Study of low mass stars in eclipsing binary systems by Radial Velocity with PARAS

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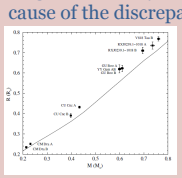
Abstract: Single-lined eclipsing binary systems via RV technique give us a unique opportunity to study the sub-stellar candidates and low mass end of the main sequence as companions to brighter primaries. Despite a large number of low mass stars present in our galaxy, masses and radii for these stars are still not determined at higher accuracies, primarily due to their fainter magnitudes in visible band. Radii for stars less massive than Sun are known to be 10% smaller theoretically than observed and temperatures are 5% higher.
A high-resolution echelle spectrograph, Physical Research Laboratory Advanced Radial-velocity Abu-sky Search (PARAS) working at a resolution (R) of 67000, coupled with the Physical Research Laboratory Mt. Abu, India 1.2m telescope is used for making observations of primary stars of F, G and K spectral type. We report discovery of two M dwarfs, a M7 and a M3.5 dwarf across two primary stars, K1 and F type stars respectively in eclipsing binary system. Both the targets are from the SuperWasp photometry catalogue. The period of one of the sources, SWASP-PARAS1 was underestimated by SuperWasp photometry which has been correctly updated by PARAS RV follow-up. The techniques and results are presented in the poster.

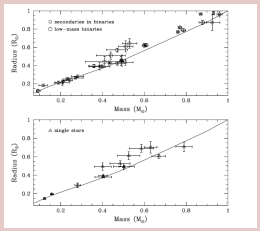
Motivation

•Low Massive End of stars consistently report radii higher than the ones theoretically computed

• Stellar activity and increased magnetic activity reported as a cause of the discrepancy



Ref: Ribas 2006, ASPC



Theoretical Baraffe Model of 1 Gyr and solar metallicity

Ref: Lopez-Morales, ApJ,2007

We need more number of samples with varying masses and different metallicities to help evaluate this discrepancy and eliminate any observational biases.

SWASP-PARAS 1 Target

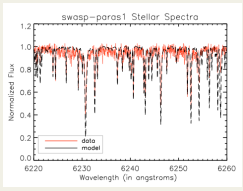
◆Super Wasp observed millions of stars between 8 and 15 magnitude from La Palma, Canary Islands in the period May-Sep 2004

◆It has shortlisted 100 s of stars as possible exoplanet candidates

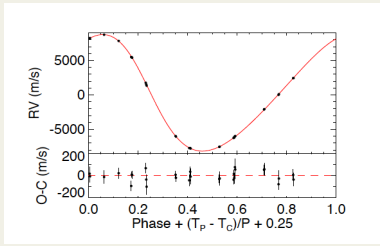
Period	4.24days
Transit depth	28.1mmag
Transit duration	2.25h
#transits	6
R_{star}	0.76$R_{\odot}$
$R_{secondary}$	0.1 $R_{\odot}$

Properties of host star known	Values
Spectral Type	K
Visual Magnitude	10.5

Ref: Christian D.J. et al. 2007, MNRAS



Observed spectra for SWASP-PARAS1 (in red solid line) overlplotted by best-fit model (in black dashed line).



SWASP-PARAS1 target Radial Velocity vs Phase plot

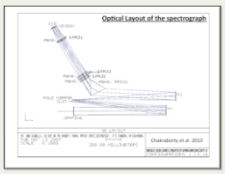
Spectral type	K2
V_{mag}	10.7
σ	25 m/s
K	8.453 km/s
Period	16.94 days (CORRECT P)
e	0.16
a	0.122 AU
V sini	3 km/sec
T_{eff}	**5125 +/- 50 K**
Fe/H	**0.1 +/- 0.1**
log (g)	**4.65 +/- 0.1**
M_1 (primary)	**0.86 +/- 0.02 M_{sun}**
M_2 (secondary)	**0.096 +/- 0.02 M_{sun}**
R_1 (Primary)	**0.75 +/- 0.03 R_{sun}**
R_2 (secondary)	**0.076 +/- 0.03 R_{sun}**

Spectral Properties obtained from PARAS spectra for SWASP-PARAS1

Instrument

At PRL, we have initiated an Exoplanet search and Eclipsing Binary program using precise RV technique. The program is called PARAS (PRL Advanced Radial-velocity Abu-sky Search) and consists of a high resolution, optical fiber-fed, cross-dispersed, Echelle spectrograph which is attached to the PRL 1.2m telescope at Gurushikhar, Mt Abu.

(Ref: Chakraborty, A. et al. 2014, PASP)



Optical Layout of the Spectrograph

Spectrograph Parameters	Characteristics
Resolution	67000
Spectral Coverage	3700-8400 A°
Calibration Source	Th-Ar lamp
Pupil Diameter	102mm
Echelle Grating	Dimension of 420.5mm x 220.5mm x 74mm; Useful ruled area 415mm x 215mm, Blaze angle 75°, used in Littrow configuration
Cross Disperser	Prism, OHARA, PBM8Y glass, apex angle 65.6°
Camera Lens System	F/5 focal length. Average transmission through lens system (total six surfaces) ~95%
CCD Detector	E2V, 4096x4096,15μ pixel
Fiber Optics	Multi mode fiber, core 50μ, length 20m. Star fiber and calibration fiber form a bundle on the spectrograph side such that these two fibers are separated by 180μ
Efficiency	5-8%
Temperature Stability	0.03°C ΔT
Pressure Stability	0.08mbar over 12hours

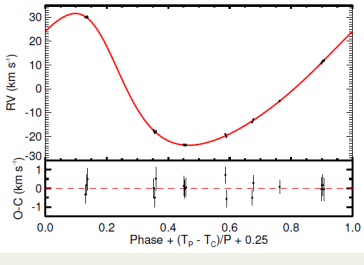
Characteristics of PARAS instrument

SWASP-PARAS 2 Target

Property	Value
Period	4.400 days
Transit depth	0.0135 mag
Transit duration	2.64 hours
Radius of Primary	1.24 Rsun
Radius of secondary	0.125 Rsun

Primary is a F8/9 type star

Ref: Street et al. 2007, MNRAS



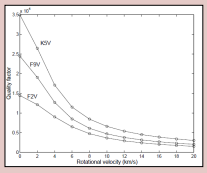
SWASP-PARAS2 target Radial Velocity vs Phase plot

Fields	Values from PARAS	Values given by SWASP
V_{mag}		9.5
σ	30 m/s	
K	27.670 km/ sec	--
Period	4.3942 days	4.4 day
e	0.247	--
a	0.0592 A.U.	--
V sini	10 km/sec	
M_1 (primary)	**1.2 +/- 0.1 M_{sun}**	--
M_2 (secondary)	**0.27 +/- 0.03 M_{su}**	
R_1 (Primary)		**1.24 R_{sun}**
*R_2 (secondary)	**0.3 R_{sun} (from Baraffe models)**	**0.125 R_{sun} ??**

Spectral Properties obtained from PARAS spectra for SWASP-PARAS2

Radial Velocity Precision

Quality factor vs Rotational Velocity



Ref: Bouchy et al 2000 , A&A

For G and K type stars & R ~ 67000

$$\sigma_{RV} \propto S^{-0.5} \cdot \lambda\lambda^{-0.5} \cdot R^{-1.5}.$$

Visual Magnitude range	PARAS RV precision
mv <=6.8	1-2 m/s
mv ~ 7 - 8	3 to 7 m/s
mv ~ 8 - 10	7 to 10 m/s
mv ~ 10	12-15 m/s
mv~ 10-11	15 to 25 m/s

Portion of raw image of a star (Tau Ceti)-Th spectra

Candidate Selection

RA and Dec: Observable from Mt Abu
Spectral Type: F, G and K
Magnitude: Brighter than V~10 mag
Transit Depth: 12 mmag to 35 mmag
Orbital Period: Few days

Photometry catalogues of **STEREO, SUPERWASP, KEPLER, COROT** and **ASAS** were searched...

•SuperWasp is a UK based extra solar planet detection program

•It consists of of two robotic observatories one which is located on the island of La Palma and other is located at the site of the South African Astronomical Observatory (SAAO) .

•The observatories each consist of eight wide-angle cameras with 7.8 ° x 7.8 FoV that simultaneously monitor the sky for planetary transit events

Reference: http://www.superwasp.org/

Conclusion

The RV measurements along with the spectral property determination has led to successful discovery of two M dwarfs. One a **very low mass M7 dwarf around a K1 dwarf in an eclipsing binary system**; second being a **M3.5 dwarf around a F9 type star** in an eclipsing binary system. We find no evidence of a higher observed value of radius than predicted by the theoretical models for both the M dwarfs in this case.

Acknowledgements

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