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Low-mass planets at long period

HIP41378: a foretaste of PLATO

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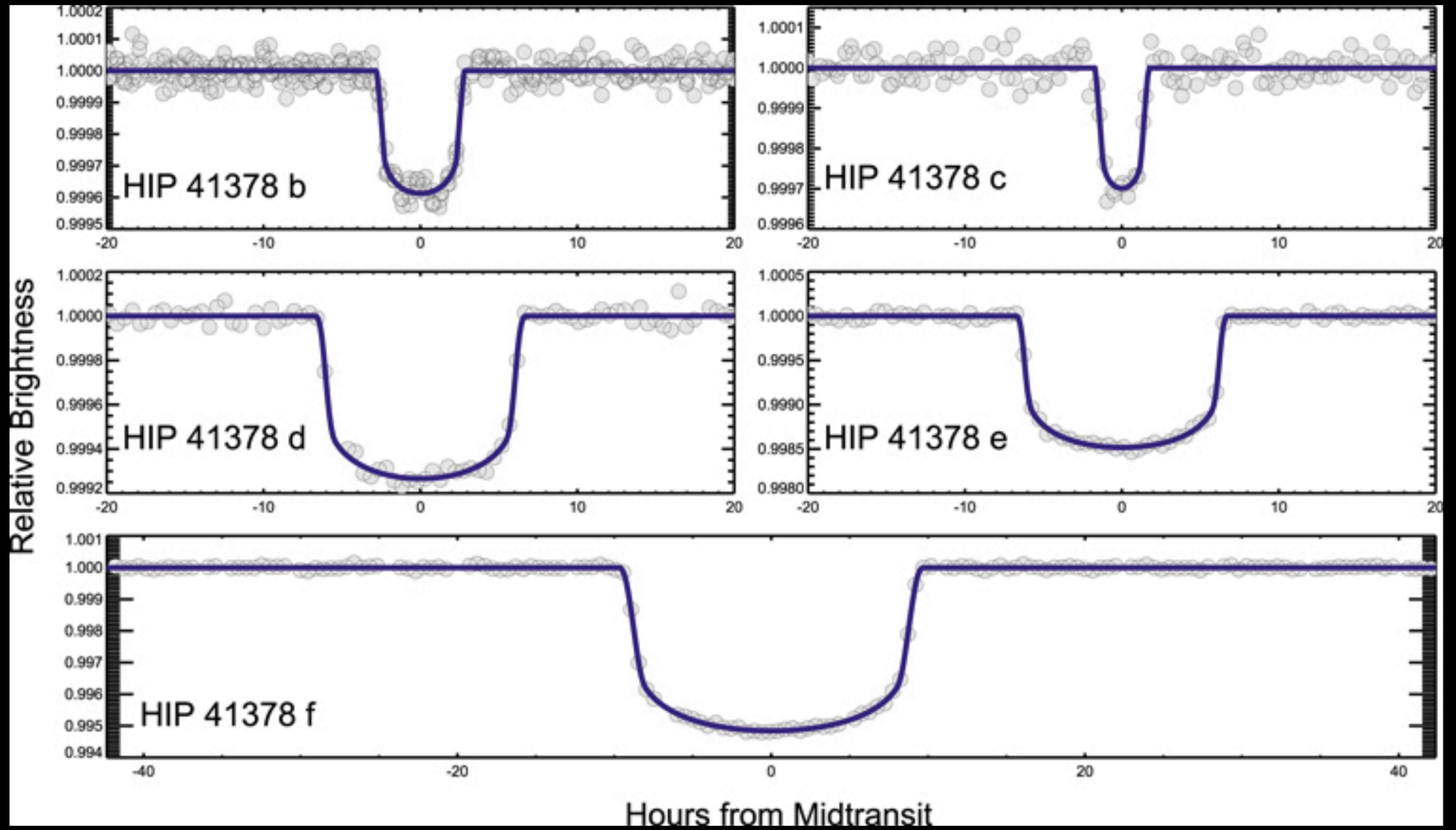
The HIP41378 system

The HIP41378 system

5 transiting planets detected by K2 in 2015



V = 8.9

Planet	Period
b	15 d
c	31d
d	mono
e	mono
f	mono

Vanderburg et al. (2016)

Re-observation by K2

Second transit of planets d and f detected in 2018

Possible orbital periods for HIP 41378 d

Orbital Period (days)	Normalized Probability
1113.4465 ± 0.0034	< 0.1 %
556.7233 ± 0.0017	< 0.1 %
371.1488 ± 0.0011	0.1 %
278.3616 ± 0.0009	0.5 %
222.6893 ± 0.0007	1.1 %
185.5744 ± 0.0006	2.4 %
159.0638 ± 0.0005	4.1 %
139.1808 ± 0.0004	5.7 %
123.7163 ± 0.0004	6.7 %
111.3447 ± 0.0003	7.1 %
101.2224 ± 0.0003	7.1 %
92.7872 ± 0.0003	7.0 %
85.6497 ± 0.0003	6.9 %
79.5319 ± 0.0002	6.8 %
74.2298 ± 0.0002	6.8 %
69.5904 ± 0.0002	6.3 %
65.4969 ± 0.0002	5.9 %
61.8581 ± 0.0002	5.5 %
58.6024 ± 0.0002	5.1 %
55.6723 ± 0.0002	4.8 %
53.0213 ± 0.0002	4.5 %
50.6112 ± 0.0002	4.2 %
48.4107 ± 0.0001	1.4 %

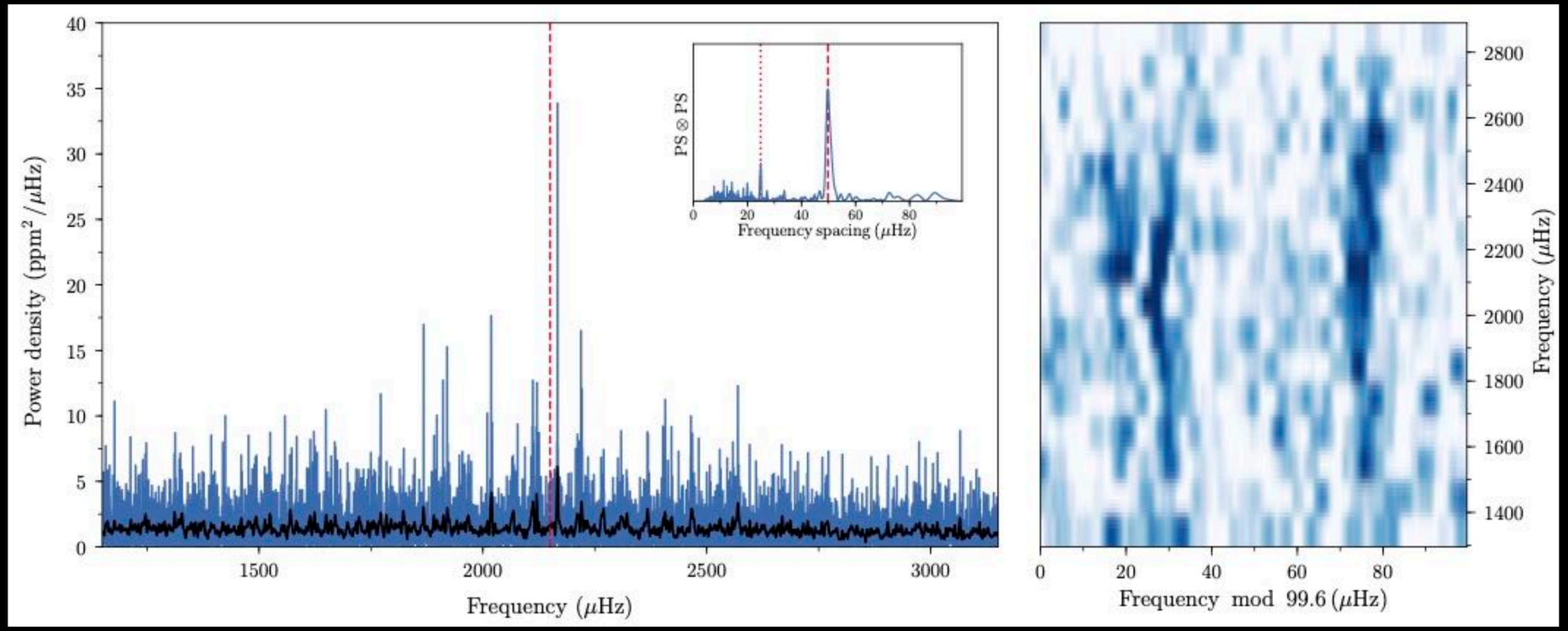
TABLE 3
Possible orbital periods for HIP 41378 f

Orbital Period (days)	Normalized Probability (w/o KELT/HAT/WASP)	Normalized Probability (w/ KELT/HAT/WASP)
1084.15946 ± 0.00086	< 0.1 %	< 0.1 %
542.07973 ± 0.00043	2.2 %	3.2 %
361.38649 ± 0.00029	19.9 %	29.7 %
271.03986 ± 0.00022	15.7 %	23.6 %
216.83189 ± 0.00017	15.2 %	22.8 %
180.69324 ± 0.00014	13.4 %	20.1 %
154.87992 ± 0.00012	14.8 %	< 0.1 %
135.51993 ± 0.00011	13.4 %	< 0.1 %
120.46216 ± 0.00010	5.0 %	< 0.1 %
108.41595 ± 0.00009	0.4 %	0.6 %
98.55995 ± 0.00008	< 0.1 %	< 0.1 %
90.34662 ± 0.00007	< 0.1 %	< 0.1 %
83.39688 ± 0.00007	< 0.1 %	< 0.1 %
77.43996 ± 0.00006	< 0.1 %	< 0.1 %
72.27730 ± 0.00006	< 0.1 %	< 0.1 %
67.75997 ± 0.00005	< 0.1 %	< 0.1 %
63.77409 ± 0.00005	< 0.1 %	< 0.1 %
60.23108 ± 0.00005	< 0.1 %	< 0.1 %
57.06102 ± 0.00005	< 0.1 %	< 0.1 %
54.20797 ± 0.00004	< 0.1 %	< 0.1 %
51.62664 ± 0.00004	< 0.1 %	< 0.1 %
49.27998 ± 0.00004	< 0.1 %	< 0.1 %
47.13737 ± 0.00004	< 0.1 %	< 0.1 %

Becker et al. (2018), Berardo et al. (2018)

Asteroseismology of the host star

High-precision stellar parameters



Planet	Period
b	15 d
c	31d
d	278 d
e	?
f	542 d

Method	Mass ($M_\odot$)	Radius ($R_\odot$)	$\log g$ (cgs; dex)	Age (Gyr)	Distance (pc)	$T_{\rm eff}$ (K)	[Fe/H] (dex)
BASTA	$1.22^{+0.03}_{-0.02}$	1.300 ± 0.009	4.298 ± 0.004	$2.07^{+0.36}_{-0.27}$	106.8 ± 1.0	6290 ± 77	-0.05 ± 0.10
Vanderburg et al. (2016)	1.15 ± 0.064	1.4 ± 0.19	4.18 ± 0.1	–	116 ± 18	6199 ± 50	-0.11 ± 0.08
Relative precision	1.6%	0.6%		15%			

Lund et al. (2019)

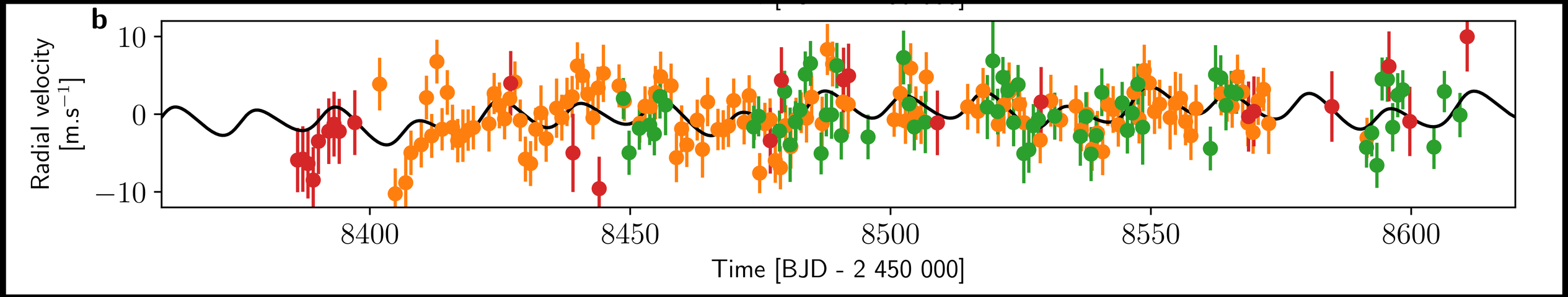
Intensive radial velocity campaign

4 EPRV spectrographs over 4 years

Instrument	Telescope time
HARPS (ESO-3.6m)	100+ hours
HARPS-N (TNG)	~ 40 hours
HIRES (Keck)	18 hours
FPS (Magellan)	5 hours

Planet	Period	Period	RV amplitude*
b	15 d	0.5 month	1.6 m/s
c	31d	1 month	1.0 m/s
d	278 d	9 months	< 1 m/s
e	~370 d	12 months	~1.1 m/s
f	542 d	18 months	1.5 m/s

* Revised values with improved data reduction

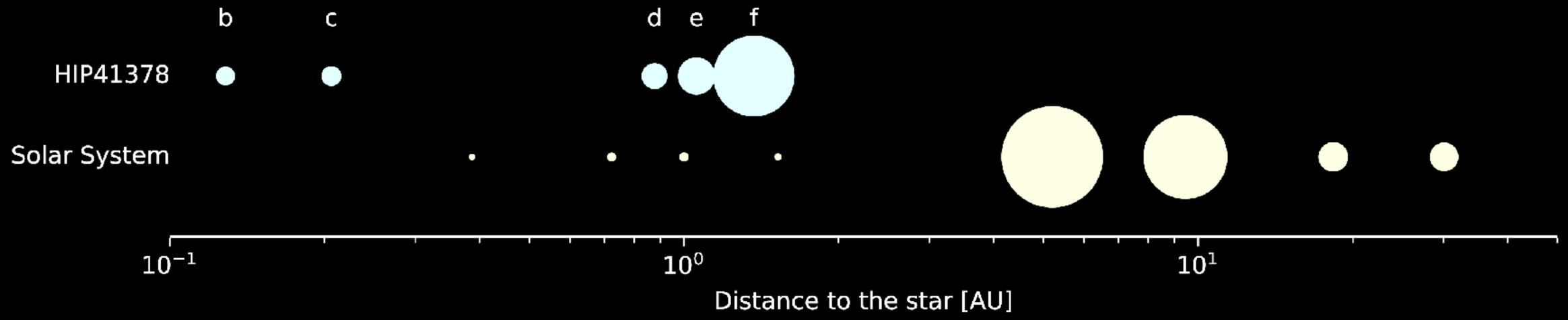


Santerne et al. (submitted)

HIP41478

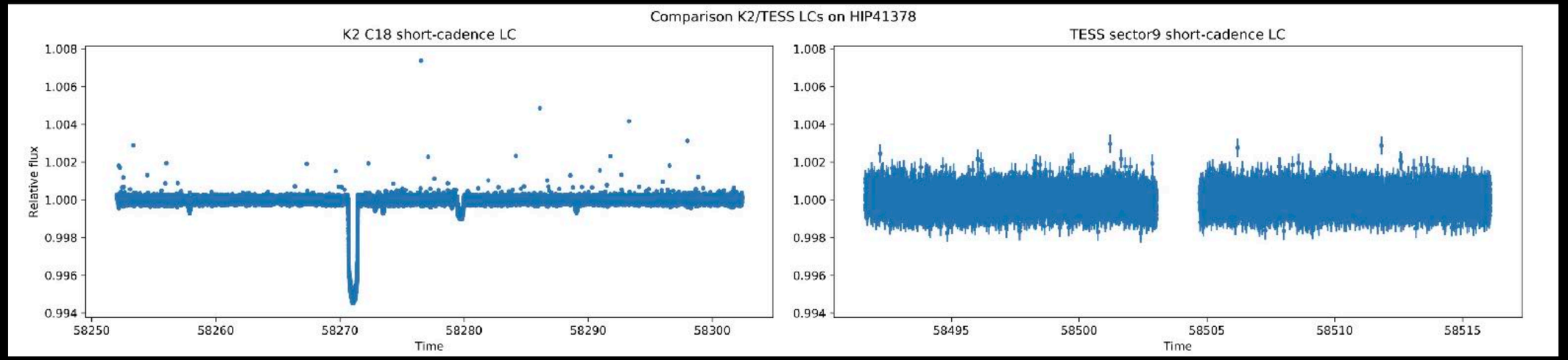
a foretaste of PLATO

- Bright (V=8.9) and relatively quiet star
- Multiplanetary system of low-mass exoplanets (sub-Neptune)
- Long orbital period planets (up to 1.5 years)
- Asteroseismology of the host star



TESS observations of HIP41378

At the overlap between two K2 fields, TESS North and TESS Ecliptic



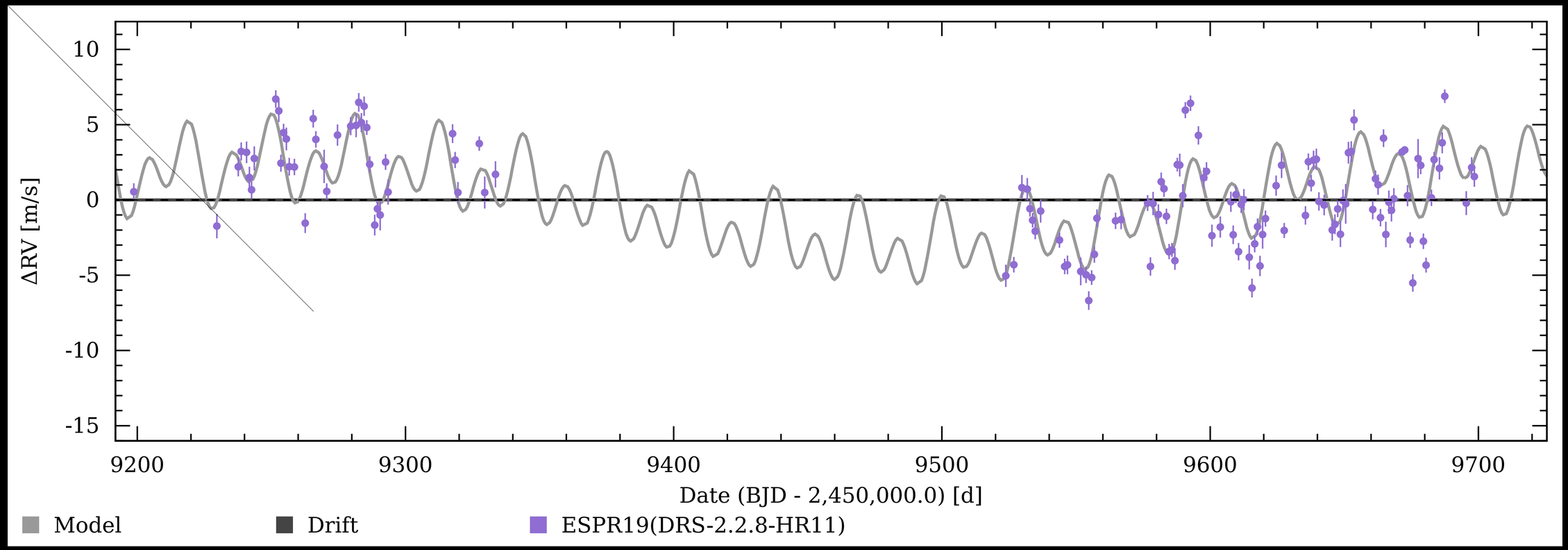
TESS sectors	Transits observed				
	b	c	d	e	f
#7	✓	✓	✗	✗	✗
#34	✓	✗	✗	✗	✗
#44	✓	✓	✗	✗	✗
#45	✓	✓	✗	✗	✗
#46	✗	✓	✗	✗	✗
#63	✓	✓	✗ !!	✗	✗

(Expected)

ESPRESSO monitoring

Low-amplitude stellar activity, extra Keplerian signals, etc…

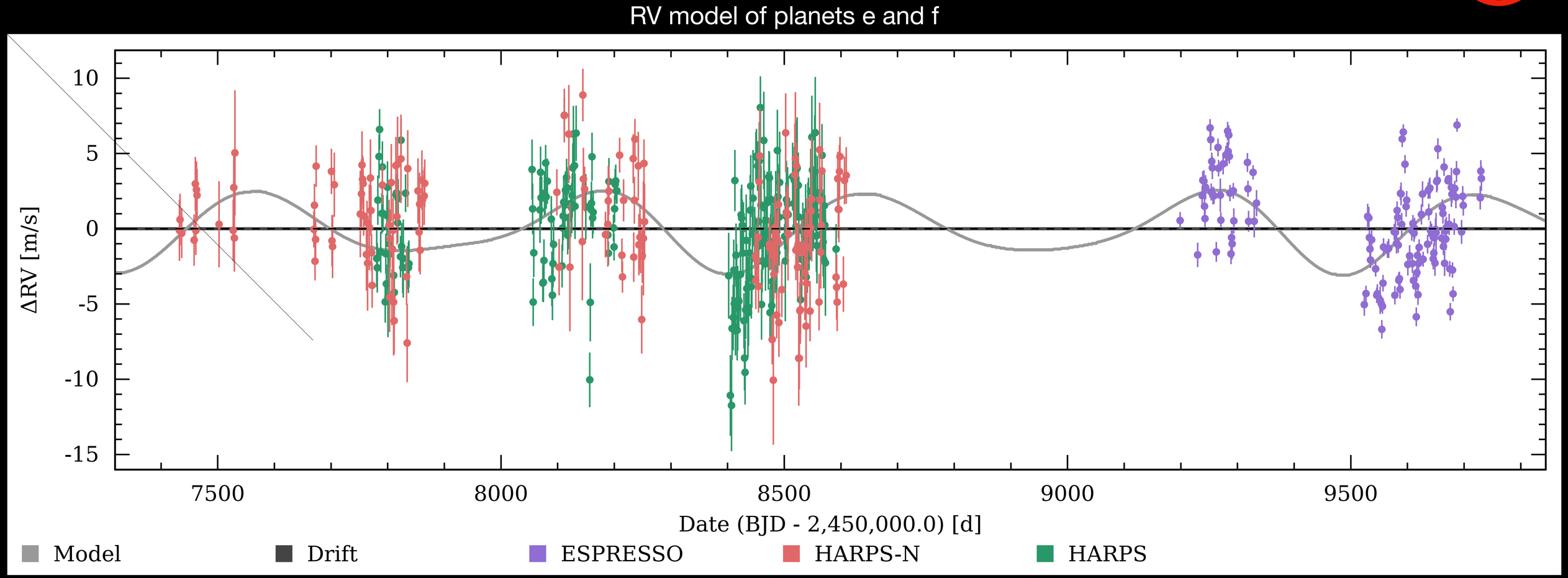
On-going radial velocity monitoring (50% completed) - 95h of VLT time granted



A dense sampling is extremely important to correct stellar activity ($P_{rot} << P_{orb}$)

Radial velocity signals of long-period planets

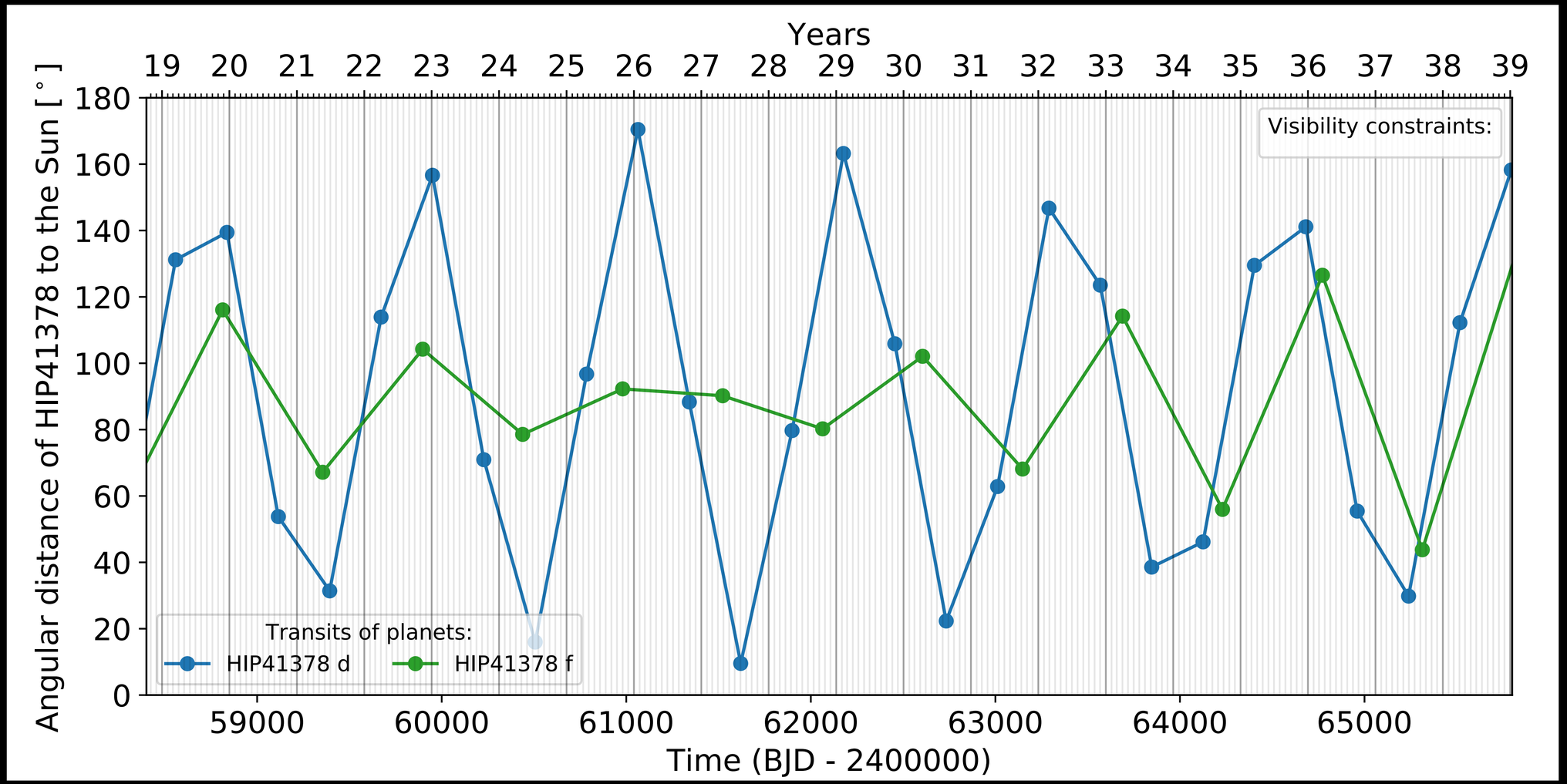
Commensurability = waving signal



Commensurability with the Earth’s orbit = poor phase coverage

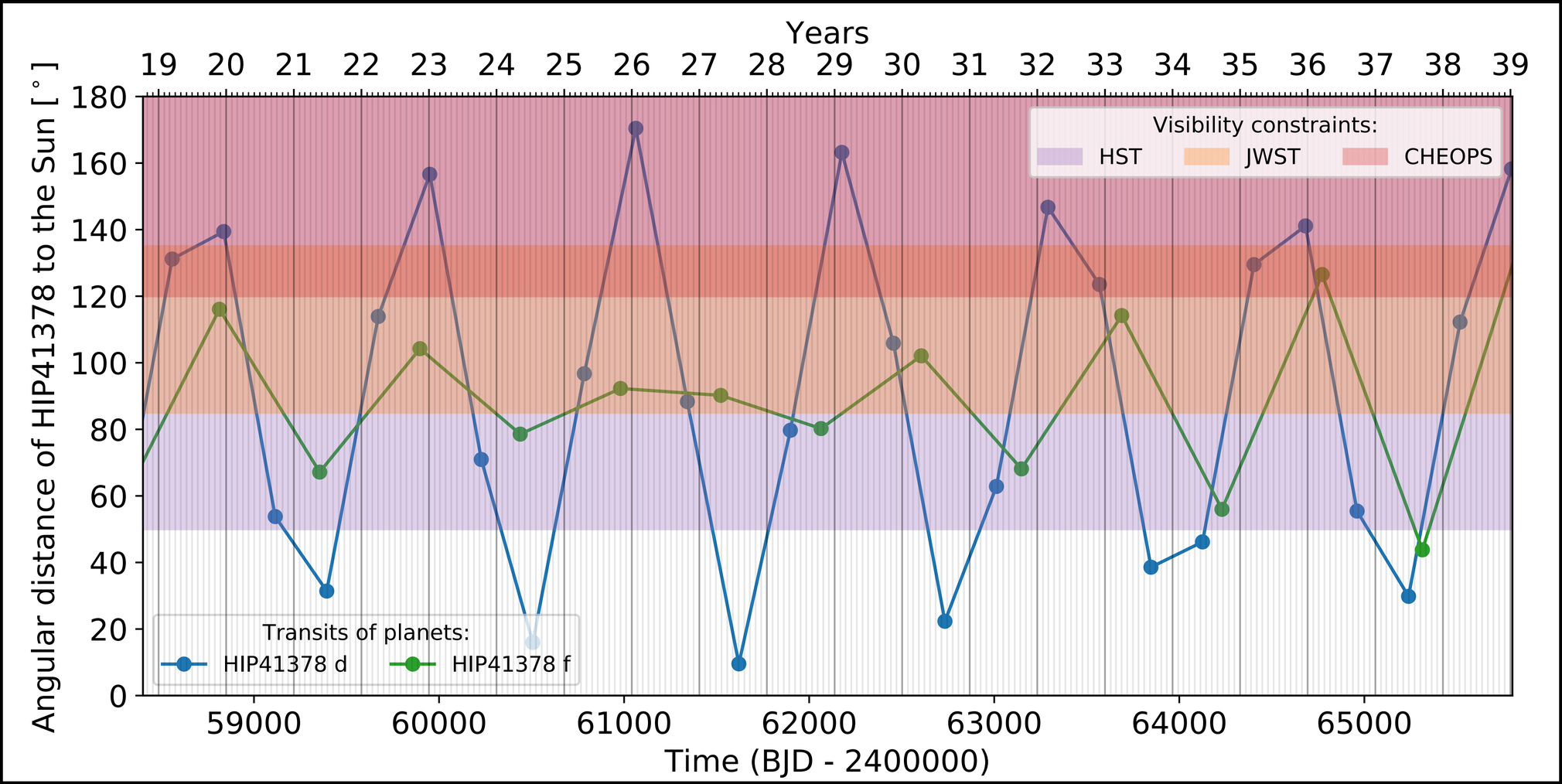
Transit follow-up

over 2 decades !



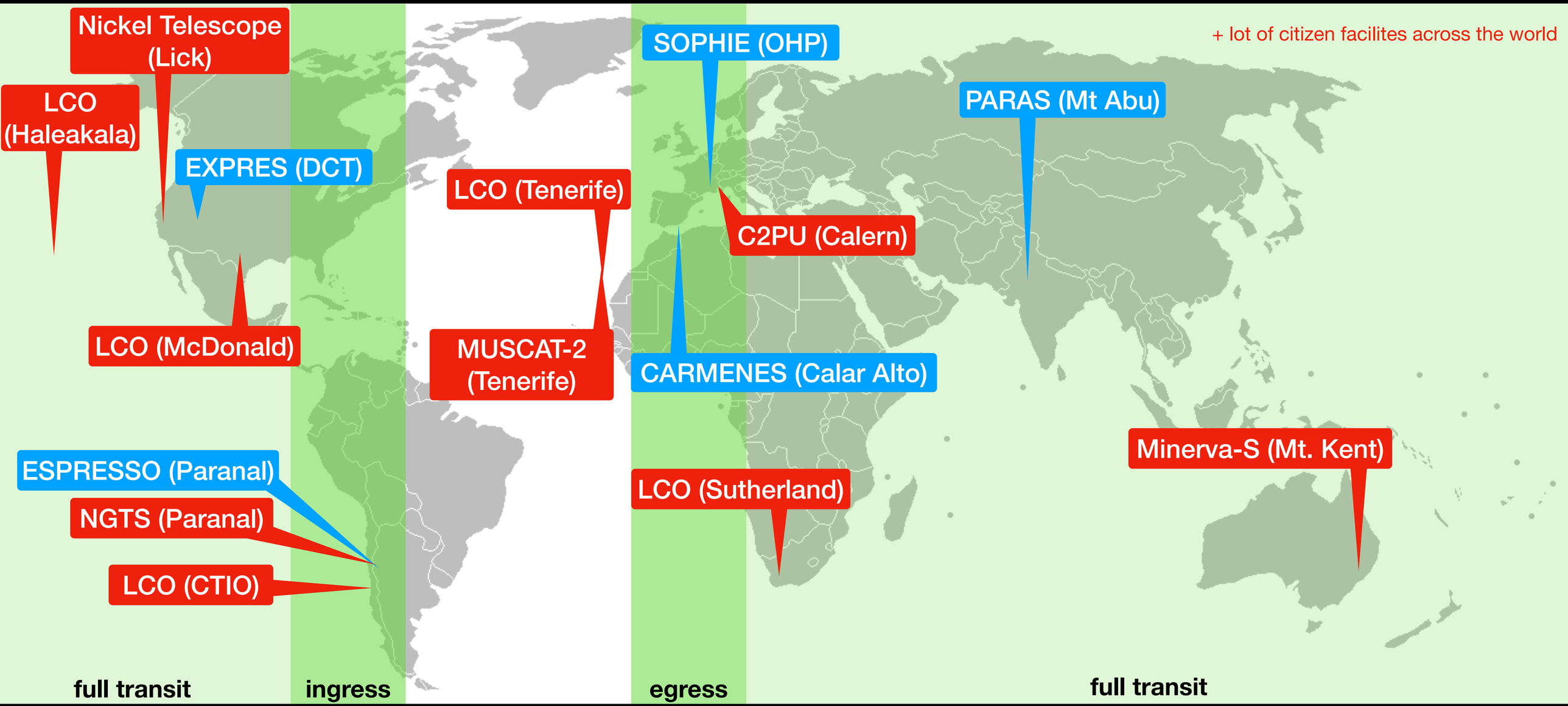
Transit follow-up

over 2 decades !



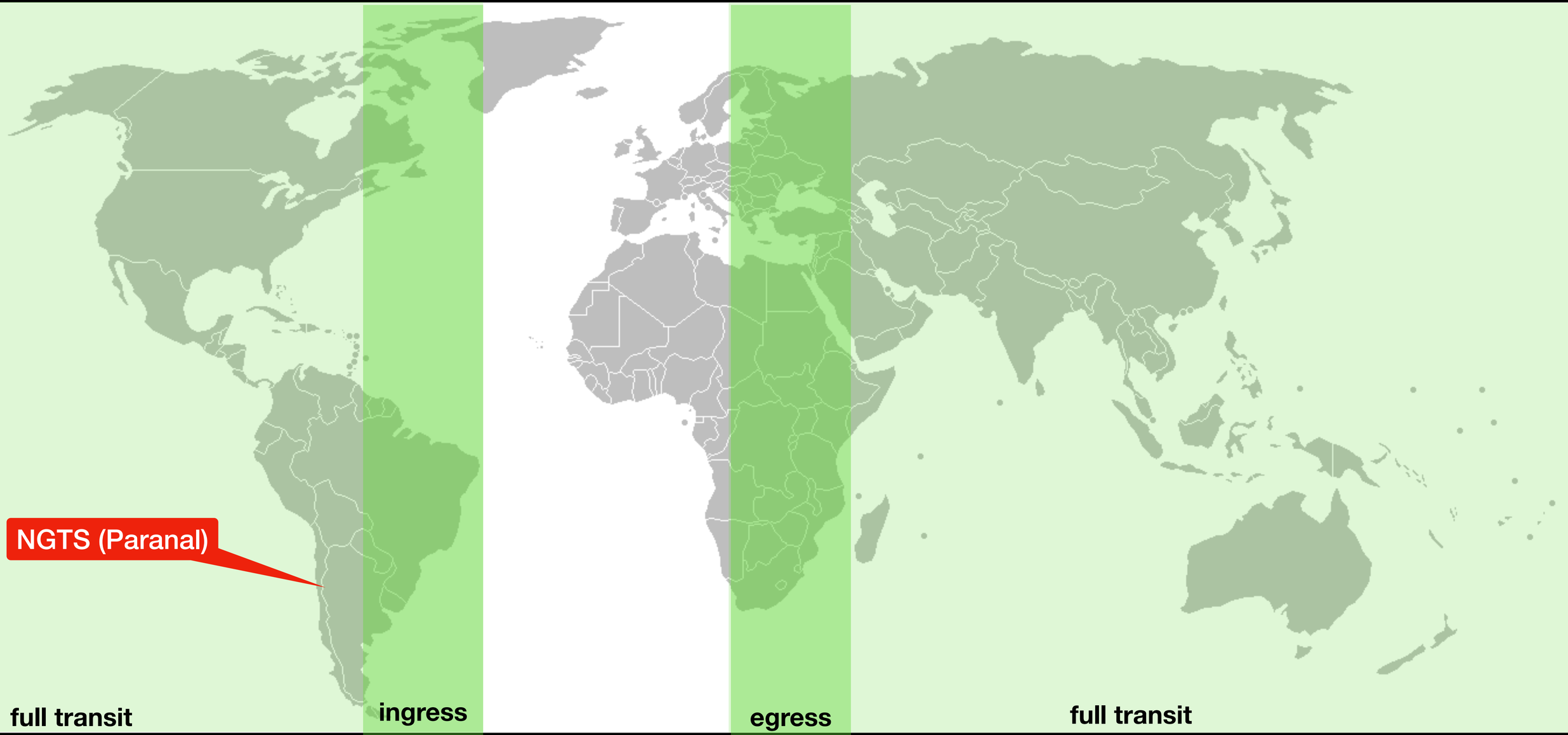
The 2019 campaign on HIP41378 f

Transit duration = 19 hours !



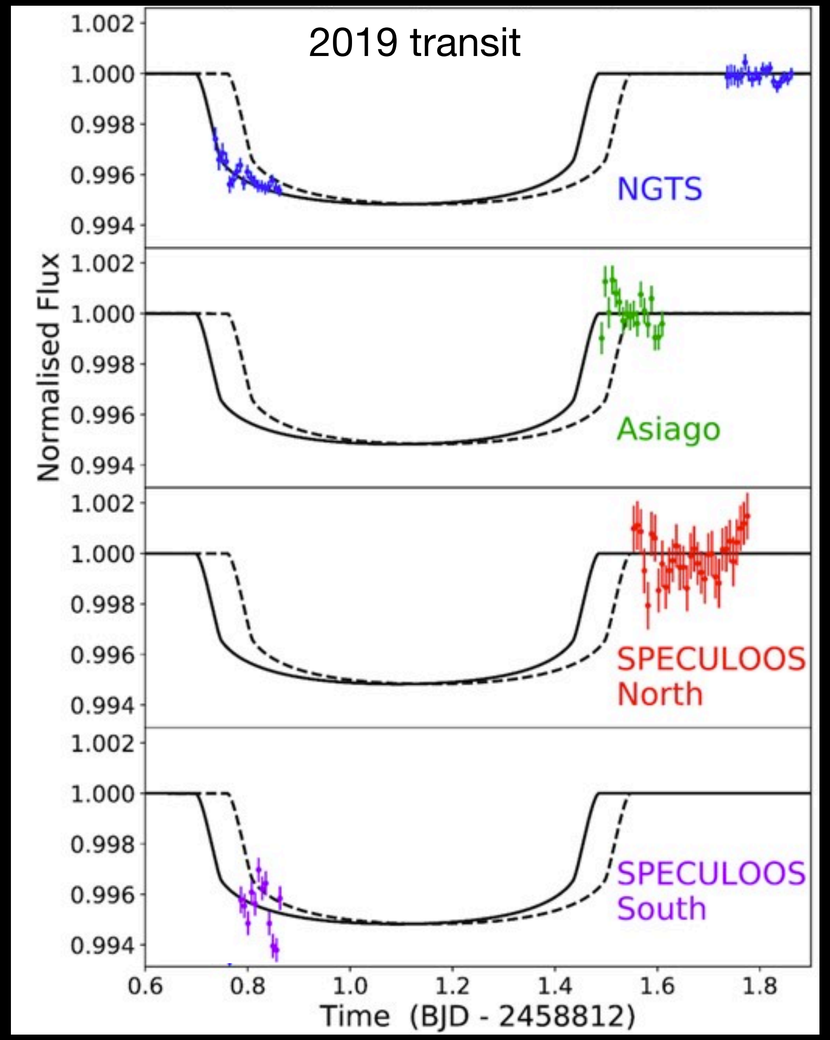
The 2019 campaign on HIP41378 f

(almost) a fiasco

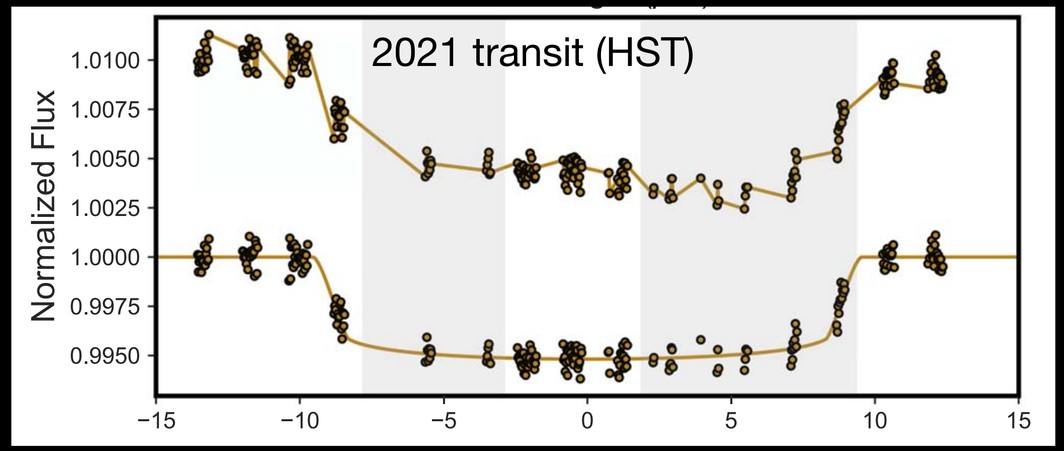


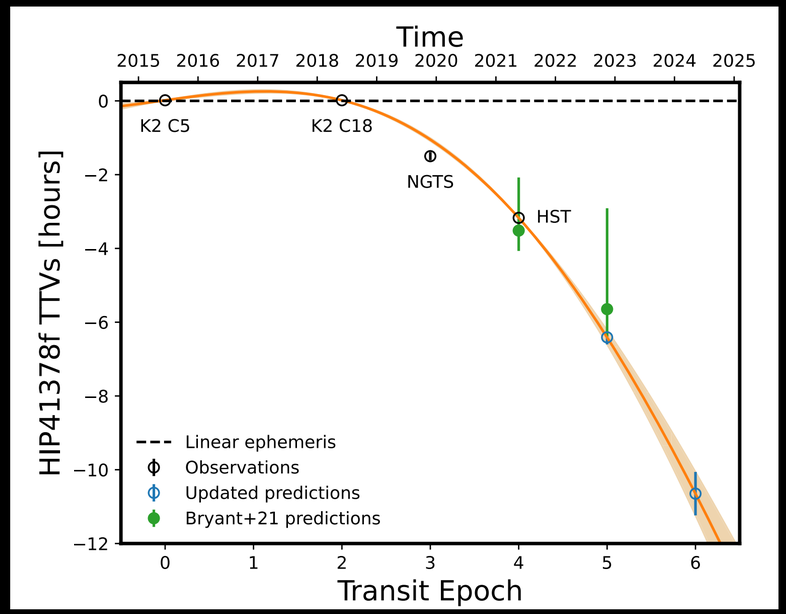
Photometric follow-up of HIP41378 f

From the ground and from space



Bryant et al. (2021)

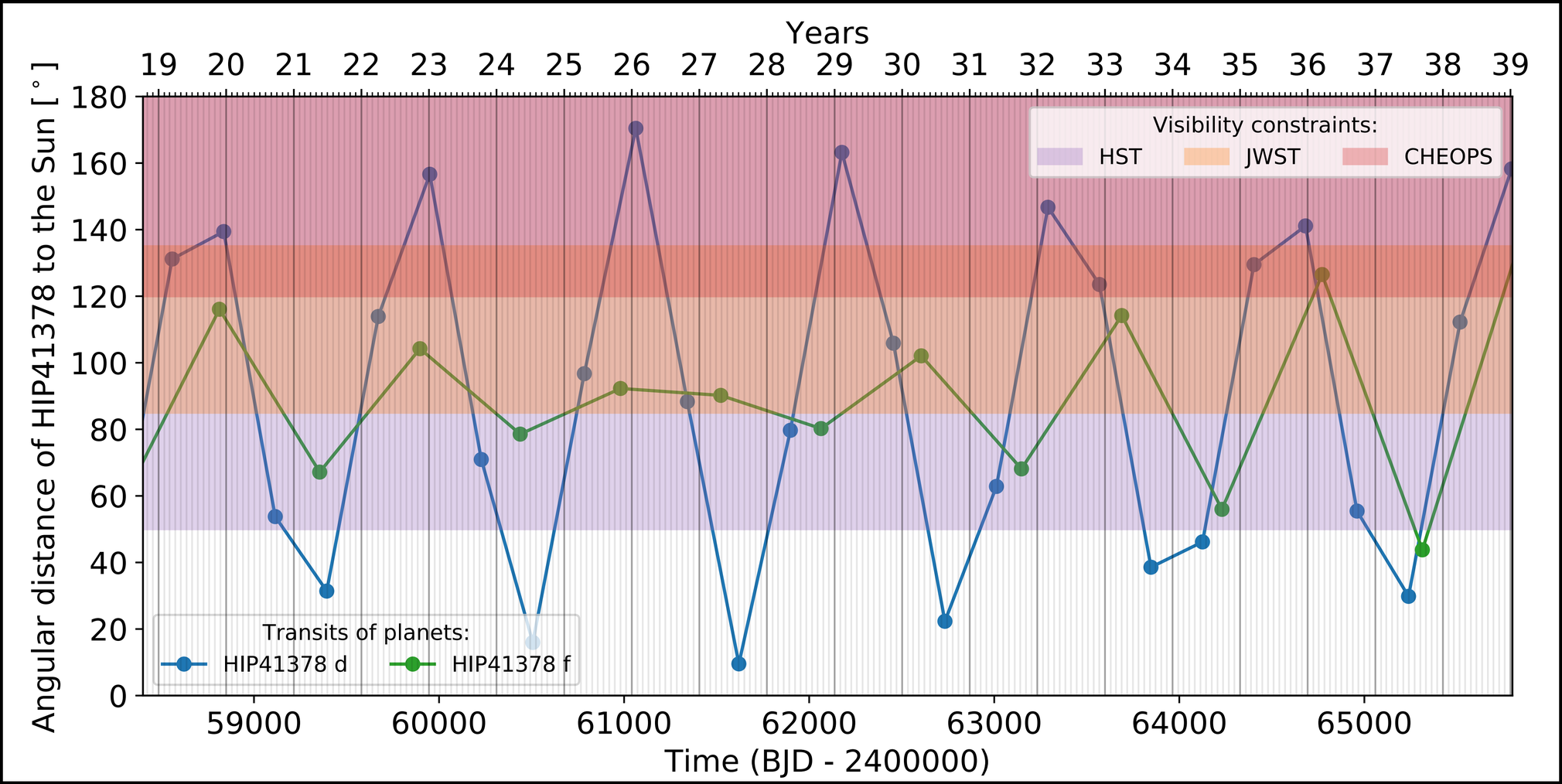




Alam et al., (2022)

Transit follow-up

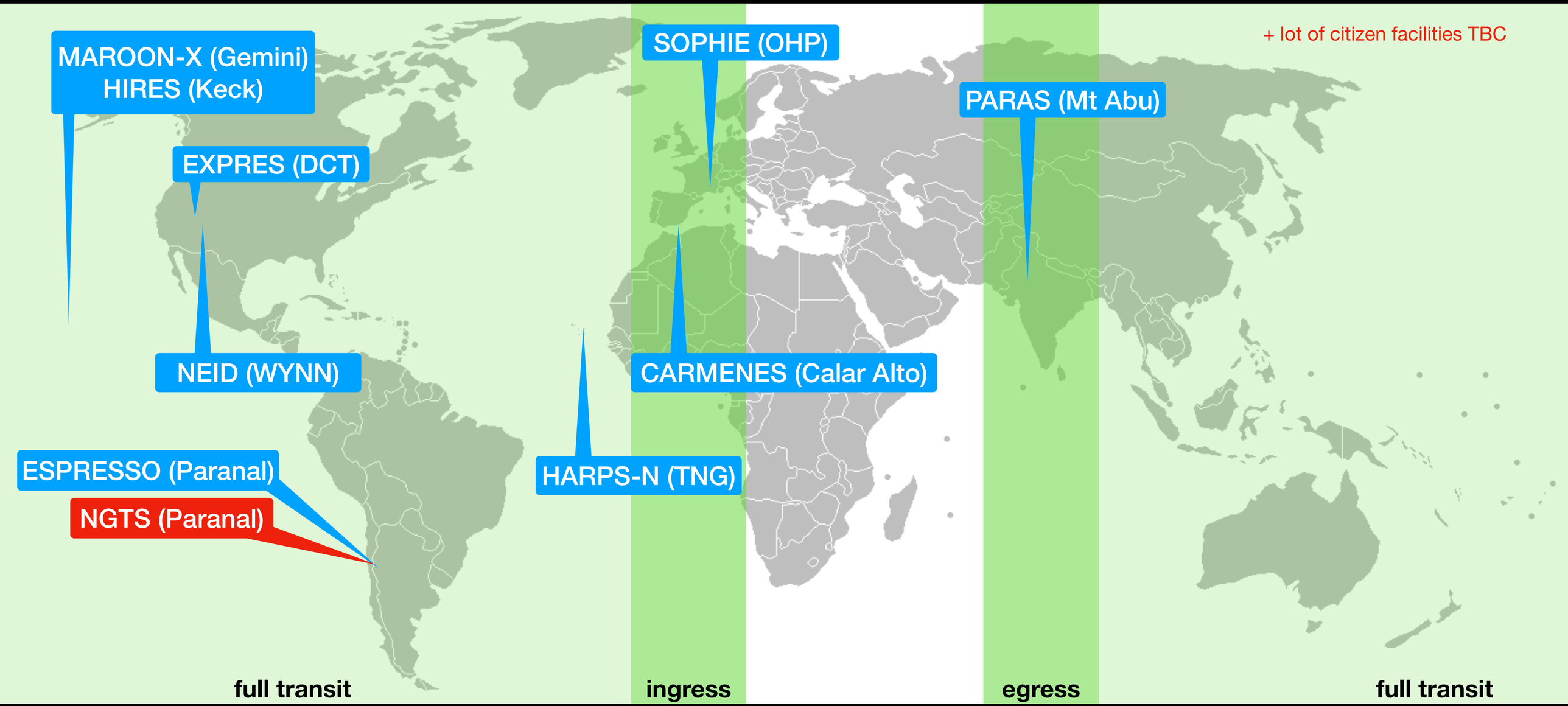
over 2 decades !



The 2022 campaign on HIP41378 f

International collaboration is the key !

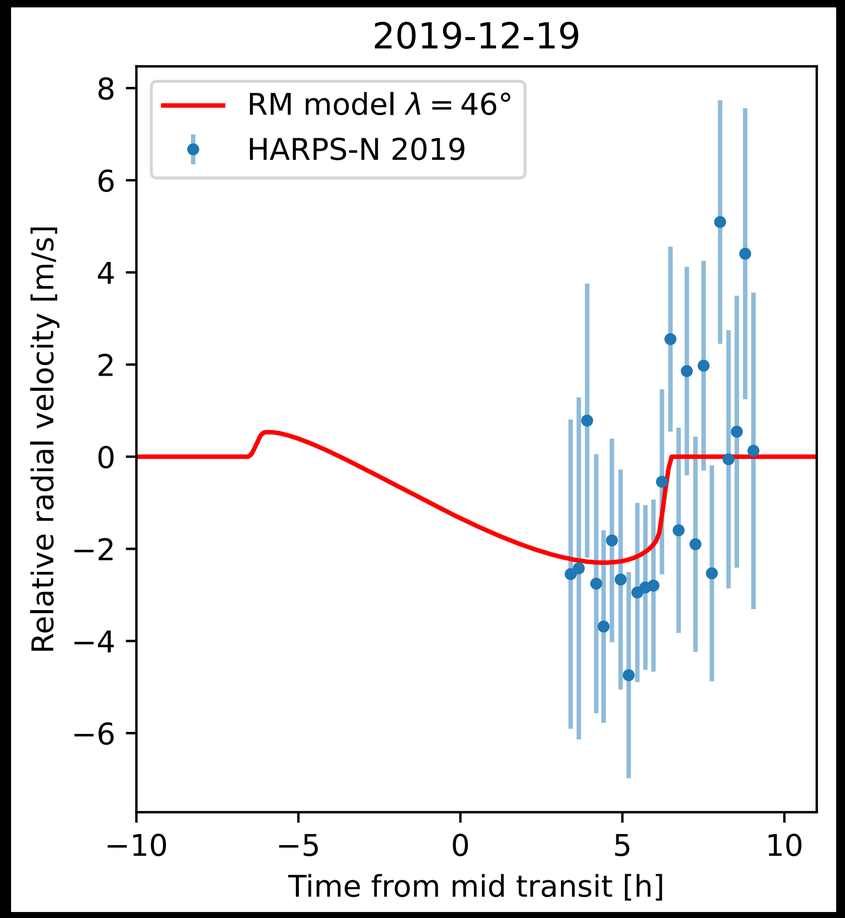
2022, November 12-13

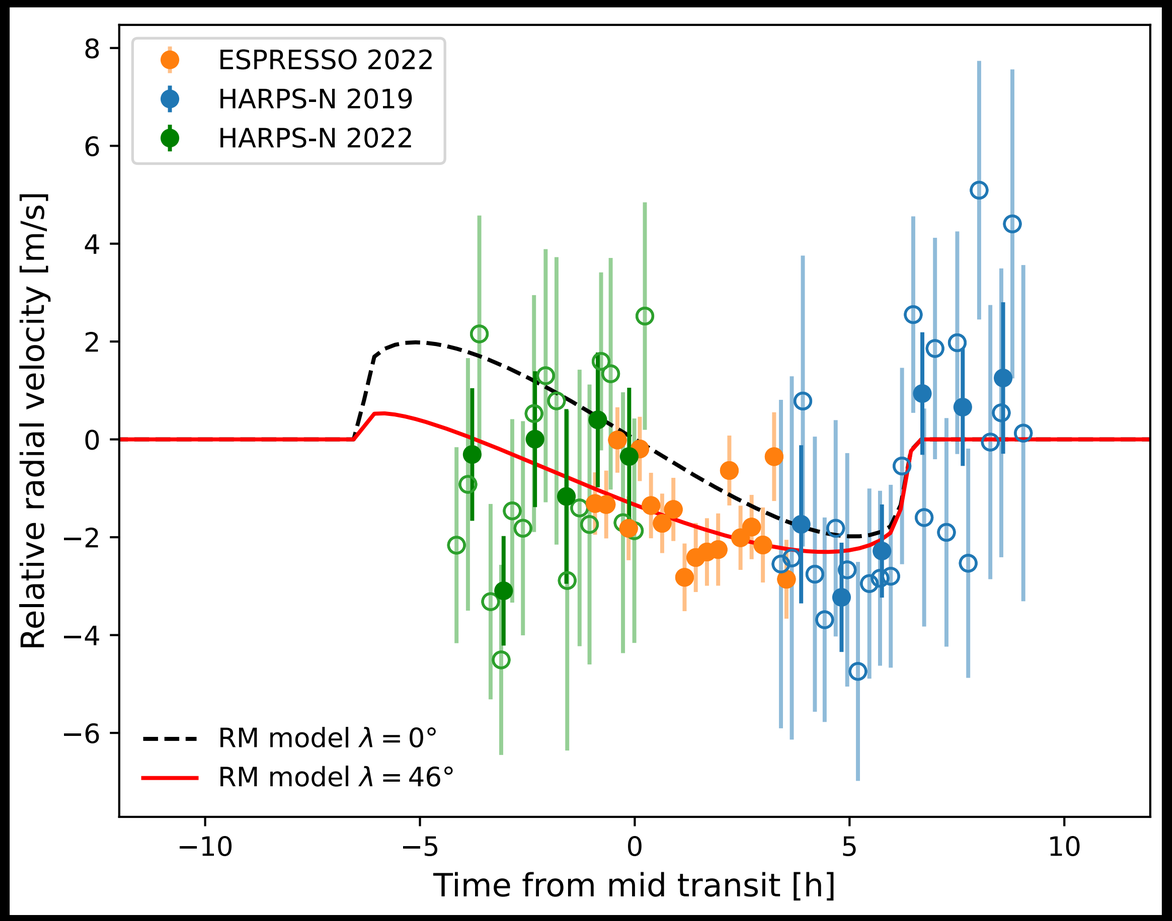


Transit follow-up of HIP41378 d

Challenging Rossiter-McLaughlin of a misaligned system ?

Transit duration = 12.5 hours - depth = 600ppm





Poor timing constraints

Grouffal et al. (submitted)

Lessons learned for the FUp of PLATO

HIP41378 as a foretaste of PLATO

- Long-period transiting planets are challenging to follow, especially in multiple systems:
  - rare transits (don’t miss the deadline !)
  - long duration (> night duration)
  - commensurability with the Earth orbit
  - low visibility from the ground and from space, etc…
- Need dense RV sampling to monitor stellar activity (with GPs), especially if $P_{orb} >> P_{rot}$.
- Need worldwide collaboration for long-period transit follow-up.
- RV detection of ~1yr planet is challenging, unless close to MMR with another planet