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Characterising the colour and vertical structure of Saturn's haze using observations from the VLT/MUSE instrument

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Abstract

Three sets of ground-based observations with the MUSE/VLT instrument were made in the visible/near-IR (0.48-0.93µm) between 2014 and 2017. We used this data to characterise the absorption spectrum of the yellow 'chromophore' compounds that dominate Saturn's visible appearance from the Earth, and map the spatial variation of chromophore abundances and vertical haze structure over the surface of Saturn. We find substantial spatial variation in chromophore morphology on Saturn that is difficult to reconcile with the hypothesis of a 'universal chromophore' (Sromovsky et al. 2017, Icarus 291, 232-244) as proposed for Jupiter. This indicates the presence of two or more competing chromophore production processes in Saturn's tropospheric haze.

1. Introduction

The appearance of Saturn's visible hemisphere is dominated by a thick haze that obscures much of its underlying cloud structure. The yellow colour of this haze is thought to be due to the presence of colour-carrying compounds known as 'chromophores'. These chromophores are not as well-studied as their red counterparts on Jupiter, and their origin and composition remain unknown. The MUSE integral field spectrograph [1], provides global observations of Saturn with comprehensive wavelength coverage in the visible/near-IR (0.48-0.93µm). We have successfully made use of MUSE observations of Jupiter in the past [2] to analyse spatial and temporal variations in colour and cloud structure, and we have now extended this analysis to Saturn in order to simultaneously constrain the absorption spectrum and altitude of Saturnian chromophore, as well as to map variations in Saturn's vertical haze structure.

2. Model and results

We make use of three sets of MUSE spectral image cubes obtained between 2014 and 2017, corresponding to the final stage of the Cassini-Huygens mission in northern summer. This data is then inverted using the NEMESIS radiative transfer and retrieval algorithm [4] in order to simultaneously retrieve spatial variations in chromophore together with tropospheric and stratospheric haze structure.

As the optical constants of both Carlson et al. [3] and Noy et al. [5] were seen to provide a poor fit to the blue-absorption gradient of Saturn spectra, we directly retrieve the imaginary refractive index spectrum of Saturn chromophore through limb darkening analysis of the NEB before applying the retrieved chromophore optical constants to other regions of Saturn. We find that we can derive more realistic values of chromophore abundance if the real part of its refractive index is set to a high value akin to that of a phosphine-based chromophore, as opposed to a chromophore produced from the reaction between ammonia and acetylene as proposed for Jupiter [3], and that this chromophore is most likely located either within the tropospheric haze itself or only just above it.

Surprisingly, we find greater spatial variation in the spectral shape of the blue-absorption gradient on Saturn than we do on Jupiter, which cannot be explained away by other variations in the structure and properties of the haze. This leads us to reject the hypothesis of a 'universal chromophore' as was proposed for Jupiter [6]. Instead, we suggest that colour production on Saturn is the result of more than one competing atmospheric process.

Summary and Conclusions

We apply a method previously perfected on Jovian spectra in order to infer the absorption spectrum of the yellow ‘chromophore’ compounds associated with Saturn’s ubiquitous haze using multiple sets of ground-based data from the VLT/MUSE instrument in the visible and near-infrared. We find that the chromophore is most likely to be located within or close to Saturn’s tropospheric haze layer, and that variations in colour are likely to be explained by the presence of more than one type of chromophore. We recommend further study of the source of apparent colour variation on Saturn, as well as long-term observations in the visible and near-infrared in order to map changes in haze structure associated with seasonal progression following on from the end of the Cassini-Huygens mission in 2017.

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