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
receding – 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 because the space has actually expanded: photons stretched.

There is much heated debate on the value of Hubble’s Constant ($H_0$) – 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 ($H_0$) gives you AGE of universe!!

Think about the reverse: galaxies rushing toward each other.
Hubble expansion \( v = H_0d \)

For how long has the universe been expanding?

Time = distance/velocity

\[ \frac{d}{H_0d} = \frac{1}{H_0} = \frac{1}{(71 \text{ km/s/Mpc})} = 13.8 \text{ Gyr} \]

For \( H_0 = 58 \text{ km/s/Mpc} \),
Hubble time < 13.8 Gyr

For \( H_0 = 74 \text{ km/s/Mpc} \),
Hubble time > 13.8 Gyr

Quasars are “quasi-stellar” objects

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
Emission spectrum: detecting glowing gas

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?

Example: moderately red shifted galaxy

486 nm (blue-green) → 563 nm (yellow)
Quasars are VERY luminous objects!

**distance**: large red shifts of spectral lines

**flux**: very large because we can easily detect them

\[
\text{flux} = \frac{L}{4\pi d^2}
\]

**LUMINOSITY**: must be very large – intrinsic!

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examples of luminosities of quasars:

Luminosity of the Milky Way: \( 2.5 \times 10^{10} \, L_\odot \) (25 billion)

Luminosity of a typical quasar (3c273): \( 2.5 \times 10^{13} \, L_\odot \) (25 trillion)

<table>
<thead>
<tr>
<th>Object</th>
<th>Luminosity (watts)</th>
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</thead>
<tbody>
<tr>
<td>Sun</td>
<td>( 4 \times 10^{38} )</td>
</tr>
<tr>
<td>Milky Way Galaxy</td>
<td>( 10^{27} )</td>
</tr>
<tr>
<td>Seyfert galaxies</td>
<td>( 10^{36} - 10^{38} )</td>
</tr>
<tr>
<td>Radio galaxies</td>
<td>( 10^{36} - 10^{38} )</td>
</tr>
<tr>
<td>Quasars</td>
<td>( 10^{39} - 10^{42} )</td>
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</table>
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
more than 200,000 ly across M87 in radio waves

10 Nov 2010

Galaxy M87

10 Nov 2010

M87 — From 200,000 Light Years to 62 Light Years

10 Nov 2010