ASTR 1040: Stars & Galaxies

Stefan's Quintet

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Lecture 24 Thur 9 Apr 2020

zeus.colorado.edu/astr1040-toomre

Quasars and Active Galaxies

- *Read Chap 21 "Galaxy Evolution" with care*
- *Quasars and active galactic nuclei* feature prominently in chapter
- So too does *Role of Supermassive BH*
- Study *grazing collision between galaxies: bridges and tails*

- New *HW #12* posted on Canvas, *HW #11* due there (with grace)

REMINDER

Measuring big distances to galaxies

"STANDARD CANDLES" -- important ones in `distance ladder '

- *0. Parallax*
- *1. Main-sequence fitting*
- *2. Cepheid variables*
- *3. Tully-Fisher relation*
- *4. White dwarf supernovae*

Brightness ~ Luminosity / (Distance)^2

REMINDER

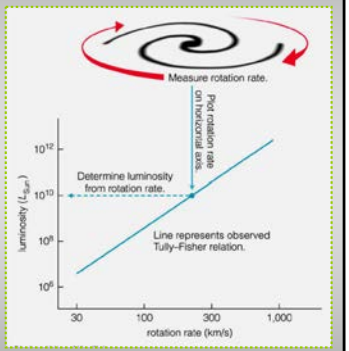
Tully-Fisher Relation

DISTANCE ESTIMATE 3

- *Fast rotation speeds in spiral galaxies*
- *→ more mass in galaxy*
- *→ higher luminosity*

Measure rotation speeds to infer luminosity

Need bright "edge-on" spirals, estimate tilt

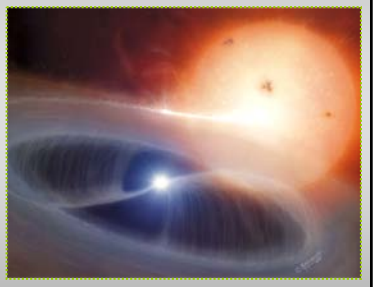


REMINDER

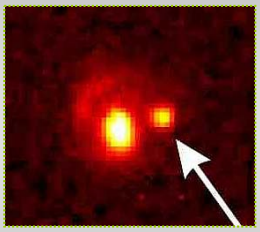
Even brighter: White dwarf supernovae

DISTANCE ESTIMATE 4

- *"Standard explosion" = fusion of 1.4 solar masses of material*
- *Nearly the same amount of energy released*

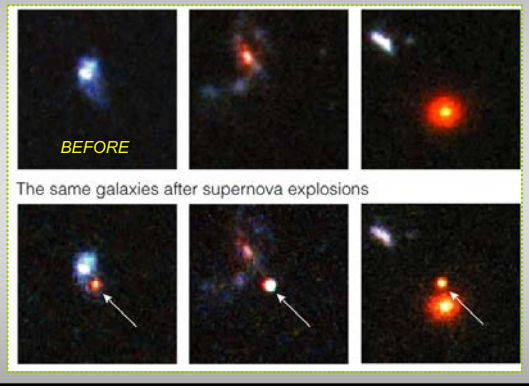


Bright enough to be seen halfway across observable universe



Useful for mapping the universe to the largest distances

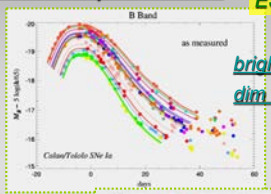
Supernovae in very distant galaxies



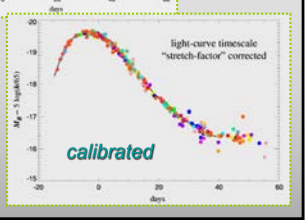
White dwarf supernovae

DISTANCE ESTIMATE 4

- Carbon fusion explosion; mass transfer in binary takes white dwarf `over the edge'
- Roughly same amount of energy released (calibrate)



brighter SN
dim more slowly!



DISTANCE ESTIMATE 5

Use Hubble's Law itself to estimate vast distances D

- Measure velocity, then: $D = v / H_o$
- Example: using H_o = 70 km/sec/Mpc, and finding that v = 700 km/sec

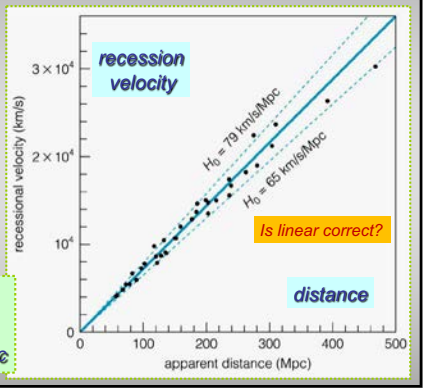
D = 700 km/sec / 70 km/sec/Mpc = 10 Mpc
= 32 million light years

REVIEW

VELOCITY = H_o x DISTANCE

"HUBBLE CONSTANT"

H_o = 71 +/- 4 km / sec / Mpc



Questions or Comments

Brief Meet-and-Greet Interval

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?)

Cosmological (Big) Redshifts
(from expansion of universe)

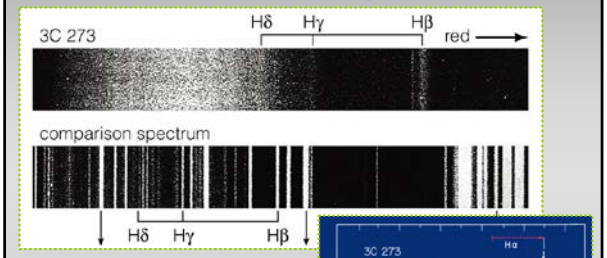
Alternative definition of redshift :

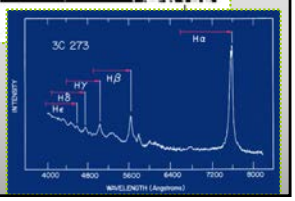
Z = redshift
= change in wavelength/ "normal" wavelength

$1 + Z$ =
observed wavelength / "normal" wavelength

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

Quasar 3C 273 spectrum



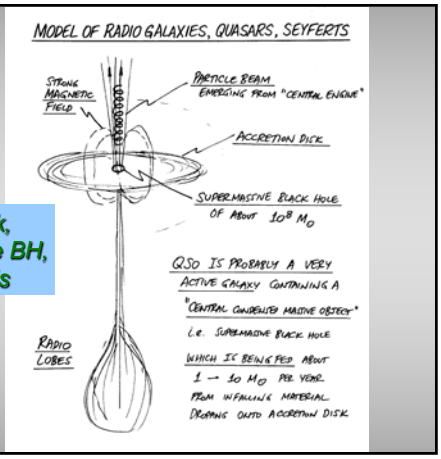


Tricky to identify
hydrogen emission lines
…. very big red shift

Maarten Schmidt, Caltech, 1967

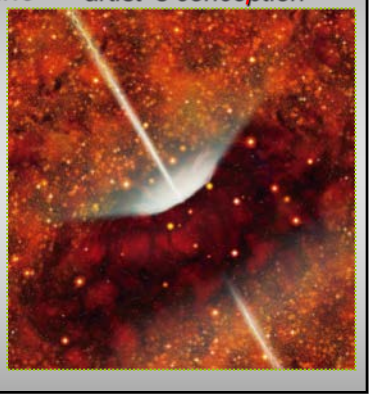
Model for "active galaxies"

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

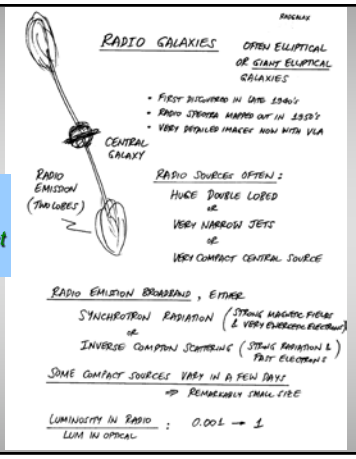


Flying toward supermassive black hole

Radio galaxies

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

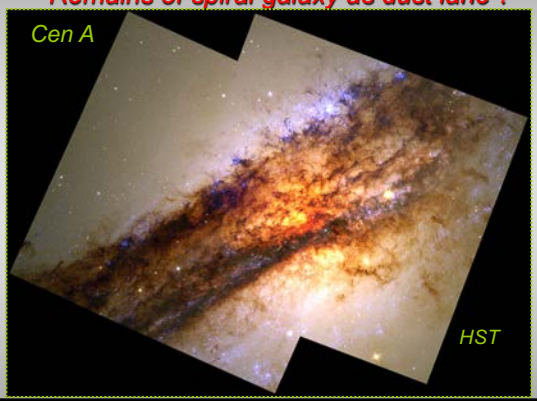
Synchrotron radiation



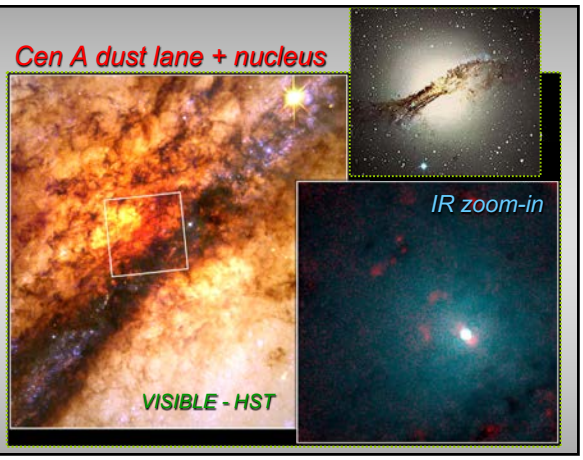
Prototypical "radio galaxy"

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

Remains of spiral galaxy as dust lane ?



Cen A dust lane + nucleus



Poll 1: Hubble's Law

Hubble's Law shows that:

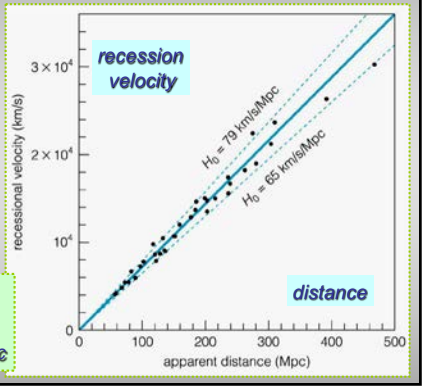
A. The further away we look in the universe, the faster things are moving
B. The further away we look in the universe, the slower things are moving
C. Everything in the universe is moving away from us at the same speed
D. Everything in the universe is staying still, we're just the ones moving
E. We must be the center of the Universe

REVIEW

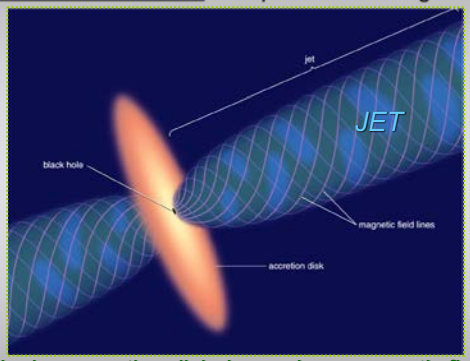
VELOCITY = H_o x DISTANCE

"HUBBLE CONSTANT"

H_o = 71 +/- 4 km / sec / Mpc



Synchrotron radiation from particles moving outward



Spinning accretion disk drags along magnetic fields

REVISIT

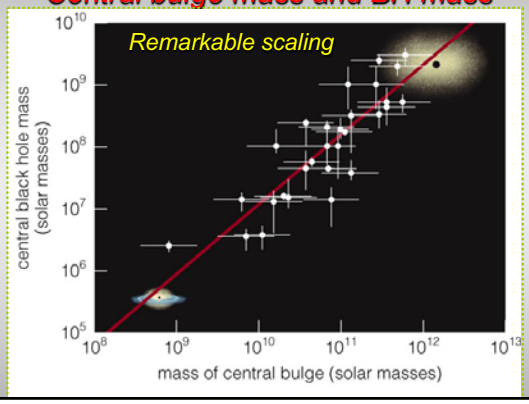
Prototypical "radio galaxy"

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

Do ALL big galaxies have supermassive black holes?

- As of 2020: probably YES !
- Part of normal 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 relatively invisible (like in our Milky Way)

Central bulge mass and BH mass



Questions or Comments

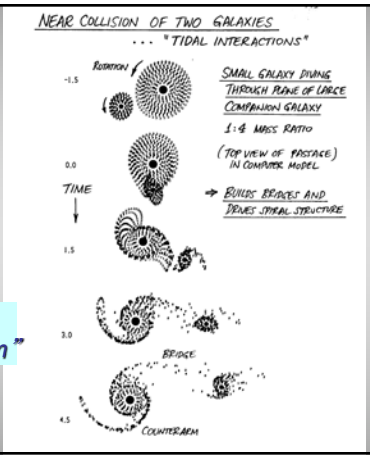
Rich galaxy cluster

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

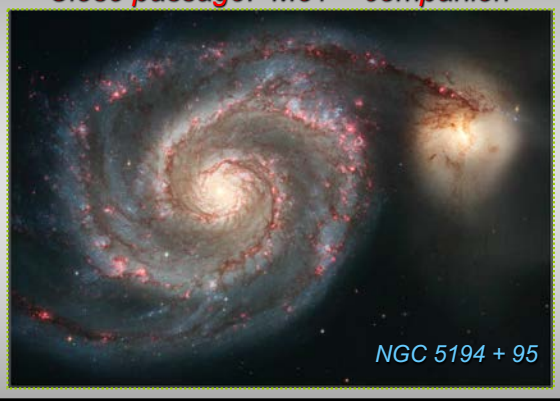
also curious arcs of light?

Collision of small galaxy with big one

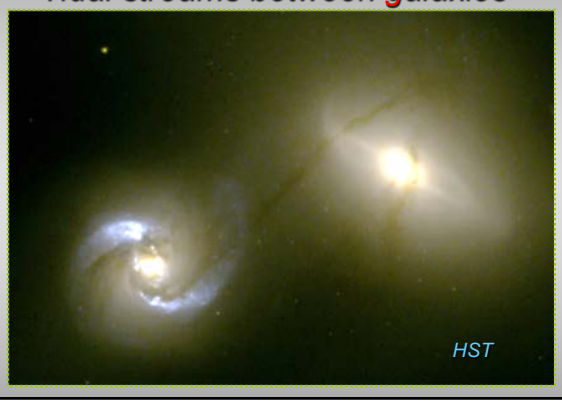
Builds "bridge" and "counterarm"



Close passage: M51 + companion



Tidal streams between galaxies



Poll 2: MC

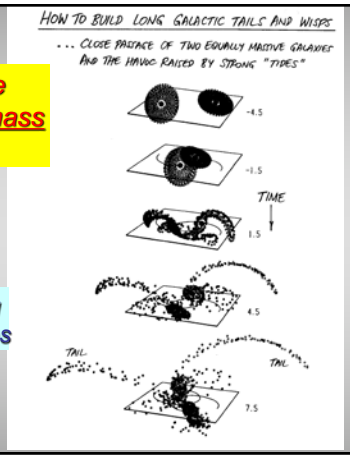
- *What are the Magellanic Clouds?* **C.**

- **A.** Two nebulae in disk of Milky Way visible only in southern hemisphere
- **B.** Clouds of dust and gas in many places throughout the Milky Way galaxy
- **C.** Two small galaxies that orbit Milky Way
- **D.** Star-forming clouds in constellation Orion

Two galaxies form "The Antennae"

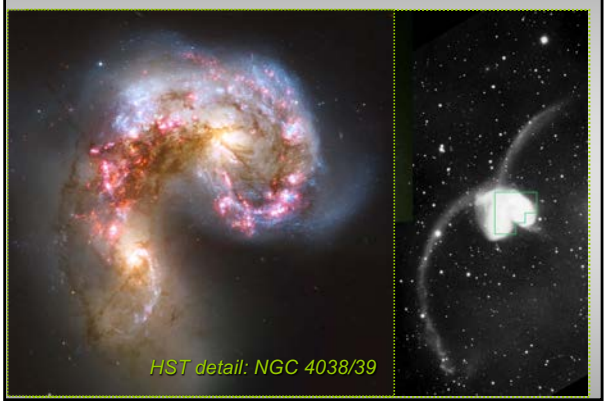
Close passage of two equal mass galaxies

Builds very long "tails" and wisps



Colliding galaxies – "The Antennae"

Vigorous star birth – "The Antennae"

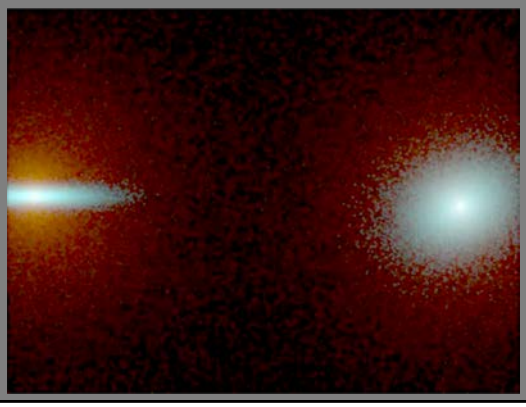


Interacting: NGC 2207 + IC 2163

A major puzzle: "The Mice" NGC 4676

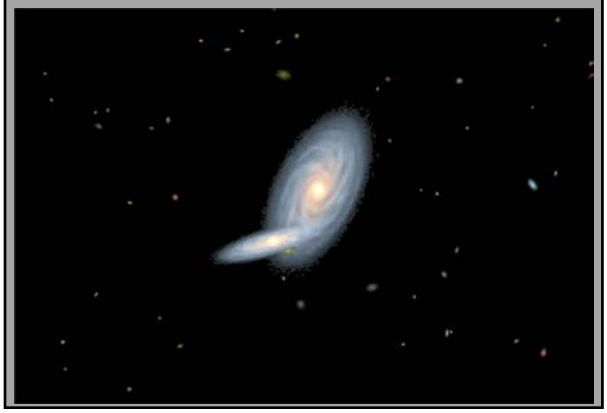
"Mice" in simulation 1

Barnes

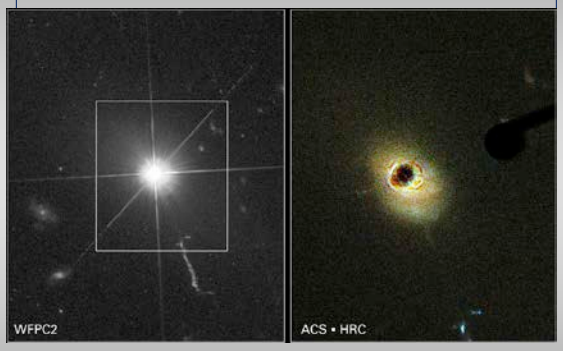


Questions or Comments

Simulation 2 of "Mice" John Dubinski

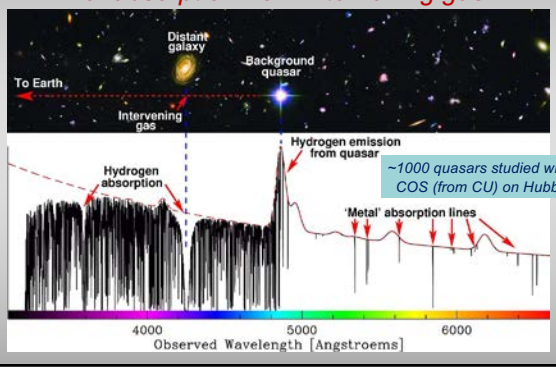


Revisit Quasar 3C273



With advanced HST instruments, can see extended surrounding galaxy

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



~1000 quasars studied with COS (from CU) on Hubble