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JASMINE: near-infrared space astrometry mission

―Japan Astrometry Satellite Mission for INfrared Exploration―

Naoteru Gouda(JASMINE Project Office/NAOJ) and JASMINE team

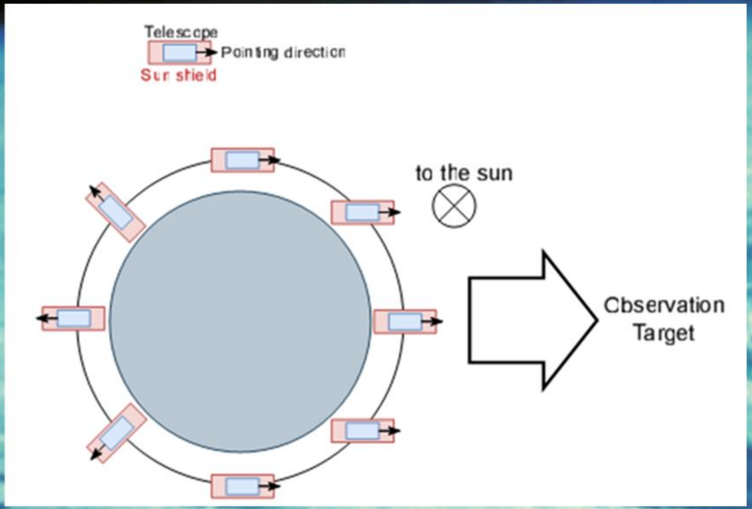
***It used to be called Small-JASMINE, but it was officially renamed JASMINE.**

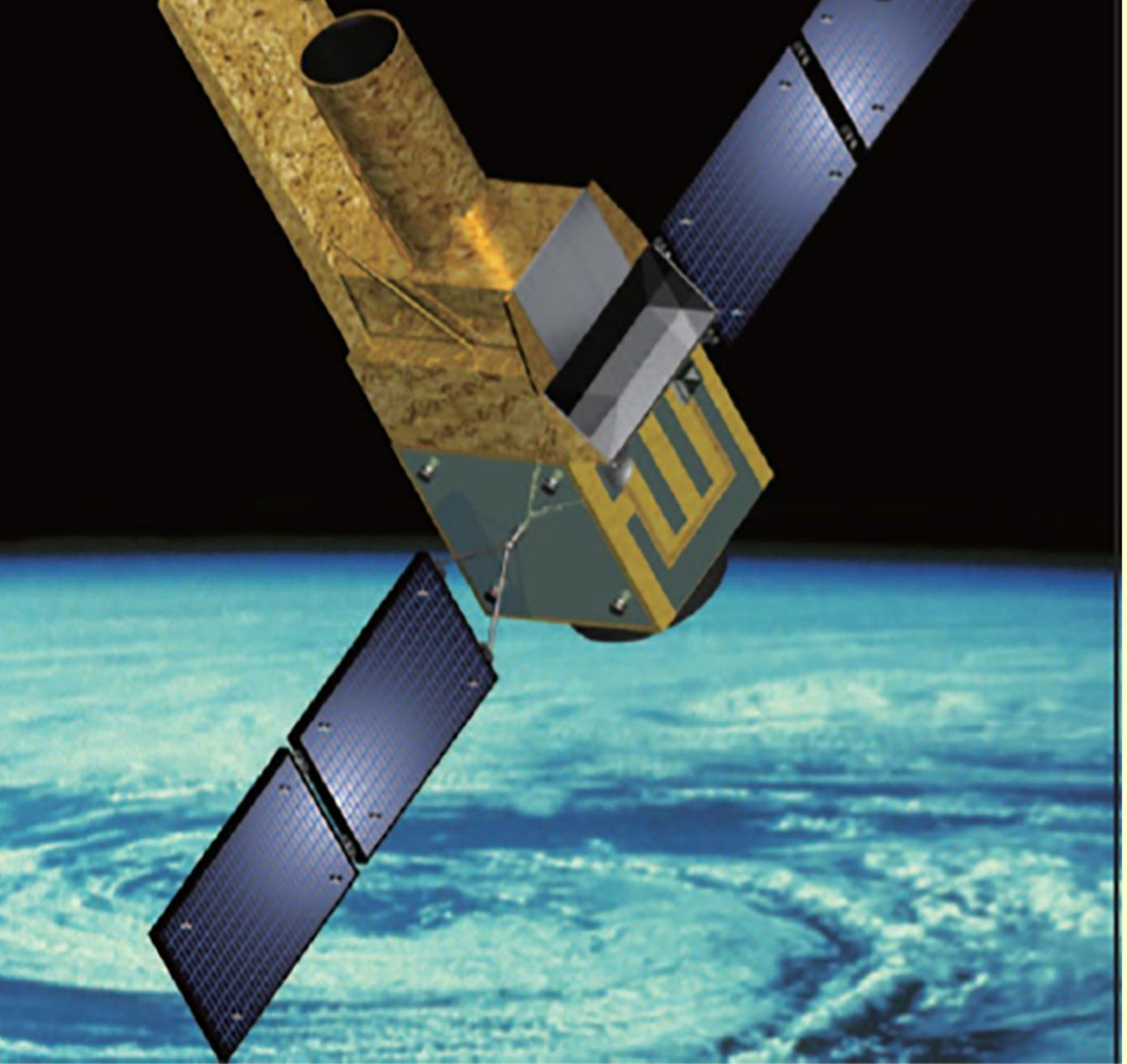
1. Mission concept of JASMINE

JASMINE：High-precision infrared astrometry satellite mission

Transit observation mission for the exploration of Earth-like planets

- highly thermal stable telescope
- Diameter of the primary mirror ～36cm
- Infrared sensor (InGaAs): 2k×2k×4
  - wavelength1.0-1.6μm
- Satellite weight ～600kg (wet)
- Launch by epsilon-s rocket (JAXA)
- science operation for 3 years (nominal)
- Sun-synchronized orbit・altitude ～600km





1. Mission concept of JASMINE(continued)

★Output data of astrometry to be provided by JASMINE

We will create a catalog of the time-series data of the stellar positions on the celestial sphere observed in the direction of the Galactic nuclear region and the annual parallaxes and proper motions of stars derived from the data, and we will make the catalog available to researchers around the world.

Spring and Autumn:

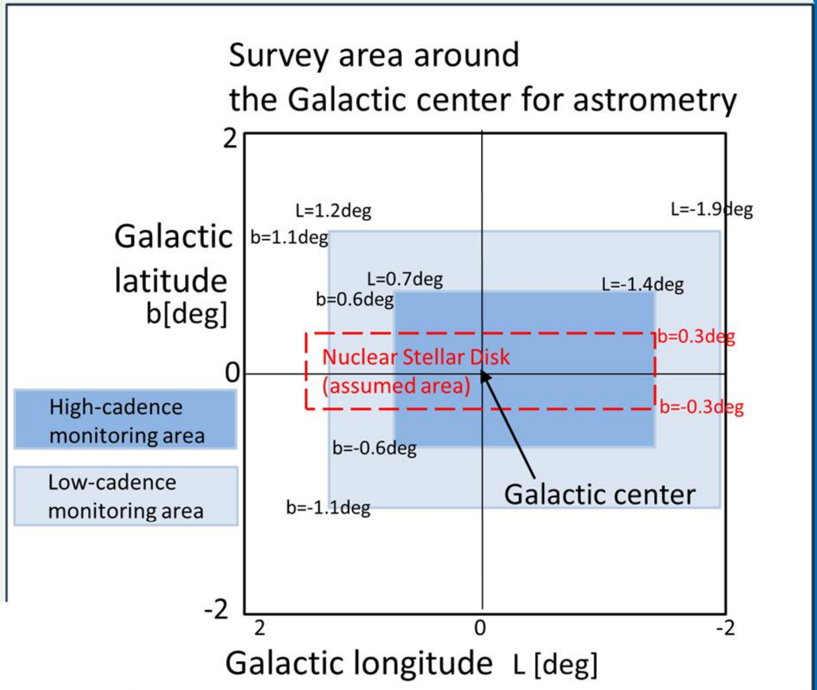
Astrometric survey in the direction of the Galactic nuclear region

Stellar images are taken continuously every about 12.5 seconds(exposure time)

Hw-band: 1.0μm～1.6μm **$*Hw \sim 0.9J+0.1H-0.06(J-H)^2$**

The magnitude range for the stars to be downloaded to the ground every exposure time➔
～10.0 mag< Hw <～14.5mag
➔ About 120,000 stars in the high-cadence monitoring area.

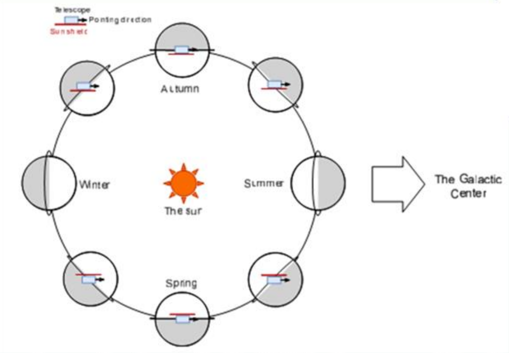
Full-frame of 1 field of view is planned to be downloaded every a few dozen exposure times.
Full-frame downloads will become possible more frequently if the amount of communication data sent to the ground increases with the support of some stations besides JAXA.



Precisions:

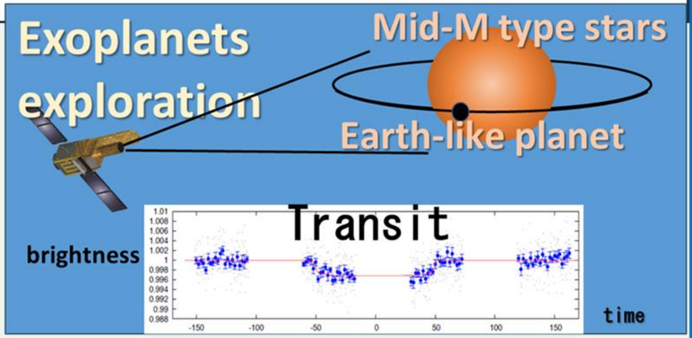
position, parallax: ＜25μas～125μas
proper motion: ＜25μas/y～125μas/y
1~5km/s tangential velocity error at 8kpc

about 35μas(μas/y) ～180μas(μas/y) for low-cadence area



Ref. Summer and Winter:

Transit observations of mid-M type stars to find Earth-like planets in the habitable zone
Time-series photometric data with photometric accuracy to detect 0.3% transit depth for 17 or more target objects (observation period of 2-5 weeks or more for one target)



2. JASMINE Current status

- **ISAS**(Institute of Space and Astronautical Science)/**JAXA** (the Japan Aerospace Exploration Agency) **selected JASMINE for the 3rd Competitive Medium-class science satellite mission in May 2019, and the launch of JASMINE is scheduled tentatively for 2028 in Space Basic Plan, Cabinet Office, the Japanese government.**

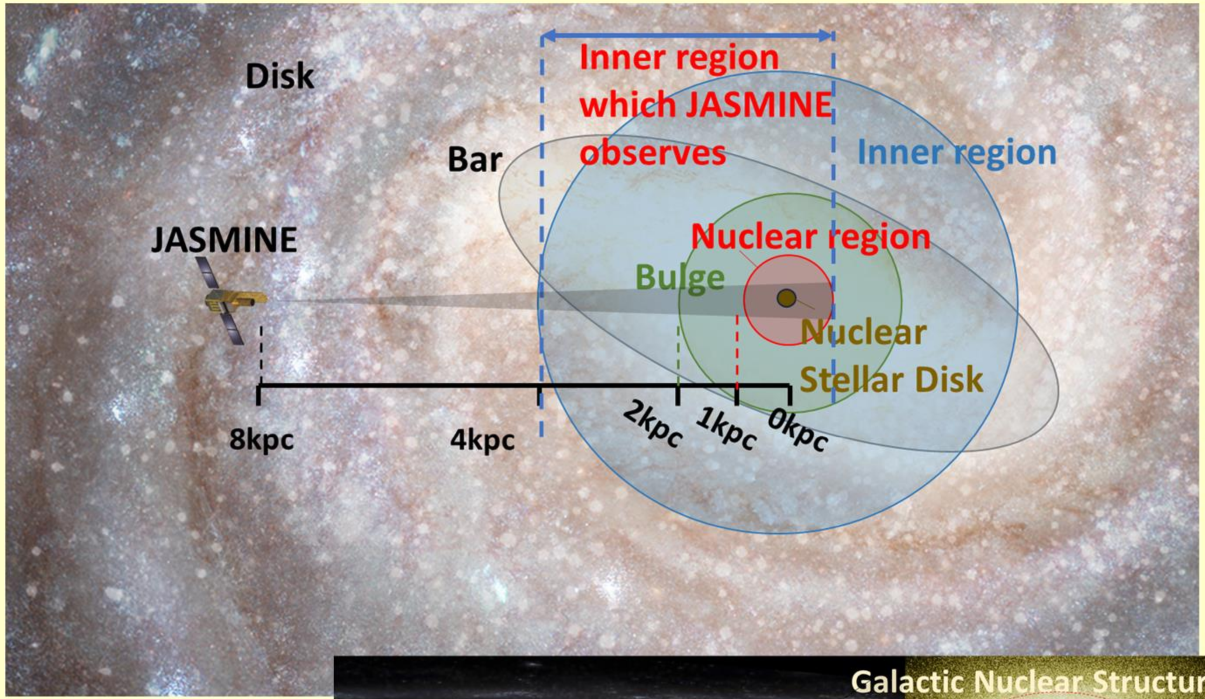
  ＊Some delay in the launch year is anticipated due to external factors such as schedule adjustment of satellite manufacturing companies.

- **We are promoting JASMINE with the aim of gradually improving the development stage at JAXA.**

- **JASMINE passed ISAS's MDR(Mission Definition Review) in July of this year and is going to Phase A study.**

3. Science Objectives of Astrometry in JASMINE

The target is the Galactic inner region along the Galactic plane around the center



★**Inner region:** Inside the radius of～4kpc along the Galactic plane from the center

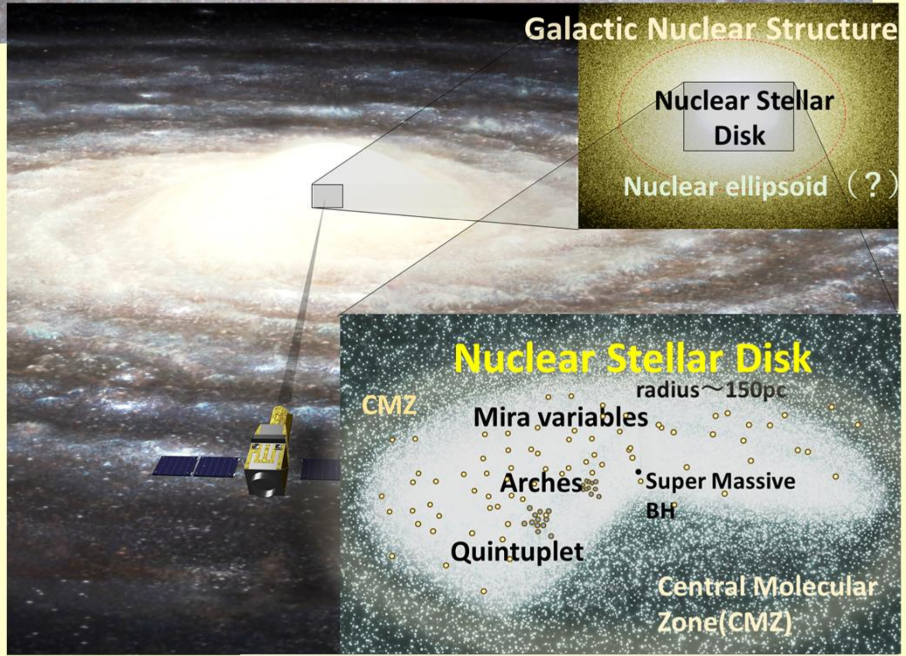
This region is hard for astrometric measurements in optical bands

1 Nuclear Region inside the radius of ＜～1kpc from the center

- Nuclear stellar disk
- Nuclear ellipsoid (classical bulge)(?)
- Nuclear star cluster

2 bulge/bar +long bar+ inner disk along the Galactic plane

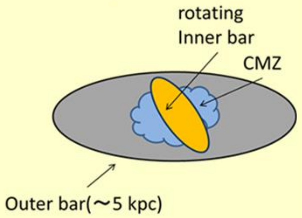
The range of the radius of ～1kpc＜r＜～4kpc from the center



There are many unknowns in the inner region, and it is an important region where a lot of important information is hidden for astronomy and astrophysics.

Our main science objectives:
A. Galactic center archeology & Galactic inner structures

(1) Clarification of the Galactic Nuclear Stellar Disk(NSD)



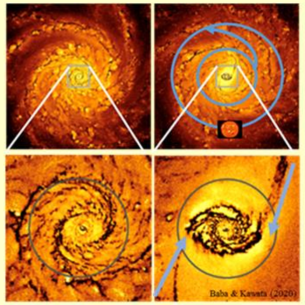
*orbit structures

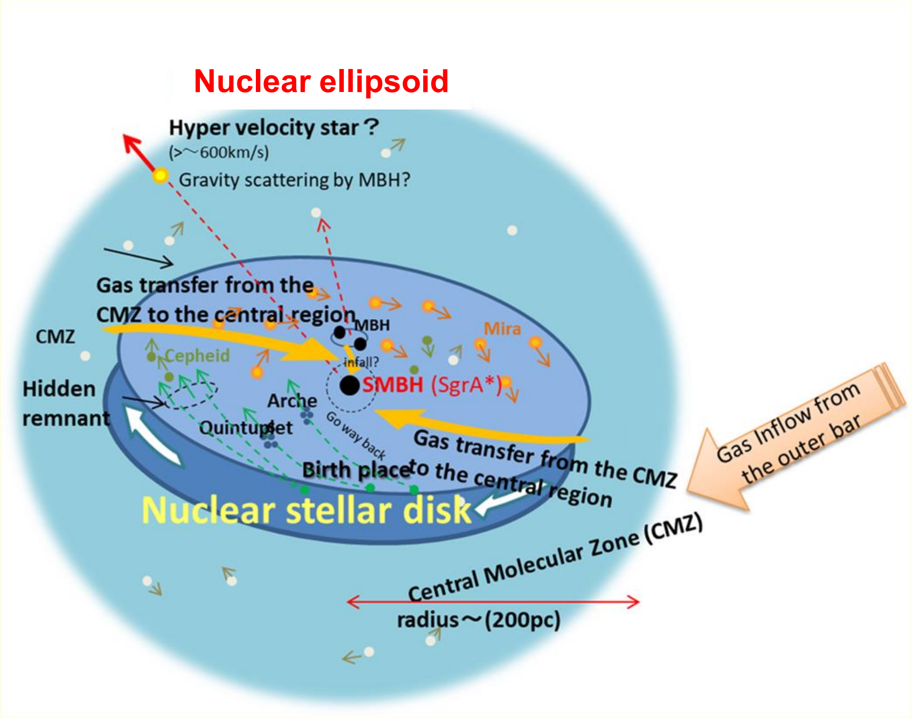
*the existence of an inner bar structure

➔growth of SMBH and activity around the Galactic center.

*formation epoch of NSD

➔formation epoch of the outer long bar





(2) Clarification of "the Nuclear Ellipsoid"

relic of the classical bulge!? or kinematical relic of infall of supermassive BHs?

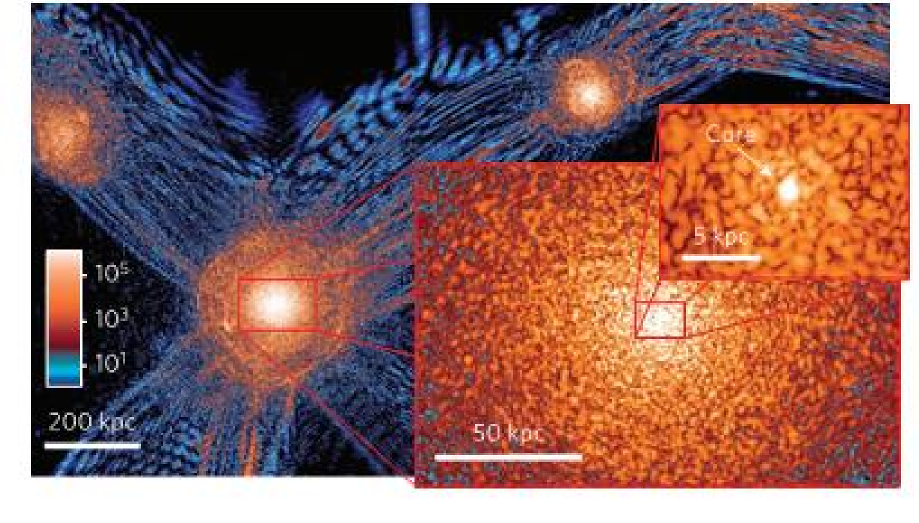
(3) Discovery of unknown star clusters in the inner region by detection of parallel movement of the stellar proper motion

(4) Dynamical structures along the Galactic plane in the region of ～1kpc＜r＜～4kpc

B. Physics hidden in the inner region
Hunt of:

(1) dark matters

DM on the inner disk/long bar ←**kinematic information**



Schive, et al. Nature Physics 2014

(2) Black Holes

- ＊ **Black Hole-star binaries** ←**orbital analysis of stars**
- ＊ **Intermediate Massive Black Holes** ←**gravitational lens effects**

(3) Orbital analysis of X-ray binaries ➔ **compact objects**

(4) Stellar physics, star formation, 3-dimensional distribution of inter-stellar dust

⋮

Please refer to JASMINE White Paper
(Kawata, D. et al.,
Publications of the Astronomical Society of Japan, Advance Access Pub Date: April 2024)

Publ. Astron. Soc. Japan (2023) 00(0), 1–50
doi: 10.1093/pasj/xxx000

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arXiv:2307.05666v1 [astro-ph.IM] 11 Jul 2023

JASMINE: Near-Infrared Astrometry and Time Series Photometry Science

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★Cooperation with other observation projects for the Galactic nuclear region

*Photometry+Astrometry: VVV, GALACTICNUCLEUS, Ultimate-Subaru, ROMAN,JWST, GREX+,GaiaNIR ,…
(for faint stars)

*Catalogue of Mira variables: PRIME

*Techniques: HiZ-GUNDUM

*Spectroscopy: Subaru-PFS, APOGEE-2,MOONS, Milky Way Mapper, …

*Observations with other wavelengths: JEDI, ALMA, SKA, ngVLA, …

Subaru-PFS (spectral observation) can measure the radial velocity (+metals) of all stars targeted by JASMINE before JASMINE's launch.

The stars targeted by JASMINE can have six-dimensional phase space information. They will be very unique and valuable information in the Galactic nuclear region.

Telescope/Instrument	Aperture of the primary mirror	Field of view [square degrees]	Number of the fibers	Observation wavelength range	Wavelength resolution ($\lambda/\Delta\lambda$)
Subaru/PFS	8.2 m	1.25	2,400	0.38-1.26	4300@<1.26μm

★Mission instruments

Optical design: Modified Korsch System with 3mirrors and two folding flats to fit the focal length

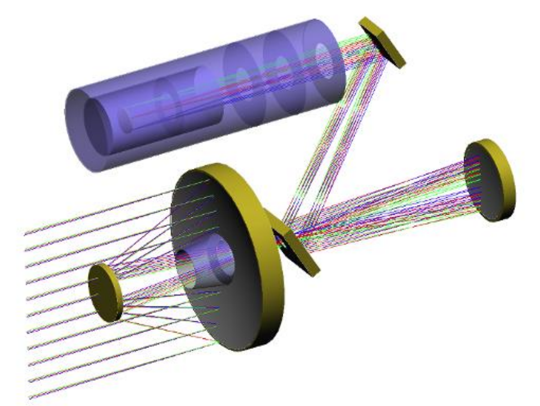
- **Aperture size: 0.36m**
- **Focal length: 4.37m**
- **Field of view: 0.55°× 0.55 °**
- **Detector: 4× domestic CMOS sensors**

T～278K

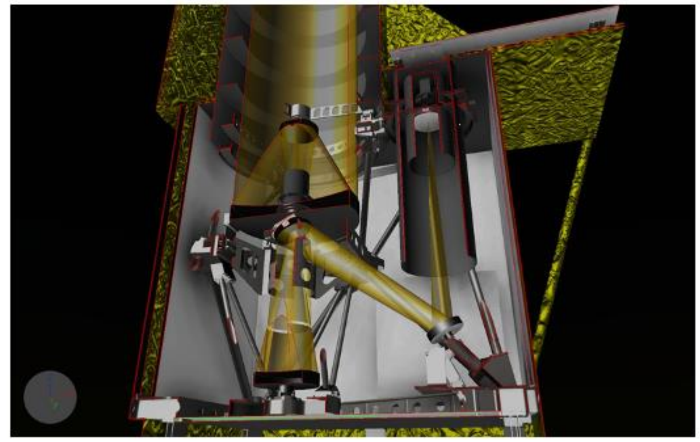
InGaAs (2k×2k)

Hw-band:1.0～1.6μm

operating temperature: <~173K



Preliminary optical design

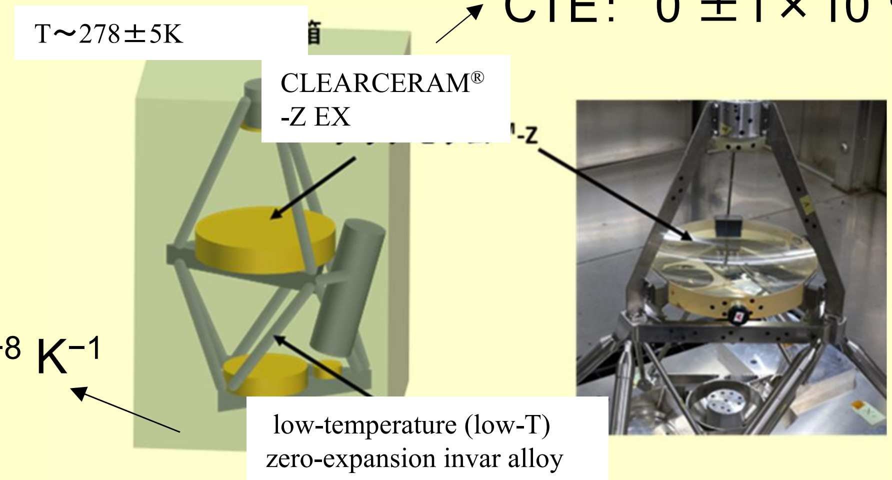


An example of schematic view of the payload layout

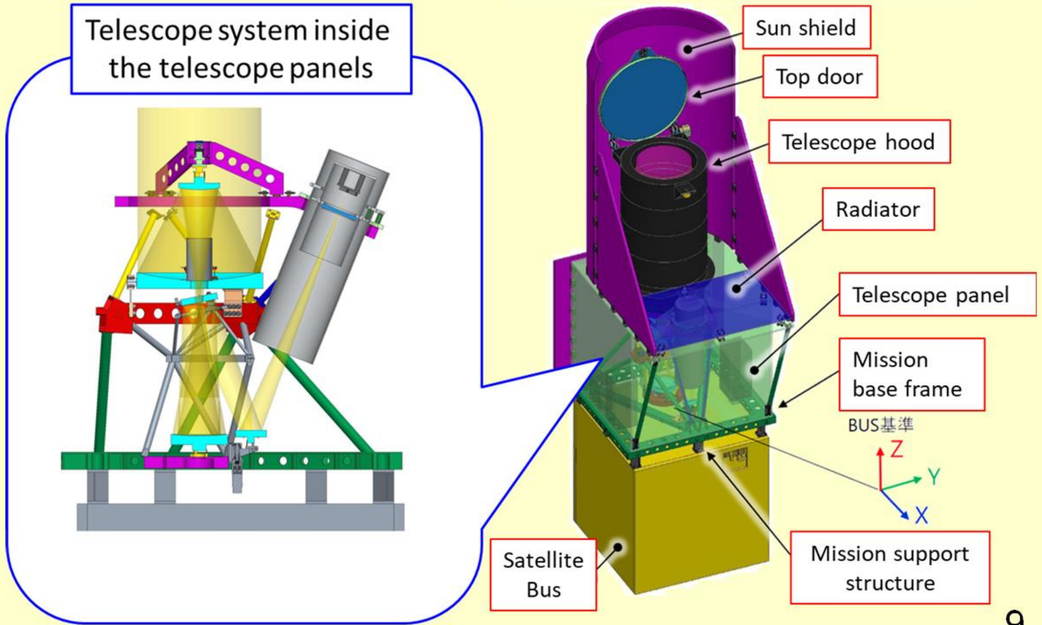
（Kawata et al.2024）

Telescope structure with little thermal structure time-variation

CTE： 0 ±1×10^{-8} K^{-1}



CTE：
0 ±5×10^{-8} K^{-1}

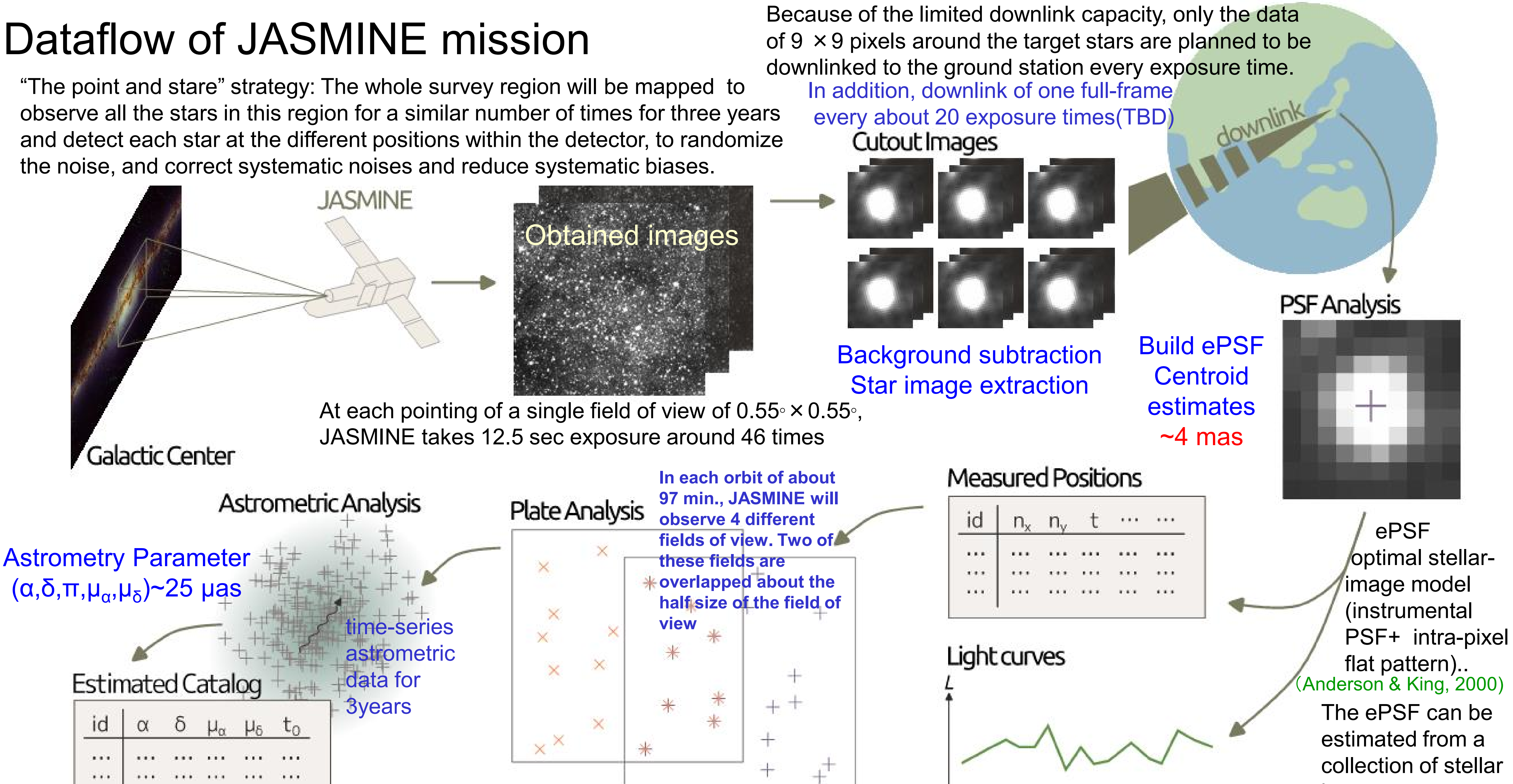


Dataflow of JASMINE mission

“The point and stare” strategy: The whole survey region will be mapped to observe all the stars in this region for a similar number of times for three years and detect each star at the different positions within the detector, to randomize the noise, and correct systematic noises and reduce systematic biases.

Because of the limited downlink capacity, only the data of 9 × 9 pixels around the target stars are planned to be downlinked to the ground station every exposure time.

In addition, downlink of one full-frame every about 20 exposure times(TBD)



Distortion correction, using stars in the overlapped frames and Gaia references. **Thermal structure stability!**

Main contributors: Ohsawa &kawata

JASMINE observation simulation software for feasibility evaluation of our data analysis method

End-to-End simulation (E2E)

Mock Catalogue, which compiles the near Infrared sources inside the JASMINE survey area (+α) already observed by other point source catalogues(VVV,SIRUS, 2MASS) in the literature. In addition, we add proper motions and distances from Gaia and a Galactic model.

Mock Catalog

id	α	δ	μ_α	μ_δ	t_0
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...

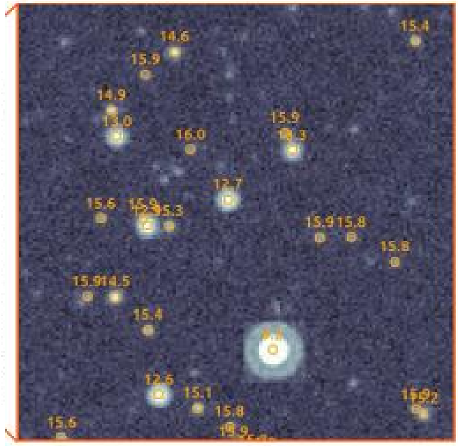
Observation Schedule

id	α	δ	θ	t	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...

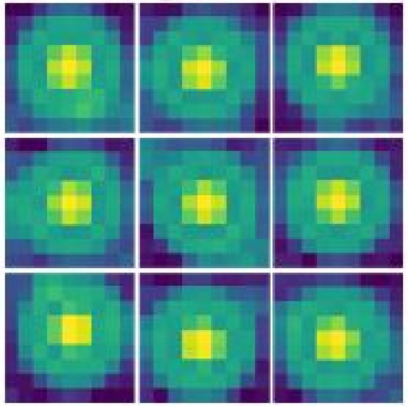
Imagesim

We develop an image simulation software which produces realistic observation images.

Simulated Images

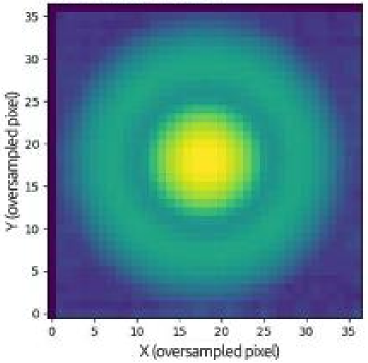


stellar images



. This software takes into account various factors such as the optical PSF, telescope jitter caused by the satellite's attitude control error, detector flat patterns, exposure timing differences between detector pixels, and various noise factors.

estimated ePSF



Measured Positions

id	n_x	n_y	t	...	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...

We confirmed that the center position can be estimated with high accuracy by applying one of the star image models, the ePSF method.

Light curves

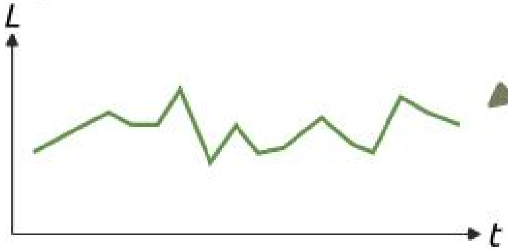
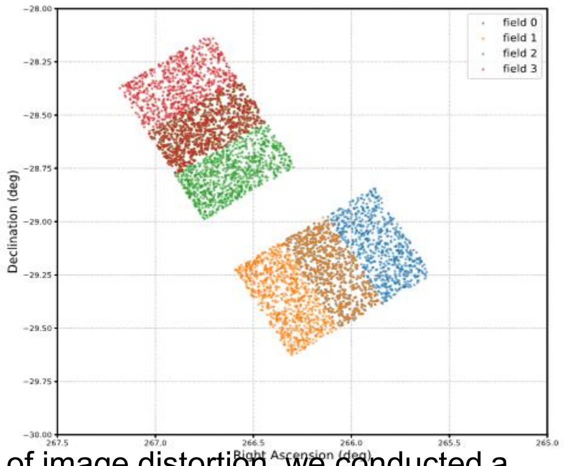
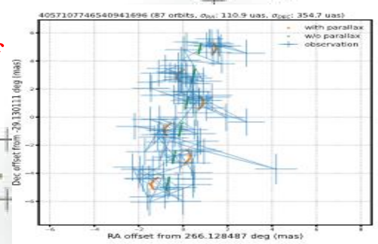


Plate Analysis



To verify analysis of image distortion, we conducted a mini-survey simulating observation data for 100 orbits.

Astrometric Analysis



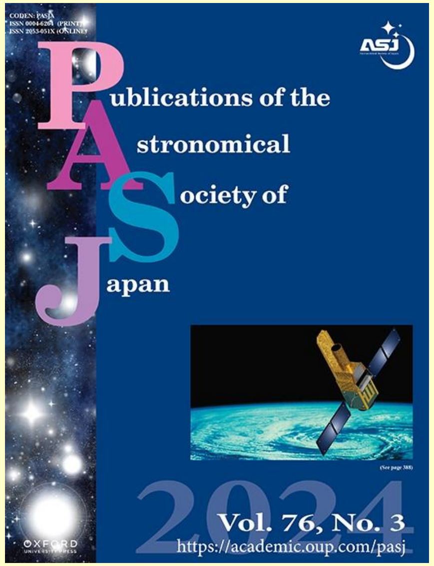
By using an appropriate reference star catalog, image distortion analysis could be performed self-consistently. The time series transition of the estimated coordinates reproduced the proper motions and annual parallaxes in the mini mock survey of JASMINE.

Estimated Catalog

id	α	δ	μ_α	μ_δ	t_0
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...

Main contributors: Ohsawa, kawata, Kamizuka, Kawahara, Ramos

5. International Collaboration



○ Investigations of scientific outputs to be expected by JASMINE
*We published the White Paper in PASJ by international collaboration

○ an ARI (Astronomisches Rechen-Institut) group at the Heidelberg University in Germany has already started on the collaboration of the data analysis of JASMINE. We have regular joint meetings.
Furthermore, a group at Technische Universität Dresden is considering the collaboration on the data analysis.

○Scientific cooperation with other observations for measurements of radial velocities, chemical compositions and photometry is very strong synergy for studies of the Galactic nuclear region.
e.g. APOGEE2, VVV, GALACTICNUCLEOUS, MWM, MOONS, Roman, JWST, ･･･

○ Collaboration in the downlink of scientific data
*ESA is now considering the support of ground stations for the down link of scientific data to be provided by JASMINE. ISAS/JAXA will start to negotiate with ESA.

JASMINE project is seeking for more bandwidth in foreign ground stations for download of scientific data.

This is required for improving overall scientific productivity of the mission for more frequent downloads of full-frames.

Jasmine

Thank you for your support!