

Second-timescale Glints from Satellites and Space Debris Detected with Tomo-e Gozen

Tomo-e Gozenによる人工衛星・スペースデブリ 秒スケール発光現象の観測

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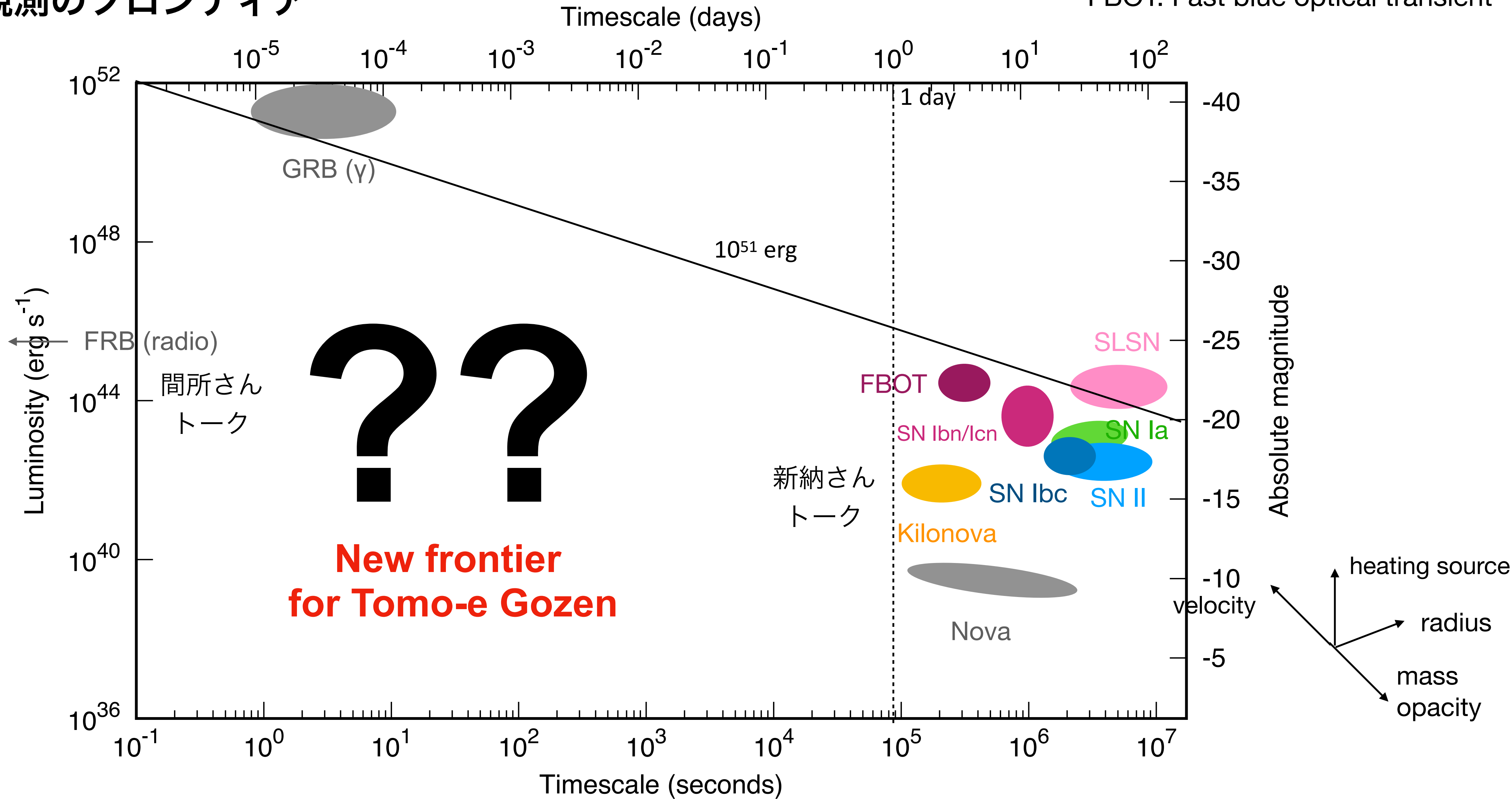
酒向重行、有馬宣明、新納悠、衣笠健三、小林尚人、近藤荘平、森由貴、高橋英則、瀧田怜 (東京大学)、

小久保充、富永望、大澤亮 (国立天文台)、諸隈智貴 (千葉工業大学)

Frontier of transient sky

突発天体観測のフロンティア

SN: supernova
SLSN: superluminous SN
FBOT: Fast blue optical transient

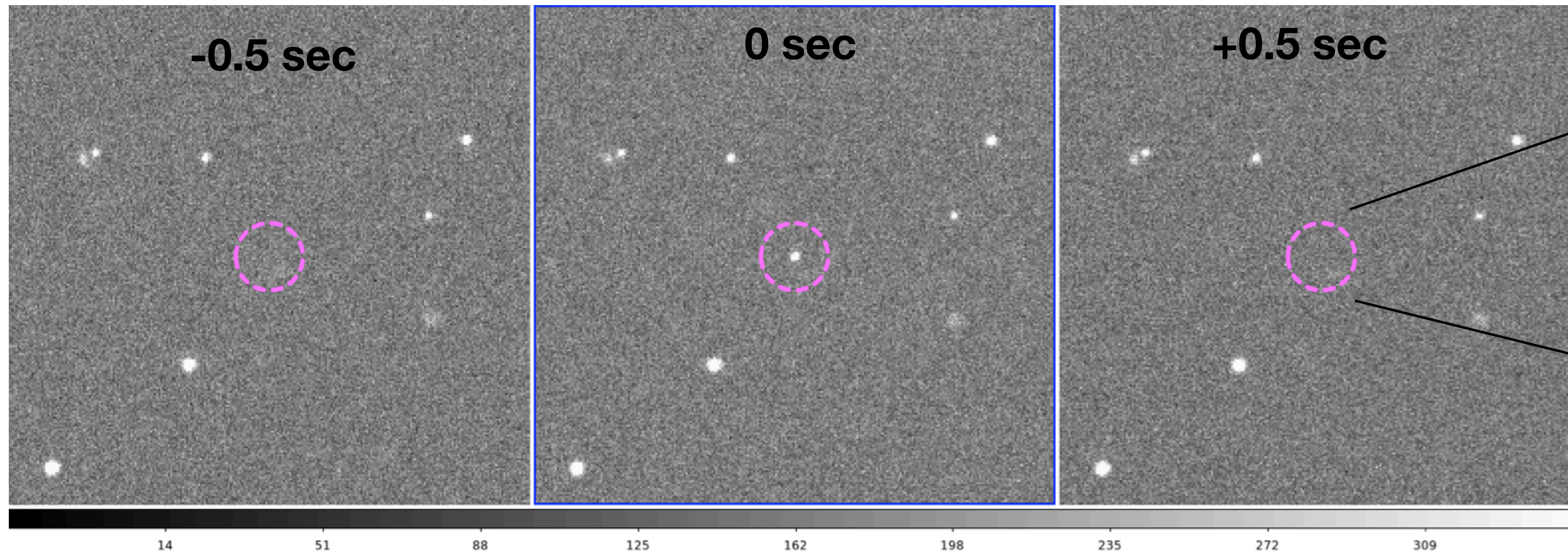


History

秒スケール突発天体：歴史

2015 December:
“Tomo-e flash” detected with Tomo-e PM

菊池さん修士論文 (2016年)



Just on top of a galaxy
(at $z \sim 0.04$)

Follow-up observations (e.g., Swift) => No detection...

**Reflection of small body orbiting the Earth
can cause short-timescale “glint”**

2016-: Observations toward the Earth’s shadow

Richmond+20, Arima+26
直川さんトーク

History repeats 歴史は繰り返す

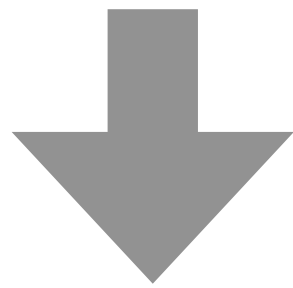
THE ASTROPHYSICAL JOURNAL, **307**:L33–L37, 1986 August 1
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Katz+1986

OPTICAL FLASHES IN PERSEUS

BILL KATZ, DAN DRISCOLL, KAI MILLYARD, BRUCE WATERS, MARK ZALCIK, JOE ADAIR, ANDREAS GADA,
WAYNE HAYES, RICHARD KELSCH, RICHARD MCWATTERS, RICHARD ROKOSZ, AND JOHN ZEHETHOFER
North York Astronomical Association

“Perseus flasher” (PF)

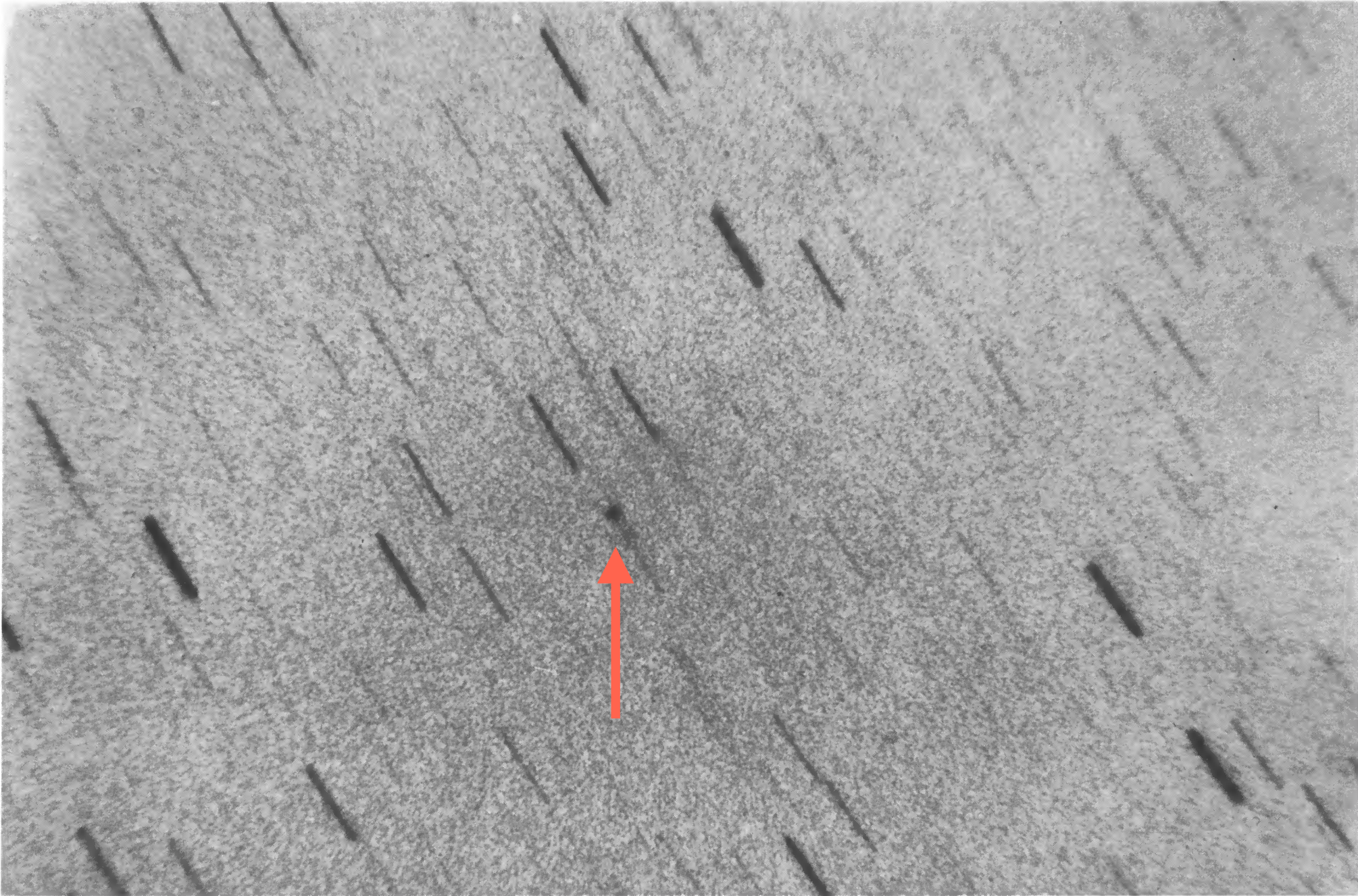


THE ASTROPHYSICAL JOURNAL, **320**:398–404, 1987 September 1
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Schaefer+1987

THE PERSEUS FLASHER AND SATELLITE GLINTS

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Received 1987 February 9; accepted 1987 February 26

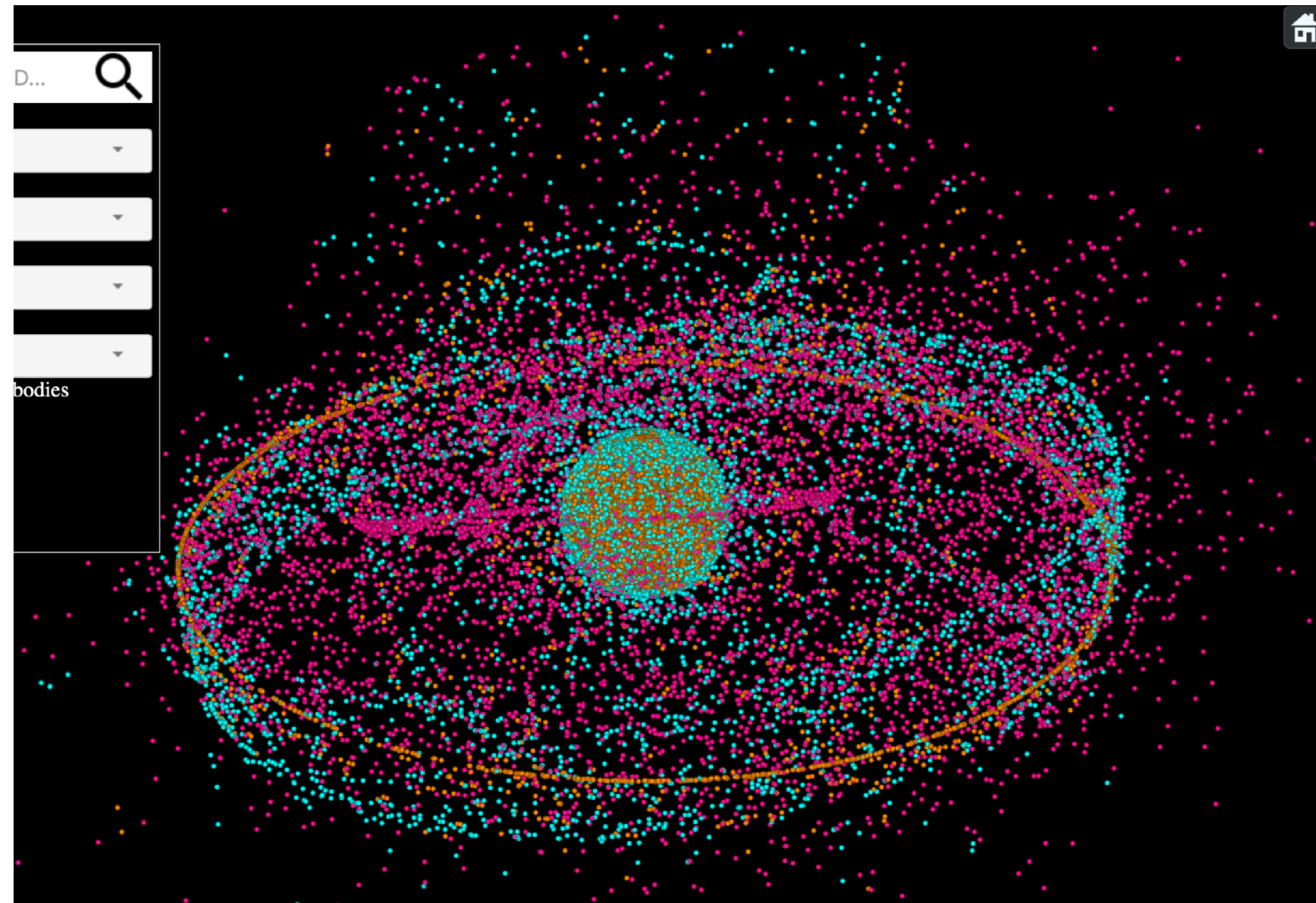


Unfortunately, we have found that the PF is *not* an astrophysical source but is instead merely the observation of glints of reflected sunlight from artificial Earth satellites. This conclusion is supported by the following

New probe for space debris?

スペースデブリの新しいプローブ？

Rapid increase of space debris

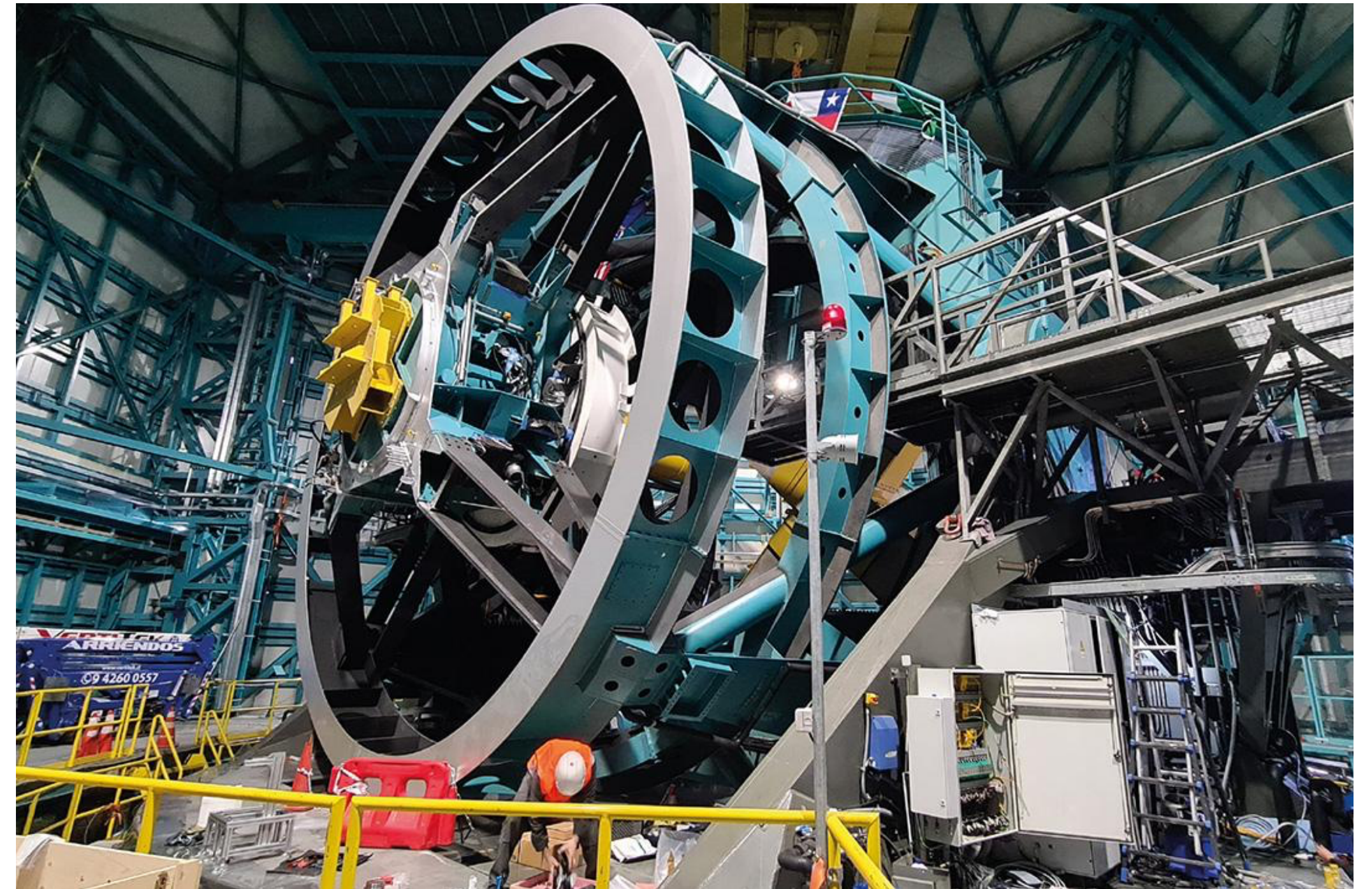


<http://astria.tacc.utexas.edu/AstriaGraph/>

Impact to deep survey?

Deep surveyへの影響は？

Rubin/LSST (6.5m, 9.6 deg²)



(C) Rubin Obs/NSF/AURA.

**Systematic study of short-timescale “glint”
with Tomo-e Gozen**

A search for second-timescale glint

秒スケール現象の探査

- **Data**

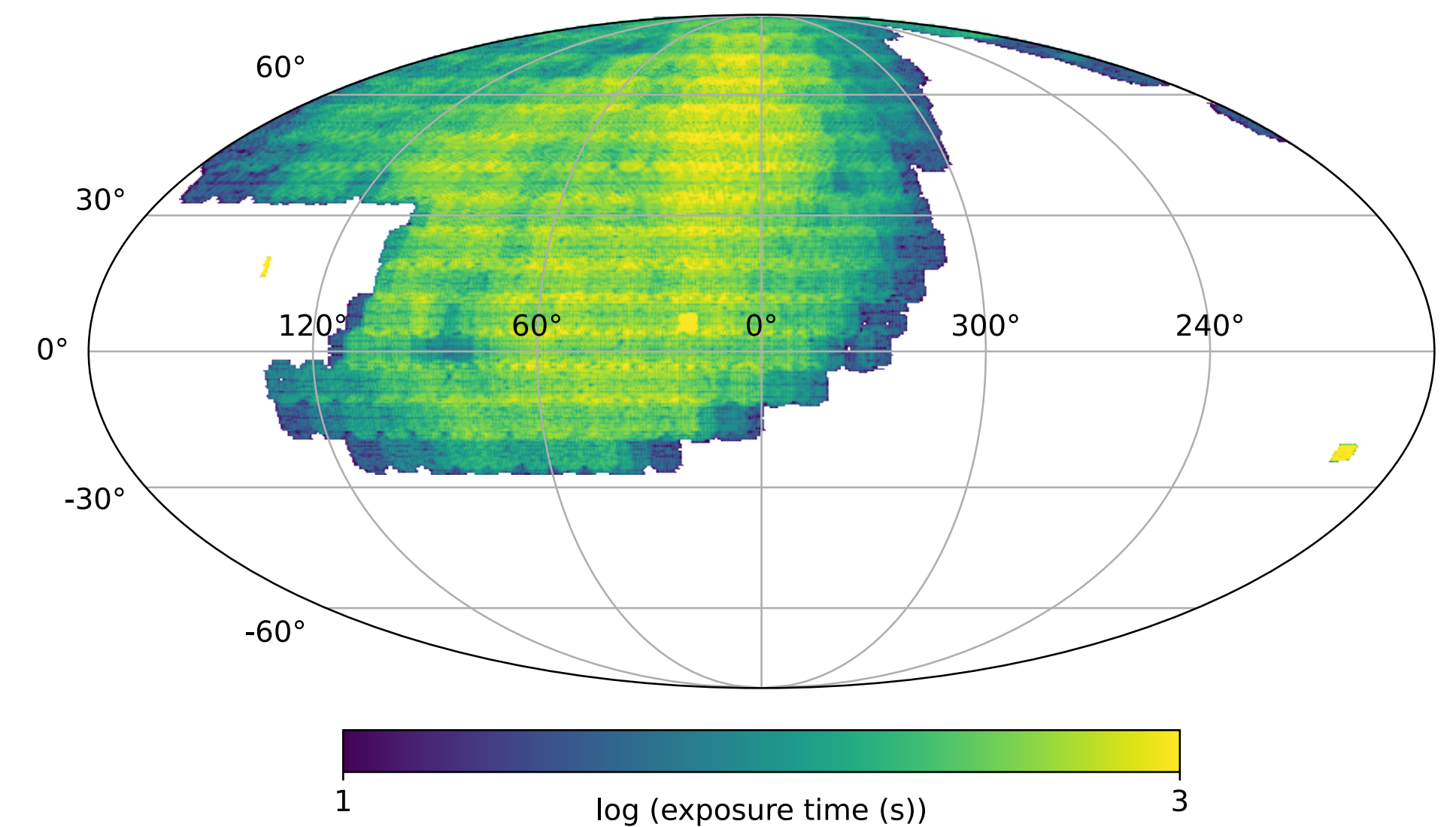
- 21 nights in 2023 Jan - Feb
- All sky survey (~ 3 hr after the sunset)
- 0.5 sec x 18 frames => 16.5 mag (5σ)
- “Areal exposure” = 173 deg² hr
- 87.4 TB in total

- **Detection**

- Detection with “Single shot multibox detector (SSD)”
 - Non detection => Point source => Non detection
- Matching with known satellites (SpaceTrack + Skyfield)

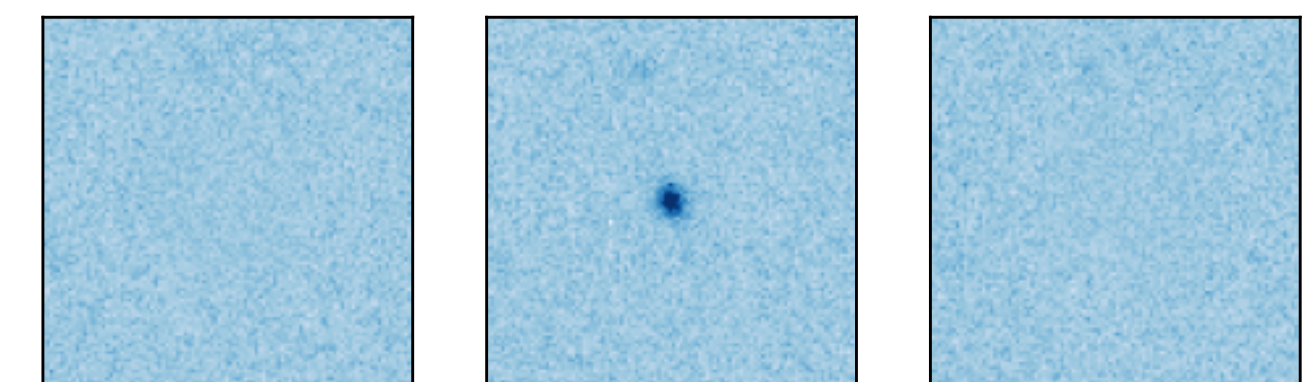
線状のものは無視している
(大井さんトーク)

Exposure map

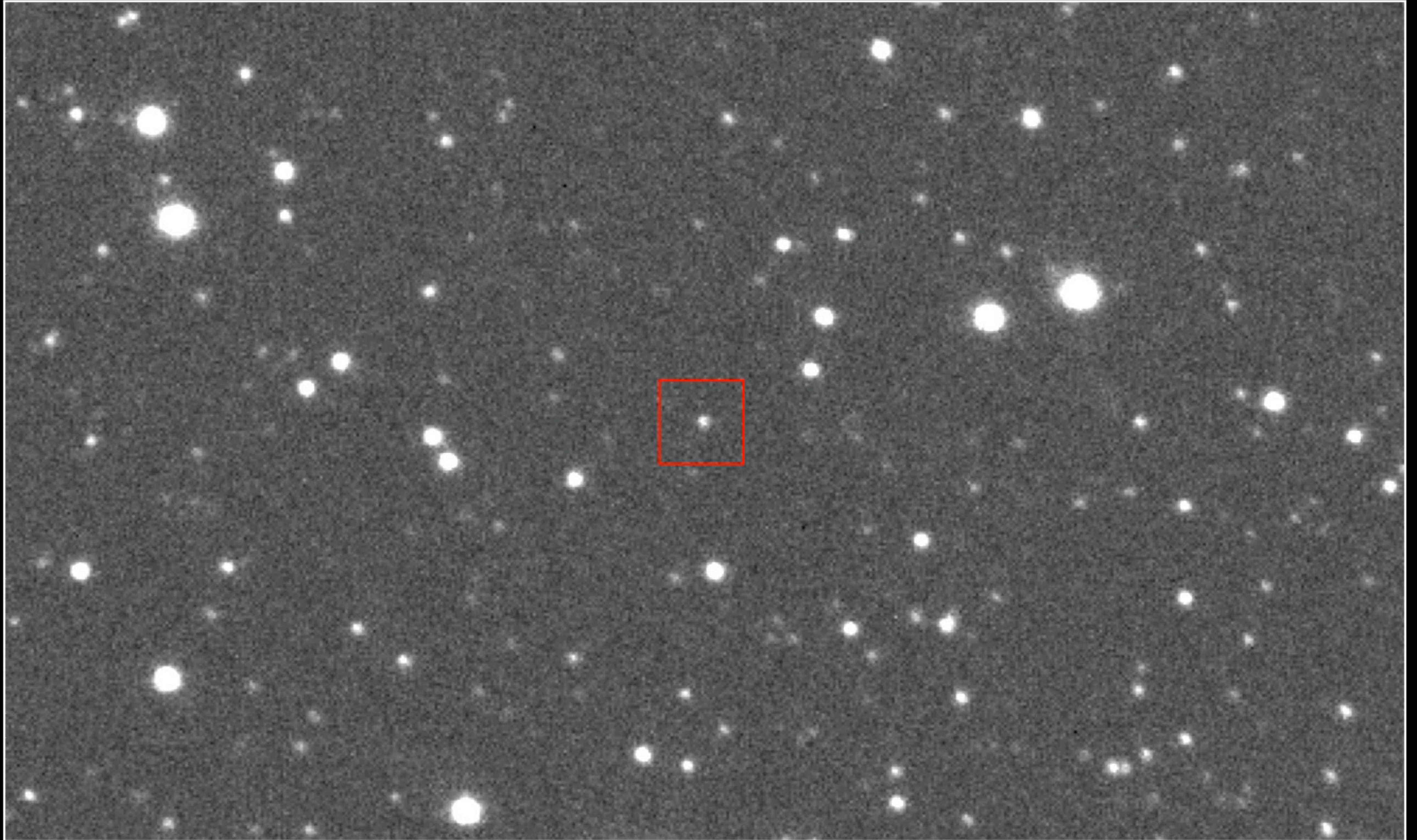


Single Shot Multibox detector (SSD)

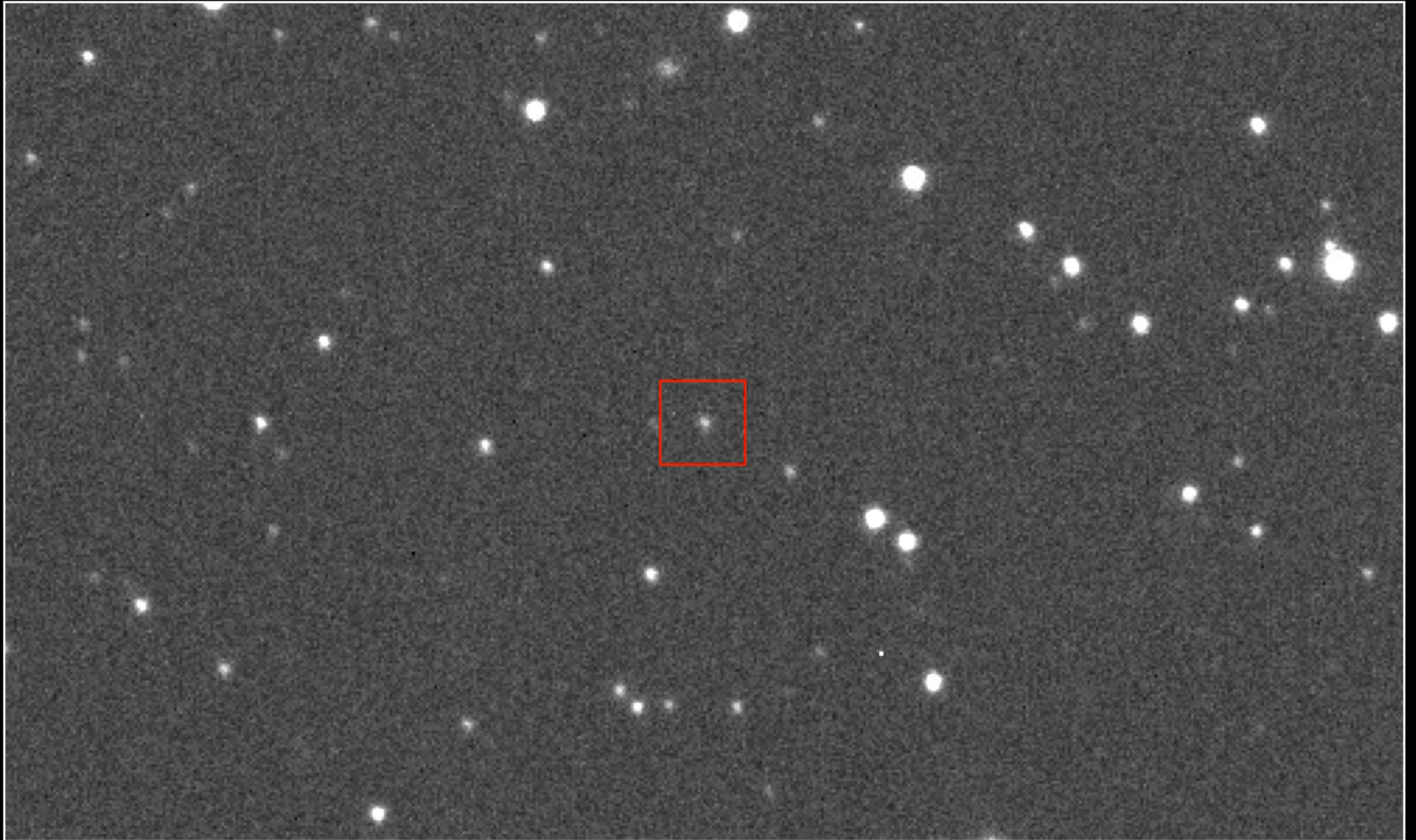
Liu et al. (arXiv:1512.02325)



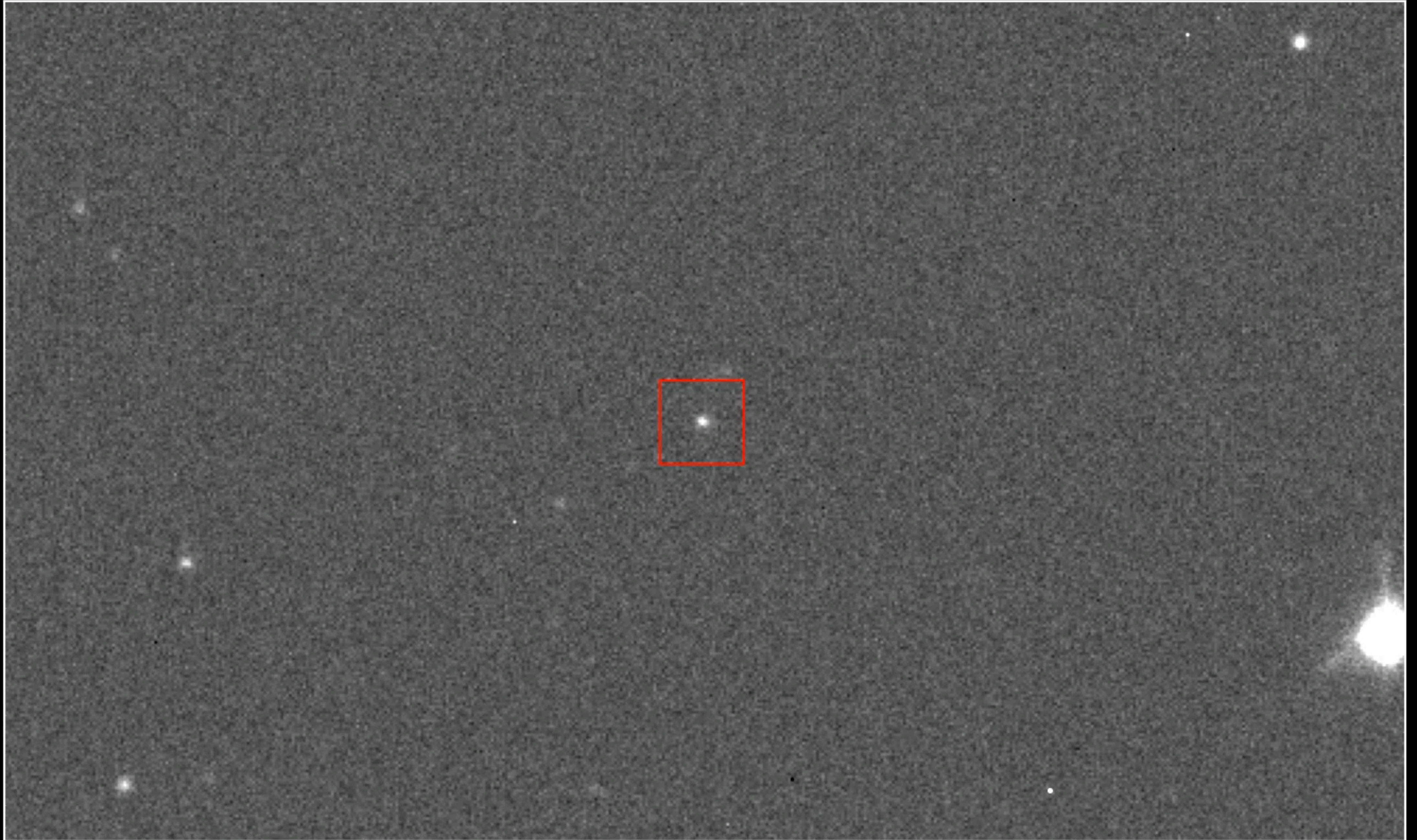
0.0 s



0.0 s



0.0 s

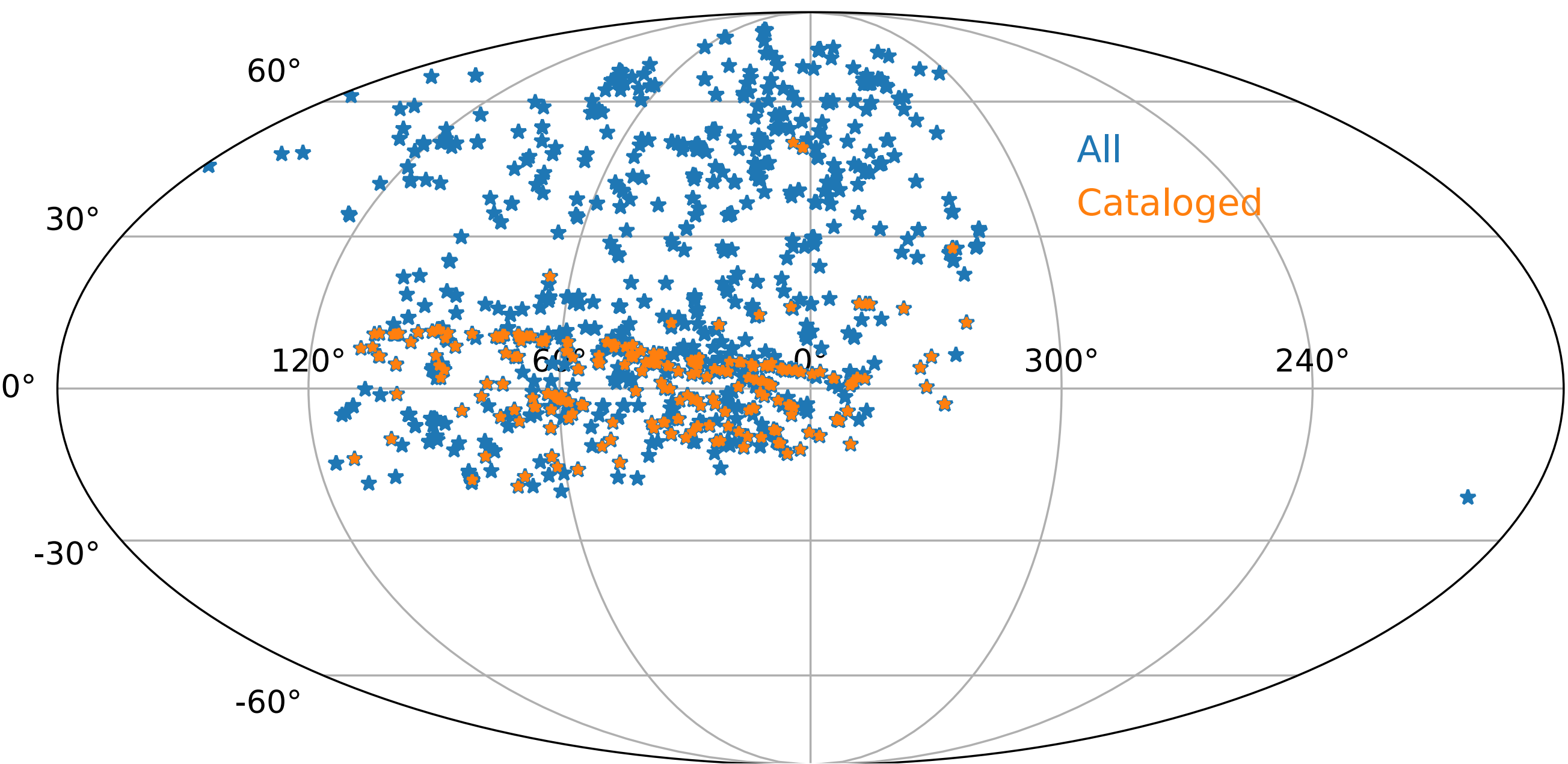


Results

結果

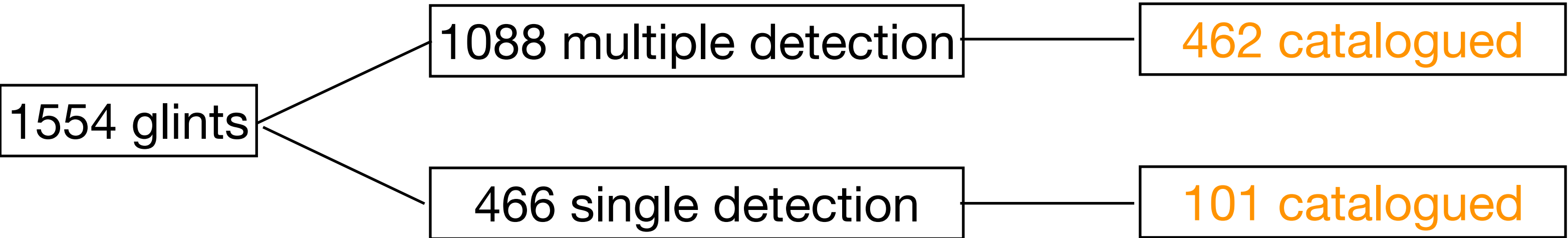
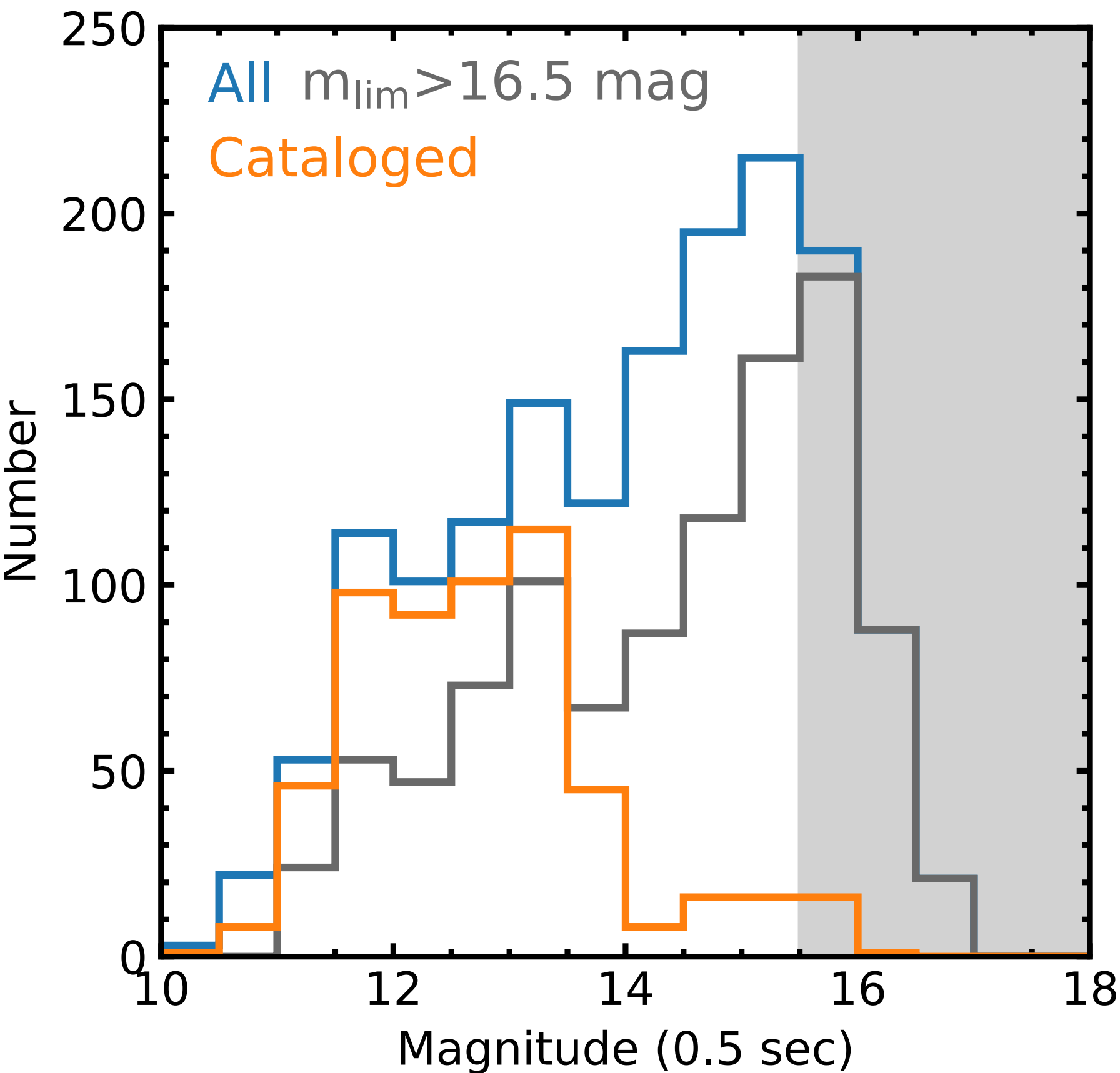
Sky distribution

天球面上の分布



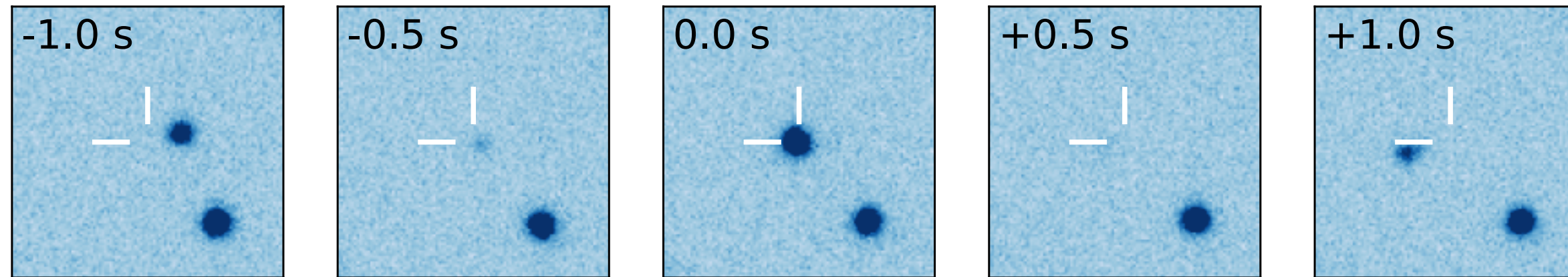
Brightness distribution

明るさ分布

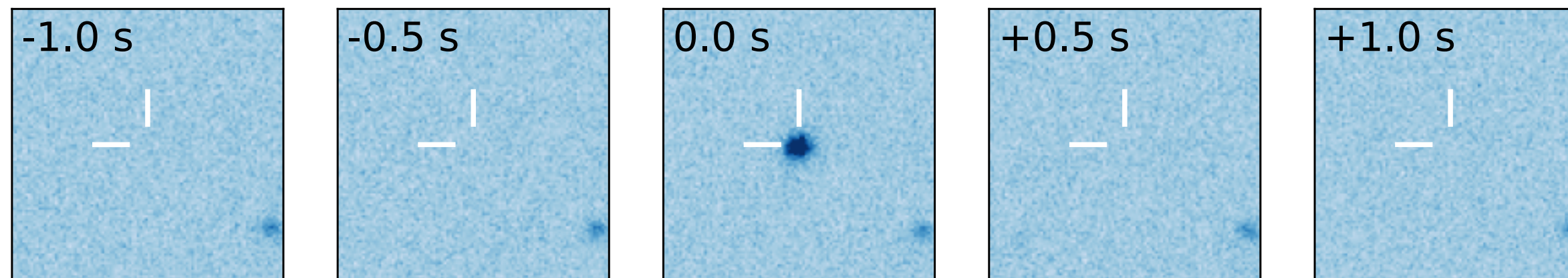


Closer look よく見てみる

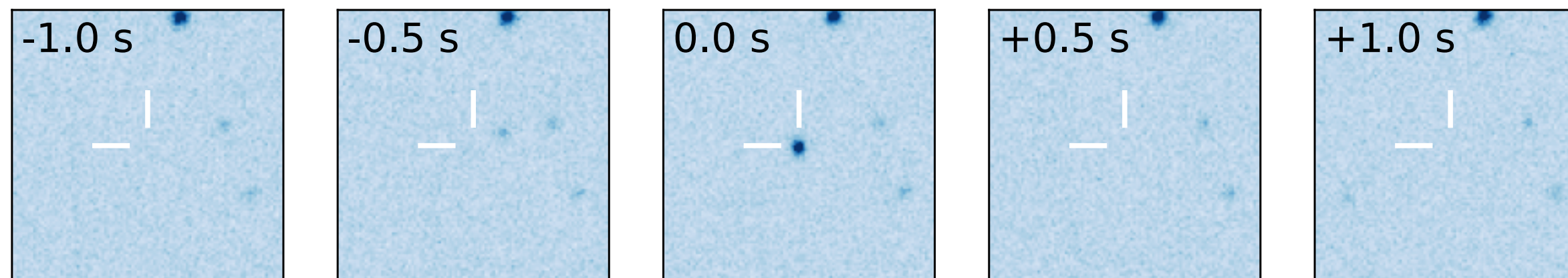
ARIANE 44L DEB
Multiple (3)
13.1 mag



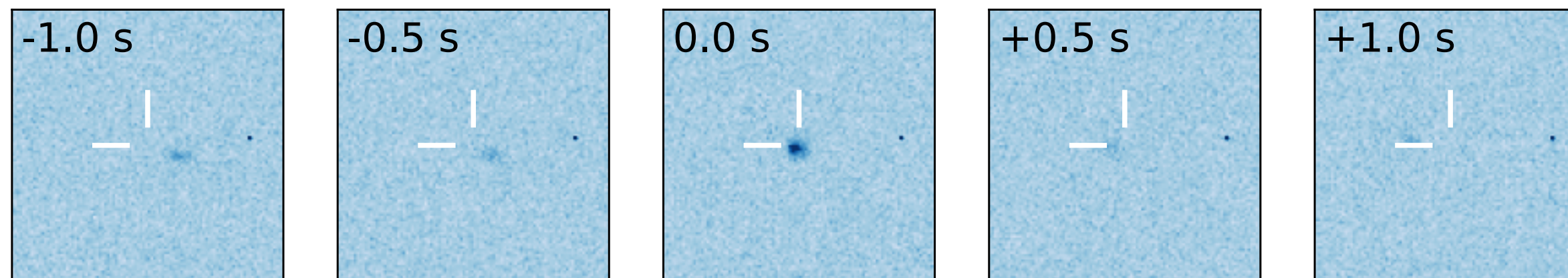
Uncataloged
Single
14.1 mag



Uncataloged
Multiple (4)
14.6 mag



HIMAWARI 5 AKM
Single
14.8 mag

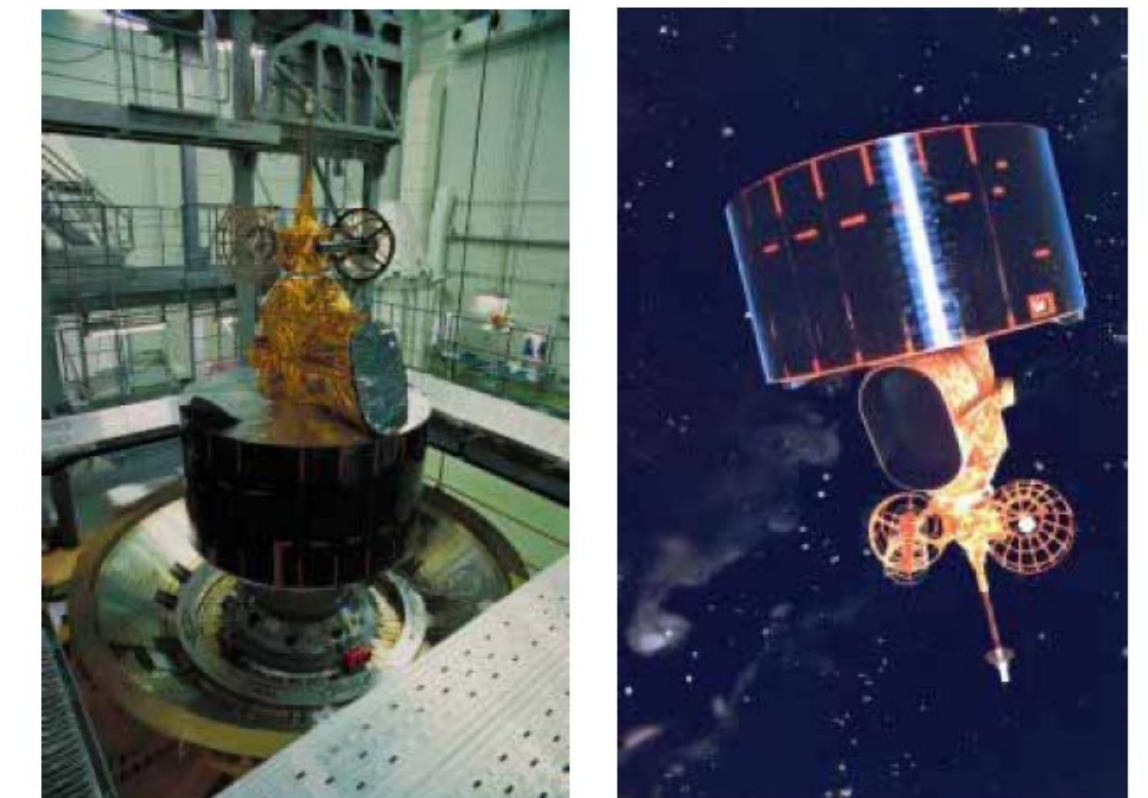


Ariane 44L



ひまわり5号 (1995)

AKM: Apogee Kick Motor



H-II ロケット試験機3号機との結合状態(左)、軌道上想像図(右)

右側画像 : https://space.skyrocket.de/doc_lau_det/ariane-44l_h10-3.htm

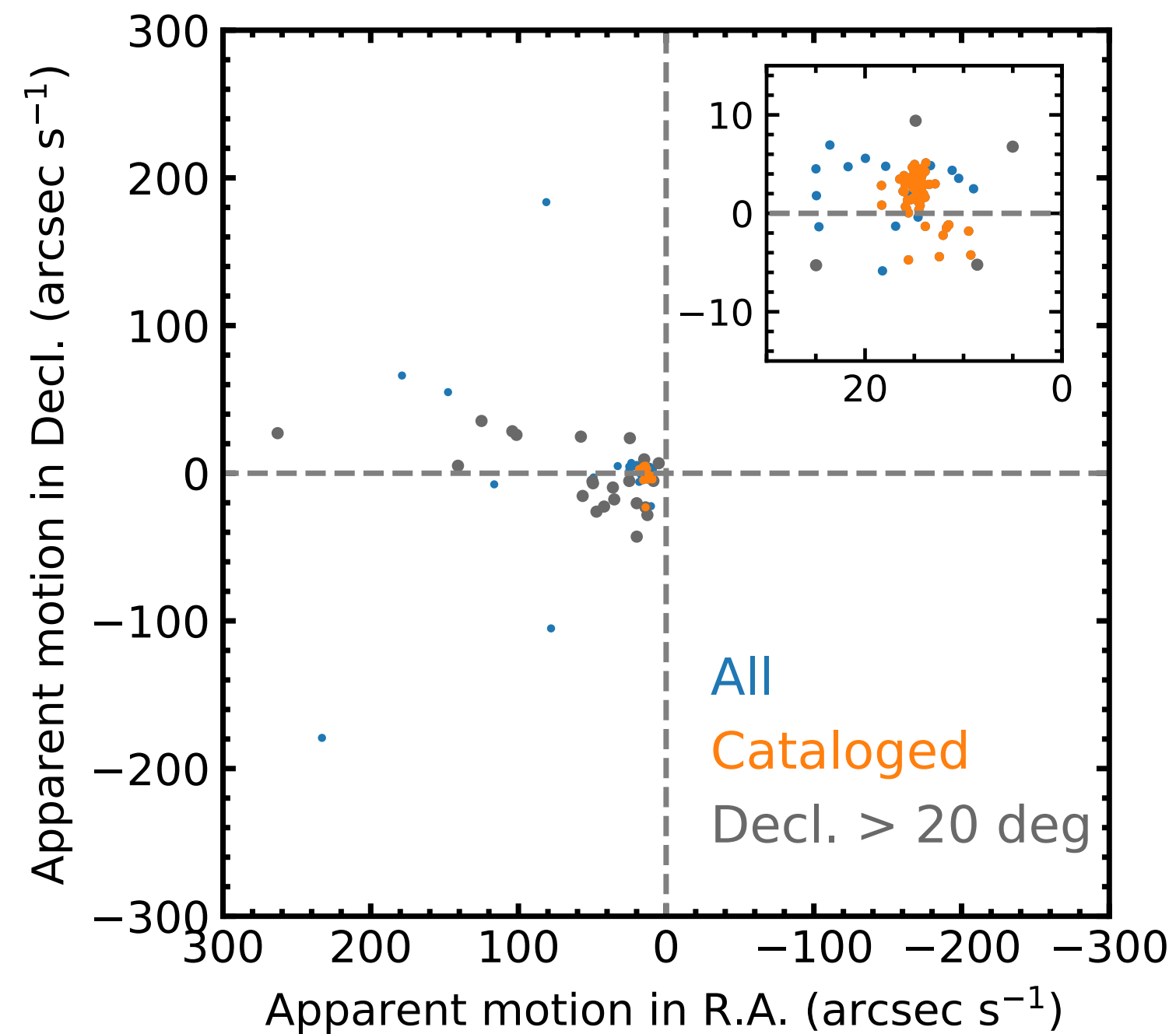
https://www.jaxa.jp/press/2005/07/20050720_sac_gms5_j.html

Which orbit? 物体の軌道は？

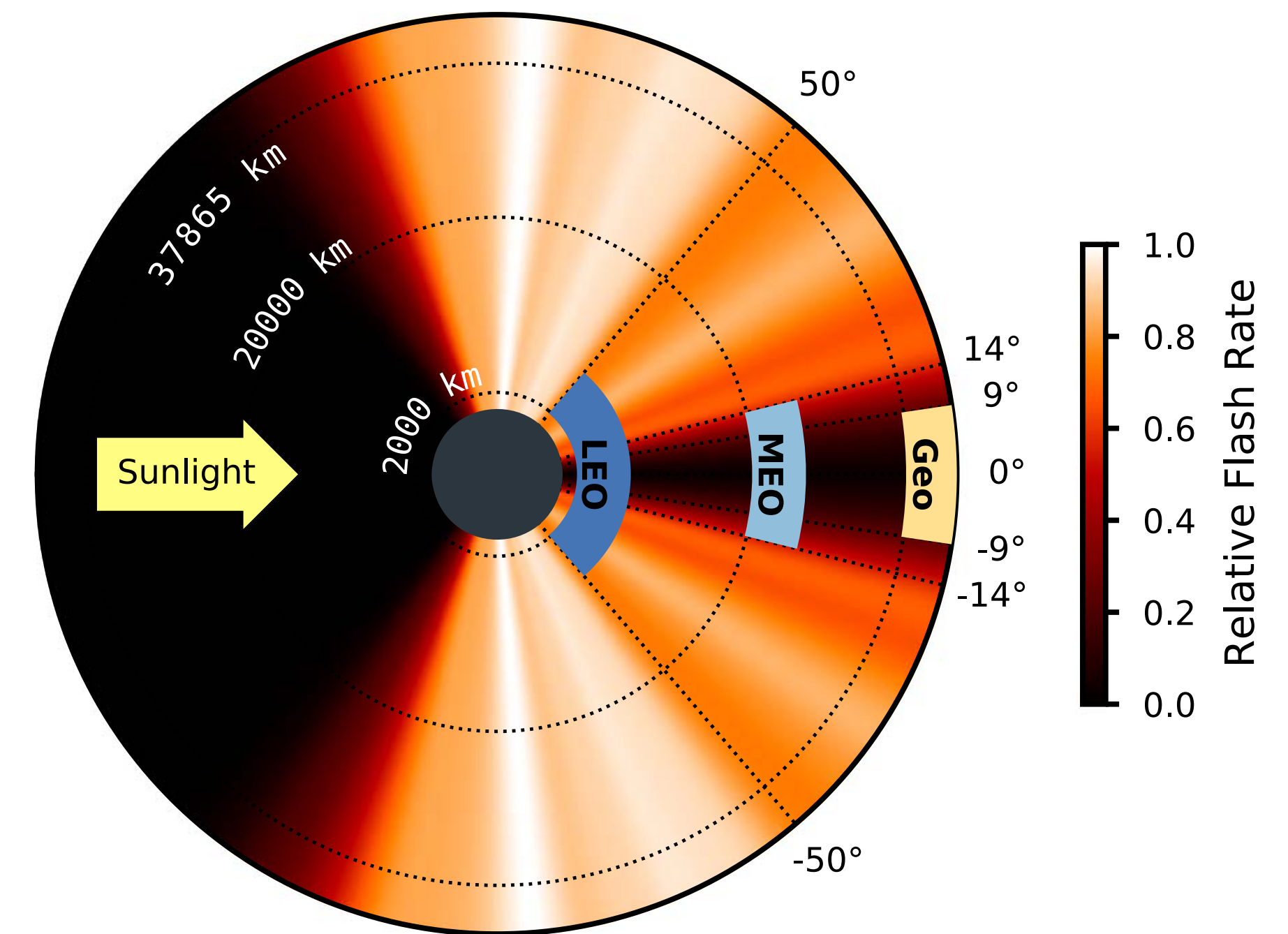
Motion on the sky

15 arcsec / s => Geosynchronous orbit (GEO)

静止軌道



* Among 70 unique catalogued objects, 59 objects are on GEO



Corbett+2020 (Evryscope)
see also Nir+2021 (W-FAST)

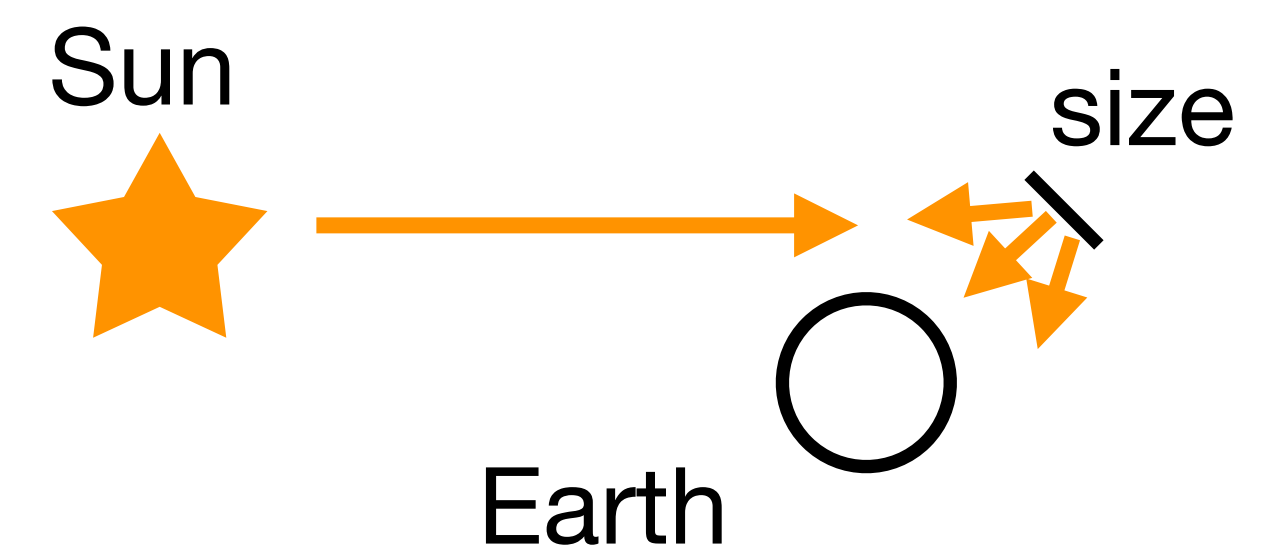
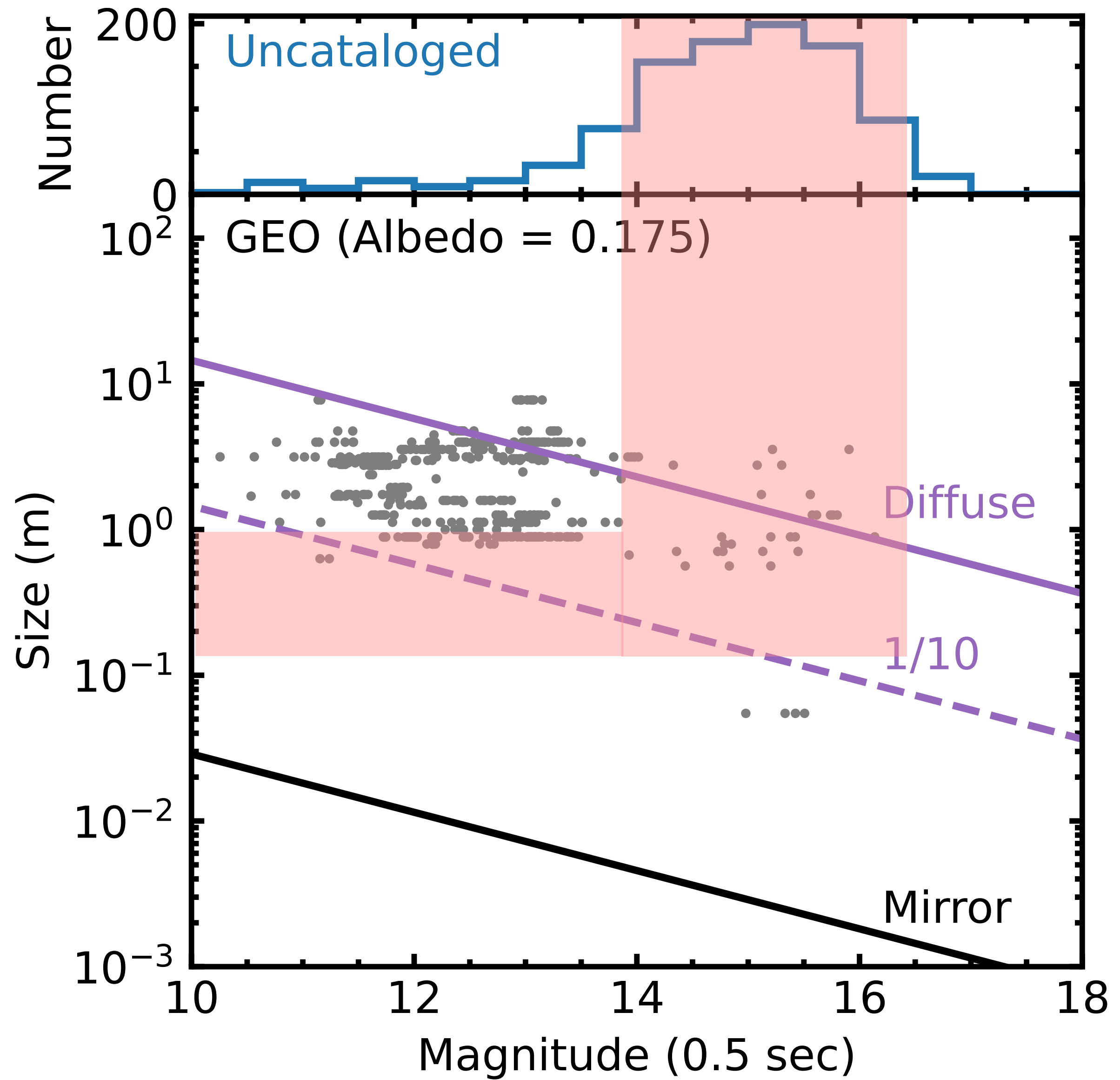
Many of the detected glints seem to be at the GEO

* Selection bias (our method detect only point sources)

Size?

物体の大きさは？

Estimated size by radar
(catalogued objects
at the GEO)



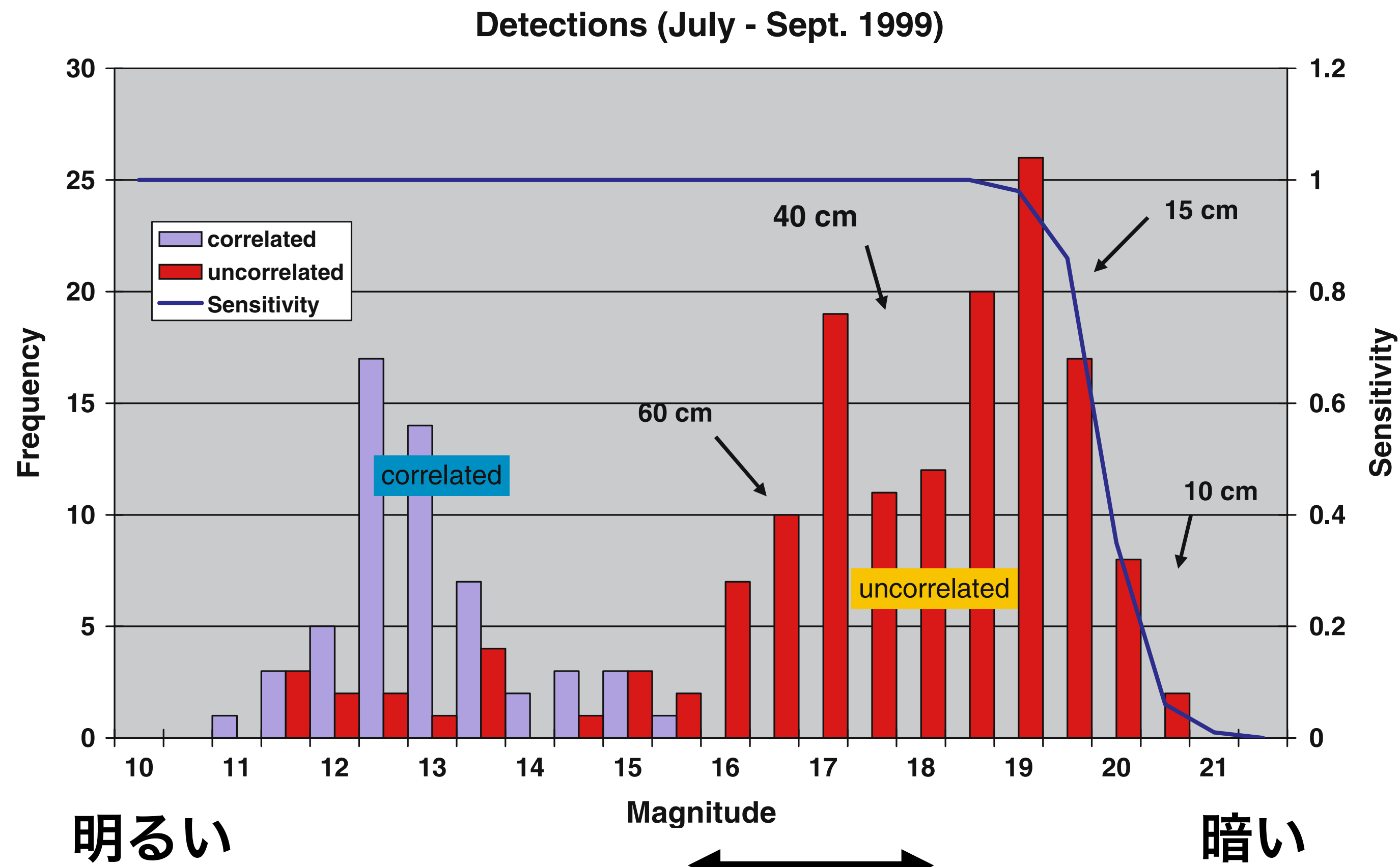
乱反射
アルベド = 0.175

1 - 10 m 0.3 - 1 m

What are they? どういう物体？

GEO survey

(long exposure without tracking)



Schildknecht+2004

積分時間が長いので
この図の方が「暗く」なる

Orbital evolution => “area to mass ratio”

Catalogued objects

$\sim 0.01 \text{ m}^2 / \text{kg}$ ($= 100 \text{ kg} / \text{m}^2$)

Uncatalogued objects

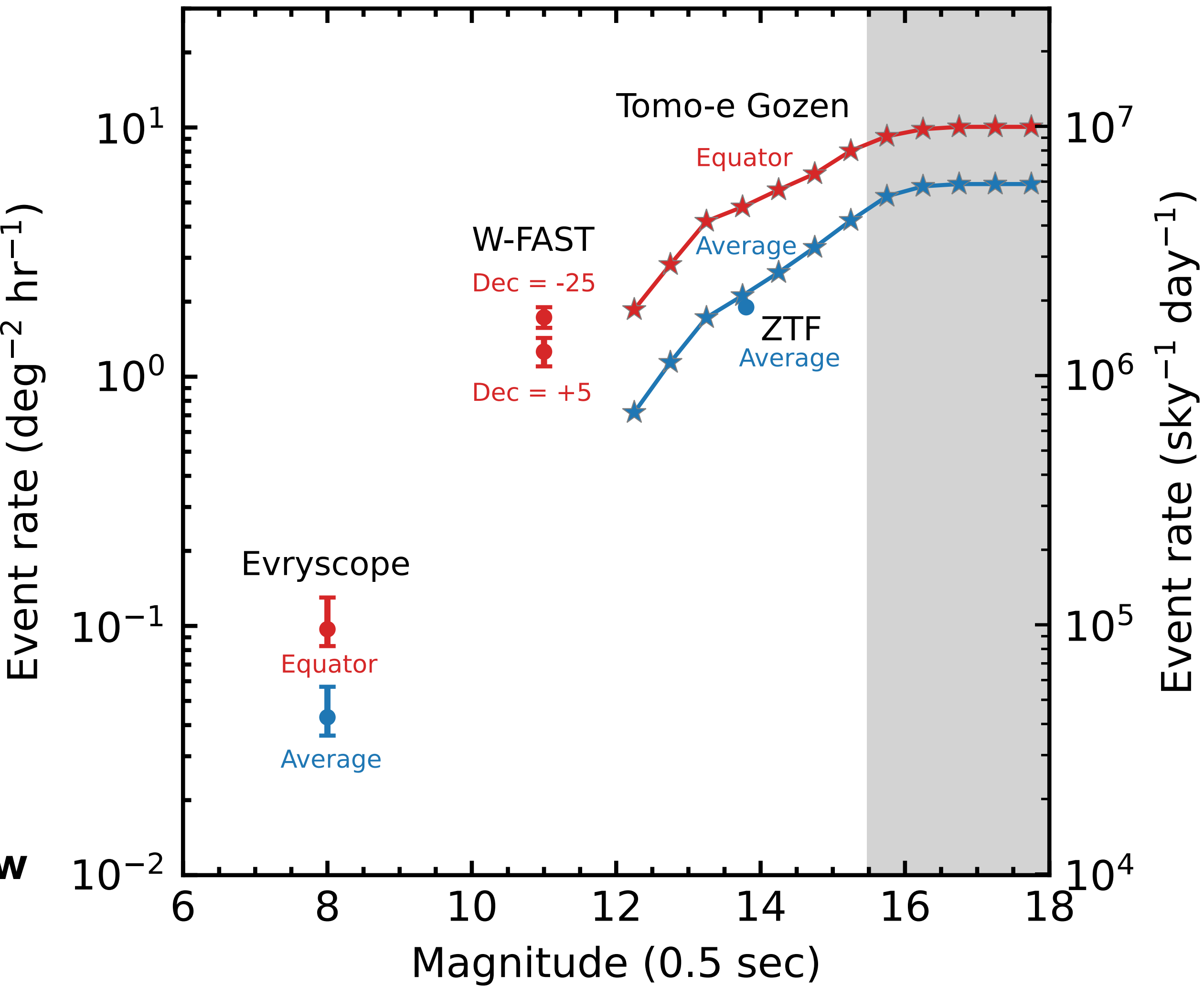
$\sim 10 \text{ m}^2 / \text{kg}$ ($= 0.1 \text{ kg} / \text{m}^2$)

(例) 紙切れ $\sim 15 \text{ m}^2 / \text{kg}$ ($= 0.07 \text{ kg} / \text{m}^2$)

**Sheets/filaments
separated from satellites??**

Event rate

閃光の発生率



Limit from the Earth's shadow

$R < 4 \times 10^{-3} \text{ deg}^{-2} \text{ h}^{-1}$
(Arima+2026)

FRB

$R < 8 \times 10^{-4} \text{ deg}^{-2} \text{ h}^{-1}$
(CHIME 2022)

Extremely high foreground rate
for astronomical search