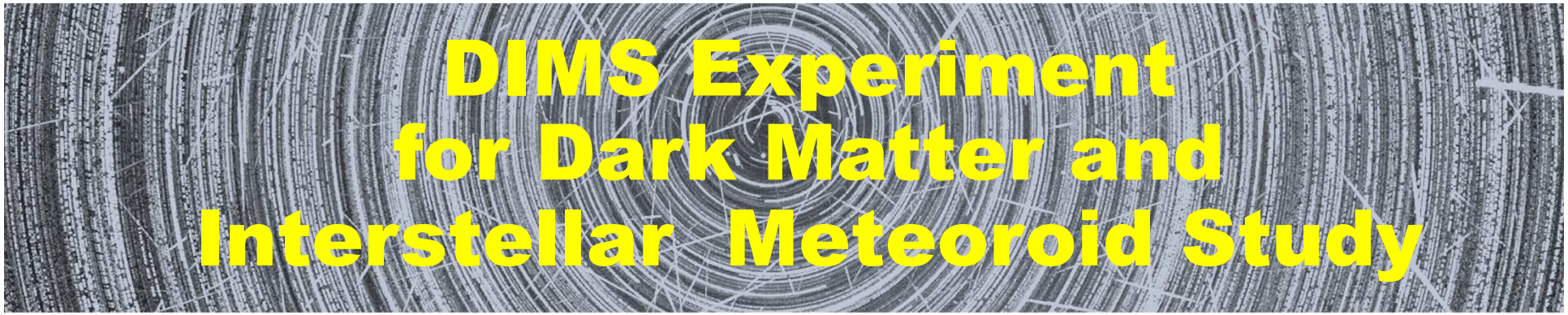


The DIMS Collaboration

S. Abe[a], M. Arahori[b], D. Barghini[c,g], M. Bertaina[c], M. Casolino[e,f], A. Cellino[g], C. Covault[r], T. Ebisuzaki[e], M. Endo[a], M. Fujioka[j], Y. Fujiwara[h], D. Gardiol[g], M. Hajdukova[j], M. Hasegawa[a], R. Ide[b], Y. Iwami[j], F. Kajino[b*], M. Kasztelan[q], K. Kikuchi[a], S.-W Kim[k], M. Kojro[l], J.N. Matthews[m], K. Nadamoto[b], I.H. Park[n], L.W. Piotrowski[o], H. Sagawa[p], K. Shinozaki[q], D. Shinto[j], J.S. Sidhu[r], G. Starkman[r], S. Tada[b], Y. Takizawa[e], Y. Tameda[j], and S. Valenti[c], M. Vrabel[q]

* *Presenter*

a Department of Aerospace Engineering, Nihon University, Japan
b Department Of Physics, Konan University, Japan
c Department of Physics, University of Turin, Italy
d National Institute for Nuclear Physics (INFN) – Turin, Italy
e RIKEN (Institute of Physical and Chemical Research), Japan
f National Institute for Nuclear Physics (INFN) – Rome Tor Vergata, Italy
g Observatory of Turin, National Institute for Astrophysics (INAF), Italy
h Nippon Meteor Society (NMS), Japan
i Astronomical Institute, Slovak Academy of Sciences, Slovakia
j Department of Engineering and Science, Osaka Electro-Communication University (OECU), Japan
k Korea Astronomy and Space Science Institute (KASI), Republic of Korea
l Faculty of Physics and Applied Informatics, University of Lodz, Poland
m Department of Physics and Astronomy, University of Utah, USA
n Department of Physics, Sungkyunkwan University, Republic of Korea
o Department of Physics, University of Warsaw, Poland
p Institute for Cosmic Ray Research, University of Tokyo, Japan
q National Center for Nuclear Research (NCBJ), Poland
r Department of Physics, Case Western Reserve University, USA

37th International Cosmic Ray Conference ICRC 2021

The Astroparticle Physics Conference

July 12-23, 2021

Online conference

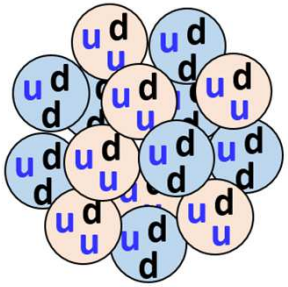
Objects of DIMS Experiment

- Search for nuclearites and Strange Quark Matters as the candidates of the macroscopic dark matters
- Study of meteoroids, especially interstellar meteoroids.
- Study of other Transient Luminous Effects (TLE's)
- Co-observation with JEM-EUSO program such as EUSO-TA, Mini-EUSO, K-EUSO etc.

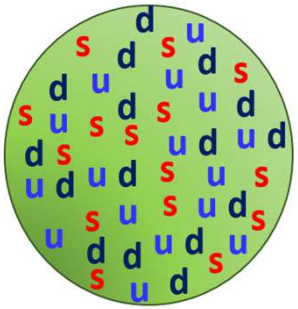
Dark Matter

- There are many dark matter (DM) candidates such as WIMPs, Axions, Primordial Black Holes …
- DM are generally thought to interact weakly.
- DM don't have to interact weakly, if they are very massive. Either small σ_x or large M_x.
- Large M_x DM : macroscopic DMs (macros).
- Candidate of the macros : Nuclearite
- Nuclearite : Strange Quark Matter (SQM) + Electrons.

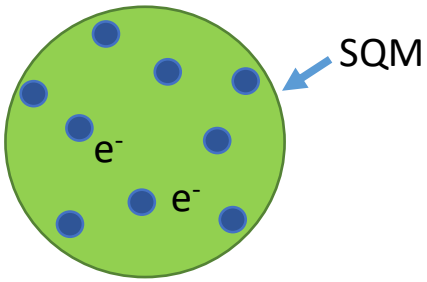
A. De Rujula and S. L. Glashow, 1984



Usual nucleus :
made of 3 quarks



Strange Quark Matter (SQM) :
made of u, d, s quarks



Nuclearite :
SQM + electrons

Macroscopic Dark Matter Interaction

Macros are supposed to interact through their geometrical cross-section

$$\sigma_X = 2 \times 10^{-10} cm^2 \left(\frac{M_X}{g}\right)^{\frac{2}{3}} \left(\frac{\rho_N}{\rho_X}\right)^{\frac{2}{3}} \qquad (1)$$

$\rho_N \approx 10^{14} g\ cm^{-3}$: Nuclear density

Energy loss rate of the macros travelling through the Earth's atmosphere

$$\frac{dE}{dx} = -\rho_{atm} \sigma_X {v_X}^2 \qquad (2)$$

Model A : Macros quasi-elastically collide with the ambient atoms resulting in black-body radiation from an expanding cylindrical thermal shock.

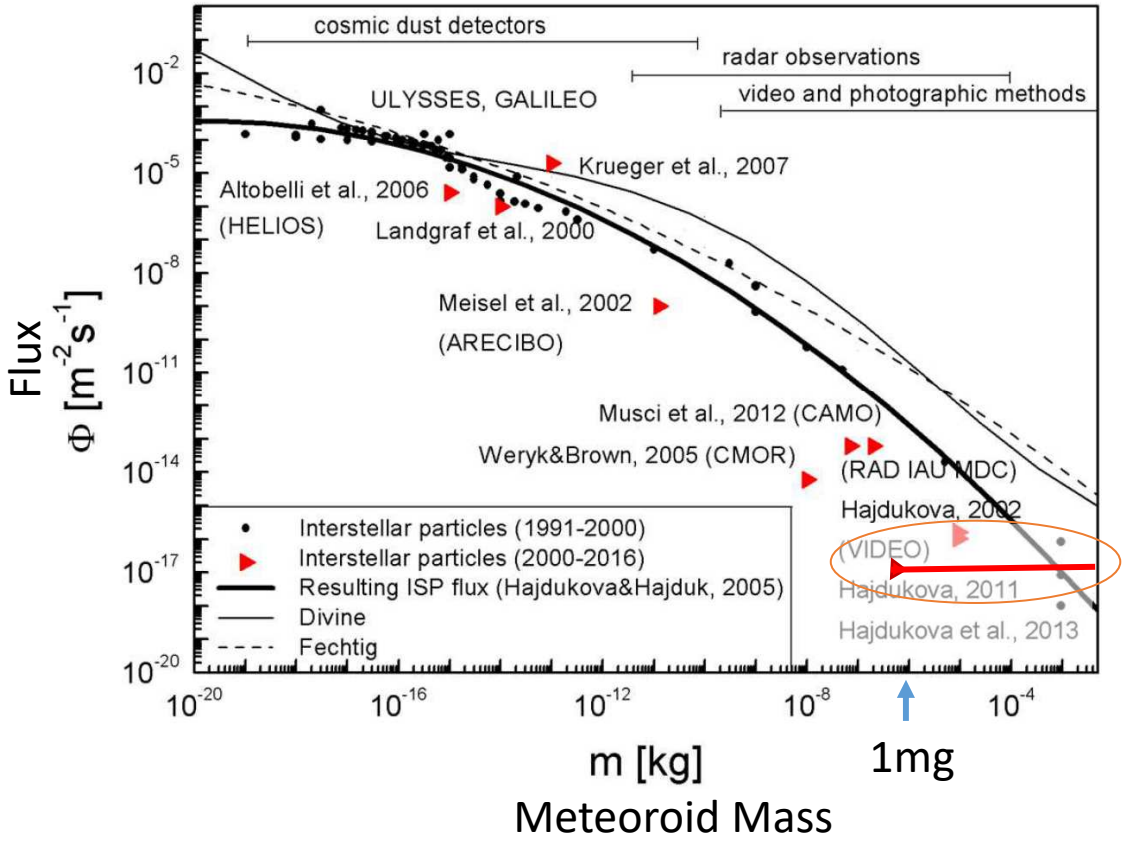
A. De Rújula and S. L. Glashow, Nature 312, 734 (1984).

Model B : Macros scatter with the molecules resulting in formation of plasma and radiation of photons.

J. Sidhu et al. , JCAP2019, 037 (2019).

There is a large difference between A and B on the radiated amount of photons.

Interstellar Meteoroids from Outside the Solar System



DIMS expected flux limits with 1 year observation

F ~ 1.3×10^{-17} $m^{-2}\,s^{-1}$ with meteoroid mass > 1mg

(Observation efficiency in time is assumed to be 0.09)

DIMS Observation Concept

Meteoroids evaporate in the atmosphere resulting in light emission by ionized gas

"Ordinary" meteors are bound in the Solar System
Heliocentric **$V_{ordinay\ meteors}$** < 42 km/s (escape v.)

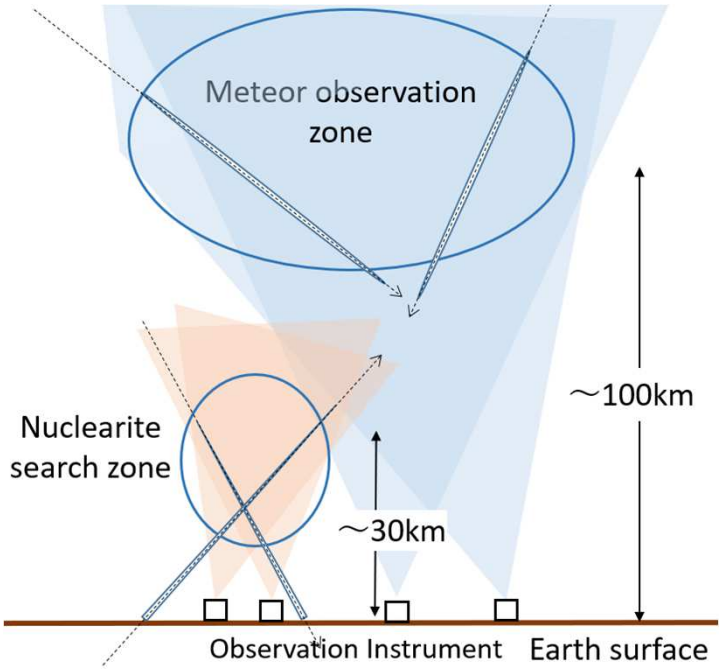
Heliocentric **$V_{interstellar\ meteoroids}$** > 42 km/s

Luminous altitude: ~80 -- 120 km

Nuclearites

Macroscopic dark matters are bound in Milky Way Galaxy
V_{macros} ~ 250 km/s in the Galaxy frame
(cf. Rotation velocity ~250 km/s & escape velocity ~550 km/s near Sun)

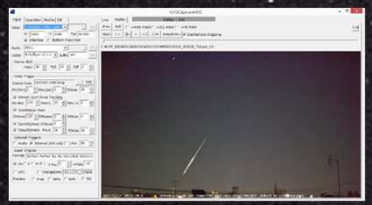
Luminous altitude:
< ~30 km for mass of our interest



Key Elements of DIMS Detector

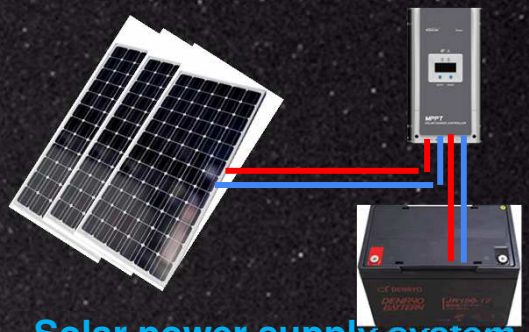
Canon ME20F-SH CMOS camera
- Max. sensitivity ~ ISO 4,000,000 (ISO 204,800 for present setup)
- 1920 x 1080 pixels at 29.97 fps
- FOV ~57°x34° with 35 mm

Work on Windows PC



UFOCapture
- Motion capture software by sonotaCo.com

Camera box
- Acrylic dome with sunshade
- Accommodating camera, PCs, fans, heater, alt-azimuth mount, monitors

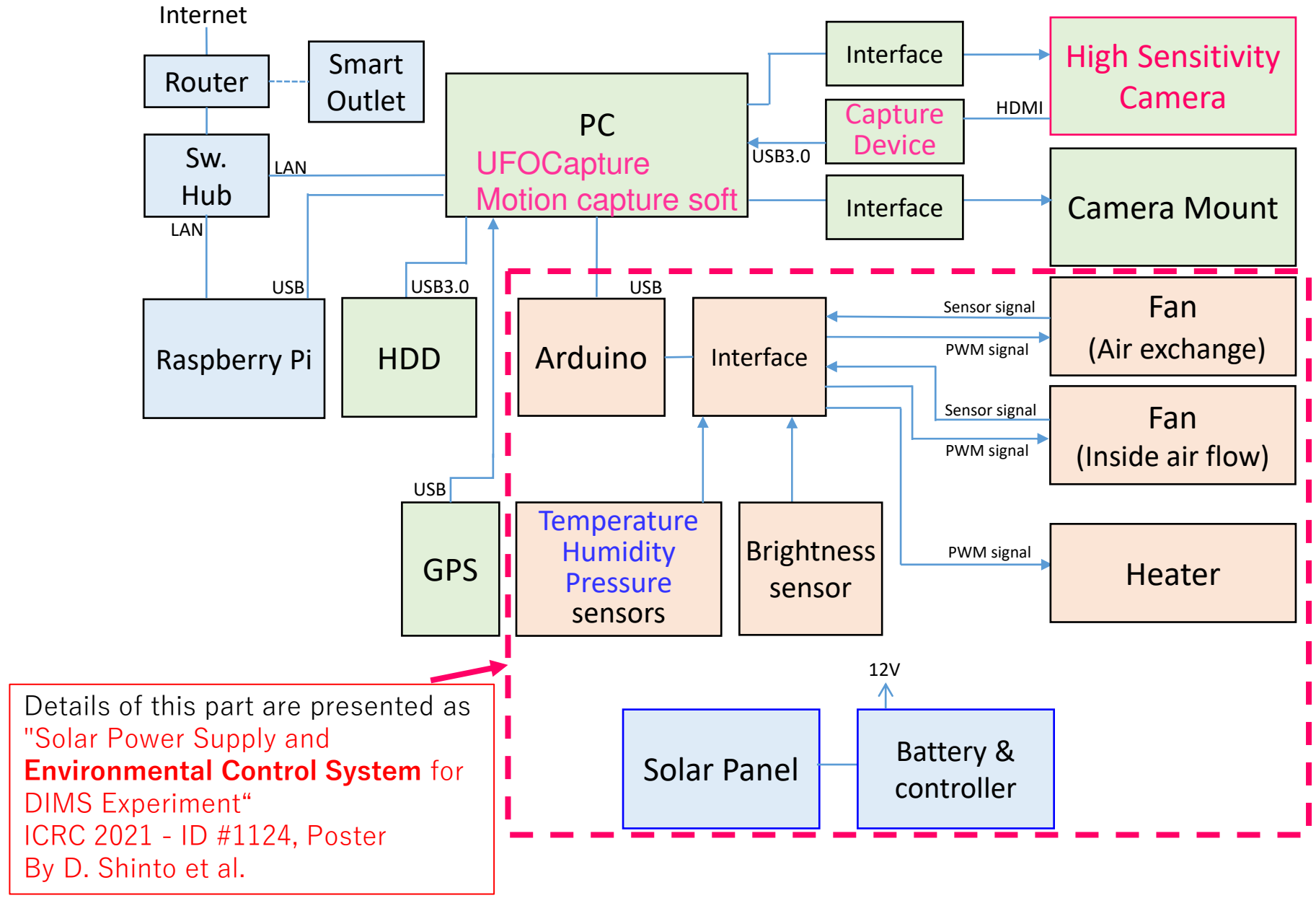


Solar power supply system
- AT-MA200A solar panels (200 W)
- Tracer6420AN charge controller
- JR130-12 batteries

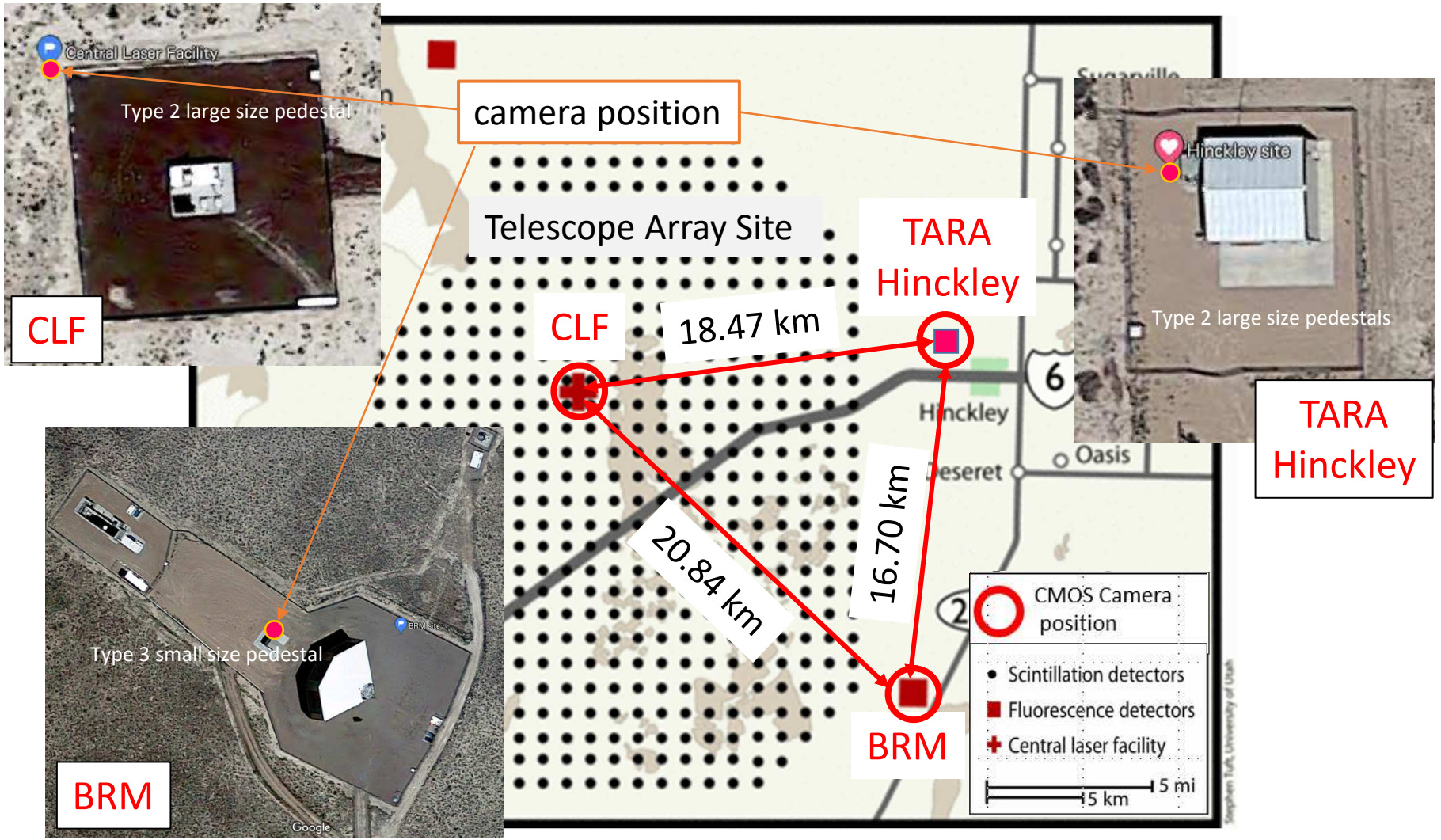
Self-supply system only required for the operation at Central Laser Facility , TA site, Utah

2019/09/01 10:34:01.2 00001 00000 057 Canon_ME20F_SH EF35mm_F1.4L_II_USM Utah_UT2 N2 UFOCaptureHD2

DIMS Camera System



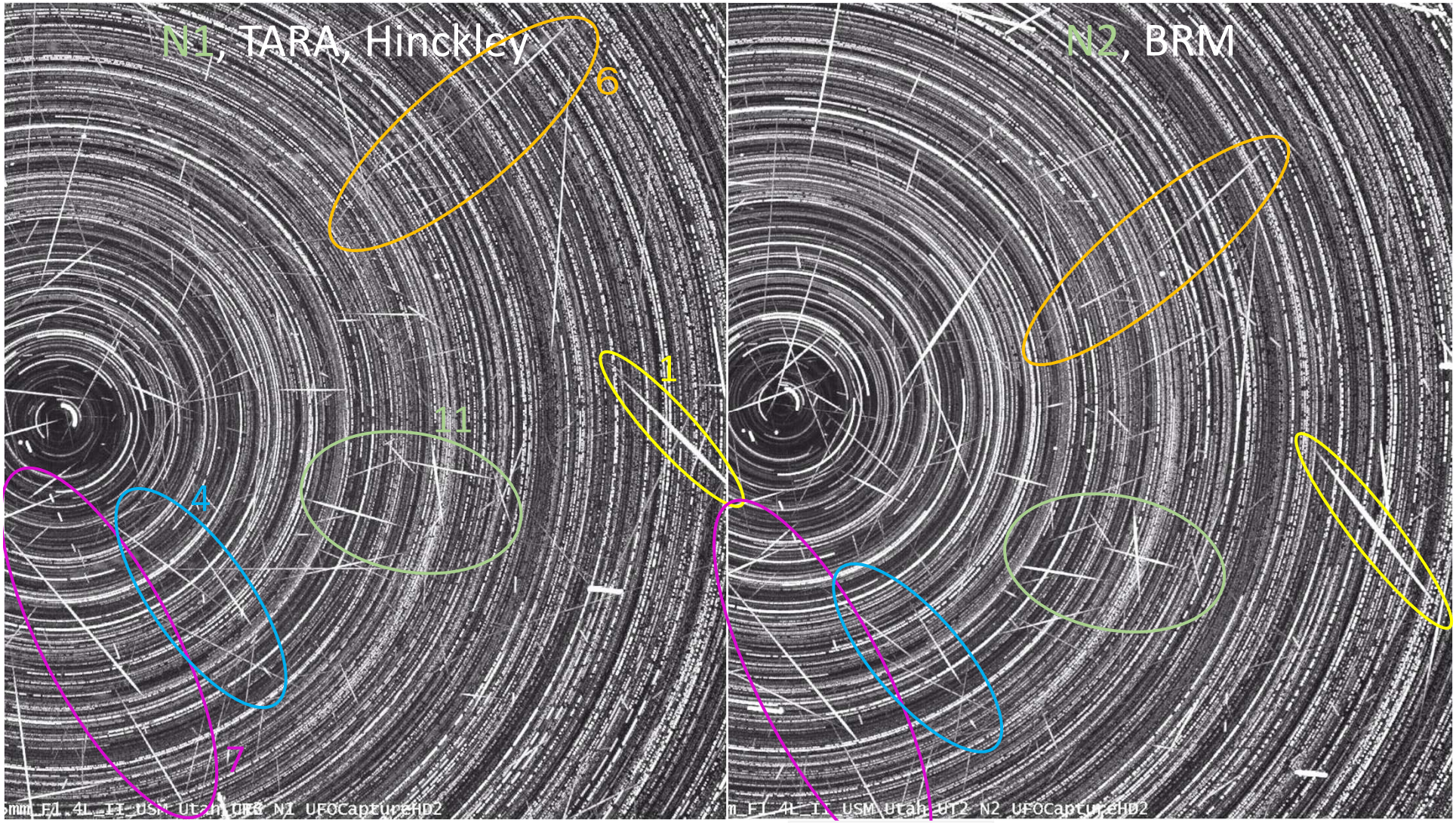
Test Observation Site in 2019



2 cameras were used at a time for the observation.

Simultaneous Events

4th night: 8/31 22:29 – 9/1 5:00 MDT, 2019 (6h 31min)

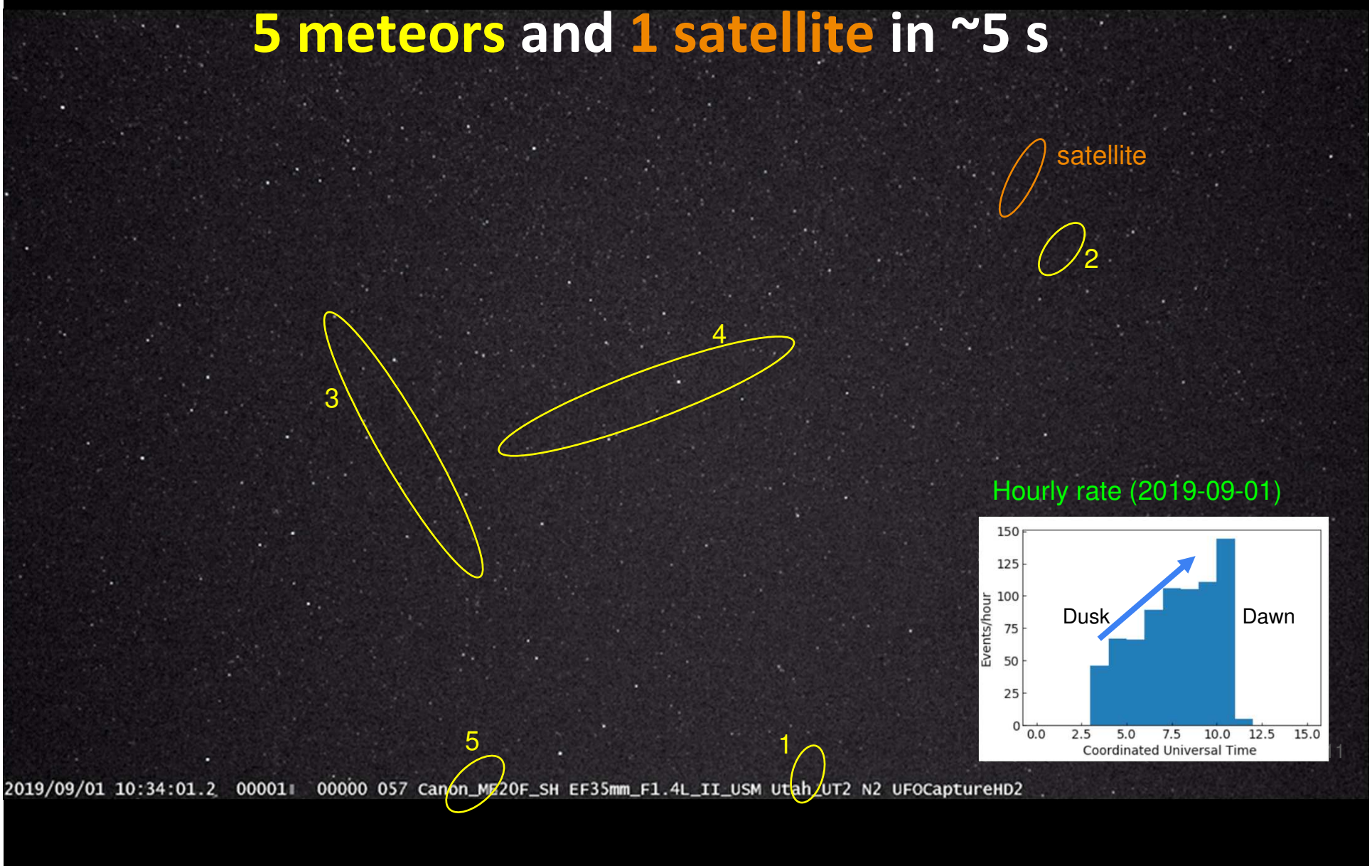


About 75% of events in N1 are observed simultaneously in N2.

Number of the simultaneous events are estimated to be roughly 400 in this night.

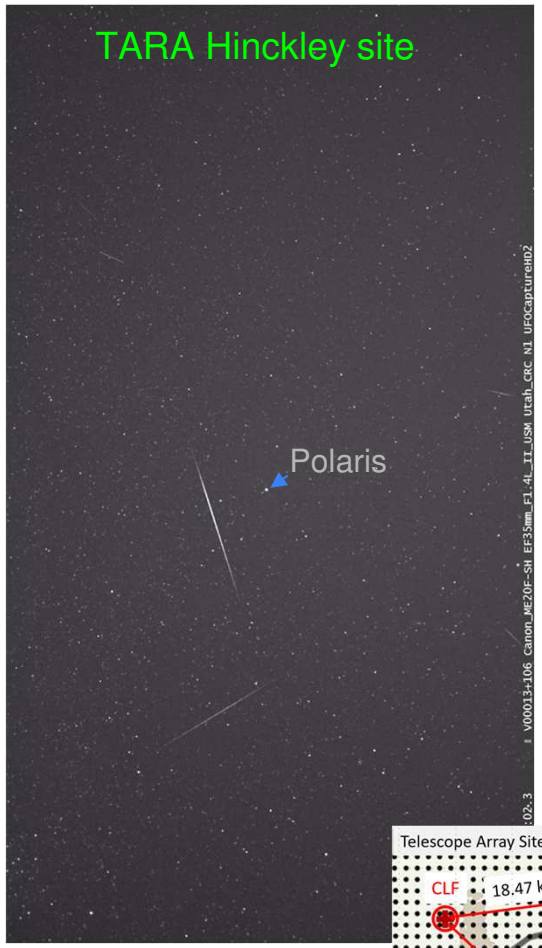
A Video Example of the Test Operation Data at Utah in 2019

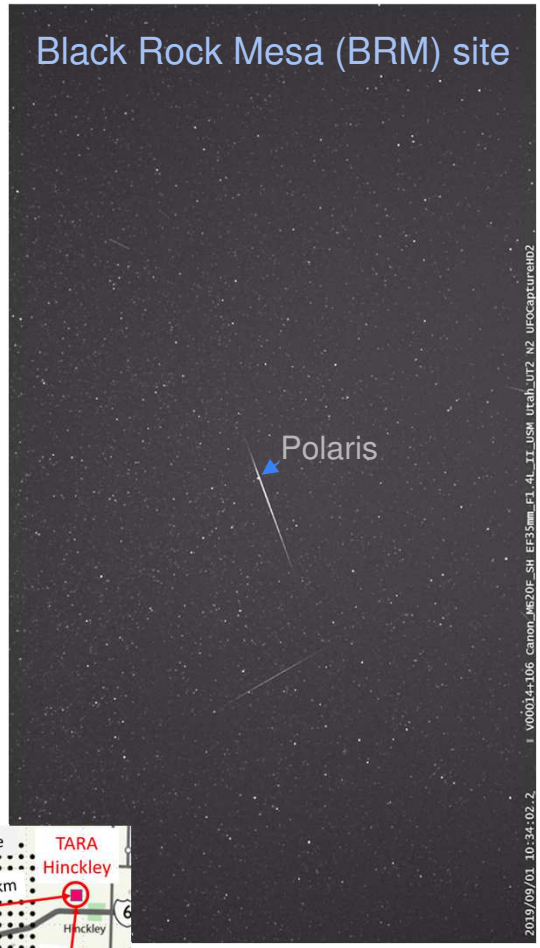
5 meteors and 1 satellite in ~5 s

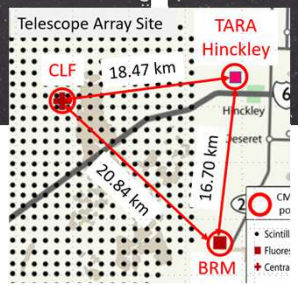


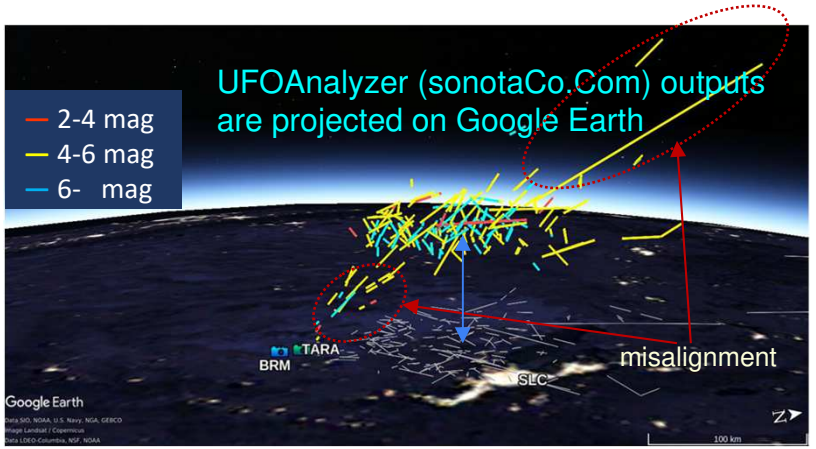
Hourly rate (2019-09-01)

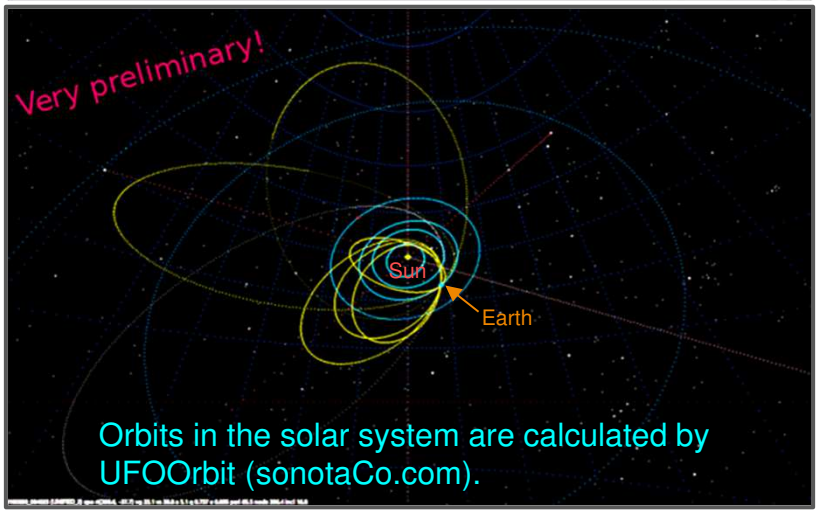
Standard Reconstruction by UFOAnalyzer & UFOOrbit Softwares



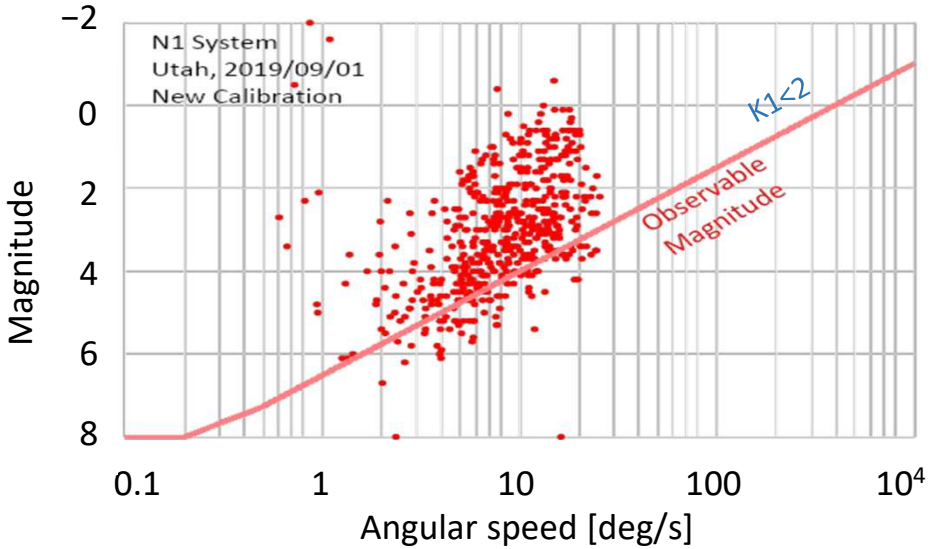


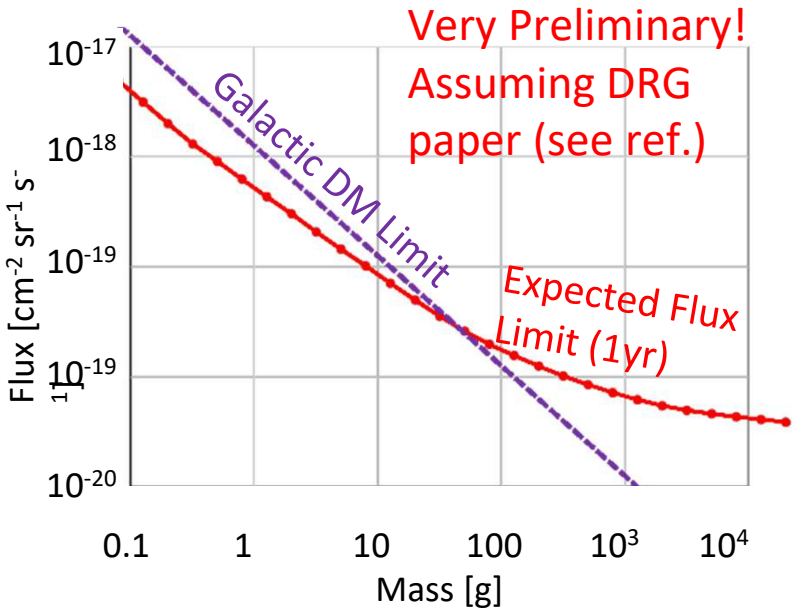






Limiting Magnitudes for Meteors and Expected Sensitivity to Nuclearite



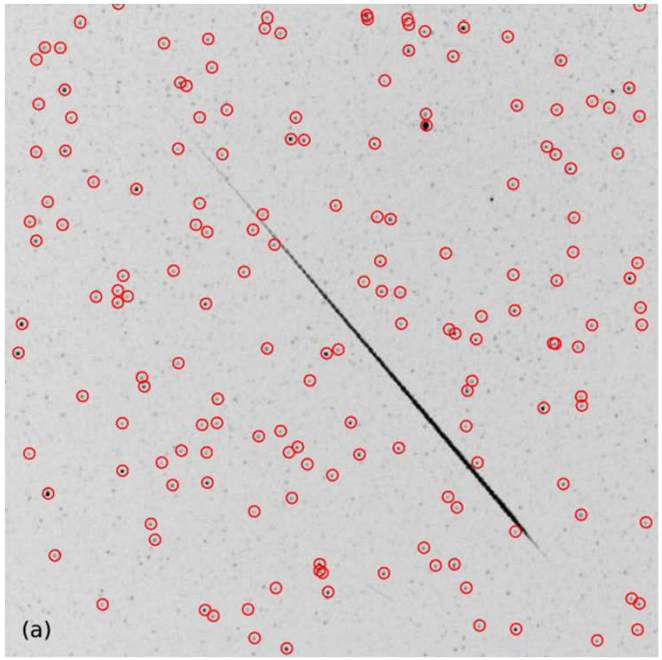


Expected nuclearite flux limit per year (5% duty cycle) operation using three cameras based on K1<2 line (limiting magnitude @ 1 rad/s < 2)

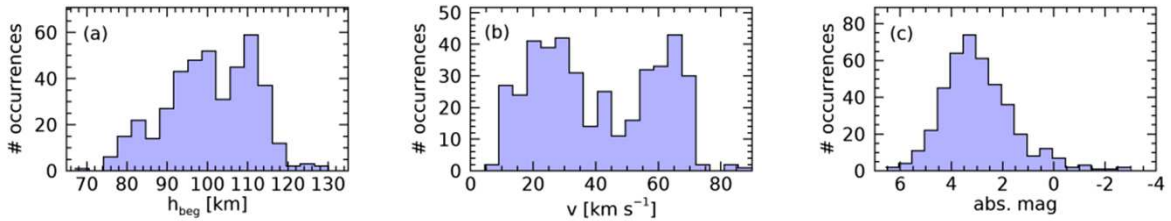
Ref: A. De Rújula and S. L. Glashow, Nature 312, 734 (1984).

Analysis Tool Development

Astrometry and photometry are applied to the detector calibration and data analysis.



A portion of the FoV.
A meteor and identified stars, as red circles, up to +8 mag are seen.
~900 stars are identified in an image.



We obtained meteor beginning height, velocity, magnitude distributions.

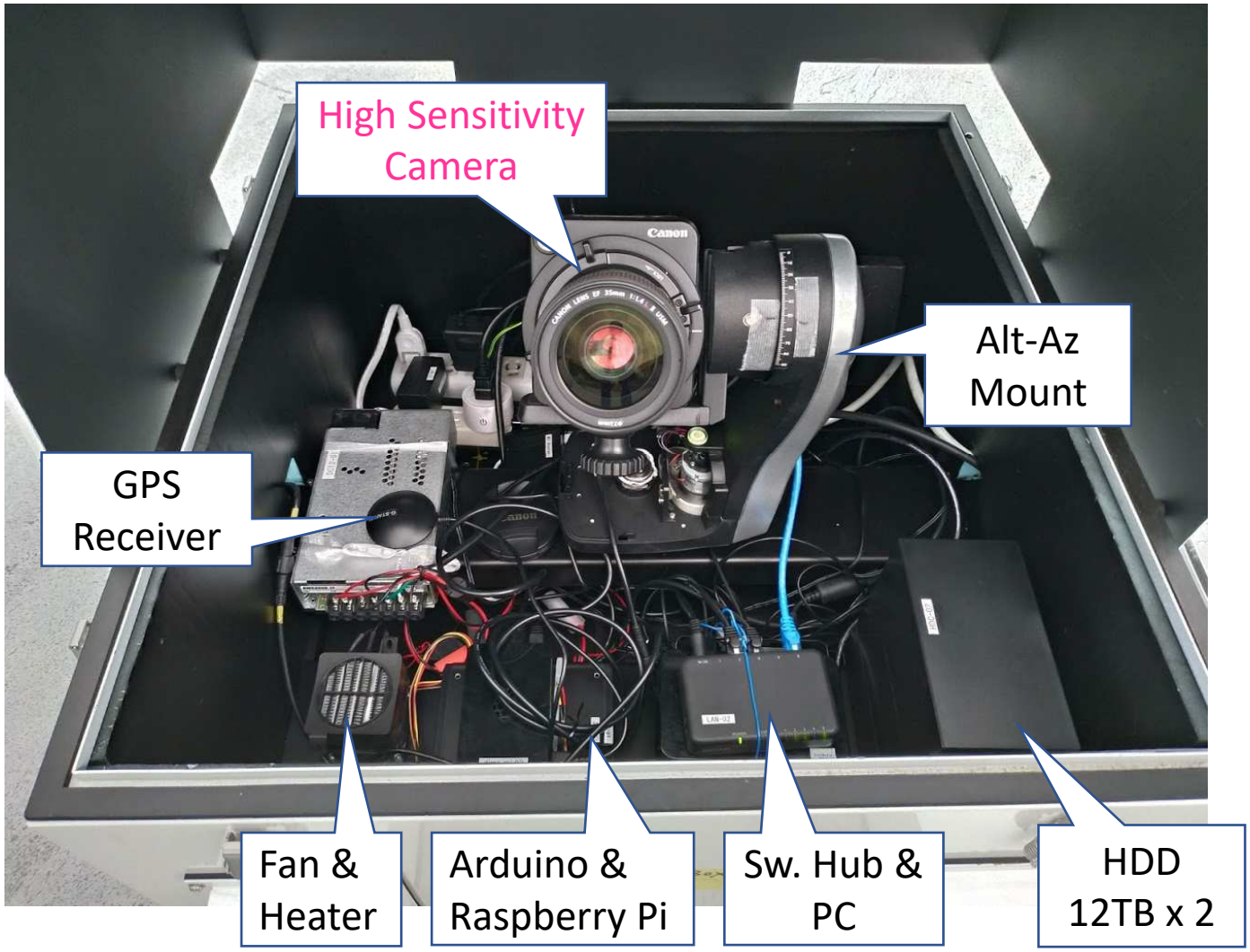
Constraints for macros by the DIMS experiments are discussed.

Details of the analysis are presented as
"Characterization of the DIMS system based on astronomical meteor techniques for macroscopic dark matter search "
ICRC 2021 - ID #767, Poster
by Dario Barghini

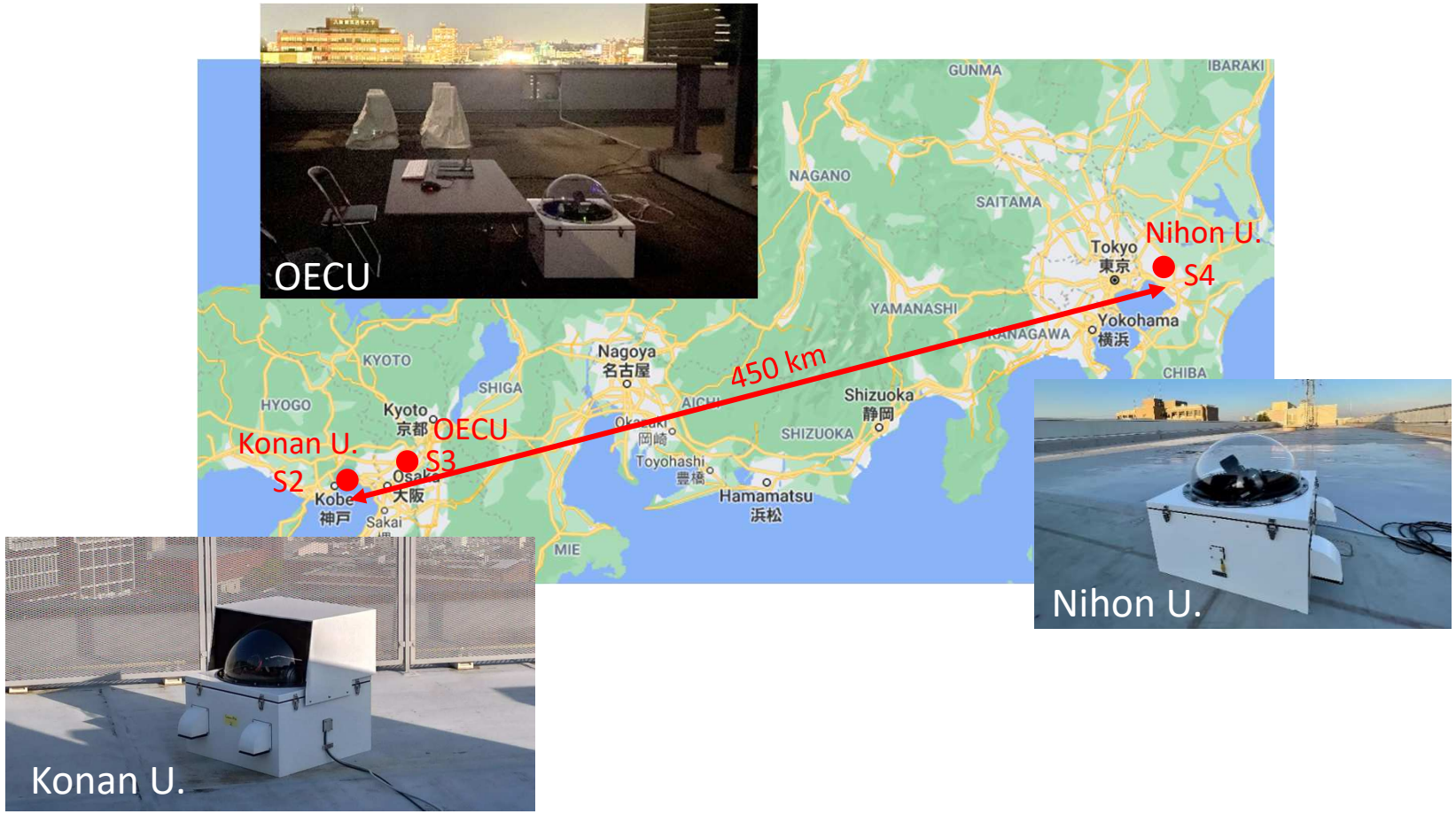
DIMS Camera Box

A high sensitivity CMOS camera is installed in a stainless steel box with an acrylic dome.

Camera Box Inside



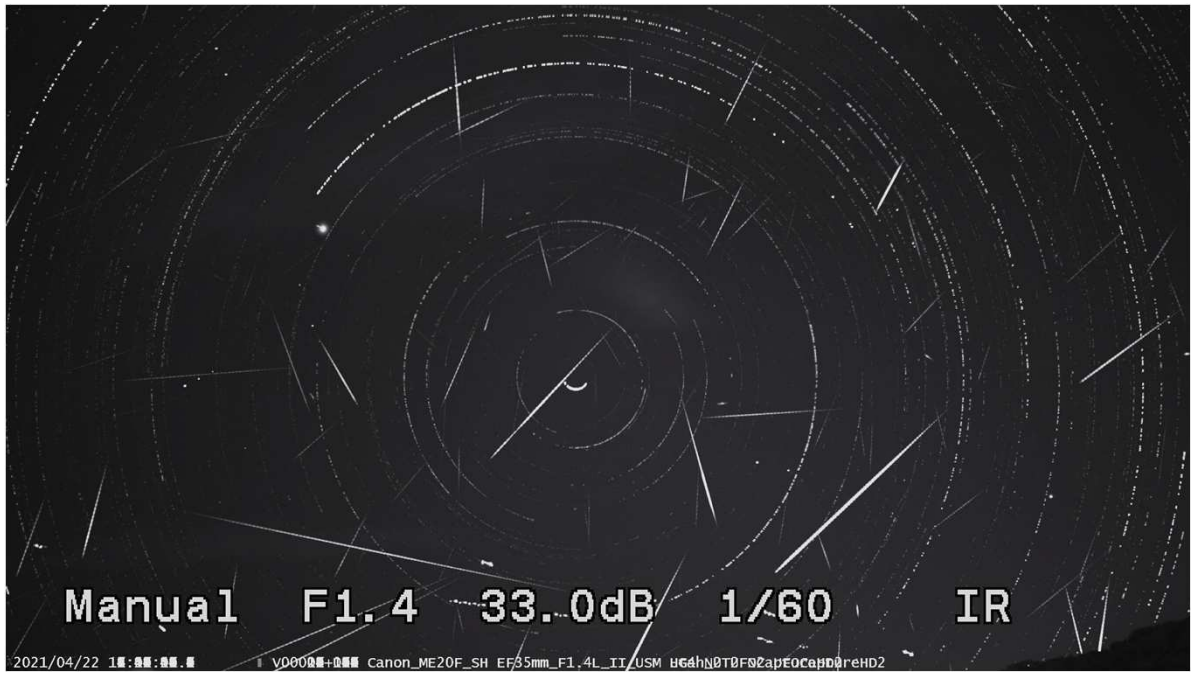
3 Camera Stations at Rooftops



3 camera stations are set on rooftops on 3 universities in Japan for the operation test from April, 2021.

April Lyrids Meteor Shower

An activity of the April Lyrids meteor shower was predicted to reach its maximum on April 22.



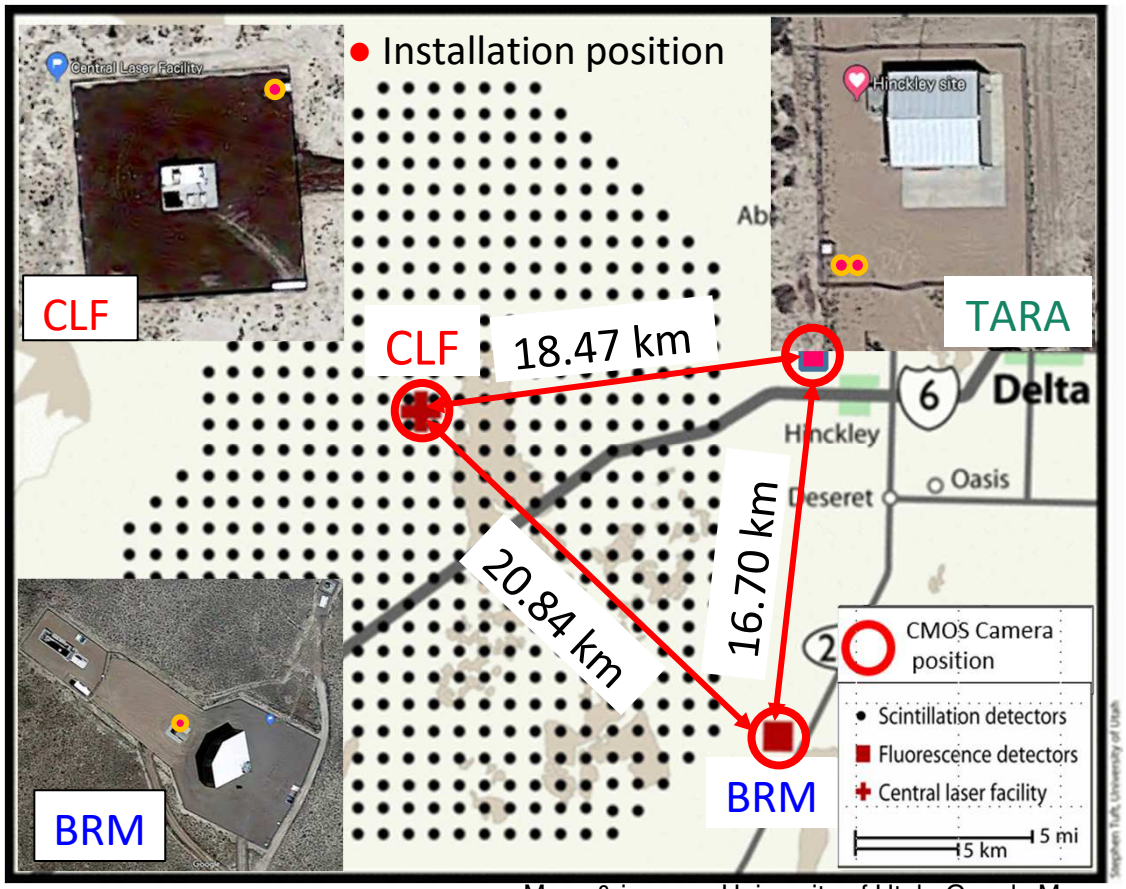
There are about 190 meteors in this composite picture.

DIMS meteor detection at a night on April 22, 2021

Place	Number of meteors
Konan U.	190
Nihon U.	167
OECU	67
Total	424

DIMS FoV: 56.2° × 33.4°

Aiming to Deploy of 4 cameras at the Telescope Array Site in Summer 2021



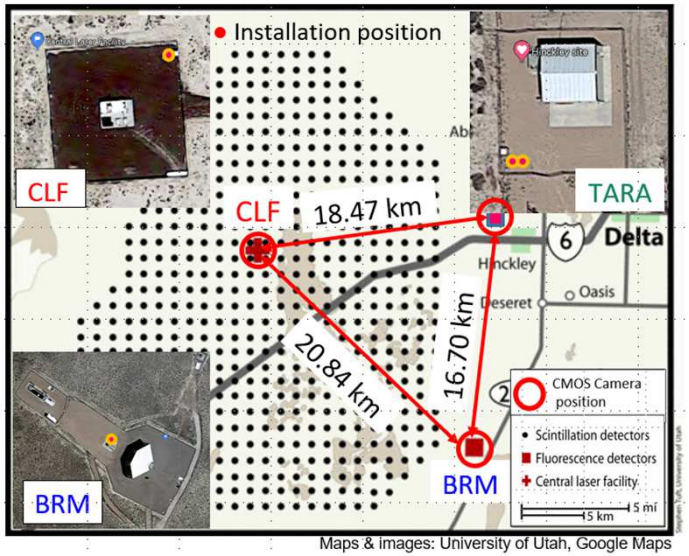
Maps & images: University of Utah, Google Maps

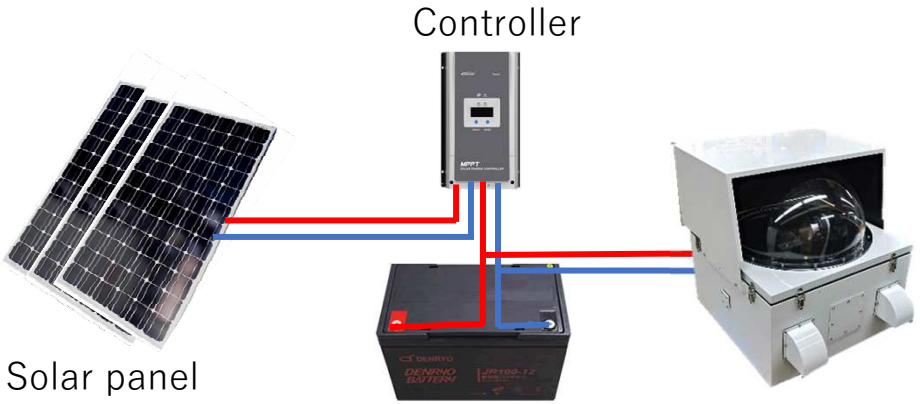
One camera box shipped to Utah in March 2020

5th camera module will be installed in near future.

Solar Power System

- There is no power line coming from the power company at TA-CLF site.
- Therefore, we developed a power self-supply system with solar power.

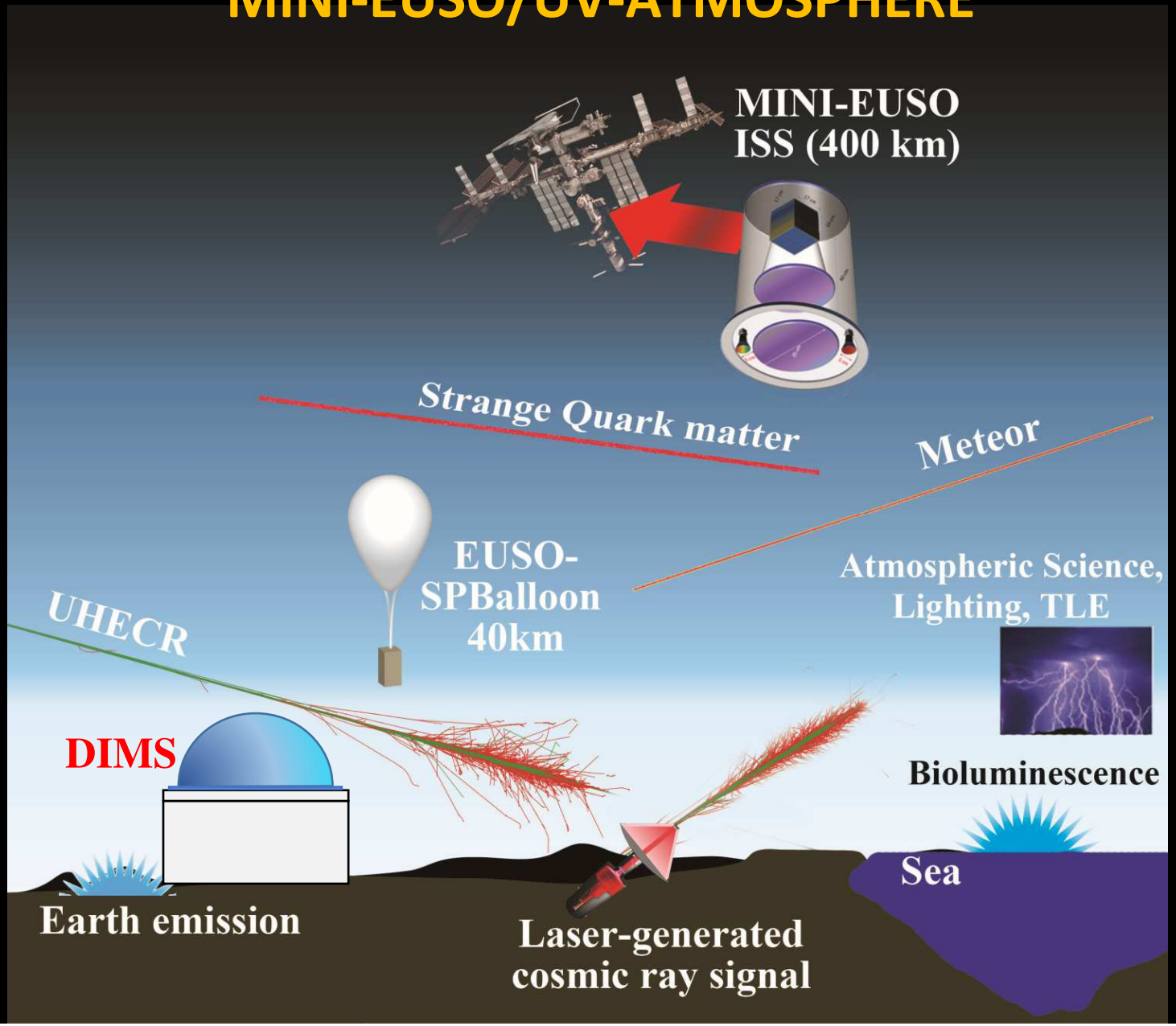




Details of this system are presented as "**Solar Power Supply** and Environmental Control System for DIMS Experiment“ ICRC 2021 - ID #1124, Poster by D. Shinto et al.

Co-observation with JEM-EUSO program

MINI-EUSO/UV-ATMOSPHERE



Summary

- We are developing DIMS experiment project to search for macroscopic dark matter and interstellar meteoroids.
- 3 camera stations are set at 3 univ. in Japan at present.
- 4 camera stations will be set at TA site in summer/fall.
- One more station will be added later.
- DIMS will co-observe with JEM-EUSO program such as EUSO-TA, mini EUSO, K-EUSO, Tomo-e Gozen …
- Though the schedule is delaying by COVID-19,

  DIMS observation in Utah is coming soon!