31 August 2009, Heidelberg Milky Way conference

JASMINE projects:

Series of Infrared Space Astrometry Missions

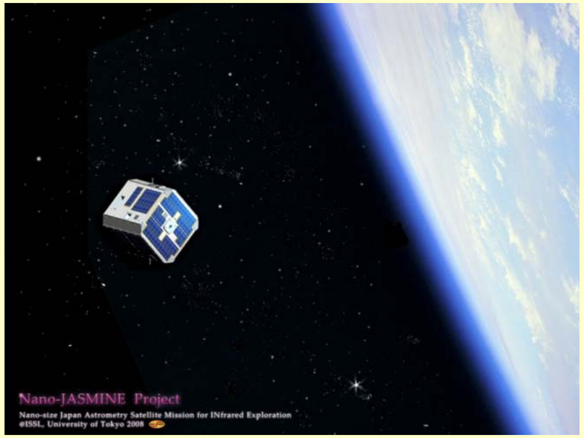
N.Gouda[1] and JASMINE Working Group

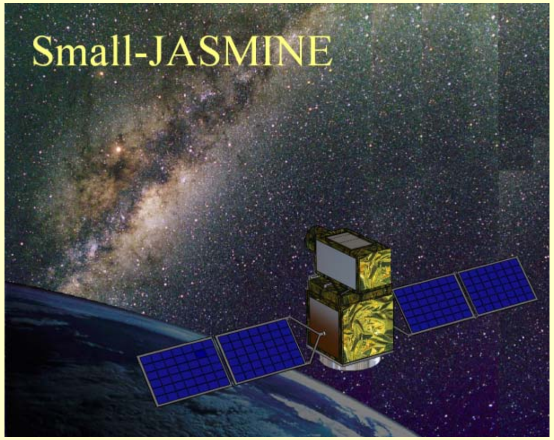
1:National Astronomical Observatory of Japan

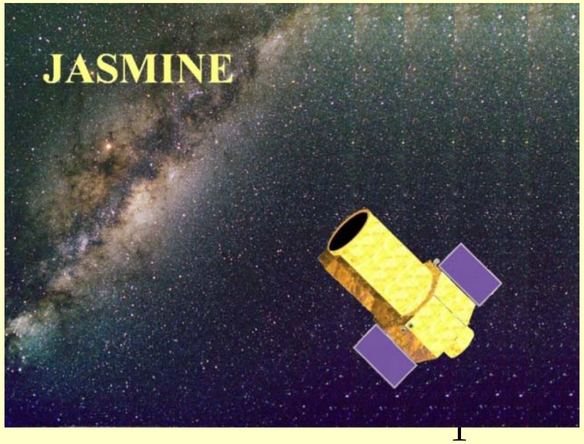
JASMINE

---Japan Astrometry Satellite Mission for INfrared Exploration---

Nano-JASMINE	Small-JASMINE	JASMINE







Space Astrometry Projects

Mission	Agency	Method	Launch	#of Stars	Mag.limit	Accuracy
Hipparcos	ESA	teles.	1989	120000	12	1mas@V=10
GAIA	ESA	teles.	2012	1 billion (all sky survey)	20	12-25μas@V=15
SIM-Lite	NASA	interf.	~2018 (?)	10000	20	4μas @ V=20
J-MAPS	USNO	teles.	~2012	ten millions (all sky survey)	14	1mas@I=12
Nano-JASMINE	NAOJ	teles	2010	1 million (all sky survey)	10	3mas@z=7.5
Small-JASMINE	NAOJ	teles.	~2015	several tens of thousands (bulge)	12 (Kw-band)	10μas@Kw=11
JASMINE	NAOJ	teles.	the first half of the 2020's	ten millions (bulge)	14 (Kw-band)	10μas@Kw=11

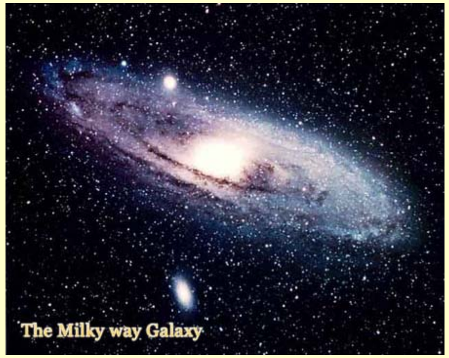
Remark: Infrared astrometry missions (Small-JASMINE and JASMINE) have advantage in observing stars in the Galactic bulge, hidden by interstellar dust in optical bands.

Hop: Nano-JASMINE launch date: the second half of 2010

very small nano-satellite: 25kg, 50^3cm^3

the diameter of a primary mirror: 5cm

the first space astrometry in Japan



Step: Small-JASMINE target launch date : ~2015

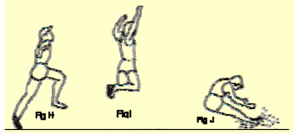
step -by-step approach to JASMINE for both science and techniques

the diameter of a primary mirror: 30cm

weight of a satellite: ~400kg

survey toward the restricted regions of the Galactic bulge

Jump: JASMINE target launch date: the first half of 2020’s



the diameter of a primary mirror: 80cm

weight of a satellite: ~1500kg

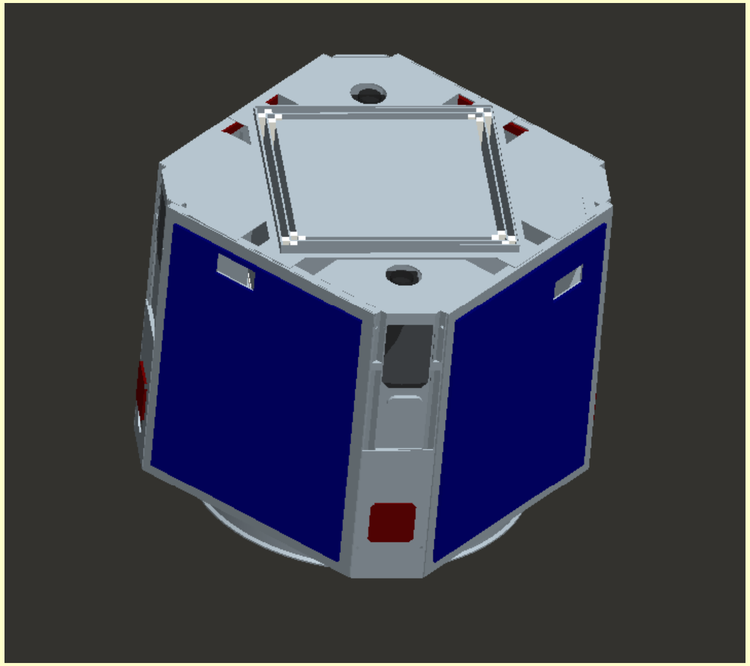
survey toward the whole region of the Galactic bulge

1 Nano-JASMINE

First space astrometry in Japan

use of a very small satellite (nano-satellite)

Nano-JASMINE satellite:



- size~50^3cm^3
- weight~25 kg
- 5cm diameter
  of a primary mirror with
  a focal length of ~1.67m
- Target accuracy of parallaxes:
  ~3mas at z=7.5mag, operation in z-band(~0.9 micron)
- Orbit: sun-synchronized orbit
- Observing strategy :Hipparcos and GAIA type

◎Objectives of Nano-JASMINE

*first demonstration of space astrometry in JAPAN
We can experience almost the same process from the preliminary design, development to the operation as that in a big satellite.

*Examinations of technical issues for Small-JASMINE and JASMINE

- on-board processing: stellar image extractor
- feed back of stellar images to attitude control

*To get proper motions with high accuracies combining a Nano-JASMINE catalogue with the Hipparcos catalogue

◎ Launch: the second half of 2010

Launcher:

*Cyclone4(Yuzhnoye: Ukraine)

Development of spacecraft bus system

↓

Prof.Nakasuka's laboratory at the University of Tokyo

Collaboration on N-J data analysis with GAIA data analysis team is ongoing.

Spaceport@Alcantara, Brazil

Please refer to Yamada's presentation

2. Small-JASMINE (tentative name) & (JASMINE)

Astrometric Measurement in Kw-band

(central wavelength: 2.0 μm, bandwidth: 1.0μm(1.5μm~2.5μm)

Infrared astrometry missions have advantage in surveying the Galactic bulge, hidden by interstellar dust in optical bands!

Accuracy:

parallax:

~10 μ as for Kw<11mag

proper motion:

~8 μ as/yr for Kw<11mag

(~4 μ as/yr for Kw<11mag)

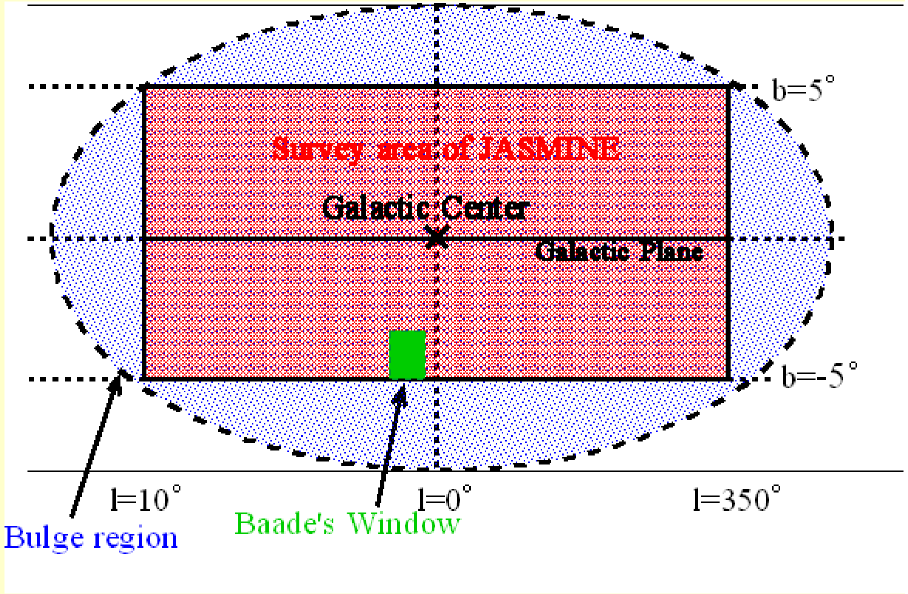
position:

~7 μ as for Kw<11mag

Survey Area:

3 regions, each having 1 square degree

(l=350 degree~10 degree, |b|<10 degree)



The Number of Objects:

about several tens of thousands in the Galactic bulge

(about ten million stars around the bulge)

Observing strategy : Frames –Link Method

The target launch date is around ~2015 (the first half of 2020's)

Mission life: ~2 years (~5years)

Orbits: sun synchronized orbit (L2-Lissajous, HCPO, etc.)

Launcher: solid rocket under development by JAXA

(H-IIA (dual launch))

Small JASMINE(& JASMINE)

⇩

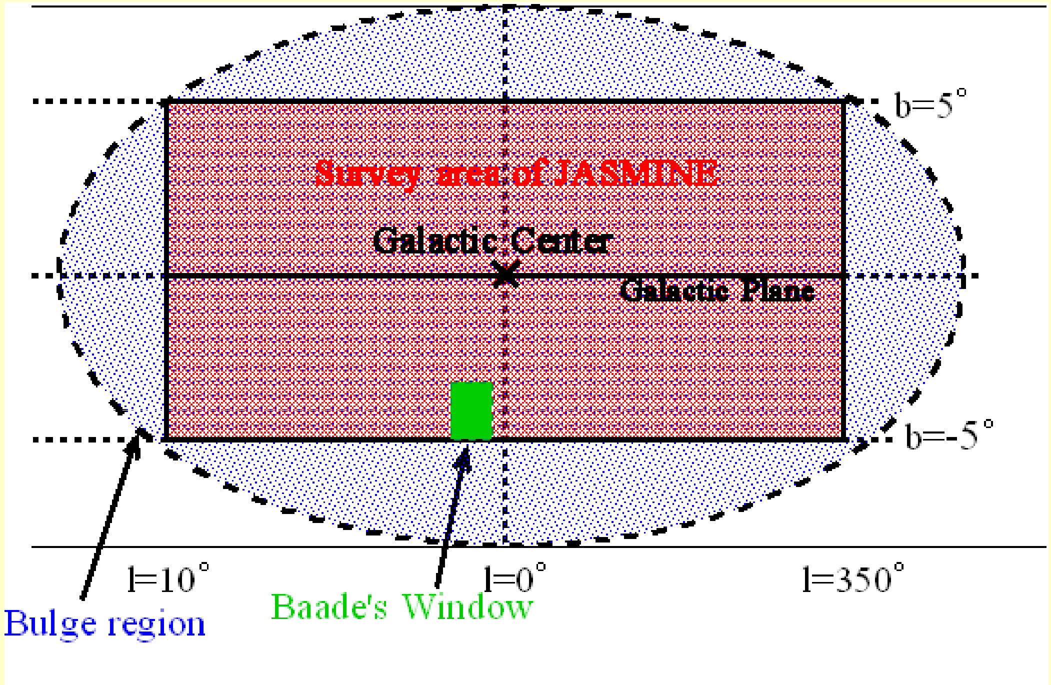
Development effort of NAOJ

with JAXA (Japan Aerospace eXploration Agency)

and universities in Japan

◎ Advantage of JASMINE, Small-JASMINE

Small-JASMINE and JASMINE are the unique space astrometric measurements in Kw-band to get the accurate astrometric data for many stars in the Galactic bulge.



JASMINE: ~a few 10^6 stars of the bulge in the survey area (with σ/π <0.1)

* GAIA: ~400 stars in the same area as that in JASMINE (with σ/π <0.1)

Small-JASMINE: ~ a few 10^4 stars of the bulge in its small survey area (with σ/π <0.1)

Scientific targets of Small-JASMINE and JASMINE

5-Dimensional data (distance(1D), position(2D), tangential velocity(2D))

in the phase space of the Galactic bulge stars

↓ +radial velocity, chemical composition

- Structure, Kinematics and Dynamics of the Galactic Bulge
- Stellar evolutions in the Bulge
- Dust information
- Gravitational lens effect caused by disk stars

Scientific Data provided by Small-JASMINE&JASMINE

Small-JASMINE (launch ~2015):

Parallax accuracy: 10 μ as(for Kw<11mag)

⟶ Distance accuracy: ~640pc @8kpc

Proper motion accuracy: ~8 μ as/yr(for Kw<11mag)

⟶ Tangential velocity accuracy: ~400m/s @8kpc

Survey area: 3 regions, each having 1 square degree

(places: TBD from scientific requirements)

~a few 10^4 stars

JASMINE(launch:~2022):

Parallax accuracy: 10 μ as(for Kw<11mag)

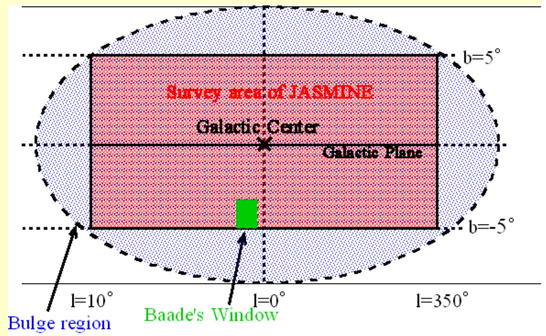
⟶ Distance accuracy: ~640pc @8kpc

Proper motion accuracy: ~8 μ as/yr(for Kw<11mag)

⟶ Tangential velocity accuracy: ~400m/s @8kpc

Survey area: 20 degree × 10 degree

~a few 10^6 stars



JASMINE is desirable….

Need of Small-JASMINE:

Earlier realization of infrared astrometry measurements in the Galactic bulge is required

(sufficient data of radial velocity and chemical components in the Galactic bulge are coming soon (BRAVA, APOGEE, …)

and GAIA data will be provided in around 2017)

* JASMINE: Getting budget and overcoming techniques ➔ long time

*Small-JASMINE: budget is not so expensive, technical requirements to the satellite system are not so severe

➔early realization may be possible as a step to JASMINE.

direct distance estimates and tangential velocities of many Galactic bulge stars with high accuracies first in the world!!

Scientific Targets of Small-JASMINE

◎ Structure, Kinematics of the Galactic Bulge and Co-evolution of the Supper Massive BH and the bulge

*galactic bulges=>key to study the galaxy formations and evolutions

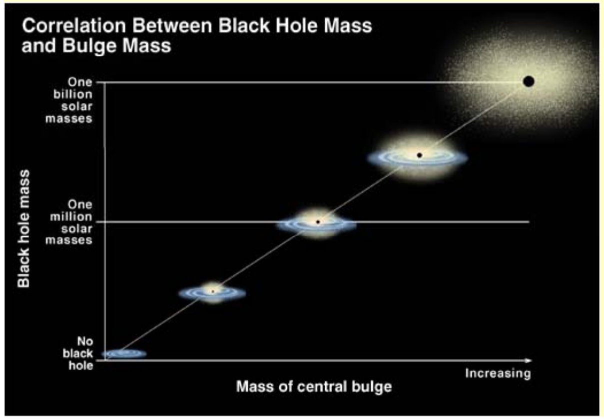
*the Growth of bulges➔ Evolution of the Hubble type

⬇

Supper massive BH at the galactic center➔ Activity of the galaxy

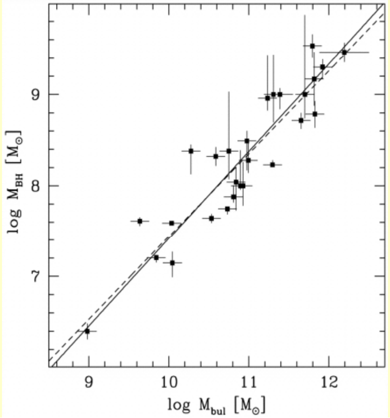
⬇

Co-evolutions of super massive BH s and bulges



Magorrian relation

(STScI/NASA)



(Marconi & Hunt 2003, ApJ, 589, L21)

Example 1:

The origin and evolution of the Galactic bulge

Two types of bulges

Similar to elliptical galaxies

origin：merging of galaxies

classical

pseudo

boxy/peanut-shaped

Disk-like profile

Origin：vertical bar instability

old population

Clarkson et al.(2008)

Howard, et al.(2009)

Our Galactic bulge

Star formations during long period

secular evolution owing to bar structures of bulges

Star Fomation History ← CMD (+chemical compositions)

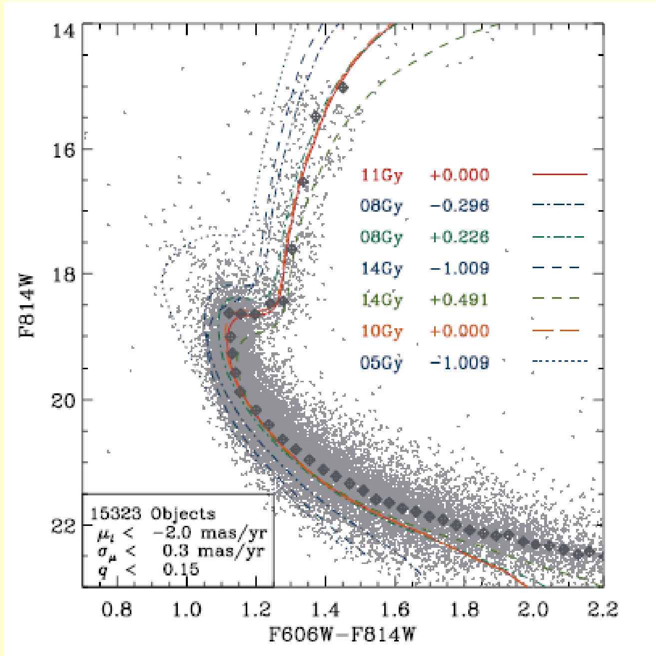
Separation between bulge stars and disk stars is a difficult task.

⇓

Accurate distances +3-D velocities of stars → necessary for discriminating bulge stars from disk stars

distance → Absolute magnitude

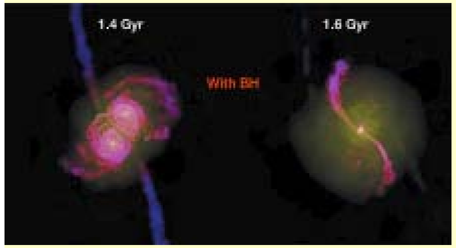
Sagittarius window



(Clarkson et al.(2008))

Remark: data of distances and 3-D velocities are very important.
Small-JASMINE can provide complementary data to radial velocity and chemical composition→ collaborations for further investigations

Determination of Structure Formation Model of the Galactic bulge by using kinematics of bulge stars



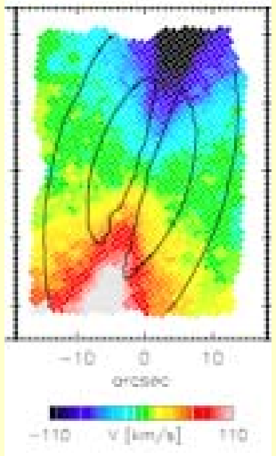
di Matteo + 2005

Gradient of rotation velocity along the vertical direction to the galactic plane

Merging vs. Bar instability

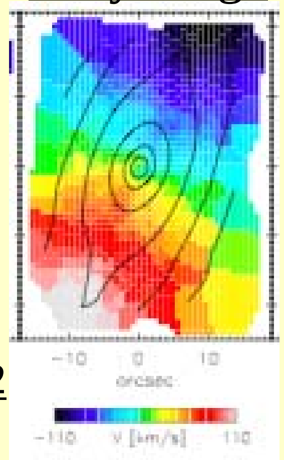
Sauron survey (Falcon-Barroso + 2004)

classical bulge

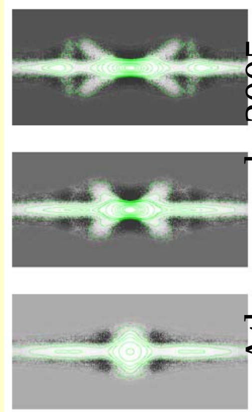


NGC 5866

boxy bulge



NGC 7332



Athanassoula 2005

cylindrical rotation

Constant rotation velocity along the vertical direction to the galactic plane

Howard, et al.(2009) ⟹ Cylindrical rotation of the Galactic bulge

Distance+ proper motion +radial velocity➔

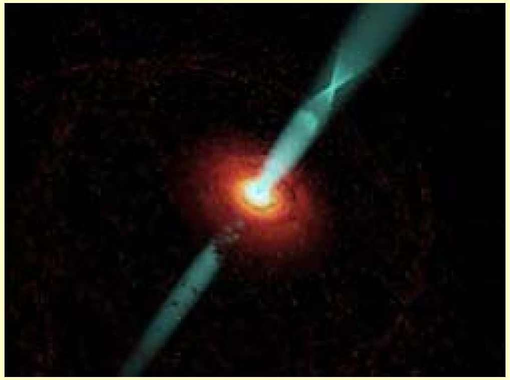
clarification of the origin of the Galactic bulge structure

Small-JASMINE can provide complementary data to radial velocity

➔ collaborations for further investigations

Example2:

Origin and evolution of the super massive black hole at the Galactic center



merging of small and/or medium BHs?

gas accretion?

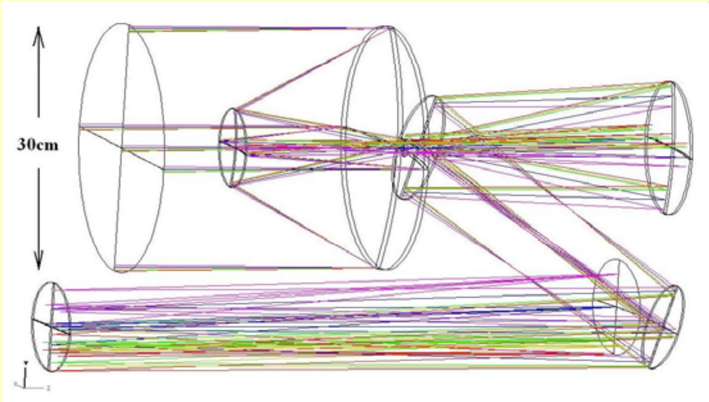
➔Information of the evolution is imprinted in 3-D velocity distribution along the radial direction around the Galactic center!

(Umemura: private communication)

We need your advices for scientific targets of Small-JASMINE and strong support for Small-JASMINE

Preliminary design of Small-JASMINE instrument

- Optics design: Modified Korsch System (3mirrors)
- Material: Synthetic Silica (a candidate)
- Aperture size: 0.3m
- Focal length: 4.9m
- Field of view: 0.87 degree × 0.87 degree
- Detector:



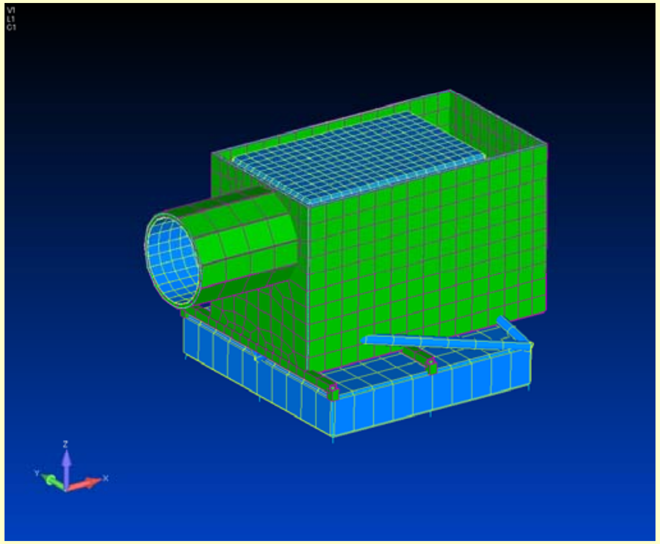
Kw-band: HgCdTe, Number of detectors: 4(2×2)

pixel size:18μm

the number of pixels:2048×2048

potential well:150,000

read-out noise :18e



Structure model of the mission system (JAXA)

3. Observing strategy and data reduction

3-1. Two types of observing strategy

HIPPARCOS, GAIA

Nano-JASMINE

Small-JASMINE, JASMINE

Astrometry (absolute parallax, proper motion)

All sky survey

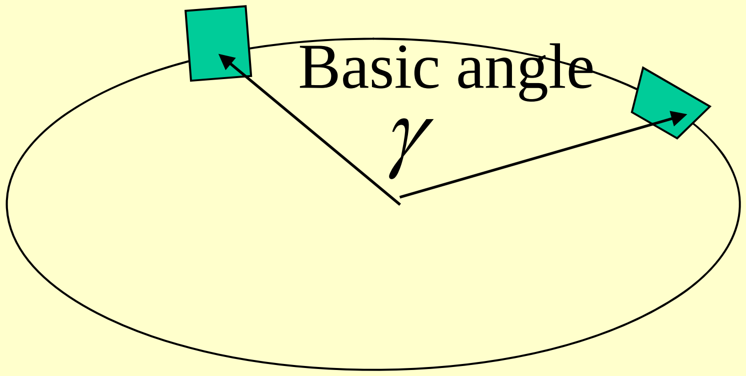
Partly a few stars

local survey (bulge)

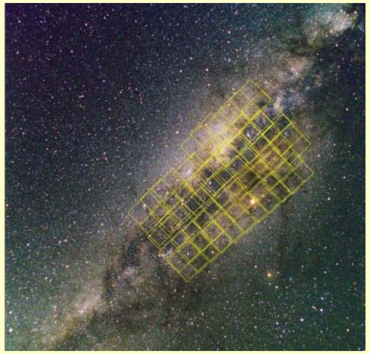
many stars anywhere + calibration

astronomical objects

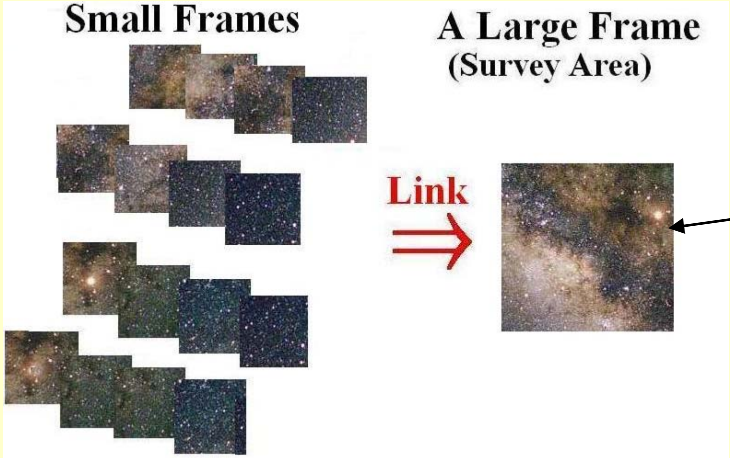
Frames-Link method

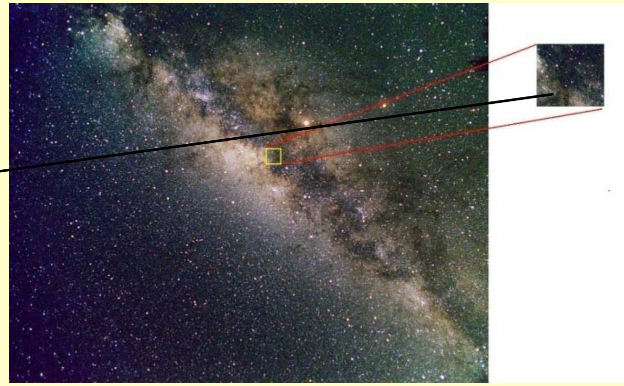


The whole survey region is composed by combining the small fields by using many stars in an overlap region between two consecutively observed adjacent small-fields. This method is applicable only to survey of the Galactic bulge because there is a sufficient number of stars to link small-fields with good accuracy.



3-2.Outline of Frames-Link method for Small-JASMINE





Survey area :

$1.7^{\circ} \times 1.7^{\circ}$

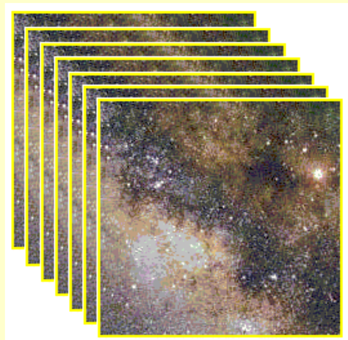
(which consists of 2 or 3 sub-areas) toward the Galactic bulge

Field of view: 0.9 degree × 0.9 degree

Stage 1: Stellar images on this field of view will be taken with an integration time of 3 seconds. 16 sets of stellar images exposed successively 16 times on a field of view is termed ``a small-frame''.

Stage 2: The telescope moves toward another adjacent field of view (small-frame) overlapping the previous small-frame (overlapping area is about a half of the frame). In about 20 minutes, the telescope takes the stellar images over the whole survey region, covering it by 16 small-frames.

Stage 3:We repeat the procedure at the stage 1 and 2 during the whole mission life and finally about 26,000 large- frames will be observed. Combining these large- frames allows determining the astrometric parameters using calibration stars whose astrometric parameters have been already determined accurately. Linear and annual variation of size, location, orientation, distortions of each large-frame can be fixed by calibration stars.

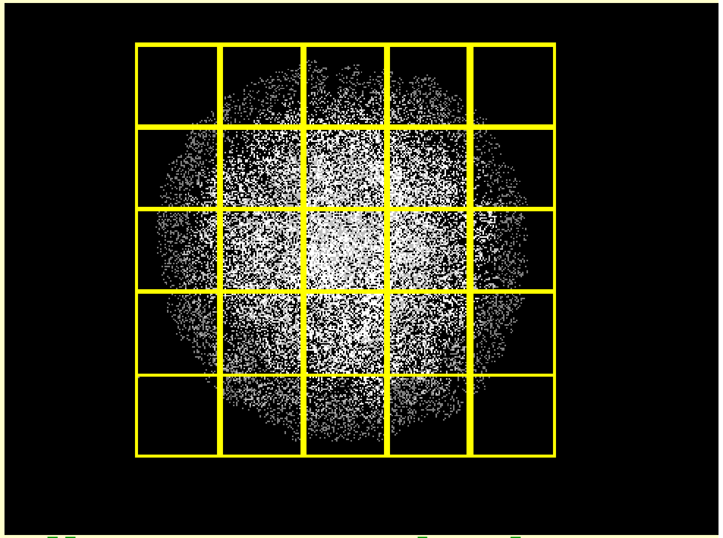


4. Critical error sources and requirements to a satellite system

(1) Random noise

e.g.

* photon number noise $\sigma \sim \lambda / \left(D\sqrt{N}\right)$



Stellar image on the detector

* linking of the small-frames

There is a sufficient number of stars in the overlapping region of two adjacent small-fields to decrease the errors

*smearing of stellar images due to fluctuations of the telescope pointing ⇨ stability of the telescope pointing

the specification of the size of the mirror, the size of the field of the view and the mission life is determined to attain ~7μas random errors of parallaxes at the final stage.

○Stability of the telescope pointing and the attitude control

Requirements:

○Pointing stability in the Small-JASMINE mission:

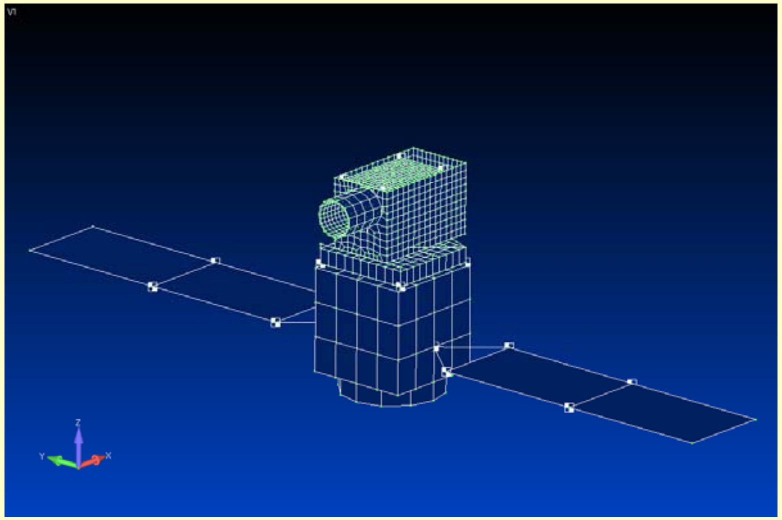
280 mas/3 sec ⟹ Tip Tilt Mirror

○Consumed Time for

Attitude Maneuver + relaxation to a state of rest: ~30 sec

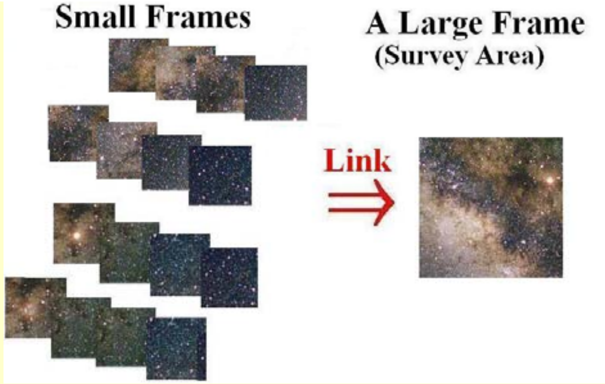
○ absolute pointing: ~0.1°

Engineers at JAXA are investigating detailed methods in real situations.



Structure model of
the Small-JASMINE satellite (JAXA)

(2) Systematic noise
At stage2:



Critical Systematic Error sources:

small-frames may have different sizes and distortions caused by the change of the telescope geometry according to temperature time variations

↓

This fact requires very small temperature variations around the telescope and also the small change of the telescope geometry

↓

Small-JASMINE :

Within ~10nm/20minutes variations of telescope geometry

↓

Ultra low expansion telescope, structure of the satellite achievable to highly stability of temperature around the telescope

○Thermal stability of instruments

Low CTE materials should be used for the mirrors and the strucuture of the telescope:

e.g. Synthetic Silica

CTE :~10^{-7}@180K

about 0.4K time-variations of temperature should be attained within around 20 minutes for Small-JASMINE.

Engineers at JAXA are investigating detailed methods in real situations.

Demonstration experiments are ongoing.

*There are other systematic noises, …..

Small-JASMINE and JASMINE (STEP➔JUMP)

Scientific data	Small-JASMINE	JASMINE
Annual Parallax accuracy (distance accuracy)	10 μ as(for Kw<11mag) (~640pc @8kpc)	10 μ as(for Kw<11mag) (~640pc @8kpc)
Proper motion accuracy (tangential velocity accuracy)	8μ as/yr(for Kw<11mag) (~400m/s @8kpc)	8μ as/yr(for Kw<11mag) (~400m/s @8kpc)
Survey area	~3 regions, each having 1 square degree	20 degree ×10 degree
Number of stars $(\sigma / \pi < 0.1)$	a few 10^4	a few 10^6

Techniques	Small-JASMINE	JASMINE
Diameter of the primary mirror	**30cm**	**80cm**
Orbit	**Sun synchronized**	**L2-Lissajous**
Pointing stability	**280mas/3sec**	**100mas/2.2sec**
Thermal stability	**0.4K/20 minutes**	**4mK/10 hours**

5 Management and Schedule

- JASMINE project office at NAOJ 2004.4~
- JASMINE working group at JAXA 2008.3~
- Small-JASMINE working group at JAXA 2009.1~
- Launch of Nano-JASMINE 2010
  (data release ~2012)
- Proposal of Small-JASMINE mission to JAXA
  ~2010(target)
- Launch of Small-JASMINE ~2015(target)
- Operation ~2 years
- Data release ~2018(target)
- Target Launch of JASMINE ~(2020 ~2024)

Jasmine

We would like to ask you for your continuous cooperation and encouragement