STELLAR SPECTRA

ASTROPHYSICS

Dr H.T.Sener

VOCABULARY

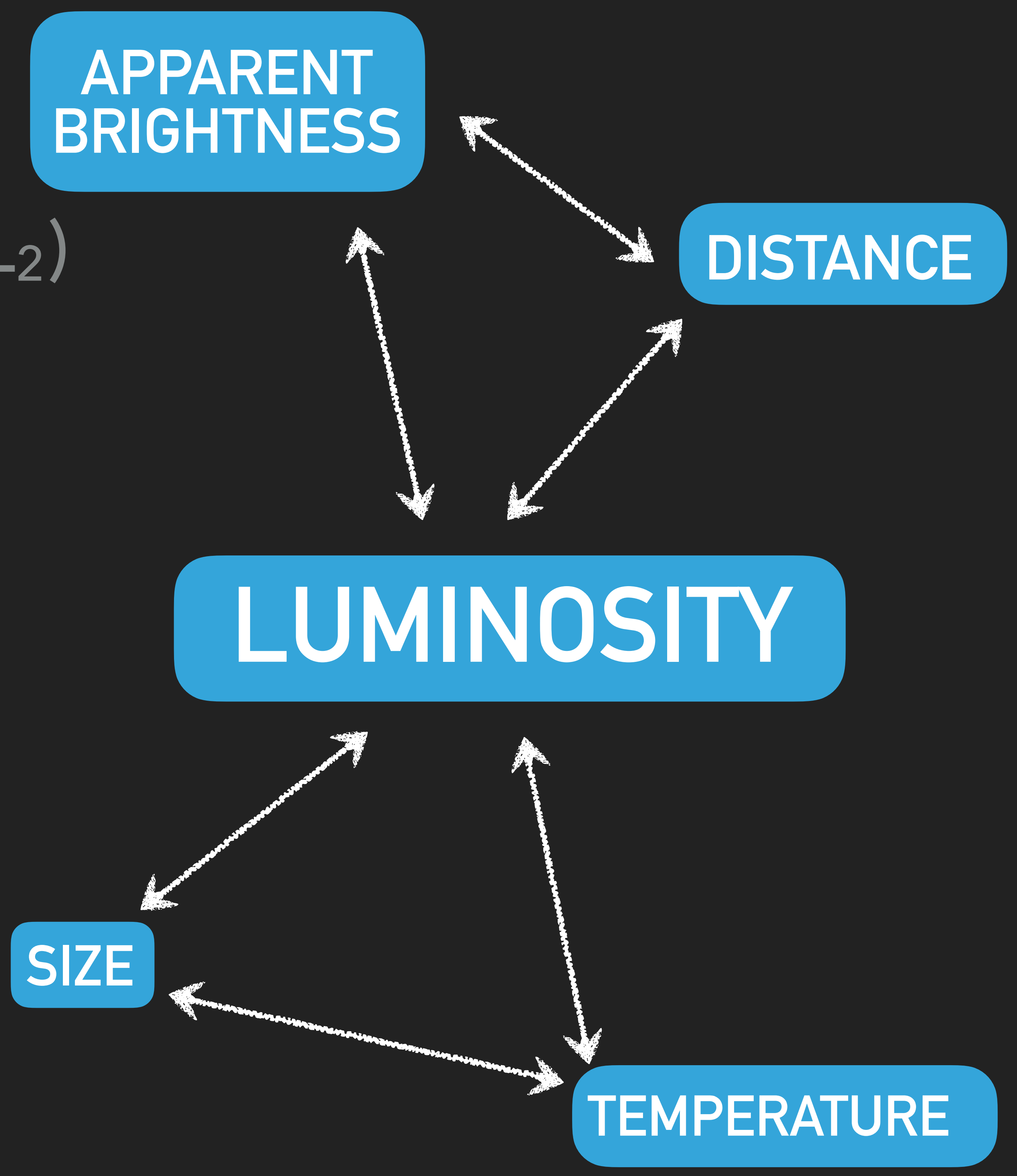
Astronomy Term	Definition
Absolute Magnitude "M"	
Apparent Magnitude brightness "m"	
Apparent Magnitude scale	
Intensity	
Luminosity	
Parallax Angle	
Parsec	
Relative Brightness scale	

VOCABULARY

Astronomy Term	Definition
Absolute Magnitude "M"	The apparent magnitude a star would have at 10 parsecs (32.6 light years)
Apparent Magnitude brightness "m"	Each division is 2.51 times brighter than the next magnitude, sun has m= -26
Apparent Magnitude scale	A modern version of Hipparchus scale
Intensity	Power per unit area at the observer: $I=P/4\pi r^2$
Luminosity	Total power radiated by a star (joules/sec=watts), depends on the temperature and distance between the star and the observer. $L= d^2T^4$
Parallax Angle	The shift, relative to the background, caused by a shift in the observer's position.
Parsec	The distance at which one AU subtends an angle of one arc second (1/3600th of a degree), 1 pc = 3.26 light years
Relative Brightness scale	A scale created by in 120 BC where 1 is the brightest star and 6 is the dimmest star

SUMMARY

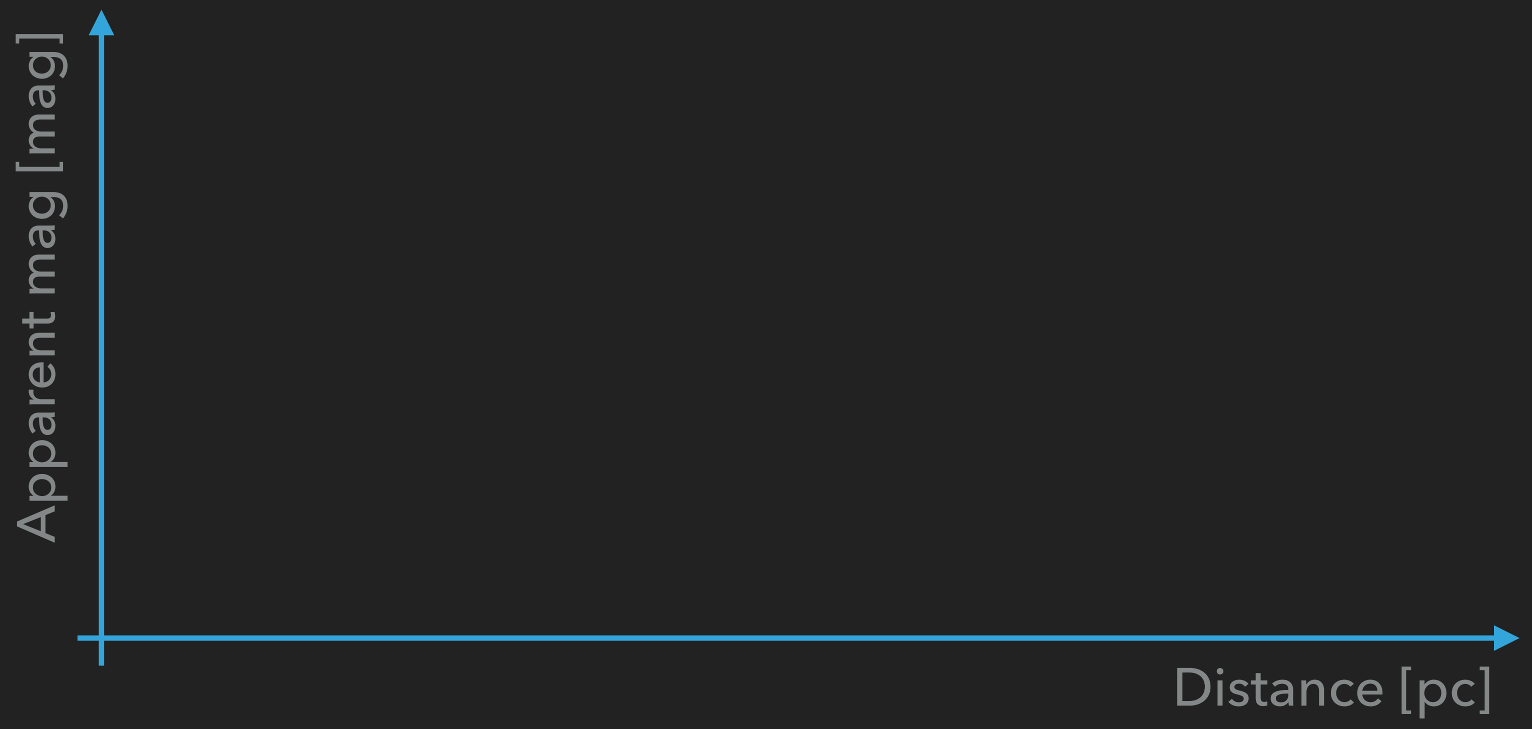
- Apparent brightness
  - $m_2 - m_1 = 2.5 \log (L_1/L_2)$
- Absolute magnitude
  - $m - M = 5 \log (d/10)$
- Luminosity
  - $L = \sigma T^4 \times 4 \pi r^2$
- Flux
  - $F = L / 4 \pi d^2$



HOMEWORK

- Given an absolute magnitude of 3.0, find the apparent magnitude at a distance of 5pc, 10pc, 15pc, 20pc, 50pc and 100pc.

- Plot these data on distance vs apparent magnitude.



- How far away must the star be to have an apparent magnitude of 5.0?

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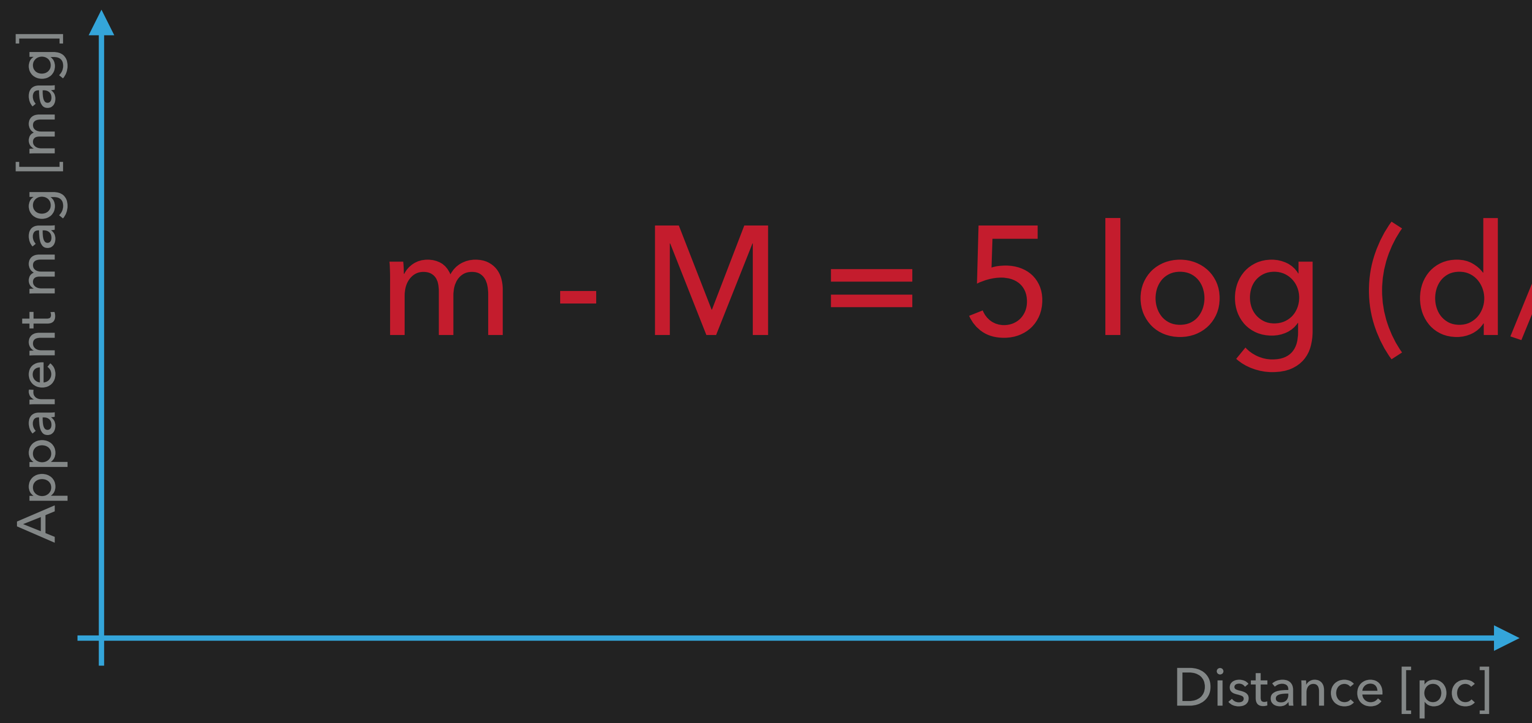

$$m - M = 5 \log (d/10)$$

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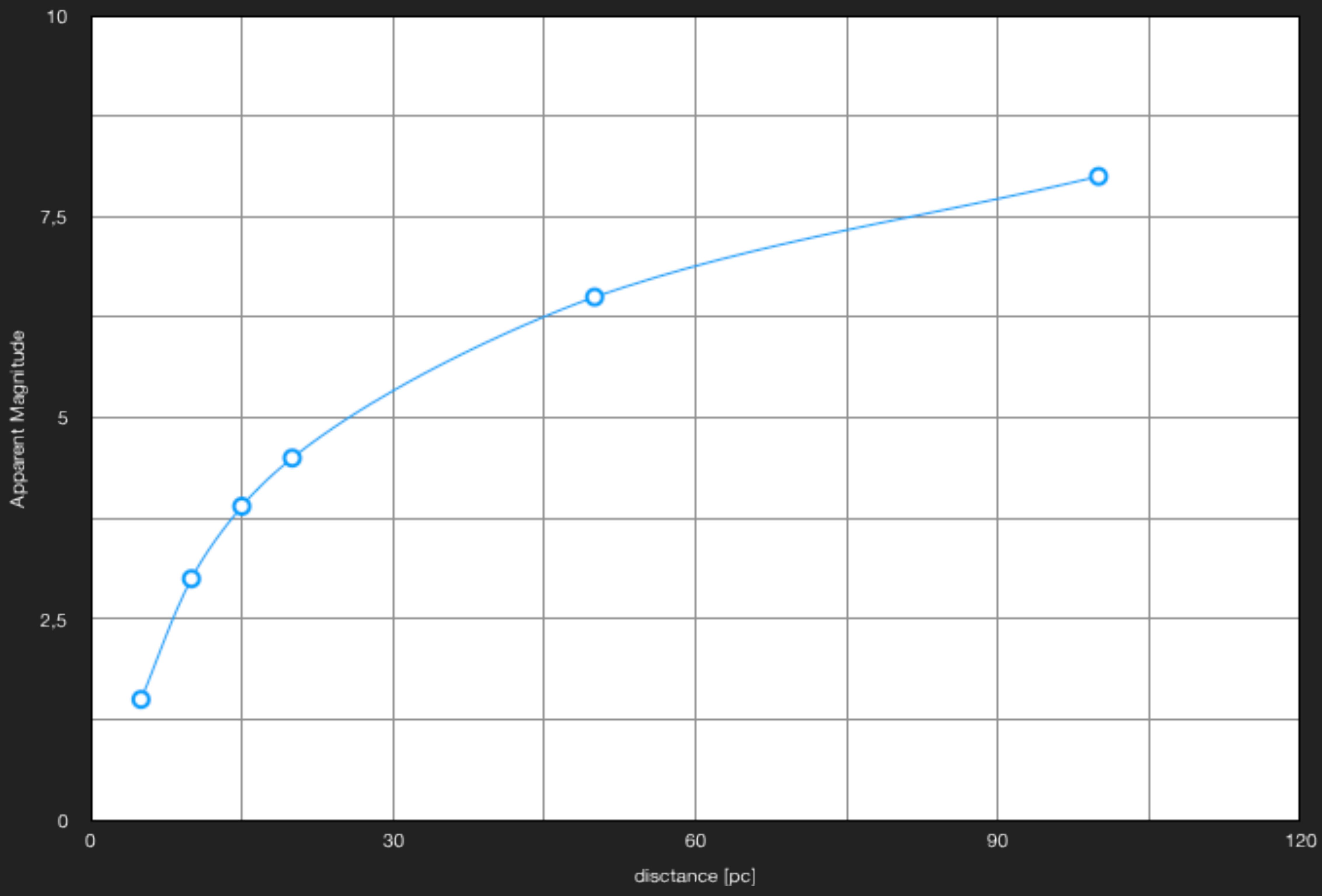
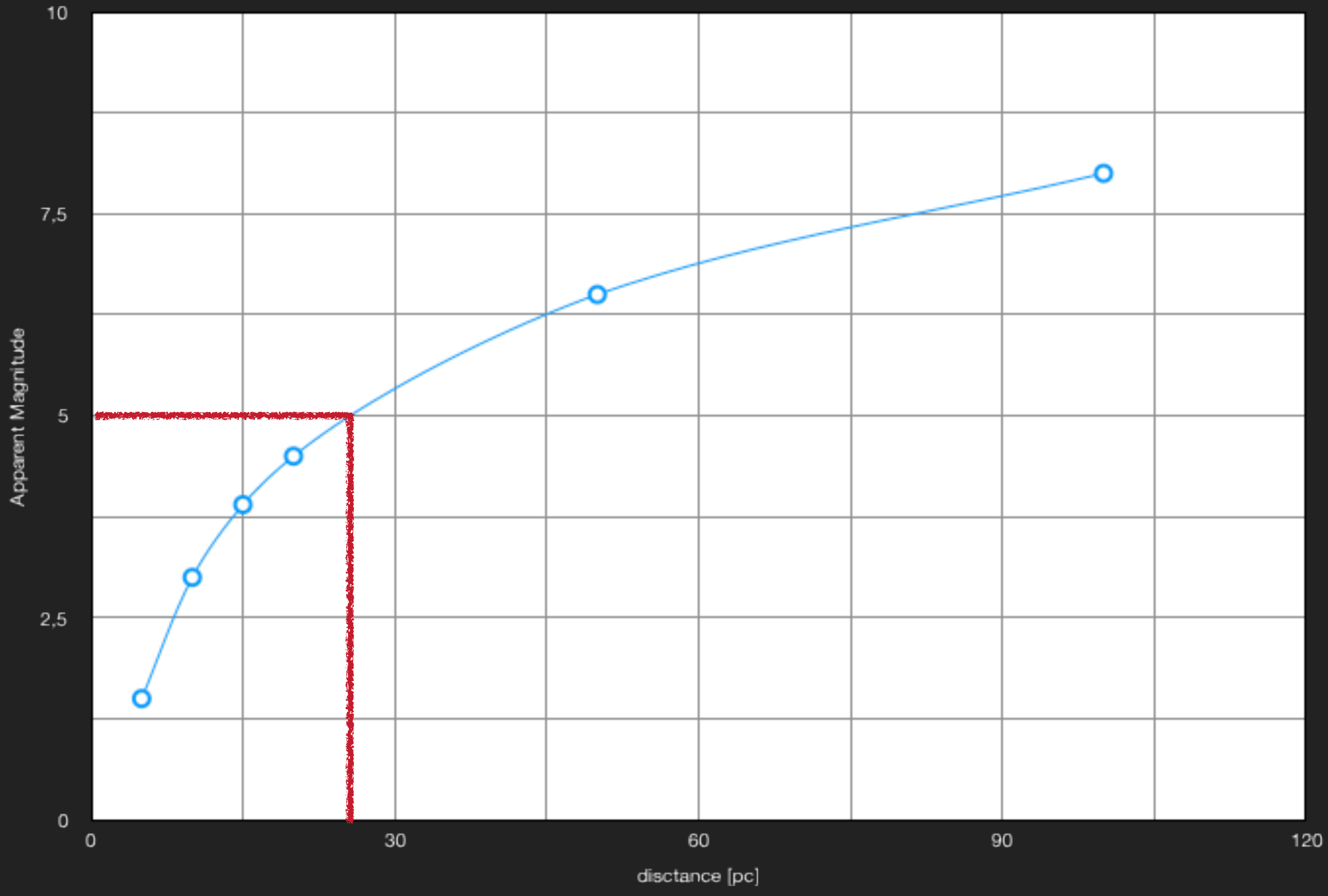
$$m - M = 5 \log (d/10)$$



HOMEWORK

$$5 - 3 = 5 \log (d/10)$$



HOMEWORK

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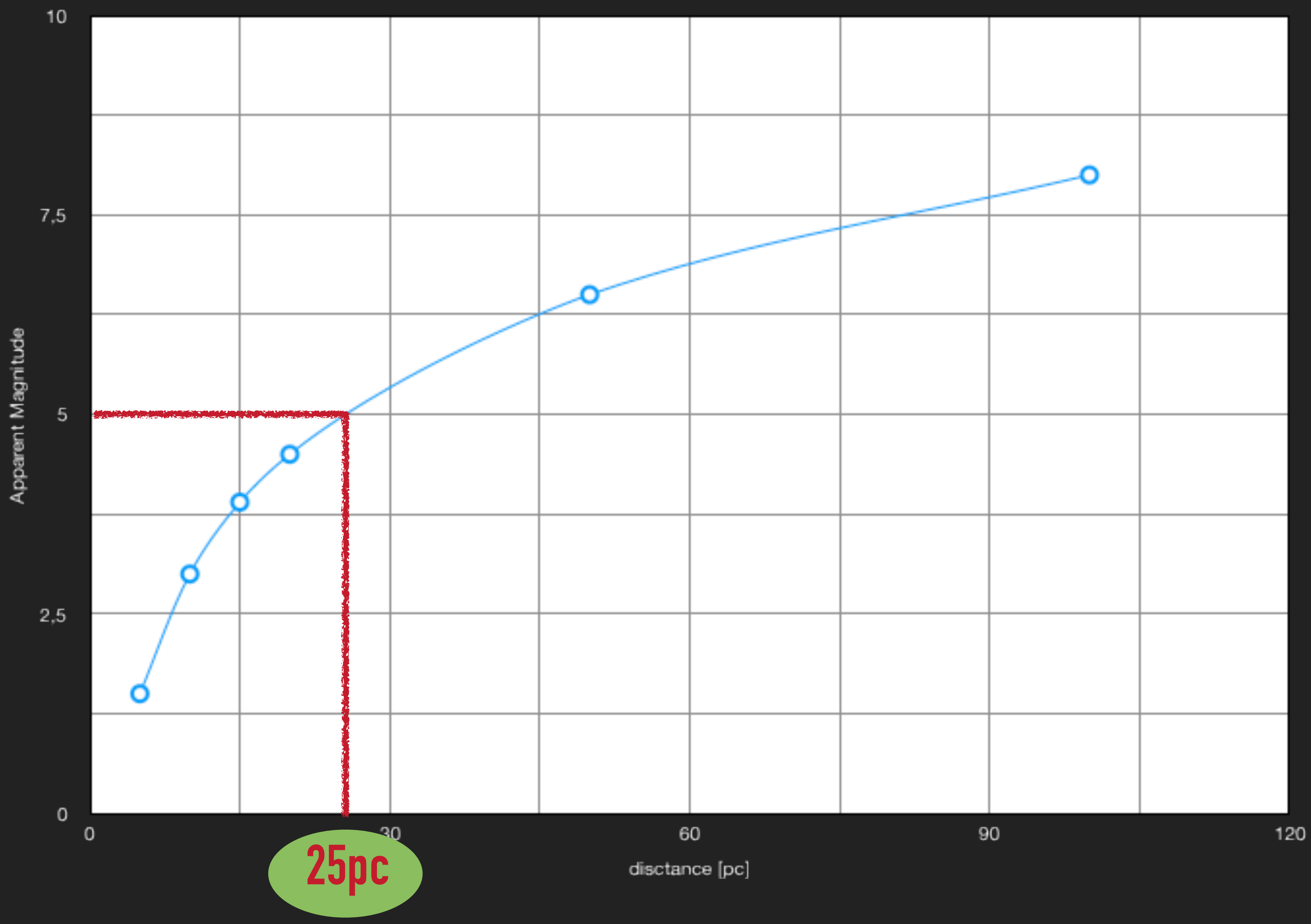
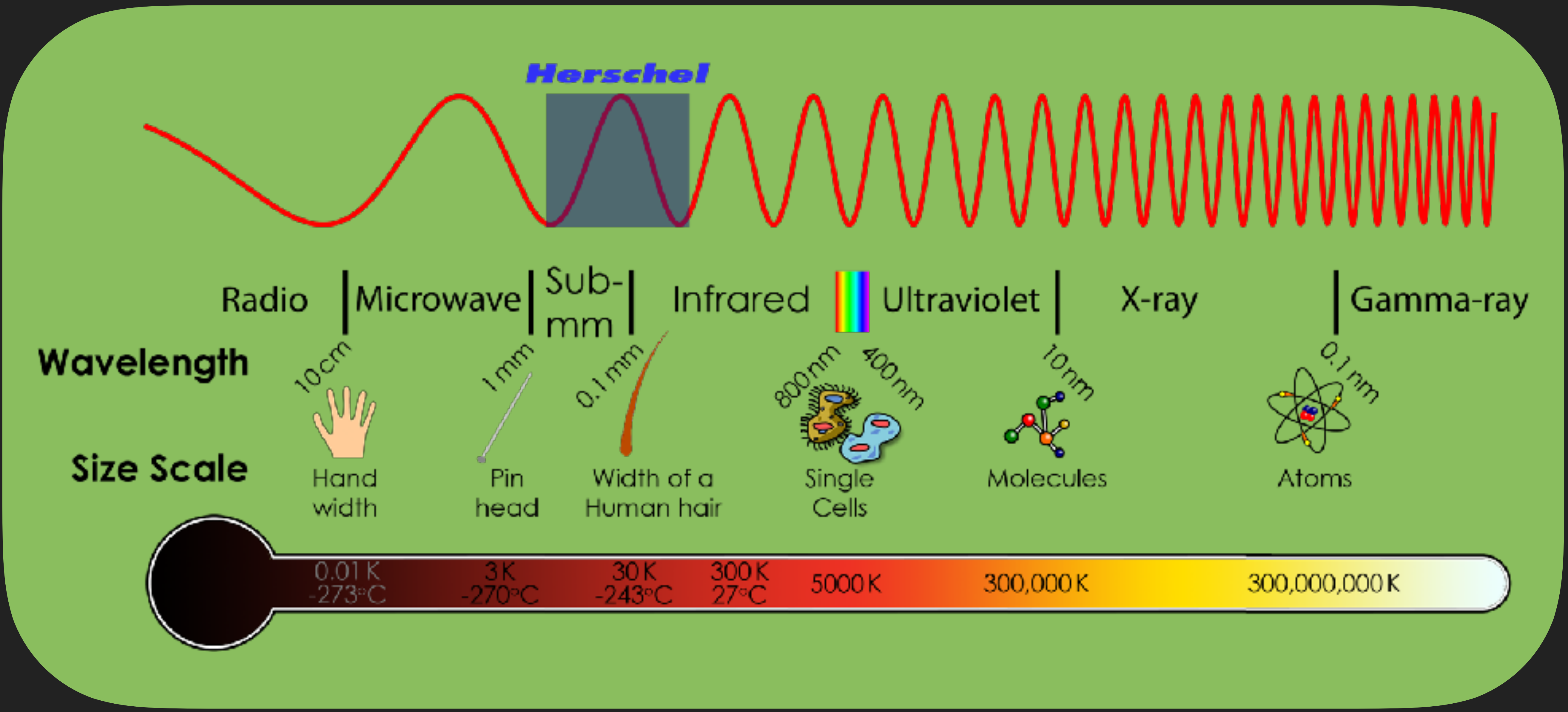


ELECTROMAGNETIC SPECTRUM



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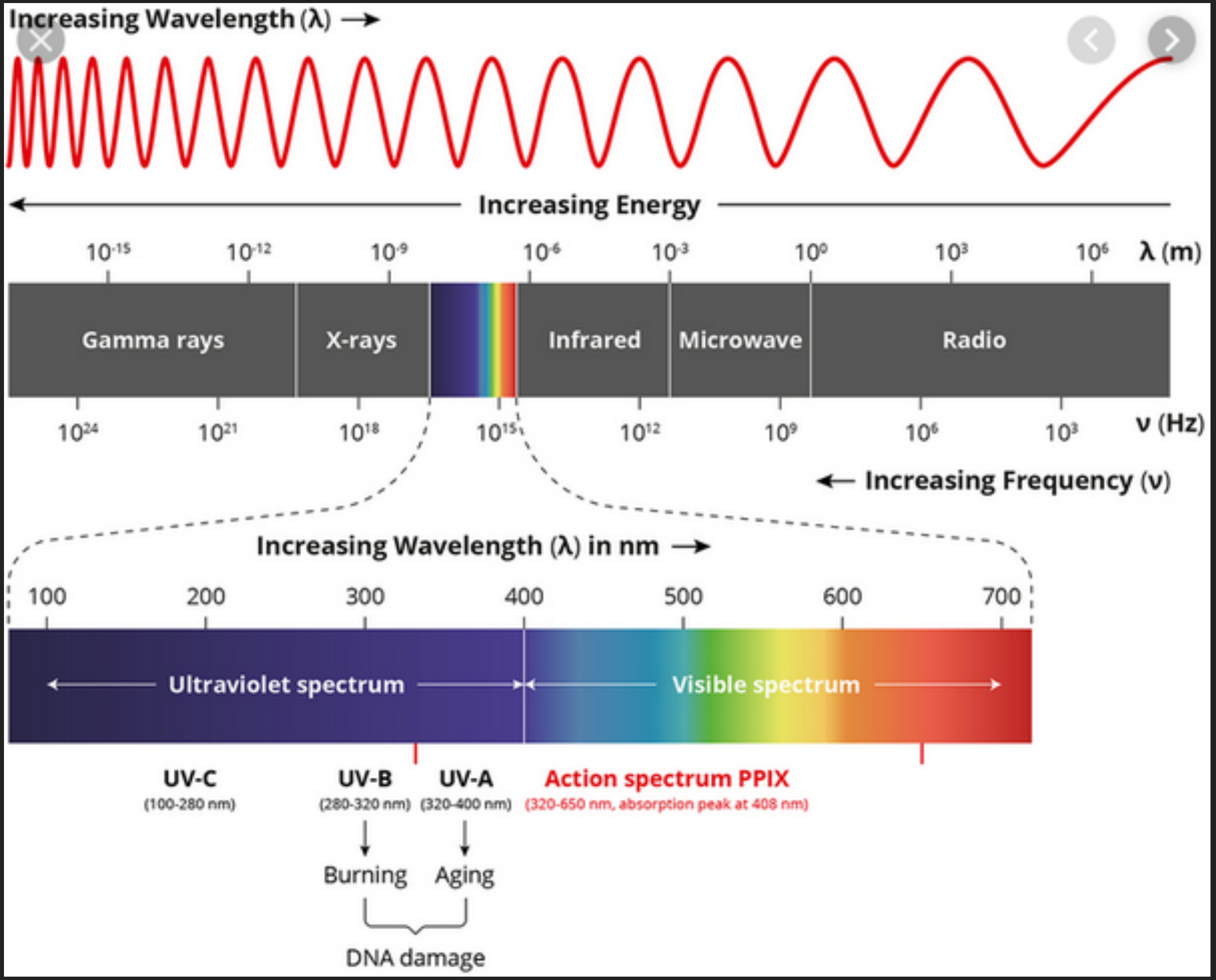

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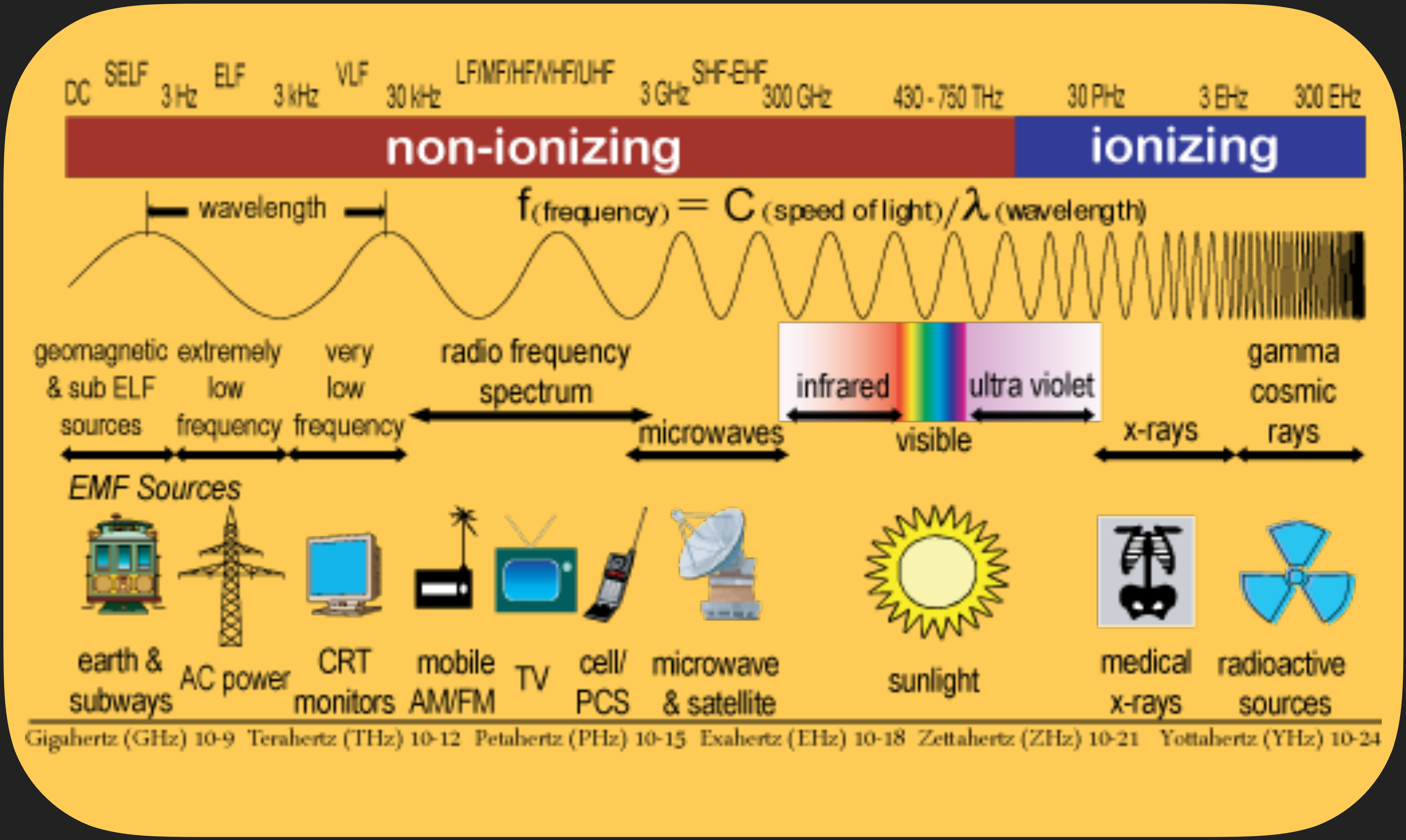
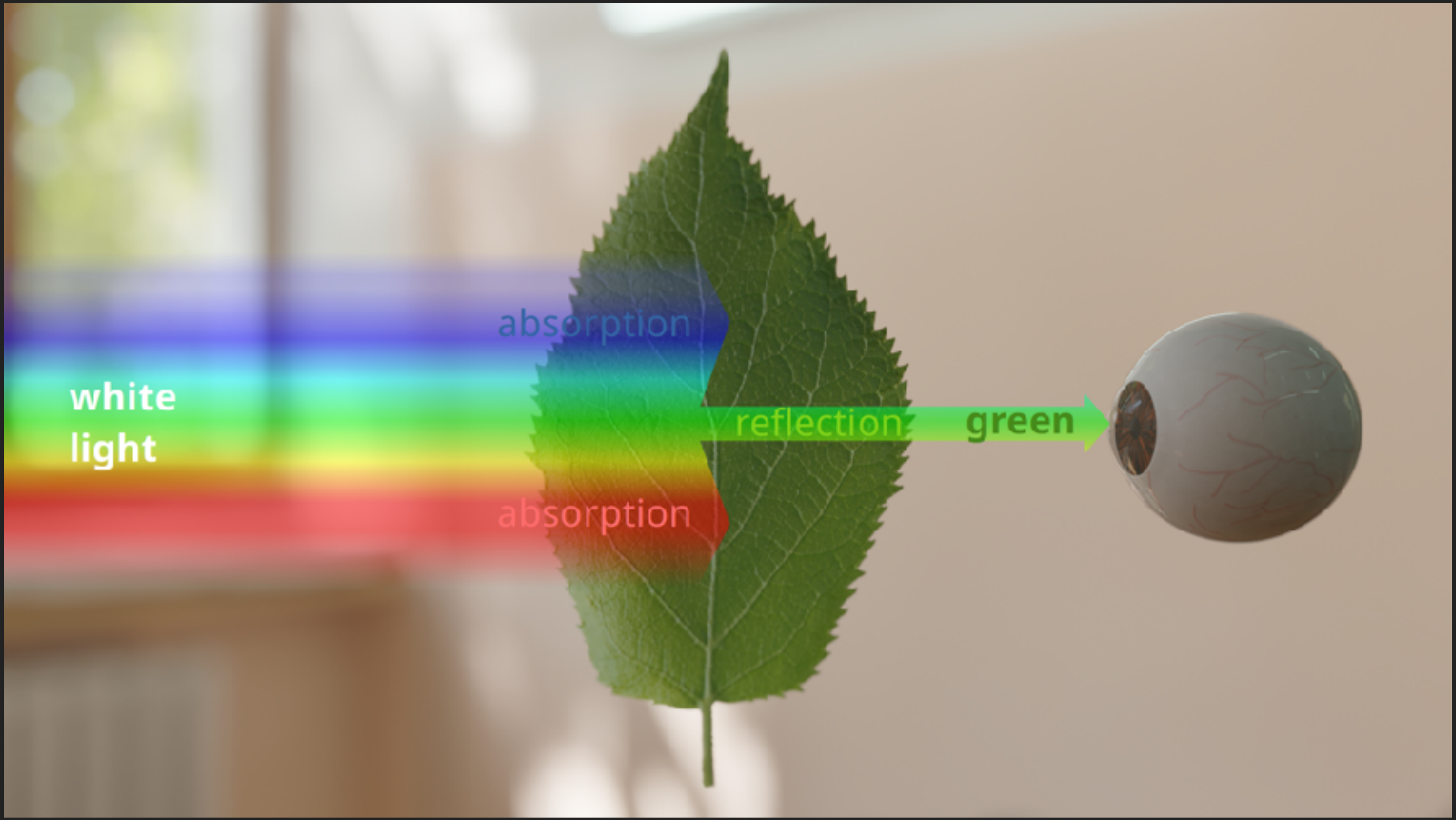


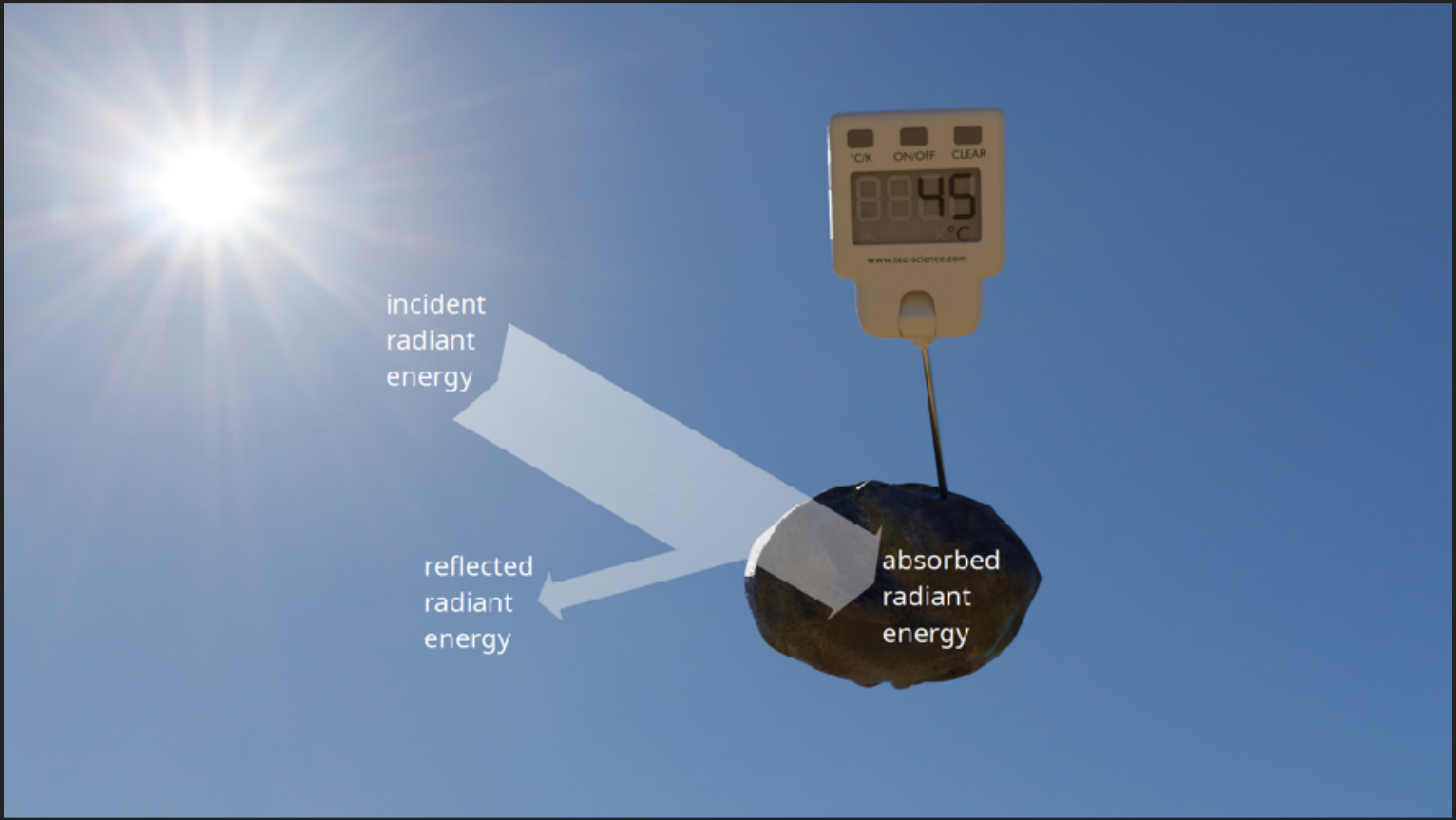
BLACKBODY RADIATION



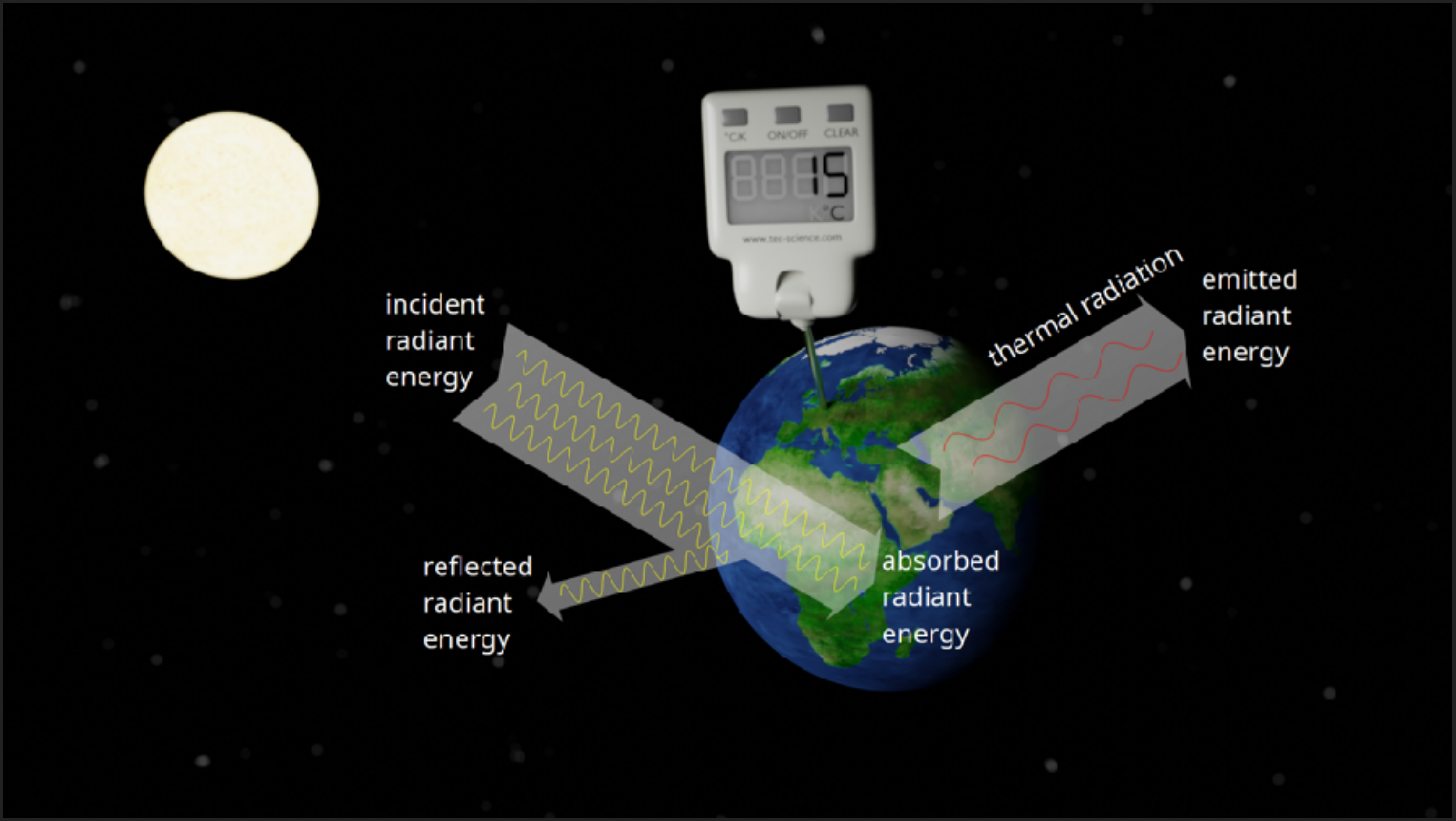
BLACKBODY RADIATION

- A blackbody is an idealized object that absorbs all incident electromagnetic radiation!

THERMAL RADIATION



THERMAL RADIATION



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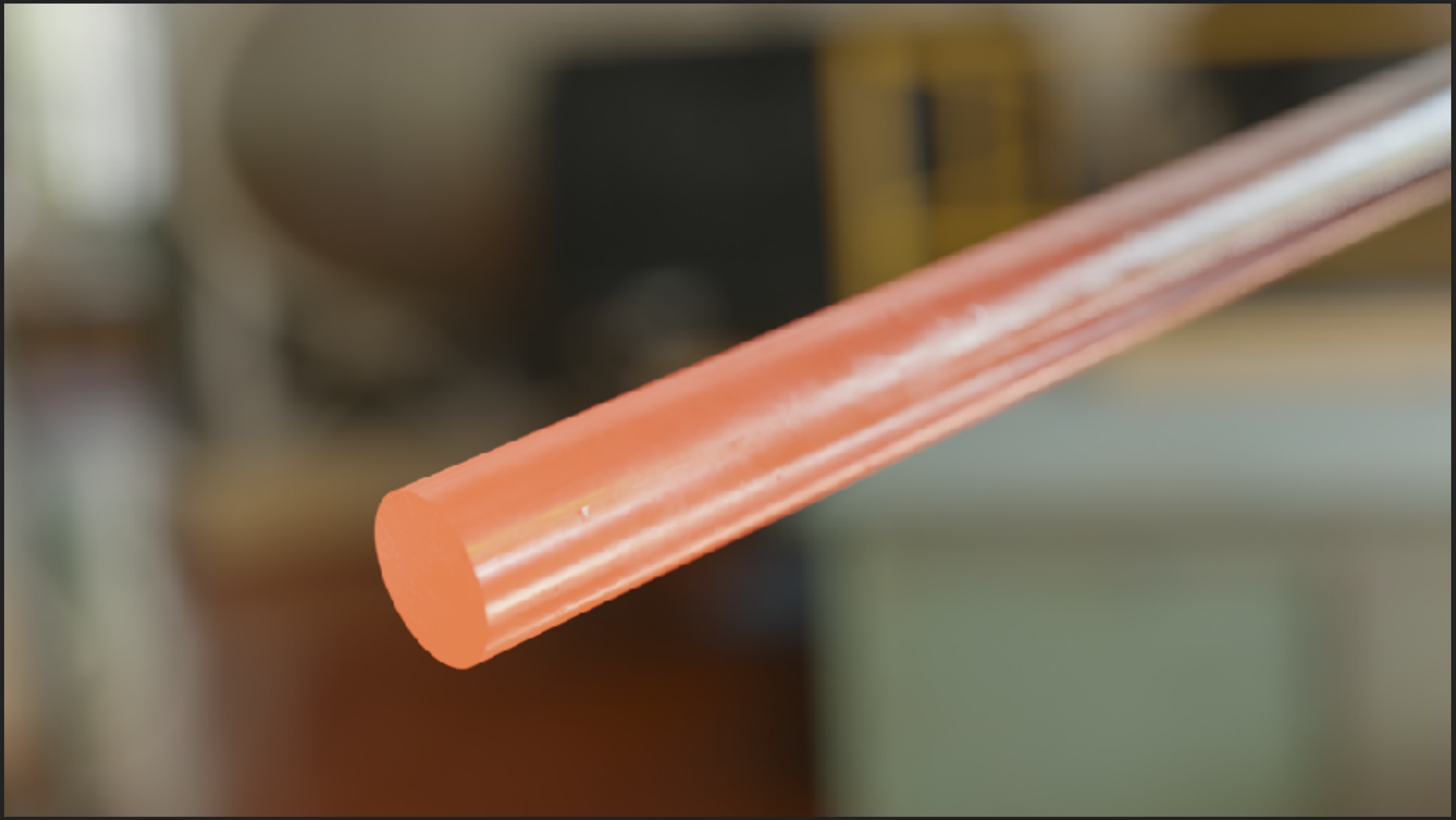
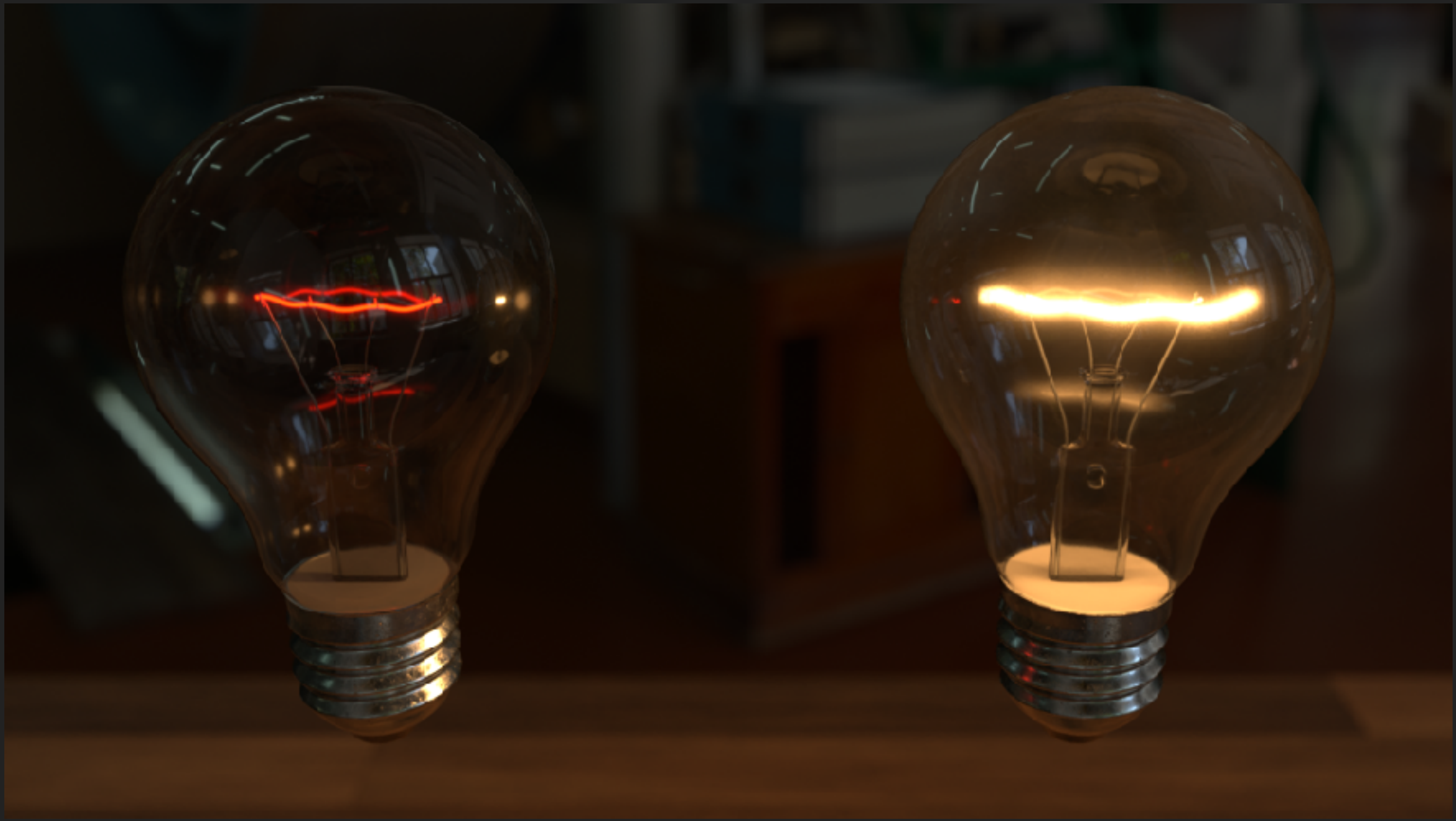


- Thermal radiation is the radiation emitted by a body in thermal equilibrium due to its temperature!

THERMAL RADIATION



- Thermal radiation comes from oscillations of the atoms!

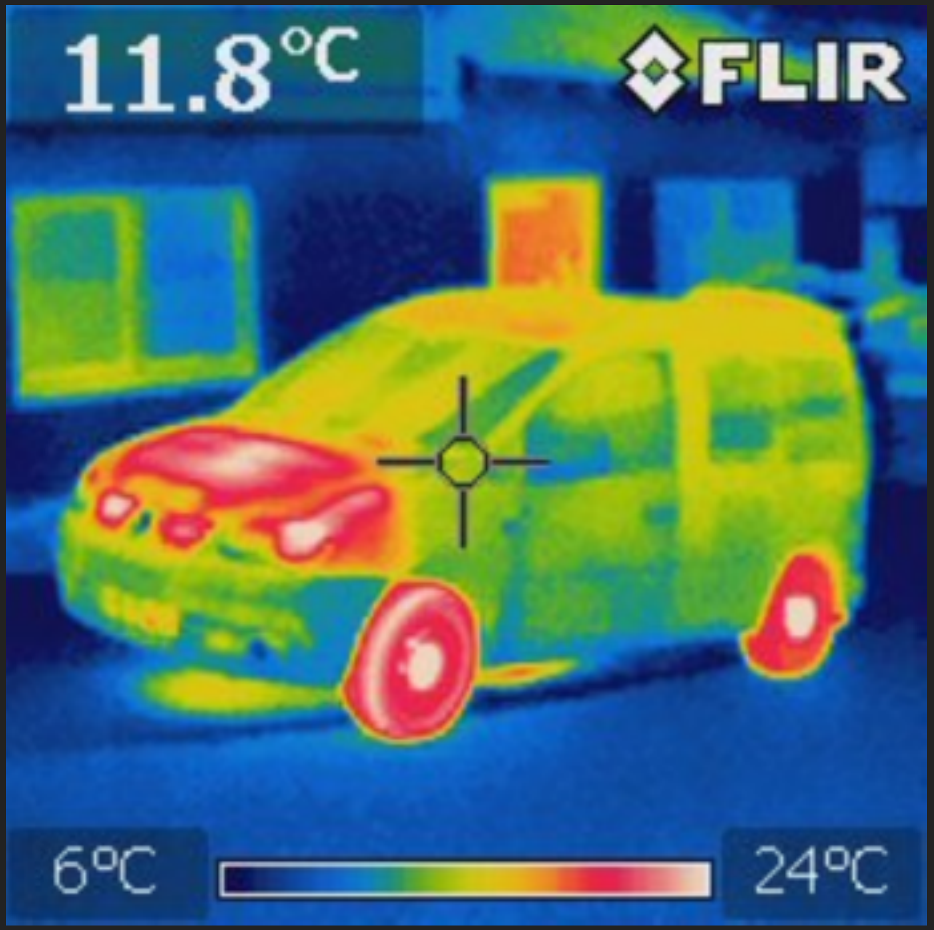
BLACKBODY RADIATION

- An ideal black body must emit thermal radiation. Even if by definition a blackbody absorbs all incident radiation, it still emits radiation. This is not reflected radiation, but radiation which the body emits “from inside” due to the oscillation of the atoms.
- All radiation is absorbed!
- Only if the temperature is increased very strongly and the body starts to glow, radiation in the visible wavelength range is emitted.
- Does not have to be black!

BLACKBODY RADIATION

- A blackbody is particularly suitable for the investigation of the spectral distribution of thermal radiation, since the radiation does not contain any reflecting parts of interference sources!

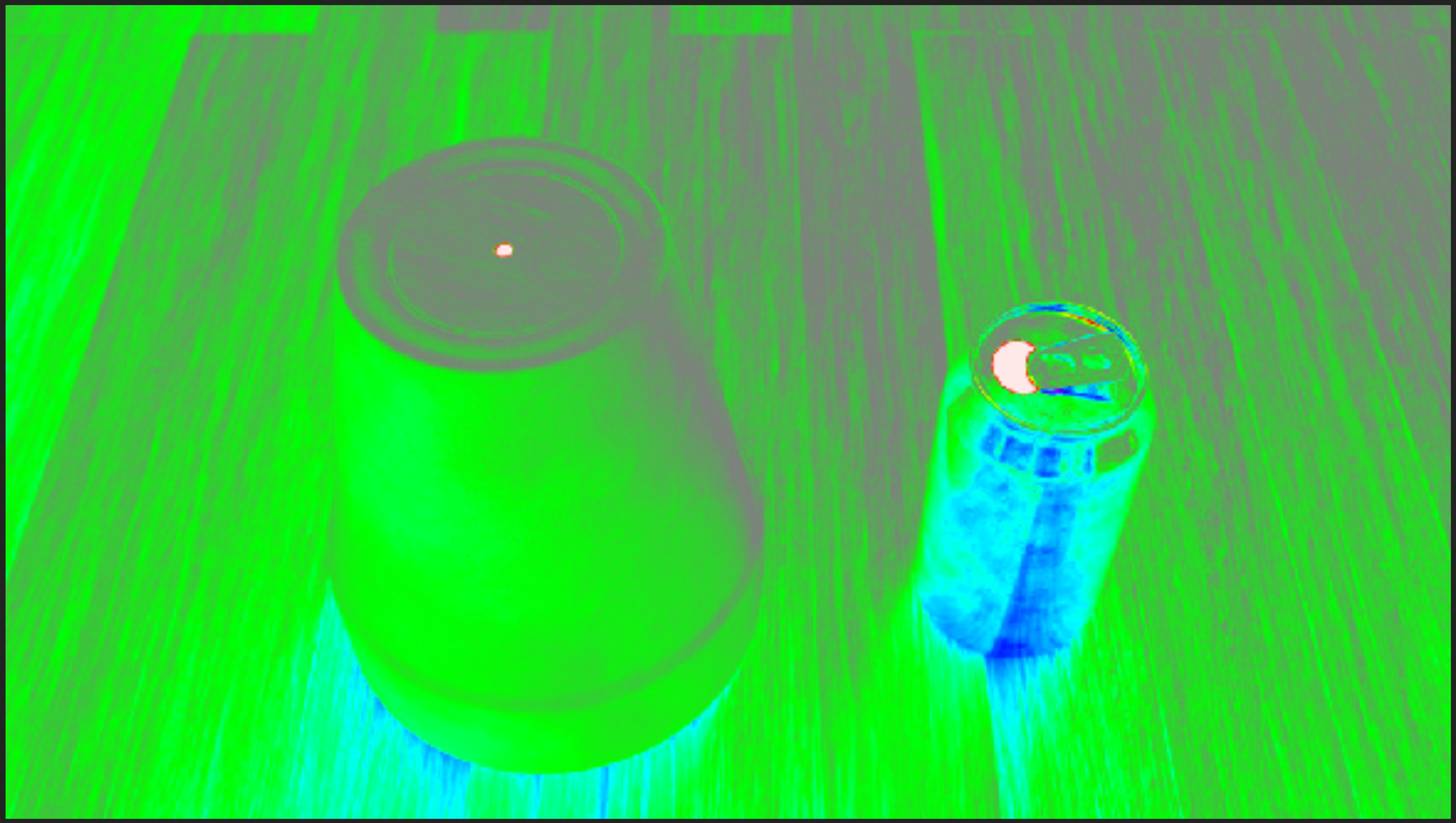
- The emitted thermal radiation of a black body is called blackbody radiation!



REALIZATION OF BLACKBODIES IN PRACTICE (CAVITY RADIATION)

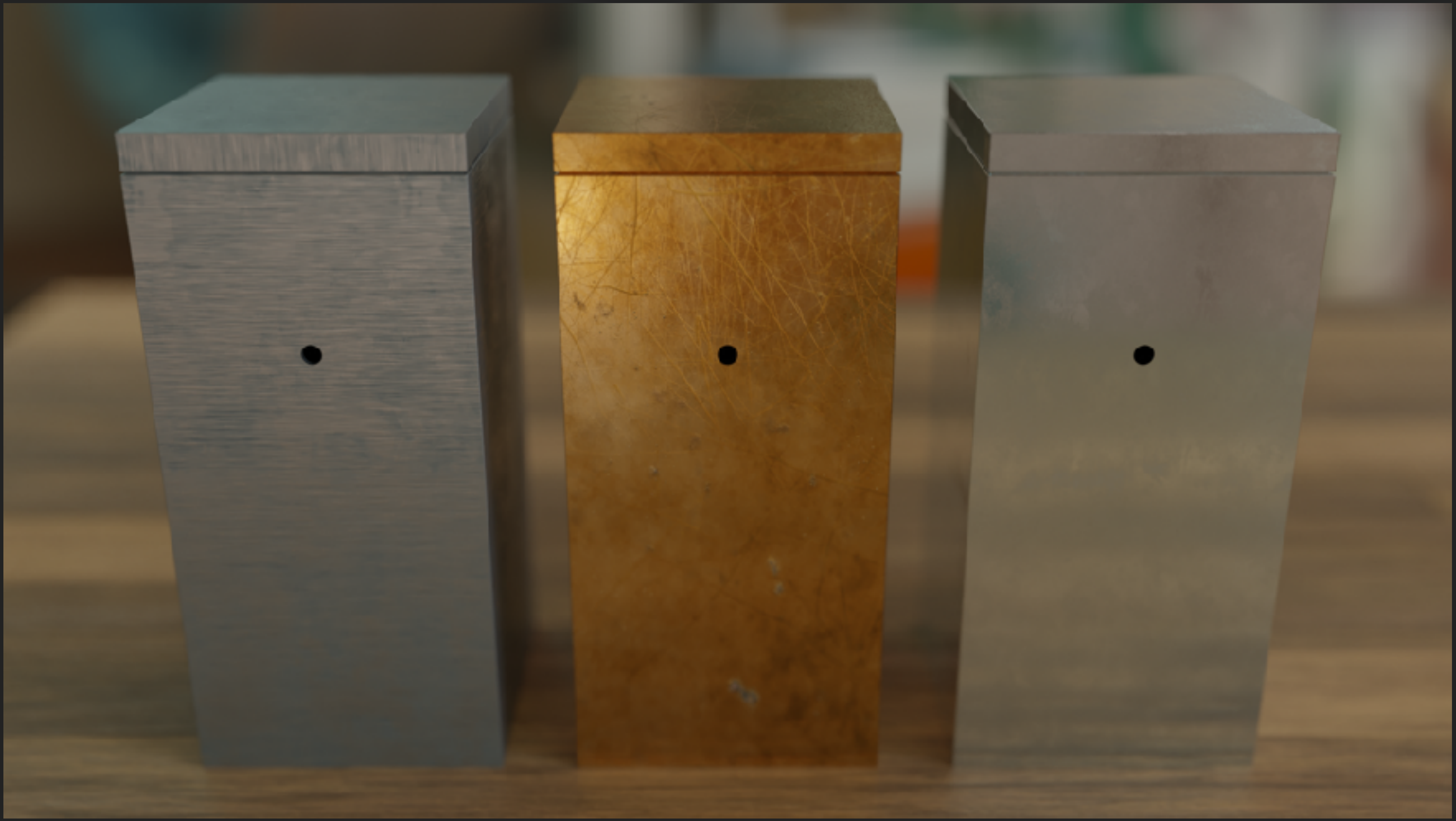
BLACKBODY RADIATION

- only the cavity or hole - not to the object itself!



SPECTRAL DISTRIBUTION OF BLACKBODY RADIATION (PLANCK SPECTRUM)

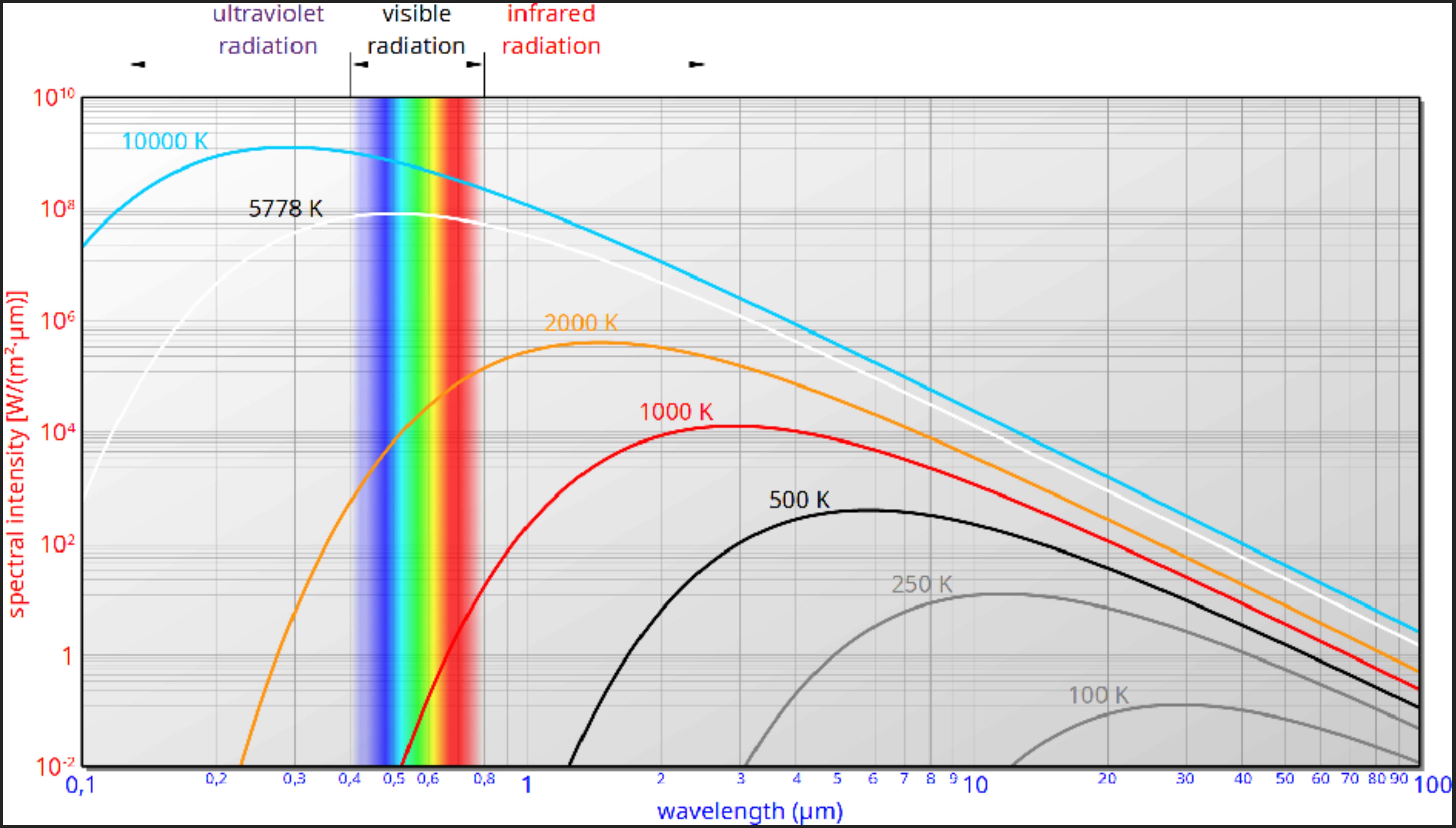
- Different materials at different temperatures.



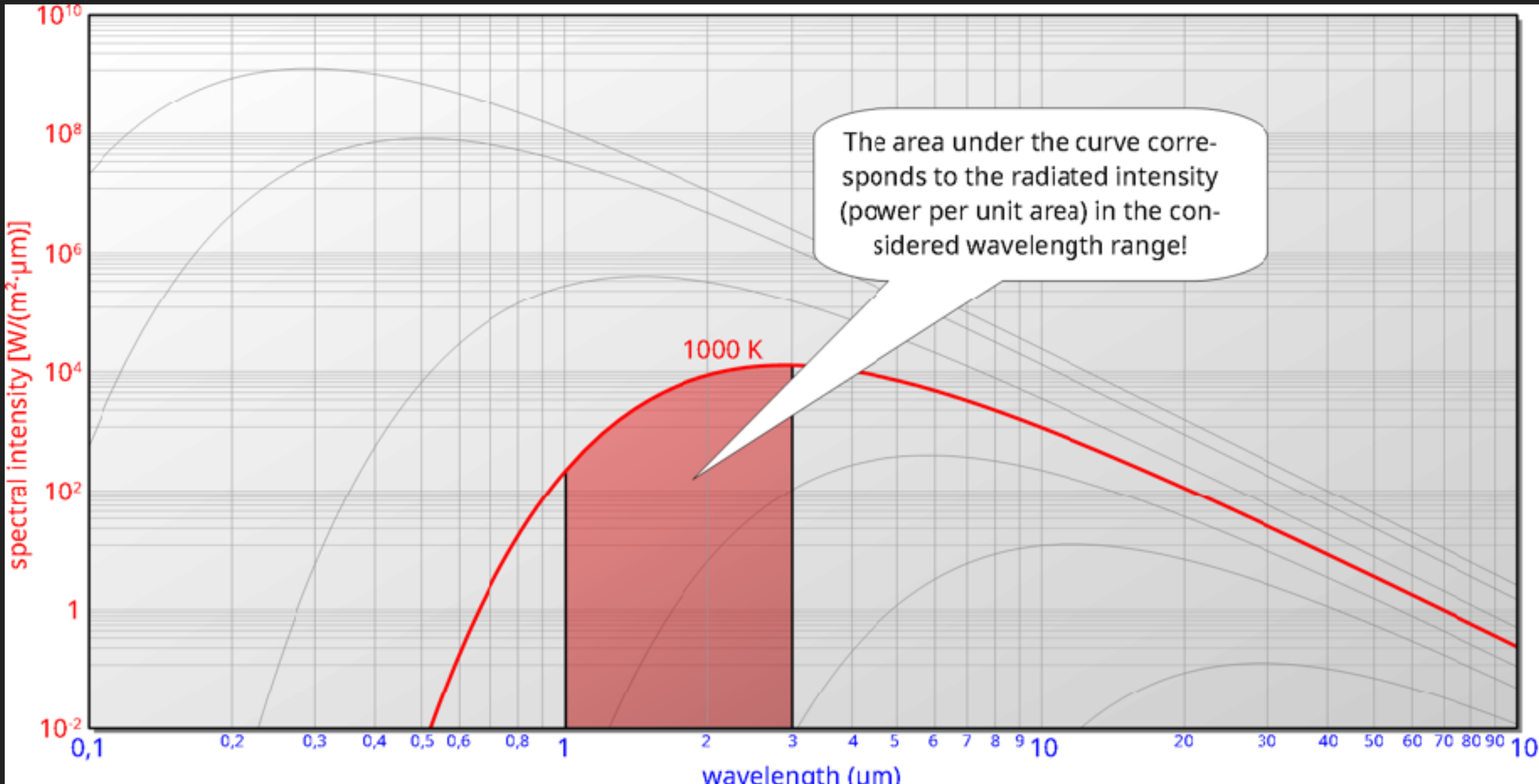
BLACKBODY RADIATION

- Radiation enters through a hole, but does not exit due to absorption.

BLACKBODY RADIATION

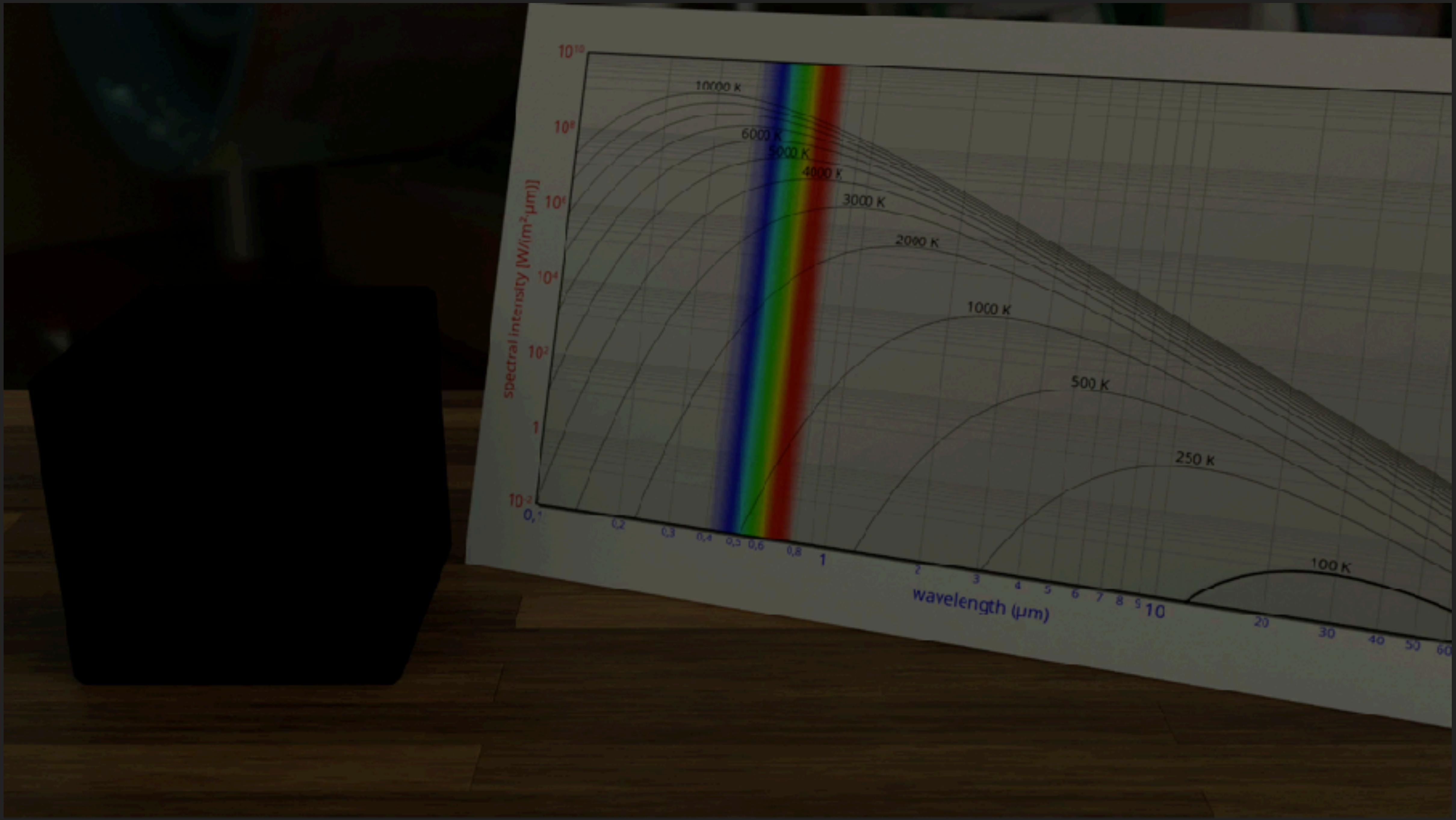


BLACKBODY RADIATION



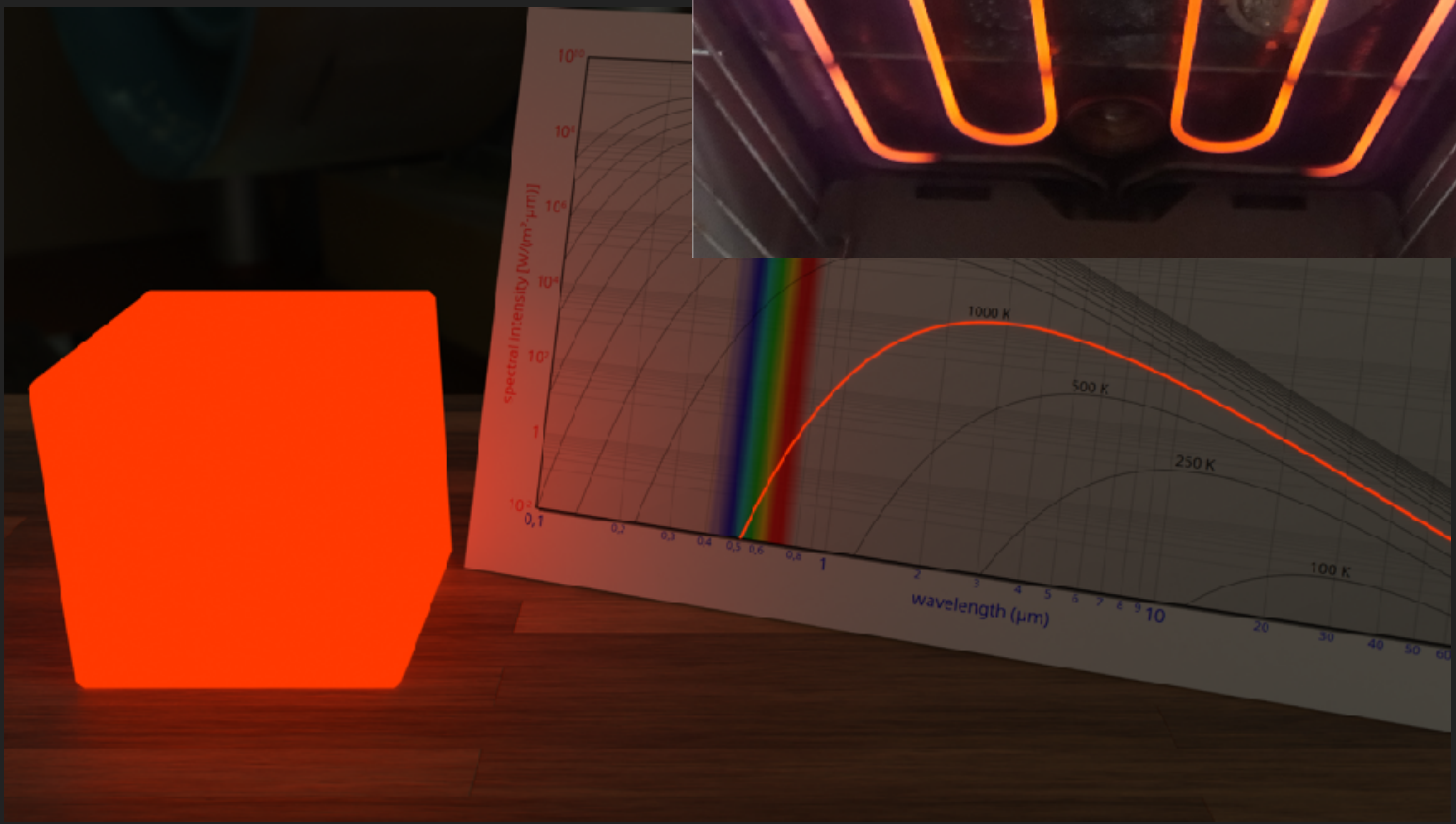
- The wavelength spectrum of blackbody radiation depends only on the temperature and not on the material!

BLACKBODY RADIATION



BLACKBODY RADIATION

- approx. 1000 K



BLACKBODY RADIATION

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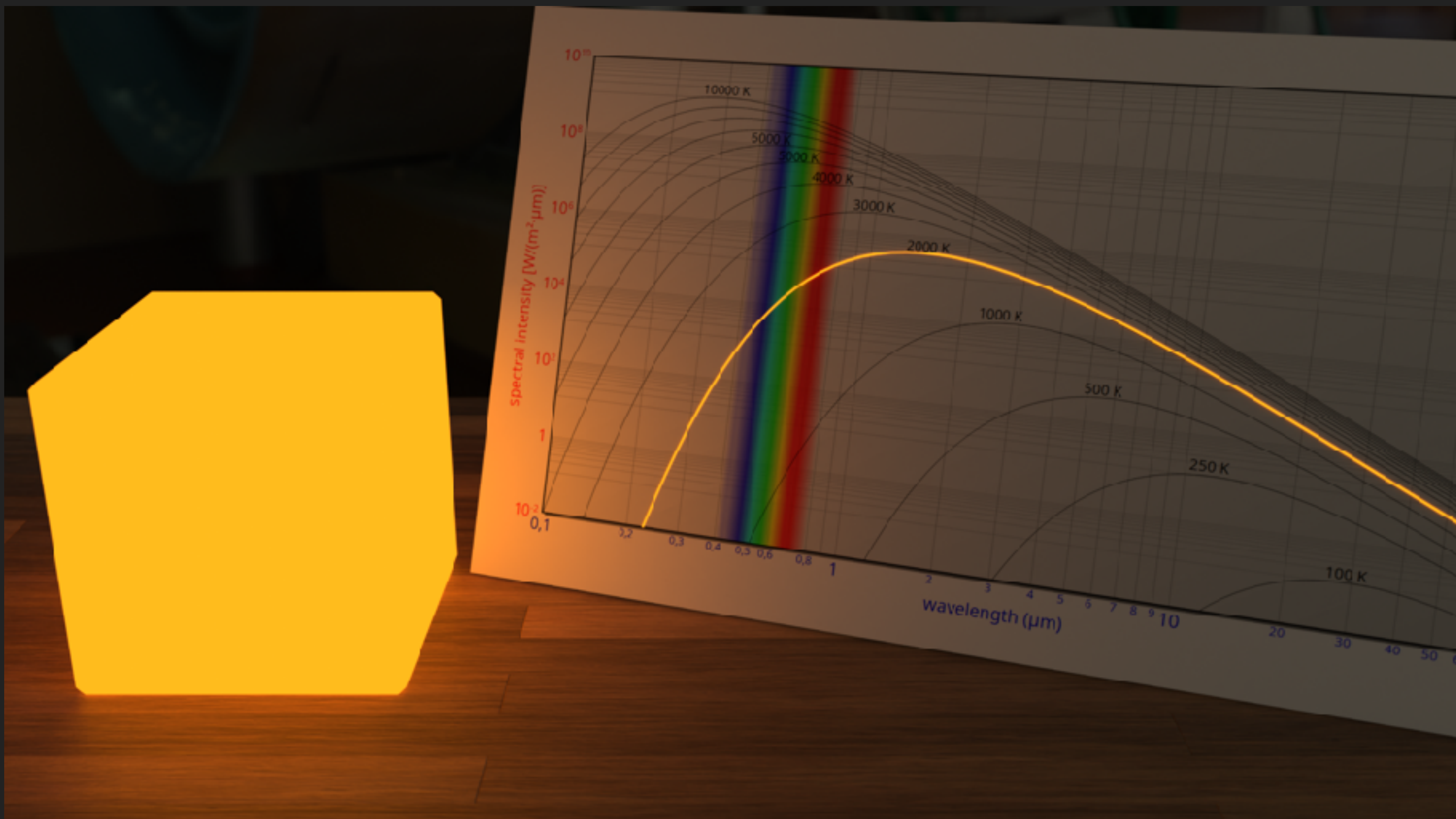
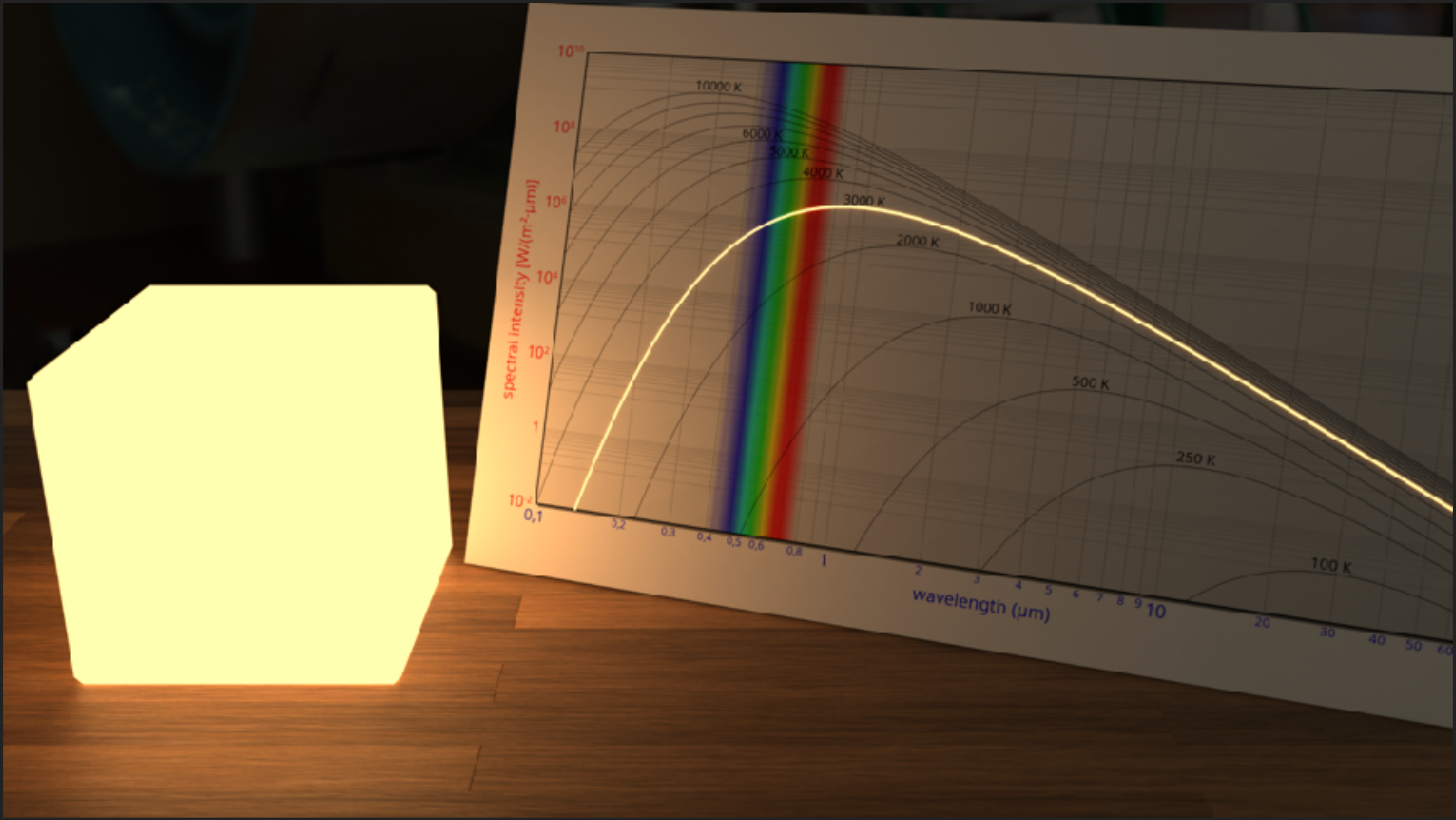


BLACKBODY RADIATION

- The white : over 3000 K

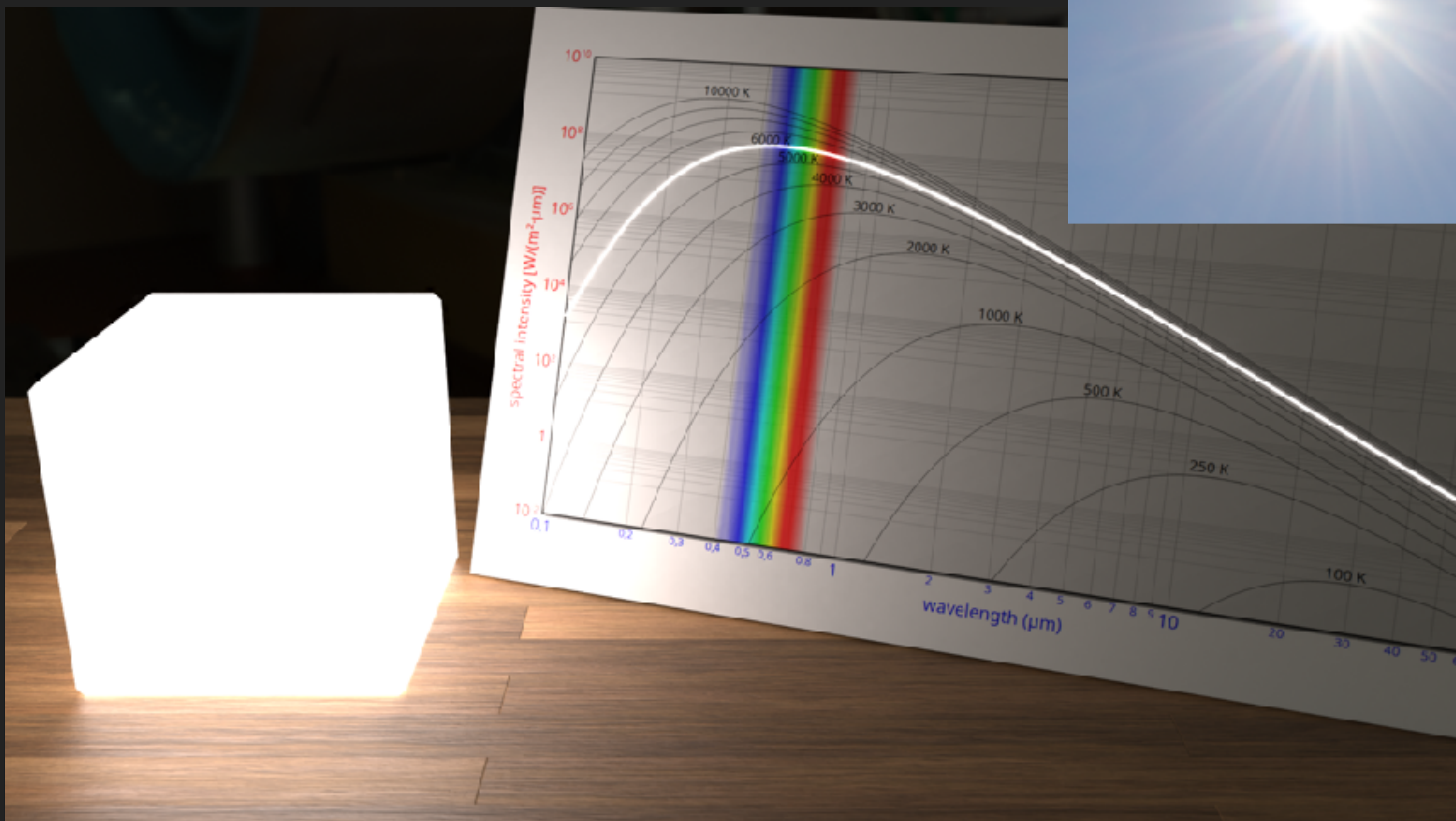
BLACKBODY RADIATION

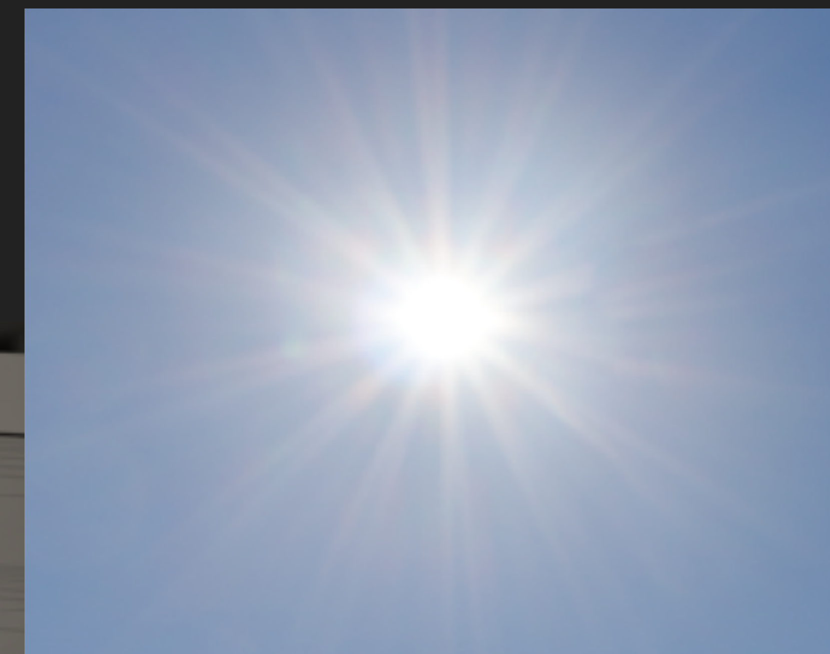
- over 3000 K more ultraviolet radiation (UV radiation)



BLACKBODY RADIATION

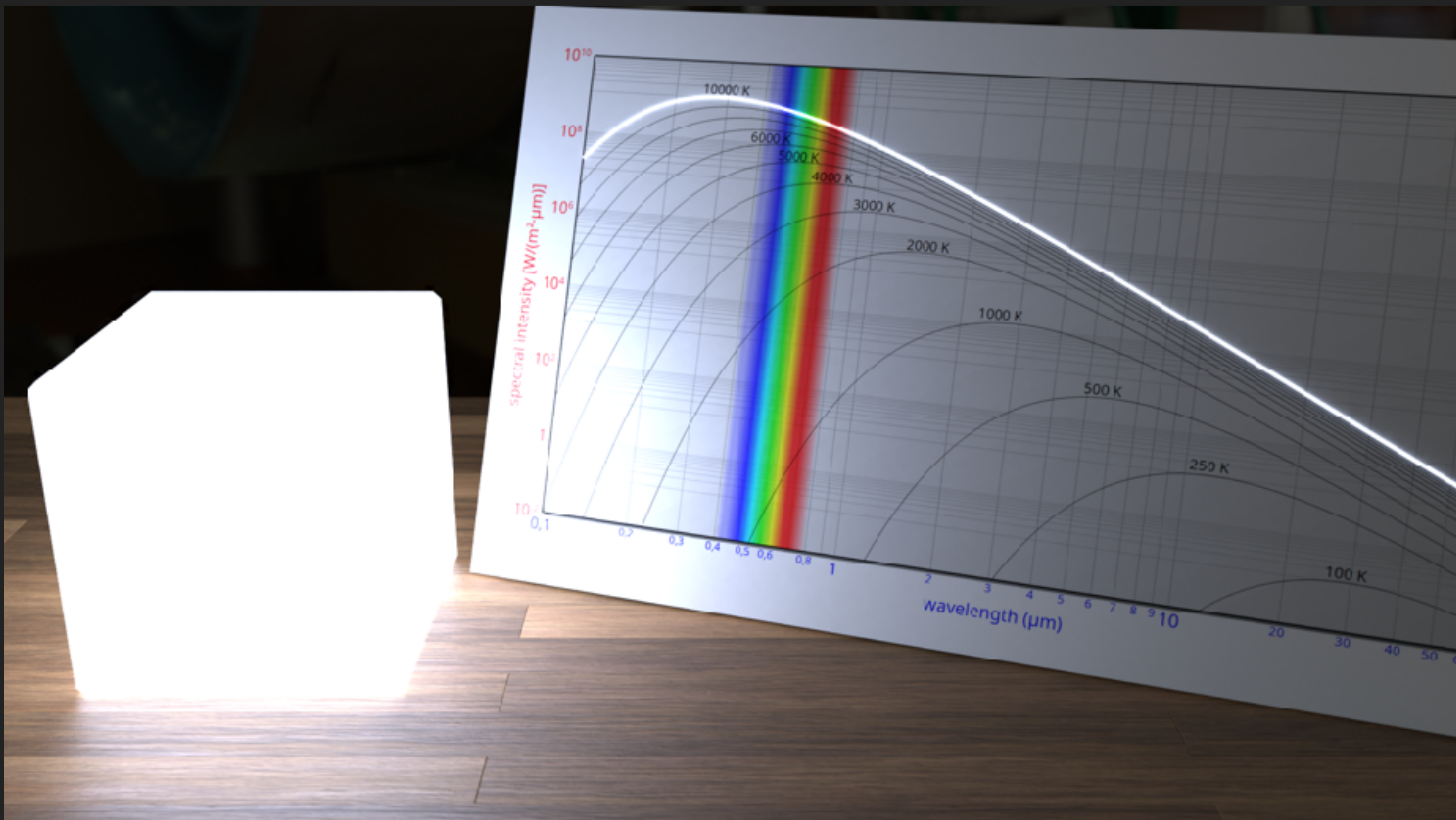
- about 6000 K





BLACKBODY RADIATION

- Blue giants more than 10,000 Kelvin.



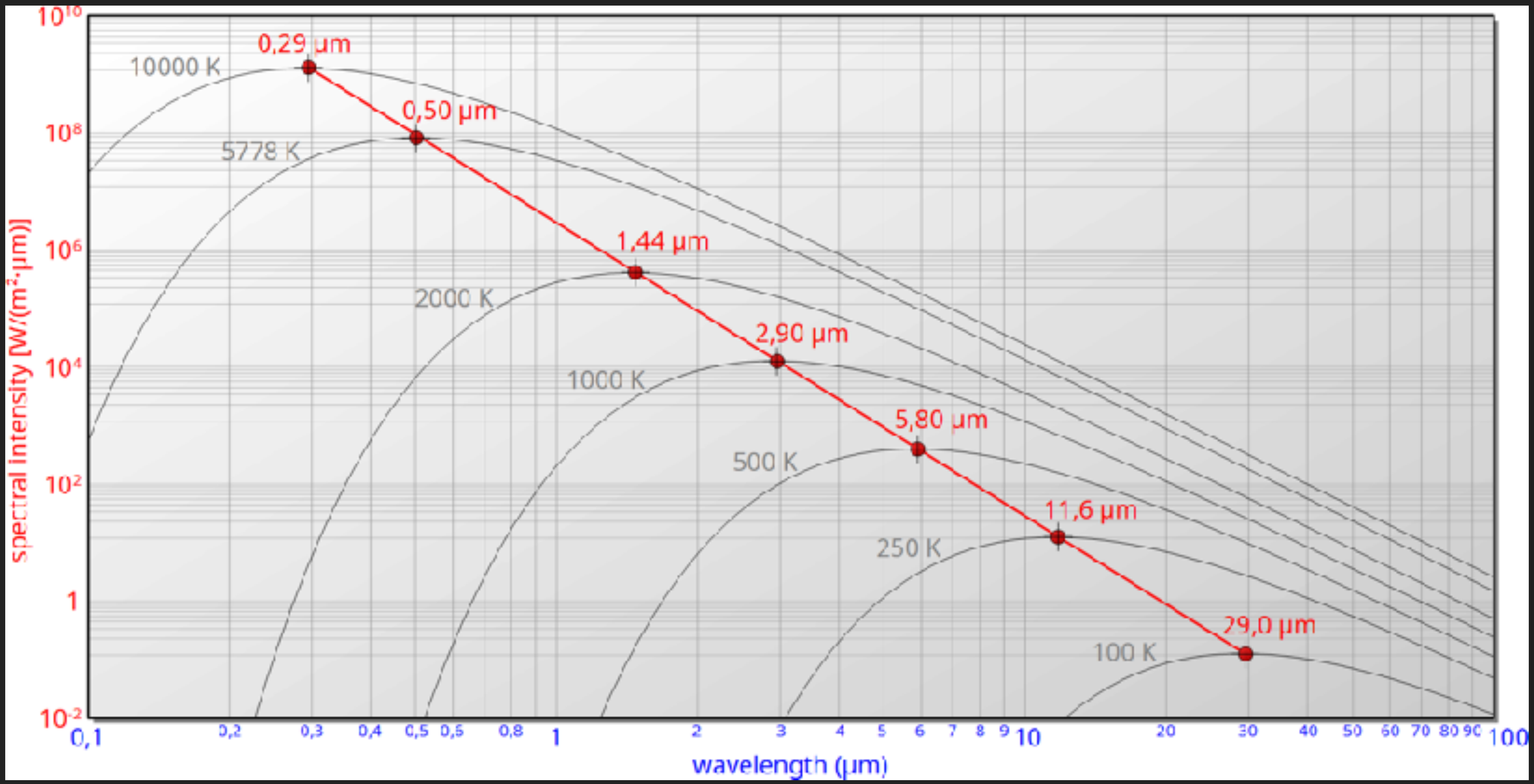
WIEN'S DISPLACEMENT LAW

- The maximum of the curve shifts with increasing temperature to ever shorter wavelengths.

$$\lambda_{max} = \frac{2897,8\ \mu m\ K}{T}$$

!

- The Wien's displacement law can be obtained by determining the maxima of Planck's law.

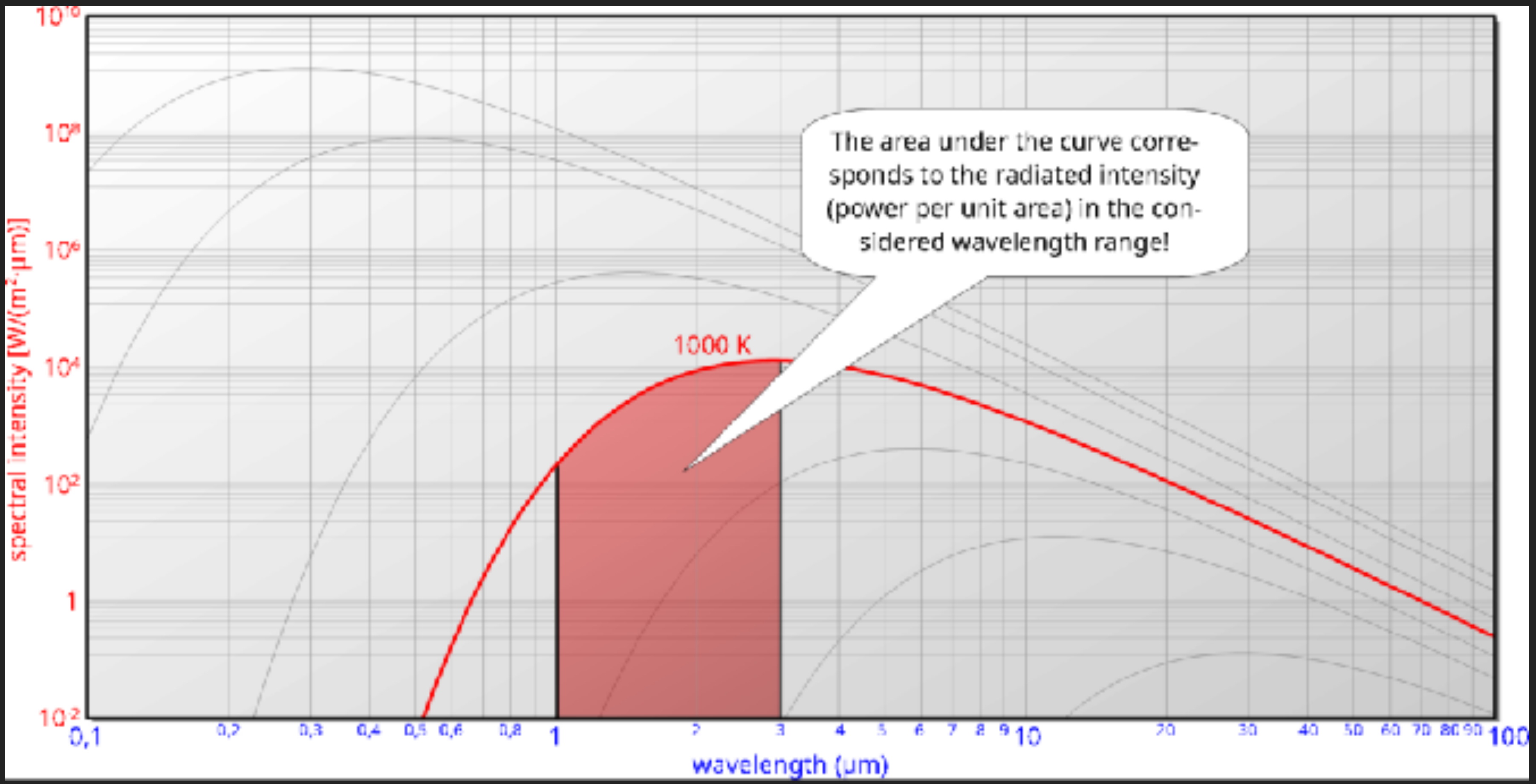


PLANCK'S LAW

- Relationship between the wavelength λ of a radiation and its frequency f.
- Results from the speed of propagation of the radiation, which in this case corresponds to the speed of light c ($c=\lambda \cdot f$).
- Therefore the spectral distribution of the intensity can also be expressed as a function of frequency:

$$I_s(\lambda) = \frac{2\pi h c^2}{\lambda^5} \cdot \frac{1}{\exp\left(\frac{hc}{\lambda k_B T}\right) - 1}$$

Planck's Law (wavelength form)



STEFAN – BOLTZMANN LAW

- The radiated intensity results from the area under the spectral intensity distribution.
- Planck's law must therefore be integrated over the entire wavelength range or frequency range.

$$\boxed{I = \sigma \cdot T^4} \quad \text{and} \quad \boxed{\sigma = \frac{2\pi^5 k_B^4}{15 h^3 c^2}} = 5,670 \cdot 10^{-8} \frac{\mathrm{W}}{\mathrm{m^2 K^4}}$$

- The constant quantities can be combined to a new constant, the so-called Stefan-Boltzmann constant σ.
- The radiated intensity of a black body is therefore only dependent on the temperature. It increases with the fourth power of the temperature. This is also called Stefan-Boltzmann law.

STEFAN – BOLTZMANN LAW

- The intensity of the blackbody radiation in thermal equilibrium is proportional to the fourth power of the temperature!

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- The intensity I can be used to determine its energy emitted per unit time.

$$\boxed{\Phi(T, A) = \sigma \cdot A \cdot T^4}$$

EXERCISE

- In what wavelength region would you look for a star at T=1000 K?
    -
-
    -

EXERCISE

- In what wavelength region would you look for a star at T=1000 K?
  - Wien's Law

$$\lambda_{max} = \frac{2897,8 \ \mu\text{m K}}{T}$$

$2,9 \times 10^{-6}$ m

- Your body is about 35C. What is your peak wavelength?
  -

EXERCISE

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$2,9 \times 10^{-6}$ m

- Your body is about 35C. What is your peak wavelength?
  - C → K

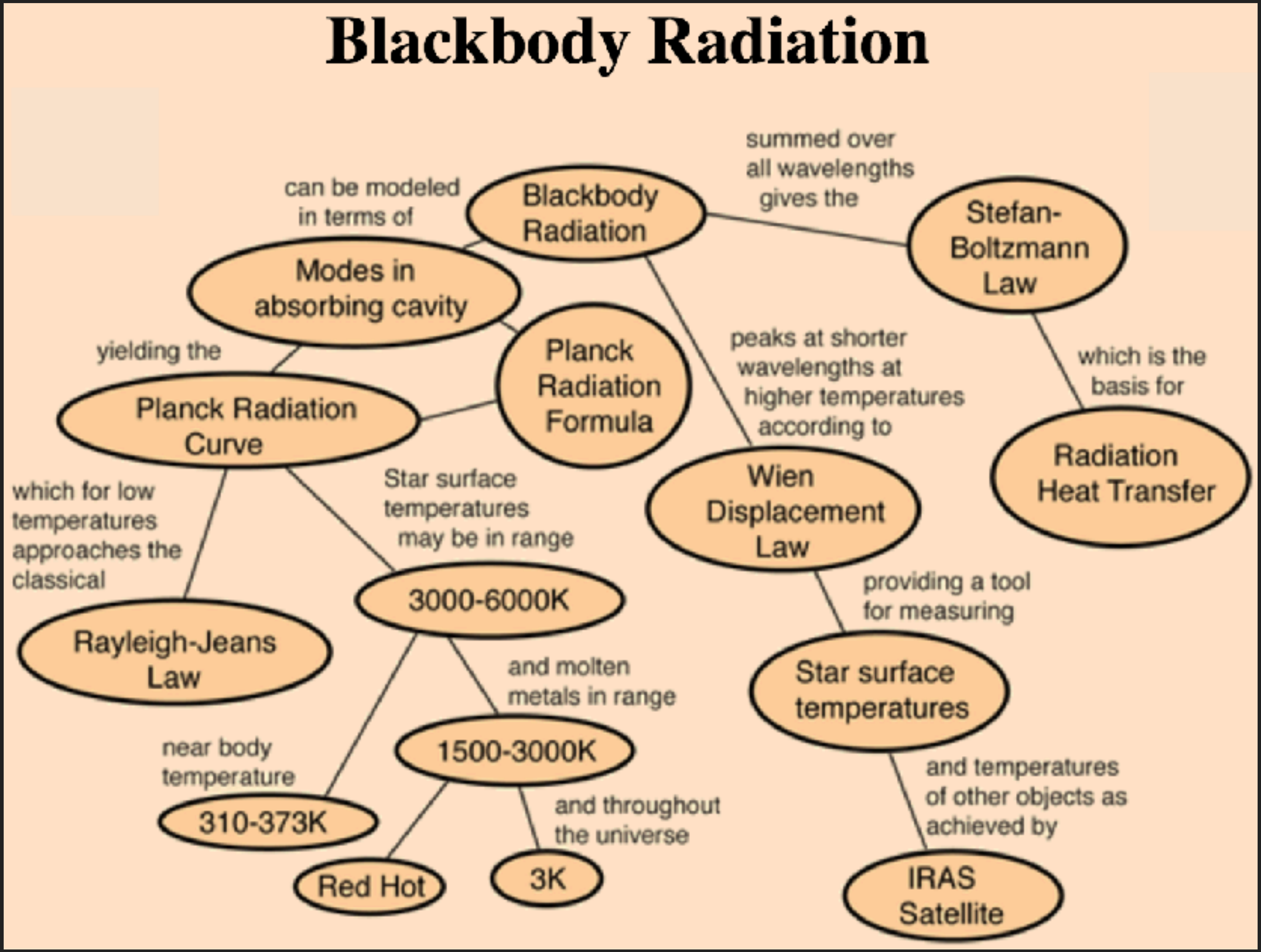
$$\lambda_{max} = \frac{2897,8\ \mu m\ K}{T}$$

$9,4 \times 10^{-6}$ m

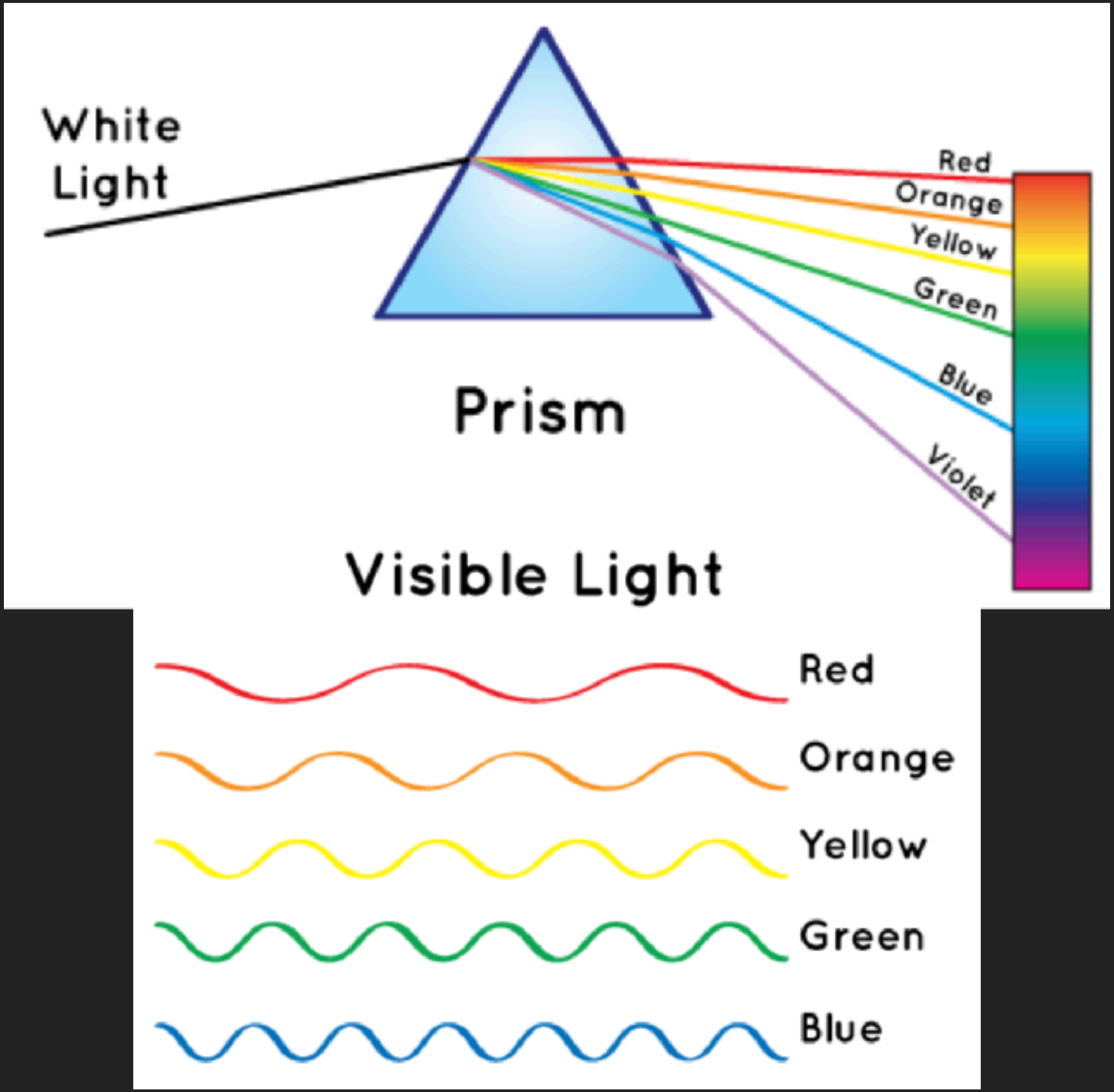
SUMMARY

Property	Technique	Range of values
Distance	Trig Parallax	$1.3 \Rightarrow 80$pc
	Spect. Parallax	1 Mpc
Surface Temp.	Colors, Wein's Law Spectral Types	$3000K \Rightarrow 50000K$
Luminosity	Apparent brightness plus Distance*	$10^{-5} \Rightarrow 10^{6} L_{\odot}$
Radius	Stephan's Law	$0.01 R_{\odot} \Rightarrow 800 R_{\odot}$
Masses	Binary orbits	$0.08 M_{\odot} \Rightarrow 80 M_{\odot}$

PHYSICS BEHIND THE CLASSIFICATION



PHYSICS BEHIND THE CLASSIFICATION



EXERCISE

Photon A

Photon A	Wavelength	Frequency	Energy	Velocity (in space)	Photon B
Red	larger the same smaller	larger the same smaller	larger the same smaller	larger the same smaller	**Blue**
Green	larger the same smaller	larger the same smaller	larger the same smaller	larger the same smaller	**Orange**
InfraRed	larger the same smaller	larger the same smaller	larger the same smaller	larger the same smaller	**Visual**
Visual	larger the same smaller	larger the same smaller	larger the same smaller	larger the same smaller	**Microwave**
X-rays	larger the same smaller	larger the same smaller	larger the same smaller	larger the same smaller	**Gamma-ray**

(Hint: the speed of *all* photons is the same.)

RESOURCES

- https://spaceplace.nasa.gov/blue-sky/en/
- http://hyperphysics.phy-astr.gsu.edu/hbase/bbcon.html
- https://www.tec-science.com/thermodynamics/temperature/black-body-radiation/
- https://www.tec-science.com/thermodynamics/temperature/plancks-law-of-blackbody-radiation/
- http://hosting.astro.cornell.edu/academics/courses/astro201/kirchhoff.htm
- http://hyperphysics.phy-astr.gsu.edu/hbase/hyde.html
- https://www.webassign.net/ncchem/bohr.html
- https://collection.sciencemuseumgroup.org.uk/objects/co3632/william-herschels-infrared-prism-prism-optical-demonstration
- https://cas.sdss.org/dr6/en/proj/basic/spectraltypes/lines.asp
- https://www.scienceinschool.org/2007/issue4/spectrometer
- http://www.cs.cmu.edu/~zhuxj/astro/html/spectrometer.html
- https://astro.unl.edu/naap/hydrogen/naap_hydrogen_sg.pdf
- https://astro.unl.edu/naap/hydrogen/hydrogen.html
- https://calgary.rasc.ca/stellarmagnitudes.htm
- https://www.youtube.com/watch?v=iwlMmJs1f5o
- https://earthsky.org/space/what-is-a-parsec
- https://www.astronomynotes.com/index.html

RESOURCES

- https://courses.lumenlearning.com/towson-astronomy-2/chapter/using-spectra-to-measure-stellar-radius-composition-and-motion/
- https://www.nobelprize.org/prizes/themes/how-the-sun-shines-2
- https://sites.ualberta.ca/~pogosyan/teaching/ASTRO_122/lect6/lecture6.html
- https://pages.uoregon.edu/jimbrau/astr122/Notes/Chapter4.htm
- https://thecuriousastronomer.wordpress.com/tag/spectra/
- https://docs.kde.org/trunk5/en/extragear-edu/kstars/ai-colorandtemp.html
- https://www.handprint.com/ASTRO/specclass.html