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Persistent meteoric trains in a movie of the Leonid storm 2001

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Abstract: For the purpose of working group, Real?Universe, we observed and made an exciting movie of Leonid meteor stroms in Nov. 18, 2001. In this movie there are lots of meteors and many meteoric trains crossing beautiful night sky. To check the possibility of this observational procedure, we tried to derive some scientific results from this educational movie. For meteors, we could obtain the activity profile of Leonid meteor storm. And for meteoric trains, we got various sample of appearance change, derived moving velocity of them, and found some correlation between meteors and meteoric trains. Although this observation is made of educational purpose, we can obtained valid results. If you pay more attention for observation procedure, more accurate information could be obtained by this observation. Therefore, we conclude that this observation technique has a potential for scientific use and mention about some idea of observation for next Leonids.

1. INTRODUCTION

To make many people become familiar with starry sky and have interests in universe, we established a research working group named 'Real? Universe' in spring of 2000 and have been made several contents. We are mainly active to make movies about astronomical phenomena, which is, for example, a diurnal motion, motion of planet and so on. The movies are opend to public on our Web page (`http://www.obs.jp/links/RealUniverse/index-e.html`) and on some occasions to present our results at research conferences or publications. Not only movie itself also descriptions of how to make a movie is important our contents (Ishikawa et al. 2002).

Based on an educational view, to show an unusual but remarkable phenomenon is a very good opportunity to make people have an interest in that. The Leonids is one of the most known and exciting astronomical phenomenon, due to strong meteor storm which is originated from a comet, 55P/Tempel-Tuttle. This is thought to be a good target for achieving aims of our activity. Therefore, we observed and made a movie of the Leonids 2001 by our own procedure.

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2. OBSERVATION AND DATA TRANSFORMATION

We made an observation in the night of Nov. 18, 2001. Observed location is Misato Observatory, Wakayama pref., where is a suburb of Osaka (34 deg 9′N, 135 deg 28 E, H = 420m). To take images having a strong sense of reality, we used an electric-cooled color CCD camera (Bitran Co., type BJ-31C) along with a C-mount camera lens (f= 3.5mm, F1.4, type TC3514, by TOKINA Co.). This system gives south sky images whose field-of-view of 100 deg ×60 deg. Therefore, image contains terrestrial scenery in a view and you may easily understand the bearings in the image.

This system is controlled by an exclusive software installed in a personal computer. The exposure time is setted as 40 seconds and the interval timing of taking image as 1 minute. Following these setup item, the control software takes images continuously. We called this photographing procedure as 'slow speed photograph'. The obtained data which is FITS format is stored in computer automatically.

Many obtained still images are transformed into movie by an editing software. Movie editing software is a software for taking in movies shooted by video camera, editing them as you wish and making a new movie. Recently it is called a non-linear movie editing software. In this software, one still image is allocated to several frames, from 3 to 10 frames (from 0.1 to 0.3 second) is suitable value. By this transformation, an output new movie is shown an appearance of one night within just about one minute.

3. RESULTS

In our movie about Leonid meteor storm 2001, not only many meteors also meteoric trains are seen. To count meteors and meteor trains, we inspected each image by three people independently. After that, for meteor trains, we made a cross-check by all inspectors. The results and characters of these are mentioned as follows.

3.1 Leonid meteors

In order to check a time variation of number of meteors, meteors are counted by each observed frames. The counted number is added for smoothing. The plot of time variation is shown in Fig. 1. In this figure, an abscissa is a universal time (UT) of November 18 and an ordinate is a count of meteors in each 10 minutes. More precisely, it is a count in two-thirds of 10 minute. Because, one-thirds of total time is used not for exposure, but for reading out data. Although it is just a count, not hourly rate (HR) or zenithal hourly rate (ZHR). We can see that the number is increasing toward the prediction peak time, around 18:00. After the first peak, the number is fallen suddenly and rise up quickly. And then, it decreases slowly. But unfortunately, we cannot point out the observed peak time correctly, because the time of operating PC was not correct at observation.

We could obtain the activity profile of Leonid meteor storm from our educational movie, although it has some uncertainty about observational time. So we may say that about meteor activity we got just a qualitative results. To obtain quantitative results from these data such as HR/ZHR of meteors, we should pay attention to time accuracy of PC, viewing angle of image, and so on. We will mention these point later.

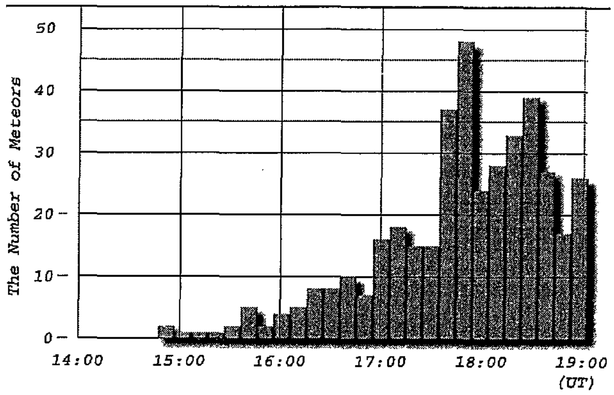

Fig. 1: This plot is a time variation of Leonid meteor storm 2001. An abscissa is a universal time (UT) of November 18 and an ordinate is a count of meteors in each 10 minutes.

3.2 Leonid meteoric trains

As we mentioned previously, we made an inspection by three people independently. We searched objects which is suddenly appeared and is seen at almost the same position in next image, until we could not recognize in the image. After inspection, to pick up more reliable meteoric trains, we made cross-check by all inspectors. And here we show two plots about a trend of appearance of meteoric trains. The lower graph (Fig. 2b) is shown when a meteor train is appeared and how long it is lasting, and upper (Fig. 2a) is a time variation of frequency of meteor trains.

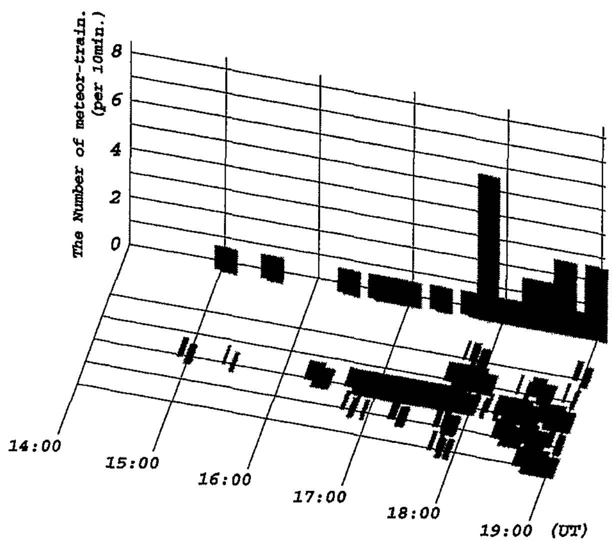

Fig. 2: Two plots about meteoric trains are shown. Upper (2a) displays a time variation of frequency of meteor trains, and lower (2b) indicates when trains are appeared and how long they are lasting. Abscissa of both graph is time of UT. The ordinate upper graph is a number of trains appeared in every 10 minutes, on the other hand, the ordinate of lower is arbitrary.

First, we consentrate the lover plot (Fig. 2b). Abscissa of this graph is time of UT and the ordinate is arbitrary. Here is all trains we inspected in the movie. Each bar represents one meteoric train. Longer bar means that the train is seen in long time. As you see in this graph, 27 meteor trains are shown here. All of them are seen in more than 2 frames of images, i.e., it is lasting more than 20 seconds. So they are thought to be persistent meteor trains. You may find there is several trains which is lasting more than 10 minutes. Moreover, the longest meteoric train we detected is lasting over one hour! This is an exceptional phenomenon. As far as we know this is one of the longest persistent meteoric train.

The upper graph (Fig. 2a) shows a time variation of frequency about meteoric trains. Abscissa is UT and ordinate is a number of trains appeared in every 10 minutes, this is the same as Fig. 1. We counted only at an appeared instant of meteoric train. Although the total number is not so large, you may see that the number is obviously large after the predicted peak time.

In order to discuss correlation between meteors and meteoric trains, the time variation of meteor trains is over-plotted on the plot of meteors (Fig. 3). Abscissa is UT and ordinate is a number in every 10 minutes, left one is for meteors and right for trains. Backward gray column represents meteors and forward white as meteoric trains. Around predicted peak time both data shows peak number and after the peak both shows more number than before peak. From this plot, we may say that there is some correlation between meteors and meteoric trains.

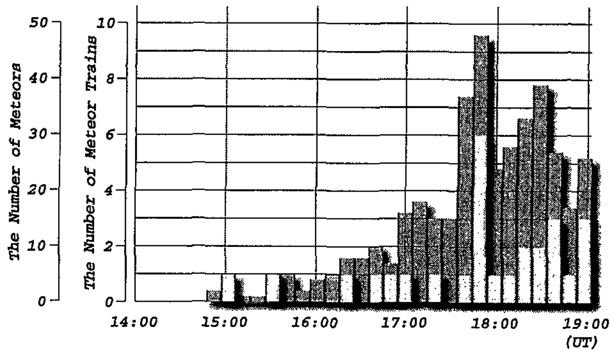

Fig. 3: In order to show correlation between mateors and meteoric trains, the time variation of meteor trains is over-plotted on the plot of meteors. Abscissa is UT and ordinate is a number in every 10 minutes, left one is for meteors and right for trains. Backward gray column represents meteors and forward white as meteoric trains.

3.3 Seven distinct meteoric trains

Among all 27 meteoric trains, 7 trains are found by all three inspectors. In other word, these 7 meteoric trains are distinct and remarkable. We mention these hereafter. These 7 meteoric trains are listed in Table 1. As shown in Fig. 4, we obtained various sample of appearance change of meteoric trains. In the movie a moving direction of them is not the same, by appearing time and position in the sky.

We derived moving velocity of these meteoric trains. Since our observation was made at only one location, we cannot decide accurate positional information about these phenomenon. Therefore, we suppose a height of them as 100 km above sea level. Each derived velocities of

Table 1: Seven distinct meteoric trains.

ID	start (UT)	duration (minutes)	velocity (km/sec)
1	16:13	8	6.3
2	16:38	61	4.6
3	17:36	20	2.0
4	18:14	16	2.9
5	18:30	4	3.6
6	18:36	20	3.3
7	18:40	16	5.4

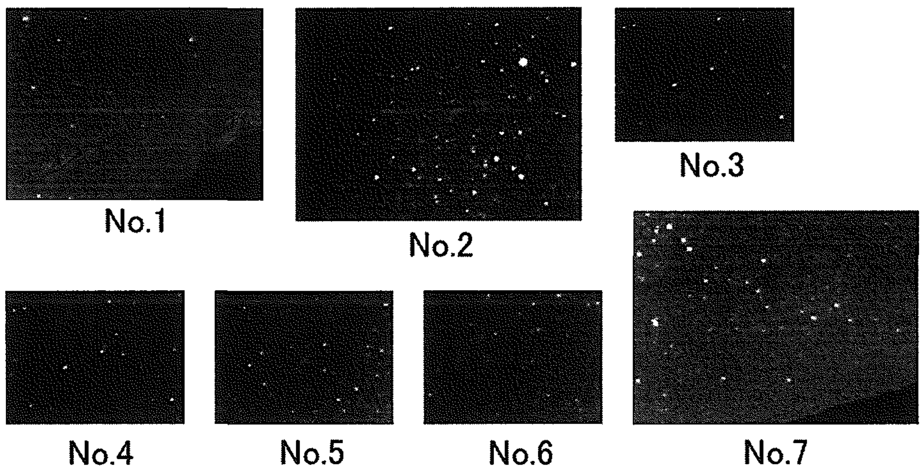

Fig. 4: Appearance variation of 7 distinct meteoric trains from observed images is shown. Each frames are not the same spatial scale.

trains are shown in Table 1. They are several times 10 m/sec or several km/sec. They are valid value when comparing with results from other instruments.

By assuming the height of trains, we can get each position of them. Moreover, we can change a viewing angle to see a meteoric train. For example, we will show the aspect of movement of the longest trains watching from the upper sky (Fig. 5). Each line represents one meteor train at different time and time-step of them is 5 minutes. The origin of figure is observation location and one grid is 50 km. Top is southward and left is eastward. Not only this train, all of these moving from top (south) to bottom (north). From these plots, we can see how spreads the meteor train with time.

4. SUMMARY AND CONCLUSIONS

We observed night sky of the Leonid meteor storm 2001, obtained many images, and made an exciting movie of it. From this educational movie, we succeeded to derive some results

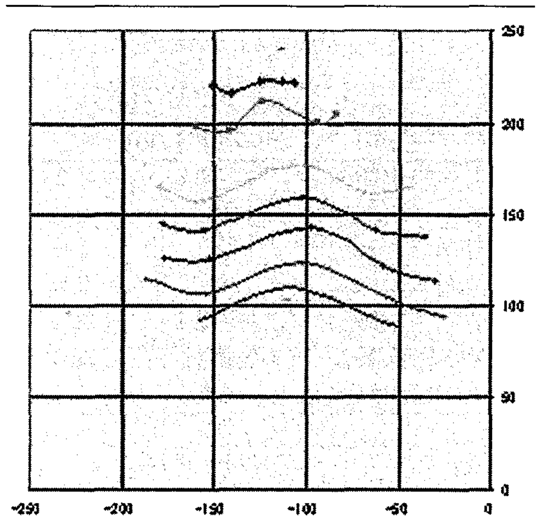

Fig. 5: This graph shows the aspect of movement of trains watching from the upper sky. The origin of figure is observation location and one grid means 50 km. Top is southward and left is eastward. Each line represents one meteor train at different time and time-step of them is 5 minutes, which is moving from top (south) to bottom (north).

about meteors and meteor trains. You may see lots of meteors which shows clear peak around prediction time and, moreover, many meteoric trains are detected. Although it is not high time/space resolution, we obtained many sample of appearance of trains. For some of them, we could also derive valid value of moving velocity. Comparing the count of meteors and meteoric trains, you may find that the frequency of meteoric trains correlates with the activity of meteors activity. Therefore, we can conclude that these results suggest that a long exposure instrument is effective in detecting faint objects like meteor trains, and show that this observation technique has a potential for scientific use. So we mention about what is needed for further scientific observation.

Because the movie was taken for not scientific purpose, some problem was contained in these data. In order to obtain qualitative results from these movie, such as the observed peak time and the HR/ZHR, we just solve some tiny problem of observation, for example, time uncertainty. To avoid mistake, taking care of observation is important thing, although it is superfluous to say so. Just do this, the accuracy of data is improved easily.

We could get information about many meteoric trains by just one observation. If some sets of these equipments are used for observing the same sky area from many location, as you may imagine this easily, this gives more detailed results of meteors and meteor trains. Collaboration with other instruments will also give further scientific information.

From this conference, we found that the high-sensitivity video camera is a very common and useful instrument. Collaborate with a high-sensitivity video camera is one example. To know a character of meteor generating meteoric train is interesting subject. Video camera use for detecting faint meteors and by using this procedure we can observe more fainter trains that is not found by people eyes. From this collaboration, we may discuss a lower limit of brightness of meteor that generates meteoric train or a character of train itself. Of course, more subjects exists, for example, luminosity function, mass index, and so on. We think this observation could reveal these subjects.

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