

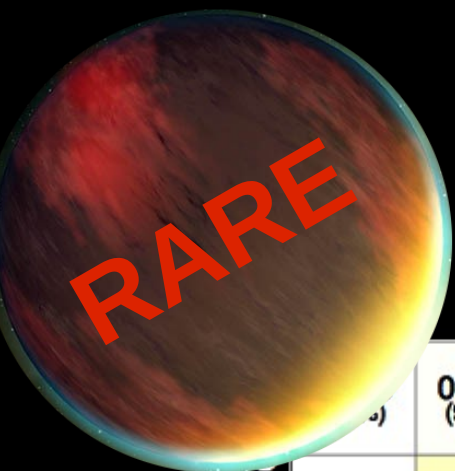
Small Planets, Small Stars: The K2 M Dwarf Program



Ian Crossfield (UA/LPL)
2015/05/07

Collaborators: **E. Petigura, J. Schlieder, B. Benneke, C. Beichman, A. Howard, H. Knutson, D. Dragomir, E. Sinukoff, BJ Fulton, S. Lepine, H. Isaacson, J. Krick, J. Livingstone, M. Werner, T. Barclay, C. Obermeier, K. Aller, L. Kaltenegger, J. Crepp, J. Christiansen, T. Barman, Th. Henning, B. Hansen, M. Liu, T. Greene, D. Ciardi, N. Deacon, E. Schlafly**

Planet frequency increases toward smaller and cooler planets: (for both **M stars** & **FGKs**)



Planet Occurrence (%)



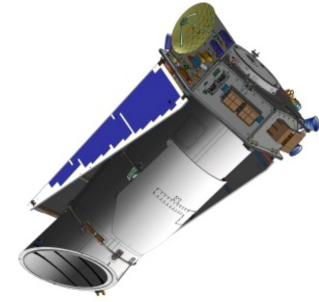
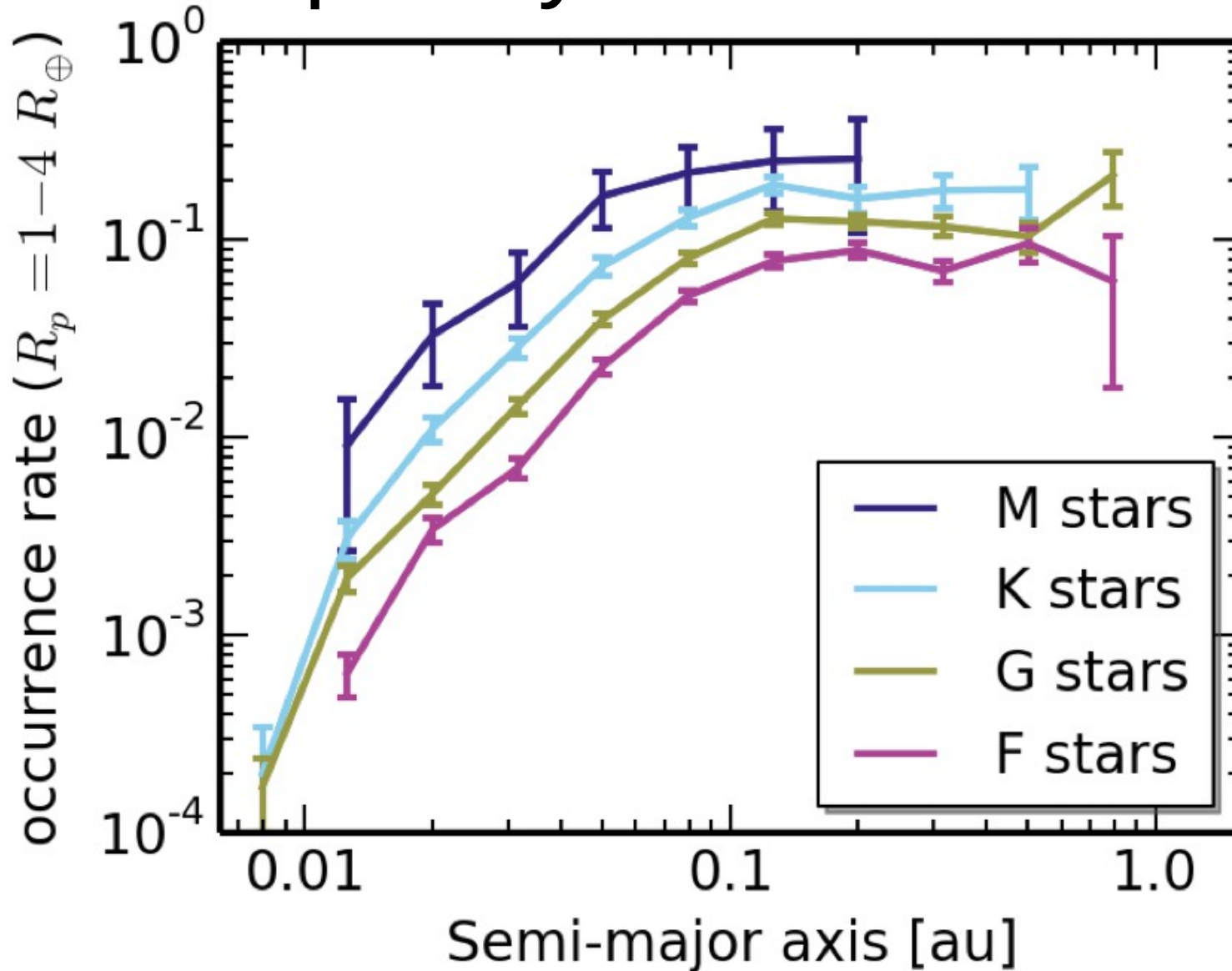
Dressing+2013, 2015,
Howard+2012,
Petigura+2013a,b

COMMON?



1 10 100
Period (Days)

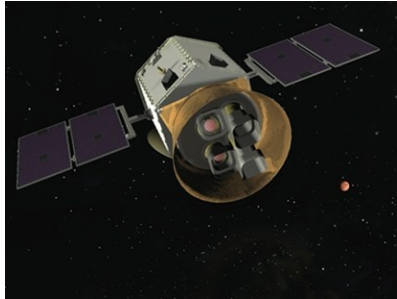
Small planets occur 2–3x more frequently around cooler stars:



Mulders+2014

TESS

2017-2019



Sky coverage



Kepler

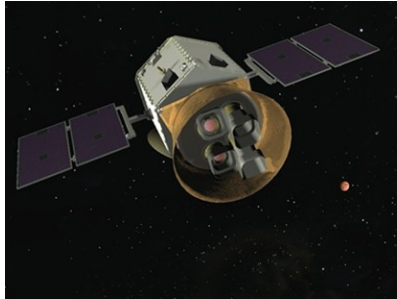
2009-2014

Temporal coverage



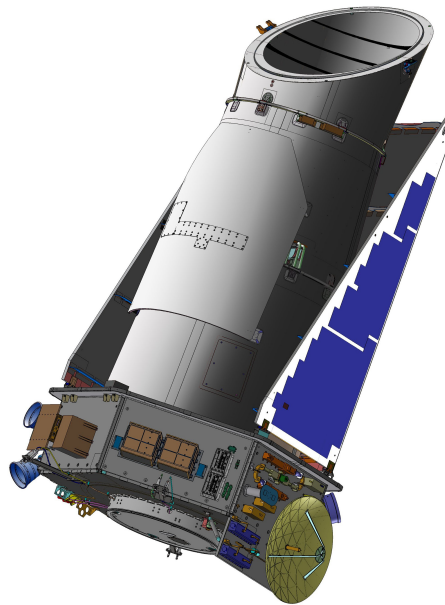
TESS

2017-2019



K2

2014-2017



Kepler

2009-2014



Sky coverage

Temporal coverage



K2 M Dwarf Advantage: Numbers

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- Kepler sample (Dressing et al. 2015):
 - 2543 stars (all observed for ≥ 1000 days)
 - Most have $T_{\text{eff}} \geq 3500$ K, $R \geq 0.4 R_{\text{sun}}$
 - 157 planet candidates

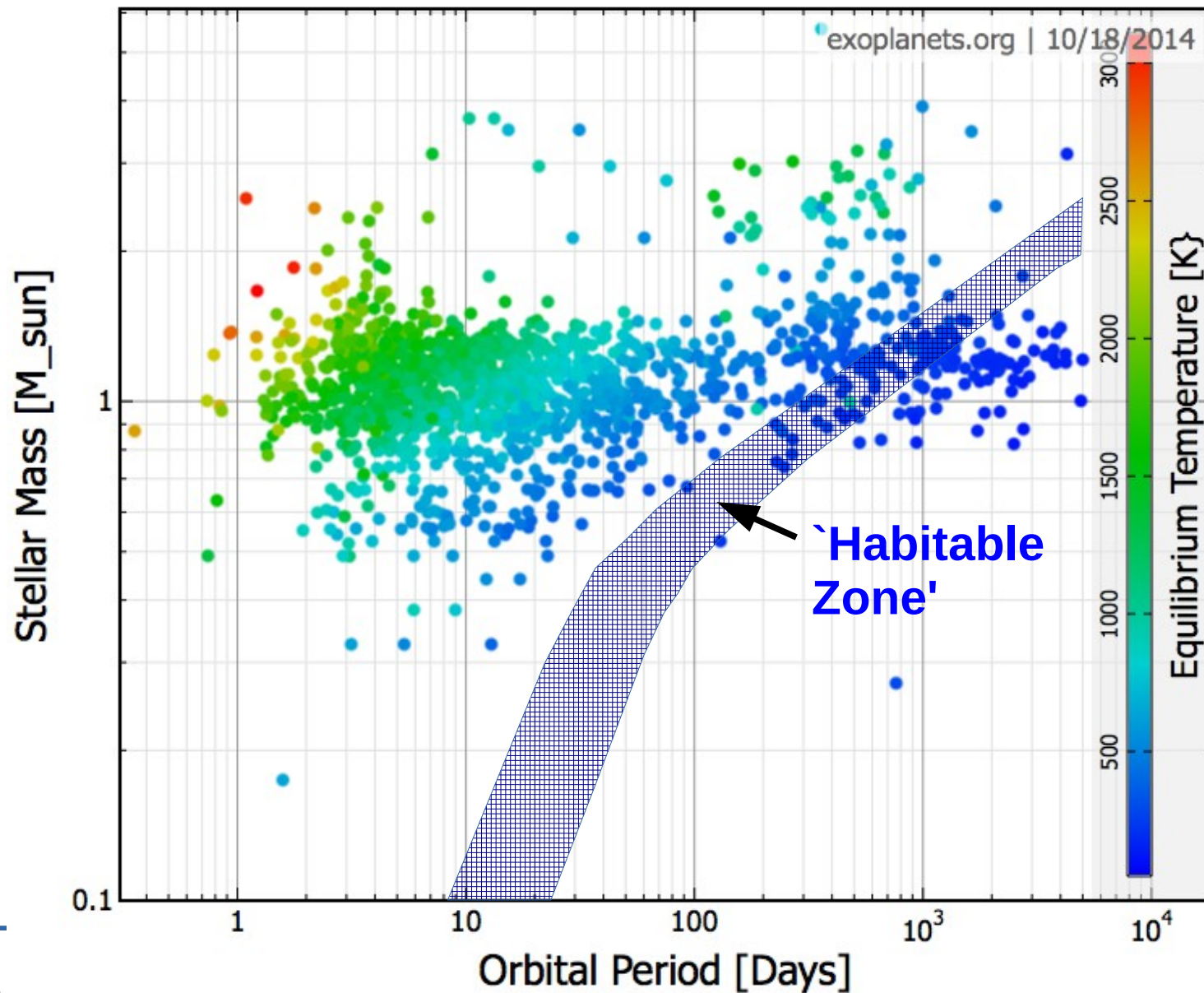
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- K2:
 - Observing ~ 5000 M dwarfs per field
 - ≥ 10 fields, ~ 80 days each

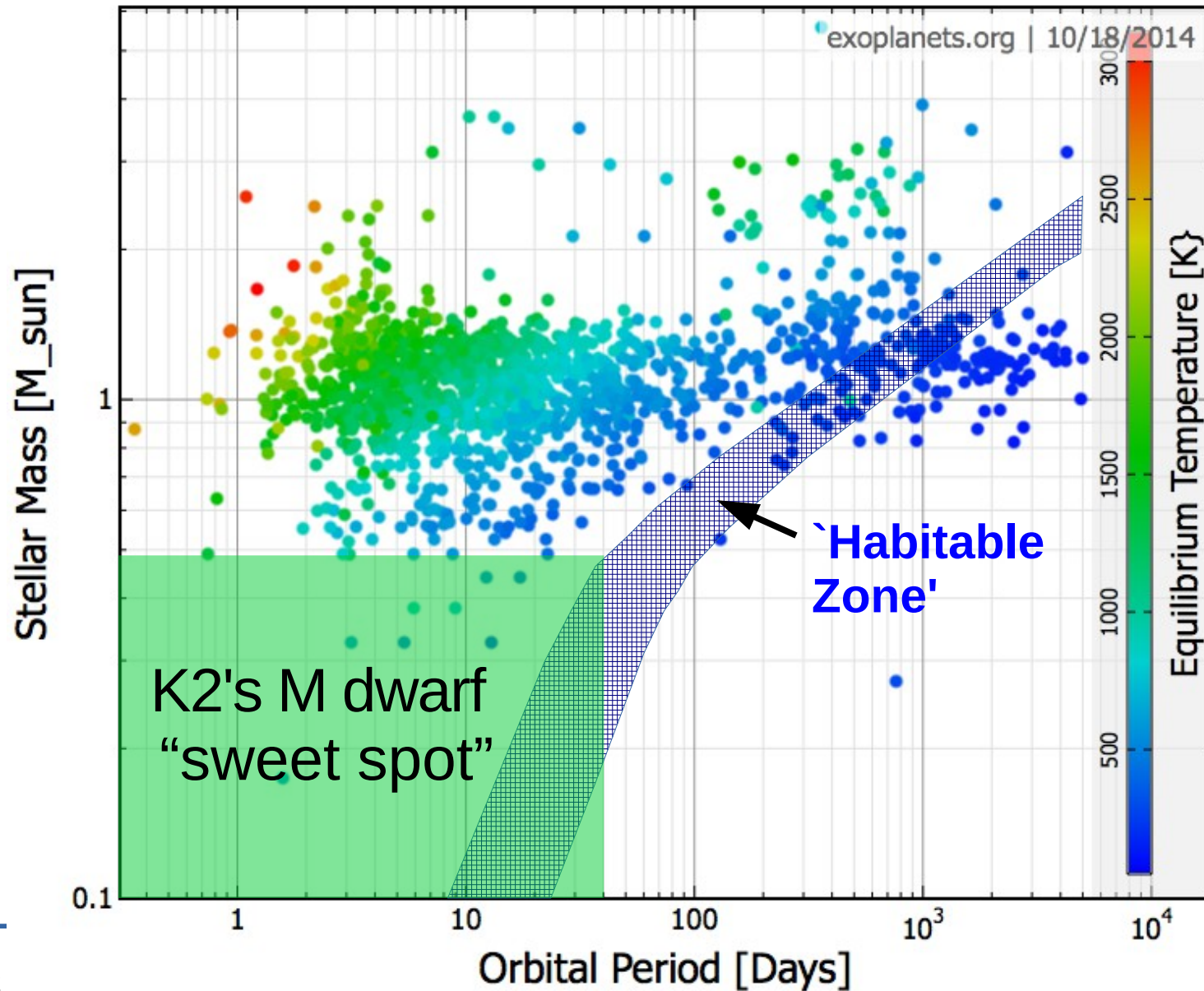
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- The K2 M dwarf advantage:
 - $5000 * 80 * 10 / 2543 * 1000 * 1 \sim 1.5x$

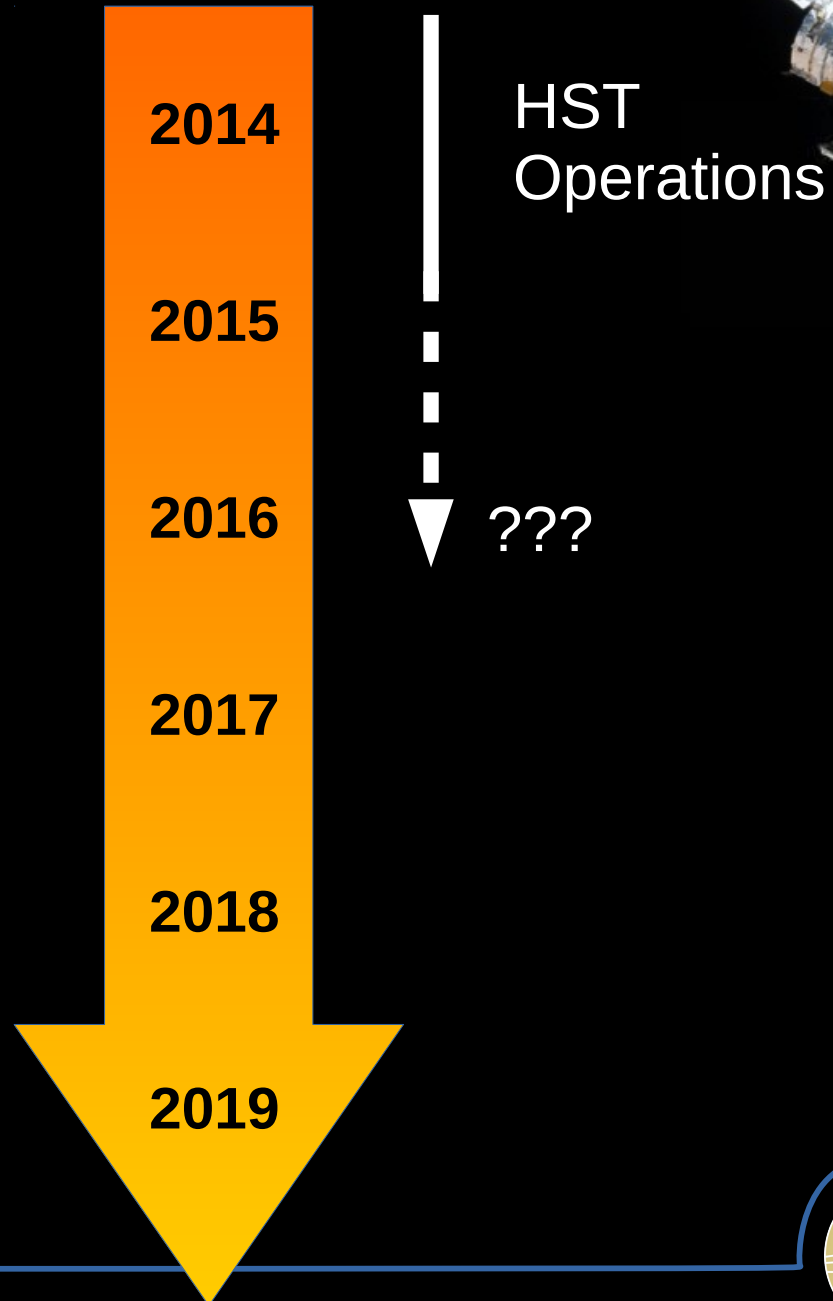
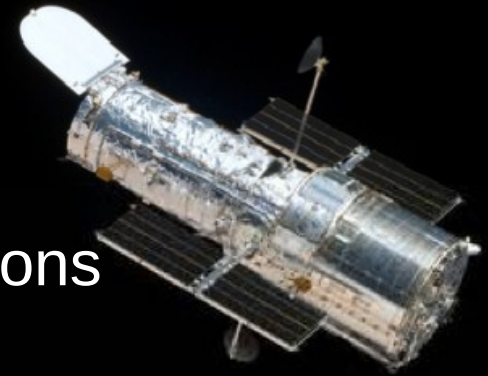
K2 M dwarf advantage: M dwarf Habitable Systems



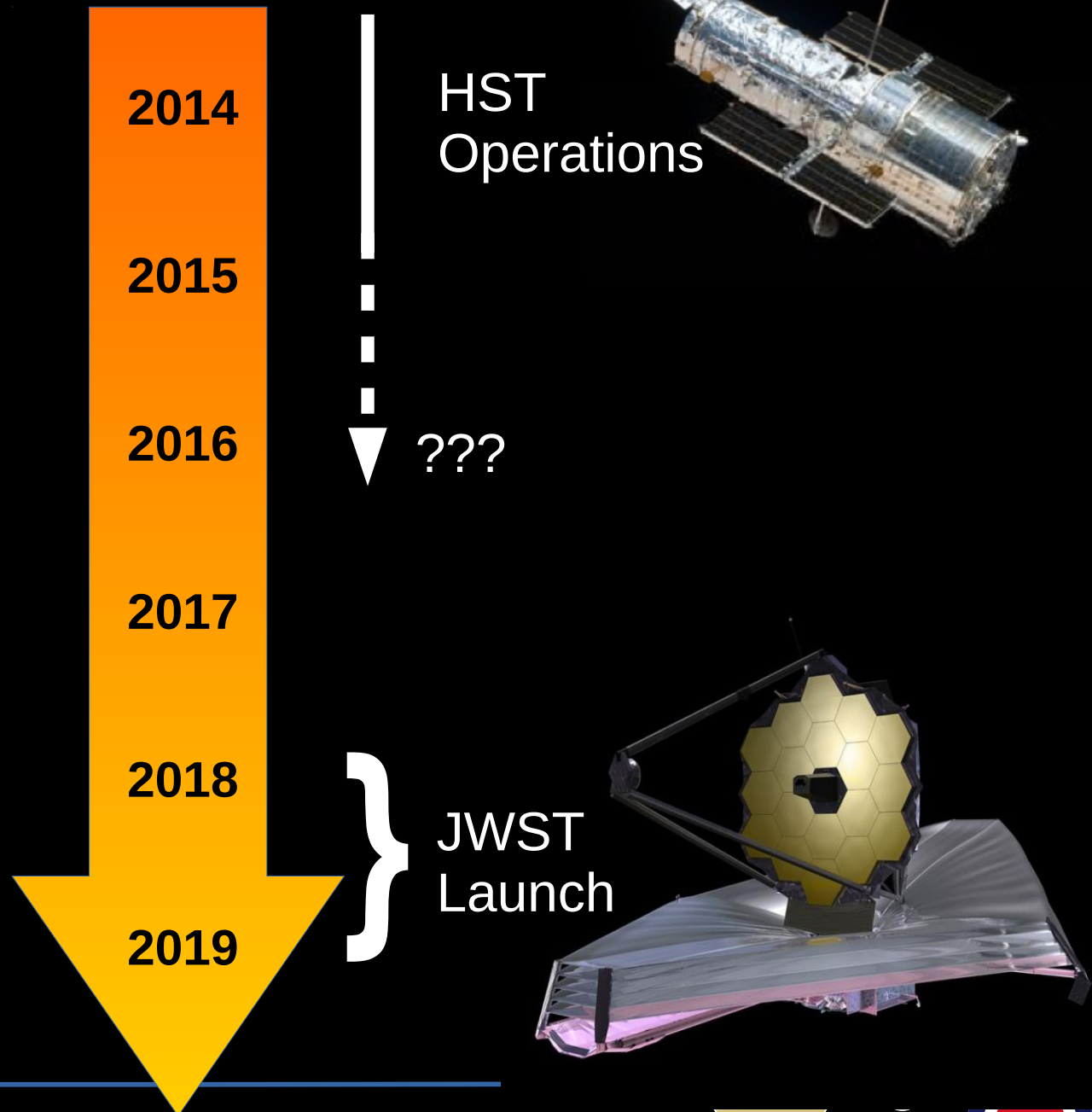
K2 M dwarf advantage: M dwarf Habitable Systems



K2 Advantage: Timing



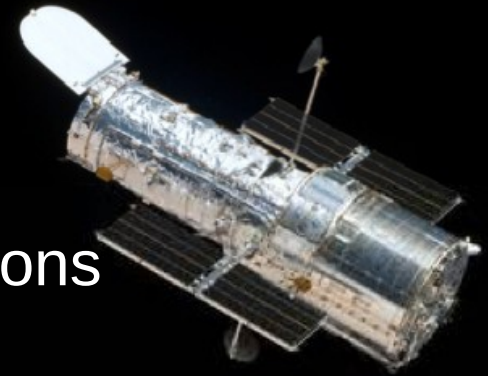
K2 Advantage: Timing



K2 Advantage: Timing

2014

HST
Operations



2015

2016

???

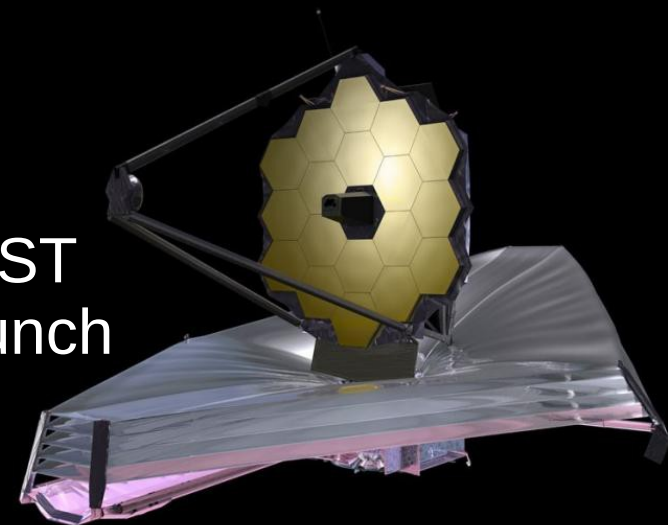
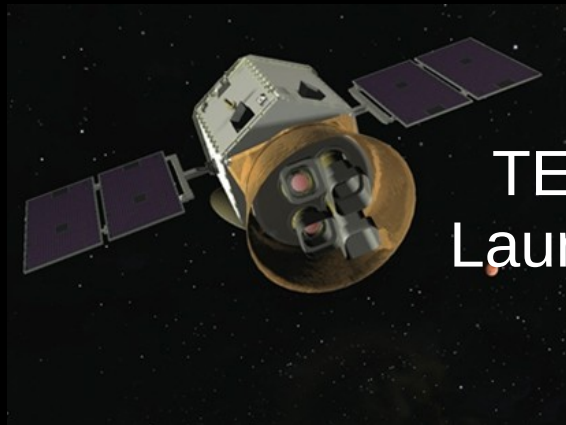
2017

TESS
Launch

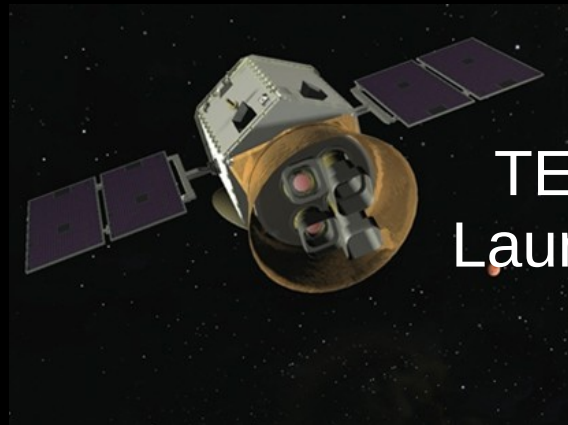
2018

JWST
Launch

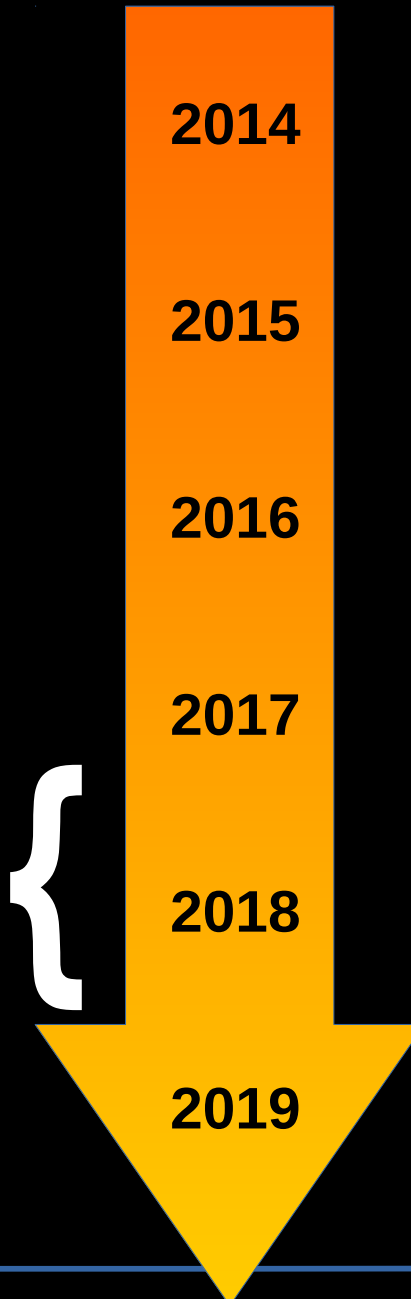
2019



K2 Advantage: Timing



TESS
Launch



2014

2015

2016

2017

2018

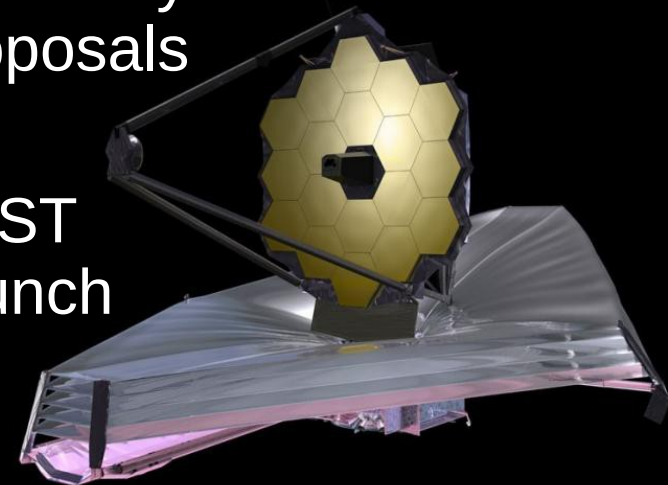
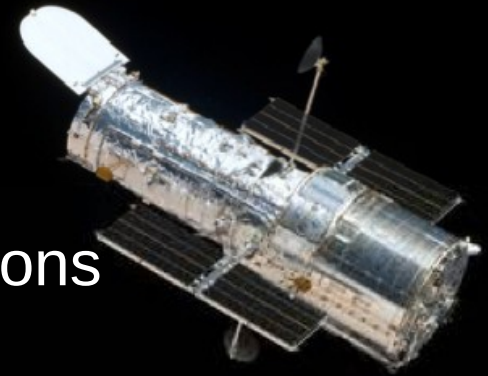
2019

HST
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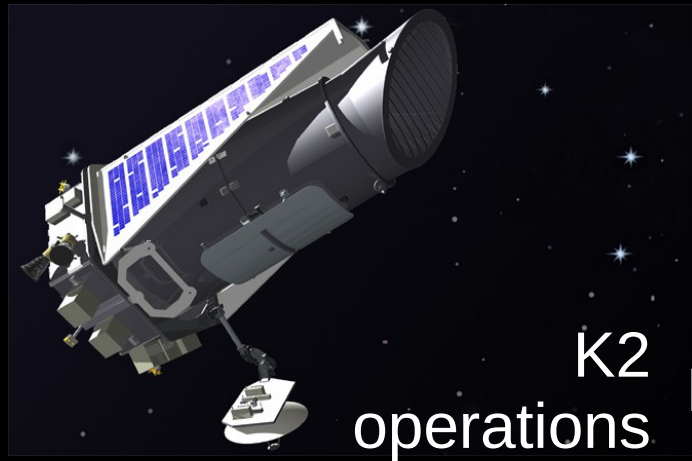
???

JWST Calls for
GTO & Cycle 1
Proposals

JWST
Launch

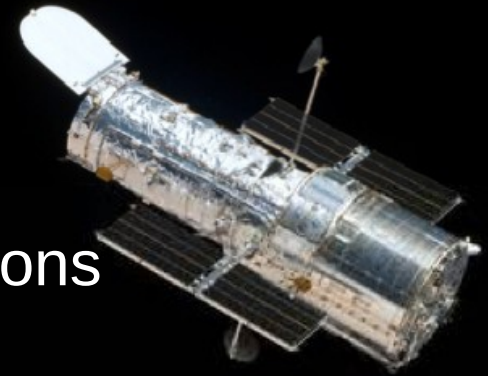


K2 Advantage: Timing



2014

HST Operations



2015

2016

???

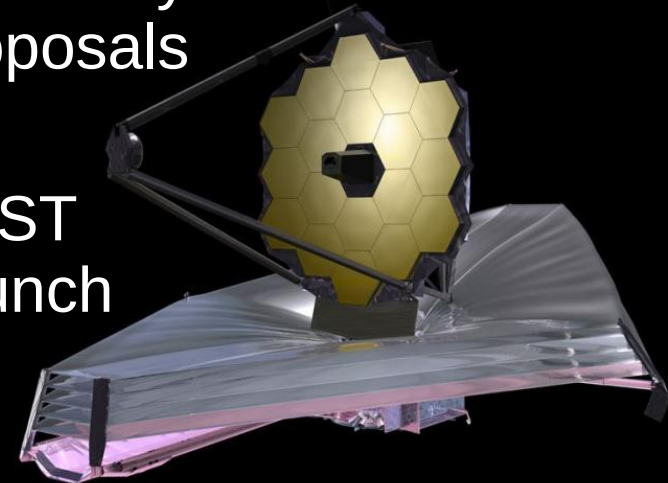
2017

JWST Calls for GTO & Cycle 1 Proposals

2018

JWST Launch

2019



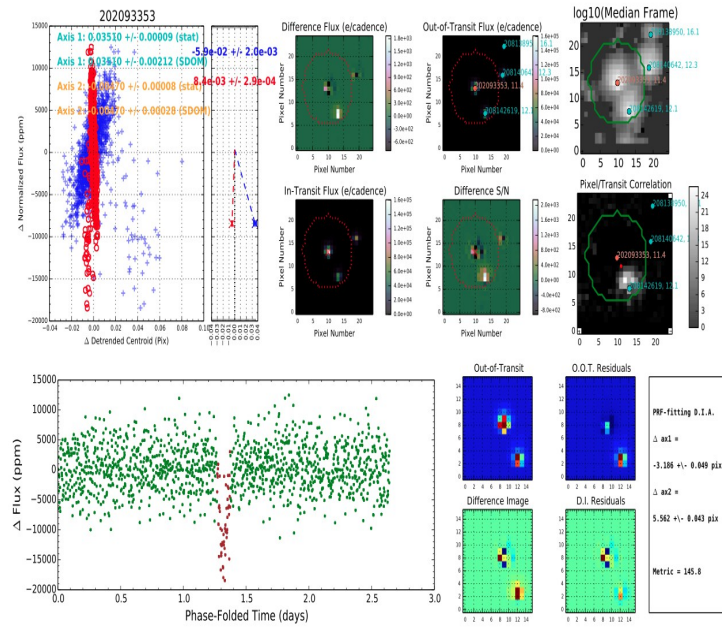
Many candidates found to date

~1/3 orbiting M dwarfs

(figure removed)

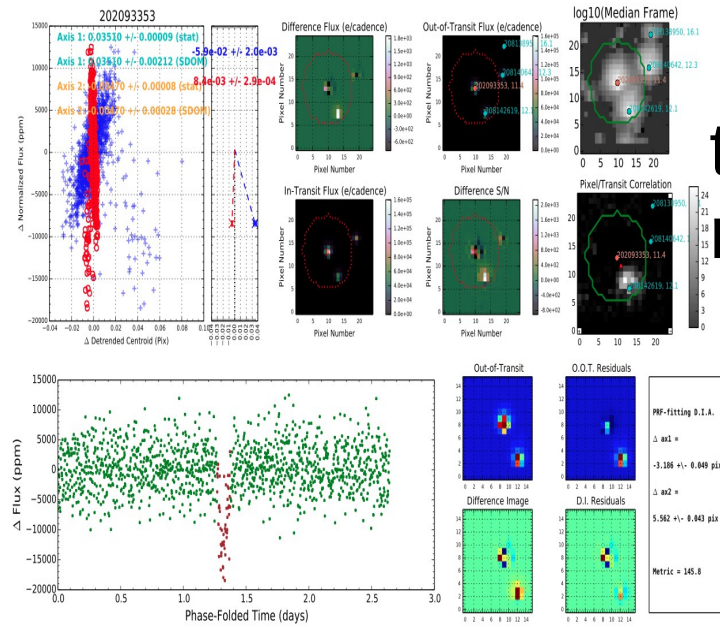
See also:
Foreman-Mackey et al. 2014,
Montet et al. 2015

Candidate Validation is Underway:



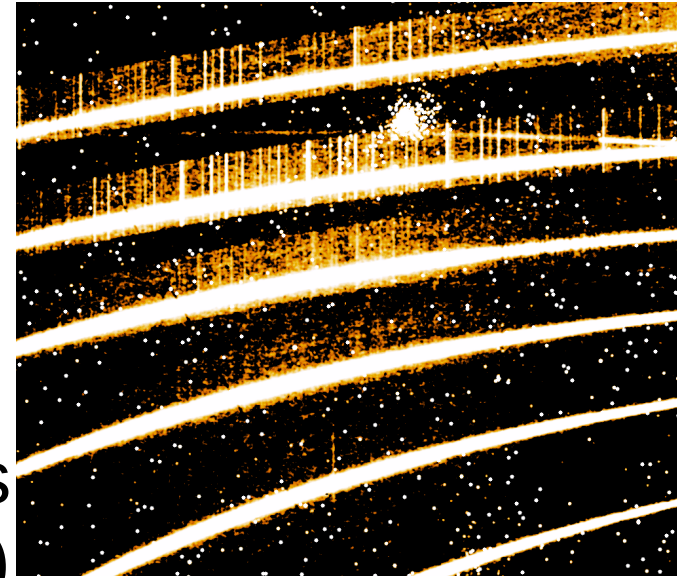
Candidate Validation is Underway:

← K2 data analyses:
transit fitting, centroid
motion, diff. images

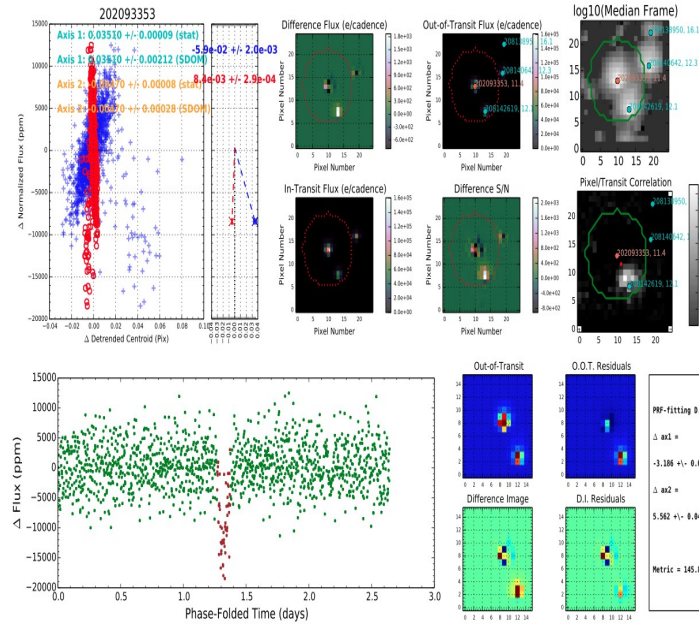


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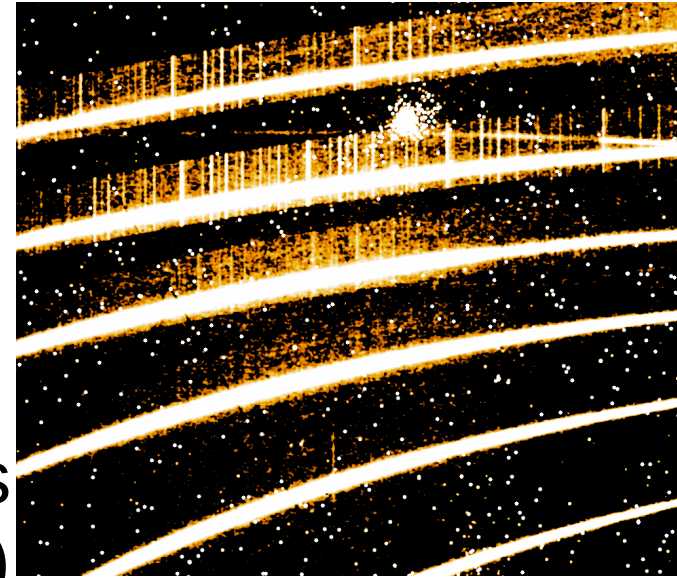


Stellar spectra →
give system params
(ESO/NTT, 70 nights)
and RV masses

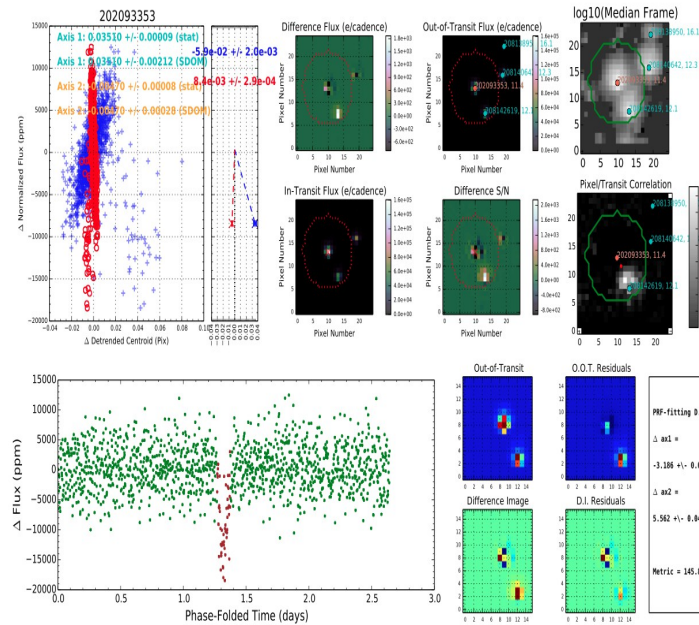


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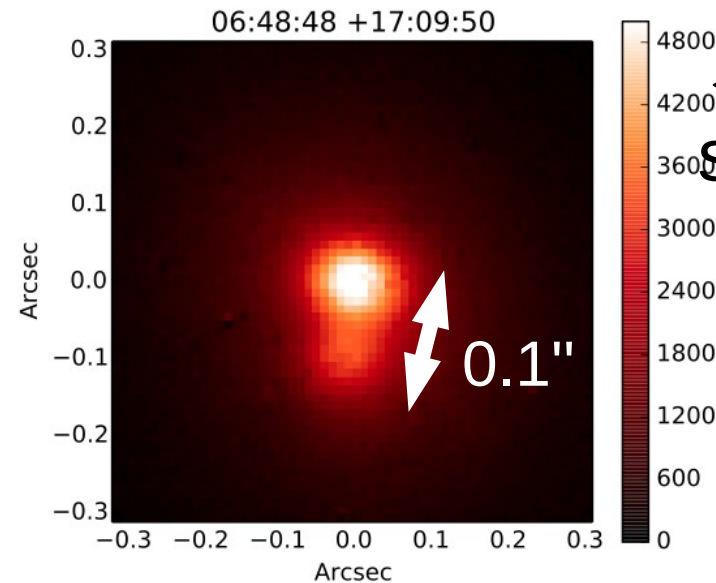
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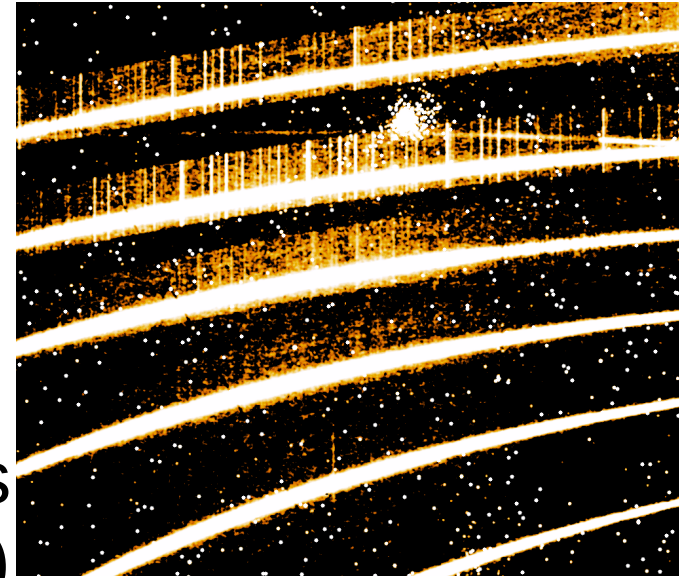


← Adaptive optics
search for blends

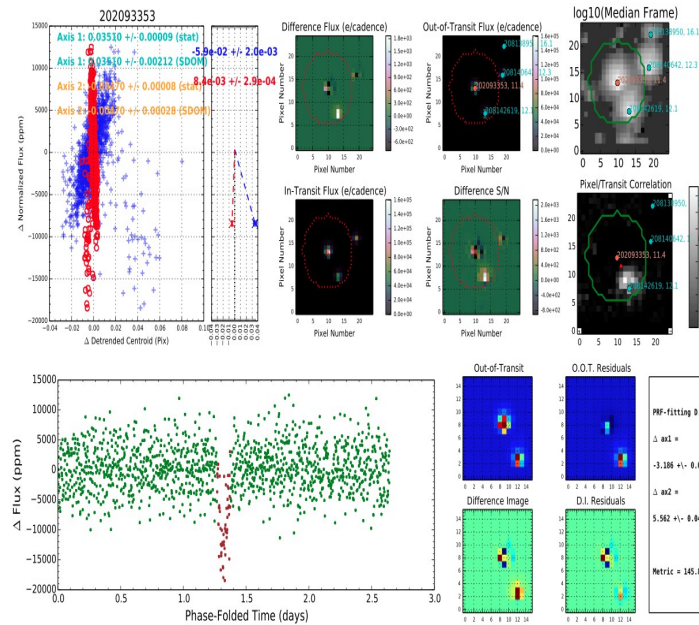


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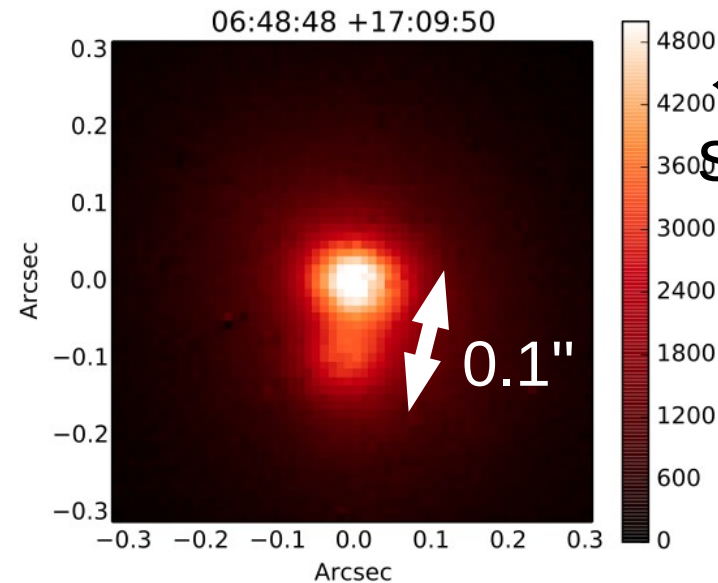
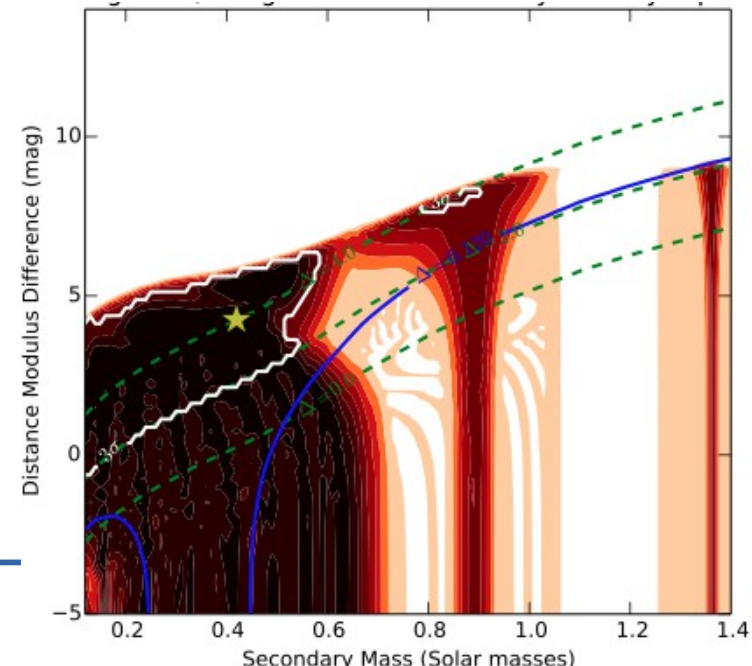


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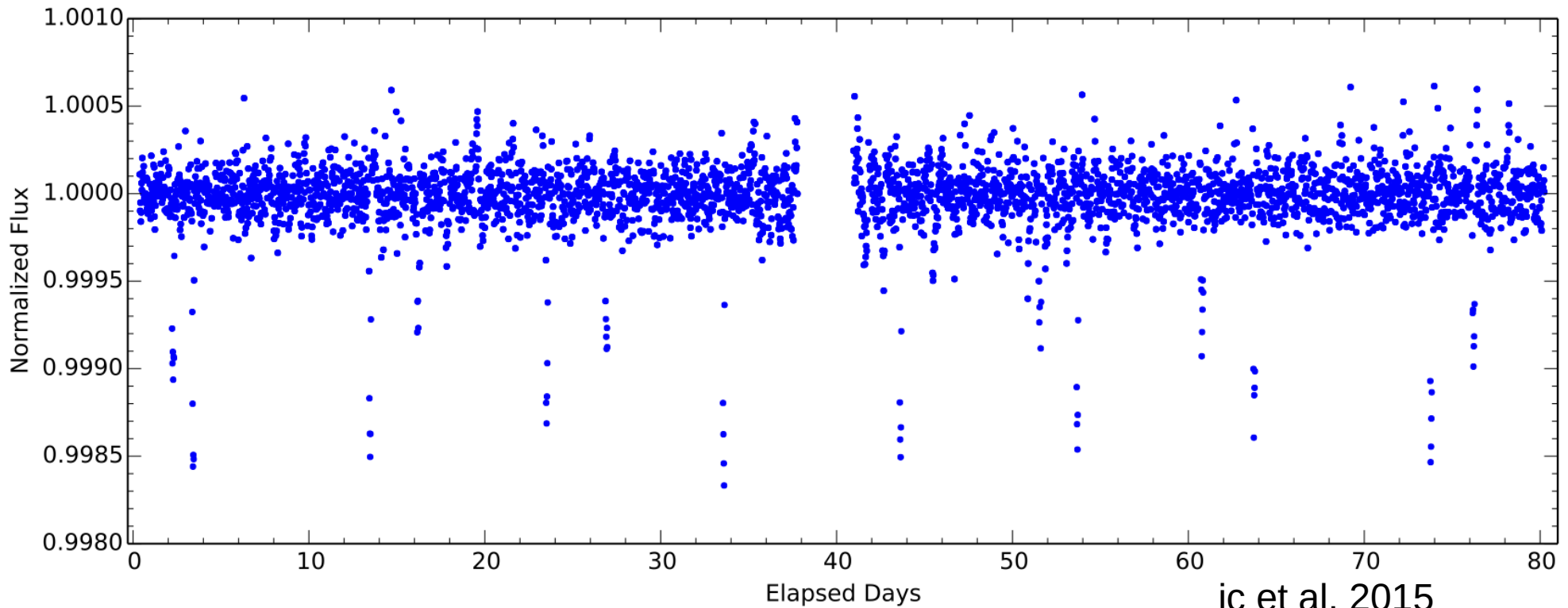
BLENDER →
To quantify false-
positive likelihood



K2-3 bcd: Three small planets transiting a bright M dwarf

A NEARBY M STAR WITH THREE TRANSITING SUPER-EARTHS DISCOVERED BY K2

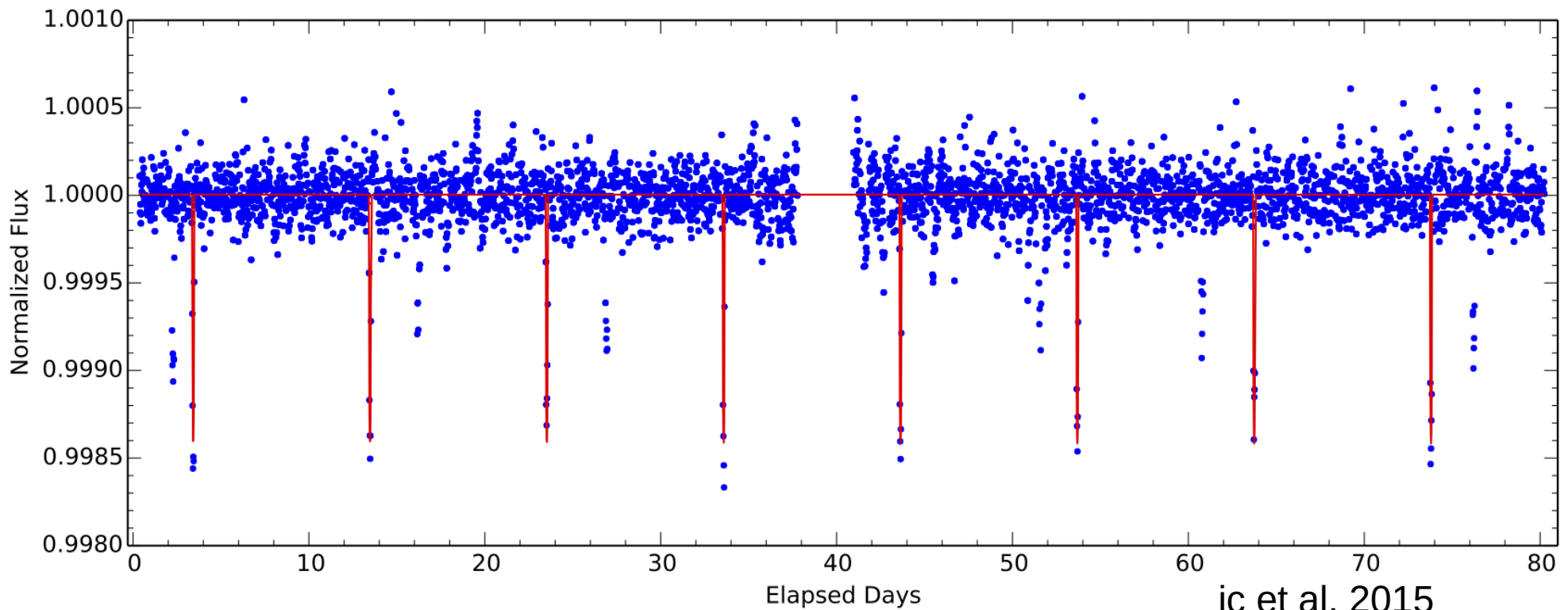
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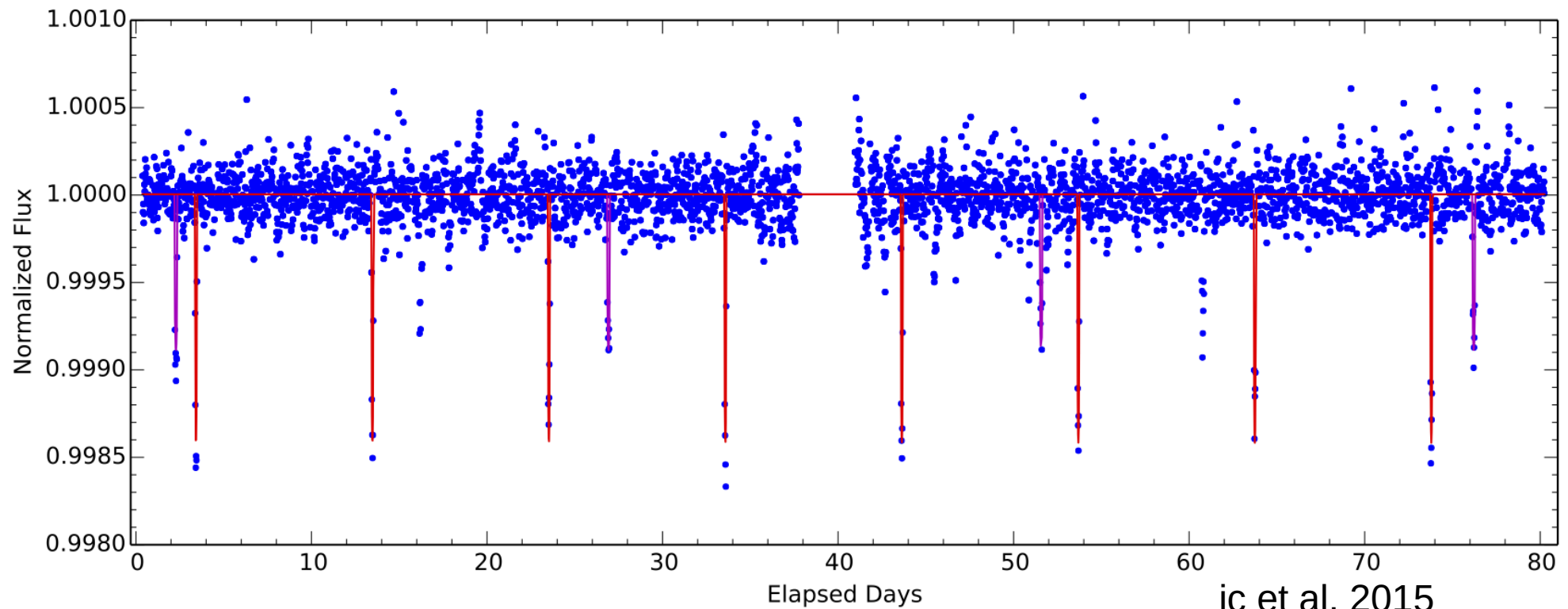
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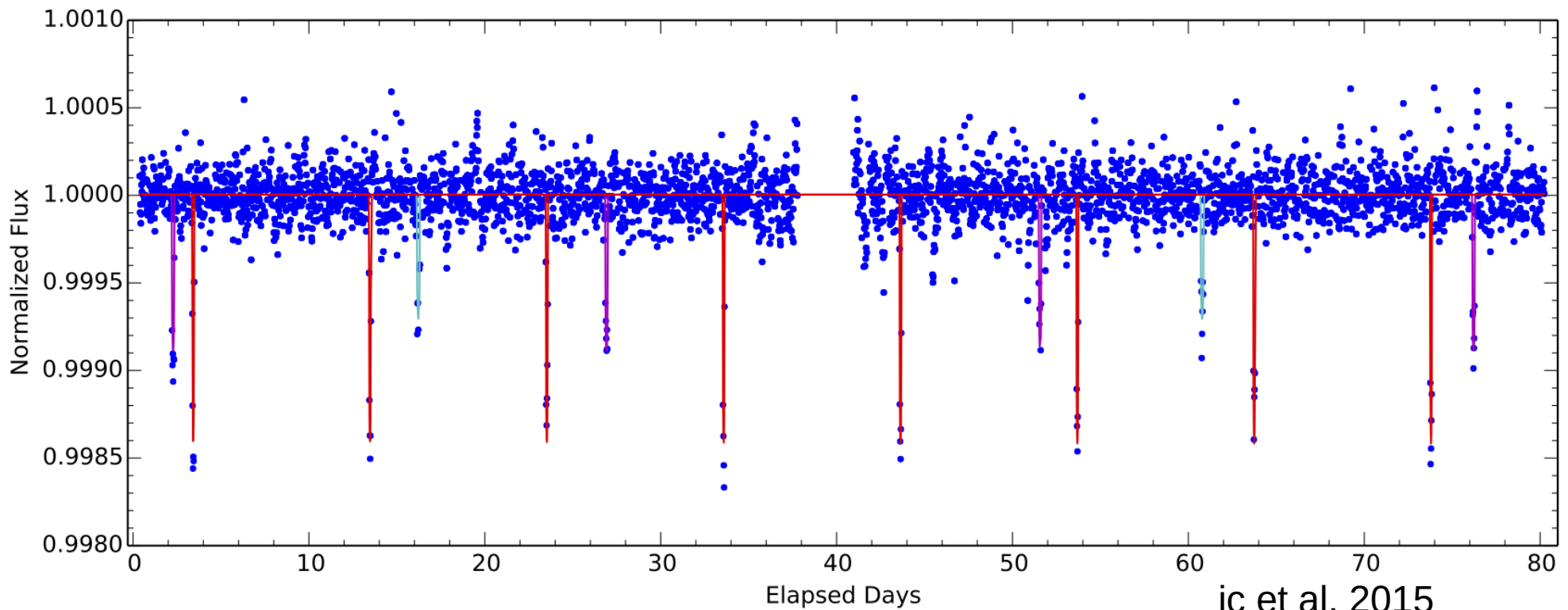
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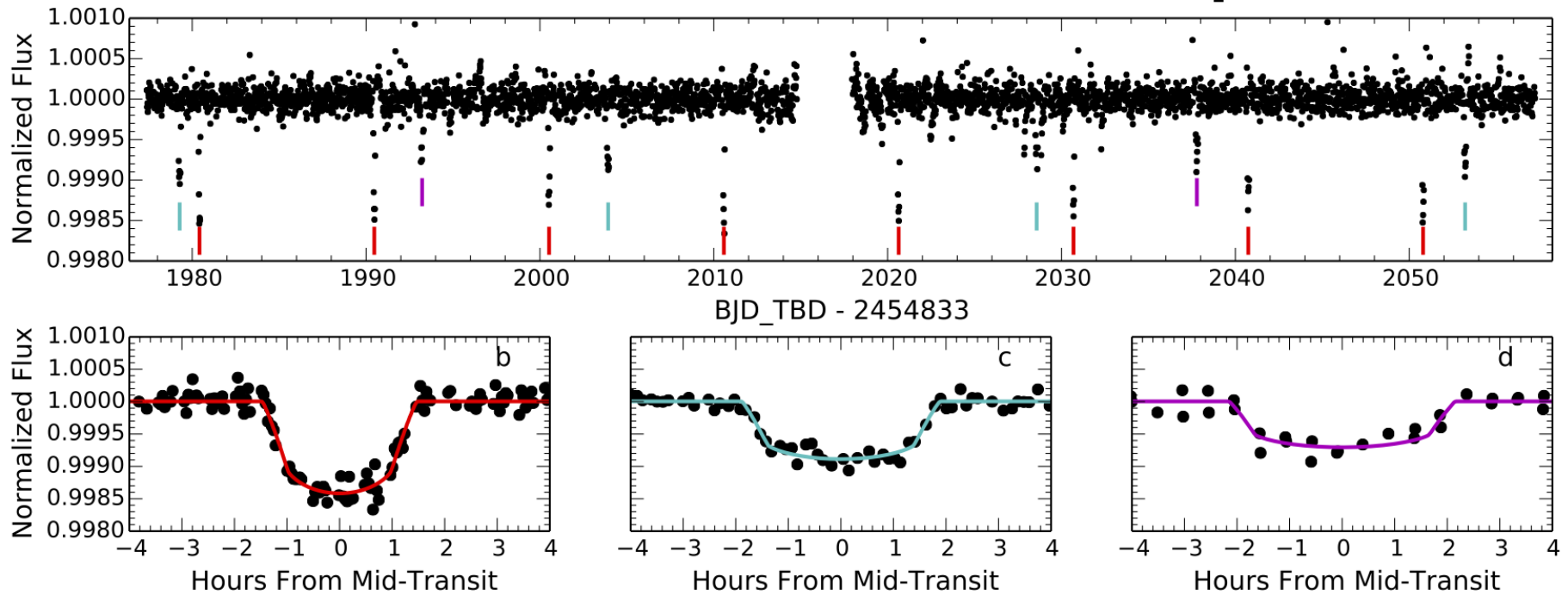
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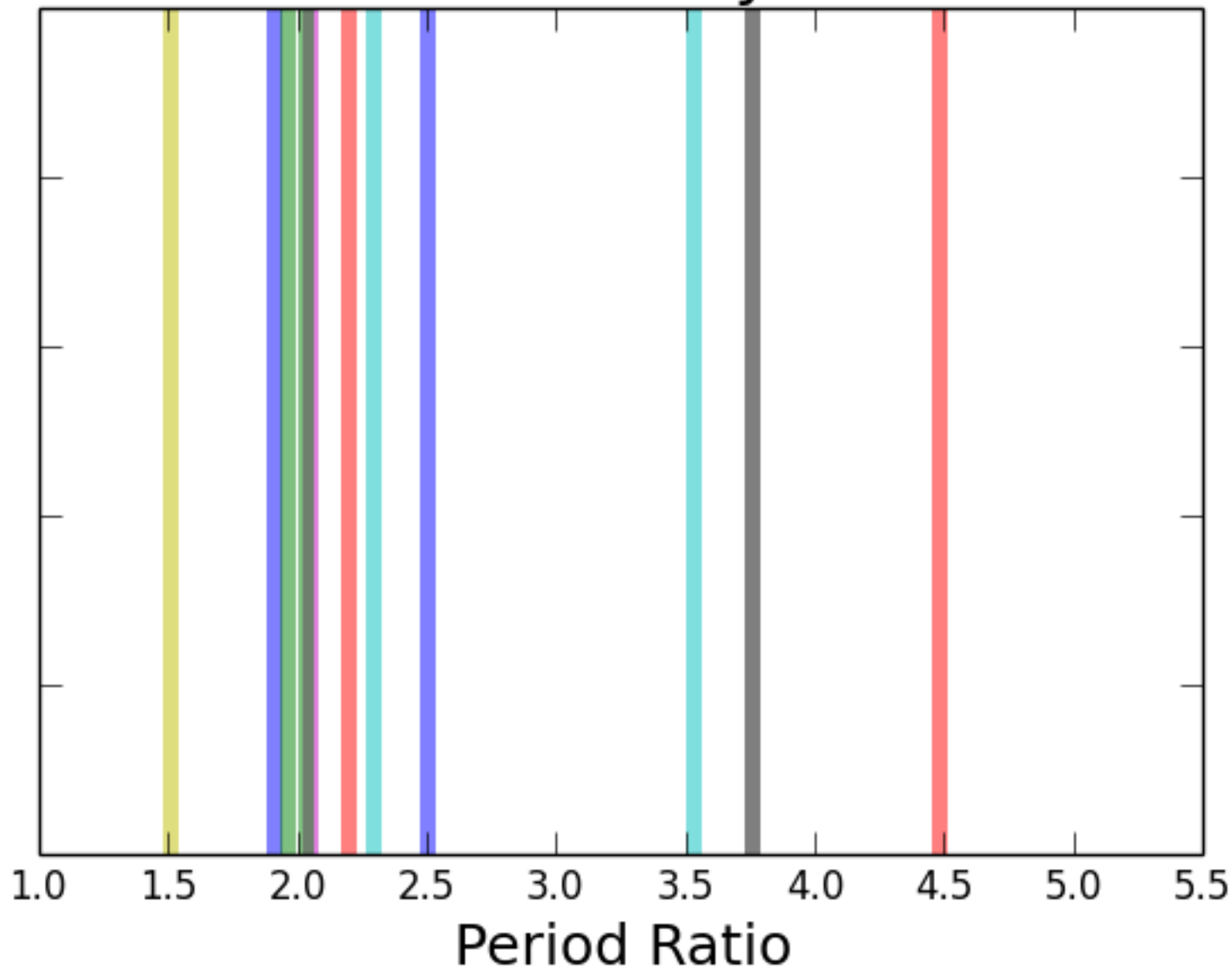
K2-3 bcd: Three small planets



	K2-3b	K2-3c	K2-3d
R / R_{Earth}	2.1 ± 0.2	1.7 ± 0.2	1.5 ± 0.1
$F_{\text{inc}} / F_{\text{Earth}}$	11 ± 3	3.3 ± 0.9	1.5 ± 0.5

ic et al. 2015

Period Ratios of Multi-planet systems:



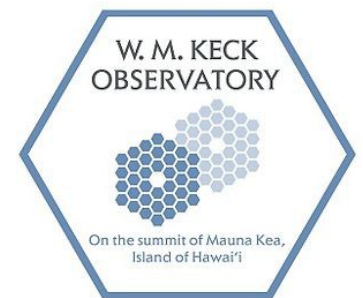
Mass/density measurements underway:

$\rho_b = 11 \text{ g/cc}$

$\rho_c = 3.6 \text{ g/cc}$

ρ_d unconstrained

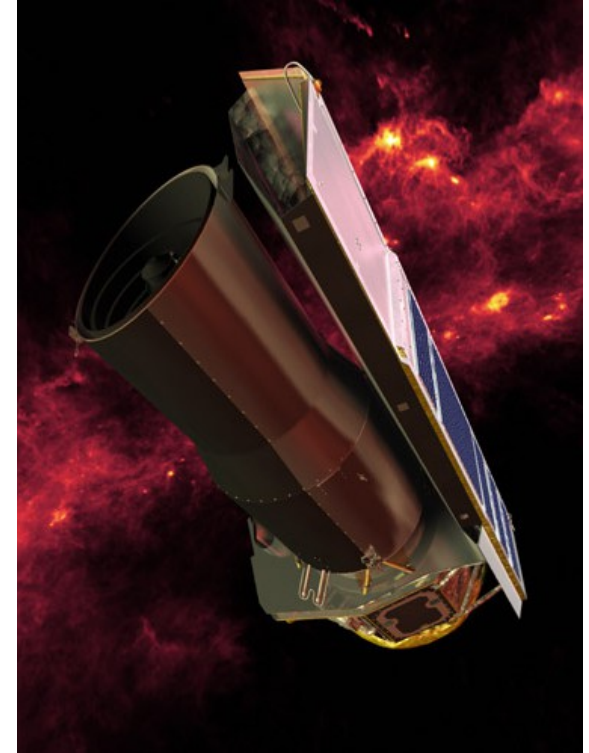
(figure removed)



Spitzer transit observations underway:

Two transits of K2-3b:

(figure removed)



Transit of K2-3c:

(figure removed)

PI: Mike Werner
Analyses: Jessica Krick,
John Livingstone

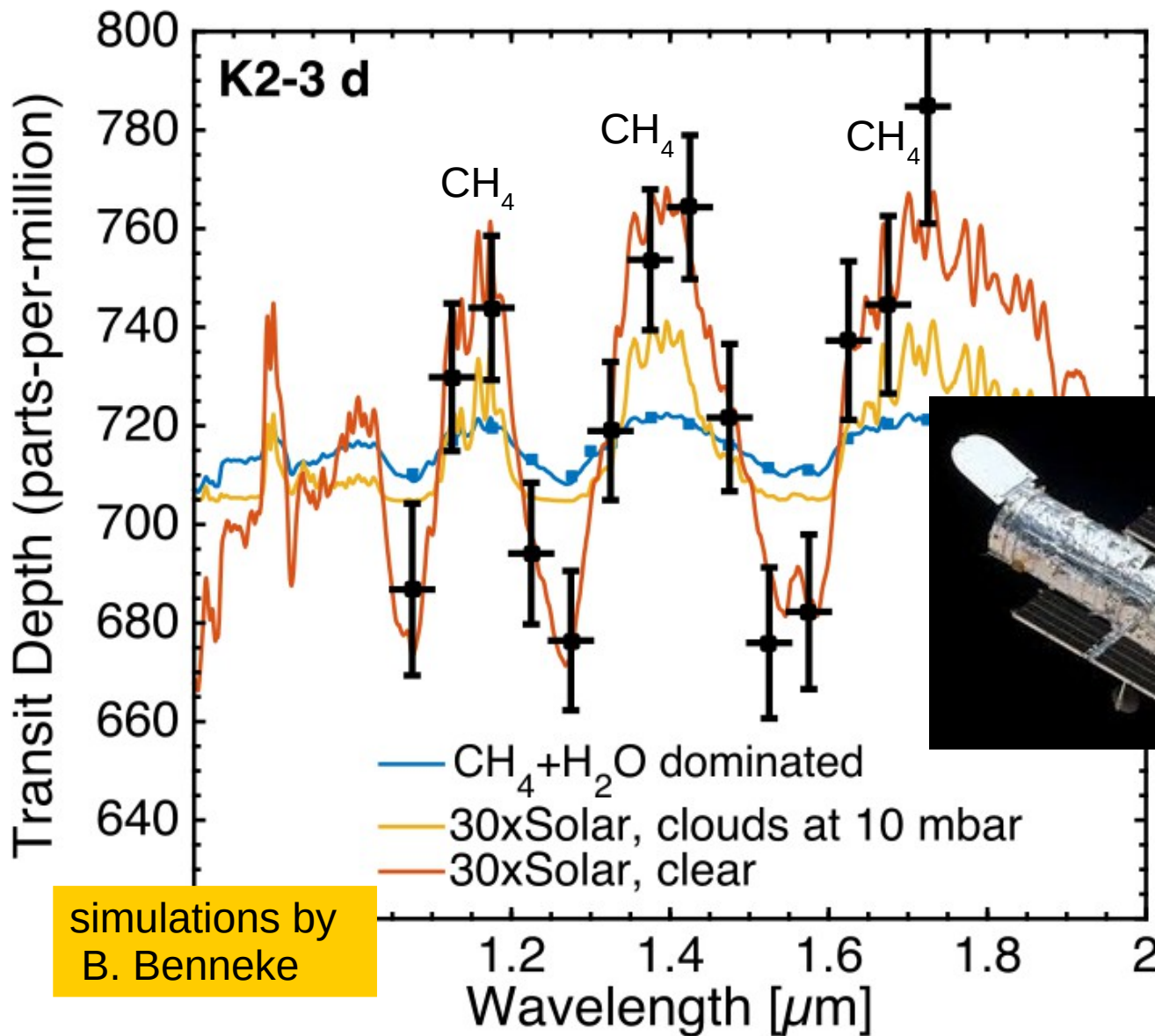
Planet Size vs. Stellar Magnitude

(figure removed)

★ GJ1214

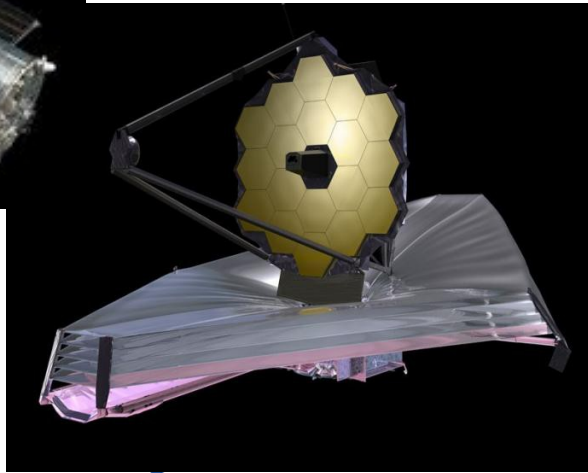
See also:
Foreman-Mackey et al. 2014,
Montet et al. 2015

Finding excellent targets for atmospheric studies with HST+JWST:



simulations by
B. Benneke

First of many
K2 targets for
JWST Cycle 1
observations!



K2 Take-home Points:

- Many new K2 candidates to date
- New multi-planet & M-dwarf systems
- Validation & vetting ongoing
- Mass measurements underway
- Good targets for Spitzer, HST, & JWST
- We expect ~5x more data by end-of-mission