

Slide - Horses at Lilloet - EXPLAIN LATER!

Slide - William Herschel (1738 - 1822) What is the Universe?

Last decades of 18th Century, in middle age took up telescope-making. Discovered Uranus in 1781 - first planet find since pre-Greek times. Got famous and got money for great telescopes.

Slide - Herschel's 48-inch telescope.

Set out to survey heavens.

Lacking method of distance measurement, used BRIGHTNESS = NEARNESS.

Slide - Star cluster in Milky Way.

Counted stars at different levels of brightness.

Found concentrated to band of Milky Way.

But "ran out" of faint stars.

Concluded he was seeing to the edge of the Stellar Universe.

Flattened disc of stars with Sun near centre.

In among the stars, some NEBULAE (foggy patches)

Slide - M31.

One of these is here. Known since 10th Century A.D. as a fuzzy object in sky. As late as 1920 thought by many to be some sort of gas cloud in among stars.

1920 saw the first of the big new telescopes, Mt. Wilson's 100-inch, "cut its teeth".

Slide - Mt. Wilson 100-inch.

In hands of EDWIN HUBBLE, Mt. Wilson telescope resolved this NEBULA into stars.

Slide - M31 resolved

Slide - NGC 628

> "Spiral" nebulae, star systems.

Early 1920's saw comparison of stars in these nebulae with stars of Milky Way. All stars in nebulae v. faint — showed they were entirely beyond the Milky Way.

This brings me to first major question. Before we talk about The Universe, be clear what we mean by it. To Herschel, indeed up until the 1920's, it was "our Milky Way star system".

Today our Milky Way is recognised as but one of nearly 10 billion galaxies detectable with the Palomar 200-in telescope, the world's best.

### Slide — Milky Way schematic

~ 1 or 2 hundred billion stars in flattened lens ~ 100,000 L.Y. across. Sun ~  $\frac{2}{3}$  way out from centre, in stellar suburbs. Billions of other stars like it in our galaxy alone. Scale: Sun = proton!

### Slide — Hercules cluster

The Universe is full of galaxies.

### Slide — Corona cluster

Clumped into clusters, 100's or 1000's of galaxies per cluster

Clusters are 5-10 million L.Y. across.

Biggest "clumps of matter" known.

### Slide — Hydra cluster.

On and on as far as we can see. No end in sight.

An enormous Universe.

### Slide — 200-inch telescope.

This 200-inch telescope has gained more information about distant Universe than any other on Earth.

### Slide — 200-inch mirror and prime focus cage.

Huge concentration of light at prime focus → take galaxy spectra

## Slide - galaxy spectrum.

After night of swinging around sky, exposing galaxy light through spectroscope, get galaxy spectrum (ring).  
light is total light of billions of stars.

## Slide - data.

Bright galaxies nearby - small red shift.  
Faint galaxies distant - large red shift.

$\frac{\Delta\lambda}{\lambda} = \text{constant}$ , as in Doppler shift.

Red shift  $\rightarrow$  recession.

## Slide - Hubble plot.

Red shift  $\propto$  distance.

If it is due to recession, then velocity  $\propto$  distance from us.

WHY US?

## TRANSPARENCY - Galaxy motions.

It only looks that way!

For velocity  $\propto$  distance, all observers would see same expansion relative to them.

But is it expansion? If so, from what? Why?

hardest systematic phenomenon in Universe!

## TRANSPARENCY - Universes that might work.

If gravity were only long-range force, everything attracts everything. Four ways to build a Universe shown.

#4 might be ours?

## TRANSPARENCY - Big Bang / oscillating

Possibilities.

# Velocity-distance relation for galaxies



1. The "ACTUAL" Expansion  
Velocity increases with distance from "The Centre"  
— BUT —

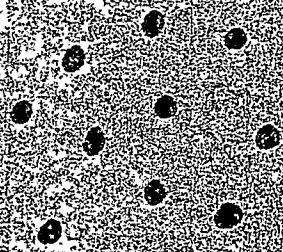
2. What we observe — the motion of other galaxies  
relative to motion of our own:



N.B. Nothing  
"odd" about  
apparent motion  
of the "actual centre"

# WAYS TO BUILD A UNIVERSE WITH GRAVITY AS ONLY LONG-RANGE FORCE

## 1. STATIC

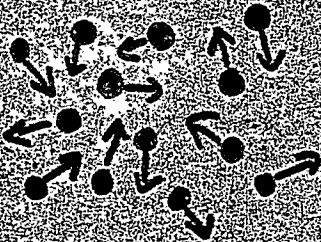


NOW

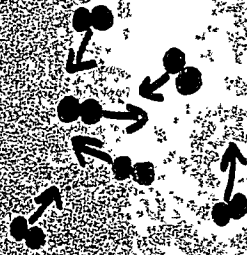


LATER

## 2. CHAOTIC



NOW



LATER



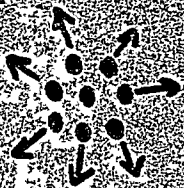
MUCH LATER

## 3. SPINNING

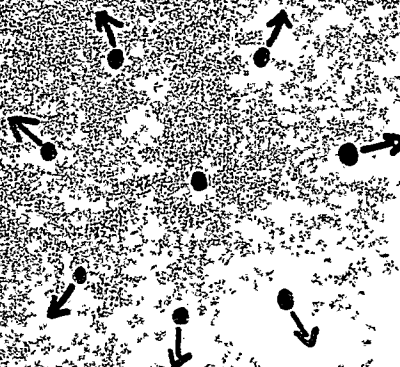


STABLE !

## 4. EXPANDING



NOW

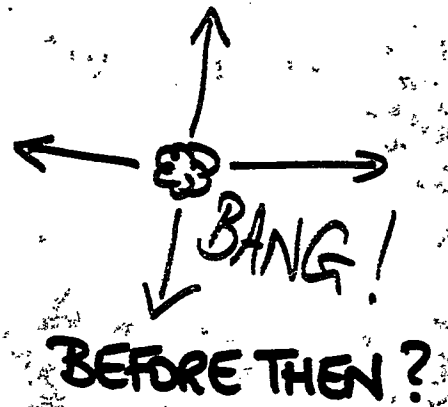
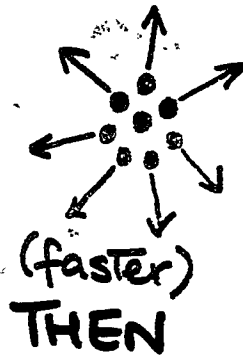
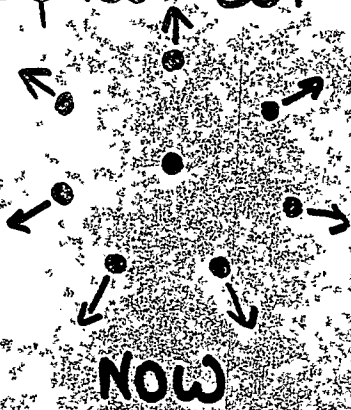


LATER

MUCH LATER ?

# NAIVE COSMOLOGY #1.

If galaxies are receding now they must have been closer in the past. So:—

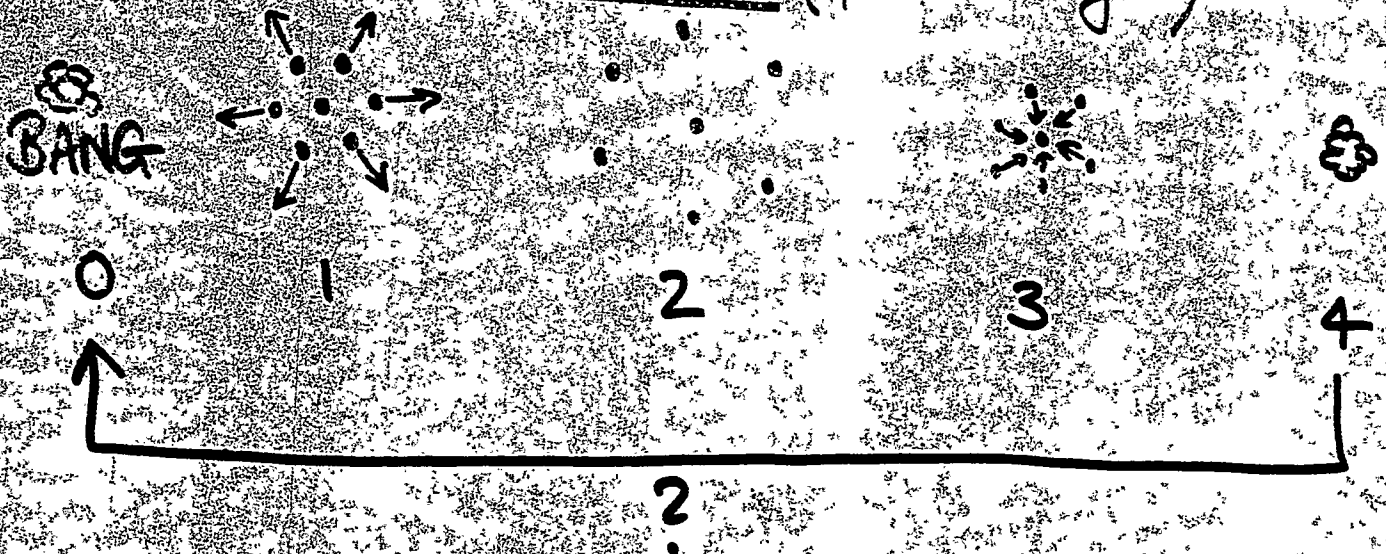


"Big Bang" started it going in the past?

# NAIVE COSMOLOGY #2A (forwards this time)



# NAIVE COSMOLOGY #2B (forwards again)



Now the question is: can so naive a picture derived from the data possibly be right?

First - look at details of Big Bang expectation, essentially obtained by extrapolating backwards.

TRANSPARENCY - Big Bang development.

Early state hot, dense, nuclei too delicate a structure, broken up by photons and collisions. Just particles, e, p, n, h $\nu$ .

Evolution of nuclei, atoms, galaxies (on transparency)

TRANSPARENCY - tests! (ages)

- 1) Steady-State invoked to explain Hubble's error. Underestimated galaxy distances. SLIDE - Peanuts
- 2) If slowdown is fast, may have a problem, age  $\ll H^{-1}$ !

TRANSPARENCY - tests. (Hot dense past)

SLIDES - Penzias and Wilson  
- Element Abundances.

So Big Bang picture is favoured by data.

Next question - will it slow down?

TRANSPARENCY - slowdown  $\bar{f}$ .

TRANSPARENCY - defecting slowdown.

Data on hairy edge of whether or not it will oscillate!

So not clear whether it will "fall back" on itself.

# Big Bang Development

TIME	CONDITION OF MATTER	
0	BIG BANG.	NO ATOMS, NUCLEI SINGLE PARTICLES, PHOTONS
1 sec	$T \sim 10^{10}$ K.	$\gamma + \gamma \rightleftharpoons e^+ + e^-$ $n + e^+ \rightleftharpoons p + \bar{\nu}$ $p + e^- \rightleftharpoons n + \nu$
1 hour	$T \sim 10^8$ K	BUILDUP OF NUCLEI TO He <sup>4</sup>  UNCHANGED UNCHANGED
1 day	$T \sim 3 \times 10^7$ K	
1 year	$T \sim 10^6$ K	
100,000 yrs	$T \sim 5000$ K	ATOMS OF H AND He CAN FORM BY CAPTURING ELECTRONS
1 million yrs.	$T \sim 1800$ K	GALAXIES BEGIN TO AGGREGATE UNDER GRAVITY
1 billion yrs	$T \sim 50$ K	STARS FORMED. FIRST MASSIVE STARS "COOK" H AND He TO HEAVY ELEMENTS
10 billion yrs	$T \sim 10$ K	FORMATION OF SUN, SOLAR SYSTEM, ETC.

PARTICLES AND NUCLEI }  
 ATOMS } structures formed  
 GALAXIES AND STARS }



# TESTING "BIG BANG" THEORY

## 1. Ages of Things in Universe

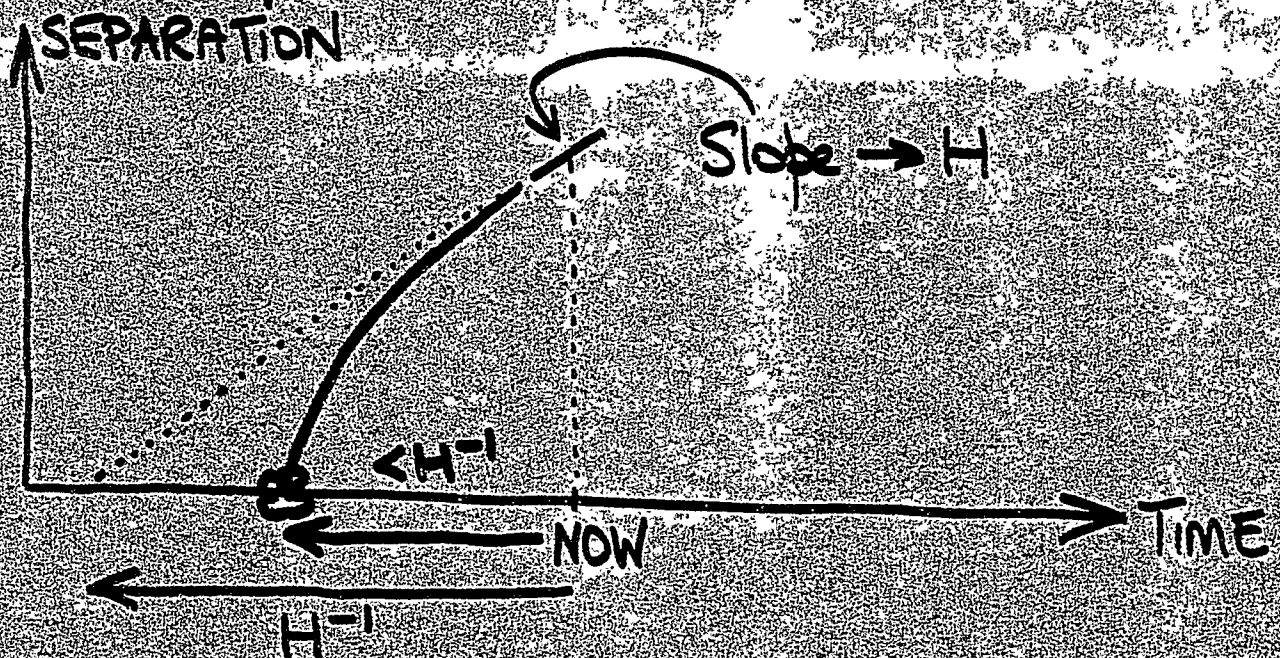
Age of Earth (from crustal rock radioactivities) 4.6 billion yrs  
( $\rightarrow$  TROUBLE when  $H^{-1} = 2$  billion years!)  
(This  $\rightarrow$  Steady-State Theory (1945-50))

Ages of oldest stars (theory of stellar energy production) 11 billion yrs  
in globular clusters

Ages of heavy chemical elements (theory of stellar element production) 10-15 billion yrs

$H^{-1}$  (1973 value) = 19 billion years

BUT - is gravity of galaxies slowing down the expansion?



# TESTING "BIG BANG" (continued)

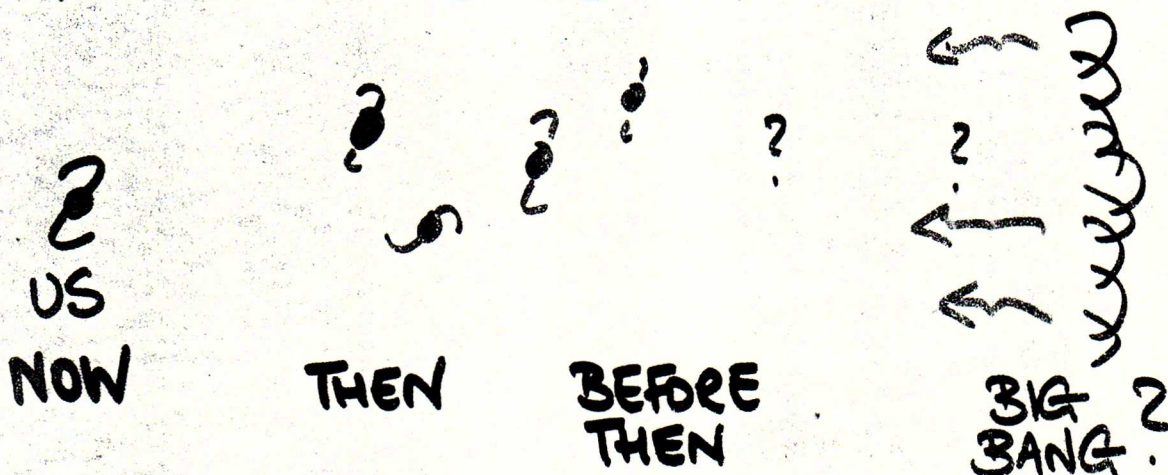
2. Any sign of hot dense past?

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DISTANT GALAXIES (looking back in time)  
CLOSER TOGETHER?  
INCONCLUSIVE

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RADIATION FROM BIG BANG?



Radiation would be

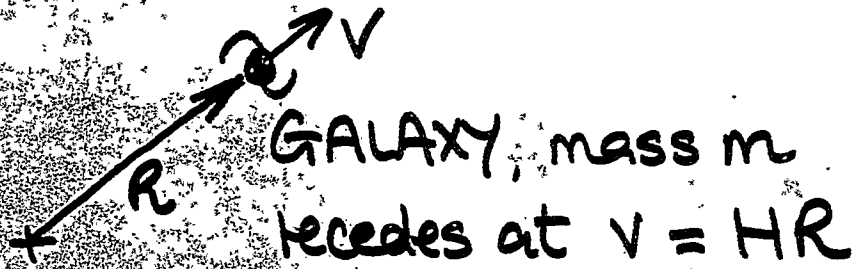
1) FAINT	✓ observed!
2) ISOTROPIC	✓ observed!
3) BLACK-BODY	✓ observed!

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CHEMICAL MIX PRODUCED WHILE UNIVERSE  
HOT AND DENSE.

Expected ~ 70% HYDROGEN  
~ 30% HELIUM ] by mass ✓ observed (?)

# WILL THE UNIVERSE SLOW DOWN?



$$\text{Mass inside radius } R = \frac{4}{3}\pi R^3 \bar{\rho}$$

Gravitational Potential Energy of galaxy

$$= -\frac{GMm}{R} = -G \cdot \frac{4}{3}\pi R^3 \bar{\rho} \cdot \frac{m}{R}$$

$$= -\frac{4\pi G R^2 \bar{\rho} m}{3}$$

$$\text{Kinetic Energy of galaxy} = \frac{1}{2}mv^2 = \frac{1}{2}mH^2R^2$$

LIMITING CASE (STOPS AT  $R = \infty$ )

$$\frac{mH^2R^2}{2} = \frac{4\pi G R^2 \bar{\rho} m}{3}$$

$$\bar{\rho} = \frac{3H^2}{8\pi G} = 4.7 \times 10^{-39} \text{ gm/cm}^3$$



## TRANSPARENCY - Problems.

Missing Mass - Is gravity the only long-range force?  
Quasar redshifts. - Is red shift due to expansion

## SLIDE - Jet galaxies.

Discrepant red shifts.

Is Universe expanding or all?

Transparency - Black Hole Sun.

A way of hiding mass?

Transparency - Black Hole properties.

Transparency - Black Hole Universe?

- Universe of Black Holes? Will our slide inside of B.H.?

## SLIDE - "Ages" of Universe.

# PROBLEMS (DATA)

## 1. "MISSING MASS"

Observed slowdown requires 100 times more matter than is visible as galaxies

Clusters of galaxies have 100 times too little mass to retain their moving members.

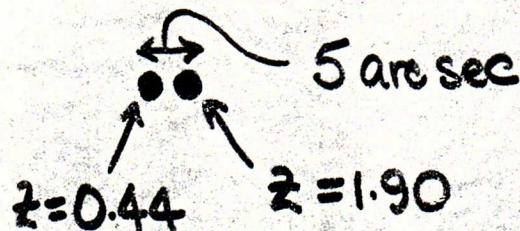
Are we seeing only  $\sim 1\%$  of Universe?  
Is gravity only long-range force?

## 2. QUASARS ("Starlike" objects)

Enormous redshifts yet rapidly variable.  
i.e. huge luminosity if truly distant.      i.e. small in size.

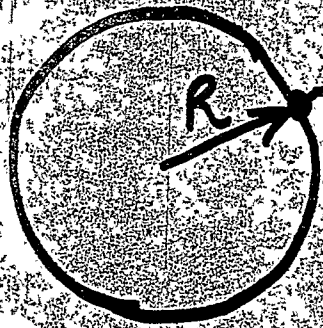
Associated with galaxies of much smaller redshift? — i.e. redshifts not related to distance or to velocity, or to either?

4C11.50 - double quasar?



Red shifts due to something other than velocity.  
Hoyle  $\rightarrow$   $e/m$  for electron varies?

# Black Hole



MASS  $M$

$$\text{Put } E (= h\nu) = mc^2$$

equivalent mass  
of photon

General Relativity  $\rightarrow$   $m$  acted on by gravity.

LIMITING CASE (PHOTON 'TRAPPED')

$$mc^2 = \frac{GMm}{R}$$

No photon can escape from mass  $M$  in radius  $R$  if  $GM = Rc^2$  (or more).

"BLACK HOLE" radius  $R = \frac{GM}{c^2}$

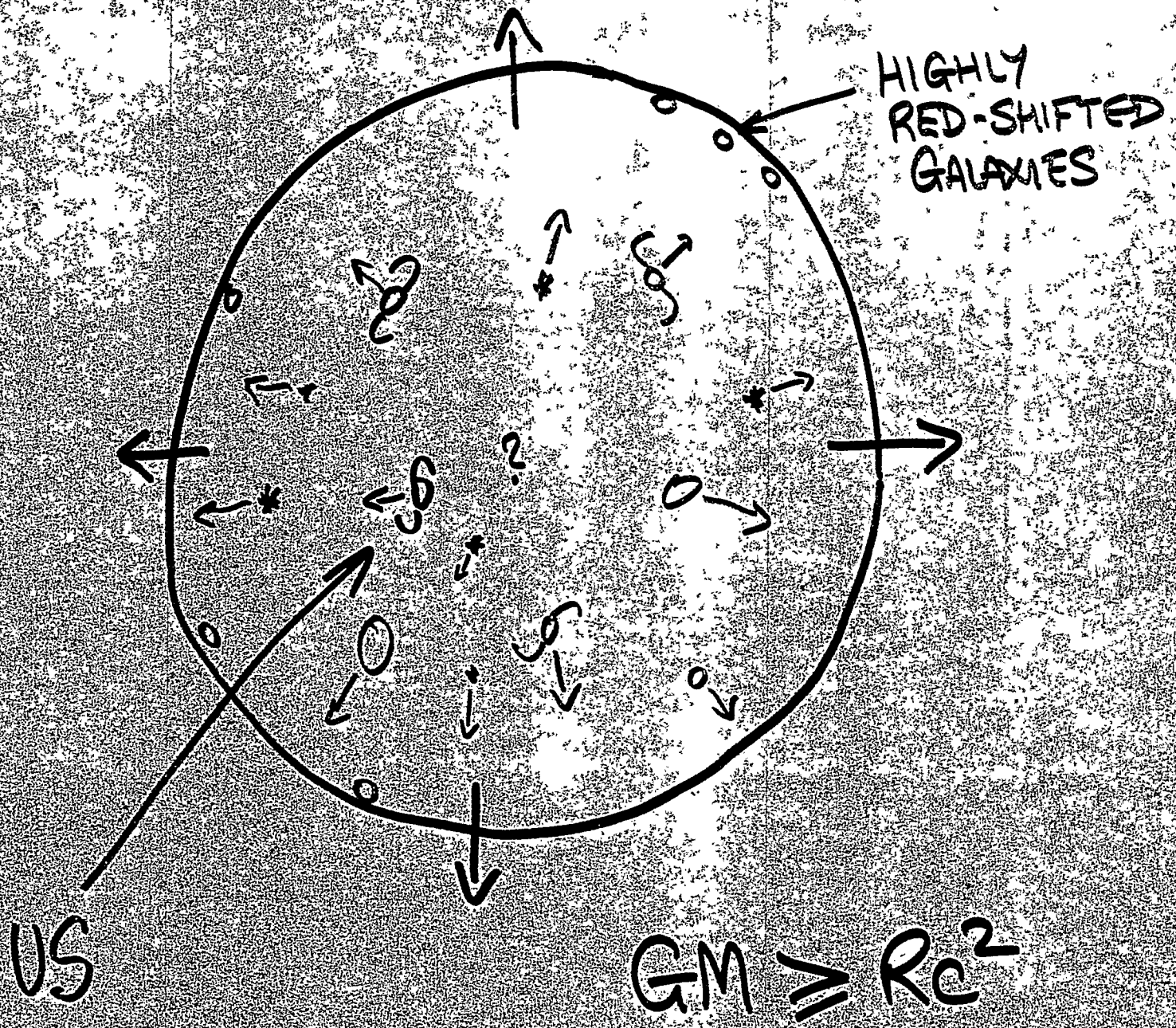
# Types of "Black Hole"

MASS	RADIUS	DENSITY
1 gram	$7 \times 10^{-29}$ cm	$6 \times 10^{83}$ g/cm <sup>3</sup>
"Earth"	0.4 cm	$2 \times 10^{28}$ g/cm <sup>3</sup>
"Sun"	1.5 km	$1.5 \times 10^{17}$ g/cm <sup>3</sup>
"Spiral Galaxy"	2000 A.U.	$4 \times 10^{-6}$ g/cm <sup>3</sup>
"Cluster of Galaxies"	3 light-years	$4 \times 10^{-10}$ g/cm <sup>3</sup>
"The Universe"	20 billion light-yrs	$4 \times 10^{-30}$ g/cm <sup>3</sup>

ARE WE INSIDE A BLACK HOLE ?

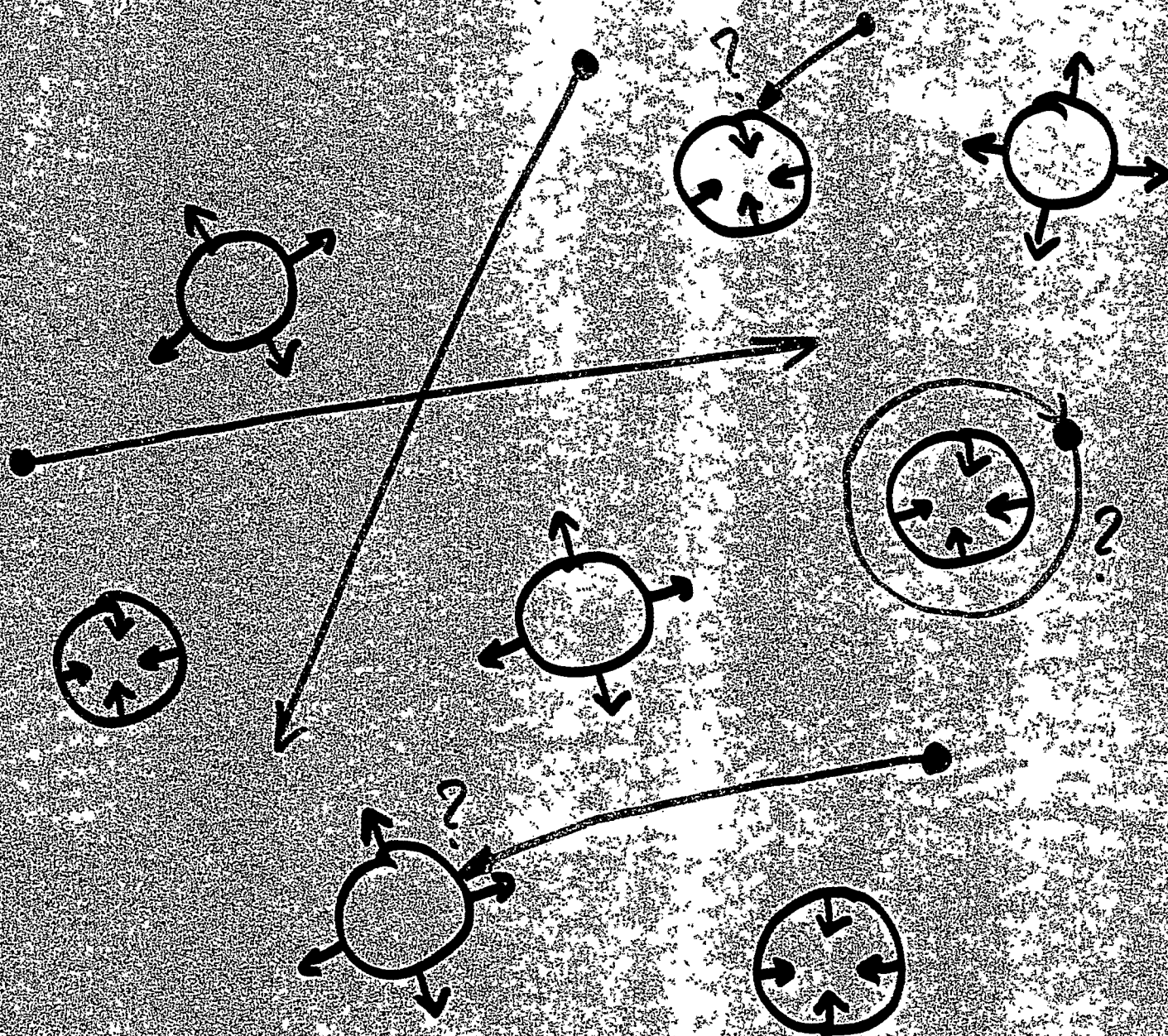


# A BLACK HOLE UNIVERSE?



# A "Universe" of "Black Hole Universes"

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WHAT DO ● ARRIVALS  
LOOK LIKE FROM INSIDE ?

# PROBLEMS (CONCEPTS)

## 1. "CREATION"

Big Bang "Genesis"?  $\left\{ \begin{array}{l} \text{"One Big Bang"} - \text{YES} \\ \text{Oscillating Model} - ? \end{array} \right.$

What was before?  $\left\{ \begin{array}{l} \text{"One Big Bang"} - t=0 \text{ like } T=C \\ \text{Oscillating Model} - ? \end{array} \right.$

## 2. FINITE UNIVERSE?

No edge in sight — not looked far enough?  
— we are near actual centre?

No edge at all — "One Big Bang" multiply infinite density at  $t=0$  ( $\therefore$  "Genesis")  
— Oscillating Model "bounces" while still of finite size?

## 3. ODDS AGAINST BEING "RIGHT" NOW?

Always have under-estimated totality of Universe

in past — e.g. Ptolemy  
Herschel etc.