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 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^h49^m
HD 209458	7.7	1.50	3^h04^m
HD 149026	8.2	0.29	3^h17^m
HD 17156	8.2	0.70	3^h06^m
HAT-P-2	8.7	0.49	4^h14^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 lenght = 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)

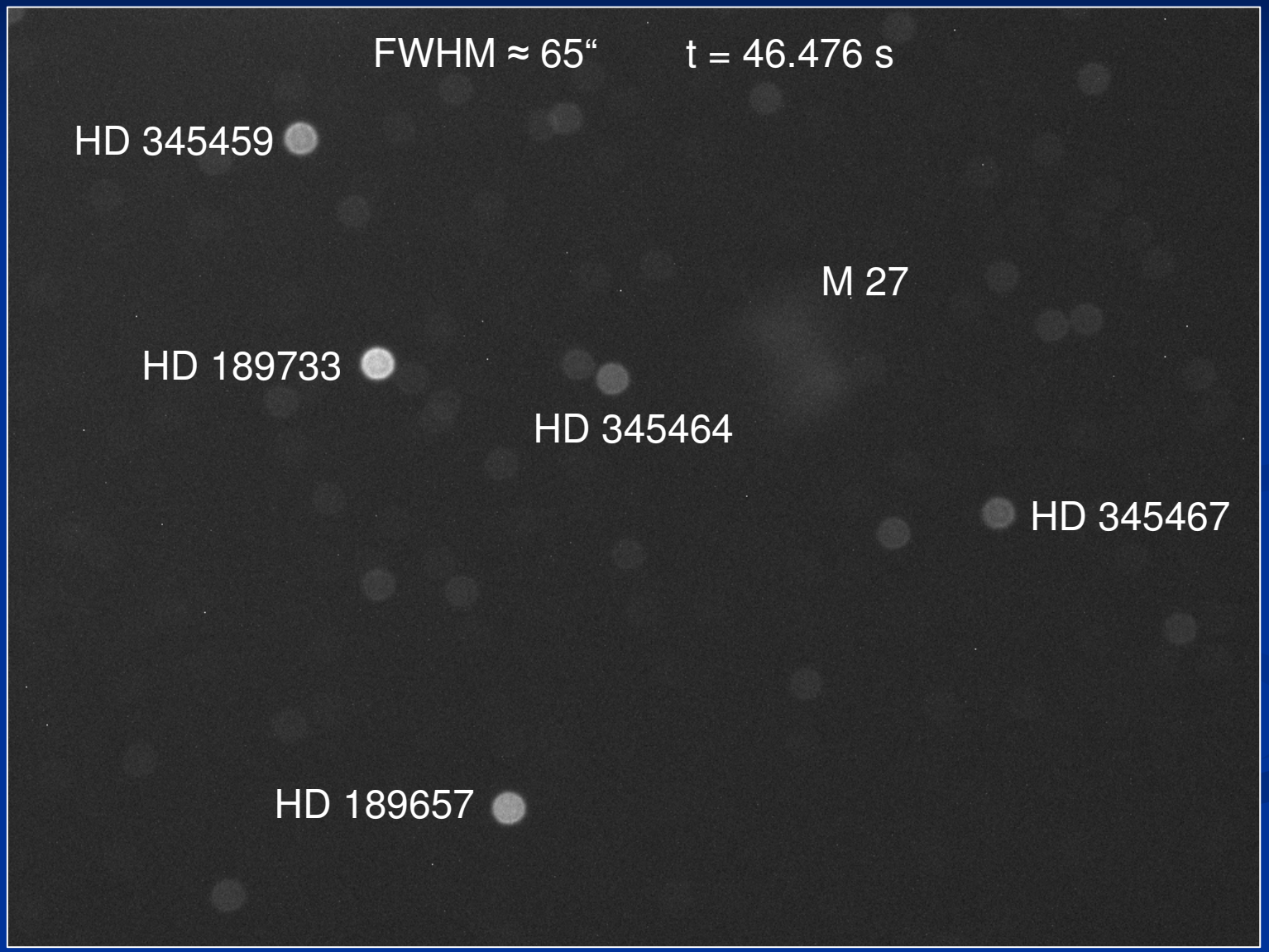
$$B_i(t) = \sum_{j=0}^{n_i - 1} S_{i,j} \qquad n_i : \text{Number of pixels in } S_i$$

- Divide the time series + normalization

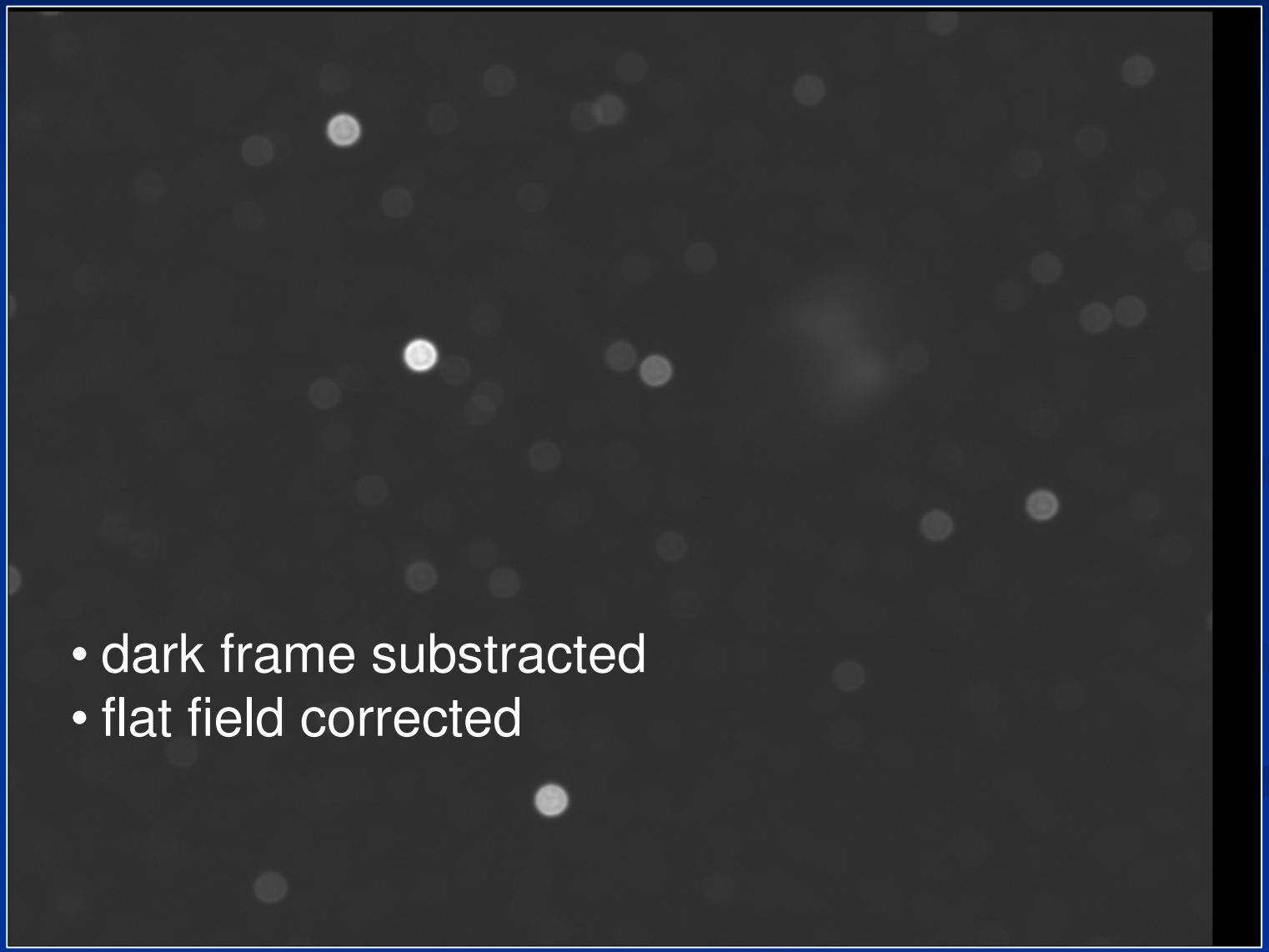
$$r(t) = \frac{B_1}{B_2 \cdot \overline{B_1 / B_2}}$$

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

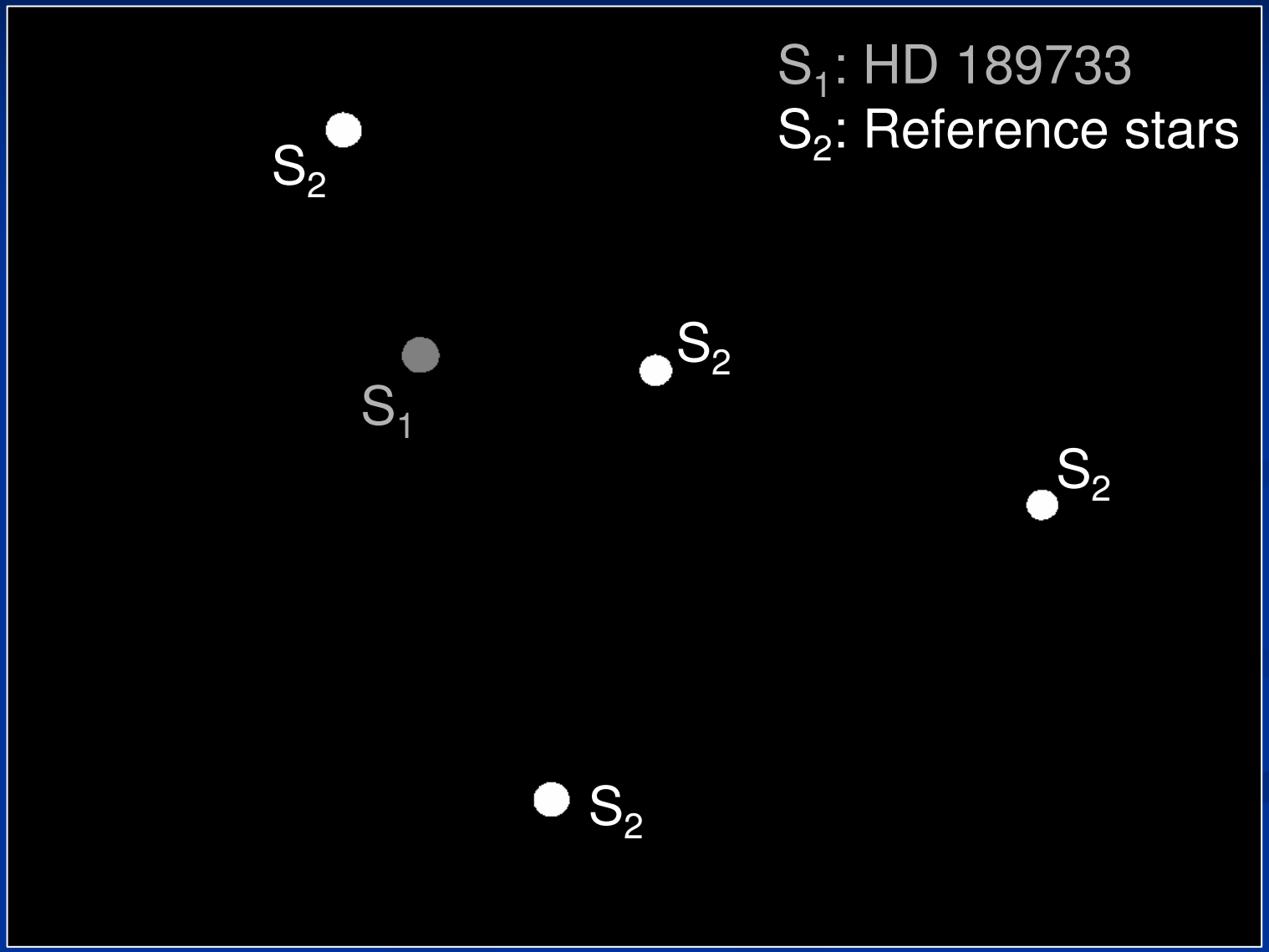
Typical single image



Average frame



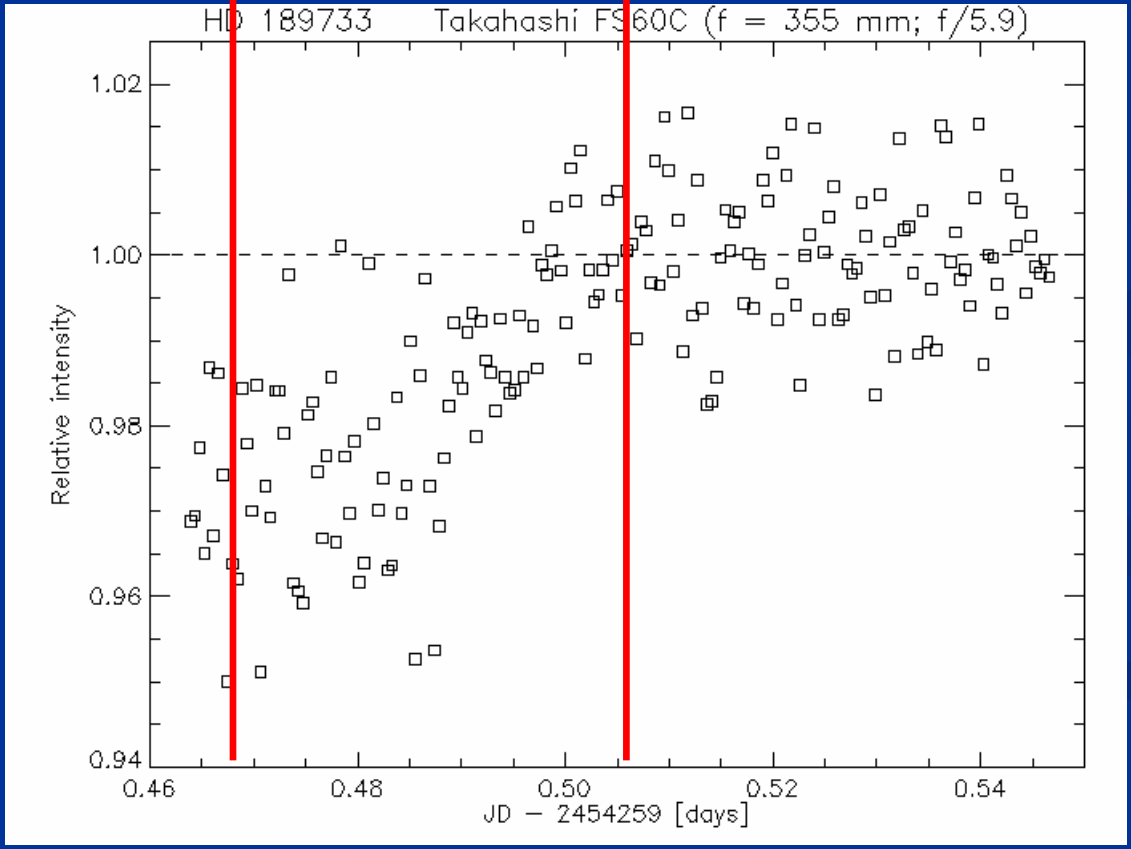
Mask



First Observation – 07 June 2007, 23:14 UT

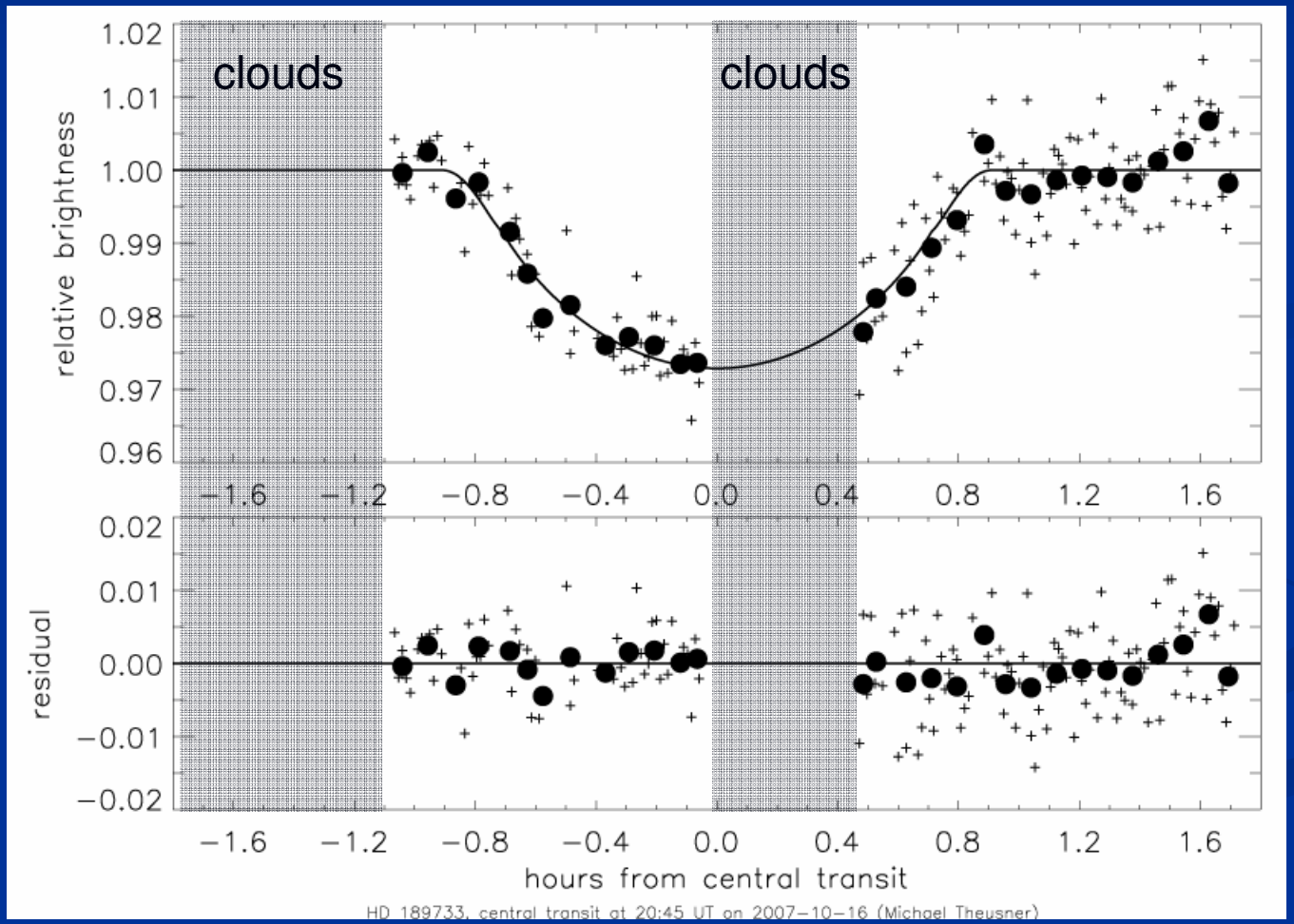
- Ambient temperature: +18°C to +20°C
- Clear skies

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



+ original data points
- 5-minute-average

Summary

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