EPSC Abstracts
Vol. 11, EPSC2017-772, 2017
European Planetary Science Congress 2017

A Compact, Multi-view Net Flux Radiometer for future Uranus and Neptune Probes

S. Aslam (1), M. Amato (1), D. H. Atkinson (2), T. Hewagama (1), D. E. Jennings (1), C. A. Nixon (1), and O. Mousis (3)
(1) NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA (shahid.aslam-1@nasa.gov / Fax: +1-301-2861683); (2) Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91109, USA; (3) Aix Marseille Universit´e, CNRS, Laboratoire d'Astrophysique de Marseille, UMR 7326, 13388, Marseille, France.

Abstract

A Net Flux Radiometer (NFR) is presented that can be included in an atmospheric structure instrument suite for future probe missions to the icy giants Uranus and Neptune. The baseline design has two spectral channels *i.e.*, a solar channel (0.4-to-3.5 μm) and a thermal channel (4-to-300 μm). The NFR is capable of viewing five distinct viewing angles during the descent. Non-imaging Winston cones with band-pass filters are used for each spectral channel and to define a 5° angular acceptance. Uncooled thermopile detectors are used in each spectral channel and are read out using a custom radiation hard application specific integrated circuit (ASIC). The baseline design can easily be changed to increase the number of detector channels from two to seven.

1. Introduction

Knowledge of the atmospheric thermal structure, and global energy balance of the ice giants Uranus and Neptune, Fig. 1, is required for quantitative investigations of the atmospheric dynamical regime and associated energy transport processes [1, 2]. The temperature at the top of the convective zone and the internal energy flux are fundamental parameters needed to constrain models of the interior and the evolutionary history of these planets. Information on temperature is also required to address problems in atmospheric chemistry and cloud physics. Ideally, it would be desirable to have in-situ measurements of the temperature and the down- and up-welling energy flux from the exosphere down into the deep planetary interior (~10 bar). The planetary energy balance, *i.e.*, the thermally emitted flux to the absorbed solar flux, is significantly smaller for Uranus than for the other three giant planets. Voyager 2 measurements [1] provided extensive phase angle coverage and a more nearly global determination of the thermal emission, establishing new limits on the internal energy flux, however an in-situ measurement would greatly constrain interior structure *via* thermal history models, and clarify the difference in heat flow as compared to Jupiter, Saturn and Neptune. Clouds and aerosols in the atmospheres of Uranus and Neptune are related to the atmospheric composition, chemistry, motion, and temperatures, but the physical processes that control the interactions among these are not known. For example, clouds on both Uranus and Neptune appear at certain latitudes, but the reasons are still unclear [3]. The NASA Planetary Decadal Survey noted that the "best approach to truly understand giant planet heat flow and radiation balance would be a systematic program to deliver orbiters with entry probes to all four giant planets in

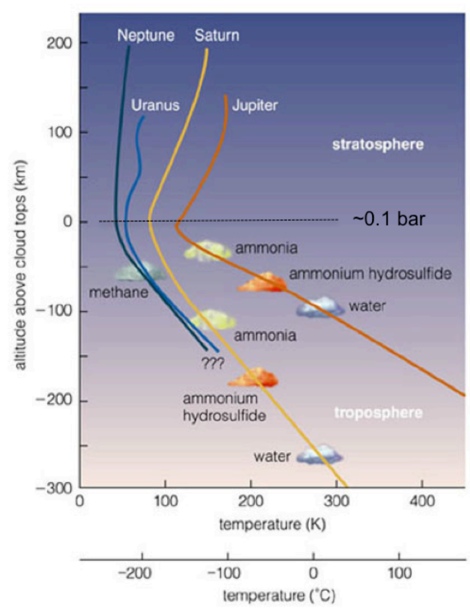

Figure 1: The atmospheric thermal structure and predicted cloud layers for the giant planets. A net flux radiometer would provide crucial ground-truth measurements to test these models.

the solar system. The probes would determine the composition, cloud structures, and winds as a function of depth and location on each planet." A probe would carry a complement of instruments to investigate giant/icy planet atmospheric dynamics along its descent trajectory, from (1) the vertical distribution of the pressure, temperature, clouds and wind speeds, and (2) deep wind speeds, differential rotation and convection, by combining probe, gravity and radiometric measurements. The thermal structure of *e.g.,* Uranus' atmosphere is expected to result in CH_4 and NH_3 clouds at p ~1 bar and ~3 bar, respectively. In the spectrum of Uranus, the S(0) and S(1) bands of H_2 tend to be opaque at p >300 mbar. Solar insolation dominates the heat flux at p <100 mbar. The net flux transition region depends on the opacity source. A NFR with spectral bandpass channels carefully tuned to sense these contributions will address the heat balance in the atmosphere.

2. Net Flux Radiometer

The NFR, Fig. 2, measures upward and downward radiation flux in a 5° field-of-view at five distinct look angles, i.e., ±80°, ±45°, and 0°, relative to zenith/nadir. The radiance is sampled at each angle approximately once every ~ 2s.

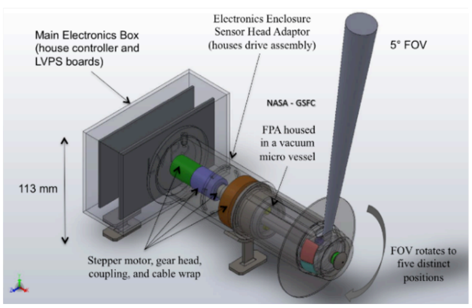

Figure 2: NFR instrument schematic showing a 5° field-of-view that can be rotated by a stepper motor into five distinct look angles.

The windowed vacuum micro-vessel, Fig. 3, houses the folding mirrors, non-imaging Winston cone concentrators, and thermopile focal plane assembly and is rotated to the look angle by a stepper motor. For a Uranus probe NFR, assuming a thermopile voltage responsivity of 295 V/W, an optical efficiency of 50%, a detector noise of 18 nV/√Hz and an ASIC input referred noise of 50 nV/√Hz, 1s integration with 12-bit digitization gives a system signal-to-noise ratio of 62 to 69 in the solar spectral channel (04-3.5 μm) and 27 to 9116 in the thermal spectral channel (4-300 μm) for atmospheric temperature and pressure ranges encountered in the descent, *i.e.,* ~70 to 300 K and 0.1 to 10 bar respectively.

Figure 3: Vacuum micro-vessel with sapphire and diamond windows. Each window has a 5° field-of-view.

3. Volume, Mass, Power, Data Rate

2-channel NFR
Mass: ~2.4 kg
Volume: ~113 mm x 144 mm x 279 mm
Basic Power: ~5 W
Average Data Rate: ~55 bps
Total Data Volume: ~297 kbits (90-minutes)

4. Summary and Conclusions

NASA GSFC has designed a NFR that will be suitable for integration into an atmospheric instrument suite on-board a future Uranus and Neptune Probe Mission. If the exacting field-of-view can be opened up from 5° to 7° then the design of the NFR can easily be reconfigured to incorporate up to seven channels with an overall reduction of volume and hence mass.

References

[1] Conrath B. J., *et al*., Chapter in Uranus (Planet), p. 204, Bergstralh J. T., Miner, E. D., and Mathews, M. D., editors University of Arizona Press (1990).
[2] Bishop, J., *et al*., Chapter in Neptune and Triton, p. 427, Cruikshank, D. P., ed., University of Arizona Press (1996).
[3] Hofstadter, M., *et al*., The atmospheres of the ice giants, Uranus and Neptune, White Paper for the NASA Planetary Decadal Survey, 2013-2023.