

## ASTR 1020: Stars & Galaxies

April 14, 2008

- **Exam 3 next class, Wednesday, April 16<sup>th</sup>.**
- **Extra credit:** Fiske Planetarium shows every Thursday and SBO observing.

1

## Exam #3 on April 16th

- Study with a buddy!
- Chapters 19.3-19.4, 20, 21, and 22.1-22.3.
- Review notes on class website, *MasteringAstronomy* assignments, clicker questions, key concepts.
- Same format: 20 multiple choice questions, 5 true-false and 3 short-answer questions.
- Review sheet on CULearn.
- Review session during recitations.

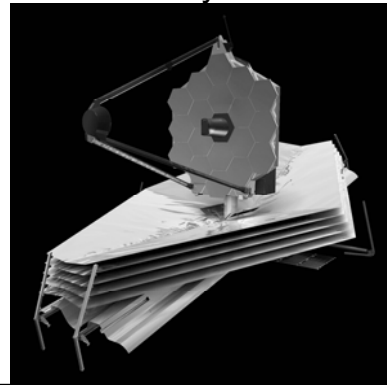
2

## Be sure to bring to Exam

- A number 2 pencil.
- Your CU ID.
- One page (front and back) of notes for the exam.
- A calculator.

3

## Astronomy Picture of the Day



James Webb  
Space Telescope  
Mirror = 6.5 meters  
Launch = 2013

4

## Last Time

- Evidence for Dark Matter- galaxies, galaxy clusters
- Dark matter vastly outweighs normal “baryonic” matter
- Most likely a subatomic particle (wimps) - as yet unidentified!

5

**Clicker Question:** Dark Matter is inferred to exist because

- a) We see lots of dark patches in the sky
- b) It explains how the expansion of the universe can be accelerating
- c) We can observe its gravitational influence on visible matter

6

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7

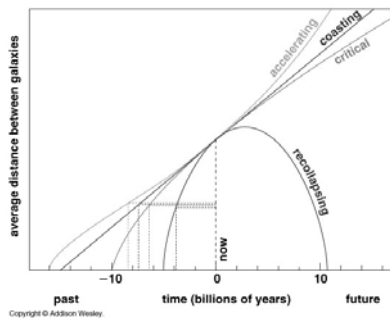
## Today

- Chapter 22, Section 4: Dark Matter and the fate of the Universe.
- On Friday: Dark Energy

8

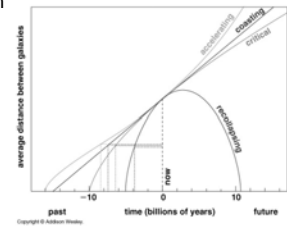
## Dark Matter and the Fate of the Universe

- Expansion begins with the Big Bang
- Several different models for Past and Future



## Important Diagram

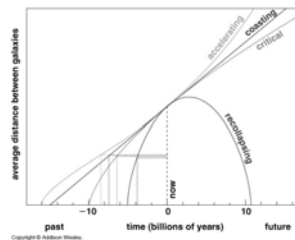
- "Average distance between galaxies"  
=  $1 / \text{expansion factor}$   
=  $1 / (1+z)$
- NOW is fixed in time ( $z=0$ )
- Hubble constant NOW sets the slope of the line = how fast the universe is expanding NOW



Big Bang= when distance is zero;  
 $z=\text{infinity}$

10

- But the expansion rate is not necessarily constant for all time....
- Gravity will SLOW expansion rate  $\rightarrow$  deceleration
- Different models for different amounts of dark matter



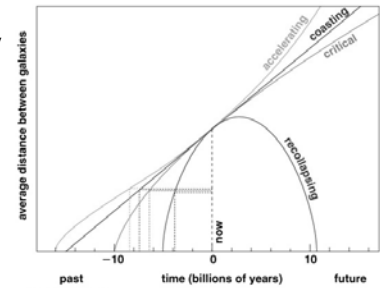
11

## Model Universes: Recollapsing Universe

Dark matter density is greater than "critical density"  
( $\sim 10^{-29}$  grams/cc = a few atoms in a closet)

Expansion will stop in the future, will collapse

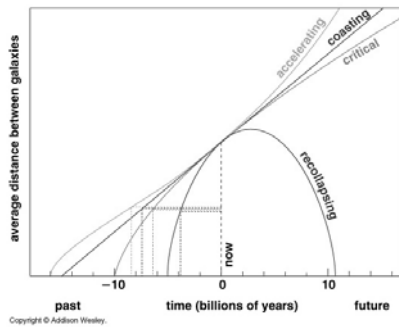
Oscillation?



12

## Critical Universe

- Density = critical density
- No dark energy
- Will expand forever, but just barely

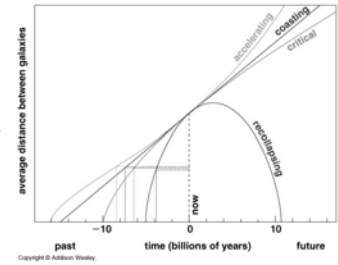


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13

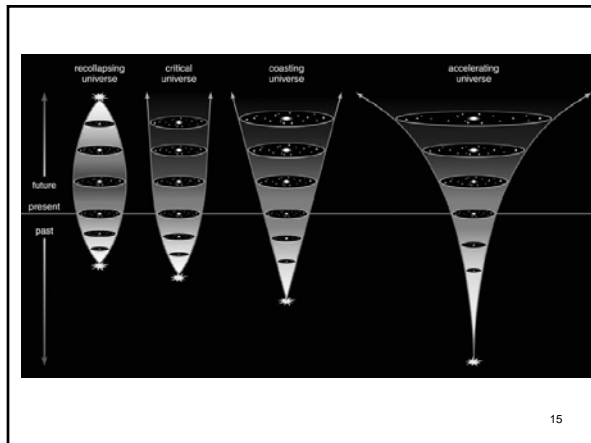
## Coasting (or Open) Universe

- Has always expanded at the same rate (no deceleration from gravity!)
- No dark energy & density < critical density
- Age of universe is  $1/H_0$



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14



15

## What is the fate of the Universe?

- Recollapse: crushing heat, destruction of all matter, ?rebirth?
- Eternal expansion: cold, galaxies dimming
  - star formation slowing
  - everything winds up as a brown dwarf, black dwarf, neutron star or black hole

16