Active Galactic Nuclei (AGNs):

- Galaxies with lots of activity

- Some galaxies at high redshift (large lookback times) have extremely active centers
  - More than 1000 times the light of the entire Milky Way combined from a point source at the center!!

A type of AGNs: Quasars

- Quasi-Stellar Radio Source

- Nuclei so bright (at nearly all wavelengths) that the rest of the galaxy is not easily seen

- First discovered as radio sources - then found to have very large redshifts!

Whatever is powering these QSO’s must be very small!!

- Some quasars can double their brightness within a few hours.

- Therefore they cannot be larger than a few light-hours across (solar system size)
  - Why? Think about the time it takes light from the front of the object to get to us compared to the light from the back.
Quasar Central Engines

How do quasars emit so much light in so little space?

- They are powered by accretion disks around supermassive black holes
- In some quasars, huge jets of material are shot out at the poles. These jets are strong radio sources.

"Central Engine" -- artist's conception

- Accretion disk around supermassive black hole
- Disk itself may or may not be obscured by dust
- If bright nucleus is visible, looks like a quasar; if not, then it's a radio galaxy

Prototypical "radio galaxy"

Giant elliptical galaxy NGC 5128 with dust lane (from spiral galaxy?)

Centaurus A radio source (color lobes)

Cygnus A radio jets

Jet as fine thread, big lobes at end, central hot spot
Radio tails: many shapes

NGC 1265 – 100 kly

3C 31 – 2 M light years

M87 – elliptical with jet

- Active galactic nucleus beams out very narrow jet
- Accretion disk shows gas orbiting a 2.7 billion solar mass black hole – first real proof in an active nucleus!

Another example of “central beaming engine”

400 light year wide disk of material in core of elliptical galaxy with radio jets – looks like a supermassive black hole at work!

Disk around ‘black hole’ in NGC 7052
Do ALL galaxies have supermassive black holes in their centers?

- likely YES!
- Linked to the process of galaxy formation
- More quasars seen in the distant (early) universe than now
- Black holes gradually grow, but can run out of available fuel and become nearly invisible (like in our Milky Way)

Observations show that SMBHs grow together with galaxies during formation

BH Activity resurrected by galaxy collisions?

- Many galaxies with bright nuclei show signs of being disturbed
- Collisions funnel material down into the black hole lurking at the core
- Expect more such collisions in denser early universe
  - This may help explain why fewer quasars today

Clicker Question

Supermassive black holes at the center of galaxy are believed to be produced

A. by the death of supermassive stars
B. by mergers of many solar mass black holes
C. during the process of galaxy formation
D. soon after the creation of the universe
E. by a magician :-)
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Next....

more on the..

PAST of the Universe:
structure formation

FUTURE of the Universe:
what is its fate?

QUIZ #6

a) Describe the observations which revealed that the Universe is expanding. [2pt]

b) Who performed the observations in a) and what type of measurements did he/she take? [2pt]

c) Some elliptical galaxies display dust lanes in them. How did they get there given that ellipticals have very little dust? [2 pt]

d) Where do Quasars get all their energy from? [2pt]

e) How do we know that supermassive black holes grow together with their host galaxies? [2pt]