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WTS Difference Imaging

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Outline

Introduction

- Difference Imaging photometry (DI)

DI light curve analysis

- Comparison with aperture photometry
- Correction of DI light curves error bars
- Detection algorithm & Selection criteria (V-shape parameter)
- Presentation of Candidates

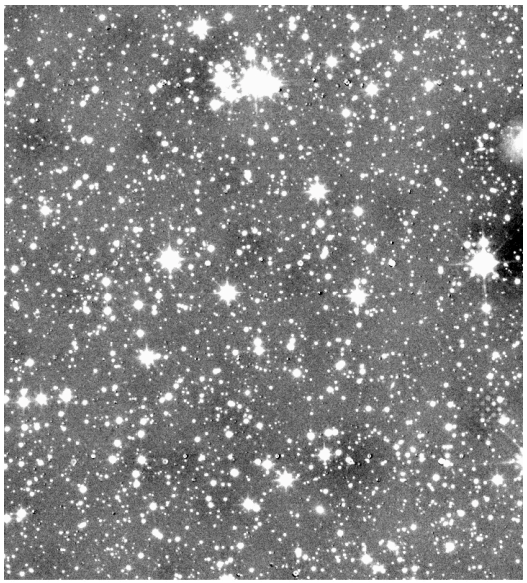
Other applications of DI light curves

Conclusions

Difference Imaging

The difference imaging represents one of the most successful method to obtain high precision light curves in crowded fields (Tomaney & Crotts 1996 and Alard & Lupton 1998).

19hr field



Single Image

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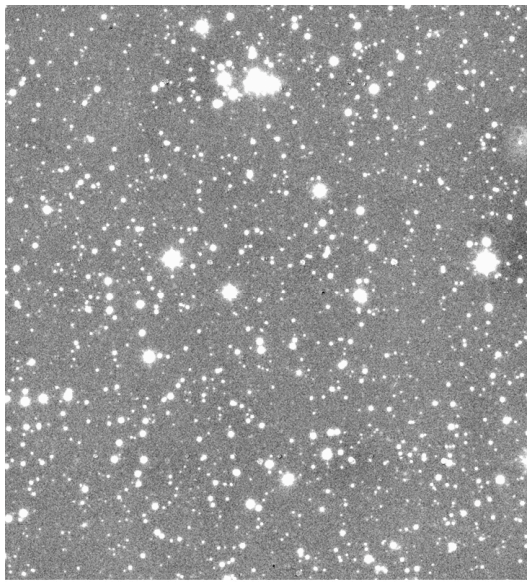

Convolved reference image

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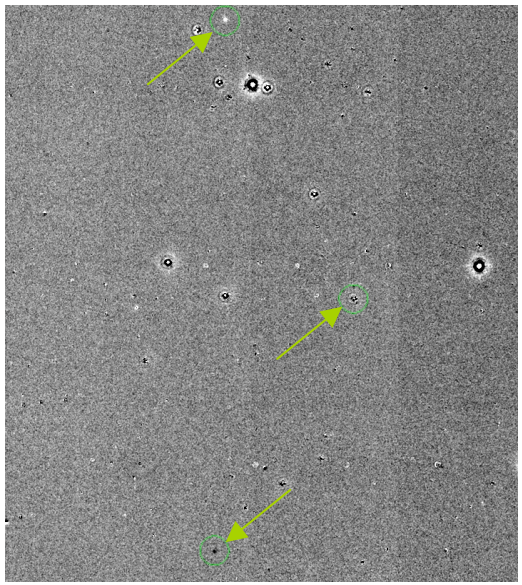
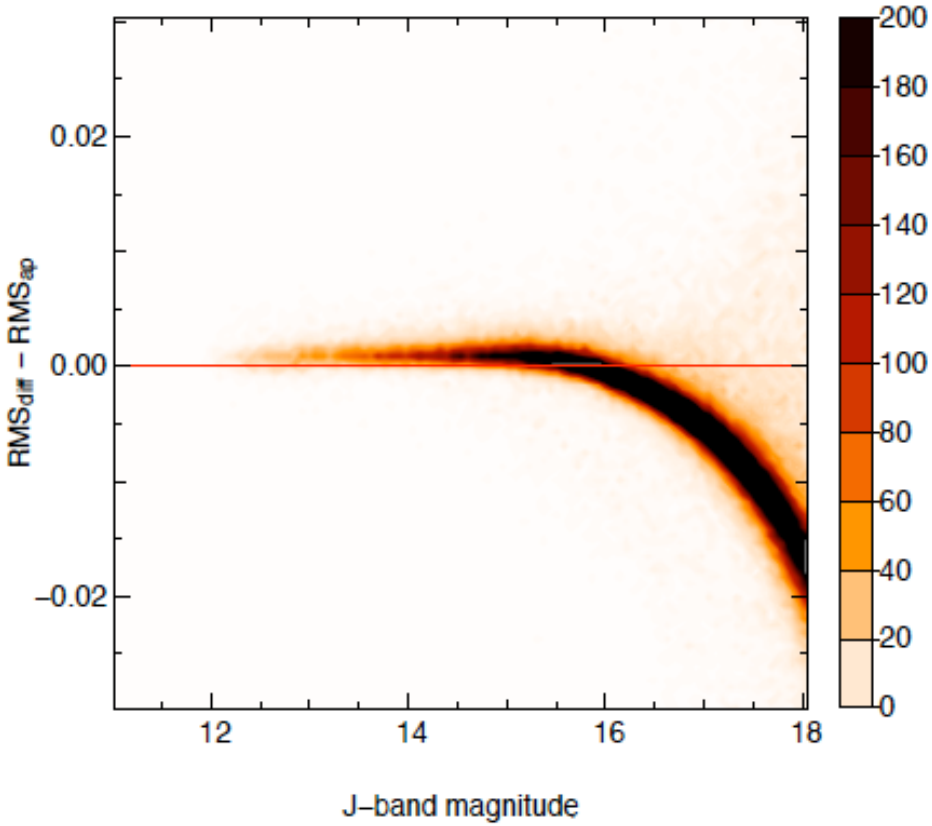


Difference imaging

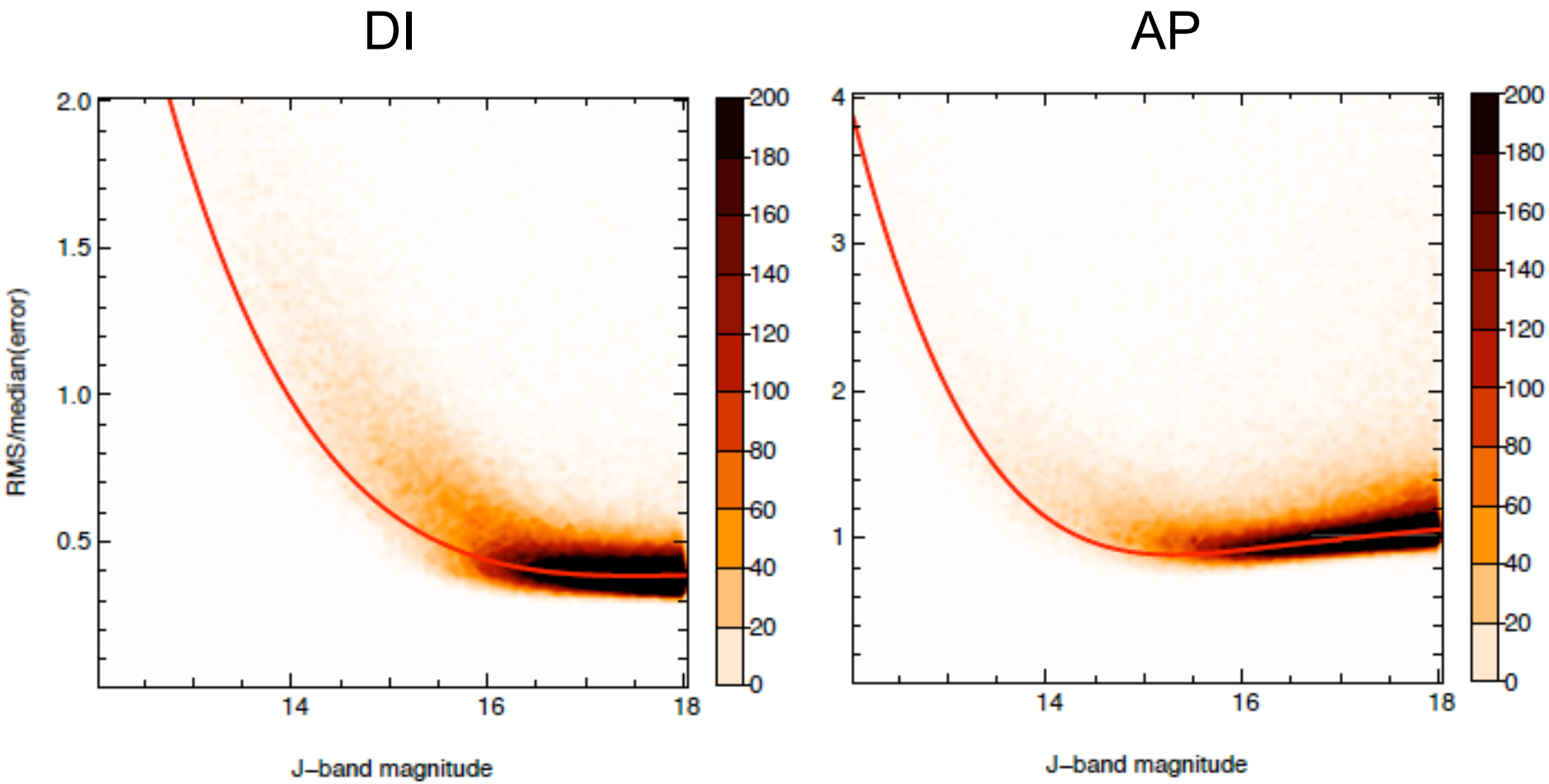
Does difference imaging provide better photometric precision than aperture photometry?

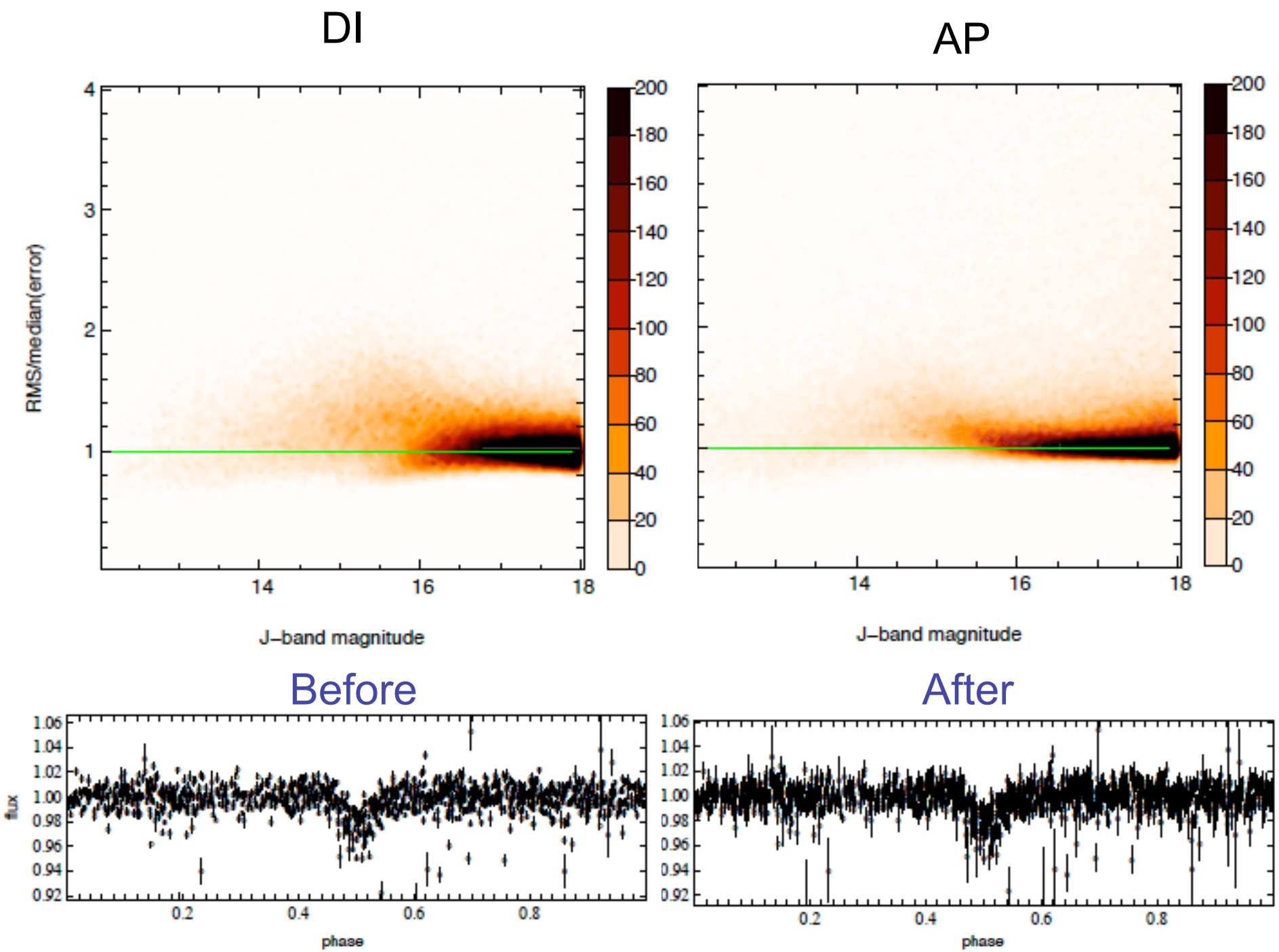
Quantitative comparison between DI and AP light curves
- Removed systematic effects (*sysrem*)



DI light curves provides an improvement for objects with J >16.5

Error bars underestimated

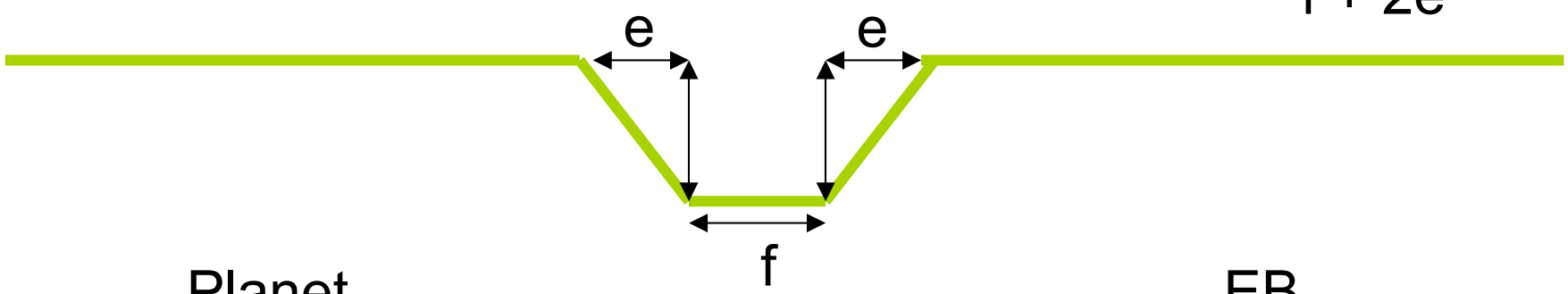



DI
AP
RMS/median(error)
J–band magnitude
J–band magnitude
Before
After
flux
phase
phase

Transit detection algorithm

A modified version of the box-fitting least squares algorithm (Kovács et al 2002), which includes a trapezoidal re-fitting of the box-shaped eclipse found by BLS.

Modifications
- New estimate of the transit depth
- V-shape parameter $\longrightarrow V = \dfrac{2e}{f + 2e}$



Planet

$e=0 \Rightarrow V \sim 0$

EB

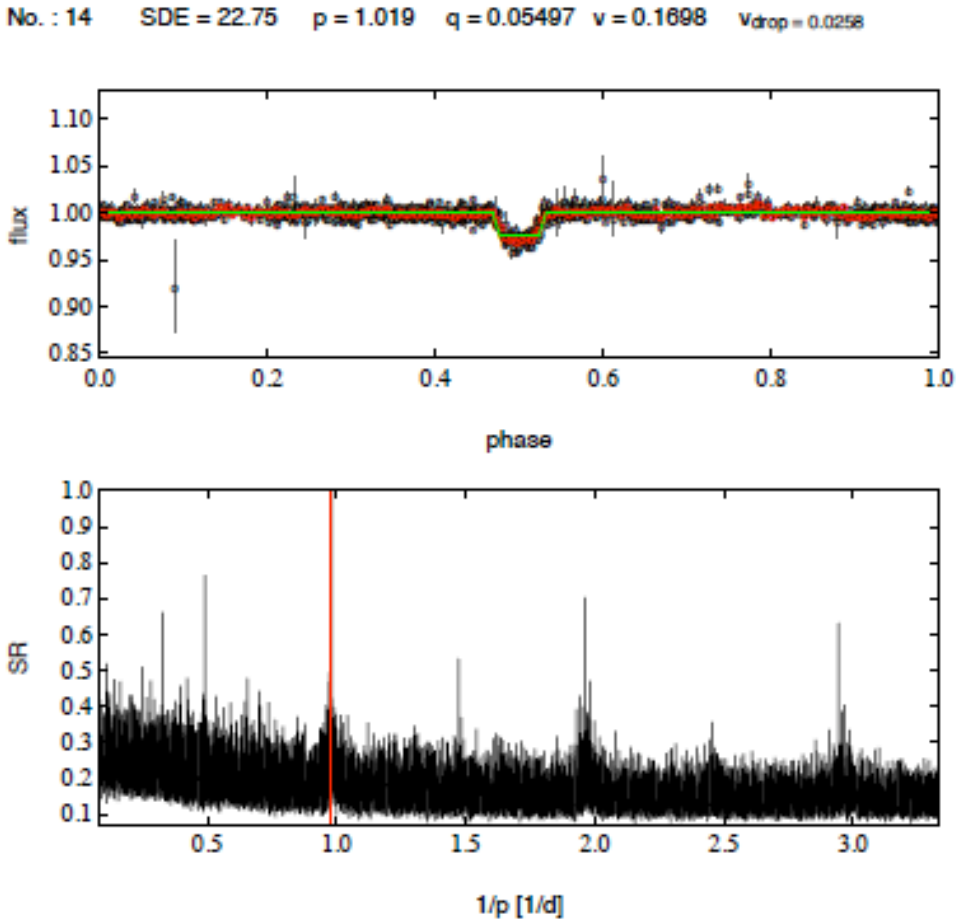
$f = 0 \Rightarrow V = 1$

Selection criteria

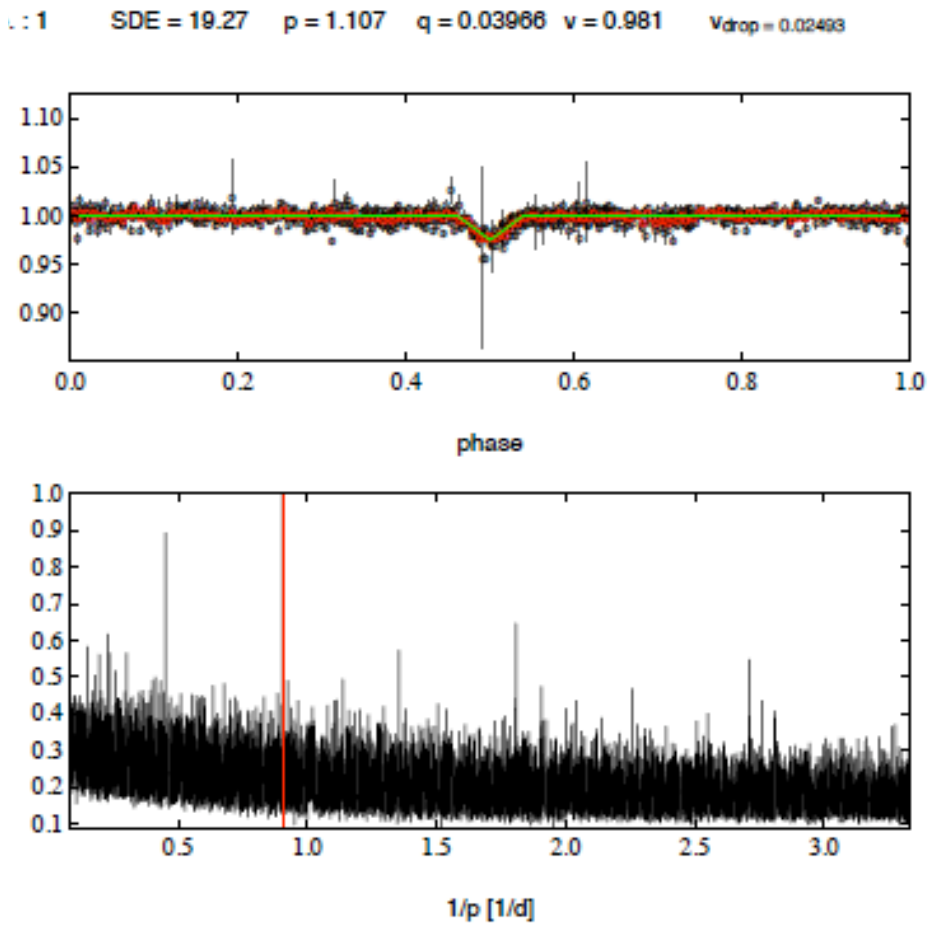
- Exclude objects J-band ≥ 18
- Excluded periods ~ 0.5 / 1 / 2 / 3 days
- Drop ≤ 0.1
- S/N ≥ 20
- S/N-S/N_removed ≥ 8*
- No. transit point ≥ 20
- $\chi^2 \leq 3.5$
- V-shape ≤ 0.75*

Examples of the V-shape parameter

Planet (WTS2b)

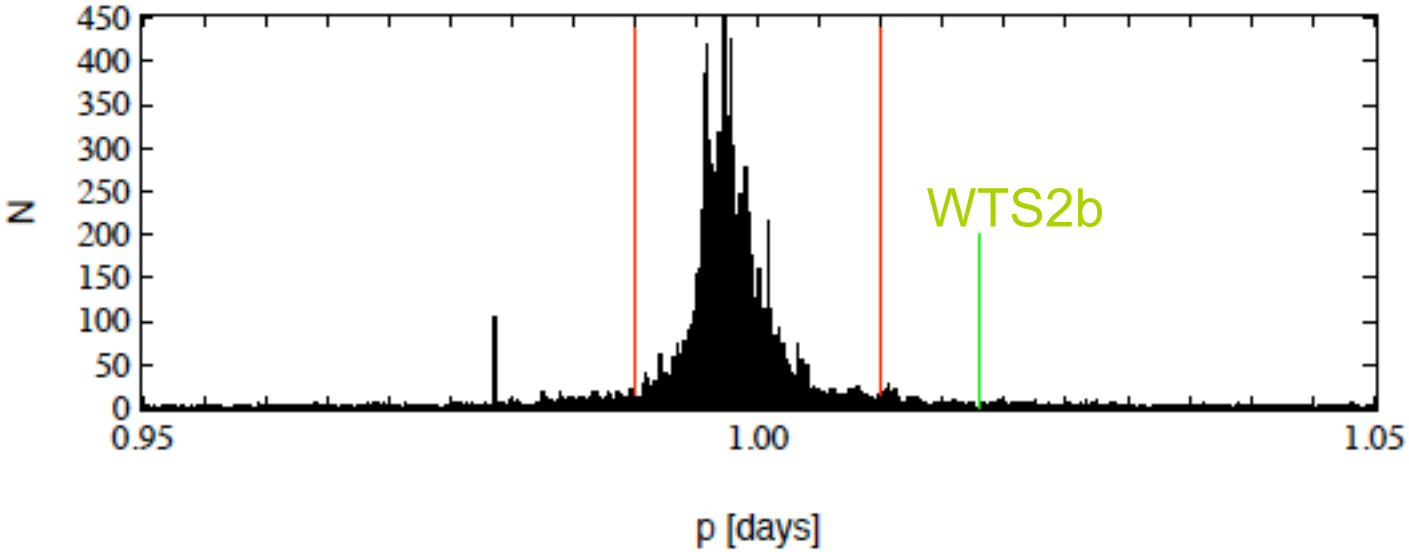


EB



Aliases: ~ 0.5/1/2/3 days

((period-alias)^2)^1/2 > 0.015



Results

We apply our detection algorithm to AP and DI light curves. After using the selection criteria, the number of objects was reduced considerably. This facilitates a visual inspection of the detections.

Aperture photometry

Criterion	Remaining objects	Removed	%
$J \leq 18$	127389	311914	87.78
Removed alias period	91422	32967	25.87
$S/N > 20$	5468	85954	94.01
$S/N\text{-}S/N_{rem} > 8$	2979	2489	45.52
Transit points > 20	623	2356	79.09
$\chi^2 < 3.5$	142	481	77.70
$V_{shape} < 0.75$	103	39	27.46
depth ≤ 10 %	38	65	63.10

Difference imaging

Criterion	Remaining objects	Removed	%
$J \leq 18$	112803	362445	76.26
Removed alias period	80718	32085	28.44
$S/N > 20$	6412	74306	92.05
$S/N\text{-}S/N_{rem} > 8$	3632	2780	43.35
Transit points > 20	559	3073	84.60
$\chi^2 < 3.5$	157	402	71.91
$V_{shape} < 0.75$	88	69	43.94
depth ≤ 10 %	52	36	40.90

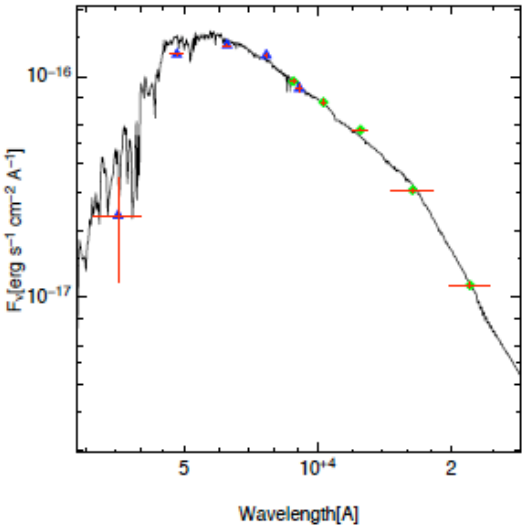
- ~500 000 objects ⟶ 90 detections(AP & DI)
- Two confirmed planet are in the final sample.
- Visual inspection: 12 candidates that were not reported before.

We carry out a detailed analysis to the 12 candidates:

1.- Characterization of the host star (SED analysis, VOSA)

2.- Transit fit J-band light curves (Mandel & Agol 2002)

3.- Secondary eclipse fit for the eclipsing binary scenario.

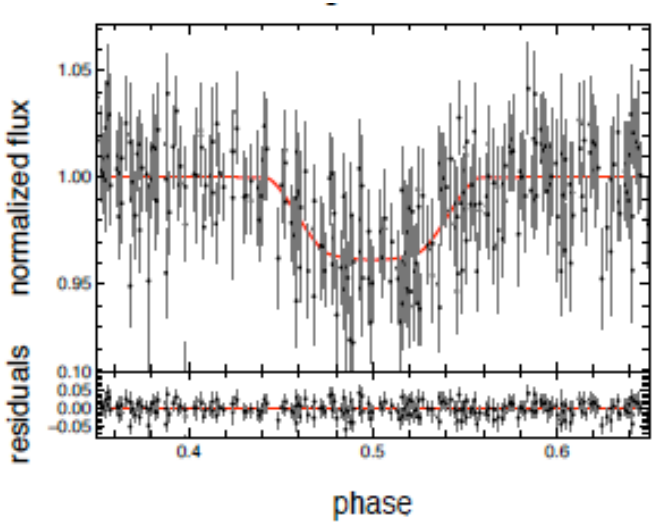


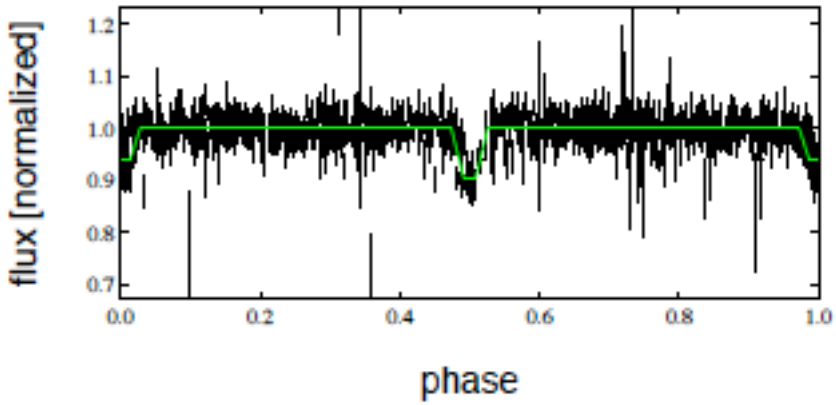
T_{eff}
log g } Spectral Type

R_*

R_{planet}

EB-test(χ^2-comparison)



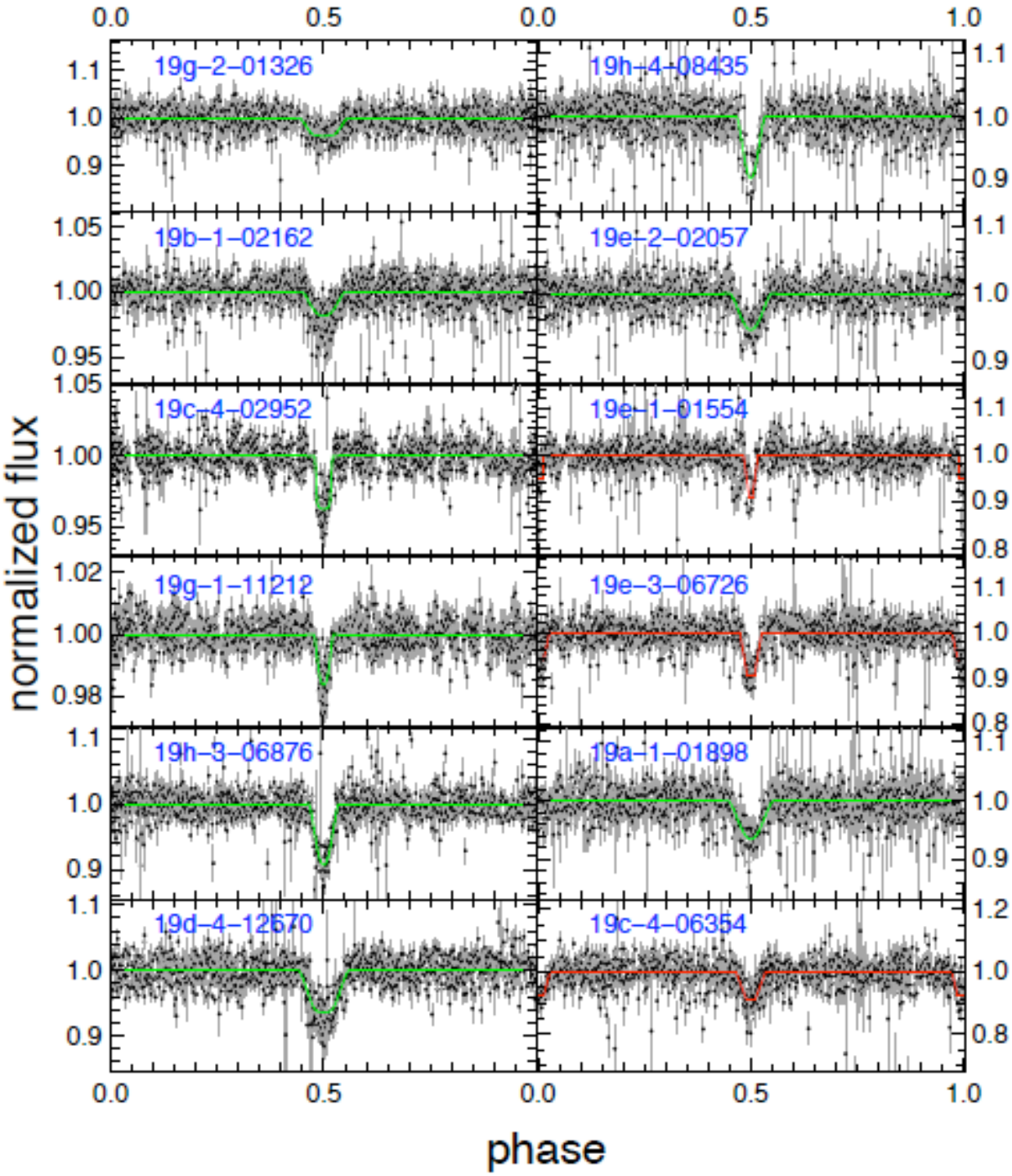


Priority list

Object	Period(days)	$i(^o)$	$R_{planet}(R_{jup})$	$R_{min}(R_{jup})$	$R_{max}(R_{jup})$	T_{eff}(K)	ST	J_mag	Class
19g-2-01326	0.428	75.920	1.51	1.44	1.55	5000	K1	17.04	P1
19b-1-02162	0.598	69.413	1.74	1.59	2.30	5750	G5	15.93	P2
19c-4-02952	3.429	89.984	2.20	2.18	2.21	6750	F3	15.83	P2
19g-1-11212	2.773	80.222	2.31	1.99	3.50	6500	F5	14.01	P2
19h-3-06876	1.190	81.441	2.45	2.29	4.65	4000	K8	16.73	P2
19d-4-12670	0.576	76.107	2.34	2.24	2.45	5000	K1	17.10	P2
19h-4-08435	0.709	78.789	2.61	1.92	5.02	4000	K8	17.51	P2
19e-2-02057	0.665	69.036	4.55	2.04	11.34	5250	K0	17.28	P2
19e-1-01554	1.483	83.118	2.15	1.98	4.18	4000	K8	17.46	B
19e-3-06726	0.926	80.340	2.48	2.37	4.77	4000	K8	17.48	B
19a-1-01898*	0.581	66.751	4.58	2.16	9.97	3750	M1	17.62	B
19c-4-06354*	0.382	65.951	3.36	2.35	6.99	3750	M1	17.97	B

- Only the target 19g-2-01326 is classified as a high priority planet candidate P1. We propose this object for follow-up in the near future.

- There are two candidates orbiting M-dwarf stars with J_mag > 17. Therefore, we confirm the result presented in Kóvacs et al. (2012) about the sensitivity of the WTS for giant planets around M-dwarfs.

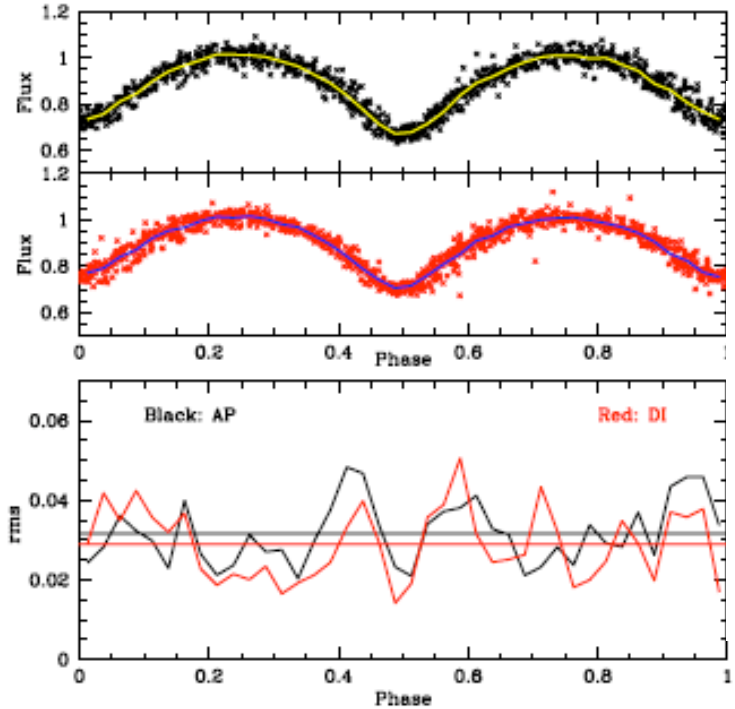


Quick overview of the candidates

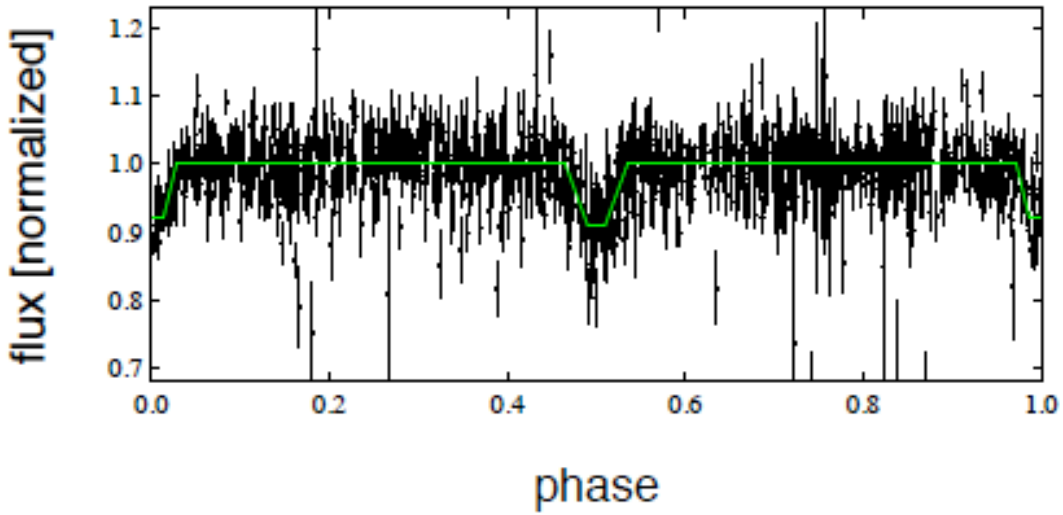
Other applications of WTS DI light curves

- Extremely-short period eclipsing binaries (Nefs et al. 2012)
- M-dwarf eclipsing binary systems (Birkby et al 2012)

19d-4-05861, P≈0.272days, J-band=17.14



19c4-06354, P≈0766days, J-band=17.97



Conclusions

- Aperture photometry light curves give excellent results for stars with J_mag < 16.5, however difference imaging light curves achieve a significant improvement for objects with magnitudes above this limit.
- We propose a clear criteria selection based on the results of our transit detection algorithm. Our selection criteria is able to reduce the number of detections considerably and provide a concrete list of candidates, including the 2 confirmed planet of the WTS.
- We provide a priority list of 12 new candidates that were not previously reported. The object 19g-2-01326 was classified as high priority planet candidate (P1) and we propose this object for follow-up in the near future.
- So far, we found only two candidates orbiting around M-dwarfs with J_mag>17, therefore we confirm the results presented in Kóvacs et al. (2012) about the sensitivity of the WTS for giant planet around M-dwarfs.
- Difference imaging light curves can be used for further purpose specially if we go through fainter magnitudes, for instance detection and characterization of variable stars, such as uncommon eclipsing binary systems.
- Although we are currently limited to follow-up planet candidates around faint stars, the development of new instruments and telescopes might provide new perspectives in the search for extra-solar planets. If we go through fainter magnitudes, the photometry will become harder, and here difference imaging light curves excel compared to aperture photometry.

Thanks