NEAT - Nearby Earth Astrometric Telescope

High precision astrometry mission for the search for habitable Earths within the nearest 15 pc

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YETI meeting - Jena, Germany - 17 November 2010

ESA Cosmic Vision call for M Mission

Compelling science from the Cosmic Vision plan :

- Habitable Earth-mass planets in the 0.1-10 AU range
- Astrometry highly complementary to other techniques in that respect

Call for M Mission ≤ 470M€ for 2022-2020 launch date

It must be supported by the community:

- Cosmic Vision Plan, Decadal Survey
- Blue Dot team as the exhaustive way to identify such planets

➡ more than 60 supporters from 15 different countries

➡ Theoreticians, observers, instrumentalists

High Precision Astrometry mission

Technique

- Measurement of celestial angles between target and references

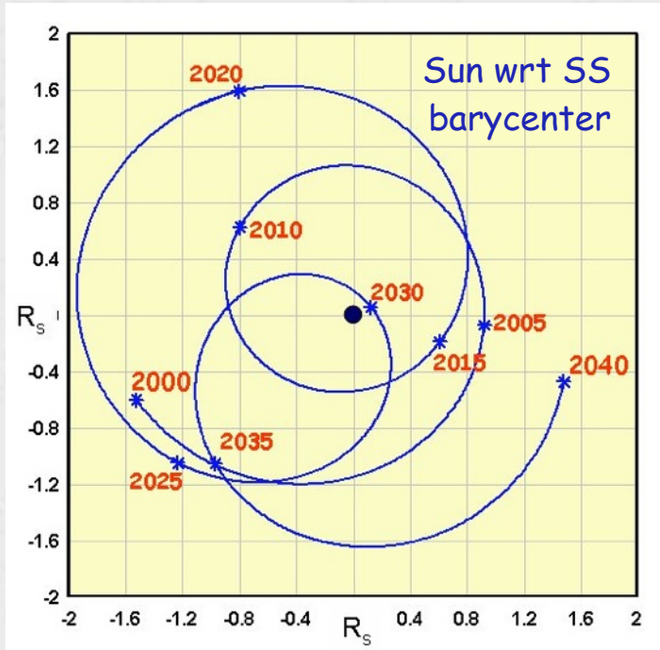
Objective

- Measure the reflex motion of the host stars to the presence of planets
- Measure *P*, M_P, a_P, *i*, *e*

Challenges

- Noise floor of 0.05µas (GAIA ~ 7µas) for detection at SNR=6
- Simplest calibrable instrument

Sun reflex motion



	Giants planets, solar-type stars			Telluric planets		
	Classical	Young	Hot	Hot super Earth, M stars	HZ, solar-type stars	HZ, M stars
M_P (M_E)	300	300	300	5	1	1
a_P (AU)	5	5	0.1	0.1	1	0.28
P (yr)	11	11	0.03	0.05	1	0.2
M_* (M_S)	1	1	1	0.45	1	0.45
d (pc)	10	150	10	2.5	10	9
θ(in µas)	**495**	**33**	**10**	**1**	**0.3**	**0.2**

Quantified objectives

Program:

- **Habitable Earth-mass planets at 0.05 µas (70%)**

- **Other planetary systems at ~1 µas (20%)**

active stars, young stars, in multiple systems,...
2,500 pointings to be allocated

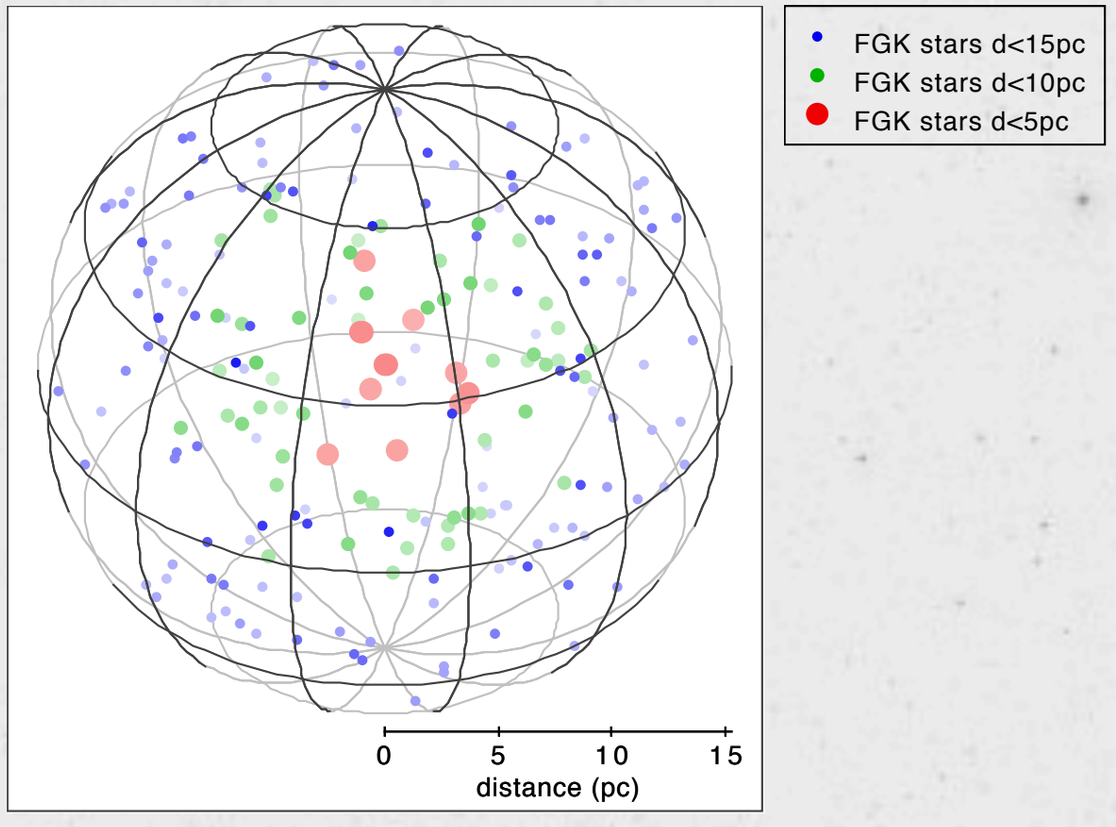
M stars (5 targets @ 1ME, 10 @ 2ME, and 50 @ 5ME)
2,500 pointings to be allocated

- **Other science (10%): GAIA follow-up, 10x better accuracy**

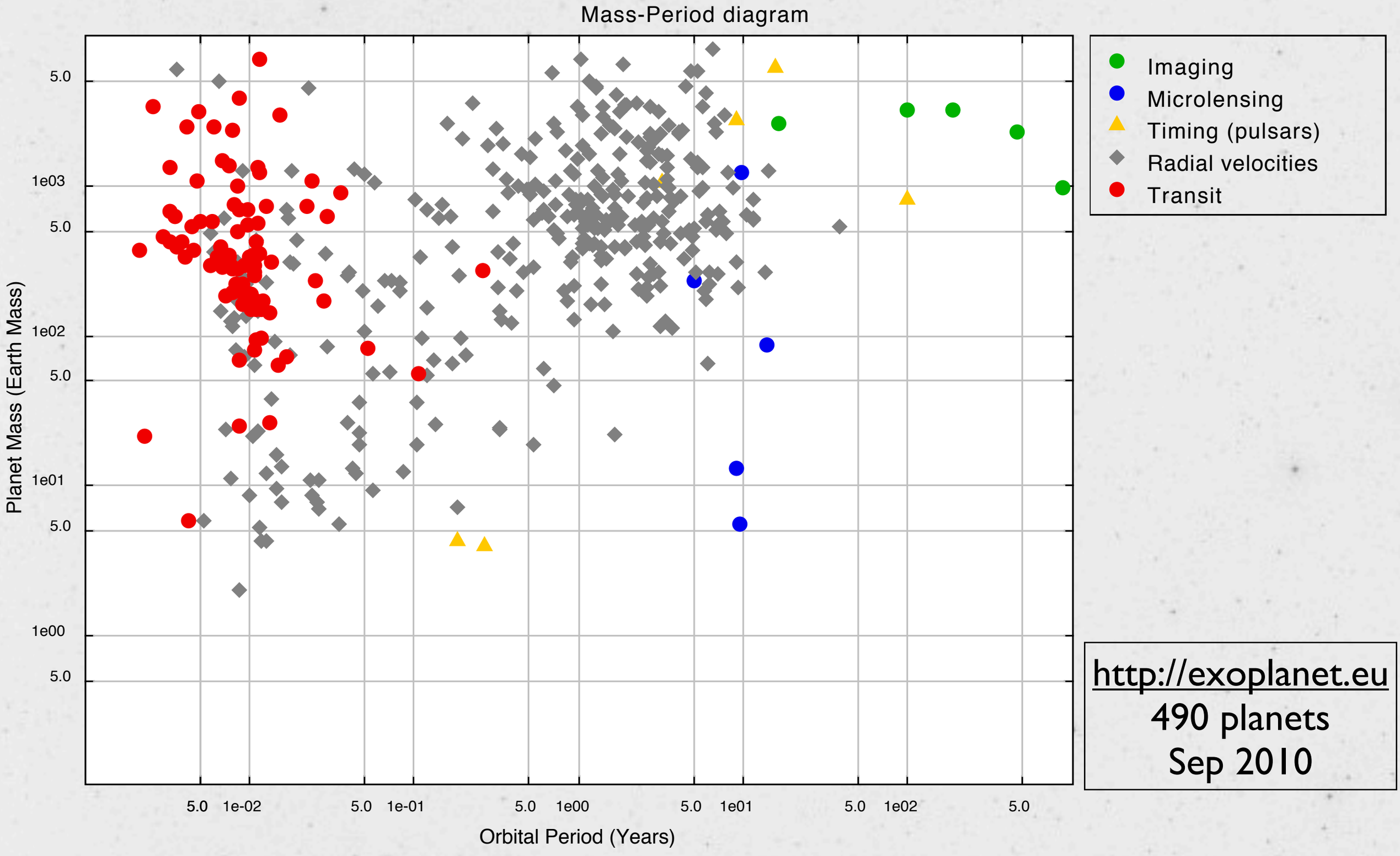
interacting binaries, Galaxy tidal tails, low-mass binaries,...
2,500 pointings to be allocated

Targets	Detection limit	Distance	Closest FGK stars	Nvisits	Ttotal
FGK stars	0.5 ME	<4.5pc	***1-10***	500	1785h
	1 ME	<9.5pc	***11-75***	3,250	15,260h
	5 ME	<13.4pc	***76-200***	6,250	3970h
Total			**200**	**10,000**	**21,140h**

Closest FGK stars

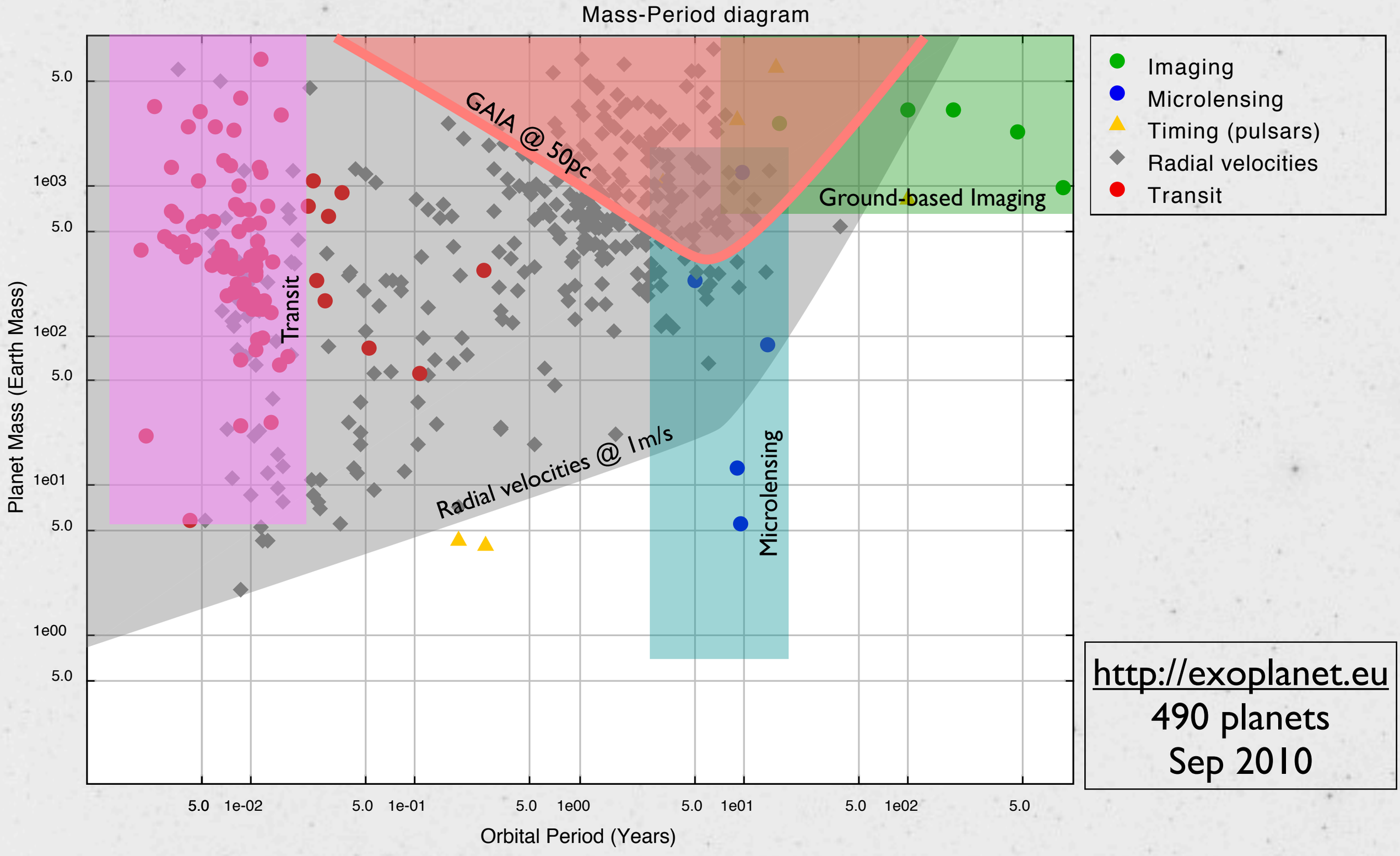


Astrometry aims at unexplored region



http://exoplanet.eu
490 planets
Sep 2010

Astrometry aims at unexplored region



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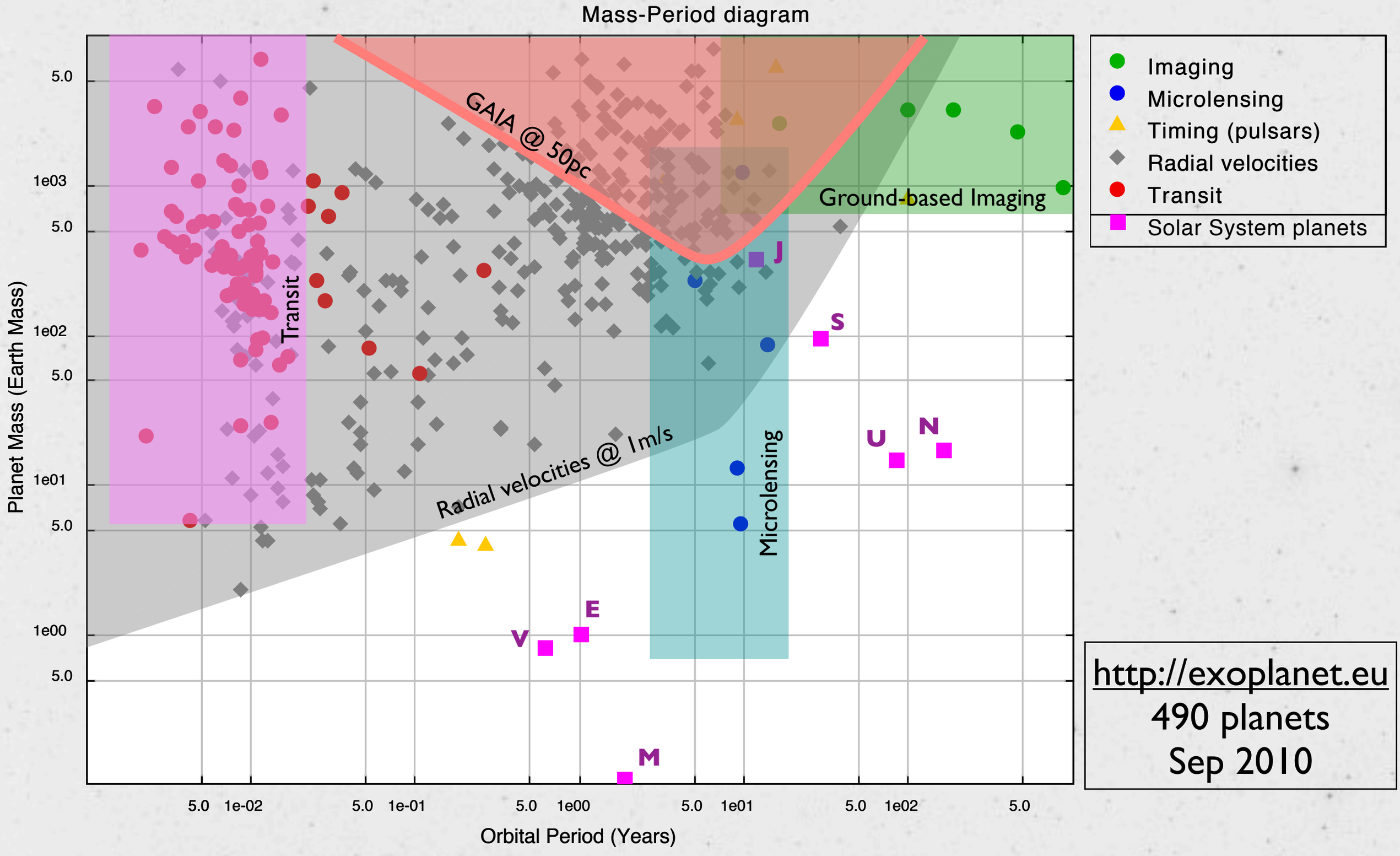

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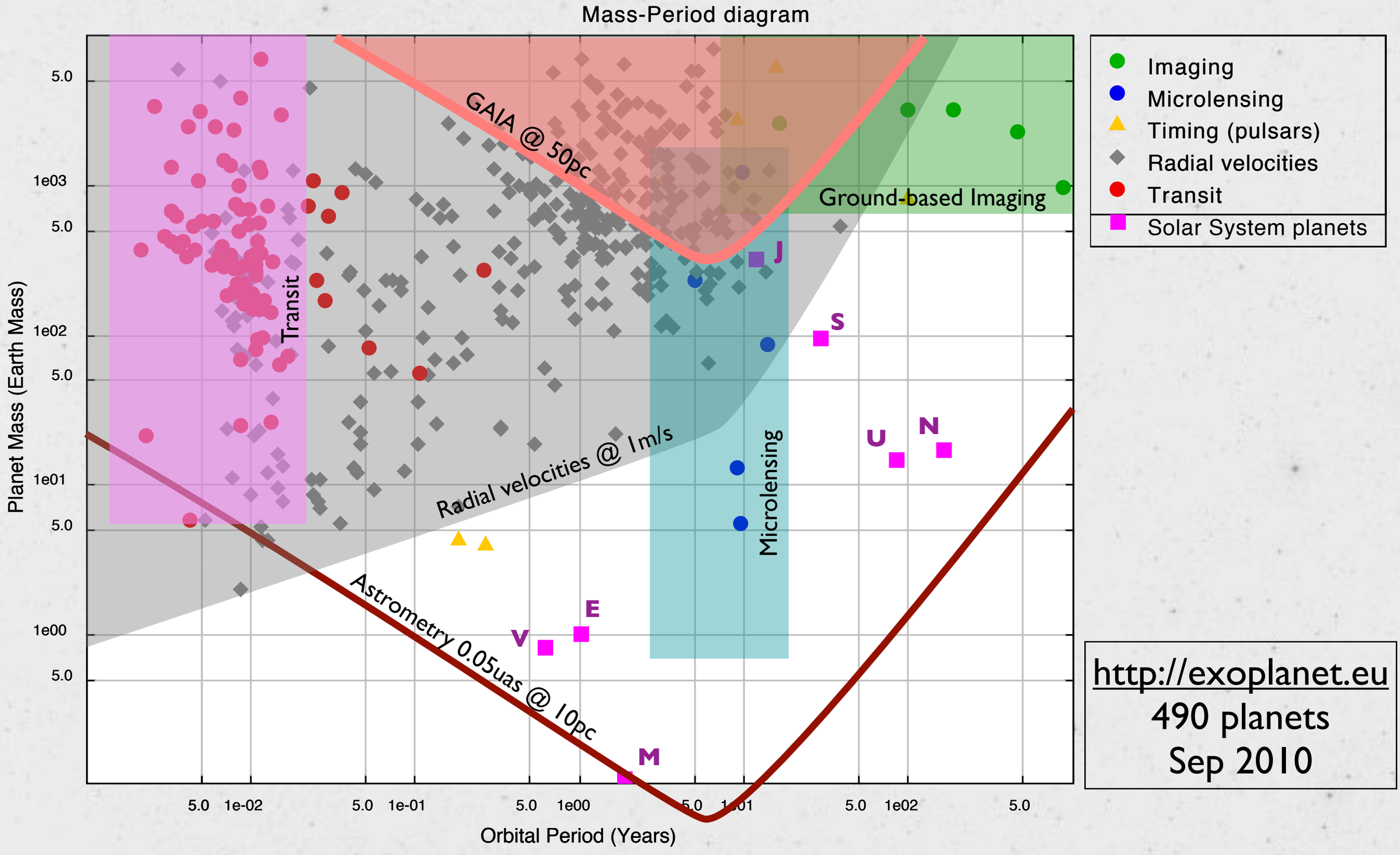

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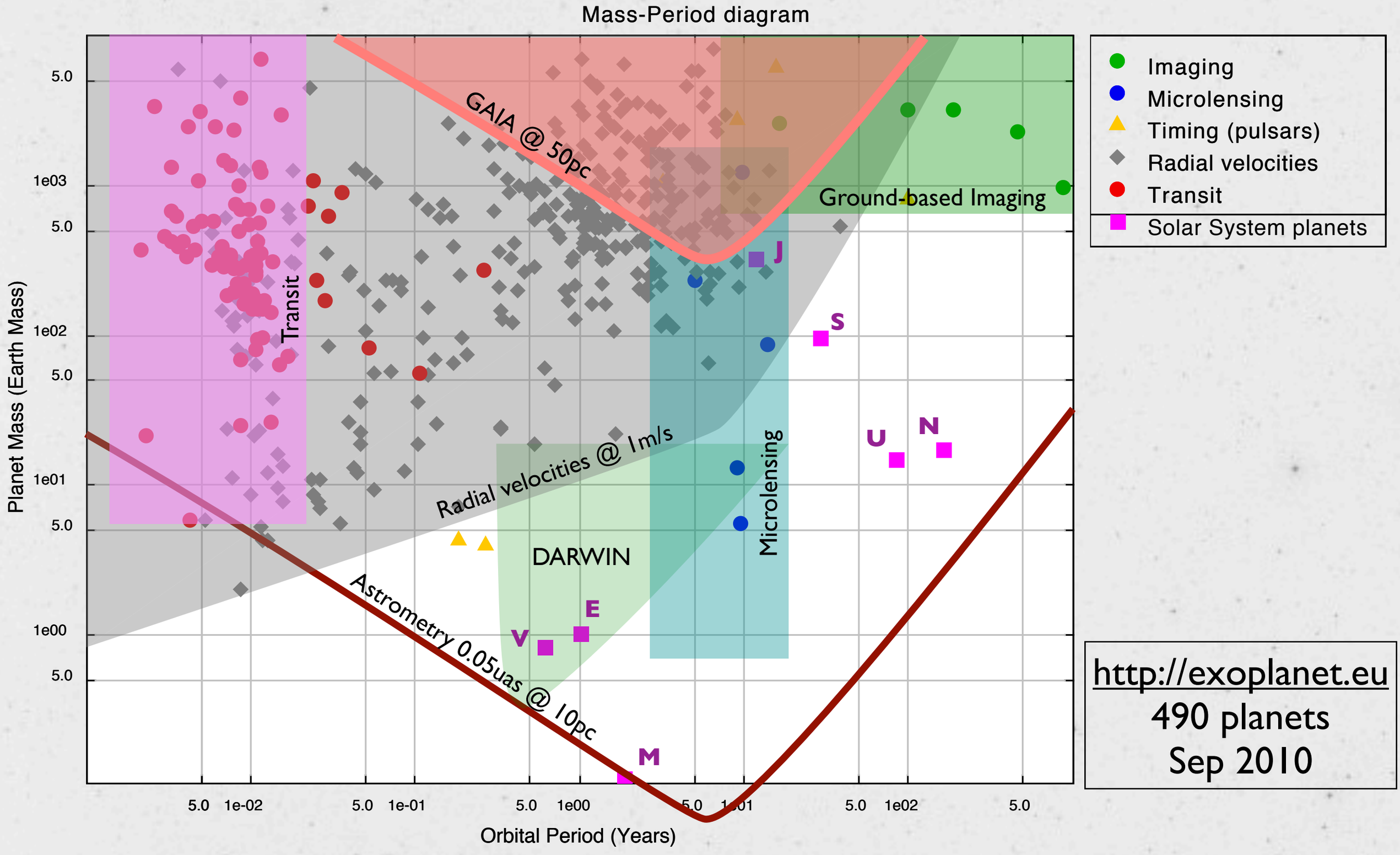

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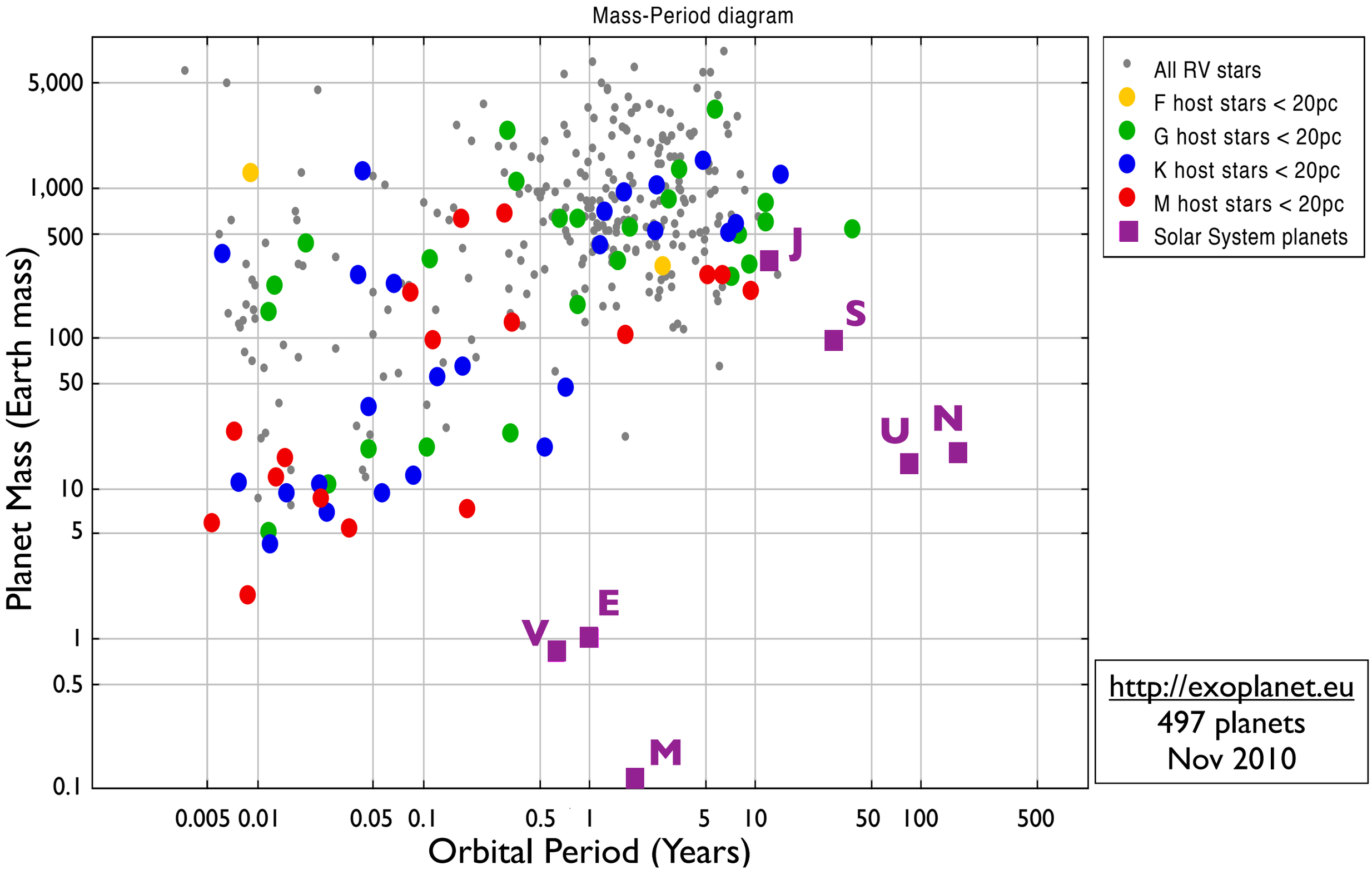
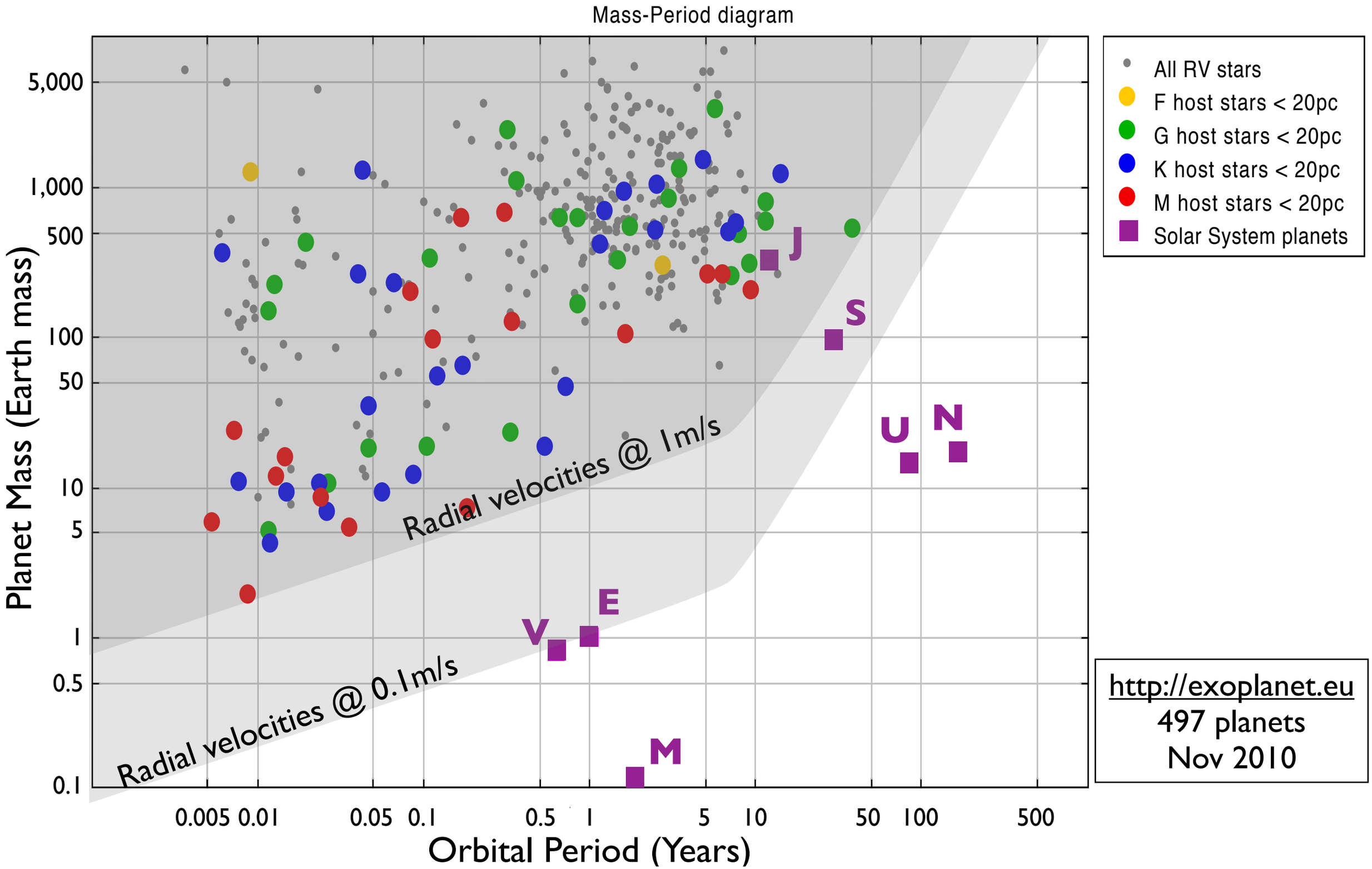
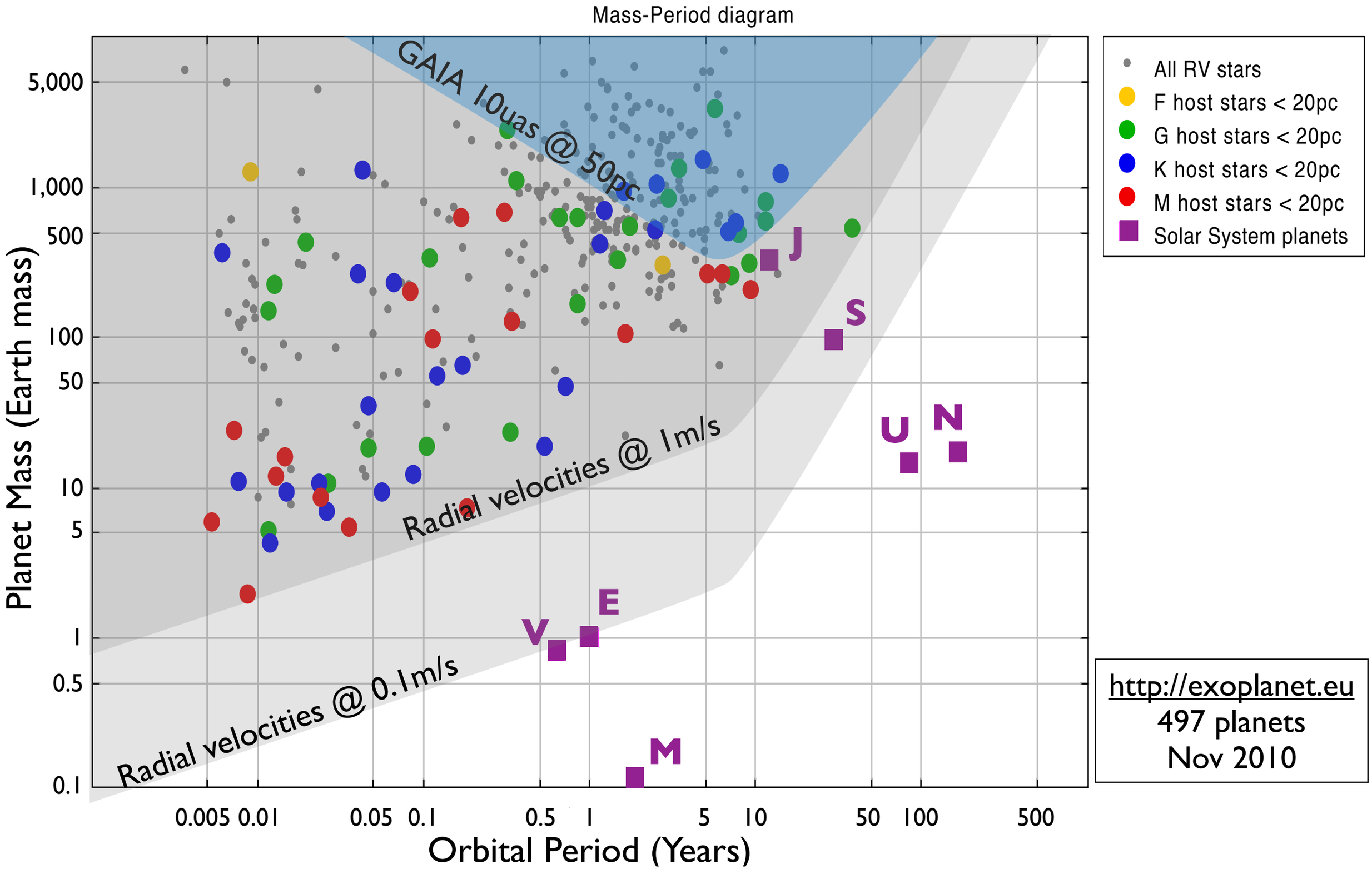
Habitable zone of nearby stars



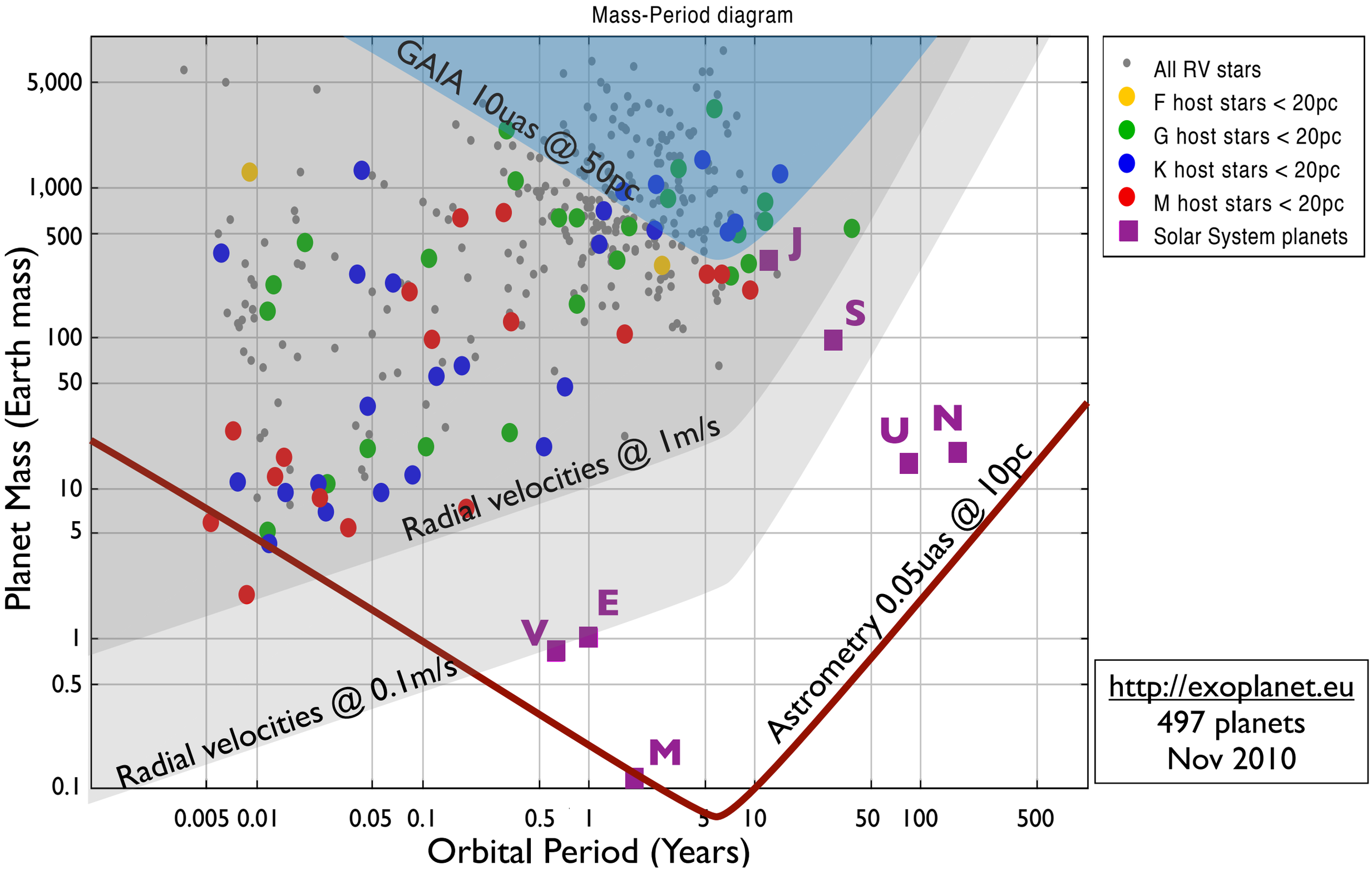
Habitable zone of nearby stars



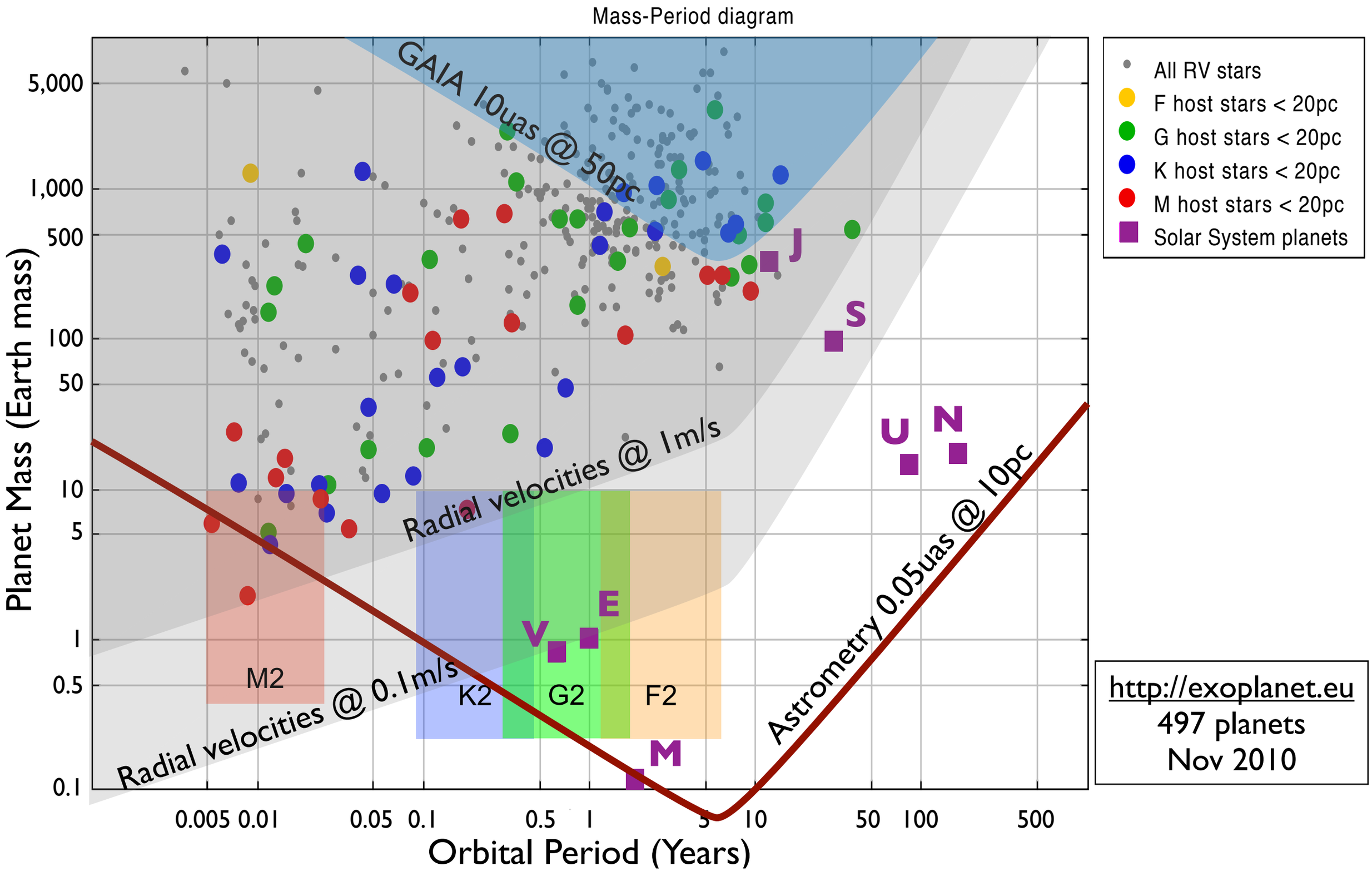
Habitable zone of nearby stars



Habitable zone of nearby stars



Habitable zone of nearby stars



Astrometry from ground and space

Ground-based single telescopes limited by the atmosphere

- Lindegren (1980): rms motion in case of a pair of stars $\propto \theta/D^{2/3}$,
  ➡ ~ 1 mas (binary orbits,...)
- Lazorenko et al. (2002, 2006): rms motion $\propto \theta^{11/6}/D^{3/2}$
  ➡ ~ 100-300 μas on VLT (Jupiter?)

Ground-based dual-star interferometers (PTI, VLTI/PRIMA, KI) limited by the atmosphere too but benefit from long B

- Shao & Colavita (1992): jitter $\propto \Delta\theta/B^{2/3}$,
  ➡ ~ 10-30 μas in 1h on VLTI

Space-borne instrument (HST/FGS)

➡ ~ 1 mas limited by spacecraft jitter

Space-borne survey (Gaia)

➡ ~ 7 μas end-of-mission, high number of objects (Giant planets)

Need for sub-μas requires space project !

Programmatic context

Cosmic Vision plan for 2015-2025 and EPRAT

→ **Theme 1**: *What are the conditions for planet formation?*

→ **Sect. 1.2**: Search for planets around stars other than the Sun...

« On a longer timescale, a complete census of all Earth-sized planets within 100 pc of the Sun would be highly desirable. Building on Gaia's expected contribution on larger planets, this could be achieved with a ***high-precision terrestrial planet astrometric surveyor****. »*

Decadal survey Astro2010 and EXOPAG

→**Panel report** on Planet and Star Formation:

→ **Section**: Do Habitable Worlds Exist Around Other Stars...?

« A space-based astrometric survey of the closest 100 Sun-like stars with a precision sufficient to detect terrestrial planets in the habitable zones » ... although SIM-Lite was not considered cost efficient (15° FOV required only for global astrometry).

Barcelona conference «Pathways Toward Habitable Planets»

Milestone #2: *« Carry out a space mission that could complete a survey of all the habitable exoplanets that fall within a radius of 50 light years from our Sun. These systems are close enough to be studied in detail. The astrometry technique has shown to be the most suitable method for this objective. »*

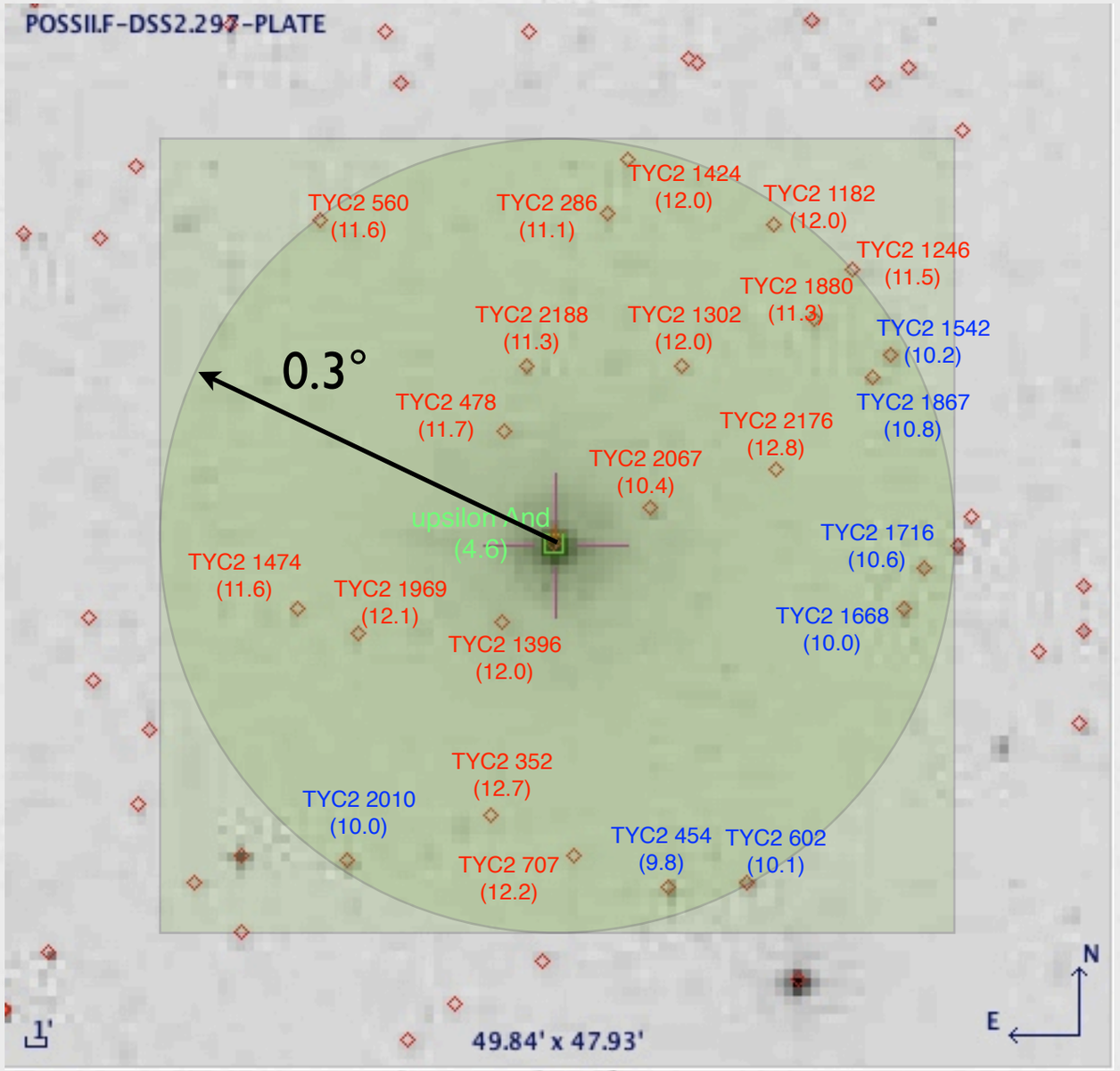
High precision astrometry

- **Specifications:**
  0.3uas → 0.05 uas (SNR=6) mission
  → ~0.5 uas/hr with 100 pts

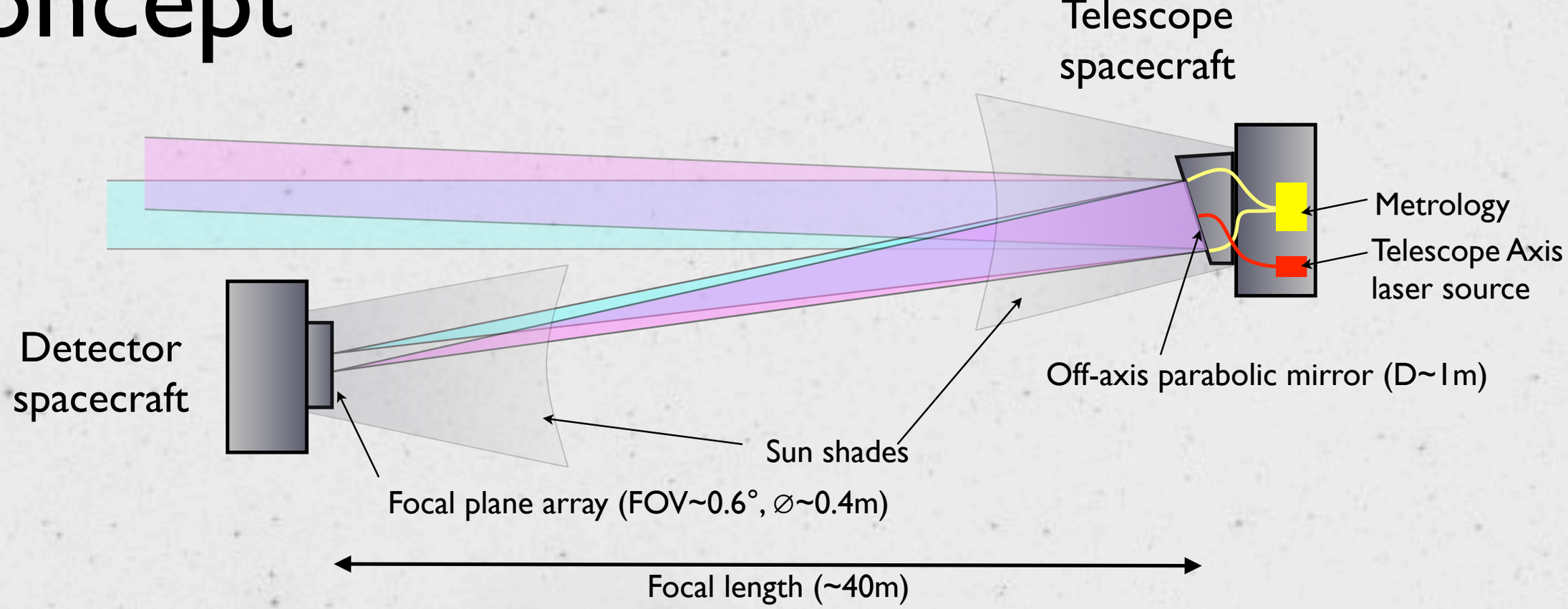
- **Limitation of differential astrometry:**
  - angle calibration (beam walk, pixels, PSF, QE...)
  - photon noise

- **Challenge**:
  - resolution (~0.5uas/hr) vs FOV (0.6 deg)

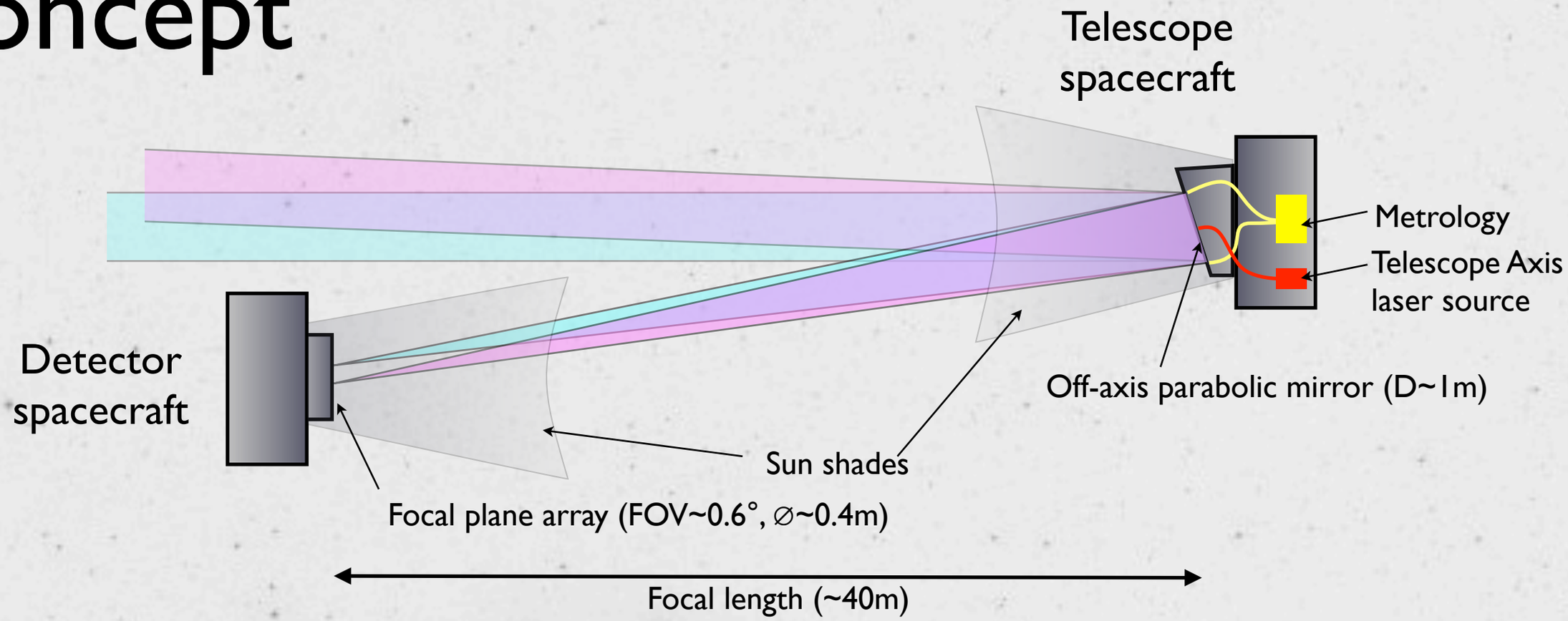
➡ 1 : 2 10^9 !!!

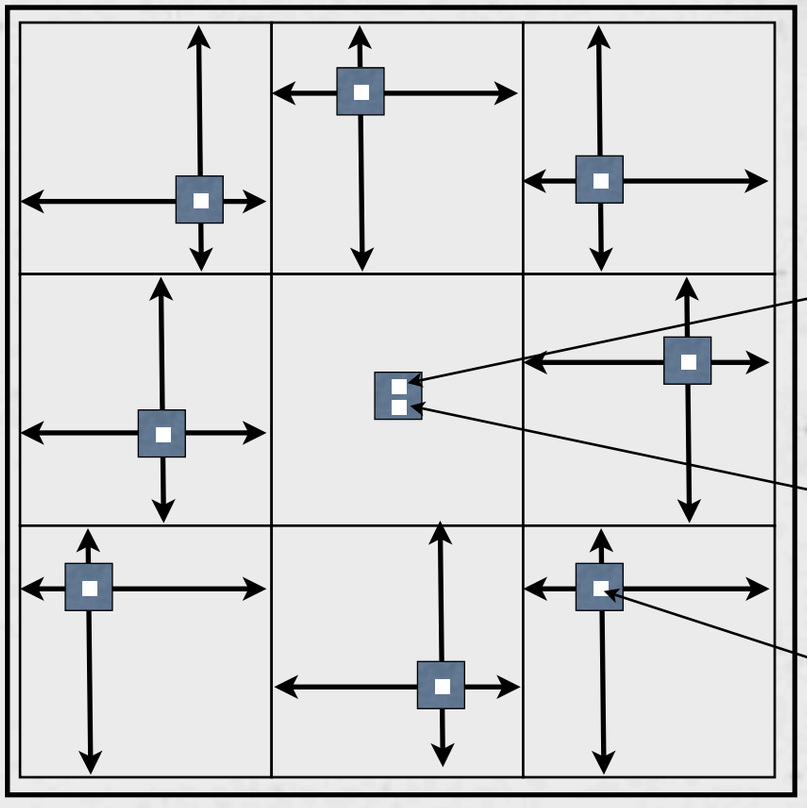


Concept


Telescope spacecraft
Metrology
Telescope Axis laser source
Detector spacecraft
Off-axis parabolic mirror (D~1m)
Sun shades
Focal plane array (FOV~0.6°, ⌀~0.4m)
Focal length (~40m)

Concept



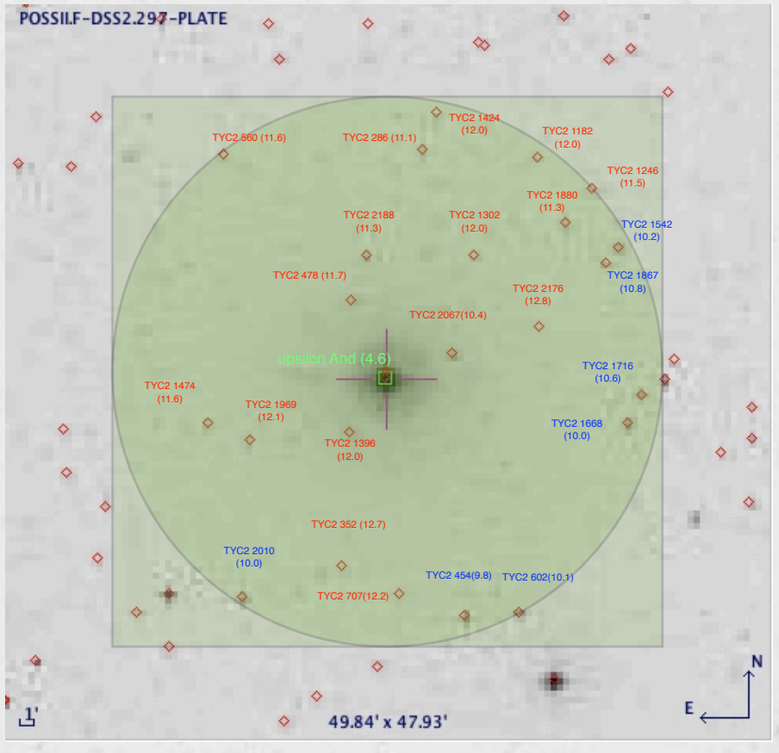


Focal plane

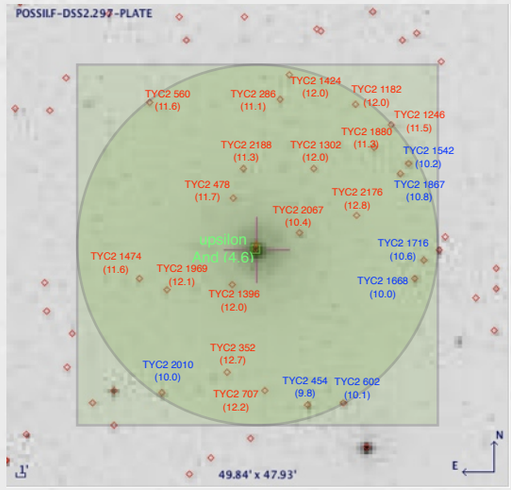
1 fixed CCD (target star)

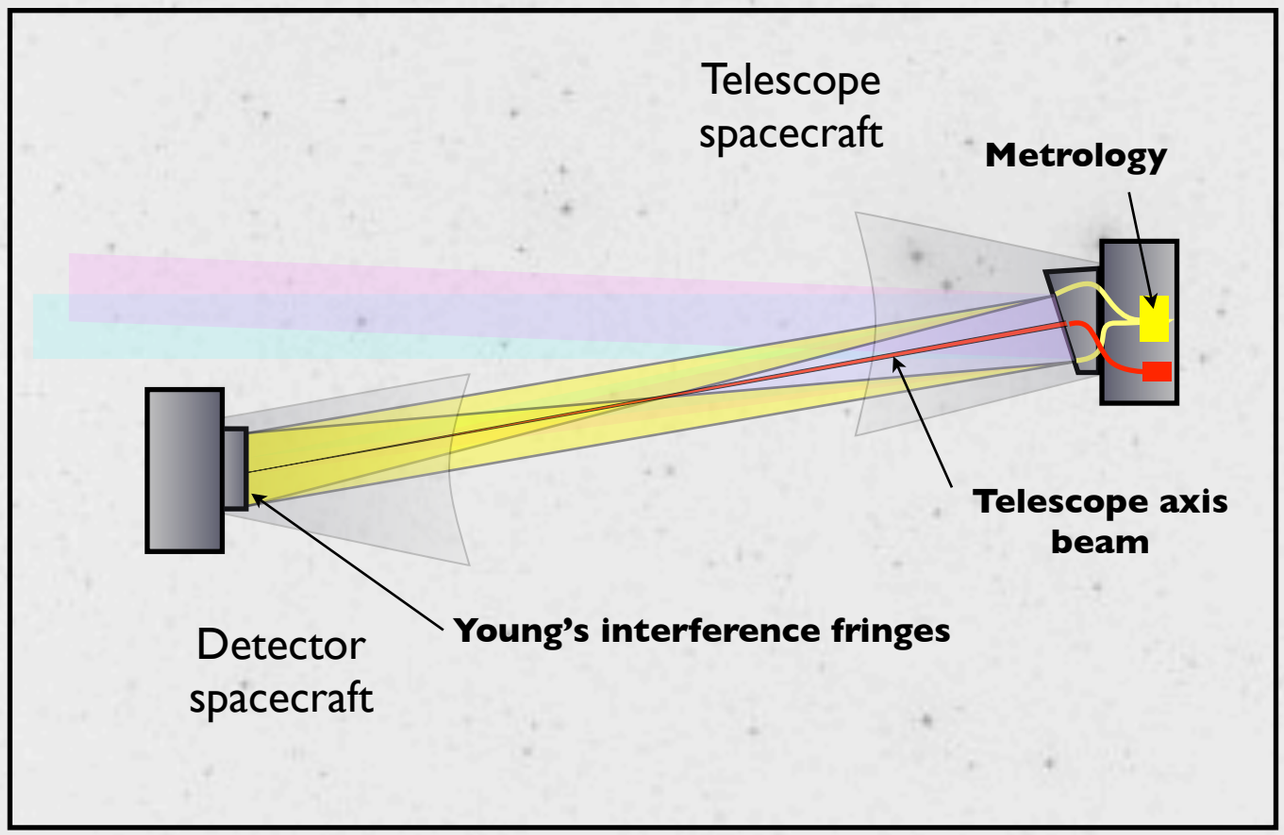
1 fixed CCD (telescope axis tracker)

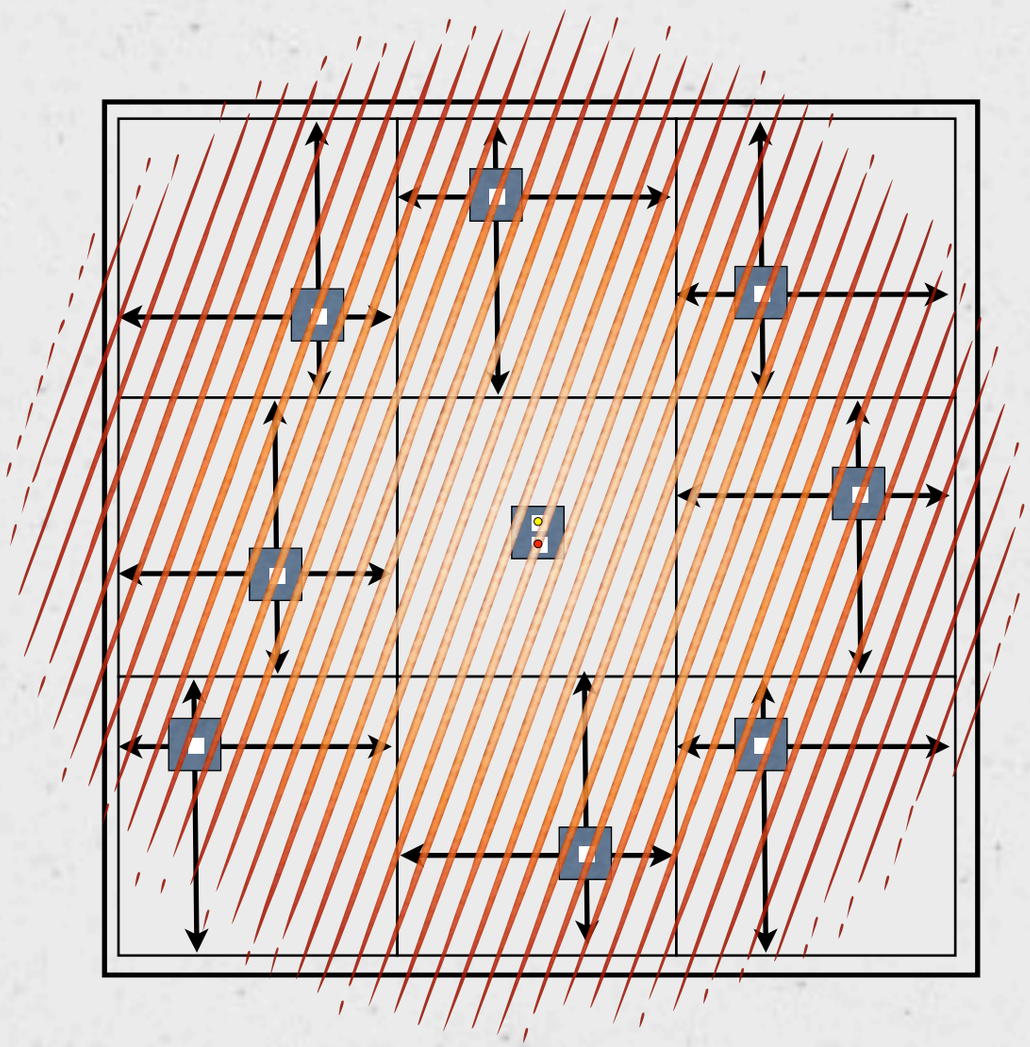
8 movable CCDs (reference stars)



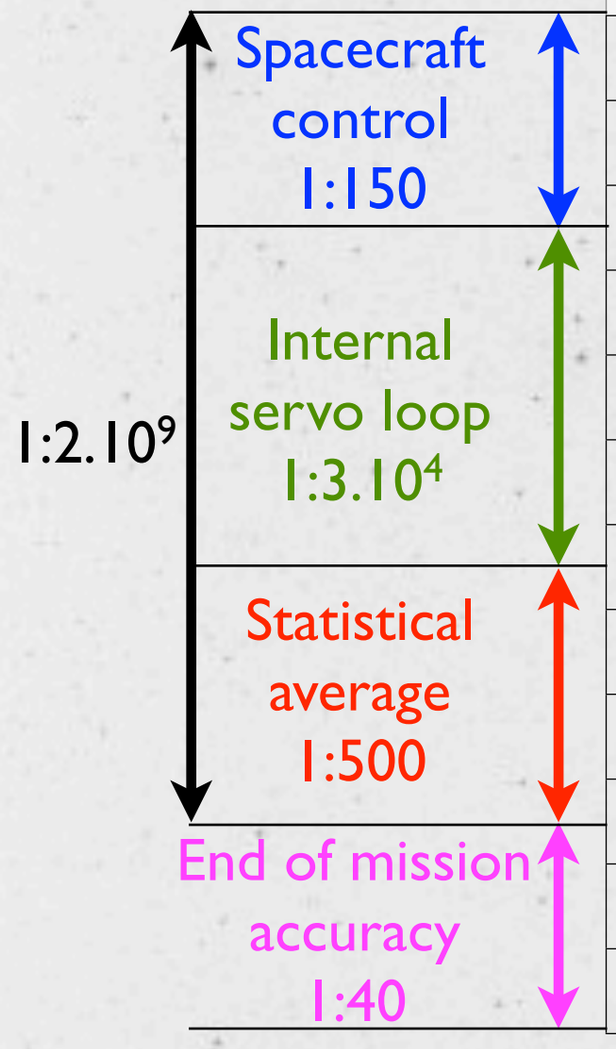
The focal plane and how to measure the angles with metrology







Control Strategy



Focal plane		Astrometry	
metric	pixel	angle	scale
403 mm		0.56 deg	Field of view
143 mm		0.2 deg	Ref-Target separation
2.5 mm	256	13 as	CCD detector
200 microns	20	1 as	ACS one-sigma
10 microns	1	50 milli-as	CCD pixels
1 micron	0.1	5 milli-as	
0.1 micron	0.01	0.5 milli-as	
10 nanometers	1 milli-px	0.05 milli-as	
1 nanometer	0.1 milli-px	5 micro-as	1 minute integration
200 picometers	20 micro-px	1 micro-as	~1 hour visit
60 picometers		0.3 micro-as	1 Earth at 10 parsec
5 picometers		25 nano-as	End of mission floor

Astrometry mission

- Formation flying spacecrafts with specifications close to those of Simbol-X (~350M€) with smaller payload (boom option too)
- L2 orbit to control only the formation against solar radiation pressure
- Fuel needed to have ~20,000 visits over 5 years
- All the required technology has been validated (PRISMA, PROBA-3, SIM-Lite),
- metrology/CCD performance (on-going tests)

Summary

- Unique science case: probe all our neighboring planetary systems (200 FGK stars up to 15pc) down to the telluric planets
- Explore other systems: GAIA legacy, young stars, active stars
- Space segment: formation flying spacecrafts (PRISMA heritage), but possibility to use deployable boom
- Astrometry: a European speciality. Requires to go space to reach high accuracy measurements
- First step to identify possible targets for spectroscopic characterization (TPF-C, DARWIN).