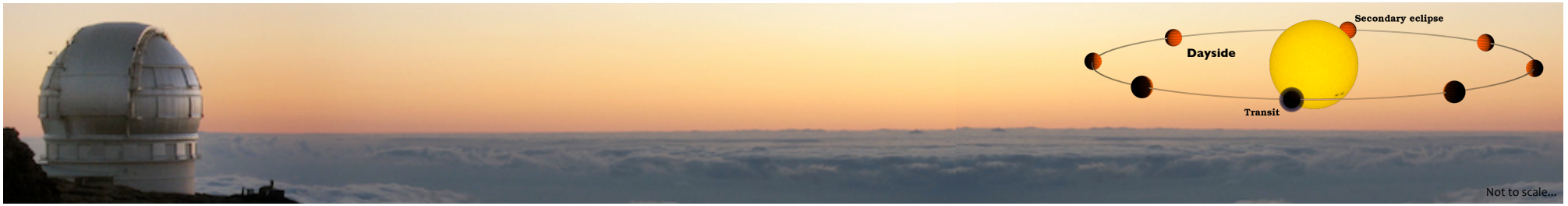

Observing Thermal Emission and Reflected Light from Exoplanets with the Gran Telescopio Canarias

Jayne Birkby

Leiden Observatory, The Netherlands (birkby@strw.leidenuniv.nl)

Ignas Snellen, Matteo Brogi, Bas Nefs (Leiden Observatory, The Netherlands)
Ernst de Mooij (University of Toronto, Canada) **Remco de Kok** (SRON, The Netherlands)
Simon Albrecht (MIT, USA) **Johannes Koppenhofer** (University Observatory Munich, Germany)
Ian Skillen (Isaac Newton Group, Spain) **Adam Burrows** (Princeton University, USA)

Ground-based optical secondary eclipses?

Secondary eclipses (occultations) measure the planet-star flux ratio --> gives planet temperature --> vital for understanding atmospheric chemistry, structure and dynamics

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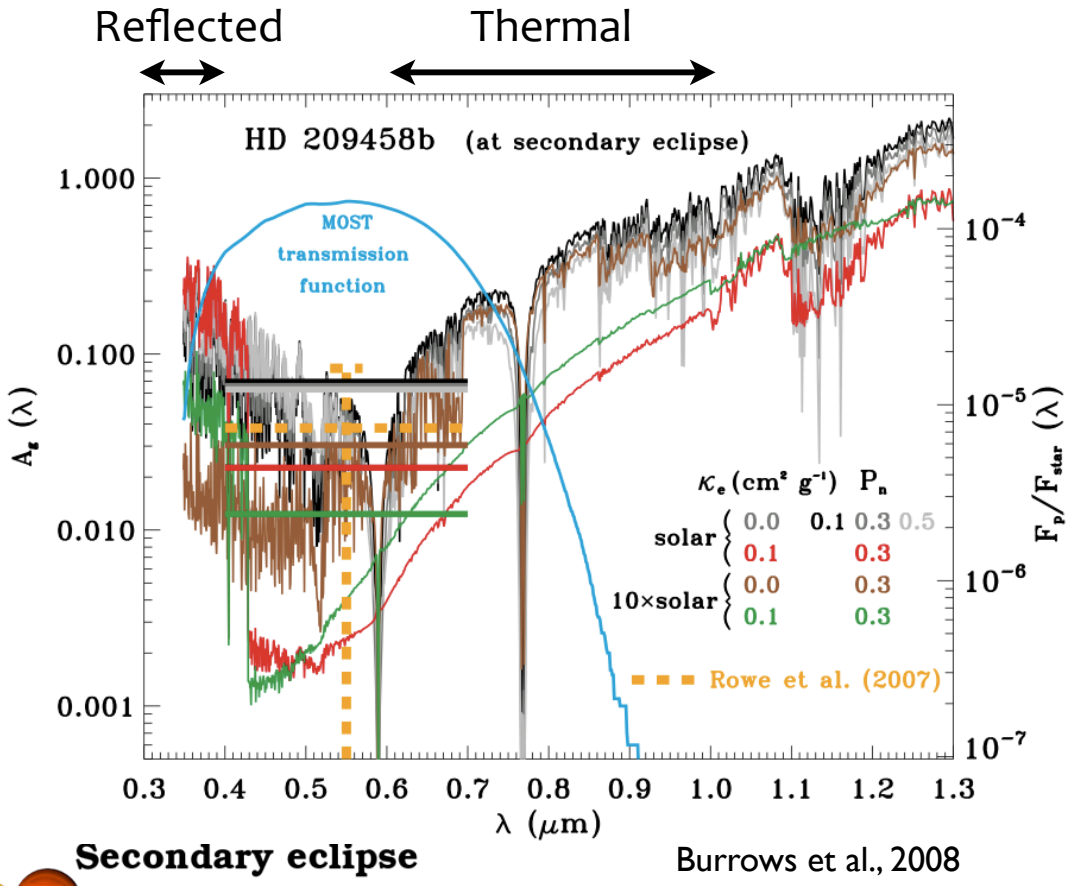

Burrows et al., 2008

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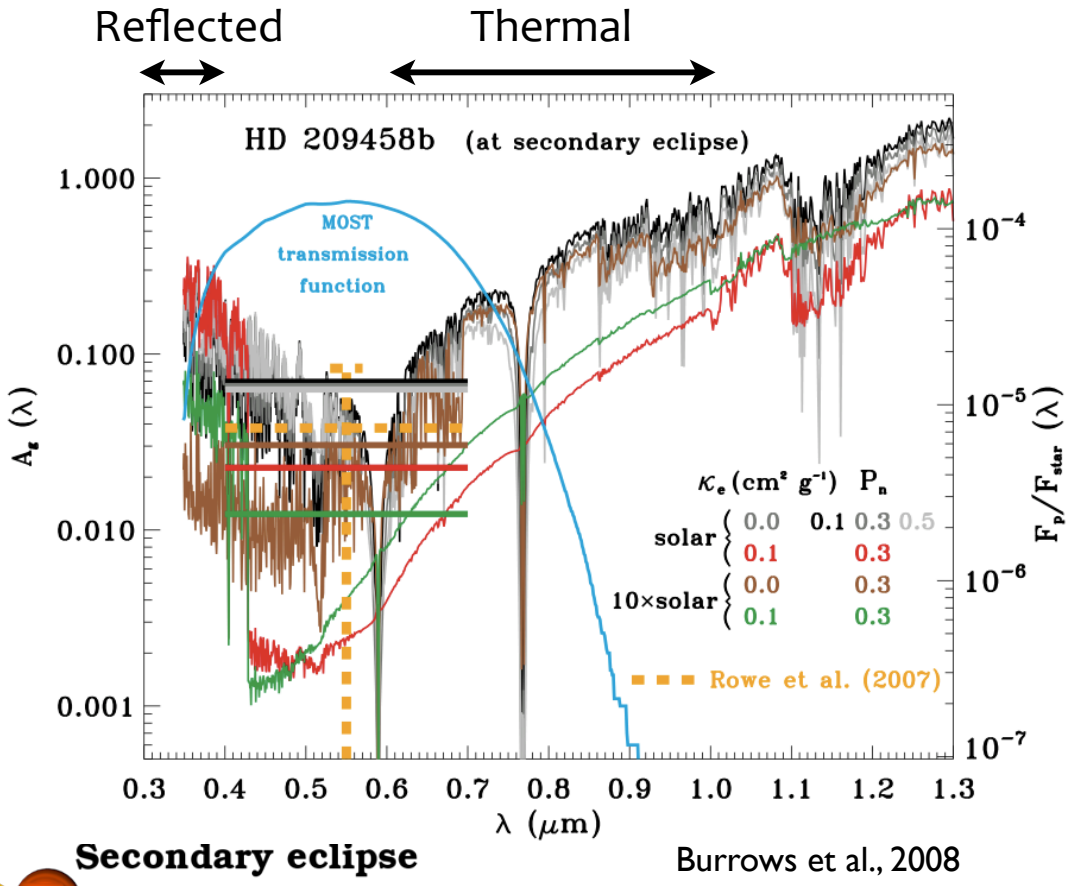

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- day-side temperature
- incident stellar irradiation
- reflected light due to scattering and possible clouds
- absorbing species
- global heat transport
- short-wards of Spitzer: H_2O, CO_2, CH_4 and CO molecular bands

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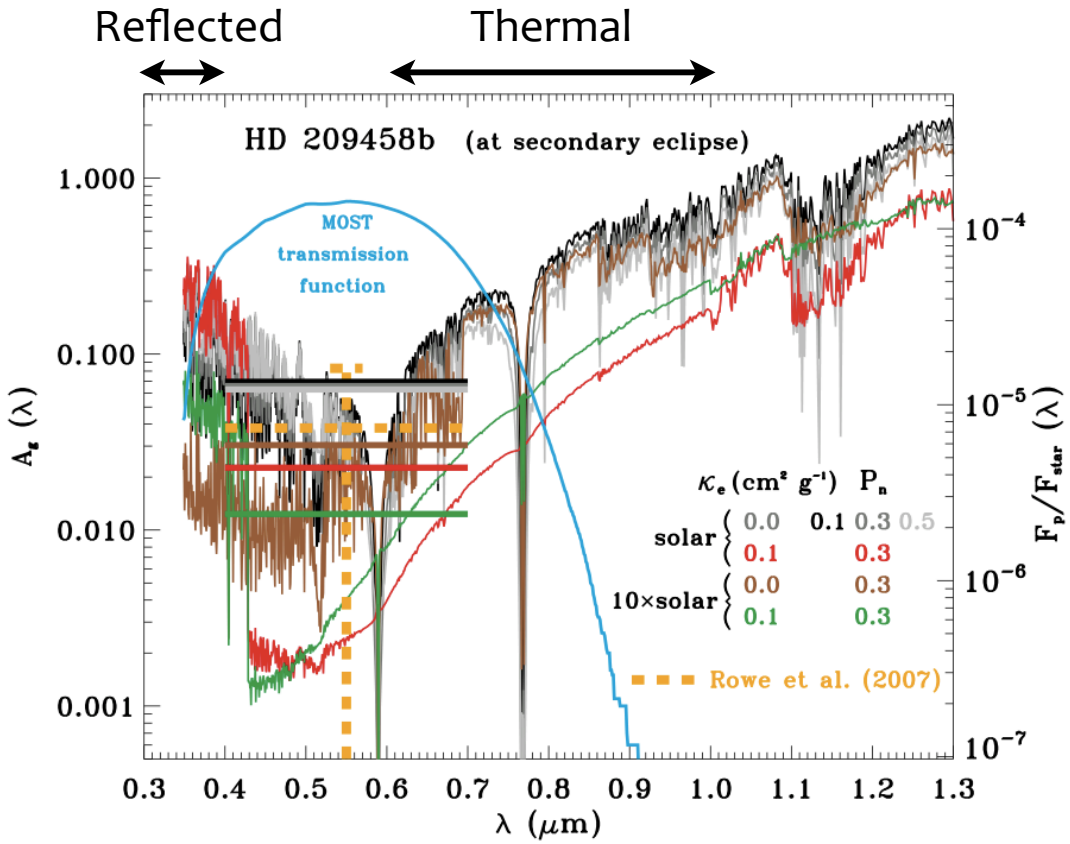

Burrows et al., 2008

Poster: Sukrit Ranjan HST/WFC3 occultations 1.1-1.7microns

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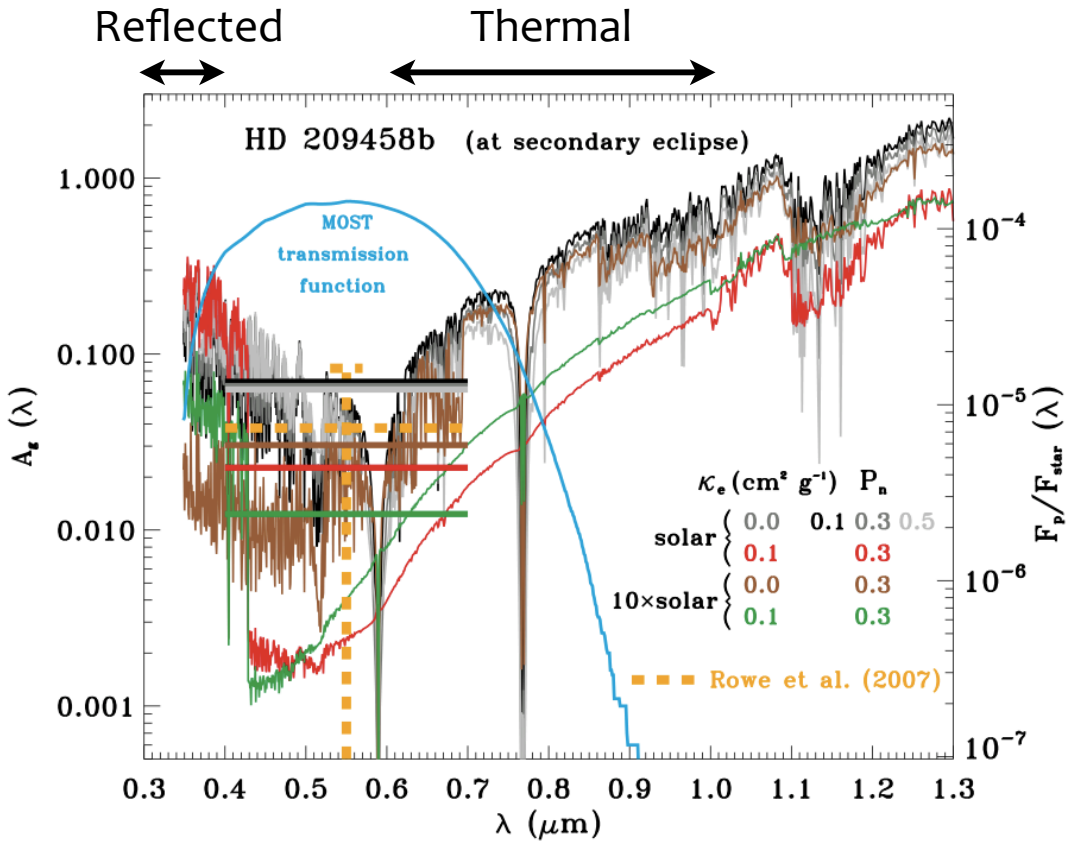

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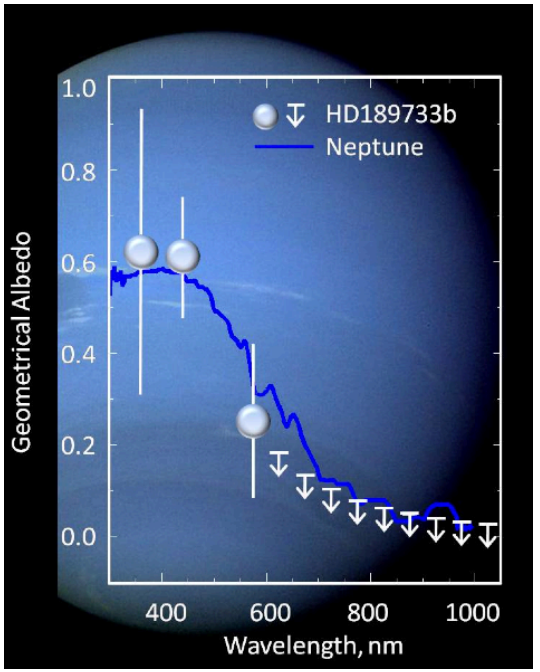
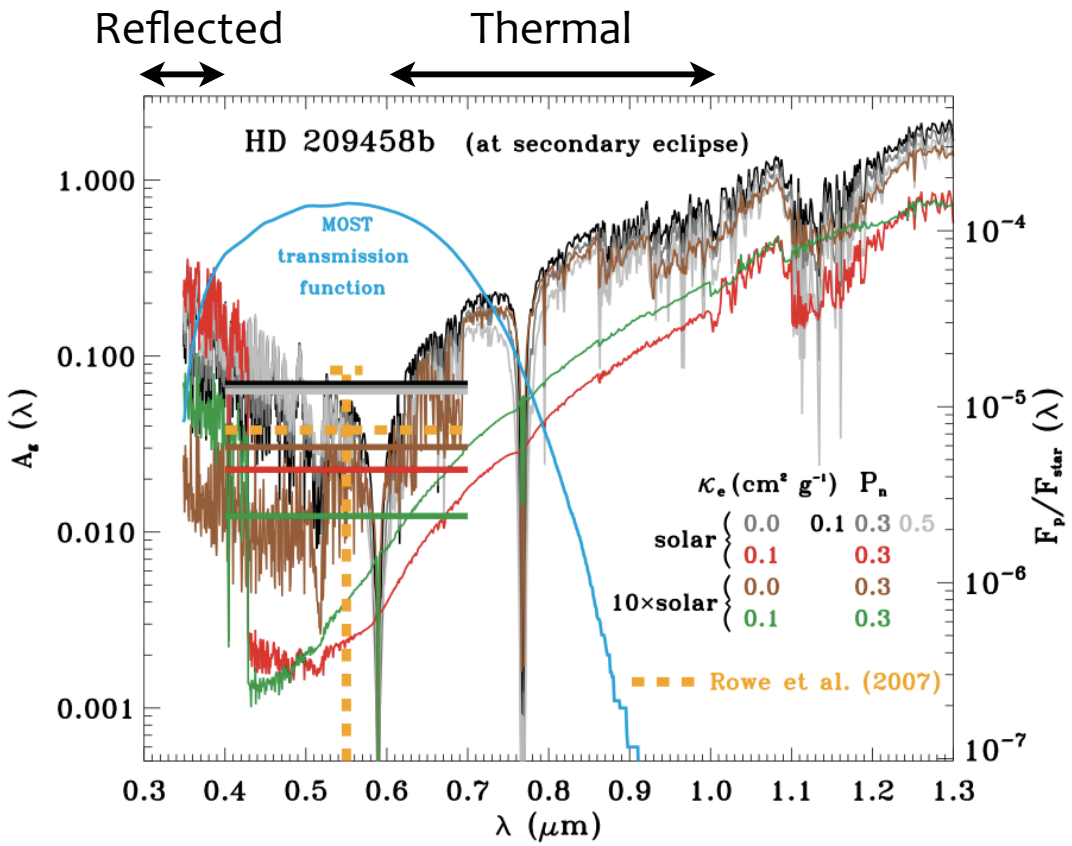


Polarised light Berdyugina et al. 2011

Rayleigh scattering (by H2 molecules) expected to dominate reflection spectrum (Burrows, Ibgui & Hubeny 2008; Fortney et al. 2008)

Ground-based optical secondary eclipses?

Why from the ground? Money, money, money...



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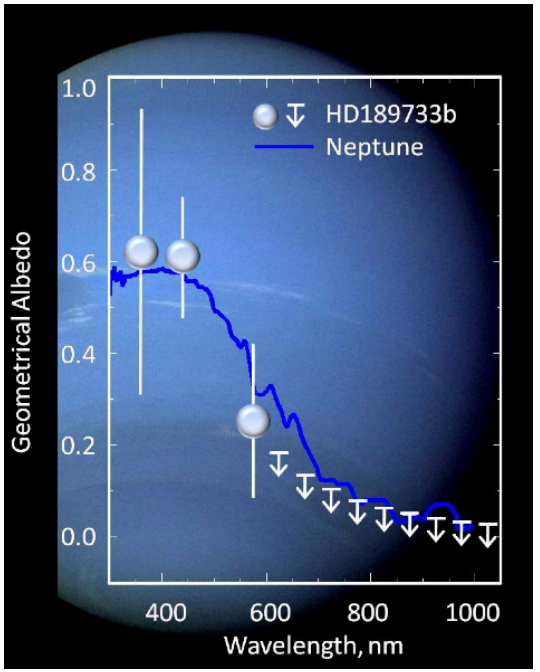

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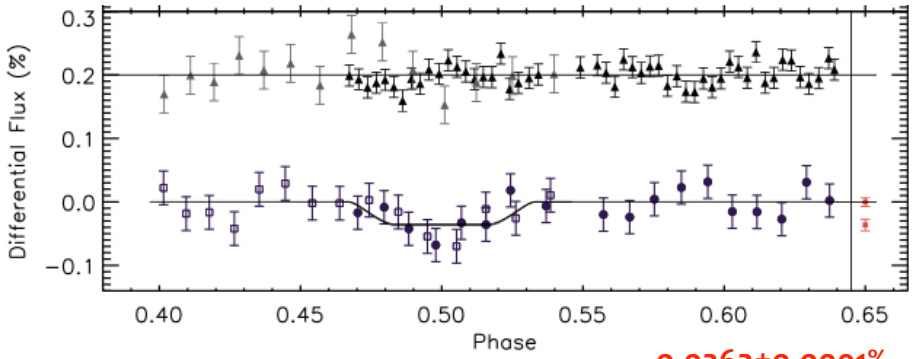
Existing ground-based optical secondary eclipses

OGLE-TR-56b z′-band V=16.6 (GV):
Sing & Lopez-Morales 2009
(VLT/FORS2 8.0m & Magellan/MagIC 6.5m)



0.0363±0.0091%

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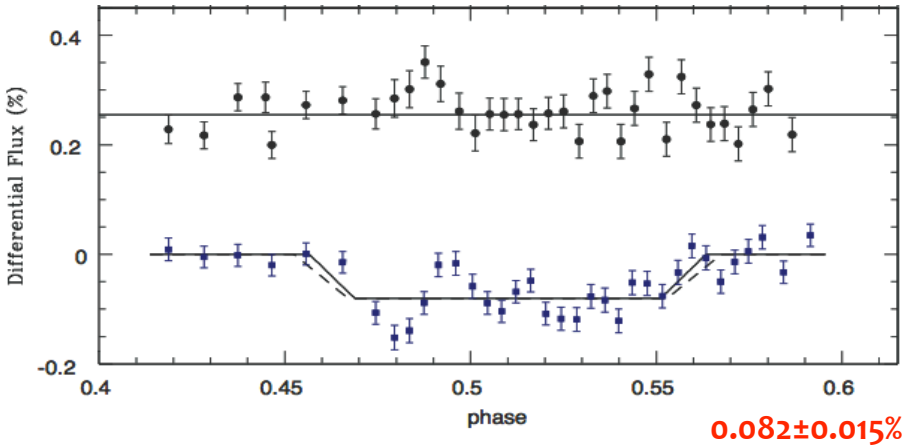

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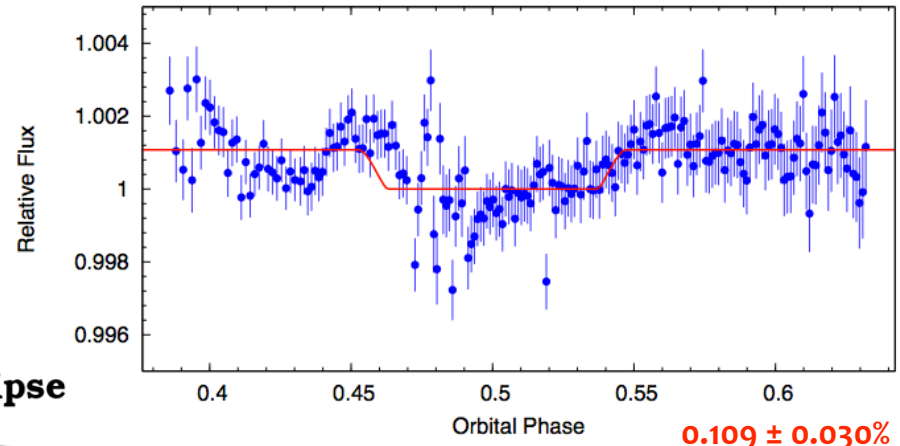

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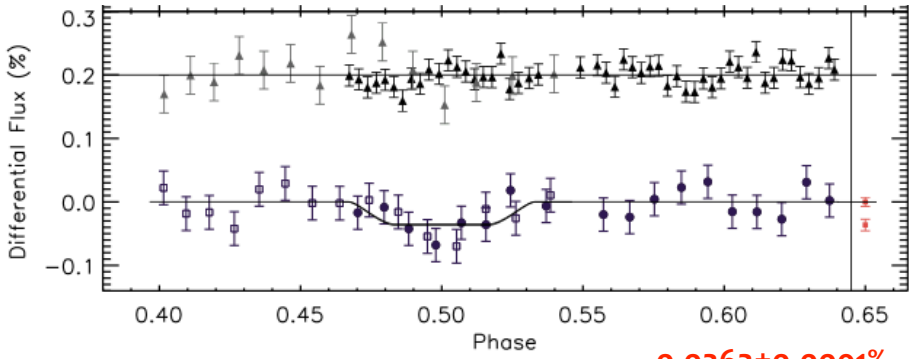

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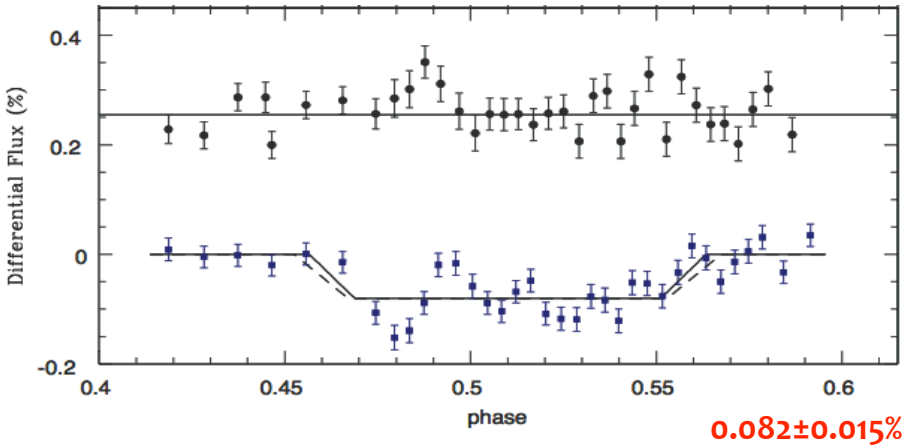

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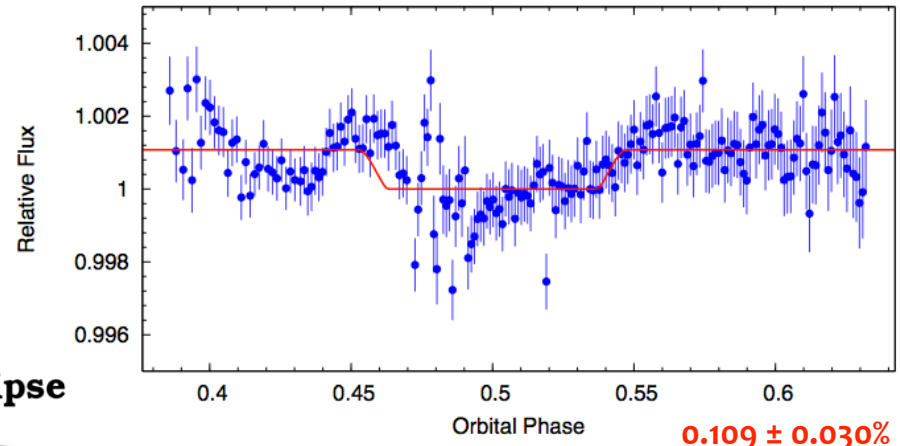

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Instrument: OSIRIS broad-band imaging CCD (7.8 x 8.5 arcmin) on the 10.4m GTC

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Dome restriction - can't observe above 73 degrees elevation

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- defocus (avoid saturation and flat fielding errors)
- sufficient baseline for accurate depth measurement and decorrelation of systematics (90 hour large ESO program)

Survey Status

The ‘good’…

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z'-band: HAT-P-23 b, TrES-3 b, CoRoT-1 b

Survey Status

The ‘good’...

z'-band: HAT-P-23 b, TrES-3 b, CoRoT-1 b

u'-band: HAT-P-23 b, TrES-3 b

Survey Status

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The bad...

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The bad...

WASP-12 b: no observations yet (u', g', r', z')

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u'-band: HAT-P-23 b, TrES-3 b

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And the ugly...

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And the ugly...

z'-band: HAT-P-7 b

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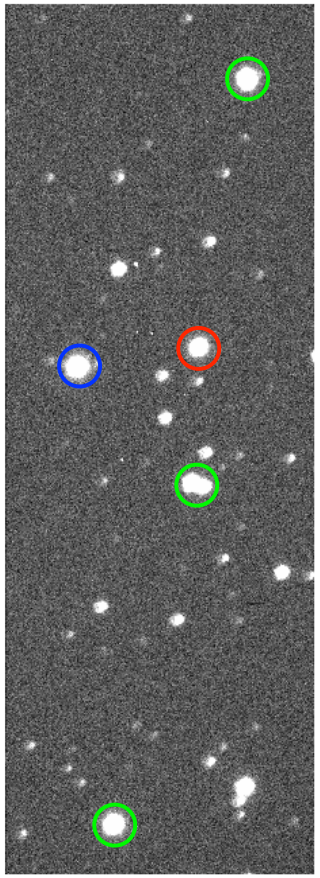
Preliminary Results

CoRoT-1b z'-band



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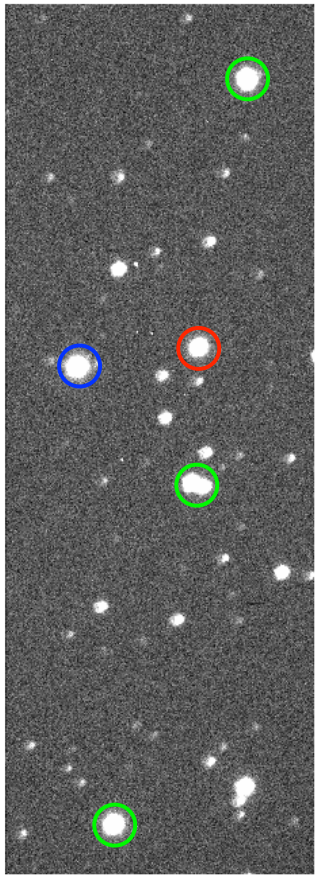

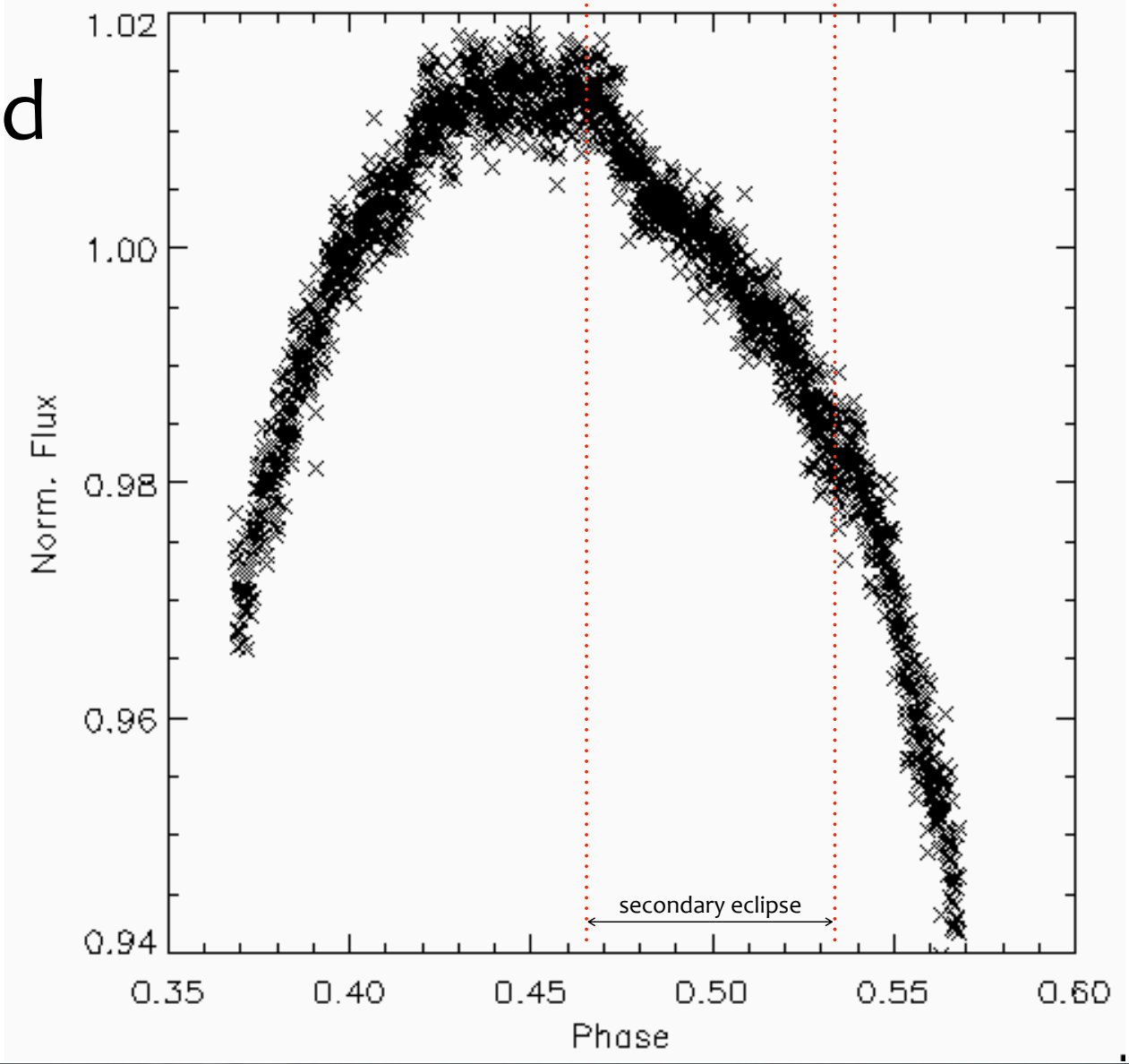

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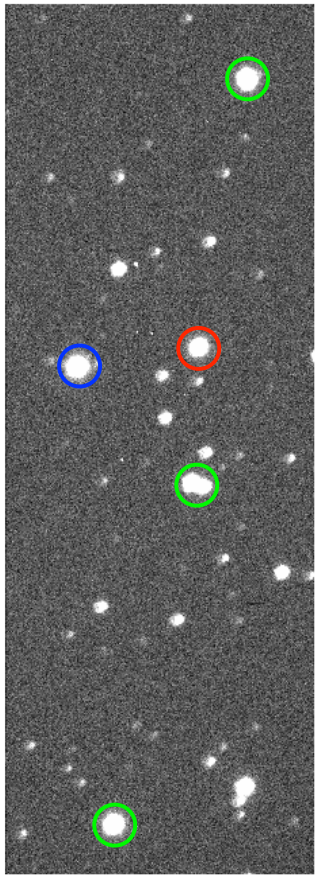

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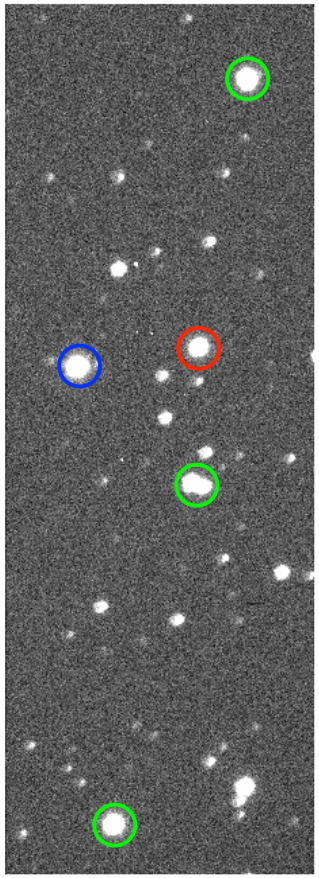
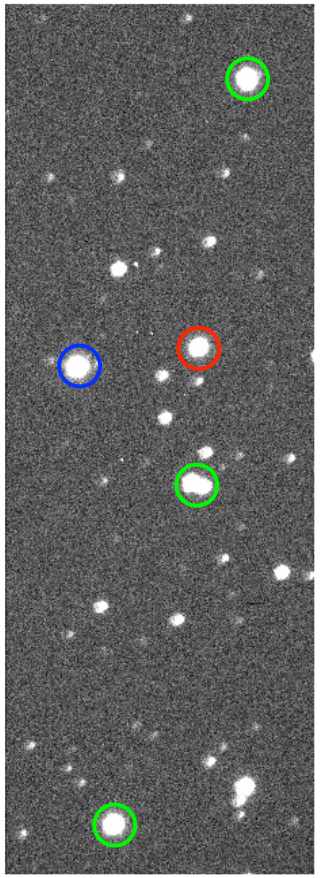


Fringe and illumination correction

Preliminary Results

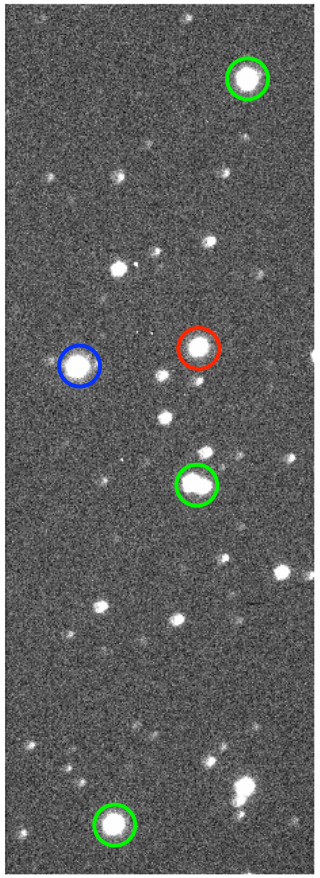
CoRoT-1b z'-band



Fringe and illumination correction
Divide target by master reference star

Preliminary Results

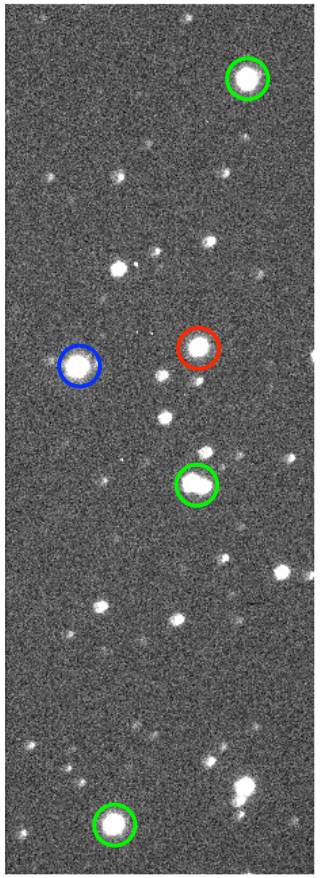
CoRoT-1b z'-band



Fringe and illumination correction
Divide target by master reference star
Multiple linear regression fit:

Preliminary Results

CoRoT-1b z'-band

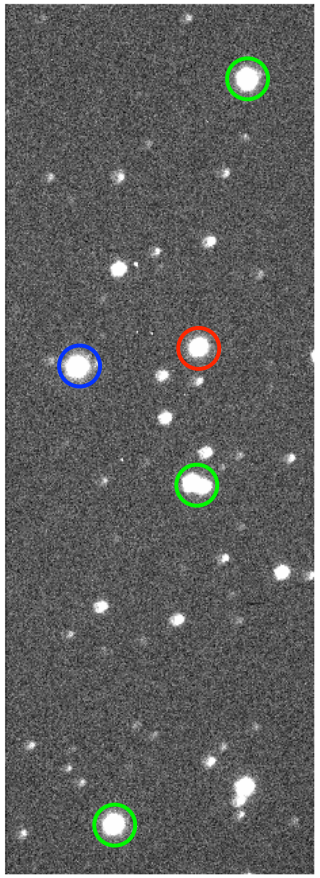


Fringe and illumination correction
Divide target by master reference star
Multiple linear regression fit:

- Model

Preliminary Results

CoRoT-1b z'-band

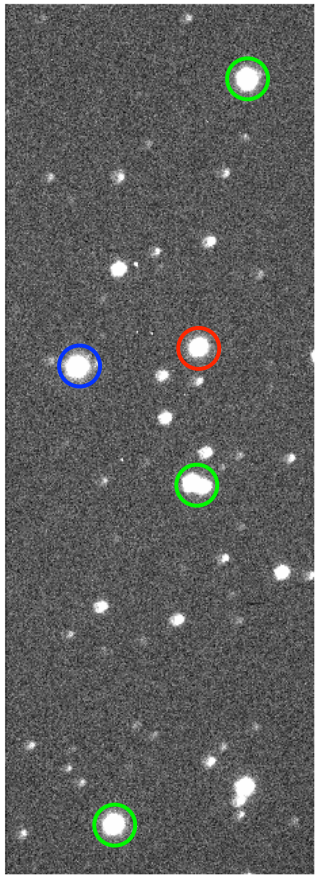


Fringe and illumination correction
Divide target by master reference star
Multiple linear regression fit:

- Model
- Airmass

Preliminary Results

CoRoT-1b z'-band

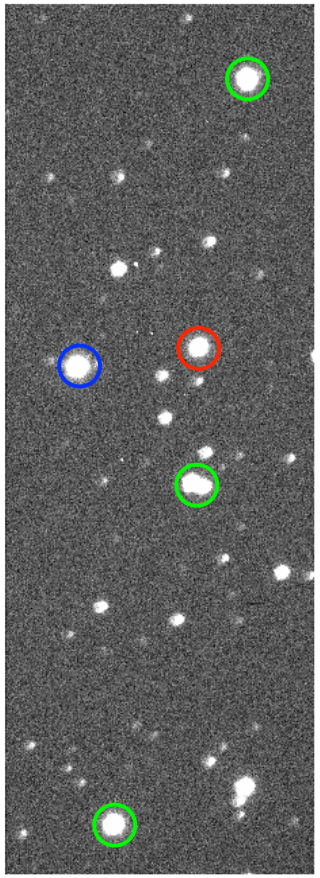


Fringe and illumination correction
Divide target by master reference star
Multiple linear regression fit:

- Model
- Airmass
- Seeing

Preliminary Results

CoRoT-1b z'-band

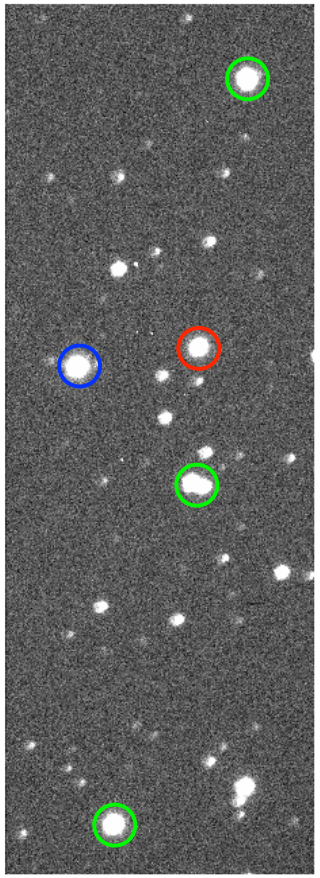


Fringe and illumination correction
Divide target by master reference star
Multiple linear regression fit:

- Model
- Airmass
- Seeing
- X position

Preliminary Results

CoRoT-1b z'-band



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- Airmass
- Seeing
- X position
- Y position

Preliminary Results

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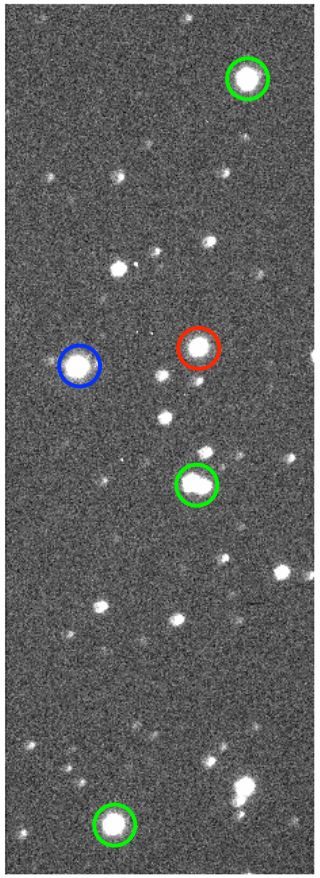

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- Y position
- Sky brightness

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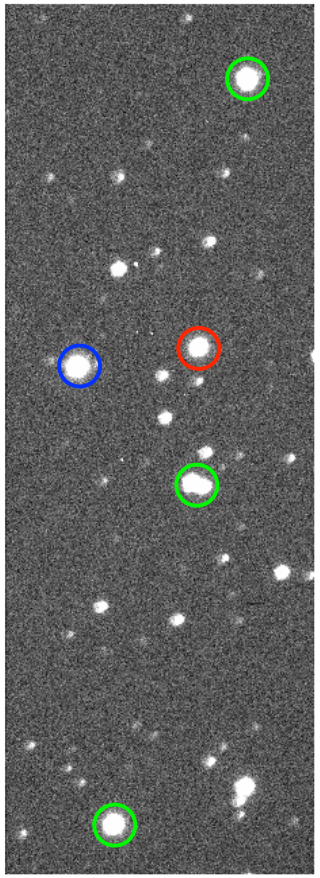
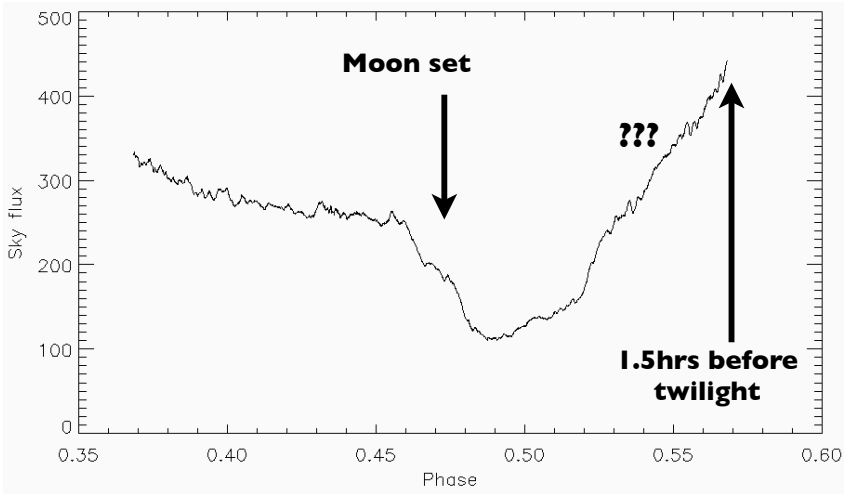
Preliminary Results

CoRoT-1b z'-band



Fringe and illumination correction
Divide target by master reference star
Multiple linear regression fit:

- Model
- Airmass
- Seeing
- X position
- Y position
- Sky brightness



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Potential sources of residual systematics

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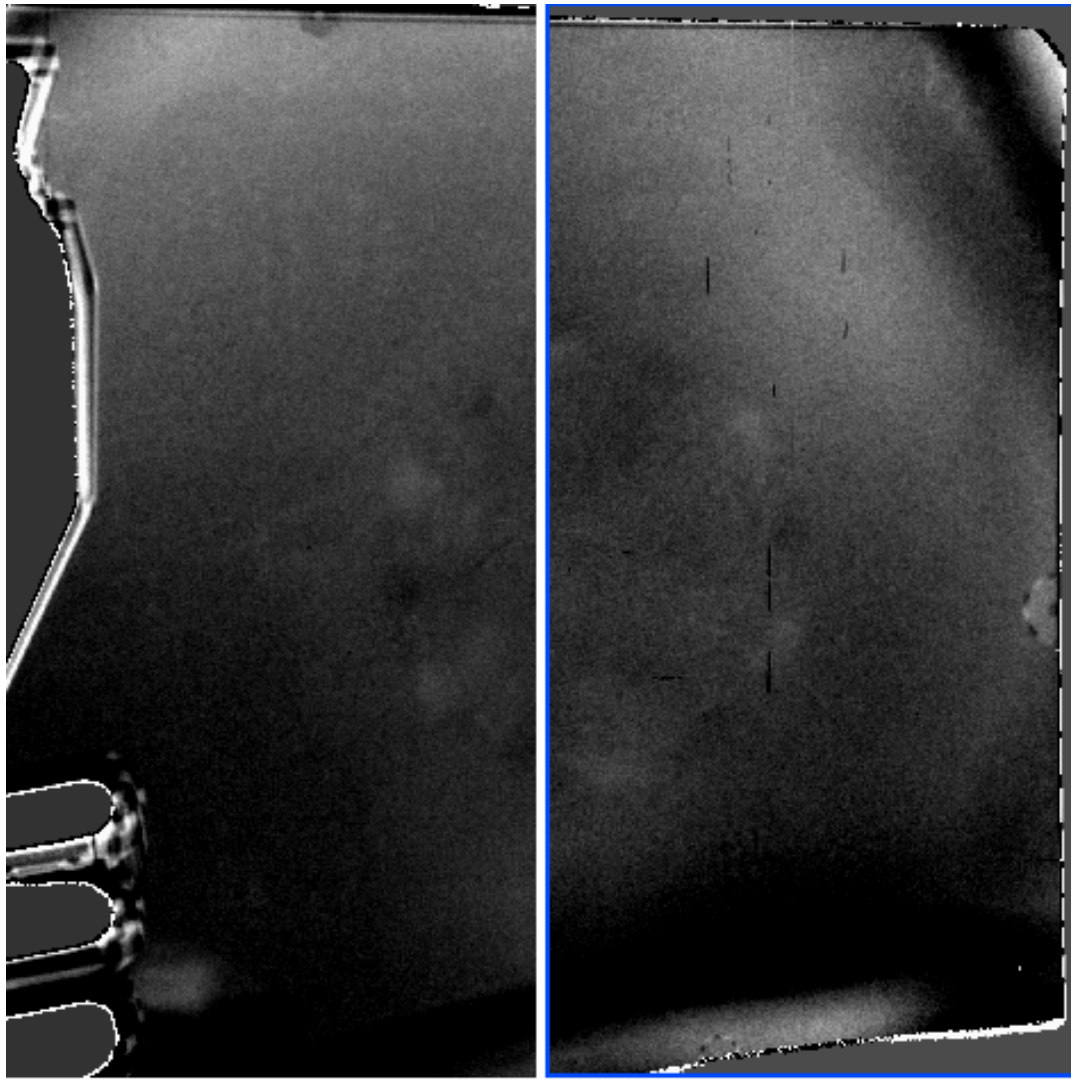

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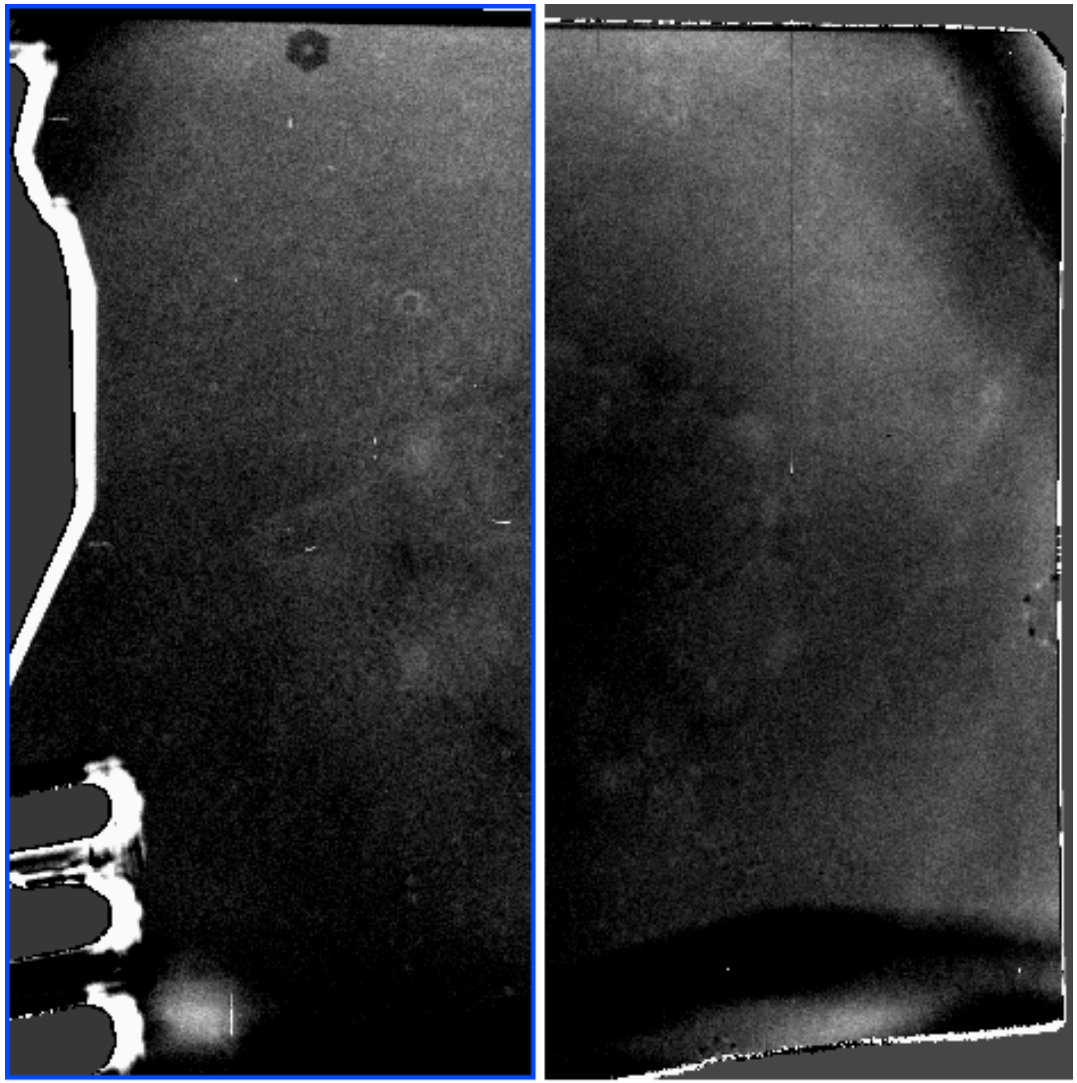

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- Precipitable water vapour variations? No data available!

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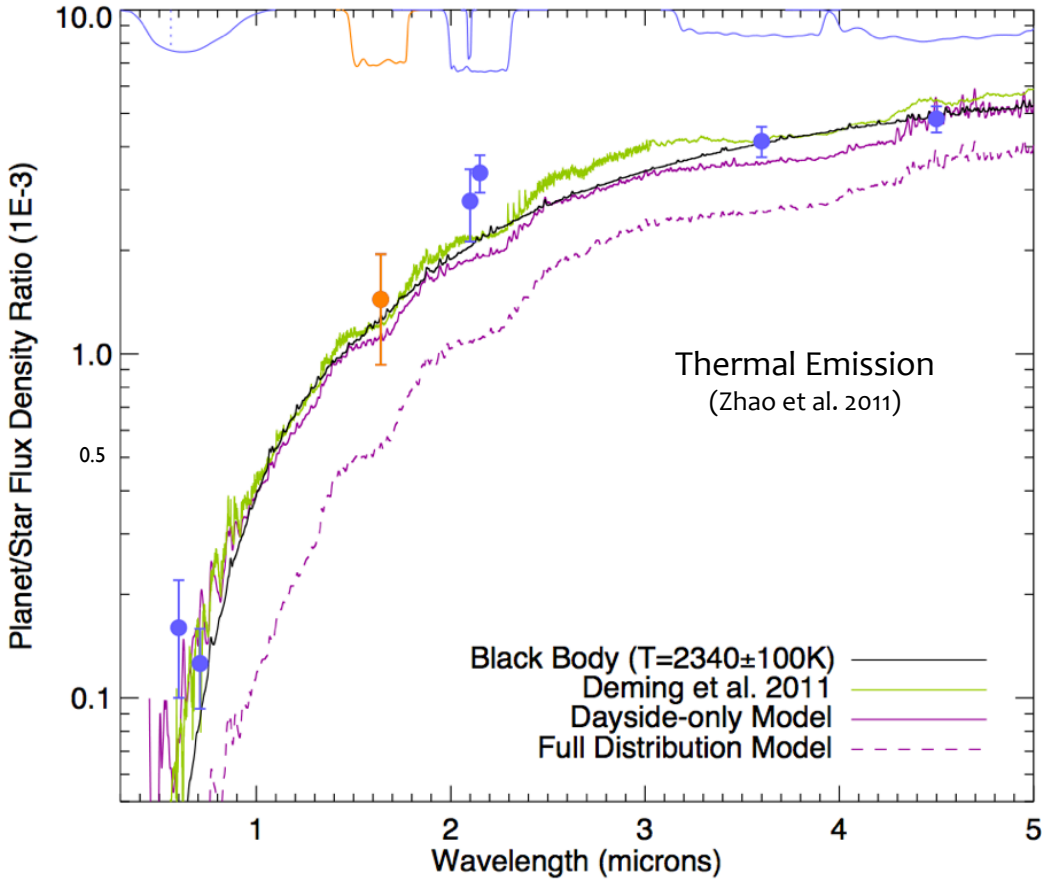

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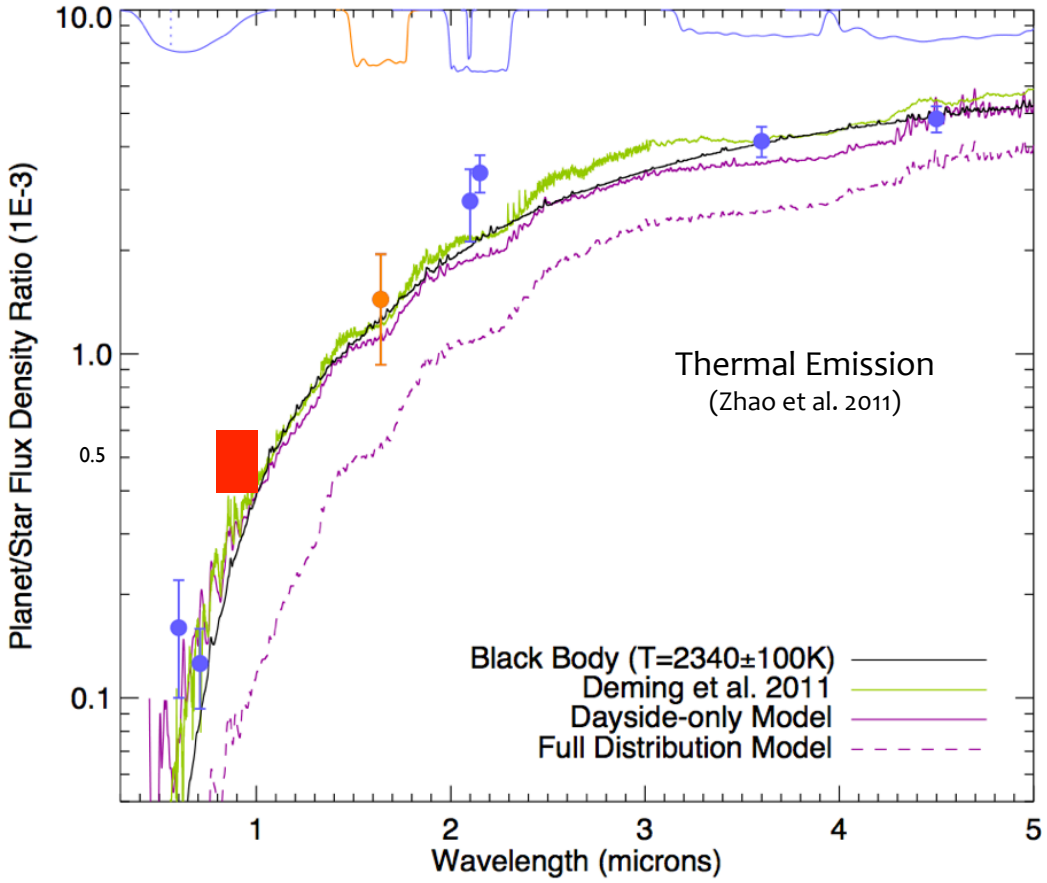

PRELIMINARY

Broadly agrees with previous findings of no heat redistribution

Preliminary Results

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- Additional K_s-band secondary eclipses with LIRIS/ WHT as part of the GROUd-based Secondary Eclipses (GROUSE) Project e.g. TrES-3b de Mooij & Snellen (2009) (HAT-P-23b and CoRoT-1b under analysis)

Alternatives

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Aim: first optical spectrum of an exoplanet at 0.6-1.1 microns

Conclusions

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- Ground-based secondary eclipse measurements are becoming ‘routine’ but this does not mean they are easy...
- Key to success is identifying and monitoring systematic sources and/or removing them effectively
- We have a tentative detection of secondary eclipse in z-band of CoRoT-1b, need to investigate PCA methods for removal of systematics
- Non-detections in u-band - upper limits on the albedo
- Optical spectophotometry from the ground at secondary eclipse is a promising alternative