STUDIES ON PHYSICS OF SOLAR SYSTEM PLANETS IN SHAMAKHY ASTROPHYSICAL OBSERVATORY

Atai A.A.
Shamakhy Astrophysical Observatory named after N. Tusi of ANAS
atai51@mail.ru

I. Planets of the solar system

The twentieth century brought many achievements in the study of the planets of the solar system using terrestrial and space means. About 30 astronomical observatories and stations in the territory of the former Soviet Union, including Azerbaijan, were created and restored in this century; on the eastern side of Mount Pirkuli, a place was chosen for the present Shamakhy Astrophysical Observatory named after N. Tusi (ShAO).

The aim of this work is to describe the main scientific results of planetary studies obtained by the staff of the ShAO NAS of Azerbaijan.

At the beginning of the 60s of the last century, to the west of the ShAO, on the spurs of Mount Kartdag, at an altitude of about 2000 m above sea level, one of the observatory employees was N.B. Ibragimov, whose name was subsequently named one of the craters on map of Mars, made observations of the planet Mars. It was during these years that the foundations of planetary research in the ShAO and N.B. Ibragimov, working under the supervision of the academician of the Ukrainian National Academy of Sciences Barabashev N.P. from the Kharkiv State University, conducted the integral spectrophotometry of Mars.

As is known, the method of integrated spectrophotometry allows one to study changes in the amount of reflected energy from the visible surface of a celestial body in different parts of the spectrum under different lighting conditions. As a result of such observations, conclusions can be drawn about the geometric, optical and physical properties of the surfaces and atmospheres of the planets.

Mars

Based on spectrophotometric observations of Mars during the confrontation in 1960-1961, N.B. Ibragimov determined the phase coefficients, spherical albedo and stellar magnitudes of the planet at 20 wavelengths in the range 50 λλ 4050–6360 Å [1]. The results showed that the geometric albedo of Mars monotonically increases with the wavelength, while the phase coefficient decreases with increasing wavelength and has a minimum near λ = 5050 Å. It was found that the intensity distribution of the reflected radiation over the Mars spectrum is well represented by the values of the spectrophotometric gradient in two parts of the spectrum: λλ 4050-5100Å and λλ 5100-6360Å; and also revealed a difference in the course of the gradients G_1 (λλ 4050-5100Å) and G_2 (λλ 5100-6360Å) with a change in the phase angle α and it was found that the nature of the change in gradients is not the same. In addition, it was found that the color index of Mars with an increase in the phase angle somewhat increases. For the gradient G_1, there is a minimum near $\alpha = 24^0$, and for the gradient G_2, the maximum is at $\alpha = 34^0$, i.e. changes in the gradients G_1 and G2 are of a different nature [1]. It should be noted that this data was of great importance for subsequent research of the Red Planet.

Based on the data obtained, it was found that in the short-wavelength part of the spectrum in the Martian atmosphere, the true absorption plays a significant role (ω = 0.55 for λ 4050 Å and ω = 0.60 for λ 4250 Å, where ω is the single scattering albedo), light scattering does not obey the law Rayleigh, and the scattering indicatrix is stretched forward [2]. It was assumed that a significant role in the short-wavelength region of the spectrum in the atmosphere of Mars is played by large particles.

In July-August 1971, during the great confrontation of Mars, photographic observations of the Red Planet were carried out and it was found:

- an unexpected increase in the contrasts of certain details on the Mars disk can be explained by the assumption that at the time of observation above these regions there were purple clouds;
- contrasts "sea - mainland" had a different course along the spectrum for different objects. A slight change and a gradual increase in contrasts to the red end of the spectrum were also revealed;
- the contrast "sea - polar cap" is progressively decreasing from the blue region to the IR region, which is consistent with [4,5];
- the obtained data showed that the reflectivity curves of polar caps are very different from each other. This fact suggests that dust particles (raised by winds from the surface of the continents) float in the atmosphere of Mars, which give color caps to polar caps (as well as seas) [6]. Subsequently, this result was confirmed by the data of the spacecraft that investigated Mars in the early 90s.

Mars was also studied by the spectral method.

On the spectrograms of the planet, the band λ 6200 Å (with components at λ 6201 Å and λ 6216 Å) was sharply distinguished [7].

In the planet's atmosphere, an upper limit of NO_2 ~ 0.02 mm · atm was found. [8].

It was found that the violet clouds are "clumps" of aerosol particles that are constantly present in the Martian atmosphere and create the famous violet haze effect [9].

The causes of a dust storm in the atmosphere of this planet were studied, and the spectral properties of specially selected terrestrial rocks as probable analogues of matter on the surface of Mars were investigated [10].

It should be noted that the results of studies by N.B. Ibragimov were highly evaluated by scientists [11, 12] and this was described in [13].

Venus

In 1967, the Cassegrain focus of the 2nd ShAO reflector using a prism spectrograph (dispersion 93 Å / mm for Hγ) yielded about 20 spectrograms of the night side of Vienna. Emission lines (the most intense of them were λ 3903 Å and λ 3898 Å), detected on one of the spectrograms [14], were interpreted by the presence of lightning in the planet's atmosphere. Closest to them are the CO_2 bands λ 3890 Å, λ 3904.5 Å, as well as the CO_2 band λ 3893 Å. However, only one of these bands at 3904.5 Å was noted by N.A. Kozyrev [15].

The spectrograms of Venus investigated the dark and light details of the planet terminator and studied the energy distribution in the spectrum of these parts, as well as the brightness distribution along the terminator at different wavelengths (λ 3900 - 4400 Å) [16]. For the first time, it was found that the bright parts of the terminator are caused by the clouds of the upper tier, illuminated by the rays of the sun. As for the dark details, this can be either "holes" (dips in the cloud layer), or clouds with other sizes and particle properties (the latest results were also confirmed by further studies of this planet with the help of the spacecraft "Venus").

Jupiter and Saturn

At the 2nd reflector of the ShAO, the fine structure of the absorption bands CH_4 λ 6190Å, NH_3 λ 6475Å in the Jupiter spectrum and CH_4 λ 6190Å, CH_4 λ 6800Å in the Saturn spectrum was studied. Based on the measured half-widths of the lines in these bands, the gas pressure in the atmospheres of these planets was estimated [17].

In the spectrum of Jupiter, along the lines of the absorption band of NH_3 λ 6475Å, the pressure values were estimated: P_{H_2}= 0.6 atm., P_{He}= 0.3 atm. And along the lines of the strip of CH_4 λ 6190Å – P_{H2}= 2.2 atm., P_{He}= 4 atm.

N.B. Ibragimov [18] reliably recorded the components of R and P-branches of the absorption band of CH4 λ 6800 Å in the Saturn spectrum; from the same lines of this band, he determined the pressure values PH2 = 1.3 atm., PHe = 2.3 atm. for the atmosphere of this planet.

Due to the lower temperature of Saturn's atmosphere, a certain part of the gaseous ammonia should freeze out, turning into crystals, thus forming a visible cloud layer of the planet. Therefore, in the visible part of the spectrum of Saturn, one can observe only the absorption band of NH_3 λ 6475Å and its intensity will be different at different points of the Saturn disk [19].

In the spectrograms of Saturn, obtained in 1969, 1971 and 1974, in the visible region of the spectrum of the planet, more than 40 weak depressions of absorption lines were detected in the NH_3 λ 6475Å region. It was found that the intensity of the depressions in the region of λ 6445 Å and λ 6475 Å varies markedly from date to date. Based on the results of these observations, some characteristics of Saturn's atmosphere were determined: rotational temperature, pressure, and volume concentration of ammonia $T_{вр}$=129±8K, P =1.7±0.14 atm, $n(NH_3)=(6.7\pm1.2)\cdot10^{12sm}sm^{-3}$, respectively. It was found that $n(NH_3)/n(CH_4)=(0.76\pm0.13)\cdot10^{-2}$ is 5÷9 times lower compared to Jupiter [19, 20].

The intensities of the absorption bands of CH_4 λλ 5430, 6190, 7020, 7250, 7980+7820Å in the Saturn spectrum and CH_4 λλ7020, 7250, CH_4 7980+$NH_3$7920 +CH_4 7820Å in the Jupiter spectrum were studied [17].

Based on lengthy studies of the absorption lines of NH_3 λ 6475Å from the Jupiter disk, the ammonia content ((17±4) m·atm) in the planet's atmosphere was determined [21]. It has been established that the effect of center-edge to the western and eastern limbs is of a different nature. This is due to the fact that the atmosphere of Jupiter is vertically heterogeneous; such heterogeneity in itself is unstable.

Temperature inhomogeneity, a change in aerosol concentration, the course of gas absorption in different regions of the disk, and the dependence of such properties on time are important factors in studies of the atmospheres of giant planets.

We also note that the rotational temperatures in the Jupiter cloud layer in GRS, EZ, and SEB correspond to the following values: 162±25K, 145±31K and 150±46K,, respectively. These values were obtained according to the 1970 data, which had a slightly higher value compared to the values of 1971.

Comparative spectrophotometry of the details on the Jovian disk along the lines and absorption bands of molecular gases allows us to draw the following conclusions:

1. The thermal conditions in the details of GRS, EZ, and SEB on Jupiter's disk are not the same and vary with time. This is reflected in their color (or color contrasts) and in the change in gas content (this is especially true for NH_3),
2. In the cloud layer of the equatorial zone, the relative concentration of aerosol over the depth of the atmosphere of Jupiter is not stable.
3. Details of EZ, SEB, and GRS on the Jovian disk at the depth at which weak ammonia lines are formed do not differ much in their optical properties and even the BKP becomes indistinguishable from the neighboring STrZ surrounding it [22].

An increase in absorption in the NH_3 λ 6475Å by 2÷3 times, revealed in 1970-71, suggests a large spatial expansion of the ammonia cloud layers of Jupiter. This fact was confirmed by computer images of Jupiter obtained using the Galileo space probe in 1998 and the Habble orbital telescope [23,24]. As a result of lightning detected by "Galileo", crystalline ammonia sublimating can transfer to a gas state, which can lead to an increase in the intensity of absorption bands of ammonia by 2-3 times. The existence of such powerful lightnings inherent in Jupiter does not exclude the possibility of convection or powerful solitons in its atmosphere. And this, in turn, can lead to a change in contrast on his disk. In this case, the penetration depth of the sun's rays decreases and the differences observed in different parts of the equatorial part of the Jupiter disk merge [25].

We studied the distribution of the intensities of the quadrupole lines линий S(1) λ6367.76Å over the Jupiter disk and the lines S(0) λ 6435.03Å and S(1) λ 6367.76Å, belonging to the H_2 (4-0) band on the disk of Saturn. Within the framework of a two-layer model of the atmosphere, the hydrogen content in the above-cloudy atmosphere of these planets was determined. On Jupiter, these values are 7.6 ÷ 9.6 km·amag, on Saturn 11÷17 km·amag. Estimates of the rotational temperature of different portions of the Saturn disk lying along the intensity equator (99-115K) [26] are in good agreement with the results of measurements obtained from the NH_3 λ 6450Å absorption lines in the spectrum of this planet [19 , 20] .

An analysis of observational and calculated data showed that at the depth at which the S(1) H_2 λ 6367.76Å line is formed, the physical conditions in GRS, SEB, and EZ are not the same, and also vary significantly with time, and this greatly acts on the formation of molecular lines. Further calculations showed that 1) the content of molecular hydrogen in the above-cloudy atmosphere is $U(H_2)=5.4\div8.8$ km·amag; 2) the amount of absorbing gas per average mean free path of photons between two scattering events in the cloud layer $A_L=2.7\div4.5$ (km·amag) and 3) the specific gas content per unit length free path $w_S=(2.7\div4.5)\cdot10^{-6}$ ((km·amag)·sm^{-1}) at a pressure of $P_{H2}=0.12\div0.19$ атм [27].

The atmosphere of Jupiter in the absorption bands of molecular gases in the visible region of the spectrum was also studied by the method of integrated spectrophotometry. Observations of Sh.M. Namazov [28] showed that the intensity of the weak bands for the 28 "diaphragm is 10-15% lower than for the 3.5" diaphragm. However, the intensity of weak bands changes by 1.5–2 times, and the intensity of the CH_4 λ 7250Å на 25-30%. by 25-30%. Since weak absorption bands are formed in the deeper layers of the atmosphere, it can be assumed that significant changes in the intensity of molecular bands occur mainly due to changes in physical conditions in the cloud layer. Based on the results of these observations, a new technique was used to determine the physical parameters of the atmosphere of Jupiter in the absence of data on the darkening to the edge of the planet's disk.

An analysis of the observational and calculated results, as well as a comparison with the results of previous works, show that for the methane absorption band λ 7250 Å, the quantity τν (optical thickness of the atmosphere) varies from 0.50 to 0.138, i.e. almost 3 times. This ratio is also preserved for weak absorption bands of methane and ammonia, respectively (λ 7020 Å and λ 6450 Å).

From the found values of τ_ν for the CH_4 λ 7250Å band, the methane content in the upper pure gas atmosphere of Jupiter was determined, which varies from 13.6 to 37.4 m·atm. And the content of methane and ammonia along the mean free path of the photons between the two scattering events in the Jupiter cloud layer for CH_4 λ 7020Å and λ 7250Å varies from 4.25 to 8.5 m·atm, while for NH_3 λ 6450Å from 0.2 to 0.30 m·atm. If for the absorption bands CH_4 λ 6190Å and NH_3 λ 6450Å, the volume scattering coefficients can be considered approximately the same, then we obtain $(C_L)NH_3/(C_L)CH_4= (4.8\div3.5)\cdot10^{-2}$ [29].

To clarify the values of the monochromic absorption coefficient obtained under laboratory conditions in the absorption bands λ 5520 Å and λ 6475 Å ammonia, we proposed a simple method based on analysis the observed spectrum of the planets and the laboratory spectrum of this band of molecular gas [30].

The calculation results show that under the atmospheric conditions of Jupiter and Saturn in the far wings of the NH_3 λ 6475Å absorption band, the values of k_ν are comparable to laboratory measurements, and in the central parts of this band the deviation increases even to ~2.8 times.

The spectral behavior of the ratio of the calculated values of the monochromatic absorption coefficient to laboratory measurements has a complex form and resembles the absorption behavior along the NH_3 λ 6475Å band for both planets. The curve describing the ratio of the calculated monochromatic absorption coefficients of Jupiter to Saturn is consistent with the peculiarities of the absorption path of NH_3 λ 6475Å. Similar calculations were performed for Jupiter in the weak absorption band of NH_3 λ 5520Å.

According to laboratory measurements, the band $6\nu_1$ (λ 5520Å) is weaker than the band $5\nu_1$ (λ 6475Å) by approximately 6.5 times. The calculated integral absorption coefficients for the bands NH_3 λ 6475Å and λ 5520Å in the Jupiter spectrum differ by ~ 8 times. The values of the calculated integral absorption coefficient for Jupiter are ~ 1.65 and ~ 2.1 times different from laboratory values for the bands λ 5520 Å and λ 6475 Å, and for the absorption band of NH_3 λ 6475Å under Saturn conditions differ from laboratory values by ~ 1.65 times. Compared with Jupiter in Saturn, the temperature decreases, as a result of which the pressure of saturated vapors sharply decreases. Maybe this is due to the fact that part of the ammonia gas on Saturn is condensed, forming a crystalline cover of the planet, and thereby shields the inner cloud layer of the planet, which is responsible for gas absorption.

Uranus and Neptune

By the spectrogramms of Uranus the absorption bands of methane and the pressure-induced hydrogen line H_2– S(0) (4 - 0) λ 6420Å [31] is studied. In the spectrum of Uranus in the region λλ6500-6750Å, 45 intense lines were detected. In addition, methane absorption bands λλ 5340, 5840, 6140, 6560, and 6620 Å were clearly recorded on the spectrogram of Uranus. Based on these data, it was found that the absorption band of 6190Å methane consists of three bands. Using two spectral programs of Uranus, we studied the variations in the intensity of the absorption bands of methane upon transition from the center to the edge and found that the intensity across the planetary disk does not change. The height of the spectrum was about 0.4 mm. According to visual estimates during the observation period, the diameter of the image of the disk of a star located at the same zenith distance as the planet was d=0.3"-0.5", and the ephemeral diameter of Uranus 3.8". With this ratio between d and the ephemeral diameter of the planet, it is possible to conduct, at least roughly, surface spectrophotometry of Uranus [32].

Namely, by these spectrograms the absorption bands CH_4 λλ 5430, 5570, 5970 and 6190Å were studied and some optical parameters (σ_α ,τ_ν, λ_ν, L(CH_4) etc.) of the atmosphere of this planet were determined [33]. The results of the work of Yu.D. Daudovud and N.B. Ibragimov [32] were confirmed, which indicated the existence of an optically thin supercloud layer of the atmosphere τ<0.1, self-centered mainly in absorption [31]. And in the work of Pilcher [34], published several years later, it is assumed that this over-cloud layer can play a significant role in increasing the albedo in the centers of strong absorption bands [31].

Further studies [35,36,37, 38] showed that in the visible region of the spectrum of Uranus and Neptune there are many depressions that are not on the list [39]. Later, E. Karkoshka [40] confirmed the existence of three more absorption bands in the spectra of Uranus and Neptune, identifying them with methane, which were previously discovered in our works [35,36,37] and published on the pages of central editions. These absorption bands correspond to λ 4060 Å (4070 Å in [37]) 4200 Å, 4656 Å.

We established that in the central part of the absorption band of methane CH_4 λ 6190Å, the monochromatic absorption in the Uranus spectrum was greater than that in Neptune [35, 41]. In weak and moderate absorption bands, Neptune is darker than Uranus. In the central parts of strong absorption bands, Neptune becomes brighter. Sometimes this brightening disappears in moderate absorption bands and is observed only in sufficiently strong methane absorption bands. This fact was also revealed from the records of the spectrum of Uranus and Neptune, obtained by other authors [34]. It can be assumed that Neptune has an aerosol density in the upper atmosphere proposed in [31, 32, 34] higher than that of Uranus, which is why the residual in strong bands the intensity is increasing. It is clear that strong bands are formed mainly near the upper boundary of clouds or haze, while weak bands in deeper layers of the atmosphere. This important fact, indicating a difference in the degree of vertical inhomogeneity of the cloud cover of Uravan and Neptune, was again mentioned in the literature after more than ten years [42].

The observed spectral behavior of the geometrical albedo of Uranus is compared with theoretical calculations for the three simplest models for the formation of absorption bands: simple reflection models, models with a homogeneous scattering semi-infinite aerosol layer and models with a homogeneous semi-infinite p Rayleigh atmosphere ($\sigma \sim \lambda^4$). The latter model shows the best agreement with the geometric albedo of Uranus both in the centers of weak and moderate absorption bands of CH_4, and in a continuous spectrum between the bands.

It was found that the calculated values of $A_g(\lambda)$for Neptune in the framework of the two-layer model and for the scattering model, unlike Uranus, do not correspond to the observed values even for weak and moderate bands [43]. An analysis of the observed data on the intensity of the absorption bands in the Neptune spectrum showed that there is some correlation between the short-wavelength absorption in the continuous spectrum and the absorption in the methane absorption bands [38].

Bright satellites of the giant planets

At the beginning of the 70s, the spectral features of the bright satellites of the giant planets were also studied in the ShAO: the Galilean satellites of Jupiter and the satellite of Saturn - Titan [31]. A high porosity of the surface layers of the satellites was revealed.

In addition, it was unequivocally established that the color of Io changes sharply with the phase of rotation, reaching in the U-V values of about 0.m65 $0.^m65$ ($\sim 0.^m2$ in B-V и $\sim 0.^m45$ in U-B). This means that the magnitude of the longitudinal effect in the brightness of Io increases from V to U. In other words, the contrast of dark formations on the surface of the satellite with respect to their surroundings increases to the violet end of the spectrum. Such an effect that is observed in Io could be caused by an atmosphere in which the true absorption prevails over scattering, and the optical thickness grows toward the violet end of the spectrum [44].

A particular attention was paid to the study of Io, the satellite of Jupiter in 1975-77. [45]. The IO spectrograms obtained on the 2nd ShAO reflector with a dispersion of 12 and 15 Å / mm were used to study the emission line profiles of NaI, FeI, MgI, CaI. It was found that the contours of these lines are asymmetrical in shape. It was shown that variations in the intensity ratio D2 / D1 in the Io spectrum are real and vary within 1.6 ± 0.3. The intensity of sodium D-lines at $\Phi=90^0$ is approximately 40% higher than at $\Phi=270^0$. In addition, the numbers of emitting neutral sodium atoms and the lower limit of the number of emitting atoms of iron, magnesium, calcium along the line of sight were calculated, which in order of magnitude are $\cdot 10^{11}$, $2\cdot 10^{12}$, $5\cdot 10^{10}$ atoms$\cdot$sm^{-2}, respectively. The results obtained in ShAO, i.e. estimates of the number of radiating atoms along the line of sight $(2\div4)\cdot 10^{11}$ atoms$\cdot$sm^{-2} are in good agreement with estimates of other authors [46, 47].

The characteristic lines of metal radiation we studied by us in the Io spectrum already proved the existence of active processes on the surface of this satellite of Jupiter, but before the Voyager 1 flight such a conclusion would, at that time, still not be proved. After the discovery of volcanoes on the Io KA USA “Voyager-1”, our observations were repeatedly mentioned in various works [48, 49].

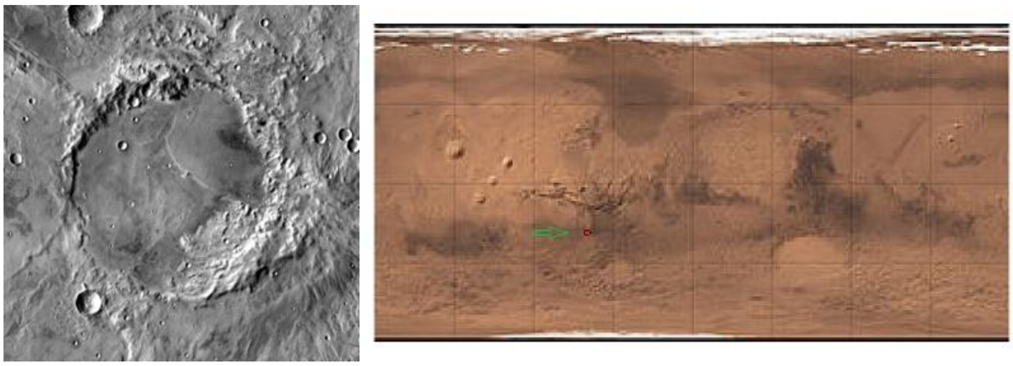
Further, the intensity of the absorption band of CH_4 λ 6190Å in the Titan spectrum was determined, but careful measurements of the spectrograms of the Jupiter satellites did not show any trace of this band.

Based on spectrophotometric studies of bright satellites of giant planets, the following results were obtained [50, 51]:

- in the visible region of the spectrum in Europe, Ganymede and Callisto no emission lines are detected,
- the search for ammonia lines in the Io spectrum yielded a negative result,
- in the spectrum of Titanium there are no absorption bands of methane λ 4860Å and λ 5430Å.

Note that we cited the results of the most important studies on the planets of the solar system obtained by ShAO staff; most of these works were published on the pages of the central journals, and were also reflected in the monograph [52]. For example, in [53], to observe the weak absorption bands of methane in the rigorous theory of the spectra of planets with a two-layer atmosphere, the observable data obtained by N.B. Ibragimov in the spectrum of Jupiter. The value of the above results is also confirmed by references to these works [54,55, 56].

The study of planetary atmospheres in the ShAO continues today. Further study of the physical properties and dynamic processes in the upper layers of the atmospheres of Jupiter, Saturn, Uranus and Neptune, as well as a study of the features of the formation of absorption bands in the spectra of planet giants, will contribute to the development of metrology of the planets, in solving the problems of evolving the atmospheres of planets and cosmogony in general. Research of N.B. Ibragimov in the field of physics of planetary atmospheres, especially according to Mars, was highly appreciated at the meeting of the General Assembly of the International Astronomical Union, held in August 1982 and it was decided to name one of the craters on the map of Mars - "Ibragimov" is a crater on Mars. Diameter - 87 km; located in the east of the plateau of Tavmasia (center coordinates - 25.43° S lat 59.57° W lon).



Ibragimov is a crater on Mars. Diameter - 87 km; It is located in the east of the Tavmasia plateau (the coordinates of the center are 25.43° S lat. 59.57° W lon

Named in August 1982 at the General Assembly of the International Astronomical Union in honor of the Azerbaijani and Soviet astrophysicists Nadir Ibragimov, engaged in spectrophotometry of planets, in particular, Mars, and received valuable data on its surface and atmosphere.

II. Research on origin and evolution of the minor planets (supervised by G.F.Sultanov)

For more than 200 years, astronomers from around the world have been solving the issue of the origin of small bodies of the solar system. However, there is still no consensus on their origin. Supporters of the first group believe that small planets (asteroids) are the remains of protoplanetary matter from which the planets of the solar system were formed. According to others, they are the products of successive decays of primary large bodies. Without resorting to a detailed analysis, a number of researchers support the view that asteroids occur as a result of successive decays of a few larger bodies, which are unaccumulated bodies that arose at the first stage of evolution of protoplanetary matter.

Comparing a number of characteristics that take place in the statistical distributions of asteroids, the shape of the orbit of primary large bodies and their position in space are first determined.

The specific values of the maxima and minima that occur in the distributions of asteroids over the accepted elements have shown that primary large bodies moved between the orbits of Mars and Jupiter before decay.

It was established that the decay of one planet cannot explain the observed distribution of asteroids.

1. The laws of the distribution of fragments of primary large bodies over selected elements of their orbits and their systems are drawn up under various assumptions about the magnitudes and directions of their relative velocities.
2. It is shown that by compiling the distribution functions of several primary large bodies, we obtain the distribution function of fragments with several maxima and minima that are in the distribution of asteroids.
3. Besides, that the number of maxima and minima and the numerical values of the accepted invariant elements corresponding to these maxima and minima are almost the same for each population and it is concluded that these patterns remain unchanged with annual increases in discovered asteroids.

In conclusion, we can assume that the revealed lows in the distributions of asteroids and fragments of primary large bodies by elements, characterizing their physical and orbital features, and a comparison of these patterns offer great opportunities for further studies of the origin of small planets and the cosmogony of the solar system as a whole . Note: Some results of completed and published works were reported at the All-Union Conference on the Study of Minor Planets and Comets and at a number of annual scientific sessions of the Academy of Sciences of the Azerbaijan SSR, and are also included and discussed in the following monographs and periodicals (In the References II).

III. Research on obtaining all possible solutions for the problems of multy actively graving material centers (Supervisor G.T. Arazov)

Using the Hamilton-Jacobi method, a solution is obtained to the generalized problem of two fixed centers in a coordinate system rigidly connected with a planet, i.e. The relative satellite motion of a spheroidal planet is investigated.

One method is proposed for constructing an analytical theory of the motion of a satellite of a spheroidal planet in the case of small eccentricity and low inclination. Using this method, an analytical theory of the motion of the V satellite - Amalthea - Jupiter is built. According to the obtained working formulas, calculations are made. Comparison of theoretical calculations with observations.

The problem of n fixed centers is solved. In other words, particular solutions of one case of the problem of n fixed centers are obtained. It was suggested that the fixed centers are located on the axis of the applicate so that the passively gravitating point moves in the x-y plane.
The generalized plane problem of three fixed centers is solved. It is shown that the generalized plane problem of three fixed centers is divided into three: real, external and internal variants.
The real version of the generalized plane problem of three fixed centers is solved.The external version of the generalized plane problem of three fixed centers is solved.

The internal version of the generalized plane problem of three fixed centers has been solved.
Working formulas are obtained for all three variants of the generalized plane problem of three fixed centers, which can be used as intermediate (unperturbed) orbits in solving a number of problems of celestial mechanics and astrodynamics.

The generalized spatial problem of three fixed centers for the case of a small inclination of the orbit is solved. In this case, solutions were obtained separately that correspond to the real, external, and internal versions of the generalized plane problem of three fixed centers.

Based on the spatial solution corresponding to the orbits of the external version of the generalized problem of three fixed centers, the analytical theory of the 5th satellite of Jupiter - Amalthea is constructed. It is shown that the main properties of the power function of the external version of the generalized problem of three fixed centers make it possible to widely use its solution to solve various problems related to the study of the motion of artificial satellites, the study of the gravitational field and the figure of the Earth.

Based on the planar solution corresponding to the orbits of the internal version of the generalized planar problem of three fixed centers, the evolutions of the orbits of diurnal Earth satellites such as AirlieBird, Sinkom-2 and Sinkom-3 are determined.

All possible orbits are found in the generalized plane problem of three fixed centers. Moreover, all types of motions are constructed for any masses of fixed centers, in particular, negative and complex, corresponding to the real potential (In the References III) .

IV. Investigaton of the theory of determining the orbits of artificial satellites of the earth by complete and incomplete optical observations

(Supervised by R.A. Zeynalov)

The determination of the orbits of both natural (planets and comets) and artificial celestial bodies is one of the important tasks of celestial mechanics and is of great theoretical and practical interest. It is known that it consists of two parts, first, the preliminary (initial) orbit is determined by the minimum number of observations, and then the resulting orbit is improved by many observations. The latter consists in determining a system of elements of the orbit that would best satisfy the entire set of available observations.

Note that to determine the orbits of celestial bodies from observations, there are many different both classical and modern methods, the diversity of which is due to the choice of unknown coordinate systems.Since the average daily movements of the planets and comets are very small, the error in fixing the observation time, sometimes reaching up to several minutes, did not play any role. Therefore, before the advent of artificial earth satellites (AES), the development of methods for determining the orbits of these bodies did not take into account observation time errors at all.

The situation changed significantly after the appearance of satellites, the movement of which in the celestial sphere is so fast that their movements relative to the observer reach 2°.5 in 1 sec. time, which is 10" in 0.001 seconds. Therefore, the obtained satellite observations can have low accuracy. We called such observations incomplete.

Accurate determination of time moments during observations is possible only at first-class observatories and stations equipped with special equipment for storing and measuring time.

Thus, the task of determining satellite orbits using incomplete optical observations has become urgent. The solution to this problem was carried out according to the following points:

I. Determination of the initial satellite orbits from complete and incomplete optical observations

II. Improvement of the satellite orbits according to observations with approximate time moments

III. On the determination of zero points and systematic errors of fundamental stellar catalogs from satellite observations with inaccurate time instants.

IV. On the determination of satellite orbits and station coordinates from optical observations with inaccurate time recording.

V. On determination of fundamental stellar catalogs and coordinates of observational stations from satellite observations with inaccurate time instants.

Conclusion

Detailed calculations carried out according to the developed programs for various cases show the full possibility of solving the basic problems of satellite astronomy and geodesy based on optical observations of satellites with time errors.

In the future, based on these results, it is supposed to investigate the possibility of determining the elements of the orbits, station coordinates, parameters of the gravitational field and the Earth's figure, atmospheric drag, effects of light pressure, pole coordinates, universal time, etc. using conditional equations free of time errors and use the results for processing real observations of satellites and other objects (minor planets and comets). (In the References IV)

REFERENCES I

1. *Ибрагимов Н.Б.*1965. Интегральная спектрофотометрия Марса. Кандидатская диссертация(С.124), Харьков.
2. *Ибрагимов Н.Б.*1965. Определение оптических параметров атмосферы Марса //Вестник ХГУ, № 8, Серия астрономическая, В.2, С.38-41.
3. *Аврамчук В.В., Гайдук А.Р., Давудов Ю.Д, Ибрагимов Н.Б., Коваль И.К., Кругов В.Д.* 1972.Фотографические наблюдения Марса в период великого противостояния 1971 г. // Астрон. Вестник, Т. 6, № 3, С.165-167.
4. *Бронштэн В.А., Ибрагимов Н.Б.*1976. Спектрофотометрия материков, морей и Южной Полярной шапки Марса в июле-августе 1971 г. // Астрон. вестник, Т. 10, № 1, С.38-43.
5. *Ибрагимов Н.Б.*1971. Уровень контраста некоторых деталей Марса в июле 1971 года //Астрон. Цирк.,№ 656, ноябрь 9, С.3-5.
6. *Бронштэн В.А., Ибрагимов Н.Б.*1971. Спектрофотометрия материков, морей и полярных шапок Марса на двухметровом рефлекторе Шемахинской обсерватории в 1969 г. // Астрон. Вестник, Т.5, №1, С.16-22.
7. *Ибрагимов Н.Б.*1969. О полосе NO_2 λ6200 Å в атмосфере Марса //Астрон. Цирк., № 533, окт. 22, С. 3-4.
8. *Ибрагимов Н.Б., Бронштэн В.А.*1975. О присутствии NO_2 в атмосфере Марса //Письма в Астрон. Журн., Т. 1, № 11, С.45-48.
9. *Ибрагимов Н.Б., Коваль И.К.*1971. О фиолетовых облаках Марса // Астрометрия и Астрофизика, № 14, С.3-8.
10. *Таран М.Н., Хоменко В.М., Голубева Л.Ф., Шестопалов Д.И.*1993. Спектрофотометрия горных пород , окрашенных оксидами железа, как вероятных аналогов грунта Марса // Астрон.Вестник, Т.27,№5,С. 56-65.
11. *Тейфель В.Г.*1967. Итоги Науки. Серия Астрономия, М. ВИНИТИ, С.252.
12. *Барабашов Н.П.*1969.О фазовой кривой Марса и распределении яркости на его диске //Астрон. Журн.,т. 46, № 6, С. 1249-1257.
13. *Атаи А.А., Зейналов Р.А.* 2008. Академическая биография Н.Б.Ибрагимова // Астрон. Журн. Азербайджана, № 1-2, С.32-37.
14. *Ибрагимов Н.Б.*1969. О свечении ночного неба Венеры //Астрон. Цирк,№533, окт. 22, С.3-4.
15. *Козырев Н.А.*1954. О свечении ночного неба Венеры // Изв.Кр.АО. Т.12, С.169-176.
16. *Ибрагимов Н.Б.*1970.Спектрофотометрическое исследование деталей на Венере //Астрон. Вестник, Т. 4, № 1, С.31-33.
17. *Ибрагимов Н.Б.*1974. Исследование планеты Юпитера и Сатурна на двухметровом рефлекторе ШАО //Астрон. Журнал, Т.51, №1, С.178-186.
18. *Ибрагимов Н.Б.*1970. О тонкой структуре полосы поглощения CH_4 вблизи λ6800Å в спектре Сатурна //Астрон. Цирк., № 566, С.4-6.
19. *Аврамчук В.В., Кармелюк А.И.*1984.Исследование полосы поглощения аммиака вблизи λ6450А в спектре Сатурна. I. Наблюдения //Астрометрия и Астрофизика, Т. 51, С. 51-56.

20. *Аврамчук В.В., Кармелюк А.И* 1984.Исследование полосы поглощения аммиака вблизи λ6450Å в спектре Сатурна. II. Количественный анализ наблюдений //Астрометрия и Астрофизика, Т. 52, С.30-37.
21. *Ибрагимов Н.Б.* 1975.Определение содержания аммиака в атмосфере Юпитера //Астрон. Журнал, Т. 52, № 4, С.895-898.
22. *Атаи А.А., Намазов Ш.М., Мамед-заде А.М.*1994. О физическом различии некоторых структурных образований атмосферы Юпитера //Астрон.Вестник,Т.28, №1, С.3-12.
23. *Аткинсон Д.Х.* 2001. Эксперимент по изучению ветра в атмосфере Юпитера путем измерения доплеровских скоростей с помощью космического зонда «Галилео Юпитер» //Астрон. Вестник, Т.35, № 5, С. 387-413.
24. *Chanover N.J., Kuehn D.M. and Beebe R.F.*1997.Vertical Structure of Jupiter's Atmosphere at the Galileo Probe Entry Latitude //Icarus, V.128, P. 294-305.
25. *Атаи А.А., Намазов Ш.М., Ахундова М. Дж.*2003.О различии физических условий в атмосфере Юпитера вблизи восточного и западного краев его диска //Цирк.ШАО, № 106, С.8-15.
26. *Аксенов А.Н., Атаи А.А.*1978. Ибрагимов Н.Б. Исследование квадрупольных линий водорода в спектрах Юпитера и Сатурна //Астрон.Вестник,Т. 12, № 2, С.101-106.
27. *Атаи А.А.* 1990. Молекулярный водород в Большом Красном Пятне Юпитера //Астрон. Вестник, Т.24,№ 2, С. 121-126.
28. *Намазов Ш.М.*1986. Об интенсивности молекулярных полос поглощения метана и аммиака в спектре Юпитера //Астрон. Цирк., № 1470, С. 3-4.
29. *Атаи А.А., Намазов Ш.М.*1992. Временные изменения физических параметров атмосферы Юпитера //Астрон. Вестник,Т. 26, № 1, С. 51-61.
30. *Атаи А.А.* 2009. О переопределении значении монохроматических коэффициентов поглощения для полос NH_3 $5\nu_1$ λ6475Å и $6\nu_3$ CH_4 λ6190Å в условиях атмосферы Юпитера // Астрон. Журн. Азерб., №1-2, С.31-38.
31. *Давудов Ю.Д.*1972.Спетрофотометрия Урана и ярких спутников планет-гигантов. Кандидатская диссертация(С.122), Баку.
32. *Ибрагимов Н.Б., Давудов Ю.Д.*1975.Спектрофотометрия Урана в области λ5000-6800Å // Астрон. Журнал, Т.52, № 5, С. 1029-1033.
33. *Атаи А.А., Ибрагимов Н.Б.*1977. Исследование полос поглощения CH_4 в спектре Урана //Астрон. Вестник, Т. 11, № 2, С. 90-93.
34. *Pilcher C.P., Cruikshank D.P., Morrison D.*1977.Evidence for weather on Neptune I. // Astrophys. J., V. 214, № 2, Pt. 1, P. 657-662.
35. *Атаи А.А.*1980.Спектрофотометрия Урана и Нептуна в области λ4300- 7000Å //Астрон. Вестник, Т.14, № 3, С.154-161.
36. *Атаи А.А., Кырхларов Ф.Н.*1985. Полосы поглощения в спектре Нептуна в области λ4000-5000Å //Астрон. Цирк., №1391, июль, С.5-7.
37. Атаи А.А., Гусейнов Н.А. Полосы поглощения в спектре Урана в области λ4000-5000Å. Астрон. Цирк., 1987, №1475, январь, С.1-3.
38. *Атаи А.А., Кырхларов Ф.Н.*1988. Поглощения в спектре Нептуна в области λ4000-5000Å //Цирк. ШАО, № 81, С.13-18.
39. *Мороз В.И.*1967.Физика планет, Изд-во. «Наука», Москва, с.580.
40. *Karkoschka E.* 1994.Spectrophotometry of the Jovian Planets and Titan at 300-to 1000-nm wavelength: The methane spectrum //Icarus, V. 111, № 1, P.174-192.
41. *Атаи А.А.* 1980.СпектрофотометрияУрана, Нептуна и ярких спутников планет-гигантов. Кандидатская диссертация (С.130) , Баку.
42. *Тейфель В.Г.*1992. Аэрозольная составляющая атмосфер планет-гигантов // Астрон. Вестник, Т.26, № 1, С.3-27.
43. *Атаи А.А.*1986.Спектрофотометрия Нептуна в области λ4700-7000Å //Цирк. ШАО,№ 78-79, С.40-50.
44. *Давудов Ю.Д., Коваль И.К.*1971. Спектрофотометрические особенности некоторых спутников планет //Астрометрия и Астрофизика, № 14, С.49-54.

45. *Атаи А.А., Ибрагимов Н.Б.* 1978. Исследование эмиссионных линий в спектре Ио //Астрон. Вестник, Т. 12, № 1 , С.27-33.
46. *Parkinson T.D.*1975. Sodium airglow from Io. Atmospheres of Earth and planets. Ed. McCormac B.M., Dordrecht, Boston, P.433-440.
47. *Trafton L., Parkinson T., Macy W.*1974. The spatial extent of sodium emission around Io //Astrophys. J., V. 190, № 2, P.85-89.
48. *Куликовский П.Г.*2002.Справочник любителя астрономии. Под. ред. Сурдина В.Г., Изд-во Москва, Эдиториал УРСС, 688 С.
49. *Силкин Б.И.*1982.В мире множество лун. Москва, «Наука», 208 С.
50. *Атаи А.А.*1980. Спектрофотометрия галилеевых спутников Юпитера //Астрон. Цирк., № 1092, С.5-7.
51. *Атаи А.А.*1979. Спектрофотометрия Титана в области λ4000-7000Å. Астрон. Цирк., № 1047, с.6-8.
52. *Гайдук А.Р., Ибрагимов Н.Б., Коваль И.К.*1975.Фотометрические характеристики Марса по данным фотографических наблюдений в период великого противостояния 1971. Киев, Изд-во « Наукова Думка ».
53. *Аниконов А.С.* 1974. Интерпретация слабых полос поглощения в спектре Юпитера //Астрон. Вестник, Т.8, №4, С. 223-228.
54. *Douglas N.G.*1996. Optical methane band observations of Jovian SL-9 impact debris //Astron. And Astrophys., V.313, № 1, P.315-321.
55. *Neff J.S., Humm D.C., Bergstralh J.T., Cochran A.L. et.al.*1984. Absolute spectrophotometry of Titan, Uranus and Neptune: 3500-10500Å //Icarus,V.60, № 2, P.221-235.
56. *Baines K.H. and Bergstralh J.T.*1986. The structure of the Uranian atmosphere: constraints from the geometric albedo spectrum and H_2 and CH_4 line profiles //Icarus,V.65, №2/3, P.406-441.

REFERENCES II

1. Sultanov G.F., Theoretical distributions of the elements of the orbits of the fragments of the hypothetical Olbers planet. Report by GAISH, 1953, Moscow.
2. Sultanov G.F., Theoretical distributions of the elements of the orbits of the fragments of the hypothetical Olbers planet. Trans. of AS of Azerb. SSR, No.8, 1953, Baku
3. Sultanov G.F., Two-averaged Gauss type scheme. Doclady AS of Azerb. SSR, vol.XII, No.2, 1956, Baku.
4. Sultanov G.F., Decay of the primary large body and determination of the elements of its orbit. Trans. of AS of Azerb. SSR, (Series of physico-mathematical and technical sciences) No.3, 1964, Baku.
5. Sultanov G.F., Basic patterns in the distribution of asteroids and fragments of primary large bodies over the invariant elements of their orbits. Abstracts of the scientific session of the Academy of Sciences of Azerbaijan. SSR, dedicated to the 150th anniversary of joining to Russia, 1964, Baku.
6. Sultanov G.F., Basic laws in the distribution of asteroids and fragments of primary large celestial bodies according to their physical and orbital features. Suvey report on the works works submitted for the degree of Doctor of Physics and Mathematics, 1967, Moscow

REFERENCES III.

1. Arazov G.T., On the problem of three motionless centers, Letters to Astron. J., 1975, v.1, no.6, pp.42-45.
2. Arazov G.T., The solution of the internal problem of three fixed centers. Letters to Astron. J.,

1975, v.1, no.7, pp.42-43.
3.Arazov G.T., The Problem of Three Fixed Centers, Astron. Well, 1976, vol.73, no.3, pp.639-646.
4. Arazov G.T., Particular solutions of one case of the problem of n fixed centers, Letters to Astron. Well, 1976, vol.2, no.10, pp.509-511.
5. Arazov G.T., Gabibov S.A., Theory of motion (126) Vellada. Astron Well, 1984, vol.61, no.6, pp.1205-1210.
6. Arazov G.T., On the application of the external version of the generalized problem of three fixed centers in geophysics. Astron. J., 1980, vol.57, no.1, pp.190-194.
7. Arazov G.T., Solution of the plane problem of n fixed centers, Celest. Mech., 1977, vol.15, pp.41-44.
8. Arazov G.T., On some applications of the problem of many fixed centers Geophysics-Celest. Mech., 1981, vol.25, pp.345-352.
9. Arazov G.T., Gabibov S.A., Qualitative analysis and classification of types of movements in the generalized plane problem of three fixed centers. Celest. Mech., 1978, vol.17, pp.49-81.

REFERENCES IV

1. Zeynalov R.A. Determination of the satellite's circular orbit from optical observations with unknown instants of time. Astron J., USSR Acad. of Sciences, 1973, vol.50, No.1, pp.201-206.
2. Zeynalov R.A. A method for determining the satellite's circular orbit from optical observations with unknown instants of time. Bull. ITA AN USSR. 1975, vol.XIV, No.2(155), pp.87-94.
3. Zeynalov R.A. Calculation of the satellite's circular orbit in the case when the time moments of the observations are unknown Observations of artificial Earth satellites, Bulgarian Academy of Sciences, 1979, pp.131-146.
4. Zeynalov.R.A. On a possibility of determining the elliptical orbits by observation unknown moments of time. Rep. National Acad. of Sciences of Azerbaijan, 2005, v.LXI, No.3, pp.53-57.
5. Zeynalov R.A. On the improvement of satellite orbit elements together with the refinement of the observation times. Astron. J. of USSR Acad. of Sciences. 1985, vol.62, No.6, pp.1193-1200.
6. Zeynalov R.A. On the determination of zero points and systematic errors of fundamental catalogs from satellite observations with inaccurate points in time. Astron. J. of USSR Academy of Sciences, vol. 62, No.4, 1985, pp.803-809.
7. Zeynalov R.A. On the determination of satellite orbits and station coordinates from optical observations with inaccurate time recording. Scientific information of the Astrocouncil of USSR Academy of Sciences, No.62, 1987, pp.62-70.