

Semillero de Investigación “Hands - on” Computer Vision



A thermal image showing a group of people. The image is overlaid with white rectangular boxes and temperature readings in degrees Celsius. The readings are: 37,2°C (top left), 37,5°C (top right), 37°C (middle left), 36,2°C (middle right), and 36,8°C (bottom right). The text 'SESIÓN 8: IMÁGENES TÉRMICAS' is written in large, bold, white capital letters across the center of the image.

37,2°C

37,5°C

37°C

36,2°C

36,8°C

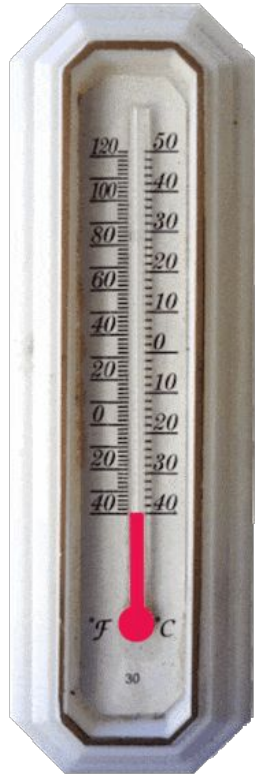
SESIÓN 8: IMÁGENES TÉRMICAS

Contenidos

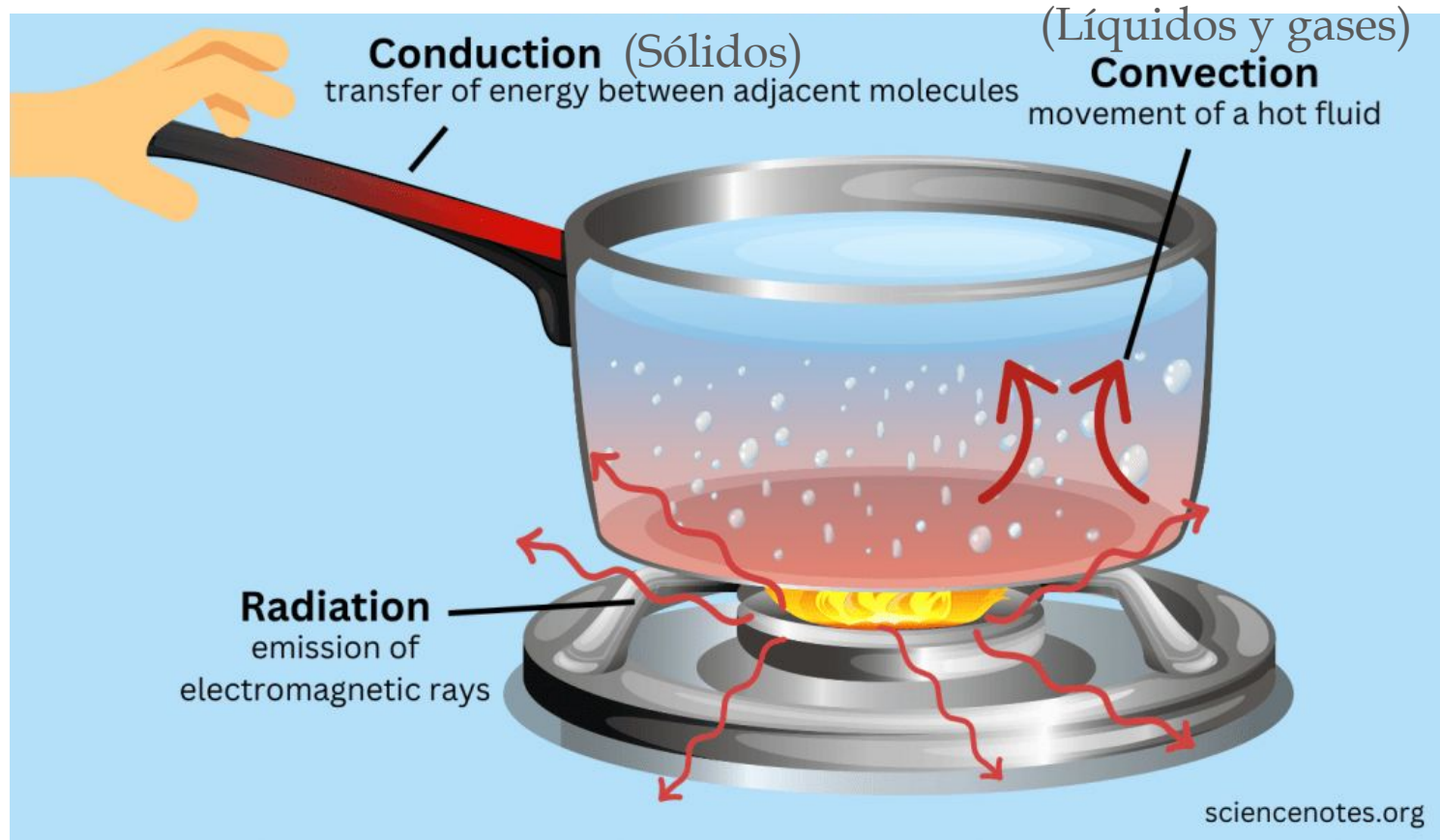
1. Imágenes térmicas y aplicaciones
2. Luz y radiación
 - a. Ley de Kirchhoff
 - b. Radiación de cuerpo negro (Planck)
 - c. Emisividad y atenuación
3. Imágenes espectrales térmicas
4. Thermal & CV
5. Hands-on Thermal Imaging



¿Cómo podemos medir la temperatura?



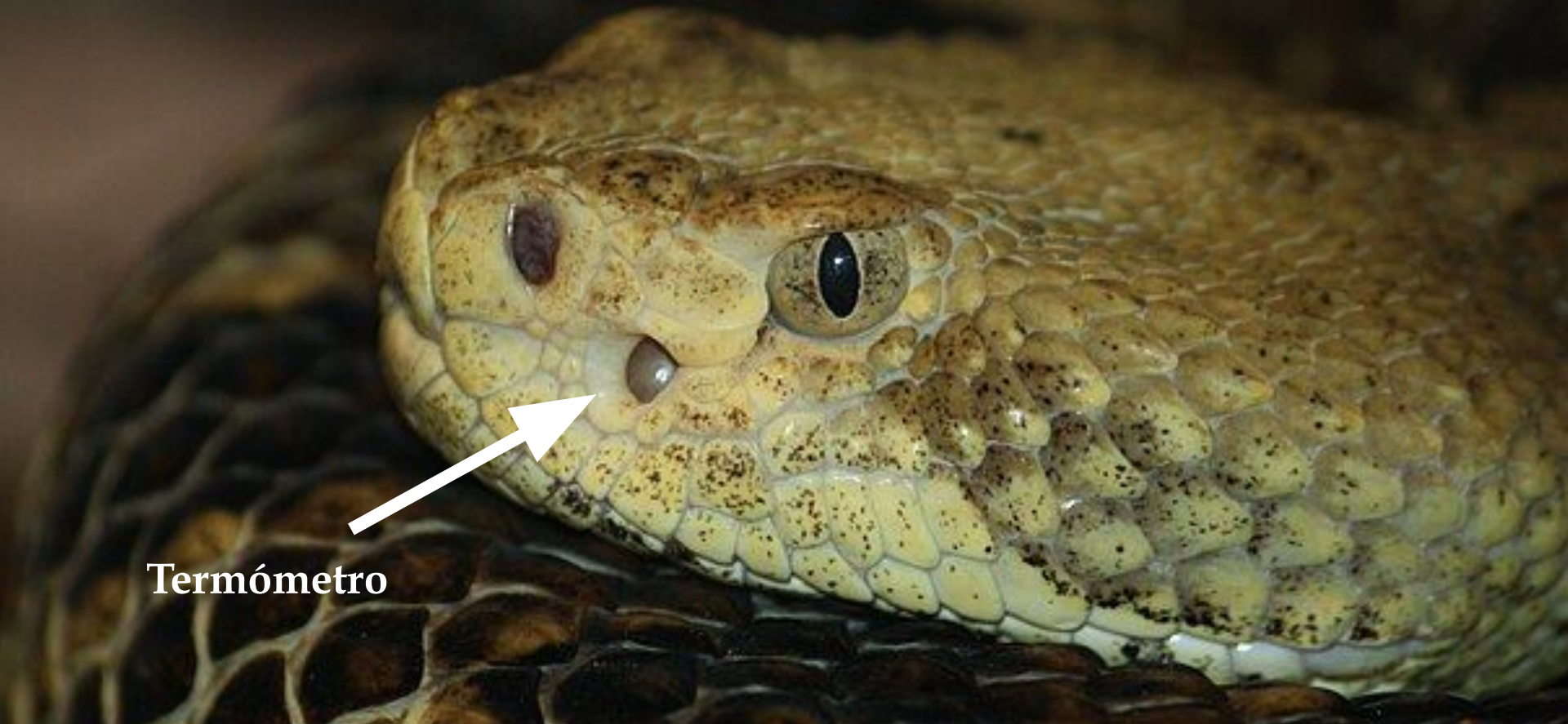
Transferencia de calor



La conducción requiere contacto. La convección requiere flujo de fluido. La radiación no requiere ningún medio.

Sensores térmicos en la naturaleza

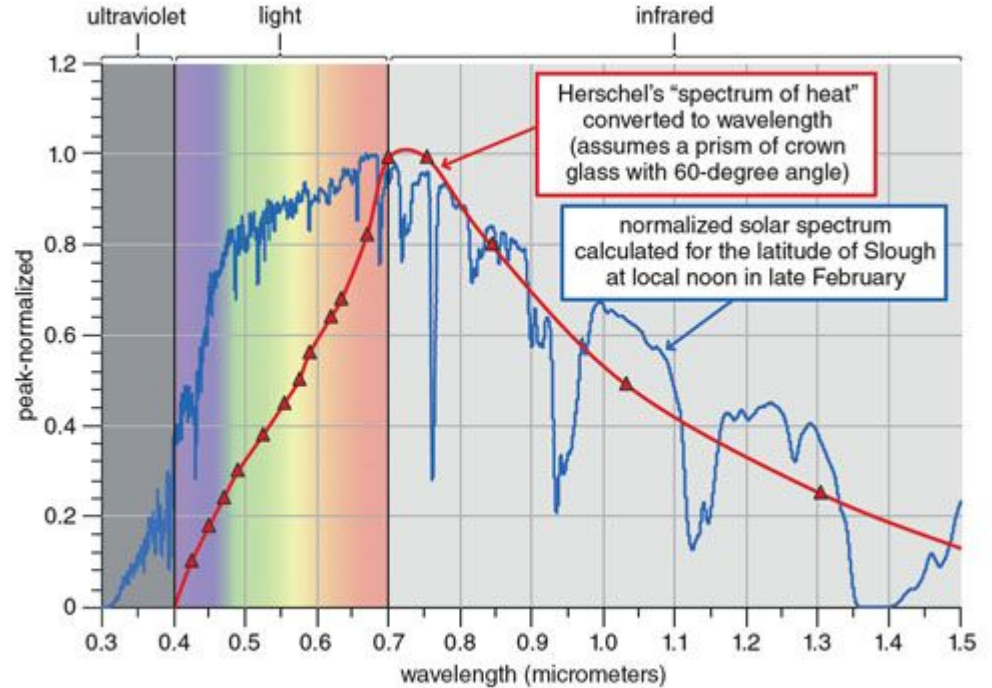
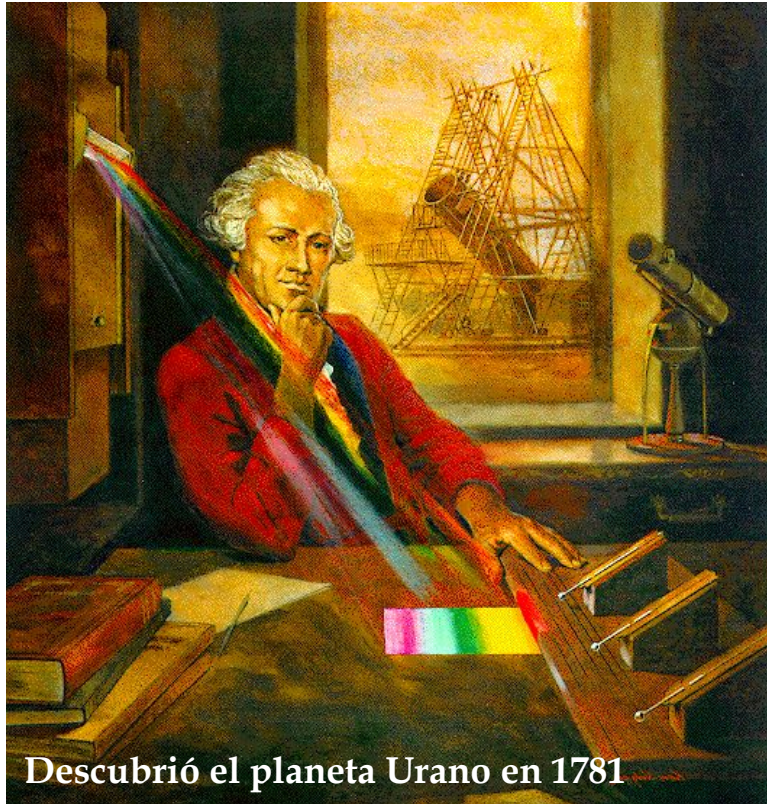
Víboras: pitones, boas y
serpientes de cascabel



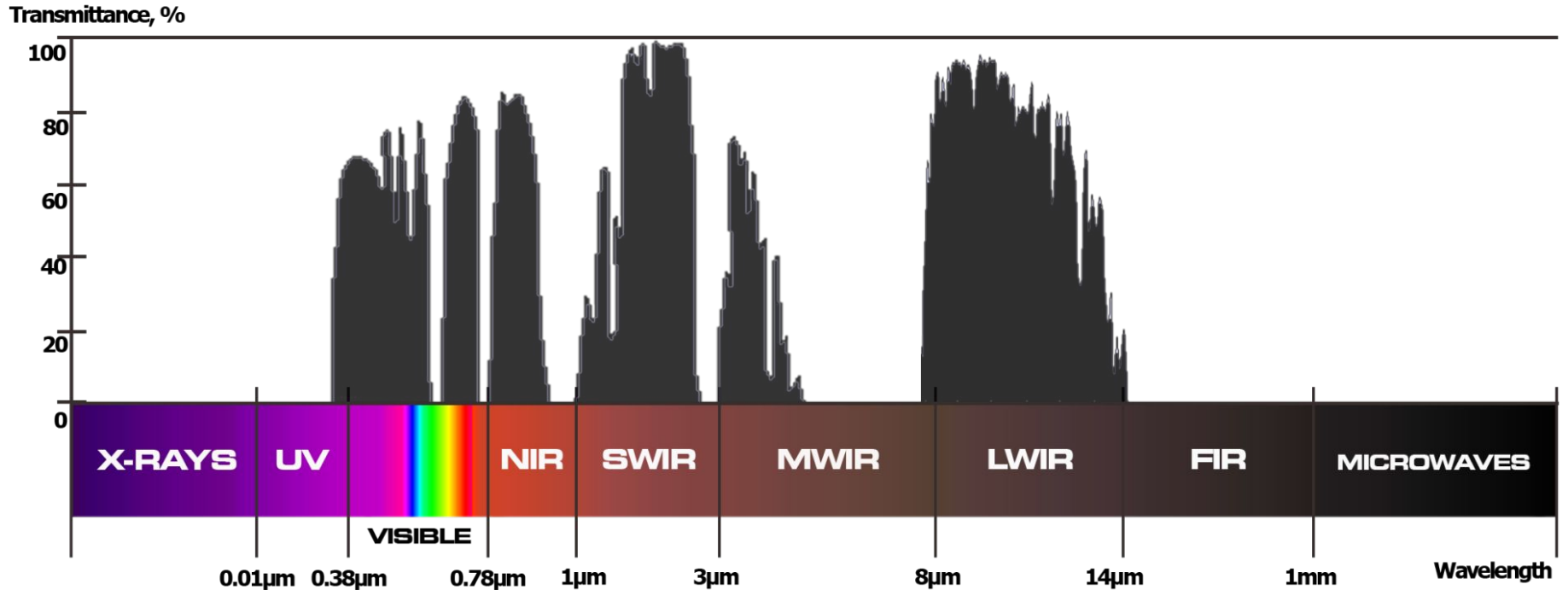
Termómetro

1. Imágenes Térmicas

Infrared light discovery (Frederick W Herschel in 1800)

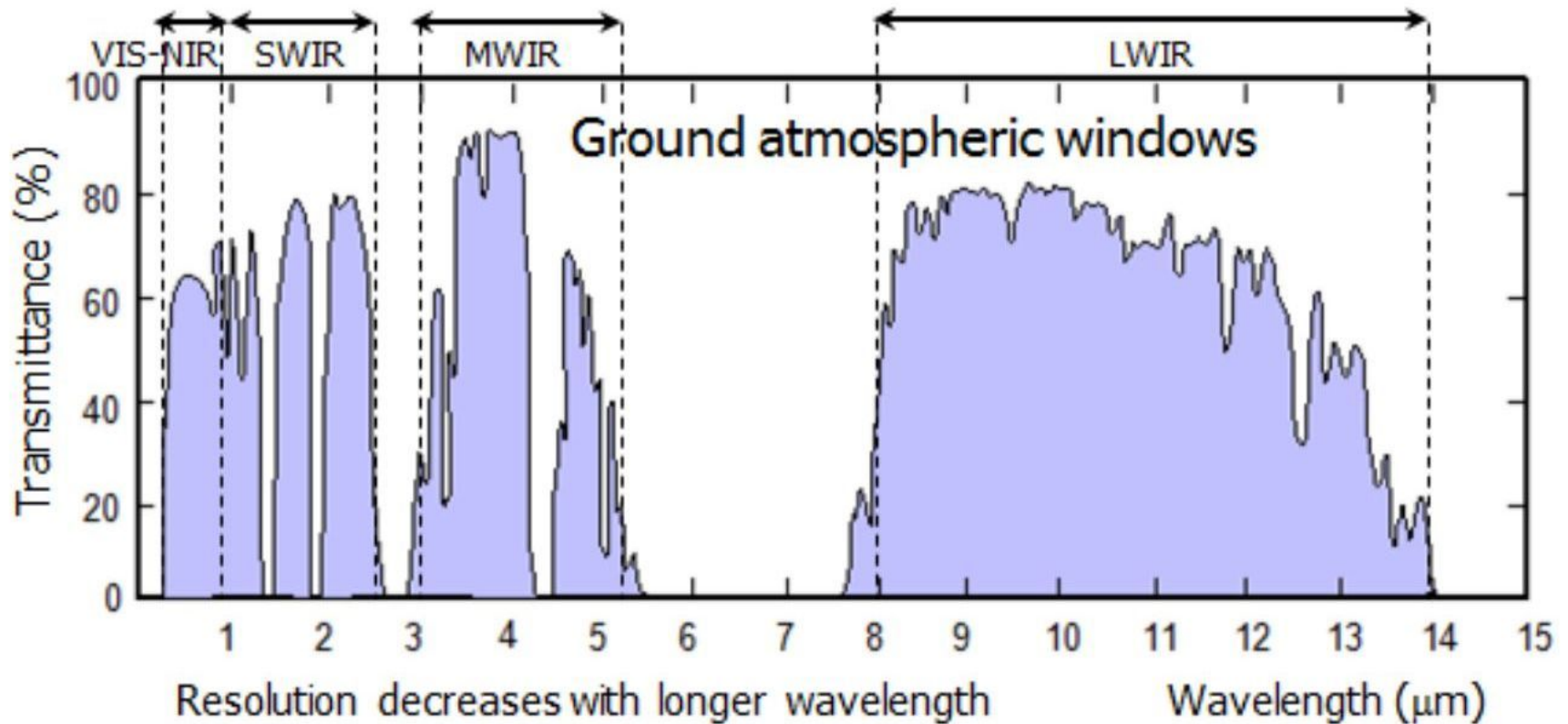


Espectro electromagnético



Térmico = LWIR

Importancia de la Atmósfera





Visible



SWIR



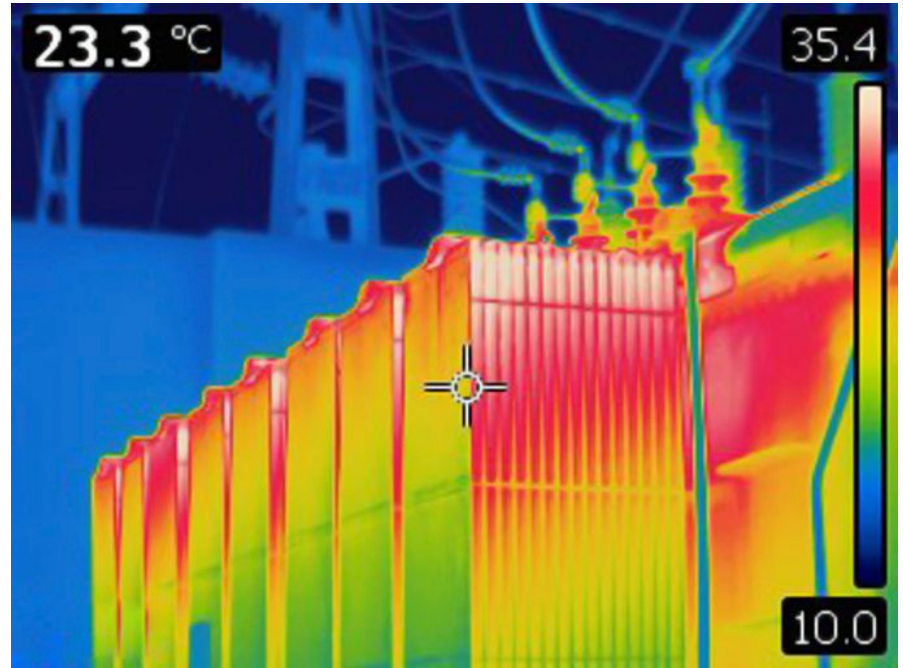
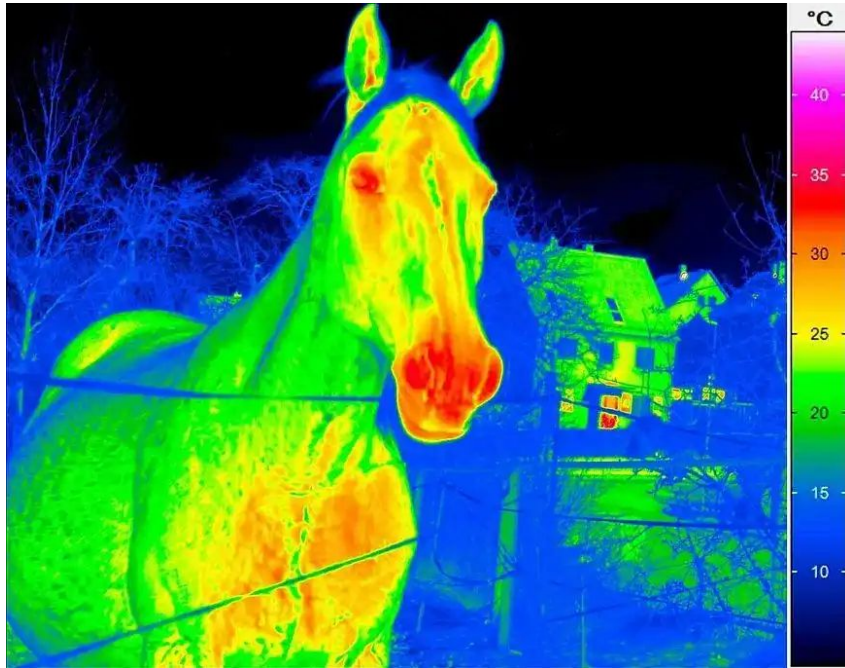
MWIR



LWIR

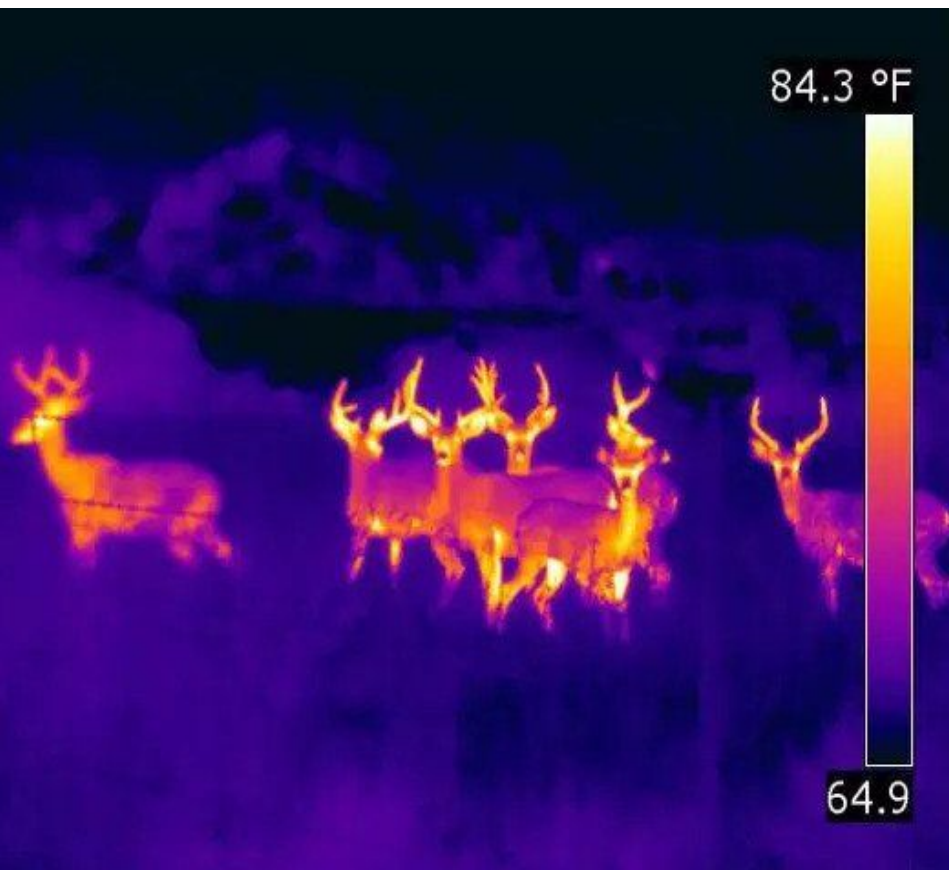


Imágenes térmicas



- Un termograma es una representación digital de la radiación térmica emitida por los objetos
- Las cámaras termográficas permiten detectar esta radiación en forma de luz infrarroja
- Una imagen térmica nos permite detectar de forma remota la temperatura de un objeto

Imágenes térmicas



 FLIR

Pioneer

FLIR

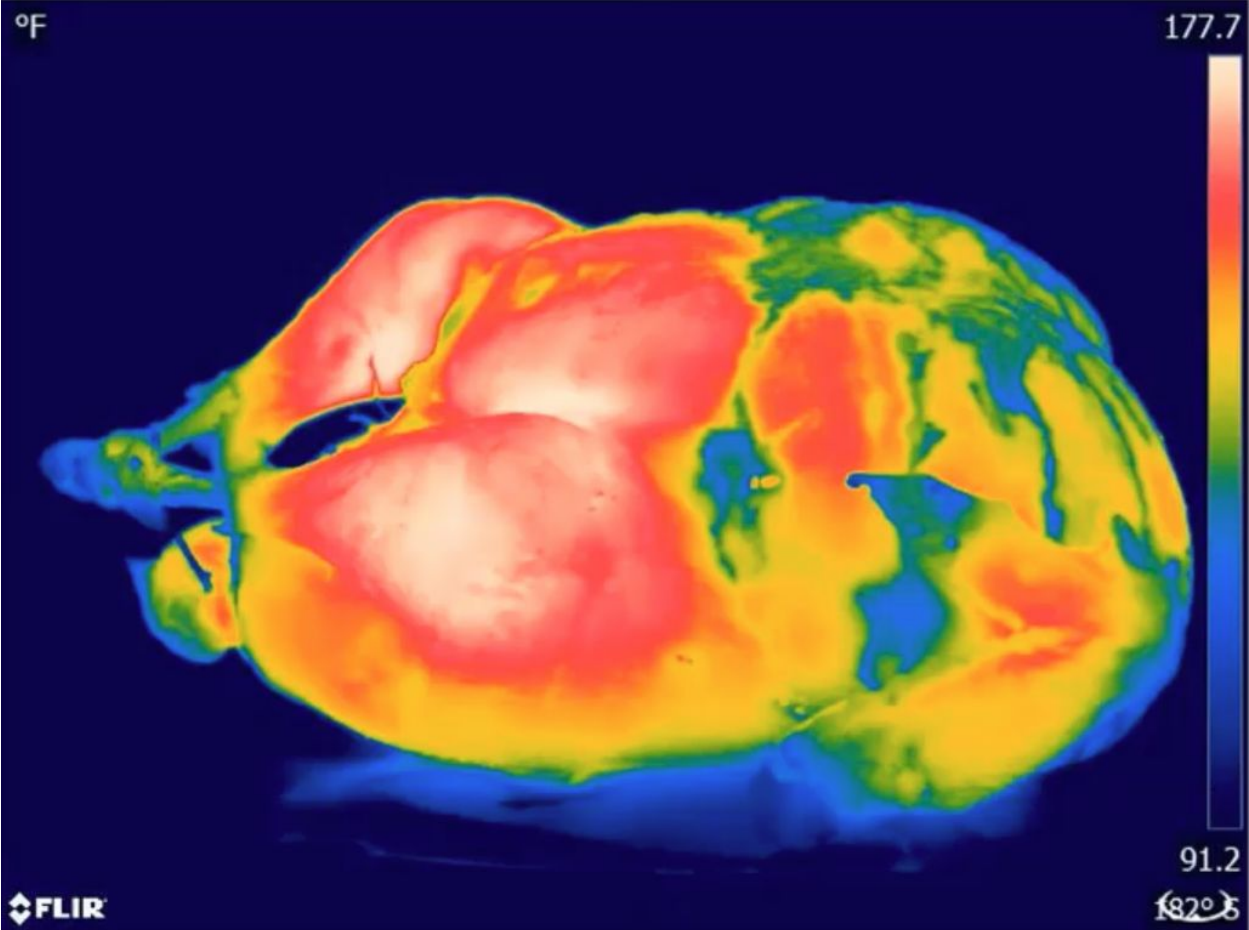
FLIR



Cool stuff



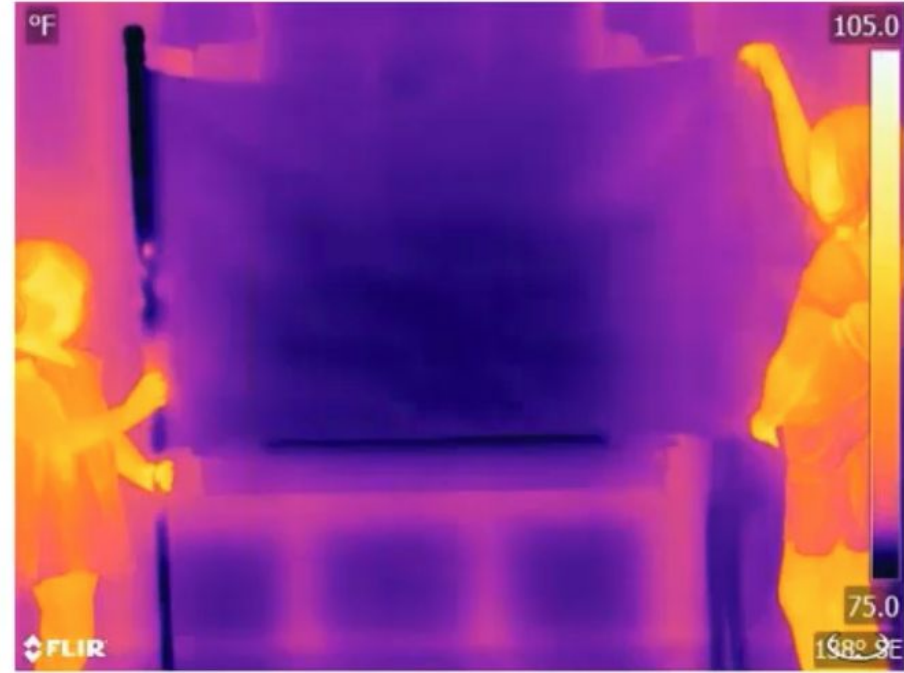
Las alas se enfriaron más rápido (heat capacity, humedad)



Por qué la bandera se ve diferente?



Afuera de casa

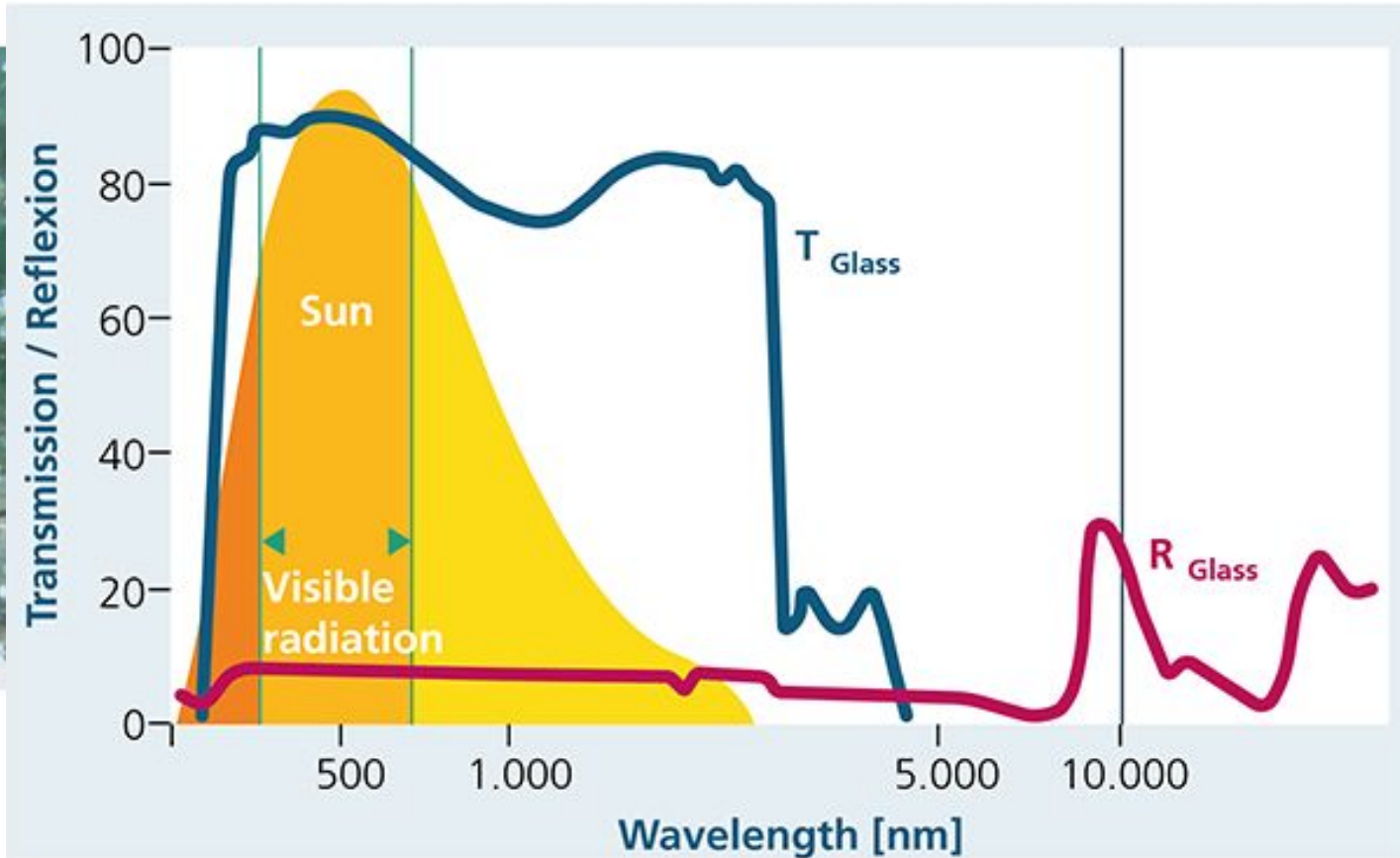


Dentro de casa

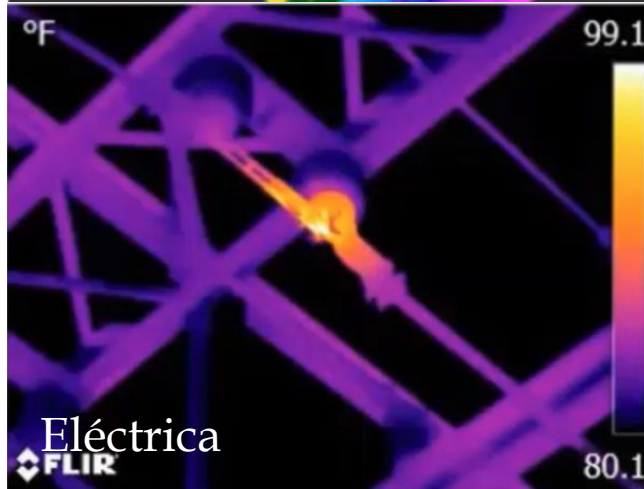
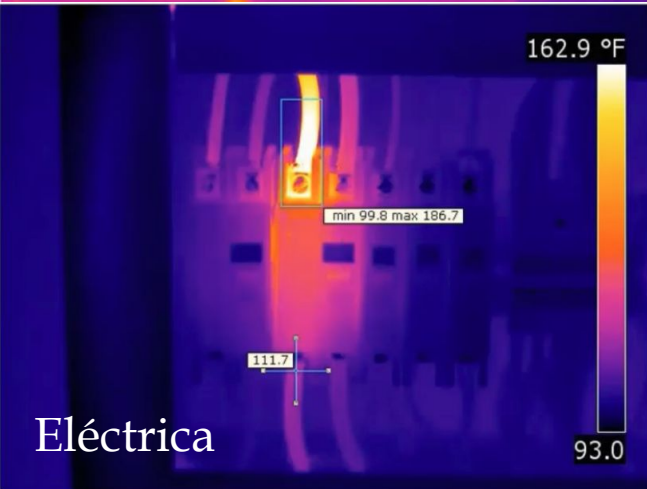
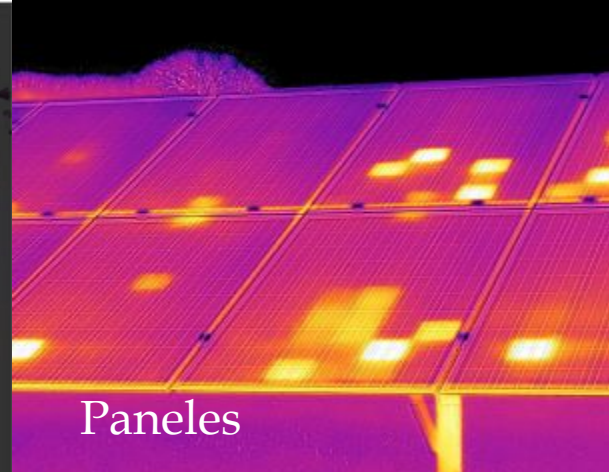
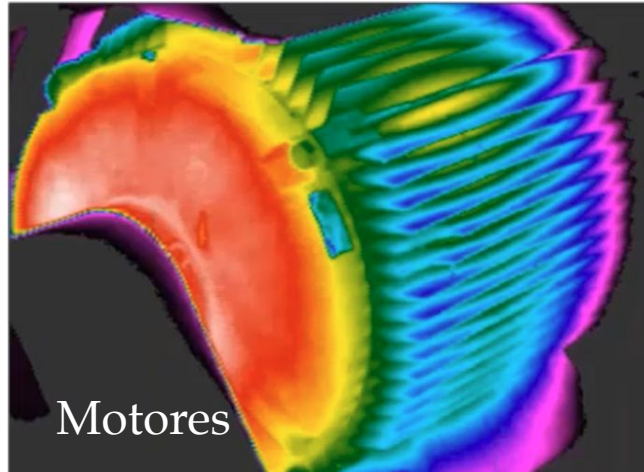
Metales reflejan luz y pueden ser difíciles de medir



Los vidrios son opacos en el rango térmico

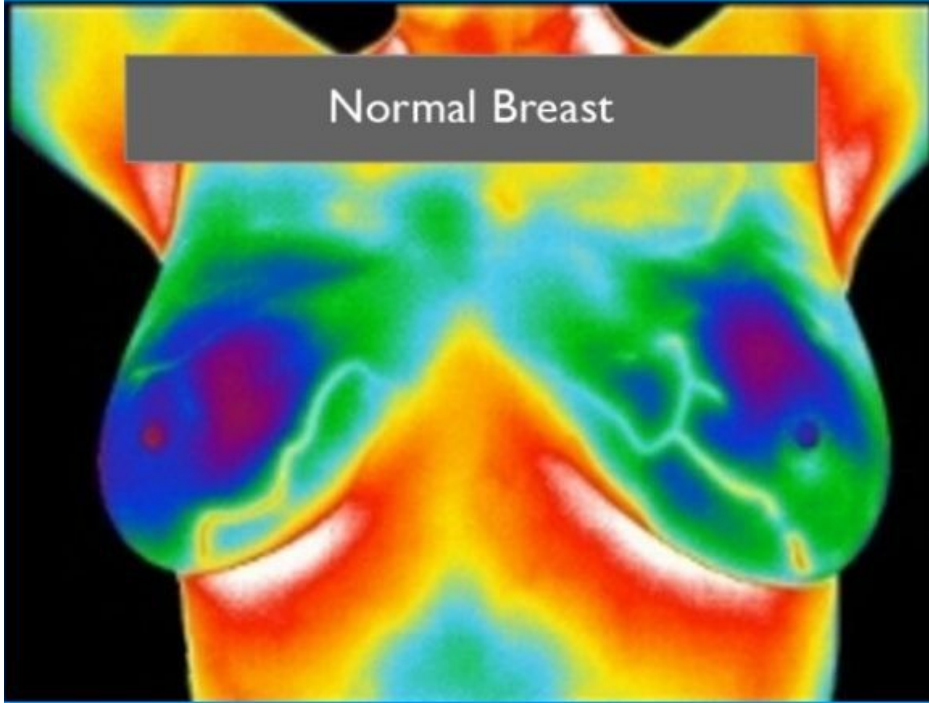


Aplicaciones

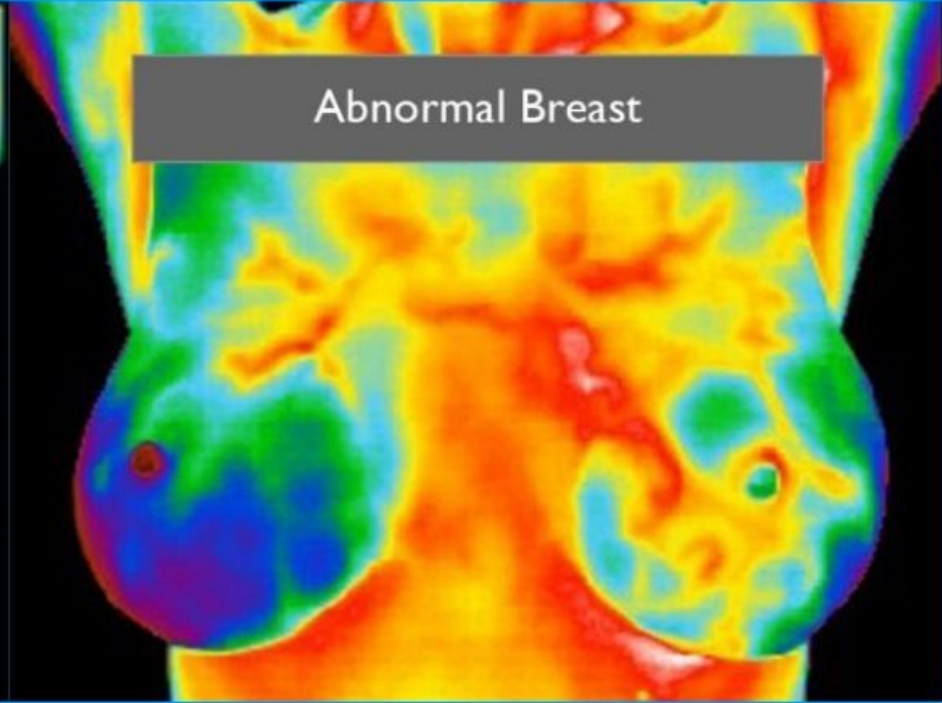


Aplicaciones en Salud

Normal Breast



Abnormal Breast





36.8°C

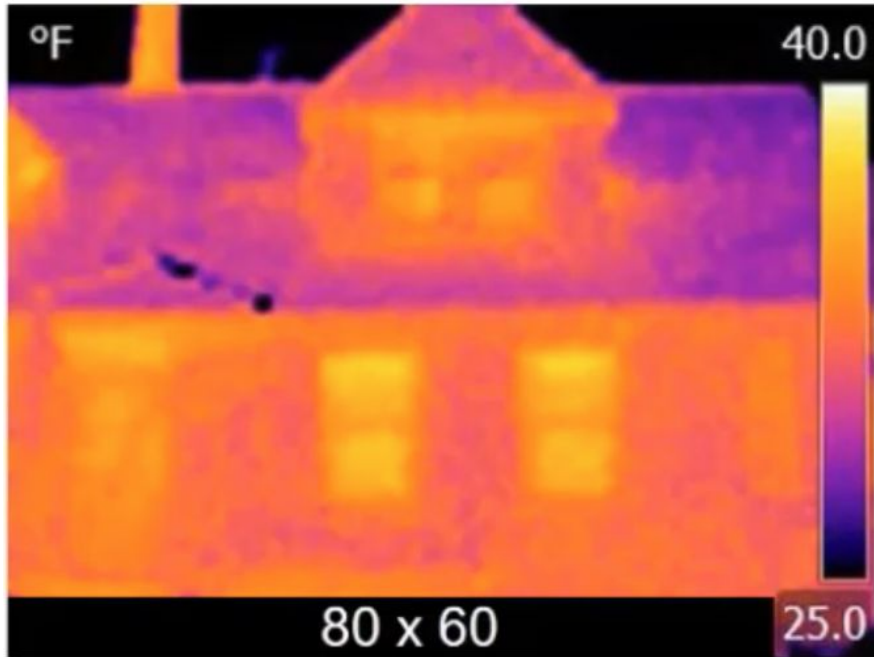
36.7°C

36.6°C

38.3°C

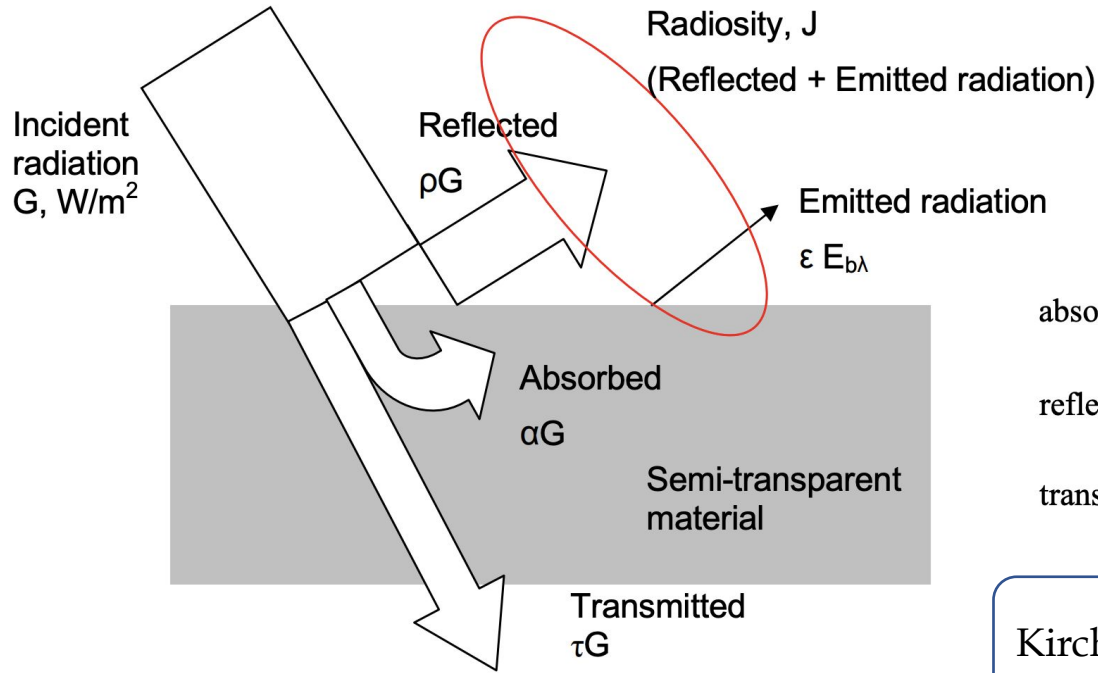
35.9°C

Efecto de resolución



2. Luz y radiación

Radiation



By first law of thermodynamics
(conservation of energy):

$$G_{abs} + G_{ref} + G_{tr} = G$$

$$\alpha + \rho + \tau = 1$$

absorptivity : $\alpha = \frac{\text{absorbed radiation}}{\text{incident radiation}} = \frac{G_{abs}}{G} \quad 0 \leq \alpha \leq 1$

reflectivity : $\rho = \frac{\text{reflected radiation}}{\text{incident radiation}} = \frac{G_{ref}}{G} \quad 0 \leq \rho \leq 1$

transmissivity : $\tau = \frac{\text{transmitted radiation}}{\text{incident radiation}} = \frac{G_{tr}}{G} \quad 0 \leq \tau \leq 1$

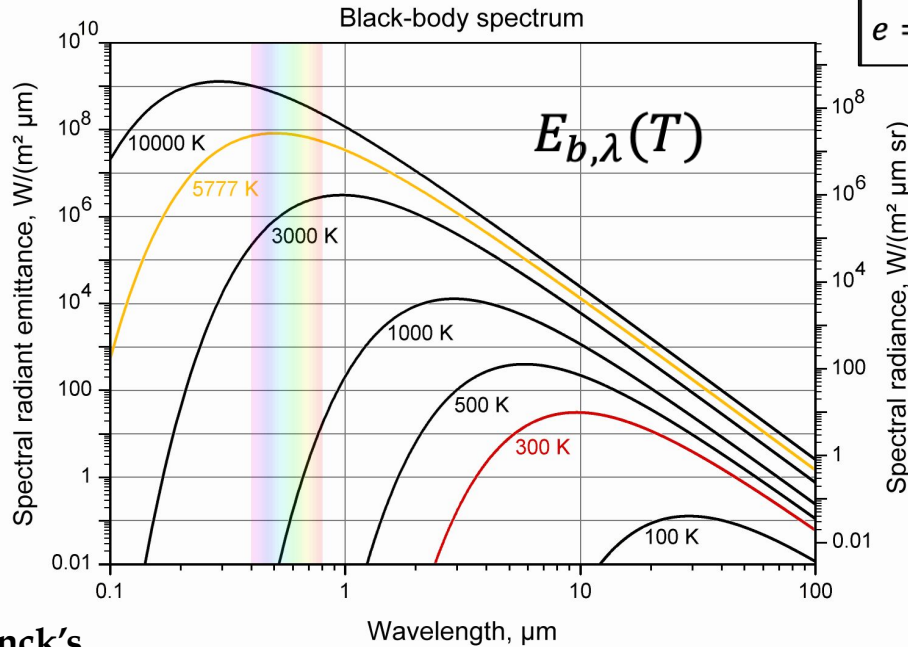
Kirchhoff's law: $\alpha = 1 - \tau$, Transparent ($\rho = 0$)
 $\alpha = 1 - \rho$, Opaque ($\tau = 0$)

The radiation energy incident on a surface **per unit area** per unit time is called **irradiation**, G .

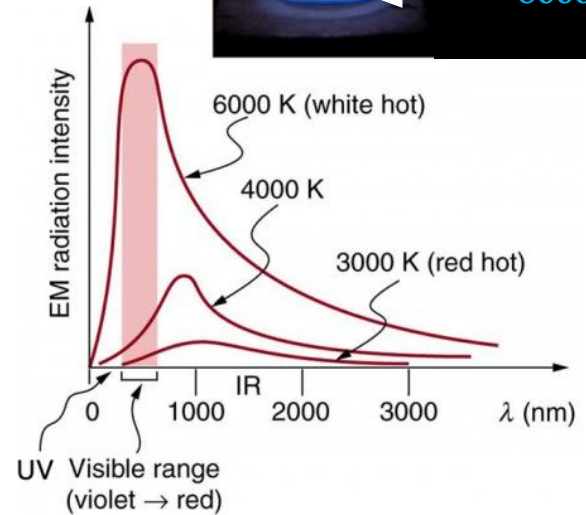
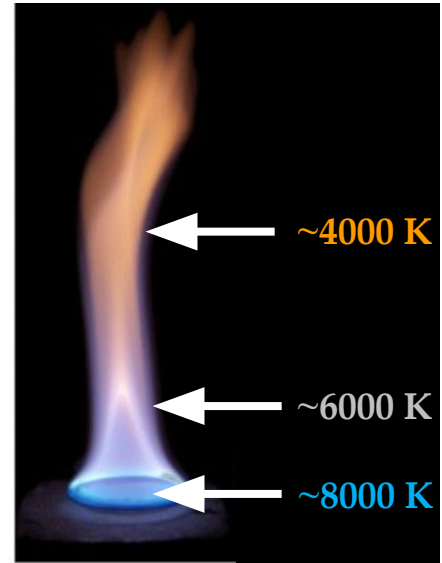
Blackbody radiation

- At a fix T and λ , no surface can emit more energy than a blackbody
- Einstein: "Energy of a photon is inversely proportional to its wavelength"

$$e = h\nu = h\frac{c}{\lambda}$$



Spectral radiance, $W/(m^2 \mu m sr)$



Planck's

law:

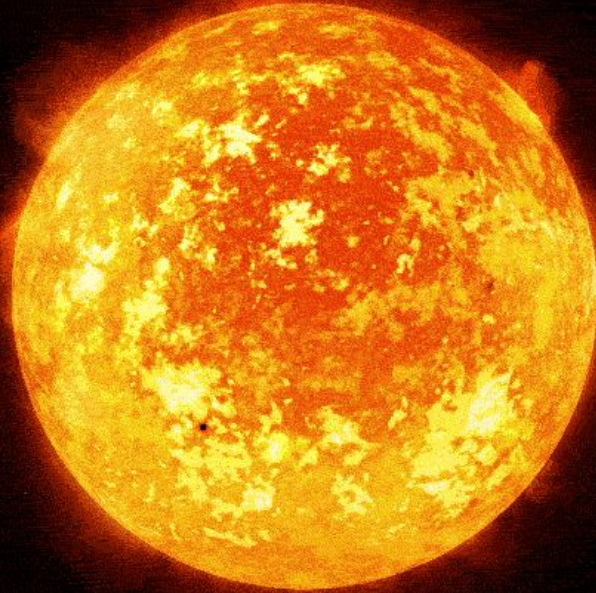
$$E_{b,\lambda}(T) = \frac{2hc^2}{\lambda^5 \left(e^{\frac{hc}{\lambda kT}} - 1 \right)} \left(\frac{W}{m^2 \cdot \mu m} \right)$$

- c : Speed of light
- h : Planck's constant
- k : Boltzmann's constant

Incandescencia



Lava 700 - 1,200 °C



Superficie: 5600 °C; Centro: 15.000.000 °C

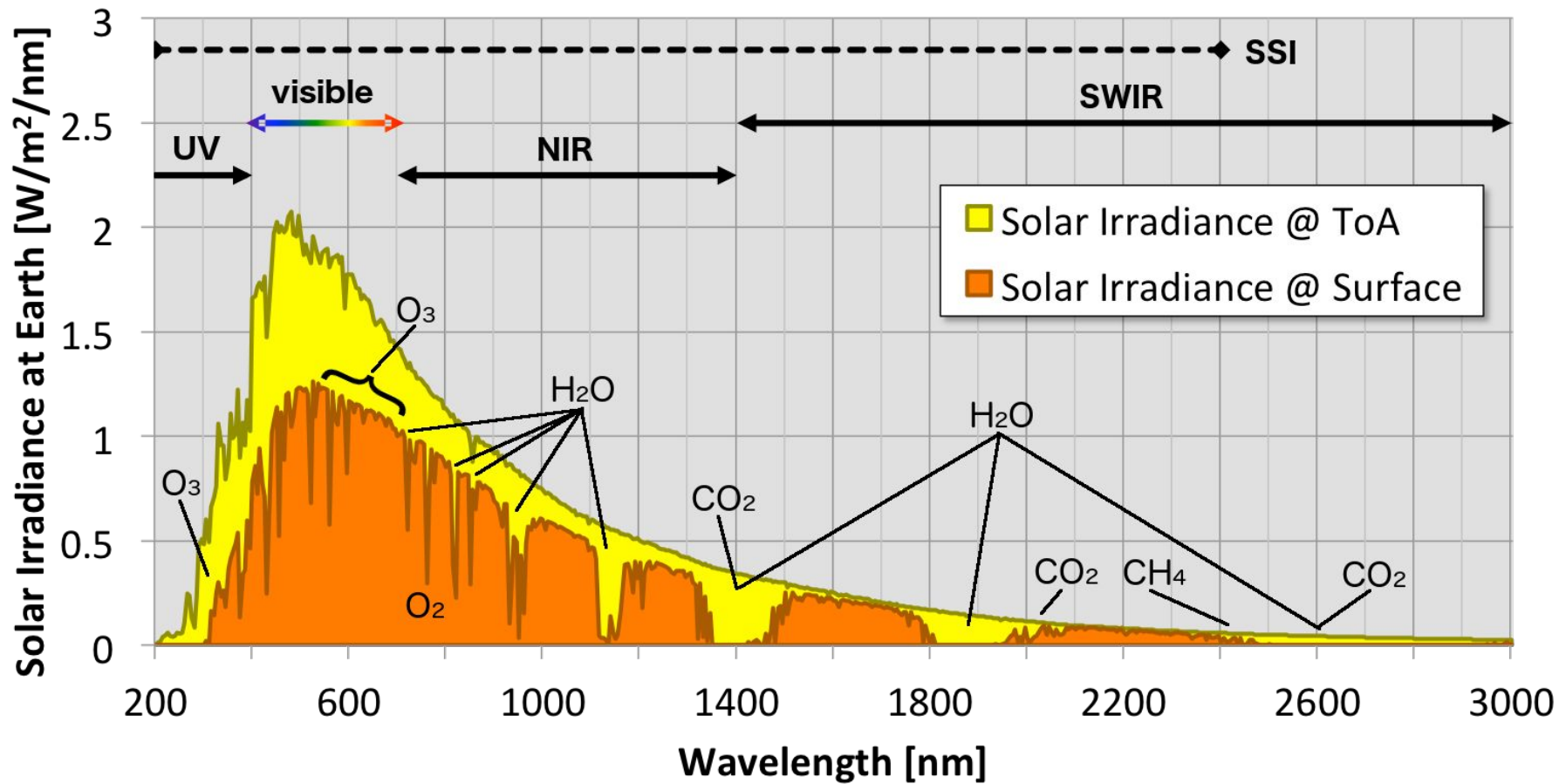


1500 to 20.000 °C



300 to 800 °C

Irradiancia Solar



Apparent
Temperature

\neq

Actual
Temperature



TOTAL

% emission

% transmission

% reflection

Reflected
Apparent
Temperature

$\epsilon < 1.0$

Apparent
Temperature

=

Actual
Temperature



100% emission



$\epsilon = 1.0$

Apparent
Temperature

\neq

Actual
Temperature



TOTAL

75% emission

25% reflection

Reflected
Apparent
Temperature

$\epsilon = 0.75$

Apparent
Temperature

<

Actual
Temperature
40°C



TOTAL

75% emission

25% reflection

Reflected
Apparent
Temperature
0°C

$\epsilon = 0.75$



Apparent
Temperature

>

Actual
Temperature
40°C



TOTAL

75% emission

25% reflection

Reflected
Apparent
Temperature
500°C

$\epsilon = 0.75$

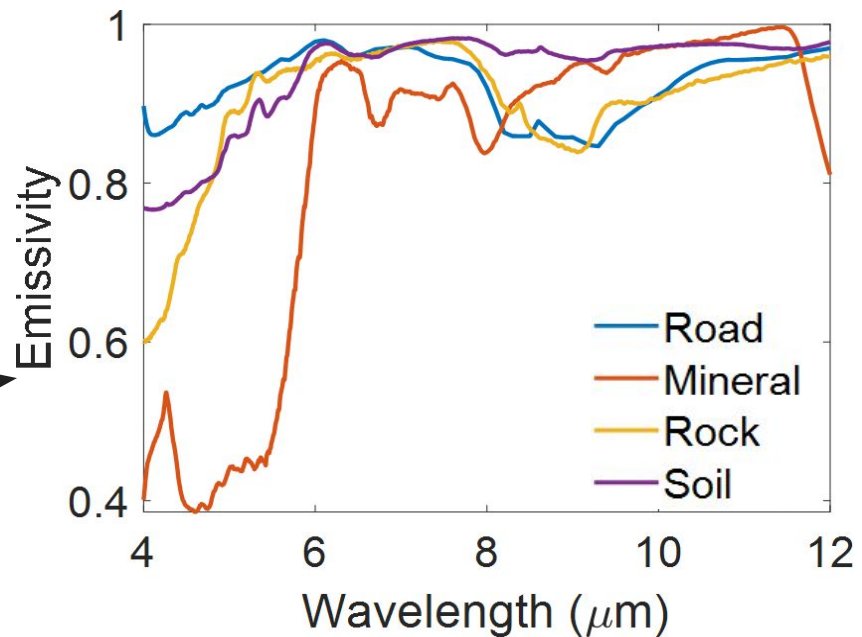
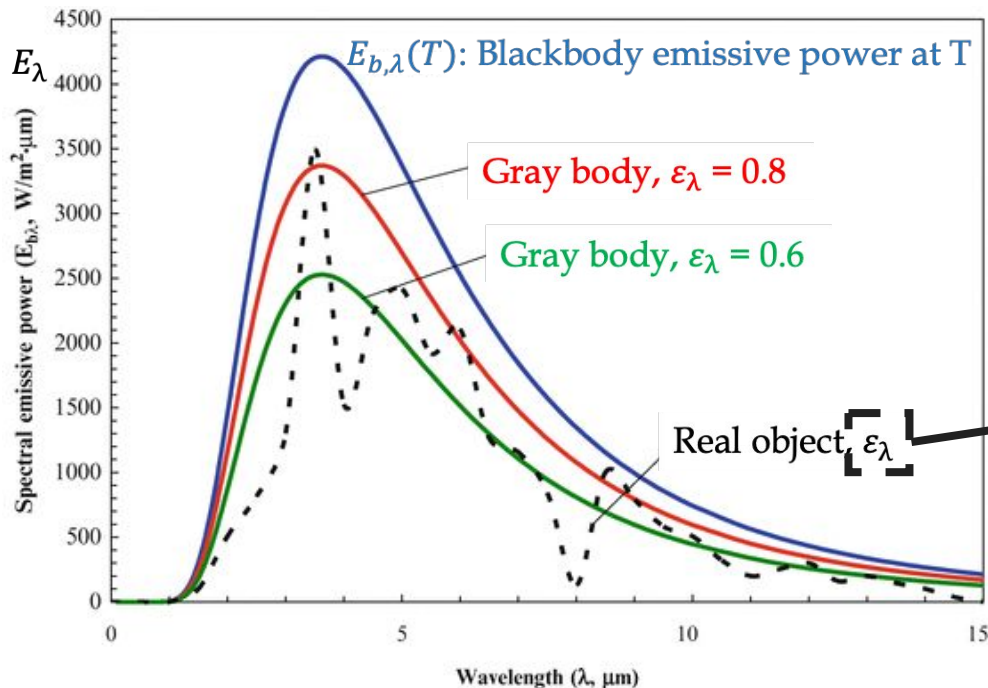
Emissivity de materiales comunes

Metal	Emissivity	Non-metal	Emissivity
Bare aluminum	0.02–0.4	Concrete (rough)	0.93–0.96
Gold	0.02–0.37	Glass	0.76–0.94
Copper	0.02–0.74	Wood	0.8–0.95
Lead	0.06–0.63	Carbon	0.96
Brass	0.03–0.61	Human skin	0.98
Nickel	0.05–0.46	Paper	0.7–0.95
Steel	0.07–0.85	Plastic	0.8–0.95
Tin	0.04–0.08	Rubber	0.86–0.94
Silver	0.01–0.07	Water	0.67–0.96
Zinc	0.02–0.28	Sand	0.76–0.9

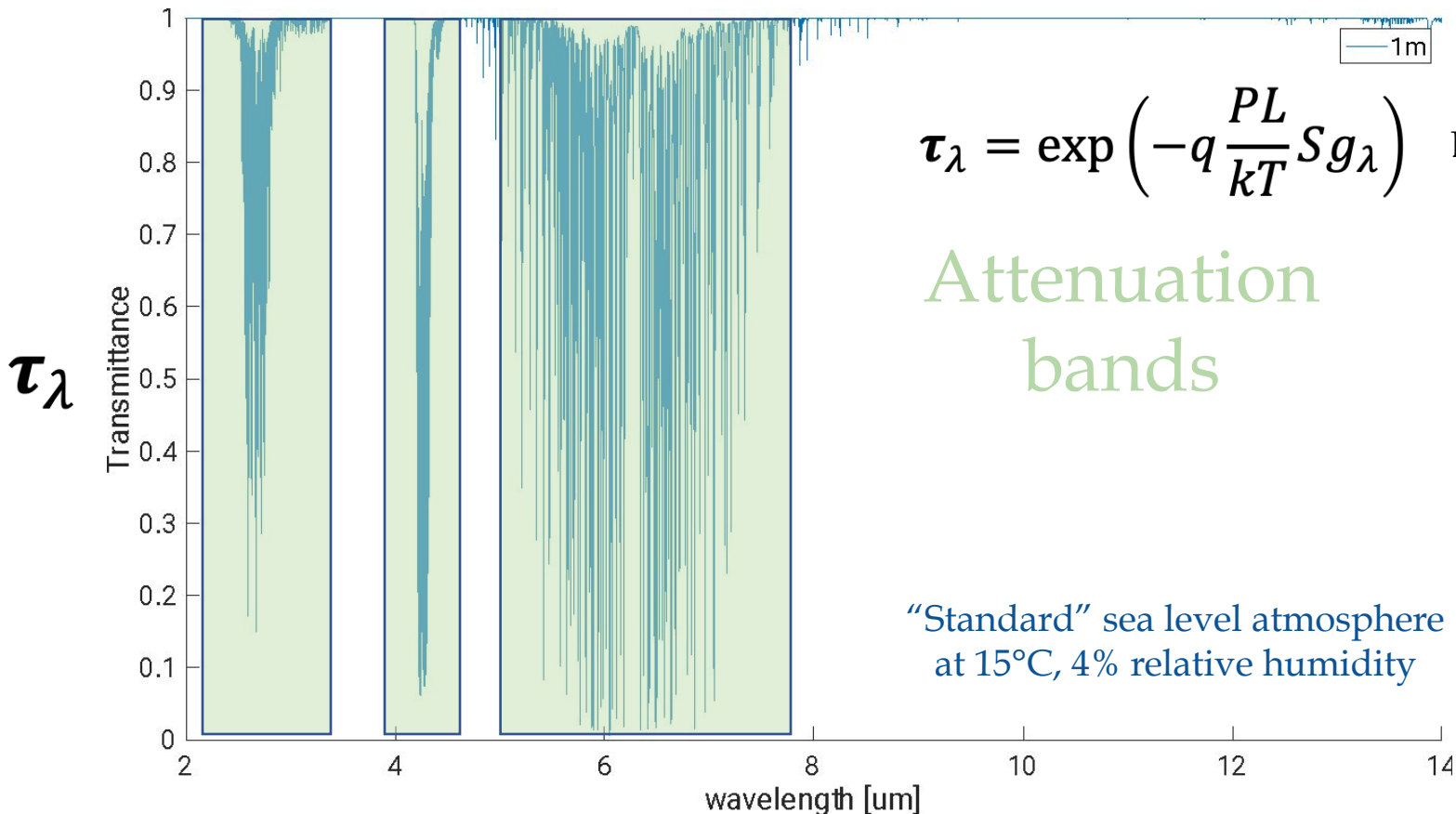
3. Imágenes Espectrales Térmicas

Emissivity depends on λ

$$E_{\lambda}(T) = \varepsilon_{\lambda} E_{b,\lambda}(T)$$



Atmospheric transmittance



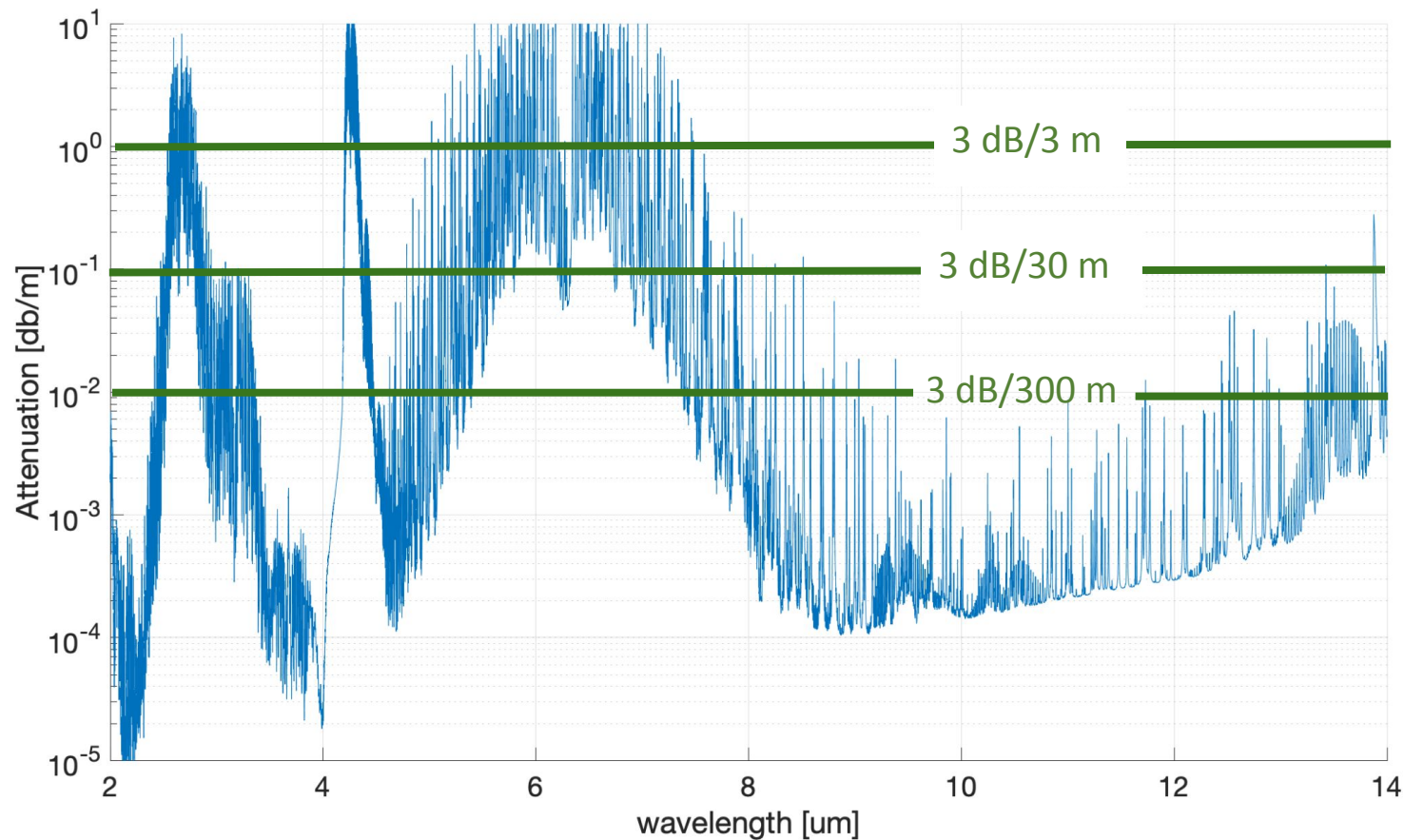
$$\tau_\lambda = \exp\left(-q \frac{PL}{kT} S g_\lambda\right) \quad \text{Beer-Lambert}$$

Attenuation
bands

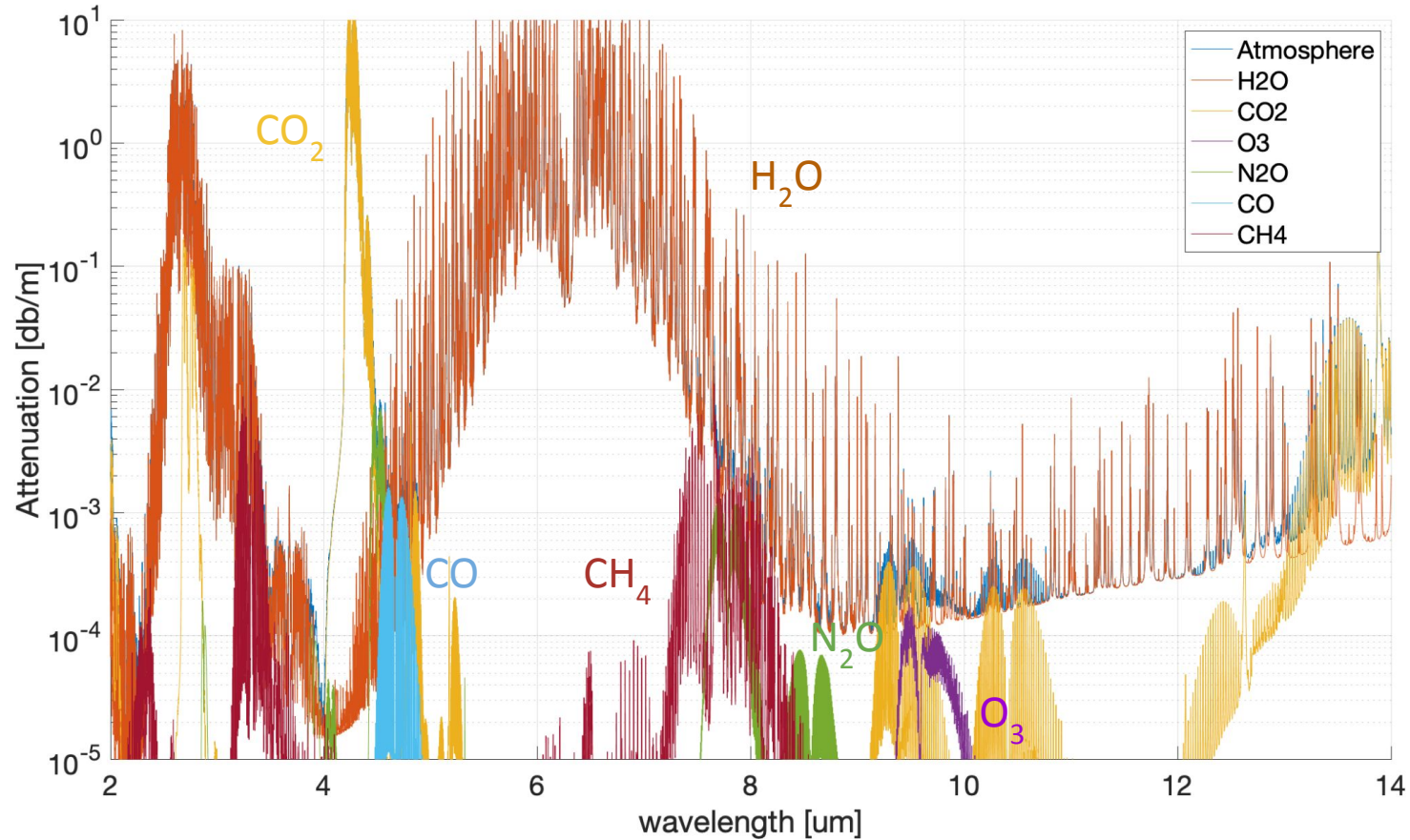


“Standard” sea level atmosphere
at 15°C, 4% relative humidity

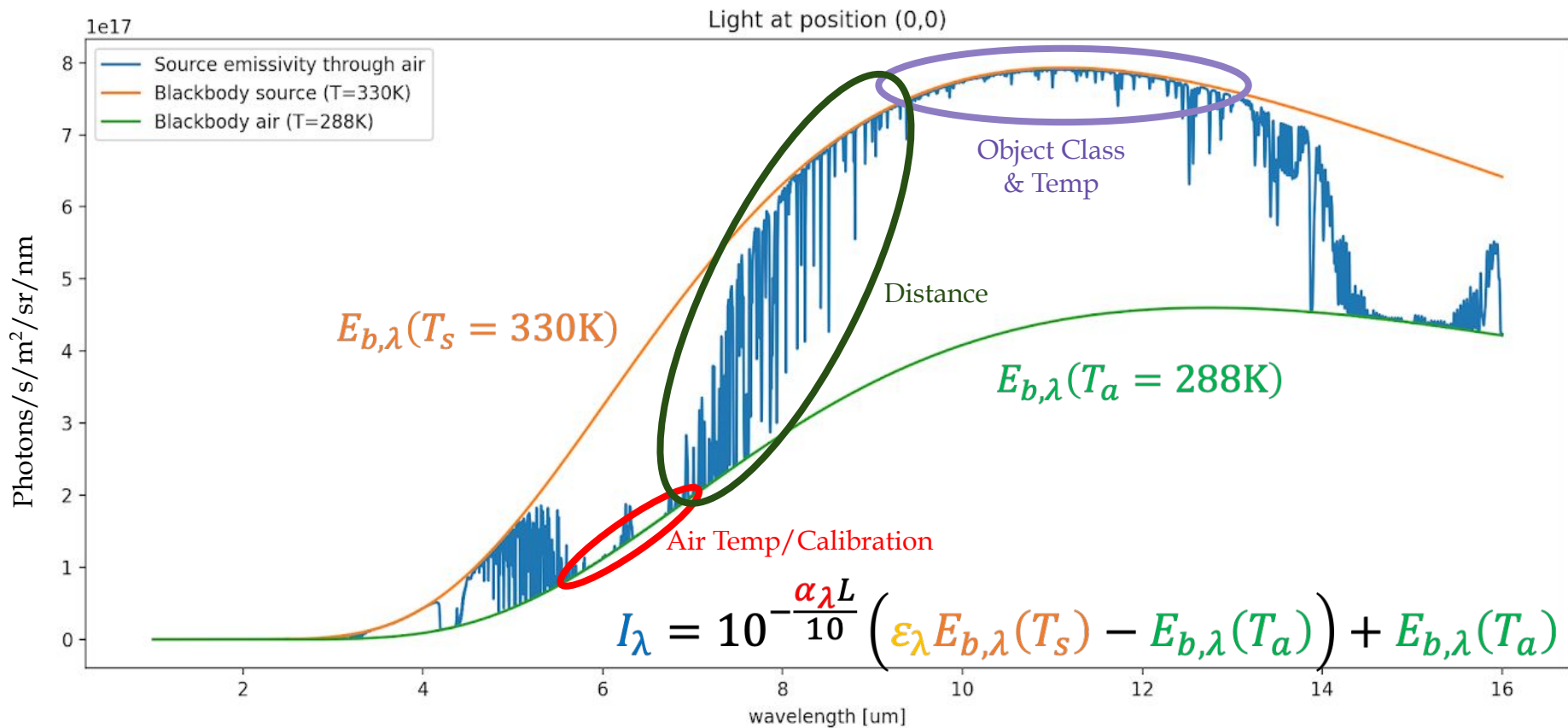
Atmospheric attenuation



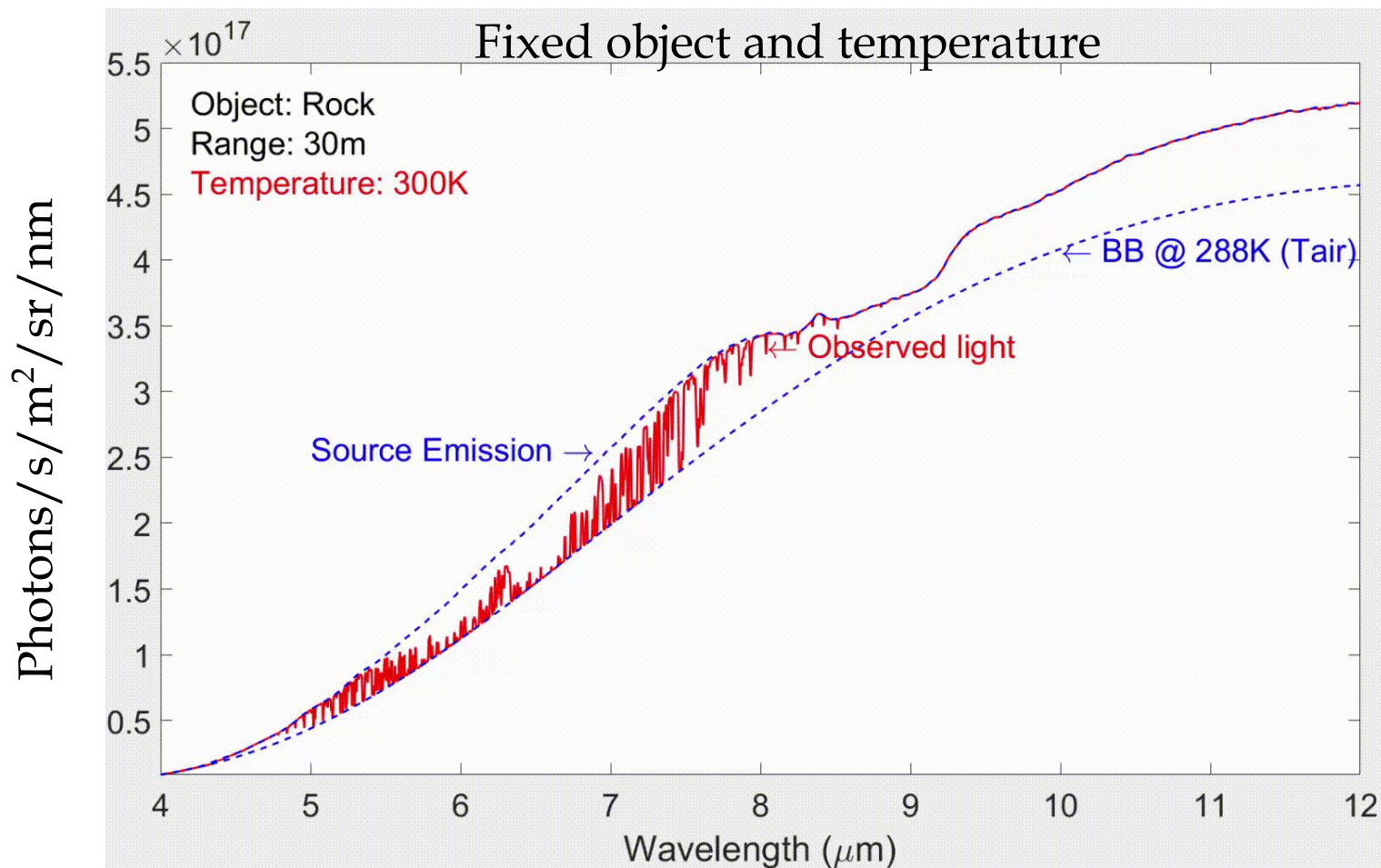
Atmospheric attenuation by gas composition



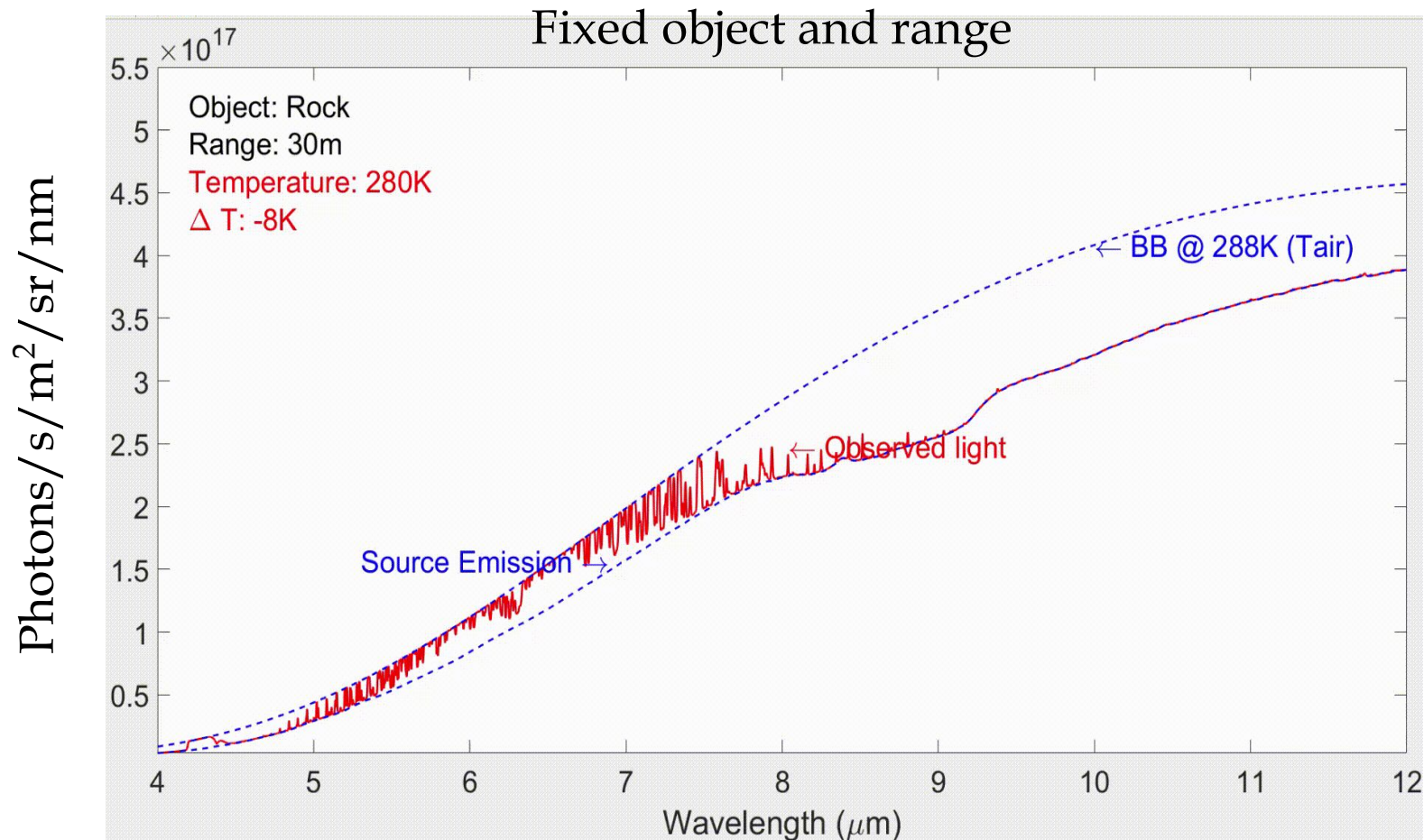
Emissivity through air



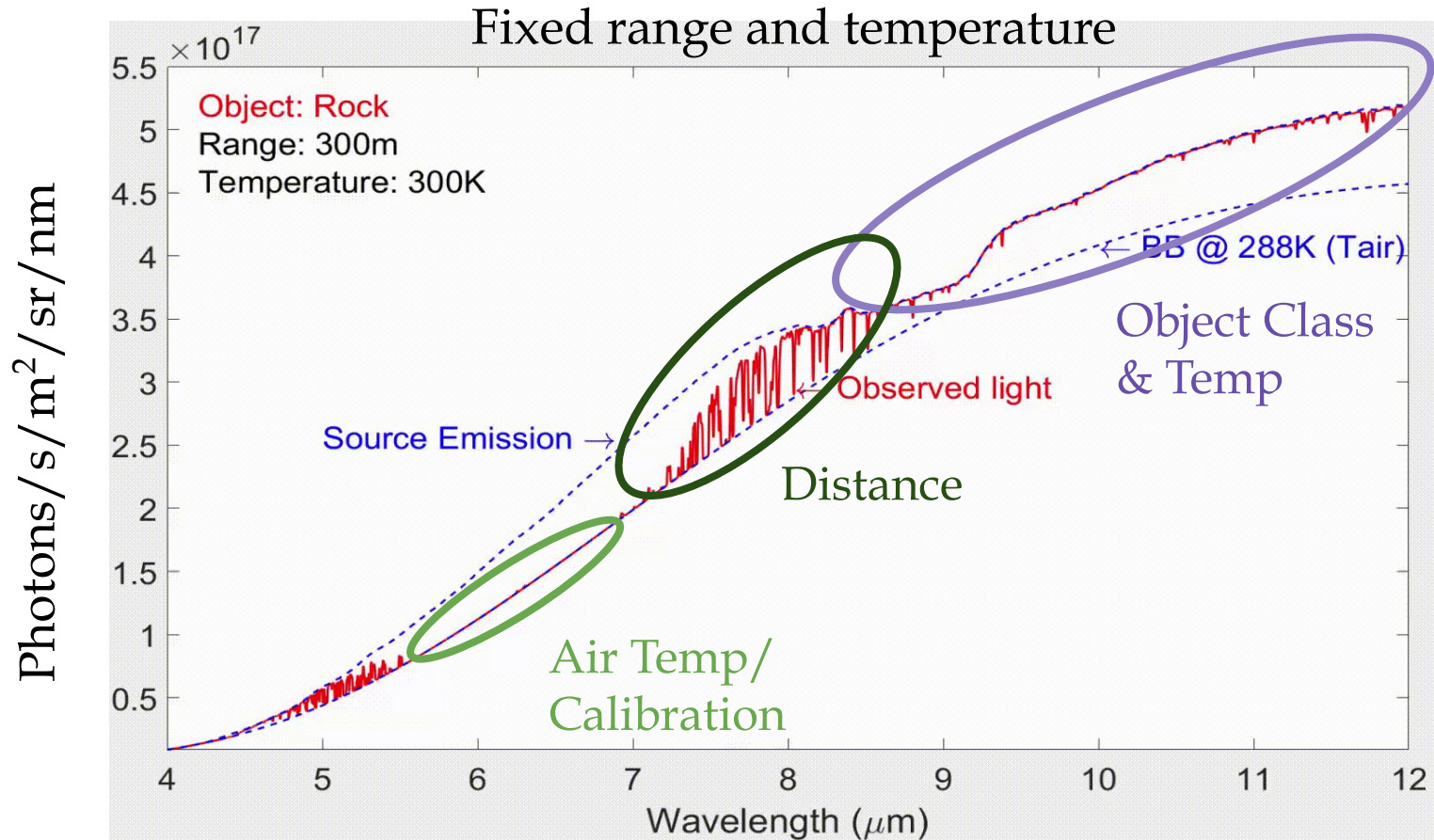
Range variation



Temperature variation



Emissivity variation



4. Thermal & CV

<https://www.nature.com/articles/s41586-023-06174-6>

The international journal of science / 27 July 2023

nature



NIGHT VISION

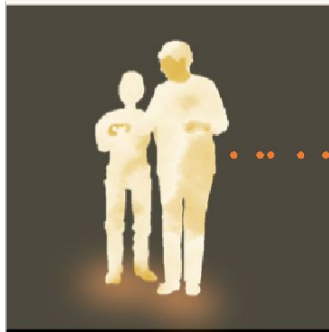
Thermal physics and AI combine to let machines see in the dark

- Turing point**
The hunt for better ways to test the intelligence of chatbots
- A place out of the sun**
Why planning for shade is key to keeping cool in hot cities
- Parasite restrained**
A sustainable way to tackle the snails behind schistosomiasis

Vol. 618, No. 7571
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TeX Vision: Temperature, emissivity, teXture

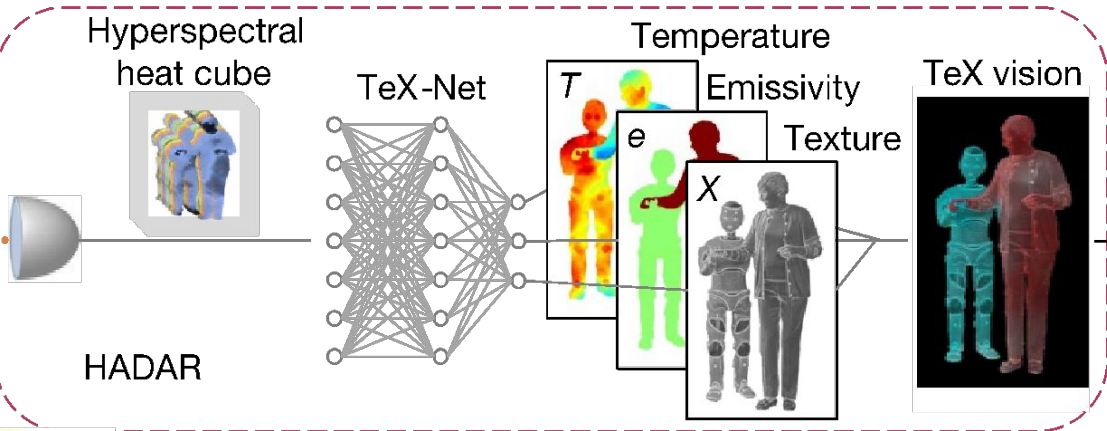
Ghosting effect
(TeX degeneracy)



Hyperspectral
heat cube



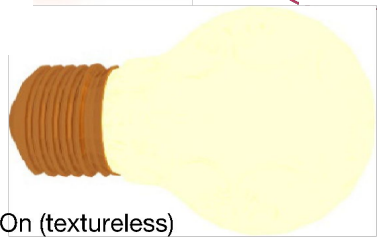
HADAR



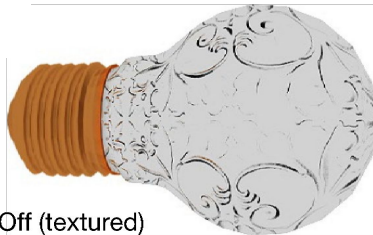
HADAR perception

Metallic
robot Human
body

Enhanced depth



On (textureless)



Off (textured)

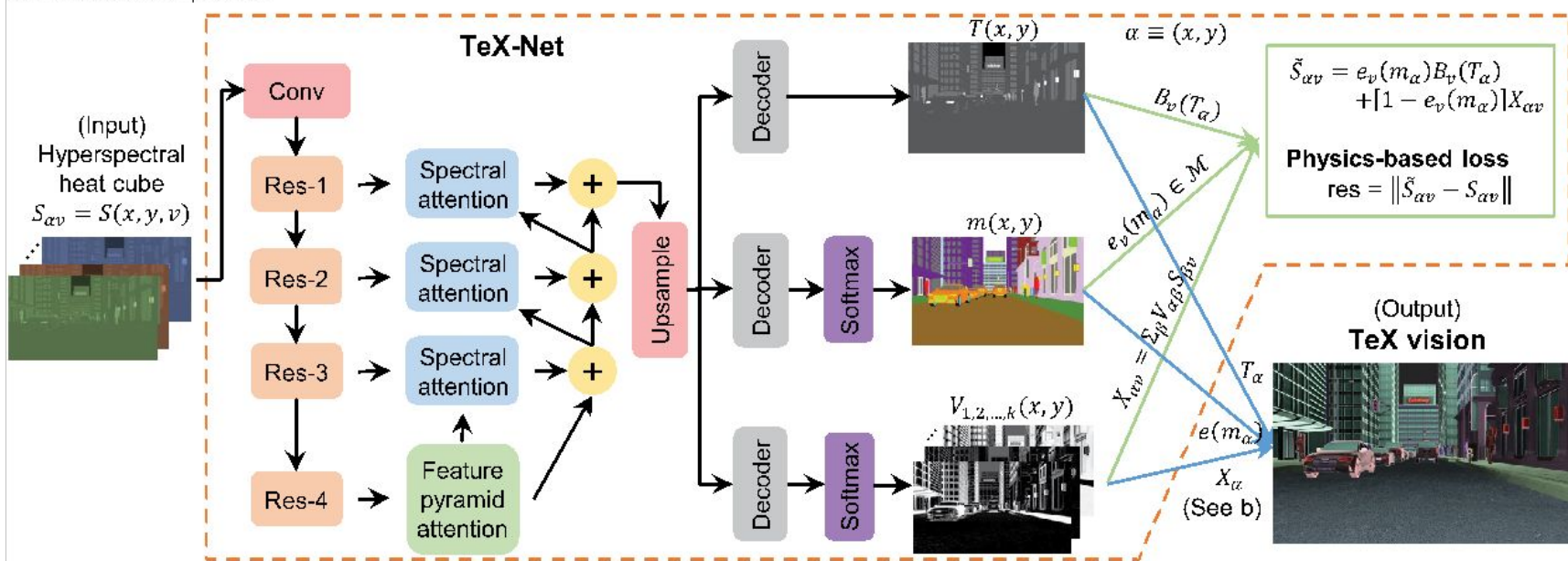
$$I_{\lambda} = 10^{-\frac{\alpha_{\lambda} L}{10}} \left(\varepsilon_{\lambda} E_{b,\lambda}(T_s) - E_{b,\lambda}(T_a) \right) + E_{b,\lambda}(T_a)$$

$$I_{\lambda} = 10^{-\frac{\alpha_{\lambda} L}{10}} \left(\varepsilon_{\lambda} E_{b,\lambda}(T_s) \right) + \left(1 - 10^{-\frac{\alpha_{\lambda} L}{10}} \right) E_{b,\lambda}(T_a)$$

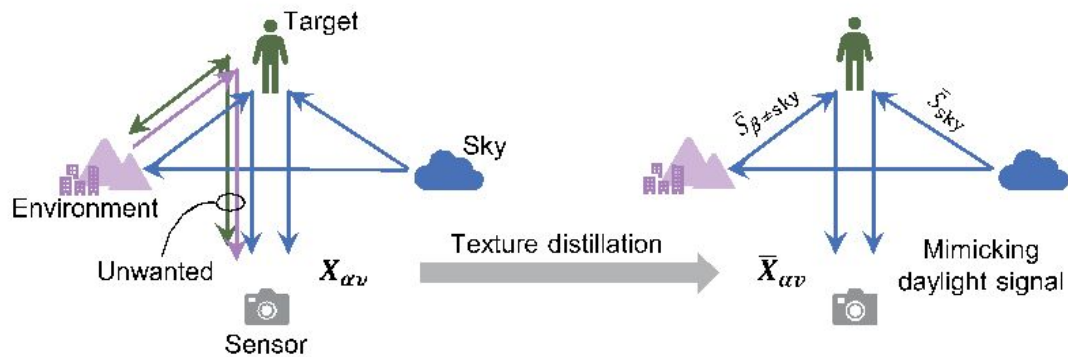
$$S_{\alpha v} = e_{\alpha v} B_v(T_{\alpha}) + [1 - e_{\alpha v}] X_{\alpha v}$$

TeX-Net

a Inverse decomposition



b Forward rendering

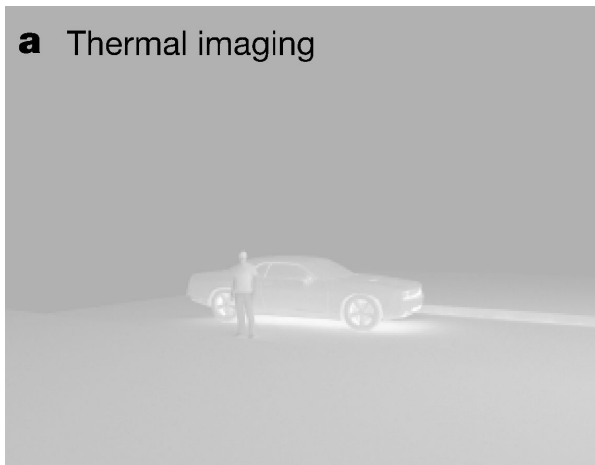


Forward texture distillation procedures:

- (1) $\bar{S}_{\gamma v} \equiv \begin{cases} S_{\beta v | \beta = \gamma}, & \gamma = \text{sky} \\ 0, & \text{otherwise} \end{cases}$
- (2) $\bar{S}_{\beta v} \equiv [1 - e_v(m_\beta)] \cdot \Sigma_\gamma V_{\beta \gamma} \bar{S}_{\gamma v}, \quad \beta \neq \text{sky}$
- (3) $\bar{X}_{\alpha v} \equiv \Sigma_\beta V_{\alpha \beta} \bar{S}_{\beta v}$
- (4) $X_\alpha \equiv \Sigma_v \bar{X}_{\alpha v} \oplus \text{res}$

HADAR: Fundamental limits in ranging

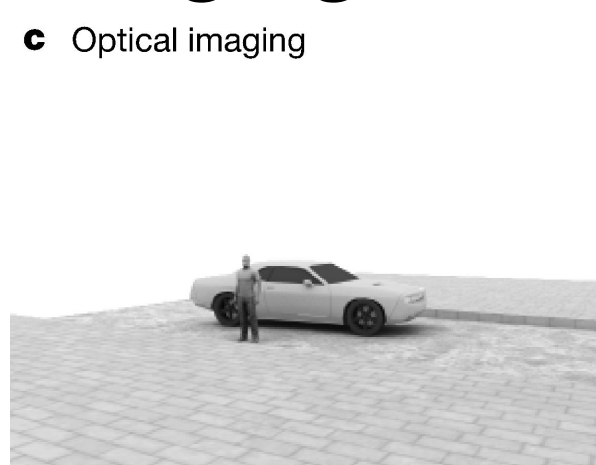
a Thermal imaging



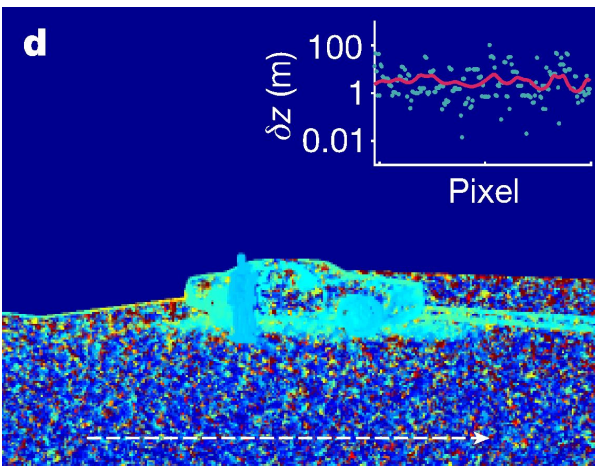
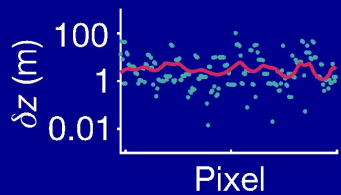
b HADAR



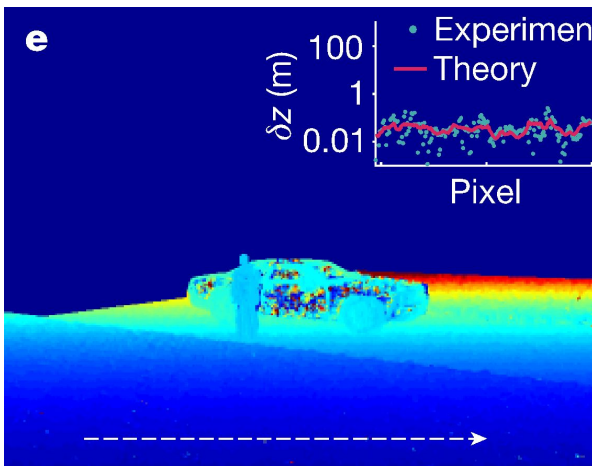
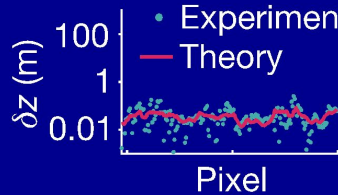
c Optical imaging



d

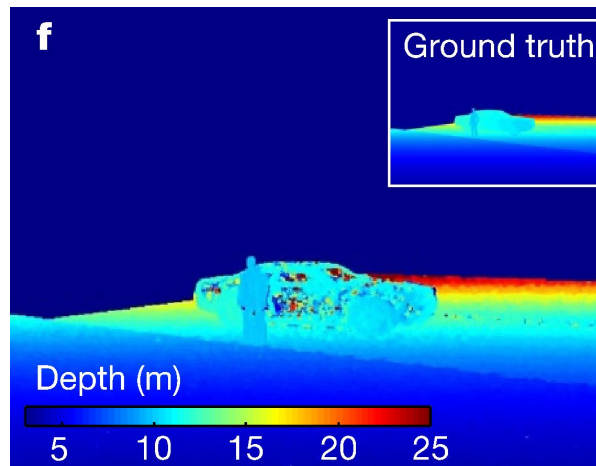


e

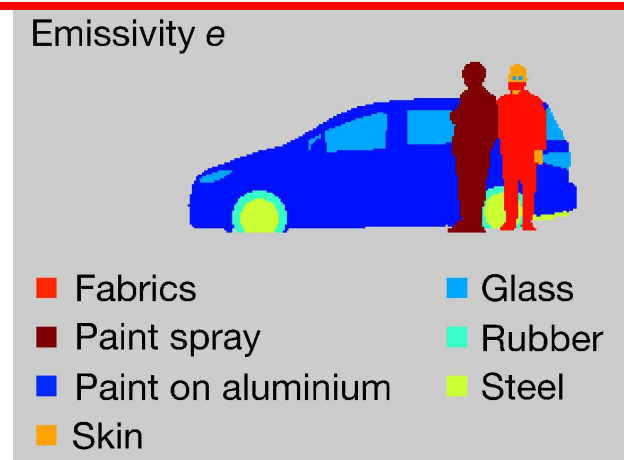
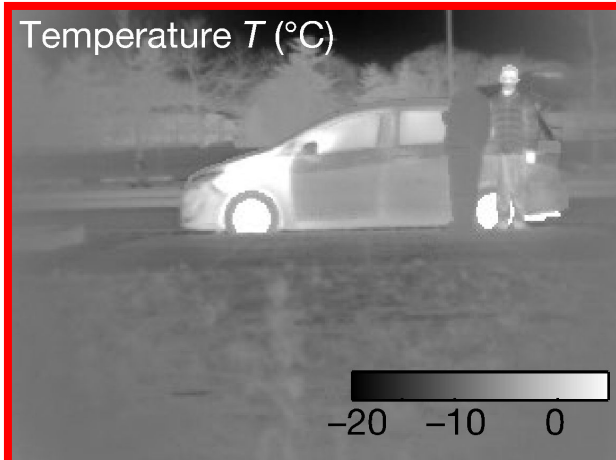
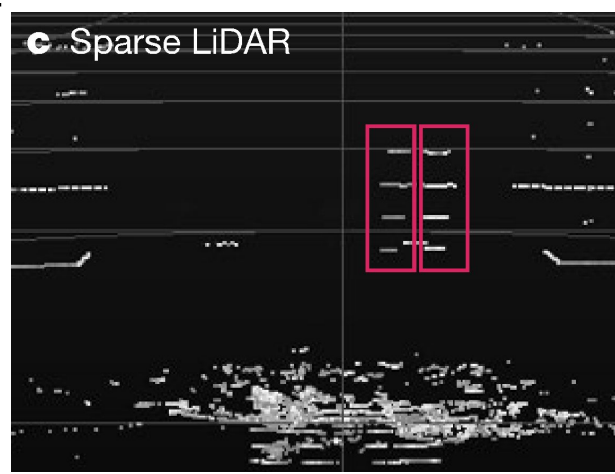
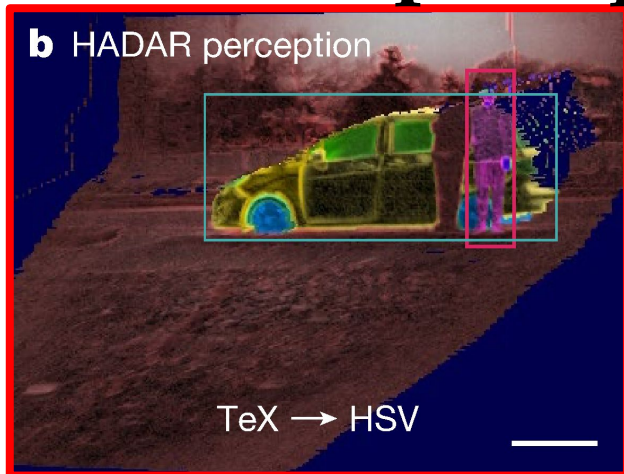
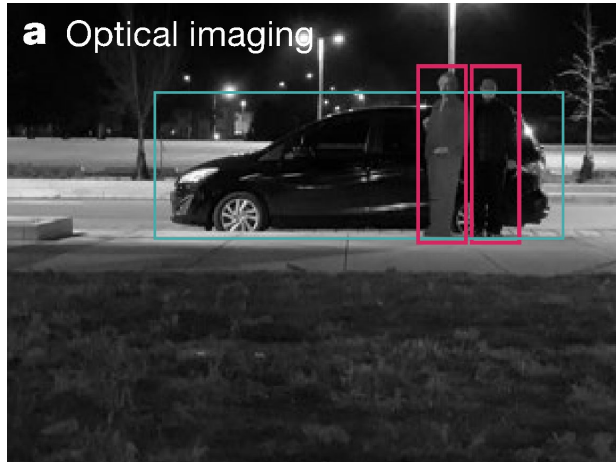


f

Ground truth



HADAR: Physics-driven perception



Thermal Semantic Segment.

(DANet)

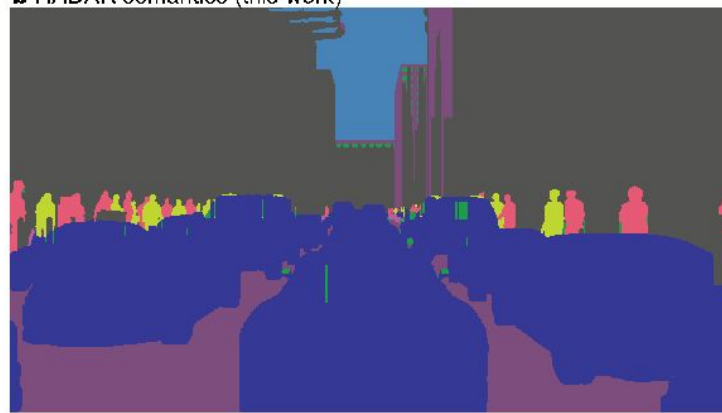
Fu, J. et al. in *CVPR*
3146–3154, 2019.

mIoU:
pixelwise mean
intersection
over union.

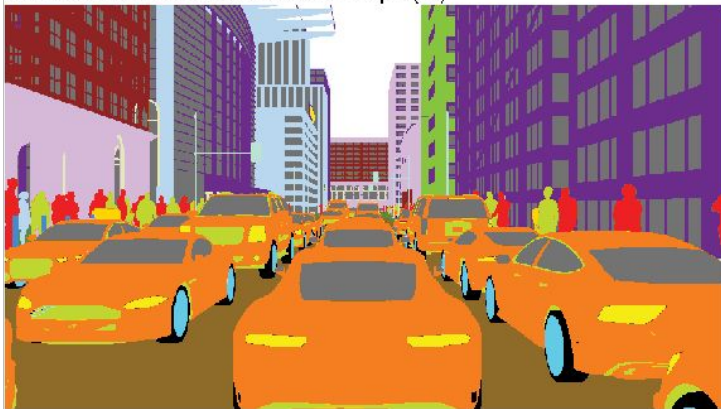
a Thermal vision + AI (state-of-the-art)



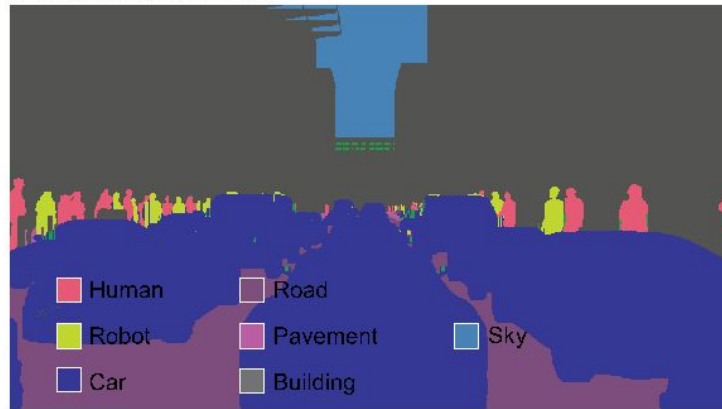
b HADAR semantics (this work)



c Ground truth HADAR material map e(m)



d Ground truth semantics



mIoU %	Human	Robot	Car	Road	Pavement	Building	Sky
Thermal vision + AI	33	0	90	67	25	69	16
TeX vision + non-AI	94	84	98	92	87	84	90

09-25-2022 Sun 05:43:22



Grill Temp: 451° F

Tri Tip 1	Sausage 1
Start: 05:40PM	Start: 05:41 PM
Duration: 02m:53s	Duration: 01m:30s
Temp: 261.4° F	Temp: 253.2° F

Tri Tip 2	Sausage 2
Start: 05:40PM	Start: 05:41 PM
Duration: 02m:53s	Duration: 01m:30s
Temp: 262.0° F	Temp: 254.1° F

Tri Tip 3	Sausage 3
Start: 05:40PM	Start: 05:41 PM
Duration: 02m:47s	Duration: 01m:30s
Temp: 261.5° F	Temp: 253.6° F

Sausage 4
Start: 05:41 PM
Duration: 01m:30s
Temp: 263.8° F

Car

PLAINSIGHT

Navigation



person 97.65%

person 98.82%



vehicle

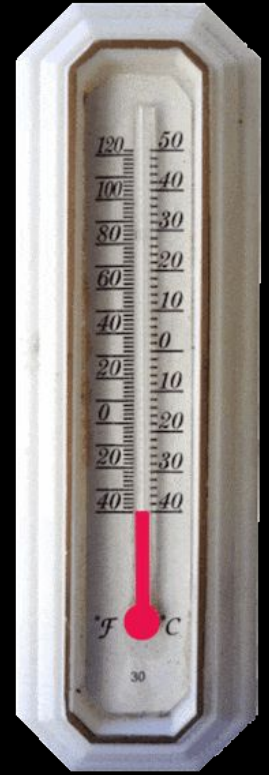
vehicle vehicle eh vehicle

ve vehicle v vehicle cle vehicle

vehicle

person person

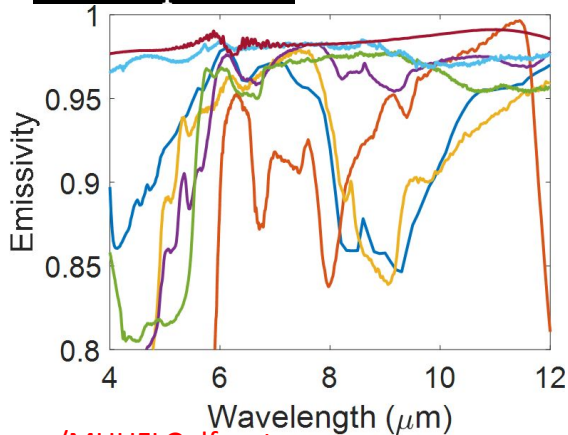
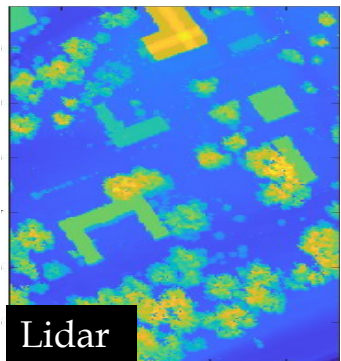
5. Hands-on: Thermal Imaging



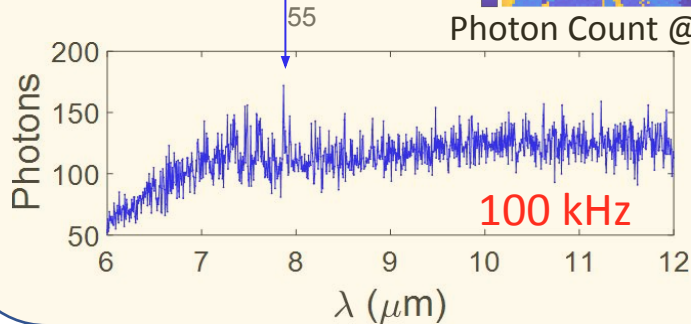
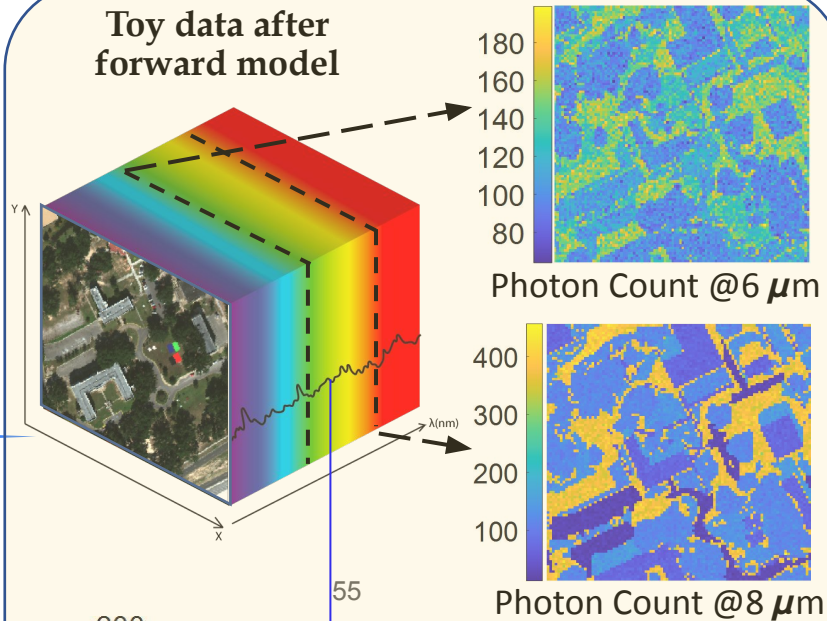
Computational image formation and analysis



- unlabeled points
- trees
- mostly grass
- mixed ground surface
- dirt/sand
- road
- water
- building shadow
- buildings
- sidewalk
- yellow curb
- cloth panels



Toy data after forward model



Actualicemos el repositorio!

main

1 Branch 0 Tags

Go to file

t

Add file

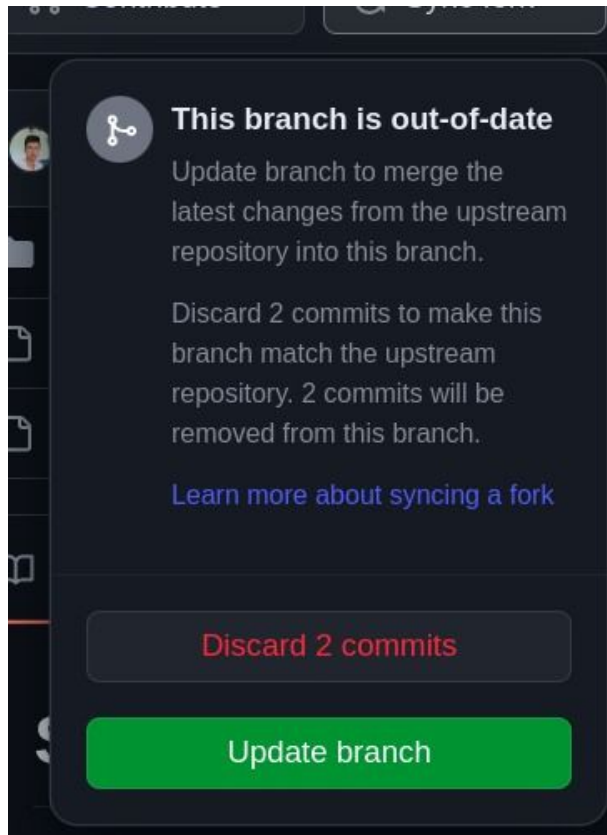
Code

This branch is 2 commits ahead of, 3 commits behind `semilleroCV/Hands-on-Computer-Vision:main`.

Contribute

Sync fork

Actualicemos el repositorio!



Actualicemos el repositorio!

main

1 Branch 0 Tags

Go to file

t

Add file

Code

This branch is 2 commits ahead of, 3 commits behind `semilleroCV/Hands-on-Computer-Vision:main`.

Contribute

Sync fork