Curtin University

Astronomy & Earth Observing Synergy: a Space-based Bioluminescence Sensor

by

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Synergies for Earth and Space Observing Systems

There are a number of synergies between space-based sensors that either are intended to look outward to space or downward to the Earth. Astronomy sensor attributes might include:

- high sensitivity,
- high angular resolution,
- visible spectrum operation,
- spectral characterisation,
- low noise levels,
- pointing knowledge/accuracy,
- imaging capability,
- night-time operation etc

for observing low magnitude astronomical objects or transient events.

Earth Observations with Cubesats

- A number of these instrument attributes, when written into a specification, also may be appropriate to support Earth-viewing space-based missions and thereby permit joint development of hardware with significantly common requirements.
- So, in one sense, this presentation is a plea to ensure that the technology that underpins cubesat development is shared within the research community irrespective of the applications.
- The above list of sensor attributes certainly apply in the case of sensing of ocean bioluminescence

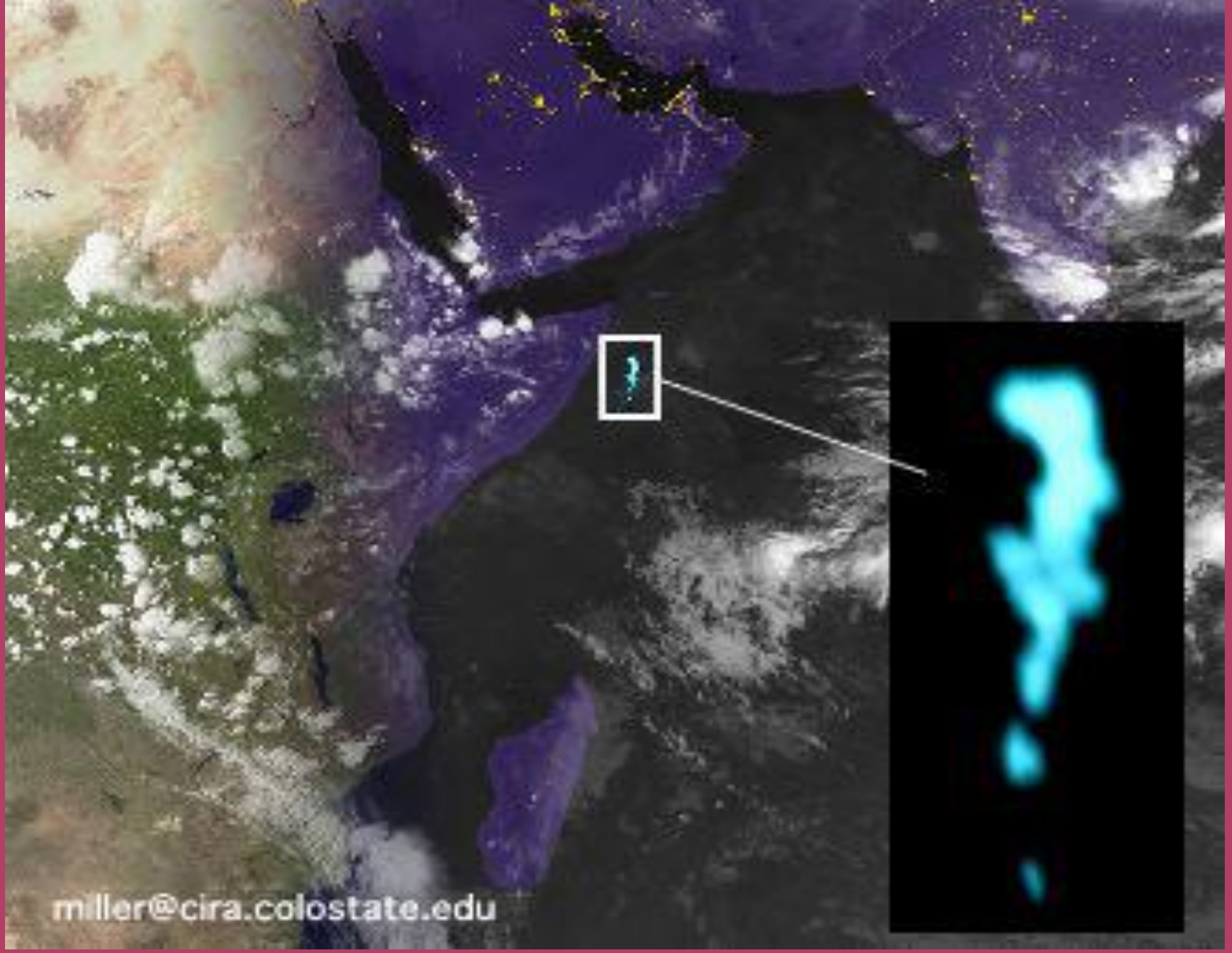
The Occurrence of Bioluminescence in the Oceans

It "*is so widespread in the sea that its absence is more remarkable than its presence (Kelly and Tett, 1978). Dinoflagellates are typically the most abundant sources of bioluminescence in coastal waters; at concentrations greater than 100 cells* l^{-1} *they emit sufficient bioluminescence to highlight moving objects (Morin, 1983), ship wakes (Bityukov, 1971; Hastings, 1975), submarines (Tarasov, 1956; Staples, 1966), divers (Lythgoe, 1972), seals (Steven, 1950; Williams and Kooyman, 1985) and fish (Harvey, 1952; Hardy, 1956; Morin, 1983) have all been observed to produce bioluminescent signatures.*

Nocturnally foraging predators may use the bioluminescence inadvertently stimulated by swimming animals to locate their prey (Hobson, 1966; Mensinger and Case, 1992; Fleisher and Case, 1995).

Bioluminescence stimulated by shoals of fish has been used in aerial assessments of pelagic fish stocks (Roithmayr, 1970; Cram and Hampton, 1976)."

(J Rohr et al 1998)


miller@cira.colostate.edu

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, with an appropriate detector, may persist and be observable for several hours.
- A large ship's propellers, despite being below the surface, could generate bioluminescence that would propagate to the ocean surface and also be detectable from space.

Bioluminescence

- Almost all polar orbiting satellites are turned off at night.
- Those few that remain turned on at night have resolution typically of ~ 1 km.
- 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

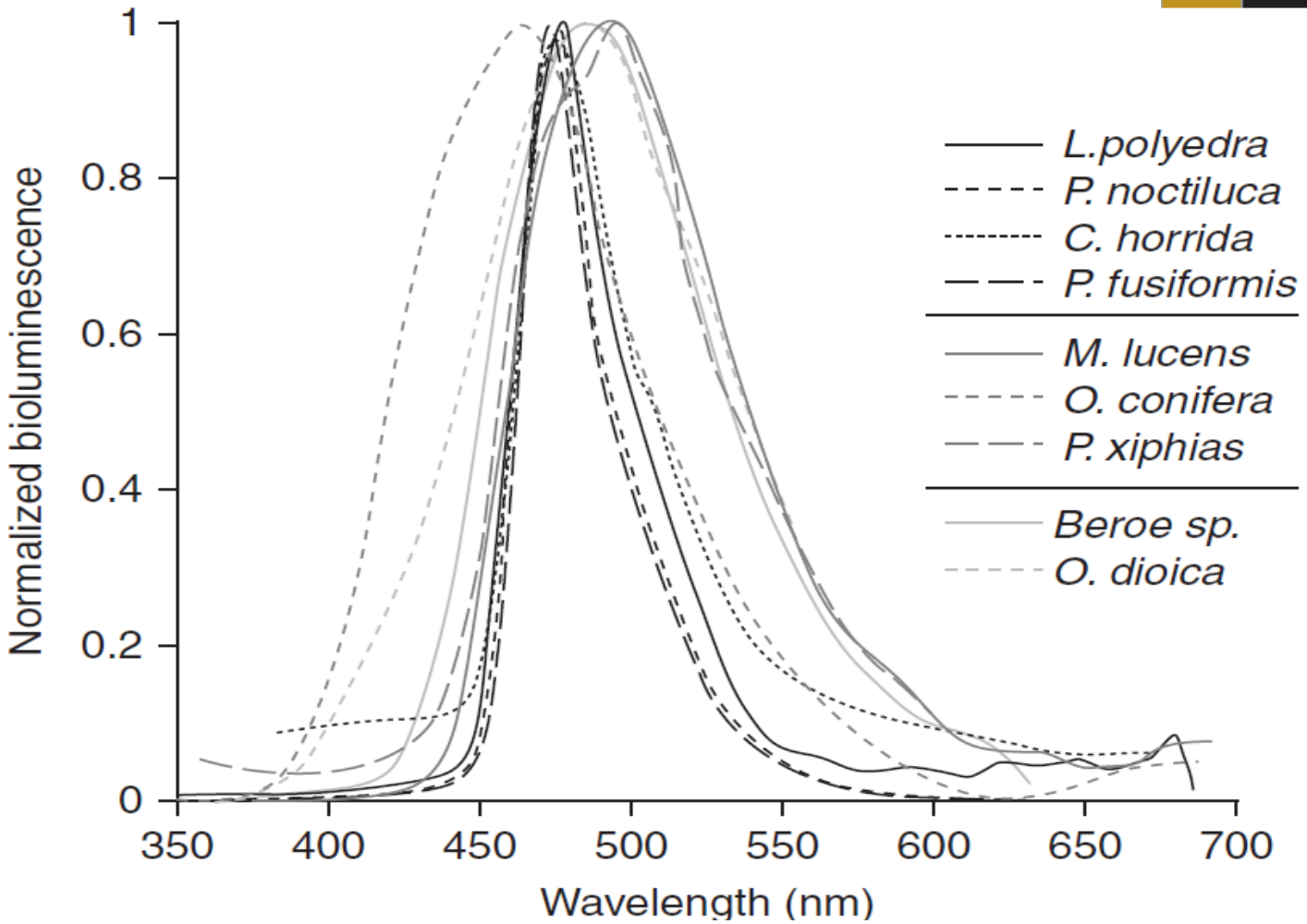
The proposal is for the specification and development of a prototype Cubesat sensor to be initially trialled at night by deployment from:

a) a small craft and sensing bioluminescence irradiance levels from marine vessels' wake / mechanical turbulence,

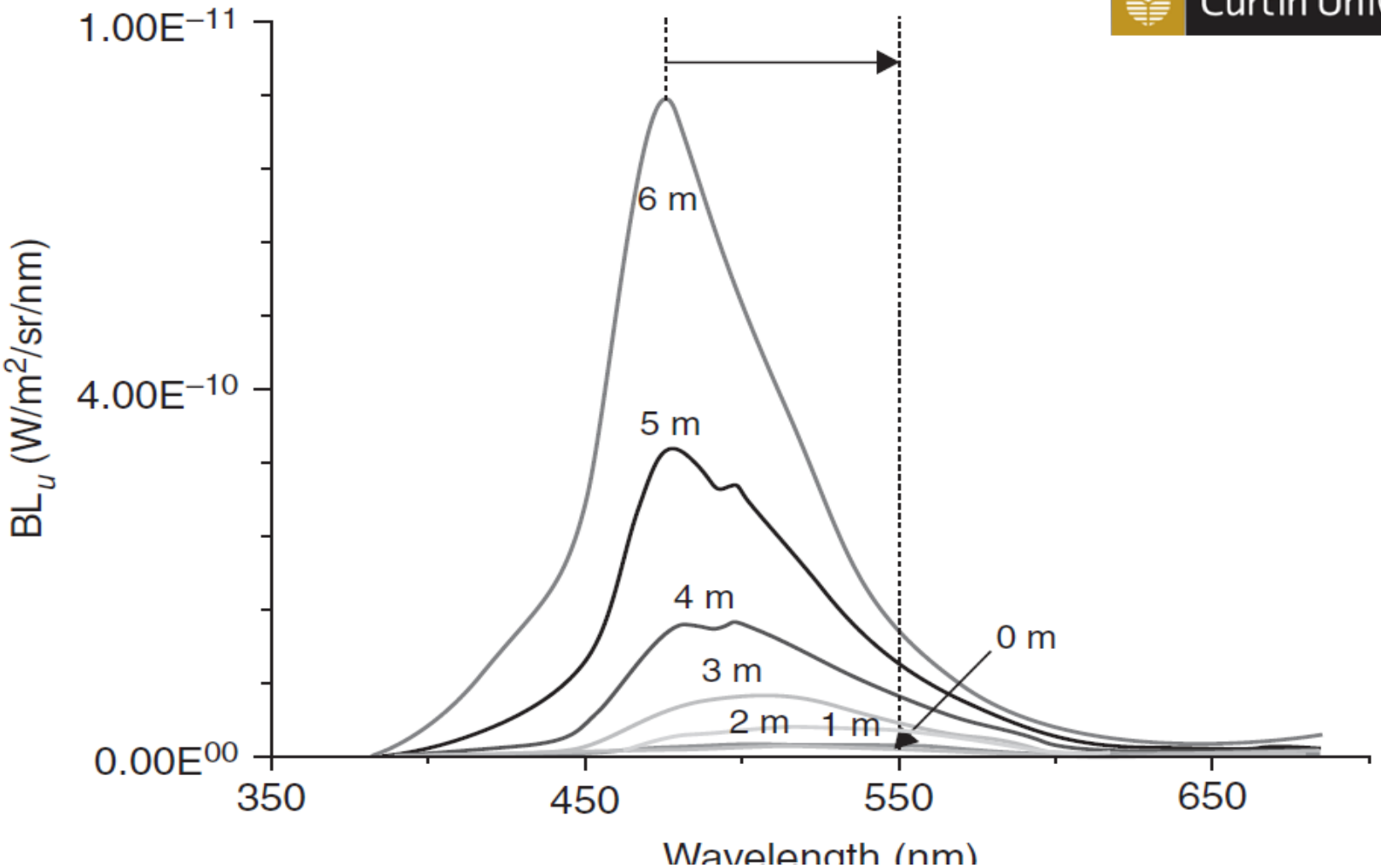
b) observing bioluminescence stimulated by a surface /sub-surface high irradiance LED light source located at various depths in the ocean,

c) sensing bioluminescence using a light aircraft or drone flying over these same targets, and

d) developing a cubesat.

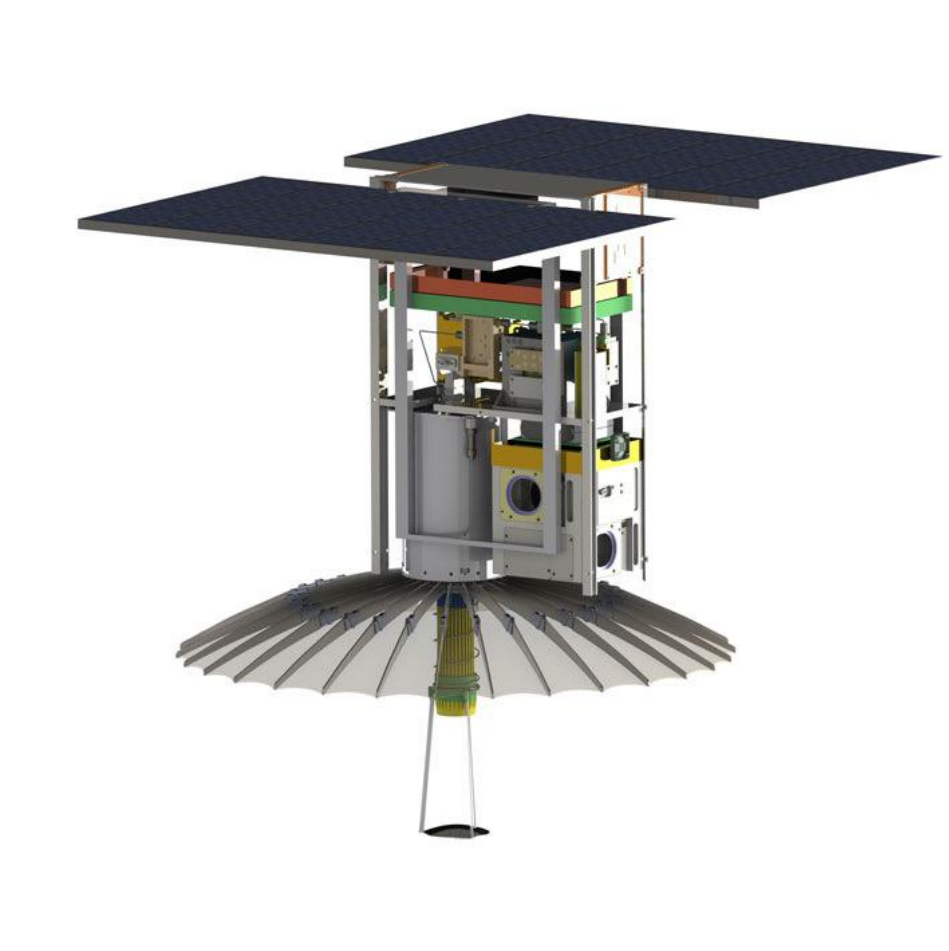


7.2 Spectral differences in nine commonly occurring bioluminescent species. The four species indicated with black lines are dinoflagellates, while the dark gray are copepods and the light gray lines show *Beroe* sp., a ctenophore, and *Oikopleura dioica*, an appendicularian. While dinoflagellates are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



7.7 Example of the spectral shift in the maximum wavelength of the upward bioluminescence radiance (BL_u) at meter intervals away from the source predicted by from Hydrolight based on stimulation of bioluminescence at 7 m. This example was for one depth for one of the 48 daily profiles of the 23 day study (Moline *et al.*, 2007). Simulation used measured BP, spectral scattering, spectral absorption, and backscatter at each meter depth interval.

The end



Mission Title: Ocean Bioluminescence Astronomy,

Proposed by: Adjunct Prof Merv LYNCH et al, Department of Physics and Curtin University, PO Box U1987, Perth, WA 6845

Parameters	Risk Assessment Low	Medium	High	Comments
Science Objective				
Mission Requirements		X		The assessments below are very preliminary and would be adjusted one the specification of the mission was refined. Generally, where decisions are to be made, the approach will be to "keep it simple stupid".
Target Orbit	X			No requirement for a high orbit. 400 – 500 km would be fine.
ACDS			X	This will become more demanding as the spatial / angular resolution of the sensor is improved.
Power		X		Because the unit operates at night it will be recharged through the day. Also, it is intended to operate mainly over Australian waters and perhaps part of the Indian Ocean.
Communications Data		X		An imaging system would increase the data transmission demands.
On-board Processing	X			
Thermal Control	X			
Radiation Level	X			
Size	X			
Mass	X			
Cost		X		

Preparatory Activities

- Observe ship wakes for bioluminescence intensity, duration, geographic variability, seasonal variability
- Continental water column properties
- Hydrolight modelling of deep water bioluminescence sources and detectibility
- Specifications for detection systems eg low noise detector, quantisation, spectral coverage; multiple channel to observe spectrum?