Gaia and WEAVE/WxES: supporting The PLATO Exoplanet Hunter

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WEAVE – Gaia – PLATO
a winning planet hunter combo

- Gaia releases its first all sky astrometric catalogues late 2017
- WEAVE begins on sky operations in 2018
- PLATO begins its planet hunt in 2024

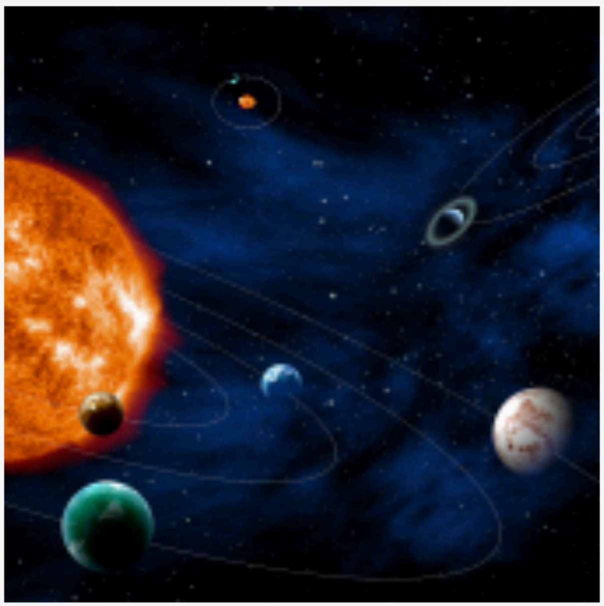
- Why are these events linked?

- Finding and characterising extra solar planets requires a detailed knowledge of the host stars
  - And it helps to know your target stars before you observe them

PLATO set for 2024

plato

esa



ESA selects planet-hunting PLATO mission

19 February 2014 A space-based observatory to search for planets orbiting alien stars has been selected today as ESA's third medium-class science mission. It is planned for launch by 2024. Read more

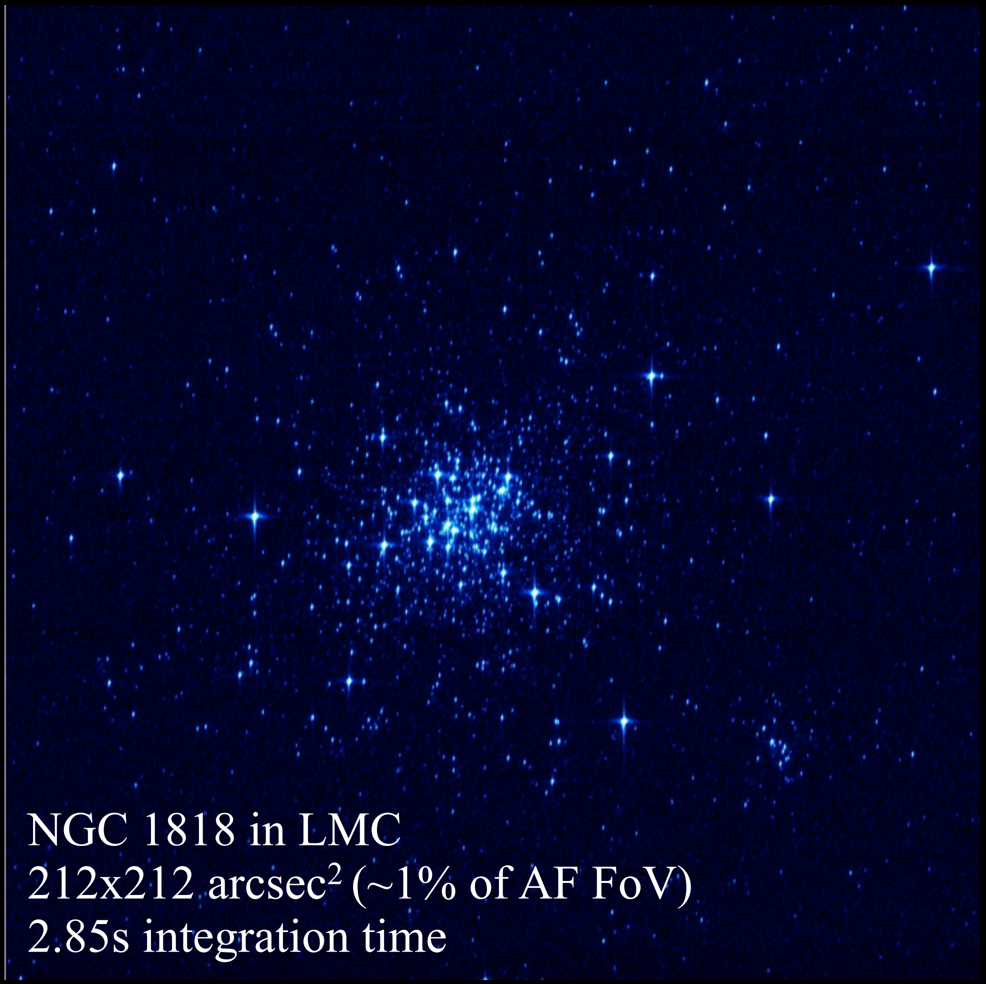
… but first … Gaia's role in planets

Recall Carme Jordi's talk earlier this week

Gaia

a powerful complement to PLATO

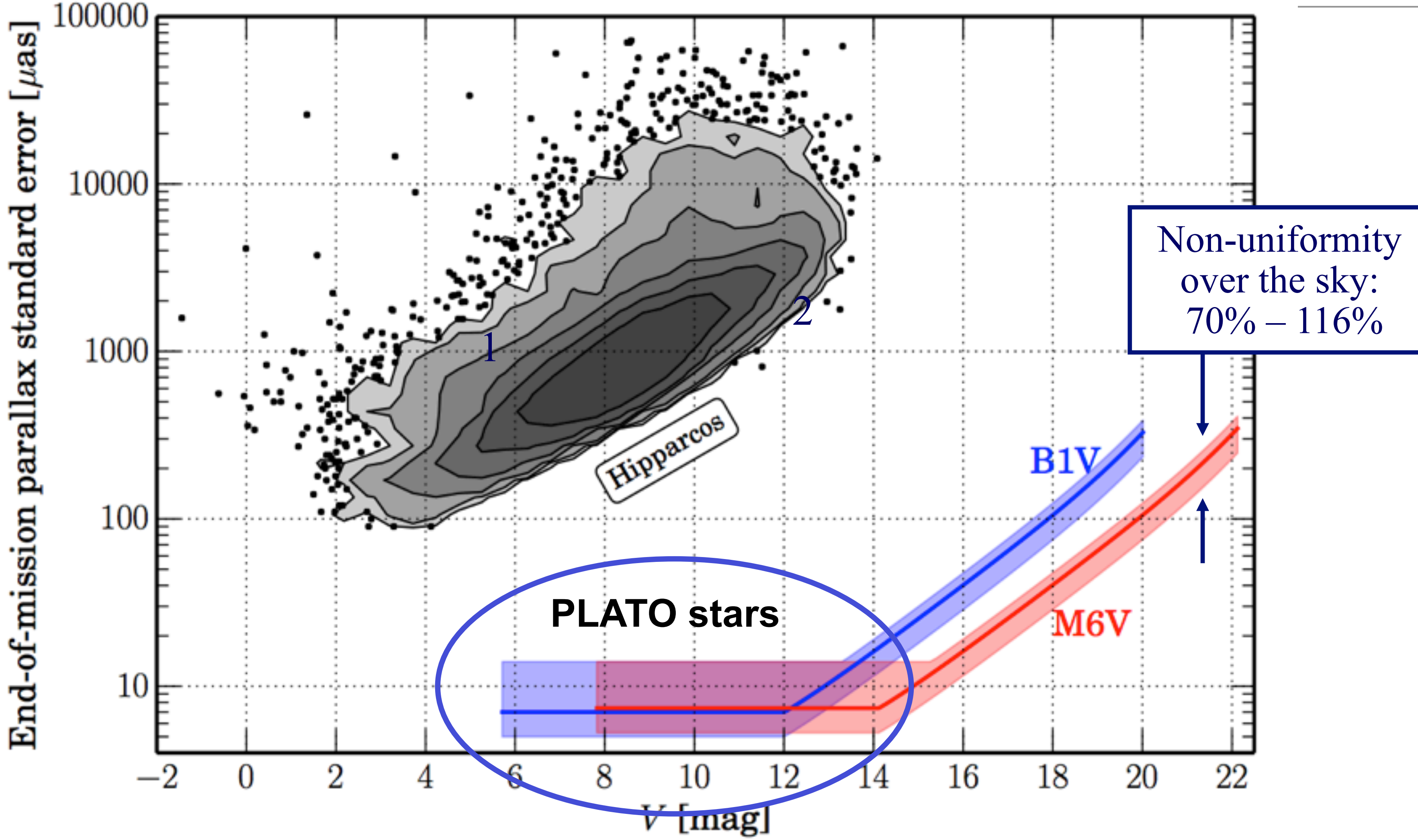
launched 19 Dec 2013



NGC 1818 in LMC
212x212 $arcsec^2$ (~1% of AF FoV)
2.85s integration time

Gaia End-of-Mission Parallax Errors

Apply factors of ~ 0.7 and ~ 0.5 for positions and proper motions



http://www.rssd.esa.int/index.php?project=GAIA&page=Science_Performance

1. bright-star regime (calibration errors, CCD saturation)
2. photon-noise regime, with sky-background noise and electronic noise setting in around G ~ 20 mag (equivalent to V = 20 to 22)

Gaia Performance (at IOCR)

http://www.cosmos.esa.int/web/gaia/science-performance

Typical PLATO star

	B1V	G2V	M6V
V-I$_C$ [mag]	-0.22	0.75	3.85
Bright stars	5-14 µas (3 mag < V < 12 mag)	5-14 µas (3 mag < V < 12 mag)	5-14 µas (5 mag < V < 14 mag)
V = 15 mag	26 µas	24 µas	9 µas
V = 20 mag	600 µas	540 µas	130 µas

Astrometric Performance

	B1V			G2V			M6V		
G [mag]	G	BP	RP	G	BP	RP	G	BP	RP
15	1	4	4	1	4	4	1	7	4
18	2	8	19	2	13	11	2	89	6
20	6	51	110	6	80	59	6	490	24

Photometric Performance

Spectral type	V [mag]	Radial-velocity error [km s^{-1}]
B1V	7.5	1
	11.3	15
G2V	12.3	1
	15.2	15
K1III-MP (metal-poor)	12.8	1
	15.7	15

Spectroscopic Performance

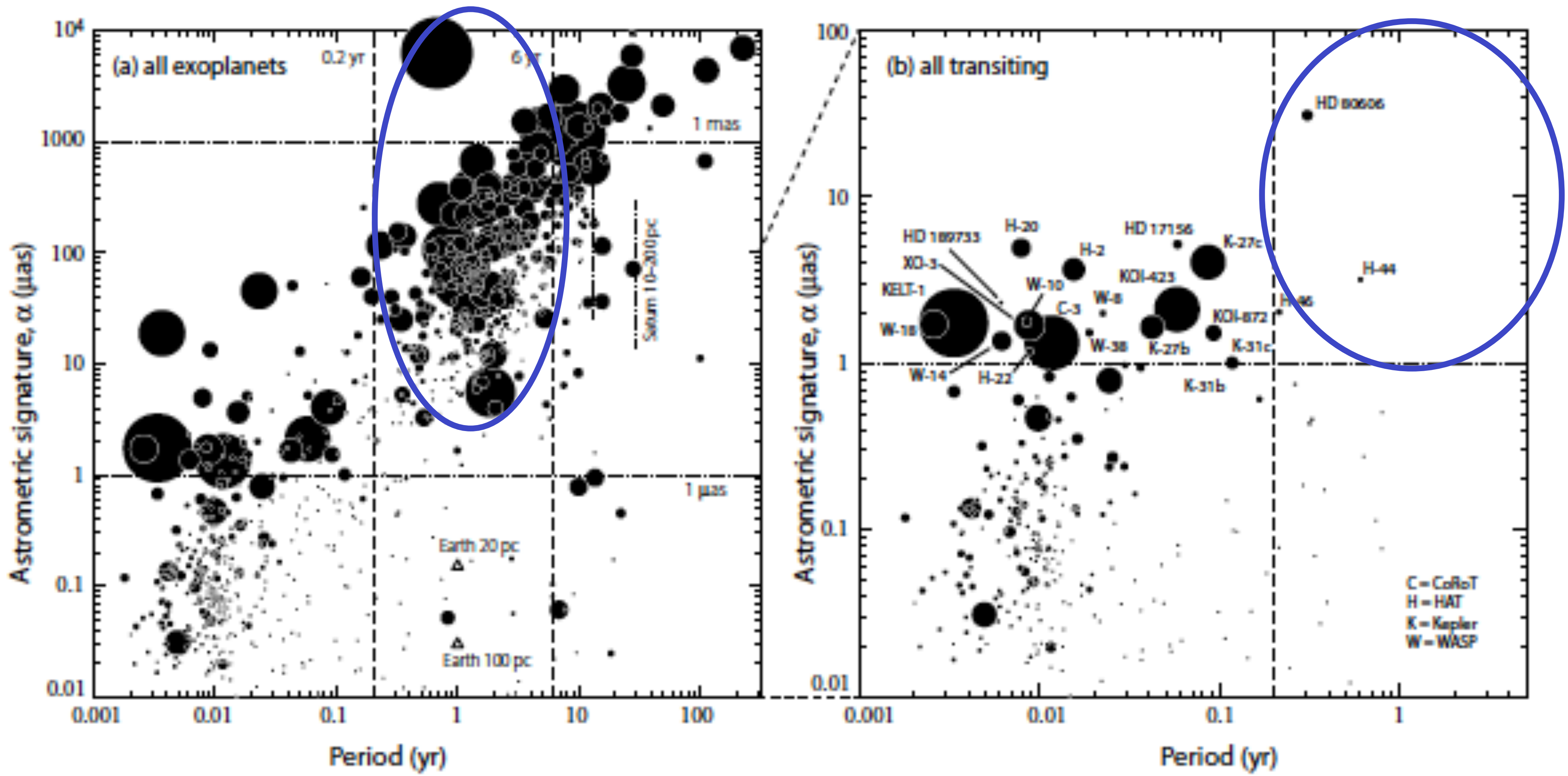
Gaia Data … Soon a Reality

http://www.cosmos.esa.int/web/gaia/release

- GDR1 ~7/16: positions, G-magnitudes (all sky, single stars) proper motions for Hipparcos stars (~50 μarcsec/yr) – the Hundred Thousand Proper Motions (HTPM) catalogue
- GDR2 ~2/17: + radial velocities for bright stars, two band photometry and full astrometry (α, δ, ϖ, μ_α, μ_δ) where available for intermediate brightness stars
- GDR3 ~1/18: + first all sky 5 parameter astrometric results (α, δ, ϖ, μ_α, μ_δ) BP/RP data, RVS radial velocities and spectra, astrophysical parameters, orbital solutions short period binaries
- GDR4 ~1/19: + variability, solar system objects, updates on previous releases, source classifications, astrophysical parameters, variable star solutions, epoch photometry
- GDR-Final: final data release (thus in 2022/23)

Gaia as a Planet Finder

Gaia will detect most RV discovered systems, but not most current transit ones

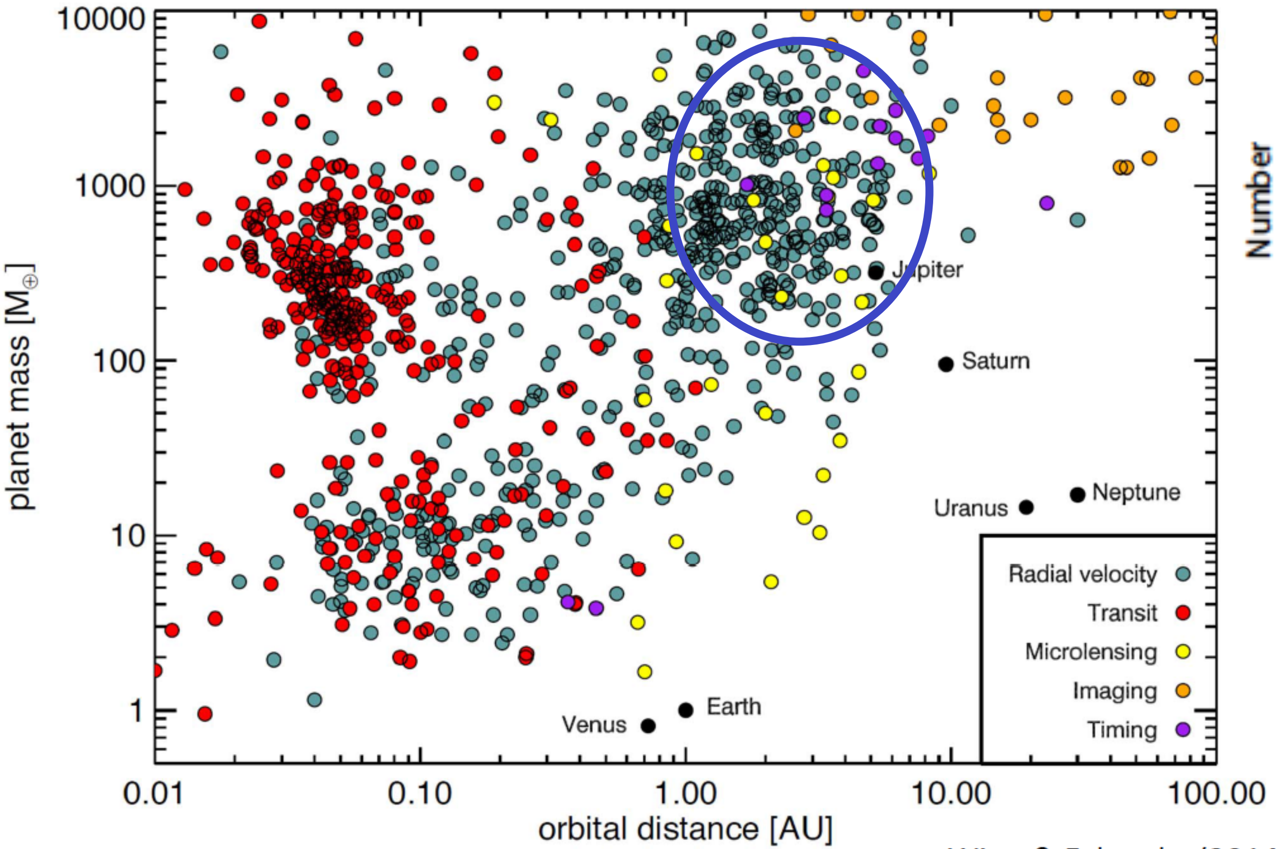


Recent calculations: Perryman et al, 2014

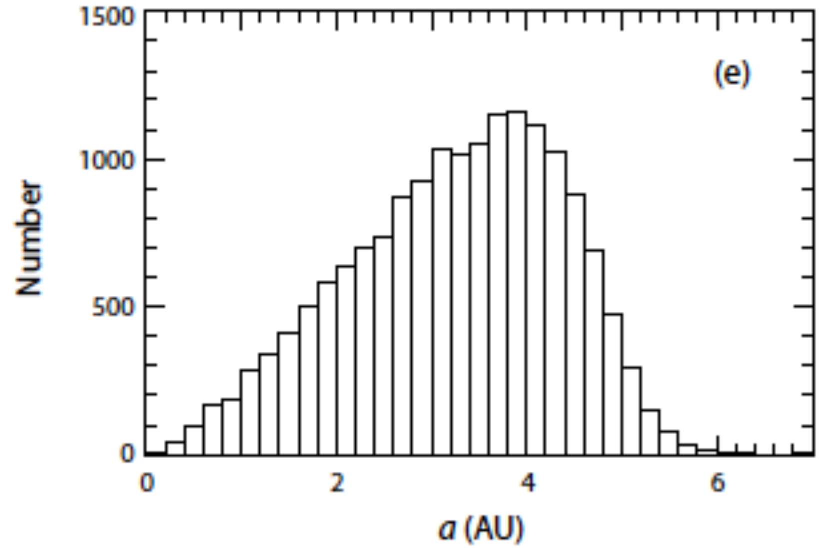
Gaia planets in star of all types (RV limited to well behaved stars)

Gaia as a Planet Finder

GAIA Astrometric Planets



Winn & Fabrycky (2014)



For the baseline Gaia 5 year mission expect >20,000 high mass 1-15 M_J planets out to distances of 500 pc (1000+ planets in M dwarfs to ~100pc)

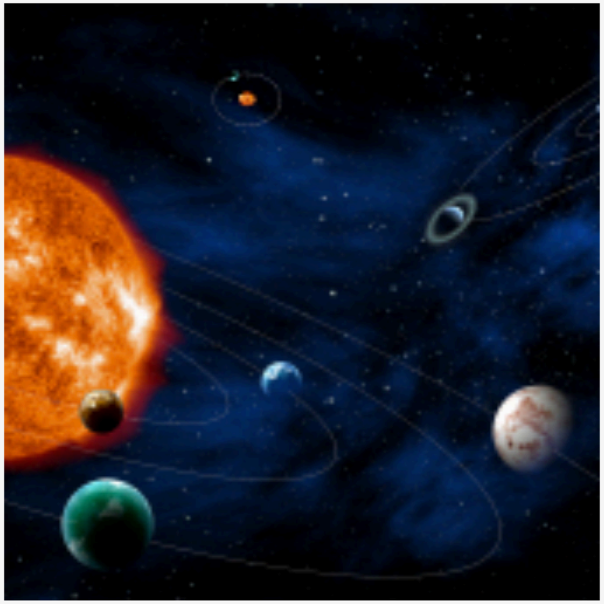
Recent calculations: Perryman et al, 2014, Sozzetti et al 2014
Circumbinary planets: Sahlmann et al 2015

Gaia will also find 100's of close in hot Jupiters via transits (Dzigan & Zucker 2012)

Gaia as a PLATO helper

- Gaia provides detailed properties for all PLATO host stars (distances, T_{eff}, radius, log g, [Fe/H], A_v, etc)
- Gaia enables the selection of PLATO target stars – ability to type all input stars (e.g. select dwarfs, careful selection of activity type)
- Gaia astrometry will allow for detection of more massive planets in PLATO target systems
- Gaia will allow characterisation of the PLATO target fields – also at the pixel level (one PLATO pixel = over 20,000 Gaia pixels!!)

… back to … PLATO set for 2024



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The PLATO Mission
http://sci.esa.int/plato

- Detect planets in statistical numbers, including terrestrial planets in the habitable zone
- Constrain planet formation and evolution
- Reveal the interior of planets and stars
- Provide accurate ages of planetary systems
- Provide targets for atmosphere spectroscopy
- PLATO – optimised for the discovery of small planets in long period orbits (including habitable planets)
- PLATO – the search for exo-earths

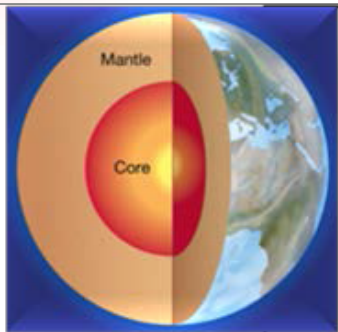
PLATO Science

- Detect & characterize small planets out to 1 AU orbital distance with accurate radius, mass and age
- Detect & characterize planets around stars with different metallicity, age, activity, system architectures, ...
- Correlate planet bulk properties & system architectures with age (young and old stars)
- Detect exo-moons, planetary rings, Trojan planets; planets around giants and cool dwarfs
- Constrain which planets likely have atmospheres
- Probe stellar physics
- Probe galaxy structure and evolution

Planet diversity and planet formation

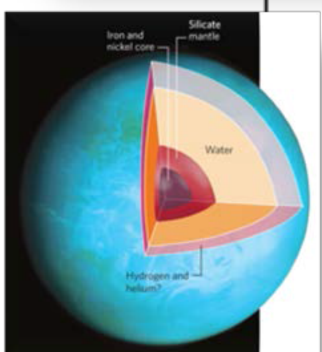
Earth:

5.5g/cm^3



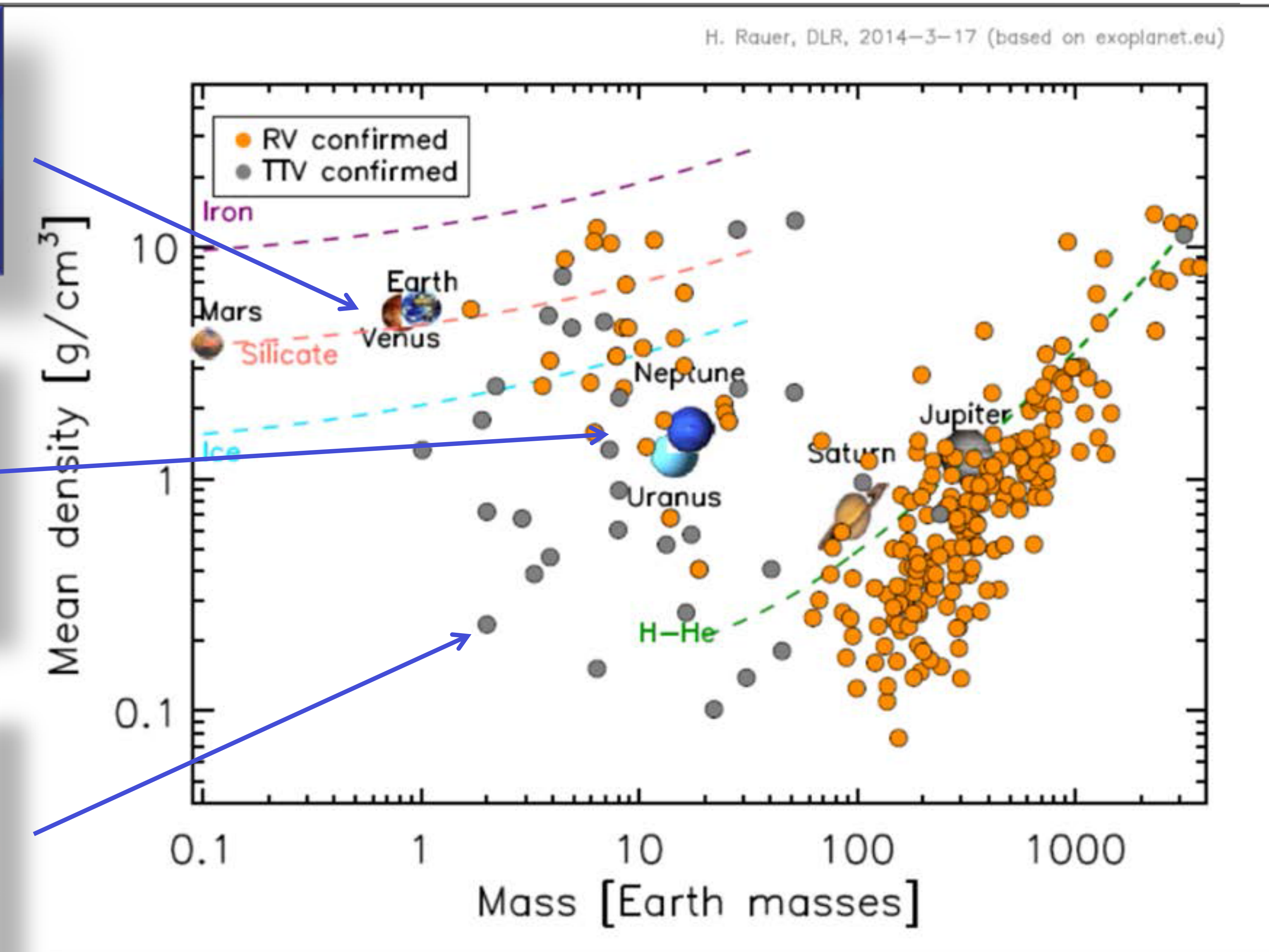
GJ1214b:

1.6g/cm^3



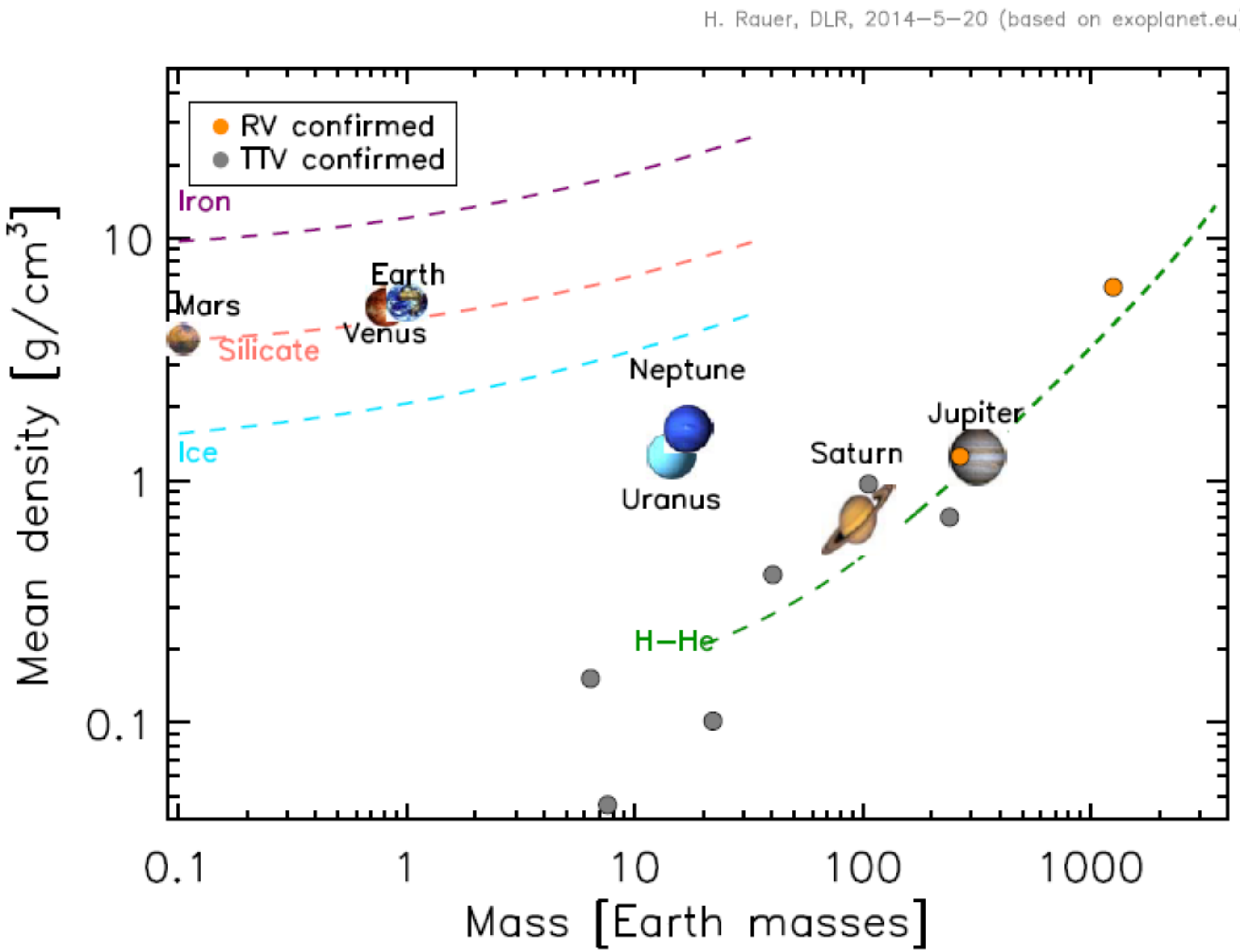
Mini gas giants:

<~1g/cm^3



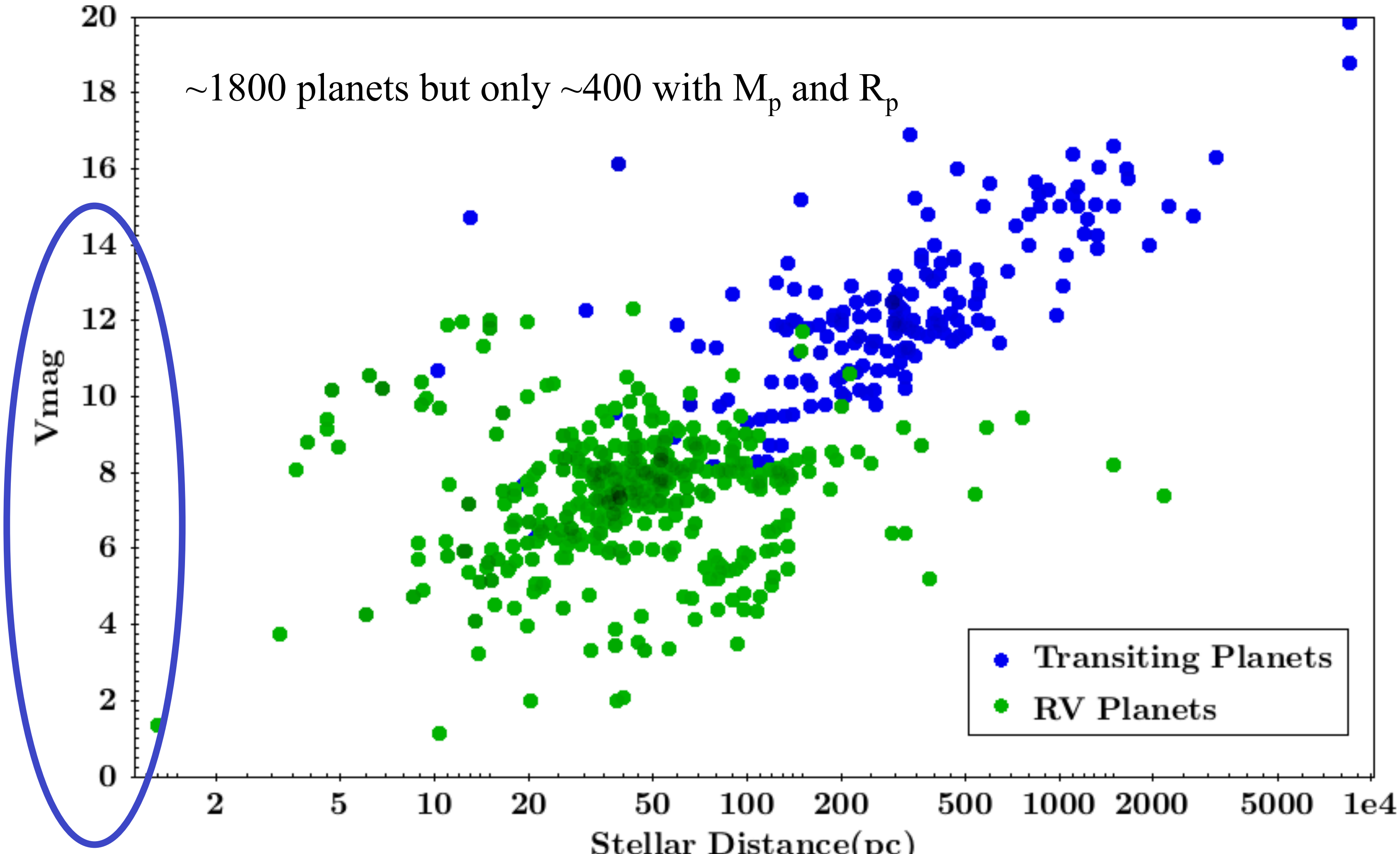
Planet diversity at P > 80 days

- Current knowledge of long period planets poor (and will remain so)
- PLATO will find the long period planets



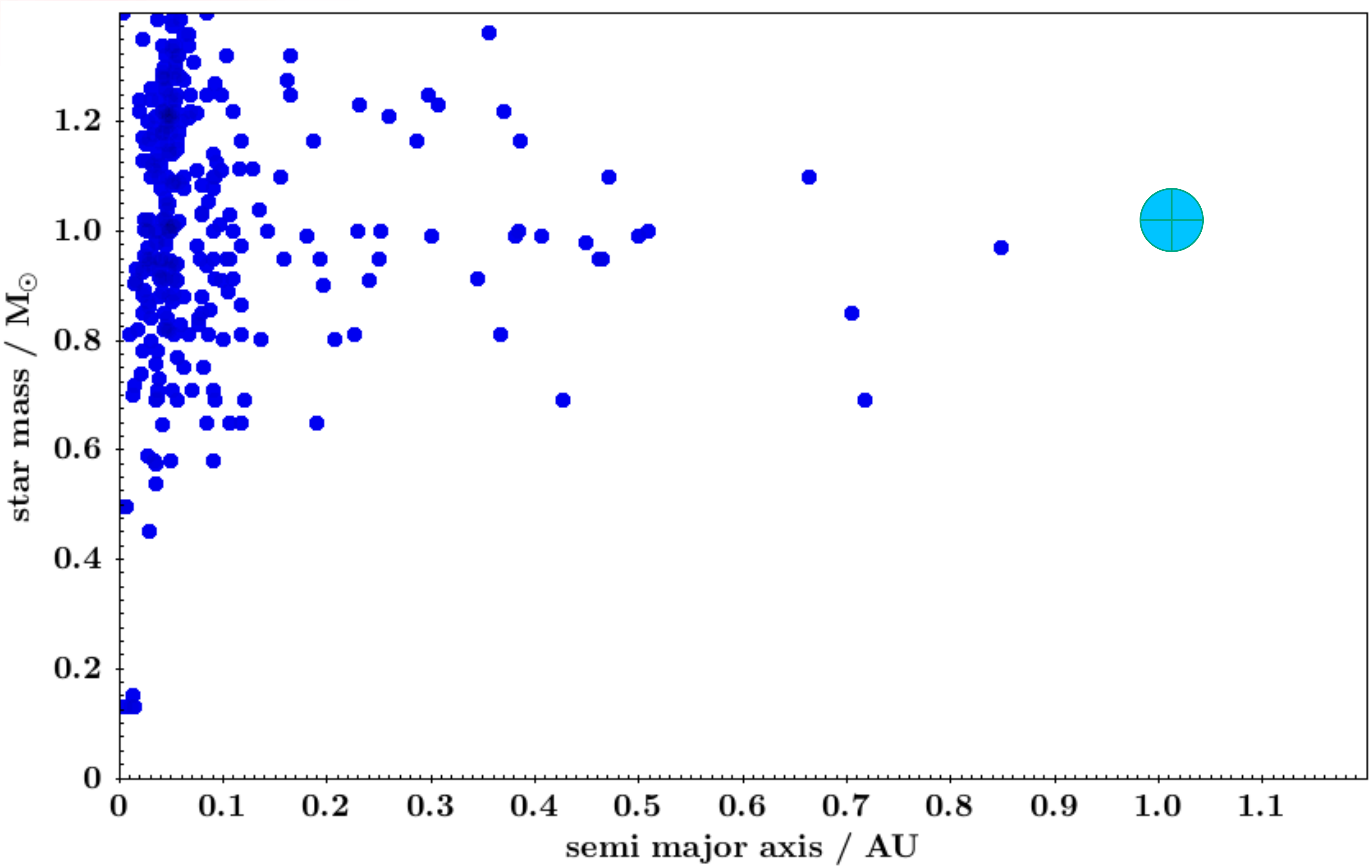
PLATO will target bright and nearby stars

Current (ish) (20140929) list of planets adapted from exoplanet.eu



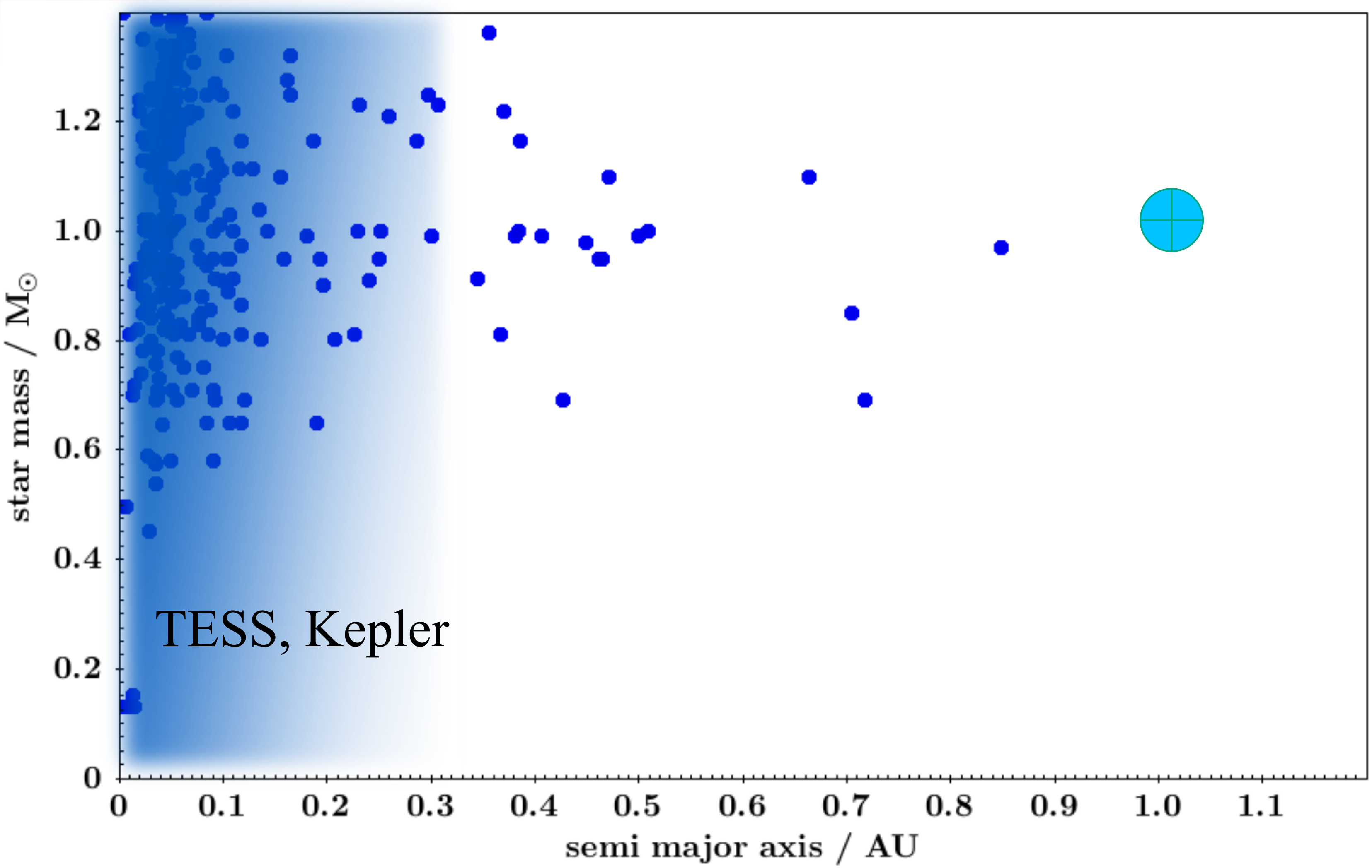
All characterised by GAIA

Looking for 'Earths'



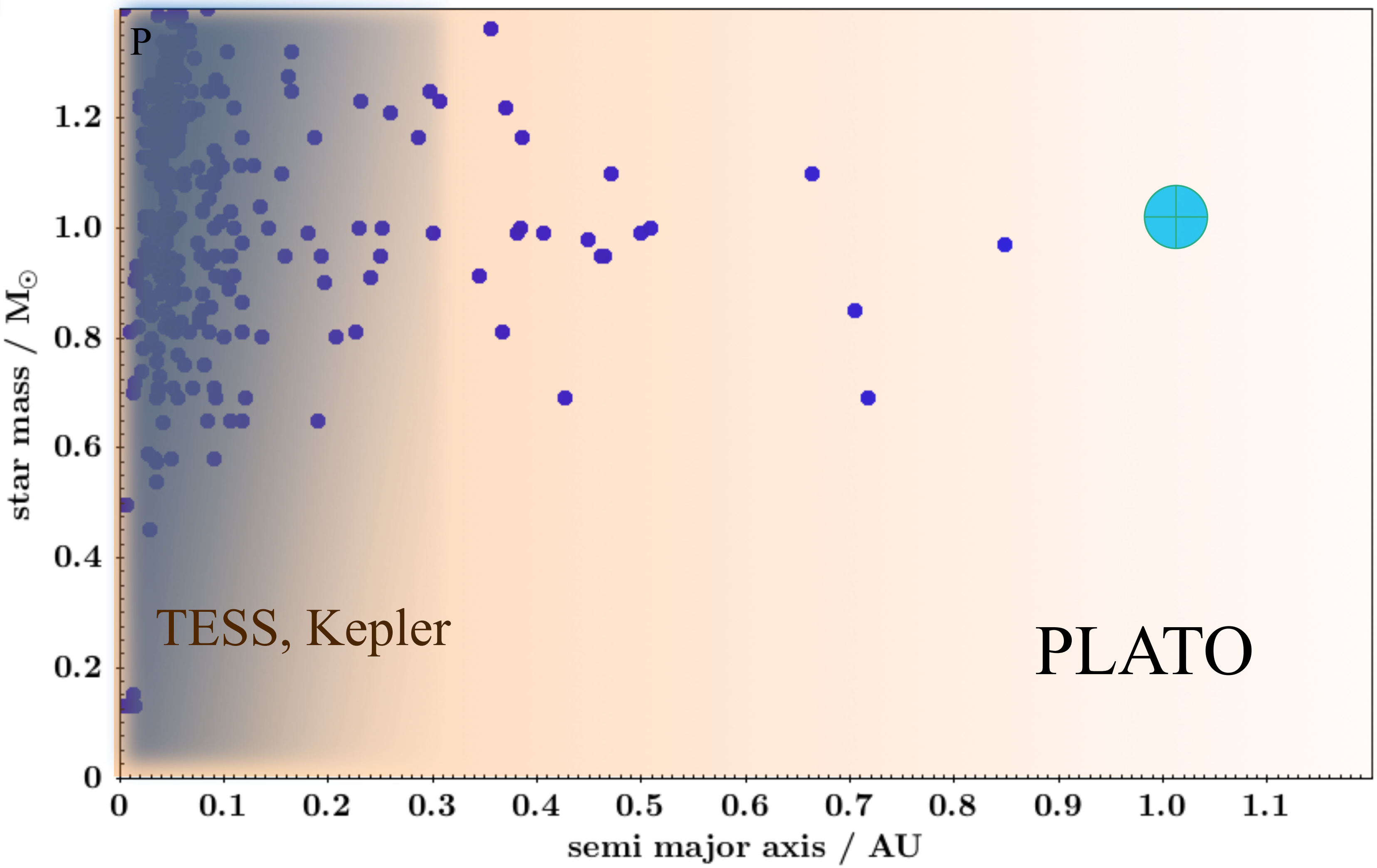
Fully characterised systems with M and R (as of Sep 2014)

Looking for ‘Earths’



Fully characterised systems with M and R

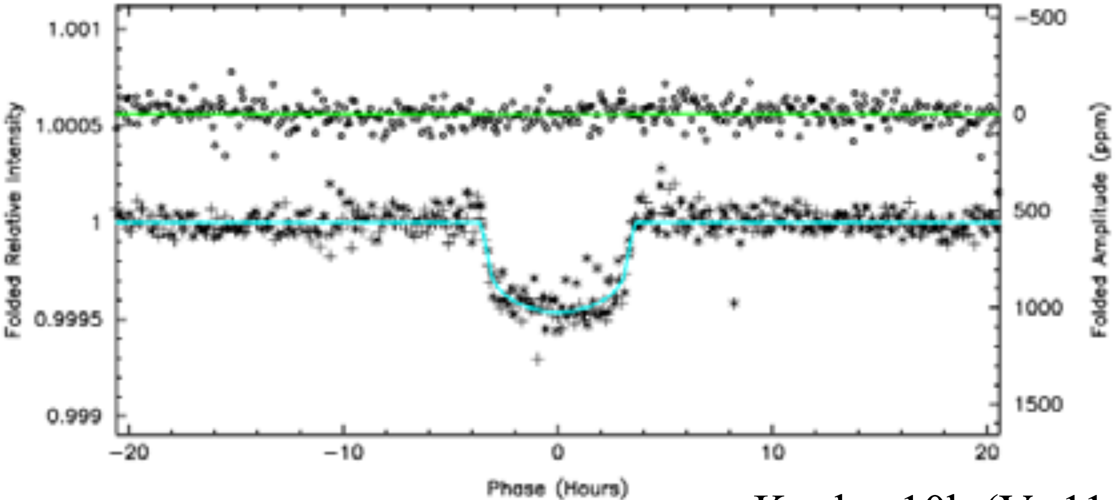
Looking for 'Earths'



Fully characterised systems with M and R

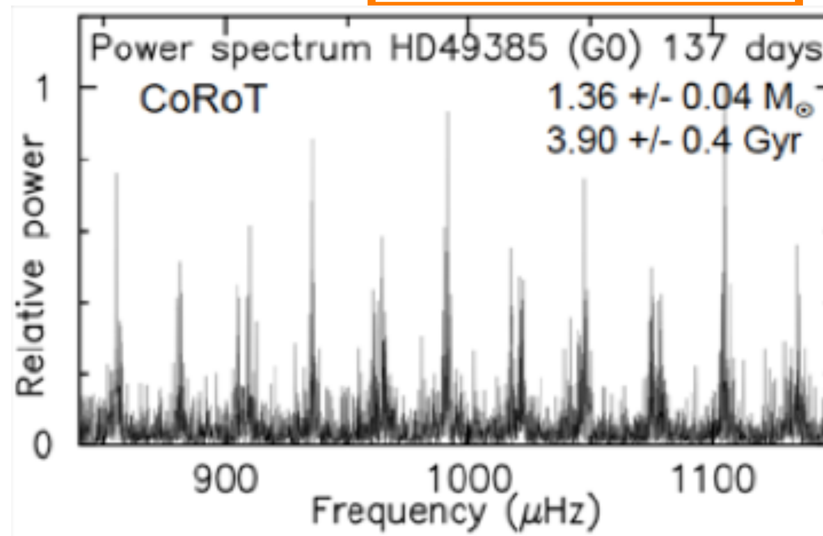
PLATO: Technique

Photometric transits ....



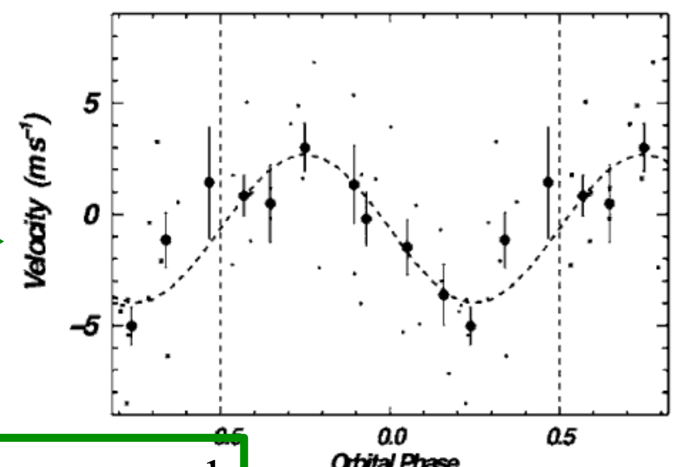
e.g. Kepler-10b (V=11.5)

Asteroseismology



For solar like stars PLATO will give:

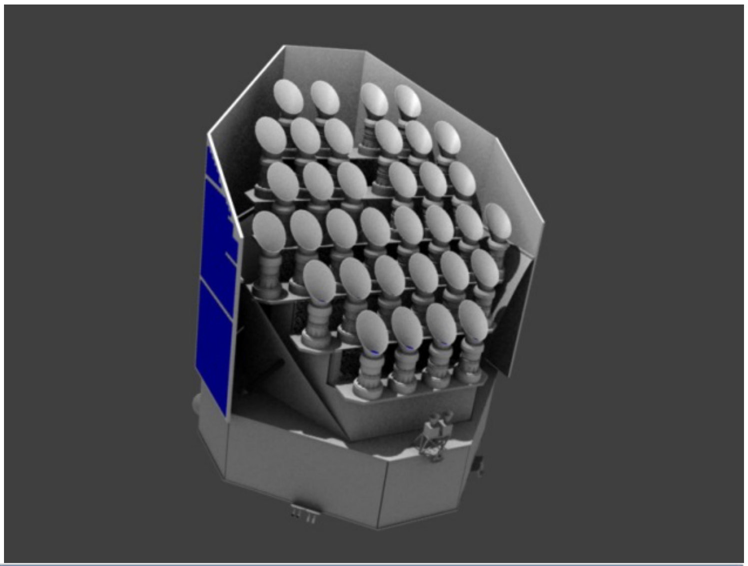
- **Radius to ~2%**
- **Mass to ~10%**
- **Age to ~10%**

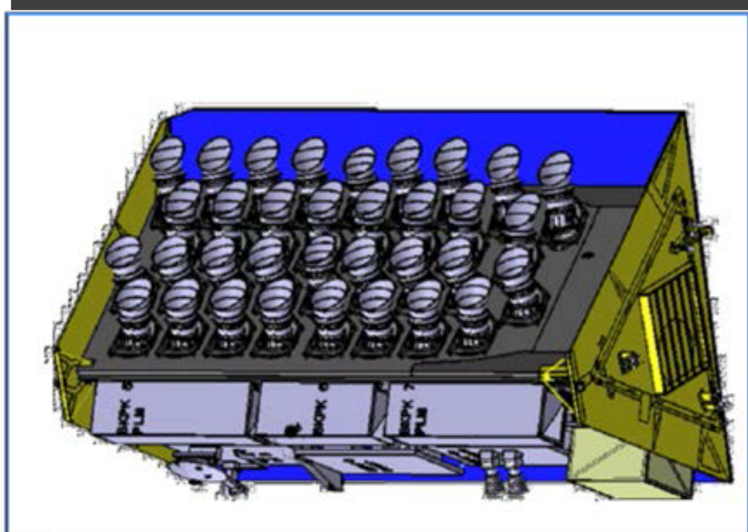


RV follow-up from ground

PLATO Mission

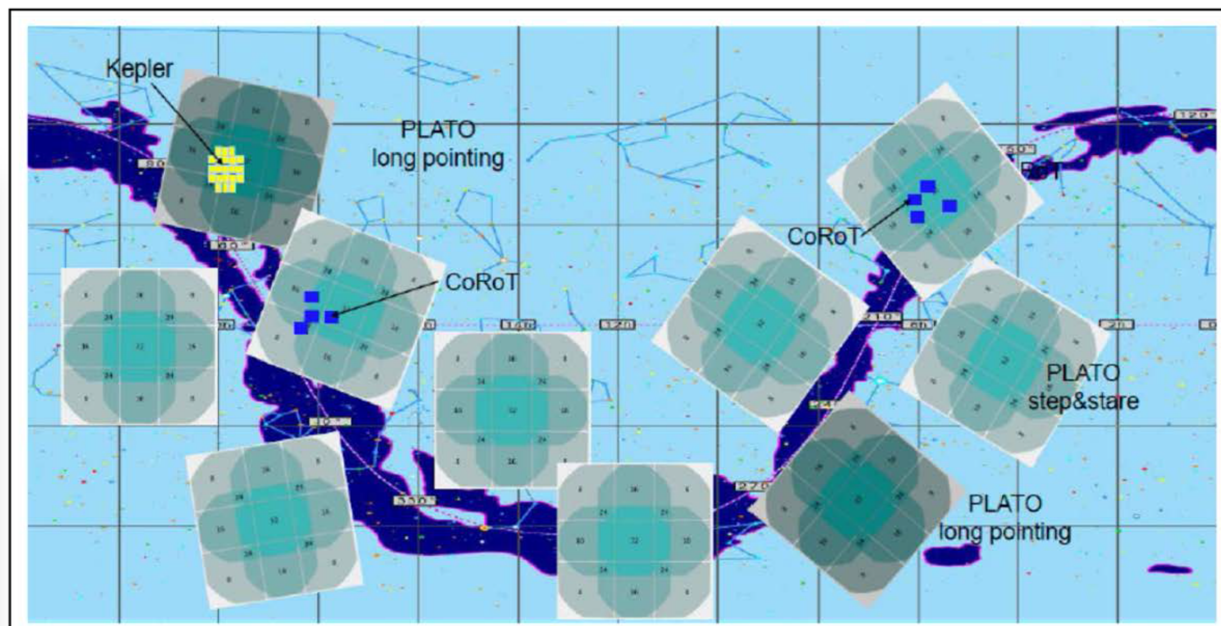
Two design concepts …





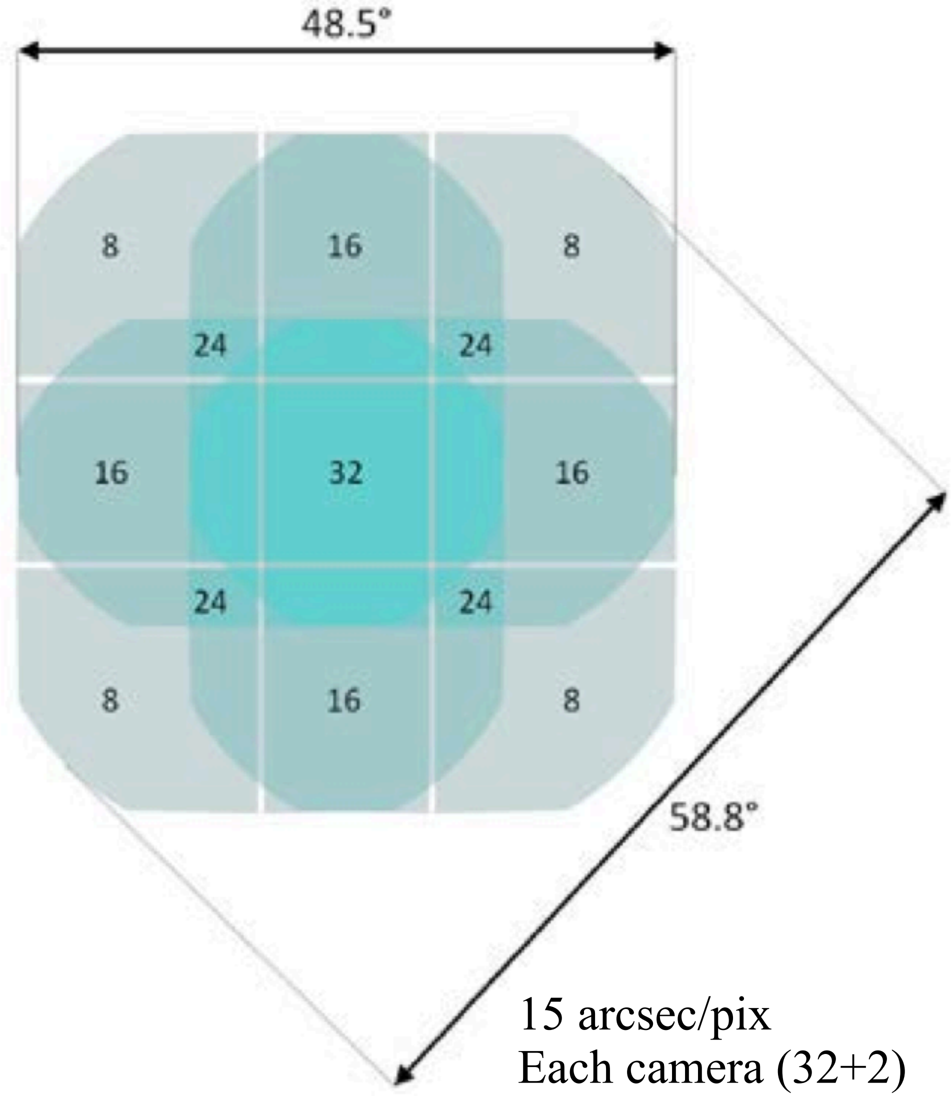
Baseline survey strategy envisages covering 50% of the sky

- 6 year nominal mission
- 2 long 2-3 year pointings
- Step and stare of 2-5 months/ pointing



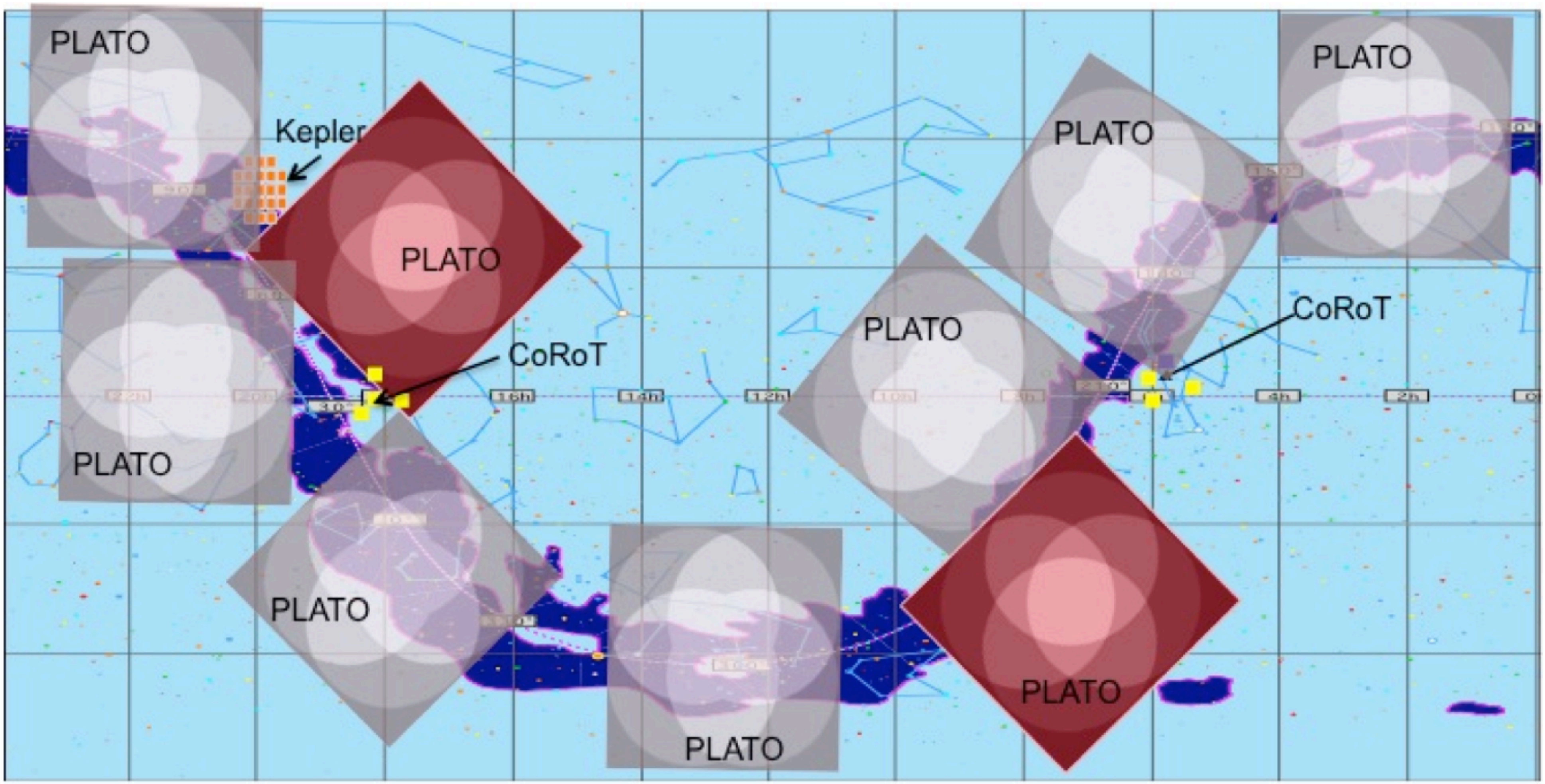
PLATO: Field of View
~2,250 deg^2 per pointing

- Overlapping line of sight for 4 groups of 8 cameras
- CCD camera readout asynchronously
  - Each Tel: 1100 deg^2 FoV
  - Fast Tel: 550 deg^2 FoV
- Optimizing:
  - No. of stars at given noise level
  - No. of stars at given magnitude



15 arcsec/pix
Each camera (32+2)
4x4510x4510 pixels
(18μm)

PLATO: Field of View
covers half the sky



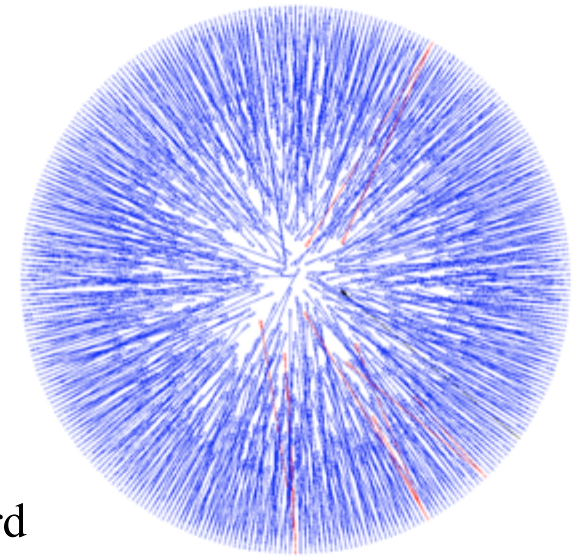
- Start with step-and-stare phase for large coverage in the early phase → red fields (3+2 yrs)
- Stare at regions with interesting objects and shorter stares (2 to 5 months)

PLATO Samples

long pointings	step & stare	mag	Noise in central field	spectral type	sampling rate (phot./cent.)
P1: 20 000 stars		V<11	34 ppm	F5/K7	50s/600s
P2: 1 000 stars	P3: 3 000 stars	V<8	34 ppm	F5/K7	50s/600s 50s/50s
P4: 5 000 stars V<16	5000 stars V<15	V<15 V<16	800 ppm	M	600s/- 50s/50s
P5*: 245 000 stars		V<13	80 ppm	F5/K7	600s/- 50s/50s

* P5 for long and step/stare phases: ~ 1 Million light curves at <13 mag

Capable WEAVE



PI: Gavin Dalton - Oxford

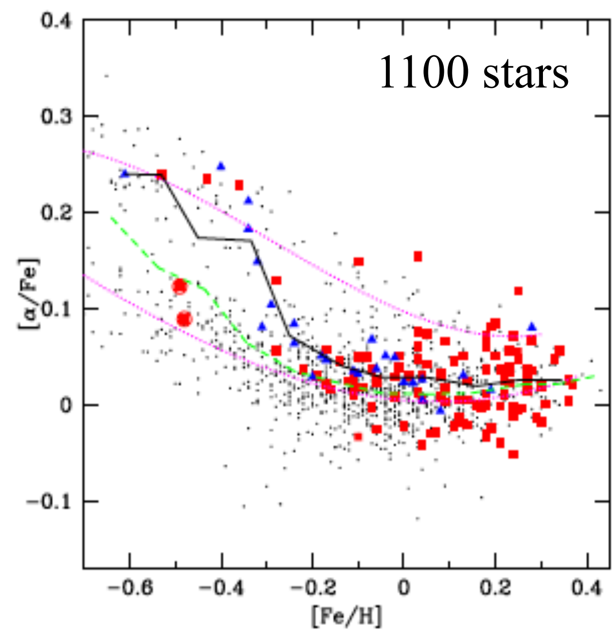
~1000 fibres (+mIFU and IFU) over ~π deg^2 at R~5,000 & R~20,000 for λ ~367-984nm

WHT on sky surveys from 2018

5 year survey ~20x10^6 objects

WEAVE exoEarth survey (WxES)

- Jupiters found in higher Z hosts than those with Neptunes (e.g. Sousa et al 2008). Effect ~0.2 dex
- Alpha-element overabundance for low metallicity planet hosts (e.g. Adibekyan et al 2012)
- Indication that low metallicity thick disk stars preferentially host planets
- Smaller planets found in stars with lower metallicities (Buchhave et al 2014, based on study of ~400 host stars)
- Some evidence for Si as a pointer of planets (e.g. Brugamyer et al 2011)



Adibekyan et al, 2012

AIM: Massive survey to investigate in depth, host star metallicity/ planet relationships

Reveal formation scenarios, investigate planet impact on stellar metallicity

Implementing WxES

- R=20,000 (~1kms^{-1}) mode spectra of the ~500,000 host stars to be observed by PLATO (visible to the WHT)
  - FAST survey of the brighter (6 < 9th mag) PLATO stars
  - Requires new 'config' mode for efficiency
- Main northern field – 120,000 stars
  - Equates to ~ 150 stars per WEAVE pointing
  - Main field survey ~ 750 fields / 75 (bright) nights
- Outputs: elemental abundances to 0.05 dex
  - (alpha-elements, Fe peak) Ca, Si, Cr, Ni, Fe
  - (s-process) Ba, Sr and Na, Mg, Al, Sc, Ti, V, Mn, Co
- Identify spectroscopic binaries (rule out candidate false positives)
  - Double line in one shot, single line via multiple obs.

WxES Summary

- In combination: Gaia – WEAVE – PLATO – a powerful probe of planet formation scenarios
- WEAVE / WxES planet focussed survey – definitive survey of planet host stars
  - Can begin 2021/22 with knowledge of PLATO input catalogues
    - Requires some enhancements to WEAVE configuration s/w to optimise short field exposures
  - Initial pilot survey of Kepler and SuperWASP fields