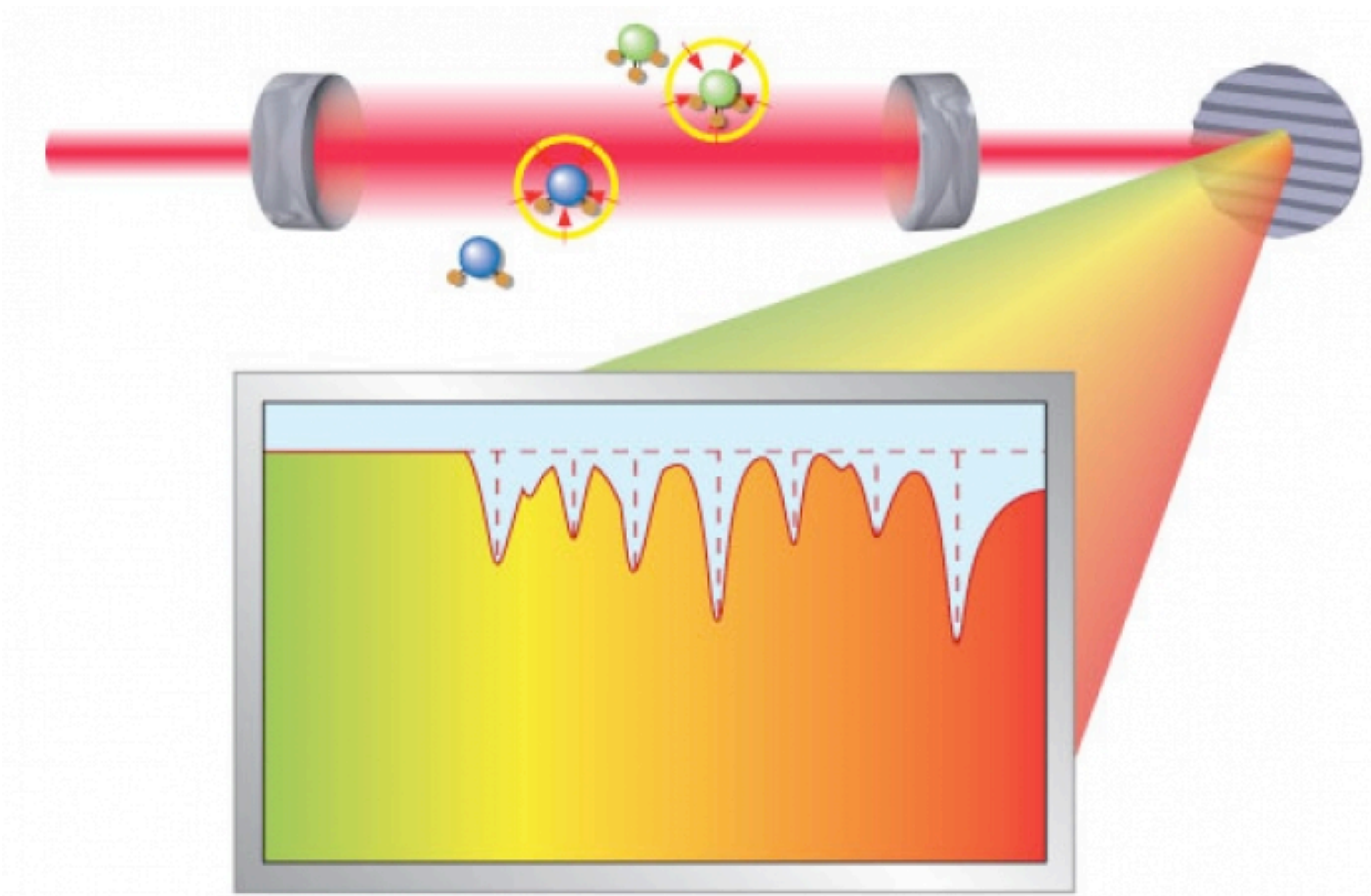
Spectroscopy: The Study of Squiggly Lines

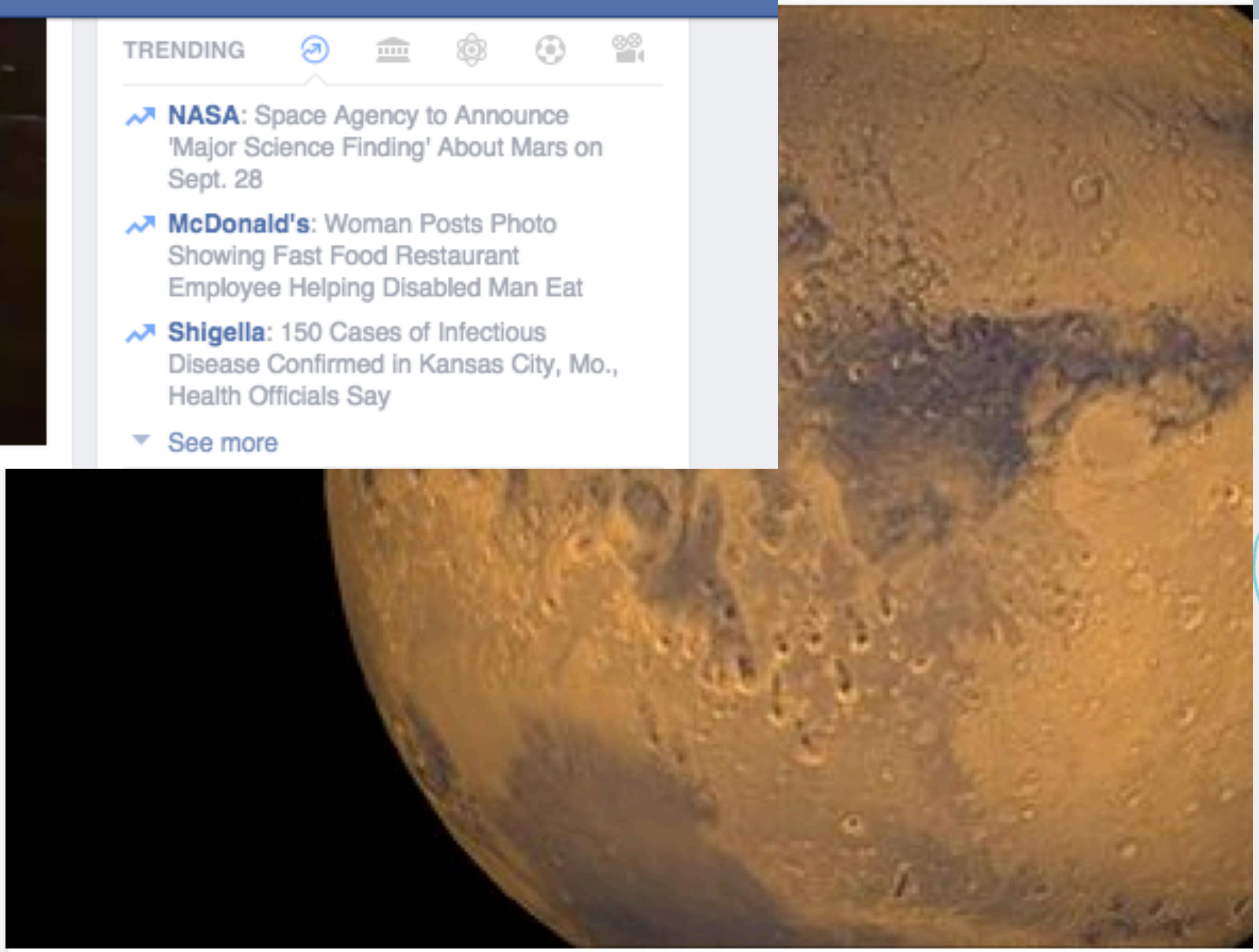


Reflectance spectroscopy: light absorbed at specific wavelengths corresponding to energy level transitions

TRENDING

- **NASA**: Space Agency to Announce 'Major Science Finding' About Mars on Sept. 28
- **McDonald's**: Woman Posts Photo Showing Fast Food Restaurant Employee Helping Disabled Man Eat
- **Shigella**: 150 Cases of Infectious Disease Confirmed in Kansas City, Mo., Health Officials Say

See more



91% 11:30 AM

5898 Social Sciences Study links U.S. political polarization to TV news deregulation following Telecommunications Act of 1996 (lofalexandria.com)
1600 comments science

3040 So is my Kinect broken, or is there something wrong with me that I don't know about... (imgur.com)
343 comments gaming

5244 In case you didn't know, this is what moose babies look like (imgur.com)
563 comments aww

2445 What's considered trashy if you're poor, but classy if you're rich? (self.AskReddit)
1748 comments AskReddit

5472 NASA Will Announce A Major Mars Discovery On Monday (iflscience.com)
3412 comments worldnews

4516 Other I am Les Stroud (aka Survivorman), a filmmaker, outdoor adventurer, singer-songwriter and performer and I'm back for another AMA. Ask Me Anything! (self.IAmA)
1663 comments IAmA

5237 Original in Comments Johnny Carson's musical guest for the Tonight Show cancelled at the last minute, so Johnny invites a random audience member to play the piano during the

NASA to Announce Mars Mystery Solved

NASA will detail a major science finding from the agency's ongoing exploration of Mars during a news briefing at 11:30 a.m. EDT on Monday, Sept. 28 at the James Webb Auditorium at NASA Headquarters in Washington. The event will be broadcast live on...

NASA.GOV

nature geoscience

LETTERS

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Spectral evidence for hydrated salts in recurring slope lineae on Mars

Lujendra Ojha[1]*, Mary Beth Wilhelm[1,2], Scott L. Murchie[3], Alfred S. McEwen[4], James J. Wray[1], Jennifer Hanley[5], Marion Massé[6] and Matt Chojnacki[4]

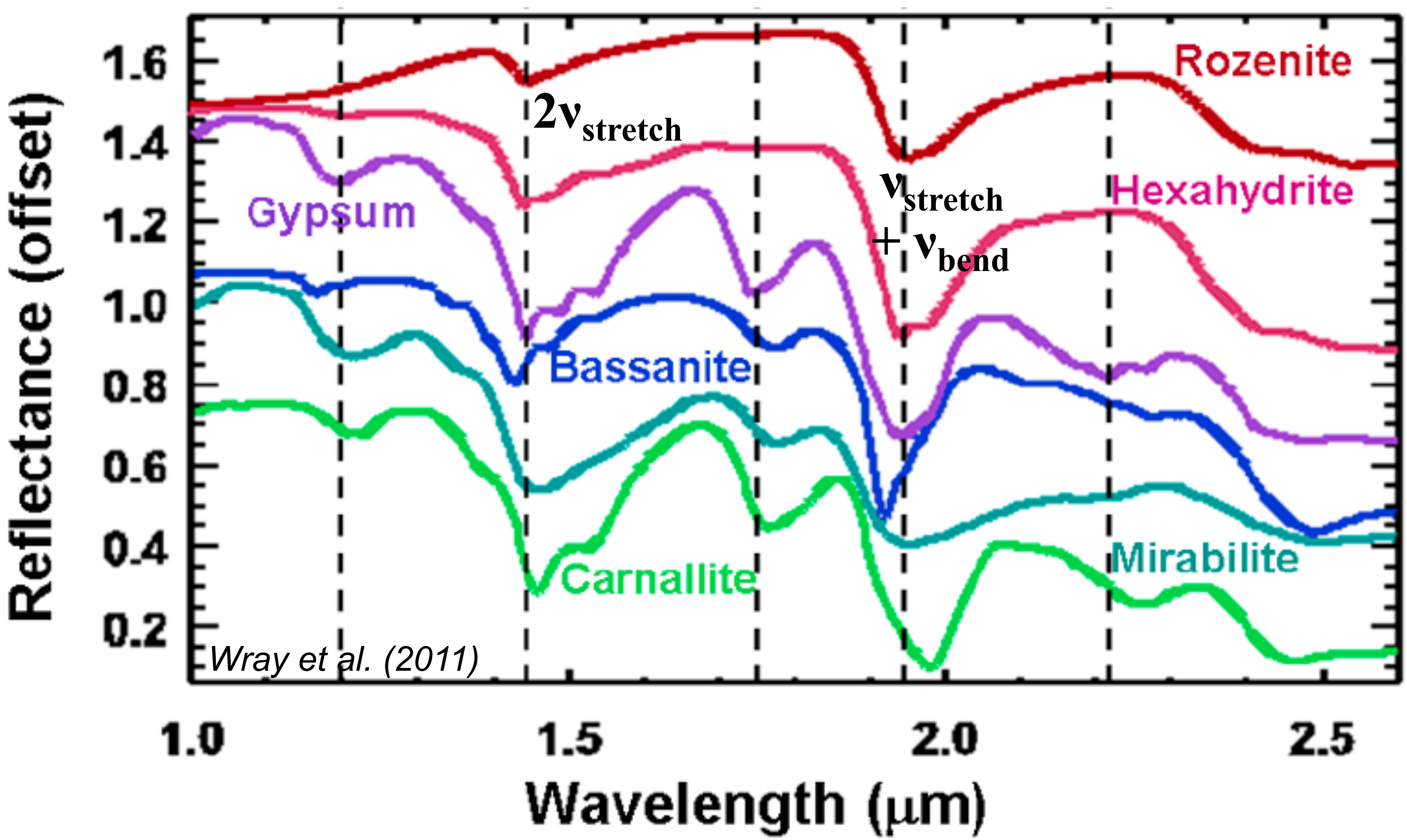
Determining whether liquid water exists on the Martian surface is central to understanding the hydrologic cycle and potential for extant life on Mars. Recurring slope lineae, narrow streaks of low reflectance compared to the surrounding terrain, appear and grow incrementally in the downslope direction during warm seasons when temperatures reach about 250–300 K (refs 1–3), a pattern consistent with the transient flow of a volatile species[1–3]. Brine flows (or seeps) have been proposed to explain the formation of recurring slope lineae[1–3], yet no direct evidence for either liquid water or hydrated salts has been found[4]. Here we analyse spectral data from the Compact Reconnaissance Imaging Spectrometer for Mars instrument onboard the Mars Reconnaissance Orbiter from four different locations where recurring slope lineae are present. We find evidence for hydrated salts at all four locations in the seasons when recurring slope lineae are most extensive, which suggests that the source of hydration is recurring slope lineae activity. The hydrated salts most consistent with the spectral absorption features we detect are magnesium perchlorate, magnesium chlorate and sodium perchlorate. Our findings strongly support the hypothesis that recurring slope lineae form as a result of contemporary water activity on Mars.

the surface, or detection of hydrated salts precipitated from that water.

The mineralogic composition of RSL and their surroundings can be investigated using orbital data acquired by the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) on the Mars Reconnaissance Orbiter (MRO), which acquires spectral cubes with 544 spectral channels (~0.4 to 3.92 μm; ref. 14). Within the infrared (IR) detector spectral range of CRISM (1–3.92 μm), both liquid water and hydrated salts have diagnostic absorption bands at ~1.4 μm, ~1.9 μm and a broad absorption feature at ~3.0 μm (ref. 15; Fig. 1). In addition, hydrated salts may exhibit combinations or overtones at other wavelengths from 1.7 to 2.4 μm. Given the coarser spatial sampling of CRISM (~18 m $pixel^{-1}$) compared to HiRISE, few locations exist in which RSL are wide or dense enough to fill even a single CRISM pixel. In this work, we devised a variety of methods to reduce uncertainties from extraction of CRISM spectra from individual pixels (Supplementary Information), allowing examination of pixels mostly filled by RSL.

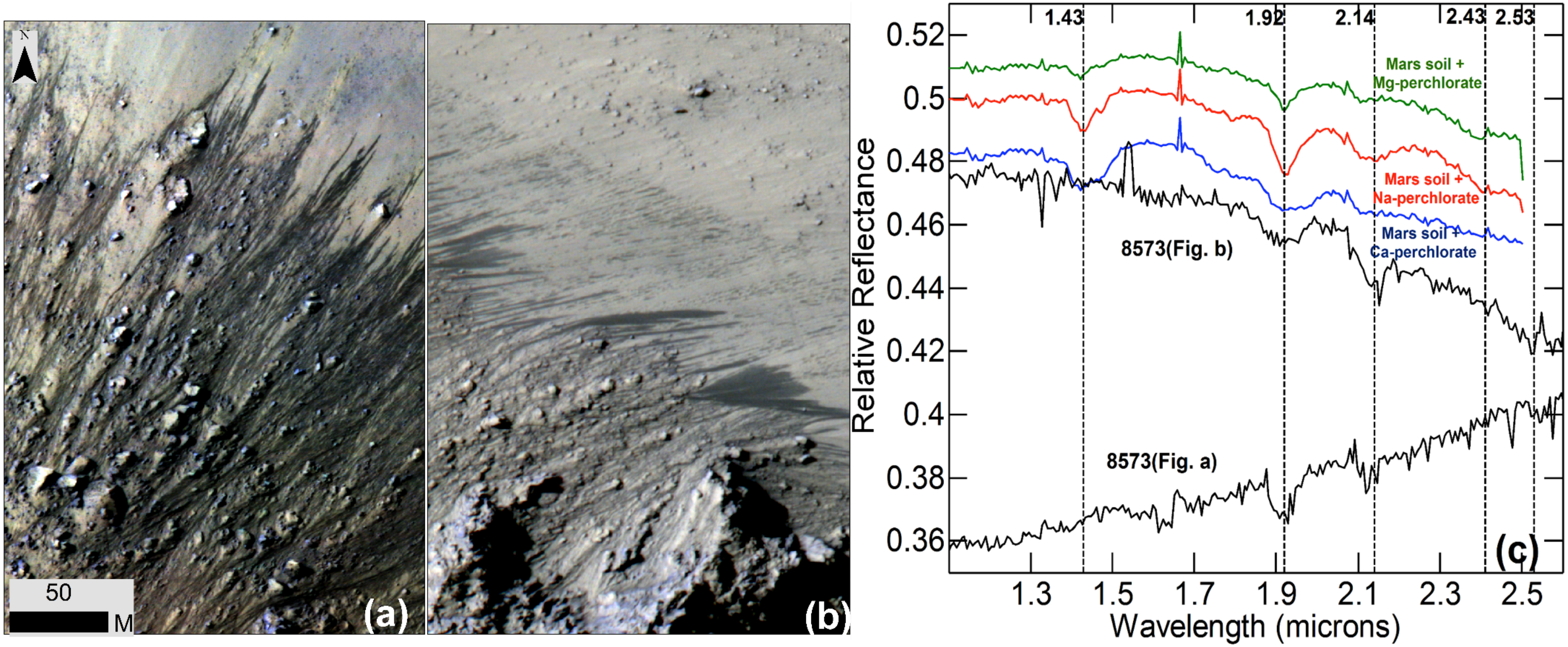
At Palikir crater, RSL are observed to be longest and widest towards the end of the southern summer. In the HiRISE image acquired at the end of the southern summer of Mars Year (MY) 30, wide RSL were observed on the slopes of Palikir (Fig. 1

Hydrated salt spectra



Essentially all features due to H_2O/OH vibrations

Central peaks of Horowitz Crater



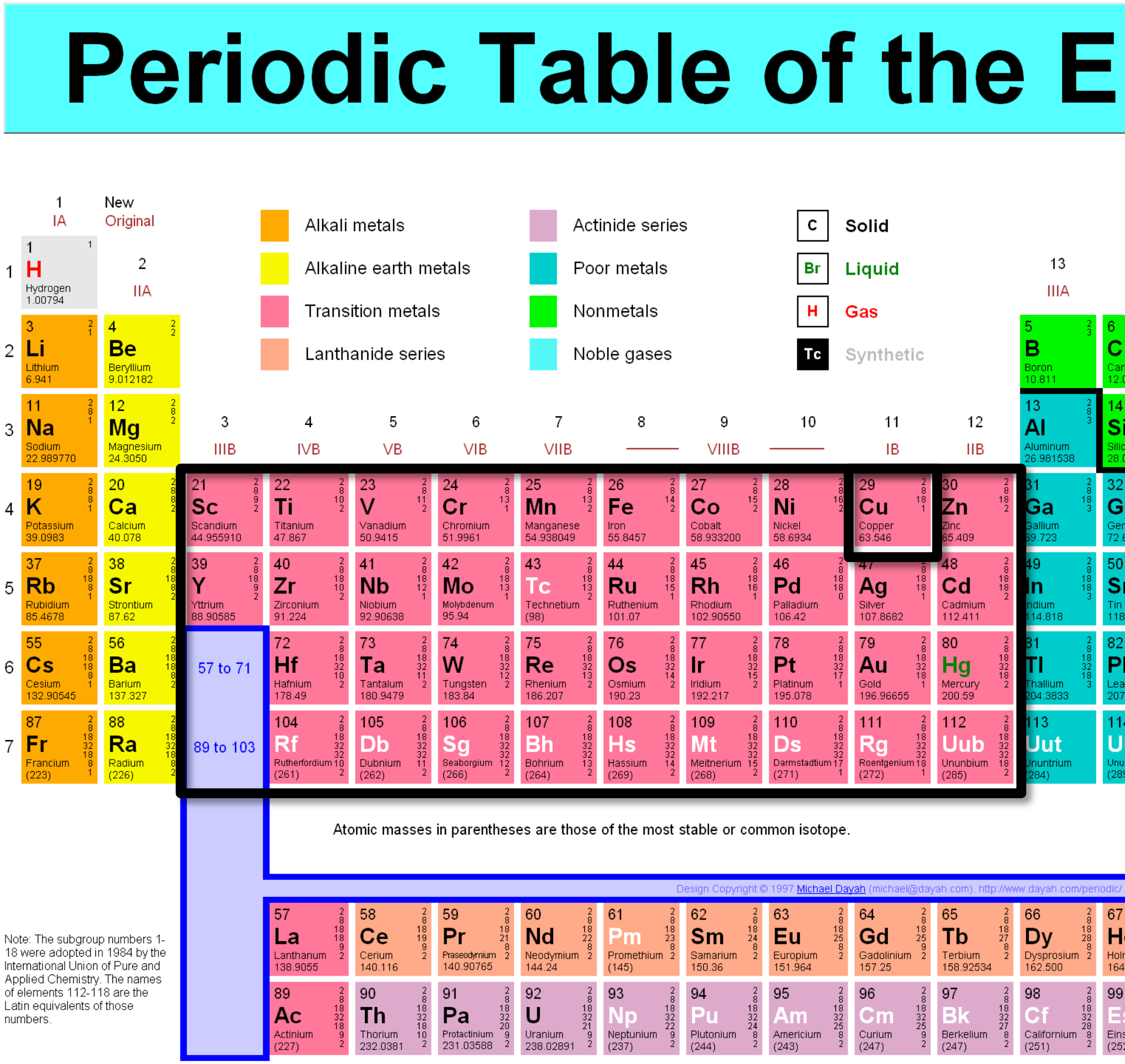
Implication for Water on Mars

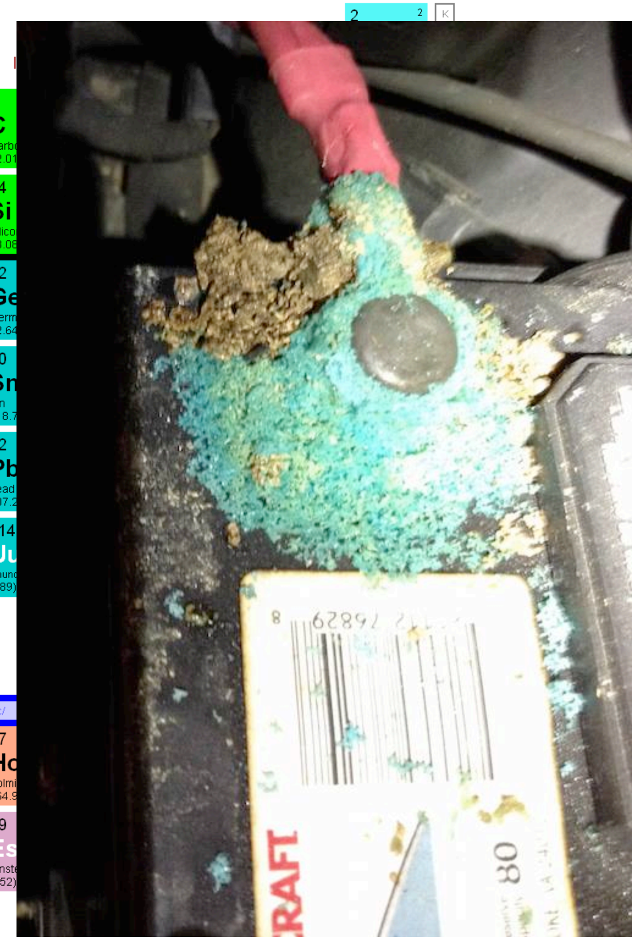
Stability of **<u>Pure Water</u>** on the Surface of **<u>Earth</u>**

Stability of **<u>Pure Water</u>** on the Surface of **<u>Mars</u>**

Stability of **<u>Perchlorate-brine</u>** on the Surface of **<u>Mars</u>**

Unfilled *d* orbitals: the transition metals

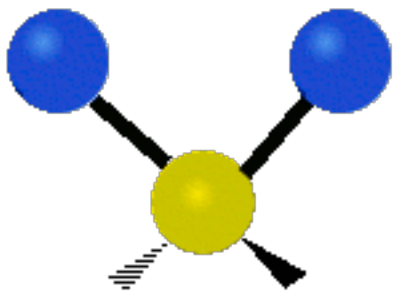




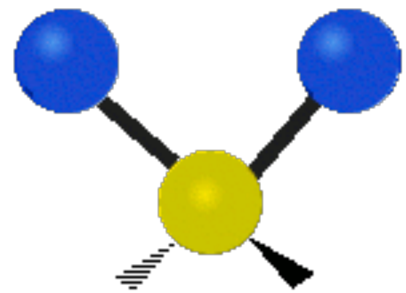
Iron is the most geologically abundant transition metal

Molecular vibrations

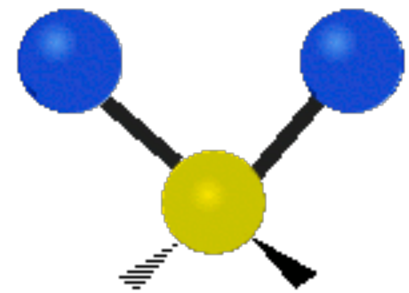
Symmetric stretch



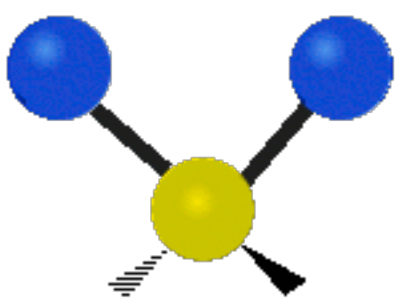
Asymmetric stretch



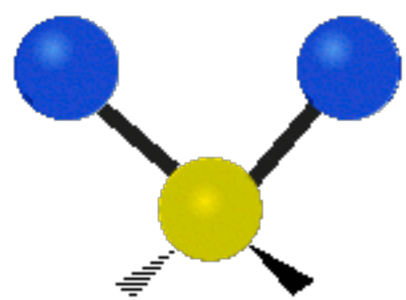
Scissor/bend



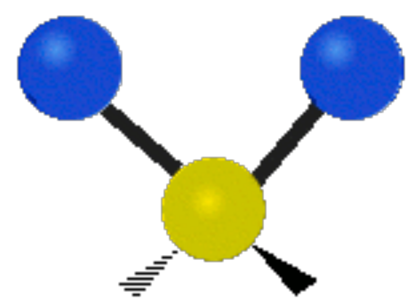
Rocking



Wagging



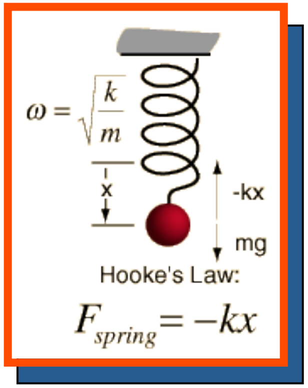
Twist



Vibrational Processes

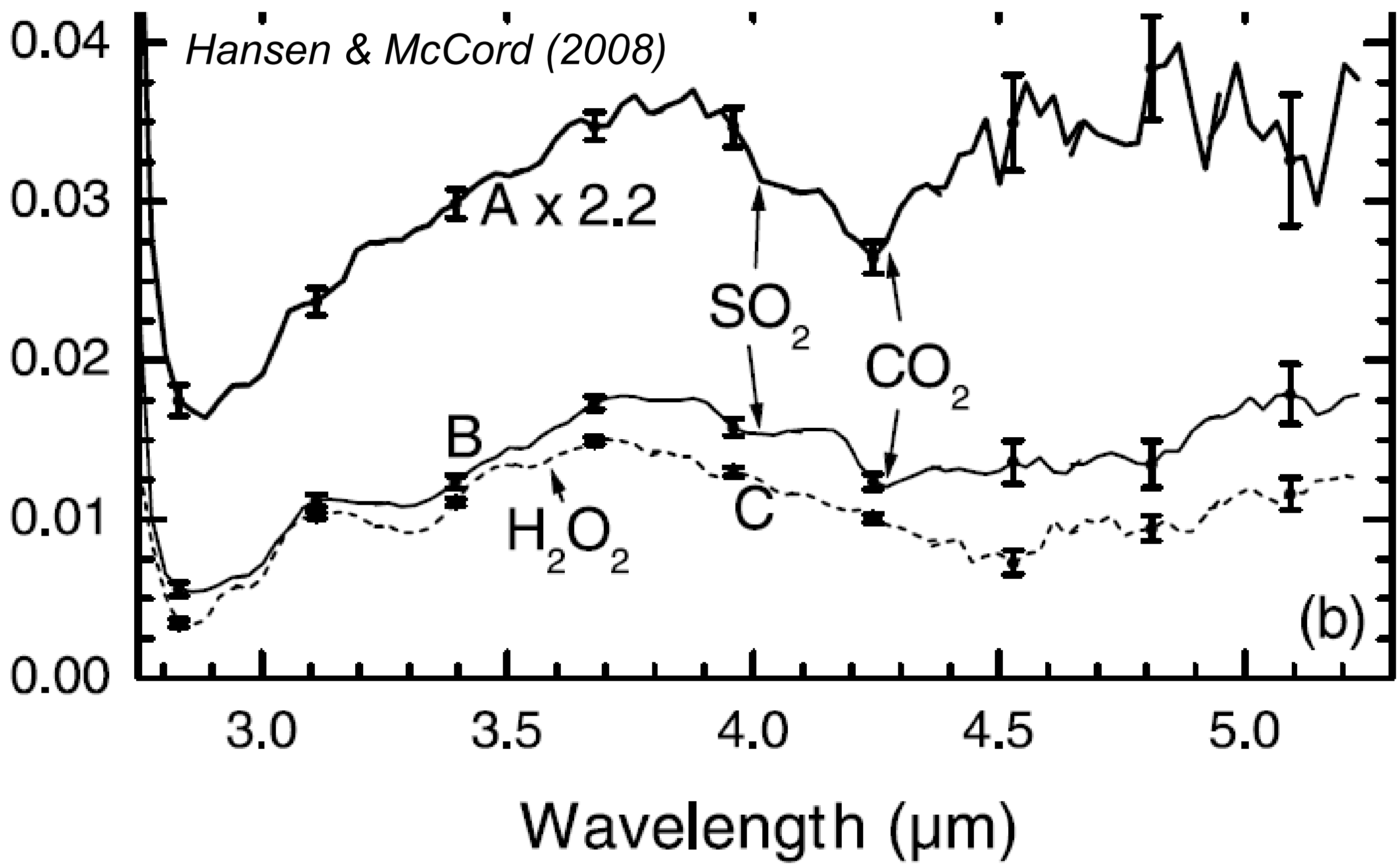
The bonds in a molecule or crystal lattice are like springs with attached weights: the whole system can vibrate. The frequency of vibration depends on the strength of each spring (the bond in a molecule) and their masses (the mass of each element in a molecule). For a molecule with N atoms, there are 3N-6 normal modes of vibrations called fundamentals.* Each vibration can also occur at multiples of the original fundamental frequency (overtones) or involve different modes of vibrations (combinations).

* In general, a molecule with N atoms has 3N-6 normal modes of vibration but *linear* molecules have only 3N-5 normal modes of vibration as rotation about its molecular axis cannot be observed.

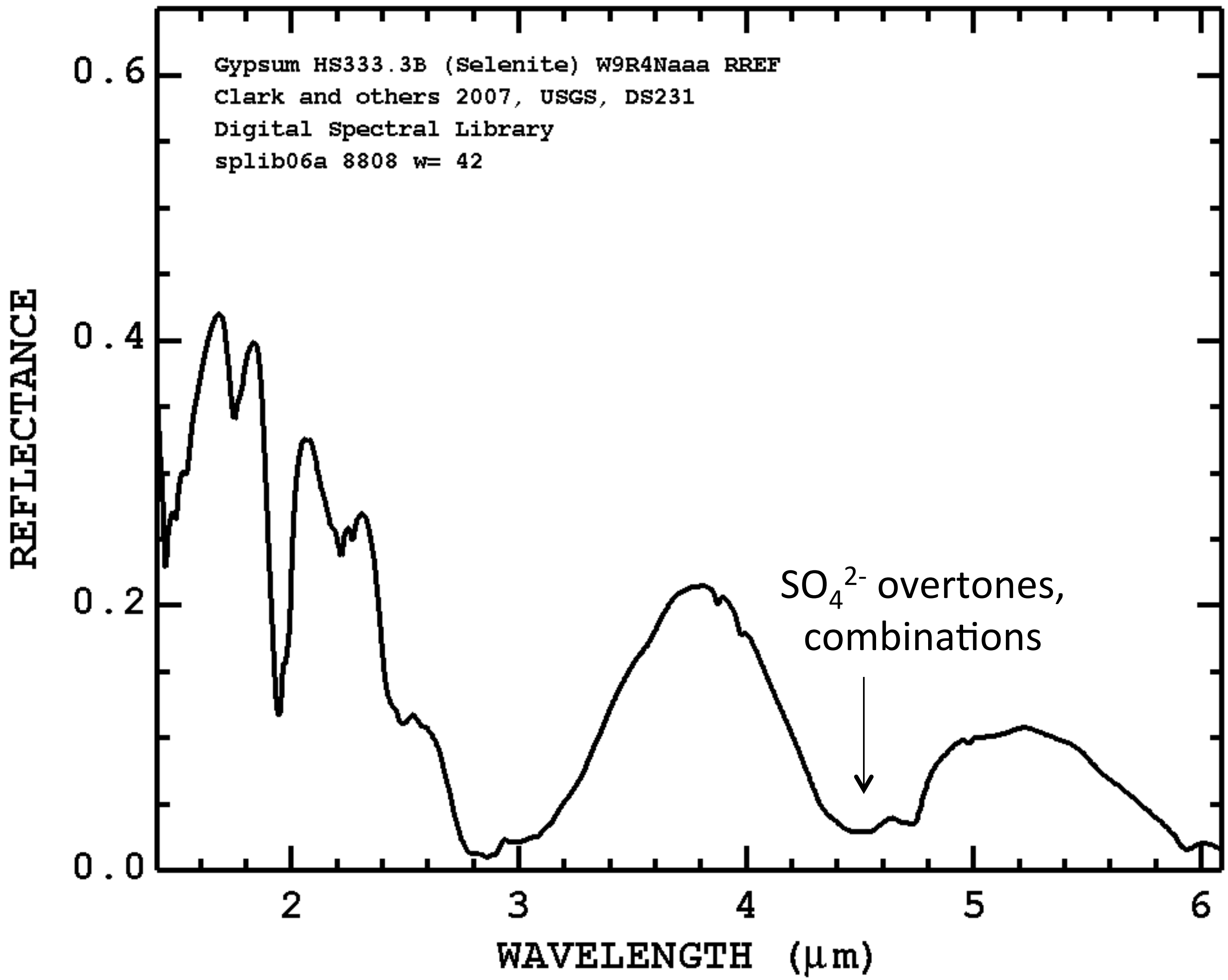


Peroxide, CO_2 and more on Europa

(and Ganymede, Callisto)



Sulfate vibrational absorptions



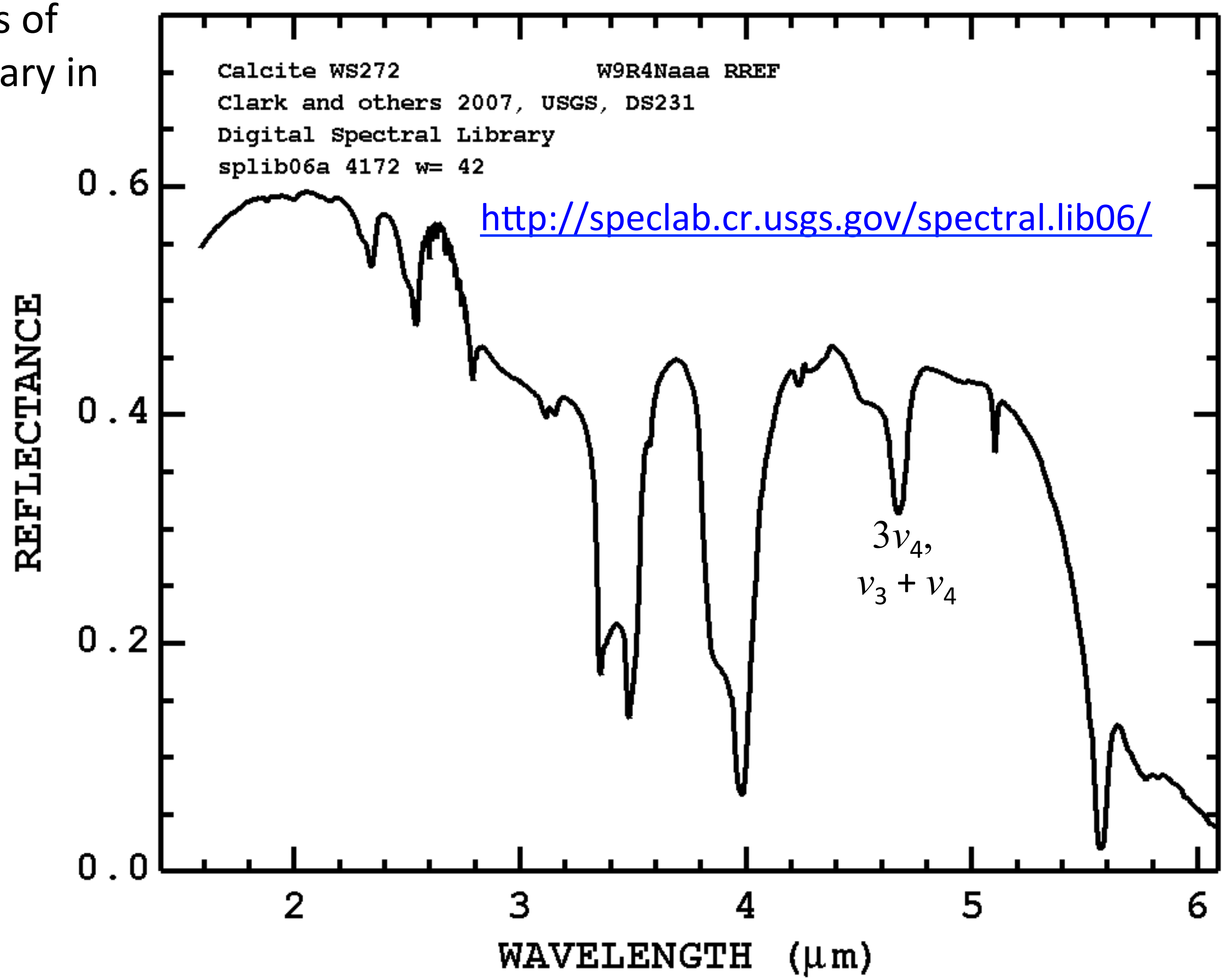
http://speclab.cr.usgs.gov/spectral.lib06/

Carbonate vibrational absorptions

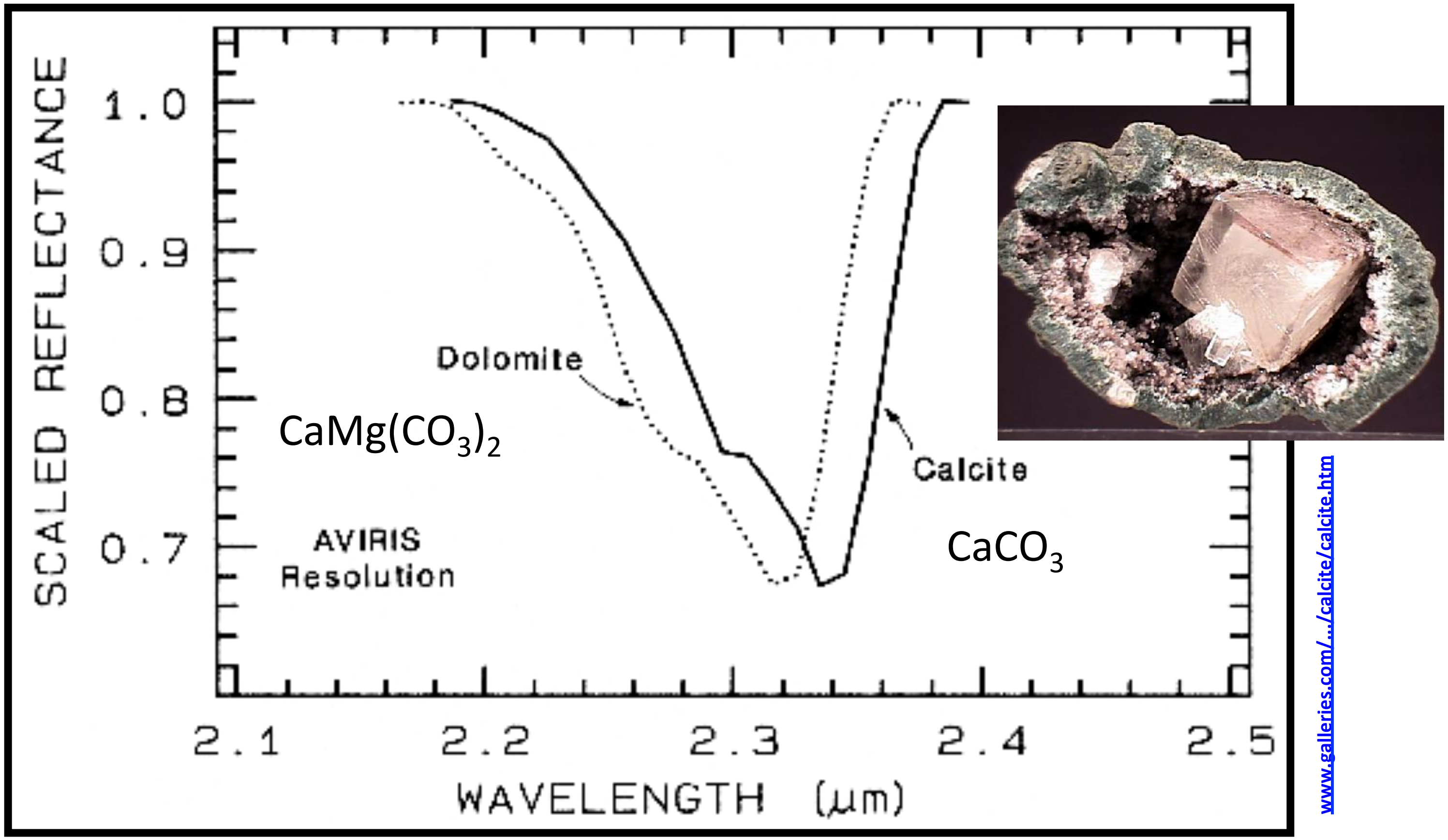
Fundamental modes of free CO_3^{2-} ion (will vary in minerals):

v_1 = 9.407 µm
v_2 = 11.4 µm
v_3 = 7.067 µm
v_4 = 14.7 µm

Combination / overtone bands are weaker



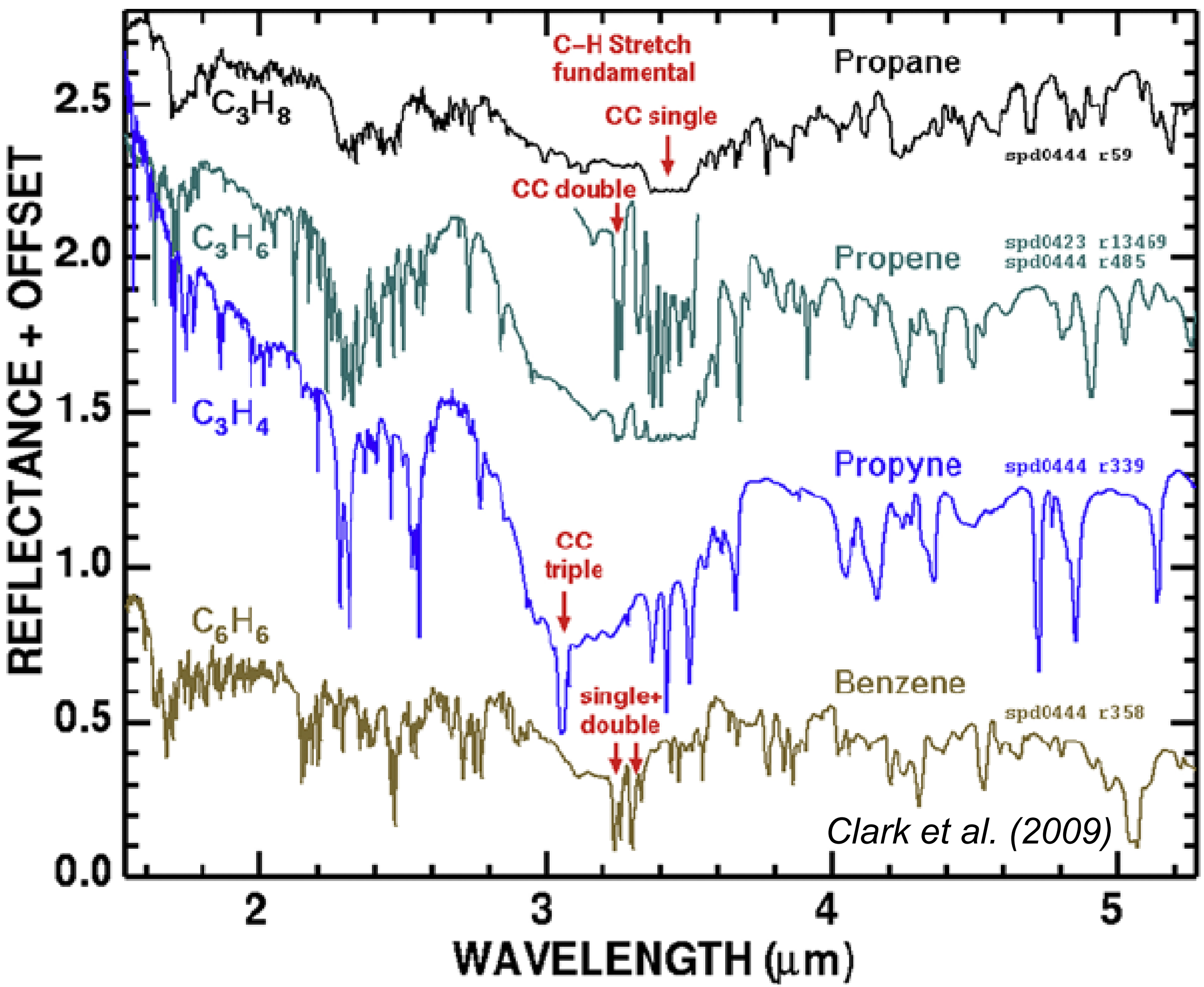
Band position in carbonate minerals shifts with composition



www.galleries.com/.../calcite/calcite.htm

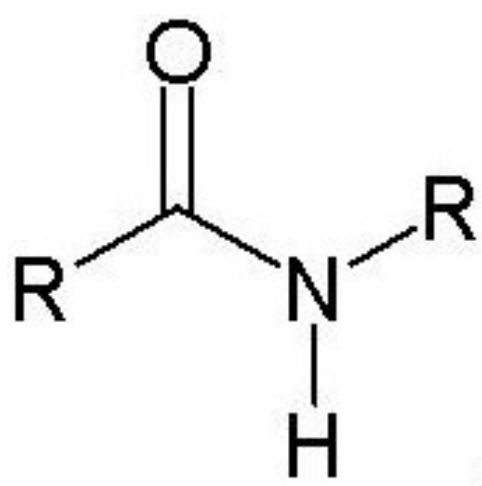
Organic molecules

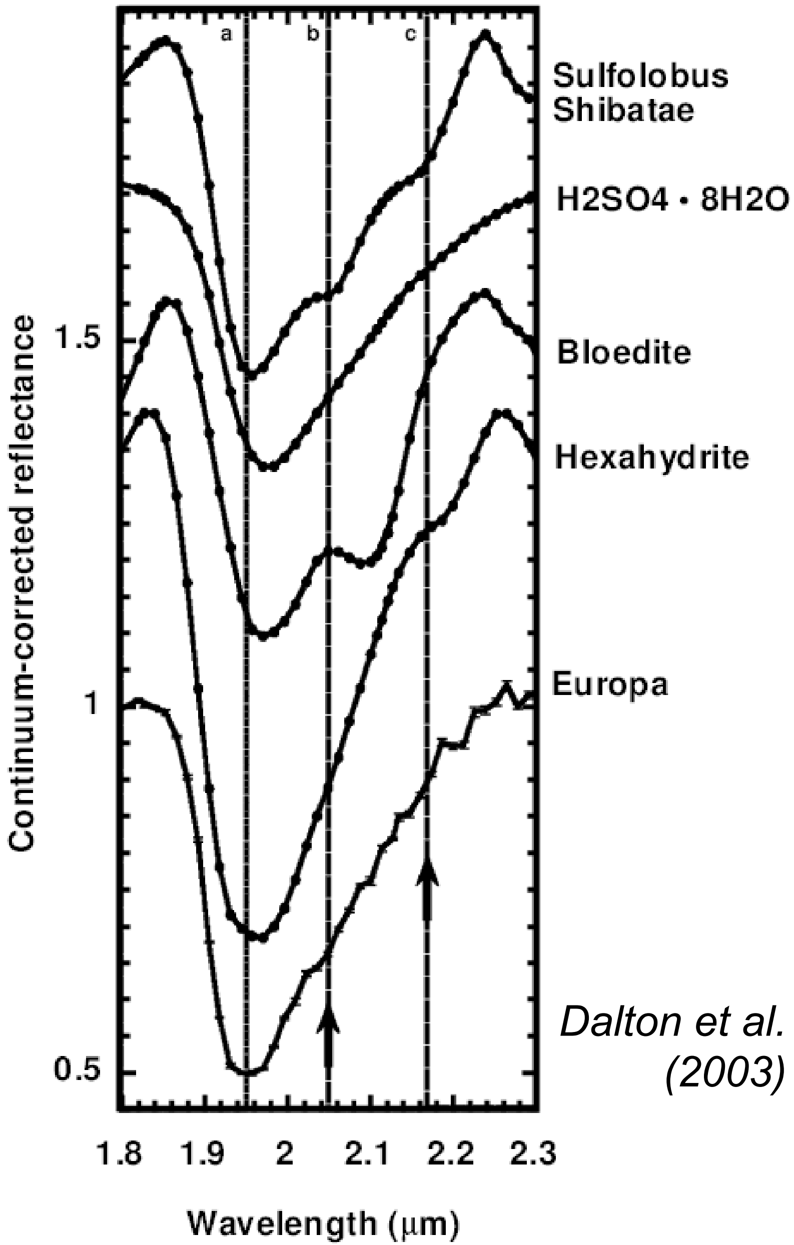
Identified on several moons of Jupiter and Saturn



Amides: Spectral biomarkers?

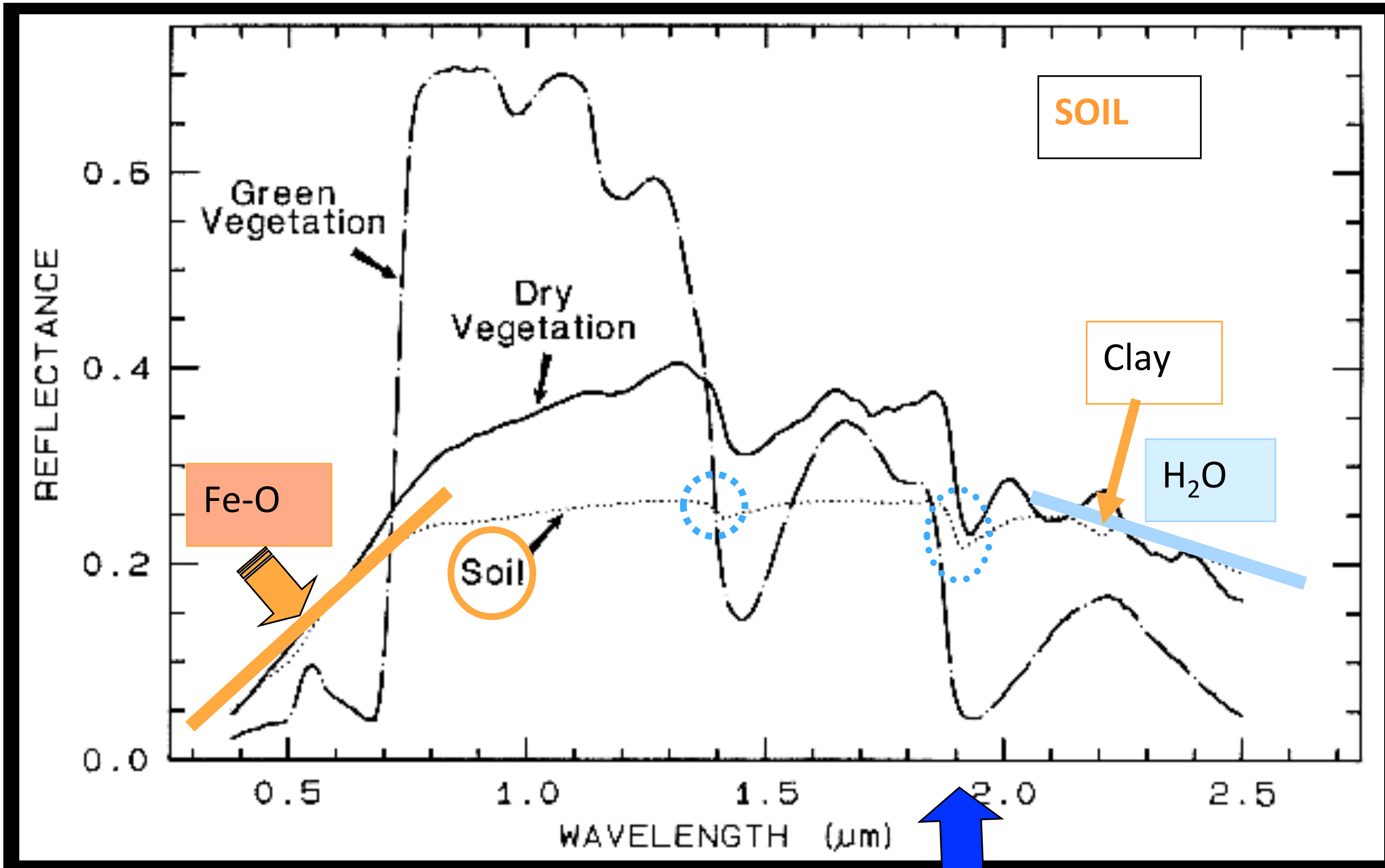
- Link amino acids in proteins, with distinct IR signature → *biomarker*
- NIR bands ambiguous; stronger fundamental bands at ~6 µm

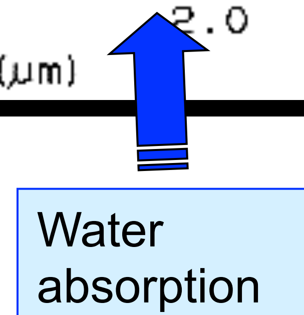




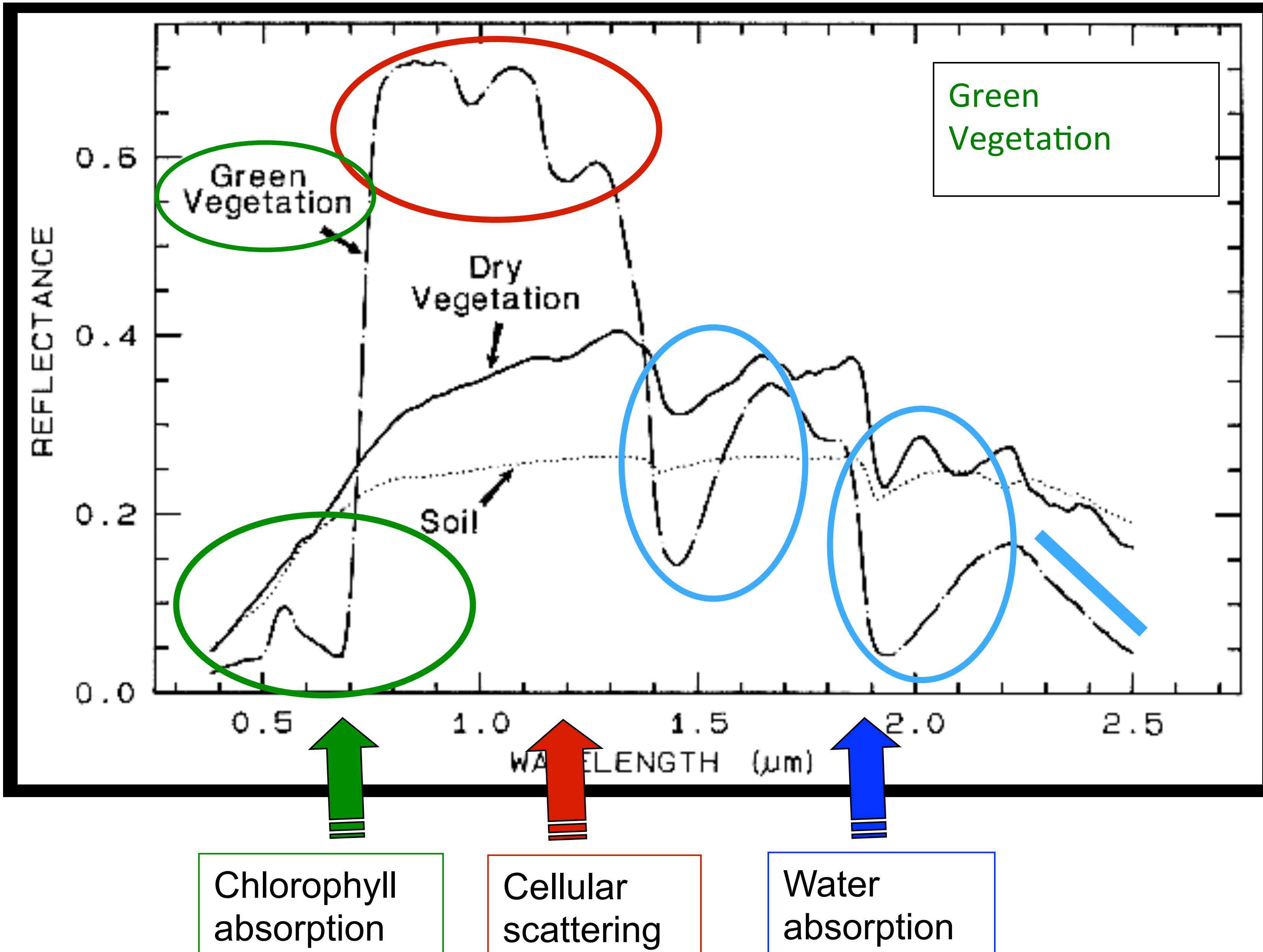
Dalton et al. (2003)

Spectra of common Earth-surface materials

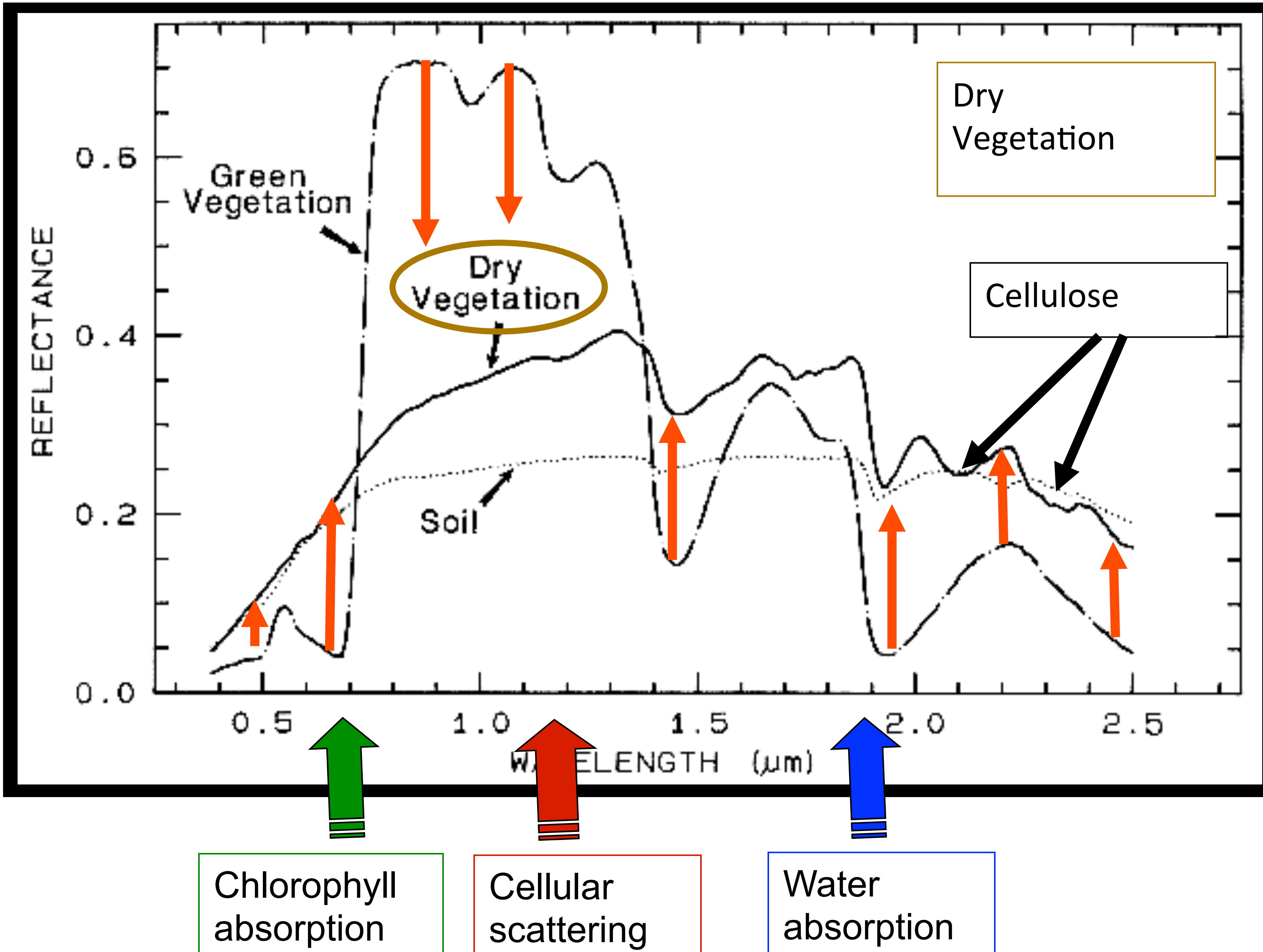




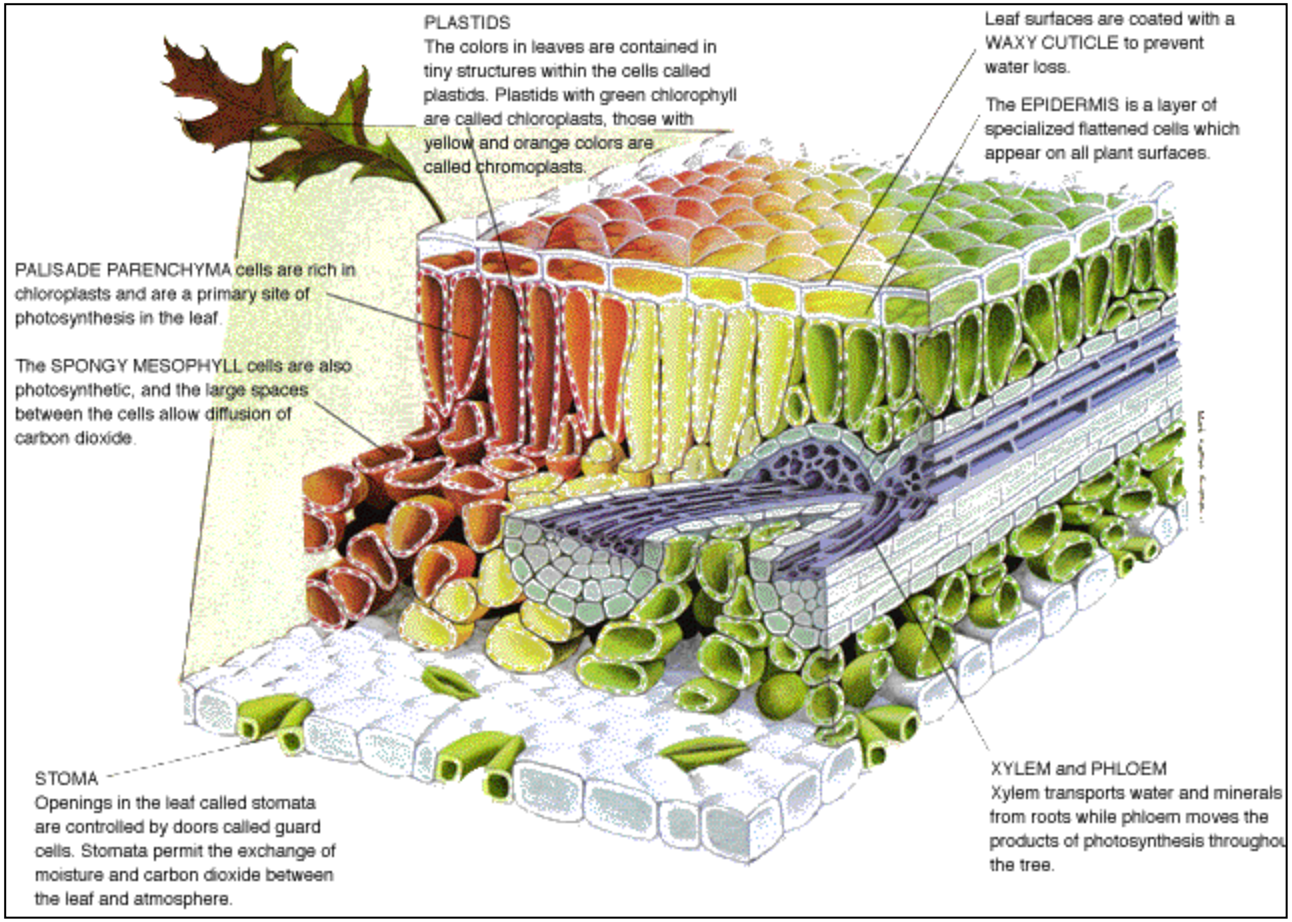
Spectra of common Earth-surface materials



Spectra of common Earth-surface materials

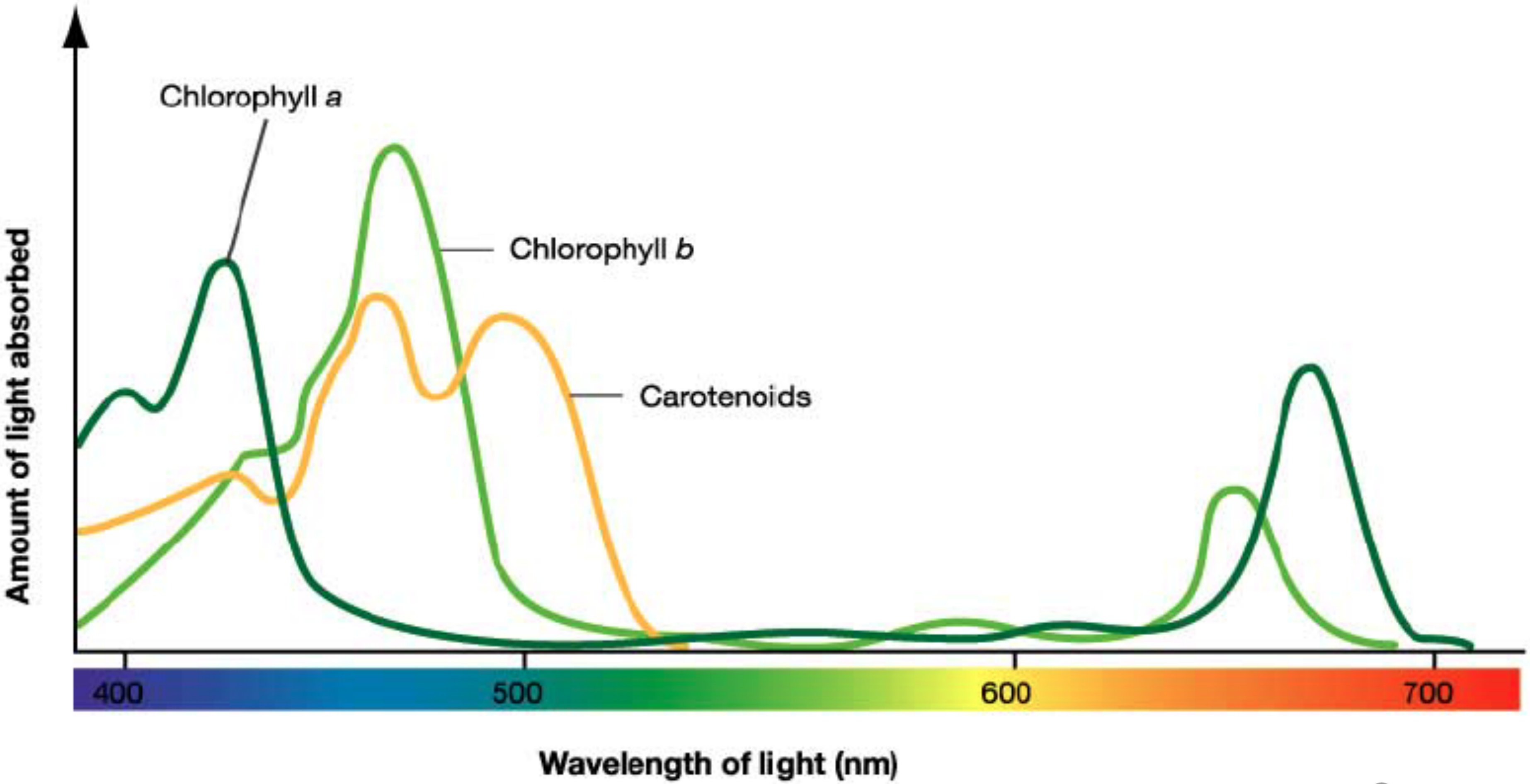


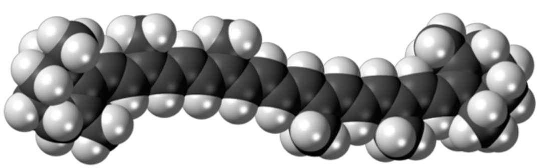
Leaf structure and its relation to spectra



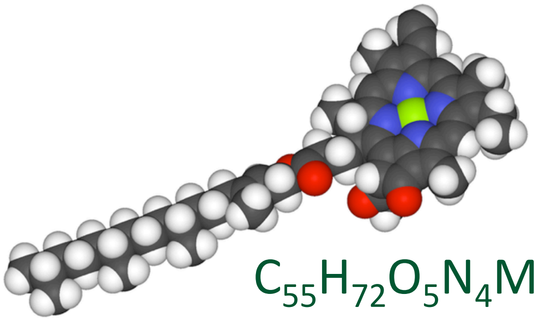
Absorption band in red: chlorophyll pigment
Reflective NIR: scattering in the prismatic leaf cells
SWIR absorption: absorption by leaf water

Plant Pigments



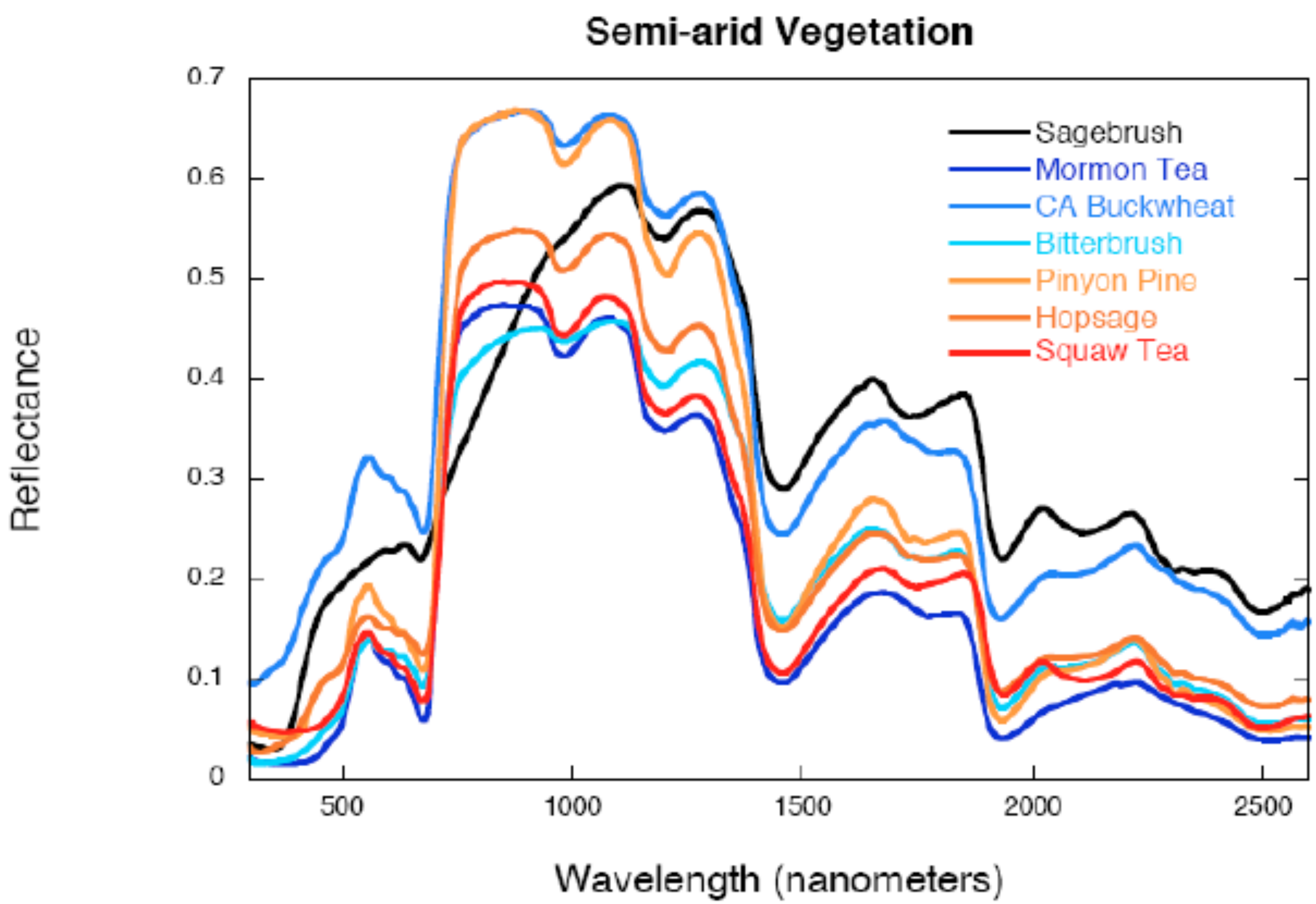


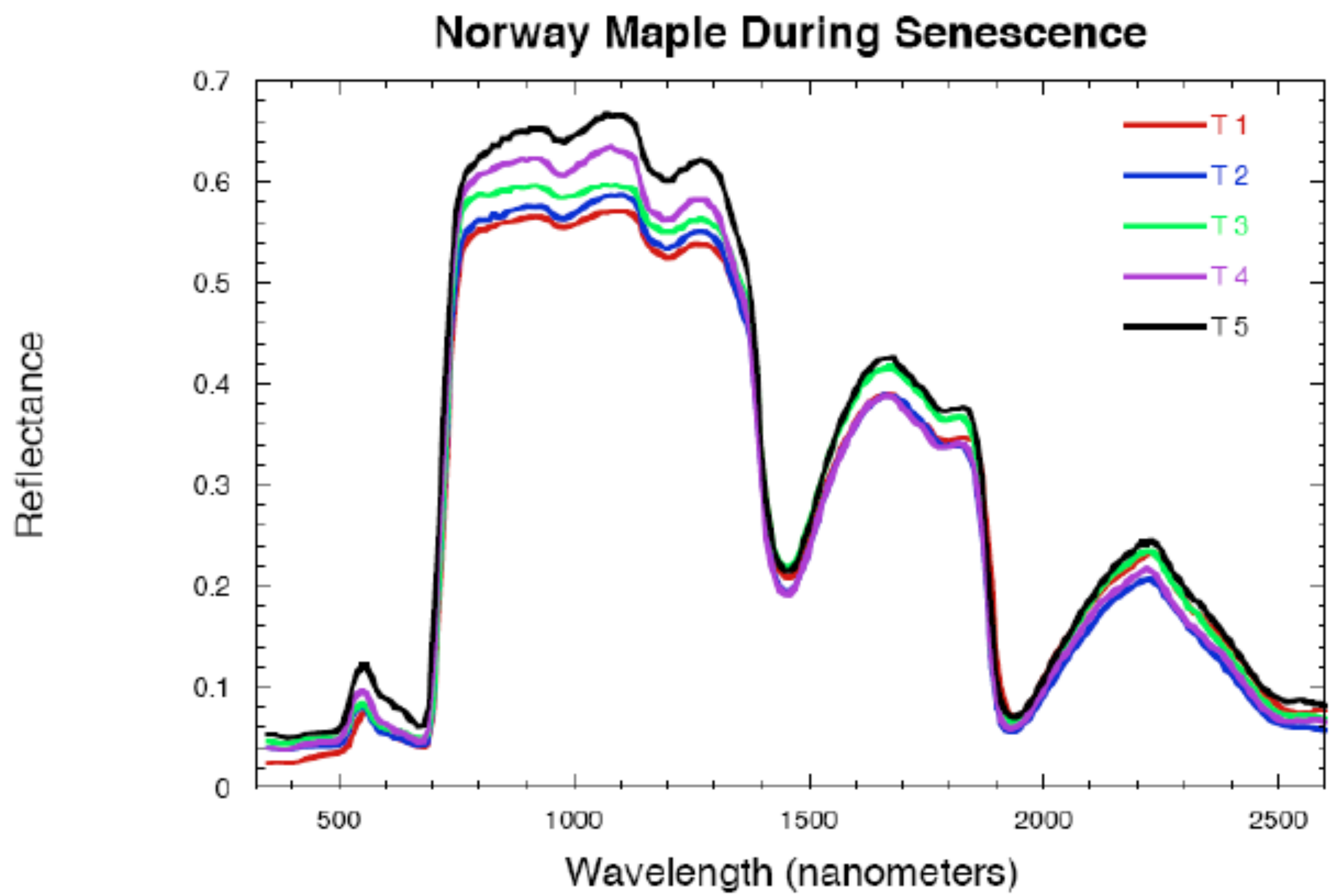
$C_{40}H_{56}$



$C_{55}H_{72}O_5N_4Mg$

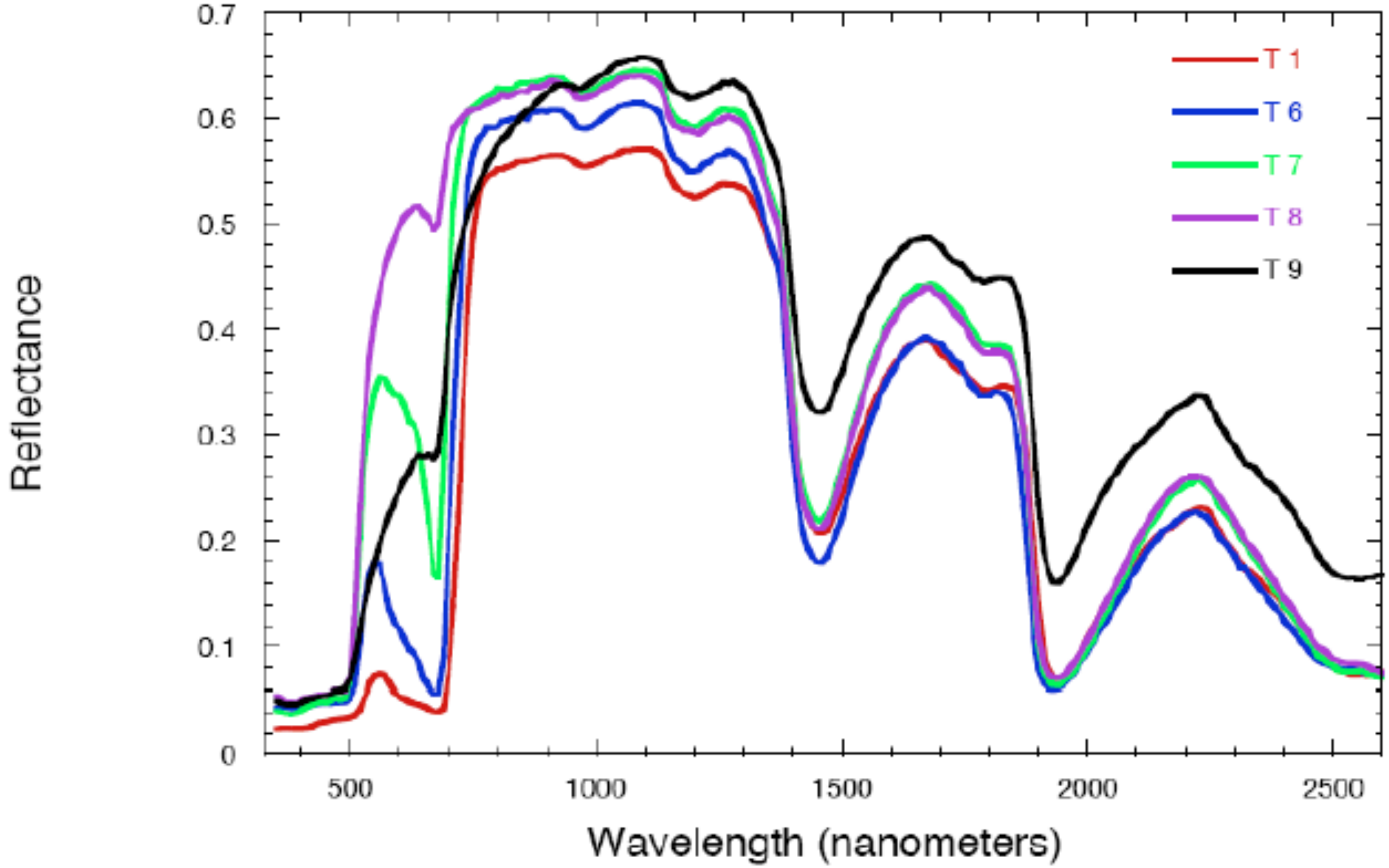
Variations from one species to another

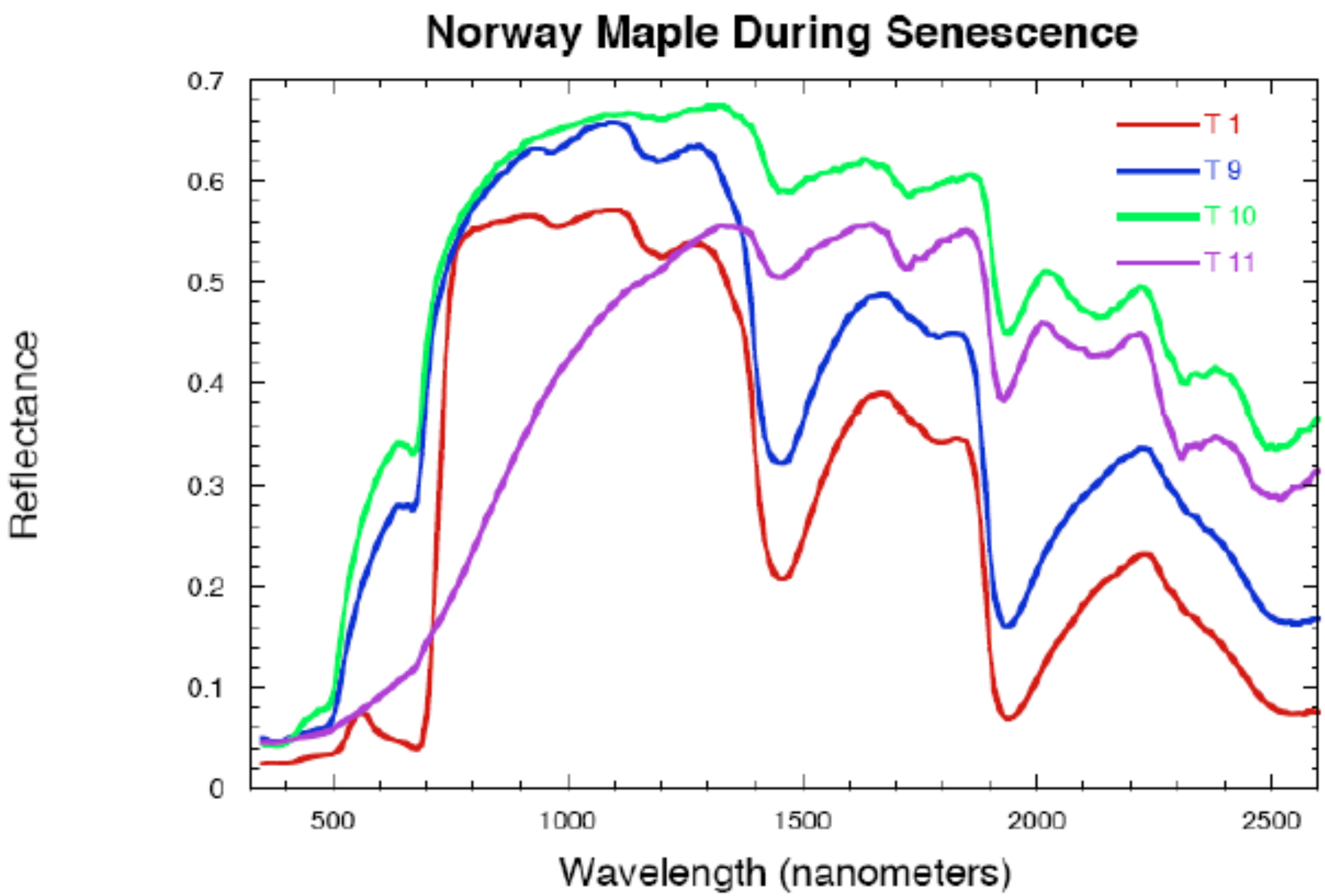




Norway Maple During Senescence
Reflectance
Wavelength (nanometers)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
500
1000
1500
2000
2500
T 1
T 2
T 3
T 4
T 5

Norway Maple During Senescene

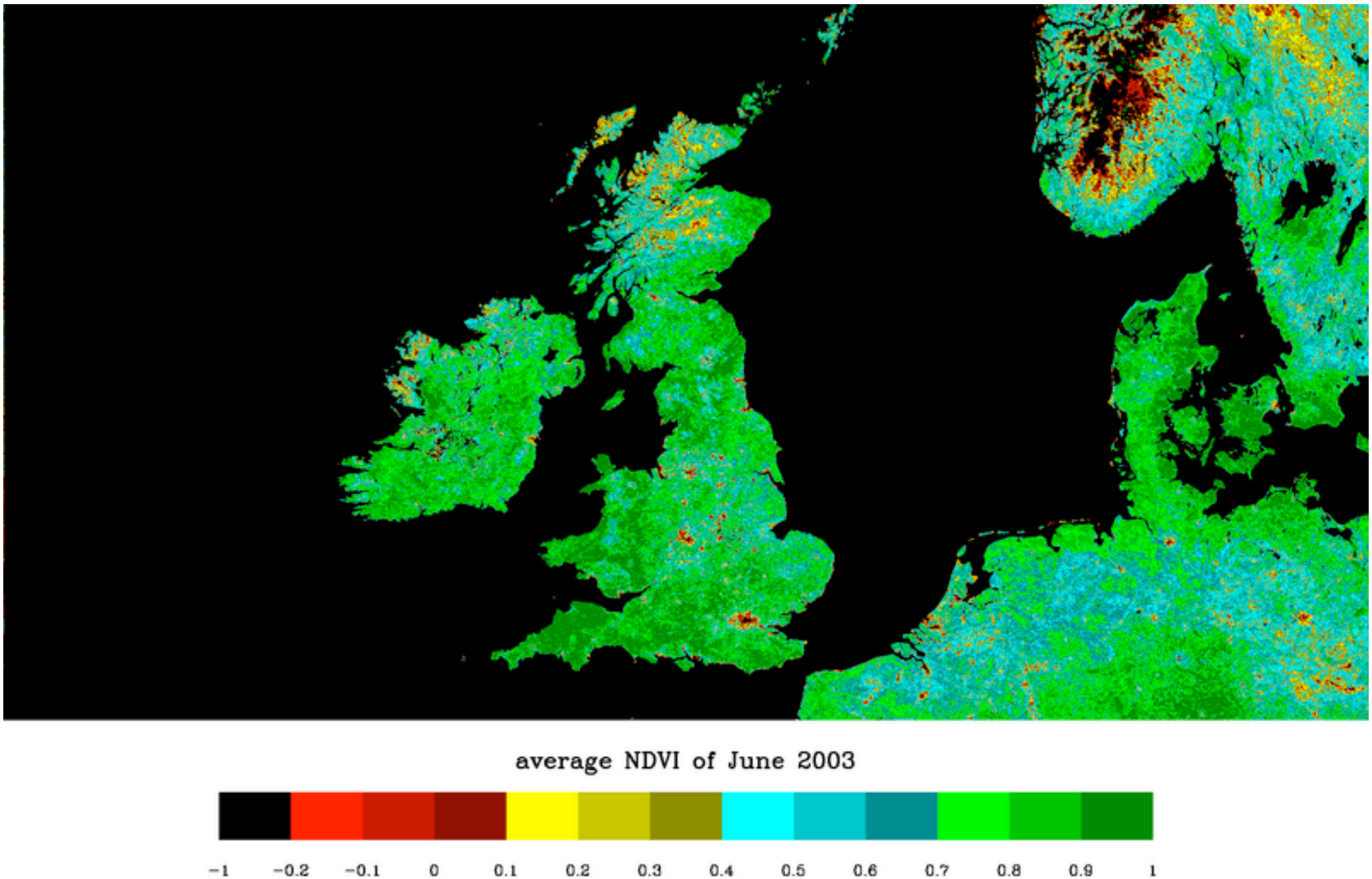




Norway Maple During Senescence
Reflectance
Wavelength (nanometers)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
500
1000
1500
2000
2500
T 1
T 9
T 10
T 11

Normalized Difference Vegetation Index

$$\mathrm{NDVI} = \frac{(\mathrm{NIR} - \mathrm{VIS})}{(\mathrm{NIR} + \mathrm{VIS})}$$



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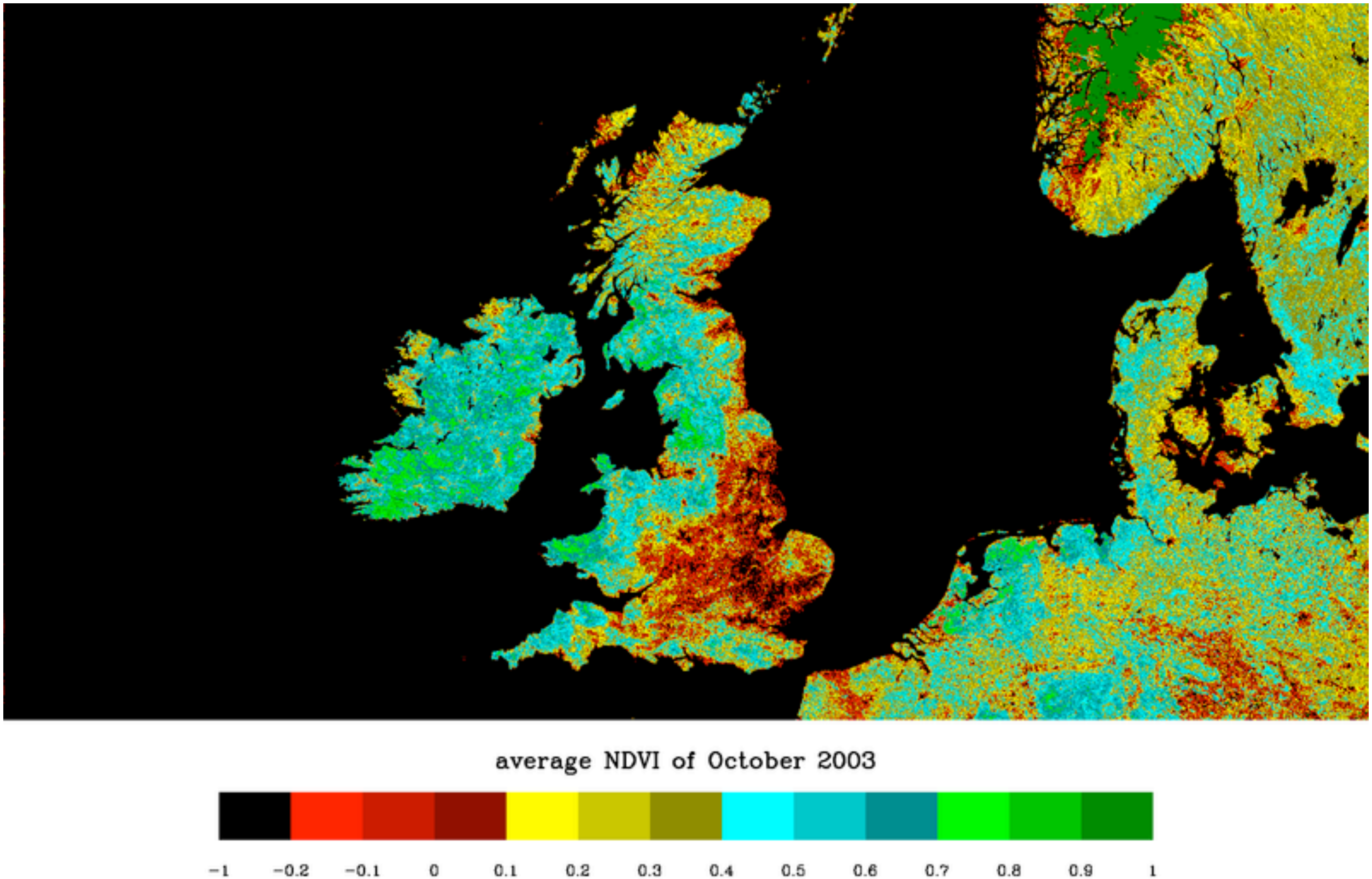
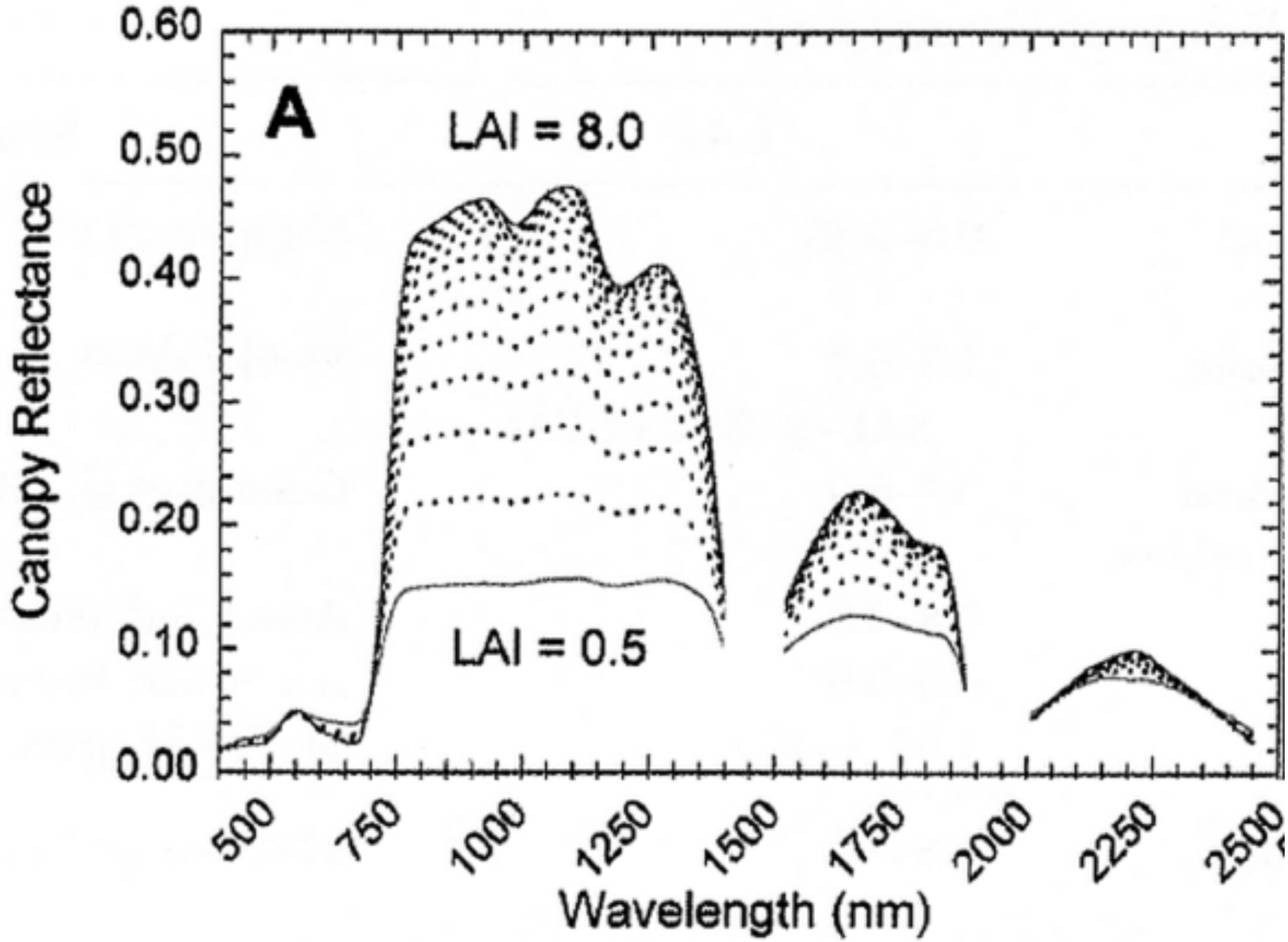


Thicker canopy = *more* reflective

(at wavelengths where absorption is minimal)



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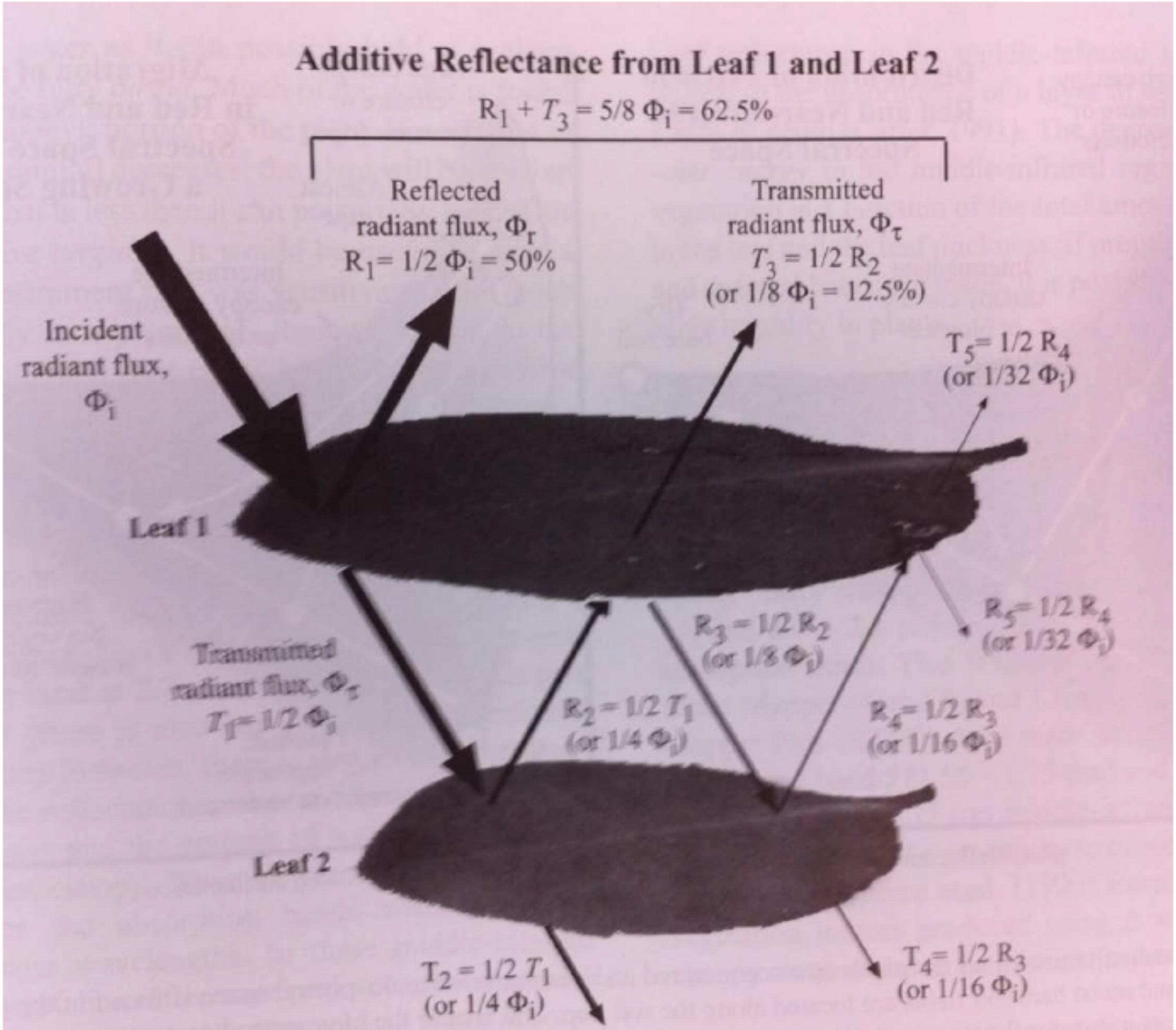
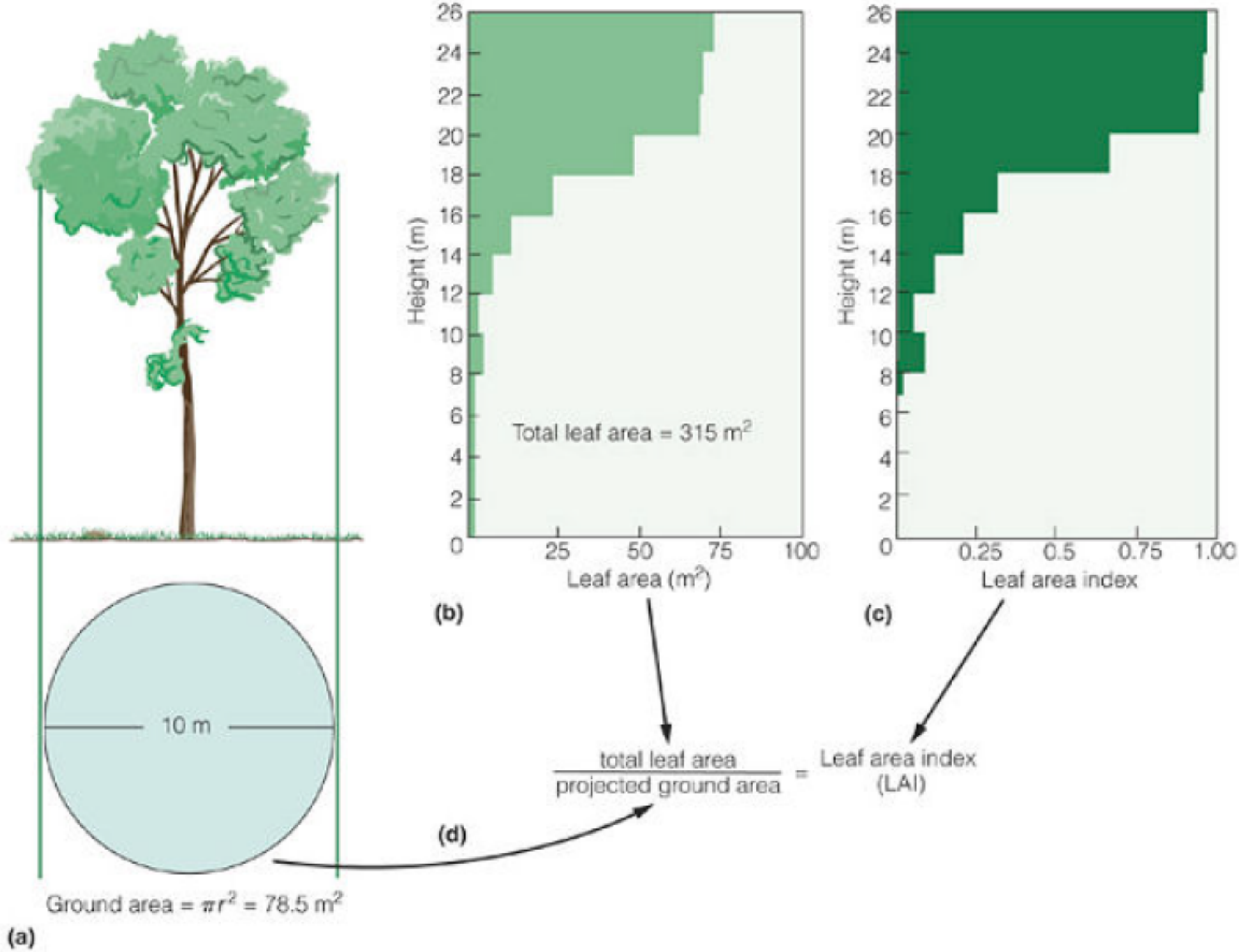
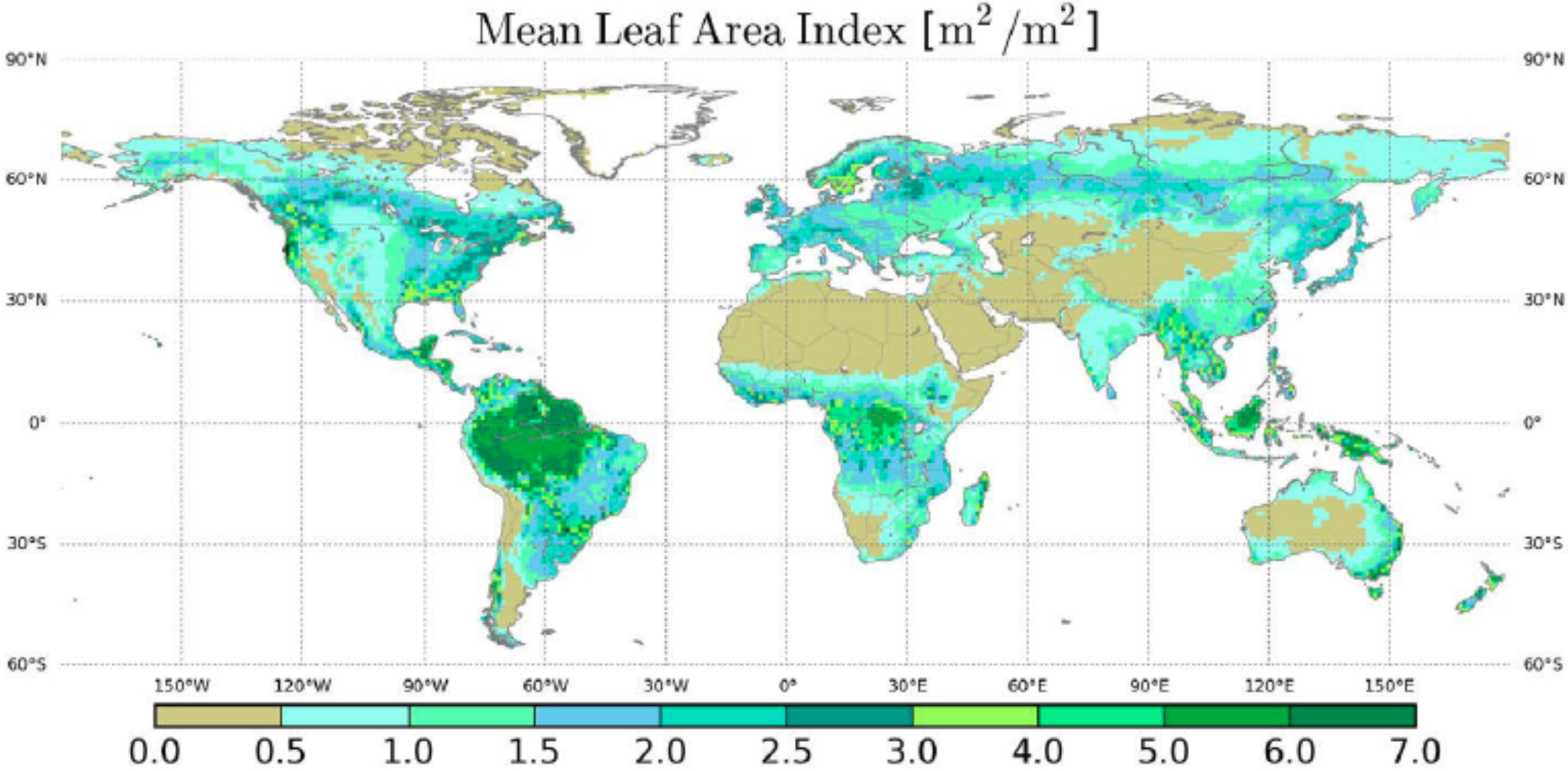


Leaf Area Index (LAI):

the one-sided green leaf area per unit ground surface area




Mean Leaf Area Index [m^2/m^2]
90°N
60°N
30°N
0°
30°S
60°S
150°W
120°W
90°W
60°W
30°W
0°
30°E
60°E
90°E
120°E
150°E
0.0
0.5
1.0
1.5
2.0
2.5
3.0
4.0
5.0
6.0
7.0

$$EVI = G \times \frac{(NIR - RED)}{(NIR + C1 \times RED - C2 \times Blue + L)}$$