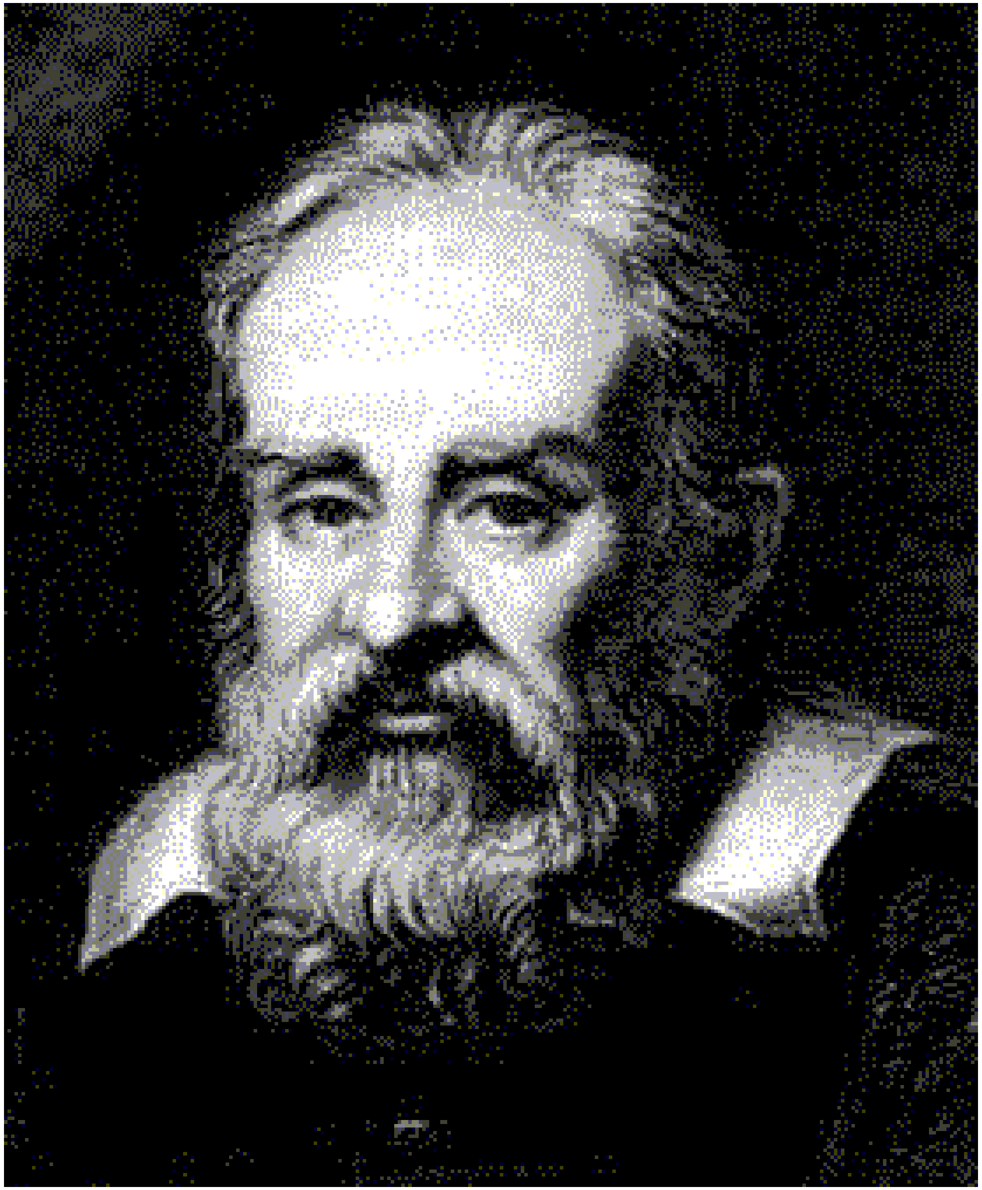
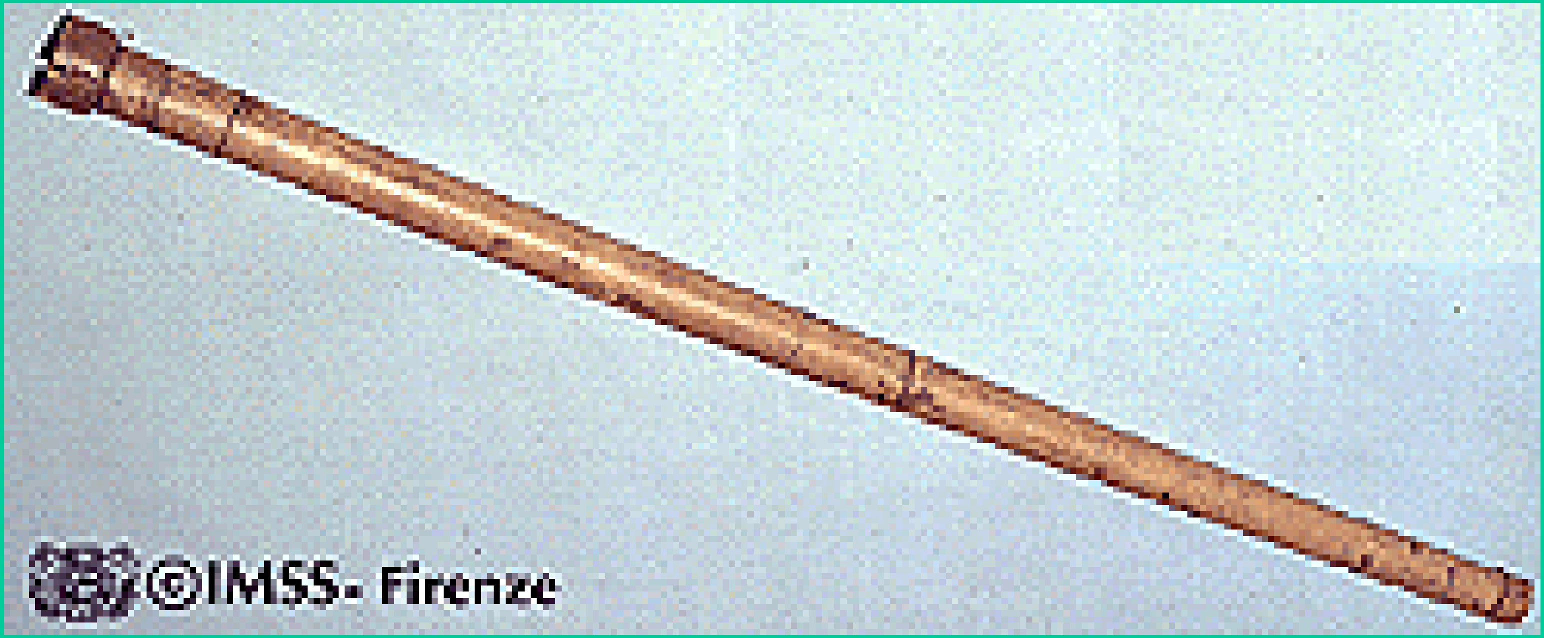
Krótka Historia Wszechświata

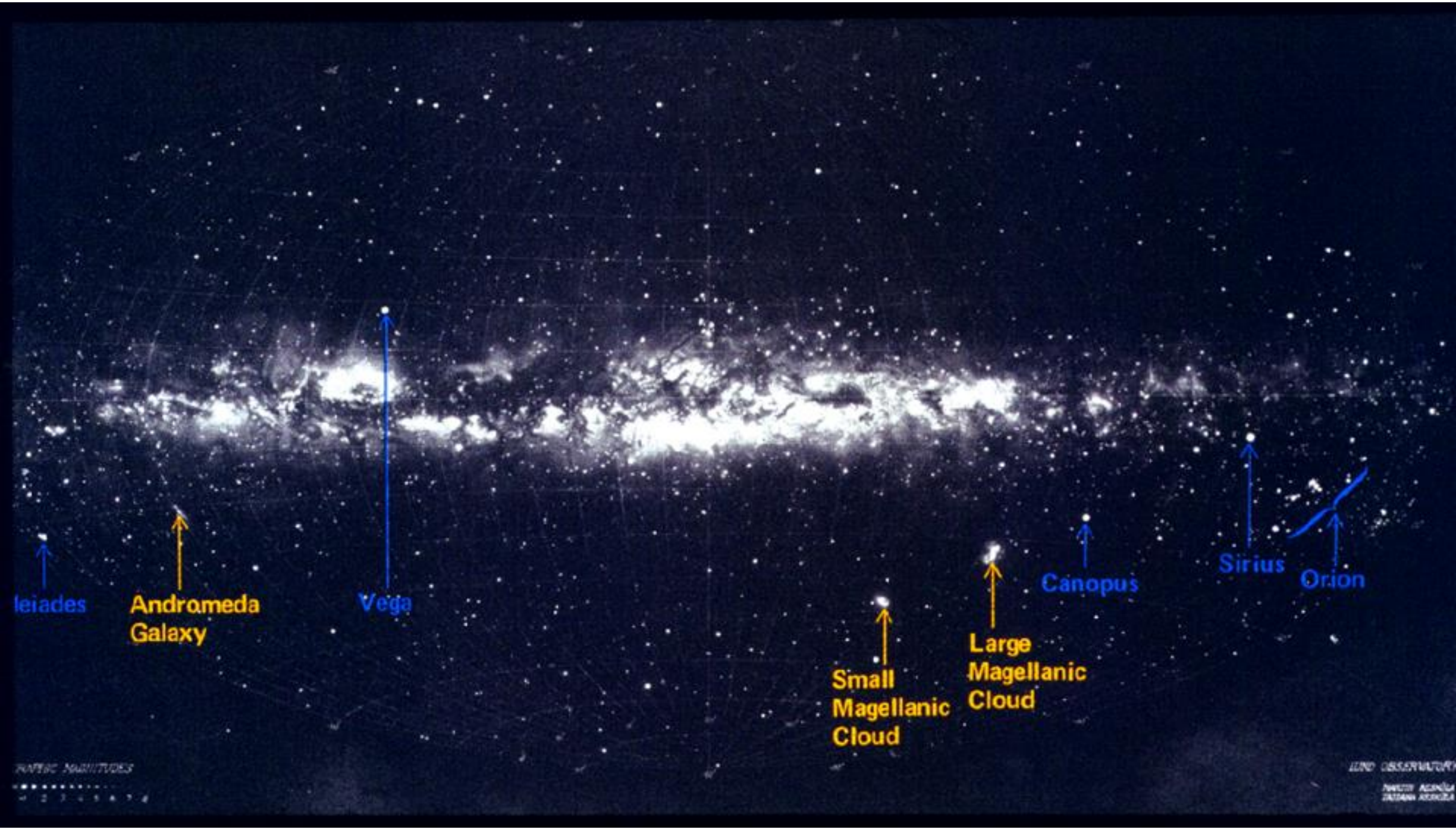
Marek Demiański

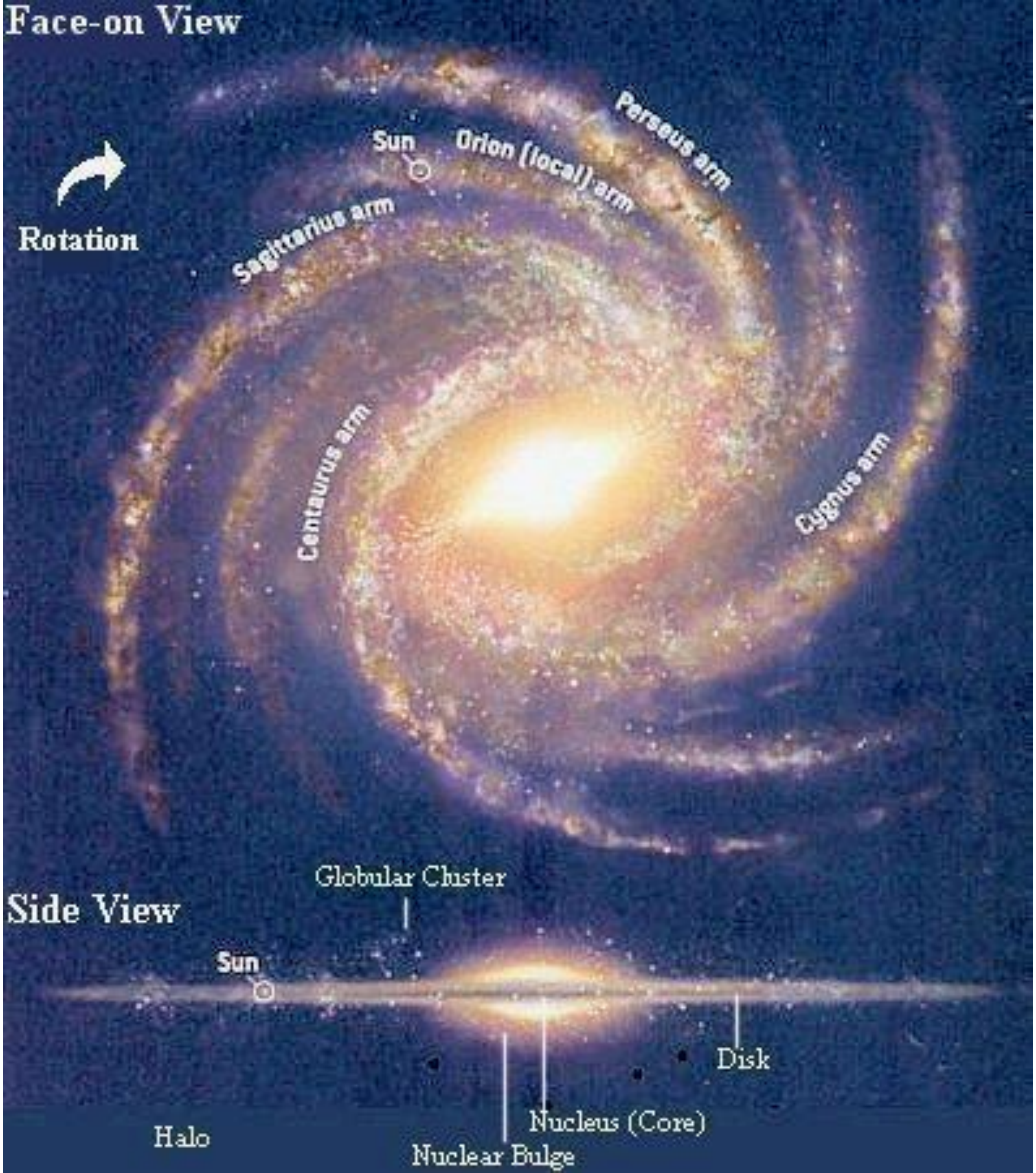
Instytut Fizyki Teoretycznej

Uniwersytet Warszawski






leiades
Andromeda Galaxy
Vega
Small Magellanic Cloud
Large Magellanic Cloud
Canopus
Sirius
Orion


Face-on View
Rotation
Sun
Orion (local) arm
Perseus arm
Sagittarius arm
Centaurus arm
Cygnus arm
Globular Cluster
Side View
Sun
Disk
Nucleus (Core)
Halo
Nuclear Bulge


D39 L

Fig. 2.

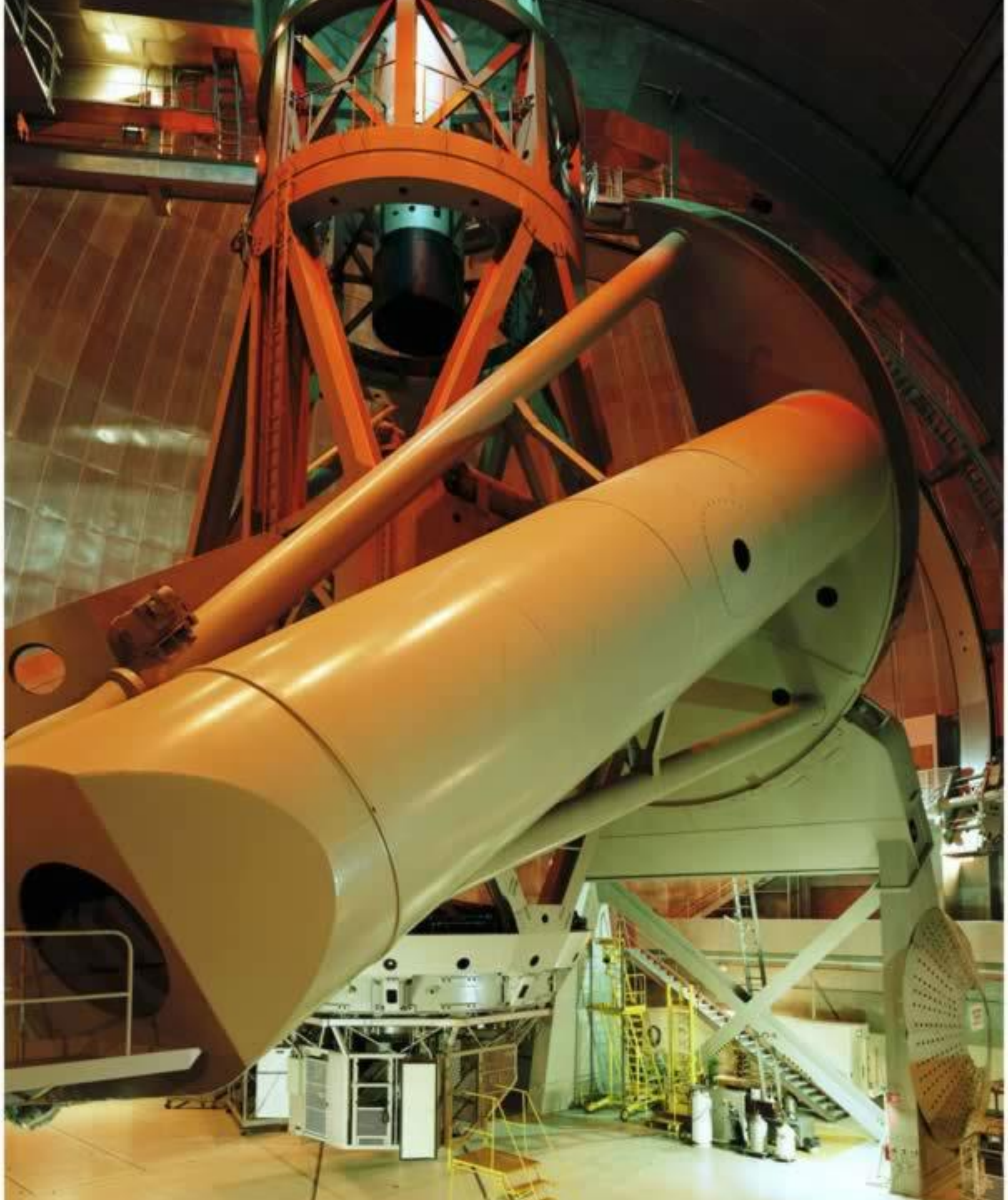
Fig. 5.

gezeich. u. gest. v. Fraunhofer

Skład chemiczny Wszechświata

~ 75% H

~ 25% He



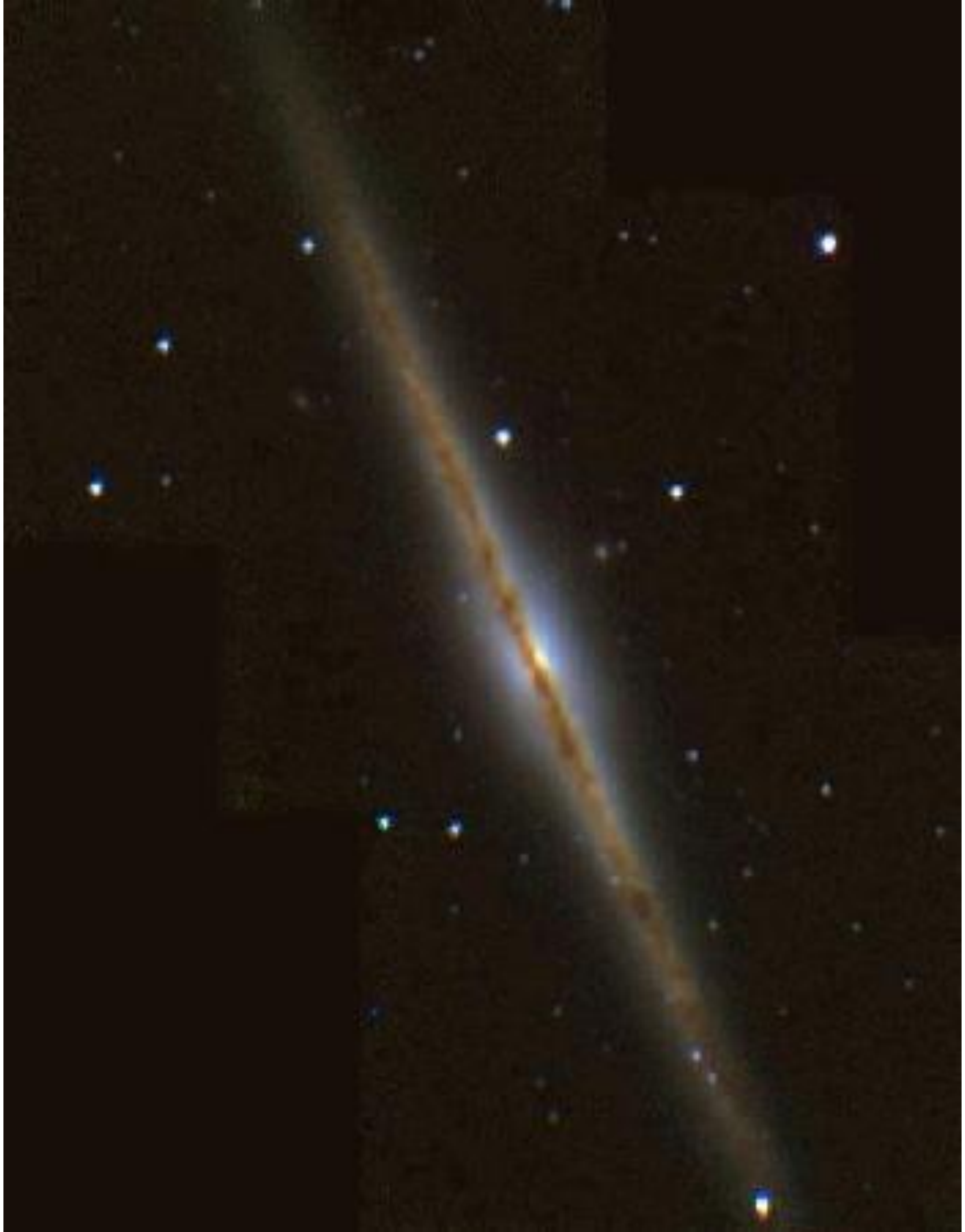
Spiral Galaxy NGC 1232 - VLT UT 1 + FORS1

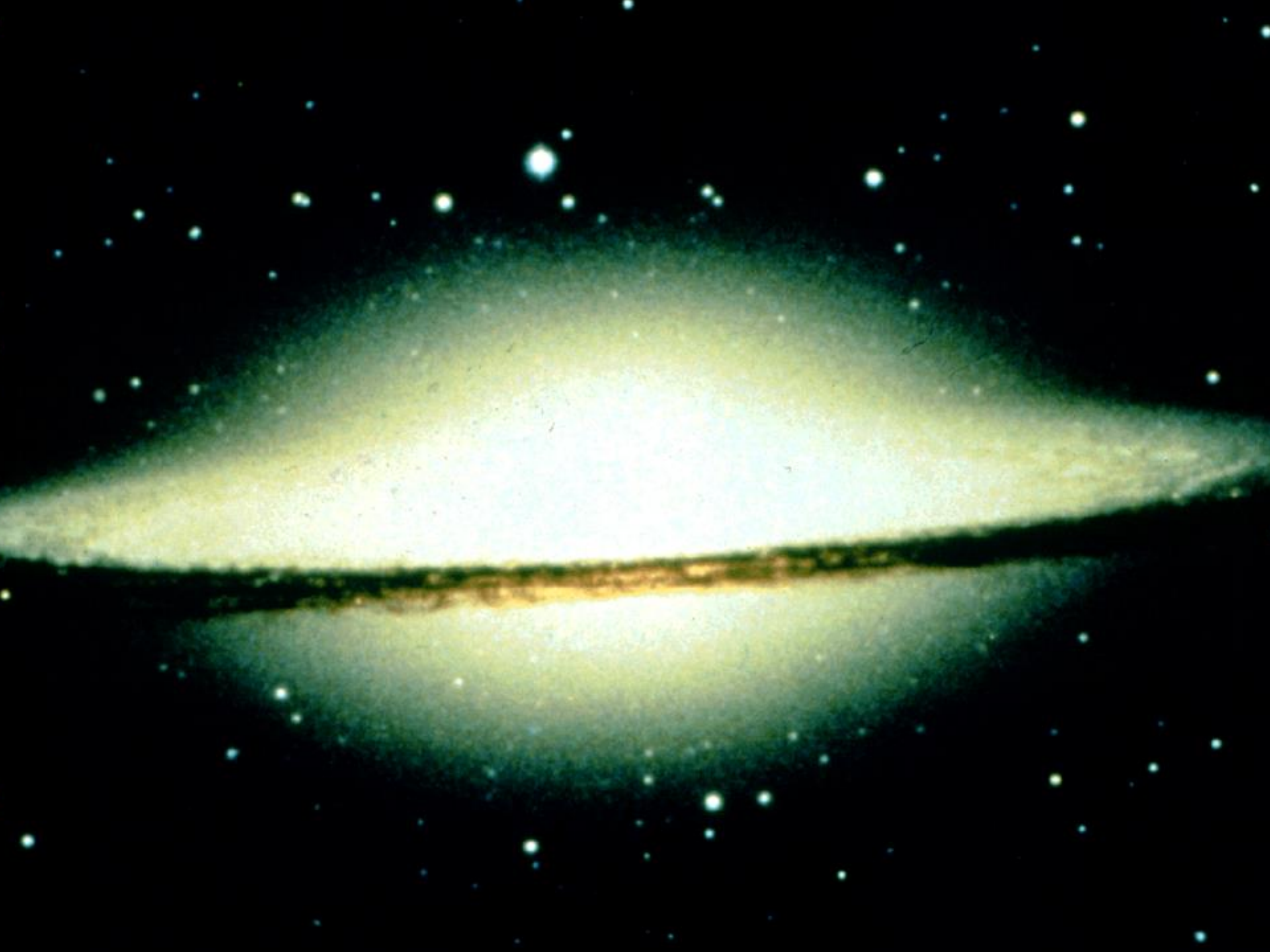
ESO PR Photo 37d/98 (23 September 1998)

Whirlpool Galaxy • M51

NASA and The Hubble Heritage Team (STScI/AURA)
Hubble Space Telescope WFPC2 • STScI-PRC01-07


Hubble

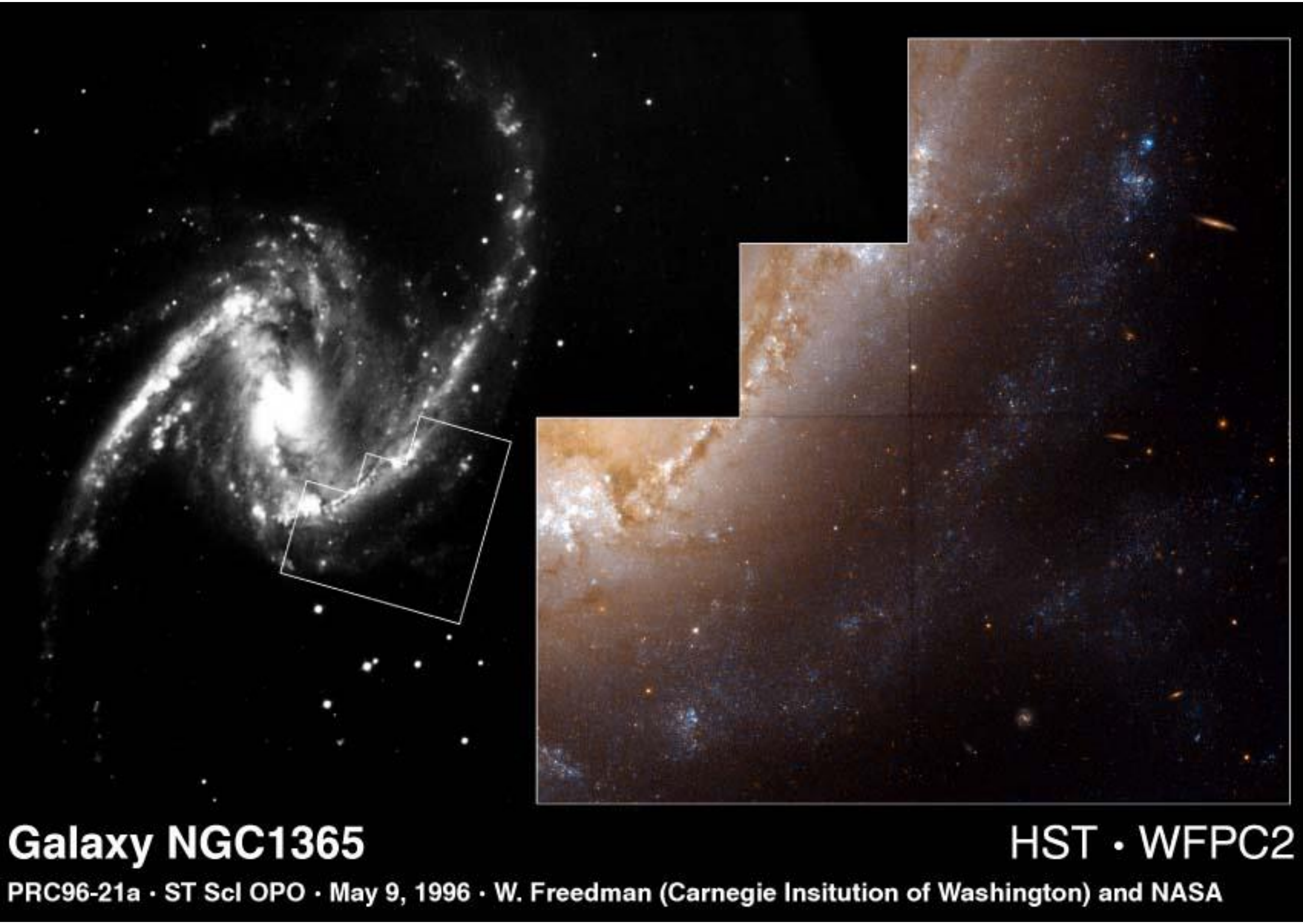




Polar-Ring
Galaxy
NGC 4650A
PRC99-12
Space Telescope
Science Institute
Hubble Heritage Team
(AURA/STScI/NASA)
Hubble
Heritage

Barred Galaxy NGC 1365
(VLT UT1 + FORS1)

ESO PR Photo 08a/99 (27 February 1999)



Galaxy NGC1365

HST • WFPC2

PRC96-21a · ST ScI OPO · May 9, 1996 · W. Freedman (Carnegie Insitution of Washington) and NASA

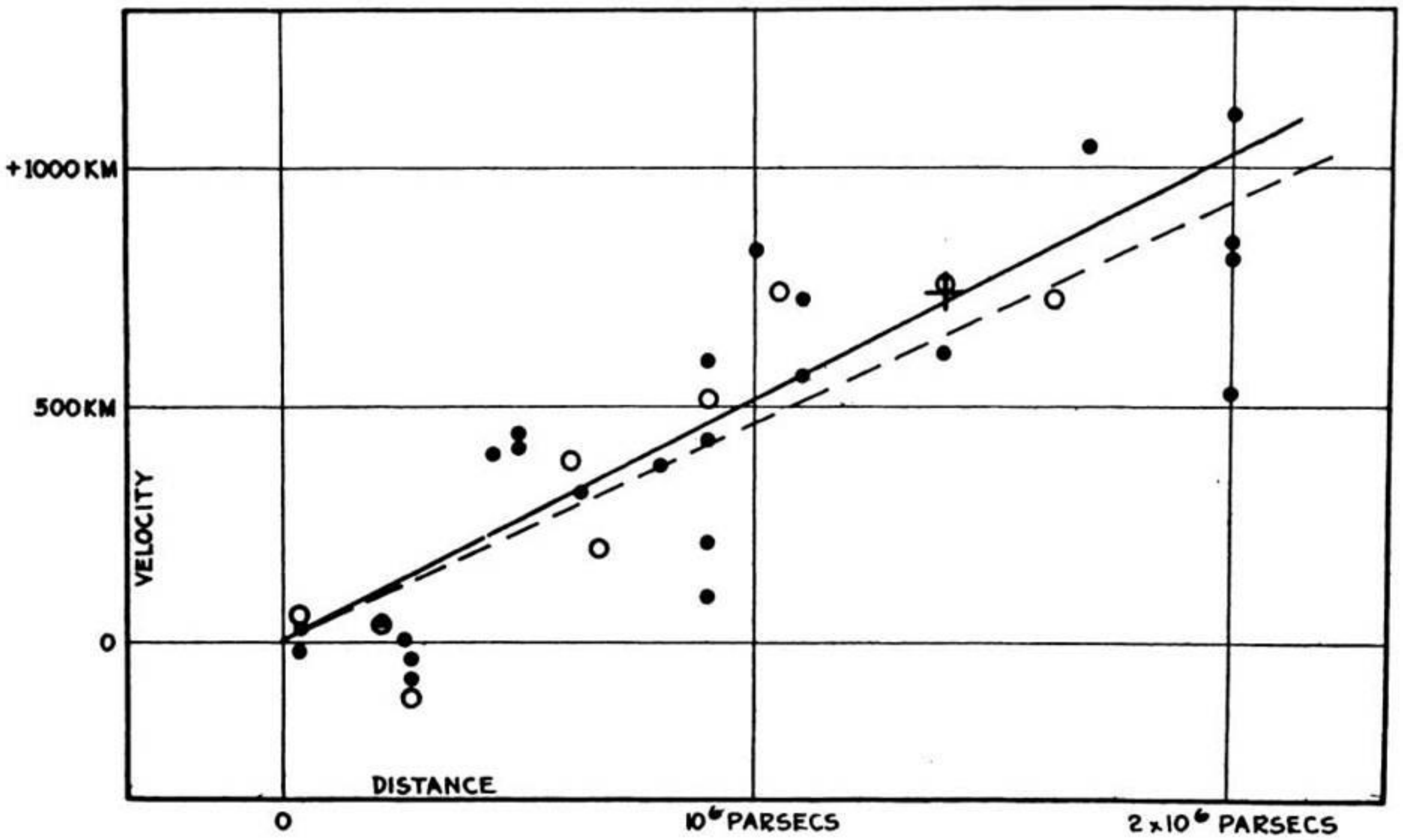
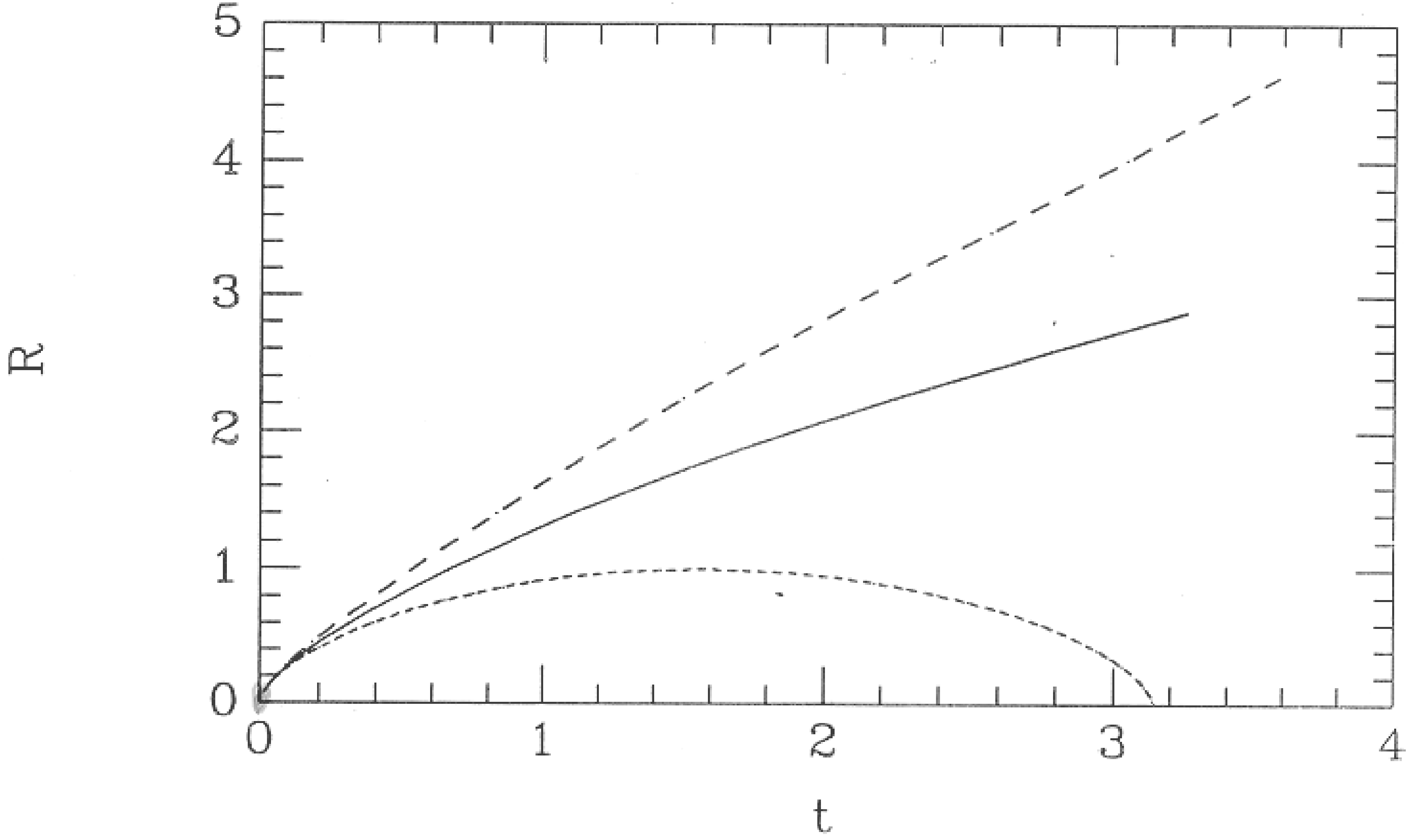
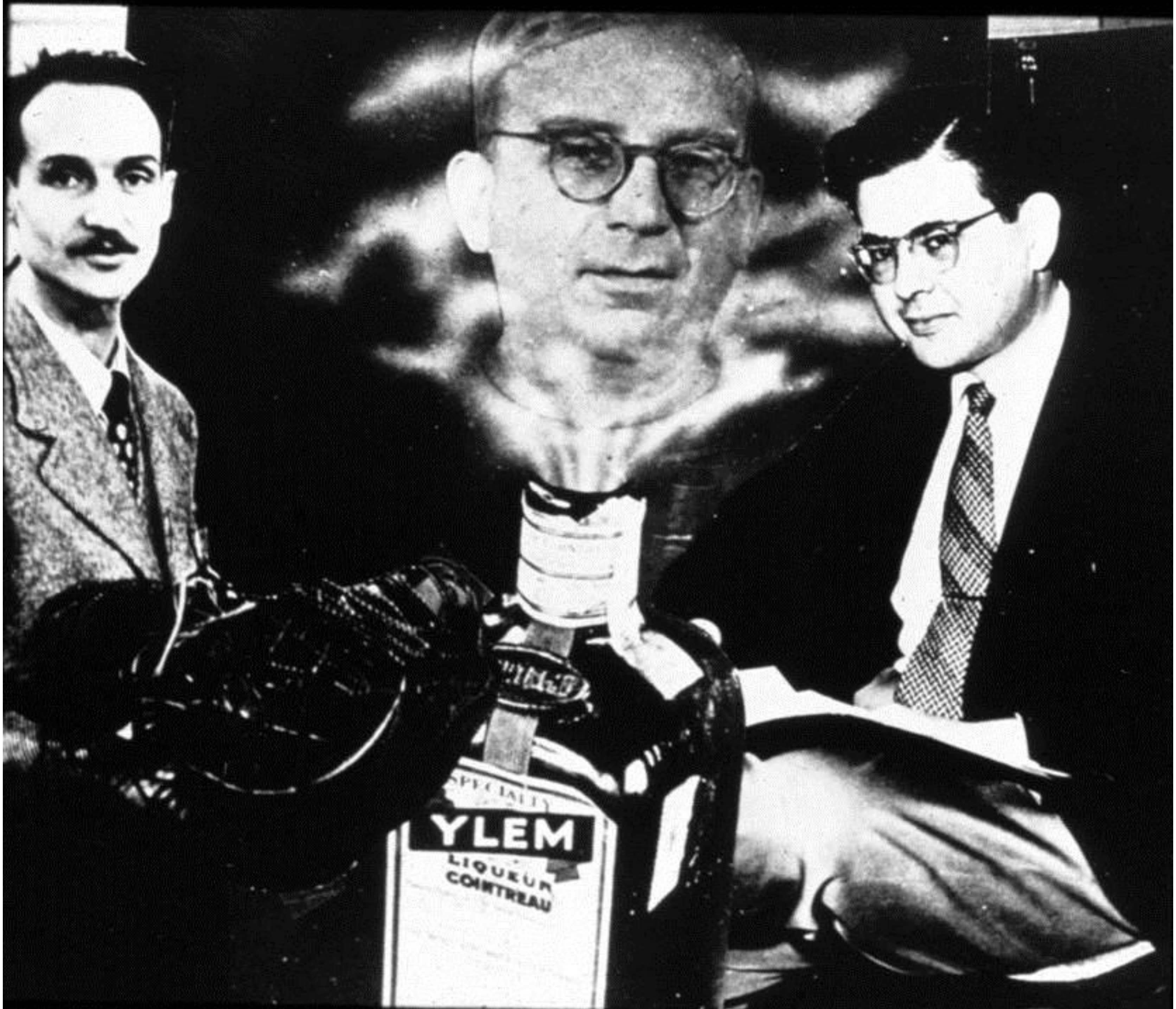
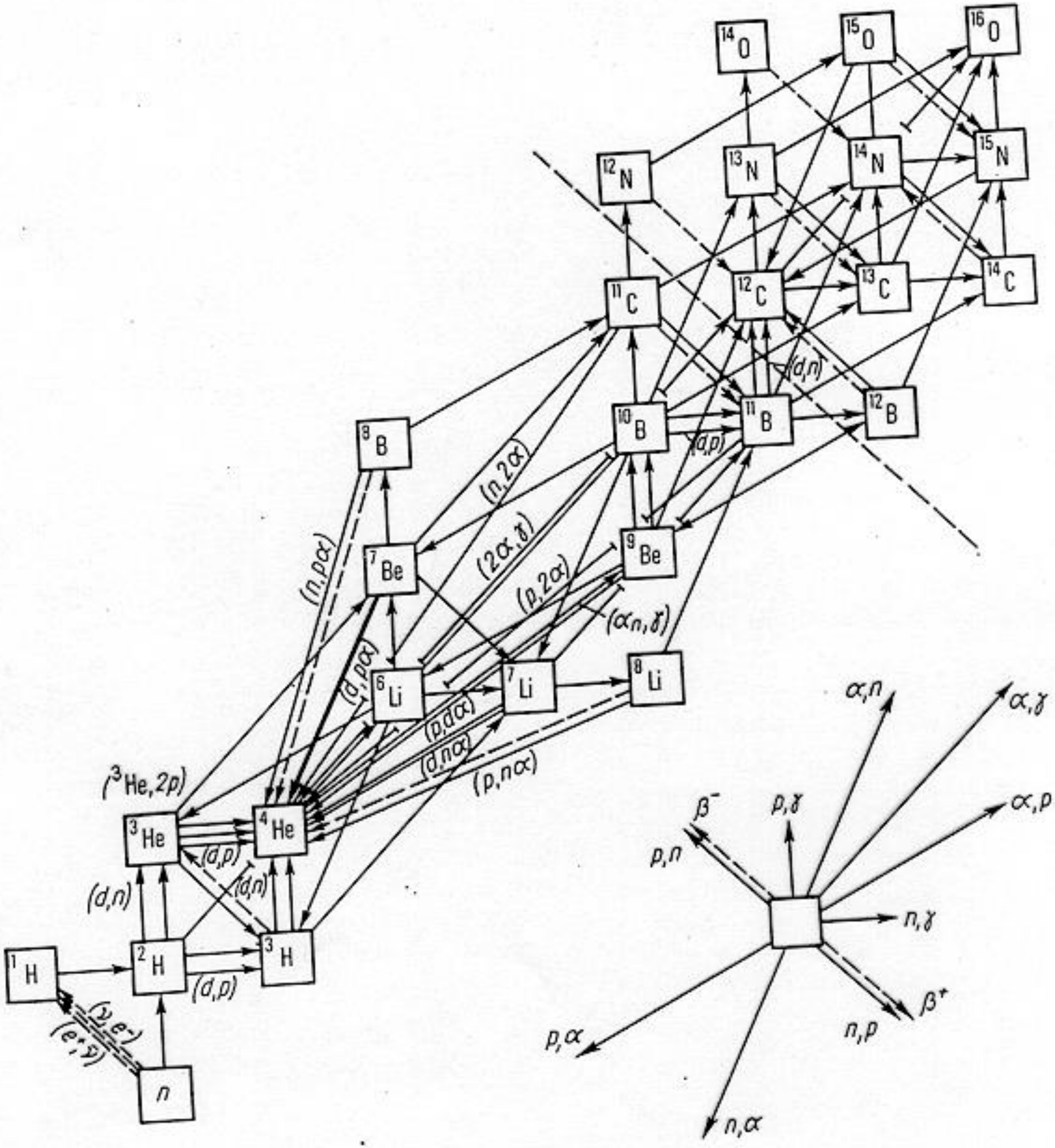


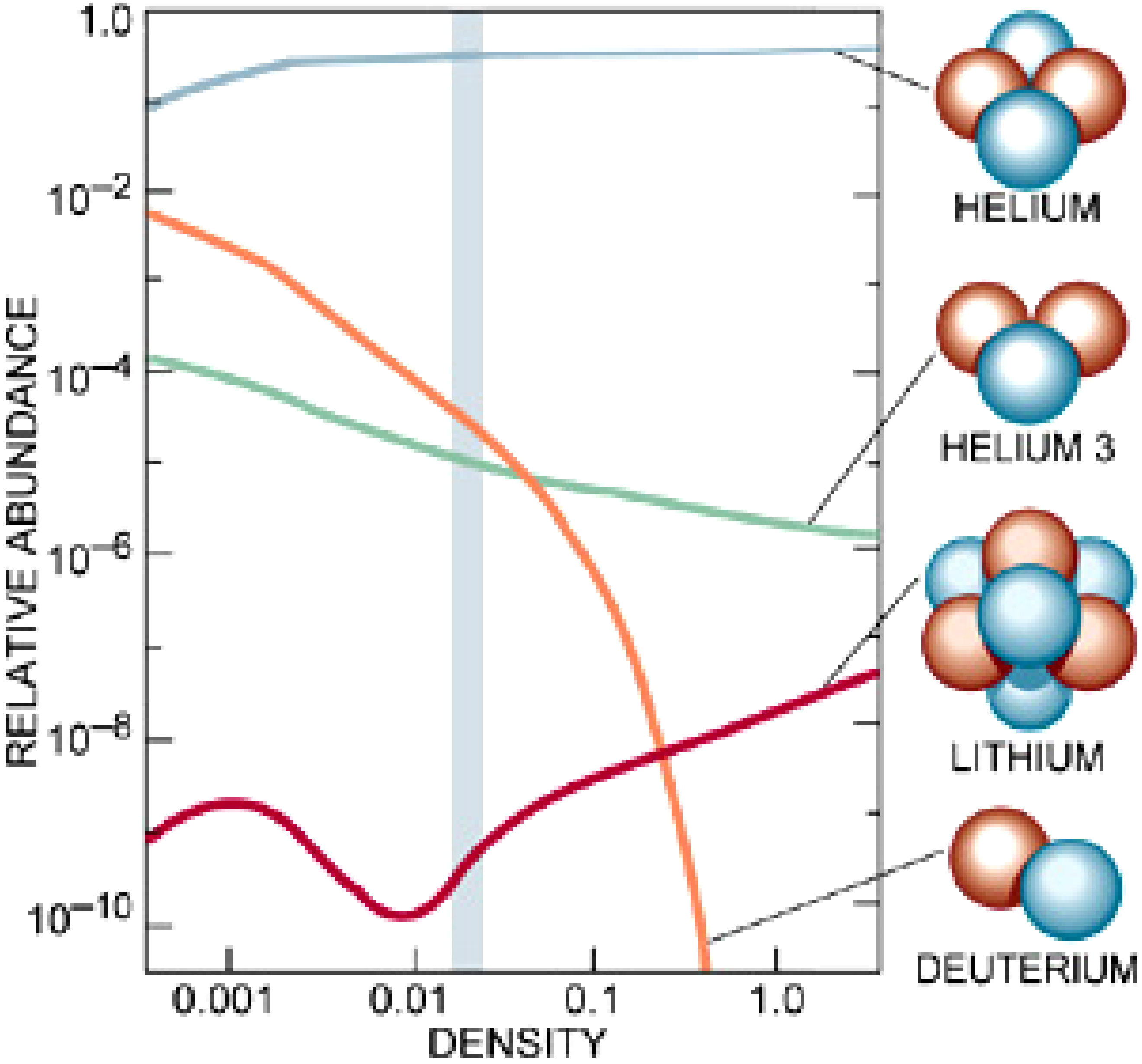
Fig. 16-27a, p.331


R
t
0
1
2
3
4
5
0
1
2
3
4


SPECIALTY
YLEM
LIQUEUR
COINTREAU



^{14}O
^{15}O
^{16}O
^{12}N
^{13}N
^{14}N
^{15}N
^{11}C
^{12}C
^{13}C
^{14}C
^{9}B
^{10}B
^{11}B
^{12}B
^{7}Be
^{9}Be
^{6}Li
^{7}Li
^{8}Li
^{3}He
^{4}He
^{1}H
^{2}H
^{3}H
n
(d,n)
(d,p)
(n,2α)
(2α,γ)
(p,2α)
(αn,γ)
(n,pα)
(d,pα)
(p,dα)
(d,nα)
(p,nα)
(^{3}He,2p)
(d,p)
(d,n)
(d,n)
(d,p)
(ν,e⁻)
(e⁺,ν)
α,n
α,γ
α,p
β⁻
p,γ
p,n
n,γ
β⁺
n,p
p,α
n,α


1.0
10^{-2}
10^{-4}
10^{-6}
10^{-8}
10^{-10}
RELATIVE ABUNDANCE
0.001
0.01
0.1
1.0
DENSITY
HELIUM
HELIUM 3
LITHIUM
DEUTERIUM

Similarly, noticing that, in the present era, the radiation-density must vary in inverse proportion to the fourth power of the time (because $\rho \approx T^4$, $T \sim l^{-1}$, and $l \sim t$), we find,

$$\rho_{\text{rad.}}\ (\text{present}) = \frac{3{\cdot}1 \times 10^{37}}{t^4}\ \text{gm per cm}^3. \qquad \ldots.(10)$$

For the present density of residual radiation we obtain 6×10^{-32}, corresponding to about 6 K. Thus we may conclude that the residual heat found at present in the Universe is comparable with the heat provided by nuclear transformations in stars.

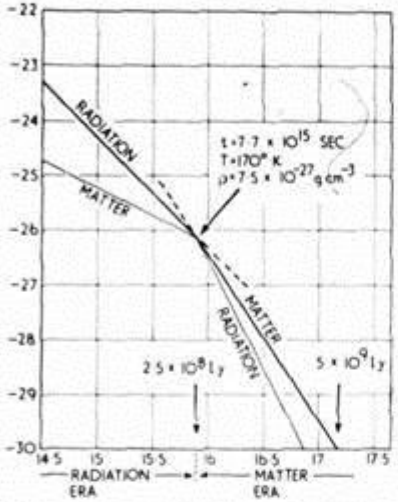
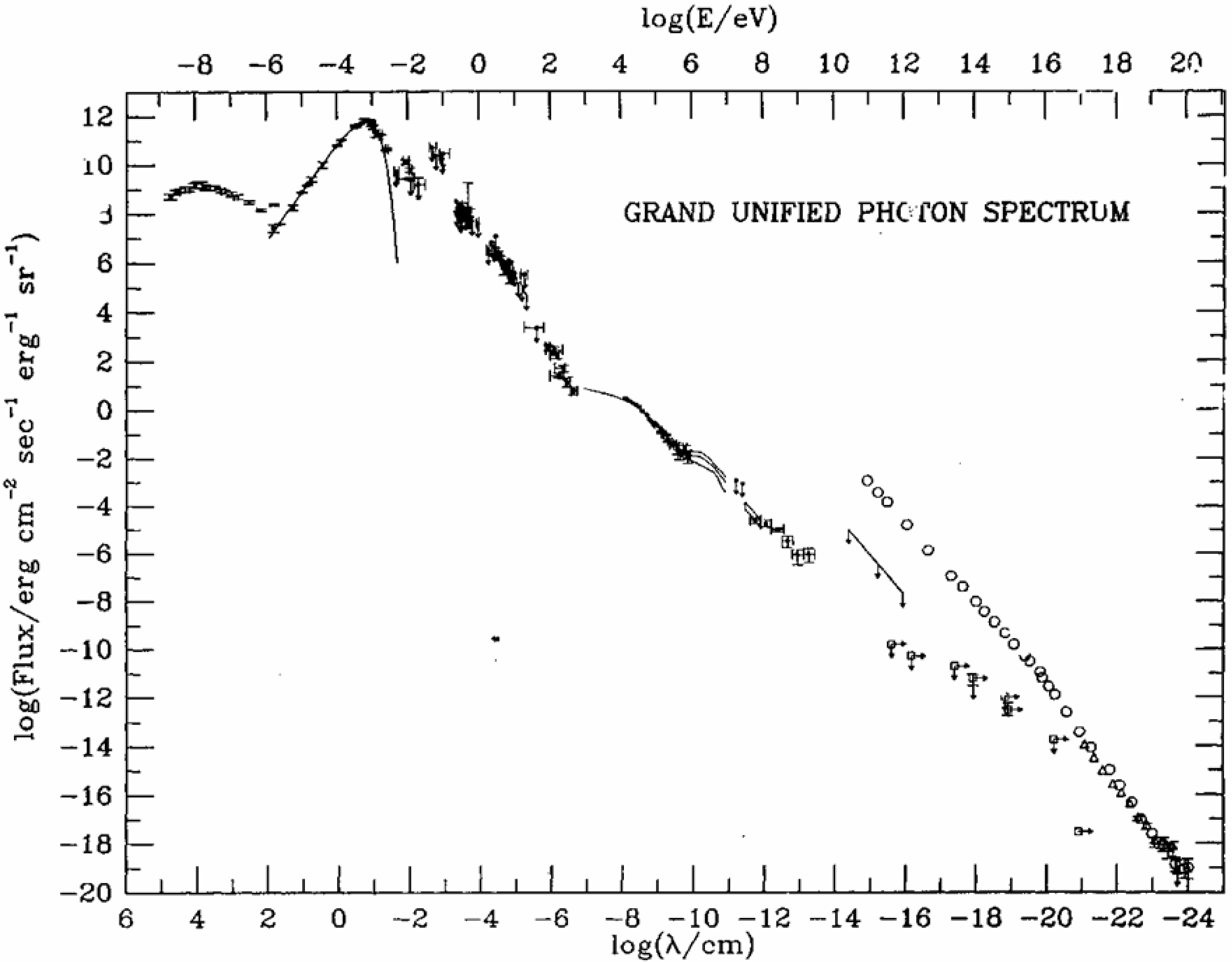
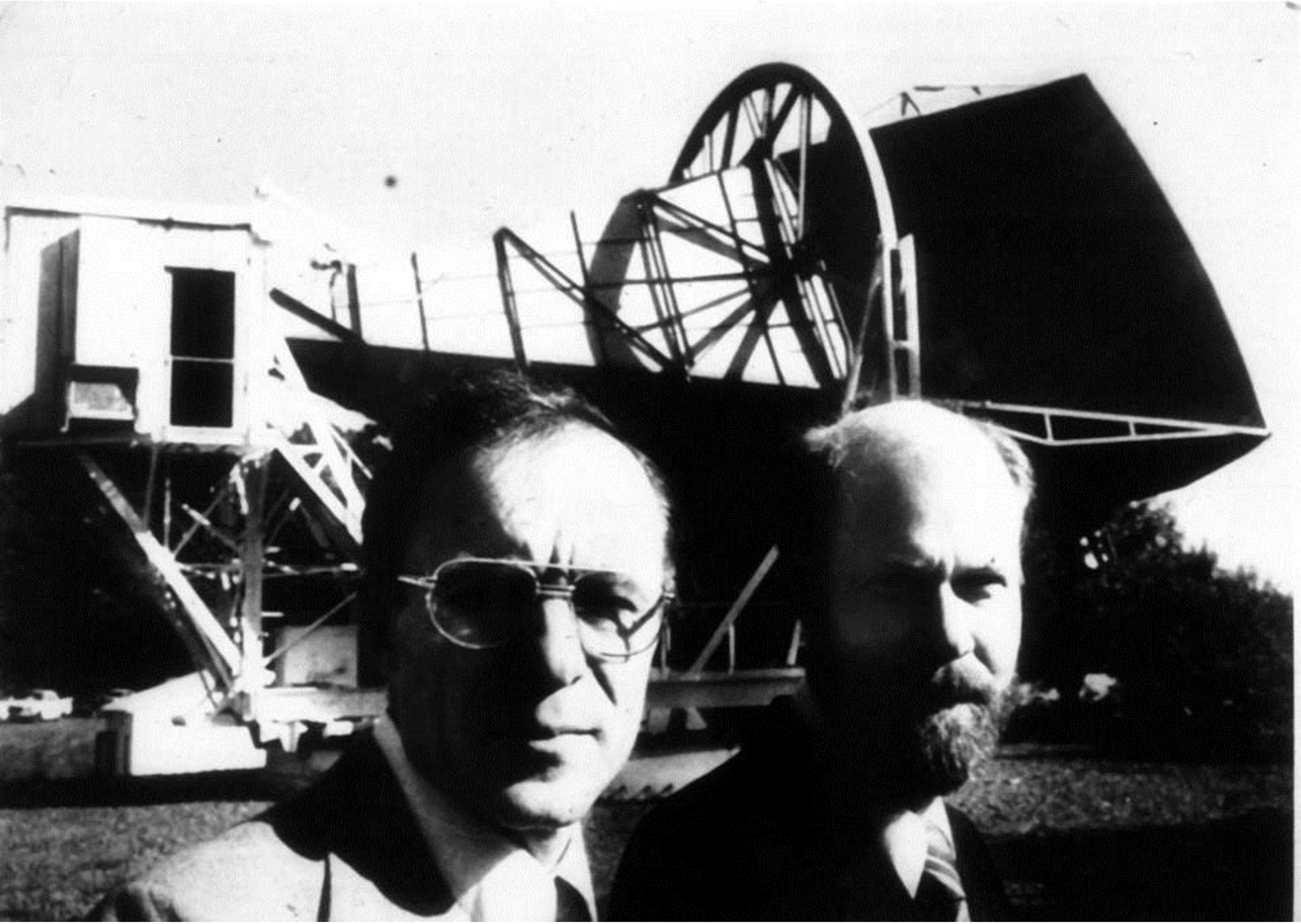


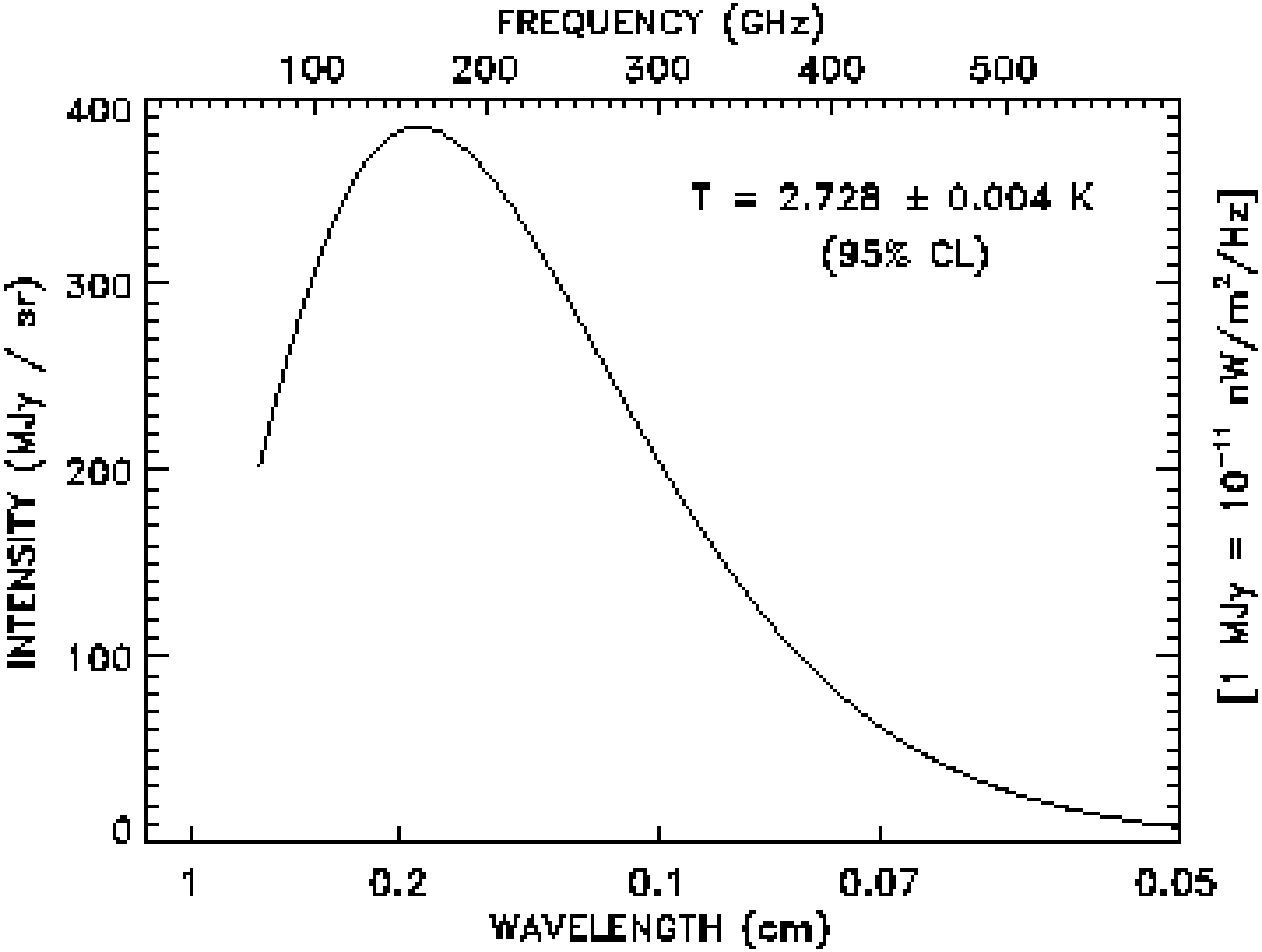
Fig. 1. The densities, in gm per cm³, of matter and radiation (ordinates) plotted against time in seconds (abscissae); logarithmic scale

4. FORMATION OF CHEMICAL ELEMENTS AND ORIGIN OF GALAXIES

The above considerations give us a general picture of changing physical conditions characteristic of the evolutionary history of our Universe. We will indicate here only quite briefly how this information can be used for the explanation of various characteristic properties of the Universe as we know it to-day. First of all, it may be suggested that, at least partially, the relative abundances of the atoms of various chemical elements were conditioned by thermonuclear reactions which took place at high speed during the very early stages of expansion while the temperature of the Universe was exceedingly high. And, in fact, the calculations in that direction, carried out by the present writer*, and later in some more detail by FERMI and TURKEVICH,† lead to a value of the H/He ratio which is in good agreement with observational data. However, there are still some difficulties to be overcome in understanding the abundances of heavier elements, and there is a possibility that the original distribution was partially modified by various processes during the later stages of the evolution.

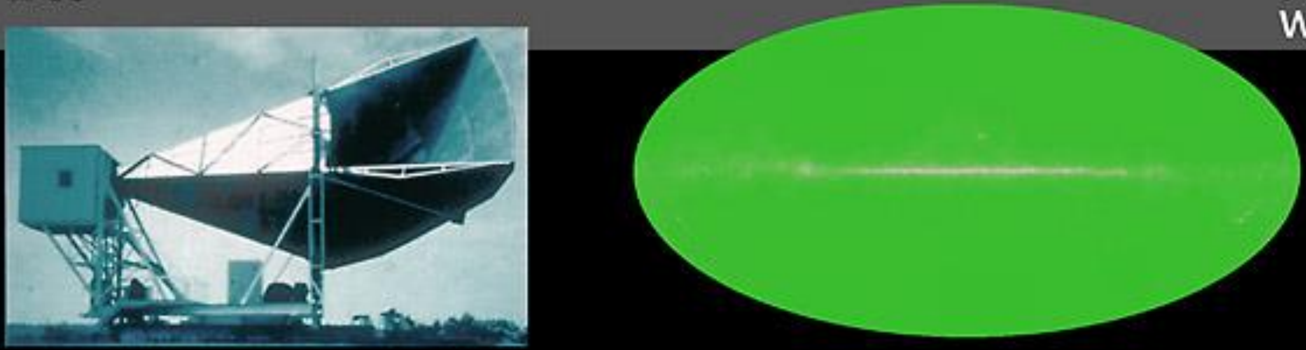

log(E/eV)
−8
−6
−4
−2
0
2
4
6
8
10
12
14
16
18
20
GRAND UNIFIED PHOTON SPECTRUM
log(Flux/erg cm^{-2} sec^{-1} erg^{-1} sr^{-1})
12
10
8
6
4
2
0
−2
−4
−6
−8
−10
−12
−14
−16
−18
−20
6
4
2
0
−2
−4
−6
−8
−10
−12
−14
−16
−18
−20
−22
−24
log(λ/cm)




FREQUENCY (GHz)
100
200
300
400
500
400
300
200
100
0
INTENSITY (MJy / sr)
T = 2.728 ± 0.004 K
(95% CL)
[1 MJy = 10^{-11} nW/m^2/Hz]
1
0.2
0.1
0.07
0.05
WAVELENGTH (cm)

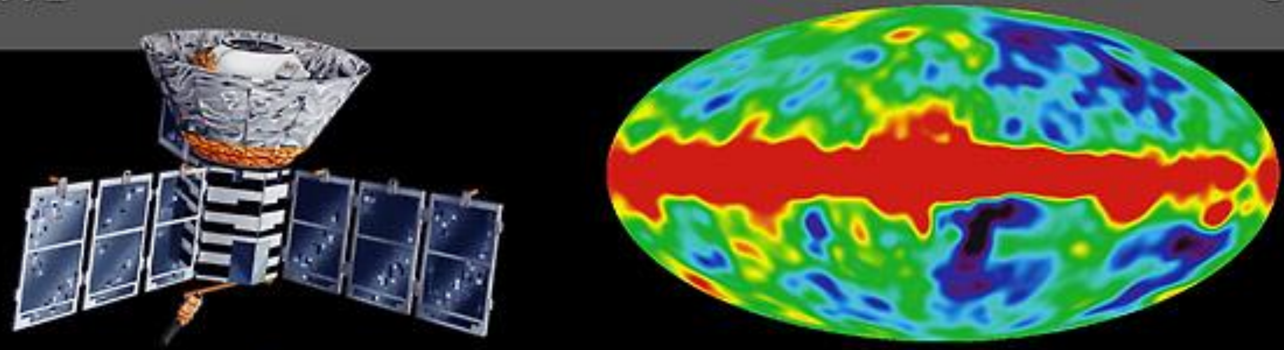
1965

Penzias and
Wilson



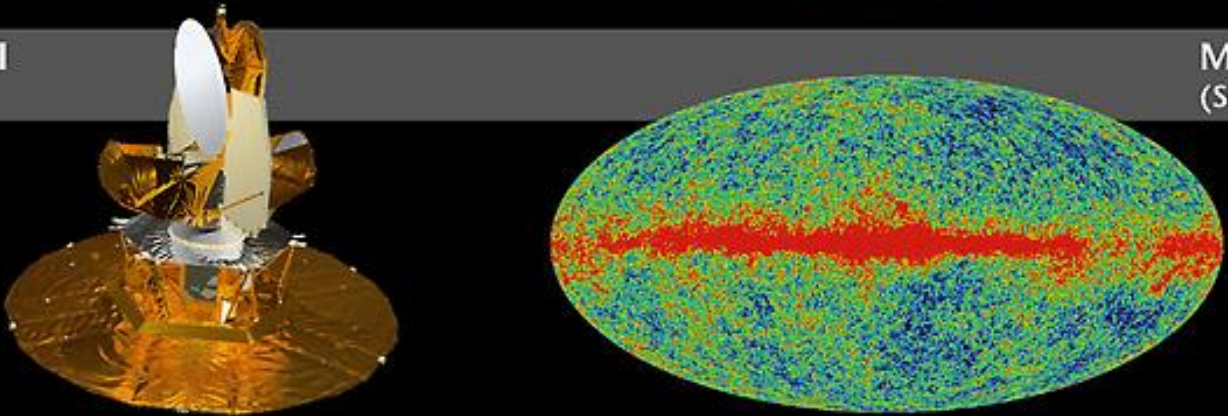
1992

COBE

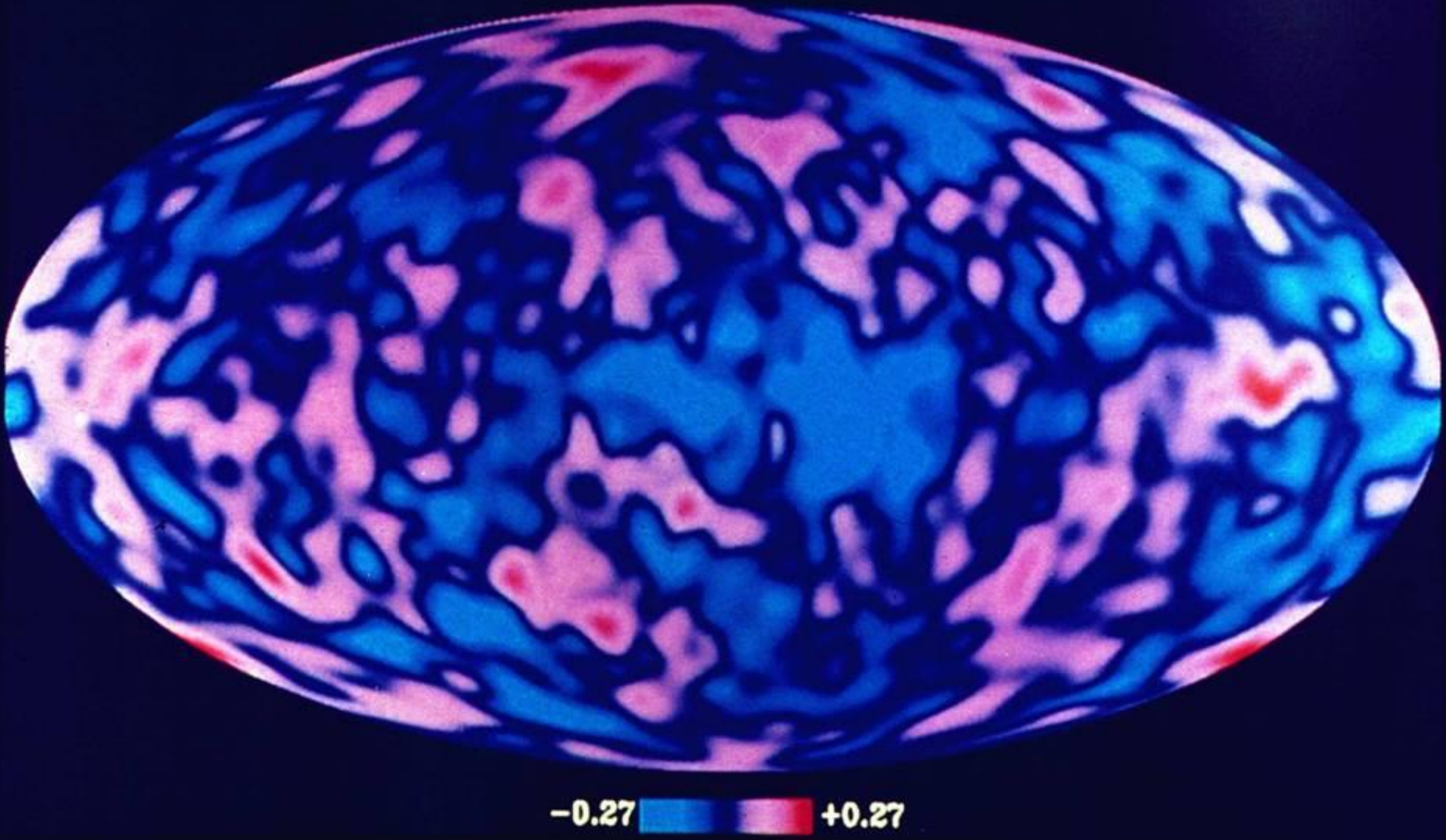


2001

MAP
(Simulated)

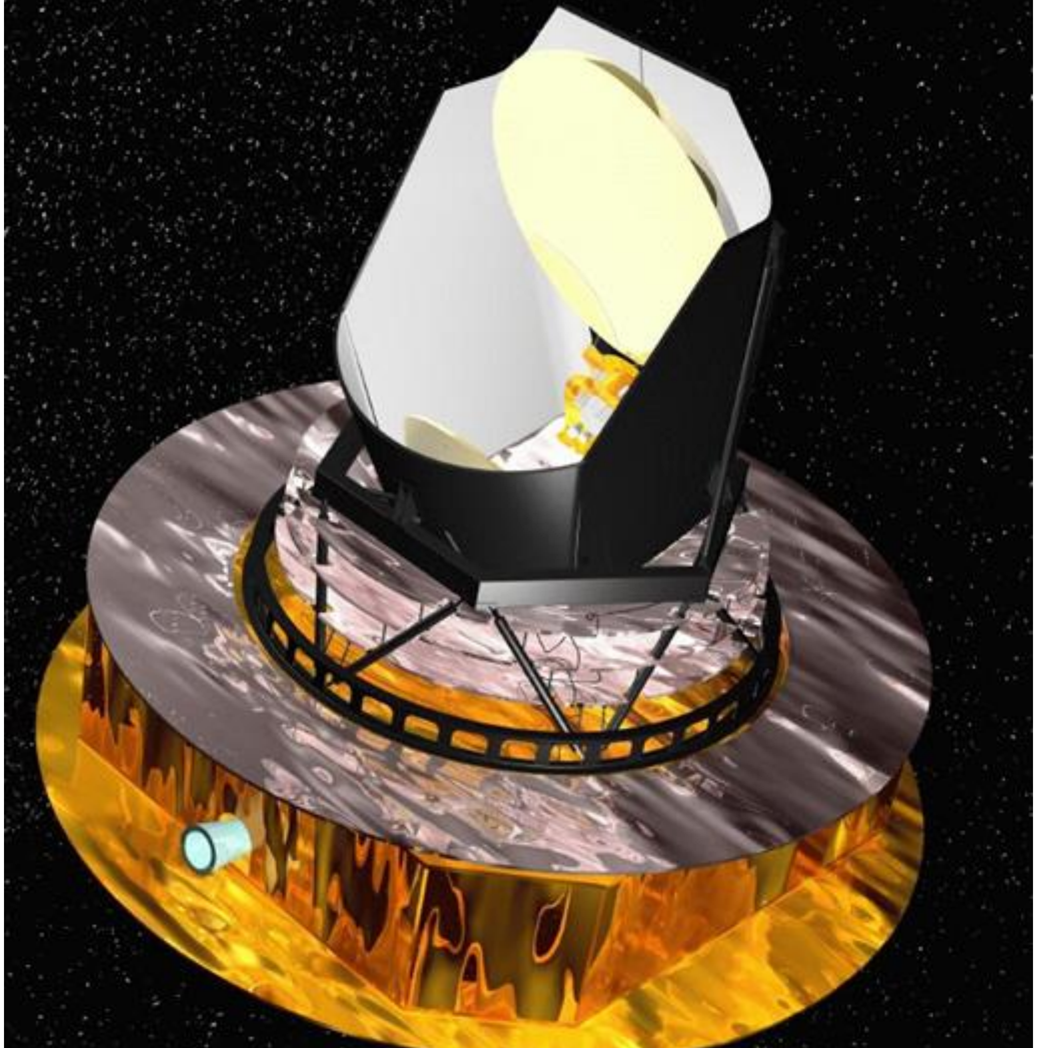


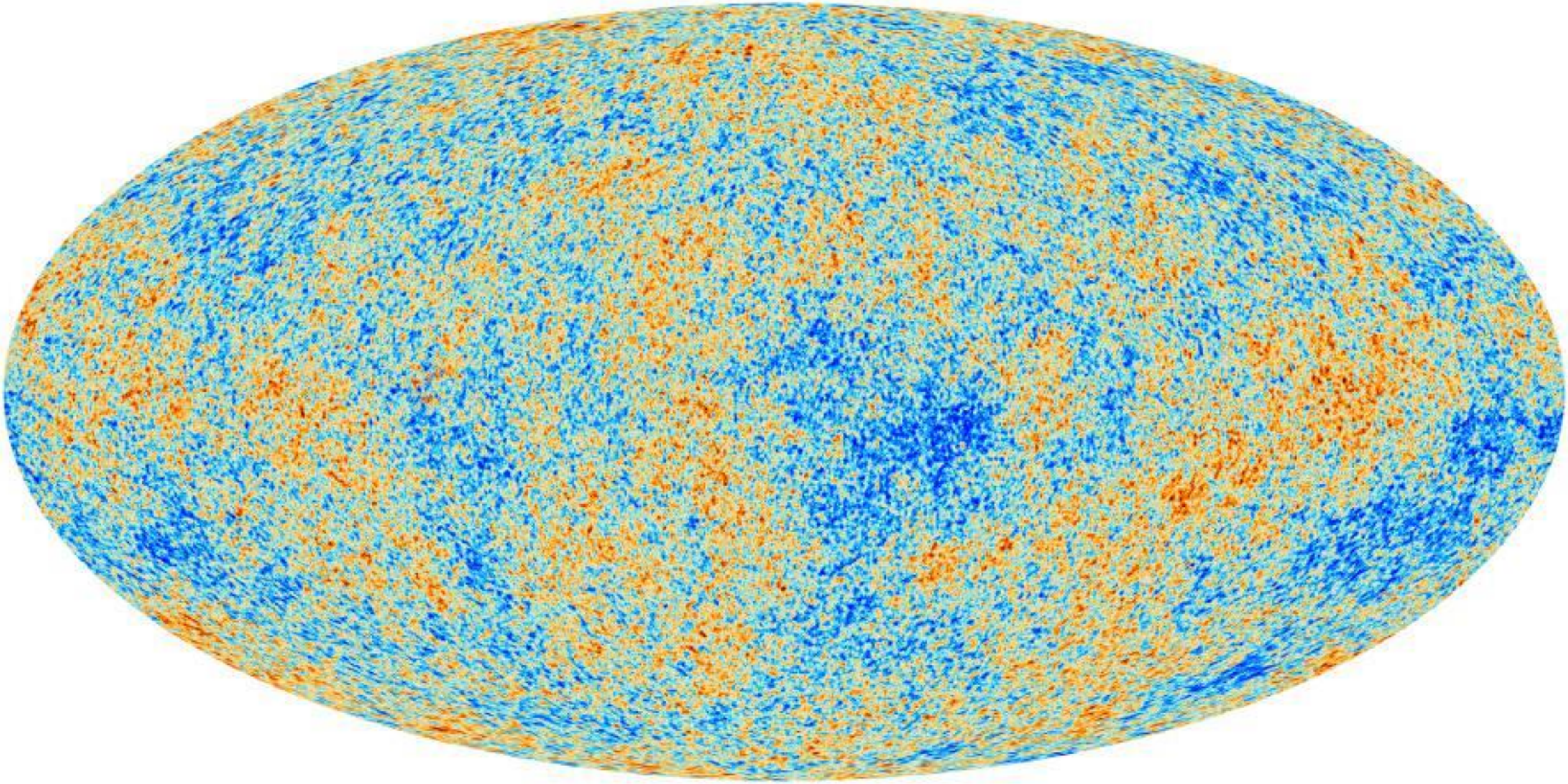
COBE DMR

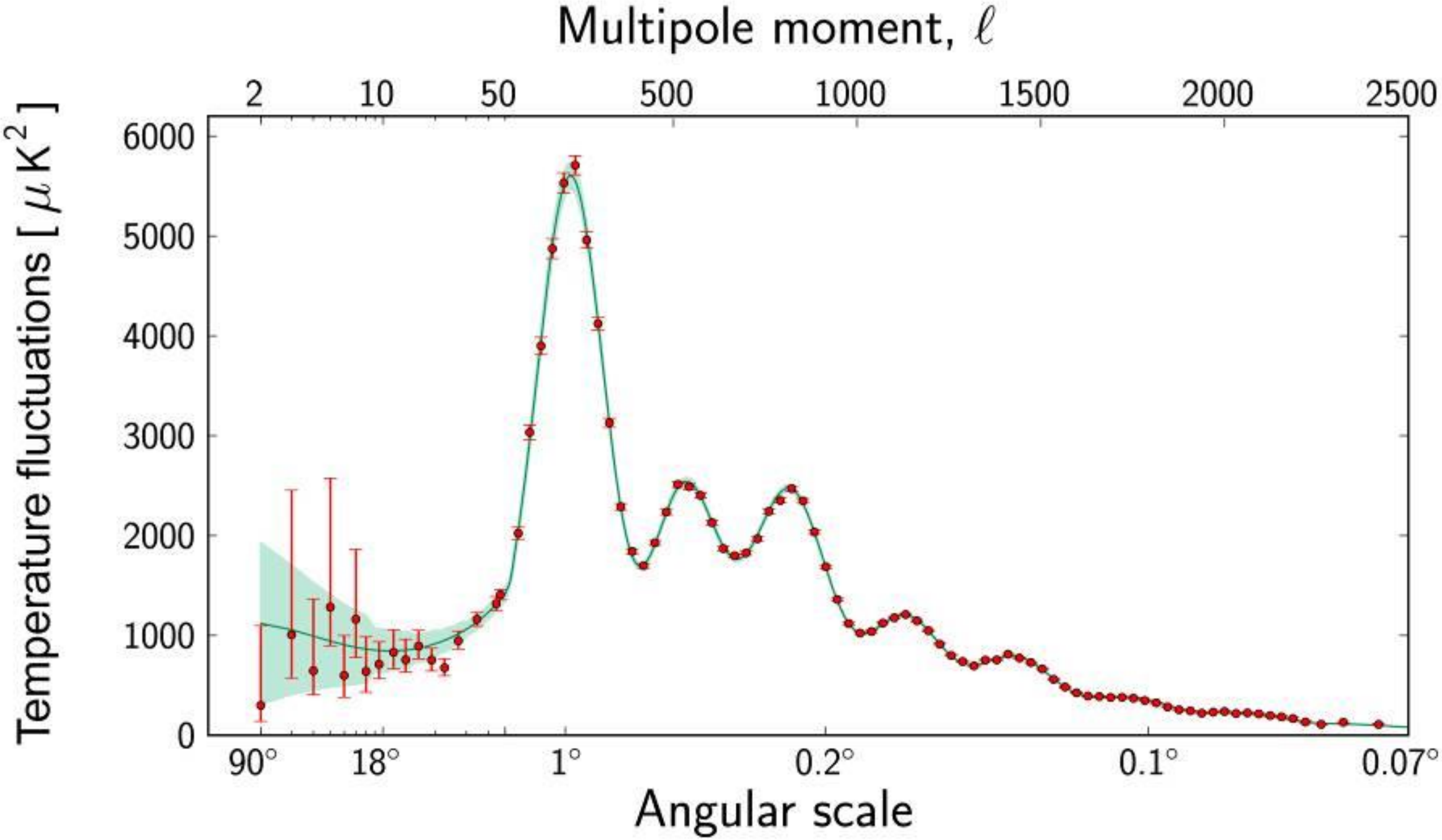


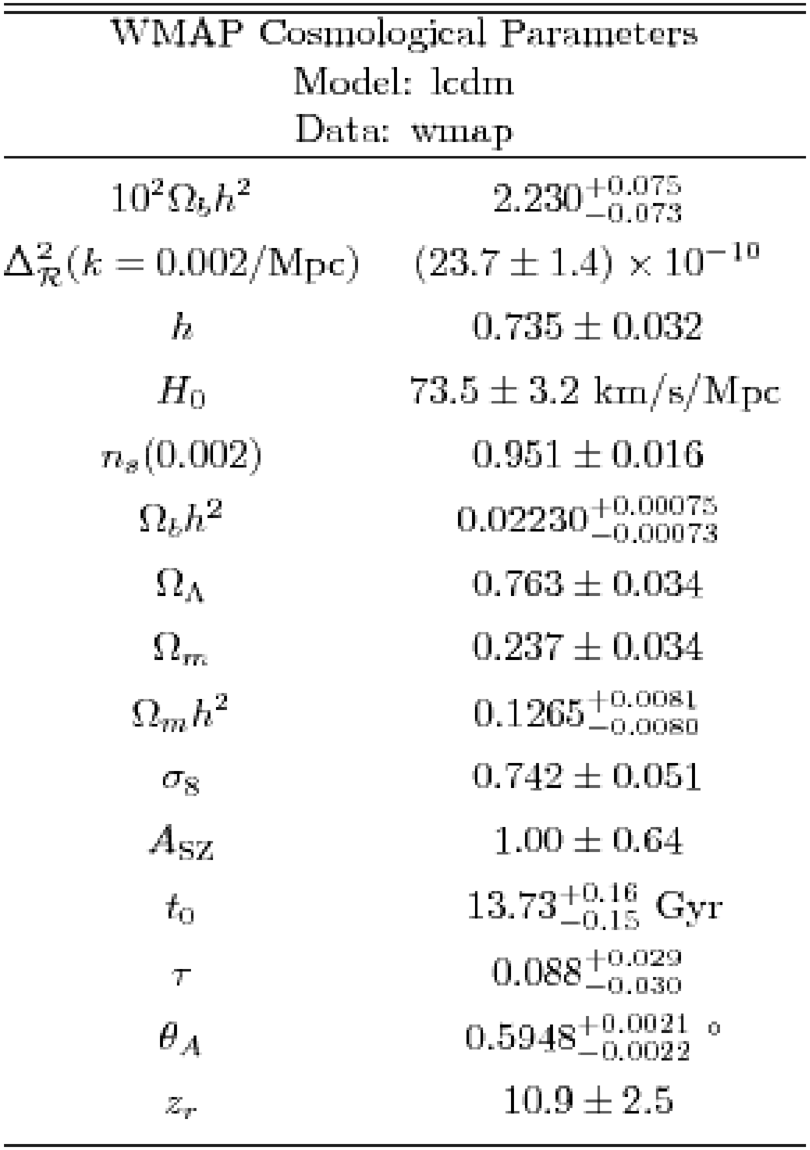
PLANCK

ALCATEL



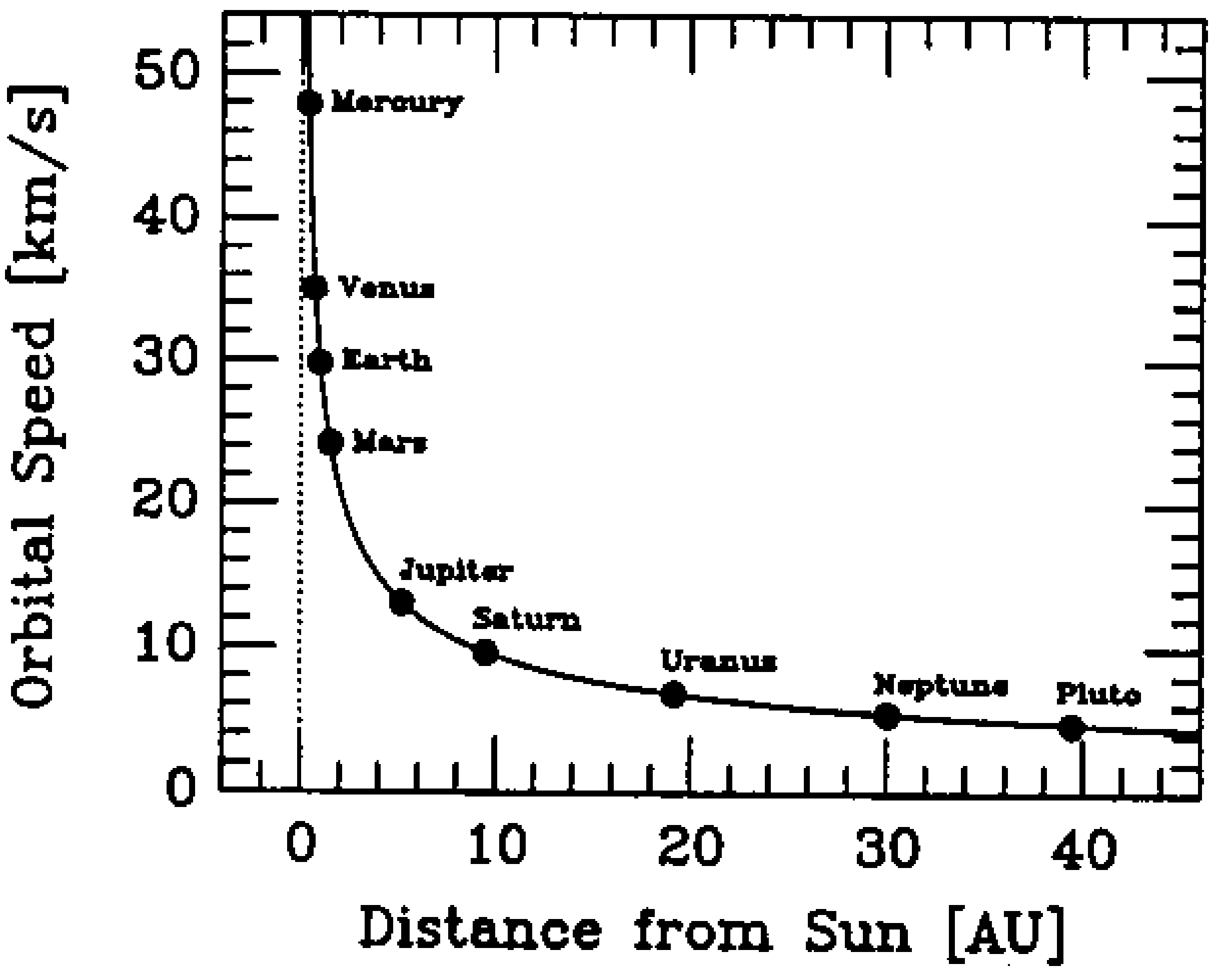


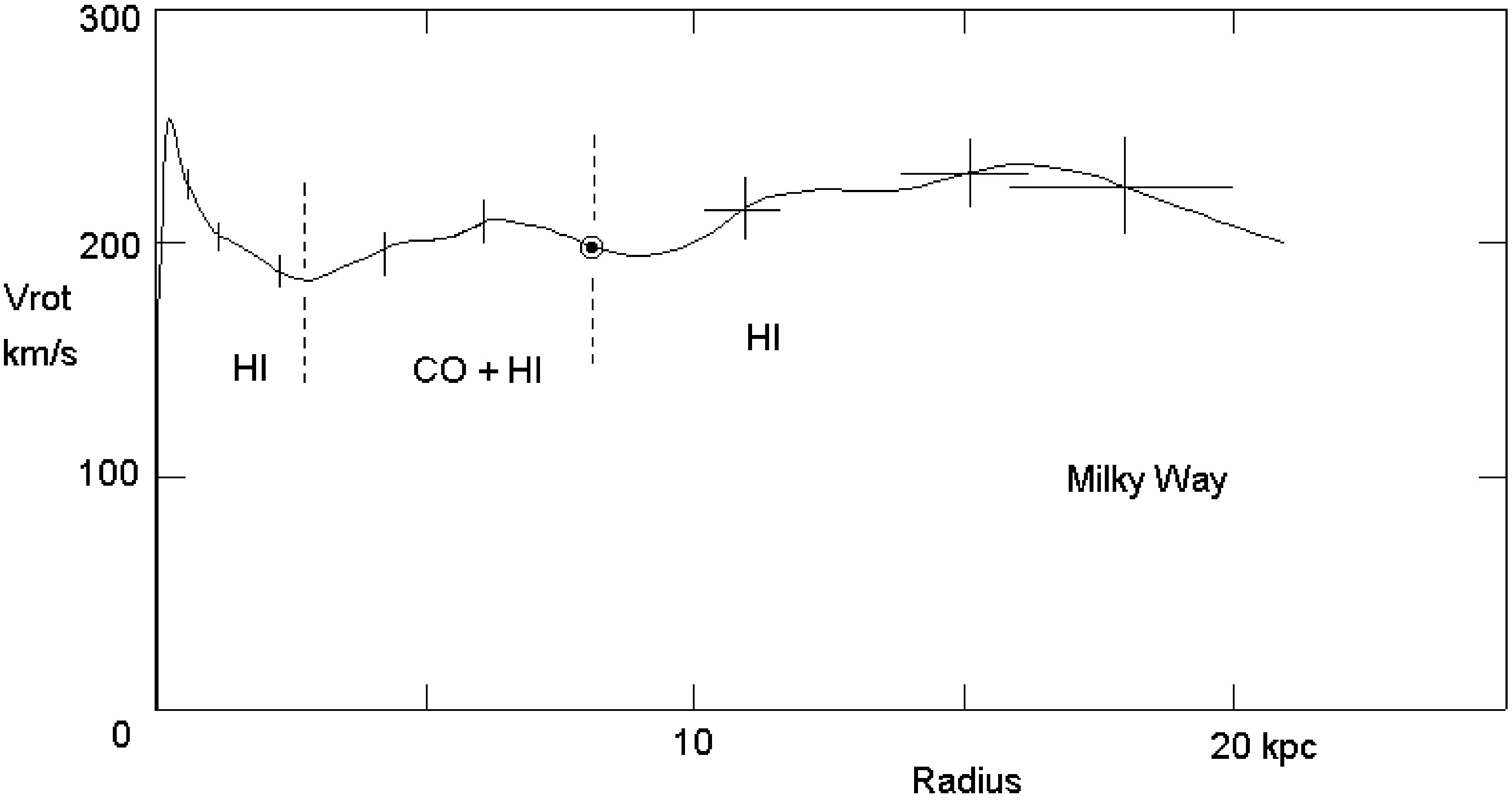

Multipole moment, ℓ
2
10
50
500
1000
1500
2000
2500
Temperature fluctuations [μK^2]
6000
5000
4000
3000
2000
1000
0
90°
18°
1°
0.2°
0.1°
0.07°
Angular scale

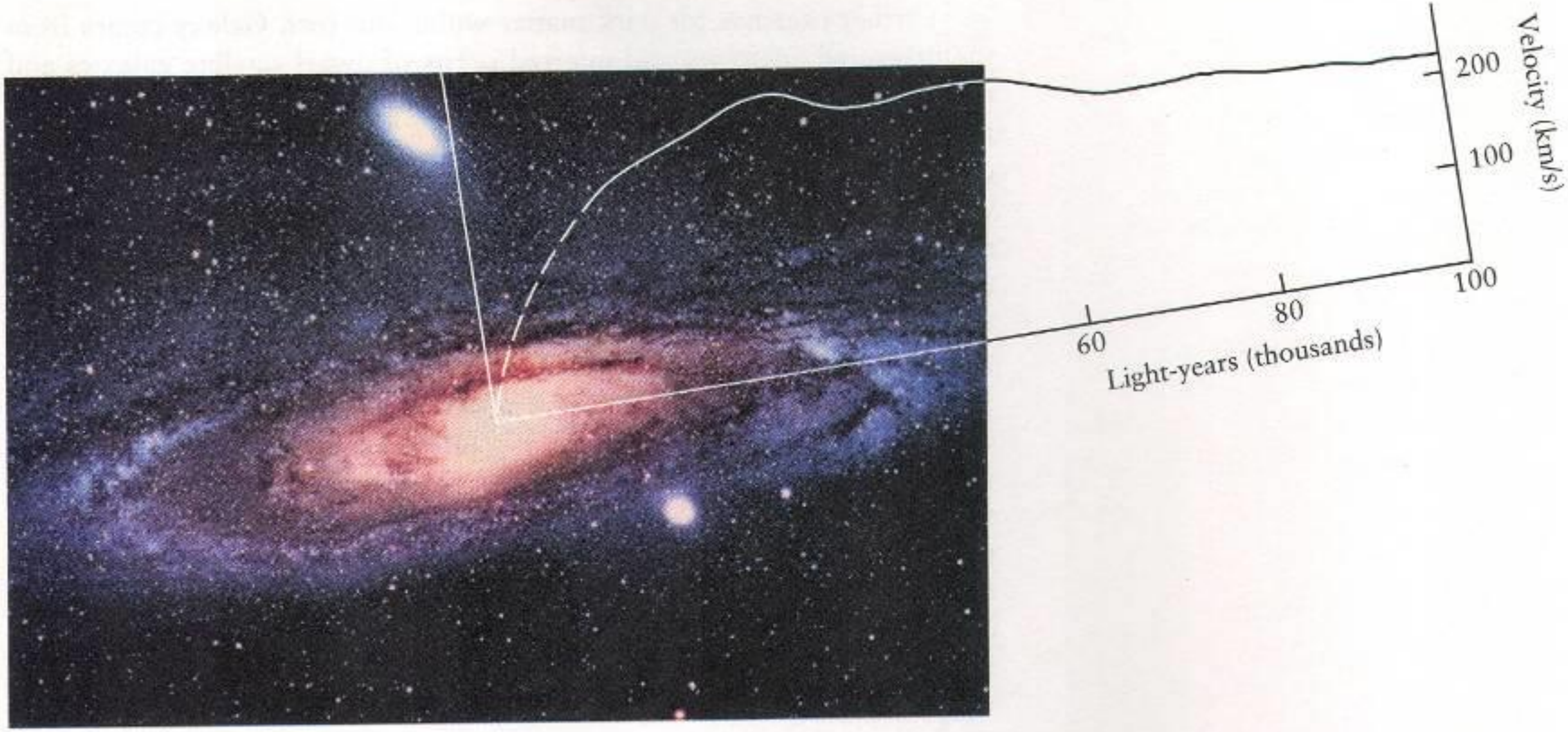


WMAP Cosmological Parameters
Model: lcdm
Data: wmap

$10^2\Omega_b h^2$	$2.230^{+0.075}_{-0.073}$
$\Delta^2_{\mathcal{R}}(k = 0.002/\mathrm{Mpc})$	$(23.7 \pm 1.4) \times 10^{-10}$
h	0.735 ± 0.032
H_0	73.5 ± 3.2 km/s/Mpc
$n_s(0.002)$	0.951 ± 0.016
$\Omega_b h^2$	$0.02230^{+0.00075}_{-0.00073}$
Ω_Λ	0.763 ± 0.034
Ω_m	0.237 ± 0.034
$\Omega_m h^2$	$0.1265^{+0.0081}_{-0.0080}$
σ_8	0.742 ± 0.051
A_{SZ}	1.00 ± 0.64
t_0	$13.73^{+0.16}_{-0.15}$ Gyr
τ	$0.088^{+0.029}_{-0.030}$
θ_A	$0.5948^{+0.0021}_{-0.0022}$ $^\circ$
z_r	10.9 ± 2.5


Orbital Speed [km/s]
Distance from Sun [AU]
0
10
20
30
40
50
0
10
20
30
40
Mercury
Venus
Earth
Mars
Jupiter
Saturn
Uranus
Neptune
Pluto


300
200
100
0
Vrot
km/s
HI
CO + HI
HI
Milky Way
10
20 kpc
Radius

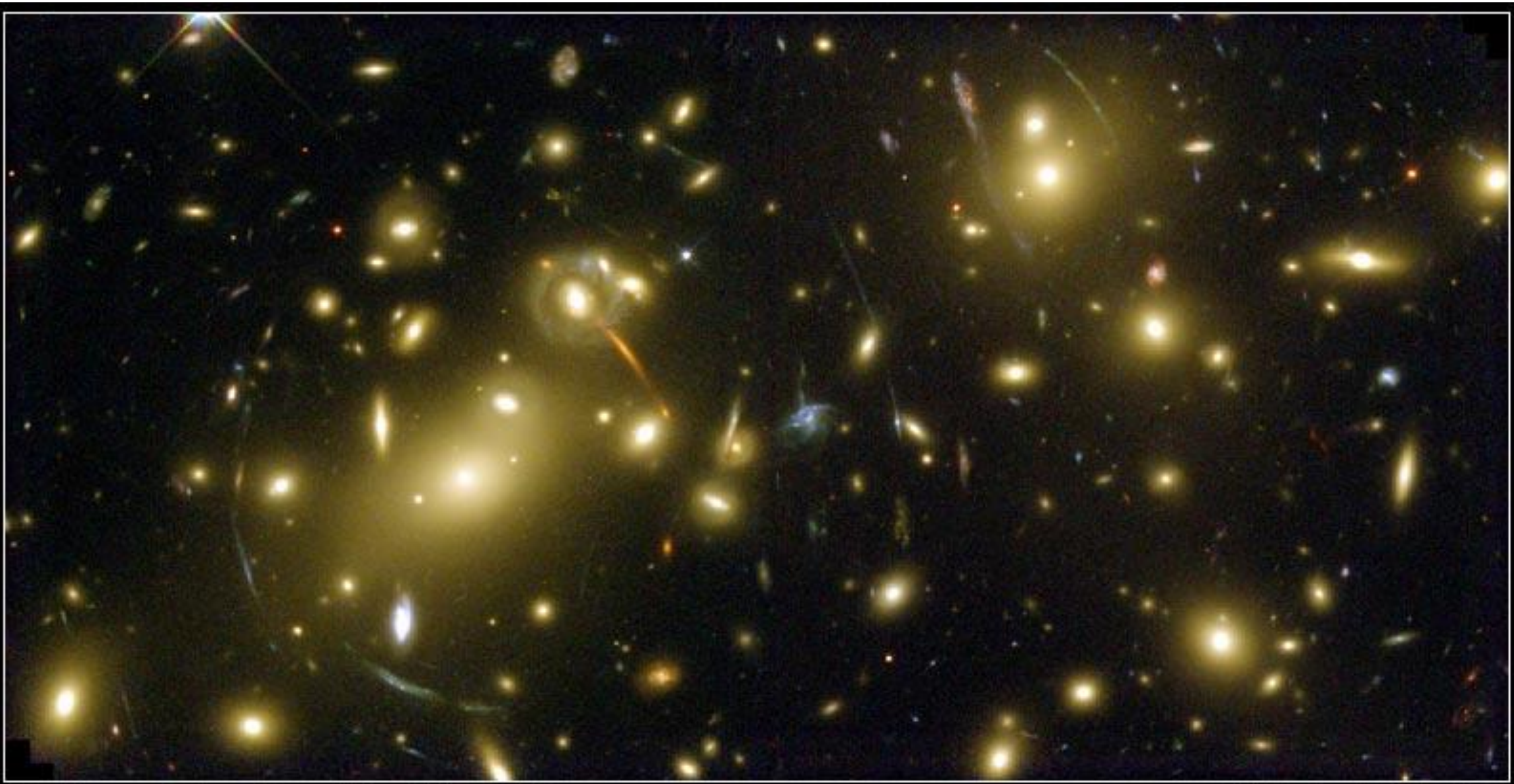

Velocity (km/s)
200
100
100
80
60
Light-years (thousands)

Wnioski z prawa Keplera

$$v(r) = (GM(r)/r)^{1/2} = \mathrm{const}$$

$$M(r) \sim r$$

❐ $\sim 1/r^2$



Galaxy Cluster Abell 2218 **HST • WFPC2**

NASA, A. Fruchter and the ERO Team (STScI, ST-ECF) • STScI-PRC00-08

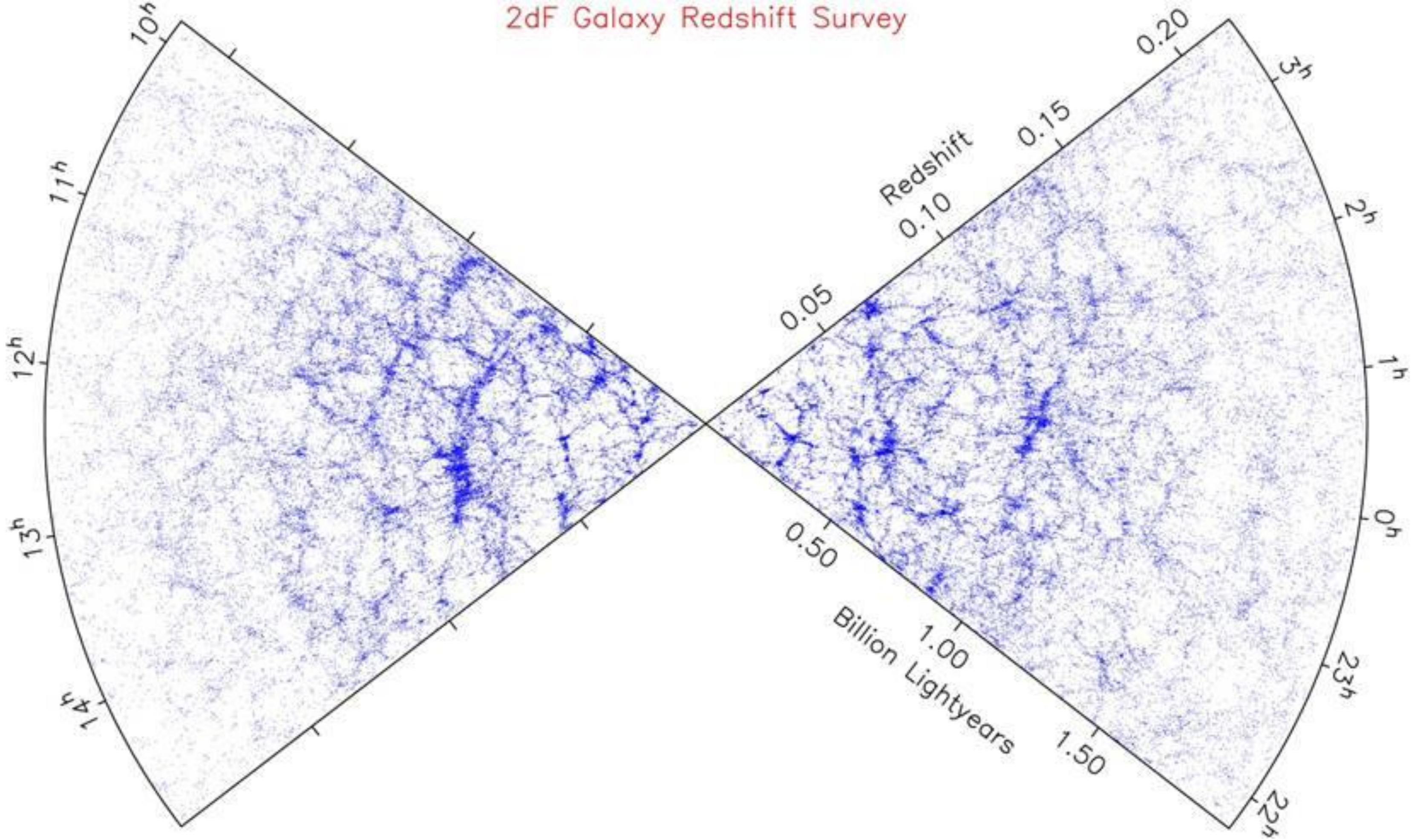
Stosunek masy do jasności

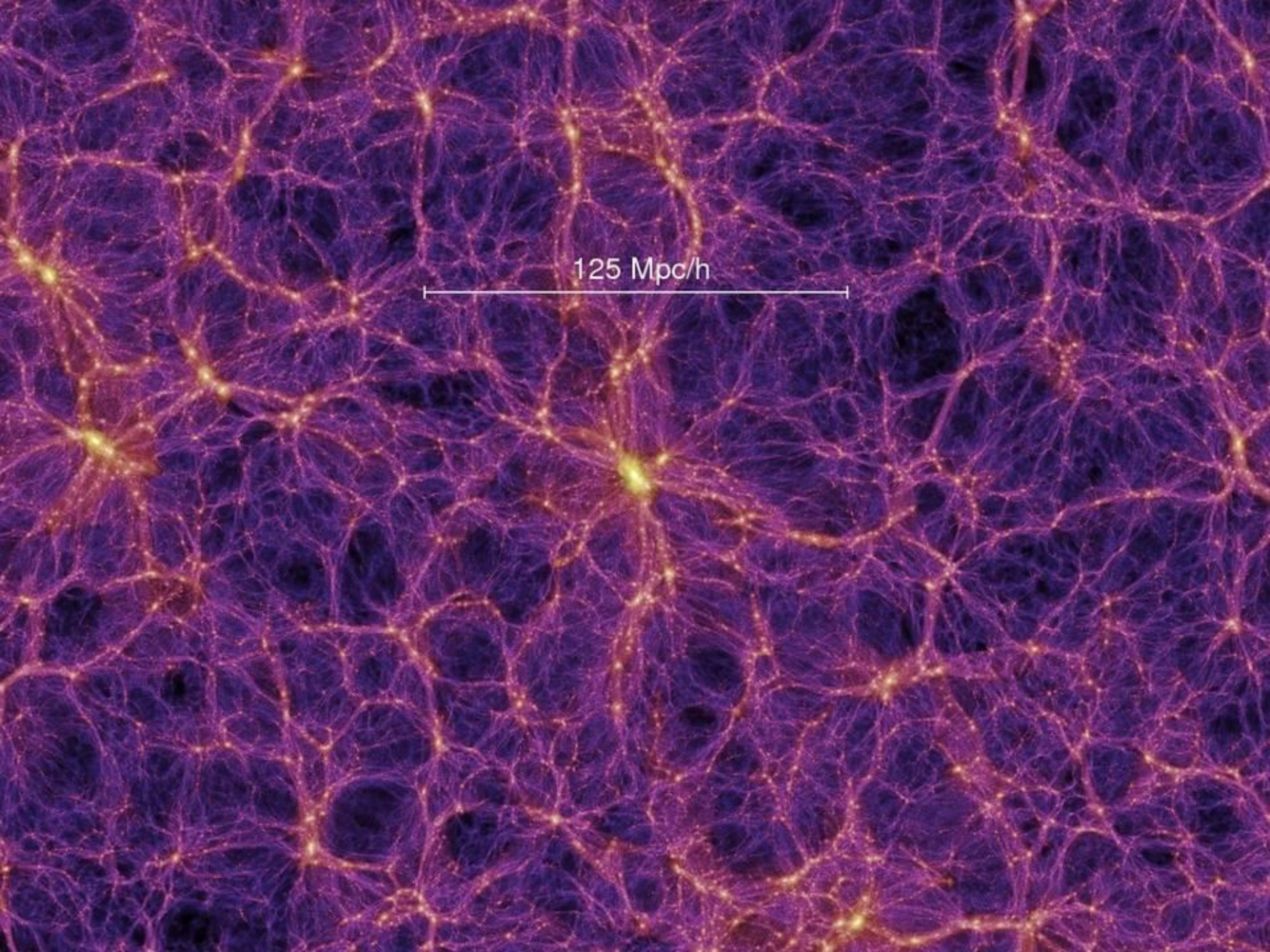
galaktyki M/L ~ 5 – 50

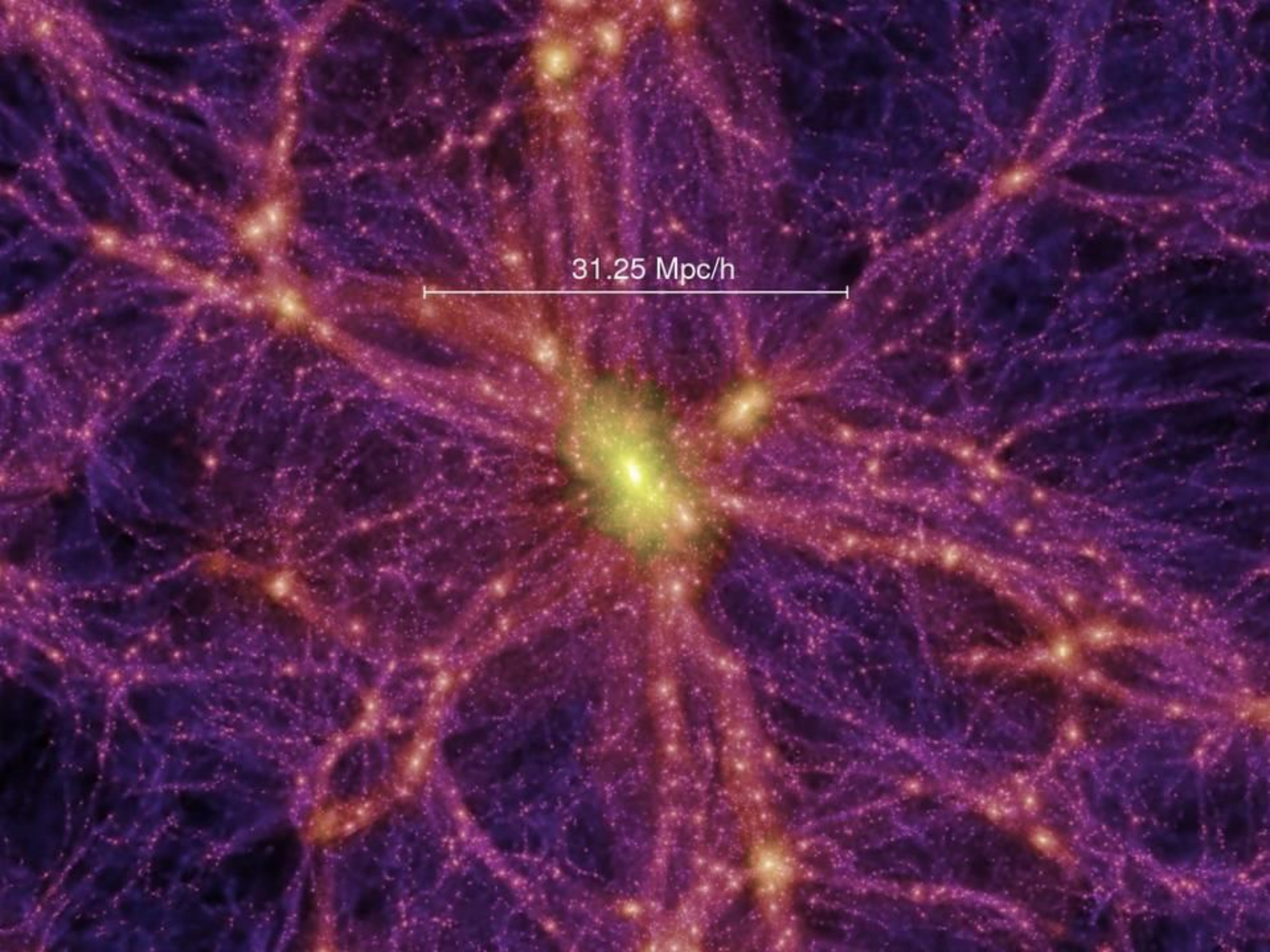
gromady galaktyk
M/L ~ 100 - 500

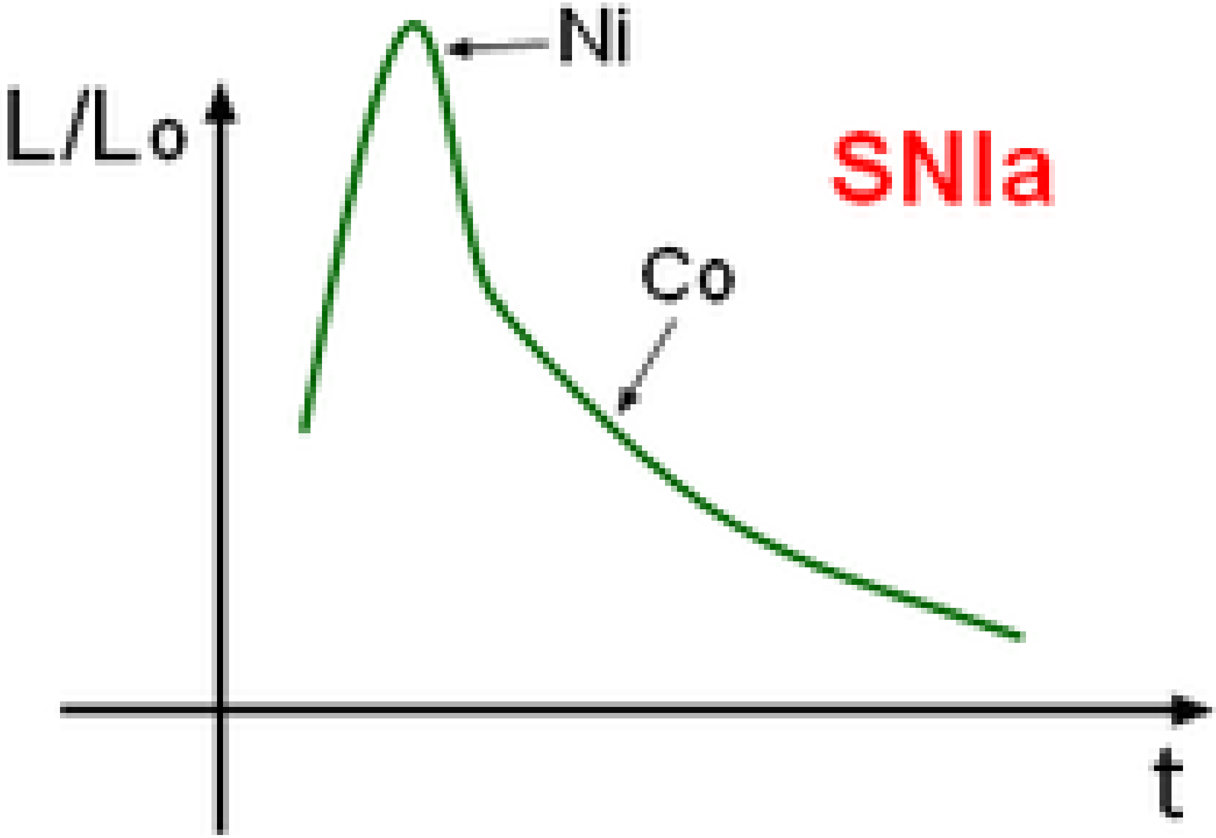
Gęstość cząstek ciemnej materii w otoczeniu Słońca

n_{DM} 🕔 $0.3(1\mathrm{GeV}/m_{DM})\ 1/\mathrm{cm}^3$

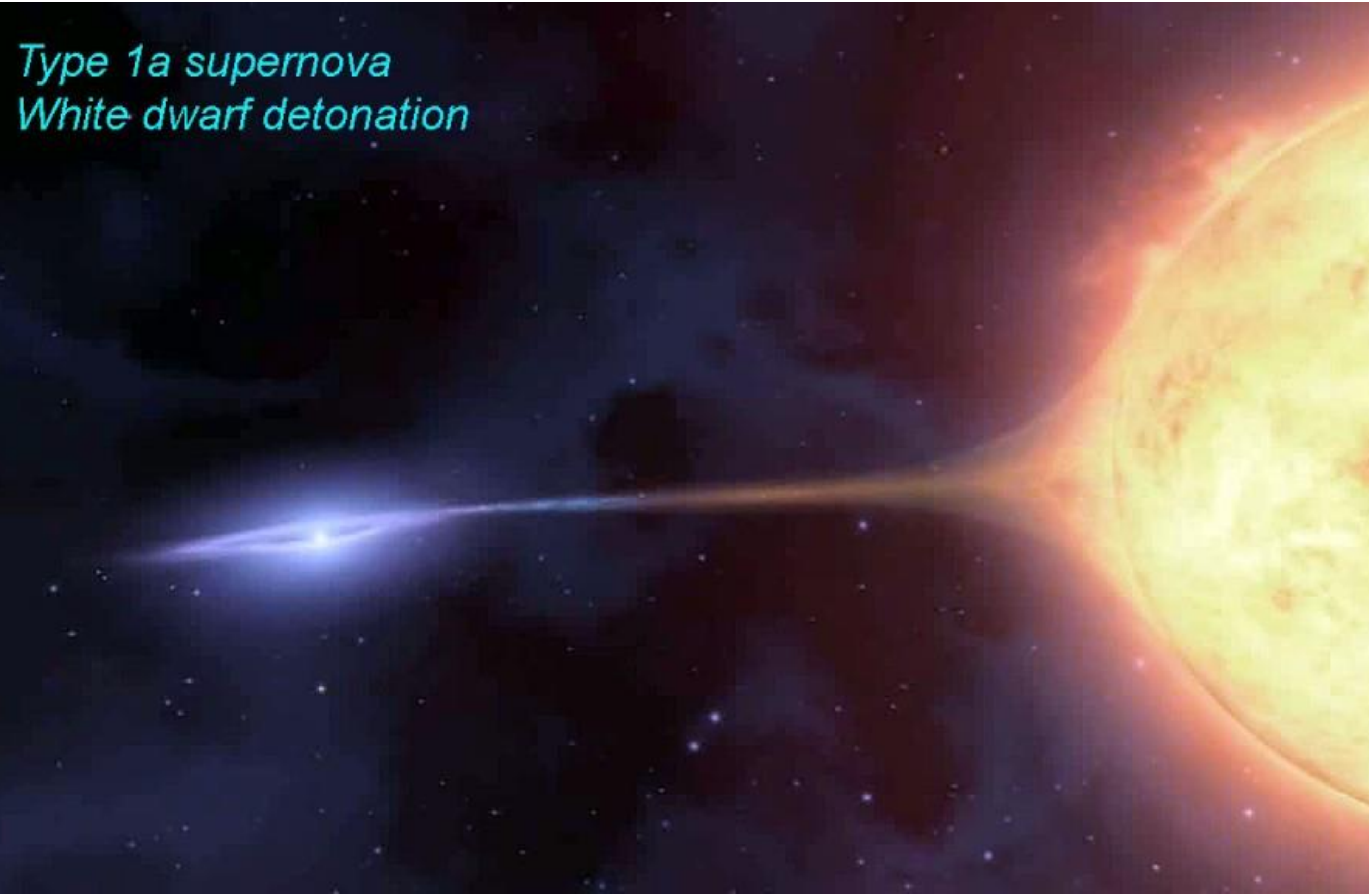

2dF Galaxy Redshift Survey
10h
11h
12h
13h
14h
0.20
0.15
Redshift
0.10
0.05
3h
2h
1h
0h
23h
22h
0.50
1.00
1.50
Billion Lightyears


125 Mpc/h

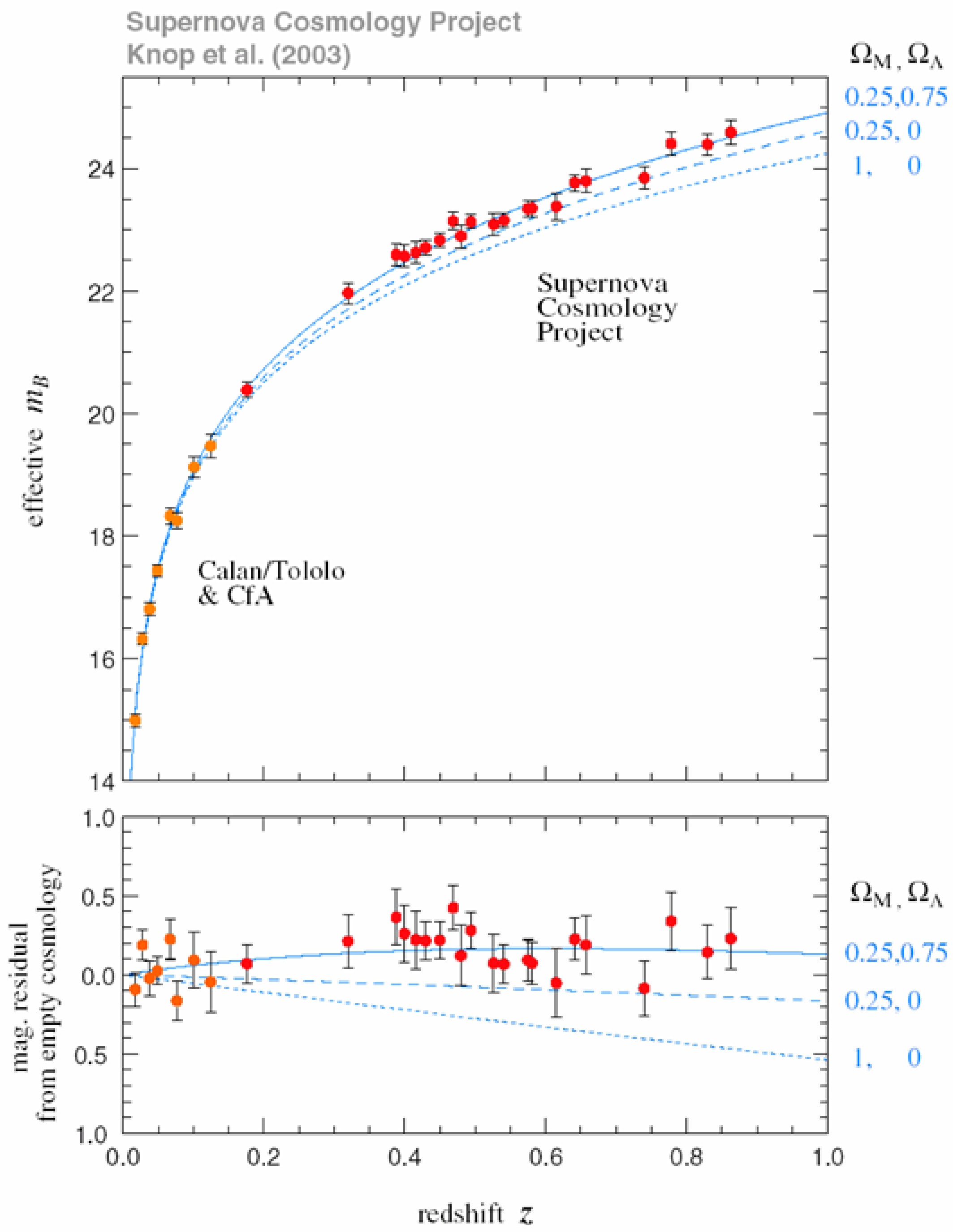

31.25 Mpc/h


Ni
L/Lo
SNIa
Co
t

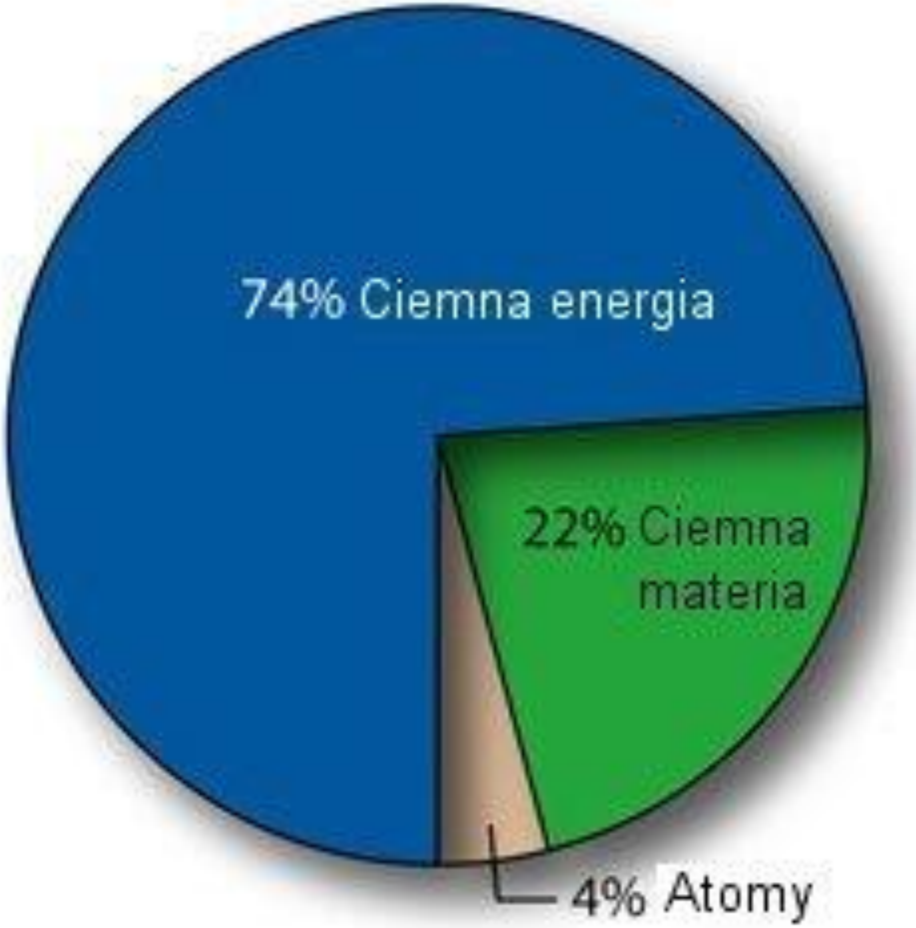

SN 2011fe



Type 1a supernova
White dwarf detonation



Supernova Cosmology Project
Knop et al. (2003)

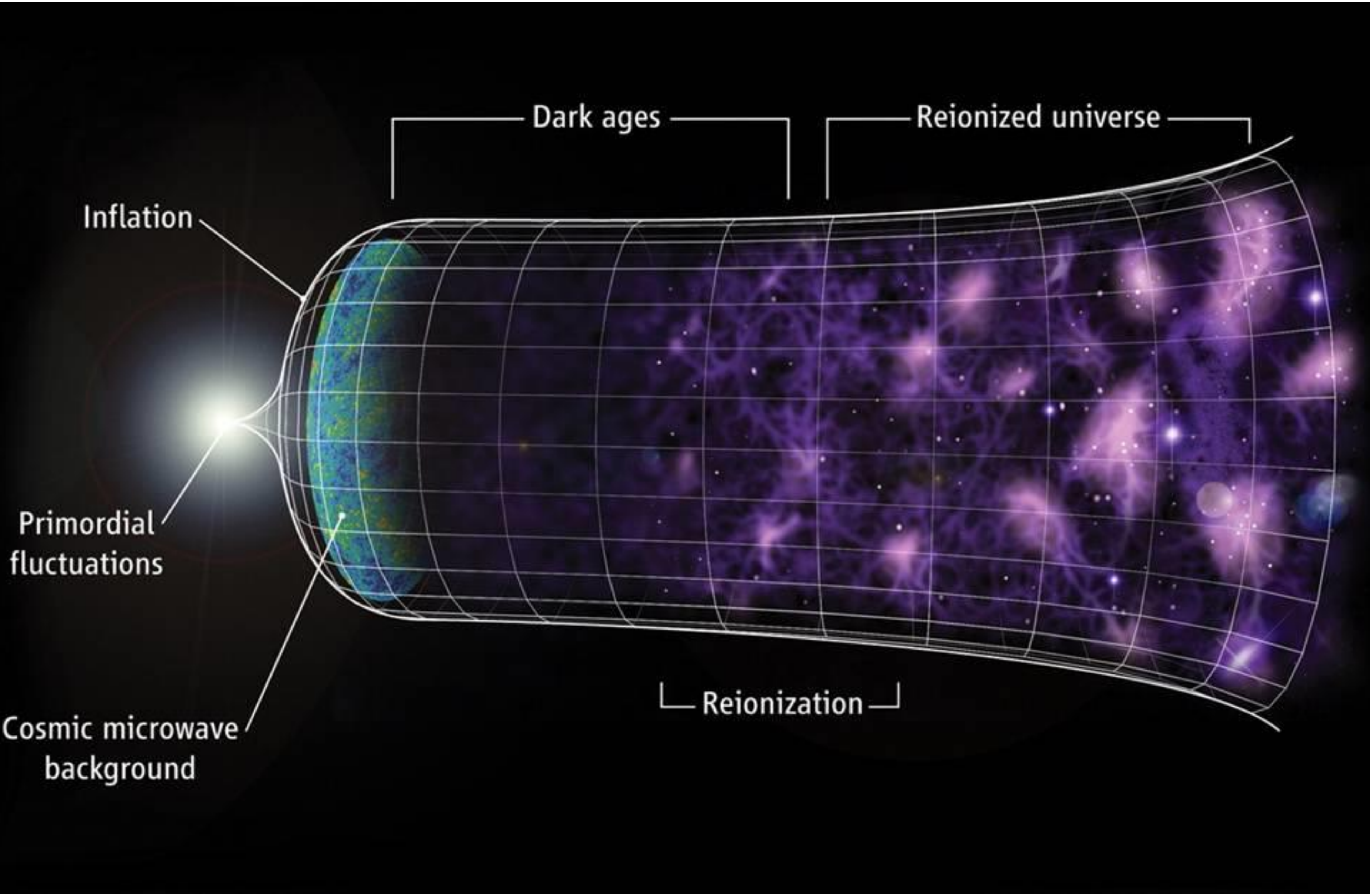

74% Ciemna energia
22% Ciemna materia
4% Atomy

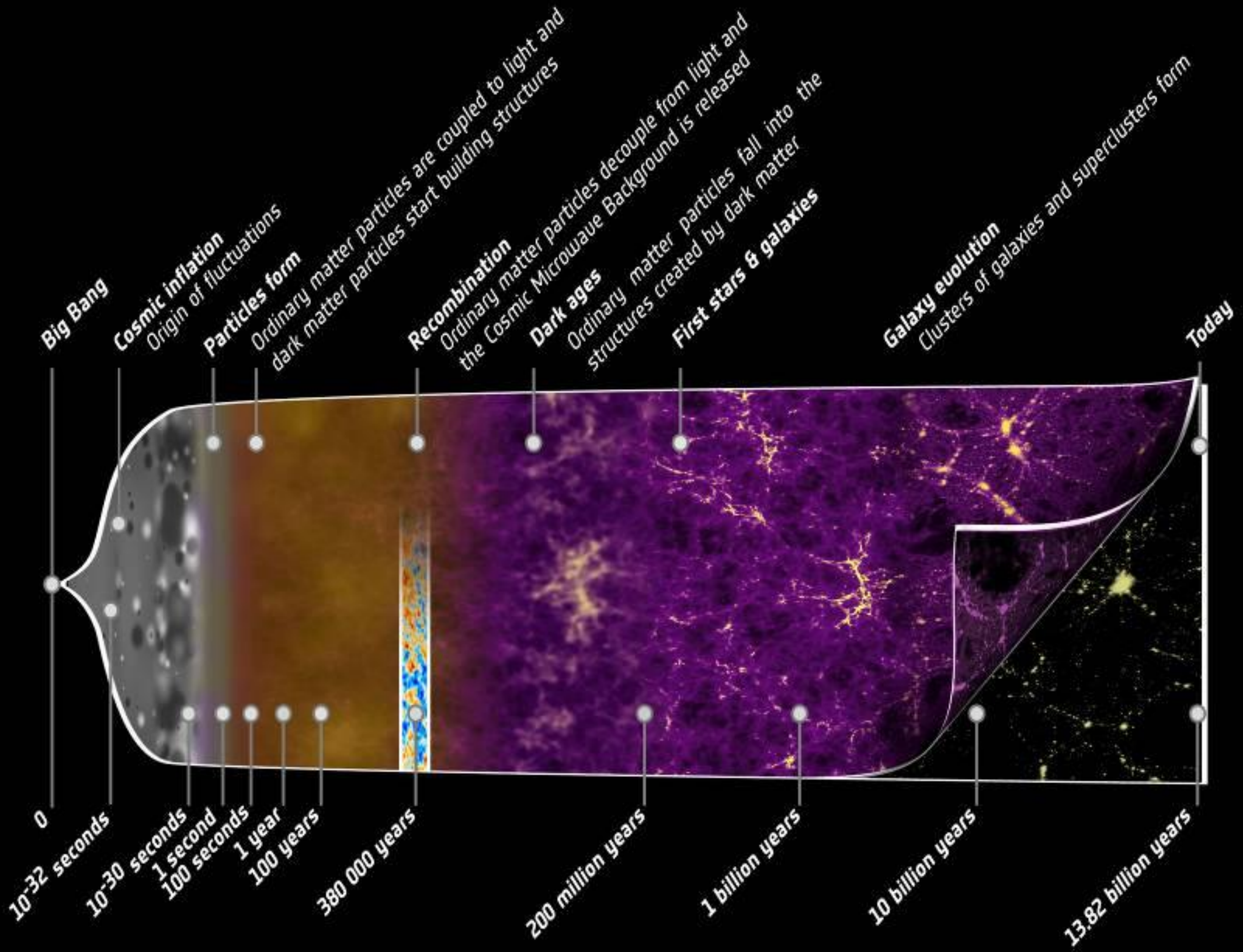
Możliwe fizyczne modele ciemnej energii:

a) energia próżni pól kwantowych

b) energia potencjalna samooddziałującego pola skalarnego

c) wielkoskalowa niejednorodność wszechświata


Dark ages
Reionized universe
Inflation
Primordial fluctuations
Cosmic microwave background
Reionization


Big Bang
Cosmic inflation
Origin of fluctuations
Particles form
Ordinary matter particles are coupled to light and dark matter particles start building structures
Recombination
Ordinary matter particles decouple from light and the Cosmic Microwave Background is released
Dark ages
Ordinary matter particles fall into the structures created by dark matter
First stars & galaxies
Galaxy evolution
Clusters of galaxies and superclusters form
Today
0
10^{-32} seconds
10^{-30} seconds
1 second
100 seconds
1 year
100 years
380 000 years
200 million years
1 billion years
10 billion years
13,82 billion years