

Exoplanet Transit Observations with Amateur Equipment

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Considerations

- Already a number of successful detections by advanced amateurs
 - Usually larger telescopes ($>10''$)
 - Cooled CCD (expensive)
 - Guided imaging
- Can amateurs detect exoplanet transits with inexpensive equipment?

Considerations

- Webcam / Firewire cam
 - uncooled
 - 8-bit dynamic range
- Small scope
 - 2'' to 4''
- Unguided imaging
- Method of relative photometry

Problems

- Low dynamic range of the sensor
 - Quickly saturated
 - relatively insensitive to brightness differences
 - Sensitivity needed is much less than one level
- Uncooled sensor
 - Noise much stronger
 - Low SNR
- Unguided imaging
 - Blurring of the stars

Problem resolution

- Intentional defocusing
 - Professionals often use $\text{FWHM} = 3''$ to $4''$
- Much stronger defocusing needed here
 - Prevents quick saturation (only 8-bit!)
- Integrate over all pixels of the star
 - Artificial increase of the dynamic range
 - Much better sensitivity to brightness changes
 - Much improved SNR
 - Limits the effects of image blur

Limitations

- Exposure time increases
- Detection limited to “bright” stars

The brightest exoplanet transit stars

Name	Mag.	Depth (%)	Duration
HD 189733	7.7	2.63	1 ^h 49 ^m
HD 209458	7.7	1.50	3 ^h 04 ^m
HD 149026	8.2	0.29	3 ^h 17 ^m
HD 17156	8.2	0.70	3 ^h 06 ^m
HAT-P-2	8.7	0.49	4 ^h 14 ^m

HD 189733

- Large transit depth
- Short transit
- Constellation Vulpecula
- Observable vom spring through autumn

Observation location

- Suburb of Hannover
- South looking balcony

Instrumentation

- Takahshi FS-60C (+f/6.1 corrector lens)
 - Aperture = 6 cm = 2.4"
 - Focal length = 372 mm
- DMK 31AU03.AS
 - Firewire camera
 - 8-bit dynamic range
 - 1024 x 768 pixel (FOV = 45' x 30')
- German equatorial mount
 - careful polar alignment

Methodology/Processing

- Record uncompressed AVI film
- Dark frame subtraction + flat field
- Align the frames on HD 189733
- Generate an average frame
- Generate a mask
 - only allow pixels of HD 189733 (S_1) and reference stars (S_2)

Methodology/Processing

- Coadd pixels of S_1 and S_2 separately (for each time step)

$$B_i(t) = \sum_{j=0}^{n_i-1} S_{i,j} \quad n_i : \text{Number of pixels in } S_i$$

- Divide the time series + normalization

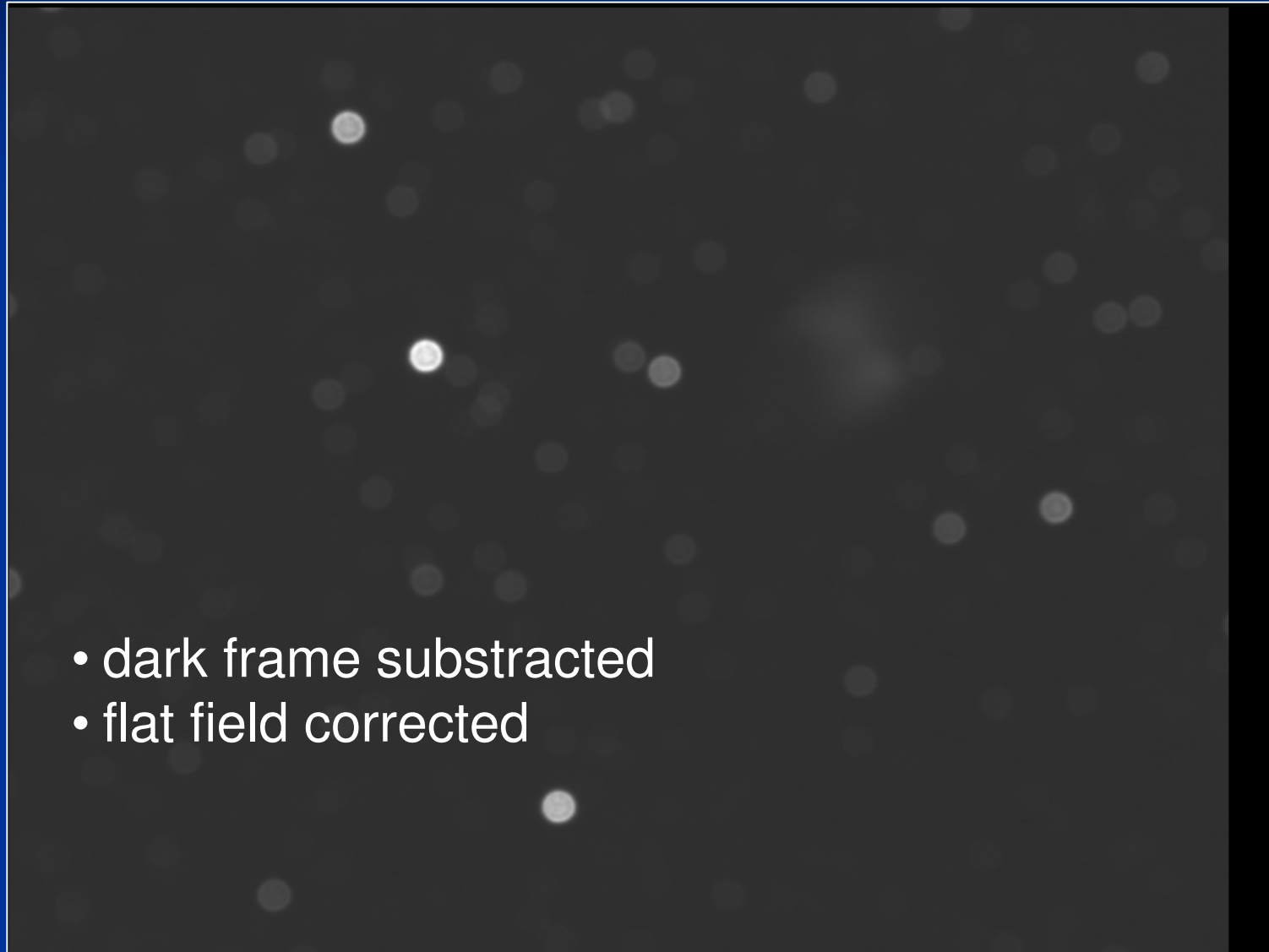
$$r(t) = \frac{B_1}{B_2 \cdot B_1 / B_2}$$

- Fit a transit light curve
 - after MANDEL and AGOL, 2002

Typical single image

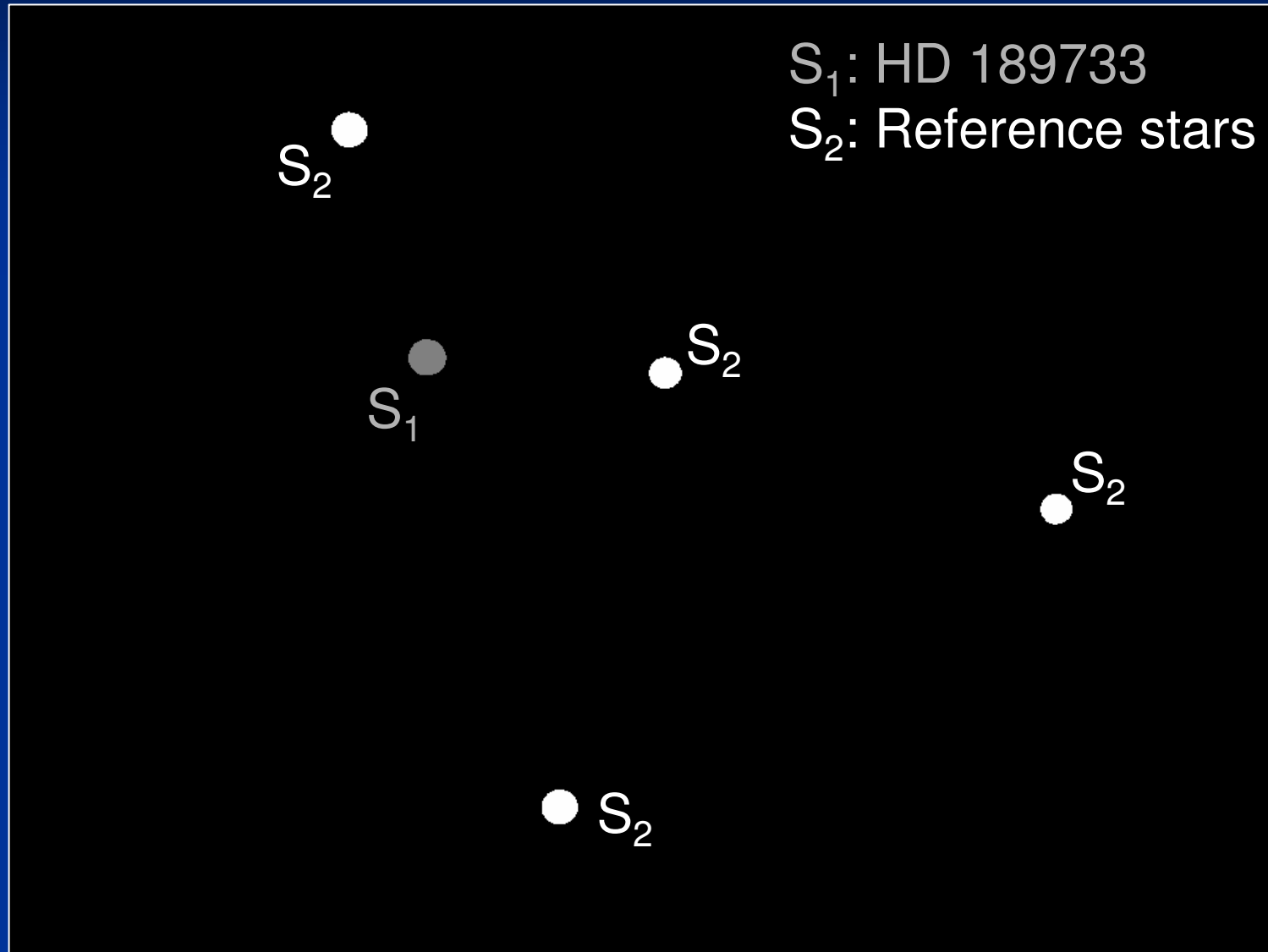


Average frame



- dark frame substracted
- flat field corrected

Mask

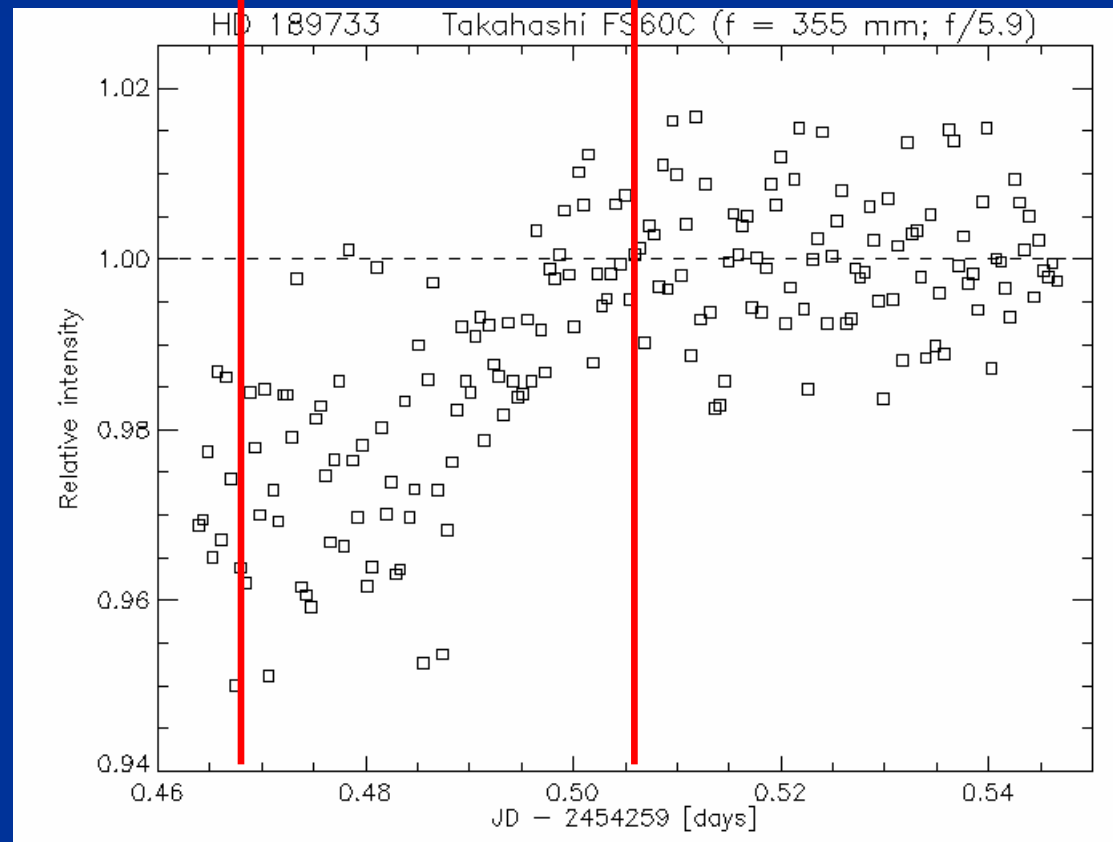


First Observation – 07 June 2007, 23:14 UT

- Ambient temperature: +18°C to +20°C
- Clear skies

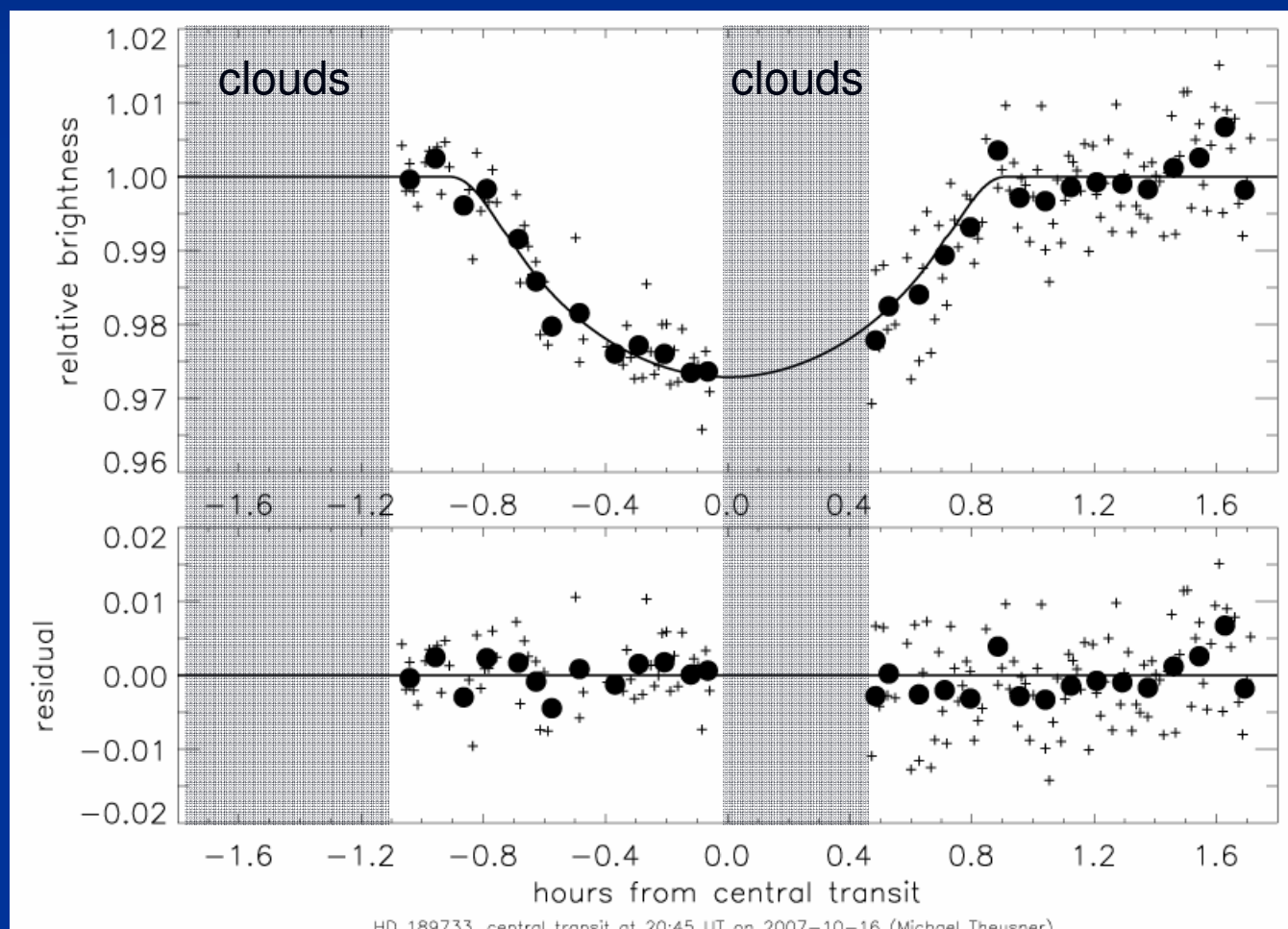
Central transit, 23:14 UT

End of transit, 00:09 UT (08 June)



Second Observation – 16 Oct 2007, 20:45 UT

- Ambient temperature: +12°C to +14°C
- Clear skies, intermittent cloud fields



HD 189733, central transit at 20:45 UT on 2007-10-16 (Michael Theusner)

- + original data points
- 5-minute-average

Summary

- Exoplanet transit observation is possible with modest amateur equipment
- Strong defocusing increases SNR
- Sophisticated data analysis necessary