OBSERVATION OF THE N = 8-7 RYDBERG TRANSITION OF HYDROGEN IN EMISSION IN THE SOLAR INFRARED SPECTRUM AND THE SEARCH FOR EQUIVALENT MAGNESIUM LINES

T.A. CLARK
Department of Physics and Astronomy, University of Calgary,
2500, University Dr., N.W., Calgary, AB, Canada, T2N 1N4

D.A. NAYLOR AND G.J. TOMPKINS
Department of Physics, University of Lethbridge,
Lethbridge, AB, Canada, T1K 3M4

INTRODUCTION

This paper describes observations of the HI n = 8-7 Rydberg line in emission on the solar disk at 524.6 cm\(^{-1}\) (19.06 μm) and the search for equivalent MgI lines, taken through the highly structured and variable 20 μm atmospheric window on three relatively dry days (1 to 4 mm precipitable \(H_2O\)) from Mauna Kea. This HI line has previously been identified only at the extreme solar limb (\(μ = 0.14\)) by Brault & Noyes (1983) at 15% above the continuum and on a few preliminary disk-center spectra taken in 1989 from Mauna Kea (Boreiko et al. 1993).

Over the past 12 years, discoveries of such high-n Rydberg transition lines of HI, MgI and other heavy elements in the solar IR spectrum, from the ground (\(n = 7-6\), Murcray et al. 1981, Brault & Noyes 1983), from balloon altitudes (\(n = 6-5\), Murcray et al. 1981, \(n = 12-11\) to 16-15, Boreiko & Clark 1986, Boreiko et al. 1993) and from the Space Shuttle ATMOS experiment (lower n transitions, Farmer & Norton 1989), have led to a new and distinct method for defining the physical conditions in the Sun's high photosphere and chromosphere. Comprehensive modeling by Carlsson et al. (1992), Chang et al. (1991) and Avrett et al. (1993), has demonstrated convincingly that the MgI lines are produced by slight departures from LTE in the high photosphere and are relatively sensitive to assumed collisional and photo-ionization rates but insensitive to atmospheric model characteristics. In contrast, the HI emission lines from \(n > 8\) are produced in the low chromosphere (Carlsson & Rutten 1992) and are more sensitive to atmospheric conditions at their source heights (Avrett et al. 1993).

OBSERVATIONAL TECHNIQUE

Spectra were taken in May, 1993 with a new Martin-Puplett polarizing interferometer equipped with metal grid beamsplitters on polypropylene substrates. This instrument provided a resolving power of 125,000 over the spectral range 480-540 cm\(^{-1}\) in a scan time of 5 minutes. One port of this instrument viewed a 1.1 arc minute portion of the solar disk image produced by 127mm f/24 primary optics fed by a heliostat on the roof of the NASA IRTF Coudé room, while the
FIGURE I  A 523-533 cm\(^{-1}\) section of 3 averaged disk-center spectra from 3 different days, showing the effect of strong \(H_2O\) and weaker \(CO_2\) and isotopic \(H_2O\) lines. Positions of solar HI, MgI and OH transitions (\(v = 0, N'' = 14\)) are indicated.

second port viewed an LN\(_2\) cold source.

OBSERVATIONS

Figure I shows the relevant sections of 3 averaged spectra, taken under different conditions of air mass, water vapor and resolution. A normalized spline-fitting technique has been used to isolate the \(n = 8-7\) HI line at 524.604 cm\(^{-1}\). The line has a peak height at disk center of \(3.0 \pm 0.3\%\) and evidence of limb brightening to about \(5.5\%\) at \(\mu=0.5\), a FWHM of \(71 \pm 15\) mK, and an equivalent width of about \(3 \pm 1\) mK, \((1\) mK = 0.001 cm\(^{-1}\)). Much of the uncertainty arises from the spline fitting approach to the determination of the continuum envelope on the side of a deep absorption line.

Of the equivalent MgI lines, the \(n,l = 8,7 - 7,6\) transition is obscured by a strong \(H_2O\) line, the \(8,6 - 7,5\) line is apparently very weak or absent, and the \(8,5 - 7,4\) line is detected only by differential measurements near the limb.

CONCLUSIONS

The line intensity for the HI line is in qualitative agreement with the modeling of Carlsson & Rutten (1992), as seen in their Figure 3, fitting between the “no-chromosphere” and the “hot chromosphere” model calculations along with the higher-\(n\) balloon observations of Boreiko et al. (1993). The width of this line, \(0.071\) cm\(^{-1}\), is somewhat puzzling in view of the prediction by Hoang-Binh (1982) that Doppler broadening dominates lines for \(n > 7\), since this would imply a very high effective temperature. Obviously, some other broadening mechanism must play a role. This width, if caused by Zeeman broadening, would imply fields at the line source height of greater than 1000 Gauss even though the Zeeman sensitivity of this high-\(n\) line is high.
FIGURE II  The n = 8-7 HI line on 3 averaged spectra, shown with an adjacent atmospheric isotopic $H_2O$ line, with intensity scale indicating the fraction of the continuum envelope.

The absence of an observed MgI 8i - 7h feature is somewhat surprising, in view of the detection of the 8h - 7g 531 cm$^{-1}$ line.

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REFERENCES


