

**ASTR 1040: Stars & Galaxies**



HST Abell 2218

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Lecture 25 Tues 14 Apr 2020  
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**Galaxy Evolution and AGNs**


- Revisit collisions between galaxies, plus their implications (even Andromeda+ MW!)
- Look at “active galactic nuclei” (AGN)
- Examine dark matter in galaxies
- HW #11 graded, answers posted
- Third Mid-Term Exam next Tues Apr 21
- Review Set #3 posted
- Read: 23.2 Evidence for Dark Matter
- Re-read: Chap 21 Galaxy Evolution

**REVISIT**

**Rich galaxy cluster**

Galaxies have many neighbors  
“interactions” most likely!

interesting “arcs of light”



Abell 1689 - HST

**Stefan’s Quintet in HST detail**



**Present Day – distant Andromeda**



5

**Future: 2 billion years -- predicted**



6

**Future: 3.75 billion years**



7

**Future: 3.85 billion years (getting close)**



8

**Future: 3.9 billion years (very close)**



9

**Future: 4 billion years (heading out)**



10

**Future: 5.1 billion years (coming back in)**



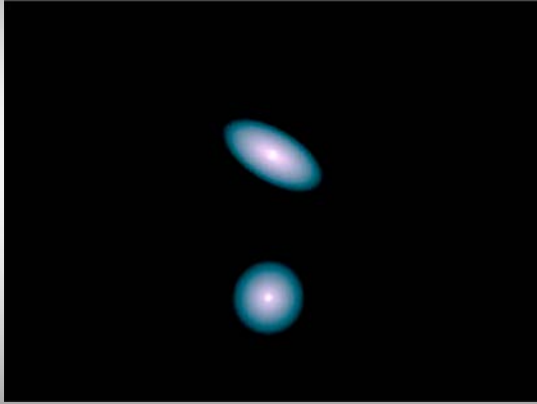
11

**Future: 7 billion years**



12

### Milky Way collision with Andromeda ?



### Questions or Comments

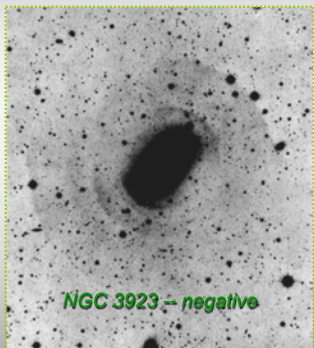
#### Poll 1: galaxy collisions

- Why are collisions between galaxies more likely than between stars within a galaxy?
- **A.** Galaxies are much larger than stars
- **B.** Galaxies travel through space much faster than stars
- **C.** Relative to their sizes, galaxies are closer together than stars
- **D.** Galaxies have higher redshifts than stars

#### 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**)

#### Signs of having collided: elliptical galaxy with shells



NGC 3923 -- negative



"Polar ring" galaxy



Seyfert Sextet - HST




### Starburst Galaxies




*M82 - visible*                      *Chandra - X-ray*

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

### M82 "Cigar" composite HST+Chandra+Spitz

*M106 has 36 M solar mass black hole at its center*


10,000 light-years

a This composite image of M106 shows emission of visible light (yellow), x-rays (blue), radio waves (purple), and long-wavelength infrared light (red). The radio waves show that jets of energetic plasma are shooting out from the center of the galaxy, and the x-rays show that those jets are heating gas above and below the galaxy's disk.

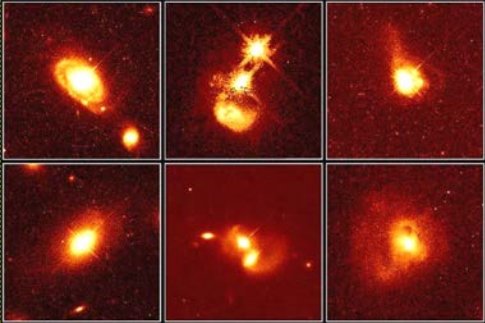
### Starburst galaxy in fine detail

NGC 3310 - HST

*Big open two-sided spiral structure  
--> tidal interaction*



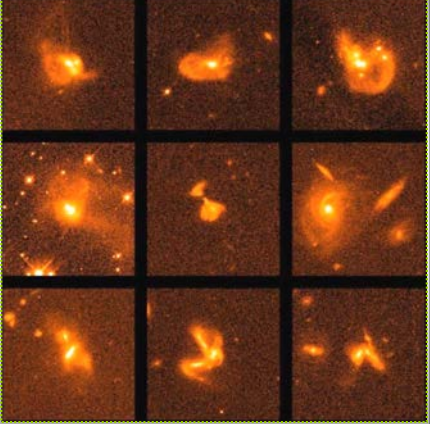
### Distant galaxies with "active nuclei" - HST



- Galaxies with odd stuff going on in their cores
- Nuclei as bright as rest of galaxy

### Many interacting galaxy systems

*Very distant (big lookback time) with HST*



Questions or Comments

REVISIT ACTIVE GALACTIC NUCLEI

400,000 ly

lobe hot spot jet core

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

Cygnus A radio jets

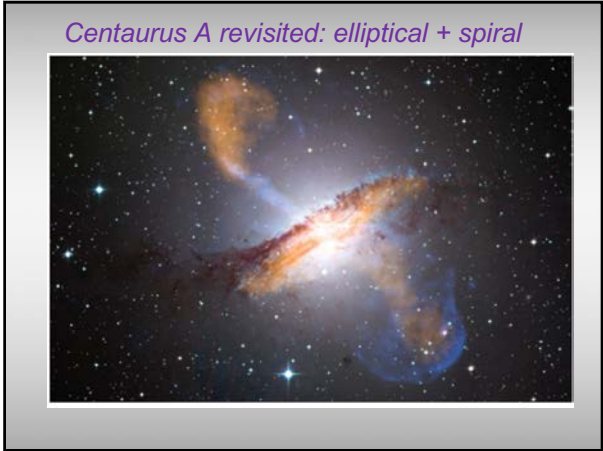
VLA

Cygnus A in more detail

lobe active galactic nucleus hot spot jet lobe hot spot jet visible galaxy

100,000 light-years

VLA imaging



Radio galaxy Hercules A

lobe galaxy jets lobe


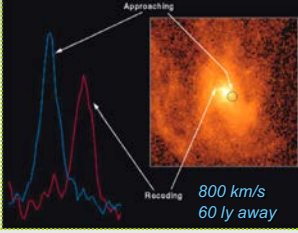
500,000 light-years

Radio tails: many shapes

NGC 1265 – 100K ly

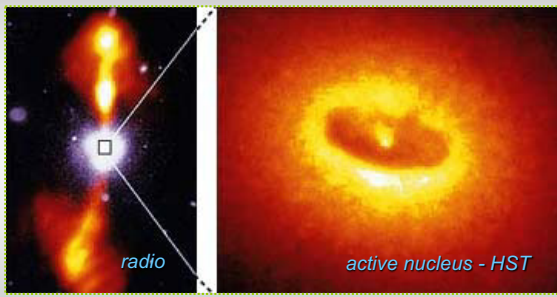
3C 31 – 2 M light years

### M87 – elliptical with jet

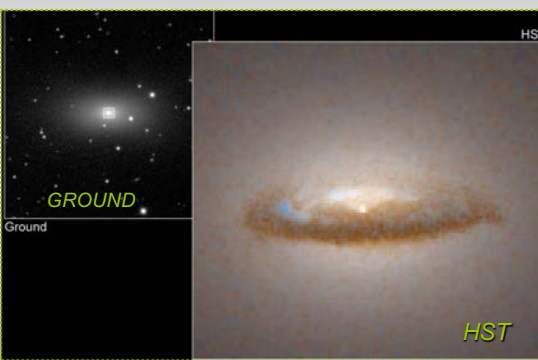
- Active galactic nucleus beams out **very narrow jet**
- Accretion disk shows gas orbiting a **2.7 billion** solar mass black hole – **first real proof!**

### Another example of “central beaming engine”



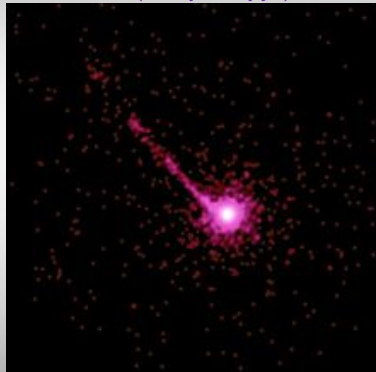
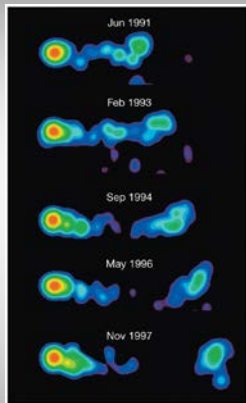
- 400 light year wide disk of material in core of elliptical galaxy with radio jets – looks like supermassive BH at work!

### Disk around ‘black hole’ in NGC 7052



### Jet in Chandra view of very distant quasar

(10 Bly, 1 Mly jet)

Ejection of plasma “blobs” along jet from quasar 3C 345 (left) moving nearly at speed of light

### Typical properties of “active galaxies”

**synchrotron emission!**

**source very small in size**

**Most quasars present when universe was young**

**PROPERTIES OF “ACTIVE GALAXIES”**  
 RADIO GALAXIES, SEYFERT GALAXIES, BL LACERTINE OBJECTS, QUASARS “SOME HAVE MORE THAN OTHERS!”

- HIGH LUMINOSITY**  
 = MUCH MORE LUMINOUS THAN NORMAL GALAXIES
- NON-THERMAL EMISSION**  
 = EXCESS RADIATION IN UV, IR, RADIO, X-RAY  
 = IMPULSIVE SYNCHROTRON EMISSION FROM RELATIVISTIC ELECTRONIC SPINNING IN MAGNETIC FIELD
- SMALL, CONTACT SIZE OF INTENSE EMISSION**  
 = INCLUDE VERY BRIGHT COMPONENTS REAR OF GALAXY
- RAPIDLY VARYING EMISSION**  
 = SOURCE MAY BE A FEW LIGHT HOURS OR DAYS IN SIZE
- EXPLOSIVE FEATURES**  
 = JETLINE EXTENSIONS, FILAMENTS
- GRAVITATIONAL DISTURBANCES**  
 = VERY HIGH INTERNAL VELOCITIES DERIVED FROM BEAM SPREADING EMISSION LINES  
 = PECULIAR OPTICAL APPEARANCE
- LARGE REDSHIFTS**  
 = IMPLYING HIGH RECESSIONAL VELOCITIES, VERY LARGE DISTANCES

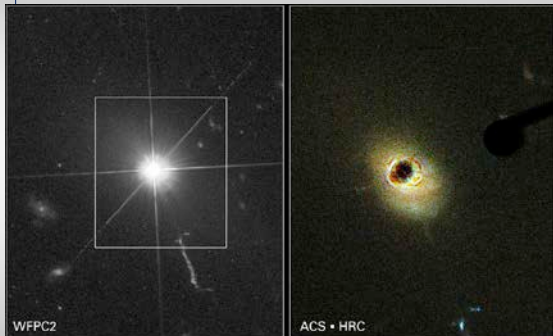


Questions or Comments

Poll 2: the boss galaxy

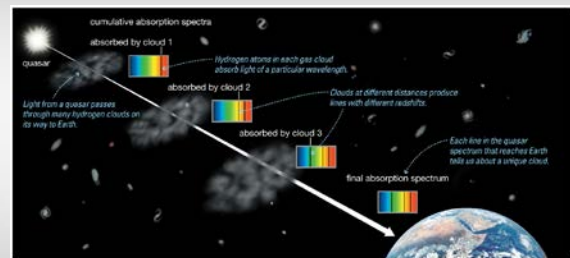
- Which of the following is **NOT** a feature of a central dominant (cD) galaxy in clusters?
- **A.** They are often spiral galaxies
- **B.** They are found in clusters of galaxies
- **C.** They often have multiple galactic nuclei near their centers
- **D.** They are thought to form by the merger of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

Revisit Quasar 3C273



With advanced HST instruments, can see extended surrounding galaxy

Sampling intervening atomic hydrogen clouds between us and very distant quasar (Lyman alpha)



Viewing distant quasar: "Lyman alpha forest" of absorption from intervening gas

