Today’s “Ride to the Wild Side”

- Today discuss active galaxies – quasars, starburst galaxies, radio galaxies
- All from Chap 21: Galaxy Evolution – start overview reading Chap 22: Dark Matter for Wed lecture

- Third Mid-Term Exam this Friday 15 April
- Review Set 3 available, Ben Brown runs evening review this Wed 7-9pm
- Homework Set 9 Planet Finder closes Wed

Reading clicker – the boss galaxy

- Which of the following is NOT a feature of a central dominant galaxy?
  
  A. They are often spiral galaxies
  B. They are found in clusters of galaxies
  C. They often have multiple galactic nuclei near their centers
  D. They are thought to form by the merger of several smaller galaxies

Simulation: tidally interacting galaxies

Another pair – galaxies tumble together

Galaxies are not lonely – many “interactions” most likely!
also curious arcs of light?

Rich galaxy cluster

Abell 1689 – HST

ABELL 1689 – HST

Another pair – galaxies tumble together

Barnes

Simulation: tidally interacting galaxies

Barnes
**Messages from galaxy interactions**

1. In dense clusters, galaxy collisions (grazing or even head-on) must have been common
2. With successive passages, spiral galaxies can tumble together to form a big elliptical
3. Vastly increased star birth from shocking the gas and dust (star burst galaxies)
4. Start rapid feeding of supermassive black hole lurking at center of most galaxies (quasars)

**Starburst Galaxies**

- Milky Way forms about 1 new star per year
- Starburst galaxies form 100’s of stars per year

**Vigorous star birth – “The Antennae”**

**Starburst galaxy in fine detail**

NGC 3310 - HST

Big open two-sided spiral structure → tidal interaction
Quasars

- Quasi-stellar Radio Source (QSOs)
- Nuclei so bright that the rest of the galaxy is not easily seen
- First discovered as radio sources - then found to have high redshifts! (far, far away?)

Quasars – what are they?

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3C 273
redshift Z = 0.16
1000 times brighter than Milky Way!
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Cosmological (Big) Redshifts
(from expansion of universe)

Alternative definition of redshift:

\[ Z = \frac{\text{change in wavelength}}{\text{"normal" wavelength}} \]

\[ 1 + Z = \frac{\text{observed wavelength}}{\text{"normal" wavelength}} \]

Redshifts always have \( Z > 0 \)
(redder light has larger wavelengths)

Quasar spectra

Redshifts from emission lines
Many absorption lines (forest)

"Lyman Alpha Forest"

Model for "active galaxies"

Accretion disk, supermassive BH, beams on axis

What causes it?

QSO "forest"
“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 a radio galaxy

Radio galaxies

Central elliptical galaxy, huge lobes of emission, compact central source

Synchrotron radiation

Prototypical “radio galaxy”

Giant elliptical galaxy NGC 5128 with dust lane (from spiral galaxy?)
+ Centaurus A radio source (color lobes)

Remains of spiral galaxy as dust lane?

Cen A dust lane + nucleus

IR zoom-in

VISUAL - HST

Clicker – what makes the light?

- **What is most likely source of light from bright nuclei (radio, visible, x-rays) in active galaxies?**

  - A. Thermal radiation from a massive star cluster
  - B. Emission lines from hot gas
  - C. 21 cm from hydrogen
  - D. Synchrotron radiation from a black hole
Spinning accretion disk drags along magnetic fields

Synchrotron radiation from particles moving outward

Radio tails: many shapes

Typical properties of "active galaxies"

Cygnus A radio jets

Jet as fine thread, big lobes at end, central hot spot

Radio tails: many shapes

3C 31 – 2 M light years

MGC 1265 – 100 k ly

Typical properties of "active galaxies"

1. SCINTILLATION
   - high angular sizes, small angular sizes
2. NON-TEORIAL Emission
   - Scintillation in X, IR, Radio, Radio
   - Zeeman, Faraday Rotation, Electric Fields
   - Doppler, Radio Emission in young, old
3. Rare Emission, Emission
   - Source has a few very small at times
   - 1988
4. SCINTILLATION
   - Rare Emission, Fluctuations
5. Size, Size
   - Size of normal, varies among dunes, sand, dunes
6. Spatial, Spatial
   - Spatial, Spatial, Spatial
7. Large, Large
   - Large, Large, Large