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JASMINE: Japan Astrometry Satellite Mission for INfrared Exploration

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Abstract. We introduce a Japanese plan for infrared (z-band: 0.9 μm) space astrometry (the JASMINE-project). It will measure parallaxes, positions with the accuracy of 10 μas and proper motions with the accuracy of 10 μas/yr for stars brighter than z$\sim$14. JASMINE can observe about 10^8 stars belonging to the disk and bulge components of our Galaxy which are hidden by interstellar dust extinction in optical bands. The number of stars with $\sigma_\pi/\pi < 0.1$ in the direction of the Galactic central bulge is about 10^3 times larger than those observed in optical bands, where π is a parallax and σ_π is an error of the parallax. The main objective of JASMINE is to provide very useful and important astrometric parameters for studying fundamental structures and evolution of the disk and bulge components of the Milky Way Galaxy. Furthermore, the astrometric parameters given by JASMINE will give us exact absolute luminosities and motions of many stars in the bulge and the disk far away from us, so it will promote the study of stellar physics. The information of infrared astrometry that JASMINE will provide is very useful also for investigating stars in star formation regions, gravitational lens effects due to disk stars, extra-solar planets, etc. JASMINE will be launched around 2014 and a candidate for the orbit is a Lissajous orbit around the Sun-Earth L2 point with about a 5-yr mission life. We adopt a 3-mirror optical system (modified Korsch system) with a primary mirror of $\sim$1.5-m diameter in an instrument design of JASMINE. A beam combiner should be used for performance of the global astrometry as used in the Hipparcos satellite. On the astro-focal plane, we put about 100 new-type CCDs for the z-band in which TDI mode (drift scan mode) can be operated. The effective field of view is 0.23 square degrees. The consideration of overall system (bus) design is now going on in cooperation with the Japan Aerospace Exploration Agency (JAXA). Furthermore, we introduce the Nano-JASMINE project which uses a nano-satellite with a size of about 20 cm^3 and a weight of a few kg. The objective of Nano-JASMINE is verification of the observing strategy adopted in JASMINE and examination of some important technical issues for the JASMINE project. It will be launched around 2006.

1. Introduction

Astrometric measurements provide the most fundamental parameters of stars such as the absolute trigonometric parallaxes (i.e. distance), positions on the celestial sphere

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and proper motions, which are the backbone in many branches of astronomy and astrophysics. So the improvement of astrometric parameters enables advances across numerous branches of astronomy and astrophysics. The Hipparcos satellite was launched to measure the astrometric parameters without certain limitations (atmospheric turbulence and refraction, etc.) in the ground-based measurements. Hipparcos provided remarkably interesting results in many fields of astronomy.

The success of Hipparcos has triggered several proposals for astrometric satellites that would observe more stars with better accuracies than those in Hipparcos. We need better astrometry because a drastic increase in the accuracy and the number of parallaxes and proper motions will result in remarkable advances in kinematics and dynamics of the Galaxy and furthermore in fields of stellar evolution, extra-solar planets and the extragalactic distance scale.

If we have parallaxes with errors larger than about 10%, we would have some biases in deriving distances by the parallaxes and so we could not determine the distances with enough accuracy. The accuracy of the parallaxes in Hipparcos is about 1 mas, thus we cannot accurately evaluate the distances of the stars which are about 100 pc or more distant from us using the parallaxes given by Hipparcos. But we require the accurate distances of stars which are at least around 10 kpc distant from us in order to investigate the bulge component and almost the inner disk structure of the Galaxy. Hence we need a level of 10 μas accuracy in parallax. Proposed astrometric satellites perform astrometric measurement with this level of accuracy.

The proposed space projects of optical astrometry are Gaia and SIM. Gaia is a survey type astrometric mission for all-sky survey, which is proposed by ESA. Gaia aims at measuring positions and parallaxes accurate to 10 μas at $V = 15$ with proper motion errors 10 μas/yr. The limiting magnitude is $V = 20$. SIM is a NASA's mission using optical interferometer with a 10-m baseline. SIM is not a sky-scanning, but rather a pointing instrument which is set on selected targets of about 10^4 stars brighter than $V = 20$. SIM has the capability to measure absolute parallaxes accurate to 4 μas. It should be noted that both Gaia and SIM observe stars in optical bands. In Japan we have two projects which perform the global astrometry. Those are VERA and JASMINE which measure astrometric parameters in radio and infrared bands, respectively. They have advantages in observing stars on the Galactic plane which are hidden by the interstellar dust in optical bands. VERA is a VLBI system dedicated to differential VLBI to measure the astrometric parameters of about 1000 masers with 10 μas level accuracy. VERA will achieve the targeted accuracy of the parallax only in a few years and determine accurately some fundamental parameters of the Galaxy such as the distance to the Galactic center.

JASMINE is an infrared (z-band: 0.9 μm) astrometric mission designed to perform an astrometric survey on the Galactic plane, determining positions and parallaxes accurate to 10 μas for stars brighter than z= 14, with proper motion errors of $\sim$10 μas/yr. JASMINE will observe about 10^8 stars around the bulge and the disk of the Galaxy; VERA does not observe stars themselves but maser sources and the number of targets is only 1000. We expect that JASMINE will extend the area of studies on Galactic structure and stellar populations after the success of VERA.

In this paper, we introduce the outline of the JASMINE project. §2 is devoted to the scientific objectives of JASMINE. We briefly review a mission design, an instrument design and a spacecraft system in §3, §4 and §5, respectively. In §6 a management plan of JASMINE is briefly mentioned. Finally, §7 is a summary.

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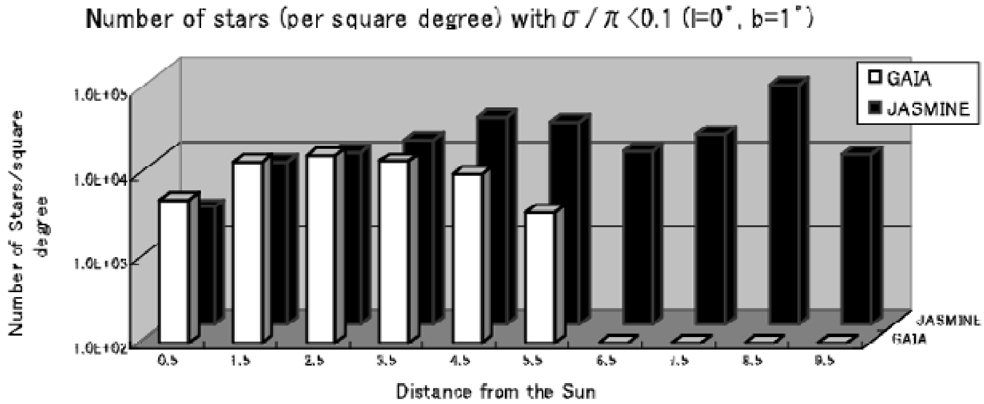

Figure 1. Number of stars (per square degree) measured with $\sigma/\pi \leqslant 0.1$ toward the direction of $\ell = 0°$ and $b = 1°$.

2. Scientific objectives

As mentioned in §1, JASMINE will provide the astrometric parameters to promote studies in many branches of astronomy and astrophysics. One of the most important scientific objectives among them is the formation, evolution and structure of the Milky Way Galaxy. The quantitative analysis of the Galaxy needs distances, 2-dimensional (or even better, 3-dimensional) motions of stars in the Galaxy. Especially, most of the stars, and almost all of the interesting dynamics, are found at low Galactic latitudes in crowded fields. So there is a great requirement to measure accurate astrometric parameters of stars in the fields at low Galactic latitudes. On the other hand, the light in optical bands from the stars at low Galactic latitudes is effectively absorbed by interstellar dust. This extinction effect decreases both the number of observable stars and the accuracy of the astrometric parameters. So we need to survey the Galactic plane to measure the astrometric parameters in near infrared bands which penetrate the obscuring dust. Then, at first, we will explain the necessity of infrared astrometry based on the quantitative analysis using a Galaxy model. After that, we will mention a few important topics of science which can be expected to make remarkable progress by JASMINE.

2.1. *Advantages of infrared astrometry*

JASMINE performs unique astrometric measurements in the infrared band (z-band: $0.9\,\mu$m) in order to get the accurate astrometric parameters of many stars on the Galactic plane. The galactic bulge is an important scientific target as explained in §2.2. Then we focus on the galactic central bulge as an example for showing an advantage of infrared astrometry. Interstellar dust effectively absorbs visible light and a large amount of dust is located in the direction of the galactic bulge. However, there are a few windows where the amount of dust is rather smaller than that in other central regions, so we can observe many stars through those windows. A famous window is Baade's window ($\ell = 0°, b = -3.9°$) with an area of $\sim$1 square degree. Gaia will detect about 8000 stars with parallax accuracies of $\sigma/\pi \leqslant 0.1$ (Vallenari et al. 1999). Here π is the parallax of a star and σ the error of that parallax. If $\sigma/\pi \leqslant 0.1$, then we do not need worry about errors due to biases which arise in converting parallaxes to distances. However, Gaia will not detect a large number of stars with such good parallax accuracies toward directions other then the central bulge.

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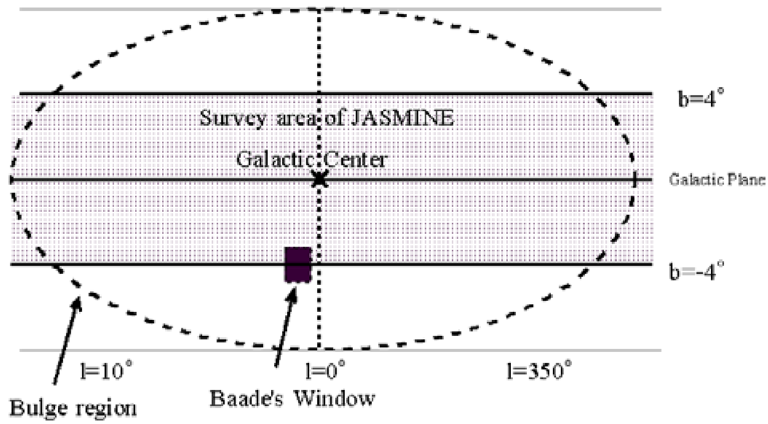

Figure 2. Survey area of JASMINE around the bulge and Baade's window.

For example, Fig. 1 shows the expected numbers of stars per square degree to be observed with $\sigma/\pi \leqslant 0.1$, estimated using our Galactic model. This model is based on the "sky" model developed by Cohen and his collaborators (Wainscoat et al. 1992; Cohen 1994; Cohen, Sasseen & Bowyer 1994; Cohen 1995). The center of the field of view is pointed toward Galactic longitude $\ell = 0°$ and Galactic latitude $b = 1°$. The horizontal line represents the distance from us. The Galactic center is assumed to be at 8.5 kpc. The black histogram shows the number of the stars evaluated for z-band observations of JASMINE while the white histogram shows those for V-band observations with parallax accuracies (e.g. 10 μas accuracy at $V = 15$) of Gaia design. We can see from Fig. 2 that the number of stars observed in the z-band is much larger than that observed in the V-band at distances of more than a few kpc from the sun on the Galactic plane. JASMINE can detect about 7.3×10^5 stars of the bulge within its survey area ($|b| \leqslant 4.0°, \ell = 0° - 360°$), while Gaia will detect about 400 stars of the bulge in the same area, excluding Baade's window. Then JASMINE will measure the distances and proper motions of many stars of the central bulge with high accuracies over the large survey area within the inner parts of the bulge at lower galactic latitudes than the latitude of Baade's window (see Fig. 2). This is the most important advantage of infrared space astrometry. We hope that JASMINE can be complementary to Gaia for the survey of the bulge.

We think that some may worry about the confusion limit. That is, that we cannot accurately determine the position of stars fainter than the confusion limiting magnitude due to contamination in crowded regions. We estimated the confusion limit magnitude in the survey area of JASMINE using our Galactic model and found that the minimum magnitude of the confusion limit, which is achieved around the center of the Galaxy, is z= 18. This value is above the limiting magnitude of JASMINE (∼17), so we need not worry about confusion in JASMINE.

2.2. *Structure, formation and evolution of the Galaxy*

Dynamical analysis, derived primarily from accurate distances and kinematics data is the key to understand the structure, formation and evolution of the Galaxy. The Galaxy is believed to be representative of the giant spiral galaxies which dominate the luminosity of the Universe. Then a well studied template in the Galaxy underpins analysis of unresolved galaxies.

The proper motions and distances obtained by JASMINE will give the distribution of matter, high-luminosity and dark, in the bulge and disk of the Galaxy. We will have

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an accurate 3-dimensional map of significant portions of the Galaxy to understand the structure. Size, shape and kinematic properties of the different components of the Galaxy such as the bulge, spiral arms, thin and thick disk, and warp are pending problems in the Galaxy. These problems will be resolved by JASMINE. For example, the formation, evolution and dynamics of the bulge is an unresolved interesting problem. JASMINE will provide important information on distances and transverse motions of stellar populations in the bulge to resolve the problem using other information on radial velocities, metallicities and ages of the stars given by other facilities.

Many questions about shape, dynamical structure and formation history of the galactic bulge still remain open. For example, the shape of the bulge is still not clear while there is substantial evidence for a bar structure. Several models for the density distribution in the bulge have been proposed over the years from spherical to triaxial systems. So to know exact distances of stars in the bulge is the key to clarify the shape of the bulge. Furthermore, investigation of the dynamics in the bulge derived from distances and kinematics is the key not only to resolve the formation and evolution of the bulge, but also to study the dynamical structure such as the character of the steady state mechanism of relaxation process in self-gravitating, many-body systems.

The origin of spiral arms is also an interesting problem. We can determine whether spiral arms are due to density waves, or not, using our analysis technique (Yano, Chiba & Gouda 2002) with JASMINE data. This technique is based on the kinematic analysis of the Galactic disk stars to clarify whether the internal motions of the stellar system in spiral arms follow those expected in the density wave theory. The method uses the linear relation between the phases of spatial positions and those of epicyclic motions of stars, as predicted by the theory.

As mentioned before, the Galaxy is believed to be typical of the mean population in the universe. So detailed analysis of the Galaxy can contribute to the general study of galaxy formation and evolution in the early universe. That is, the Galaxy should retain a fairly direct fossil record of the conditions at the time of Galaxy formation in the early universe. Information such as 3-dimensional positions and motions, and absolute luminosities of stars is necessary to resolve the structure and evolution of the Galaxy. The astrometric parameters of many stars in the bulge and the disk obtained by JASMINE give information on Galactic formation. On the other hand, Gaia will accurately provide the structure of the halo and the disk within a few kpc from us. Then JASMINE can be complementary to Gaia.

2.3. *Stellar evolution*

All the models of internal structure of stars are very strongly constrained by models built for the Sun. But the characteristics of the stars especially in the Galactic bulge are not known well. The extension to other types of stars would demand more accurate information on the characteristics of many different types of stars. This requires accurate distances of stars in the bulge and JASMINE will provide those. The extensive amount of data of extreme accuracy given by JASMINE will stimulate a revolution in the exploration of stellar formation for many types of stars crowded at the Galactic plane. Furthermore, exact luminosities calibrated by accurate trigonometric parallaxes are based on the distance indicator.

2.4. *Gravitational lensing effect*

The gravitational lensing effect causes the luminosity of a star to change with time. In fact, this phenomenon has been observed in the Galaxy by the MACHO project on disk stars. But information about a lens is restricted because mass, motion of the lens, the

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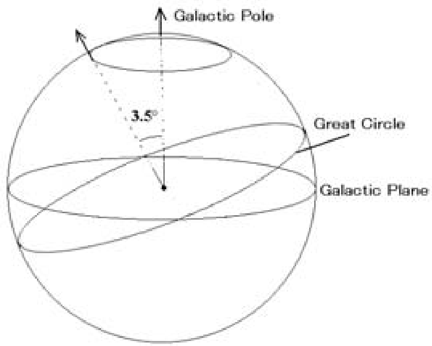

Figure 3. The spin axis of the JASMINE spacecraft is aligned 3.5° from the Galactic pole – the spacecraft line with a rotation period of about 5 hr.

distance to the lensed star, and the position of the lens on the celestial sphere cannot be separately resolved only using the light curve of the lens. On the other hand, the lensing effect results in a elliptical motion of the lensed star. Highly accurate astrometry can measure this motion and this information can resolve the degeneracy of the characteristics of the lens, such as mass. JASMINE will observe a large number of stars in the Galactic plane. The fraction of lensing events is about 10^{-3}, so about 10^4 lensing events might be expected in JASMINE. The information will be useful to resolve the mass and kinematics of lensing objects.

2.5. *Extra-solar planets*

Astrometric measurement of a star allow the detection of extra-solar planets due to nonlinear motion of the star with planets and is complementary to radial velocity measurement of the star. JASMINE might detect extra-solar planets of stars covered by a dust layer or bright stars in the z-band.

2.6. *Reference frame*

JASMINE will provide positions and proper motions with high accuracies in the z-band. The combination of JASMINE data with other data observed by Gaia and radio catalogues will result in an accurate reference frame in the z-band. This reference frame will be a useful catalogue for many purposes in astronomy.

2.7. *Other scientific objectives*

The data of JASMINE will promote some other important investigations on stellar physics of binary stars, variable stars and novae. Moreover, we can test general relativity using measurements of the gravitational lensing effect with high accuracies.

3. Mission design

3.1. *Observing strategy*

A possible candidate for the orbit of JASMINE is a Lissajous orbit around the Sun-Earth Lagrange point L2, because this region provides a very stable thermal environment, amongst other advantages. The JASMINE spacecraft rotates slowly with a period of about 5 hr with a perpendicular rotation axis to look in the directions of two fields of view. The CCDs in the telescope focal plane are clocked in time-delayed integration (TDI) mode so that the accumulated charge packets track star images as they sweep across the

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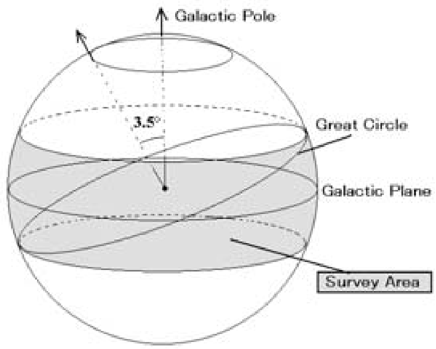

Figure 4. The JASMINE spacecraft precesses around the Galactic pole with a period of about 37 d and the sky area around the Galactic plane is scanned with this precession.

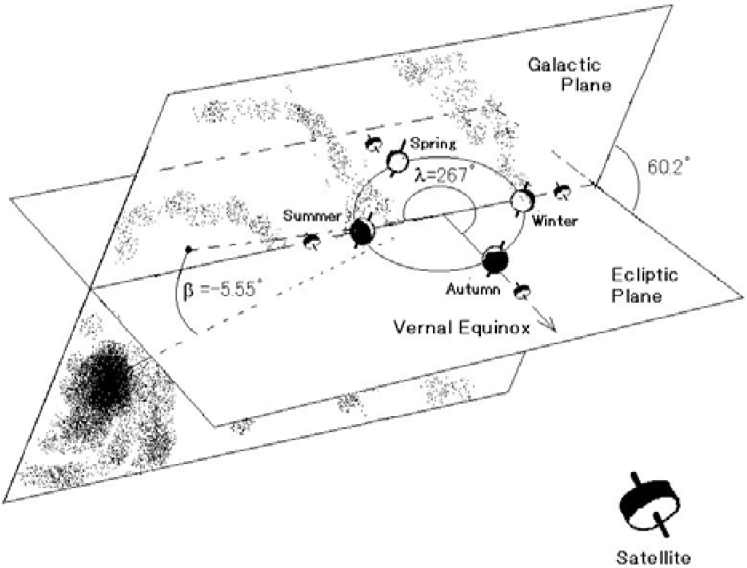

Figure 5. The Galactic plane and the Ecliptic plane.

CCD. TDI mode makes it possible to decrease the effect of readout noises on the signal of star images. The rotation axis of the JASMINE spacecraft will be aligned 3.5° from the spacecraft – Galactic pole line as shown in Fig. 3. The precession of the JASMINE spacecraft will be forced and JASMINE can survey the Galactic plane with a region of 360° (along Galactic longitude)×7° (along the Galactic latitude) with a precession period of about 37 d as shown in Fig. 4. The mission life will be 5 yr.

As seen from Fig. 5, the direction toward the sun from the spacecraft overlaps with that of the Milky Way in two quarters of a year (summer and winter seasons). In these seasons, the spin axis of the JASMINE spacecraft is changed to be almost perpendicular to the Galactic pole – spacecraft line and then JASMINE observes toward the Halo regions instead of the Milky Way. The observing mode for the Milky Way is then restricted to a half of the total mission life.

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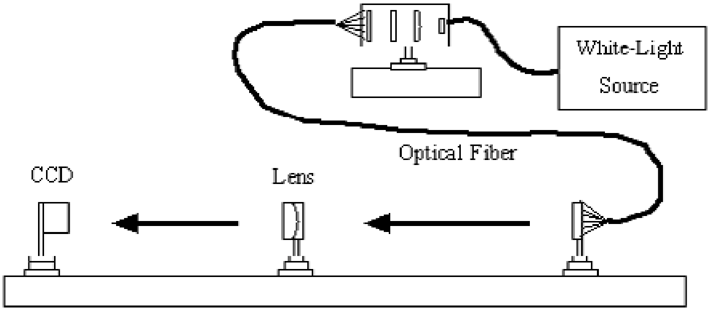

Figure 6. Centroiding Experiment Layout

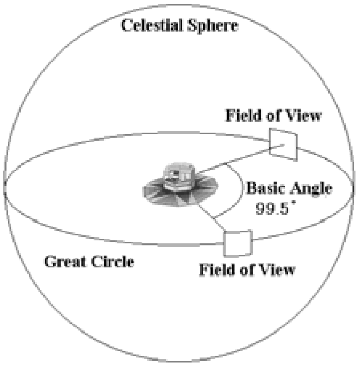

Figure 7. The two fields of view are perpendicular to the rotation axis and are separated by a 99.°5 basic angle.

3.2. *Astrometric data reduction*

The data analysis for JASMINE will proceed as follows:

(i) A star image is sampled in a binned window with 5 pixels (along the scan direction) $\times$ 9 pixels (along the cross-scan direction). The centroid of the star image in the scan direction is required to reach an accuracy of about 1/140 pixel for JASMINE. We perform the measurements of centroids using our algorithm which takes a weighted mean of photon numbers with correction factors of some errors (Yano et al. 2004).

We need demonstrate that the required single look centroiding precision can be achieved in an simulated operating environment using a CCD. We have carried out experiments on the ground measuring centroids of artificial star images on a CCD for test of our algorithm and verification of technical issues (Yano et al. 2004). These experiments have been done in collaboration with ILOM (In-situ Lunar Orientation Measurement)-project team at the National Astronomical Observatory of Japan. The schematic layout of our centroiding experiment is shown in Fig. 6. It consists of a star field projector which produces point spread functions and a CCD focal plane on a precision linear stage to simulate the linear sweep of the star field across the CCD array. We have found that the accuracy of the centroids reaches about 1/300 pixel while the TDI mode has not been operated yet. The experiments are going on in operating the TDI mode.

(ii) As JASMINE rotates, the field of view will map out a spiral band on the sky as described in the previous subsection. The next stage of data reduction is to determine the relative positions of the centered images of stars along the observing spiral. JASMINE

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observes two fields of view separated by 99°.5 simultaneously as shown in Fig. 7. The separation of view is referred to as the basic angle. This limits the growth of errors in relative star positions over large angles. The relative positions of stars are determined by the angular velocity $\omega(t)$ of the spacecraft and transit times of the centroid images. A Fourier expansion of $\omega(t)$ will be integrated over the time for a star to cross both fields of view. The Fourier coefficients are obtained by equating such integration to the basic angle. This use of the two fields of view is taken from the Hipparcos design.

(iii) The next stage is the determination of individual stars' astrometric parameters using the relative star positions on many spiral bands: The observing spiral bands are then combined to form a single global system in this stage. The next procedure is to determine individual stars' astrometric parameters (position, proper motion, and parallax), observing-spiral origins and orientations, local parameters of the instruments and the spacecraft, and global parameters. The local parameters are included in models which describe thermal and/or machinery time variations with *short* periods, of some instruments and the spacecraft system while the global ones represent time variations with *long* periods. A system of observation equations can be formed from the data. The astrometric parameters and both local and global parameters are determined using least squares fits. The entire process is iterated until corrections to the parameters converge. Residuals will be examined for signs of nonlinear proper motion, which would indicate the presence of a nearby gravitating body or a gravitational lensing effect.

4. Instrument design

The JASMINE instrument uses a beam combiner to observe two fields of view simultaneously. The JASMINE beam combiner consists of two flats that feed a common telescope with fields of view separated by the basic angle of 99°.5. The value of the basic angle should avoid unwanted correlations of measurements on successive scans and so its value should not be an integer divisor of 360°. These values are ideally determined by limits of certain Fibonacci series. The basic angle of about 99°.5 is the limit of a Fibonacci series in which the first and the second term are $2\pi/3$ and $2\pi/4$, respectively.

The two fields of view are fed into a common telescope with a 50-m focal length and a circular primary mirror with a 1.5-m diameter. The JASMINE telescope has three mirrors (modified Korsch system) with 4 folding flats to fit the back focal length into the available volume (Fig. 8; see Yano et al., these proceedings). The acceptable mass budget at launch requires that the weight of the telescope should be as little as possible. Furthermore, it is desirable that the telescope has low thermal expansion, high stiffness and high thermal conductivity. Therefore we need to develop suitable new materials with these desired characteristics. One candidate is the use of a new, high-strength, reaction-sintered silicon carbide (RS-SiC) which is now being developed at a Japanese company. We are now trying to make a prototype telescope with a 5-cm diameter primary mirror using this RS-SiC.

The telescope provides a flat image plane consisting of an array of large format CCDs. A total of 98 4k×2k CCDs with 15 μm square pixels are read out in TDI mode to transfer the charge across the devices at the same rate that the images are moving due to the spacecraft rotation. JASMINE observes in the z-band so we need CCDs whose sensitivity is very high around the z-band. Thus we are developing a new type of CCD in collaboration with a Japanese company. This is a back-illuminated, fully-depleted CCD image sensor. The quantum efficiency of the CCD will be about 90% at the z-band.

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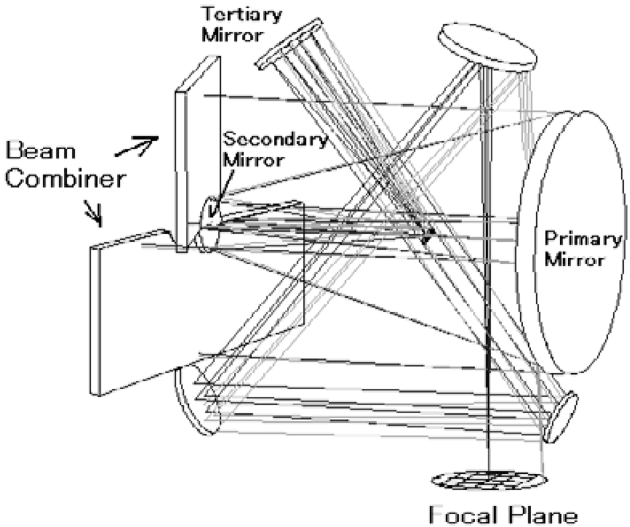

Figure 8. Optics of JASMINE telescope.

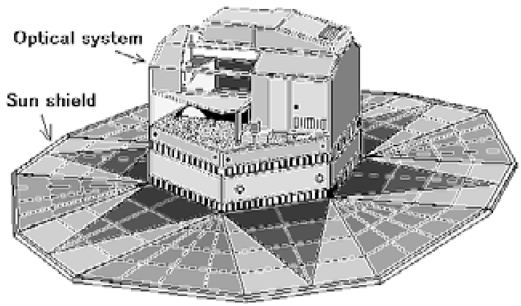

Figure 9. Schematic figure of the JASMINE spacecraft.

5. Spacecraft system

The spacecraft subsystems provide all the necessary support to the payload instruments. The JASMINE spacecraft system has been investigated in collaboration with Japan Aerospace Exploration Agency (JAXA).

A Lissajous orbit around the Sun-Earth Lagrange point L2 is a preferred option because this region provides a very stable thermal environment, minimization of eclipses, and other advantages. The launch strategy is based on a dual launch with H-IIA rocket of JAXA. The mission lifetime will be 5 yr.

The JASMINE spacecraft rotates slowly and precesses, as mentioned in §3. A 3-axis stabilization will be carried out during the observation phase. The attitude control system must meet stringent requirements on the instrument line-of-sight stability, as well as on the spin-axis pointing and rate measurements during the operation mode. The relative pointing error of 60 mas is required during 3.5 s in order to avoid blurring during each sub-field of view integration time of 3.5 s. The absolute pointing error is about 3 arcmin in order that a coming spiral band after one revolution can overlap along the cross-scan direction at least by 1/8 region of the spiral band observed just before.

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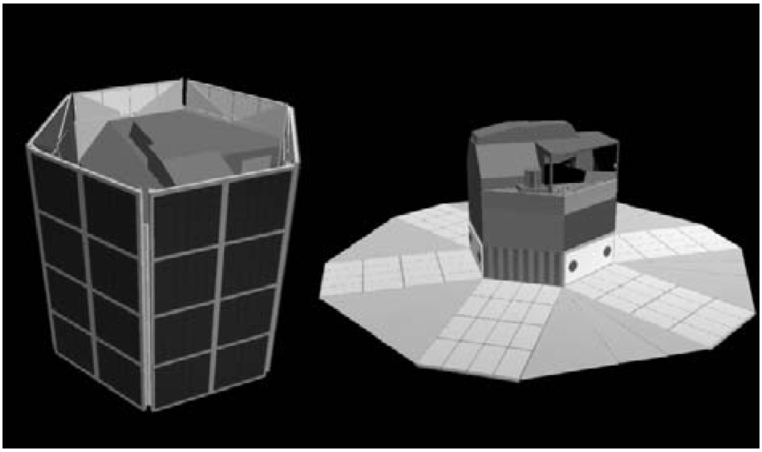

Figure 10. Sunshield of JASMINE. The left figure shows the satellite at launch and the right one shows the satellite in orbit.

Opto-mechanical high stability of the payload is required in the JASMINE spacecraft. Especially high stability of the basic angle of the beam combiner is required over the satellite revolution period (5 hr). The short-term basic angle stability over 5 hr is the only critical parameter so far identified which cannot be properly calibrated by on-ground data processing. A basic angle stability of 10 μas rms should be attainable. A basic angle variation of 10 μas rms corresponds to a thermal gradient variation of $\sim$1 mK at the beam combiner. We are examining methods of thermal control in the JASMINE spacecraft. If such stability is not attainable, we should measure the variation of the basic angle with an accuracy of 10 μas. We are investigating measurement devices such as a wave-front sensor.

The Sun shield for JASMINE is a large shield used to protect the JASMINE payload and service module from direct sun illumination. Due to its large size, it is necessary to fold it for launch, to comply with the volume of the launcher fairing. In Fig. 10 the schematic spacecraft with the sunshield is shown.

The total science raw data rate is about 0.42 Mbps on the sky average. If the possible time duration of the downlink is 8 hr, the telemetry rate is about 1.3 Mbps. We suppose that an electrically scanned phased array antenna is preferred to avoid turbulence to the attitude control of the spacecraft. But the acceptable maximum telemetry rate of the phased array antenna is about 1 Mbps. So we need reduce the data rate such that it becomes compatible with the actual telemetry link. We are considering some methods of data compression.

We have other technical problems beside those described above. The investigations are going on in collaboration with JAXA. Furthermore, we plan a Nano-JASMINE project whose objective is the verification of observing strategy and examinations of some technical issues in JASMINE. Nano-JASMINE uses a nano-satellite whose size and weight are about 20 cm^3 and a few kg, respectively. The definition of a “nano-satellite” is that the range of its weight is between 1 kg and 10 kg.

The optics of Nano-JASMINE are similar to that of JASMINE and the size of the telescope is reduced to the 5 cm diameter of a primary mirror with a focal length of about 1.7 m. We put one CCD with 1k $\times$ 1k pixels on the focal plane. The candidate orbit is a sun-synchronous orbit. The detailed objective of Nano-JASMINE is the verification of the observing strategy adopted in JASMINE such as a great circle reduction. Furthermore,

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Table 1. Summary of the instrument parameters

Optics design	Korsch System (3 mirrors)
Aperture size	1.5 m
Focal length	50.0 m
pixel size	15 μm
pixel on sky	61.9 mas
Array size	6 cm $\times$ 3 cm
Pixels per detector	4096 $\times$ 2048
Number of detectors	98 (7 $\times$ 14)
Basic Angle	$99^{\circ}.5$

Table 2. Summary of the scanning law

Mission Time	5 yr
Rotation Period	5.0 hr
Precession Period	36.9 d
Rotation Axis	around the Galactic Pole
Launcher	H-II A
Orbit	Lissajous orbit around the Sun-Earth L2 point

we will examine the operation of the TDI mode on the new type of CCD, damages due to radiation on the CCD, on-board processing, thermal variation of the basic angle, and so on. The cost of Nano-JASMINE is low and it will be launched about 2006. The development of the spacecraft is going on in collaboration with Prof. Nakasuka and his group at the University of Tokyo. His group successfully launched a nano-satellite whose name is Cube-Sat(XI-IV) in 2003 June.

6. Management of JASMINE

The establishment of the JASMINE working group at JAXA was approved last year by a science committee of ISAS (Institute of Space and Astronautical Science) of JAXA. The working group includes many scientists and engineers who are investigating the basic design of JASMINE and technical problems. The working group aims at proposal of the JASMINE mission to JAXA to get an approval for launch in 4 or 5 years.

7. Summary

JASMINE will measure parallaxes, proper motions and positions of about 10^8 stars mainly within the central bulge and disk components of the Galaxy. JASMINE aims at high precision astrometry of 10 μas for stars brighter than z= 14 in the z-band. The primary scientific targets of JASMINE are to clarify the structure and evolution of the bulge and the disk. The instrument parameters and scanning law of JASMINE are summarized in Table 1 and Table 2, respectively.

Jasmine is a name of a plant. The flower language of jasmine is elegance. Thus we greatly hope that JASMINE will be *elegantly* successful in the future. (Please refer also to the JASMINE web page: http://www.jasmine-galaxy.org/index.html)

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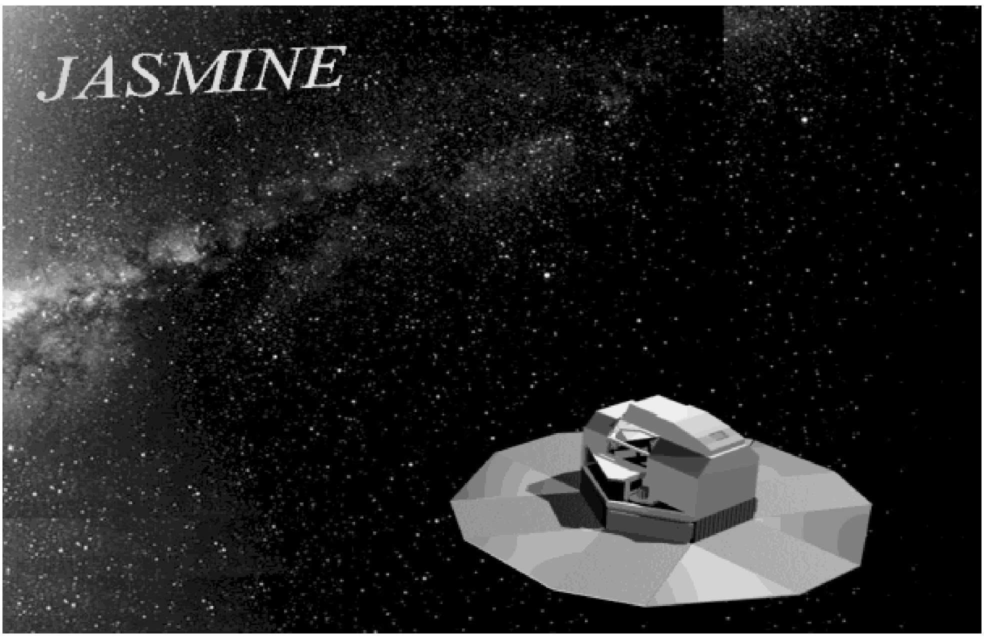

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Discussion

Coryn Bailer-Jones: I'm slightly concerned about your scanning law because your satellite is keeping a constant axis pointing in the galactic plane. This means, as it orbits the sun, some aspect angle will change enormously. Doesn't this mean that sometimes you are actually illuminating payload and not being blocked by the sunshield, so you get thermal gradients on the satellite? This means that for the some of the orbit around the sun, the sun shield will be pointing away from the sun not towards the sun.

Naoteru Gouda: Yes. In the summer and winter seasons the payload is illuminated. We can observe in the autumn season and the spring season – for only half of a year.

Floor van Leeuwen: The way that you described the scanning strategy you will be observing virtually in the ecliptic plain at some point. This means you are going to get problems with scattered light inside the instrument from the sun. This is not what you want. It looks, from both Coryn's and my point of view, that the scanning strategy that you are proposing for your mission is the opposite of what you want in terms of thermal stability, for which you would like to have a constant fixed solar aspect angle. I don't understand this strategy.

Naoteru Gouda: Yes, I agree. We are now investigating the method.

Dave Monet: Overlapping fields in the galactic plane – in particular, in Baade's window – prevent severe image crowding. Are you adopting special tactics for dealing with centroiding in such crowded fields?

Naoteru Gouda: Yes, there are many stars and some problems with contamination. We have investigated the contamination; of course, the centre we cannot see, but excluding the galactic centre the computed limit is about $z = 18$. Then it is safe for JASMINE.

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