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MOLECULAR ABSORPTION BANDS IN JUPITER TROPOSPHERE RESEARCH

Abstract. Based on spectrophotometric observations of Jupiter, made since 2004, some features of the behavior of the methane and ammonia absorption bands on the planet's disk, are discussed. In the meridional course of the observed variations in the equivalent widths of both ammonia and methane in the 6000A - 8000A spectral range, there are both similar elements and differences. Variations in the equivalent widths of ammonia absorption bands at 6450 Å and 7870A show a decrease in absorption in the low and moderate latitudes of the northern hemisphere. In the 7870 Å band, compared to the 6450 Å band, the ammonia absorption depression in the region of the Northern Equatorial Belt is narrower in latitudes and some more deeper. With similar latitudinal variations in methane absorption, systematic differences are observed in the position of extrema for different bands of ammonia and methane. The importance of studying the behavior of absorption bands for optical probing of the troposphere of Jupiter is noted. The alternatives of the model of the troposphere structure and ammonia cloud on Jupiter are discussed. The first model assumes the existence of a geometrically and optically thick ammonia cloud layer. In this layer, the formation of the observed molecular absorption bands in the process of multiple scattering mainly occurs. An alternative model assumes the presence of a geometrically and optically thin layer of ammonia clouds. The bulk of the molecular absorption in this case is created in the troposphere between the cloud layers of ammonia and ammonium hydrosulfide. The need for further research in this direction is noted. One of the important results, so far preliminary, was the differences we found in the latitudinal position of the extremes of the intensities of the molecular absorption bands on Jupiter. This feature is most likely due to the difference in the conditions of formation of different absorption bands in the ammonia cloud layer and the underlying troposphere. The complexity and ambiguity of the mechanism of formation of molecular absorption bands requires further consideration of both various models of the structure of the Jovian atmosphere and further detailed spectral observations of Jupiter, with particular emphasis on the study of weak and moderate absorption bands, which we would like to draw attention to in this publication
Keywords: Jupiter, atmosphere, troposphere, spectrophotometry, ammonia, methane, ammonium hydrosulfide, molecular absorption bands.

Introduction. Along with many unsolved problems associated with the study of Jupiter, one of the main problems is the structure and dynamics of its atmosphere, including the nature and structure of cloud layers located in the troposphere of the planet. Of particular importance in this regard is the study of ammonia, which is one of the small but important components of the atmosphere of Jupiter. Ammonia is one of the cloud-forming substances in the troposphere of Jupiter, and, like methane, plays an important role in the transfer and release of thermal radiation in the infrared and microwave spectral regions. In the process of research of Jupiter atmosphere, study of the behavior of the methane and ammonia molecular absorption bands, observed in the visible and near infrared spectral regions of 5000–9000 Å, becomes necessary. Weak and moderate ones of them can form in the relatively deep layers of the Jovian troposphere, and their observed variations can carry information about local differences in atmospheric structures, including the structure of the planet’s cloud cover. The formation of these bands is rather complicated, and therefore, the interpretation of observational data requires both model calculations and laboratory studies. Studies of the methane and ammonia absorption bands behavior in different regions of the Jovian disk have been repeatedly considered by some authors, for example, [1-3] for the purpose of using the above bands as a probe of local vertical transparency in the line of sight. It is from these positions that an approach is needed to further study the behavior of molecular absorption, both in the visible spectrum and in the ranges of thermal infrared and radio emission. But it is precisely the visible and nearest infrared region of the spectrum that makes it possible to study the Jovian troposphere based on measurements of the incident and diffusely reflected solar radiation.

Laboratory ammonia and methane spectra

Quantitative estimates of the gas content in the planetary atmosphere require knowledge of the characteristics of the absorbing properties of the molecules of these gases obtained in laboratory studies. Unfortunately, there are not so many laboratory studies of the methane and ammonia absorption bands located in the visible spectrum. Of interest to us are those works that were performed with spectral resolution close to what we used when observing Jupiter. First of all, we mean the works {4-6].

In [1], laboratory profiles of the 5520 Å and 6450 Å ammonia absorption bands, and the growth curves for them, are presented. The growth curve of the 6450 Å NH3 band is important for us. The growth curve is a dependence of the absorption band intensity (equivalent width) on the equivalent thickness or optical path of the absorbing gas, expressed in units of m –amagat. Thus, entering the growth curve with the equivalent absorption band widths observed in the Jupiter spectrum, we can determine the equivalent absorption path in these units. However, we note that this is not equal to the gas abundance in the atmosphere because of the above complex mechanism of absorption bands formation in the gas-aerosol atmosphere of Jupiter.

Similar coefficients for the growth curve of the methane CH4 6190 A absorption band are given in [1]. Weak and moderate absorption bands in the spectrum of Jupiter fall on the linear part of the growth curves, in contrast to strong saturated bands. Due to this, for the NH_3 6450 Å band, we have a ratio of equivalent width and equivalent thickness as 1A per 4 m-amagat, and for 6190 A methane band 1A of equivalent width corresponds to 22 m-amagat of equivalent gaseous thickness. Unfortunately, for other absorption bands, it was not possible to find growth curves in the literature. The study of ammonia absorption in the visible spectral region is described in [7,8] as well as in recent publications [9,10].

Jupiter spectral absorption bands

As noted above, our studies of ammonia absorption on Jupiter were launched in 2004 along with ongoing studies of methane absorption bands. Annual observations are carried out according to a single method and cover more than one period of Jupiter's revolution around the Sun, which is 12 years. The previous results of observations, as well as the methods for their obtaining, are described in a number of our publications, including [11-14]. Most of the observations obtained, were used to study latitudinal variations in ammonia absorption from spectrograms of the central meridian of Jupiter. In addition, we used zonal spectra obtained by scanning the Jovian disk from the south pole to the north one with the spectrograph slit oriented parallel to the equator of the planet. Such measurements give a complete picture of the meridional course of ammonia absorption and the first results were published in 2005 in [15]. Then we drew attention to the presence of a pronounced depression in the intensity of the 7870Å NH3 absorption band in the region of the Northern Equatorial Belt (NEB) on Jupiter.

Figure 1 shows a sample of the Jupiter spectrum with absorption bands of methane and ammonia after dividing by the reference Ganymede spectrum. Particular attention is paid to the study of two weak absorption bands of ammonia on the disk of Jupiter.

Both NH3 6450 Å and NH3 7870 Å bands have relatively low intensity, especially the NH3 6450 Å band. Its equivalent width averages from 5 to 7 Å and the depth at the maximum absorption does not exceed 0.10. The equivalent width of the 7870 Å NH3 band reaches 16–18 Å and its central depth is about 0.2. Note, that earlier, some measurements of the NH3 6450 Å absorption band in some latitudinal belts of Jupiter were described by other authors in [1,16,17].

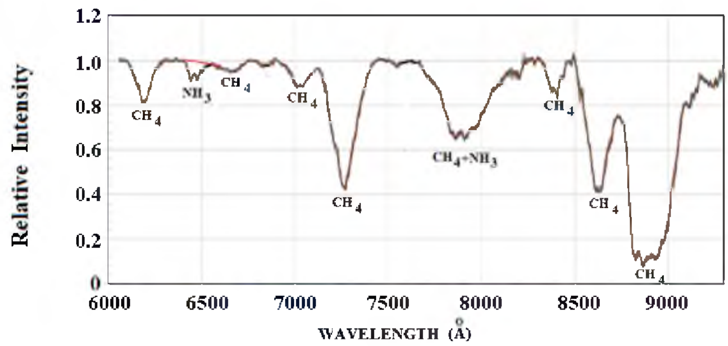

Figure 1 - Jupiter spectrum with absorption bands of methane and ammonia in the wavelength range of 6000 - 9500 Å (SGS spectrograph 4.3 A / pixel).

Table 1 shows these data, as well as our results as the averaged equivalent widths for 2005–2015 years, indicating standard deviations (s_W). In addition, the second column provides the results of observations in 2018 for comparison. The measurements of the same ammonia absorption band in the central part of the Jovian disk and its longitudinal variations are described in [18]. The same authors [19] studied the temporal variations in ammonia absorption for 1979 and 1980.

Table 1 - Equivalent widths of the 6450 Å NH3 absorption band

Region	Year 2018	Tejfel 2018 [12]		Moreno et al. 1988 [14]	Luts, Owen 1980 [2]	
	W(A)	W(A)	sW	W(A)	W(cm-1)	W(A)
SPR	4.2			5.6		
STB	5.1			5.7		
STrZ	5.7	5.92	0.49	7.8	26.4	11.00
SEB	6.0	6.78	0.45	9.8	30.9	12.90
EZ	6.2	6.75	0.32	7.7	23.1-33.0	9.6-13.8
NEB	5.5	6.35	0.35	4.9	20.1	8.30
NTrZ	4.4	5.38	0.36			
NTB	4.7			5.7		
NPR	4.6			7.2		
GRS	4.7				22.2	9.3

The equivalent width in these works was found to be 6 ± 1 Å, which almost coincides with our estimates. Noticeable differences in the estimates of the equivalent width occur in [1 and 16]. And this is true despite the fact that the general nature of the differences in latitudinal belts is similar across all observations. The overall difference in absolute values, as the authors of [1 and 16] correctly point out, is most likely connected with the methodology for conducting the level of the continuous spectrum. The fact is that the 6450 Å NH3 band is superimposed on the short-wavelength wing of the more intense methane absorption band of CH4 6750 Å. Although the residual intensity in this wing is very small, it is still necessary to take it into account when isolating the profile of the ammonia band.

The situation with the separation of the 7870 Å NH3 absorption band is more complicated, since it falls into the center of the more powerful methane band CH4 of 7900 Å. The only way to isolate ammonia absorption is to calculate the ratio of the spectrum of Jupiter to the spectrum of the center of the disk of Saturn, in which ammonia absorption is practically imperceptible. The spectrum of Saturn's disk center was used as a standard for processing all spectrograms. For all other methane and ammonia absorption bands the spectrum of the Saturn ring or the Ganymede spectrum was used as a reference spectrum. An additional control was provided by measurements of the equivalent width of the 7600 Å O_2 (oxygen) telluric absorption band on the spectrograms of the central meridian of Jupiter. The constancy of its value over the entire spectrogram width testified to the reality of the latitudinal variations of the Jupiter absorption bands obtained.

As an example, Fig. 2 shows the results of measurements of the equivalent widths of two ammonia absorption bands and three methane absorption bands in 2017, 2018, and 2019. For ease of comparison and preservation of scale, all values of equivalent widths are normalized to the corresponding values of equivalent widths of each band in the equatorial zone. The graph for 2018 additionally shows the relative course of the equivalent width of the 8870 Å methane absorption band.

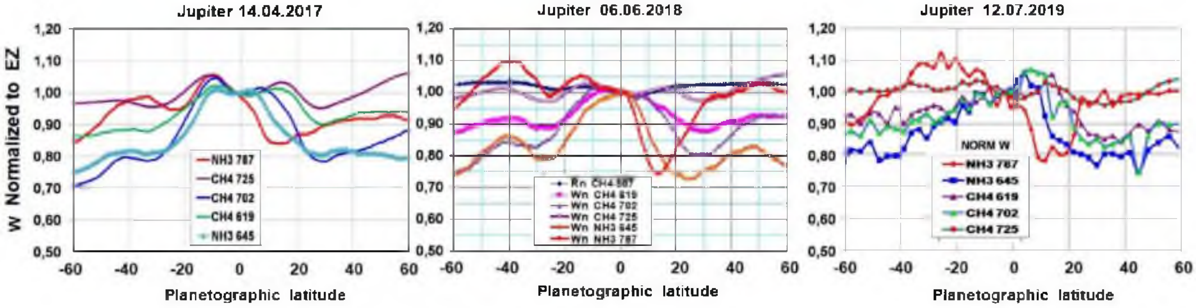

Figure 2 - Relative latitudinal changes in the equivalent widths of the absorption bands of ammonia and methane according to observations in 2017 - 2019

In the meridional course of the observed variations in the equivalent widths of both ammonia and methane in the spectral range of 6000 Å - 8000 Å, there are both similar elements and differences. Variations in the equivalent widths of both methane at 6190 Å and 7020 Å, and ammonia at 6450 Å show a decrease in absorption in the temperate latitudes of the northern hemisphere. Given that methane does not condense and is considered uniformly mixed, this fact most likely indicates local differences in the density and vertical structure of ammonia clouds in the northern and southern hemispheres. In figure 2, one can see that the relative variations in the ammonia band of 7870 Å NH3 compared to the 6450 Å NH3 band are more pronounced and noticeable differences in the latitudinal course at these bands at high latitudes, especially in the northern hemisphere. This feature persists for many years, like the depression in ammonia absorption in the region between EZ and NEB. The maximum ammonia absorption occurs in the temperate latitudes of the southern hemisphere.

The observed difference in the latitudinal position of the extrema of the absorption in different bands deserves special attention and further studies. Similar features of latitudinal shifts of the extrema of the intensities of different methane absorption bands, which are systematic in nature, for all longitudes on Jupiter were discovered and presented earlier in [20], so the reality of such features is not in doubt.

Discussion. As noted above, the observed variations in the molecular absorption bands should be considered as evidence of the presence of zonal and local inhomogeneities in the structure of that part of the Jovian troposphere that is involved in the formation of these bands. As extreme cases, two alternative models can be called. The first assumes the existence of a geometrically and optically thick ammonia cloud layer. Through this layer, deeper into the atmosphere, only part of the scattered radiation can penetrate, while direct sunlight does not pass through this layer. In this case, the theory of radiation transfer can consider this layer as semi-infinite (in the accepted terminology). Almost all of the observed absorption in weak and moderate molecular bands is formed in the process of multiple scattering inside this cloud medium. A small fraction of the absorption of methane bands can be created in the atmospheric layer above clouds, while the concentration of ammonia above the cloud layer decreases sharply, by several orders of magnitude. In this model, the observed absorption variations can be associated with variations in the concentration and volume scattering coefficient of cloud particles and some other factors affecting the effective absorption path. This pathway is estimated from the intensity of the absorption bands and cannot be considered as an estimate of the relative abundance of the absorbing gas in the troposphere.

In an alternative model, it is assumed that the ammonia cloud layer has a relatively small geometric thickness and passes a significant part of direct solar radiation into the atmosphere. In this case, direct sunlight at least reaches a deeper cloud layer. According to most models of the atmosphere of Jupiter, such a layer is a layer of ammonium hydrosulfide NH4SH. This substance has a significant color, but its albedo is not yet known. If it is not too close to zero, then some of the sunlight diffusely reflected by this layer can go outside. In this case, the intensity of the observed absorption bands will be determined by the double passage through the gas layer located between the two cloud layers. With a very dark substrate of ammonium hydrosulfide, we could not observe absorption in a pure gas. In this case, the presence of scattering particles inside this layer is required.

Even these two idealized models indicate the complexity of the formation of molecular absorption bands observed in the visible and near infrared spectra of Jupiter. In the more distant region of thermal infrared and microwave radio emission, the picture is completely different, since the aerosol component is transparent for these radiations. Zonal and local brightness temperatures of the emitted heat radiation are determined by other factors, as discussed in a number of works carried out for many years under the direction of Glenn Orton (Jet Propulsion Laboratory, California Institute of Technology, Pasadena) and Imke de Pater (University of California, Berkeley). As an example, we note their recent publications [21-24].

The three cloud model of Jupiter's troposphere is considered by many authors, starting with the publication [3,25]. We examined a number of such published models, differing mainly in the accepted initial values of the contents of condensing gases. Estimates of the maximum concentration of particles in the ammonia cloud layer in these models, as a rule, refer to the base of the cloud layer and range from $1 \cdot 10^{-6}$ g / cm^3 [26] to $7 \cdot 10^{-6}$ g / cm^3 [27]. In all models, cloud density decreases with height, but the total thickness of the aerosol layer can be 10 km or more. However, it should be noted that the horizontal and vertical scales of the details of the cloud cover of Jupiter are incommensurable, since even the smallest details which are distinguishable in the best pictures of the planet, have a horizontal length of 1000 or more kilometers. Therefore, significant local variations in the thickness and density of the ammonia cloud layer are quite possible. Regarding presence of a scattering medium in the space between the ammonia and hydrosulfide cloud layers, so far we can only refer to a unique experiment on direct sounding of the atmosphere of Jupiter by a descent vehicle in the Galileo Jupiter Mission [28] project. Although it is believed that the probe fell into a not quite typical region of the planet. Judging by the probe nephelometer, there is a slightly dense aerosol haze rising above the cloud layer of ammonium hydrosulfide.

Based on laboratory growth curves for the absorption bands of ammonia 6450 Å and methane 6190 Å, which were mentioned above, one can show that when these bands are formed inside the inter-cloud gas layer, their equivalent widths may be close or even coincide with those observed. This means that it can be far from simple to separate the two models for the formation of molecular absorption bands discussed above.

Conclusion. Due to limitations on the admissible volume of the article, we examined only briefly and fragmentarily some results and problems of studying the structure of the Jovian atmosphere from the standpoint of its optical sounding. One of the important results, so far preliminary, was the differences we found in the latitudinal positions of the extrema of the intensities of the molecular absorption bands on Jupiter. This feature is most likely due to the difference in the conditions of formation of different absorption bands in the ammonia cloud layer and the underlying troposphere. The complexity and ambiguity of the mechanism of formation of molecular absorption bands requires further consideration of both various models of the structure of the Jovian atmosphere and further detailed spectral observations of Jupiter with special emphasis on the study of weak and moderate absorption bands, which we would like to draw attention to in this publication.

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ЗЕРТТЕУДІҢ МОЛЕКУЛАЛЫҚ ЖҰТЫЛУ ЖОЛАҚТАРЫ ЮПИТЕР ТРОПОСФЕРАСЫ

Аннотация. Алып планеталарды, оның ішінде Күн жүйесіндегі ең ірі Юпитер планетасын қашықтан бақылау және өлшеу осы планеталардың физикалық табиғатын зерттеуде жалғыз әдіс болып қала бермек.

1995 жылы іске асырылған ғарыштық міндеті бар GALILEO құрылғысы Юпитердің атмосферасын алдын ала тікелей тексеру бойынша қайталанбас және бірегей болып табылады. Юпитердің тропосферасын қашықтан оптикалық алдын ала тексеру бойынша әдістің бірі планета спектрінің көрінетін және жақын инфрақызыл аймағында бақыланатын метан мен амммиактың молекулалық жолақтарының жұтылу тәртібін зерттеу болып табылады. Аталған екі ғаз Юпитер атмосферасының терең қатпарларынан шығатын инфрақызыл және микротолқынды сәулелену жылу диапазонында жұтылу жолақтарын пайда болдырып айтарлықтай рөл атқарады. Сонымен қатар, аммиак планетаның көрінетін бұлтты жамылғы құрамының негізі бола отырып Юпитерде бұлт пайда болдыратын фактор болып табылады. Спектралды бақылаулар Юпитер дискіндегі әр түрлі аумақтағы жұтылу жолақтарының интенсивтілігінің вариацияларын зерттеуге мүмкіндік береді және оның тропосферасын оптикалық алдын ала тексерудің әдісі ретінде қызмет атқарады. Біз және басқа да авторлар орындаған жұмыстар, яғни осындай вариацияларды бірнеше жыл бойы зерттеудің нәтижесі бірнеше қызық ерекшеліктерді анықтады, оларды түсіндіру айтарлықтай қиын және бірмәнді емес. Сандық бағалау үшін зертханалық зерттеулерден алынатын молекулалық жолақтардың интенсивтілігі туралы мәліметтер қажет. Алайда мұндай зерттеулер спектрдің көрінетін аймағында әзірше өте аз және олар барлық жұтылу жолақтары үшін емес. Атап айтқанда, интенсивтіліктің (немесе балама ендігі) жұтылған ғаз қалыңдығына (жұтылудың эквивалентті жолы метрмен - амаго) тәуелділігін көрсететін қисық сызықтар NH3 6450А аммиак пен метан CH4 6190А жолақтары үшін ғана алынған. Осындай қисық сызықтар Юпитер спектрінде осы жолақтарды зерттеу бойынша балама жұтылу жолдарын бағалауға мүмкіндік береді. Біз Юпитердегі аммиакты жұтылуды зерттеуді 2004 жылы бастадық және қазіргі таңда да зерттеу жалғасуда. Аталған зерттеулер толқын ұзындығының миллиметрлік диапазонындағы радио бақылаулар мәліметтерімн сәйкес келетін аммиакты жұтылу вариация енінде бірқатар қызық ерекшеліктерді анықтады. Атап айтқанда, Юпитердің солтүстік экваториалды белдеуіне жақын жерде табылған аммиакты жұтылудың депрессиясы милиметрлік диапазондағы радиотемпературананың максимум жарықтылығына сәйкес келді. Осылайша, метан мен аммиактың әр түрлі жолақтарындағы экстремум жұтылулары ендік жағдайда бұрын айтылған айырмашылықтарды растады. Негізінде жұтылу жолақтарының кеңістік-уақыттық вариациясын зерттеу, тропосфера аймағындағы және бұлтты жамылғының құрылымында болып жатқан өзгерістер туралы, қалай болғанда NH4SH аммоний гидросульфидіндегі терең бұлтты қабатына дейін ашуға мүмкіндік береді. Юпитер тропосферасының бірнеше модельдерінде қалың геометриялық және оптикалық аммиакты бұлтты қабаттың бар екені болжануда. Сонымен қатар мұндай бұлтты қабат бұлтты бөлшектердегі көп ретті таралуының арқасында әлсіз молекулалық жұтылу жолақтары үшін де негізгі және басымдылық танытатын рөл атқаруы керек. Ол таза газды атмосферадан жәй ғана қос өтуден артық, тиімді оптикалық жұтылу жолын және бақыланып отырған жолақтың интенсивтілігін шарттауы мүмкін. Осылайша, жұтылу жолағындағы бақыланып отырған вариациялар бұлтты қабаттың көлемді тығыздық вариациясы мен оптикалық сипаттамасымен байланысты болуы керек. Тропосфераның ішіне қарай өтетін тікелей күн сәулесі үшін айтарлықтай мөлдір және оптикалық және геометриялық жіңішке аммиакты бұлтты қабат болып табылатын баламалы модель, яғни гидросульфидті бұлтты қабатқа дейін болуы да мүмкін. Осылайша, бақыланып отырған молекулалық жолақтар газды қабатта осы бұлттардың арасында пайда болады. Қисық сызықтарға сүйене отырып осы тропосфера аймақтағындағы жұтылу, дәл сондай яғни Юпитер спектрінде бақыланатын жұтылу жолағының интенсивтілігіне әкеліп соғуы мүмкін. Осы мақалада біз мына жәйтқа, яғни көрінетін спектр аймағындағы радиобақылаулар мен инфрақызыл мәліметтерімен молекулалық жолақтардың жұтылуын зерттеудің қажеттілігіне, Юпитерде болып жатқан өзгерістерді зерттеу мен оның тропосферасының құрылымының барабар үлгісін таңдауға назар аударғымыз келеді.

Түйін сөздер: Юпитер, атмосфера, тропосфера, спектрофотометрия, аммиак, метан, аммоний гидроульфиді, молекулалық жұтылу жолақтары.

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МОЛЕКУЛЯРНЫЕ ПОЛОСЫ ПОГЛОЩЕНИЯ В ИССЛЕДОВАНИИ ТРОПОСФЕРЫ ЮПИТЕРА

Аннотация. Дистанционные наблюдения и измерения в исследовании планет-гигантов, в том числе крупнейшей планеты Солнечной системы Юпитера, до сих пор остаются и будут ещё долго оставаться единственным способом изучения физической природы этих планет. Осуществлённое в 1995 году прямое зондирование атмосферы Юпитера спускаемым аппаратом космической миссии GALILEO является уникальным и неповторимым. Одним из способов дистанционного оптического зондирования тропосферы Юпитера может служить изучение поведения молекулярных полос поглощения метана и аммиака, наблюдаемых в видимой и ближней инфракрасной области спектра планеты. Оба этих газа играют также немаловажную роль, создавая полосы поглощения в диапазонах теплового инфракрасного и микроволнового излучения, выходящих из глубоких слоёв юпитерианской атмосферы. Кроме того, аммиак является облакообразующим фактором на Юпитере, будучи основой состава видимого облачного покрова планеты. Спектральные наблюдения дают возможность исследовать вариации интенсивности полос поглощении в разных участках диска Юпитера и могут служить средством оптического зондирования его тропосферы. Выполнявшиеся нами, наряду с работами других авторов, многолетние исследования таких вариаций выявили ряд интересных особенностей, интерпретация которых представляется достаточно сложной и неоднозначной. Для количественных оценок необходимы данные об интенсивности молекулярных полос, получаемые по лабораторным исследованиям. Однако таких исследований в видимой области спектра пока очень мало и выполнены они не для всех полос поглощения. В частности, кривые роста, представляющие зависимость интенсивности (или эквивалентной ширины) от толщи поглощающего газа (эквивалентный путь поглощения в метрах- амаго) получены только для полосы аммиака NH3 6450А и метанаСН4 6190А. Такие кривые позволяют оценить эквивалентные пути поглощения по измерениям этих полос в спектре Юпитера. Исследования аммиачного поглощения на Юпитере были начаты нами в 2004 году и продолжаются регулярно по настоящее время. Эти наблюдения выявили ряд интересных особенностей в широтных вариациях аммиачного поглощения, коррелирующих с данными радионаблюдений в миллиметровом диапазоне длин волн. В частности, депрессия аммиачного поглощения, обнаруженная вблизи Северного экваториального пояса Юпитера, совпала с максимумом яркостной радиотемпературы в миллиметровом диапазоне. Подтверждаются отмечавшиеся нами ранее различия в широтном положении экстремумов поглощения у разных полос как метана, так и аммиака. Исследования пространственно-временных вариаций полос поглощения, в принципе, дают возможность судить об изменениях, происходящих в структуре облачного покрова и находящейся под ним области тропосферы, по крайней мере, до более глубокого облачного слоя из гидросульфида аммония NH4SH. В большинстве моделей тропосферы Юпитера предполагается существование достаточно толстого геометрически и оптически аммиачного облачного слоя. При этом такой облачный слой должен играть основную и преобладающую роль в формировании даже слабых молекулярных полос поглощения благодаря многократному рассеянию на облачных частицах. Оно может обусловливать эффективный оптический путь поглощения и соответственно интенсивность наблюдаемой полосы, больше чем при простом двойном прохождении через чисто газовую атмосферу. В таком случае наблюдаемые вариации у полос поглощения должны быть связаны с вариациями объёмной плотности и оптических характеристик самого облачного слоя. Однако не исключена и альтернативная модель, в которой аммиачный облачный слой является оптически и геометрически тонким и достаточно прозрачным для прямого солнечного излучения, которое может проходить вглубь тропосферы, по крайней мере, до более глубокого гидросульфидного облачного слоя. В таком случае наблюдаемые молекулярные полосы формируются в газовом слое между этими облаками. Можно показать, основываясь на кривых роста, что поглощение в этой области тропосферы может приводить почти к той же интенсивности полос поглощения, что и наблюдаемая в спектре Юпитера. В данной статье мы хотим обратить внимание на необходимость продолжения исследований молекулярных полос поглощения в видимой области спектра в сочетании с данными инфракрасных и радионаблюдений с целью изучения происходящих на Юпитере изменений и выбора наиболее адекватной модели структуры его тропосферы.

Ключевые слова: Юпитер, атмосфера, тропосфера, спектрофотометрия, аммиак, метан, гидросульфид аммония, молекулярные полосы поглощения.

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