RAMAN SCATTERING EFFECT IN ATMOSPHERES OF GIANT PLANETS OF THE SOLAR SYSTEM FROM HIGH-RESOLUTION SPECTRAL DATA

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Some results of study for high-resolution spectra of Jupiter and Saturn atmospheres are presented. The spectral data are derived with the help of the coude echelle spectrometer installed on the 2-m telescope at the Terskol Observatory (the Northern Caucasus). The investigations are carried out with consideration for Raman light scattering. Calculations for molecular scattering effect in the atmospheres of giant planets are made for visible part of the spectrum. Wavelengths of Fraunhofer lines and their strongest ghosts caused by the rotational $S(0)$, $S(1)$, $O(2)$ and the vibrational $Q_1(1)$ transitions are used.

INTRODUCTION

During a molecular scattering process, the photon may loose energy according to certain molecular transitions. Theoretical description of Raman scattering is presented by Cochran and Trafton [1]. Raman scattering causes emission features in the planetary albedo spectrum at each solar line and several absorption features, Raman "ghosts", longward of each solar line. The emission features at solar lines are quite obvious in the ultraviolet. Because of the multitude of solar lines, emission and absorption features superposed at almost every wavelength. Usually, Raman scattering is considered for three major hydrogen transitions, the rotational $S(0)$ and $S(1)$ as well as the vibrational $Q_1(1)$ transitions, which produce significant Raman ghosts. Raman scattering due to all other transitions, including multiple Raman scattering, is too small to be observable by their ghosts, but their combined effect may significantly increase the emission features. The corresponding emission peaks in the planetary spectra are easily visible and accurately measurable. This provides the amount of Raman scattering due to all transitions combined [2].

OBSERVATIONS

The spectra presented were obtained with the use of 1024×1024 pixel CCD-matrix in the coude echelle spectrometer of the 2-m telescope of the Terskol Observatory (the Northern Caucasus) on March 11 and 13, 2001. Optical scheme of the coude echelle spectrometer is described in [5]. We obtained four separate data sets: one for the Jovian equatorial region, one for the Jovian north equatorial band, one for the Saturnian equatorial region, and one for the Saturnian north polar cap. To take into account contribution of solar spectrum to planet spectra, we used observational data for the Sun analogue HD 89010 (35 Leo). Parameters of objects at the observation moment are listed in Table 1. Technical characteristics of observation apparatus and the procedure used for data processing are described in [3].

Table 1. Observational characteristics of objects

Object	Magnitude	Exposure, s	Signal-to-noise ratio
Jupiter	−2.2	300	200
Saturn	0.2	900	100
35 Leo	5.9	3600	185

RESULTS

The aims of our investigations are:

1. To detect the presence of Raman scattering by H_2 in the atmospheres of Jupiter and Saturn using spectra of these planets.

2. To find values of the relative contribution of Raman light scattering to separate morphological details of Jovian and Saturnian discs.

   We consider the spectral region from 3938 Å to 8743 Å. Unfortunately, the solar line Ca II K is located out of this spectral region. An example of the primary Saturnian equatorial region spectrum in the vicinity of the solar Ca II H line is presented in Fig. 1.

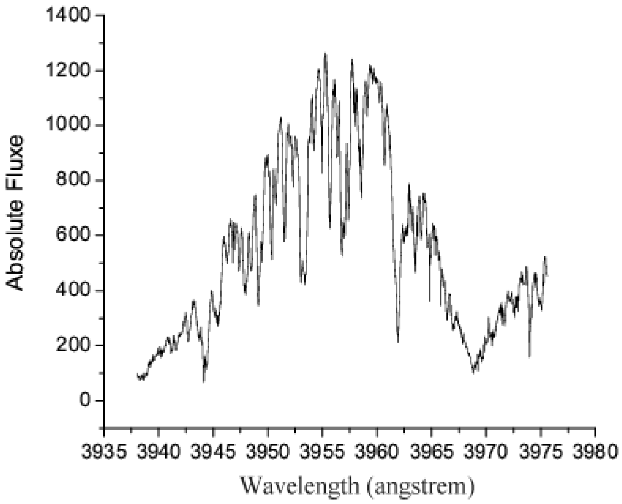
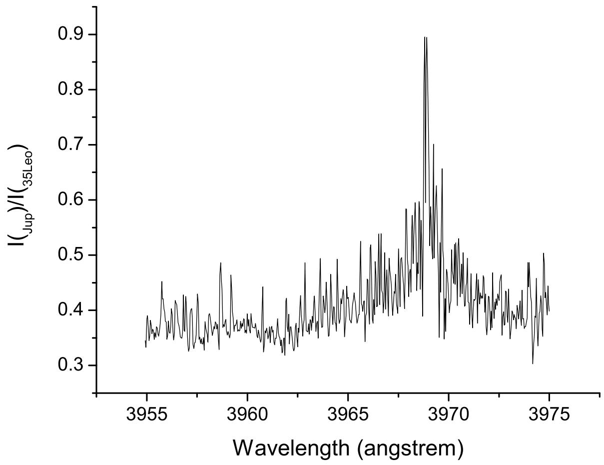


Figure 1. Saturnian equatorial region spectrum in the vicinity of the solar Ca II H line

On subtracting the solar contribution from the planet spectra with the help of a spectrum of the Sun analog 35 Leo, numerous pseudoemission peaks were detected in the obtained planet spectra. This is evidence of Raman light scattering presence in the Jovian and Saturnian atmospheres. Figure 2 shows a small part of the resulting spectrum of the Jovian equatorial region including the Ca II H line. The lower half of the figure displays the spectrum, while the upper half shows the Jupiter / 35 Leo ratio spectrum. The ratio spectrum has a peak arising as a result of Raman scattering of photons. Well visible Stoks ghosts are detected for both lines Ca II H and K but are more significant for hydrogen transitions, namely, $S(0)$ and $S(1)$ corresponding to 354 and 587 cm^{-1} removals. Further, we find the values of relative contribution of Raman light scattering for Jupiter and Saturn using pseudoemission peak in the field of the Ca II H line. It is made by means of division of light field spectrum by the dark field spectrum for single planet disc. It is noted that, for giant planets, aerosol layer in dark fields is located lower than in light fields. Accordingly, in the dark fields, there is a larger quantity of gas (H_2) and a larger contribution of Raman light scattering takes place than in the light fields. This fact is confirmed by obtained values of relative contribution of Raman light scattering to spectra of Jupiter and Saturn. The above-mentioned values are presented in Table 2.

Table 2. Values of relative contribution of Raman light scattering to spectra of Jupiter and Saturn

Object	Light field / dark field	Relative contribution of Raman light scattering, percent
Jupiter	equatorial region / north equatorial band	7.6
Saturn	equatorial region / north polar cap	39.0



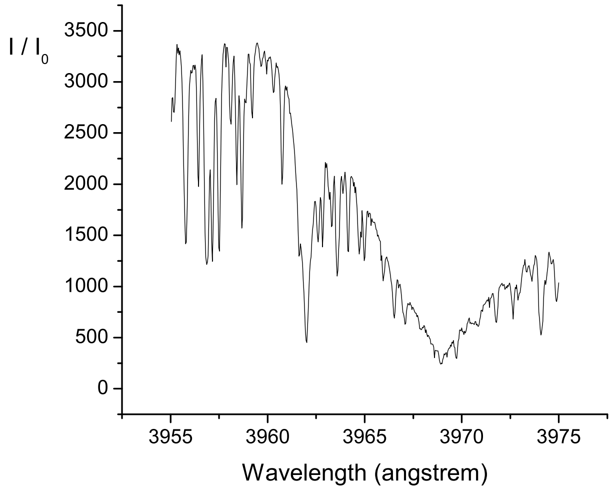


Figure 2. A small part of the resulting spectrum of the Jovian equatorial region in the vicinity of the Ca II H solar line. The lower half of the figure displays the spectrum, while the upper half shows Jupiter / 35 Leo ratio spectrum

Our calculations of absolute values of Raman light scattering contribution to spectra of separate morphological details of the Jovian and Saturnian discs are made with the help of Morozhenko's methods [4].

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