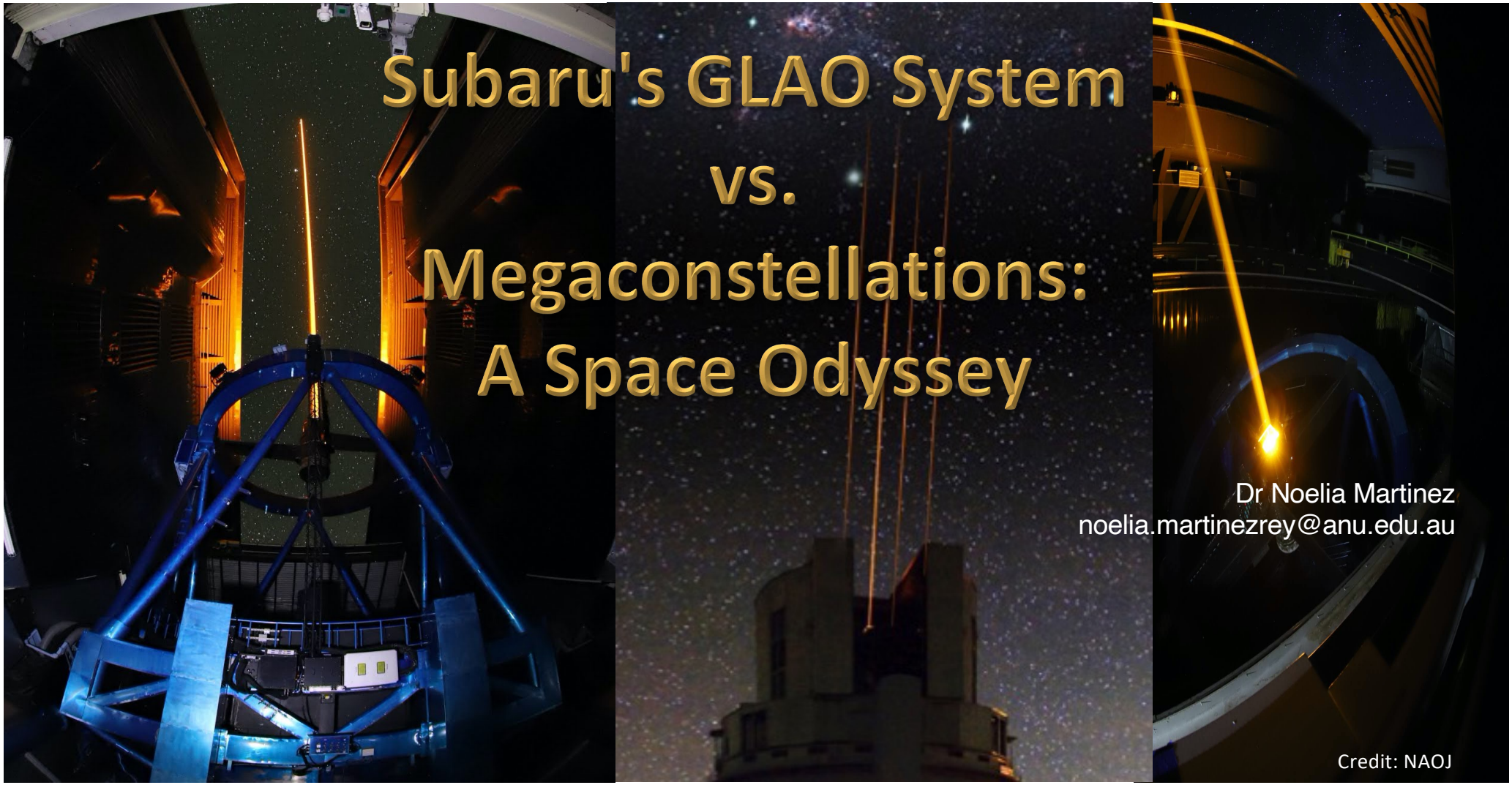


Subaru's GLAO System vs. Megaconstellations: A Space Odyssey

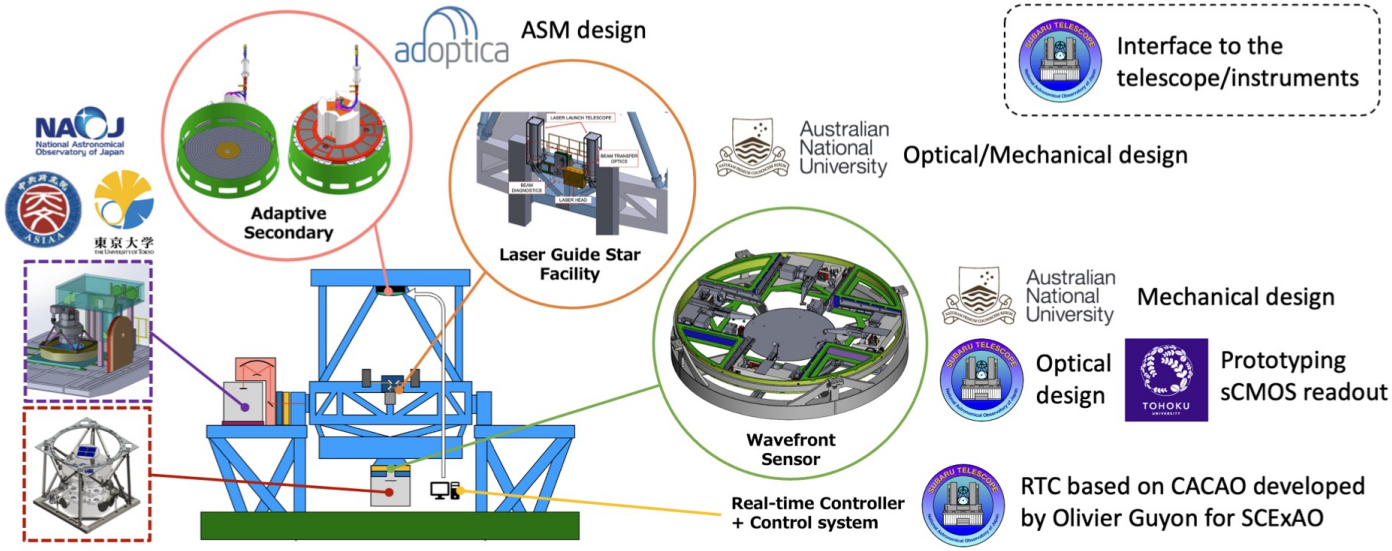
Dr Noelia Martinez
noelia.martinezrey@anu.edu.au

Credit: NAOJ

ULTIMATE-Subaru: Instrument Overview

Ultra-wide **L**aser **T**omographic **I**mager and **M**OS with **A**O for **T**ranscendent **E**xploration

GLAO assisted wide-field NIR instruments

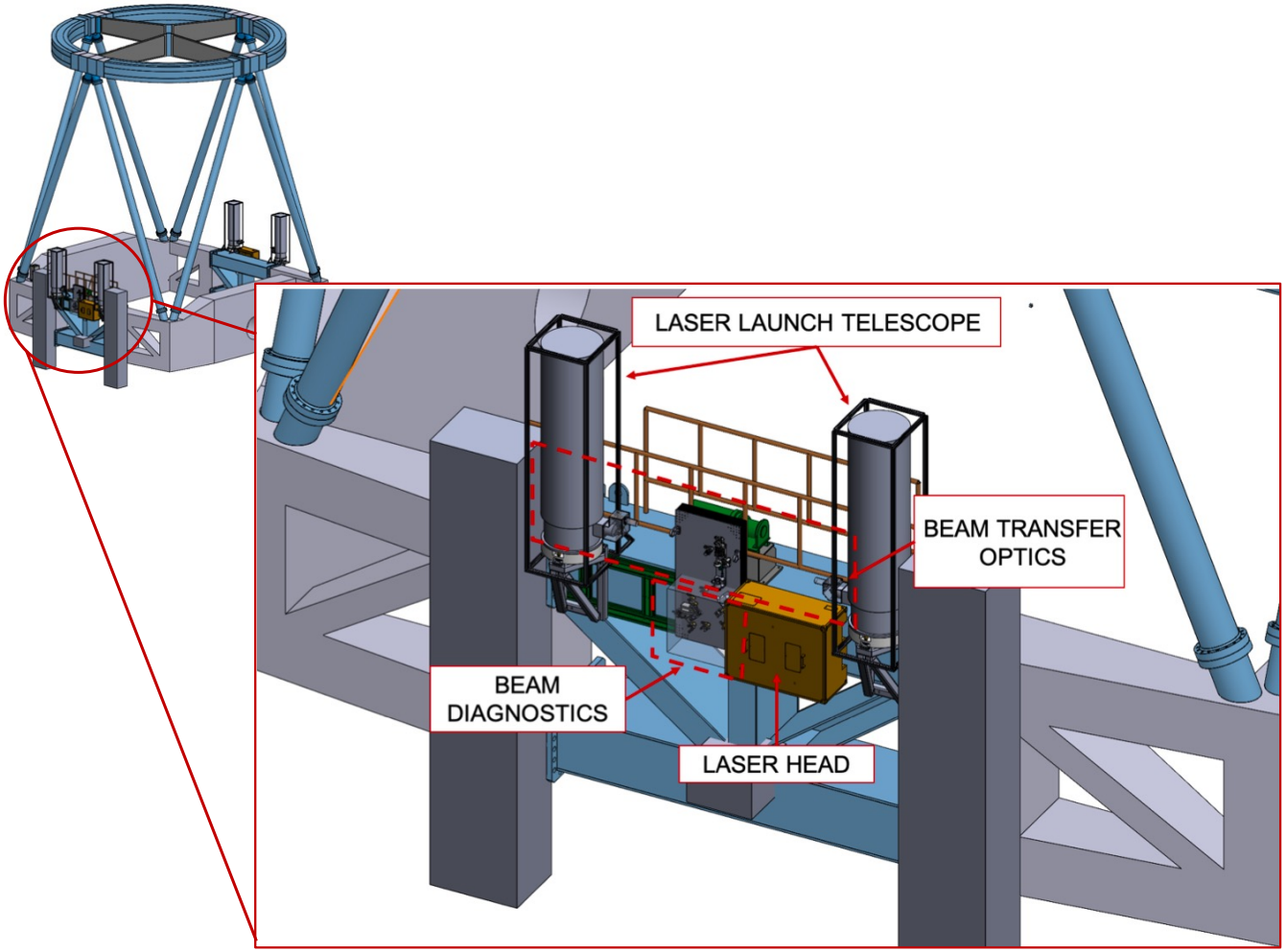


- ASM finished the final design. Procurement started for long-lead optical components.
- GLAO preliminary design study completed, PDR in Nov 2022, Starting final design phase.

Subaru/NAOJ-led project in collaboration with

Australian National University (Australia)
Tohoku University (Japan)
Academia Sinica Institute of Astronomy and Astrophysics (Taiwan)
University of Tokyo (Japan)

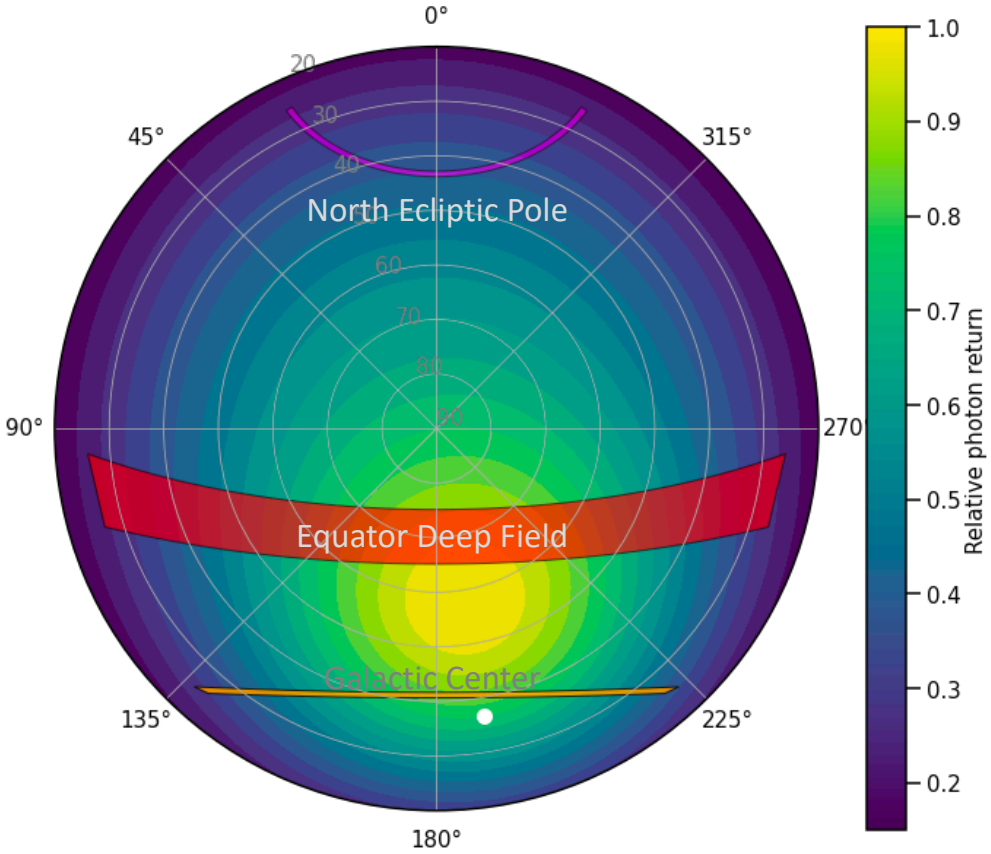
ULTIMATE-Subaru: LGSF Overview



Martinez, N. et al. 2022 Proc. SPIE

- 4 laser beams are propagated from the front/rear side of the telescope center section.
- Use two TOPTICA 20W lasers, split the laser beam into two (~**10W each**)
- LGSF is composed by the diagnostic part (power, wavelength, alignment), beam transfer part (expand, split the beam, jitter control), and launching part (LLT, field steering mirror)
- The asterism can be configured at **any diameter within 0 – 20 arcmin**.

ULTIMATE-Subaru: Science Cases



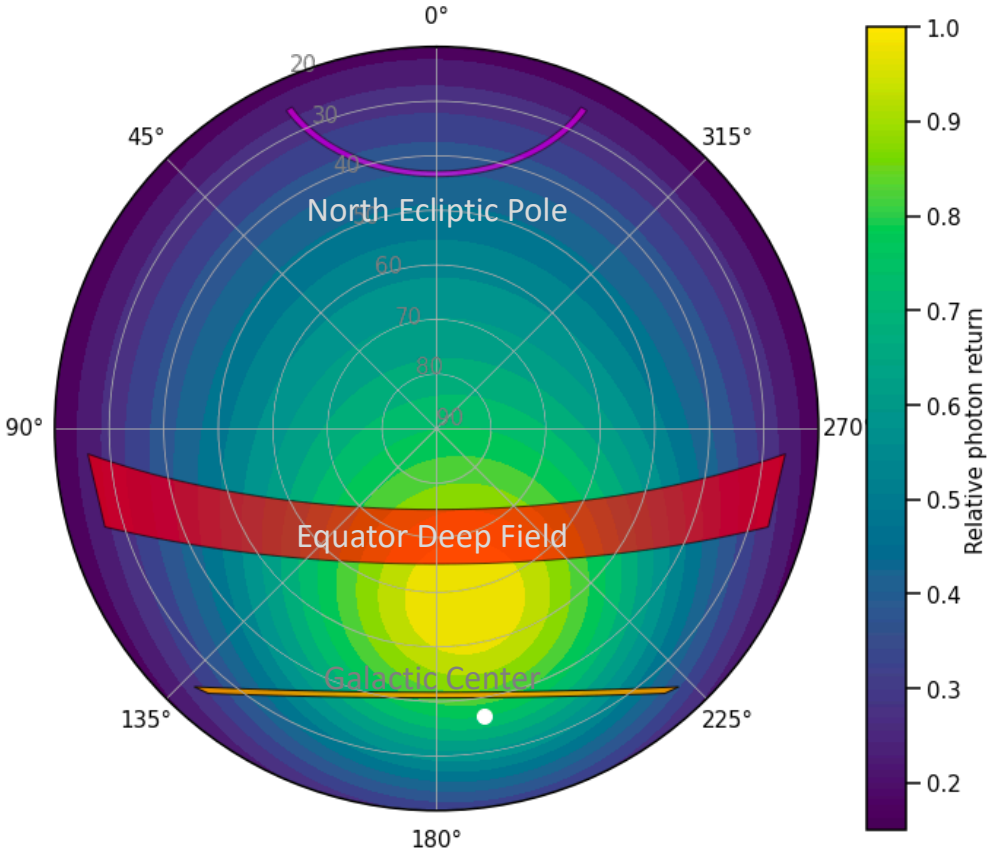
LGS Photon return map @ Maunakea

Holzlöhner et al. 2010

Science goals of ULTIMATE-Subaru:

1. Birth of galaxies: galaxies in the very early universe, redshifts >>7
2. Present-day of galaxies: systematic survey of nearby galaxies
3. Growth of galaxies: history of star formation and origin of galaxy structures

ULTIMATE-Subaru: Science Cases



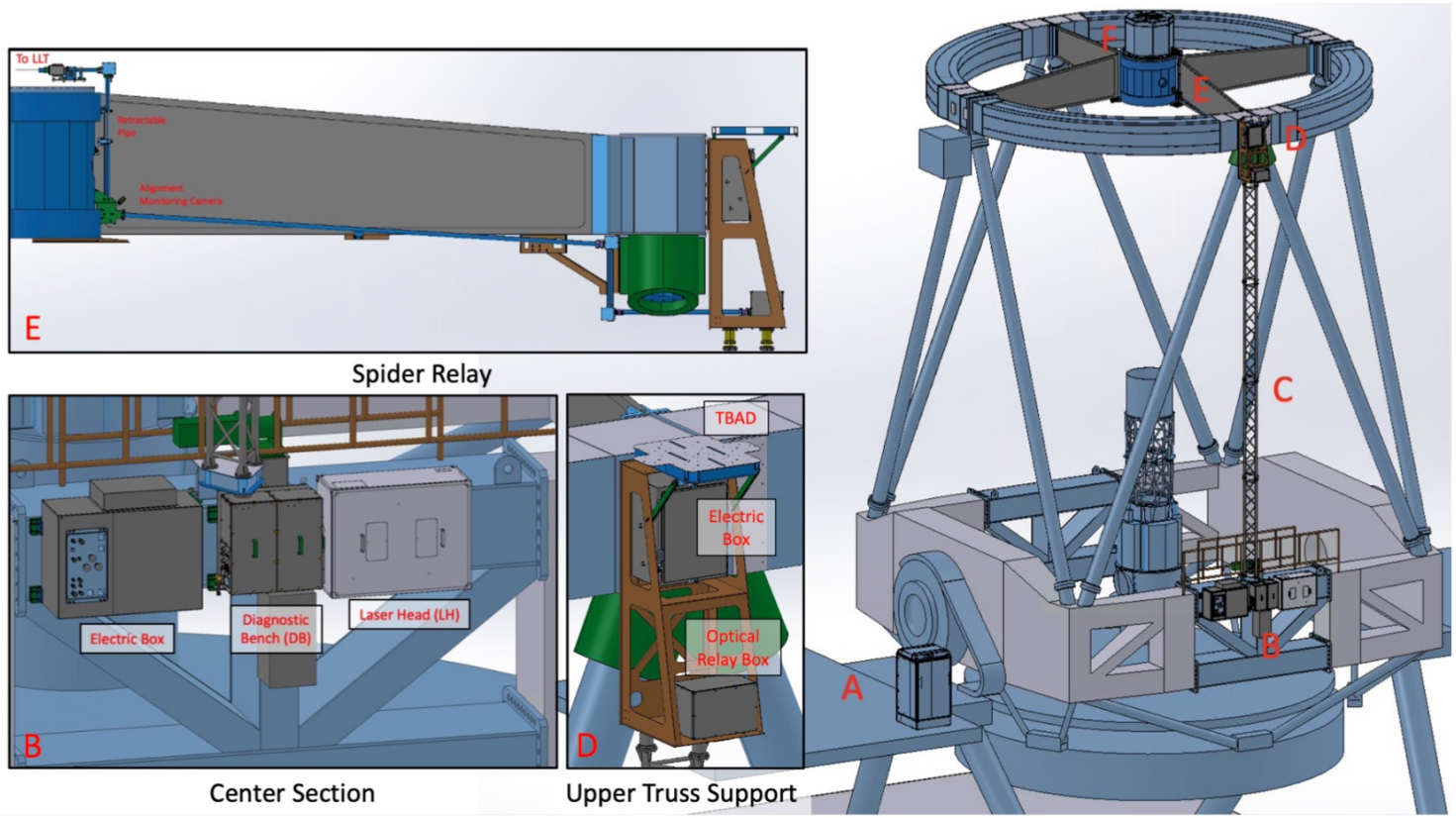
LGS Photon return map @ Maunakea

Holzlöhner et al. 2010

Fraction of the observing time planned to be used for the science target field.

Celestial Equator Deep Field: $-5.0 < \delta < 5.0$	60 %
Galactic Center: $\delta \sim -29.0$	15 %
Other fields: various δ	20 %
North Ecliptic Pole: $\delta \sim 66.0$ (Euclid northern survey field)	5 %

Subaru Laser Guide Star System Upgrade



Laser upgrade (2019-2022)

- Use a TOPTICA laser
- Laser transfer by a relay of mirrors

→ Open use restarted since 2023

Subaru Laser Guide Star System Upgrade

GLAO prototyping activities

1. TOPTICA laser characterization
- Photon Return at MaunaKea
- Spot size
- Response to the Laser polarization state

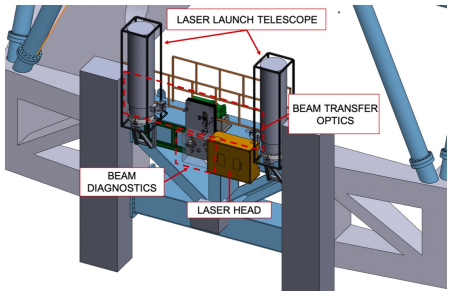
2. Laser beam jitter control
- Active control of the jitter in the long relay path (~20m)
- Compensation of the slow beam mis-alignment due to the telescope deflection
- Laser jitter PSD including atmosphere

3. Laser Safety
- Development of a new laser safety system based on a PLC
- Establish an Administrative Control procedure

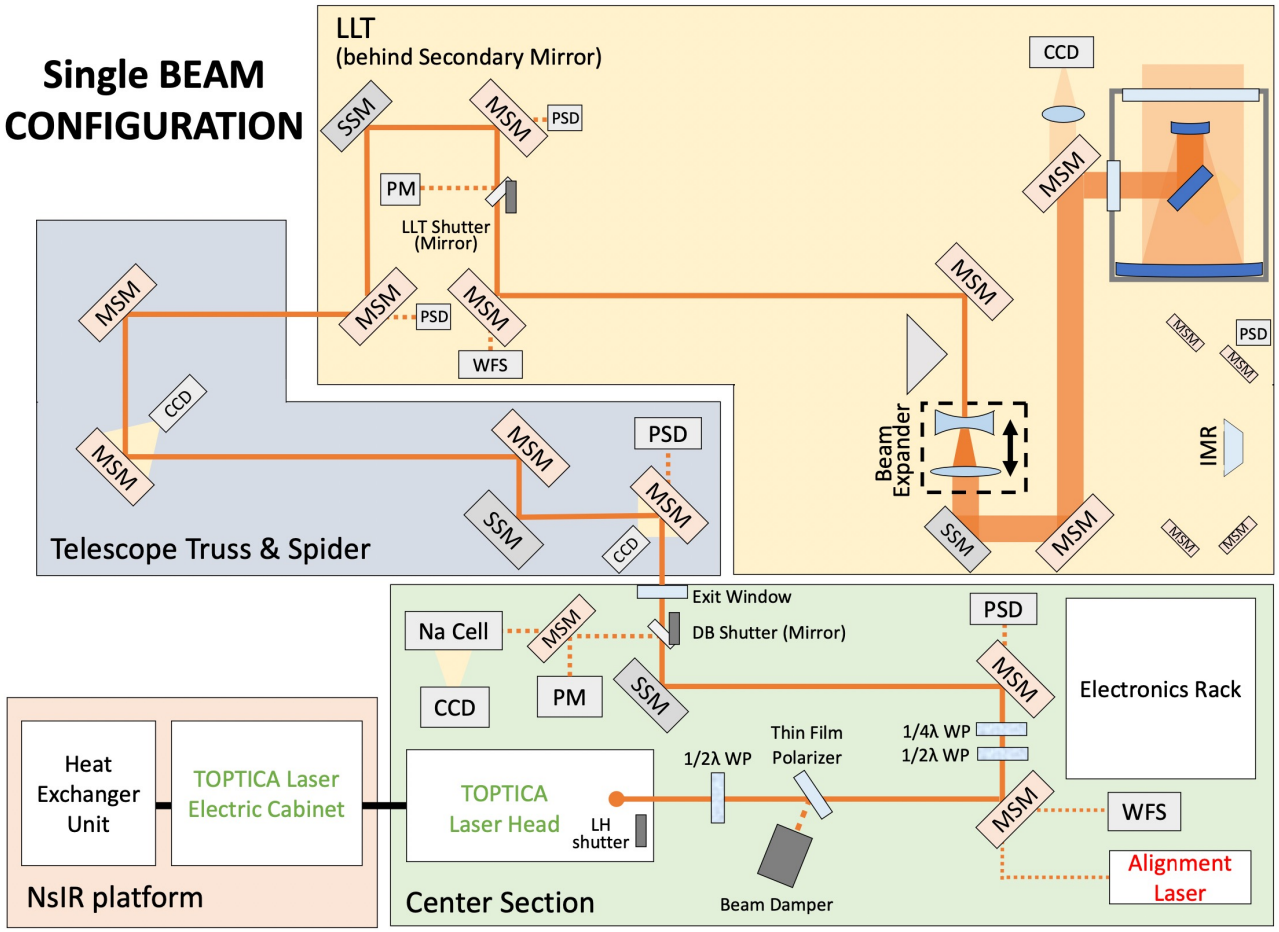
4. Multiple-Laser beam (LGS asterism)
- Split the laser beam into 4
- Control the asterism configuration

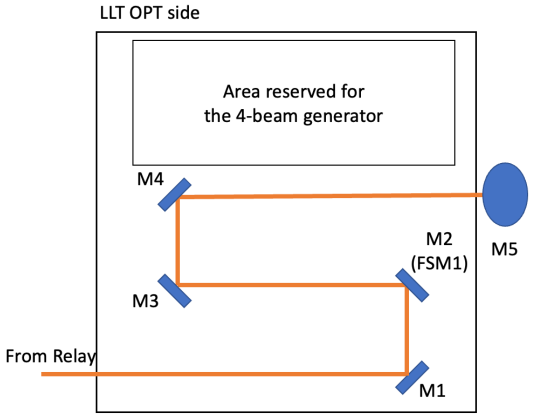
Fundamental technology for the future GLAO system and more

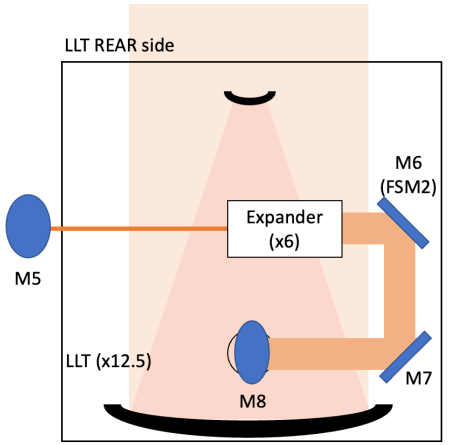
- ULTIMATE-Subaru



Subaru Laser Guide Star System Upgrade

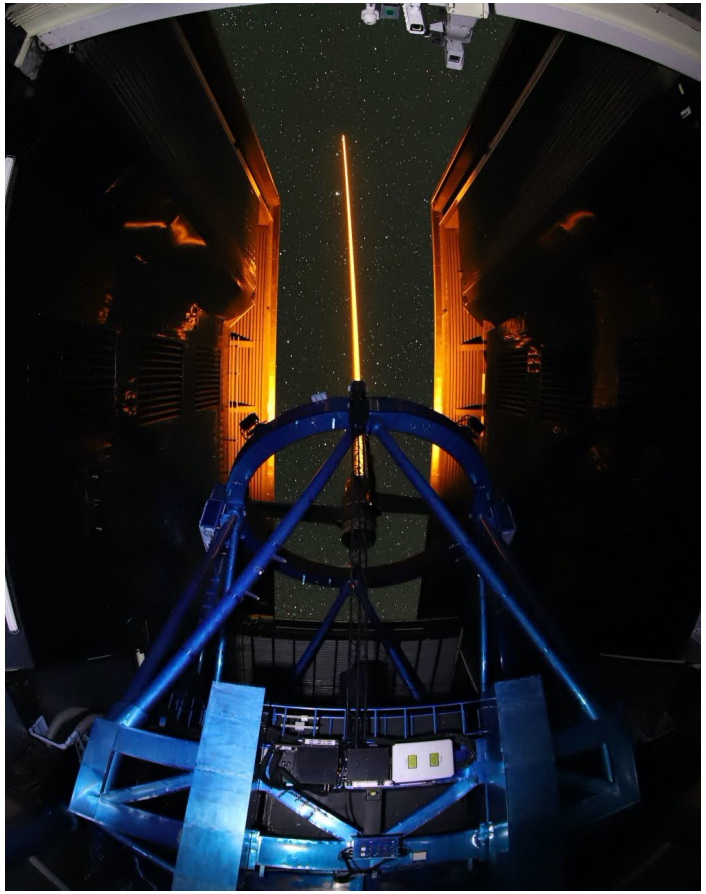


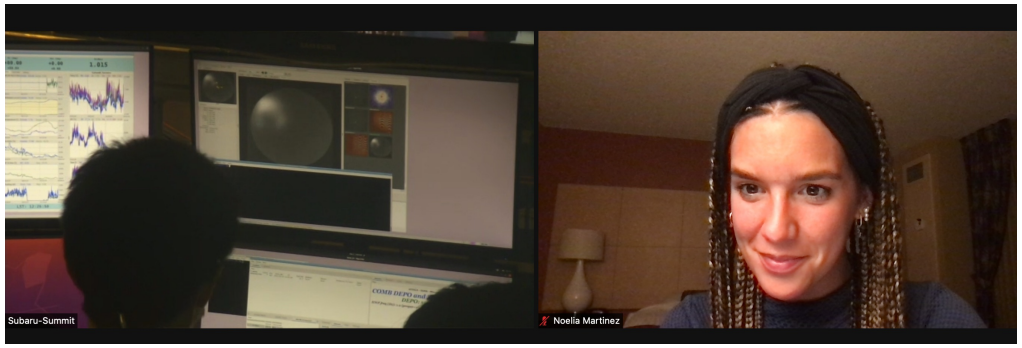


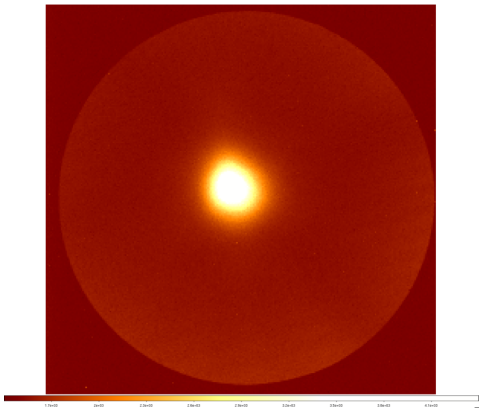


Subaru Laser Guide Star System Upgrade

March 2nd, 2022



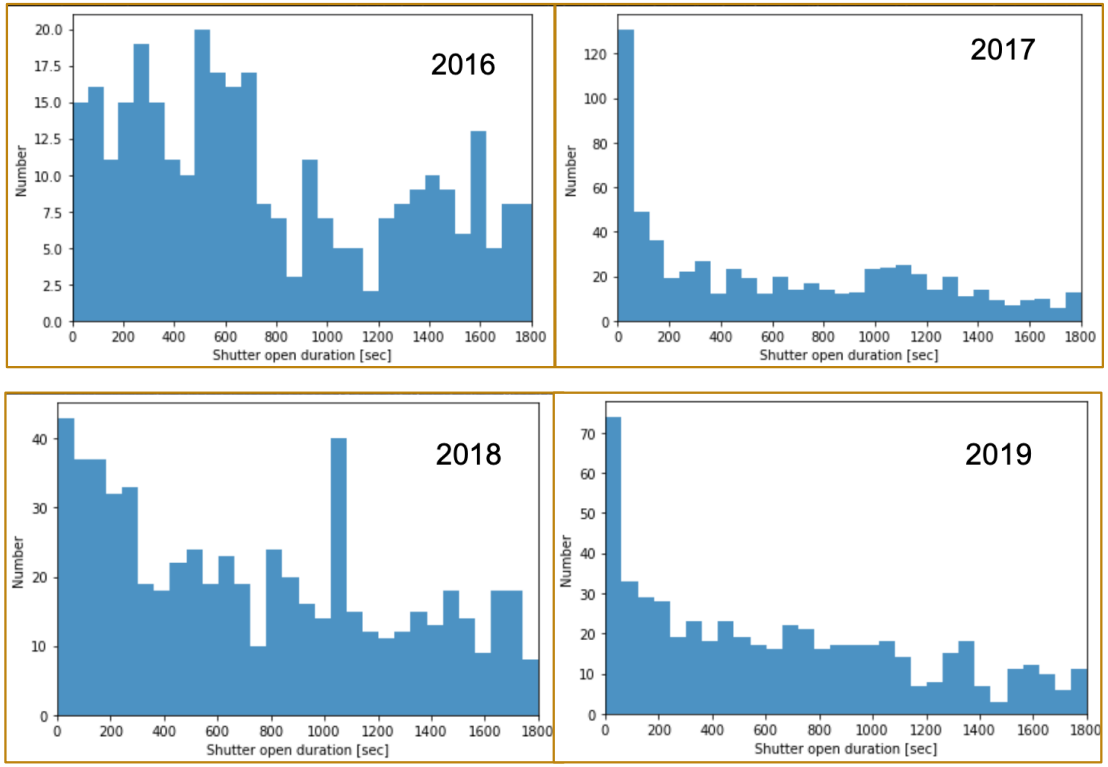




Saw a LGS right away with the very first launch!

From past to present: satellite closures @ Subaru Telescope

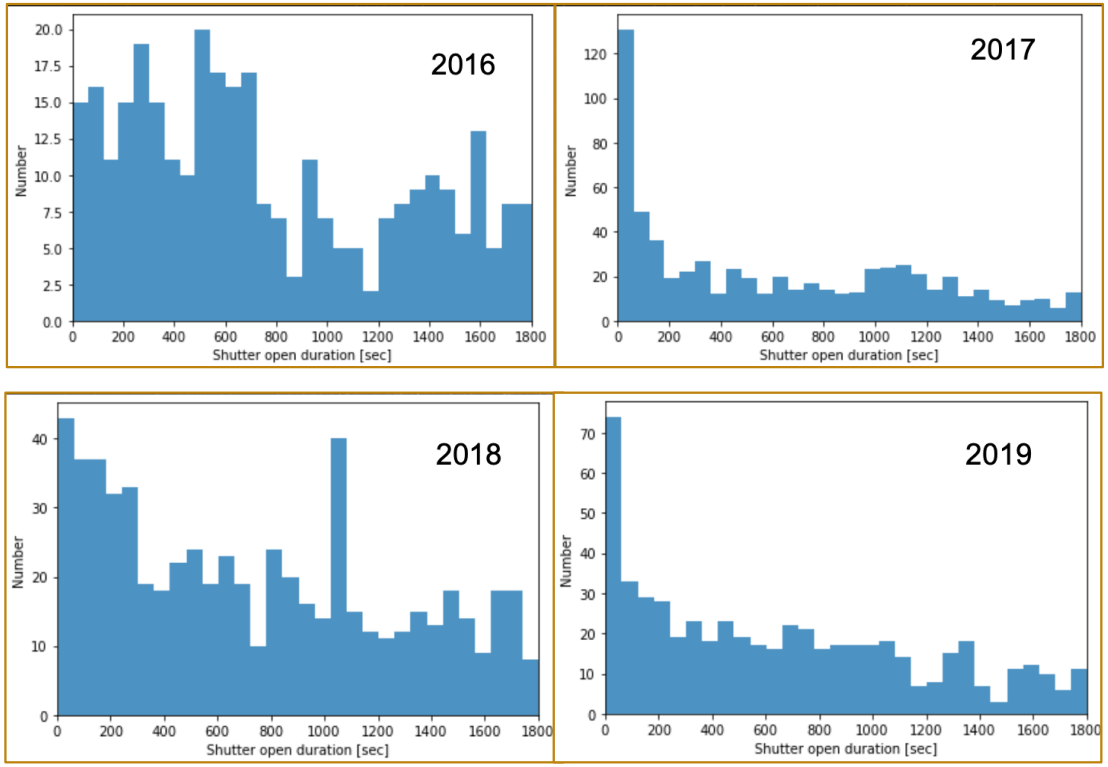
Histogram of the open shutter duration at the fixed Az/EL

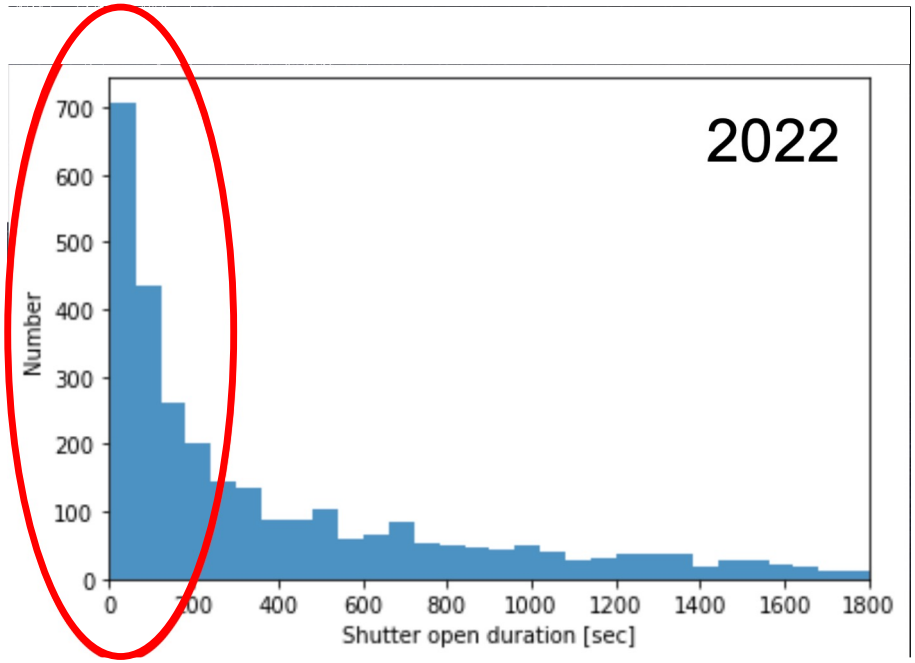


Data from the Predictive Avoidance Approval Messages (PAM)

From past to present: satellite closures @ Subaru Telescope

Histogram of the open shutter duration at the fixed Az/EL





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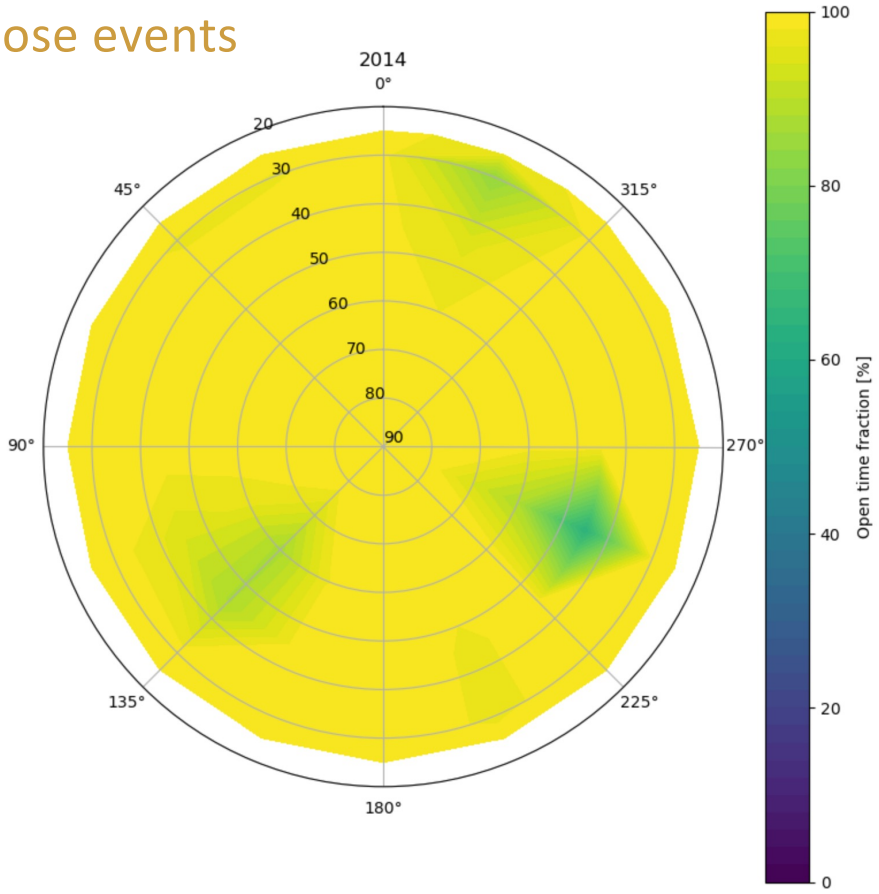
From past to present: satellite closures @ Subaru Telescope

2014 – 2023

Number of the shutter close events



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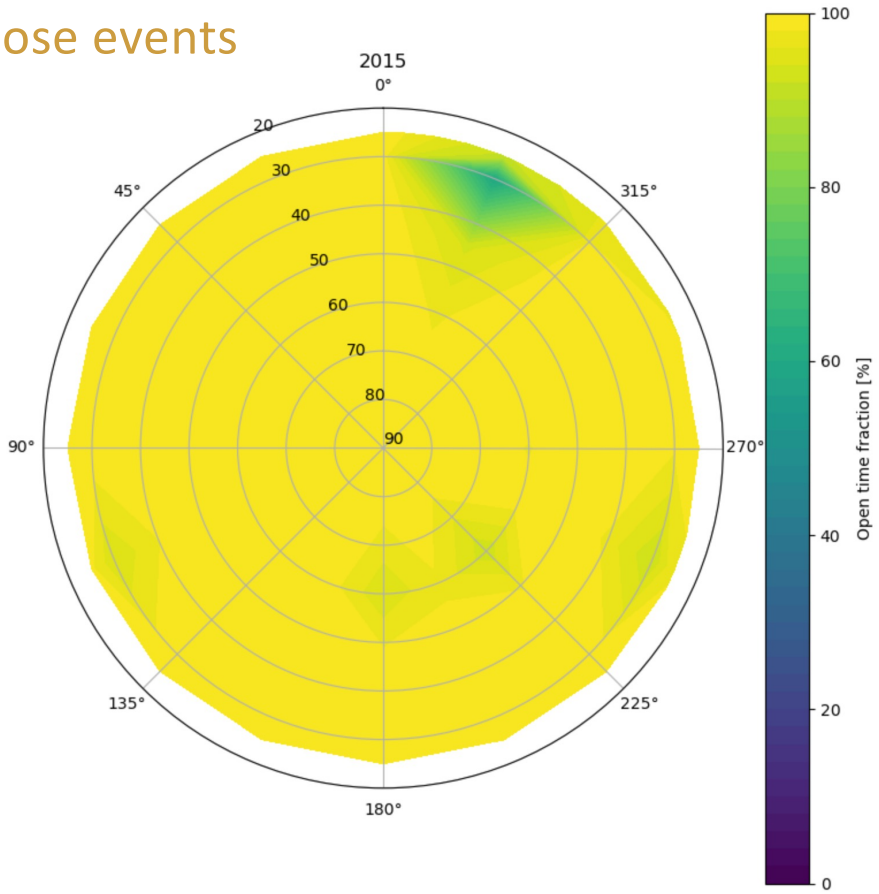

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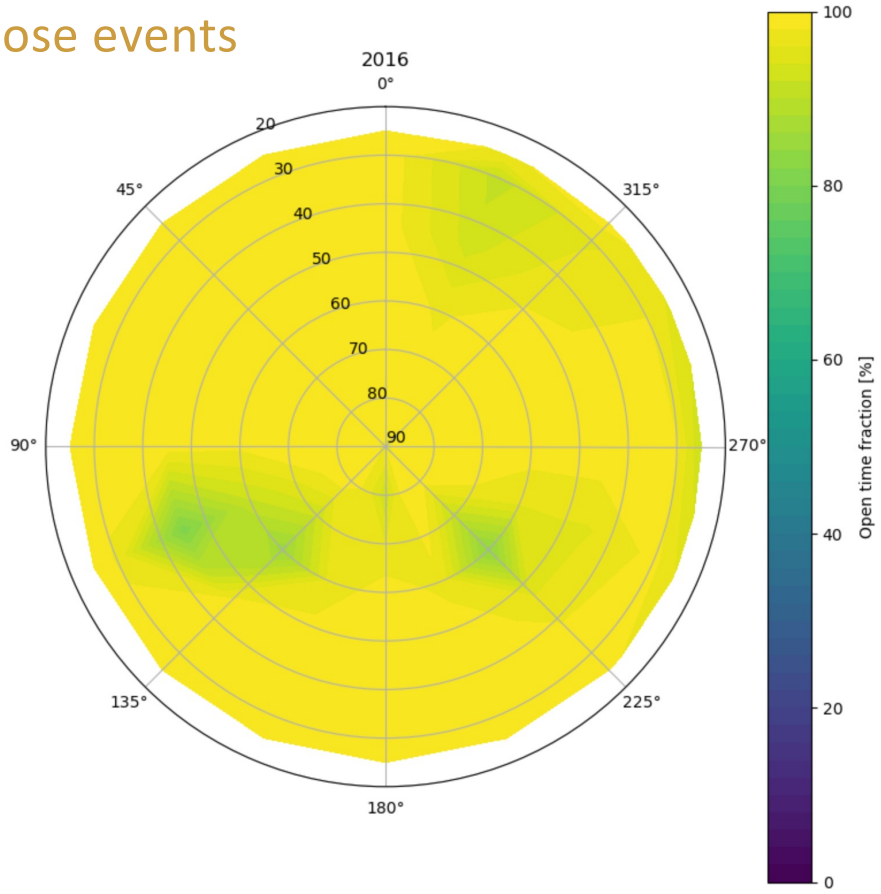

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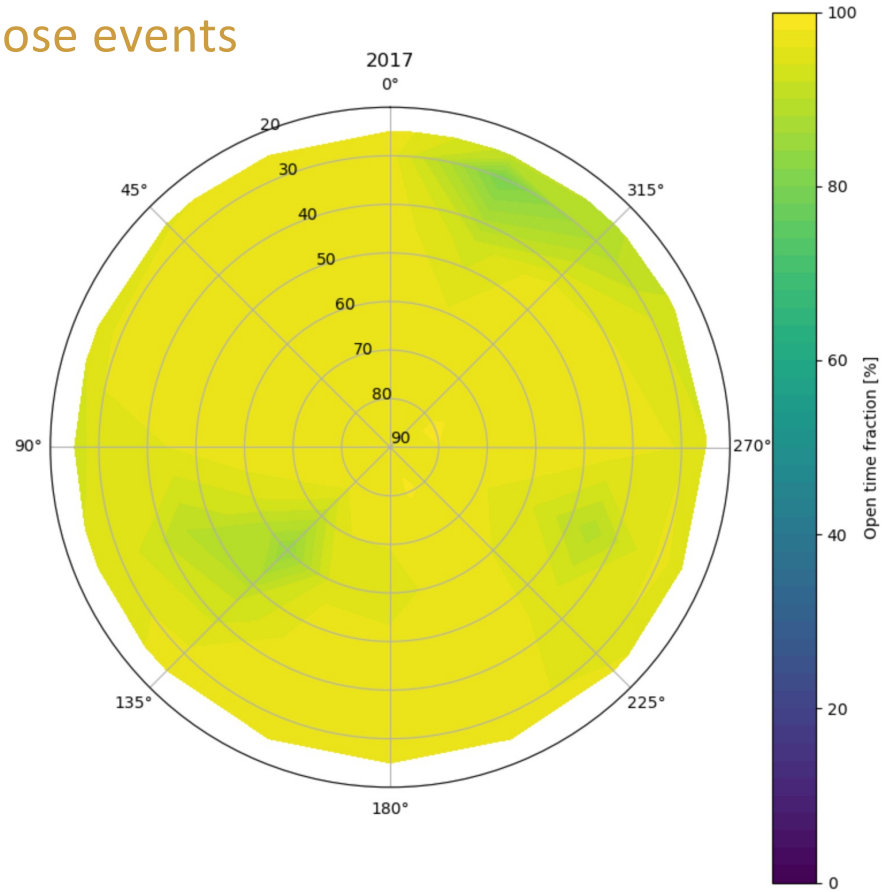

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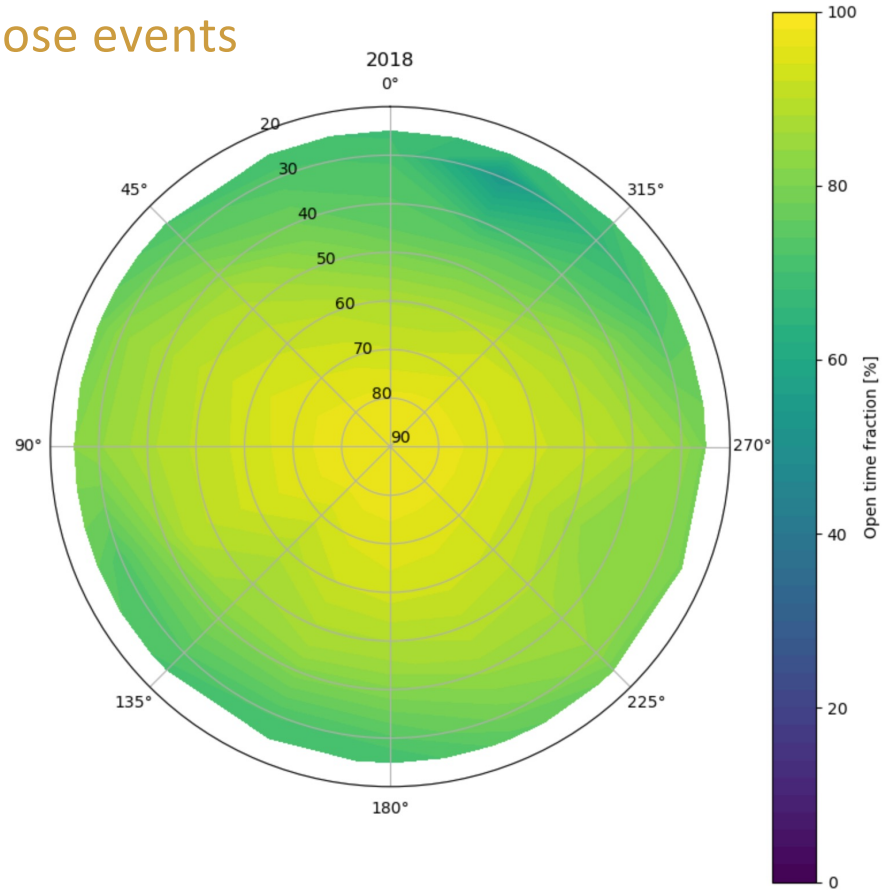

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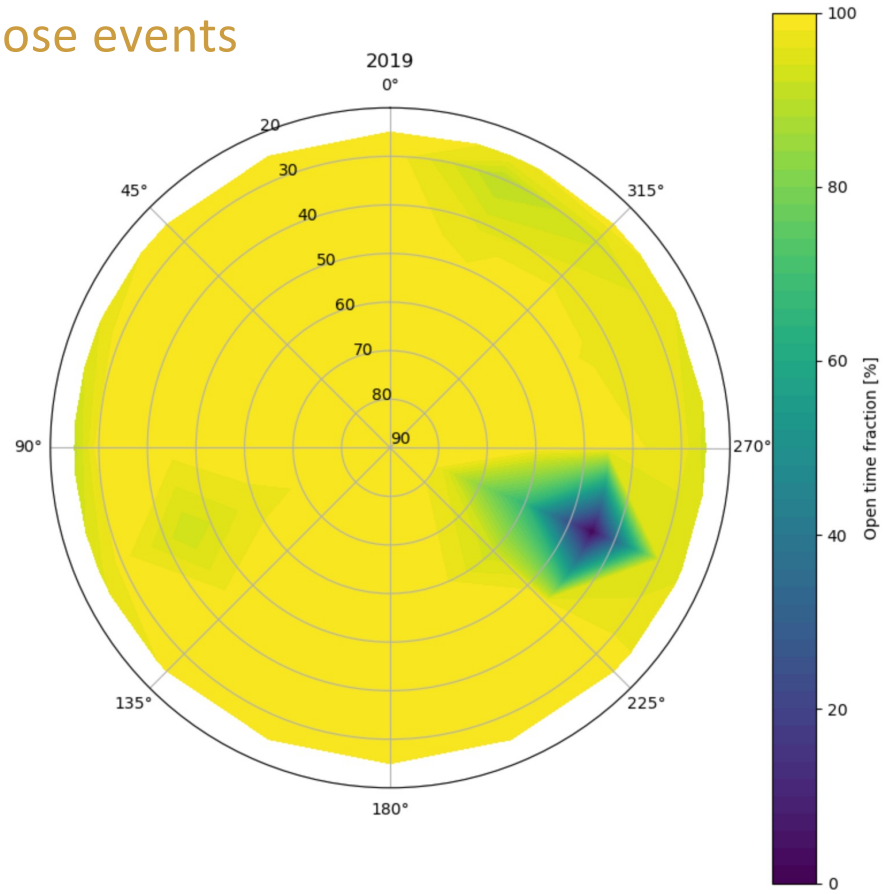

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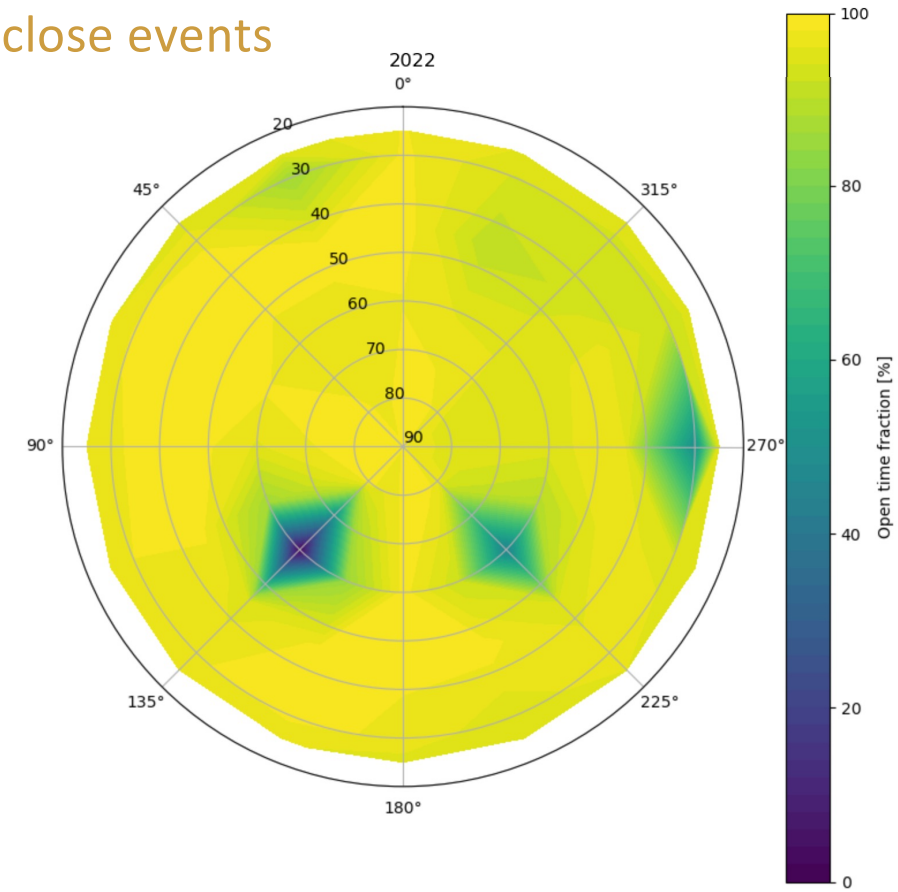

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2014 – 2023

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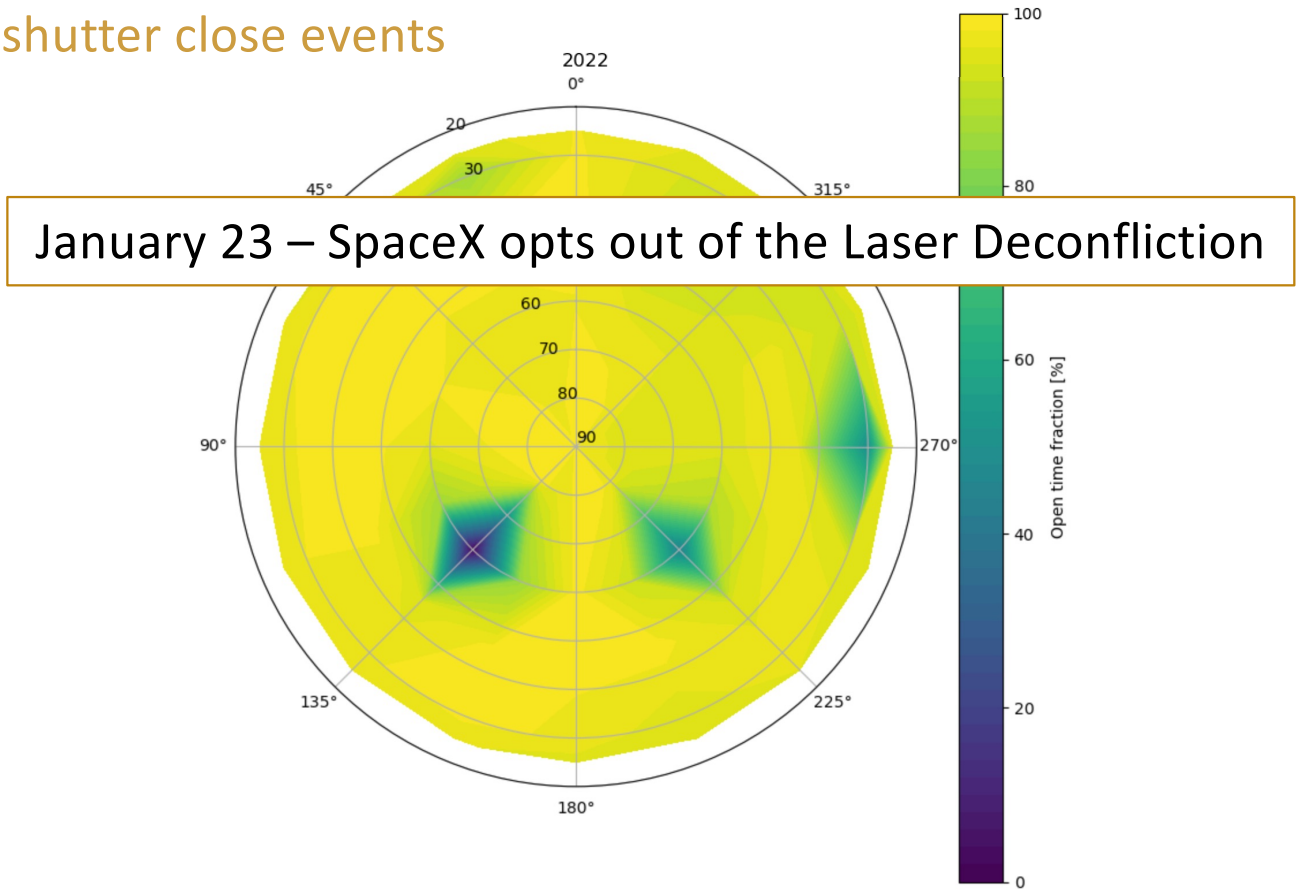

January 23 – SpaceX opts out of the Laser Deconfliction

From past to present: satellite closures @ Subaru Telescope

2014 – 2023

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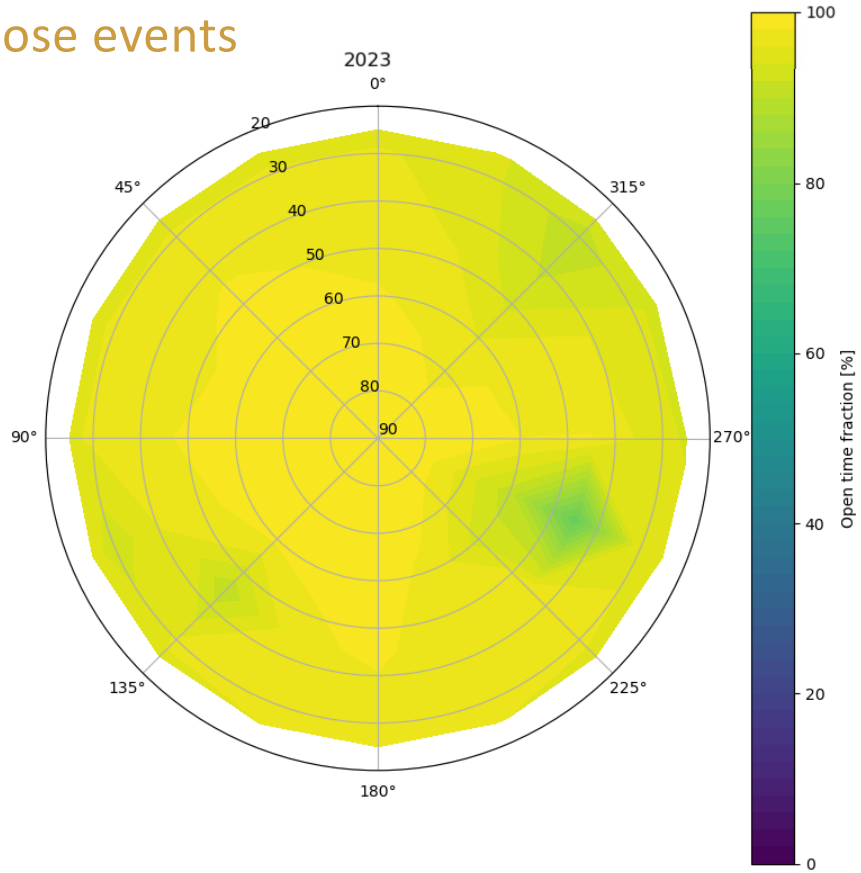

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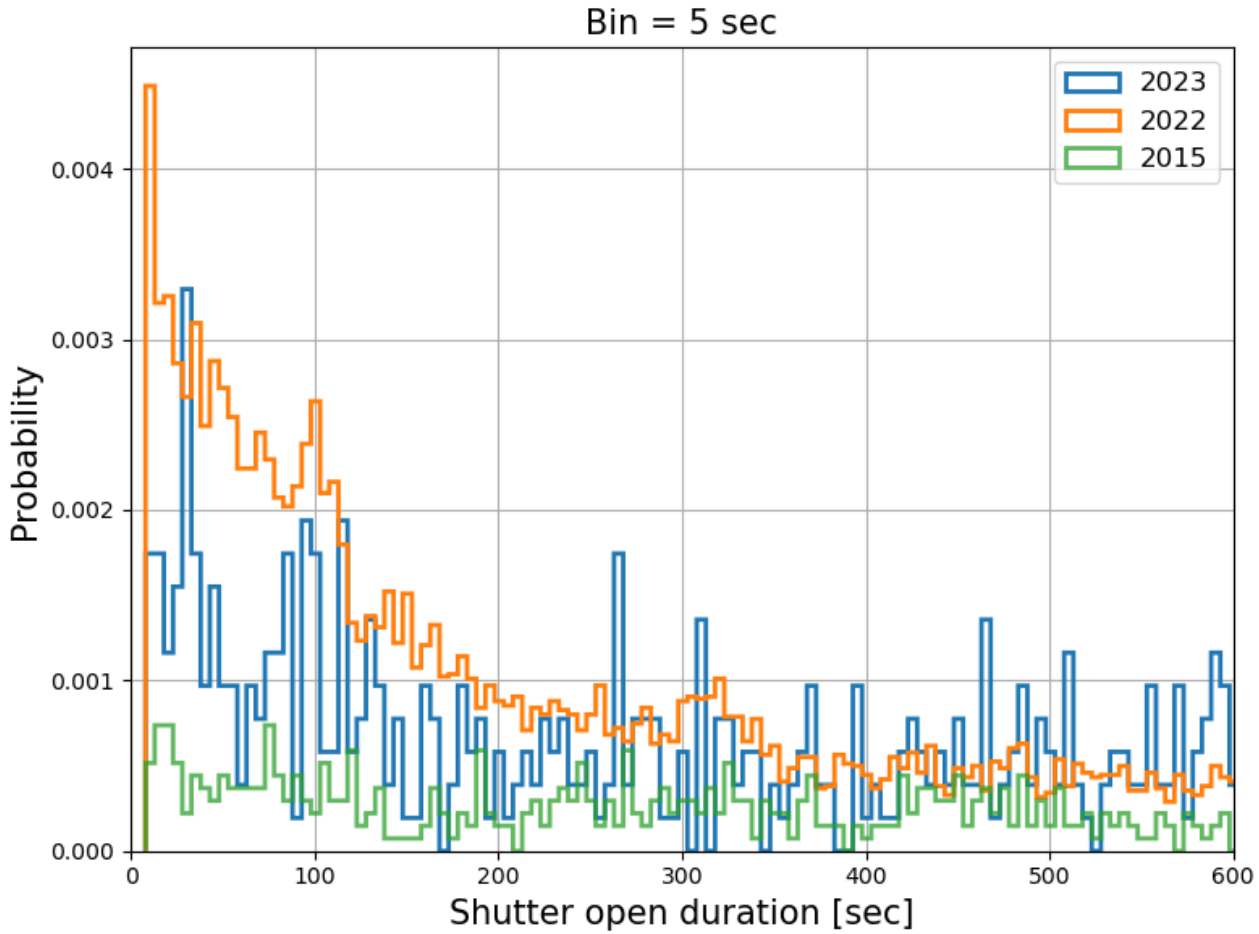


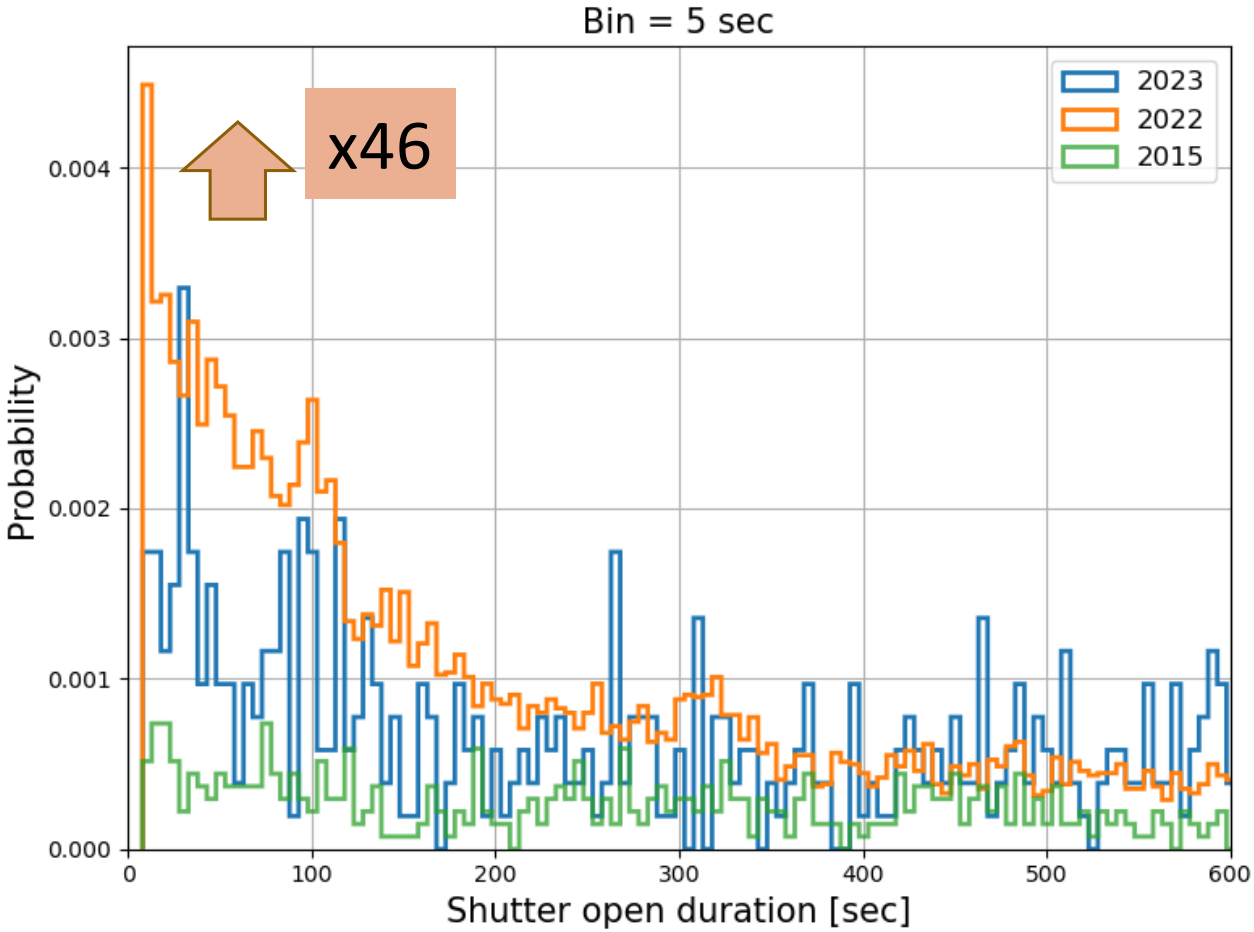
Into the future

COMPANIES PLANNING TO LAUNCH >1000 SATELLITES

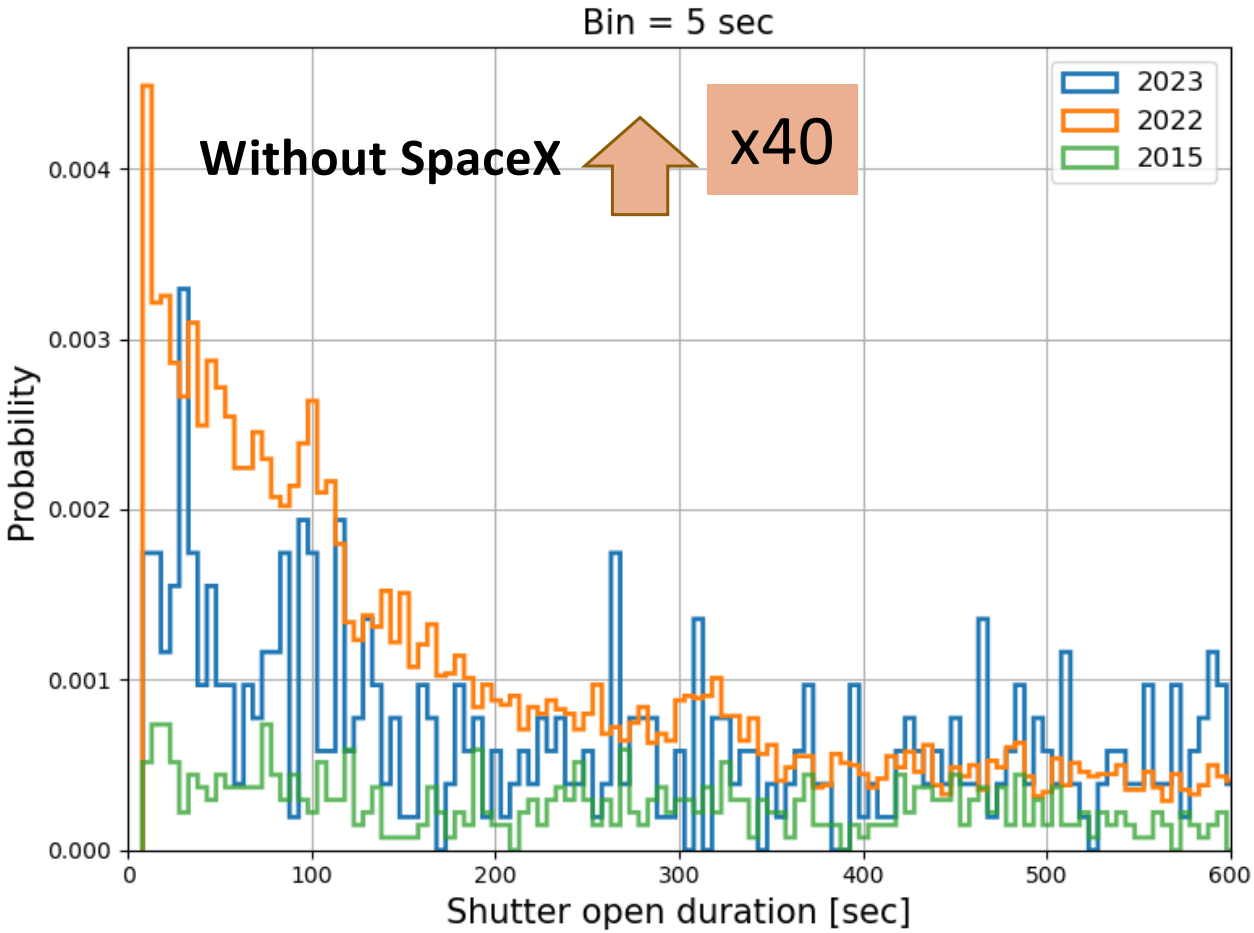
Company	Total # of satellites proposed for next gen	Total proposed	Type	Country	Type
E-Space	100000	327000	Comms	Rwanda	Commercial
SpaceX	19500	41998	Comms	USA	Commercial
Astra	40	13620	Comms	USA	Commercial
Guowang	12992	12992	Comms	China	Commercial
Kuiper	3236	7774	Comms	USA	Commercial
OneWeb	6372	6372	Comms	UK	Commercial
Boeing	5789	5789	Comms	USA	Commercial
Lynk	10	5000	Comms	USA	Commercial
Stellar	2484	2484	Comms	France	Commercial
Hanwha Systems	2000	2000	Comms	South Korea	Commercial
Hughes	1440	1440	Comms	USA	Commercial
Telesat	298	1373	Comms	Canada	Commercial
Spinlaunch	1190	1190	Comms	USA	Commercial
SatRev	50	1024	Optical	Poland	Commercial
Galaxy Space	1000	1000	Comms	China	Commercial
Total proposed satellites, constellations > 10 sats (80	~162000	~437000			

Credit: Therese Jones, Satellite Industry Association

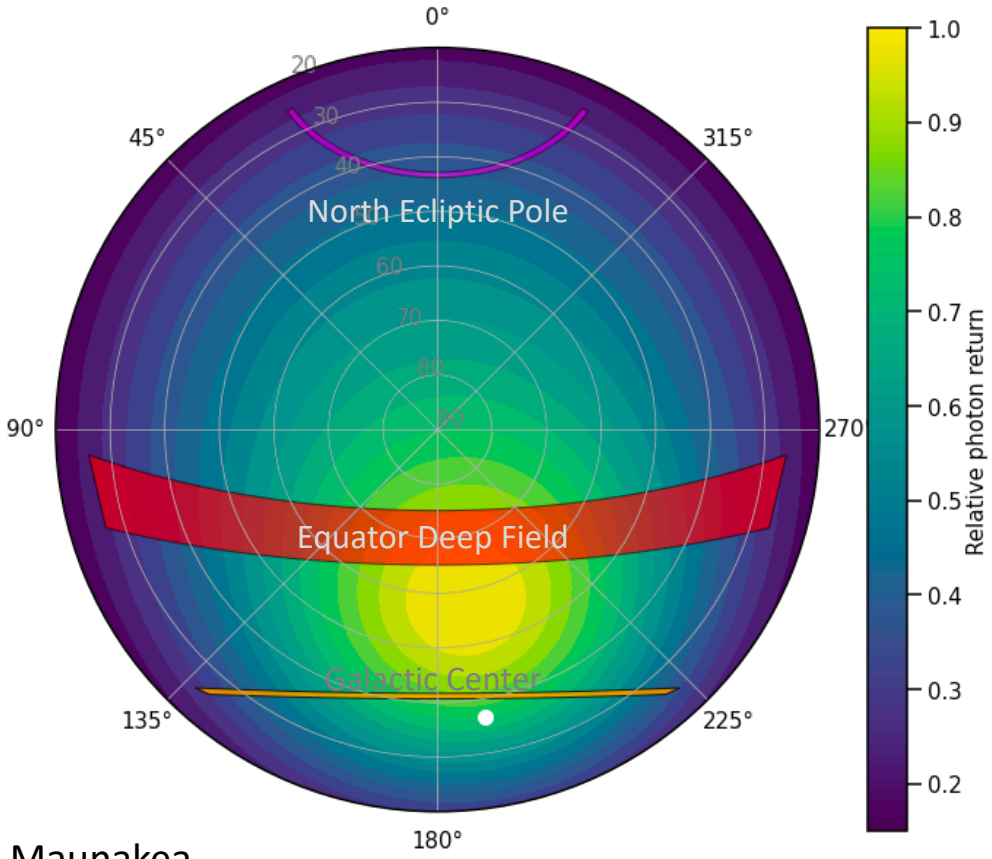
Into the future



Into the future



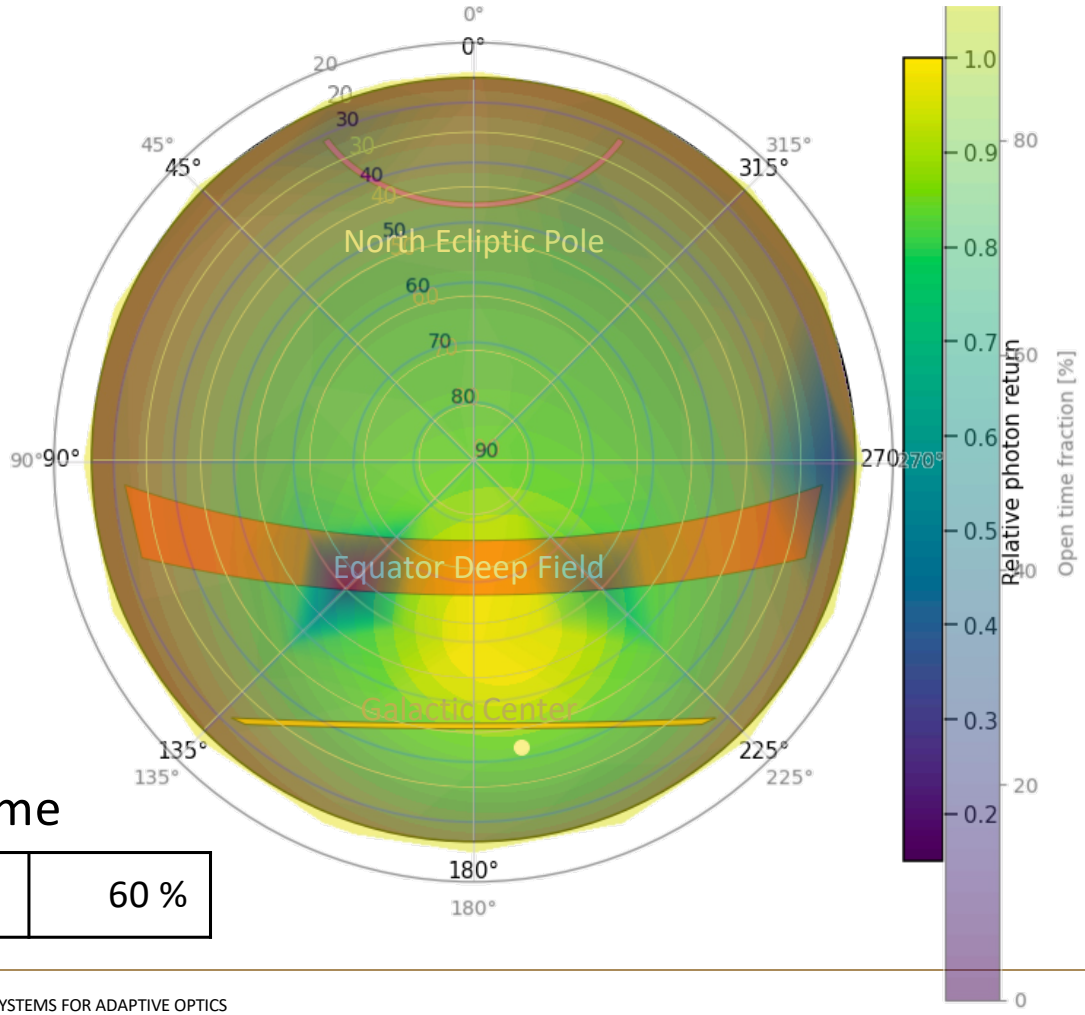
Effect to ULTIMATE-Subaru Science



LGS Photon return map @ Maunakea

Holzlöhner et al. 2010

Effect to ULTIMATE-Subaru Science

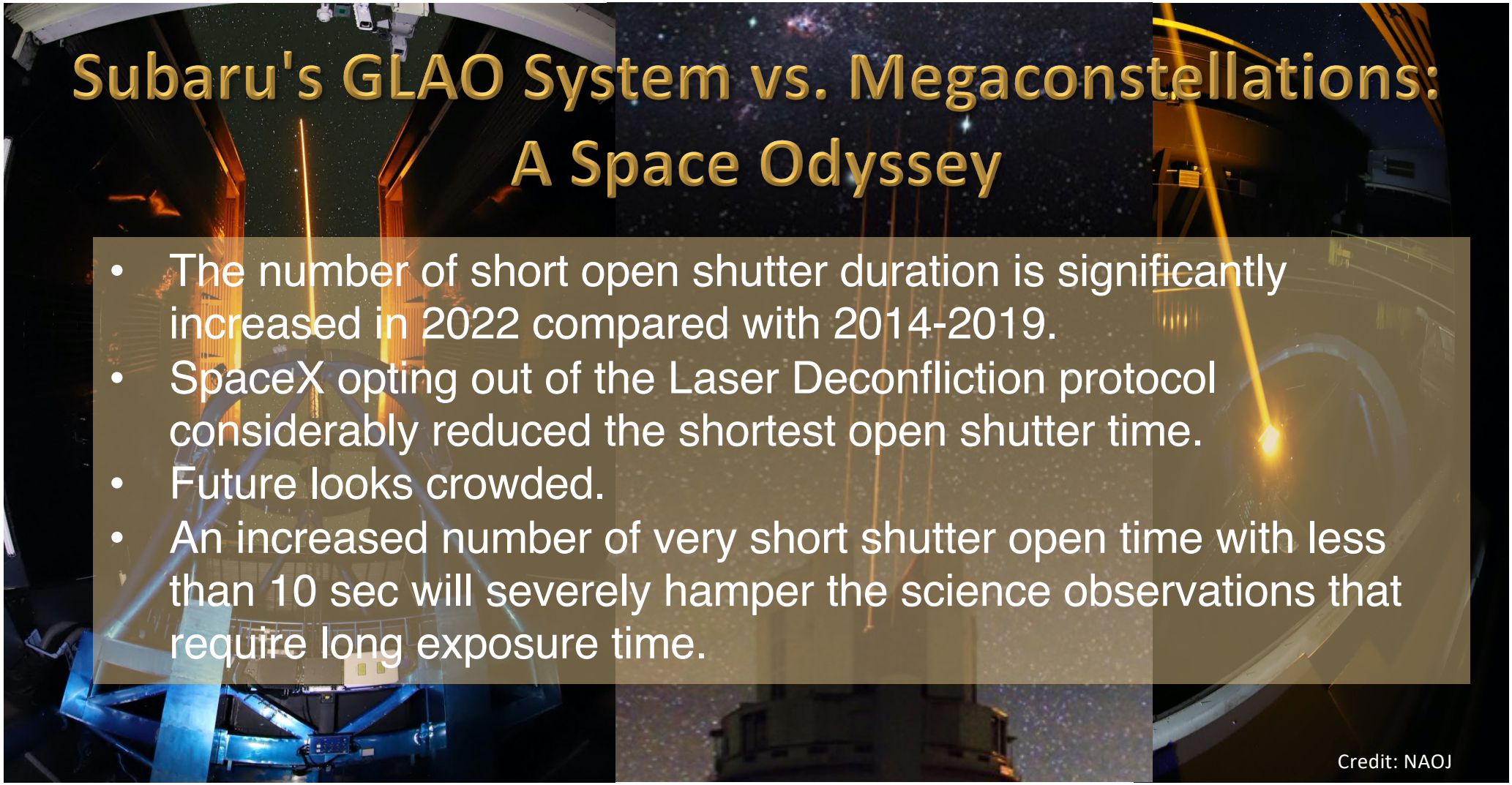


Fraction of observing time

Celestial Equator Deep Field	60 %

Subaru's GLAO System vs. Megaconstellations: A Space Odyssey

- The number of short open shutter duration is significantly increased in 2022 compared with 2014-2019.
- SpaceX opting out of the Laser Deconfliction protocol considerably reduced the shortest open shutter time.
- Future looks crowded.
- An increased number of very short shutter open time with less than 10 sec will severely hamper the science observations that require long exposure time.




Subaru's GLAO System vs. Megaconstellations:
A Space Odyssey
THANK YOU
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Credit: NAOJ