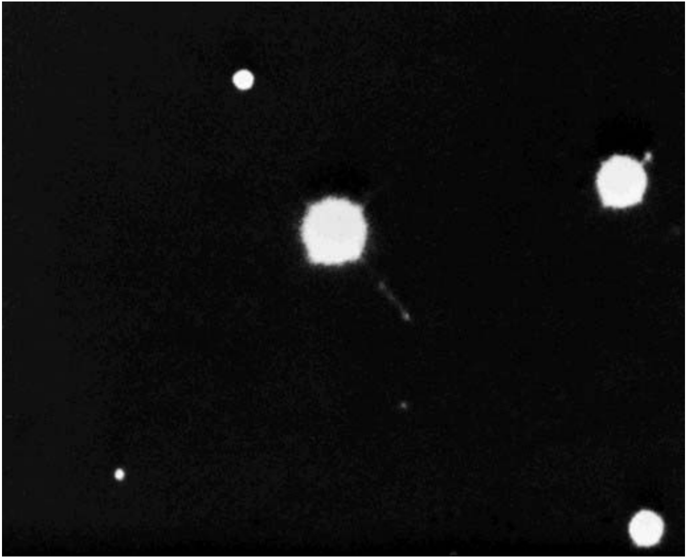
Cygnus A



Quasars

- more unusual radio sources were discovered (e.g., 3C 273, 3C 48)
- looked like stars in the visible
- normal stars don't show strong radio emission
- $\rightarrow$ clear that these are weird objects
- spectrum: initially it appeared impossible to interpret the strange lines
- 1963 $\rightarrow$ 3C 273 optical counterpart has $z = 0.158$
- $\rightarrow$ distance of $\approx 600\,\mathrm{Mpc}$
- extremely powerful source

3C 273



Quasars !!

- objects like this were named
  quasi-stellar radio sources (quasars)
- discoveries of large redshift radio-quiet star like objects
  $\rightarrow$ *quasi-stellar objects (QSOs)*
- optical spectra show very strong emission lines
- $>$ 10000 quasars are known today!
- redshifts from 0.06 to $>$ 5.0 (94% of c, 3600 Mpc distance)
- very remote objects: relation between redshift and distance depends on how the universe evolves

Quasars !!

- no quasars with small z
- $\rightarrow$ no nearby quasars (closest one $\approx 250\,\mathrm{Mpc}$)
- larger distance means looking farther back in time!
- thus: no nearby quasars
  $\rightarrow$ quasar activity ended about 1 billion years ago
- appear to be common in the past

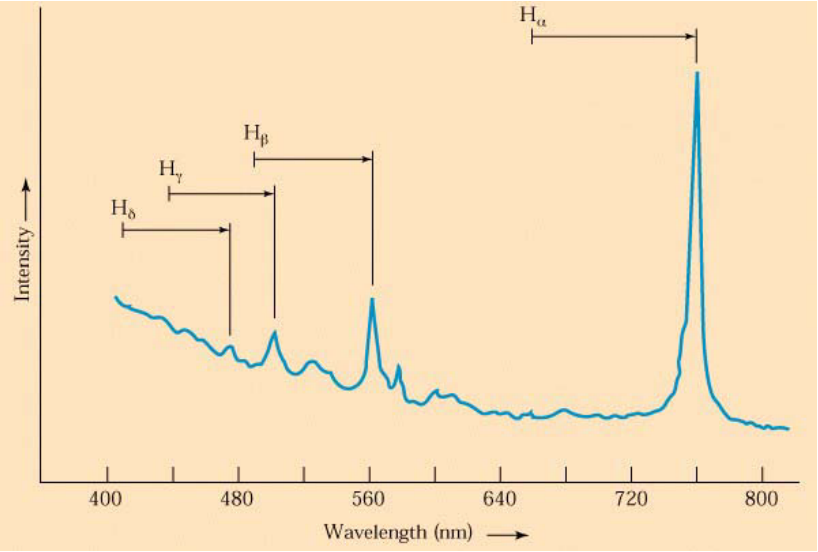
Quasars !!

- quasars are extremely luminous
- range $10^{38\ldots42}$ W (normal galaxy: 10^{37} W)
- spectrum of stars $\rightarrow$ *thermal spectrum*
- quasars emit a very different type of spectrum
- intensity decreases with frequency, no maximum!
- called *non-thermal spectrum*
- produced by extremely fast moving (“relativistic”) electrons spiraling around a magnetic field
- $\rightarrow$ *synchrotron radiation*

Quasars

- quasar spectrum is more complex than this simple picture
- emission lines are broad
- indicating motions of the emitting clouds with $10000\,\mathrm{km\,s^{-1}}$ inside the quasar

3C 273

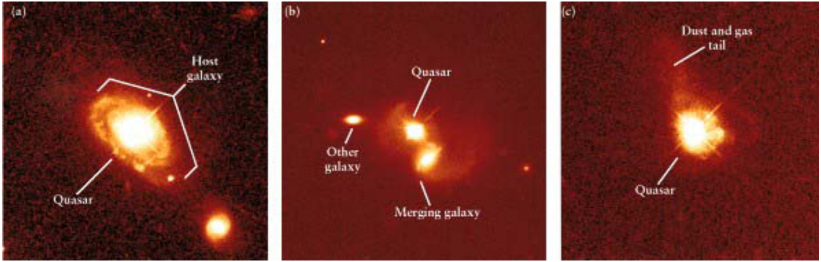


H_α
H_β
H_γ
H_δ
Intensity
400
480
560
640
720
800
Wavelength (nm)

Quasars

- 1980s: quasars are located inside their host galaxy
- hard to observe host galaxy due to brightness of quasar
- some basic observations:
  - radio-quiet quasars $\rightarrow$ spiral galaxies
  - radio-loud quasars $\rightarrow$ elliptical galaxies
  - large fraction of very distorted or peculiar galaxies
  - many with nearby companion galaxies
- $\rightarrow$ link between collision/merger and quasar?

Quasar & host galaxy !!



Seyfert galaxies

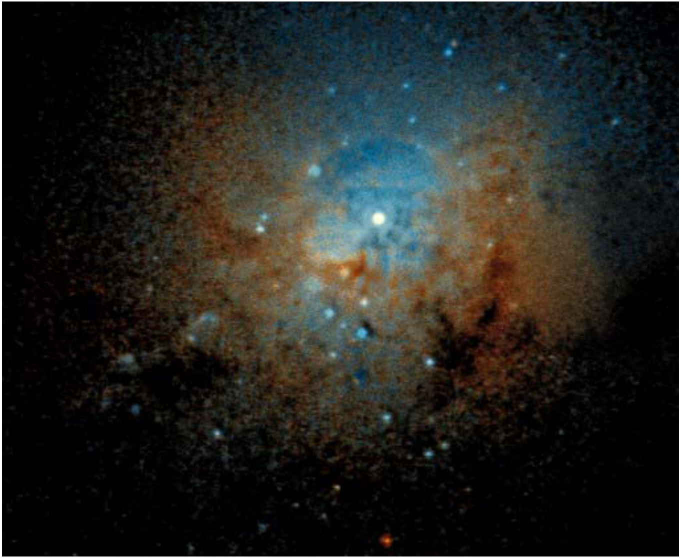
- huge gap between L of normal galaxies and quasars
- $\rightarrow$ intermediate stage?
- Seyfert (1943): spiral galaxies with bright, compact nuclei
- show signs of intense activity
- $\rightarrow$ *Seyfert galaxies*
- 10% of high L spirals are Seyfert galaxies
- today > 700 are known
- $L \approx 10^{36\dots38}\,\mathrm{W}$

Seyfert galaxies

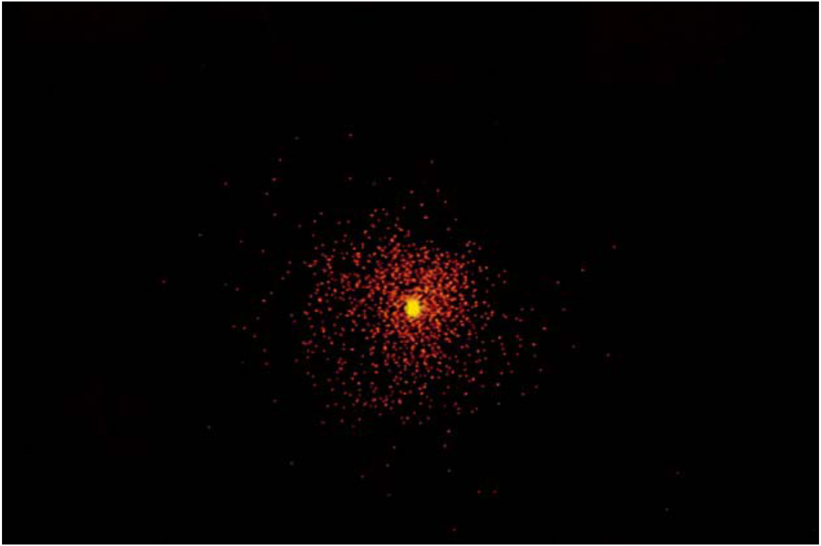
- max L of Seyfert galaxy comparable to min L quasar
- some Seyferts show signs of collision/merging

Seyfert galaxy NGC 1566

Seyfert galaxy NGC 1275



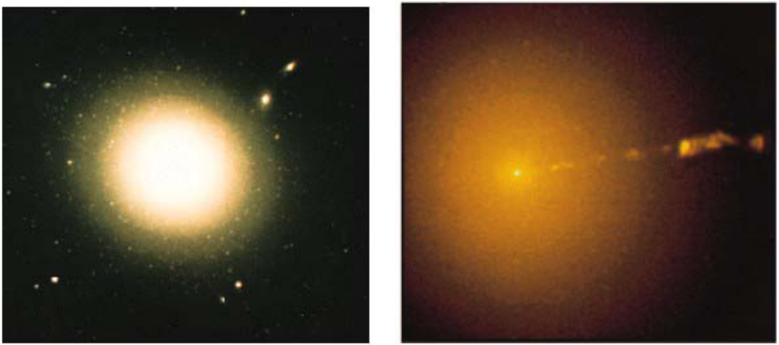
Seyfert galaxy NGC 1275



radio galaxies

- $\rightarrow$ like dim, radio loud quasars
- show strong radio emission
- first discovered in the optical as peculiar galaxies
- Example: M87 with bright compact nucleus and jet
- central region: thermal radiation
- jet: synchrotron radiation

M87

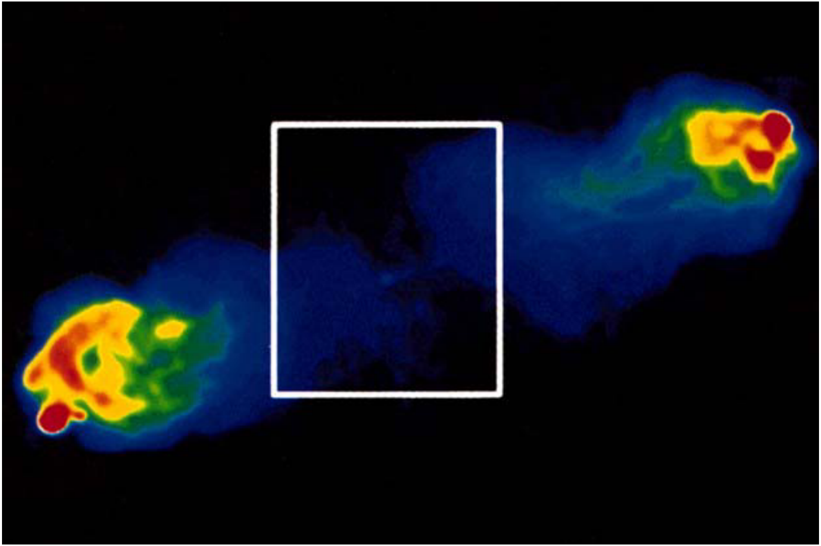


a b

radio galaxies

- radio galaxies generally have 2 *radio lobes*
- span 5–10 times the size of the galaxy itself
- $\rightarrow$ *double radio sources*
- in general: radio spectrum $\rightarrow$ synchrotron radiation
- $\rightarrow$ jets of relativistic particles

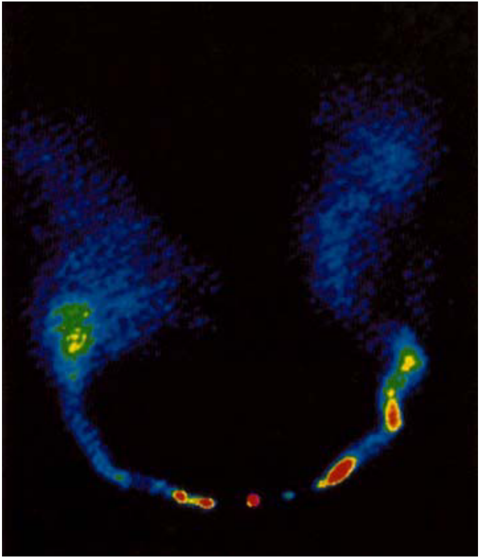
Cygnus A



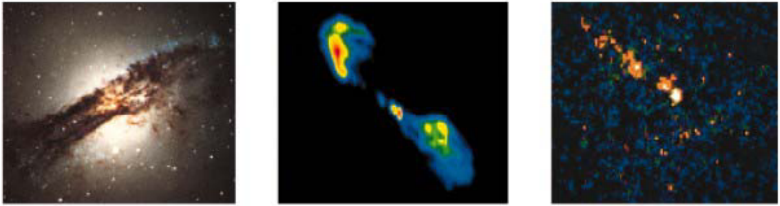
radio galaxies

- *head-tail sources*
- head with strong radio emission
- weaker tail “behind” the head
- fast moving galaxies, ejected particles deflected by intergalactic medium
- most radio galaxies located in center of rich clusters $\rightarrow$ typical for giant ellipticals!
- energy output comparable to Seyferts
- quasars $\rightarrow$ Seyfert/radio galaxies

NGC 1265



NGC 5128

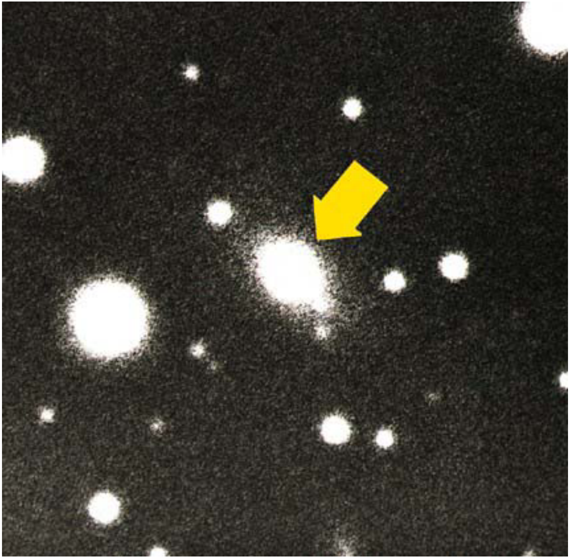


a b c

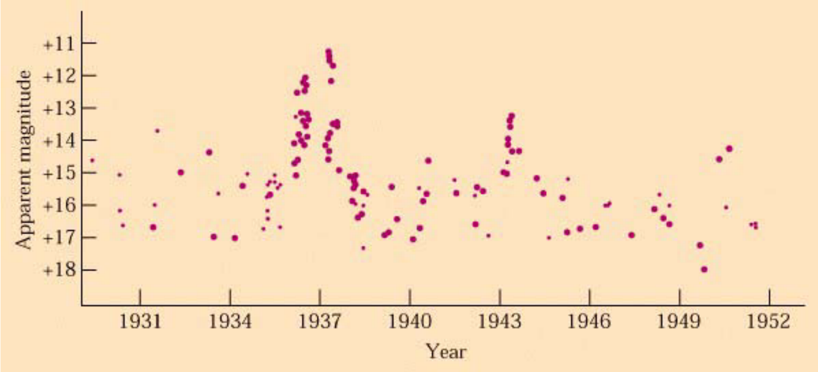
active galaxies

- 1929: discovery of a strange type of variable object (BL Lac)
- varies by factor 15 over a few months
- spectrum featureless, no lines
- but shows fuzzy image
- fuzzy material's spectrum looks like elliptical galaxy
- prototype of *blazars*

BL Lac



3C 279

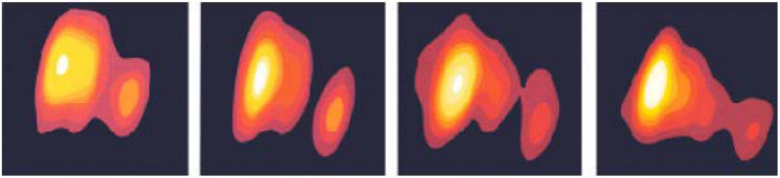


Apparent magnitude
+11
+12
+13
+14
+15
+16
+17
+18
1931
1934
1937
1940
1943
1946
1949
1952
Year

active galaxies !!

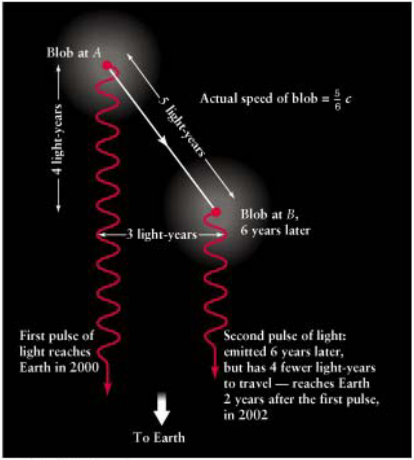
- synchrotron spectrum
- show prominent outbursts (factor 25!)
- radio $\rightarrow$ double radio sources
- oriented so that we see their jets end-on!
- *superluminal motion*: appear to eject material with speeds $> c$
- projection effect: we can see only the proper motion in the plane of the sky
- but the jets need to actually move at speeds quite close to c

Superluminal Motion in 3C 273

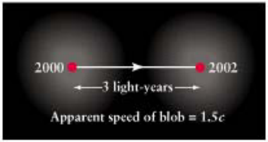


July 1977 | March 1978 | July 1979 | July 1980

Superluminal Motion !!



a View from above

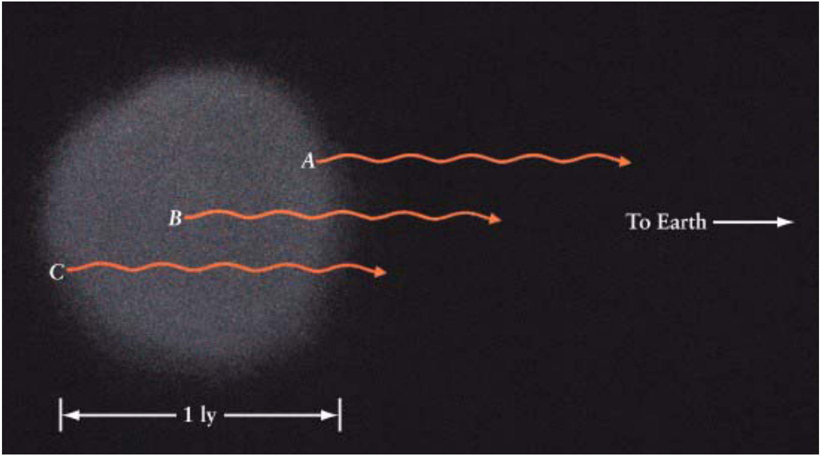


b View from Earth

active galaxies !!

- all these objects (quasars, blazars, Seyferts etc) are collectively called
- *active galaxies*
- most of the energy comes from their nuclei
  $\rightarrow$ *active galactic nuclei (AGN)*
- variability of AGN limits the size of the active region
- some blazars variable within 3–24h!
- object cannot vary on time scales that are shorter than its light crossing time
- $\rightarrow$ emit their energy from a volume smaller than the solar system!

Variability vs. Size



The Central Engine !!

- feasible power source for AGN?
- $\rightarrow$ black hole "eating" material
- material radiates *strongly* before taking the dive through the event horizon
- how massive has the BH to be?
- limit on luminosity that a BH can produce
- too much output $\rightarrow$ radiation pressure pushes material away

The Central Engine !!

- $\rightarrow$ *Eddington limit*

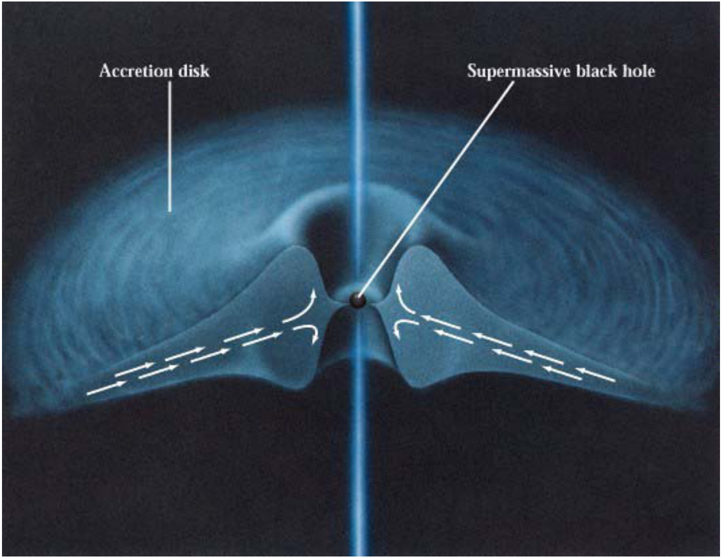
$$L_{\mathrm{Edd}} = 30000 \frac{M}{\mathrm{M}_\odot} \, \mathrm{L}_\odot$$

- example: quasar 3C 272: $L = 3 \times 10^{13} \, \mathrm{L}_\odot$
- $\rightarrow M > 10^9 \, \mathrm{M}_\odot$
- $\rightarrow$ *supermassive black hole*
- evidence for their existence numerous
- Milky Way has one, too
- M31: orbit of stars close to center $\rightarrow$ high speed $\rightarrow$ 10 million $\mathrm{M}_\odot$ within 5pc of the center

Unified Model !!

- tries to explain different types of active galaxies with a single model
- different objects are then just different views
- basic idea:
- supermassive BH surrounded by accretion disk
- friction heats and slows the gas in the disk
- it spirals closer to the BH

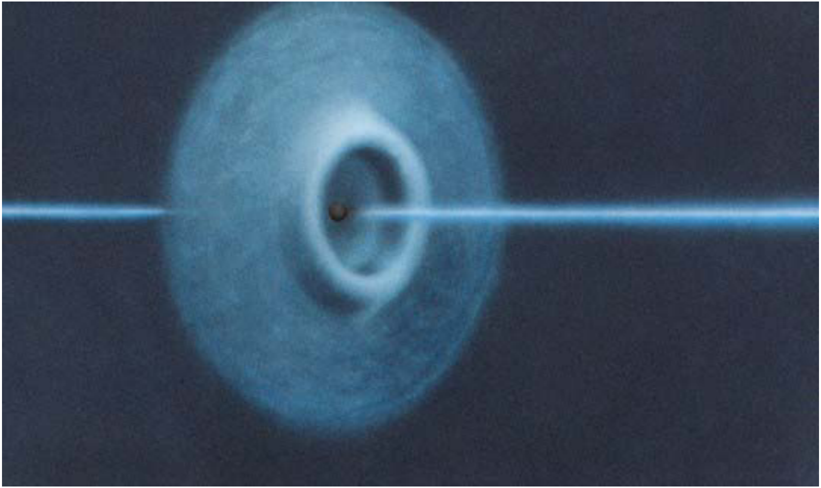
Central Engine



Unified Model

- simulations $\rightarrow$ not all the gas reaches the BH
- stalls in orbit close to BH
- heats up, pressures rise
- way out: funnel shaped cavity at the poles of the disk
- $\rightarrow$ jets
- viewing angle of disk then "selects" the type of object we see
- over time, most of the material in the disk is either "eaten" or ejected
- no feeding $\rightarrow$ quasar dies
- collision/merger $\rightarrow$ deliver fresh fuel

Central Engine



NGC 4261