Mullard Space Science Laboratory

UCL

The JASMINE mission
(Japan Astrometry Satellite Mission for INfrared Exploration)

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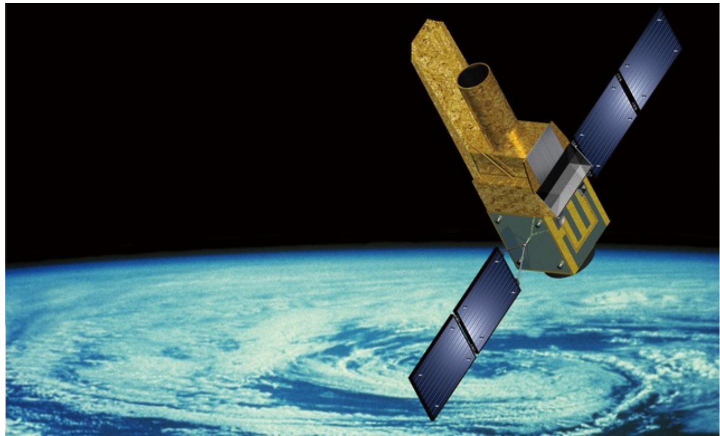
Naoteru Gouda (JASMINE Principal Investigator, NAOJ)
and
JASMINE team

JASMINE White Paper!
(Kawata et al. arXiv:2307.05666, submitted to PASJ)



MWGaiaDN
This project is a Horizon Europe Marie Skłodowska-Curie Actions Doctoral Network funded under grant agreement no. 101072454.

UK Research and Innovation

NAOJ National Astronomical Observatory of Japan

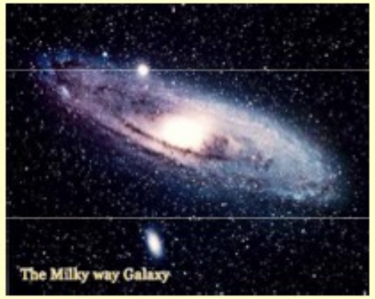
ISAS JAXA

In Japan, NIR astrometry mission planning started around 2000.

Gouda et al. (2009)

Hop: Nano-JASMINE launch date: July 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

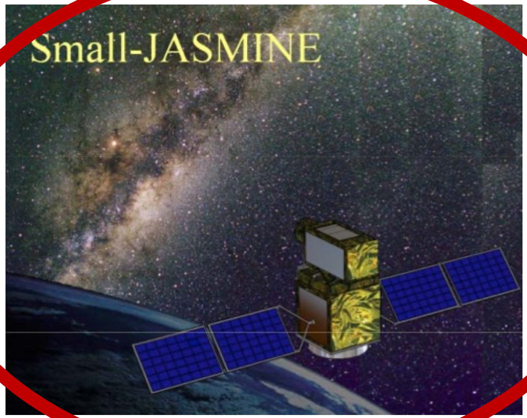
step -by-step approach to JASMINE for both science and techniques
the diameter of a primary mirror: 30cm
weight of a satellite: ~400kg
survey toward the restriced regions of the Galactic bulge

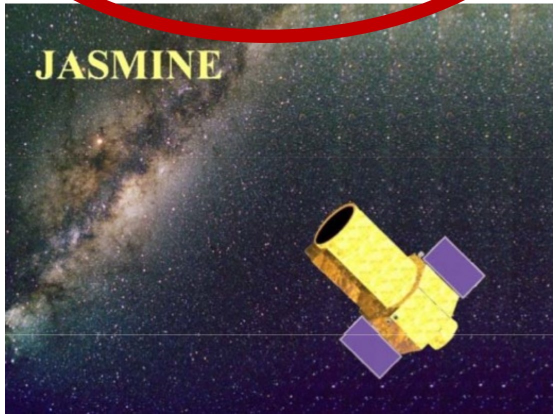
Jump: JASMINE target launch date: the first half of 2020's

the diameter of a primary mirror: 80cm
weight of a satellite: ~1500kg
survey toward the whole region of the Galactic bulge

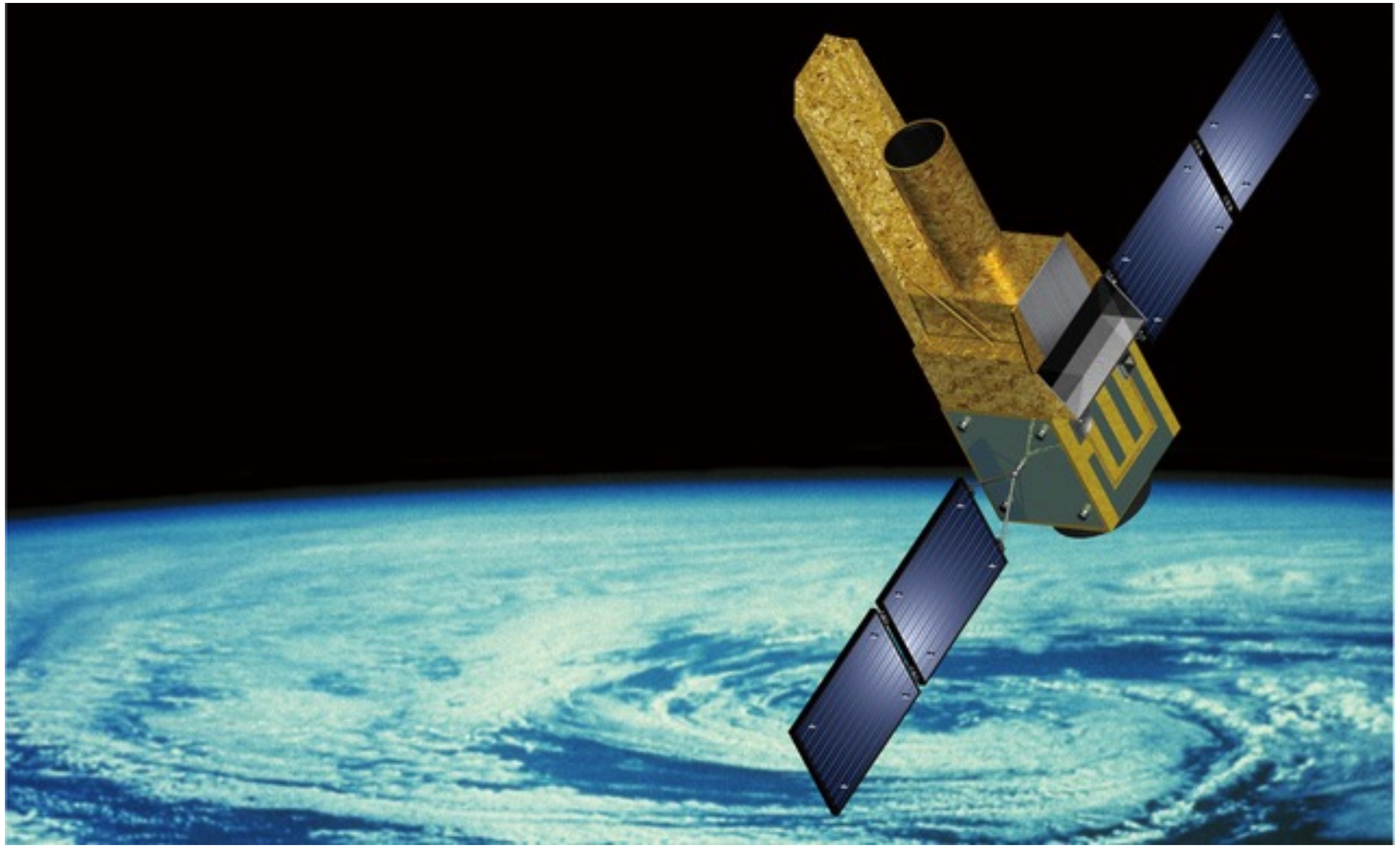
JASMINE

<< GaiaNIR





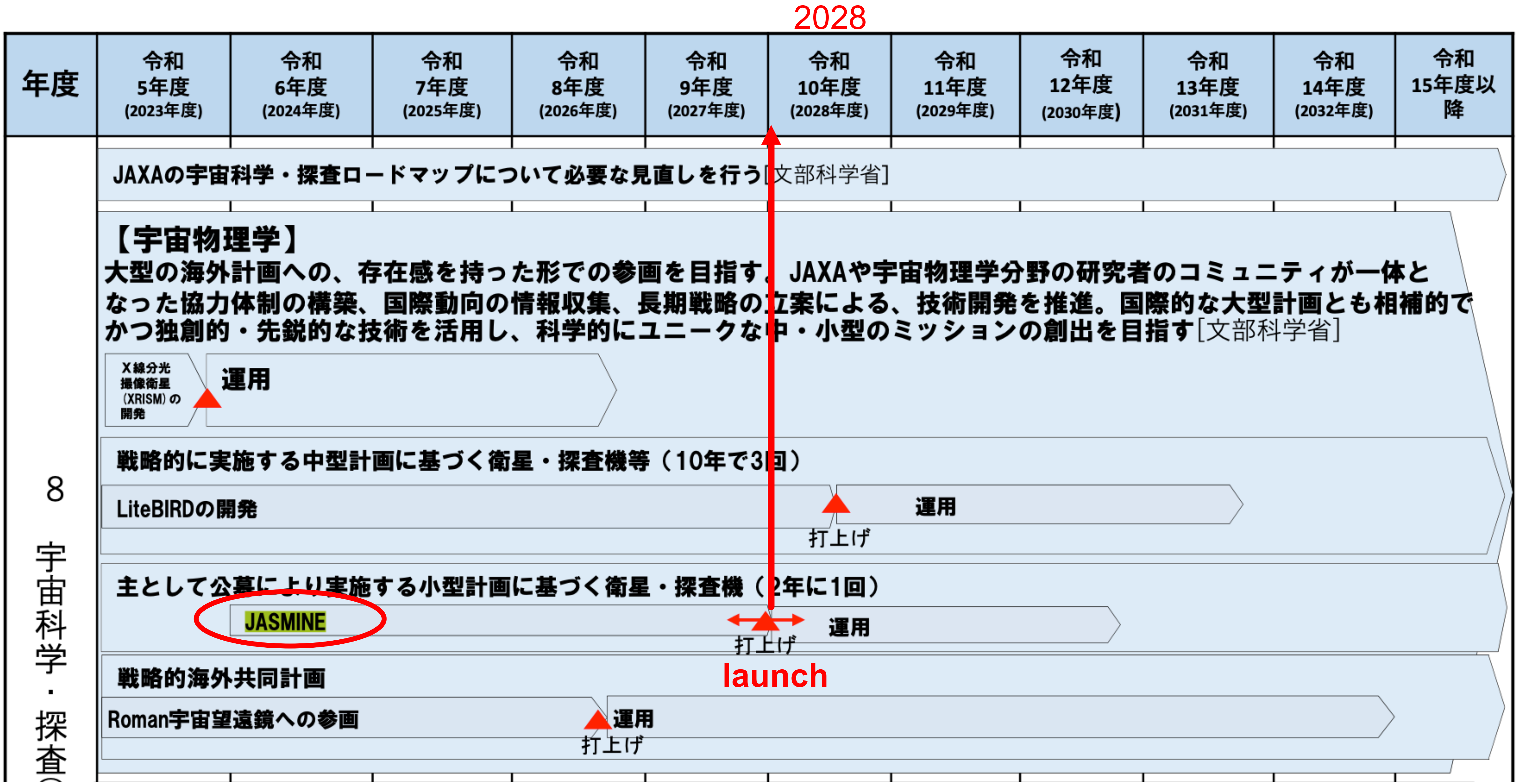
JASMINE (Japan Astrometry Satellite Mission for INfrared Exploration)
selected for JAXA Science Mission (planned launch in 2028)
Near-IR (NIR) astrometry and time-series NIR photometry
PI: Naoteru Gouda, PS: Kawata



36 cm diameter, 3 years mission

Hw(1.0-1.6 μm)=9-14.5 mag, $Hw \sim 0.9J+0.1H-0.06(J-H)^2$

Japan space science programme roadmap (13 June, 2023, Cabinet Office website)



Japanese Consortium and International collaboration

ISAS
空へ挑み、宇宙を拓く JAXA 宇宙航空研究開発機構
国立天文台 NAOJ National Astronomical Observatory of Japan
KYOTO UNIVERSITY FOUNDED 1897 KYOTO JAPAN
Astrobiology Center
TOHOKU UNIVERSITY 東北大学 TOHOKU UNIVERSITY
統数研
東京大学 THE UNIVERSITY OF TOKYO
むすんで、うみだす。京都産業大学 KYOTO SANGYO UNIVERSITY
HIROSHIMA 広島大学

真の強さを学ぶ。新潟大學 NIIGATA UNIVERSITY
お茶の水女子大学 Ochanomizu University
国立大学法人 東京海洋大学 Tokyo University of Marine Science and Technology
宮教大 宮城教育大学
独立行政法人 国立高等専門学校機構 高知工業高等専門学校 National Institute of Technology, Kochi College
弘前大学 Hirosaki University

愛媛大学 EHIME UNIVERSITY
国立大学法人 鹿児島大学 KAGOSHIMA UNIVERSITY
GUNMA ASTRONOMICAL OBSERVATORY 県立ぐんま天文台
大阪大学 OSAKA UNIVERSITY

USNO
UCL
ZAH
DLR
LIBERTAS PERFUNDET OMNIA LVCE UNIVERSITAT DE BARCELONA
esa

JASMINE two main science goal

- Galactic Centre Archaeology
  - To reveal the Milky Way's central core structure and its formation history
  - To explore the formation history of the Milky Way structures, like the bar, which triggered the radial migration of the Sun

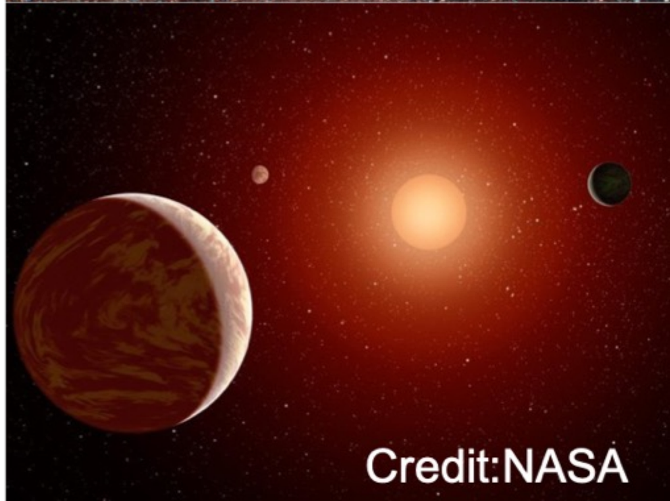
  ⟸ **NIR astrometry of the Galactic centre**

  Unexplored territory of the ESA Gaia mission, but NIR MOS (MOONS, SDSS-V, Subaru/PFS) will provide spec data in late 2020s!

- Exoplanets
  - To discover Earth-like habitable exoplanets

  ⟸ **NIR time-series photometry of M-dwarfs**

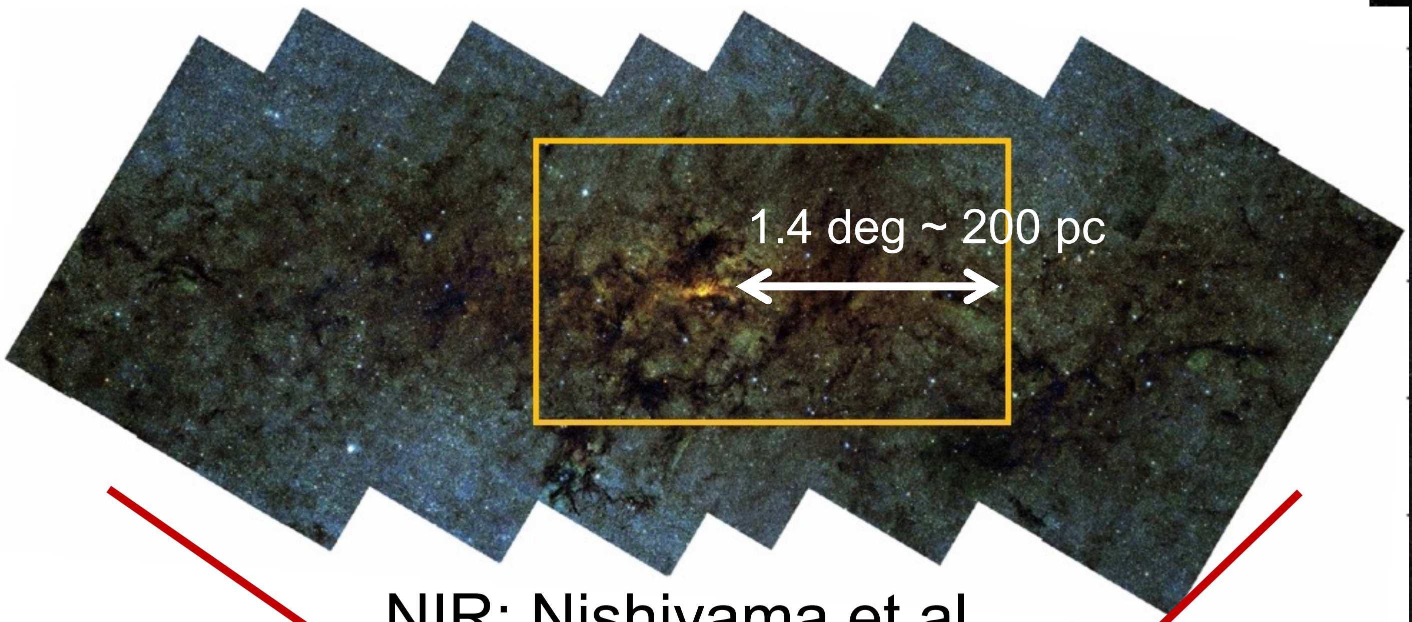
  Target for JWST, ARIEL spec follow-up!



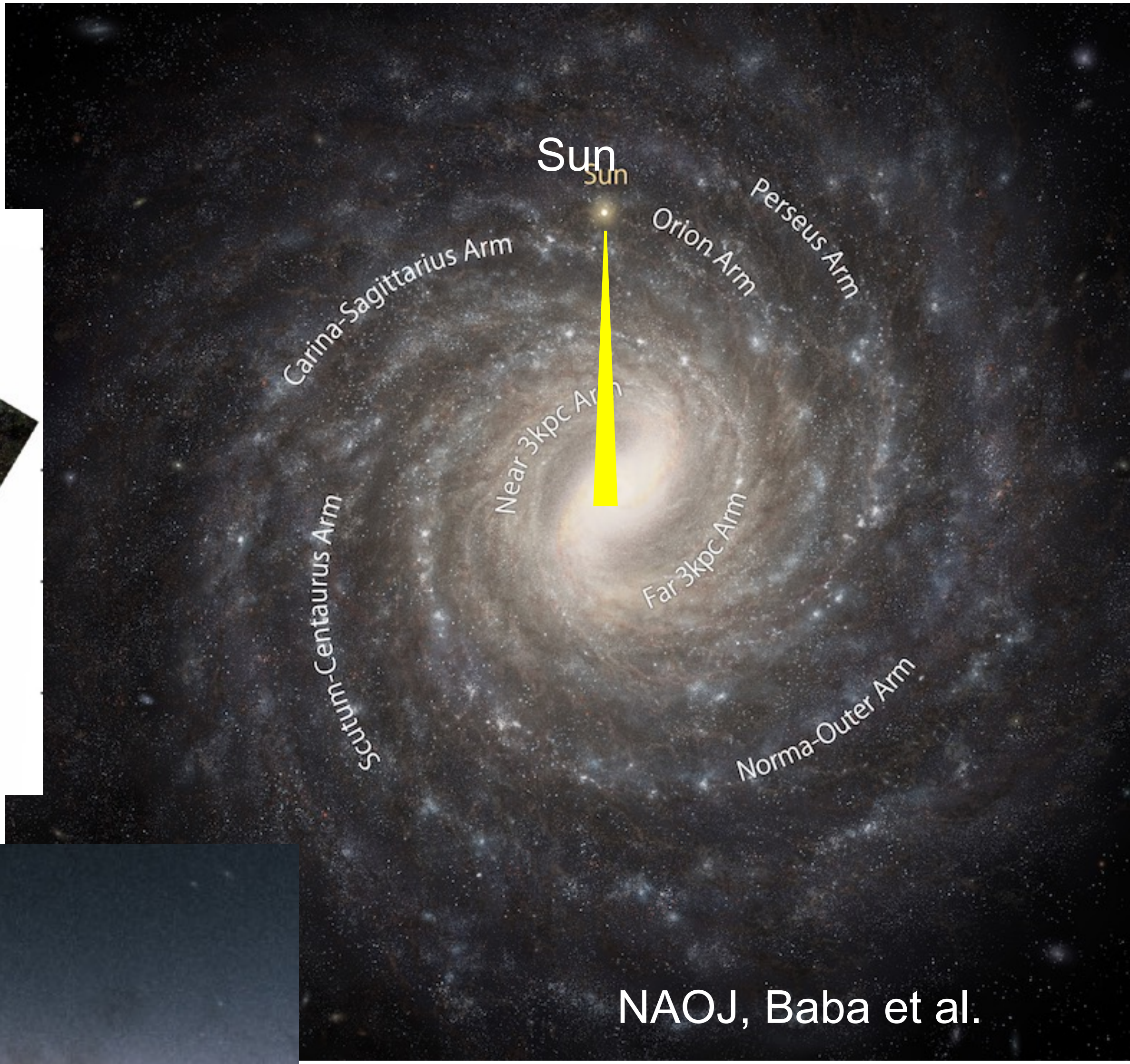
国立天文台 NAOJ National Astronomical Observatory of Japan
ISAS JAXA

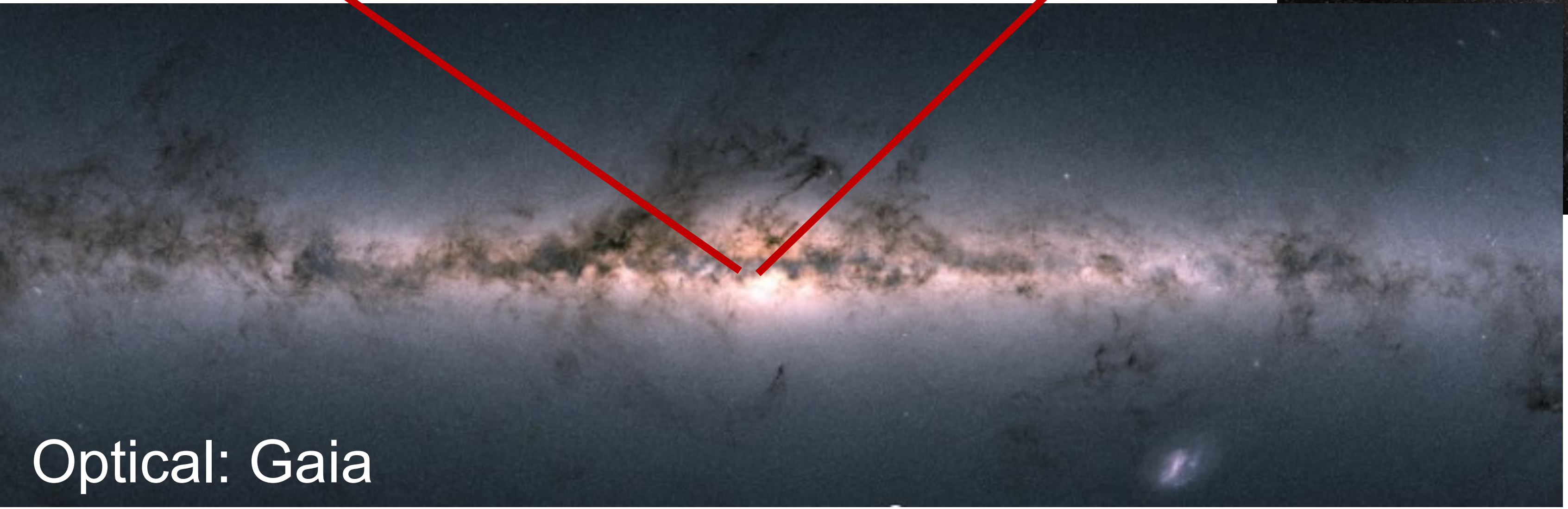
Galactic Centre Survey (Rgc~200 pc)

Near-IR : see through the dust in the disk



NIR: Nishiyama et al.



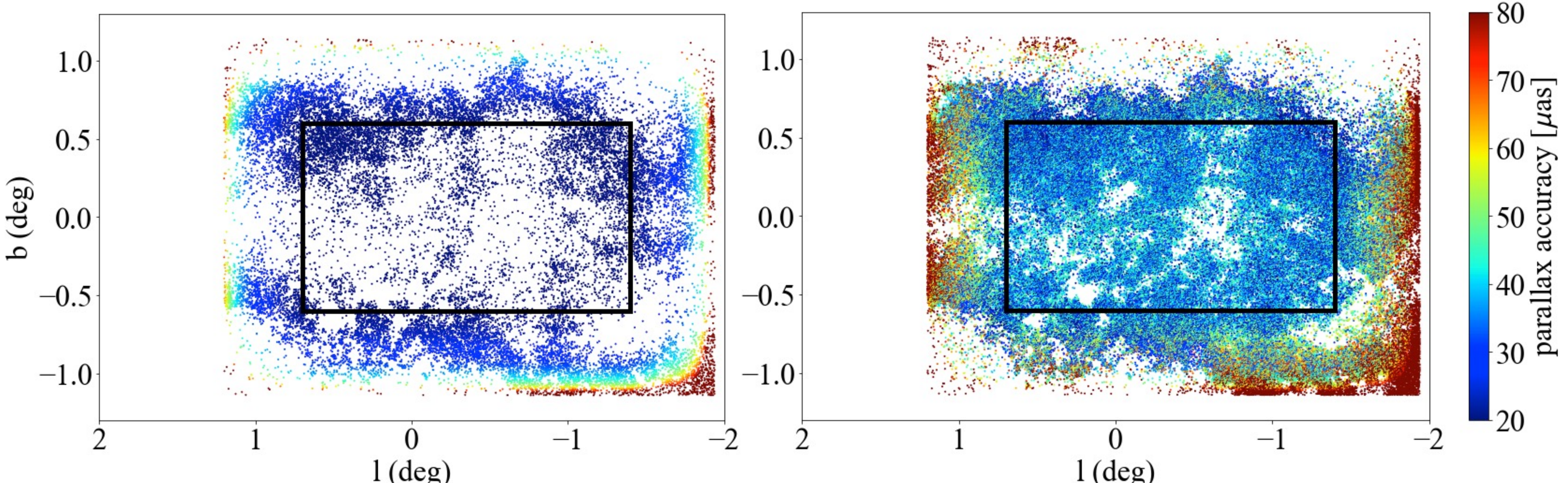


JASMINE Galactic Centre Survey (JGCS) Field and Extra Surrounding Data Field

- JGCS: −1.4 < l < 0.7, −0.6 < b < 0.6 (or −0.7 < l < 1.4, −0.6 < b < 0.6)
- Precise NIR astrometry, with ~60 K obs. in 3 years (spring and fall only).
- 12.5s exp. x 46 every ~ 530 min cadence photometry (TBD)
- Extra ~0.5 deg surrounding region, less accurate, but the data will be available.

Hw<12.5mag (~15K stars, ~6K with J-H>2)
~25 μas parallax accuracy
20% distance error at GC

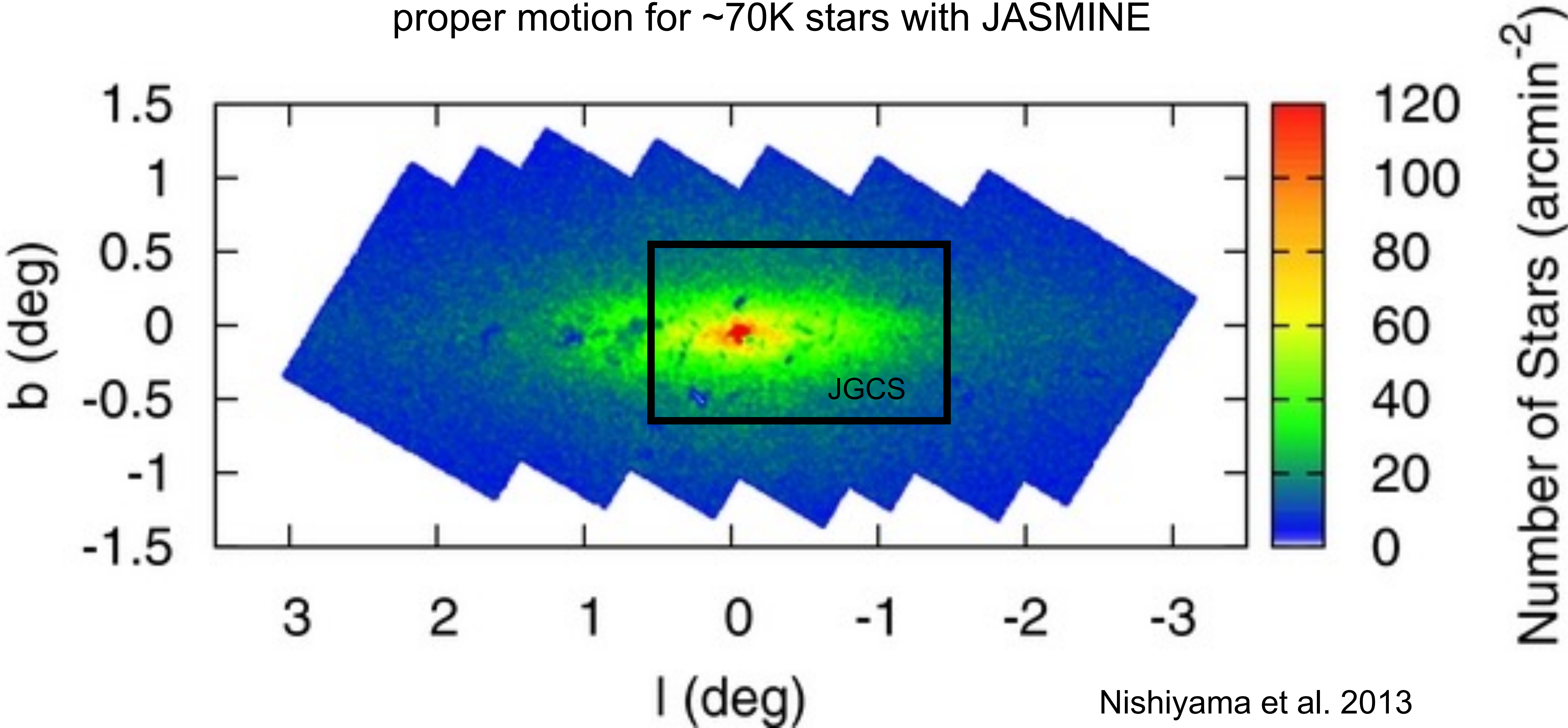
Hw<14.5mag (~120K stars, ~68K with J-H>2)
< 125 μas/yr proper motion accuracy
<~5 km/s velocity accuracy at GC



Galactic Centre Archaeology: Galactic Nucleus Stellar Disk (NSD)
Main JASMINE target!

Parallax for ~6000 stars, confirming the distance of the NSD stars

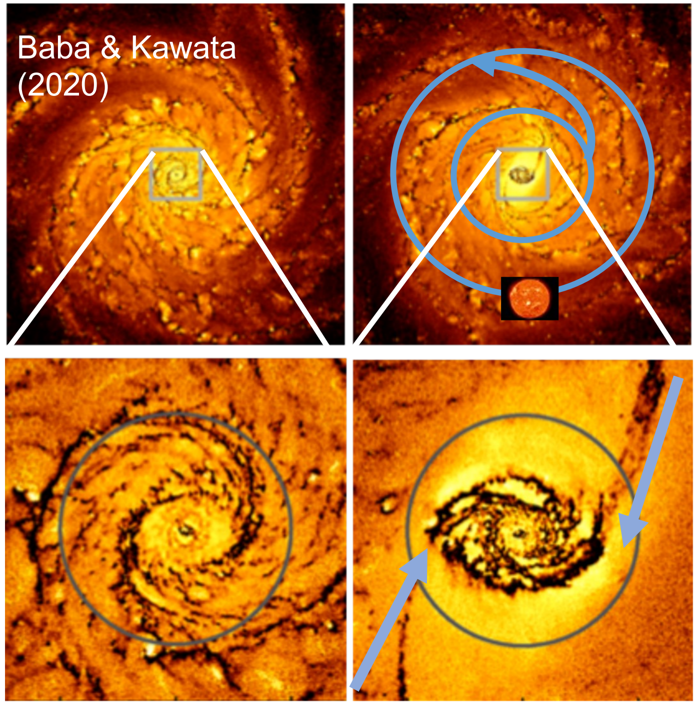
proper motion for ~70K stars with JASMINE

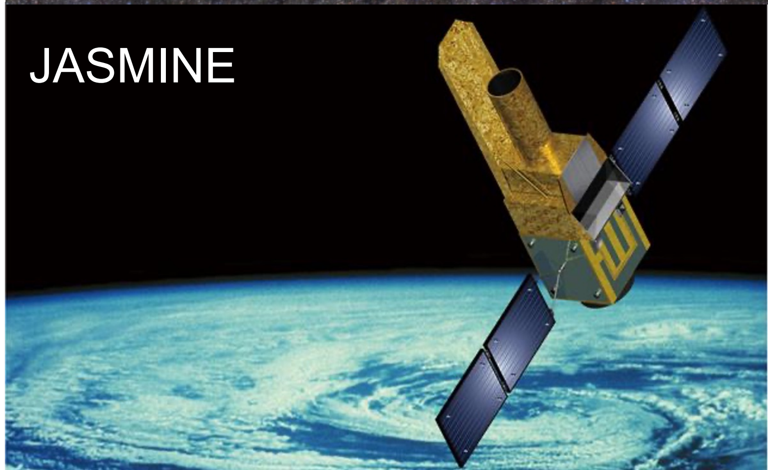


Nishiyama et al. 2013

NSD will tell us the epoch of the Galactic bar formation

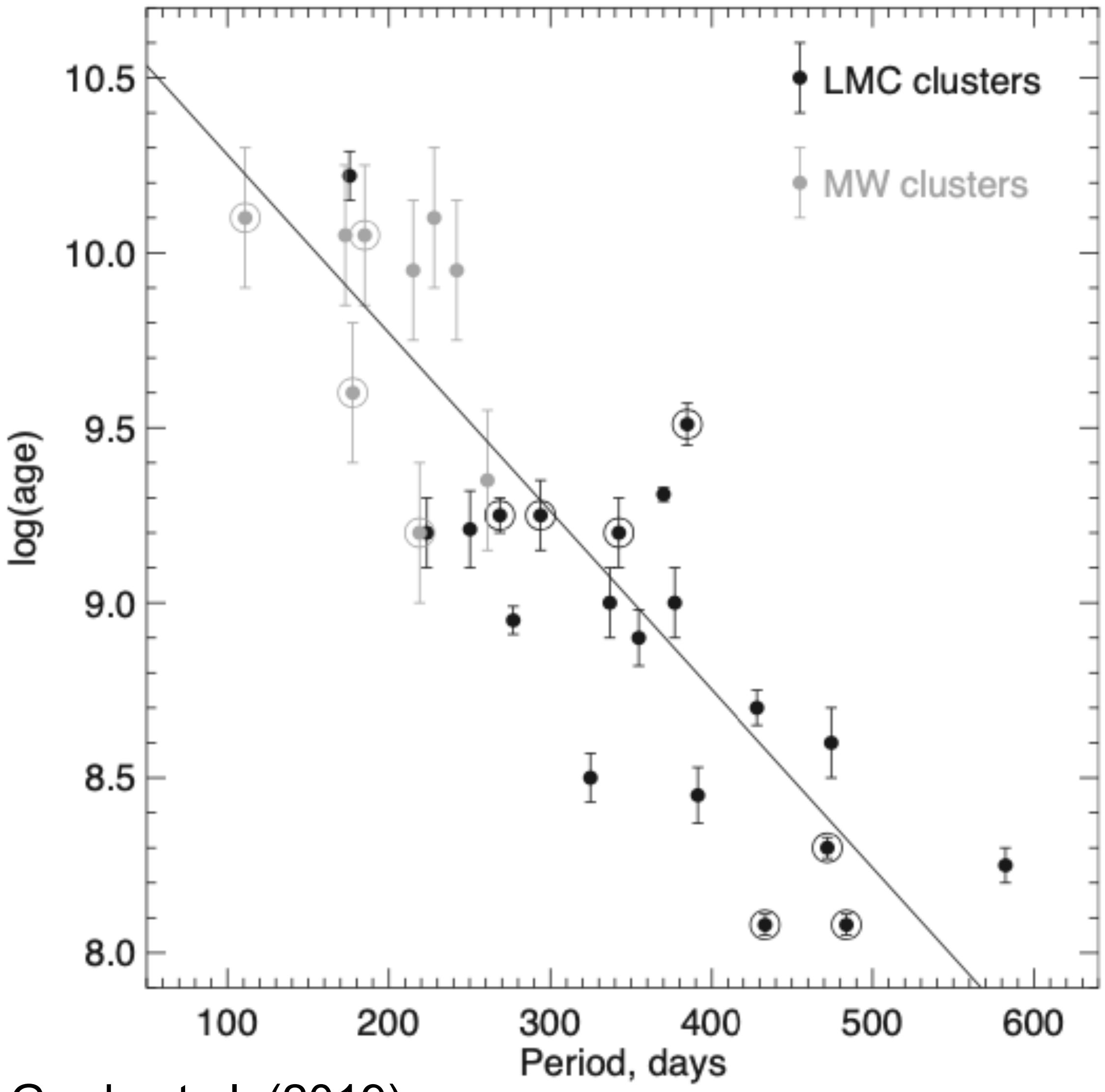
Hierarchical clustering at the early Universe



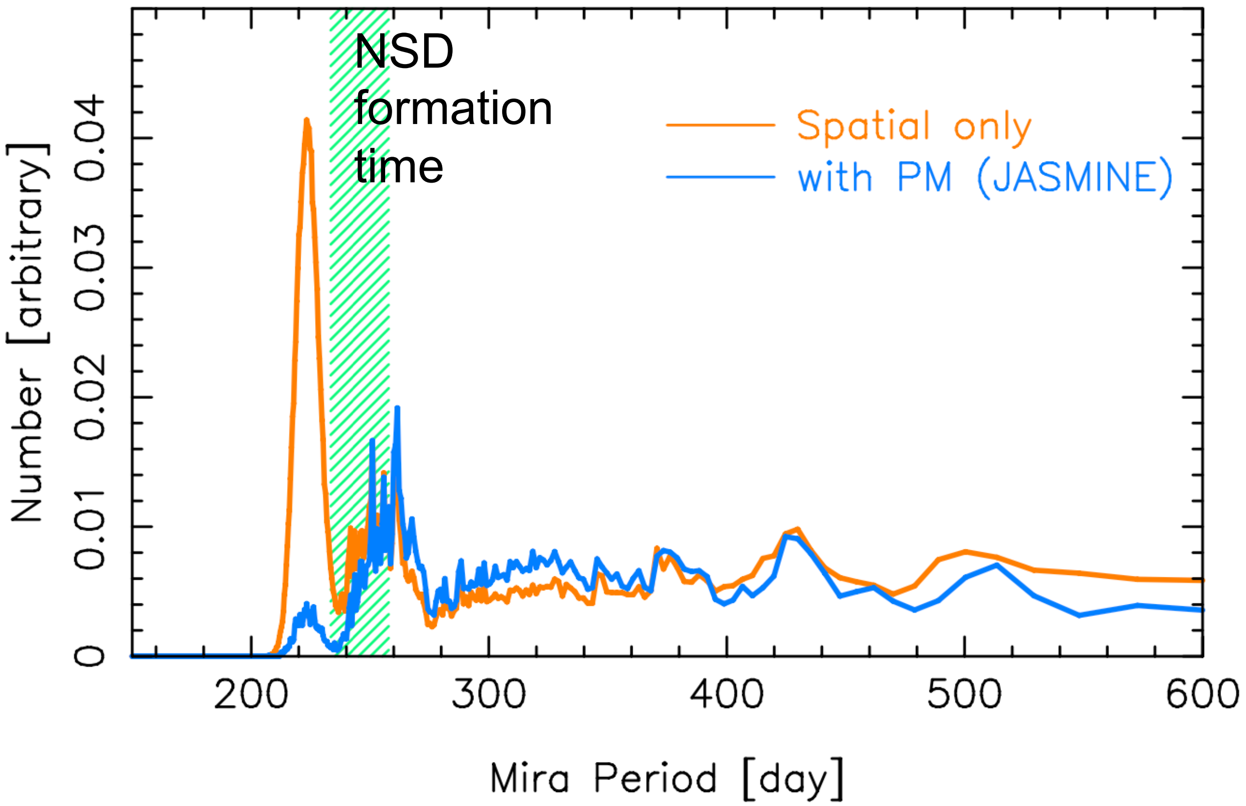


The burst of star formation in the cold nuclear disk (NSD)
= the formation epoch of the Galactic bar
Bar formation epoch ~ formation epoch of NSD
Impact to radial migration of the Sun?

Age tracers: Mira variables' period – age relation



Grady et al. (2019)



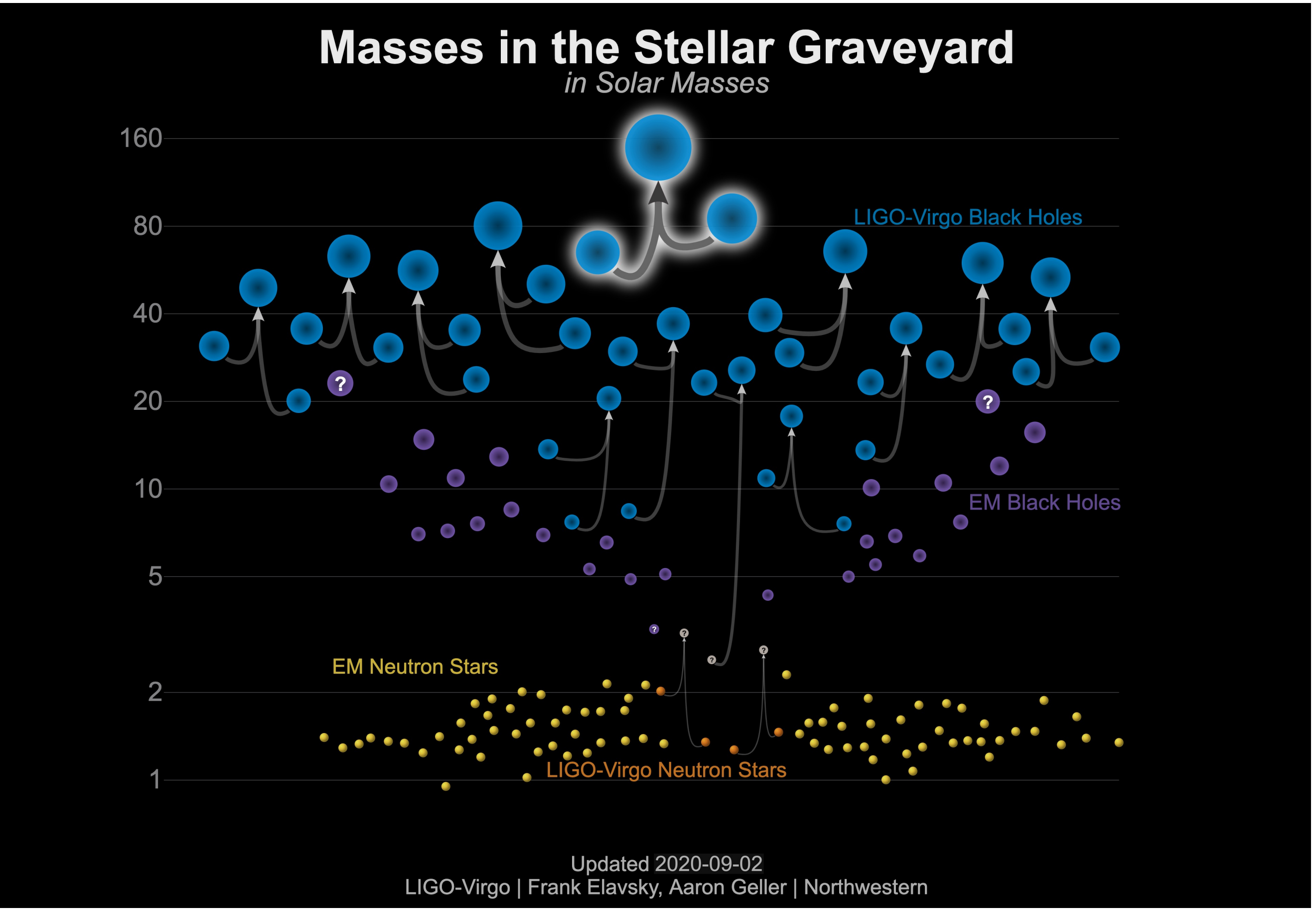
Proper motion from JASMINE will help to select NSD Miras (Baba & Kawata 2020).

Identifying Galactic Centre Miras with
PRIME (NIR bulge microlensing survey telescope
2023- led by Osaka U.)

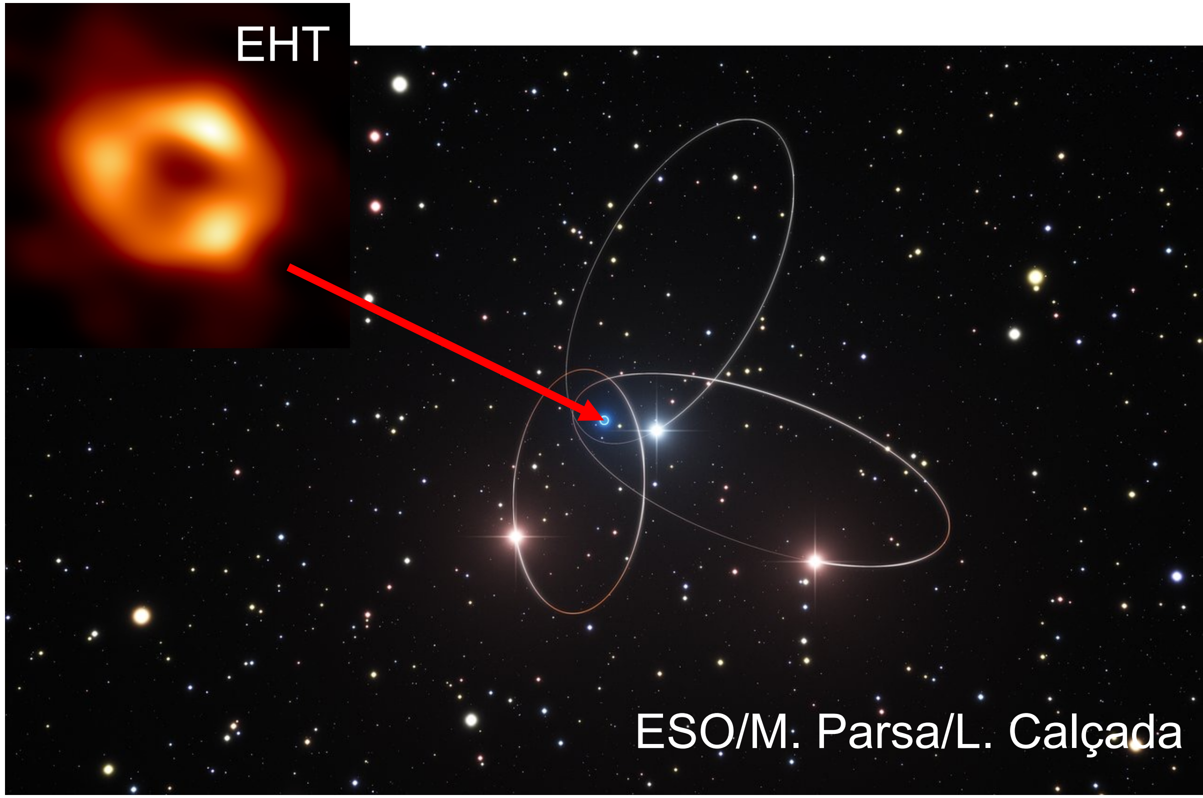
Missing Intermediate mass (100-10^5 $M_\odot$) Black Hole (IMBH)!

Stellar mass BH(<~100 $M_\odot$)

Super-massive BH
(e.g. Galactic SMBH, 4×10^6 $M_\odot$)



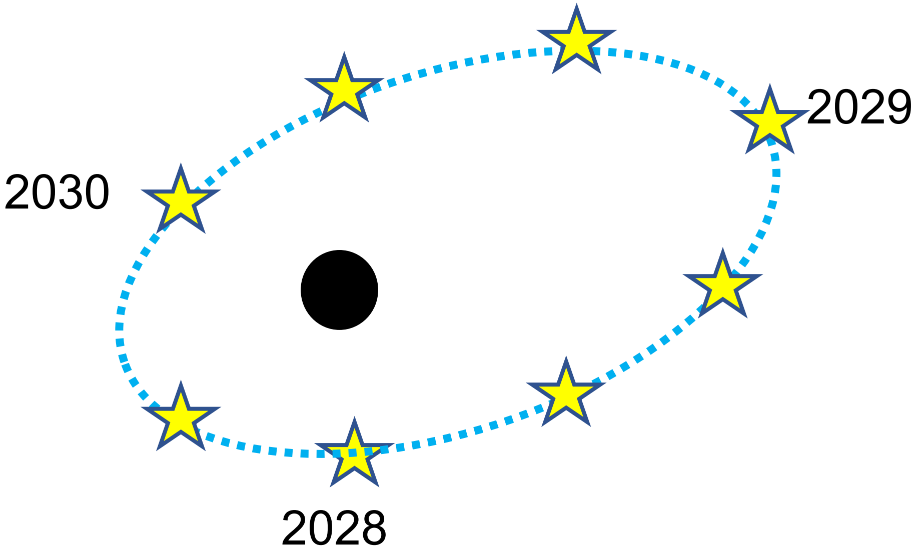
Gravitational Wave detection of BHs
(2017 Nobel Prize)



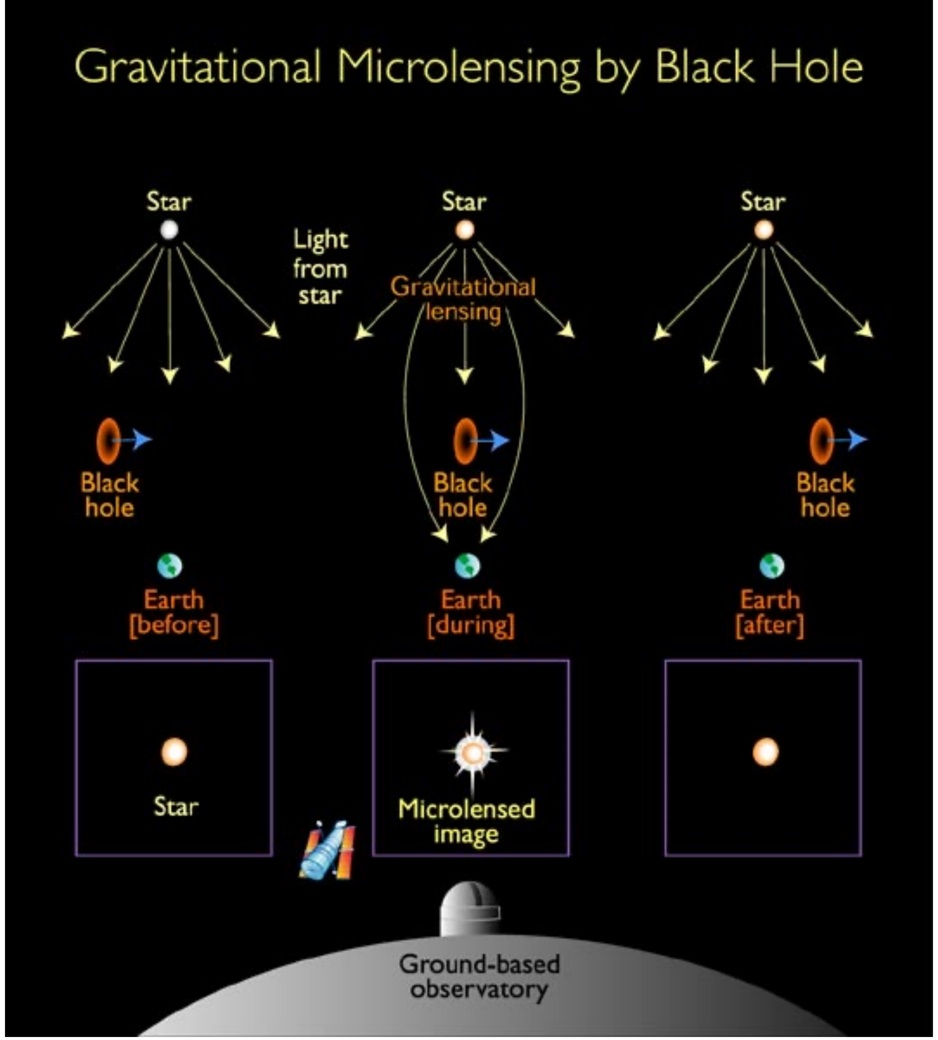
~20 years of motion of stars around the SMBH
(2020 Nobel Prize)

Hunting (IM) Black Holes in the Galactic centre?

e.g. Runaway merger IMBH near SMBH
(e.g. Portegies Zwart et al. 2006)
Remnants of dwarf galaxy mergers



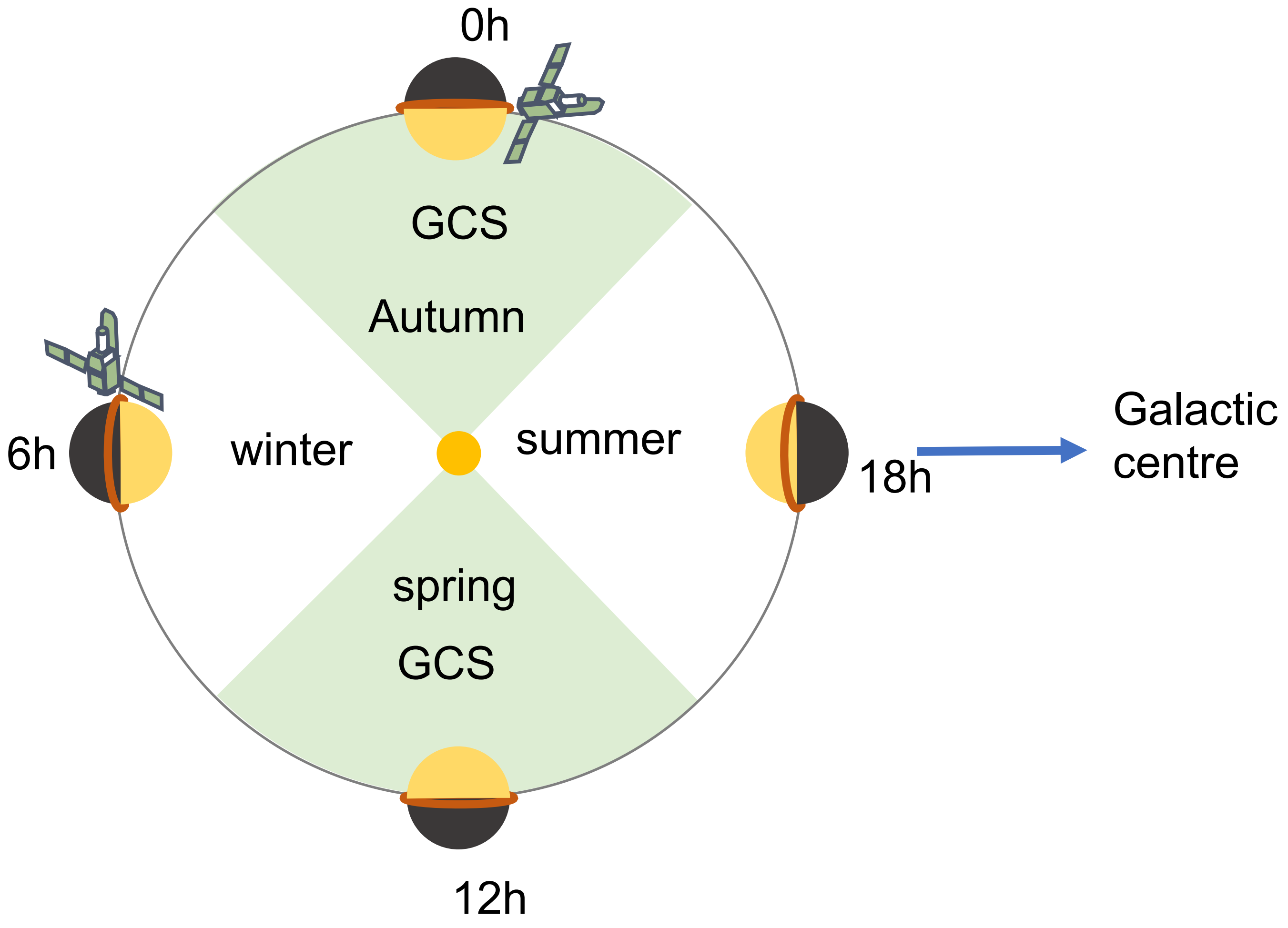
~30 non-interacting BH-star binary expected from JASMINE Galactic Centre Survey (Yamaguchi et al. 2018).



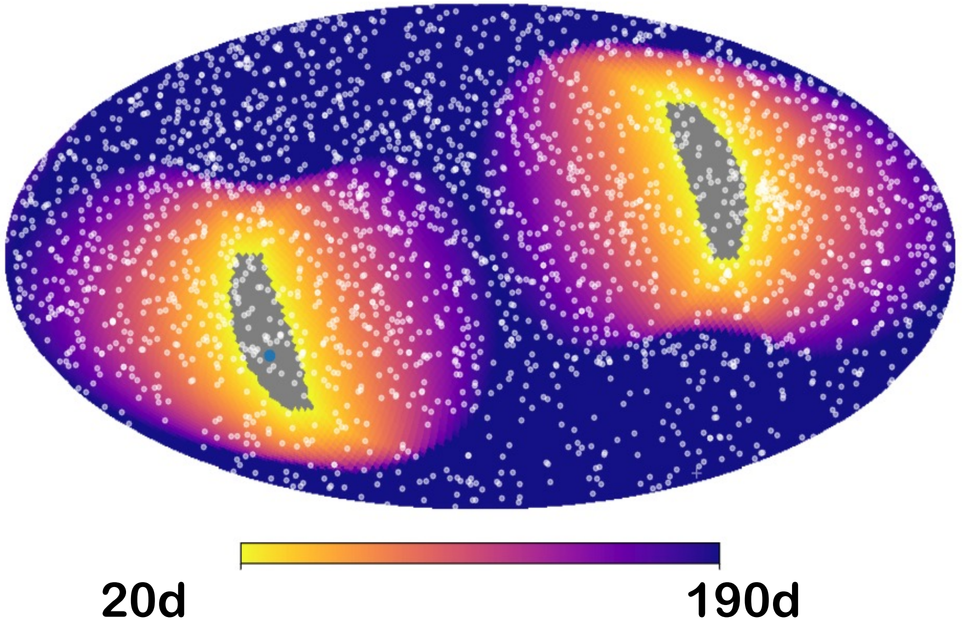
About 10 microlensing event expected. Photometric + Astrometric microlensing 1000 $M_{\odot}$ BH@d=7.5 kpc, ~700 days Θ_E~8.2 mas (Toki & Takada 2022)

Synergy with SUBARU ULTIMATE (NIR wide-field AO, faint stars populations and motion with JASMINE reference frame)

Spring and Autumn: NIR Astrometry Galactic Centre Survey (GCS)
Summer and Winter: Exoplanet survey (EPS): M-dwarf transit



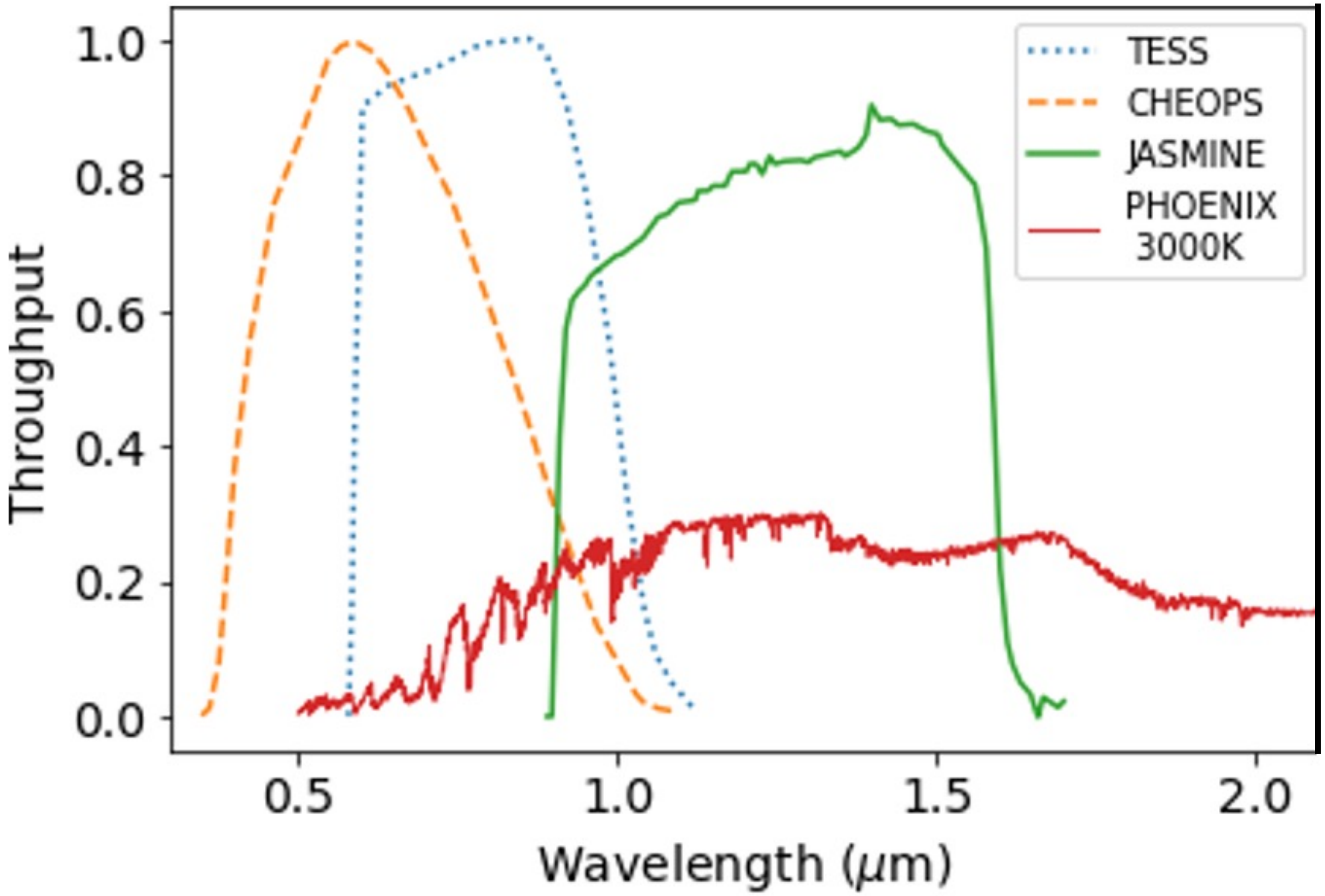
EPS potential target M-dwarf



Observable days in summer and winter

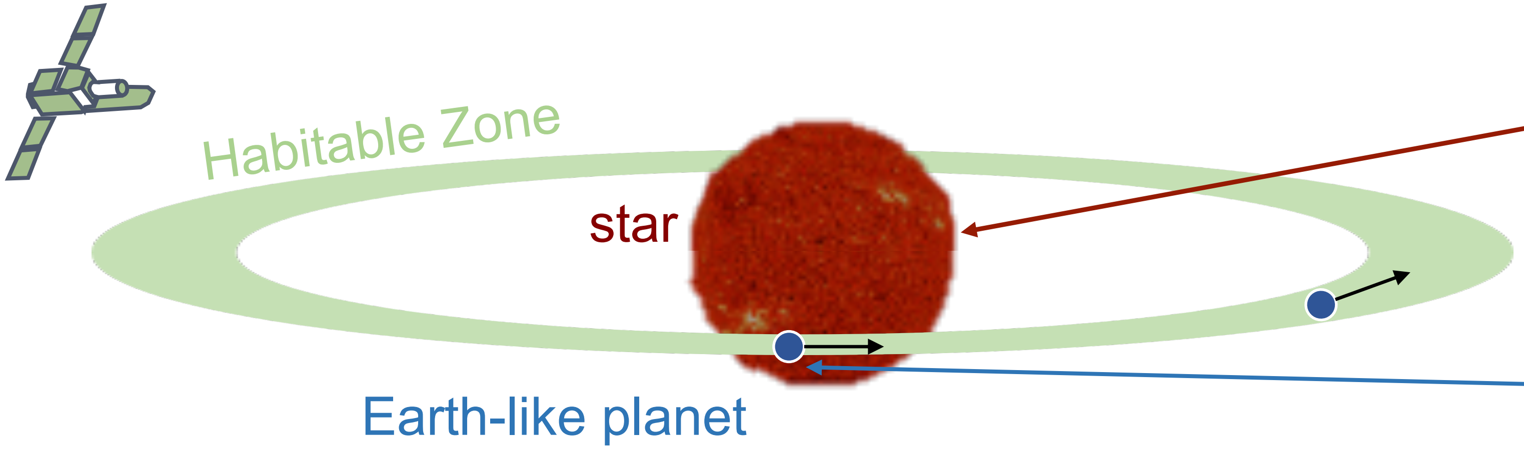
Exoplanet Science Team: **Kawahara**, Masuda, Fukui, Hirano, Kotani, Kodama, Kuzuhara, Omiya, Takahashi, Kasagi, Kawashima, Tada, Miyakawa

M-type cool stars are brighter in NIR



High-precision photometry exploration of Habitable Zone (HZ) Earth-like planets

NIR photometry



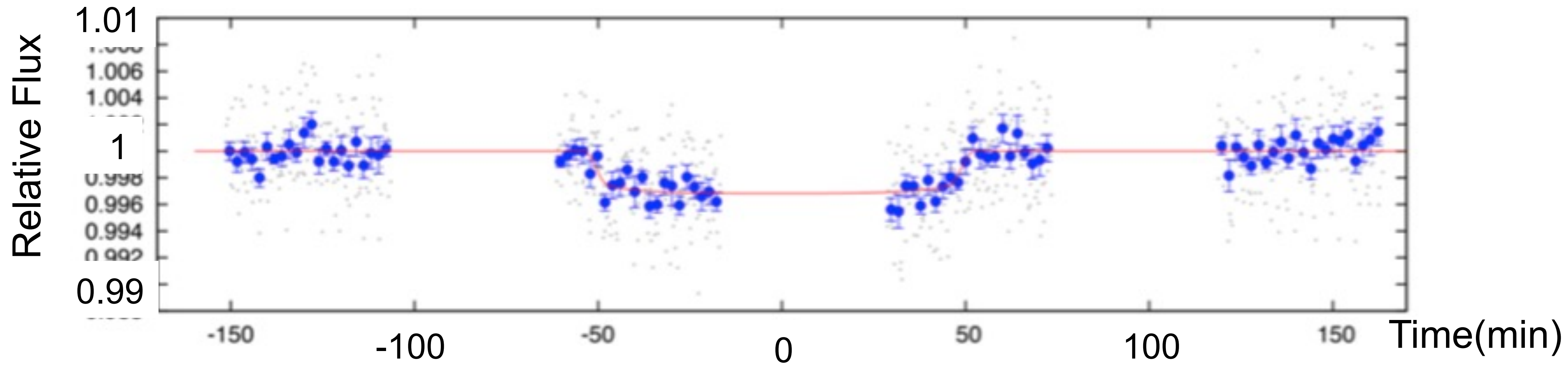
3000K, 0.2 $R_\odot$, 0.2 $M_\odot$

Earth-size transit depth=0.2-0.3%

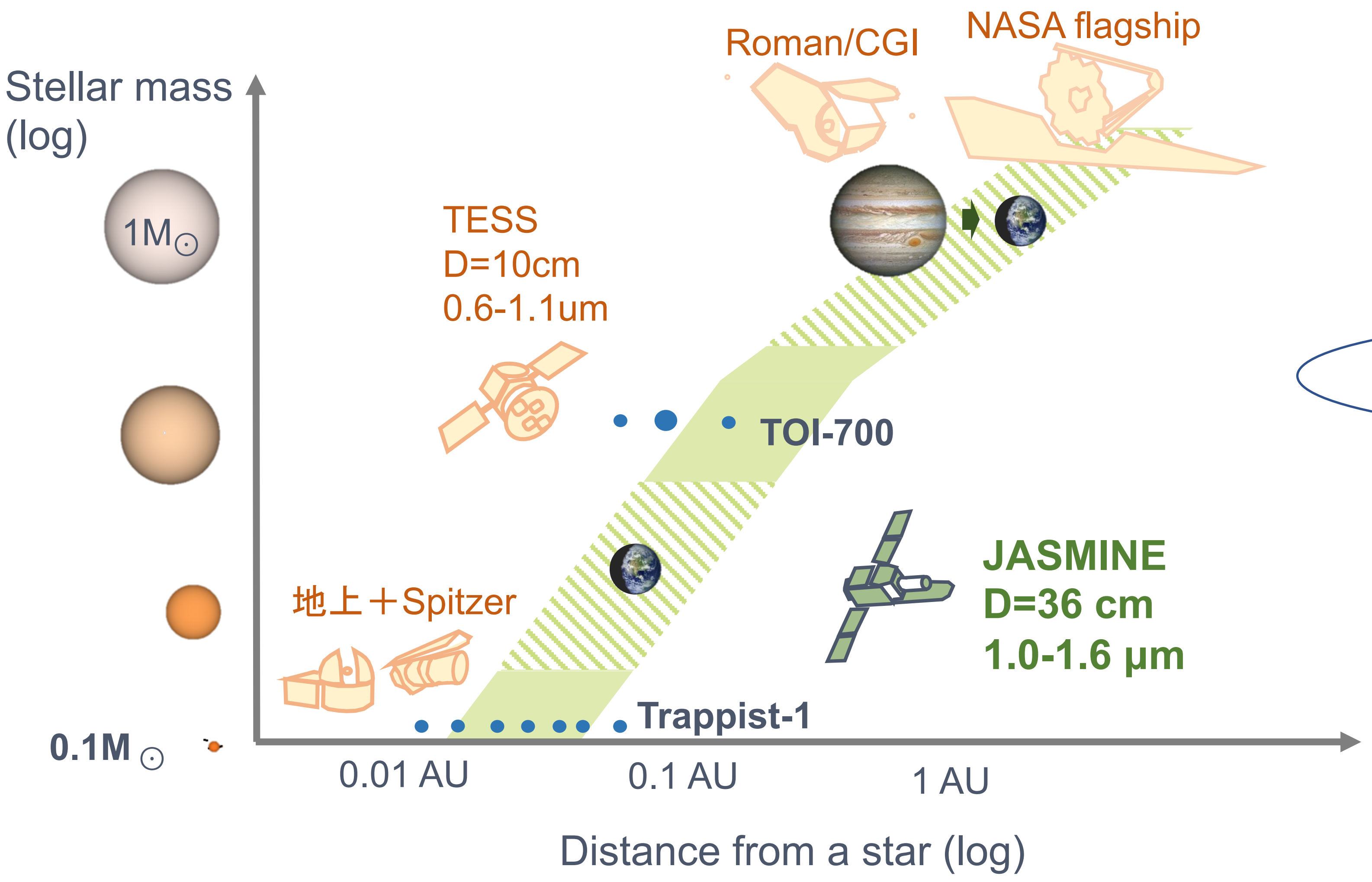
HZ orbits ~ 2 weeks

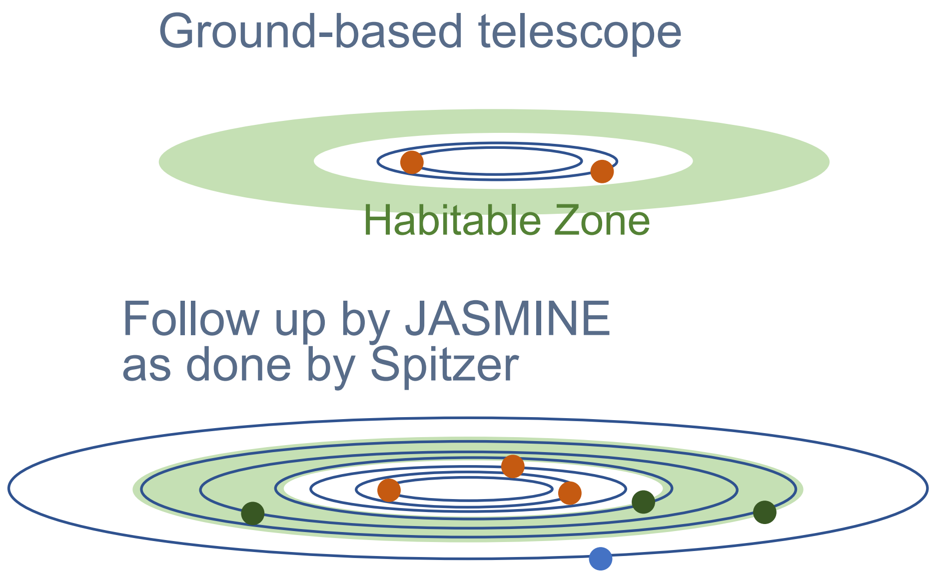
High precision space photometry monitoring

JASMINE Transit Simulation (Hirano et al.)



Niche capability of JASMINE Exoplanet survey



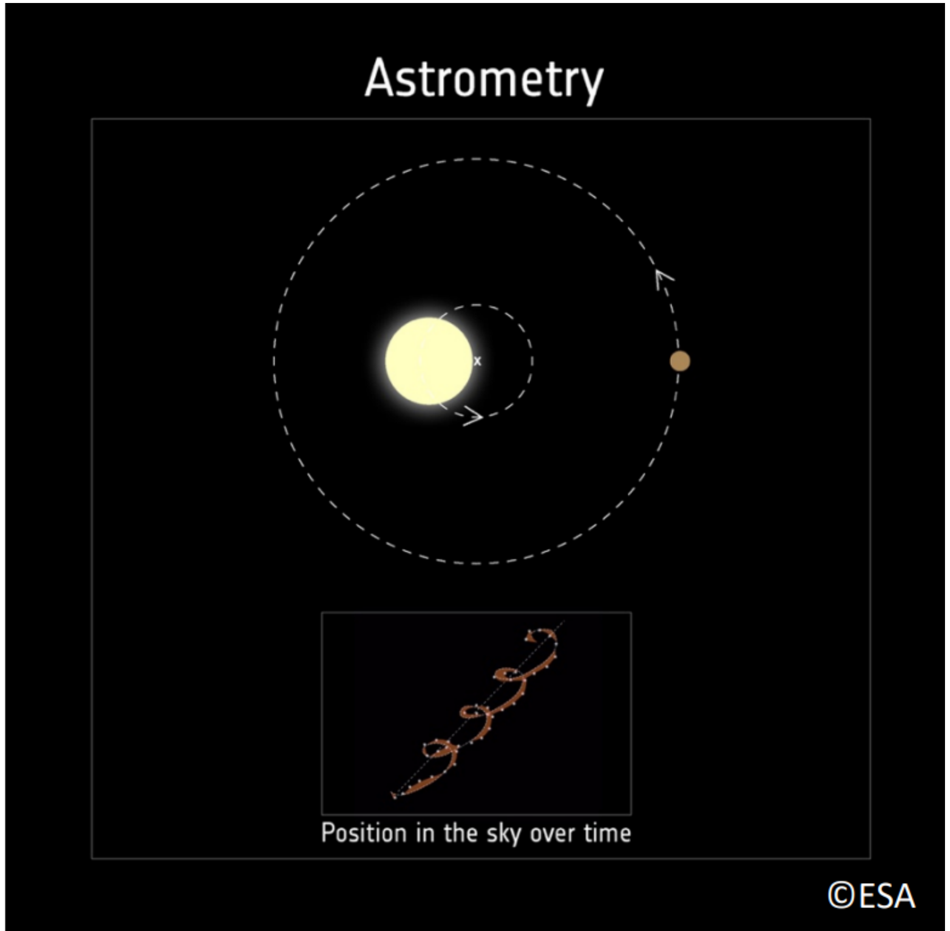


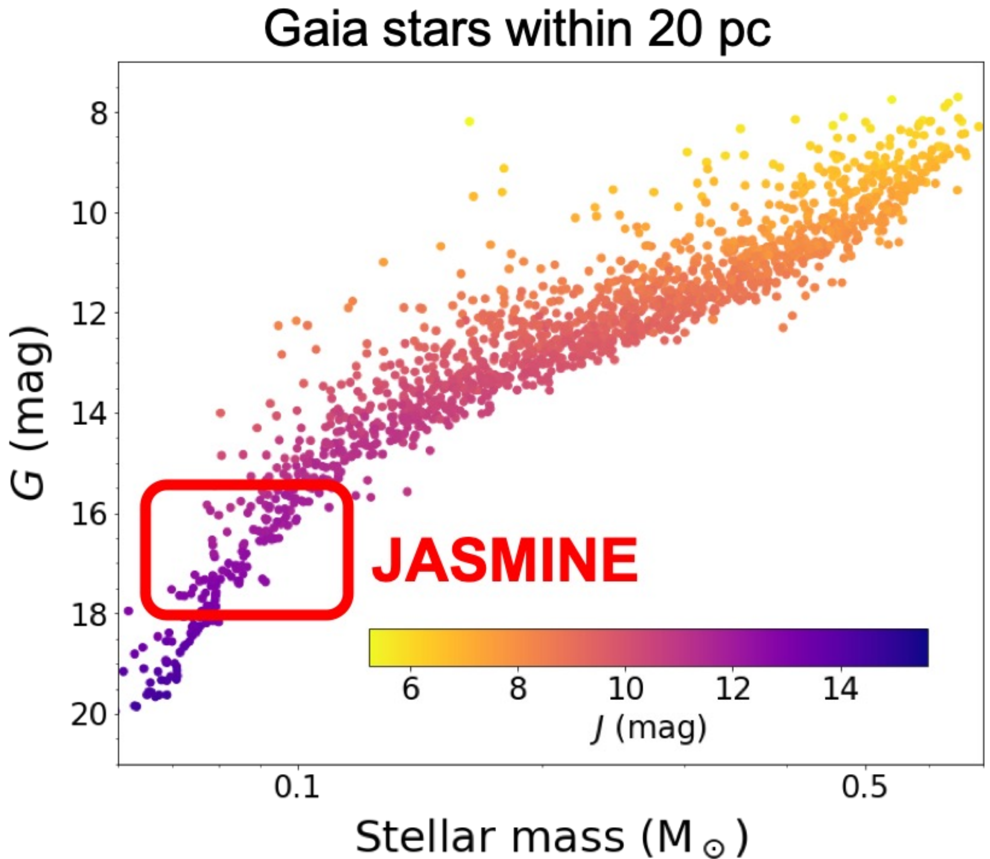
HZ transit detection rate for the system found with inner planet transit = 20-40%

2~5 HZ Earth-like planets from 25 observations

Astrometric Planet Survey

- Ultra cool dwarfs (too red for Gaia): Is there any giant planets?
- Known RV lor DI long-P system, combined with Gaia, ~20 years baseline
- Astrometric microlensing for nearby (<500 pc, very rare) microlensing sources
- **3 years of Galactic centre survey: astrometric and transit**



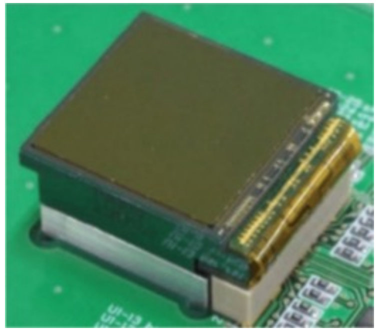


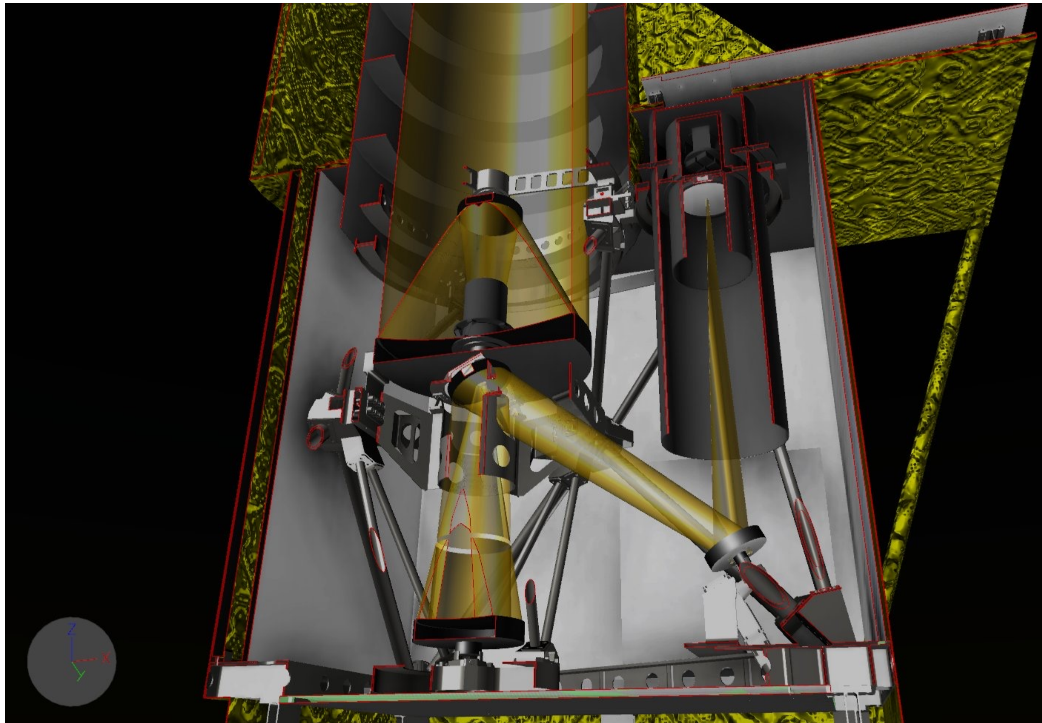
Preliminary Payload design

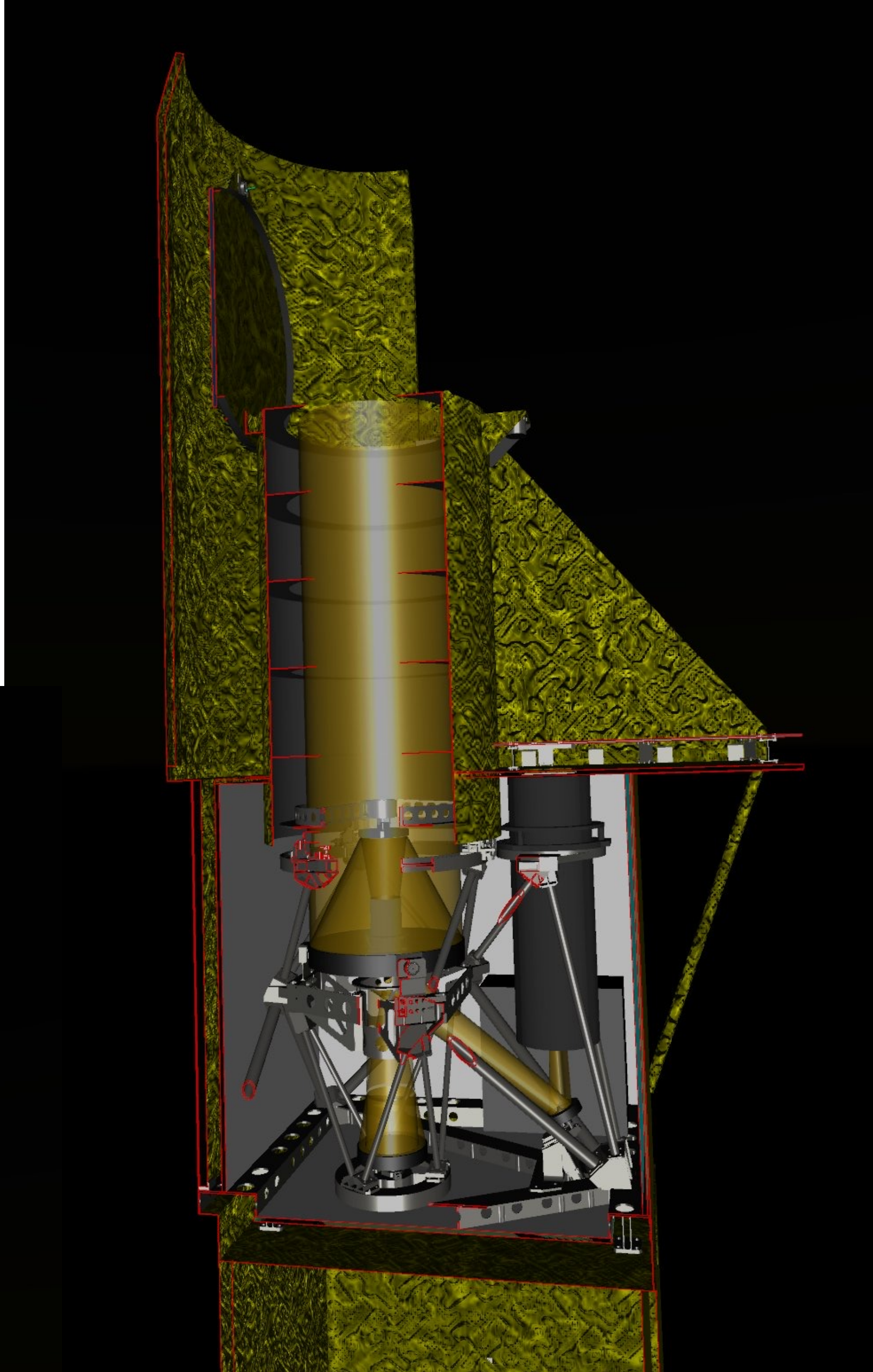
Thermal stability is crucial
Super-Super Invar alloy (coefficient of thermal expansion)
$0 \pm 5 \times 10^{-8}$ /K
Mirrors of CLEARCERAM®-Z EX (CTE: $0 \pm 1 \times 10^{-8}$ /K)
Telescope temperature control within 278±0.1 K for 50 min.

2x2 New InGaAs NIR detector (1920x1920 pix, NAOJ)

Flat calibration for inter- and intra-pixel uniformity is crucial.
Flat light source on board (Kotani et al.)

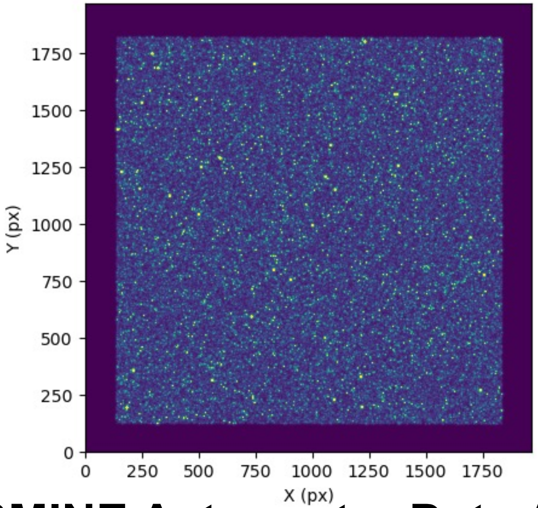




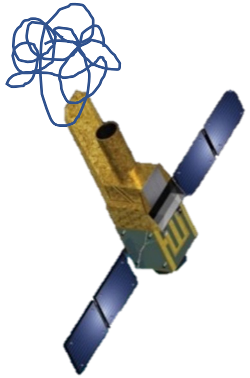


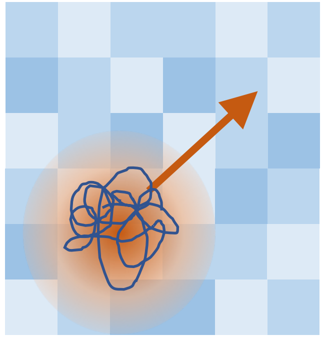
Astrometric and photometric accuracy with many images, end-2-end simulation team:
Japan: Ohsawa, Kamizuka, Kawahara, Hirano, Aizawa, Miyakawa, Ramos, Yamada, Kataza et al.
ARI-Heidelberg: Michael Bierman, Wolfgang Löffler et al.

JASMINE Image Simulator (JIS)

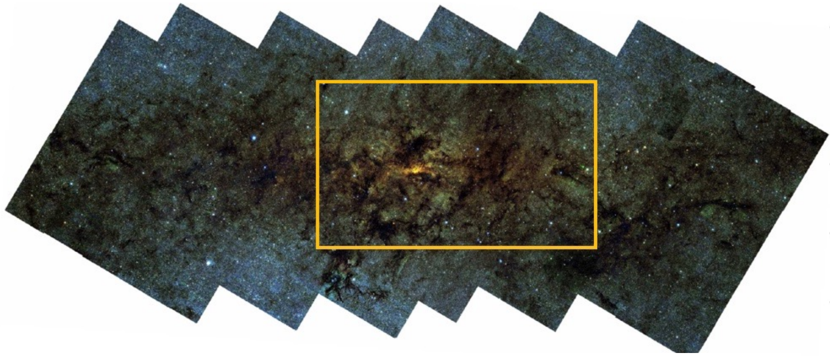


Wave Front Error (PSF, optical distortion chromatic aberration), Detector (inter/intra pixel sensitivity, pixel distortion, noise), Attitude Control Error, Aberration

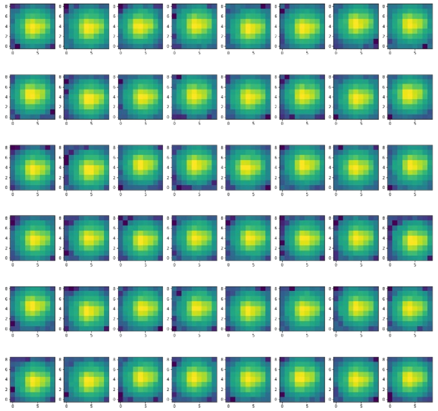




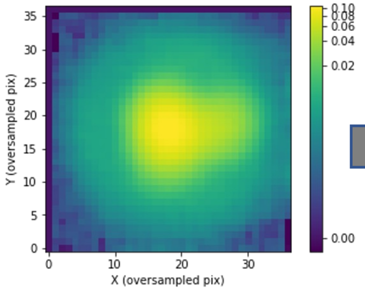
in point source catalogue (α,δ,π,μ_α,μ_δ),
From catalogue, (2MASS, Sirius, VVV),
incl. background stars
+ binary, variables, microlensing…



JASMINE Astrometry Data Analysis (JADA)



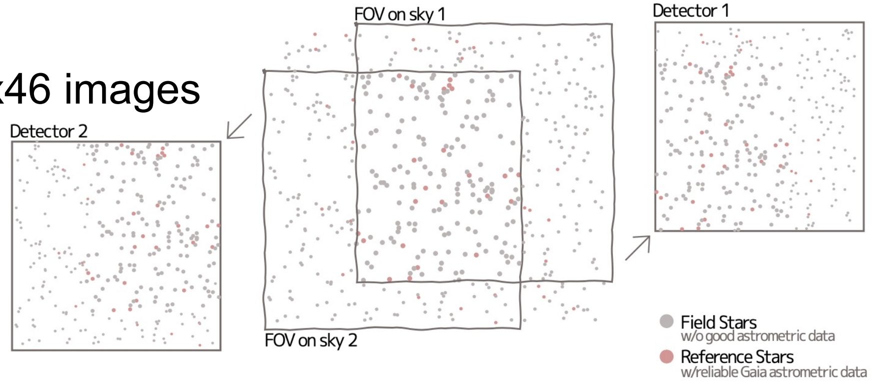
Background subtraction
Star image extraction



Build ePSF
Centroid estimates
~4 mas

1 image

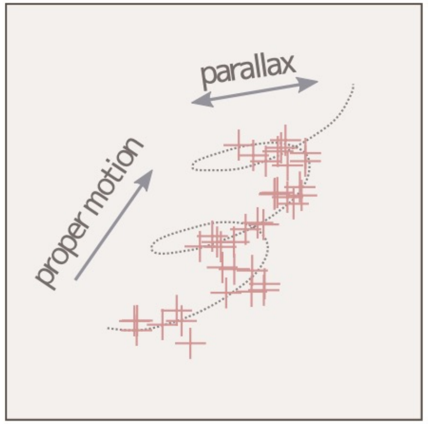
x46 images



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

1 orbit

60,000 obs



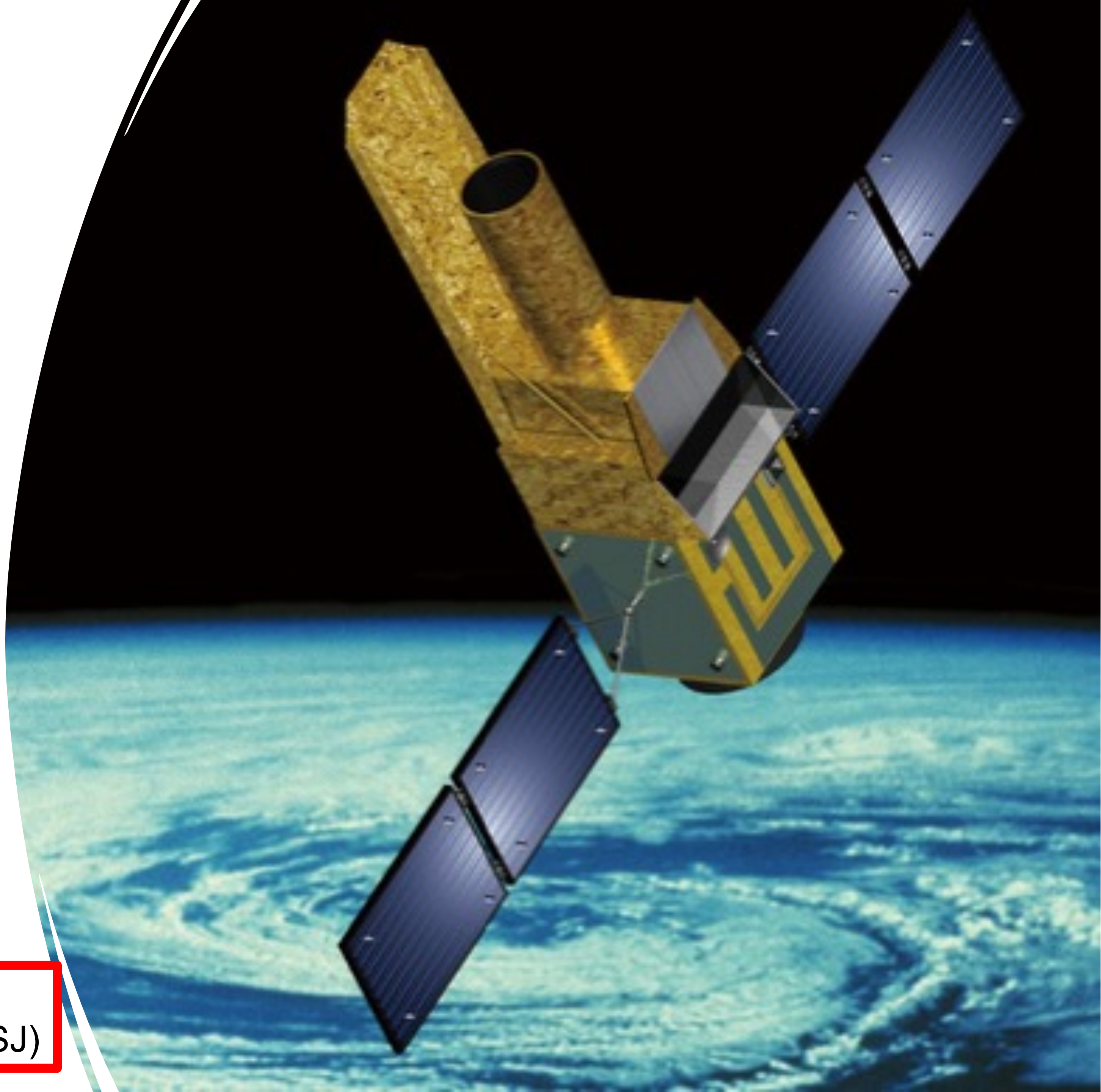
Astrometry Parameter
(α,δ,π,μ_α,μ_δ)~25 μas

3yrs data, 6,528 orbits

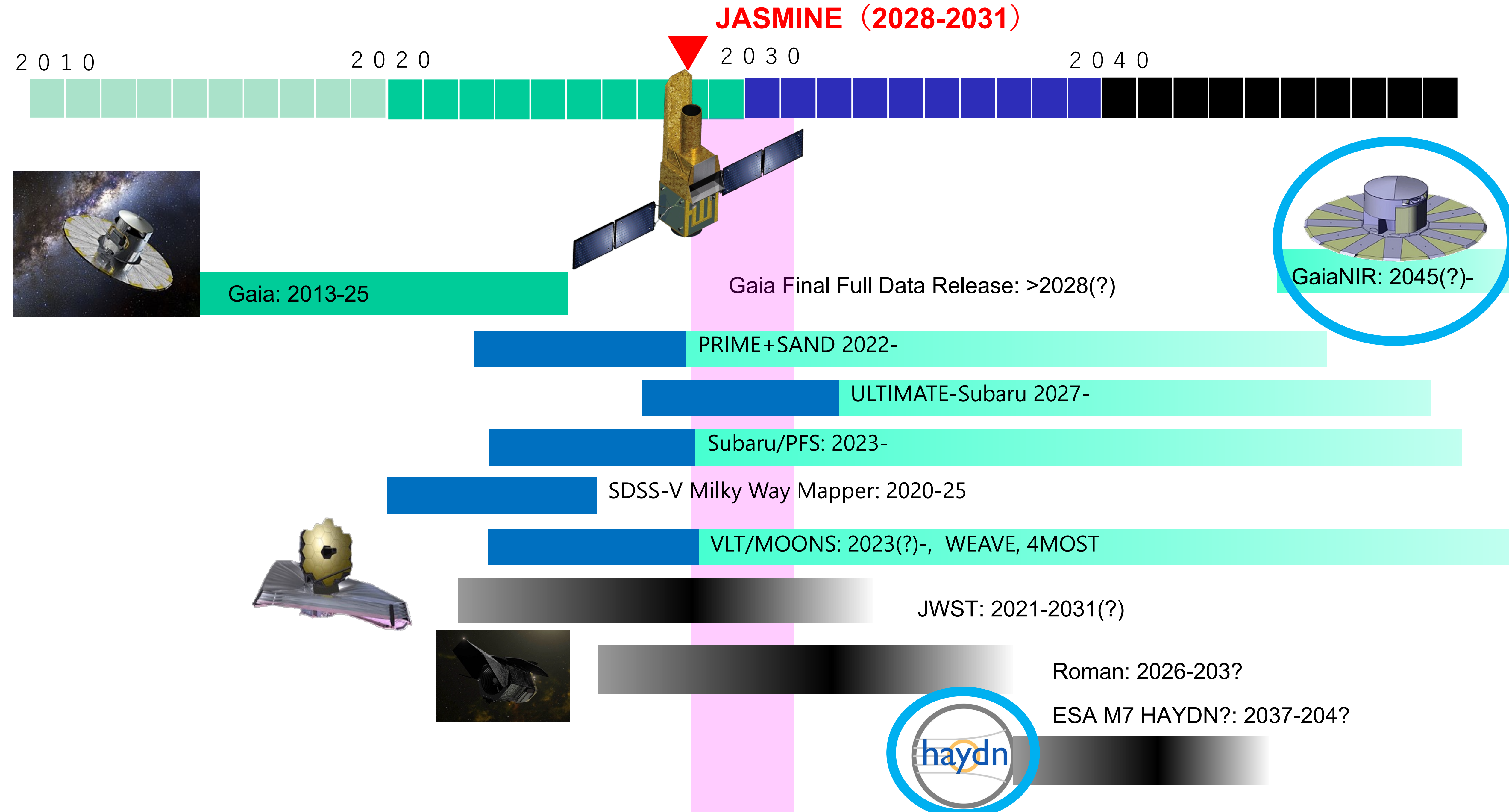
Summary

- JASMINE will be the first NIR space astrometry mission with planned launch in 2028,
  a pioneer for GaiaNIR.
- Two goals of Galactic centre archaeology and exoplanet science.
- As seen in Gaia, the astrometry mission provides the new dimension of data: the JASMINE data will be valuable for wide-range of sciences, including targeted and serendipitous targeted discovery of diverse exoplanet populations.
- You are welcome to join!

JASMINE White Paper!
(Kawata et al. arXiv:2307.05666, submitted to PASJ)

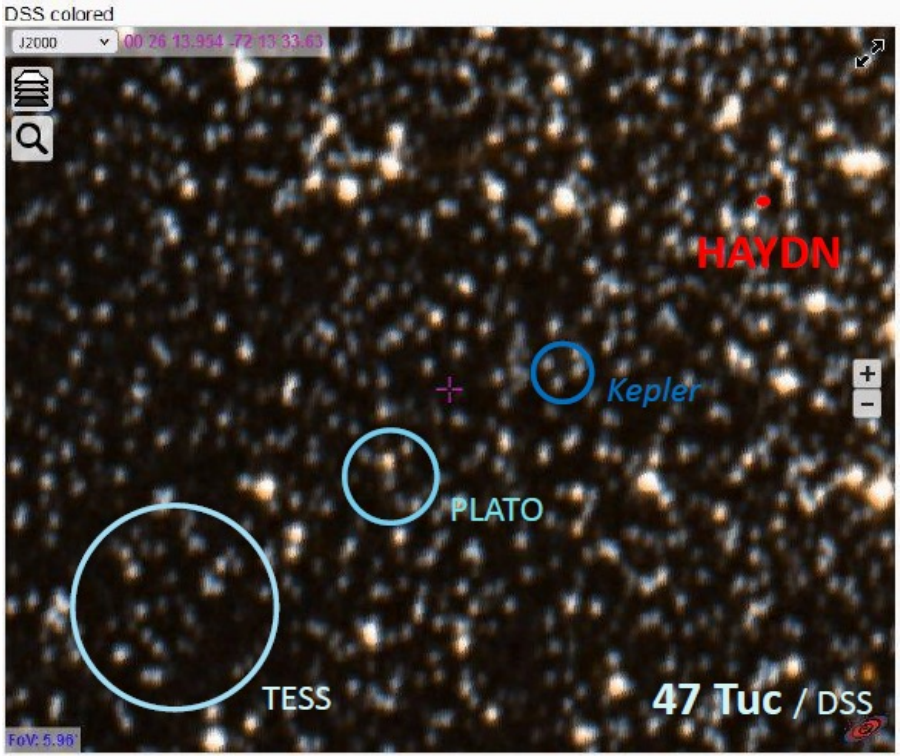


Synergy with the other missions and projects



HAYDN: High-precision AsteroseismologY of DeNse stellar fields
PI: Andrea Miglio (Bologna)
one of five ESA M7 candidates (2037 launch)

High-precision, high-cadence (1, 8 min), long photometric observations of open and globular clusters to obtain asteorseismic properties of stars.
⇒ exquisite inference for
- Characteristics of exoplanet host stars.
- Absolute age scale of stars for Galactic archaeology
- Exoplanet in star clusters



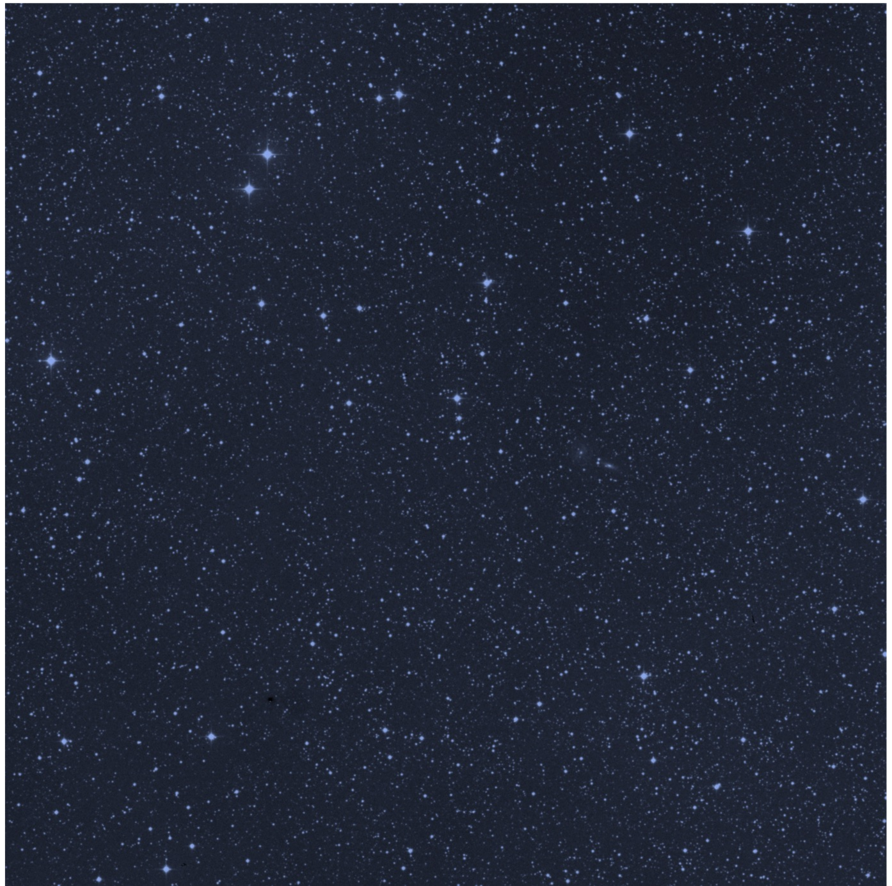
Targets (V<~16 mag)
- 47 Tuc: 18 month, M67: 9 month, ωCen: 6 months
- Baade's Window (bulge stars): 6 months
- M4, M22 and more : 3 months.

1.3m optical telescope with 9k x 9k CMOS detector, FoV : 1 deg x 1 deg

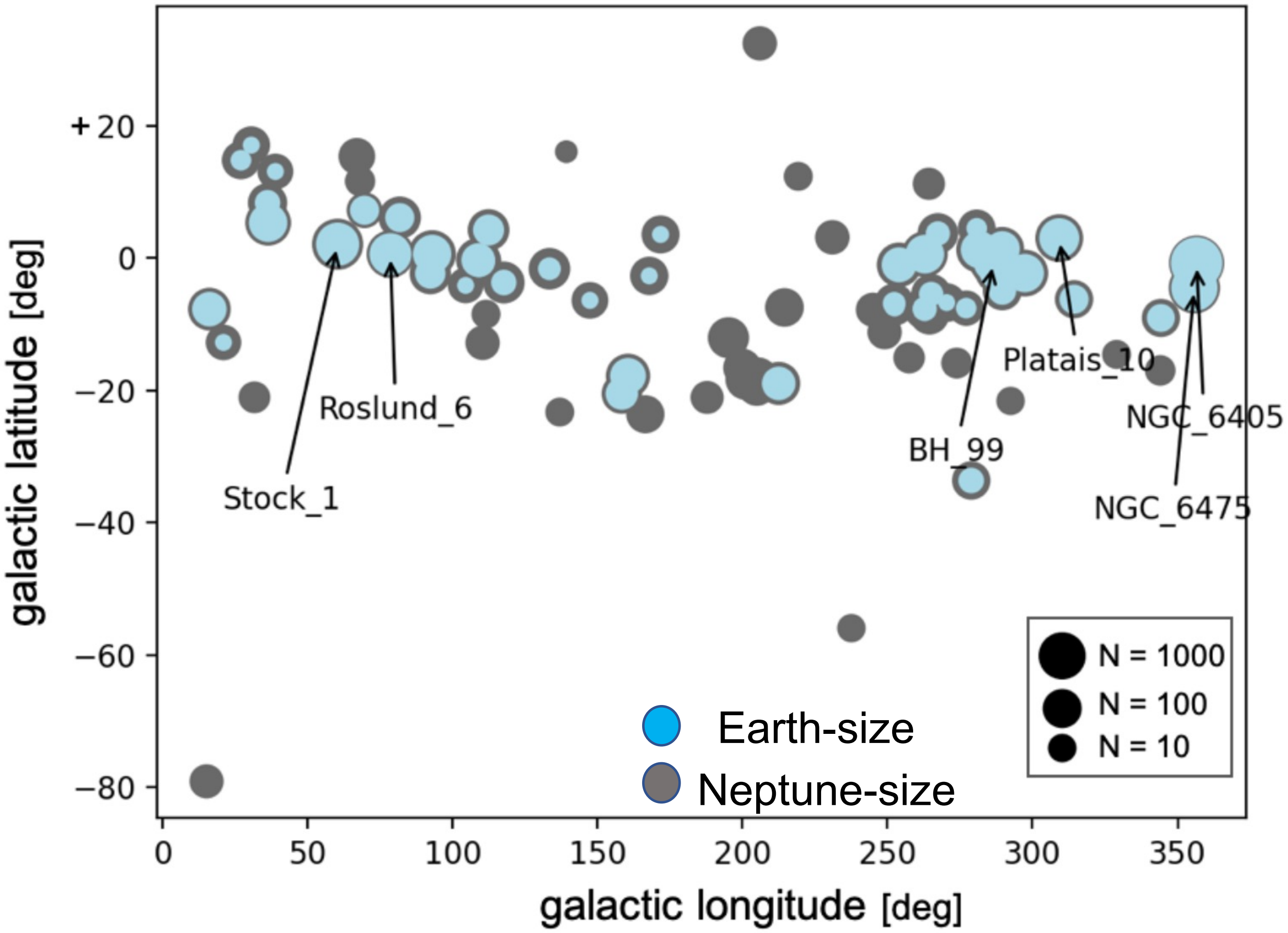
Other potential targets for exoplanet survey I: Young star clusters

- Exoplanets around ~1,000 cool young stars?
- Taking an advantage of FoV 0.55 x 0.55 deg^2, small pixel size of 0.47 arcsec

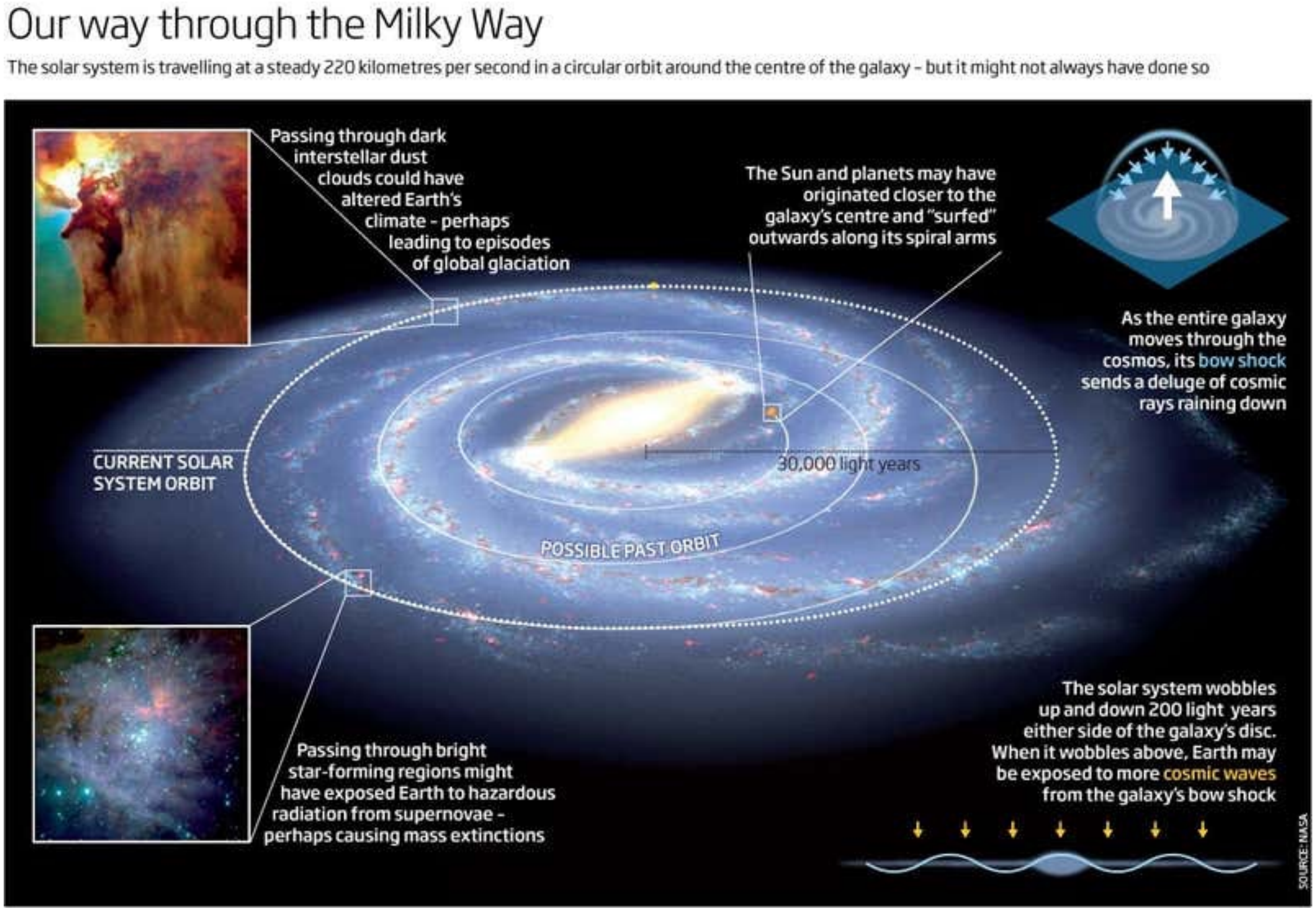
M39 (0.6 x 0.6 deg^2)



Star clusters < 500 pc

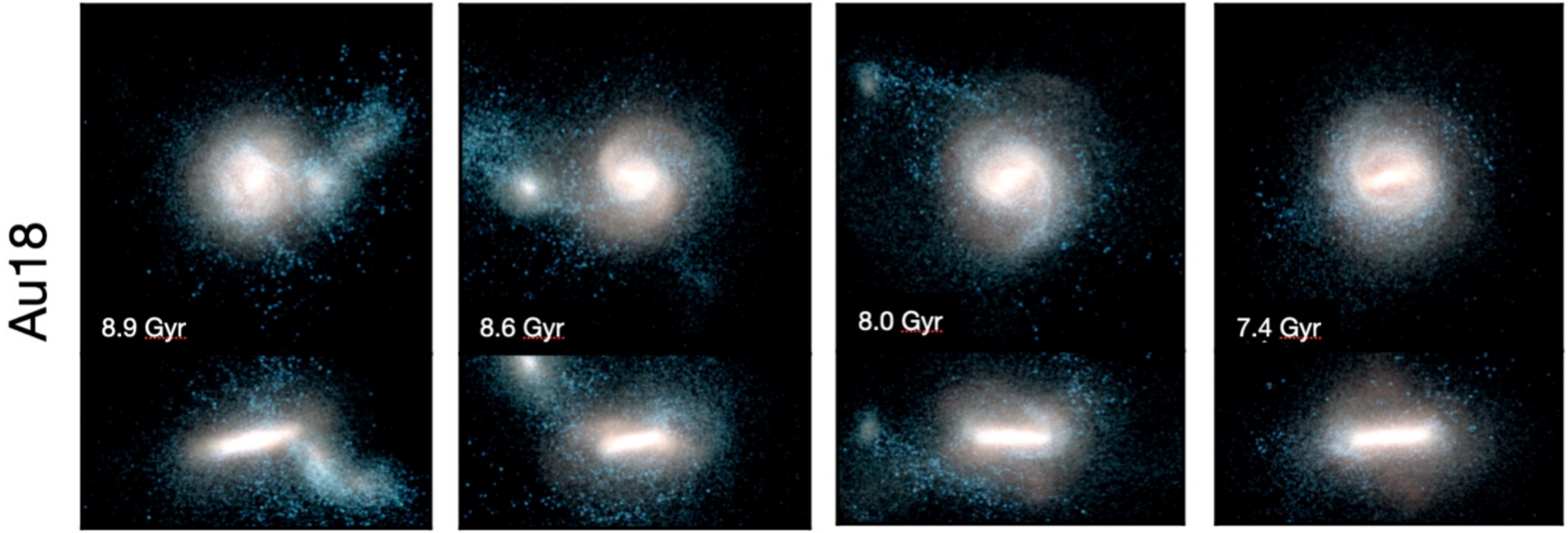


Bar (strong impact on the orbits of stars) or the Sun, which one formed earlier?
key to study the past orbit of the Sun.



New Scientist

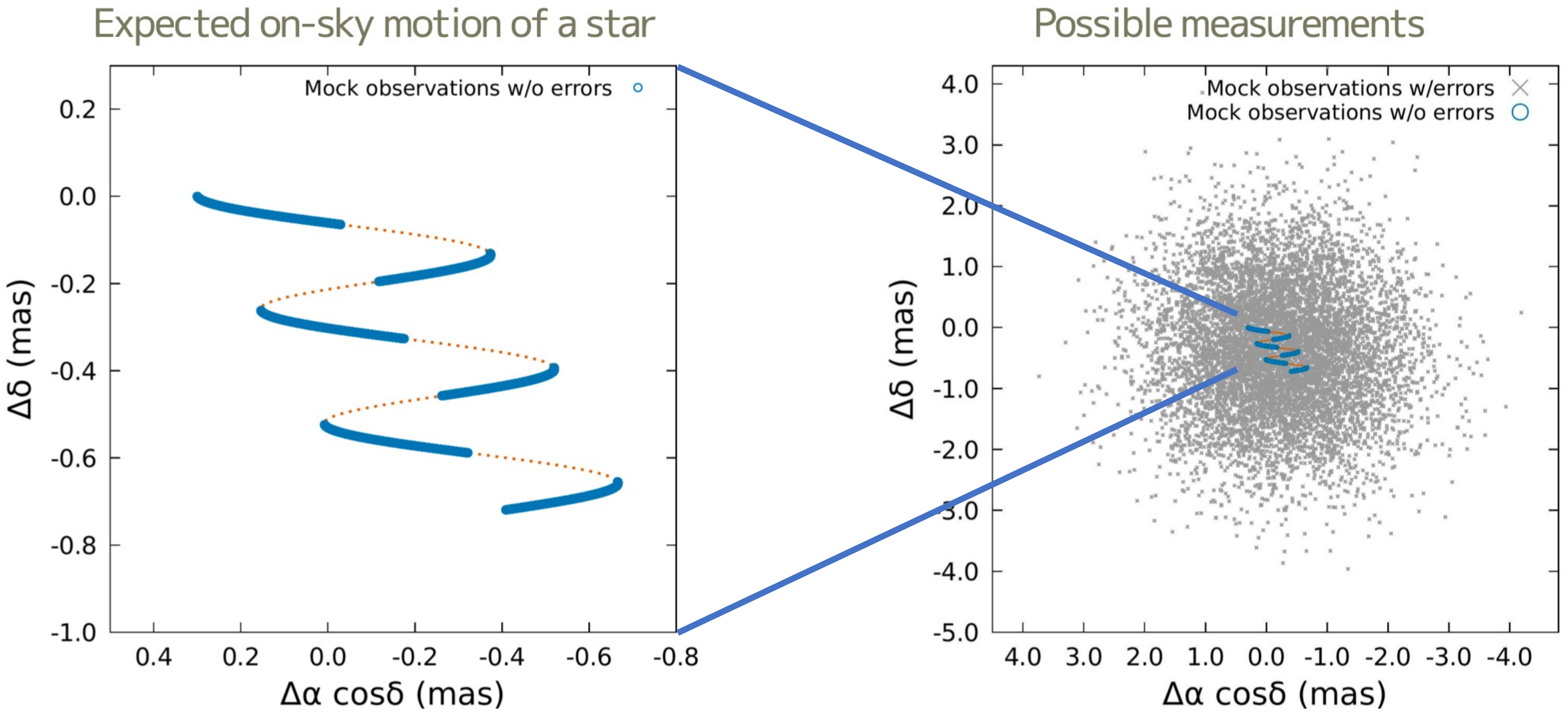
The last significant merger of the Milky Way, Gaia Enceladus Sausage (GES), at ~10 Gyr ago, also induced the bar formation?



Auriga simulation: Grand et al.

Tentative observational evidences suggest the bar formation around the same time as the GES merger. (Age metallicity distribution within the bar: Ciucă, Kawata et al. in prep.)

In more realistic mock data



ω=0.3 mas, μ=0.3 mas/yr, σ=1 mas

Credit: R. Ohsawa