ASTR 1040: Stars & Galaxies

Stefan's Quintet

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Lecture 24 Thur 13 Apr 2017

zeus.colorado.edu/astr1040-toomre

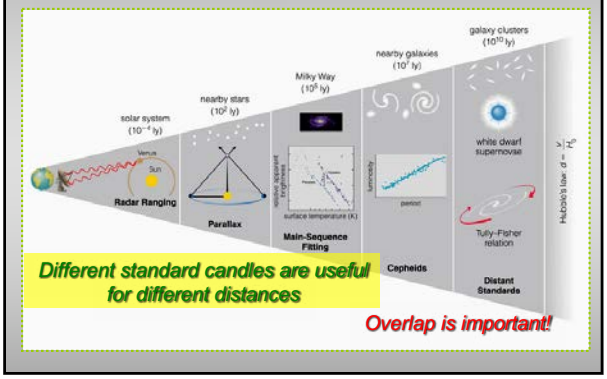
Our Schedule

- Mid-Term Exam 3 in class next Thur Apr 20
- Review Sheet #3 passed out today, with review next Wed Apr 19 5pm-7pm (Piyush)
- Observatory Nights (proj A+spectroscopy), next Wed (Apr 19) and Thur (Apr 20), 8:30pm onward (signup)
- Re-read 21.3 Quasars and active galactic nuclei with care
- Overview read Chap 22 Birth of Universe

Number of Fuzzier Distance Estimators

- A. Apparent brightness of (resolved) red and blue supergiants
- B. Size and brightness of H II regions (emission nebulae) or starbirth regions
- C. Intercompare distances so deduced for specific galaxies (overlapping rungs in `distance ladder')

Distance ladder to measure universe



Different standard candles are useful for different distances

Overlap is important!

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

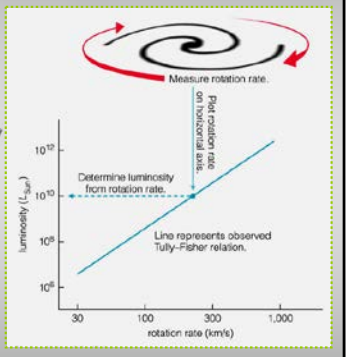
Tully-Fisher Relation

DISTANCE ESTIMATE 3

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

Measure rotation speeds to infer luminosity

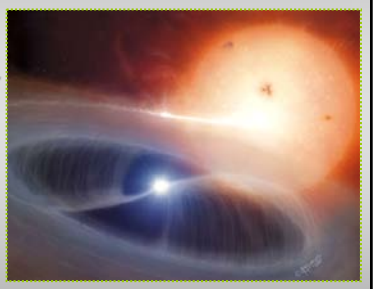
Need bright "edge-on" spirals, estimate tilt



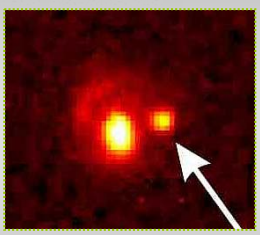
DISTANCE ESTIMATE 4

Even brighter: White dwarf supernovae

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

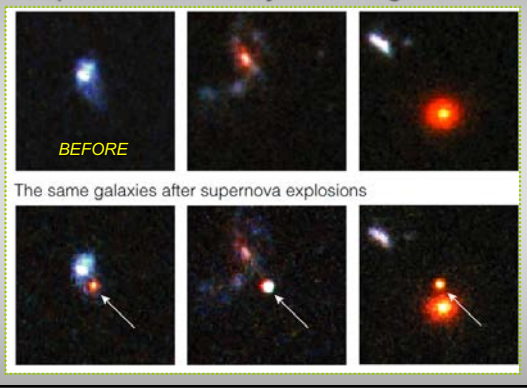


Bright enough to be seen halfway across observable universe



Useful for mapping the universe to the largest distances

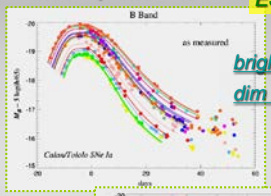
Supernovae in very distant galaxies



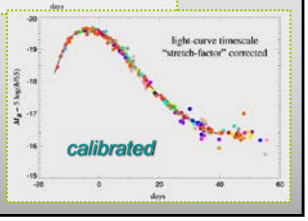
White dwarf supernovae

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!

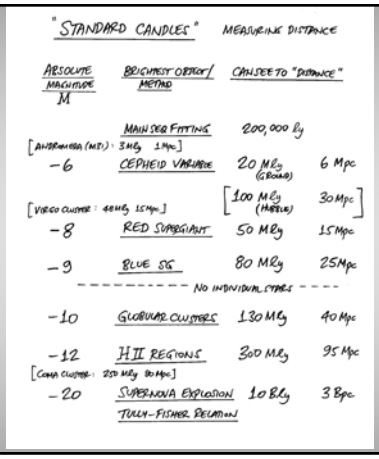


calibrated

"Distance ladder"

Overlapping "standard candles"

DEMO



"STANDARD CANDLES" MEASURING DISTANCE

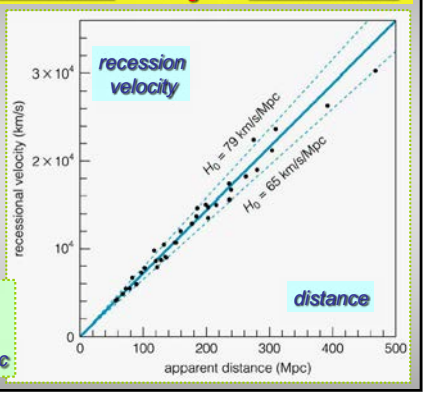
ABSOLUTE MAGNITUDE M	BRIGHTEST OBJECT/METHOD	CAN SEE TO "DISTANCE"
	MAIN SEQ FITTING	200,000 ly
[ANDROMEDA (M31): 3 M$_\odot$ 1 Mpc]		
−6	CEPHEID VARIABLE	20 M$_\odot$ (GLOBAL) 6 Mpc
[VIRGO CLUSTER: 40 M$_\odot$ 15 Mpc]		[100 M$_\odot$ (HUBBLE) 30 Mpc]
−8	RED SUPERGIANT	50 M$_\odot$ 15 Mpc
−9	BLUE SG	80 M$_\odot$ 25 Mpc
	---------- NO INDIVIDUAL STARS ----	
−10	GLOBULAR CLUSTERS	130 M$_\odot$ 40 Mpc
−12	HII REGIONS	300 M$_\odot$ 95 Mpc
[COMA CLUSTER: 250 M$_\odot$ 80 Mpc]		
−20	SUPERNOVA EXPLOSION	10 B$_\odot$ 3 Bpc
	TULLY-FISHER RELATION	

REVIEW

VELOCITY = H_o x DISTANCE

"HUBBLE CONSTANT"

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



DISTANCE ESTIMATE 5

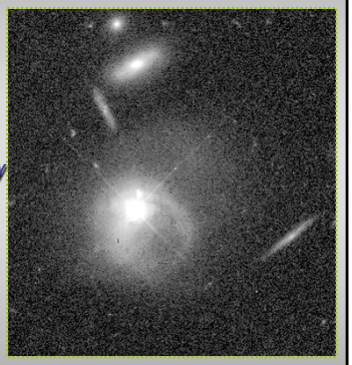
Use Hubble's Law itself to estimate vast distances D

- 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

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)

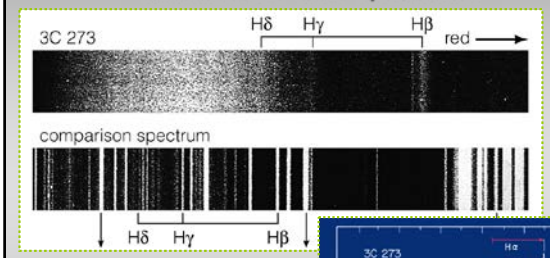
Alternative definition of redshift :

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

1 + Z =
observed wavelength / "normal" wavelength

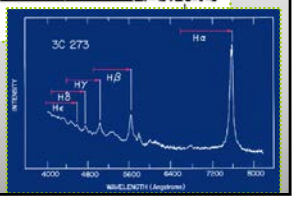
redshifts always have Z > 0
(redder light has larger wavelengths)

Quasar 3C 273 spectrum



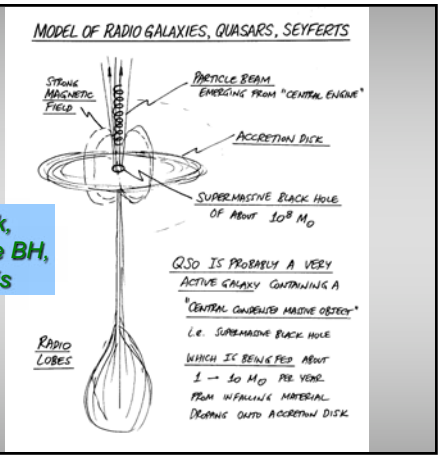
Tricky to identify hydrogen emission lines
…. very big red shift

Maarten Schmidt, Caltech, 1967



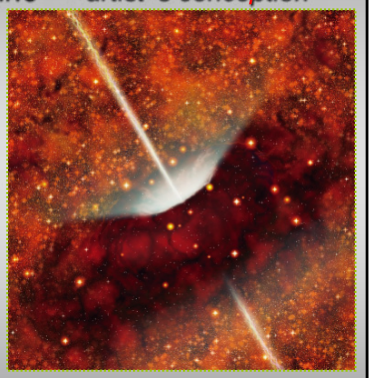
Model for "active galaxies"

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

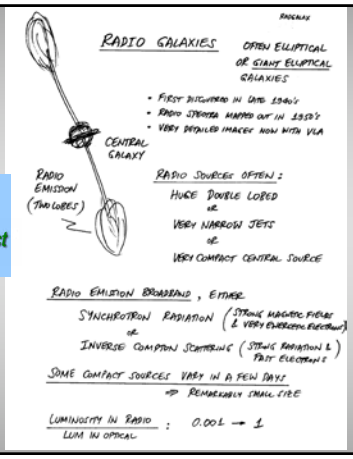


Flying toward supermassive black hole

Radio galaxies

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

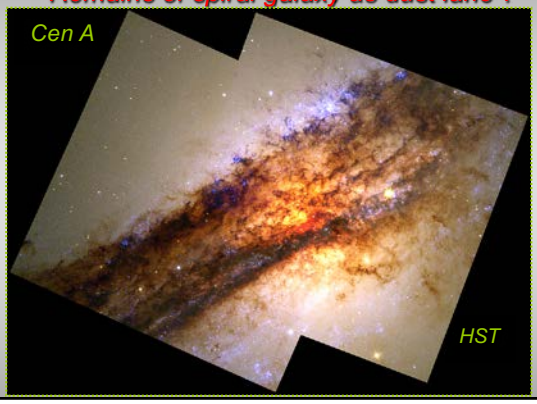
Synchrotron radiation



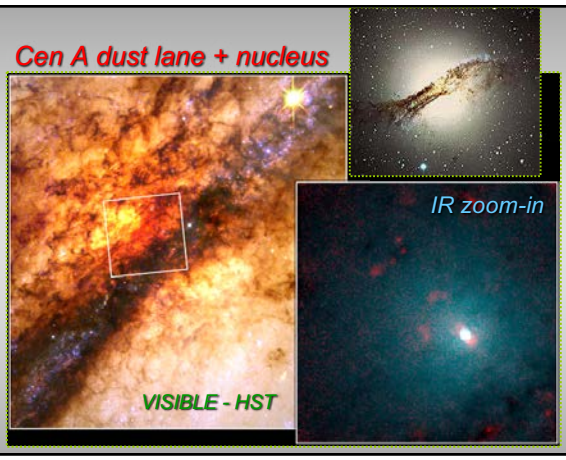
Prototypical "radio galaxy"

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



Clicker Question

Hubble's Law shows that:

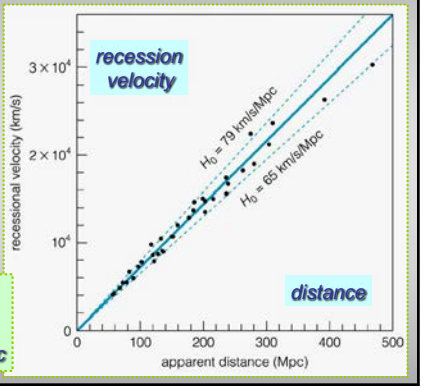
A. The further away we look in the universe, the faster things are moving
B. The further away we look in the universe, the slower things are moving
C. Everything in the universe is moving away from us at the same speed
D. Everything in the universe is staying still, we're just the ones moving
E. We must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

REVIEW

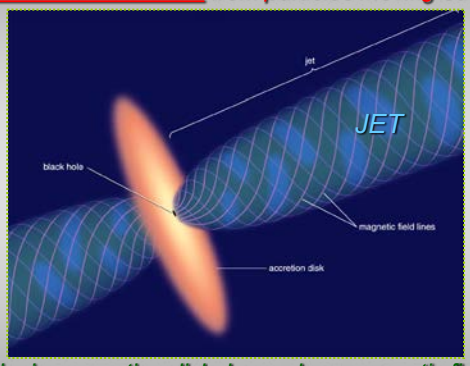
VELOCITY = H_o x DISTANCE

"HUBBLE CONSTANT"

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



Synchrotron radiation from particles moving outward



Spinning accretion disk drags along magnetic fields

REVISIT

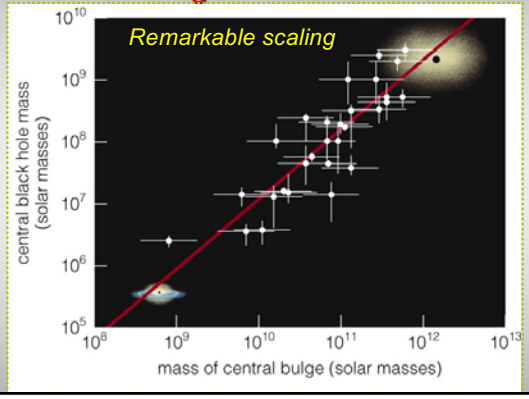
Prototypical "radio galaxy"

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 2017: 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

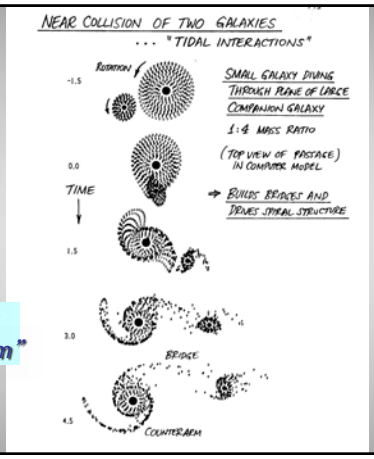


Rich galaxy cluster

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

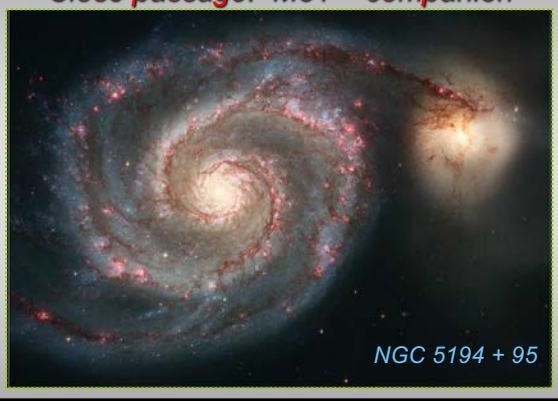
also curious arcs of light?

Collision of small galaxy with big one

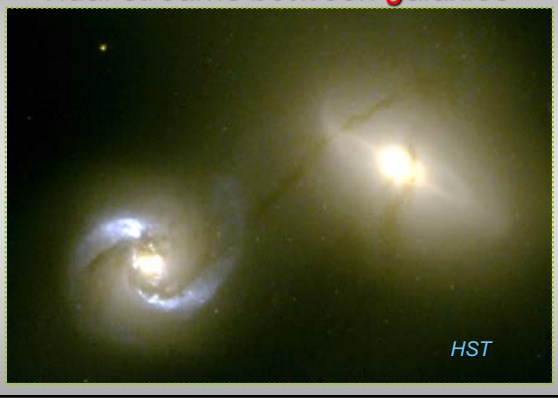


Builds "bridge" and "counterarm"

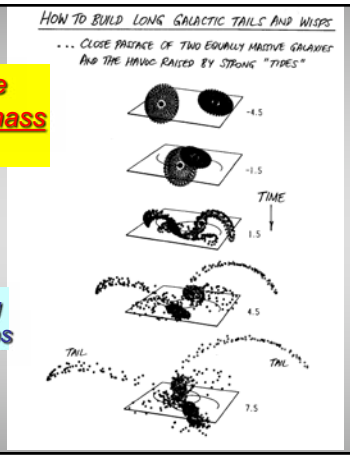
Close passage: M51 + companion



Tidal streams between galaxies



Close passage of two equal mass galaxies

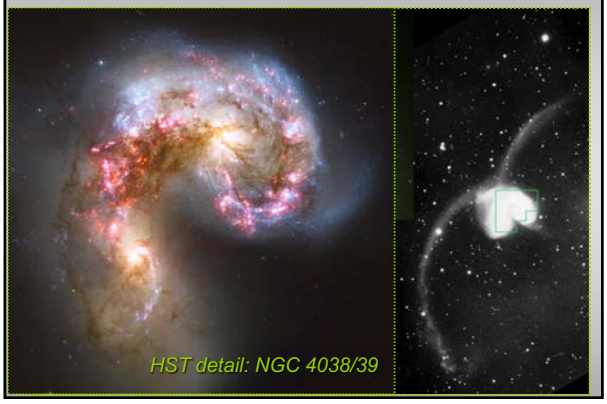


Builds very long "tails" and wisps

Two galaxies form "The Antennae"

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

Simulation 2 of "Mice" John Dubinski