Nobeyama 45-m telescope:

experimental field for next-generation technologies and astronomy with large-aperture millimeter-wave telescope

Atsushi Nishimura
(Nobeyama Radio Observatory, NAOJ)

1. Summary of the proposal: NRO 45m

One of the largest mm-wave single dish in the world

- Large area mapping capability
- Multi-lines: density, temperature, chemistry
- mm-wave VLBI

Easy to access

- for development
- for education

New scheme for income-earning

- Charged telescope time
- Cooperation with local government

Implementation period under NAOJ

- 1982 – until alternative project is ready

Budget

130 MJPY/year

（120M: 運営費交付金）

2. Science goals

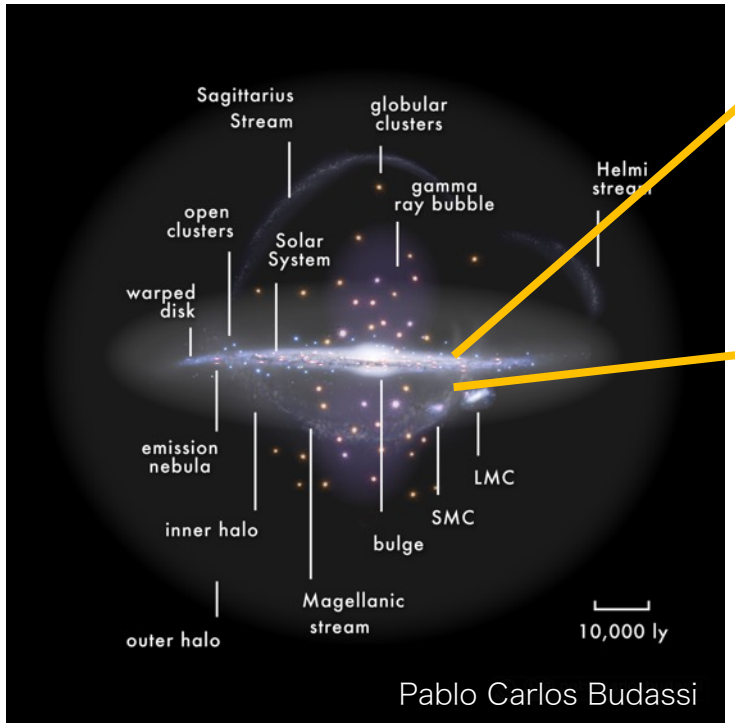
Material transportation

Intergalactic → Halo → Disk → Cloud → Filament → Core → Disk → Star

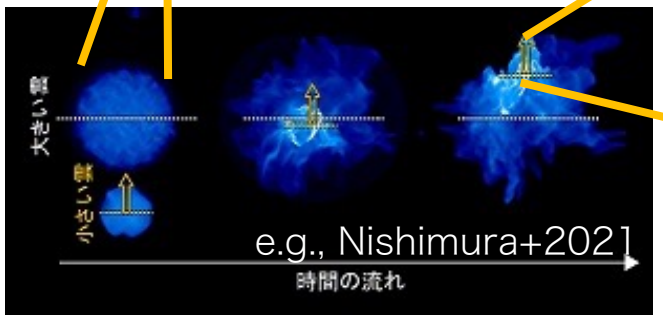
Interaction in upper layer affecting lower layer is commonly observed.

Comprehensive picture is crucial. High-dynamic range is essential.

・Mass cycle ・Chemical evolution

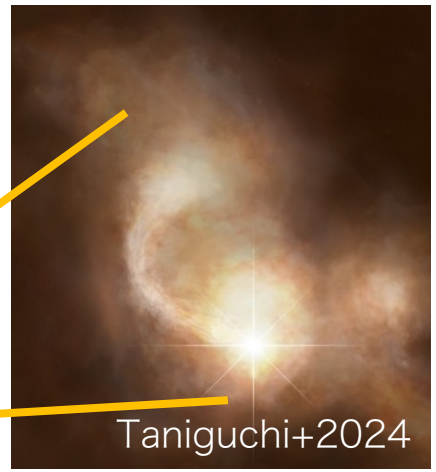


Intergalactic-space to disk



Cloud-cloud interaction

Filament formation and fragmentation

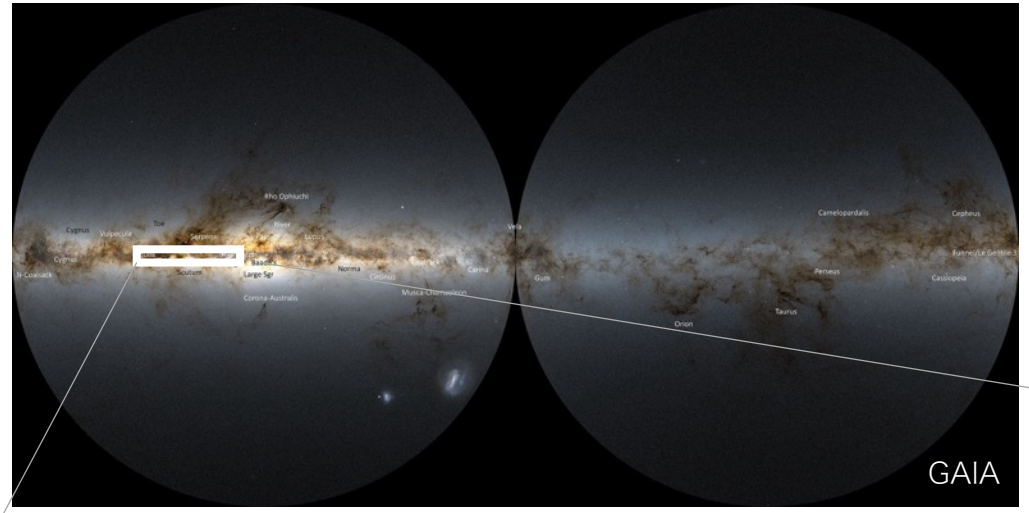


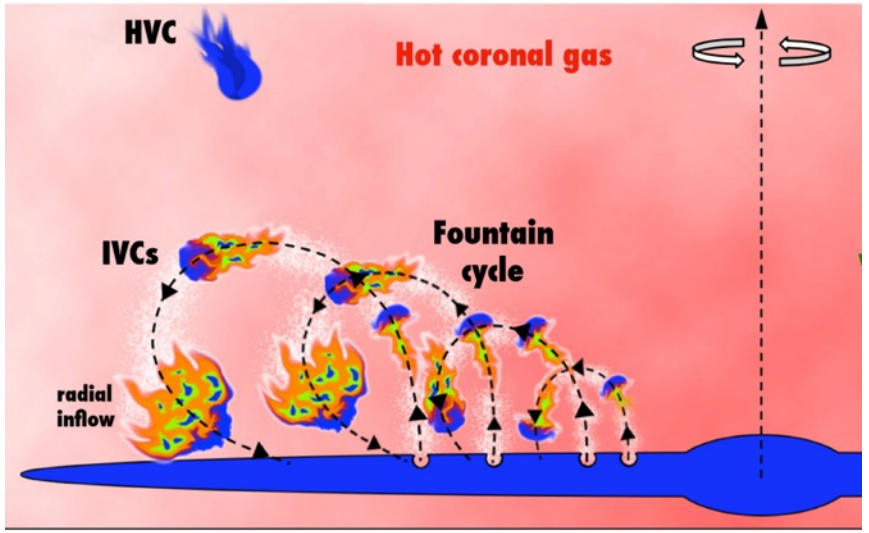
Mass supply from outside of core

3. Scientific objectives

(1) All sky survey of CO(1-0) and SiO(2-1)

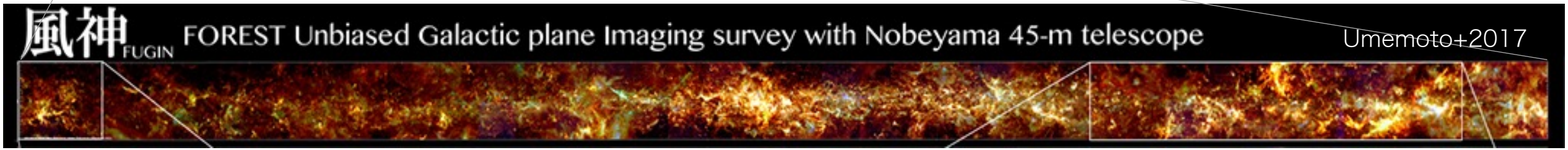
- Reveal material distribution and transportation in the Galaxy
  - ・Ultimate dataset of molecular gas
  - ・Mass supply to the disk　・G-dwarf problem
  - ・Star formation difference across the galaxy





Marasco et al. (2013)

Archive: 20 papers/year, 70% are by foreign PI



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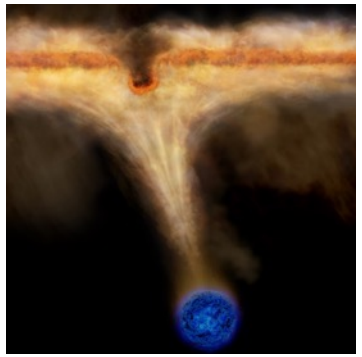
  - ・Star formation difference across the galaxy

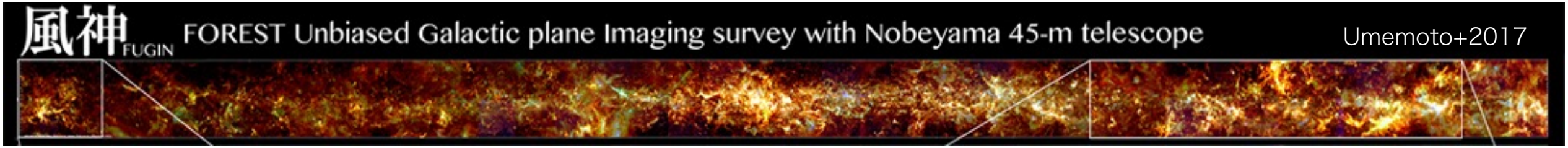
- Hunt unknown objects interacting with IMS such as missing blackholes, dark matter subhalos (DMSH) and buried SNe.

Missing blackholes candidates

Yokozuka+2024



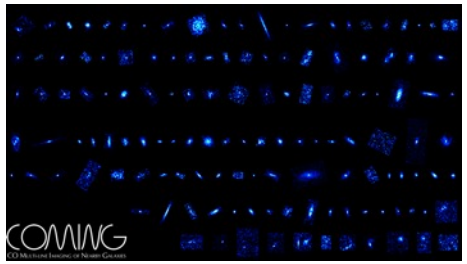
DMSH candidates



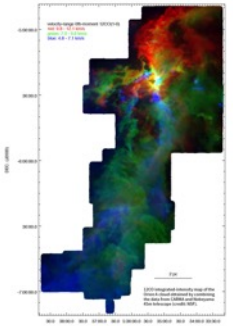
3. Scientific objectives

(2) ISM: density, chemistry, ionization, magnetic field

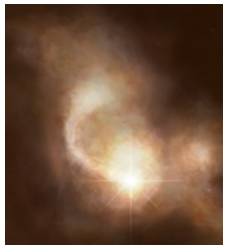
- Large-scale mapping, high sensitivity and multi-lines observations for the Galactic and extra galactic ISM.
- Also useful for supplemental purpose of other wavelengths, and preliminary study of competitive telescope such as ALMA.



COMING Legacy



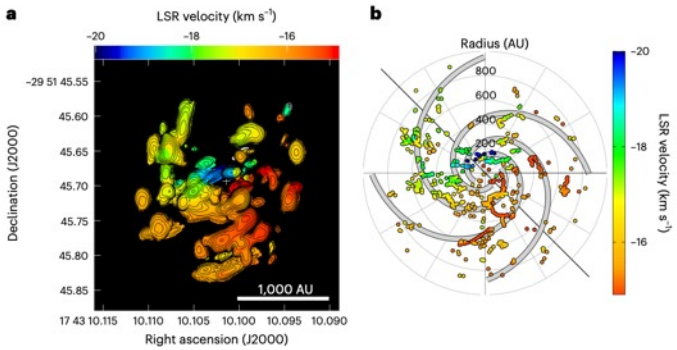
SF Legacy



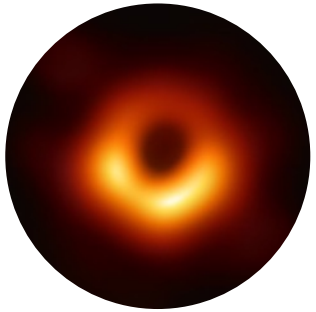
Taniguchi+2024

(3) mm-wave VLBI

- Multi-line maser monitoring
- Event horizon



Burns et al. (2023)



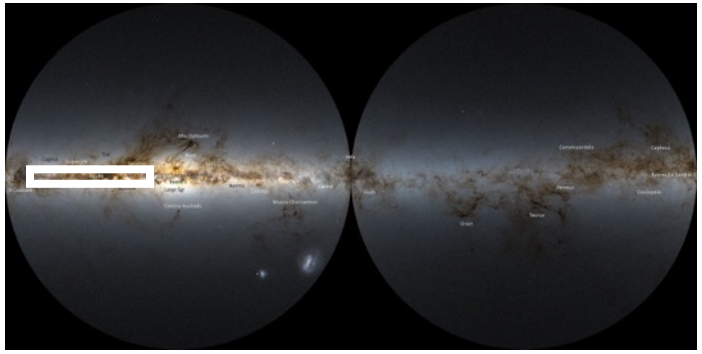
Event Horizon Telescope Collaboration et al. (2019)

4. Science investigations

Scientific objectives will be realized with newly developed instruments and systems.

Until 2033

- Operation
  - Continue charged-telescope-time operation.
  - Repair broken parts of the telescope.
- Development
  - New spectrometer [PI: Nishimura (NAOJ), KAKENHI requesting]
  - Wide-band receiver (20-150 GHz) [PI: Imai (KagoshimaU), KAKENHI Kiban-S requesting]
  - 20-element multi-beam [PI: TBD]
  - Improve surface accuracy [PI: Tamura (NagoyaU), ongoing]
- Observation
  - Galactic plane: 5x wider area than FUGIN will be mapped
  - Individual investigation will be performed

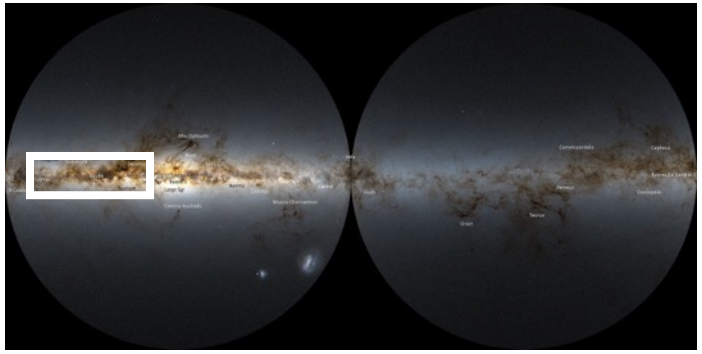


4. Science investigations

Scientific objectives will be realized with newly developed instruments and systems.

Beyond 2034

- Operation
  - Continue until alternative telescope is available.
- Development
  - 100-element multi-beam [PI: TBD]
  - Wide-band receiver (20-230 GHz) [PI: Imai (KagoshimaU)]
- Observation
  - Galactic plane: 25x wider area than FUGIN will be mapped
  - Individual investigation will be performed



5. Instruments and data to be returned

Instruments

- New spectrometer
- 100 GHz multi-beam receiver (20 element, 100 element)
- Wide-band receiver (20-150 GHz, 20-230 GHz)
- New techniques improve surface accuracy

Data

- Large-scale mapping data of the Galactic plane (CO, SiO, etc)
- Archive of individual observations

6. Originality and international competitiveness

Antenna

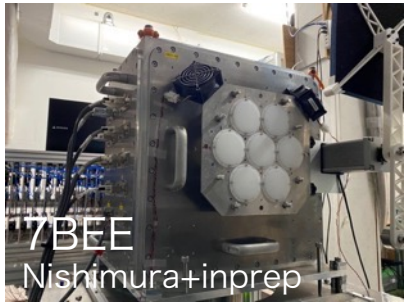
Telescope	Diameter	Surface accuracy	Year	Note
NRO	**45 m**	**100 μm**	**1982**	**(This proposal)**
LMT	**50 m**	**50 μm**	2017	Mainly focusing on 1mm observations
IRAM	30 m	**40 μm**	1985	Smaller diameter
JCMT	15 m	**40 μm**	1987	Smaller diameter
GBT	**100 m**	200 μm	2002	Lower surface accuracy
Effelsberg	**100 m**	550 μm	1971	Lower surface accuracy
SRT	**64 m**	300 μm	2013	Lower surface accuracy
Yebes	40 m	180 μm	2007	Lower surface accuracy

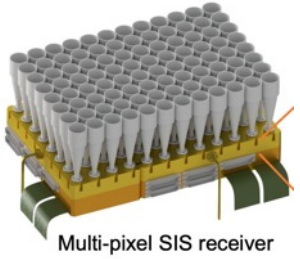
→ NRO 45m is still one of the largest mm-wave antenna in the world!

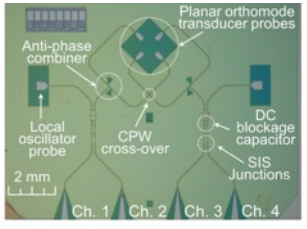
6. Originality and international competitiveness

Receiver (heterodyne camera)

Receiver	Telescope	Beam	Pol	Tsys (K)	RF (GHz)	IF (GHz)	Year	Note
BEARS	**NRO 45 m**	25	1	500	82 - 116	0.6	1998	SIS
FOREST	**NRO 45 m**	4	2	200	80 - 116	14	2011	SIS
7BEE	**NRO 45 m**	7	2	200	72 - 116	30	2023	HEMT
20-element	**NRO 45 m**	20	2	200	72 - 116	30	2030 ?	HEMT? SIS?
100-element	**NRO 45 m**	100	2	200	72 - 116	30	2037 ?	HEMT? SIS? PAF?
Argus	GBT 100 m	16	1	200 ?	74 - 116	1.25	2016	HEMT
SEQUOIA	LMT 50 m	16	1	200	85 – 115.5	15	2017	HEMT
CARUSO	SRT 64 m	16	2	?	70 - 116	16	2024 ?	HEMT



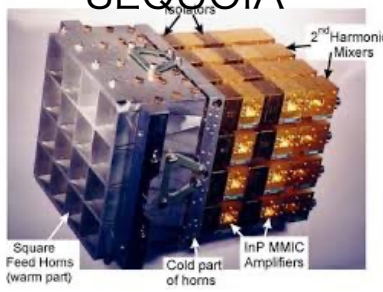


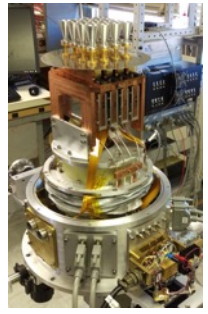


Integrated SIS mixer circuit chip

Wenlei+ (NAOJ, ATC)

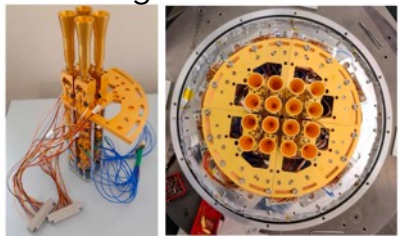
SEQUOIA





Argus
Sieth+2015

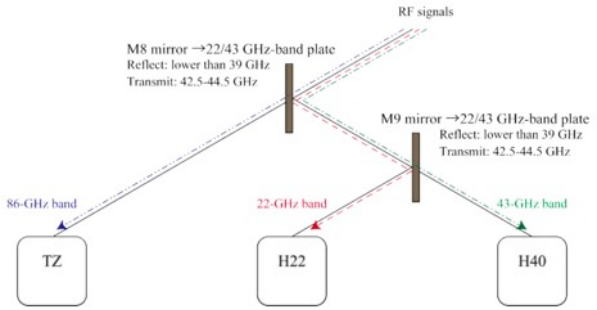
CARUSO
Daghestani+2024

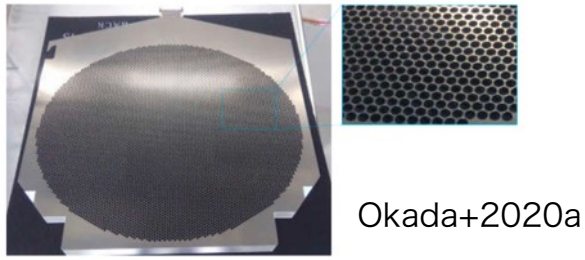


6. Originality and international competitiveness

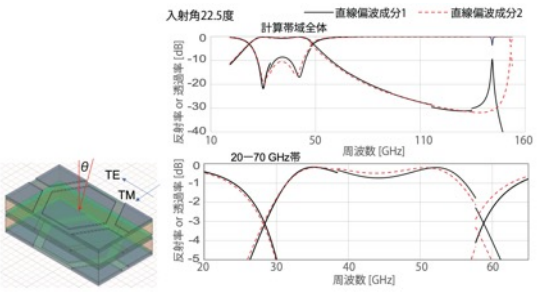
Receiver (wide band)

- HINOTORI (PI: Imai [KagoshimaU])
  - 22 and 43 GHz (Okada+2020a)
  - 22, 43 and 86 GHz (Okada+2020b)
- NOCTURNE (PI: Imai [KagoshimaU])
  - 20-60, 70-116, and 120-150 GHz (KAKENHI Kiban-S requesting)
  - 20-60, 70-116, 120-150, 200-230 GHz
- Korea telescopes have similar filter system (22, 43, 86 and 129 GHz)





Okada+2020a



Yamasaki+

Spectrometer

- SAM45: 2 GHz x 16 arrays (Kamazaki+2012)
- RFSoC spectrometer (PI: Nishimura [NAOJ])

SAM45

RFSoC

7. Current status

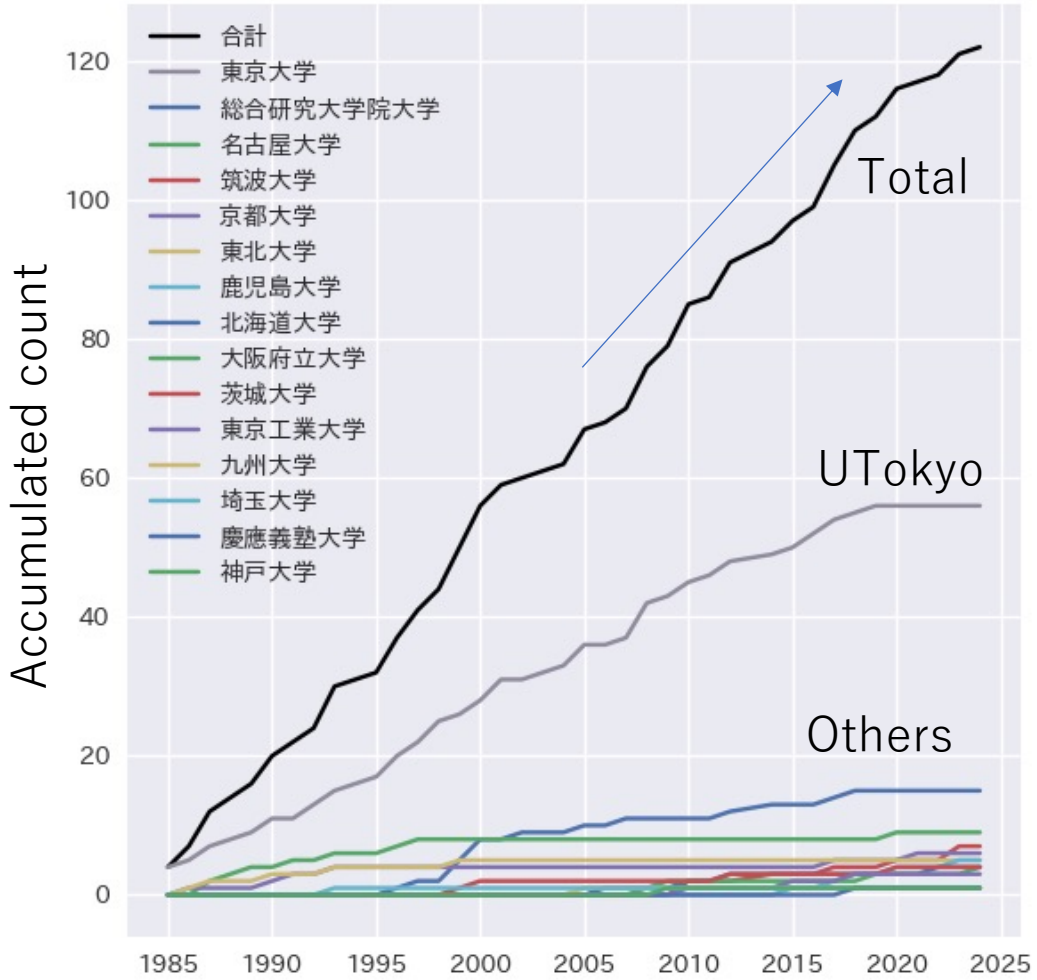
FY2023 statistics

https://www.nro.nao.ac.jp/news/2024/0411-data.html

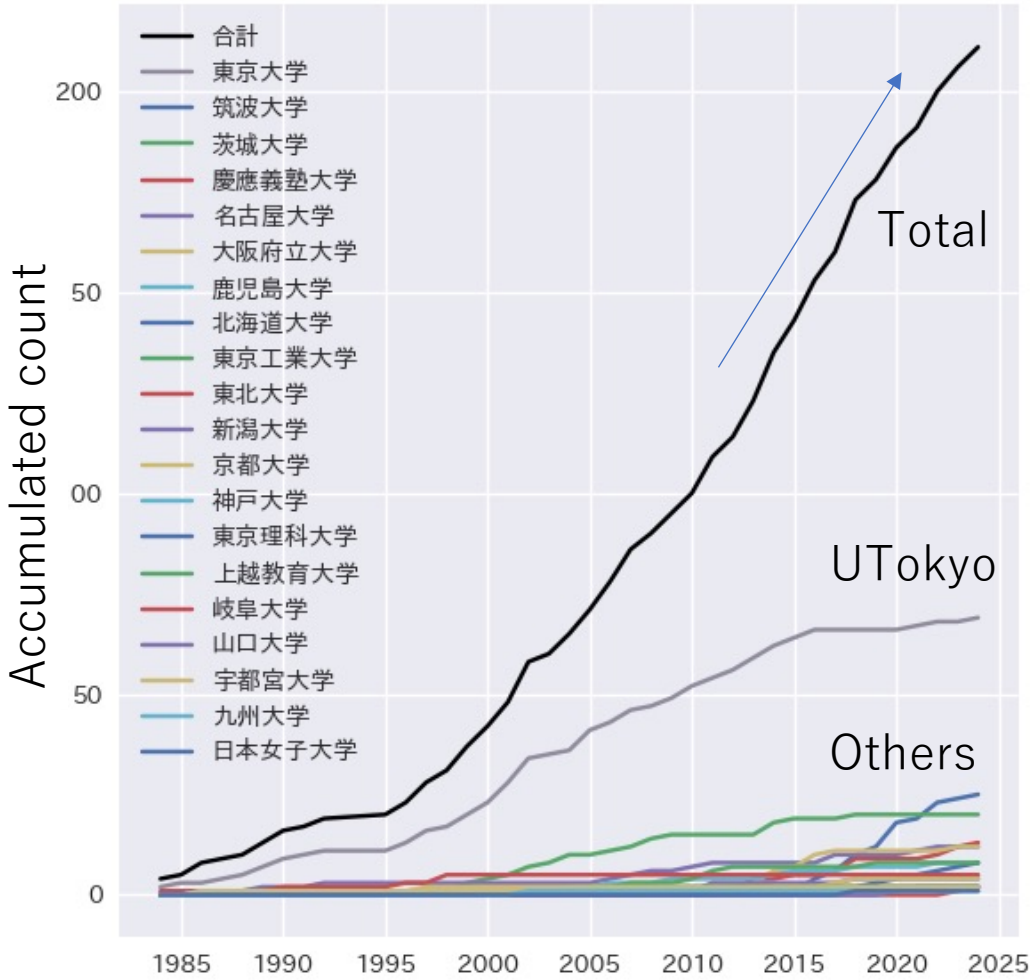
Observation	35 proposals、**2378** hours (179 people, 39 organizations, 10 country) Observatory revenue: 19.2 M JPY
Development	**9** projects are in progress https://www.nro.nao.ac.jp/~nro45mrt/html/develprop/
Publications	**35** refereed papers (FUGIN: ~20, COMING and/or CO atlas: ~5) https://www.nro.nao.ac.jp/~nro45mrt/html/publications/#2023
Education	PhD : **2** people/year (5 years average) Master: **6.6** people/year (5 years average)
Press release	4 releases
Visitor	39,217 people
Cooperation with local government	71 daytime tour, 30 night tour, etc. Totally 3,075 people joined paid events Definite fraction of LG income will send to the NRO. Observatory revenue: 0.7 M JPY (2023)

7. Current status

PhD theses

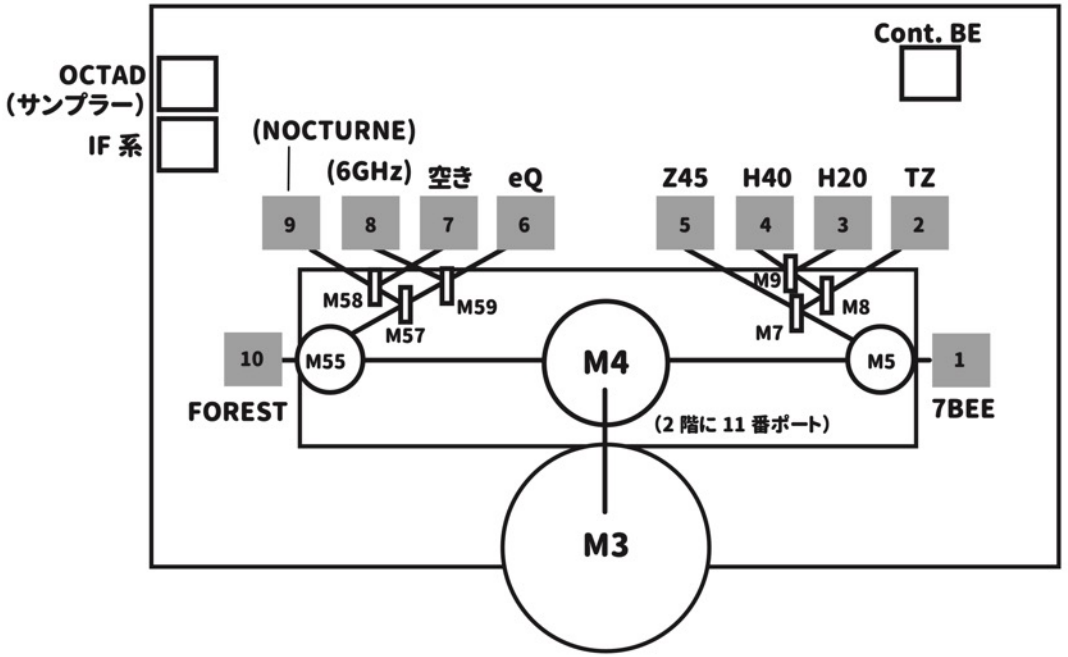


Master theses



7. Current status

Receiver cabin



Port	Rx	RF (GHz)	Beam	Pol	PI	Status
1	7BEE	70-116	7	2	Tatematsu (NRO)	under CSV
2	TZ	80-116	1	2	Niinuma (Yamaguchi U)	under CSV
3	H20	20-25	1	2	NRO	Open
4	H40	42.5-44.5	1	1	NRO	Open
5	Z45	42-46	1	2	Nakamura (NAOJ)	Open
6	eQ	30-50	1	2	Chiong (ASIAA)	under CSV
7	(open)					
8	6 GHz Rx	6.5-12.5	1	2	Yonekura (Ibaraki U)	Budget requiring
9	NOCTURNE	20-150	1	2	Imai (Kagoshima U)	Budget requiring
10	FOREST	80-116	4	2	NRO	Open
11	Tsukuba-cam	100	109	N/A	Kuno (U Tsukuba)	under CSV

HINOTORI Filter		
H22 & H40	Imai (Kagoshima U)	Open
H22 & Z45	Imai (Kagoshima U)	Open
H22 & H40 & TZ	Imai (Kagoshima U)	under CSV

- 11 receiver ports available
- Development opportunities are opened for universities
- NRO development roadmap is mainly based on proposals submitted
- 9 projects are ongoing

Developer meeting 2023

Developer meeting 2024

Freewheeling development experience develops experts

Dr. Akio Taniguchi (2018)

Kitami Inst. Tech., Project Asst. Prof.

Development of a new analyze technique using data science method.

Dr. Sho Masui (2022)

ATC, NAOJ, Asst. Prof.

Development of wideband receivers

Dr. Yosuke Murayama (2022)

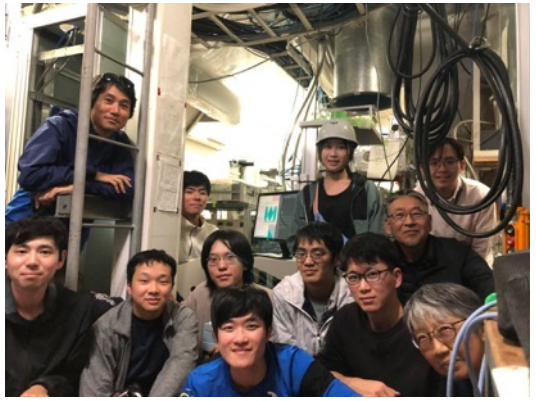
ATC, NAOJ, Project Researcher

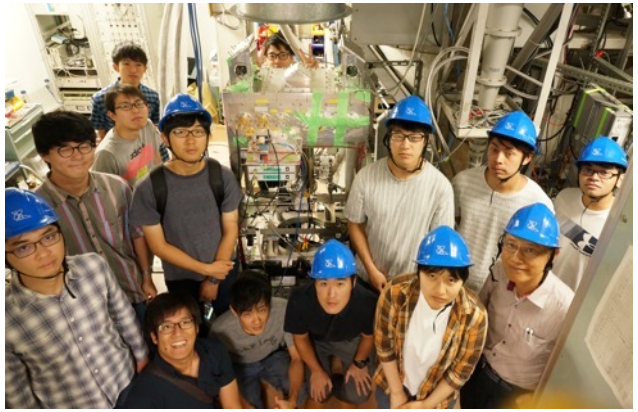
Development of an MKID camera.

Dr. Yasumasa Yamasaki (2023)

ALMA, NAOJ, JSPS Postdoc. Fellow

Development of wideband optics systems





8. Cost assessments, budget line and status

Operation Cost

- 130M JPY is required
- Detail
  - Yearly Maintenance: ~53M JPY (antenna, receiver, refrigerator, computers, etc.)
  - Electricity: ~30M JPY
  - + Human resource (at least 1 more project staff)
  - Repair of unexpected hardware trouble is not included.

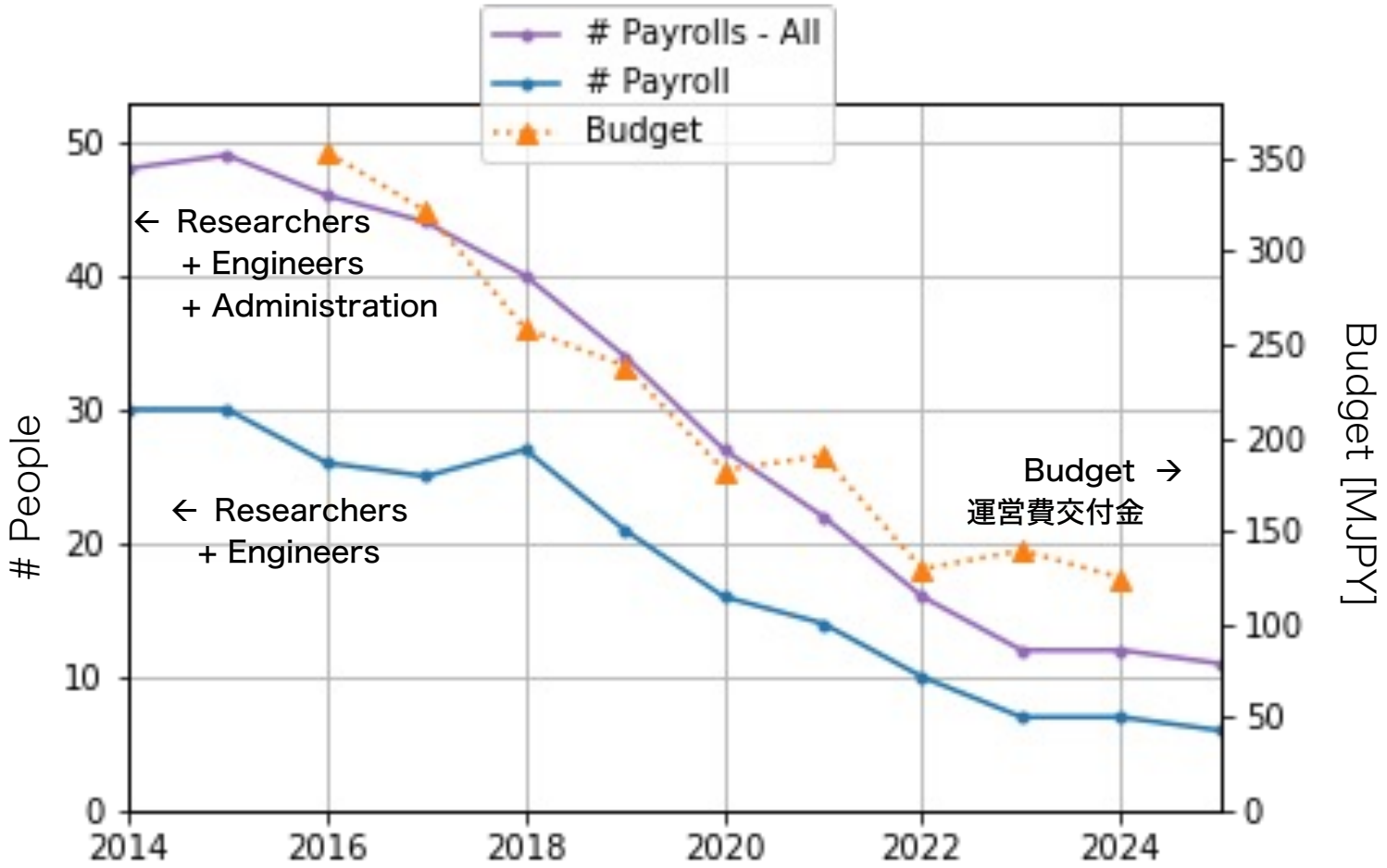
Budget

- 120M JPY from 運営費交付金
- 10M JPY from telescope charge

Breakdown of telescope charge usage

- We expect 20M JPY/yr will be gathered
- 10M JPY for operation
- 10M JPY for unexpected hardware trouble

8. Cost assessments, budget line and status



- By improving efficiency and doing selection and concentration, NRO is operating at minimum budget.
- In the last 8 years,
  - 65% budget reduced
  - 74% staff reduced
- Basically, new development will be promoted with external budget like KAKENHI by university staffs.
- NRO gathers external budget such as the telescope charge and LG cooperation for cost of operation and hardware repair.
- Hardware trouble due to ageing is big issue.
  - Collimater shutter broken (2023, 16MJPY)
  - SAM45 trouble (2023, 13MJPY)
- Possible hardware failure:
  - Master collimater, Motor, Motor Controller
  - Main reflector, Az rail

8. Cost assessments, budget line and status

External Budget

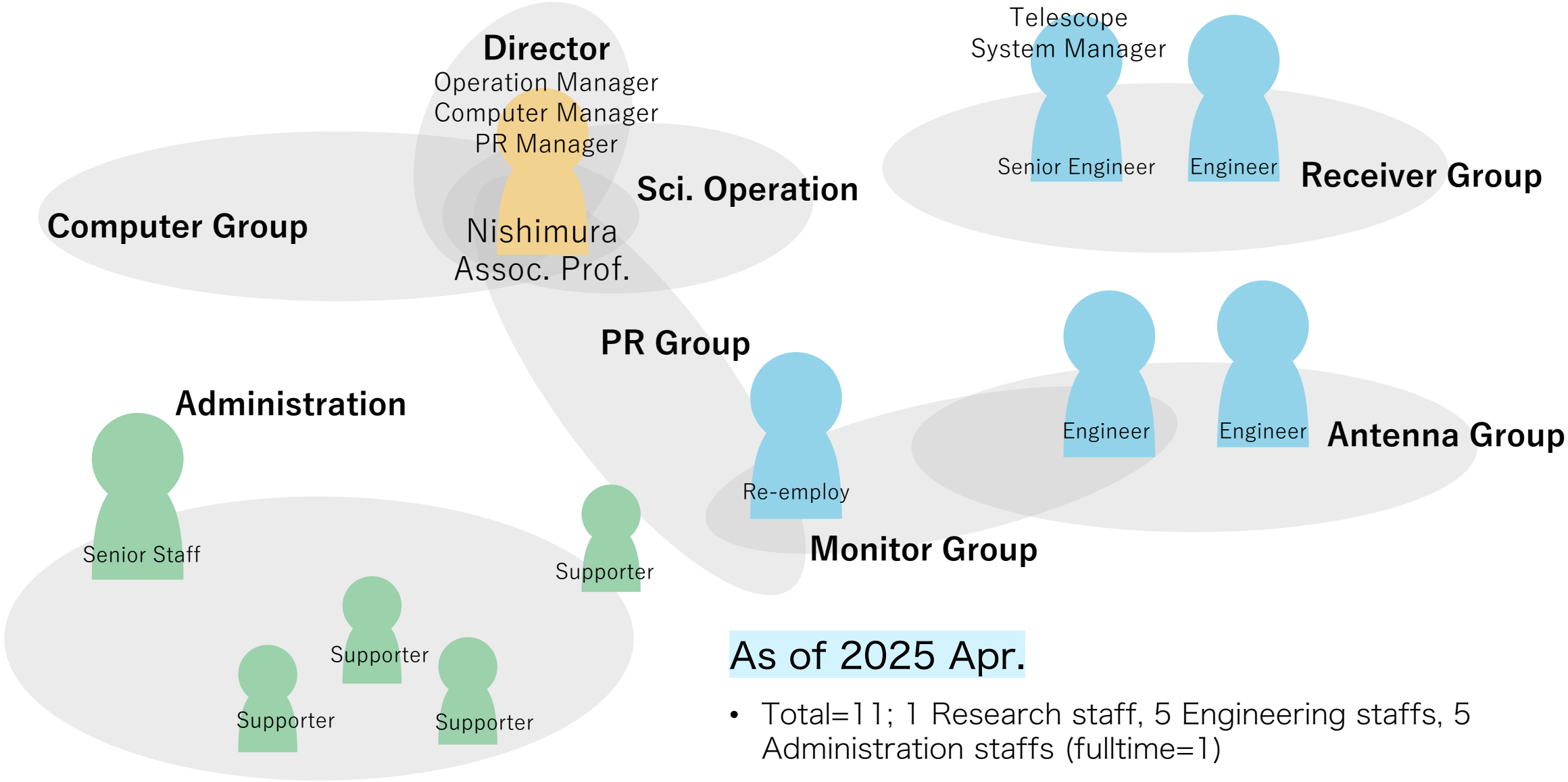
- Telescope charge
  - 1 hour 10 kJPY for domestic institute, 30 kJPY for foreign institute
  - Results:
    - (2022) 35.6 MJPY
    - (2023) 19.2 MJPY
    - (2024) 15.5 MJPY
  - Promotion to the community especially to foreign users are urgent issue

- Cooperation with local government (LG)
  - Definite fraction of LG income will send to the NRO
  - Results:
    - (2020) 125 kJPY [COVID19]
    - (2021) 167 kJPY
    - (2022) 468 kJPY
    - (2023) 727 kJPY
  - Nearly 2x increase each year

Daytime tour

Night tour

9. Project organization



As of 2025 Apr.

- Total=11; 1 Research staff, 5 Engineering staffs, 5 Administration staffs (fulltime=1)
- More staff needed (especially research staff)

10. Why NAOJ?

Because

- NRO supports a lot of universities staffs
- Operation scale is still large for universities

However

- Amount of own budget is possibly increasing
- It is not entirely unrealistic to expect all operation cost to be covered by own budget in ~10 years

Summary of the proposal: NRO 45m

One of the largest mm-wave single dish in the world

- Large area mapping capability
- Multi-lines: density, temperature, chemistry
- mm-wave VLBI

Easy to access

- for development
- for education

New scheme for income-earning

- Charged telescope time
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Implementation period under NAOJ

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Budget

130 MJPY/year

（120M: 運営費交付金）