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Leonids 2001 by radio meteor observaiton all over the world

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Abstract: In 2001, Leonids meteor shower was expected the impressive appearence would be seen. It was very important to monitor and catch the Leonids meteor activity at all times. Radio Meteor Observation is one of the best method for monitoring meteor activity. Because it is possible to observe at all times even if in bad weather and at twilight time. In addition, by unifying worldwide data, the radiant elevation problem can be solved. In this research, the Leonids active structure and characters are made clear by using worldwide data. These data were provided by the global project of Radio Meteor Observaiton. This project participants were 91 observing sites in 15 countries. As a result, the high activity kept for 17 hours since 6:00UT 18th. The half width time of the first peak (America) was three hours and the main peak (Asia and Australia) was 10 hours. In addition, from Japanese data, we found the complicated peak structure. The Asian peak was made up of three types. They were main peak around 18:30UT, sub peak around 21:30UT and bright meteors compornent.

1. INTRODUCTION

When the meteor enters the atmosphere, the ionized trail is produced. Generally, it is impossible to receive the direct radio wave from the transmitting station because the distance between transmitting and receiving station is very long. The ionized trail, however, reflect the radio wave (30MHz-300MHz) from transmitting station to the receiving station. At the receiving station, the signal reflected from meteor is presented. This method is Radio Meteor Observation (Foward scattering). It became popular in the middle 1980's.

Radio Meteor Observation is possible to observe even if it is bad weather, twailight time and daytime. Therefore, for monitoring meteor activity, this method is very effective. Only

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one site, however, there is serious problem which is radiant elevation. Therefore, by unifying worldwide data, it became possible to obseve and to monitor a meteor activity at all times without these problems. Until now, worldwide data have been collected on one paper such as *RMOB(Radio Meteor Observaiton Bulliten by Christian Steyaert)*, but the unification between worldwide data have not been done. This is because it is difficult to unify world wide data because of various observational system and complex reflecting mechanism. In our previous research, the method for unifying worldwide data has been researched (Ogawa, et al. 2001). Therefore, we have the unifying method and can monitoring whole meteor activity at all times.

In 2001, the Leonids meteor showers was expected to show the great appearence in America, Asia and Australia (McNaught and Asher 1999; E. Lyytinen 2000; Lyytinen, et al. 2001). Therefore it was important to monitor Leonids activity at all times, and necessity to announce Leonids information. This study is the report of planning of global project for Radio Meteor Observation and the analysis of the Leonids active structure.

2. OBSERVING METHOD AND PARTICIPANTS

There are four types in Radio Meteor Observation. This is difference of using radio wave. The popular method in the world is the use of radio wave from FM radio broadcast station. This is named FRO (FM-band Radio Observation). Another method is the use of TV broadcast station. In Japan, the method using Ham-band radio wave is mejor. Finally it is the use of radar wave. In this project, there was no recommended method because it was difficult to observe by same system and method. Therefore, the original method each observers was recommended. In analysis of observaitonal data, this factor is corrected. Also, the observational period is at least 25 days from 1st to 25th November. The background level was also difined data from 1st to 14th. Then the result was reported by E-mail. The number of participants were 91 observing sites in 15 countries. In paricular, there were many sites in Japan (77sites).

3. ANALYZING METHODS

The unifying method of all data is "Activity Level" which is the relative value. By using this index, it became possible to unify all data, and we could see the whole Leonids activity. Around Leonids peak in Japan, however, it became impossible to count the number of echoes because of long echoes increase. Therefore, other analyzing method, "Reflection Time" was used.

3.1 Activity level

"Activity Level" was calculated the following formla (1). "H" means the number of echoes during a certain one hour "H". "H_0" means the average of "H" during two weeks, and it means the background echo rate. The calculated results, $AL(H)$ means how many times are echoes observed compared to background echo rate for a certain one hour "H".

$$AL(H) = \frac{\mathrm{H_0 - H}}{\mathrm{H_0}} \tag{1}$$

$$AL(H)_{total} = \frac{\sum_{\mathrm{i=1}}^{\mathrm{N}} \mathrm{AL(H)_i}}{\mathrm{N}} \tag{2}$$

The formla (1) calculates "Activity Level" at each site. Then each $AL(H)$ is averaged, and the total activity level "$AL(H)_{total}$" is calculated by the formla (2). $AL(H)_i$ means the $AL(H)$

at certain observational site "i". "N" is the number of observational sites. If there are no meteor activity, $AL(H)_{total}$ is around 0. In addition, since there are many observational sites in Japan, Japan is divided five areas, and further, next two factors are corrected.

One factor is the "radiant elevation facter". In this time, only data whose radiant elevation was from 20 deg. to 80 deg. were used. Then, the same factor as visual observaiton, $1/\sin(h)$ (h: radiant elevation) is corrected. Usually, since the reflecting mechanisum of radio wave is very complicated, the same factor as visual cannot be used. However, most of Leonids echoes are overdense echoes because the meteor geocentric velocity is very fast (about 70km/s). Therefore, in Leonids, it is possible to use this factor.

The other factor is the elimination of observing error. There are sometimes clear observing error data. Since $AL(H)_{total}$ is averaged all data, it is necessary to eliminate unusual data. This research defines $AL(H)$ within $\pm 1.5\sigma(H)$ is useful data. Finally, the parcentage of used data is 91 % of total.

3.2 The definition of "Reflection Time"

In Japan, it became impossible to count the number of echoes because of increases of long echoes around the Leonids peak. Therefore, we have to analyze by other method. Its method is to estimate Leonids activity from the reflection time of echoes. This method is named "Reflection Time". This analysis was expected Leonids peak structure and characters became clear. Almost of Japanese observers use the observational software "HROFFT" (for Windows). This software was developed by Mr. Kazuhiko OHKAWA. This software analyze the intensity of echo by FFT every one second. The intensity is shown "dB", ($X_{[dB]} = 10 \log P$, P:intensity). Then, in every 10 minutes, one observational image of PNG-file was produced.

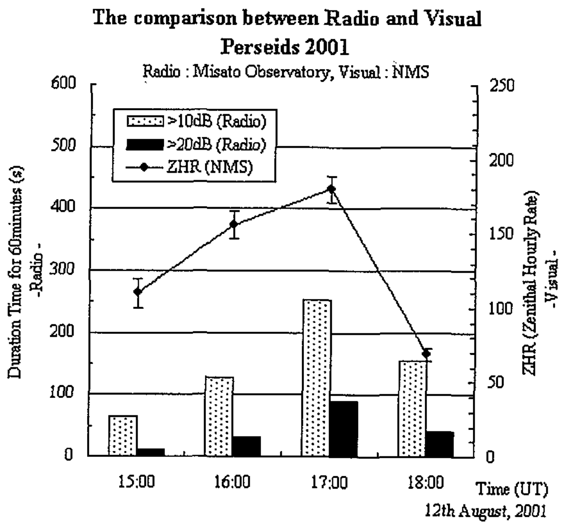

Fig. 1: The comparision between "Reflection Time" and visual observation (NMS)

In this time, the total time of more than definite echo intensity is researched every 10 minutes, and the definite echo intensity has four types which are 10 dB, 20 dB, 30 dB and 40 dB. Then the total time is defined "Reflection Time". Since the analysis using "Reflection Time" is first time, we needed to confirm this method was wether effective on estimating meteor activity or not. It was confirmed in Perseids 2001 which is similar in characters to Leonids. Figure 1 is the result of comparision between "Reflection Time" and visual observation result. Refletion Times of more than 10dB and 20dB echoes were researched. visual observation result was provided by *The Nippon Meteor Society (NMS)* (NMS (2001)). Both Reflection Time showed same trend as visual observation result. Therefore, this method is effective on estimating meteor activity.

4. RESULTS

4.1 The whole Leonids activity

The whole Leonids activity was analyzed by using 3.1 method. Figure 2 is the graph of its result. This value is calculated every one hour. Then three types sine curves are radiant elevation each site (Japan, USA and UK). The activity level means $AL(H)_{total}$. If there is no Leonids activity, "$AL(H)_{total} = 0$".

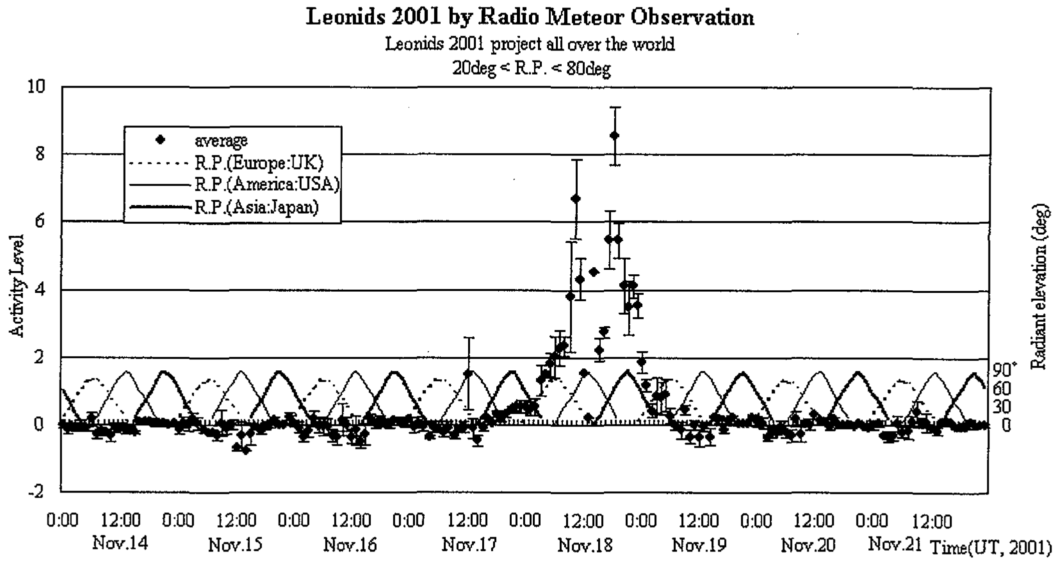

Fig. 2: The Leonids 2001 result

The Leonids clear activity began at 3:00 UT 18th. Then around 5:00 UT, the Leonids activity became high activity more and more. From 9:00 UT to 20:00 UT, the Leonids maximum was observed. The maximum was composed of clear two peaks and some small peaks. First peak was occered in America at 10:00 UT 18th. Second peak was in Asia an Australia at 18:00 UT 18th. Around second peak, however, it was impossible to count the number of echoes in Japan. Therefore, data around second peak were not sure. Maybe $AL(H)_{total}$ value was much higher than this result.

Clear two peaks corresponded to the Visual Observational result. Visual Observational result is the report by *International Meteor Organization (IMO)* (Arlt et al, 2001). The first peak corresponded to the report of ZHR 1,620 at 10:39 UT in America. Then the second peak, main peak corresponded to the report of ZHR 3,430 at 18:16 UT in Asia and Australia.

4.2 The peak structure and characters

Around the main peak, it became impossinle to count the number of echoes because of increases of long echoes. Therefore, Japanese data were analyzed by "Reflection Time" method, and the effectiveness of this method has already confirmed in the previous section. In this time, the reflection time of meteor echoes with the intensity over 10 dB, 20 dB, 30 dB and 40 dB every 10 minutes was researched. The number of observational sites is 26 sites. From this results, the peak structure and characters were become clear. The peak structure is very complicated and we found the unpredicted peak.

The Reflection Time Analysis

All 26 site were analyzed, and some analyzed data are shown in Figure 3. This result is the reflection time of echoes with the intensity over 20dB and Fig.4 is the reflection time over 30dB. These observational sites are Hakodate, Tsukuba, Aichi and Tokushima. Data were analyzed every 10minutes. The curve is a radiant elevation.

Most of the observation sites showed the same trend to have clear two peaks. Since Japanese data corresponded to the main peak, the main peak composed of two clear peaks. One was around 18:20–18:30 UT. The other was around 21:20 UT. Each half width time was $+88$ min./$-$96 min. and $+46$ min./-42 min. From the previous confirmation of this method and the same trend in many observation sites, this activity curve was real. Besides, since most of Leonids meteor echoes are overdense echoes, it is possible to ignore the effectiveness of radiant elevation when the radiant comes around zenith. Therefore, this activity curve was real and the main peak was composed of two different clear peaks. On the 21:20 UT peak, since Japan came morning twilight from 20:00 UT, this trend was not confirmed clearly by visual observation. However, there were many visual reports which was to see some meteors in morning twilight sky.

There was no clear peak like the reflection time of echoes with the intensity over 20 dB. The meteor echo with the intensity over 30 dB correspond to bright meteor like fireball. Therefore, the bright meteor activity (fireball component) was very flat. Although there were fireball component during Leonids maximum, this was not high activity and not high meteor density. This trend has already been confirmed in the visual observational research. From this research, the activity of meteors of magnitude -2 or brighter appears to be nearly constant (Ogawa and Uchiyama 2001).

On the other hand, detailed peaks are observed simultenously from several observational sites. This is shown in Figure 4 with alphabets. The time of each alphabet was 16:50, 17:20, 18:20, 19:10 and 21:00 UT. This result means the appearence time of fireballs. Because the meteor echoes with the intensity over 30 dB correspond to big fireball meteors, then the fireball meteor leaves meteor train. Therefore, these small peaks were produced by the big fireball meteors and their persistent trains. At least, five fireballs appeared, and some of them were confirmed visual observation, too (Shiba 2002).

5. CONSIDERATION AND DISCUSSION

5.1 The wide high Leonids activity

Leonids high activity kept from 5:00 UT 18th to 0:00 UT 19th. In the previous Leonids activity, the high activity time was very narrow (Arlt et al. 1999). In 2001, however, the half

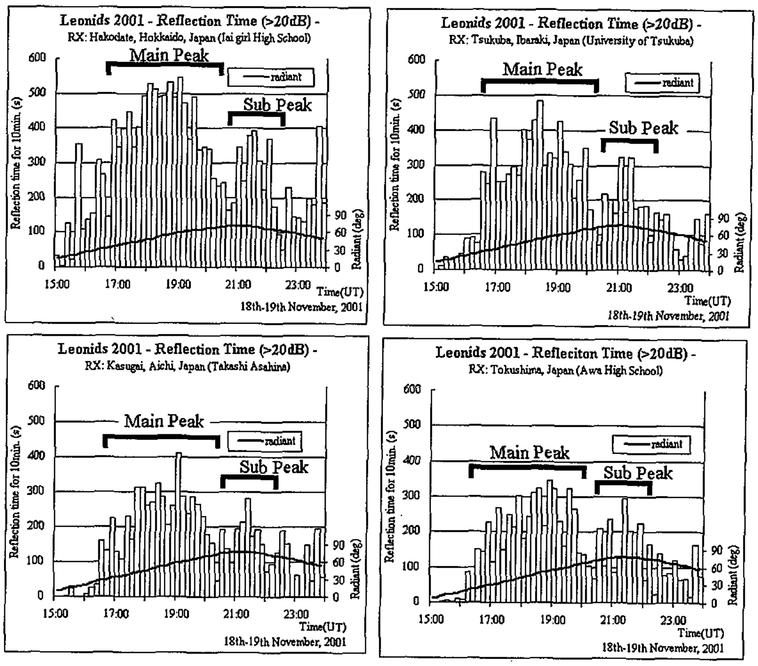

Fig. 3: Reflection Time results of meteor echos with the intensity over 20 dB in 10 minute bin

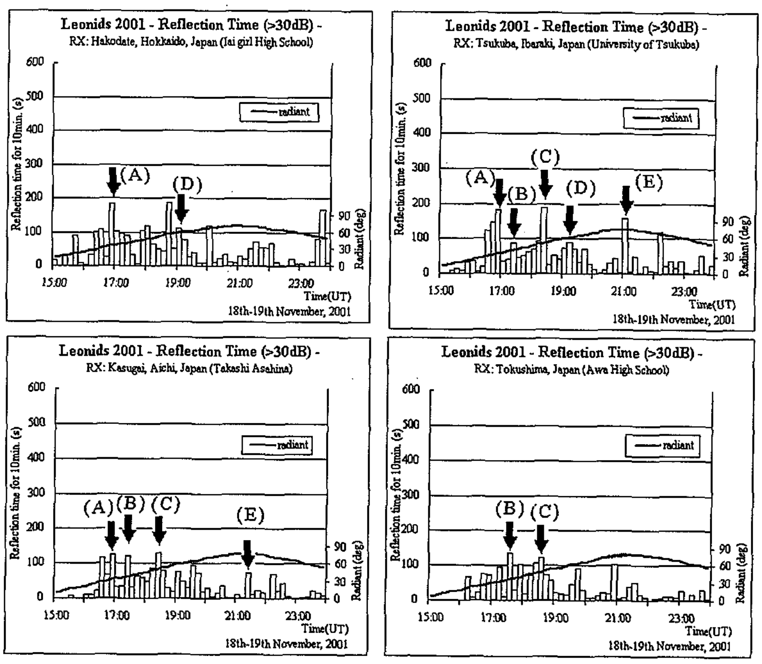

Fig. 4: Reflection Time results of meteor echoes with the intensity over 30 dB in 10 minute bin

width time of main peak was six hours. Given the revolution velocity of the earth and the orbital inclination of the parant comet, we can calculate the dust trail length of each peak. The v_E is 30 km/s, and i is 163 degrees. In 2001, the total width of dust trail corresponded to 1.9×10^5 km. Since it was 3.1×10^4 km in 1999, it was six times longer than that in 1999. The prediction by E. Lyytinen, et al. is also the 6.0×10^4 km (Lyytinen, et al. 2001). Therefore the high activity of the main peak of the Leonids in 2001 kept for a long time.

5.2 The complicated peak structure

From the reflection time of echoes with the intensity over 20 dB and 30d B, the Leonids peak structure were estimated. The reflection time of echoes with the intensity over 20dB showed two different peaks. On the other hand, over 30 dB was flat activity, then this trend was fireball compornent. The total length on the dust trail orblt of each peak was estimated as next. The main peak was $9.68 \pm 0.96 \times 10^4$ km, the sub peak was $4.63 \pm 1.01 \times 10^4$ km and the fireball compornent was $1.75 \pm 0.32 \times 10^5$ km. Given the earth went through the center of dust trail and the dust trail width was real circle, the position map of dust trails around maximum can be shown as Figure 5.

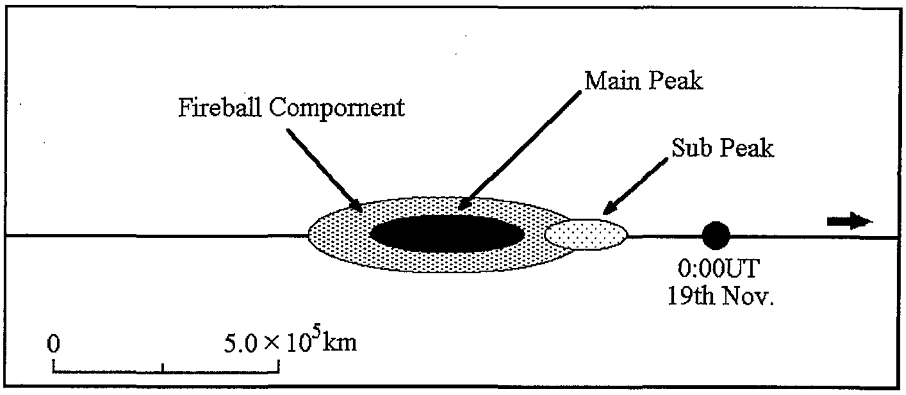

Fig. 5: The dust trails position around Asian and Australian peak

In Figure 5, the straight line is the orbit of the earth, and the black dot is the position of the earth on 0:00 UT 19th November. The earth moves from the left to the right. The main peak dust trail was high in density of meteoroids. On the other hand, the fireball compornent was low in density.

Then we also compared between predicitions and results. At this time, predictions by two research groups are used (McNaught 2001, and Lyytinen, et al. 2001). The main peak corresponds with two dust trails that are generated from four and nine revolutions. However it was impossible to separate these two dust trails. The sub peak is not corresponded to their predictions. Therefore this peak was unpredicted and an unexpected peak. Also, the fireball compornent is background of either the four and nine revolution dust trails or 10 and 11 revolution dust trails.

6. CONCLUSION

In the 2001 Leonids, the great meteor activity was shown and the Radio Meteor Observation project was able to monitor the whole Leonids activity. The main peak strucutre was also clearly identified by Japanese results. From the research of the whole Leonids activity, it became clear when the Leonids peak time and how long the high activity was kept. The peak time was between 10h and 18h 18th UT. In addition, some sub peaks were observed. The high activity ($AL(H)_{total} > 2$) kept about 19 hours from 5:00 UT 18th to 0:00 19th. The half width time of first peak in America was three hours and the main peak in Asia and Australia was six hours. There were few Leonids activities except the maximum day.

From the reflection time of echoes with the intensity over 20 and 30 dB, the peak structure and characters were clarified. The result of echoes with the intensity over 20 dB found two different sub peaks within the main peak. Since there were not enough visual results around 21:00 UT, this information was very important for understanding Leonids activity better. On the other hand, the result of echoes with the intensity over 30 dB caught the compornent of bright fireballs. Some detailed peaks were observed by several observational sites at the same time. Then its compornent showed a very flat peak with the low meteor density.

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