Ground-based Secondary Eclipse detection of Ogle-Tr-56

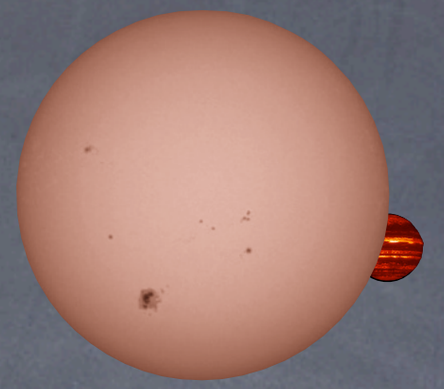
David Sing
Institut d'Astrophysique de Paris

Mercedes Lopez-Morales
Carnegie Institution of Washington

Overview

- Introduction
  motivation & theory
- Observations
  VLT & Magellan
- Analysis & Discussion
  interpretation of results
- Conclusions

Introduction

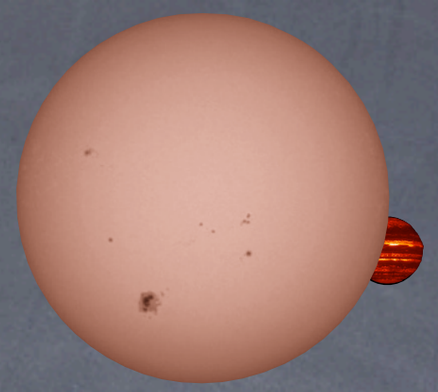


- Revolution with Spitzer anti-transit measurements (Deming 05; Charbonneau 05; Knutson 07, ect.)

- Past ground-based attempts (Knutson 07; Deming 07; Snellen 05; Snellen & Corvino 07, ect.)
  - near-IR, difficult to do precision photometry

- Lopez-Morales & Seager (2007)
  - Significant optical flux for very-hot Jupiters Teff ~ 2500 - 3000 K
  - precision optical photometry easier than in near-IR

Prediction



- Lopez-Morales & Seager (2007) ; z' band

  - Thermal Emission or Reflected light

    f = re-radiation factor

    A_B = Bond albedo

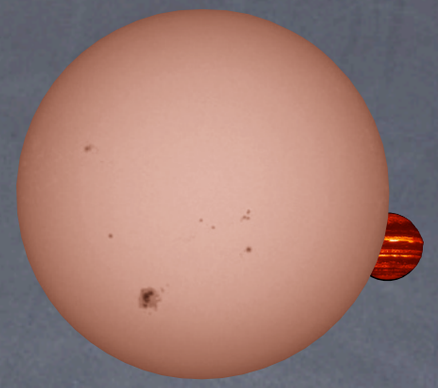
$$T_p = T_* \left(\frac{R_*}{a}\right)^{1/2} [f(1 - A_B)]^{1/4}$$

$$F_{p\,\mathrm{th}} = \frac{2h\nu^3}{c^2} \frac{\pi R_p^2}{e^{h\nu/kT_p} - 1} \frac{1}{D^2}$$

$$F_{p\,\mathrm{ref}} = F_* \tfrac{2}{3} A_B \frac{R_p^2}{a^2}$$

$$|\,\Delta\mathrm{mag}\,| = 2.5 \log\left(1 + \frac{F_p}{F_*}\right)$$

Prediction



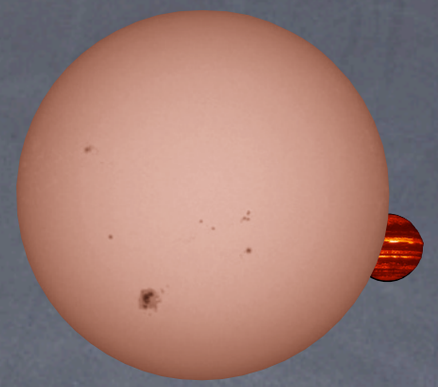
- Lopez-Morales & Seager (2007)

TABLE 1

EFFECTIVE TEMPERATURES OF THE 11 KNOWN TRANSITING VHJS, FOR $A_B = 0.0$

Planet	$T_p(K)$ $f = \frac{2}{3}$; $A_B = 0$	$T_p(K)$ $f = \frac{2}{3}$; $A_B = 0.3$	$T_p(K)$ $f = \frac{2}{3}$; $A_B = 0.5$	$T_p(K)$ $f = \frac{1}{4}$; $A_B = 0$
OGLE-TR-56b	2889 ± 24	2642 ± 22	2429 ± 20	2260 ± 19
OGLE-TR-113b	1717 ± 14	1570 ± 13	1444 ± 12	1344 ± 11
OGLE-TR-132b	2615 ± 36	2392 ± 32	2199 ± 30	2046 ± 28
HD189733b	1500 ± 10	1372 ± 9	1261 ± 8	1174 ± 8
XO-2b	1682 ± 15	1539 ± 14	1415 ± 13	1316 ± 12
Corot-exo-1b	2225	2036	1871	1742
WASP-1	2177 ± 61	1991 ± 56	1831 ± 51	1704 ± 48
WASP-2	1615 ± 96	1478 ± 87	1358 ± 80	1264 ± 75
HD140926b	2226 ± 30	2036 ± 27	1872 ± 25	1742 ± 23
TrES-2	1882 ± 15	1722 ± 14	1583 ± 13	1473 ± 12
TrES-3	2100 ± 32	1921 ± 29	1766 ± 27	1643 ± 25

Prediction



- Lopez-Morales & Seager (2007)

EFFECTIVE TEMPERATURES

Planet	$T_p(K)$ $f = \frac{2}{3}$; $A_B = 0$	f
OGLE-TR-56b	2889 ± 24	

< 0.5 mmag for Ogle-Tr-56

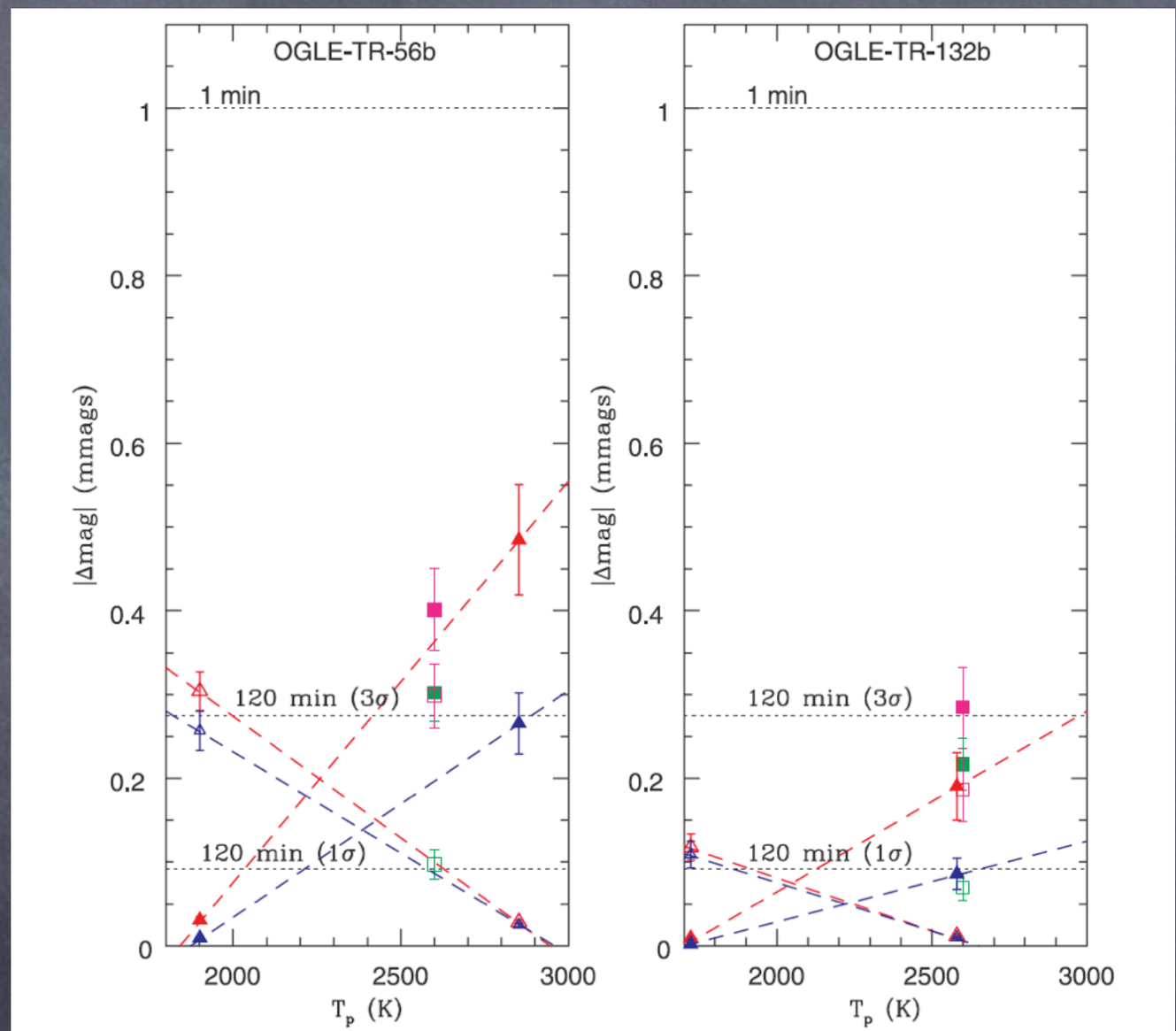
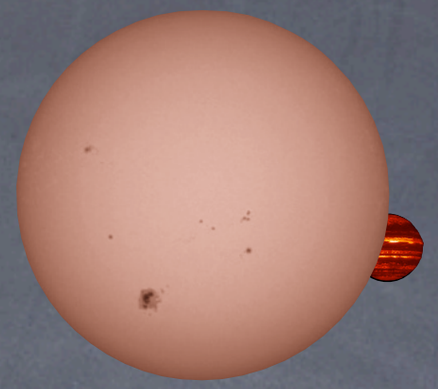


FIG. 2.—Expected depths of secondary transits, | Δmag |, as a function of T_p for OGLE-TR-56b (*left side*) and OGLE-TR-132b (*right side*). Filled tri-

Observations



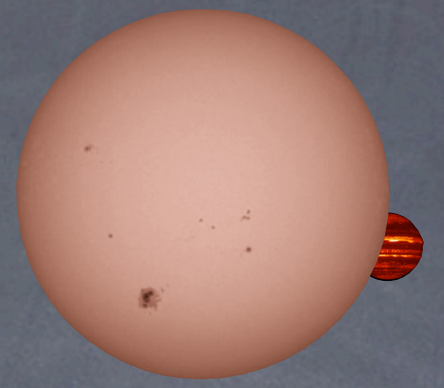
Challenges for Ogle-Tr-56

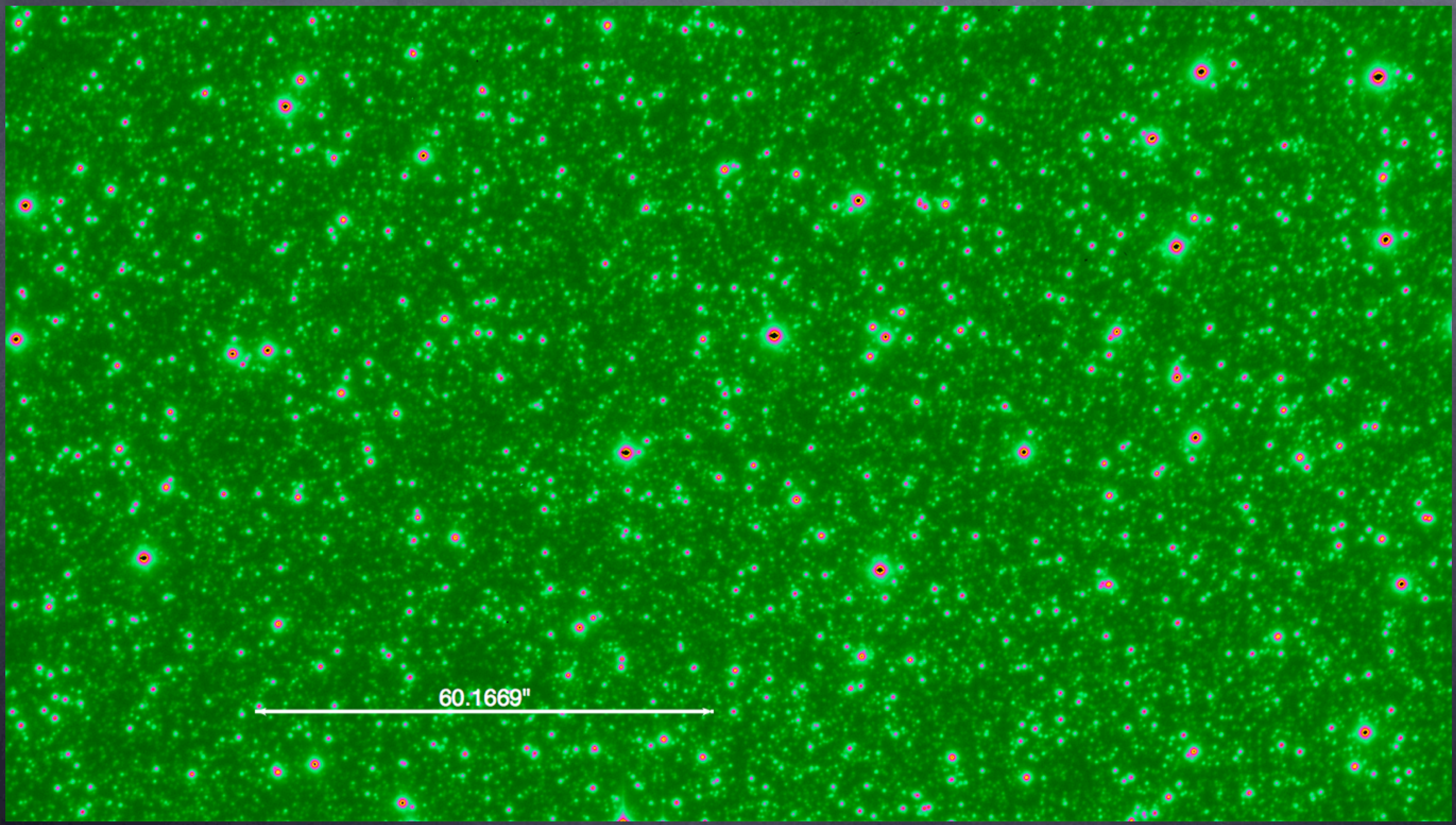
1) Faint (V=16.56); harder to reach necessary precision; 0.01% ⇨ 10^8 photons/1 hour

2) Small signal; secondary eclipse depth of < 0.05%

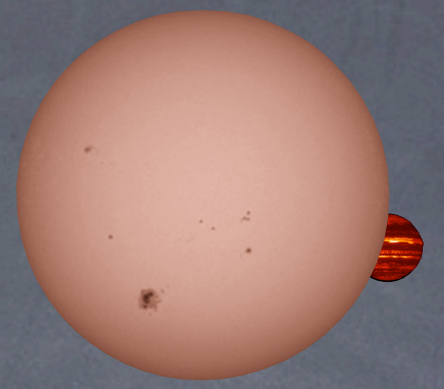
3) Crowded Field toward galactic center

Observations





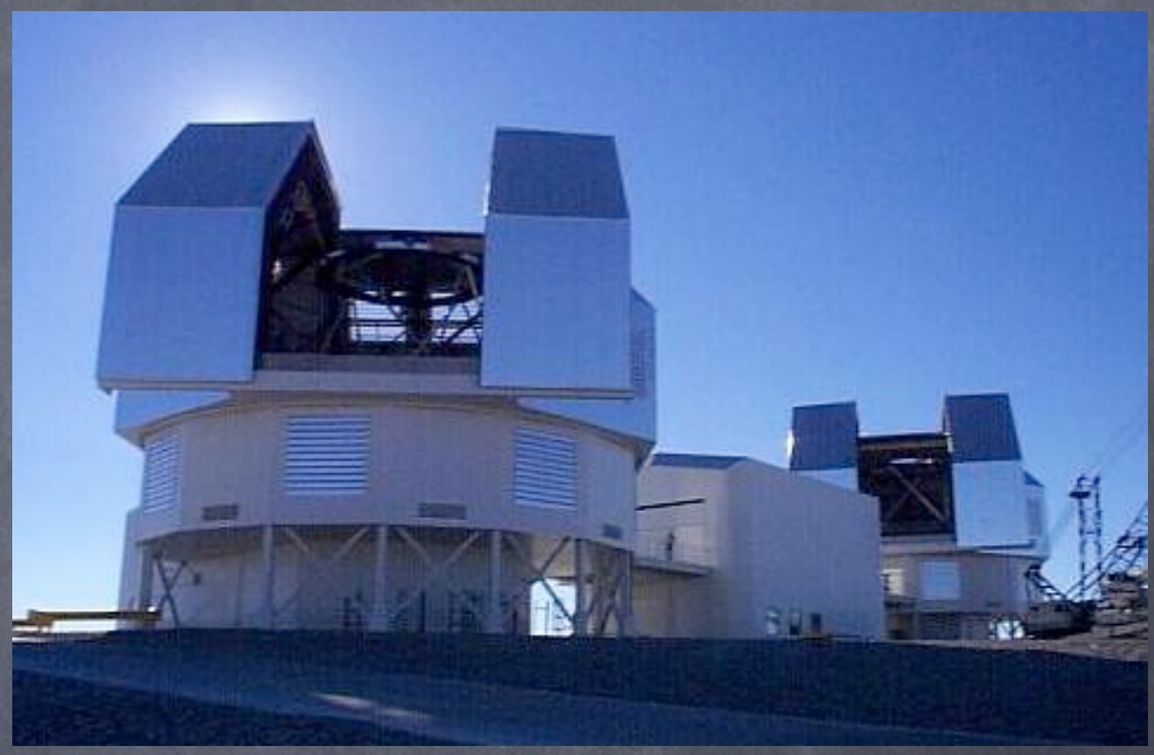
Observations



VLT 8.2 m

July 2, 2008
FORS2 camera

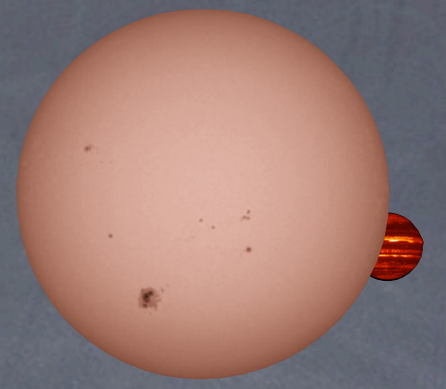
Magellan 6.5m



August 3, 2008
MagIC-E2V
frame transfer

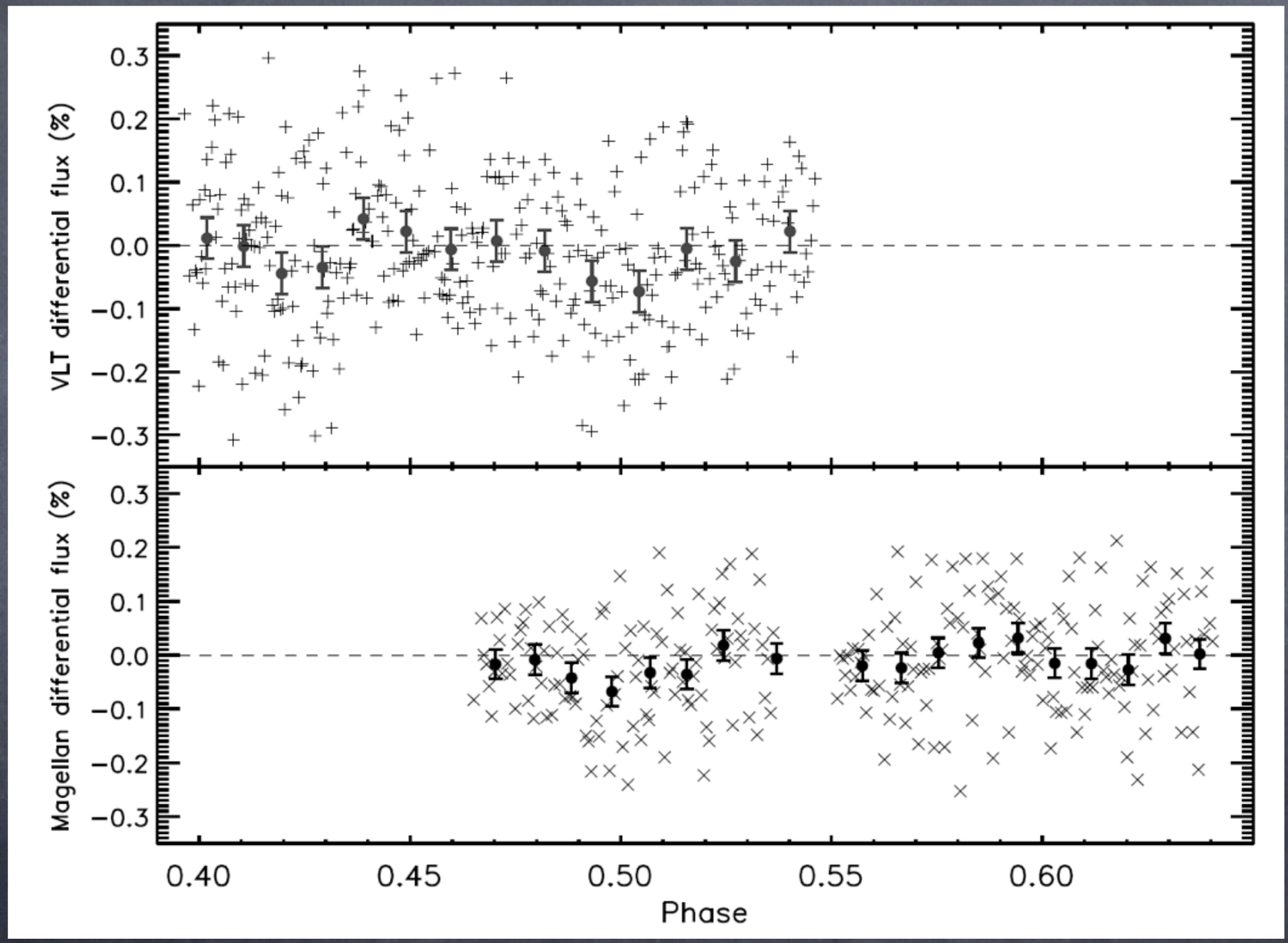
Z band

Observations



- Aperture photometry
- Remove systematic errors with
  - SysRem algorithm (Tamuz et al. 05)
  - multiple linear regression (xposs, yposs, fwhm, airmass)

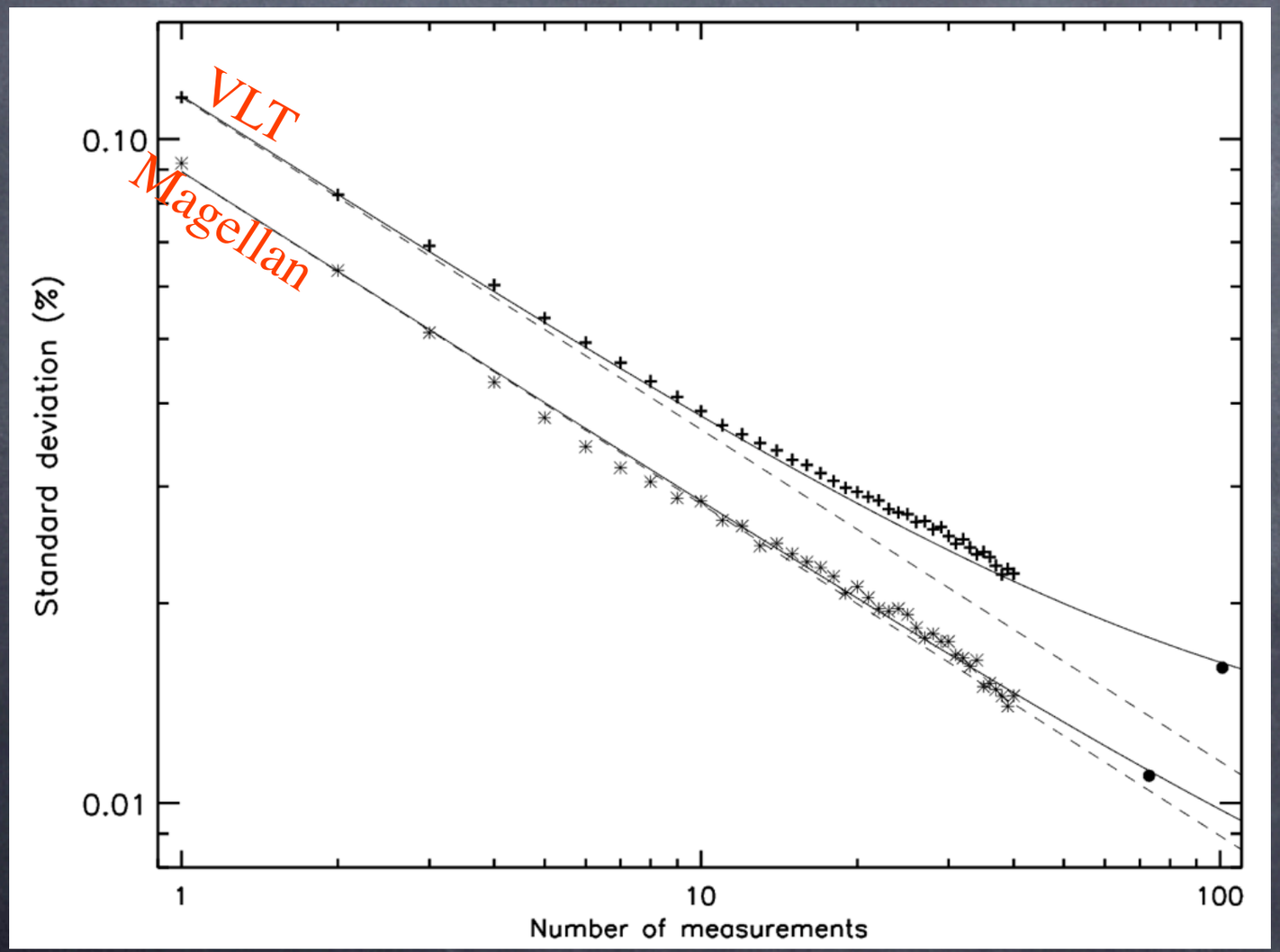
Analysis


VLT differential flux (%)
0.3
0.2
0.1
0.0
−0.1
−0.2
−0.3
Magellan differential flux (%)
0.3
0.2
0.1
0.0
−0.1
−0.2
−0.3
0.40
0.45
0.50
0.55
0.60
Phase

Analysis

- ~1 mmag/min
- red-noise estimated with "prayer-bead" method

$$\sigma^2_{depth} = \sigma^2_w/N + \sigma^2_{red}$$



VLT

$\sigma_{red} = 1.1 \times 10^{-4}$

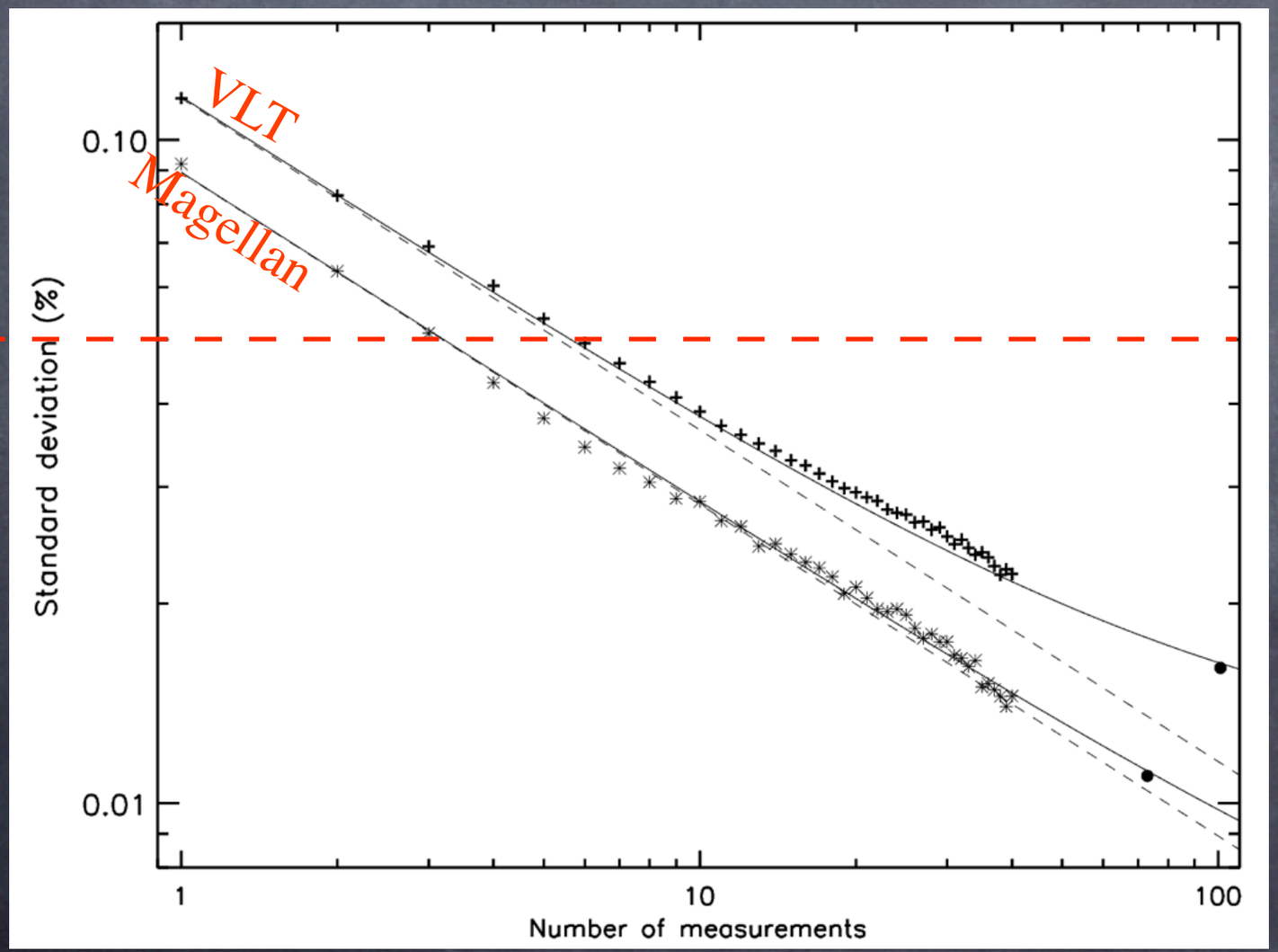
Magellan

$\sigma_{red} = 4 \times 10^{-5}$

Analysis

- ~1 mmag/min
- red-noise estimated with "prayer-bead" method

$$\sigma^2_{depth} = \sigma^2_w/N + \sigma^2_{red}$$

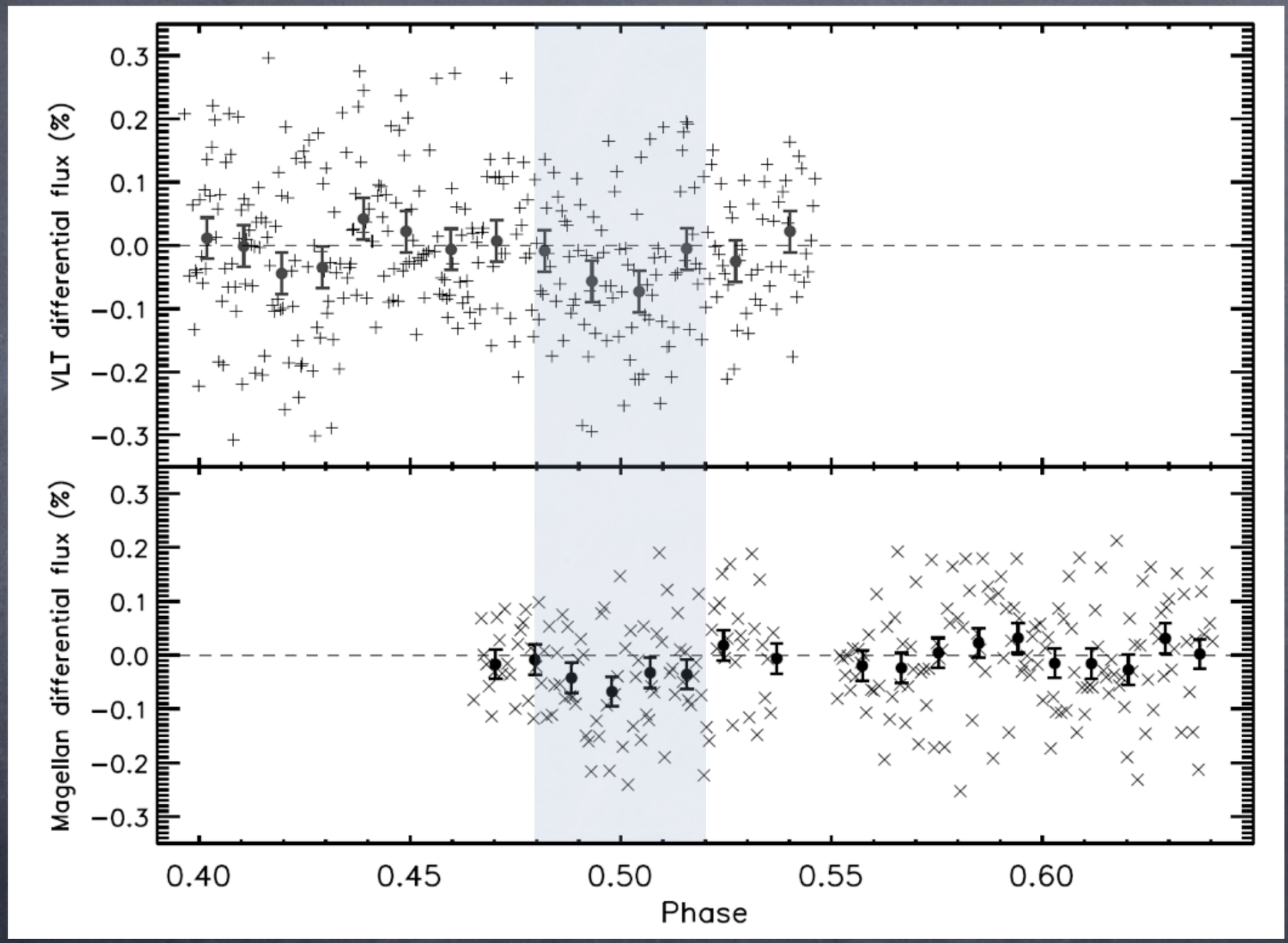


0.05%

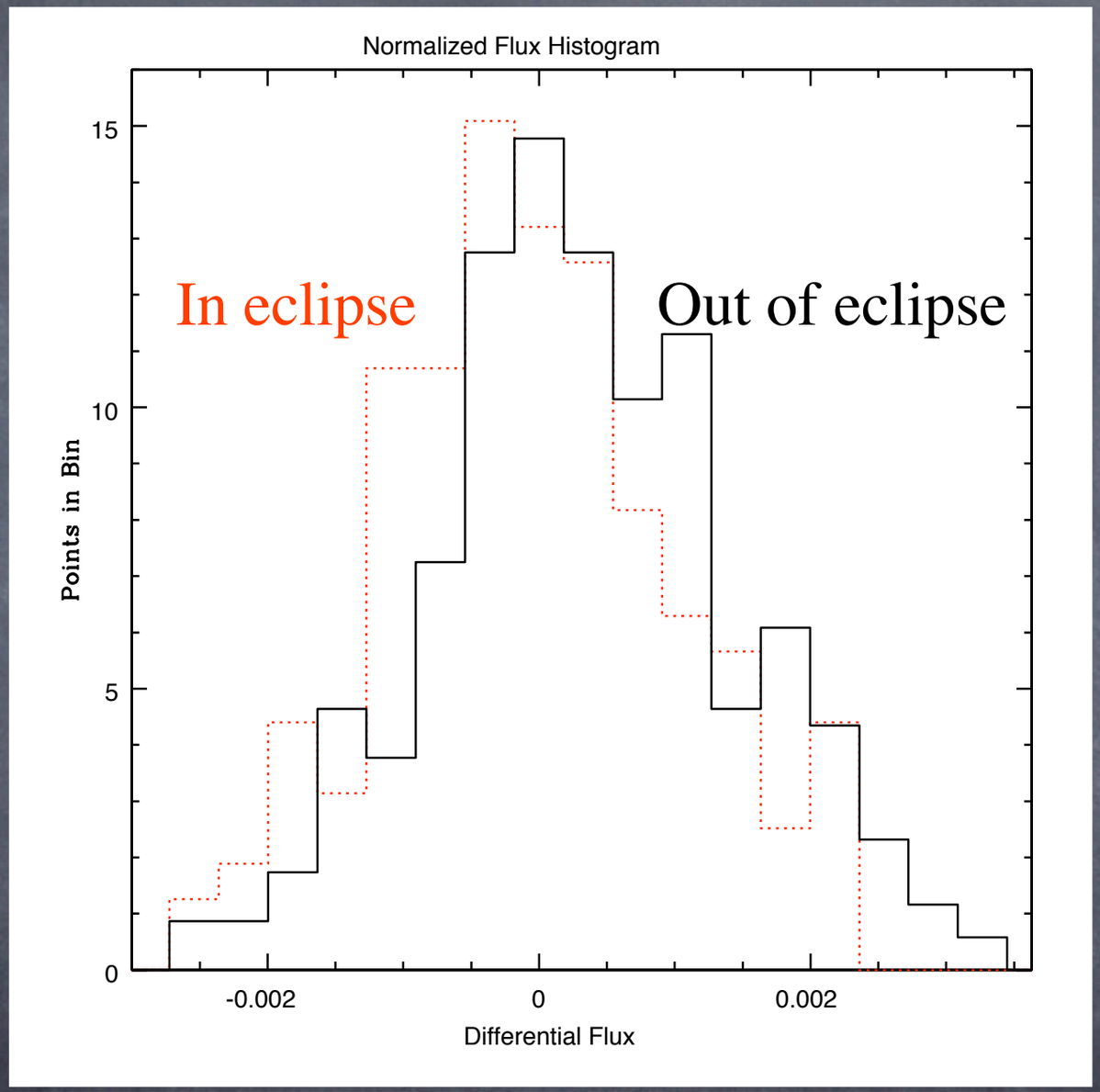
VLT
$\sigma_{red} = 1.1 \times 10^{-4}$

Magellan
$\sigma_{red} = 4 \times 10^{-5}$

Analysis

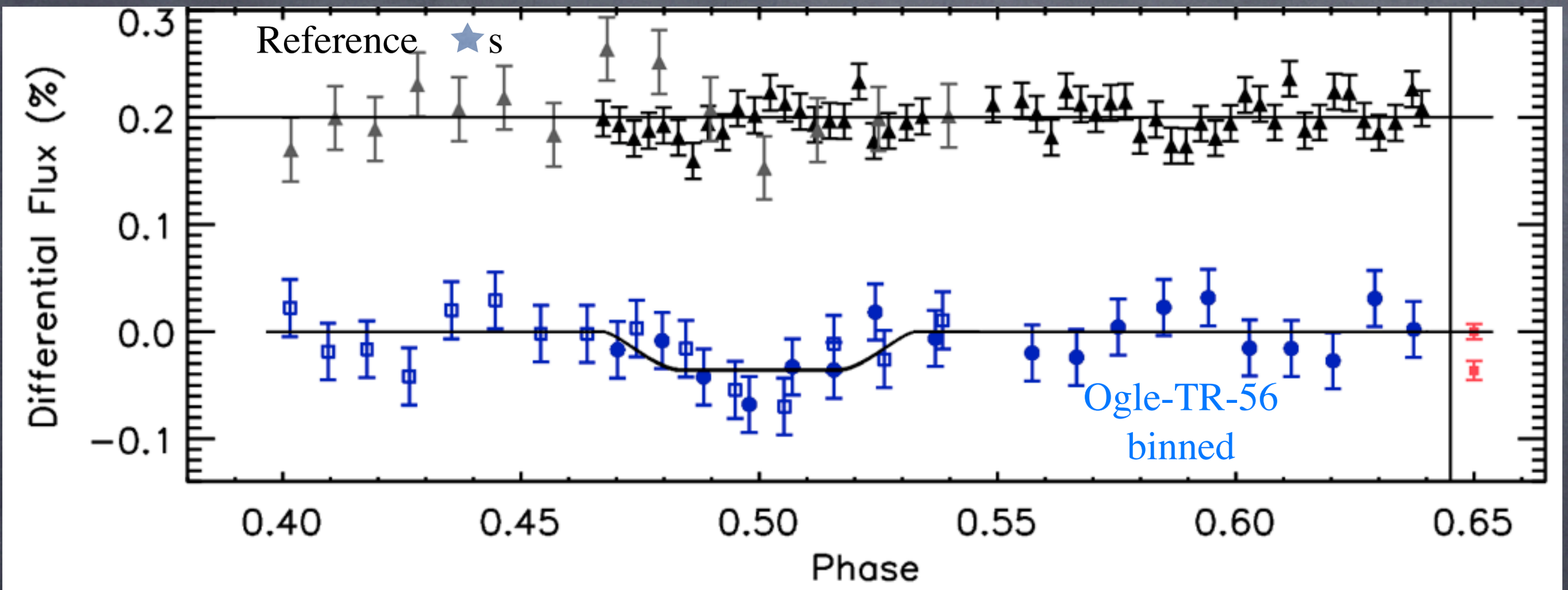

VLT differential flux (%)
Magellan differential flux (%)
0.3
0.2
0.1
0.0
−0.1
−0.2
−0.3
0.40
0.45
0.50
0.55
0.60
Phase

Analysis



0.036% lower flux for points in eclipse

Analysis

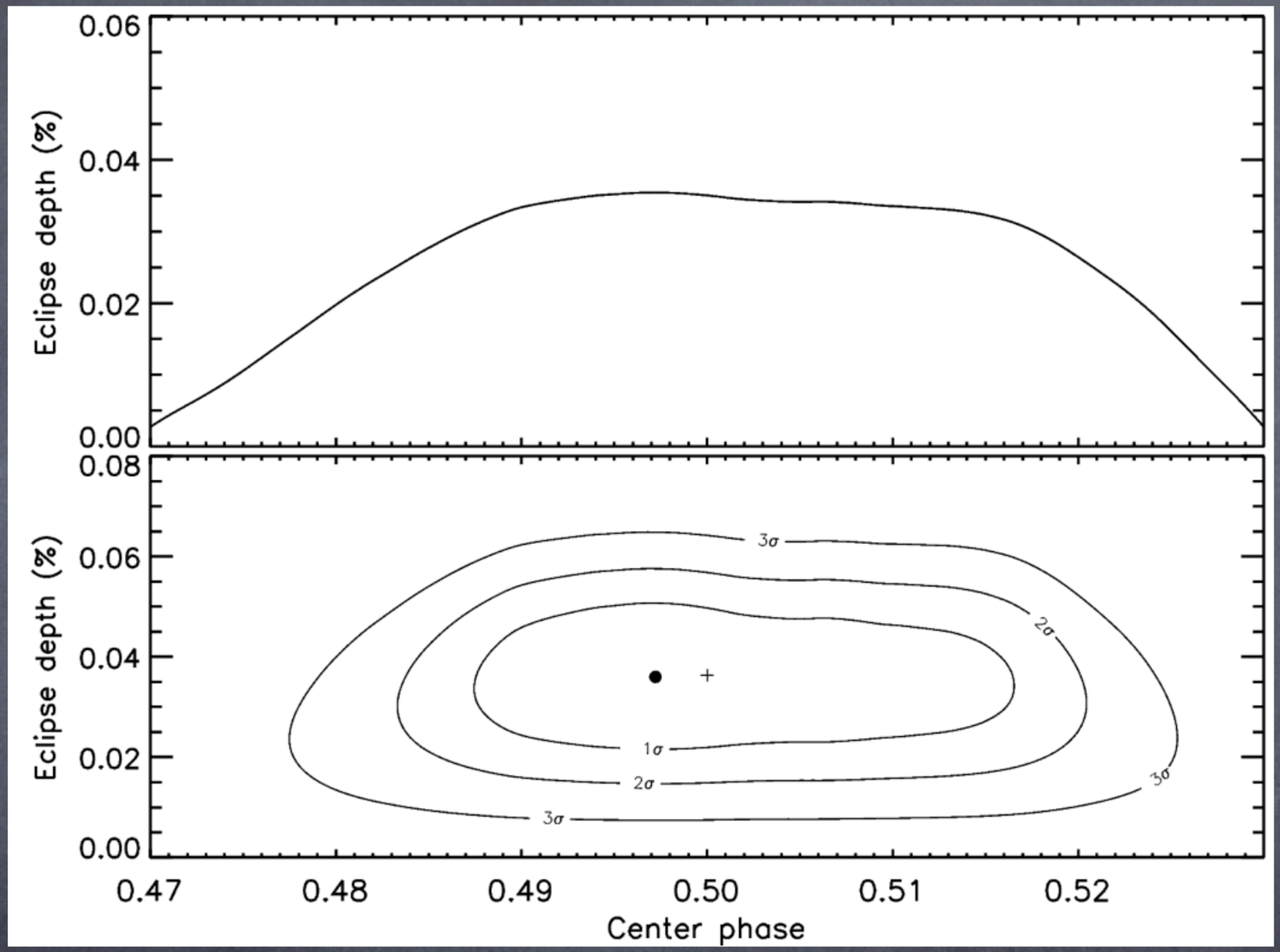


VLT Eclipse Depth = 0.037% ± 0.016% $\chi^2_\nu = 0.90$

Magellan Eclipse Depth = 0.036% ± 0.011% $\chi^2_\nu = 0.93$

Total Eclipse Depth = 0.0363% ± 0.0091%

Analysis

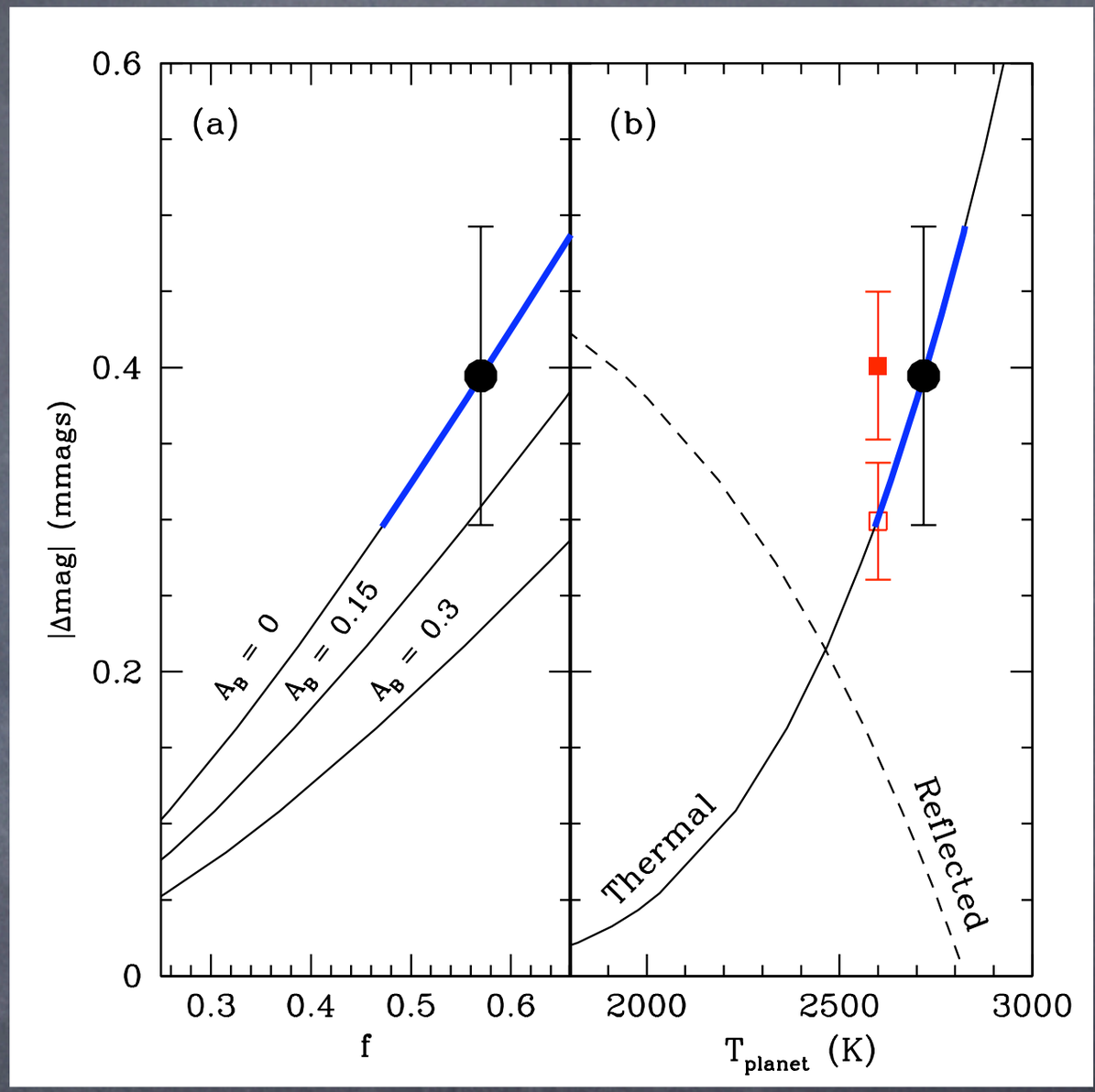


- Consistent with circular orbit

Analysis

Black Body

- T_{eff} = 2718±117 K
- Low albedo
- instant re-radiation
  f > 0.47



Non-black body Models

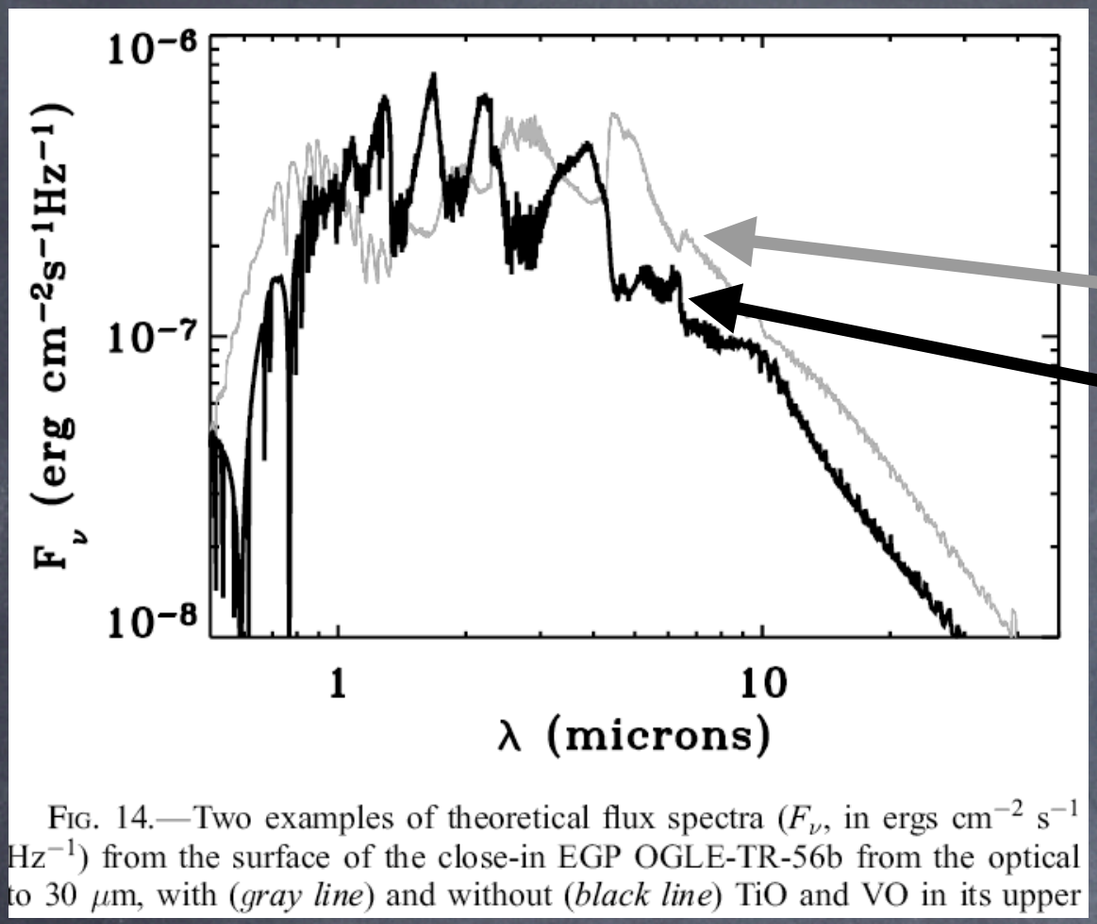
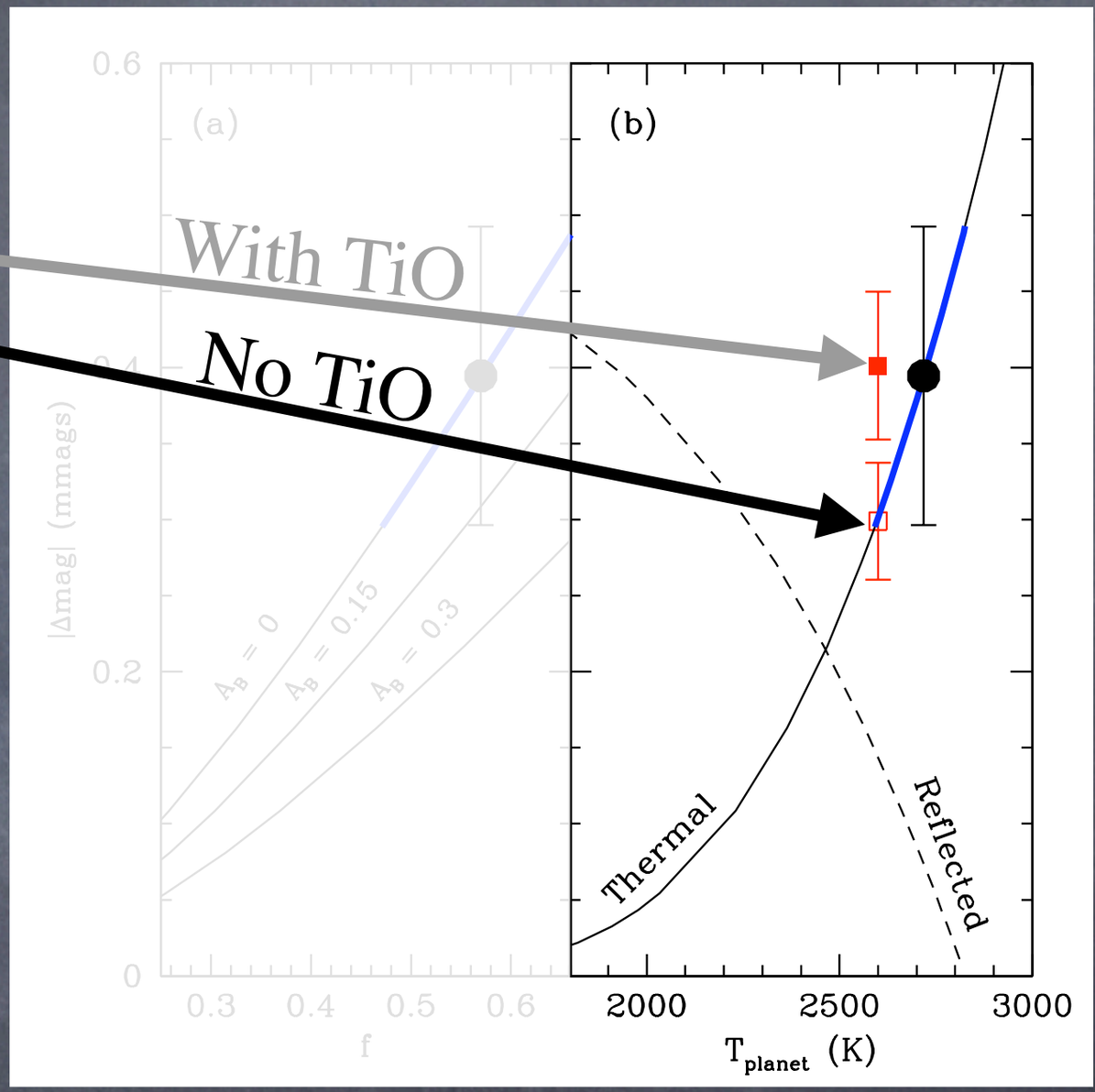


FIG. 14.—Two examples of theoretical flux spectra (F_ν, in ergs cm^{-2} s^{-1} Hz^{-1}) from the surface of the close-in EGP OGLE-TR-56b from the optical to 30 μm, with (*gray line*) and without (*black line*) TiO and VO in its upper



Hubeny 03

- Can not distinguish between models with and without TiO

Conclusions

- Ground-based secondary eclipse detected for Ogle-Tr-56
- HOT Dayside temperature; 2718±117 K
- Recirculation and Albedo are consistent with pM class planets
- Do Not have precision to distinguish between models blackbody, with/wo TiO
- Other optical wavelengths and/or near-IR needed
- Other very-hot Jupiters can be detected in z’