Low-mass companions to Bright Giants.

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Planets around other stars.

1992 – Wolszczan & Frail - first planet around other star PSR B1257+12 b (c, d).

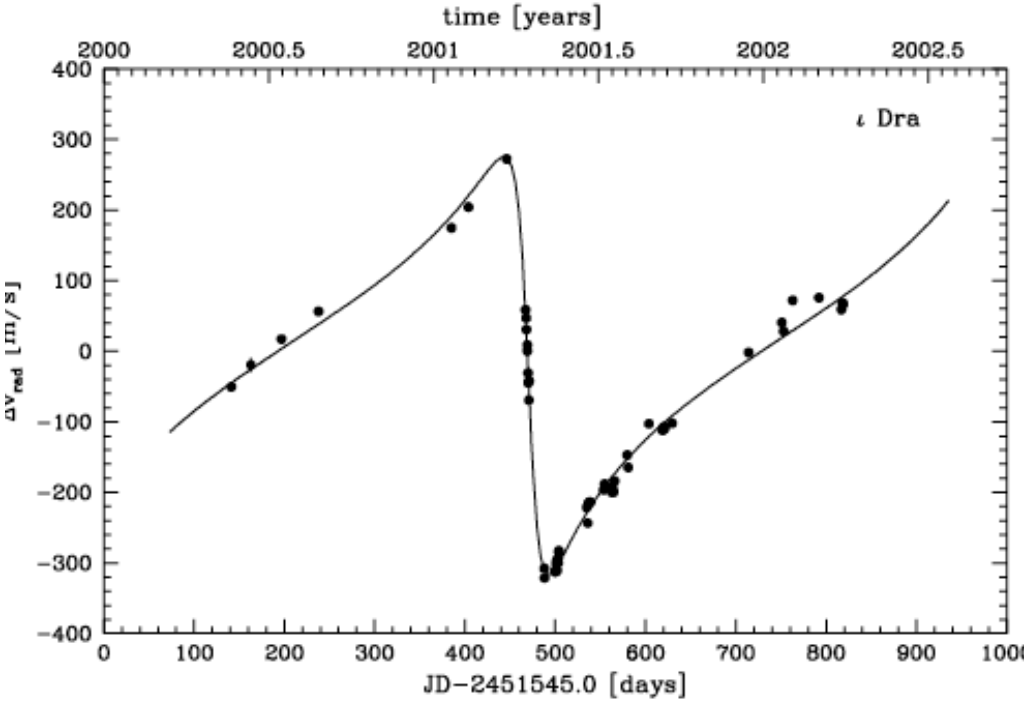
1995 – Mayor & Queloz - first planet around a solar-type star 51 Peg b.

2002 – Frink et al. - first planet around a giant – ι Dra b.

TABLE 2

SPECTROSCOPIC ORBITAL ELEMENTS FOR ι DRA

Element	Fitted Value	Estimated Uncertainty
Period P (days)	536	5
Periastron time T_0	2,452,015.8[a]	0.2[b]
Longitude of periastron ω (deg)	95.9	0.1
Eccentricity e	0.70	0.01
Mass function $f(m)$[c] $(M_\odot)$	5.1×10^{-7}	0.2×10^{-7}



The PennState - Toruń Planet Search. Motivation.

1. Search for planets around intermediate-mass stars.
2. Search for planets around evolved stars.
3. Star-planet interactions.
4. Evolution of planetary systems with ageing stars.
5. Bonus: Lots of stellar astrophysics for free.

The PennState – Toruń Planet Search (PTPS).

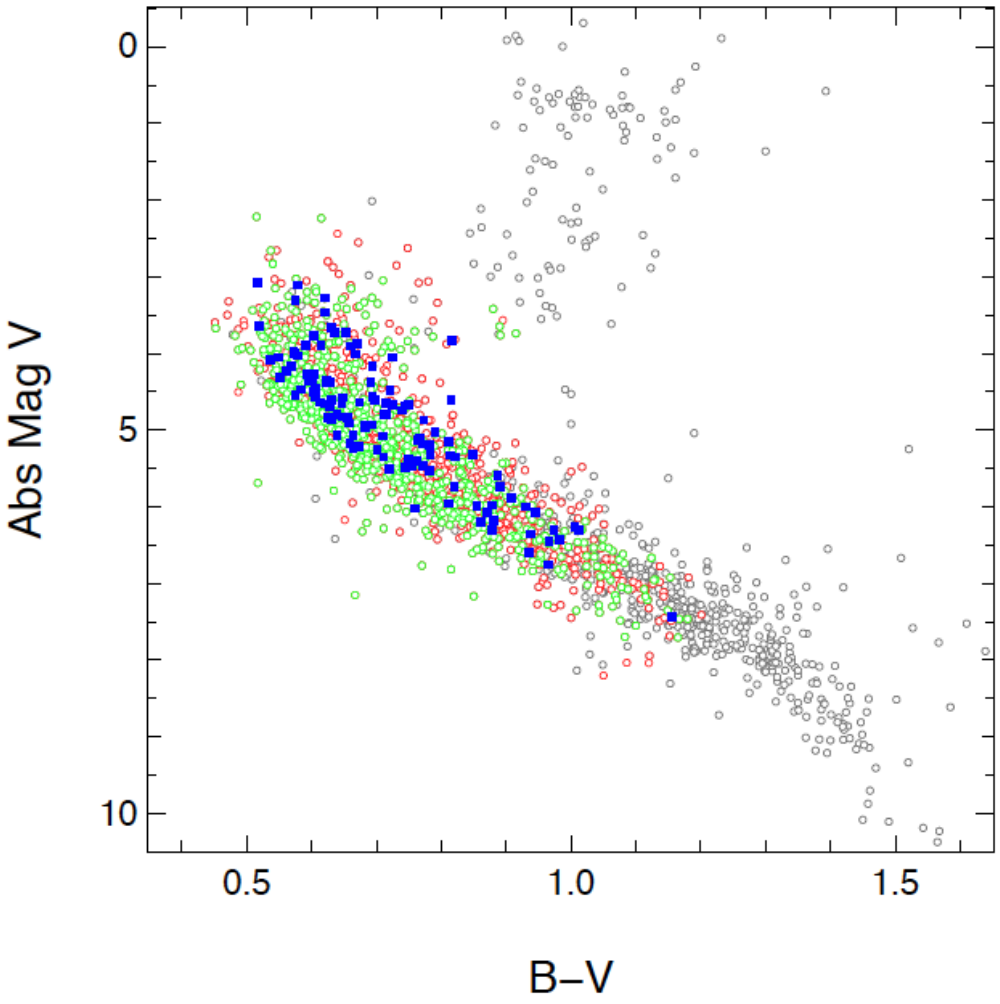
Instrument:
9.2m Hobby-Eberly Telescope (HET).
High Resolution Spectrograph (HRS)
R=60.000 & gas cell (I2).
RV from 17 orders of blue CCD
(5045-5920 Å). P4.

Precision:
~5 ms^{-1}

Strategy:
Strategy focused on long-term variations.
Sample & cadence randomized by the queue scheduled observing mode.

Sample:
Sky coverage: DEC -10°20’ ÷ 71°40’
Uniform distribution in (RA, DEC).
Most stars fainter than V=8.5.

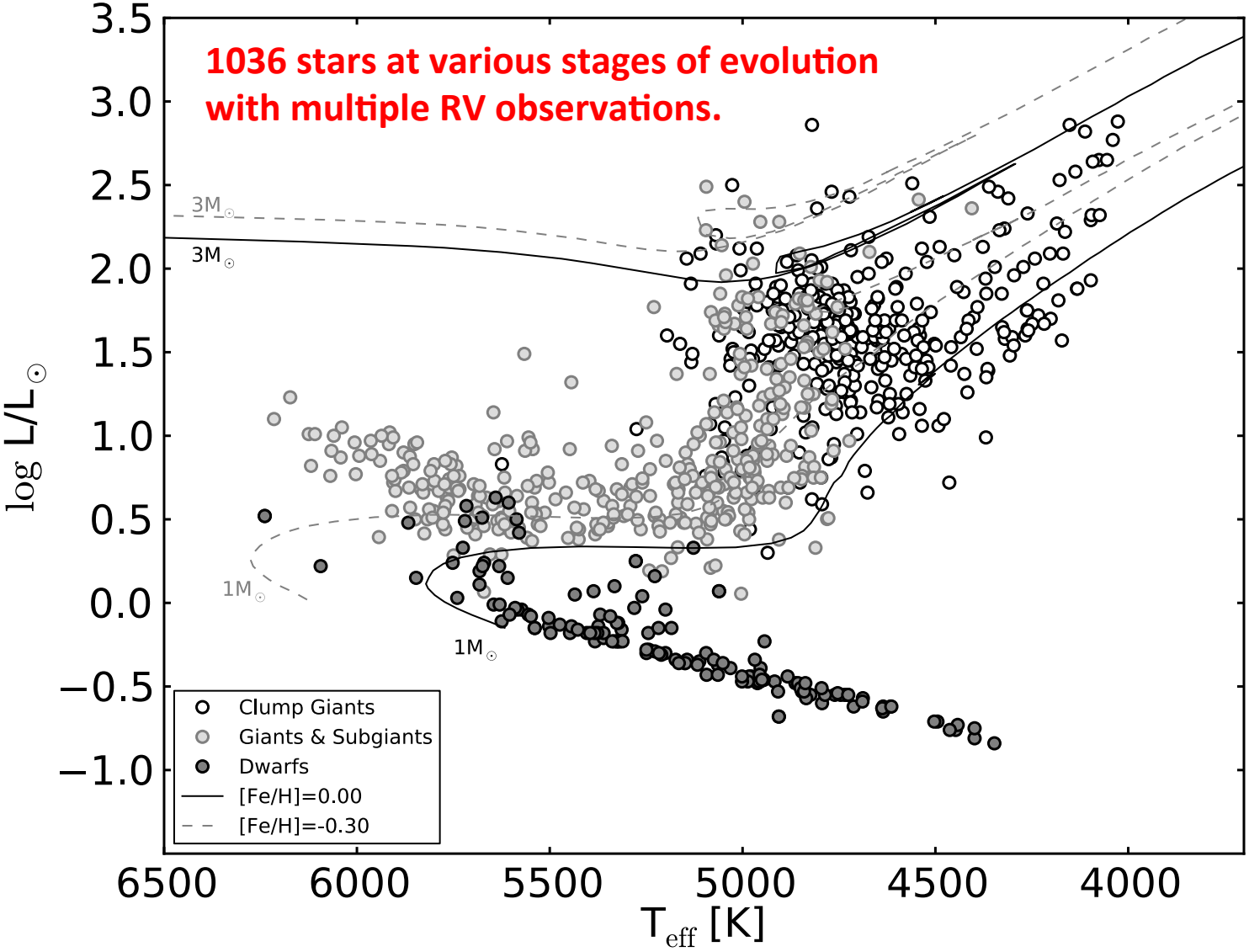
Typical RV planet search sample.



Mayor et al. 2011

Fig. 1. HR-diagram of Hipparcos 2008 catalogue (black) , CORALIE volume limited sample (red), HARPS sample of low activity stars (green) and stars with planetary systems (blue)

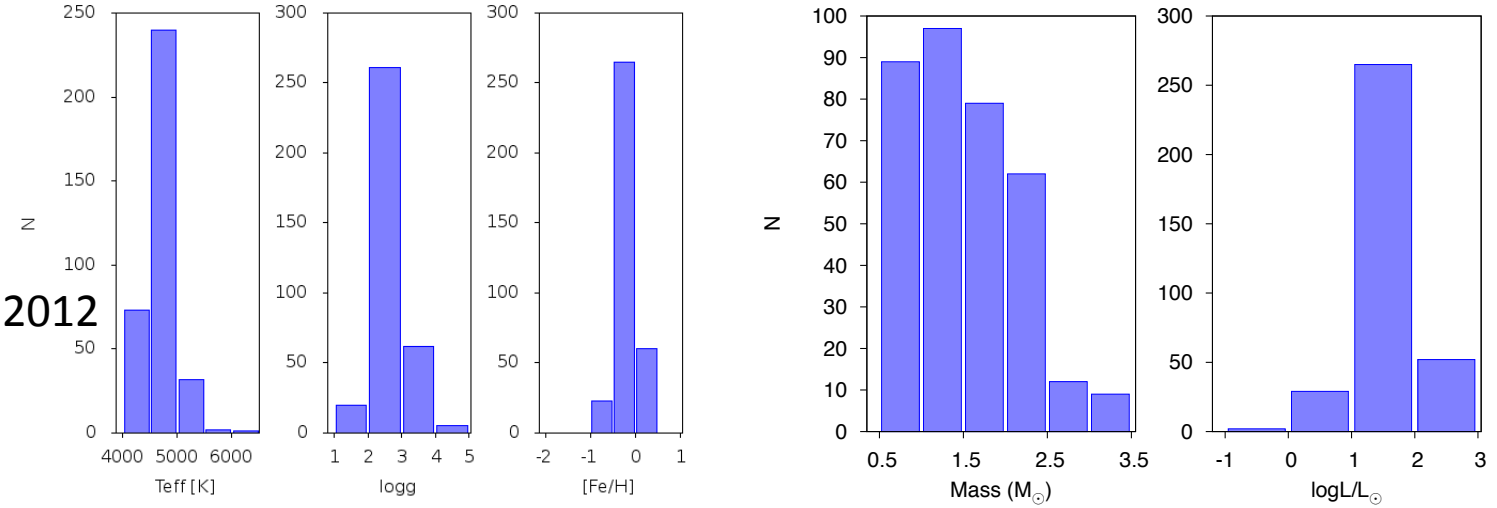
PTPS sample.


1036 stars at various stages of evolution
with multiple RV observations.
3M⊙
3M⊙
1M⊙
1M⊙
Clump Giants
Giants & Subgiants
Dwarfs
[Fe/H]=0.00
[Fe/H]=-0.30
log L/L⊙
T_eff [K]
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
6500
6000
5500
5000
4500
4000

PTPS sample.

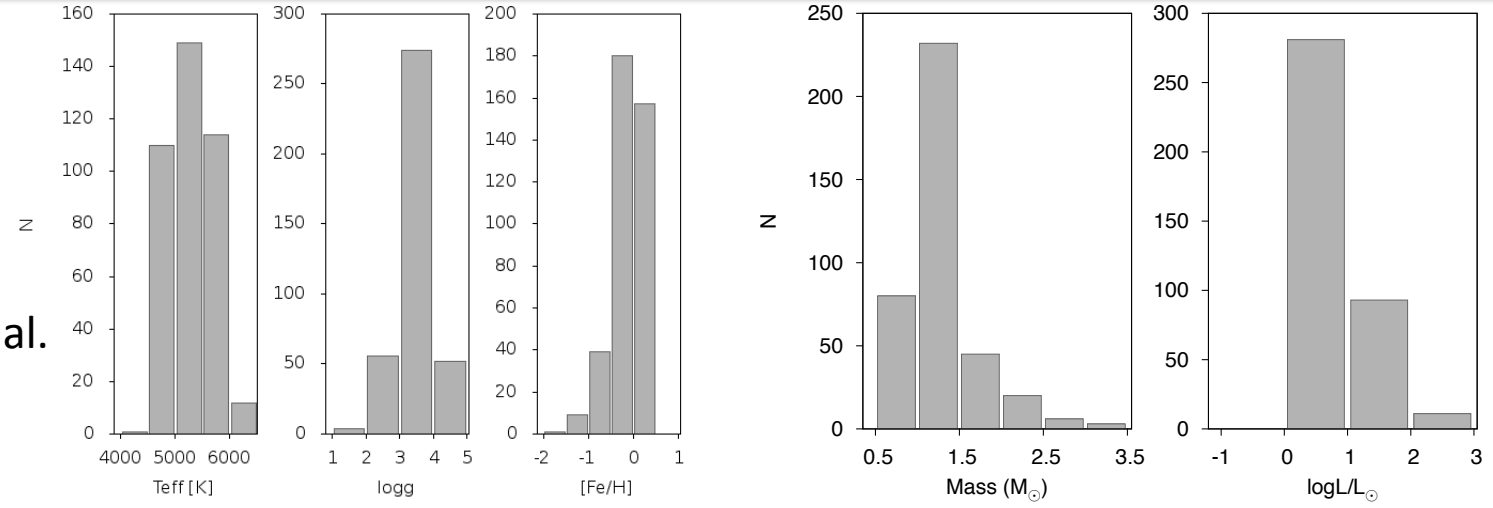
Clump Giants

Zieliński et al. 2012



Giants
& Subgiants

Niedzielski et al.
in prep.



RV search for planets around Clump Giants. Limitations.

K giants are RV variable stars (Walker et al. 1989 ApJ 343, 21)
(30-300 m/s rms)

Short period variations are due to p-mode oscillation (Hatzes & Cochran 1998).

Long-period variations are due to:

non-radial pulsations (?),
rotation-induced activity (spots),
low-mass companions.

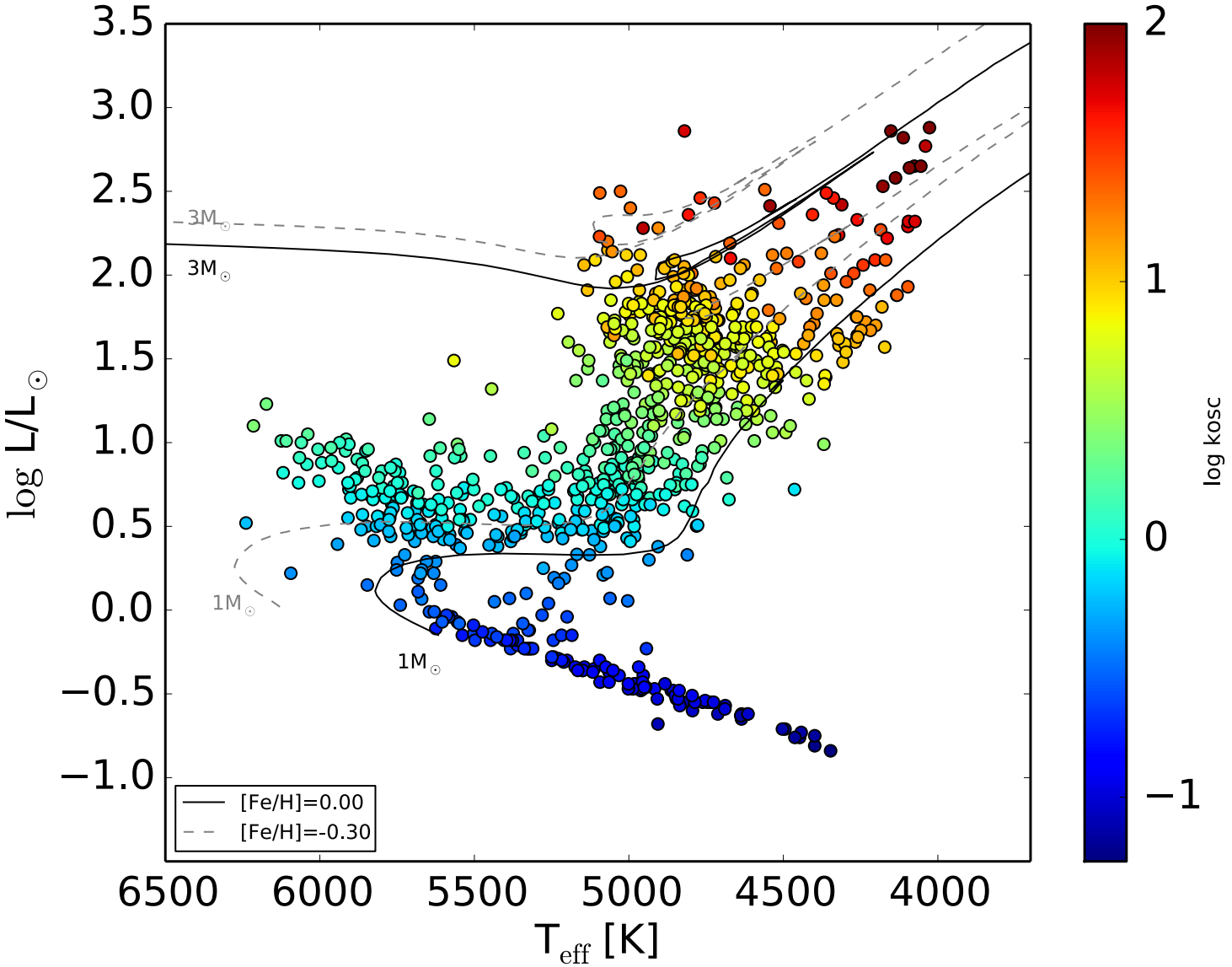
Solar-type p-mode oscillations may be estimated from Kjeldsen & Bedding (1995) scaling relations:

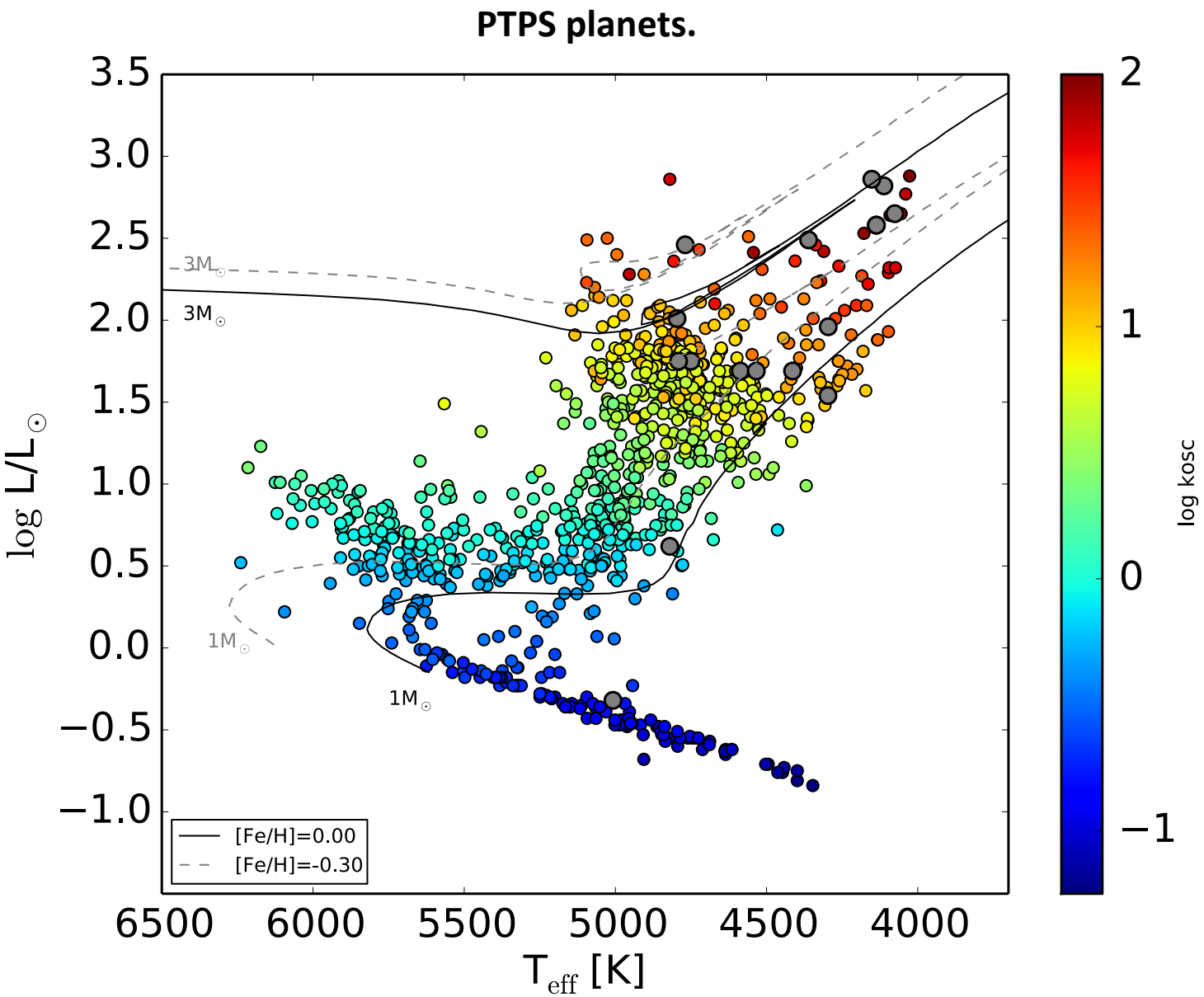
amplitudes (~L/M): of up to ~200 ms^{-1}
periods (~$(R^2(T_{eff})^{½})$/M): ~hours-days

When unresolved introduce noise (jitter) to RV.

Evolutionary track overlap. Stellar parameters (mass, age) and evolutionary stage uncertain.

PTPS sample vs. oscillations.




PTPS planets.
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
log L/L⊙
3M⊙
3M⊙
1M⊙
1M⊙
[Fe/H]=0.00
[Fe/H]=-0.30
6500
6000
5500
5000
4500
4000
T_eff [K]
2
1
0
−1
log kosc

Planets around evolved/intermediate-mass stars. General properties.

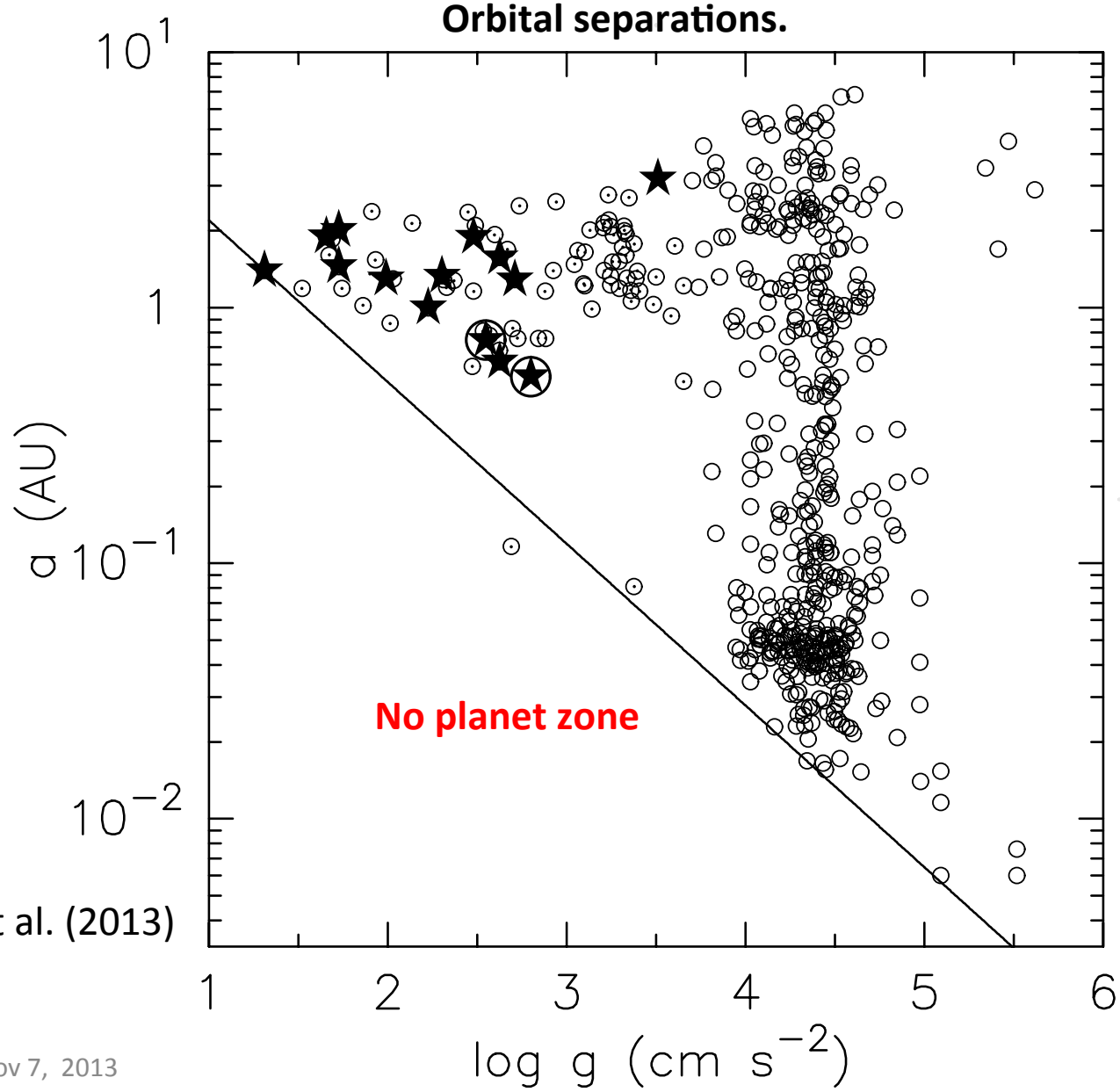
1. Planets around massive stars are more frequent.
   (Johnson et al. 2007, Kennedy & Kenyon 2008, Johnson et al. 2010)

2. No planets within a<0.6 AU (primordial or due to engulfment?).
   (Villaver & Livio 2007, 2009, Johnson et al. 2007, Burkert & Ida 2007, Sato 2008, Currie 2009, Kunitomo et al. 2011)

3. Stellar mass – planetary system mass relation.
   (Lovis & Mayor 2007, Bowler et. 2010)

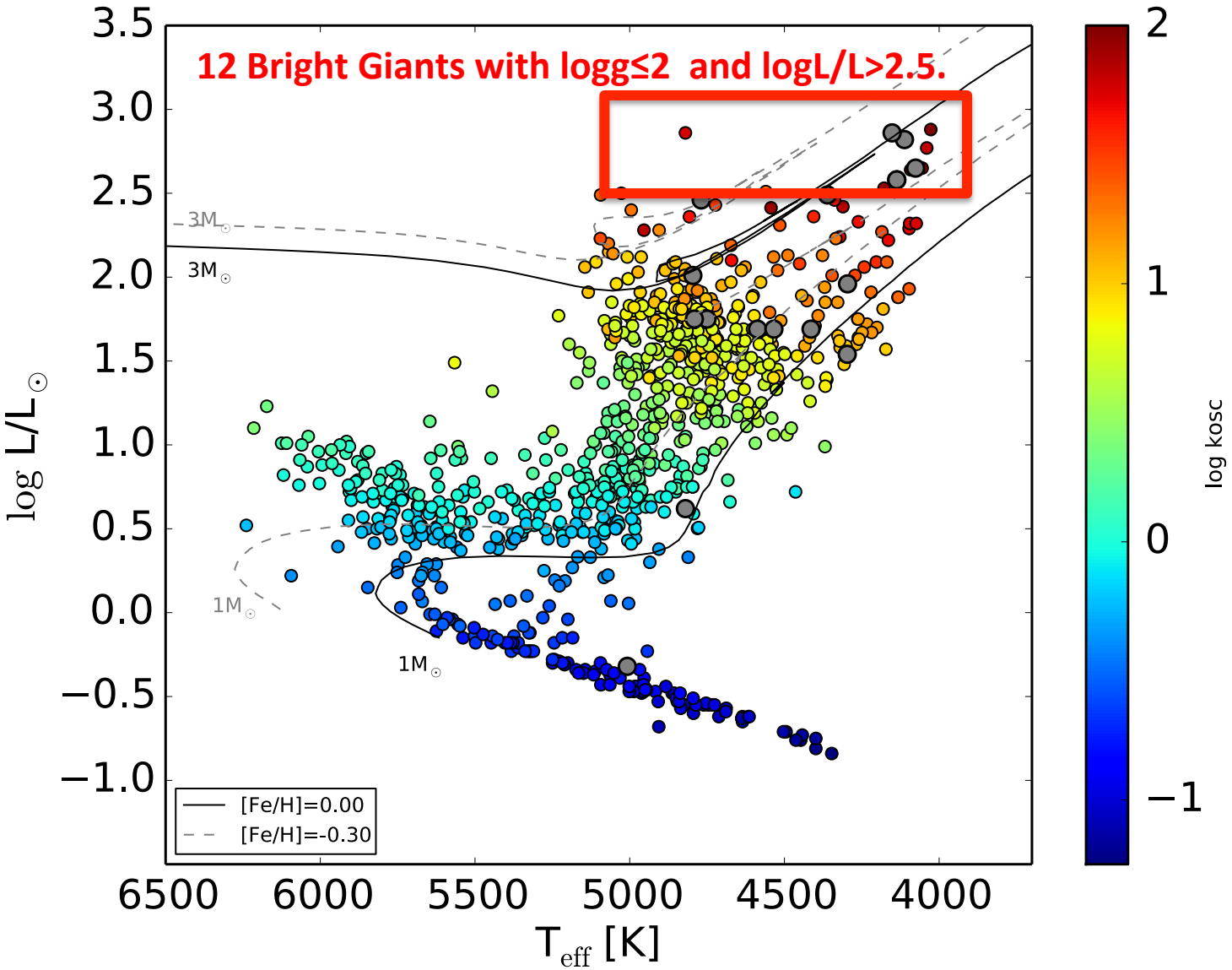
4. No planet occurrence – metallicity relation.
   (Pasquini et al. 2008, Zieliński et al. 2010, Ghezzi et al. 2010, Mortier et al. 2013)

Orbital separations.

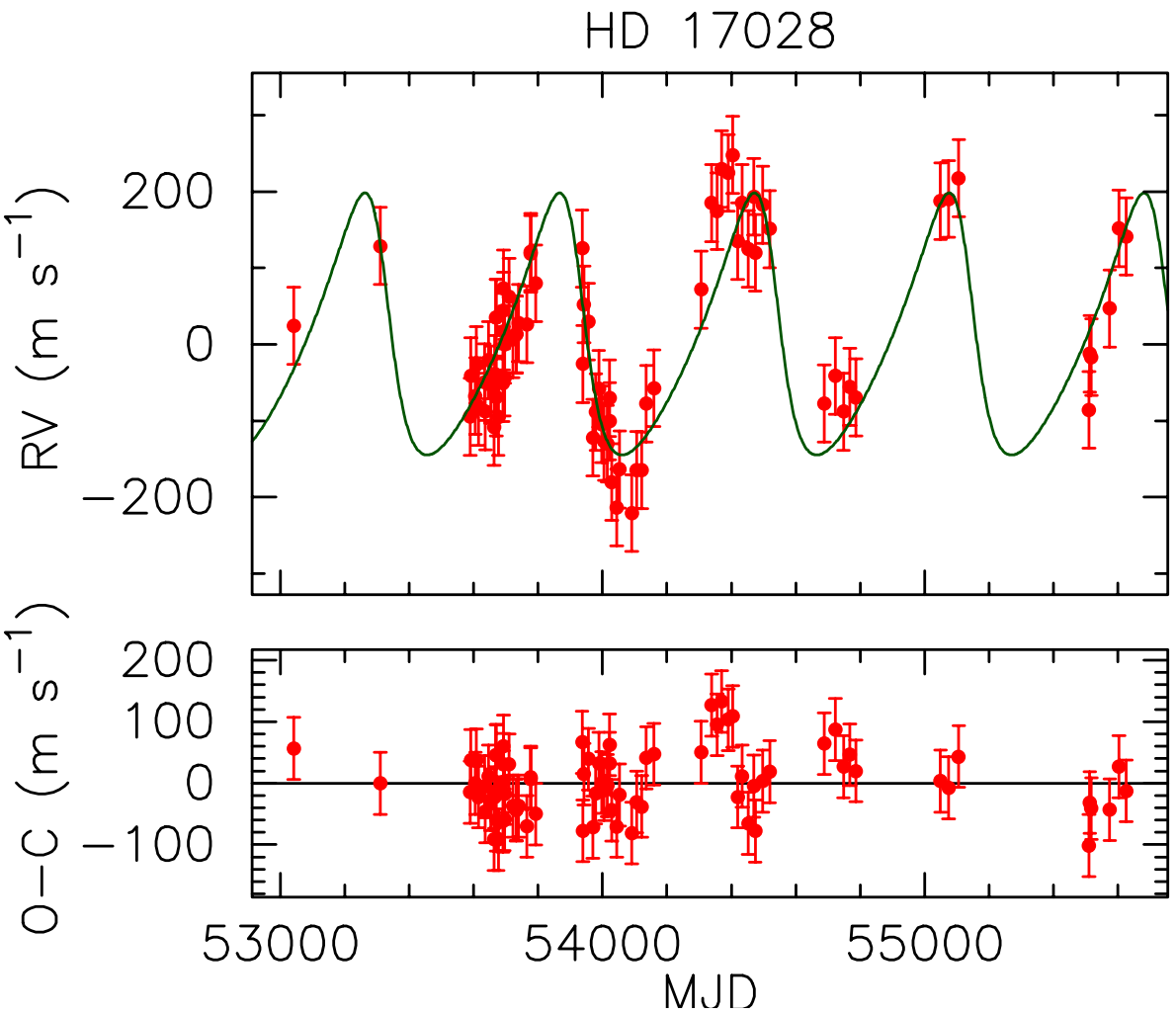


Nowak et al. (2013)

Bright Giants in PTPS.

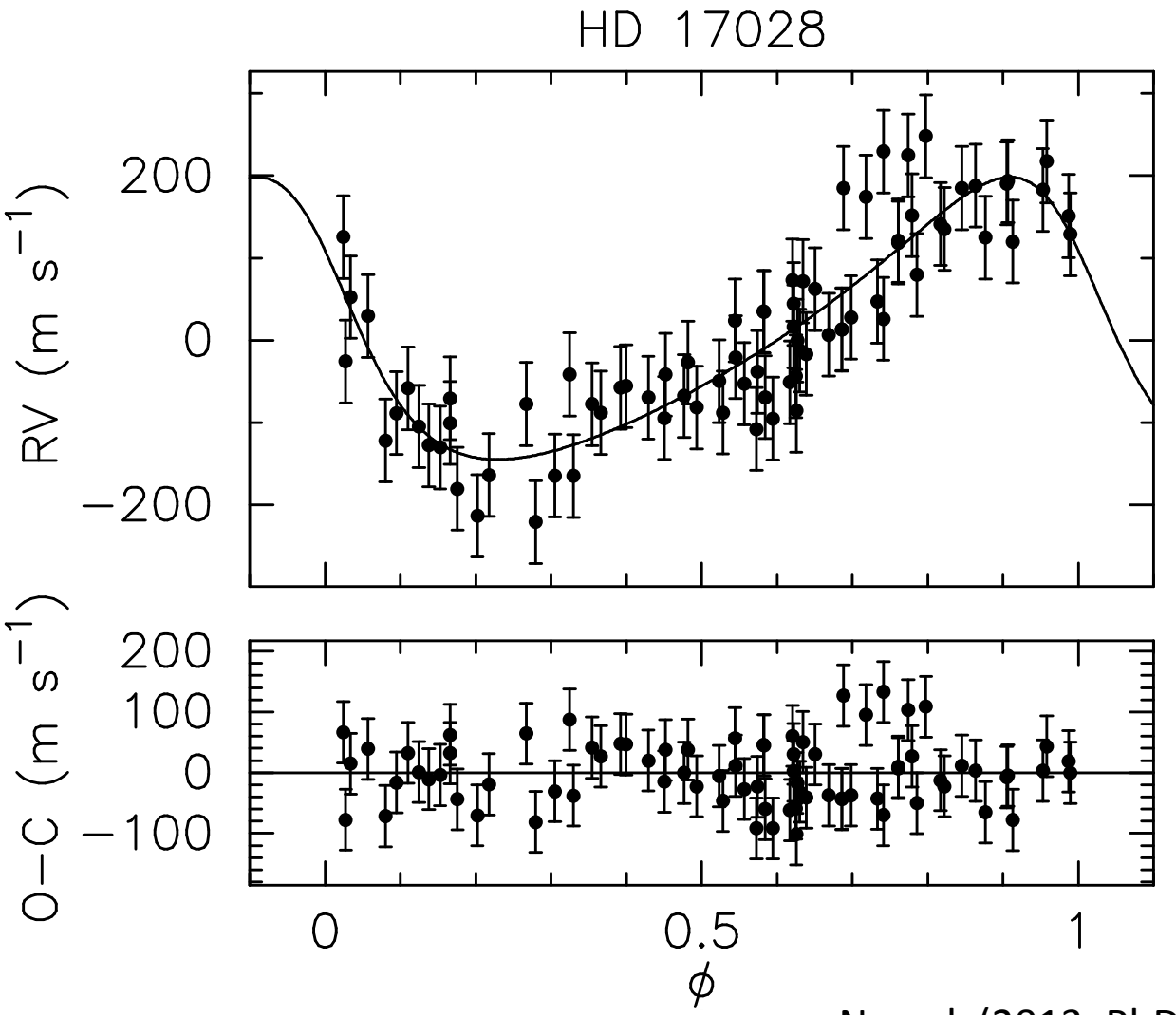


Bright Giants in PTPS.



Nowak (2013, PhD Thesis)

Bright Giants in PTPS.



Nowak (2013, PhD Thesis)

Bright Giants in PTPS.

Star	Teff [K]	logg	[Fe/H]	$\log L/L_\odot$	M $[M_\odot]$	R$[R_\odot]$	logAge	K_{osc} $[ms^{-1}]$
HD 96127	4152±23	2.06±0.09	-0.24±0.1	2.86±0.47	0.9±0.2	52±5	4.5-8.5	188
HD 17028	4112±33	1.9±0.14	-0.28±0.13	2.82±0.8	0.9±0.2	51±8	4.5-8.5	172
PTPS 15	4076±15	1.61±0.08	-0.91±0.09	2.65±0.14	0.8±0.2	43±2	5.6-7.9	131
BD+20 2457	4137±10	1.51±0.05	-1.0±0.07	2.58±0.15	0.8±0.2	38±2	4.1-7.9	111

companion	P [day]	K $[ms^{-1}]$	e	a	m sini $[M_J]$	RV rms $[ms^{-1}]$	
HD 96127 b	647±17	105±11	0.3±0.1	1.4	4.0	50	Gettel et al. (2012)
HD 17028 b	605±6	172±11	0.32±0.05	1.35	6.27	53	Nowak (2013, PhD)
PTPS 15 b	436±3.3	378±26	0.25±0.07	1.05±0.1	12	66	Niedzielski et al. in prep.
BD+20 2457 b BD+20 2457 c	379.6±2 622±10	322±10 160±7	0.15±0.03 0.18±0.06	1.05±0.07 1.5±0.1	11.9 6.9	60 60	Niedzielski et al. (2009)

4 out of 12 Bright Giants in PTPS host low-mass companions

Bright Giants. A wider perspective.

STAR	MSINI mjupiter	A au	PER day	ECC	K m/s	LOGG	MSTAR msun	RSTAR rsun
HD 220074 b	11,19	1,60	672,10	0,14	230,80	1,30	1,20	54,71
HD 208527 b	10,01	2,10	875,50	0,08	155,40	1,60	1,60	41,05
11 UMi b	11,09	1,53	516,22	0,08	189,70	1,60	1,80	44,65
PTPS 15	12,00	1,05	436,00	0,25	378,00	1,60	0,80	43,00
NGC 4349 127 b	9,89	1,68	677,80	0,19	188,00	1,64	1,37	42,37
42 Dra b	3,73	1,17	479,10	0,38	110,50	1,71	0,92	22,04
BD +20 2457 c	6,90	1,46	621,99	0,18	160,03	1,77	1,06	32,96
BD +20 2457 b	11,89	1,05	379,63	0,15	322,35	1,77	1,06	32,96
4 UMa b	7,13	0,88	269,30	0,43	215,55	1,80	1,23	34,61
HD 13189 b	7,12	1,25	471,60	0,27	173,30	1,83	1,17	32,32
HD 17028	6,30	1,35	605,00	0,32	172,00	1,90	0,90	51,00
epsilon CrB b	6,05	1,24	417,90	0,11	129,40	1,94	1,44	29,12
Tau Gem	20,60	1,17	305,50	0,03	350,20	1,96	2,30	26,80
gamma Leo A b	10,37	1,30	428,50	0,14	208,30	1,97	1,57	27,43
HD 96127 b	4,01	1,42	647,30	0,30	104,80	2,06	0,91	23,23

15 Bright Giants with logg≤2 and low-mass companions.

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Bright Giants. A wider perspective.

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8 Brown Dwarfs (out of 15).

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Most if not all within the engulfment zone.

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Planets around Bright Giants. Conclusions.

1. Low-mass companion to Bright Giants are very common.
   In PTPS 4 out of 12 (30%) Bright Giants host low-mass companions.

2. Brown Dwarfs frequently present.
   Of 15 Bright Giants with low-mass companions 8 host Brown Dwarfs
   (see also Mitchell et al. 2013).

3. Majority if not all of low-mass companions to Bright Giants have orbits
   within the engulfment zone. No APN progenitors?