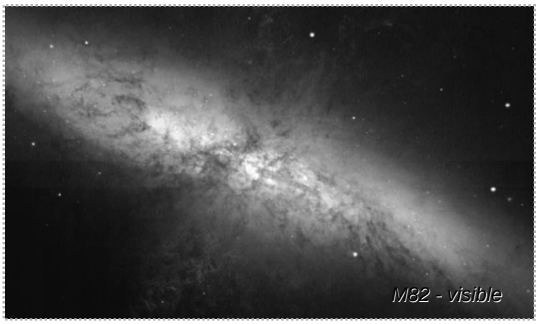
ASTR 1120: Stars & Galaxies



Prof. Juri Toomre TA: Ben Brown/Amy Bender

Lecture 36 Mon 11 Apr 05

zeus.colorado.edu/astr1120-toomre

Today's "Ride to the Wild Side"

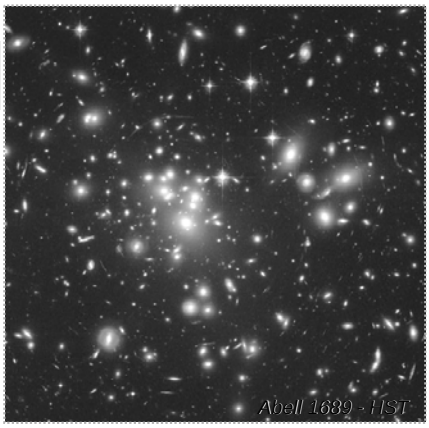
- Today discuss *active galaxies – quasars, starburst galaxies, radio galaxies*
- All from *Chap 21: Galaxy Evolution* – start overview reading *Chap 22: Dark Matter* for Wed lecture

- *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

Rich galaxy cluster

Galaxies are not lonely -- many "interactions" most likely!

also curious arcs of light?



Reading clicker – the boss galaxy

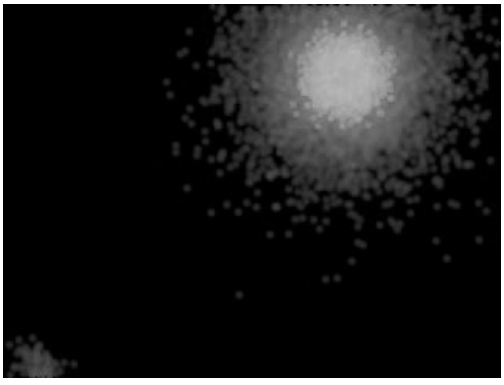
- *Which of the following is NOT a feature of a central dominant galaxy ?*

A.

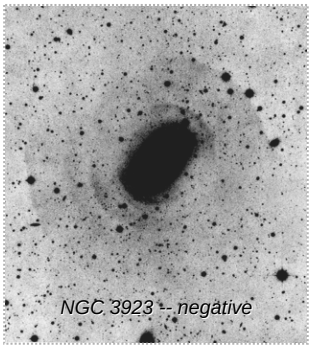
- *A.* They are often spiral galaxies
- *B.* They are found in clusters of galaxies
- *C.* They often have multiple galactic nuclei near their centers
- *D.* They are thought to form by the merger of several smaller galaxies

Simulation: tidally interacting galaxies Barnes

Another pair -- galaxies tumble together Barnes

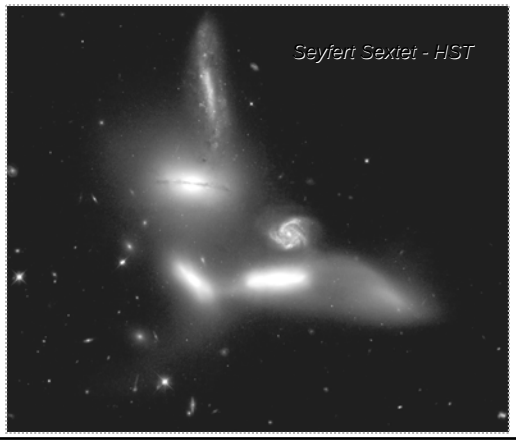


Signs of having collided: elliptical galaxy with shells



NGC 3923 -- negative

"Polar ring" galaxy

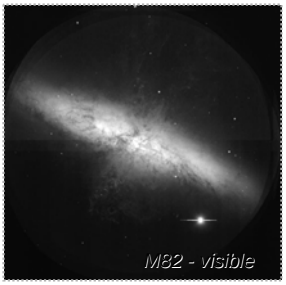


Seyfert Sextet - HST

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

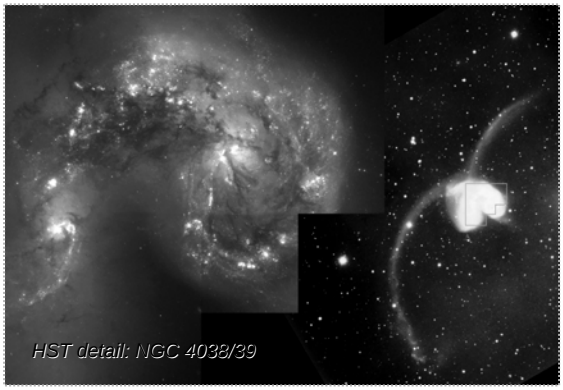


M82 - visible

Chandra – X-ray

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

Vigorous star birth – "The Antennae"

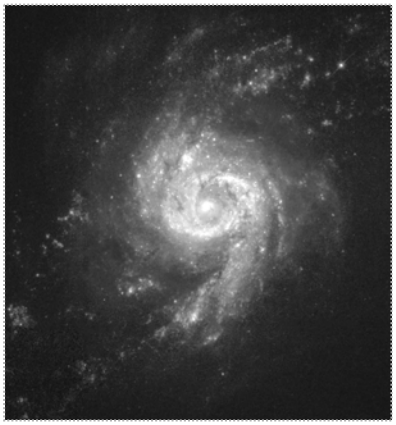


HST detail: NGC 4038/39

Starburst galaxy in fine detail

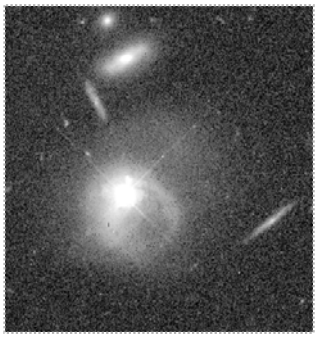
NGC 3310 - HST

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?

" 3C 273 "
redshift Z = 0.16

1000 times brighter than Milky Way !

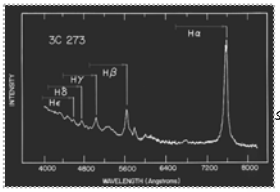
WHAT IS A QUASAR ? (QSO)

QUASI - STELLAR RADIO SOURCE OBJECT

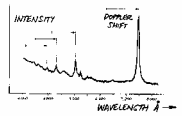
1960: 3C 48 FIRST QSO DISCOVERED (3rd CAMBRIDGE RADIO CATALOG) SPEED ≈ 30% c

1963: 3C 273 MAARTEN SCHMIDT (CALTECH) SOLVED OUT PUZZLE OF SPECTRUM — VERY LARGE RED SHIFTS IN HYDROGEN! EMISSION LINES — BROAD & DISPLACED DOPPLER SHIFT = 15% c (SPEED OF LIGHT) (Z = 0.158 ; 3 B LY AWAY)

QSO:
TOTAL OPTICAL LUMINOSITY (IF AT COSMOLOGICAL DISTANCES) ~ 10^{13} $L_\odot$
NORMAL GALAXY ~ 10^{10} $L_\odot$
ABOUT 10% QSO's ARE RADIO SOURCES



SPECTRUM OF 3C 273



Cosmological (Big) Redshifts
(from expansion of universe)

Alternative definition of redshift :

Z = redshift
= change in wavelength/ "normal" wavelength

1 + Z =
observed wavelength / "normal" wavelength

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

Quasar spectra

Redshifts from emission lines + Many absorption lines (forest)

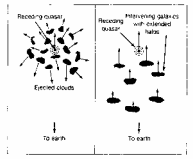
QUASAR SPECTRA

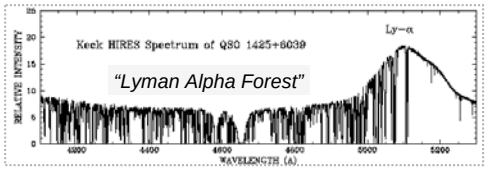
- REDSHIFTS DETERMINED FROM STRONG EMISSION LINES OF HIGHLY IONIZED GAS

QSO: COMPACT BLUE OBJECTS, SOME WITH RADIO & X-RAY EMISSION

- BUT ALSO WHOLE "FOREST" OF ABSORPTION LINES AT VARIOUS SMALLER REDSHIFTS

EITHER:
- ABSORPTION IN CLOUDS EJECTED FROM QUASAR OR (MORE LIKELY)
- FROM EXTENDED HALOS OF INTERVENING GALAXIES

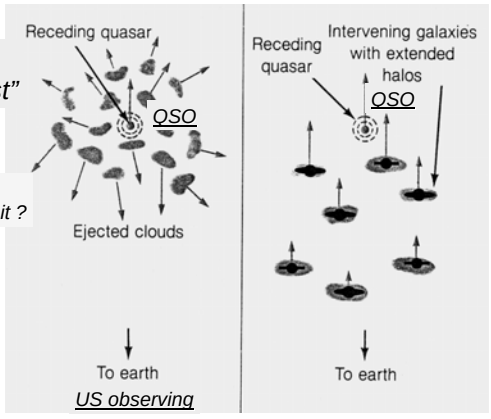




"Lyman Alpha Forest"

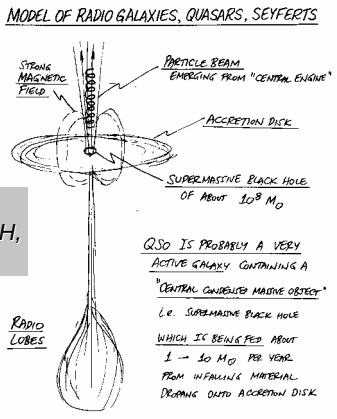
QSO "forest"

What causes it ?



Model for "active galaxies"

Accretion disk, supermassive BH, beams on axis



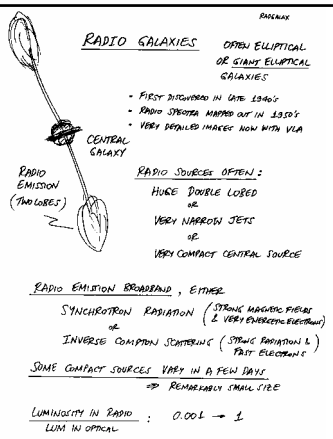
"Central Engine" -- artist's conception

- *Accretion disk around super-massive 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

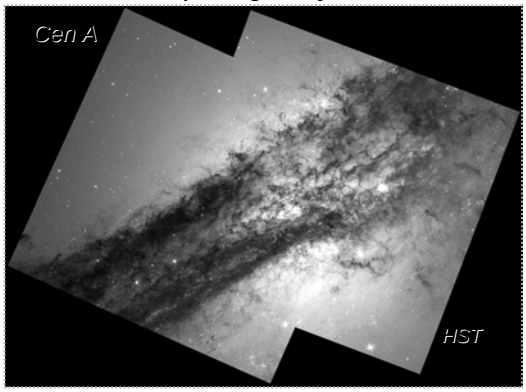
Synchrotron radiation



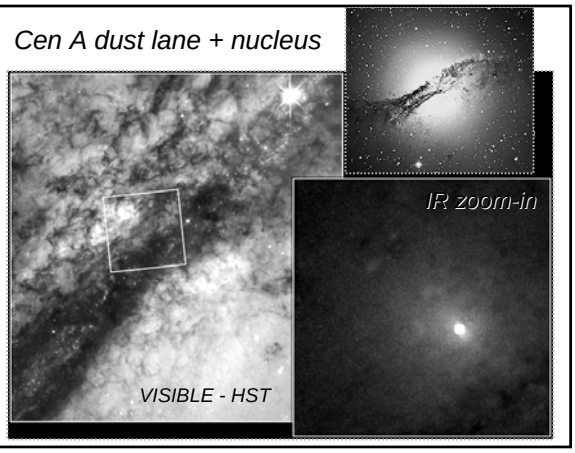
Prototypical "radio galaxy"

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



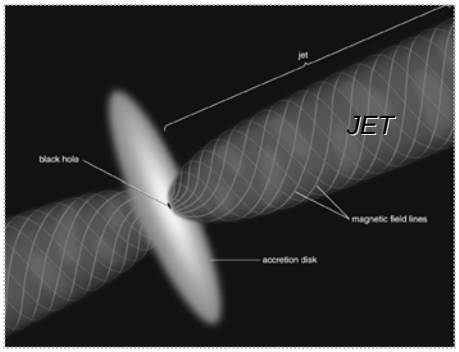
Clicker – what makes the light?

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

D.

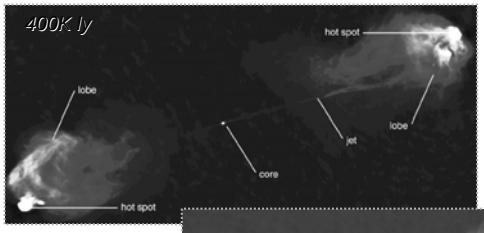
- *A.* Thermal radiation from a massive star cluster
- *B.* Emission lines from hot gas
- *C.* 21 cm from hydrogen
- *D.* Synchrotron radiation from a black hole

Synchrotron radiation from particles moving outward

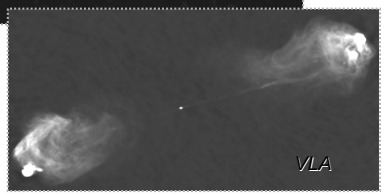


Spinning accretion disk drags along magnetic fields

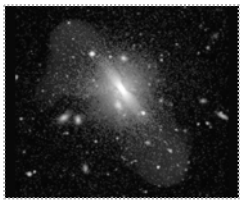
Cygnus A radio jets

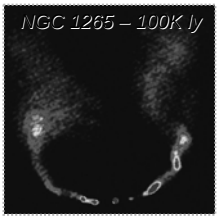


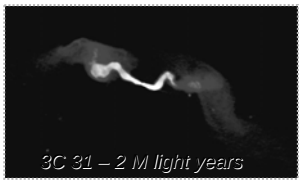
Jet as fine thread, big lobes at end, central hot spot

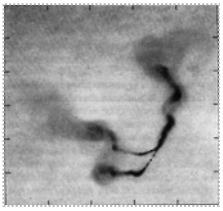


Radio tails: many shapes









Typical properties of "active galaxies"

synchrotron emission !

source very small in size

PROPERTIES OF "ACTIVE GALAXIES"

RADIO GALAXIES, SEYFERT GALAXIES, BL LACERTAE OBJECTS, QUASARS "SOME HAVE MORE THAN OTHERS!"

1. HIGH LUMINOSITY
   - MUCH MORE LUMINOUS THAN NORMAL GALAXIES
2. NON-THERMAL EMISSION
   - EXCESS RADIATION IN UV, IR, RADIO, X-RAY
   - IMPLYING SYNCHROTRON EMISSION FROM RELATIVISTIC ELECTRONS SPIRALING IN MAGNETIC FIELDS
3. SMALL, COMPACT SIZE OF INTENSE EMISSION
   - NUCLEUS VERY BRIGHT COMPARED TO REST OF GALAXY
4. RAPIDLY VARYING EMISSION
   - SOURCE MAY BE A FEW LIGHT HOURS OR DAYS IN SIZE
5. EXPLOSIVE FEATURES
   - JET-LIKE EXTENSIONS, FILAMENTS
6. GRAVITATIONAL DISTURBANCES
   - VERY HIGH INTERNAL VELOCITIES DEDUCED FROM BROAD SPECTRAL EMISSION LINES
   - PECULIAR OPTICAL APPEARANCE
7. LARGE REDSHIFTS
   - IMPLYING HIGH RECESSIONAL VELOCITIES, VERY LARGE DISTANCES