µAstrometry

Exploring planets in the solar neighbourhood

Alexis Brandeker

Stockholm Observatory, Sweden

Baoquan Li (NSSC, China)
Björn Jakobsson (OHB Sweden)
Alain Leger (IAS, France)
Fabien Malbet (IPAG, France)
Feng Tian (Tsinghua univ, China)
Bart Vandenbussche (KU Leuven, Belgium)
Jianfeng Zhou (Tsinghua univ, China)
Ding Chen (NSSC, China)

Background image: wallsank.com

µAstrometry

A mission to detect planets around the *200 nearest* solar-like stars by ultra-high precision astrometry (~µarcsec)

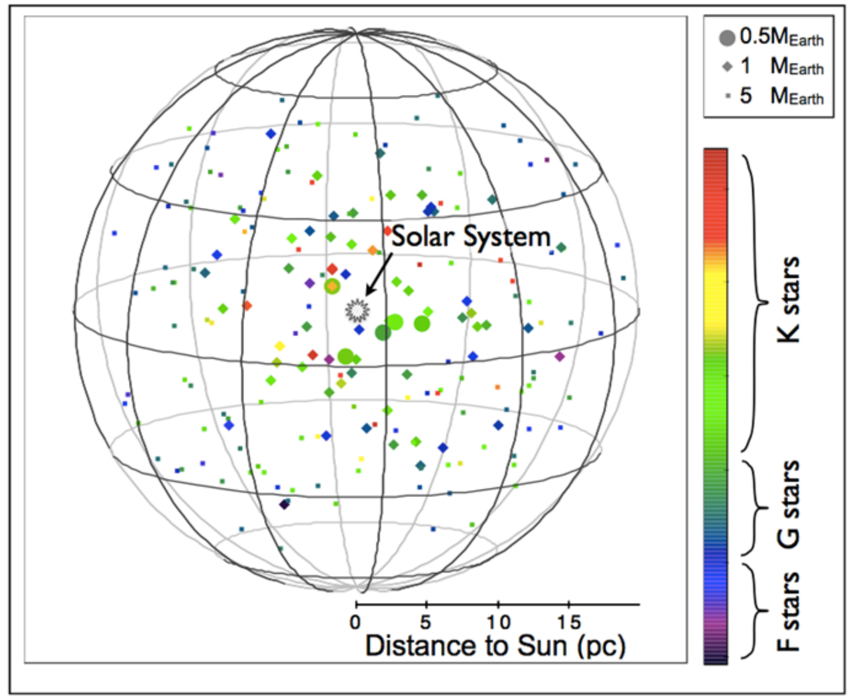
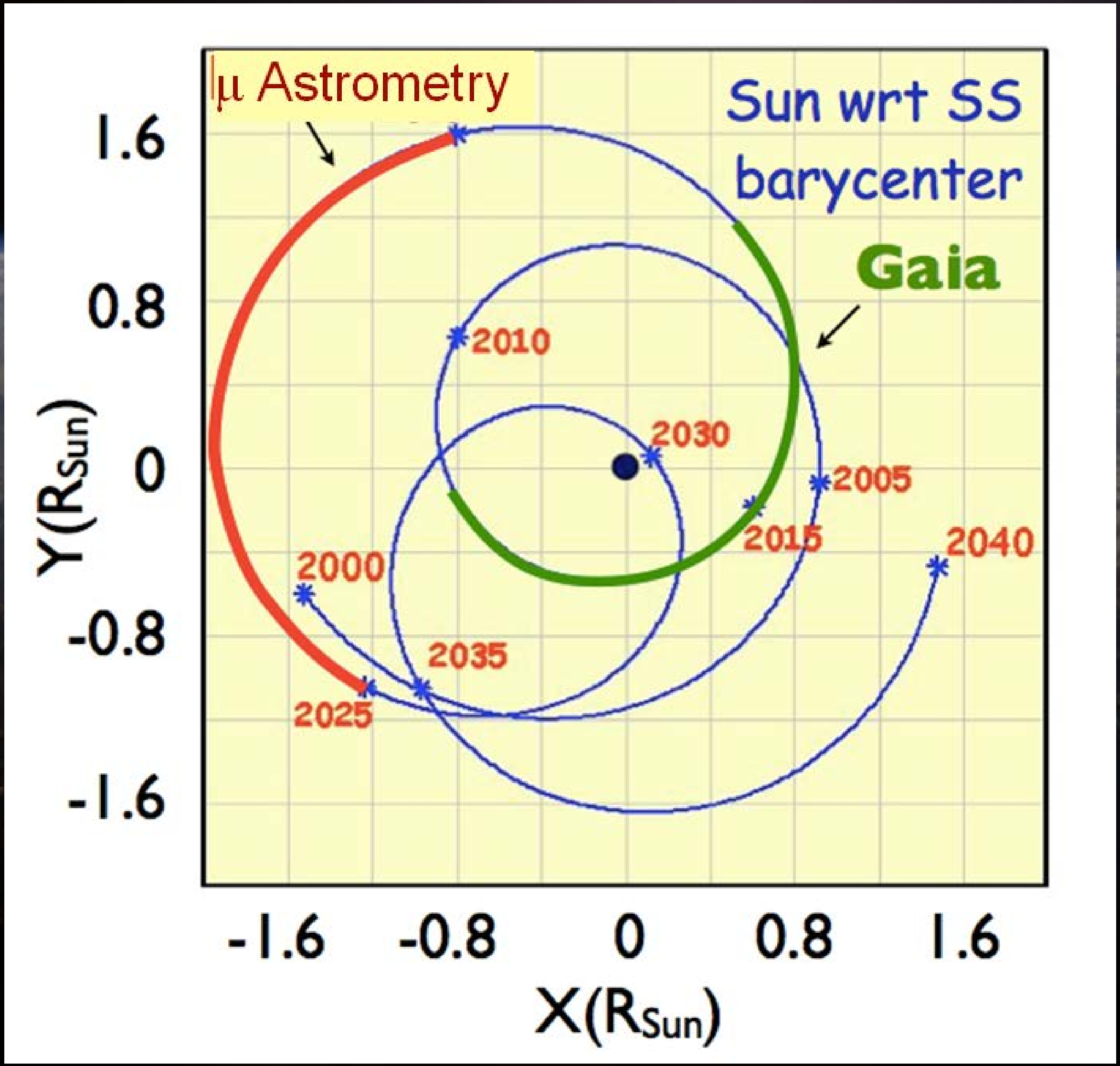


Fig.1: A 3D representation of the F, G, K stars within 15 pc from us.

Astrometric signal



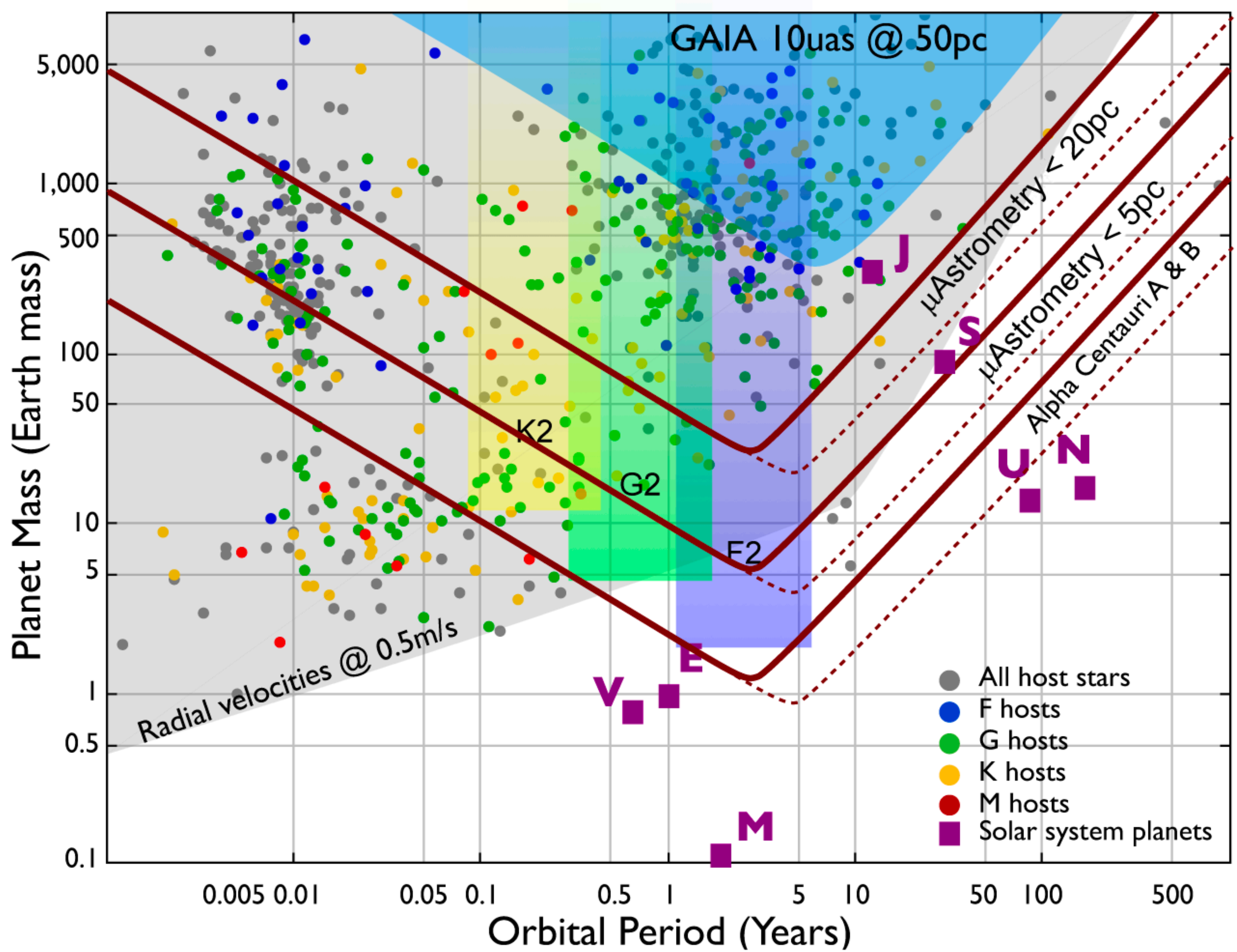
Why nearby systems?

- Best opportunities for high-S/N studies of planets
- Prime targets for direct detection and future *spectroscopic* missions (e.g. TPF, Darwin)
- Strongest astrometric signals for given planets:

$$A \sim 3\mu as\ (M_P/M_{Earth})\ (a/AU)\ (D/pc)^{-1}$$

Why astrometry?

- Transits searches will not find the *nearest* planets because of required geometry
- Radial velocity most sensitive to *shorter period planets* around *"nice" stars*
- The astrometric sensitivity *increases* with orbital period, up to the mission duration – ideal for planets in the *"Habitable Zone"*
- GAIA will find thousands of massive planets, but will saturate for nearby stars (V<6 mag)

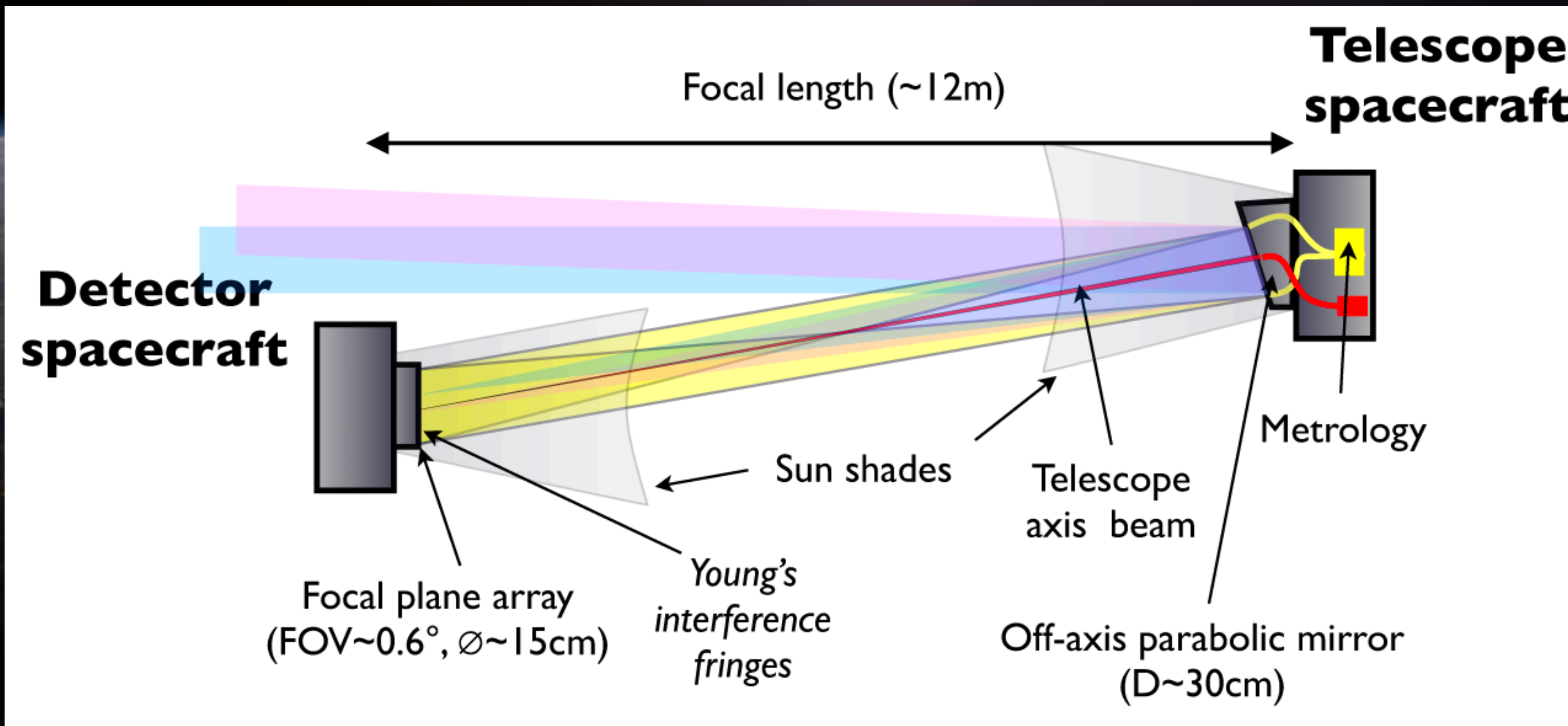


GAIA 10uas @ 50pc
µAstrometry < 20pc
µAstrometry < 5pc
Alpha Centauri A & B
Radial velocities @ 0.5m/s
K2
G2
F2
J
S
U
N
E
V
M
All host stars
F hosts
G hosts
K hosts
M hosts
Solar system planets
Planet Mass (Earth mass)
Orbital Period (Years)
5,000
1,000
500
100
50
10
5
1
0.5
0.1
0.005
0.01
0.05
0.1
0.5
1
5
10
50
100
500

Primary objectives

- Exhaustively detect *all* gas giants planets in the *Habitable Zone*, i.e. jupiters, saturns (down to 50 M_{Earth}), around our 200 nearest solar-like stars
- Down to 10 M_{Earth} around the nearest 25 stars
- For α Cen A & B, sensitivity down to Earth-mass!
- Complete characterisation of orbits (inclination, eccentricity, semi-major axis, planet mass)

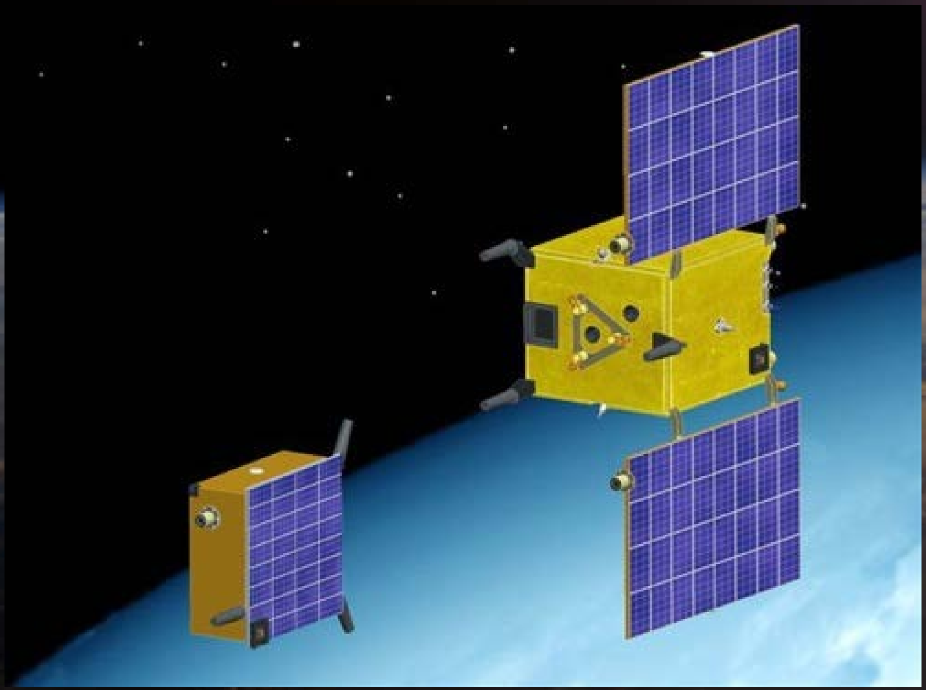
µAstrometry



Characteristics

- Mirror module and focal plane array module
- Spacecraft separation 12m
- Precision formation flying (< 1 cm)
- 30 cm mirror with tip-tilt at 50 Hz
- Precision focal plane array metrology ($<4\times10^{-5}$ pix)
- L2 orbit, 3 year mission

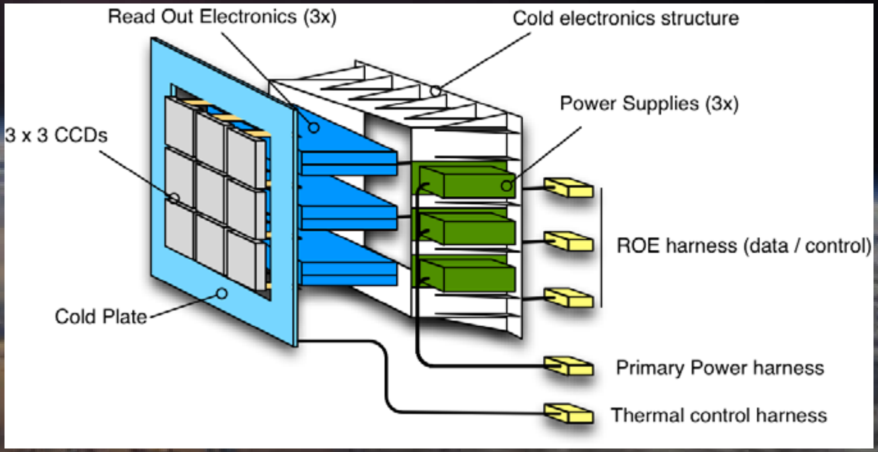
PRISMA

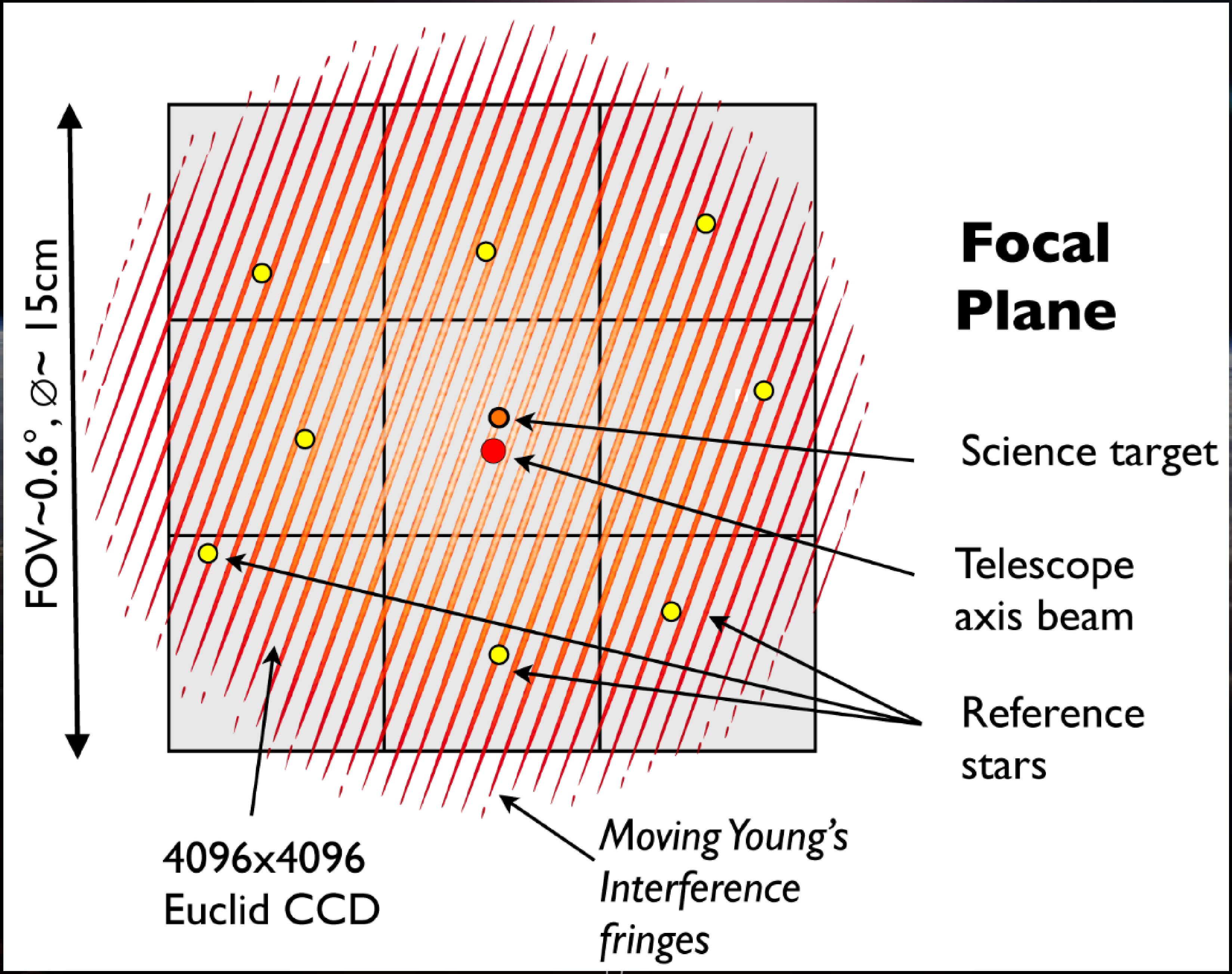


Cost-effective: space-proven formation-flying with off-the-shelf hardware. Estimated cost for platform with modifications to suit µAstrometry: 20 M€

Precision metrology

- 3×3 array of CCDs developed for EUCLID
- Position accuracy of metrology system achieved in lab: <4×10^{-5} pixel




Focal Plane
FOV~0.6°, ∅~ 15cm
Science target
Telescope axis beam
Reference stars
4096x4096 Euclid CCD
Moving Young's Interference fringes

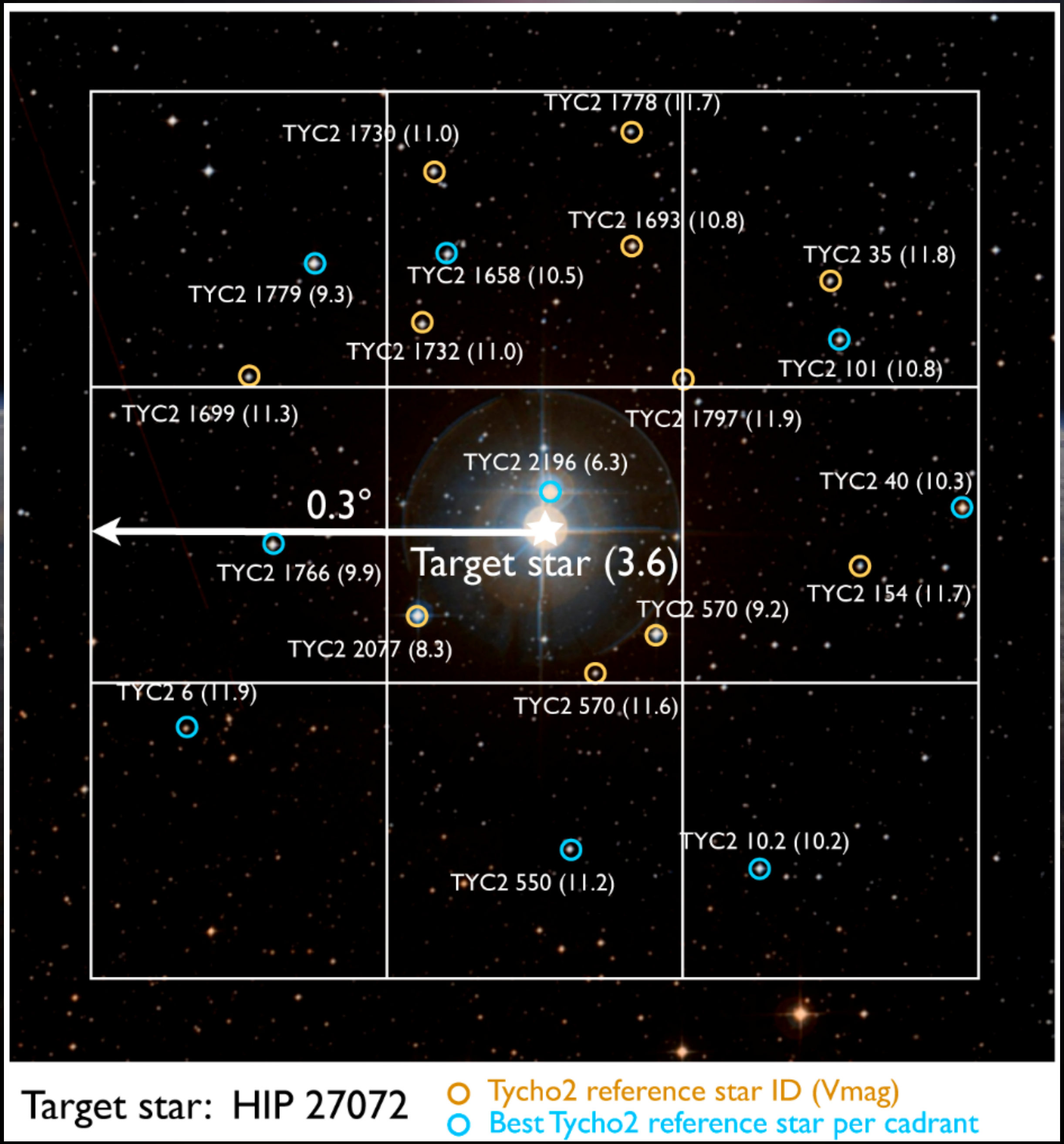
Summary

- μAstrometry has unique science capabilities not found in existing and planned exoplanet missions

- μAstrometry is proposed to build upon the existing and proven formation-flying platform PRISMA, providing a very cost efficient solution

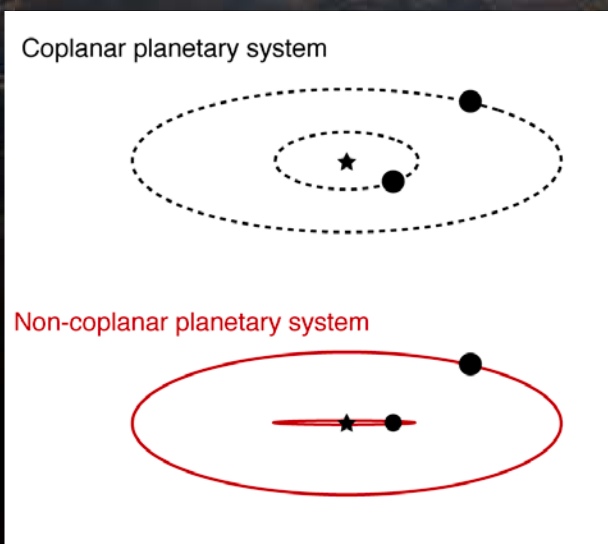
- The required metrology precision has been proven in the lab

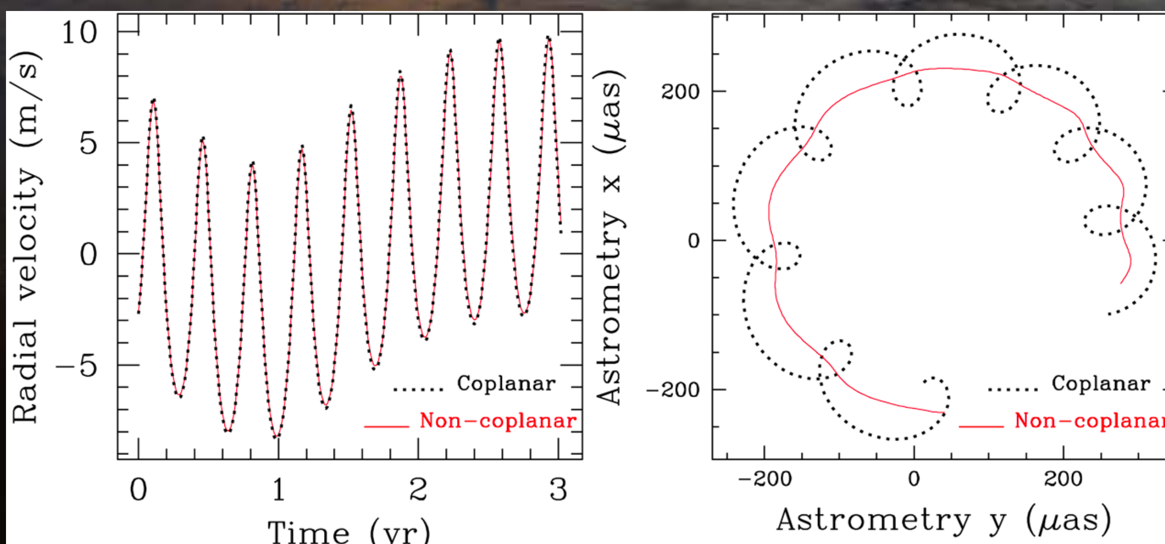
Small mission, big impact


TYC2 1778 (11.7)
TYC2 1730 (11.0)
TYC2 1693 (10.8)
TYC2 35 (11.8)
TYC2 1658 (10.5)
TYC2 1779 (9.3)
TYC2 1732 (11.0)
TYC2 101 (10.8)
TYC2 1699 (11.3)
TYC2 1797 (11.9)
TYC2 2196 (6.3)
TYC2 40 (10.3)
0.3°
TYC2 1766 (9.9)
Target star (3.6)
TYC2 154 (11.7)
TYC2 570 (9.2)
TYC2 2077 (8.3)
TYC2 6 (11.9)
TYC2 570 (11.6)
TYC2 10.2 (10.2)
TYC2 550 (11.2)
Target star: HIP 27072
Tycho2 reference star ID (Vmag)
Best Tycho2 reference star per cadrant

Science questions

- How frequent are planetary systems in the HZ?
- What is the architecture of planetary systems in the HZ?





PRISMA accuracy

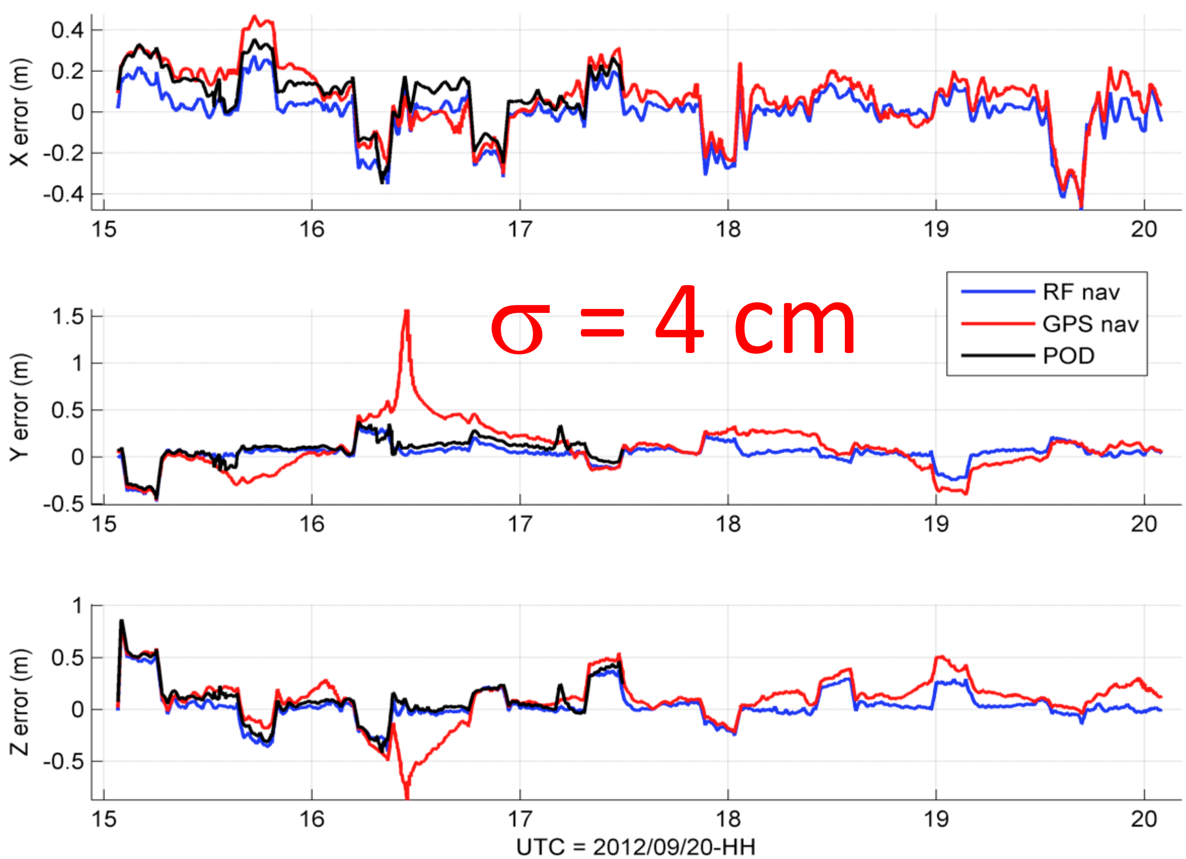
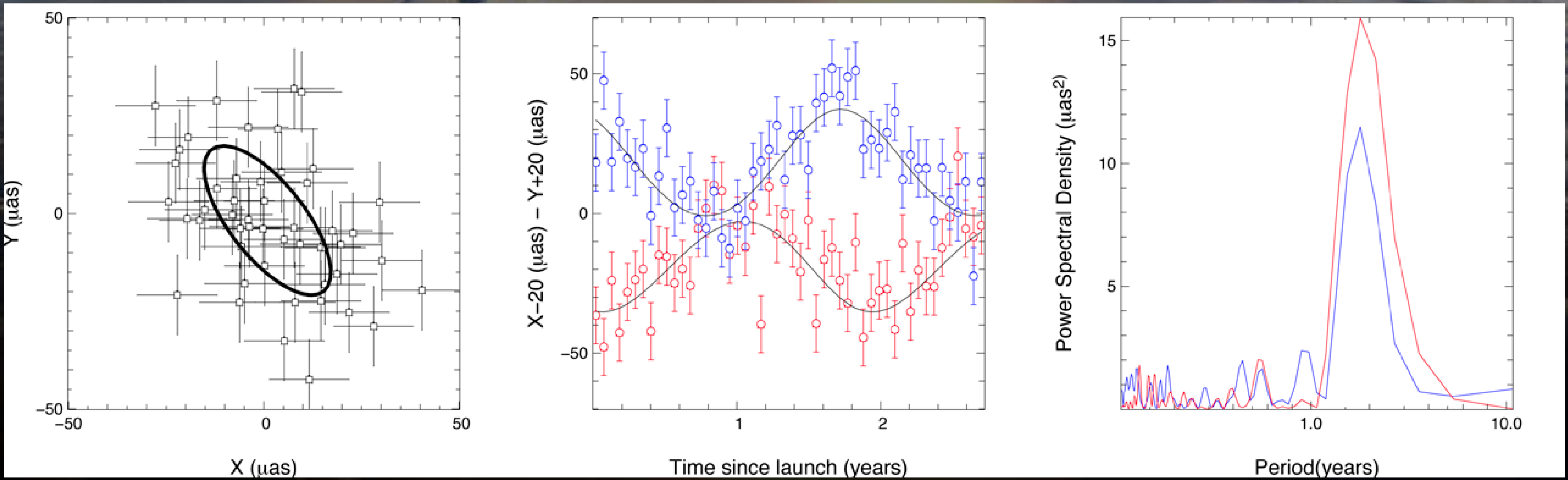


Figure 9: Control error observed by RF nav, GPS nav. and POD during the 1st session

Simulation (50 M_{Earth}, 1.5 AU, 10 pc)



Targets distance distribution