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The Svyatskiy Stream Hypothesis: The Tunguska Event and the Future Risks of Cosmic Collisions

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ABSTRACT

This article examines the significance of Daniil Svyatskiy's research in unraveling the enigma of the Tunguska event. It aims to introduce a novel perspective on the origins and aftermath of the Tunguska Cosmic Body, alongside evaluating the potential hazards it poses to Earth. To achieve this goal, scientific papers addressing the Tunguska meteorite and its consequences, as well as chronicles describing the events under consideration, were analyzed. The chronicles support the hypothesis of a stable stream of comet fragments that could endanger Earth. Extensive areas between the 50th and 60th latitudes could be affected. The next manifestation of this stream is possible in 2038 or 2049. If the existence of the stream is confirmed in 2038 or 2049, it could pose a significant danger to the planet's population, emphasizing the need to monitor the Svyatskiy stream. The novelty of the study stems from the detailed examination of this hypothesis, which has not been taken seriously before.

1. INTRODUCTION

The Tunguska explosion, also referred to as the Tunguska event, is recognized as the most powerful explosion attributed to an asteroid impact on Earth, known as the Tunguska Cosmic Body (TCB), in recorded history [1]. Occurring on June 30, 1908, near the Podkamennaya Tunguska River in Krasnoyarsk Krai, Russia, this event is notable for several critical reasons: Its vast magnitude, the mystery of its origin, and the insights it provided into the environmental and scientific implications of cosmic threats to Earth [2]. Since the first scientific expedition to the site in 1927, led by Russian mineralogist Leonid Kulik, numerous studies and expeditions have investigated the event. Despite thorough research, no remnants of the meteorite have been definitively found [3], leading to various hypotheses about the object, including theories suggesting it was a comet, asteroid, or even a mini black hole. The explosion had catastrophic environmental consequences [4], such as the radial toppling of trees and the creation of a bright sky glow visible across Eurasia [5]. It is also suspected of causing genetic mutations in the local flora and fauna. The Tunguska event remains a pivotal incident in the study of impact phenomena, continuing to captivate both the scientific community and the public with the looming danger Earth faces from space objects.

Despite all efforts, a unified and comprehensive hypothesis capable of explaining all aspects of this mysterious event has not yet been formulated [6]. Various scientific schools and researchers have proposed diverse theories and interpretations, but none satisfactorily explain all aspects of the Tunguska meteorite.

The hypothesis proposed by Daniil Svyatskiy in 1928 offers a novel perspective on the Tunguska event by drawing parallels with historical events recorded in Russian chronicles. Svyatskiy's hypothesis suggests a potential link between the 1908 Tunguska explosion and similar phenomena observed near Veliky Ustyug in the 13th century. He noted striking similarities in the descriptions of these events, including their dates (differing by only three days), the occurrence of high temperatures, and extensive forest damage. The chronological proximity of Svyatskiy's theory to the Tunguska event itself adds to its significance in the ongoing debate about the event's origins.

The aim of this study is to explore and analyze the potential connection between the Tunguska event of 1908 and historical events in the 13th century near Veliky Ustyug, as recorded in Russian chronicles, through a detailed examination of the hypothesis suggesting a flow of comet fragments. This research seeks to:

- Investigate Russian historical records for references to celestial phenomena or impacts around Veliky Ustyug in the 13th century that may suggest a precedent or link to the Tunguska event.
- Analyze existing theories and data on the TCB to assess the possibility of a recurring or related cosmic event involving comet fragments impacting Earth's atmosphere.
- Evaluate the hypothesis of comet fragments' flow as a contributing factor to both the 13th-century events and the Tunguska explosion, considering the environmental, astronomical, and historical evidence available.
- Contribute to the broader understanding of the Tunguska event's origins by integrating historical chronicle analysis with contemporary scientific research, thereby offering a novel perspective on one of the 20th century's most significant

and unresolved natural mysteries.

Through this multidisciplinary approach, the study aims to bridge the gap between historical records and modern scientific inquiry, providing insights into the long-term implications of celestial impacts on Earth and the potential for recurring cosmic events.

2. METHODS AND METHODOLOGY

The primary research method employed in this study is a comprehensive analysis of Russian chronicle sources, which often contain valuable records of astronomical phenomena such as solar eclipses and cometary appearances, as well as descriptions of powerful destructive events like hurricanes and severe thunderstorms. The selection criteria for relevant events focus on identifying occurrences that share similarities with the documented effects of the Tunguska meteorite impact. Key indicators include mentions of stones falling from the sky, evidence of thermal effects, and descriptions of fiery clouds. Additionally, the temporal aspect is considered, with a focus on events occurring during the summer months.

Each identified event undergoes a thorough analysis to assess the degree of correspondence with a set of predefined factors associated with the Tunguska event. Some records demonstrate complete alignment, while others show partial matches but lack comprehensive descriptions. To maintain the integrity of the probability assessment for random event coincidence, only fully matching events are included in the final analysis, though partially matching events are still documented for reference.

It is important to note that the linguistic characteristics of the chronicles, which differ significantly from modern language, present certain challenges and may affect the precision of the assessment. The exclusive use of Russian chronicles allows for coverage of approximately a thousand-year period but limits the geographical scope of event detection to a relatively small region.

To address these limitations, future research could expand the scope to include additional sources and regions, potentially revealing a more comprehensive picture of similar events across a broader geographical and temporal range. This expansion would allow for a more nuanced understanding of the frequency and distribution of Tunguska-like events throughout history.

By employing this methodological approach, the study aims to determine whether the Tunguska meteorite impact was an isolated occurrence or part of a more extensive natural phenomenon, contributing to our understanding of rare celestial events and their historical precedents.

3. RESULTS

The TCB event of 1908 has been the subject of extensive research, with recent findings shedding new light on its nature and trajectory. In 1996, researchers from the State Center “Priroda” made a significant discovery while decoding satellite images. They identified peculiar fan-shaped reliefs in Siberian territory, hypothesizing a connection to the TCB [7]. This discovery was further substantiated by V.V. Burmakin, who surveyed several dozen similar reliefs in the Sayan Mountains and other locations, suggesting multiple impacts during the 1908 catastrophe.

Despite not receiving sufficient attention, these discoveries were attributed to formation created by hurricanes and fires. However, several expeditions were still conducted to these formations, confirming their connection to the events of 1908. Detailed information about these formations is provided in the works [8, 9]. Siberian Fan Reliefs (SFR) unequivocally indicated the falls of the TCB from the west. Based on additionally discovered testimonies and objective information, the Western trajectory of the fall was constructed using seven points [10]. The length of the TCB’s flight path of 3,500 km indicates that the fall of the TCB and its fragments occurred from a near-Earth orbit. In the work [11], the parameters of this orbit and the conditions for entering and leaving it are determined. The connection between the TCB and Comet 29P Schwassmann–Wachmann is substantiated. Capture into orbit occurred 2-3 months before the fall, with confirmation found in the observations at the Mount Wilson Observatory, where atmospheric dust of cosmic origin was recorded on June 4, 1908, i.e., before the fall of the TCB. Moreover, this dusting was more powerful than the trace from the fall of the TCB [12]. Stretched elliptical near-Earth orbits, under the influence of the Moon and the Sun, can descend tens of kilometers per day, potentially leading to falls [13].

Based on these findings, the TCB can be classified as a microcomet captured into Earth’s orbit by the Earth-Moon system. The orbit was unstable and declining due to lunar and solar influences. The comet consisted of a monolithic core surrounded by a shell of several dozen or hundreds of smaller fragments. Upon initial contact with the atmosphere, these fragments separated from the core and fell independently.

The main body of the TCB was destroyed in a powerful air explosion. The trajectory’s angle of inclination in the dense atmospheric layers was approximately one degree. Atmospheric braking released energy equivalent to 40 kilotons of TNT per kilometer of the trajectory. The earlier-separated fragments, typically 10-20 meters in size, decelerated in the upper atmosphere and penetrated deeper, with some reaching the Earth’s surface. These impacts formed characteristic fan-shaped footprints, with estimated energies up to 20 kilotons.

The TCB exhibited several distinctive properties: a shallow fall trajectory, a powerful ballistic wave during movement, destruction of the main body in an air explosion, absence of a crater, and numerous secondary falls along an extensive trajectory. Notably, space markers were present at the fan-shaped relief (SFR) formation sites but absent at the air explosion location. These findings provide a comprehensive picture of the Tunguska event, challenging existing theories and offering new insights into the nature and behavior of near-Earth objects.

3.1 The Tunguska meteorite and the “stone cloud”

The first scientist to visit the site of the presumed Tunguska meteorite impact was Kulik. He published information about his expeditions in the journal “Mirovedenie”. Kulik’s descriptions indicated extensive forest devastation and traces of burning on trees. From 1912 to 1930, Daniel Osipovich Svyatskiy served as the editor of the journal “Mirovedenie”. He was one of the first to read Kulik’s article and published a brief note about the similarities between the Tunguska meteorite fall and the accounts in chronicles.

The article was titled “Similar Features in Meteoric Phenomena of 1908 in Tunguska and the 13th Century near Veliky Ustyug” [14]. Svyatskiy wrote [15]: “L.A. Kulik’s

expedition to Podkamennaya Tunguska, to the site of the grand meteorite fall on June 30, 1908, confirmed by direct inspection the accounts of the Tungus people about the felled and burned forest at the crash site and around it over a large area."

The life of Prokopius of Ustyug mentions an incident where, at noon over Ustyug, a dark cloud suddenly appeared, rapidly increasing in size, engulfing the entire horizon, followed by thunder and lightning, ground shaking, and a "very large fiery heat" in the air, followed by a sudden cooling and silence. Twenty versts from Ustyug, "Many and countless stones broke the forest and debris, some trees were torn up by the roots, and others were felled ... a fiery stone rain crushed and burned many forests."

As we can see, Ustyug experienced the same heat as Podkamennaya Tunguska, where it was "hot as in a bath", "The heat enveloped me so that it seemed like my shirt was on fire." The picture of the burned, uprooted, and felled forest precisely matches what Kulik's expedition discovered.

The time of the fall is June 25, 1290 AD, or June 3 in the new style. Svyatskiy concluded: "The three-day difference is very small if we assume the common origin of the Ustyug and Tunguska rains, whose orbits at that time must intersect the Earth and can be identified with the orbit of Comet Pons-Winnecke."

The hypothesis about the connection with this comet was put forward by Kulik, but it did not withstand criticism, and he later abandoned it. There is another interesting coincidence: The latitude of the explosion over Tunguska is 60°54′07′′, and the latitude of the "stone cloud" fall near Veliky Ustyug is 60°54′35′′. The difference is 28′′.

So, what could it have been? This does not resemble the fall of one or several meteorites. They would all fly on parallel courses, leave distinct traces, and while the traces could merge into a cloud, according to the description, flames erupted from the cloud.

Some believe it was a powerful hurricane or tornado. Hurricanes and tornadoes are quite common phenomena, but only individual details coincide, not the overall picture. The hurricane could have felled the forest, lightning strikes occurred, but what about the heat and the indication that the desert and debris were burned?

It resembles the fall of TCB as described in the Vanavara region, which Svyatskiy noticed. But the coincidence is only partial; Svyatskiy was not familiar with the circumstances of the TCB fall at the time. At Tunguska, there was an explosion at a height of about six kilometers. The consequences, such as the felled and burned forest, coincide.

We still have the option of the fall of similar to those that led to the formation of Siberian Fan Reliefs (SFR).

In satellite images, SFR view is given in the Figure 1.

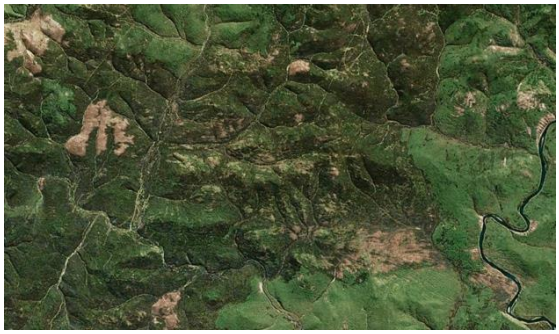

Figure 1. Fan Reliefs of Telegash-Agul. Image coordinates: 55°00'03.56"N, 96°19'03.08"E. Image capture year: 2000

In the terrain, SFR is manifested today by continuous fallouts of trees in one direction for tens of kilometers. The fallouts are overgrown with forest. Only in some places, the most decay-resistant trees such as larches, which have been standing for centuries, remain lying. The affected areas are subject to secondary forest fires, which in some cases still allow them to be distinguished against the background of untouched taiga. The photo of it was taken by V.V. Burmakin in 2020 and is presented in Figure 2 below.

Figure 2. Forest fall in the area near the Telegash stream

In terms of energy, the events leading to the formation of the SFR are significantly less powerful than the explosion over Tunguska. If the latter is estimated at approximately 10-13 Mt in TNT equivalent, then SFR ranges from units to tens of kilotons.

The energy is provided by the kinetic energy of the falling fragment. For cosmic ice to generate heat, it must go through several stages: Heat up from -250°C, melt, heat water to 100°C, vaporize, and heat up to at least five hundred degrees, with the heating being at least three times greater than that of the air. Consequently, each kilogram of ice must possess kinetic energy of 5,720,500 joules.

This energy of an ice body corresponds to a speed of 3,382 m/s. The speed at which the explosion over Tunguska occurred was about 5,000 m/s, and the explosion occurred at an altitude of 6,000 meters with an air density of 0.6601 kg/m³. At the same strength of ice near the Earth with an air density of 1.25 kg/m³, the critical speed will be 4,540 m/s.

The range of possible speeds for a bolide can be 3,400-4,500 m/s. The TNT equivalent corresponds to a speed of 3,500 m/s. Let's assume this speed for the bolide.

Let's assume, for example, the hypothetical diameter of the Ustyuzh bolide is 10 meters, then its "power" in TNT equivalent will be 4,188,000 kg, or 4.2 Kt. This is half of Hiroshima. Although a significant part of this energy will be spent on heating and vaporizing the bolide substance, this will be enough to cause the phenomena described in the chronicles.

The destruction of the ice bolide begins when the pressure on the surface exceeds the tensile strength of the bolide substance. The process is stretched over time and space. The intensity of fragmentation depends on the structure of the fragment.

The bolide may disintegrate into fine dust, which will quickly react with the air. Externally, this would appear as a powerful flash. Similar flashes were observed near Vanovara a few minutes after the TCB explosion.

The bolide can break apart into different fragments. Subsequently, the small fragments will decelerate more rapidly, and the swarm of debris will stretch for hundreds of

kilometers. The large surface area will cause intense evaporation, which will leave a trail that will eventually turn into a cloud. According to the law of conservation of momentum, this cloud will move in the direction of the bolide's movement. The speed of such a steam-air flow can be several hundred meters per second. There are prerequisites for such a cloud to turn into a hurricane. Significant temperature gradients are necessary for a powerful hurricane. Local temperatures in the cloud can exceed a thousand degrees, hot zones will mix with the surrounding air, and the average temperature will remain higher compared to a regular hurricane.

Powerful upward flows may occur, which is a prerequisite for lightning formation. Comet ice contains organic and mineral components. Aerosols can form from them, which themselves contribute to the formation of droplets from the moisture of the surrounding air. A lot depends on the humidity of the air here. This can be clearly seen from the contrails of airplanes. Sometimes there is no trace at all, and sometimes it stretches across the entire sky and lasts for a long time. Consequently, the specific characteristics of an ice bolide's fall can vary widely.

The organic component may be significant. There is a hypothesis that there may be enough organics to form an explosive mixture, which can be used to explain the aerial explosion over Tunguska. A similar mechanism may explain local flashes resulting from the ignition of such a mixture by lightning.

In the chronicles, lightning and fire are mentioned separately. Lightning emerging from the cloud is easily identifiable, but discharges inside the cloud may look like prolonged luminescence very similar to fire or indeed the burning of organics produces a glowing effect.

Infrared radiation from the cloud can create a sensation of heat or warmth noted in the chronicles. This phenomenon was not observed with tornadoes, hurricanes, or even the most powerful thunderstorms. The release of energy equivalent to 4.2 Kt over several minutes is sufficient to provide a grandiose light and sound show. This is a cache of explosives from 70 to 60-ton railway cars.

Larger fragments of the disintegrated bolide may fly ahead of the cloud as leaders. If this is accompanied by intense fragmentation, they will appear as fiery stones. The ballistic shock wave and explosions upon their destruction will significantly exceed thunderclaps and cause soil shaking. Small fragments that separated in the early stages of destruction will slow down and fall behind, but they can catch up with the forming cloud and pass through it, extending the spectacle of falling stones.

The event's duration was limited, as described in the chronicle: "At the same time, the air changed, and there was great silence, and there was no lightning or thunder, and the fiery clouds dispersed in all directions." This account suggests that the heat quickly subsided, silence fell, lightning and thunder ceased, and the clouds dispersed.

No cosmic stones were found at the crash site [16]. This circumstance speaks in favor of the cometary origin of the phenomenon.

Ice moving at speeds exceeding 3,500 m/s can cause damage and burns comparable to those inflicted by heated stones. It is well known that meteorites do not have time to heat up during atmospheric passage; burns could occur in the event of a powerful ground explosion, but no craters were found at the crash site.

The formation of fan-like structures occurs when falling at a slight angle to the surface. In the case of TCB and SFR, this angle was about one degree.

Thus, the "stone cloud" could well have been formed by an icy bolide, although the mechanism may differ from the one proposed here.

3.2 Working hypothesis

Svyatskiy's hypothesis proved to be readily verifiable.

Let us consider the following scenario. The Earth-Moon system passes close to a certain stream with comet fragments. With a favorable combination, it is sometimes possible to capture individual fragments into elliptical near-Earth orbits. Under the influence of the Moon and the Sun, the orbits of the fragments are lowered, they enter the upper layers of the atmosphere, and falling becomes possible. The crucial factor is the precise position of the Moon at the moment of capture. It is this that allows shedding excess speed and sending fragments into near-Earth orbits.

In the work [11], the connection of TCB with the Schwassmann-Wachmann comet was substantiated. Of all known meteor streams, the stream associated with this comet has the minimum velocity, approximately 12-14 km/s, but even this does not allow for a direct entry into a near-Earth orbit, the involvement of the Moon is mandatory.

On the eve of the TCB fall, a solar eclipse occurred. Let's consider the map at the moment of the fall on June 30, 1908, which is given in Figure 3.

Venus, Neptune, and Mercury can be disregarded, but Jupiter and Mars can definitely influence the process. The Sun provides a reference to a specific date and may contribute to lowering the elliptical near-Earth orbits.

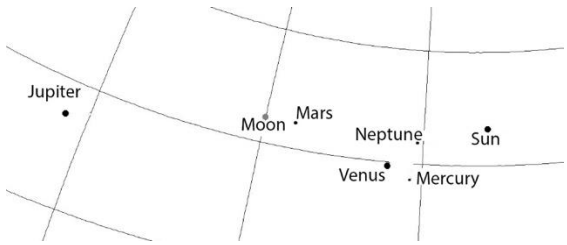

Figure 3. Planets and the Moon on June 30, 1908

If there is a connection between the chronicle events and the fall of 1908, the positions of these planets should also be considered at the end of June and the beginning of July of each year. The Moon should be near the new Moon phase. Although the exact date of the possible capture is not yet known to us, such an approach ensures that the position of the Moon will be similar to its position in 1908.

3.3 The fall of the "stone cloud" in Veliky Ustyug

Svyatskiy determined the time of the fall to be June 25, 1290 AD. However, the positions of the planets in this year do not align. It is important to note that the beginning of the year according to Russian chronicles was not January 1st. It could have been from February to April, or fall on September 1st. In each case, it needs to be examined individually. Thus, the year 1290 in the chronicle was actually the year 1291 according to modern chronology. And in this year, the position of the planets was as given in the Figure 4:

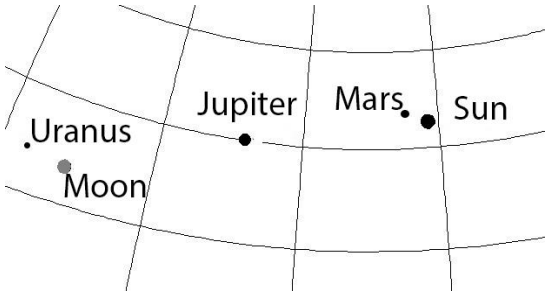

Figure 4. Planets on June 30, 1291, in Veliky Ustyug

We have a match with the positions of the planets in 1908.

3.4 Stones from the sky in 1421

Two events are not sufficient to definitively speak of a pattern, so the search should continue. Svyatskiy writes:

"In the Nikonov Chronicle under the year 6929 [1421 AD], we read [15]: 'A very terrible sign. This spring, on May 19, on the feast of All Saints in Veliky Novgorod, at midnight, there was a great shaking in the air: A huge black cloud came with thunder and lightning, which cannot be imagined, threatening to burn people with its fire, and when it came, it hovered over the city and changed its appearance from rainy to fiery. People, fearing to be burned as sinners and horrified, began to cry out 'Lord have mercy' and other prayers, and to make vows to the Mother of God and all His saints. And there was great rain and hail, and stones fell from the clouds ... By morning, silence came, and the cloud disappeared, and scarcely did people recover from this horror'."

In the Pskov II Chronicle, apparently the same phenomenon is dated May 25: In the same spring, in the fast of Peter, on May 25, a terrible rain cloud fell on Novgorod, and stones fell with the rain like apples and eggs, and in Pskov on the same night, fiery clouds were seen.

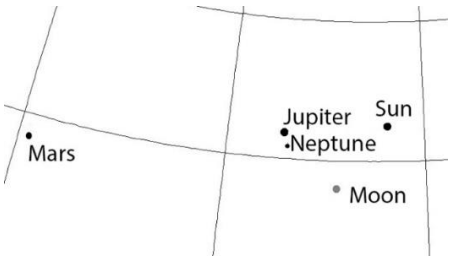

Figure 5. Planets on June 30, 1421, in Veliky Novgorod

As we can see in Figure 5, all the key players are in position. Jupiter is the main conductor, with the cometary progenitors of the stream from its family. Mars is smaller, but closer to the presumed stream. The orbits of the planets are synchronized according to a known law, just as our stream is synchronized. This potentially makes it stable.

3.5 The year 1114

Since the presumed pattern is traceable, it is advisable to continue the search and review the chronicles. At the very beginning of the Hypatian Chronicle, the chronicler writes that he visited Ladoga and there the Ladogans told him that there was a great cloud, and after it, children found glassy stones of various sizes, some with holes, the appearance of the stones is diverse. Witness to this is the head of the city of Pavel Ladogsky and all the Ladogans.

The chronicler approached the event in his own way, scientifically: 'What's surprising about it?', he writes, and cites the story of Novgorod hunters as "eyewitnesses" to the falling directly from the clouds of young deer and squirrels in the lands of Yugra and Samoyeds. For those who doubt even this, the chronicler recommends reading the Chronograph and refers to more ancient times when even more amazing things fell from the clouds.

In any case, there was a cloud, and from it fell unusual glassy stones. The date is not specified, but the year 6622 from the creation of the world corresponds to 1114 AD. The position of the planets on that time is given in Figure 6.

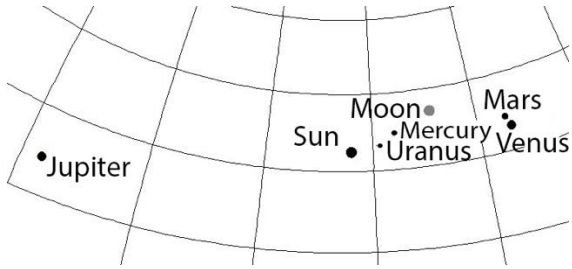

Figure 6. Planets on July 2, 1114, in Ladoga

On July 2nd, we observe a full Moon and the same participants.

3.6 The year 1280

Regarding the same Svyatskiy, we have:

"A meteor in the year 1280?" [15].

In the Nikon Chronicle under the year 6788, we read: "In this same year, there was a sign in the sky: There was a cloud in the western lands, and sparks came from it onto the whole Earth; and after standing for a while, it disappeared."

The place of the event is indicated in the western lands, it may be possible to find a description of the event in western chronicles. We have a fiery cloud and sparks falling from it as shown in Figure 7:

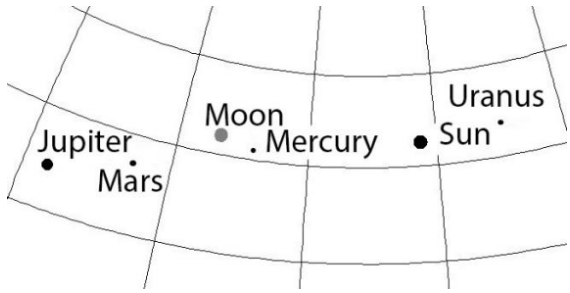

Figure 7. Planets on June 30, 1280

3.7 The year 1385

Very interesting events relevant to our study occurred in 1385. In the Nikon Chronicle, we have:

"In the year 6893. There was a sign: In the month of September, on the 23rd day, at the first hour of the day at sunrise, and a cloud came from the west to the east, and darkness swallowed the daylight until the third hour, and it was dark as in the dark autumn night, and people did not understand what was happening, and great sorrow came upon the people. Similarly, clouds of yellow and crimson color were

seen, and thin clouds as well. In other lands, in the afternoon and at noon, there were fiery clouds, and sparks fell to the ground and ignited; and it was so terrible and frightening that everyone thought it was the second coming of Christ."

In the Tver Chronicle, the event is described somewhat differently, although some parts are repeated verbatim.

"Year 6891. ... In the same autumn there was a sign, on September 23, the darkness was frightening at one o'clock in the afternoon because a cloud came from the west very quickly, and the light disappeared until three o'clock; flying birds fell to the ground and people did not understand what was happening. There were also clouds of a very yellowish and thin type ... and it was in Kiev."

In the Tver Chronicle, this event is dated to 1383. However, such discrepancies are common for chronicles. The chronicler has several sources of information often without precise dating, and the task is to arrange them in the correct sequence. They usually prefer not to specify time intervals but rather attribute events to a specific year. As a result, one chronicler attributed the event to 1385, while another to 1383.

The place of the event or events is not specified. This indicates that the description came from a location far from the chronicler. The first hour in the chronicles marks the beginning of the day and, consequently, the start of daytime reckoning. It corresponds to 6:00-7:00 AM in modern timekeeping. The third hour corresponds to 9:00 AM. Lunchtime falls at approximately 10:00 AM. We have three events:

First. With the sunrise at six in the morning, a cloud appeared moving from west to east, soon it became as dark as in a moonless autumn night, the people were very saddened and frightened by this. The darkness continued until 9 in the morning.

Second. Yellowish, crimson, and thin clouds were observed. These are completely different clouds, in a completely different place.

Third. "In other lands, at 8-9 o'clock in the morning after lunch, i.e., at 10 o'clock and later, fiery clouds were seen, from which sparks fell to the ground. And it was so terrible, as the second coming of Christ." The second coming signifies the End of the World.

The account describes three events and three types of clouds.

During the night after the fall of the TCB and later in Europe, noctilucent clouds (NLC) were observed. "Clouds of yellow and crimson color and thin clouds" are indeed NLC. The term "thin clouds" fits perfectly with silvery clouds. For example, such a description of NLC in 1908: "In the Kursk province, on June 29, from 22 to 23 hours after the evening twilight, a golden, 'electric' light appeared, remaining pale blue on the horizon. The clouds turned a weak pink hue, and then crimson. By midnight, the phenomenon had almost disappeared, but the 'white night' lasted until morning."

While NLC are typically not observable in Kiev during autumn, their visibility in summer could be explained by the capture of comet material in spring. And it is clear that we are talking not about a single observation but about many. Like in the summer of 1908, NLC were visible in many countries. Information about such observations could have been brought by merchants. They should have been observed after sunset and before sunrise. It is impossible to attribute the specified daytime "at lunchtime" to them; this time is clearly applied to the "stone clouds". Other countries most likely refer to Western Europe.

The darkness-causing cloud appeared in autumn. If it was indeed related to the meteorite falls, we can hypothesize a mechanism for its formation. Aerosols and water from the comet formed an unusual, powerful, extensive, and stable cloud, but weather conditions did not allow it to turn into a thunderstorm. Perhaps the "stones" fell from it somewhere far from the observation site, so it was not recorded. But perhaps this phenomenon is related to other events, such as a dust storm. The chronicles contain other descriptions of the onset of such darkness.

The scale of the 1385 event may be comparable to the TCB fall; the phenomena described are reminiscent of those observed in the summer of 1908. The fact of observing powerful NLC in Kiev indicates the extraordinary nature of the event.

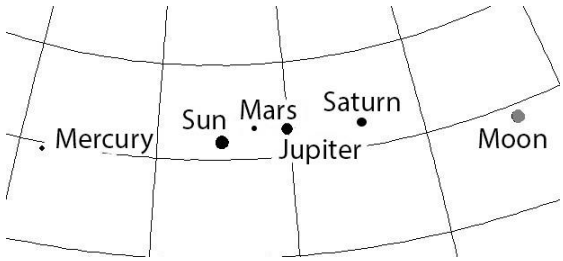

Figure 8. Planetary alignment on July 5, 1385

As shown in Figure 8, the main participants are in place, with the Moon given in position for July 5.

1505-1508. Veliky Novgorod.

Very strange events are described in the third Novgorod Chronicle in the years 1505 and 1508. In 1505, the monk Tarasy was visited by the spirit of the venerable Varlaam Khutynsky. At his command, Tarasy climbed the top of the church three times and saw Lake Ilmen hovering over the city, angels shooting fiery arrows, and a fiery cloud. In 1508, a terrible fire occurred in Veliky Novgorod, accompanied by a fiery whirlwind of such force that it uprooted trees in the garden. And there was a whirlwind on the Volkhov River that sunk many ships with people. The chronicle states that initially, due to the sins of Veliky Novgorod, it was supposed to sink into Lake Ilmen, but by the intercession of Varlaam, the punishment was mitigated.

Of course, one could say that the story of Varlaam and Tarasy was later attributed by chroniclers for moralizing purposes. But in 1505, the capture was possible, and the position of the planets and the Moon approximately corresponded to it. Climbing to the top of the church in this year, the monk Tarasy could see a fiery cloud and flying arrows over Lake Ilmen. He could report to the authorities, who at that time did not attach importance to it or gave a more prosaic explanation, but after the disasters of 1506-1508, the report of the monk Tarasy was reconsidered and given an interpretation that fully corresponded to the traditions of the chronicles.

3.8 Ivan the terrible and TCB, 1530

In this year, the chronicles record an unusual, but known to many, event:

A powerful storm swept across the entire realm, so powerful that the Earth trembled. It is widely known that Ivan the Terrible was born during a thunderstorm and it was from this event that he received his nickname. It is often stated that such a storm had not occurred in a hundred years. The configuration

of the planets indicates that the capture of comet material in 1530 was possible.

Any connection between Ivan the Terrible's birth and the TCB fall would be, at most, an intriguing coincidence. What interests us is the mention of an unusually powerful storm accompanied by Earth-shaking, coinciding with the favorable planetary alignment for the presumed fall, which is shown in Figure 9.

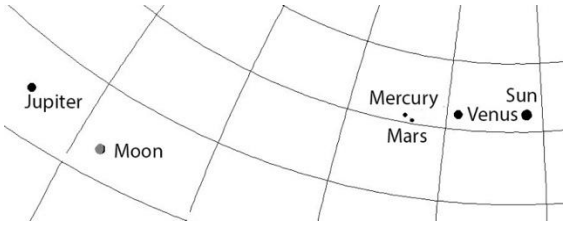

Figure 9. Planetary alignment on June 30, 1530

3.9 Novaya Yerga, 1662

The researcher extensively examined the events in Novaya Yerga [15]. On December 9, 1662, a rather strange fall occurred here. It cannot be unequivocally attributed to the sample of interest to us. However, there are still some signs of connection. In separate sources, both a stone cloud and burned forest are mentioned. Stones were falling, but researchers failed to discover any stones of cosmic origin. Later, cosmic markers were found at the presumed fall site, but overall, there is almost no new information compared to Svyatskiy's work.

The nearest favorable configuration occurred in 1658. However, this does not exclude a connection with the proposed capture mechanism. It is quite likely that individual fragments captured in 1908 fell much later. Recall the famous "procession" on February 9, 1913. The duration of the fragments' stay in near-Earth orbit depends on orbital parameters, and ice falls can occur at any time, even many years after capture.

The coordinates of the Novaya Yerga fall, 59°23', are very close to the coordinates of all the historical "stone clouds".

3.10 Brazilian Tunguska, 1930

The conjunction of Jupiter and Mars occurs approximately every 11 years. At that time, events similar to the TCB fall are also possible. In 1930 (1908 + 11 + 11), such an event was recorded in Brazil. L. Kulik first noted the similarity between these events.

On August 13, 1930, at eight o'clock in the morning, in the area of the Zhavari River and its tributary Kurusy, a deafening roar was heard, and the Earth shook three times. The explosions were heard from a distance of 240 km. The seismic observatory recorded three shocks: Two strong ones and a third that was barely discernible. The 24-second interval between the first and second shocks suggests that multiple celestial bodies entered the Earth's atmosphere, rather than a single body breaking up in the atmosphere. The explosion's power was estimated at one megaton. No crater was discovered, nor was any meteoritic material found. The direction of the fall was from north to south. There is evidence of a severe fire at the fall site. The simultaneous fall of several bodies in one location with significant time intervals between them, combined with the absence of a crater and meteoritic material, indicates similarities to the TCB. Near the equator, when falling from an intermediate near-Earth orbit, the direction of fall should be from north to south or from south to north.

3.11 Svyatskiy's stream

There are ten events that presumably have a connection to the TCB. These events occurred with Jupiter, Mars, and the Moon in a specific configuration around June 30. The nature of the events' description in the chronicles does not allow for an unequivocal identification of some of them. Therefore, events from the years 1114, 1505, 1530, 1662, and 1930 should be dismissed as insufficiently substantiated. However, the events of 1280, 1291, 1385, 1421, and 1908 should not raise doubts. It is worth noting that almost all similar events have been selected, and there are no other similar events recorded in the chronicles.

Suitable configurations occur 3-5 times per century. Let's assume the probability of random coincidence for each case is 1:20. The reliable probability of discovering the established pattern can be estimated at a minimum of 0.9999996875 considering five events. The events not yet included definitely increase the probability, as they are related to the TCB in their manifestations, by the date of the event, or geographically.

The most plausible explanation for the repetition of similar events is the existence of a stable stream of cometary material fragments. This stream, named after the first person to propose its existence, undoubtedly should be called Svyatskiy's stream. The stream is synchronized with the orbits of Jupiter, Mars, and Earth. When the Moon is in a specific position, fragments can be captured from the stream into Earth's orbit. Although this seems strange, the fragments have a high probability of entering an orbit corresponding to the TCB's near-Earth orbit. The orbit's inclination is approximately 60°. The cities where "stone clouds" were observed — Ladoga, Veliky Ustyug, Veliky Novgorod twice, Pskov, Novaya Yerga — are located around the latitude of 60°.

It is worth noting that the variant of capturing bodies from the stream with subsequent falls is much more probable than a direct collision with Earth, provided that the stream's speed is suitable for capture.

The stream consists of fragments of comets or one comet. There is information that the Schwassmann-Wachmann comet has similarities with the Pons-Winnecke comet. It is assumed that there was an initial comet that split in 950 AD. Possibly, at the same time, the stream formed. The first evidence in 1114 confirms this. Comet Encke may also be related. It is not about a specific modern comet, but fragments of comets formed around 950 AD from the original comet could enter the Svyatskiy stream and replenish it.

In the stream, there may be icy fragments of a wide fractional composition, from very small to several hundred meters in diameter. The total volume of fragments in the Svyatskiy stream could be tens or even hundreds of cubic kilometers. Over several hundred years of exposure to the Sun's proximity, the fragments developed a thin layer of organic material and became charred. The fragments have a very low albedo, making them difficult to detect.

3.12 The Svyatskiy stream and noctilucent clouds

The existence of the Svyatskiy stream, near which the Earth passes each spring, suggests that the regular appearance of NLC is associated with it. Initially, the appearance of NLC

was believed to be related to a series of volcanic eruptions [17]. However, regular observations of NLC have shown no correlation with volcanic eruptions. The appearance of NLC is now associated with an increased concentration of methane attributed to anthropogenic influence. However, methane can also come from comet material. The gas belt is more extensive and more exposed to solar wind. However, with regular replenishment from the degassing of fragments in the Svyatskiy stream, it can remain stable and annually release methane into the Earth's atmosphere.

NLC was first observed in 1885. It is possible that changes in the stream at that time led to the release of methane and other gases into the Earth's atmosphere. The yet-to-be-discovered Comet 29P Schwassmann-Wachmann approached Earth in 1886, assuming its orbit period was the same as in 1886 [18]. As it is known, the Schwassmann-Wachmann comet later actively disintegrated, with ice and gas eruptions originating from it. These processes could have occurred in 1885 as well [19], replenishing the Svyatskiy stream and activating it.

The events of 1385 are strongly associated with the stream, likely marking the first recorded mention of NLC.

3.13 Hypotheses on the origin of TCB

The existence of the Svyatskiy stream unequivocally indicates the cometary origin of the TCB. This renders previously proposed hypotheses suggesting alternative origins for the TCB obsolete. Other cometary hypotheses can be integrated into the proposed Svyatskiy stream hypothesis. The assessment of the explosion power over the Podkamennaya Tunguska utilized data collected by numerous expeditions over an extended period of Tunguska meteorite research.

However, alternative hypotheses fail to account for the multiple impact events on June 30, 1908. The flight paths of secondary debris have been mistakenly interpreted as the trajectory of the main body. Considering the entirety of available information, the proposed hypothesis can be viewed as an evolution of previously advanced cometary hypotheses. L. Kulik temporarily adhered to the comet theory. D. Svyatskiy was among the first to propose the comet hypothesis. Nearly a century ago, he provided the key to resolving all Tunguska meteorite issues by connecting it to similar events described in historical chronicles. It is regrettable that his insight went unheeded. The detection of the Svyatskiy stream's activity confirms that the hypothesis of preliminary comet material entry into near-Earth orbit is currently the most plausible, as such events have occurred regularly over an extended period. Should the proposed hypothesis prove unsatisfactory, the development of alternative explanations must consider the totality of facts presented in this and previous publications. Earlier hypotheses relied on limited sets of facts, leading to contradictions with other evidence. We have endeavored to incorporate all available information collected by our predecessors into the event narrative, thus considering them all as co-authors.

3.14 The Svyatskiy stream and cosmic winter

There exists a hypothesis that aligns perfectly with the Svyatskiy stream hypothesis. Its authors also noted that certain catastrophic events occur in late June. In 1990, astrophysicist V. Clube and astronomer B. Napier published "The Cosmic Winter" [20], analyzing the orbital motion of several meteor showers. Using computer simulations, they traced the movements of comets, asteroids, and meteor showers thousands of years into the past. They discovered interconnections among many meteor showers, such as the Taurids, Perseids, and Orionids. Additionally, some large cosmic objects were found to be interrelated, including Comet Encke, the asteroid Oljato, and approximately 100 others. These scientists concluded that all these cosmic bodies originated from a massive comet that first entered our Solar System 20,000 years ago. The combined size of all fragments from this proto-comet would be enormous. The authors posited that the comet's fragments had a detrimental impact on Earth. The authors also calculated that due to minor orbital changes of various space objects, Earth intersects the densest part of giant comet clouds approximately every 2,000-4,000 years. The quantities of iridium, helium-3, and other cosmic markers increase and decrease simultaneously, creating notable peaks around 18,000, 16,000, 13,000, 9,000, 5,000, and 2,000 years ago. The Svyatskiy stream hypothesis also suggests a recurrence of catastrophic events but differs from their hypothesis in the mechanism by which comet fragments impact Earth through an intermediate near-Earth orbit. This mechanism yields a higher probability of catastrophic events compared to random collisions, though direct impacts remain possible. Integrating these hypotheses when considering the Svyatskiy stream would be highly beneficial.

3.15 Early manifestations of the Svyatskiy stream

Several well-known events can be examined as potential manifestations of the Svyatskiy stream. The most renowned event is the destruction of Sodom and Gomorrah, as described in the Bible. One site proposed as Sodom is the Bronze Age settlement of Tall el-Hammam, located on the eastern bank of the Jordan River. Research was conducted by a multidisciplinary team comprising 21 specialists from the United States, Canada, and the Czech Republic, including archaeologists, geologists, geochemists, geomorphologists, mineralogists, paleobotanists, impact event experts, and physicians. The study was led by archaeologist Phillip J. Silvia from Trinity Southwestern University in Albuquerque, New Mexico. The findings were published in Scientific Reports [21] under the title "A Tunguska sized airburst destroyed Tall el-Hammam a Middle Bronze Age city in the Jordan Valley near the Dead Sea." The article meticulously details numerous indicators suggesting the settlement's destruction resulted from a cosmic catastrophe.

Highly significant information is recorded on a clay Sumerian disk, known as exhibit No. K8538 of the British Museum. Alan Bond and Mark Hempsell studied and decrypted the disk. It describes the movement of a comet and indicates its fall date as June 29, 3123 BCE. This date closely aligns with the June 30 date of the TCB event. Clay tablets have also been preserved containing Sumerian lamentations or city dirges. These lamentations, traditionally performed in temples, described a catastrophe that destroyed numerous cities. The "Lament for Ur" enumerates 19 Sumerian cities simultaneously devastated by a terrible storm. Evidence suggests that cometary material fell across a wide area in Mesopotamia, with the nature of destruction corresponding to the falls that formed the SFR. It is logical to infer that this occurred on June 29, 3123 BCE. In India, the Kali Yuga cycle of the "Iron Age" began in 3102 BCE. The great battle of the Indian epic Mahabharata concluded 35 years prior. Although

the events of this battle were described as a war of gods employing powerful weapons, it bears a stronger resemblance to a series of natural disasters. The "Great Cycle" of the Maya calendar commences in 3114 BCE. All these events could share a common cause and be associated with a powerful manifestation of the Svyatskiy stream. This date corresponds to the recorded peak in iridium content 5,000 years ago.

3.16 The Svyatskiy stream and cycle of cosmic catastrophes

The most extensive events potentially linked to the Svyatskiy stream occurred in North America 12,835 ± 100 years ago. The work "The Cycle of Cosmic Catastrophes" [22] presents a hypothesis explaining the onset of the Younger Dryas cooling period as a result of a cosmic catastrophe. While cosmic traces of the disaster have been identified on all continents, North America hosts the most intriguing natural formations for our study: The "Carolina Bays". These features were discovered in the early 20th century following the advent of aviation and aerial photography capabilities. Numerous elliptical formations were observed. The bays are distributed in distinct clusters, ranging from Georgia to California, with the majority located in North and South Carolina. Subsequent investigations revealed additional groups in Alabama, Florida, and New York State. Most researchers estimate the number of these lakes at a minimum of half a million, with some projections reaching 2.5 million. Their dimensions range from several tens of meters to 11 kilometers in diameter. The authors proposed that a meteorite or comet impact on the substantial ice sheet covering Lake Michigan at the time caused the dispersal of glacial ice, forming the bays. However, this explanation is questionable, as the ice would likely have been fragmented into minute pieces. An alternative explanation for the formation of the Carolina Bays involves impacts similar to those that created the SFR. In Siberia, fragments fell in mountainous terrain, resulting in fan-shaped impressions. When impacting a flat, moist sandy surface at a shallow angle, small-depth craters with elliptical shapes are formed. According to the proposed SFR analogy, the flight direction of fragments may not originate from a single center but converge towards a unified point. This aligns with the flight patterns of secondary bodies observed in 1908. To generate 2.5 million craters, the comet's diameter would need to be approximately 1.5 km. However, given that the catastrophe affected all continents, the body's size must have been significantly larger. This event triggered an abrupt cooling period and other climatic changes lasting nearly a millennium. The authors provide evidence that the catastrophe was accompanied by prolonged periods of heavy rainfall, potentially giving rise to flood myths among numerous cultures.

3.17 Recent manifestations of the Svyatskiy stream

Characteristic features of bodies falling from the Svyatskiy stream include a shallow trajectory and the absence of a crater. Numerous reports describe the passage of powerful fireballs, yet no material evidence has been found at the supposed impact sites. There are also documented instances of cosmic ice falls. On the night of September 24-25, 2002, an American satellite recorded a powerful bolide, later termed the Vitim event. At the impact site, forest falls covering an area of 100 square kilometers and traces of fire were documented. Ice of cosmic origin was also discovered. The patterns of destruction correspond to SFR characteristics. A swarm of numerous ice fragments impacted this location. The latitude of the fall, 59°30', aligns with the latitude of the TCB explosion. The positions of the Moon and planets coincide precisely. It can be asserted that the activity of the Svyatskiy stream persists, and its manifestations remain potent.

4. DISCUSSION

Is a future manifestation of the Svyatskiy stream possible? The closest approaches during the required configuration of Jupiter, Mars, and the Moon, as shown in Figure 10 and Figure 11, are expected to occur in 2038 and 2049. Such a configuration is a necessary but not sufficient condition. The stream may occupy only part of the orbit, be sparse, and capture may not always occur. On average, significant events occurred once every hundred and forty years. Since 1908, no catastrophic events have been observed, so the likelihood of significant events in 2038 and especially in 2049 is elevated. Regular appearances of NLC may indicate that the stream still exists.

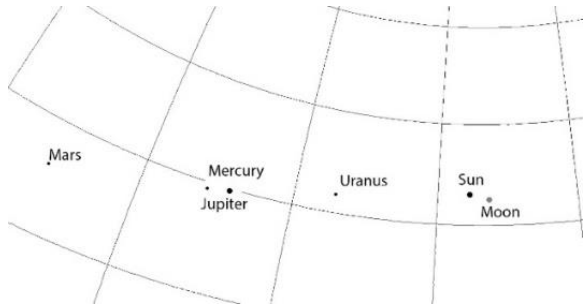

Figure 10. Planetary alignment on June 30, 2038

Among all known meteor streams, the fragments of the Svyatskiy stream are the most "benign"; even in a direct collision, their relative velocity should not exceed 14 km/s. When deviating from orbit, it will be around 11 km/s, similar to the TCB. However, a 500-meter comet nucleus would produce a blast power of 60 Mt in TNT equivalent at a height of 10 km. It is possible that individual large fragments from the stream have already been detected. Nevertheless, attention should be paid to the Svyatskiy stream.

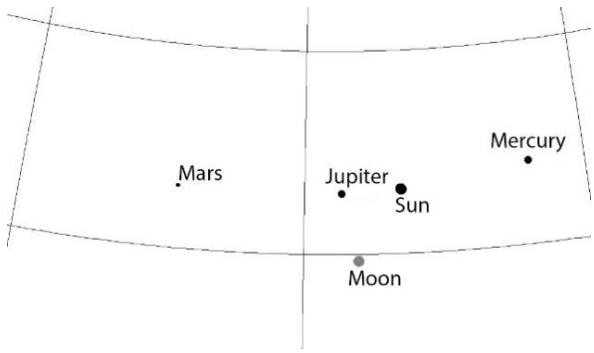

Figure 11. Planetary alignment on June 30, 2049

The occurrences in Ladoga, Veliky Ustyug, Veliky Novgorod, Pskov, and Novaya Erga are very close geographically. This distribution is undoubtedly influenced by

the selection based on chronicle sources. Falls are possible across the entire 60th latitude, and their actual number may be significantly higher. However, accumulated statistics indicate a high probability of falls in Northern Europe, including cities such as Oslo, Stockholm, Helsinki, St. Petersburg, and several cities in Northern Russia. Significant fragment falls in 1908 occurred as far as the 50th latitude. The continuous swath of destruction could extend up to 30 kilometers in length and 4-5 kilometers in width.

Over its nearly millennium-long history, the manifestations of the Svyatskiy stream have not led to catastrophic consequences and have primarily occurred in sparsely populated areas. Although the probability of such an event is low, if one of the major European cities were struck, it could become the most significant natural disaster in human history.

Clube and Napier assert that since 2000, Earth has been in a dangerous 400-year period during which orbital changes will expose us to the threat of collision with the densest part of the comet cloud, containing the largest debris. The predicted manifestations of the Svyatskiy stream in 2038 and 2049 fall within this threatened period.

The calculations from 1990 need to be updated, taking into account new information and utilizing modern computational power. The impact of bodies from the Svyatskiy stream occurs exclusively through an intermediate near-Earth orbit, with the Moon involved in the capture process. For reasons not yet fully understood, manifestations of the Svyatskiy stream occur with a periodicity of 100-150 years. This necessitates a reassessment of asteroid hazard evaluations. Celestial bodies currently considered non-threatening due to their significant distance from Earth may enter the orbital capture zone.

If it becomes possible to model the Svyatskiy stream, bodies belonging to it can be searched for purposefully. This approach could enable the detection of all dangerous asteroids larger than 20-50 meters. The albedo of cometary matter located between Earth's and Mars's orbits is very low, potentially rendering conventional detection methods ineffective.

While there is a general trend towards decreasing intensity in the Svyatskiy stream's manifestations, its history includes a global-scale event that led to significant climate change. If a mechanism for replenishing the stream exists, its threat may be a constant factor endangering humanity.

It's possible that at some point, an icy body of considerable mass could enter Earth's orbit, raising the question of whether anything can be done about it. To make informed decisions, it's crucial to study everything related to the Svyatskiy stream. The impact of numerous small fragments could potentially be more dangerous than a single air explosion.

5. CONCLUSION

The work substantiates the high probability of the existence of the Svyatskiy stream, consisting of comet fragments. Within this hypothesis, the TCB event is considered not to be a random occurrence. Similar events have occurred in the past and are possible in the future.

The capture and fall of the TCB occurred through a non-obvious and complex scenario. This circumstance prevented other researchers from proposing comprehensive hypotheses that encompass all the facts.

The discovery of similar events in Russian chronicles confirms the validity of the previously proposed hypothesis about the fall of the TCB from an intermediate near-Earth orbit. This hypothesis reconciles all observational facts and available objective data, resolving all contradictions. In particular, it explains the light phenomena observed before the fall. The "mysteries" of the Tunguska Meteorite can largely be considered solved.

In light of the presented information, efforts should be directed towards studying the threat posed by the bodies of the Svyatskiy stream, with the aim of assessing and potentially mitigating it. The nearest possible dates for a potential catastrophe are in 2038 and 2049. Preventing a collision with a large comet is currently impossible, but the fragments of the Svyatskiy stream might be destroyed if necessary. However, this can only be achieved through international cooperation. Otherwise, saving one city could lead to the destruction of another.

It is also imperative to finally begin studying the SFR (Siberian Fireball Region). The catastrophe of 1908 had a wider geographical impact and was not limited to the Tunguska event. This work is based on materials from Russian chronicles, but there may be descriptions of similar events in other Northern European countries.

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