Modelling the expected observations of the Advanced Ice Giants Net Flux Radiometer (IG-NFR) instrument concept, under study for future entry probe missions to Uranus or Neptune.

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The NASA Ice Giants Pre-Decadal Survey Mission Report (2017) recommended the high scientific importance of sending a mission with an orbiter and a probe to one of the Ice Giants, with preferential launch dates in the 2029-2034 timeframe. Such a mission concept is equally well supported by European scientists and Mousis et al (P&SS, 155, 12, 2018) give compelling scientific rationales for the exploration of these worlds with missions carrying in situ probes.

In this presentation we will outline the conceptual design of the Advanced Ice Giants Net Flux Radiometer (IG-NFR) instrument, currently being designed by NASA Goddard Space Flight Center to make in situ observations of the upward and downward fluxes of solar and thermal radiation in the atmospheres of Uranus and Neptune. The IG-NFR is designed to: (i) accommodate seven filter bandpass channels in the spectral range 0.25-300 µm (ii) measure up and down radiation flux in a clear unobstructed 10° FOV for each channel; (iii) use thermopile detectors that can measure a change of flux of at least 0.5 W/m² 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 technology for the thermopile detector readout; (vii) be able to integrate radiance for 2s or longer, and (vii) sample each view angle including calibration targets. The IG-NFR system noise equivalent power at 298 K is 73 pW in a 1 Hz electrical bandwidth.

We present initial simulations of the anticipated observations using two radiative transfer and retrieval tools, NEMESIS (Irwin et al., JQSRT, 109, 1136, 2008) and the Planetary Spectrum Generator (PSG, Villanueva et al., 2017, https://psg.gsfc.nasa.gov). For the NEMESIS modelling the radiative fluxes observable at varying pressure levels were calculated with a Matrix-Operator plane-parallel multiple-scattering model, using between 5 and 21 zenith angle quadrature points and up to 38 Fourier components for the azimuth decomposition. We also employed PSG to further validate our flux estimates, providing an important benchmarking and comparison test between both models. PSG solves the scattering radiative transfer employing the discrete ordinates method, with the scattering phase function described in terms of an expansion in terms of Legendre Polynomials. Molecular cross-sections are solved via the correlated-k method employing the latest HITRAN database (Gordon et al., 2017), which are completed with the latest collision-induced-absorption (CIA, Karman et al., 2019), and UV/optical cross-sections from the MPI database (Keller-Rudek et
al., 2013). For the nominal case the Sun was assumed to be at an altitude of 10° above the horizon. The internal radiance field was calculated at each internal level for a standard reference Uranus atmosphere (e.g., Irwin et al., 2017) with the addition of a single cloud layer, based at 3 bar and composed of particles with a mean radius of 1.0 µm (and size variance 0.1) and assumed complex refractive index of $1.4 + 0.001i$ at all wavelengths. The opacity and fractional scale height of this cloud were fitted in both models to match the combined near-infrared observations of HST/WFC3, IRTF/SpeX and VLT/SINFONI analyzed by Irwin et al. (2017). The internal radiance fields were calculated from 0.4 to 300 µm using this atmospheric model.

We will show how these simulations are being used to guide the choice of spectral filter bandwidths and centres to optimize the scientific return of such an instrument. We will show that observations with such an instrument can be used to constrain effectively the radiation energy budget in the atmospheres of the Ice Giants and can also be used to determine the pressures of cloud and haze layers and broadly constrain particle size. Such modelling also allows us to simulate the visible appearance of Uranus’ atmosphere during a descent and to perform detailed validations of the simulations by comparing the two radiative transfer models (NEMESIS and PSG).