Mapping vegetation photosynthetic activity with chlorophyll fluorescence: the FLuorescence EXplorer (FLEX) mission
Science objectives

(a) Global vegetation fluorescence, and derived photosynthesis, CO₂ fluxes, carbon assimilation:
- Mapping photosynthetic efficiency
- Activation/deactivation status of photosystems

(b) Coupling of photosynthesis (carbon) and transpiration (water) at a global scale:
- Coupling of carbon and water cycles (light use efficiency versus water use efficiency)

(c) Vegetation stress monitoring:
- Early indicators of environmental stresses

(d) Anthropogenic impacts associated to land use changes and varying management practices (food security)
De-excitation pathways

- **Photosynthesis**
  - Excited state (Ch*)
  - Photochemistry
  - Fluorescence
  - Constitutive heat dissipation
  - Regulated heat dissipation

- Incident sunlight
  - Excited state (Ch*)
  - GROUND STATE (Ch)

- **Regulation factors**

**Absorption (a.u.)**

- Wavelength (nm): 600 to 800
- Absorption peaks at 680 nm

**Fluorescence**

- Wavelength (nm): 680 to 700
- Lower energy fluorescence emission

**Internal conversion**
Vegetation stress

Photosynthetic Strain

- Water deficit
- Nutrient deficit
- Pests
- Elevated CO2
- Herbicides
- Pollutants
- Insecticides
- UV
- Acid rain
- Heat
- Salinity
- Weeds
- High light
- Ozone
- Heavy metal toxicity
- Photosynthesis decline, NPQ* increase, Fluorescence decreases
- Chlorophyll decrease, Fluorescence increases

* Non-Photochemical Quenching
DYNAMICS OF REFLECTANCE AND FLUORESCENCE

Ivy

Cabbage

Tobacco
Fluorescence emission spectra from two different species exposed at two levels of air pollution. Different peak ratios (i.e. different shapes) can result in similar total SIF. Thus a single fluorescence band is not sufficient to accurately estimate SIF$_{\text{tot}}$.

Fluorescence versus water stress on tobacco through a 22 days period under laboratory conditions

Peak ratio changes through the day and between days as stress increases, changing the shape of the emission spectrum

Amoros et al., IGARSS 2007, doi:10.1109/IGARSS.2007.4423663
Spectral and radiometric requirements

Two oxygen absorption bands (O$_2$-A and O$_2$-B) are at the right spectral region for fluorescence retrieval.
Determination of fluorescence from apparent reflectance

\[ F_s/L_{WLR} \]

apparent reflectance

actual reflectance \( r_0 \)

IMG1 O2-B (w/noise)

IMG1 O2-A (w/noise)

Estimated SIF [mW/m^2/nm/ster]

Real SIF [mW/m^2/nm/ster]

Wavelength [nm]
NOTE:
The FLEX retrieval scheme produces as output the full shape of the actual reflectance plus the full spectral curve of fluorescence emission.

This is a key element because it allows:
(a) To derive fluorescence integral energy, peak-ratios, etc.
(b) Biophysical parameters such as chlorophyll, LAI, etc. from the actual reflectance (actual red-edge)