EPSC Abstracts
Vol. 11, EPSC2017-192, 2017
European Planetary Science Congress 2017

Absorption of Ammonia (NH_3) in the visible/near-infrared reflectance spectrum of Jupiter

P.G.J. Irwin (1), R. Garland (1) and A. Braude (1)
(1) Atmospheric, Oceanic and Planetary Physics, University of Oxford, Parks Road, Oxford OX1 3PU, UK

Abstract

Observations of the visible/near-infrared reflectance spectrum of Jupiter have been made with VLT/MUSE in the spectral range 0.48 – 0.93 μm, in support of the NASA/Juno mission. These spectra contain spectral signatures of gaseous ammonia (NH_3), whose abundance above the cloud tops can thus be determined if we have reliable information on the its absorption spectrum. While there are a number of sources of NH_3 absorption data in this spectral range, they cover small sub-ranges, which do not necessarily overlap and have been determined from a variety of sources. There is thus considerable uncertainty regarding the consistency of these different sources when modelling the reflectance of the entire visible/near-IR range. In this paper we will analyse the VLT/MUSE observations of Jupiter to determine the optimal way of modelling the absorption of ammonia.

1. Introduction

The reflectance spectrum of Jupiter contains a number of absorption features of ammonia gas at 550 nm, 650nm, and then further bands increasing in strength from 740 nm to 1000 nm. In support of the NASA/Juno mission we have recently observed Jupiter with the MUSE instrument at the Very Large Telescope, which records complete visible/near-IR spectra (0.48 – 0.93 μm) from all points on the observable disc. Given reliable information on the strength of these bands we can use these wavelengths to determine the abundance of ammonia above the cloud tops. However, available data come from a range of sources whose consistency with respect to each other has not been properly tested. In this paper we assess the consistency of these data sets.

1.1 VLT/MUSE Observations

The MUSE instrument at the Very Large Telescope in Chile is an Integral Field Spectrograph, which records images of 300 × 300 resolution from a field of view of 60″ × 60″ (in wide field mode), but where each pixel contains a complete visible/near-IR spectrum (0.48 – 0.93 μm) with a spectral resolving power of ~3000. The observations of Jupiter recorded by MUSE have excellent spatial resolution (due to the location of VLT) as can be seen in Fig.1.

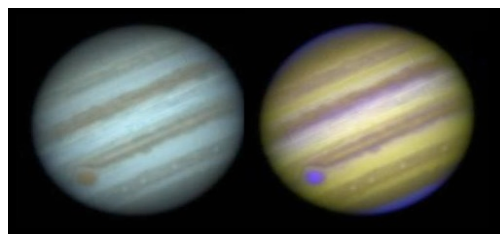

Figure 1: Left: Colour-composite MUSE image constructed from data recorded in March 2016. The GRS is clearly visible at lower left. Right: False-colour image, where red is reflection at 630 nm (weak methane absorption), green is reflection at 510 nm (sensitive to blue-absorbing 'chromophores'), and blue is reflection at 890nm (strong methane absorption, sensitive only to high level hazes).

Figure 2 shows a typical spectrum extracted from the MUSE data for a zone together with the spectrum modeled with our NEMESIS[3] radiative transfer and retrieval tool, using ammonia data [1] and [4]. To show the location of the ammonia features, Fig. 2. also shows the spectrum calculated with the ammonia abundance increased.

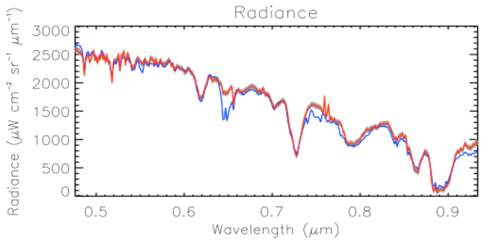

Figure 2. Typical MUSE spectrum (and estimated error) shown in grey, with the fit of our NEMESIS retrieval model shown in red. The blue line is the modelled spectrum calculated with an increased abundance of ammonia, showing the position of the ammonia features.

2. Data Sources

There are four main sources of ammonia absorption data in this spectral region. The data reported by Bowles et al. (2008)[1], Giver et al. (1975)[2] and Lutz and Owen (1980)[4] come from measuring the absorption of ammonia gas in a laboratory path at medium or high resolution and fitting either band models [1], mean absorptions [2,4] or in one case line strengths[2] for a selection of the strongest lines. In most cases (except [1]) these observations are limited to be near room temperature and thus it is difficult to know how well they may be extended to the colder temperatures on Jupiter. In addition they are measured under self-broadening conditions only, rather than H_2/He-broadening as experienced in Jupiter's atmosphere. The 550 nm band is only reported by [4], while the 640 nm band is reported by both [4] and [2]. The laboratory data of Bowles et al. (2008)[1] covers wavelengths longer than 740 nm in the form of band model coefficients, which have some temperature dependence. More recently the ExoMOL project has computed an *ab initio* line table for NH_3 from first principals [5]. These data cover wavelengths longer than 800 nm, but include line strengths and lower state energies only. Hence, further analysis and assumptions have to be made in order to assign line widths (under H_2/He-broadening conditions) and also the temperature dependence of these line widths.

3. Conclusion

In this paper we will assess the reliability and consistency of these different sources of ammonia absorption data when modelling the reflectance spectra of Jupiter from our VLT/MUSE observations. We will analyse the likely temperature dependence of the data and also assess the possible corrections needed to account for broadening by an H_2-He atmosphere under Jovian conditions. Finally, we will make recommendations on the optimal combination of these data sources when analyzing the visible/near-infrared spectra of cool Jupiter-like planets in our own solar system and, as exoplanetary observations improve, of such planets about other stars also.

Acknowledgements

We would like to acknowledge the support of the UK's Science and Technology Facilities Council.

References

[1] Bowles, N., Calcutt, S., Irwin, P., and Temple, J.: Band parameters for self-broadened ammonia gas in the range 0.74 to 5.24 μm to support measurements of the atmosphere of the planet Jupiter, Icarus 196, 612 – 624, 2008.

[2] Giver, L.P., Miller, J.H., and Boese, R.W.: A laboratory atlas of the $5\nu_1$ NH_3 absorption band at 6475Å with applications to Jupiter and Saturn, Icarus 25, 34 – 48, 1975.

[3] Irwin, P.G.J., et al.: The NEMESIS planetary atmosphere radiative transfer and retrieval tool. J.Q.S.R.T. 109, 1136 – 1150, 2008.

[4] Lutz, B.L., and Owen, T.: The visible bands of Ammonia: Band strengths, curves of growth, and the spatial distribution of Ammonia on Jupiter. Astrophys. J. 235, 285 – 293, 1980.

[5] Yurchenko, S.N., Barber, R.J., Tennyson, J.: A variationally computed line list for hot NH_3, Mon. Not. R. Astron. Soc. 413, 1828–1834, 2011.