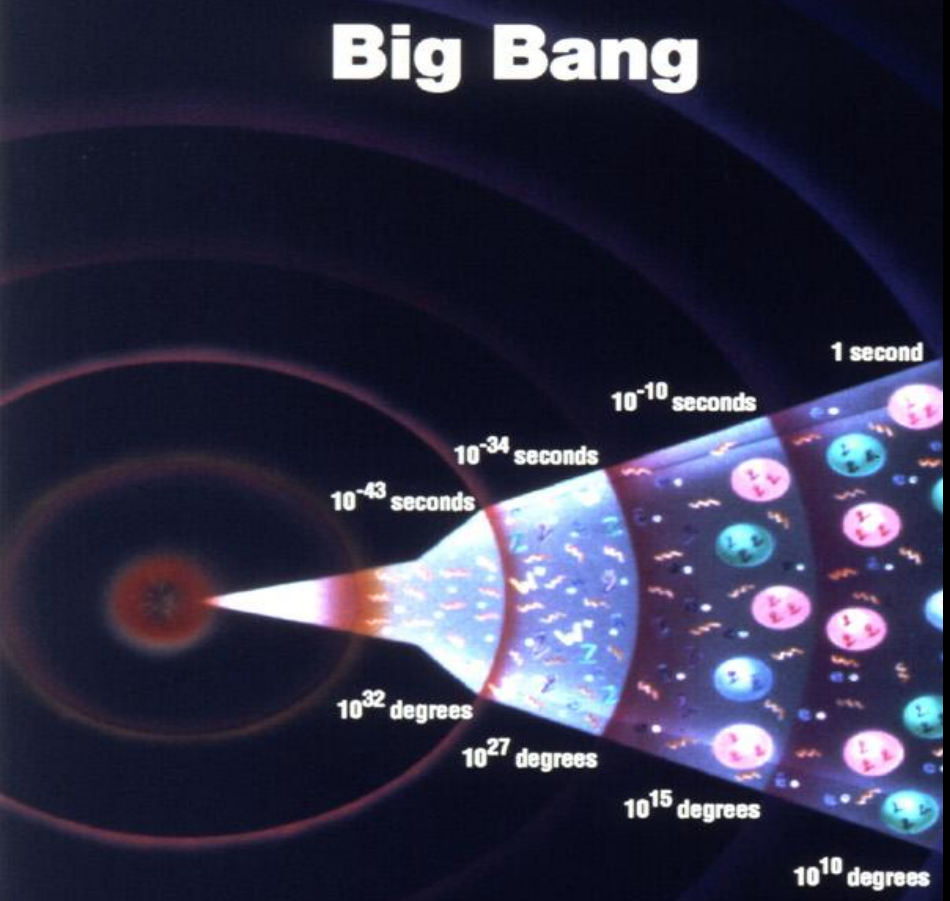
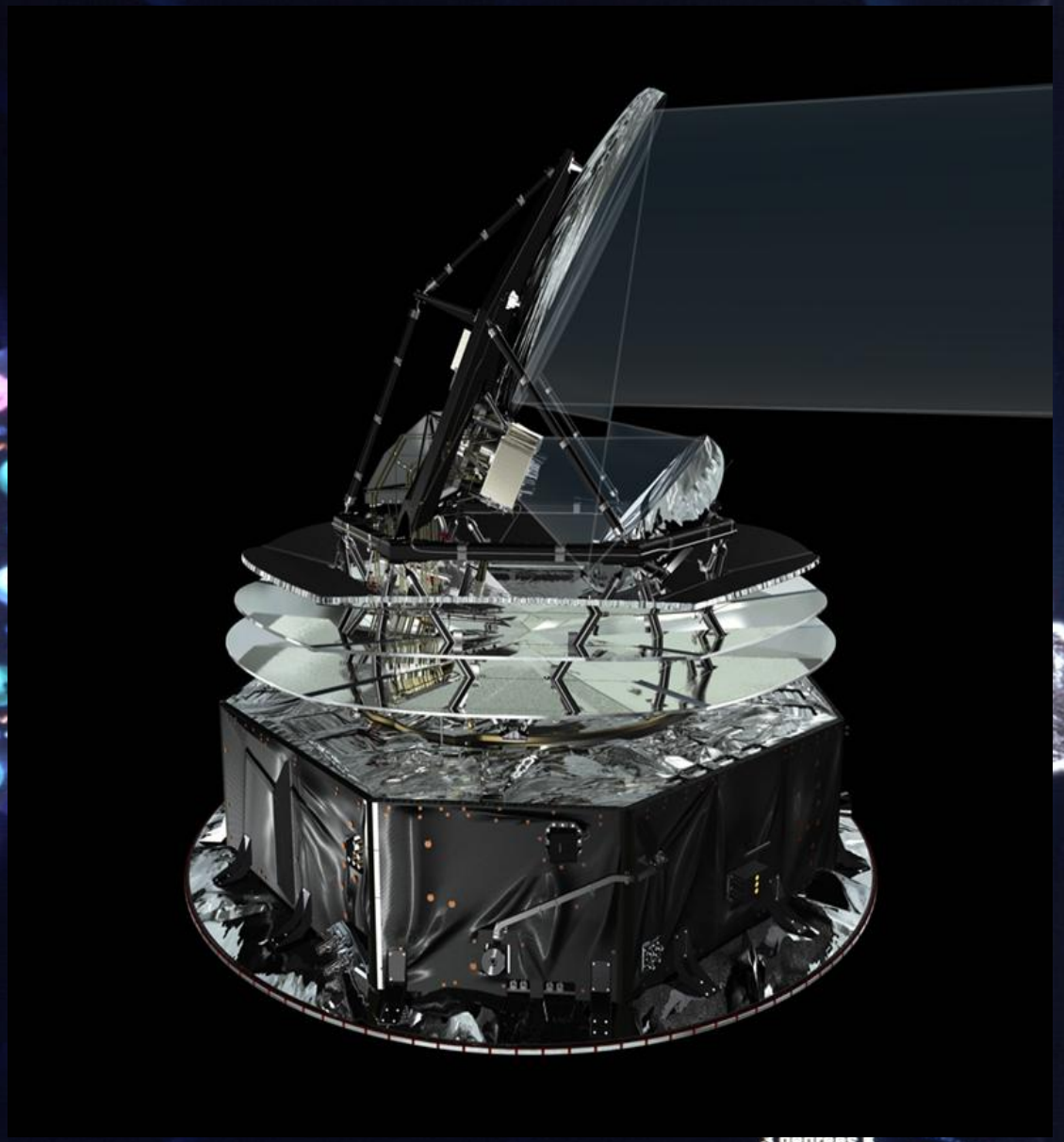
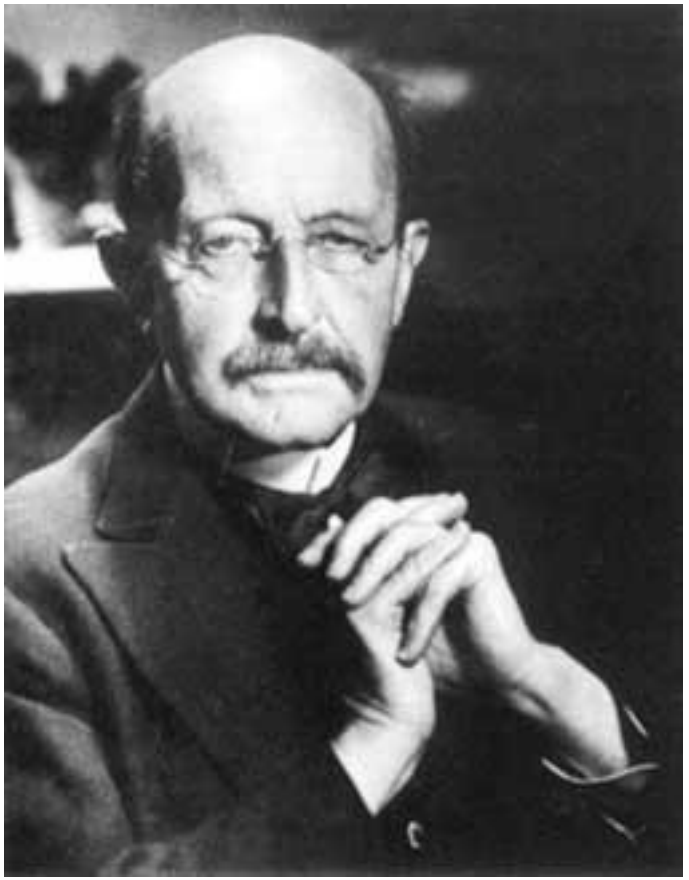
Probing Fundamental Physics with Planck





George Efstathiou
Kavli Institute for Cosmology, Cambridge
RAL 9/12/2010



Planck Units

$$\hbar, \quad c, \quad G$$

$$\text{Planck length} : \left(\frac{\hbar G}{c^3}\right)^{1/2} = 1.6 \times 10^{-35} \text{ metres}$$

$$\text{Planck mass} : \left(\frac{\hbar c}{G}\right)^{1/2} = 2.1 \times 10^{-8} \text{ kgrams}$$

$$\text{Planck time} : \left(\frac{\hbar G}{c^5}\right)^{1/2} = 5.4 \times 10^{-44} \text{ seconds}$$

$$\text{Planck energy} : \left(\frac{\hbar c^5}{G}\right)^{1/2} = 1.2 \times 10^{19} \text{ GeV}$$

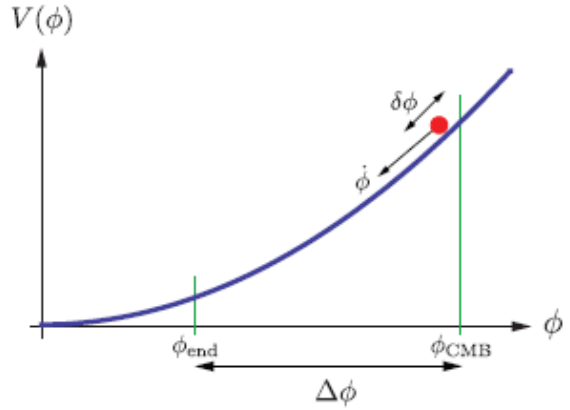
SOME 'BIG' COSMOLOGICAL QUESTIONS :

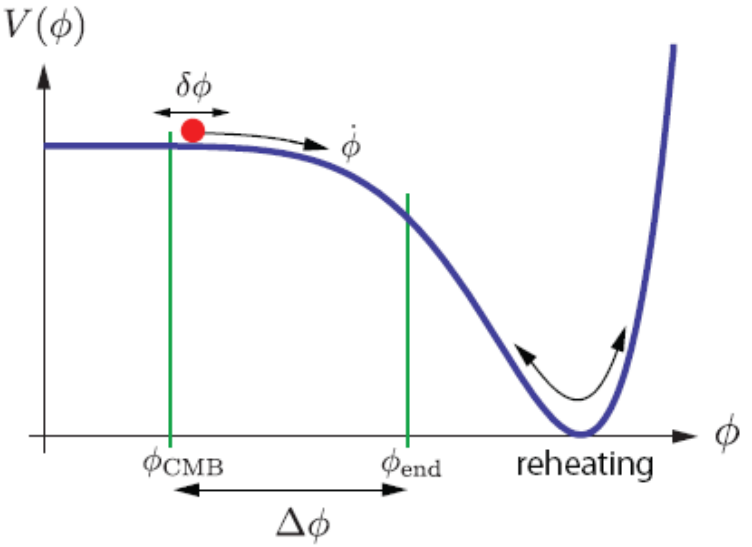
1. **Why is the Universe so big?**
2. **Why is the Universe so old?**
3. **Why is the entropy so big?**
4. **Why is the entropy so small?**
5. **Why is the Universe so uniform and isotropic?**
6. **Where did the structure – stars, galaxies, clusters of galaxies...come from?**
7. **What happened at the Big Bang?**
8. **Can we probe physics before the Big Bang?**
9. **What is the fate of the Universe?**
10. **.....**

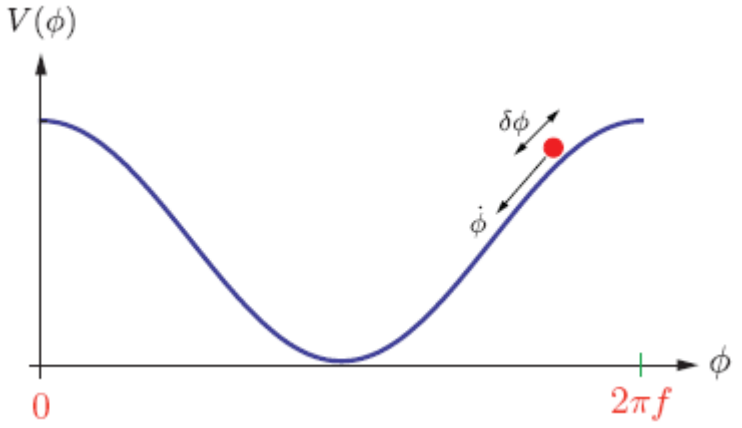
In fact there are many, many, models of inflation..... @ Paul Shellard

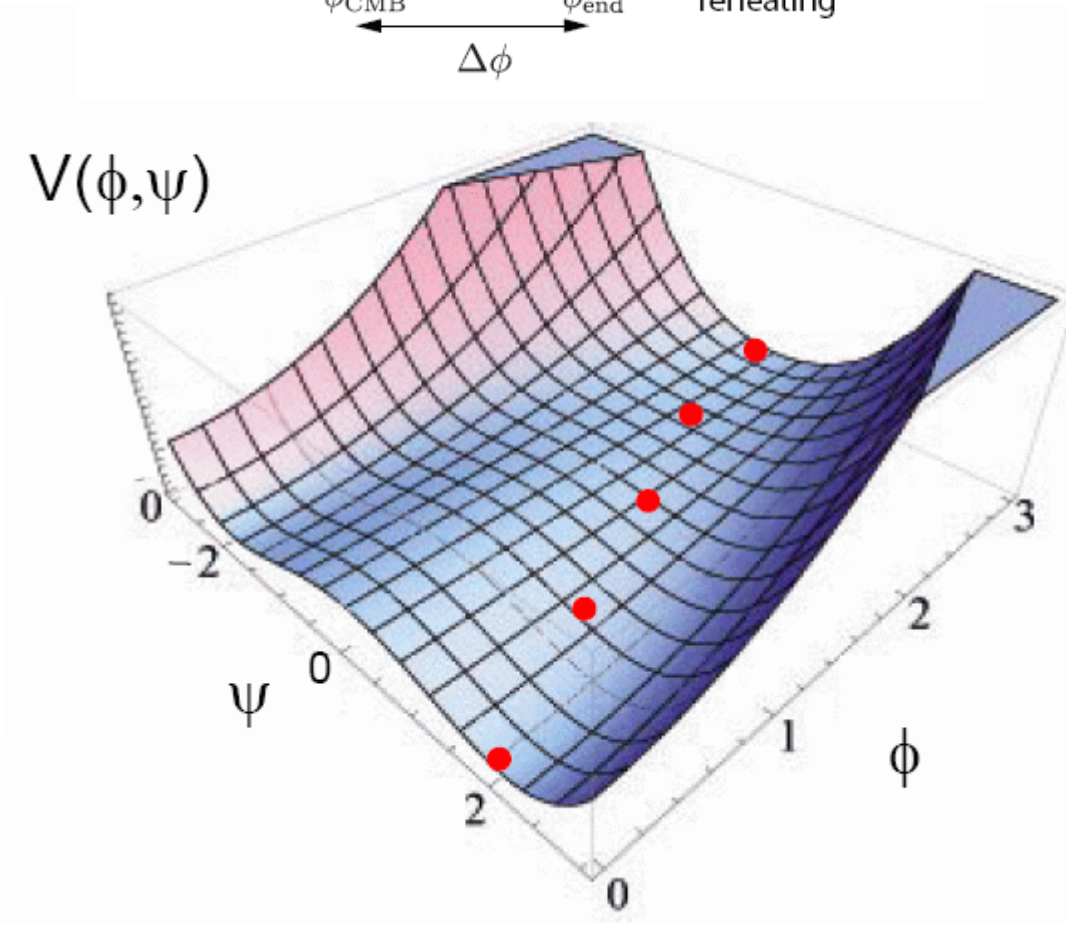
S-dimensional assisted inflation
assisted brane inflation
anomoly-induced inflation
assisted inflation
assisted chaotic inflation
boundary inflation
brane inflation
brane-assisted inflation
brane gas inflation
brane-antibrane inflation
braneworld inflation
Brans-Dicke chaotic inflation
Brans-Dicke inflation
bulky brane inflation
chaotic inflation
chaotic hybrid inflation
chaotic new inflation
D-brane inflation
D-term inflation
dilaton-driven inflation
dilaton-driven brane inflation
double inflation
double D-term inflation
dual inflation
dynamical inflation
dynamical SUSY inflation
eternal inflation
extended inflation
extended open inflation
extended warm inflation
extra dimensional inflation
F-term inflation
F-term hybrid inflation
false-vacuum inflation
false-vacuum chaotic inflation
fast-roll inflation
first-order inflation
gauged inflation
Hagedorn inflation
higher-curvature inflation
hybrid inflation
hyperextended inflation
induced gravity inflation
intermediate inflation
inverted hybrid inflation
isocurvature inflation.....

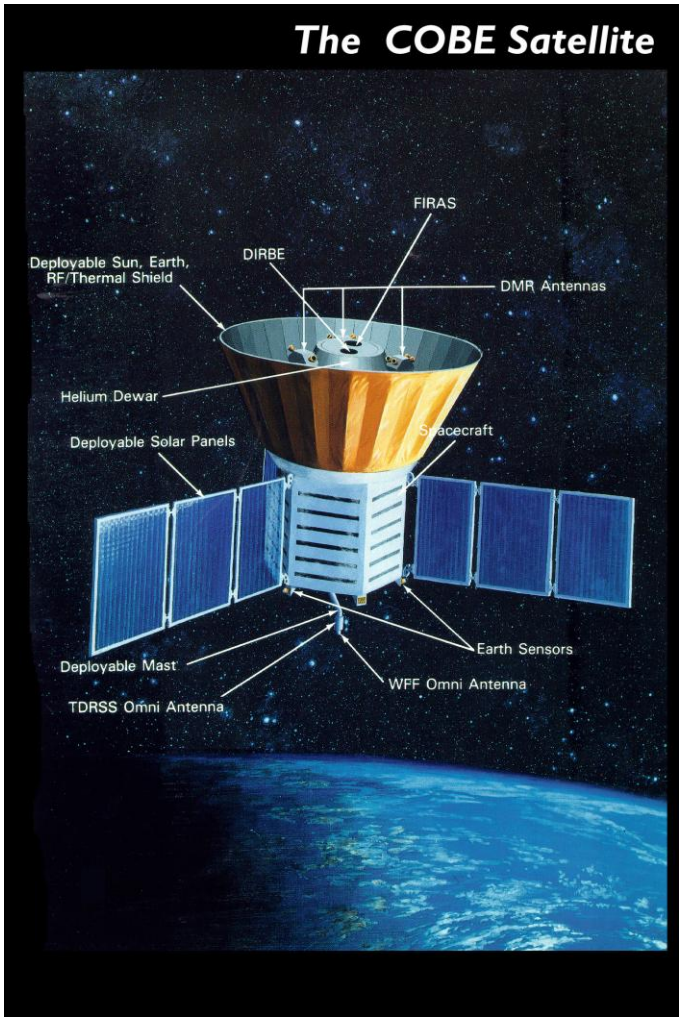
Inflation can be realised in many different ways, and can involve more than one field:





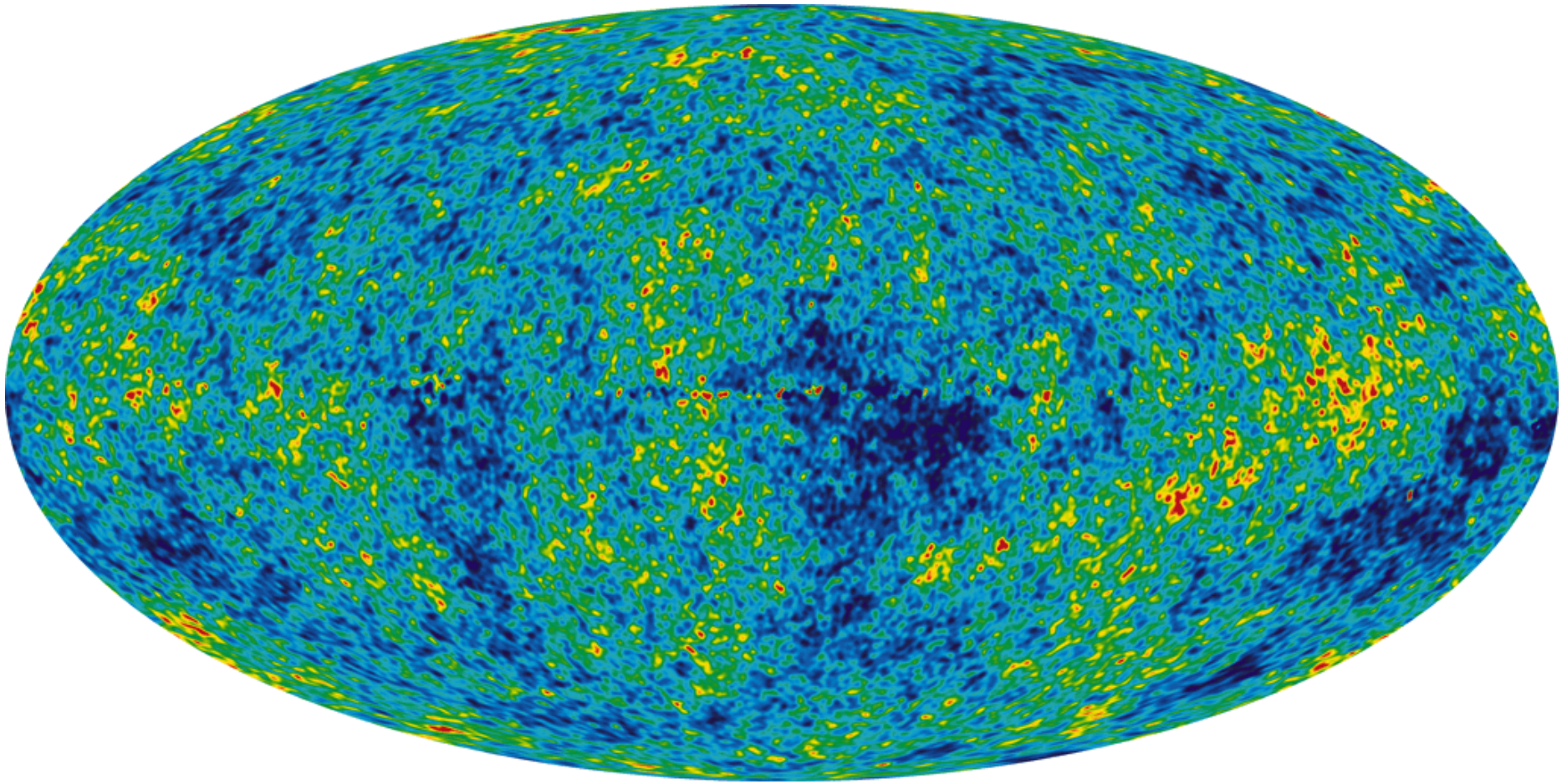


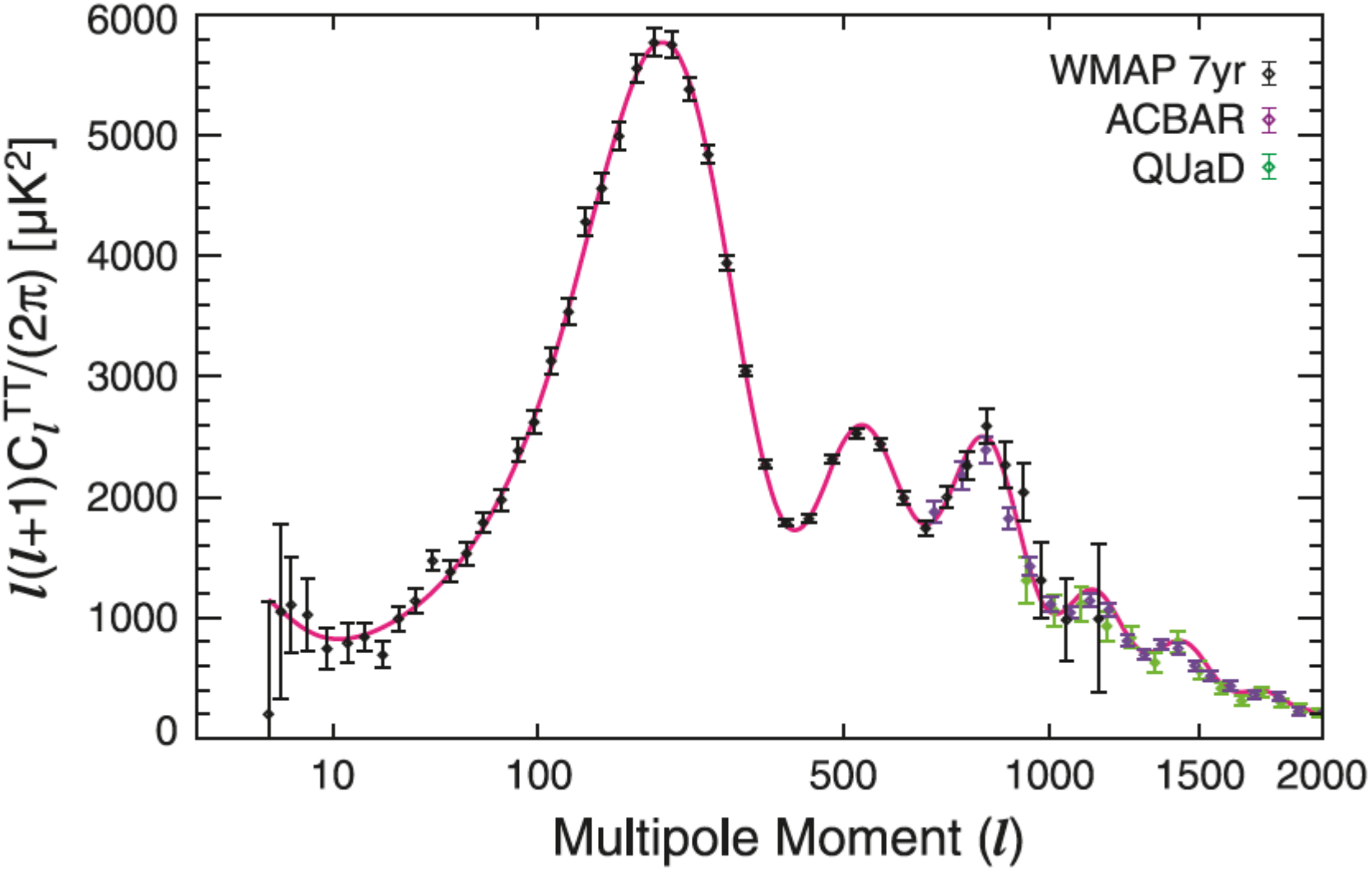


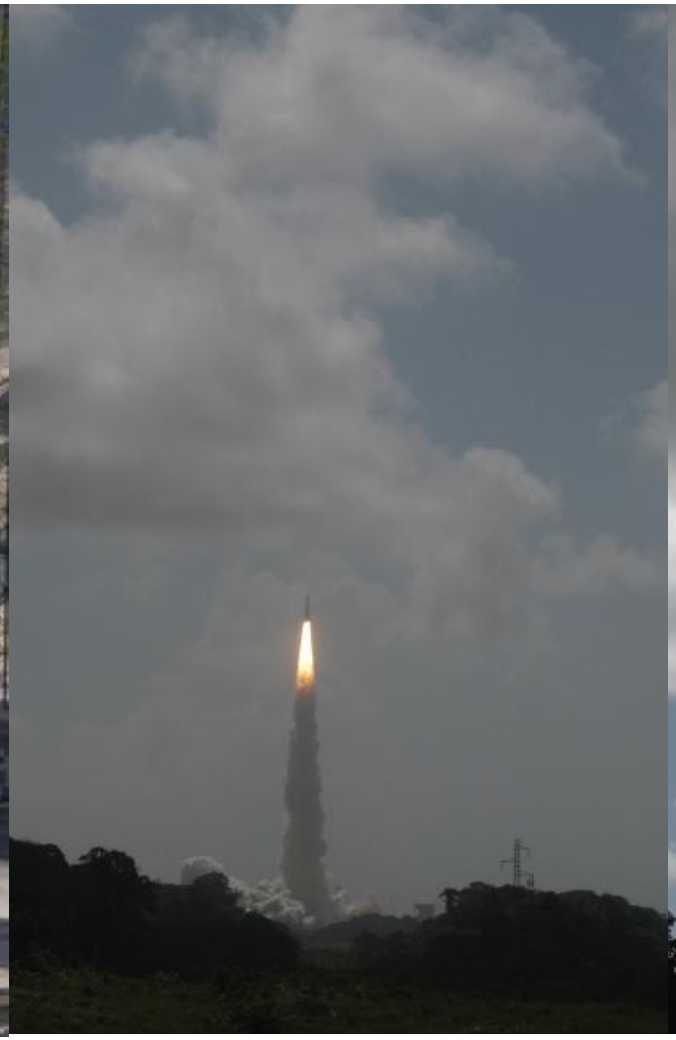


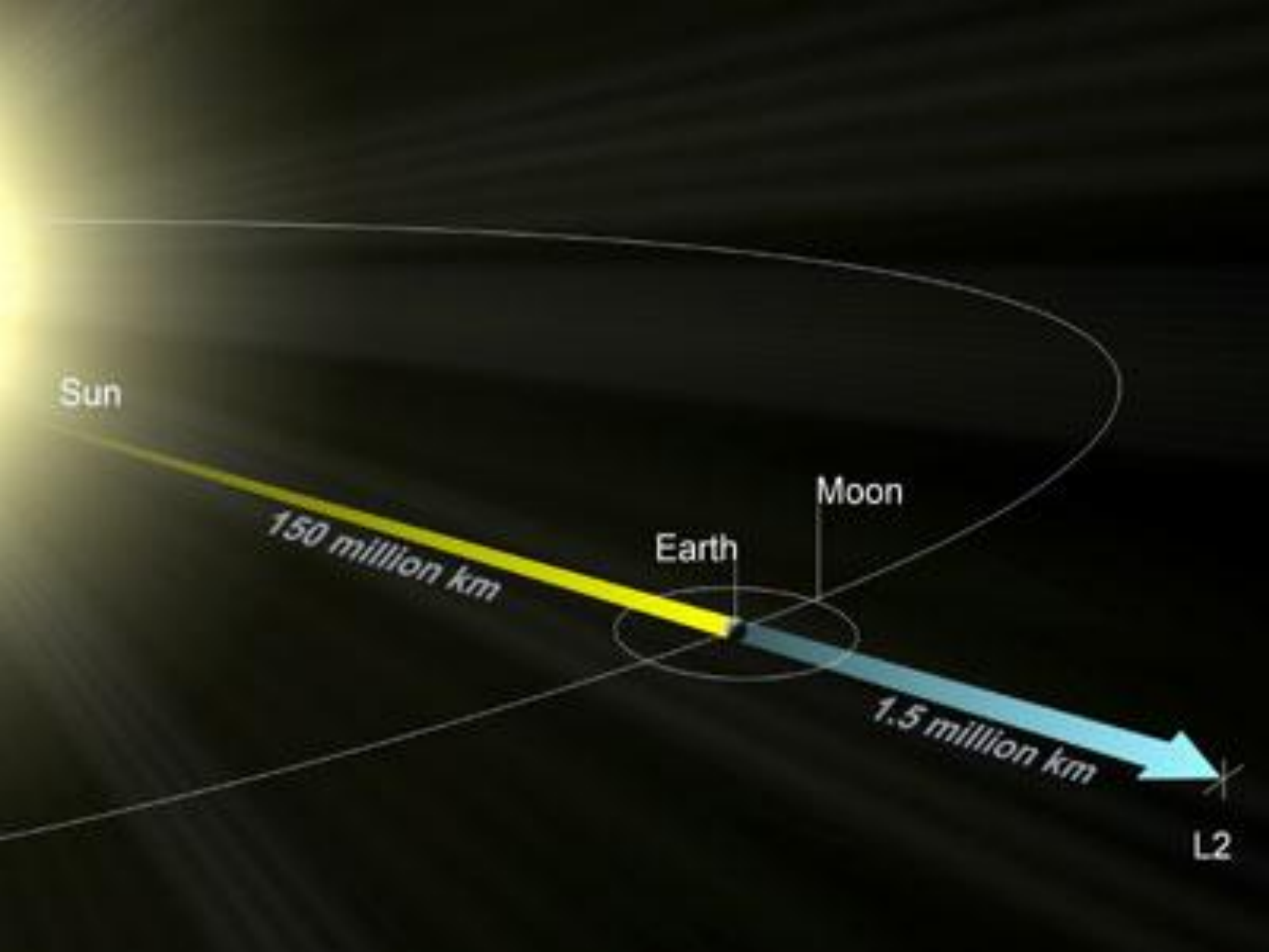
COBE 1989

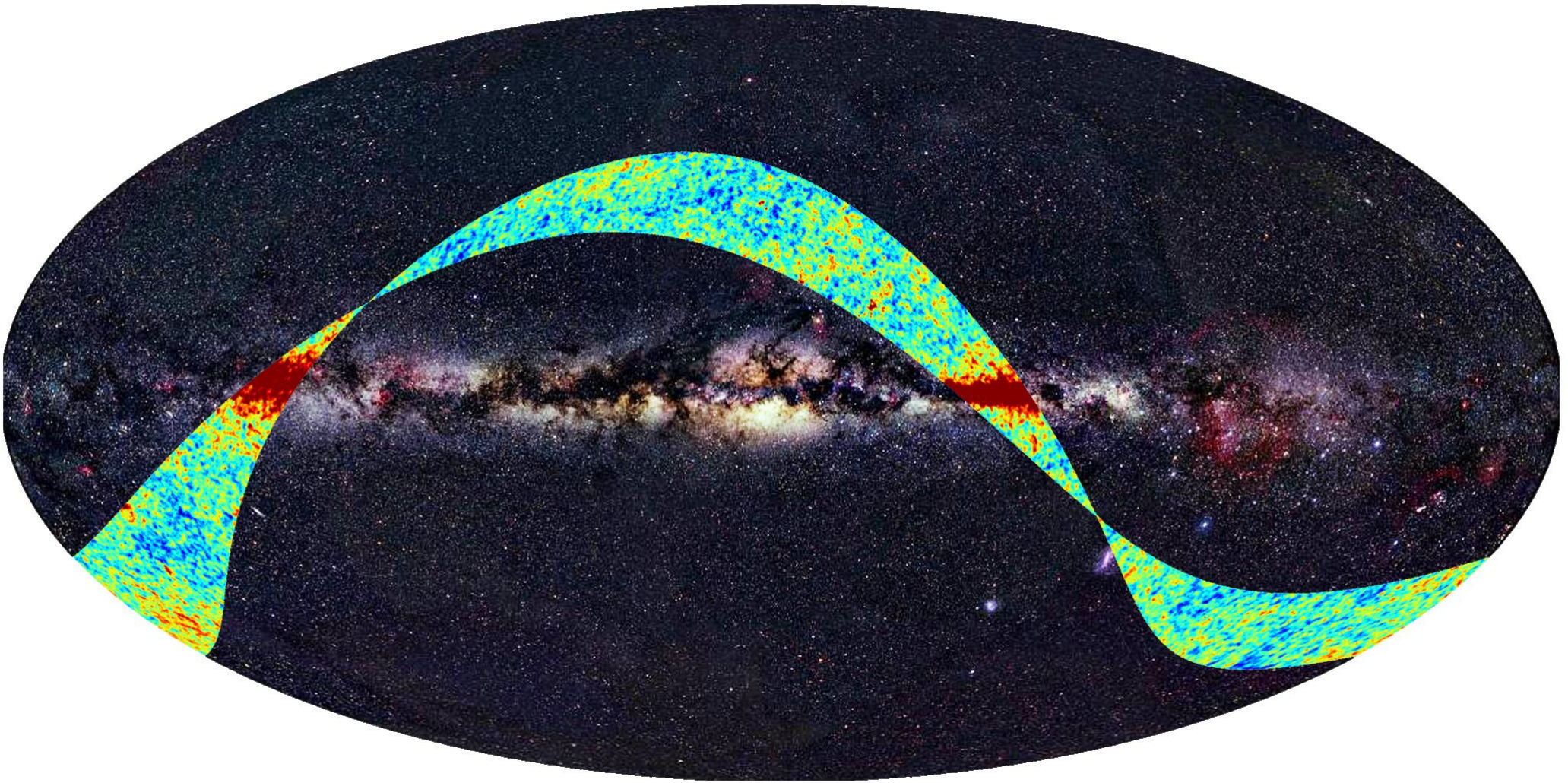
WMAP 2001

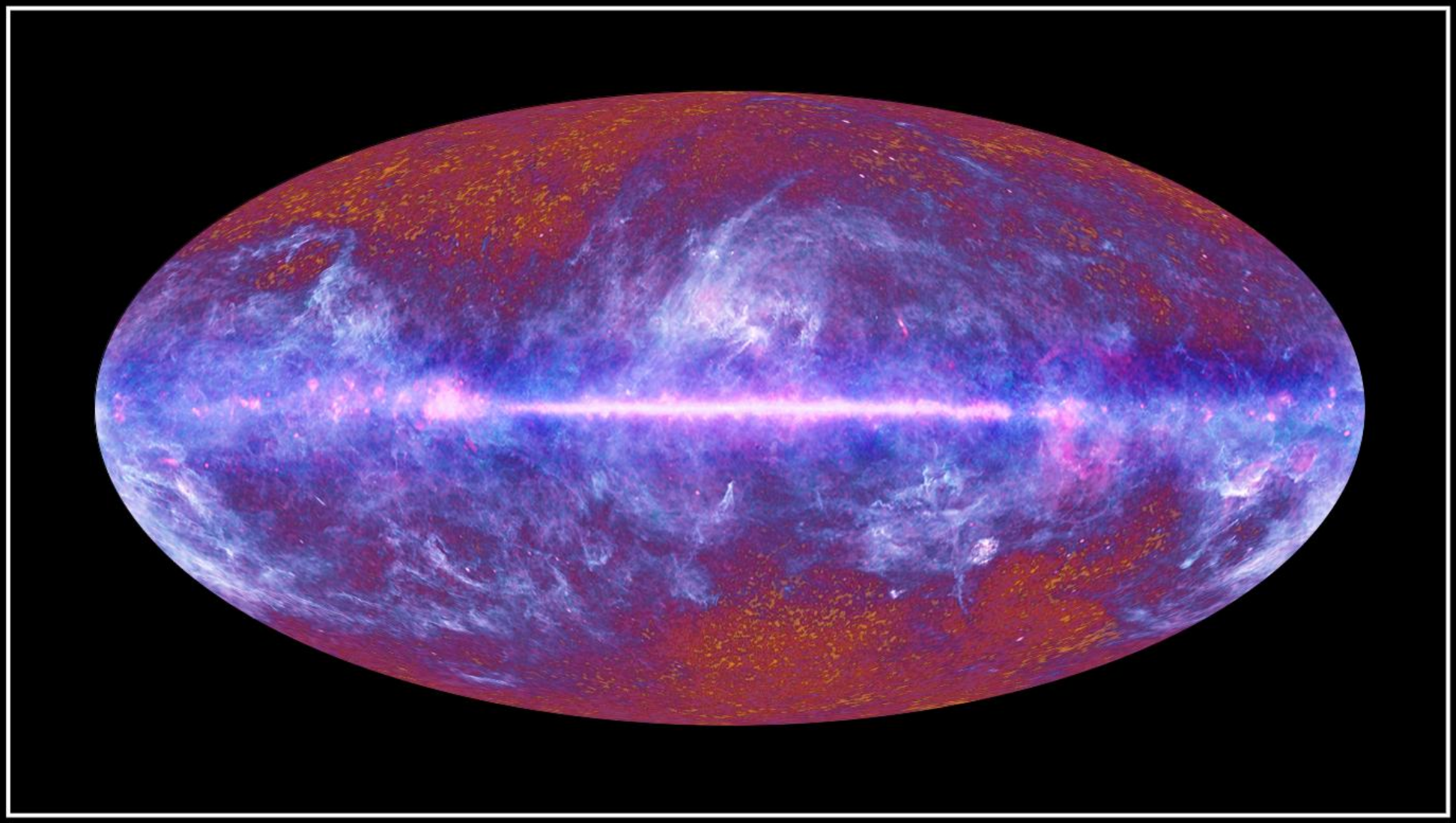



6000
5000
4000
3000
2000
1000
0
$l(l+1)C_l^{TT}/(2\pi)$ [μK^2]
10
100
500
1000
1500
2000
Multipole Moment (l)
WMAP 7yr
ACBAR
QUaD

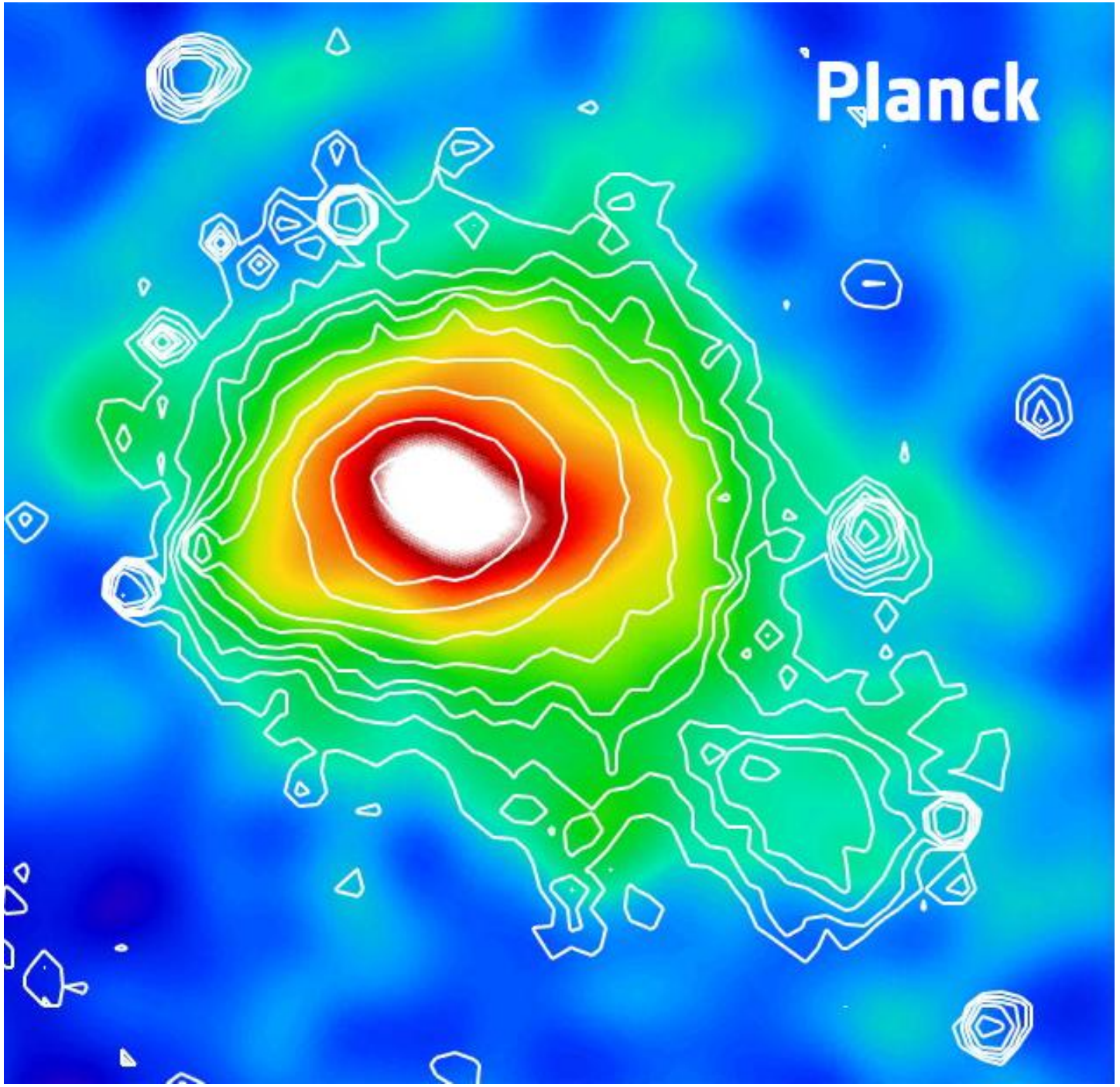


Sun
150 million km
Earth
Moon
1.5 million km
L2

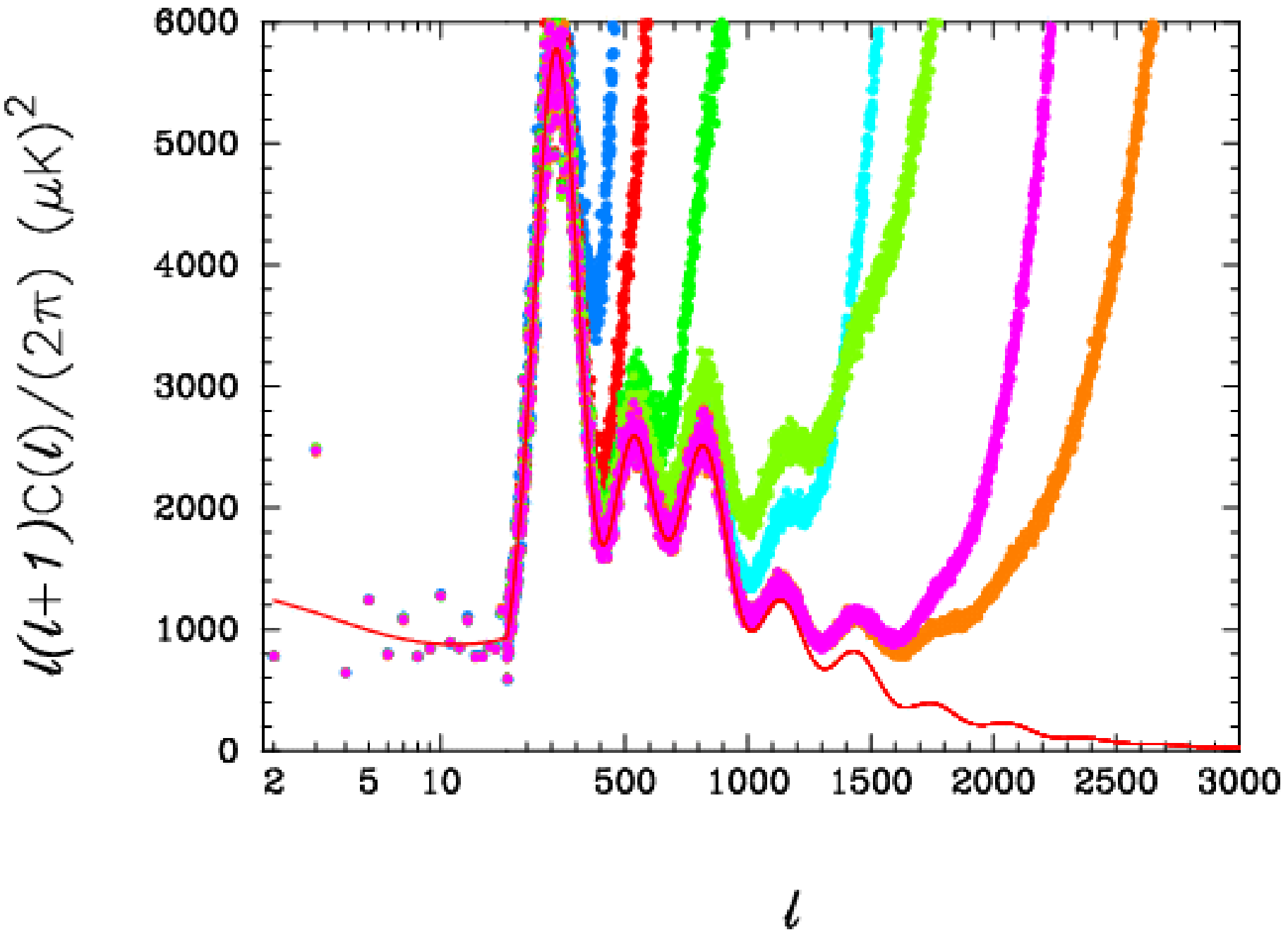


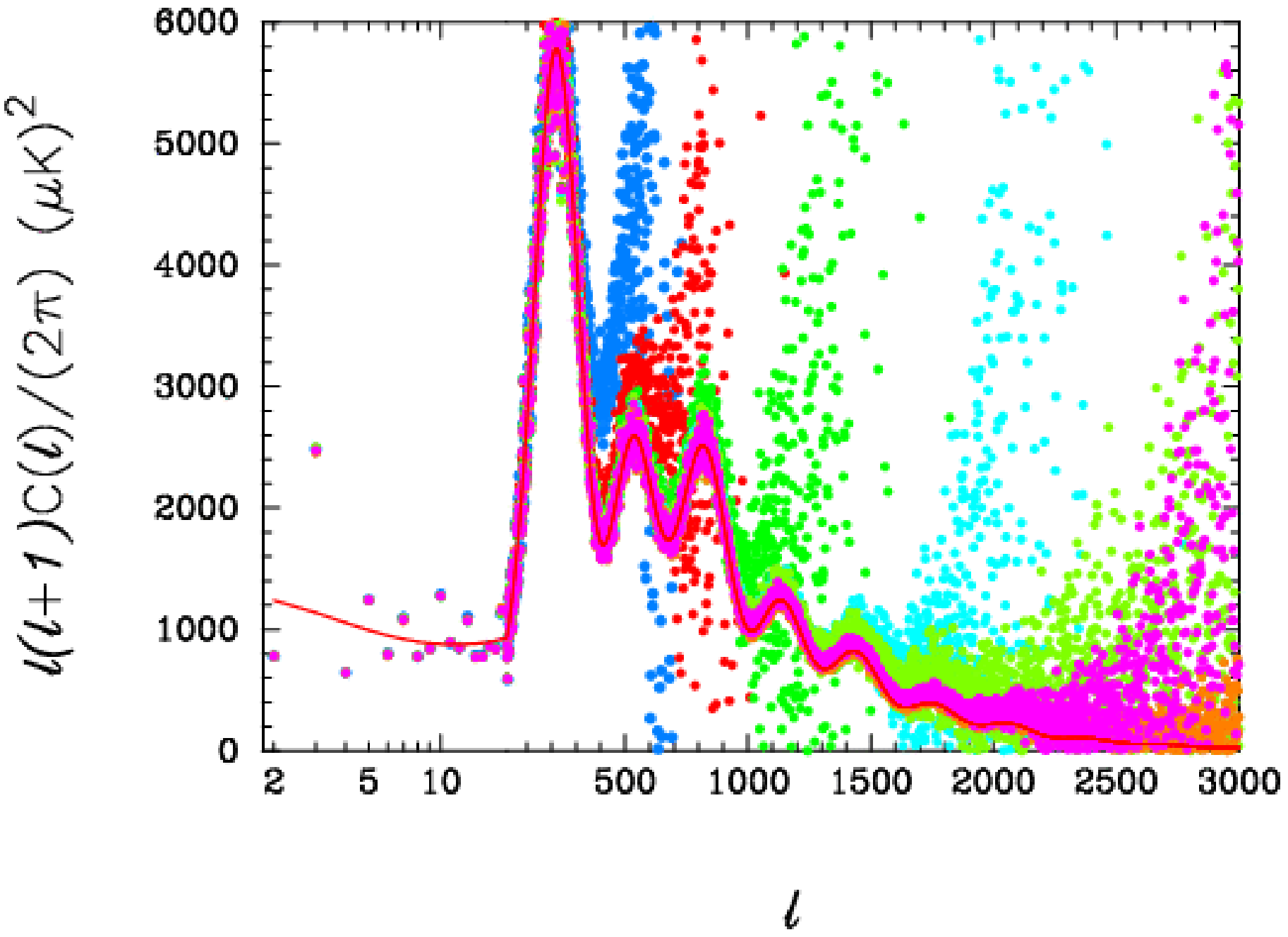


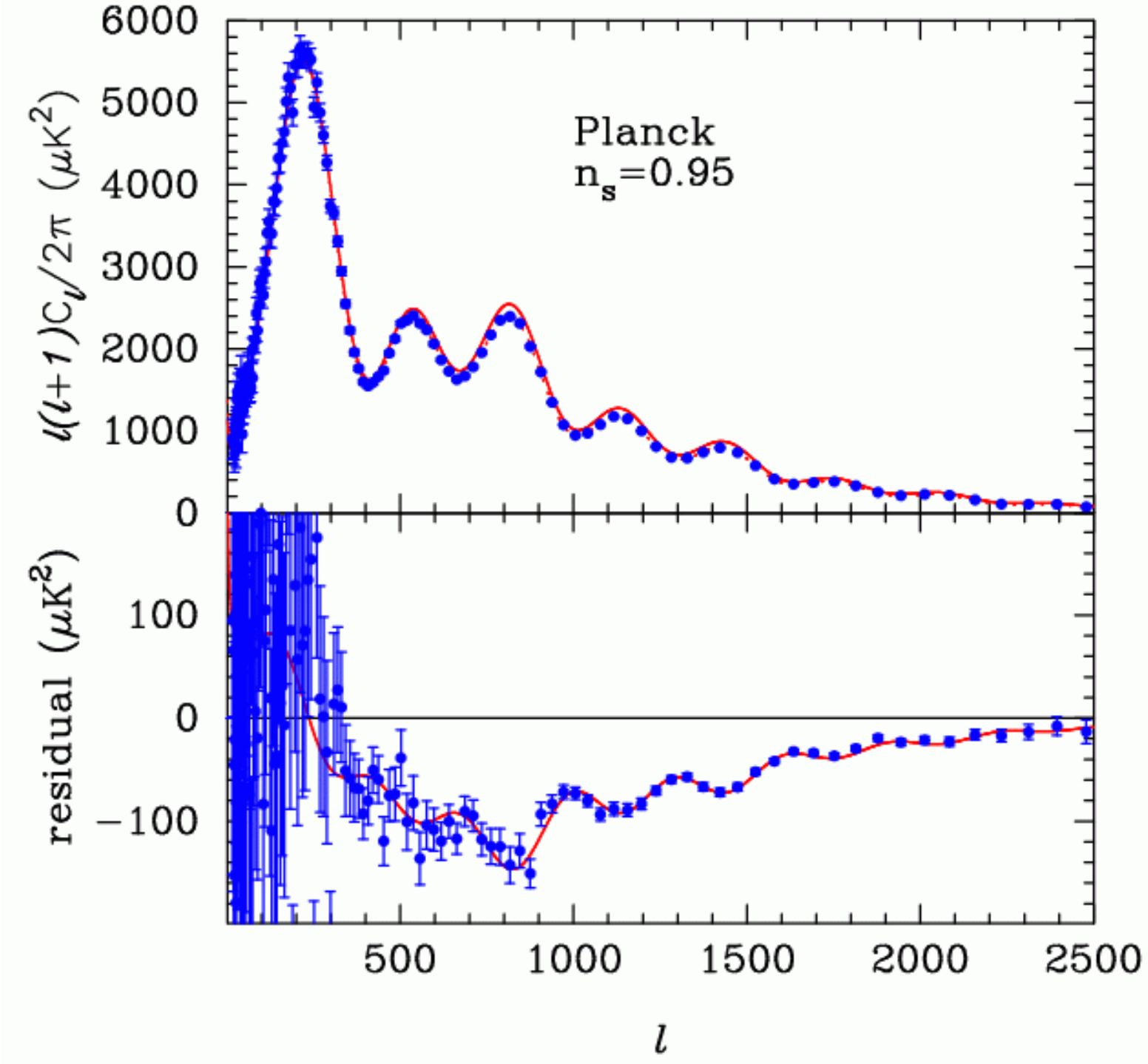
The Planck one-year all-sky survey

esa

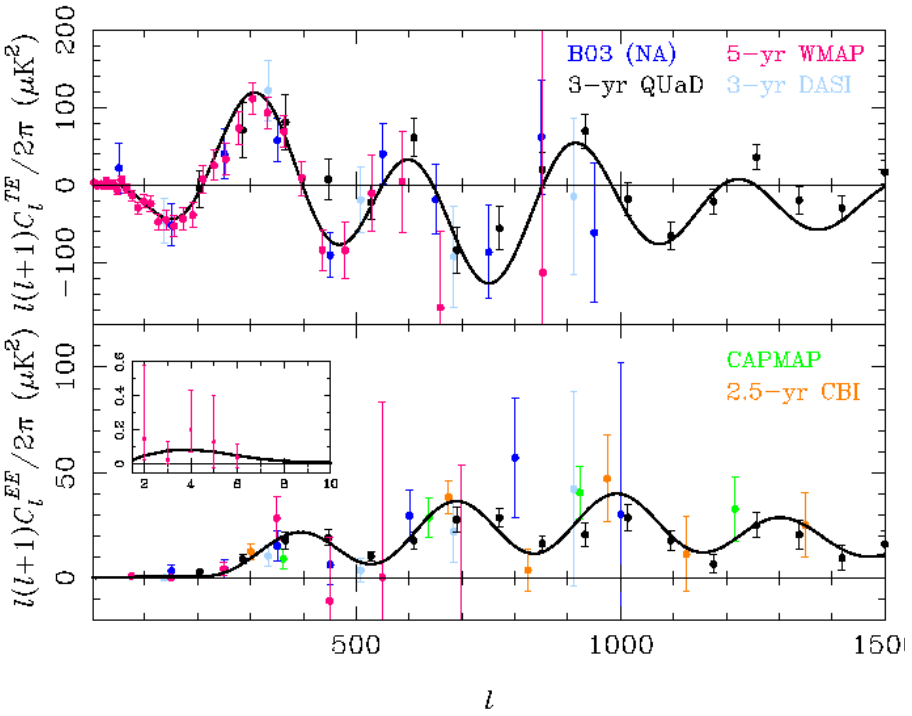

Planck


6000
5000
4000
3000
2000
1000
0
2
5
10
500
1000
1500
2000
2500
3000
$l(l+1)C(l)/(2\pi)\ (\mu K)^2$
l

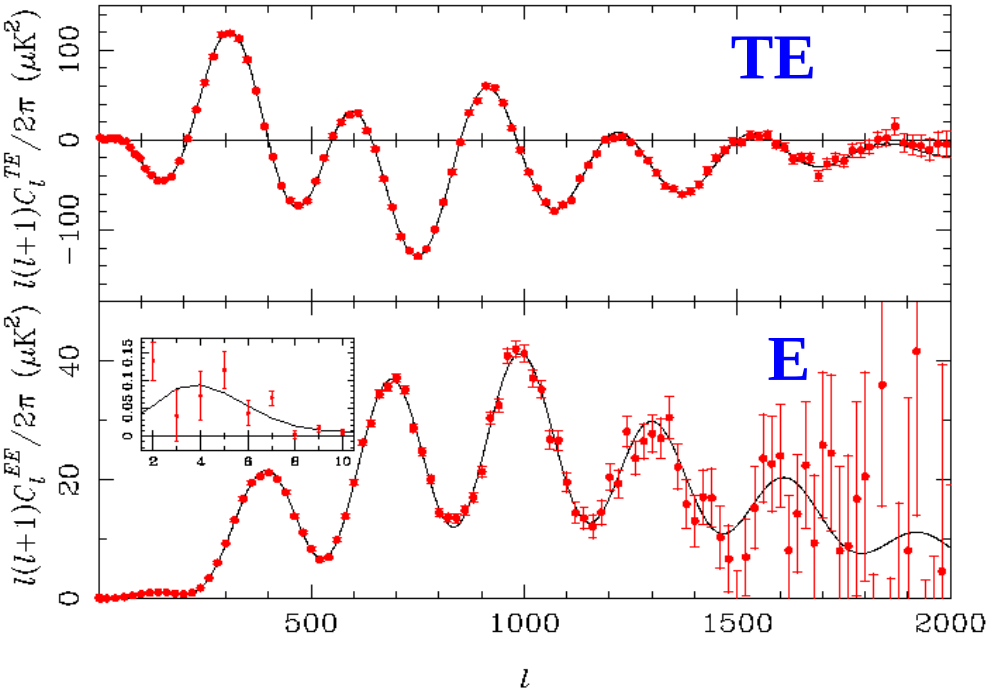

$l(l+1)C(l)/(2\pi)\ (\mu K)^2$
6000
5000
4000
3000
2000
1000
0
2
5
10
500
1000
1500
2000
2500
3000
l


Planck
n_s=0.95
$l(l+1)C_l/2\pi$ (μK^2)
residual (μK^2)
6000
5000
4000
3000
2000
1000
0
100
0
−100
500
1000
1500
2000
2500
l

CURRENT OBSERVATIONS

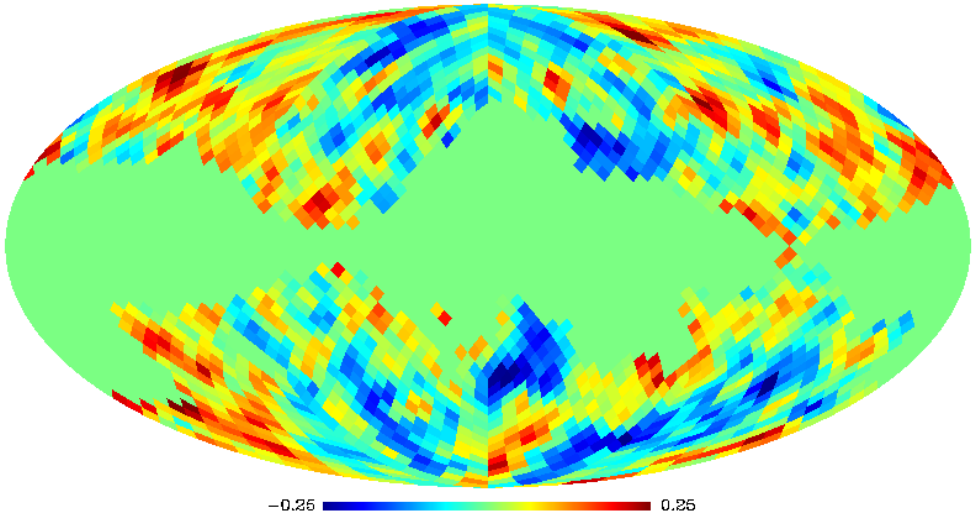


PLANCK FORECAST

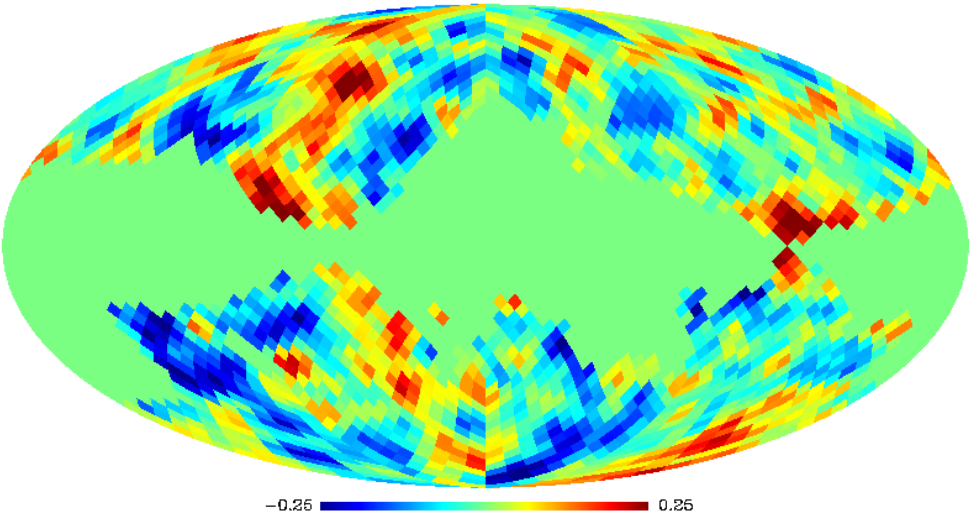


GRAVITATIONAL WAVES EXTENDED MISSION: 4 SKY SURVEYS

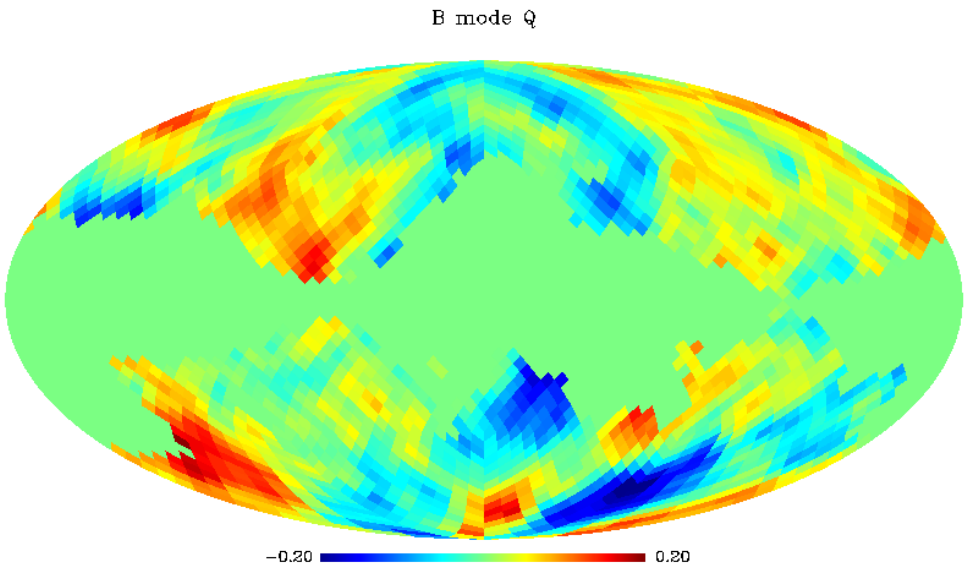
B−mode r=0.1 Q foreground subtracted extended mission

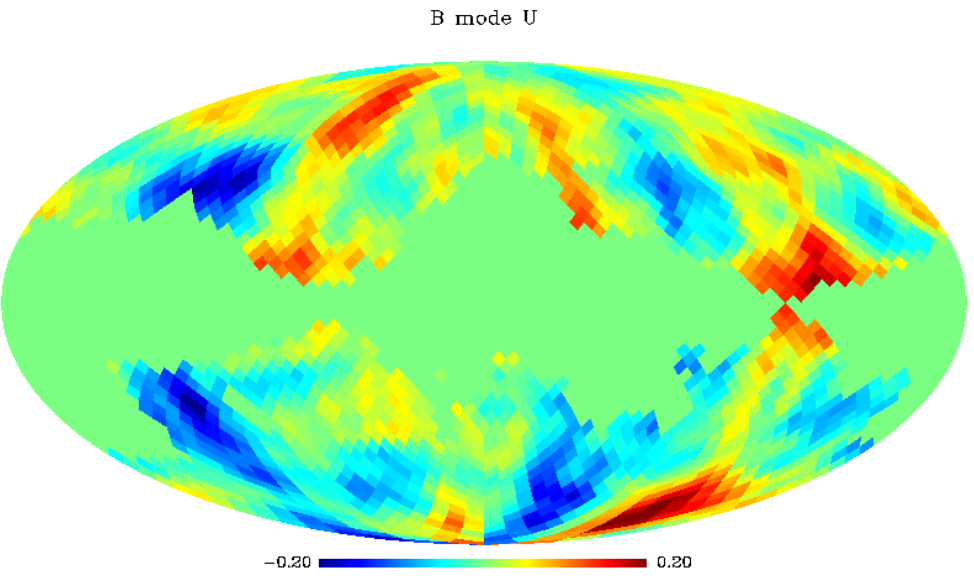


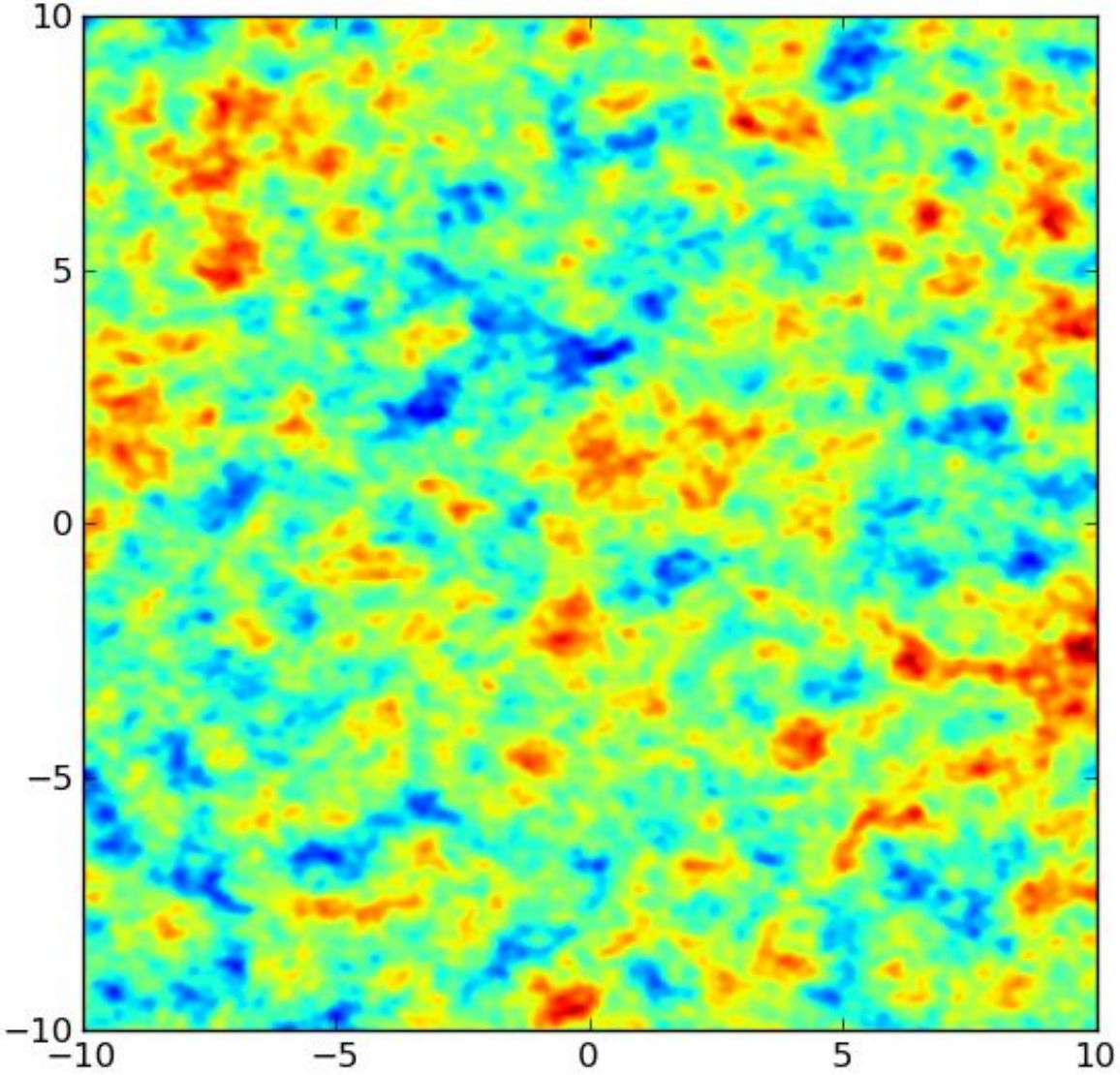
B−mode r=0.1 U foreground subtracted extended mission

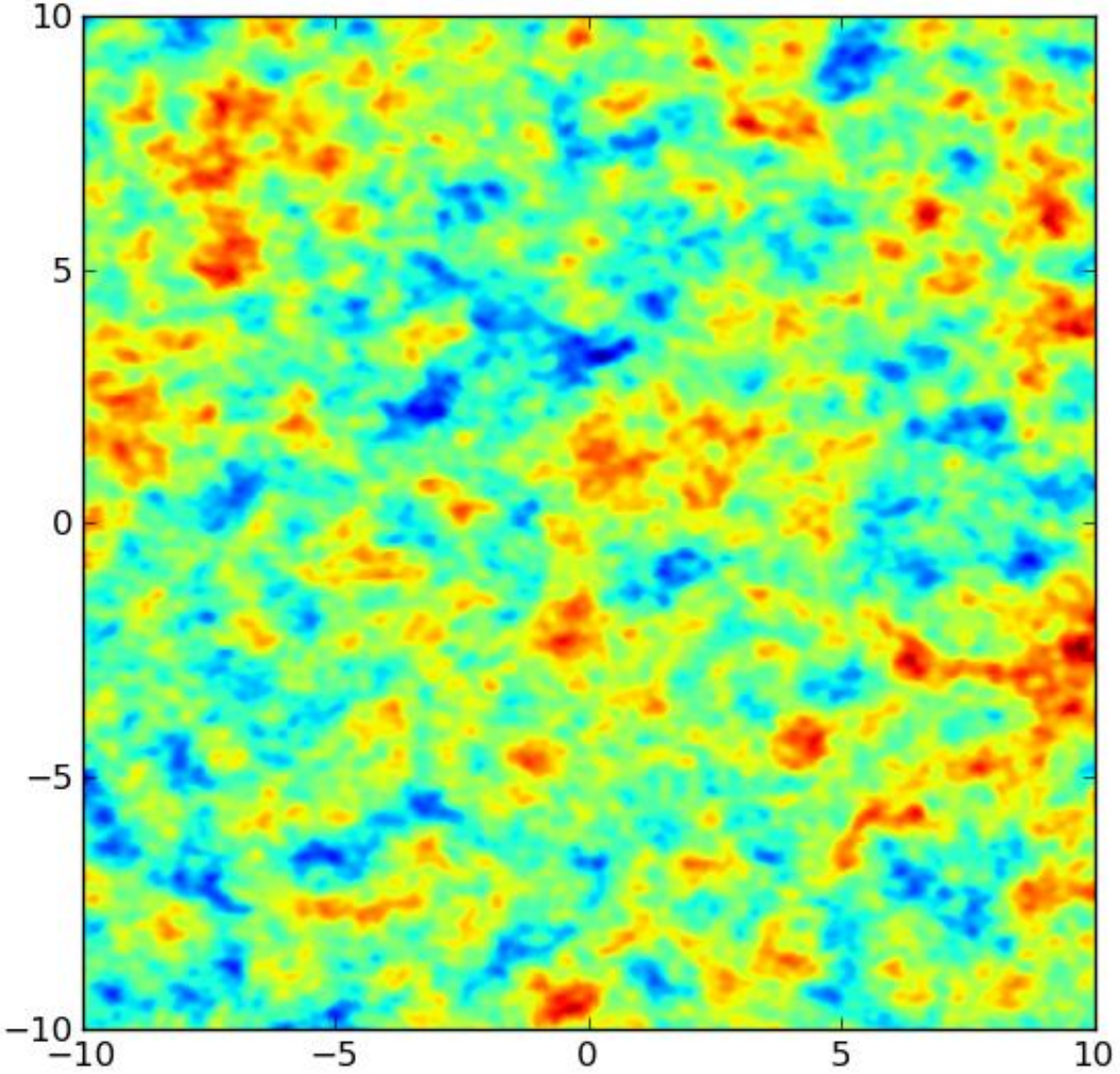


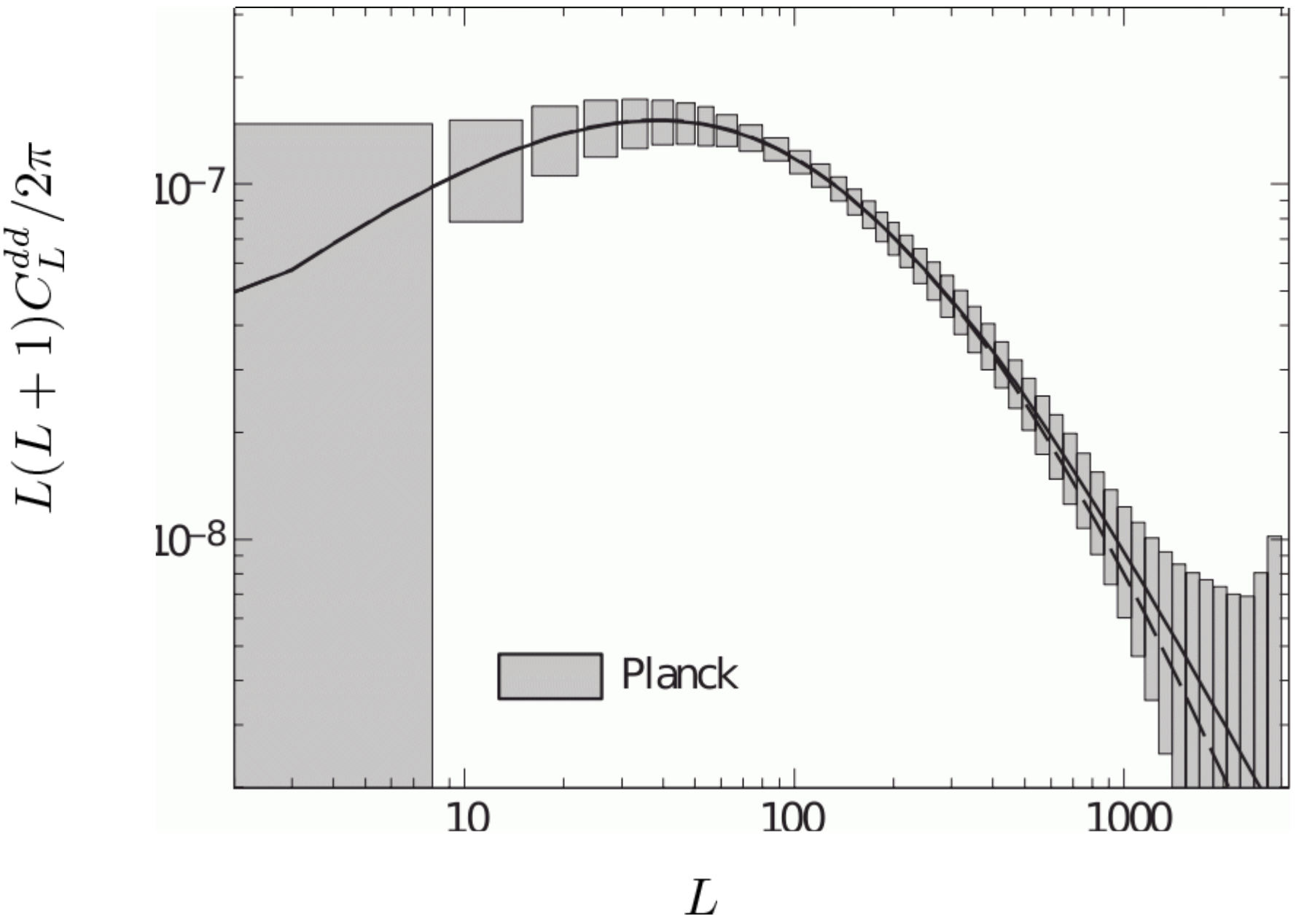
GRAVITATIONAL WAVES THEORETICAL MODEL





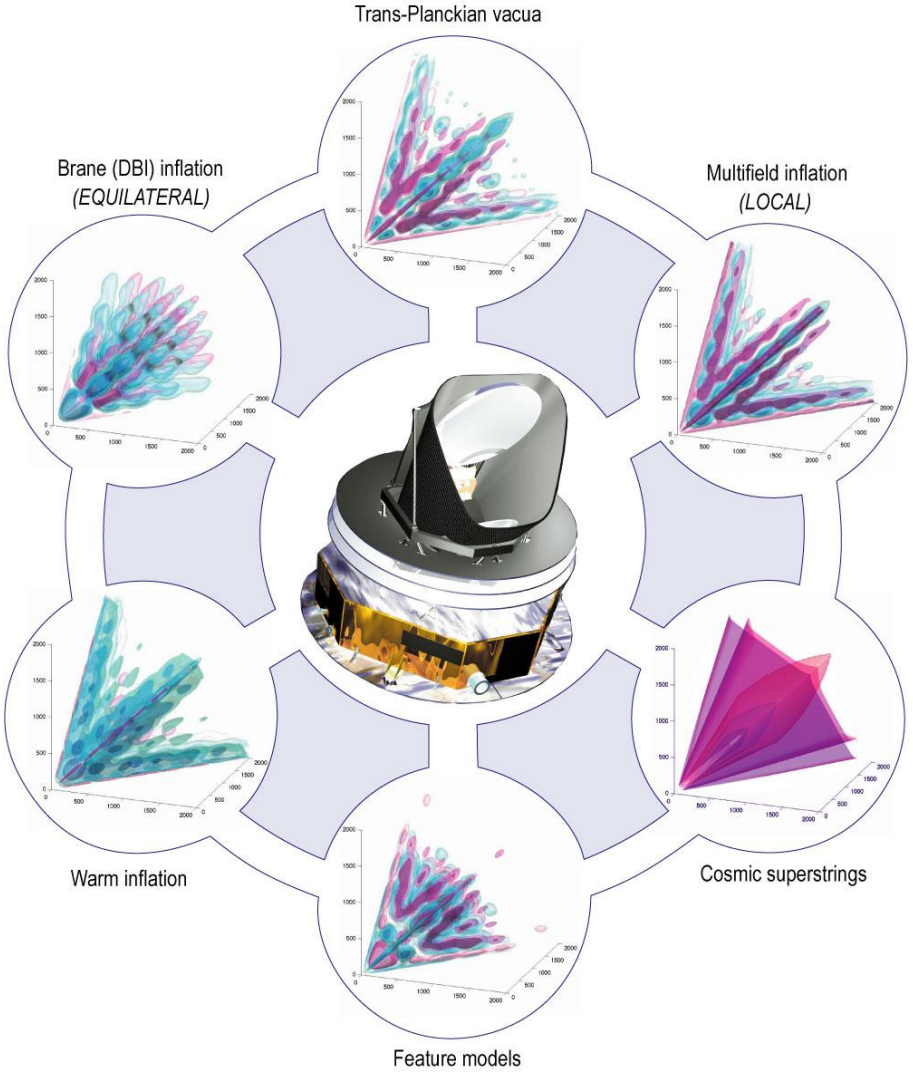

10
5
0
−5
−10
−10
−5
0
5
10

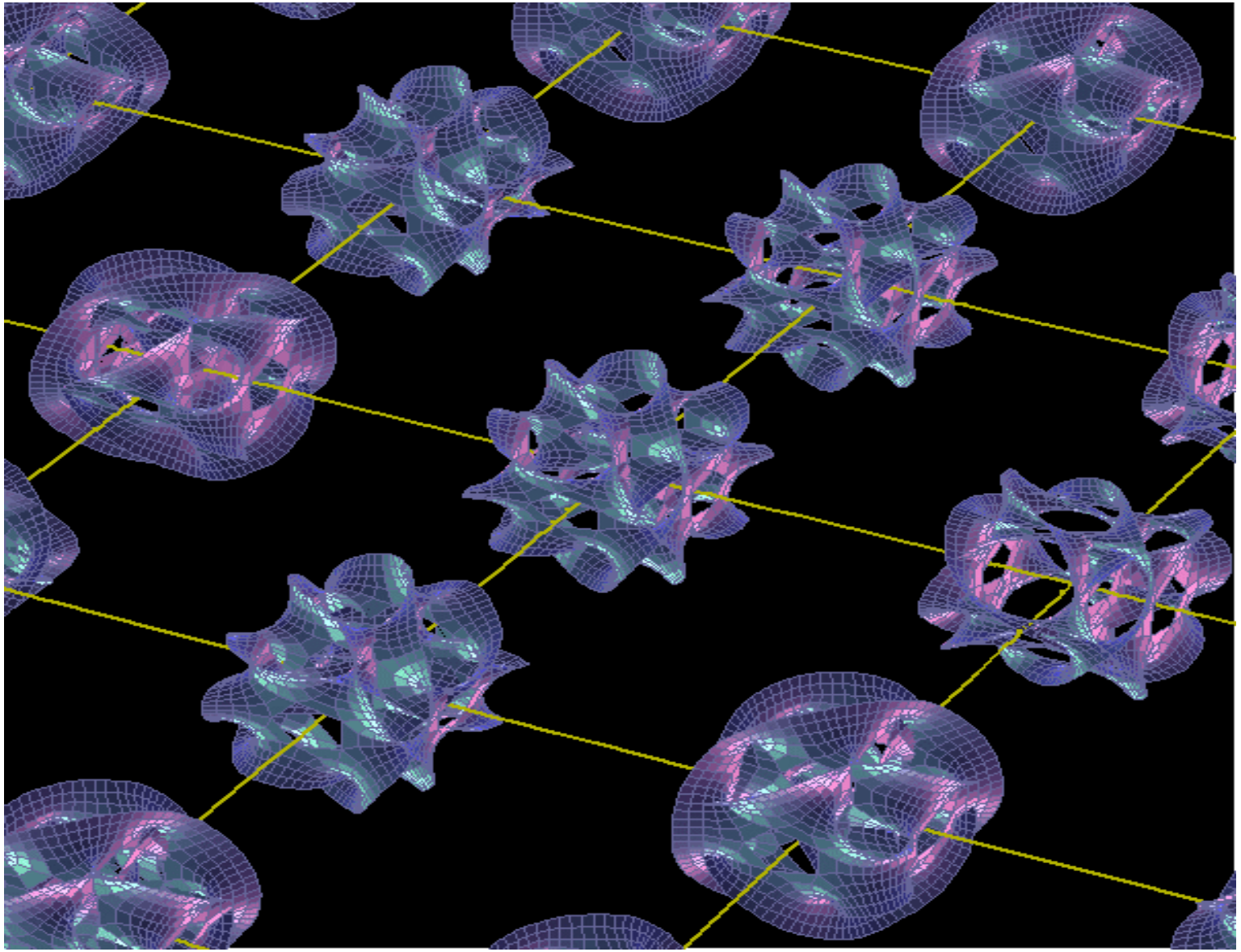

10
5
0
−5
−10
−10
−5
0
5
10


$L(L+1)C_L^{dd}/2\pi$
10^{-7}
10^{-8}
Planck
10
100
1000
L

Primordial Non-Gaussianity

$$\langle \Phi(\boldsymbol{k}_1)\Phi(\boldsymbol{k}_2)\Phi(\boldsymbol{k}_3)\rangle = (2\pi)^3\delta^D(\boldsymbol{k}_1+\boldsymbol{k}_2+\boldsymbol{k}_3)F(k_1,k_2,k_3).$$





Timeline for Planck

October 2010: End of nominal mission

January 2011: ERCSC release

few hundred point sources (blazars/ quasars/IR gals/cold cores)

~ 100 SZ clusters of galaxies

January 2011: Planck early science papers

February 2012: End of extended mission

January 2013: Data/legacy catalogue/papers from nominal mission

January 2014: Data/legacy catalogue/papers from extended mission


observing at microwave wavelengths to
sure tiny fluctuations of the first light in the Universe
with unprecedented accuracy. These new data will help
astronomers to peer into the early universe – more than
13 billion years ago - giving us the sharpest picture ever
of the early Universe.
Launch: 2009
Scale: 1:10
esa
to the Universe
Herschel, New Light on Star and Galaxy Formation
Herschel, the largest infrared space observatory ever
penetrating hidden clouds of cold gas and dust to
of the origins and evolution of stars and galaxies in the
year all-sky survey, Milky Way
measurements of the
erstanding of how our
A C E
Stimulating Innovation and Growth
Outer frame
Fly wheel
SIP cage