SILVIA:

In-orbit Demonstration of Ultra-Precision Formation Flying

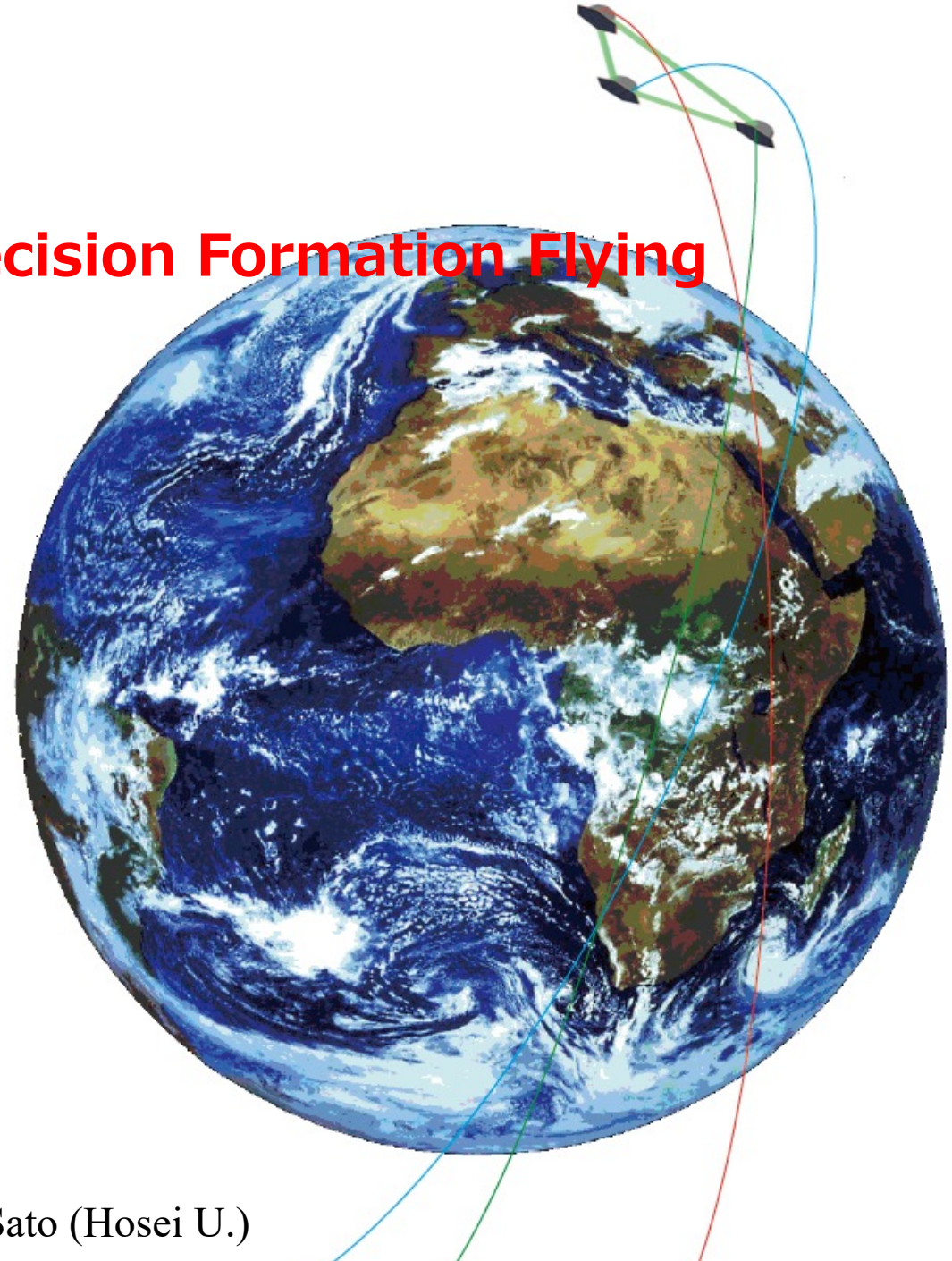
Kiwamu Izumi
(ISAS/JAXA)

2024/Dec/4, NAOJ Future Symposium

SILVIA

Technology demonstration relevant to precision Formation Flying

- **JAXA's M-class mission concept**
  - Use of Epsilon launch vehicle
  - Proposed in Feb. 2020
- **Technology demonstration**
  - Precision formation flying
  - Inter-satellite laser interferometer



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Organization

Working as a pre-project candidate team

- Team lead : Kiwamu Izumi (JAXA)
- Principal Investigator : Takahiro Ito (JAXA)
- Representative at NAOJ: Tomotada Akutsu (GWSP)
- Number of collaborators: 42
- Name list of the collaborators belonging to NAOJ: T. Akutsu
- Institute leading the project: JAXA

Funding since 2010

Total amount of direct expenses of competitive funding received since 2010 for the proposal: 248,600 kJPY

List of the top-5 competitive funding (FY, Type, Total amount of direct expenses, Title)

	Year	Type	Direct expense	Title
1	FY2021-FY2025	ISAS front loading 宇宙科学研究所技術フロントローディング	（投影のみ）	Preparation of a platform of cooperative control experiments for precision formation flying 精密編隊飛行のための協調制御系実験プラットフォーム構築
2	FY2018-FY2021	Strategic R&D budget by the Space Technology Committee 宇宙工学委員会戦略的開発経費	43,000 kJPY	Formation flying working group R&D フォーメーションフライトWG技術検討
3	FY2024-FY2027	JSPS Kakenhi Grant-in-Aid for Challenging Research (Pioneering) 科研費挑戦的研究（開拓）	18,100 kJPY	Breaking the limitation of external force measurements for precise physics experiments using space 宇宙空間を利用した精密物理実験のための外力擾乱測定の限界打破
4	FY2024-FY2026	JSPS Kakenhi Grant-in-Aid for Scientific Research (C) 科研費基盤研究（C）	3,500 kJPY	On-ground demonstration of a method to avoid adhesion of test masses by quasi-static separation for space high-precision accelerometers 宇宙高精度加速度計のための試験質量の準静的分離における凝着回避法の地上実証
		TOTAL	（投影のみ）	

Communities

Related research community

- Formation-flying working group in JAXA
- JGWC (Japan Gravitational Wave Community)
- GOPIRA

SILVIA recieved recommendation letters from

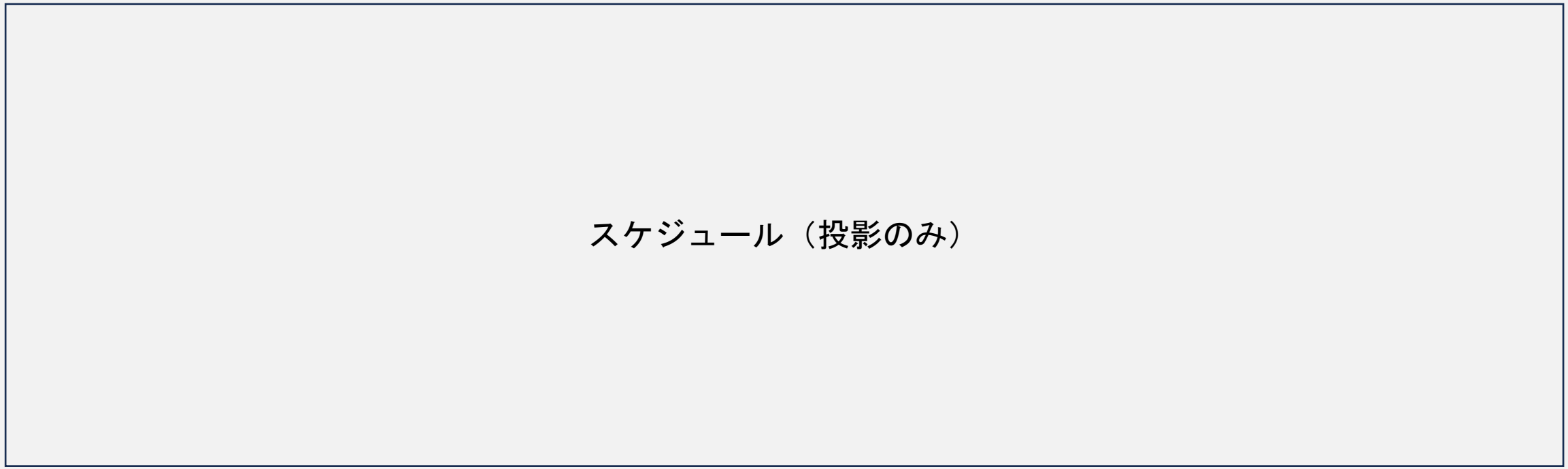
- JGWC steering committee chair
- Dr. Charles Beichman (JPL
- Prof. Sascha Quanz (ETH Zurich), LIFE Pincipal Investigator

Promotion of FF research activities in domestic meetings

- OSs in Space Sciences and Technology Conferences (宇科連)
- OS in ASJ meeting (天文学会年会) 2023

Schedule

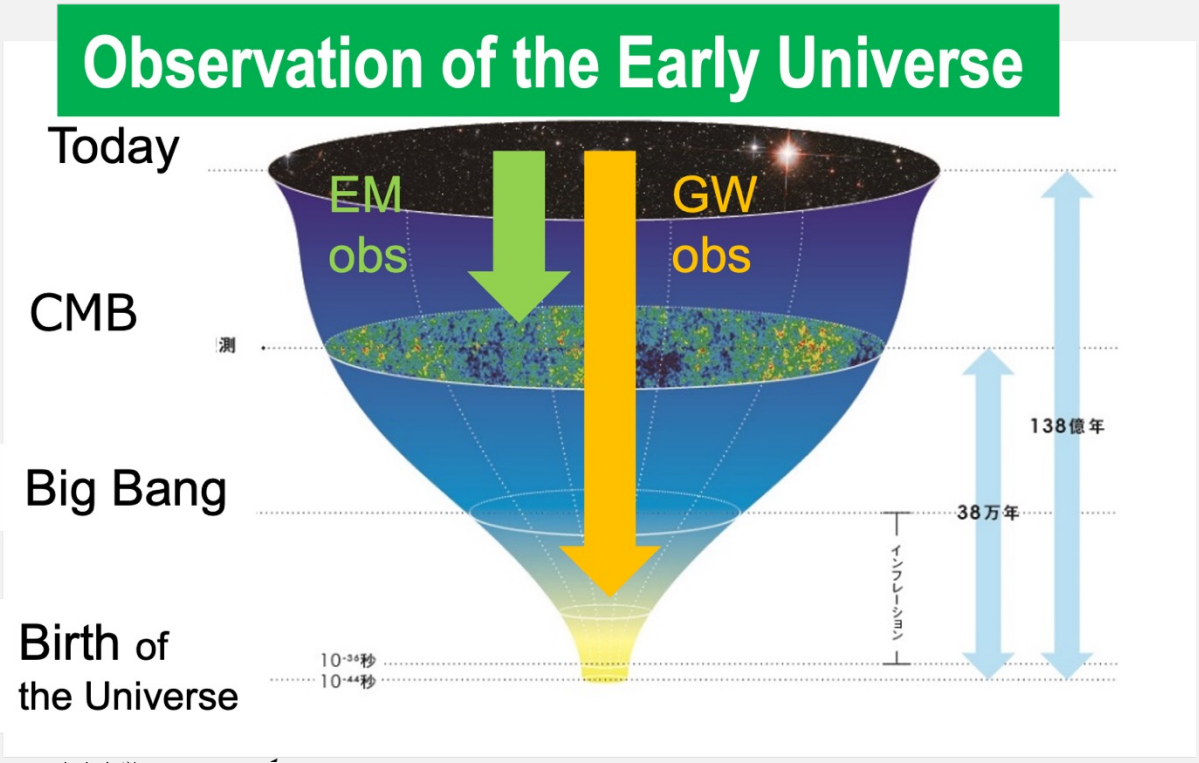
- Implementation period: FY2020-FY2034
- Current status: Mission Definition Phase (Pre-Phase A2 in JAXA)
- Expected status during the 5th Mid-Term Objective period (FY2028-2033): Design, Production, Launch, and Operation

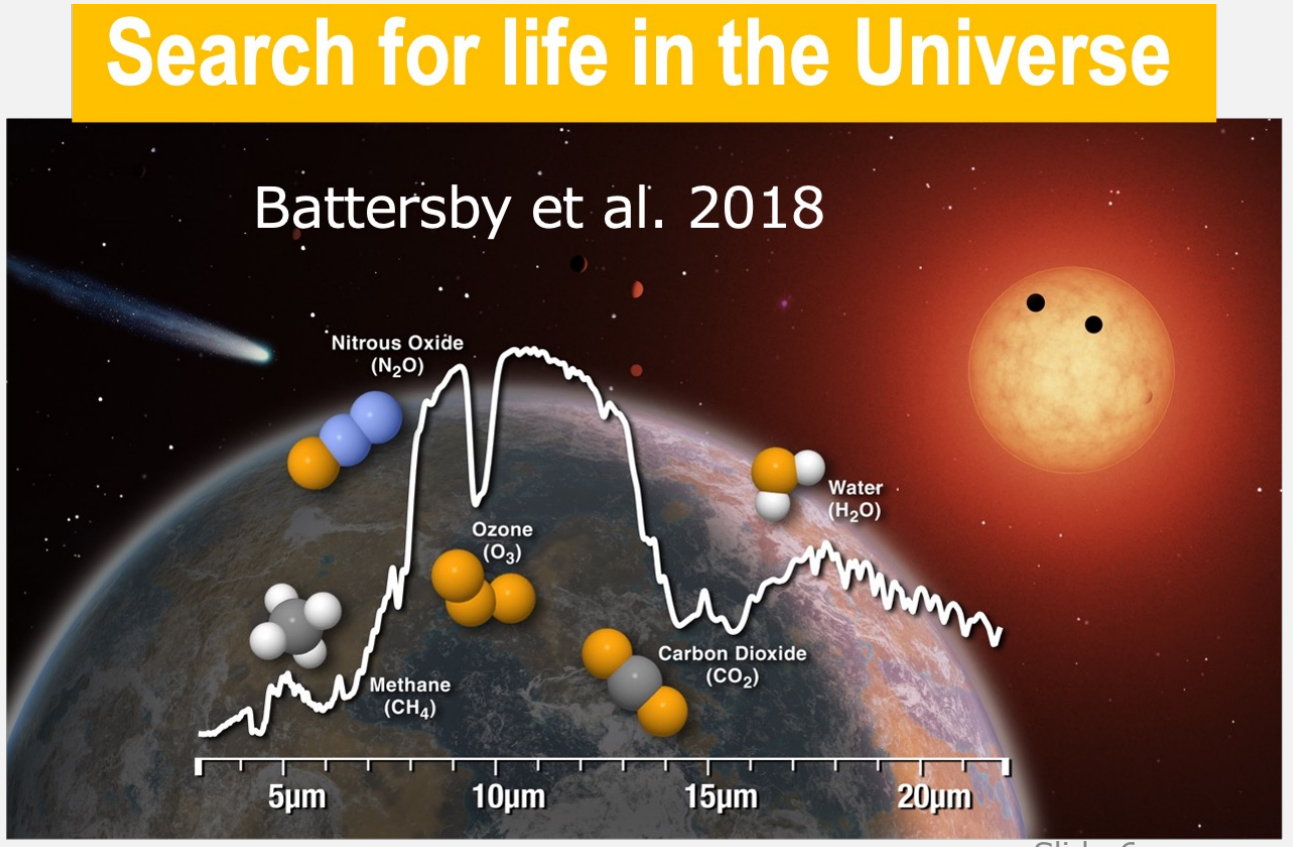


Science goal

Questions we would like to answer

(1) How did the universe begin?
(2) What compose the atmosphere on habitable exoplantes?





Scientific objectives

Long-term objectives

1. Directly probing the inflation by directly searching for the gravitational-wave background in the 0.1 Hz frequency band.
2. Analyzing atmospheric compositions on exoplanets by achieving high spatial resolution in the mid-infrared band.

SILVIA's objectives

- Obtaining the formation flying technology required for these ambitious astronomical observation concepts.
- Bringing a technology breakthrough for achieving large observatories that cannot be realized with a conventional single spacecraft.

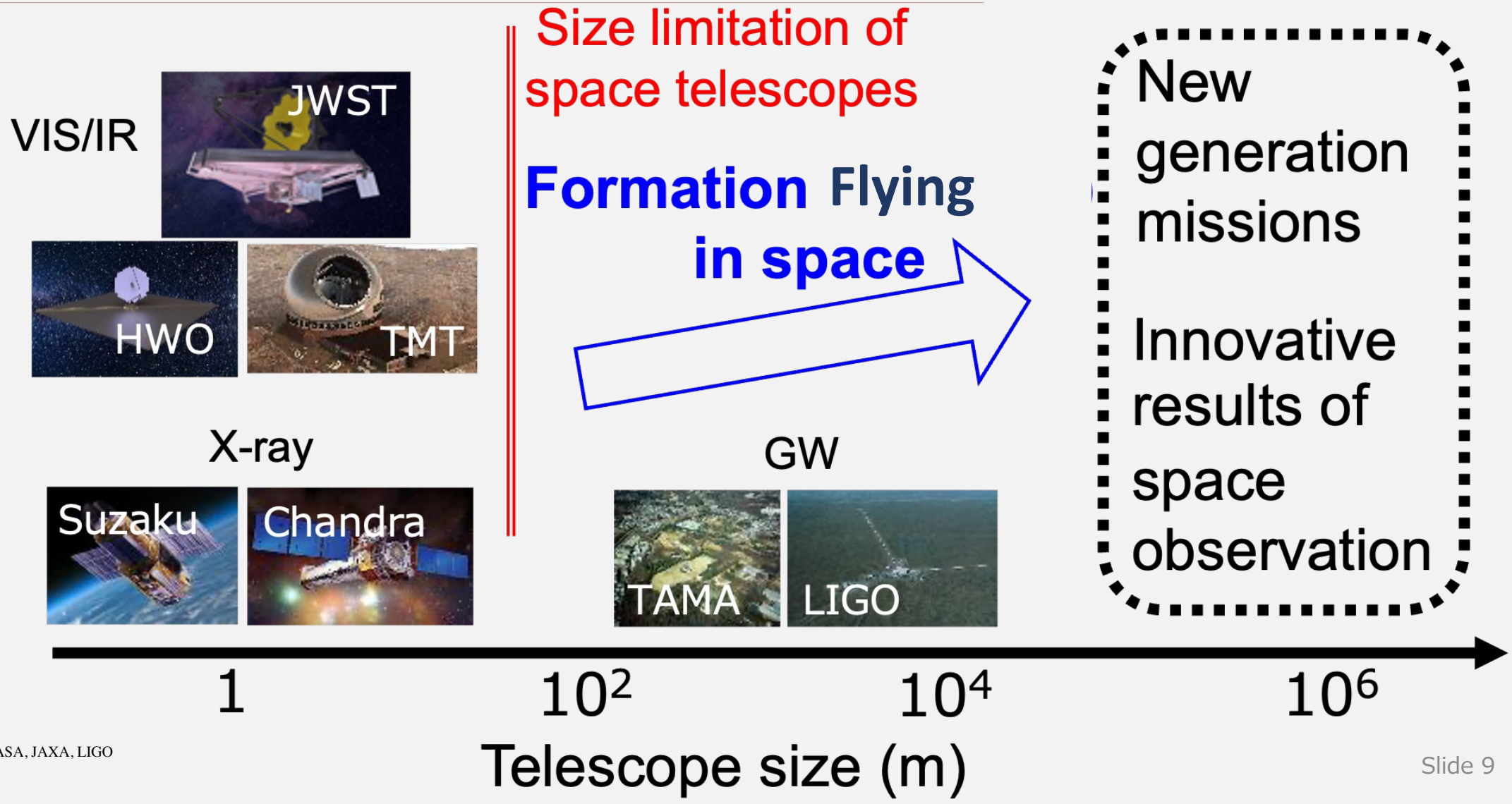
Science investigations

Three spacecrafts, separated by about 100 m are deployed.
Experiments for ultraprecision formation flying will be conducted in orbit.

(a) Demonstration of control on relative displacement between spacecrafts with sub-micron precision by laser interferometry
(b) Demonstration of observability of celestial objects by a prototype visible-infrared interferometer (Optional; TBD).

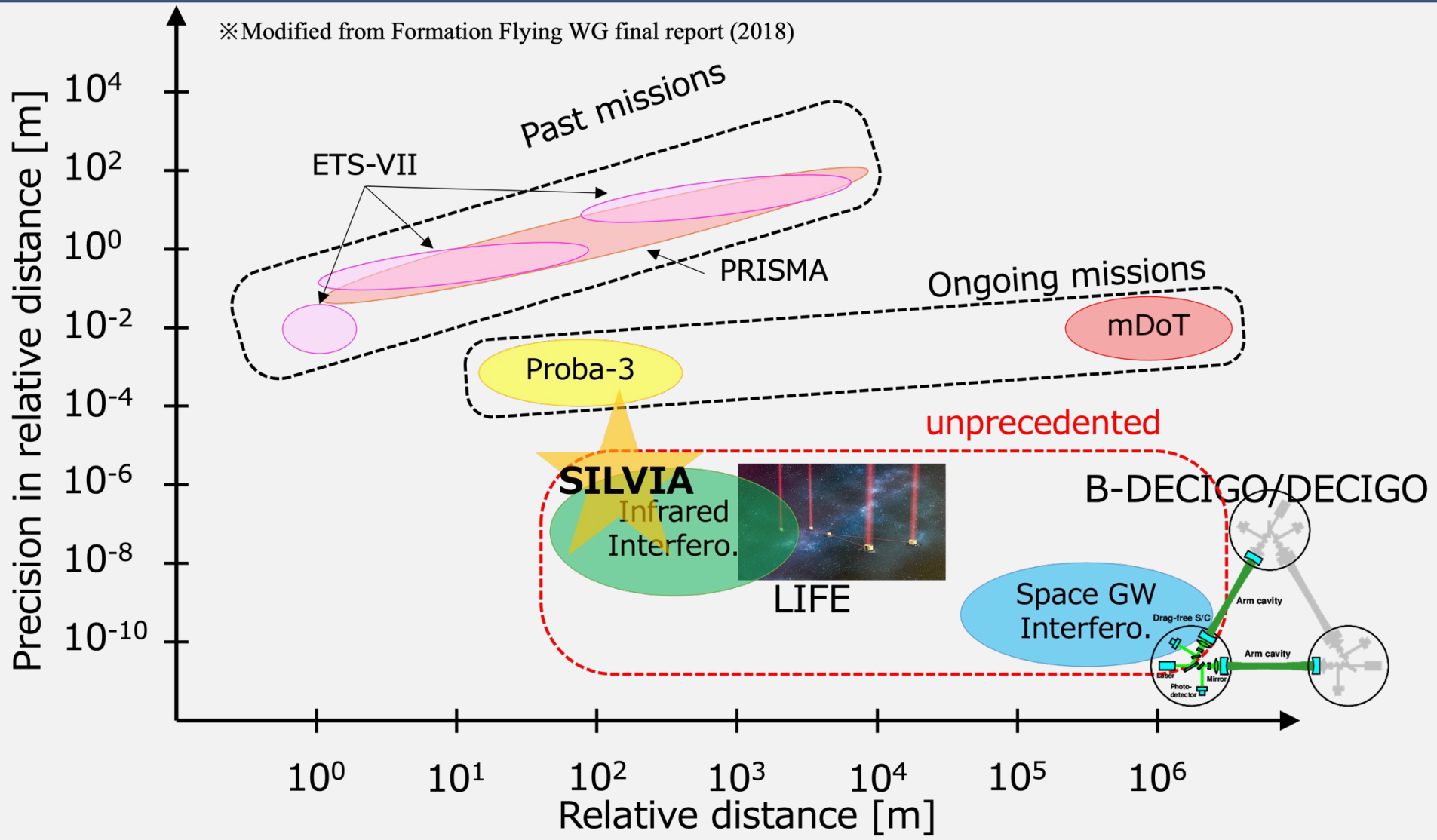
Item (a) also serve as a platform demonstration, which is indispensable the future space gravitational wave observatory. We also plan to demonstrate the flexibility of the flying formation.

Status of research fields: Size



画像：NAOJ, NASA, JAXA, LIGO

Status of research fields: Precision



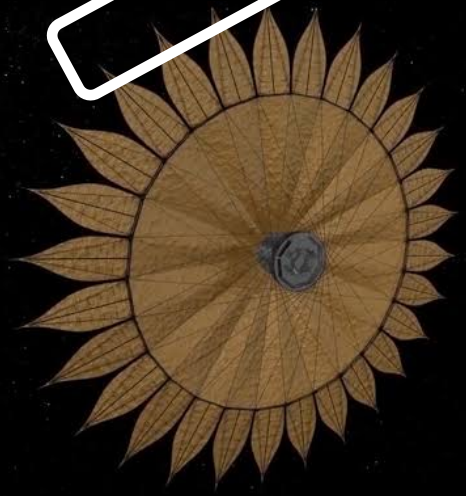
Advantages of SILVIA

SILVIA has the best formation precision among the similar concepts

Concepts	Objectives	# of S/C	Launch	Baseline length
Starling	Demonstration of swarm	4	2023	A few 100 m
VISORS	Demonstration of formation flying	2	2024	A few 10 m (with mm-cm precision)
POC_ESSAIM	Demonstration of swarm	3	2027	A few 10 m – 10 km
SEIRIOS	Demonstration of infrared astronomical interferometer (lead by Japan)	3	Around 2030	A few 10 m

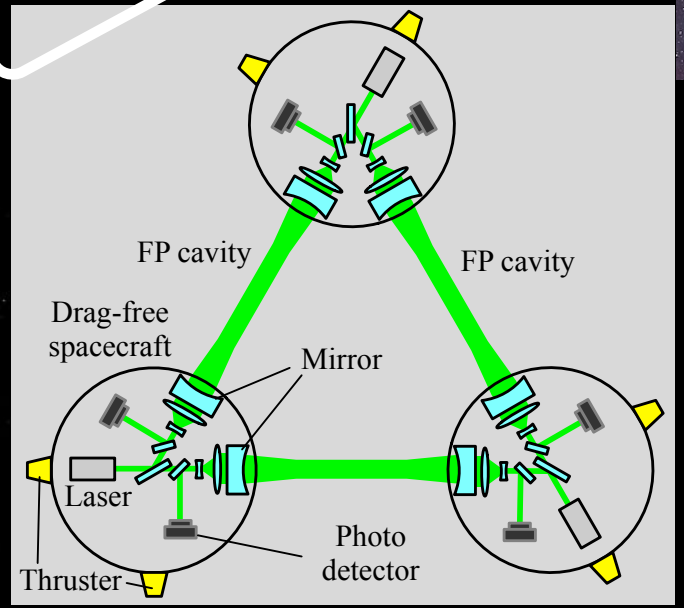
Broader impacts

Occulter



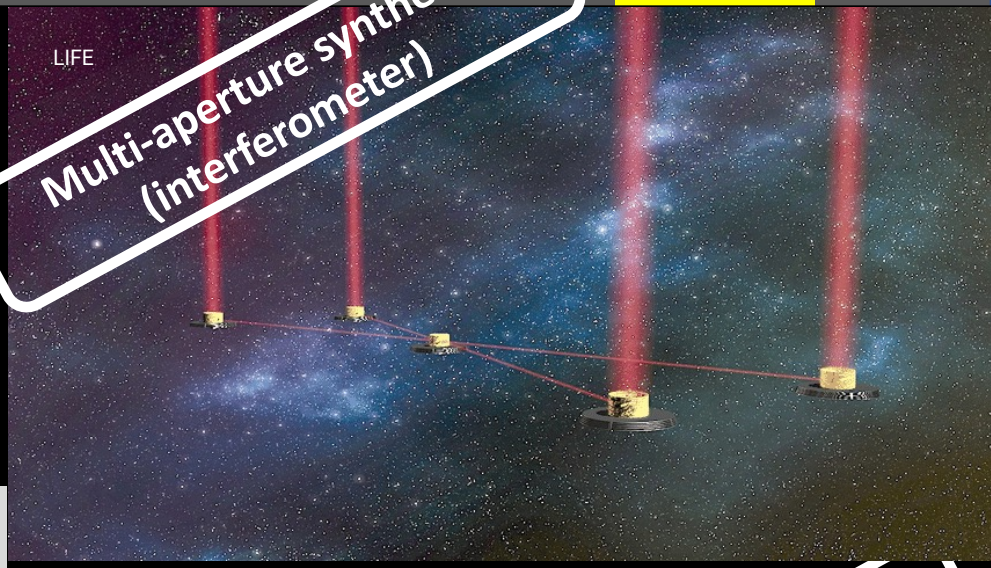
Starshade (NASA)

Gravitational wave observatories

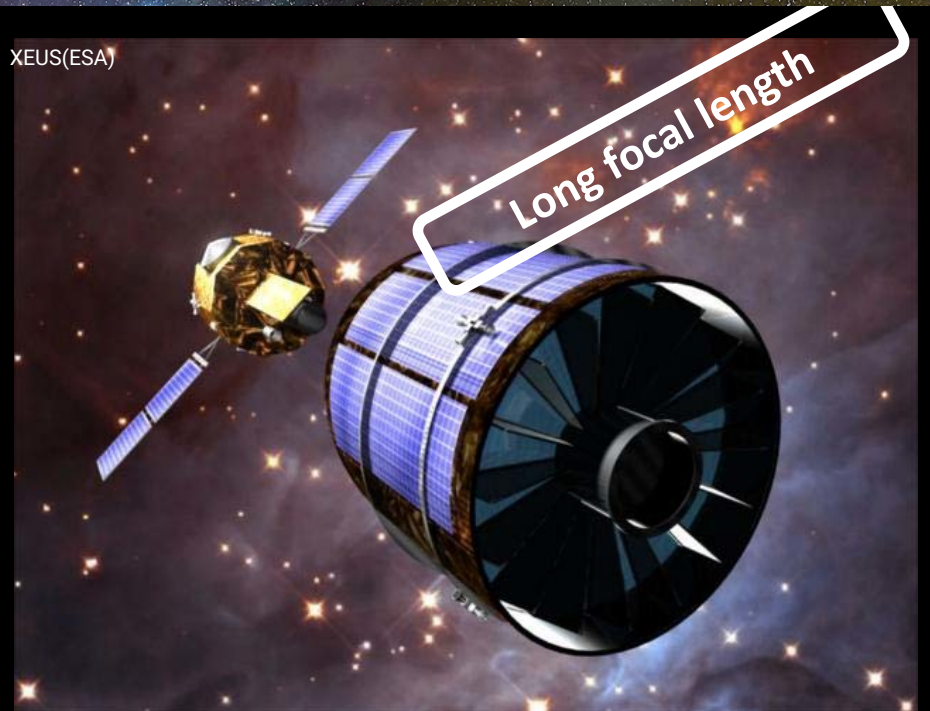


B-DECIGO/DECIGO (Japan)

Multi-aperture synthesis (interferometer)



Long focal length



Budget and funding sources

- Overall budget size: ~ 15,000,000 kJPY
- NAOJ fund expected: **15,000 kJPY/year** ~~**1B JPYs total**~~

Funding sources

I. Budgets implemented by other institutes
(e.g. universities and ISAS/JAXA)
II. Management Expenses Grants
(Incl. existing projects, basic developments of new plans)
III. External or competitive fund

Expectations to NAOJ

Activity at NAOJ

Development of the laser interferometer subsystem.
Budget (15,000 kJPY/yr) will be spent for development and evaluation costs

Why NAOJ

- **Expansion of technologies:** Application of heritage in NAOJ with optical telescopes and GW laser IFOs.
- **Growth of community:** SILVIA provides collaboration with young scientists/engineers. NAOJ hosts large science communities including optical/infrared astronomy. Collaboration between the science and engineering teams maybe effective in securing human resources in future.

Roles expected to NAOJ (especially request for ATC/ADC, lab space, data archive, etc)

- Design and development of laser interferometer subsystem
- ATC: Technical supports for the design, development, and evaluation of the laser IFO subsystem.
- Use of ATC's facilities not determined.