MU radar と Tomo-e Gozen による 2020年ふたご座流星群の同時観測

Koki Nonaka(1), Shinsuke Abe(1), Akira Hirota(1), Kohei Morita(1),
Shigeyuki Sako(2), Ryou Ohsawa(2),
Johan Kero(3), Daniel Kastinen(3),
Takuji Nakamura(4), Koji Nishimura(4),
Yasunori Fujiwara(5), Junichi Watanabe(6)

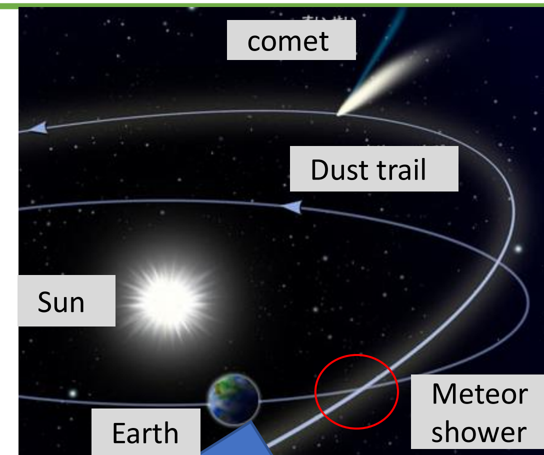
(1)Nihon University, Dept. Aerospace Eng., Japan
(2)Institute of Astronomy, The University of Tokyo, Japan
(3)Swedish Institute of Space Physics, Kiruna, Sweden
(4)National Institute of Polar Research, Tokyo, Japan
(5)Nippon Meteor Society, Japan
(6)National Astronomical Observatory of Japan, Mitaka, Tokyo, Japan

Introduction

Origin of Meteors

It is believed to be small bodies that emit dust.

Comets, in particular, create dust trails and are considered the origin of meteor showers.



astro-dic.jp

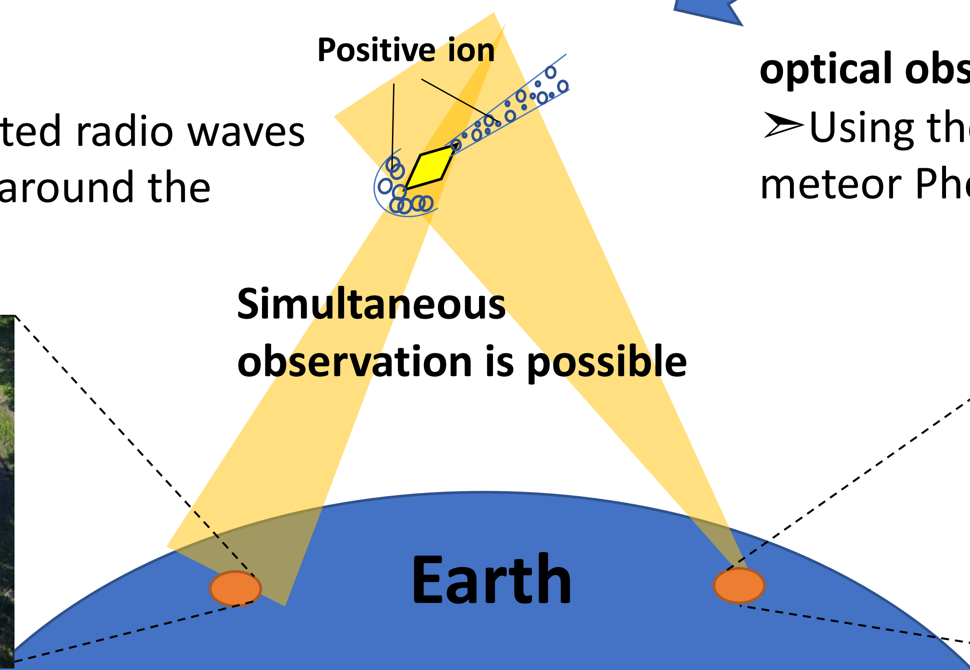
Meteor Observation Techniques

Radio observations

➢Observing the reflected radio waves by the plasma formed around the meteoroid.

optical observations

➢Using the light produced during meteor Phenomena



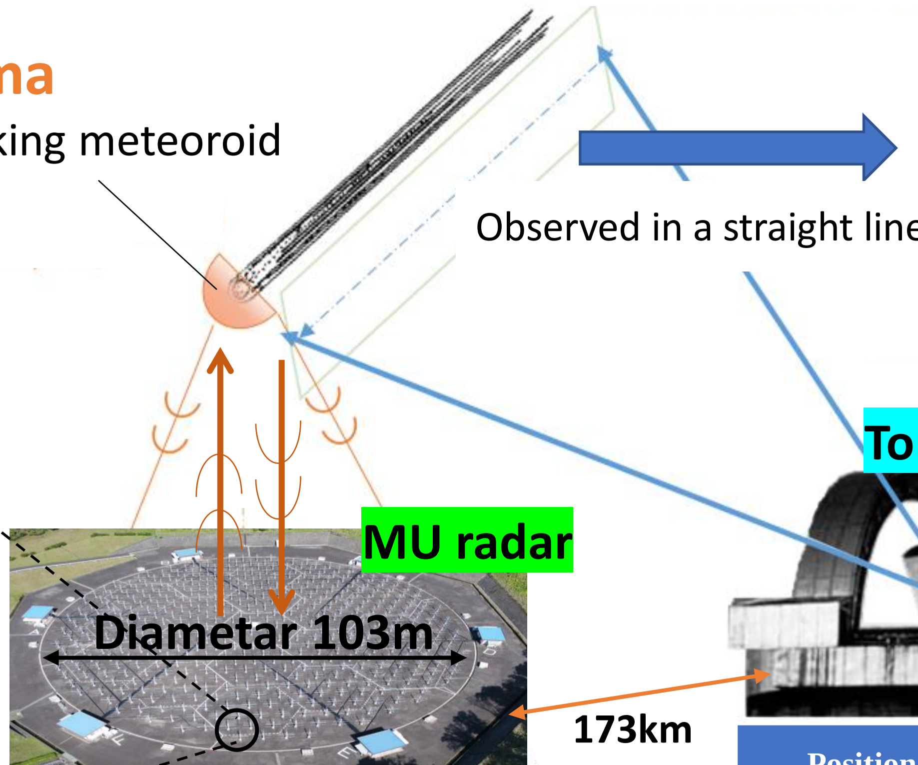
introduction

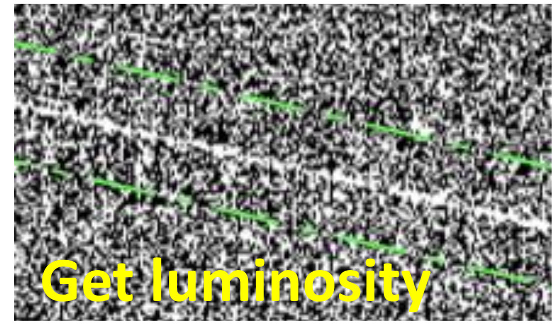
simultaneous observation of MU radar and Tomo-e GOZEN

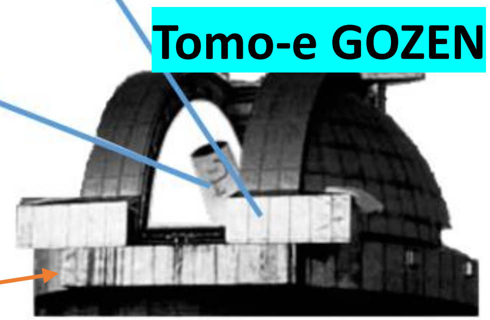
Head Plasma

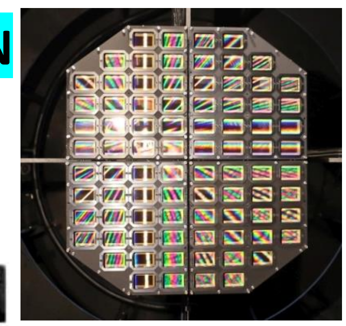
Assuming tracking meteoroid

Get orbit









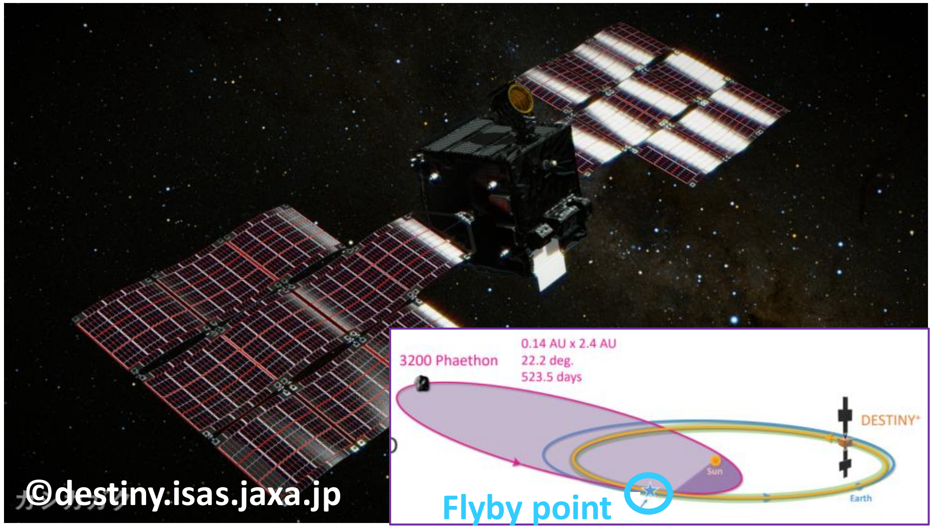
Position	MU Observatory (34° .51'N,136° 06'E)
Center frequency	46.5MHz
Beamwidth	3.6°
Output power	1MW

Position	Kiso Observatory (35° .47'N,137° .37'E)
Sensor	84 COMS sensors
FOV	20 deg^2,(39.7' × 22.4' × 84)
Frame rate	2 fps(Full Frame)
Filter	350-800nm

Faint meteors of about 10 magnitude(about 10^{-4}g) can be detected by simultaneous observation (Ohsawa et al 2018)

introduction

Destiny⁺



What's Destiny⁺ ?

It is Flyby observation mission planned by JAXA/ISAS, where 3200 Phaethon is the target object.

3200 Phaethon

- Active Asteroids
- parent body of Geminids

Destiny⁺ Objectives

- Investigation of the dust emission mechanism of active asteroids
- Investigation of the characteristics of dust emitted from Phaethon

Mass distribution in Phaethon orbit is important for payload estimation

Using simultaneous observations of Tomo-e Gozen and MU radar to study the mass distribution of the faint Geminids meteors.

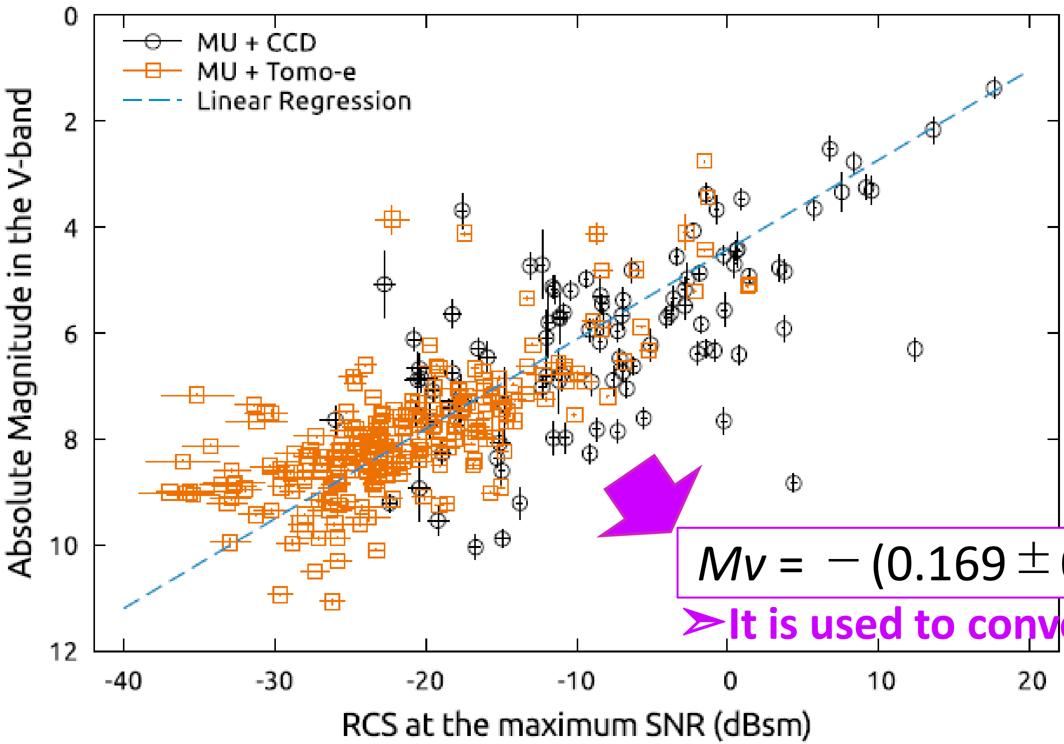
introduction

In Ohsawa et al. (2020), the mass is calculated using simultaneous observations

Two simultaneous observations are summarized(<u>Target : Sporadic</u>)

①MU radar and intensified CCD camera(10days in total) → 103events

②MU radar and Tomo-e Gozen(36hours in total) → 228events



$$RCS = \frac{(4\pi)^3 P_r R^4}{G_r(\theta,\phi) G_t(\theta,\phi) \lambda^2 P_t}$$

G : Gain

P : Received and Transmission power

λ : Radar wavelength

R : Target range

The reflective capability of a reflective object

$Mv = -(0.169 \pm 0.006) \times RCS + (4.43 \pm 0.13)$

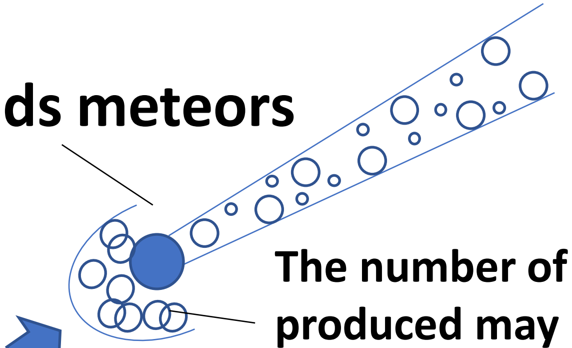
➢**It is used to convert RCS to magnitude (mass)**

RCS is important parameter for the calculation of mass

※ Note that there is uncertainty in the calculated masses due to effects such as luminous efficiency and fragmentation

introduction

Geminids meteors

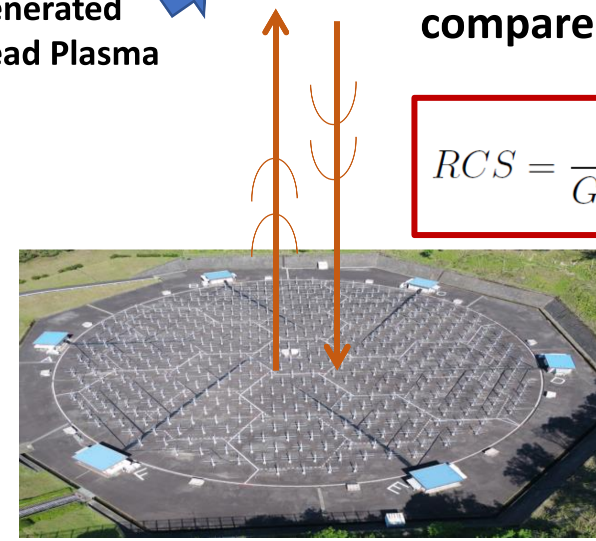


Generated Head Plasma

The number of electrons produced may be different compared to a typical meteor

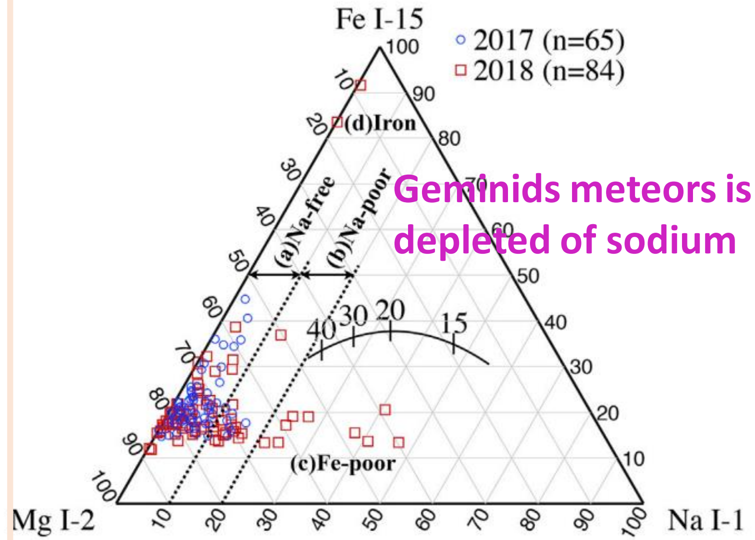
$$RCS = \frac{(4\pi)^3 P_r R^4}{G_r(\theta,\phi) G_t(\theta,\phi) \lambda^2 P_t}$$

G：Gain
P：Received and Transmission power
λ：Radar wavelength
R：Target range



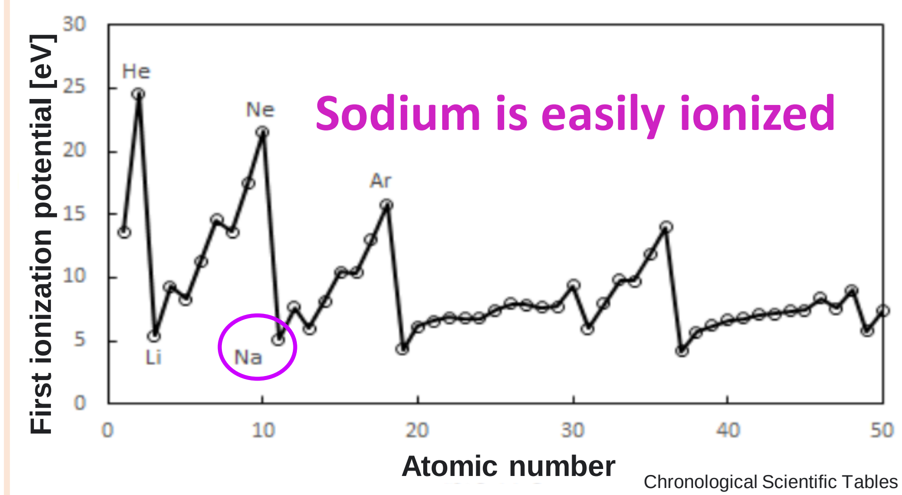
RCS of Geminids meteors may show trends by composition

We added spectroscopic observations to the simultaneous observations



Abe et al(2020)

The intensity ratios of Fe I, Mg I, and Na I emission lines from spectroscopic observations of the Geminids.



Chronological Scientific Tables

Observation

・ **MU radar and Tomo-e Gozen(Target:Gemnids)**

Dec. 12-13 18:00～06:00(JST) (12hours in total)

Dec. 13-14 18:00～22:00(JST) (4hours in total)

(Peak of the Geminids : Dec. 14 09:00(JST))

Total: 16hours,120 events*

＊ MU radar data is preliminaries data

＊Number of events is estimated from past observations

・ **MU radar and Tomo-e Gozen, Spectroscopic observation(Target:Gemnids)**

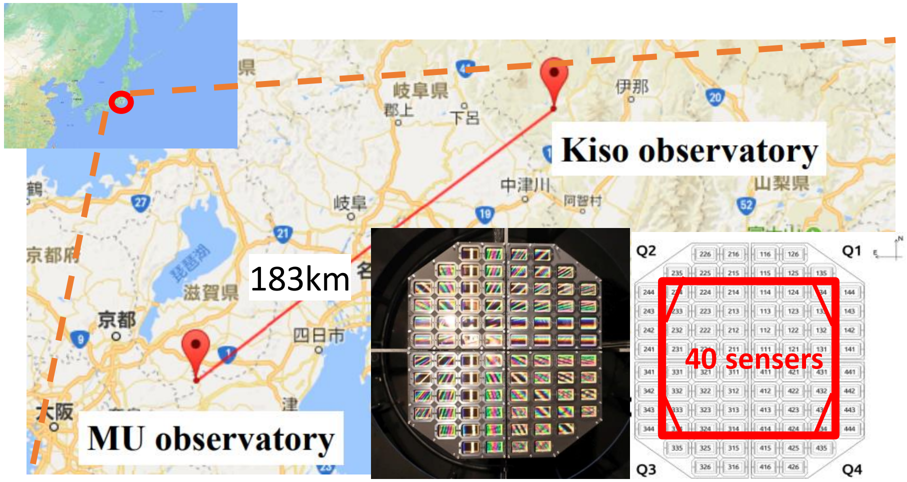
Dec. 13-14 19:30～22:00(JST) (2.5hours in total)

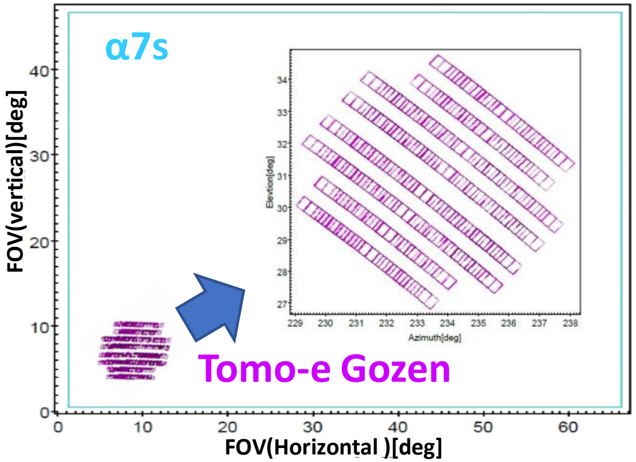
(Peak of the Geminids : Dec. 14 09:00(JST))

・ **Gratings**

VIS 600GPM

observation point	Camera	Wavelength range[nm]	azimuth [deg]	Elevation [deg]	lens	FOV (hor,ver)[deg]	counts
MU observatory (34° .51'N, 136° 06'E)	SONY A 7s	400-700	180	60	SIGMA 35mm F1.4	64.0,46.3	48





Flow chart of analysis

<Analysis Flow >

Tomo-e Gozen Data

Ohsawa's code

Reducted data

100,000 frames

MU radar Data

6739 events(preliminary data)

Azimuth,Elevation,
Altitude at MU radar

Azimuth,Elevation,
Altitude at Tomo-e Gozen

6739(347)events

Time

Simultaneous meteor
by time

2227(156)events

Hough
transformation

Calculate the location
of the meteor trajectory.

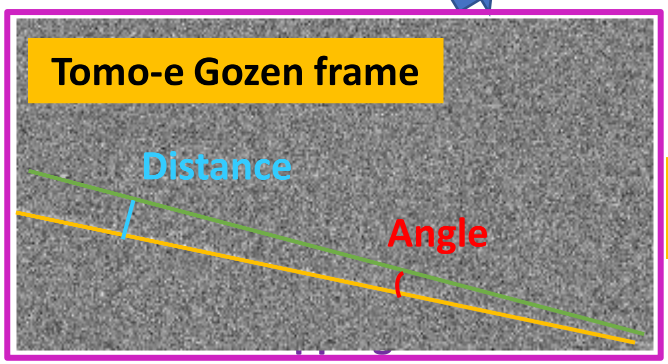
Analyzing Now …

Selection by
angle and distance

Simultaneous
meteor

magnitude

Removed meteor

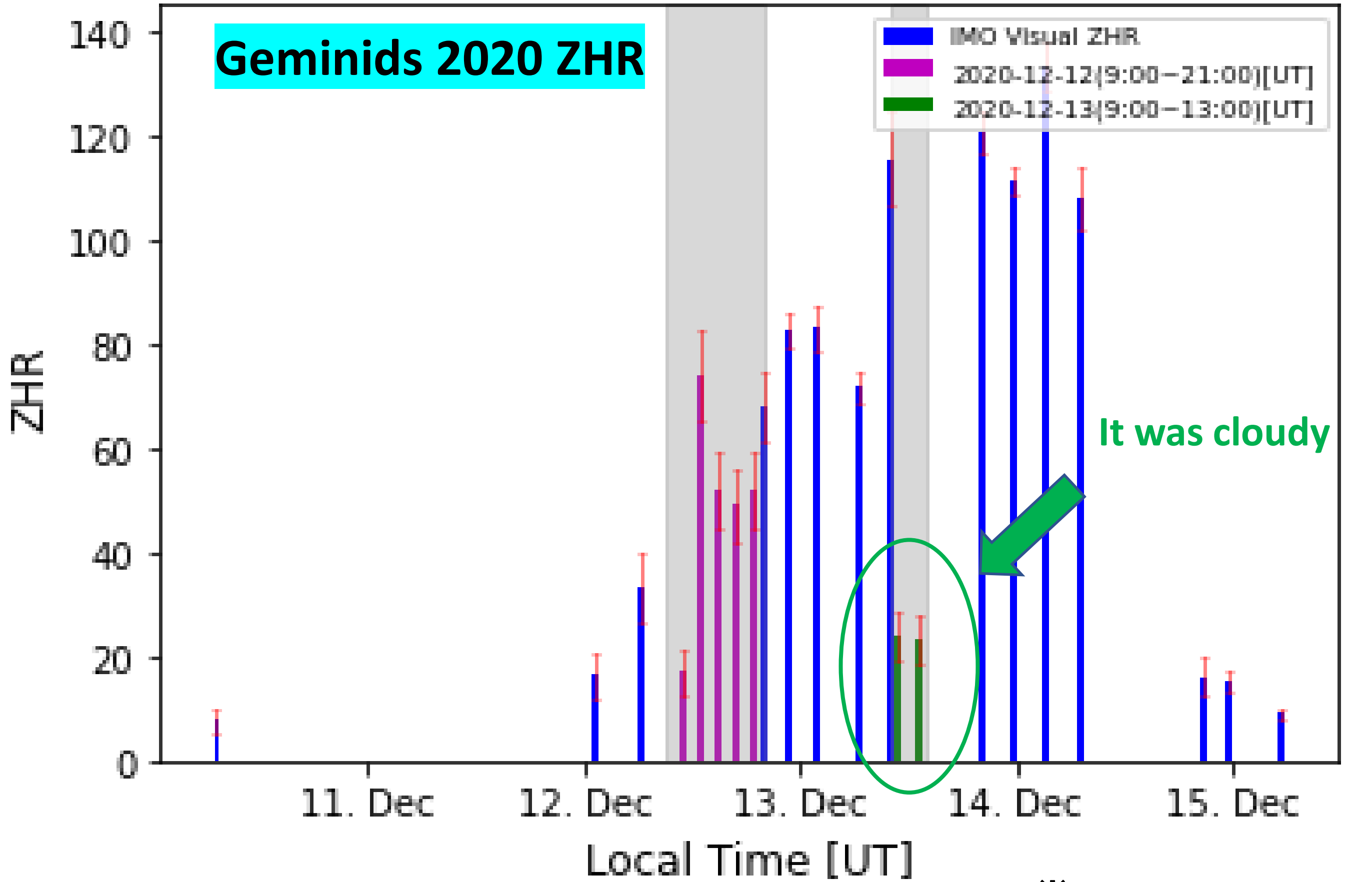


Results

ZHR(Zenithal Hourly Rate)

Number of meteors observed assuming that the radiant point is at the zenith.

It's an index of how many meteors we can observe.



※ IMO Visual ZHR is referenced from IMO

Results

- <u>MU radar and Tomo-e Gozen</u>

Currently, the photometry is under analysis

We calculated the magnitude from the RCS using the RCS-Mag relationship formula introduced in Ohsawa et al (2020).

$$Mv = -(0.169 \pm 0.006) \times RCS + (4.43 \pm 0.13)$$

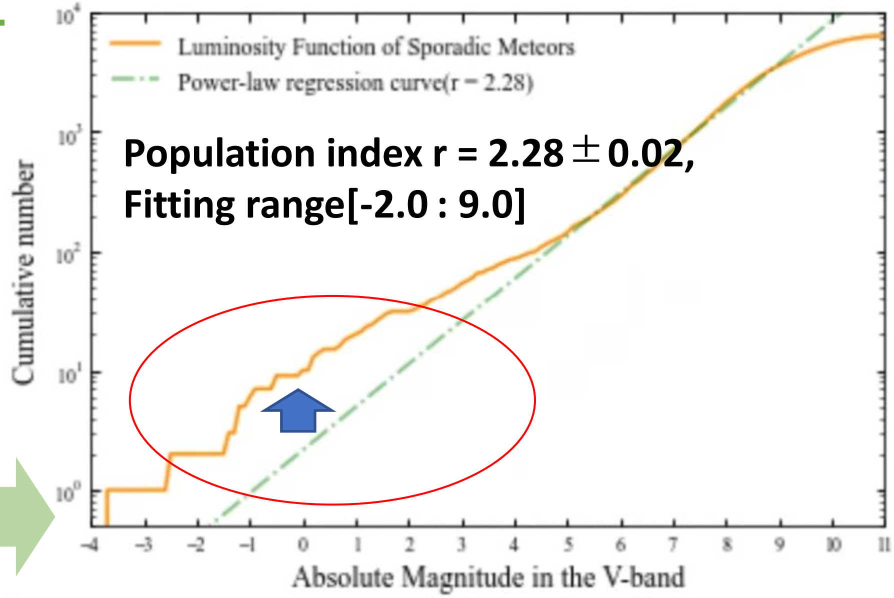
➢ **The larger the RCS, the smaller the magnitude**

Brighter meteors (larger RCS) cannot be approximated by a straight line

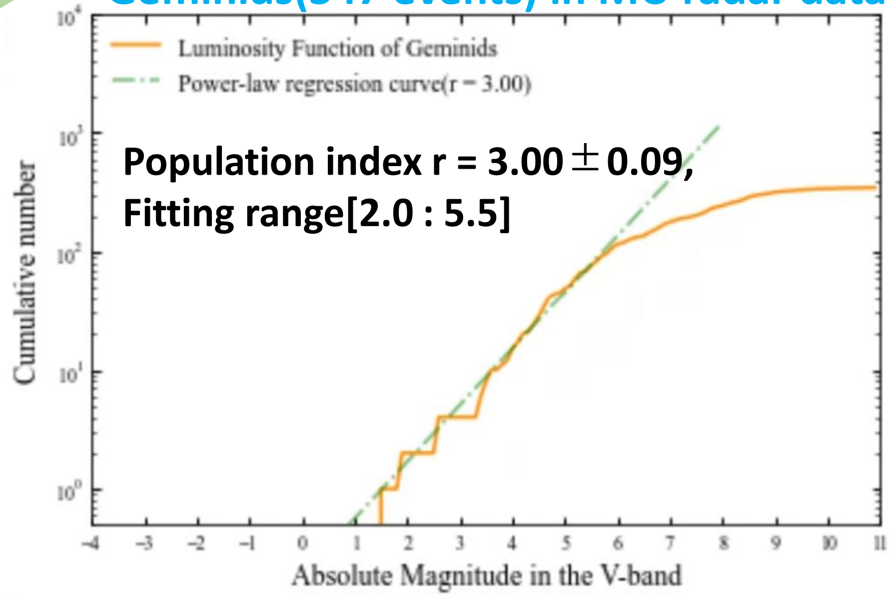
High reflectivity is observed even in areas with low sensitivity in MU radar

After this, I plan to derive the RCS-magnitude relation separately for Geminids and Sporadic meteors.

Sporadic Meteors(6392 event) in MU radar data



Geminids(347 events) in MU radar data

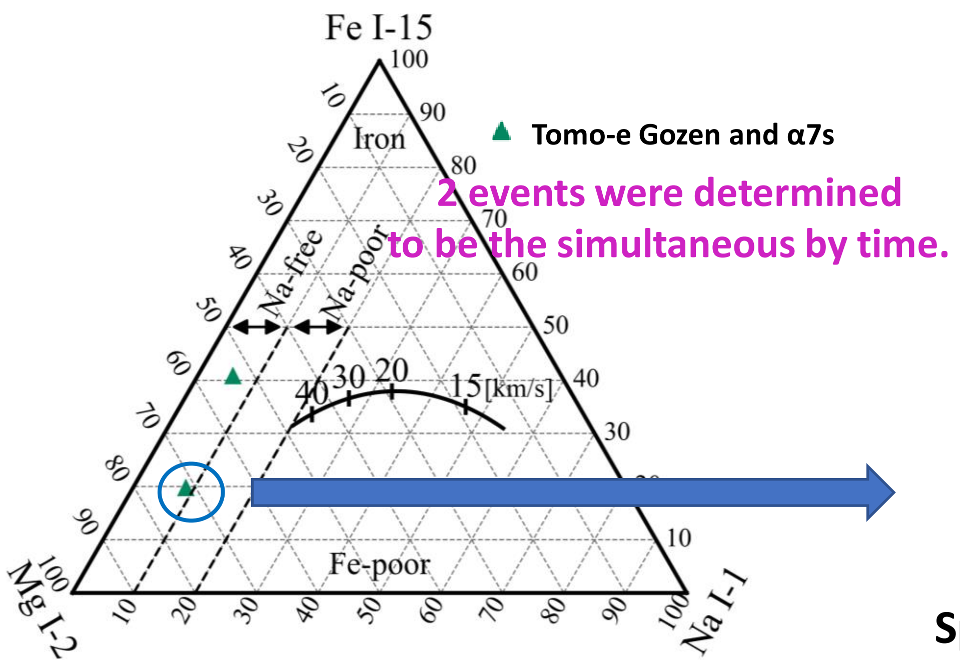


Results

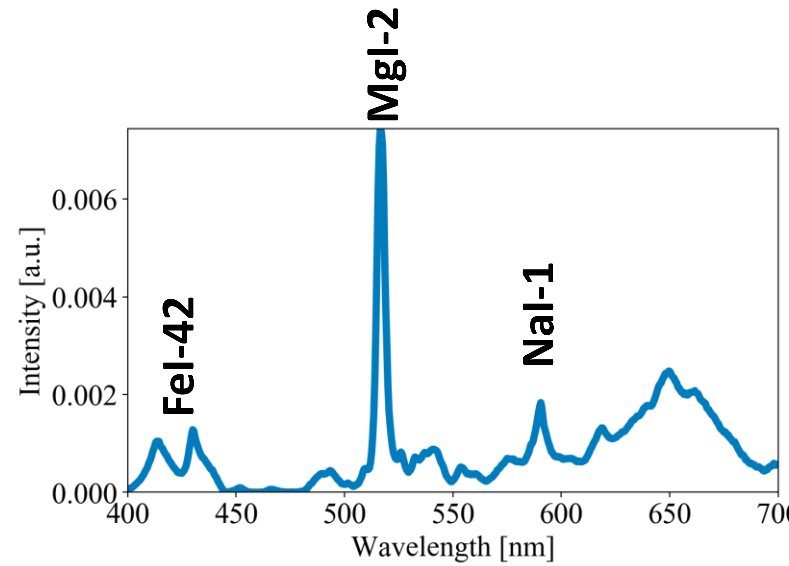
- <u>**MU radar and Tomo-e Gozen, Spectroscopic observation**</u>

Simultaneous meteor observations using three instruments are currently under analysis, so only the results of simultaneous "Tomoe Gozen" and "Spectroscopic Observation" are shown.

In this case, 2 events of Geminids were determined to be the simultaneous meteors by time.



The intensity ratios of Fe I, Mg I, and Na I emission lines from spectroscopic observations of the Geminids



Spectra of meteors observed simultaneously

After this, we will use the RCS information from MU radar in addition to the composition information to study the trend of simultaneous meteors.

Results in 2018,2019

Simultaneous observation campaign using MU radar and Tomo-e GOZEN (2018,2019))

・MU radar and Tomo-e Gozen(Target:Sporadic)

Apr . 18-22 in 2018 (36hours in total) → 228 events
Nov. 04-06 in 2019 (16hours in total) → 145 events

Total: 52hours,373 events

373 simultaneous events detected in 52 hours

Equivalent to 7.17 events per hour

Reference	Observational instruments	Simultaneous events/hour
Campbell-Brown et al. (2012)	EISCAT＆two optical cameras	4 meteors/11 hours
Michell et al. (2015)	SAAMER ＆ optical camera	6 meteors/1night
P Brown et al. (2017)	MARRSY ＆ two optical camera	105 meteors/242 hours

Simultaneous observations in this study have high detection efficiency

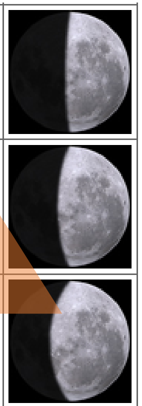
Future work

Age of the moon when the Geminids meteor shower is coming

2021 ＞ 2022 ＞ 2023 ＞ 2024

2021

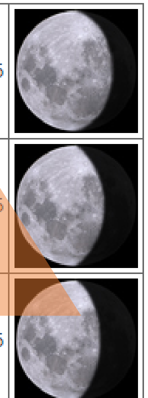
2021年12月12日	日	7.8
2021年12月13日	月	8.8
2021年12月14日	火	9.8



No observations

2022

2022年12月12日	月	18.16
2022年12月13日	火	19.16
2022年12月14日	水	20.16



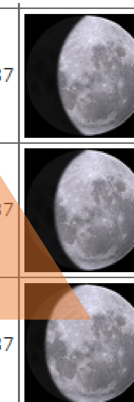
2023

2023年12月12日	火	28.74
2023年12月13日	水	0.14
2023年12月14日	木	1.14

good conditions!!

2024

2024年12月12日	木	10.87
2024年12月13日	金	11.87
2024年12月14日	土	12.87



Destiny^{+} is scheduled for launch

We are planning to observe the Geminids meteor shower continuously until Destiny^{+} is launched.