DESIGN OF AN ADVANCED, COMPACT ICE GIANTS NET FLUX RADIOMETER.

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Introduction: Two science objectives, relevant to our advanced Ice Giants Net Flux Radiometer (IG-NFR) capability, were identified in the Ice Giant Pre-Decadal Study Science Traceability Matrix [1], *i.e.*, (i) determine the planet's atmospheric heat balance, and (ii) determine the planet's tropospheric 3-D flow. It is not known in detail how the energy inputs to Uranus' or Neptune's atmosphere, *via* solar insolation from above and the remnant heat-of-formation from below, interact to create the planetary-scale patterns seen on these ice giants [2].

An understanding of circulation in these planetary systems requires knowledge of the vertical profile of radiative heating and cooling and its horizontal distribution. *In situ* measurements with our IG-NFR, using judiciously chosen filter channels [3][4], will determine the balance between the upward and downward solar and thermal radiation fluxes, Fig. 1. These measurements will enable us to evaluate effects due to primary opacity sources, and to establish the extent of deep solar heating, *e.g.*, below 1 bar pressure for the ice giants.

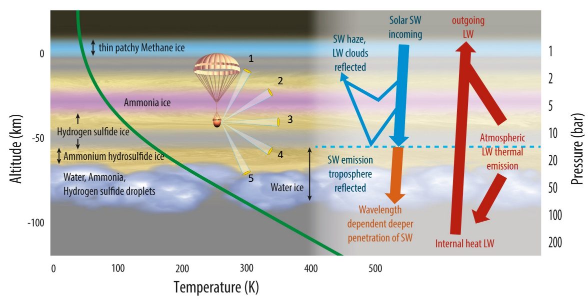

Fig. 1. Illustration of a probe descent through either Uranus or Neptune's poorly understood active and complex atmosphere. Our IG-NFR will reveal thermal structure, opacity sources, and help provide a global radiative balance. As the probe descends, seven spectral channels, each with 10° Field-Of-View (FOV), measure energy flux, sequentially and repetitively (clockwise and anti-clockwise) at five viewing angles. All seven channels are measured in parallel. The viewing angles (1-to-5) are shown at 2.5 s time intervals (2 s integration and 0.5 s slew to the next position). The sequence repeats anti-clockwise (5-to-1). Each spectral channel samples different physical processes. SW - Short Wave radiation; LW - Long Wave radiation.

Instrument Design: Our IG-NFR, Fig. 2, onboard a probe descending deep into the atmosphere, is designed to: (i) accommodate seven filter bandpass channels (ii) measure up and down radiation flux in a clear unobstructed 10° FOV for all seven channels in parallel; (iii) use thermopile detectors that can measure a change of flux of at least 0.5 W/m^2 per decade of pressure; (iv) view five distinct view angles (±80°, ±45°, and 0°); (v) predict the detector response with changing temperature environment; (vi) use Application Specific Integrated Circuit (ASIC) technology for the thermopile detector readout; (vii) be able to integrate radiance for 2 s or longer, and (viii) sample calibration targets every 19 s. Presently, uncooled single pixel thermopile detectors are chosen for good detection sensitivity of both visible and infrared radiation flux for all seven channels due to the ease of cross calibration between detectors. However, we are assessing the use of quantum photovoltaic detectors for the visible channels with regards to higher fidelity science return, detector cross calibration scheme and its implication on system complexity.

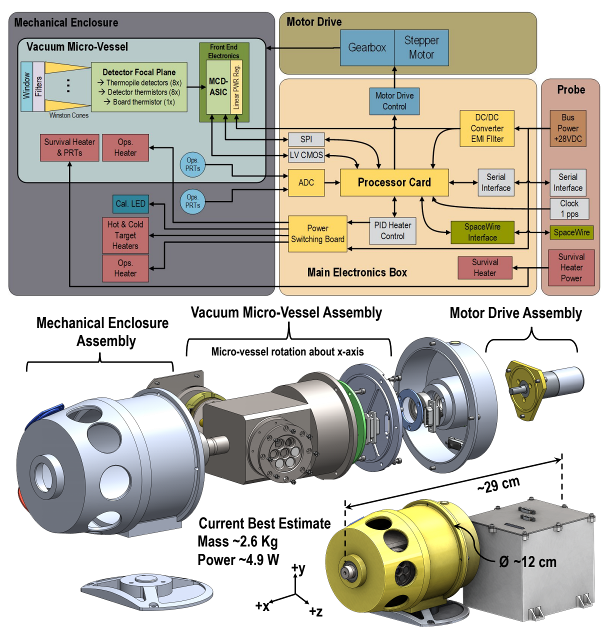

Fig. 2. IG-NFR system block diagram and exploded mechanical view showing sub-assemblies.

References: [1] Ice Giants Pre-Decadal Survey Mission Study Report 2017 (JPLD-100520). [2] Mousis, O., et al., PSS, 155, 12-40, 2018. [3] Aslam S., et al., Space Sci. Rev. 216:11, 2020. [4] Irwin P. G. J., et al., EPSC 2020, DOI:10.5194/epsc2020-306.