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# On the detectibility of $HeH^+$ in the solar photospheric spectrum

K. Sinha
*U. P. State Observatory, Manora Peak, Naini Tal 263 129*

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**Abstract.** In a recent publication of the Bulletin of the Astronomical Society of India, the possibility of detection of the (1-0) vibration-rotation lines of $HeH^+$ molecules in the solar photospheric spectrum has been suggested. Taking cue, the *Photometric Atlas of the Solar Spectrum from 1850 to 10,000* $cm^{-1}$ was scanned for the suggested lines in the present preliminary investigation. It is tentatively concluded that (i) it seems rather difficult to detect the $HeH^+$ lines and (ii) observations from above the terrestrial atmosphere may be required for firm conclusions.

*Key words* : photospheric spectrum—photospheric atlas—ionic molecules

## 1. Introduction

The first molecular ion to be detected in the sun was $SiH^+$ (Grevesse & Sauval 1970). It lead to a spurt in activities regarding detection of similar molecules and a list of ionic species was prepared for identification in the sun (Sinha & Tripathi 1990a). In all such efforts, it is important to select stable molecules i.e., molecules with sufficient dissociation energies. Also, the atoms forming the molecule should be fairly abundant in the sun and one of them should have a low ionisation potential. In this respect papers on $CH^+$ (Grevesse & Sauval 1971; Sinha & Tripathi 1990b) and $MgH^+$ (Sinha *et al.* 1988) can be cited.

## 2. The molecule $HeH^+$

Association of the Helium atoms with protons is known to form the $HeH^+$ molecules. The ionisation potential of Si, Mg, C, H and He are 8.151, 7.646, 11.260, 13.598 and 24.587 eV respectively (Allen 1973) whereas the dissociation energies of the molecules $SiH^+$, $MgH^+$, $CH^+$ and $HeH^+$ are 3.17, 2.08, 4.08 and 1.845 eV respectively (Huber & Herzberg 1979). The solar abundance of Si, Mg, C and He are 7.55, 7.58, 8.56 and 10.99 on the usual log N(H) = 12.00 scale (Anders & Grevesse 1989). Thus, it is the large abundances of H and He atoms which favour $HeH^+$ formation in the sun and the ionisation potential and the dissociation energies seem less favourable for the same purpose. The combined result of all these factors is assessed in the calculations of partial pressures and better still, in equivalent width calculations.

## 3. Suggestions regarding $HeH^+$

In a recent publication Gaur, Joshi & Pande (1992) considered the following to assess the chances of detection of $HeH^+$ in the solar atmosphere :

(i) Since vibration-rotation lines of HCl are present in *sunspot* spectra, partial pressures of HCl and $HeH^+$ in a photospheric model can be compared. It was found that HCl abundances are many orders more at and around temperature minimum ($-4 < \log \tau < -3$), but in the deeper layers, the abundances of $HeH^+$ exceed that of HCl,

(ii) Oscillator strengths for $HeH^+$ lines are larger than those of HCl,

(iii) $HeH^+$ lines should have maximum intensity around rotational quantum number $K = 7$, and

(iv) The maximum equivalent widths for the P and the R branch lines are 28 mÅ and 22 mÅ respectively in the solar photosphere. It is concluded by Gaur, Joshi & Pande (1992) that the $HeH^+$ lines can easily be detected in the solar infrared spectrum. However, they also indicate that

(i) Wavenumber measurements are available for only nine lines of $HeH^+$ viz., R(0), R(1), R(2), R(3), R(4), P(1), P(2), P(3) and P(4). It is claimed that wavenumbers very close to the observed values can be predicted with the help of molecular constants of Bernath & Amano (1981) and

(ii) No independent check upon the value of the utilized electronic dipole moment is available.

## 4. A search or $HeH^+$ lines in the solar spectrum and discussion of the results

Considering that detectable equivalent widths for 35 $HeH^+$ lines were predicted by Gaur, Joshi & Pande (1992) in the infrared region of the photospheric spectrum, a search was made in FTS atlas prepared by Delbouille *et al.* (1981). The atlas is available in print and also on magtapes. Wavenumber coincidences were looked for within 0.05 $cm^{-1}$ of the lines given by Gaur, Joshi & Pande (1992). The results are summarised in table 1 where few coincidences might appear to have been found. We now proceed for a discussion of the results.

Compared to the region of occurrence of the R branch lines where the continuum is suppressed, the P branch lines fall in a better region where, however, the signal to noise ratio is inferior. If the P(04) line is assumed to be present in the atlas, it is puzzling to note that the expectedly equally intense line P(03) and P(05) do not leave any impression in the spectrum (cf. figures 1-3). Further, the equivalent width of the feature coincident with the P(04) line is 81 mÅ on the atlas against a predicted value of 21 mÅ. Similarly, serious differences in the calculated and the predicted equivalent widths of the features for which coincidences were noticed, are found.

Contrary to the well established nature of variation of molecular line intensities with different rotational quantum numbers, the line intensities on the atlas do not show a similar behaviour. We are thus led to believe that probably the $HeH^+$ lines are not present in the *Photospheric Atlas of the Solar Spectrum from 1850 to 10,000 $cm^{-1}$* prepared by Delbouille *et al.* (1981) and the few coincidences seen in table 1 should be due to chance.

**Table 1.** Summary of a search for the (1-0) vibration-rotation lines of the P and the R branches of $HeH^+$ in the solar spectrum

| | P branch | | | | R branch | | | |
|---|---|---|---|---|---|---|---|---|
| K | Wavenumber ($cm^{-1}$) | *S/N* ratio | Remarks | Predicted *EW*(mÅ) | Wavenumber ($cm^{-1}$) | *S/N* ratio | Remarks | Predicted *EW*(mÅ) |
| 00 | — | — | — | — | 2972.57 | 5190 | A | 14 |
| 01 | 2843.90 | 5080 | A | 15 | *3028.37 | 5210 | 3028.40 | 16 |
| 02 | 2771.80 | 4920 | 2771.84 | 16 | *3077.99 | 5230 | A | 18 |
| 03 | 2695.05 | 4680 | A | 17 | *3121.08 | 5220 | A | 19 |
| 04 | 2614.03 | 4380 | 2614.02 | 21 | 3157.30 | 5210 | 3157.28 | 21 |
| 05 | 2529.13 | 3920 | A | 25 | *3186.35 | 5190 | A | 22 |
| 06 | 2440.74 | 4060 | A | 27 | *3207.95 | 5190 | 3207.99 | 22 |
| 07 | 2349.21 | 4100 | TW | 28 | *3221.86 | 5180 | A | 21 |
| 08 | 2254.90 | 3870 | TW | 28 | *3227.87 | 5180 | A | 20 |
| 09 | 2158.12 | 3030 | A | 28 | *3225.81 | 5180 | A | 19 |
| 10 | 2059.19 | 1560 | 2059.20 | 26 | *3215.55 | 5180 | A | 17 |
| 11 | 1958.37 | 1140 | A | 25 | *3197.03 | 5190 | A | 15 |
| 12 | *1855.89 | 0740 | 1855.88 | 22 | *3170.21 | 5200 | A | 13 |
| 13 | 1751.95 | — | NA | 20 | *3135.13 | 5210 | 3135.09 | 11 |
| 14 | 1646.69 | — | NA | 17 | 3091.89 | 5230 | 3091.84 | 09 |
| 15 | 1540.22 | — | NA | 15 | 3040.62 | 5210 | 3040.64 | 07 |
| 16 | 1432.58 | — | NA | 12 | 2981.56 | 5190 | 2981.58 | 05 |
| 17 | 1323.77 | — | NA | 10 | 2914.99 | 5150 | A | 04 |
| 18 | 1213.70 | — | NA | 07 | 2841.28 | 5080 | 2841.25 | 03 |

Code :
* : Continuum is heavily suppressed around this wavenumber.
A : Absent.
NA : Not accessed in the atlas.
TW : Too weak signal around this wavenumber.
S/N : Signal to Noise.

An additional source of opacity, not included by Gaur, Joshi & Pande (1992) in the calculation of the equivalent widths for the ionic molecules may be the veil produced by unresolved weak absorption lines. However, the nature of this veil opacity is not known and therefore, at present, it can not be included in calculations. The veil opacity seems important for the deep seated molecules such as the ionic species in the solar atmosphere (Sinha & Tripathi 1990b).

Several telluric lines in the infrared region of the solar spectrum are found which can produce suppressed continuum in a spectral region. One may, therefore, wish to look for $HeH^+$ lines in observations obtained from space also. Such an atlas due to Farmer & Norton (1989) is not available to us. We may attempt to examine yet another FTS atlas due to Livingston & Wallace (1991) in future.

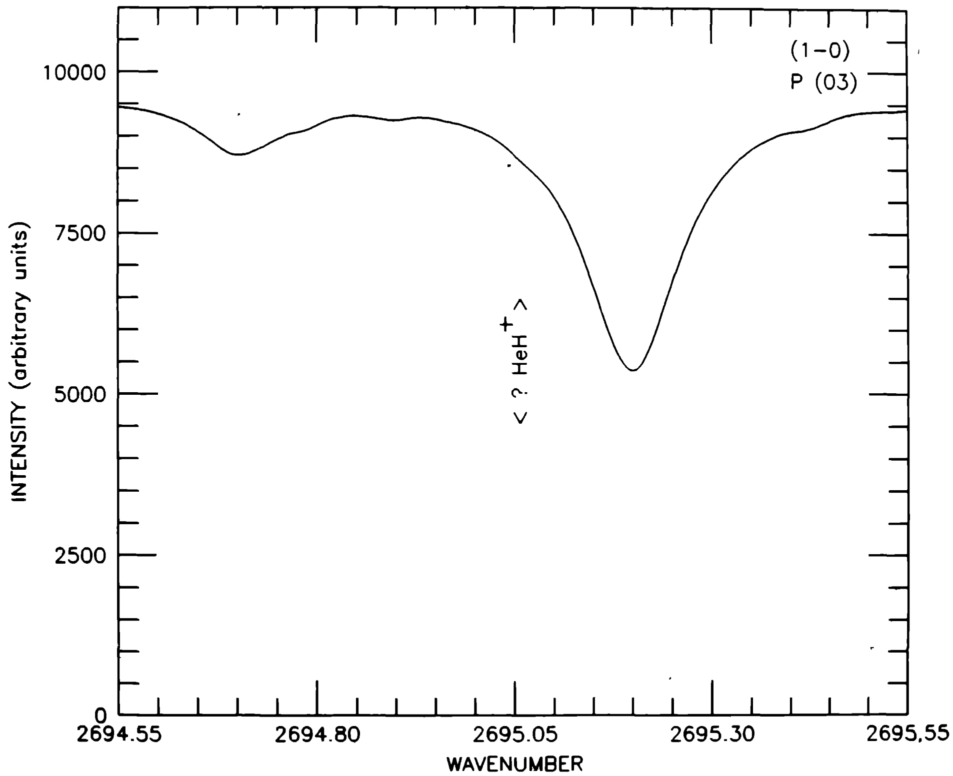


**Figure 1.** Search for the P(03) vibration-rotation line of the $HeH^+$ molecules.

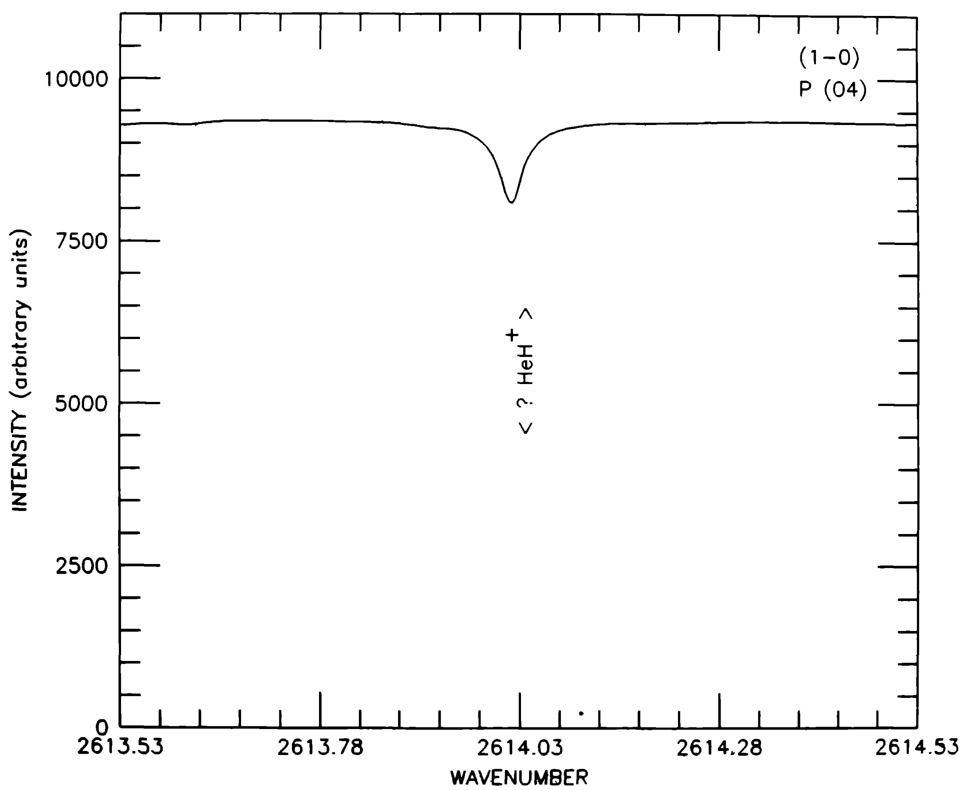


**Figure 2.** Search for the P(04) vibration-rotation line of the $HeH^+$ molecules.

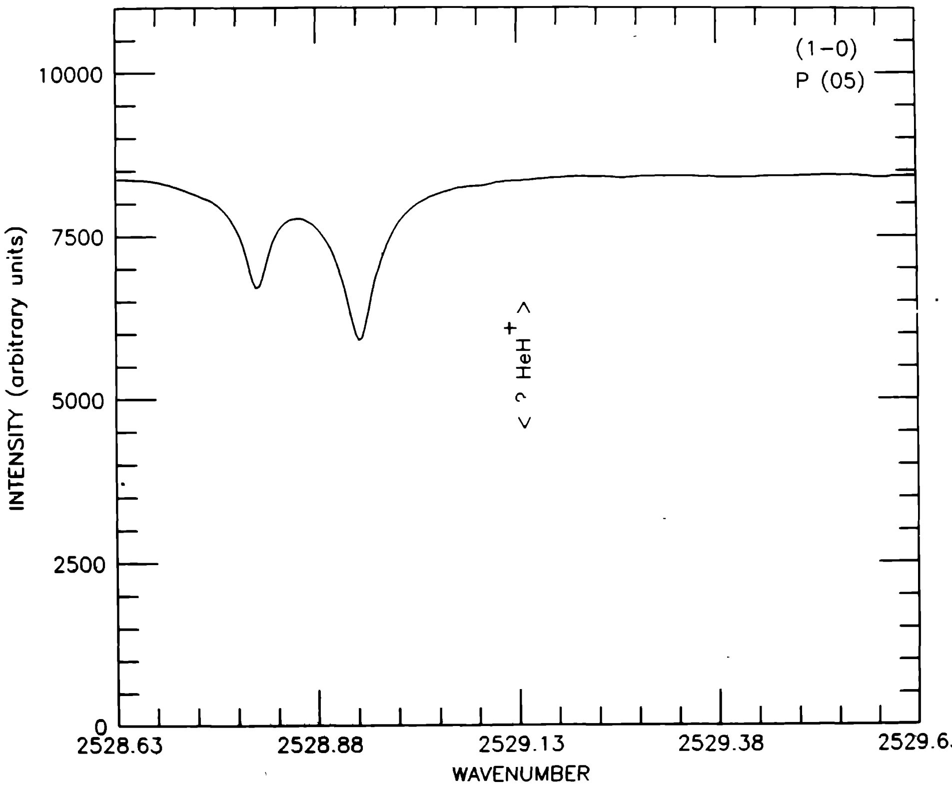


**Figure 3.** Search for the P(05) vibration-rotation line of the $HeH^+$ molecules.

## References


Allen C. W., 1973, Astrophysical Quantities, Athlone Press.

Anders E., Grevesse N., 1989, Geochim. Cosmochim. Acta, 53, 197.

Bernath P., Amano T., 1981, Am. Phys. Soc., 48, 20.

Delbouille L., Roland G., Brault J., Testerman L., 1981, Photometric Atlas of the Solar Spectrum from 1850 to 10,000 $cm^{-1}$, Tucson, Arizona.

Farmer C. B., Norton R. H., 1989, A High Resolution Atlas of the Infrared Spectrum of the Sun and the Earth Atmosphere from Space, vol. 1 : The Sun, NASA Ref. Publ. 1224, NASA Scientific and Technical Information Division, Washington, D.C.

Gaur V. P., Joshi G. C., Pande M. C., 1992, BASI, 20, 61.

Grevesse N., Sauval A. J., 1970, A&A, 9, 232.

Grevesse N., Sauval A. J., 1971, A&A, 14, 477.

Huber K. P., Herzberg G., 1979, Molecular Spectra and Molecular Structure IV. Constants of Diatomic Molecules, Van Nostrand.

Livingston W., Wallace L., 1991, An Atlas of the Solar Spectrum in the Infrared from 1850 to 9,000 $cm^{-1}$ (1.1 to 5.4 μm), N.S.O. Technical Report # 91-001, National Solar Observatory, NOAO, Tucson, Arizona.

Sinha K., Tripathi B. M., Atalla R. M., Singh P. D., 1988, Sol. Phys., 115, 221.

Sinha K., Tripathi B. M., 1990a, BASI, 18, 33.

Sinha K., Tripathi B. M., 1990b, PASJ, 42, 737.


**Note added in proof :** An *Atlas of the Solar Spectrum in the Infrared from 1850 to 9000 $cm^{-1}$ (1 1 to 5.4 μm)* by Livingston & Wallace (1991) was examined by us as indicated above. The solar and the terrestrial components of the spectra have sperately been shown in ths atlas. We found that out of the 12 lines for which chance coincidences were reported in Table 1, 9 are due to telluric lines. The features corresponding to P(10), P(12) and R(15) may be solar features but not due to $HeH^+$ as they appear too strong.