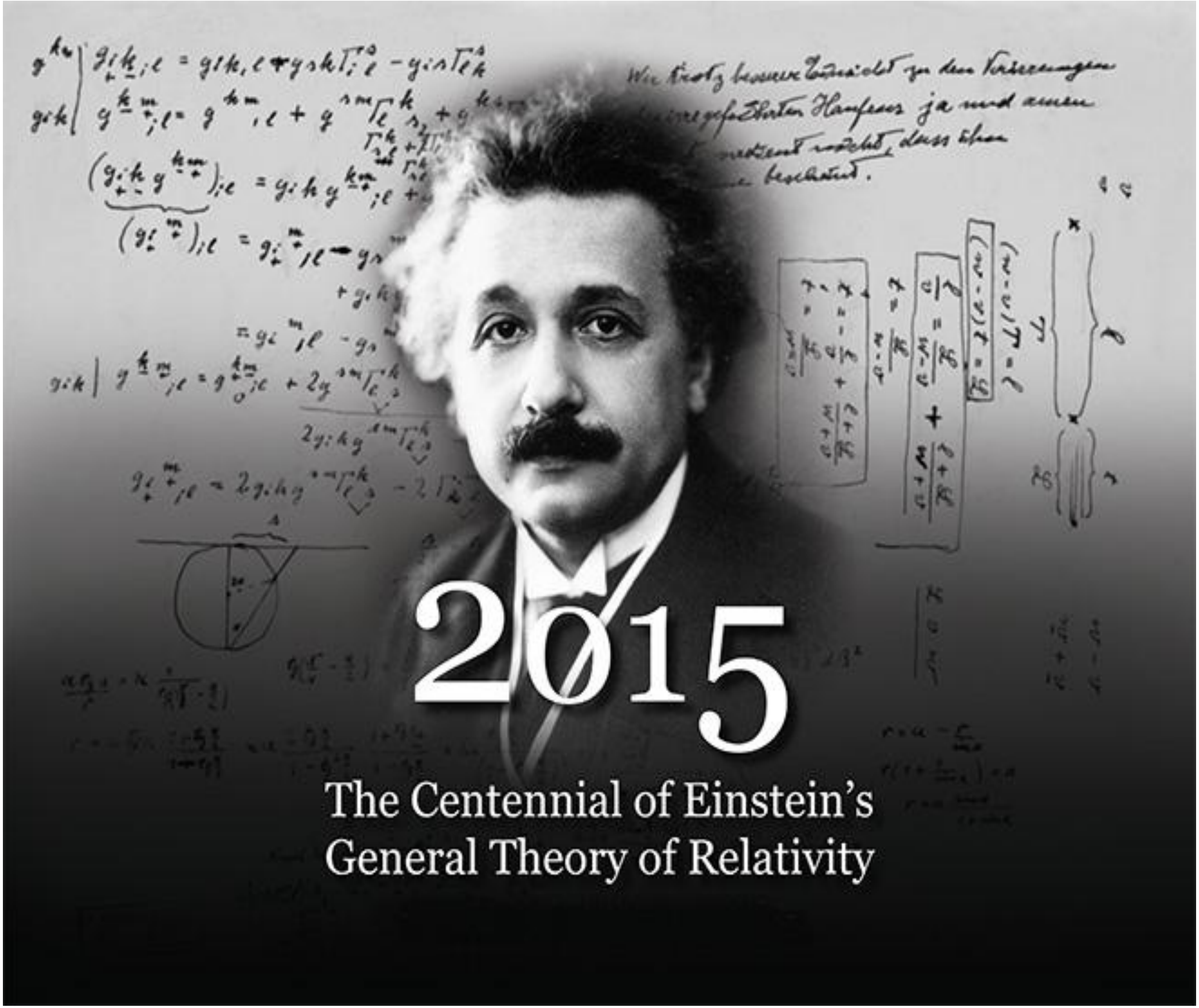
Wszechświat widziany przez satelitę Planck

Marek Demiański
Instytut Fizyki Teoretycznej
Uniwersytet Warszawski


2015
The Centennial of Einstein's
General Theory of Relativity

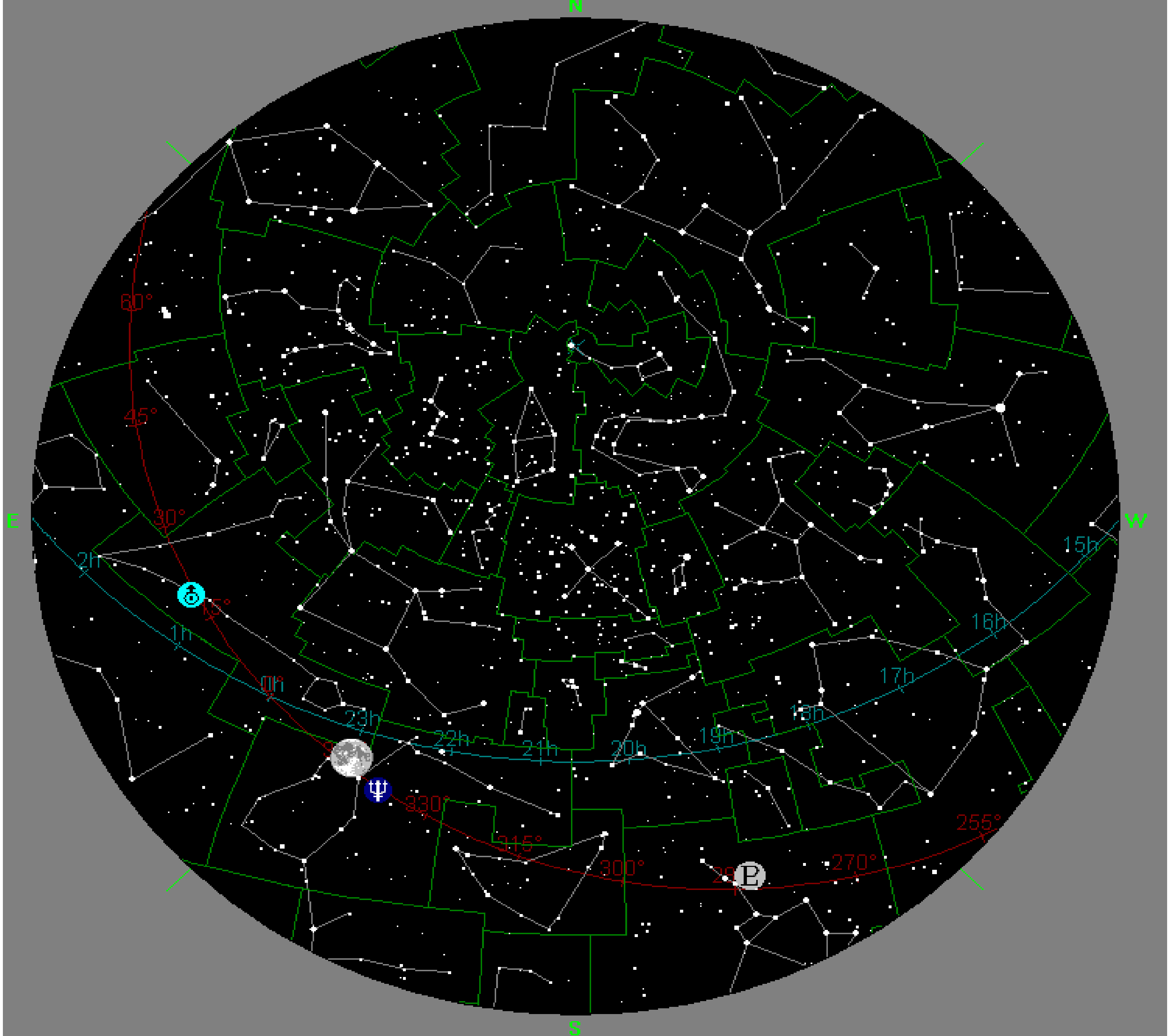
Die Grundlage der allgemeinen Relativitätstheorie

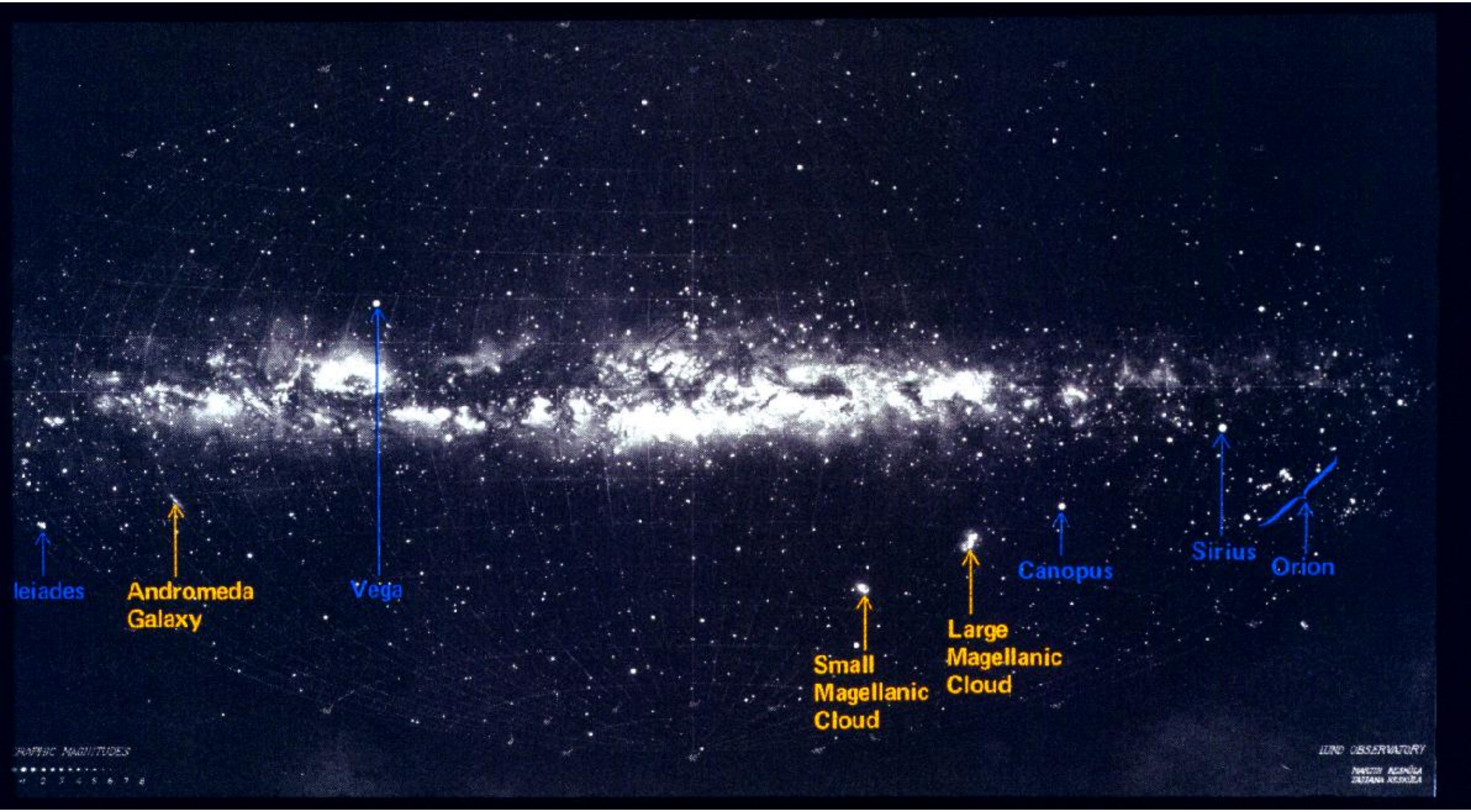
von

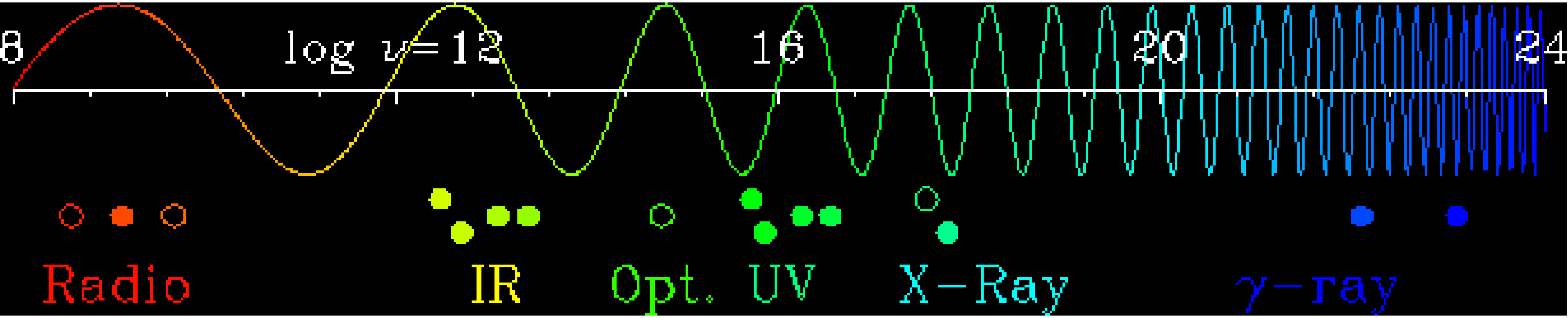
A. Einstein

Leipzig :: Verlag von Johann Ambrosius Barth :: 1916

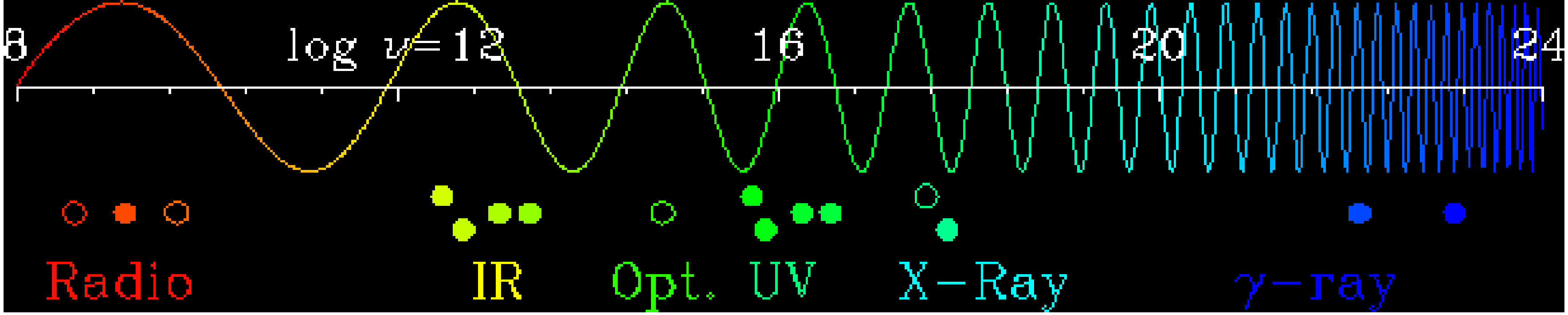
INTERNATIONAL
YEAR OF LIGHT
2015

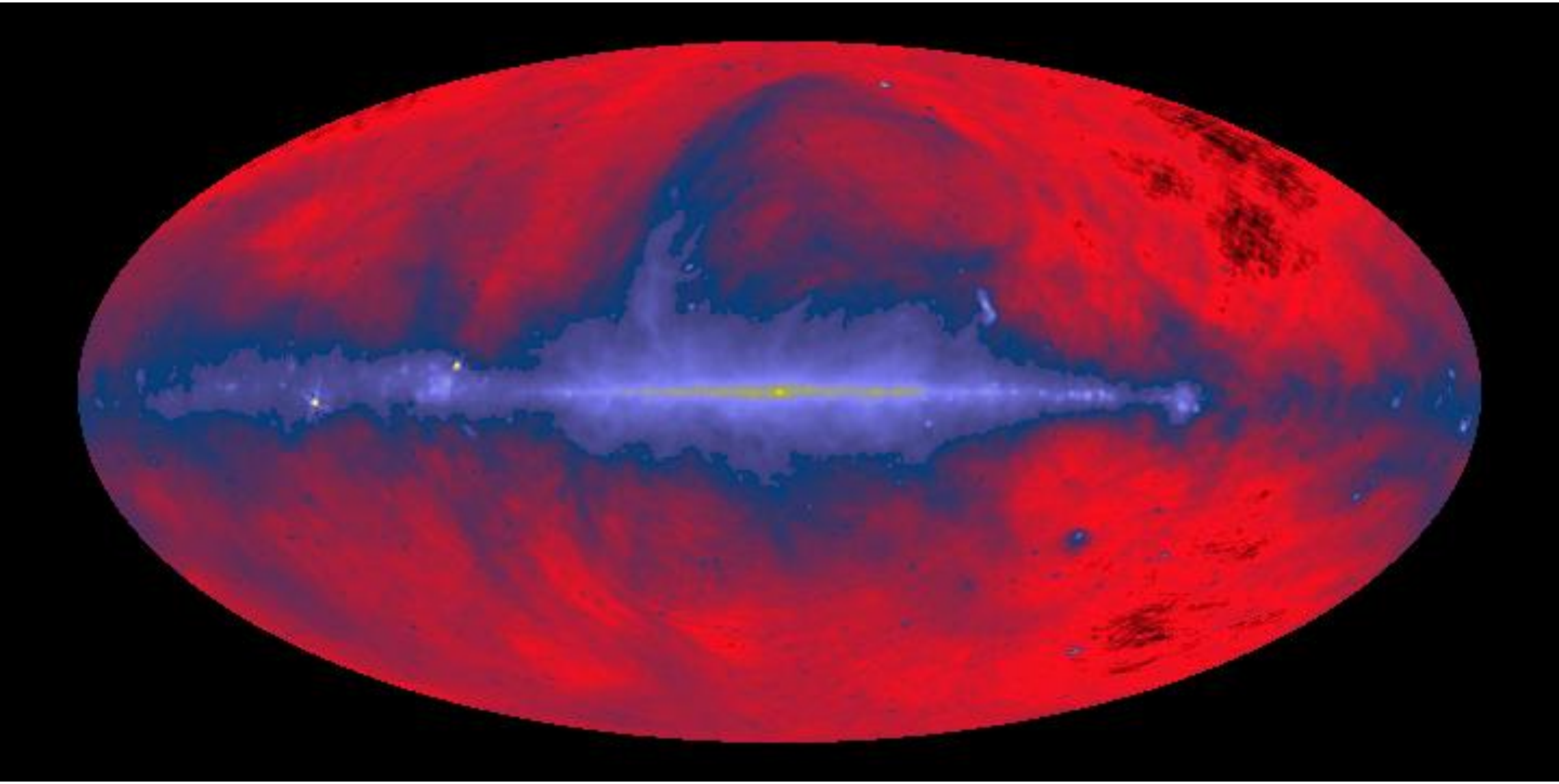

N
S
E
W
60°
45°
30°
15°
2h
1h
0h
23h
22h
21h
20h
19h
18h
17h
16h
15h
330°
315°
300°
270°
255°

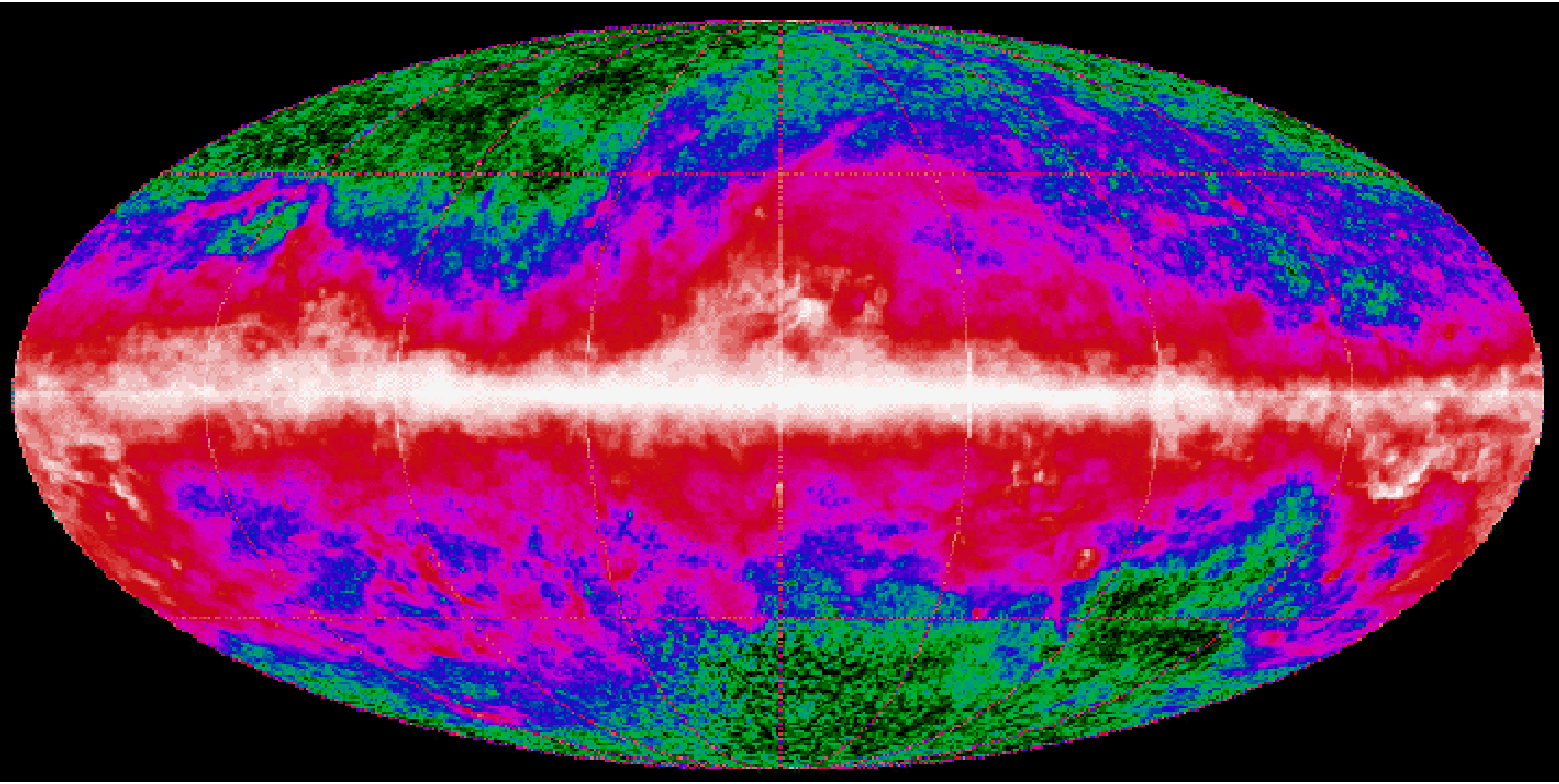

leiades
Andromeda Galaxy
Vega
Small Magellanic Cloud
Large Magellanic Cloud
Canopus
Sirius
Orion
LUND OBSERVATORY

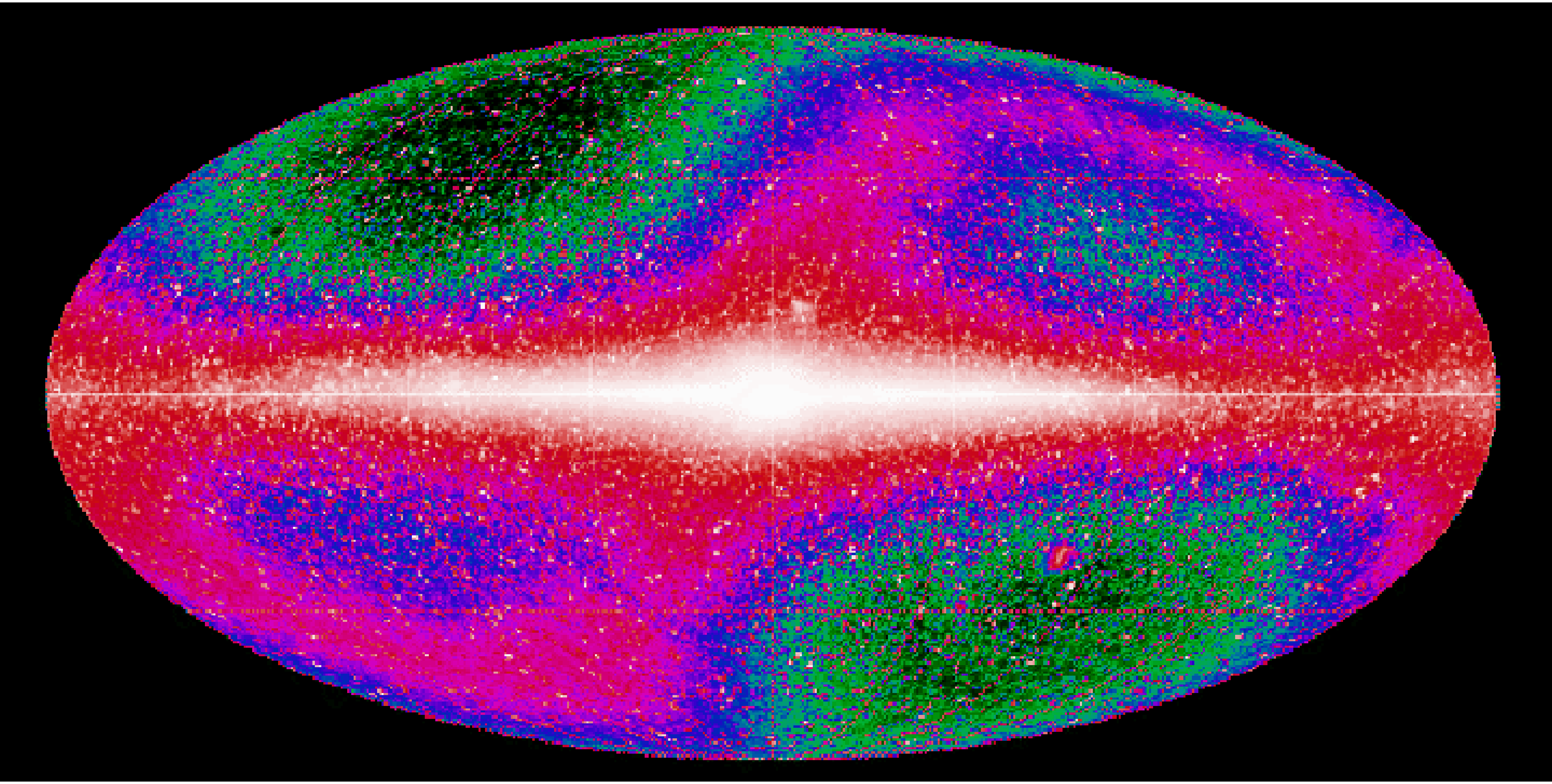


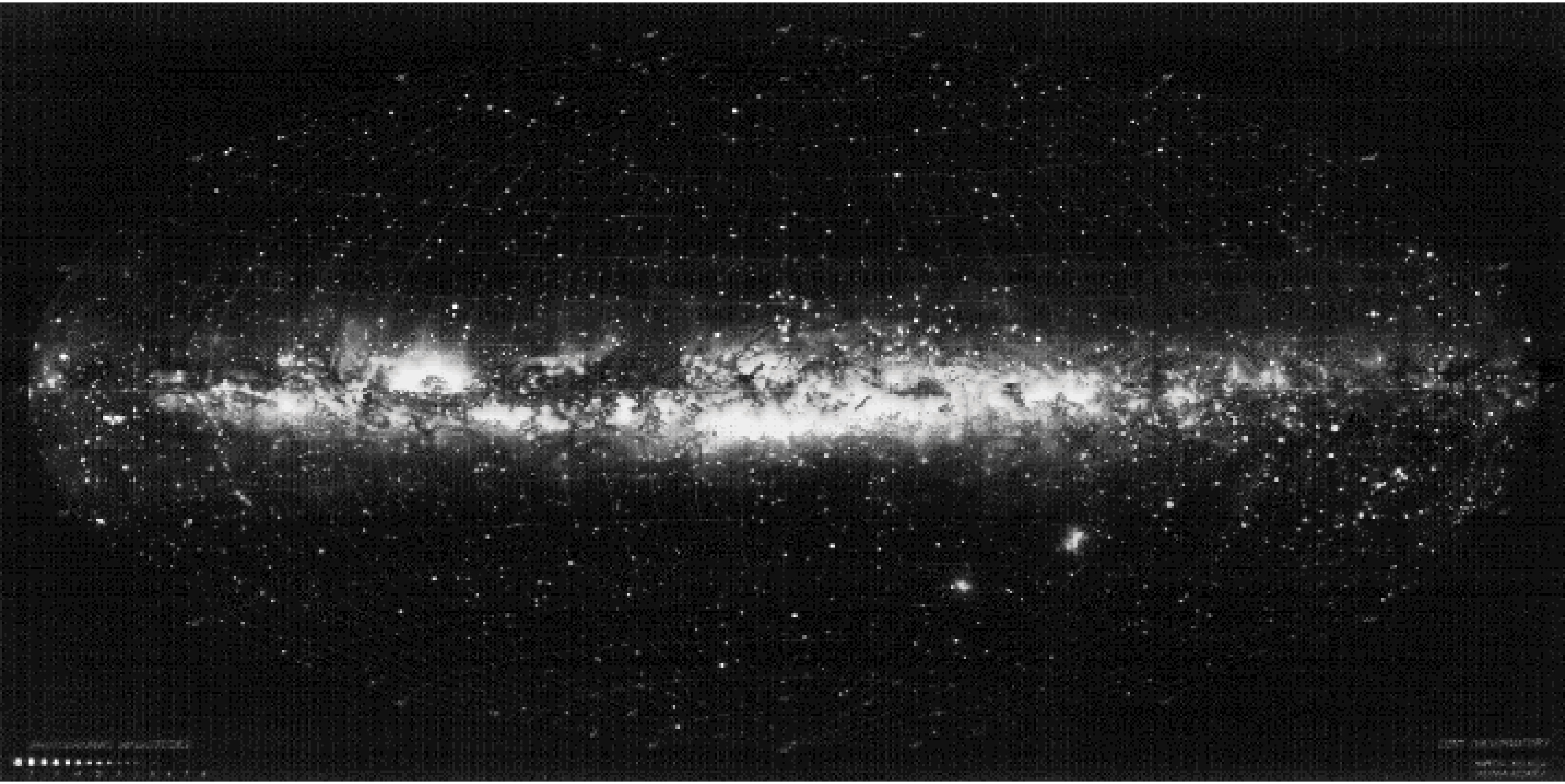
8
log ν=12
16
20
24
Radio
IR
Opt.
UV
X-Ray
γ-ray

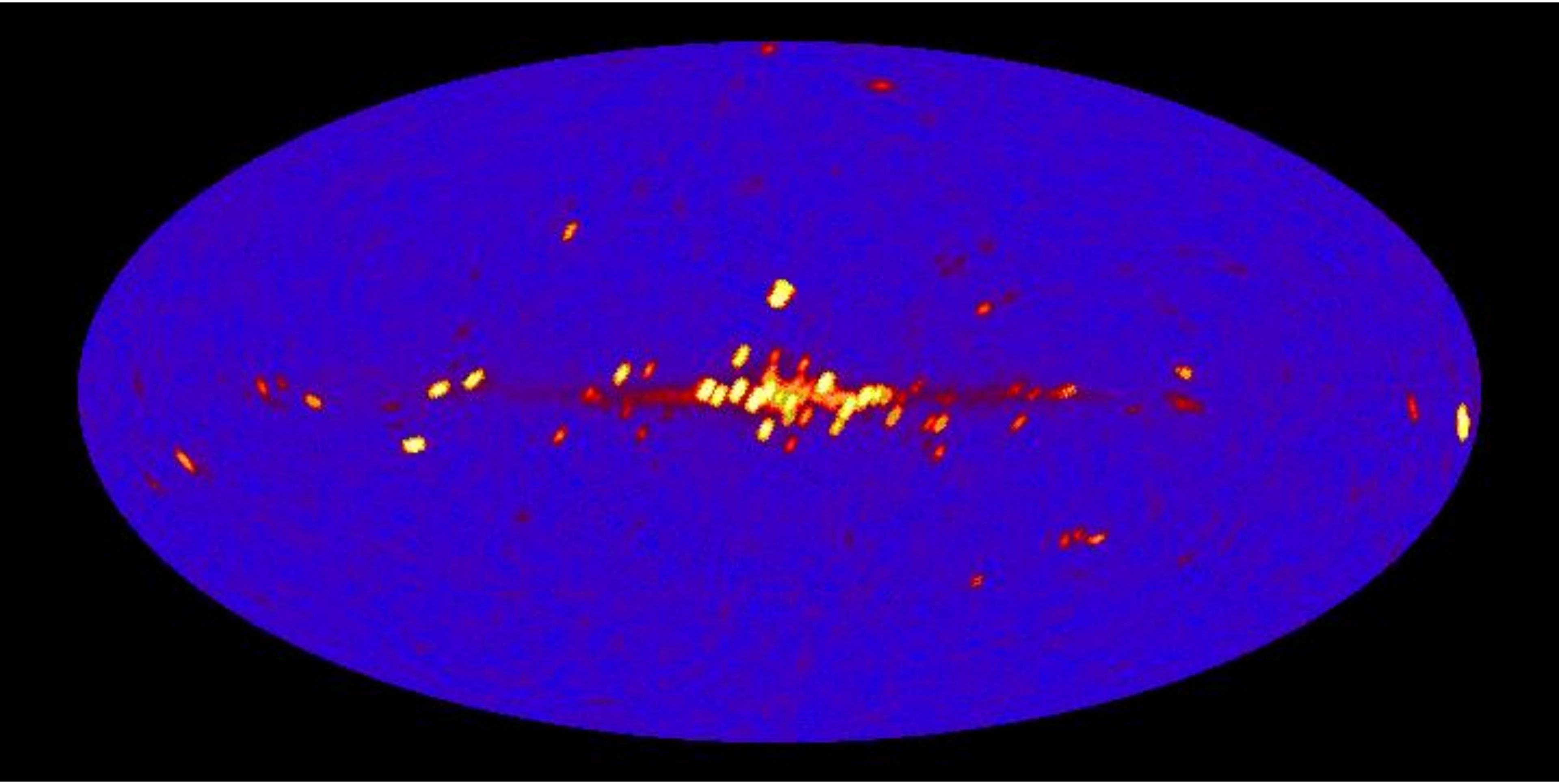

8
log ν=12
16
20
24
Radio
IR
Opt.
UV
X-Ray
γ-ray

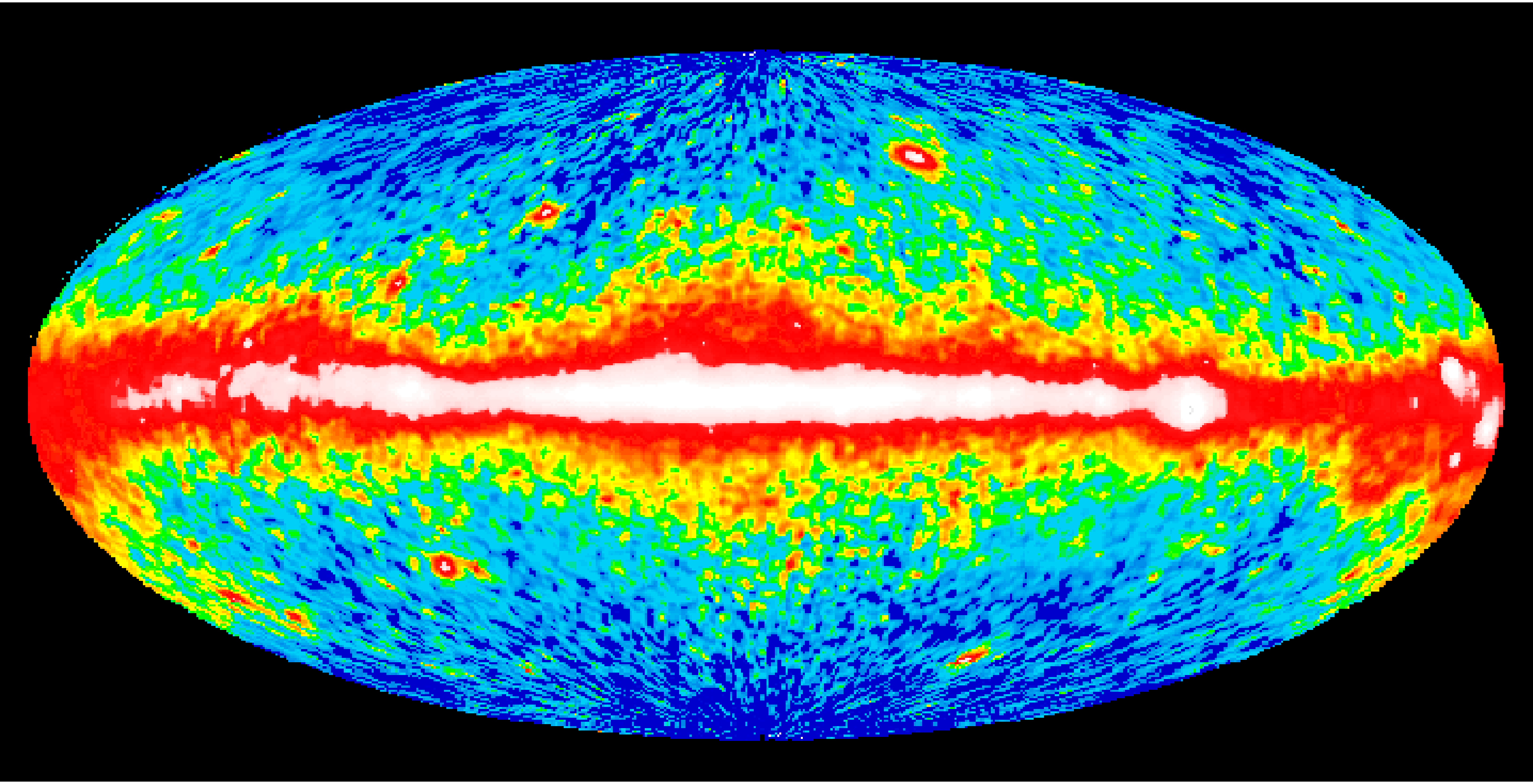


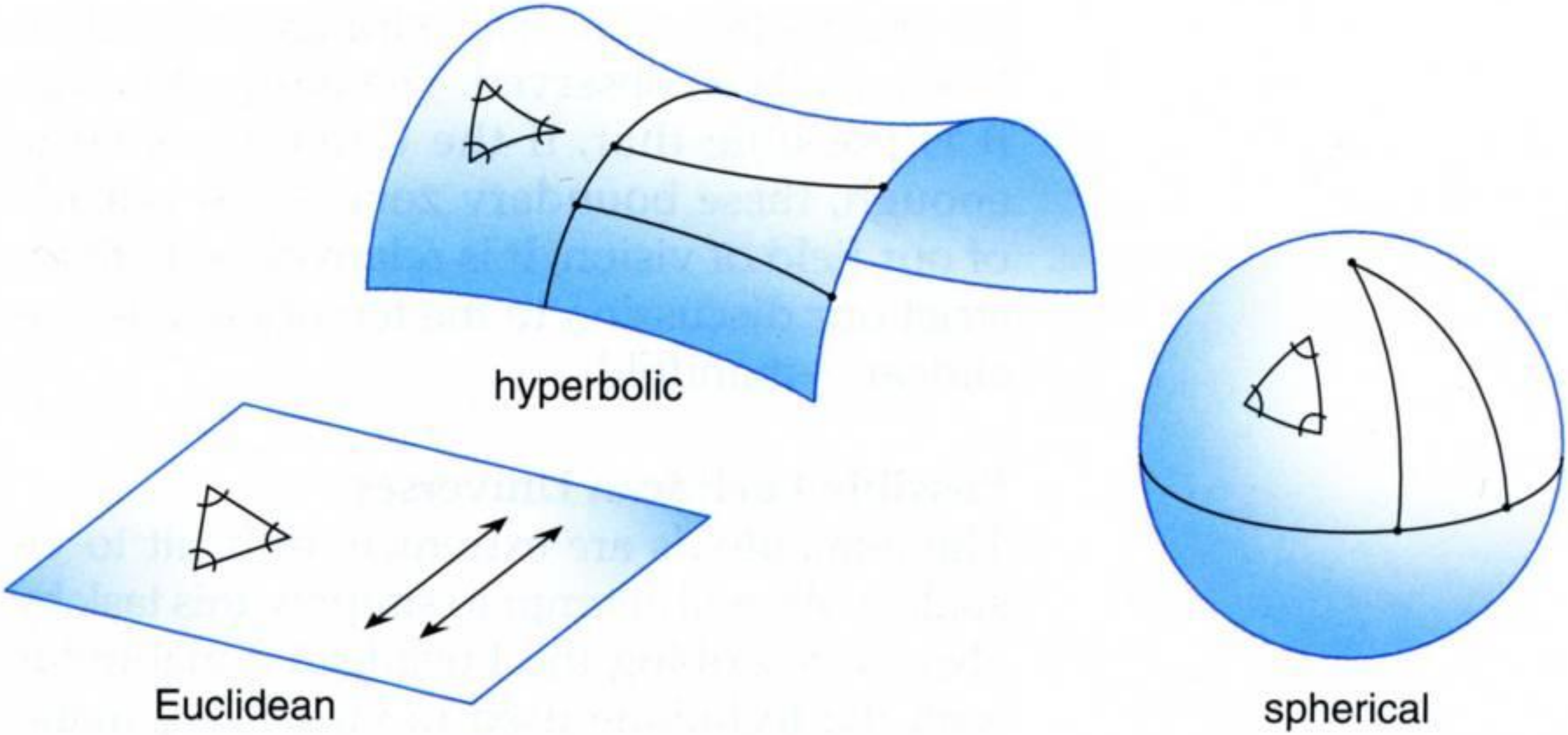


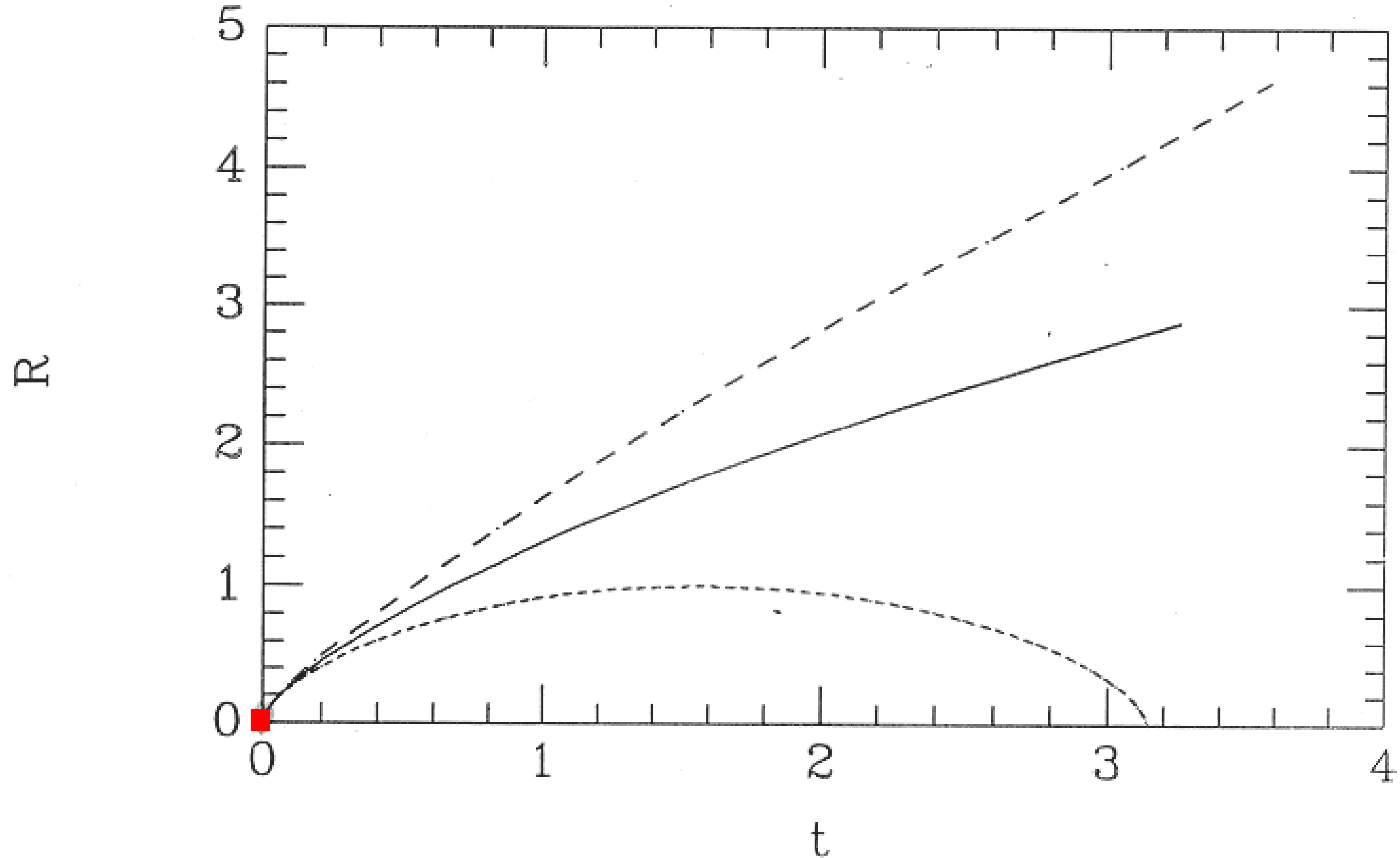




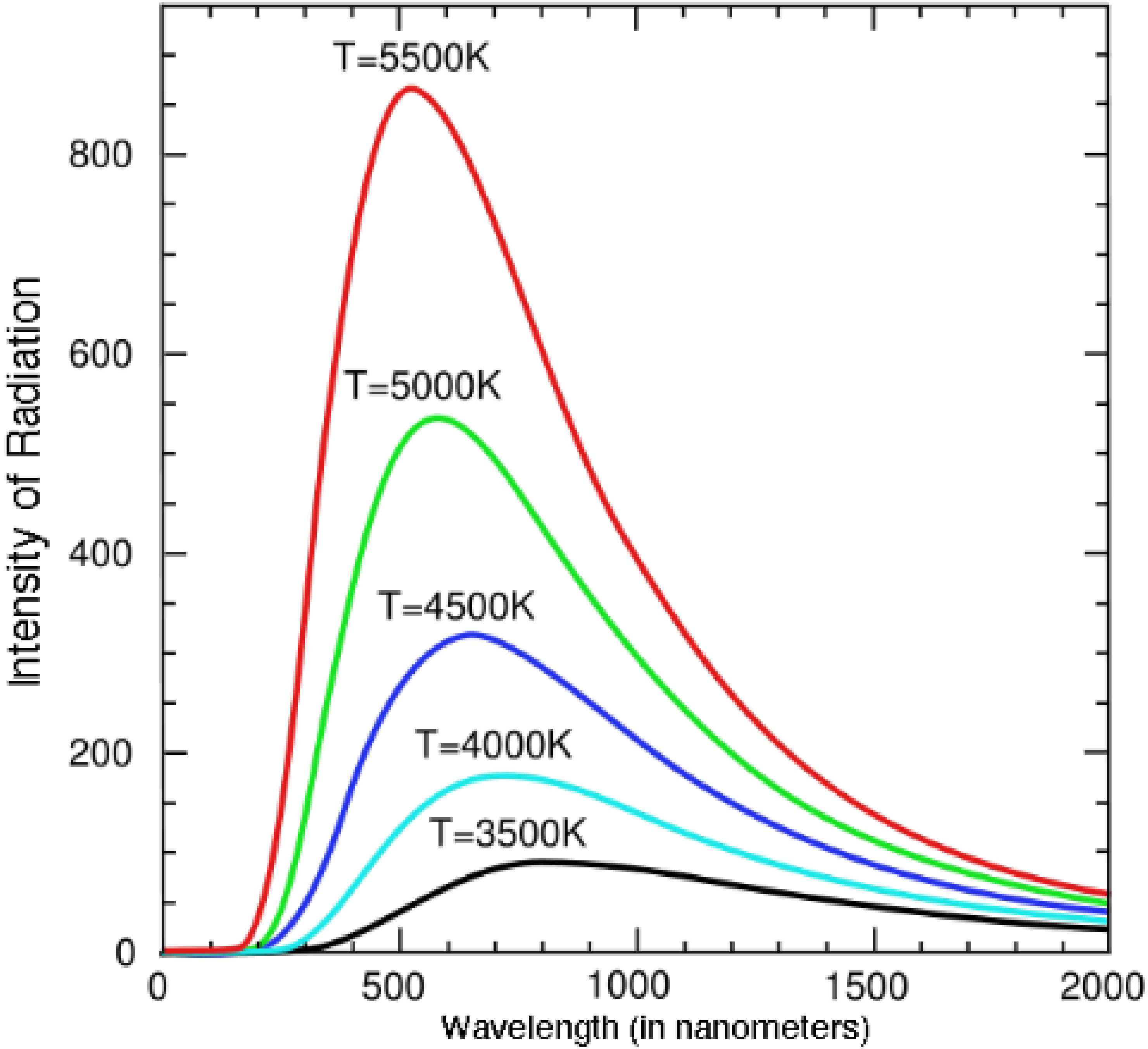


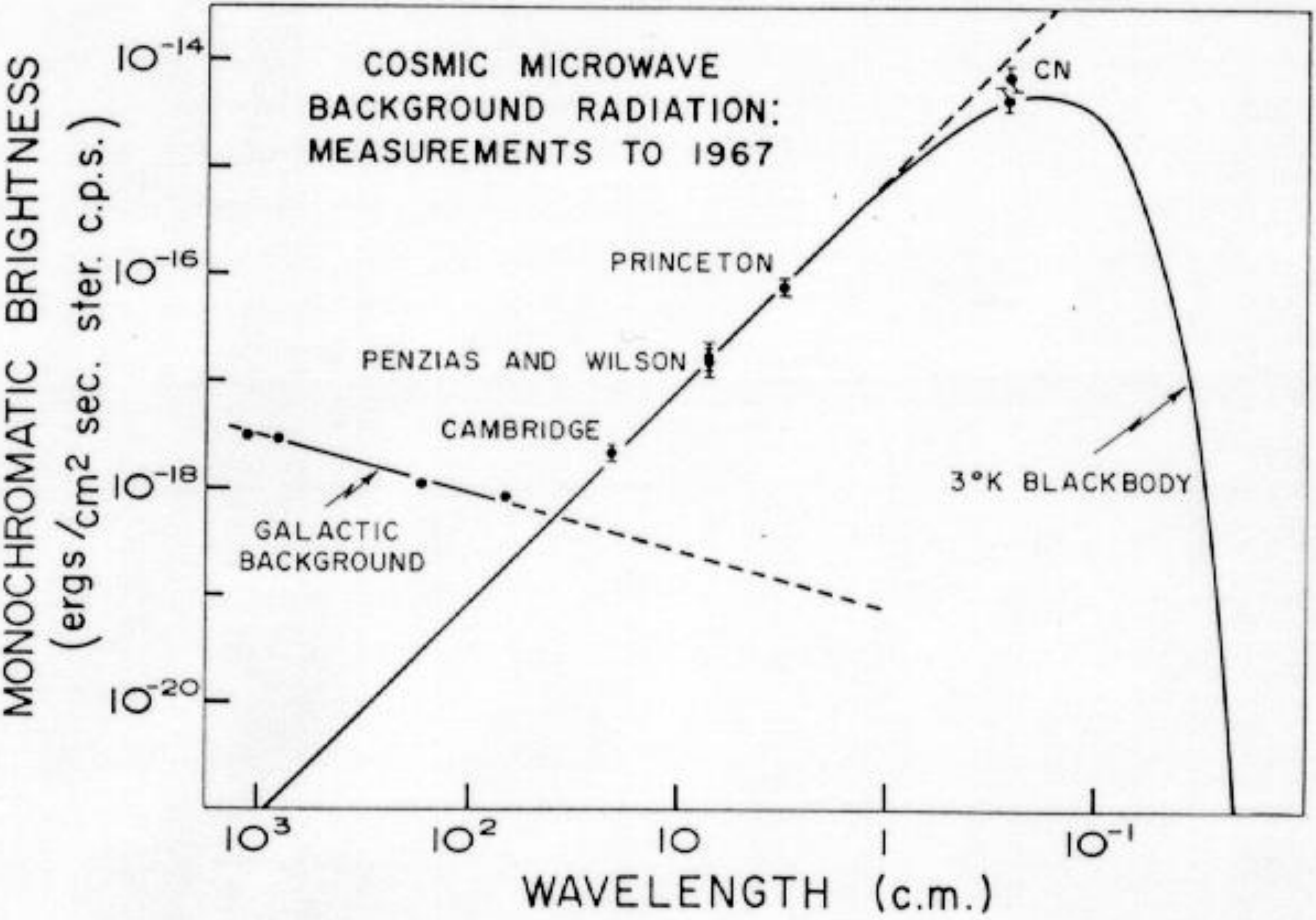



hyperbolic
Euclidean
spherical

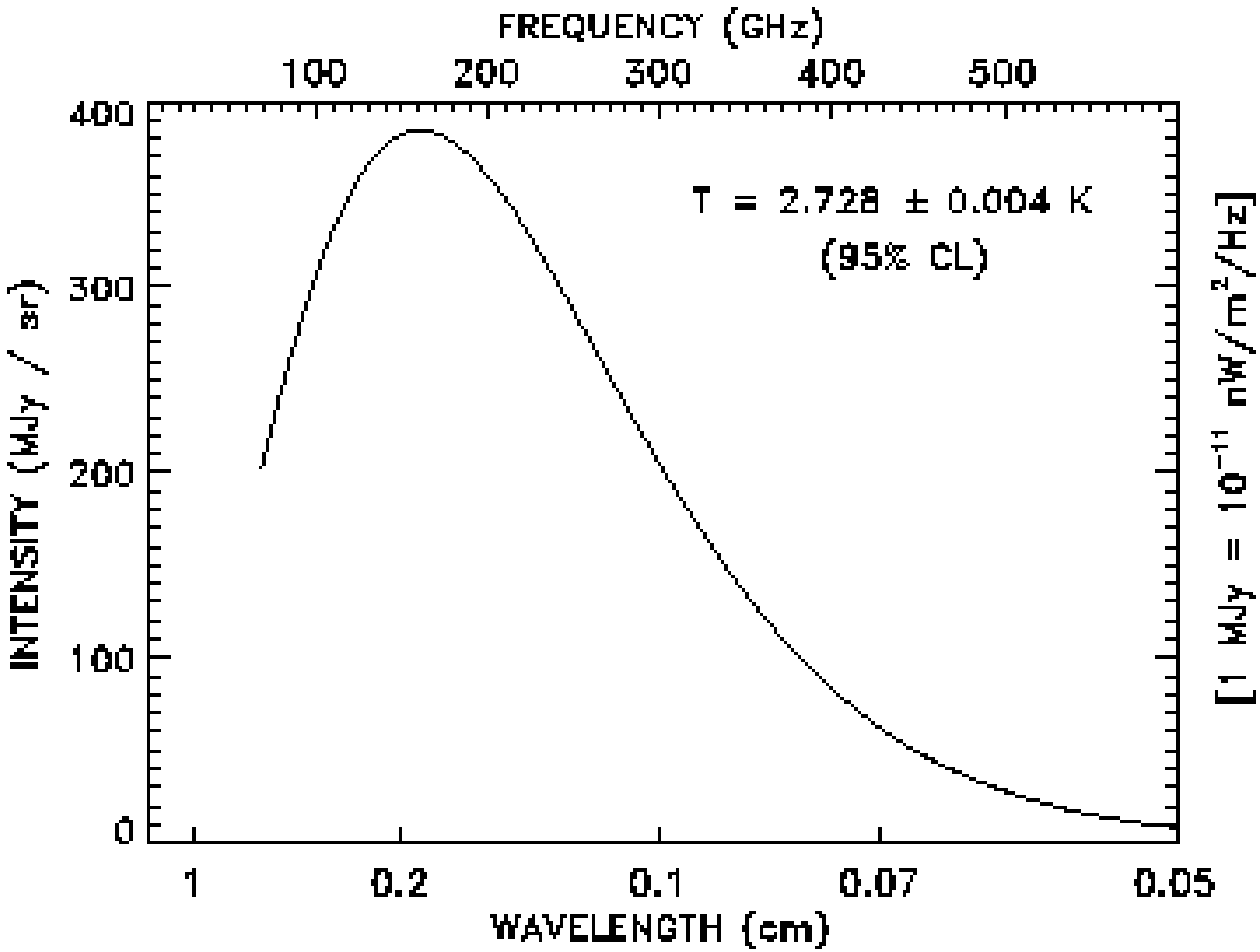

R
t
0
1
2
3
4
5
0
1
2
3
4


Universe

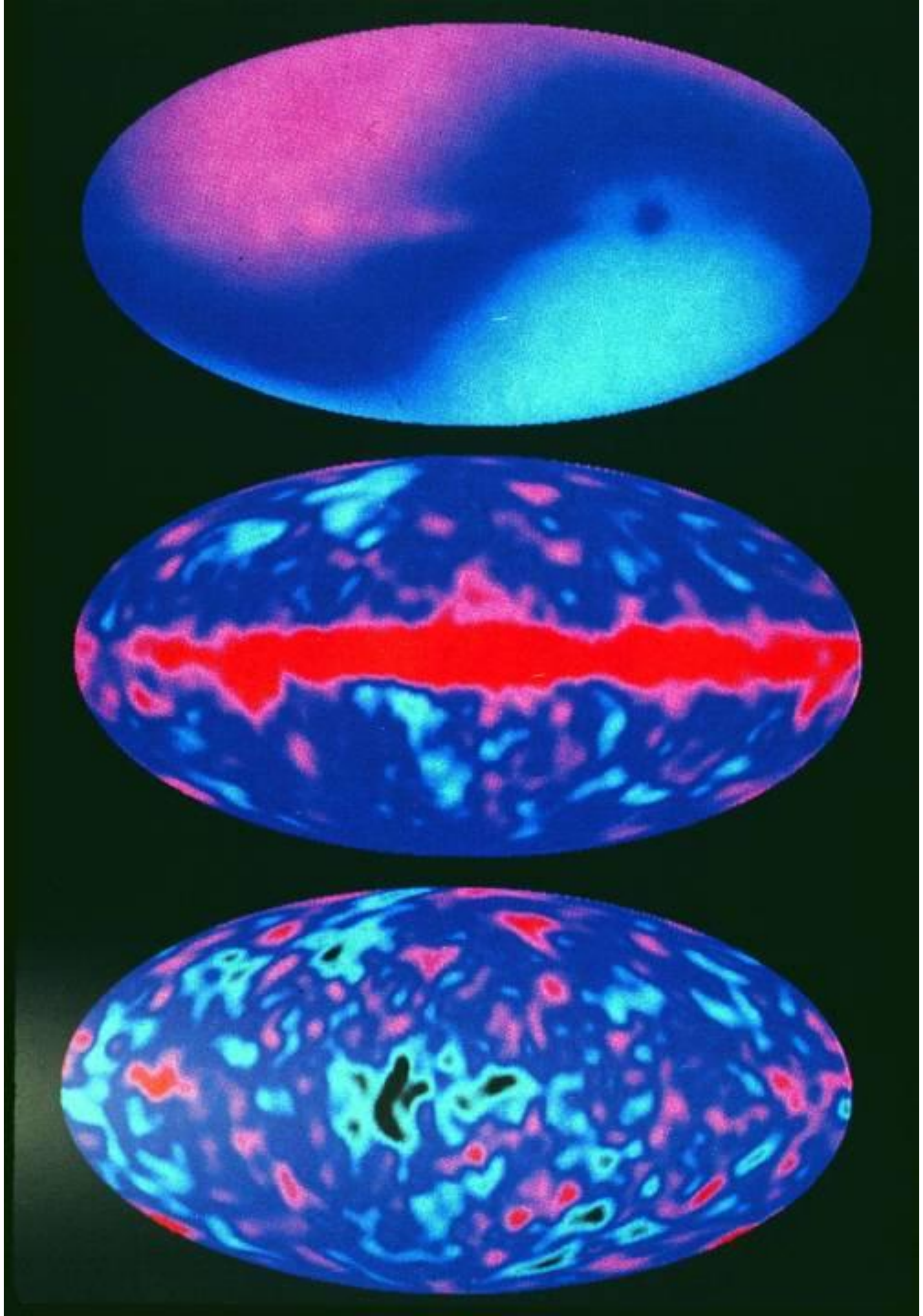

T=5500K
T=5000K
T=4500K
T=4000K
T=3500K
Intensity of Radiation
0
200
400
600
800
0
500
1000
1500
2000
Wavelength (in nanometers)

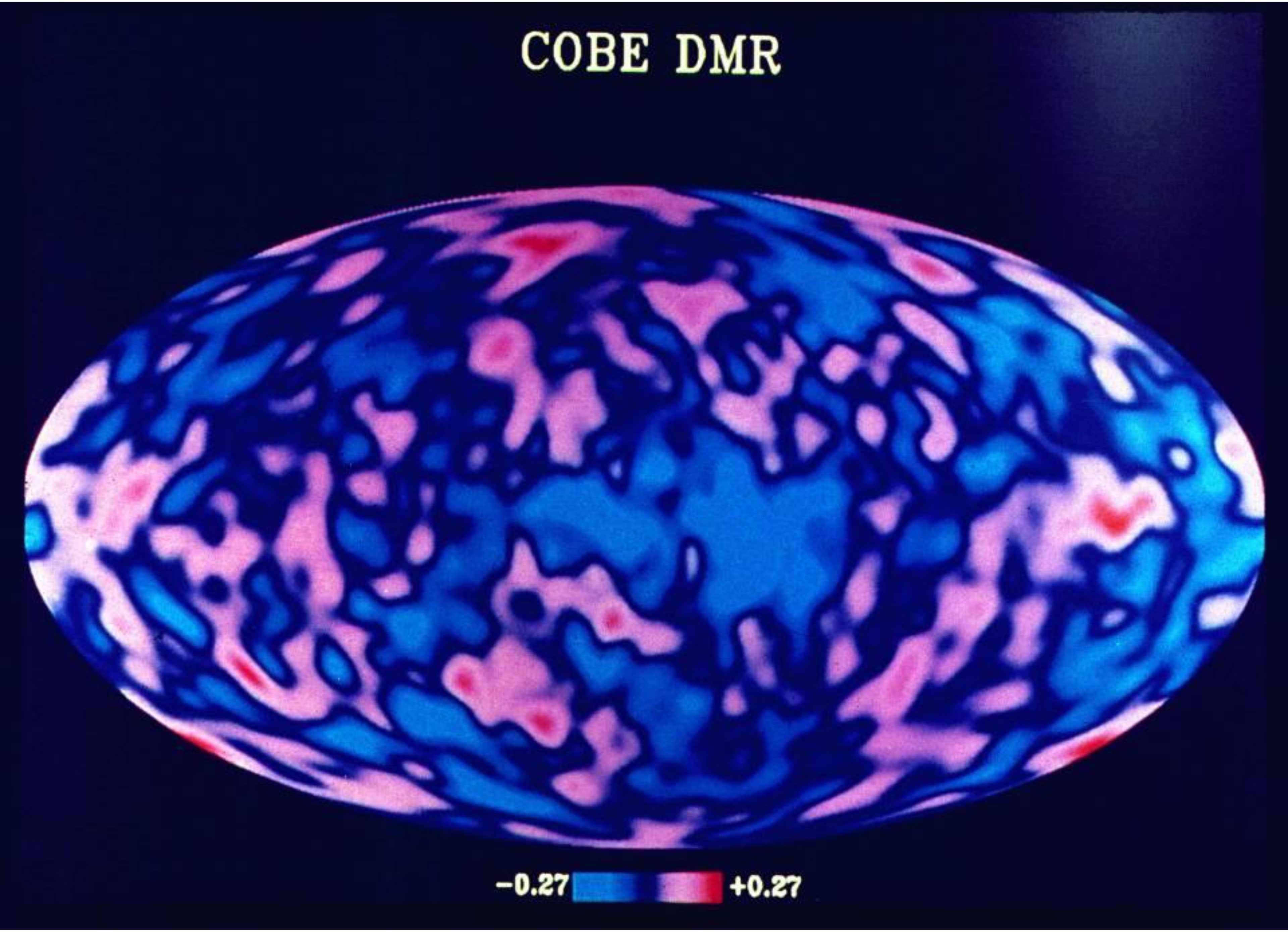


COSMIC MICROWAVE
BACKGROUND RADIATION:
MEASUREMENTS TO 1967
MONOCHROMATIC BRIGHTNESS
(ergs/cm² sec. ster. c.p.s.)
10^{-14}
10^{-16}
10^{-18}
10^{-20}
CN
PRINCETON
PENZIAS AND WILSON
CAMBRIDGE
3°K BLACKBODY
GALACTIC
BACKGROUND
10^3
10^2
10
1
10^{-1}
WAVELENGTH (c.m.)

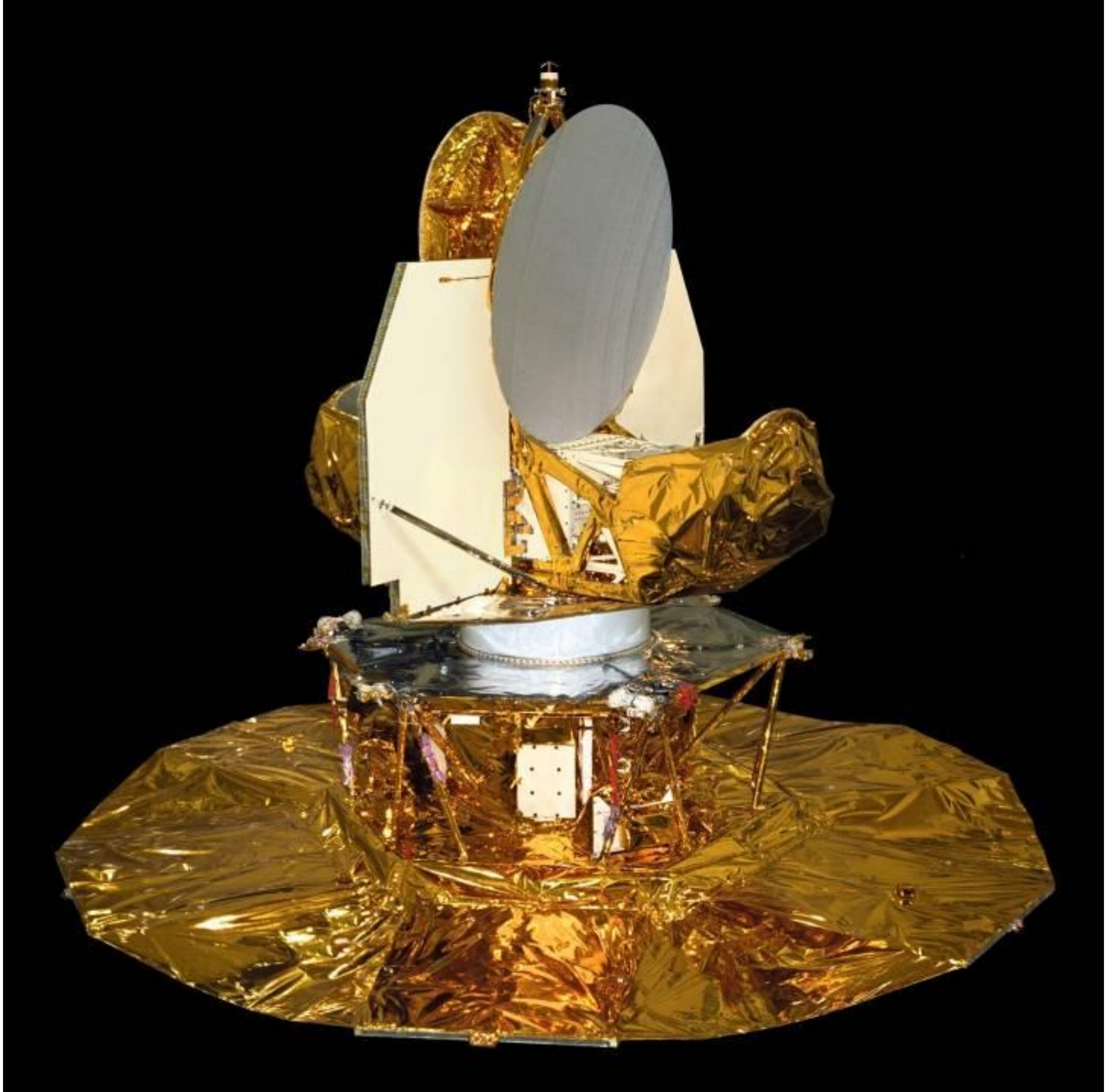


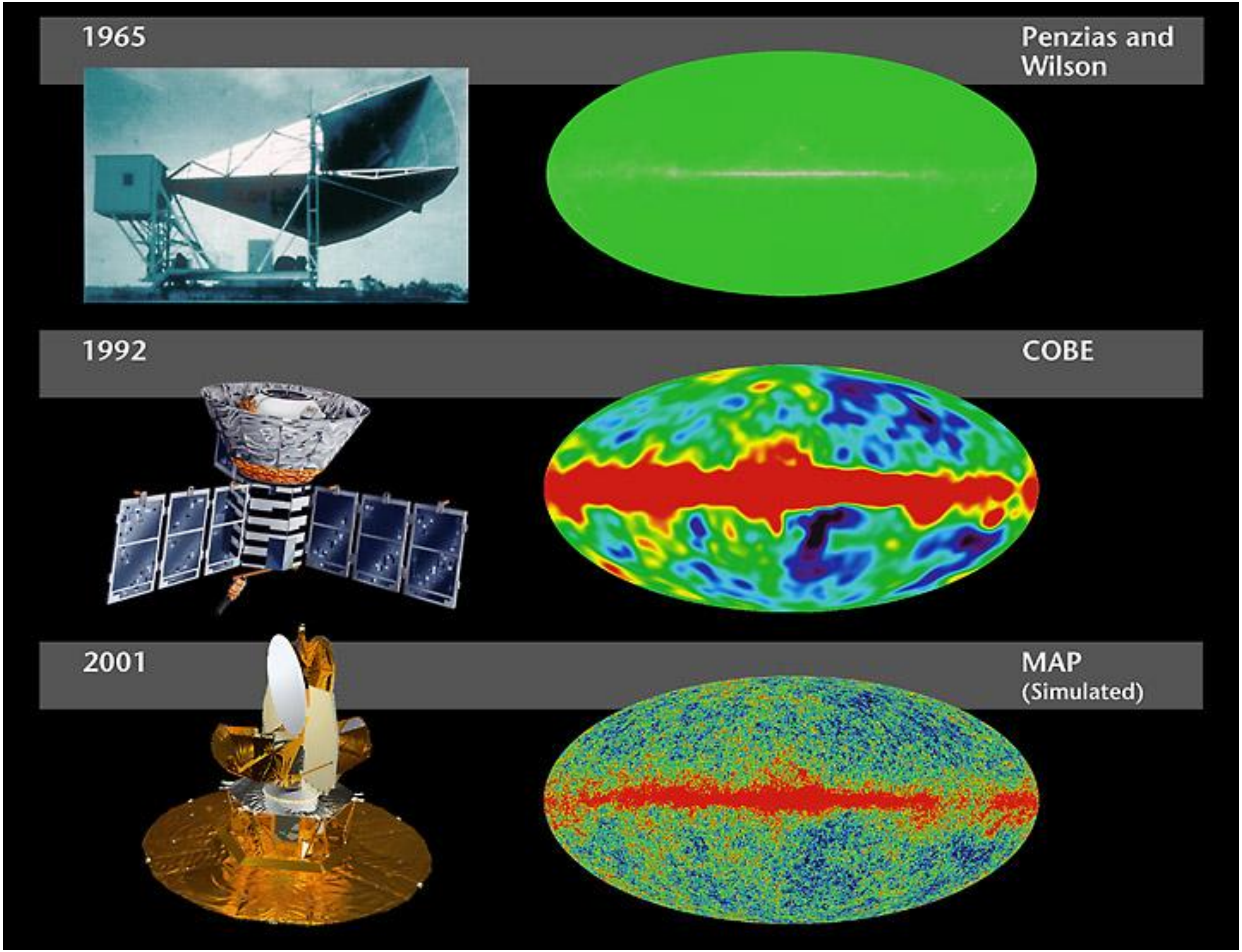
FREQUENCY (GHz)
100
200
300
400
500
400
300
200
100
0
INTENSITY (MJy / sr)
T = 2.728 ± 0.004 K
(95% CL)
[1 MJy = 10^-11 nW/m^2/Hz]
1
0.2
0.1
0.07
0.05
WAVELENGTH (cm)

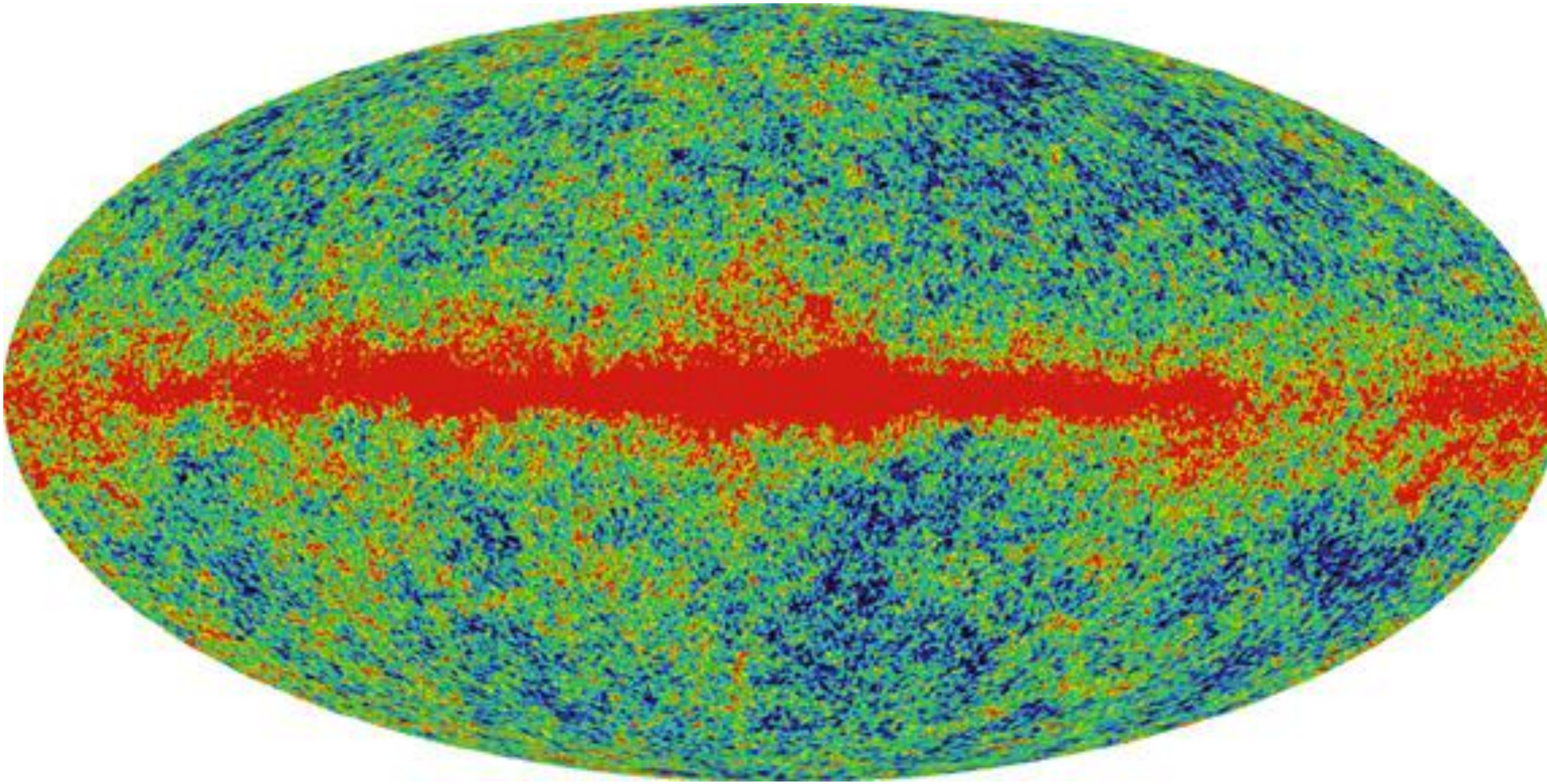



COBE DMR
−0.27
+0.27

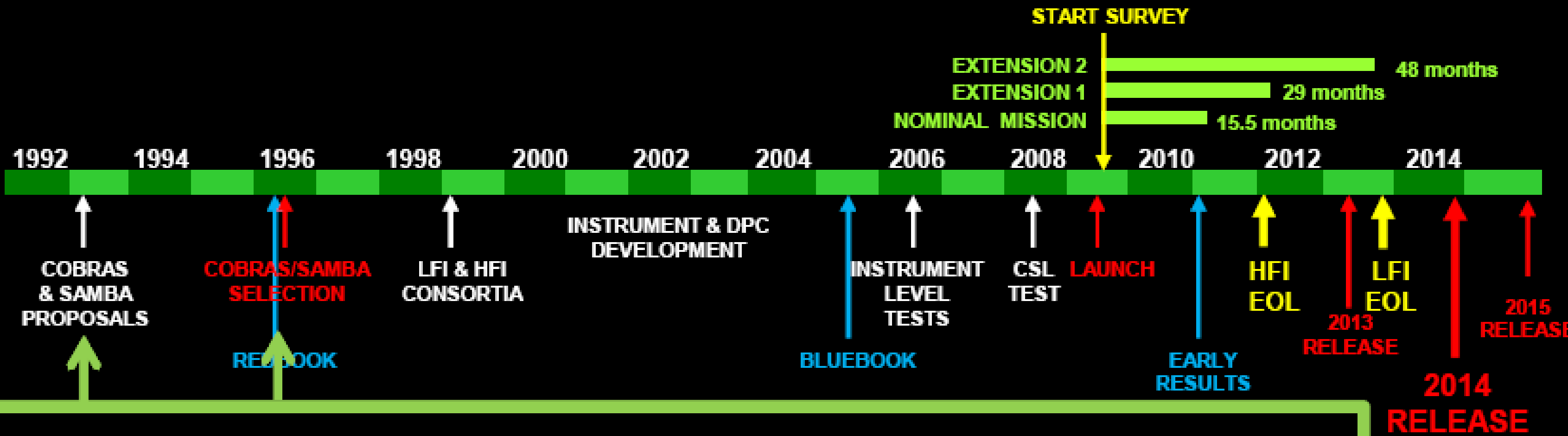
DIRBE 1.25, 2.2, 3.5 μm Composite




1965
Penzias and Wilson
1992
COBE
2001
MAP
(Simulated)



Early times



Wide spectral range (30-850 GHz)

Two different technologies

Control of systematics

PAYLOAD									
	1.5 m Diam. Gregorian; shared focal plane; system emissivity 1% Viewing direction offset 70° from spin axis.								
...ncy (GHz)	31.5	53	90	125	143	217	353	545	857
...nology	HEMT radio receiver arrays				Bolometer arrays				
...perature	~100 K				0.1-0.15 K				
...irements	Passive				Cryocooler + Dilution system				
...etectors	4	14	26	12	8	12	12	12	12
...lution (arcmin)	30	18	12	12	10.3	7.1	4.4	4.4	4.4
...mission	1	1	1	1	0.3	0.3	0.3	0.3	0.3
...)	0.15	0.15	0.15	0.15	0.37	0.37	0.37	0.37	0.37
...y per res. element ...σ, 10^{-6} units)	7.8	7.5	14.4	35.4	1.2	2.0	12.1	76.0	4166

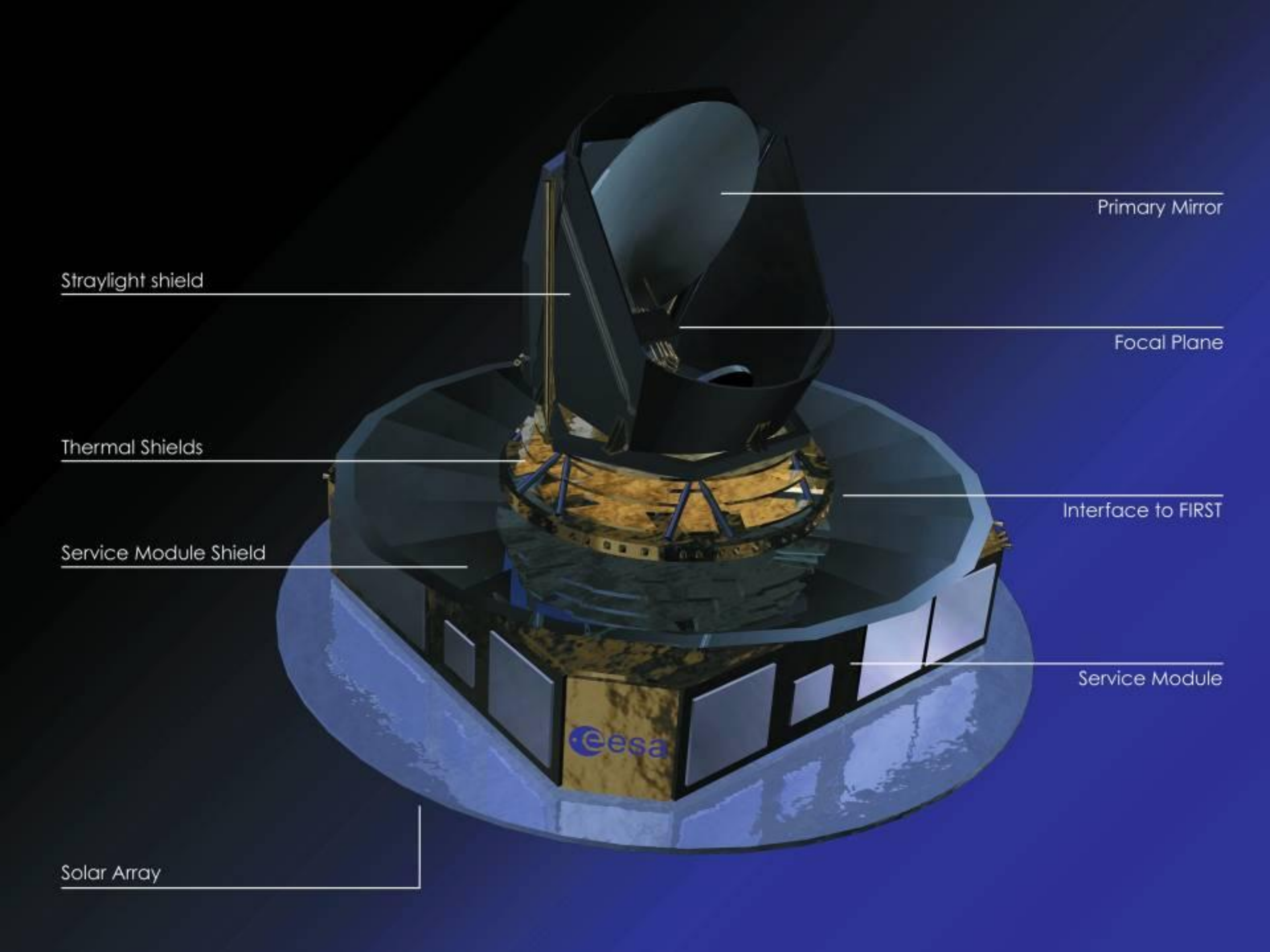
$dT/T \sim 2 \times 10^{-6}$ $\theta \sim 15'$

No requirements on polarisation

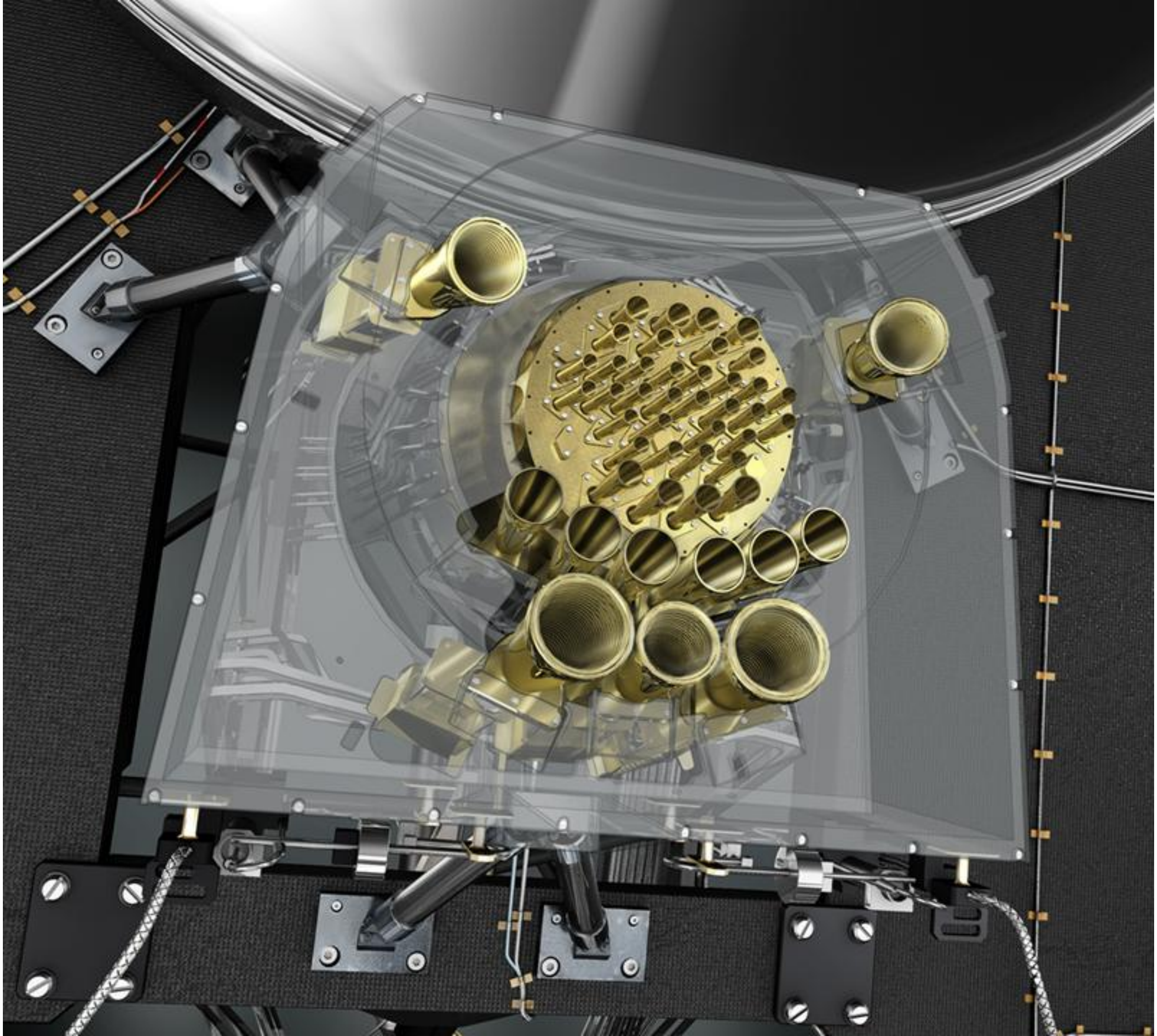
Understanding systematic effects is key

	Angular resolution	Sensitivity (90 GHz) (0.5 deg pixel)	Component separation
	7°	420 μK	31.5–90 GHz 3 channels
	0.22°	16 μK	22–90 GHz 5 channels
	0.08°	1 μK	30–857 GHz 9 channels


esa



Primary Mirror
Straylight shield
Focal Plane
Thermal Shields
Interface to FIRST
Service Module Shield
Service Module
esa
Solar Array



PLANCK

Looking back to the dawn of time

Planck Telescope
1.5x1.9m off-axis
Gregorian
T = 50 K

LFI Radiometers
30-70 GHz, T = 20 K

HFI Bolometers
100-857 GHz, T = 0.1 K

agenzia spaziale italiana

CENTRE NATIONAL D'ÉTUDES SPATIALES

Marian W Pospieszalski

Scientist, National Radio Astronomy Observatory
Electrical Engineering, Astronomy
Verified email at nrao.edu

Extremely Low-Noise Amplification with Cryogenic FET's and HFET's: 1970-2004

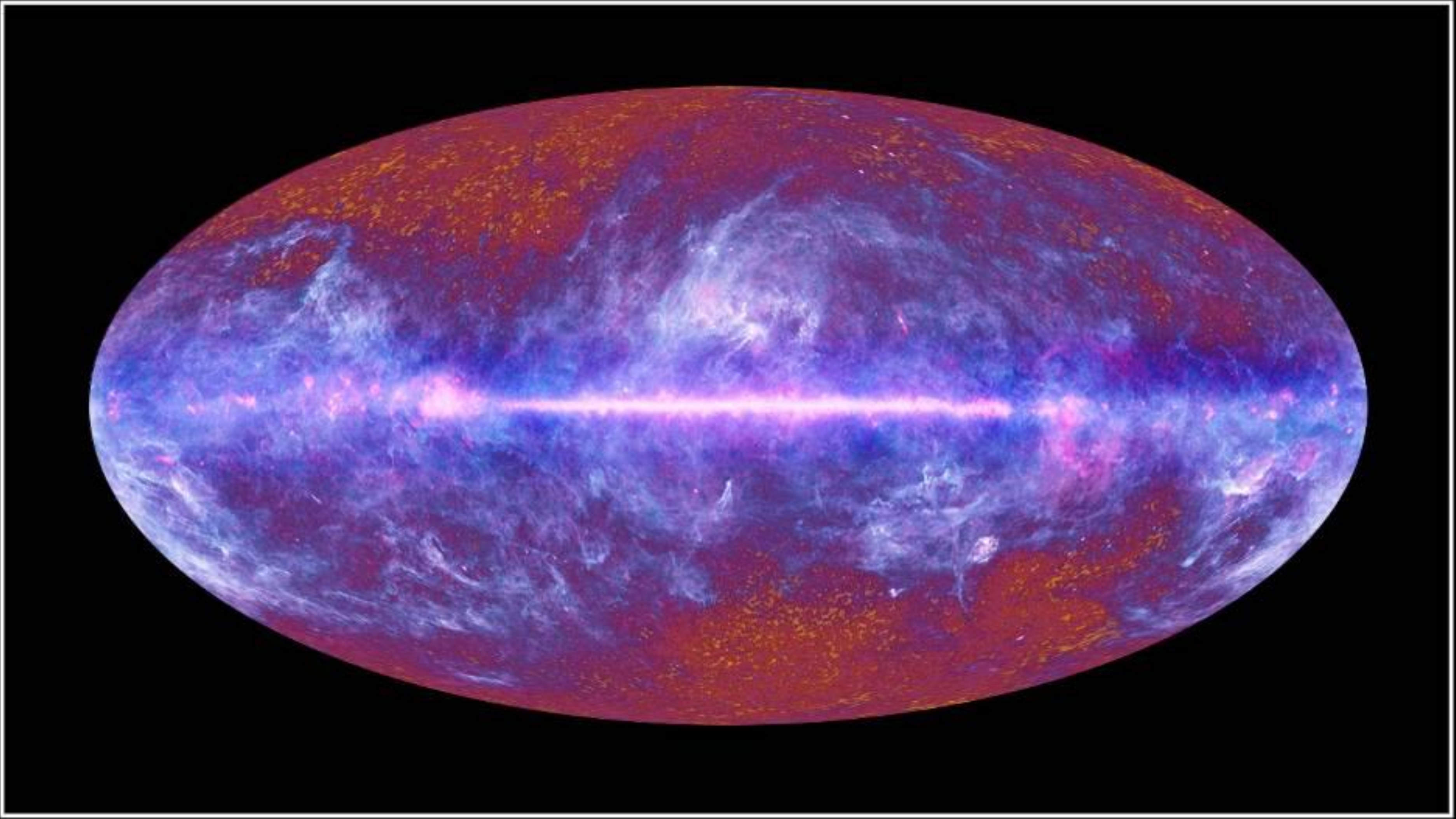
Marian W. Pospieszalski

National Radio Astronomy Observatory
Charlottesville, VA 22903

May 16, 2005

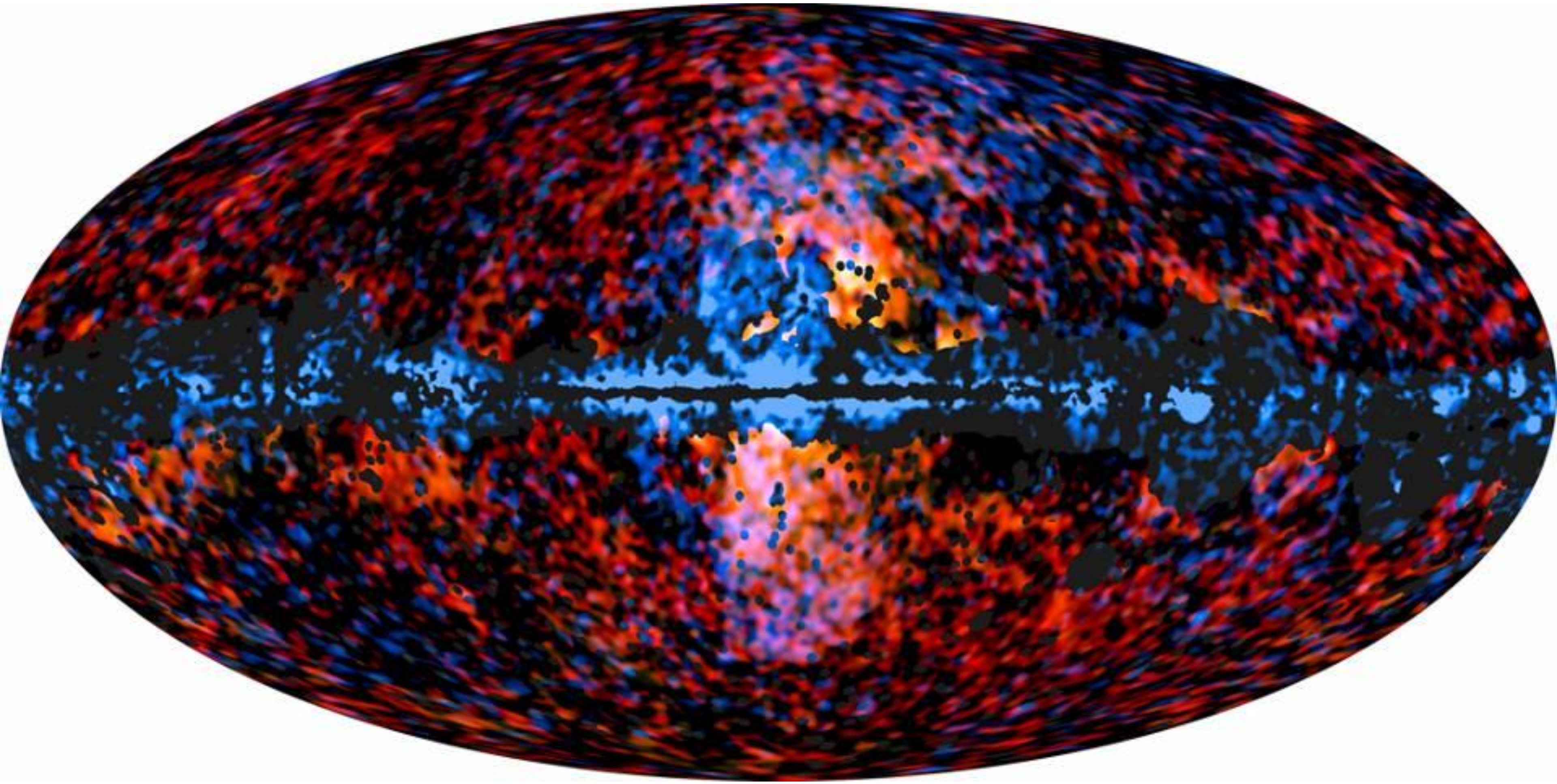
Abstract

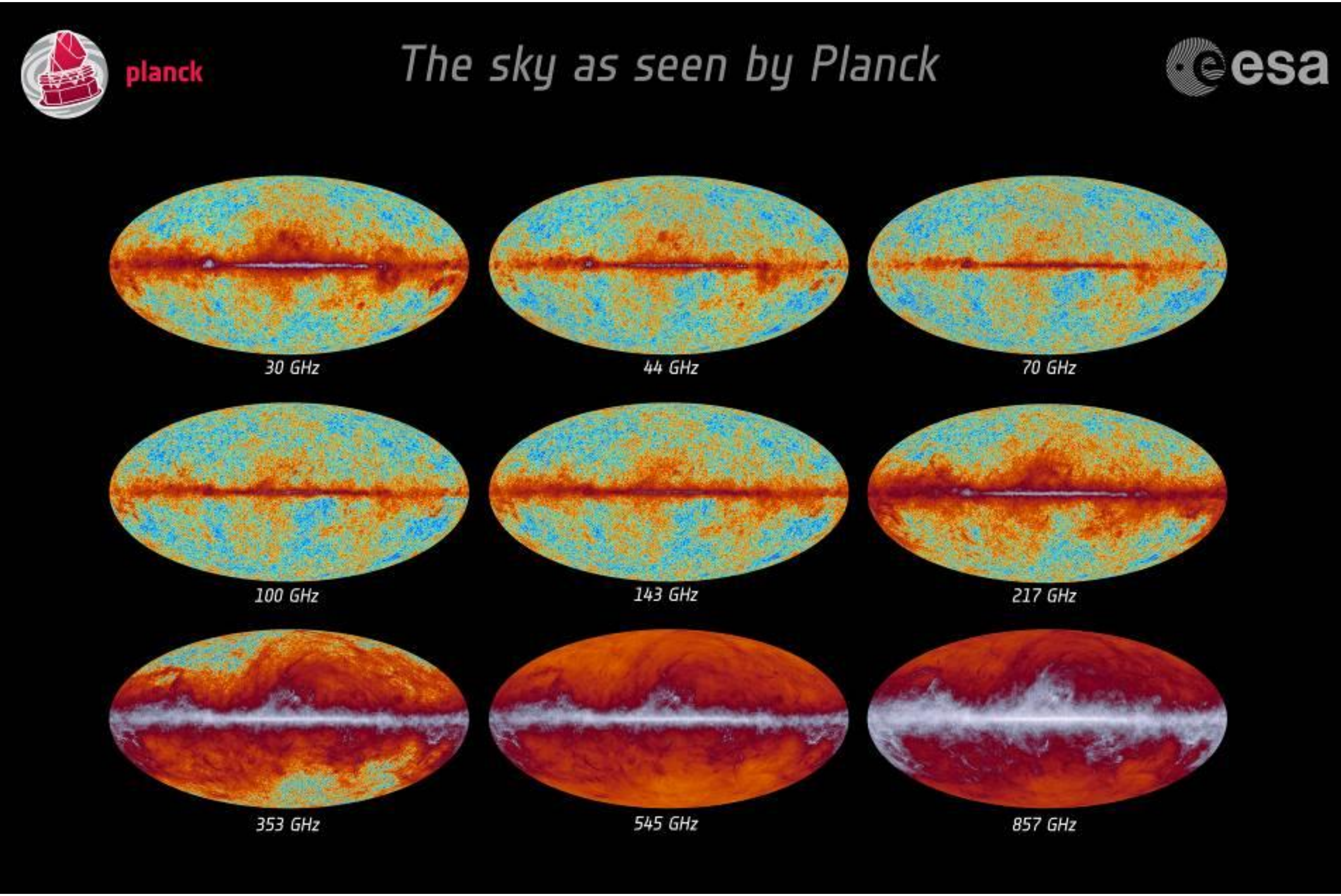
Improvements in the noise temperature of field-effect transistors (FET's) and, later, heterostructure field-effect transistors (HFET's) over the last several decades have been quite dramatic. In 1970, a noise temperature of 120 K was reported at 1 GHz and physical temperature of 77 K; in 2003, noise temperatures of 2, 8 and at 35 K were reported at 4, 30 and 100 GHz, respectively, for physical temperatures of 14 to 20 K. The paper reviews



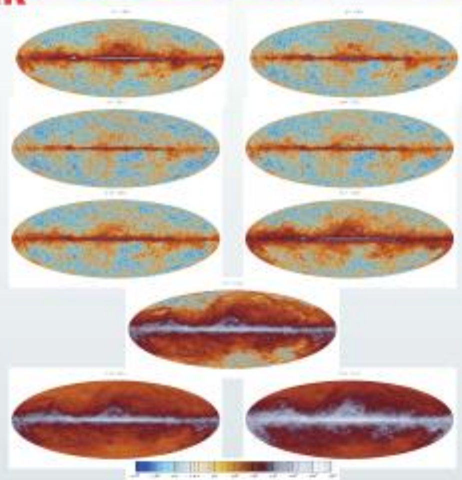
The Planck one-year all-sky survey

esa




planck
The sky as seen by Planck
esa
30 GHz
44 GHz
70 GHz
100 GHz
143 GHz
217 GHz
353 GHz
545 GHz
857 GHz

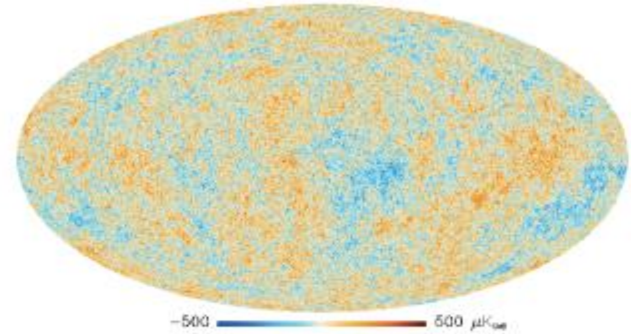
Parameter Extraction from the CMB Sky Maps (in a Nutshell)



Frequency maps

(see Bersaneli's talk)

Component Separation



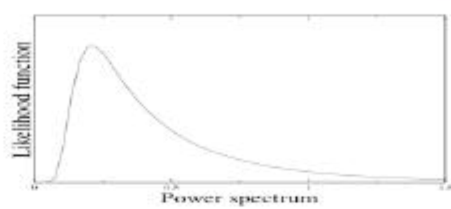
Diffuse-foreground-cleaned CMB map

directly from sky maps to the likelihood

n_s Ω_b Ω_0 σ_8 H_0 τ

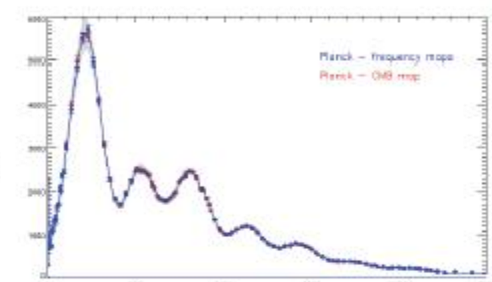
Cosmological parameters

MCMC

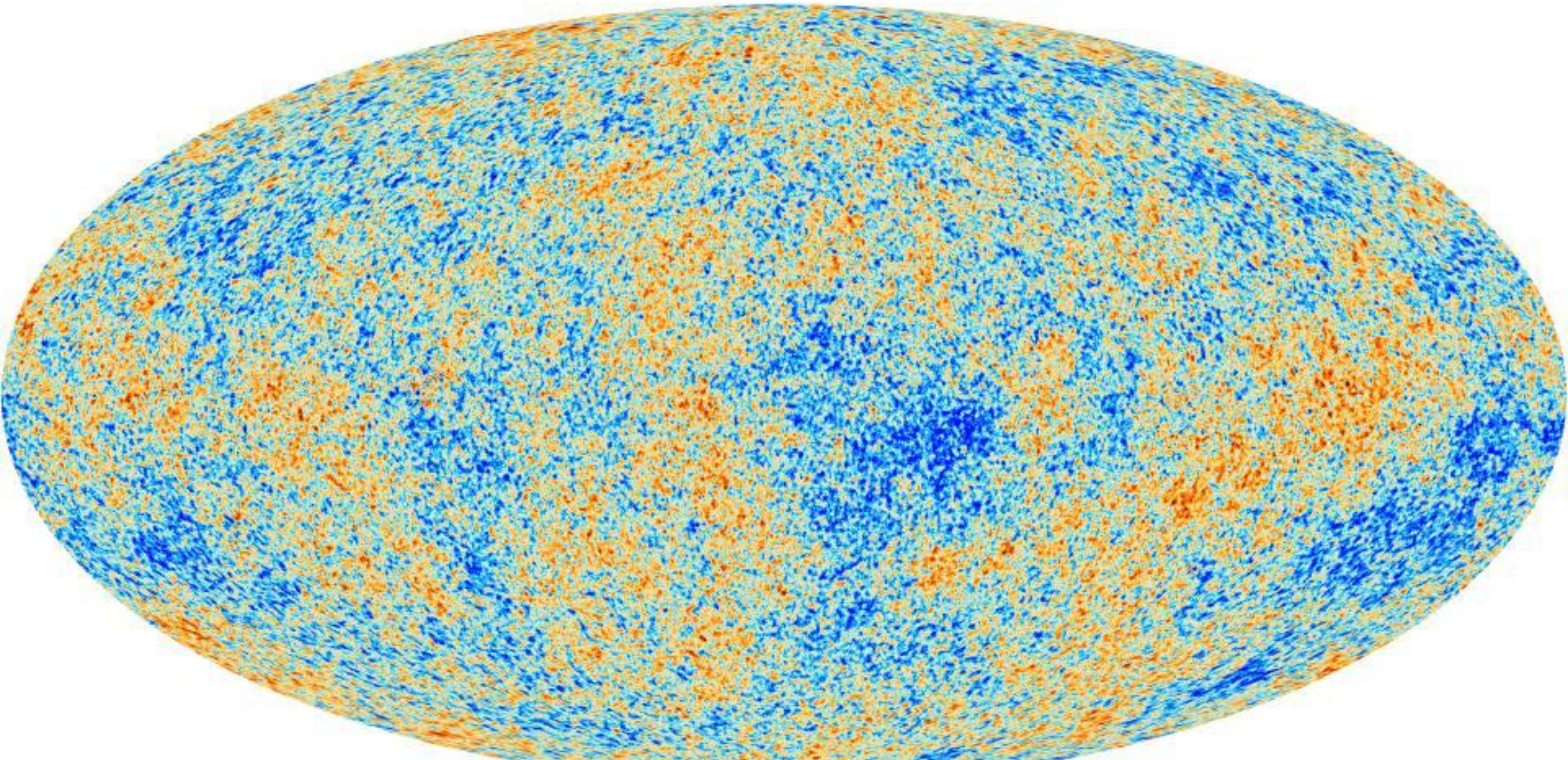


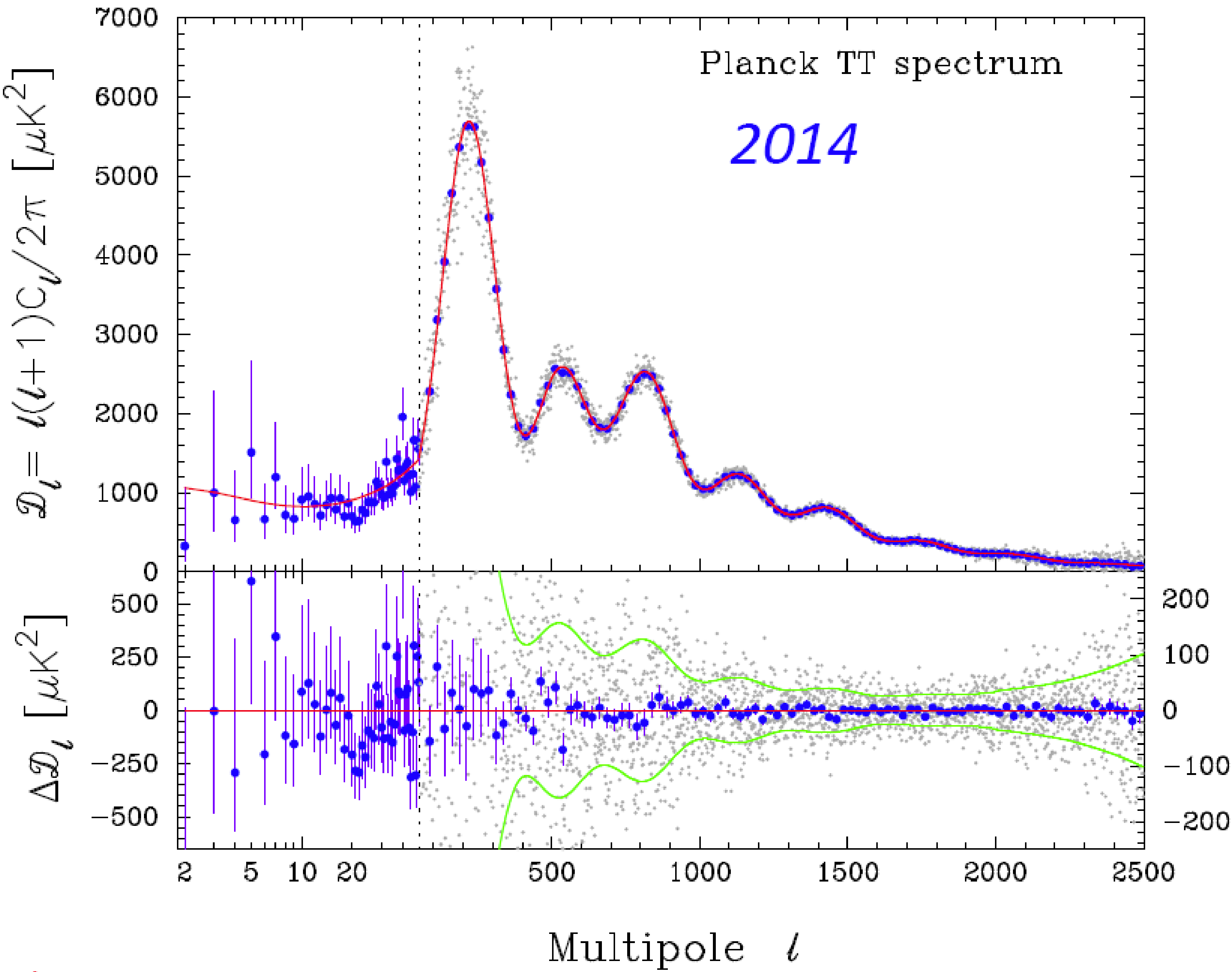
Likelihood

Remove discrete foregrounds

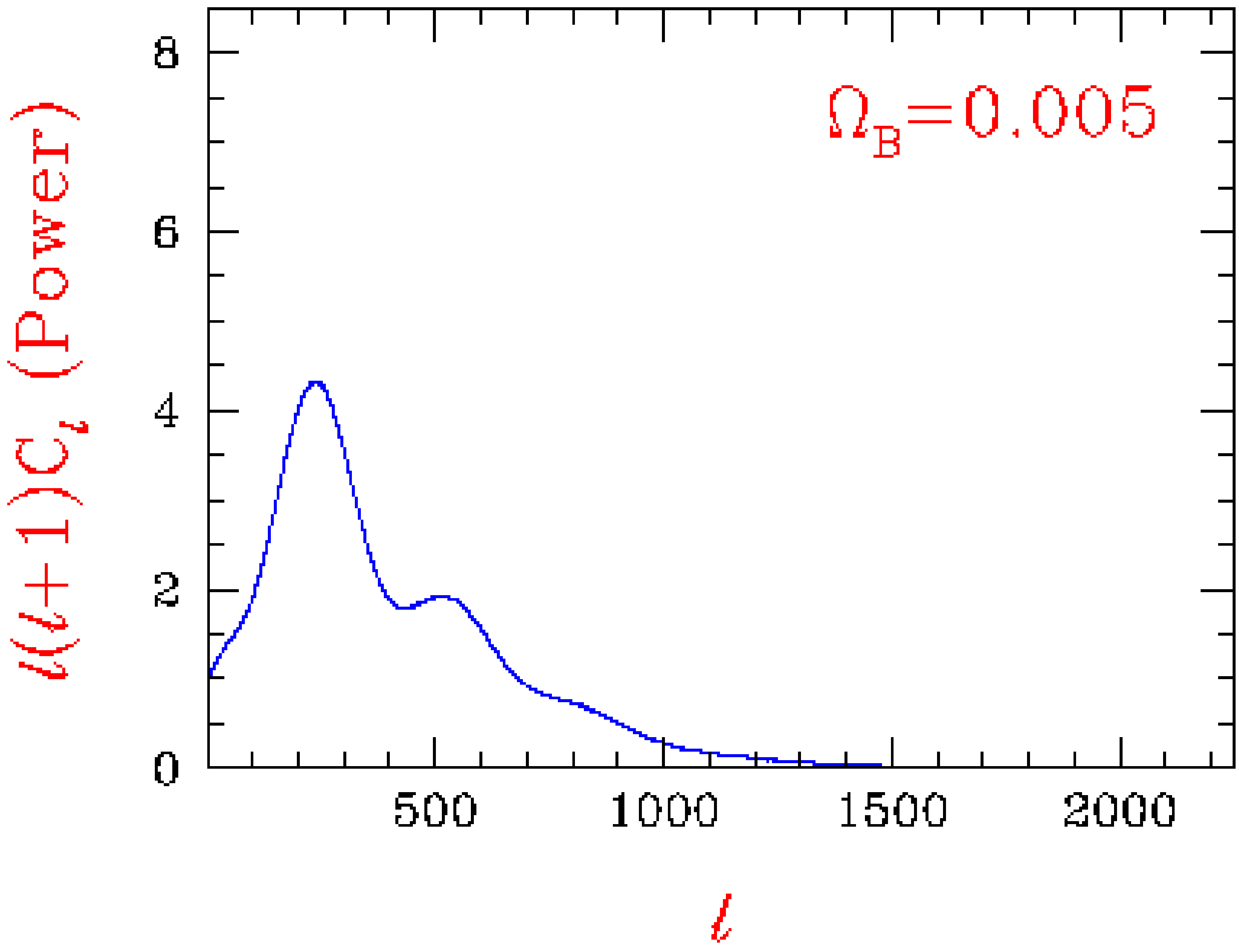


Angular Power spectrum





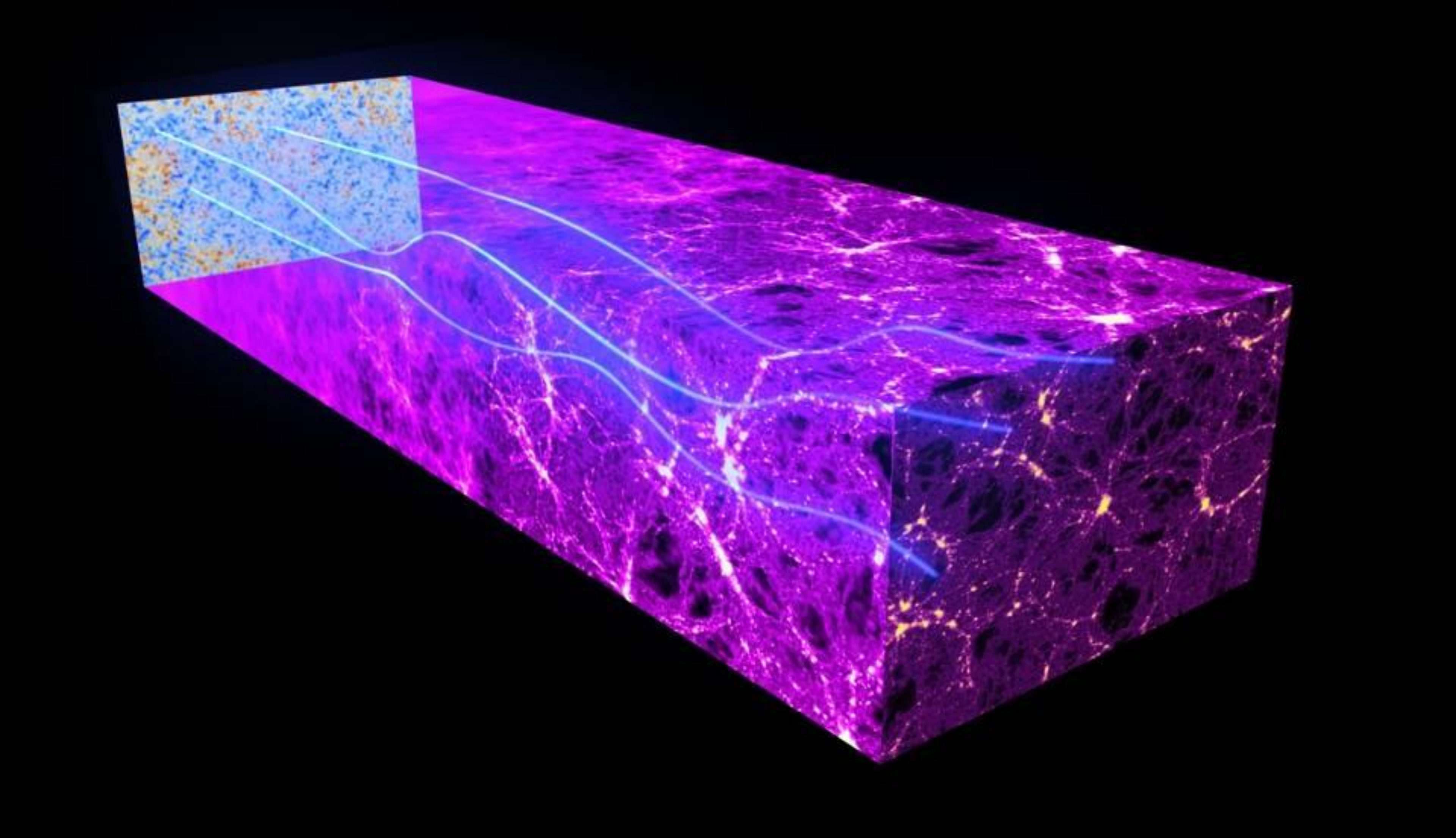
preliminary

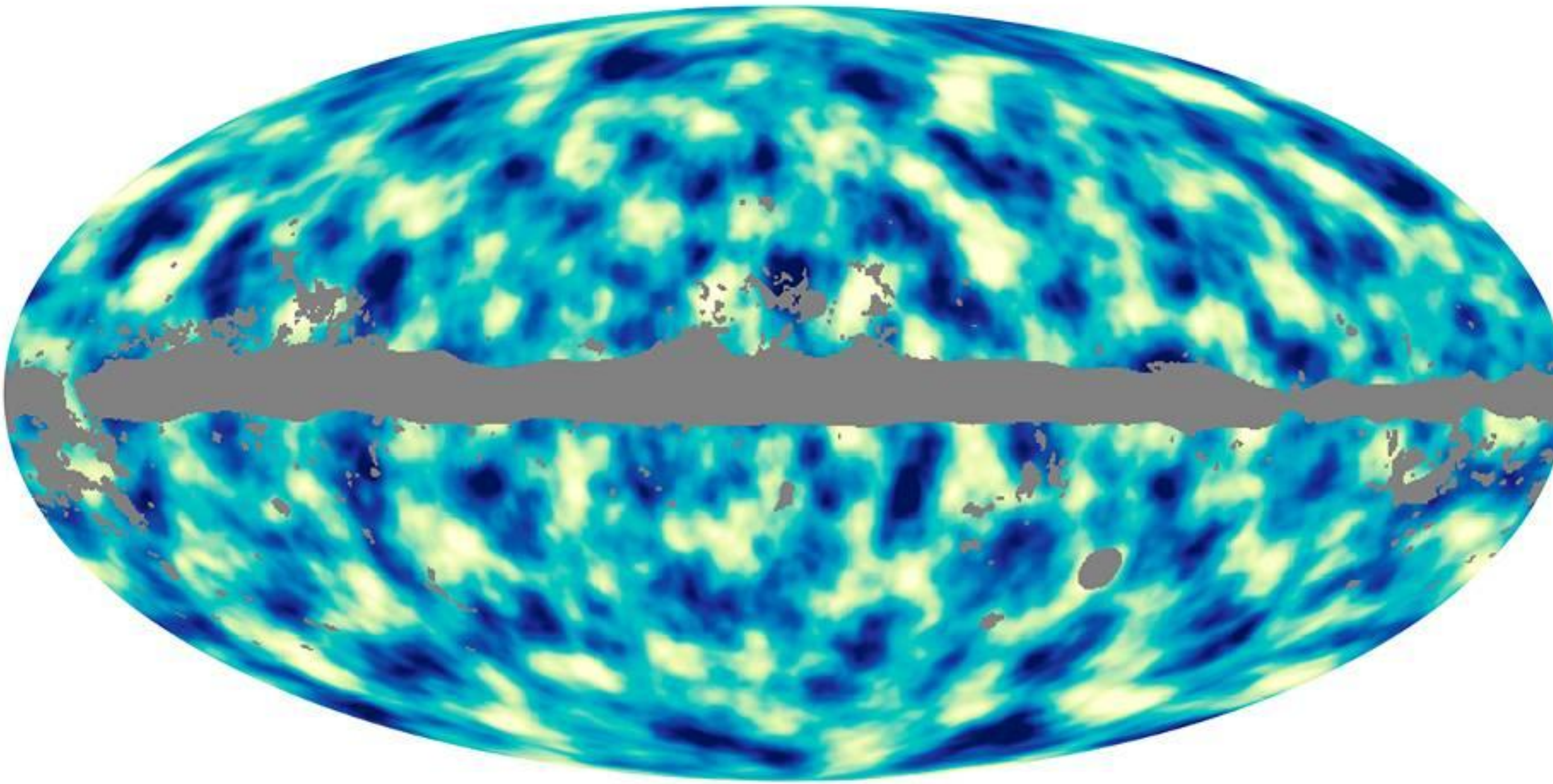


$\Omega_B=0.005$
8
6
4
2
0
500
1000
1500
2000
l
$l(l+1)C_l$ (Power)

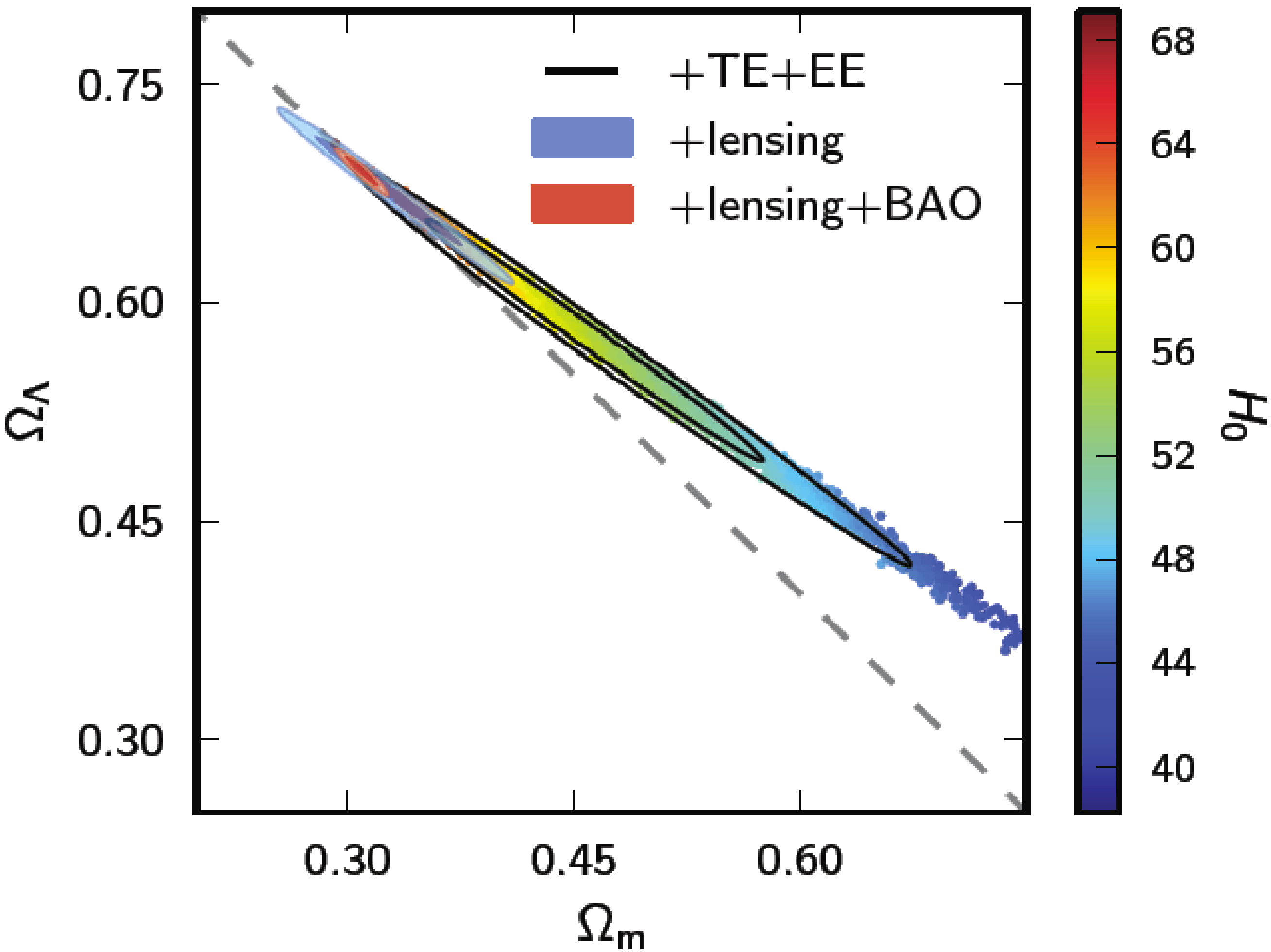
P2013 parameters for the minimal ΛCDM model

	Planck+WP	
Parameter	Best fit	68% limits
$\Omega_b h^2$	0.022032	0.02205 ± 0.00028
$\Omega_c h^2$	0.12038	0.1199 ± 0.0027
$100\theta_{MC}$	1.04119	1.04131 ± 0.00063
τ	0.0925	$0.089^{+0.012}_{-0.014}$
n_s	0.9619	0.9603 ± 0.0073
. $\ln(10^{10} A_s)$	3.0980	$3.089^{+0.024}_{-0.027}$



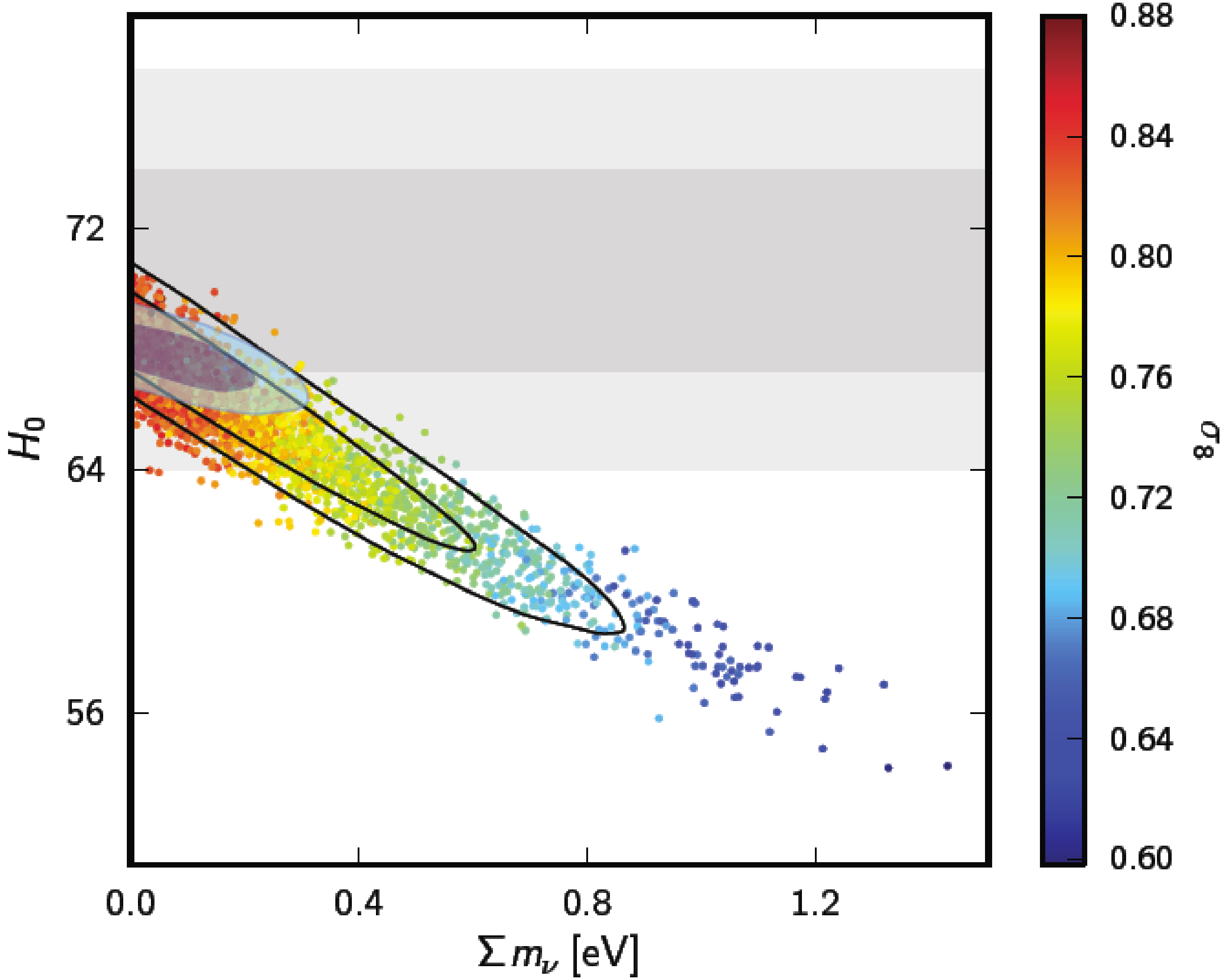


.... *leading to remarkable constraints on spatial curvature Ω_k=0.000±0.005 (95%)*

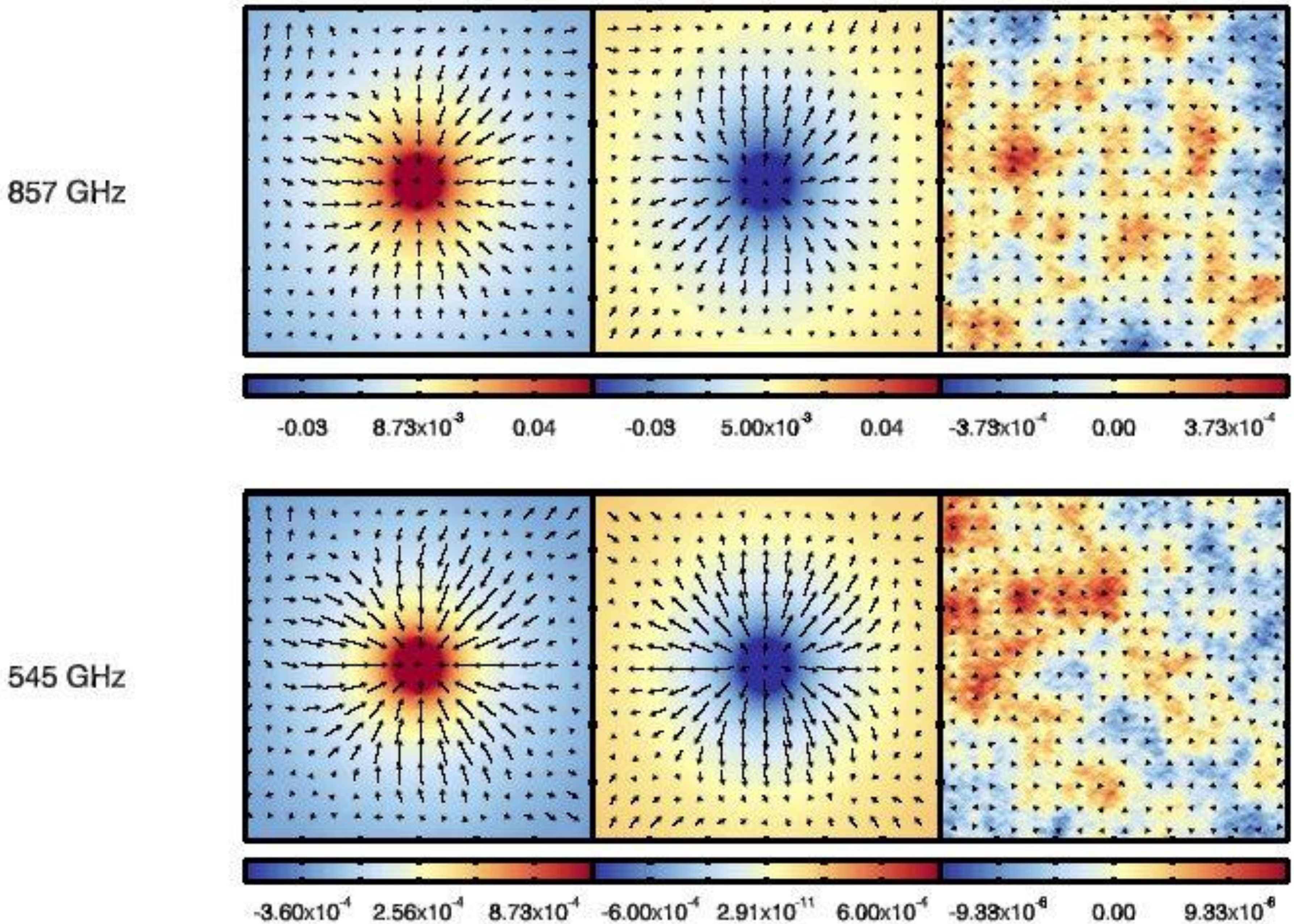


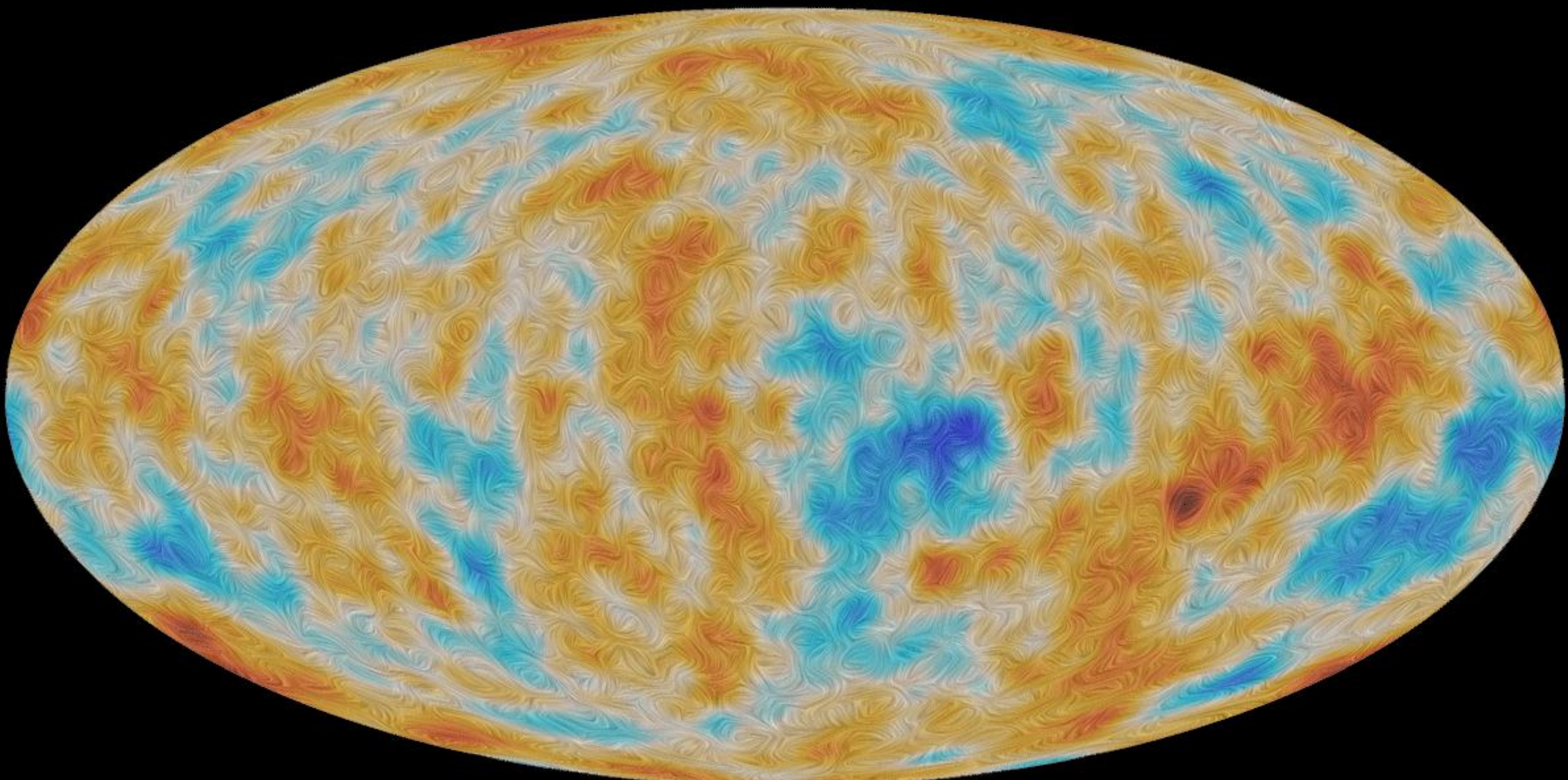
preliminary

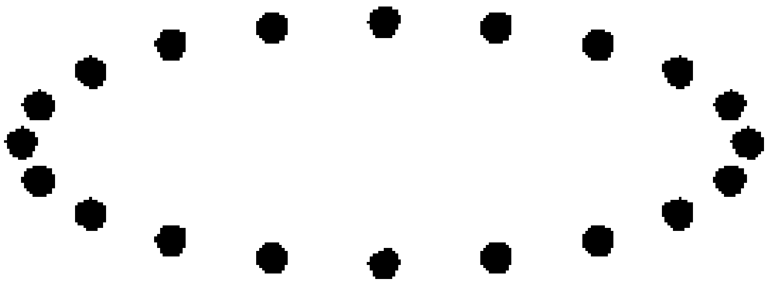
.... and to neutrino masses $\Sigma m_\nu < 0.21$ eV (95%)

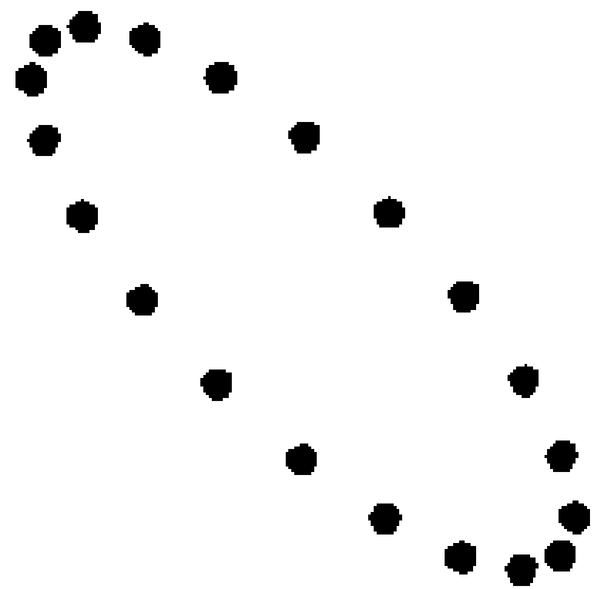


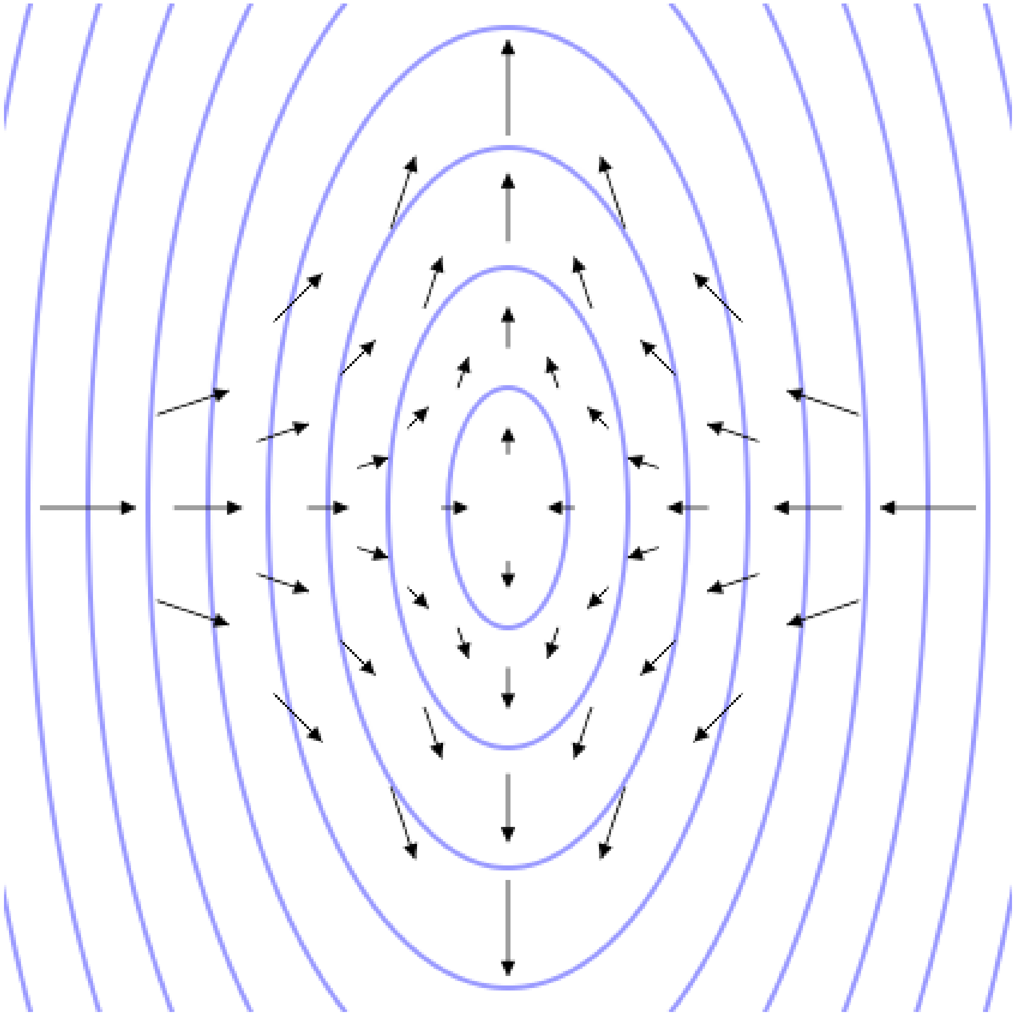
preliminary

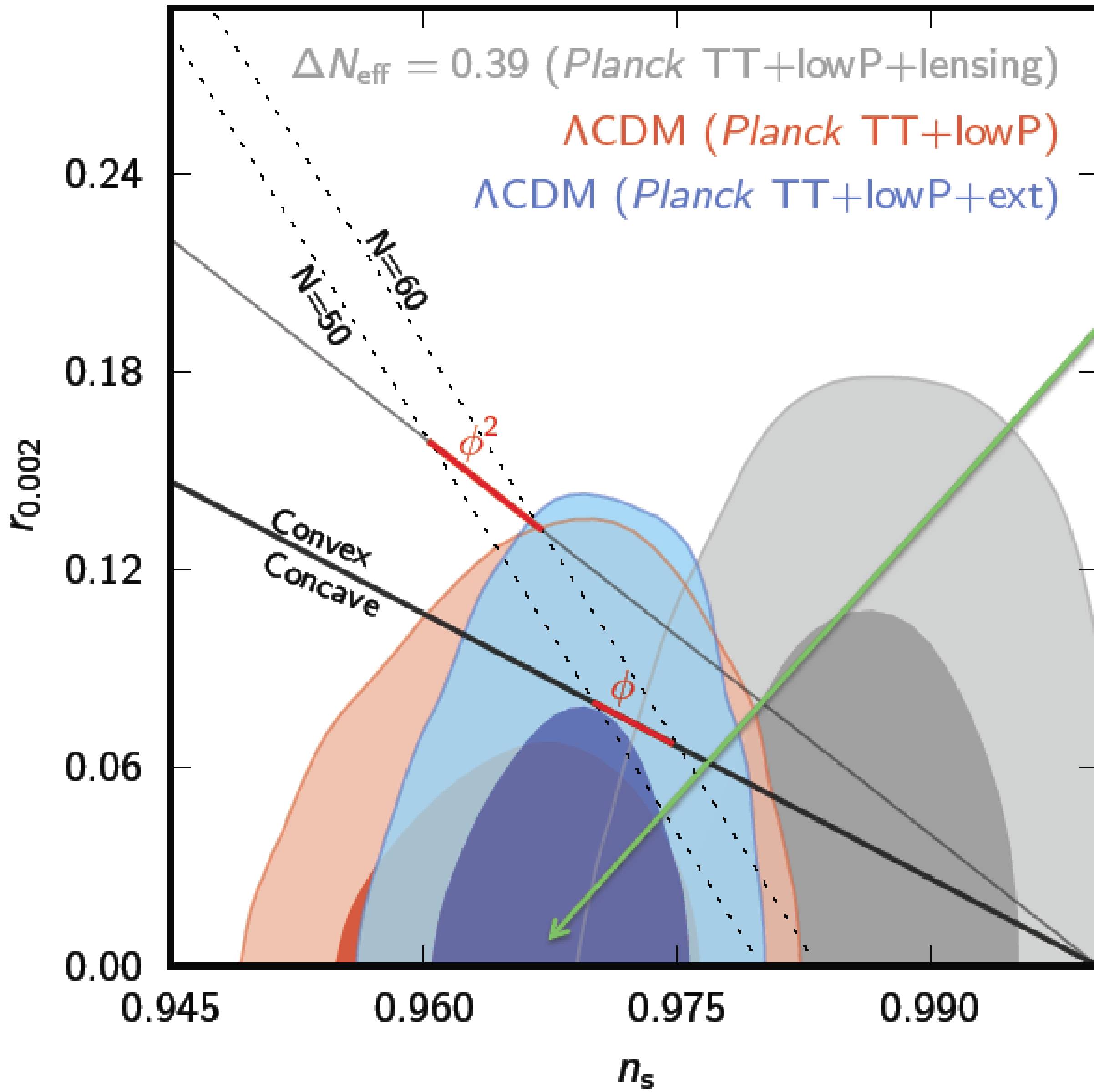

857 GHz
-0.03
8.73×10^{-3}
0.04
-0.03
5.00×10^{-3}
0.04
-3.73×10^{-4}
0.00
3.73×10^{-4}
545 GHz
-3.60×10^{-4}
2.56×10^{-4}
8.73×10^{-4}
-6.00×10^{-4}
2.91×10^{-11}
6.00×10^{-4}
-9.33×10^{-6}
0.00
9.33×10^{-6}











Starobinsky (R^2) inflatio

$n_s \approx 1 - 2/N \approx 0.967$

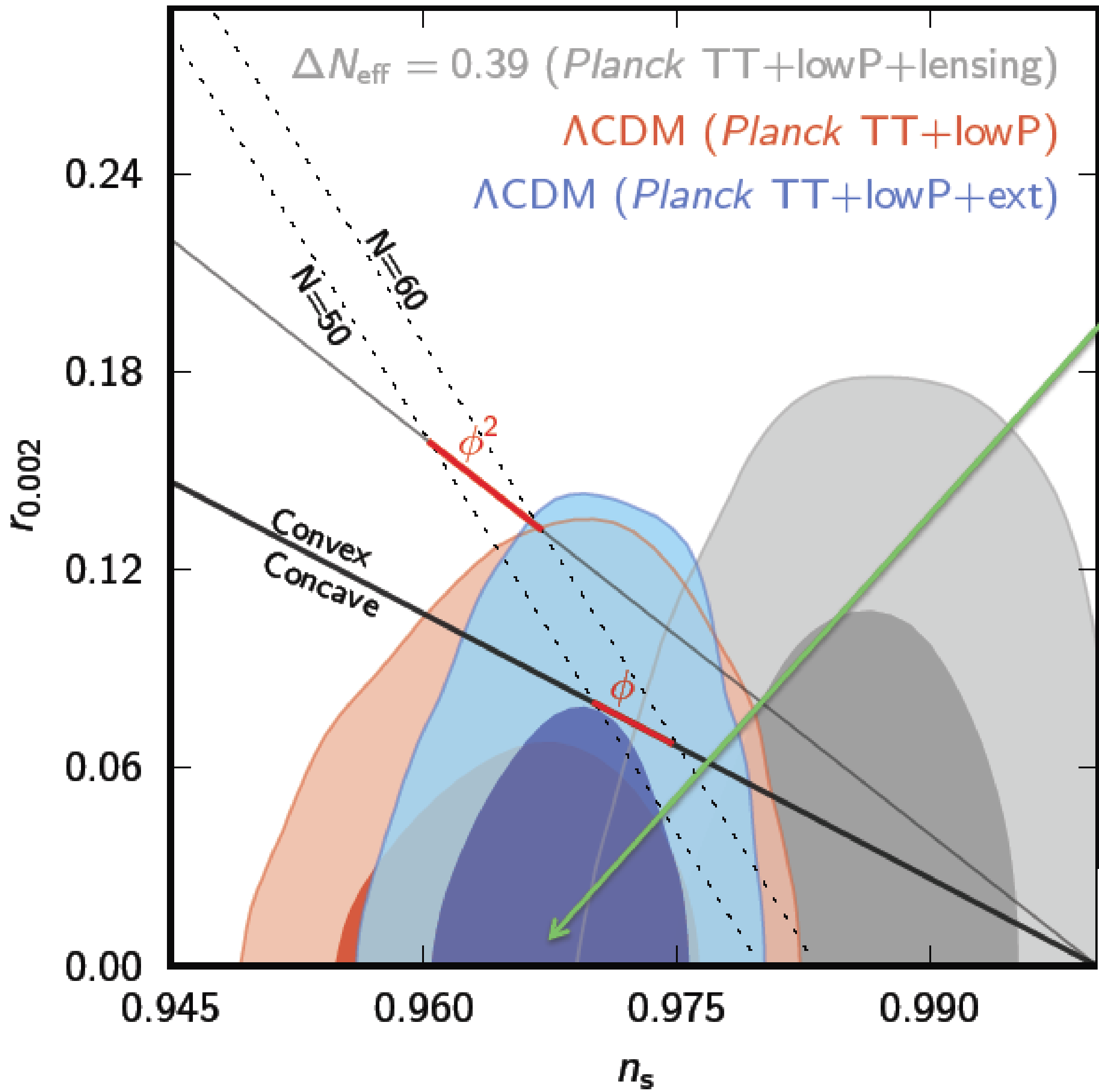
$r \approx 12/N^2 \approx 0.0033$

$dn_s/d\ln k \approx -2/N^2 \approx -0.0006$

...... but, there is plenty of room at the top

(and to the side!)

preliminary



Starobinsky (R^2) inflation

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$r \approx 12/N^2 \approx 0.0033$

$dn_s/d\ln k \approx -2/N^2 \approx -0.0006$

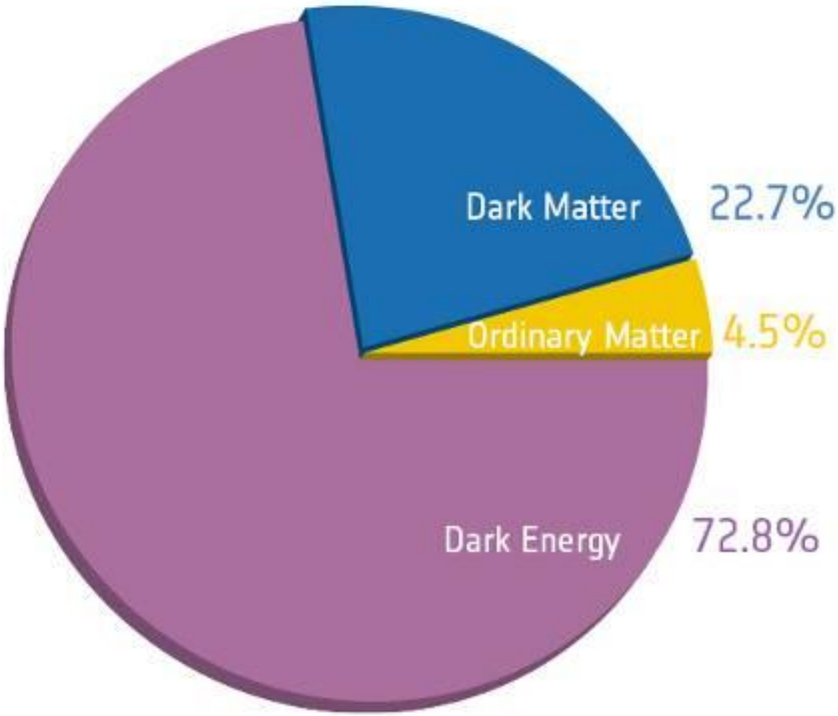
...... but, there is plenty of room at the top

(and to the side!)

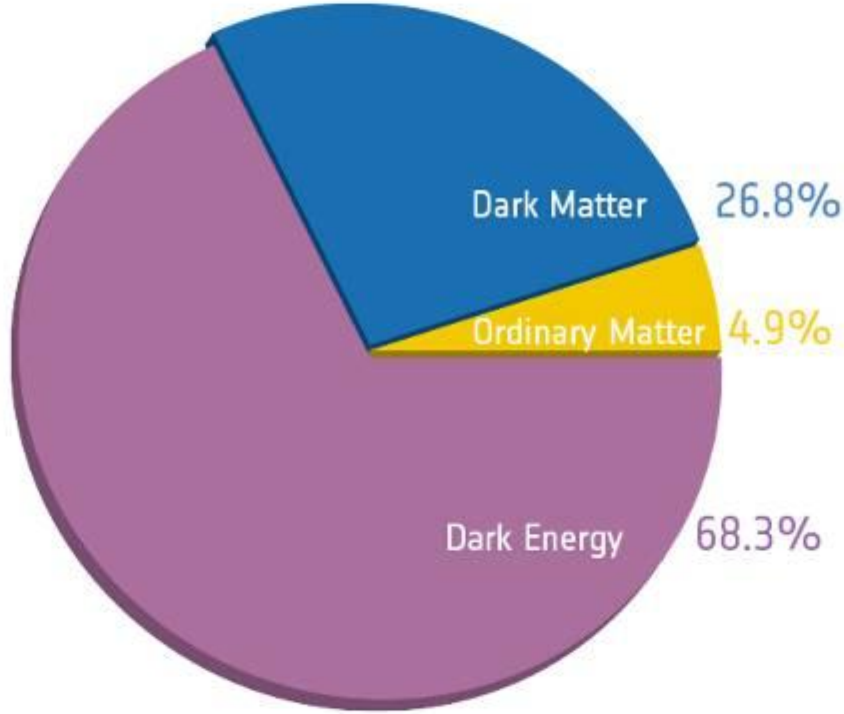
$$E_{LHC} = 6500 GeV$$

$$E_{CMB} \approx 10^9 - 10^{12} GeV$$

preliminary

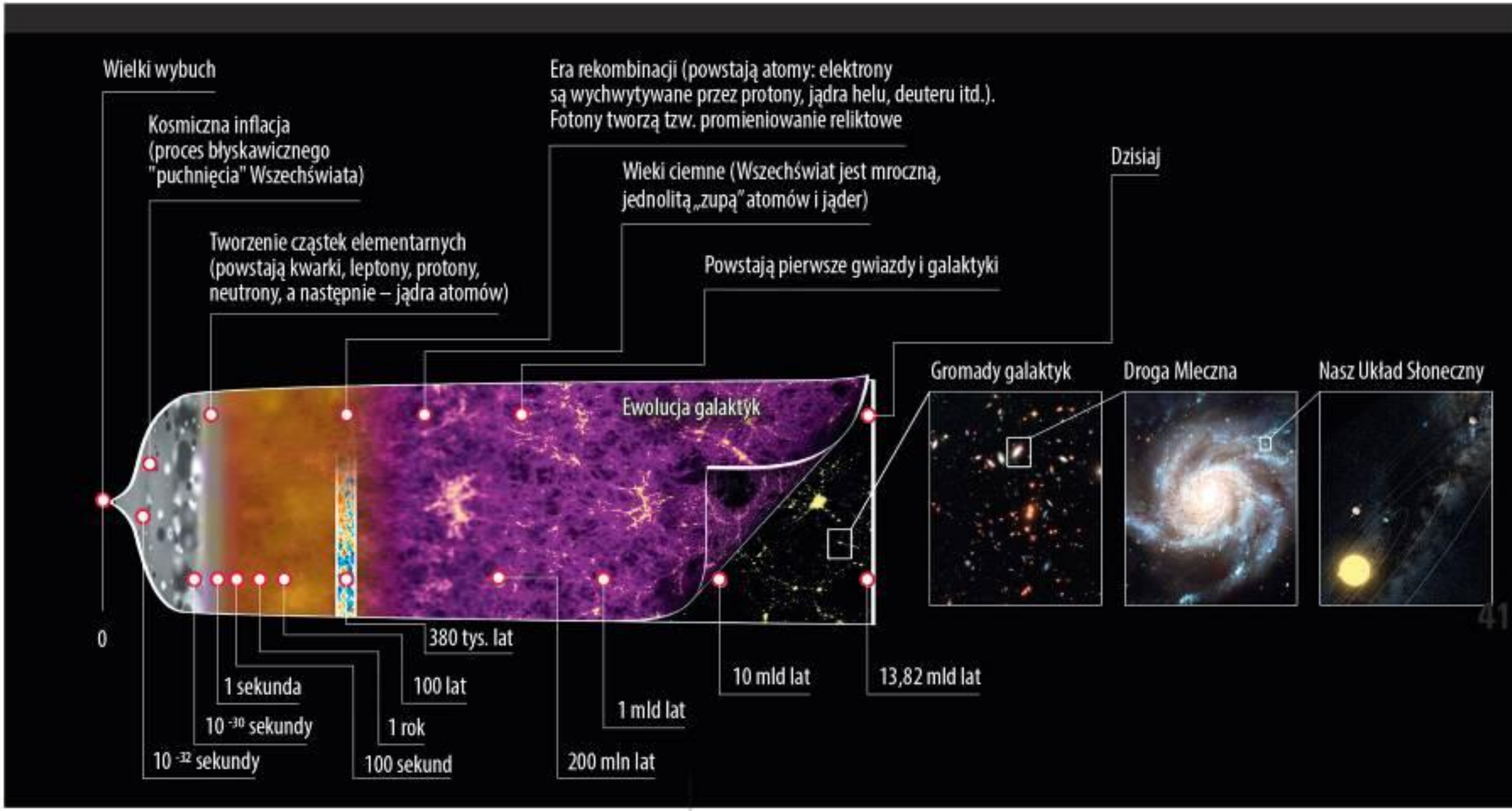


Before Planck



After Planck

Ewolucja Wszechświata




esa
planck
cnes
agenzia spaziale italiana
NASA
cnrs
DTU Space
National Space Institute
Science & Technology Facilities Council
CSIC
HFI PLANCK
LFI
IAS
IAP
National Research Council of Italy
Deutsches Zentrum für Luft- und Raumfahrt e.V.
DLR
SPACE
KICC
Kavli Institute for Cosmology Cambridge
irap
ipac
JPL
NERSC
MilliLab
UNIVERSITÉ DE GENÈVE
UNIVERSITY OF TORONTO
esa

Bardzo dziękuję

Pani mgr Urszuli Dzienisiuk,
Pani dr Renacie Purgał i
Panu dr Krzysztofowi Karpierzowi
za pomoc w przygtowaniu pokazów