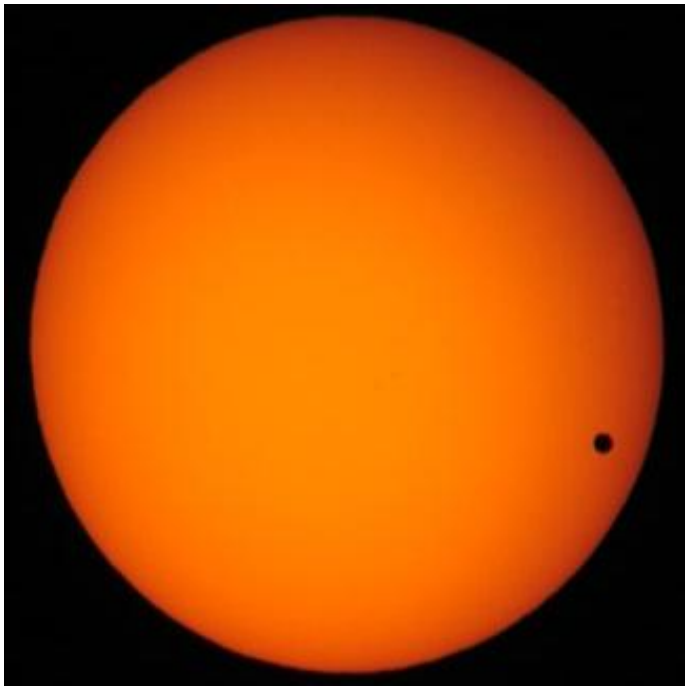
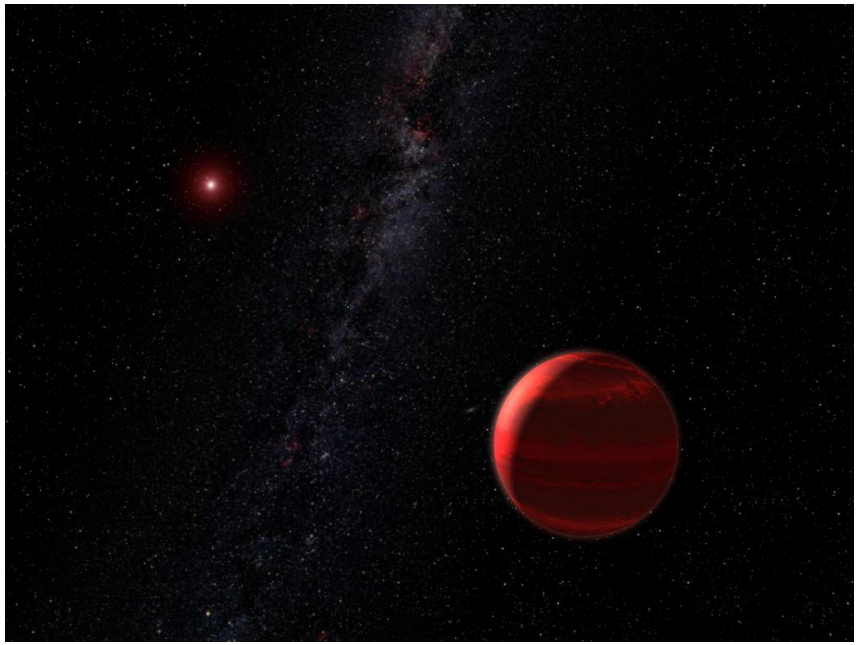
Hot Planets and Cool Stars

- Leiden Analysis and follow-up for the WTS M-dwarf Transit Survey -





Bas Nefs & Ignas Snellen – Leiden Observatory

Jayne Birkby & Simon Hodgkin – Cambridge
TENERIFE

Talk outline

-*Short Introduction*

-*WTS Lightcurve analysis*

Detrending: Sys-Rem

Transit Hunting: BLS

-*WTS follow-up*

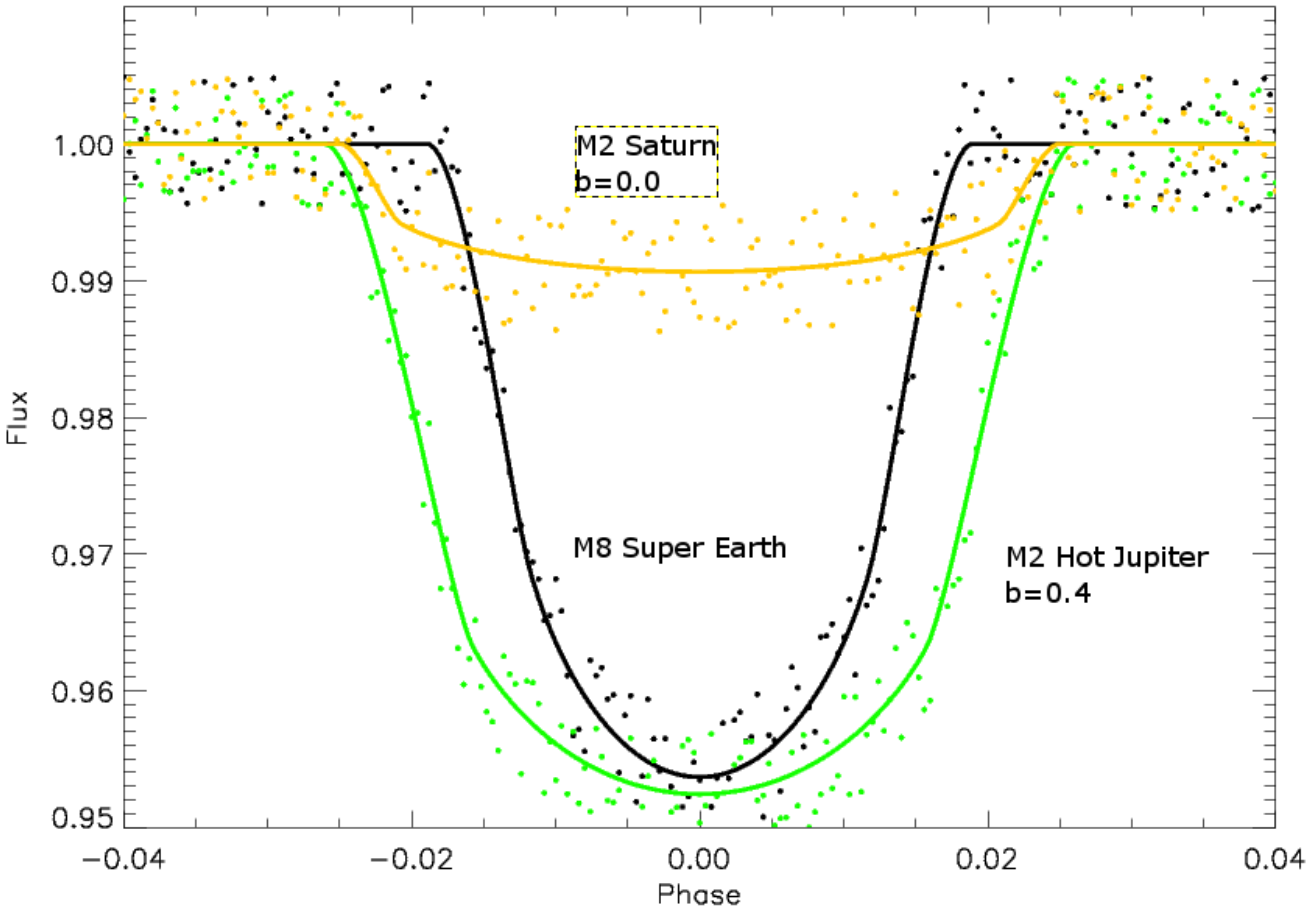
Photometric follow-up INT

Spectroscopic follow-up WHT

-*To do....*

-*Conclusions*

M dwarf planets & WTS



Work in Leiden:

(1) ***Lightcurve analysis*** *&* ***active searching*** *for WTS candidates, collaborating with Cambridge*

(2)To perform WTS candidate ***follow-up***

Detrending lightcurves: Sys-Rem

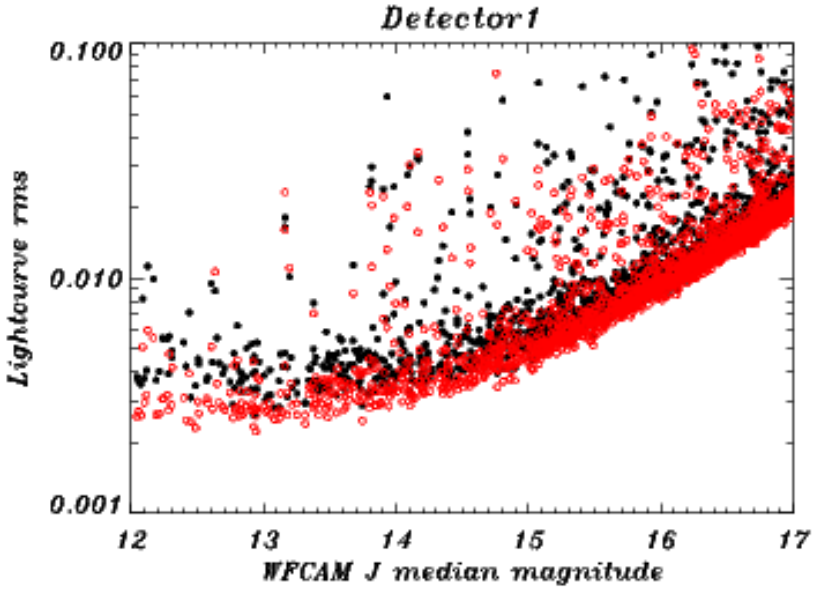
Algorithm to remove (linear) systematic trends from photometric data (Tamuz et al. 2005) – rewritten in IDL.

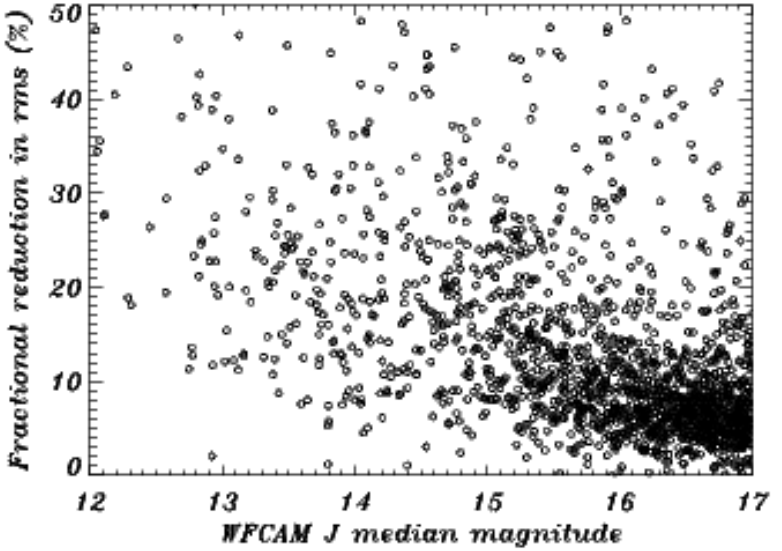
Given residuals r and errors σ, minimise (iteratively):

$$S^2 = \sum_{ij} \frac{(r_{ij} - c_i a_j)^2}{\sigma_{ij}^2}$$

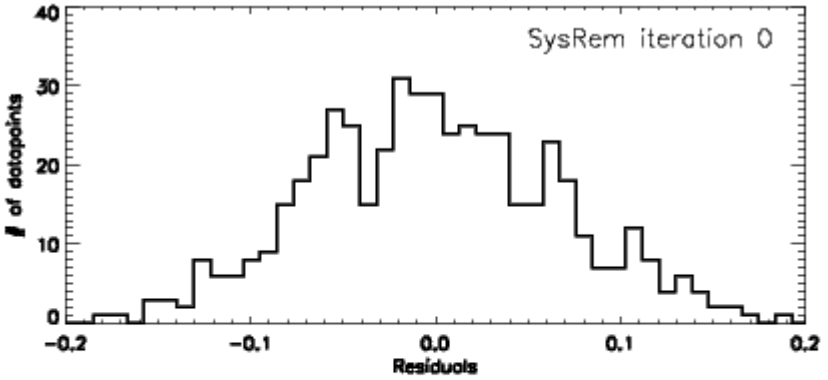
$a_j \rightarrow$ *systematic trend in frame j*

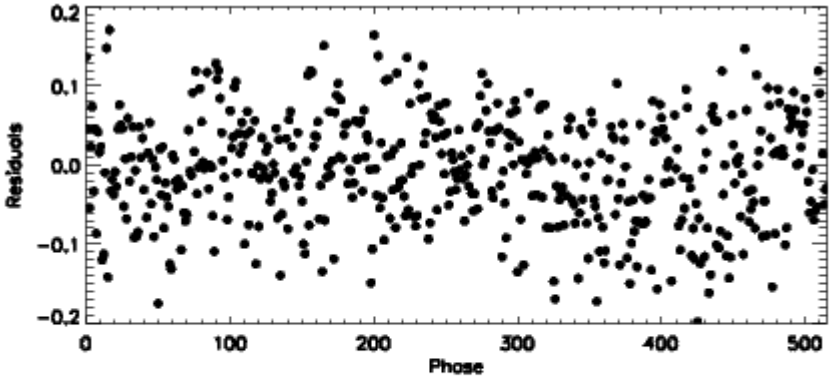
$c_i \rightarrow$ *coefficient for star i*

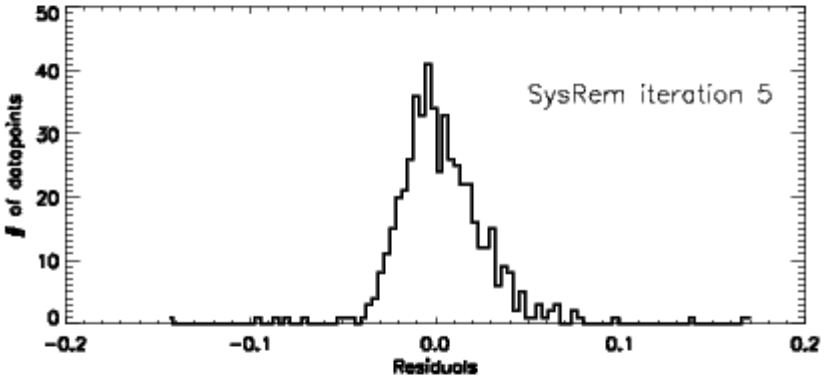


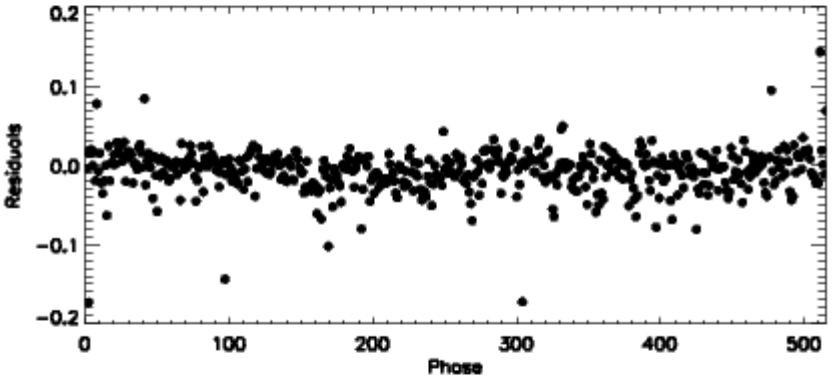


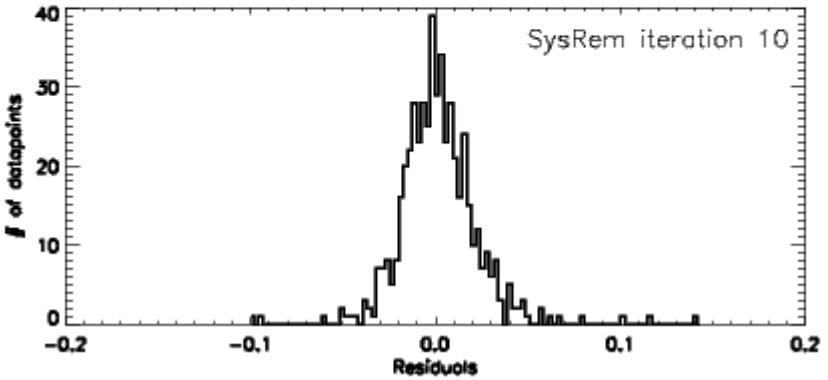
Sys-Rem at work

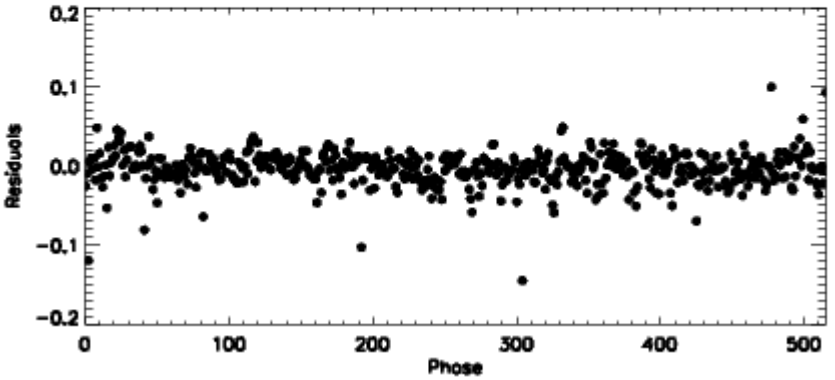




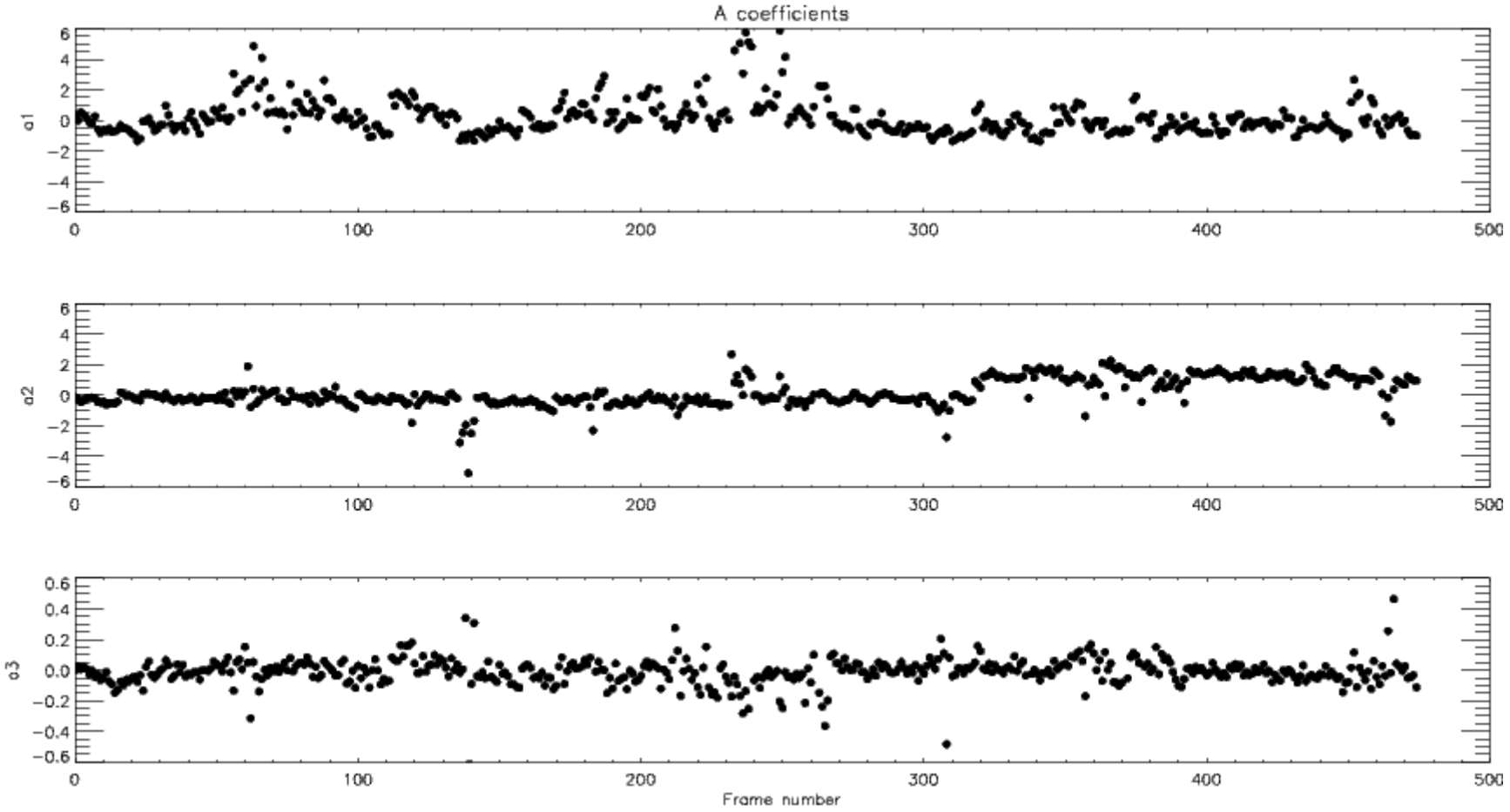






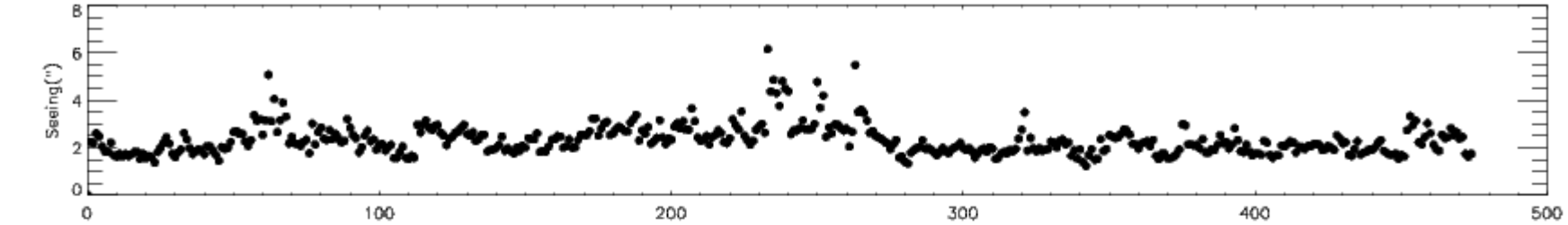


Sys-Rem base functions a_j

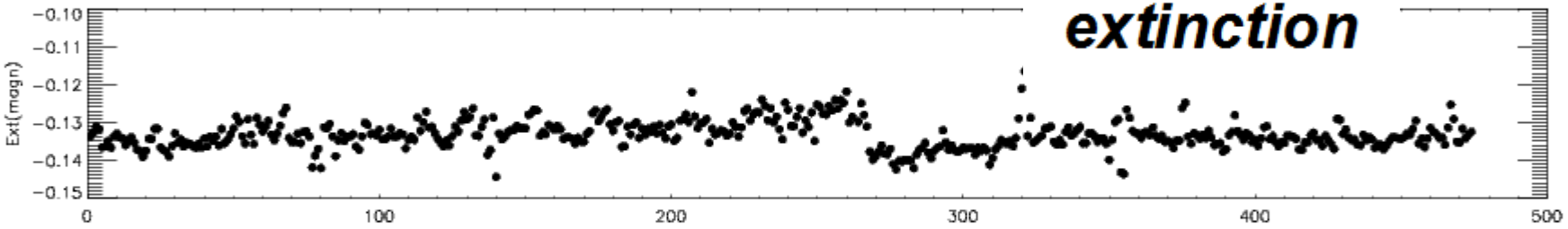


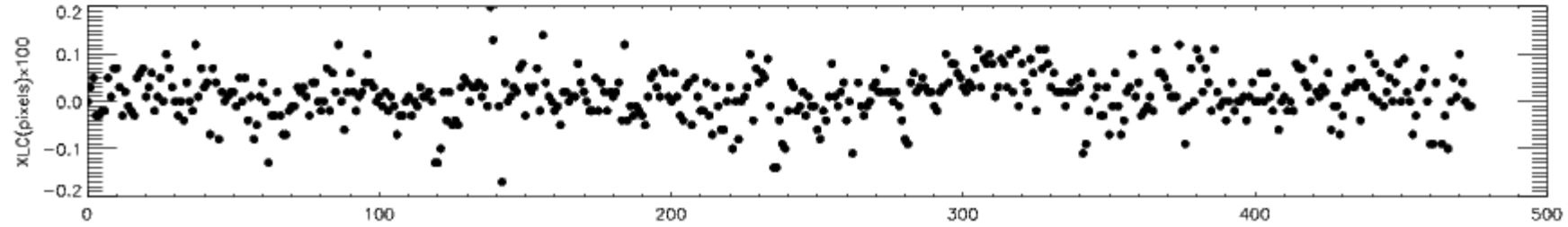
Correlated with....?

Seeiing



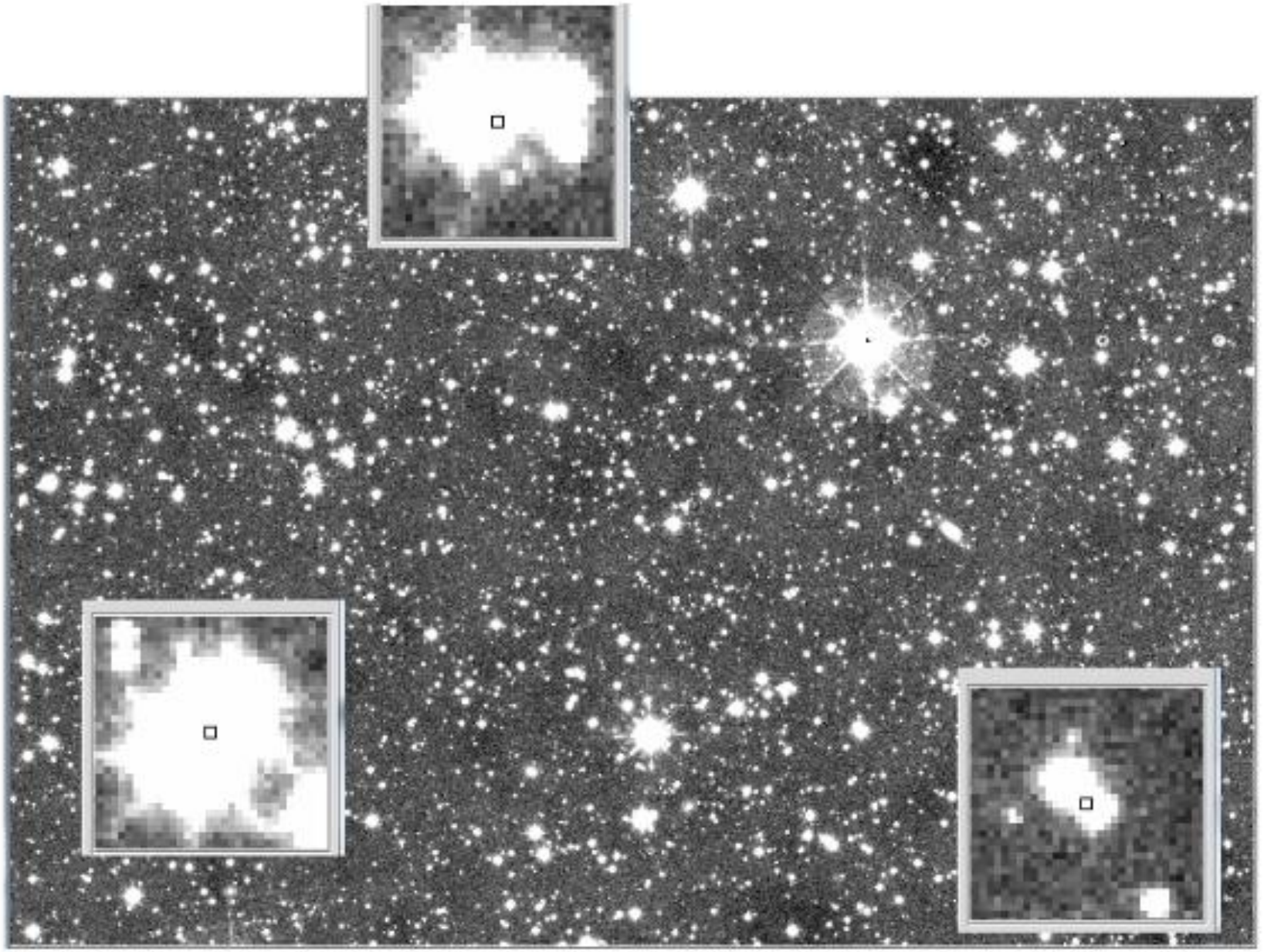
extinction



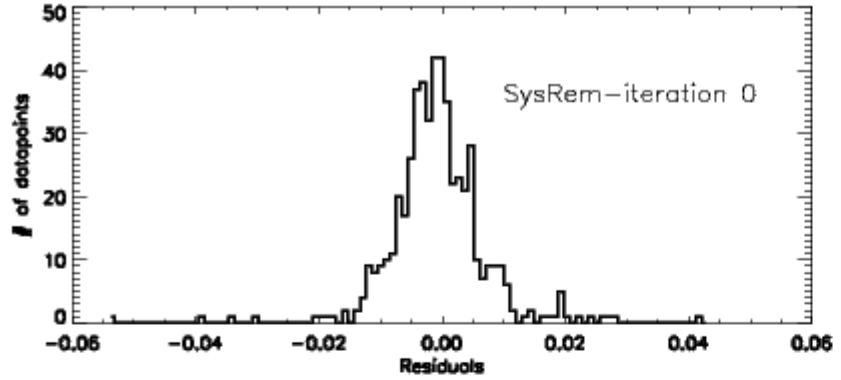


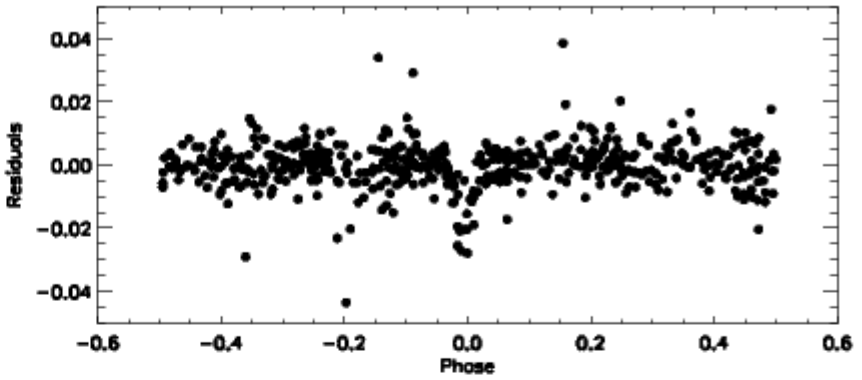
x/y offsets

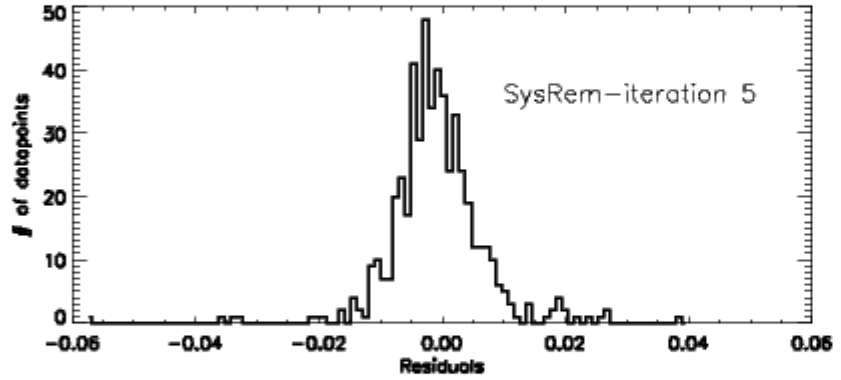
Removing residual blending?

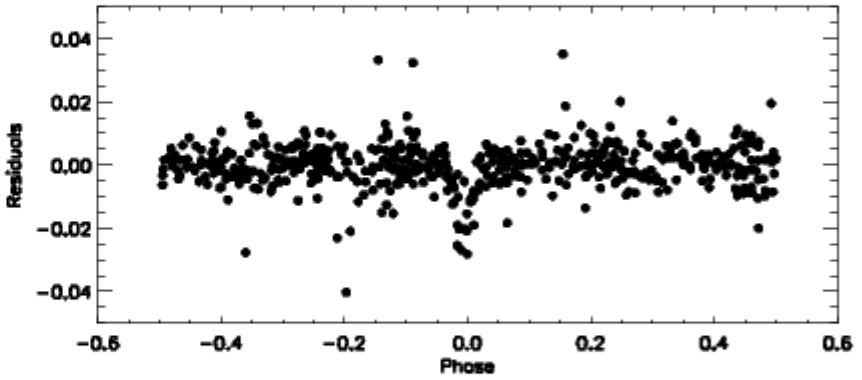


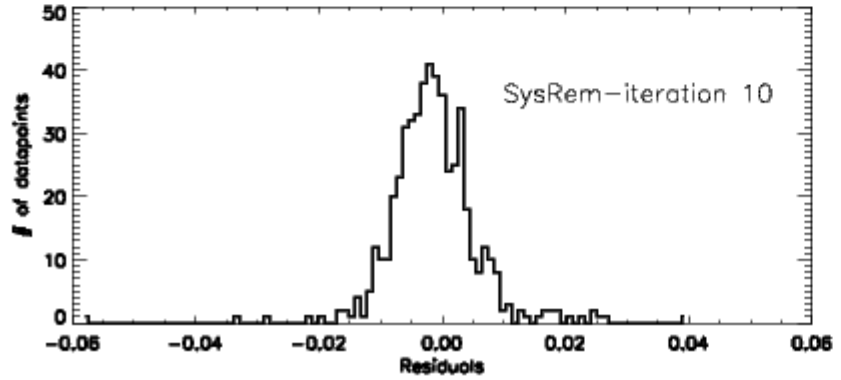
Is Sys-Rem removing transit signal?

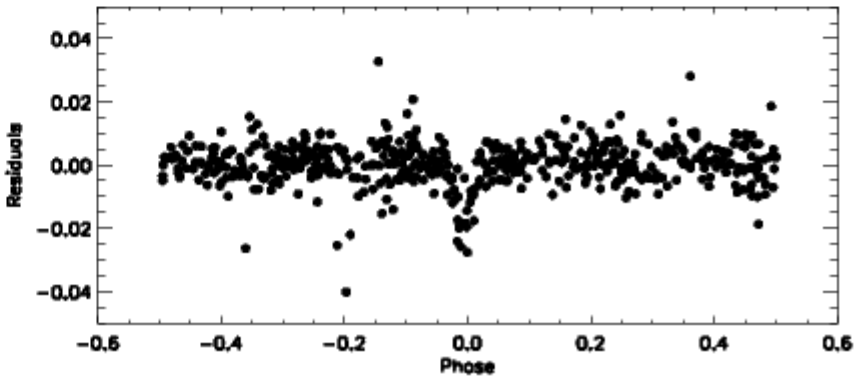




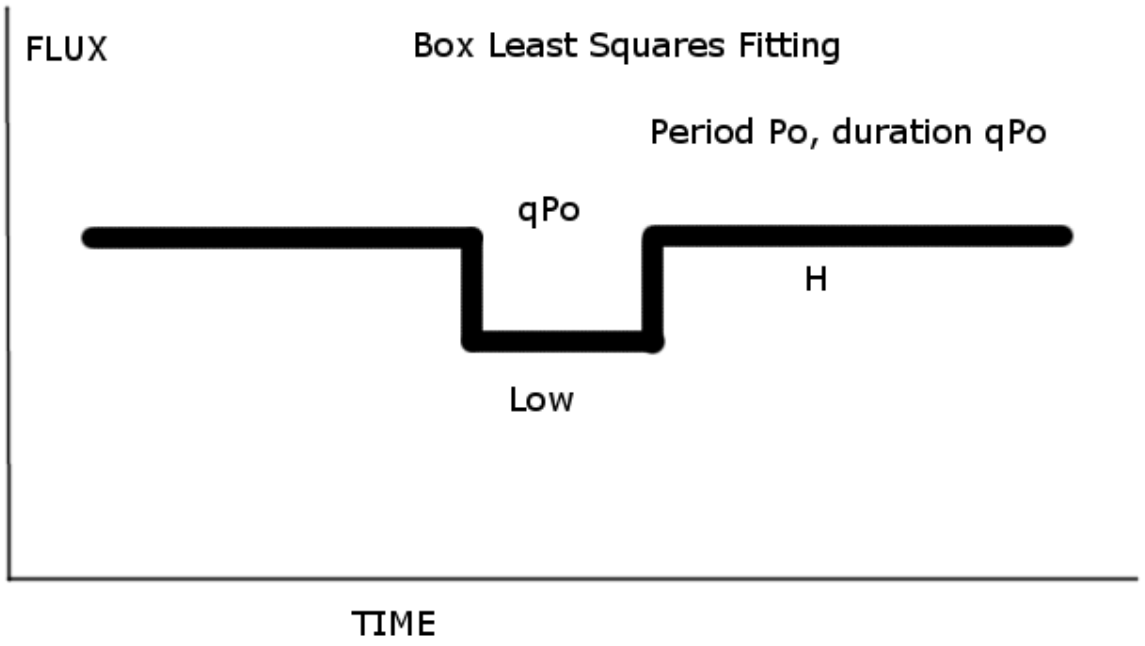








Hunting for transits: box-fitting (BLS*)



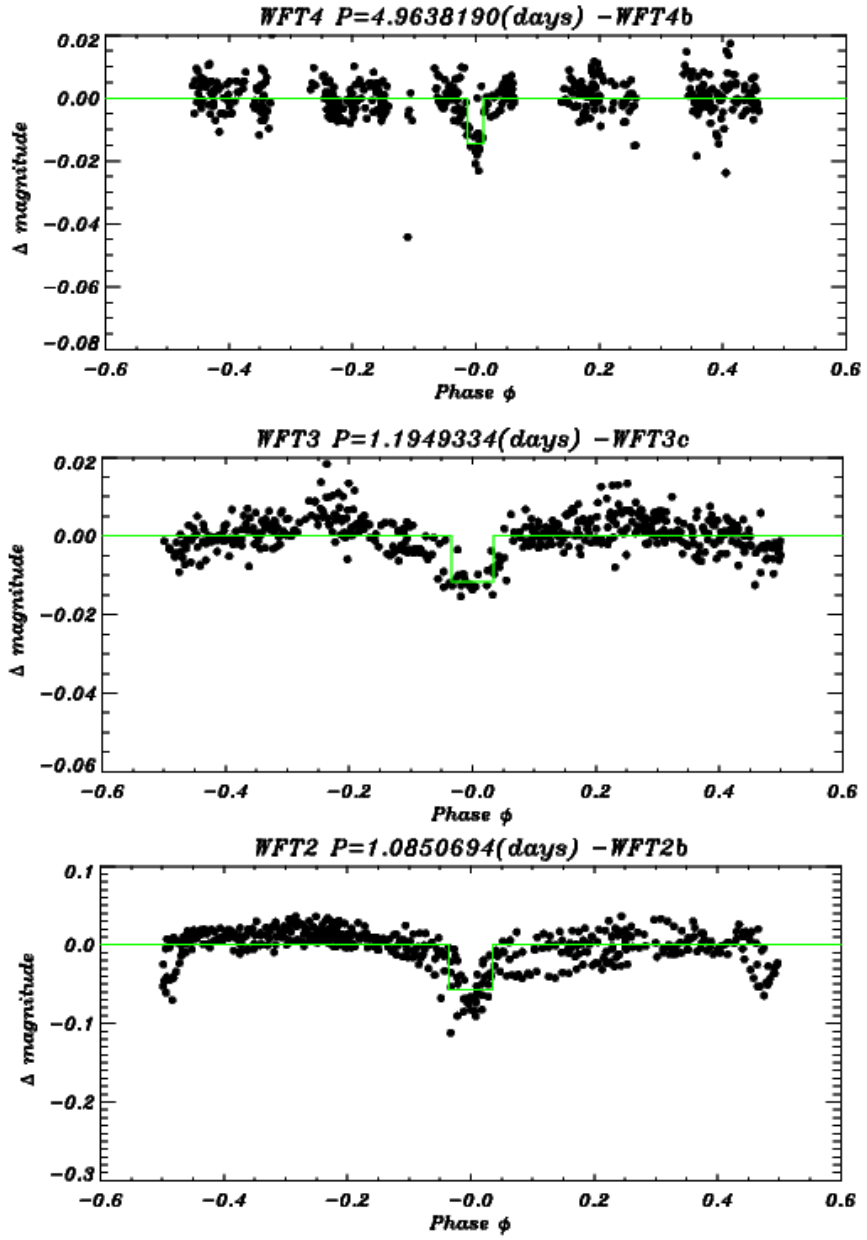
Detection criteria

-(S/N) > 8
- 12<J<17 WFCAM
-Avoid edge-of night effects around 1.0,1.5 and 2.0 days
-Period 0.7<P<5.0 days for WTS summer fields

Search code run on parallel CPU cluster

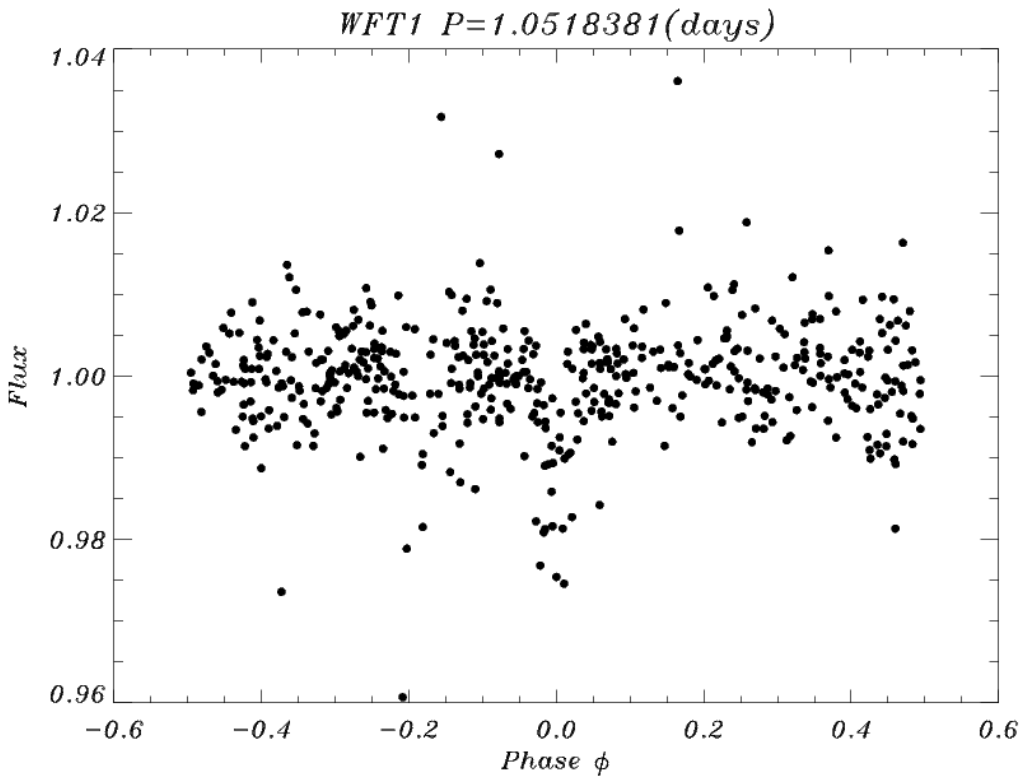
**Modification of Kovacs et al.2002*

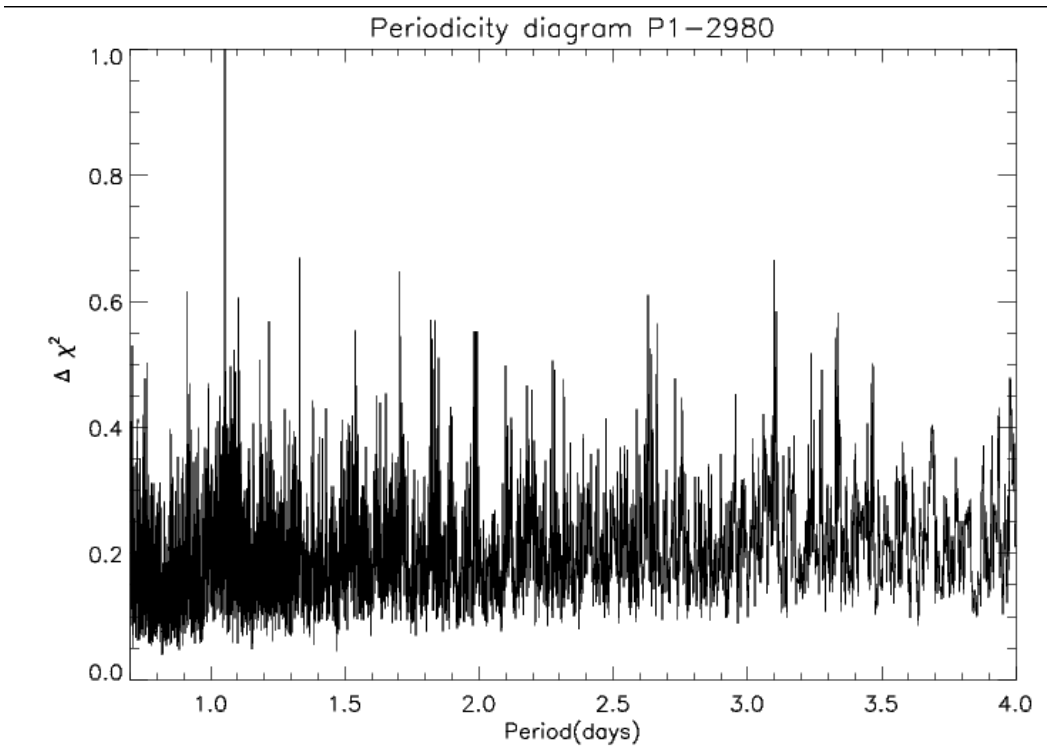
BLS: candidates



- *Initial Run on WTS test field*
- *Currently running on updated WTS release*
- *Sensitive to spiky transit events*
- *Goal: provide a cross-ID for Cambridge can- didates*

Are we detecting the same objects?





LIGHTCURVE *PERIODICITY DIAGRAM*

Example: P1_2980: period difference ~1 sec, (S/N)~11.5

Photometric follow-up WTS candidates

2.5m Isaac Newton Telescope on La Palma → Differential Photometry

To improve or obtain:

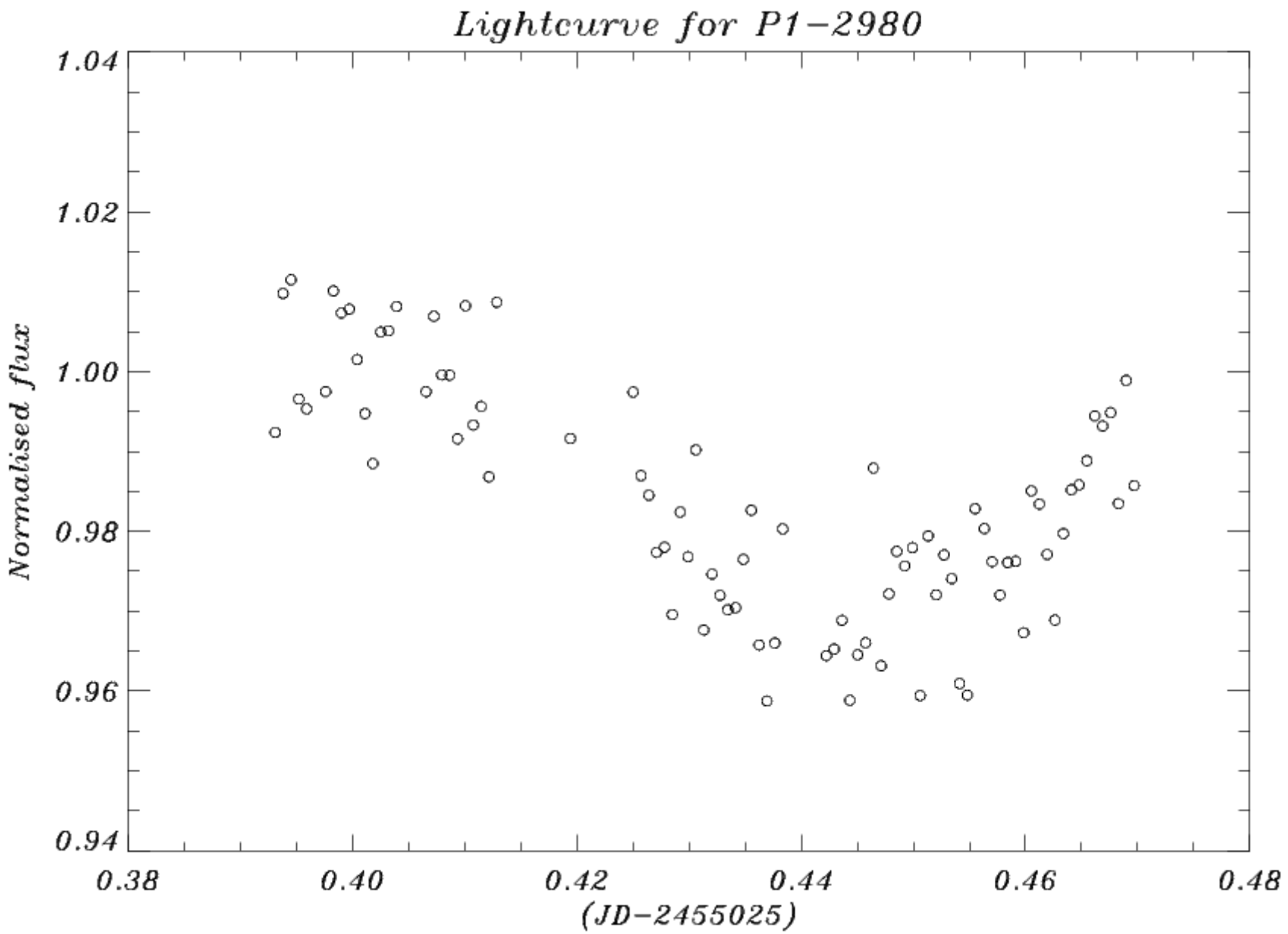
-Exclude instrumental false positives

-Refine ephemeris & period

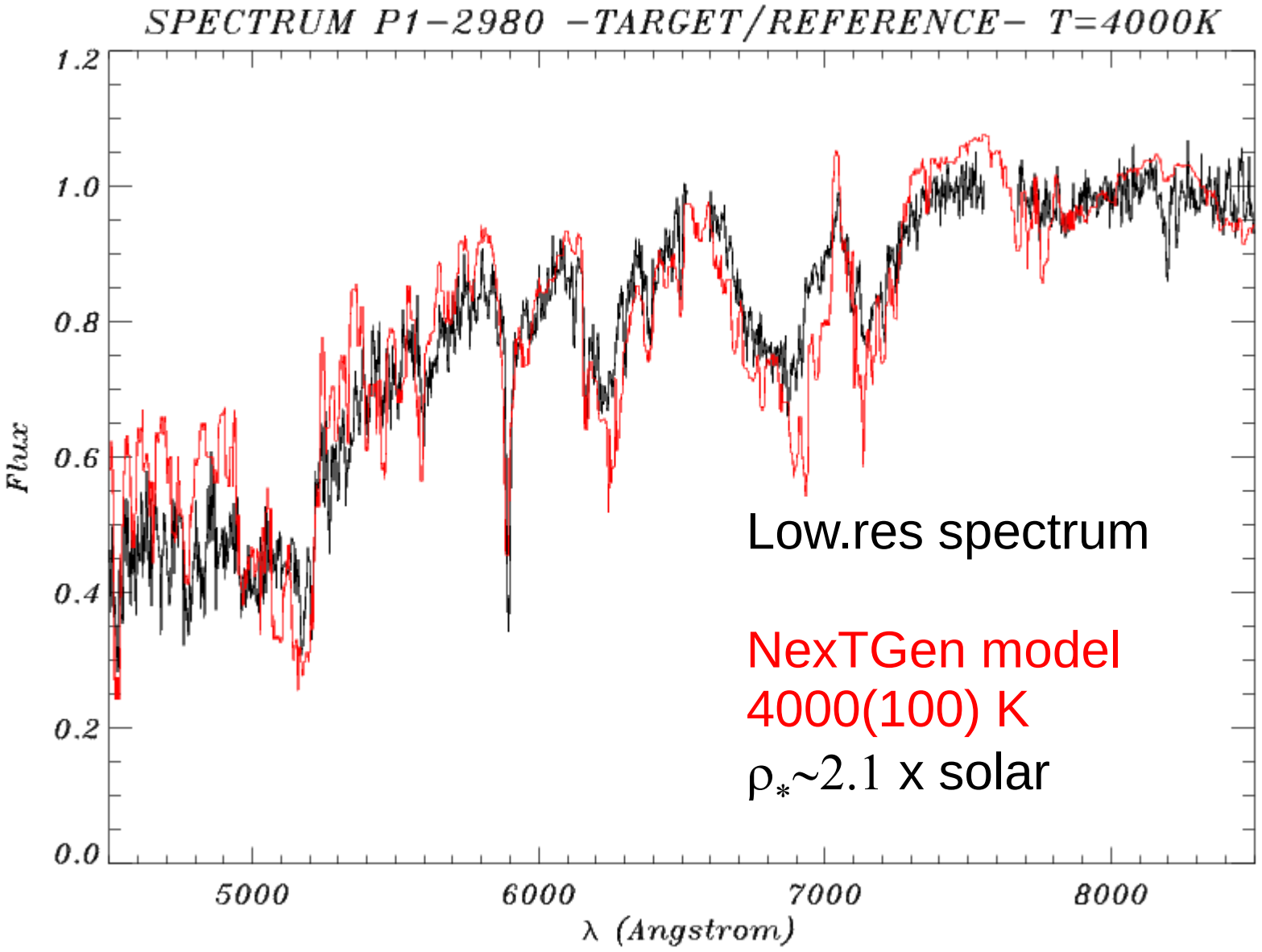
-Higher cadence photometry (30-60 sec. exposures) → modelling of system parameters

To target weak red objects (Red dwarfs!) we use sloan i → less fringing

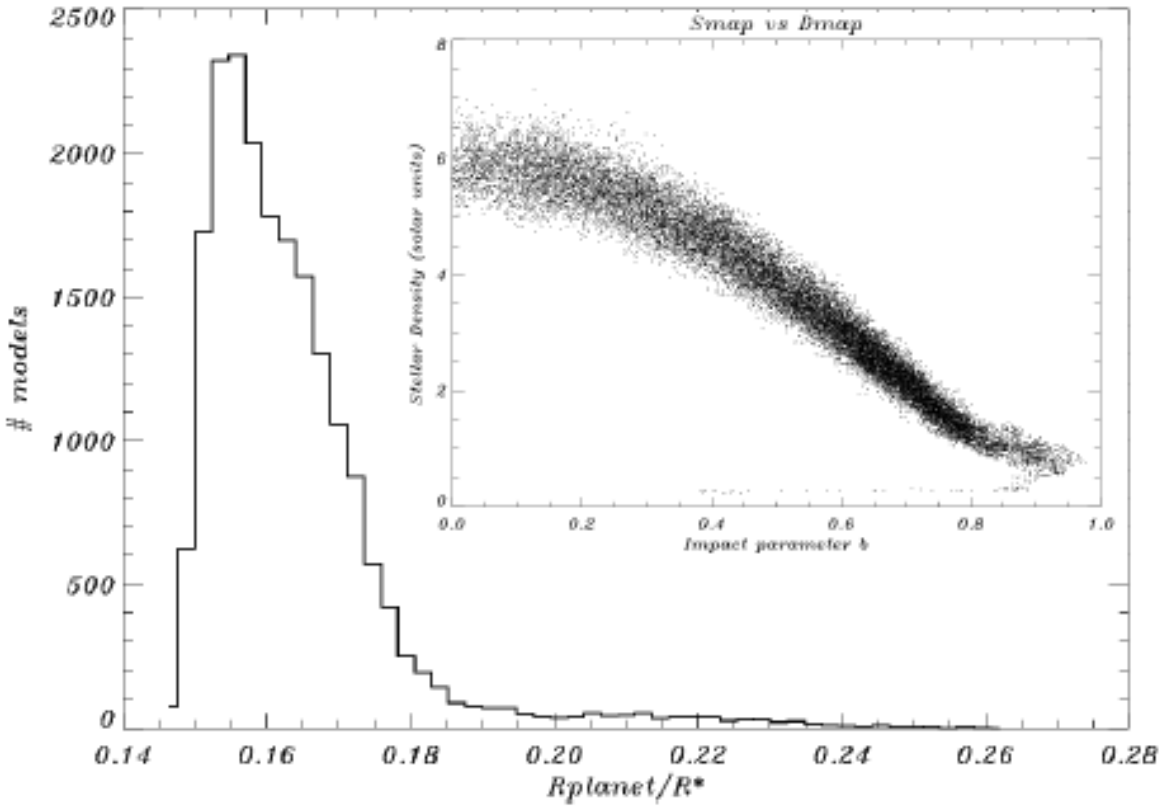
P1_2980


Lightcurve for P1−2980
Normalised flux
1.04
1.02
1.00
0.98
0.96
0.94
0.38
0.40
0.42
0.44
0.46
0.48
(JD−2455025)

WHT ACAM: low res. Spectrum P1_2980



Lightcurve modelling



- *Grid of **Mandel & Agol** transit models as input to **MCMC code** → parameter distribution and confidence levels*
- *Independent chains of 20.000 chainlets*
- *3 parameters:*

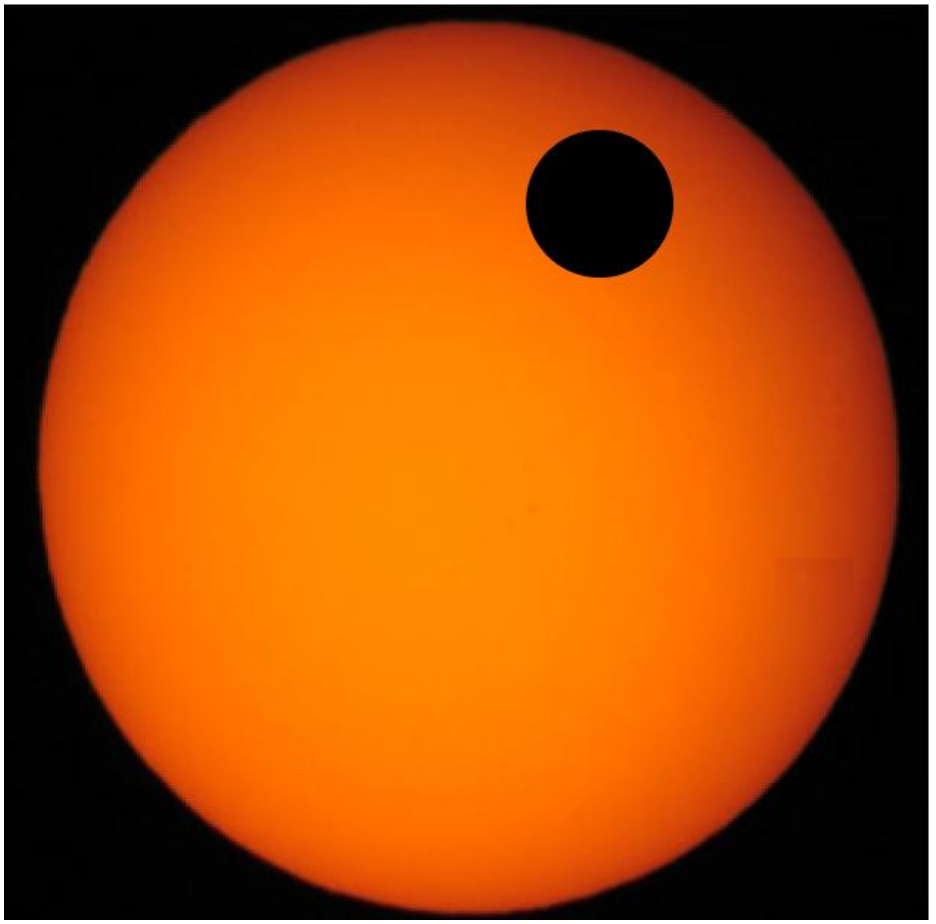
***Impact parameter** b*

***Stellar density** ρ_**

***Ratio of radii** (R_{planet}/R_{star})*

Limb darkening from Claret et al. (2004)

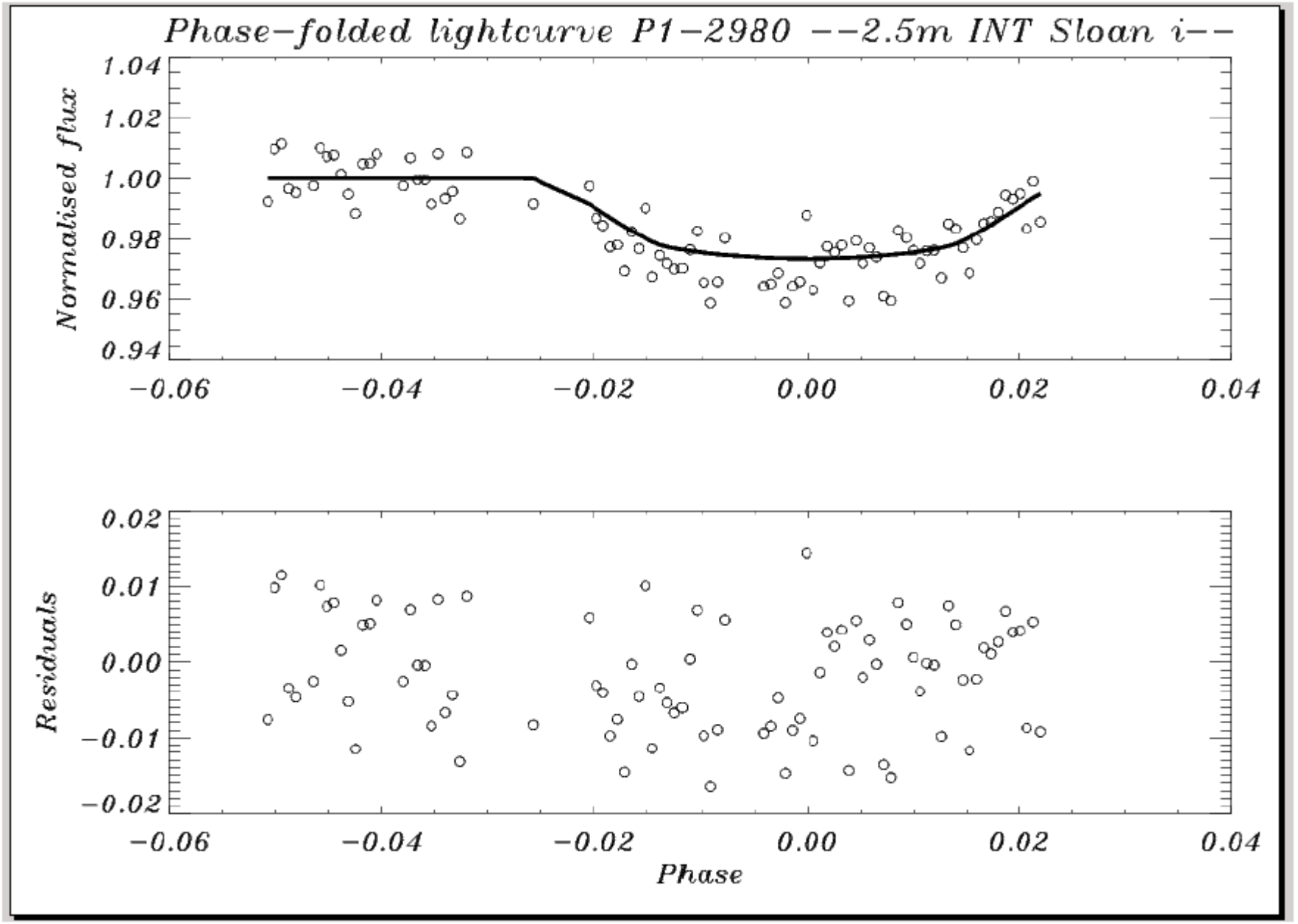
P1_2980: a hot Jupiter around a K8/M0 star?



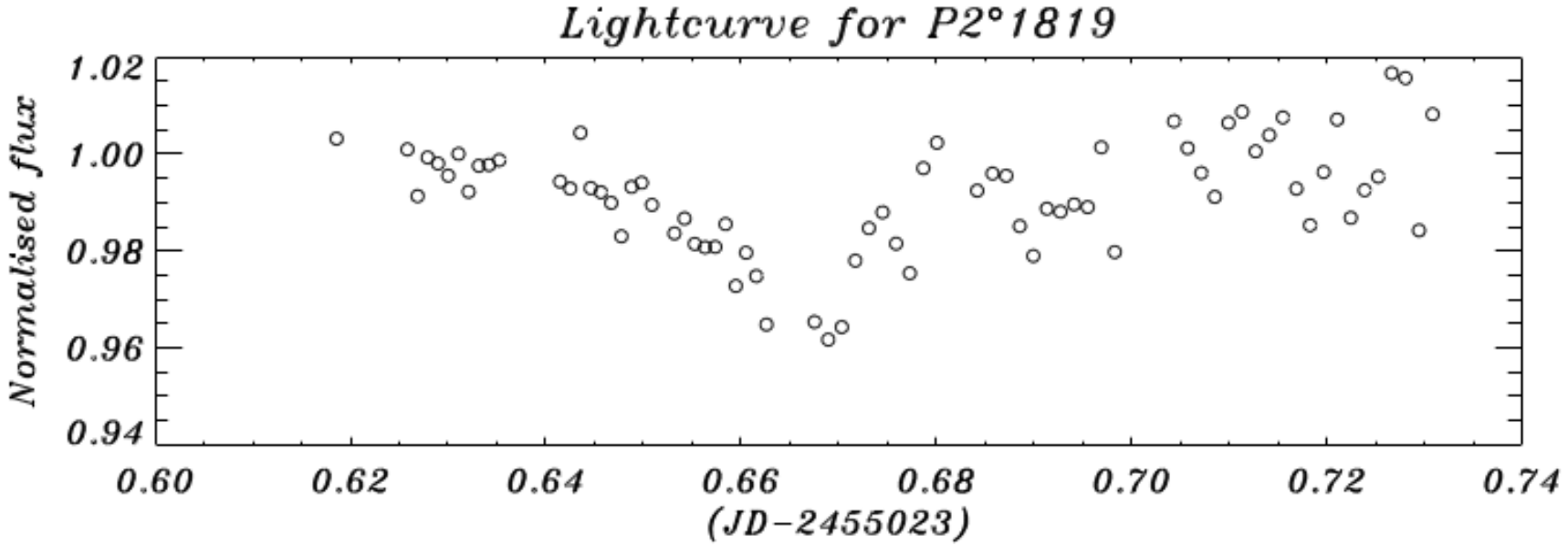
(Rplanet/R)=0.16 (0.02)*
b= 0.69 (0.13)
ρ_* = 2.34 x solar (1.54)

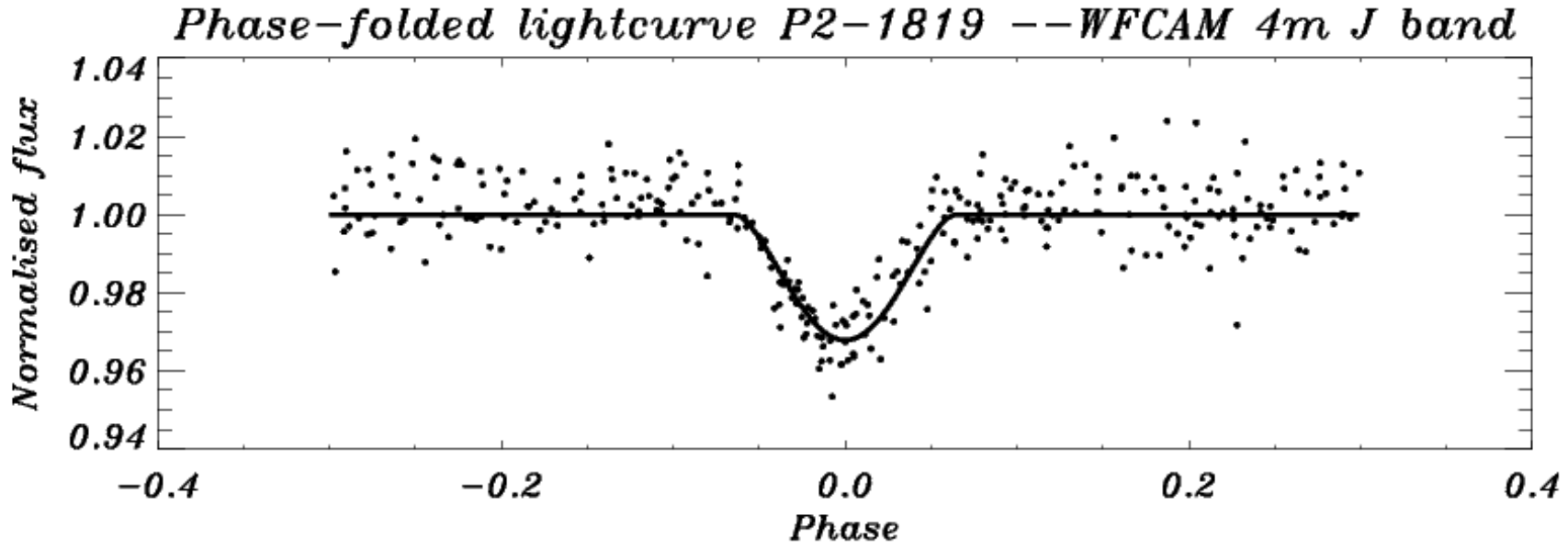
Agreement with spectrum...
P~1.05 days & D~1.05 hrs

To exclude K dwarf + late M dwarf:
RV measurements needed to constrain the (planet) mass! *Applied for Dutch time on WHT 4m (ISIS).*


Phase−folded lightcurve P1−2980 −−2.5m INT Sloan i−−
Normalised flux
1.04
1.02
1.00
0.98
0.96
0.94
−0.06
−0.04
−0.02
0.00
0.02
0.04
Residuals
0.02
0.01
0.00
−0.01
−0.02
Phase

P2_1819: a (grazing) eclipsing binary?





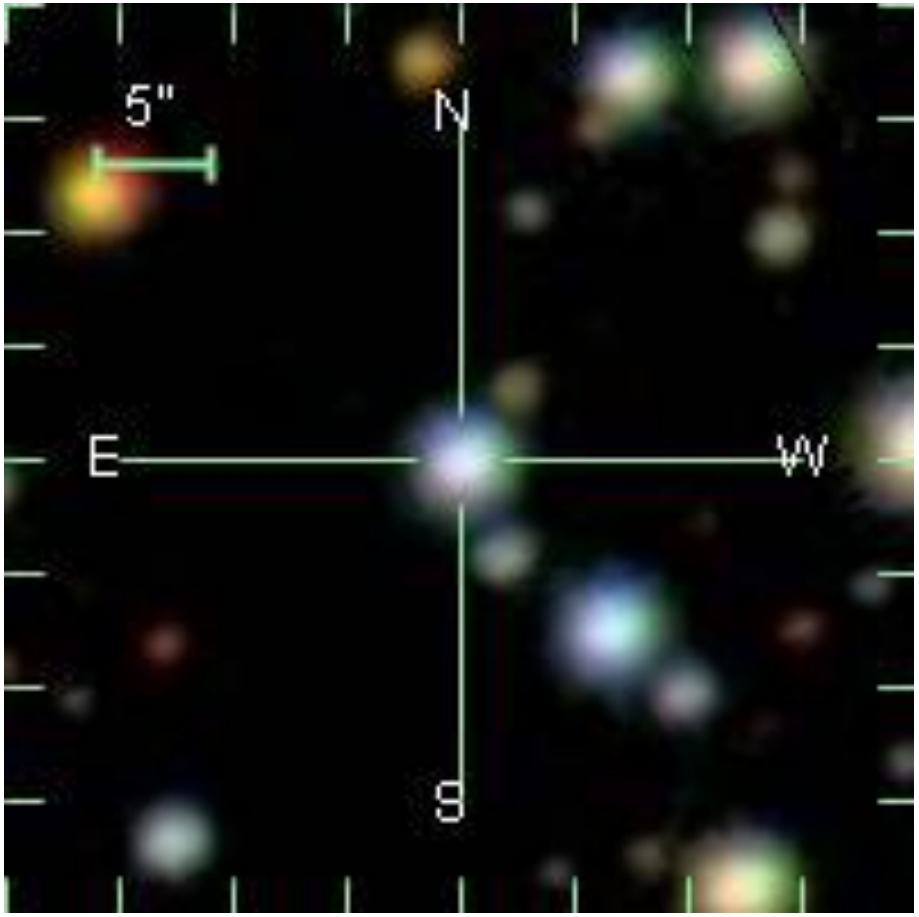
P2_1819

- *INT confirms distinct 'V shape' eclipse, but high systematics!*
- *Best-fit model indicates:*

(Rplanet/R)=0.23(0.05)*
b=0.92(0.09)
ρ_*=0.20x solar (0.07)

A (giant) A/F with a K/M dwarf?

P~0.82 days & D~2.5hr



Things to do....

*-Run the Sys-Rem → BLS code on the **WTS winter fields** (much less epochs unfortunately)*

*-Obtain high cadence photometry for any good candidate that will pop up from this sample → **9 nights of** (bad weather) **INT time**....*

*-For the fields lacking Sloan coverage, obtain **V,i',r' & B broad band** coverage by dithering (done for the 17hr field).*

*-Apply **Sys-Rem** to the **INT light-curves** to remove systematics (e.g. with P2_1819) and improve the photometry.*

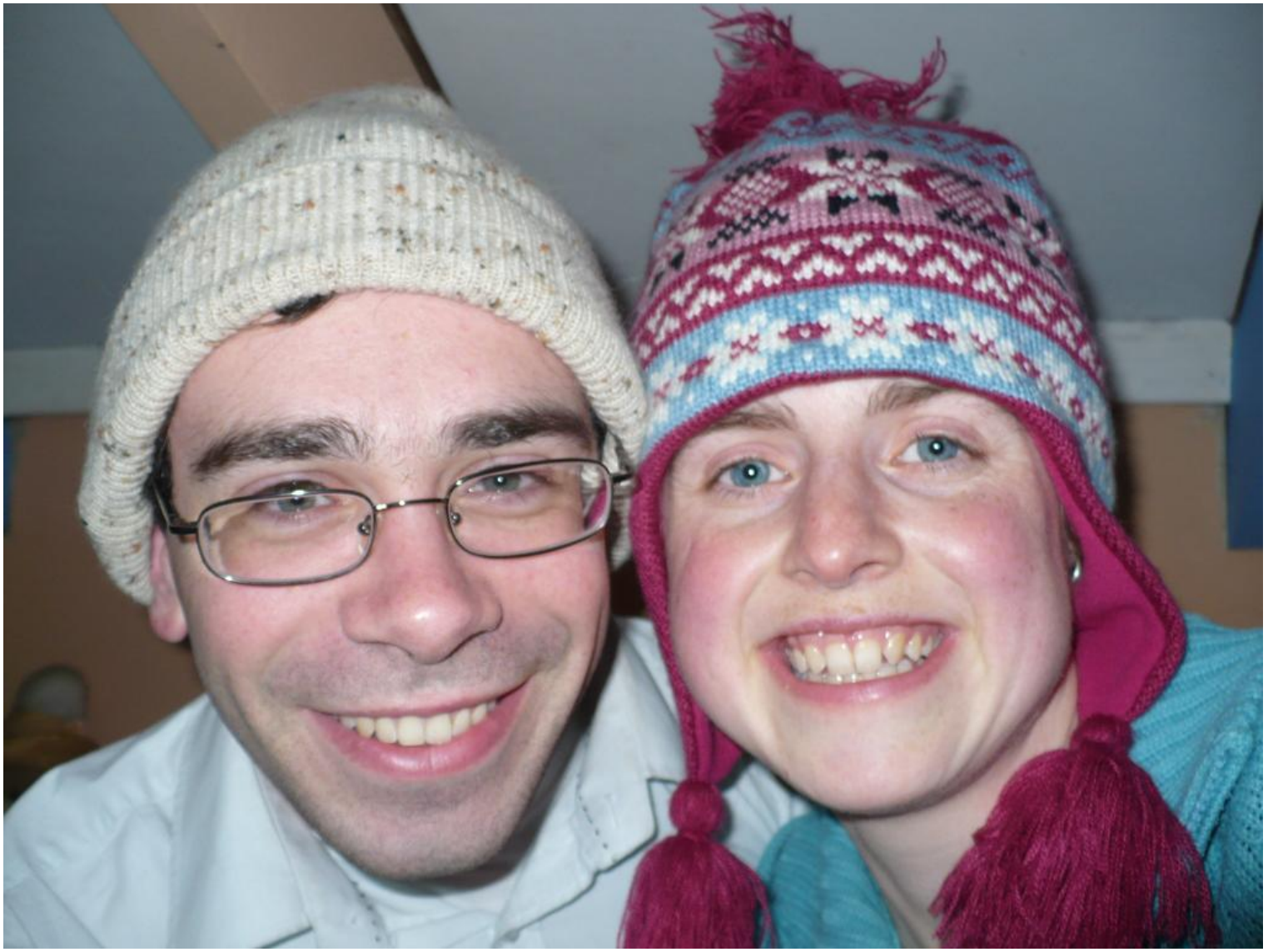
Conclusions

- *The WFCAM Survey has revealed the first **late K/early M dwarf planet candidate** in its early release, **P1_2980.***

- ***Photometric follow-up** on Isaac Newton Telescope confirms a few candidates and refines the periods, eclipse timings and system parameters.*

- ***Additional follow-up** (time request for WHT spectroscopy and INT photometry) **next summer** should constrain the candidates mass → genuine planets?*

- ***Sys-Rem** reduces remaining systematics up to and over 20-30% in rms at the bright end, **residual blending effects?***



Thank you
;)!