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METRO campaign in Japan III: High-resolution images obtained in the campaign and morphology of the meteor train

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Abstract: The persistent meteor train is observed in various forms. It is considered that these characters are caused by the tube structure of the meteor train, the turbulence along the tube surface, and the convection in the upper atmosphere. However, because of the upper atmospheric wind effects and the dissipation process of the meteoric plasma, the structure begins to disappear as soon as it appears. In Leonids shower 2001, a lot of images of the meteor train were reported to the METRO (meteor train observation) campaign in Japan: the 242 cases of 134 examples. We tried to obtain high-resolution images of the meteor train using fast-exposure photograph and video observation with telephoto lenses, particularly those of 200 mm or longer focal length. Many train images which indicated some interesting fine structures were successfully obtained by the METRO campaign during 1998–2001. In this paper, the morphology of the persistent meteor train just after its appearance is discussed.

1. INTRODUCTION

The meteor train is a plasma glow formed after the appearance of the parent fireball and continuously luminous for more than a few seconds. There are the persistent meteor trains that can be seen for more than a few tens of seconds, however, the formation process and the luminescence mechanism have not been well known yet. The structure of the meteor train changes its form just after the appearance because of the mesospheric wind and the dissipation process of its own, so that the structure of the persistent meteor train has not been investigated so much especially in the early stage of it.

Trowbridge (1907) introduced the several sketches of the train structures observed by naked eye with binoculars or telescopes in the Leonids period in 1868 or later. In the article, they

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reported that the persistent trains were appeared as the double nucleus form, and the tube structure of the meteor train was assumed for the explanation of the double nucleus form. Liller and Whipple (1954) detected several fine sequences of the persistent train using super Schmidt camera and the images showed the variations of the meteor train as time went by. Jenniskens and Nugent (2000) analyzed the structures of a persistent train observed simultaneously from two sites and showed the knot and loop structures therein and proposed a formation model of the tube structure. However, there has been no trial with collecting the large number of images of the meteor train so as to analyze the precise form of the persistent meteor train.

In the METRO (meteor train observation) campaign (Toda et al. (2002, this issue)), we conducted the observer network targeting to the persistent meteor train all over Japan during the Leonids period in 2001. Owing to the expected encounter (e.g., McNaught and Asher (1999)) to the meteor storm, the numerous images of the meteor train were successfully obtained in the METRO campaign. We tried to detect the telephotographic images of the meteor train and it successfully resulted in many clear structures of the persistent meteor train. In this paper, we present the morphology of the meteor train with showing the various fine images of the meteor train structures.

2. METHODS

In the METRO campaign in Leonids 2001, we proposed the following observation methods:
a) Once the meteor train has oppeared, the observer moves the camera to focus it and starts the exposure sequentially. The sequence should be continued until several seconds after the disappearance of the train by naked eye. The interval between the exposures is in the range between 0.5 seconds and a few seconds. The camera with 35 mm film, the digital camera, and the video camera are recommended to use.
b) In order to detect the fine structures of the meteor train, the short exposure using the telephotographic lenses is desired. For this reason, 1) The telephotographic lens with its focal length is more than 100 mm, 2) The large aperture lens with its aperture ratio (F number) less than 2.8, 3) The short exposure time of 1 or 2 seconds, and 4) The high-sensitivity negatives with the extended development (final sensitivity should be more than ISO 6400) were recommended. The examples of the instruments with the selected conditions are shown in Table 1.

Table 1: Examples of the photograph equipment for the meteor train observation with high time resolution of 1 second. Wide field lenses listed with asterisk are used for field determination by being equipped with the telephotographic lenses.

Lens	F ratio	Film(ISO)	Final sensitivity (ISO)
200 mm	F/2.0	Fuji SUPERIA800,1600	3200
300 mm	F/2.8	Kodak TMAX3200	12800
400 mm	F/3.5	Kodak TMAX3200	9600
* 58 mm	F/1.2	Fuji SUPERIA800,1600	3200
* 85 mm	F/2.0	Fuji SUPERIA1600	6400

3. RESULTS

During the Leonids period in 2001, the numerous images of the meteor trains were reported to the METRO campaign: the 242 sequences of 134 independent persistent meteor trains. Based on the database of the METRO campaign, the morphology of the meteor train was studied. There are two categories of the meteor train morphology: the single striation or double striations structure seen in the whole of the train, and the localized fine structures named as the knot, the spiral, and the mesh. We extracted the number of the samples for the two categories from the database. The classification results are summarized in Table 2. These structures are introduced by 7 fine images of 6 persistent meteor trains with the observing situations of each train in the followings.

Table 2: Classifications of the persistent meteor train for the two categories. (a) Classifications for striation structures on whole of the train. (b) Classifications for localized structures.

(a)

	Single striation	Double striations (Chopsticks)
train	66	36
example	107	64

(b)

	Knot	Spiral	Mesh
train	75	21	6
example	113	24	9

3.1 The persistent meteor train "Saku"

This train appeared at 01:47:24 LT on Nov. 19 over Saku area in Nagano prefecture in Japan. The parent meteor was one of the brightest fireballs observed with –8 magnitudes. The persistent meteor train was detected from multiple stations and two clear images simultaneously observed at an exact time are presented in this paper. These data are used for the three-dimensional analysis in another work of the METRO campaign (Yamamoto et al. 2002, this issue).

One image of the train Saku is displayed in Figure 1 (a). The image was observed at 01:47:32 LT by Youiti Ishiduka from Takayama in Gunma pref. The meteor train was seen on the Taurus and Orion background. The telephotographic lens of 400 mm, F/3.5 was used with no iris. Black-and-white high-sensitivity negative of ISO 3200 was used and the final sensitivity was ISO 9600 after the extended development. The exposure time was 1 second. Here, we can see the clear double striations structure with some knots. Note that the fireball was coming from top to bottom on the image.

Another image of the train Saku is shown in Figure 1 (b). The image was also observed at 01:47:32 LT by Satoshi Suzuki from Yachiho in Nagano pref. The meteor train was seen on the background of Lynx. The telephotographic lens of 100 mm, F/2.0 was used with no iris. A digital camera (Canon, D30) was used for this observation and the final sensitivity was ISO

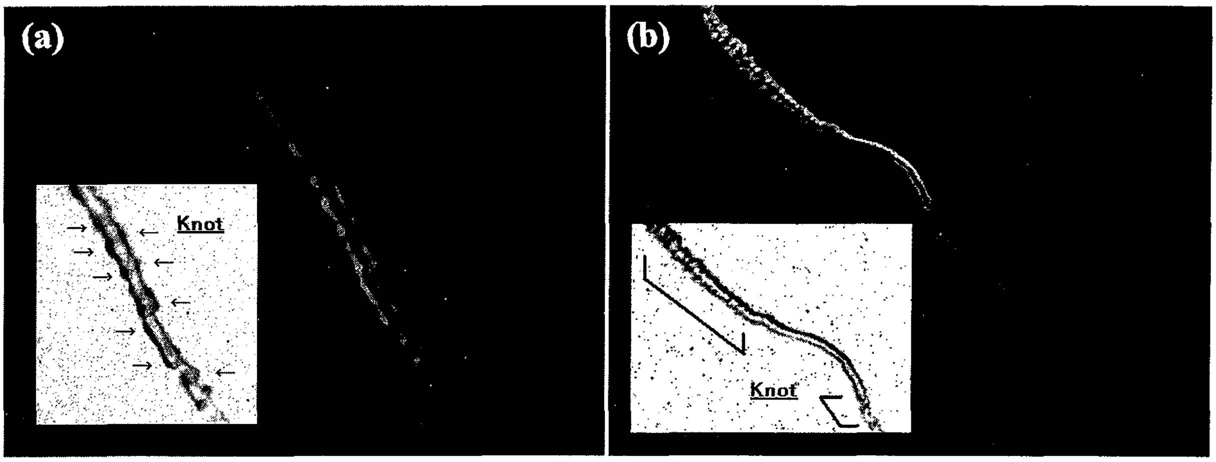

Fig. 1: The persistent meteor train "Saku." The FOV of images (a) and (b) were 4.2 (horizontally)×3.0 (vertically) degrees and 12.5 × 9.4 degrees, respectively.

1600. The exposure time was 2 seconds. We can also see the clear double striations structure with some knots. Note that the fireball was coming from bottom right to upper left on the image.

3.2 The persistent meteor train "Yonezawa"

This train appeared at 02:17:28 LT on Nov. 19 over Yonezawa area in Yamagata pref. The parent meteor was observed with –6 magnitudes. The persistent train was detected from multiple stations. One image of the train Yonezawa is displayed in Figure 2. The image was observed at 02:17:41 LT by Yoshihiro Higa from Naraha in Fukushima pref. The meteor train was seen on the Perseus. The telephotographic lens of 300 mm, F/2.8 was used with no iris. Black-and-white high-sensitivity negative of ISO 3200 was used and the final sensitivity was ISO 12800 after the extended development. The exposure time was 1 second. The clear double striations shape was seen with the spiral structure from the center to the bottom of the train. Note that the fireball was coming from top to bottom.

3.3 The persistent meteor train "Morioka"

This train appeared at 04:38:25 LT on Nov. 19 over Morioka area of Iwate pref. The parent meteor was –6 magnitudes. The image shown in Figure 3 was detected at 04:38:33 LT by Yoshihiro Higa. The observation site and conditions were the same as those of Yonezawa train. The train was seen on the Draco. In this case, the single striation was seen with the spiral or knots structure along whole of the train. The fireball was coming from top to bottom.

3.4 The persistent meteor train "Shimonita"

This train appeared at 04:55:47 LT on Nov. 19 over Shimonita area in Gunma pref. The parent meteor was seen at –5 magnitudes. The persistent meteor train was detected from multiple stations. The image shown in Figure 4 was observed at 04:55:53 LT by Masayuki Toda from Ohizumi in Yamanashi pref. The train was seen on the Ursa Major. The telephotographic lens of 200 mm, F/2.0 was used with no iris. Color high-sensitivity negative of ISO 800 was used and the final sensitivity was ISO 3200 after the extended development. The exposure time

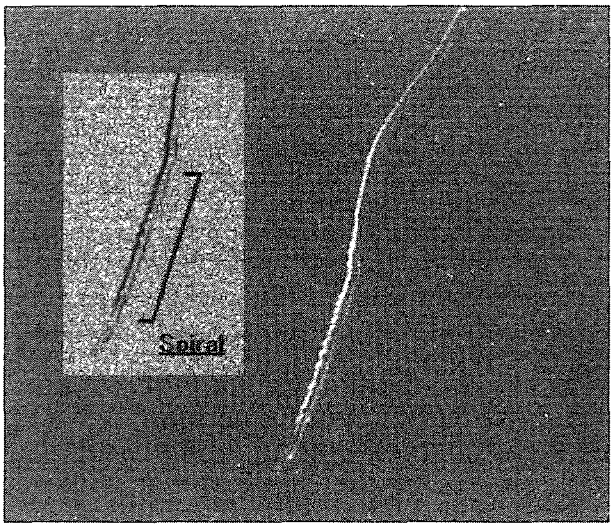

Fig. 2: The persistent meteor train "Yonezawa." FOV was 5.2 × 4.4 degrees.

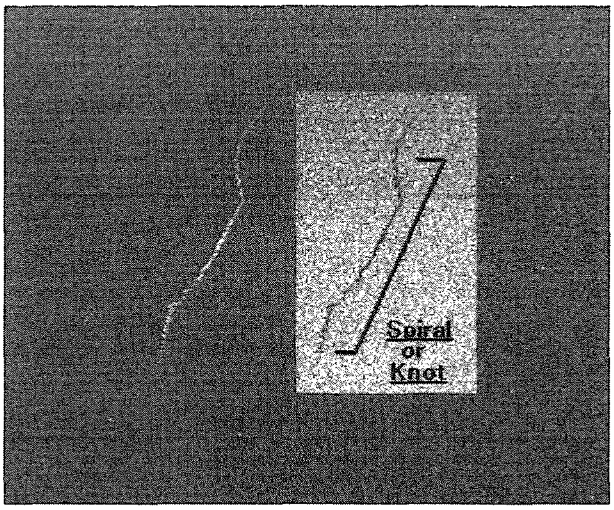

Fig. 3: The persistent meteor train "Morioka." FOV was 5.2 × 4.2 degrees.

was 1 second. The single striation shape was seen with the knots at the arrowed points on the image. Note that the fireball was coming from right to left.

3.5 The persistent meteor train "Takaoka"

This train appeared at 04:49:31 LT on Nov. 19 over Takaoka area in Toyama pref. The parent meteor was –10 magnitudes. The persistent meteor train was detected from three stations. The image shown in Figure 5 was observed at 04:49:40 LT by Masayuki Toda. The observation site and conditions were the same as those of Shimonita train. The meteor train was seen on the Perseus. The single striation shape was also seen with the knots or the mesh structure whole of the train. Note that the fireball was coming from right to left.

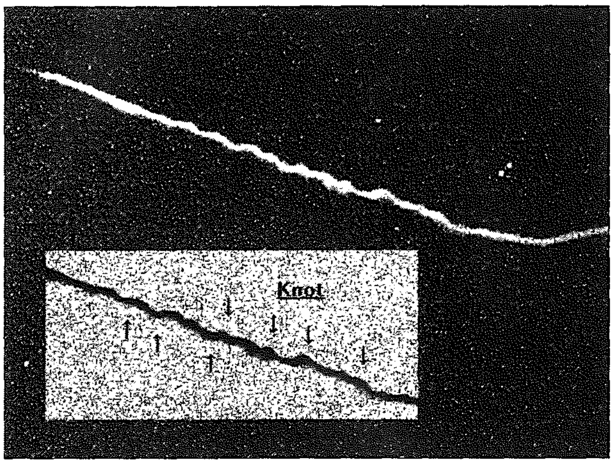

Fig. 4: The persistent meteor train "Shimonita." FOV was 2.7 × 2.1 degrees.

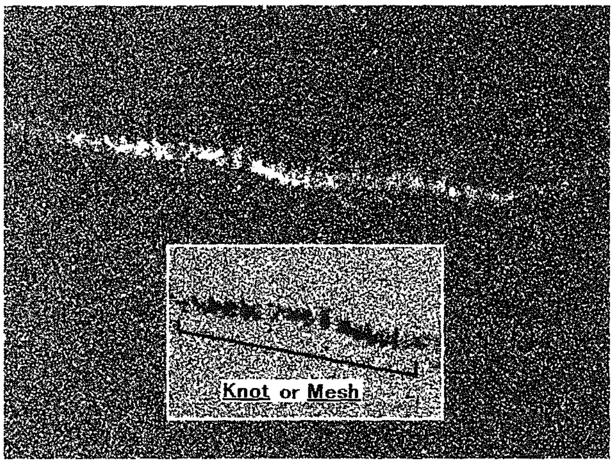

Fig. 5: The persistent meteor train "Takaoka." FOV was 2.5 × 1.9 degrees.

3.6 The persistent meteor train "Saeki"

This train appeared at 04:05:27 LT on Nov. 19 over sea area a little offing from Saeki, Oita pref. The parent meteor was –5 magnitudes. The persistent meteor train was detected by Kouji Maeda from single station at Tsuno in Miyazaki pref. using a NTSC type CCD video camera (NEC, TL-123A) with an image intensifier (HAMAMATSU, V1366P). The image sequence shown in Figure 6 was obtained by averaging of 4 individual video frames centered at 04:06:25, 04:06:35, and 04:06:45 in the local time, respectively. The time resolution was about 0.13 seconds each. The meteor train was seen on the Ursa Major. The telephotographic lens of 400 mm, F/2.8 was used with no iris. The double striations shape was seen with the clear mesh structure on the image. Note that the fireball was coming from right to left.

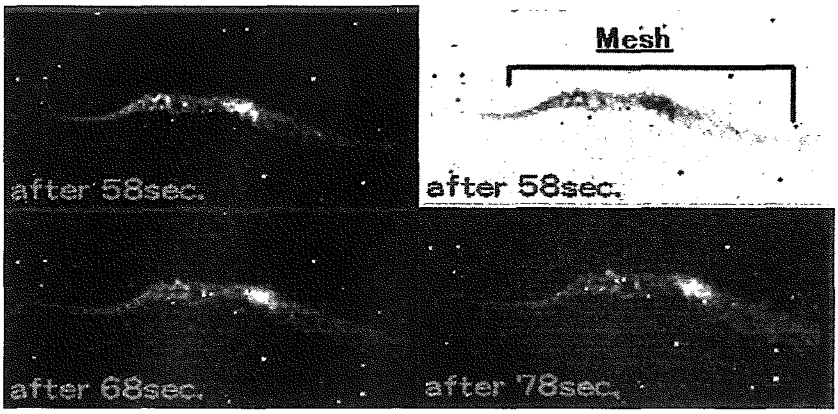

Fig. 6: The persistent meteor train "Saeki." FOV was 3.4 × 1.6 degrees each.

4. DISCUSSIONS

The morphology of the persistent meteor train was investigated using the numerous image examples of the meteor train reported to the METRO campaign, and the several specific characters of the train structure were found. At first, there were two types of the whole structure of the meteor train, that is, the single striation style and the double striations (or the "chopsticks") style. The double striations structure was introduced from the early works at the beginning of the last century (e.g., Trowbridge (1907)) and has been studied in the recent works (e.g., Jenniskens and Nugent (2000)) with some explanations of the formation mechanism of a tube structure, however, the question is still opened.

In the METRO campaign, we successfully obtained many images simultaneously observed from multiple stations. The existence of the tube structure of the persistent meteor train was experimentally proved in by Yamamoto et al. (2002, this issue) using the several fine images simultaneously observed from the different viewpoints. Thus the double striations style often seen on the meteor train images found to be explained by the tube structure. Otherwise, the single striation style could be considered as the non-tube structure.

Another category in the morphology of the persistent meteor train was determined as the localized structure on the meteor train: the knot, the spiral, and the mesh structures. The knot was frequently seen in group and the most typical structure of this category. It was seen as the thick part of the train or the bulged part on train's external wall. The spiral structure previously pointed out by Shigeno et al. (1998) was also confirmed in the METRO campaign. It was seen as corkscrew shape of the train itself. More complicated structure like the fabric textile was newly found in this study and was named as the mesh. Note that these localized structures could be seen on the both styles of the single and double striations. The turbulence on the train's wall due to the interaction between the dissipating meteoroid materials and the atmospheric particles should be considered as the causes of these localized structures. The spin motion of the meteoroid itself and the wake formation process just after the precipitating meteoroid are also the considerable generation sources.

The fine structures presented here is very difficult to observe because the persistent meteor trains are very rarely seen. Moreover, the structures begin to disappear within a short period due to the diffusion process of the train plasma and the blessed-out process by the mesospheric wind. Thus, the samples of the persistent trains have been too limited to investigate the morphology.

The METRO campaign is the first trial to obtain the large numbers of images of the persistent meteor train simultaneously during the meteor shower periods by collaborations with the amateur observer network. It revealed the morphology of the persistent meteor train in success especially from the collected data in Leonids 2001. Moreover, the first observation of the very fine structures of the meteor train in the early stage was successfully carried out by the several trained observers using the telephotographic lenses with high-sensitivity equipments. The results shows that the observation campaign with the successful broadcasting of the optimum condition to many earnest collaborators has an advantage for the detection of rarely appeared persistent train.

5. CONCLUSION

In the METRO campaign in Japan, the 242 sequences of the 134 persistent meteor trains were successfully observed during the Leonids period in 2001. It revealed the morphology of the persistent meteor train especially in the early stage. Both of the single and double striations styles were confirmed, concerning with the tube and non-tube structures, respectively, as well as the very fine localized structures of the train plasma were found as the knot, the spiral, and the mesh forms. The turbulence on the train's wall and the motion of the incident meteoroid are considerable as the generation sources of these fine structures. Comparing with the recent modeling and theoretical studies, these results can contribute to the future studies of the persistent meteor train and the meteoroid itself as well as the interaction process between the meteoroid and the mesospheric atmosphere.

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