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Neptune Clouds and Methane, from Ground-Based Visible and Near-Infrared Spectroscopy with Adaptive Optics

D. S. Tice (1), P. G. J. Irwin (1), R. W. C. Houghton (2), L. N. Fletcher (1), F. Clarke (2), J. Hurley (1), N. Thatte (2), and M. Tecza (2)
(1) Atmospheric, Oceanic and Planetary Physics Subdepartment, Department of Physics, University of Oxford, Clarendon Laboratory, Parks Road Oxford OX1 3PU, United Kingdom, (2) Astrophysics Subdepartment, Department of Physics, University of Oxford, Denys Wilkinson Building, Keble Road Oxford OX1 3RH (tice@atm.ox.ac.uk / Fax: +44-1865-272923)

Abstract

Observations of Neptune were made in June/July 2012 with the SWIFT integral field spectrometer at the Palomar Observatory's 200-inch Hale Telescope. Spectral resolutions for observations between 0.65 μm and 1.0 μm were $\mathrm{R} \geq 3250$. Palomar's PALM-3000 adaptive optics system enabled images of the full Neptunian disc to be recorded at a spatial scale of 0.08"·pixel^{-1} with a seeing of approximately 0.30" – 0.40". Retrievals of cloud properties and methane abundance in the highly dynamic atmosphere were obtained with the general-purpose retrieval tool, NEMESIS. The short wavelengths of the observations allowed for good characterisation of the scattering particles' optical properties in the many cloud and haze layers of the upper Neptunian atmosphere. A region of relatively low methane absorption and high collision-induced hydrogen quadrupole absorption at 825 nm further constrains spectral properties of clouds as distinguished from those of methane absorption.

1. Introduction

Neptune is a very meteorologically active planet with numerous visible cloud features across the disc at any given time. Using ground-based adaptive optics systems we can spatially resolve many of these features for specific analysis, as well as isolating cloud-free regions which surround them. Visible and near-infrared spectrometry lends itself particularly well to analysis of these Neptunian cloud features, including both the rapidly evolving convective cloud features and the more stable, often deeper background clouds. In the visible and near-infrared, numerous, strong methane absorption bands lie within a relatively short wavelength range, allowing us to discriminate between cloud layers at different altitudes with relative ease. Additionally, cloud retrievals at these wavelengths below 1.0 μm are a sensitive tool with which to examine the small particle sizes that are likely present in many of the cloud layers. Finally, at approximately 825 nm, a relatively weak region of methane absorption coincides with a region of strong, collision-induced hydrogen quadrupole absorption, allowing us to distinguish between spectral features that are derived from cloud opacities with those dependant on methane absorption in the atmosphere. Recent studies of Neptunian clouds have been undertaken with Gemini-North [5, 6] and HST data [8, 9], using observations from 2009 and 1994 – 2008, respectively. Our analysis will complement those studies by providing a more recent dataset from 2012, giving confirmation of the earlier results and enabling us to extend any temporal trends identified with respect to cloud evolution or latitudinal methane transport.

2. Observations and Instrumentation

Observations of Neptune were made on four nights in June and July 2012 at the Palomar Observatory's 200-inch Hale Telescope. The observations utilised the integral field spectrometer, SWIFT [12], and the recently-upgraded adaptive optics system, PALM-3000. Observations with an 0.08"·pixel^{-1} spatial scale were taken on four consecutive nights in June and July 2012, as detailed in table 1. Each observation represents a 5-second exposure of the full disc of Neptune on a 3.5" $\times$ 7.1" field of view. The spectrometer covers a wavelength range from 0.63 – 1.04 μm with a spectral resolution that rises linearly with wavelength from $\mathrm{R} = 3250$ (0.65 μm) to $\mathrm{R} = 4400$ (1.00 μm). Observational seeing on the nights of our observations varied between roughly 0.30" and 0.40". Some examples of our observations are shown in figure 1.

Table 1: 2012 SWIFT observations of Neptune. All observations listed are 5-second exposures at 0.08"·pixel^{-1} spatial scale.

Date	Number of Observations	Airmass Range
29 June	4	1.452 – 1.514
30 June	7	1.397 – 1.434
01 July	20	1.397 – 1.620
02 July	15	1.397 – 1.449

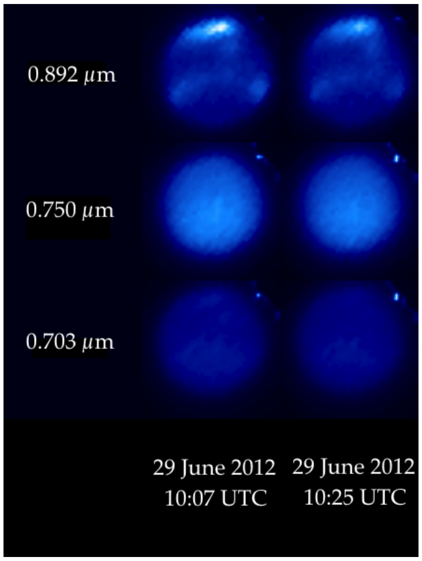

Figure 1: Sample images of SWIFT Neptune observations at three wavelengths and two times, as indicated, on 29 June.

3. Data Reduction and Analysis

Standard data reduction steps, including removal of cosmic rays, were completed with a dedicated IRAF-based pipeline, SWIFTRED [4, 1]. Additional processing in an IDL-based routine was also completed: smoothing data to the resolution of the κ-distribution tables (see next paragraph), assigning latitude and longitude values to each pixel in the data array, and performing a photometric calibration of the data using an observation of HR7950 and a published standard star spectrum [3].

Analysis of the data was achieved through use of the general purpose retrieval code, NEMESIS [7]. To increase retrieval efficiency, an optimal estimation scheme [11, 10] and a correlated-κ technique [2] were employed. Retrieval results will be detailed at the conference, including analyses of the Neptunian background, various discrete cloud features, and a vertical swath of the planet from pole-to-pole. In each of these distinct geographic locations, cloud layers are characterised in terms of optical and vertical thickness, altitude, and optical properties of the scattering particles in each layer. Latitudinal variation of methane profiles are also explored.

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