Title: Cosmology

Date: Aug 17, 2004 03:15 PM

URL: http://pirsa.org/04080014

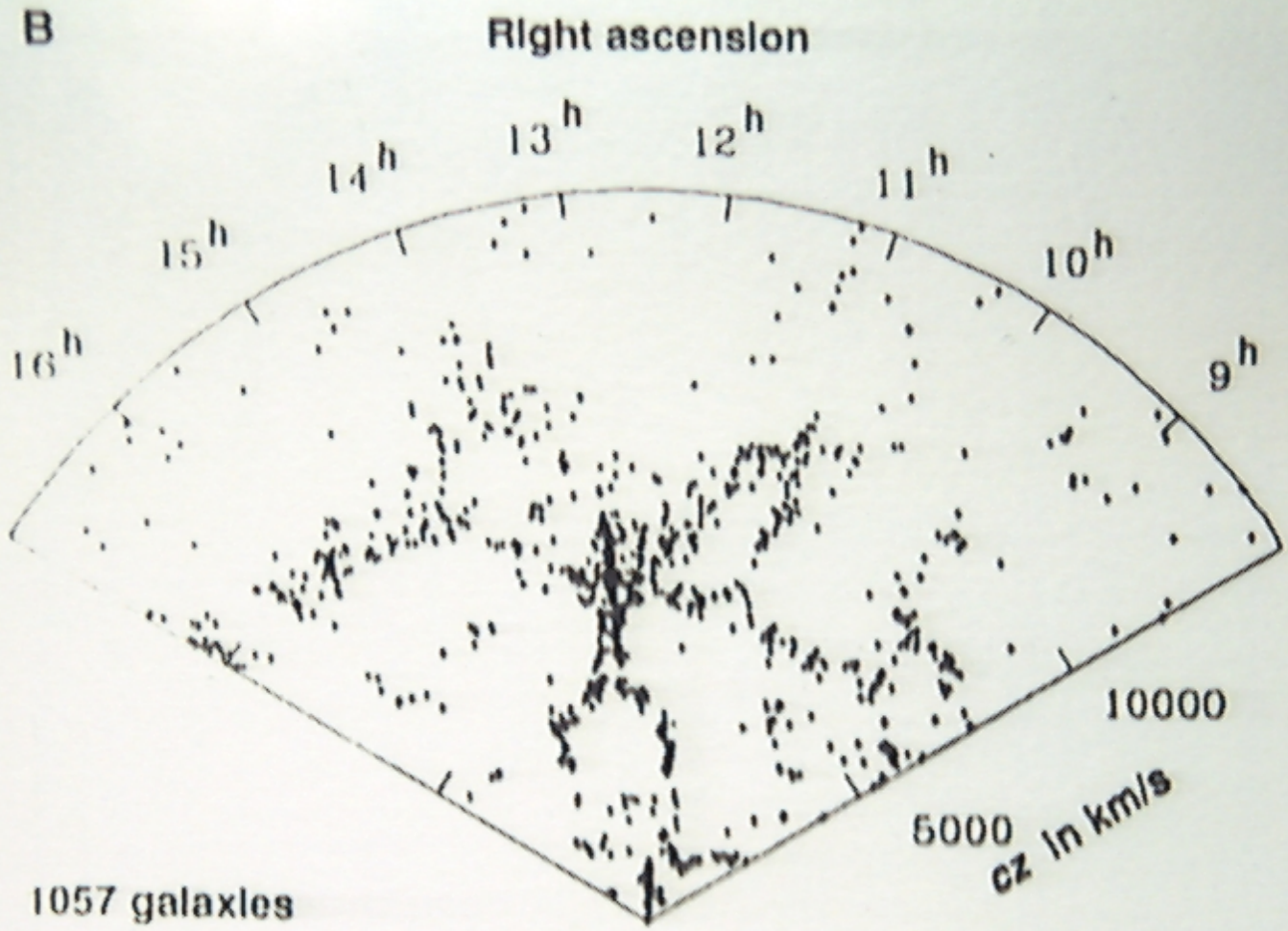
Abstract:

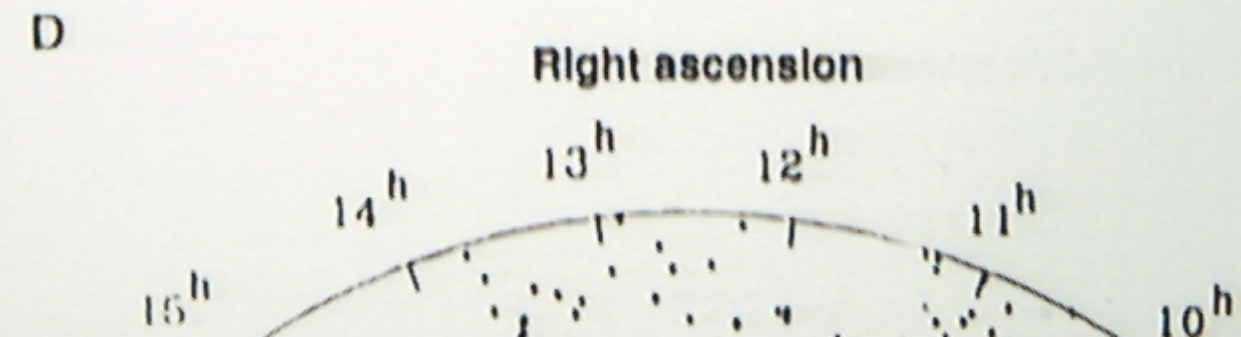
Goals of Cosmology

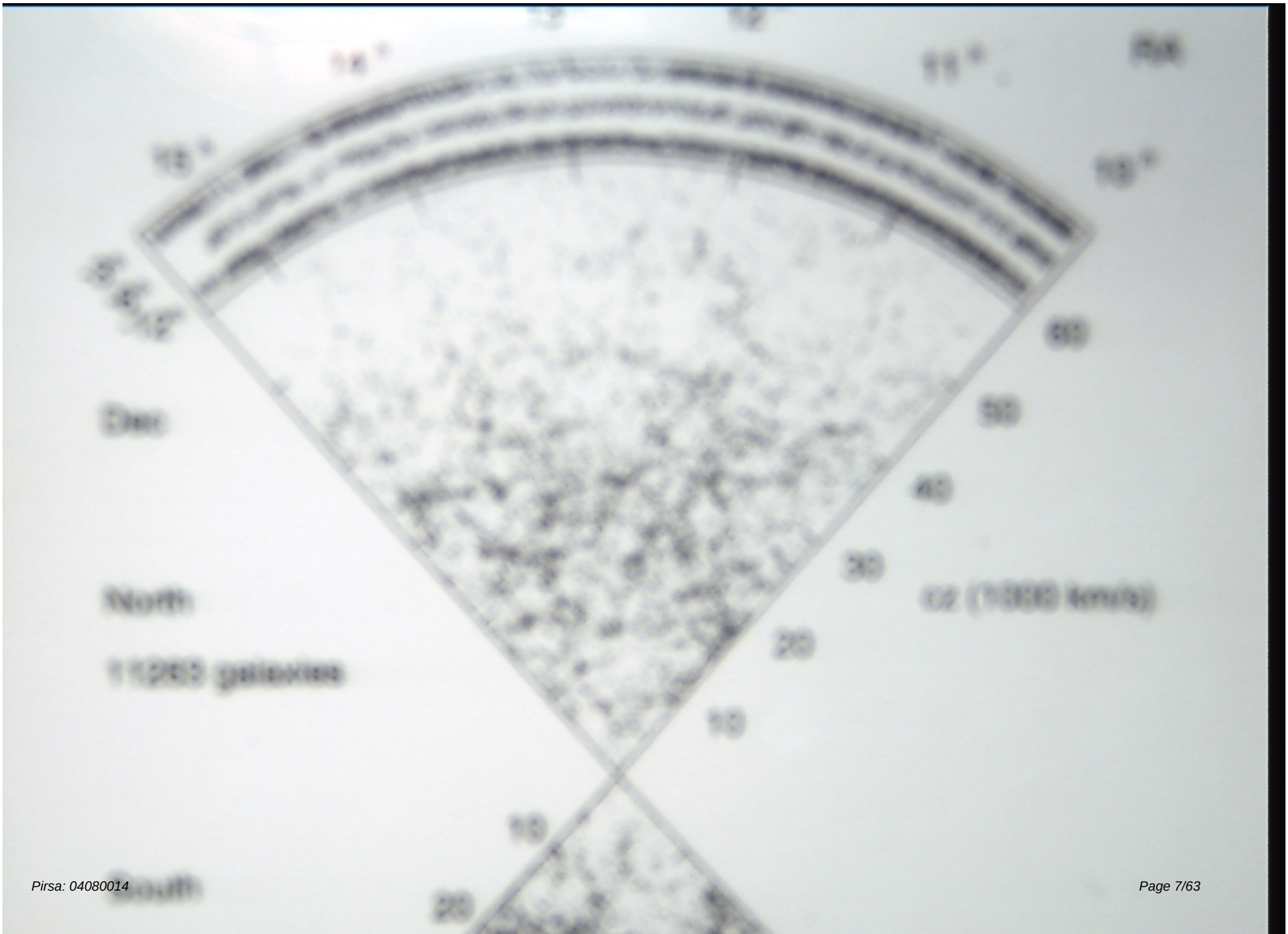
1. Understand Structure of the Universe on Large Scales

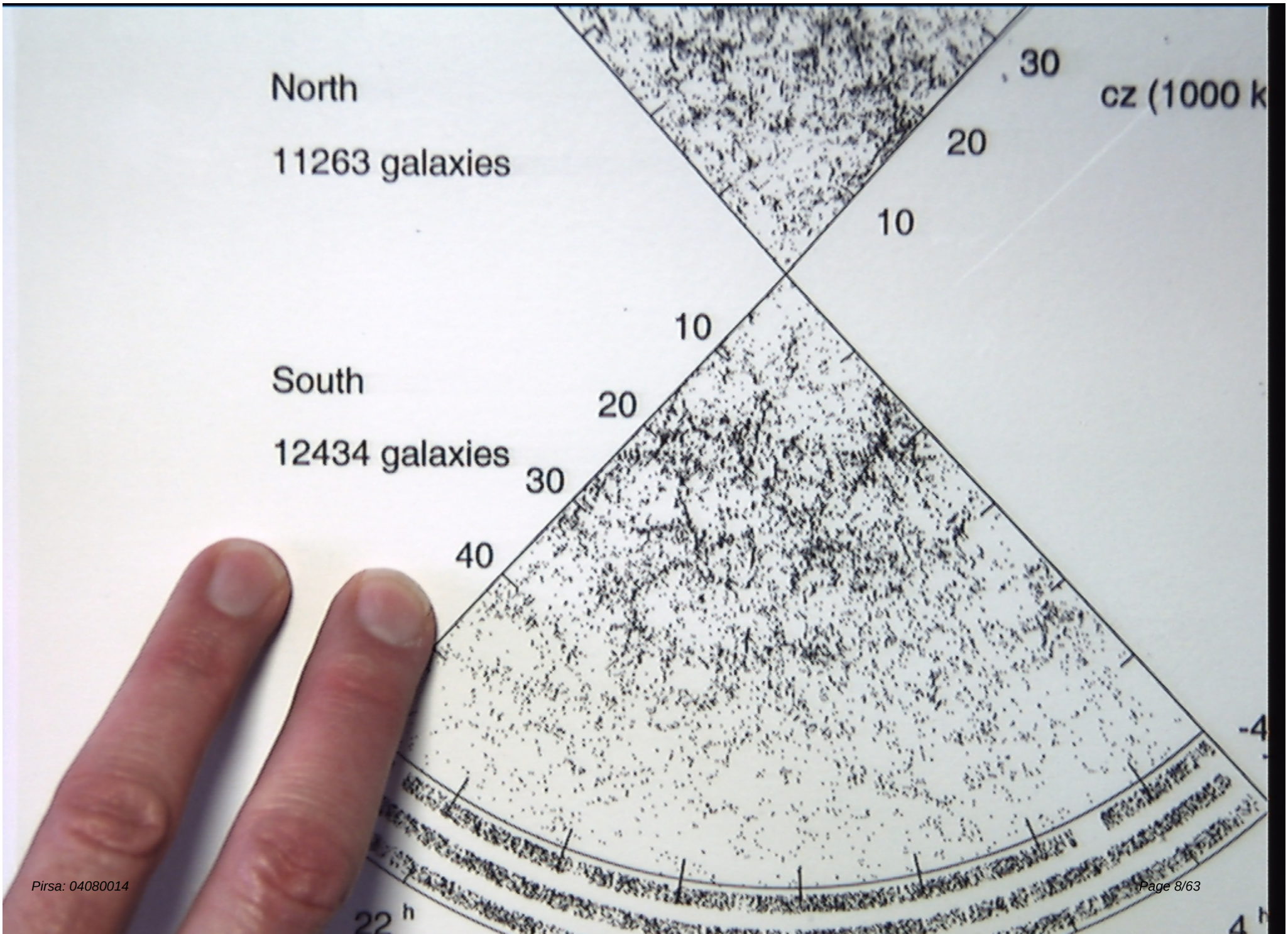
   quantitative science

2. Learn about History of the Very Early Universe

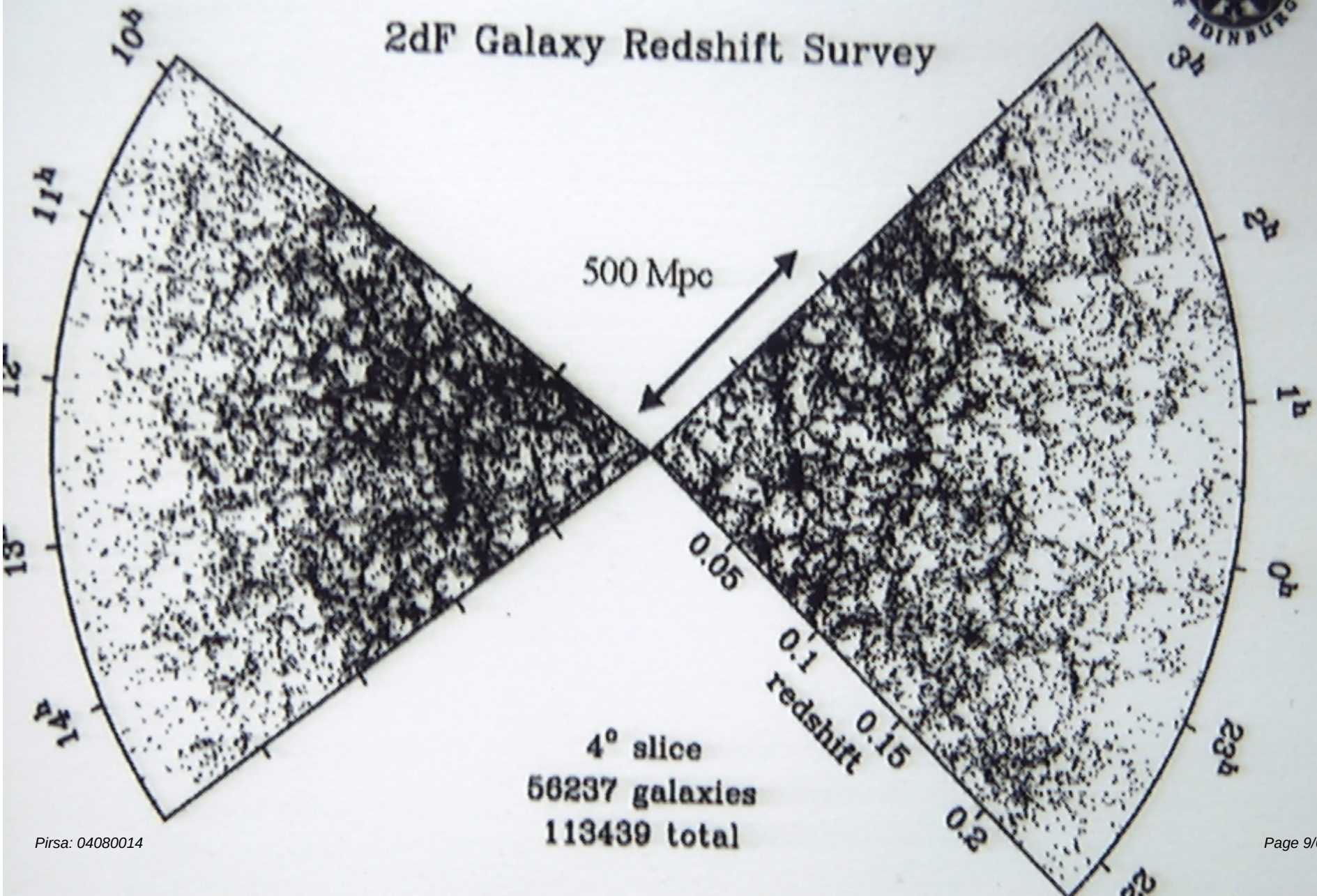

B
Right ascension
13h
12h
14h
11h
15h
10h
16h
9h
10000
5000
cz in km/s
1057 galaxies

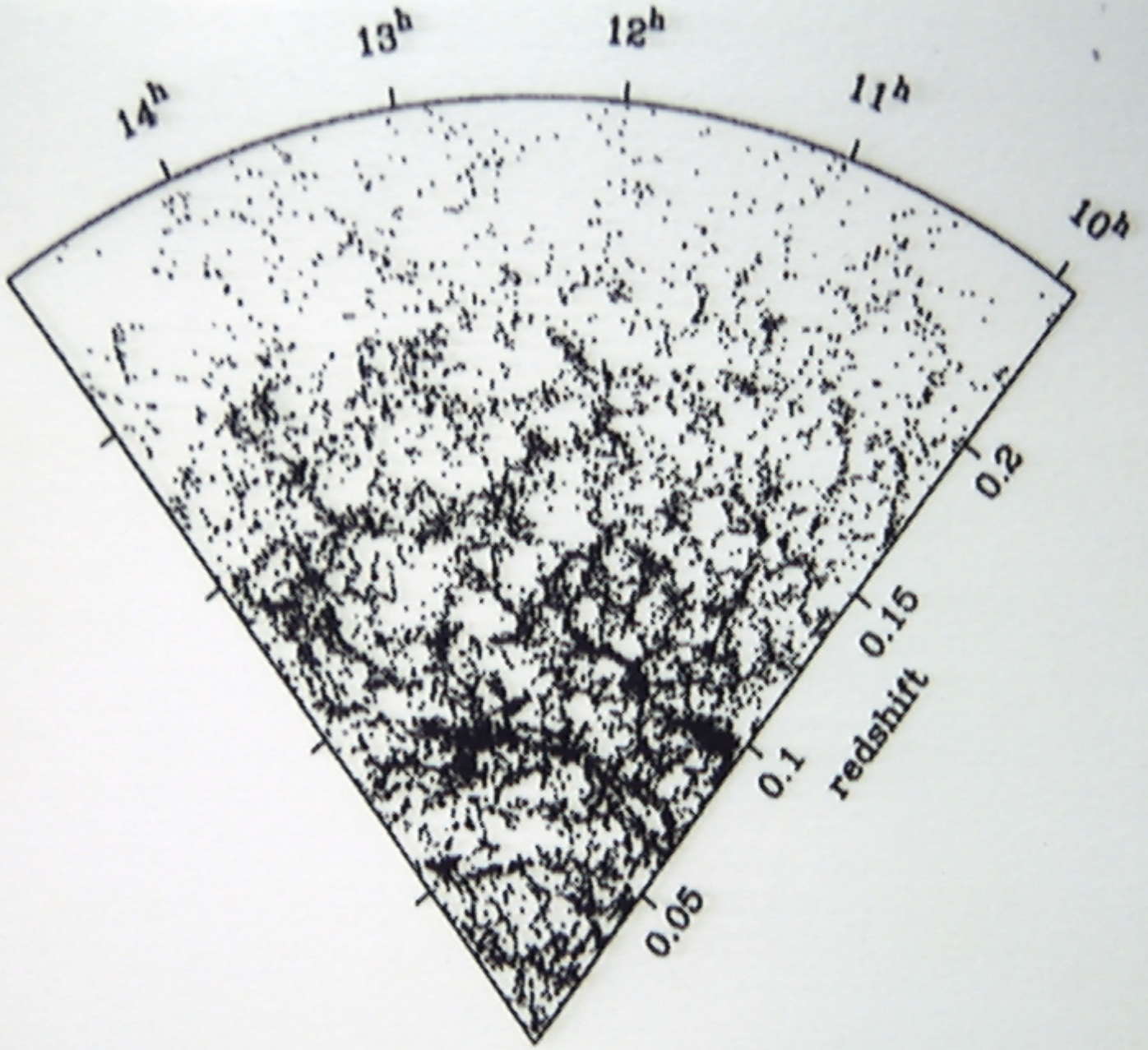

D
Right ascension
13h
12h
14h
11h
15h
10h


Dec
North
110269 galaxies
South
cz (1000 km/s)
10
20
30
40
50
60


North
11263 galaxies
South
12434 galaxies
30
20
10
10
20
30
40
cz (1000 k
-4
22 h
4 h

The state of the art in galaxy clustering




14h
13h
12h
11h
10h
0.2
0.15
0.1
0.05
redshift

COBE Microwave Sky

- The sky temperature with range from 0 - 4 Kelvin
- Microwave background is very uniform at nearly 2.73 Kelvin

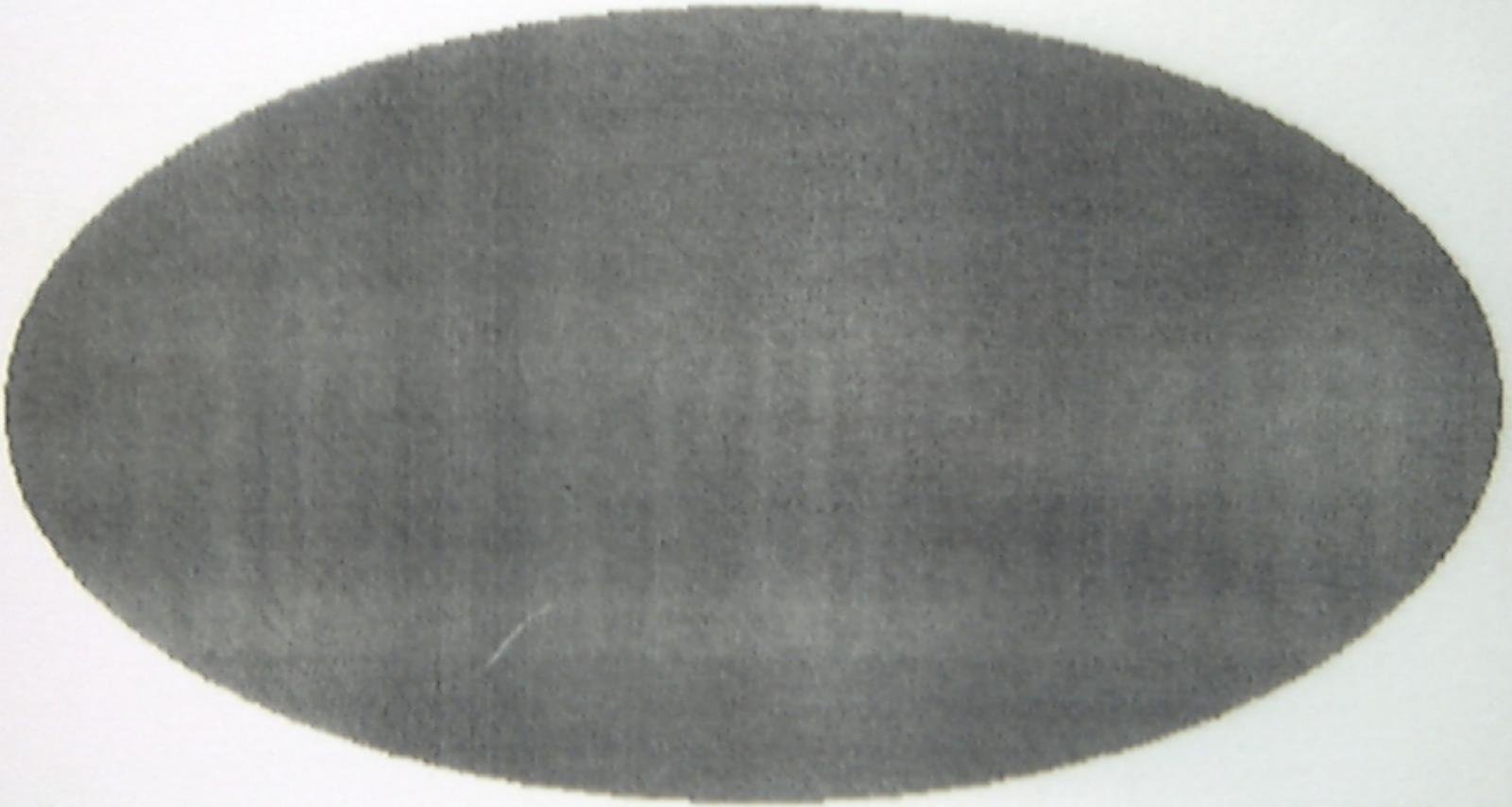
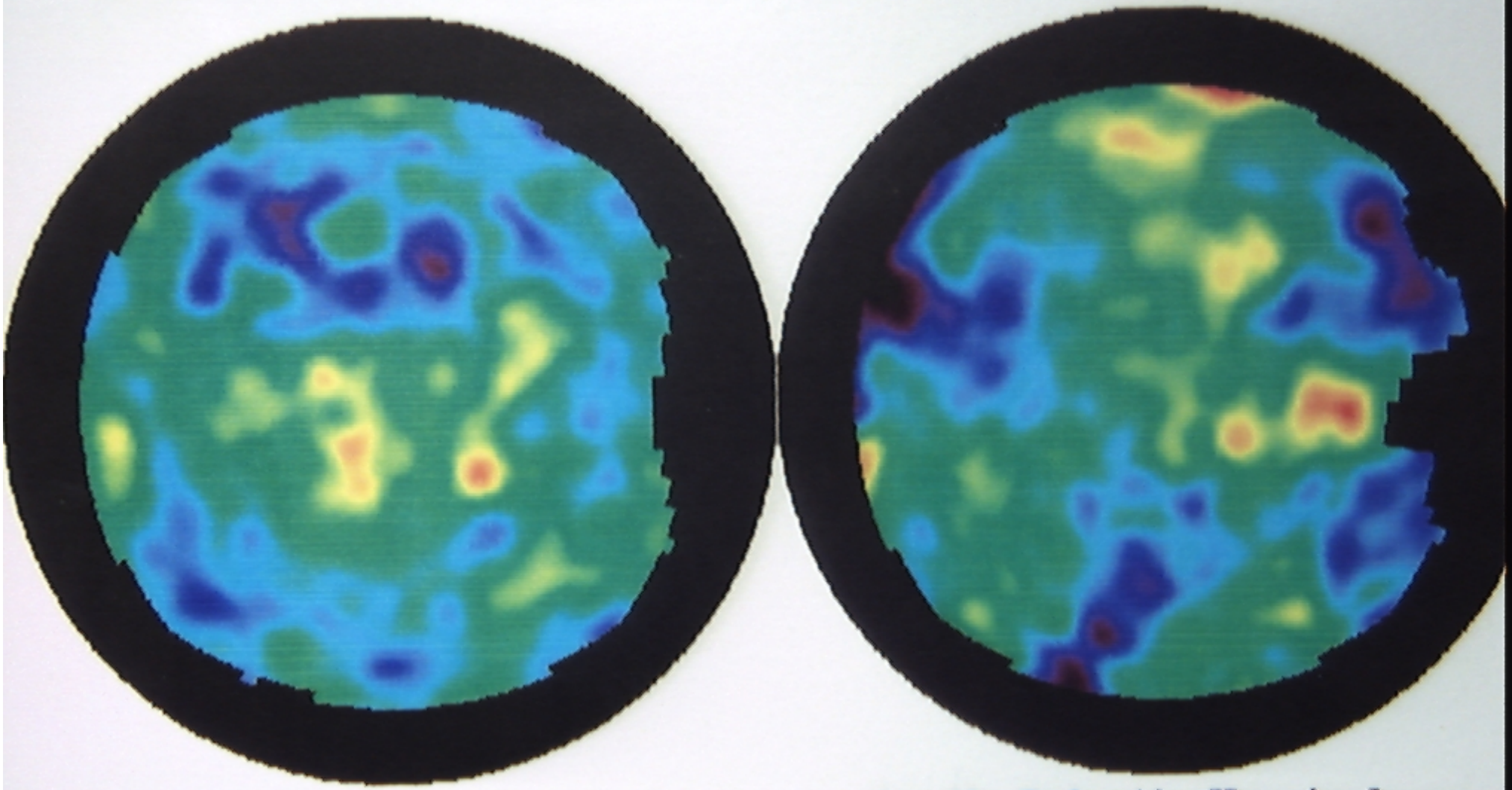


Image courtesy COBE homepage.

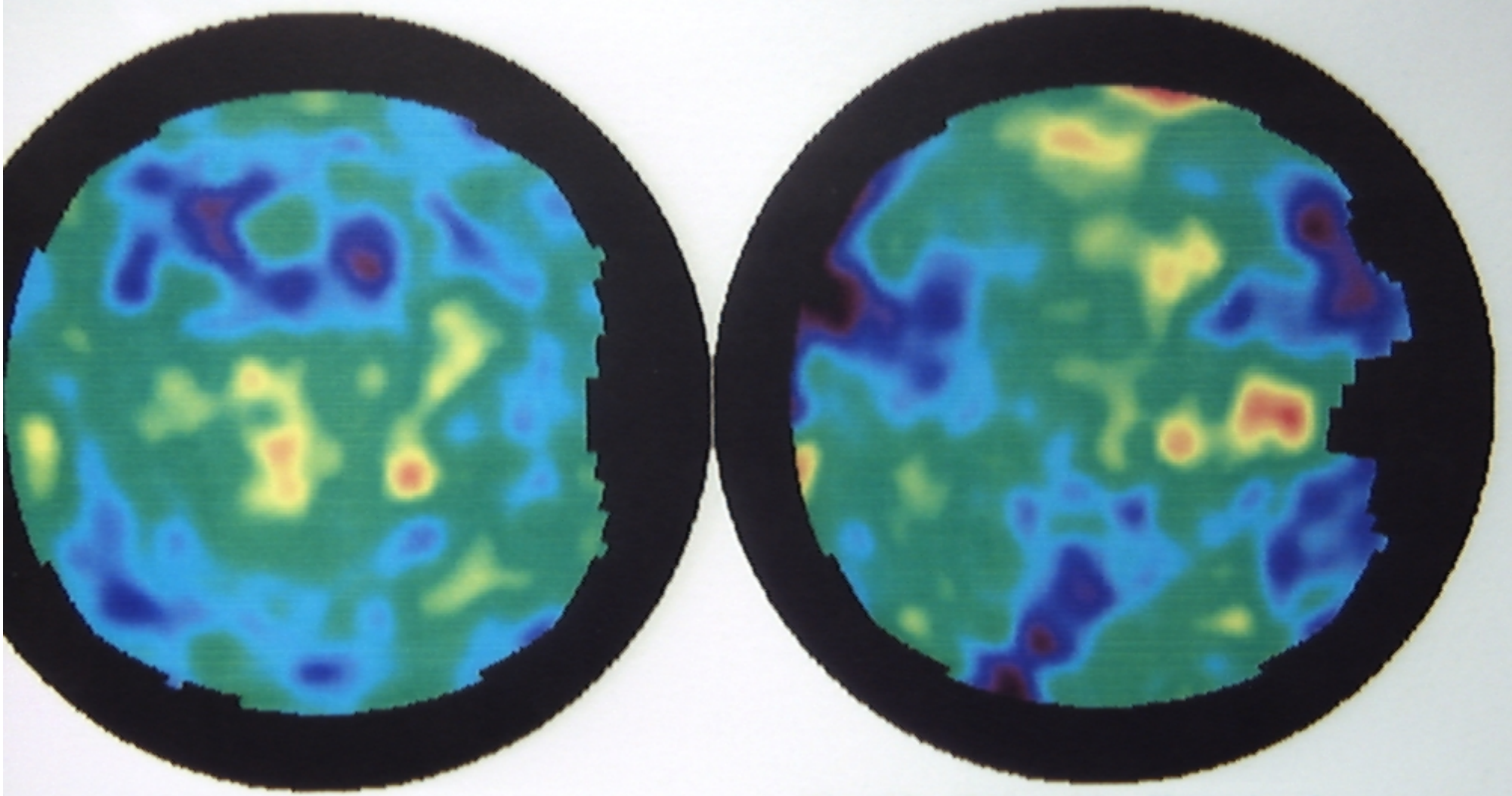
COBE–DMR Map of CMB Anisotropy



North Galactic Hemisphere

South Galactic Hemisphere

COBE–DMR Map of CMB Anisotropy



North Galactic Hemisphere

South Galactic Hemisphere

Scientific Approach to Analyzing Large-Scale Structure

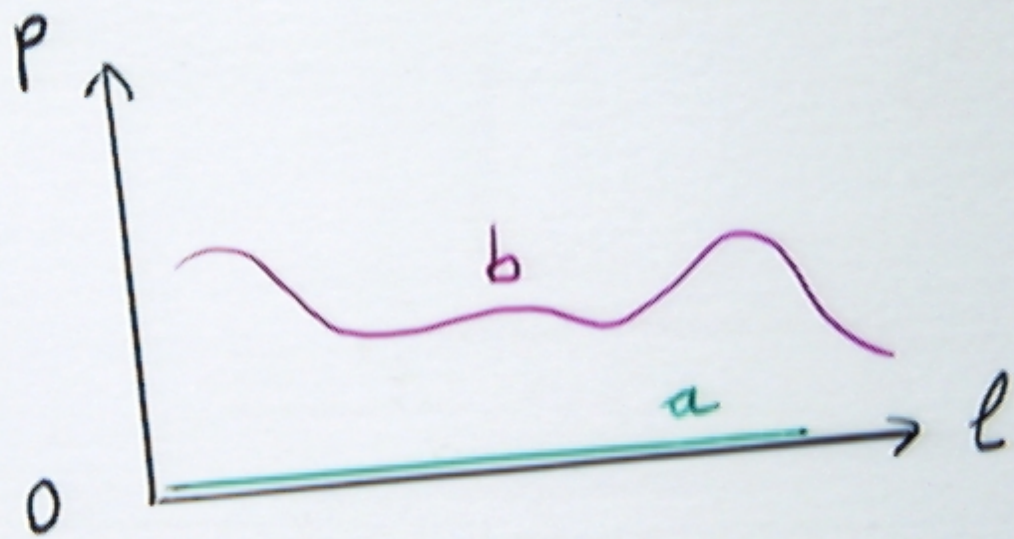
ap

Black

Black Box

$\Downarrow$

Curve

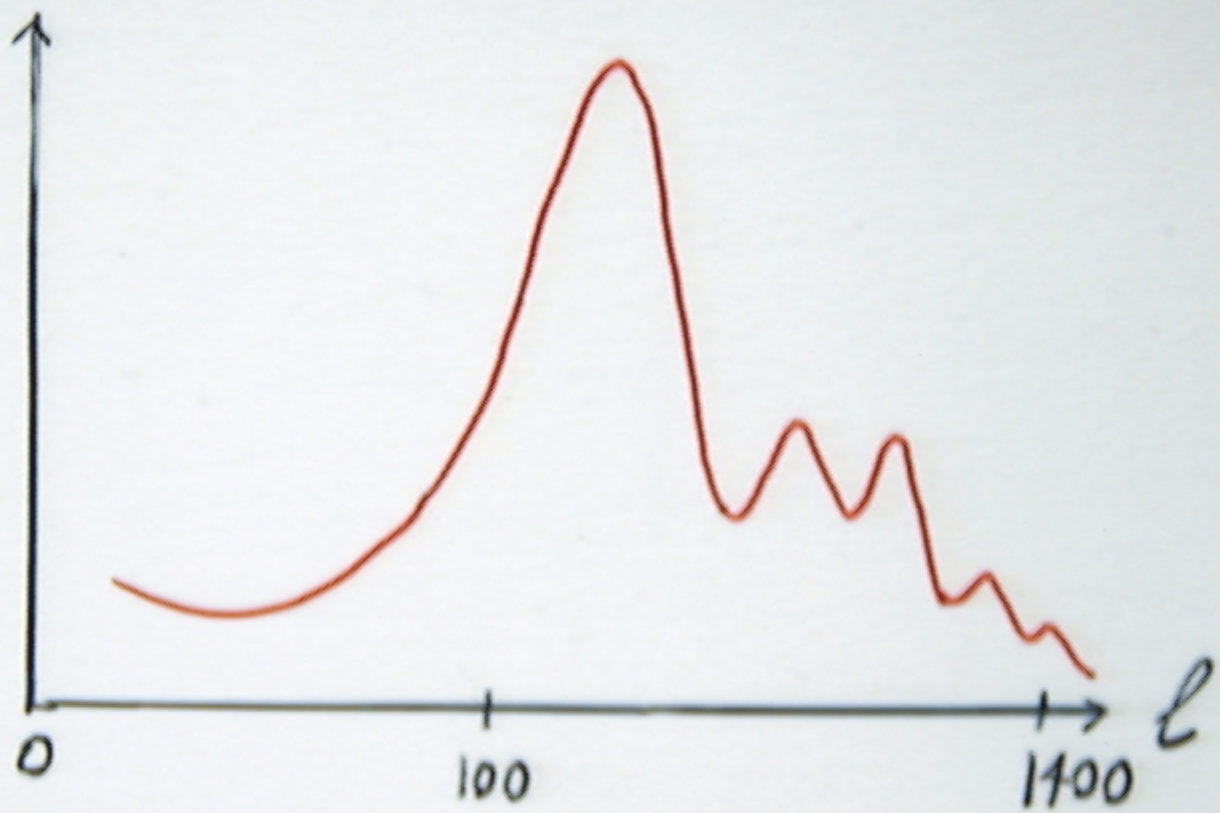


a) map uniform

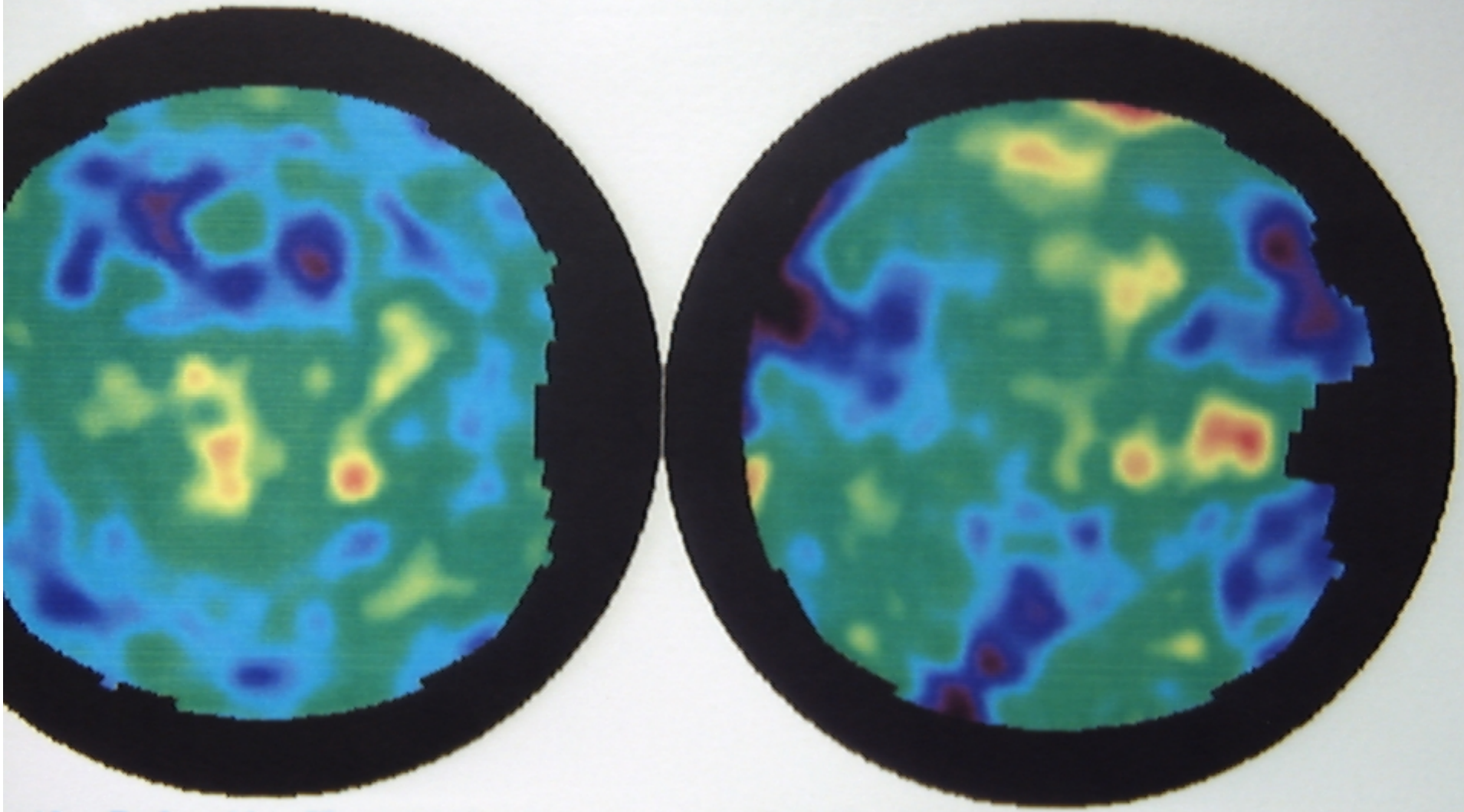
b) map not uniform

Inflationary Universe Theory

Guth, 1981

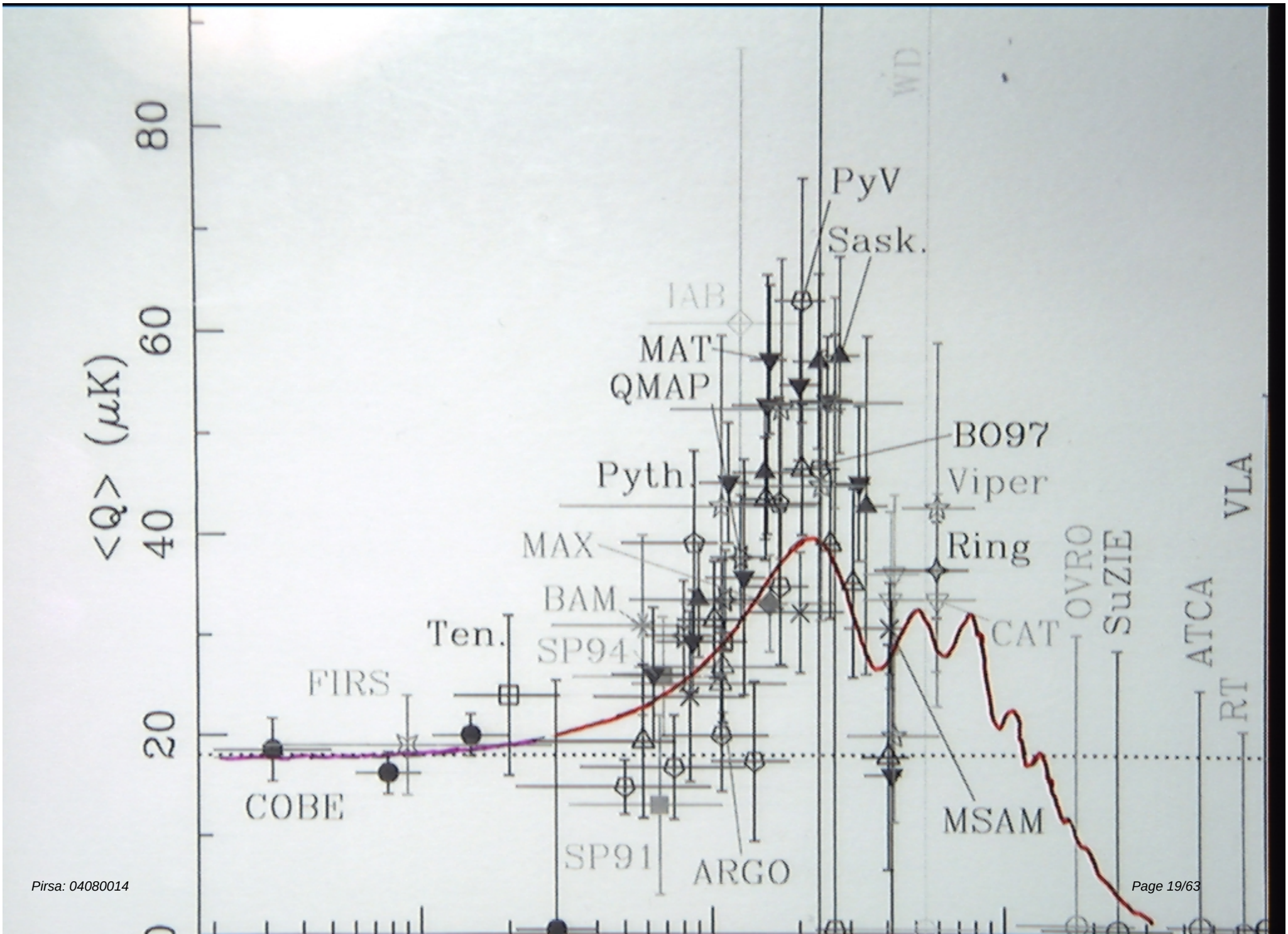


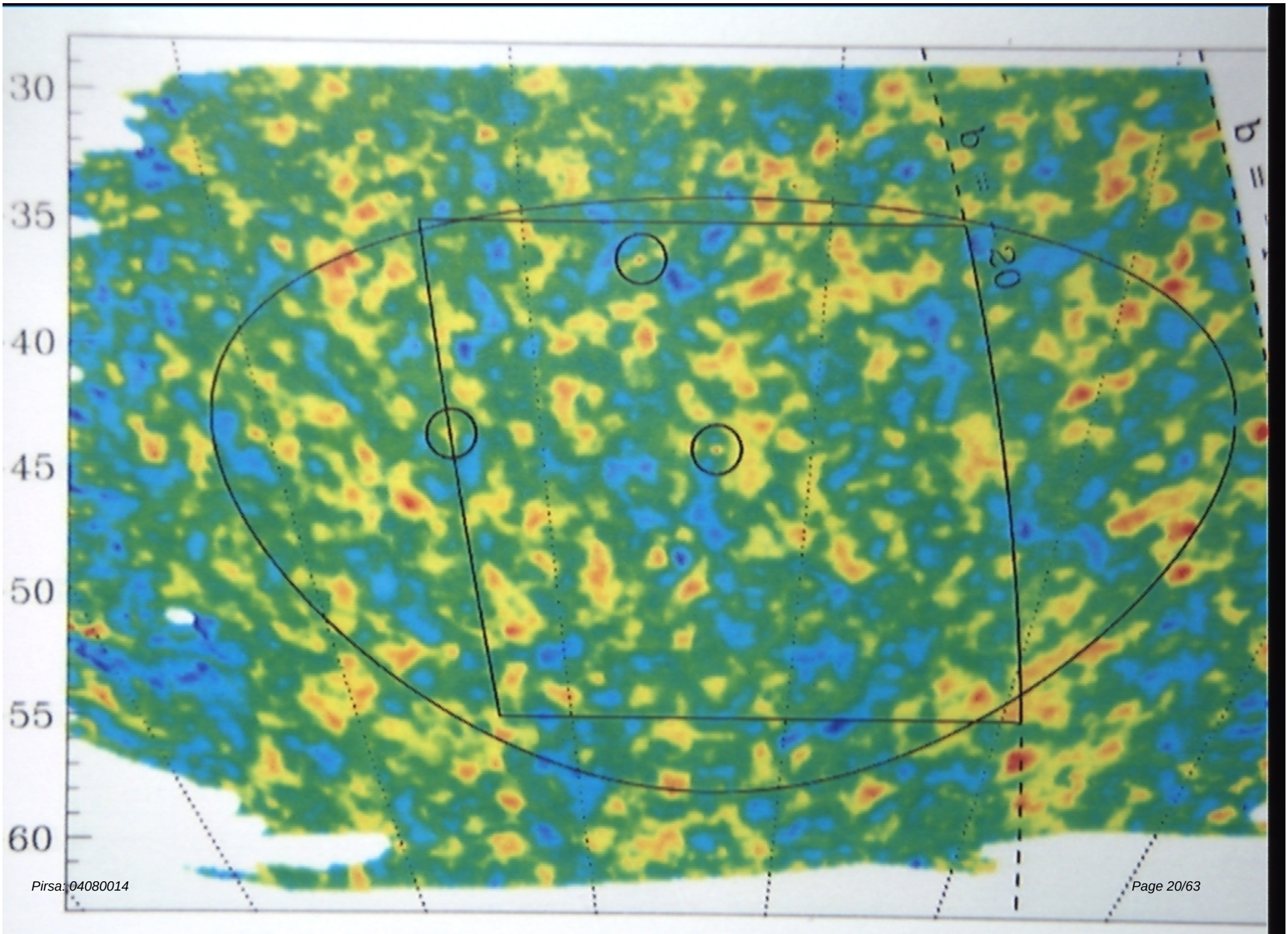
COBE–DMR Map of CMB Anisotropy

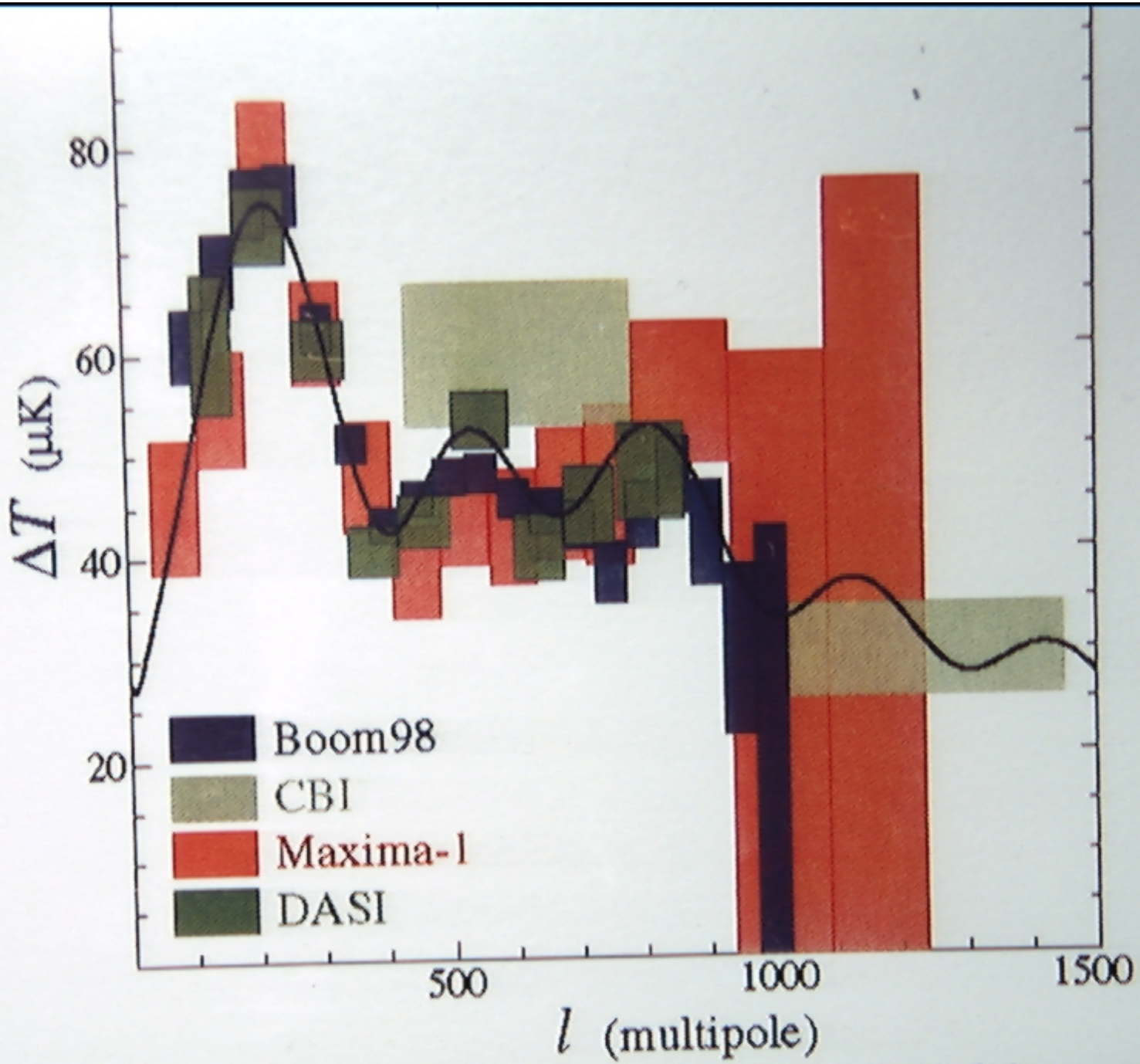


rth Galactic Hemisphere

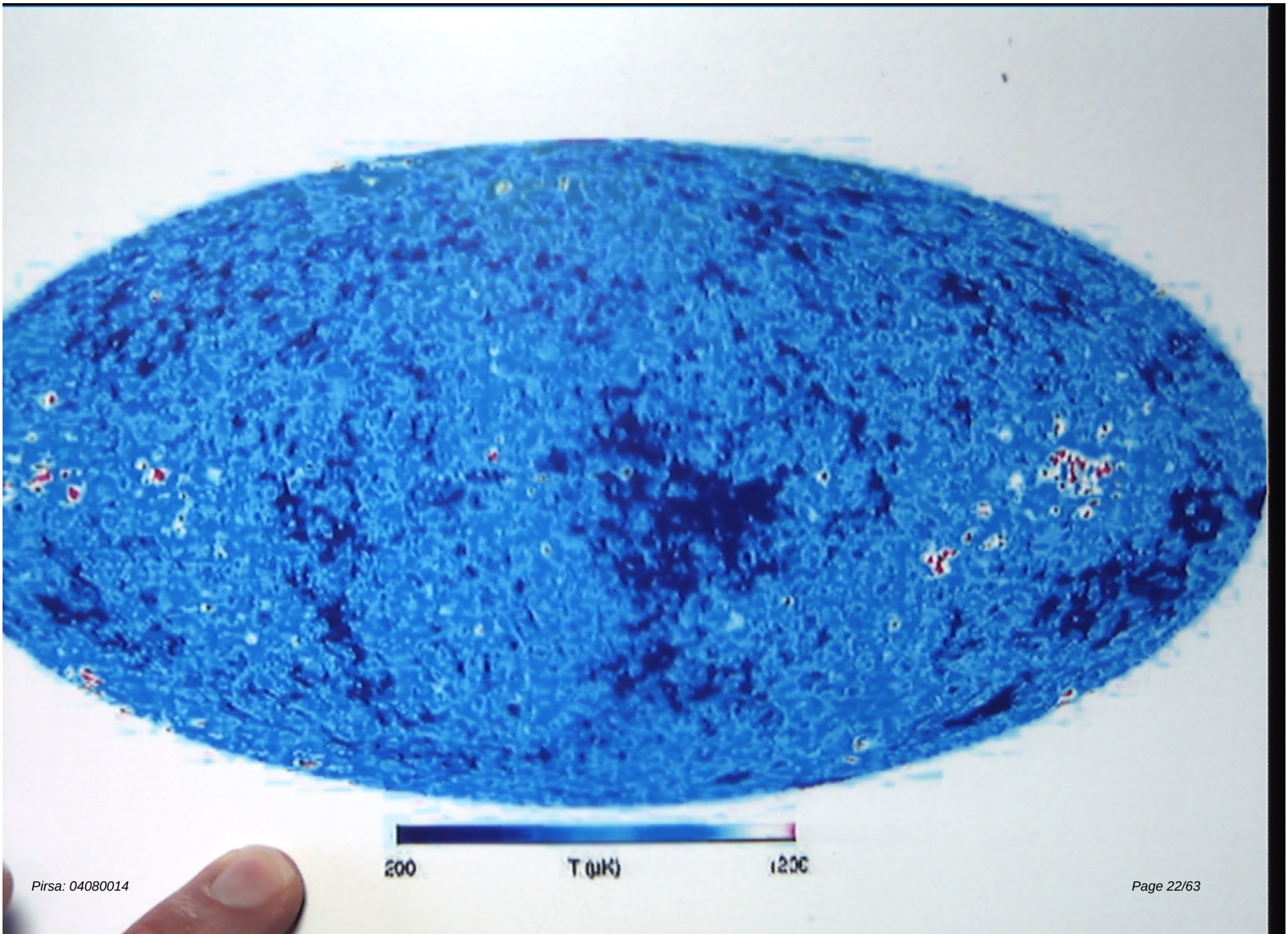
South Galactic Hemisphere


80
60
40
20
<Q> (μK)
PyV
Sask.
IAB
MAT
QMAP
B097
Pyth
Viper
MAX
Ring
BAM
CAT
Ten.
SP94
FIRS
COBE
MSAM
SP91
ARGO
OVRO
SuZIE
ATCA
VLA
RT
WD

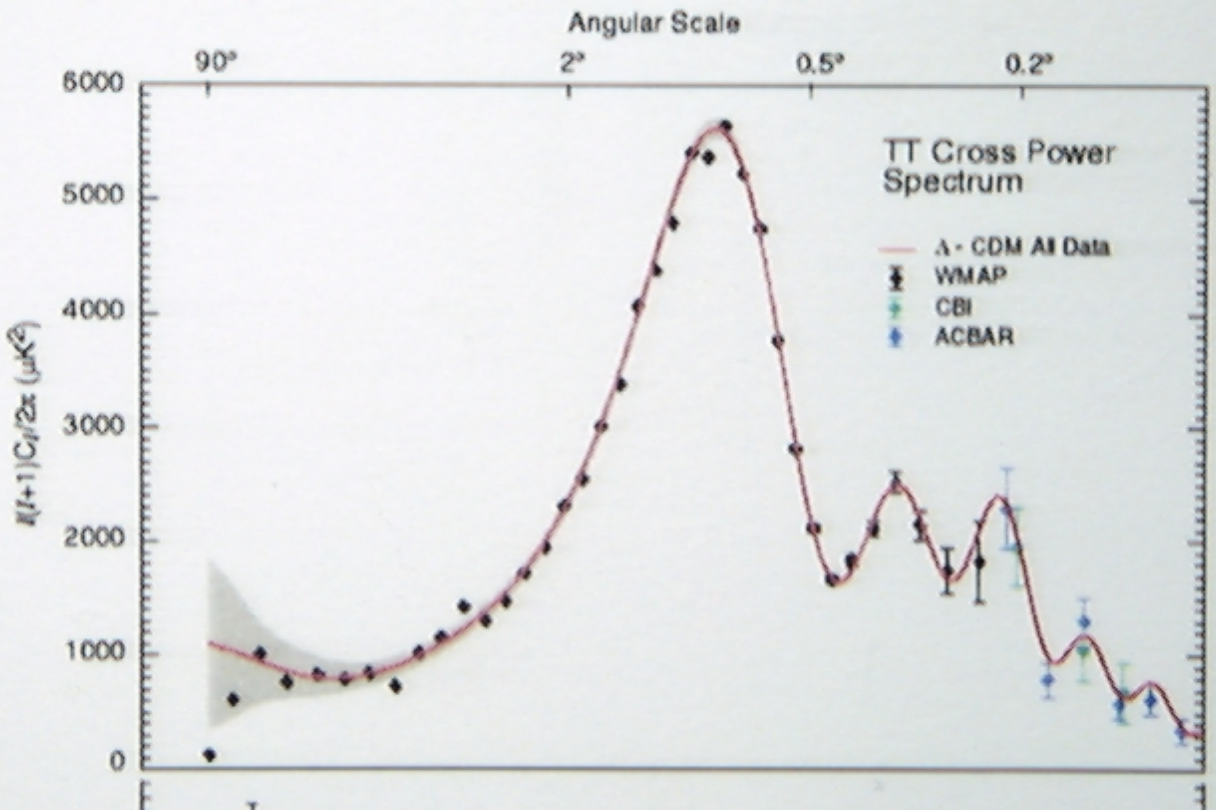

30
35
40
45
50
55
60
b = 20
b =



Boxes represent 1 sigma errors x band window width. Upper limits are plotted as 2 sigma constraints


200
T (μK)
1200

WMAP
(2003)


Angular Scale
90°
2°
0.5°
0.2°
6000
5000
4000
3000
2000
1000
0
l(l+1)C_l/2π (μK²)
TT Cross Power Spectrum
Λ - CDM All Data
WMAP
CBI
ACBAR

Theoretical Framework #1:

Standard Big Bang Model

Pillars of the Model:

1. Einstein's theory of General Relativity

matter curves space-time

space-time dynamical

replaces Newton's theory of

1. Einstein's theory of General Relativity

matter curves space-time

space-time dynamical

replaces Newton's theory of absolute space & time

2. space homogeneous & isotropic (on large scales)

2. space homogeneous

(on large scales)

↓

Space is expanding

3. matter = sum of ideal gases

dust & radiation

replaces Newton's theory of absolute space & time

space homogeneous & isotropic (on large scales)

↓

Space is expanding

matter = sum of ideal gases

Pillars of the Model:

1. Einstein's theory of General Relativity

matter curves space-time

space-time dynamical

replaces Newton's theory of absolute space & time

2. space homogeneous & isotropic

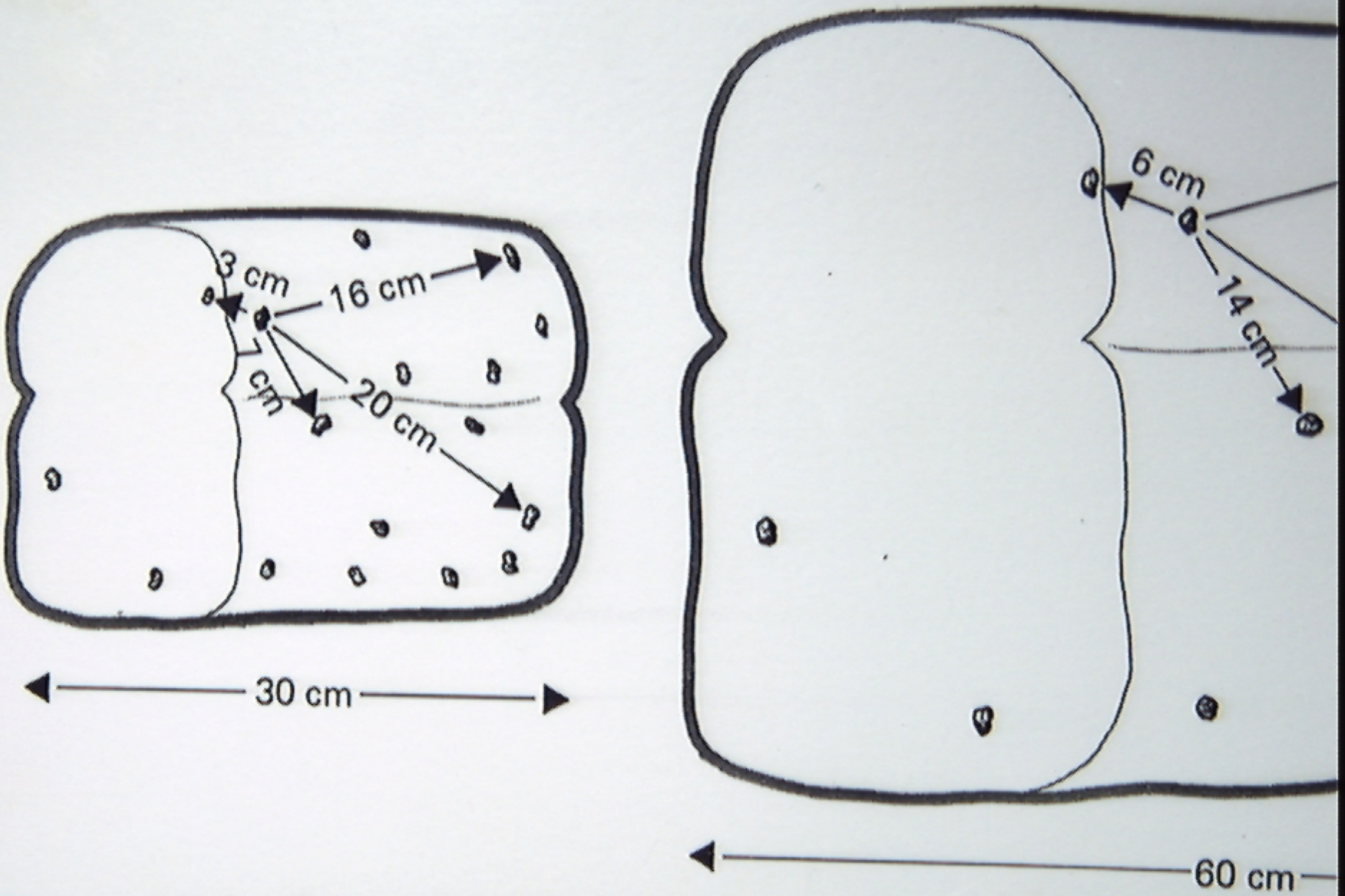
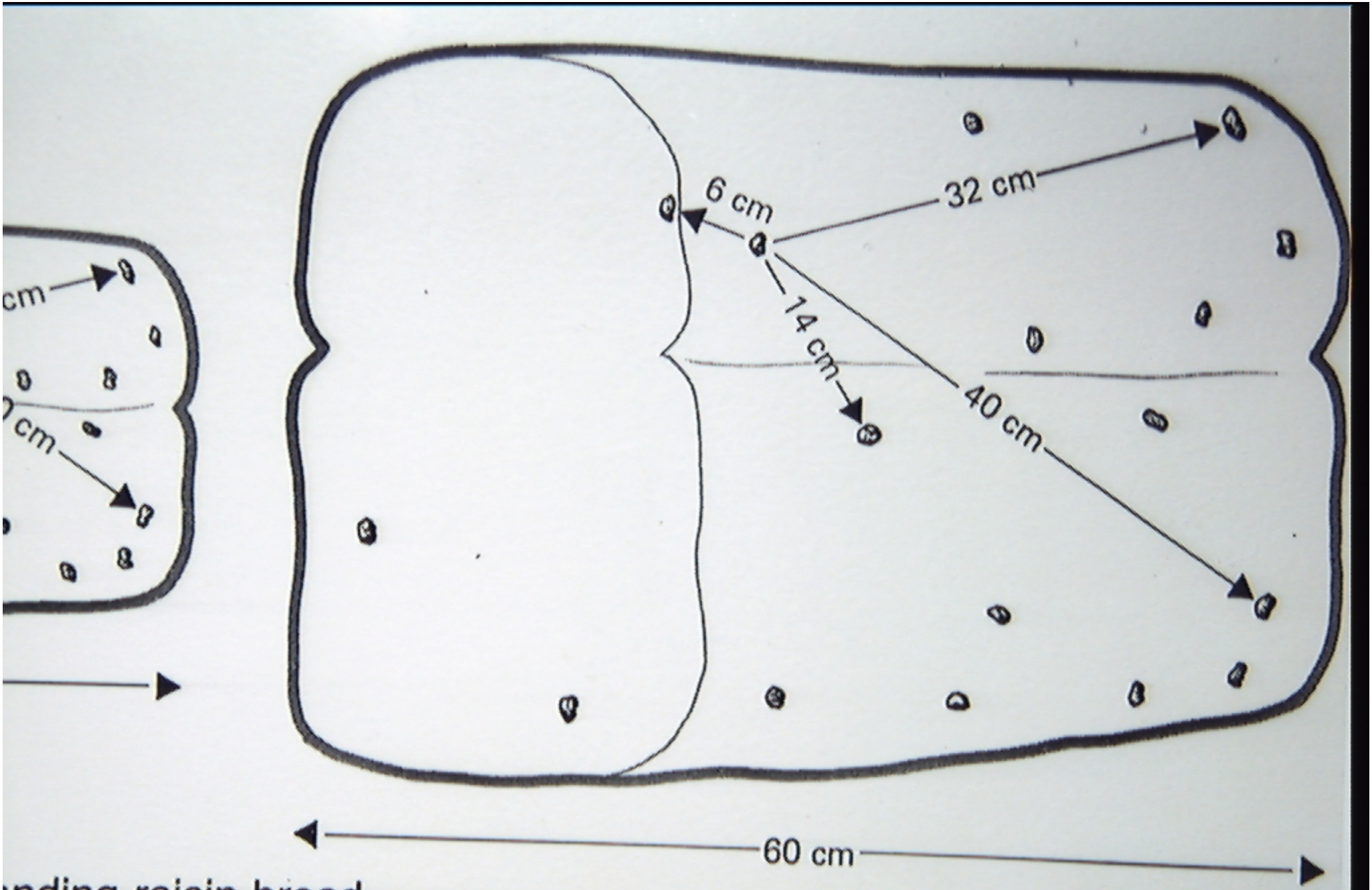
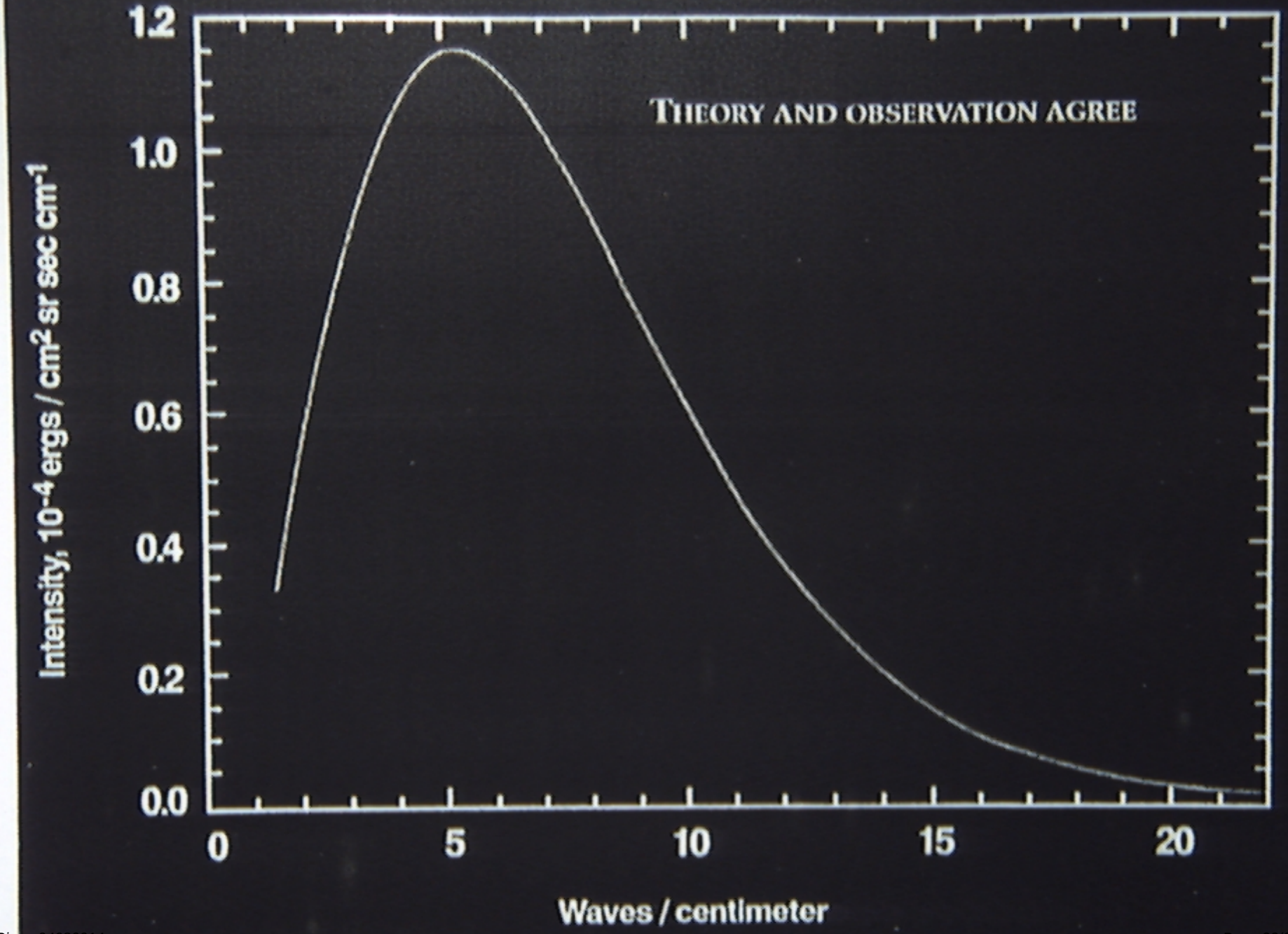


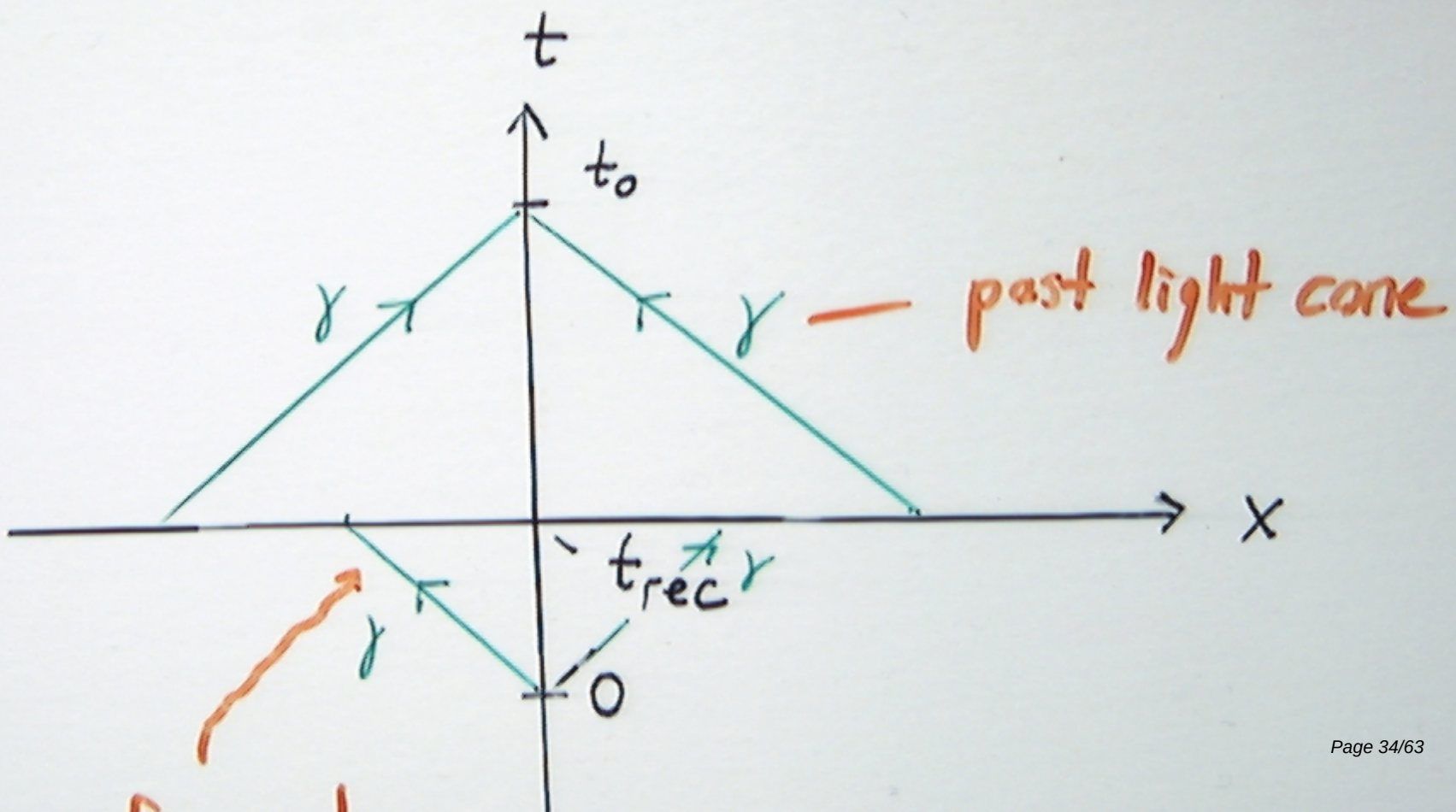
Figure 37.4 Expanding raisin bread.



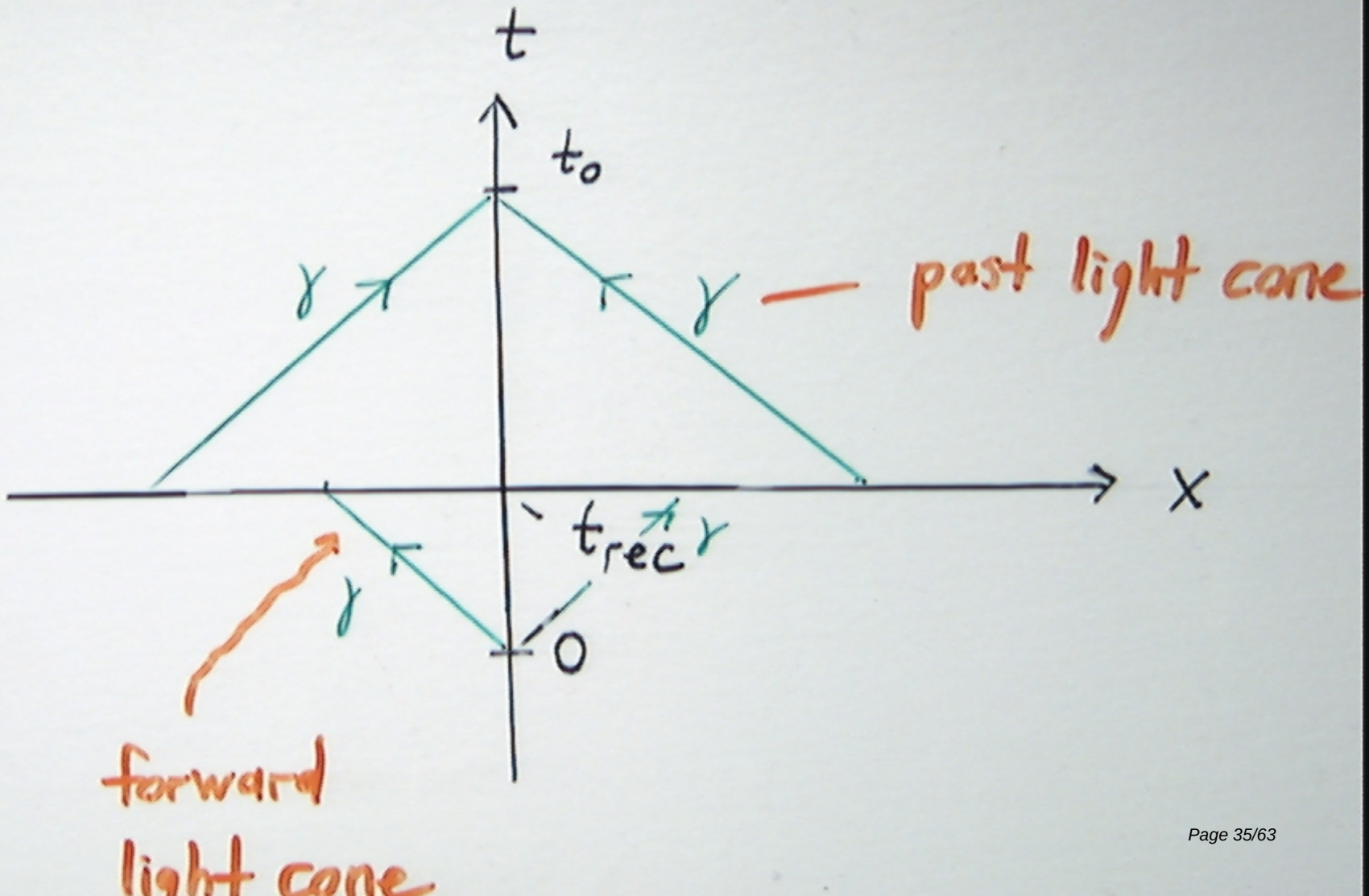
anding raisin bread.


THEORY AND OBSERVATION AGREE
Intensity, 10^{-4} ergs / cm^2 sr sec cm^{-1}
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
5
10
15
20
Waves / centimeter

SBB theory does <u>not</u> explain isotropy of CMB

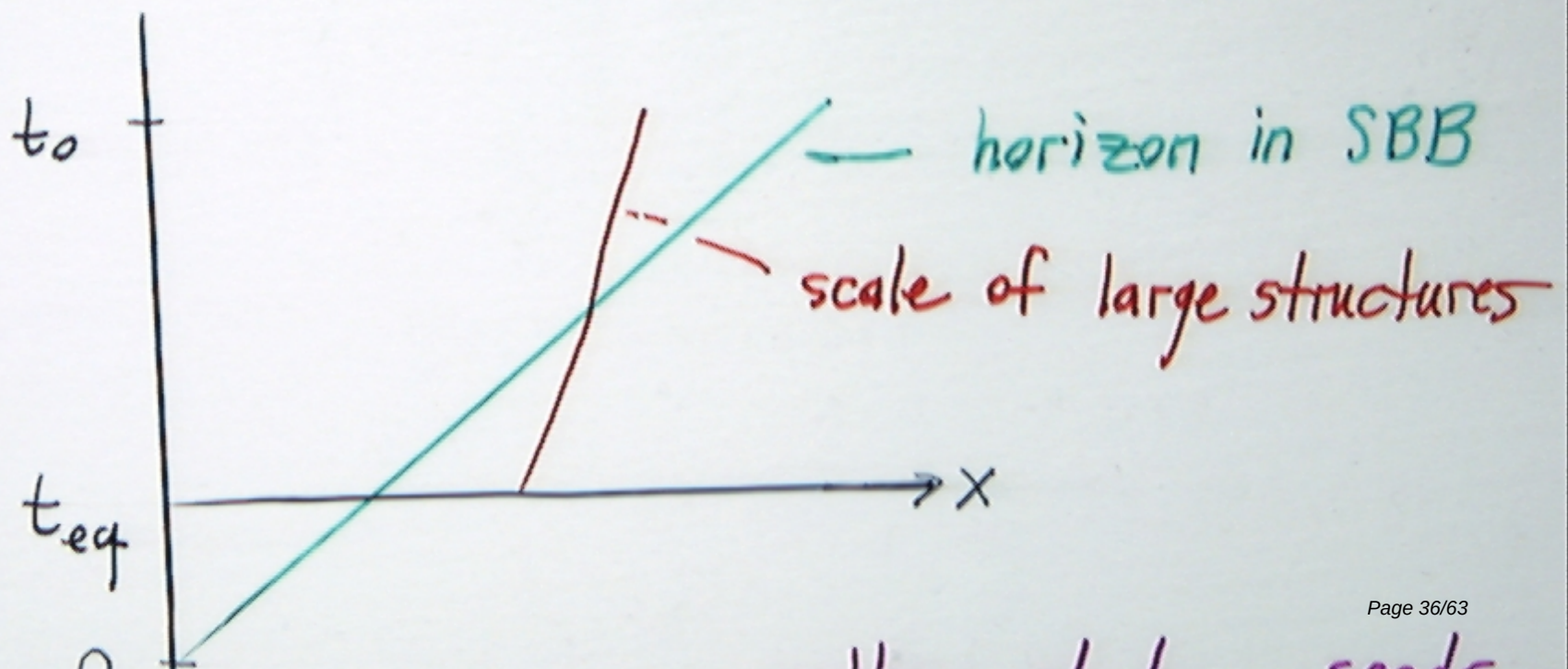


SBB theory does <u>not</u> explain isotropy of CMB



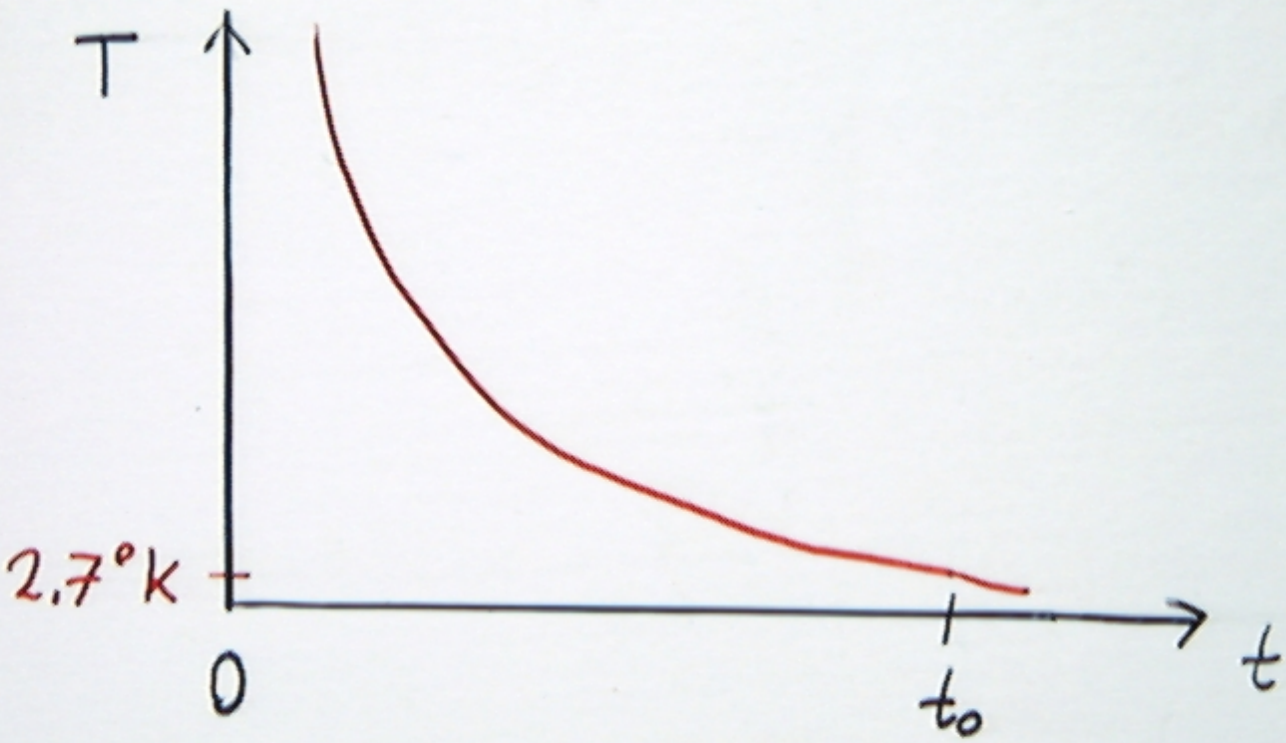
2. Fluctuation Problem

Within SBB cosmology there is no **causal** mechanism to explain the origin of fluctuations.



3. Singularity Problem

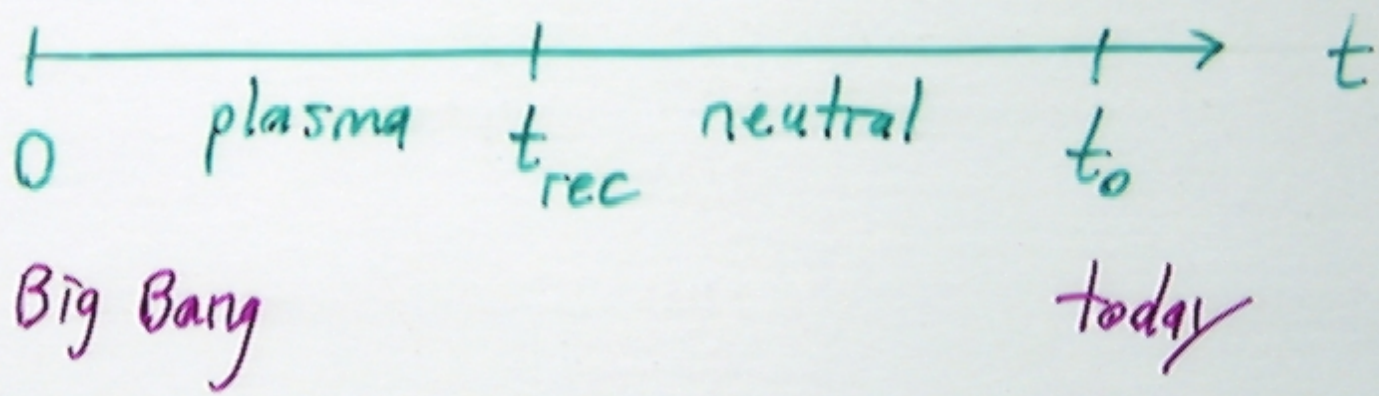
SBB theory predicts an initial singularity



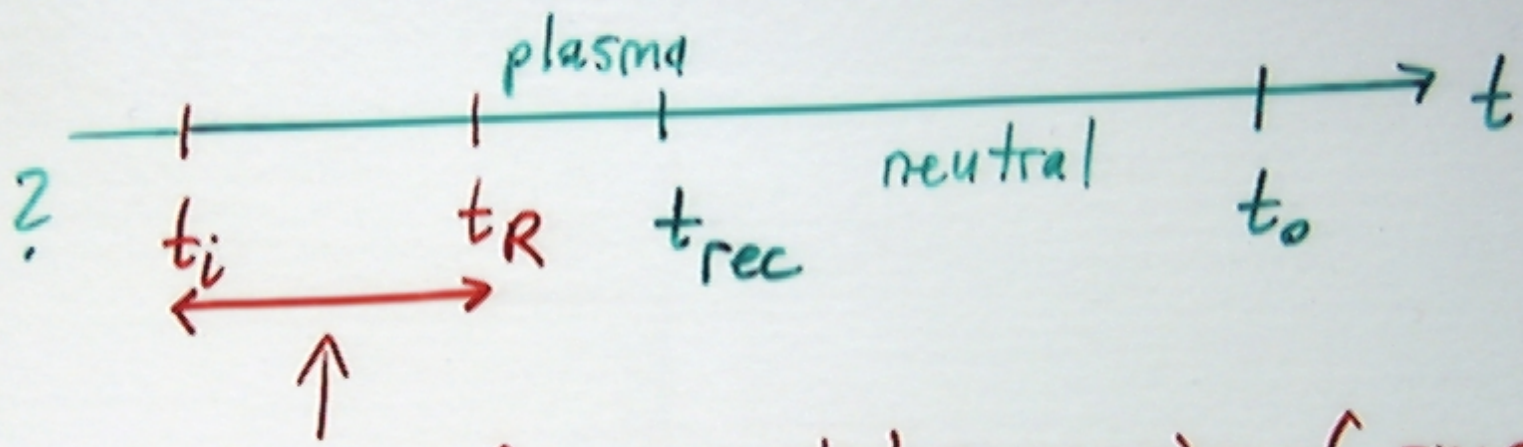
Theoretical Framework #2:

Inflationary Universe Model

Time line of SBB cosmology

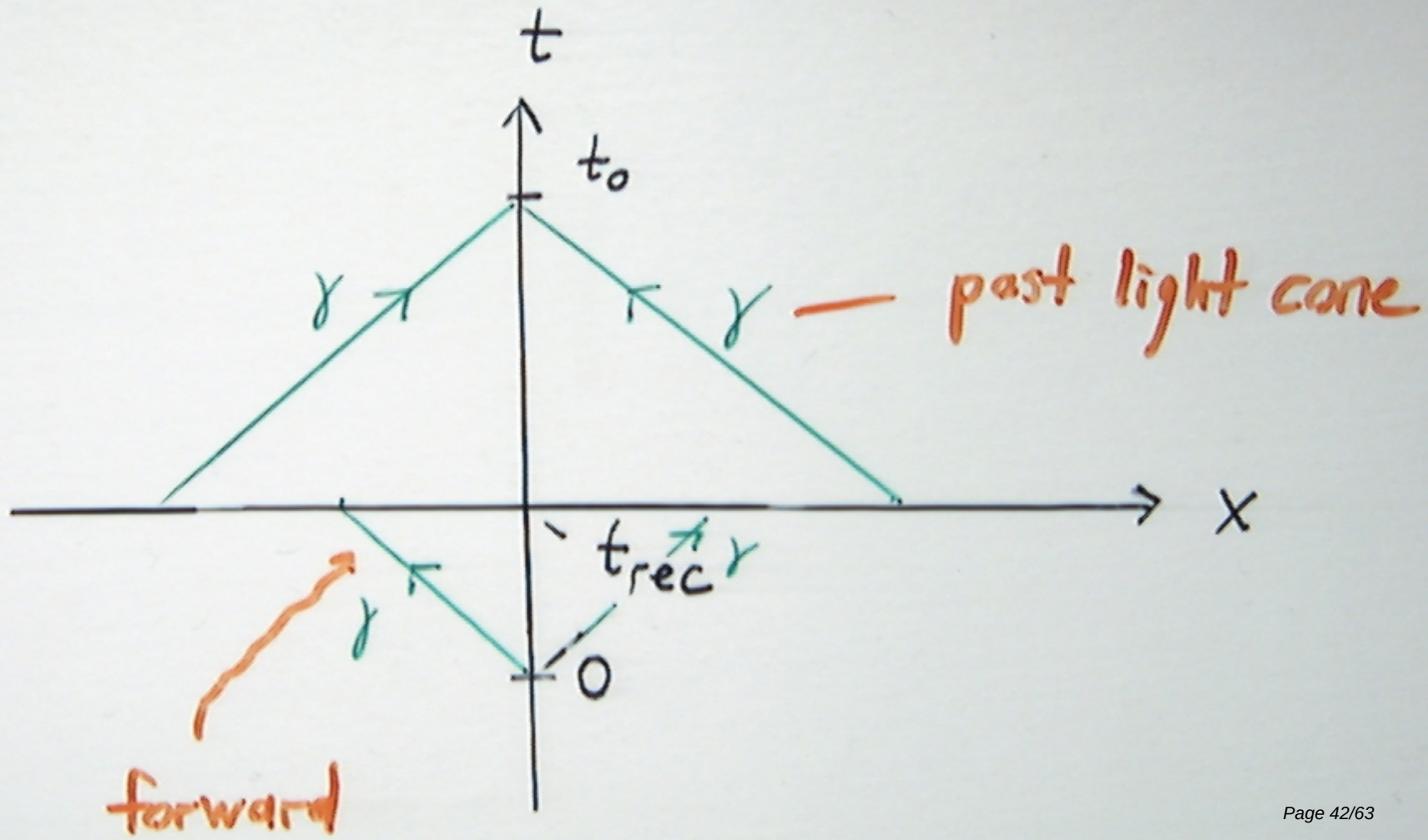


Time line of inflationary cosmology

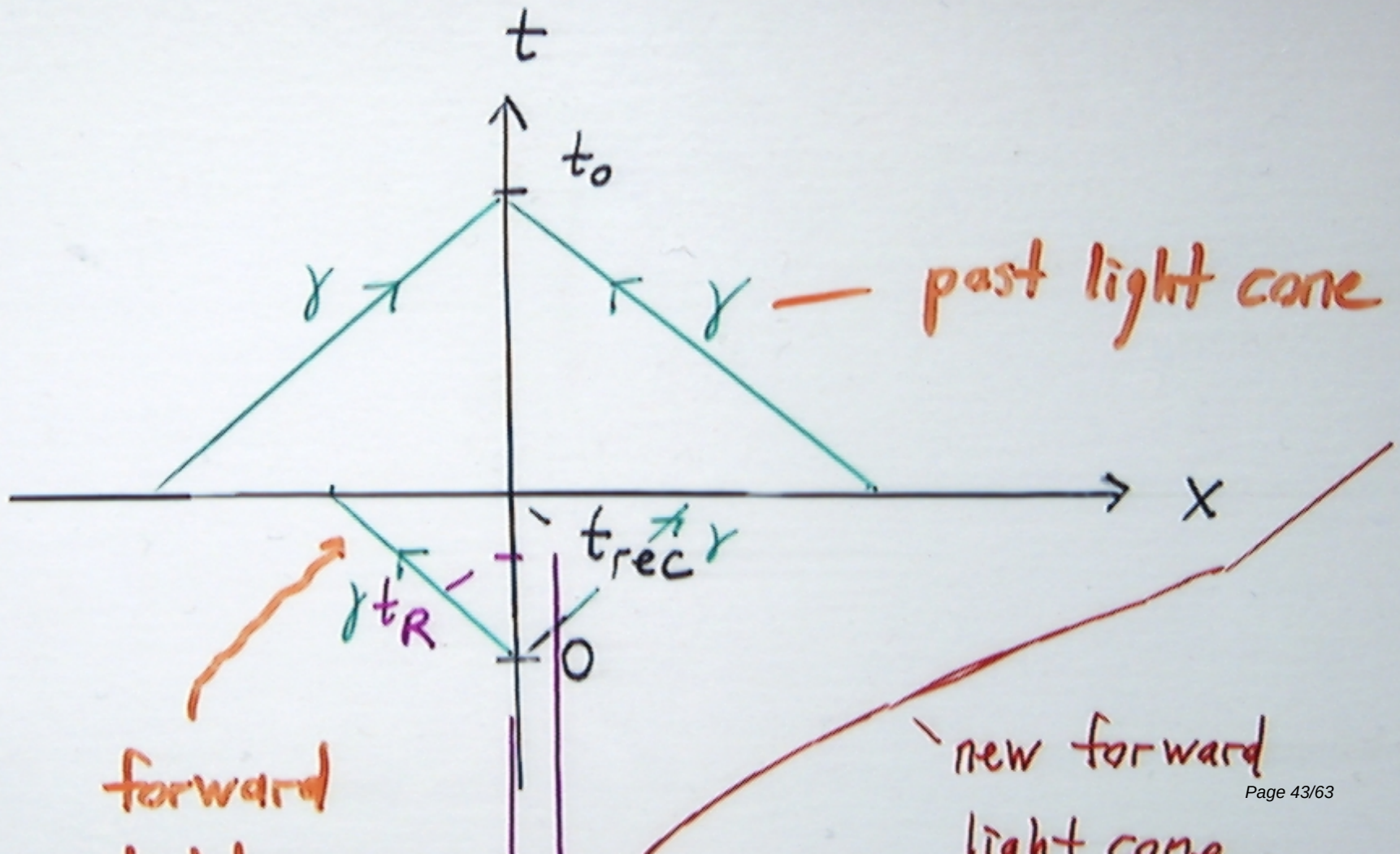


period of exponential expansion of space
(inflationary)

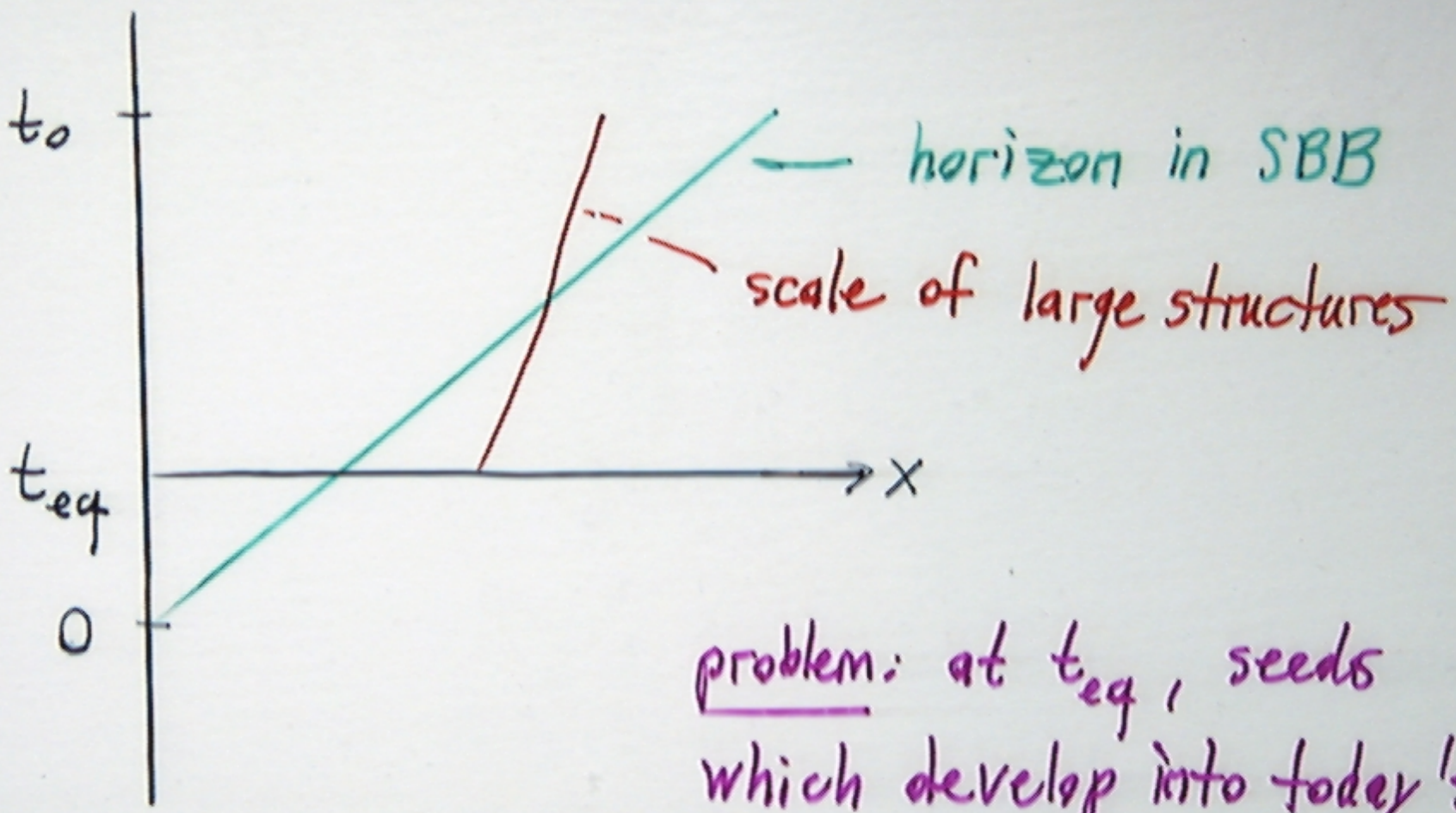
SBB theory does <u>not</u> explain isotropy of CMB



SBB theory does <u>not</u> explain isotropy of CMB

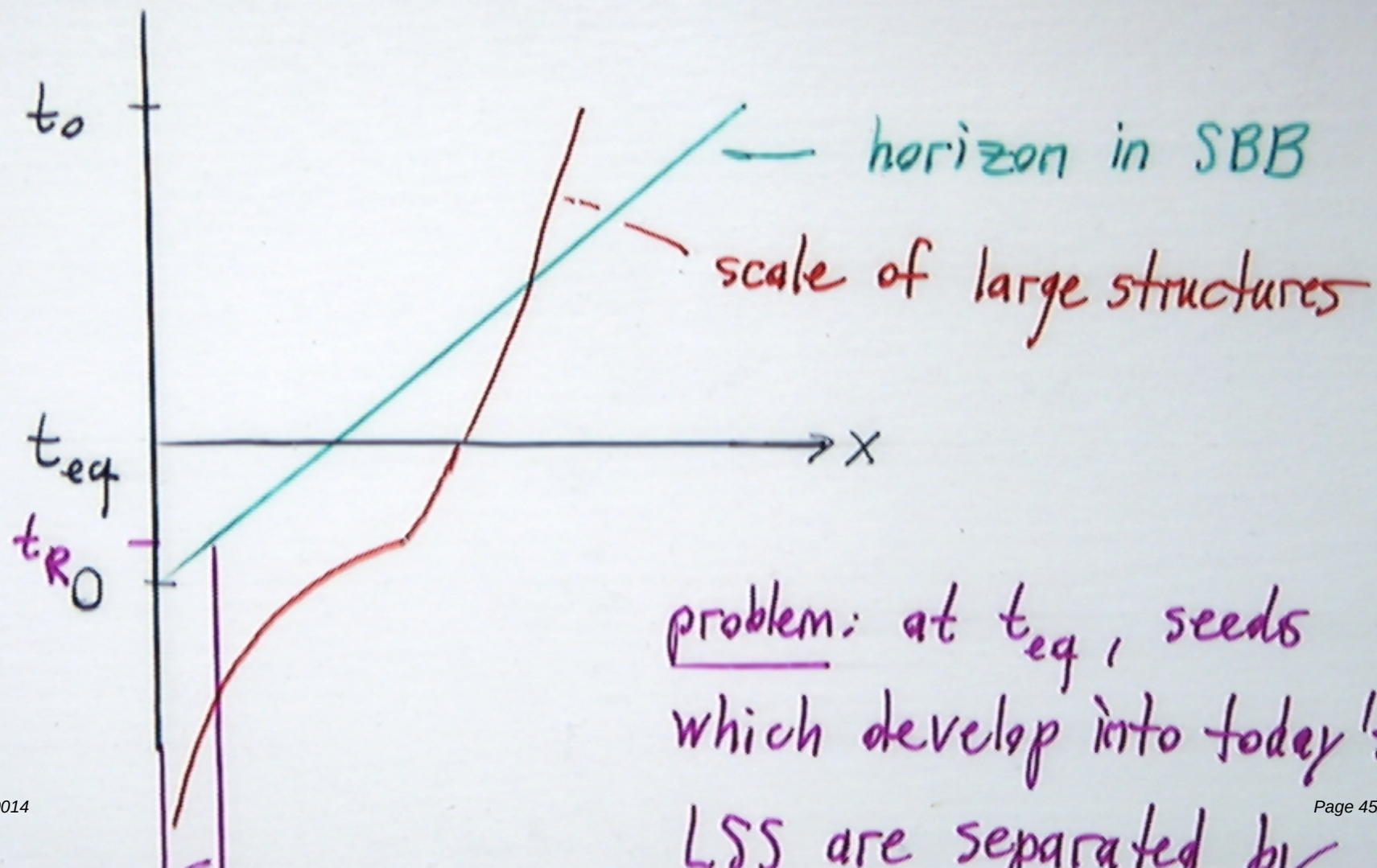


causal mechanism to explain the origin of fluctuations.

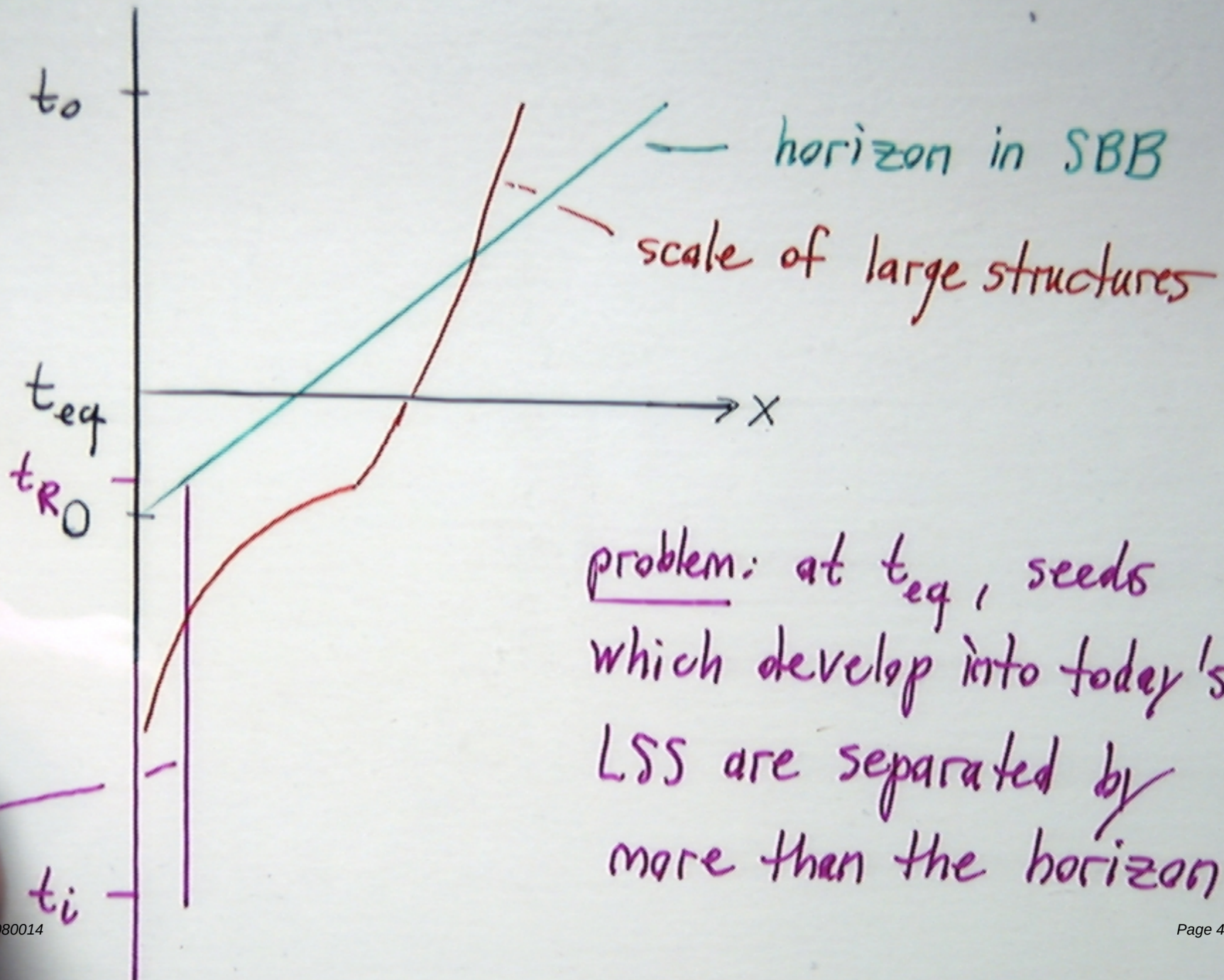


problem: at t_{eq}, seeds which develop into today's LSS are separated by

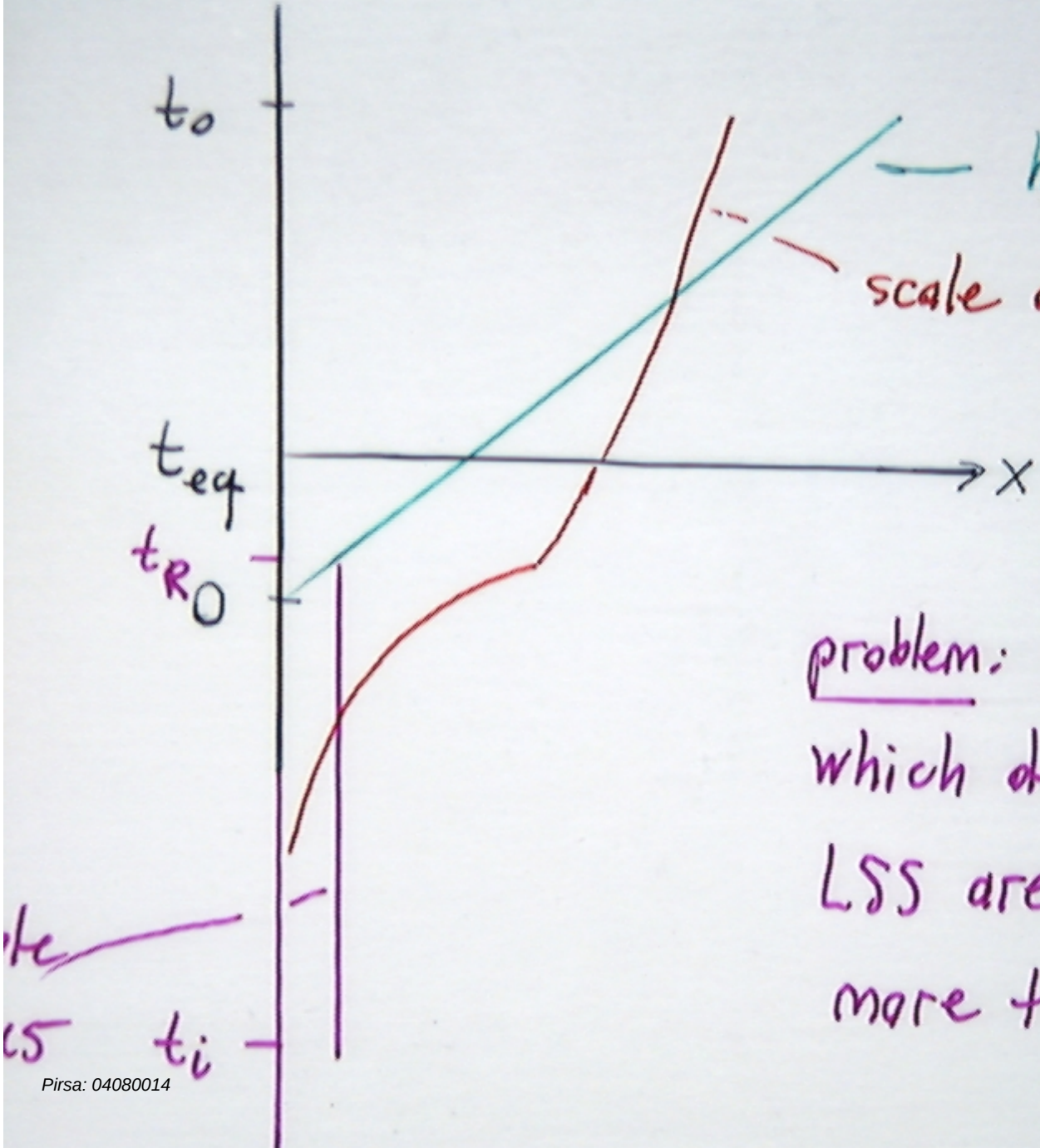
causal mechanism to explain the origin of fluctuations.



problem: at t_{eq}, seeds which develop into today's LSS are separated by

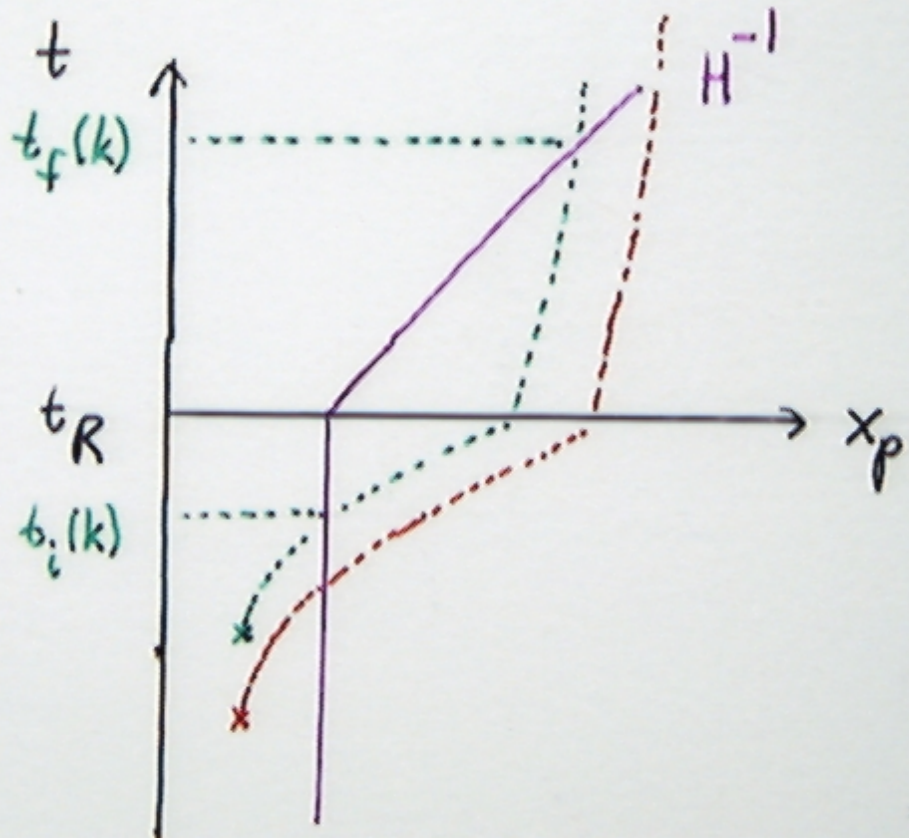


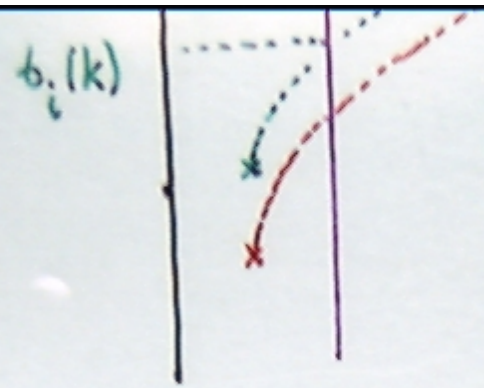
problem: at t_{eq}, seeds which develop into today's LSS are separated by more than the horizon



problem: at t_{eq}, seeds which develop into today's LSS are separated by more than the horizon

First Prediction from Inflation :



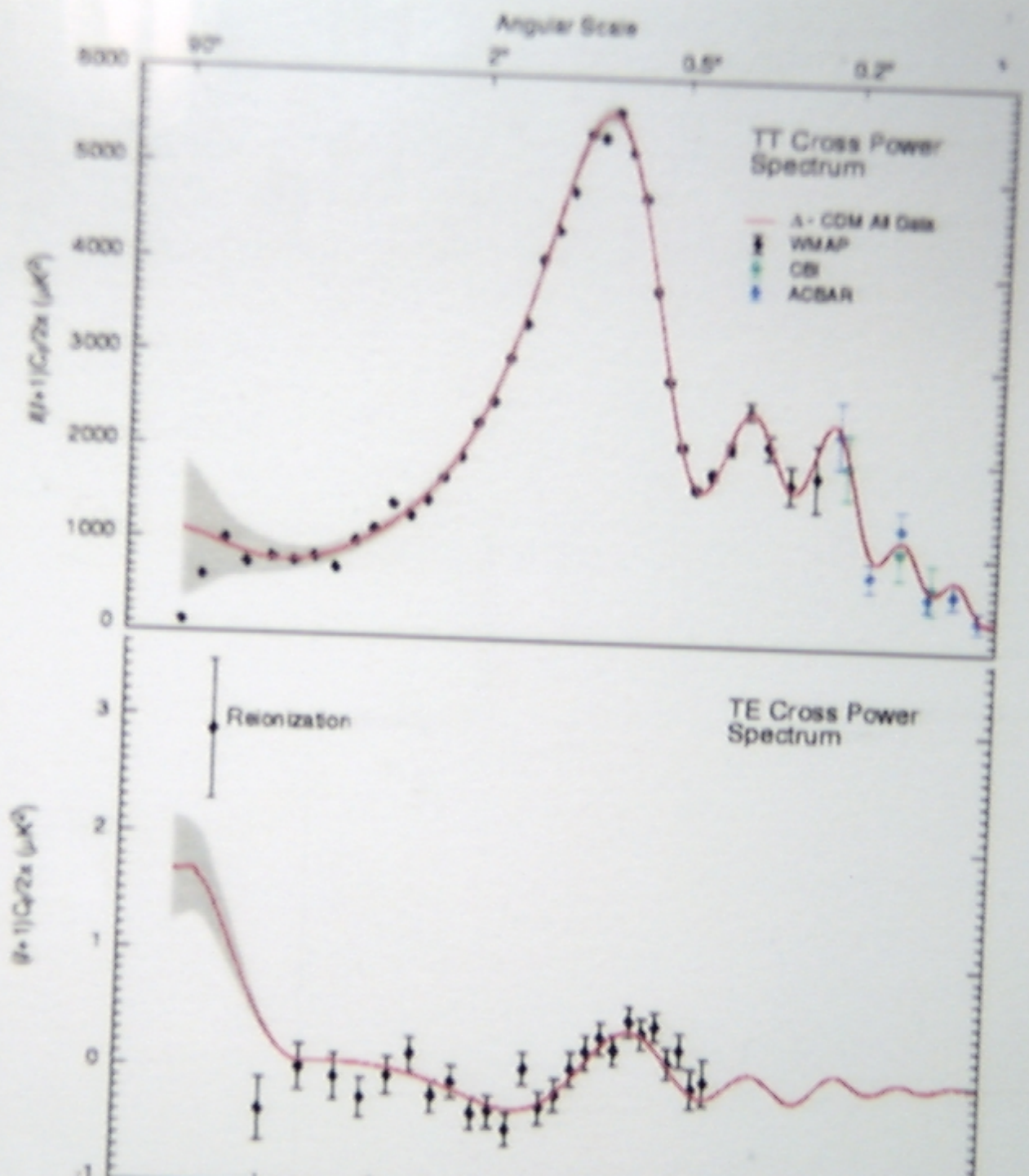


$$\frac{\delta M}{M}(k, t_i(k)) = \text{const}$$

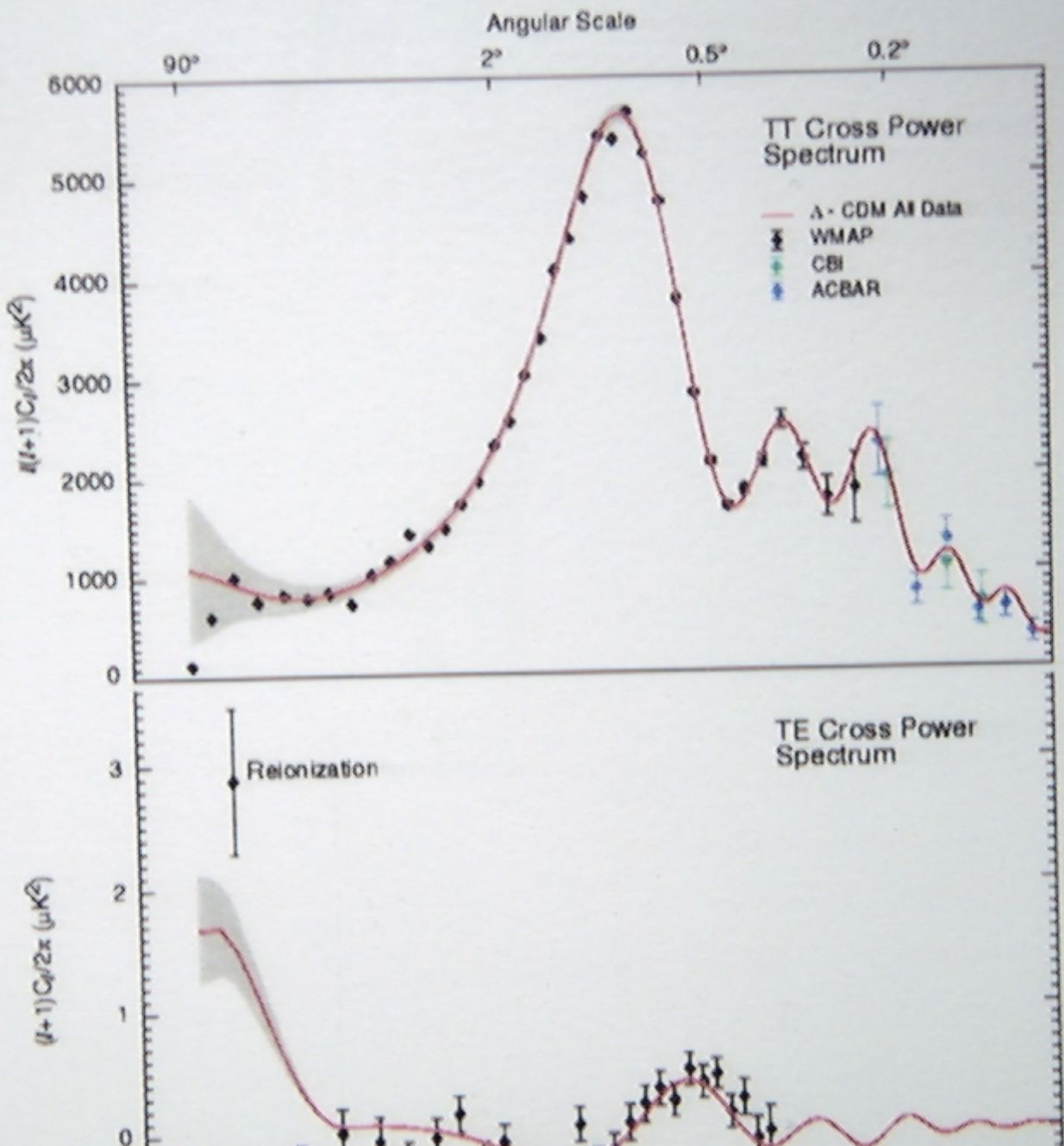
$$\Rightarrow \frac{\delta M}{M}(k, t_f(k)) = \text{const}'$$

scale invariant (Harrison–Zel'dovich) spectrum

$$\Leftrightarrow \underline{P(k) \sim k} \quad \text{(primordial spectrum)}$$


Angular Scale
90°
2°
0.5°
0.2°
TT Cross Power Spectrum
Λ - CDM All Data
WMAP
CBI
ACBAR
Reionization
TE Cross Power Spectrum

(2003)


Angular Scale
90°
2°
0.5°
0.2°
TT Cross Power Spectrum
Λ - CDM All Data
WMAP
CBI
ACBAR
l(l+1)C_l/2π (μK²)
6000
5000
4000
3000
2000
1000
0
TE Cross Power Spectrum
Reionization
(l+1)C_l/2π (μK²)
3
2
1
0

How to obtain inflation?

In the context of our current understanding of space-time physics:

exponential expansion of space

$\Downarrow$

constant energy density

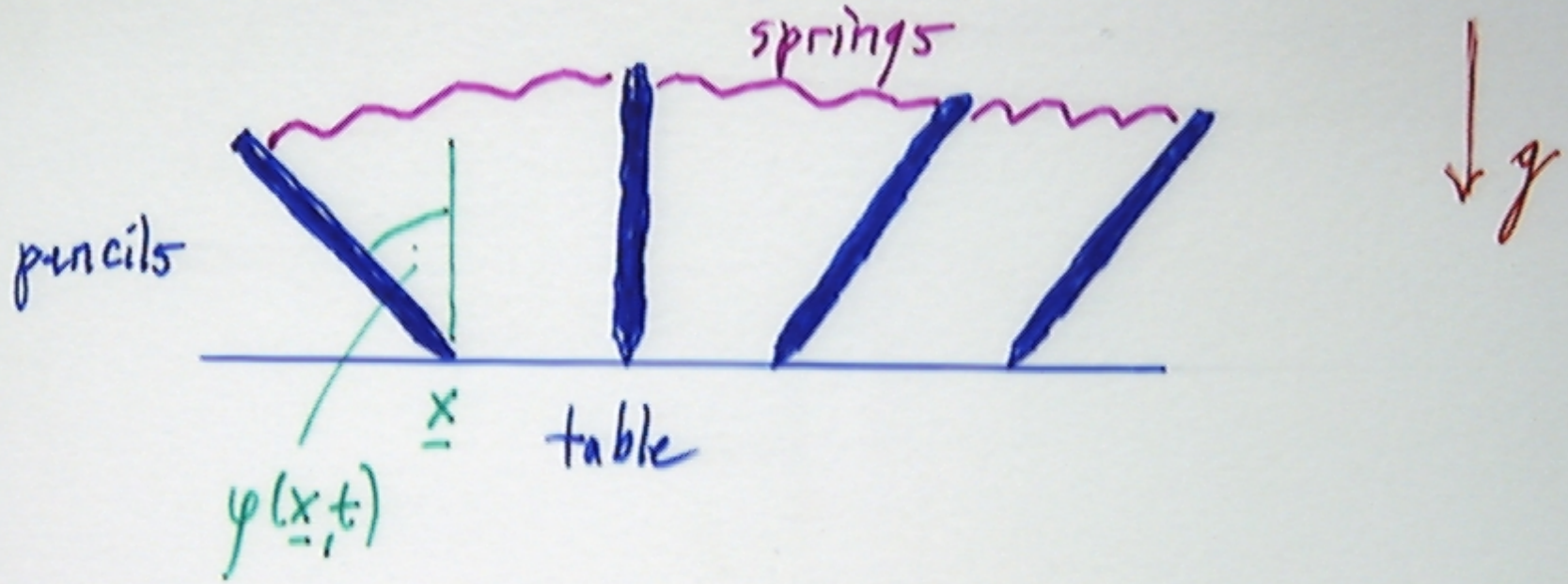
$\Downarrow$

negative energy density

$\Downarrow$

new matter physics

"Pencil Model"



energy density ρ and pressure p :

$$\rho = \frac{1}{2}\dot{\varphi}^2 + \frac{1}{2}(\nabla\varphi)^2 + V(\varphi)$$

1. Singularity Problem

Before the onset of inflation:

Universe evolves as in SBB

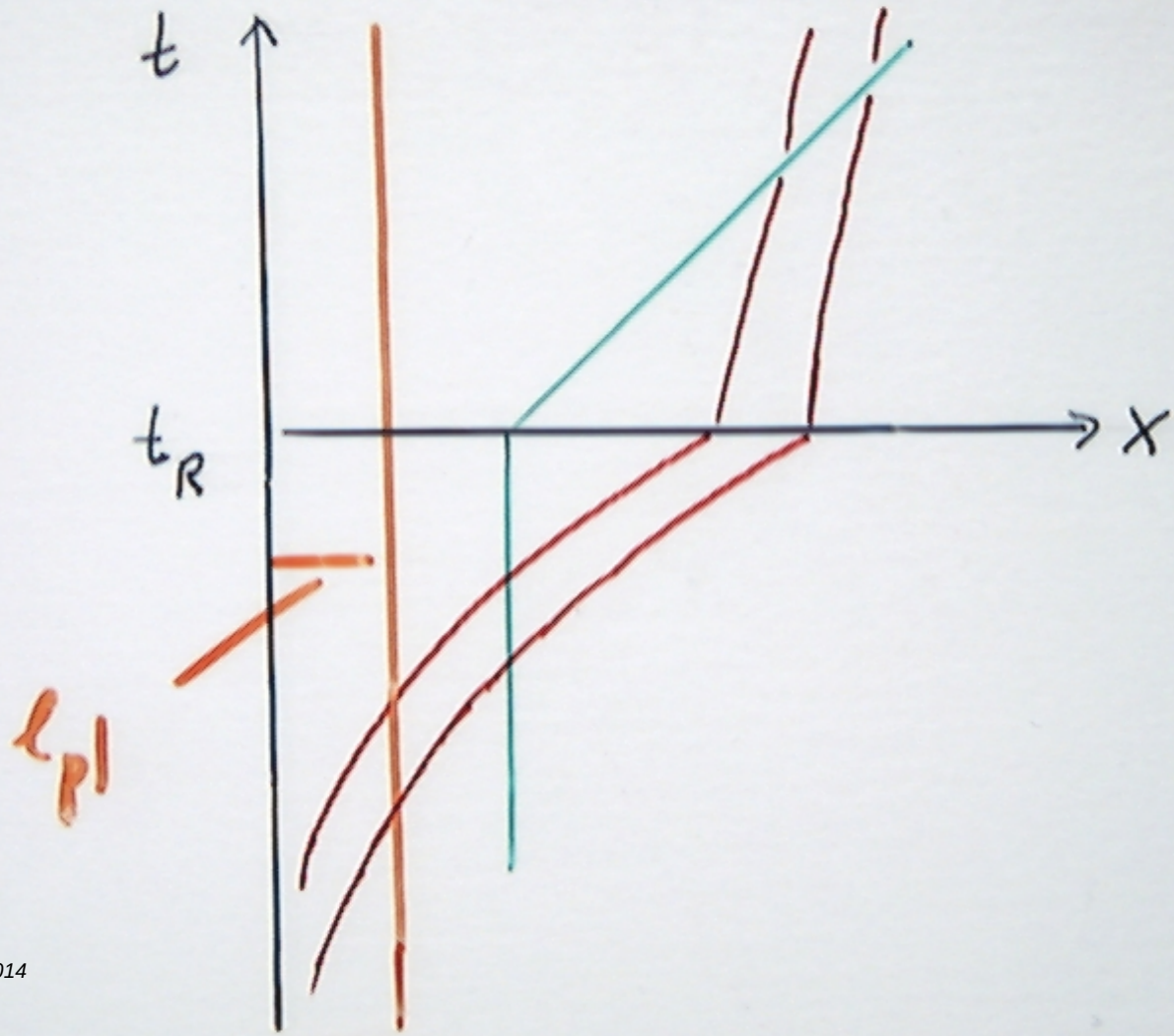
↓

Big Bang Singularity

↓

Same inconsistency problems as in SBB

Cosmology: Mechanism of structure formation



Hubble radius

fluctuation wavelength

3. Cosmological Constant Problem

In current inflationary models, inflationary expansion is generated by an effective cosmological constant

Vacuum energy → cosmological constant

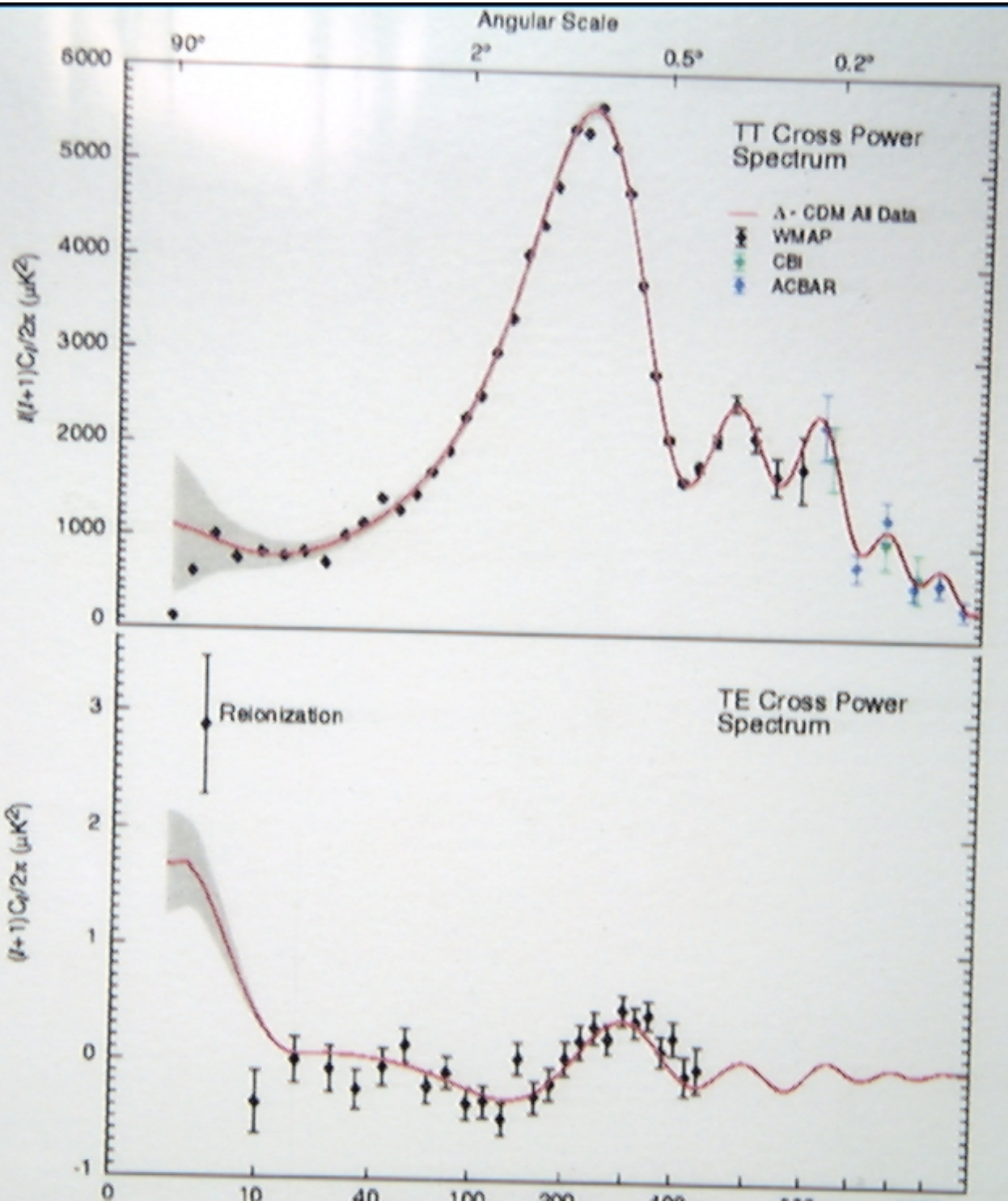
larger than the observed CC by 10^{120} !?!

In current inflationary models, inflationary expansion is generated by an effective cosmological constant.

Vacuum energy → cosmological constant

larger than the observed CC by 10^{120} !?!

key unsolved problem in fundamental


Angular Scale
90°
2°
0.5°
0.2°
6000
5000
4000
3000
2000
1000
0
l(l+1)C_l/2π (μK²)
TT Cross Power Spectrum
Λ - CDM All Data
WMAP
CBI
ACBAR
Reionization
TE Cross Power Spectrum
3
2
1
0
-1
(l+1)C_l/2π (μK²)
0
10
40
100
200

Questions for a New Cosmology:

Will it contain inflation or an alternative?

Would require a new mechanism of structure formation consistent with present observations

Mechanism of inflation?

Will it contain inflation or an alternative?

Would require a new mechanism of structure formation consistent with present observations

Mechanism of inflation?

Will it contain a Big Bang?

Cosmological constant resolution