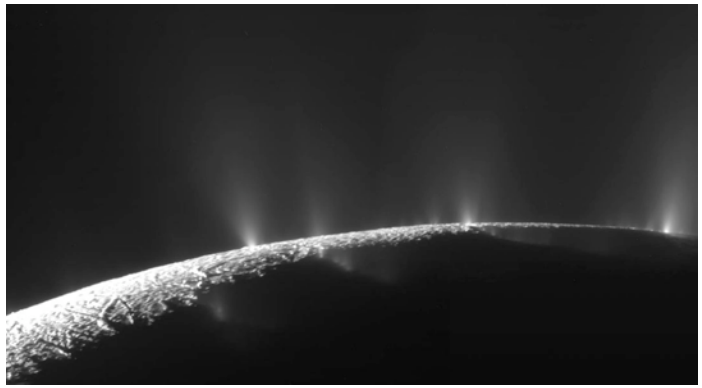
Tuesday, November 24, 2009
Fourth Exam, Thursday, December 3
Final Sky Watch, IYA reports due on Sunday, December 6 (Other Worlds Exhibit at HRC; "Forbidden Planet" last night?)

Course Evaluation Online - please do that. The TA's and I pay close attention to comments.

Astronomy/Physics in the News: Large Hadron Collider at CERN collides its first proton beams, will look for Higgs boson that gives everything mass (and also tiny black holes and hyperspace).

Wheeler Q&A on jets from black holes in *Astronomy* magazine

Pic of the day - Cassini flies by venting Enceladus, moon of Saturn



Reading for Fourth Exam: REVISED AGAIN!

Chapter 10, Sections 10.1-10.6, **10.9**-10.10
Chapter 11, Sections 11.1-11.5, **11.8**
Chapter 12, all

End of Course

Chapter 13, **SKIP**
Chapter 14, **SKIP**

The raging issue: are gamma-ray bursts produced in some form of core collapse supernova? Circumstantial evidence was followed by proof:

GRB 030329 was nearby, only 3 BILLION light years away! Relatively bright, an ideal target.

SN2003dh was discovered a week later! Spectrum of a Type Ic supernova

By now many associated supernovae have been found: **all are Type Ic supernovae**

But all Type Ic supernovae are not gamma-ray bursts

The current picture: Gamma-ray bursts result from the collapse of a massive star from which the hydrogen and most of the helium have been stripped, probably to produce a black hole, that emits a tightly focused, highly relativistic jet.

Every burst, twice a day somewhere in the Universe - the birth of a black hole aiming its jet at us?

~100 aimed elsewhere for every one aimed at us.

Have not yet proven that black holes are involved. Tough problem!

NASA Animation: Black Hole Forming in Star, producing jet and Gamma-Ray Burst

One Minute Exam

It is important to understand that gamma-ray bursts emit their energy in tightly collimated beams because otherwise

Estimates of the distance will be wrong

Estimates of the mass of the black hole formed will be wrong

Estimates of the energy emitted will be wrong

Estimates of the type of supernova in which they explode will be wrong.

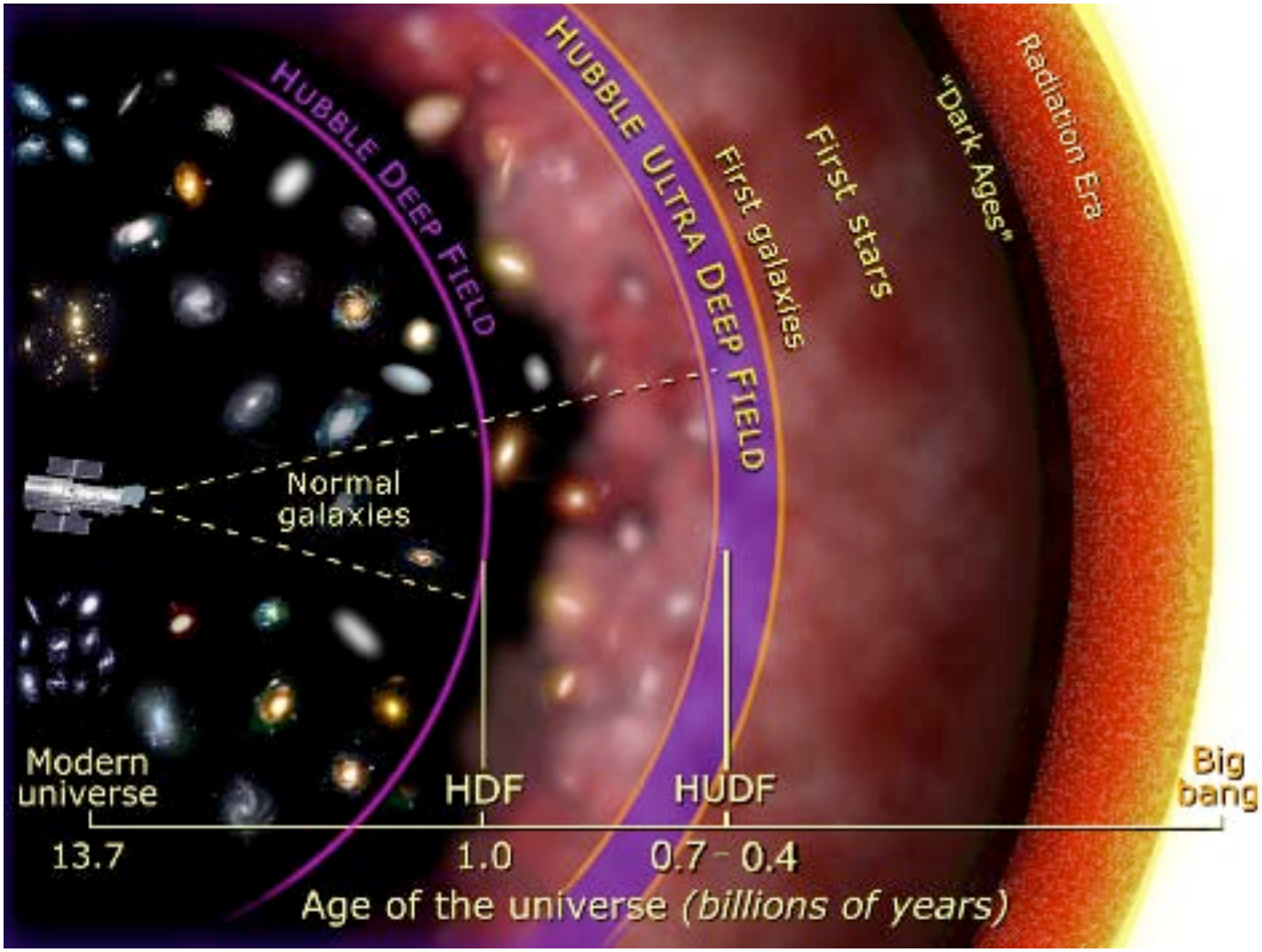
Gamma-ray bursts are intensely bright lights

Can be seen at great distance

Probe cosmology, the early Universe

Dark Ages, after the Universe cooled off a million years after the Big Bang, before stars and Galaxies first formed half a billion years later

Point toward the Big Bang.



Gamma-ray bursts could be the first objects seen at the end of the Dark Ages as the first stars are born and die, over 13 billion years ago. GRB 090423 is the first example.

Chapter 12 Supernovae and the Universe

Expanding Universe - we observe all distant galaxies (so far away we cannot sense their individual gravity) moving away from us with speed proportional to distance: as if we were in the center of an explosion.

Our Universe is not a bomb in pre-existing empty 3-D space!

Lesson from Einstein - ***space itself can expand carrying the*** (almost motionless***) galaxies***

All distant galaxies move away from all other distant galaxies.
No galaxy, certainly not us, is in the center.

The result: speed proportional to distance

Our Expanding Universe

Expanding ***surface*** of a balloon as an example

2D embedding diagram of 3D expanding Universe

No 2D center, no 2D edge, no 2D outside

There is a 3D center, a 3D edge, a 3D outside, in 3D hyperspace

Our Expanding Universe

All 3D space expands - carrying essentially motionless matter (galaxies)

No 3D center, no 3D edge, no 3D outside

As 3D astronomers, we don't have to ask what the Universe is expanding into, but if anything it is a 4 (or more) D hyperspace, just as a 2D balloon expands into 3D hyperspace.

Infinite flat rubber sheet could expand without expanding into any hyperspace (2D embedding diagram example).

Einstein's theory says that for a Universe that is the same, on average, everywhere, there are only three basic shapes it can have

The 3D analog of a spherical surface - ***Closed Universe***

The 3D analog of a "saddle" or "Pringle" shape - ***Open Universe***

The 3D analog of a flat plane - ***Flat Universe***

The ***2D embedding diagrams*** of these 3D Universes are, respectively***, a sphere, an infinite saddle or Pringle, and an infinite flat plane.***

A closed universe is finite in space and time, the other two are infinite in space and time, but all must have started 13.7 billion years ago in the Big Bang.

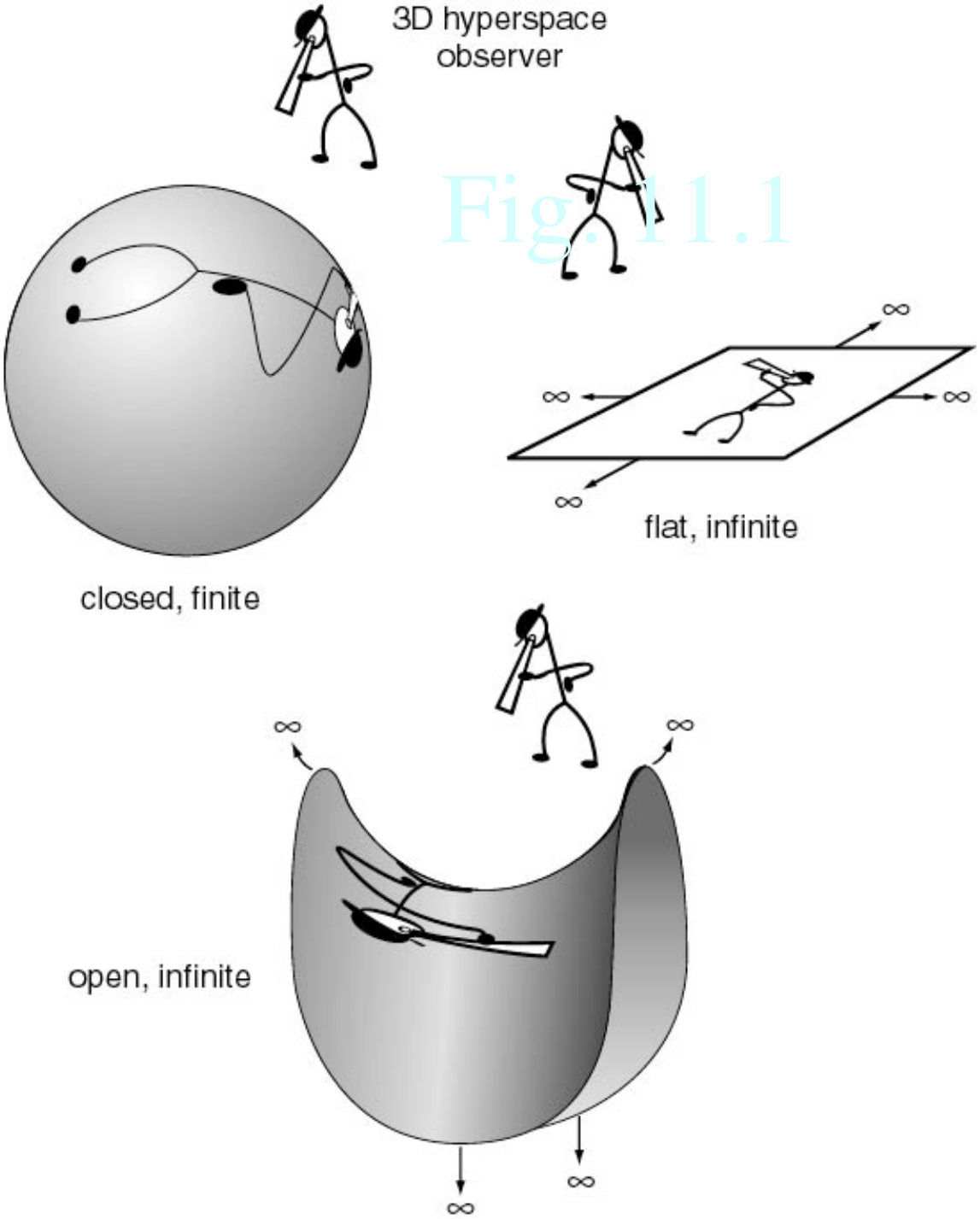


Fig. 11.1

2D embedding diagrams of possible shapes of our 3D Universe

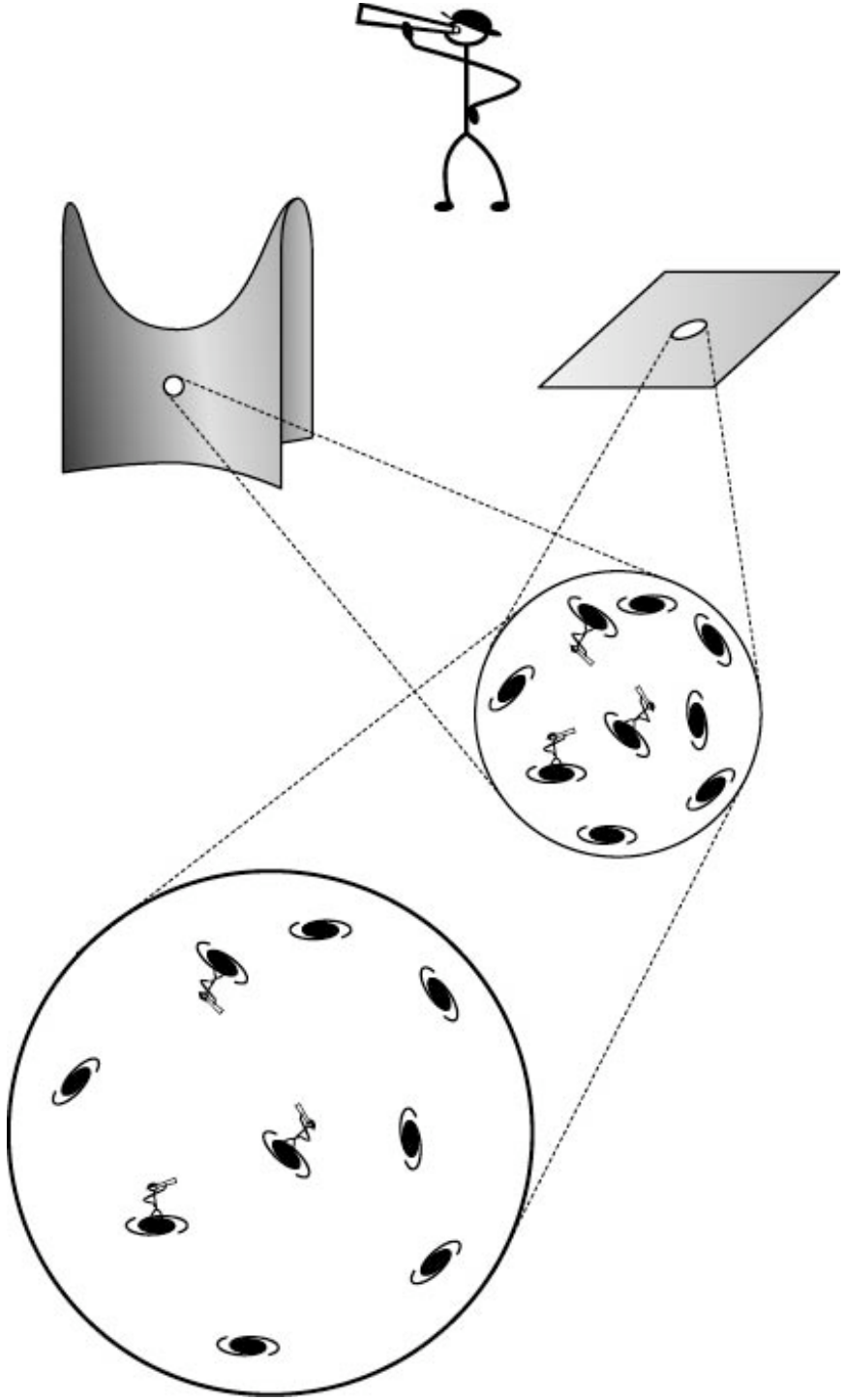


Fig 11.2

A patch of the space in a universe expands, drawing all galaxies away from all others, independent of the overall shape of the curvature of the universe.

Age and Fate of the Universe

All distances between distant galaxies are proportional to the time elapsed. Distance divided by the Velocity from the Doppler red shift $\Rightarrow$ Age of Universe ~13.7 billion years

Fate of the Universe is intimately tied to the shape (we thought!)

Simplest choices: finite age, re-collapse (closed, "sphere," **high density**, high gravity)

expand forever, $v > 0$ (open, "Pringle," **low density**, low gravity)

Special Case: expand forever, $v \rightarrow 0$ as reach infinity (flat, **very special density** and gravity)

In principle, we can figure out the shape and fate of our Universe by doing 3-D geometry in our 3-D Universe, in practice we often try to measure the density of the matter.