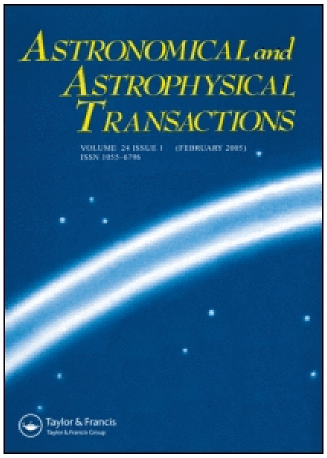

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Igor stanislavovich Astapovich (on the occasion of his 90th birthday)

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IGOR STANISLAVOVICH ASTAPOVICH (ON THE OCCASION OF HIS 90TH BIRTHDAY)

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I.S. Astapovich was the founder of meteor astronomy in the former of the USSR. His main fields of researches were: the problem of minor bodies of the Solar system (their evolution and interrelationship), the problem of meteor hazard, meteor astronomy, meteor physics, meteor geophysics, and meteoritics. The Kiev State University Astronomical Observatory and the Ukrainian Astronomical Association held in Kiev, on Dec. 17–19, 1998, an international conference 'Physics and Dynamics of the Minor Bodies of the Solar System', dedicated to the memory of I.S. Astapovich. This paper is based on the talk about Astapovich's life and activity presented to that conference by the author.

KEY WORDS Meteor radiants, showers, fireballs, meteorites, meteor trains, counterglow

January 11, 1998 is the 90th birthday of the outstanding astronomer, whom Prof. V.V. Fedynskij has called 'the founder and pioneer of Soviet meteor astronomy'. To honor the memory of Prof. I.S. Astapovich, the Astronomical Observatory of Kiev National University and the Ukrainian Astronomical Association held in Kiev, on Dec. 17–19, 1998, an international conference 'Physics and Dynamics of Minor Bodies of the Solar System'. This paper is based on the author's talk about Prof. Astapovich's life and activity presented to that conference.

I.S. Astapovich was born in the family of a pedagogical college teacher of physics and mathematics in the town of Volchansk, former Kharkov province. The mother, Elizaveta Pavlovna, was a graduated governess. The father, Stanislav Viktorovich Astapovich, was of Polish origin and a relation to Count Tyshkevich's family. The mother's father – Pavel Ivanovich Gorskij-Platonov, a nobleman of old lineage, specialist in archaeology and ancient languages, held the post of Extraordinary Professor at Moscow Ecclesiastical Academy. Vladimir Rusanov, the famous polar explorer, was the cousin of I.S. Astapovich's mother.

I.S. Astapovich spent his childhood in the town of Novgorod-Seversk, the province of Chernigov, where his father held the post of the town public schools inspector (after 1917, public education instructor). After having graduated from the professional-technical school at Nikolaev, I.S. Astapovich continued his education at

Figure 1 Igor Stanislavovich Astapovich (1908–1976).

the Moscow State University Department of Physics and Mathematics, specializing in astronomy – his subject of interest since the age of 13. When in 1928 the family moved to Leningrad, Astapovich went to the Leningrad University from which he graduated in 1930. In Moscow and Leningrad, Astapovich attended the lectures of S.N. Blazhko, S.A. Kazakov, A.A. Mikhajlov, G.A. Tikhov, S.K. Kostinskij, P.M. Gorshkov, and others. While forming as a scientist, young Astapovich was surrounded by such eminent scientists as: V.I. Vernadskij, A.E. Fersman, S.I. Vavilov, P.N. Chirvinskij, P.L. Dravert, which helped to develop his broad and thorough scientific outlook. Igor Stanislavovich always remembered V.I. Vernadskij, whom he considered his teacher, with particular warmth and respect. As early as 1925, the 17 year old Astapovich (then still living in Moscow) was elected corresponding member of the Russian Society of Natural History Amateurs (RSNHA) founded in 1909 by the famous revolutionary scientist N.A. Morozov. After having moved to Leningrad, Igor Stanislavovich worked actively at the RSNHA. Though formally he was the member of three sections: 'the Sun', 'Meteors', and 'Meteorology', his researches have been mainly into meteors and astronomical circumstances of meteorite falls including the Tunguska event. Astapovich remained in the RSNHA up to its closing down in 1930.

In 1928–1932 Astapovich, working at the Institute of Applied Geophysics, took part in numerous geophysical and astronomical expeditions to the Eastern Siberia. As a result of the field explorations, he discovered in the Eastern Siberia, by means of geophysical methods, vast deposits of magnetic iron ore that later would secure the metallurgic base for Bratsk Region, the Territory of Irkutsk. At that same period, in winters, when the field explorations data was being processed, Astapovich worked

Figure 2 I.S. Astapovich's parents: his father, Stanislav Viktorovich (1864–1931) and his mother, Elizaveta Pavlovna (1864–1943).

as non-staff investigator, under V.I. Vernadskij's and A.E. Fersman's supervision, at the Leningrad Meteorite Department of Mineralogical Institute of the Soviet Acad. Sci.

In 1933 Astapovich becomes the first director of Tadjik Republic Astronomical Observatory, of which he was the founder. In 1941 the Observatory got the name of 'Stalinabad Astronomical Observatory of the Tadjik Branch of the Soviet Acad. Sci.'; in 1958 it was transformed into the Astrophysical Institute of the Tadjik Acad. Sci., Dushanbe. Today various methods of meteor investigations are being developed at the Institute. Because of a grave illness, tropical malaria, Astapovich had to move to Moscow. In 1934–1941 he worked at Sternberg Astronomical Institute as senior investigator, and, since 1937, held the post of senior lecturer at Moscow University Chair of Comet Astronomy. In 1935 he got his Ph.D. without having to defend the thesis. The same year, he became member of the IAU Commission 22 (on Meteors). The same year 1935, together with Prof. S.V. Orlov, Astapovich created, in the frame of the Astronomical Council of the Soviet Acad. Sci., the Commission on Comets, Meteors and Asteroids, at which he worked actively up to the end of his life.

Astapovich was the first one to compose a special course on meteor astronomy, which he read at Moscow University since 1937, at Saratov University since 1938, at Ashkhabad University since 1954, and later, at the Universities of Odessa and Kiev. With the beginning of the Great Patriotic War, Astapovich joined the volunteer corps, as soldier of separate artillerist battery of the 8th Krasnopresnensk Division of the 32nd Army. After demobilization Astapovich went, at Moscow University Rector's order, to Ashkhabad (where Moscow University had been evacuated to), to organize teaching of astronomy.

Figure 3 I.S. Astapovich in his young years.

When, in 1942, the University returned to Moscow, Astapovich stayed in Ashkhabad, accepting the proposition to give some help in the preparation of local trained personnel. In 1942 he was given the post of Professor at the Ashkhabad Pedagogical Institute; from 1950 he taught astronomy at Ashkhabad University. At that same time, in 1944, he started the scientific work as senior investigator at the Physical-Technological Institute of the Turkmen Branch of the USSR Acad. Sci. In 1946, Astapovich created, within the frame of the Institute, the Astrophysical Laboratory which he would head during many years. His fate was to 'stay on' in Ashkhabad for 17 years – the most fruitful years of his life.

Radar observations of meteors were organized in Ashkhabad in 1947; photographic observations started in 1948. At the starting period the cameras with air-photo-objectives 'Xenon' were used for photographic meteor patrol. N.I. Grishin and A.P. Savrukhin (both the Astronomical-Geodetical Society Moscow branch members) used to come to Ashkhabad for the observations of major meteor showers. Later Savrukhin settled in Ashkhabad and joined Astapovich in his work. By observing meteor trains, Kh.D. Gulmedov and A.P. Savrukhin under the guidance of I.S. Astapovich determined air fluxes directions and velocities in the upper atmosphere.

During the International Geophysical Year (1957–1958) an out-of-town astronomical observatory was constructed in the village of Vannovskoe near Ashkhabad, where a new meteor patrol equipped with high-efficiency cameras and a radar station was installed.

In 1959 Astapovich moved to Ukraine, the country of his childhood and youth; there he spent the remaining 17 years of his life. In 1959–1961 Astapovich taught astronomy at Odessa University, carrying on at the same time, telescopic observations of meteors. In 1961 Astapovich moved to Kiev. He delivered lectures on General, Theoretical, Stellar, Meteor Astronomy, the Earth Interior Structure, Upper Atmosphere Physics, History of Astronomy, and some others at Kiev University Chair of Astronomy then headed by S.K. Vsekhsvyatskij.

In May, 1962, Astapovich defended his doctor a thesis in physical-mathematical science at Kazan University on the basis of his book 'Meteor Phenomena in the Earth Atmosphere' (Astapovich, 1958).

Many long years of night-time observations at Ashkhabad and intensive pedagogical activities inevitably had to affect Astapovich's health, strong as it was by nature. His physician had once said: '...to walk to the clinic having the great circle infarction... only 1% of the people have such a heart...'. Astapovich didn't know that he was walking having the infarction; the hypertension he had suffered from for many years had done its deed. After that his health became worse. In 1973 he was seriously ill; on January 2, 1976 he passed away...

Astapovich's scientific activity lasted for 50 years and the pedagogical activity, for 45 years. He published 10 monographs and more than 400 papers. An important place in Astapovich's scientific legacy belongs to his monograph 'Meteor Phenomena in the Earth Atmosphere' (Astapovich, 1958), 40 printer's sheets in size, containing the list of 1004 references. This is a really encyclopedic work, considering a vast spectrum of different problems of meteor science. The monograph has served, as K.I. Churyumov points out, 'as a handbook for three generation of specialists in meteor astronomy' not only in the former USSR, but also in Czech Republic, Bulgaria, Slovakia, and other countries. This book is often called the 'Meteor Almagest'.

Astapovich's scientific activity was really versatile; it is hard to overestimate the width of his scientific interests. He wrote in the monograph mentioned above: 'Though this book is dedicated to meteors, the reader will meet here with a variety of topics: the properties of the eye and earthquakes causes, ballistic data and history of knowledge, spectral analysis and cartography, acoustics and oceanology. But such is the object of our study – multilateral in its nature. Exploring the meteor phenomena, the investigator deals with meteor material surprisingly widely spread over the space and our planet... extragalactic astronomy has to take it into account, stellar astronomy deals with it permanently. Meteor material is met everywhere in the Solar system, from the so called Fraunhofer Corona of the Sun down to minor planets, comets, and Saturn's ring.' 'So, we should not be surprised, – Astapovich wrote in another place (Astapovich, 1956a), – that the methods for the investigation of the meteor material for its different manifestations are numerous and various. The methods may be purely 'meteor' or taken out from other sciences, but what brings them together is the object of investigation, i.e. the meteor material.'

Astapovich outlined several fields in meteor investigations: meteor astrophysics (study of the meteor material outside the Earth by means of astrophysical methods), meteor astronomy (investigation of meteor bodies' motion in celestial bodies' gravitational fields by the methods of theoretical astronomy and celestial mechanics), meteor physics (study of physical phenomena related to meteors' flight in planet atmospheres) meteor geophysics (study of physical phenomena related to interaction of meteor bodies with planets' atmosphere, hydrosphere and lithosphere), and meteoritics (study of the meteor material that has reached the surface of the Earth). Astapovich made a valuable contribution to every one of these scientific fields.

The Tunguska Meteorite problem is traditionally linked to the names of L.A. Kulik, V.G. Fesenkov, E.L. Krinov, K.P. Florenskij and other younger investigators. However, it was Astapovich who as early as in 1933 first carried out a really scientific analysis of the data on the "Tunguska Event" (Astapovich, 1933). He was the first to study the Siberian and European stations' barograms of the Tunguska explosion and the seismograms recorded at Irkutsk. On the base of the data and the most scrupulous analysis of the fall circumstances, acoustic and light effects, estimations of the number of the trees fallen, etc., he determined the moment and calculated the energy of the explosion of the meteorite – 10^{20}–10^{21} erg. It was he also who first made the main estimates of Tunguska body trajectory and orbit. Evidences of the witnesses and trees scattering maps drawn later, as I.T. Zotkin has said, 'shifted' the trajectory derived by Astapovich eastward, but his conclusions about the large eccentricity of orbit and retrograde motion were quiete convincing. In later times, Astapovich kept returning to Tunguska meteorite research. His latest paper on this topic was published in 1966.

In 1934 Francis J. Whipple brought forward the comet hypothesis for the Tunguska phenomenon. Later, Astapovich mentioned more than once his having suggested the idea of the Tunguska meteorite comet nature as early as 1930, prior to Whipple's hypothesis publishing. E.L. Krinov writes in his monograph 'The Tunguska Meteorite' (Krinov, 1949): '...Astapovich believes the meteorite to be stony and sustains the hypothesis of its being the head of a small comet, whose trail was the cause of the abnormally bright nights. He had put forward that idea prior to Whipple's hypothesis publishing'. For reasons unknown Astapovich's publication on the topic is lacking. V.A. Bronshten argues as follows: Astapovich might have talked of the Tunguska meteorite as possibly being a small comet nucleus at the RSNHA meeting in 1930, of which Krinov could be a participant. But as the RSNHA was closed down at the end of that same year, no publishing of Astapovich's hypothesis would follow.

Astapovich also studied the second of the two of the most large meteorite falls – the Sikhote-Alin one. He determined its trajectory flight in the atmosphere, estimated the impact energy as 2.5×10^{18} ergs, and the meteorite full mass as more than 10^3 tons, that is, one and a half order of value less than that of Tunguska meteorite (40×10^3 tons) (1958).

As early as 1939 Astapovich published in Astronomicheskij Zhurnal a large paper considering the results of the investigations 66 meteorites' orbits (Astapovich, 1939a). By 1938, 584 observed meteorite falls all over the world were known. Atmospheric flight trajectory and radiant could be derived with higher or lower degree of reliability for only 66 of the cases. The orbits were calculated assuming three values of the semimajor axis: $a = 2.0$ (ellipse), $a = \infty$ (parabola), $a = -0.5$ (hyperbola). Besides, there are several indirect methods for determination of meteor

Figure 4 In Sternberg Astronomical Institute, Moscow, 1949 (from left to right): V.V. Fedynskij, A.M. Bakharev, and I.S. Astapovich.

velocities which, used together, yield mutually consistent result. Because of all this Astapovich was able to analyse every velocity estimation. Therefore he had a possibility to determine the orbits of the meteorites and to reveal their relationship with meteor showers, fireballs, and comets. He discovered a comet–meteor–meteorite system to which 10 meteorites belong (fives of them had produced rich stone swarms), the comet 1790 III (K. Gershel) and its family (1911 IV and others), and 22 meteor showers (four of them are rich). Moreover, 27 large fireballs are connected with these meteor showers. All the orbits intersect in one point in space: $\lambda = 216°$, $\beta = +2°$ at the distance $r = 1.0$ A.U. from the Sun. Astapovich thinks that 'no later than the end of XVIII century a large meteorite or comet suddenly broke up at that point and gave birth to the family of comets and the minor bodies system... The event might be the result of an impact with a small meteorite.' Until recently this minor bodies system continues to be a subject of detailed investigations. In general, it was Astapovich's opinion that on the brink of centuries dramatic events take place both on the Earth and in the Space.

Astapovich used to pay much attention to meteorite craters investigations. As early as in 1936 he, prior to many others, came to the conclusion that they played an important role in the planet's surface formation. Astapovich estimated the total number of undoubtedly meteorite craters on the Earth surface as more than 160 – which was fully confirmed by the 1970s. One of his last works was dedicated to research of the super-large scale meteor spherules (yanites) of the lower Yana, Yakutiya (Astapovich, Pereyaslov, 1971). Astapovich assumed of the existence of

Figure 5 The First Meteorite Conference (Moscow, March, 1949).

ancient fossil meteorite craters at the Kularskij Region of Yakutiya; seismic data and air-magnetic survey confirmed the assumption. Middle-pliocene age of the crater amounts to 7–8 million years.

An advantage of the wonderful sky of Turkmeniya rich in clear nights and southern location of Ashkhabad allowed Astapovich to organize in 1942–1944, among other programs, systematic observations of counterglow. This faintly glowing elliptic shape at the night sky opposite the Sun was discovered in 1803 by A. Humboldt. Later, F.A. Multon tried to interpret it as the glow of dust particles accumulations near the libration points behind the Earth orbit.

Astapovich's 1942 observations revealed the counterglow brightness variability (Astapovich, 1946, 1949). The observations performed in 1943 showed these variations were synchronous with the aurora polaris flashes from which fact Astapovich deduced the gaseous nature of the counterglow. That same year, by making observations before and after midnight he determined the diurnal parallax of the counterglow and its distance from the Earth of 130000 km. The 'Gaseous tail' of the Earth may reach as far as 50 Earth diameters length. I.S. Astapovich concluded that such a gas accumulation ought to remain in dynamical equilibrium getting a continuous supply from the Earth atmosphere. In other words, the counterglow is the Earth's gaseous tail projection on the starry sky. In 1948, N.B. Divari confirmed, by use of a photometer, Astapovich's conclusions about fast variations in the counterglow brightness, and the same year, V.G. Fesenkov determined the parallax of the counterglow by photographic method. So, a fact that Astapovich discovered by means of visual observations with the naked eye was confirmed beyond doubt. The nature of the 'gaseous tail' of the Earth was revealed much later, with the start of near-Earth space investigations with artificial satellites.

Astapovich's skill and virtuosity as a visual observer achieved the most perfection under the favourable conditions of the Ashkhabad sky. As early as 1928, he worked out the principles of the new method of visual observation of meteors in the frame of the so called 'program-maximum'. His followers too carried out the observation in the frame of this program in Ashkhabad and other sites of the USSR. According to Astapovich's (1956a) own words, the "program-maximum' is a method of visual studying of meteors in their dynamics, aimed at the utmost use of human eye abilities, taking into account its possible mistakes'. Following the method, the specialists' acute eye can catch, in a fraction of a second (0.5 sec, on the average) not only the position against the stars, and about 15 physical properties of a meteor, but also their changing with its flight, that is, the meteor gets, so to say, pictured dynamically, not statically. 'Rare are the cases of two identical meteors, – wrote Astapovich (1956a), – ... every meteor is a unique object and it should be investigated as thoroughly as possible.' It should be pointed out that the 'program-maximum' was first elaborated and put to work in the USSR.

I.S. Astapovich had a subtle perception of Nature. Romanticism was a part of his soul and in his writings, bright, emotional descriptions were typical. Here is one example of how he describes his meteor radiants observations (Astapovich, 1956a) : 'In 5–10 minutes after the beginning of the observations the eye adapts to the darkness and the experienced observer sees the sky fully alive with meteors: some radiants set, others rise, the aspect of meteors of shower changes with the radiant's height; some showers are revealed in 20–30 minutes, others, after several hours of work. In 40–60 minutes one can get already the notion of how does the meteor sky 'breathe' today. Sometimes, it breathes in the same manner for 2–3 nights in succession, changing in equal way from dusk to down. Sometimes the night that comes is quite different from the night that's gone with new radiants replacing the former ones. As a rule, however, the meteor sky life is revealed in smooth enough replacement of showers, polluted with randomly coming sporadic meteors, without origin nor home, or even sporadic radiants – those 'kings for a day' whose fate is to appear only once, sometimes, in full splendor and beauty, a short-living cluster of similar meteors, and then vanish forever. Slow meteors, reddish and orange, dominating the early evening hours, are gradually superseded by rapid blue-white meteors of pre-down showers always tracing trains. At first, at the raising of the radiant, the meteor traces are long and hazy, passing, at their extreme height, almost tangent to the Earth atmosphere. They can easily find their way back to the interplanetary space. As the radiant raises, however, a steepness of the meteor trajectory increases, they get shorter and more clear. Due to the perspective shortening, near-radiant meteors are very short and slow, the longest and speediest ones being those at the elongation of 90 degrees away from the radiant... Usually, by the end of the second hour 3–5 main showers of the night reveal themselves, the weak ones showing their existence by just individual meteors. Mentally, we find such rough radiants from observations from just one site. Coincidence of these radiants is the first evidence for the possible existence of a weak shower. After another 2 hours have elapsed, more than half of the assumed radiants have revealed themselves, proving its rightful existence. The other radiants set, leaving their problem unresolved, or discontinue the activity; that is, those should have been 'one–moment–kings' or a random coincidence of two sporadic radiants, or, sometimes, annoying observational error. However, the reliable, by now undoubted radiants keep, shooting another and yet another meteors. Sometimes, a stranger gets among them and together with the 'legitimate' shower members, thus, formally, able to claim their relationship. But it is not masked well enough: its velocity is large, while the others being slow, or it has a bluish-green colour, when the legitimate meteors being reddish. Physical and kinematical data prove it a liar, and place it among the sporadic meteors. At any given night 6–8 'good' radiants may be found in 4–6 hours, a part of them having worked yesterday, and a part of them able to live on until tomorrow. But summer and autumn nights are 2–3 times richer with active radiants, so that the observer 'gets his full share'. And only by subsequent many days long processing 30–40 radiants may be derived for certain exceptional nights. Once or twice a year a 'poor' radiant, just similar to many others, unexpectedly becomes active. It begins to shoot single meteors then meteor pairs, triplets and even hosts during few minutes. Having won the sky, the radiant sets majestically, to show its metamorphosis in other parts of the Earth. But it can suddenly rapidly slackens, so that in a couple of hours its past splendour only remains as a note in the journal of observations.'

Astapovich called the Kheirabad Region (near Ashkhabad) with more than 347 clear nights per year the 'Pole of clearness' of the USSR. Here, at the high-altitude Station of Astrophysical Laboratory ($H = 2250$ m over the sea level) with its exceptionally transparent atmosphere, Astapovich detected, in 1947, a new phenomenon, unknown until then to meteor science. He describes it as follows: 'sometimes, in the hours before dawn a faint bluish luminescence precedes the ordinary appearance of meteor. The phenomenon resembled the flight of a meteor producing a very pale ionized train. The meteor itself remained invisible and appeared in its usual form only several degrees farther, after 'the blue train' had disappeared' (Astapovich, 1951a). Astapovich proposed to call this phenomenon 'the blue train' of meteor. 'On lowland, in spite of our many attempts during 1948–1951 we did not succeed in trying to observe 'the blue trains'...', – writes Astapovich.

Basic visual meteor observations through binoculars, set in 1947–1950 allowed Astapovich to conclude that 1) conditions arise under certain circumstances that allow observation of the 'blue' trains of meteors; 2) the trains are localized at the heights of 160–120 km. Astapovich interpreted the 'blue' trains as a result, mainly, of the air ionization by high-frequency emission of meteor, or (in a far lower degree) by the impact of air particles pushed aside (Astapovich, 1951a).

One of the principal problems of meteor astronomy is to produce a general catalogue of very carefully verified meteor radiants. 'It is necessary to know the meteor system state, at least, every half a century', – argued Astapovich. This way, possibilities for studying cosmogonically important meteor showers' evolution are achieved. Astapovich revised an enormous amount of observational data on XIX century meteor radiants, collected by Denning during 1833–1899. Denning's catalogue includes 4367 radiants, obtained through observations of 120000 meteors over a 67 year interval. Astapovich was able, through a scrupulous critical analysis of the material, to exclude a large number of false radiants, derived formally, without taking into account a number of necessary criteria. That painstaking work resulted in 'The Principal Catalogue of XIX Century Meteor Radiants', published in 1956 (Astapovich, 1956b), that containing the data on 887 radiants of meteor showers.

Astapovich planned to continue the work for other epoch - that of 1900–1950. For this goal he organized in Ashkhabad in 1942–1945 re-observation of all now active radiants. Astapovich observed every clear moonless night under invariable standard conditions. We should note, that there are usually more than 300 clear nights per year in Ashkhabad, at the same time, he carried on an intense pedagogical work for three institutes. So then, in 1200 observational hours Astapovich registered 17000 meteors. This long observational data sequence processing took several years and was carried out in different lines of meteor investigations. More than 20 articles on meteor astronomy, meteor physics and meteor geophysics based on this material were published by Astapovich and his followers. The main results of the labor, however, were the catalogues of more than 400 meteor radiants with the geocentric velocities values. In particular, E.M. Proskurina published catalogues of meteor radiants, based on 1943 and 1944 observations (Proskurina, 1949, 1957).

Astapovich's observational archive containing data for a total of 40000 meteors is to date unsurpassed in the world. Unfortunately, a part of it remains unprocessed, as, for example, 400 meteor light curves, obtained, as all his observational material, in the frame of the 'program-maximum'.

Comparison of Ashkhabad sequences meteor radiants observations with the XIX century radiants revealed, quite unexpectedly, meteor activity instability and a relatively fast rate of meteor systems evolution. About 2/3 of radiants of meteor showers continue to be active over a period of several tens of years. The remaining 1/3 of radiants disappeares completely, and a similar number of new radiants appears.

Meteor radiants evolution investigation in general led to the conclusion that the dynamical equilibrium of appearing and disappearing meteor radiants is kept in the Solar system. Astapovich called it: 'the present day meteor activity balance is deficitless'.

To investigate meteor showers evolution, Astapovich processed the ancient China observations published by E. Biot in 1848 (material recorded in volumes 191 and 192 of the well-known XIII century Encyclopaedia of Ma Touan-lin and other sources). In 1951 Astapovich published the radiants of principal meteor showers as observed in China in X–XII centuries (Astapovich, 1951b). Later, Astapovich and Terentjeva (1968), processed fully and completely the observations of fireballs recorded during 24 centuries (mainly over the XI century) included in the three Biot's catalogues. We succeeded in processing 1220 fireballs, thus deriving the radiants for 153 meteor showers, 7 of which belong to major showers. Out of the remaining 146 radiants of minor showers, 80 radiants are most reliable. Over the past millennium only those streams have survived whose orbits did not have the close approaches to the outer planets orbits. Several of the showers which were active in early centuries are

Figure 6 I.S. Astapovich with his wife, A.K. Terentjeva (Kiev, 1965).

unknown now; on the other hand, some showers which are well known now were not observed in the Middle Ages.

During his Kiev period Astapovich together with Kazimirchak-Polonskaja, Beljaev and Terentjeva participated in the investigation of the Leonid meteor stream perturbed motion. The investigation is based on the system of elements, obtained by Astapovich and Terentjeva from the best observations made during the maximum of the meteor swarm in 1866. This system represents the most probable orbit of the dense part of the Leonid stream (Ortho-Leonids), which passed perihelion during the years 1864–1867. Differential equations of the Leonid stream motion have been integrated by Cowell's method of quadratures, taking account of perturbations from eight planets (Venus–Pluto) over the interval of 1700–2000. Conditions for an encounter of the stream with the Earth for the interval 1898–2000 have been studied, and forecasts have been made for the times of maximum activity of the shower in the years 1966–1968 and 1997–2000. Based on the secular motion in longitude of the ascending node of the Leonids, we predicted the time of the maximum of the meteor swarm in 1966 with an accuracy of two hours. And with excellent accuracy (to half an hour) we obtained this time of the maximum on the basis of the result of numerical integration of the stream motion equations (Astapovich, Terentjeva, 1966; Kazimirchak-Polonskaja *et al.*, 1967; Kazimirchak-Polonskaja *et al.*, 1968; Astapovich, Terentjeva, 1972).

As early as 1939 and 1941, on the basis of the analysis of meteor trains drifts, Astapovich arrived at an important conclusions on the regularities of air circulation in a lower thermosphere. This was confirmed long afterwards by radar observations.

Figure 7 I.S. Astapovich with his sister V.S. Astapovich (Novgorod-Seversk, the Ukraine).

The last piece of Astapovich's research in this field came in 1966 (Astapovich, 1966). There he sums up the results of his visual observations of meteor trains over the interval of 20 years (1942–1962). During 1500 hours of observations in Ashkhabad and Odessa, Astapovich obtained 150 persistent meteor trains. He presents a catalogue of these trains, containing direction and velocity of drift, and investigation results of diffusion, turbulence and physical properties of the trains.

In 1951, Astapovich, for the first time in the world, published a catalogue of 163 electrophonic fireballs (Astapovich, 1951c). He draws an analogy of electrophonic fireballs phenomena with the sounds from aurora polaris and discharges of lightnings and sums up the observational data.

From the study of noctilucent clouds Astapovich estimated a radius of its particles as of 0.1 micron (Astapovich, 1939b). In 1936 he found the noctilucent clouds coat to be very thin (1–2 km). The mass composing an average cloud (about 20000–50000 km^2 in area) may amount to several kilogrammes (Astapovich, 1939b).

Astapovich was the head of expeditions for total solar eclipse observation: Sagarchin (Orenburg Territory), June 1936; Archman (100 km distant from Ashkhabad), February 1952; Dzhankoj (the Crimea), February 1961.

In summer, 1957, the Astronomical Council of the USSR Acad. Sci. and the Ashkhabad Astrophysical Laboratory of the Physical-Technological Institute of the Turkmen Branch of the USSR Acad. Sci. organized the School for training the leaders of the Stations for observations of the Artificial Earth Satellites ('sputniks'), the first in the USSR. There were in total 70 such stations in the territory of the USSR. Astapovich made a considerable contribution into the organizing of the School and training of skilled personnel for the sputniks observation. Ashkhabad was not selected arbitrarily as a place for such a school. In the Astrophysical Laboratory they had an experienced group of observers of fast-moving objects – meteor bodies. Astapovich gave lectures on how to observe meteors and how the sputniks should be observed. Sputniks observations were to be performed by means of a special visual wide field telescope AT-1. The sputniks observation methods is described in the monograph by I.S. Astapovich and S.A. Kaplan 'Visual Observations of the Artificial Earth Satellites' (Moscow, 'Gostechizdat', 1957).

Astapovich possessed of a thorough knowledge of the history of astronomy. A number of his scientific works concerns to the history of meteor investigations in Russia, West Europe and China. We should also mention Astapovich had a phenomenal memory. I.T. Zotkin recalls his being surprised at Astapovich's mastery in translating from all the European languages, including Danish, Portuguese, Italian, Serbian-Croatian, etc. Therefore he was a wonderful bibliographer. The references listed in his papers used to cover the subject entirely and had an independent importance.

While living in Ashkhabad, Astapovich could not pass over the history of earthquakes in Southern Turkmenistan seismic zone. He managed to reveal out of large and specific destructions of ancient cities and individual buildings (in the territory of once powerful Parthian Kingdom), the catastrophic earthquakes periodicity (1000 years). He came to the conclusion that 'an earthquake in Ashkhabad is just about to happen'. Astapovich wrote an article on this matter for one of the local journals, but the editor told he could not publish the forecast, because 'people would start packing'. 'My duty of a scientist is to present my conclusions, – answered Astapovich, – while you being the editor are free to act as you will'. The editor has fallen a victim to the earthquake that took place at the night of 1948 Oct. 5/6. In the ruins of the editorial office building Astapovich's manuscript was found. The lines that concerned the forecast of the earthquake were crossed out with a red pencil. The earthquake consequences are known: about 60000 persons perished and about 20000 were injured. When A.A. Nikonov, seismologist, doctor of geologic-mineralogical science (Schmidt Institute of Earth Physics, RAS, Moscow) learned 50 years later (Smirnov, 1998) about that exceptional fact he wrote an interesting paper titled 'And there was no warning' (Science in Russia, No. 6, 1998). 'This must have been the first, at least in this country, – says Nikonov, – case of a scholar gathering and quoting so boldly and directly the earthquake statistics for one and the same area over the years. This approach, which yields amazing results today, was practically unheard of 50 years ago. As such it would have been most certainly rejected or ignored by experts at that time... And there is no denying the fact that it took considerable courage and scientific intuition for Astapovich to voice his forecast'.

Astapovich contributed in a considerable degree to young astronomers' training, particularly, in Turkmenistan, where he spent his best years. Under his supervision, 17 postgraduates prepared and defended their thesis.

Astapovich worked actively for popularization of astronomy. He delivered more than 1000 popular lectures. He lectured with enthusiasm, enchanting the audience with his encyclopedic knowledge and inexhaustible wit.

Figure 8 Participants of the First Conference 'Physics and Dynamics of Minor Bodies of the Solar System' dedicated to the memory of Professor I.S. Astapovich (Kiev, Dec. 17–19, 1998).

'I often recollect meetings with Igor Stanislavovich, – writes in his letter to me A.K. Osipov (Astronomical Observatory of the Kiev University). – The first was in April 1949, about half of a century ago. Igor Stanislavovich presented a paper at the meeting of our observatory. He told us about his discovery of a gaseous tail of the Earth and the earthquake in Ashkhabad. We listened to him very attentively, it could not be otherwise. A slender, lively person, presenting his story picturesquely in a rapid tempo, he practically bewitched the audience. The next meeting took place in 1957 in Firuza, a suburb of Ashkhabad, where he was the instructor of the school for training the leaders of the tracking stations which were being organized of the soon to be launched artificial satellites. There we had the possibility to be convinced of his talent as a lector and of his erudition. We also met frequently in Kiev. Igor Stanislavovich belonged to the generation of astronomer – romantics, in love with the stars in the sky, with astronomical observations. He belonged to the same generation as P.P. Parenago, B.V. Kukarkin, V.P. Tsesevich, E.K. Kharadze and many others.'

Astapovich was decorated with the Order of the Red Banner of Labour, the Order of the Badge of Honour and the Medal for Labour Valour by the Soviet Government. The minor planet No. 2408 discovered by N.S. Chernykh at Crimean Astrophysical Observatory in 1978 was named for Astapovich.

In conclusion, I would like to cite a quotation from Professor K.I. Churyumov's opening speech at the International Conference dedicated to Astapovich's 90 birthday: 'The name of Igor Stanislavovich Astapovich inspires now and will for long time continue to inspire many meteor phenomena researchers'.

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