STARRY Conference - June 18, 2019

Optical variability of T Tauri stars from ground-based and *Kepler* observation

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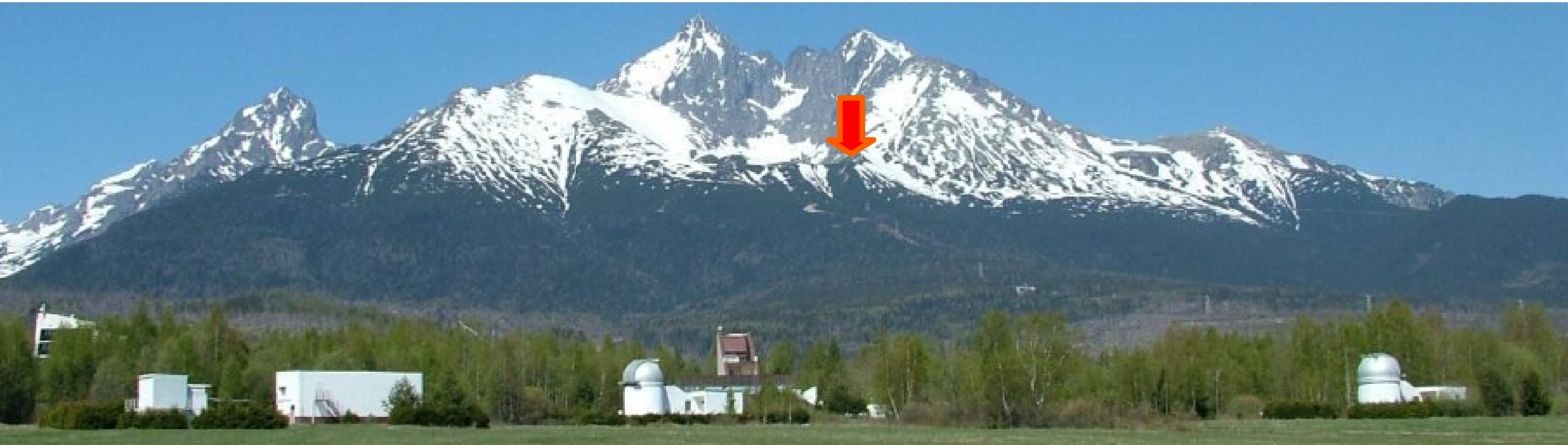
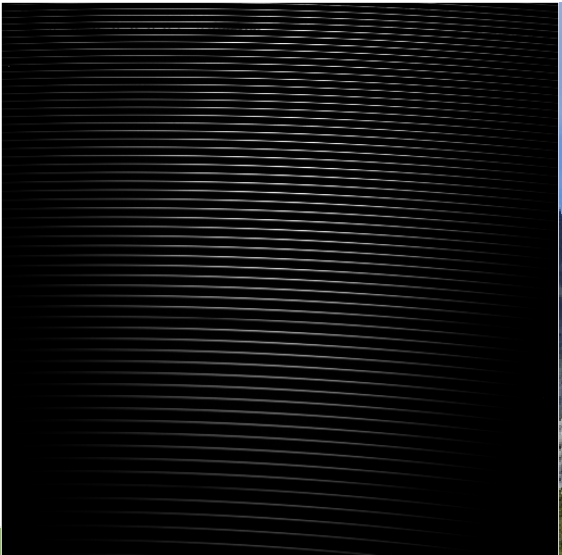
Astronomical Institute of SAS

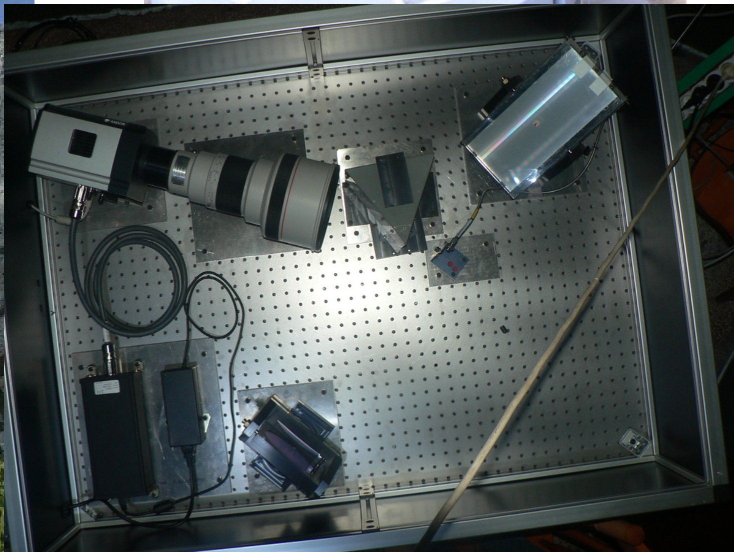
- Skalnaté Pleso observatory est. 1943 (1786 m a.s.l.)



Astronomical Institute of SAS

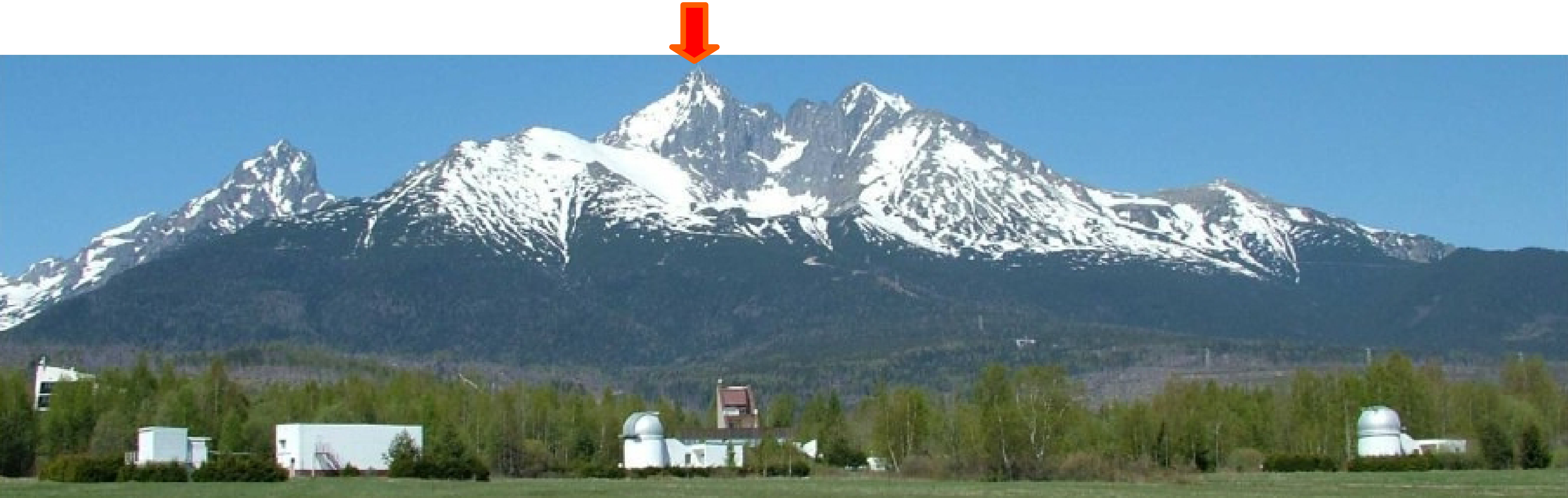
- 1.3m, f/8.36 Nasmyth-Cassegrain
- MUSICOS design spectrograph
- R=38000 echelle, 4250-7375Å





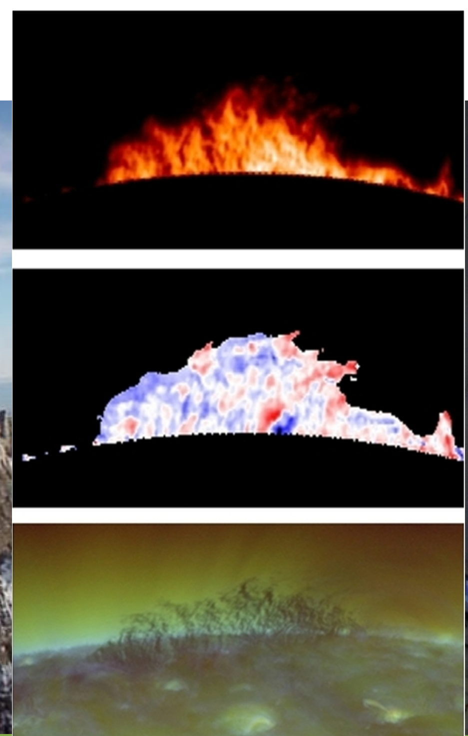
Astronomical Institute of SAS

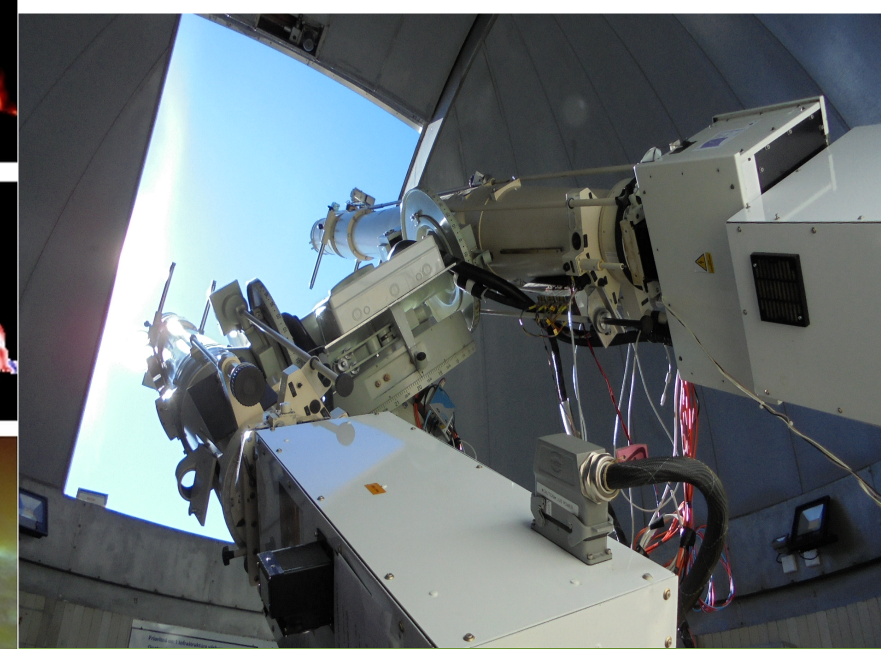
- Skalnaté Pleso observatory est. 1943 (1786 m a.s.l.)
- Lomnický peak observatory est. 1962 (2632 m a.s.l.)



Astronomical Institute of SAS

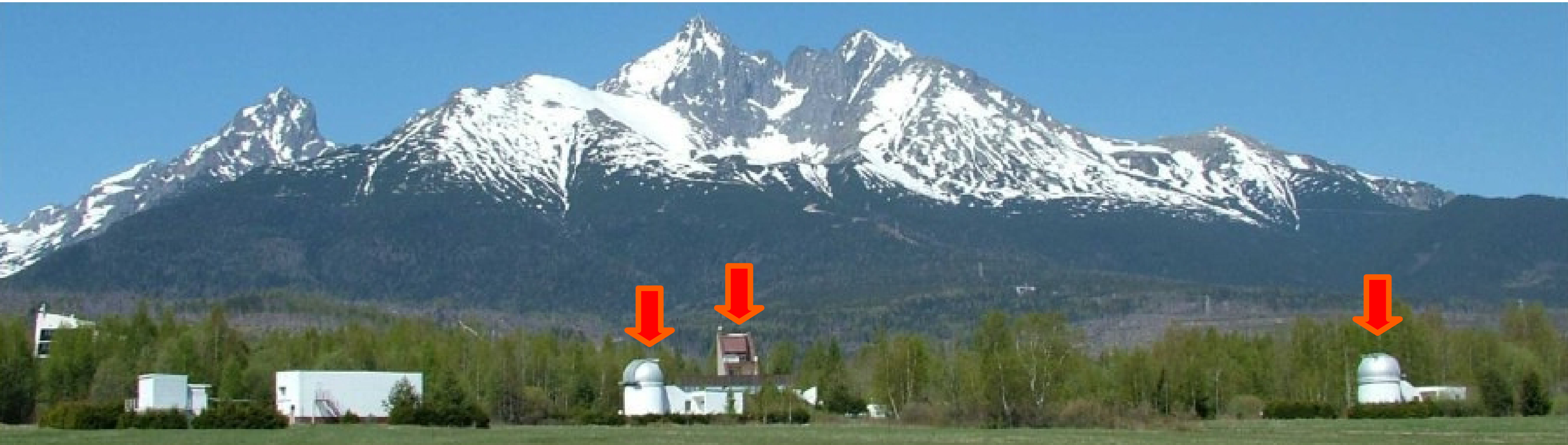
- Twin solar coronagraph
- Coronal Multi-channel Polarimeter
- Solar Chromospheric Detector





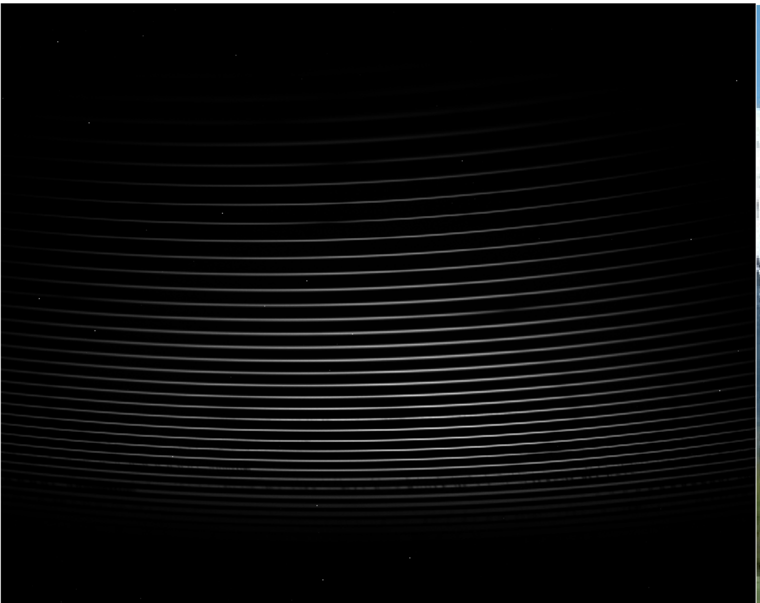
Astronomical Institute of SAS

- Skalnaté Pleso observatory est. 1943 (1786 m a.s.l.)
- Lomnický peak observatory est. 1962 (2632 m a.s.l.)
- Stará Lesná HQ and observatories est. 1987 (785 m a.s.l)



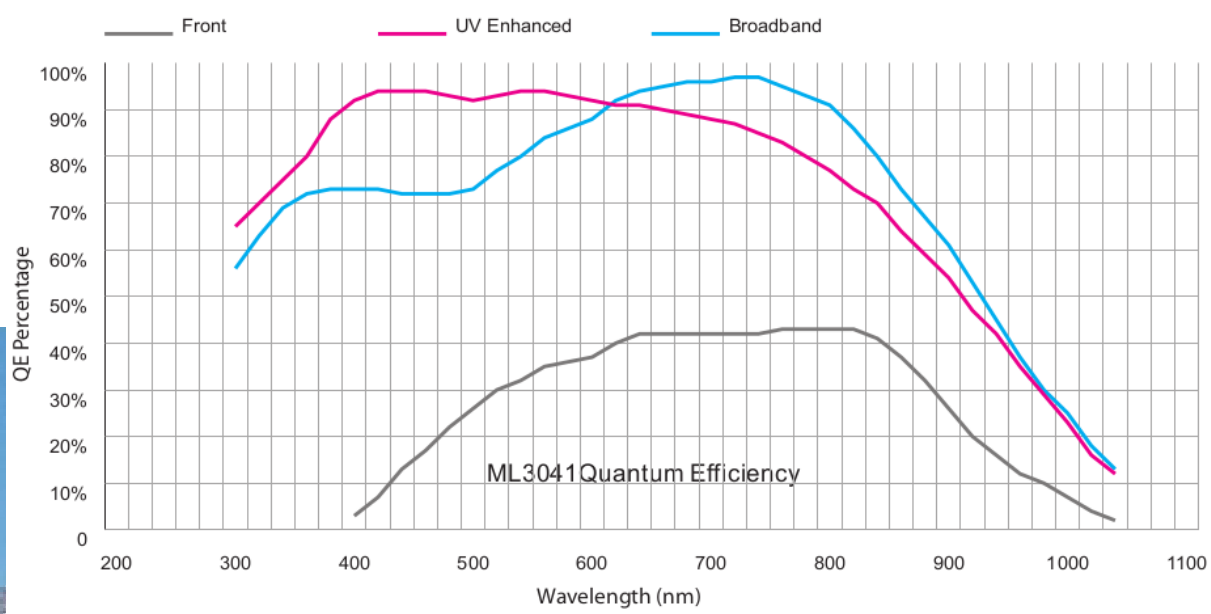
Astronomical Institute of SAS

- 0.6m, f/12.5 Zeiss Cassegrain
- R=11000 echelle, 4150-7600Å



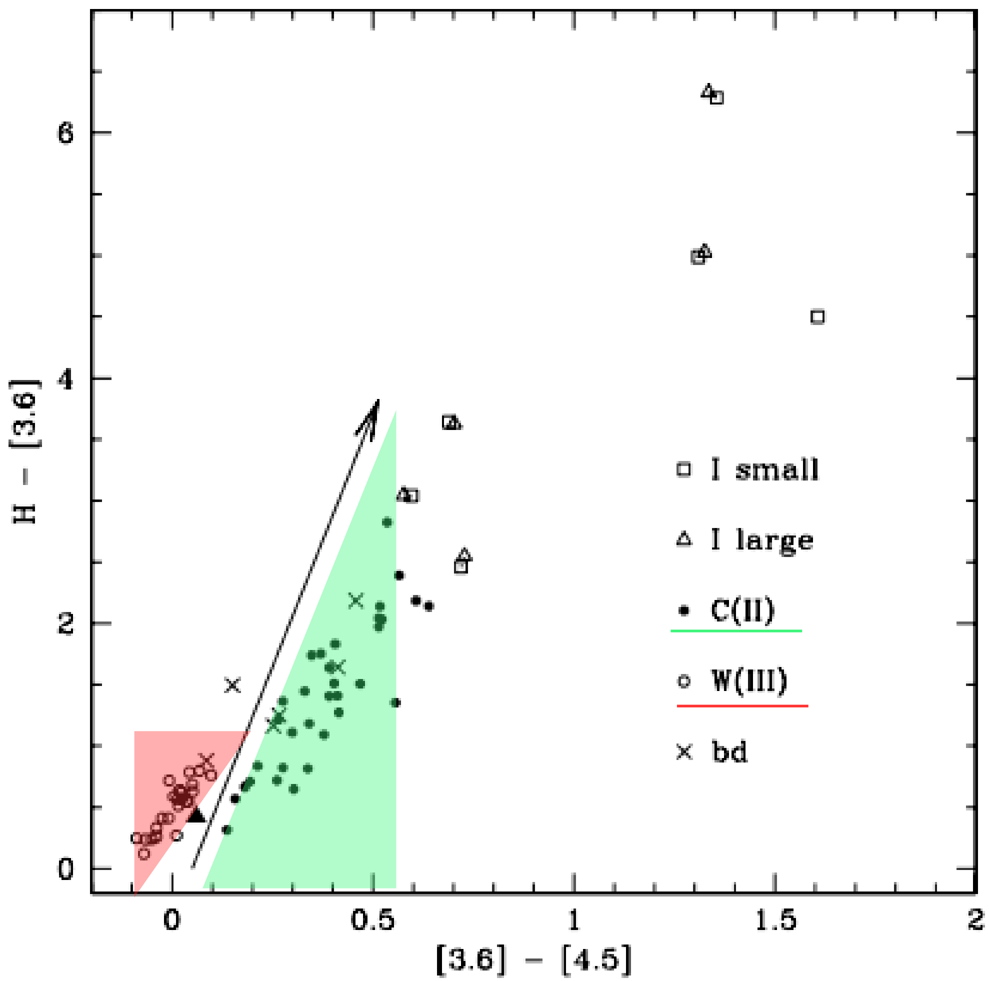
Astronomical Institute of SAS

- 0.6m, f/12.5 Zeiss Cassegrain (other)
- Johnson-Cousins $U\ B\ V\ R_C\ I_C$ Bessel filters
- 2048x2048, 15 μm back illuminated



Sample selection

- Tau-Aur members
- classified as WTTS
- $V < 11$ mag
- dubious/unknown P_{rot} in literature
- contradicting physical parameters (e.g. Sp. type)



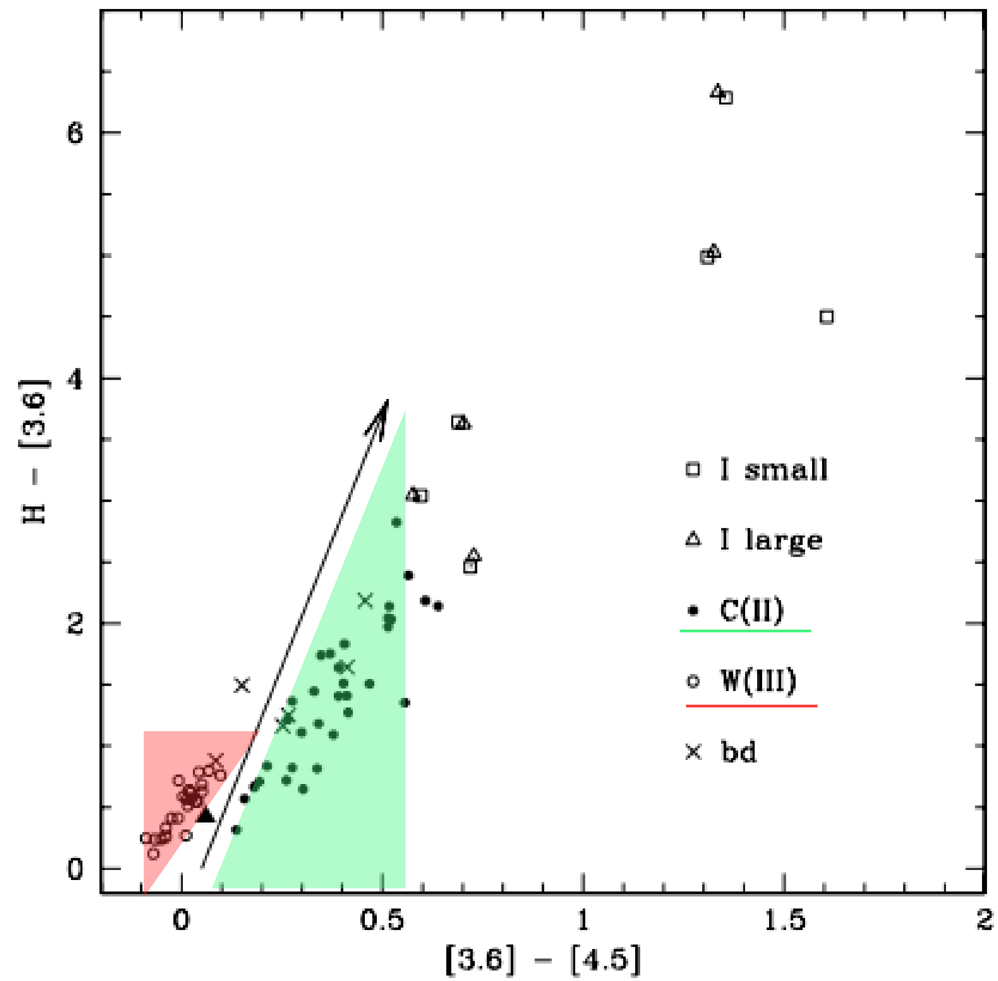
Hartmann+ 2005

Sample selection

- Tau-Aur members
- classified as WTTS
- *V* < 11 mag
- dubious/unknown P_{rot} in literature
- contradicting physical parameters (e.g. Sp. type)

20 stars
crossref data from NSVS and SWASP

+ 168 spectra taken (so far)



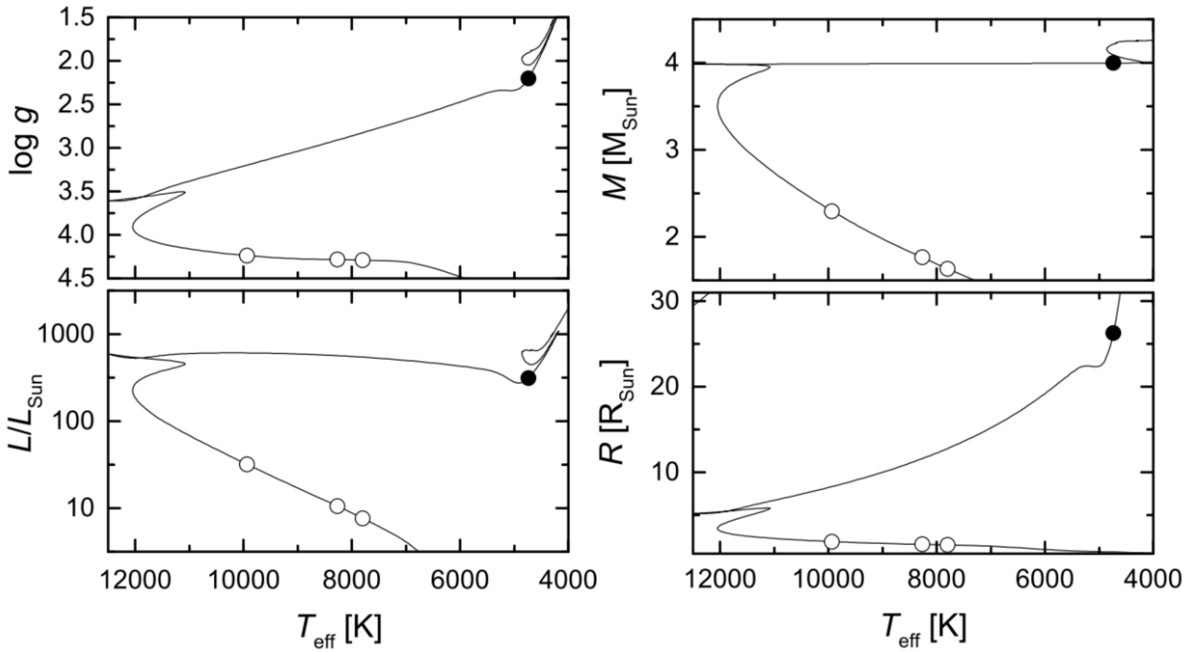
Hartmann+ 2005

V501 Aur (HD 282600)

- Part of original sample of supposed WTTS
- Hα emission (Wichmann+, 1996) OR absorption? (Martín & Magazzú, 1999)
- Proper motion – member of Tau-Aur SFR (Frink+, 1997)
- Photometric P_{phot} ~ 55 d (Grankin+, 2008)
- Spectroscopic P_{spec} = 68.8 d

V501 Aur (HD 282600) **NOT T Tau!**

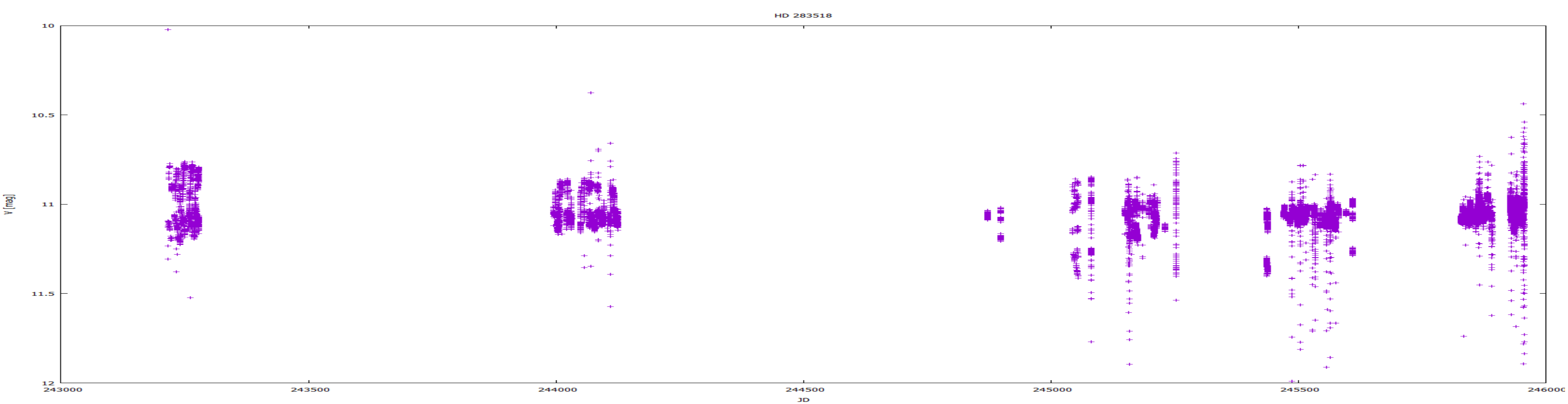
- we found log *g* = 2.0 – 3.0 by modelling with `iSpec`
- high *v* sin *i* = 24.7 km/s + Prot → R_{min} > 26.3 R_{Sun}
- *Gaia* parallax distance =
- MESA solution: log age = 8.25, *L* ~ 300 L_{sun}, log *g* = 2.19



More in:
Vaňko+ 2017 MNRAS, 467, 4902

NSVS+SuperWASP data

Season	Start	End	Duration [d]
0	1999-08-06	2000-03-26	233
1	2004-07-29	2004-09-30	63
2	2006-09-17	2007-02-27	163
3	2008-01-25	2008-02-06	12
4	2008-10-13	2009-03-07	145
5	2009-08-12	2010-03-26	226
6	2010-08-27	2011-02-16	173
7	2011-09-24	2012-01-30	128
Σ	1999-08-06	2012-01-30	4560
C4	2015-02-08	2015-04-20	70
C13	2017-03-08	2017-05-27	80



NSVS+SuperWASP data

Star	V_{mag}	Spectral type	Period [d] (literature)	Distance [pc]	Nights	Points	Cadence [s]	Window [d]	Seasons
HD 285281	10.17	K1	1.1683	135.3±1.2	240	19313	72.58	2696.9	6
BD+19 656	10.12	K1	2.86/0.741	108.5±0.7	263	20917	71.71	2738.8	6
HD 284135	9.39	G3V	0.816	N/A	278	21432	71.71	2738.8	6
HD 284149	9.63	G0	1.079	118.2±0.7	268	21447	61.34	2738.8	6
HD 284691	10.68	G8III	2.74 ?	110.3±0.5	268	20452	73.44	2738.8	6
HD 284266	10.51	K0V	1.83	119.9±1.0	278	29876	38.02	2738.8	6
HD 284503	10.24	G8	0.736	111.6±0.7	281	22553	72.58	2738.8	6
HD 284496	10.80	K0	2.71	125.8±0.6	281	22487	72.58	2738.8	6
HD 285840	10.85	K1V	1.55	90.5±0.3	173	17052	44.06	1834.9	6
HD 285957	10.86	K1	3.07	139.2±1.1	306	23115	64.80	1947.9	7
HD 283798	9.55	G7	0.6?	110.8±0.6	241	16743	71.71	2723.8	6
HD 283782	9.48	K1	?	168.0±6.8	254	17175	71.71	2723.8	6
HD 30171	9.36	G5	1.104	184.9±3.9	302	20659	70.85	1966.8	7
HD 31281	9.14	G1	?	122.4±0.6	74	3725	268.70	1619.7	2
HD 286179	10.39	G3	3.33	123.7±1.0	235	15627	44.06	1619.7	6
HD 286178	10.54	K1	2.39	74.3±3.5	253	26721	38.02	1619.7	6
HD 283447	10.68	K3V	51	128.1±2.3	278	34966	38.02	2739.8	5
HD 283572	9.03	G5	1.529	130.3±0.9	179	4885	279.94	2722.8	5
HD 285778	10.22	K1	2.734	120.1±0.8	247	29498	38.02	1960.9	7
HD 283518	10.75	K3V	1.87	130.4±0.9	278	18933	72.58	2739.8	6

NSVS+SuperWASP data

Star	V_{mag}	Spectral type	Period [d] (literature)	Distance [pc]	Nights	Points	Cadence [s]	Window [d]	Seasons
HD 285281	10.17	K1	1.1683	135.3±1.2	240	19313	72.58	2696.9	6
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HD 284496	10.80	K0	2.71	125.8±0.6	281	22487	72.58	2738.8	6
HD 285840	10.85	K1V	1.55	90.5±0.3	173	17052	44.06	1834.9	6
HD 285957	10.86	K1	3.07	139.2±1.1	306	23115	64.80	1947.9	7
HD 283798	9.55	G7	0.6?	110.8±0.6	241	16743	71.71	2723.8	6
HD 283782	9.48	K1	?	168.0±6.8	254	17175	71.71	2723.8	6
HD 30171	9.36	G5	1.104	184.9±3.9	302	20659	70.85	1966.8	7
HD 31281	9.14	G1	?	122.4±0.6	74	3725	268.70	1619.7	2
HD 286179	10.39	G3	3.33	123.7±1.0	235	15627	44.06	1619.7	6
HD 286178	10.54	K1	2.39	74.3±3.5	253	26721	38.02	1619.7	6
HD 283447	10.68	K3V	51	128.1±2.3	278	34966	38.02	2739.8	5
HD 283572	9.03	G5	1.529	130.3±0.9	179	4885	279.94	2722.8	5
HD 285778	10.22	K1	2.734	120.1±0.8	247	29498	38.02	1960.9	7
HD 283518	10.75	K3V	1.87	130.4±0.9	278	18933	72.58	2739.8	6

Evolutionary status

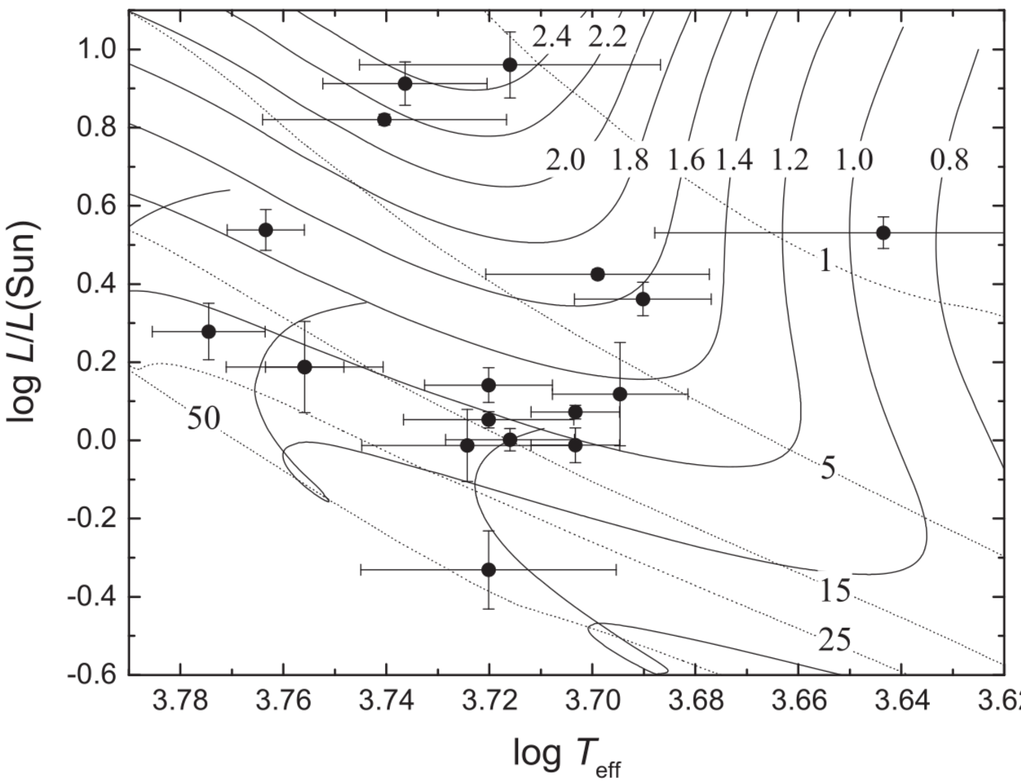
- *ubvyβ* photometry (Paunzen, 2015) + `TempLogG TNG` (Kaiser, 2006)
- PISA stellar models (Tognelli+, 2011)
- Solar metallicity [Fe/H]=-0.01 ± 0.05 (D'Orazi+, 2010)
- Distances from *Gaia* DR2
- Reddening from literature

Meištas & Straišys, 1981 Chavarría-K+, 2000

Grankin, 2013 Herczeg & Hillenbrand, 2014

- BC for PMS stars

Pecaut & Mamajek, 2014



Evolutionary status

Star	V_{mag}	Spectral type	AV	log Teff	BCV	log L/Lo	M [Mo]	age [Myr]
HD 285281	10.17	K1	0.47(2)	3.699(22)	−0.27	+0.43(1)	1.4–1.7	1–8
BD+19 656	10.12	K1	0.27(4)	3.703(9)	−0.26	+0.07(2)	1.2–1.3	7–12
HD 284135	9.39	G3V						
HD 284149	9.63	G0	0.19(18)	3.775(11)	−0.04	+0.28(5)	1.0–1.2	15–25
HD 284691	10.68	G8III	0.19(11)	3.703(9)	−0.26	− 0.01(4)	1.1–1.3	8–18
HD 284266	10.51	K0V	0.16(23)	3.724(20)	−0.18	− 0.01(9)	1.0–1.2	15–30
HD 284503	10.24	G8	0.19(5)	3.720(17)	−0.19	+0.05(2)	1.1–1.3	10–20
HD 284496	10.80	K0	0.21(7)	3.716(13)	−0.21	+0.00(3)	1.1–1.2	12–20
HD 285840	10.85	K1V	0.17(25)	3.720(25)	−0.19	− 0.33(10)	0.8–1.0	20–70
HD 285957	10.86	K1	0.27(33)	3.695(13)	−0.29	+0.12(13)	1.2–1.5	3–13
HD 283798	9.55	G7	0.00(1)	3.756(8)	−0.09	+0.19(1)	0.9–1.3	17–21
HD 283782	9.48	K1	0.63(19)	3.716(29)	−0.21	+0.96(18)	1.8–2.7	<3
HD 30171	9.36	G5	0.36(13)	3.736(16)	−0.15	+0.91(6)	2.1–2.5	2–4
HD 31281	9.14	G1	0.26(13)	3.763(7)	−0.06	+0.54(5)	1.4–1.6	8–12
HD 286179	10.39	G3	0.44(29)	3.756(15)	−0.09	+0.19(12)	1.1–1.4	10–35
HD 286178	10.54	K1						
HD 283447	10.68	K3V	0.95(10)	3.690(13)	−0.30	+0.36(4)	1.4–1.7	2–4
HD 283572	9.03	G5	1.10(10)	3.643(44)	−0.60	+0.53(4)	0.5–1.6	<2
HD 285778	10.22	K1	0.48(3)	3.740(24)	−0.14	+0.82(1)	1.8–2.5	2–5
HD 283518	10.75	K3V	0.15(11)	3.720(12)	−0.19	+0.14(4)	1.2–1.4	8–15

Evolutionary status

PISA Stellar models

Star	V_{mag}	Spectral type	AV	log Teff	BCV	log L/Lo	M [Mo]	age [Myr]
HD 285281	10.17	K1	0.47(2)	3.699(22)	−0.27	+0.43(1)	1.4–1.7	1–8
BD+19 656	10.12	K1	0.27(4)	3.703(9)	−0.26	+0.07(2)	1.2–1.3	7–12
HD 284135	9.39	G3V						
HD 284149	9.63	G0	0.19(18)	3.775(11)	−0.04	+0.28(5)	1.0–1.2	15–25
HD 284691	10.68	G8III	0.19(11)	3.703(9)	−0.26	− 0.01(4)	1.1–1.3	8–18
HD 284266	10.51	K0V	0.16(23)	3.724(20)	−0.18	− 0.01(9)	1.0–1.2	15–30
HD 284503	10.24	G8	0.19(5)	3.720(17)	−0.19	+0.05(2)	1.1–1.3	10–20
HD 284496	10.80	K0	0.21(7)	3.716(13)	−0.21	+0.00(3)	1.1–1.2	12–20
HD 285840	10.85	K1V	0.17(25)	3.720(25)	−0.19	− 0.33(10)	0.8–1.0	20–70
HD 285957	10.86	K1	0.27(33)	3.695(13)	−0.29	+0.12(13)	1.2–1.5	3–13
HD 283798	9.55	G7	0.00(1)	3.756(8)	−0.09	+0.19(1)	0.9–1.3	17–21
HD 283782	9.48	K1	0.63(19)	3.716(29)	−0.21	+0.96(18)	1.8–2.7	<3
HD 30171	9.36	G5	0.36(13)	3.736(16)	−0.15	+0.91(6)	2.1–2.5	2–4
HD 31281	9.14	G1	0.26(13)	3.763(7)	−0.06	+0.54(5)	1.4–1.6	8–12
HD 286179	10.39	G3	0.44(29)	3.756(15)	−0.09	+0.19(12)	1.1–1.4	10–35
HD 286178	10.54	K1						
HD 283447	10.68	K3V	0.95(10)	3.690(13)	−0.30	+0.36(4)	1.4–1.7	2–4
HD 283572	9.03	G5	1.10(10)	3.643(44)	−0.60	+0.53(4)	0.5–1.6	<2
HD 285778	10.22	K1	0.48(3)	3.740(24)	−0.14	+0.82(1)	1.8–2.5	2–5
HD 283518	10.75	K3V	0.15(11)	3.720(12)	−0.19	+0.14(4)	1.2–1.4	8–15

Post T Tau?
10-100 Myr

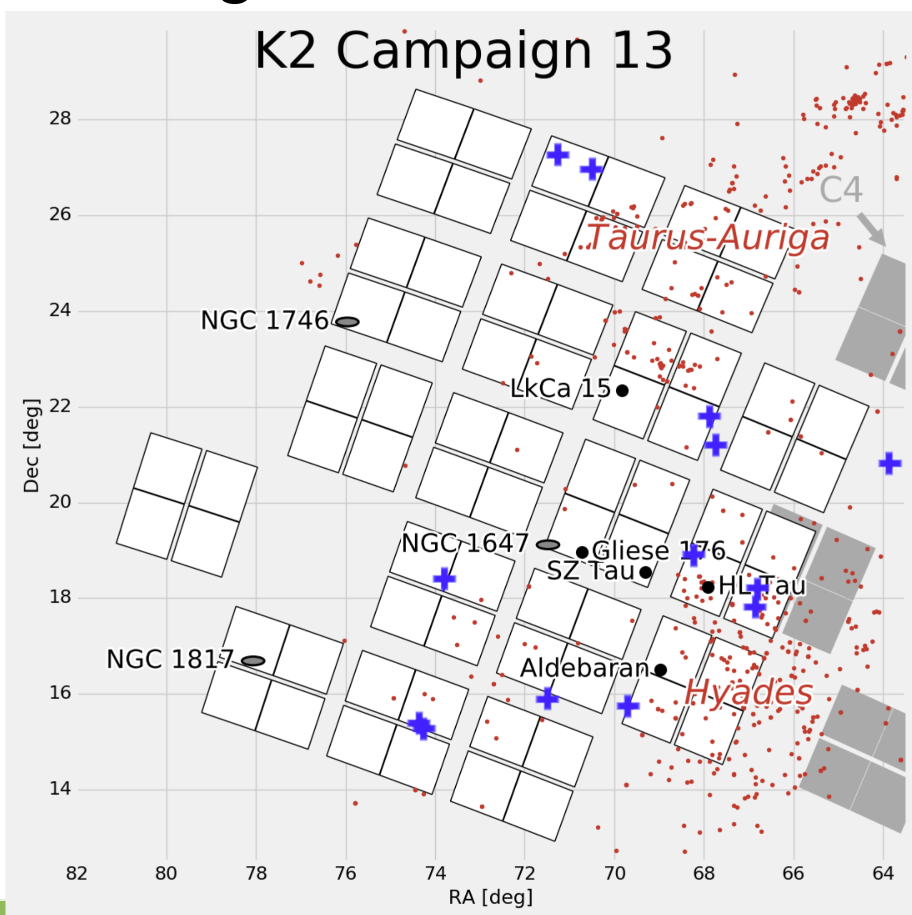
- Strong H_{α} emission
- High surface Li abundance
- Irregular variability

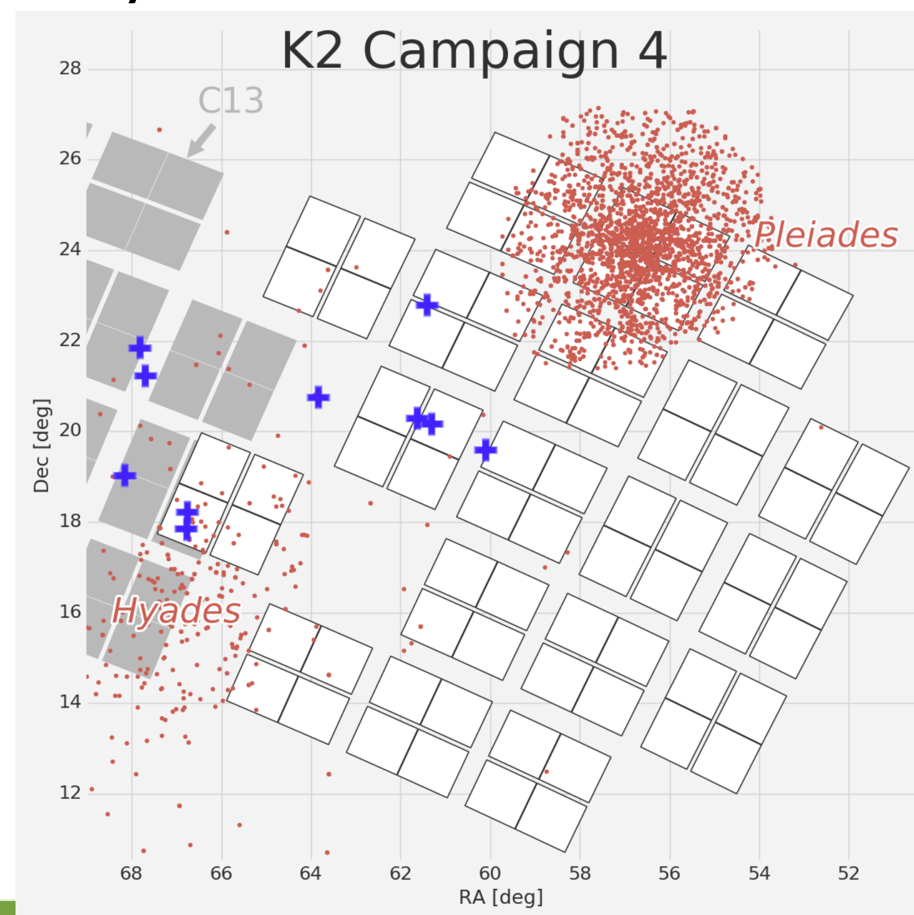
Evolutionary status

Star	V_{mag}	Spectral type	AV	log Teff	BCV	log L/Lo	M [Mo]	age [Myr]	EW Li 6707 [mÅ]	EW Hα [mÅ]
HD 285281	10.17	K1	0.47(2)	3.699(22)	−0.27	+0.43(1)	1.4–1.7	1–8	423	
BD+19 656	10.12	K1	0.27(4)	3.703(9)	−0.26	+0.07(2)	1.2–1.3	7–12	376	254
HD 284135	9.39	G3V							193	824
HD 284149	9.63	G0	0.19(18)	3.775(11)	−0.04	+0.28(5)	1.0–1.2	15–25	169	720
HD 284691	10.68	G8III	0.19(11)	3.703(9)	−0.26	− 0.01(4)	1.1–1.3	8–18	342	145
HD 284266	10.51	K0V	0.16(23)	3.724(20)	−0.18	− 0.01(9)	1.0–1.2	15–30	239	408
HD 284503	10.24	G8	0.19(5)	3.720(17)	−0.19	+0.05(2)	1.1–1.3	10–20	274	125
HD 284496	10.80	K0	0.21(7)	3.716(13)	−0.21	+0.00(3)	1.1–1.2	12–20	288	297
HD 285840	10.85	K1V	0.17(25)	3.720(25)	−0.19	− 0.33(10)	0.8–1.0	20–70	214	
HD 285957	10.86	K1	0.27(33)	3.695(13)	−0.29	+0.12(13)	1.2–1.5	3–13	411	155
HD 283798	9.55	G7	0.00(1)	3.756(8)	−0.09	+0.19(1)	0.9–1.3	17–21	243	380
HD 283782	9.48	K1	0.63(19)	3.716(29)	−0.21	+0.96(18)	1.8–2.7	<3	237	-3937
HD 30171	9.36	G5	0.36(13)	3.736(16)	−0.15	+0.91(6)	2.1–2.5	2–4	273	706
HD 31281	9.14	G1	0.26(13)	3.763(7)	−0.06	+0.54(5)	1.4–1.6	8–12	167	970
HD 286179	10.39	G3	0.44(29)	3.756(15)	−0.09	+0.19(12)	1.1–1.4	10–35	N/A	1316
HD 286178	10.54	K1							166	211
HD 283447	10.68	K3V	0.95(10)	3.690(13)	−0.30	+0.36(4)	1.4–1.7	2–4	500	-1397
HD 283572	9.03	G5	1.10(10)	3.643(44)	−0.60	+0.53(4)	0.5–1.6	<2	274	899
HD 285778	10.22	K1	0.48(3)	3.740(24)	−0.14	+0.82(1)	1.8–2.5	2–5	269	510
HD 283518	10.75	K3V	0.15(11)	3.720(12)	−0.19	+0.14(4)	1.2–1.4	8–15	517	

Additional *Kepler* data

- *Kepler* K2 data (70 and 80 days, 30 min cadence)
- C4 and C13 fields in 2015, 2017 (● = clusters / + = our sample)
- Weighted Wavelet Z-transform by `VSTAR`





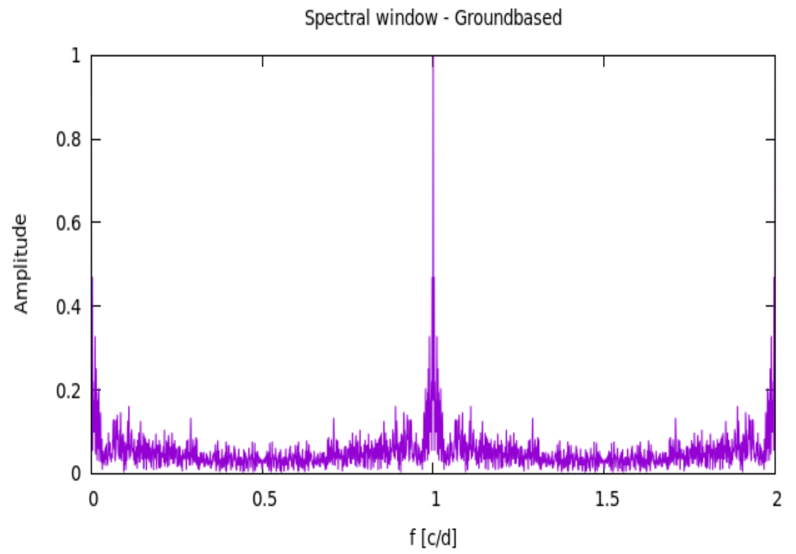
Period estimation

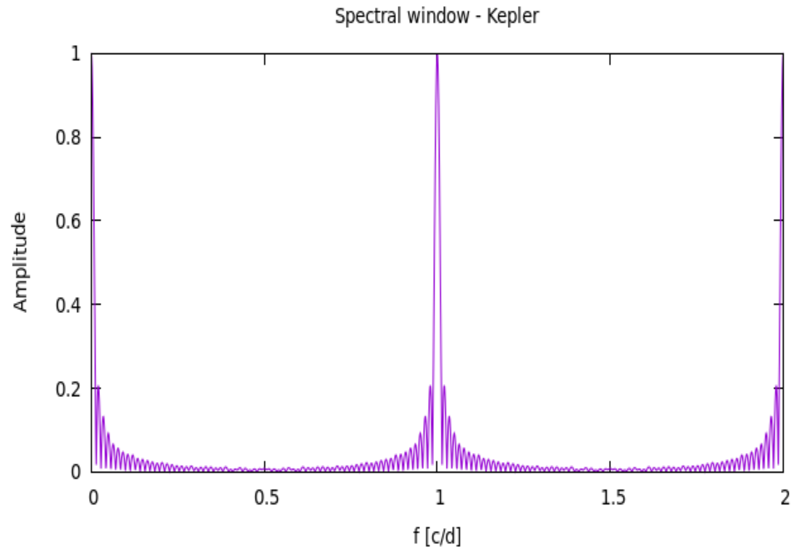
- Groundbased and *Kepler* C4, C13
- Season-wise and total
- NSVS data shifted to SuperWASP

  DC DFT: `VSTAR` & `PERIOD04`

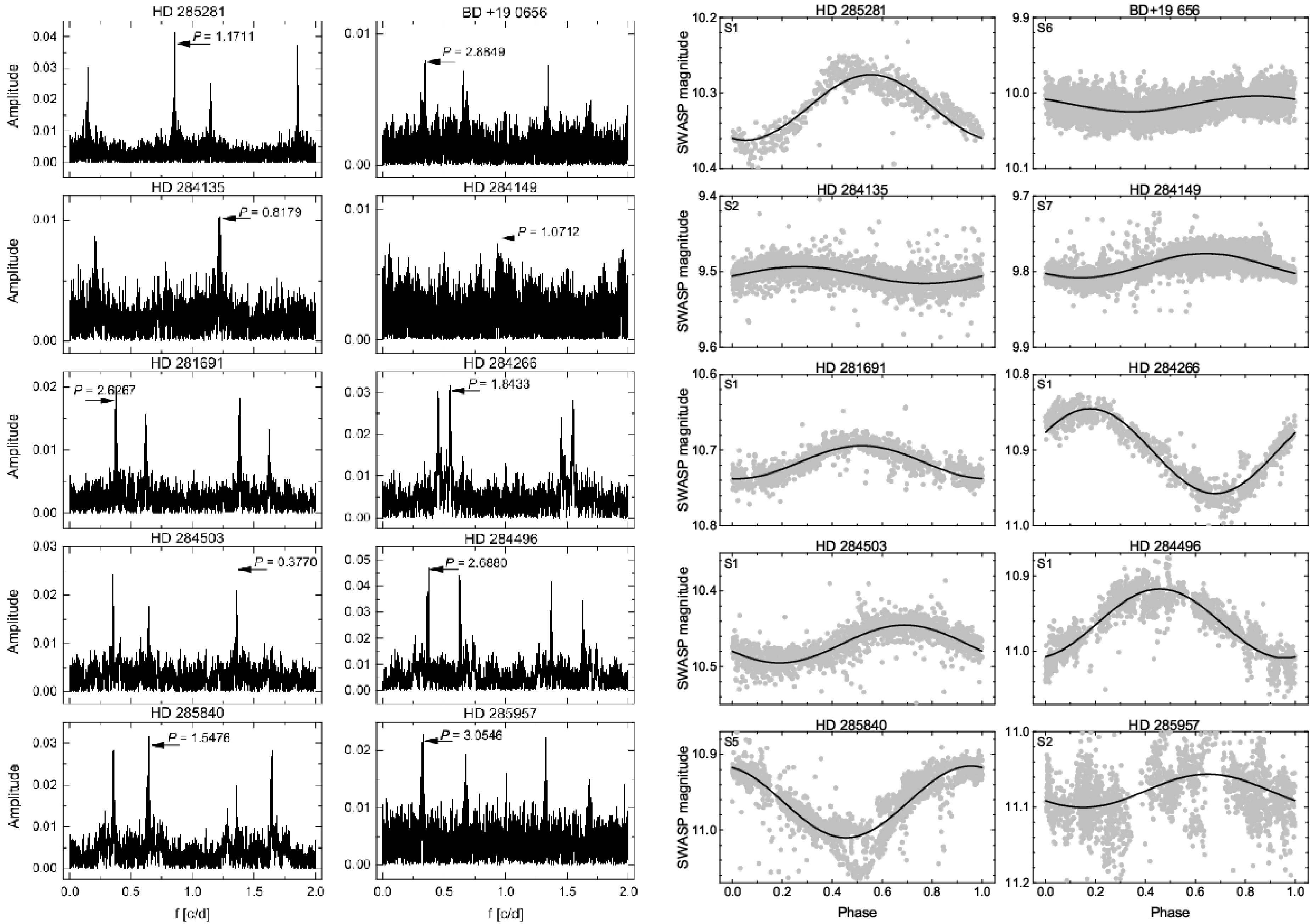
  f = 0.1-2 c/d

  Δf = 0.00001 c/d
- Period pre-whitening
- Errors by MCMC

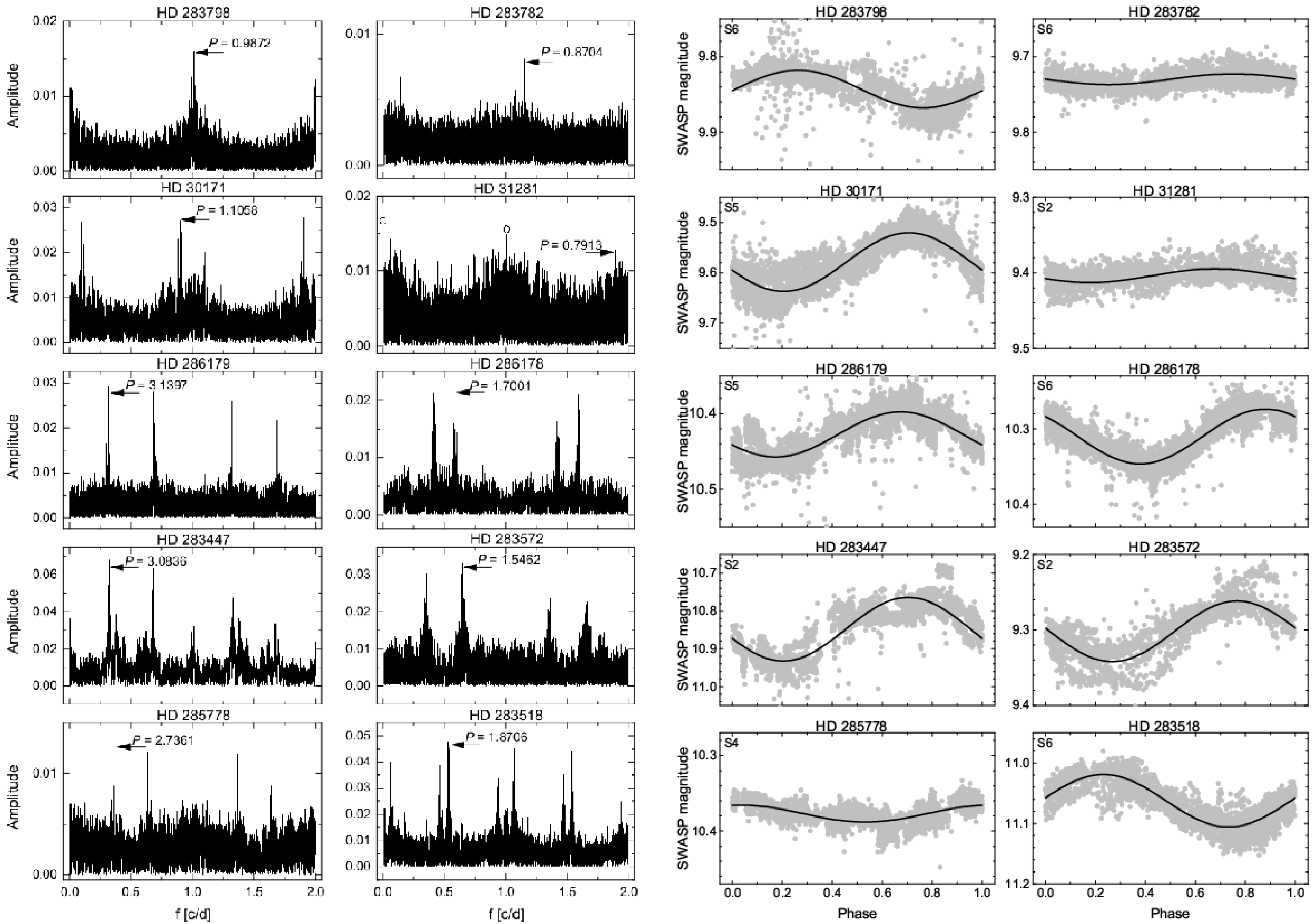




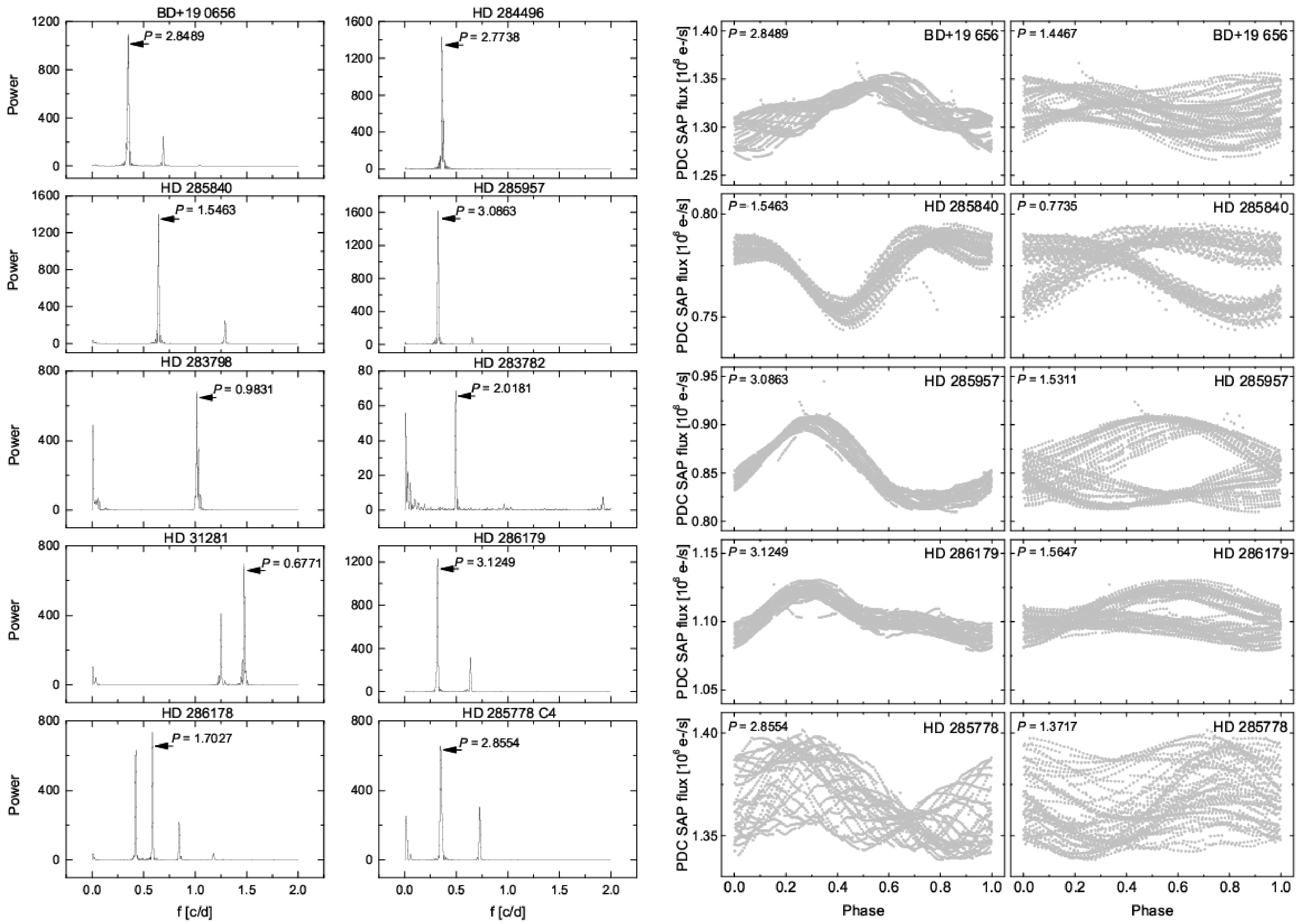
Period estimation



Period estimation



Period estimation



Period estimation

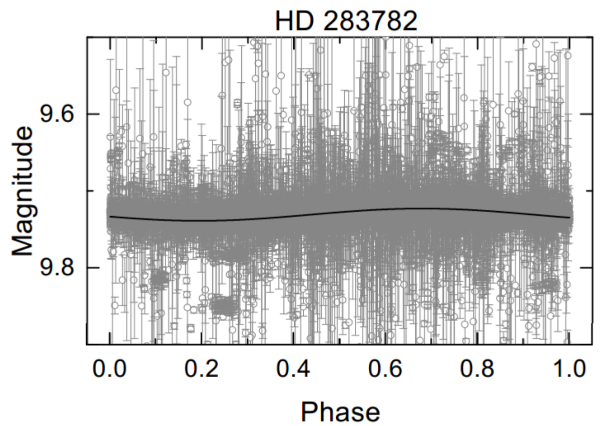
Star	Period [d] (literature)	Seasons	Period [d] (ground)	Amplitude [10^{-4} mag]	Quarter	Period [d] (Kepler)
HD 285281	1.1683	6	1.1711(37)	413(51)		
BD+19 656	2.86/0.741	6	2.8849(51)	80(3)	C4	2.8489(8)
HD 284135	0.816	6	0.8179(58)	106(20)		
HD 284149	1.079	6	1.0712(7)	84(3)		
HD 284691	2.74 ?	6	2.6267(237)	177(17)		
HD 284266	1.83	6	1.8433(10)	315(4)		
HD 284503	0.736	6	0.7370(3)	267(25)		
HD 284496	2.71	6	2.6880(195)	486(23)	C13	2.7738(8)
HD 285840	1.55	6	1.5476(67)	315(26)	C13	1.5463(2)
HD 285957	3.07	7	3.0546(255)	251(15)	C13	3.0863(10)
HD 283798	0.6?	6	0.9872(33)	159(5)		
HD 283782	?	6	0.8704(1106)	81(26)	C13	2.0181(4)
HD 30171	1.104	7	1.1058(33)	272(13)		
HD 31281	?	2	0.7913(15)	98(12)	C13	0.6771(1)
HD 286179	3.33	6	3.1397(221)	294(13)	C13	3.1249(20)
HD 286178	2.39	6	1.7001(81)	231(37)	C13	1.7027(6)
			2.4125(164)	227(37)		2.3562(11)
HD 283447	51	5	3.0836(210)	695(24)		
HD 283572	1.529	5	1.5462(38)	386(22)		
HD 285778	2.734	7	2.7361(204)	132(32)	C4	2.8554(17)
					C13	2.7510(15)
HD 283518	1.87	6	1.8706(14)	491(18)		

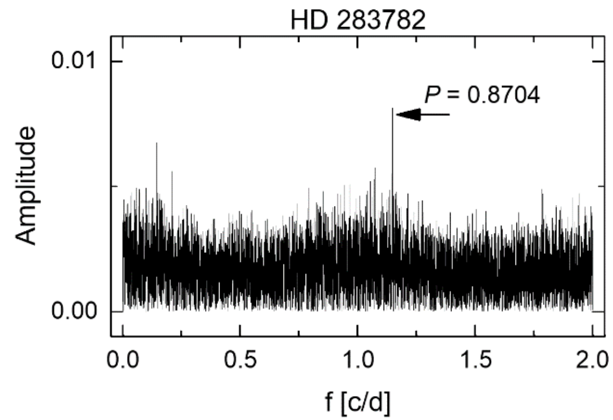
Period estimation

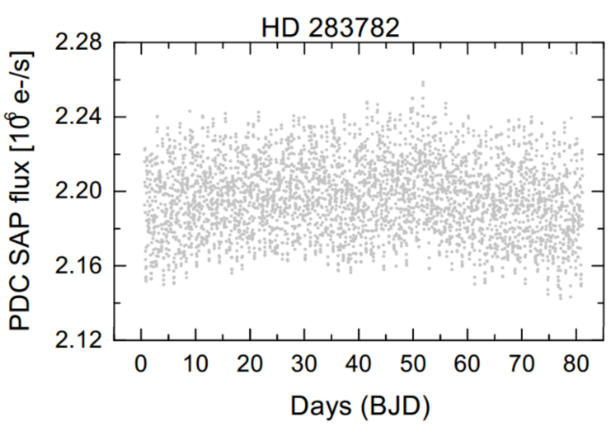
Star	Period [d] (literature)	Seasons	Period [d] (ground)	Amplitude [10^{-4} mag]	Quarter	Period [d] (Kepler)
HD 285281	1.1683	6	1.1711(37)	413(51)		
BD+19 656	2.86/0.741	6	2.8849(51)	80(3)	C4	2.8489(8)
HD 284135	0.816	6	0.8179(58)	106(20)		
HD 284149	1.079	6	1.0712(7)	84(3)		
HD 284691	2.74 ?	6	2.6267(237)	177(17)		
HD 284266	1.83	6	1.8433(10)	315(4)		
HD 284503	0.736	6	0.7370(3)	267(25)		
HD 284496	2.71	6	2.6880(195)	486(23)	C13	2.7738(8)
HD 285840	1.55	6	1.5476(67)	315(26)	C13	1.5463(2)
HD 285957	3.07	7	3.0546(255)	251(15)	C13	3.0863(10)
HD 283798	0.6?	6	0.9872(33)	159(5)		
HD 283782	?	6	0.8704(1106)	81(26)	C13	2.0181(4)
HD 30171	1.104	7	1.1058(33)	272(13)		
HD 31281	?	2	0.7913(15)	98(12)	C13	0.6771(1)
HD 286179	3.33	6	3.1397(221)	294(13)	C13	3.1249(20)
HD 286178	2.39	6	1.7001(81)	231(37)	C13	1.7027(6)
			2.4125(164)	227(37)		2.3562(11)
HD 283447	51	5	3.0836(210)	695(24)		
HD 283572	1.529	5	1.5462(38)	386(22)		
HD 285778	2.734	7	2.7361(204)	132(32)	C4	2.8554(17)
					C13	2.7510(15)
HD 283518	1.87	6	1.8706(14)	491(18)		

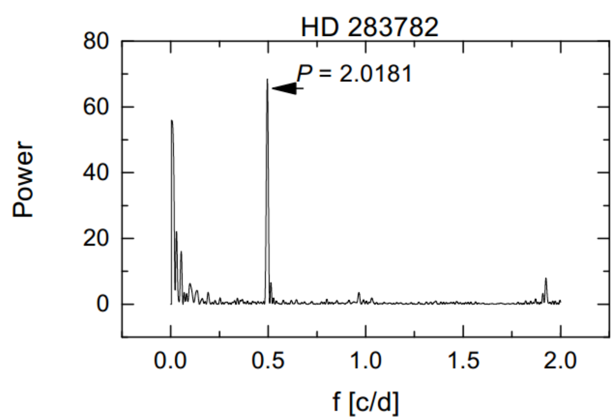
HD 283782

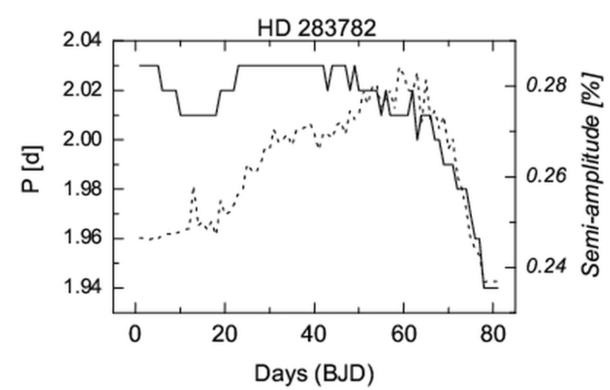
$P_{literature}$ = ??? d
P_{SWASP} = 0.8704(1106)? d
P_{KEPLER} = 2.0181(4) d





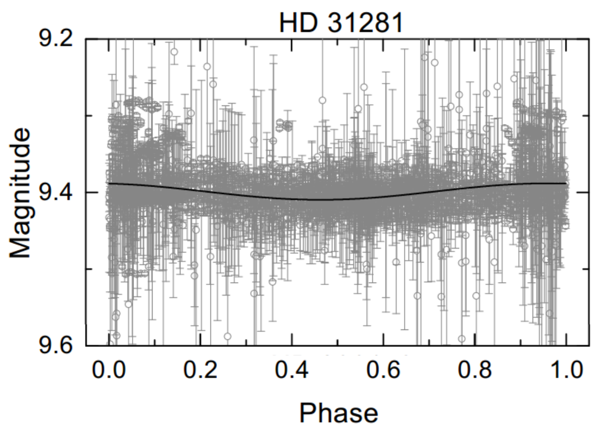


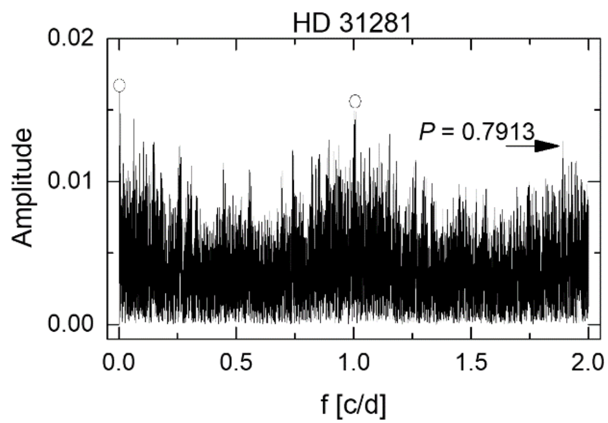


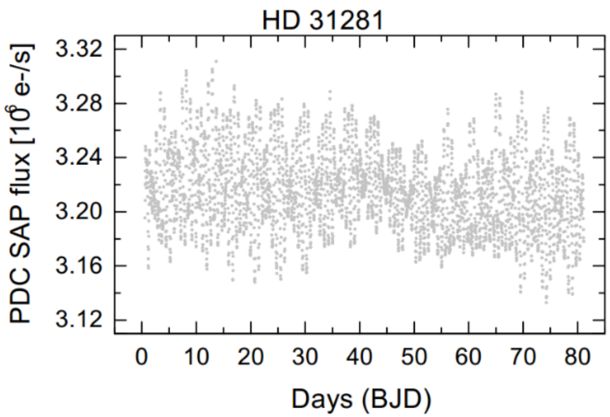


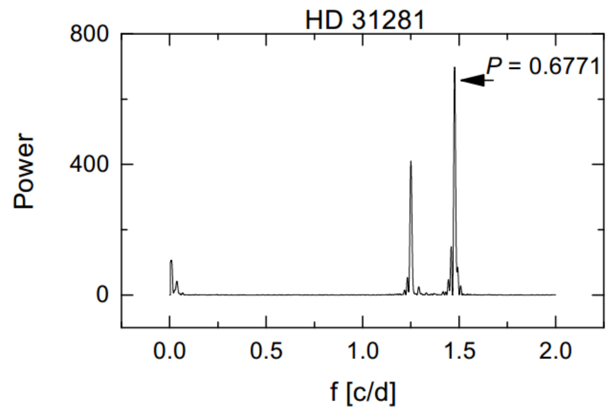
HD 31281

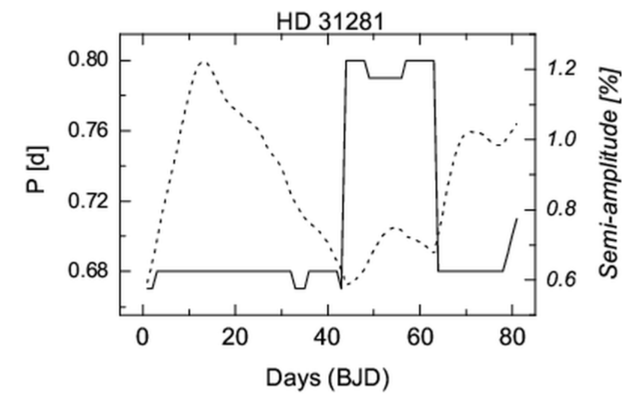
$P_{literature}$ = ??? d
P_{SWASP} = 0.7913(15)? d
P_{KEPLER} = 0.6771(1) / 0.7999(1) d





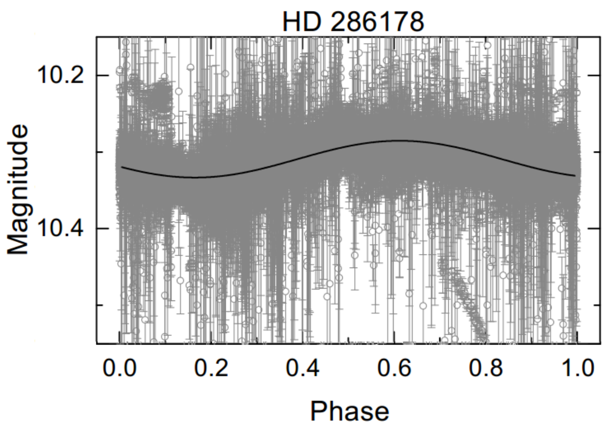


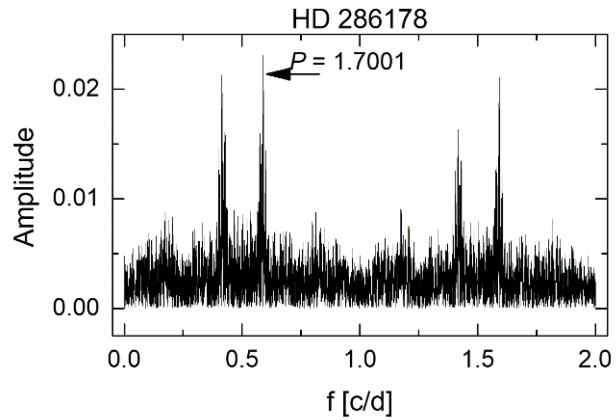


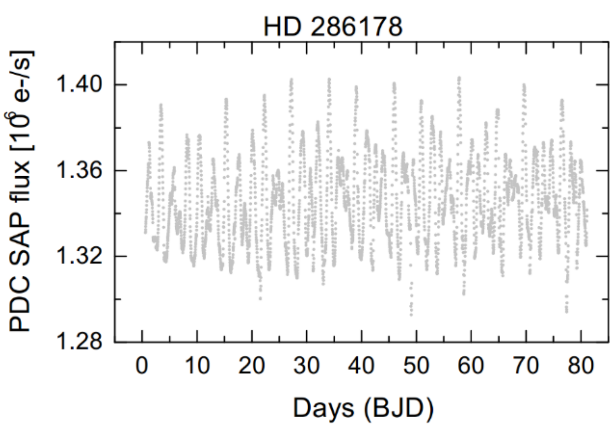


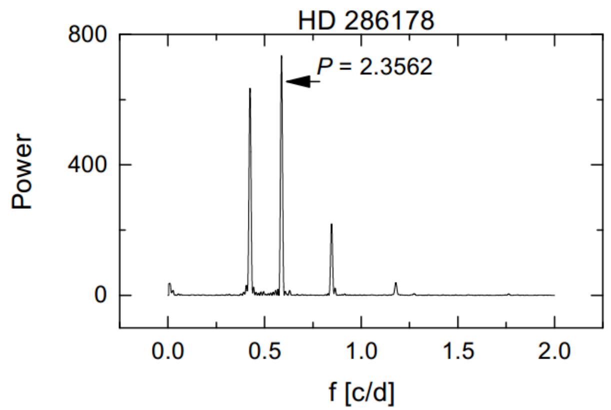
HD 286178

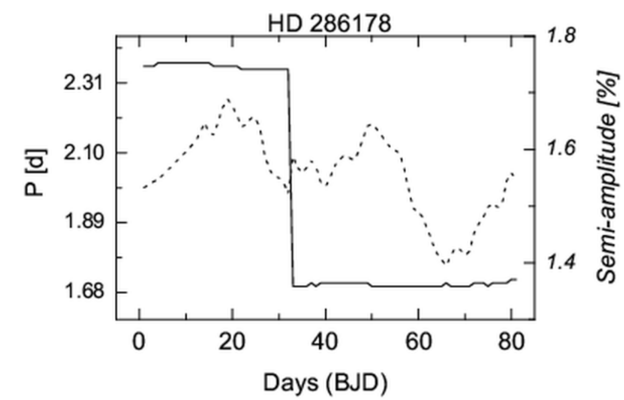
$P_{literature}$ = 2.39 d
P_{SWASP} = 2.4125(164) / 1.7001(81)? d
P_{KEPLER} = 2.3562(11) / 1.7027(6)? / 1.1813(3)? d





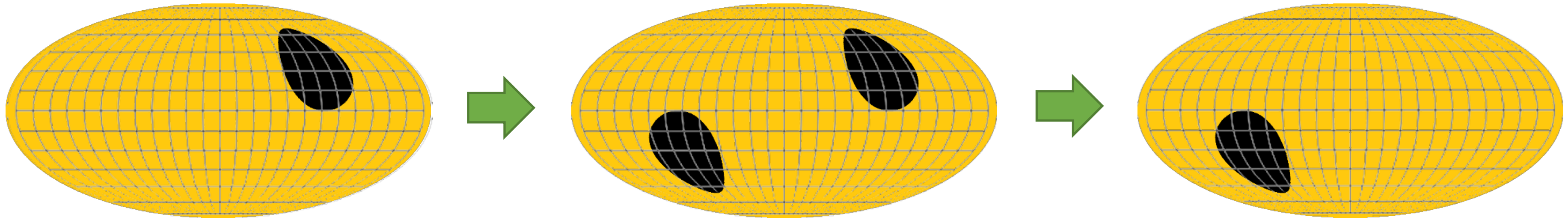






Simple spot model

- Multiple spots (no overlapping)
- Spot activation/deactivation (visibility change)

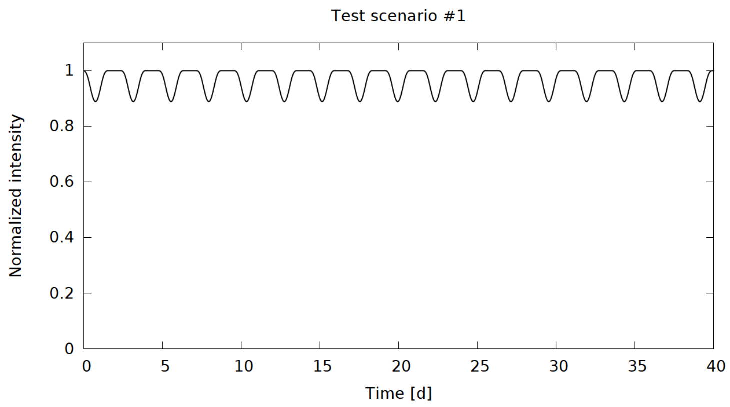


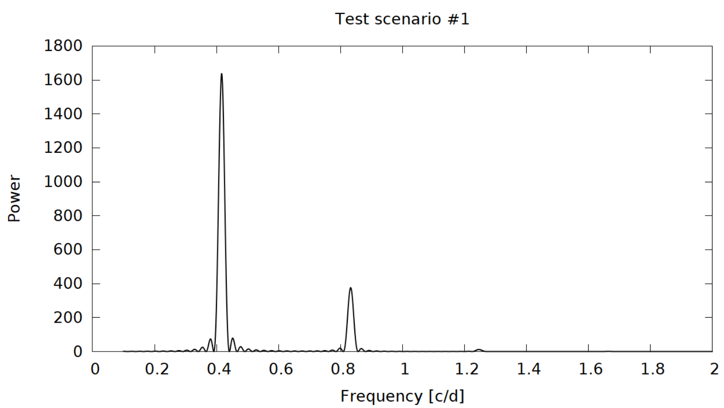
Model parameters:

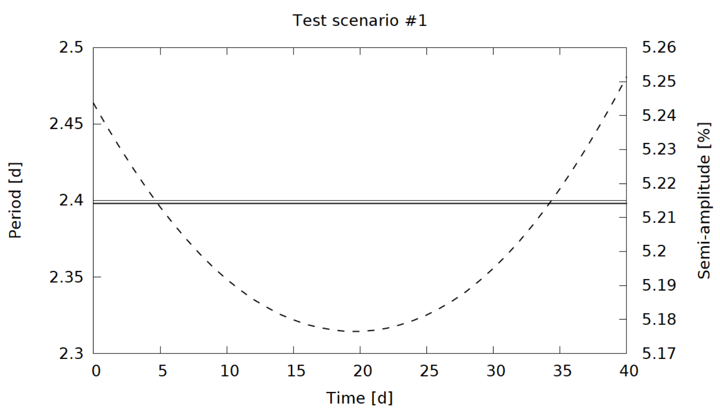
λ_S – spot longitude [deg]
Φ_S – spot latitude [deg]
r_S – spot radius [deg]
T_S – spot temperature [K]
u – linear limb darkening coefficient []

P_{rot} – rotation period [d]
Δt – timestep [d]
W – window of observation [d]
T_* – surface temperature [K]
i – inclination of rotation axis [deg]

Test scenario #1 – single spot



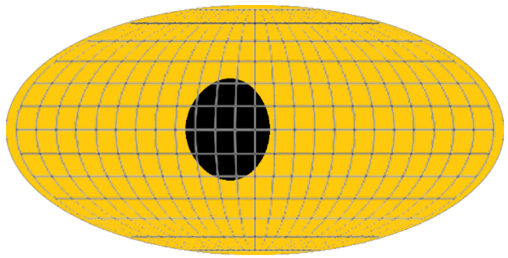




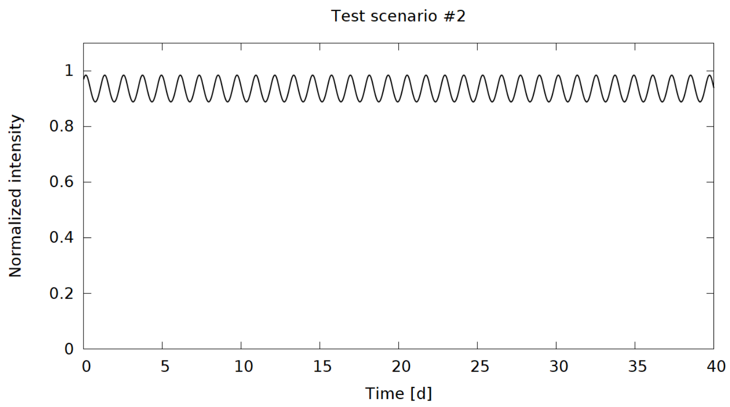
- small edge effect in semi-amplitude

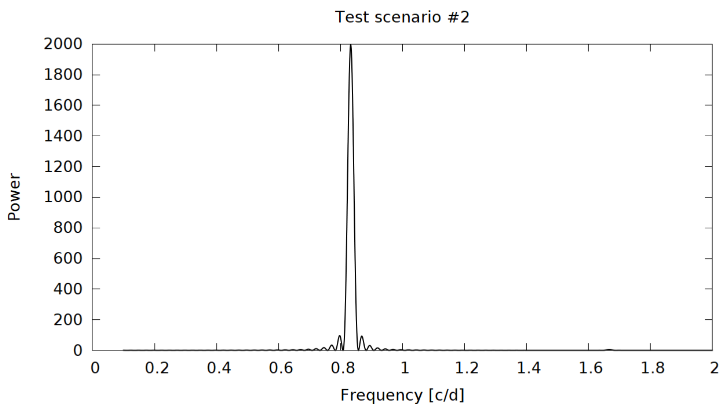
Parameter	Value
P_{rot} [d]	2.4
Δt [d]	0.01
W [d]	40
T_{*} [K]	4500
T_S [K]	4000
u []	0.7
i [deg]	0

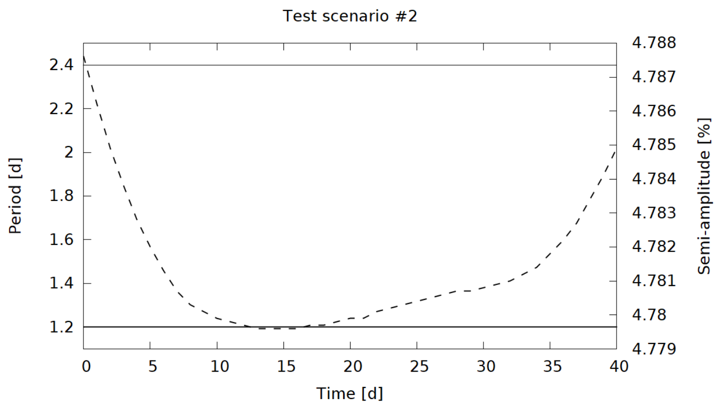
	Spot 1	Spot 2
λ_S [deg]	340	N/A
Φ_S [deg]	0	N/A
r_S [deg]	30	N/A



Test scenario #2 – two opposite spots



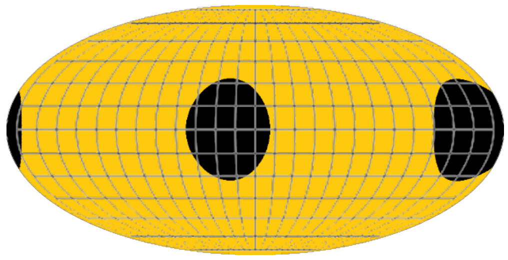




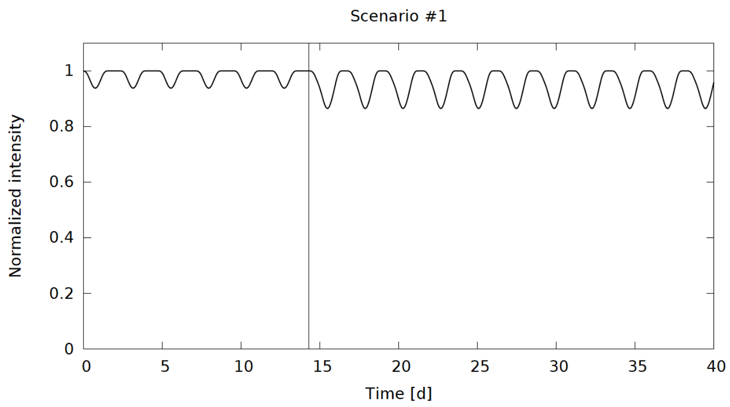
- small edge effect in semi-amplitude
- ½ of true period

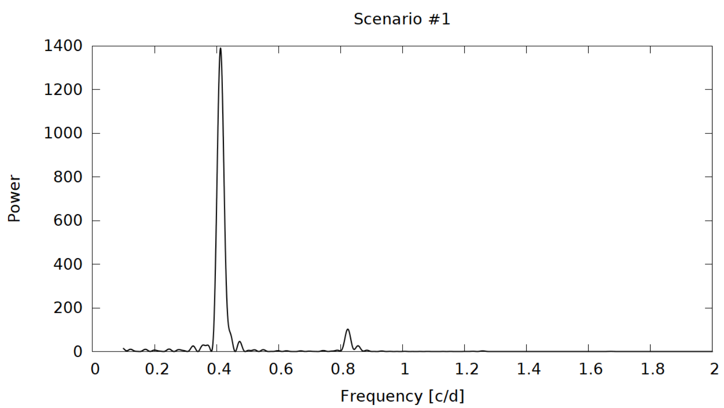
Parameter	Value
P_{rot} [d]	2.4
Δt [d]	0.01
W [d]	40
T_* [K]	4500
T_S [K]	4000
u []	0.7
i [deg]	0

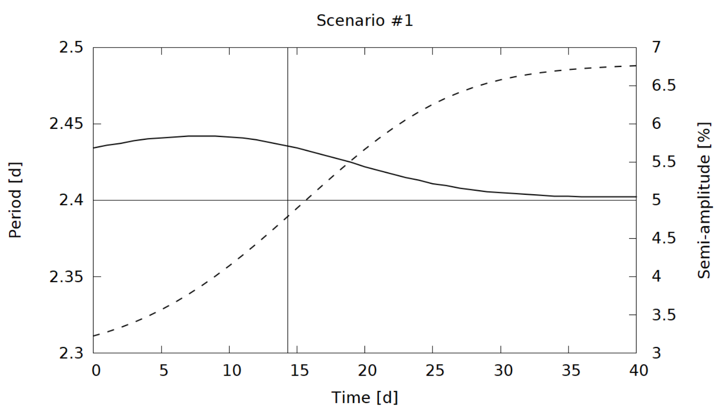
	Spot 1	Spot 2
λ_S [deg]	340	160
Φ_S [deg]	0	0
r_S [deg]	30	30



Scenario #1 – new close spot



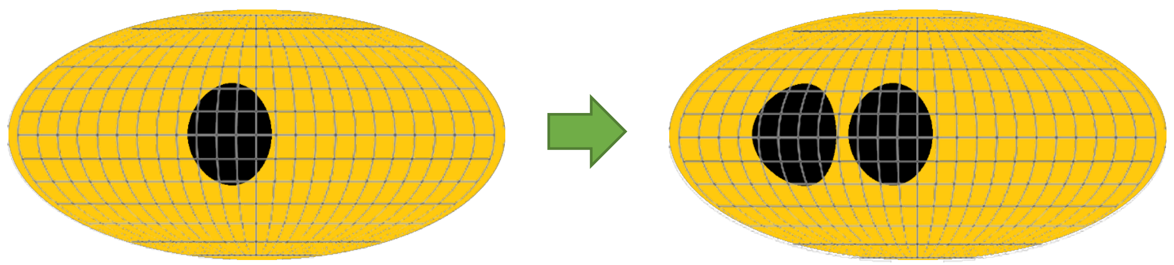




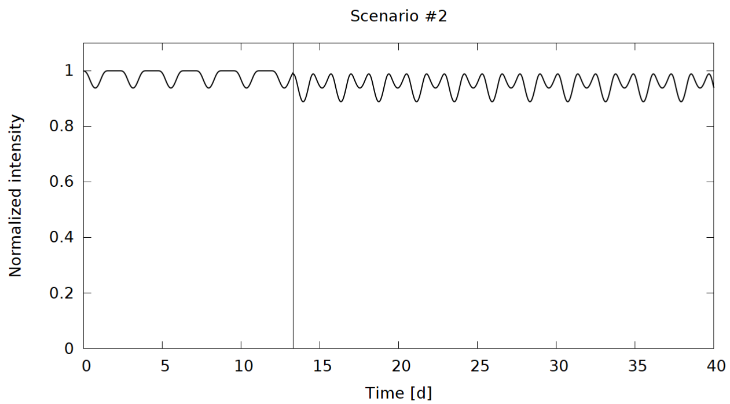
- sharp change of amplitude is not reflected in WWZ
- period in WWZ reacts smoothly when close spots

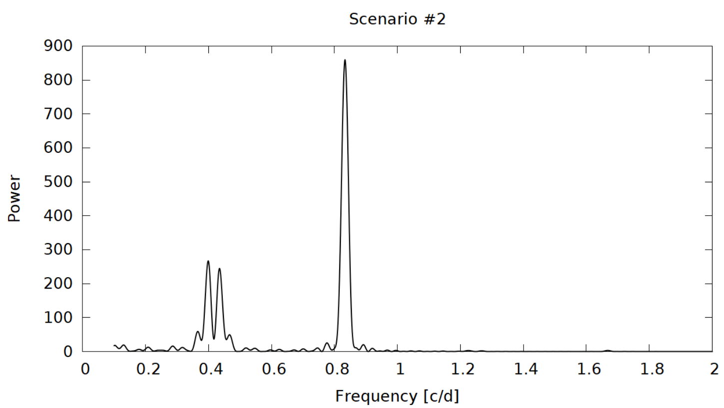
Parameter	Value
P_{rot} [d]	2.4
Δt [d]	0.01
W [d]	40
T_* [K]	4500
T_S [K]	4000
u []	0.7
i [deg]	0

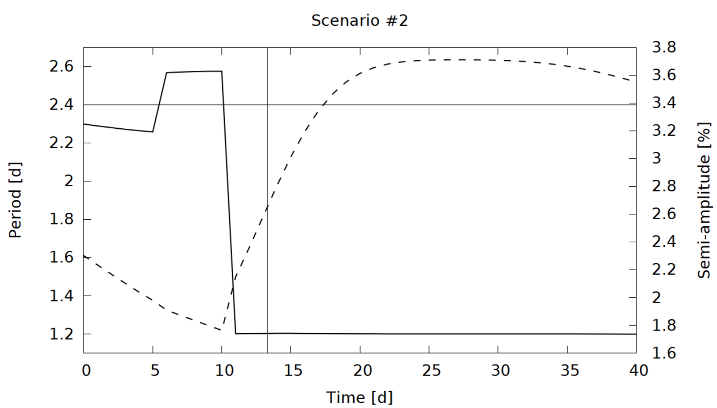
	Spot 1	Spot 2
λ_S [deg]	340	270
Φ_S [deg]	0	0
r_S [deg]	30	30



Scenario #2 – new opposite spot



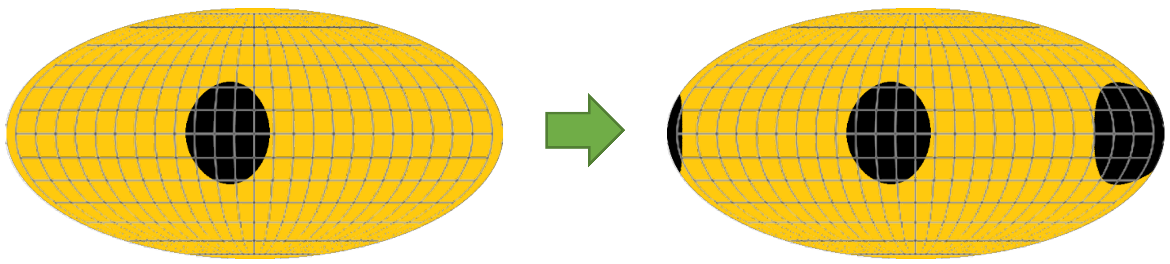




- sharp change of amplitude is reflected in WWZ
- period in WWZ reacts dramatically when opposite spots

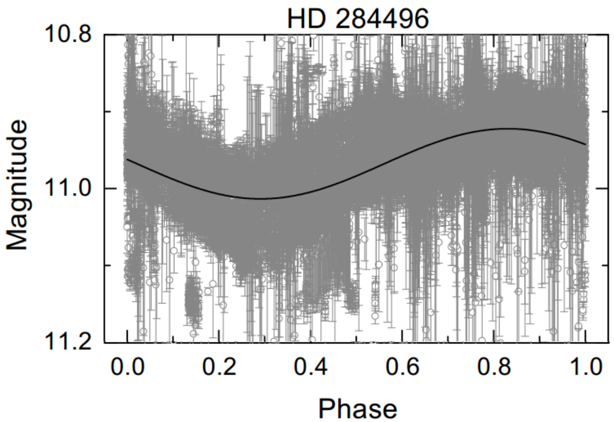
Parameter	Value
P_{rot} [d]	2.4
Δt [d]	0.01
W [d]	40
T_* [K]	4500
T_S [K]	4000
u []	0.7
i [deg]	0

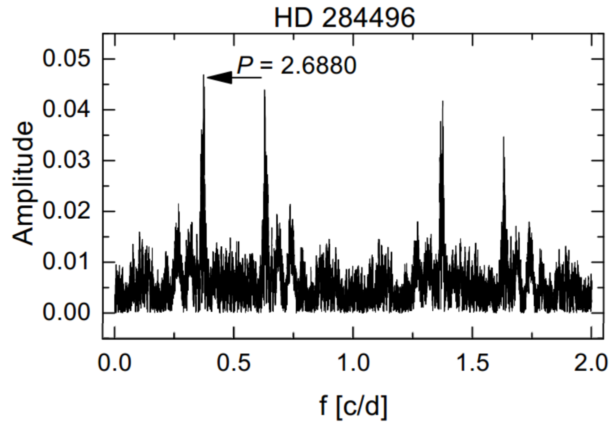
	Spot 1	Spot 2
λ_S [deg]	340	160
Φ_S [deg]	0	0
r_S [deg]	30	30

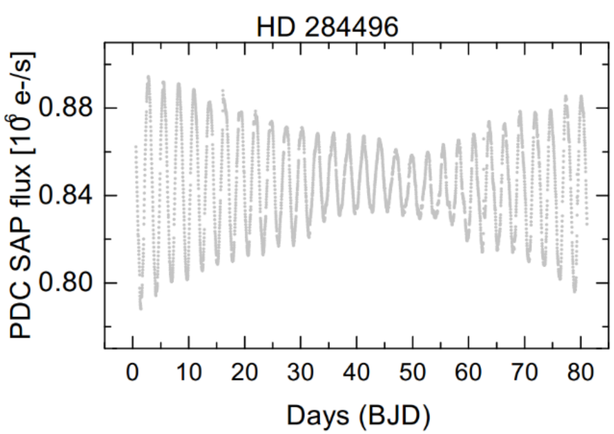


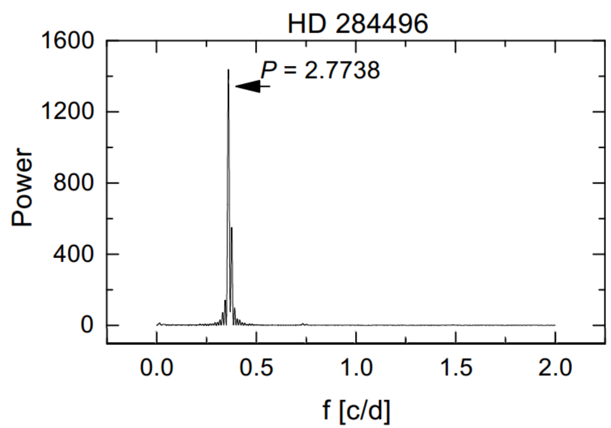
Case study HD 284496

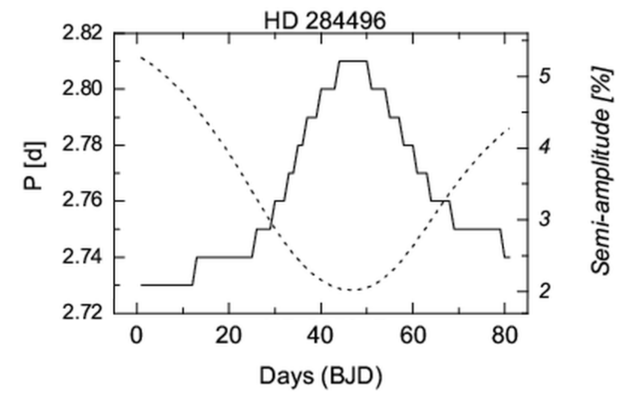
$P_{literature}$ = 2.71 d
P_{SWASP} = 2.6880(195) d
P_{KEPLER} = 2.7738(8) / 2.6525(6)? d



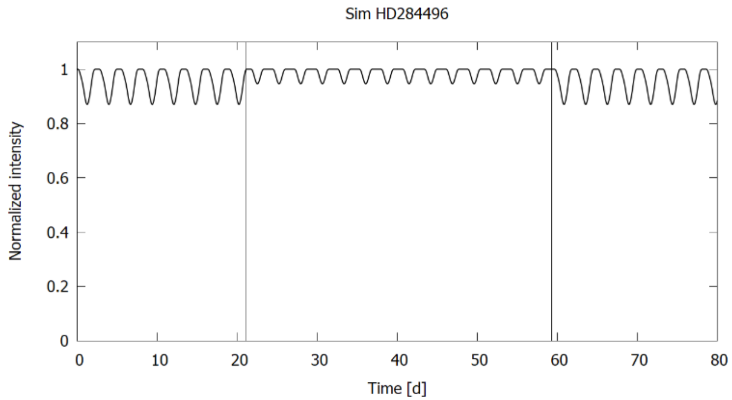


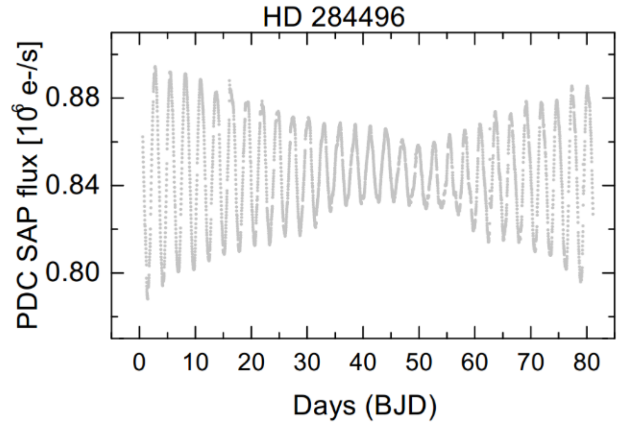




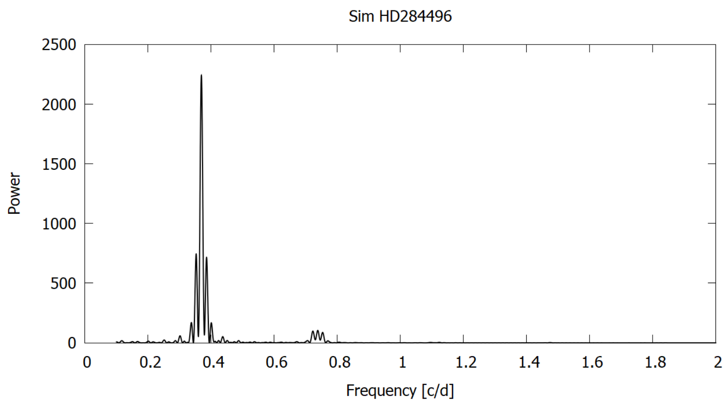


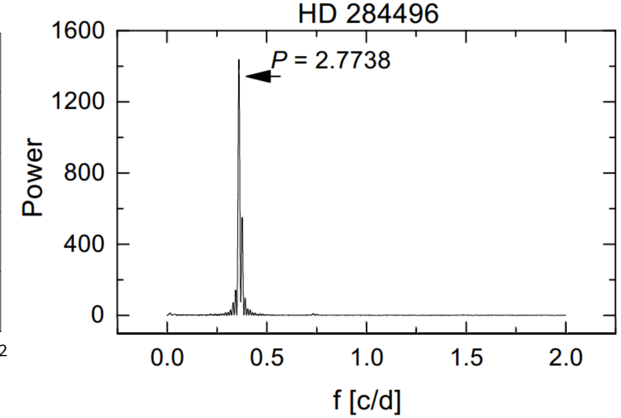
Case study HD 284496



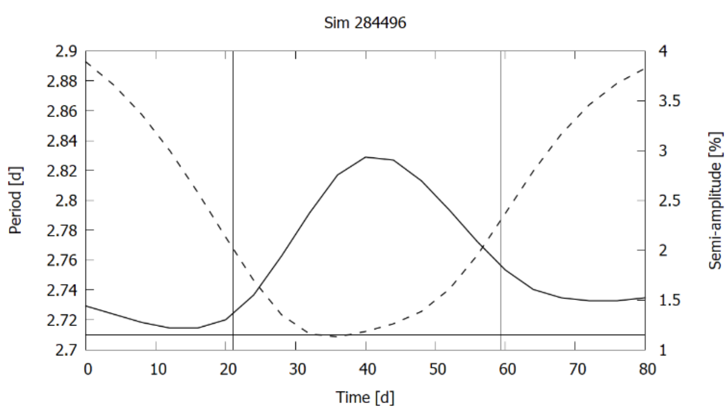


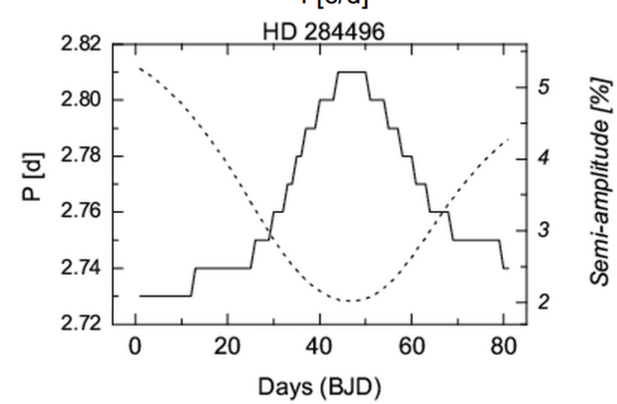
Parameter	Value
P_{rot} [d]	2.71
Δt [d]	0.01
W [d]	80
T_* [K]	4500
T_S [K]	4000
u []	0.7
i [deg]	0

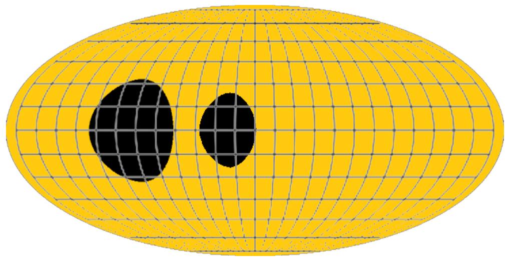




	Spot 1	Spot 2
λ_S [deg]	340	270
Φ_S [deg]	0	0
r_S [deg]	20	30

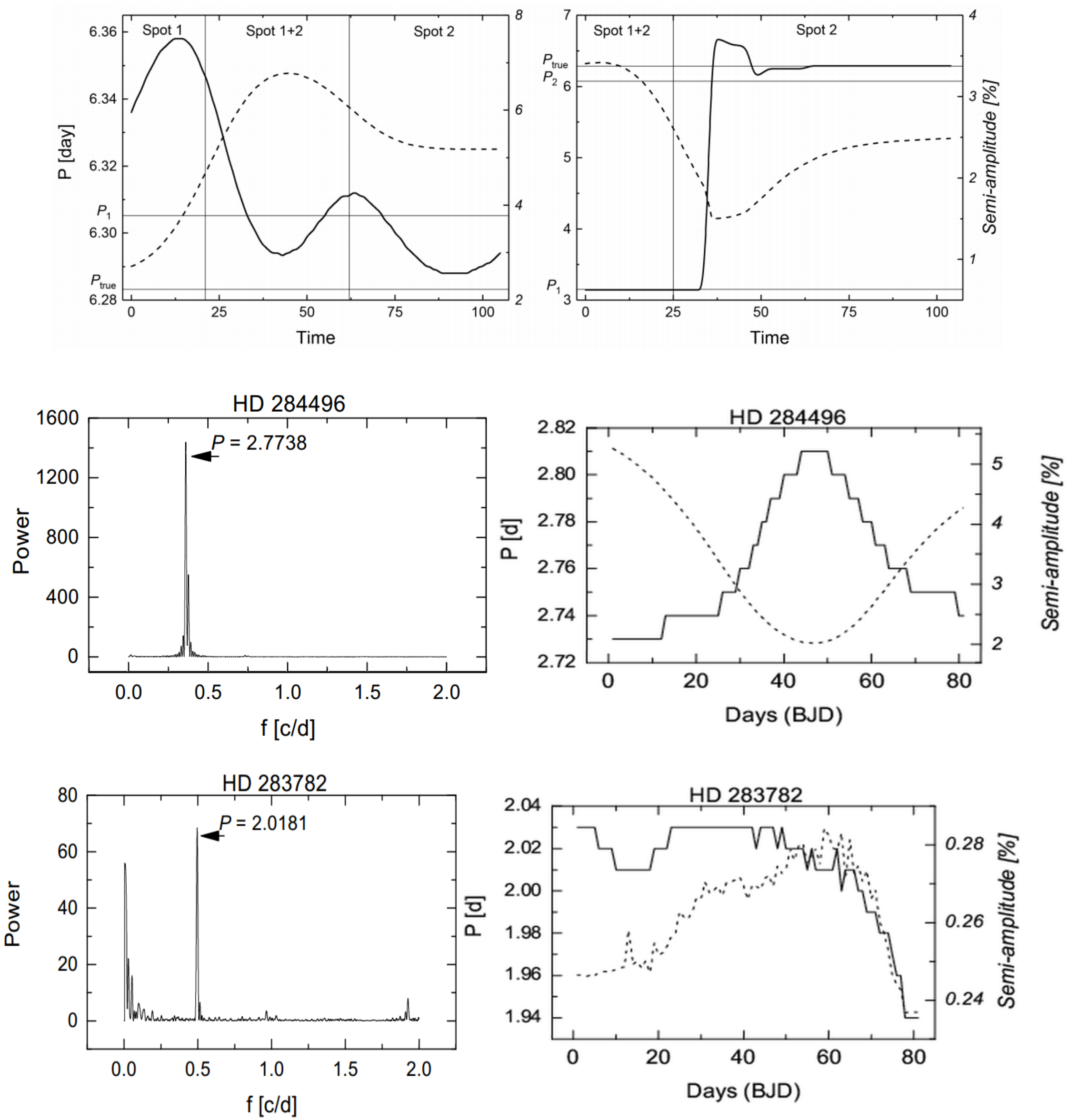




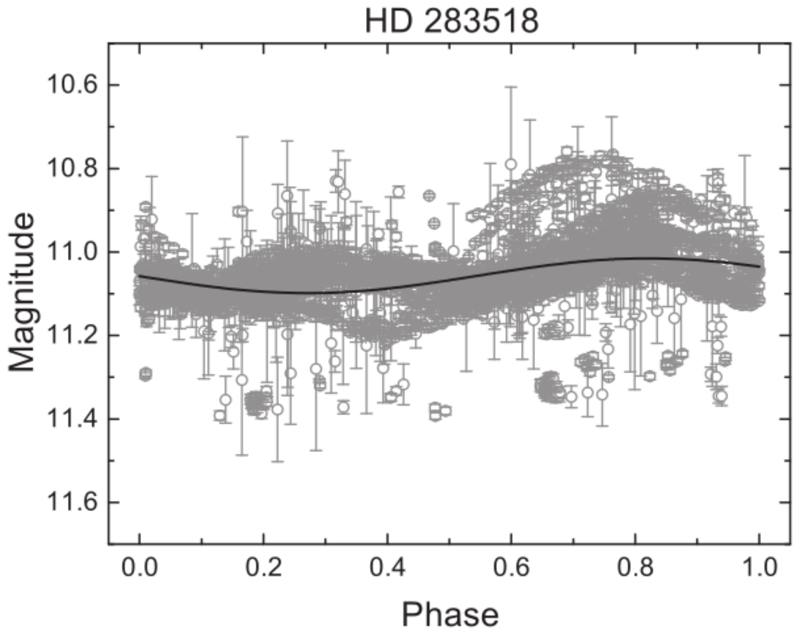


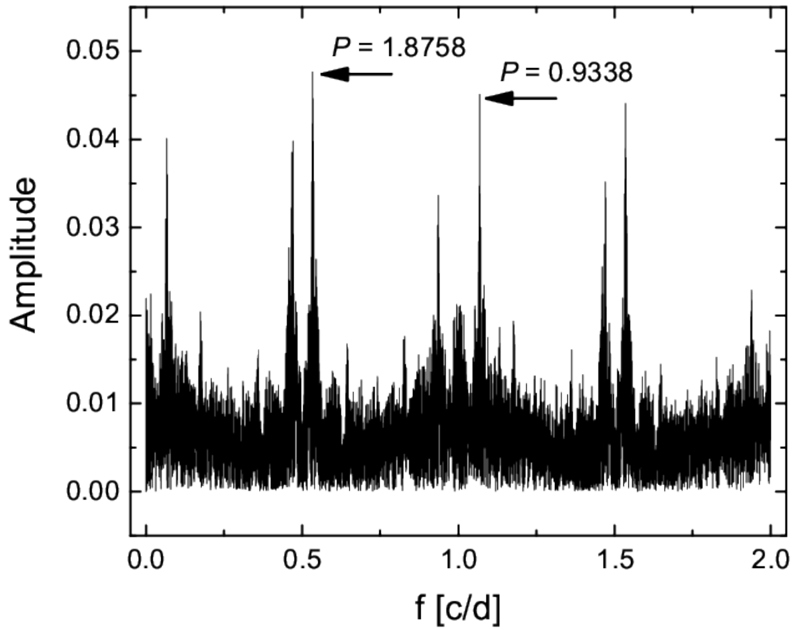
Takeaway

- Appearing/disappearing spotted regions can explain visible changes of observed photometric period
- Period with more power (periodogram) is not always the one with longer duration (WWZ) in dataset
- Sudden change of period WWZ is caused by almost opposite spots
- Downside: CPU heavy, no inversion



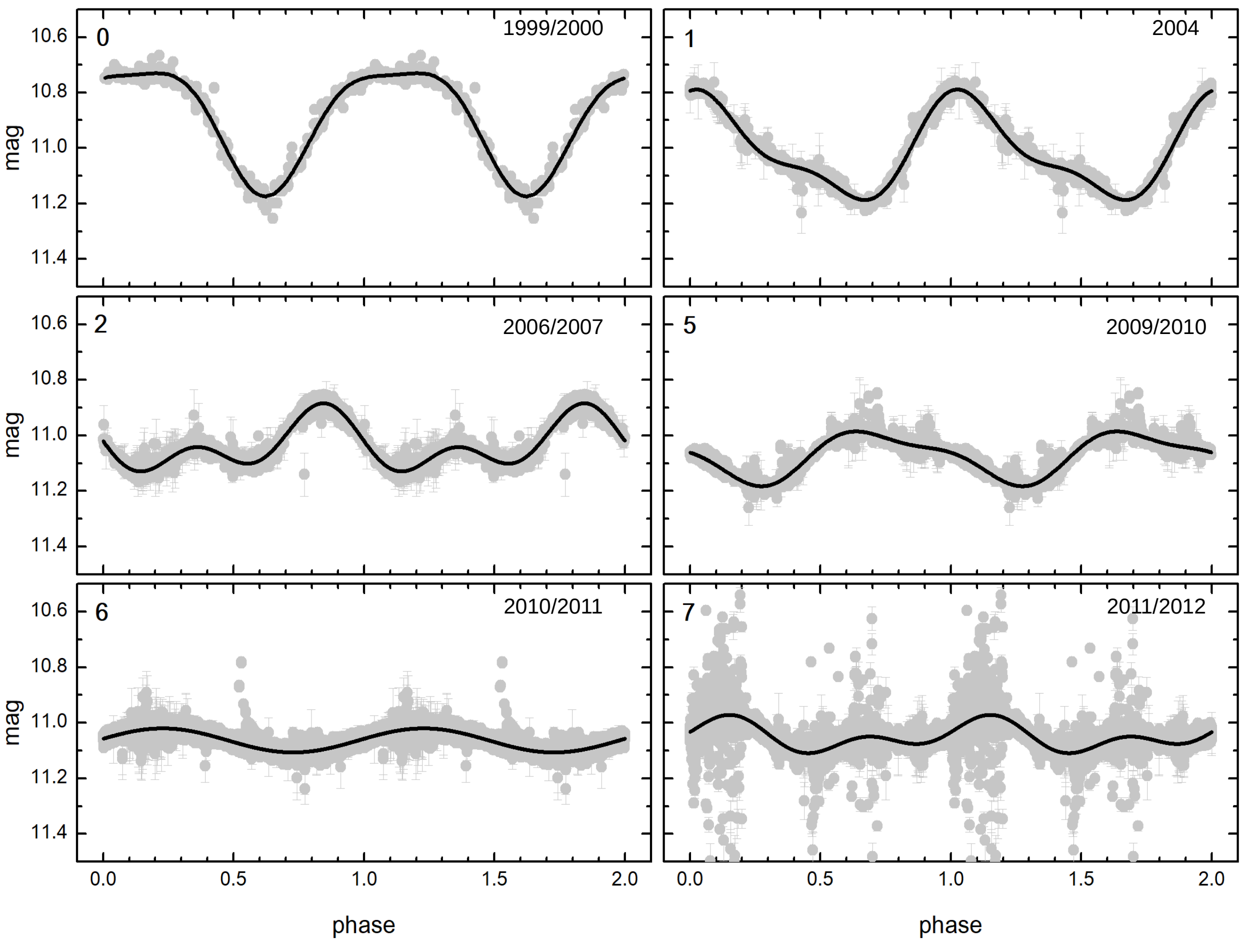
V410 Tau (HD 283518)

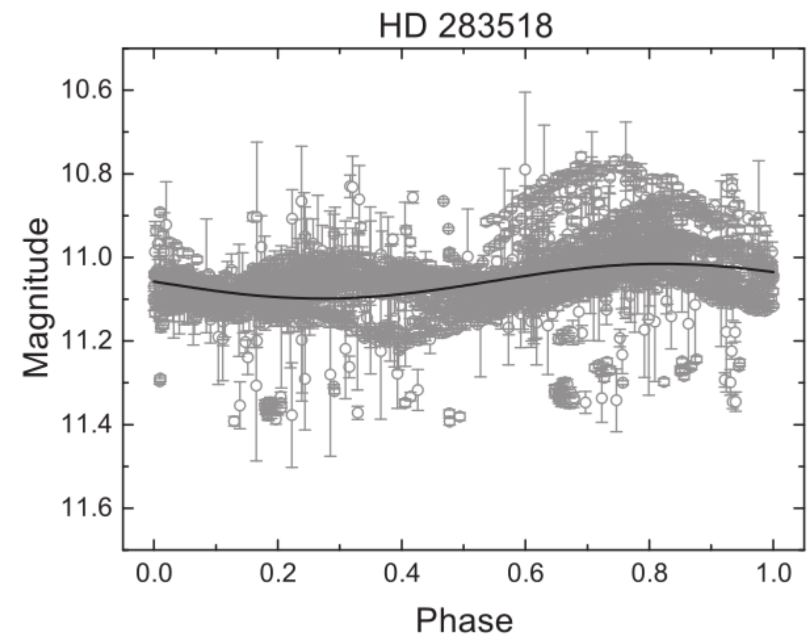


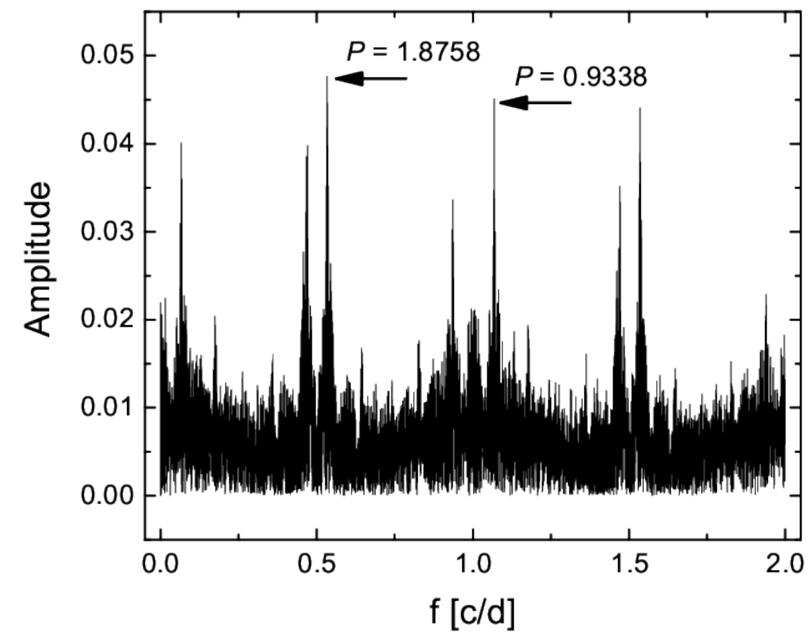


V410 Tau (HD 283518)

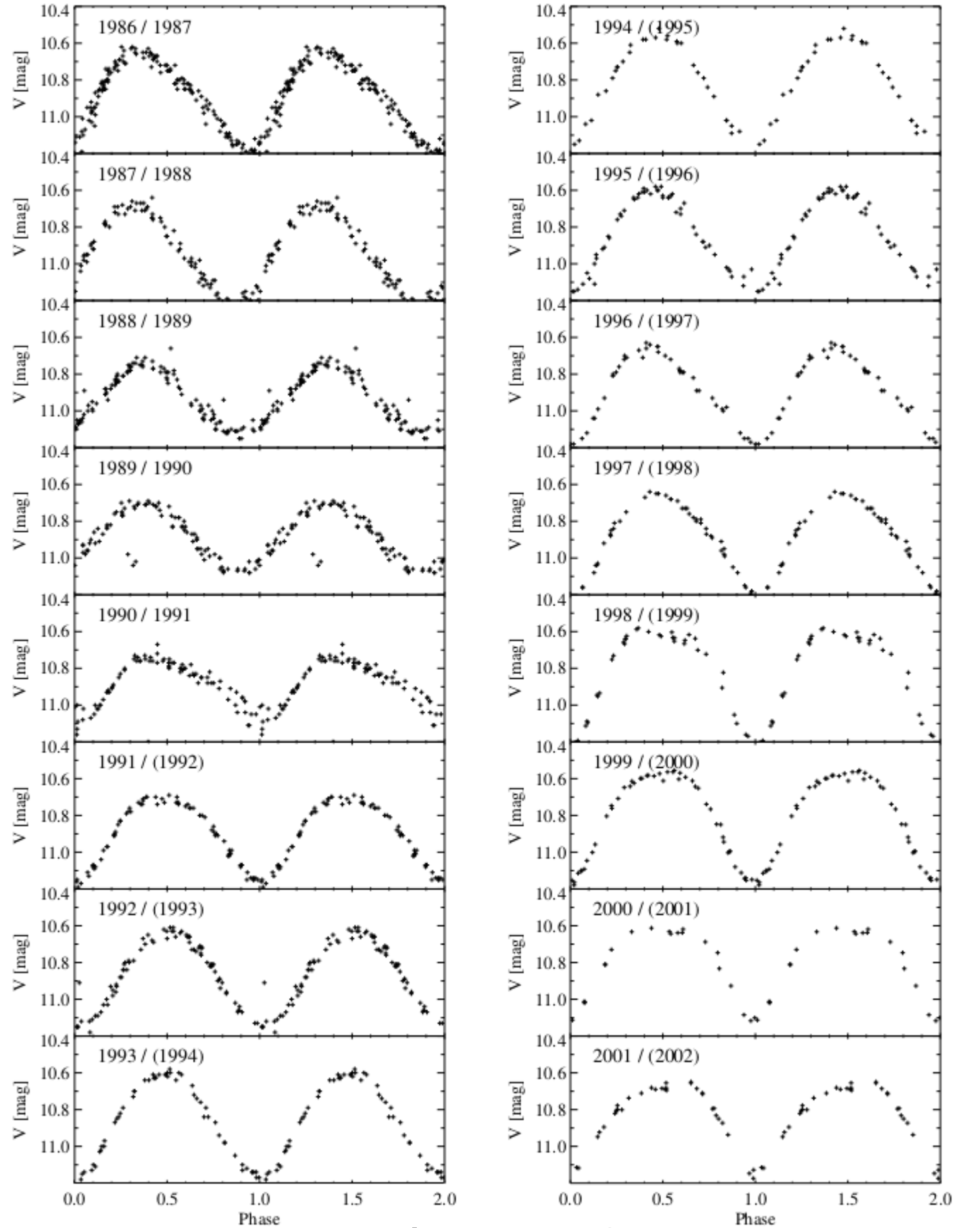
Model with additional harmonic frequency



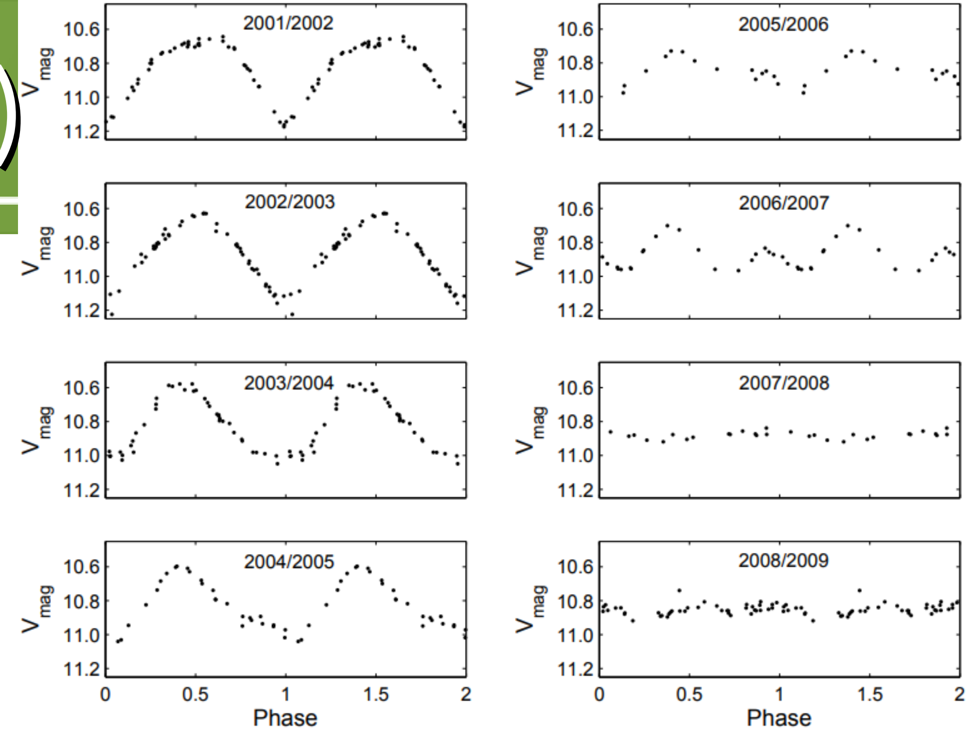




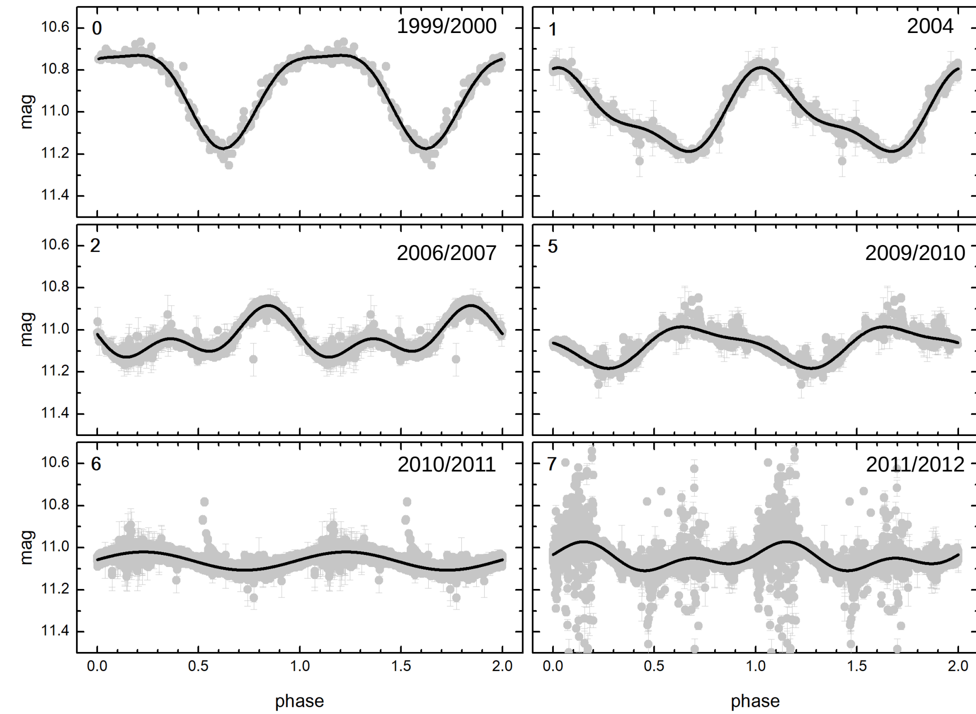
V410 Tau (HD 283518)



Stelzer+, 2008

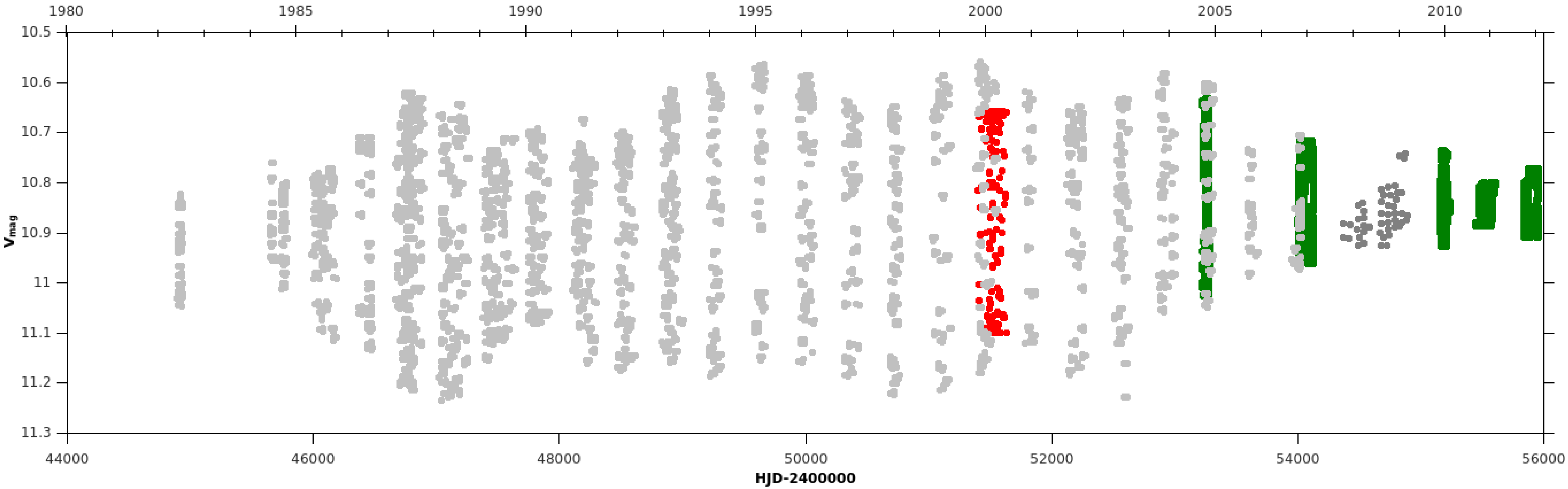


Grankin & Artemenko, 2009



V410 Tau (HD 283518)

Longterm photometric light curve



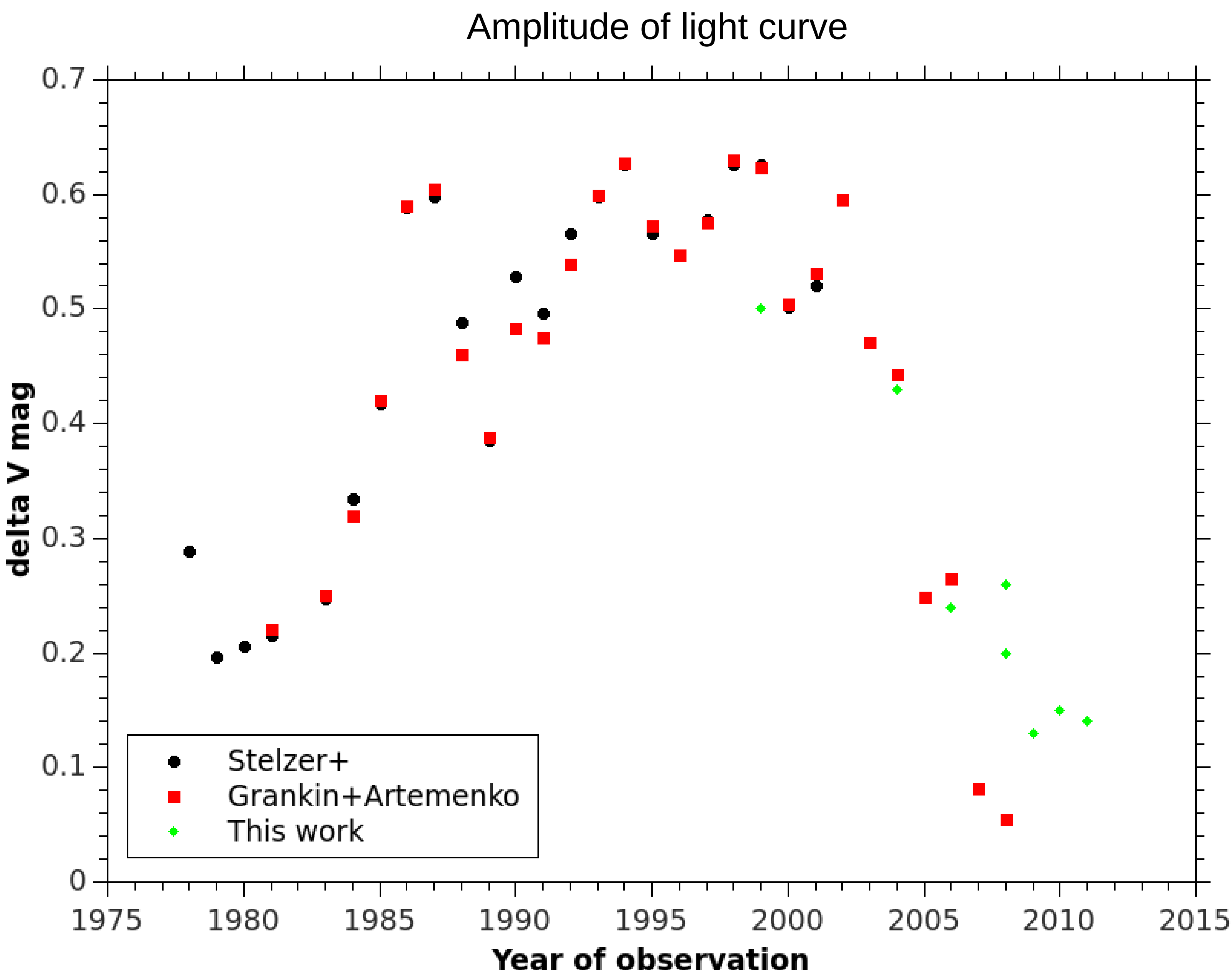
Rydgren & Vrba, 1983
Vrba, Herbst & Booth, 1988
Bouvier, Bertout & Bouchet, 1988
Herbst, 1989
Grankin, 1999
Grankin+, 2008

Grankin & Artemenko, 2009

This work, NSVS

This work, SuperWASP

V410 Tau (HD 283518)



Conclusions

- Determined *L*, T_{eff}, *M*, age based on photometry and stellar evolution models
- Period search on 20 WTTS from ground-based data
- WWZ on 10 WTTS from *Kepler* K2 data
- Previously unknown/updated periods
- Possible Post T Tauri stars?
- Magnetic dynamo cycle length in V410 Tau?
- Continuation of dedicated spectral observation and analysis

STARRY Conference - June 18, 2019

Thank you!

More info:

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T Tauri stars in the SuperWASP and NSVS surveys

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