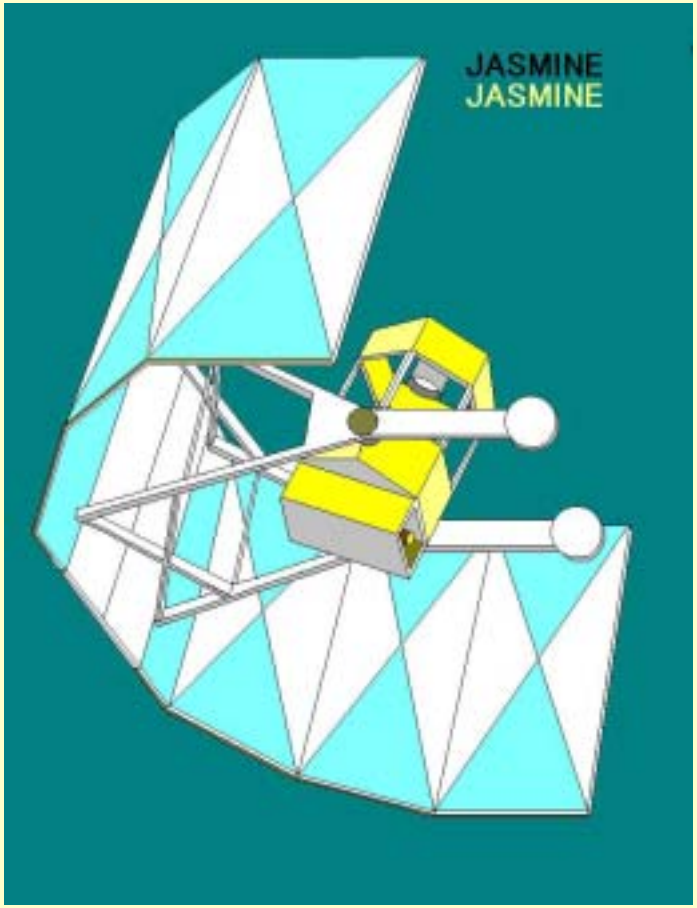
IR Space Astrometry

---JASMINE-project---



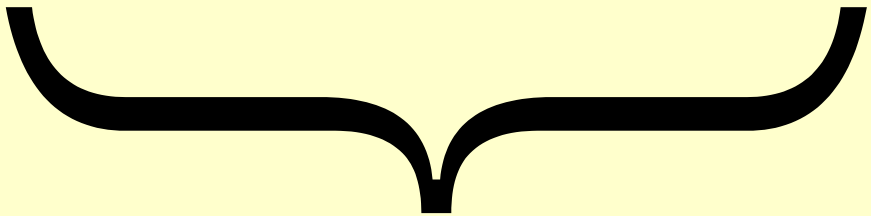
Naoteru Gouda(NAOJ)

§ 1 Astrometry

Measurement of positions, distances and proper motions of celestial objects (distance ← parallax)

+

radial velocities



6-dimensional phase space density of objects

most fundamental Information in astronomy!

★phase density of stars in the 6-dimensional space（μ-space)

→ dynamical structure → star cluster

→ dynamical structure → Milky Way

★distance of star → luminosity

→ stellar physics, distance indicator → Pulsating Stars

→ star formation, super-nova

★motions of stars → binary systems,

→ planetary systems

§ 2 “Revolution” by the Hipparcos satellite

★Hipparcos satellite(1989~1993: ESA)

V<12mag

parallax accuracy〜1mas

→ 10% distance error at 100pc

proper motion accuracy 〜1mas/yr

→ velocity error at 1kpc ~5km/s

“revolution” in astronomy

But it is a small revolution

◎necessary parallax accuracy ⟶ less than 10% error

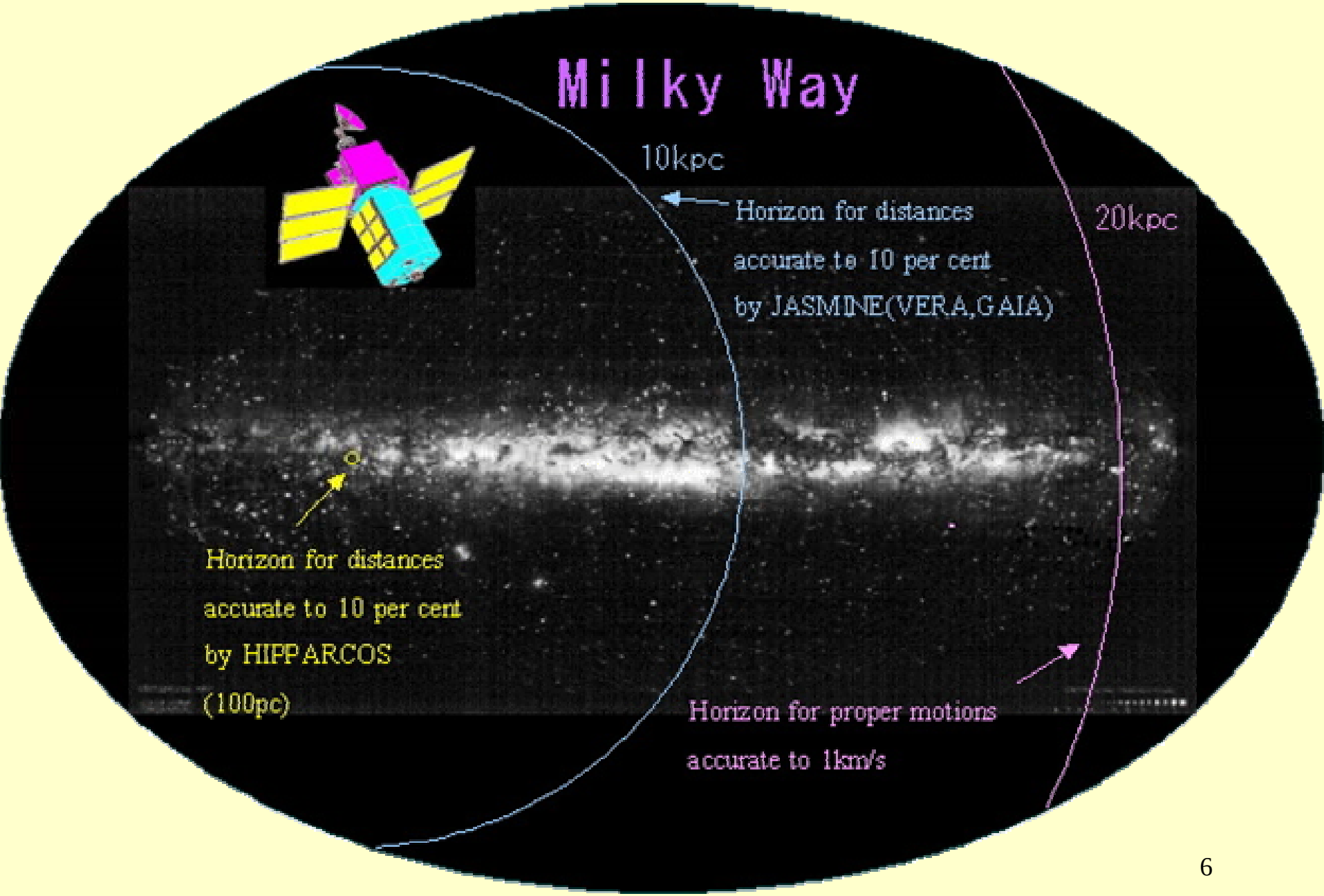
(more than 10% error ⟶ bias effects)

↓

within 100pc(<<8kpc)

↓

only a few interesting stellar objects


Milky Way
10kpc
Horizon for distances
accurate to 10 per cent
by JASMINE(VERA,GAIA)
20kpc
Horizon for distances
accurate to 10 per cent
by HIPPARCOS
(100pc)
Horizon for proper motions
accurate to 1km/s

§ 3 “Big Revolution” by high accuracy astrometry observations

Hipparcos → “small” revolution

↓

To “big” revolution

Accuracy of ~10 μas

↓

10% distance error at 10kpc!!

velocity error at 20kpc ~1km/s !!

↓

Breakthrough in many fields of astronomy

★Scientific Targets by high accuracy astrometry

I. Stellar Astrophysics

- ○distance indicators ⟶ cosmology, astrophysics
- ○stellar physics(evolutions)
- ○star formation
- ○the formation and evolution of our Galaxy

II. Galactic Structure

- ○rotation curve, dark matters
- ○MACHO

- dynamical structure: halo, bulge, disk(spiral arm, warp)
- satellite dwarfs
- distance indicator by the extra galaxies
- proper motions of galaxies : group of galaxies, dark matters in clusters

III. Planet detection

IV. Fundamental Physics: test of general relativity, reference frame

V. Unexpected Discoveries

§ 4. Future Space Astrometry Project

Mission	Agency	Method	Launch	#of Stars	Mag.limit	Accuracy
Hipparcos	ESA	teles.	1989	120000	12	1mas@V=10
DIVA	Germany	teles.	~ 2005	35million	15	250 μ as @ V=10
FAME	USNO	teles.	? ?	40million	15	50 μ as@V=9
SIM	NASA	interf.	~ 2009	10000	20	4 μ as@V=20
GAIA	ESA	teles.	~ 2012	1 billion	20	10 μ as@V=15

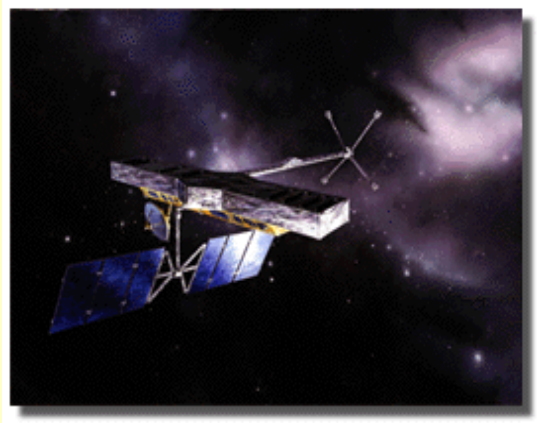
Remark: ○ observations in optical bands in all space projects

○ VERA: VLBI Exploration of Radio Astrometry

~ 1000 maser sources

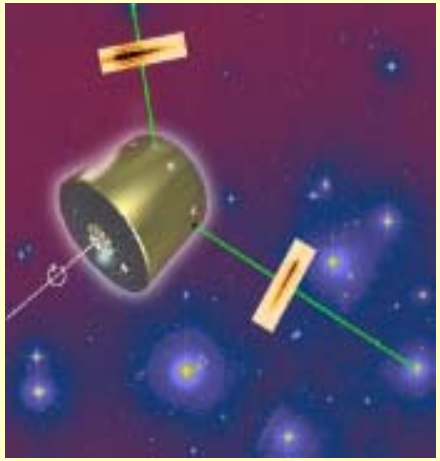
GAIA

SIM



FAME

DIVA



§5. JASMINE-project

Japanese Astrometry Satellite Mission for INfrared Exploration

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3.RIKEN(The Institute of Physical and Chemical Research)
4. The University of Tokyo

★What is JASMINE project?

- ○JASMINE is a scanning astrometric satellite for infrared exploration.
- ○Astrometry: Near Infrared----K-band(2.2 μm)
- ○Accuracy: 10 μas at K=14~15mag
- ○Number of Objects: a few hundred million stars around the bulge and the disk
- ○Photometry: J, H, K-bands

Infrared astrometry is important!

★Optical/IR interstellar extinction

Photometoric passband	Wavelenghth	Extinction(relative) (magnitude)
B	0.44	1.33
V	0.55	1.00
R	0.64	0.78
I	0.79	0.59
J	1.25	0.28
H	1.65	0.17
K	2.2	0.11

★The number of stars expected in the Galaxy

Galaxy Model ------->Sky Model

(Wainscoat et al('92), Cohen('93,'95))

+

dust map by DIRBE

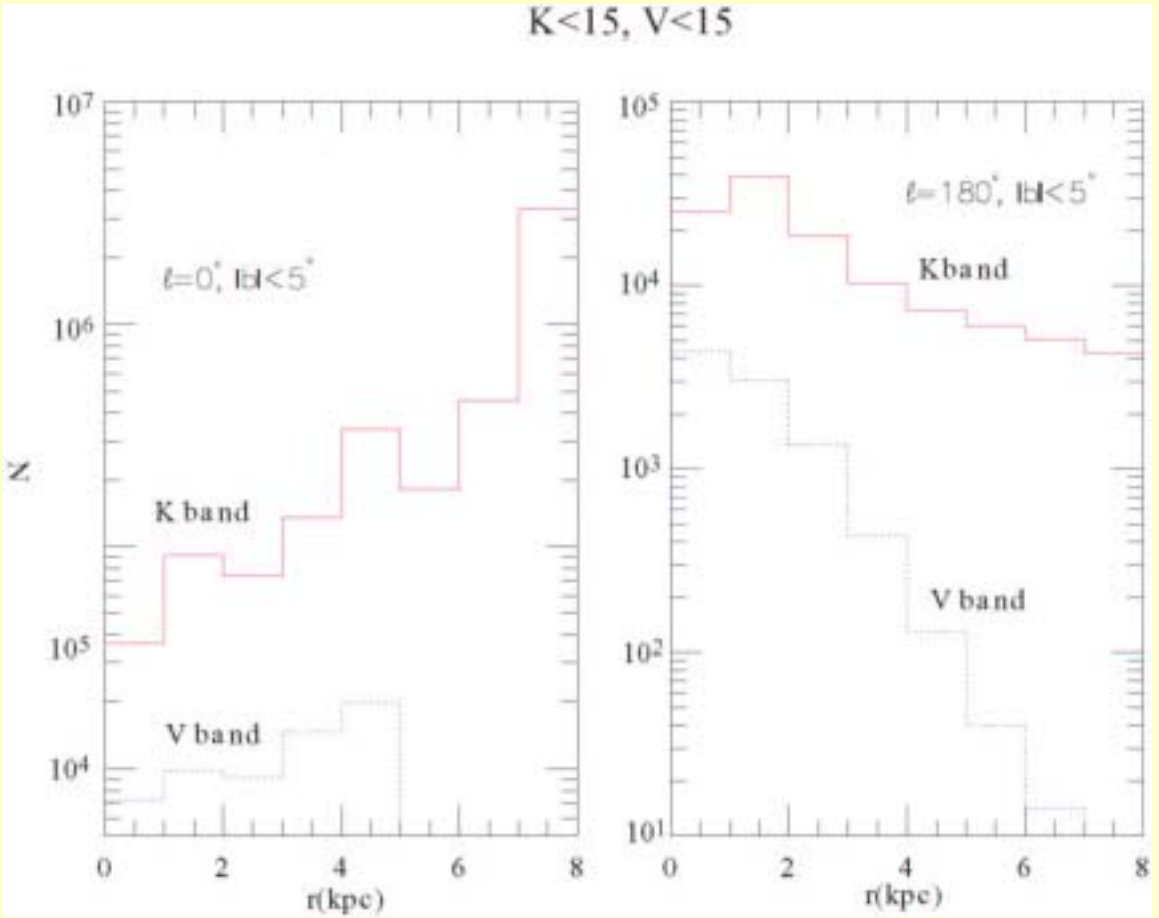
======>The averaged number of stars expected in K-band is much larger than that in V-band in the Galactic plane.

The number of stars expected in the Galaxy model

K-band(**K<15mag**) V-band(**V<15mag**)

$|b|<5^\circ$

$\delta\ell<1^\circ$



★Science Targets

- Galactic bulge: morphology, kinematics,…

  -------> formation history of the bulge

- Galactic disk: dynamics of spiral arms,

  nature of stellar warp, …

- Star formation regions
- Local group of galaxies

★Design Considerations of JASMINE

accuracy of position $\sigma \sim \lambda / D\sqrt{N}$

N:photon number

larger N is required → larger mirror

larger F.O.V. ⟶ Many good detectors

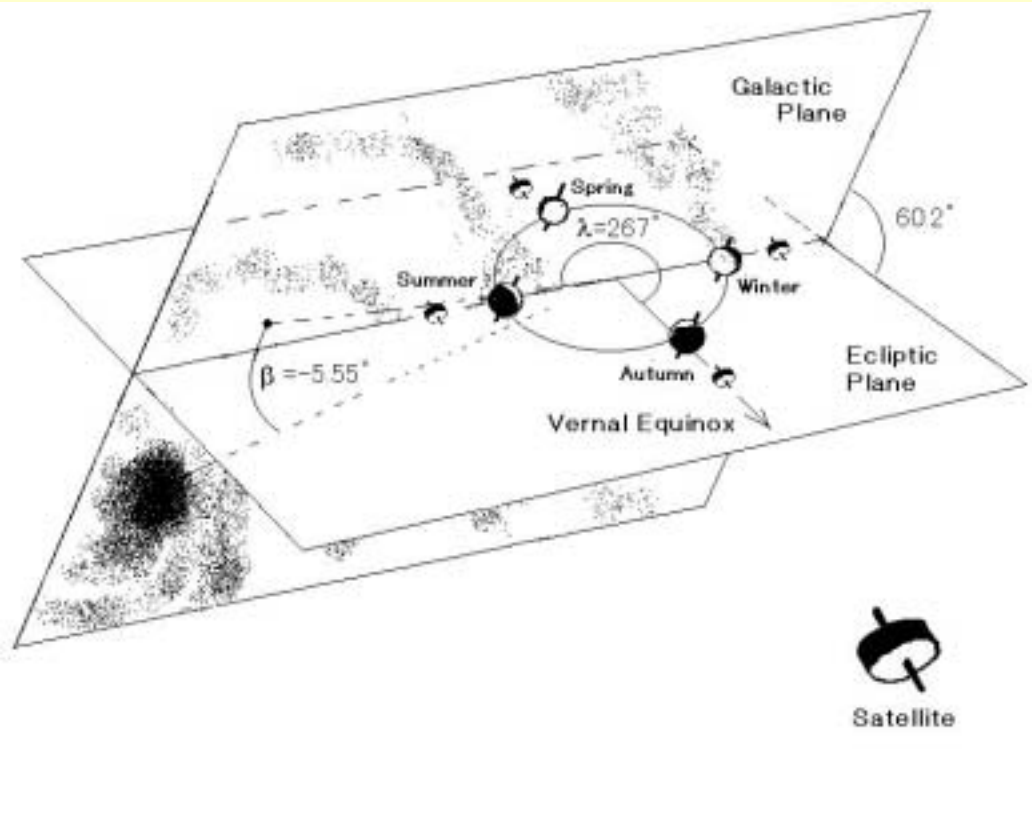
Cf. TDI mode at CCD in the optical bands

⟶ development of a new good IR detector

in which TDI mode can be operated.

★Survey method

- ○continuous sky scanning
- ○how does the satellite observe the Galactic center and/or the Galactic disk?



○Global Astrometry

simultaneous observations of two directions separated with a wide angle

JASMINE → One big mirror for scientific targets

→ One or more small mirrors for the bright guiding stars at V-band

○Orbits

the Earth-Sun Lagrange point L2

★Option I

Astrometry：Survey the Galactic plane

- Precision: ～10μas @K=14mag

  (~240°×10°)

- Mirror for scientific target: 3.6m × 1.8m
- Small mirror for guiding star~ 1m × 0.5m
- Astro focal plane: ～130detectors(HgCdTe)
- H-II A rocket

  (NASDA:NAtional Space Development Agency of Japan)
- Launch ～2015(??)

★Option II

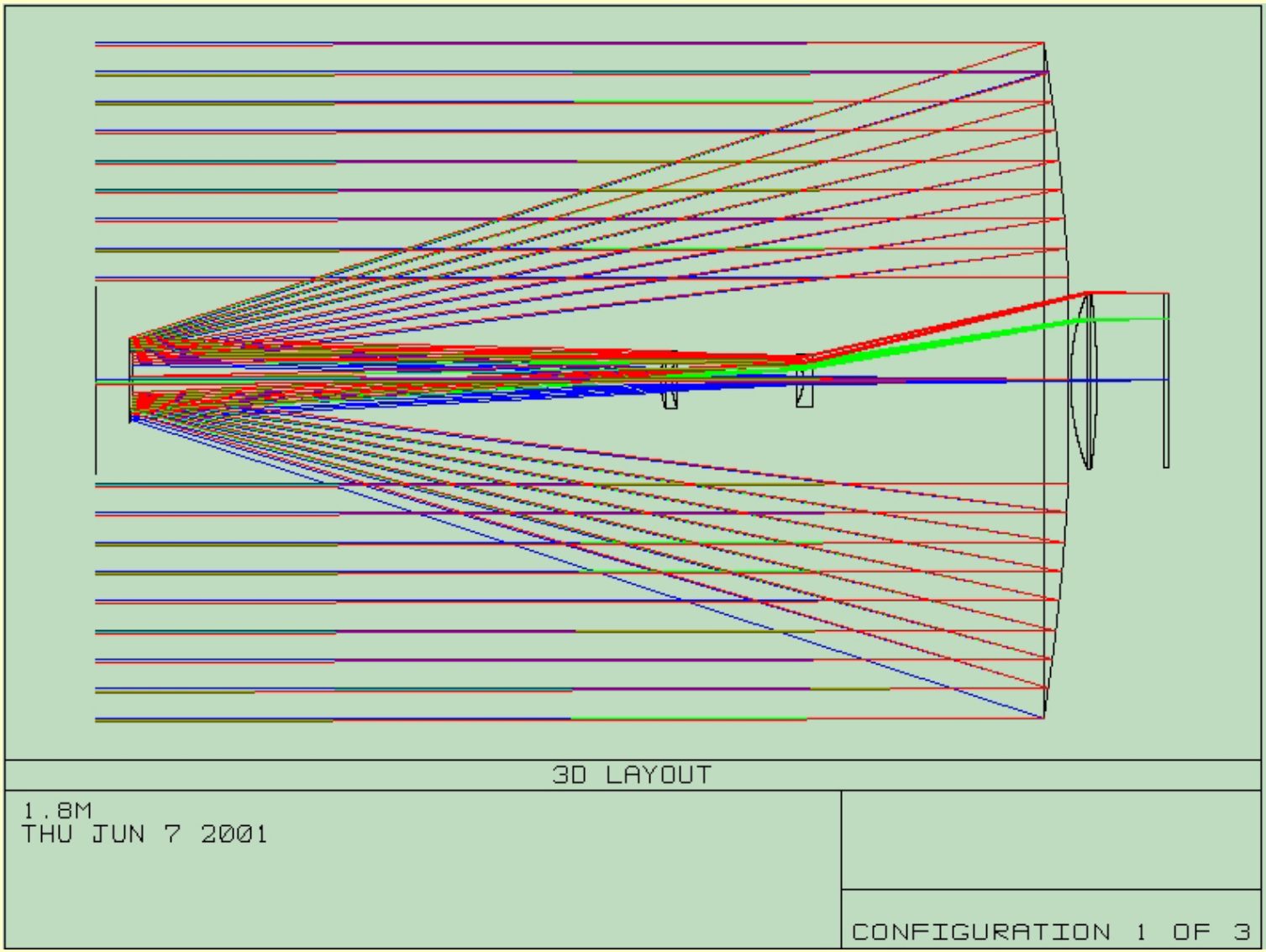
Astrometry：Survey around the Galactic bulge

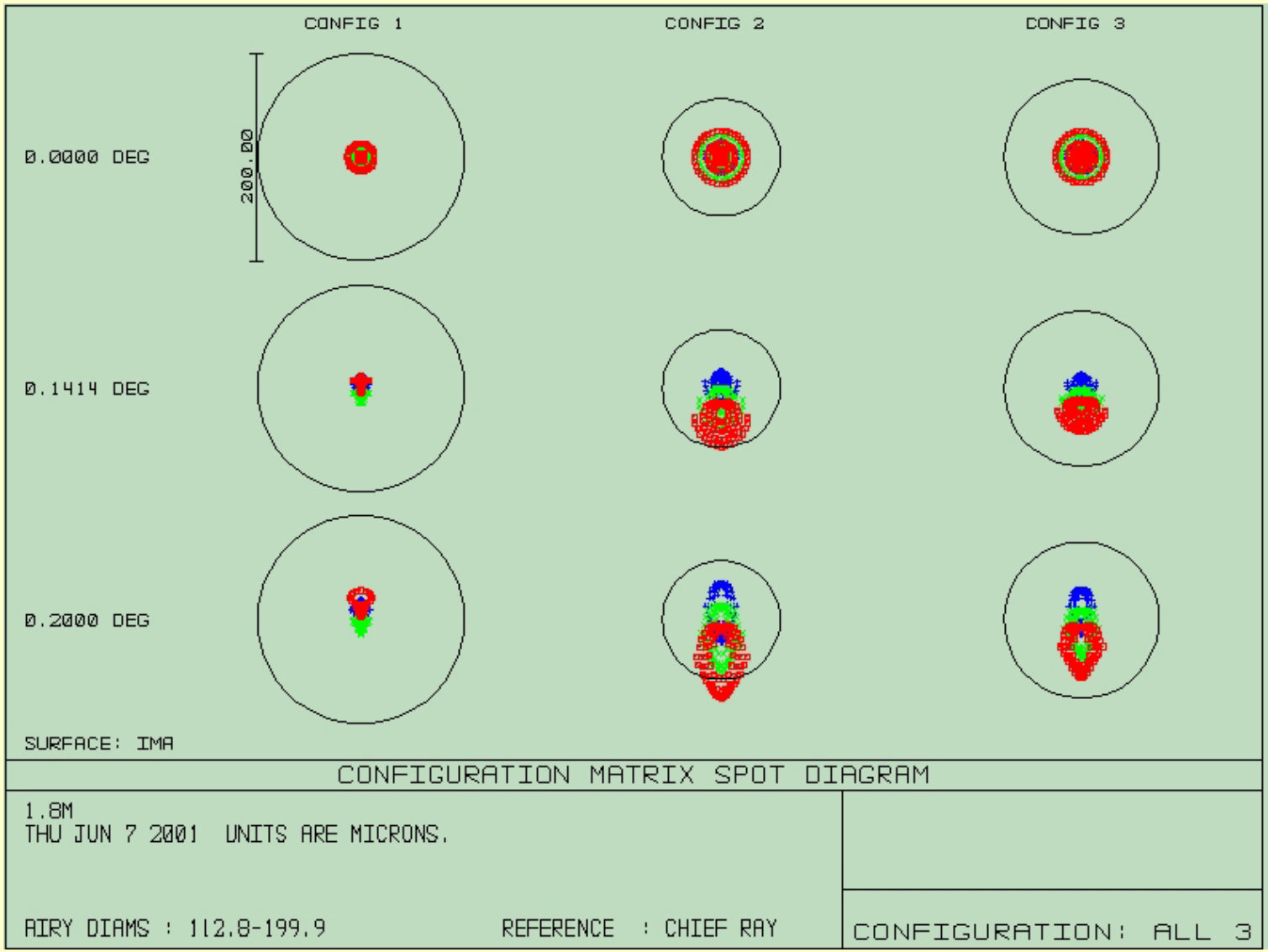
- Precision: ～10 μas @K=13mag

  (~20°×10°)

- Pupil diameter: 1.8m, Focal length: 66.6m
- Diameter of FOV: 0.4°
- Small mirrors for guiding stars ~0.5m
- Astro focal plane: ～30detectors(HgCdTe)
- M-V rocket

  (ISAS:Institute of Space and Astronautical Science)
- Launch ～2013(?)


3D LAYOUT
1.8M
THU JUN 7 2001
CONFIGURATION 1 OF 3


CONFIG 1
CONFIG 2
CONFIG 3
0.0000 DEG
0.1414 DEG
0.2000 DEG
200.00
SURFACE: IMA
CONFIGURATION MATRIX SPOT DIAGRAM
1.8M
THU JUN 7 2001 UNITS ARE MICRONS.
AIRY DIAMS : 112.8-199.9
REFERENCE : CHIEF RAY
CONFIGURATION: ALL 3

★Key Technical Challenges

- Development of Ultralightweight Mirror for M-V and H-IIA
  ～13kg/m^2---->Mirror Lab at the University of Arizona
- HgCdTe---->TDI(?)
- Stability of instruments
- Centroiding accuracy
- Orbits, Method of survey
- Data Analysis

} → JASMINE Simulator

・・・・・・・・・

★Science!

We would like to ask you for your cooperation.

Jasmine