Galaxy Evolution
21.1 Looking Back Through Time

- How do we observe the life histories of galaxies?
- How do we study galaxy formation?
What is the lookback time of the most distant galaxies we can observe?

a) 400 million years  
b) 1.3 billion years  
c) 4.5 billion years  
d) 13 billion years
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We see the most distant galaxies as they were when the universe was

a) a few thousand years old.
b) 1–2 million years old.
c) 1–2 billion years old.
d) 4–6 billion years old.
e) 13 billion years old.
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b) 1–2 million years old.

**c) 1–2 billion years old.**
d) 4–6 billion years old.
e) 13 billion years old.
According to models of galaxy formation, how long did the first generation of stars live?

a) a few thousand years
b) a few million years
c) a few billion years
d) about 10 billion years
e) more than 30 billion years
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According to models of galaxy formation, which population of stars formed first?

a) the spheroidal population
b) the disk population
c) the irregular population
d) the elliptical population
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b) the disk population  
c) the irregular population  
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How long after the Big Bang did protogalactic clouds form?

a) a few million years
b) about 100 million years
c) about 1 billion years
d) about 3 billion years
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b) about 100 million years
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d) about 3 billion years
21.2 The Lives of Galaxies

- Why do galaxies differ?
- What are starbursts?
What property of a protogalactic cloud determines if it ends up as a spiral or elliptical galaxy?

a) its composition  
b) its angular momentum  
c) its density  
d) A or C  
e) B or C
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d) A or C  
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What type of galaxy can result from collisions between galaxies?

a) spiral
b) elliptical
c) irregular
d) A or C
e) B or C
What type of galaxy can result from collisions between galaxies?

a) spiral
b) elliptical
c) irregular
d) A or C
e) B or C
What is a *lenticular galaxy*?

a) a spiral galaxy without spiral arms  
b) a spiral galaxy with tightly wound spiral arms  
c) a spiral galaxy without a central bulge  
d) a spiral galaxy without a halo
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What is a *starburst galaxy*?

a) a galaxy whose spiral arms have been stretched out into a star-like shape
b) a galaxy with a supermassive black hole at the center
c) a galaxy with a very high rate of star formation
d) a galaxy with multiple supernovae
e) a galaxy with a lot of gamma-ray emission
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In what part of the spectrum are starburst galaxies brightest?

a) X-ray
b) ultraviolet
c) visible
d) infrared
e) radio
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21.3 Quasars and Other Active Galactic Nuclei

- How are quasars powered?
- Do supermassive black holes really exist?
- How do quasars let us study gas between the galaxies?
Where in the universe are most quasars found?

a) uniformly throughout the universe
b) in space in between galactic clusters
c) more than halfway to the boundary of the observable universe
d) at small lookback times (less than 1 billion years)
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What is the luminosity of the most powerful quasars?

a) the same as a nova  
b) the same as a white dwarf supernova  
c) the same as the Milky Way galaxy  
d) 80 times the luminosity of the Milky Way galaxy  
e) 1000 times the luminosity of the Milky Way galaxy
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How big are active galactic nuclei?

a) about 1000 light-years across
b) about 100 light-years across
c) about 1 light-year across
d) a few light-hours across
e) the size of a star
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What powers active galactic nuclei?

a) clusters of supernovae
b) matter falling into a supermassive black hole
c) the merger of two galaxies
d) fusion in the accretion disk of a supermassive black hole
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Which of the following is not true of supermassive black holes in the centers of galaxies?

a) The most massive detected so far is about 50 million solar masses.
b) Their masses are proportional to the masses of the galaxies they are in.
c) We measure their mass from the Doppler shift of nearby orbiting gas.
d) They are quite common and may be at the center of all galaxies.
e) It is not currently known how supermassive black holes formed.
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How do active galactic nuclei generate jets?

A. Lots of supernovae at nearly the same time form an eruption out through the disk of the galaxy.
B. Radiation from the central object is blocked by dust in all directions except out of the plane of the galaxy, producing jets of radiation.
C. The magnetic field in the accretion disk around the supermassive black hole gets twisted and flings plasma out in jets.
D. The rapid rotation of the accretion disk generates a vortex in the nearby gas, shooting plasma out along its axis.
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How do we learn about protogalactic clouds?

a) by looking at emission lines from molecules in the clouds
b) by looking at emission lines from atomic hydrogen in the clouds
c) by looking at absorption lines in spectra of background quasars
d) by looking at thermal emission from the clouds
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