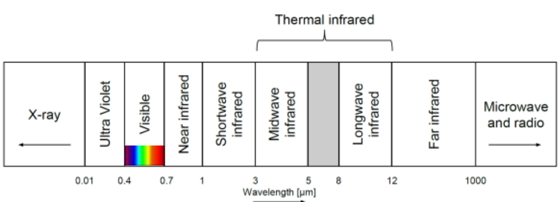
Thermal and Multispectral Imaging

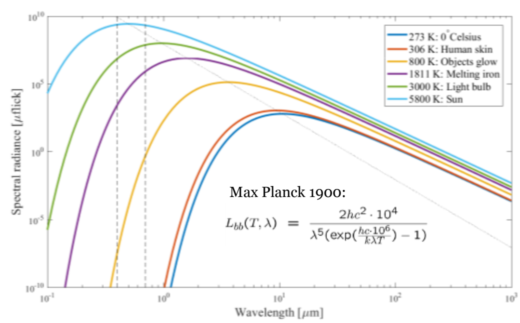
Lecture 4: Thermal analysis

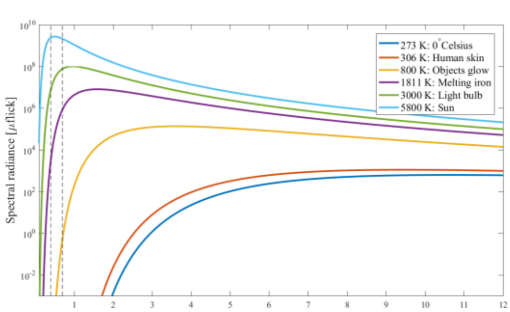
Jörgen Ahlberg

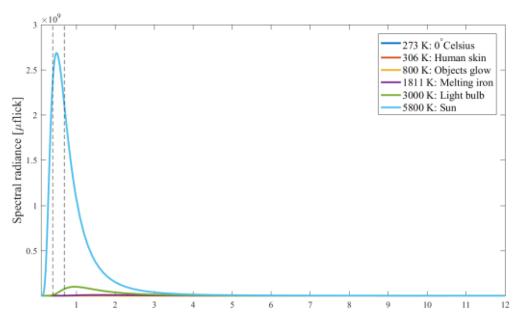
Repetition of some concepts from Lecture 1-3

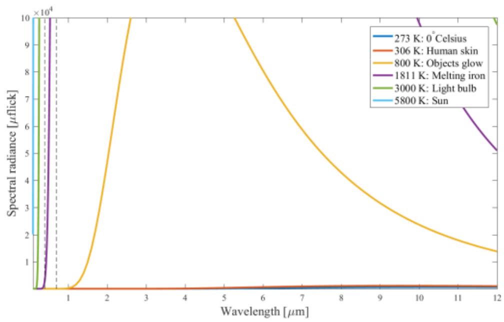
Domains and wavelengths and bands



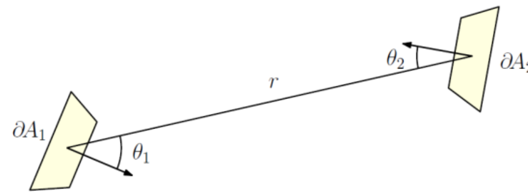




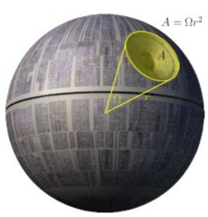




Radiative transfer

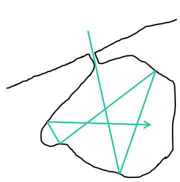


Rymdvinkel

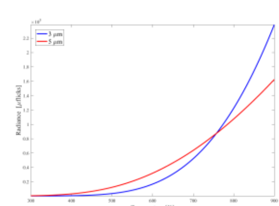


Temperature measurement

Svartkroppskavitet



Band radiance as a function of temperature



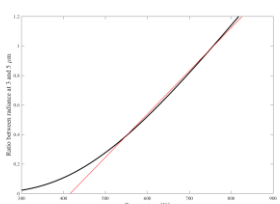
Problems

- Reflected radiation
- Unknown emissivity
- Emissivity varies with temperature
- Emissivity varies with wavelength

Apparent / equivalent temperature

$$\int_0^\infty R_\lambda B_\lambda(\lambda, T^*)\partial\lambda = \int_0^\infty R_\lambda \varepsilon_\lambda B_\lambda(\lambda, T^{\text{obj}})\partial\lambda + \int_0^\infty R_\lambda \rho_\lambda B_\lambda(\lambda, T^{\downarrow})\partial\lambda$$

Radiance ratio



Temperature-Emissivity Separation (TES)

Tarbet-Background Contast

Bacground and target radiance

$$\begin{aligned} L^{\text{bg}}(\varepsilon^{\text{bg}}, T^{\text{bg}}) &= \varepsilon^{\text{bg}} B(T^{\text{bg}}) + (1-\varepsilon^{\text{bg}})L^{\downarrow} \\ &= \varepsilon^{\text{bg}} B(T^{\text{bg}}) + \rho^{\text{bg}} L^{\downarrow} \\ L^{\text{tg}}(\varepsilon^{\text{tg}}, T^{\text{tg}}) &= \varepsilon^{\text{tg}} B(T^{\text{tg}}) + (1-\varepsilon^{\text{tg}})L^{\downarrow} \\ &= \varepsilon^{\text{tg}} B(T^{\text{tg}}) + \rho^{\text{tg}} L^{\downarrow} \end{aligned}$$

Path radiance

$$L^{\uparrow}(r,T) \quad = \quad (1-\tau(r))B(T^{\uparrow})$$

Target / background irradiance on sensor

If a target is *not* present, the irradiance on the sensor element is

$$E_{\lambda}^{\mathrm{bg}} \quad = \quad \frac{\Omega}{\pi}\cdot[\,\tau(r_{\mathrm{bg}})\cdot L^{\mathrm{bg}}(\varepsilon^{\mathrm{bg}},T^{\mathrm{bg}})+L^{\uparrow}(r_{\mathrm{bg}},T^{\uparrow\mathrm{bg}})\,]$$

With suitable assumptions (1)

$$\begin{aligned}\Delta E &= \int_{\lambda}(\,E_{\lambda}^{\mathrm{tg}}-E_{\lambda}^{\mathrm{bg}}\,)\partial\lambda \\ &= \frac{A}{\pi r^2}\cdot\tau(r)\cdot\int_{\lambda}(\,\varepsilon^{\mathrm{tg}}B_{\lambda}(T^{\mathrm{tg}})+\rho^{\mathrm{tg}}L^{\downarrow}-\varepsilon^{\mathrm{bg}}B_{\lambda}(T^{\mathrm{bg}})-\rho^{\mathrm{bg}}L^{\downarrow}\,)\partial\lambda \\ &= \frac{A}{\pi r^2}\cdot\tau(r)\cdot(\,B(T^{*\mathrm{tg}})-B(T^{*\mathrm{bg}})\,)\end{aligned}$$

With suitable assumptions (2)

$$\Delta E \quad = \quad \frac{A}{\pi r^2}\cdot\tau^{r}\cdot(\,B(T^{*\mathrm{tg}})-B(T^{*\mathrm{bg}})\,)$$

Conclusions

$$\Delta E \quad = \quad \frac{A}{\pi r^2}\cdot\tau^{r}\cdot(\,B(T^{*\mathrm{tg}})-B(T^{*\mathrm{bg}})\,)$$

- The target detection capacity increases linearly with the target area
- The target detection capacity decreases quadratically with the distance
- When the visibility is bad (τ 6≈ 1), target detection capacity decreases quickly with distance.
- The target detection capacity decreases linearly with the difference in apparent temperature between target and background.
- Low-emissivity targets are generally more difficult to detect.

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