Lecture 8

October 25, 2017

Lab 5

News

- Lab 2 & 3
  - Handed back next week (I hope).
- Lab 4
  - Due today
- Lab 5 (Transiting Exoplanets)
  - Handed out and observing will start Friday.
  - Due November 8 (or later)

Stellar Photometry in Images

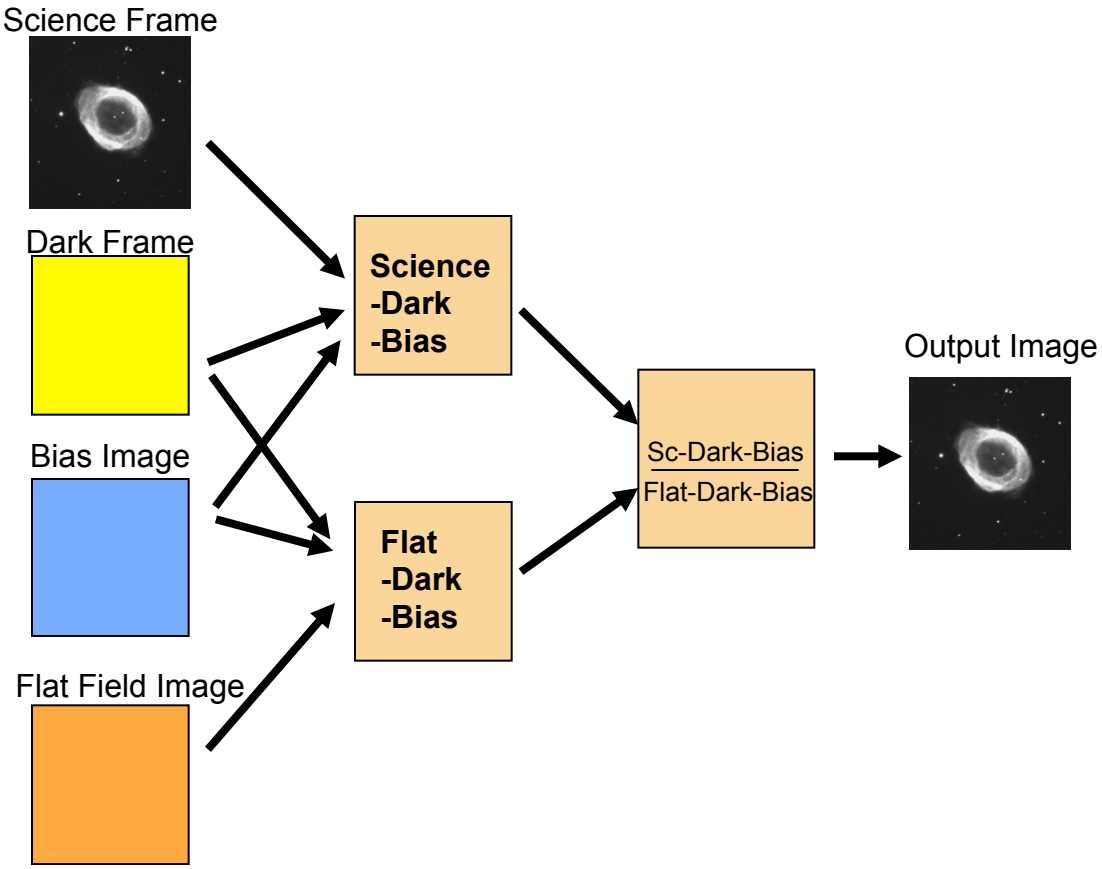
- Lab 5: Measuring the Transit of an Exoplanet
  - Determines the radius of the planet (and it's orbital period if observe multiple transits).
- The basic method is to measure the brightnesses of stars in images.
  - Will perform differential photometry by using stars in the field with known magnitudes.

Photometry in Images

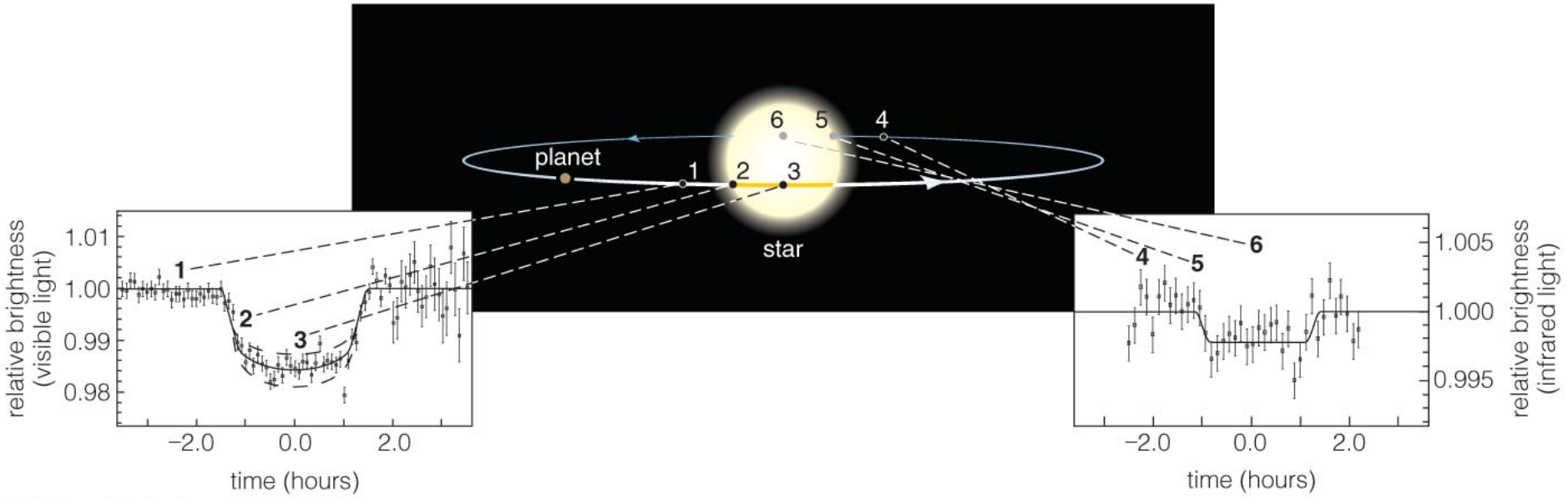
- Correct the image to a uniform, linear response.
  - Dark current and bias level subtraction either
    - done at the telescope with *autodark* subtraction or
    - done by taking separate dark images and subtracting them from the science images later.
  - Need to create an average image of a uniformly illuminated field ("flat field") and divide by it.
    - The mkflatru command.
- Identify your target and comparison stars.
- Measure the brightness of stars in all of the images.

CCD calibration

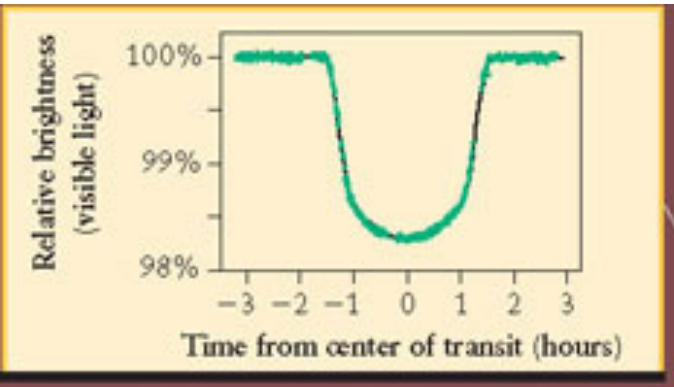
If there is significant dark current present:



Exoplanet Transits and Eclipses

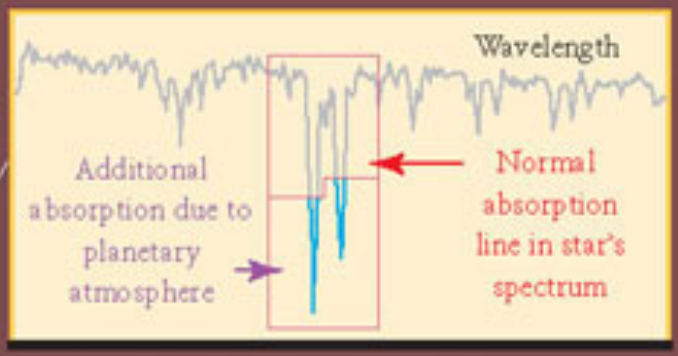


- A **transit** is when a planet crosses in front of a star.
- The resulting eclipse reduces the star's apparent brightness and this tells us the planet's radius (if the star's radius is known).
- Because the orbit must be nearly edge on, such systems can yield accurate measurements of planetary mass.



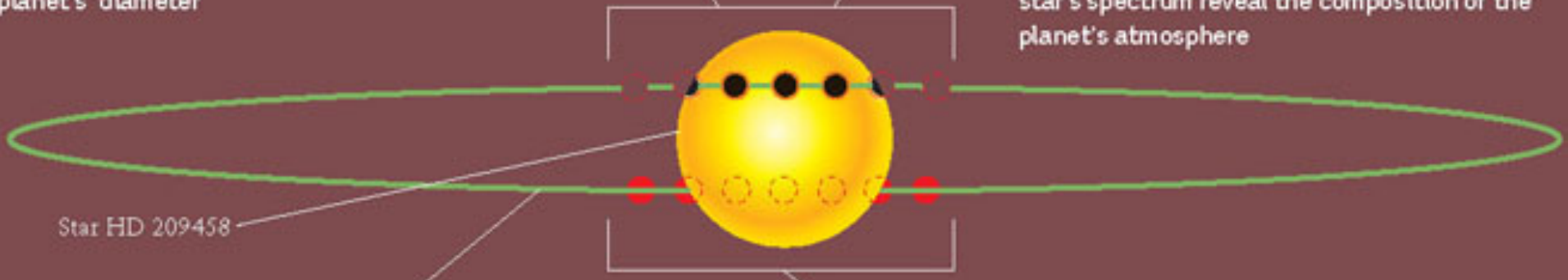
(a) When the planet transits (moves in front of) the star, it blocks out part of the star's visible light

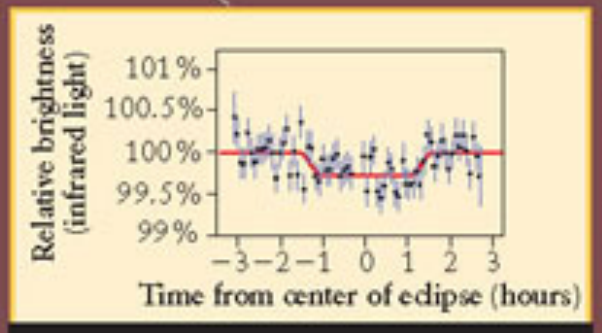
- The amount of dimming tells us the planet's diameter



(b) When the planet transits the star, some light from the star passes through the planet's atmosphere on its way to us

- The additional absorption features in the star's spectrum reveal the composition of the planet's atmosphere

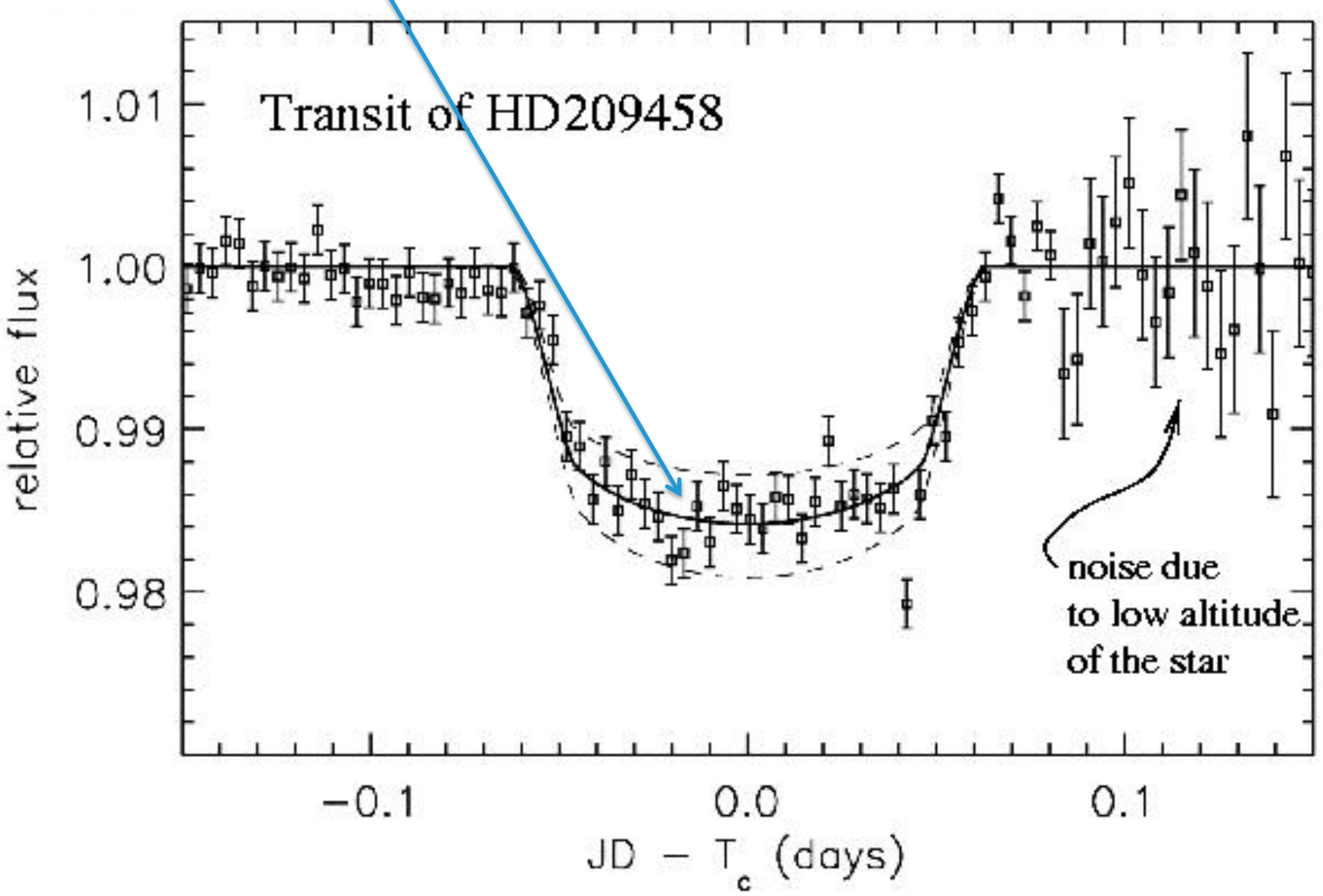




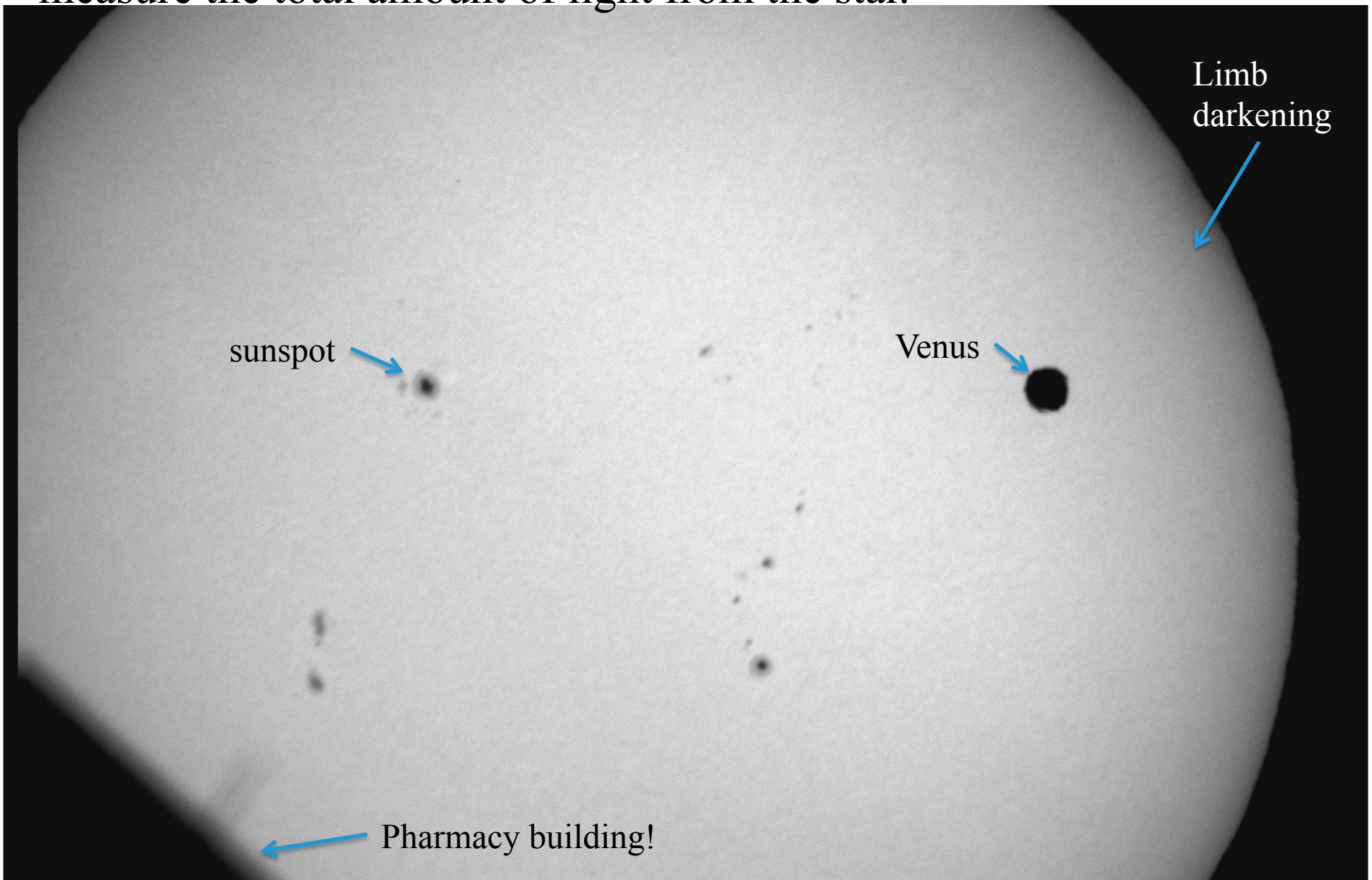
(c) When the planet moves behind the star, the infrared glow from the planet's surface is blocked from our view

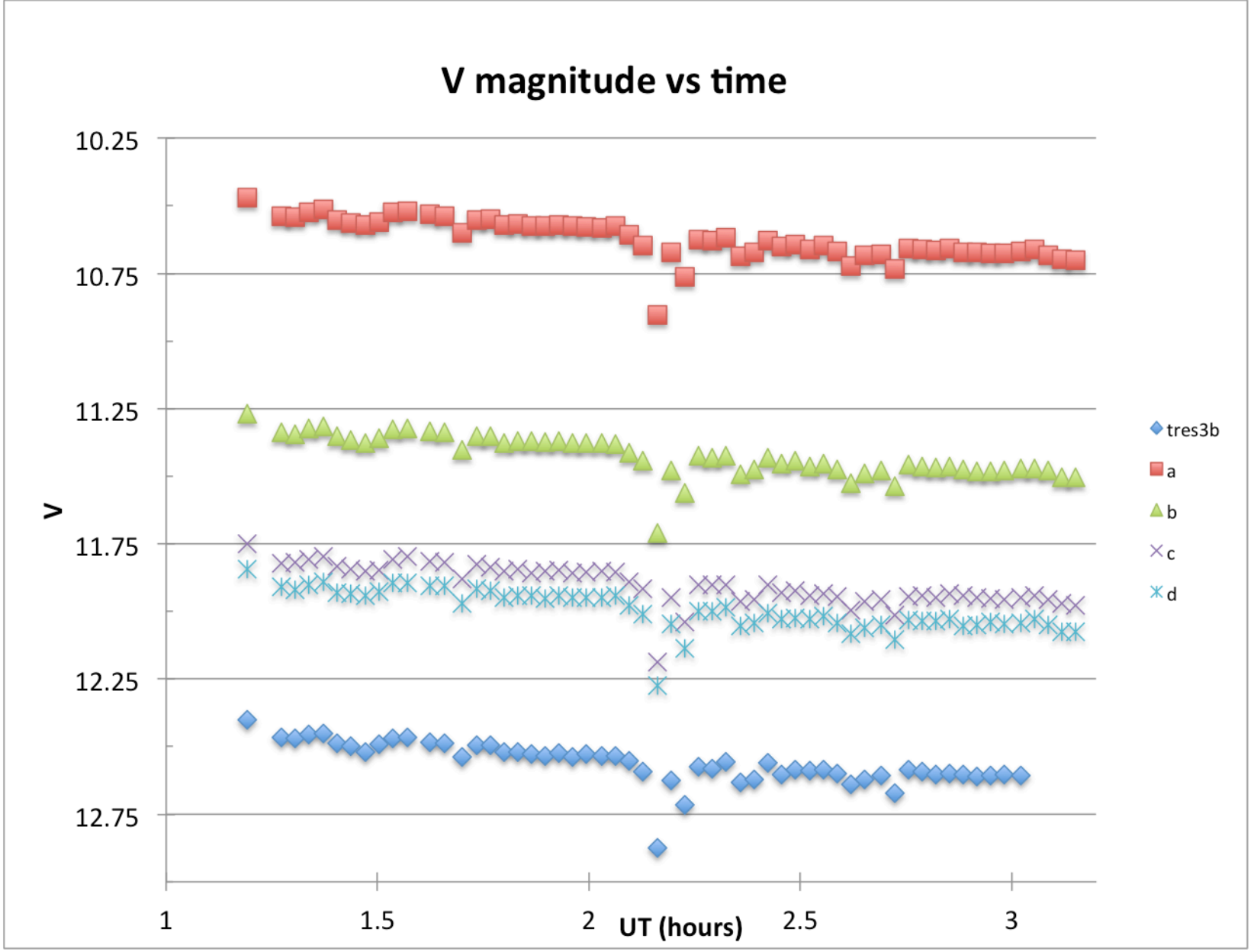
- The amount of infrared dimming tells us the planet's surface temperature

An example of a light curve for the first known transiting exoplanet. Note the curvature due to the non-constant stellar surface brightness.

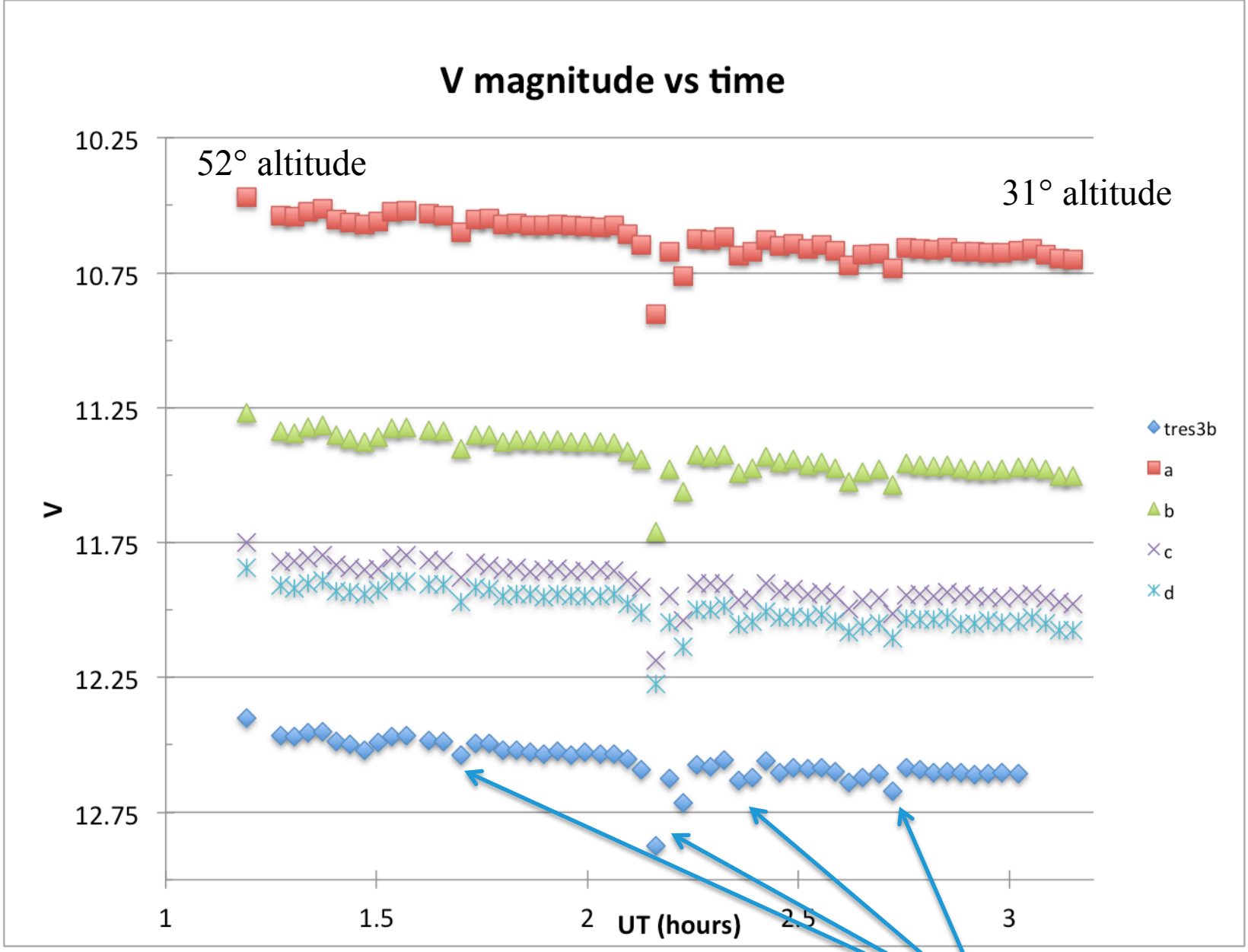


An analogy is the transit of Venus across the Sun observed at the Schommer Observatory this summer. With exoplanets we can only measure the total amount of light from the star.

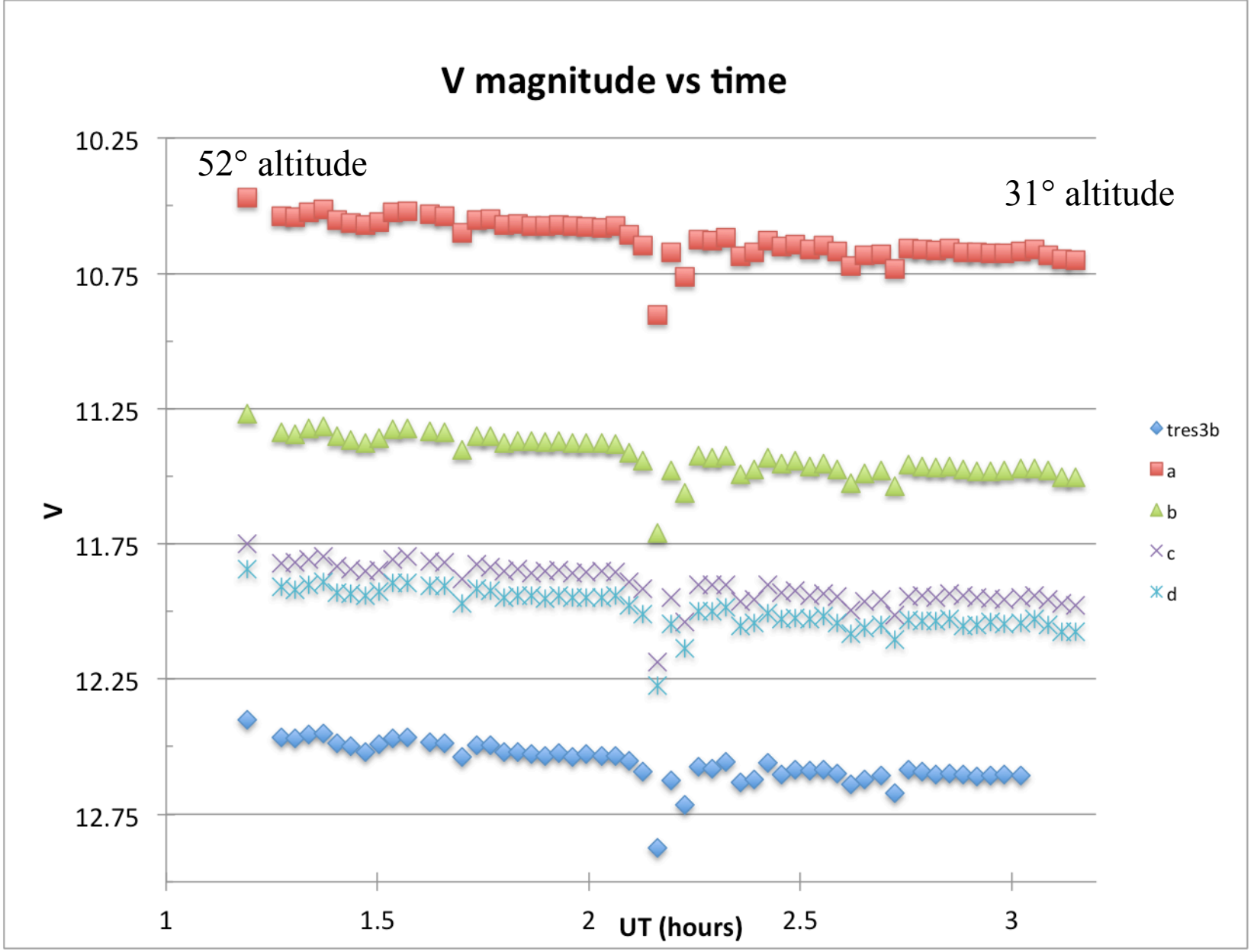




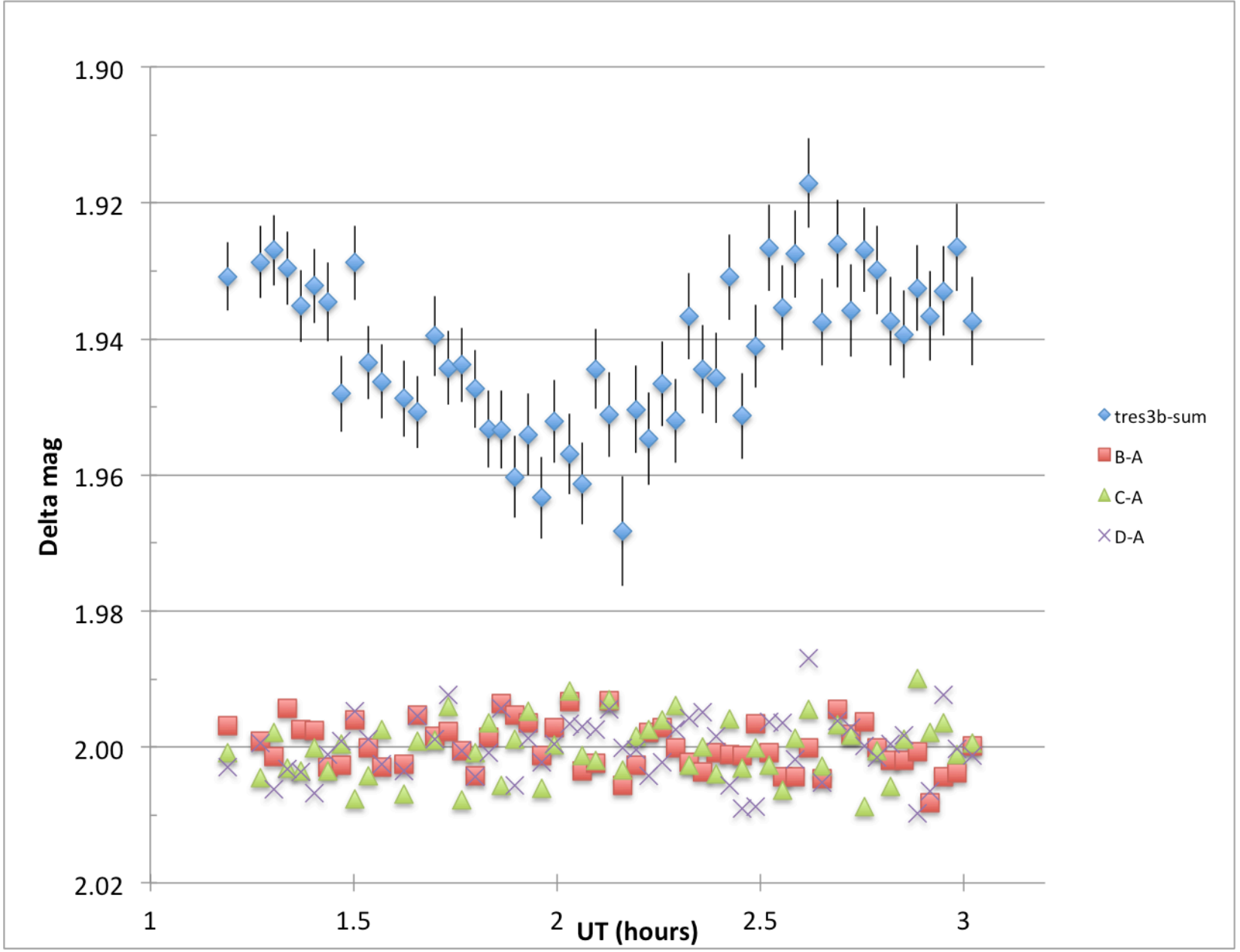
V magnitudes *vs* time for TrES-3 b and four brighter comparison stars. What explains the behavior of V with time?



All stars in the field dimmed by passing thin clouds.
The smooth decrease with time is caused by increasing airmass.



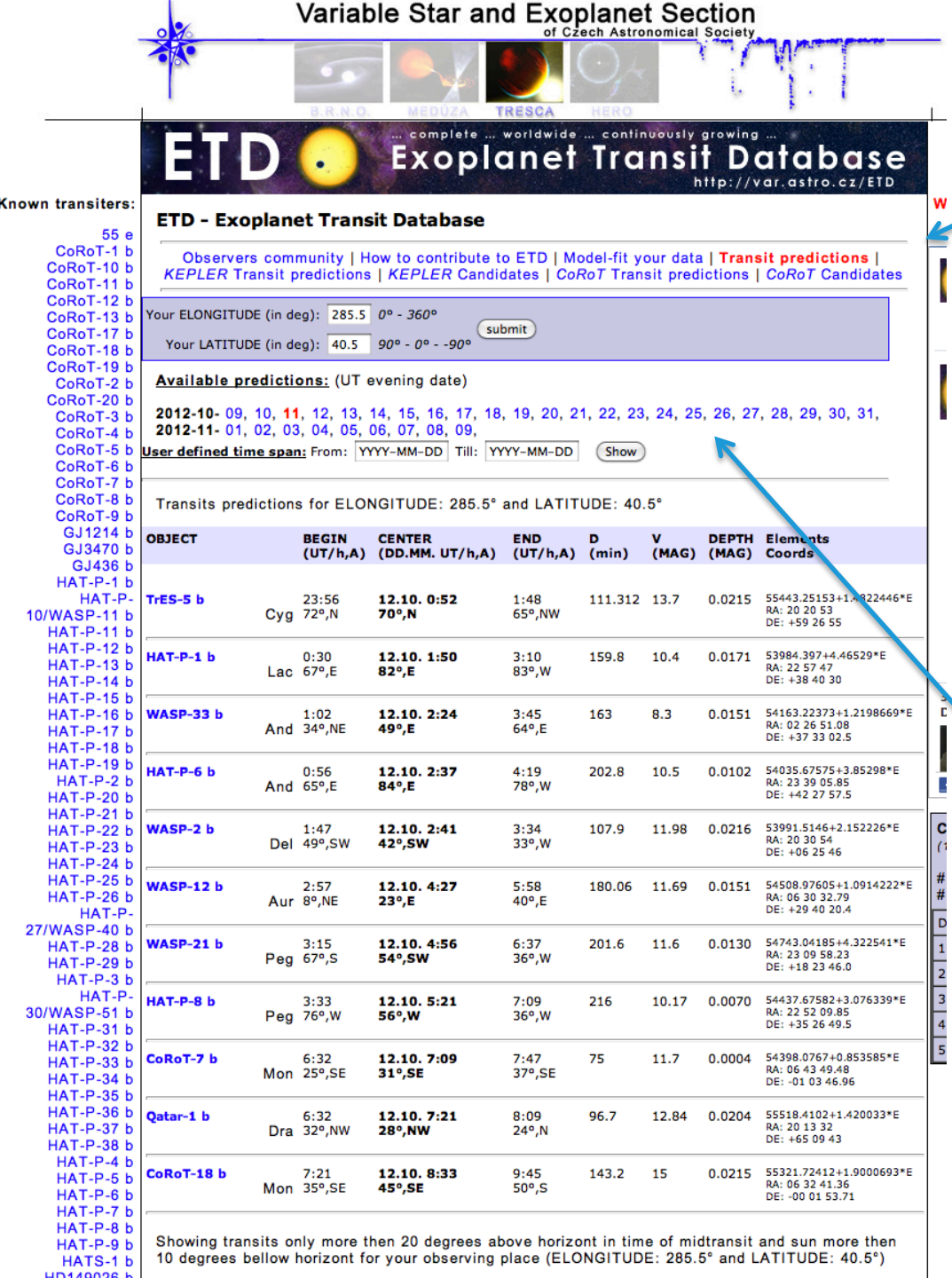
So taking the difference in magnitudes of different stars in the field will remove atmospheric effects.



Difference between the magnitude of a star and a comparison star.

Lab 5 Preparation: Choosing the Target

- Examine the transits occuring during your night(s) using the Exoplanet Transit Database.
- Choose the best transit using the criteria:
  - Transit happens during your lab period.
  - The star is bright enough (V < 13.0 or so).
  - Transit depth larger than 0.01 magnitude.
  - The altitude is not too low (preferably 45 degrees or greater).
  - The star does not cross the meridian (or crosses it less than about 45 minutes before the end of observing).



Transit predictions page

Schommer Observatory (east) longitude = 285.5°
Latitude = 40.5°

Lists the transits occurring on a selected night.

CoRoT-8 b
CoRoT-9 b
GJ1214 b
GJ3470 b
GJ436 b
HAT-P-1 b
HAT-P-10/WASP-11 b
HAT-P-11 b
HAT-P-12 b
HAT-P-13 b
HAT-P-14 b
HAT-P-15 b
HAT-P-16 b
HAT-P-17 b
HAT-P-18 b
HAT-P-19 b
HAT-P-2 b
HAT-P-20 b
HAT-P-21 b
HAT-P-22 b
HAT-P-23 b
HAT-P-24 b
HAT-P-25 b
HAT-P-26 b
HAT-P-27/WASP-40 b
HAT-P-28 b
HAT-P-29 b
HAT-P-3 b
HAT-P-30/WASP-51 b
HAT-P-31 b
HAT-P-32 b
HAT-P-33 b
HAT-P-34 b
HAT-P-35 b
HAT-P-36 b
HAT-P-37 b
HAT-P-38 b
HAT-P-4 b
HAT-P-5 b
HAT-P-6 b
HAT-P-7 b
HAT-P-8 b
HAT-P-9 b
HATS-1 b

Transits predictions for ELONGITUDE: 285.5° and LATITUDE: 40.5°

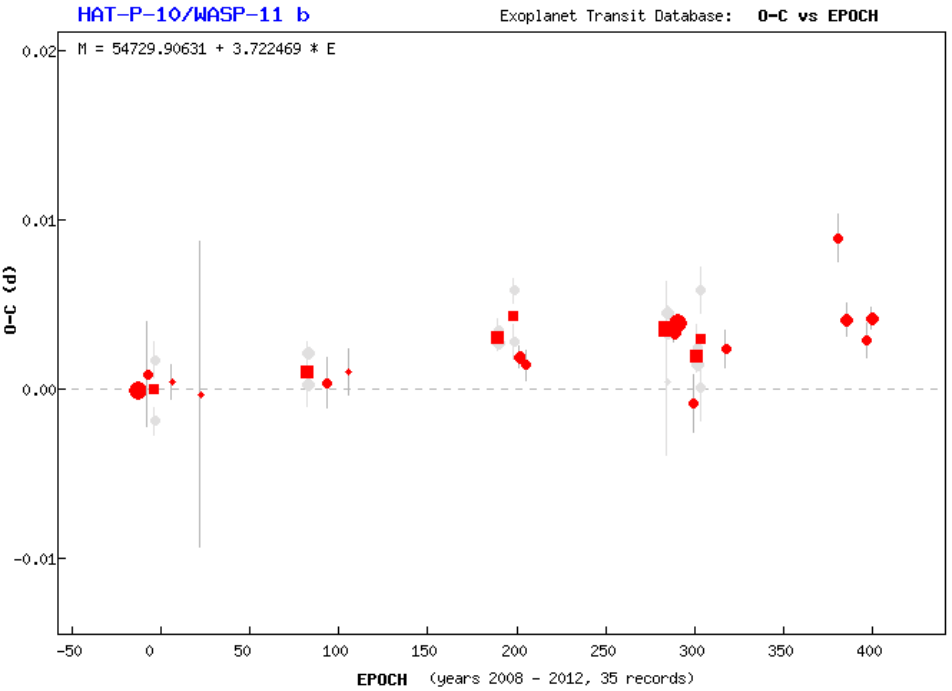
OBJECT	BEGIN (UT/h,A)	CENTER (DD.MM. UT/h,A)	END (UT/h,A)	D (min)	V (MAG)	DEPTH (MAG)	Elements Coords
TrES-5 b Cyg	23:56 72°,N	**12.10. 0:52** **70°,N**	1:48 65°,NW	111.312	13.7	0.0215	55443.25153+1.4822446*E RA: 20 20 53 DE: +59 26 55
HAT-P-1 b Lac	0:30 67°,E	**12.10. 1:50** **82°,E**	3:10 83°,W	159.8	10.4	0.0171	53984.397+4.46529*E RA: 22 57 47 DE: +38 40 30
WASP-33 b And	1:02 34°,NE	**12.10. 2:24** **49°,E**	3:45 64°,E	163	8.3	0.0151	54163.22373+1.2198669*E RA: 02 26 51.08 DE: +37 33 02.5
HAT-P-6 b And	0:56 65°,E	**12.10. 2:37** **84°,E**	4:19 78°,W	202.8	10.5	0.0102	54035.67575+3.85298*E RA: 23 39 05.85 DE: +42 27 57.5
WASP-2 b Del	1:47 49°,SW	**12.10. 2:41** **42°,SW**	3:34 33°,W	107.9	11.98	0.0216	53991.5146+2.152226*E RA: 20 30 54 DE: +06 25 46
WASP-12 b Aur	2:57 8°,NE	**12.10. 4:27** **23°,E**	5:58 40°,E	180.06	11.69	0.0151	54508.97605+1.0914222*E RA: 06 30 32.79 DE: +29 40 20.4
WASP-21 b Peg	3:15 67°,S	**12.10. 4:56** **54°,SW**	6:37 36°,W	201.6	11.6	0.0130	54743.04185+4.322541*E RA: 23 09 58.23 DE: +18 23 46.0
HAT-P-8 b Peg	3:33 76°,W	**12.10. 5:21** **56°,W**	7:09 36°,W	216	10.17	0.0070	54437.67582+3.076339*E RA: 22 52 09.85 DE: +35 26 49.5
CoRoT-7 b Mon	6:32 25°,SE	**12.10. 7:09** **31°,SE**	7:47 37°,SE	75	11.7	0.0004	54398.0767+0.853585*E RA: 06 43 49.48 DE: -01 03 46.96
Qatar-1 b Dra	6:32 32°,NW	**12.10. 7:21** **28°,NW**	8:09 24°,N	96.7	12.84	0.0204	55518.4102+1.420033*E RA: 20 13 32 DE: +65 09 43
CoRoT-18 b Mon	7:21 35°,SE	**12.10. 8:33** **45°,SE**	9:45 50°,S	143.2	15	0.0215	55321.72412+1.9000693*E RA: 06 32 41.36 DE: -00 01 53.71

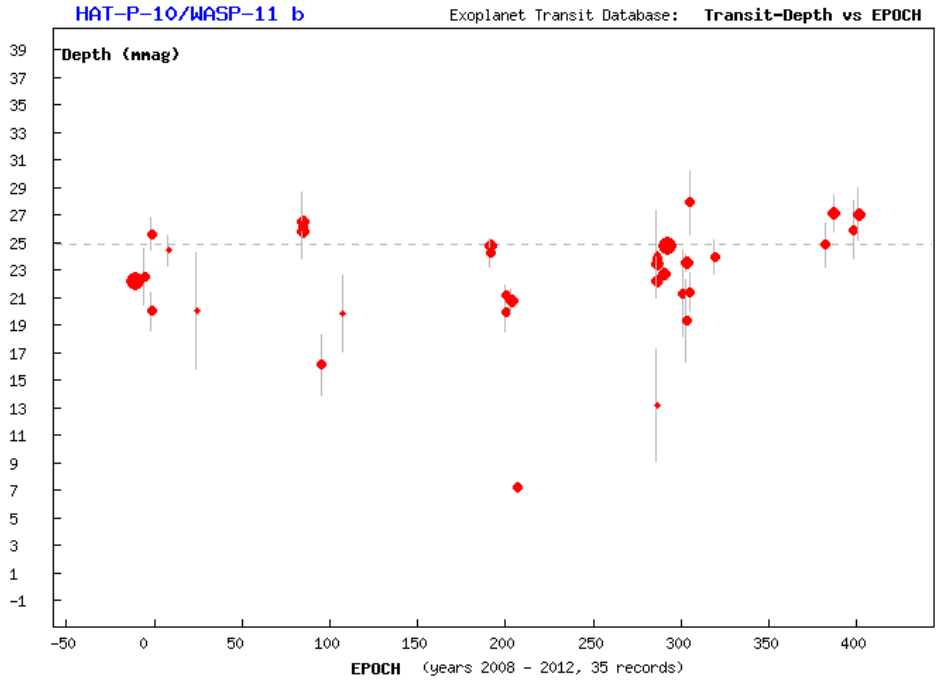
Showing transits only more then 20 degrees above horizont in time of midtransit and sun more then 10 degrees bellow horizont for your observing place (ELONGITUDE: 285.5° and LATITUDE: 40.5°)

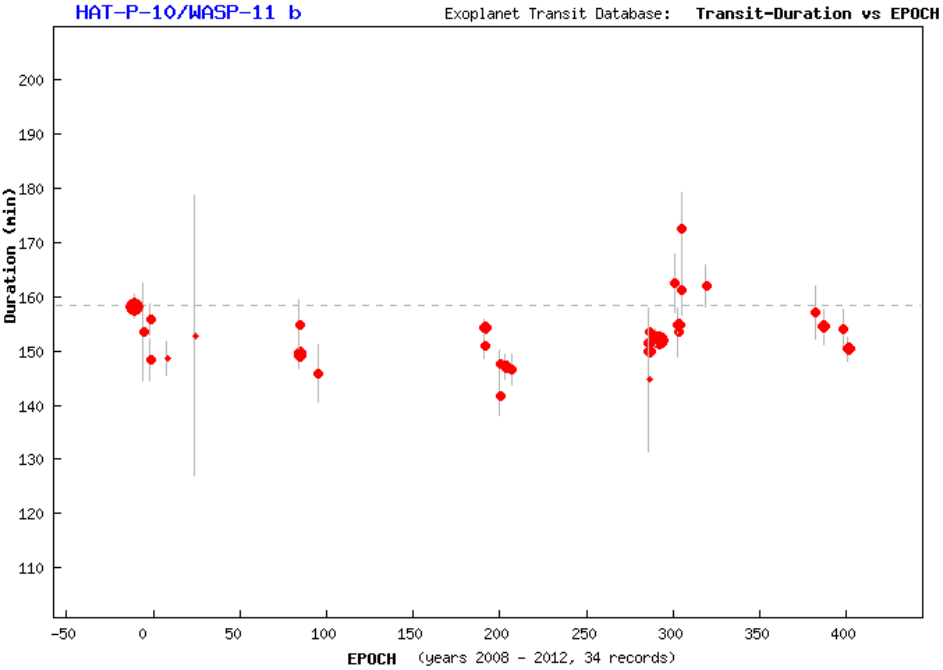
Dates and times in UT = EDT + 4 hours. So these transits are for the evening of Oct 11th.

Lab 5 Preparation: Choosing the Target

- Examine the transits occurring during your night(s) using the Exoplanet Transit Database.
- Choose the best transit using the criteria:
  - Transit happens during your lab period.
  - The star is bright enough (V < 13.0 or so).
  - Transit depth larger than 0.01 magnitude.
  - The altitude is not too low (preferably >=45°).
- Must then use *The Sky* to check:
  - Is a good guide star (brighter than 10^{th}) available.
  - Is there at least one comparison star available in the field of view of the main CCD.







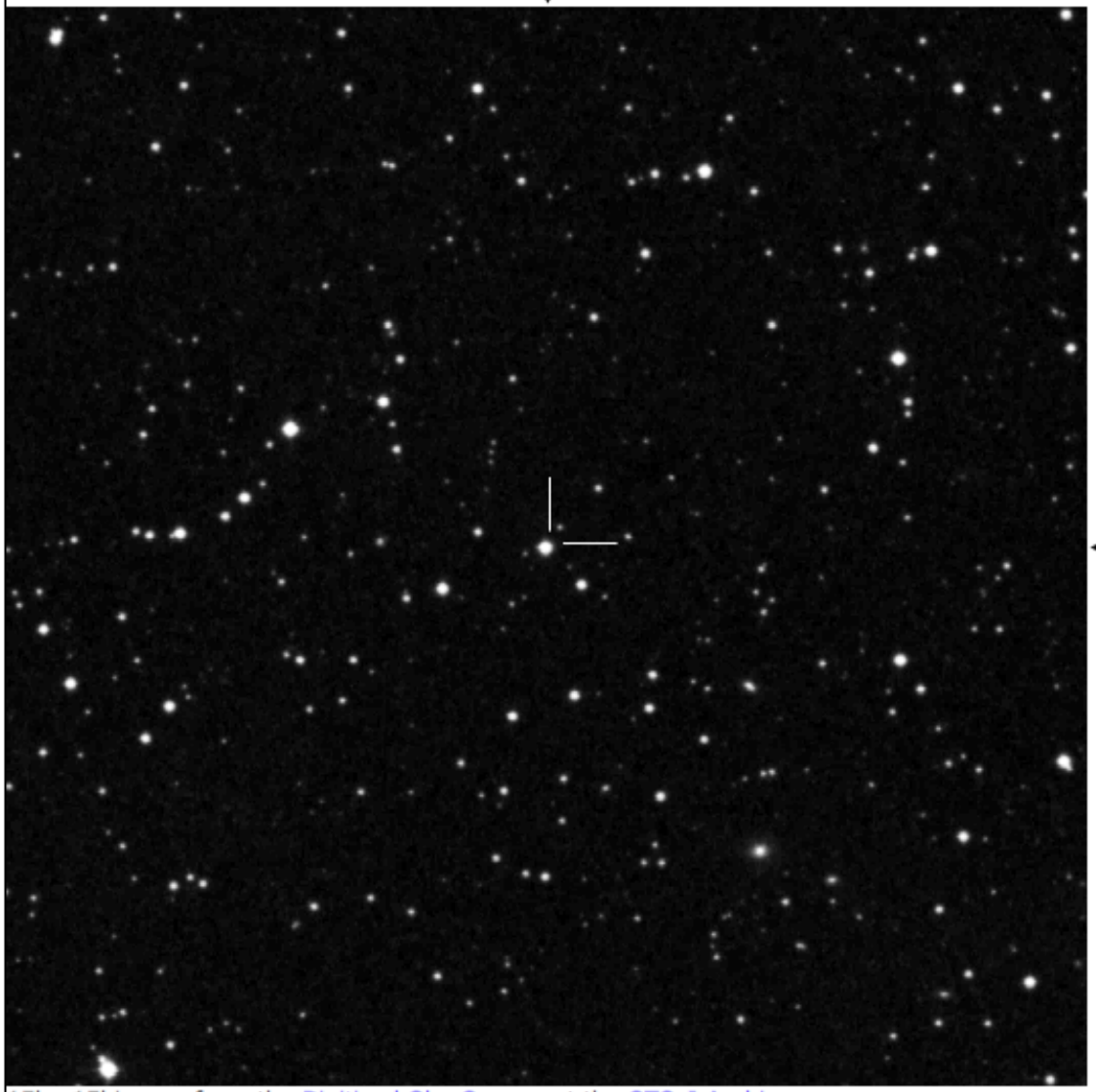
Clicking on the name of a target in the list along the left-hand side of the Exoplanet Transit Database displays recent observations of the star. These are useful for deciding how accurate the predicted start and end time are.

Observing for Lab 5

- Initial planning:
  - Use The Sky to identify nearby bright star to slew to and check pointing (3rd magnitude or brighter).
  - Also identify a nearby 7-8th magnitude focus star.
  - Plan how to get the guide star onto the small field of view of the guide CCD.

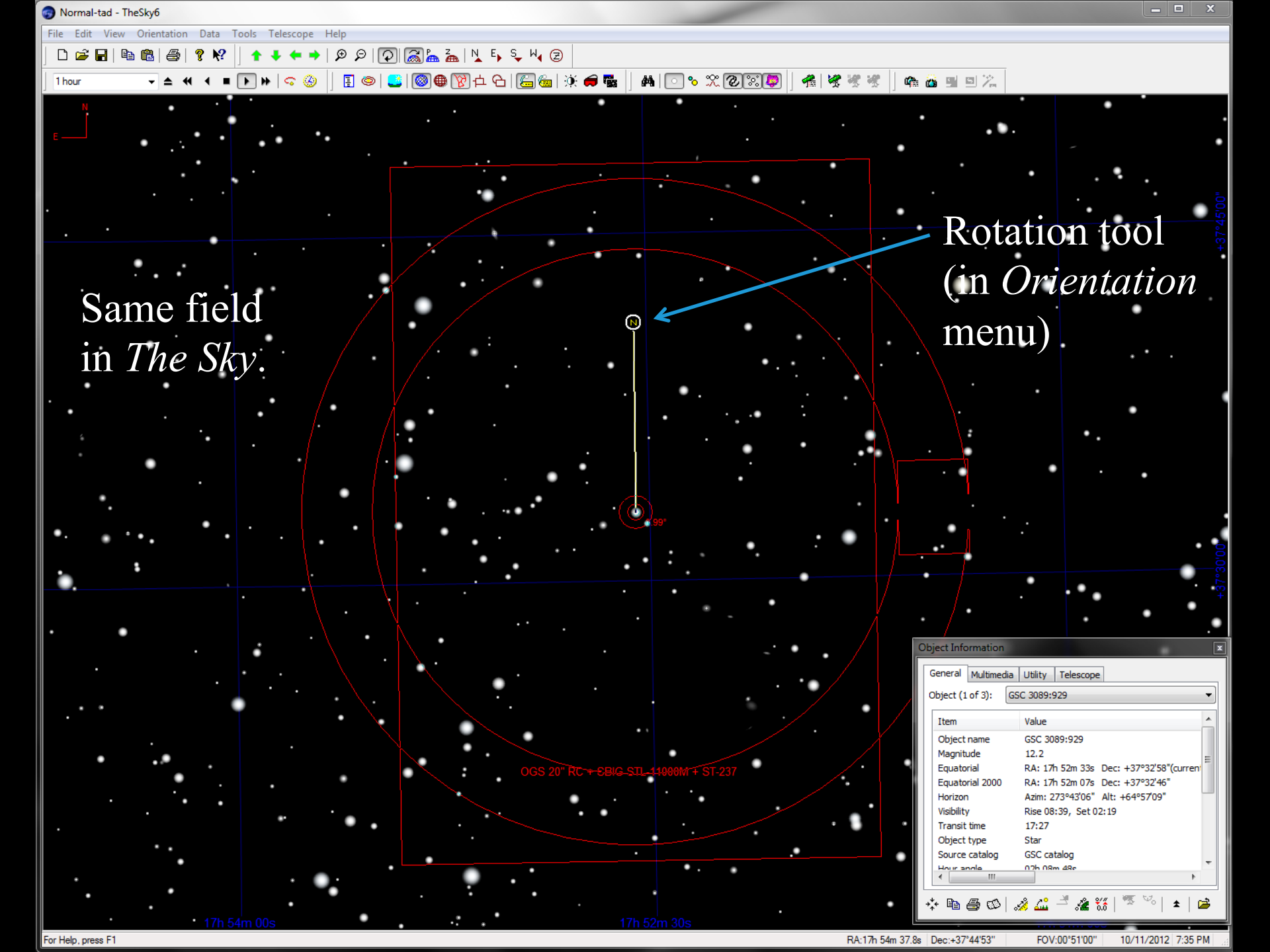
TrES-3 b (Her)

RA (J2000): **17 52 07**, DE (J2000): **+37 32 46**,
V = **12.4 mag**, dV = **0.0291 mag**, duration = **77.4 minutes**
Per = 1.3061860 **d**, T0(HJD) = 2454538.5806 compute



15' x 15' image from the Digitized Sky Survey at the STScI Archive.

Clicking on the object name brings up a finding chart. North is up, east to the left (this is conventional for astronomical images). Image width is a little less than the short side of our camera field of view.


Normal-tad - TheSky6
File Edit View Orientation Data Tools Telescope Help
1 hour
Same field in *The Sky*.
Rotation tool (in *Orientation* menu)
N
99°
OGS 20" RC + SBIG STL-11000M + ST-237
17h 54m 00s
17h 52m 30s
+37°45'00"
+37°30'00"
Object Information
General Multimedia Utility Telescope
Object (1 of 3): GSC 3089:929
Item Value
Object name GSC 3089:929
Magnitude 12.2
Equatorial RA: 17h 52m 33s Dec: +37°32'58"(curren
Equatorial 2000 RA: 17h 52m 07s Dec: +37°32'46"
Horizon Azim: 273°43'06" Alt: +64°57'09"
Visibility Rise 08:39, Set 02:19
Transit time 17:27
Object type Star
Source catalog GSC catalog
For Help, press F1
RA:17h 54m 37.8s Dec:+37°44'53" FOV:00°51'00" 10/11/2012 7:35 PM

Observing for Lab 5

- While observing:
  - Make sure that you start a new block of observations when then current one ends.
  - Keep checking and, if necessary, adjusting the dome slit so that the dome does not block the telescope aperture.
  - Keep an eye on the guide star to make sure that it has not disappeared (clouds or tracking failure).

Transits predictions for ELONGITUDE: 285.5° and LATITUDE: 40.5°

OBJECT	BEGIN (UT/h,A)	CENTER (DD.MM. UT/h,A)	END (UT/h,A)	D (min)	V (MAG)	DEPTH (MAG)	Elements Coords
Kepler-7 b Lyr	20:15 72°,E	**24.10. 22:57** **79°,W**	1:39 50°,W	324	13.9	0.0081	54967.27571+4.885525*E RA: 19 14 19.6 DE: +41 05 23.3
Qatar-5 b And	21:49 33°,NE	**24.10. 23:17** **48°,E**	0:44 63°,E	174.5	12.62	0.0119	57336.758242+2.8792319*E RA: 00 28 12.94 DE: +42 03 40.9
WASP-2 b Del	22:39 56°,S	**24.10. 23:33** **56°,S**	0:27 53°,SW	107.9	11.98	0.0216	53991.5146+2.15222144*E RA: 20 30 54 DE: +06 25 46
CoRoT-3 b Aql	21:59 50°,S	**24.10. 23:47** **44°,SW**	1:34 30°,SW	215	13.3	0.0054	54283.1383+4.2568*E RA: 19 28 13.30 DE: +00 07 18.19
WASP-151 b Psc	22:03 24°,E	**24.10. 23:53** **41°,SE**	1:43 50°,S	219.6	12.9	0.0110	57741.0081+4.533471*E RA: 23 16 15.22 DE: +00 18 24.5
HAT-P-6 b And	22:46 51°,E	**25.10. 0:28** **69°,E**	2:09 87°,NE	202.8	10.5	0.0094	54035.67575+3.852985*E RA: 23 39 05.85 DE: +42 27 57.5
WASP-52 b Peg	1:31 58°,S	**25.10. 2:25** **58°,S**	3:20 54°,SW	108.58	12	0.0290	55793.68143+1.7497798*E RA: 23 13 58.76 DE: +08 45 40.6
Mascara-1 b Equ	1:01 57°,SW	**25.10. 3:05** **39°,W**	5:10 16°,W	249	8.3	0.0068	57097.278+2.14878*E RA: 21 10 12.37 DE: 10 44 19.9
TrES-5 b Cyg	2:17 55°,NW	**25.10. 3:13** **48°,NW**	4:08 41°,NW	111.312	13.7	0.0215	55443.25153+1.4822446*E RA: 20 20 53 DE: +59 26 55
Qatar-1 b Dra	3:31 46°,NW	**25.10. 4:19** **40°,NW**	5:08 36°,NW	96.7	12.84	0.0204	55518.4102+1.4200246*E RA: 20 13 32 DE: +65 09 43
WASP-141 b Eri	2:45 8°,SE	**25.10. 4:33** **23°,SE**	6:21 30°,S	216	12.4	0.0087	57019.5953+3.310651*E RA: 04 01 32.54 DE: -20 27 03.9
HAT-P-53 b And	6:51 60°,W	**25.10. 7:55** **48°,W**	8:59 37°,NW	128.07	13.73	0.0135	55829.44781+1.9616241*E RA: 01 27 29.5 DE: +38 58 05.3
XO-2 b Lyn	6:42 50°,NE	**25.10. 8:03** **63°,NE**	9:24 75°,NE	162	11.18	0.0124	54466.88454+2.61586178*E RA: 07 48 07 DE: +50 13 33
EPIC-211089792 b Tau	7:12 74°,S	**25.10. 8:19** **67°,SW**	9:25 55°,W	133.2	12.526	0.0215	53219.0095+3.2588321*E RA: 04 10 40.955 DE: +24 24 07.35
WASP-33 b And	8:13 55°,W	**25.10. 9:35** **40°,W**	10:56 26°,NW	163	8.3	0.0151	54163.22373+1.2198669*E RA: 02 26 51.08 DE: +37 33 02.5
HAT-P-43 b Cnc	8:02 38°,E	**25.10. 9:39** **53°,SE**	11:17 60°,S	195.12	13.356	0.0154	55997.37105+3.332688*E RA: 08 35 42.18 DE: +10 12 24.0
HAT-P-25 b Ari	8:36 54°,W	**25.10. 10:00** **38°,W**	11:25 22°,W	169	13.19	0.0204	55176.85173+3.652836*E RA: 03 13 44.48 DE: +25 11 51.2