Stars, Galaxies & the Universe Announcements

- **Reading Quiz #11** – in class today
- **HW#10 in ICON** – due Friday (11/12) by 5 pm
  - available now in ICON

- **Exam #3 next Wednesday**
  – study materials available by Friday (11/12) of this week!

- **Final Exam will be cumulative; Thursday 16 Dec @7:30 am in VAN LR 1; 150 points – 50 questions @3 pts each! We will have a review session sometime during Finals Week.**

Stars, Galaxies & the Universe Lecture Outline

Expansion of the Universe

(1) Hubble's Law and its Implications

Quasars & Active Galaxies

(1) What is a quasar?

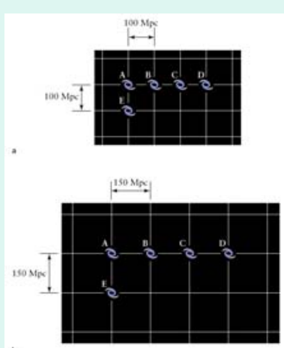
(2) Powering of active galaxies

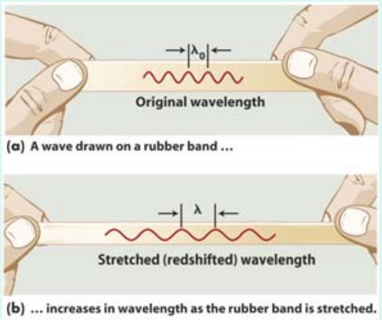
(3) Images and effect of active galaxies

- **Overall, Hubble's Law tells you that the further away the galaxy, the faster the galaxy is receeding – universe is expanding!**

- **Although universe is expanding, it looks the same from ANY galaxy – we are not at the center!**

- **The galaxies themselves are not getting bigger, expanding, but the SPACE between them is expanding**



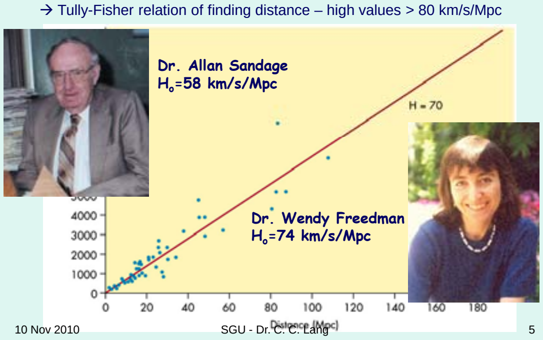


→ photons get *redshifted* as they travel toward us from distant parts of the universe

→ this is because the SPACE has actually expanded: *photons stretched!*

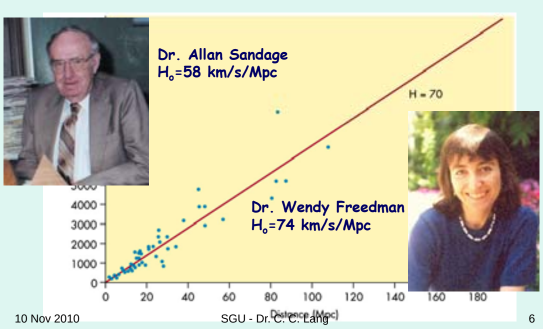
There is much **heated debate** on the value of "Hubble's Constant" H_o – depends on the distance method used

→ SN Type I method of finding distance – low values < 60 km/s/Mpc
→ Tully-Fisher relation of finding distance – high values > 80 km/s/Mpc



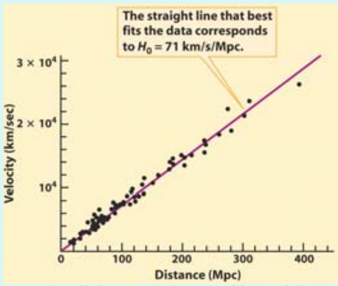
Hubble's Constant (H_o) gives you AGE of universe!!

→ think about the REVERSE: galaxies rushing toward each other



Hubble expansion $v = H_0 d$

For how long has the universe been expanding?



Time = distance/velocity

= $d/H_0 d$

= $1/H_0$

= 1/(71 km/s/Mpc)

= 13.8 Gyr

For Ho = 58 km/s/Mpc,
Hubble time < 13.8 Gyr

For Ho = 74 km/s/Mpc
Hubble time > 13.8 Gyr

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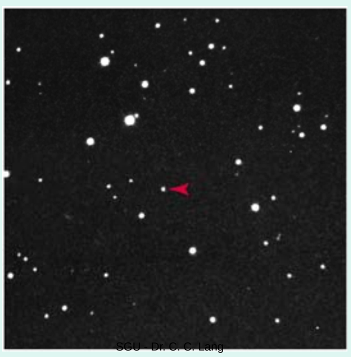
Quasars are “quasi-stellar” objects



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Quasars have VERY different properties than stars

- very RED

large redshifts
very distant objects

- very bright

large distances
very LUMINOUS

- peculiar spectra

bright emission lines
stars - absorption

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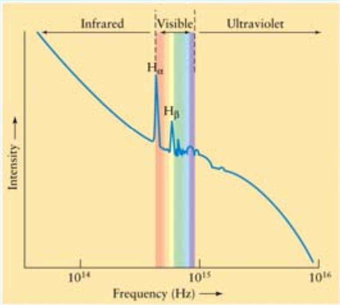
Emission spectrum: detecting glowing gas



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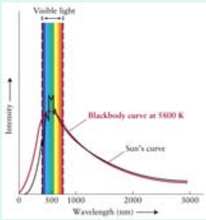
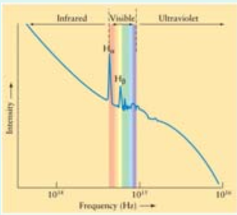
Very strong lines at several wavelengths
No blackbody shape – emits strongly at many wavelengths





Wavelengths of the emission lines REDSHIFTED by large amounts: what does this imply?

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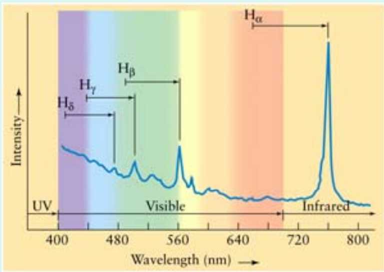

example: ***moderately red shifted galaxy***

486 nm (blue-green) → 563 nm (yellow)

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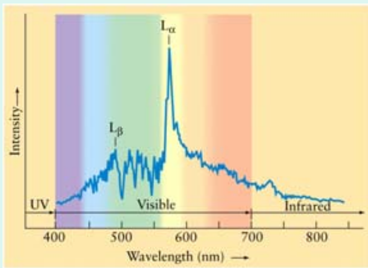


example: ***highly redshifted galaxy***

100 nm (ultraviolet) → 563 nm (yellow)

Quasars are VERY luminous objects!

distance: large red shifts of spectral lines

flux: very large because we can easily detect them

$$\text{flux} = L / 4\pi d^2$$

LUMINOSITY: must be very large – intrinsic!

examples of luminosities of quasars:

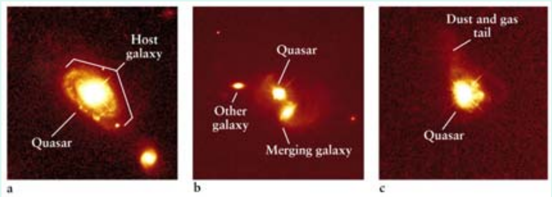
Luminosity of the Milky Way: 2.5 x 10^{10} L_o (25 billion)

Luminosity of a typical quasar (3c273): 2.5 x 10^{13} L_o (25 trillion)

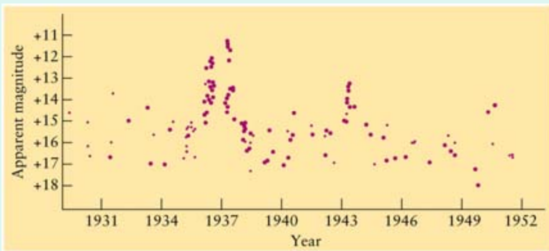
table 27-2 Galaxy and Quasar Luminosities

Object	Luminosity (watts)
Sun	4×10^{26}
Milky Way Galaxy	10^{37}
Seyfert galaxies	$10^{36} - 10^{38}$
Radio galaxies	$10^{36} - 10^{38}$
Quasars	$10^{38} - 10^{42}$

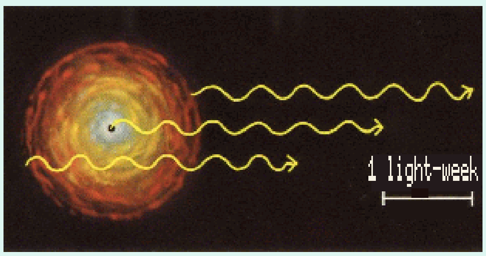
Proof that quasars are associated with galaxies:
- can detect signatures of "host galaxies" around them
- see spiral arms, structure of the host galaxy



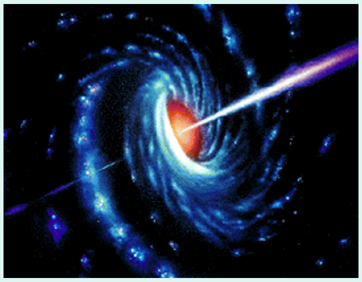
Flickering on timescales of years
– must be very small for a GALAXY



The "flickering" is caused by light from the explosive event in a quasar leaving different parts of the galaxy and arriving at different times!

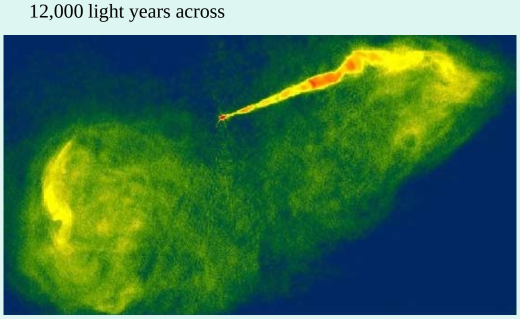


What can be causing the LARGE LUMINOSITIES from such small objects?



Accretion of galactic gas onto the accretion disk near a supermassive black hole!

12,000 light years across



M87 in radio waves