The Penn State - Toruń Planet Search

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PTPS motivation

1. Evolution of planetary systems (distant future of the Solar System).
   - Uniformly studied samples of solar-mass stars at various evolutionary stages

2. Search for planets around stars more massive than the Sun (IMS).
   - Sub-giants, Giants, Red Clump Giants

3. Nature of long-term RV variation of red giants.
   - Spots, pulsations, planets

4. Other (general astrophysics).
   - Lithium abundance, rotation velocity, …

Planets around intermediate-mass stars: why radial velocities?

Imaging:

1. HD 8799 b,c,d,e (Marois et al. 2008)
2. β Pictoris b (Lagrange et al. 2010)
3. Fomalhaut b (Kalas et al. 2008)
4. HIP 78530 b (Lafrenier et al. 2011)

Transits (MS):

1. OGLE2-TR-L9 b (Snellen et al. 2009)
2. Kepler 14 b (Buchhave et al. 2011)
3. KOI-428 b (Santerne et al. 2011)
4. WASP 33 b (Collier Cameron et al. 2010)
5. HAT P-7 b (Hartman et al. 2011)
6. more coming?

Transits (giants):

see Assef et al. (2009), Kane et al (2010). Kepler?

Radial velocities on the MS

1. HD 33654 b (Galland et al. 2005)
2. HD 60532 b (Desort et al. 2008)

Planets around intermediate-mass stars: why radial velocities?

Radial velocities off the MS (HG stars, sub-giants, giants):

- MOPS 2.7m, 9.2m HET (A. Hatzes, W. Cochran 1993 ApJ 413, 339).
- The Lick K-giant Survey (S. Frink et al. 2001 PASP 113, 173 - 179 giants).
- 1.88m Okayama Planet Search (B. Sato et al 2003 ApJ 597, 157 – 180 late G giants).
- 2m TLS- Tautenberg Planet Search (A. Hatzes et al. 2003 ESASP 539, 441 - 62 K giants).
- 1.52m ESO + FEROS (J. Setiawan et al. 2003 A&A 397, 1151 - 80 GK giants).
- 1.8m Bohyunsan & BOES (Kim et al. 2006 A&A 454, 839 – 55 K giants).
- Coralie + 3.6m HARPS (Lovis & Mayor 2007, A&A 115 red giants in clusters).
- Retired A stars and their companions (J. Johnson et al 2007 ApJ 665, 785 - 159 HG stars).
- PTPS.

+50 stars with planets!

Planets around intermediate-mass stars: summary of current results

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

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

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

4. Planet occurrence – metallicity relation?
   NO – Pasquini et al. 2008, Zielinski et al. 2009, Ghezzi et al. 2010
   YES – Quirrenbach et al. 2011 (uniform sample!)

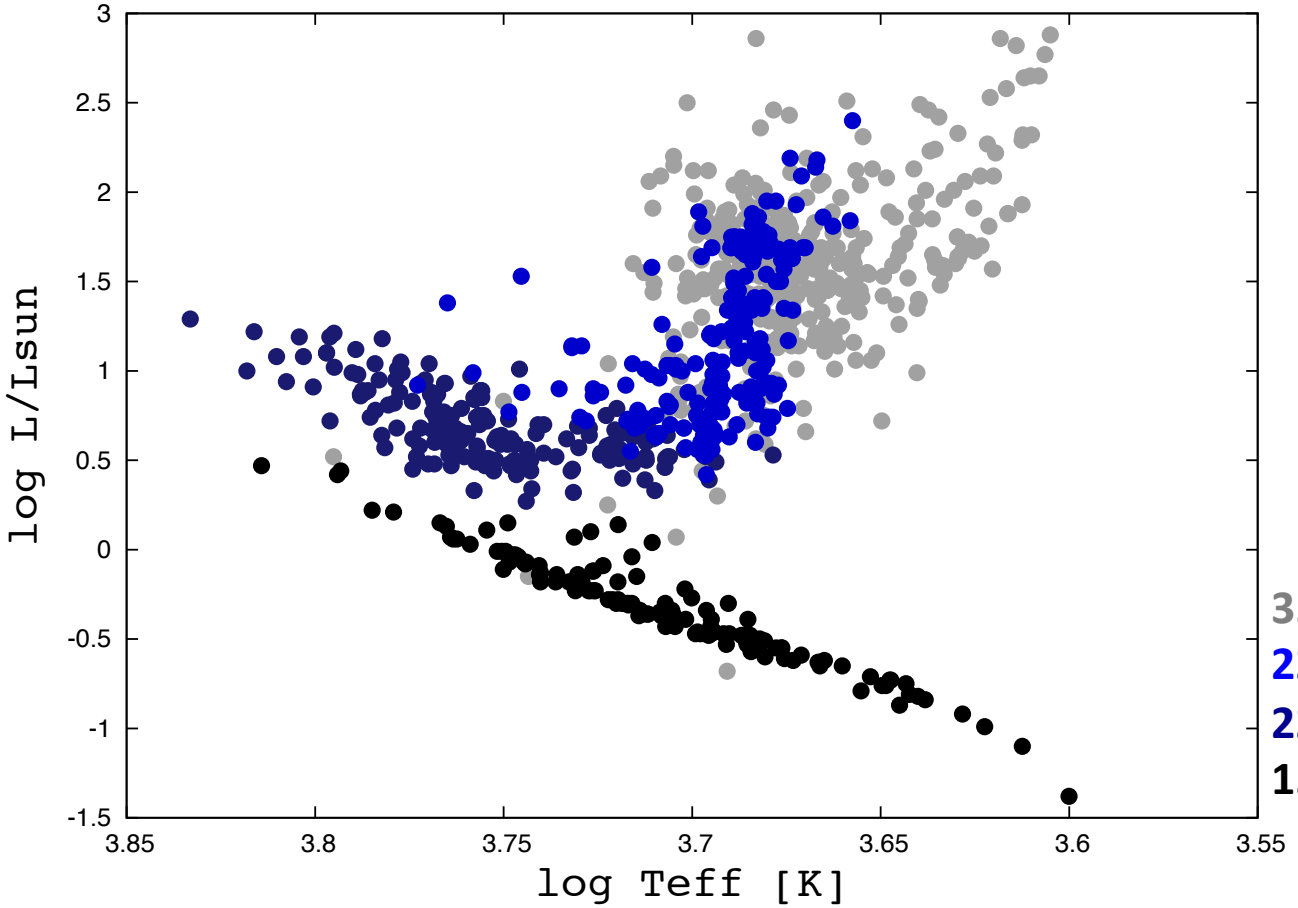
PennState – Toruń Planet Search (PTPS)

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).

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.

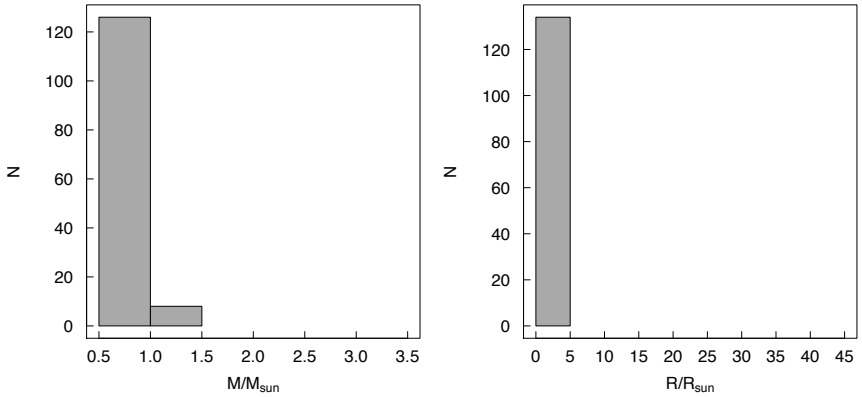
PTPS sample definition



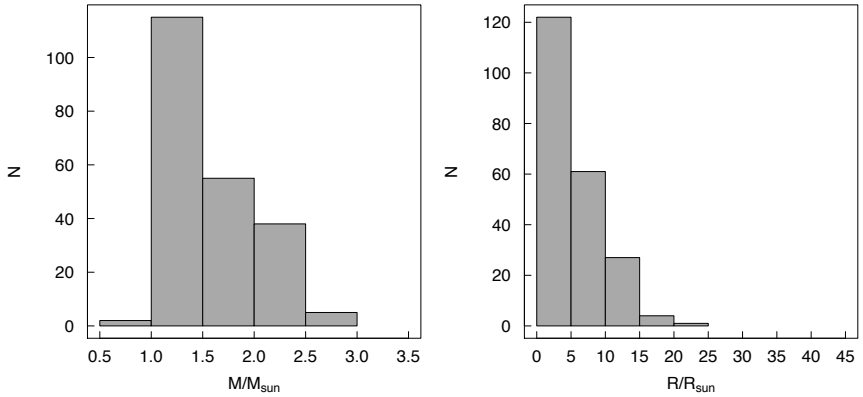
350 Red Clump Giants
225 Giants
225 Sub-giants
150 Dwarfs

PTPS sample definition

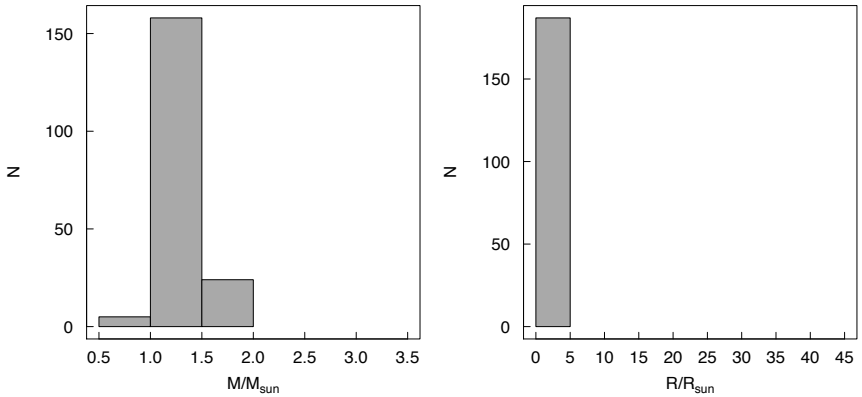
Dwarfs



Giants

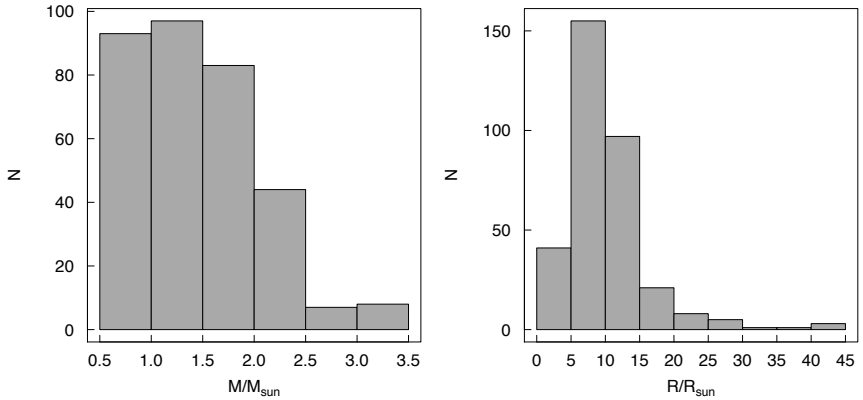


Sub-giants



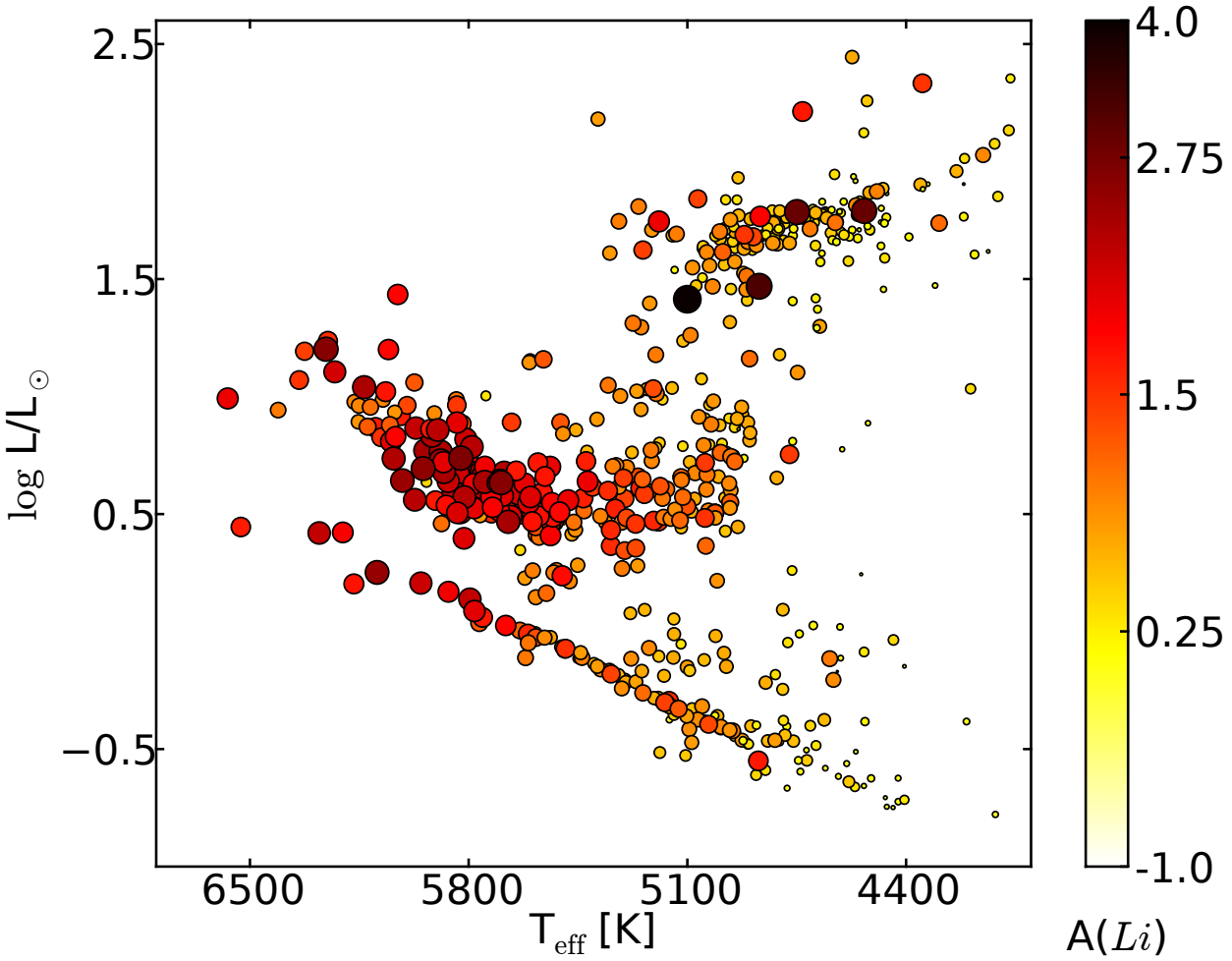
Red Clump Giants

Zieliński et al. POSTER 30.01



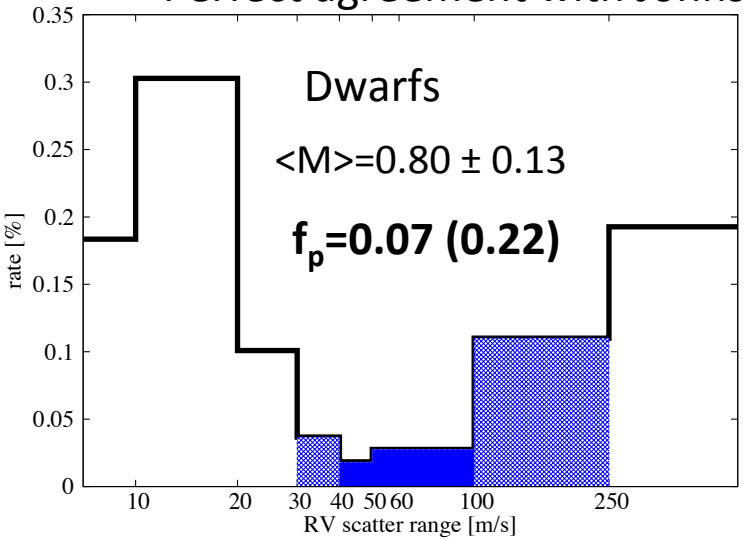
Lithium abundance in PTPS stars

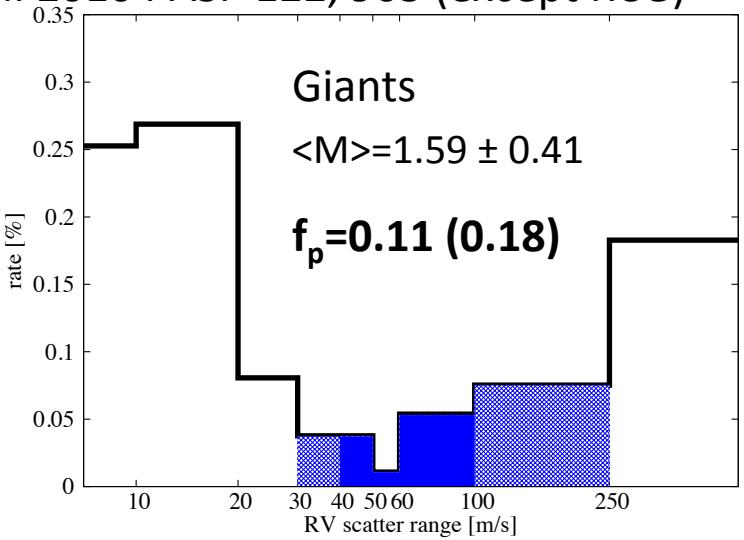
Adamów et al. POSTER 30.02

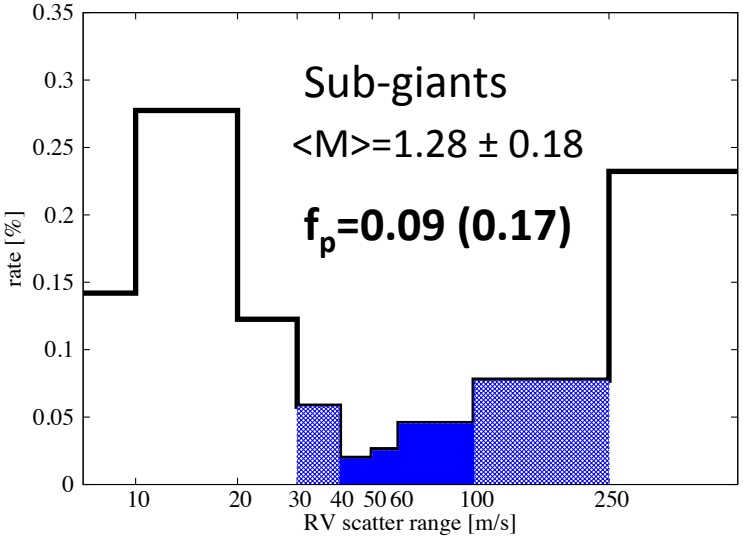


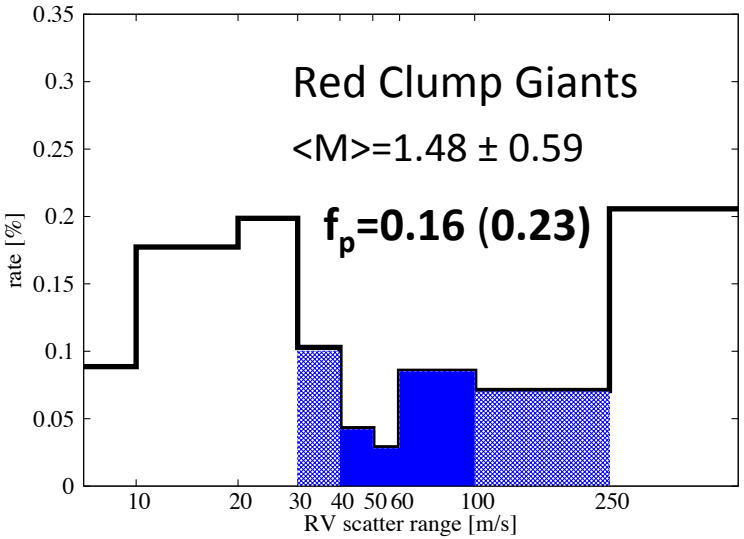
Planet candidates frequency

Perfect agreement with Johnson et al. 2010 PASP 122, 905 (except RCG)

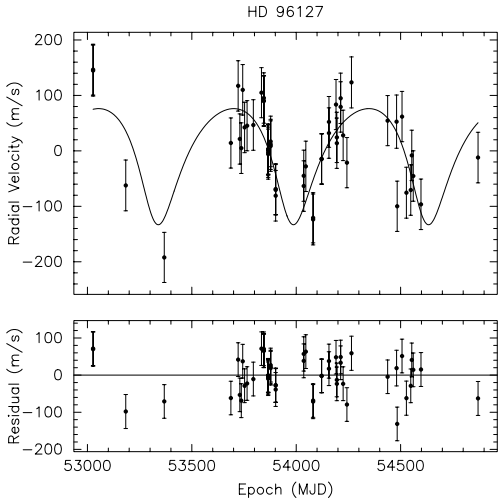


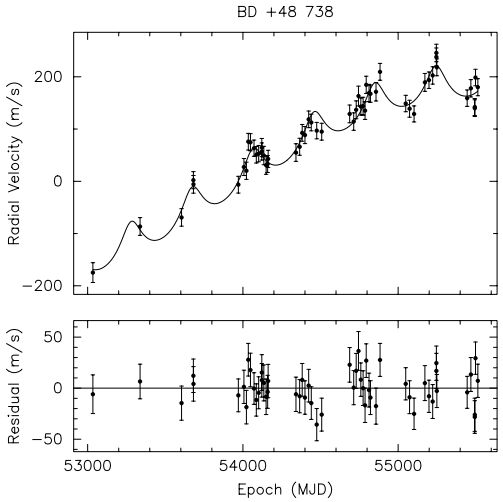


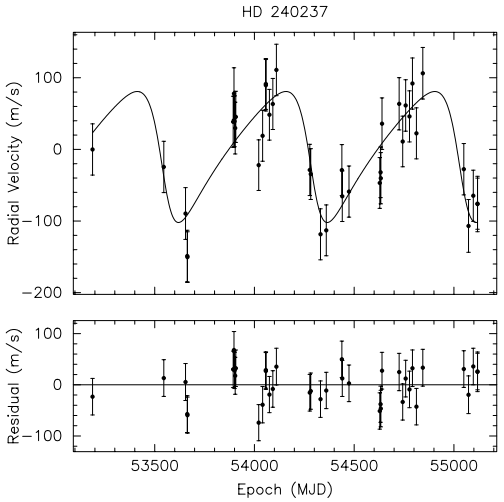




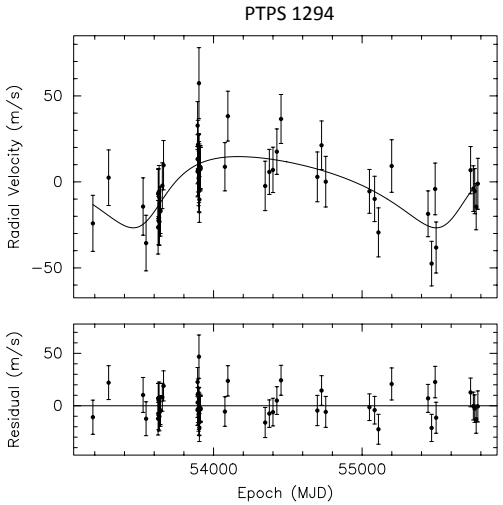
New planets

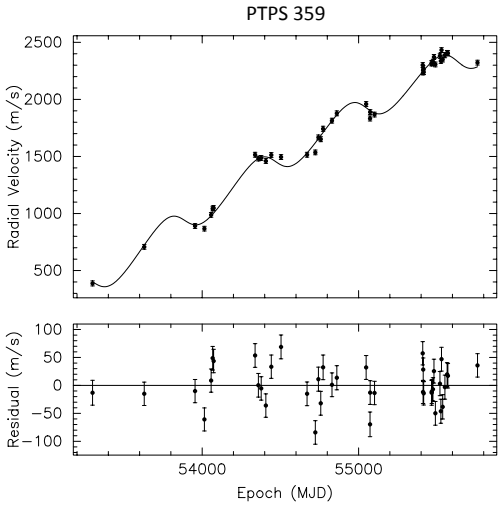






star	M_*	P [d]	Mp [M_J]	e
HD 96127 K2 III	0.91	647	4.0	0.3
BD+48 738 K0 III	0.74	393	0.91	0.2
HD 240237 K2 III	1.69	746	5.3	0.4
PTPS 1294 K III	1.0	2040	1.1	0.37
PTPS 359	0.8	581	4.1	0.14

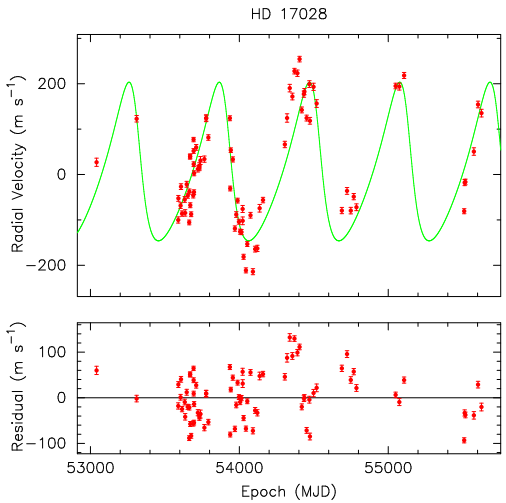


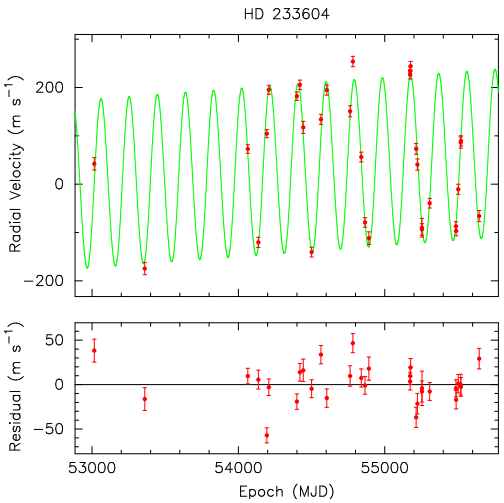


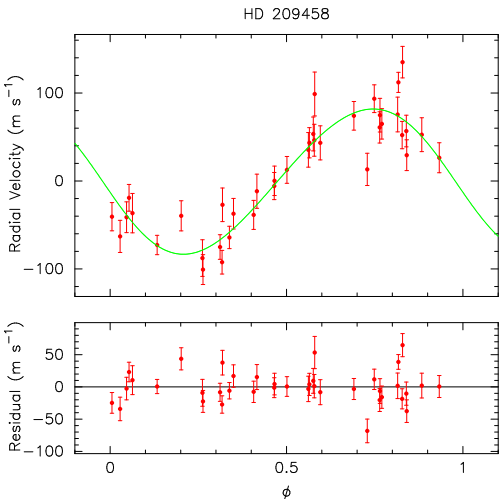
Gettel, Wolszczan, Niedzielski et al. 2011 ApJ submitted; Gettel et al in prep.

New planets

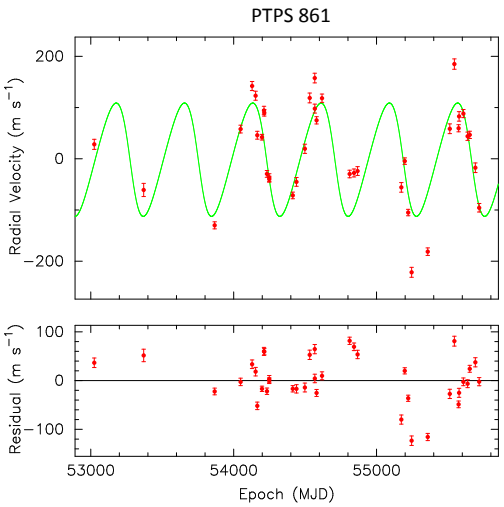
Nowak et al. POSTER 30.04

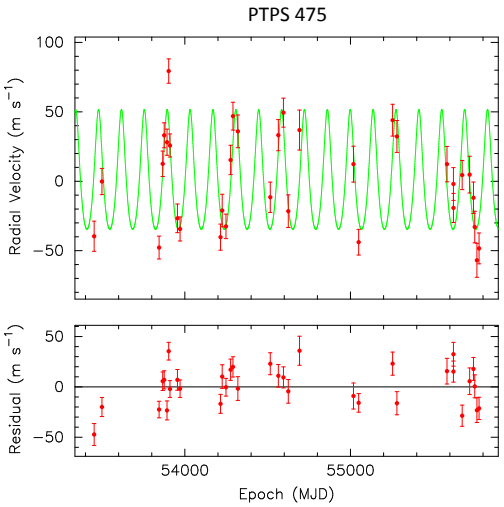






star	M_*	P [d]	Mp [M_J]	e
HD 17028 K0 III	0.9	606	6.4	0.32
HD 233604 K5 III	1.5	192	6.5	0.02
PTPS 861 K0 III	1.2	478	4.5	0.17
PTPS 475 K0 III	1.1	138	1.1	0.2
HD 209458 G0 V	1.1	3.525	0.67	0.06



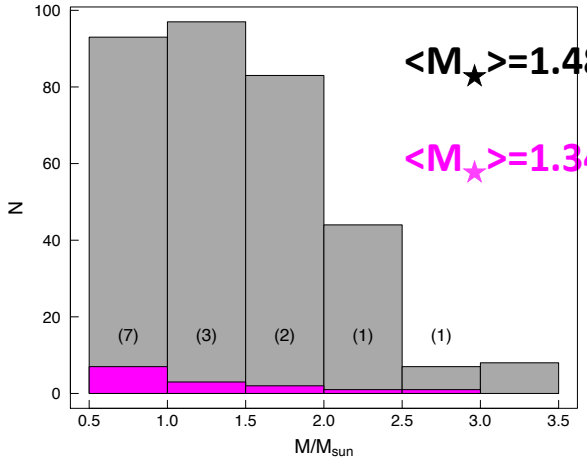


Nowak, Niedzielski, Wolszczan et al. 2011 ApJ submitted; Nowak et al. in prep.

Planets from PTPS

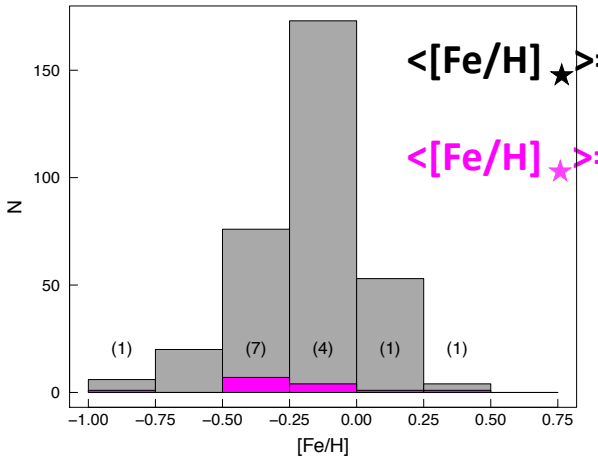
Star	Sp	M	R	[Fe/H]	Mp	A [AU]	P	e
HD 17092 b	K0III	2.3	10.9	0.22	4.6	1.3	360	0.17
HD 102272 b	K2 III	1.9	10.1	-0.26	5.9	0.61	127.6	0.05
HD 102272 c		1.9	10.1	-0.26	2.6	1.57	520	0.68
BD+20 2457 b	K2 II	(2.8)	49	-1.0	21.24	1.45	379.6	0.15
BD+20 2457 c		(2.8)	49	-1.0	12.47	2.01	622	0.18
HD 240210 b	K3 III	0.82	10.5	-0.18	5.3	1.3	537 + P2	0.12
BD+14 4559 b	K2V	0.86	0.95	0.10	1.5	0.8	269 + P2	0.23
HD 240237 b	K2 III	1.69	32	-0.26	5.3	1.9	746	0.4
BD+48 738 b	K0 III	0.74	11	-0.20	0.91	1.0	392.6 + P2	0.2
HD 96127 b	K2 III	0.91	35	-0.24	4.0	1.4	647.2	0.3
PTPS 359 b		0.8	17.3	-0.46	4.1	1.27	581.5 + P2	0.14
PTPS 1294 b	K III	1.0	2.9	-0.04	1.1	3.15	2540.1	0.37
PTPS 1260 b		0.9	13.8	-0.38	3.1	0.73	240	0.29
HD 17028 b	K0 III	0.9	17.8	-0.28	6.4	1.36	606	0.32
HD 233604 b	K5 III	1.5	10.8	-0.36	6.5	0.75	192.3 + P2	0.02
PTPS 861 b	K0 III	1.2	21.9	0.34	4.7	1.27	477.9	0.17
PTPS 475 b	K0 III	1.1	14.7	-0.28	1.4	0.54	138.1	0.2

Planets around Clump Giants



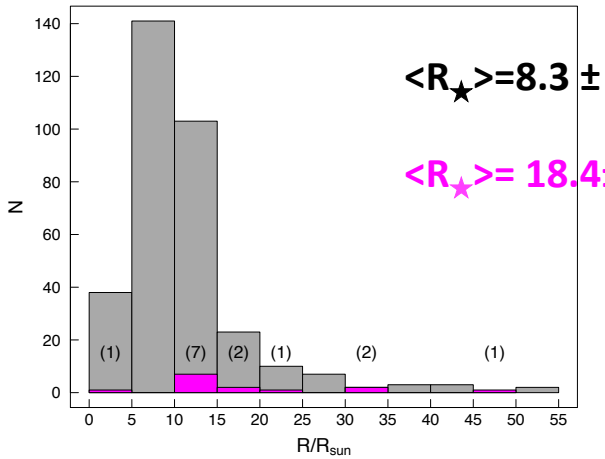
<M$_\star$>=1.48 ± 0.59

<M$_\star$>=1.34 ± 0.60



<[Fe/H]$_\star$>=-0.18 ± 0.22

<[Fe/H]$_\star$>= -0.24± 0.30



<R$_\star$>=8.3 ± 8.9

<R$_\star$>= 18.4± 11.9

N$_\star$=348
N$_p$=14
(approx. 25% of total est. population)

Summary and conclusions

PTPS status:

- Multi-epoch RV for about 800 stars
- Stars currently monitored – about 250
- Expected number of planets – about 115

Results:

- Planets detected – 17 (published – 7, submitted/in preparation – 10)
- Planets in multiple systems – common (7/15)
- Planet candidates frequency in 4 sub-samples varies between 0.07 and 0.16
- Planet candidates frequency proportional to stellar mass ($0.8<M_{\star}<1.6$)
- RCG sample:
  - stars with planets less massive than average
  - stars with planets less metal abundant than average