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Fireball on the 08th of January 2024 and meteorite fall near Rovanichi, Belarus

Abstract: Three cameras of the Belarusian Meteor Network (BMN) in Minsk and Gayany recorded a bright fireball on 8th January 2024 at 01:30:24 UTC. Calculations using UFOOrbit showed that the meteoroid belonged to the Atens group of near-Earth asteroids, whose orbits cross the Earth's orbit from the inner side (objects-like the asteroid Apophis). Camera in Gayany captured the 1st and 2nd order spectra which showed a typical picture for a meteoroid of chondritic composition. The event was also analysed in terms of meteorite fall, resulting in the calculated strewn field near Rovanichi, Minsk Oblast, Belarus.

Keywords: Belarusian Meteor Network, meteoroid, meteor spectrum, meteorite fall

Bolide

On January 8, 2024 at 01:30:24 UTC, three cameras of the Belarusian Meteor Network (BMN) recorded a bright fireball (AbsMag –8.5m), which moved across the sky for 4 seconds and had a bright green color. The Minsk_03 and Minsk_60 cameras captured the entire trajectory, while the Gayany_62 camera captured only the first half of the path.

Calculations using UFOOrbit (SonotaCo software) showed that the meteoroid entered the atmosphere at a nearly vertical angle of 81.5 degrees to the horizon, and had an initial observed velocity of Vo = 19.2 km/s and a geocentric velocity of Vg = 15.5 km/s (measured in the first second of flight). The radiant is located in the constellation of the Ursa Major and coincides exactly with the January alpha-Ursae Majorids (JAU) meteor shower. However, according to IAU MDC data (see Hajdukowa et al. 2023), the January alpha-Ursae Majorids meteors have very different orbital elements and geocentric velocity. Therefore, it appears that in this case we are dealing with an optical superimposition of the fireball radiant on the already known radiant of January alpha-Ursae Majorids.

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Fig. 1. The image created from the registrations of the bolide on January the 8th 2024, in stations Minsk_60 and Minsk_03.

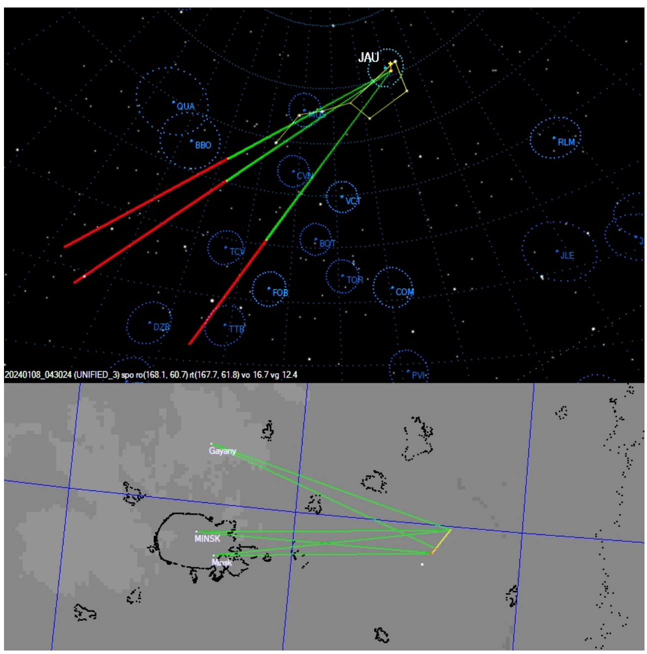

Fig. 2. The radiant of the 08.01.24 event (upper plot) and illustrative map with the trajectory of bolide (yellow line) in Belarus, determined by the UFOOrbit program (lower plot).

According to measurements of the last 400 ms of flight, the terminal velocity was 5.2 km/s and the extinction altitude was 27 km. This gives a good chance of a meteorite fall. Other factors that increase the probability of fall are:

- The angle of entry is close to vertical. This is the shortest path for meteoric material to reach Earth. The contact time with the atmosphere is minimal. Chances of fallout are increased.
- The absence of an obvious trail during the flight. This indicates the high strength of the material that made up the meteoroid. Chances of fallout are increased.

- The absence of flares during flight. This indicates the absence of catastrophic events that destroy the meteoroid in flight. The chances of fallout are increased.

At the end of the flight, separation of 4–5 smaller fragments from the main body was detected.

Orbit

The orbit turned out to be quite interesting. The meteoroid belongs to the Atens group of near-Earth asteroids, whose orbits cross the Earth's orbit from inside (their distance from the Sun at aphelion is greater than the Earth's perihelion distance, $Q > 0.983$ AU, but the major semi-axis is even smaller than the Earth's $a < 1$ AU). The most famous representative of this group is the asteroid Apophis.

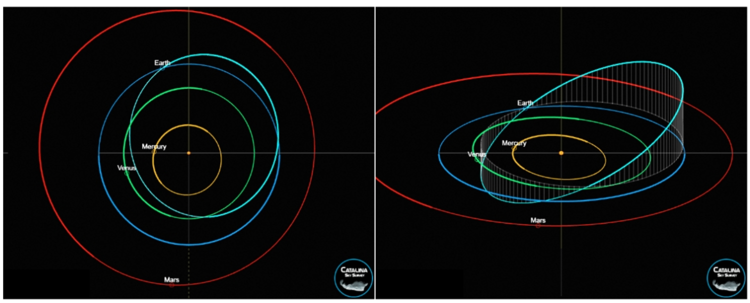

Fig. 3. The orbit of the meteoroid. Drawings of the orbits were made using CSS Orbit View application.

Given the nature of this orbit, should the meteorite be found, it could be of great interest for further research, as meteorites from the inner regions relative to Earth's orbit come rarely.

Table 1. Calculated parameters of the event on January 08, 2024 at 01:30:24 UTC. Angular quantities are given in the J2000 reference system.

Parameters of the event:	
Sol:	286.91°
RA:	170.55°
Dec:	61.11°
Vo:	19.16 km/s
Vg:	15.53 km/s
Elements of the orbit:	
a =	0.924 AU
q =	0.652 AU
e =	0.294
peri =	298.76°
node =	286.91°
incl =	25.51°

Spectrum

Gayany_62 camera, equipped with a diffraction grating, captured the plasma spectrum from the bolide, both 1st order and 2nd order spectra. The spectrum was analyzed in the RSpec program and shows the following features (NIST Atomic Spectra Database, Kramida et al. 2023; Borovicka 1994):

- In general, the spectrum shows a typical picture for a meteoroid of chondritic composition. It contains the main spectral lines characteristic of such meteoroids: Mg I, Fe I, Na I, Ca I, Si I, Cr I, Mn I. The ratio of Mg(mult.2)-Fe(mult.15)-Na(mult.1) equals to 7%–57%–36% (see Vojácek et al. 2015).

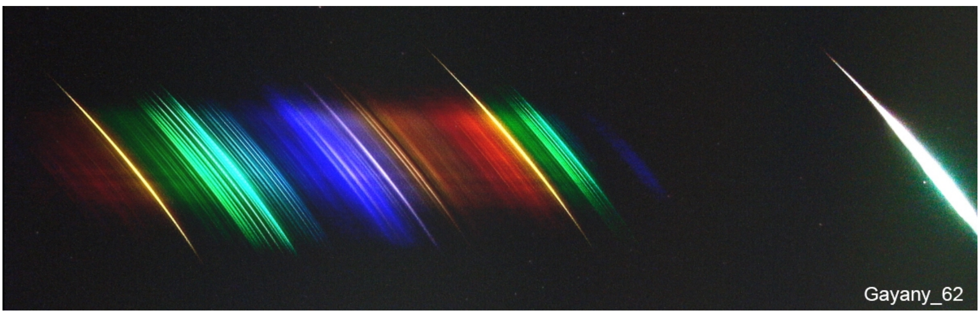

Fig. 4. The spectrum captured in the Gayany_62 camera.

- Magnesium. The problem is that among the magnesium triplet lines (5167.3Å, 5172.7Å, 5183.6Å) there is a bright iron line Fe I 5167.5Å, which greatly distorts the result. Currently, to calculate the magnesium triplet intensity, we use an experimental technique in which the intensity of the bright Fe I 5167.5Å line is subtracted from the measured magnesium triplet value. The intensity of Fe I 5167.5Å is calculated based on knowledge of the brightness of Fe I multiplet 15, an empirical relationship determined by analyzing the spectra of iron meteors. Thus, according to our methodology, the percentage of magnesium in the Mg-Fe-Na system is 7%. This is a low value. However, it does not indicate a low magnesium content, but is a result of a low meteoroid velocity. We have observed that at low meteoroid velocities (and correspondingly lower temperatures) the magnesium triplet fades away while the Fe I 5167.5Å line still continues to glow. This is due to the higher excitation energy of electrons in the magnesium atom (~2.7 eV, magnesium triplet) compared to the iron atom (1.48 eV, Fe I 5167.5Å).
- Iron. The spectrum shows very bright iron lines in the region of Fe I multiplet 15 and not only. It was primarily iron atoms that provided the beautiful green color of the fireball. And although the spectrum of meteor plasma was analysed not quantitatively, but only qualitative, we can say with confidence that the meteoroid contained substantial iron. This implies that it probably contained native iron and should have strong clearly pronounced magnetic properties. This information will be useful for those who will be engaged in the search for a meteorite.

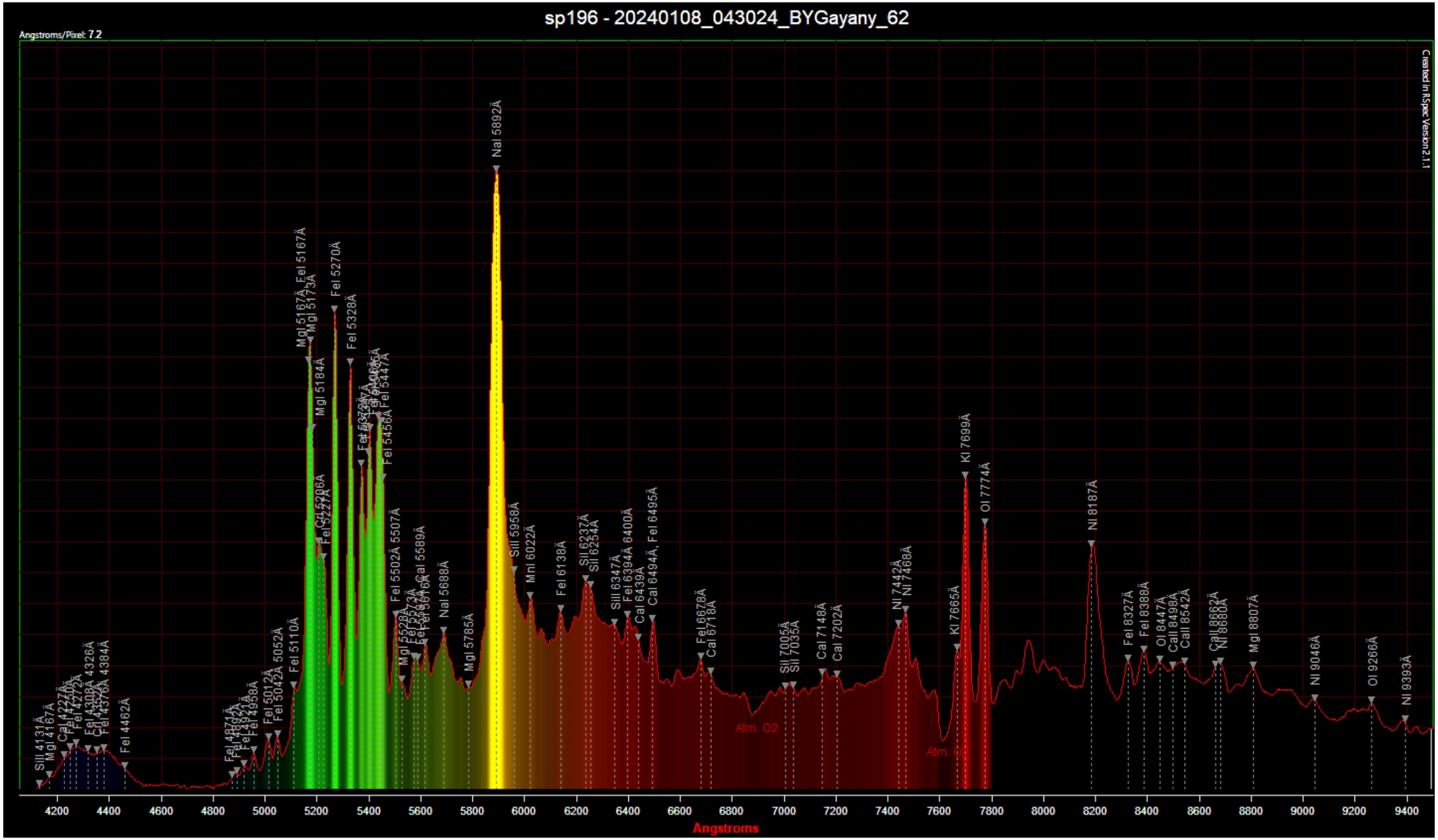

Fig. 5. The 1st spectrum order registered in the Camera Gayany_62.

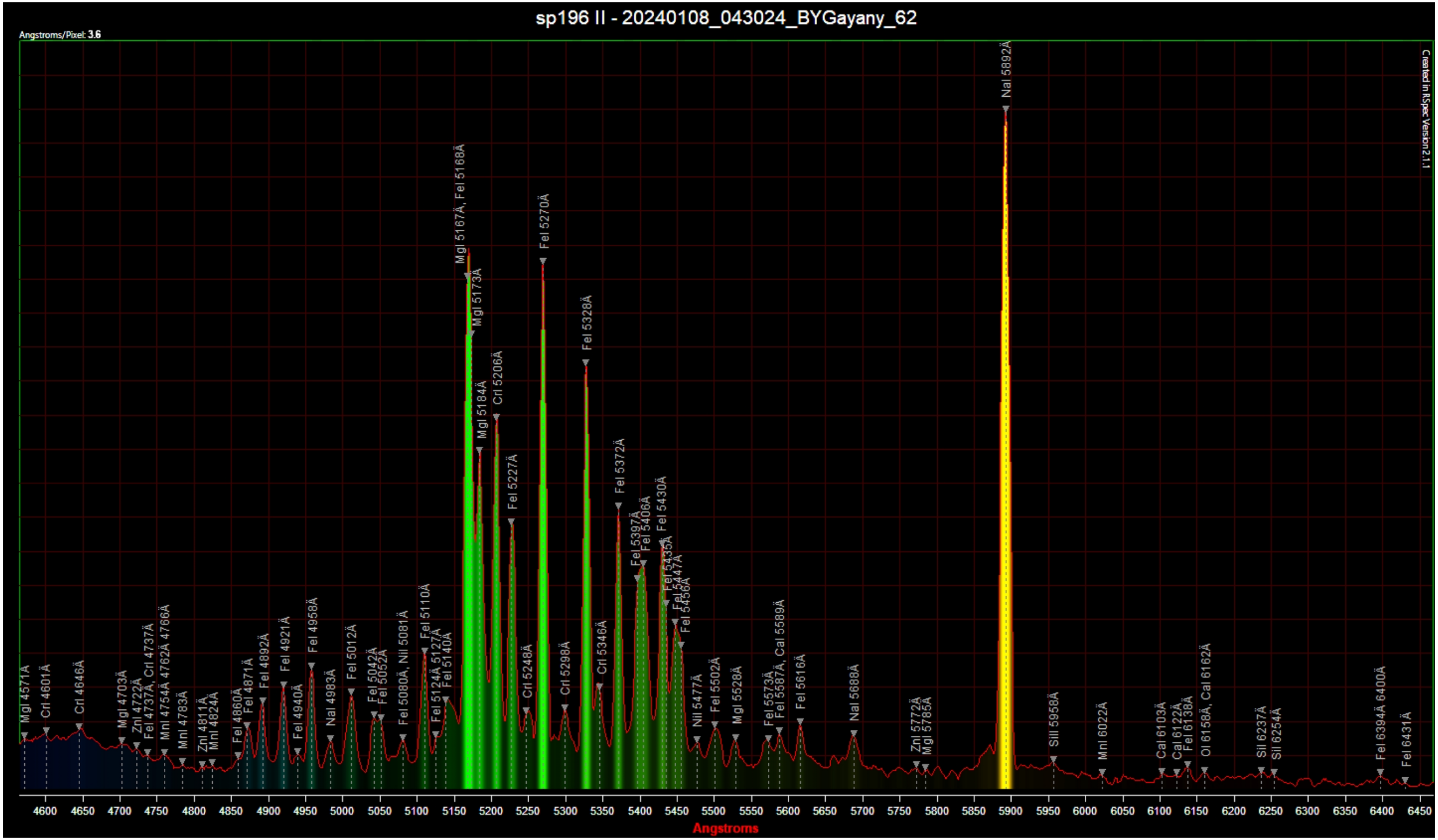

Fig. 6. The 2nd spectrum order registered in the Camera Gayany_62.

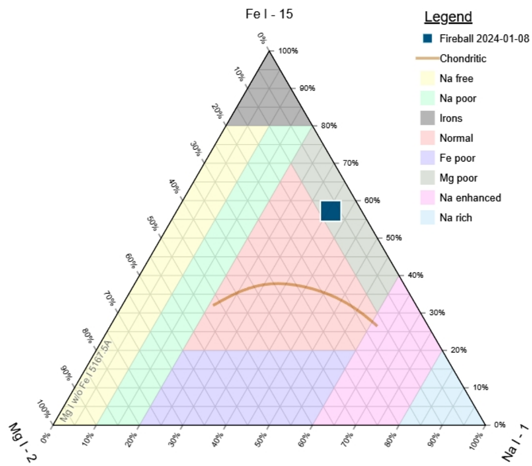

Fig. 7. Ternary plot used for the classification of meteor spectra.

- Alkali metals. The luminosity of the Na I 5892Å line is intense, which is common for chondritic meteors, especially at low velocities as in our case. It is worth noting that the spectrum also shows a bright line of another alkali metal potassium K I 7699Å.
- Nickel. Nickel lines are usually difficult to detect in meteor spectra because they are not bright and are masked by other lines, mainly iron lines. High spectral resolution is required for confident detection. In this spectrum, the nickel line Ni I 5477Å is detected quite confidently in the 2nd order spectrum, which has 2 times higher resolution than the 1st order spectrum. Nickel is an inseparable companion of iron in meteoric matter.
- Zinc. Three weak peaks in the 2nd order spectrum coincided with the bright theoretical lines Zn I 4722Å, 4811Å, and 5772Å. This was a surprise. However, the registration of this chemical element is not confident enough.
- Atmospheric gases. The luminosity of atmospheric gases is weak, which is quite characteristic of low meteor velocity. We can only note the clearly visible lines O I 7774Å and N I 8487Å, all other lines are weak.
- Ionized atoms. The lines of ionized atoms are almost invisible. We can speak only about the lines of silicon Si II and calcium Ca II visible at the error level (IR region). This once again confirms the low velocity of the meteoroid and indicates the absence of shock processes as a result of flares destroying the meteoroid (see Borovička 1994).

Strewn field and first search

Strewn field was calculated via Strewnify.com with weather conditions taken into account.

The first search for the meteorite was organized with the participation of amateur astronomers, members of the astronomical club at the Minsk planetarium and the Institute of Geology. The first expeditions did not bring any results. Further searches are planned.

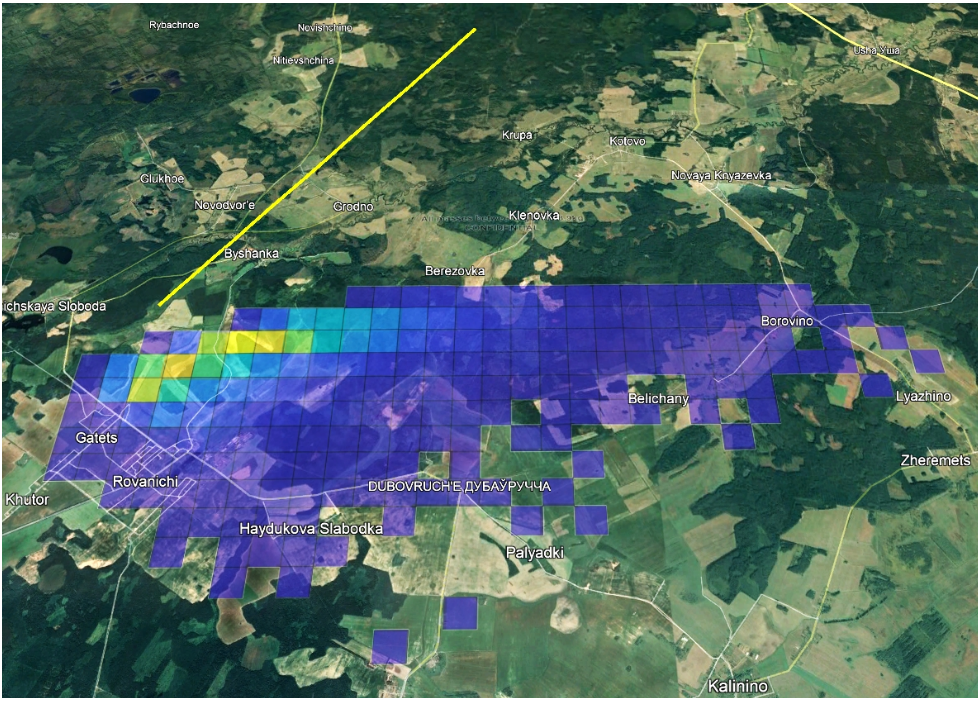

Fig. 8. Strewn field calculated via Strewnify.com. The color of the squares indicates the probability of the meteorite fragments falling out, the probability decreases from orange to green to blue.

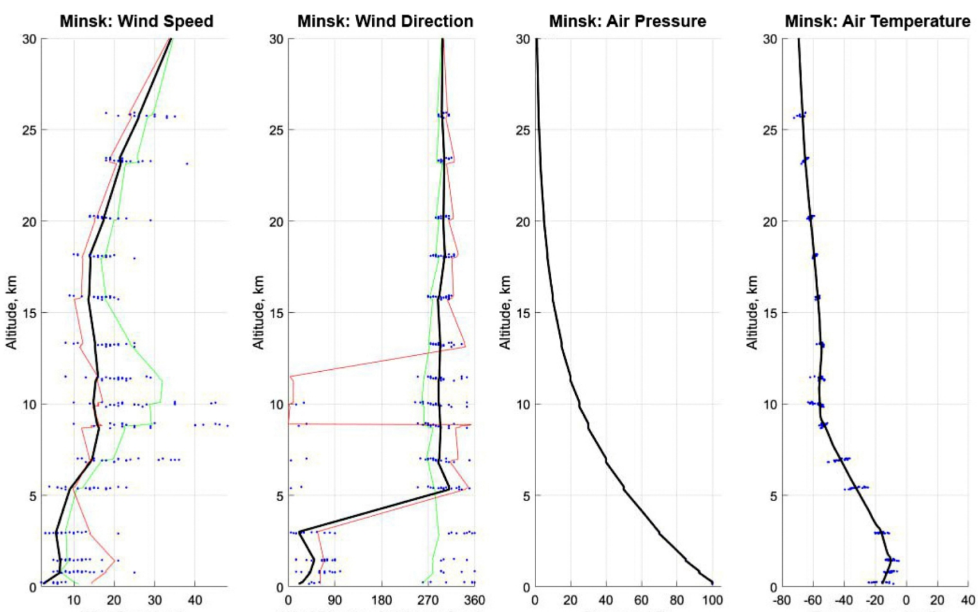

Fig. 9. Weather conditions at the location of the meteorite fall.

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