# Thoughts on Some On-orbit and other Sensors


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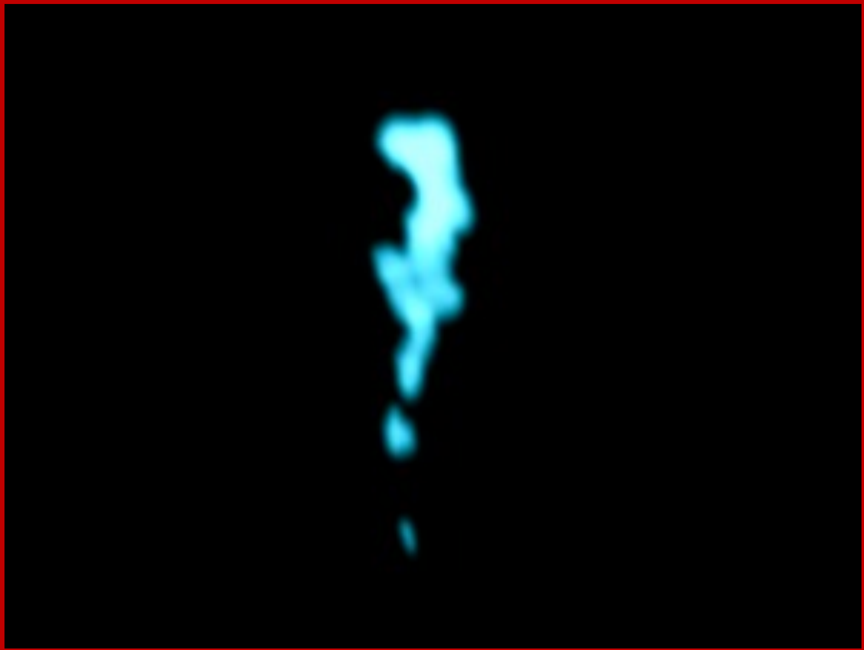
# Sensing of Ocean Bioluminescence

- a generally weak signature predominantly in the green region of the spectrum that is emitted by marine organism when they are subjected to mechanically generated turbulence or moderate levels of stimulation with optical radiation.
- For example, an outboard motor on a small craft can stimulate a trail of bioluminescence in surface waters that may persist and be observable for several hours with an appropriate detector.
- A large ship's propellers, despite being below the surface, could generate bioluminescence that would propagate to the ocean surface and be detectable from space.

It



# Bioluminescence

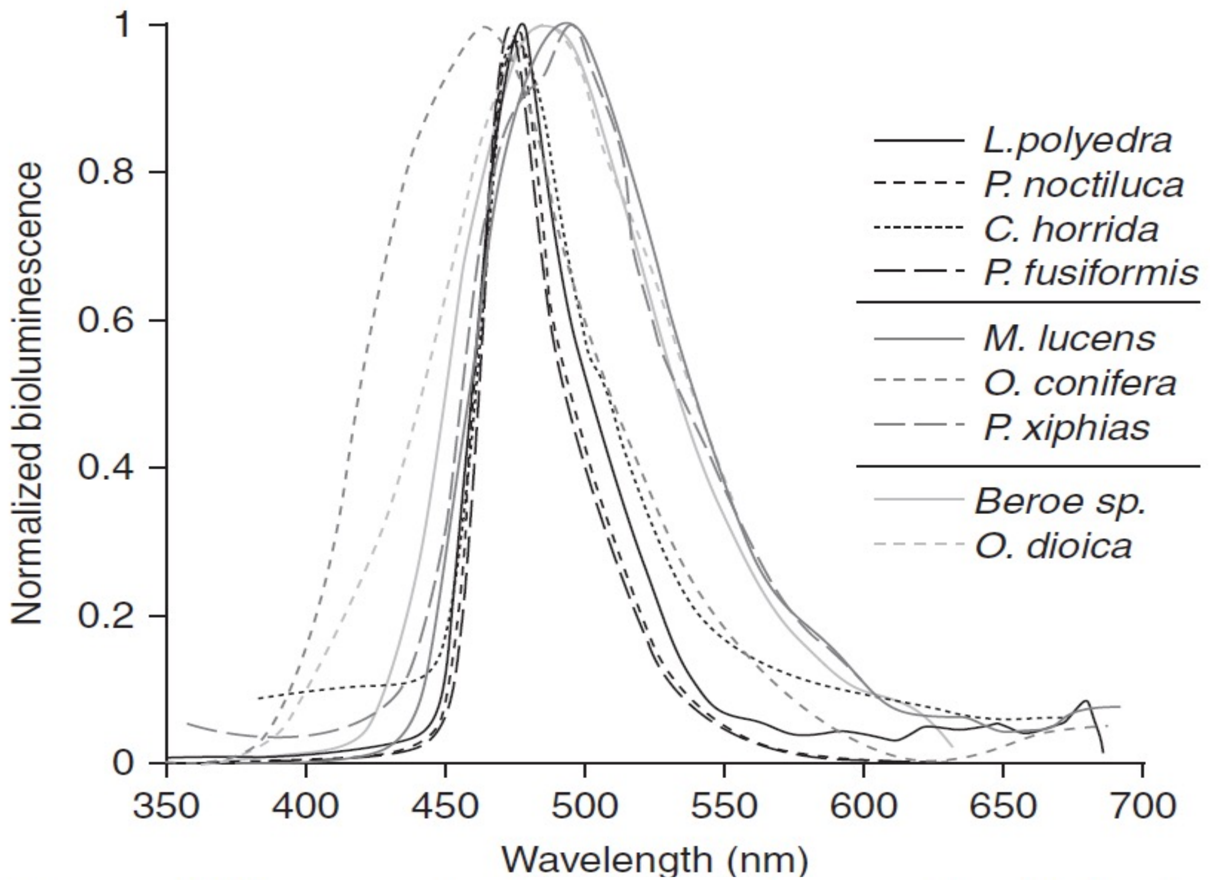
- Almost all polar orbiting satellites are turned off at night-time.
- So, here we are proposing a cubesat that, in contrast, is turned on at night-time.
- Applications could include use of bioluminescence at night to identify:

(i) vessel movement,
(ii) vessels that are illegally fishing in reserves / conservation zones,
(iii) tracking sub-surface marine vessels.

# Proposal

The proposal is for the specification and development of a prototype Cubesat sensor to be initially trialled at night by deployment from:

a) a small craft and sensing bioluminescence irradiance levels from marine vessels' wake / mechanical turbulence,
b) observing bioluminescence stimulated by a surface /sub-surface source of turbulence located at various depths in the ocean, and
c) sensing bioluminescence using a light aircraft or drone flying over these same targets.




*7.2* Spectral differences in nine commonly occurring bioluminescent species. The four species indicated with black lines are dinoflagellates, while the dark gray are copepods and the light gray lines show *Beroe* sp., a ctenophore, and *Oikopleura dioica*, an appendicularian. While dinoflagellates are closely centered at ~475 nm, high trophic levels show a larger range of color.

# Topic 2: ASHi (Spectroscopic Hazards imager)

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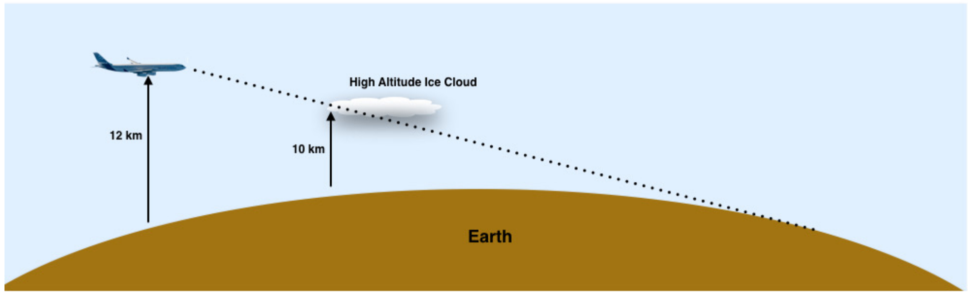
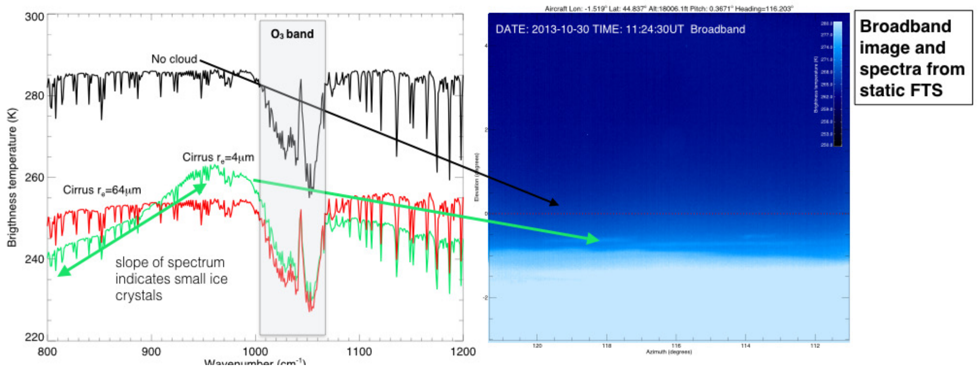



SIMULATION



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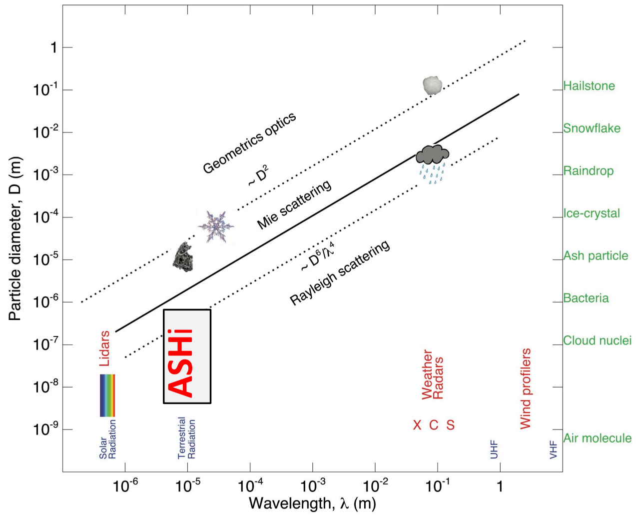
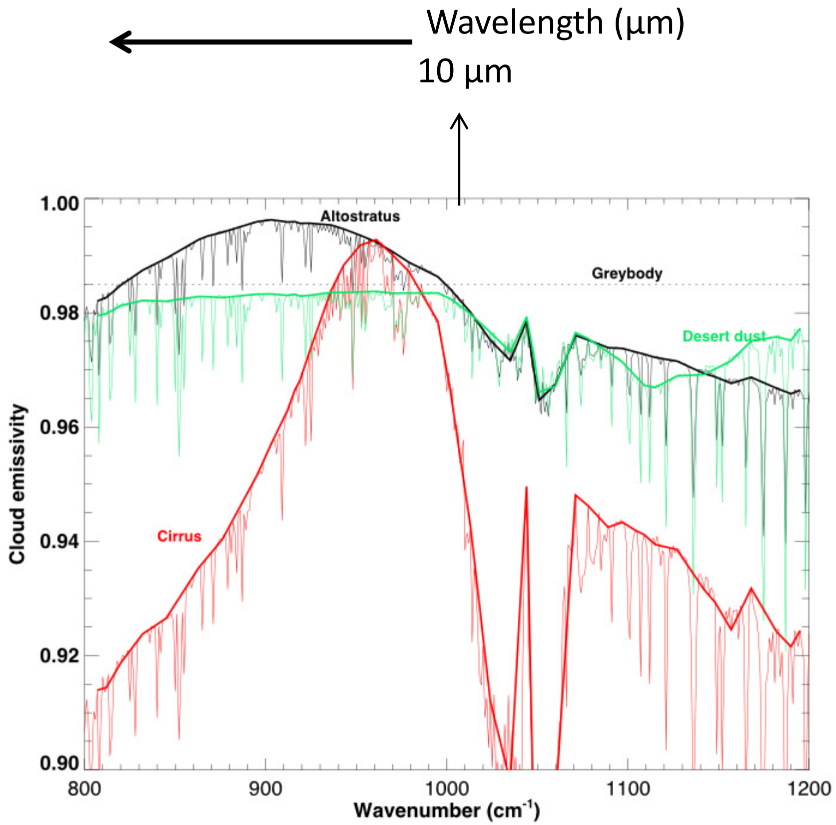
# ASHi : Advanced Spectroscopic Hazards imager




Library of "spectral shapes" is used to determine cloud or aerosol type. Shapes are normalised by calculating the cloud emissivity. $\boldsymbol{\varepsilon}_c(\boldsymbol{\lambda})=1$ represents a blackbody (e.g. the ocean surface). $\boldsymbol{\varepsilon}_c(\boldsymbol{\lambda}) < 1$ is a greybody. Generally clouds that are not opaque reveal spectral variation in $\boldsymbol{\varepsilon}$.

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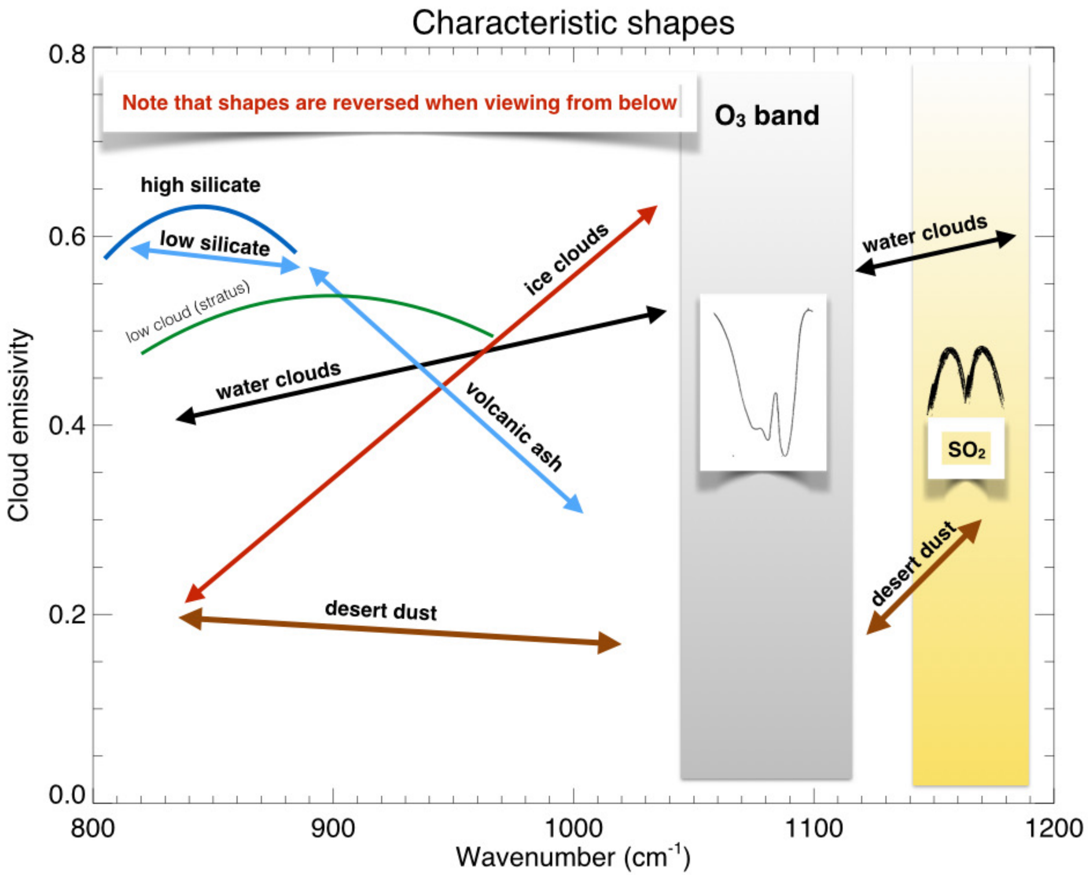
# ASHi : Advanced Spectroscopic Hazards imager




Spectral characteristic shapes of certain clouds and particles viewed against a warmer background

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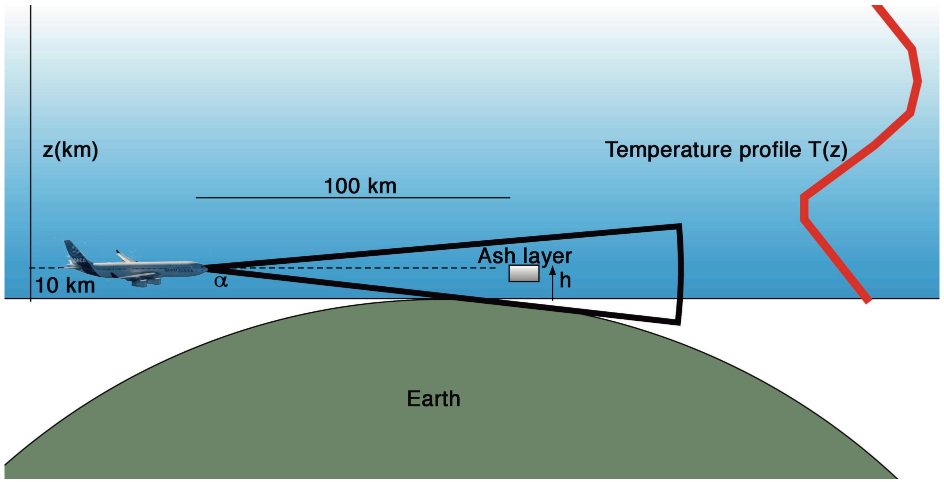
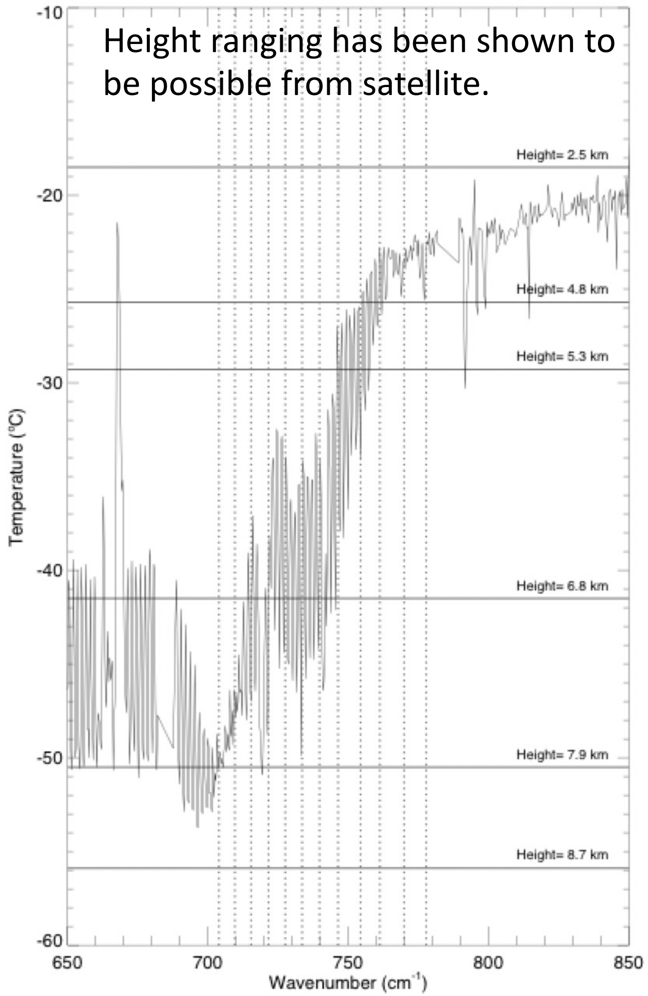
# ASHi : Advanced Spectroscopic Hazards imager

Other possibilities include ranging using spectroscopic scann




Height ranging has been shown to be possible from satellite.



# Topic 3: **Prospecting for Green Hydrogen**

- The early Universe evolve from hydrogen gas following the Big Bang over the past 13.6 or so billion years. Over time the elements of the Periodic Table were produced. So there has always been plenty of hydrogen in the Universe. Ubiquitous!

- Hydrogen gas is far more abundant than was at first believed.

- It is being regenerated continuously in th natural environment

  eg iteraction of water with iron ore deposits
  natural uranium sourced radiation and the hydrolysis of water

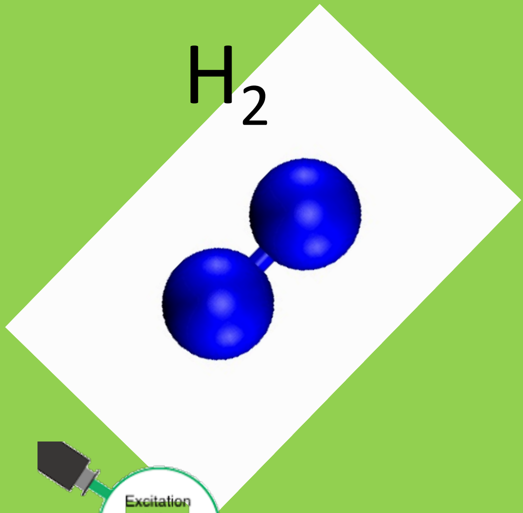
# Sub-surface Chemistry

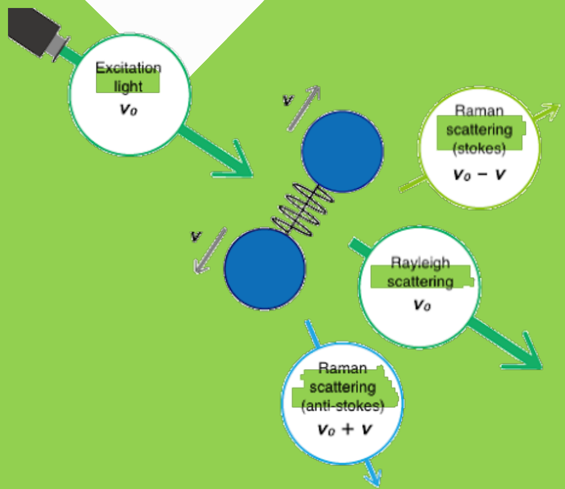
Two reactions involving iron oxides and water that release hydrogen that ultimately reaches the atmosphere

$$2FeO + H_2O \rightarrow Fe_2O_3 + H_2 \uparrow$$

$$2Fe_3O_4 + H_2O \rightarrow 3Fe_2O_3 + H_2 \uparrow$$

# What is Raman Scattering?




Raman ~Rayleigh /1000

- The $H_2$ molecule has a natural frequency of vibration.
- Three types of scattering of light by gases - Raman Stokes and Raman anti-Stokes and Rayleigh
- Light interacting with the molecule loses energy to the molecular vibration and is emitted with an energy less than it had – it's called Stokes scattering

Energy of re-emitted photon = the energy of the original photon – the energy of molecular vibration

- There's another less probable process where the photon is emitted with more energy (anti-Stokes).

All molecules have their own characteristic vibrational energy so the Raman scattering spectrum can be used to determine the molecules present in air

- If the scattered photon is the same as the incident photon – it's called Rayleigh scattering –Raman scattering about 1000 smaller than Rayleigh scattering

All light scattering becomes more efficient as the wavelength, $\lambda$, gets shorted as $\lambda^{-4}$ (it's why the sky is blue). So for Raman scattering it's better to use short-wavelength (blue) light.

# Natural hydrogen in Mali

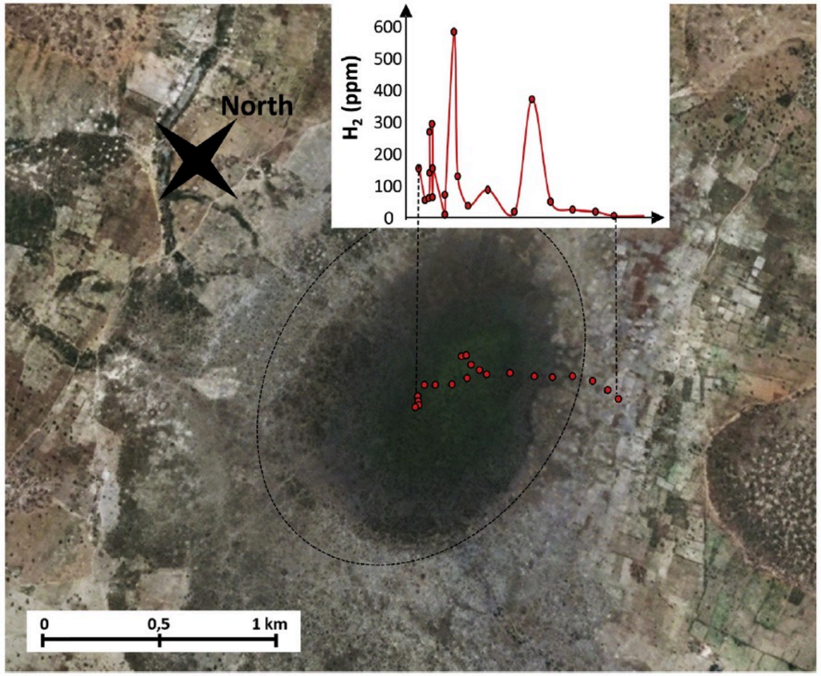
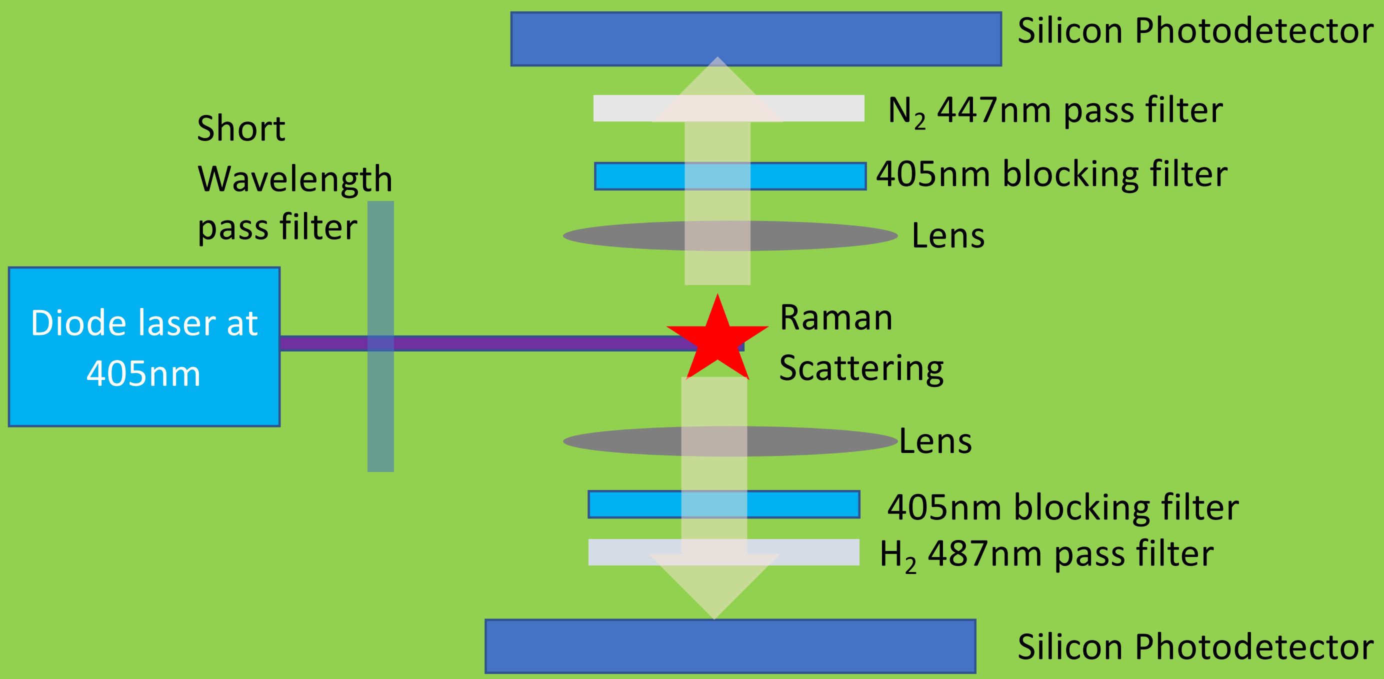



**Fig. 2 – Surface geochemistry of a circular structure located East of the block 25 of PETROMA and close to the village of Gassola. A profile of the hydrogen concentrations (in ppm) is also presented. The coordinates of the center of the structure are a latitude of 13.194605° and a longitude of –6.242527°.**

- 100-600ppm concentration of $H_2$ seeping out of circular structure in Mali
- 100m below the surface there's 98%$H_2$
- Enough gas to run a power station in Gassola

Prinzhofer, C. S. T. Cisse, and A. B. Diallo, "Discovery of a large accumulation of natural hydrogen in Bourakebougou (Mali)," *International Journal of Hydrogen Energy,* Article vol. 43, no. 42, pp. 19315-19326, Oct 2018.
Canadian Company, Petroma is now  Hydroma :-https://hydroma.ca/en/

# Diode laser based Raman System




Based on Velez et al. paper the estimated sensitivity of this set-up ~100ppm with 1 minute response time

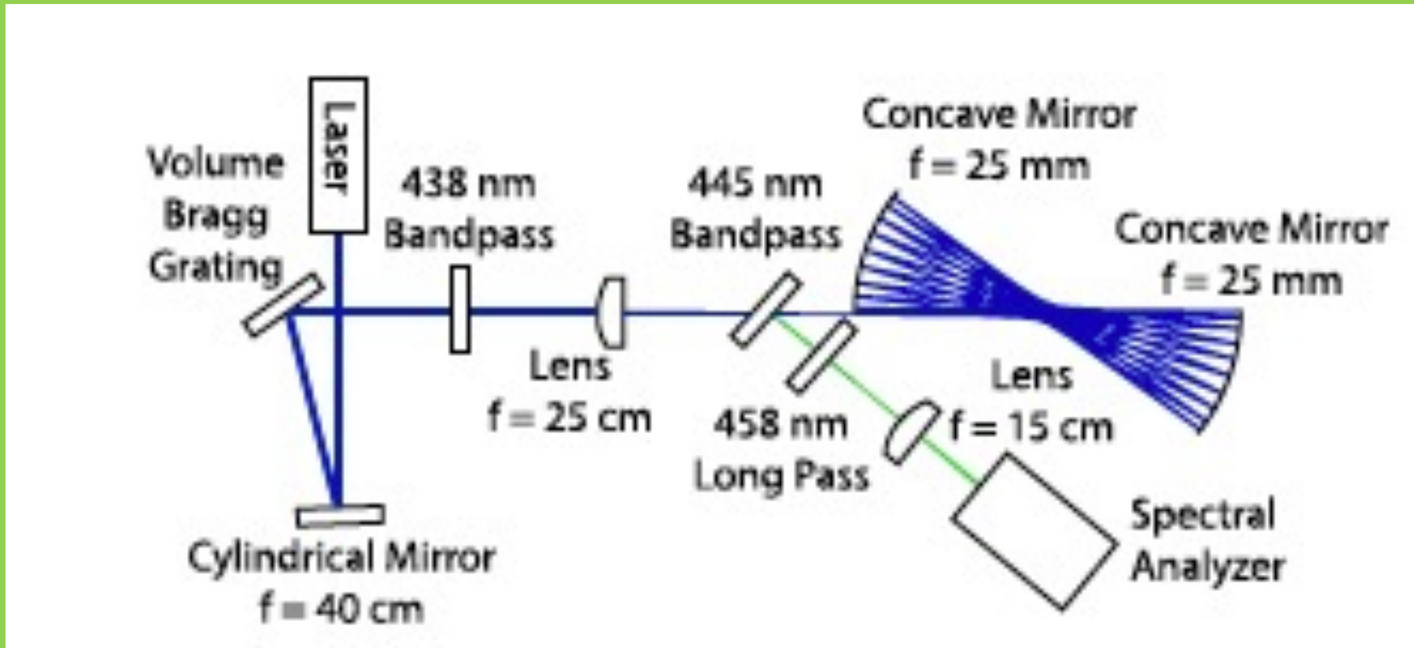
J. S. G. Velez and A. Muller, "Spontaneous Raman scattering at trace gas concentrations with a pressurized external multipass cavity," *Measurement Science and Technology,* Article vol. 32, no. 4, p. 7, Apr 2021, Art. no. 045501.

# Diode laser @405 nm Raman System
# - not eye safe since these output ~ 500 mW


https://www.amazon.com.au/Purewords-Focusable-CNC2418-Wavelength-Supportive/dp/B08D8H1VX8/ref=asc_df_B08D8H1VX8/?tag=googleshopdsk-22&linkCode=df0&hvadid=463522462473&hvpos=&hvnetw=g&hvrand=13824990486527879033&hvpone=&hvptwo=&hvqmt=&hvdev=c&hvdvcmdl=&hvl

$50 Diode lasers
$450 Laser safety glasses

# Diode laser-based Raman System – for personnel or laboratory monitoring. Role is safety.




With this system for $H_2$ the Limit of Detection (LOD) in 300s is 0.04ppm


J. S. G. Velez and A. Muller, "Spontaneous Raman scattering at trace gas concentrations with a pressurized external multipass cavity," *Measurement Science and Technology,* Article vol. 32, no. 4, p. 7, Apr 2021, Art. no. 045501.
J. G. Velez and A. Muller, "Trace gas sensing using diode-pumped collinearly detected spontaneous Raman scattering enhanced by a multipass cell," *Optics Letters,* Article vol. 45, no. 1, pp. 133-136, Jan 2020.

## Up-scaling for Airborne Prospecting

The cross-section for Raman scattering is very low and this creates some challenges.  However, scope exists in scaling including increasing

(a) the laser source*

(b) the collecting area of the receiving telescope, and

(c) the detector gain and SNR.

These options, which offer 500  to 10,000-fold increase in sensitivity will be better defined following the initial In-lab investigations.

* Subject to eye safety  requirements