

高感度CMOSカメラシステムによる 高速飛翔暗黒物質と流星の探索

DIMS (Dark matter and Interstellar Meteorid Study) Project

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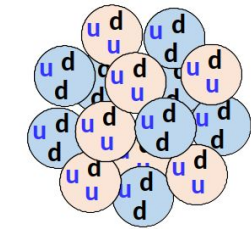
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- 査定額 研究費:1.9万円、旅費:28.5万円(ユタ)、合計:30.4万円
- 新型コロナ感染症拡大のため、次年度に全額繰越申請中

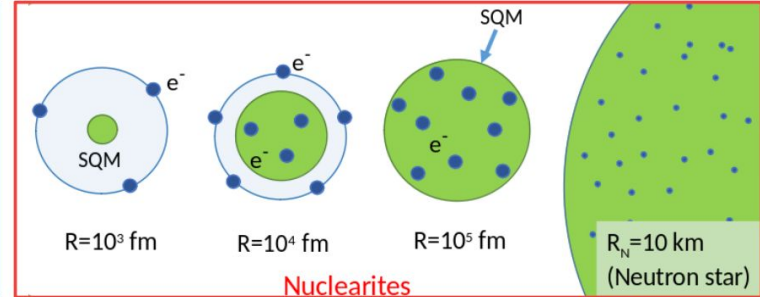
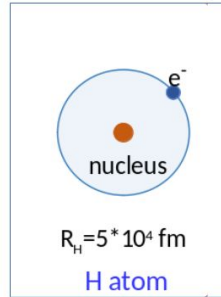
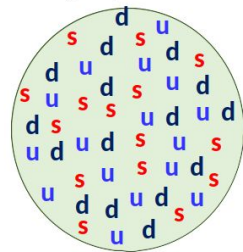
研究目的

- Macroscopic dark matterの候補のひとつである**nuclearite***の探索



Ordinary nucleus

Strange quark matter



*Strange quark matterが電子で覆われた電氣的に中性な塊である(De Rujula & Glashow 1984, Nature 312, 734)

- 流星、特に**太陽系外流星体(interstellar meteoroid)**起源の流星の探索
- その他のTLE (transient luminous event)大気発光現象の観測
- EUSO-TA(@Telescope Array)やMini-EUSO(国際宇宙ステーション)などとの共同観測

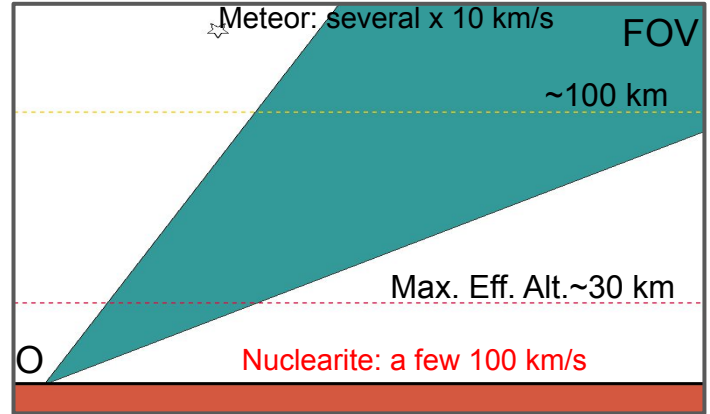
DIMS observation concept

Meteoroids evaporate in the atmosphere resulting in light emission by ionized gas observed as “meteors”

“Ordinary” meteors are bound in the Solar System
Heliocentric speed < 42 km/s (escape velocity)

Interstellar meteoroids exceed 42 km/s

Luminous altitude: ~80 -- 120 km



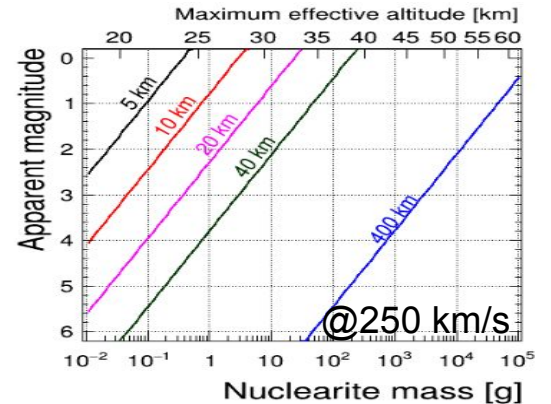
Nuclearites quasi-elastically collide with the atoms. In the expanding thermal shock, a fraction of black-body radiation is seen as visible light @ $L \sim 15[\text{W}] \cdot (m[1 \text{ g}])^{2/3} \cdot (v [250 \text{ km/s}])^3$

Macroscopic dark matter is bound in Milky Way Galaxy

Typical heliocentric speed ~250 km/s (max. 800 km/s)

(cf. Rotation speed ~250 km/s & escape velocity ~550 km/s near Sun)

Luminous altitude: < ~30 km for our interest



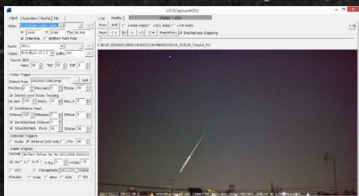
DIMS detector key elements



Canon ME20F-SH CMOS camera

- Max. sensitivity ~ ISO 4,000,000 (ISO 2,04,800 for present setup)
- 1920 x 1080 pixels at 29.97 fps
- FOV ~57°x34° with 35 mm

Controlled by Windows PC



UFOCapture

- Motion capture software

by sonotaCo.com



Camera box

- Acrylic dome with sunshade
- Accommodating camera on alt-azimuth mount, PC, fans, heater, GPS etc.



Power supply system

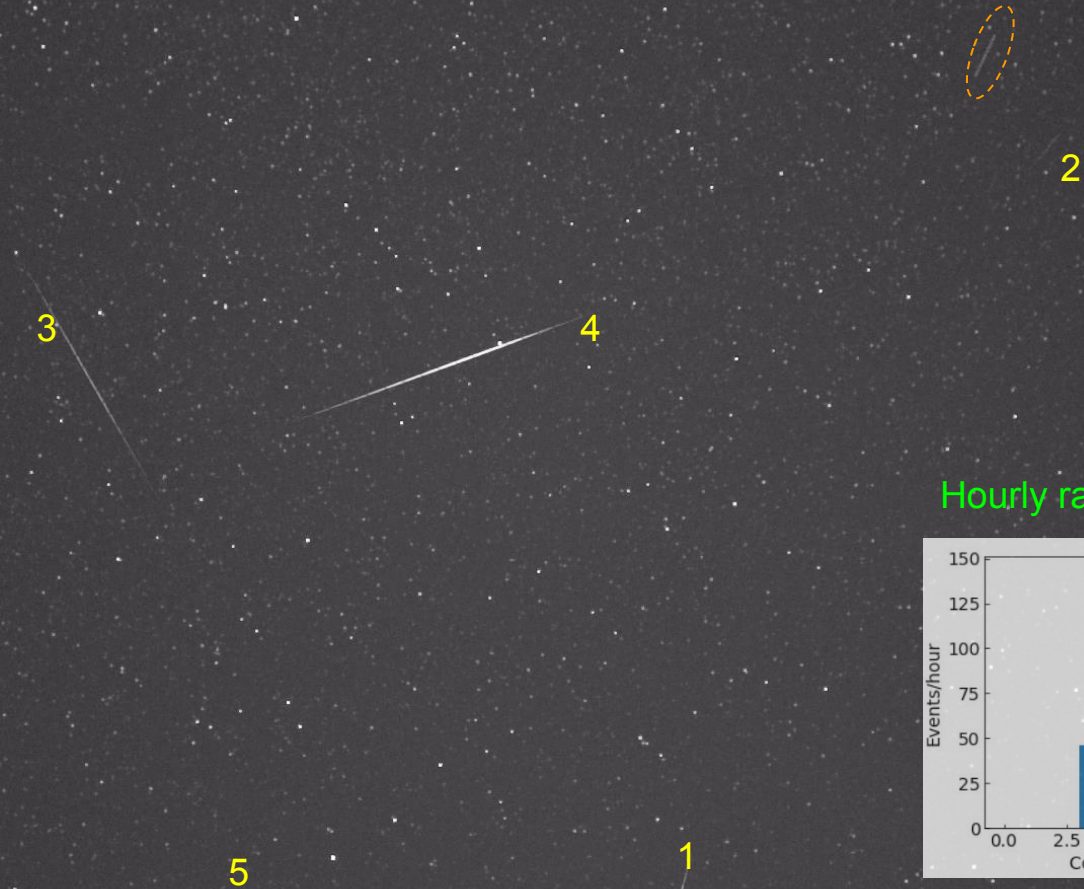
- AT-MA200A solar panels (200 W)
- Tracer6420AN charge controller
- JR130-12 batteries

(Images: chikuden-sys.com, epever.com)

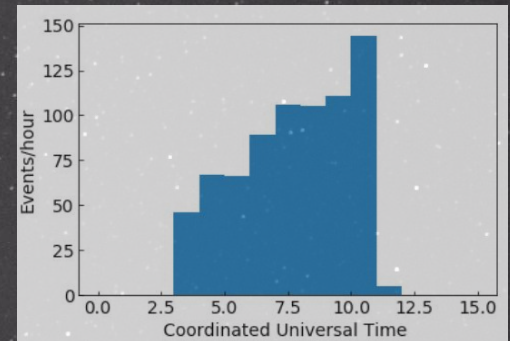
Self-supply system only required for the operation at Central Laser Facility

Test operation at Utah in 2019

Five **meteors** and one **satellite** in ~5.2 s



Hourly rate (2019-09-01)



Standard reconstruction by UFOAnalyzer & UFOOrbit

Effective separation ~10 km

TARA Hinckley

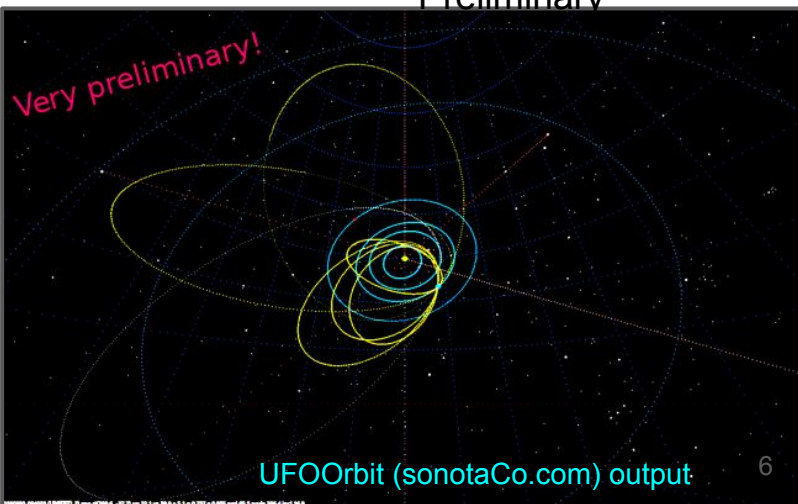
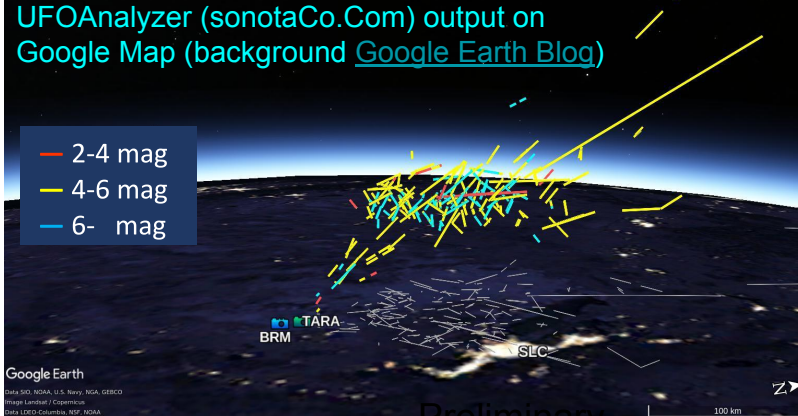
Black Rock Mesa FD site
(shown as the video)

Polaris

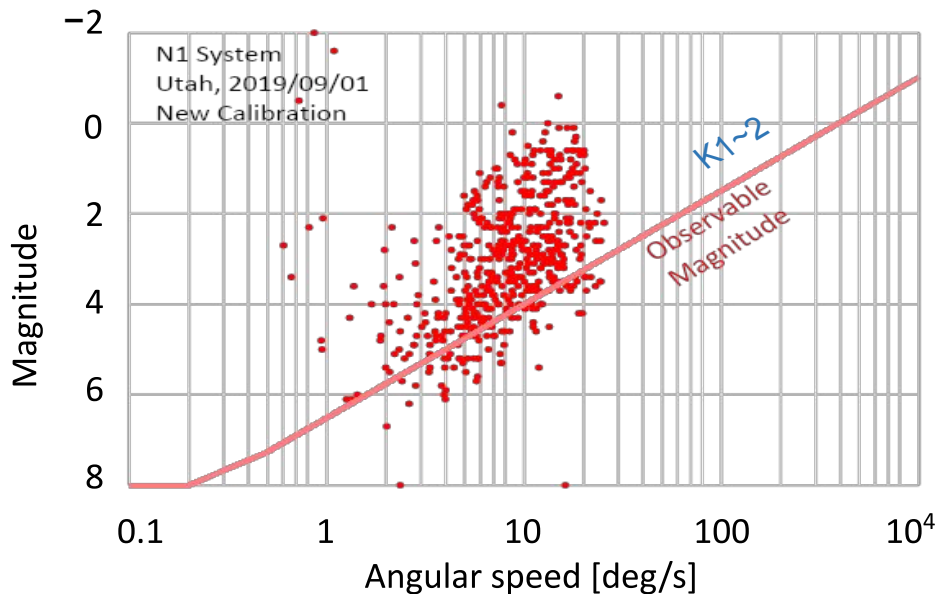
Polaris

2019/09/01 10:34:02.3 I_V00013+106 cannon_ME20F-SH_EF35mm_F1_4L-II_USM_Utah_CRC_V1_UFOcapturem2

2019/09/01 10:34:02.2 I_V00014+106 cannon_ME20F-SH_EF35mm_F1_4L-II_USM_Utah_UTZ_N2_UFOcapturem2



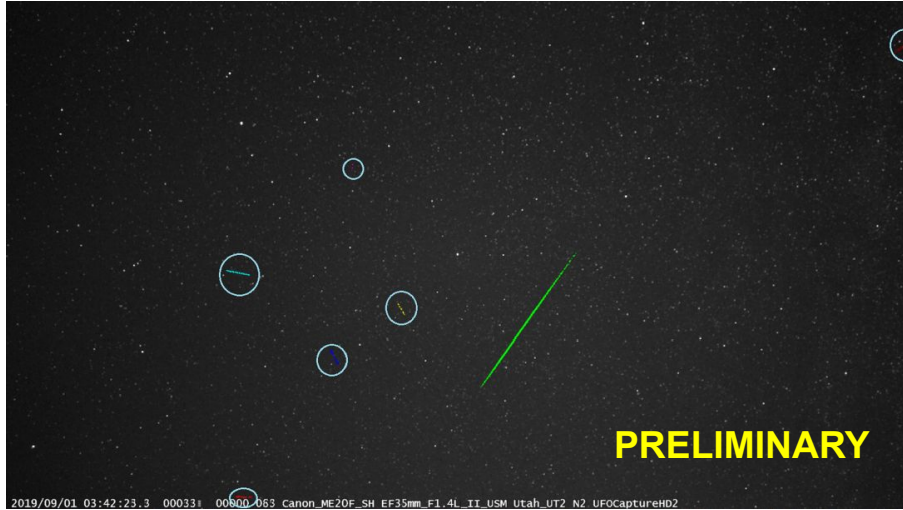
Limiting magnitudes for meteors (UFOAnalyzer) and expected sensitivity to nuclearite



Very preliminary result plot omitted. Based on the assumption, the limiting magnitude line on the left, the preliminary estimations show DIMS has a reasonable potential to give an upper limit of nuclearite in $\sim 1\text{--}10$ g range below the limit given by the dark matter density near the Sun

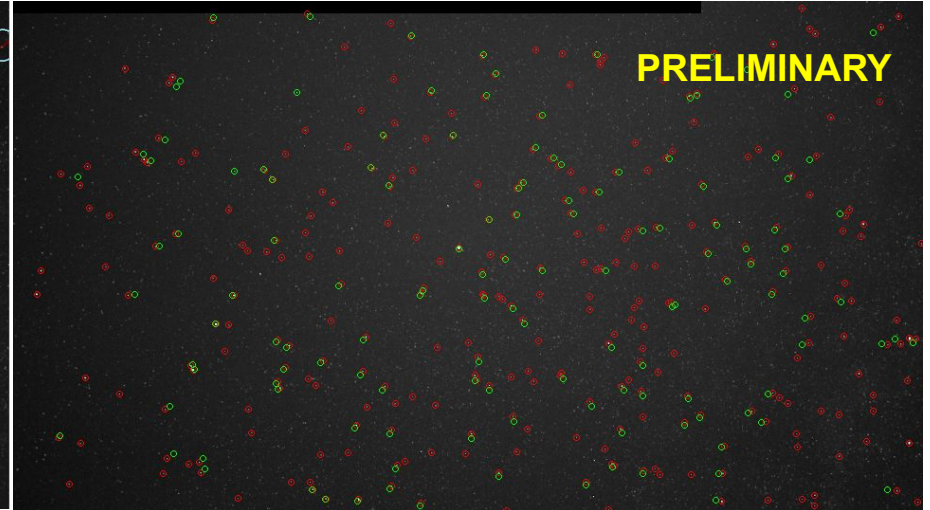
Expected sensitivity on nuclearite flux limit @ 95%CL for 1 yr operation (5% duty cycle) using three DIMS cameras based on K1~2 line (limiting magnitude >2 @ 1 rad/s)

New analysis tool development (Turin)



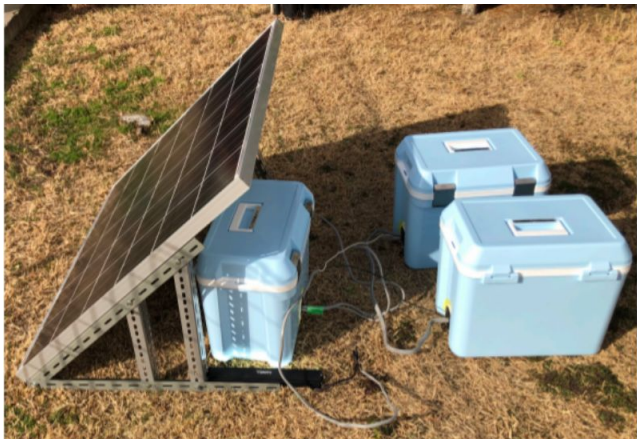
~900 clusters including planes and satellites found
(2019-09-01 N2)

- Meteor trigger algorithm developed to search videos for “clusters”
- “Astrometry and photometry applied to the detector calibration and data analysis
- Orbit calculations to be performed
- Application to nuclearite search foreseen

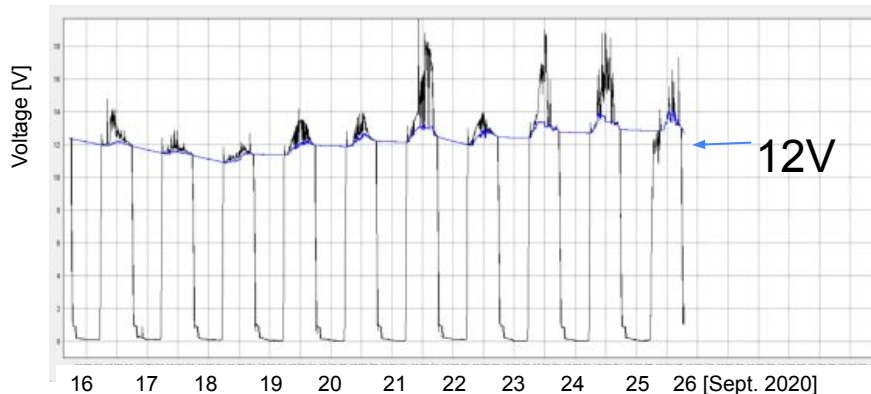


Hipparcos-Tycho catalog ~900 stars identified

Self-sufficient power supply system (OECU)



Test with Kyosera KC125TJ (125 W) in September 2020
Voltage variation for **battery** and solar panel



Two independent power supply systems developed

- System 1 (4 solar panels + 2 batteries) for CMOS camera, PC, HDD etc.
 - Requirement: $63 \text{ W} \times 10 \text{ h} \times 3 \text{ days} \sim 1900 \text{ Wh}$
- System 2 (3 solar panels + 1 battery) for other subsystems
 - Requirement: $47 \text{ W} \times 10 \text{ h} \times 3 \text{ days} \sim 1400 \text{ Wh}$

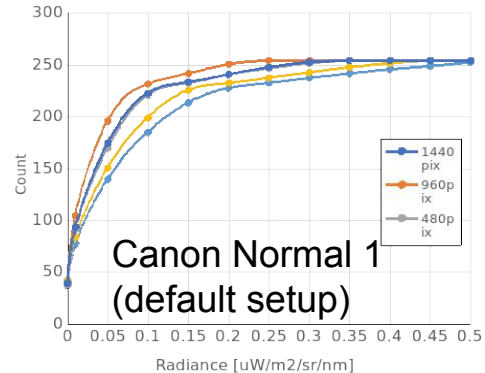
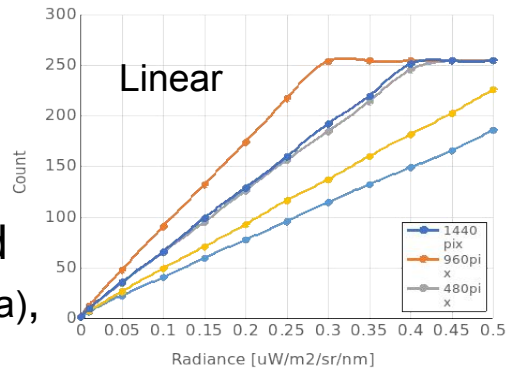
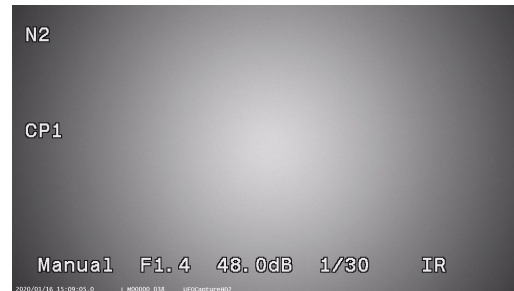
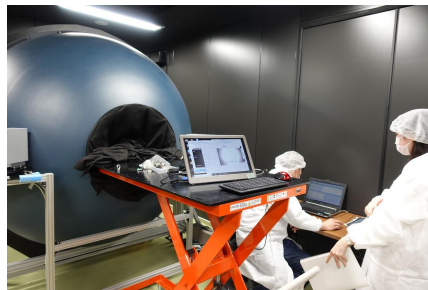
In this year, Both systems will be tested to operate a full DIMS equipment at Osaka Electro-Communication University

DIMS unit construction and calibration (Konan)



Three DIMS units ready to be tested at Konan Univ. (Kobe), OECU (Neyagawa), and Nihon Univ. (Funabashi) in March

First unit already delivered to Univ. Utah in March 2020

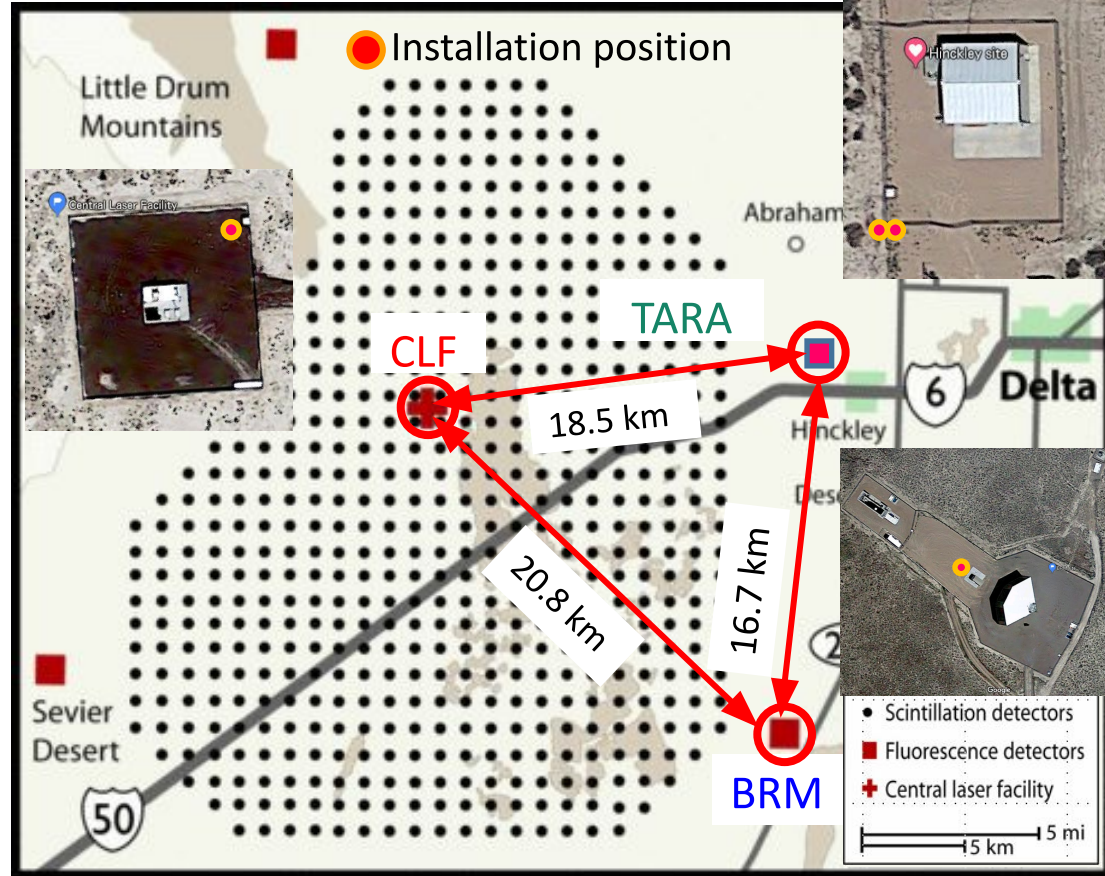


Calibration using LMS-760 integrating sphere at National Polar Institute (Tachikawa)

Aiming at deployment of four DIMS units on the Telescope Array site in August 2021



One camera box shipped to Utah in March 2020



Summary

- 高感度CMOSカメラで流星を動画で観測できるシステムを開発・試験

Macroscopic dark matter や太陽系外流星体の探索のための
DIMS (Dark matter and Interstellar Meteoroid Study) Project を推進

2020年12月に、2nd DIMS Workshopをonlineで開催

宇宙線実験・理論物理・流星体天文学の研究者・学生による
国際協力体制 (日本・アメリカ・イタリア・ポーランド・スロバキア・韓国) を構築

- 今年国内で観測試験を実施後、ユタで観測開始を予定