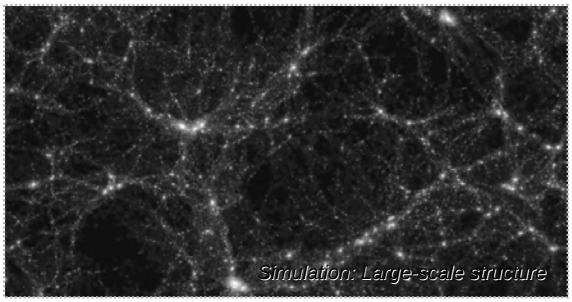
ASTR 1120: Stars & Galaxies

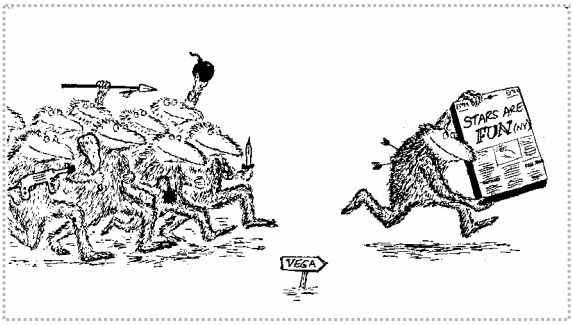


Prof. Juri Toomre TA: Ben Brown
Lecture 39 Mon 18 Apr 05
zeus.colorado.edu/astr1120-toomre

Today's `Cosmological' Events

- Today look at *models for our universe*, and what prompted ideas about *big-bang beginnings*
- *Third Mid-Term returned* graded + answers
- *Go directly to planetarium* this *Wed 20 Apr :* special new show on *Dark Matter (Ben Brown + Erica Ellingson)*
- *Observatory Night 8 this Thurs* (last one!)
- Read *22.5 Structure Formation* and *22.4 Universe's Fate* in detail

So what was with this exam?



RESULTS FROM THIRD MID-TERM EXAM

THIRD MID-TERM EXAM

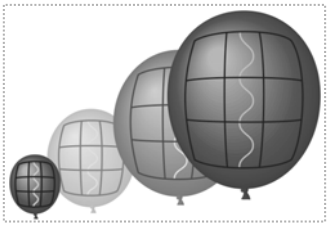
- *Grade boundaries, based on 140 points:*
- *If 112/140 (80%) or over, A's [24%]*
- *100/140 (71%) or over, B's [27%]*
- *77/140 (55%) or over, C's [36%]*
- *68/140 (49%) or over, D's [8%]*

Also +, plain, and – within these ranges
Median grade 71%
Go through answer sheet – and talk to us if do not understand our choices. Keep exam + answers for future review (comp final)

REMINDER *Redshift is "expansion factor"*

1 + Z also measures how much universe has expanded

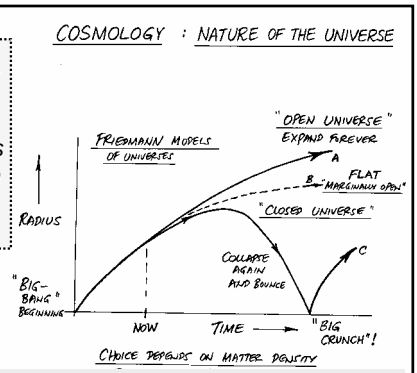
As universe expands, wavelength of light is also lengthened



1 + Z =
distance between galaxies now
distance between galaxies then

Models of our universe

Dark matter has big influence on "open" vs "closed"

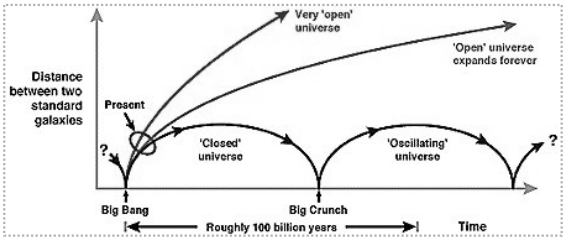


If enough mass, gravity eventually wins!

Predictions of General Relativity Theory (GTR)

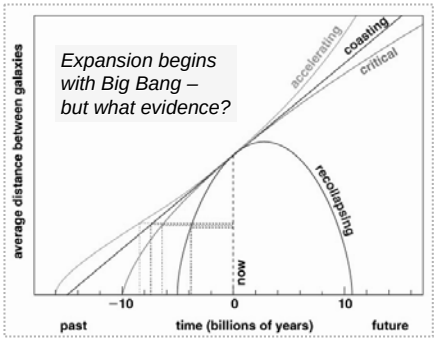
- Einstein in 1917 realized GTR predicted universes in motion, but preferred `steady state' – added `cosmological constant' (CC) as repulsive force in space-time to counteract attractive force of gravity
- Willem de Sitter (A, Dutch, 1917) solves GTR equations with no CC and low density of matter : showed universe must expand
- Alexander Friedmann (M, Russian, 1920) solves GTR with no CC but any density of matter : universes can expand forever, or collapse again, depending on mean matter density
- Georges Lemaitre (P, Belgian, 1927) rediscovers Friedmann solutions, told Hubble (observing redshifts since 1924) that cosmic expansion suggests more distant galaxies should have greater redshifts (Hubble publishes $V = H_o\, d$ in 1929)
- Einstein visited Hubble in 1932, said CC "biggest blunder"

Various Friedmann GTR solutions



Old language: Open, Marginally Open, Closed, Oscillating

Dark Matter and Fate of the Universe

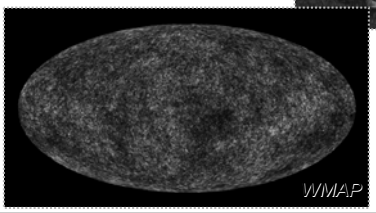


Several different models for Past and Future

Big shift in thinking .. Big Bang evidence

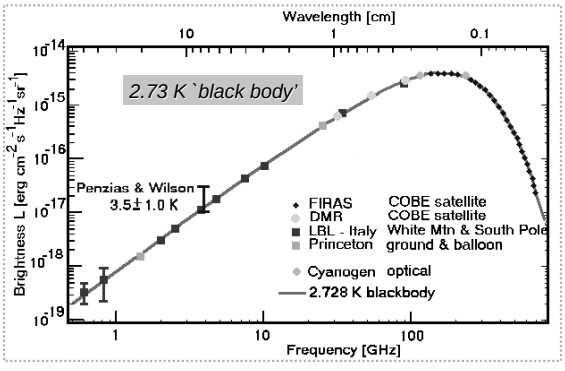
Penzias & Wilson in 1965 discovered Cosmic Microwave Background (CMB) radiation --> 2.73 K "black body"

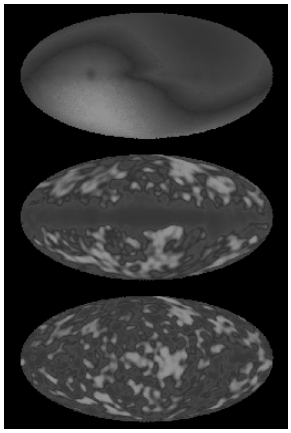
Photons created when hot universe was only 380,000 yrs old – as first atoms formed



Very uniform radiation from everywhere – 1 part in 100,000 severely redshifted by expansion of universe

Spectrum of Cosmic Microwave Background (CMB)





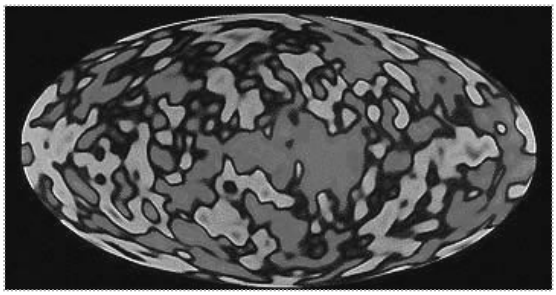
COBE Mapping Steps

Remove big "Dipole asymmetry": solar system moving at 600 km/s (few parts in 1000)

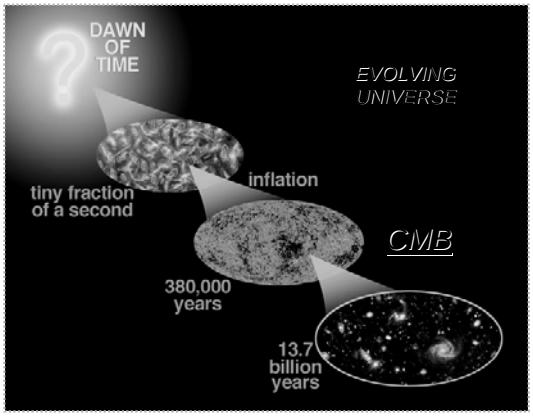
Glow from dust in plane of Milky Way (few parts in 100,000)

Cleaned up glow from "cosmic photosphere" when universe ~380,000 yrs old (few parts in 100,000)

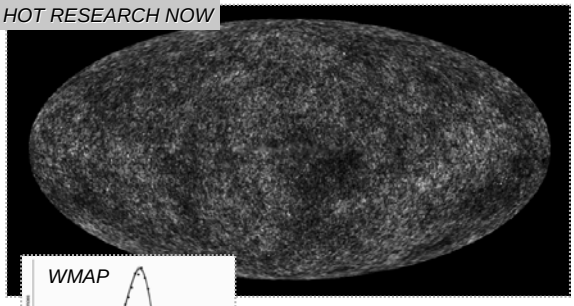
Light from beginning of time



- *This faint light looks light a solid glowing wall*
- *<u>Thermal spectrum at 3000 K</u>, if redshifted by factor ~1000 → <u>microwaves</u> !*

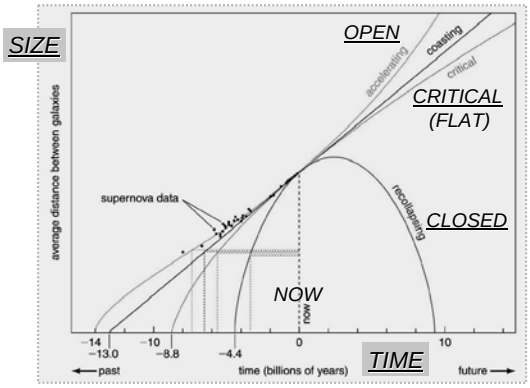


HOT RESEARCH NOW



Small temperature fluctuations used to <u>test models of universe</u> one degree scale of bump --> flat universe with early inflation

Models of universe – and its fates

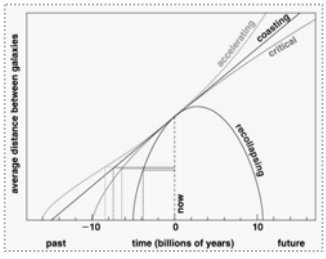


Very important diagram

"Average distance between galaxies"
= 1 / expansion factor
= 1 / (1 + Z)

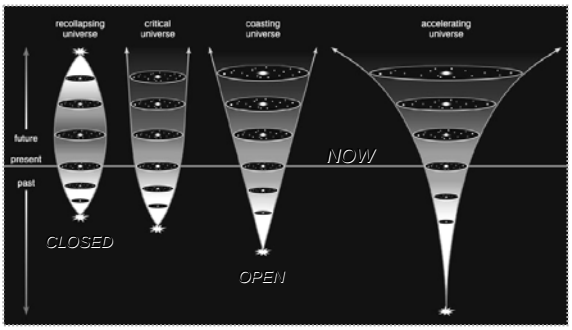
NOW is fixed in time (Z=0)

Hubble constant NOW sets slope of line = how fast universe is expanding NOW



Big Bang = when distance zero
Z = infinity

Four models for fates of universe

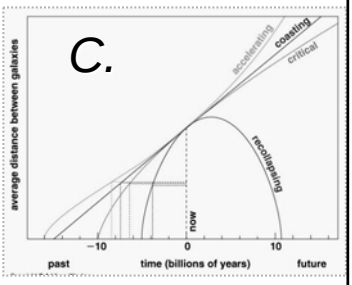


What is the fate of the Universe?

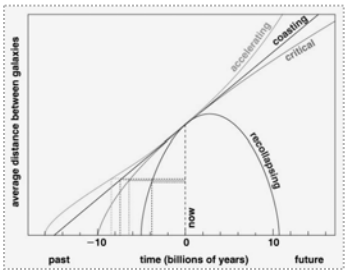
- *Recollapse to gnaB giB: crushing heat, destruction of all matter Rebirth ?*
- *Eternal expansion: cold, galaxies dimming star formation slowing*
- *Everything winds up as a brown dwarf black dwarf, neutron star or black hole*

Clicker Question

- *Which model predicts the largest age for the universe today?*
- *A. Recollapsing* (closed)
- *B. Critical* (flat)
- *C. Coasting* (open)

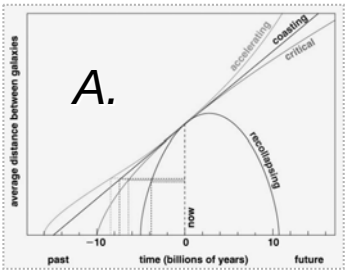


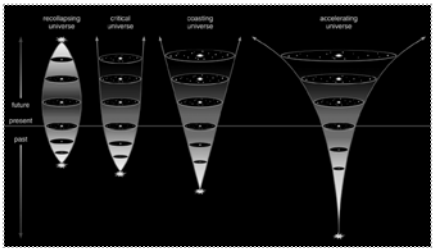
- *C. Coasting*
- *Age of universe is how far to left curves hit horizontal axis (distance between galaxies = 0)*



Double-header clicker

- *If there was really ZERO dark matter in the universe, which model would be the closest to reality?*
- *A. Coasting*
- *B. Critical*
- *C. Recollapsing*





- *Baryonic matter is only a few percent of the critical density*
- *Closest model would be the Coasting Model (no or little deceleration from gravity)*

Which is it ? Is there enough dark matter to recollapse the universe?

Baryonic matter: only few % of critical density

Dark matter: only about 25 % of what is needed

Universe is between the "coasting" and "critical" models

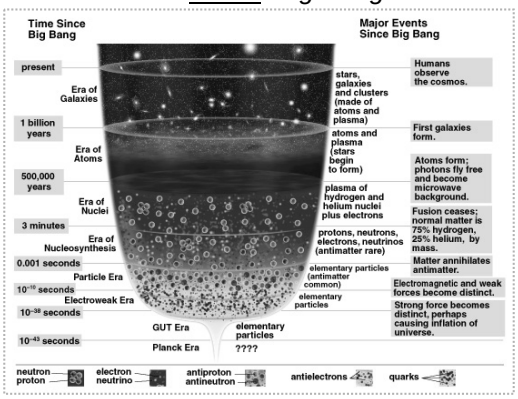
The Universe will expand forever

Some say the world will end in fire
Some say with ice
From what I've tasted of desire
I hold with those who favor fire
But if I had to perish twice
I think I know enough of hate
To say that for destruction ice
Is also great
And would suffice

-- Robert Frost

National Poet Laureat

In the VERY Beginning



Models of universe – and its fates