Title: The Universe from Beginning to End

Date: Jun 03, 2009 07:00 PM

URL: http://pirsa.org/09060059

Abstract: Astronomers believe our Universe began in a Big Bang, and is expanding around us. Brian Schmidt will describe the life of the Universe that we live in, and how astronomers have used observations to trace our Universe's history back more than 13 Billion years. With this data a puzzling picture has been pieced together where 96% of the Cosmos is made up of two mysterious substances, Dark Matter and Dark Energy. These two mysterious forms of matter are in a battle for domination of the Universe, and Schmidt will describe experiments that are monitoring the struggle between Dark Energy and Dark Matter, trying better understand these elusive pieces of our Universe, and predict the ultimate fate of the Cosmos.

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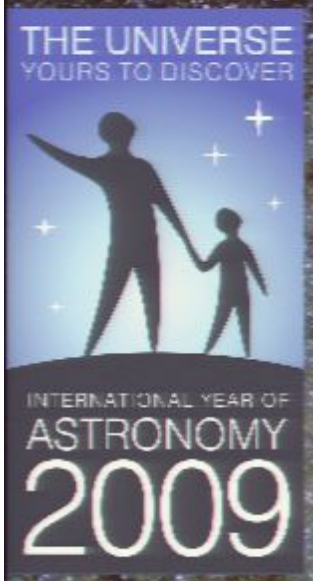
Brian Schmidt

Australian National University

INTERNATIONAL YEAR OF ASTRONOMY 2009

The Universe from Beginning to End



Brian P. Schmidt

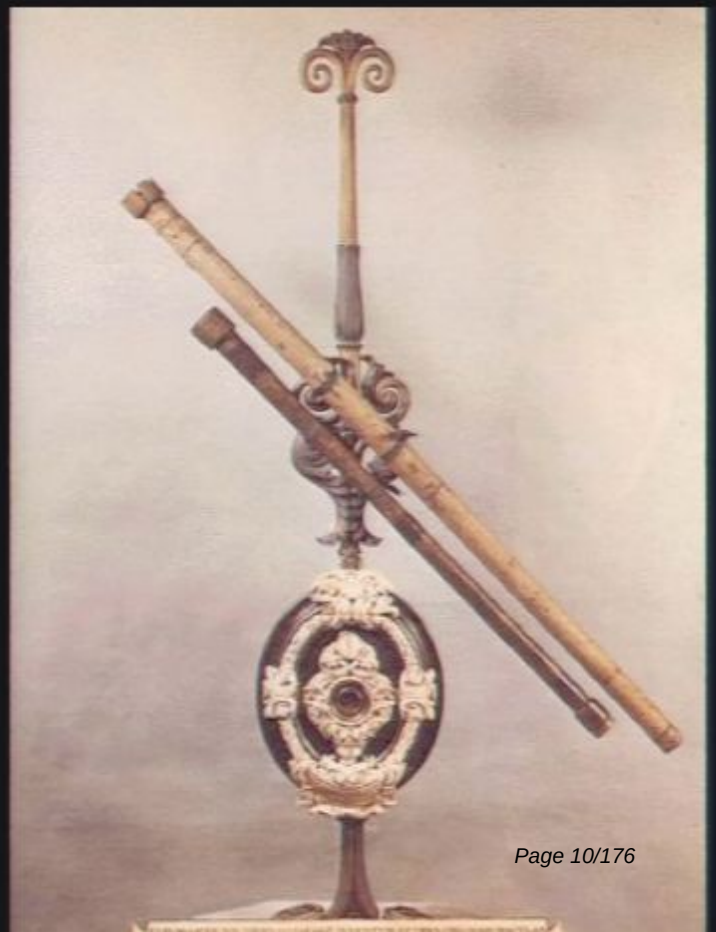
PERIMETER INSTITUTE
FOR THEORETICAL PHYSICS

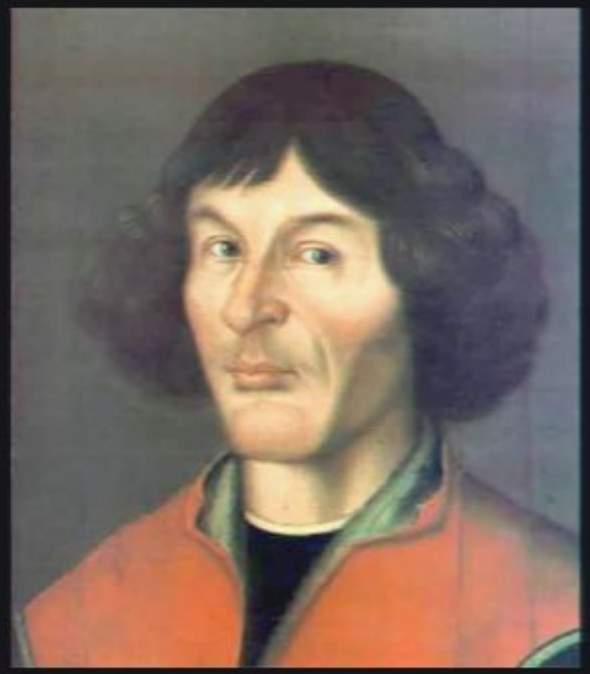
THE AUSTRALIAN NATIONAL UNIVERSITY

The Research School of Astronomy & Astrophysics
Mount Stromlo and Siding Spring Observatories

2009 is the International Year of Astronomy

We Celebrate 400th anniversary of Galileo first using a Telescope to peer at the Heavens



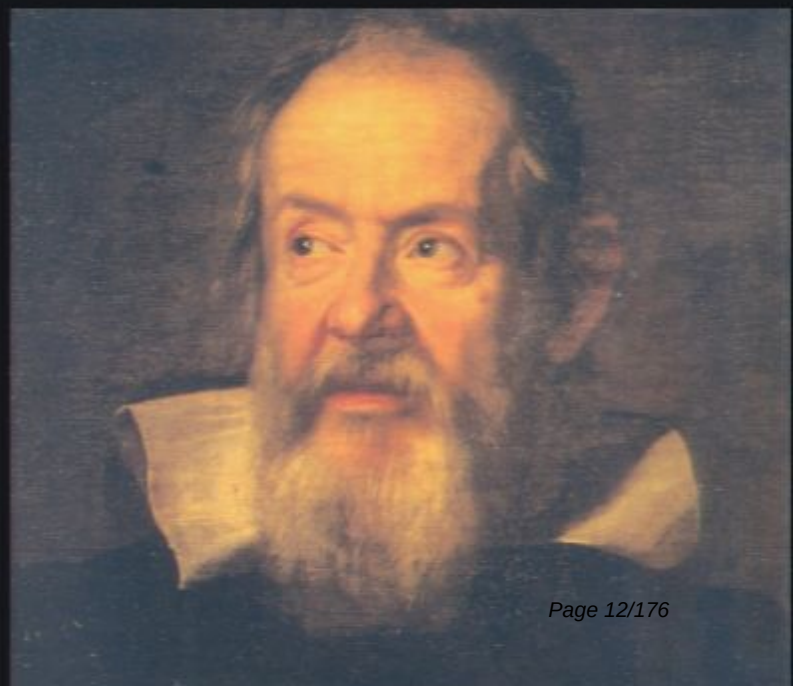


Copernicus' view of the Solar System was theoretical..

"The Sun is at the Center"

But to Galileo, a planet became this...

No longer could everything go around the Earth



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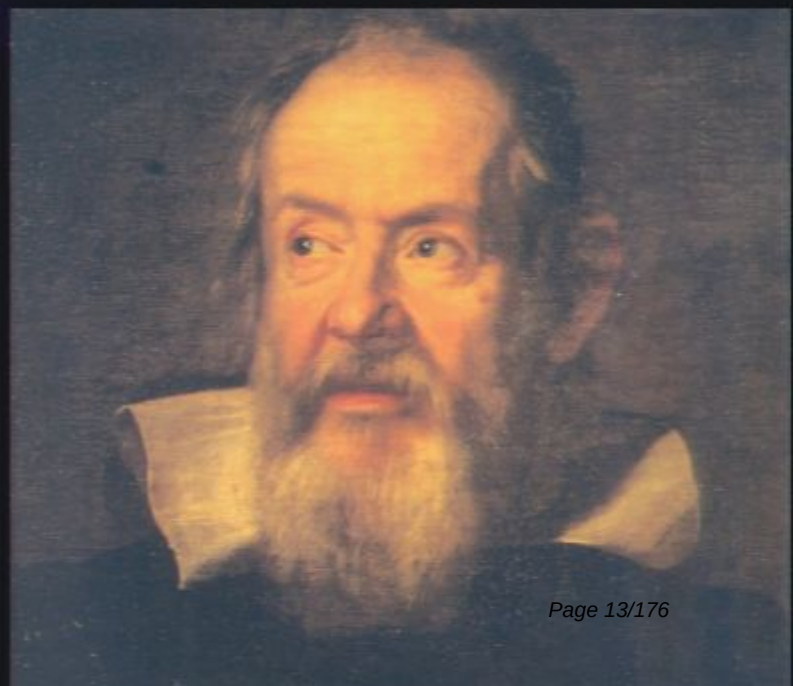
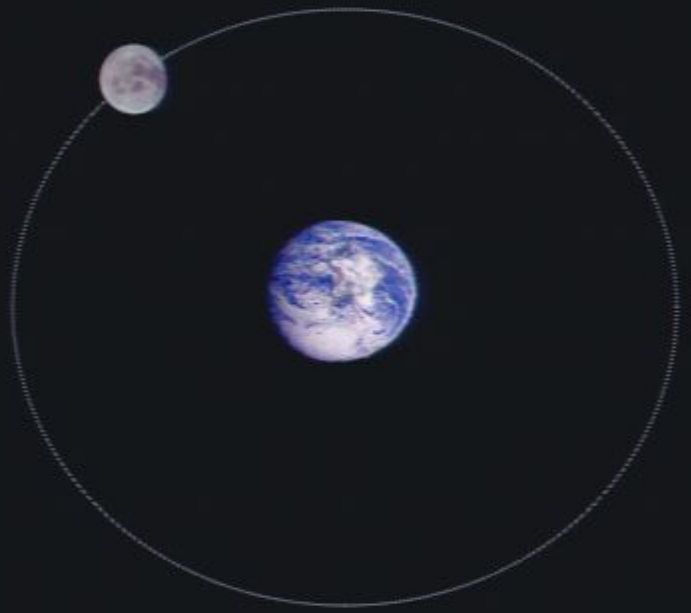


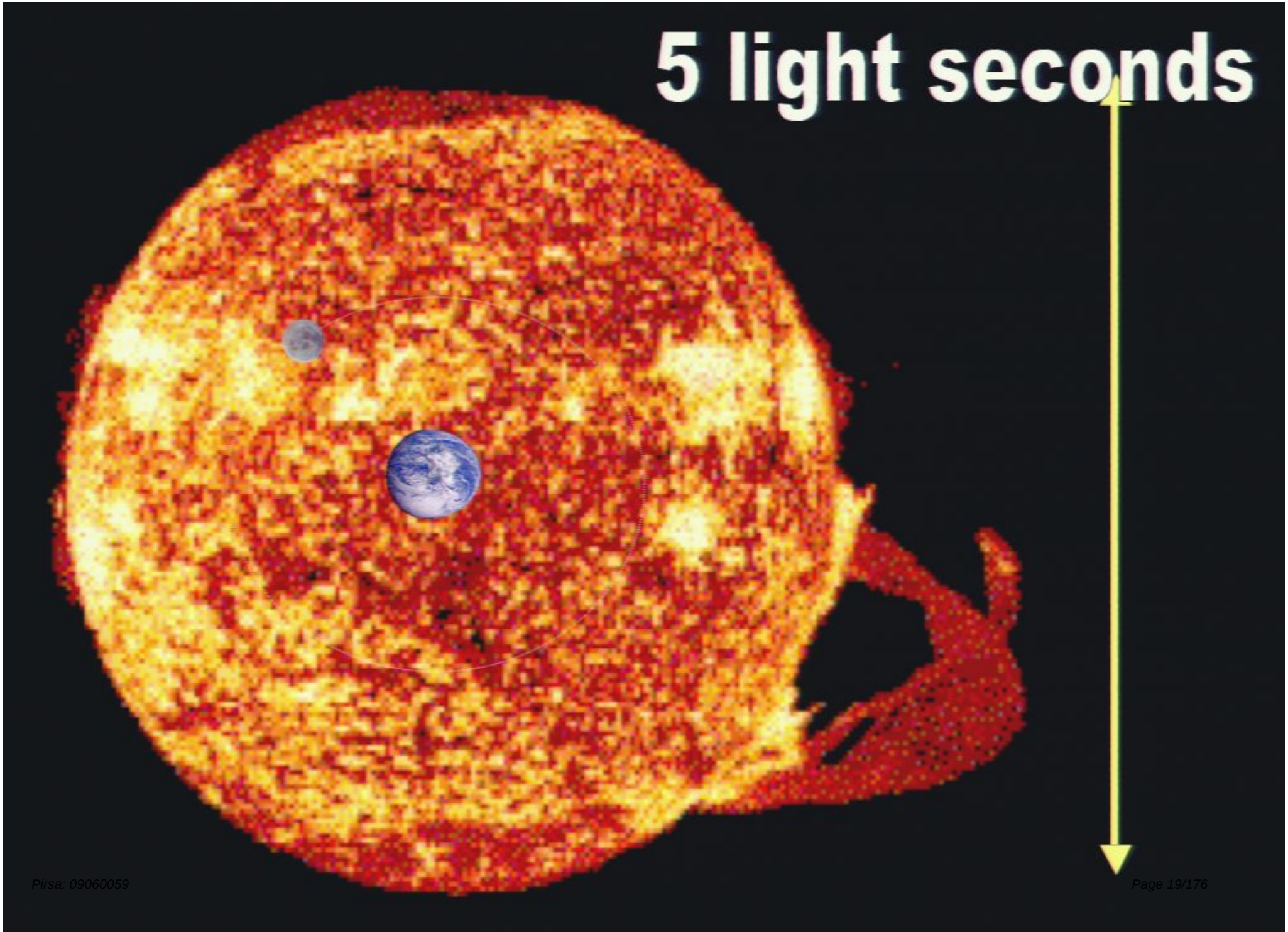
A Quick Tour of the Universe

Our Ruler: The Speed of Light

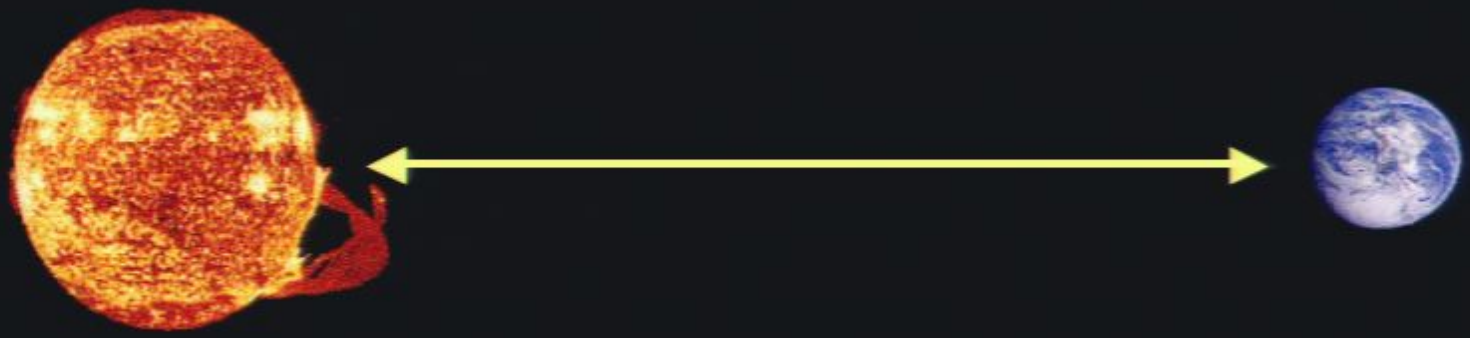
Light travels 300,000 km per sec that is 7.5 times around the Earth each second.

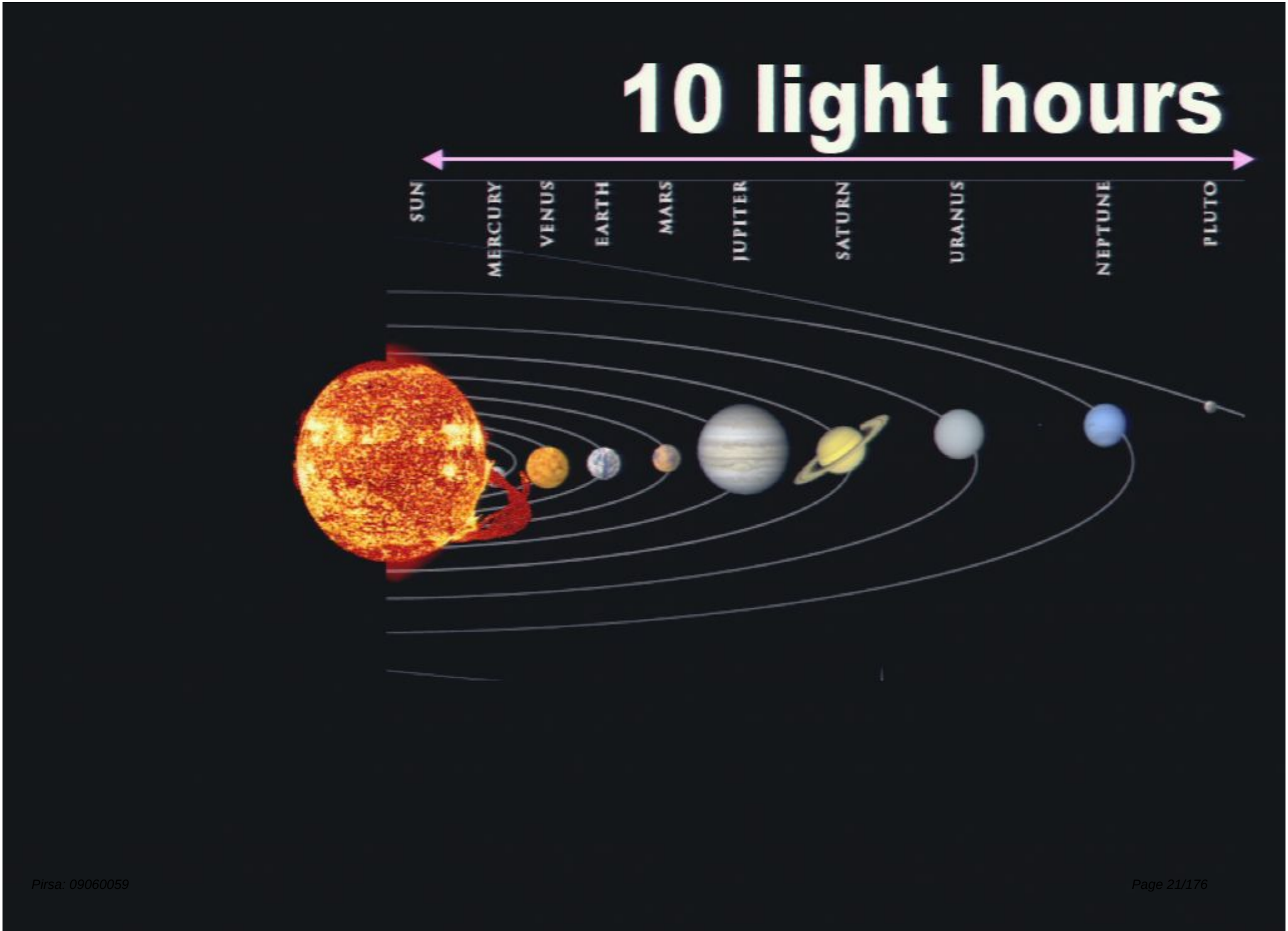


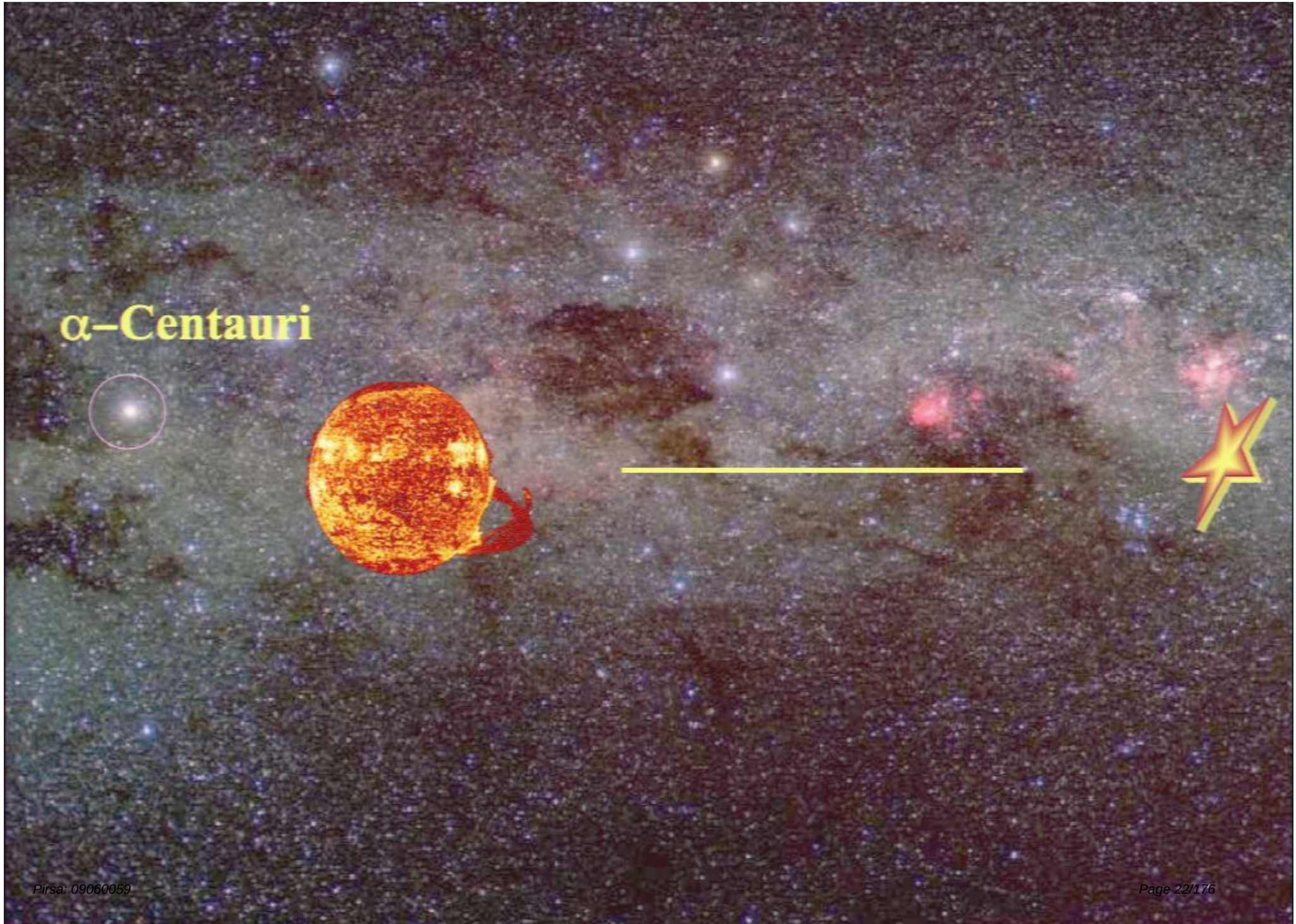
1.5 light seconds

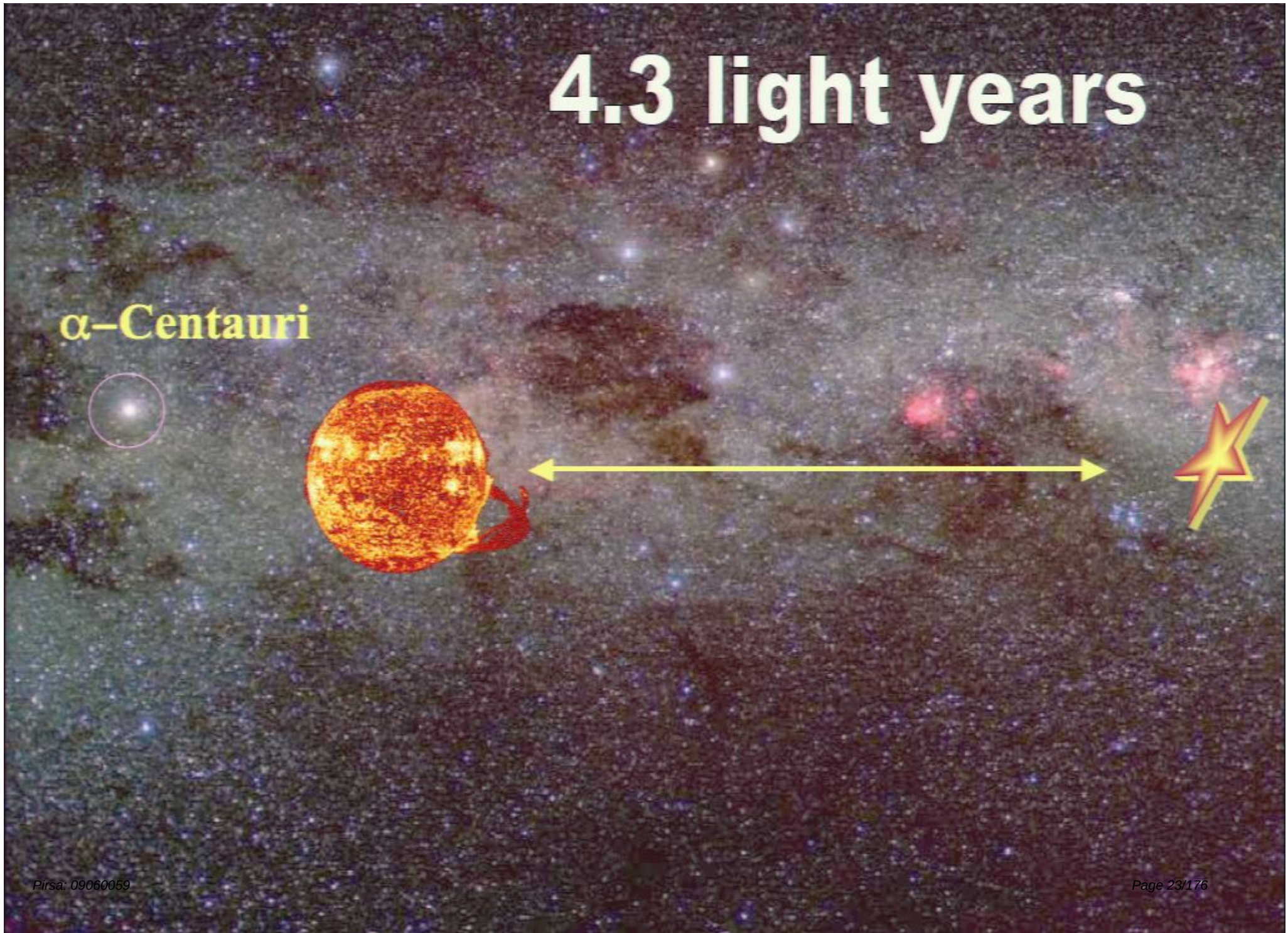

5 light seconds

8 light minutes




10 light hours
SUN
MERCURY
VENUS
EARTH
MARS
JUPITER
SATURN
URANUS
NEPTUNE
PLUTO

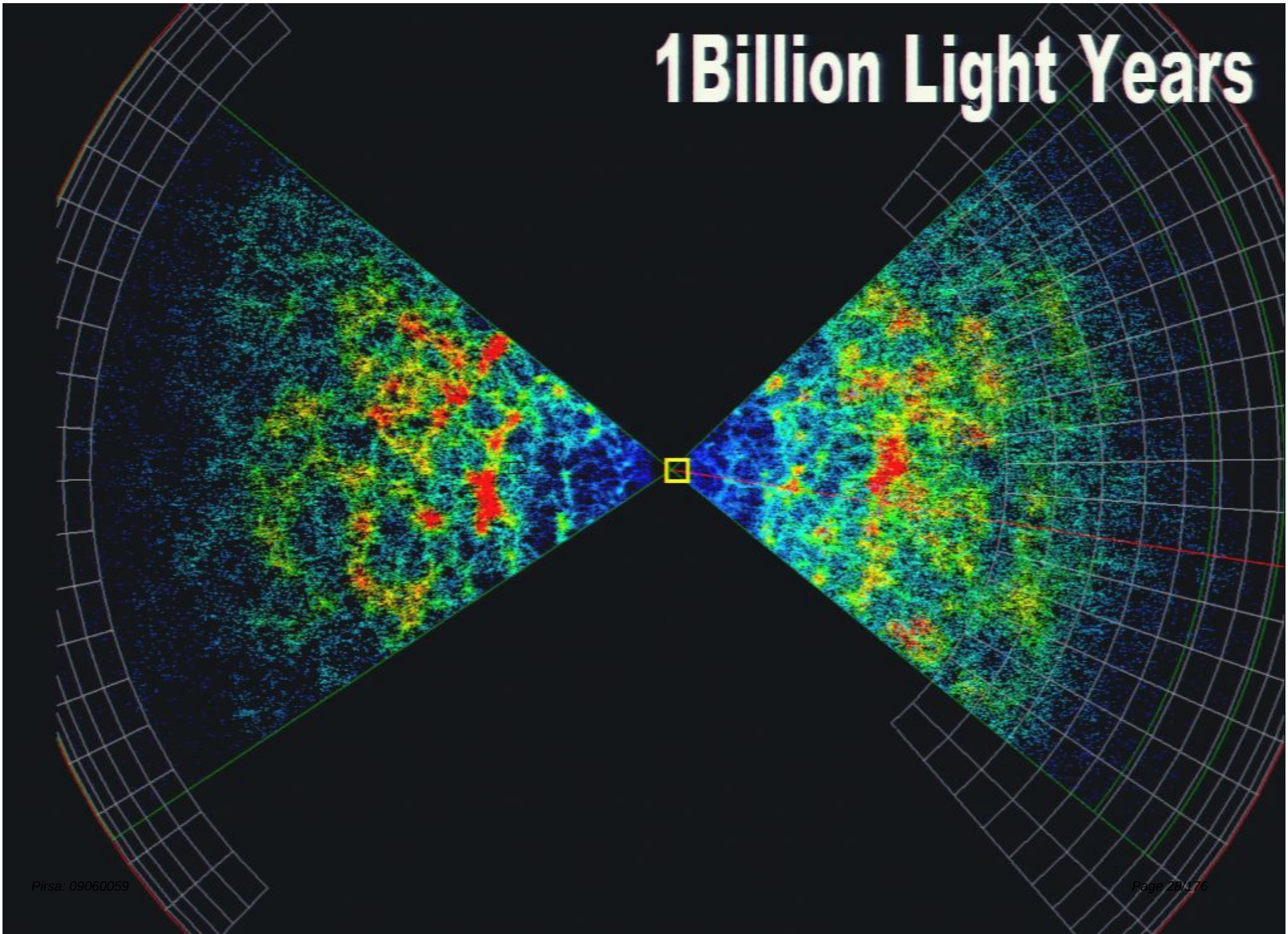

α–Centauri

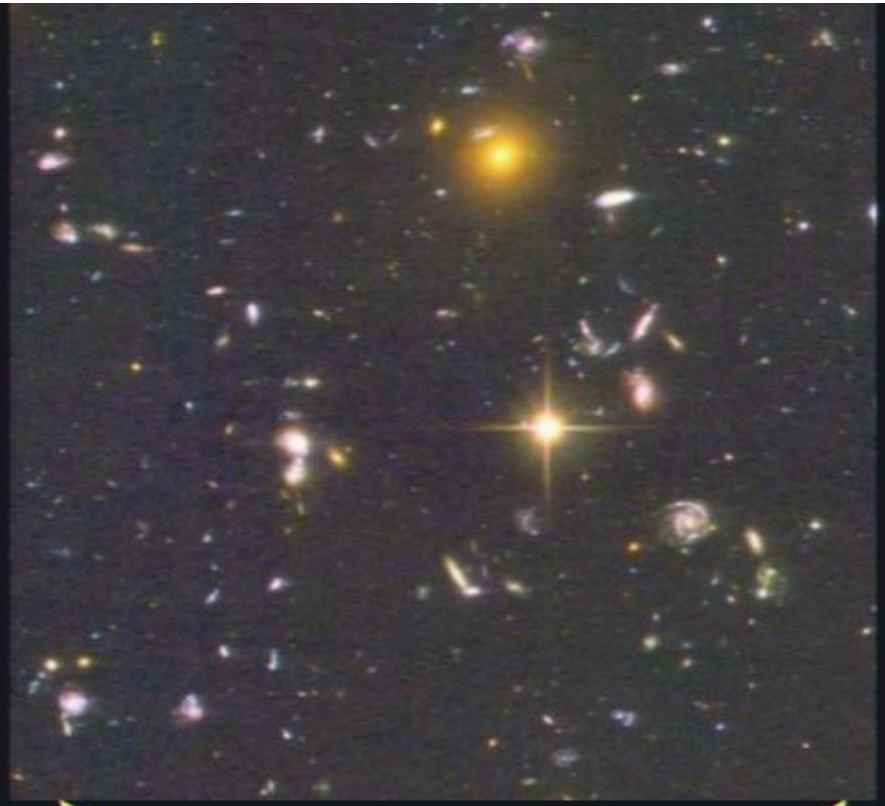

4.3 light years
α–Centauri


30,000 light years

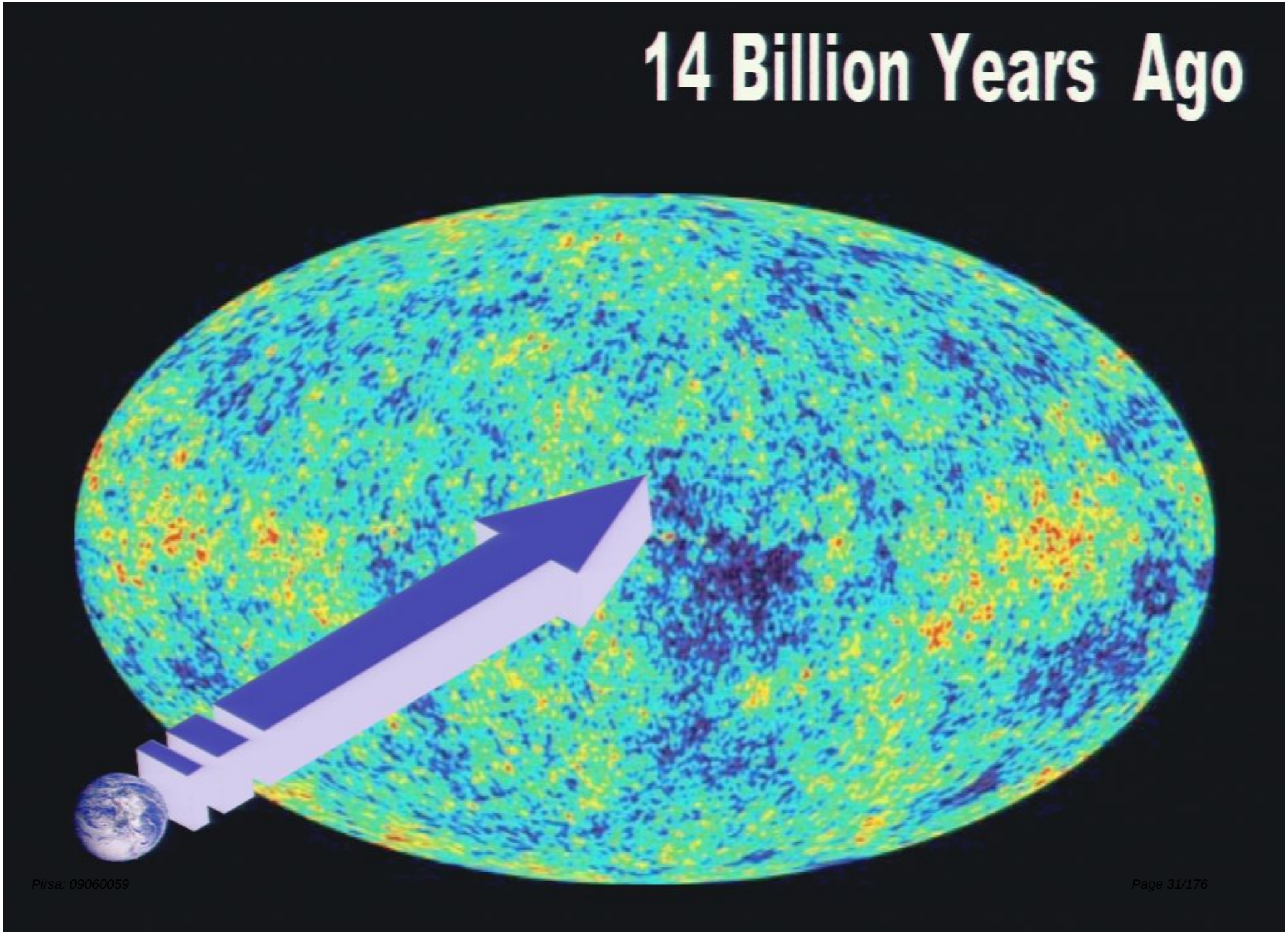
Top View


2 Million Light Years
Andromeda
Triangulum
Milky Way


1Billion Light Years



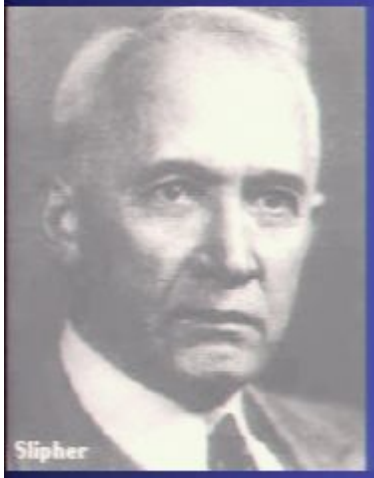

12 Billion Light Years

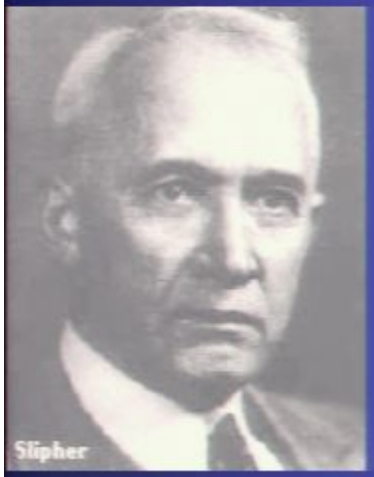

14 Billion Years Ago


Big


The
Big
Bang

The Beginnings of Cosmology


Slipher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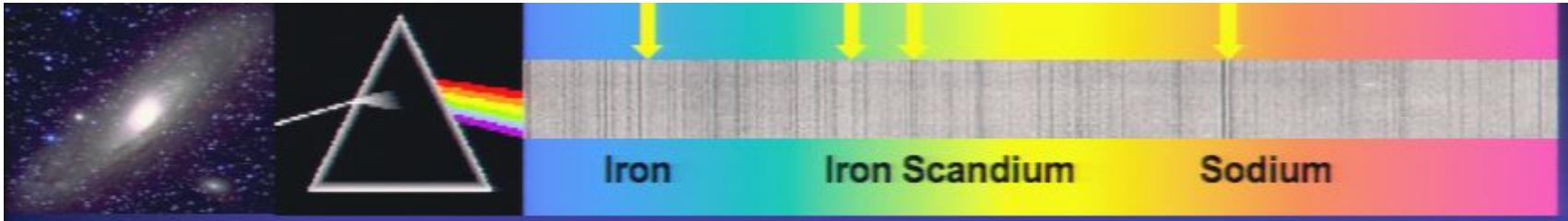
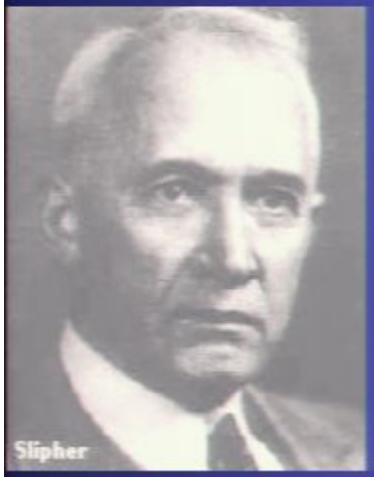
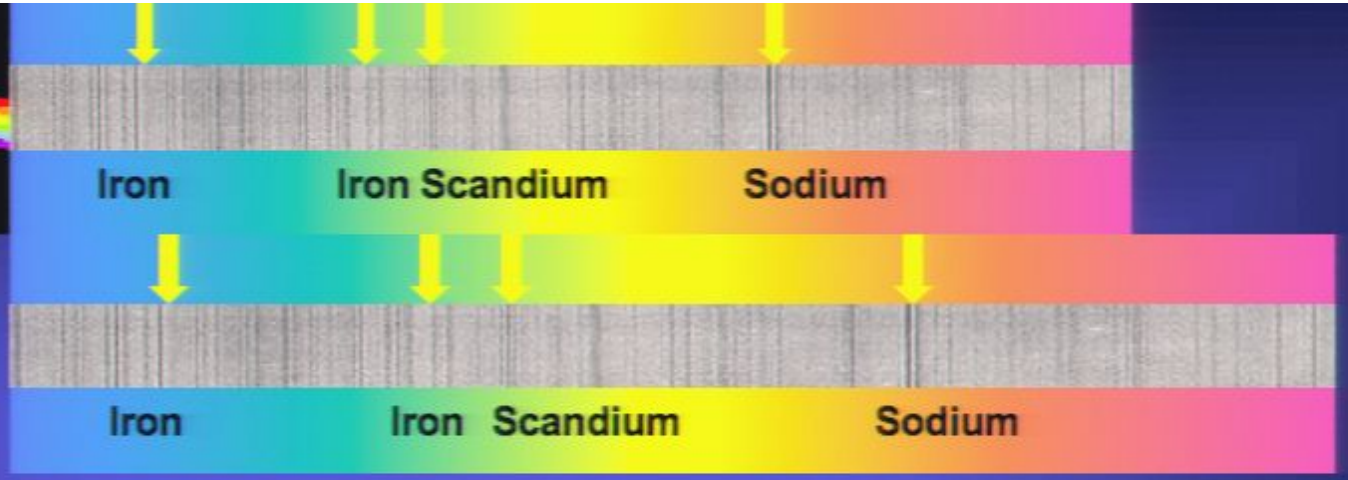
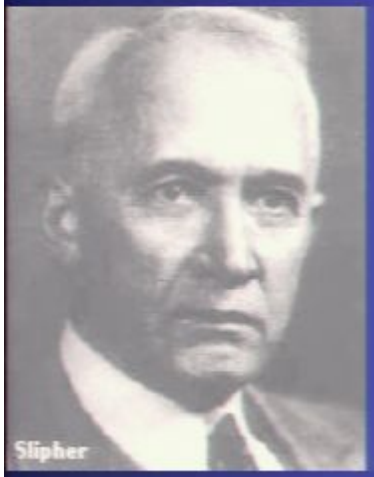
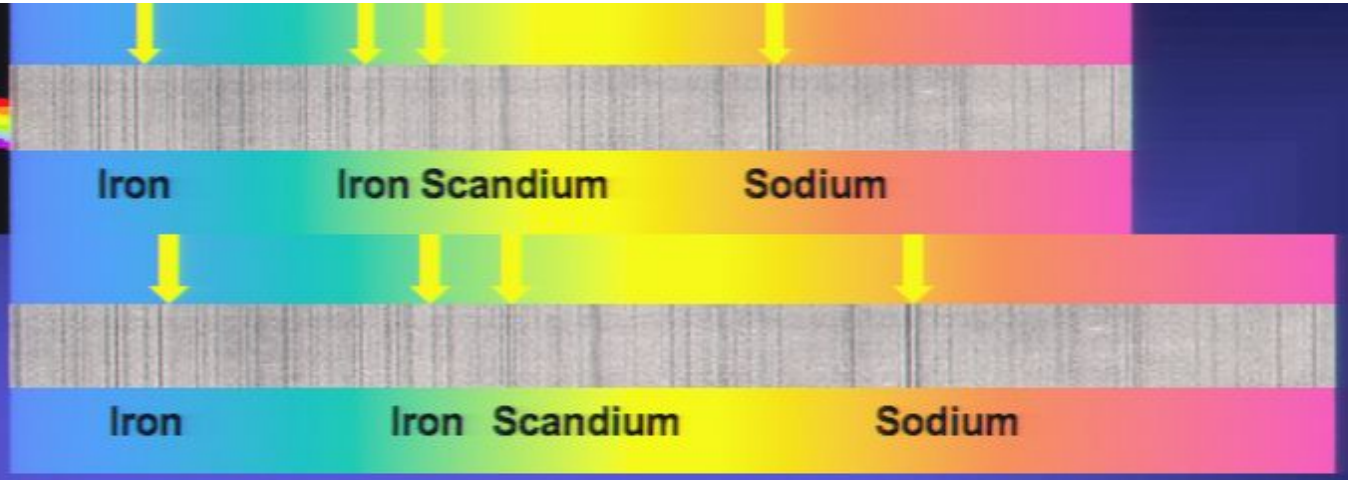

Iron
Iron Scandium
Sodium


Slipher



Doppler Shift Gives Velocity of Galaxy





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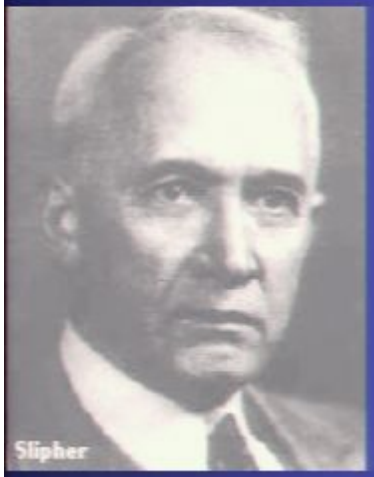

In 1916 Vesto Slipher measured velocities to nearby galaxies, and discovered they were all moving away from us.

Measuring Distances with Standard Light Bulbs

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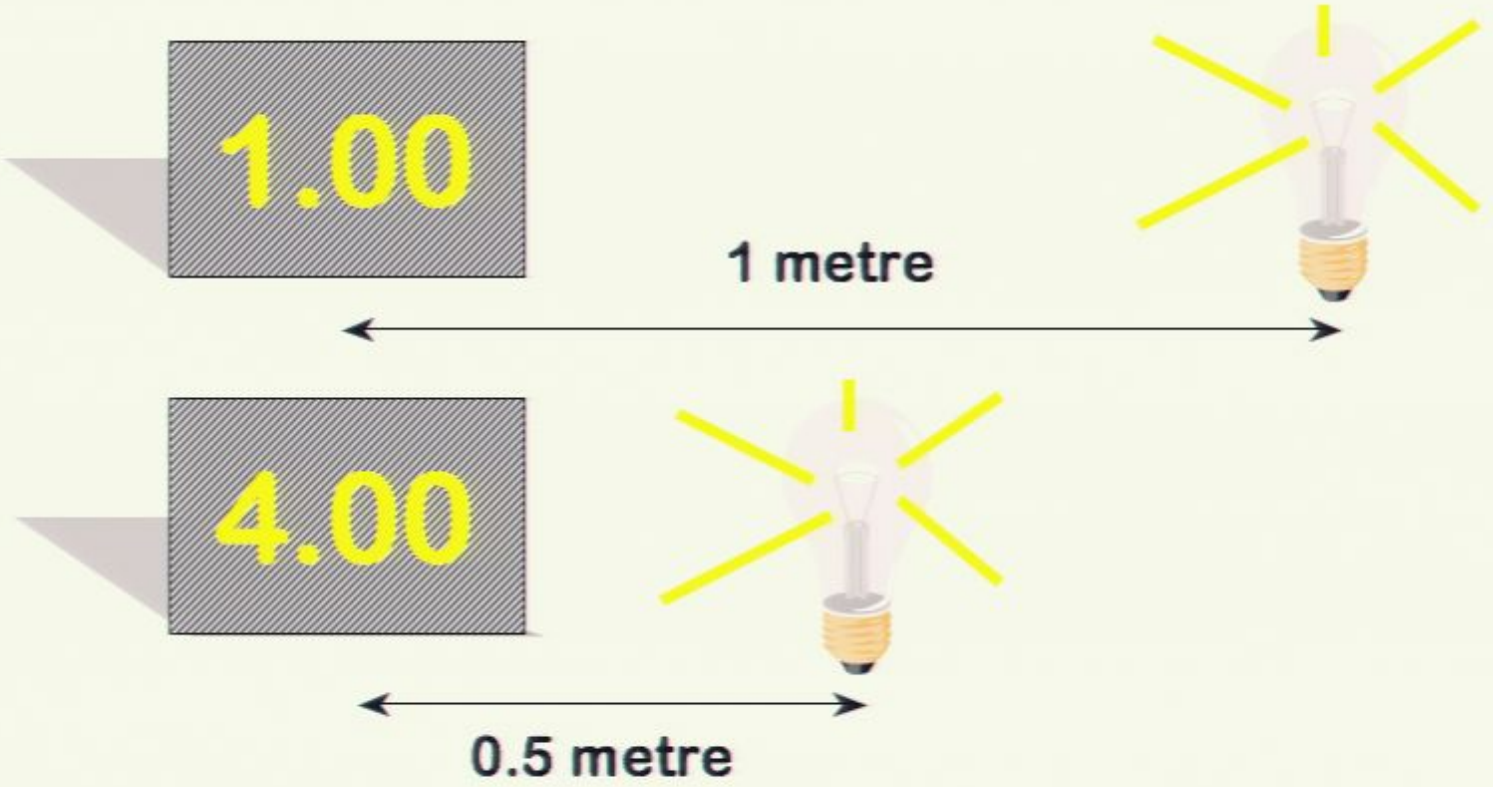
Measuring Distances with Standard Light Bulbs



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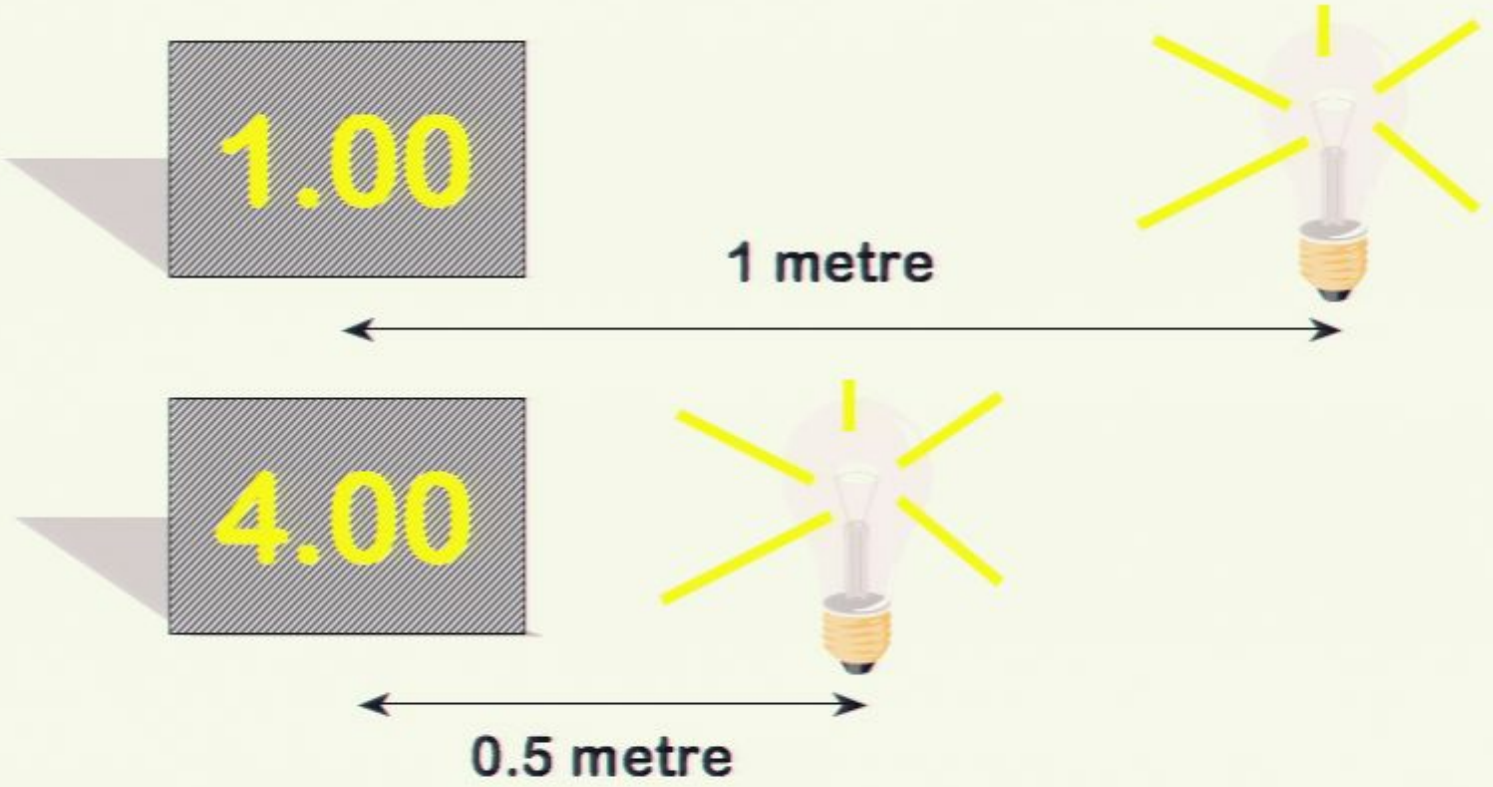


An Object becomes fainter by the square of its distance

1929, Hubble uses brightest stars to measure the distances to the nearest galaxies.

He assumes the brightest stars are all the same brightness.

The larger the redshift of the galaxy, the fainter the stars!

The Universe is Expanding

Hubble's Data

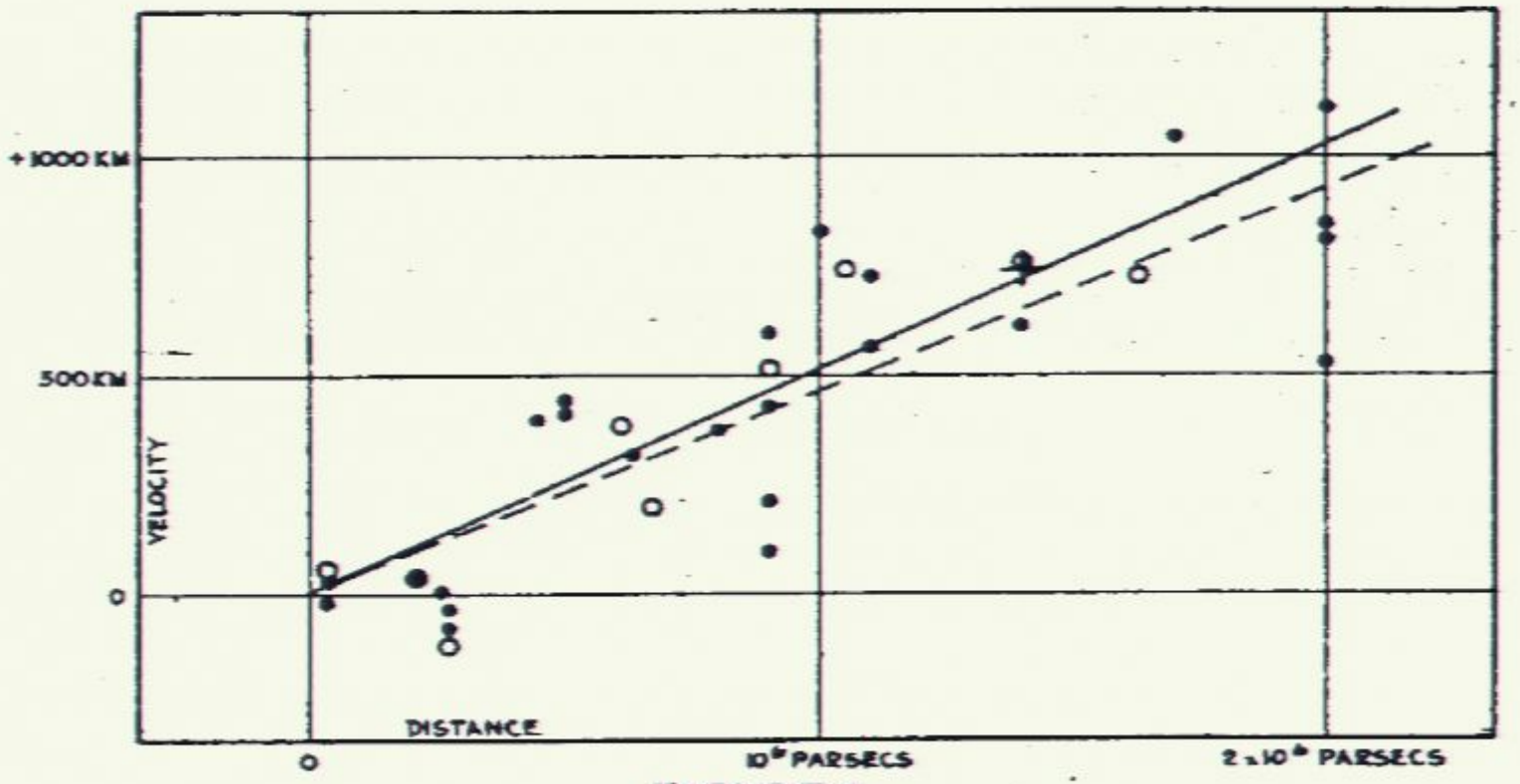
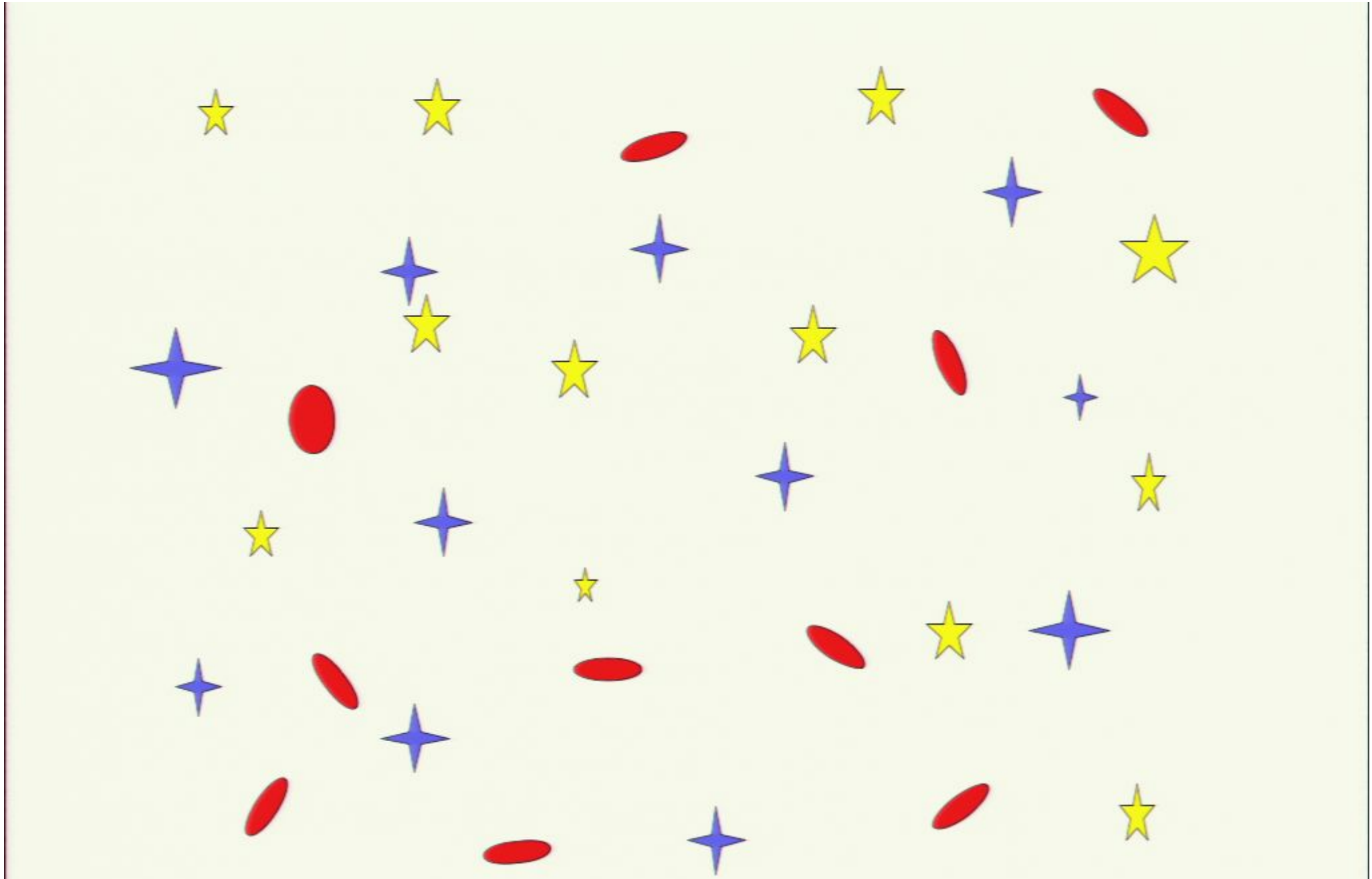
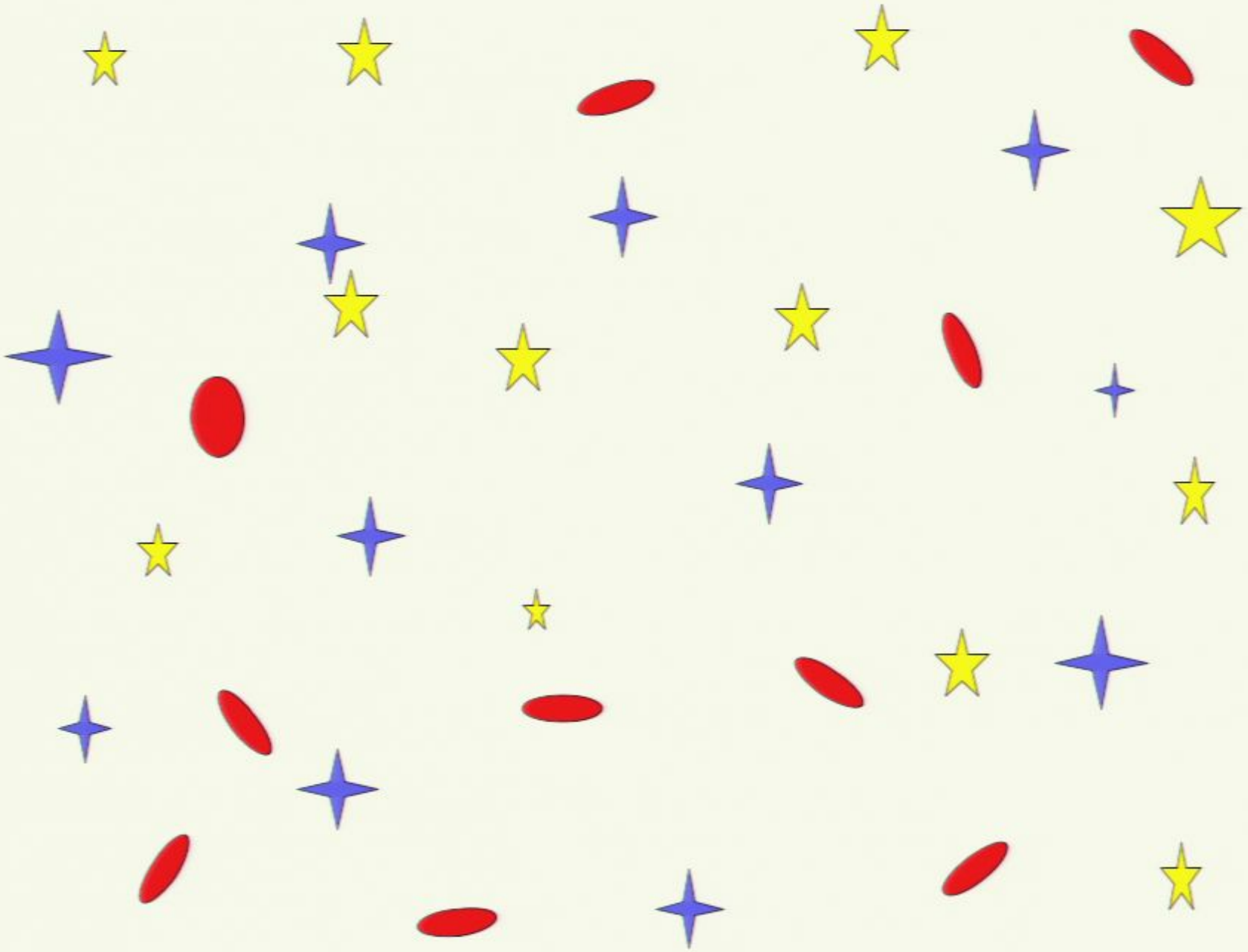
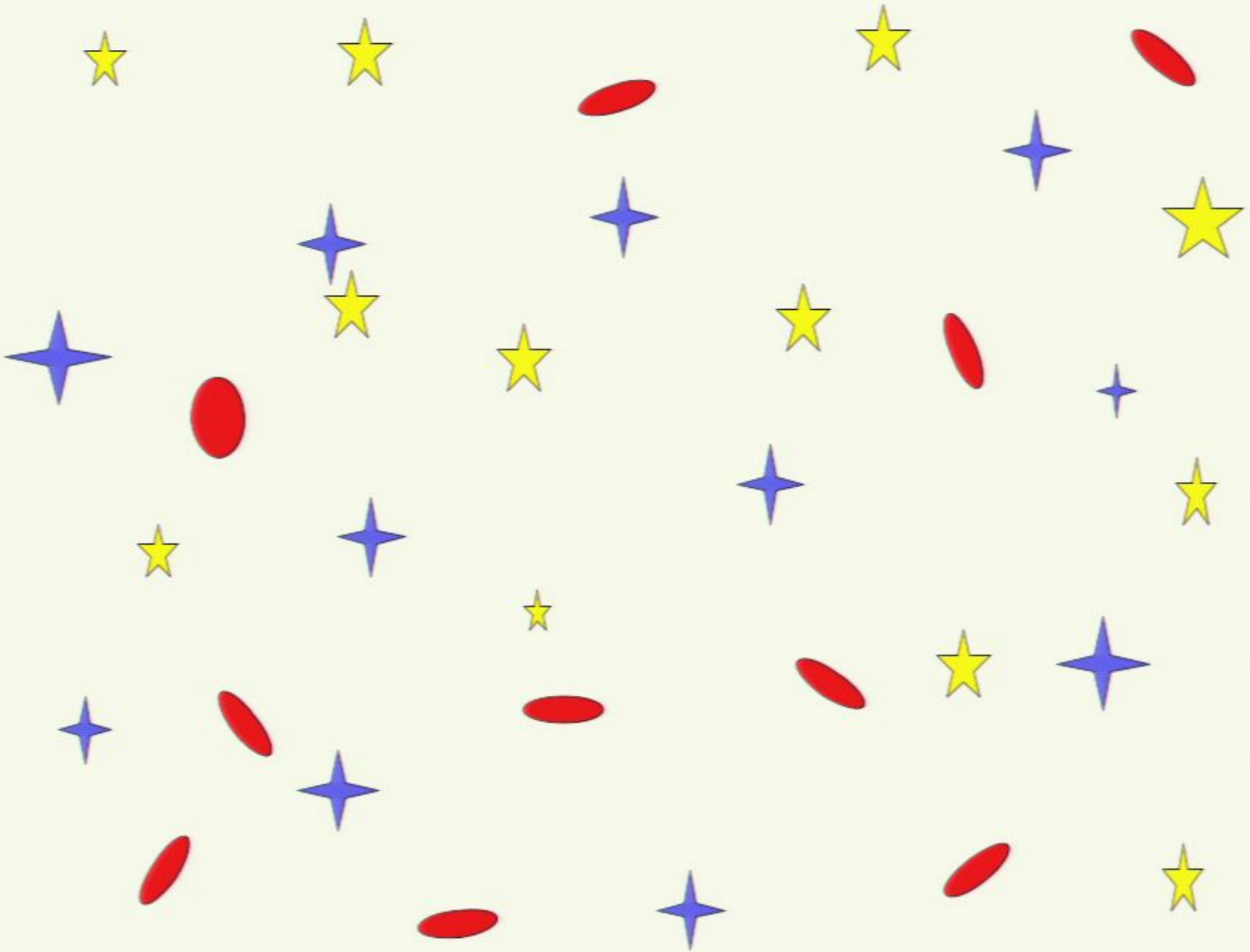


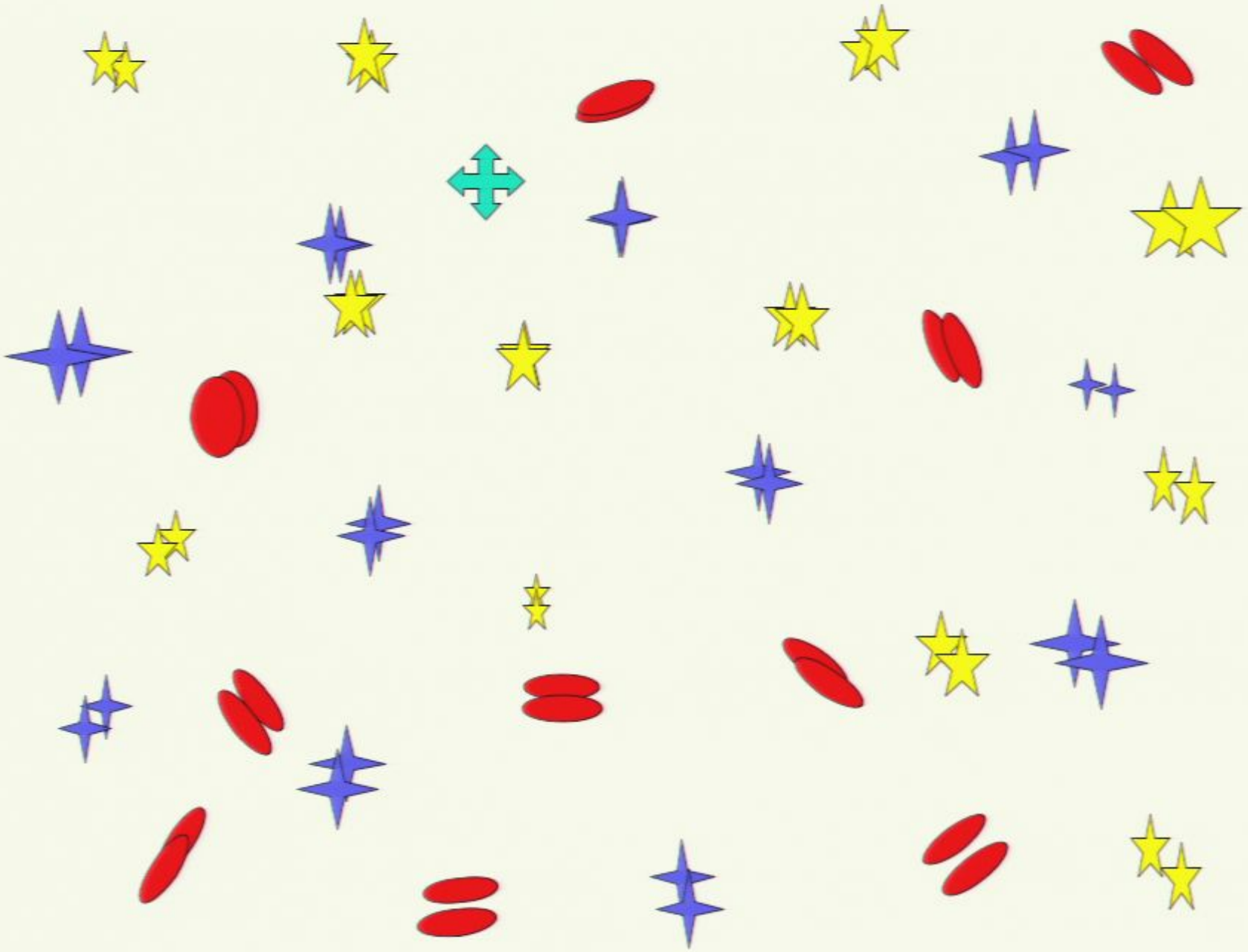
FIGURE 1

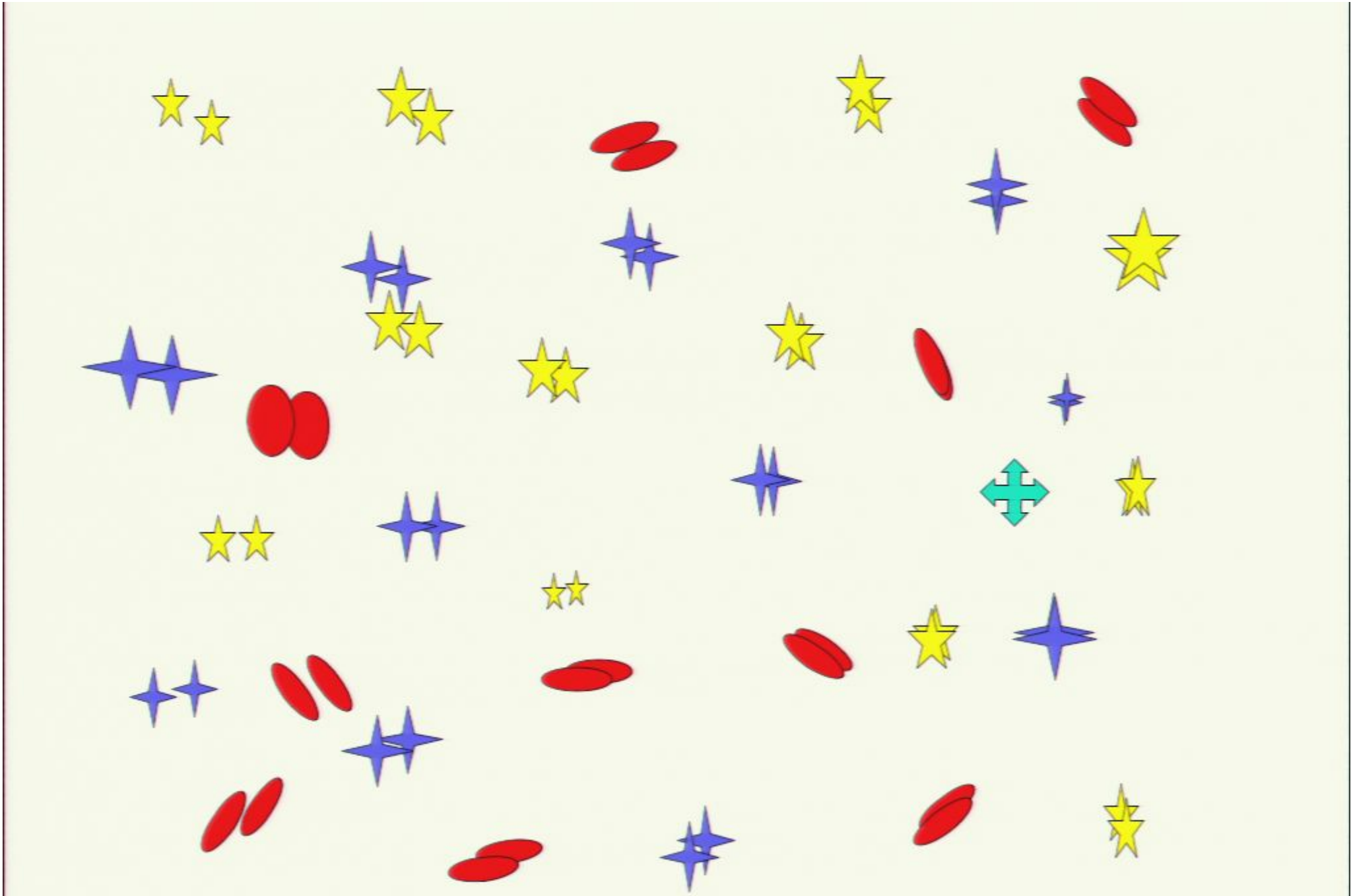


A Toy Universe

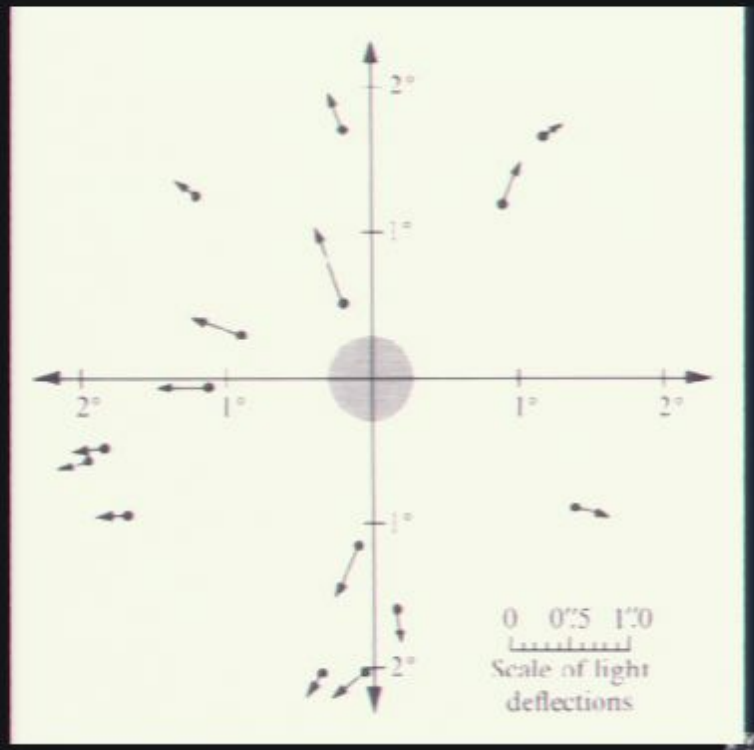


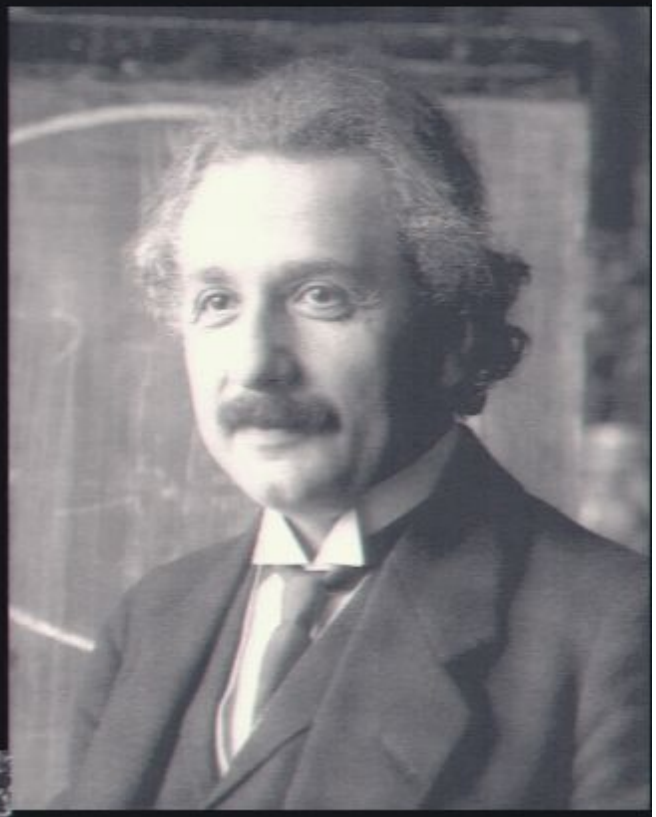






Einstein's Theory of Gravity





Our View of the Expanding Universe

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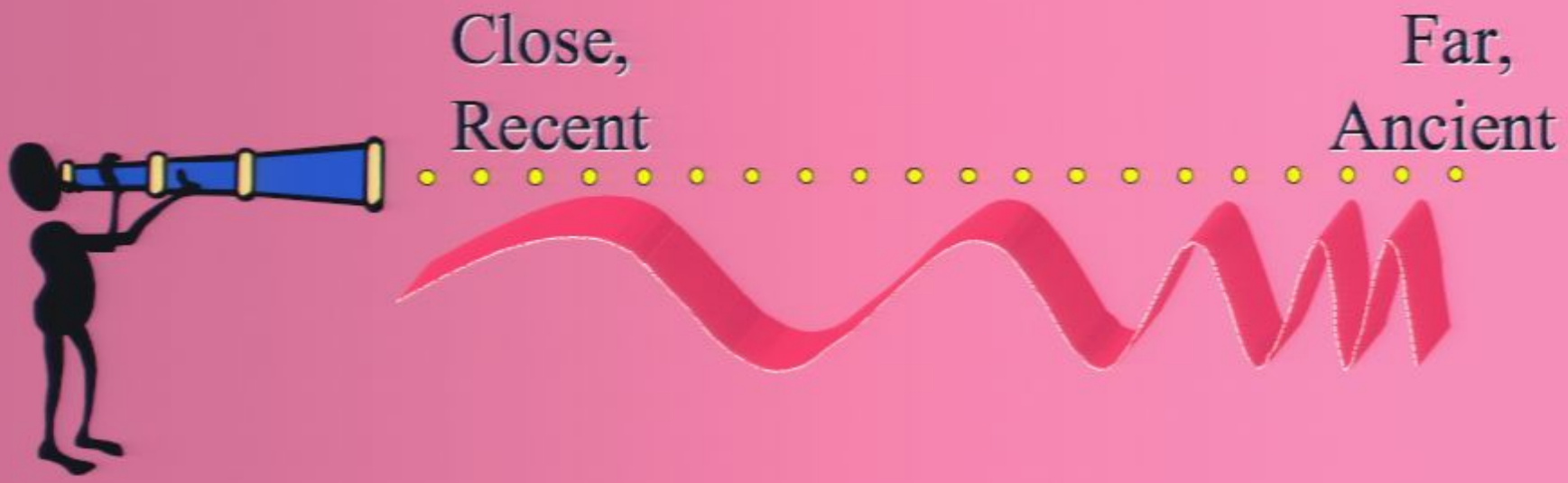


To the Future

Looking into the Past

The Big Bang


To the Future

Looking into the Past

Looking into the Past

The Big Bang

The Distance Between Two Galaxies

The Distance Between Two Galaxies

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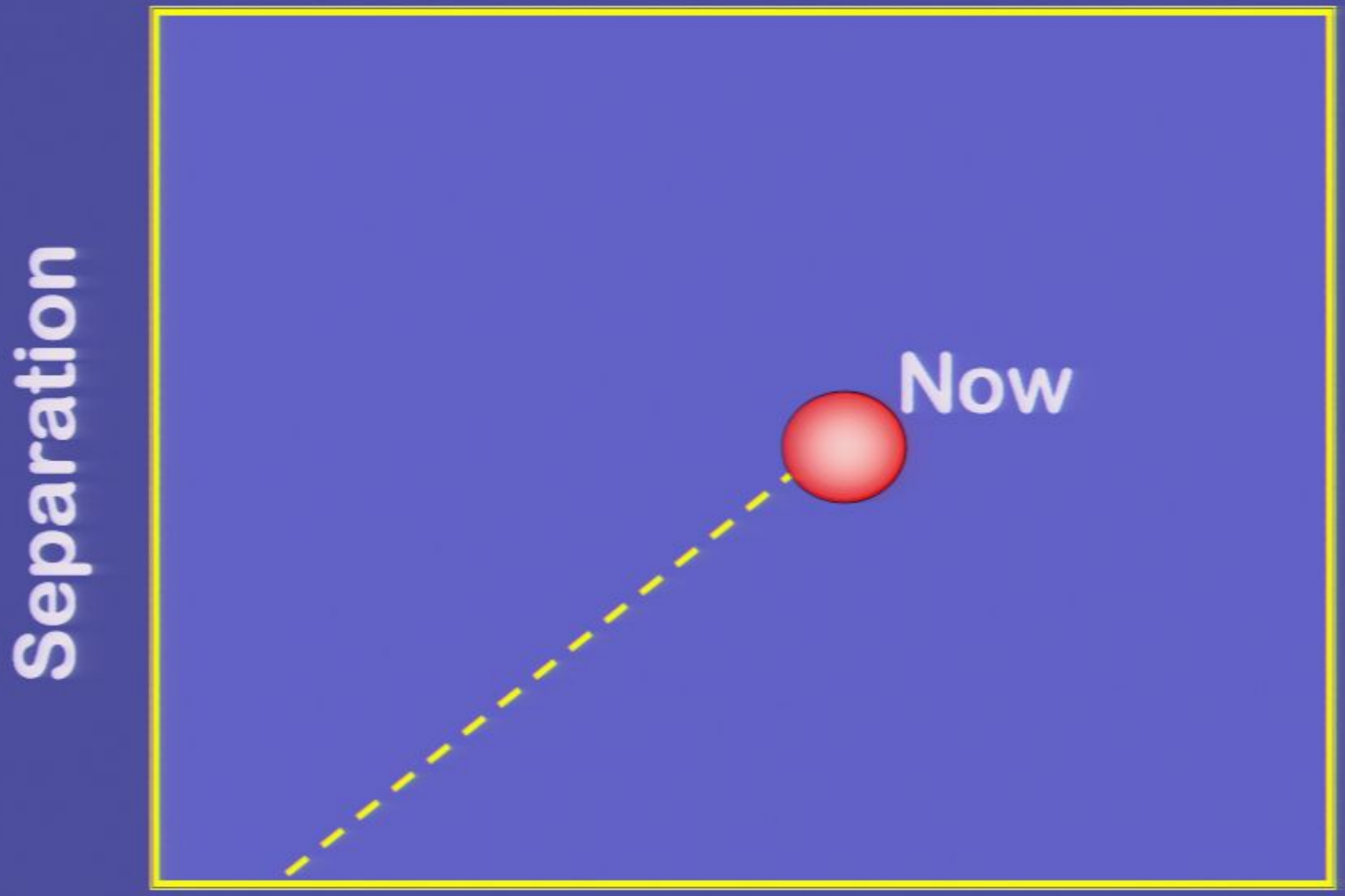

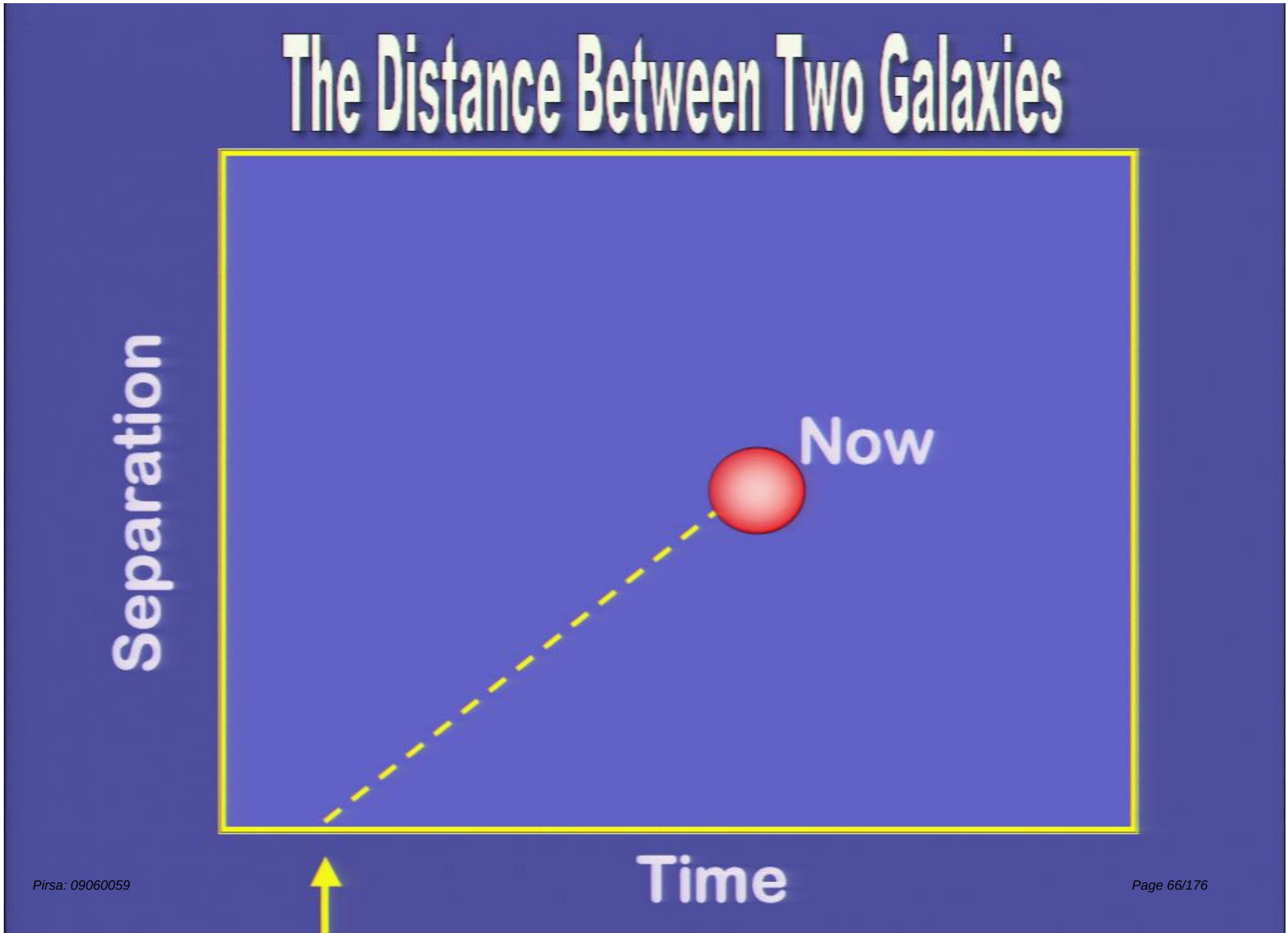
The Distance Between Two Galaxies
Separation
Now
Time

The Hubble Constant Tells us the age of the Universe...

The Hubble Constant Tells us the age of the Universe...

H_0=50	t=19.6 Billion Years
H_0=60	t=16.3 Billion Years
H_0=70	t=14.0 Billion Years
H_0=80	t=12.3 Billion Years
H_0=90	t=10.9 Billion Years
H_0=100	t= 9.8 Billion Years

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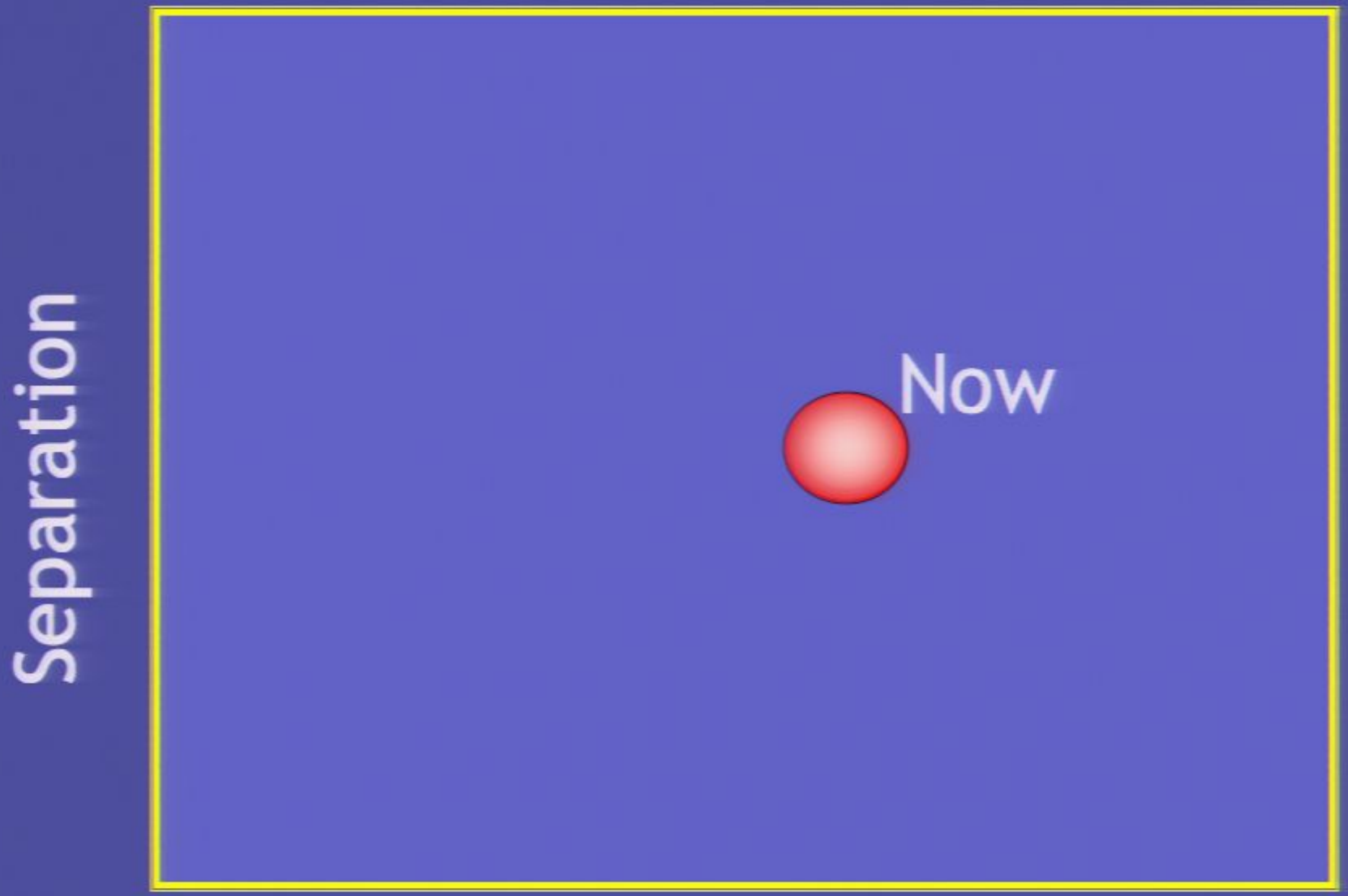
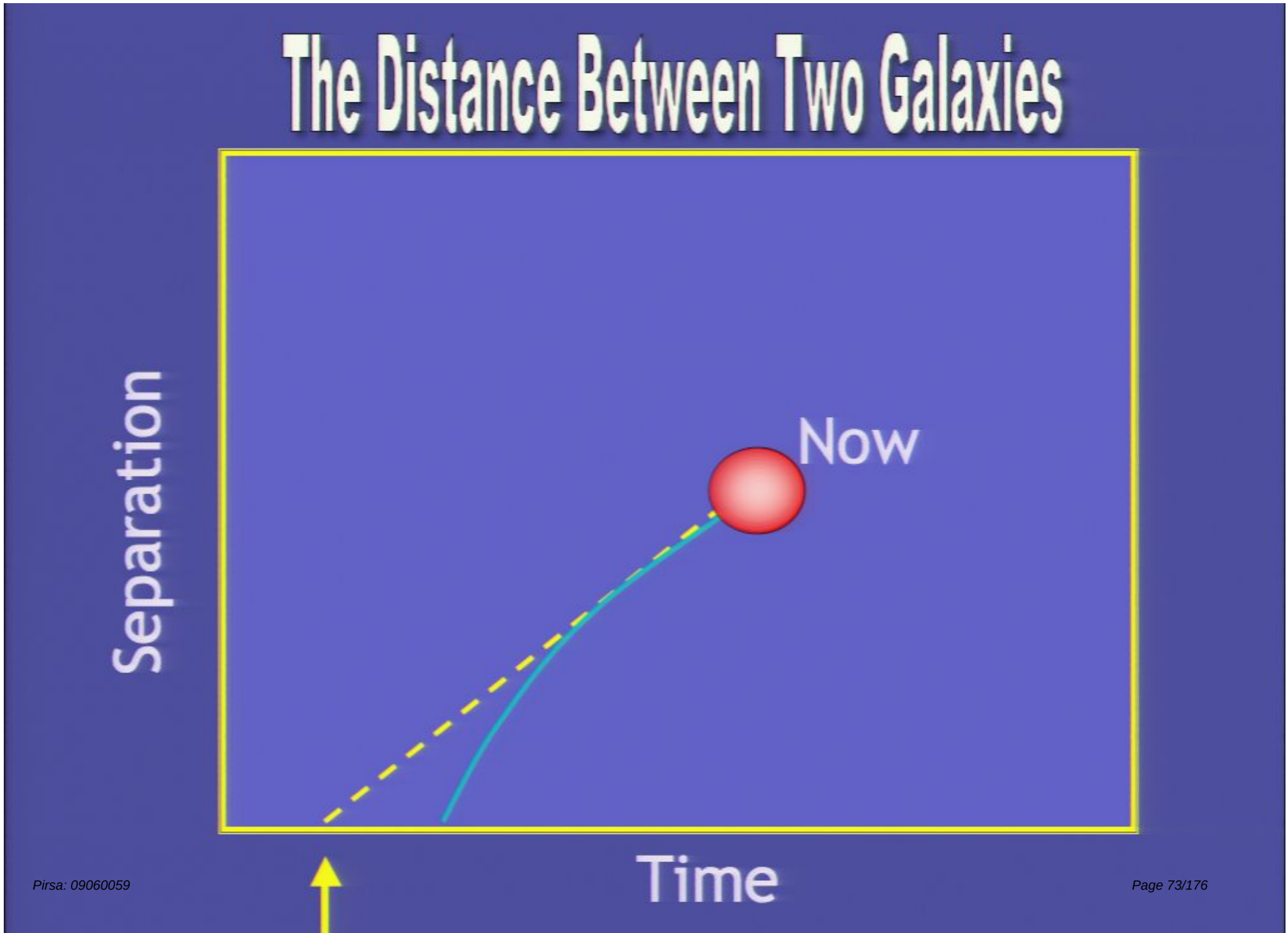
So how fast the Universe is expanding tells us about how old the Universe is...But...

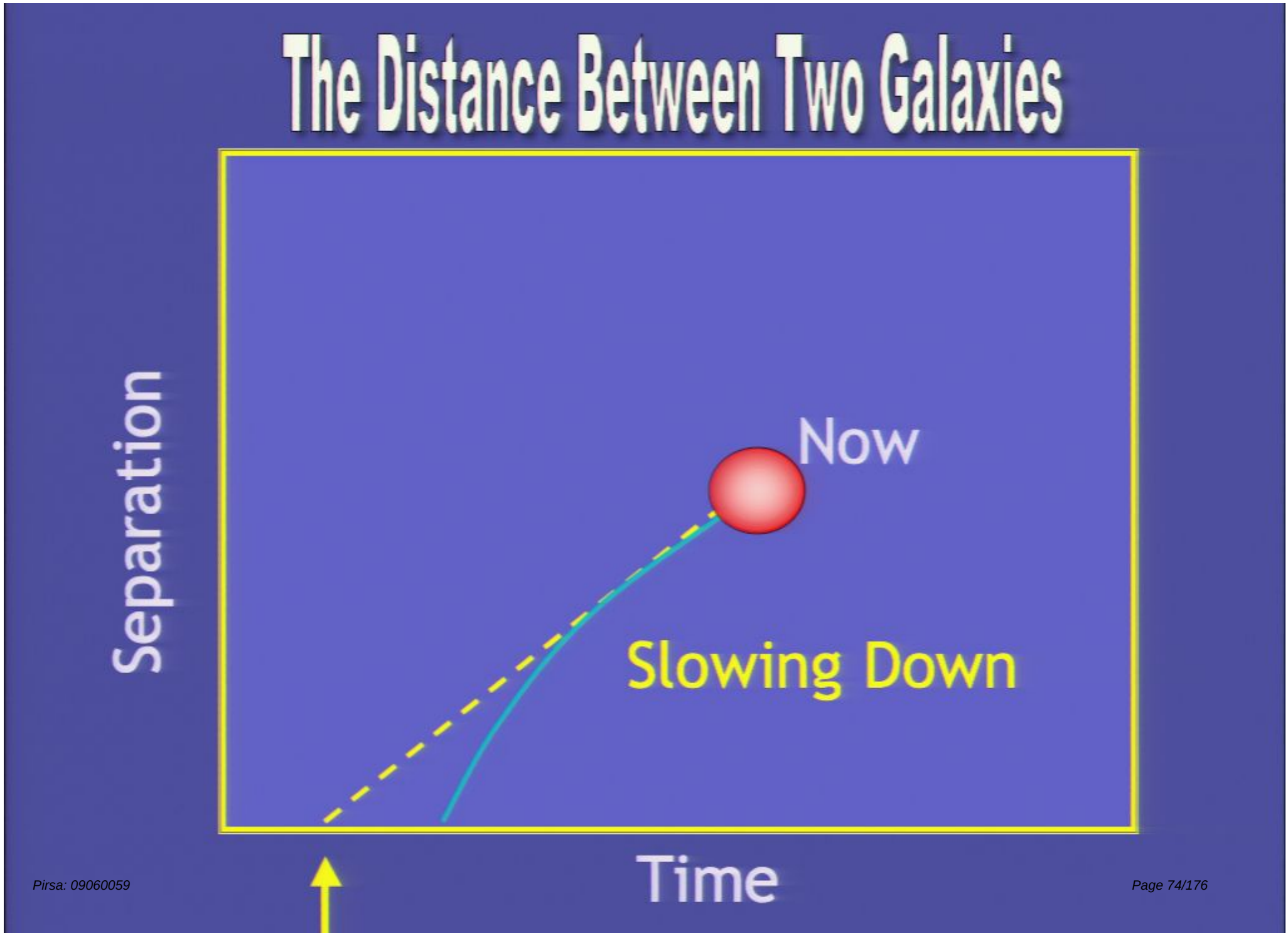
So how fast the Universe is expanding tells us about how old the Universe is...But...

Gravity pulls on the Universe as it expands, slowing it down over time

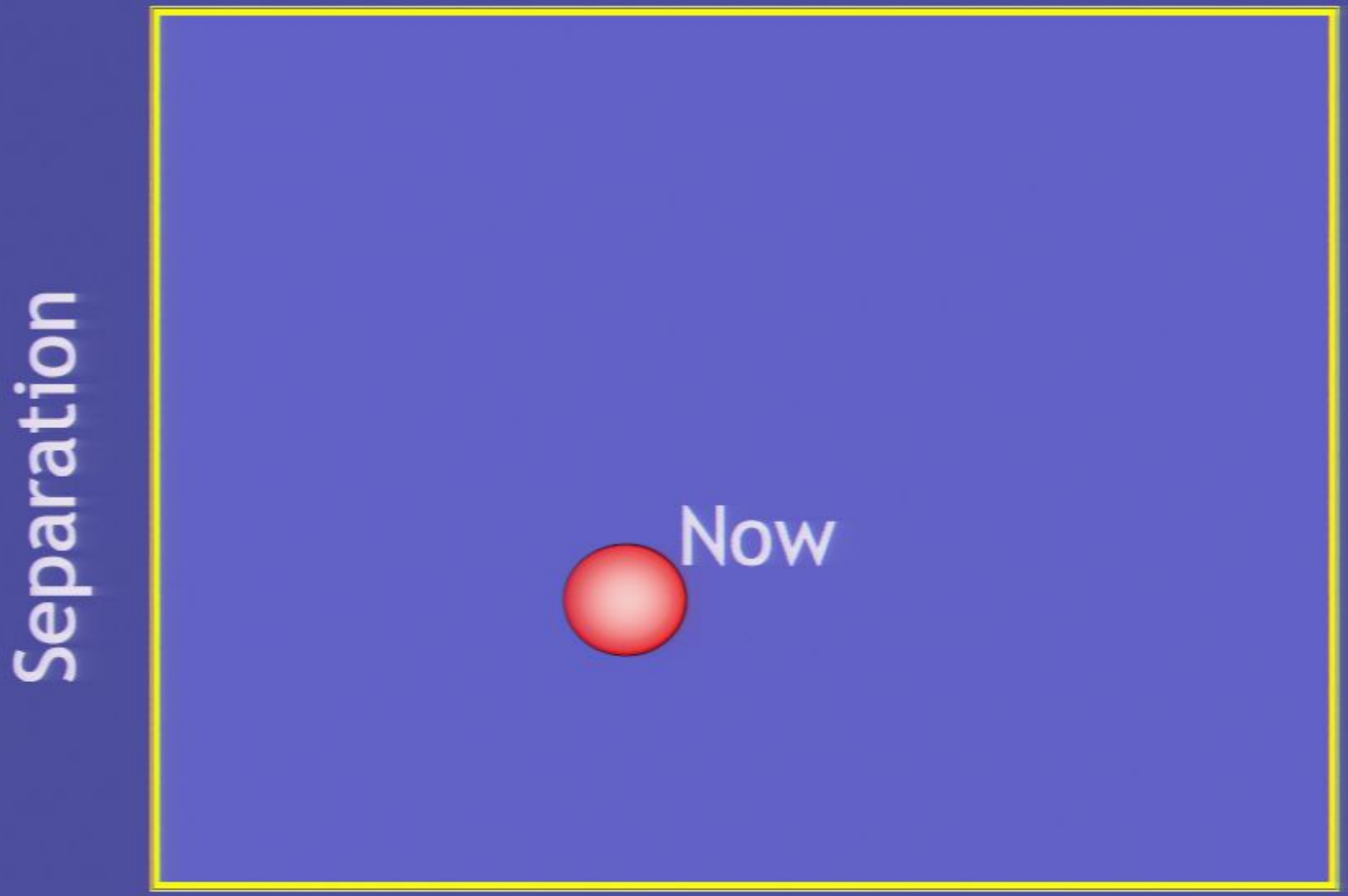
The Distance Between Two Galaxies




The Distance Between Two Galaxies
Separation
Now
Time


The Distance Between Two Galaxies
Separation
Now
Slowing Down
Time

Looking towards the Future



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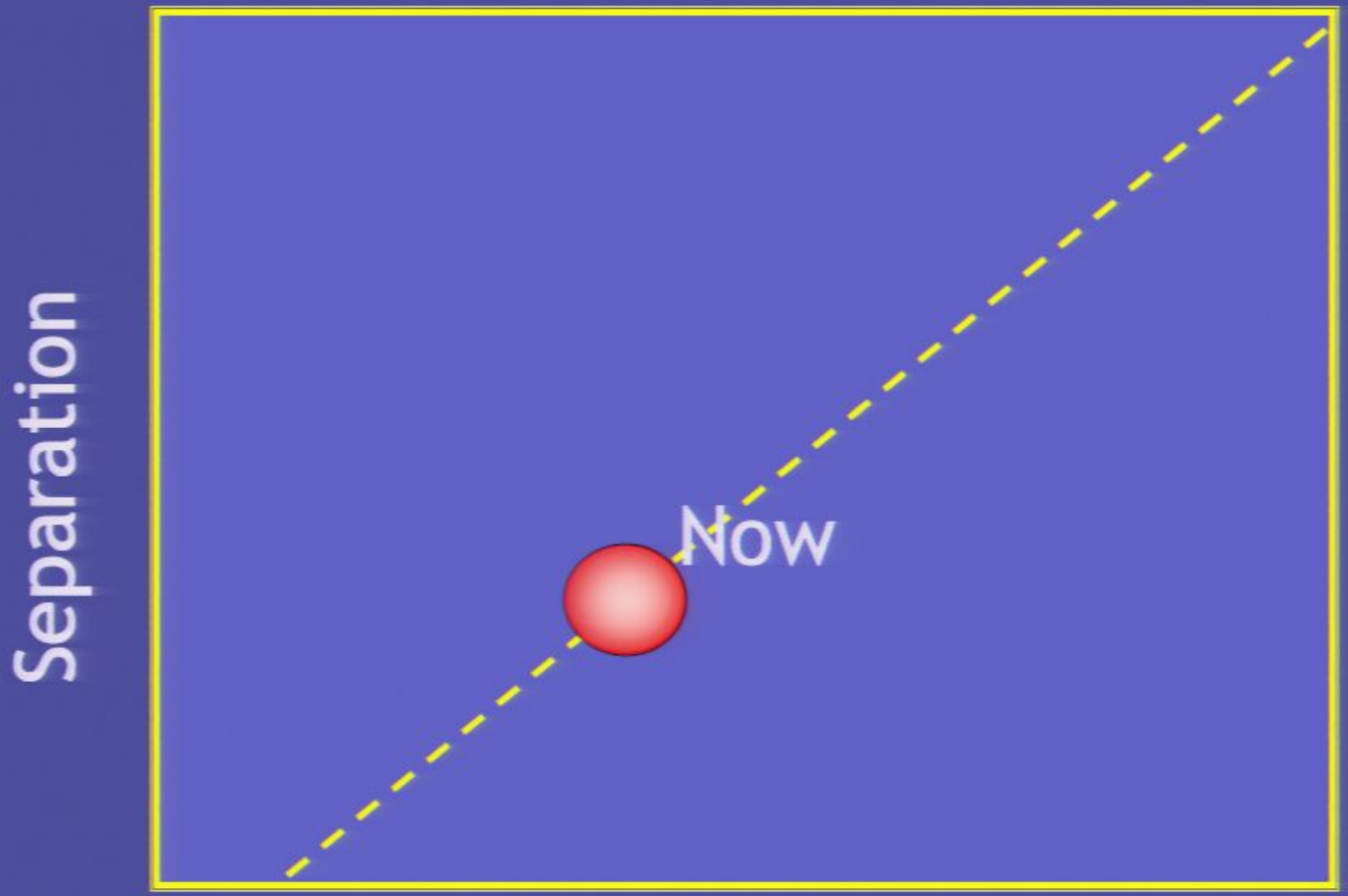

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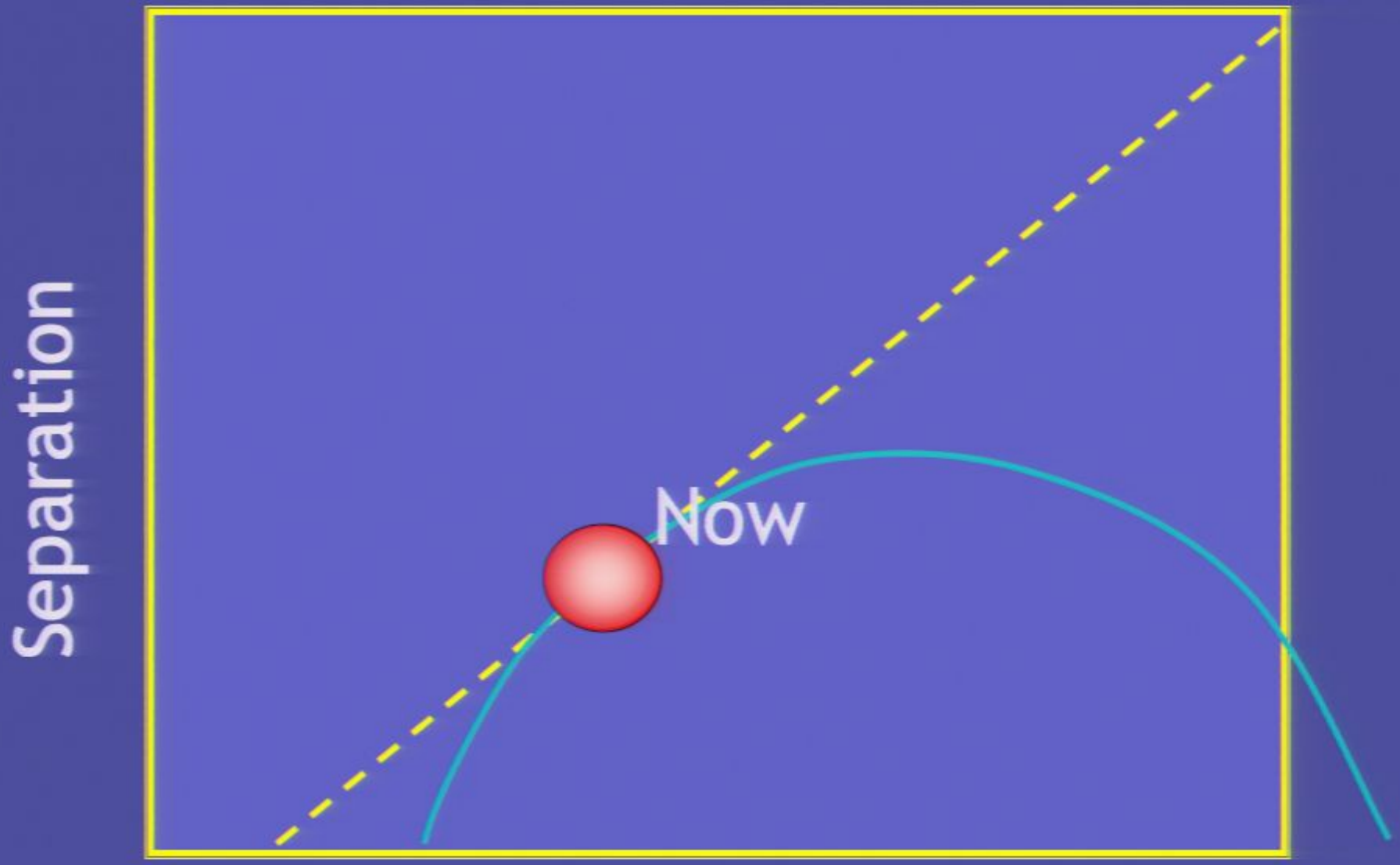

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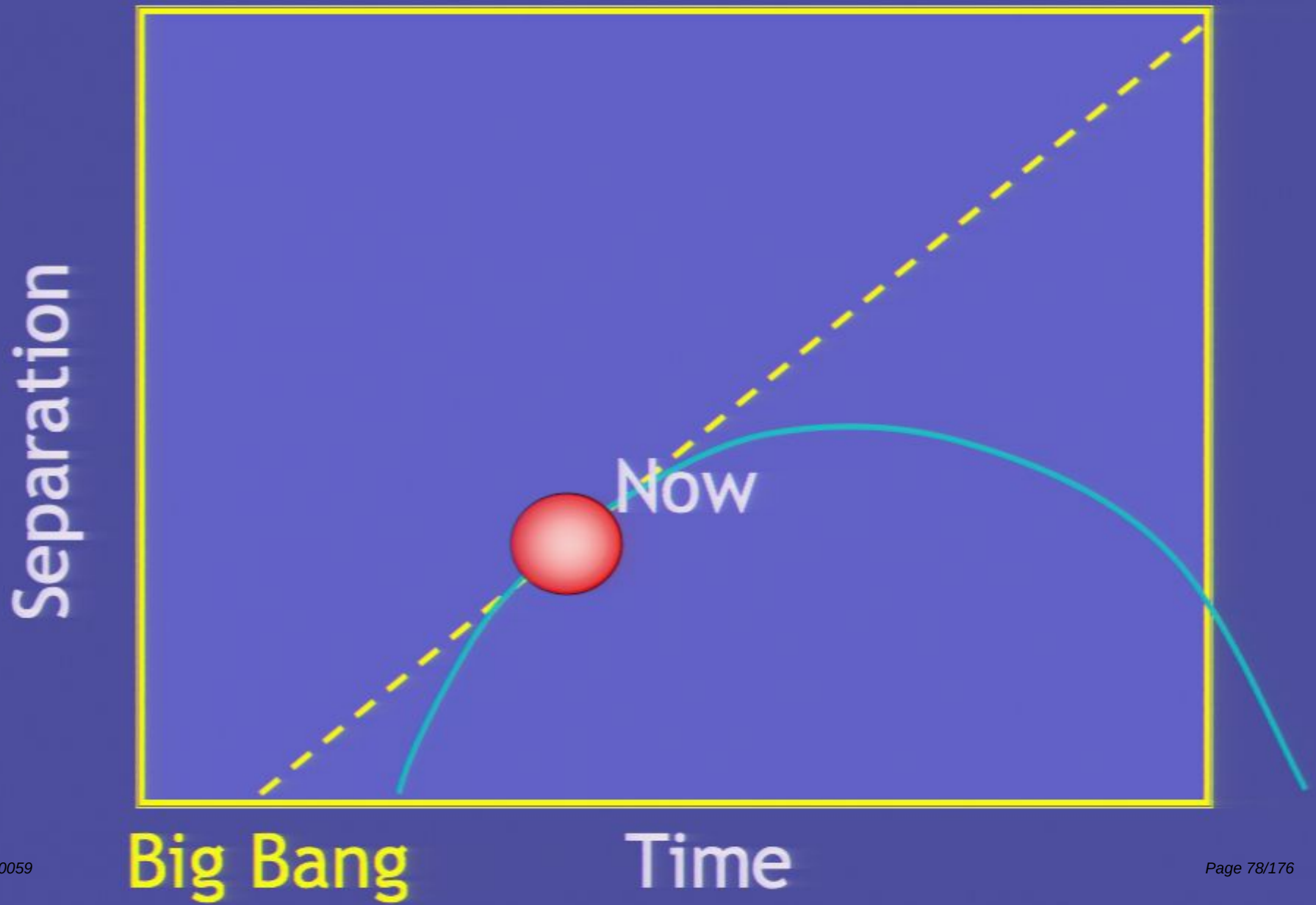

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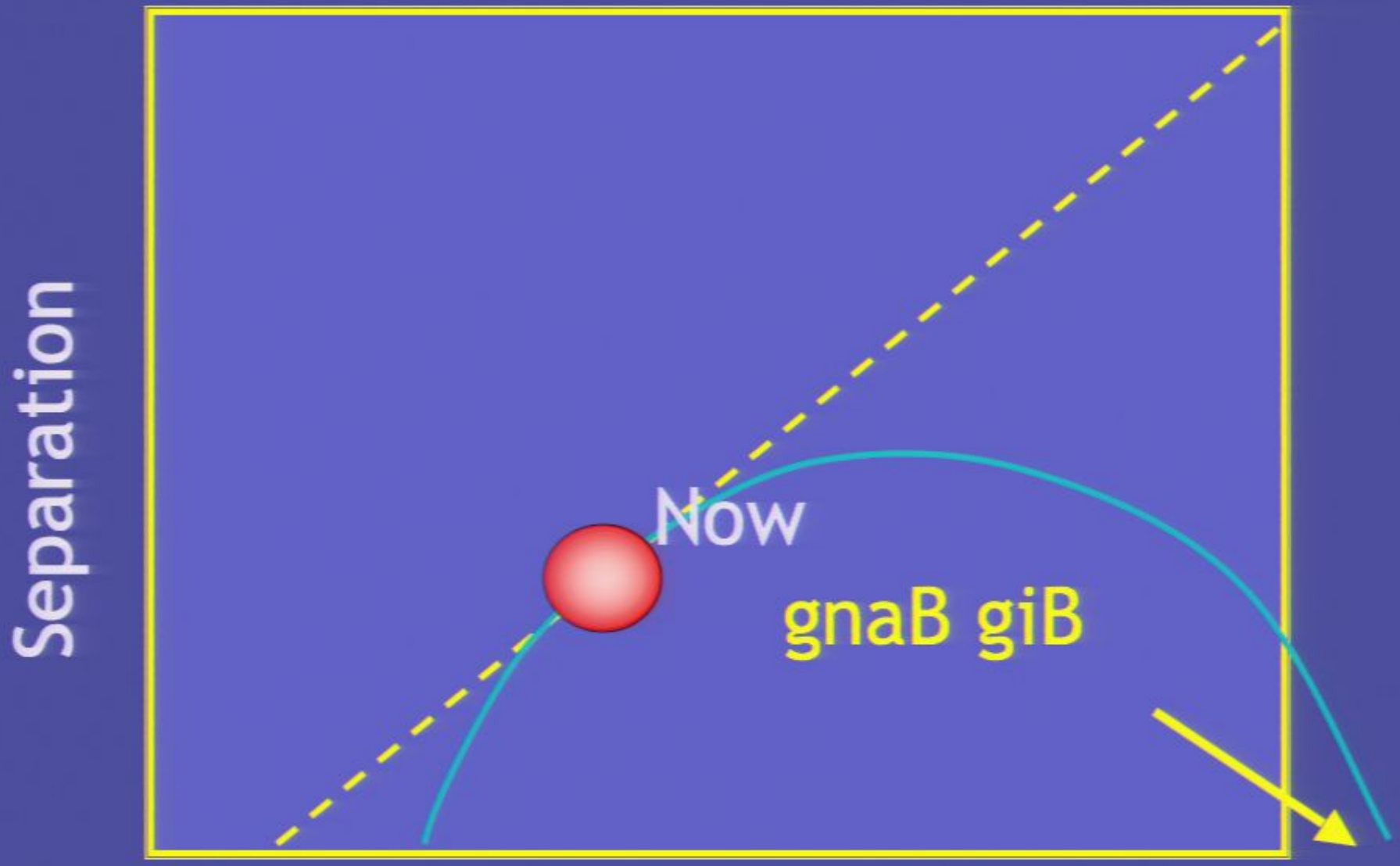

The slowing down or speeding up of the Universe

The slowing down or speeding up of the Universe

- affects How old we think the Universe is from the Hubble Constant.

The slowing down or speeding up of the Universe

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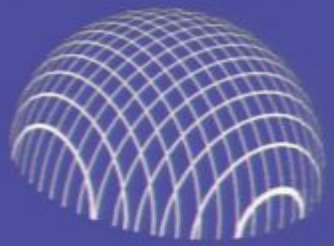
- Tells us the Ultimate fate of the Universe. Will it exist forever, or die in the "gnaB giB"

The slowing down or speeding up of the Universe

- affects How old we think the Universe is from the Hubble Constant.
- Tells us the Ultimate fate of the Universe. Will it exist forever, or die in the "gnaB giB"
- Tell us the Shape and Weight of the Universe

Cosmic Geometry-Curvature and Density



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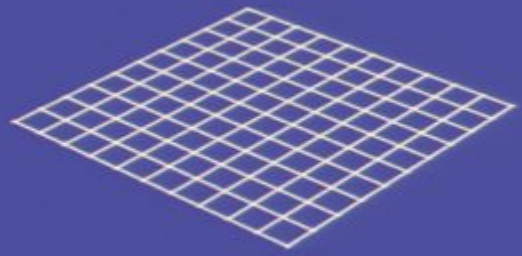
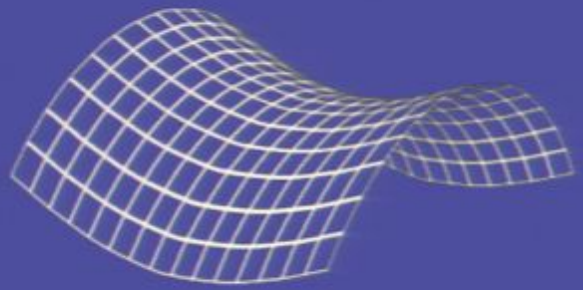


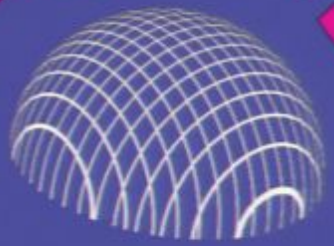
FLAT



OPEN

Cosmic Geometry-Curvature and Density

Heavy



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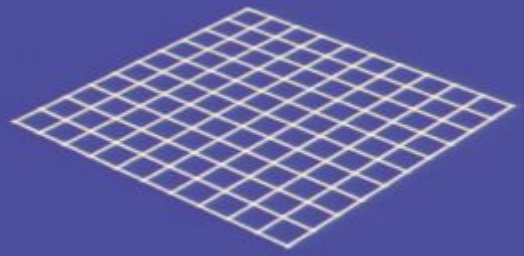

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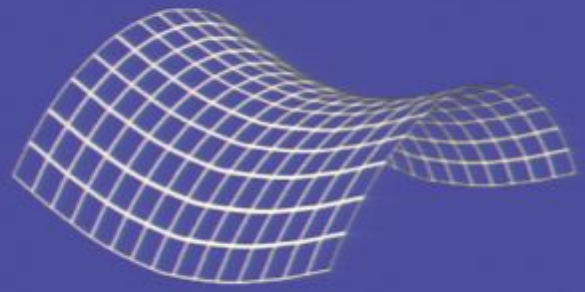
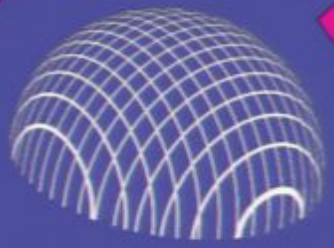


OPEN

Cosmic Geometry-Curvature and Density

Heavy



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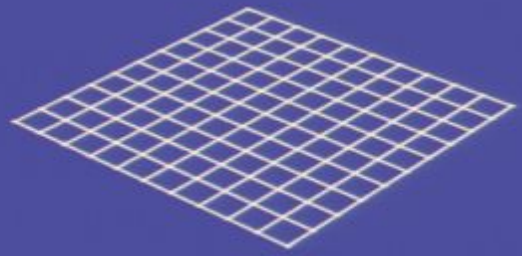


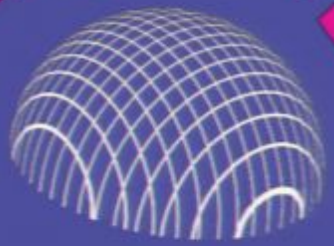
FLAT

Light

OPEN

Cosmic Geometry-Curvature and Density

Heavy



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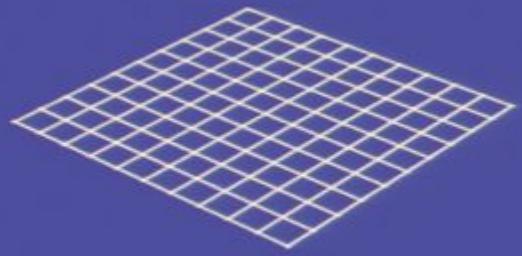


FLAT

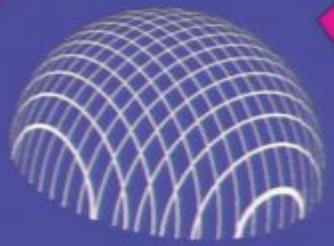
Just Right

Light

OPEN

Cosmic Geometry-Curvature and Density

Heavy



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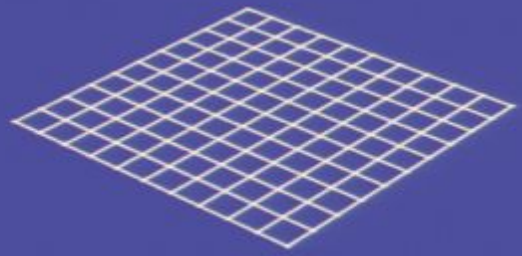


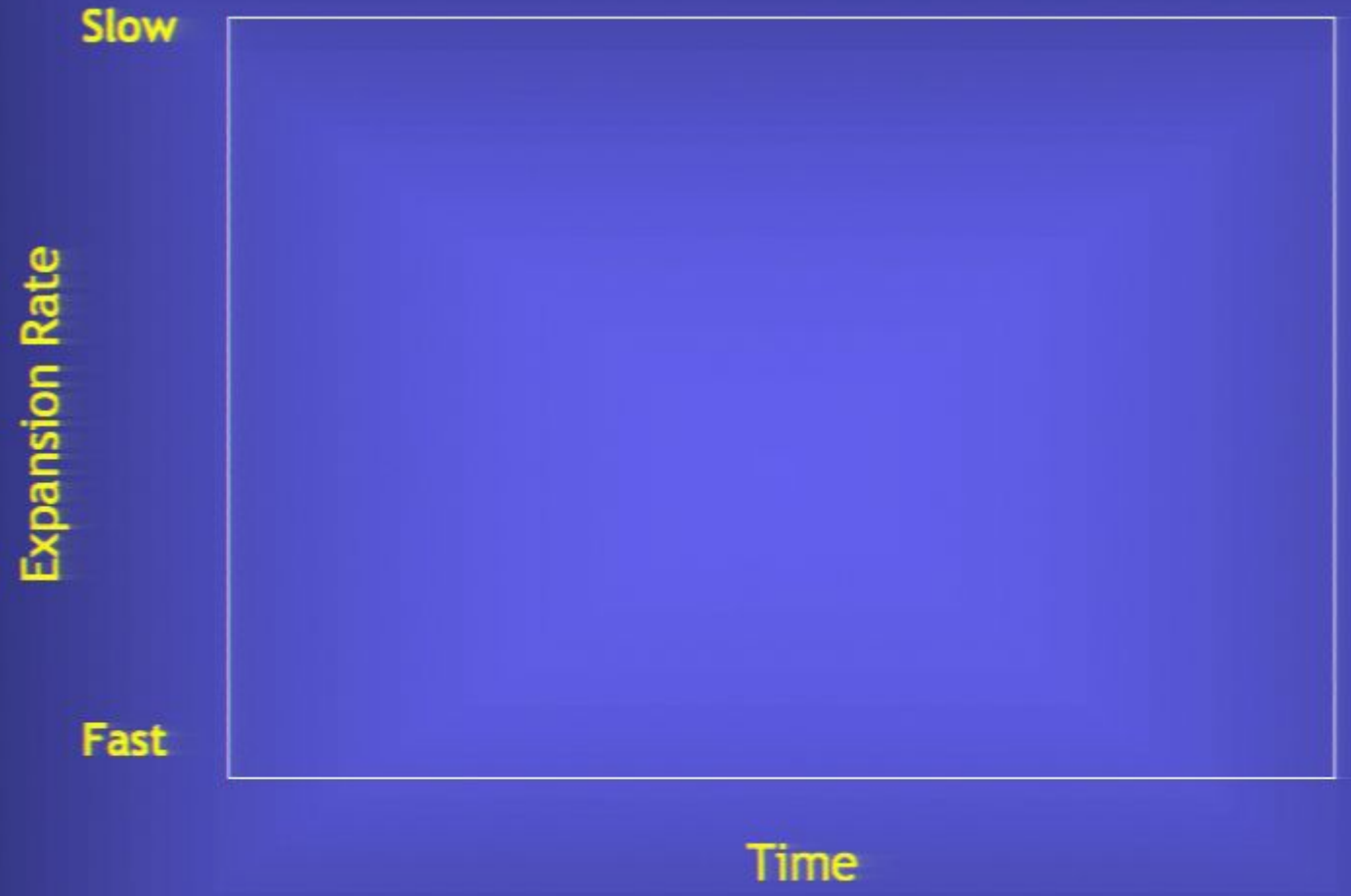
FLAT

Just Right

Light

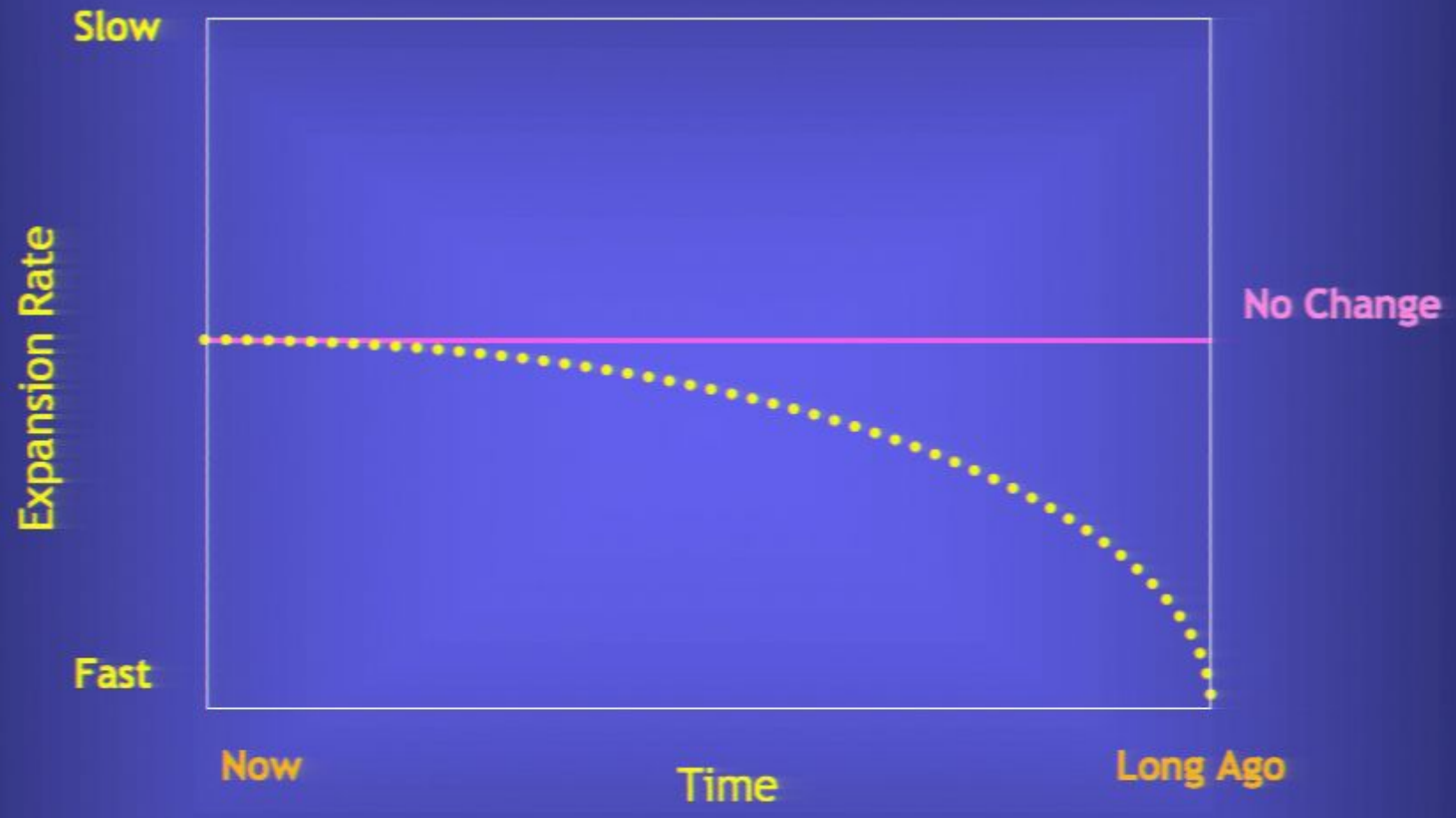
OPEN

Measure Universe's Past



Measure Universe's Past

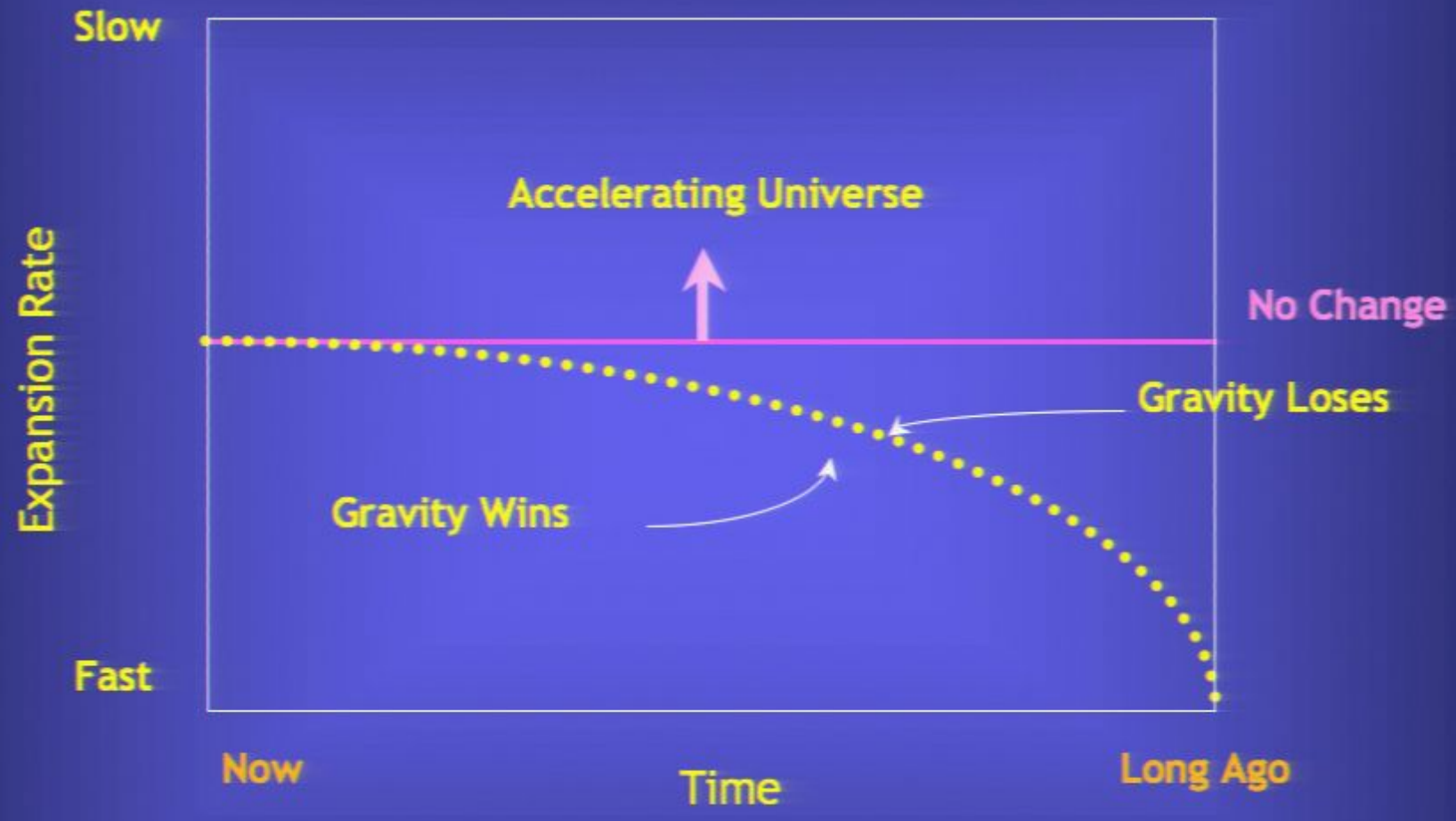
Measure Universe's Past



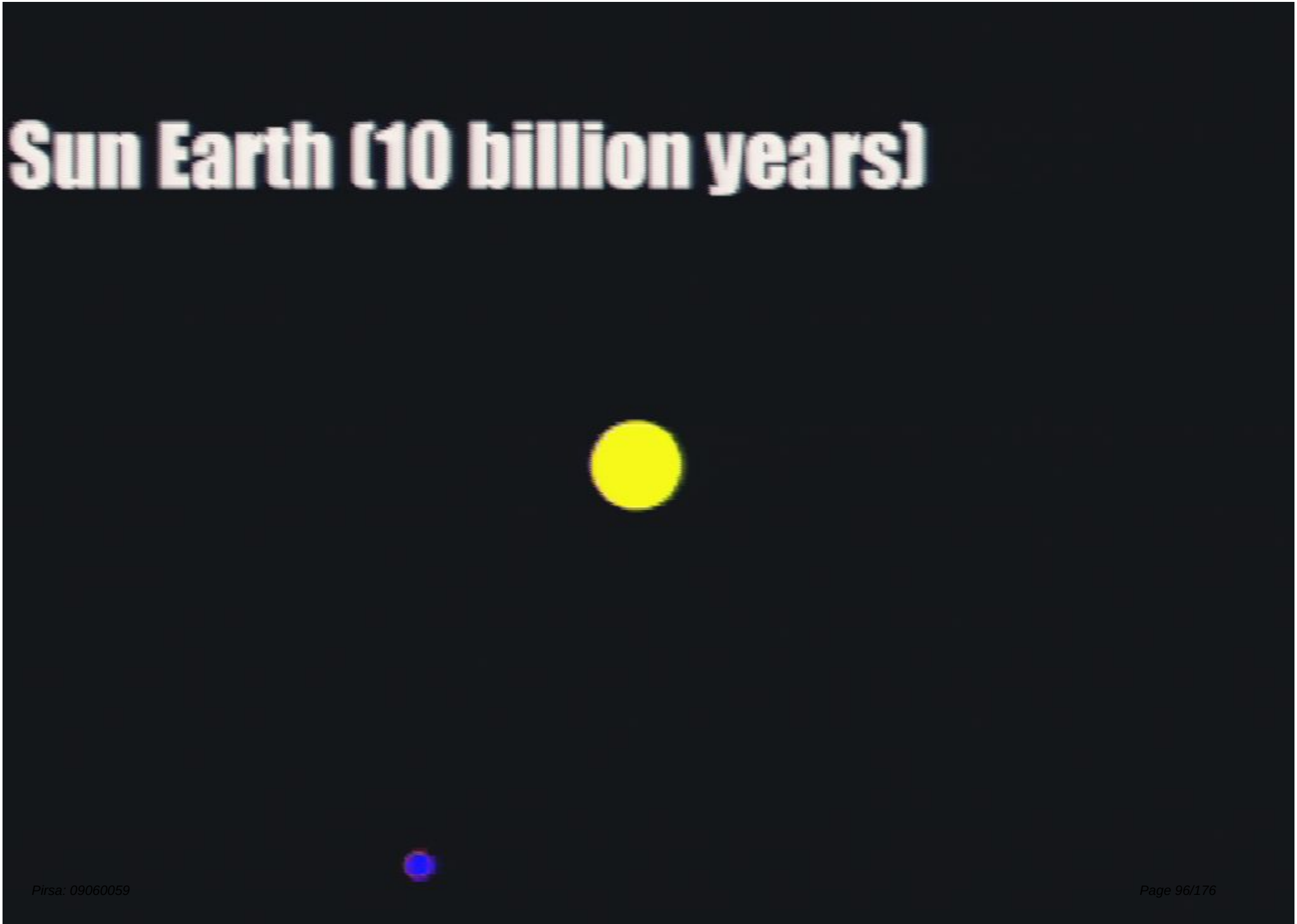
Measure Universe's Past

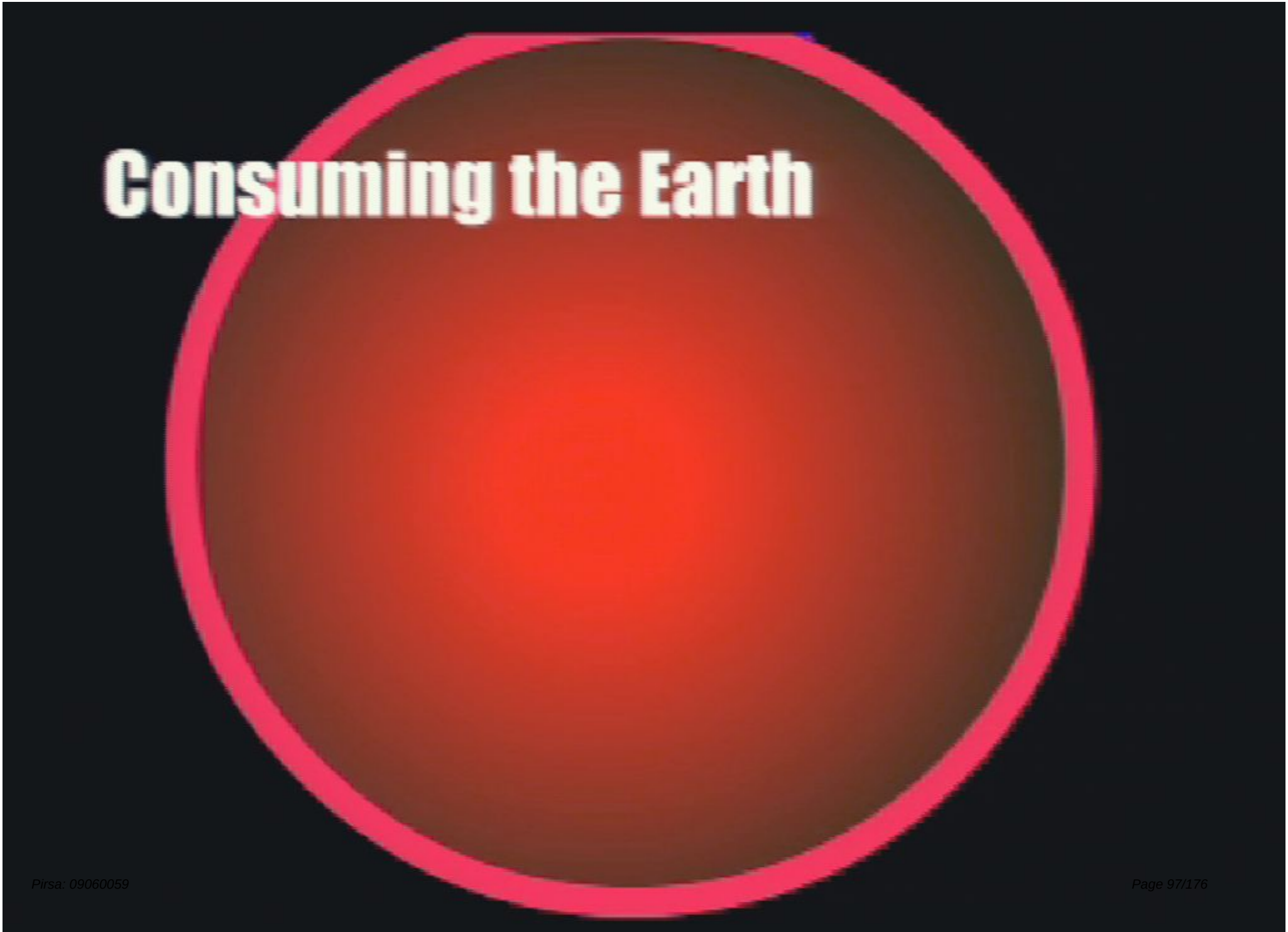
Measure Universe's Past

Measure Universe's Past

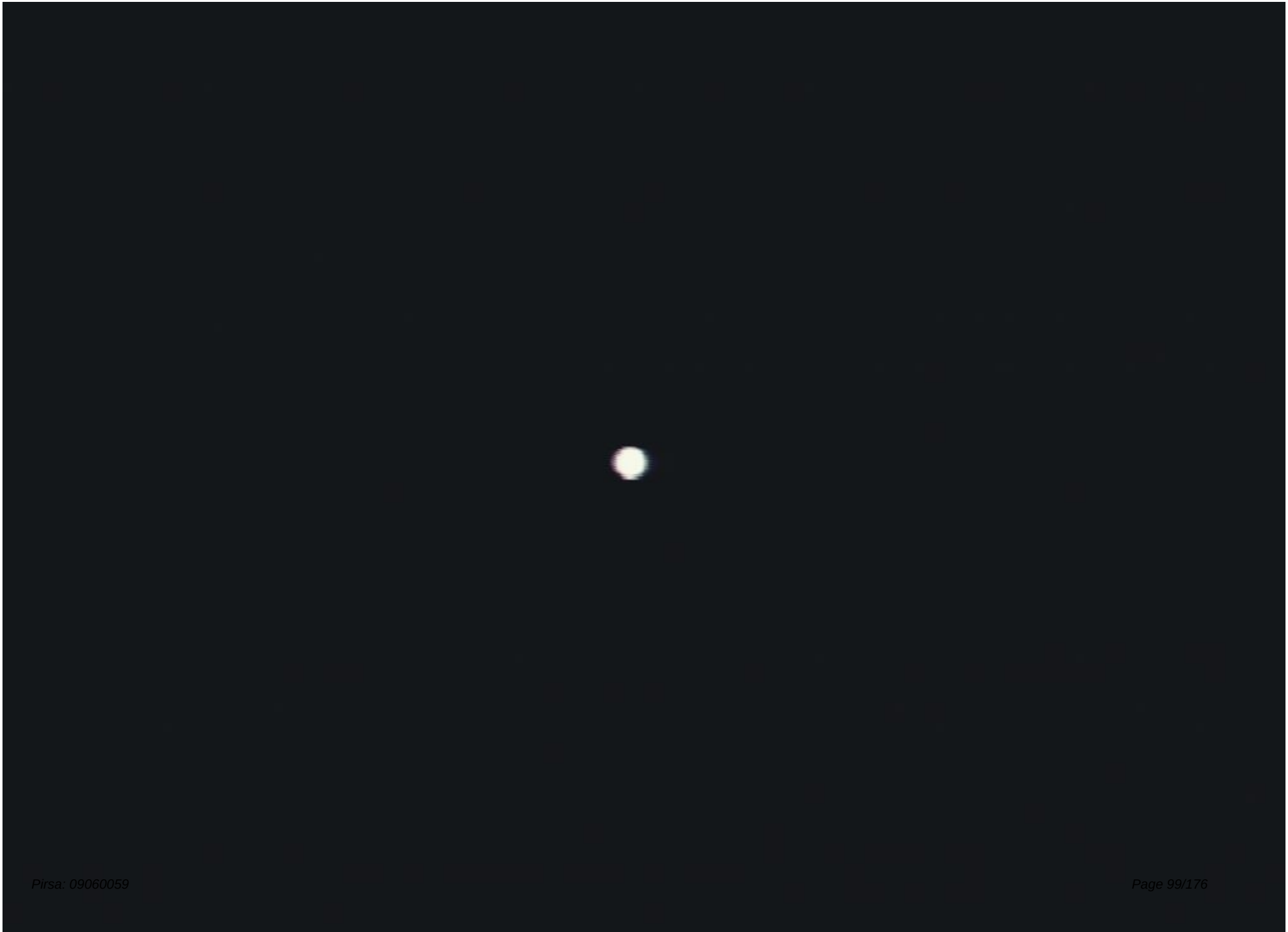


Type Ia Supernovae

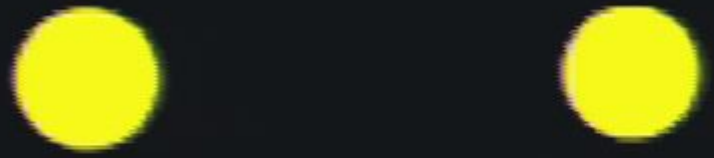

Sun Earth (10 billion years)


Consuming the Earth

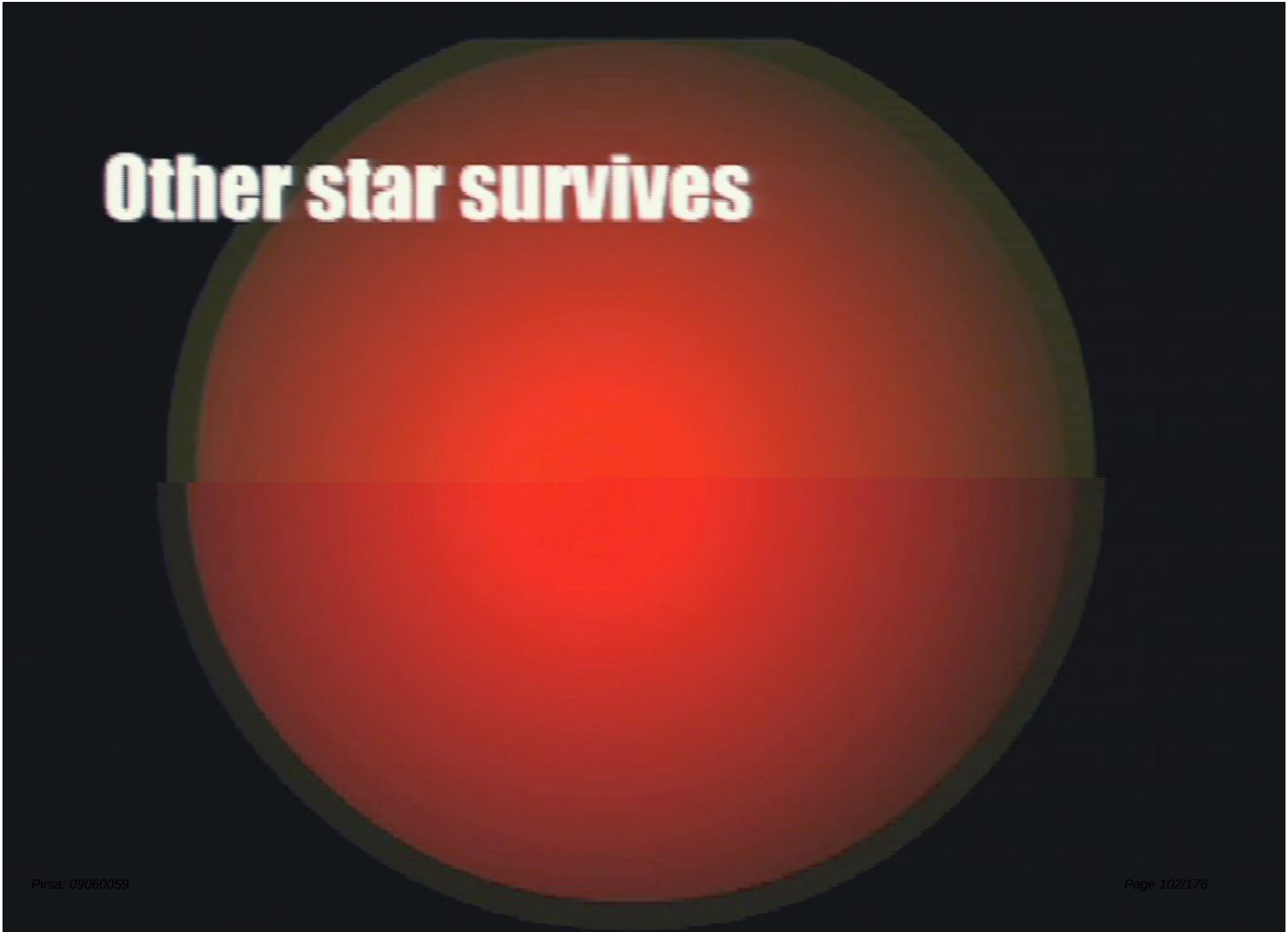

and then collapses to a
white dwarf star



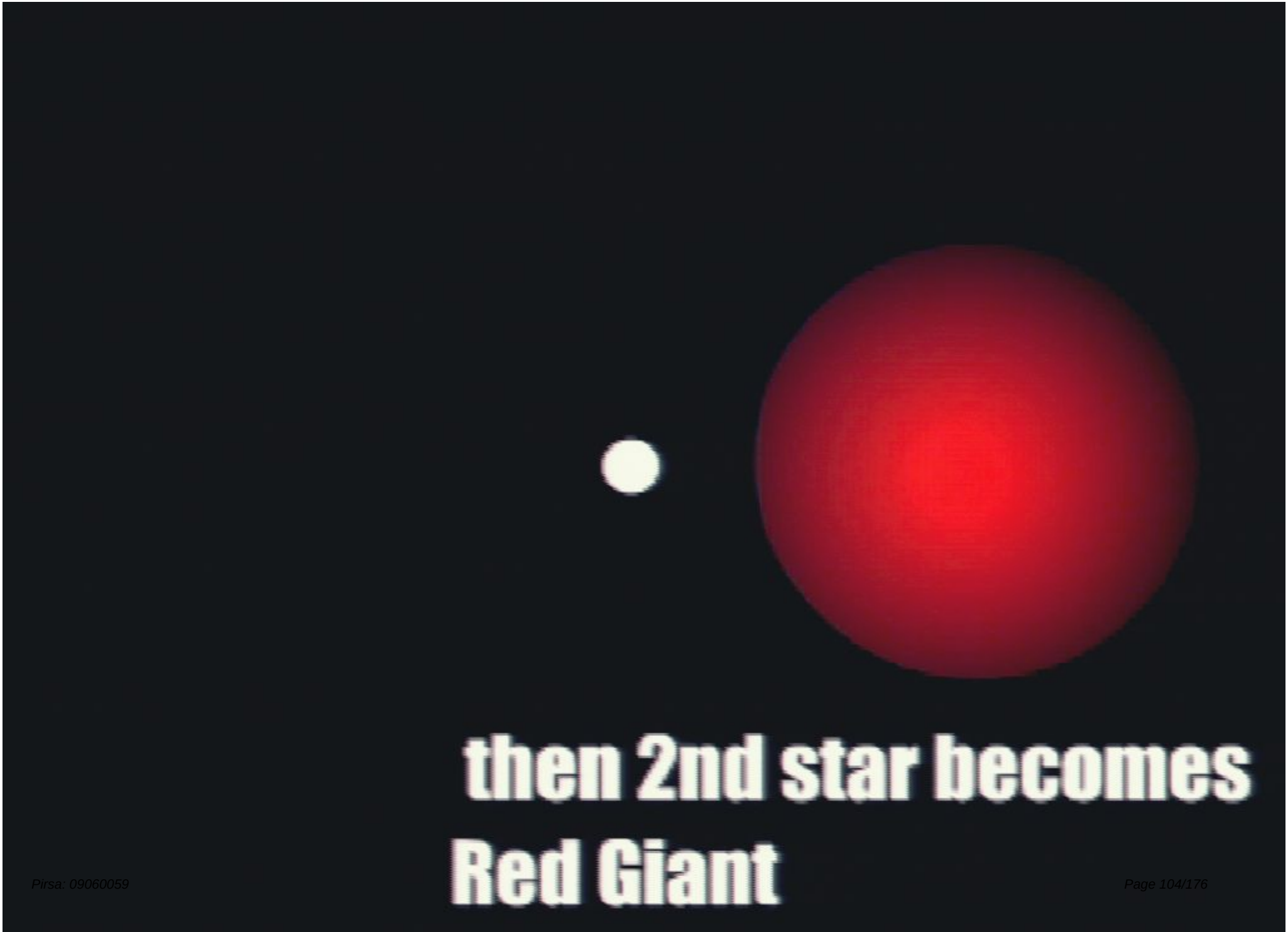
Binary Stars, different sizes

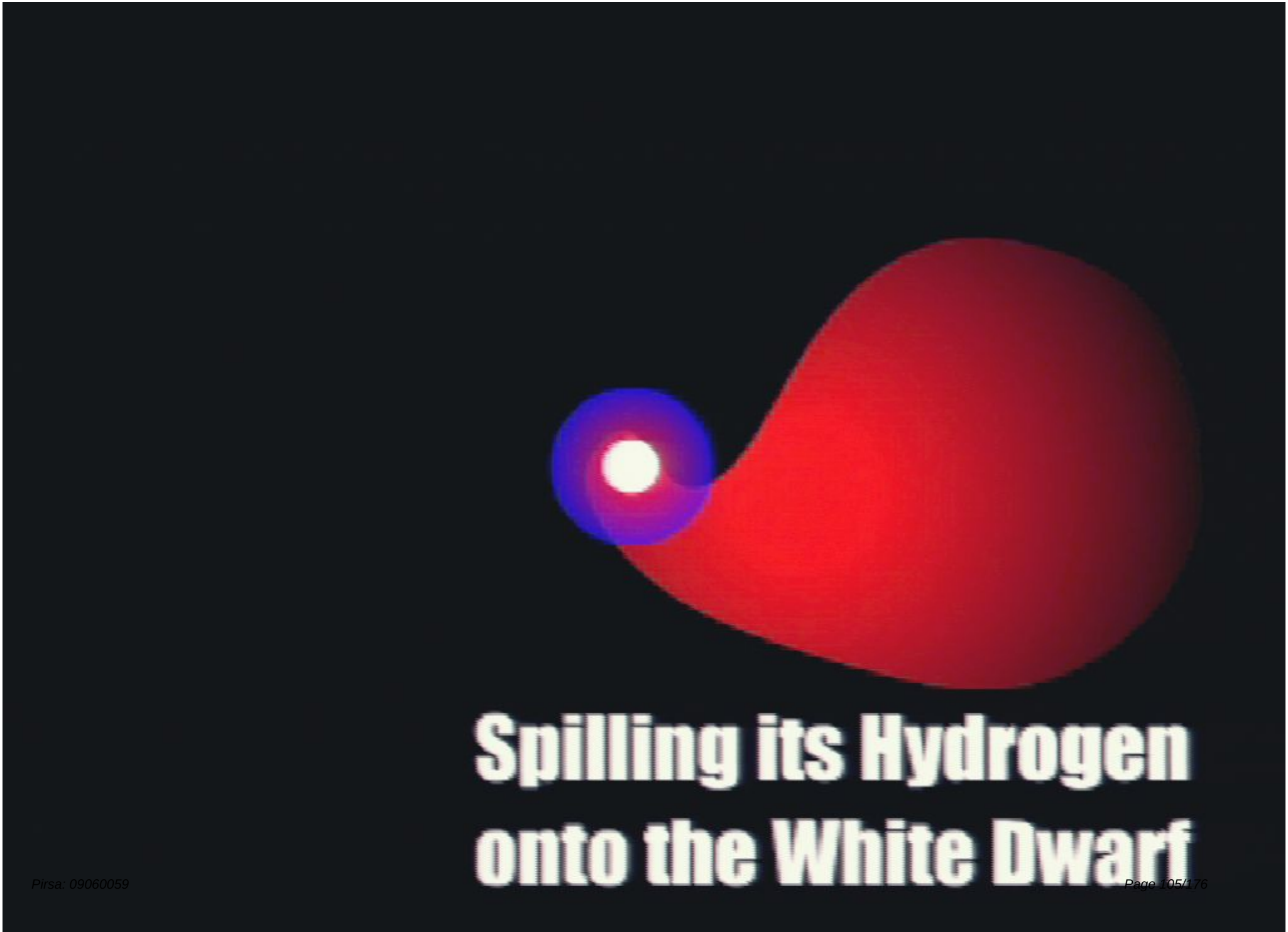


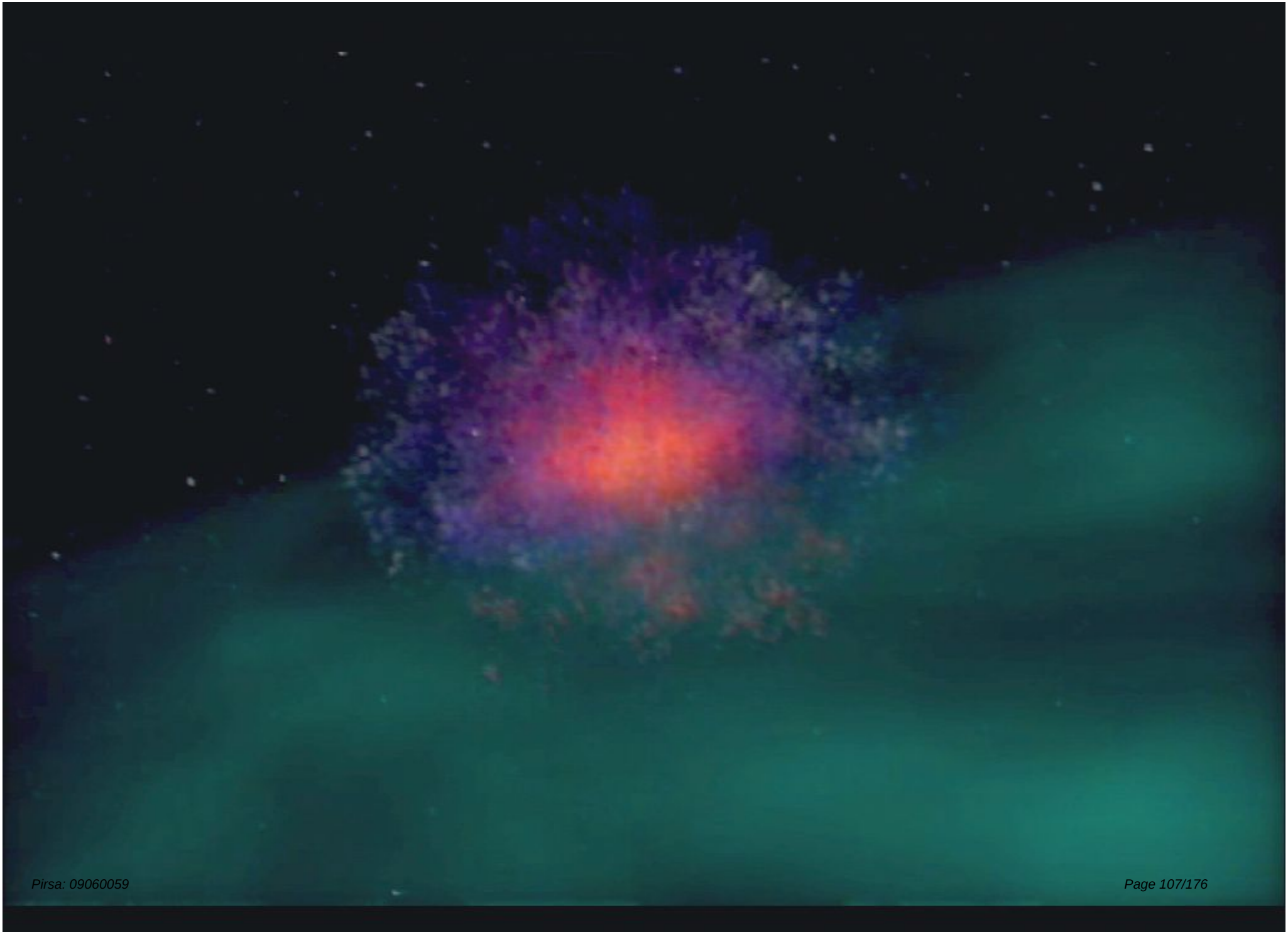
Larger one becomes Red Giant


Other star survives

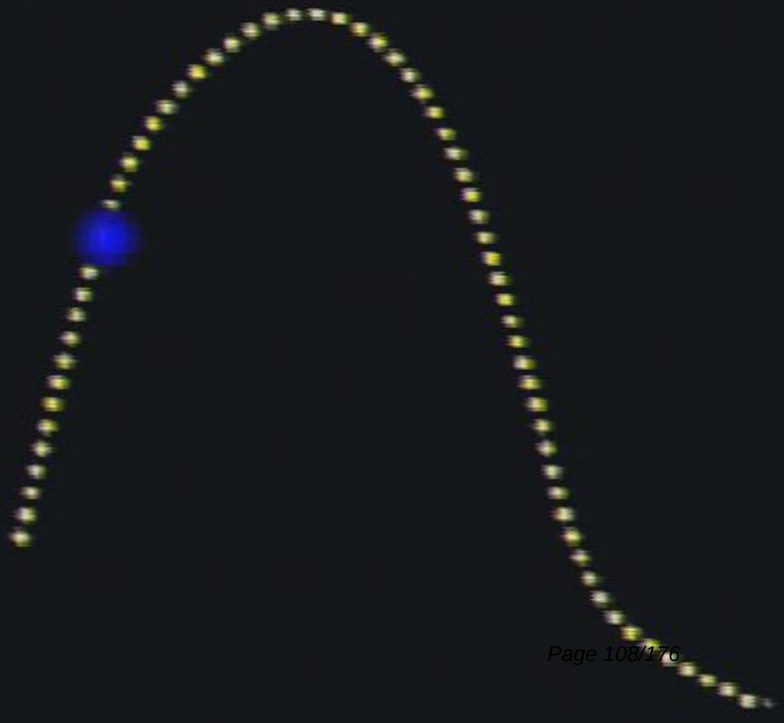

First star collapses to a white dwarf star


then 2nd star becomes
Red Giant

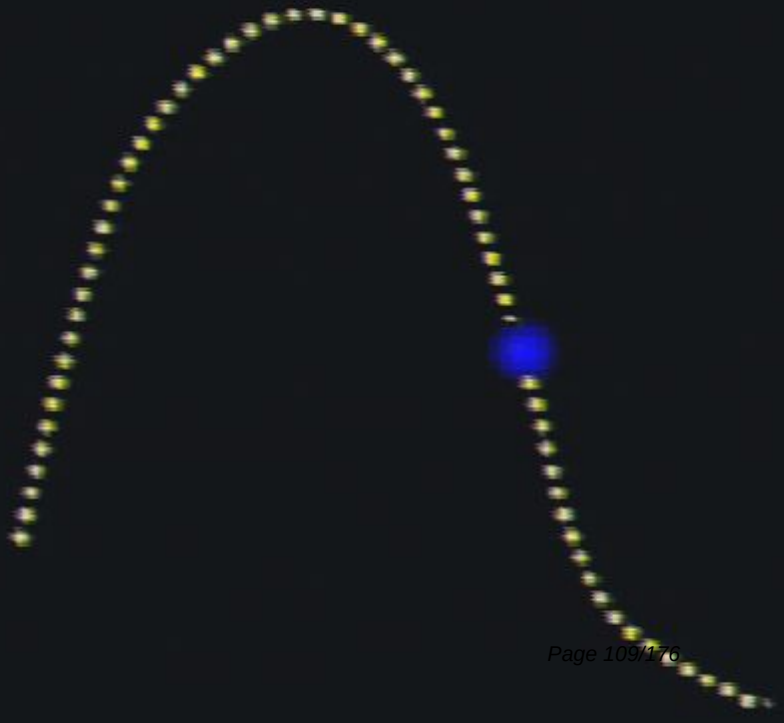

Spilling its Hydrogen
onto the White Dwarf



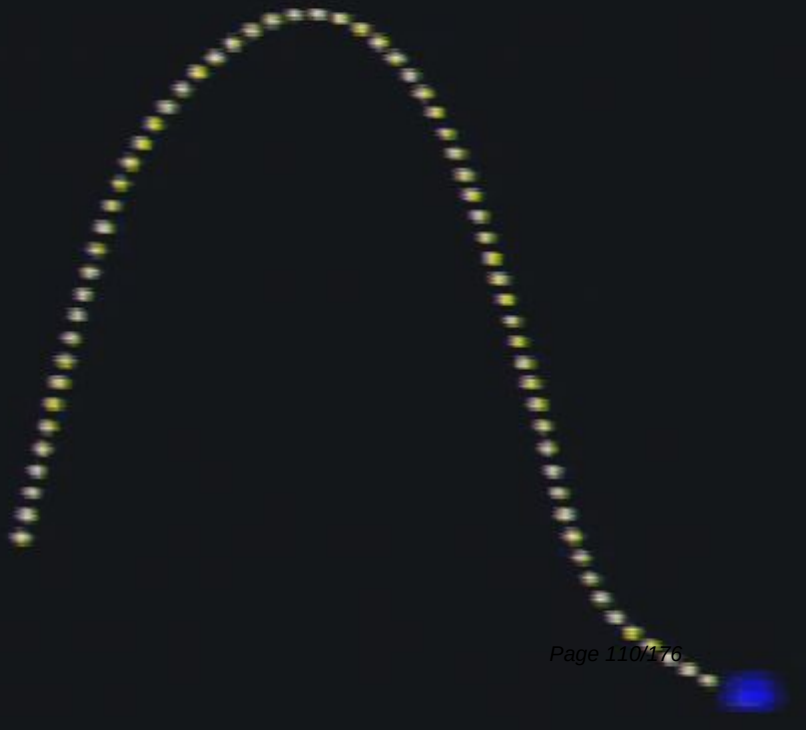
8 days



32days



44days



X-Ray Image of SN 1006

The Supernova Cosmology Project

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R. McMahon (IoIA, Cambridge)
B. Schaefer (Yale)
P. Ruiz-Lapuente (Univ of Barcelona)
N. Newberg (Fermilab)
C. Pennypacker

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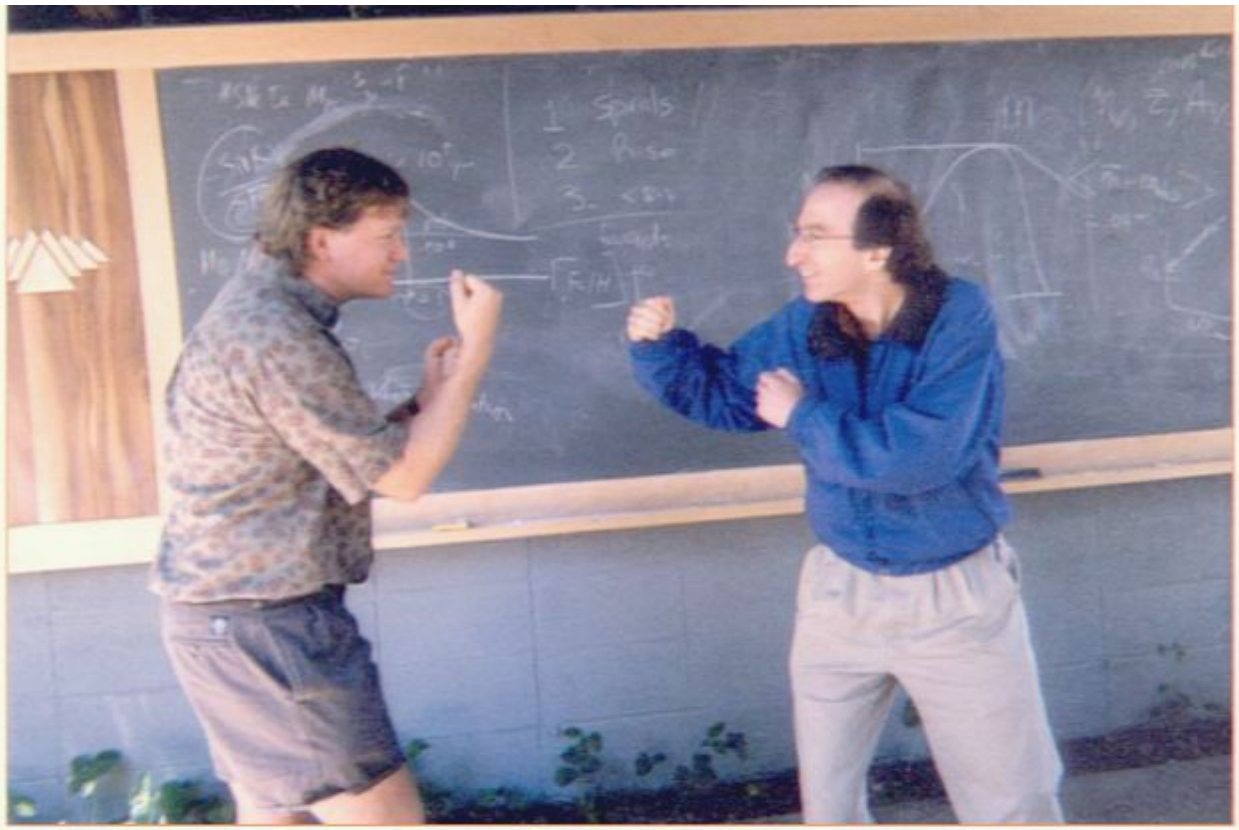

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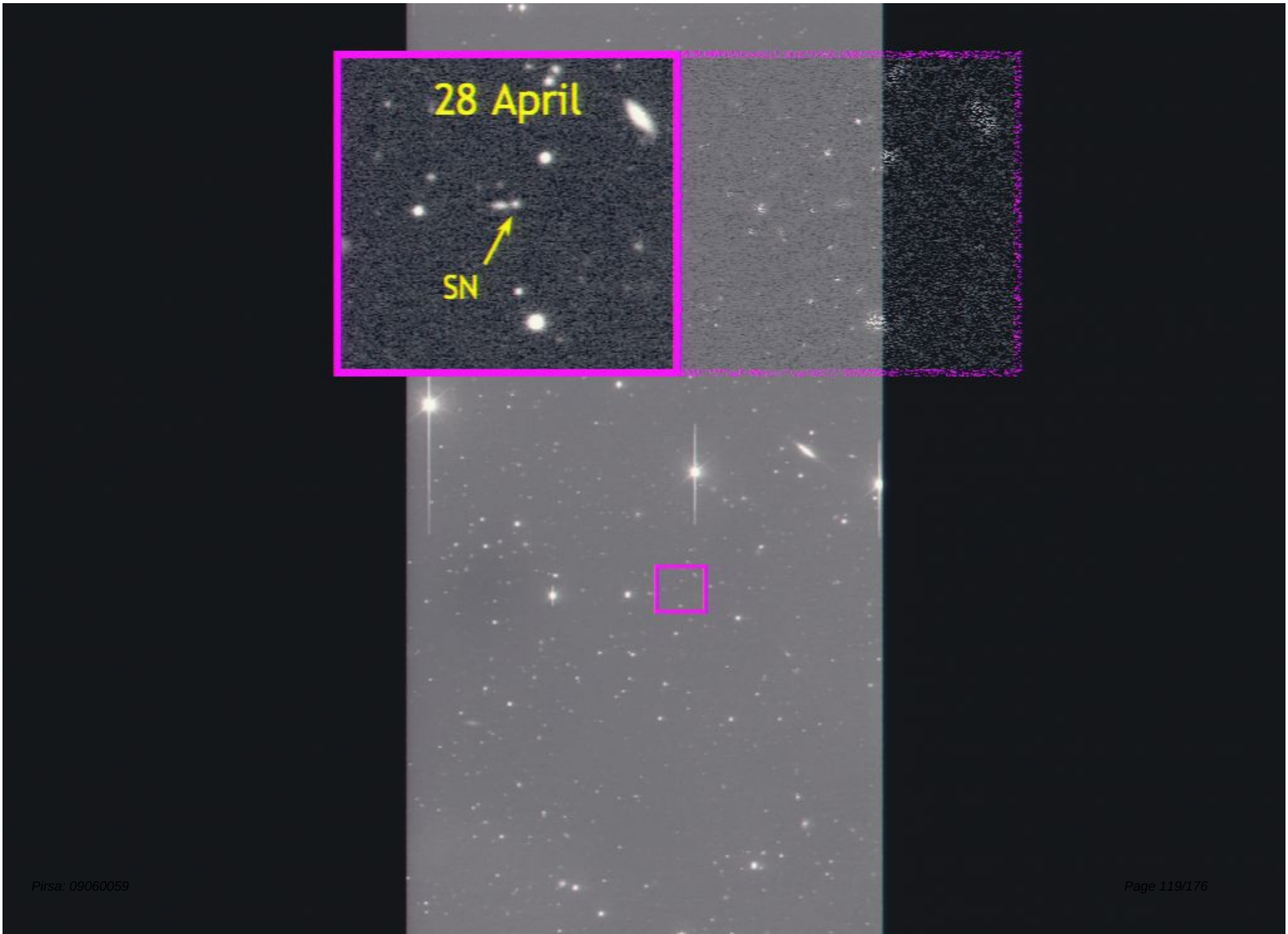
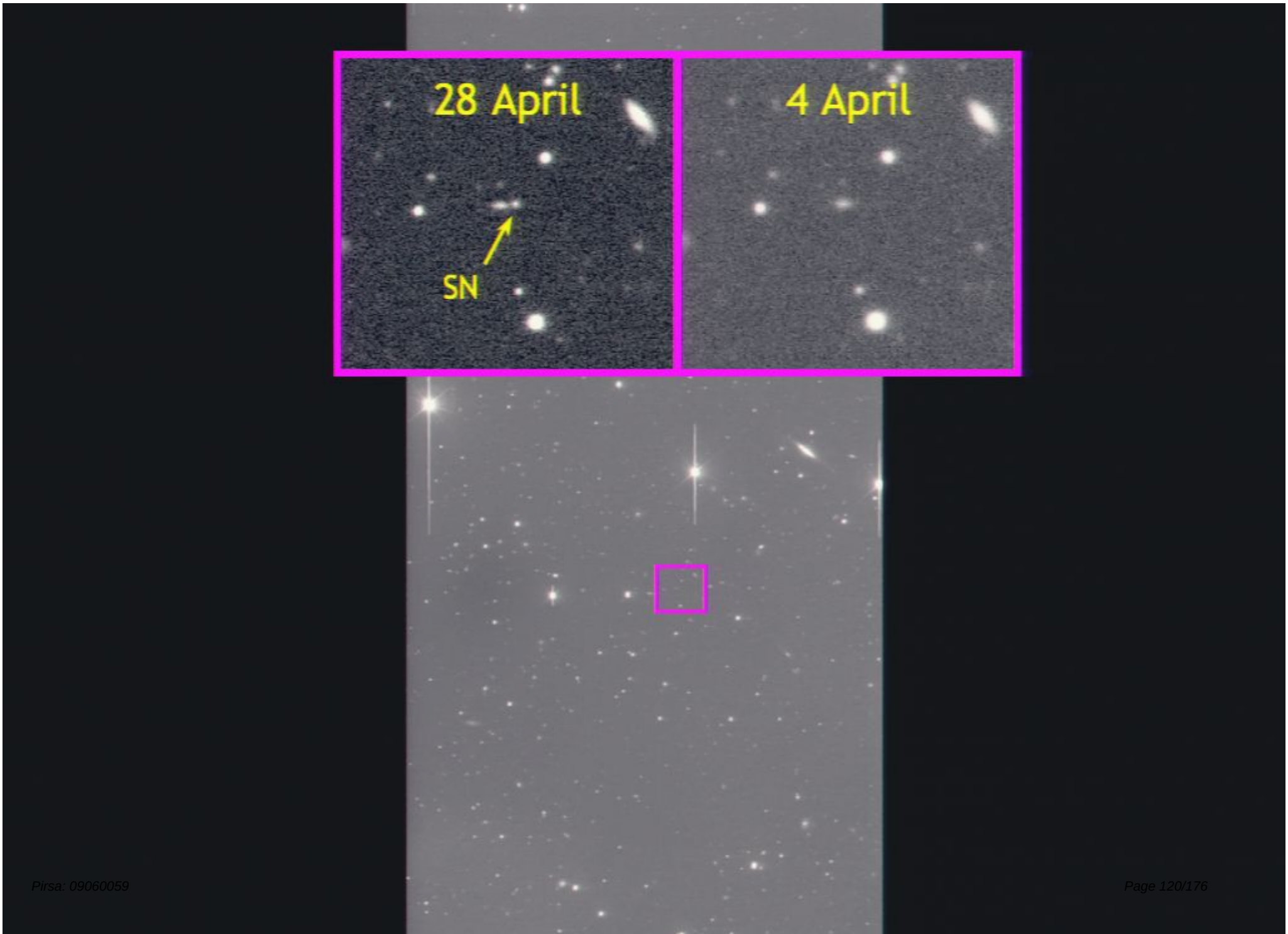
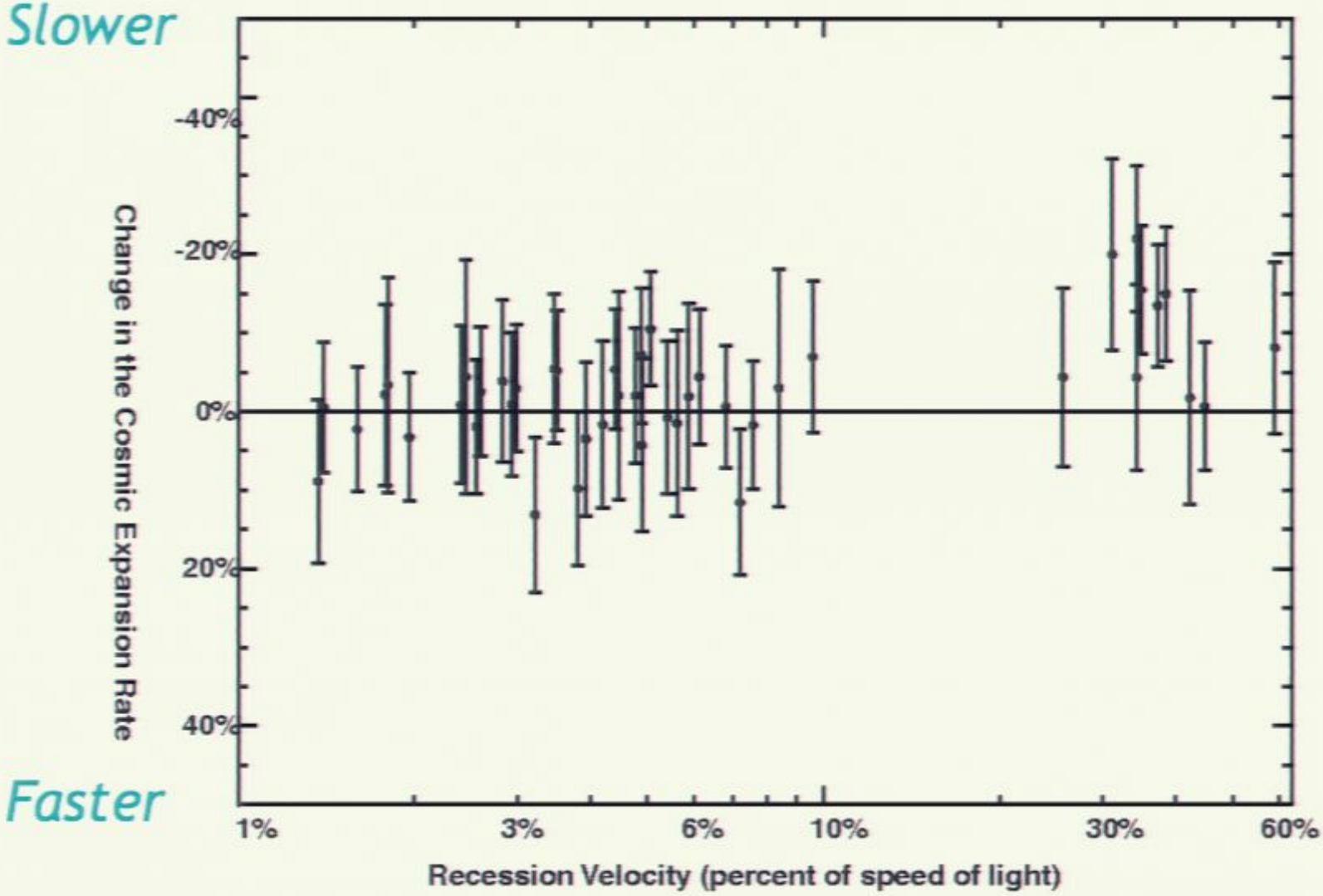
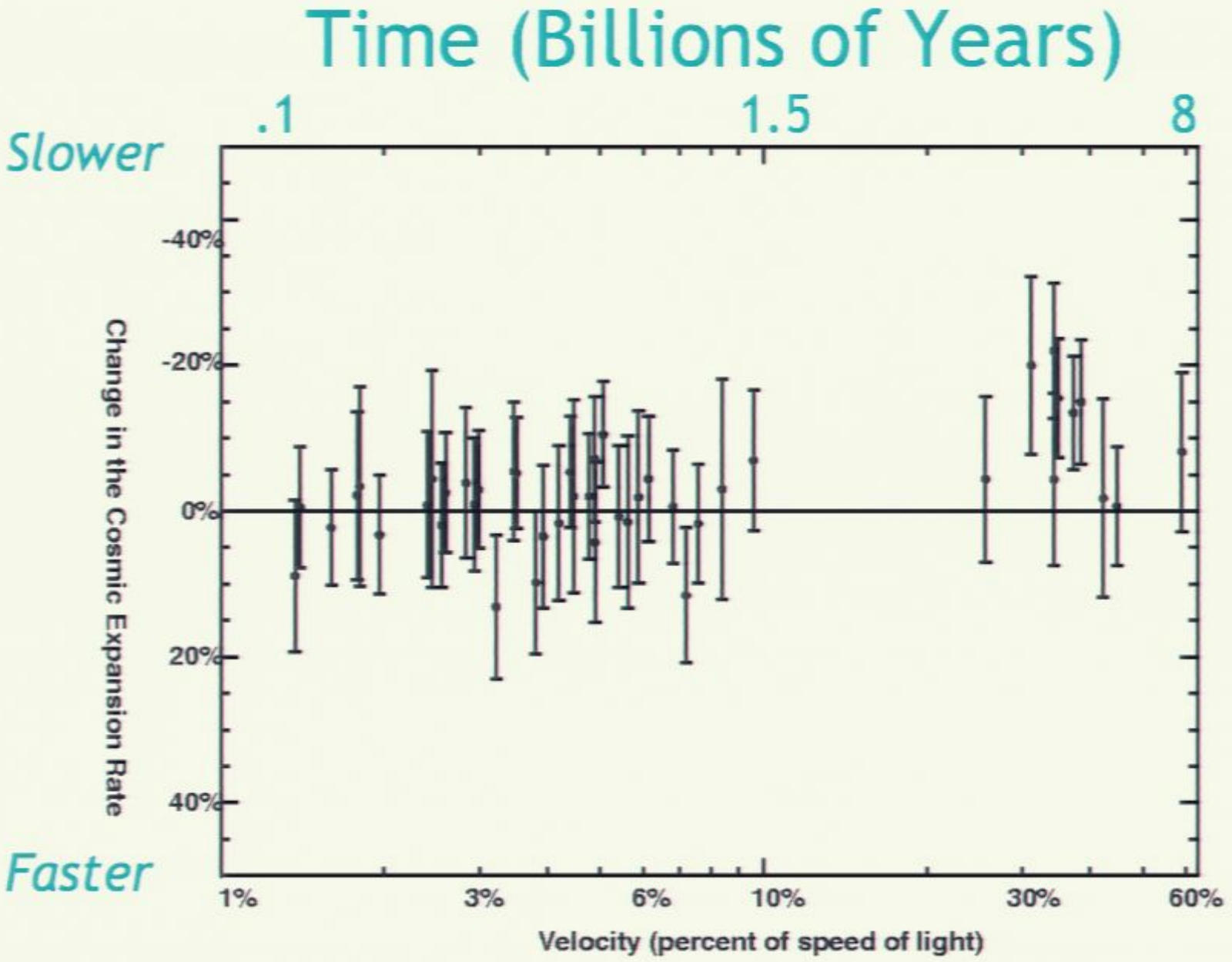
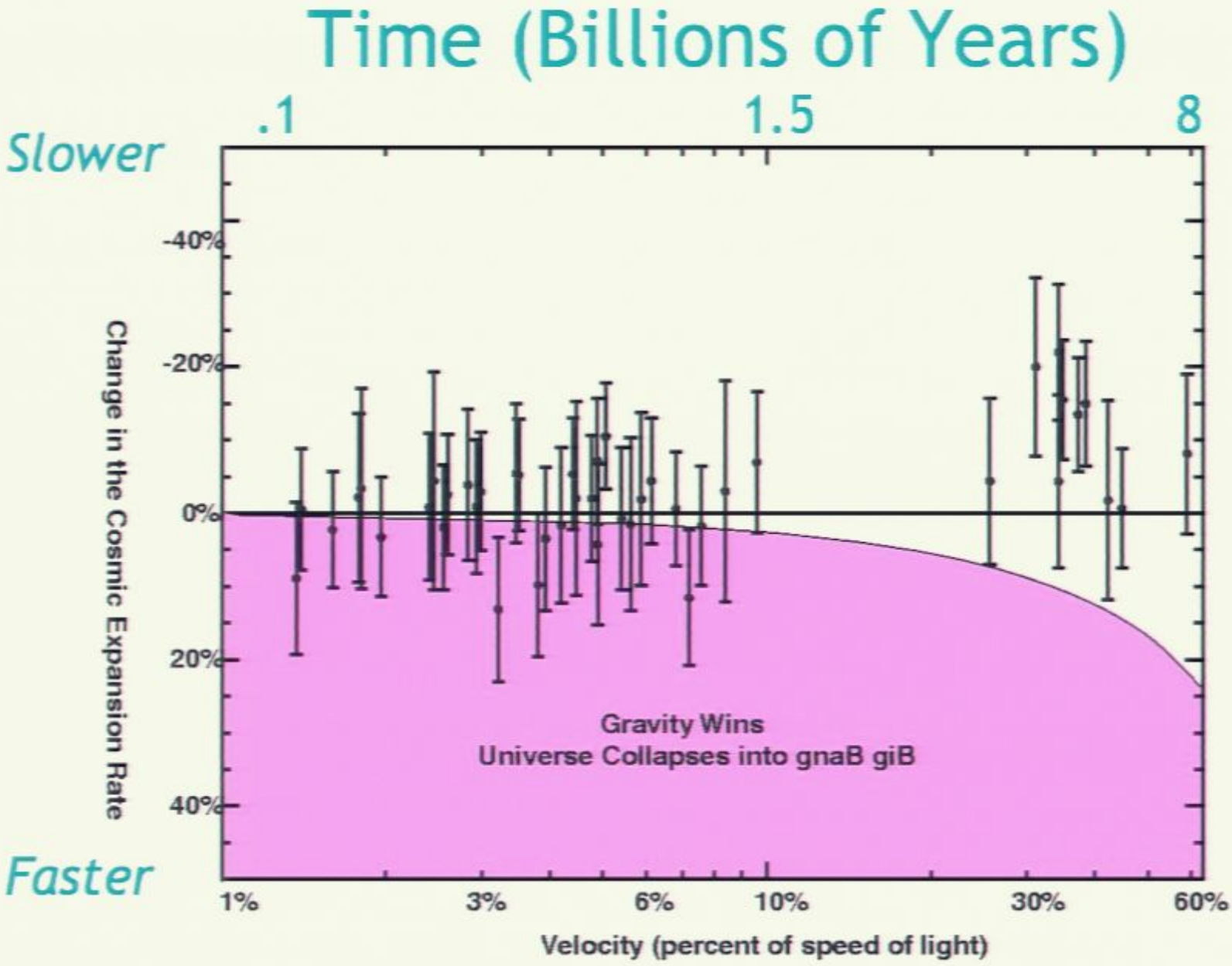
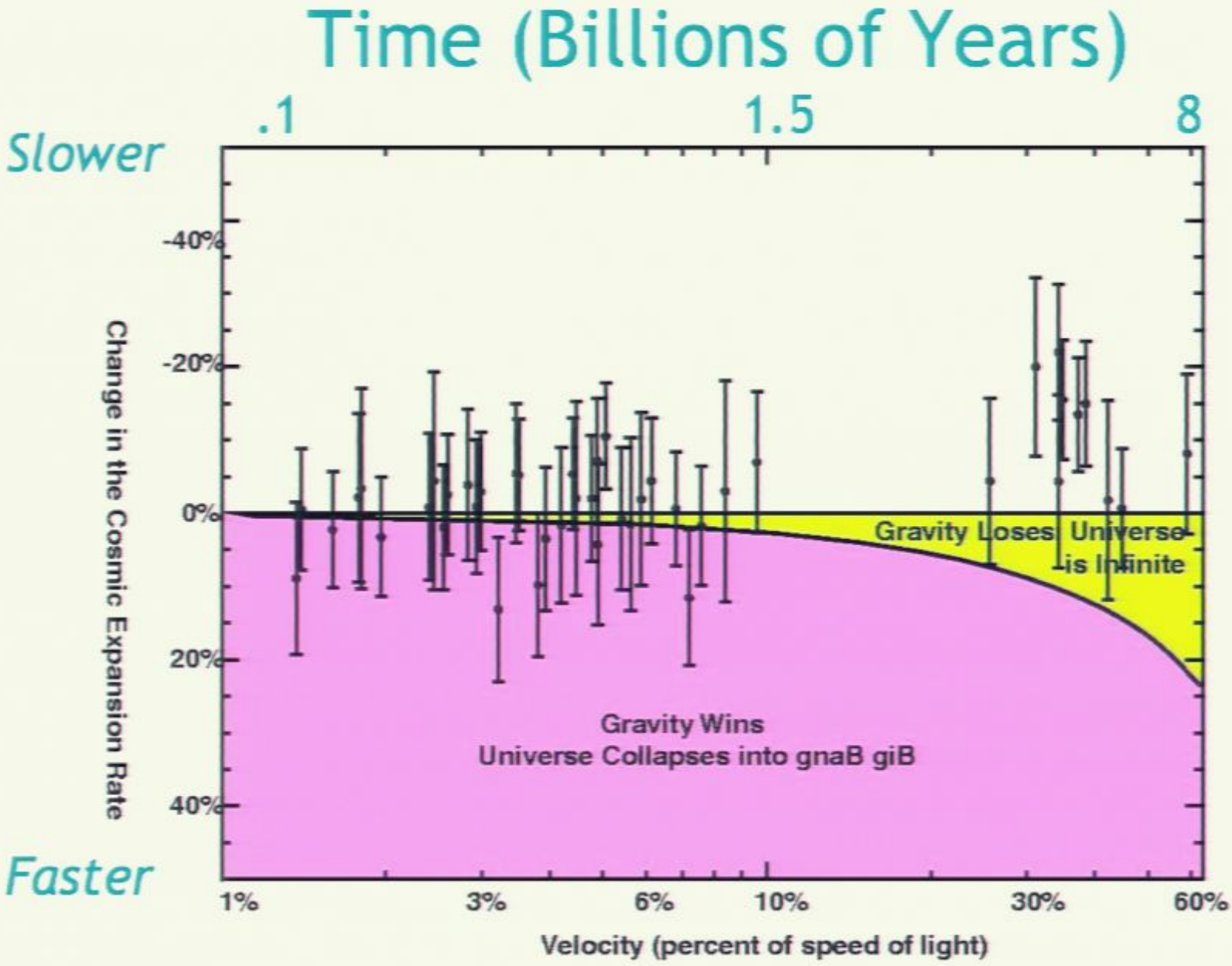

28 April
SN


28 April
SN
4 April


Slower
-40%
-20%
0%
20%
40%
Faster
Change in the Cosmic Expansion Rate
1%
3%
6%
10%
30%
60%
Recession Velocity (percent of speed of light)


Time (Billions of Years)
.1
1.5
8
Slower
Faster
-40%
-20%
0%
20%
40%
Change in the Cosmic Expansion Rate
1%
3%
6%
10%
30%
60%
Velocity (percent of speed of light)


Time (Billions of Years)
.1
1.5
8
Slower
Faster
-40%
-20%
0%
20%
40%
Change in the Cosmic Expansion Rate
Gravity Wins
Universe Collapses into gnaB giB
1%
3%
6%
10%
30%
60%
Velocity (percent of speed of light)


Time (Billions of Years)
.1
1.5
8
Slower
Faster
-40%
-20%
0%
20%
40%
Change in the Cosmic Expansion Rate
Gravity Loses Universe is Infinite
Gravity Wins
Universe Collapses into gnaB giB
1%
3%
6%
10%
30%
60%
Velocity (percent of speed of light)

OBSERVATIONAL EVIDENCE FROM SUPERNOVAE FOR AN ACCELERATING UNIVERSE AND A COSMOLOGICAL CONSTANT

ADAM G. RIESS,[1] ALEXEI V. FILIPPENKO,[1] PETER CHALLIS,[2] ALEJANDRO CLOCCHIATTI,[3] ALAN DIERCKS,[4] PETER M. GARNAVICH,[2] RON L. GILLILAND,[5] CRAIG J. HOGAN,[4] SAURABH JHA,[2] ROBERT P. KIRSHNER,[2] B. LEIBUNDGUT,[6] M. M. PHILLIPS,[7] DAVID REISS,[4] BRIAN P. SCHMIDT,[8,9] ROBERT A. SCHOMMER,[7] R. CHRIS SMITH,[7,10] J. SPYROMILIO,[6] CHRISTOPHER STUBBS,[4] NICHOLAS B. SUNTZEFF,[7] AND JOHN TONRY[11]

MEASUREMENTS OF Ω AND Λ FROM 42 HIGH-REDSHIFT SUPERNOVAE

S. PERLMUTTER,[1] G. ALDERING, G. GOLDHABER,[1] R. A. KNOP, P. NUGENT, P. G. CASTRO,[2] S. DEUSTUA, S. FABBRO,[3] A. GOOBAR,[4] D. E. GROOM, I. M. HOOK,[5] A. G. KIM,[1,6] M. Y. KIM, J. C. LEE,[7] N. J. NUNES,[2] R. PAIN,[3] C. R. PENNYPACKER,[8] AND R. QUIMBY

Institute for Nuclear and Particle Astrophysics, E. O. Lawrence Berkeley National Laboratory, Berkeley, CA 94720

C. LIDMAN

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P. RUIZ-LAPUENTE

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A. S. FRUCHTER AND N. PANAGIA[9]

Space Telescope Science Institute, Baltimore, MD

H. J. M. NEWBERG

Fermi National Laboratory, Batavia, IL

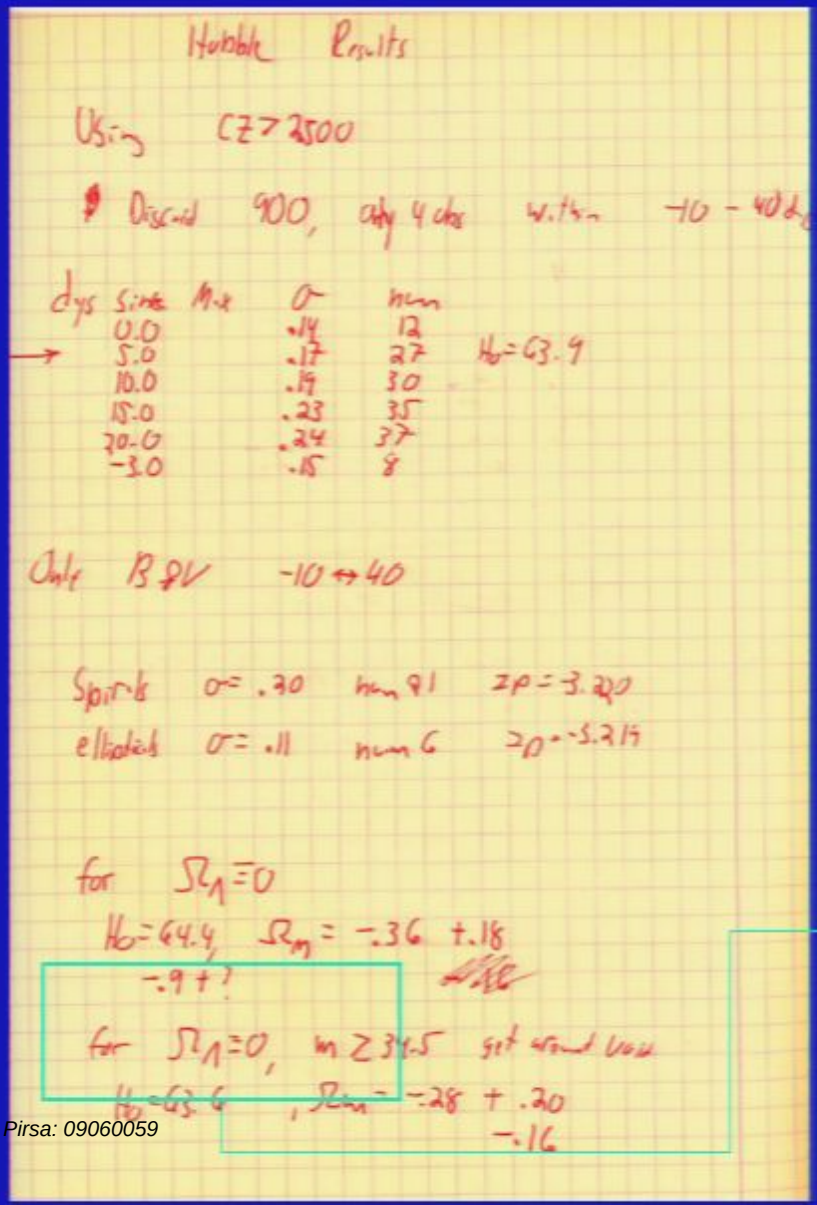
AND

W. J. COUCH

University of New South Wales, Sydney, Australia

EUREKA?

Adam's Lab book, Key Page, Fall 1997:


Hubble Results

Using cz > 2500

Discard 900, only 4 obs within -10 - 40

dys	Sinks	Mix	σ	num	
	0.0		.14	12	
→	5.0		.17	27	$H_0 = 63.9$
	10.0		.19	30	
	15.0		.23	35	
	20.0		.24	37	
	-3.0		.15	8	

Only BBV -10 ↔ 40

Spirals σ = .20 num 91 zp = 3.220

ellipticals σ = .11 num 6 zp = -5.214

for $\Omega_\Lambda = 0$

$H_0 = 64.4$, $\Omega_m = -.36 \pm .18$

$-.9 \pm ?$

for $\Omega_\Lambda = 0$, m ≥ 34.5 got around this

$H_0 = 63.6$, $\Omega_m = -.28 + .20 - .16$

Adam Riess was leading our efforts in the fall of 1997 to increase our sample of 4 objects to 15.

He found the total sum of Mass to be negative - which meant acceleration.

for $\Omega_\Lambda = 0$

$\Omega_m = -.36 \pm .18$

Accelerating Universe!

Type Ia supernovae Measurements indicate that the Universe is a 30%:70% mix of normal gravitating matter, and material which can push on the Universe…

Accelerating Universe!

Type Ia supernovae
Measurements indicate that the Universe is a 30%:70% mix of normal gravitating matter, and material which can push on the Universe…

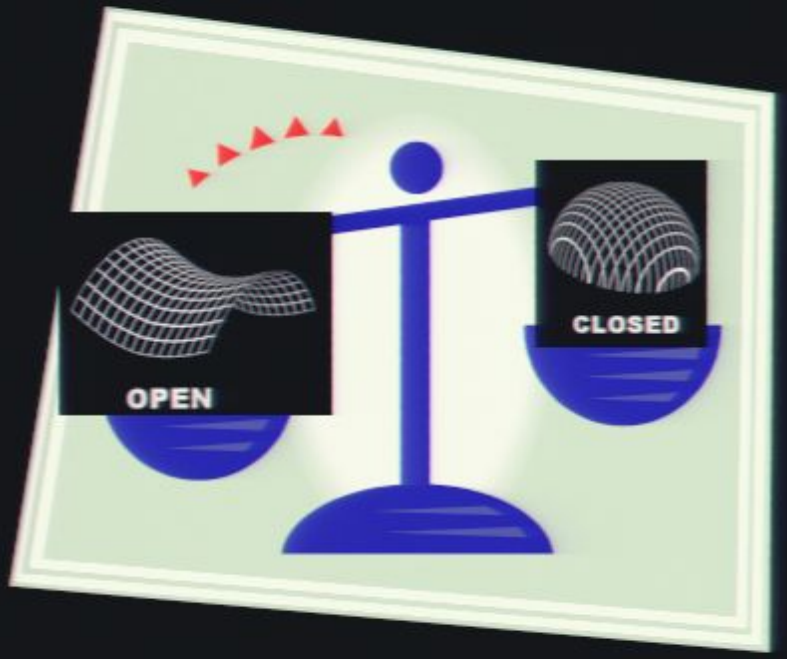
If you believe our results…

AAT-2dF & Sloan Redshift Surveys: A Census of the 1-Billion light Neighbourhood

ANGLO-AUSTRALIAN TELESCOPE

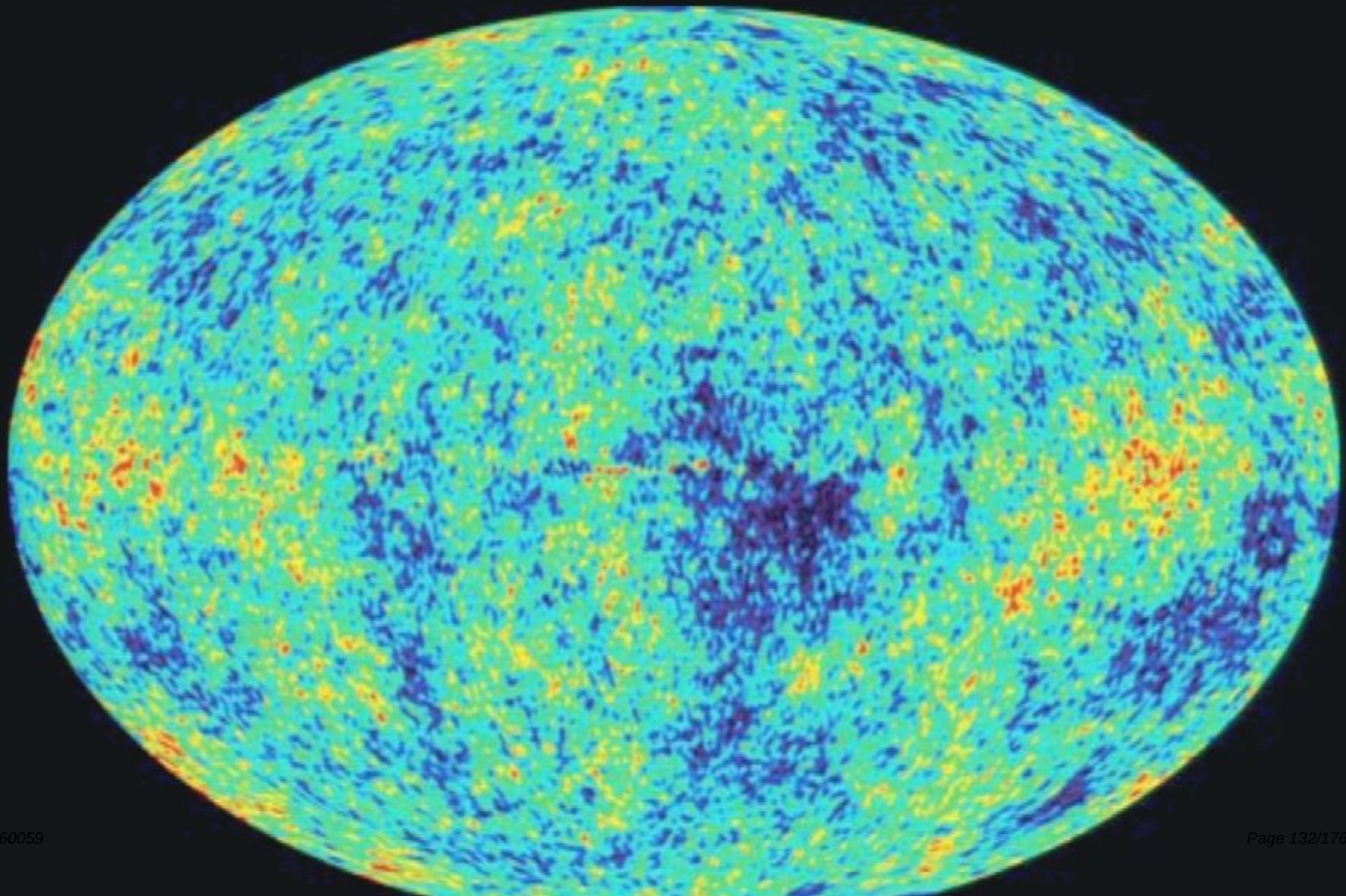
TWO-DEGREE FIELD FACILITY

The Gravity seen by the 2dF/SDSS Redshift surveys corresponds to A Universe which has 27% of density Necessary to be flat.

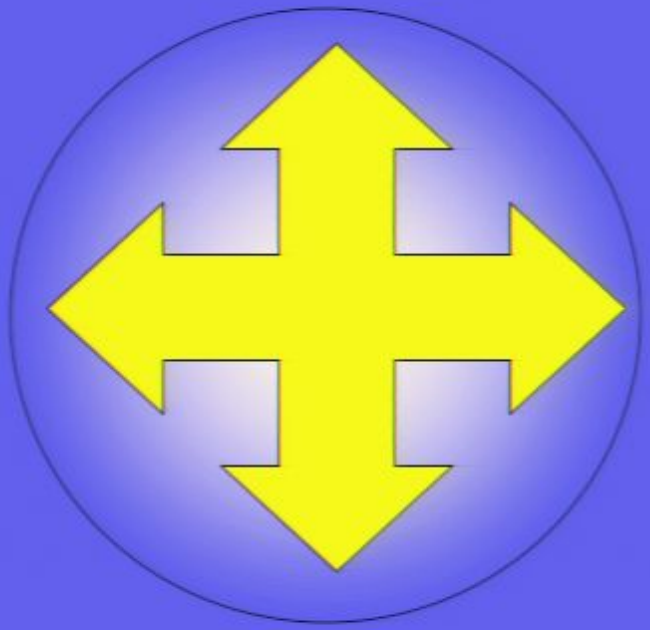


The Cosmic Microwave Background

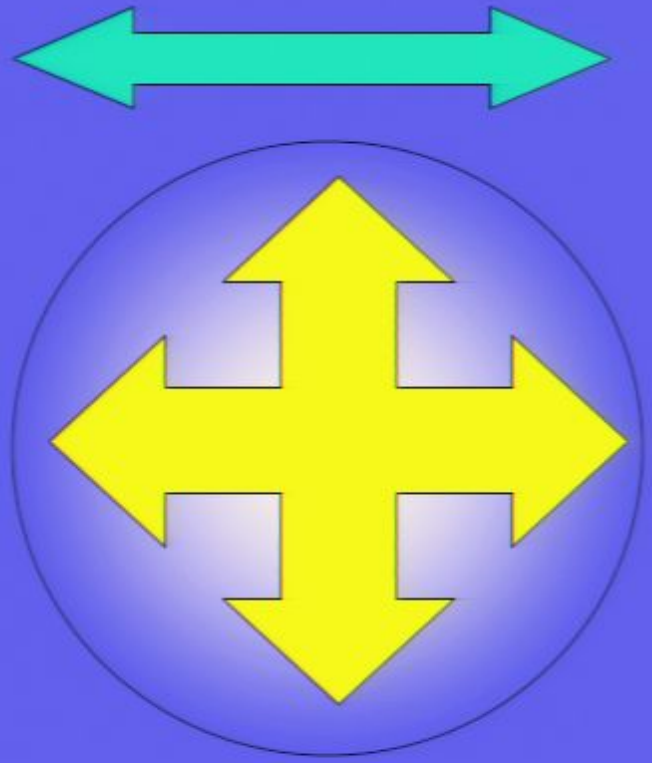
13.7 Billion Years ago...Universe 3000°C



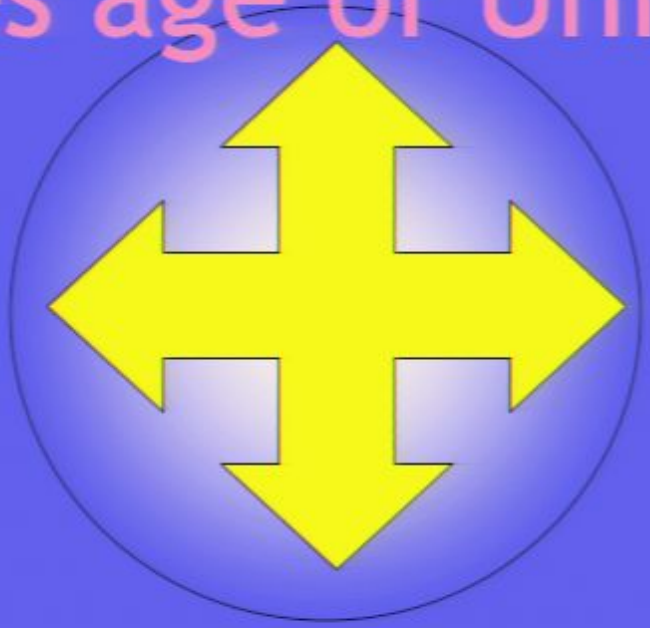
Gravitational Collapse



Heating = Pressure



Speed of sound times age of Universe



A Cosmic Ruler - Bumps in Early Universe have a size related to the speed of sound and age of the Universe

- Physics tells us how big the blobs are in the cosmic microwave background.

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- Measurement tells us how big the blobs appear to us now.

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- How big they appear tells us the geometry of space! Objects of Similar size appear larger in a finite curved space.

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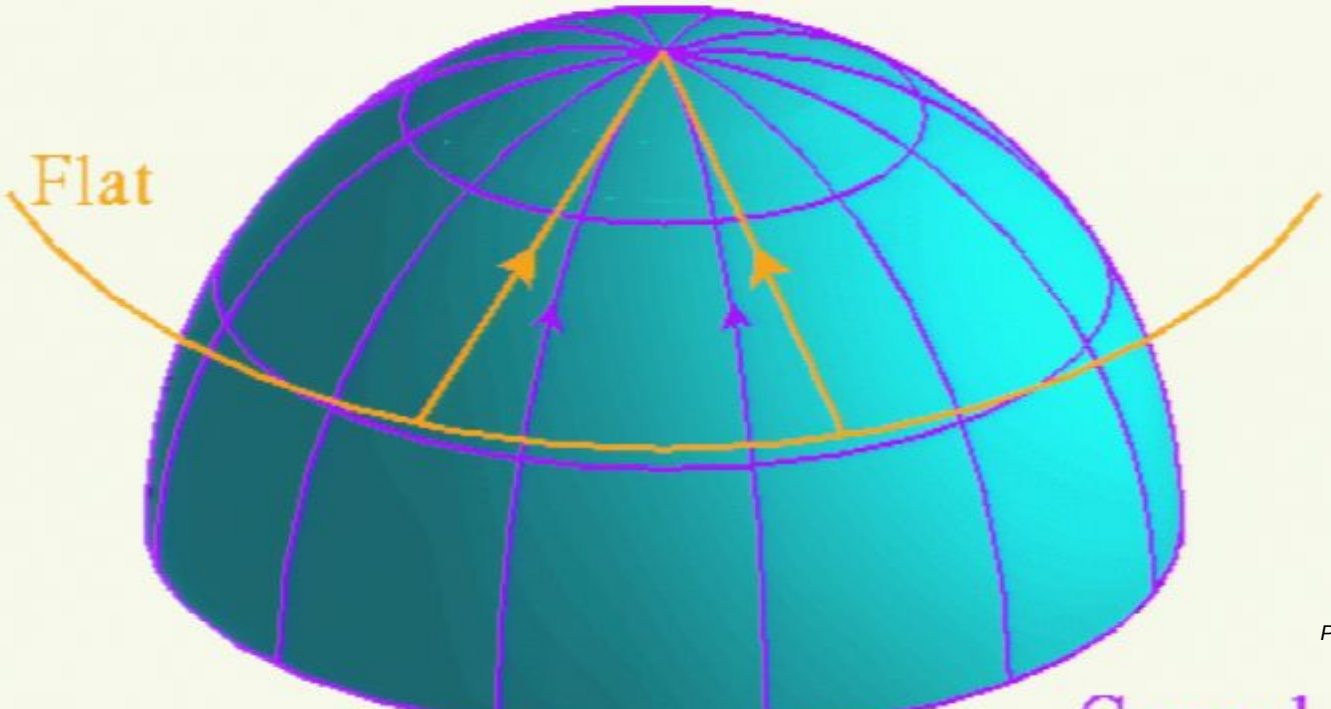

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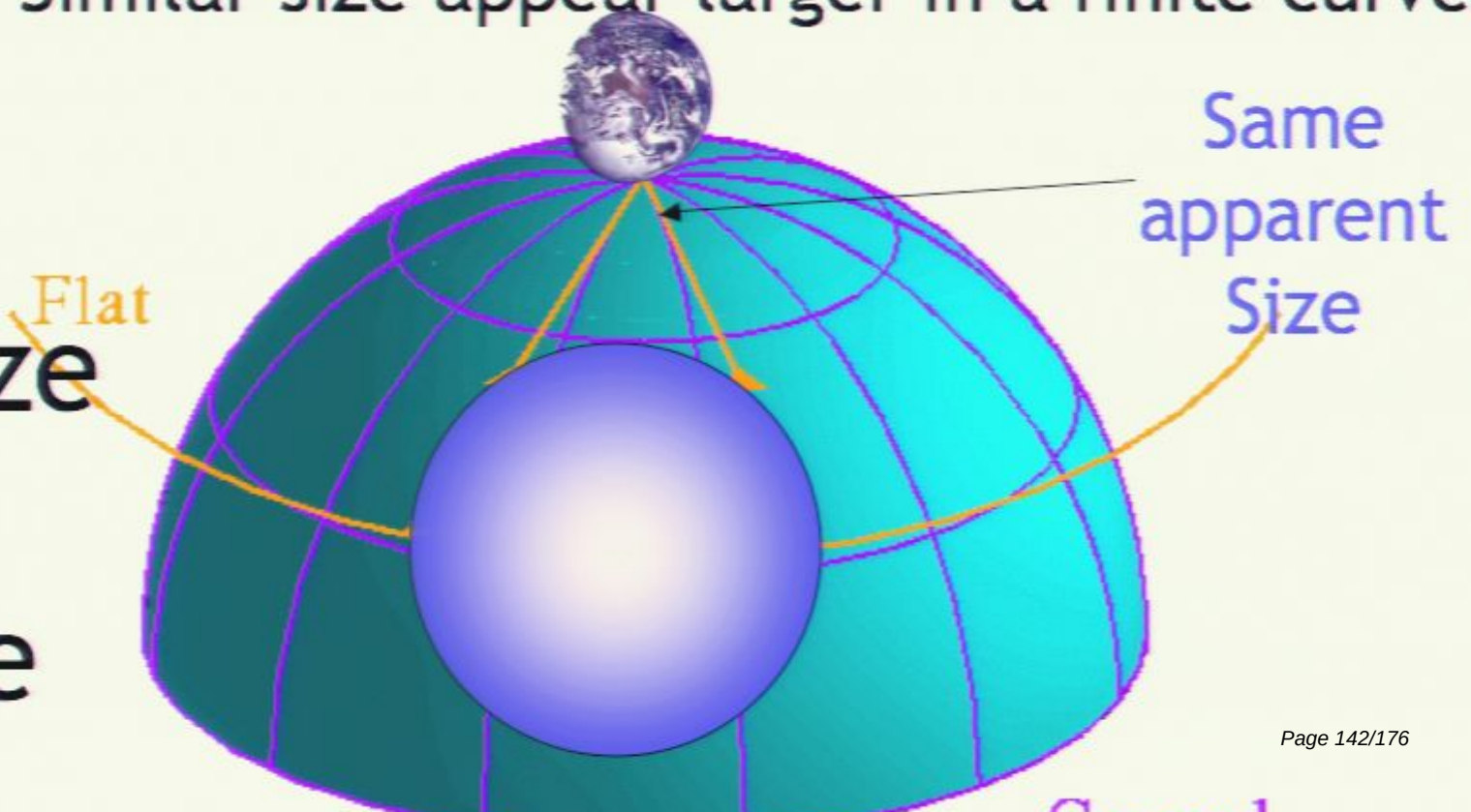

Blobs size
Flat
Universe

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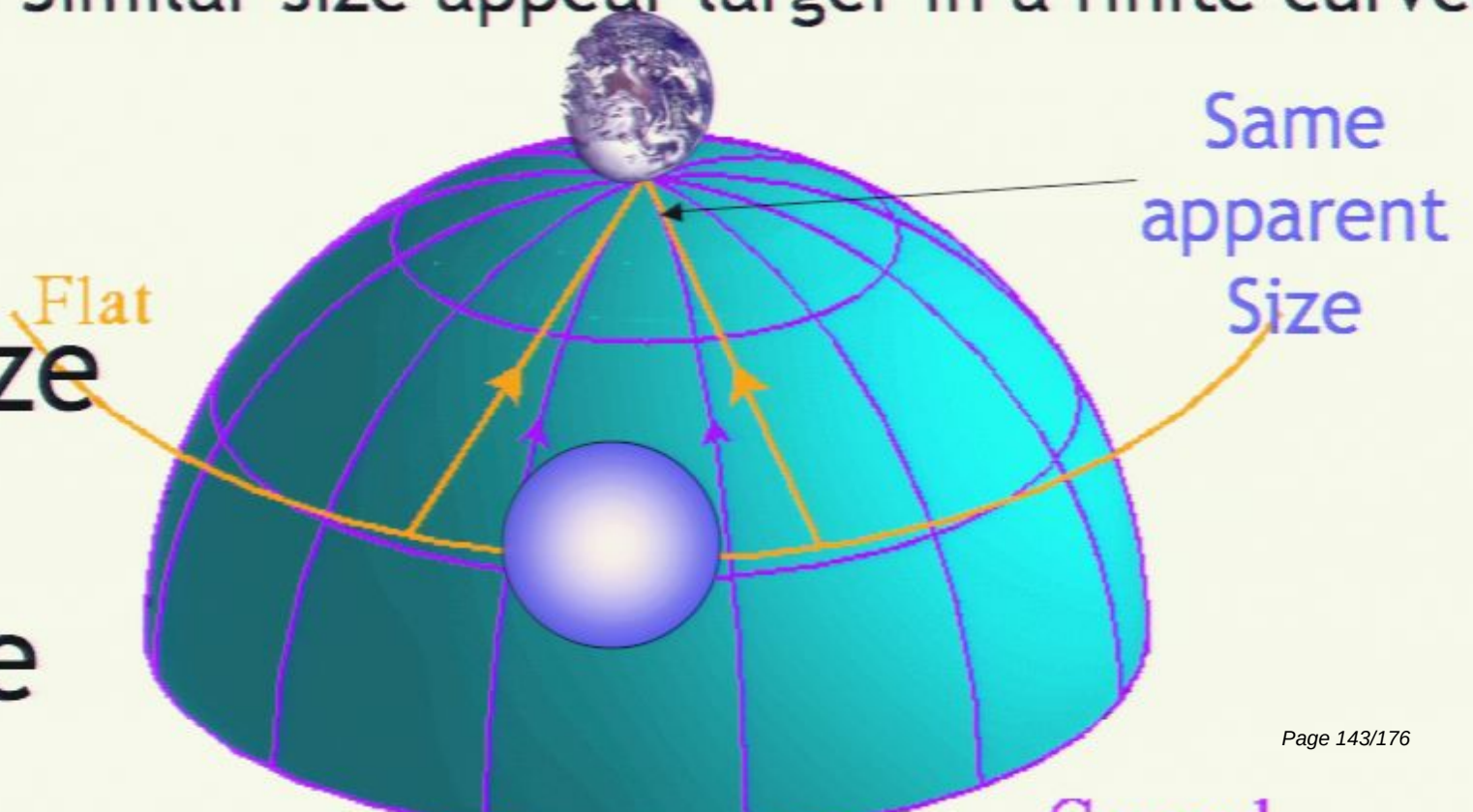
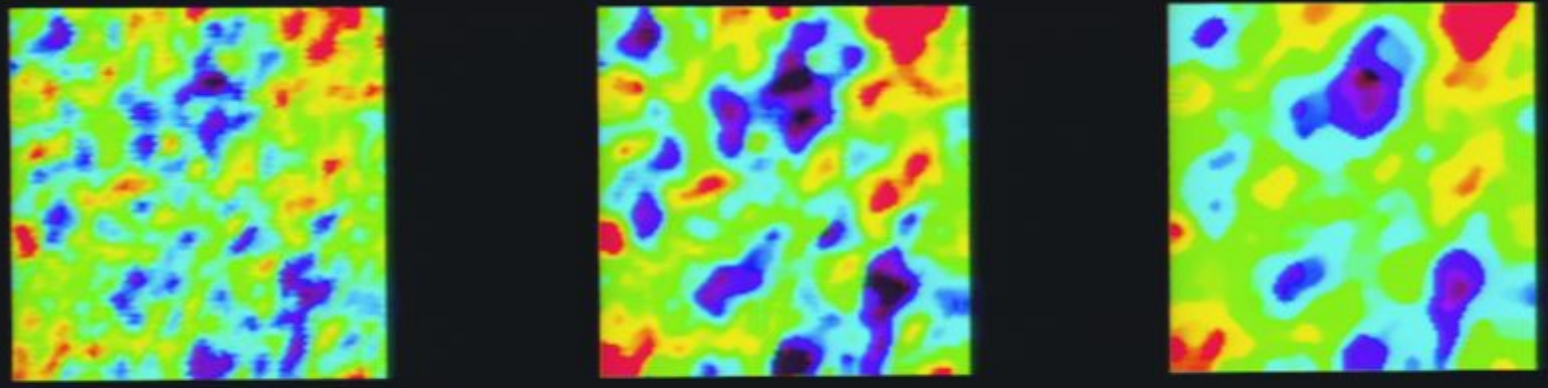
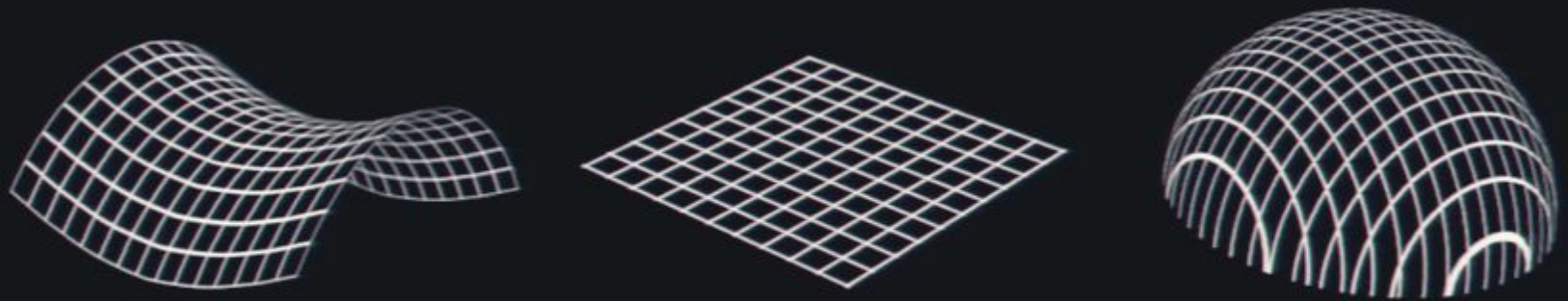


Blobs size Curved Universe

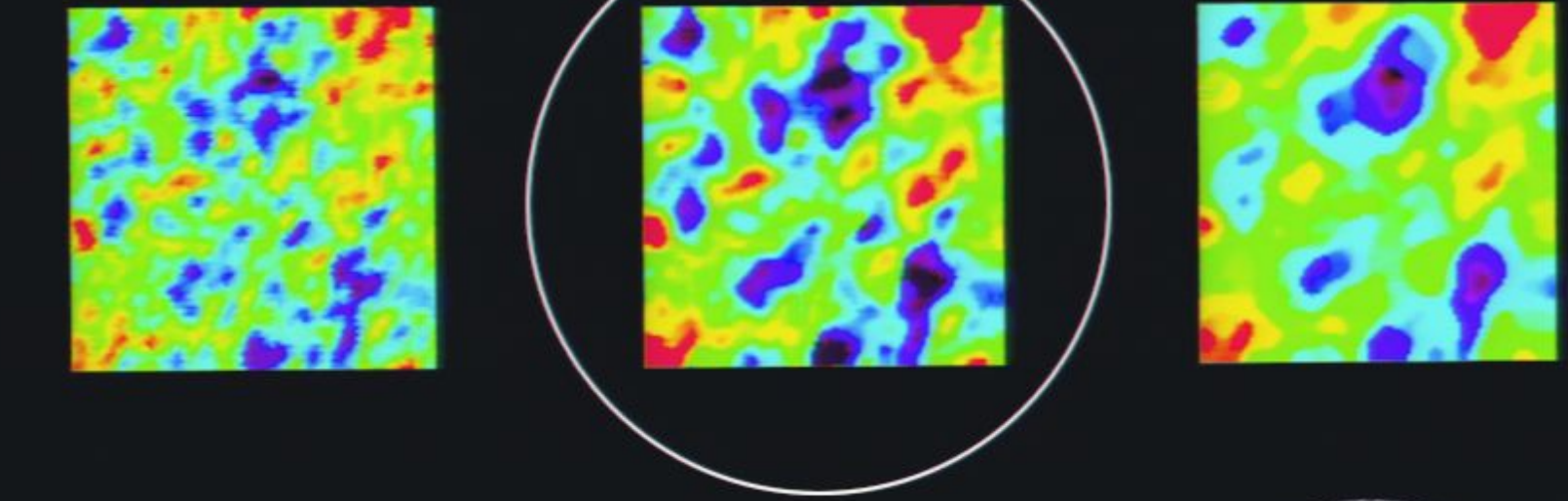
GEOMETRY OF THE UNIVERSE

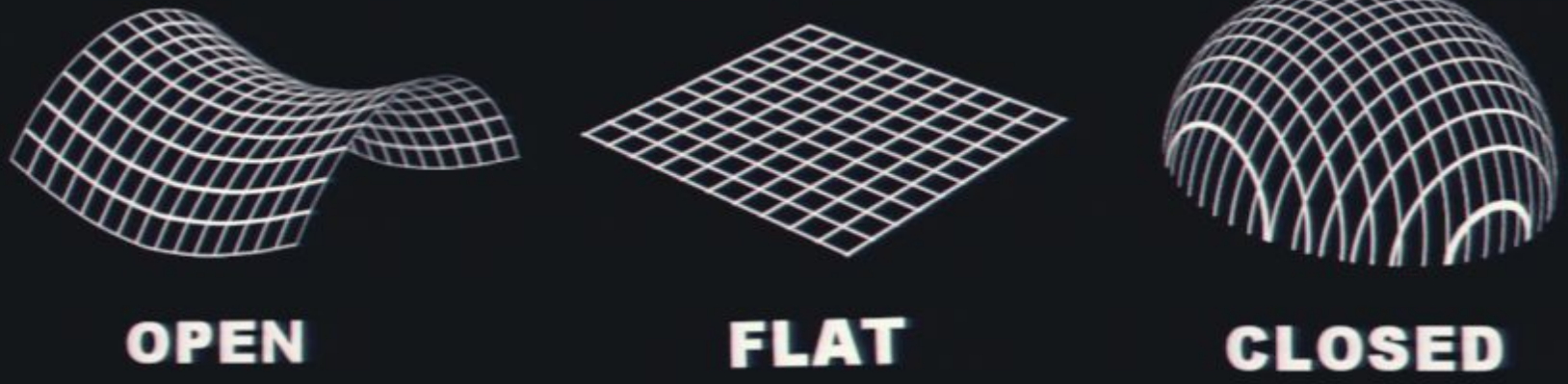




OPEN FLAT CLOSED

GEOMETRY OF THE UNIVERSE





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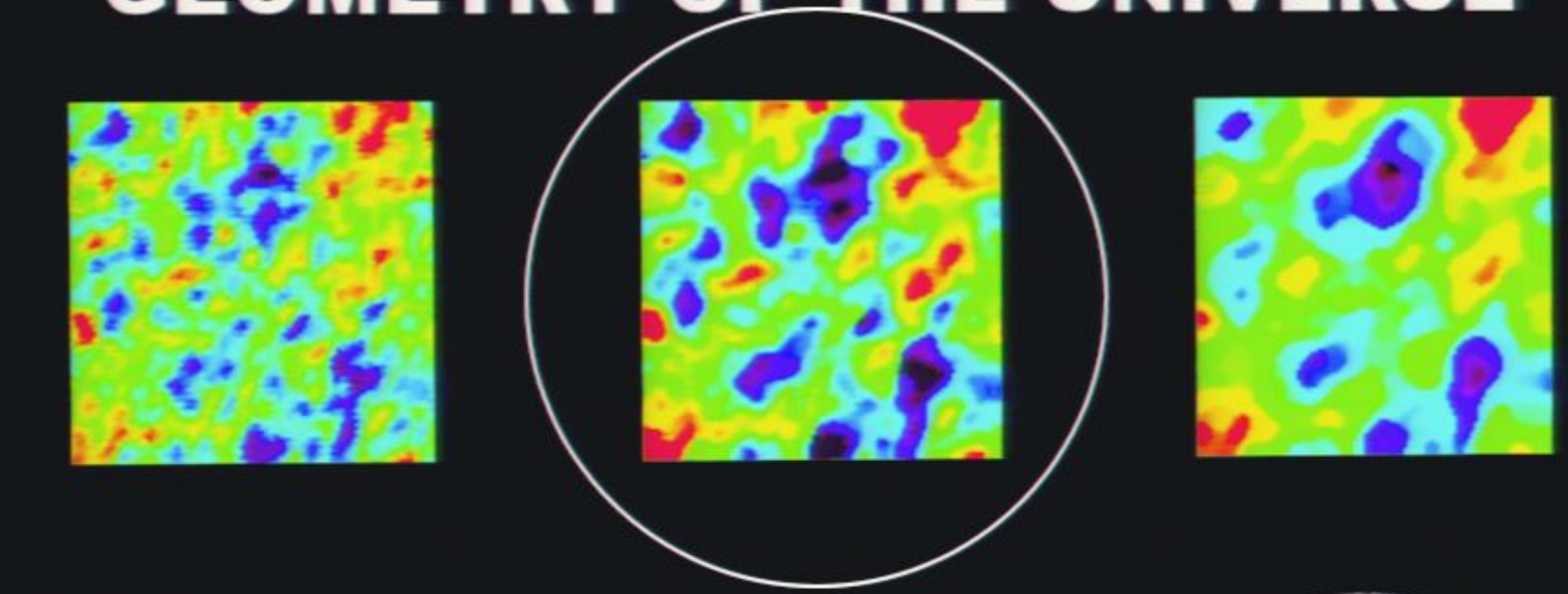
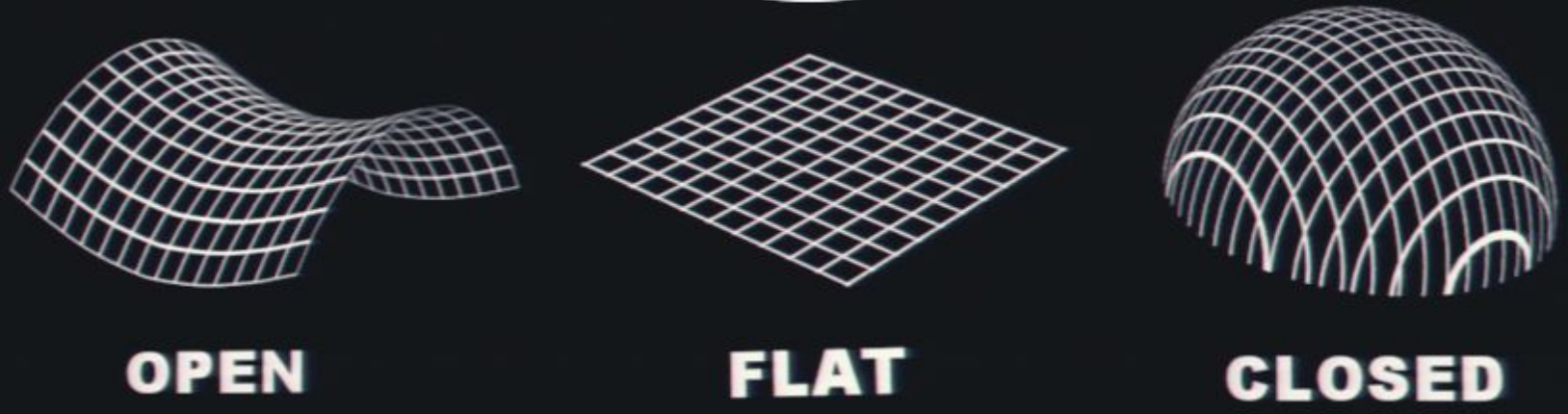




OPEN FLAT CLOSED

Universe has 102% ± 2% matter to be flat

Cosmic Subtraction

102%±2% Cosmic Microwave Background

Cosmic Subtraction

102%±2% Cosmic Microwave Background

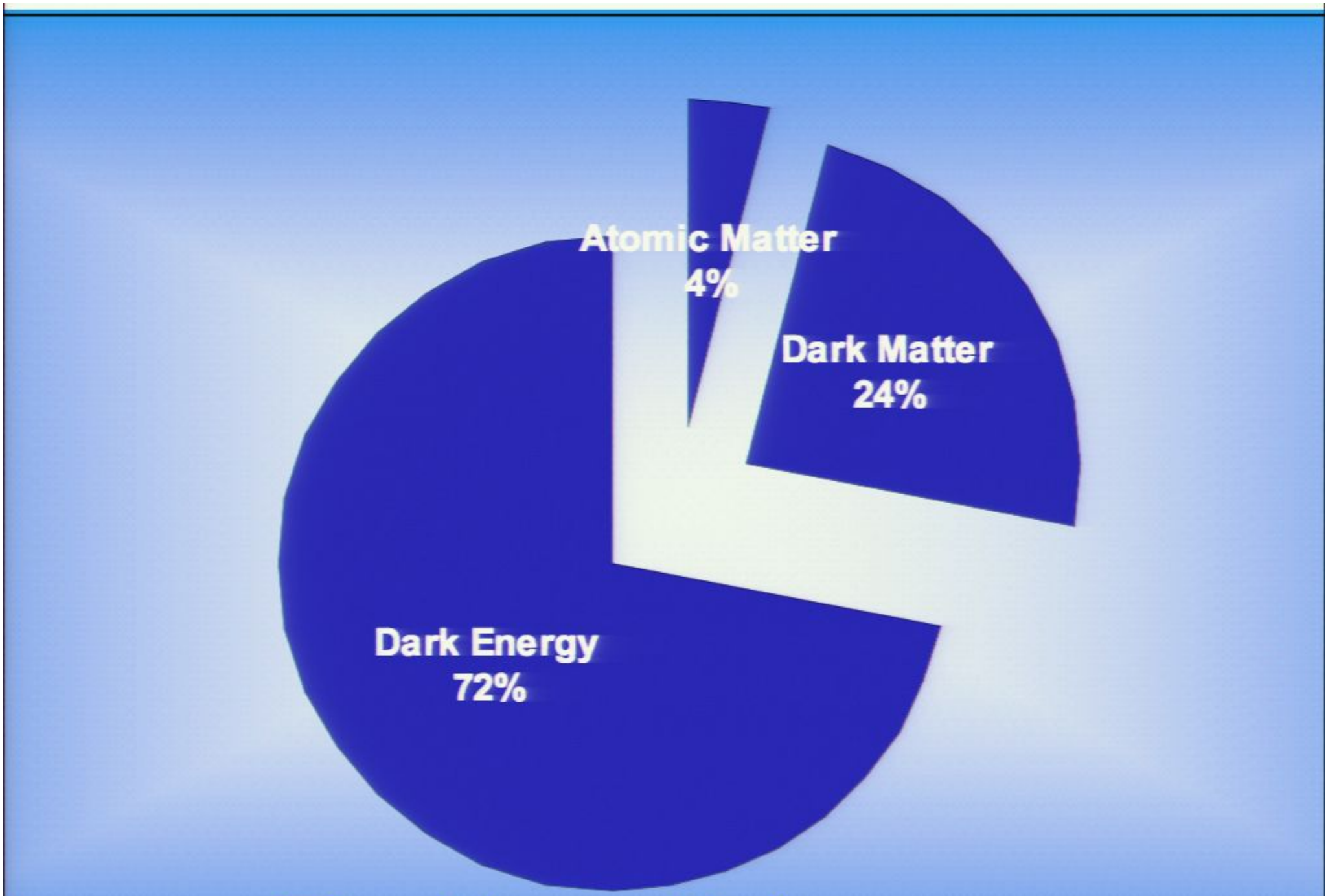
-27%±2% AAT+SDSS Experiments

Cosmic Subtraction

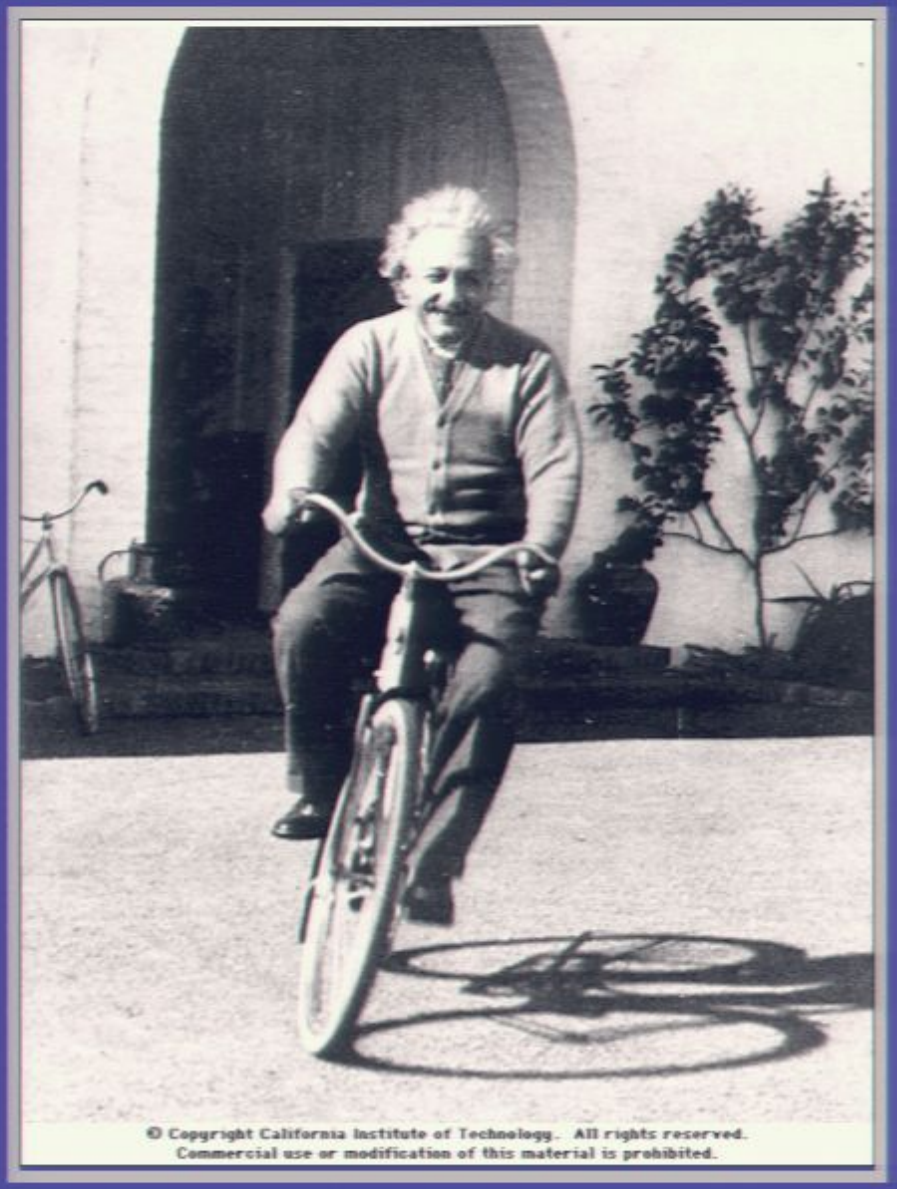
102%±2% Cosmic Microwave Background

-27%±2% AAT+SDSS Experiments

75%±4% Mystery Matter!



The Messy Universe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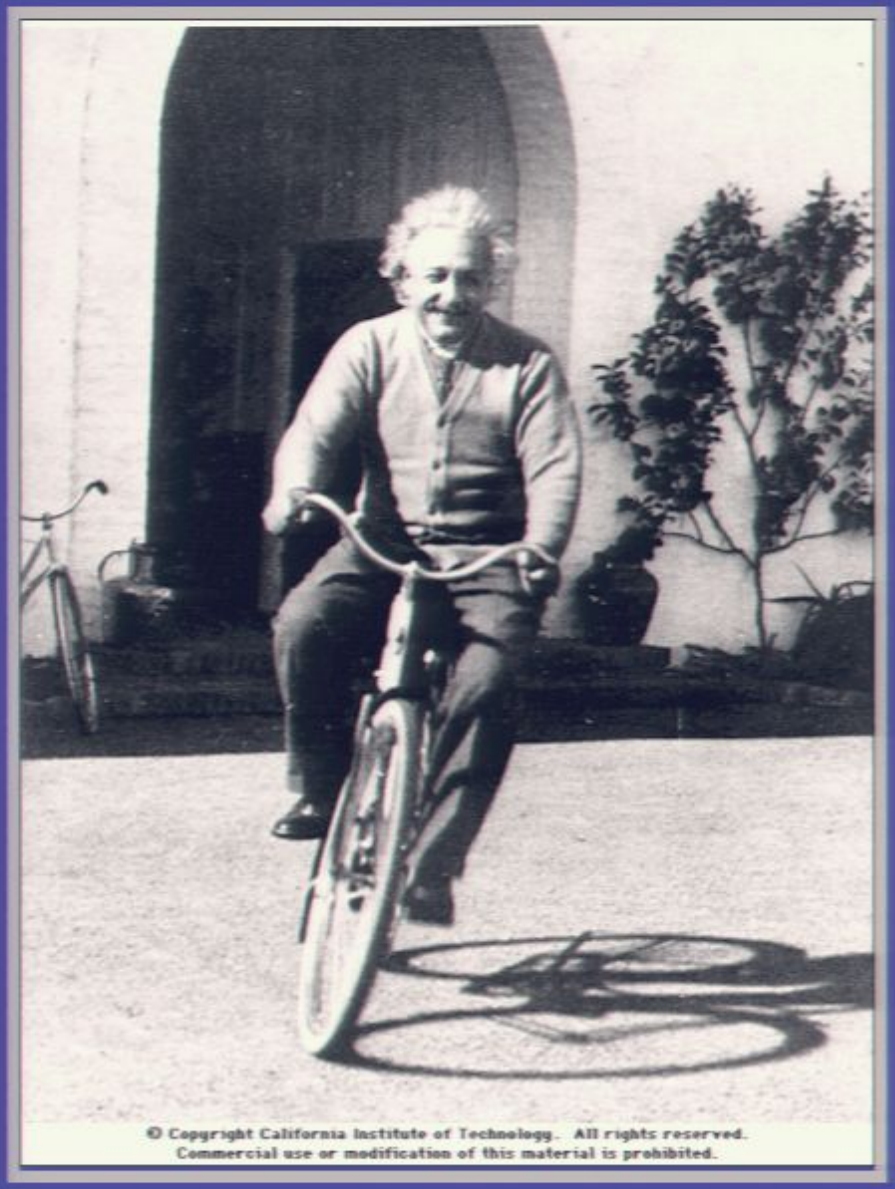
The Cosmological Constant



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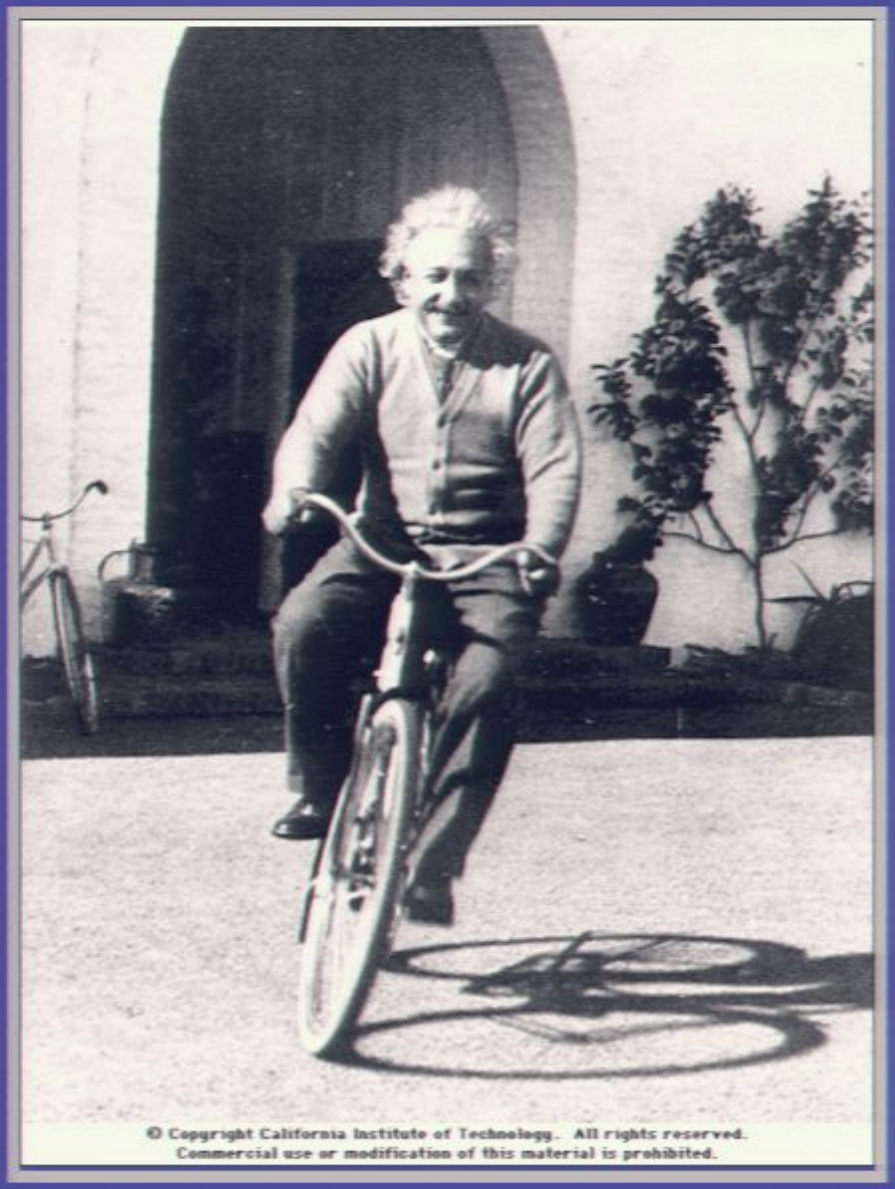
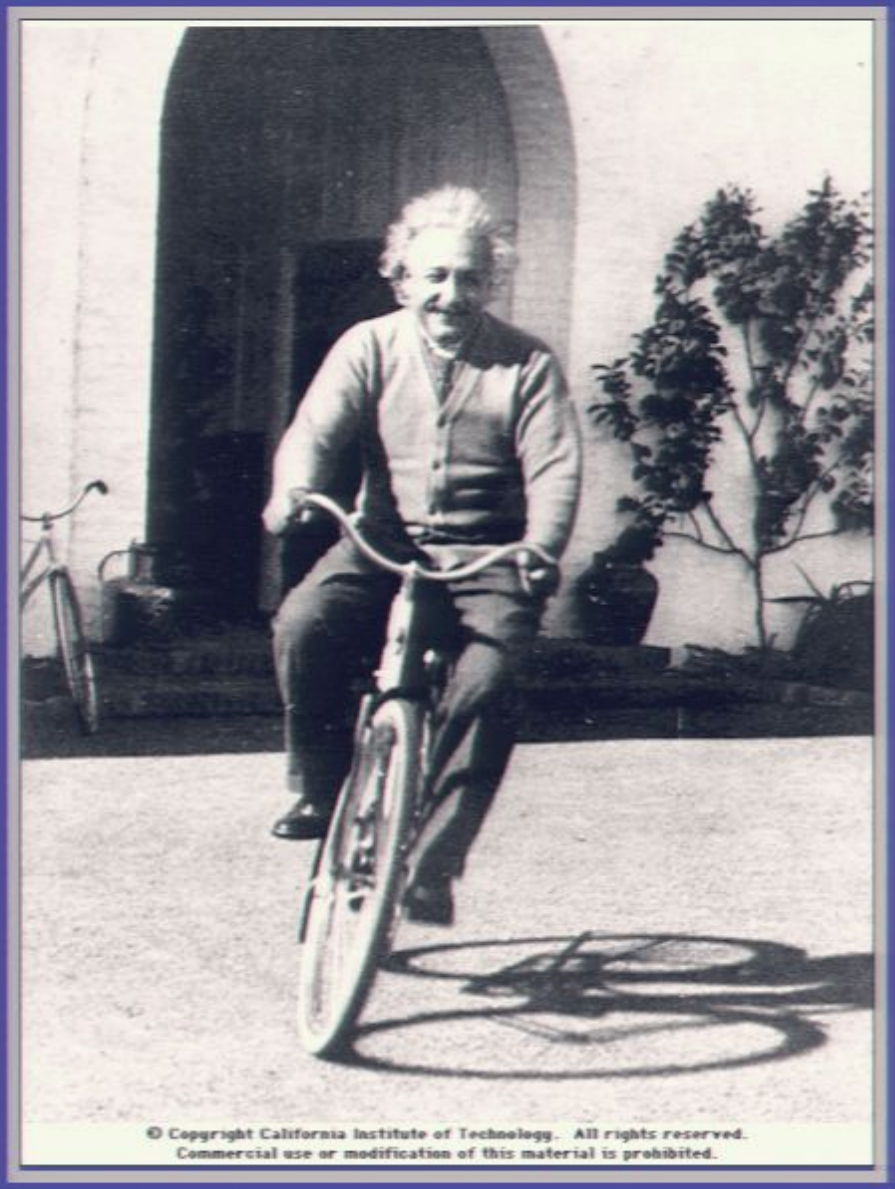
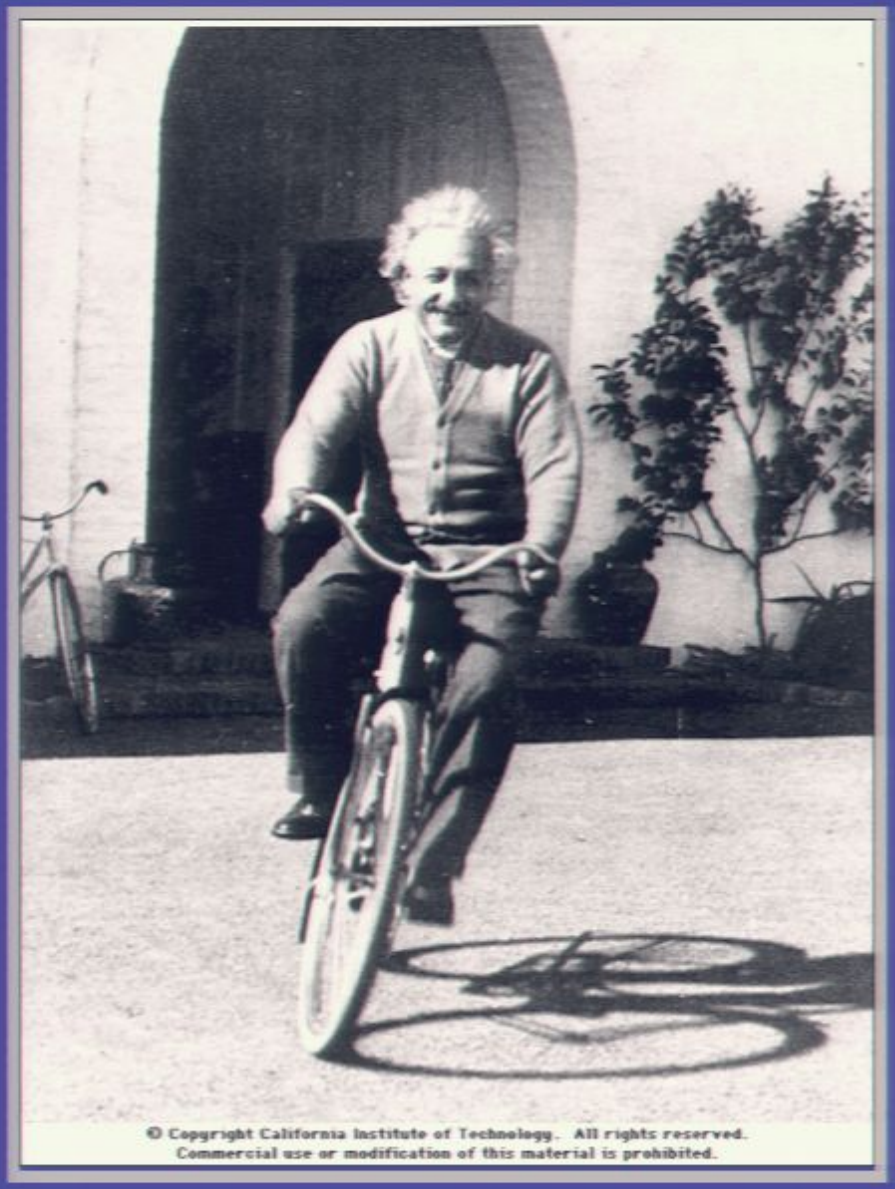




The Cosmological Constant

Originally proposed by Einstein to counteract the Universe's gravitational attraction



The Cosmological Constant

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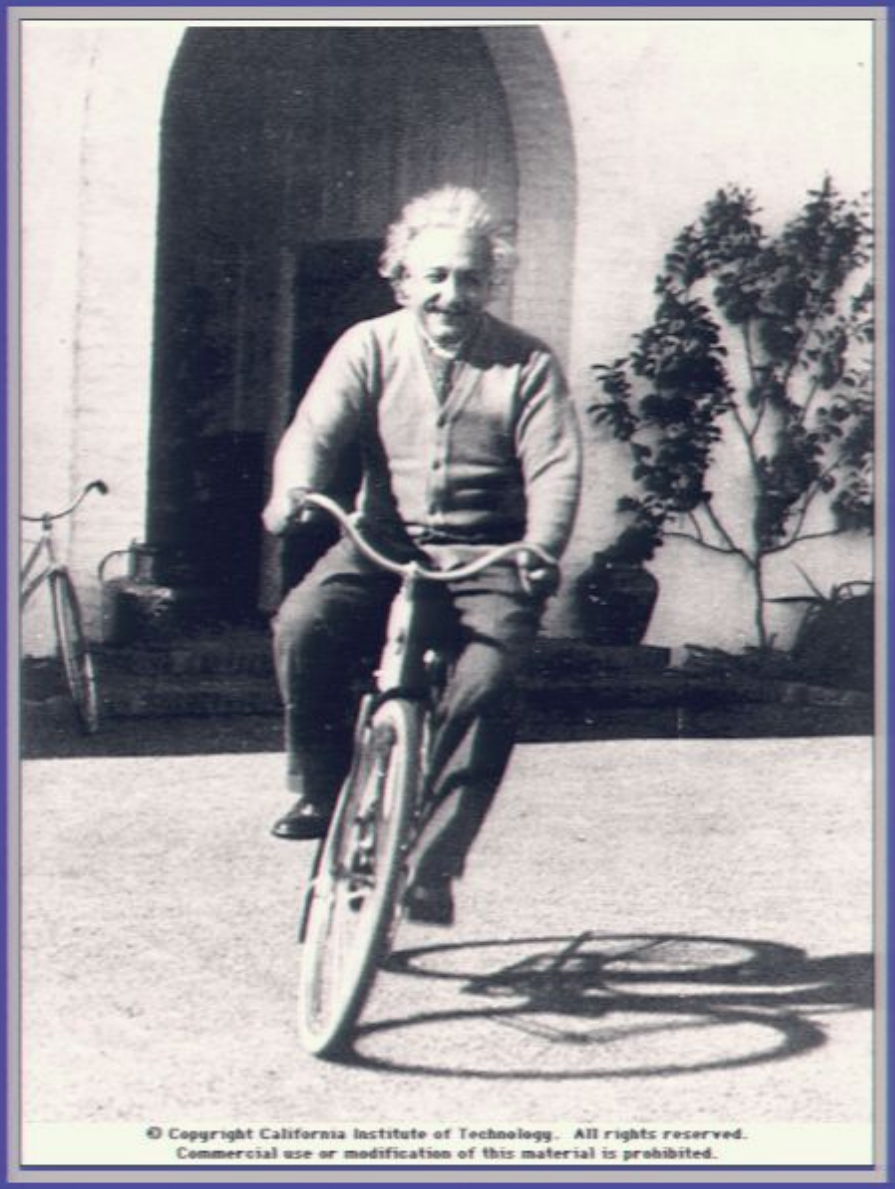
Later "retracted" once the expansion was discovered



The Cosmological Constant

Originally proposed by Einstein to counteract the Universe's gravitational attraction

Later "retracted" once the expansion was discovered

In modern terms, the cosmological constant represents the energy of the vacuum (What is there when there is nothing there!)


Dark Energy
vs.
Dark Matter

Dark Matter

Could be some un-discovered Particle that, like a neutrino, can pass through Earth.

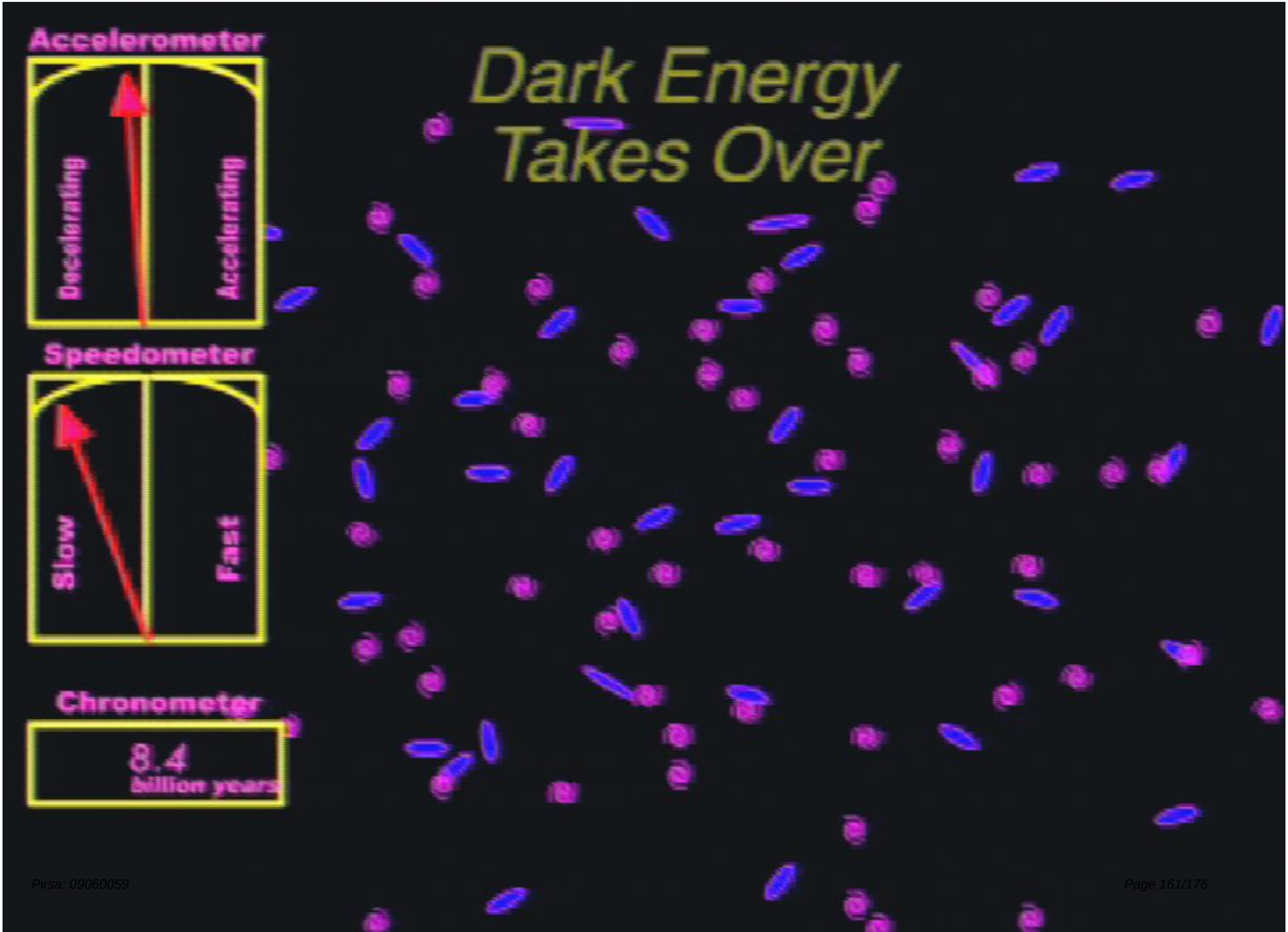
As the Universe Expands, the amount of Dark Matter Stays the same, so its density (and gravitational effect) gets smaller over time.

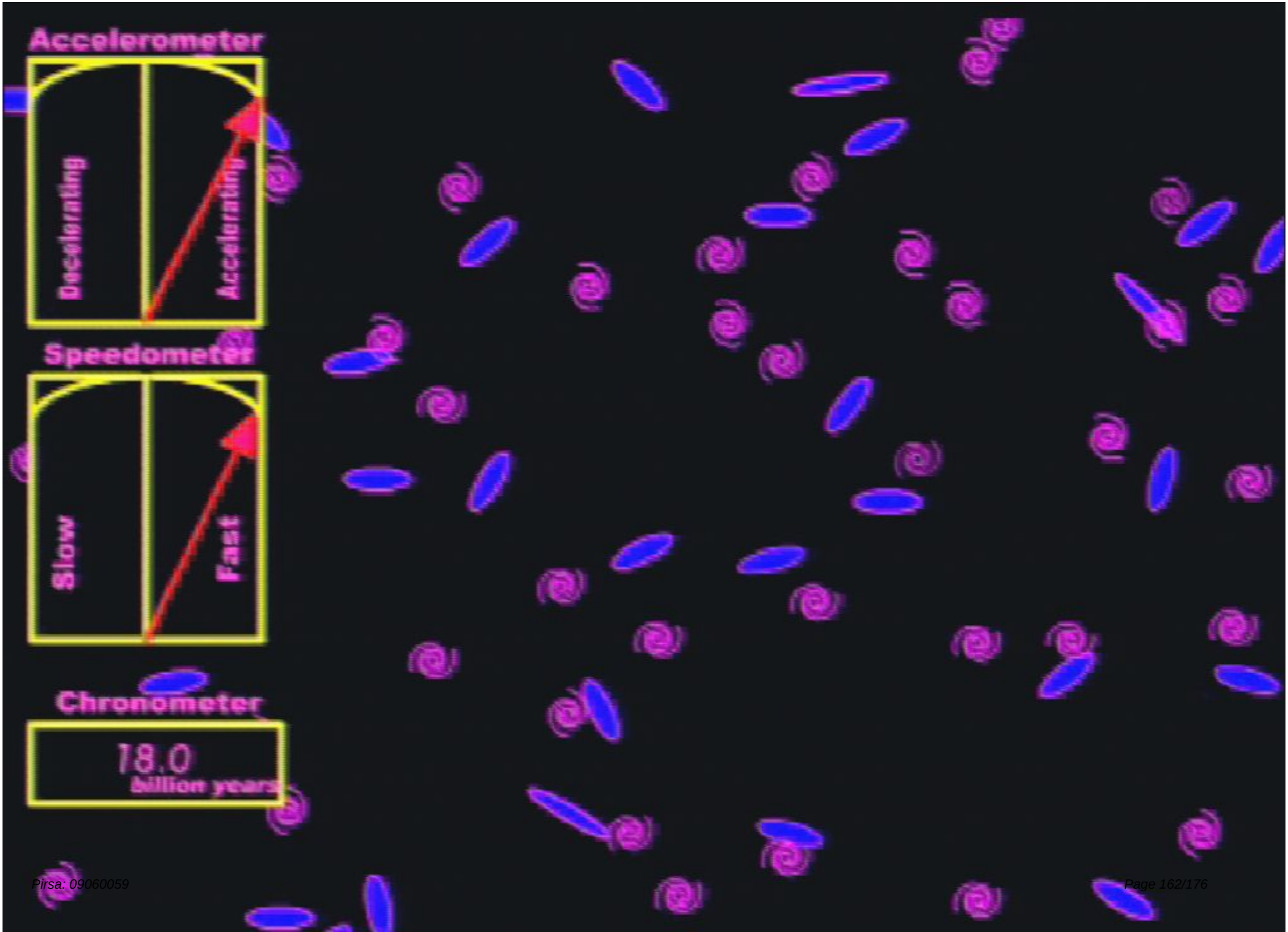
Dark Energy

Dark Energy seems tied to space itself.

As the Universe Expands, the Dark Energy gets created with the created space, and so it becomes stronger, relative to Dark Matter, over time.

Gravity Slows Down Universe


Accelerometer
Decelerating
Accelerating
Speedometer
Slow
Fast
Chronometer
8.4
billion years
Dark Energy
Takes Over


Accelerometer
Decelerating
Accelerating
Speedometer
Slow
Fast
Chronometer
18.0
billion years


11 Billion Year
Old Supernova

Goal of the Future is to Understand Dark Energy.

- Does it created exactly with space (space doubles in size, does Dark Energy double in size?) or a bit faster or a bit slower…
- This is considered one of Physics Biggest Questions, with the US, Europe, Japan, and Australia putting significant effort into understanding the answer.

The Big Chill?

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The Dark Energy gets created exactly as space get Created.

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- Dark Energy has won the battle of the Universe, and will continue to accelerate the Cosmos.

- The creation of space happens more quickly than even light can travel

- Eventually we will live in an empty universe except for our own "super galaxy"

The Big Rip

The Big Rip

Dark Energy gets created more quickly than the creation of space as the Universe expands

- every piece of the Universe will be eventually pushed away from every other piece (at the sub atomic level)

- leaving nothing…

And that is how the Universe ends...

And that is how the Universe ends...

Not with gnaB, but a whimper.

And that is how the Universe ends...

Not with gnaB, but a whimper.

Or just possibly, in a scream...During the Big Rip