Institute of Theoretical Physics and Astronomy

Vilnius University

Investigation of the transit duration parameter using different quality photometry data

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- Yuriy Chorniy

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Identifiers (4) :

TYC 2792-1700-1 GSC 02792-01700 HAT-P-16 2MASS J00381756+4227470

Basic data :

TYC 2792-1700-1 -- Star

Other object types: * (TYC,GSC), Pl? (HAT), IR (2MASS)

ICRS coord. *(ep=J2000) :* 00 38 17.5616 +42 27 47.249 [59.80 58.71 87] B 1998A&A...335L..65H

FK5 coord. *(ep=J2000 eq=2000) :* 00 38 17.562 +42 27 47.25 [59.80 58.71 87]

FK4 coord. *(ep=B1950 eq=1950) :* 00 35 34.13 +42 11 18.5 [99.88 95.25 90]

Gal coord. *(ep=J2000) :* 120.3468 -20.3426 [59.80 58.71 87]

Proper motions *mas/yr* : -20.3 -5.6 [1.6 1.5 90] B 2000A&A...355L..27H

Spectral type: F8 D 2011A&A...529A.136E

References (36 between 1990 and 2016)

The first research of HAT-P-16b :

2010ApJ...720.1118B !!!

Astrophys. J., 720, 1118-1125 (2010)

HAT-P-16b: a 4 M_J_ planet transiting a bright star on an eccentric orbit.

BUCHHAVE L.A., BAKOS G.A., HARTMAN J.D., TORRES G., KOVACS G., LATHAM D.W., NOYES R.W., ESQUERDO G.A., EVERETT M., HOWARD A.W., MARCY G.W., FISCHER D.A., JOHNSON J.A., ANDERSEN J., FURESZ G., PERUMPILLY G., SASSELOV D.D., STEFANIK R.P., BEKY B., LAZAR J., PAPP I. and SARI P.

Stellar Parameters for HAT-P-16

Parameter	Value	Source
$T_{\rm eff,\star}$ (K)	6158 ± 80	SME[a]
[Fe/H] (dex)	$+0.17 \pm 0.08$	SME
$v \sin i$ (km s^{-1})	3.5 ± 0.5	SME
$v_{\rm mac}$ (km s^{-1})	4.61	SME
$v_{\rm mic}$ (km s^{-1})	0.85	SME
$\gamma_{\rm RV}$ (km s^{-1})	-16.83 ± 0.19	D-S
a_1	0.2166	SME+Claret[b]
b_1	0.3617	SME+Claret
$M_\star$ ($M_\odot$)	1.218 ± 0.039	YY+$a/R_\star$+SME[c]
$R_\star$ ($R_\odot$)	1.237 ± 0.054	YY+$a/R_\star$+SME
$\log g_\star$ (cgs)	4.34 ± 0.03	YY+$a/R_\star$+SME
$L_\star$ ($L_\odot$)	1.97 ± 0.22	YY+$a/R_\star$+SME
v (mag)	10.812	TASS
M_V (mag)	4.03 ± 0.13	YY+$a/R_\star$+SME
K (mag, ESO)	9.596 ± 0.021	2MASS+carpenter[d]
M_K (mag, ESO)	2.74 ± 0.10	YY+$a/R_\star$+SME
Age (Gyr)	2.0 ± 0.8	YY+$a/R_\star$+SME
Distance (pc)	235 ± 10	YY+$a/R_\star$+SME

Orbital and Planetary Parameters

Parameter	Value
Light curve parameters	
P (days).....	2.775960 ± 0.000003
T_c (BJD).....	2455027.59293 ± 0.00031
T_{14} (days)[a].....	0.1276 ± 0.0013
$T_{12} = T_{34}$ (days)[a].....	0.0150 ± 0.0014
a/R_*.....	7.17 ± 0.28
ζ/R_*.....	17.73 ± 0.10
R_p/R_*.....	0.1071 ± 0.0014
b^2.....	$0.193^{+0.063}_{-0.069}$
$b \equiv a\cos i/R_*$.....	$0.439^{+0.065}_{-0.098}$
i (deg).....	86.6 ± 0.7
RV parameters	
K ($m\,s^{-1}$).....	531.1 ± 2.8
k_{RV}[b].....	−0.030 ± 0.003
h_{RV}[b].....	−0.021 ± 0.006
e.....	0.036 ± 0.004
ω.....	214 ± 8°
RV jitter ($m\,s^{-1}$).....	8.0
RV rms from fit ($m\,s^{-1}$).....	10.0

Parameter	Value
Secondary eclipse parameters	
T_S (BJD).....	2455028.929 ± 0.005
$T_{S,14}$.....	0.1234 ± 0.0020
$T_{S,12}$.....	0.0142 ± 0.0013
Planetary parameters	
M_p (M_J).....	4.193 ± 0.094
R_p (R_J).....	1.289 ± 0.066
$C(M_p, R_p)$[c].....	0.37
ρ_B ($g\,cm^{-3}$).....	2.42 ± 0.35
a (AU).....	0.0413 ± 0.0001
$\log g_B$ (g_B in cgs).....	3.80 ± 0.04
T_{eq} (K).....	1626 ± 40
Θ[d]	0.220 ± 0.011
$\langle F \rangle$ (10^9 erg s^{-1} cm^{-2})[e]	1.58 ± 0.16

Notes.

[a] T_{14}: total transit duration, time between first to last contact. $T_{12} = T_{34}$: ingress/egress time, time between first and second or third and fourth contact.

Astrophys. J., 720, 1118-1125 (2010)

The most recent reference to HAT-P-16b:

2016ApJ...823...29A
Astrophys. J., 823, 29-29 (2016)
Spin-orbit alignment for three transiting hot jupiters: WASP-103b, WASP-87b, and WASP-66b.
ADDISON B.C., TINNEY C.G., WRIGHT D.J. and BAYLISS D.

with the direct link to other sources.

2011A&A...533A.113M
Astron. Astrophys., 533A, 113-113 (2011)
Spin-orbit inclinations of the exoplanetary systems HAT-P-8b, HAT-P-9b, HAT-P-16b, and HAT-P-23b.
MOUTOU C., DIAZ R.F., UDRY S., HEBRARD G., BOUCHY F., SANTERNE A., EHRENREICH D., ARNOLD L., BOISSE I., BONFILS X., DELFOSSE X., EGGENBERGER A., FORVEILLE T., LAGRANGE A.-M., LOVIS C., MARTINEZ P., PEPE F., PERRIER C., QUELOZ D., SANTOS N.C., SEGRANSAN D., TOUBLANC D., TRONCIN J.P., VANHUYSSE M. and VIDAL-MADJAR A.

2013A&A...557A..30C
Astron. Astrophys., 557A, 30-30 (2013) !!!
Simultaneous follow-up of planetary transits: revised physical properties for the planetary systems HAT-P-16 and WASP-21.
CICERI S., MANCINI L., SOUTHWORTH J., NIKOLOV N., BOZZA V., BRUNI I., CALCHI NOVATI S., D'AGO G. and HENNING T.

The latter result:

S. Ciceri et al.: HAT-P-16 b and WASP-21 b Astron. Astrophys., 557A, 30-30 (2013)

Table 7. Physical properties of the HAT-P-16 system obtained in this work and compared with the discovery paper.

	This work (final)	Buchhave et al. (2010)
M_A ($M_\odot$)	$1.216 \pm 0.042 \pm 0.036$	1.218 ± 0.039
R_A ($R_\odot$)	$1.158 \pm 0.023 \pm 0.011$	1.237 ± 0.054
$\log g_A$ (cgs)	$4.396 \pm 0.016 \pm 0.004$	4.34 ± 0.03
ρ_A ($\rho_\odot$)	0.784 ± 0.040	–
M_b (M_{jup})	$4.193 \pm 0.098 \pm 0.083$	4.193 ± 0.094
R_b (R_{jup})	$1.190 \pm 0.035 \pm 0.012$	1.289 ± 0.066
g_b (ms^{-2})	73.4 ± 4.1	63.1 ± 5.8
ρ_b (ρ_{jup})	$2.33 \pm 0.20 \pm 0.02$	1.95 ± 0.28
T_{eq} (K)	1567 ± 22	1626 ± 40
Θ	$0.2391 \pm 0.0073 \pm 0.0024$	0.220 ± 0.011
a (AU)	$0.04130 \pm 0.00047 \pm 0.00041$	0.0413 ± 0.0004
Age (Gyr)	$0.5^{+0.4+0.5}_{-0.5-0.5}$	2.0 ± 0.8

As can be seen, authors found that the planet is 1.3σ colder and smaller (Rb=1.190±0.037RJup) than the initial estimates.

OBSERVATIONS

The observations of the star HAT-P-16b were obtained on the 5th August 2016 with the 1.65 m telescope at the Molėtai Observatory.

- Bias – 20 CCD frames
- Dark – 10 CCD frames
- Flat – 38 CCD frames
- Images – 2653 CCD frames

Software for photometry data processing

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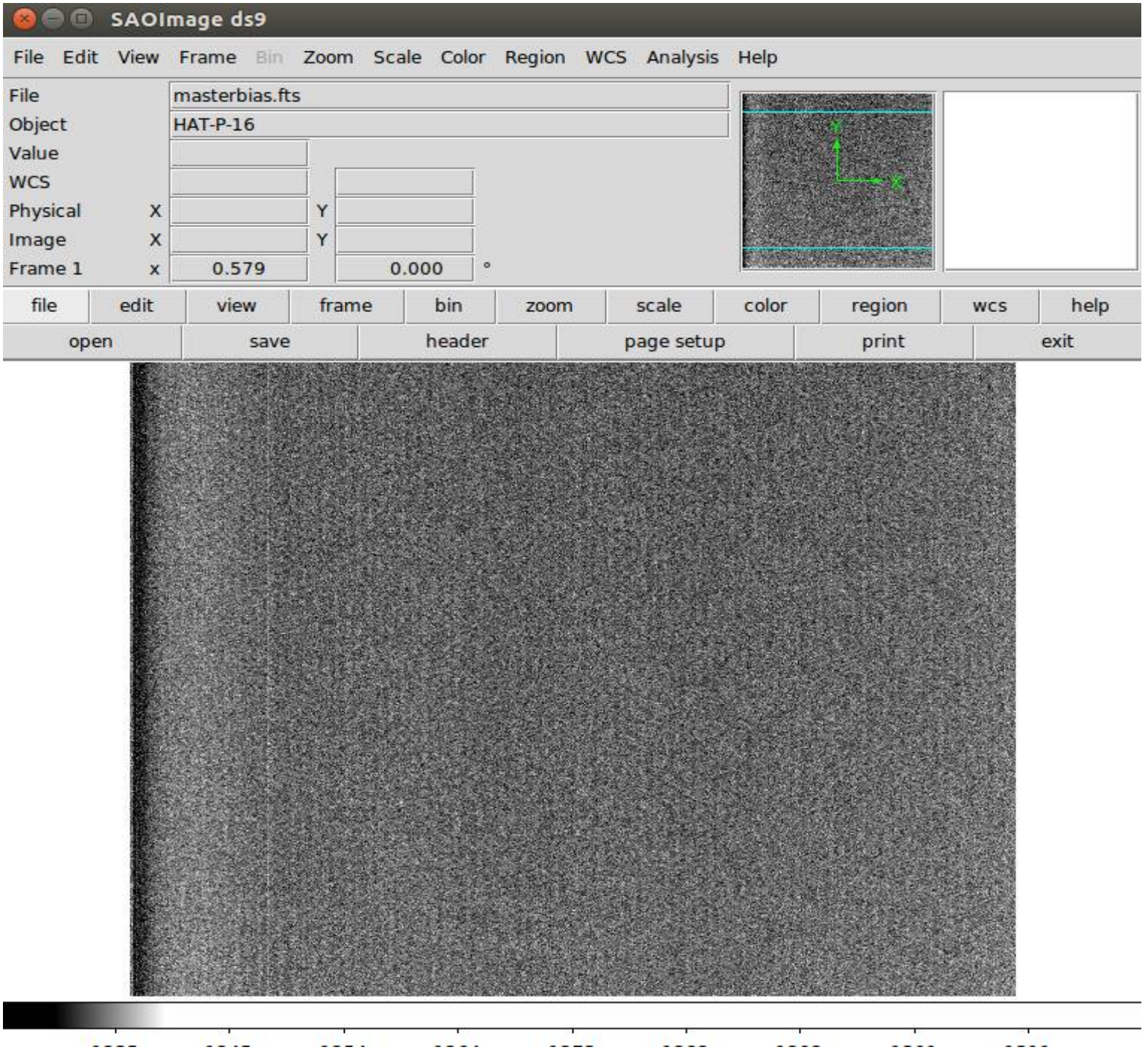
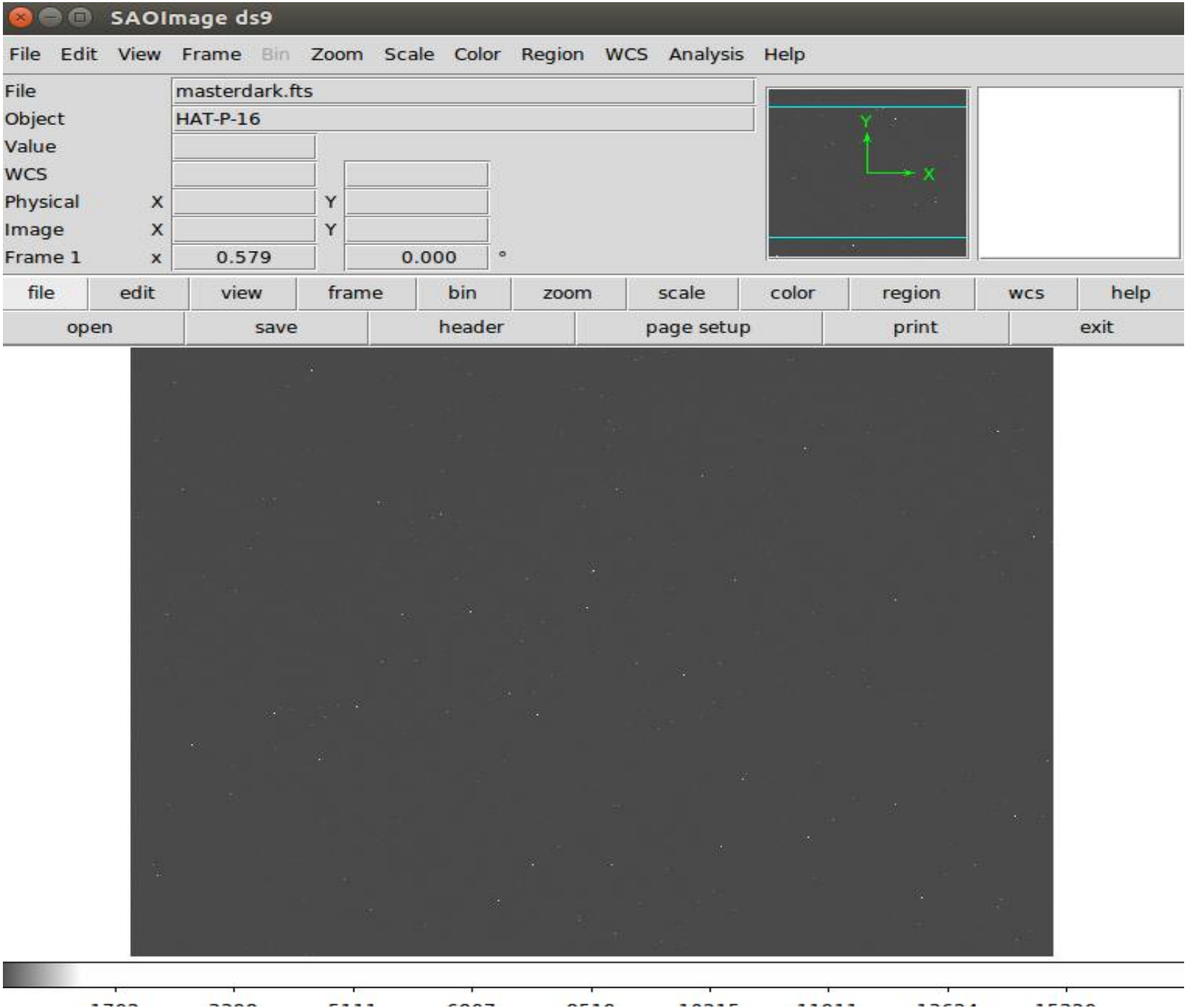
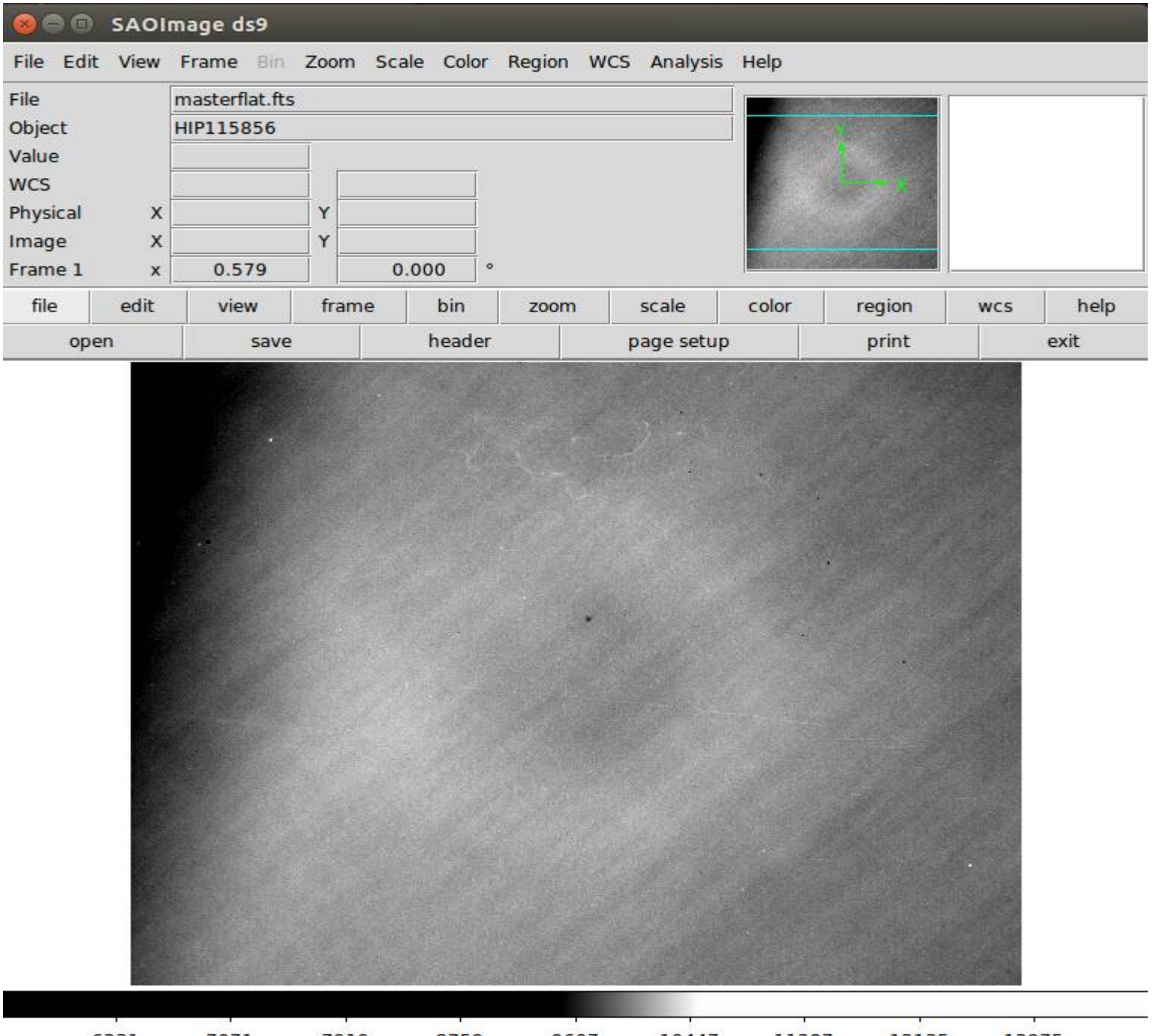
Masterbias


SAOImage ds9
File Edit View Frame Bin Zoom Scale Color Region WCS Analysis Help
File masterbias.fts
Object HAT-P-16
Value
WCS
Physical X Y
Image X Y
Frame 1 x 0.579 0.000 °
file edit view frame bin zoom scale color region wcs help
open save header page setup print exit

masterdark


SAOImage ds9
File Edit View Frame Bin Zoom Scale Color Region WCS Analysis Help
File masterdark.fts
Object HAT-P-16
Value
WCS
Physical X Y
Image X Y
Frame 1 x 0.579 0.000 °
Y
X
file edit view frame bin zoom scale color region wcs help
open save header page setup print exit

masterflat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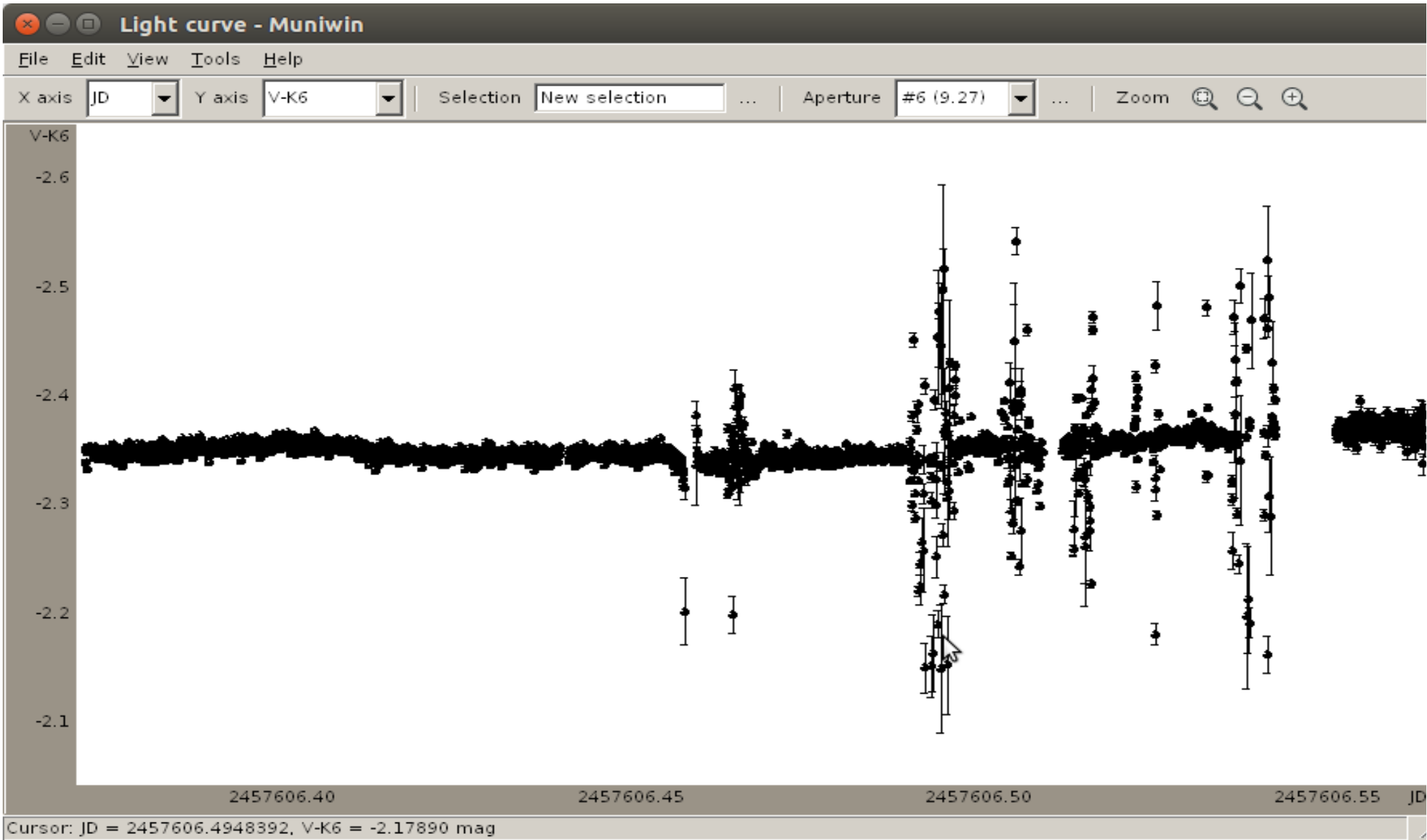
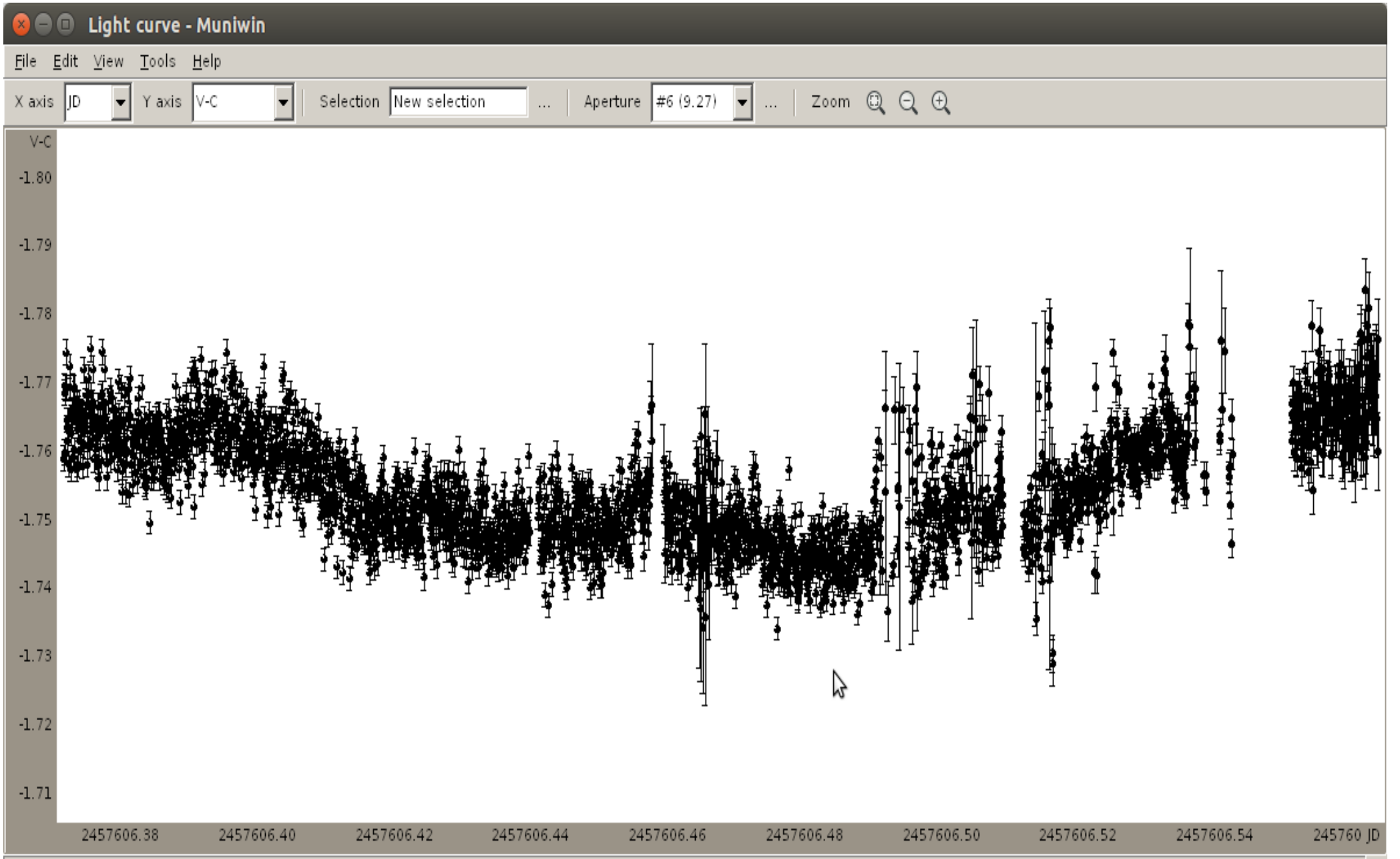
File Edit View Frame Bin Zoom Scale Color Region WCS Analysis Help
File masterflat.fts
Object HIP115856
Value
WCS
Physical X Y
Image X Y
Frame 1 x 0.579 0.000 °
file edit view frame bin zoom scale color region wcs help
open save header page setup print exit

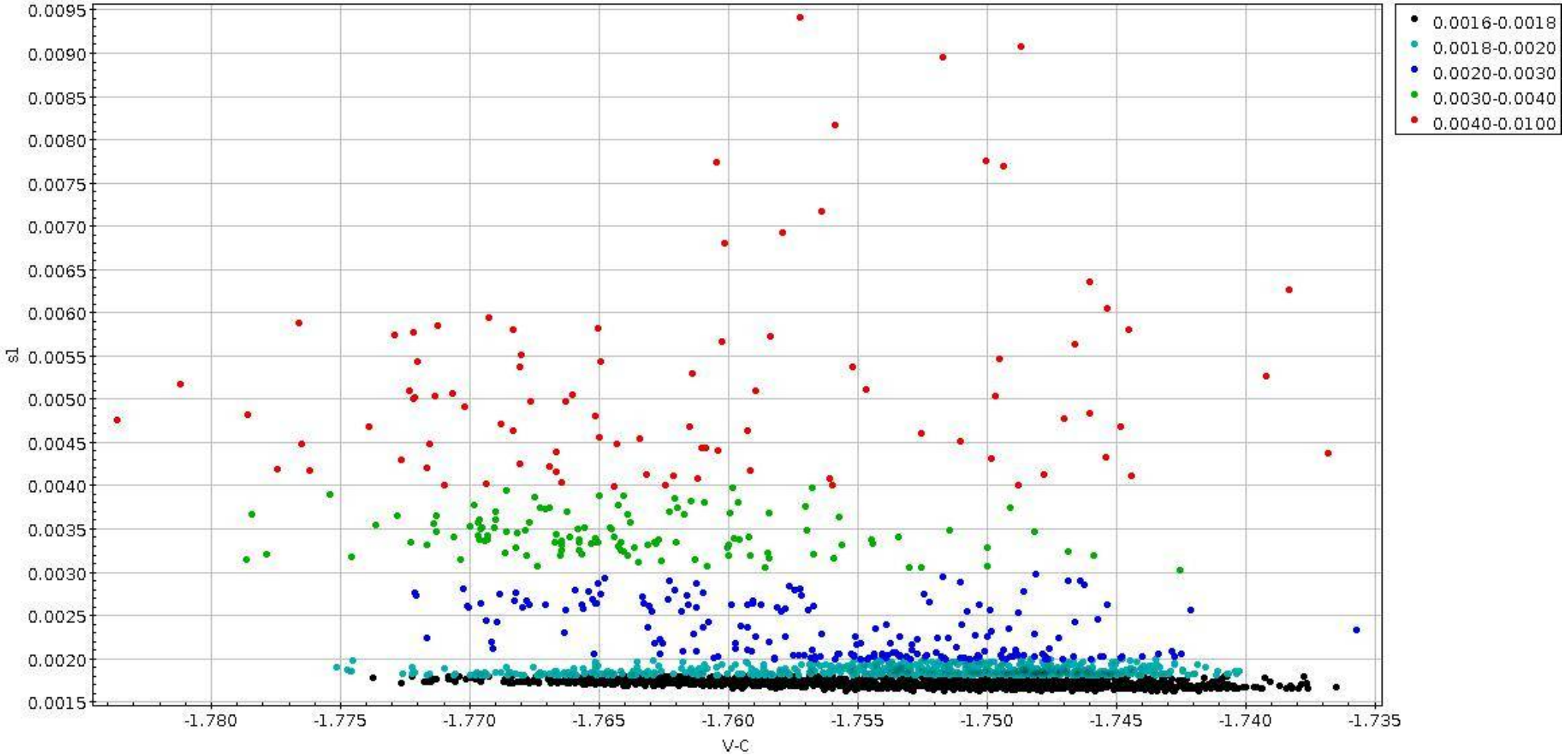
Photometry data based on all 2653 CCD image frames



Photometry data based on selected 2412 CCD image frames



Photometry quality



sig(V-C) = 0.0016 ÷ 0.0018 mag

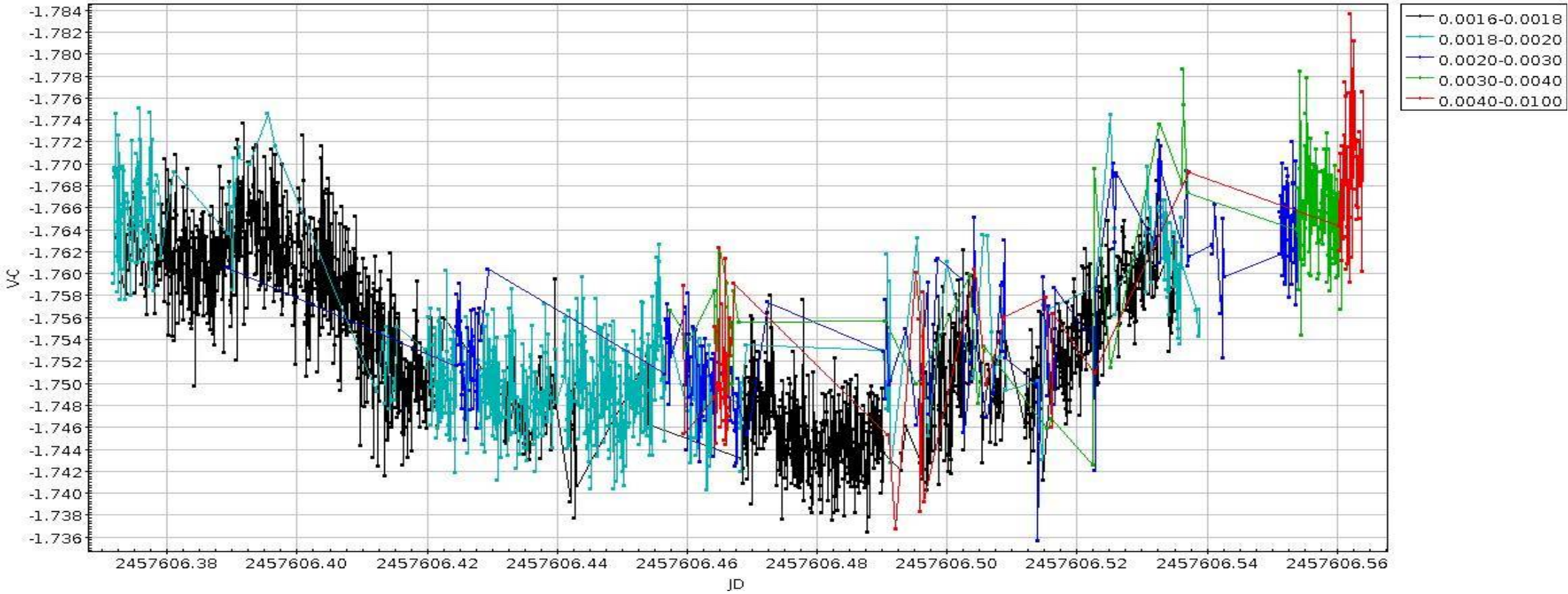
sig(V-C) = 0.0018 ÷ 0.0020 mag

sig(V-C) = 0.0020 ÷ 0.0030 mag

sig(V-C) = 0.0030 ÷ 0.0040 mag

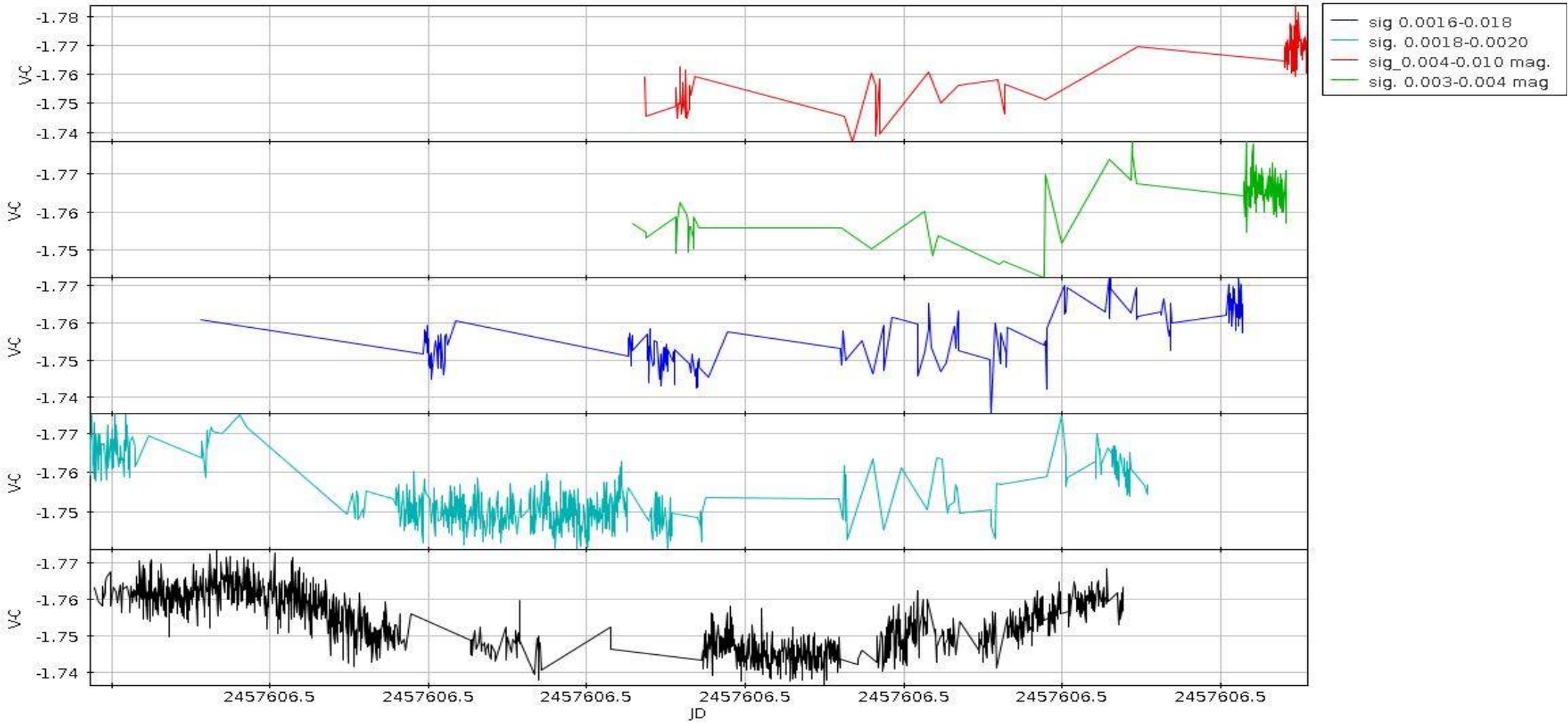
sig(V-C) = 0.0040 ÷ 0.0100 mag

Photometry quality



sig(V-C) = 0.0016 ÷ 0.0018 mag
sig(V-C) = 0.0018 ÷ 0.0020 mag
sig(V-C) = 0.0020 ÷ 0.0030 mag
sig(V-C) = 0.0030 ÷ 0.0040 mag
sig(V-C) = 0.0040 ÷ 0.0100 mag

Photometry quality



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Variable Star and Exoplanet Section
of Czech Astronomical Society

B.R.N.O. MEDÚZA TRESCA HERO

ETD ... complete ... worldwide ... continuously growing ... Exoplanet Transit Database
http://var.astro.cz/ETD

Known transiters:

- CoRoT-1 b
- CoRoT-10 b
- CoRoT-11 b
- CoRoT-12 b
- CoRoT-13 b
- CoRoT-17 b
- CoRoT-18 b
- CoRoT-19 b
- CoRoT-2 b
- CoRoT-20 b
- CoRoT-3 b
- CoRoT-4 b
- CoRoT-5 b
- CoRoT-6 b
- CoRoT-8 b
- CoRoT-9 b
- EPIC-203771098 b

ETD - Exoplanet Transit Database

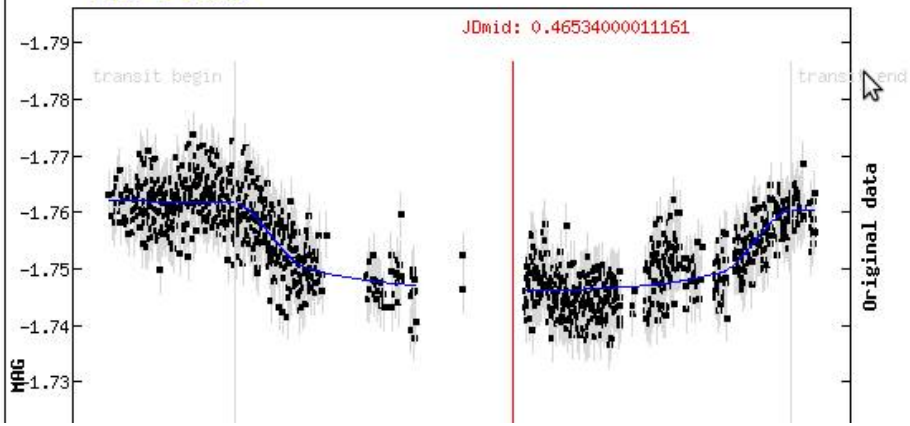
Observers community | How to contribute to ETD | Model-fit your data | Transit predictions | KEPLER Transit predictions | KEPLER Candidates

step 3 / 5

INSTRUCTION: If you are satisfied with result of fitting procedure and all three parameters HJDmid, Duration and Depth has been computed right, you can **send your observation to TRESCA database (and to ETD)**. In next steps, you'll be asked for all necessary informations.

TIP: There is text box under the light curve, where is result of a fitting procedure. You can copy and paste the data and re-plot and use them as you want.

HAT-P-16 b



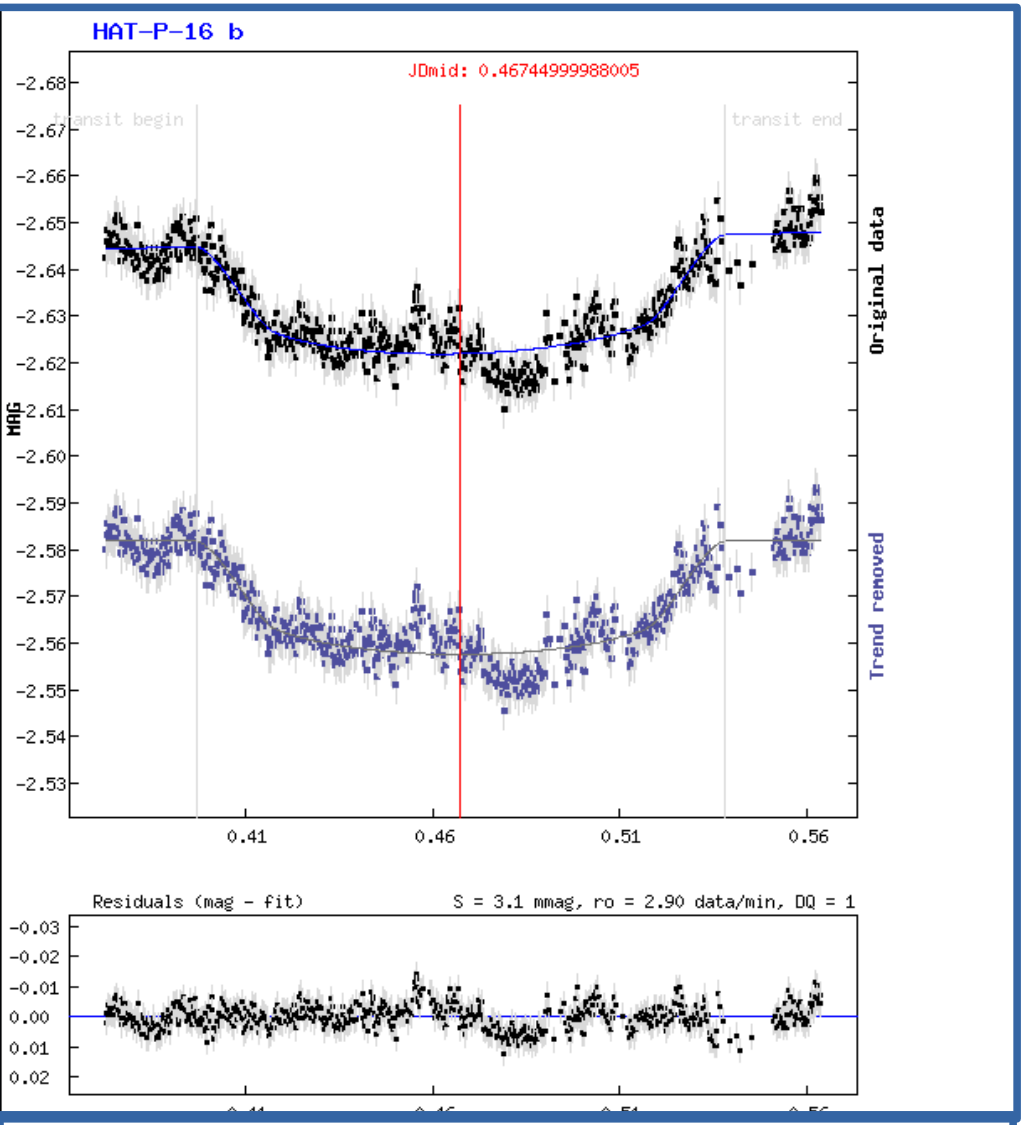
What's new: | Archive

ETD - Exoplanet Transit Database
December 17, 2014

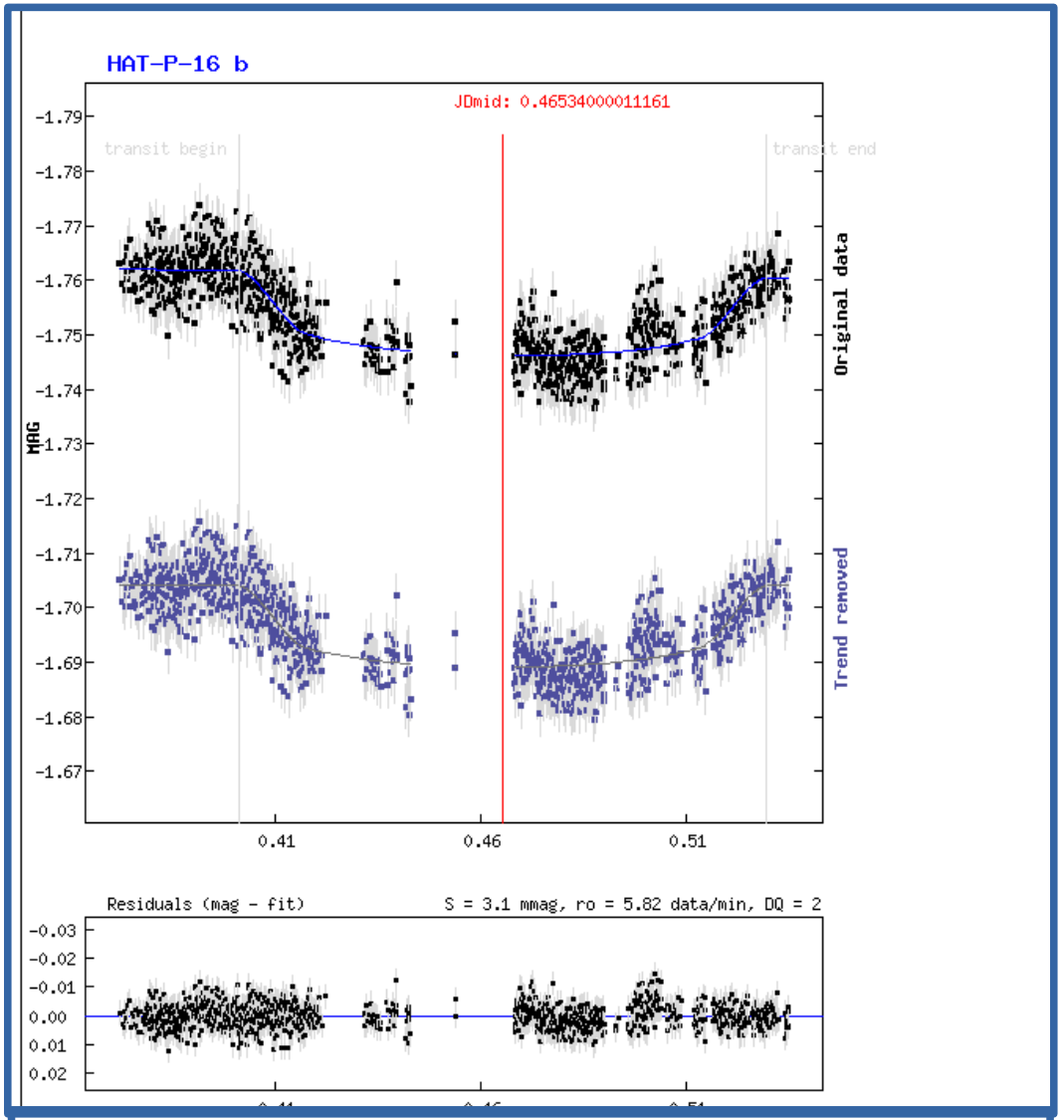
Dear observers, Exoplanet Transit Database is back on-line!

You can use all its features as usually. Sorry for long shutdown.
http://var2.astro.cz/ETD

Transit from all CCD frames and best quality (sig=0.0016÷0.0018 mag) data



All transit data



Transit data from best quality photometry sig=0.0016÷0.0018 mag.

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HAT-P-16 b (And)

RA (J2000): **00 38 17.59**, DE (J2000): **+42 27 47.2**,
V = **10.8 mag**, dV = **0.0101 mag**, duration = **184 minutes**

Per = 2.77596 **d**, T0(HJD) = 2455027.59293 compute

All transit data

JD mid: 2457606.46745 +/- 0.00037

HJD mid: 2457606.4688 +/- 0.00037 (helcor = **0.00135**)

Duration: 203.2 +/- 1.3 minutes

Depth: 0.0242 +/- 0.0004 mag

```
JD, mag, mag_fit, mag-mag_fit, rescaled error, mag-trend, ma
#midtransit: 0.467449 +/- 0.000372
#depth: 0.024198 +/- 0.000368
#duration:  0.141092 +/- 0.000879
0.372730 -2.642500 -2.644414 0.001914 0.004008 0.001914 0.00
0.372940 -2.645900 -2.644418 -0.001482 0.004008 -0.001482 0.
0.373140 -2.648400 -2.644422 -0.003978 0.004008 -0.003978 0.
0.373340 -2.645400 -2.644426 -0.000974 0.004008 -0.000974 0.
0.373550 -2.646000 -2.644430 -0.001570 0.004008 -0.001570 0.
0.373750 -2.647600 -2.644433 -0.003167 0.004008 -0.003167 0.
```

> Show transit in ETD <

Send protocol to TRESCA database >

Transit data from best photometry

JD mid: 2457606.46534 +/- 0.00037

HJD mid: 2457606.46669 +/- 0.00037 (helcor = **0.00135**)

Duration: 184.2 +/- 1.2 minutes

Depth: 0.0149 +/- 0.0004 mag

```
JD, mag, mag_fit, mag-mag_fit, rescaled error, mag-trend, ma
#midtransit: 0.465342 +/- 0.000373
#depth: 0.014919 +/- 0.000358
#duration:  0.127895 +/- 0.000801
0.372320 -1.763290 -1.762076 -0.001214 0.003983 -0.001214 0.
0.372940 -1.759280 -1.762070 0.002790 0.003983 0.002790 0.00
0.373620 -1.758180 -1.762064 0.003884 0.003983 0.003884 0.00
0.373690 -1.763530 -1.762063 -0.001467 0.003983 -0.001467 0.
0.373960 -1.760330 -1.762060 0.001730 0.003983 0.001730 0.00
0.374030 -1.761660 -1.762060 0.000400 0.003983 0.000400 0.00
```

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Send protocol to TRESCA database >

Conclusions

- During the observational night the photometric conditions varied according to the meteorological issues.

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- During the observational night the photometric conditions varied according to the meteorological issues.
- The beginning and the end of the transit was observed at the time of the best photometric quality.
- **The best transit duration time determined using the selection of the best photometry data instead of all the data. (best agreement with the EDT database and our determined light curve)**

And small can be great !!!

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And finally, the biggest thanks to our best supervisor Erika Pakštienė for her important assistance in this project.

Thank you for your attention

Questions?