Research for the Characteristics of Meteor Showers from Multi-Frequency Radio Observation

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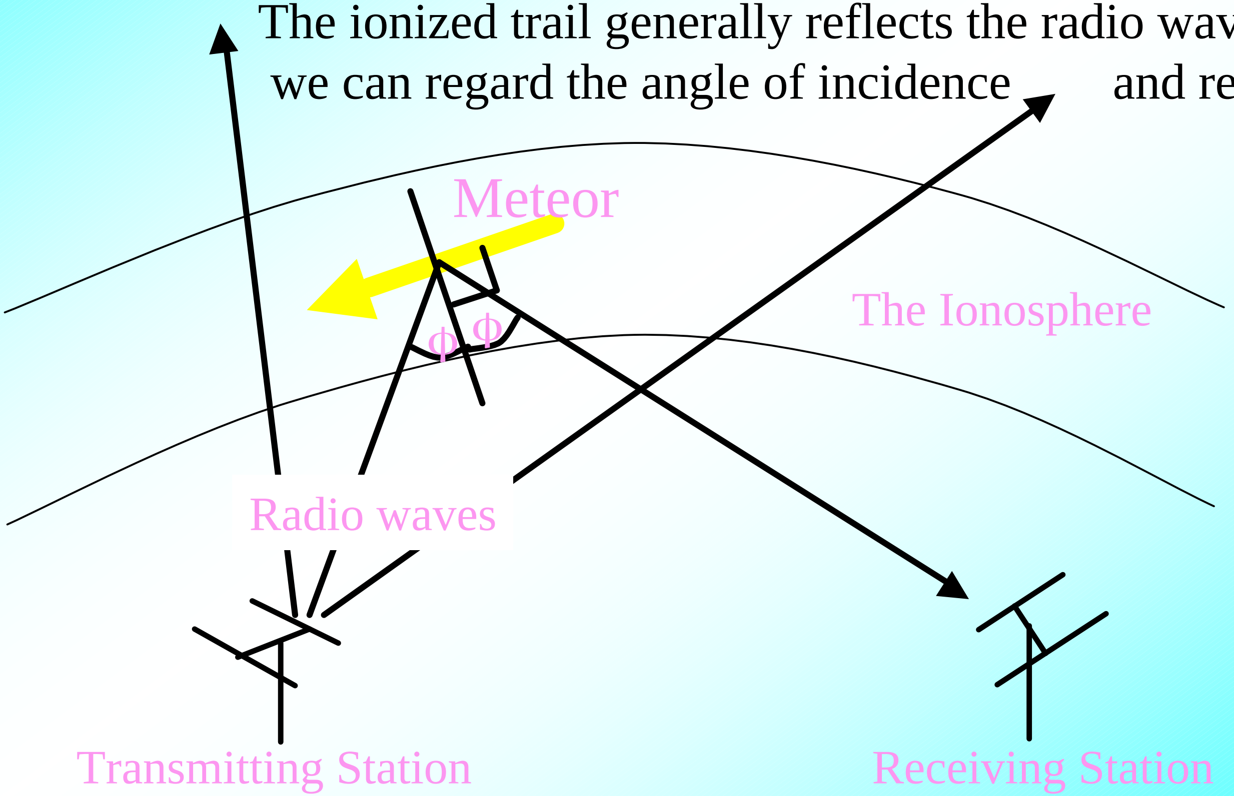
Introduction

☆ What is "Radio Meteor Observation"?

When a meteor comes into the atmosphere, it ionizes the molecules, atoms, and ions. Electrons can vibrate easier than nucleuses and scatters radio waves of VHF band wavelength which usually go through the ionosphere. The ionized area called "ionized trail".

The ionized trail generally reflects the radio waves as a mirror, so we can regard the angle of incidence and reflection are the same (f).



When we use radio for observation, observers (at Receiving stations) receive the radio scattered by meteors transmitted from Transmitting station. If the Receiving and Transmitting stations are at the same place, which means $f = 0$, this scattering system called "back scatter", and if $f > 0$, it called "forward scatter". Back scatter observation is sometimes called "radar" observation.

The figure above shows the system of forward scatter, and most Japanese observers adopt the forward scatter.

☆ There are many kinds of Radio Meteor Observation

We use some radio waves of various frequencies like this for forward scatter observation.

FRO (**F**M-band **R**adio **O**bservation)
・・・around 80MHz (76.0-108.0MHz)

HRO (**H**am-band **R**adio **O**bservation)
・・・28MHz,53MHz,144MHz

VOR (**V**HF **O**mni directional **R**ange)
・・・113MHz

In Japan, most observers do HRO, especially 53MHz radio transmitted by Fukui NCT (operated by K. Maegawa).

～ What do Different Frequencies bring? ～

Different Frequency Radio has Different Energy !!

LOW Frequency radio has LOW Energy

⇩

Even LOW Density Ionized Trail can scatter the radio

⇩

Even LOW Energy Meteor we can observe

⇩

Relatively Dark Meteor can be observed !!

So, what magnitude is the darkest we can observ

First, I calculated the higher limit of the height that underdense echoes can be received effectively, namely **Ceiling Height** from below equations.

$$Hc = 82 + 49\log_{10} V - 4.4\log_{10} q \qquad (1)$$

$$Mr = 36 + 2.5\log_{10} V - 2.5\log_{10} q \qquad (2)$$

$$\log_{10} r_0 = 0.075 \times Hc - 7.9 \qquad (3)$$

$$\log_{10} D = 0.067 \times Hc - 5.6 \qquad (4)$$

$$L_P \approx 3.8 \times 10^5 \times \frac{D}{(l \sec f)^{\frac{3}{2}} V} + 3.4 \times 10^2 \times \left(\frac{r_0}{l \sec f} \right)^2 \qquad (5)$$

$$L_{dB} = 10 \times \log_{10} L_P \qquad (6)$$

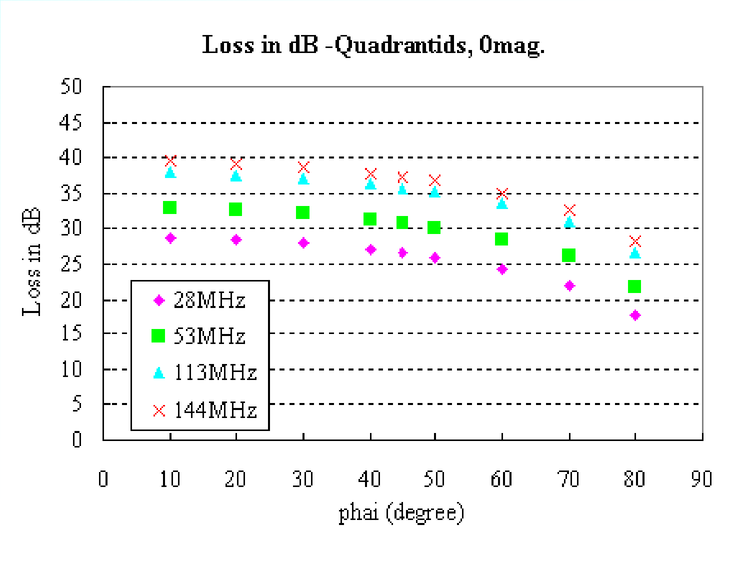
Hc : Ceiling Height (km)
q : electron density (m^{-1})
r_0 :initial radius of ionized trail (m)
L_P : total Power Loss
L_{dB} : Loss in dB (dB)

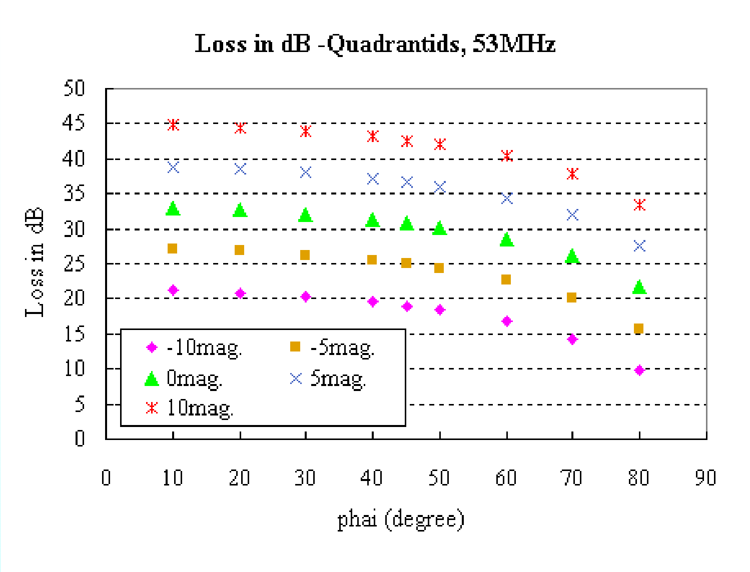
V : Geocentric Velocity (km/s)
Mr : radiation Magnitude (mag.)
D : coefficient of electron Diffusion
l : wave length (m)

Note: about ϕ

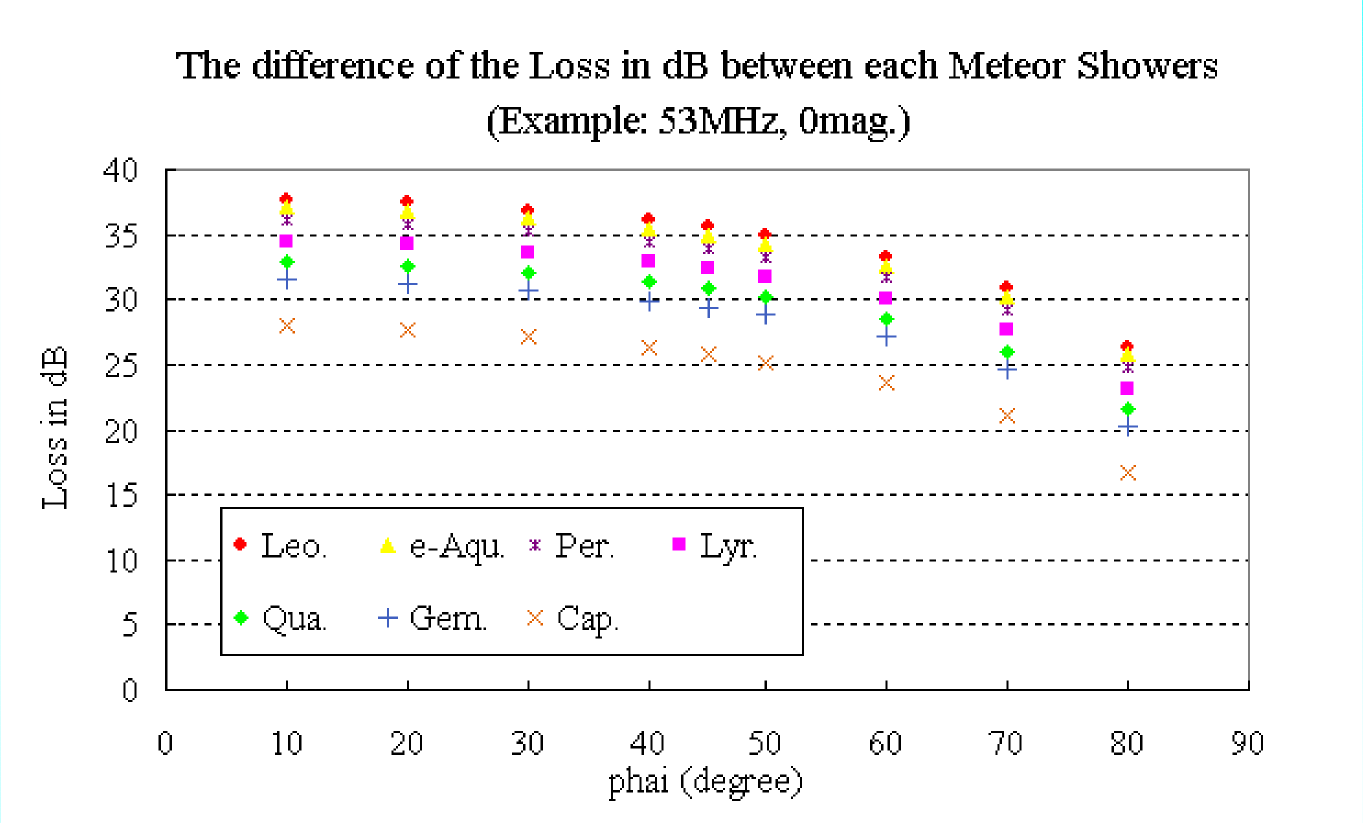
$$L_P \approx 3.8\times 10^5 \times \frac{D}{(l \sec\phi)^{\frac{3}{2}} V} + 3.4\times 10^2 \times \left(\frac{r_0}{l \sec\phi}\right)^2 \qquad (5)$$

Now forward scatter is discussed, ϕ doesn’t change to $0°$ and $90°$.
(If $\phi = 0°$, it is back scatter. And if $\phi = 90°$, it means the meteor appeared at the height of 0 km !!)
So I calculated under an assumption that ϕ changes from $10°$ to $80°$.
When ϕ changes, the Loss in dB also changes.





And these graphs about other meteor showers are very resemble in the shape.



From these graphs, we can see that the "Loss in dB"s of these seven meteor showers are almost same from $10°$ to $50°$, so, this time, I adopt the value of $f = 30°$ typical one of the values from $10°$ to $50°$.

From now on, all result of calculations are based on this value.

The list below shows the calculated result of Ceiling Height (km) and darkest Magnitude (mag.) about major meteor showers and frequencies. We always observe meteors shot under than these heights and brighter than these magnitudes.

	V	28MHz	53MHz	113MHz	144MHz
Quadrantids	41 km/s	108.2km 10mag.	101.1km 6mag.	94.1km 2mag.	92.3km 1mag.
Lyrids	49 km/s	108.1km 8mag.	102.8km 5mag.	95.8km 1mag.	92.3km -1mag
Capricornids	23 km/s	104.0km 14mag.	97.0km 10mag.	89.9km 6mag.	88.2km 5mag.
Perseids	59 km/s	109.9km 7mag.	104.7km 4mag.	95.9km -1mag.	94.1km -2mag.
Leonids	71 km/s	111.8km 6mag.	104.7km 2mag.	97.7km -2mag.	95.9km -3mag.
Geminids	35 km/s	106.9km 11mag.	99.8km 7mag.	92.8km 3mag.	91.0km 2mag.

Doing Multi-Frequency Radio Observation enables to know the meteor activity based on magnitude !!

Note: about height range (lower limit)

The previous research of back scatter observation shows that the lower limit is generally around 80km height or so. Therefore I consider the lower limit as an altitude of a little higher than 80km this time.

However, there is an idea that the height of the lower limit (H_L) of the low frequency radio is higher than that of the high frequency radio.

When we use the lower frequency radio waves, the duration time of meteor echoes at the same height will be longer. Then, when we use lower frequency radio, it is difficult to distinguish echoes scattered by the meteors and the ionosphere. In this condition, we cannot "observe" meteors.
So, in order to "observe" meteors (the duration time mustn't be too long), the magnitude of meteors must be darker. This means that the height of the meteors become higher. Therefore, the height of the lower limit for observation by low frequency is higher than that of high frequency.

Purpose and Merits

Purpose

Search for the characteristics of meteor showers by the keyword of “brightness”!!

Merits (If this study succeed, we’ll be able to….)

Radio waves can be received even in the daytime or on the rainy day

- Monitoring Outburst
  (We’ll be able to know the characteristics of the outburst which was unknown before)
- Radio Meteor Observation reveals not only the variation of the echo number but also the characteristics of the meteor shower !!
  (Even if a meteor shower wasn’t visually observed for the bad weather all over the country/world.)

Method

Gather the results of Radio Meteor Observation
using some kinds of frequencies

(Data from RMO project)

Compare the number of meteor echoes between different frequencies

1. Compare the numbers of the echoes by different frequencies directly at once

   ⇒ We can see the change of the number of echoes

2. Consider the Ratio of the number of the echoes

   ⇒ We can see the change of the brightness

   (The lower frequency we use, the darker meteors we observe)

Note: about Ratio

The term “ratio” means….

Generally, when we use radio wave of lower frequency, we’ll receive more echoes. So the numbers of the echoes align like

“114MHz < 113MHz < 53MHz < 28MHz.”

(Since these radio waves watch different height sky as the list above, they don’t always align like this.)

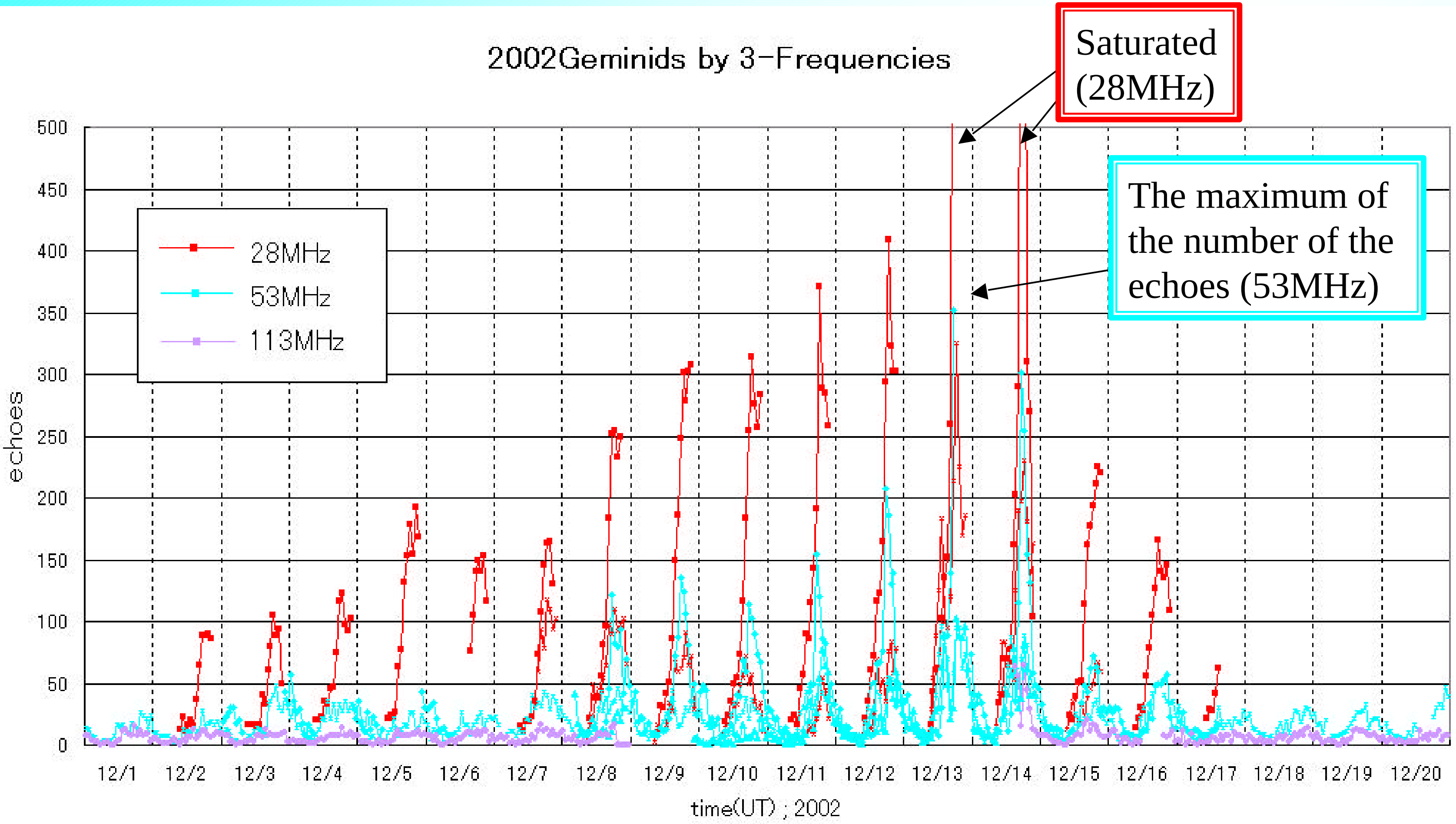
Based on this assumption, I compared their observed results by the viewpoint of the rate of the echo number of “higher frequency / lower frequency”, such as “53MHz / 28MHz” ratio.

Since these radio waves watch until different magnitude meteors as the list above, and higher frequency radio wave is watching only brighter meteors, the change of this ratio shows the change of the ratio of bright meteors to the whole.

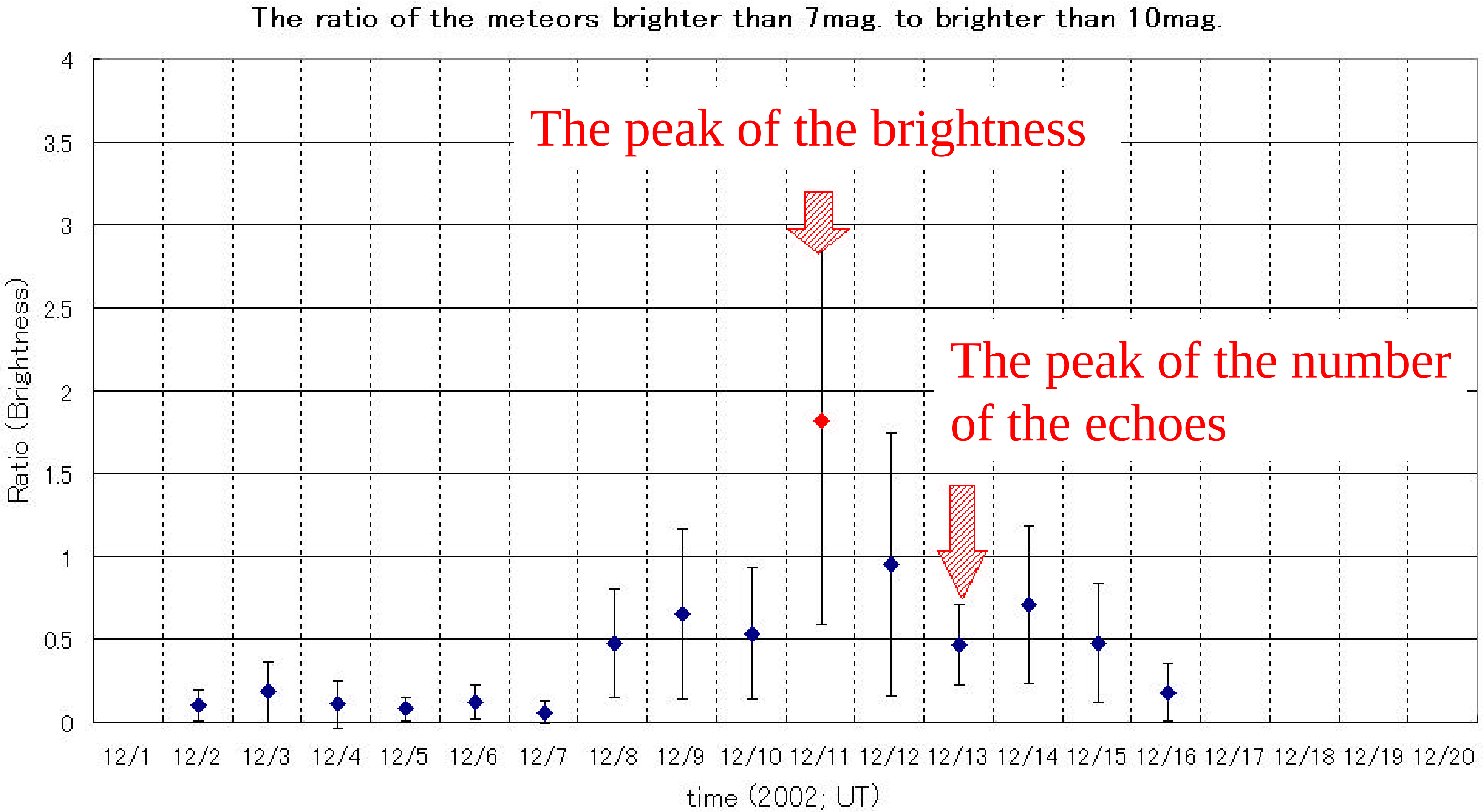
From now on, let’s regard the ratio of the number of echoes as the ratio of brightness.

Results 1

☆ 2002 Geminids



☆ 2002 Geminids --- The daily average of the ratio (53MHz/28MHz)



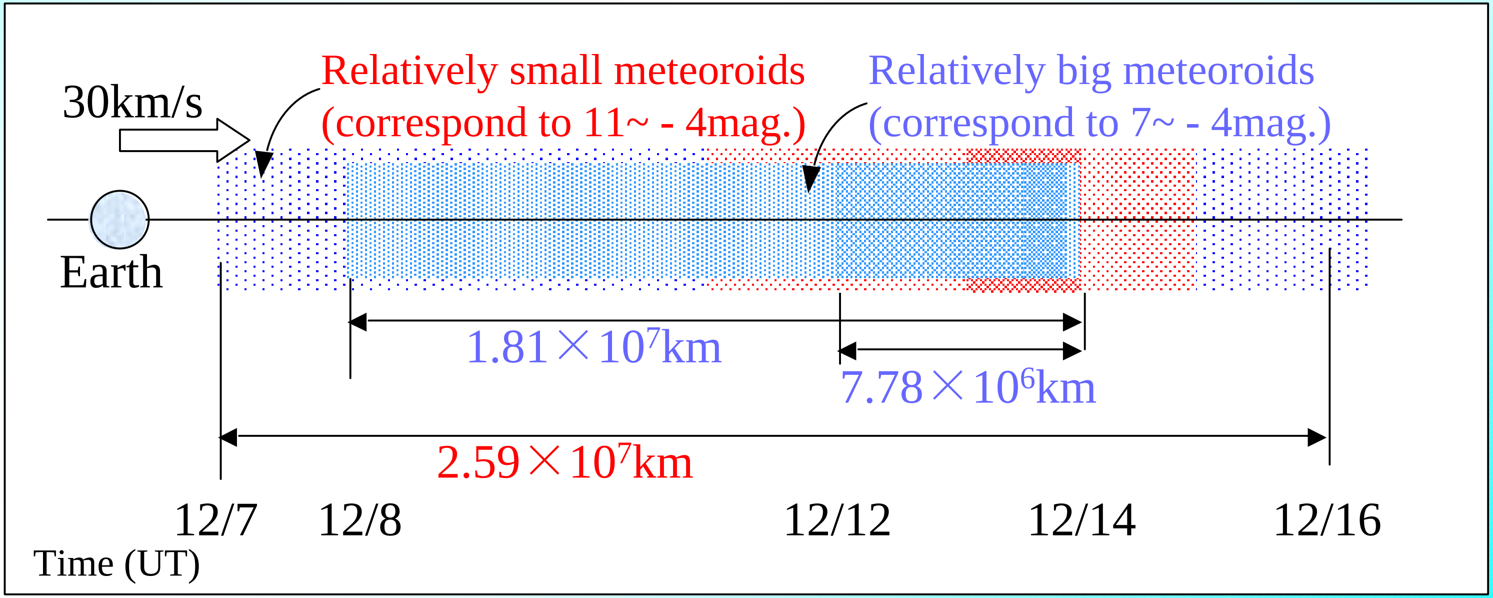
Sometimes the ratio exceeds 1.0 . This may be partly because the areas (not only height) of the sky these different radio waves differ.

☆ 2002 Geminids

28MHz(11~-4mag.) Activity : Dec.7th~Dec.16th UT
Peak : Dec.13th~14th (saturated)

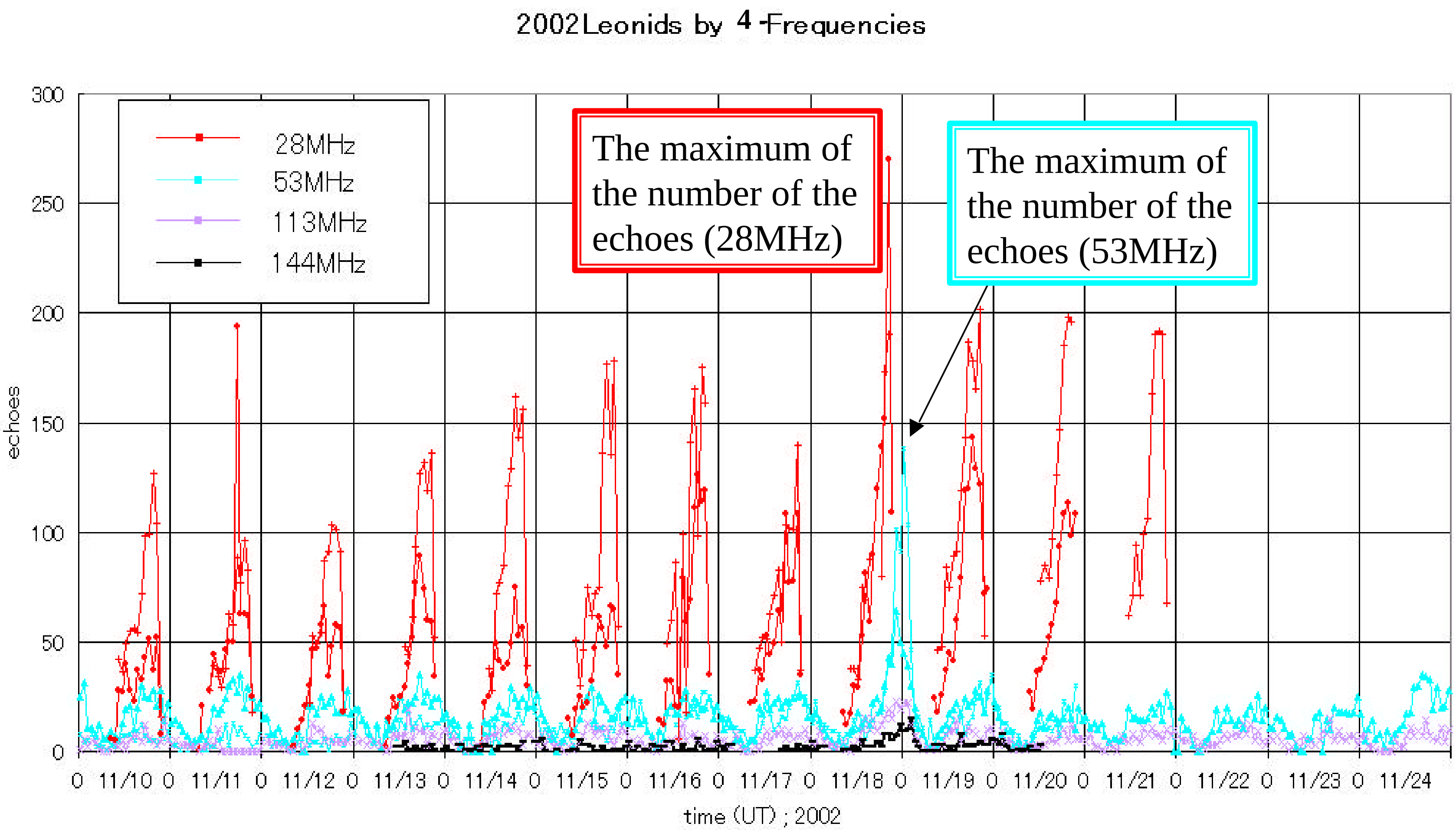
53MHz(7~-4mag.) Activity : Dec.8th~Dec.14th
Peak : around Dec.13th 17h

113MHz(3~-4mag.) Activity : decreasing Dec.14th~15th
Peak : no data gained

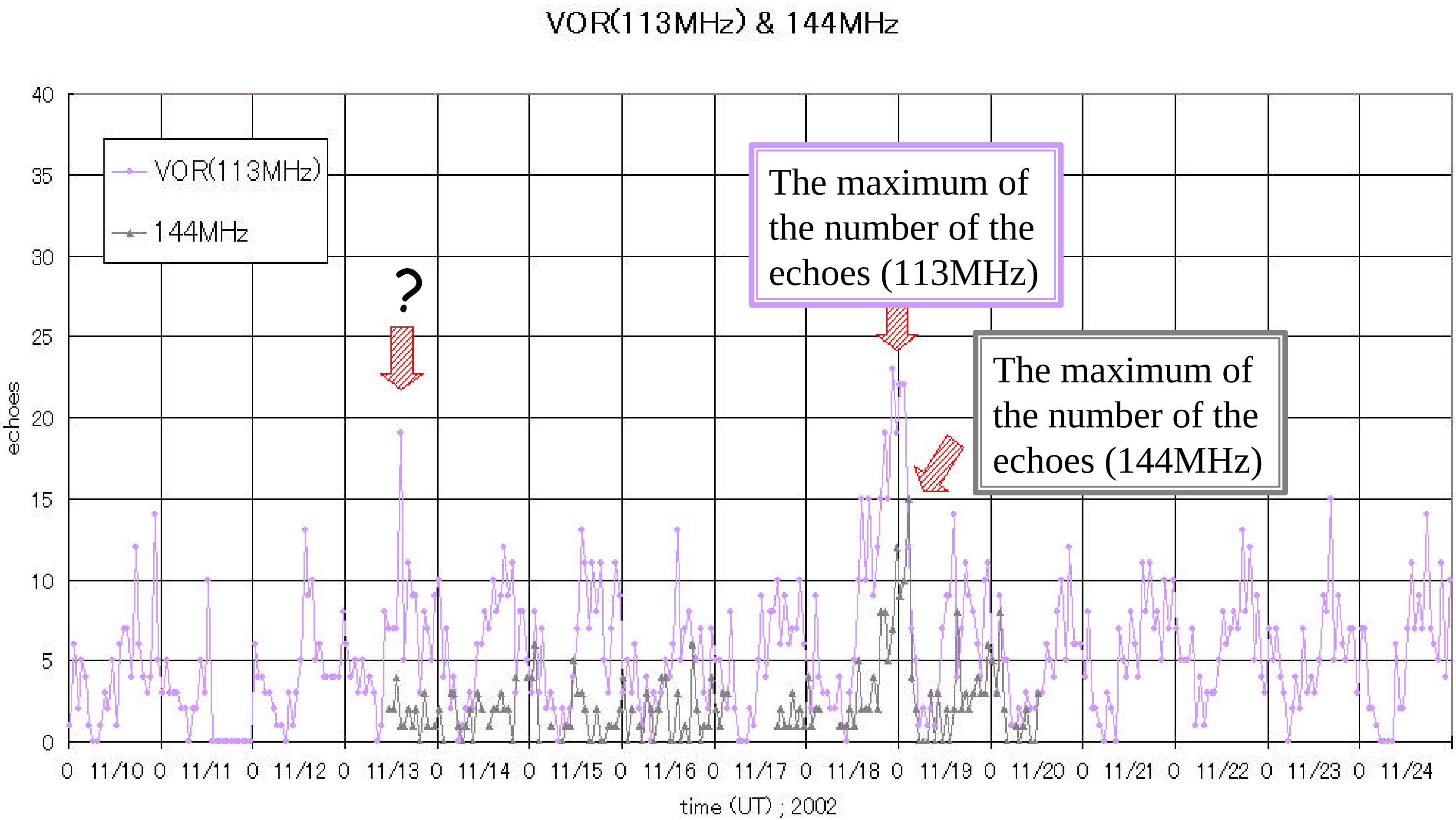


Results 2

☆ 2002 Leonids



☆ 2002 Leonids



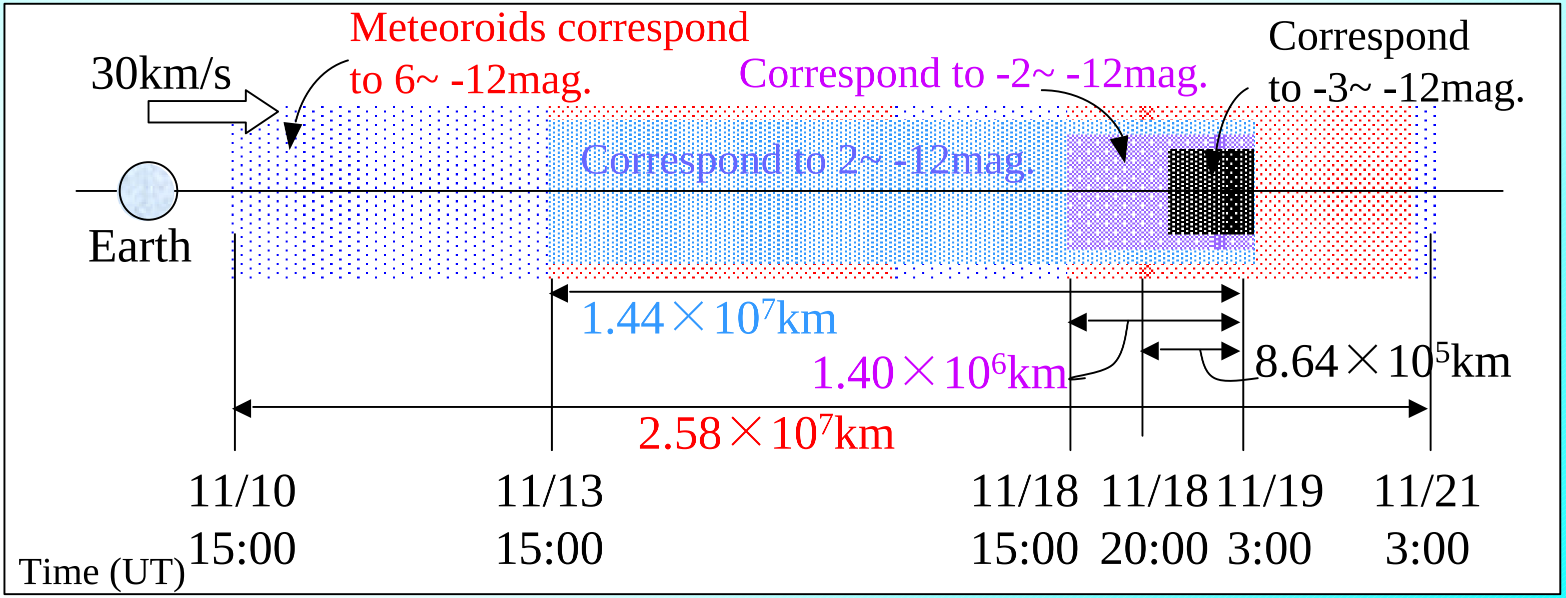
☆ 2002 Leonids

28MHz(6~-12mag.) Activity : Nov.10th 15h ~ Nov. 21th 3h
Peak : around Nov.18th 20h

53MHz(2~-12mag.) Activity : Nov.13th15h~ Nov.19th 3h
Peak : around Nov.19th 0h

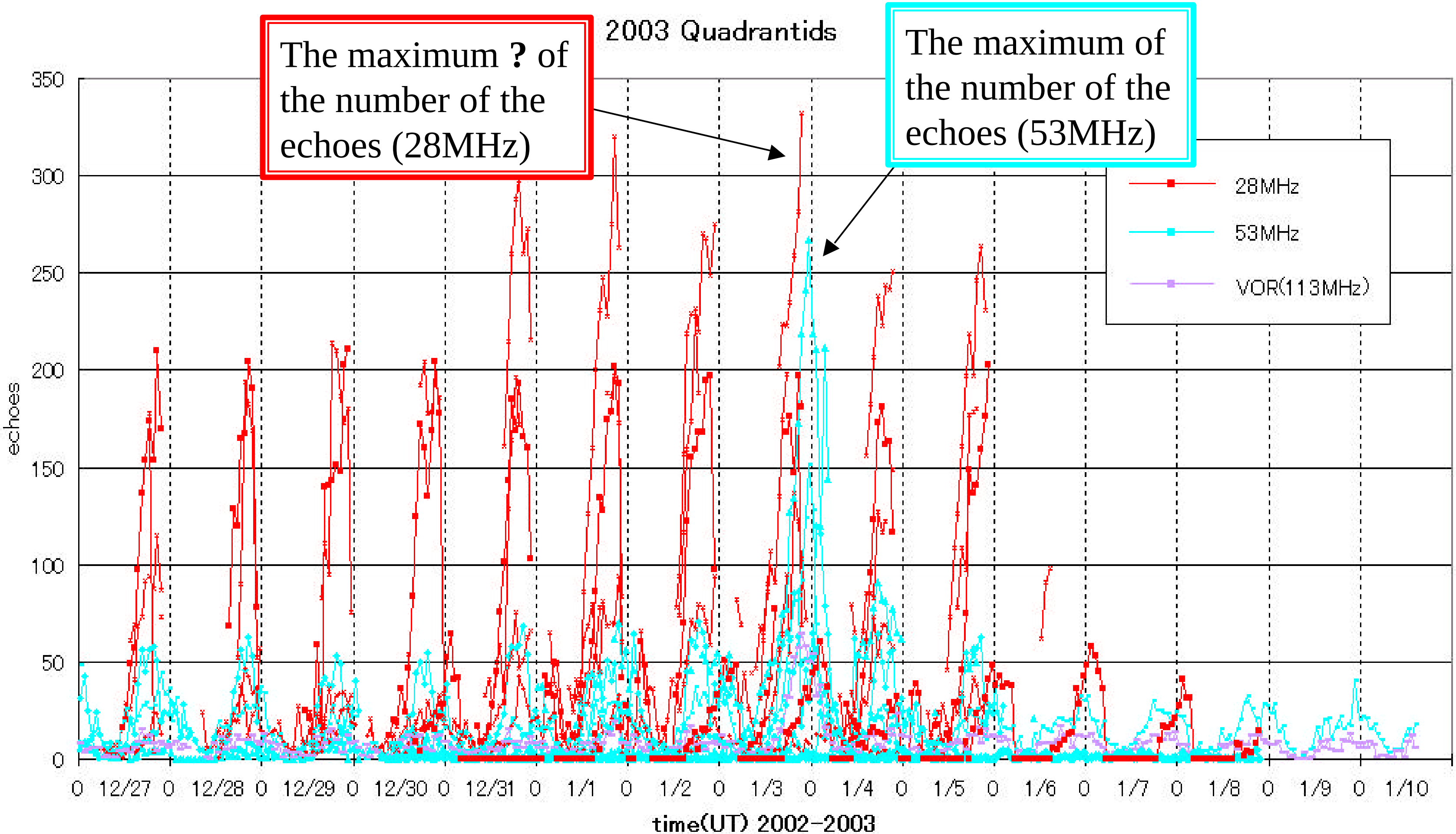
113MHz(-2~-12mag.) Activity : Nov.18th 15h ~Nov.19th 3h
Peak : around Nov.18th 22h ~Nov.19th 1h

144MHz(-3~-12mag.) Activity : Nov.18th 20th~Nov.19th 3h
Peak : Nov.19th 2h

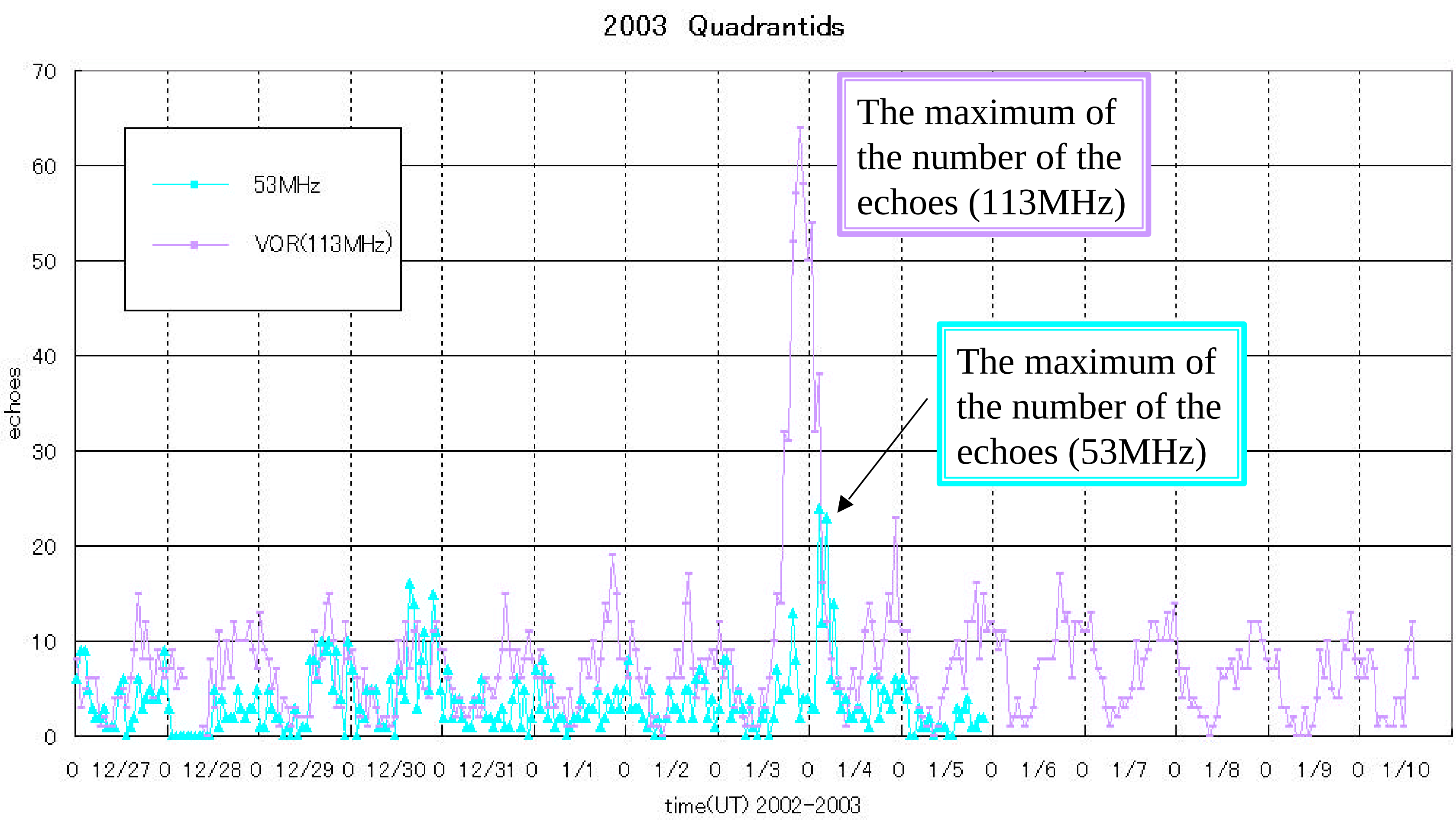


Results 3

☆ 2003 Quadrantids



☆ 2003 Quadrantids

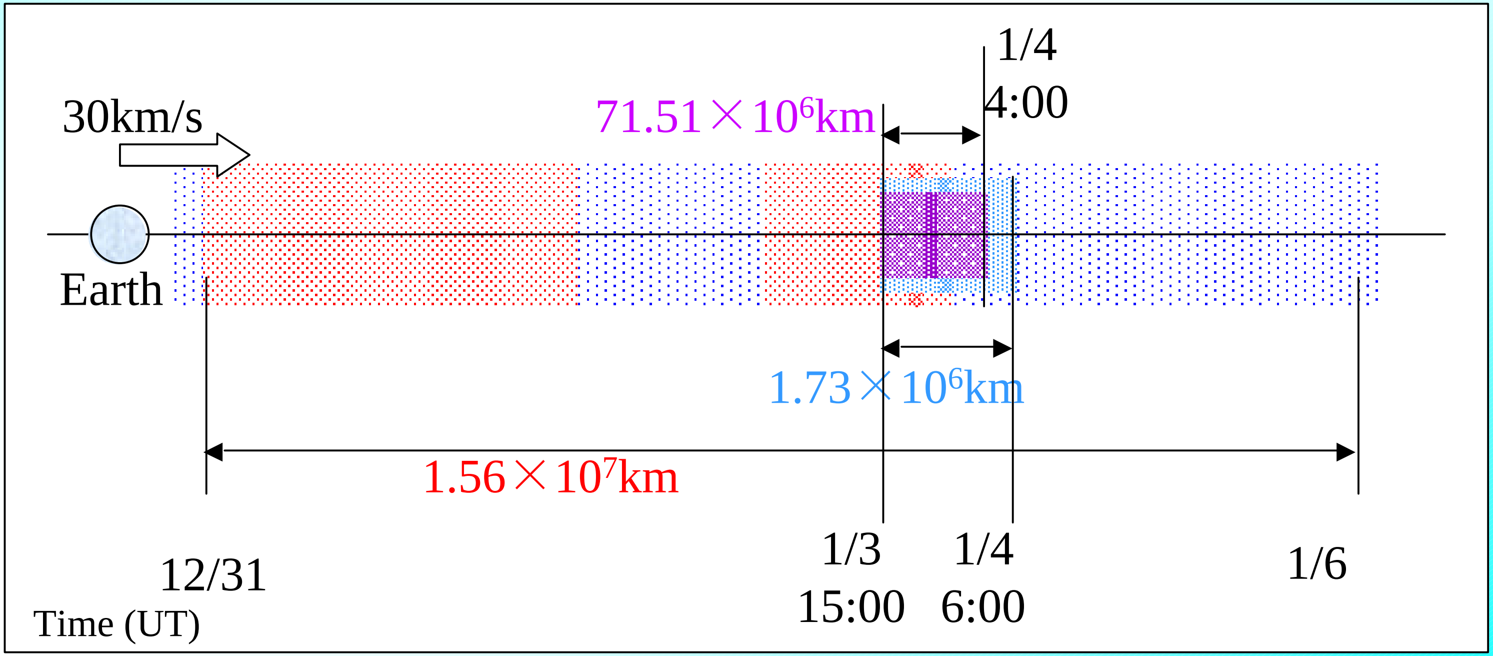


☆ 2003 Quadrantids

28MHz(10~-6mag.) Activity : Dec.31th(2002)~Jan.5th(2003) ?
Peak : around Jan.3th20h ? (very obscure)

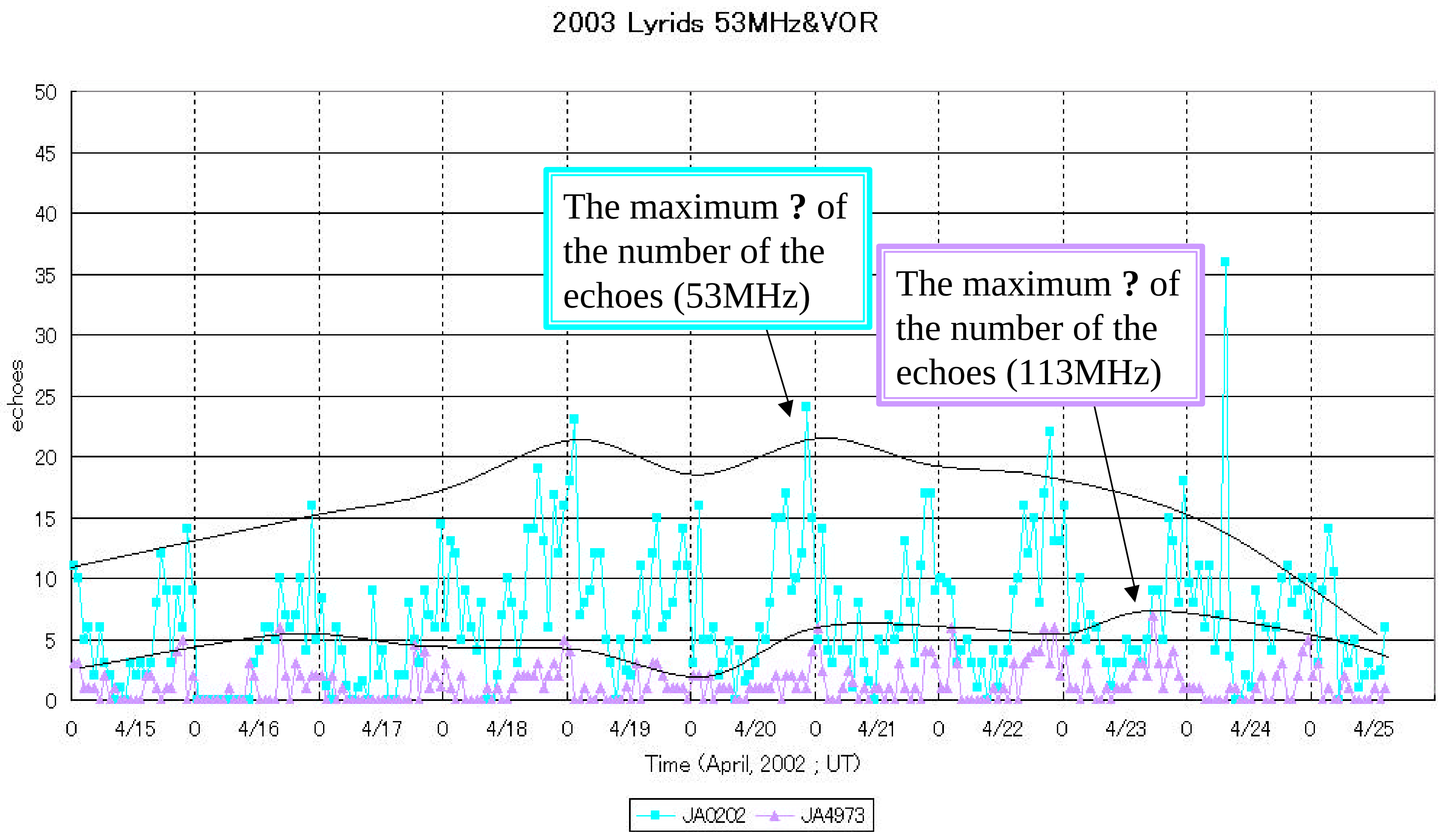
53MHz(6~-6mag.) Activity : Jan.3rd15h~ Jan.4th6h
Peak : around Jan.3rd23h (sharp peak)

113MHz(2~-6mag.) Activity : Jan.3rd15h~ Jan.4th4h
Peak : around Jan.3rd21h (sharp peak)



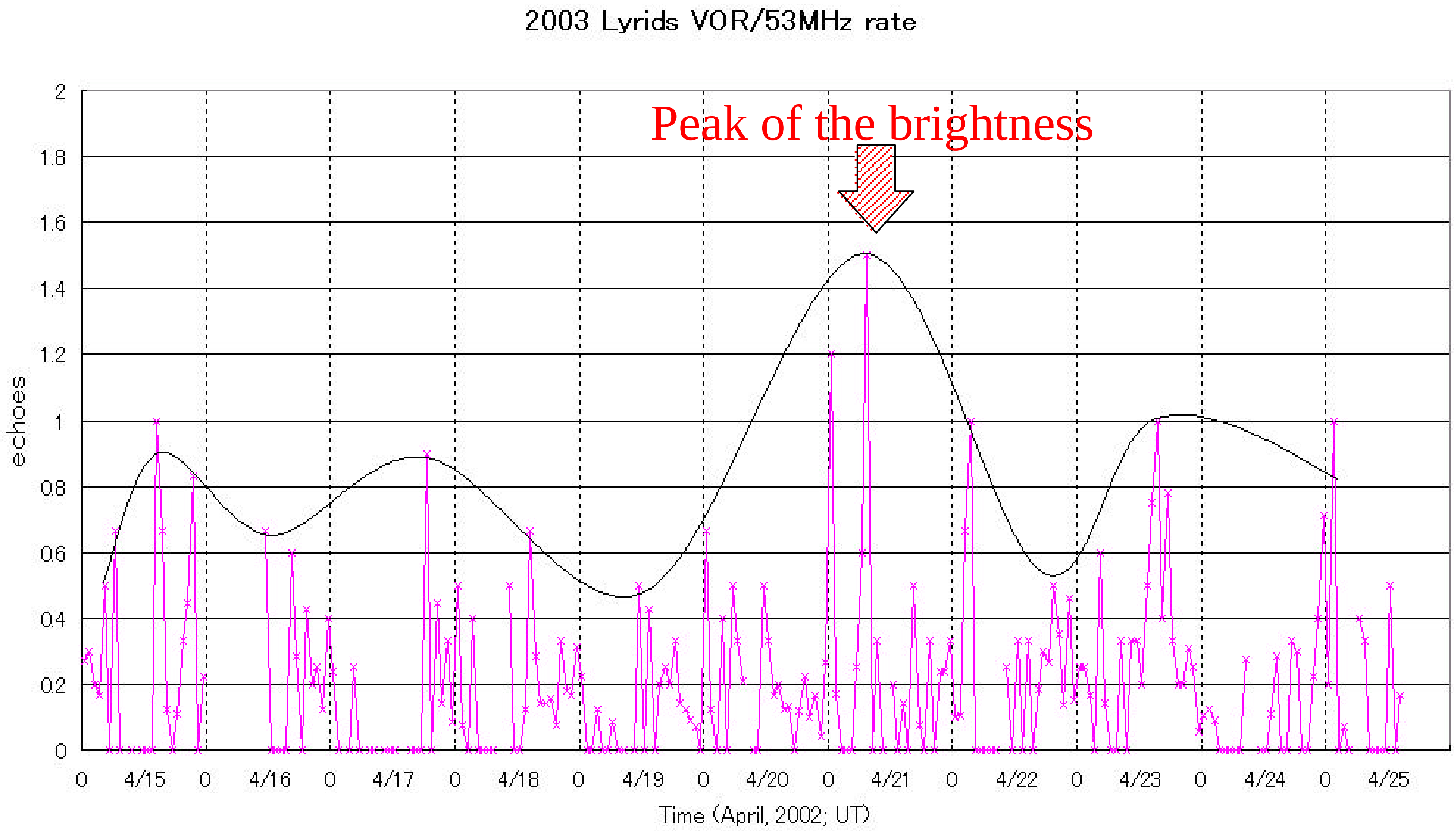
Results 4

☆ 2003 Lyrids



☆ 2003 Lyrids

This graph shows the change of the rate of bright meteors to the whole.



☆ 2003 Lyrids

・・・*Wholly gentle hilly activity*

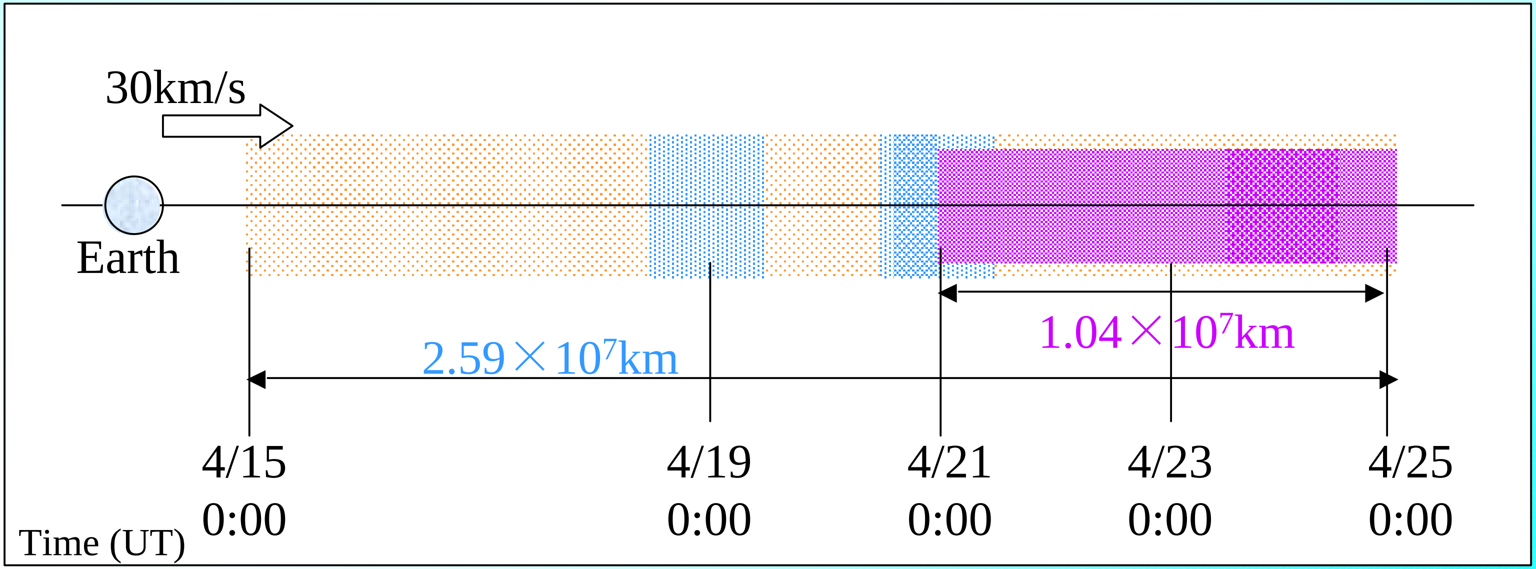
53MHz(5~-7mag.) Activity : Apr.15th 0h~Apr.25th 0h

Peak : around Apr.20th 22h (different by cite)

113MHz(1~-7mag.) Activity : Apr.21st 0h~Apr.25th 0h

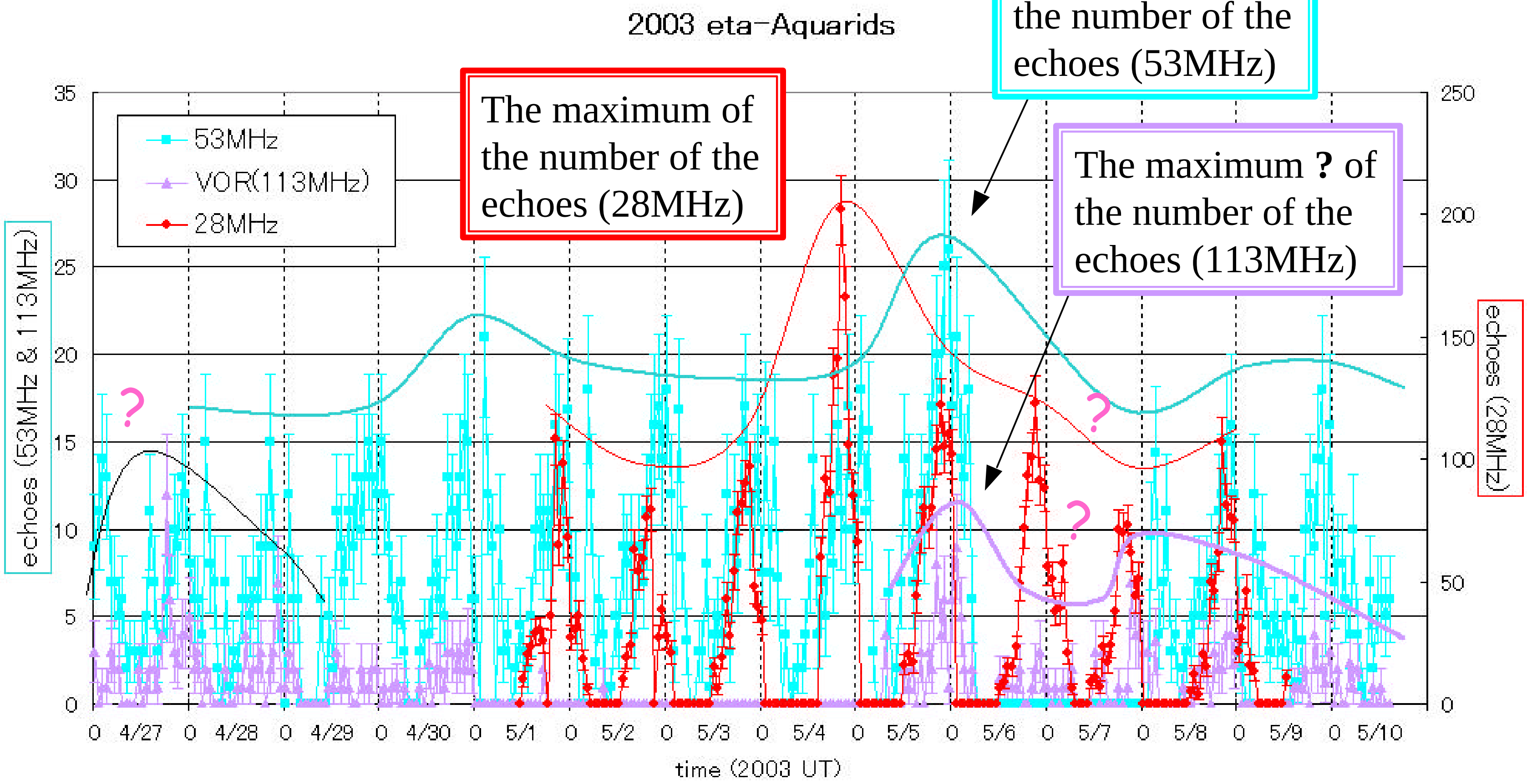
Peak : around Apr.23rd 17h (different by cite)

The ratio of the brighter meteors (1~-7mag.) to whole meteors(5~-7mag.) is the highest at around Apr.21st 7h. (by the ratio of 53MHz and 113MHz)



Results 5

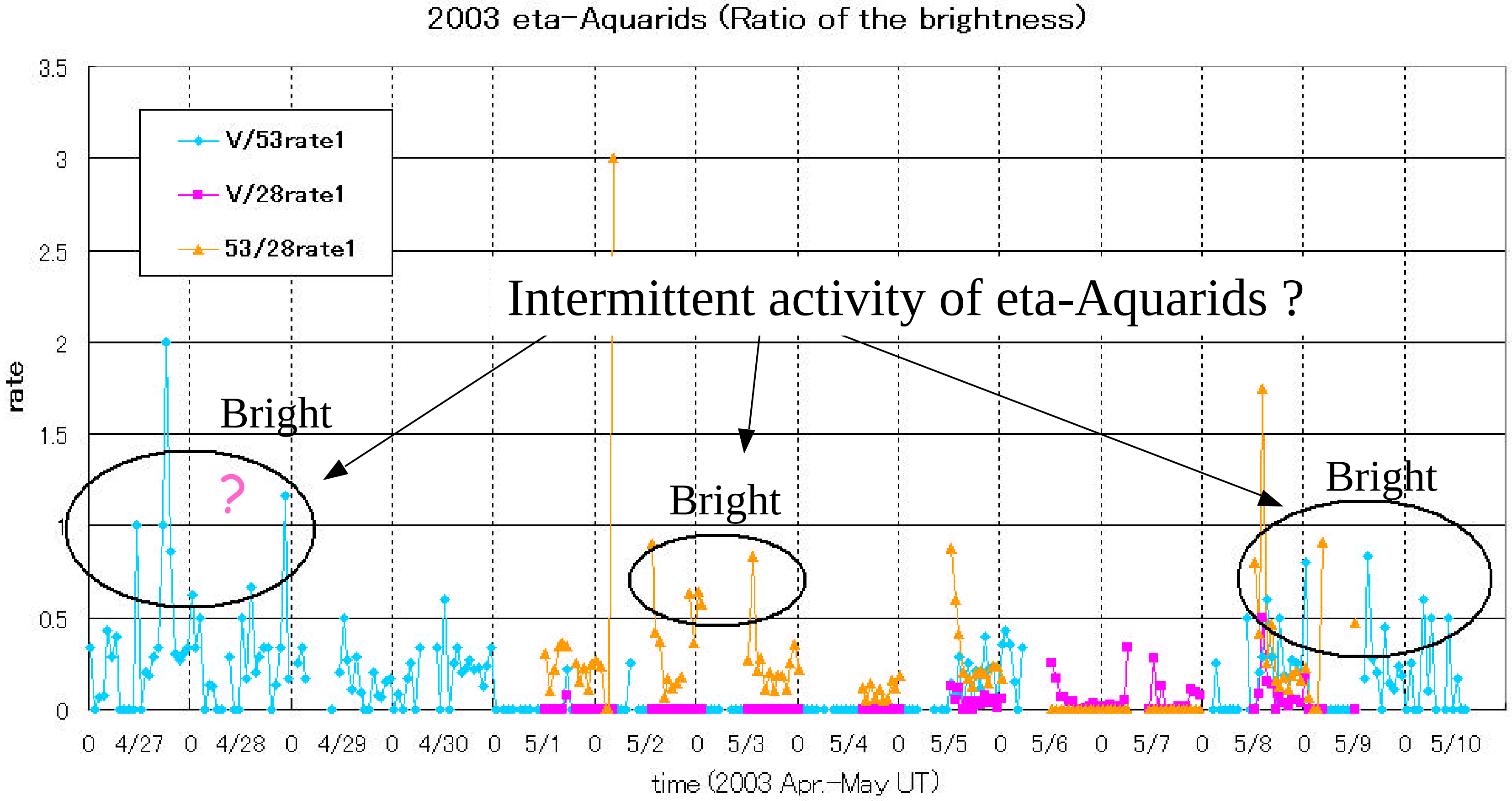
☆ 2003 eta-Aquarids



？ Why echoes increased on Apr.27 ? Why they decreased on May 7 ? ？

☆ 2003 eta-Aquarids

This graph shows the change of the rate of bright meteors to the whole.

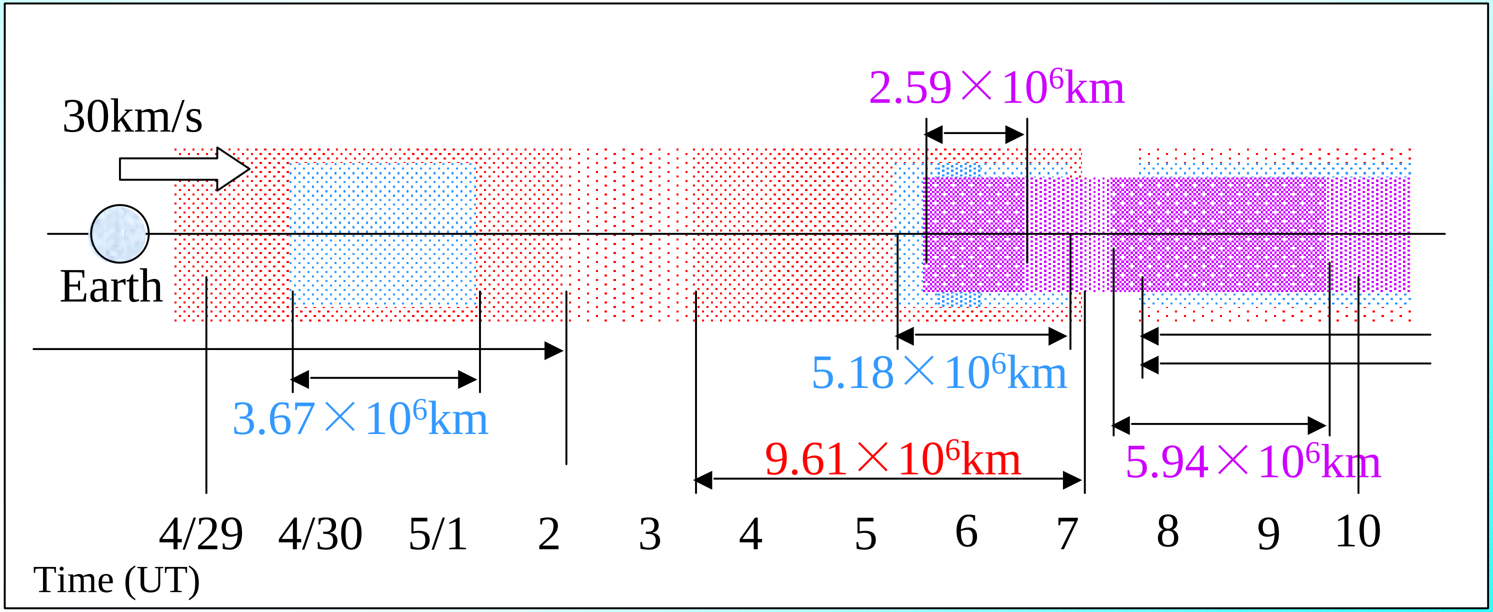


☆ 2003 eta-Aquarids

28MHz(5~-11mag.) Activity : mainly May 3rd~ May 7th
Peak : around May 4th 20h

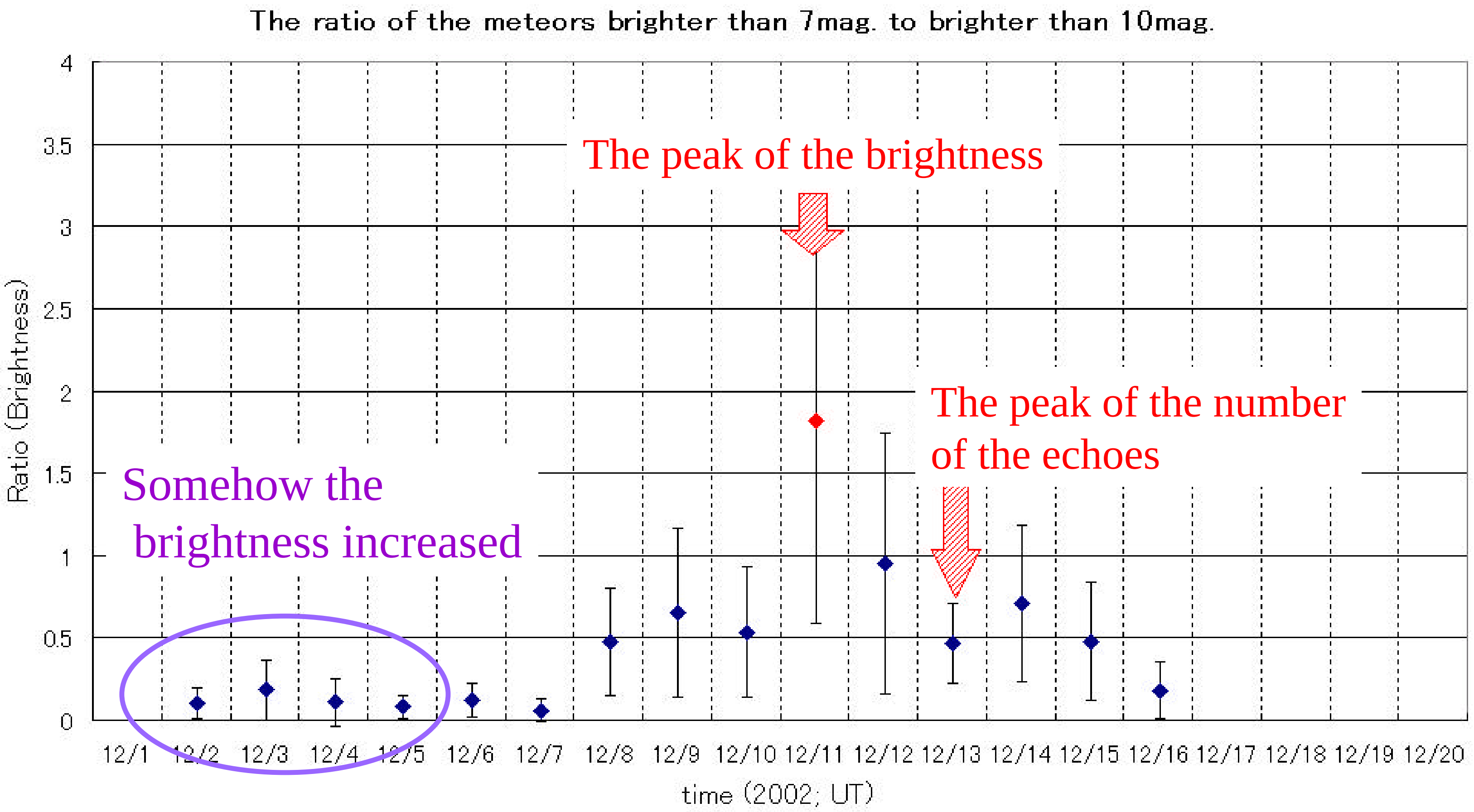
53MHz(2~-11mag.) Activity : mainly May 4th~ May7th
Peak : around May 5th23h

113MHz(-2~-11mag.) Activity : mainly May 5th ~ May 7th
Peak : around May 6th1h

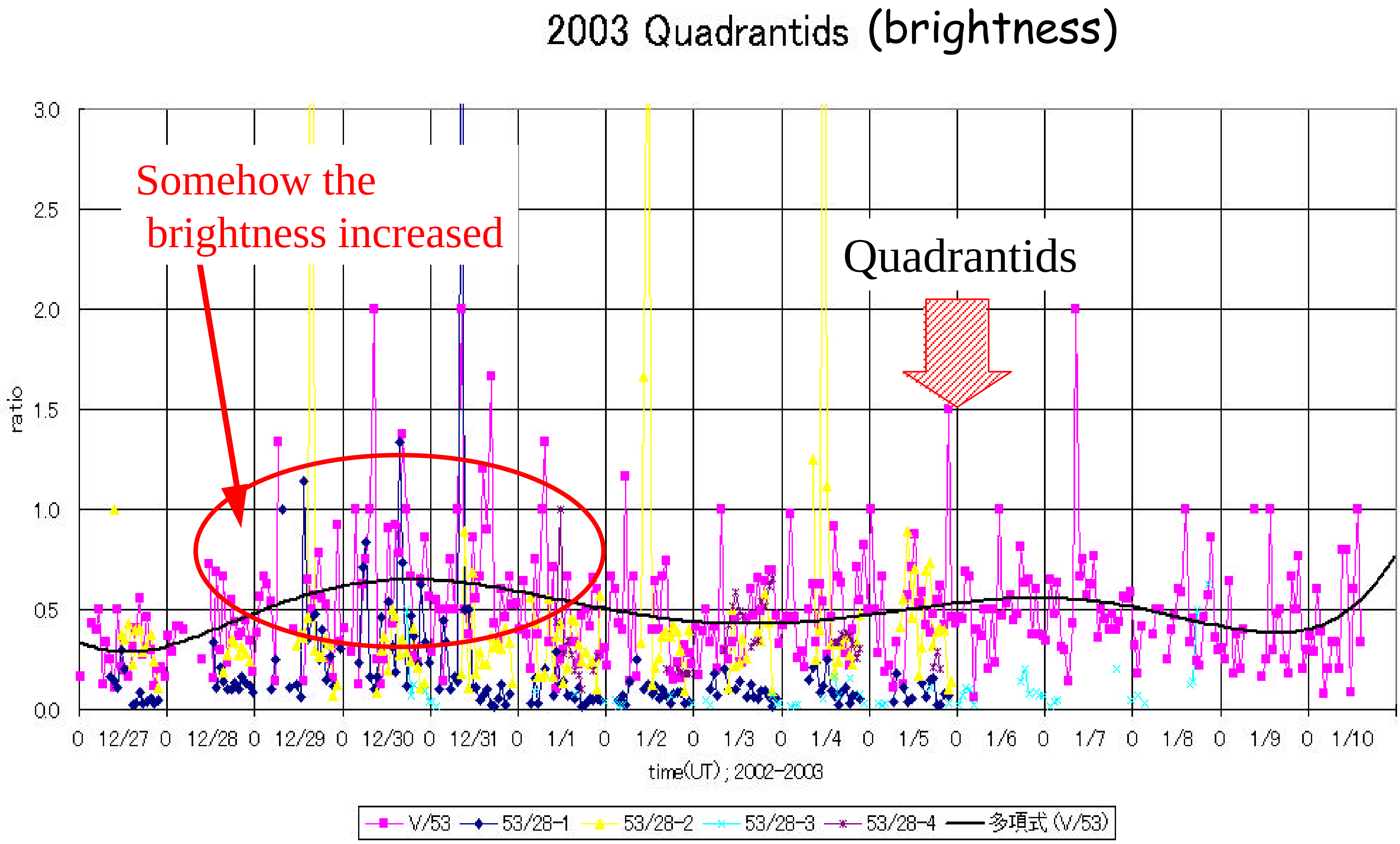


Curious things....

☆ Curious buzz 1　In the beginning of December..



☆ Curious buzz 2　In the end of December….



Conclusion

Like this, observing by multi-frequency radio waves enables to know the characteristics of meteor showers which had not revealed by radio observation, such as :

- Activity by Magnitude
- Rough images of the dust tube or trails

Future Works

- To obtain

the height of lower limit for receiving meteor echoes

where an ionized trail with

the minimum electron density which can scatter
radio waves of some kinds of frequencies

can exist stably for more than a few seconds
at the density of atmosphere there

by calculation or observation

⇒ The magnitude range of each frequency radio waves
will become clear

With more detailed and accurate activity by magnitu
reveal the spatial distribution by the mass of meteor

Collect more data by multi-frequency

The more data collected, the more various and wider discussion will become possible*!!*

Detectable area of Radio observation

At different receiving stations different areas are detected.

⇒ Consider the detectable area when compare data (especially different frequency) by different stations.

Standardization of the Background

Comparing the counted data includes a problem….

Every stations receives different level of background noises and sporadic echoes because their systems are not always the same. If we standardize the background, we can compare meaningfully.

If there're more data, we'll be able to understand the activity by magnitude more accurately !!

Why don't we try it !?

Acknowledgement

Masayuki YAMAMOTO (Kochi Univ. of Technology)

The International Project for Radio Meteor Observation

Reference

D.W.R. McKinley, “Meteor Science and Engineering”, *McGraw-Hill Book Company*, 1961

J. Rendtel, R. Arlt, and A. McBeath, “Handbook for Visual Meteor Observers”, *International Meteor Organization*, 1995