

>>> **Introduction to hyperspectral remote sensing imagery**
>>> **GRSS Summer School**

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Date: [2017-04-26 Wed 08:30]–[2017-04-26 Wed 10:00]

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2. Hyperspectral imagery

Element of physics

Digital remote sensing images

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3. Current challenges in hyperspectral

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- ★ Associated to the **DYNAFOR** lab
- ★ IEEE GRSS:
 - ★ Senior Member
 - ★ Member of the *GRSS Chapter Committee*
 - ★ IEEE JSTARS Associated Editor

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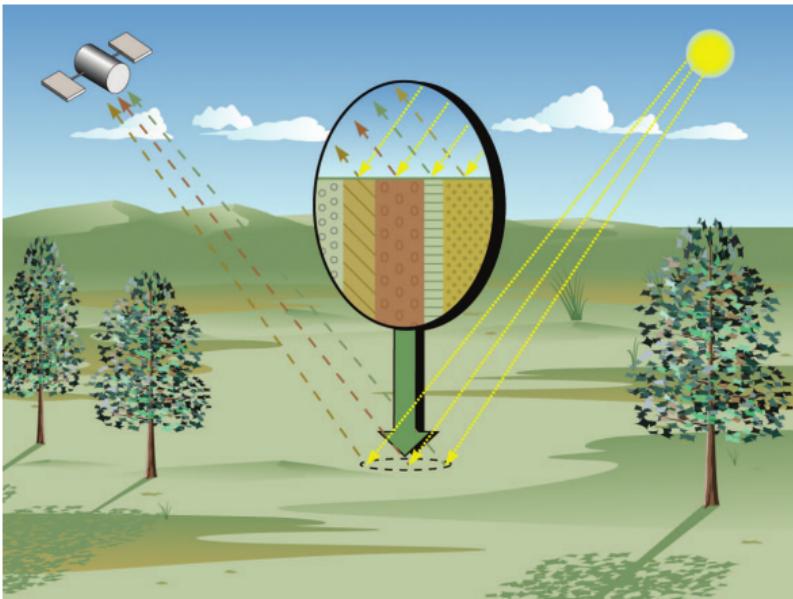
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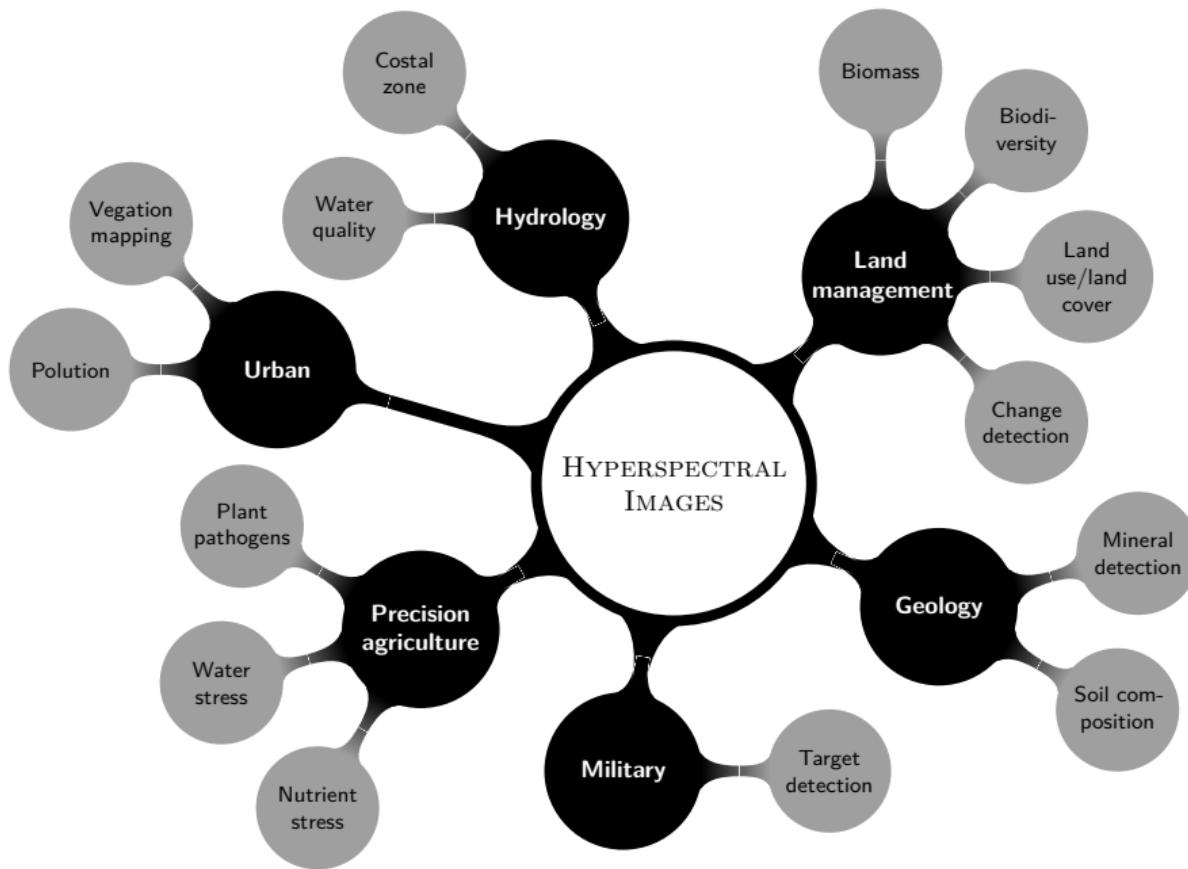
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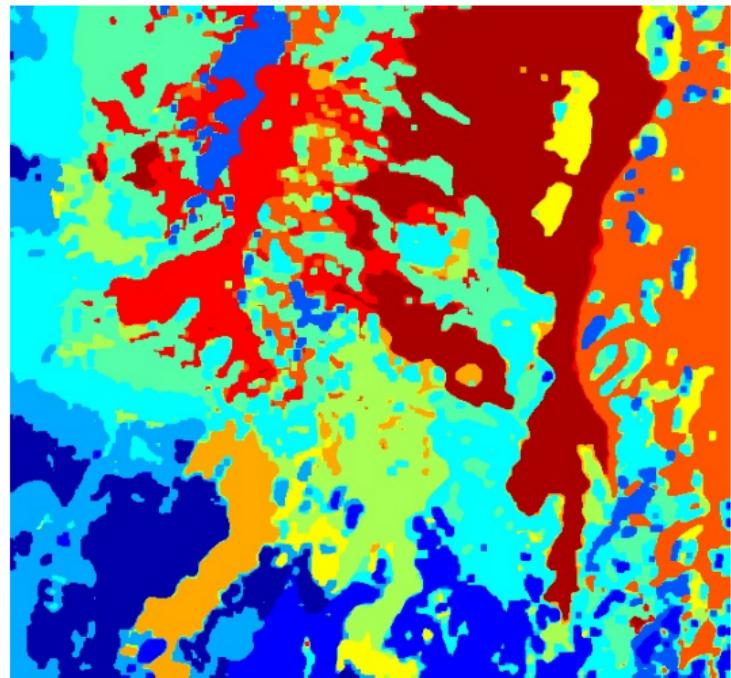
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- ★ Remote sensing provides information about landscapes.
- ★ This information is carried out by the *electromagnetic energy* and is usually formed in terms of *digital image data*.
- ★ This information can be used
 - ★ To *update* and to *supervise* landscapes in known areas,
 - ★ To *get prior* information about landscapes of unknown areas.

Image taken from [KM02].





Classes

Lava 1970, Lava 1980 I, Lava 1980 II, Lava 1991 I, Lava 1991 II, Lava moss cover, hyaloclastite formation, Tephra lava, Rhyolite, Scoria, Firn-glacier ice, Snow.

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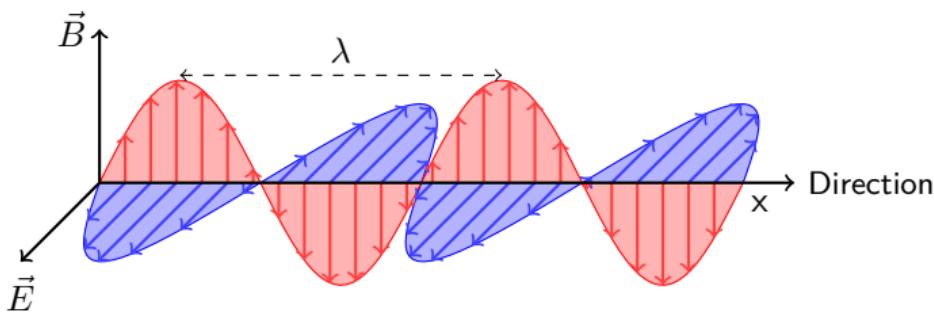
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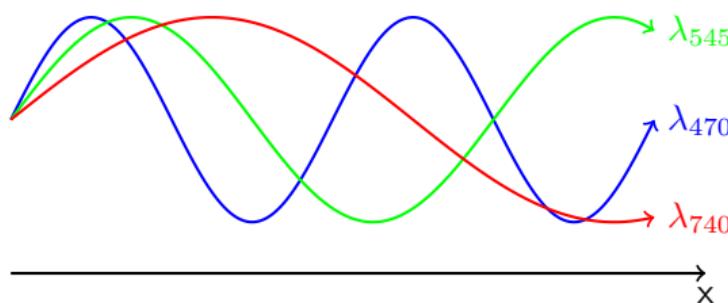
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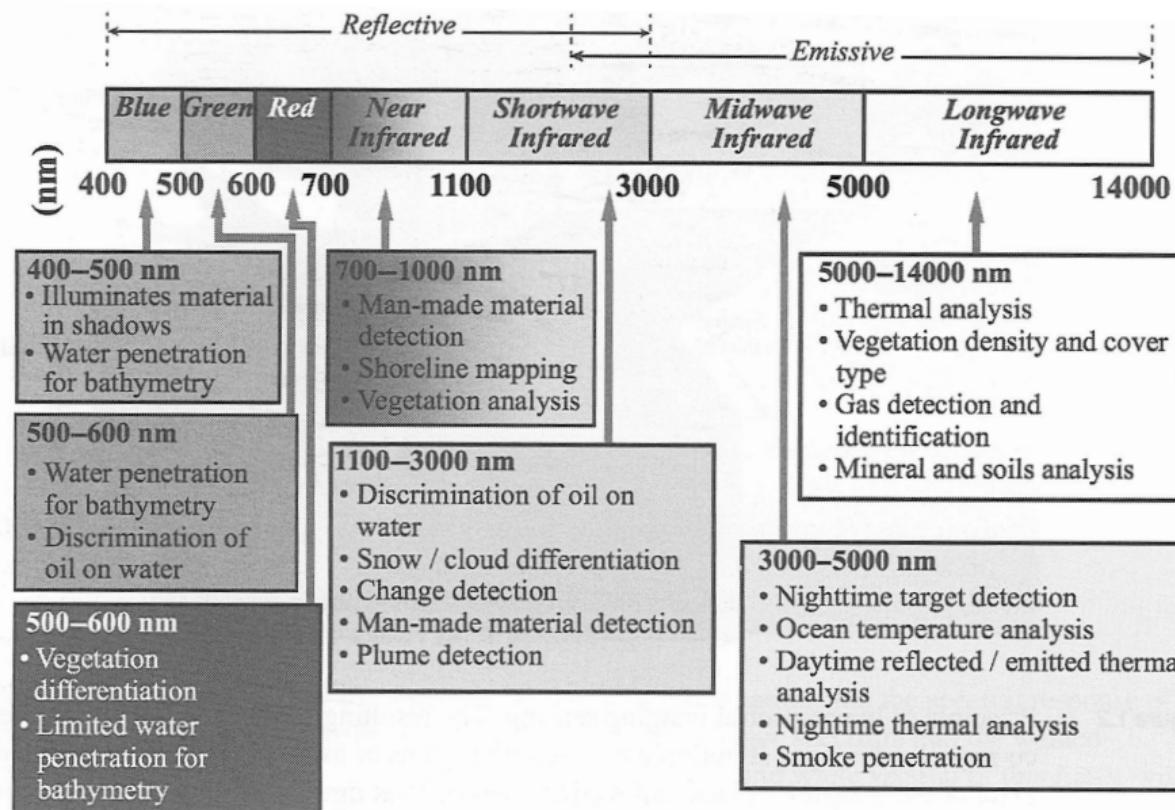
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- ★ An electromagnetic wave is a perturbation of the electric and magnetic field which propagates through space.
- ★ \vec{E} : Electric field. \vec{B} : Magnetic field.
- ★ **Wavelength (λ)**: Minimal distance between 2 points of the space for which \vec{E} and \vec{B} recover the same values.

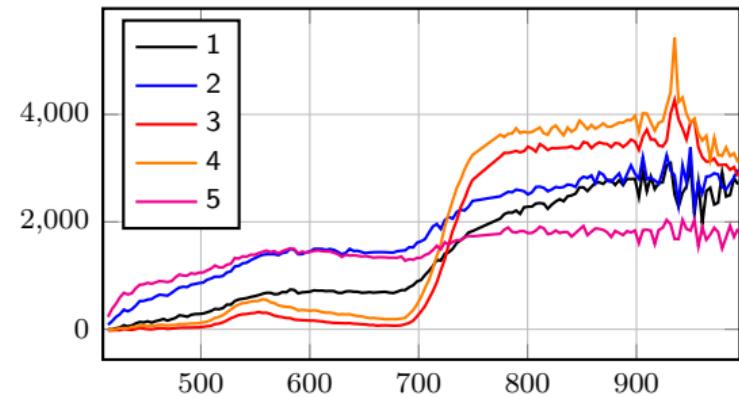




From [MLC16].

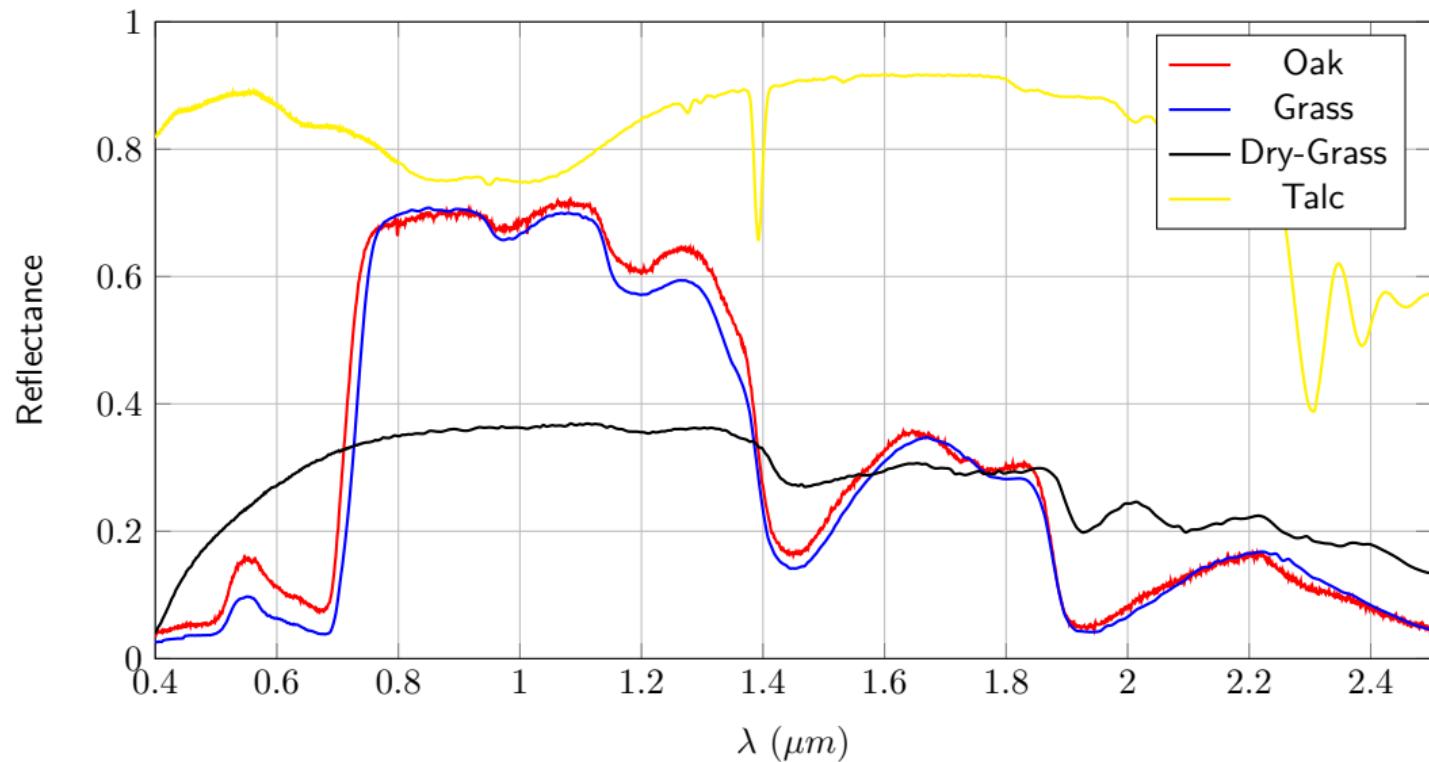
Reflectance:

- ★ Capacity of a given surface to reflect the incident light,
- ★ It is specific to each material.



>>> Spectral reflectance curves

Spectral reflectance curves or spectral signature: Radiometric identity card



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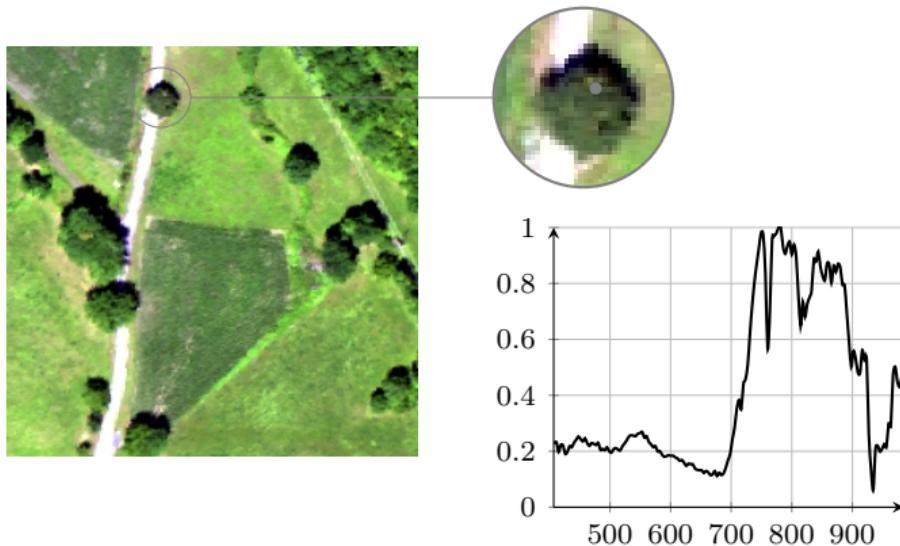
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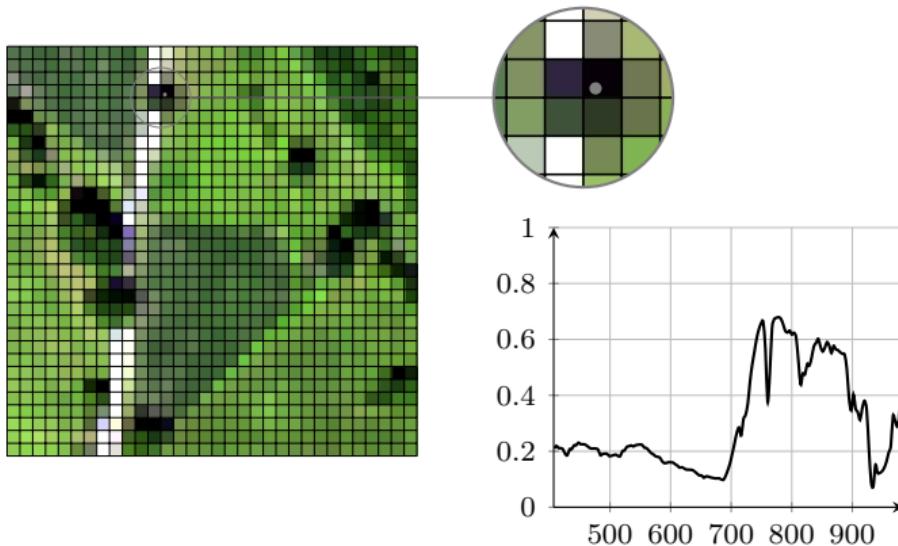
>>> Remote sensing images

A remote sensing image is a sampling of a spatial, spectral and temporal process.



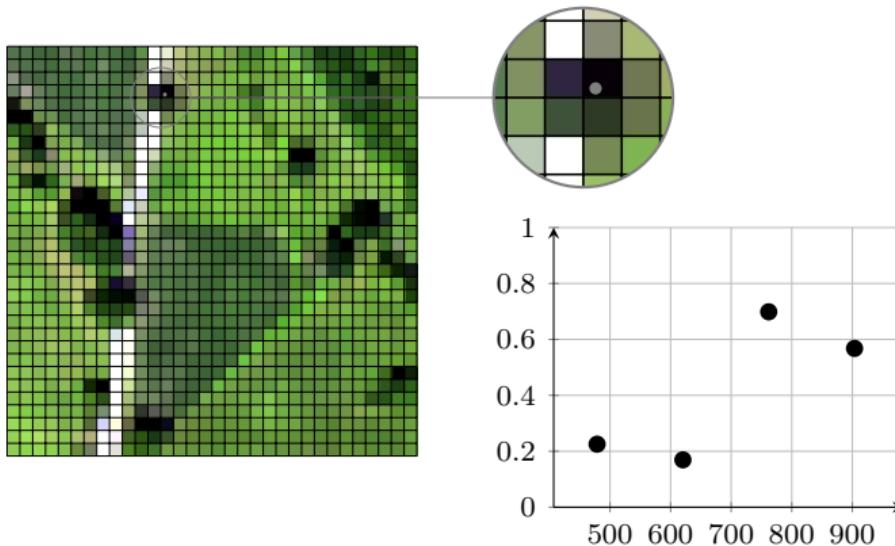
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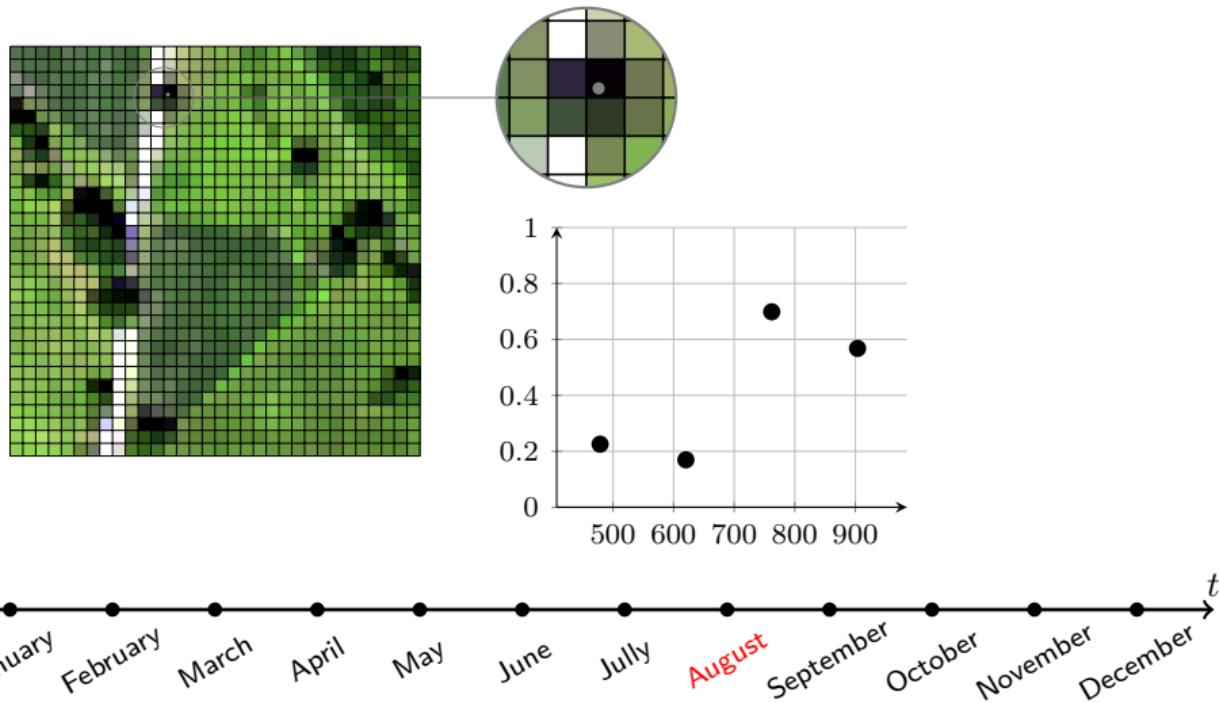
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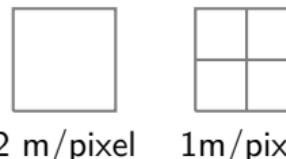
>>> Remote sensing images

A remote sensing image is a sampling of a spatial, spectral and temporal process.



>>> Characteristics of remote sensing images

- * Spatial resolution: *Ability to distinguish two closed objects.*



- * Radiometric resolution: *Smallest difference in intensity that the sensor can record.*

Coding	Quantification	Exemple:
8 bits	256	7
16 bits	65536	6.67

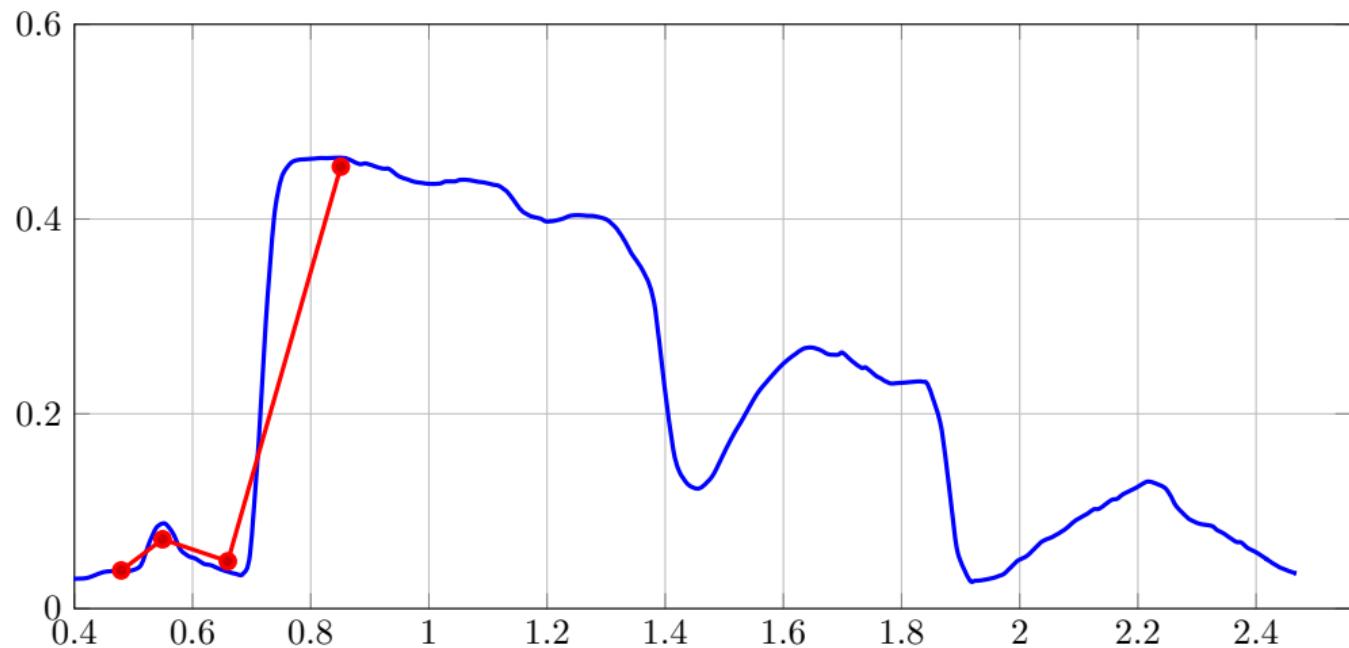
- * Spectral resolution: *Width of each band of the spectrum that can be collected.*

Image Type	Number of bands
Panchromatic	1
Multispectral	~ 10
Hyperspectral	> 100
Ultraspectral	> 100

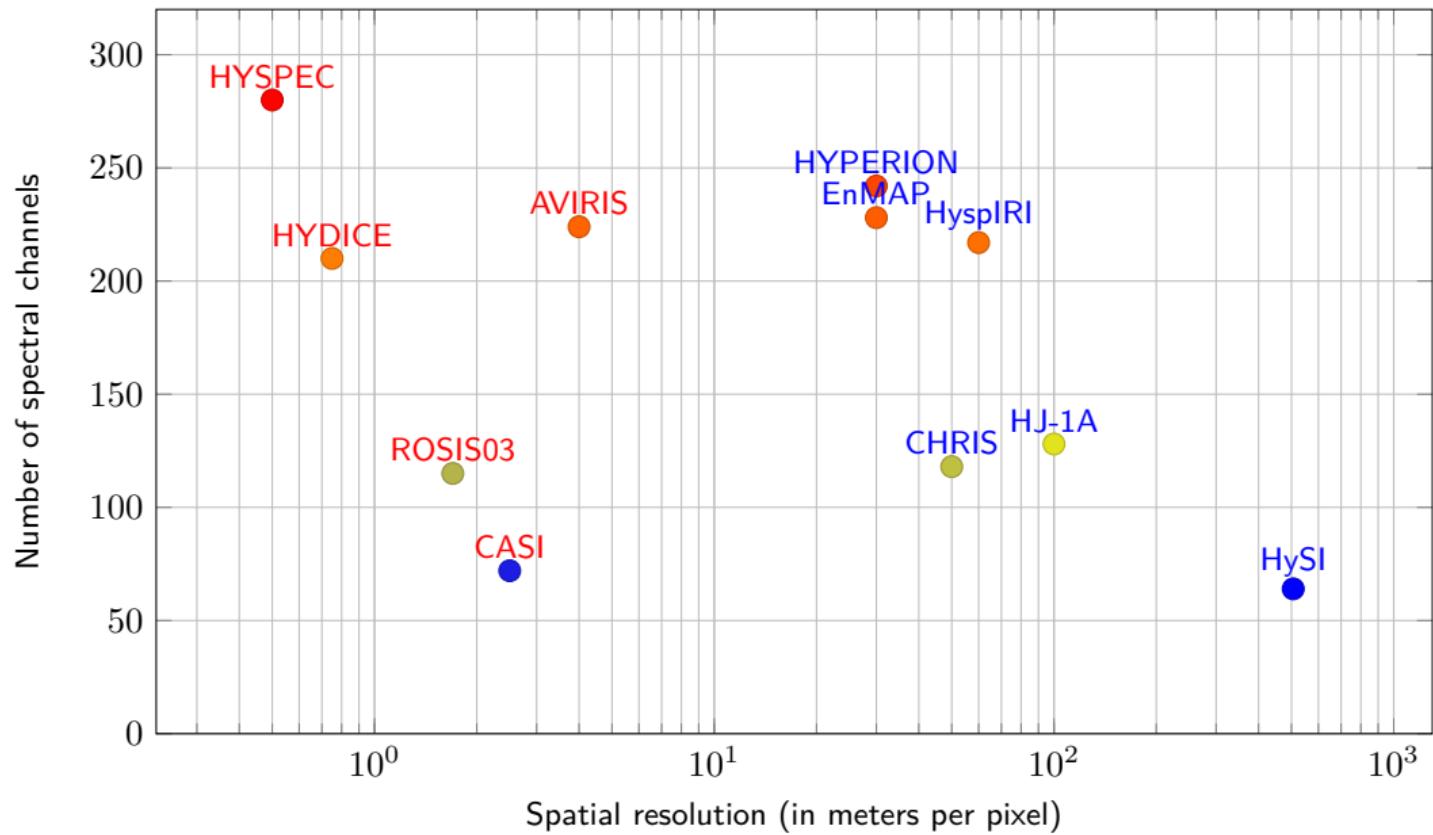
- * Spatial and spectral resolution are linked: difficult to have high spatial *and* spectral resolution at the same time.

>>> Multispectral versus hyperspectral

Pleiade versus Hypsim



>>> Hyperspectral sensors



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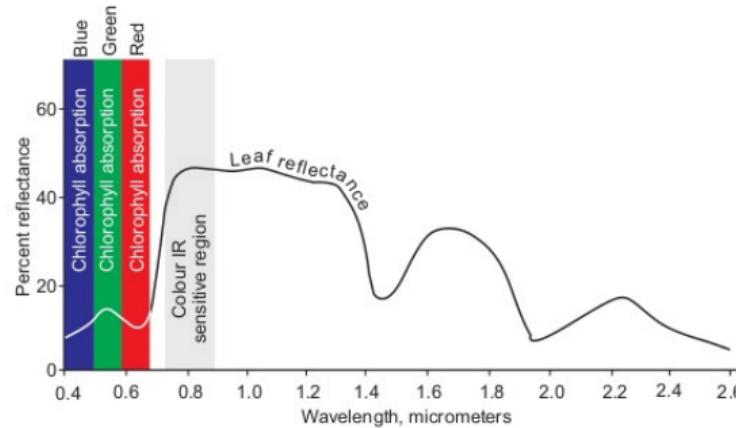
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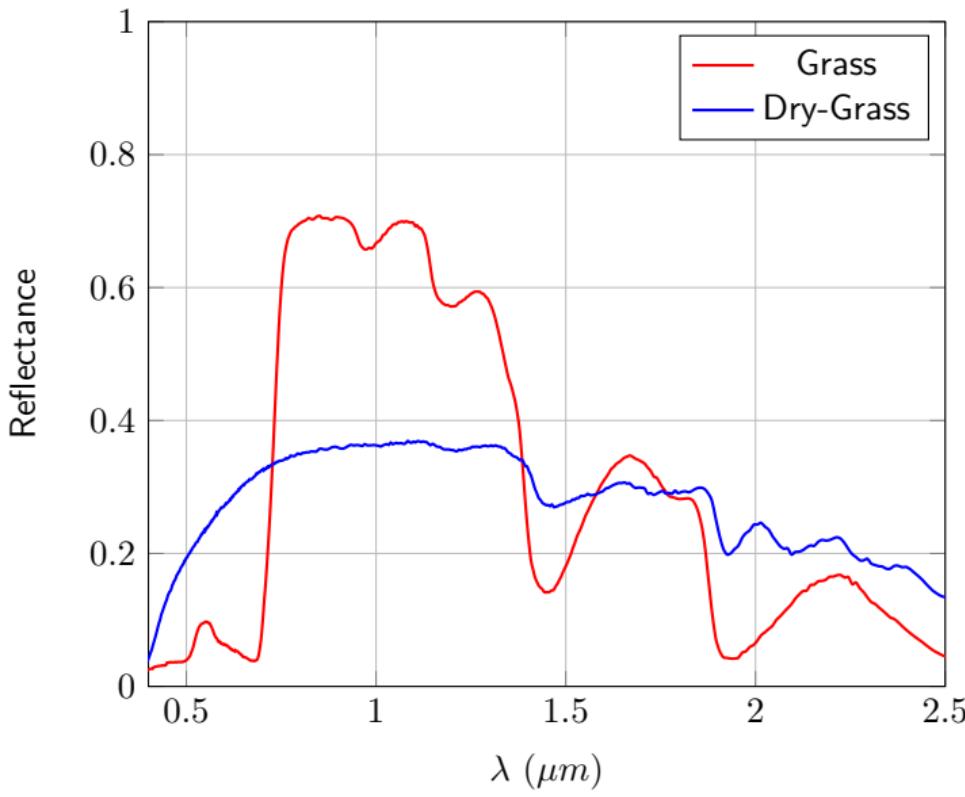
Healthy vegetation (high photosynthesis)

- ★ Absorption in *blue* and *red* domain,
- ★ *Visible to near infrared*: increase of the reflectance,
- ★ *Mid infrared*: depends on the free water in the leafs.

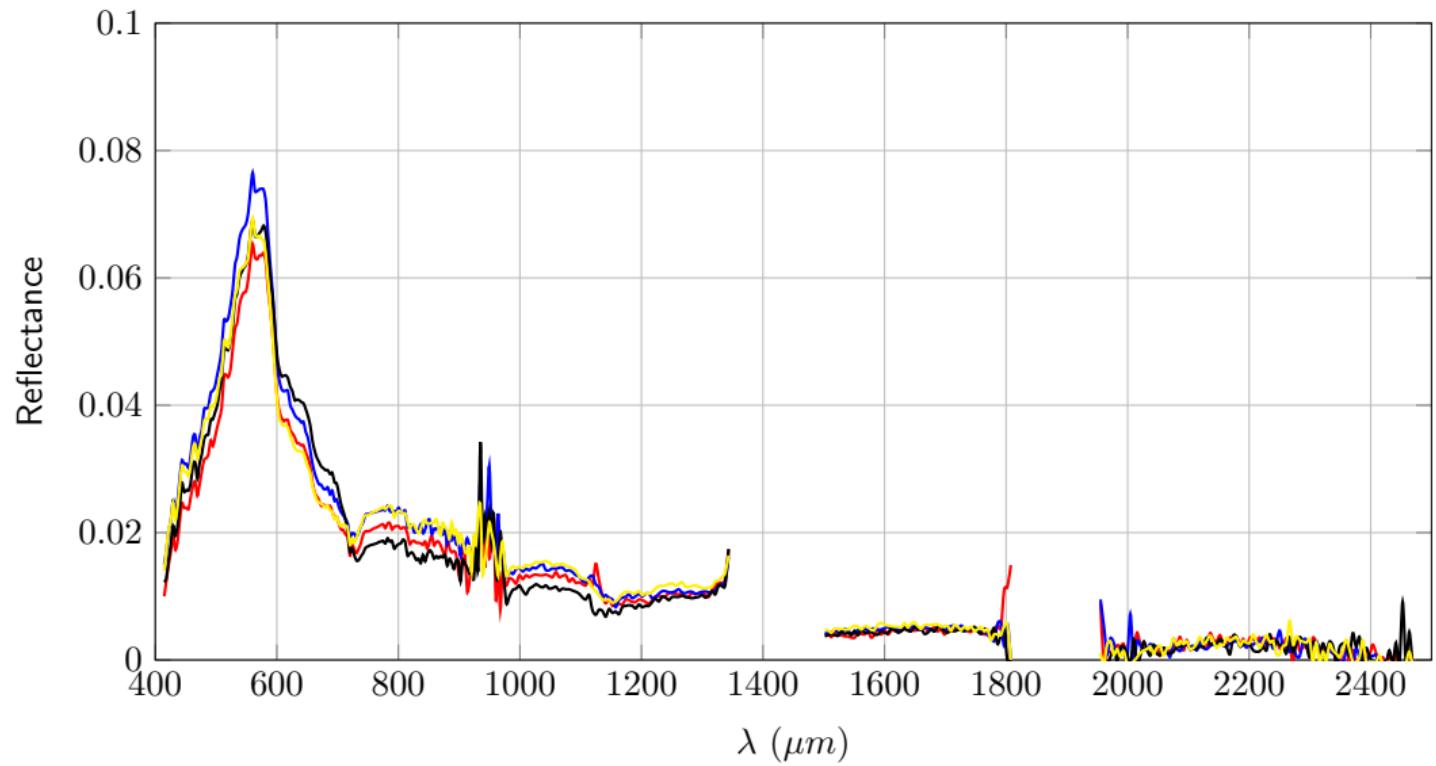


Factor modifying the reflectance

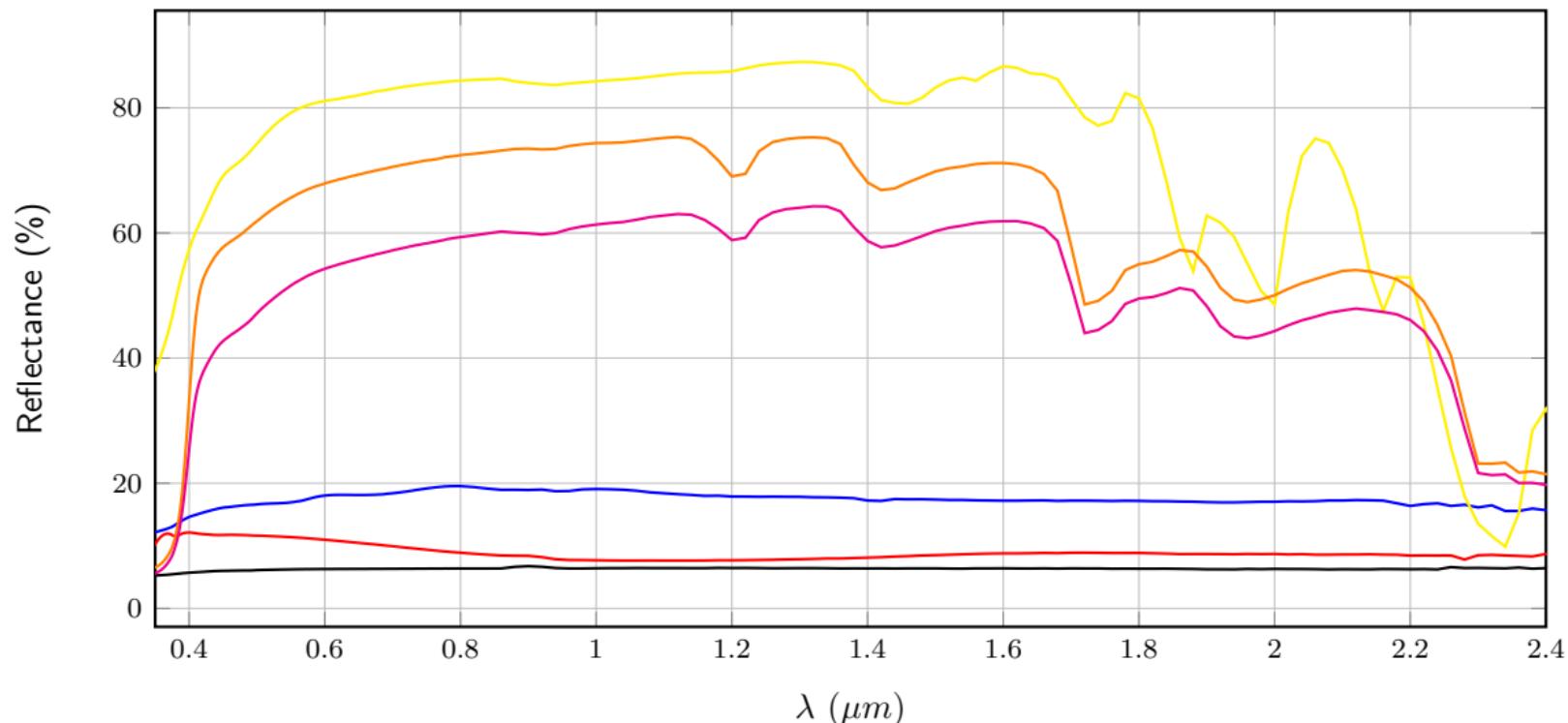
- * Leaf thickness,
- * Leaf age,
- * Water content,
- * Nitrogen content,
- * Health condition,
- * ...



>>> Water



— Black rubber — Window glass — Slate sonte
— White marble — Fiberglass — Rubberized coating



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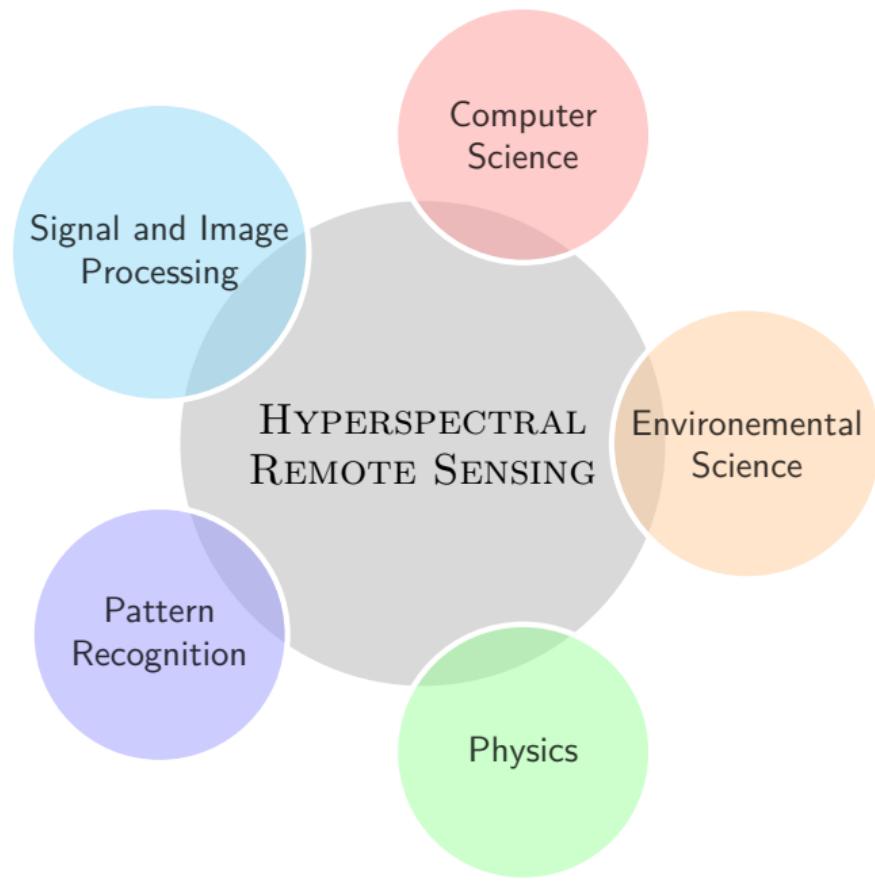
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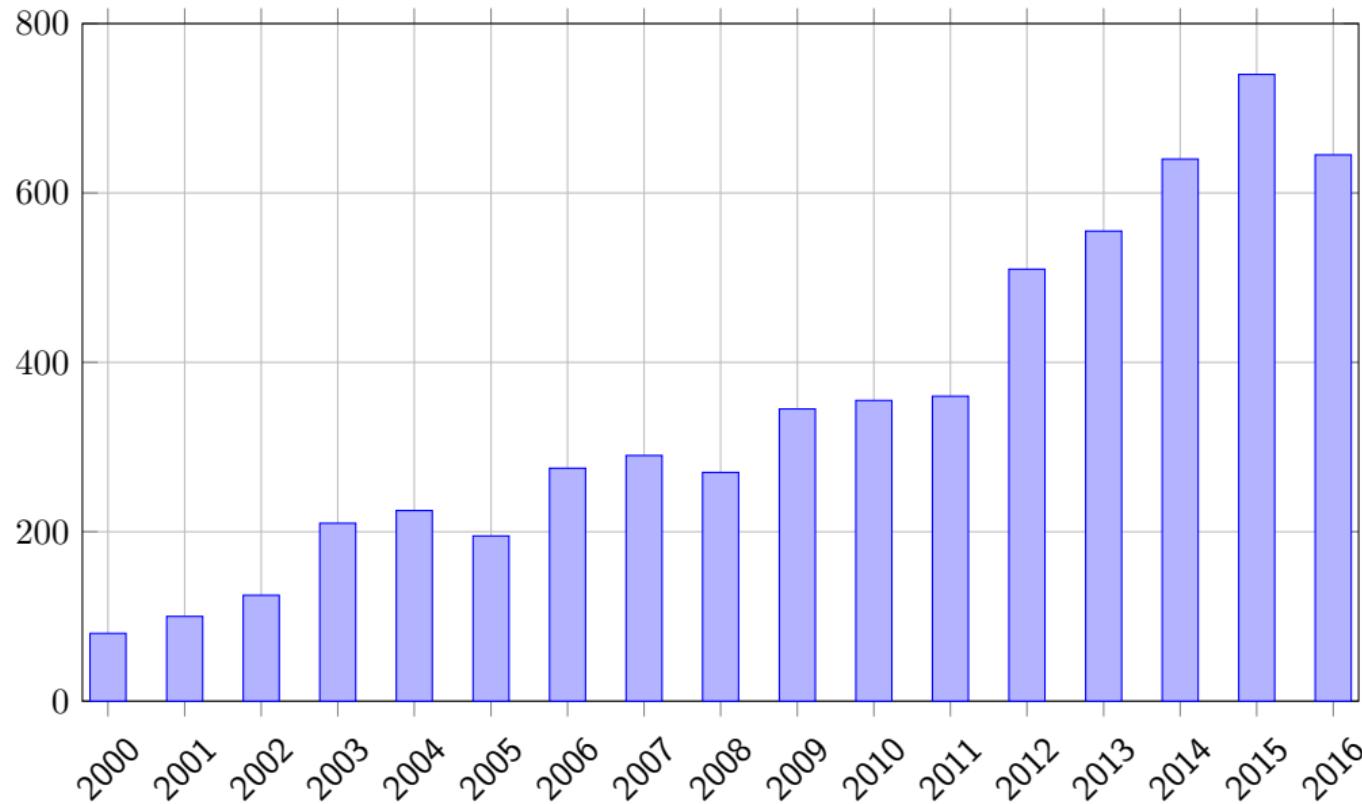
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- ★ Transmission:
 - ★ Compression.
- ★ Pre-processing:
 - ★ Geometric and atmospheric corrections,
 - ★ Data fusion,
 - ★ Feature extraction.
- ★ Information extraction:
 - ★ Classification/inversion,
 - ★ Unmixing,
 - ★ Target detection.

Number of published papers per year about "hyperspectral remote sensing" (*ISI Web of science*)



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* Pattern recognition:

- ★ High dimensional data,
- ★ Spectral variability,
- ★ Reduce ground-truth.

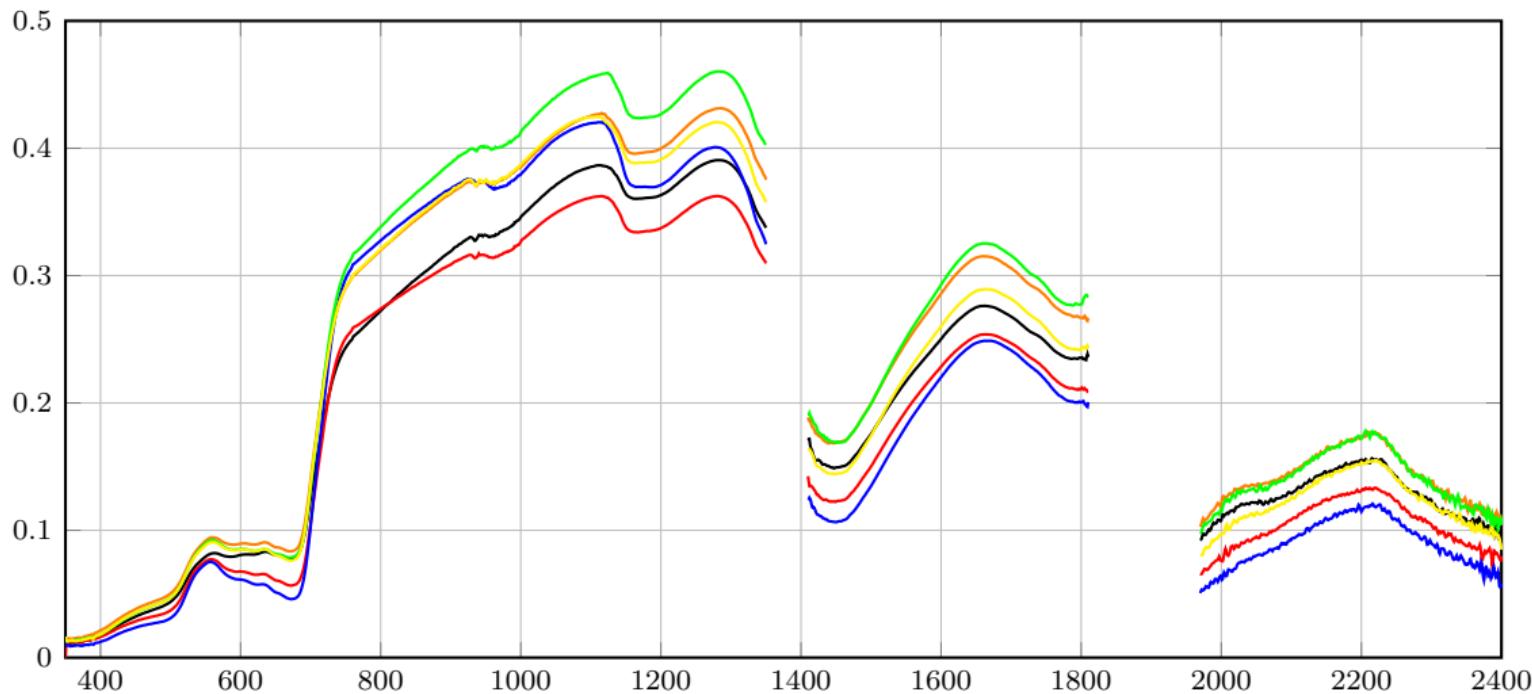
* Computer science:

- ★ Large volume of data,
- ★ Real time constraints.

* Thematic application:

- ★ Environmental issues,
- ★ Military issues,
- ★ Astrophysical issues.

Grasslands measurements



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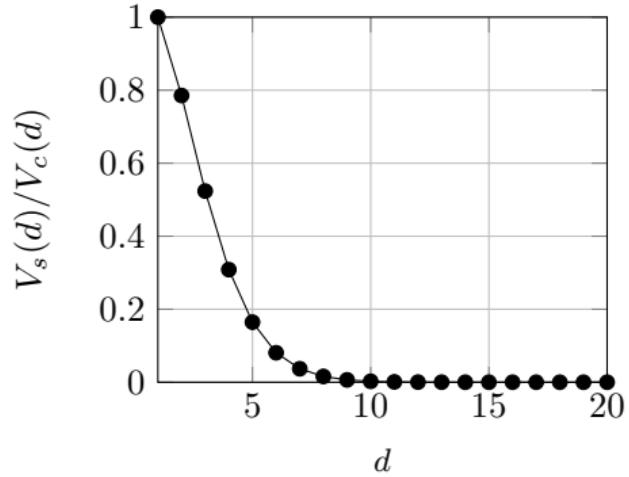
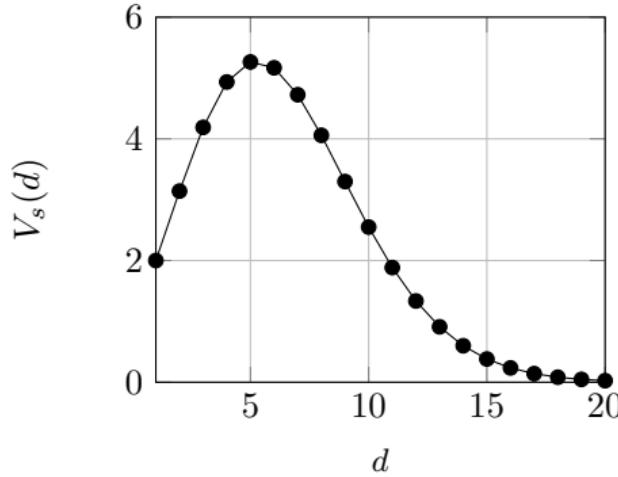
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- ★ High number of measurements d but limited number n of samples.
- ★ High dimensional space do not behave as low/moderate dimensional space [JL98]:
 - ★ Volume of an hypersphere: $V_s(d, r) = \frac{\pi^{d/2}}{\Gamma(\frac{d}{2}+1)} r^d$,
 - ★ Volume of an hypercube: $V_c(d, r) = (2r)^d$.

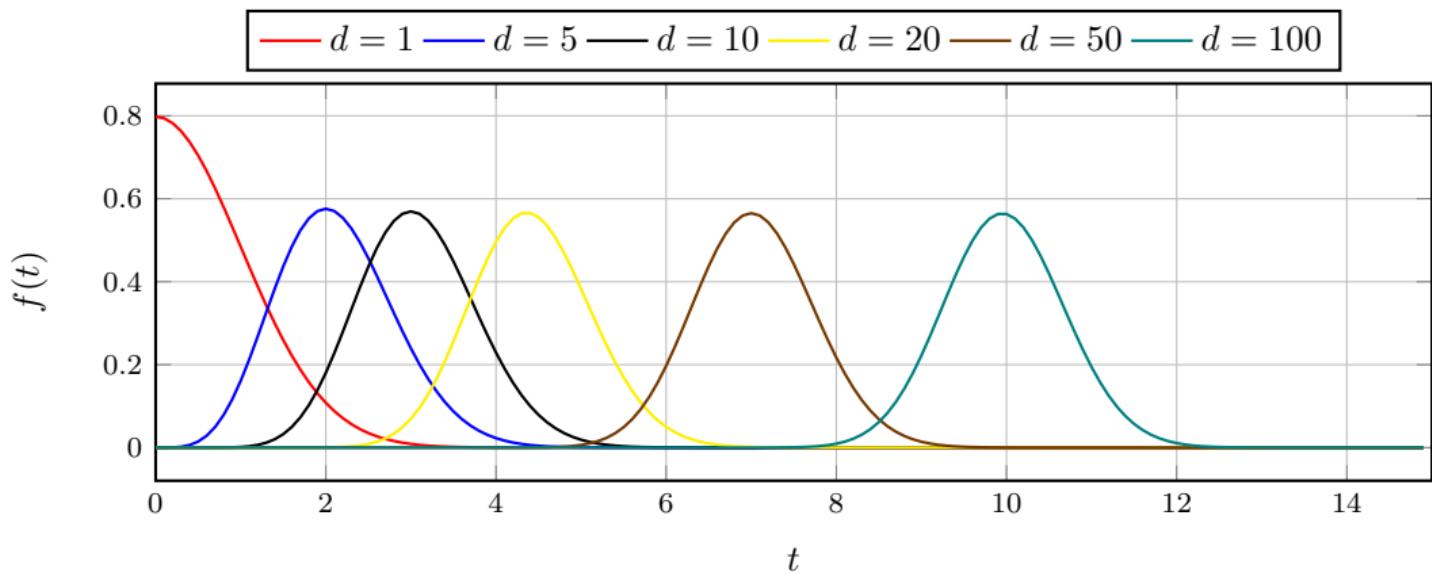


>>> Properties of HD spaces 2/3

Consider a r.v. $\mathbf{x} \sim \mathcal{N}(\mathbf{0}, \mathbf{I})$. The likelihood of $t = \|\mathbf{x}\|$ is given by

$$f(t) = \frac{t^{d-1} \exp(-t^2/2)}{2^{(d/2)-1} \Gamma(d/2)}$$

which is maximum for $t^* = \sqrt{d-1}$ [JL98].



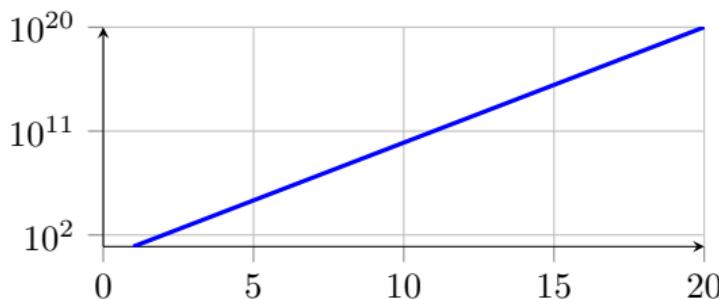
- ★ Concentration of measure phenomenon [AHK01]: if \mathbf{x} r.v. with i.i.d variables

$$\frac{d_M(\mathbf{x}) - d_m(\mathbf{x})}{d_M(\mathbf{x})} \rightarrow_p 0$$

for all Minkowski norm: $\|\mathbf{x}\| = \left(\sum_{i=1}^d |x_i|^p \right)^{1/p}$.

- ★ From [Don00]:
 - ★ Rate of convergence of estimators decreases when d increases,
 - ★ The number of model parameters increase w.r.t d .

- ★ Curse of dimensionality: Number of points to uniformly sample a unit hypercube (step=0.1)



- ★ Method based on *nearest neighbors* fail (with Euclidean distance)
- ★ Hughes phenomenon [Hug68]:

"With a fixed design pattern sample, recognition accuracy can first increase as the number of measurements made on a pattern increases, but decay with measurement complexity higher than some optimum value."

- ★ Ill-posed problem:
 - ★ Matrix inversion,
 - ★ Determinant,
 - ★ Overfitting ...

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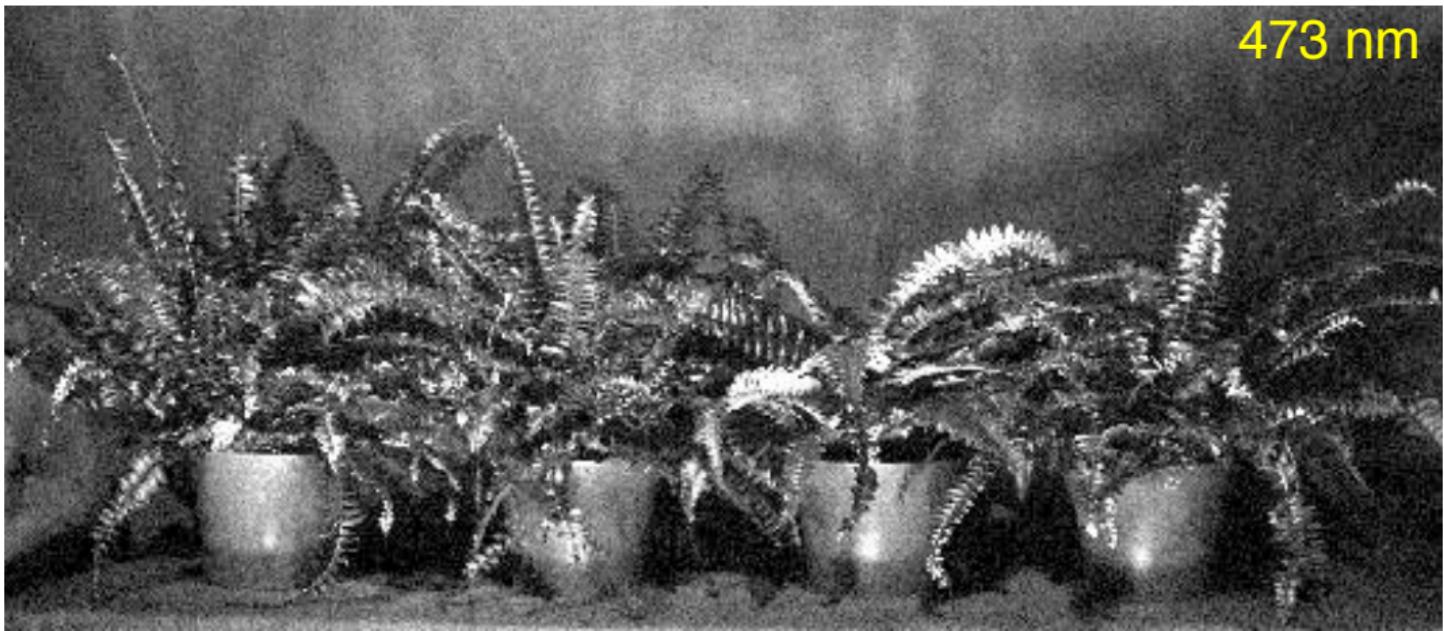
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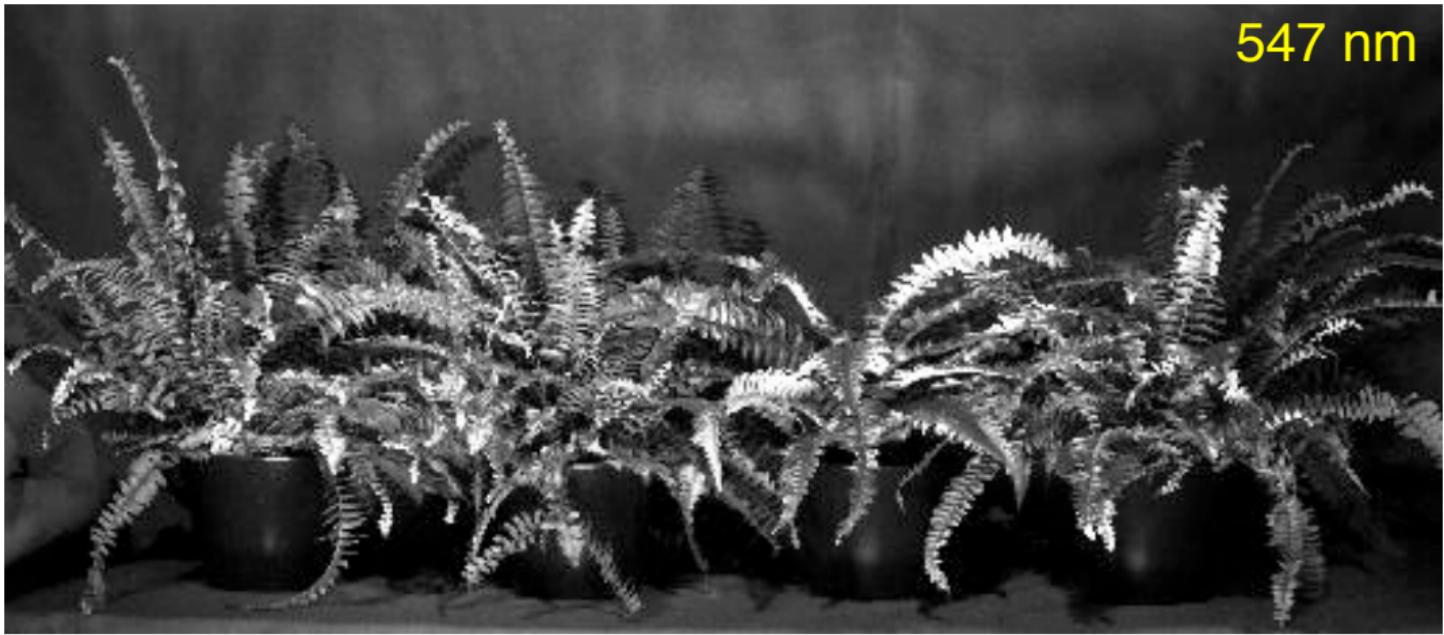
>>> Is there a fake ?



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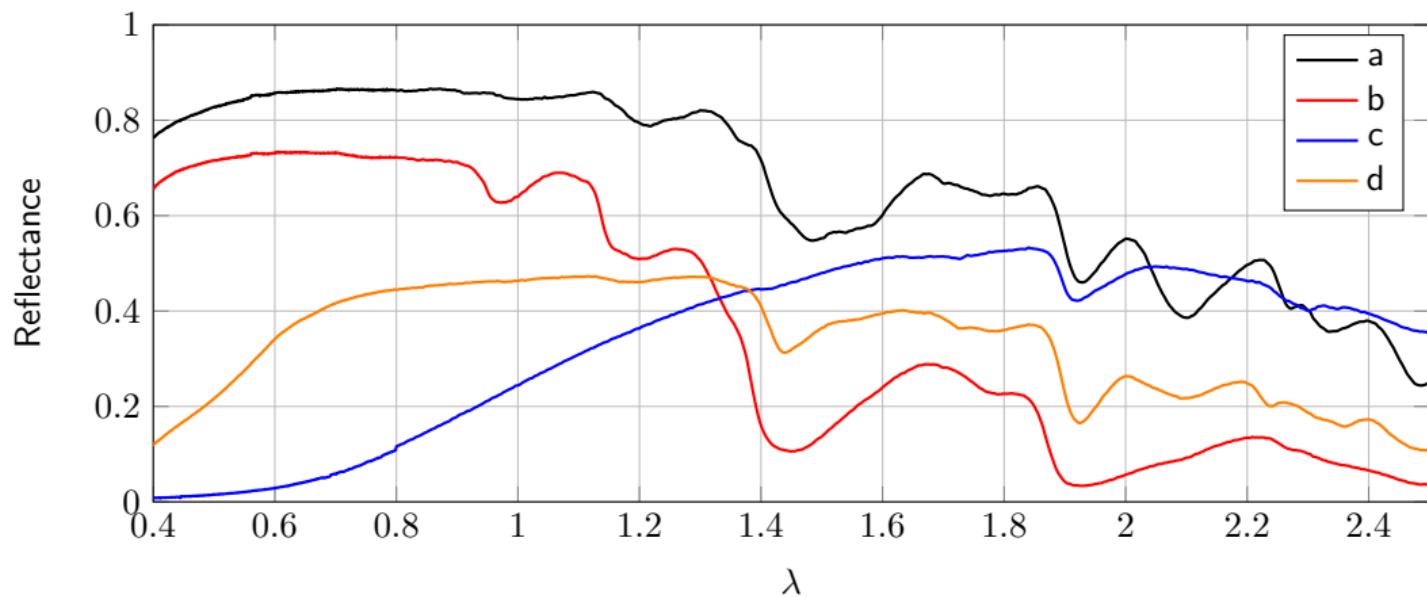


>>> Is there a fake ?



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There are two spectra of the same material (cotton), before and after drying. Which are they ?

>>> Gaussian distribution

What is the number of parameters to estimate for a Gaussian distribution

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- ★ The mean: d

>>> Gaussian distribution

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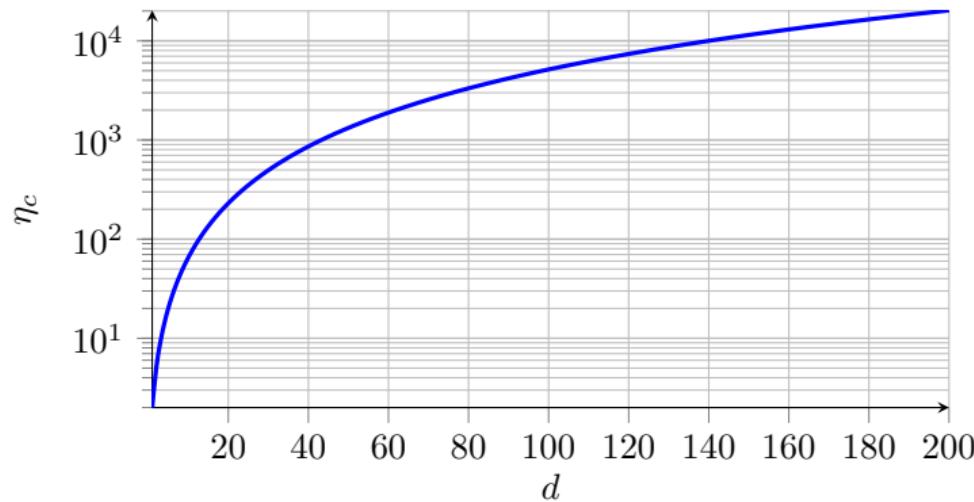
- ★ The mean: d
- ★ The covariance matrix: $d(d + 1)/2$

>>> Gaussian distribution

What is the number of parameters to estimate for a Gaussian distribution

- ★ The mean: d
- ★ The covariance matrix: $d(d + 1)/2$

Total: $d(d + 3)/2 \approx d^2/2$



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