RADIO SCIENCE EXPERIMENT (REX) ON NEW HORIZONS: RESULTS FROM THE PLUTO FLYBY

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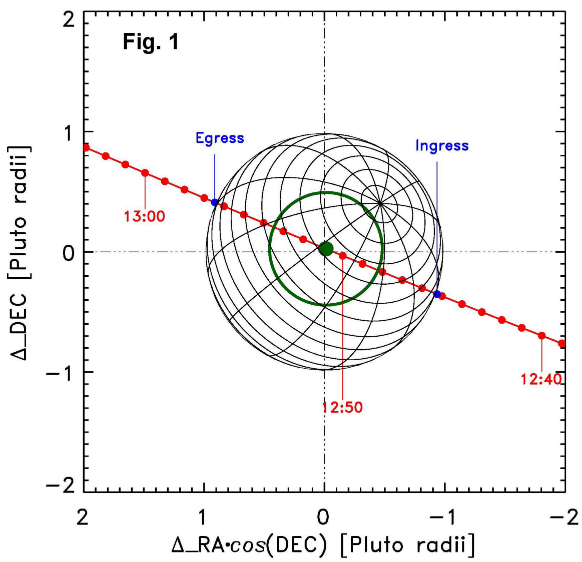
Introduction: The New Horizons Radio Science Experiment REX addressed several poorly understood issues related to the Pluto–Charon system [1]. Primary among these was a determination of the structure of the neutral atmosphere near the surface and up to about 100 km in terms of density, pressure and temperature. Secondary objectives included a search for and possible measurement of the Pluto ionosphere and a radiometric measurement of the thermal emission temperatures of Pluto and Charon at the wavelength 4.2 cm. Augmented by an additional uplink from Earth, a successful bistatic radar experiment was performed in combination with the highest resolution radiometry observations. Tertiary objectives addressed by REX were a determination of the Earth occultation chord of Pluto to high accuracy, and a determination of the Pluto–Charon system mass with a possible separation of the individual masses of Pluto and Charon. Brief summaries of the results of the REX investigations are presented below.

Atmospheric Height Profile: Approximately two hours after closest approach, on 14 July 2015, New Horizons performed a radio occultation (RO) that sounded Pluto's atmosphere down to the surface. The RO geometry, as viewed from New Horizons, is shown in Fig. 1 [2].

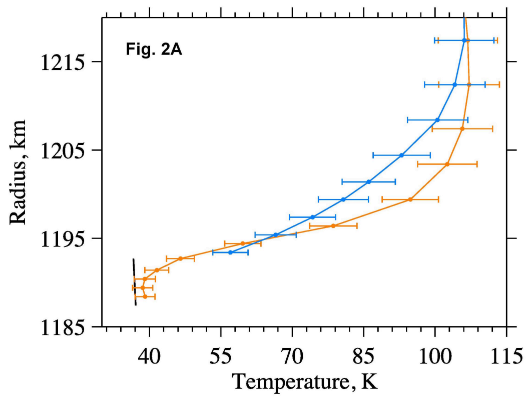
Pluto Atmosphere. Four DSN antennas, each radiating 20 kW at a wavelength of 4.2 cm, transmitted uplink signals to New Horizons during RO ingress and egress. The polarization was right circular (RCP) for one pair of signals and left circular (LCP) for the other pair. The four signals were separated for processing by two independent receivers, each referenced to a different ultra-stable oscillator. Profiles of number density, pressure, and temperature were retrieved from the combined phase measurements. The temperature profiles are shown in Figs. 2A (radial distance scale) and 2B (altitude scale) [3]. The uplinks during RO ingress sounded the atmosphere at sunset at 193.5°E, 17.0°S — on the southeast corner of Sputnik Planitia (SP); RO egress occurred at sunrise at 15.7°E, 15.1°N — near

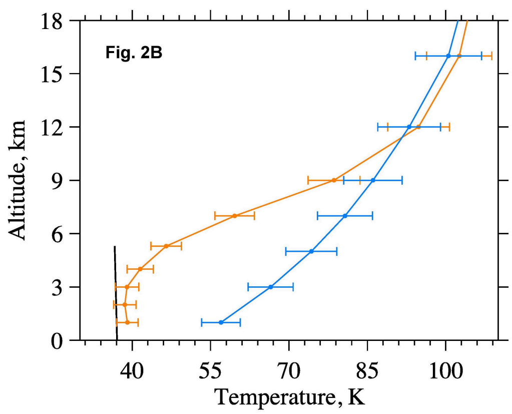


the center of the Charon-facing hemisphere. The ingress and egress profiles above 25 km are nearly identical and consistent with ground-based stellar occultation measurements. The ingress profile shows a cold boundary layer where the temperature is nearly constant, 38.9 ± 2.1 K (close to the saturation temperature of N_2). This boundary is missing in the egress profile, where the surface air temperature is 51.6 ± 3.8 K. The mean values of the pressure and radius were determined to be 11.5 ± 0.7 μbar at 1189.9 ± 0.2 km.

Pluto Ionosphere. The RO phase measurements were also carefully examined for a possible signature of the Pluto ionosphere [4]. The solar zenith angle was 90.2° (sunset) at ingress and 89.8° (sunrise) at egress. No ionosphere was detected, but a significant upper bound, corresponding to a peak electron density at the terminator of about 1000 cm^{-3}, was derived. An ionospheric model used to guide the interpretation of the data predicts an electron content at the terminator only slightly lower than the RO detection threshold.

Radio Thermal Emission: The New Horizons radio system was calibrated for REX radiometry obser-

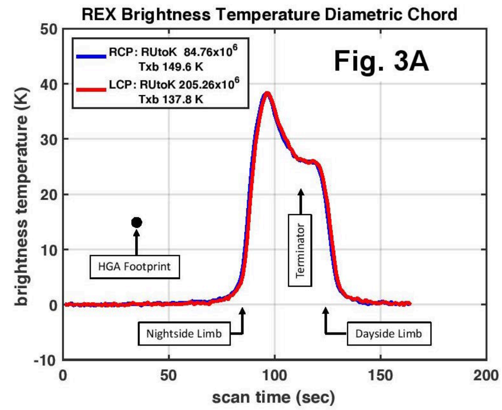


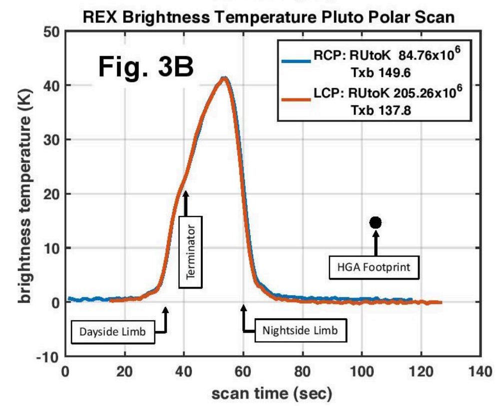


vations of the radio thermal radiation from Pluto and Charon during the flyby [5].

Measurements at wavelength λ = 4.2 cm were taken during approach, departure, and in the interval between occultation ingress and egress [2]. Two scans with the highest resolution measurements at Pluto were recorded a few minutes after closest approach: the first being diametric near the equator; the second in the reverse direction across the winter pole. The brightness temperatures for these latter scans are shown in Figs. 3A and 3B, respectively [6].

The radio flux density received from Pluto and Charon is gray-body thermal emission from a subsurface layer at depths down to the electrical skin depth, which ranges from less than 1 m for ice-free regions and perhaps up to 500 m for methane ice. The brightness temperature of Pluto across the nightside scan reached a maximum of 29.0 ± 1.5 K in the center of the disk. The drop off toward the limbs is attributed to the lower emissivity at lower emission angles. The radio emissivity is of the order of 0.7 or even lower if the atmospheric temperatures near the surface determined from the REX RO measurements are also valid for the subsurface.





Bistatic Radar: A bistatic radar experiment was conducted during the REX observation slot shortly after closest approach to Pluto. A special 80 kW transmitter at the DSN Goldstone complex was enlisted for this most distant bistatic experiment attempted to date. Echo power at an SNR near 30 dB was recorded when the signal reflected from regions near the spectral point on Pluto's surface. Interpretation of these data is ongoing.

Pluto and Charon mass determination: The system mass and the separate masses of Pluto and Charon were determined by combining regular two-way radio tracking and REX one-way uplink data recorded during selected intervals during the 24 hours about closest approach. The solution for the individual masses was not as precise as anticipated due to the copious thruster activity during the flyby, which, unfortunately, could not be fully corrected.

References: [1] Tyler, G. L., et al. (2008) *Space Sci. Rev., 140*, 217–259. [2] Bird, M. K., et al. (2019) *Icarus 322*, 192–209. [3] Hinson, D. P., et al. (2017) *Icarus 290*, 96–111. [4] Hinson, D. P., et al. (2018) *Icarus, 307*, 17–24. [5] Linscott, I. R., et al. (2017) Stanford Radioscience Report No. 17-06-01. [6] Linscott, I. R., (2019) *Icarus* (submitted).