Spitzer *Photometry of The Transiting Super-Earth* 55 Cnc e

Brice-Olivier Demory, MIT
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Sara Seager, MIT

55 Cancri, from 1997 to 2011

- Dawson & Fabrycky 2010 : tr prob from 13 to 33% -> inclusion in WS program (PI Gillon)

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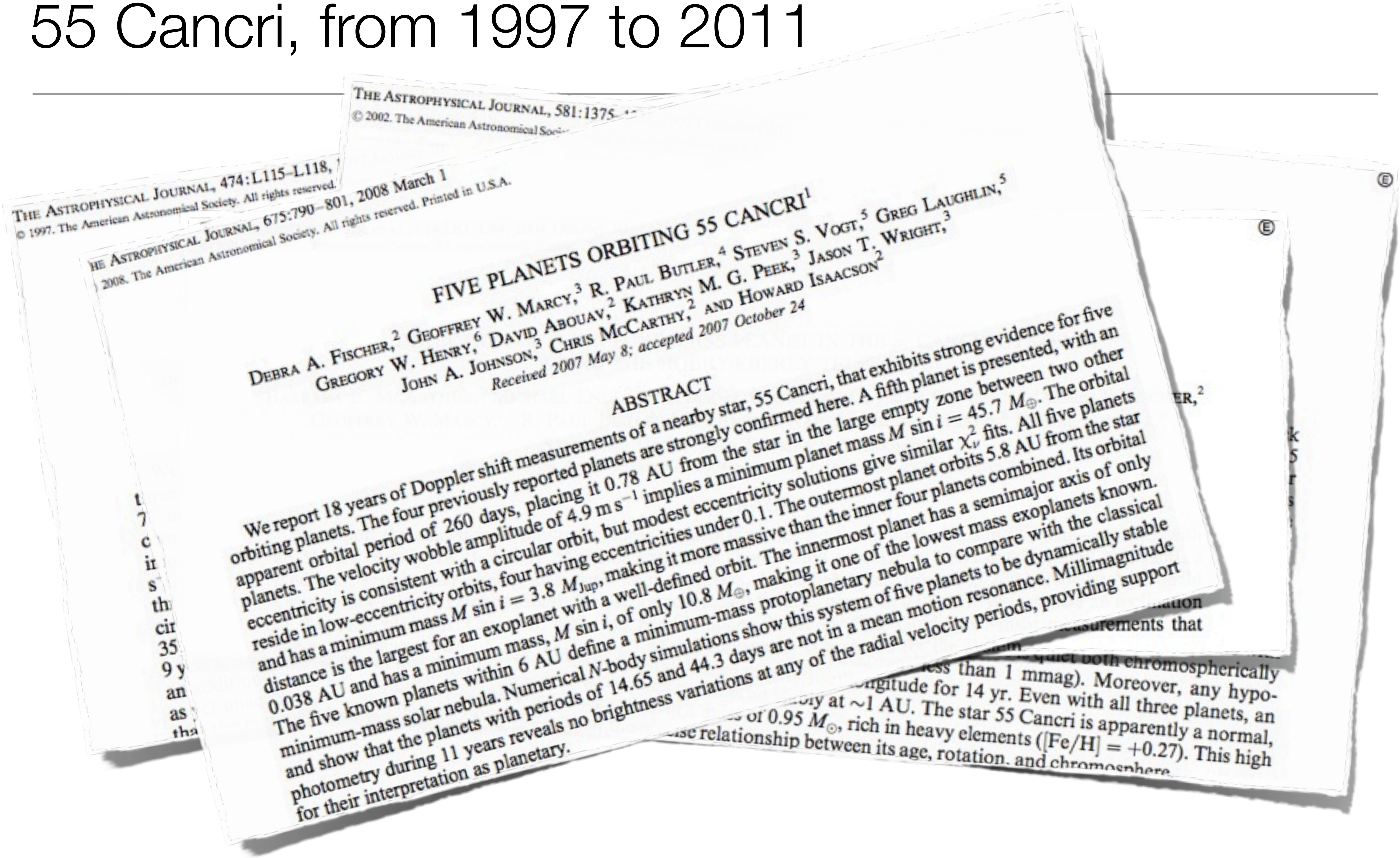

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FIVE PLANETS ORBITING 55 CANCRI[1]

DEBRA A. FISCHER,[2] GEOFFREY W. MARCY,[3] R. PAUL BUTLER,[4] STEVEN S. VOGT,[5] GREG LAUGHLIN,[5] GREGORY W. HENRY,[6] DAVID ABOUAV,[2] KATHRYN M. G. PEEK,[3] JASON T. WRIGHT,[3] JOHN A. JOHNSON,[3] CHRIS MCCARTHY,[2] AND HOWARD ISAACSON[2]

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ABSTRACT

We report 18 years of Doppler shift measurements of a nearby star, 55 Cancri, that exhibits strong evidence for five orbiting planets. The four previously reported planets are strongly confirmed here. A fifth planet is presented, with an apparent orbital period of 260 days, placing it 0.78 AU from the star in the large empty zone between two other planets. The velocity wobble amplitude of 4.9 m s^{-1} implies a minimum planet mass $M \sin i = 45.7\ M_{\oplus}$. The orbital eccentricity is consistent with a circular orbit, but modest eccentricity solutions give similar χ^2_ν fits. All five planets reside in low-eccentricity orbits, four having eccentricities under 0.1. The outermost planet orbits 5.8 AU from the star and has a minimum mass $M \sin i = 3.8\ M_{Jup}$, making it more massive than the inner four planets combined. Its orbital distance is the largest for an exoplanet with a well-defined orbit. The innermost planet has a semimajor axis of only 0.038 AU and has a minimum mass, $M \sin i$, of only 10.8 $M_{\oplus}$, making it one of the lowest mass exoplanets known. The five known planets within 6 AU define a minimum-mass protoplanetary nebula to compare with the classical minimum-mass solar nebula. Numerical *N*-body simulations show this system of five planets to be dynamically stable and show that the planets with periods of 14.65 and 44.3 days are not in a mean motion resonance. Millimagnitude photometry during 11 years reveals no brightness variations at any of the radial velocity periods, providing support for their interpretation as planetary.

Wednesday, October 5, 2011

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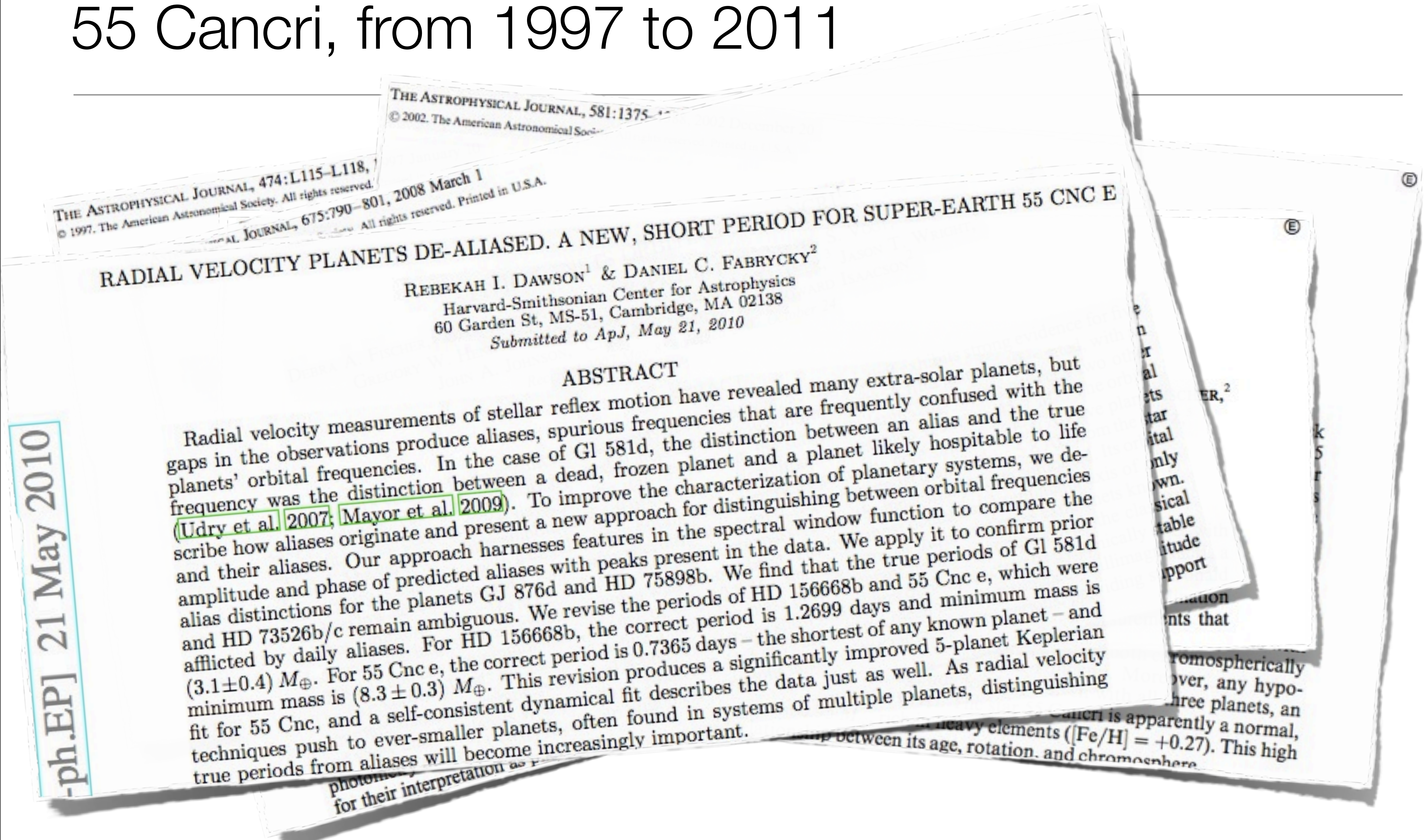

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RADIAL VELOCITY PLANETS DE-ALIASED. A NEW, SHORT PERIOD FOR SUPER-EARTH 55 CNC E

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Submitted to ApJ, May 21, 2010

ABSTRACT

Radial velocity measurements of stellar reflex motion have revealed many extra-solar planets, but gaps in the observations produce aliases, spurious frequencies that are frequently confused with the planets' orbital frequencies. In the case of Gl 581d, the distinction between an alias and the true frequency was the distinction between a dead, frozen planet and a planet likely hospitable to life (Udry et al. 2007; Mayor et al. 2009). To improve the characterization of planetary systems, we describe how aliases originate and present a new approach for distinguishing between orbital frequencies and their aliases. Our approach harnesses features in the spectral window function to compare the amplitude and phase of predicted aliases with peaks present in the data. We apply it to confirm prior alias distinctions for the planets GJ 876d and HD 75898b. We find that the true periods of Gl 581d and HD 73526b/c remain ambiguous. We revise the periods of HD 156668b and 55 Cnc e, which were afflicted by daily aliases. For HD 156668b, the correct period is 1.2699 days and minimum mass is $(3.1 \pm 0.4)\ M_{\oplus}$. For 55 Cnc e, the correct period is 0.7365 days – the shortest of any known planet – and minimum mass is $(8.3 \pm 0.3)\ M_{\oplus}$. This revision produces a significantly improved 5-planet Keplerian fit for 55 Cnc, and a self-consistent dynamical fit describes the data just as well. As radial velocity techniques push to ever-smaller planets, often found in systems of multiple planets, distinguishing true periods from aliases will become increasingly important.

-ph.EP] 21 May 2010

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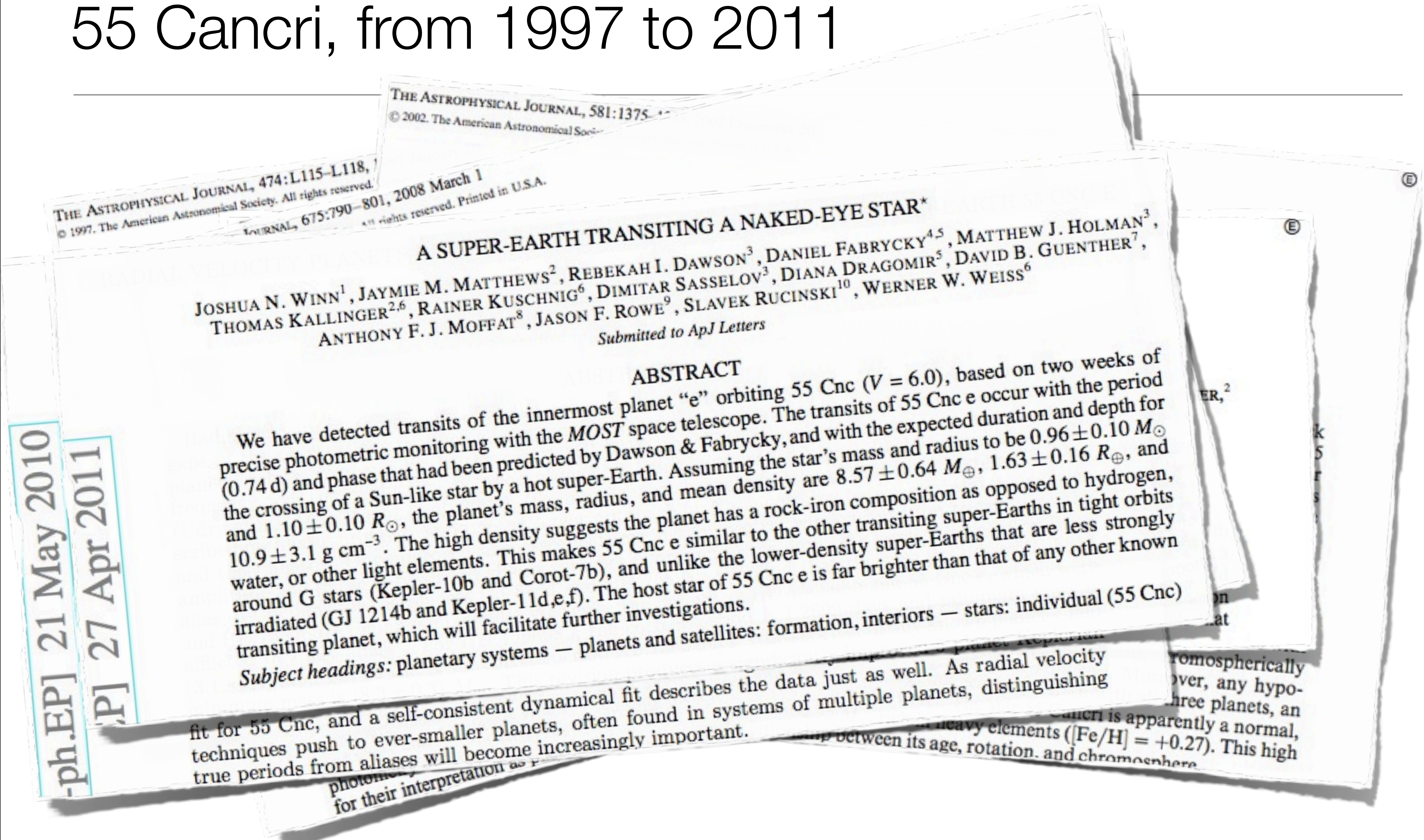

A SUPER-EARTH TRANSITING A NAKED-EYE STAR*

Joshua N. Winn[1], Jaymie M. Matthews[2], Rebekah I. Dawson[3], Daniel Fabrycky[4,5], Matthew J. Holman[3], Thomas Kallinger[2,6], Rainer Kuschnig[6], Dimitar Sasselov[3], Diana Dragomir[5], David B. Guenther[7], Anthony F. J. Moffat[8], Jason F. Rowe[9], Slavek Rucinski[10], Werner W. Weiss[6]

Submitted to ApJ Letters

ABSTRACT

We have detected transits of the innermost planet "e" orbiting 55 Cnc ($V = 6.0$), based on two weeks of precise photometric monitoring with the *MOST* space telescope. The transits of 55 Cnc e occur with the period (0.74 d) and phase that had been predicted by Dawson & Fabrycky, and with the expected duration and depth for the crossing of a Sun-like star by a hot super-Earth. Assuming the star's mass and radius to be $0.96 \pm 0.10\ M_\odot$ and $1.10 \pm 0.10\ R_\odot$, the planet's mass, radius, and mean density are $8.57 \pm 0.64\ M_\oplus$, $1.63 \pm 0.16\ R_\oplus$, and 10.9 ± 3.1 g cm^{-3}. The high density suggests the planet has a rock-iron composition as opposed to hydrogen, water, or other light elements. This makes 55 Cnc e similar to the other transiting super-Earths in tight orbits around G stars (Kepler-10b and Corot-7b), and unlike the lower-density super-Earths that are less strongly irradiated (GJ 1214b and Kepler-11d,e,f). The host star of 55 Cnc e is far brighter than that of any other known transiting planet, which will facilitate further investigations.

Subject headings: planetary systems — planets and satellites: formation, interiors — stars: individual (55 Cnc)

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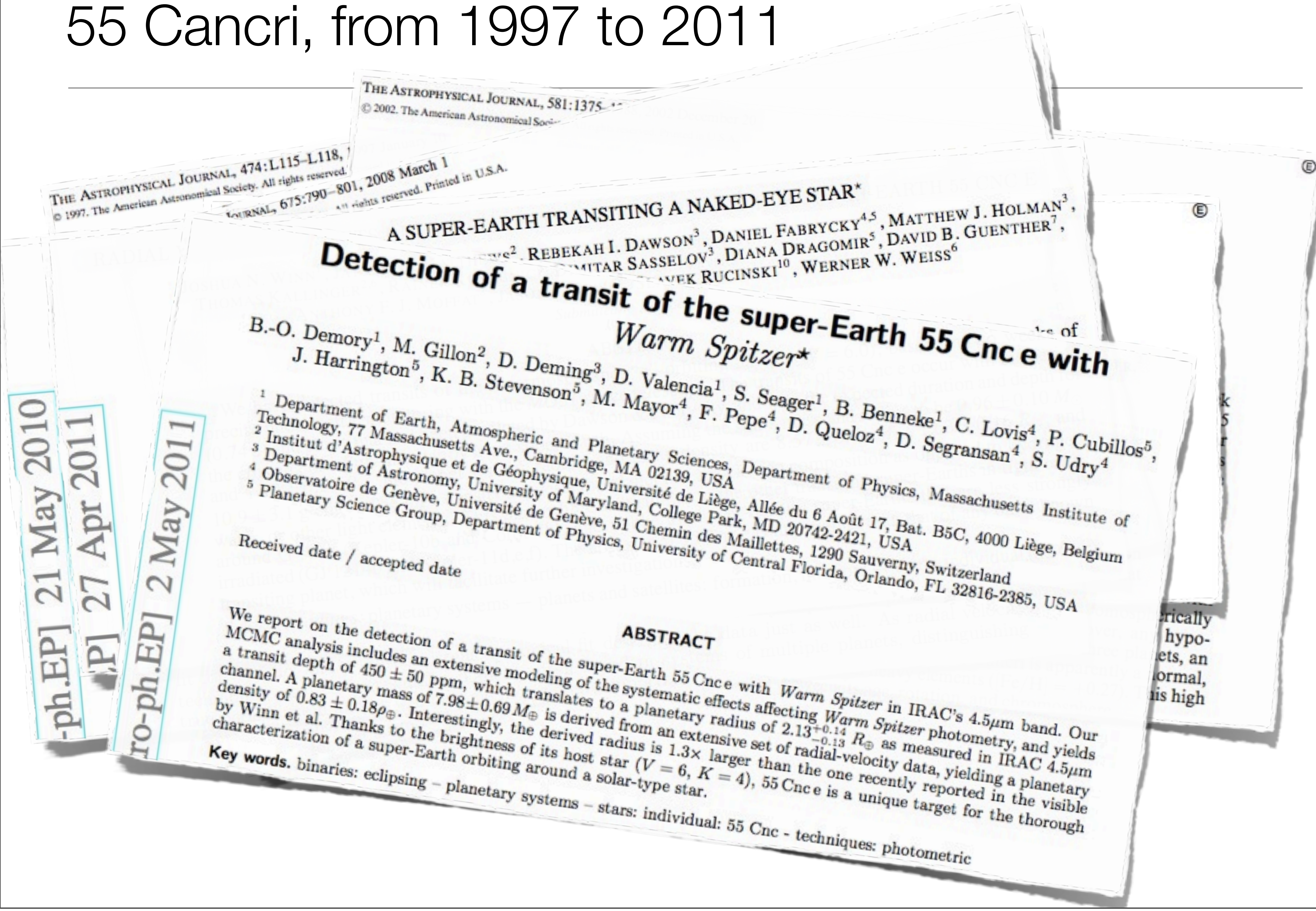

Detection of a transit of the super-Earth 55 Cnc e with *Warm Spitzer**

B.-O. Demory[1], M. Gillon[2], D. Deming[3], D. Valencia[1], S. Seager[1], B. Benneke[1], C. Lovis[4], P. Cubillos[5], J. Harrington[5], K. B. Stevenson[5], M. Mayor[4], F. Pepe[4], D. Queloz[4], D. Segransan[4], S. Udry[4]

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[2] Institut d'Astrophysique et de Géophysique, Université de Liège, Allée du 6 Août 17, Bat. B5C, 4000 Liège, Belgium
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Received date / accepted date

ABSTRACT

We report on the detection of a transit of the super-Earth 55 Cnc e with *Warm Spitzer* in IRAC's 4.5μm band. Our MCMC analysis includes an extensive modeling of the systematic effects affecting *Warm Spitzer* photometry, and yields a transit depth of 450 ± 50 ppm, which translates to a planetary radius of $2.13^{+0.14}_{-0.13} R_{\oplus}$ as measured in IRAC 4.5μm channel. A planetary mass of $7.98 \pm 0.69 M_{\oplus}$ is derived from an extensive set of radial-velocity data, yielding a planetary density of $0.83 \pm 0.18 \rho_{\oplus}$. Interestingly, the derived radius is 1.3× larger than the one recently reported in the visible by Winn et al. Thanks to the brightness of its host star ($V = 6$, $K = 4$), 55 Cnc e is a unique target for the thorough characterization of a super-Earth orbiting around a solar-type star.

Key words. binaries: eclipsing – planetary systems – stars: individual: 55 Cnc - techniques: photometric

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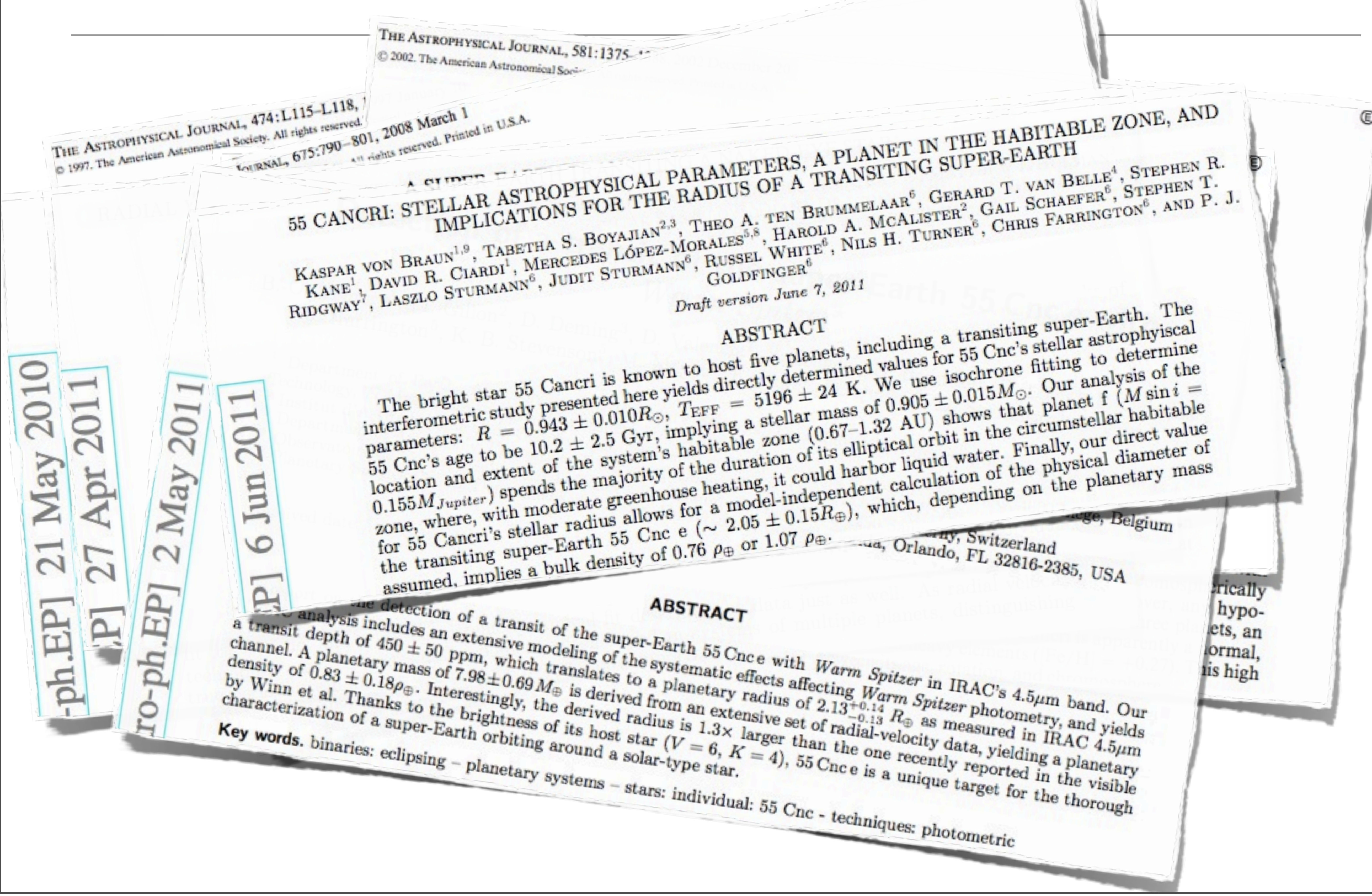

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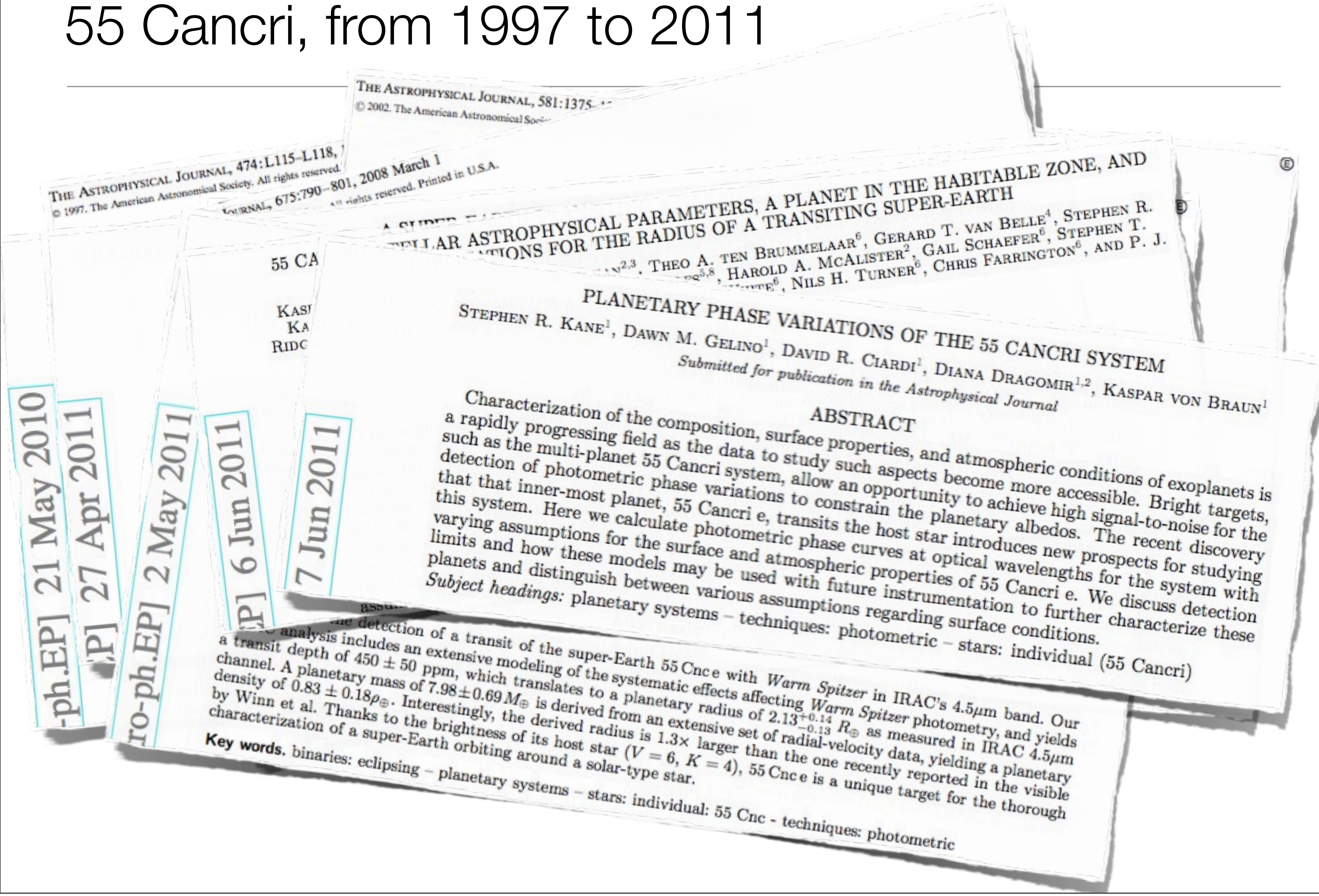

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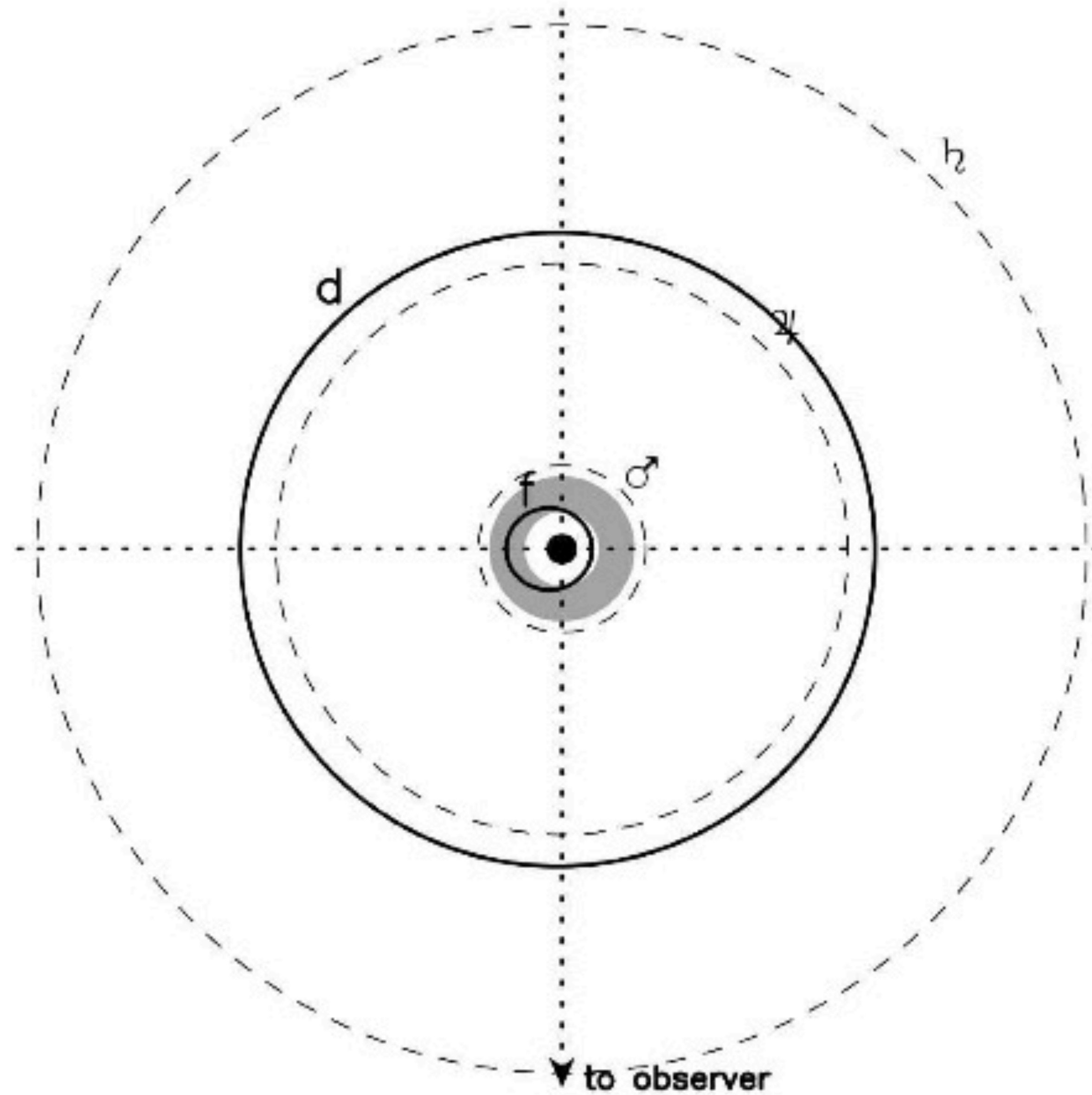
55 Cancri e

- Minimum mass : 7.80 ± 0.56 $M_{\oplus}$
- Expected radius : 1.3 - 5.7 $R_{\oplus}$
- RV semi-amplitude : 5.93 ± 0.42 m/s
- Period : 0.736d - 17hr 40min



Stellar parameters

- V magnitude: 5.96
- Stellar type : K0V - G8V (a)
- Teff : 5234 K (a)
- Mass : 0.905 ± 0.015 Msun (b)
- Radius : 0.943 ± 0.010 Rsun (b)

a) Fischer et al. 2008
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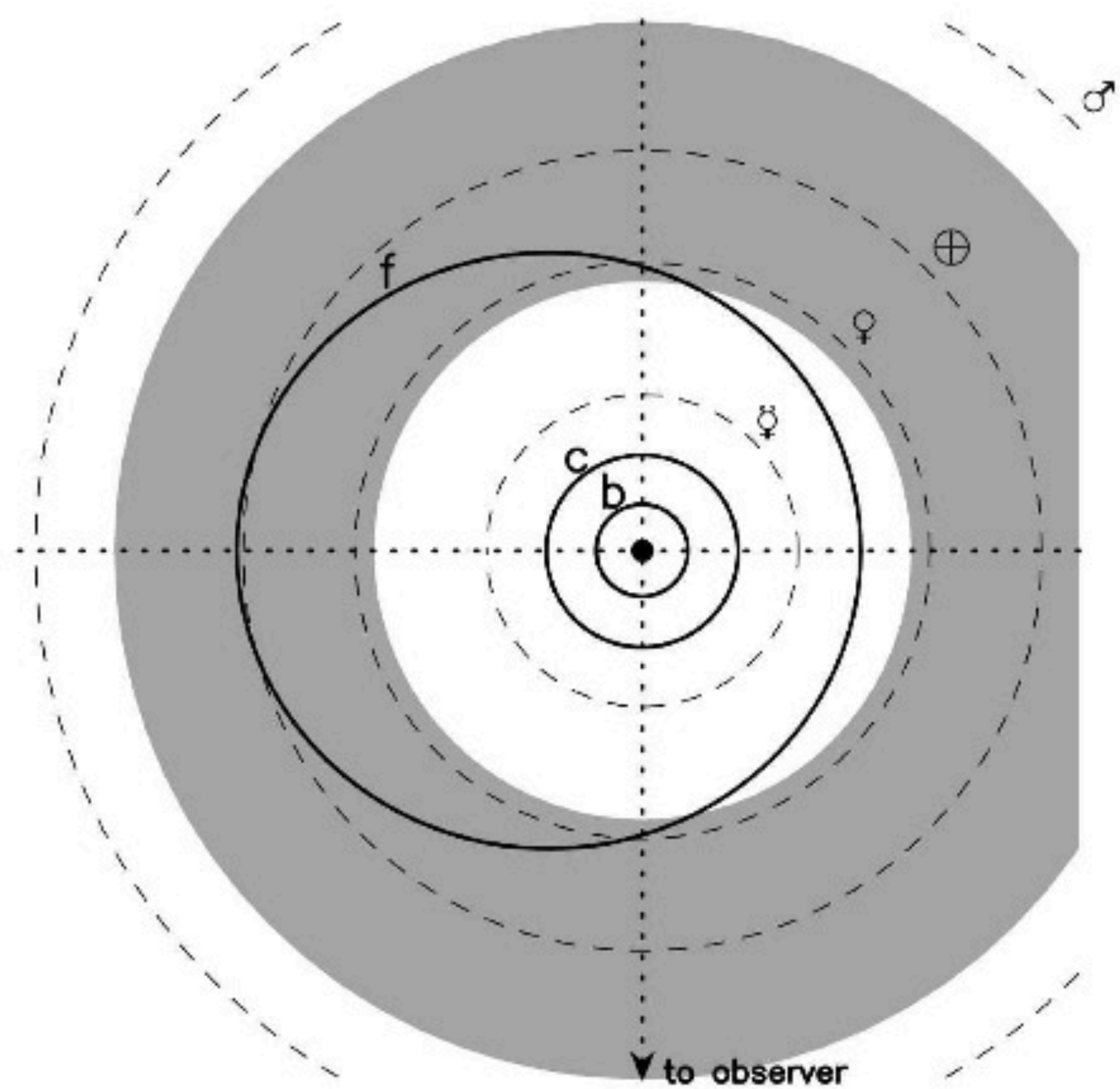

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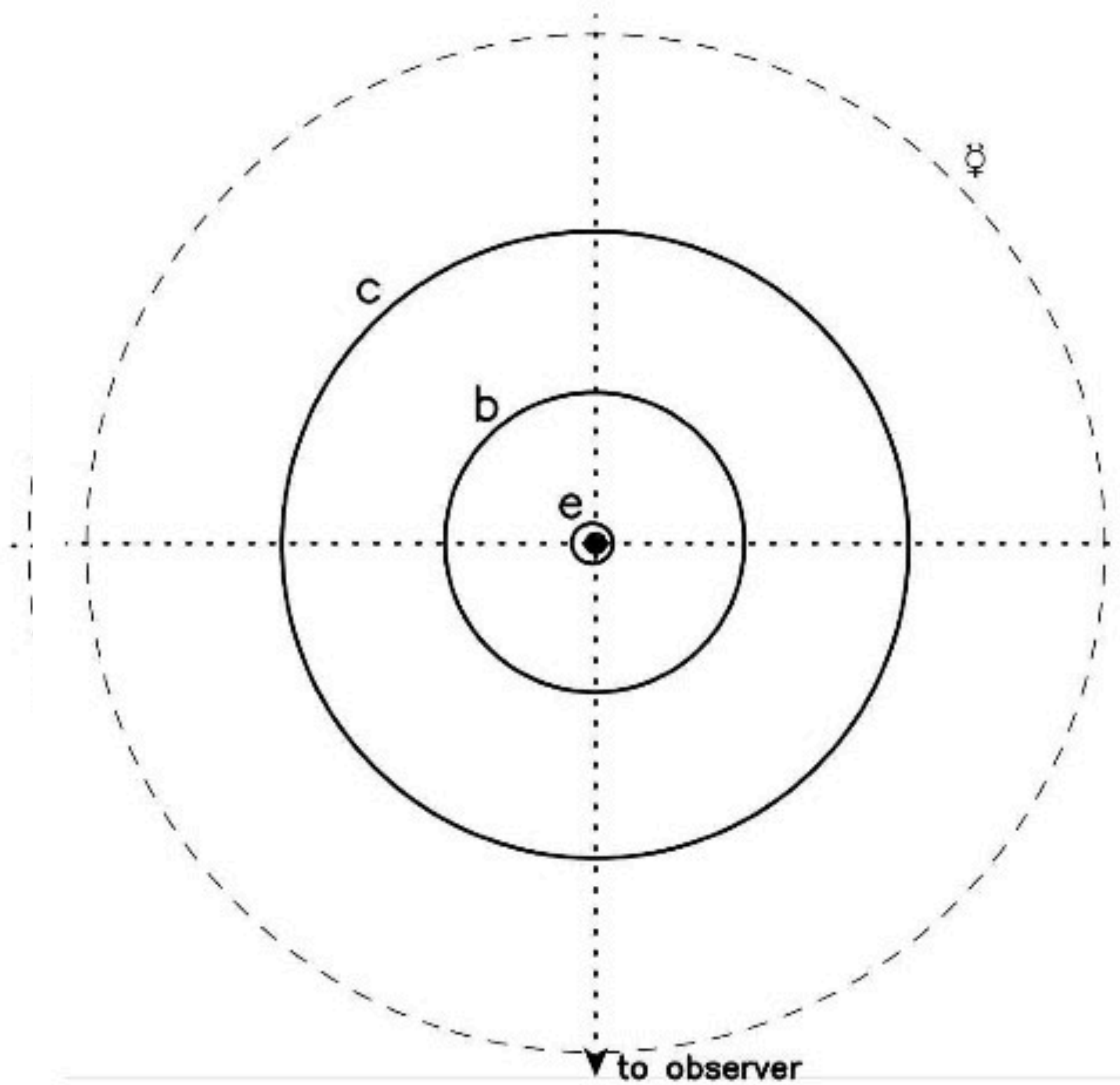

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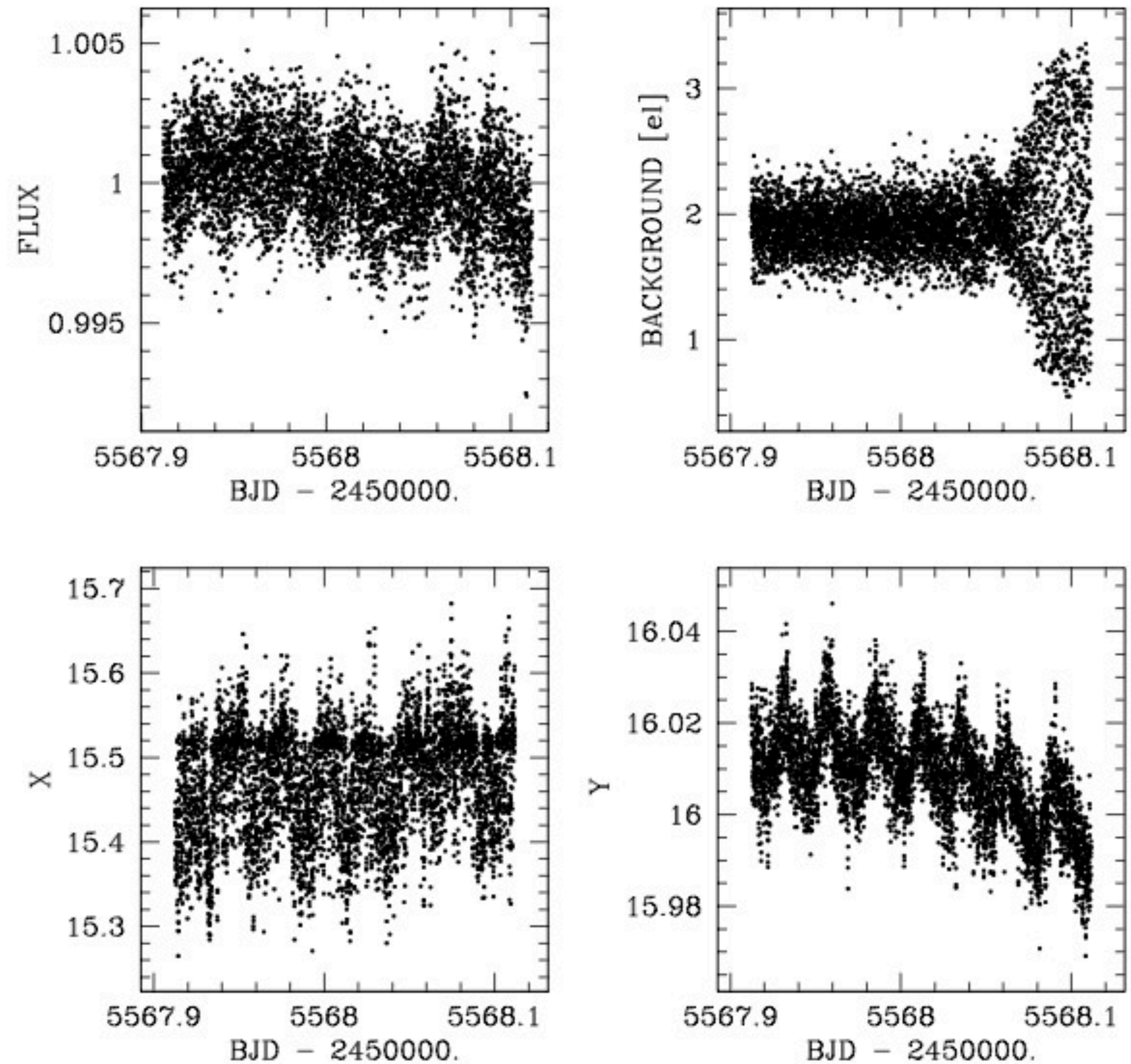
55 Cnc e's Transit on 6 January 2011

Spitzer IRAC **4.5-µm**



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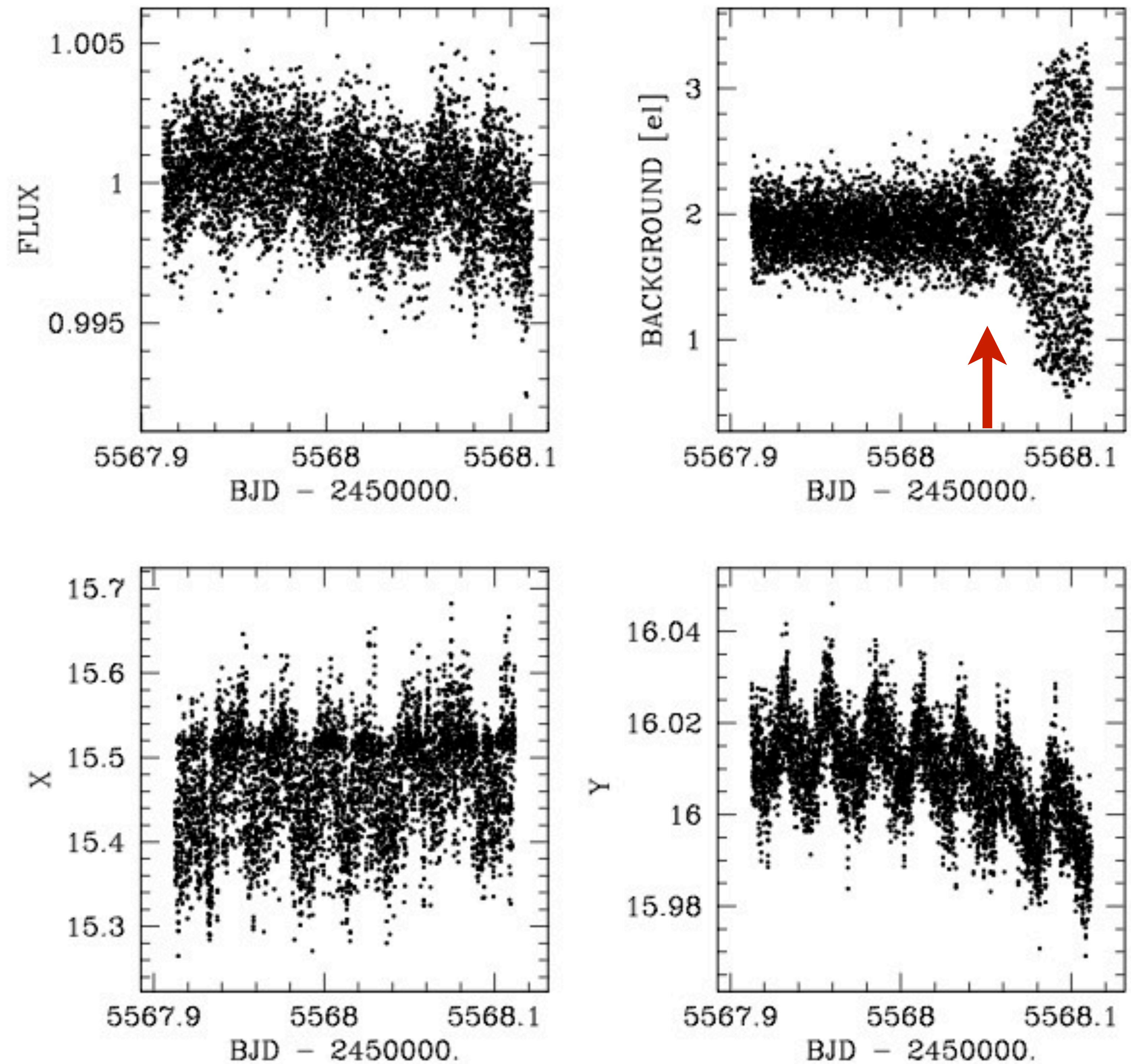

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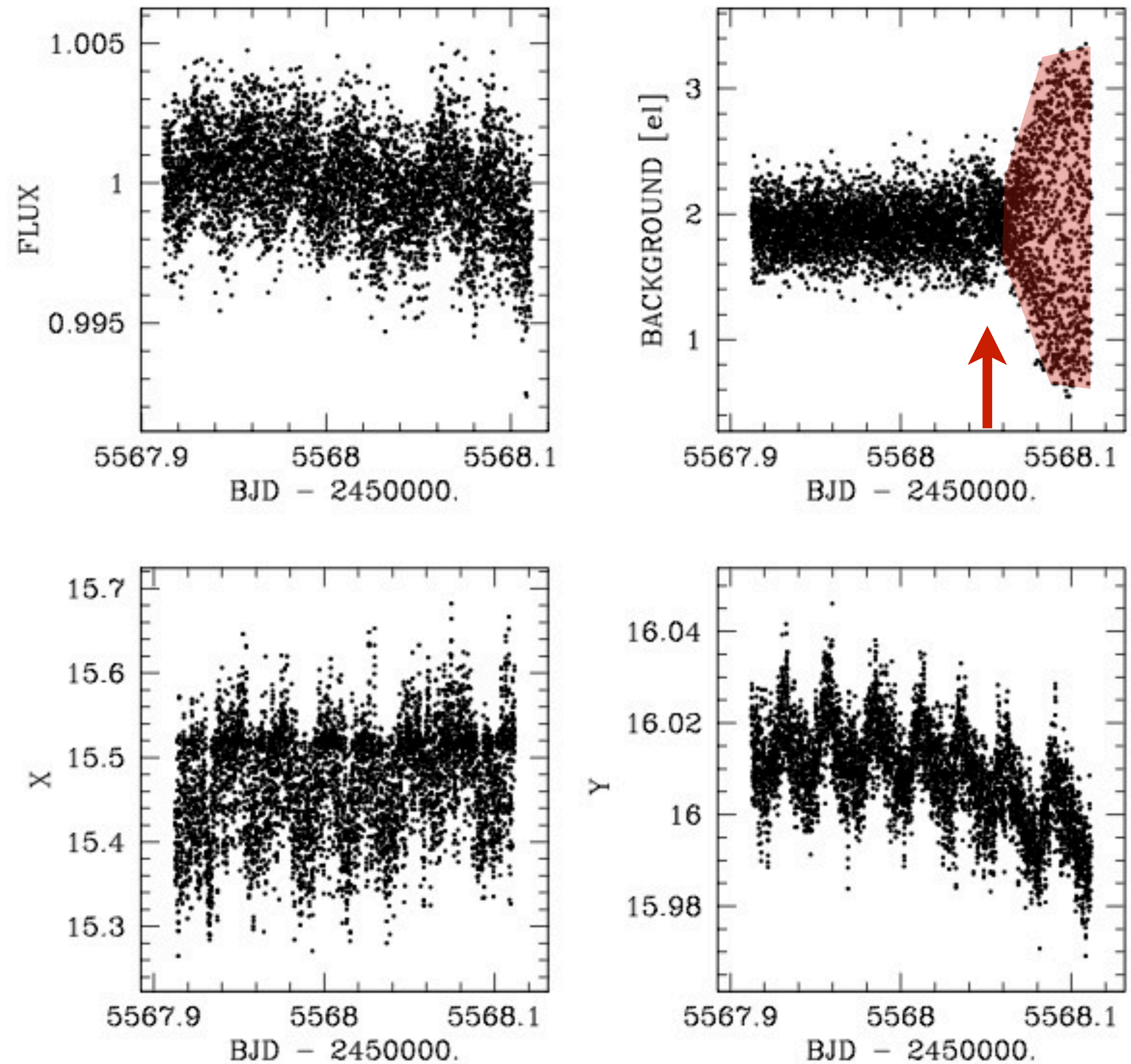

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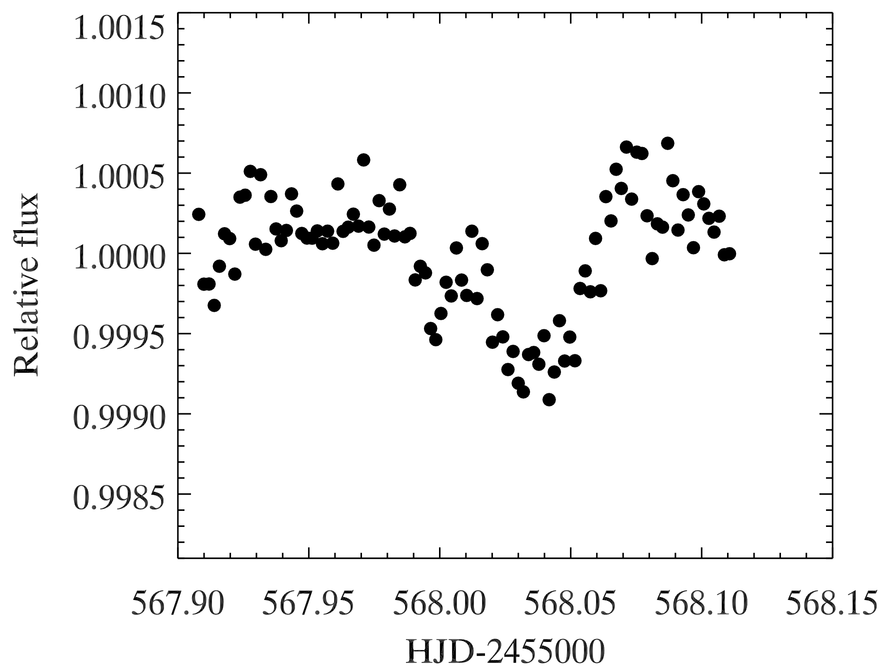

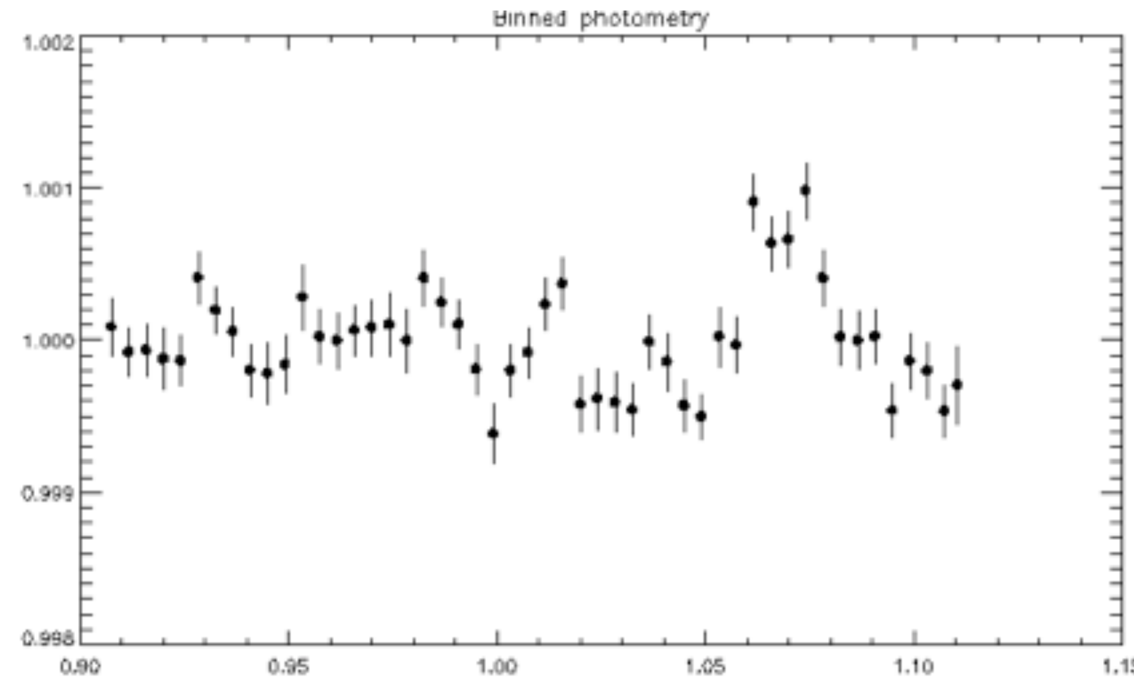

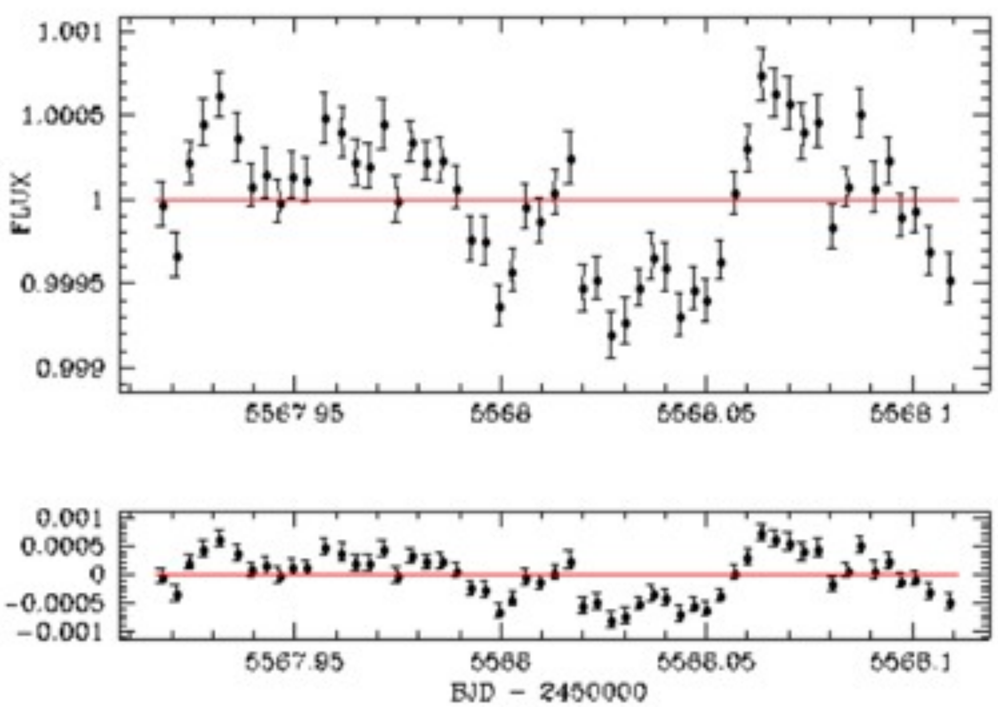

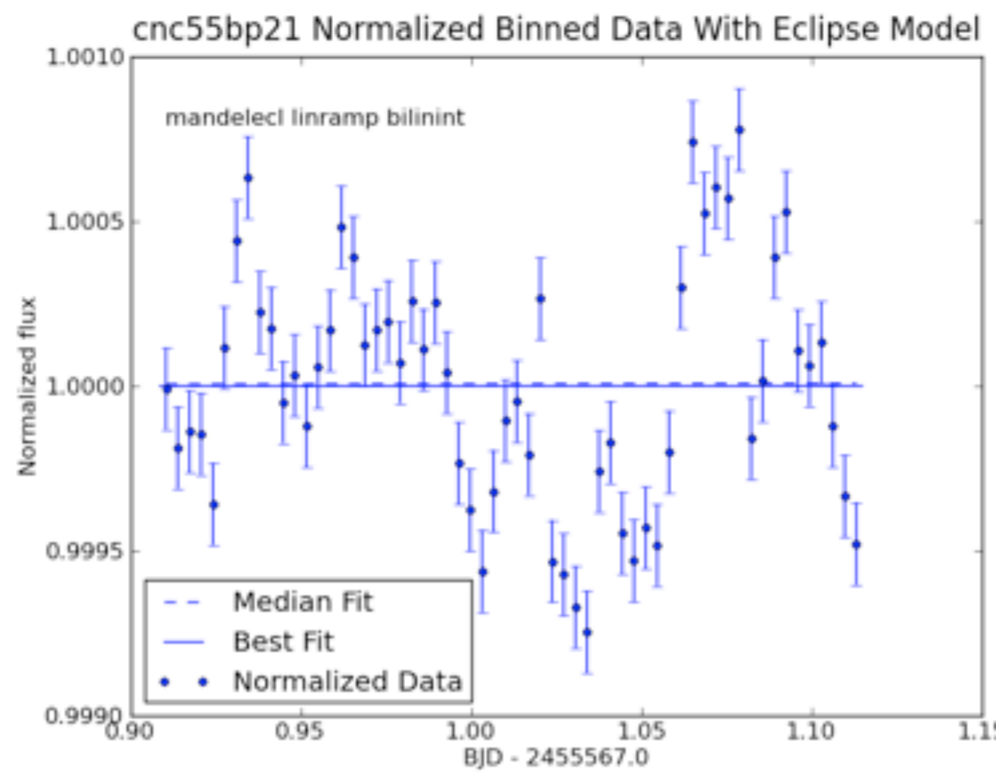

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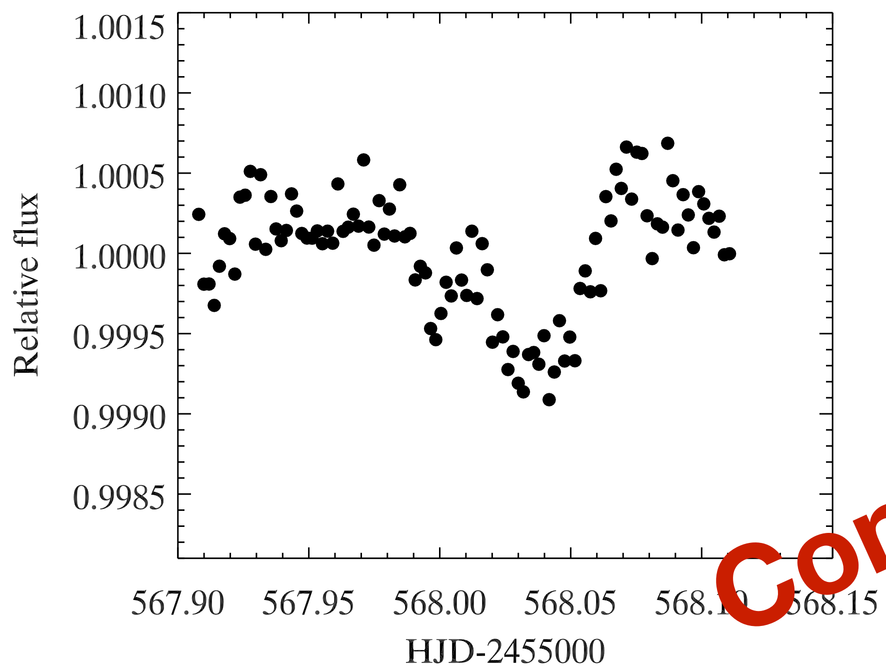
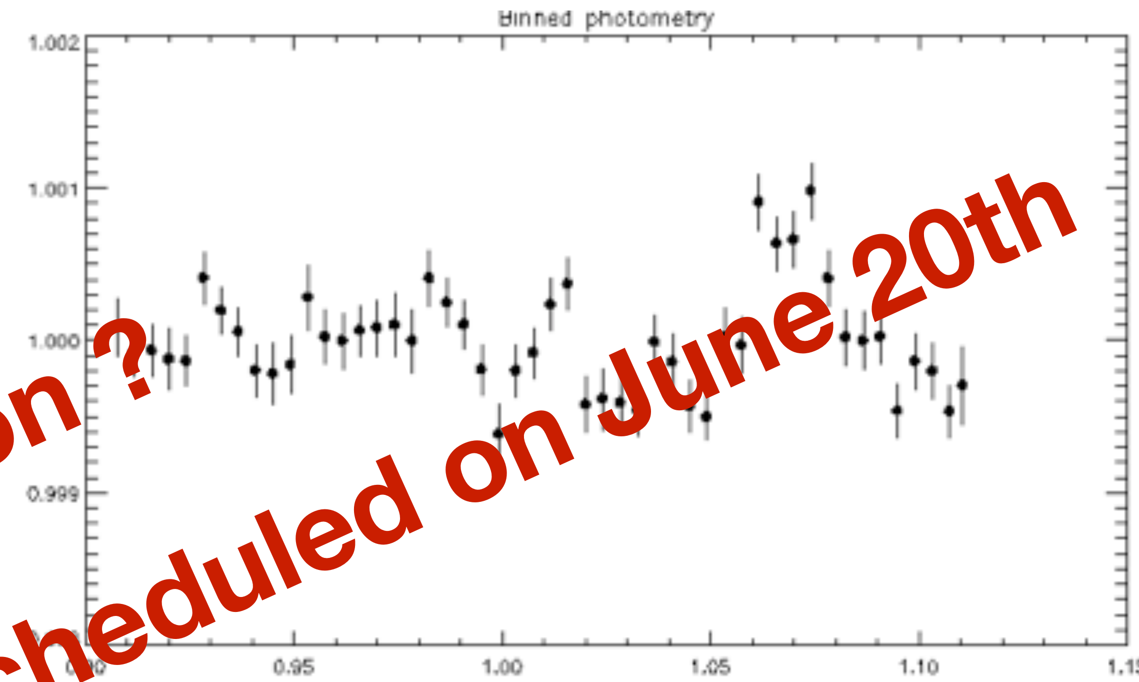
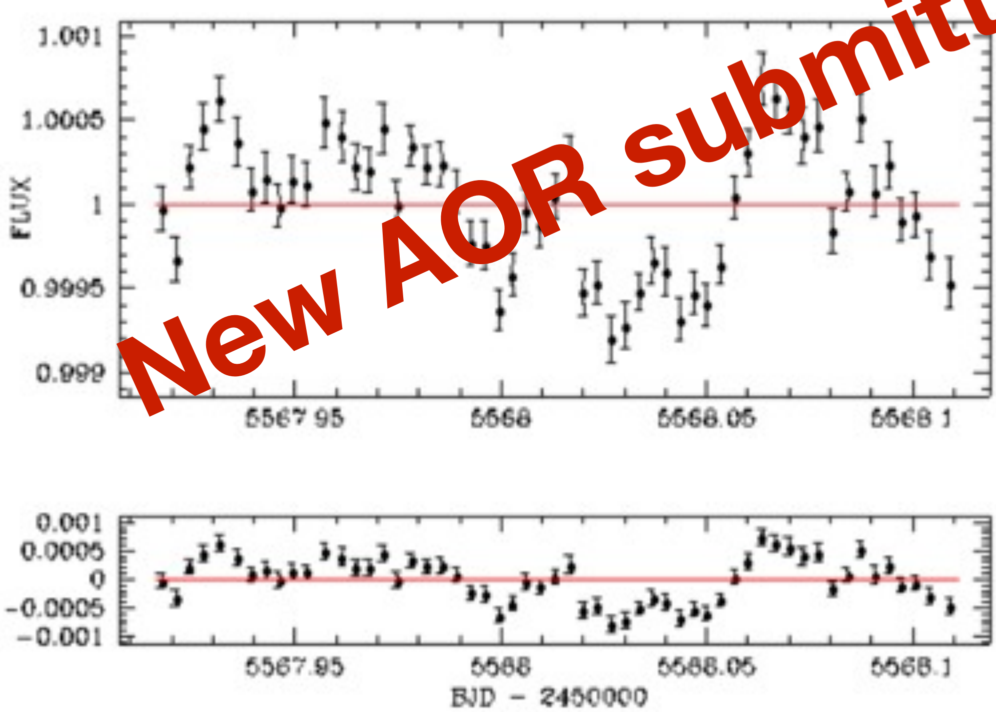
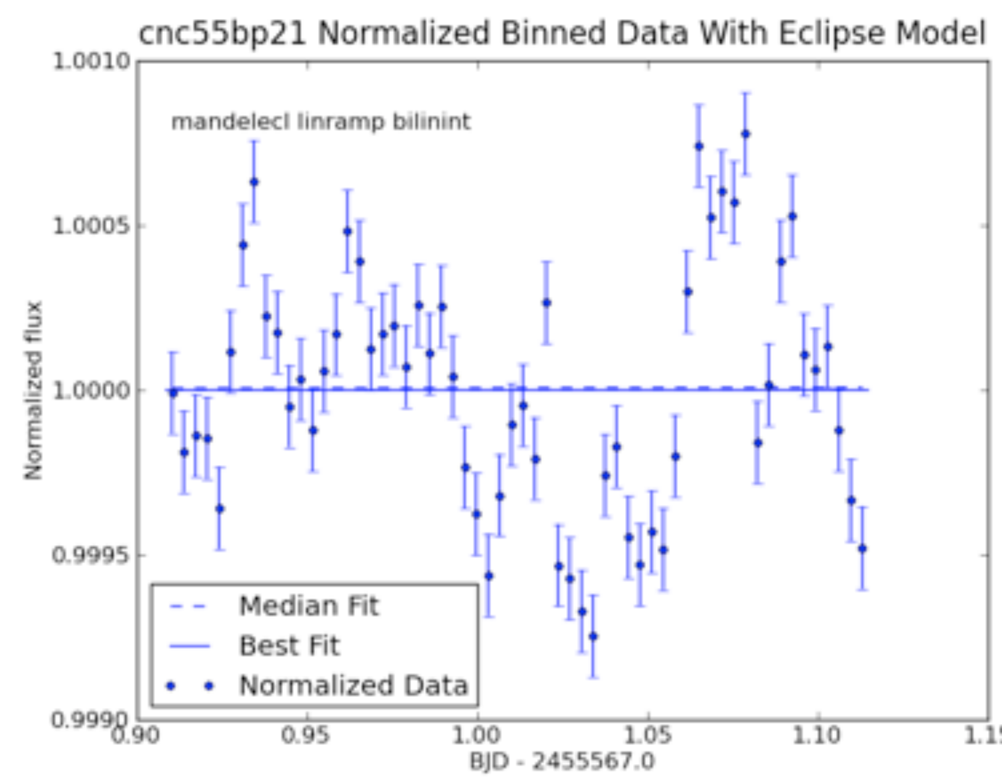




Conclusion ?

New AOR submitted, scheduled on June 20th





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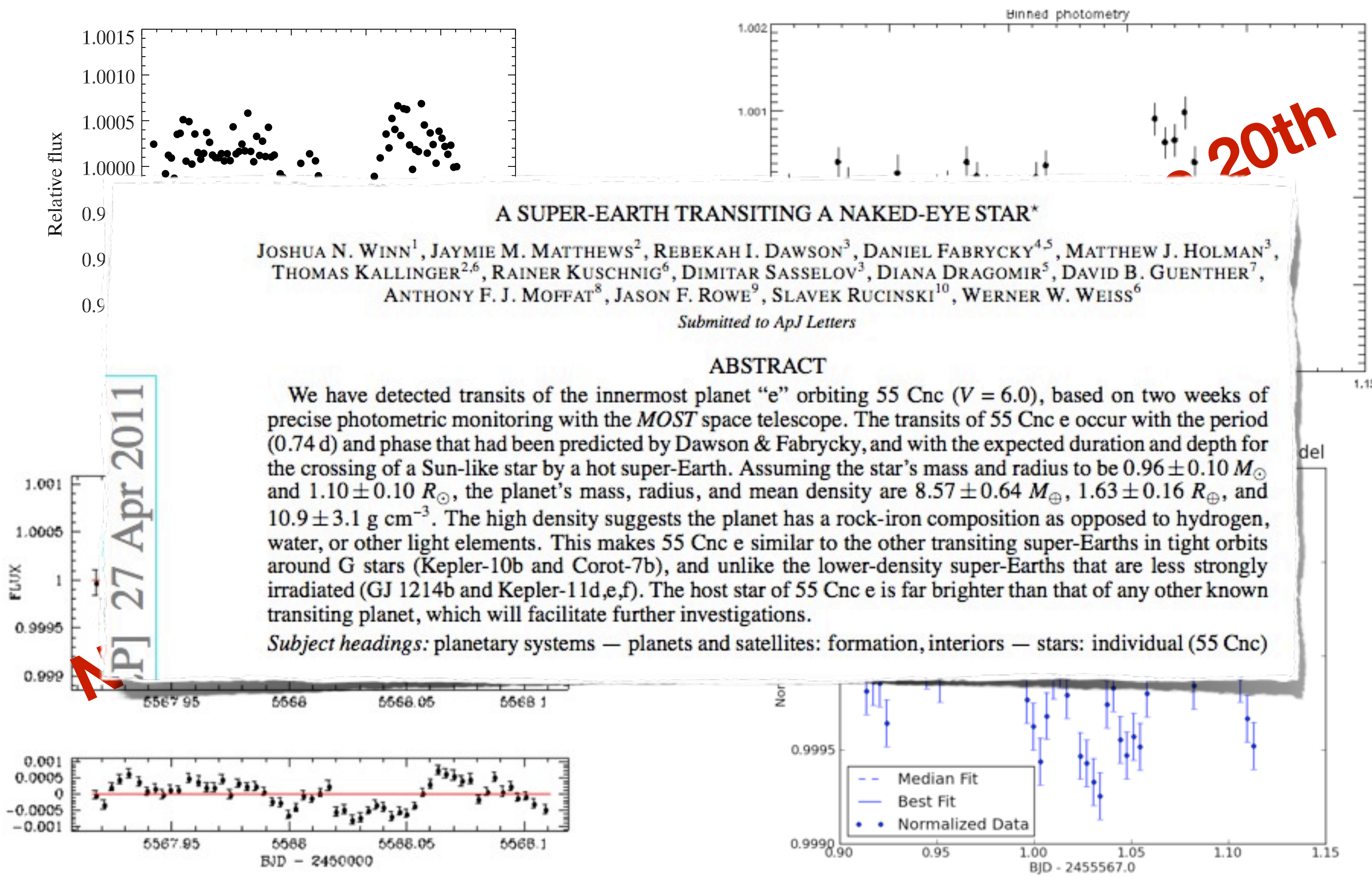

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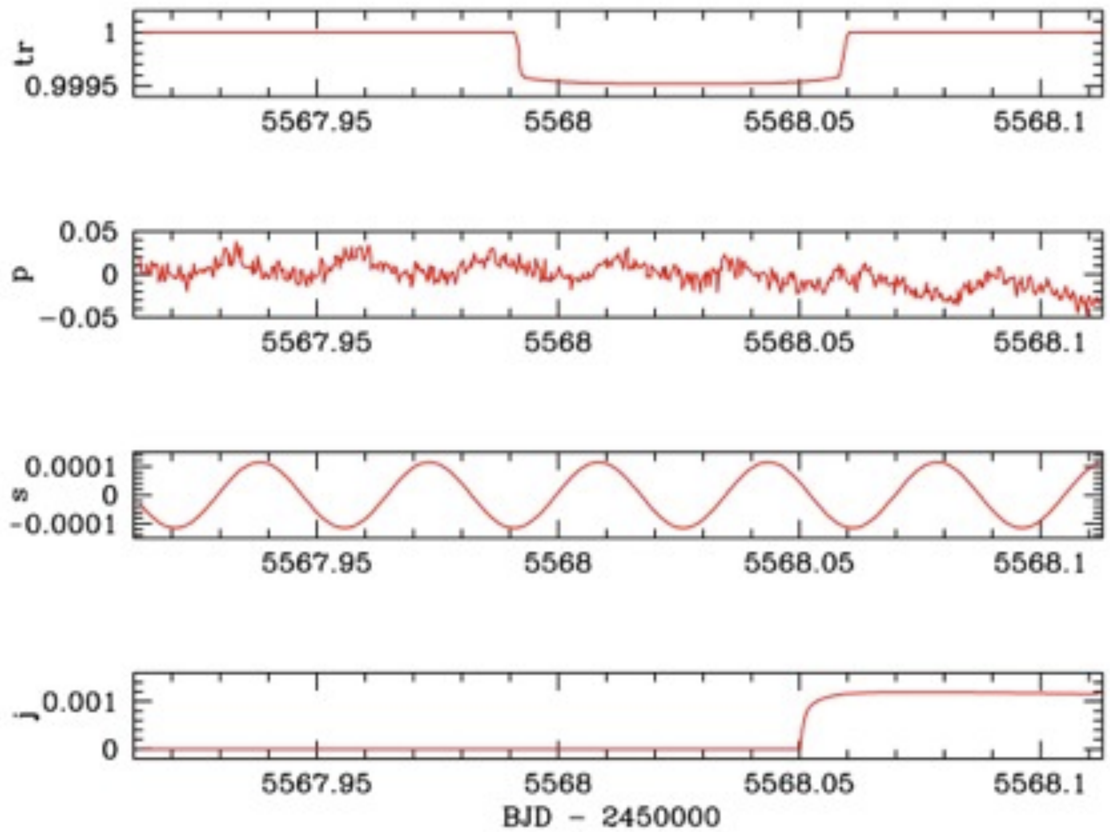

Demory et al. 2011

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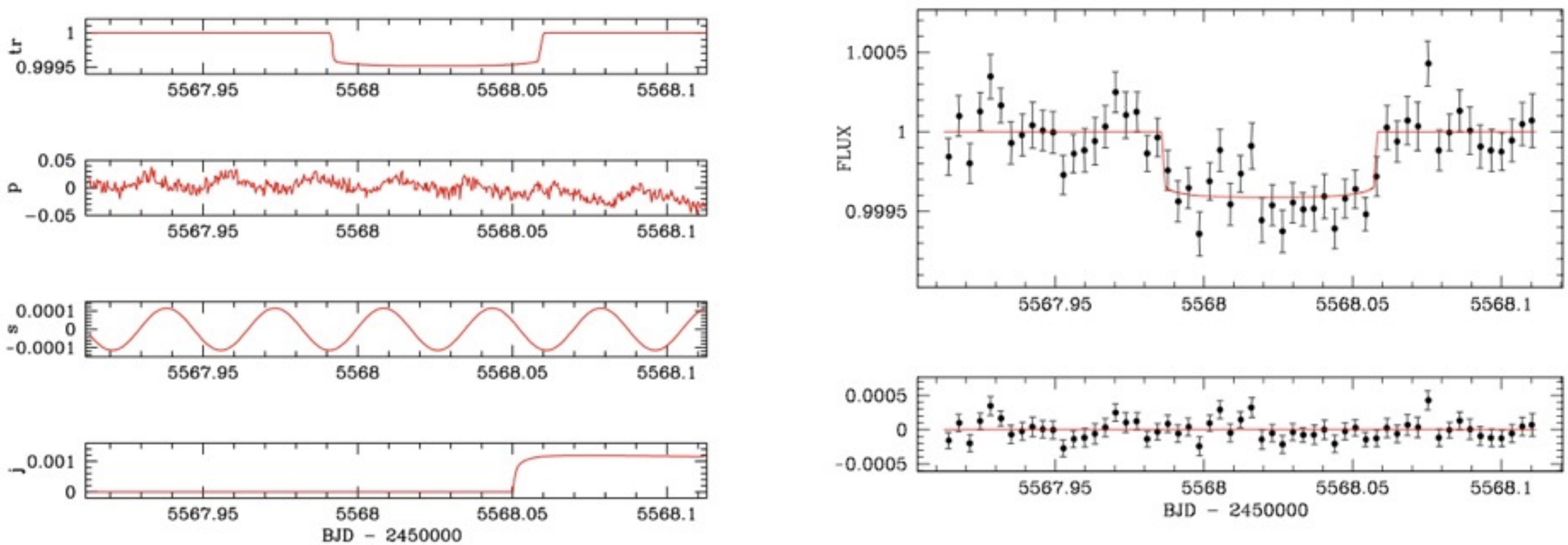
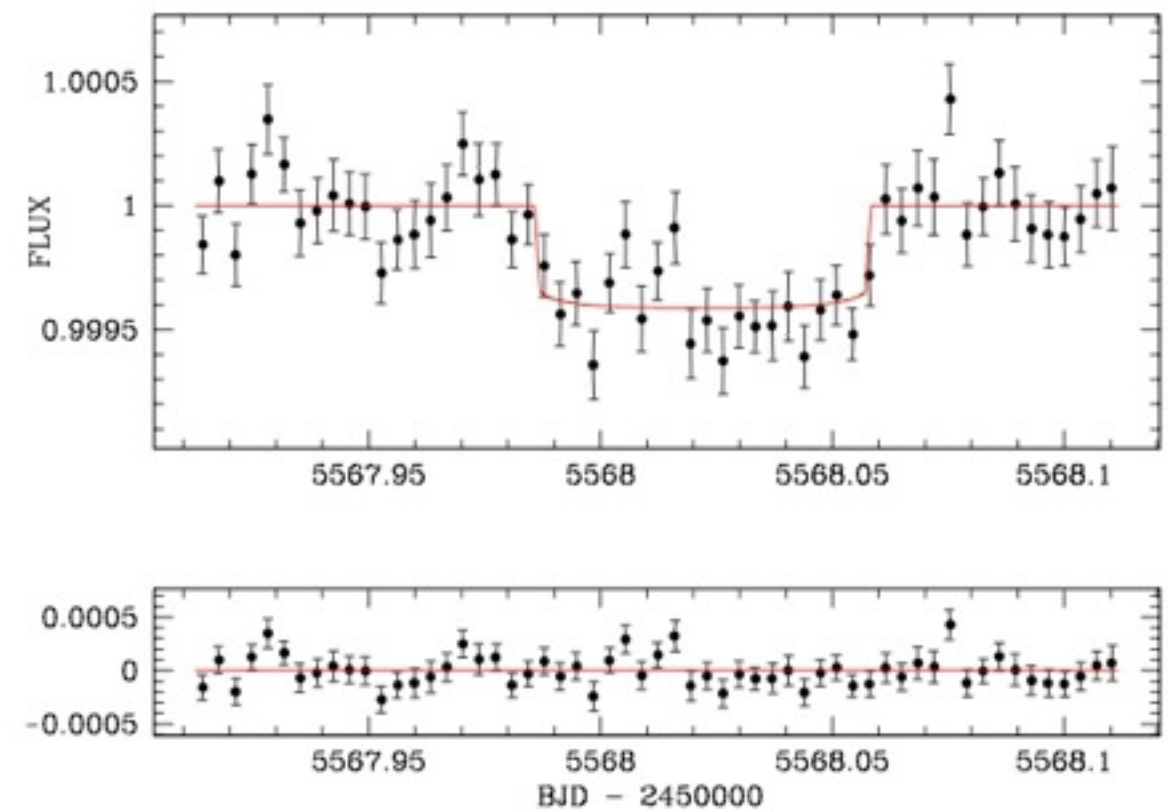


Demory et al. 2011

55 Cnc e's Transit on 6 January 2011

$(R_p/R_*)^2$ [ppm]	410 ± 63
$b = a\cos i/R_*$ [R_*]	$0.16^{+0.13}_{-0.10}$
Transit width W [d]	$0.0665^{+0.0011}_{-0.0019}$
$T_0 - 2\,450\,000$ [BJD]	$5568.0265^{+0.0015}_{-0.0010}$
R_p/R_*	$0.0202^{+0.0015}_{-0.0016}$
a/R_*	$3.517^{+0.041}_{-0.040}$
Inclination i [deg]	$87.3^{+1.7}_{-2.1}$
Radius R_p [$R_\oplus$]	$2.08^{+0.16}_{-0.17}$
Mass M_p [$M_\oplus$]	$7.81^{+0.58}_{-0.53}$
Mean density ρ_p [g cm^{-3}]	$4.78^{+1.31}_{-1.20}$



Demory et al. 2011

55 Cnc e's Transit on 20 June 2011

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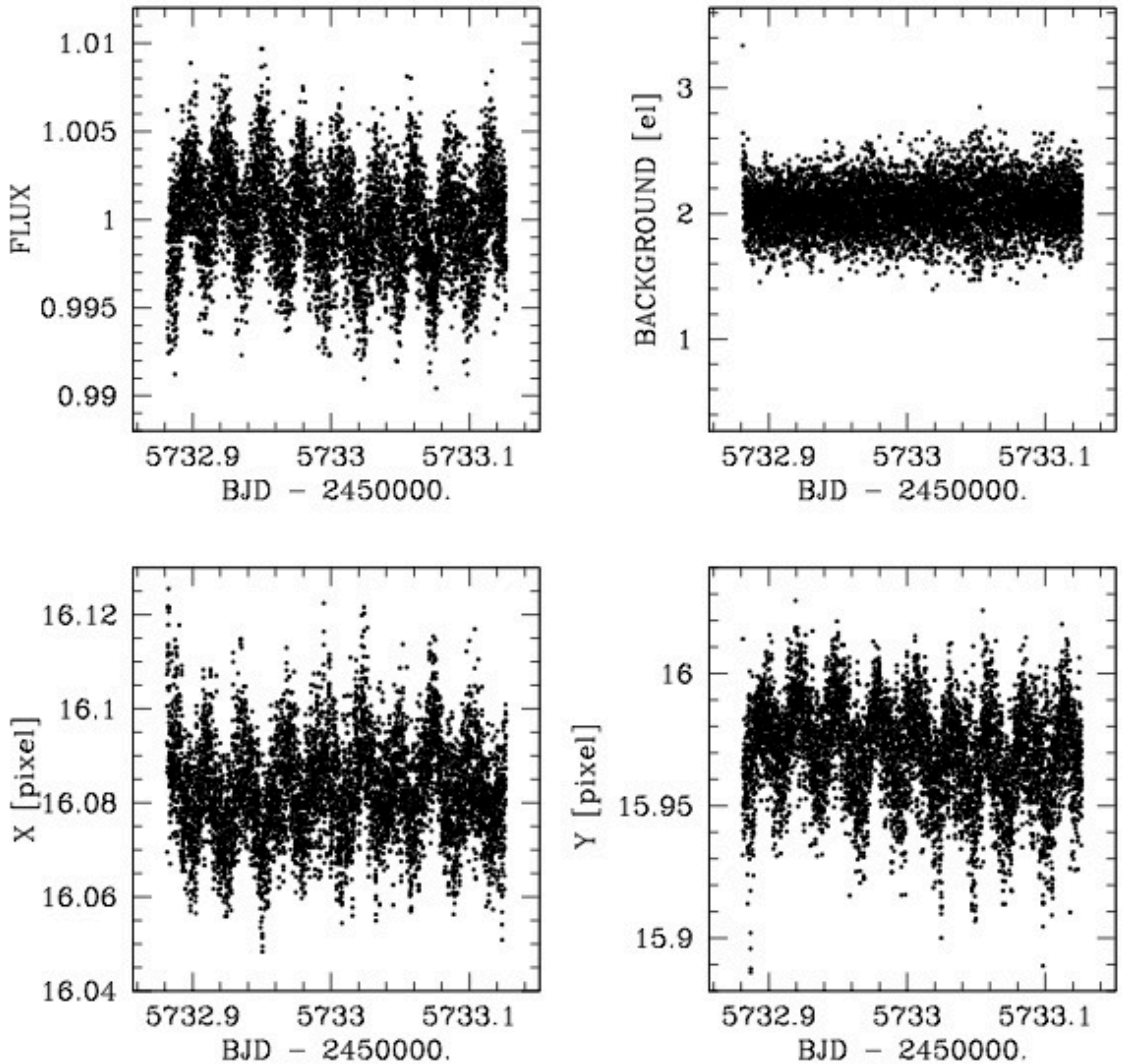

Gillon et al., in prep.

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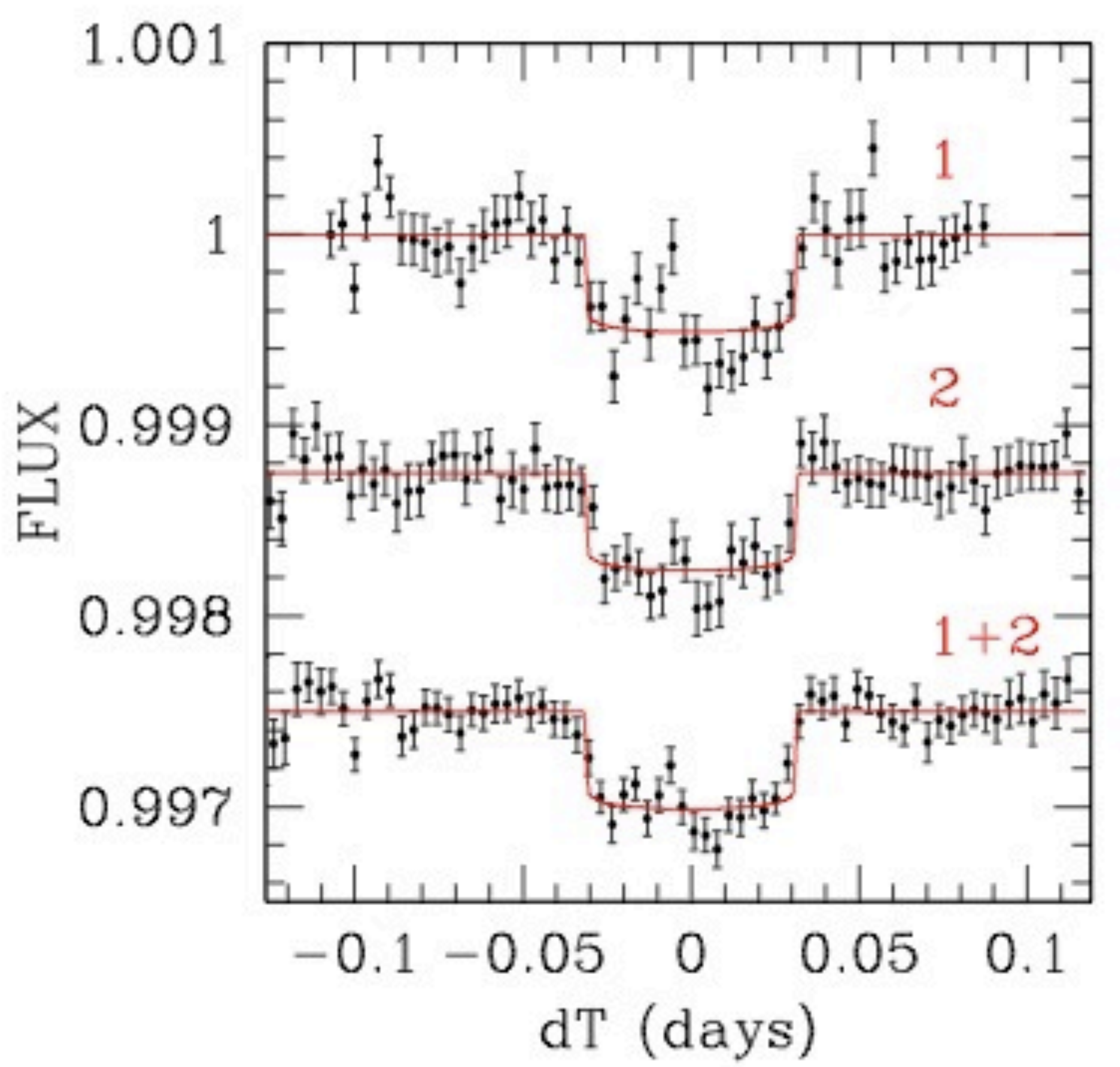

Data analysis by M. Gillon (Gillon et al., in prep.)

55 Cnc e's System Parameters

Parameter	*Spitzer* transit 2	*Spitzer* transit 1 & 2	Unit
Transit timing T_{tr}	$5733.0094^{+0.0012}_{-0.0011}$	$5733.0085^{+0.0011}_{-0.0014}$	$BJD_{TDB} - 2450000$
Orbital period P	0.7365437 (fixed)	$0.7365460^{+0.0000049}_{-0.0000046}$	days
Transit depth $(R_p/R_*)^2$	463^{+57}_{-54}	458 ± 47	ppm
Planet-to-star radius ratio (R_p/R_*)	0.0215 ± 0.0013	0.0214 ± 0.0011	
Transit circular impact parameter b	$0.509^{+0.056}_{-0.074}$	$0.500^{+0.057}_{-0.085}$	R_*
Transit duration W	$0.0589^{+0.0026}_{-0.0023}$	$0.0593^{+0.0029}_{-0.0023}$	days
Orbital inclination i	$81.7^{+1.2}_{-1.0}$	$81.8^{+1.4}_{-1.0}$ deg	
Planet radius R_p	$2.21^{+0.15}_{-0.16}$	2.20 ± 0.12	$R_\oplus$

Gillon et al., in prep.