High-Precision Astrometry for Exoplanet Detection

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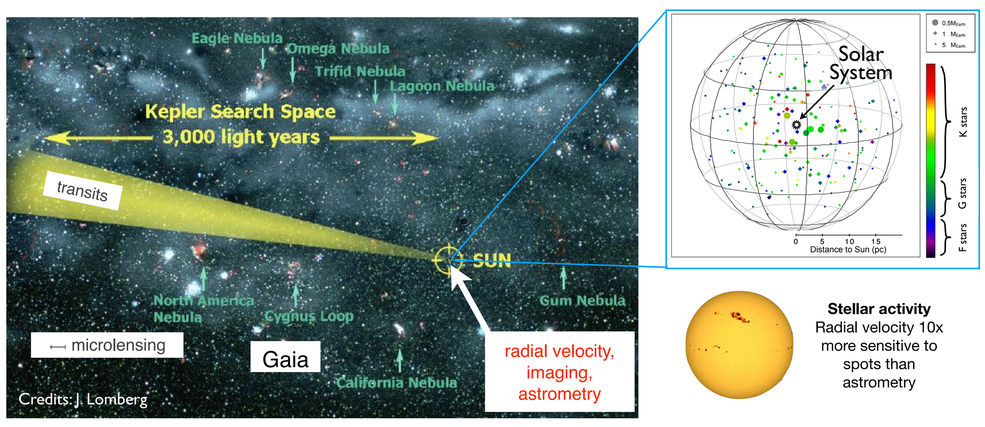
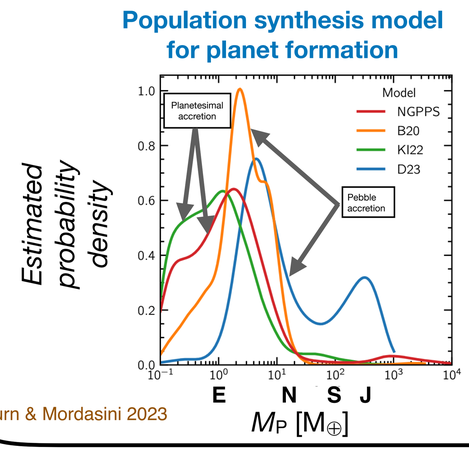
Scientific objectives

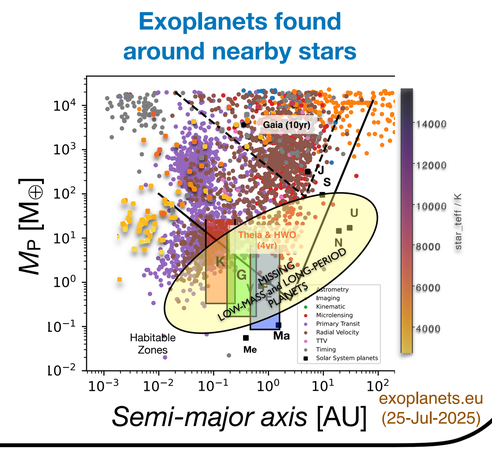
- Detection of Earth-like planets around nearby Solar-type stars



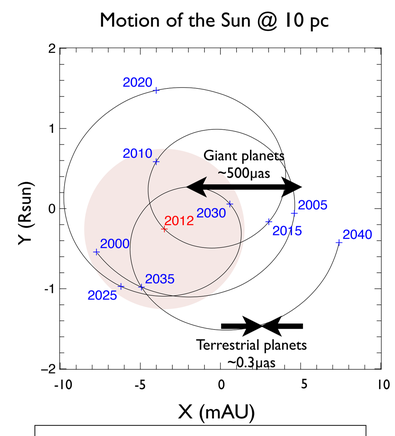
- What planetary components are we missing?



Burn & Mordasini 2023



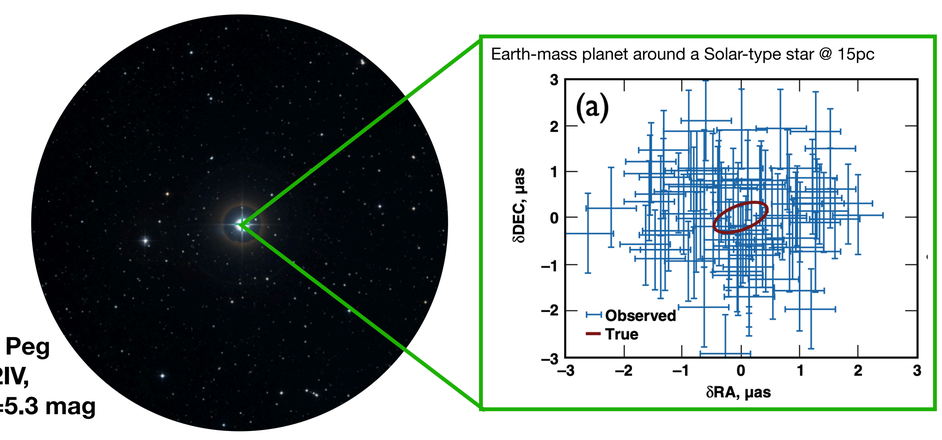
Differential high precision astrometry



$$\alpha = 0.33 \left(\frac{M_P}{1\,M_\oplus}\right)\left(\frac{a_P}{1\,\mathrm{AU}}\right)\left(\frac{M_\star}{1\,M_\odot}\right)^{-1}\left(\frac{D}{10\,\mathrm{pc}}\right)^{-1}\mu\mathrm{as}$$

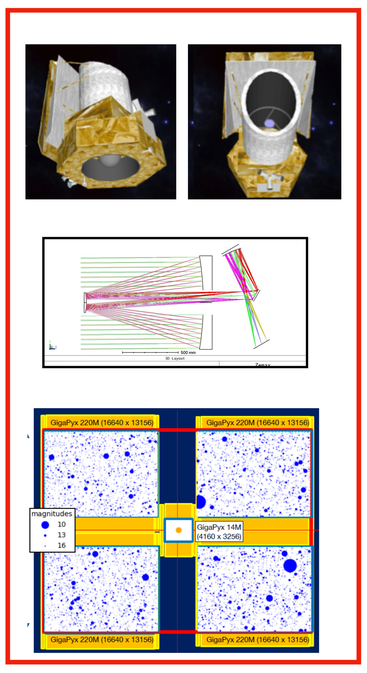
Solar system	Giants planets		Terrestrial planets	
	Jupiter@10pc	Saturn@20pc	Super Earth@5pc	Earth@10pc
M_P (M_E)	300	100	3	1
a_P (AU)	5	10	1	1
P (yr)	11	30	1	1
α (in µas)	**500**	**170**	**2**	**0.3**

Astrometry measures
$P, a, i, e, \omega, \Omega, T_0 \rightarrow M_P$



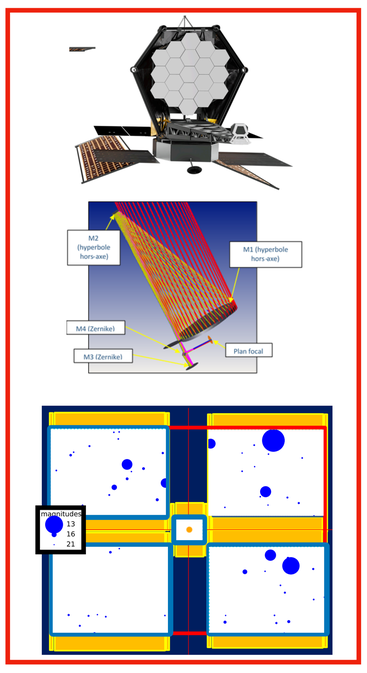
Possible future space missions

Theia



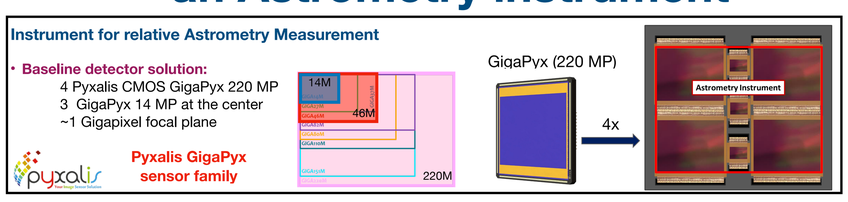
Theia		HWO
ESA	Agency	NASA
Medium (M8)	Mission type	Habitable World Observatory
0.8 m	Telescope Diameter	7 m
~2040	Launch date	~2040
L2 lissajous	Orbit	L2 lissajous
[450 nm - 900 nm]	Wavelength domain	[450 nm - 900 nm]
160 mas	Diffraction limit	14 mas
30x30 arcmin²	Field of View	4x3 arcmin²
22.500 x 22.500 px²	Focal plane size	34.300 x 25.700 px²
~500 MP	#pixels	~900 MP

HWO

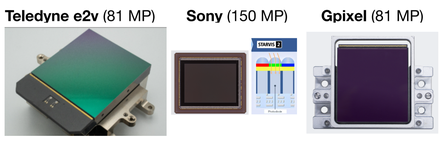


Missions require a **gigapixel** focal plane

RETINA : Technological maturation of an Astrometry instrument



- Alternative Detectors:
  - **Teledyne e2V CIS 300**: larger pixels (10.0 µm)
  - **Sony IMX 411**: micro-lens array (3,8 µm calibration issue)
  - **Gpixel GSENSE 1517**: larger pixels (15.0 µm)

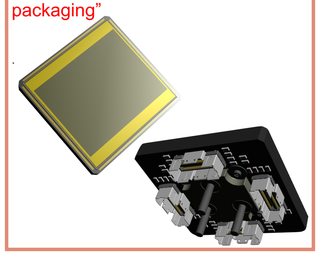


Stage 1

Assessing CMOS GygaPyx 220 MP "standard" sensor against HWO-AGATE requirements

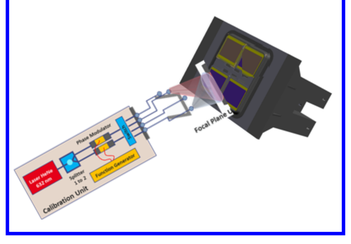
Stage 2

Validate a custom CMOS 220 MP package to withstand space applications called "Astro packaging"



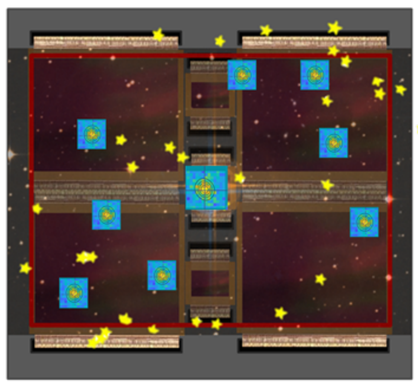
Stage 3

Validate CMOS GigaPyx 220 MP « astro » in representative environment

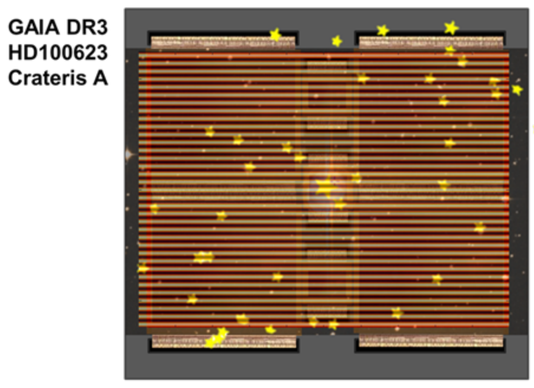


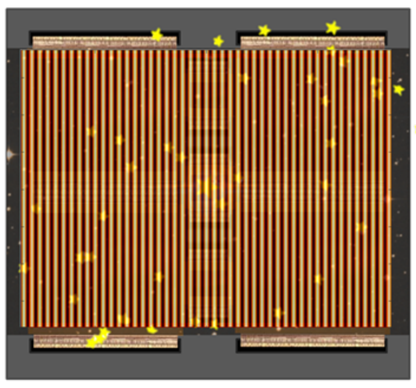
Example of relative astrometric observation of the star HD 100623

Science: star window extraction



Calibration: Young's fringe scanning (time varying) horizontal and vertical

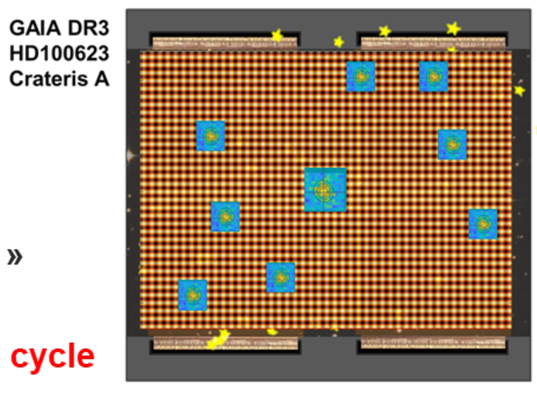




Sequence of observation:
2500-s: science data
1500-s: Calibration data

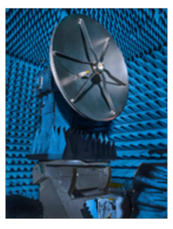
200 Tbits
100 Gbits/s

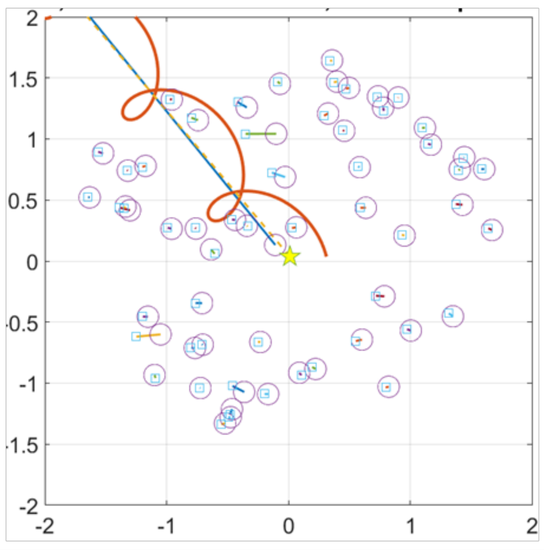
250 Tbits
150 Gbits/s



download

< 3 Tbits





On-board processing:
stars thumbnail are referenced to optical « interferometric accuracy » grid

5 Pflops per observation cycle

On-ground:
From accurately referenced relative stars astrometry, retrieval of exoplanet-star reflex motion