Black body radiation

Definition

A system that completely absorbs all incident electromagnetic energy. This absorption manifests itself as thermal agitation, which in turn gives rise to thermal radiation.

Rationale

The radiation emitted by a star can be approximated by that of a black body.
A star interior is a very thick medium, a source of energy through thermonuclear fusion.
However, the radiation is effectively “trapped” within the stellar interior by numerous interaction processes.
On average, photons require millions of years to escape. Consequently, the stellar medium behaves analogously to the cavity used to model a black body.

Planck Law

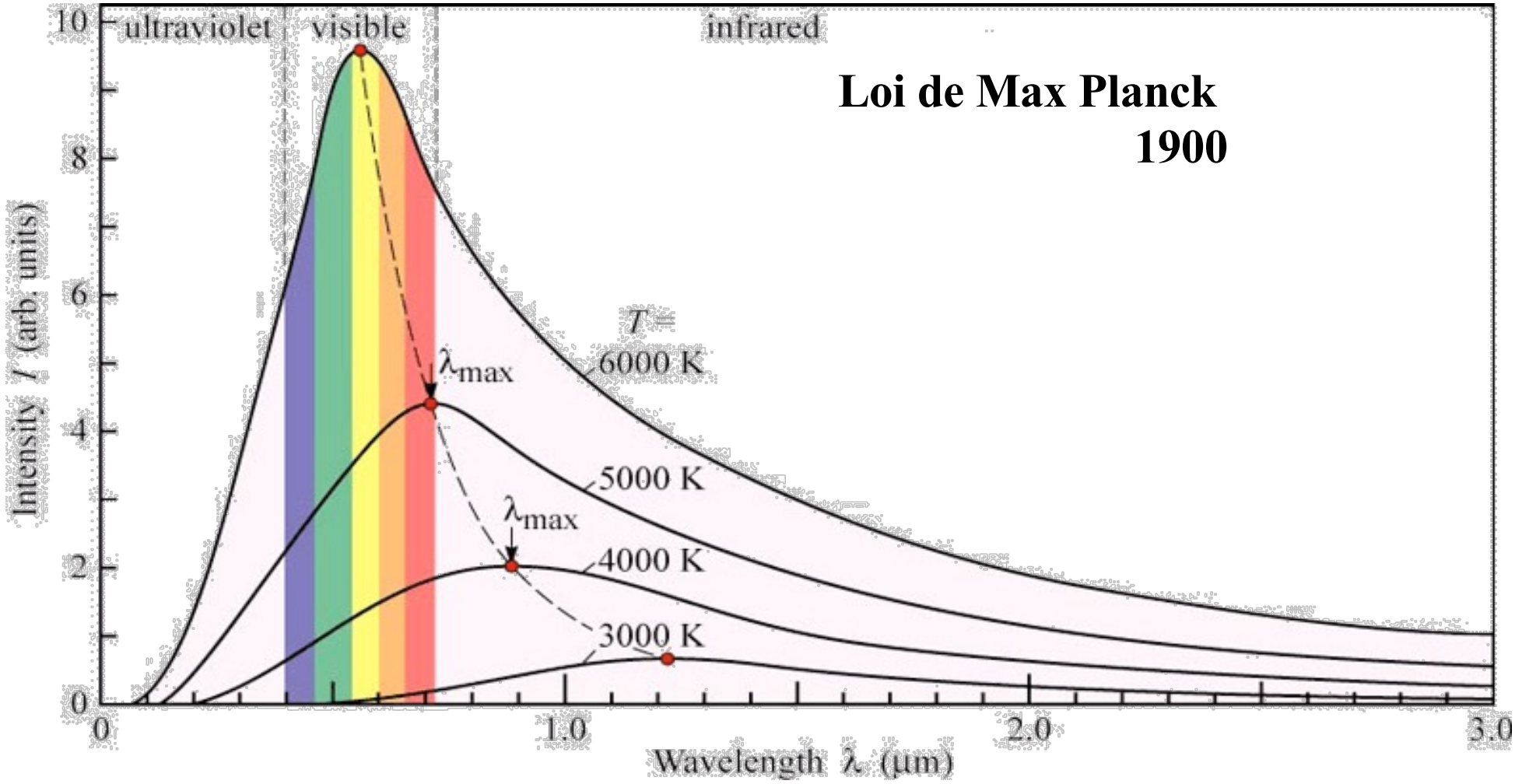
$$I_\nu = B_\nu(T) = \frac{2h\nu^3}{c^2} \frac{1}{e^{\frac{h\nu}{kT}} - 1}.$$

$$I_\nu d\nu = I_\lambda d\lambda \qquad I_\lambda / I_\nu = |d\nu / d\lambda|$$

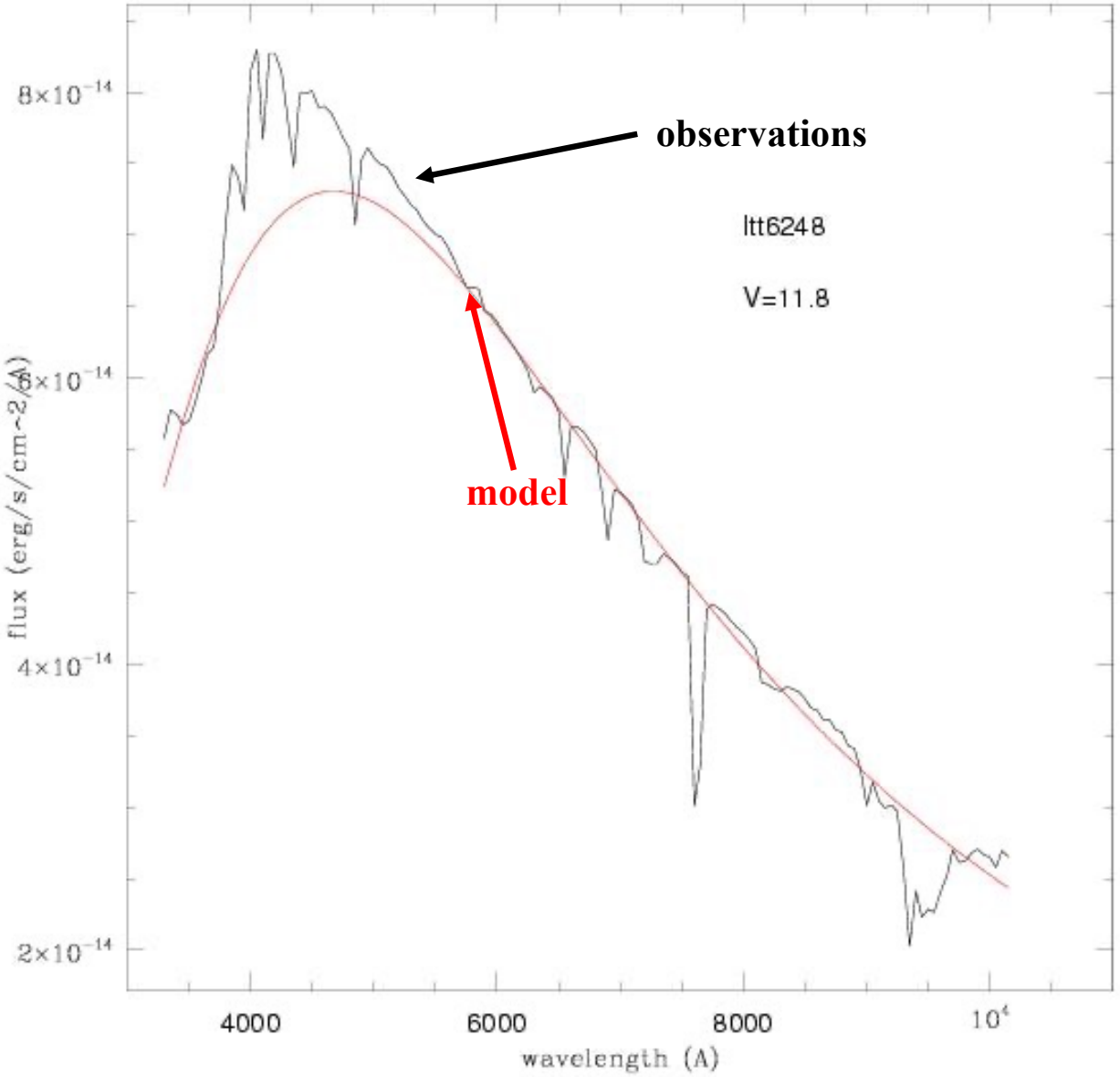
$$I_\lambda = \frac{2hc^2}{\lambda^5} \frac{1}{e^{hc/kT\lambda} - 1}$$

Boltzmann constant k = 1.3805 10^{-23} J/K
Planck constant h = 6.62 10^{-34} Js

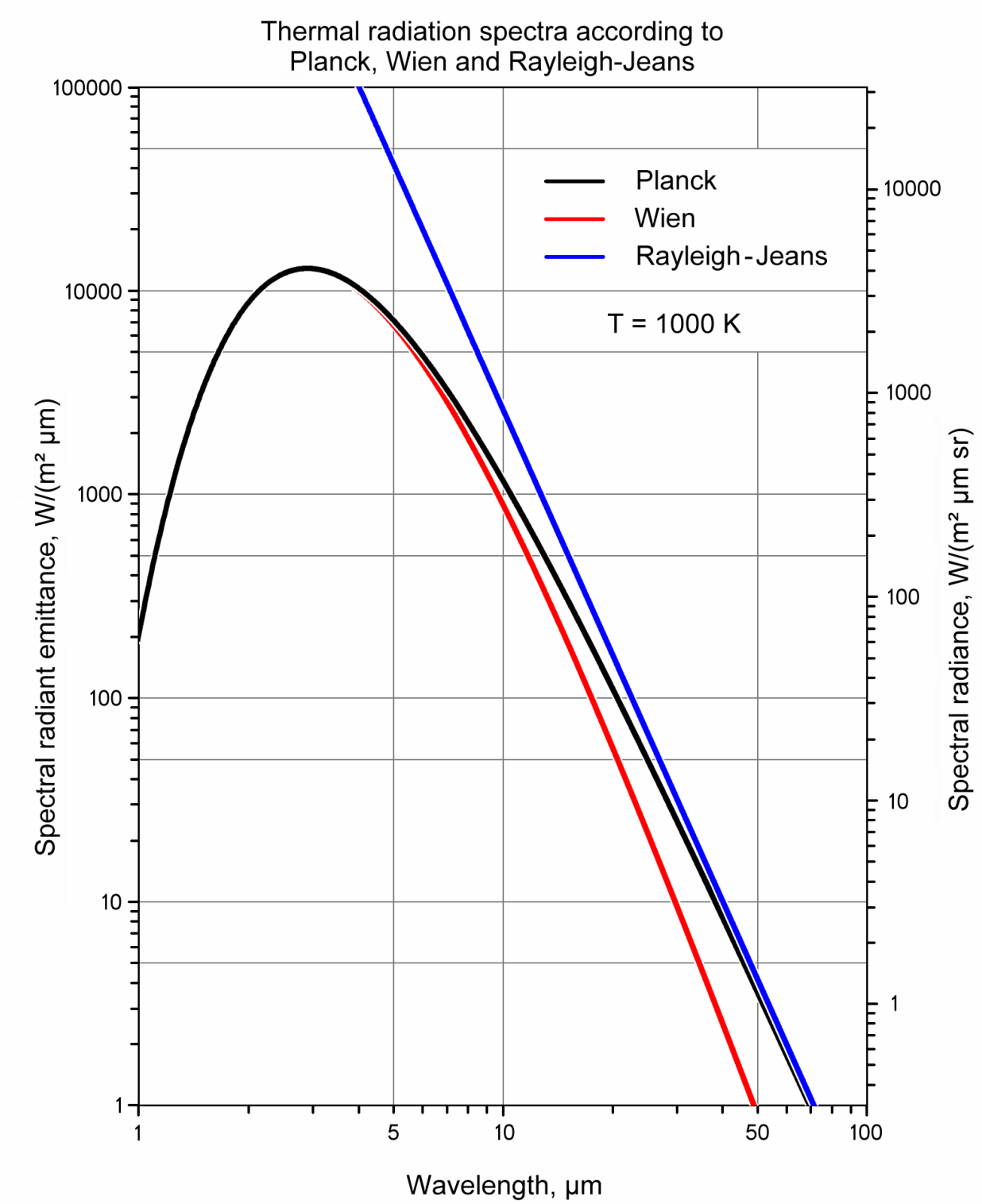
Emission from black bodies at different temperatures

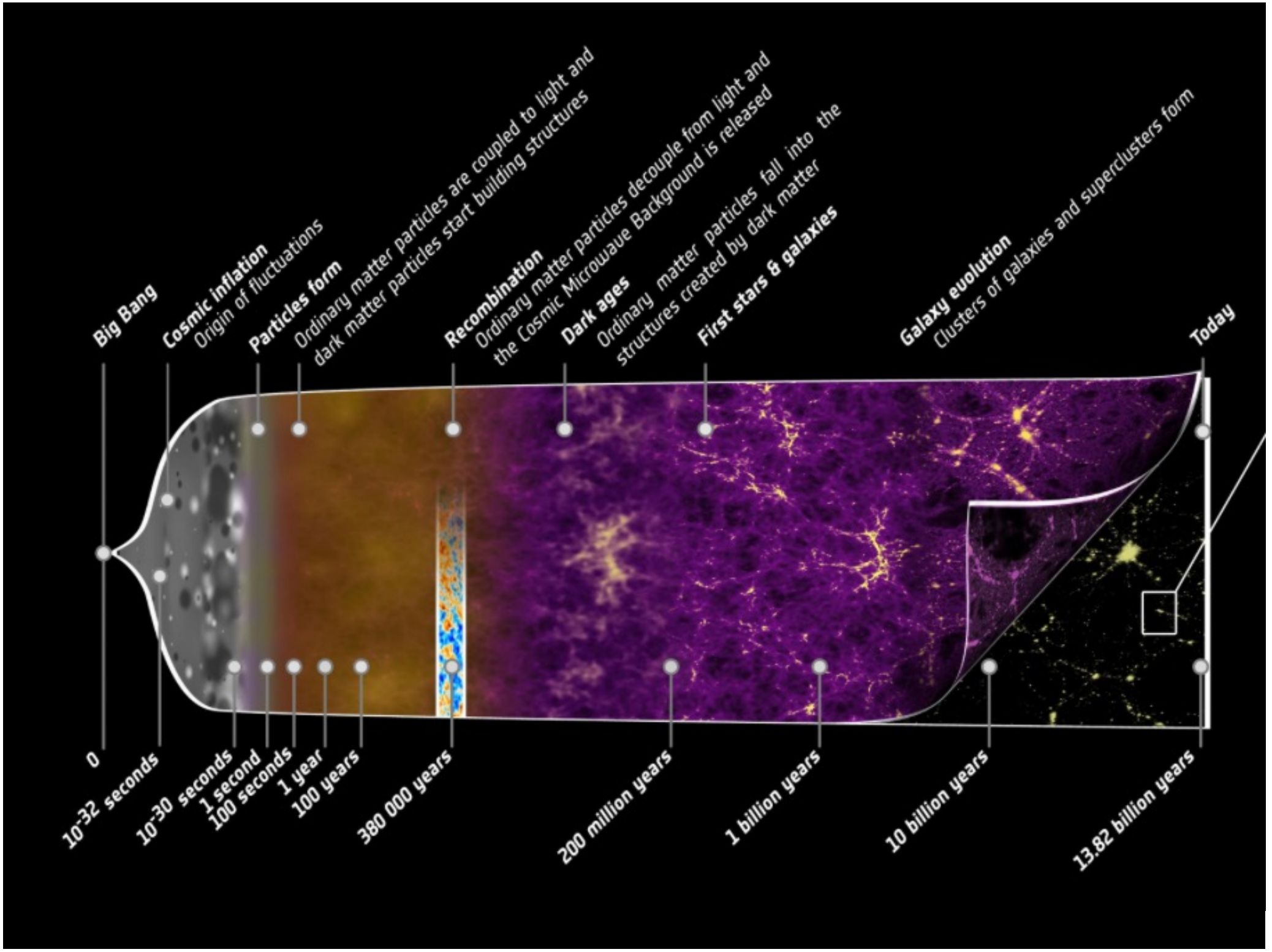


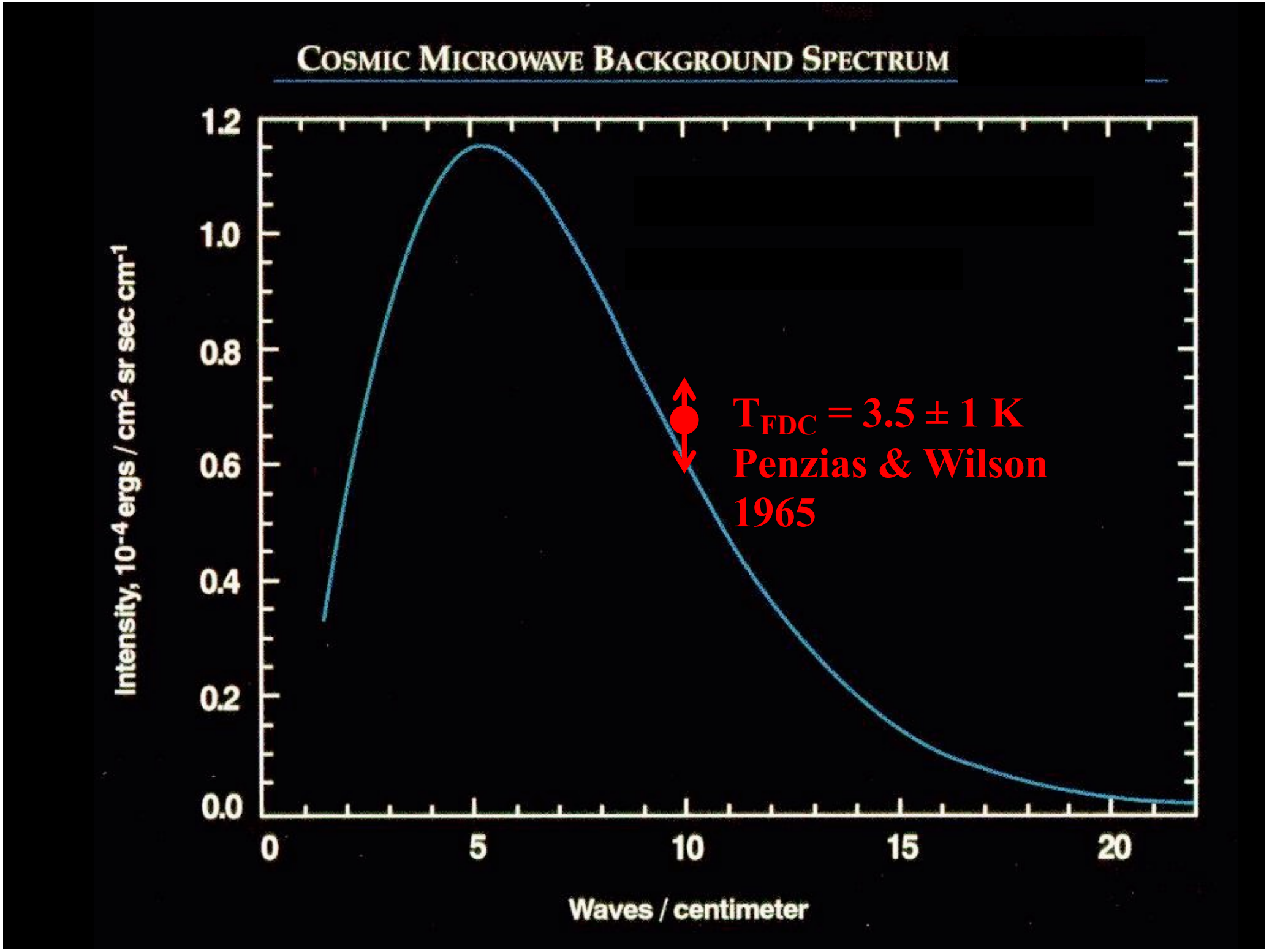
Black body analogous for stars

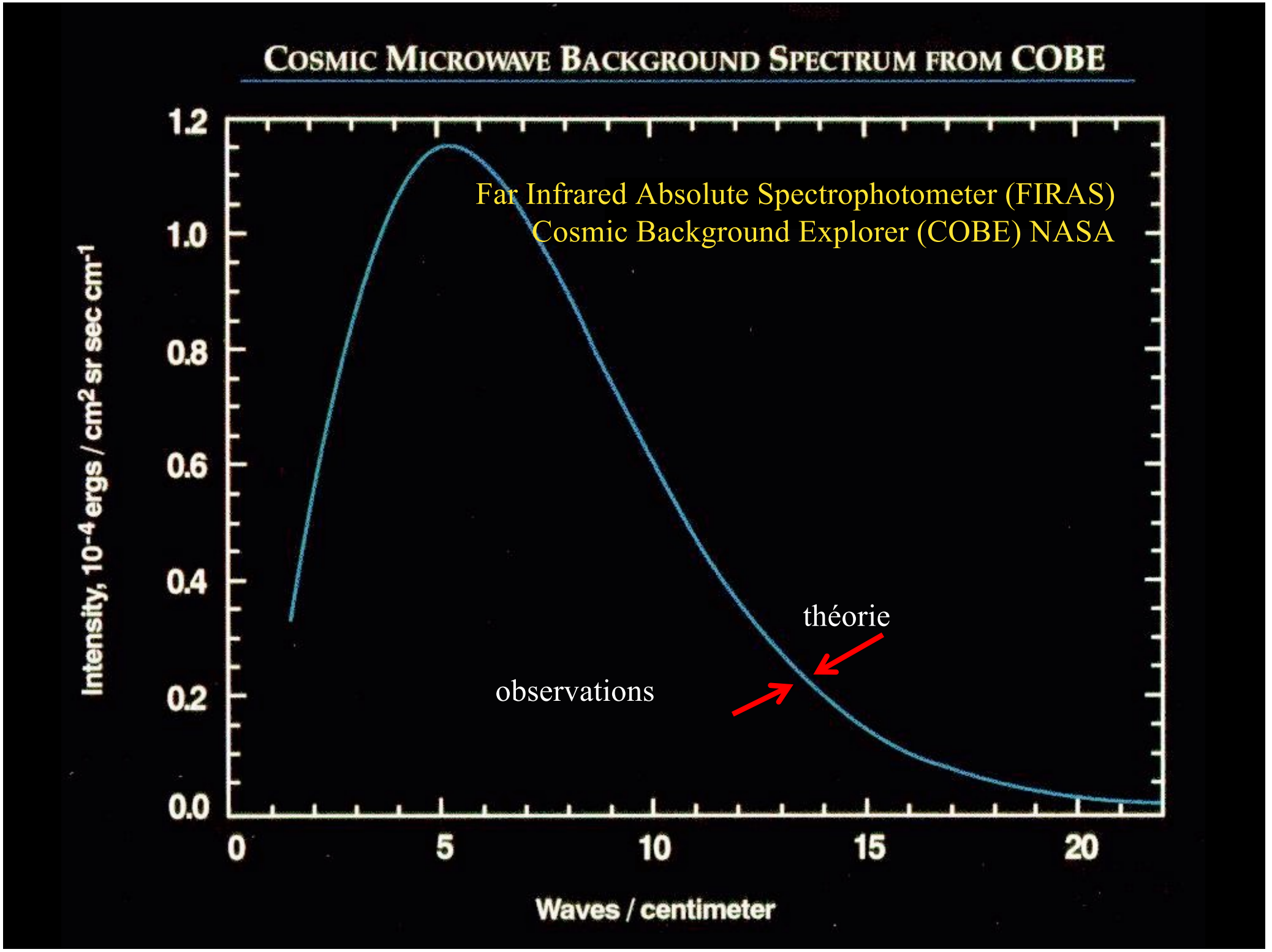


Fit at T = 5350 K


Thermal radiation spectra according to
Planck, Wien and Rayleigh-Jeans
Planck
Wien
Rayleigh-Jeans
T = 1000 K
Spectral radiant emittance, W/(m² µm)
Spectral radiance, W/(m² µm sr)
Wavelength, µm
100000
10000
1000
100
10
1
1
5
10
50
100


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


COSMIC MICROWAVE BACKGROUND SPECTRUM
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Intensity, 10-4 ergs / cm2 sr sec cm-1
0
5
10
15
20
Waves / centimeter
TFDC = 3.5 ± 1 K
Penzias & Wilson
1965


COSMIC MICROWAVE BACKGROUND SPECTRUM FROM COBE
Far Infrared Absolute Spectrophotometer (FIRAS)
Cosmic Background Explorer (COBE) NASA
théorie
observations
Intensity, 10-4 ergs / cm2 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