

# Galaxies, AGN and Quasars

Physics 113 Goderya



Chapter(s): 16 and 17  
Learning Outcomes:

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## Galaxies



- Star systems like our Milky Way
- Contain a few thousand to tens of billions of stars.
- Large variety of shapes and sizes

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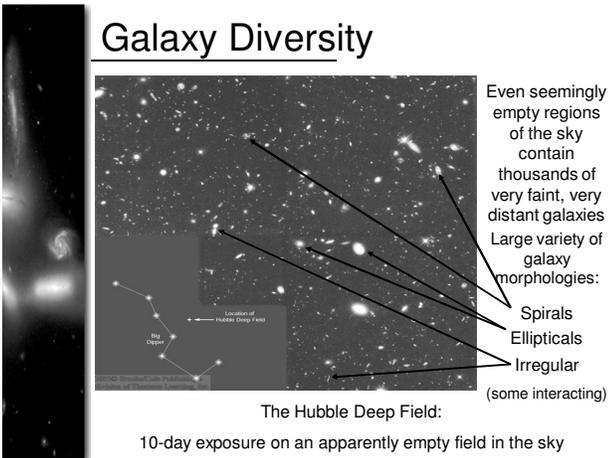
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## Galaxy Diversity



Even seemingly empty regions of the sky contain thousands of very faint, very distant galaxies. Large variety of galaxy morphologies:  
Spirals  
Ellipticals  
Irregular (some interacting)

The Hubble Deep Field:  
10-day exposure on an apparently empty field in the sky

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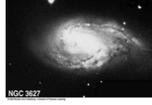
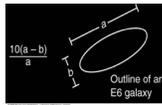
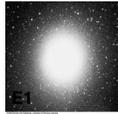
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## Galaxy Classification

E0, ..., E7

E0 = Spherical

E7 = Highly elliptical



Large nucleus; tightly wound arms

Small nucleus; loosely wound arms

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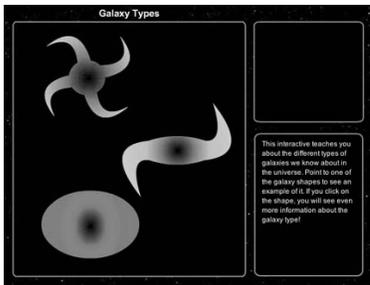
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## Galaxy Types



PLAY ANIMATION  
(SLIDESHOW MODE ONLY)

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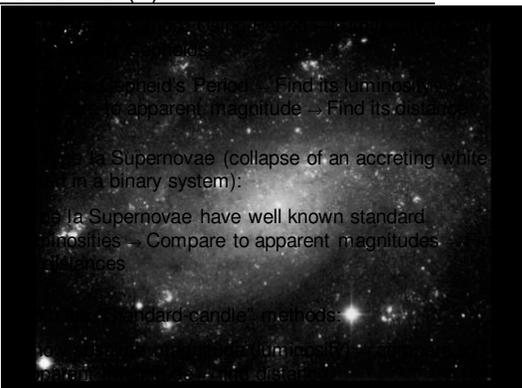
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## Distance Measurements to Other Galaxies (1)




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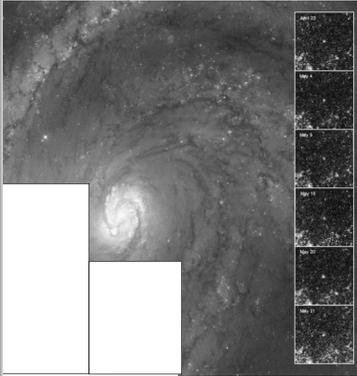
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## Cepheid Distance Measurement



Repeated brightness measurements of a Cepheid allow the determination of the period and thus the absolute magnitude.

→ Distance

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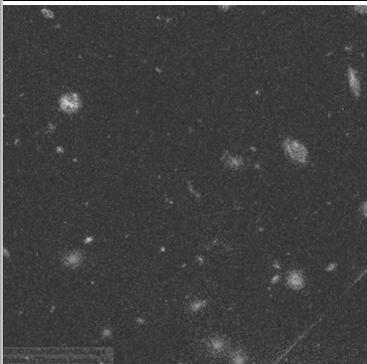
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## The Most Distant Galaxies



At very large distances, only the general characteristics of galaxies can be used to estimate their luminosities → distances.

Cluster of galaxies at ~ 4 to 6 billion light years

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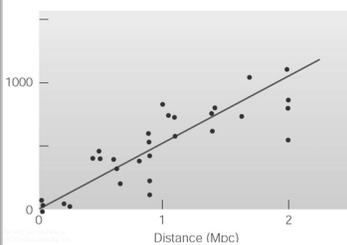
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## Distance Measurements to Other Galaxies (2): The Hubble Law

E. Hubble (1913):

Distant galaxies are moving away from our Milky Way, with a recession velocity,  $v_r$ , proportional to their distance  $d$ :



$$v_r = H_0 \cdot d$$

$H_0 \approx 70 \text{ km/s/Mpc}$  is the **Hubble constant**

- Measure  $v_r$  through the Doppler effect → infer the distance

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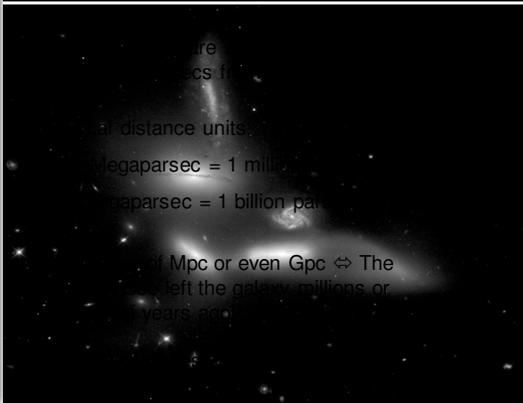
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## The Extragalactic Distance Scale




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## Galaxy Sizes and Luminosities



Vastly different sizes and luminosities:

From small, low-luminosity irregular galaxies (much smaller and less luminous than the Milky Way) to giant ellipticals and large spirals, a few times the Milky Way's size and luminosity

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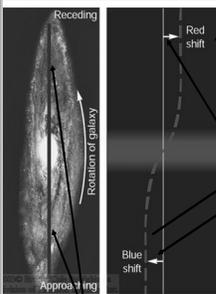
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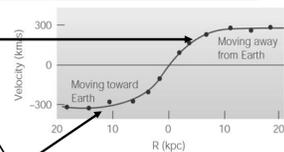
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## Rotation Curves of Galaxies



Observe frequency of spectral lines across a galaxy.



From blue / red shift of spectral lines across the galaxy  
 → infer rotational velocity

Plot of rotational velocity vs. distance from the center of the galaxy: **Rotation Curve**

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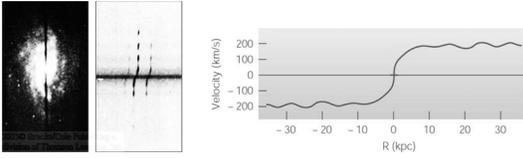
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## Determining the Masses of Galaxies



Based on rotation curves,  
use Kepler's 3<sup>rd</sup> law to infer  
masses of galaxies

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## Masses and Other Properties of Galaxies

**TABLE 16-1**  
The Properties of Galaxies\*

	Elliptical	Spiral	Irregular
Mass	0.0001–50	0.005–2	<0.0005–0.15
Diameter	0.01–5	0.2–1.5	0.05–0.25
Luminosity	0.00005–5	0.005–10	0.00005–0.1

\*In units of the mass, diameter, and luminosity of the Milky Way.

© 2005 Brooks/Cole, Thomson

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## Active Galaxies




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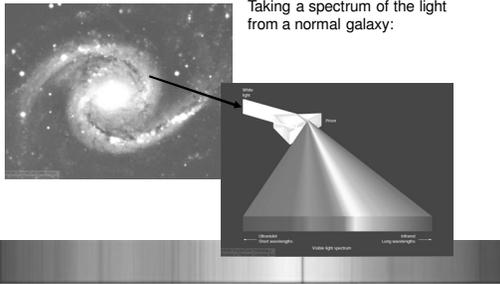
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## The Spectra of Galaxies



The light from the galaxy should be mostly star light, and should thus contain many absorption lines from the individual stellar spectra.

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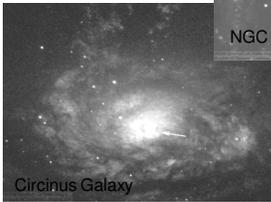
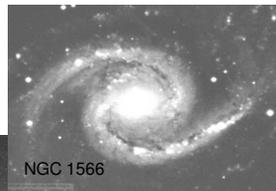
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## Seyfert Galaxies

Unusual spiral galaxies:

- Very bright cores
- Emission line spectra.
- Variability: ~ 50 % in a few months



Most likely power source:  
Accretion onto a supermassive black hole ( $\sim 10^7 - 10^8 M_{\text{Sun}}$ )

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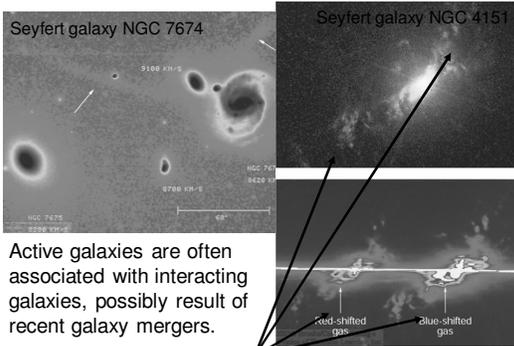
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## Interacting Galaxies




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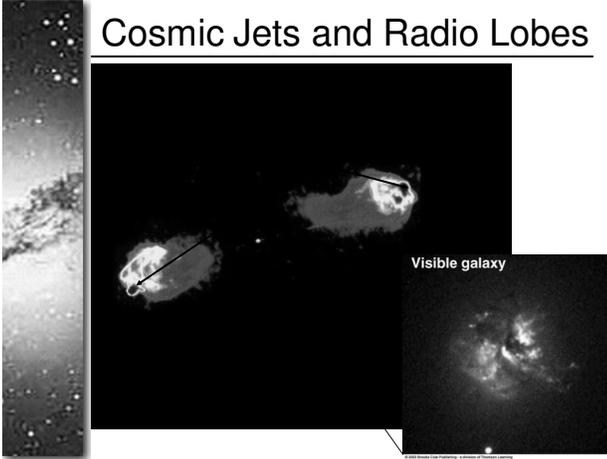
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## Cosmic Jets and Radio Lobes



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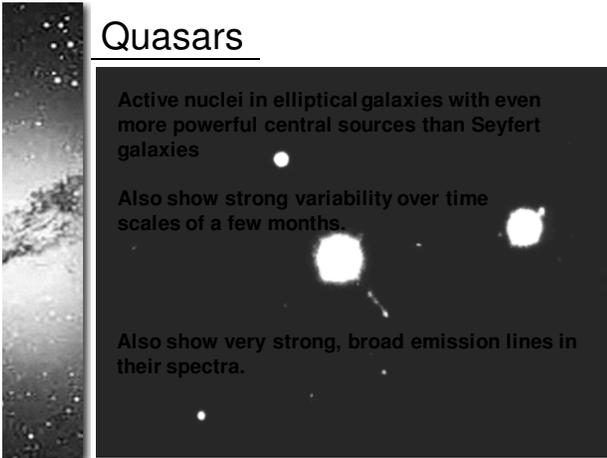
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## Quasars



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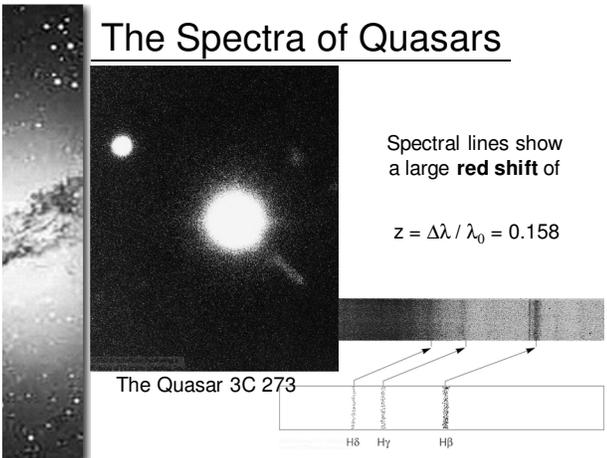
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## The Spectra of Quasars



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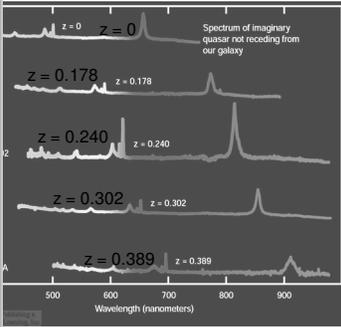
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## Quasar Red Shifts



Quasars have been detected at the highest red shifts, up to

$z \sim 6$

$$z = \frac{\Delta\lambda}{\lambda_0}$$

Our old formula

$$\frac{\Delta\lambda}{\lambda_0} = \frac{v_r}{c}$$

is only valid in the limit of low speed,  $v_r \ll c$

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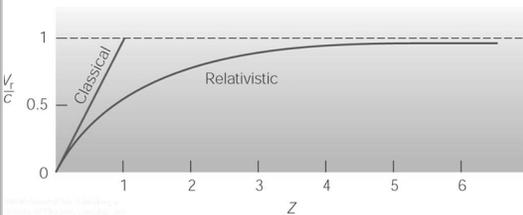
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## Quasar Red Shifts (2)



The full, relativistic expression always gives speeds less than  $c$ , but extremely large distance:

Several Gpc.

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## Studying Quasars

The study of high-redshift quasars allows astronomers to investigate questions of:

- 1) Large scale structure of the universe
- 2) Early history of the universe
- 3) Galaxy evolution
- 4) Dark matter

Observing quasars at high redshifts:

- distances of several Gpc
- Look-back times of many billions of years
- The universe was only a few billion years old!

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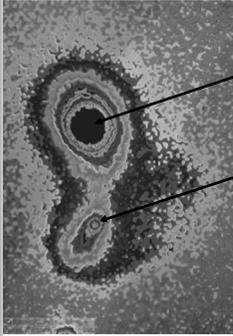
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## Evidence for Quasars in Distant Galaxies



Quasar 0351+026 at the same red shift as a galaxy

→ evidence for quasar activity due to galaxy interaction

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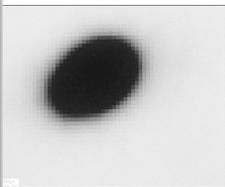
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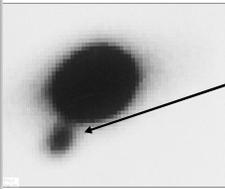
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## Galaxies Associated with Quasars



Two images of the same quasar, 1059+730



New source probably a supernova in the host galaxy of the quasar

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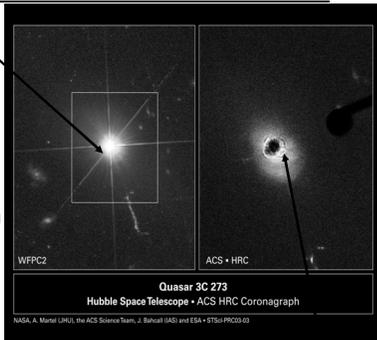
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## Host Galaxies of Quasars



Host galaxies of most quasars can not be seen directly because they are outshined by the bright emission from the AGN.



Blocking out the light from the center of the quasar 3C 273, HST can detect the star light from its host galaxy.

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