The reaction in the upper mesosphere between atomic hydrogen and ozone produces hydroxyl (OH) in excited vibrational levels \( \nu = 9 \) to \( \nu = 0 \), giving rise to the strong near-infrared airglow emission. The interpretation of the emission for remote sensing of the mesopause region relies on accurate knowledge of the population and quenching of the upper states, and open questions remain as to whether the quenching takes place through single- or multi-excitation desaturation. Here we use spectral observations of OH \((\nu, J)\) and \((\nu, 0)\) airglow emissions that are available as background measurements during standard \( K \)-band atmospheric observations from the Nordic Optical Telescope (NOT) \(22^h \ 9^m \ 29^s \) UT. These emissions, together with our recent studies, have been used to estimate the ratio of single to multi-quenching efficiencies.

**BACKGROUND AND METHOD**

The OH Airglow

The excited-state \( \text{H}_2\text{O} \) \( \text{OH} \) reaction produces vibrationally excited \( \text{OH}^* \) in quantum levels as high as \( \nu = 9 \). From there, the \( \text{OH} \) can radiate through rotational-translational rotations that form the OH airglow or be collisionally quenched. The quenching can occur in two different modes. Sudden death quenching depletes the \( \text{OH}^* \) directly into the ground state, whereas stepwise quenching brings the \( \text{OH} \) into lower vibrational quantum levels, where it can again radiate or be quenched. However, the ratio of these two quenching processes is not well determined.

In addition, recent work has shown how the temperatures derived from the \( \nu = 9 \) vibrational level appear to be anomalous. Figure 1 (from Frances 2015) shows the OH rotational temperature derived from near-simultaneous NOT observations of Meinel bands \( v = 9 \) to \( v = 0 \) on the night of 10:22 UT in 2013 in comparison with a simultaneous MSIS temperature profile, shown as the black line in the figure. Rotational temperatures were fit to the individual bands using the HITRAN line strengths, and their altitudes were estimated using a steady state model based on an MSIS background atmospheric temperature. Temperatures for bands arising from the \( \nu = 9 \) level are consistently found to be too warm in comparison with the expected temperature profile from MSIS.

**RESULTS**

**Data and error discussion**

The values for \( \nu \) vary within the data between 0.54 and 0.73. Each individual data point has a statistical error of approximately 0.01 due to uncertainties in the simulated values of the background atmosphere and the statistical error from the spectrophotometric measurement. The average and standard deviation over all values is \( \nu = 0.64 \pm 0.035 \).

**Nightly variations**

In figure 3, the data are shown against the time of the night, when they were taken. The data taken shortly after midnight yield an average of \( \langle \nu \rangle = 0.62 \pm 0.028 \), while the data taken later in the night have a higher value of \( \nu \), with a smaller variation: \( \langle \nu \rangle = 0.69 \pm 0.047 \).

**Test for Temperature Dependency**

The rotational temperature of the OH layer has previously been observed to change during the course of a night (e.g. Parther et al. 2012), with a typical rise in the temperature near sunrise. The change in \( \langle \nu \rangle \) shown above could related to this change in temperature. In figure 4, the data are plotted against the rotational temperature, but no significant correlation can be seen. The calculated correlation coefficient is \( r = 0.49 \). It is therefore unlikely that the temperature causes this change in \( \langle \nu \rangle \).

**DISCUSSION**

Variations of the results

Even though each measurement of \( \nu \) has a relatively small statistical error (\( \pm 0.02 \)), the values of \( \nu \) vary over a range of up to nearly 10 times the statistical error. A significant change can be seen at the end of the night, where the value of \( \nu \) is 50% larger than \( \nu \) at midnight. This variation could not be explained with the nightly variation of temperature, since no correlation between \( \nu \) and the rotational temperature of the OH layer could be found.

**Interpretation of \( \nu \)**

The value of \( \nu \) expresses the ratio of the stepwise quenching from the vibrational quantum level \( \nu \) to \( \nu = 0 \) over the total quenching. The data presented in this work show that stepwise deactivation occurs about 64% of the time, with quenching to lower quantum levels, including the ground level, occurring the rest of the time.

**SUMMARY & FUTURE WORK**

Summary

A value for the quenching ratio \( f \) of single to multiple quantum quenching has been calculated to be \( f = 0.64 \pm 0.021 \). A small variation during the night was observed, though no correlation between this value and the rotational temperature of the hydroxyl layer could be found. Additional data from the NOT archive will be used to examine whether the large \( \nu \) in \( \nu \) is unusual and perhaps the cause of the anomalous temperature behavior seen in figure 1.

**REFERENCES**