

Quantifying False Positive Probabilities for Transiting Planet Candidates

Timothy Morton (Princeton)

Sagan Workshop

July 20, 2016

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Name	Msin(i) mjupiter ±	Semi-Major Axis au ±	Orbital Period day ±	Orbital Eccentricity ±	Velocity Semiamplitude m/s ±	First Reference	+
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GJ 436 b	0.0726	0.02872	2.643850	0.160	18.34	Butler 2004	
HD 149026 b	0.360	0.04313	2.8758911	0	43.3	Sato 2005	
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HD 209458 b	0.689	0.04723	3.52474859	0	84.67	Henry 2000 , Charbonneau 2000	
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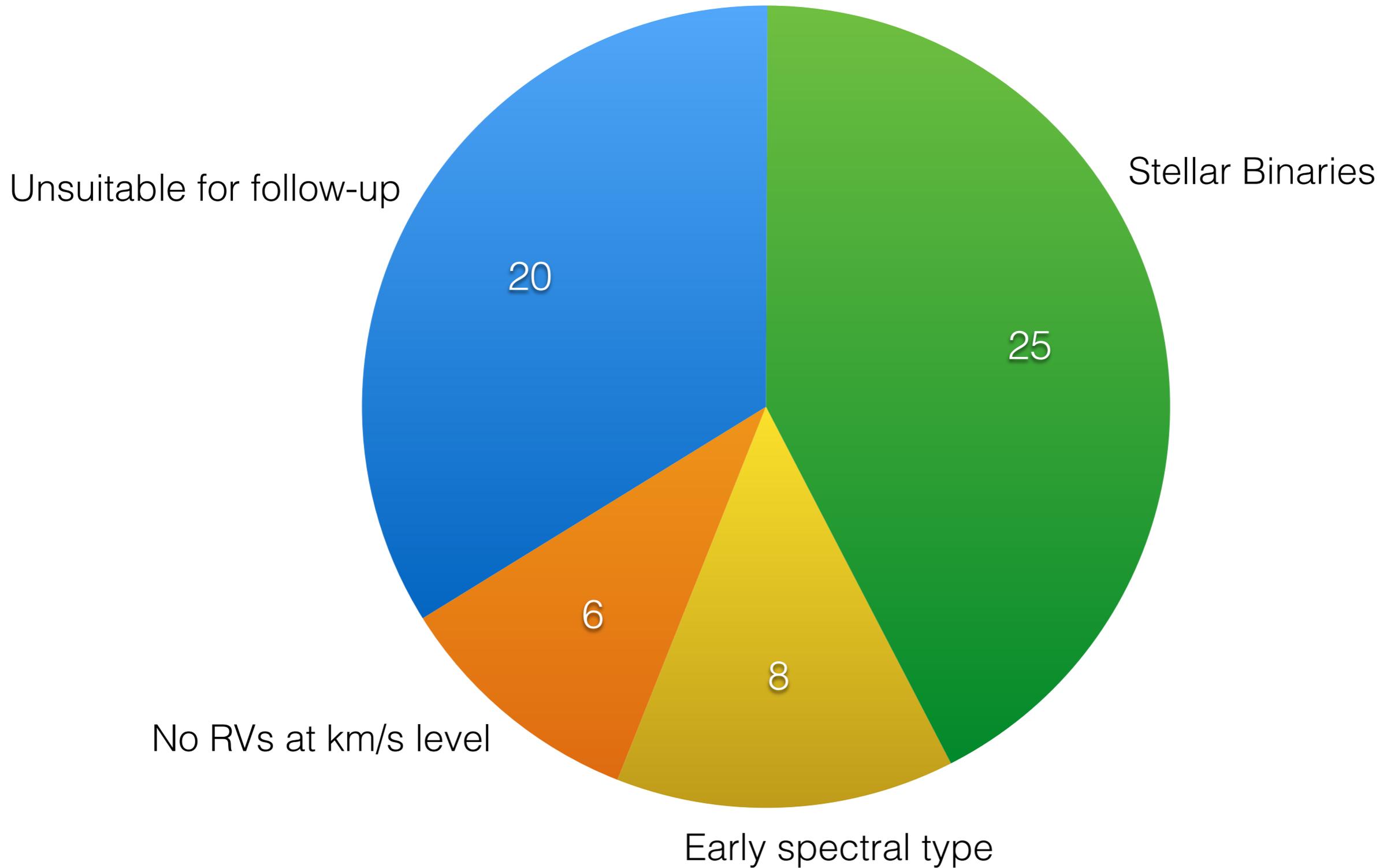
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OGLE planet candidates, c.2004



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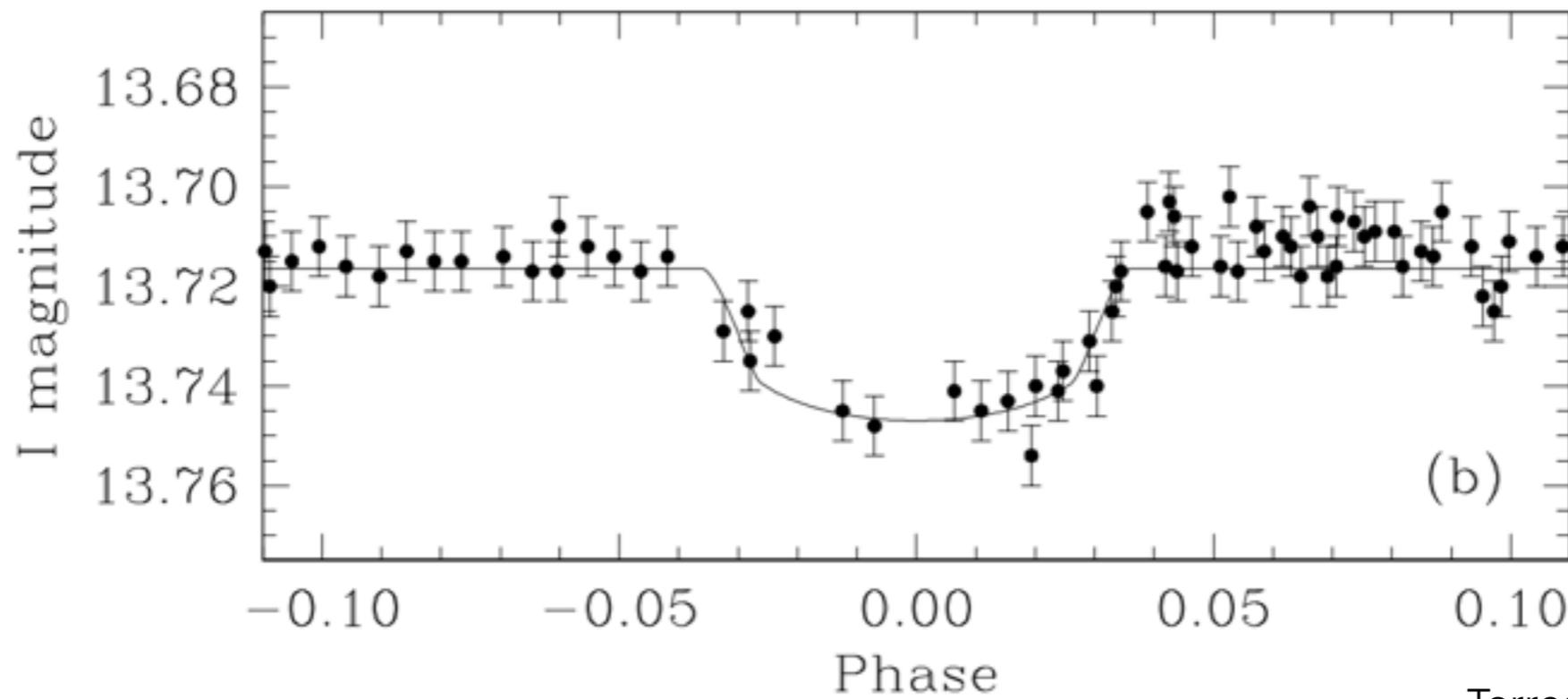
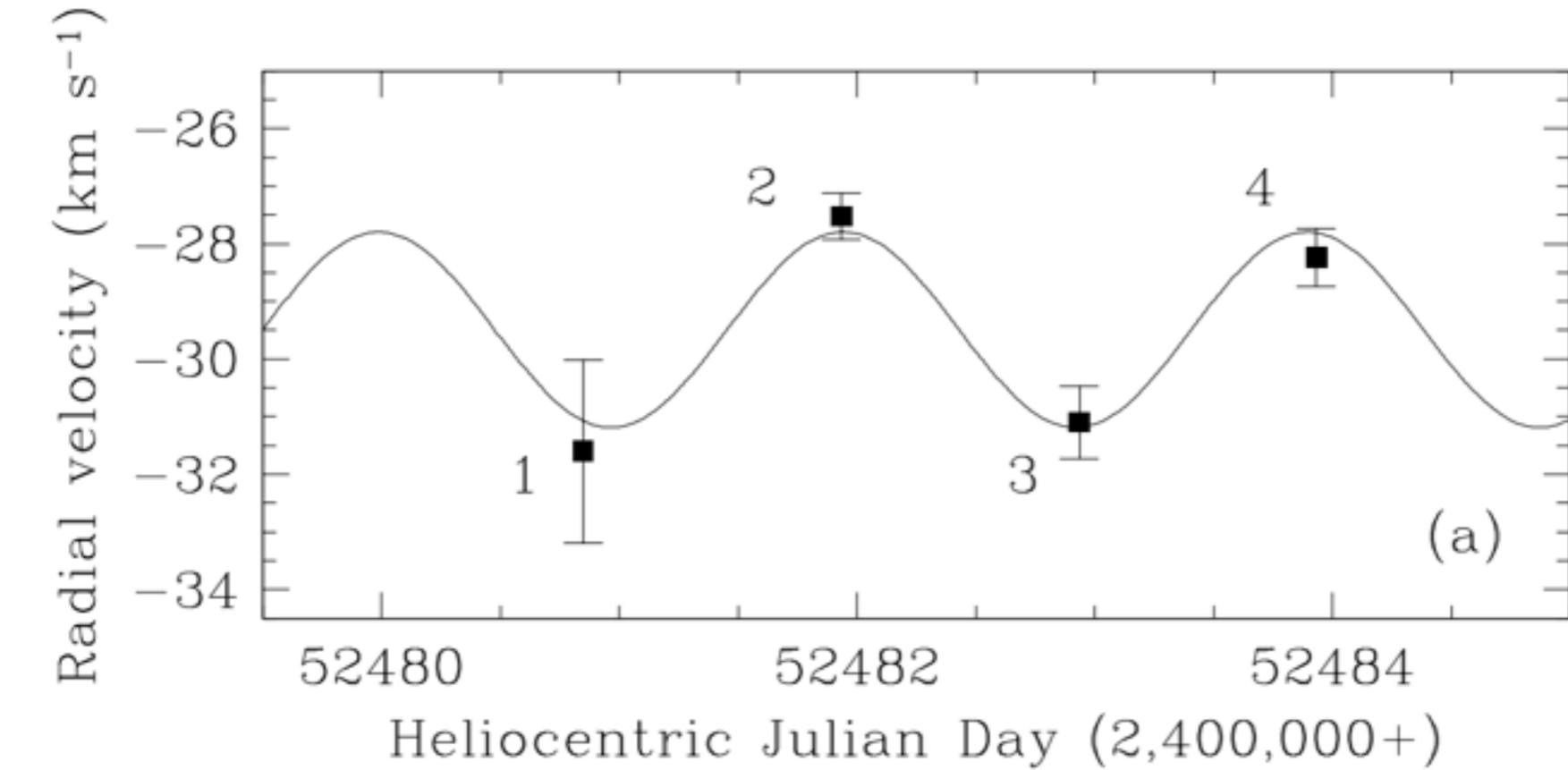
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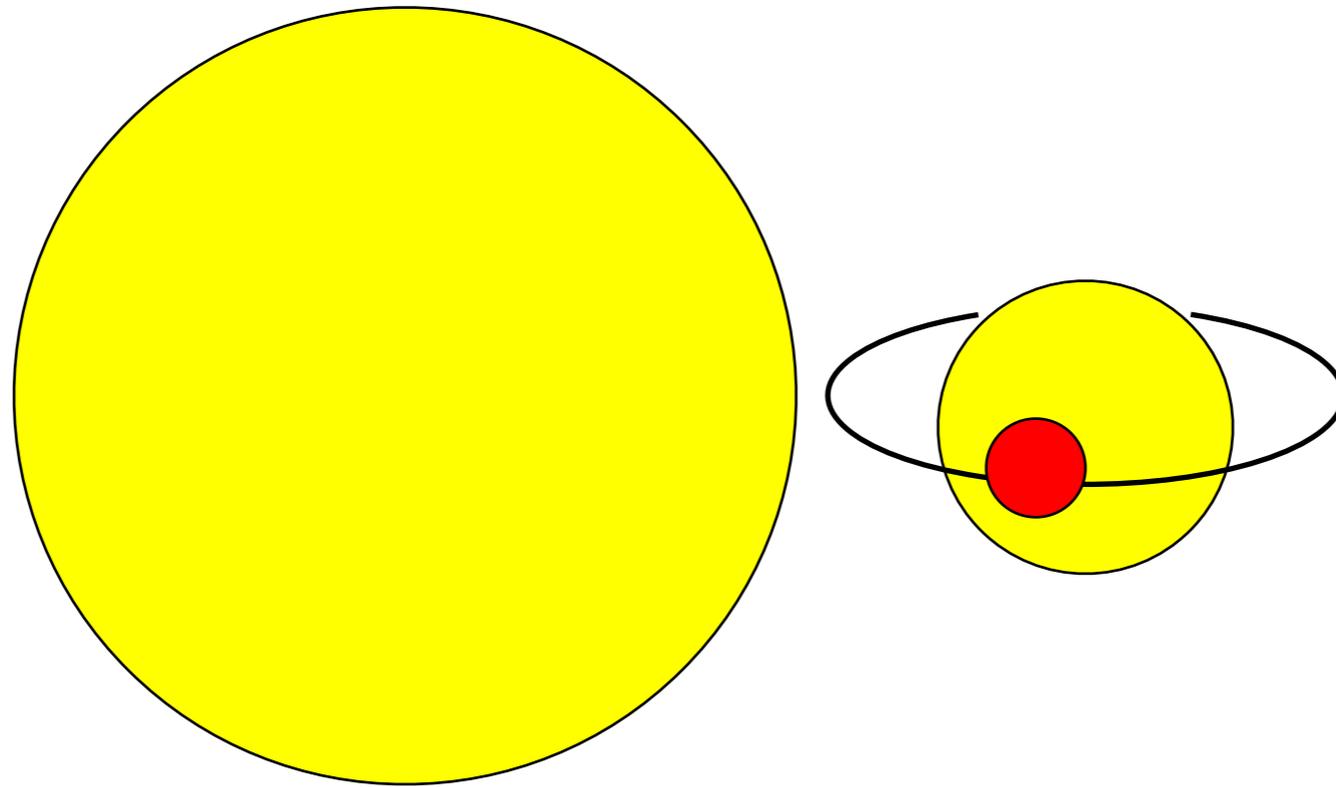
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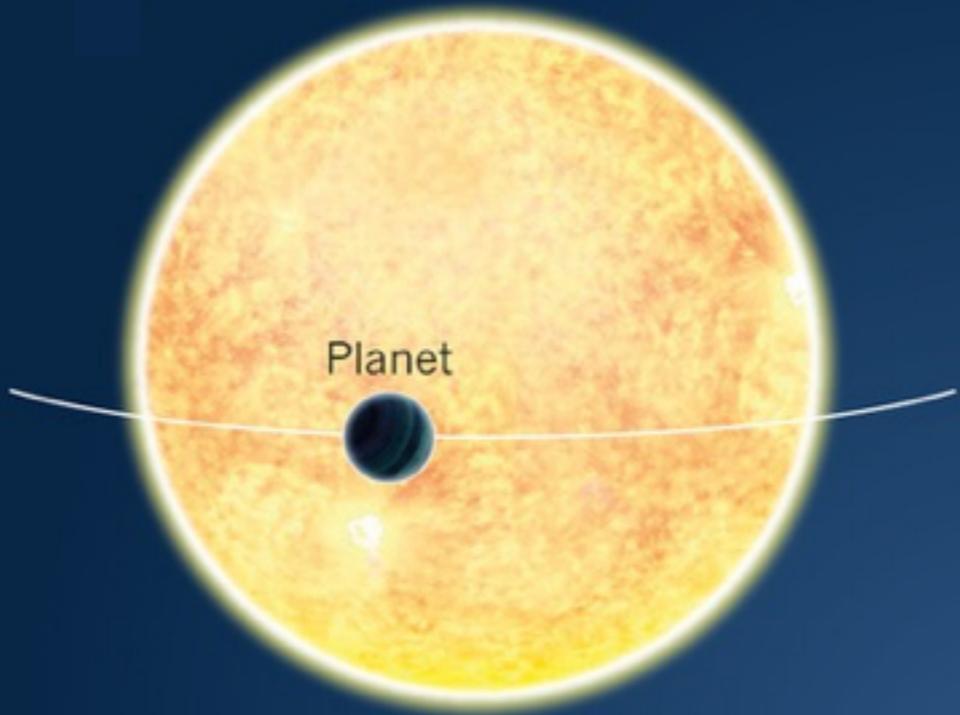
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OGLE-TR-33						Torres 2004	

OGLE-TR-33

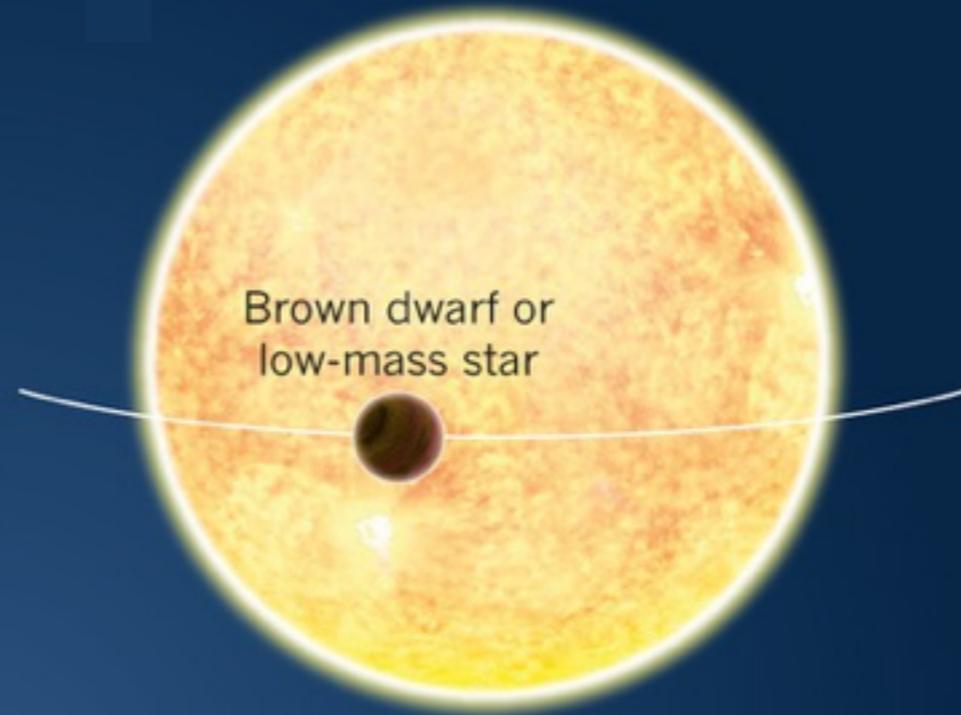




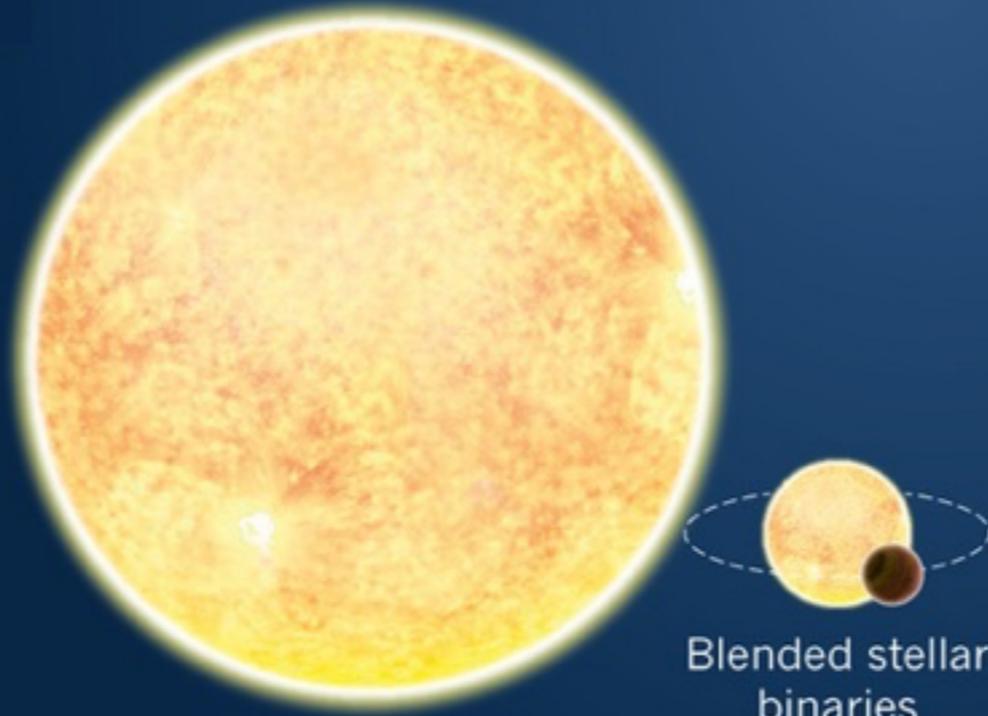


Planet

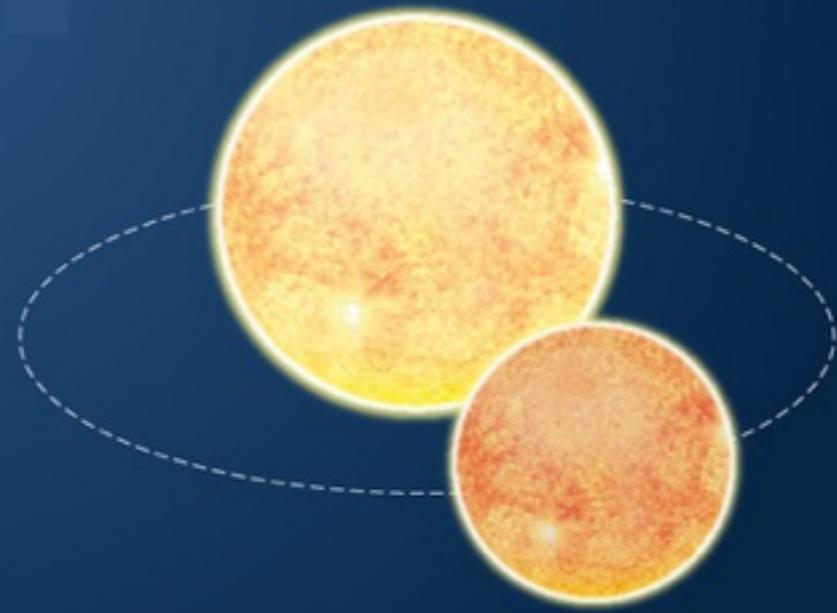
Star



Brown dwarf or
low-mass star



Blended stellar
binaries



Grazing stellar
binaries

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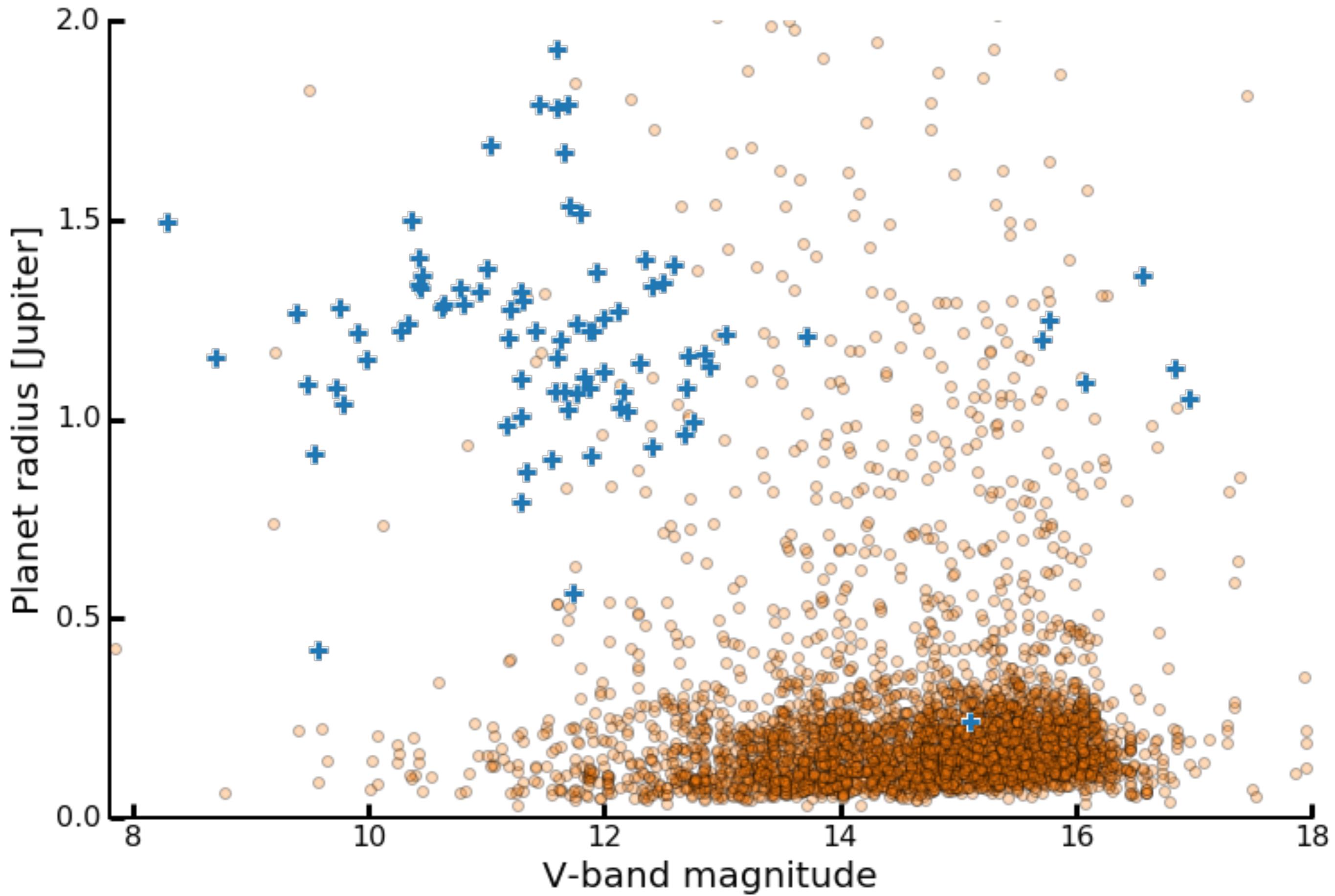
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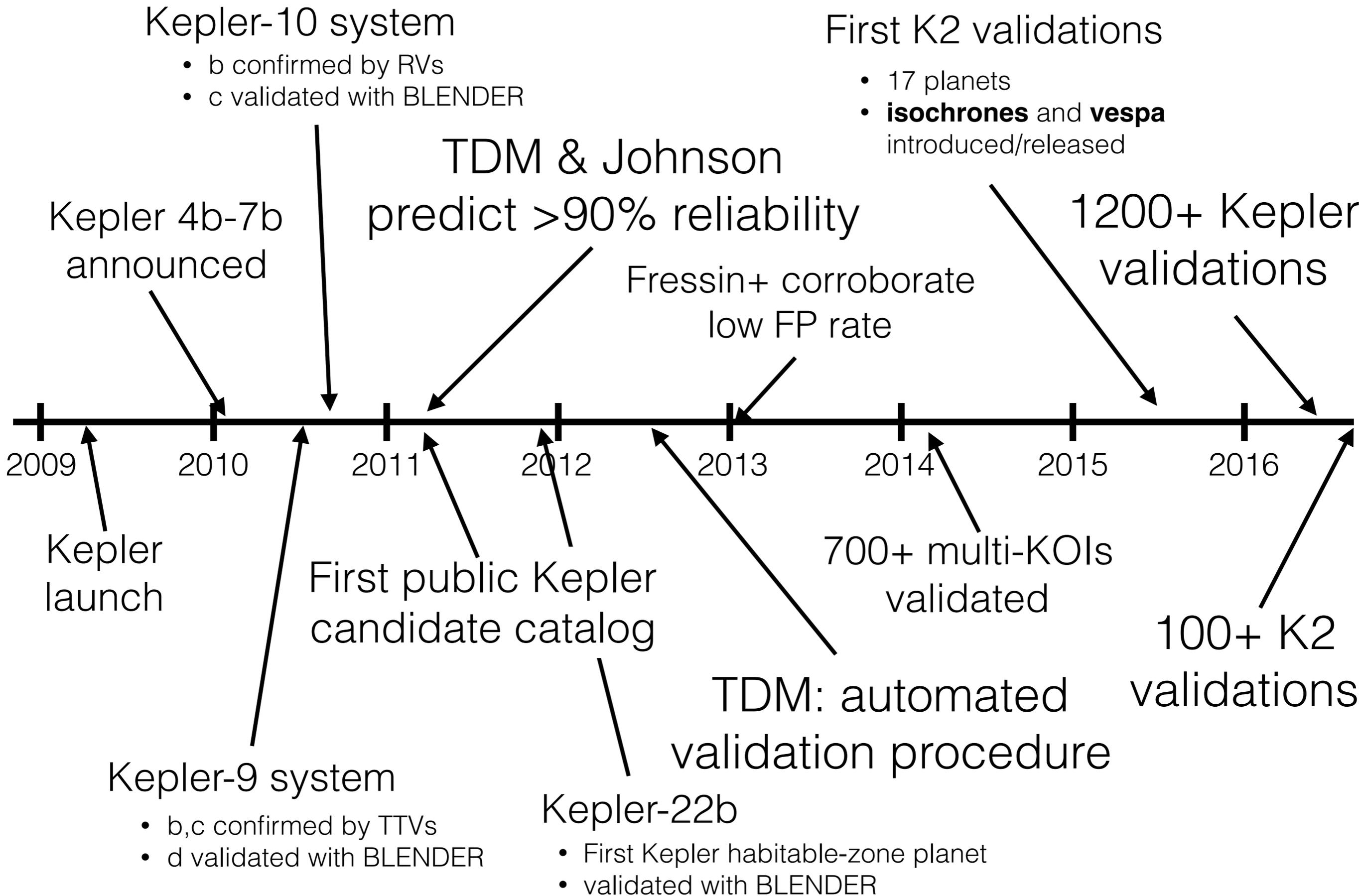
TRES-1 b

Alonso+ (2004)

- $V = 11.4$
- Follow-up observations:
 - H- and K- band AO imaging
 - Medium-resolution spectroscopy (7 epochs)
 - Multi-color transit photometry (3 facilities, 7 filters)
 - Keck/HIRES RV spectroscopy (8 epochs)
- **80% false positive rate** for this survey







Kepler-10 system

- b confirmed by RVs
- c validated with BLENDER

First K2 validations

- 17 planets
- **isochrones** and **vespa** introduced/released

TDM & Johnson
predict >90% reliability

Fressin+ corroborate
low FP rate

1200+ Kepler
validations

First public Kepler
candidate catalog

700+ multi-KOIs
validated

TDM: automated
validation procedure

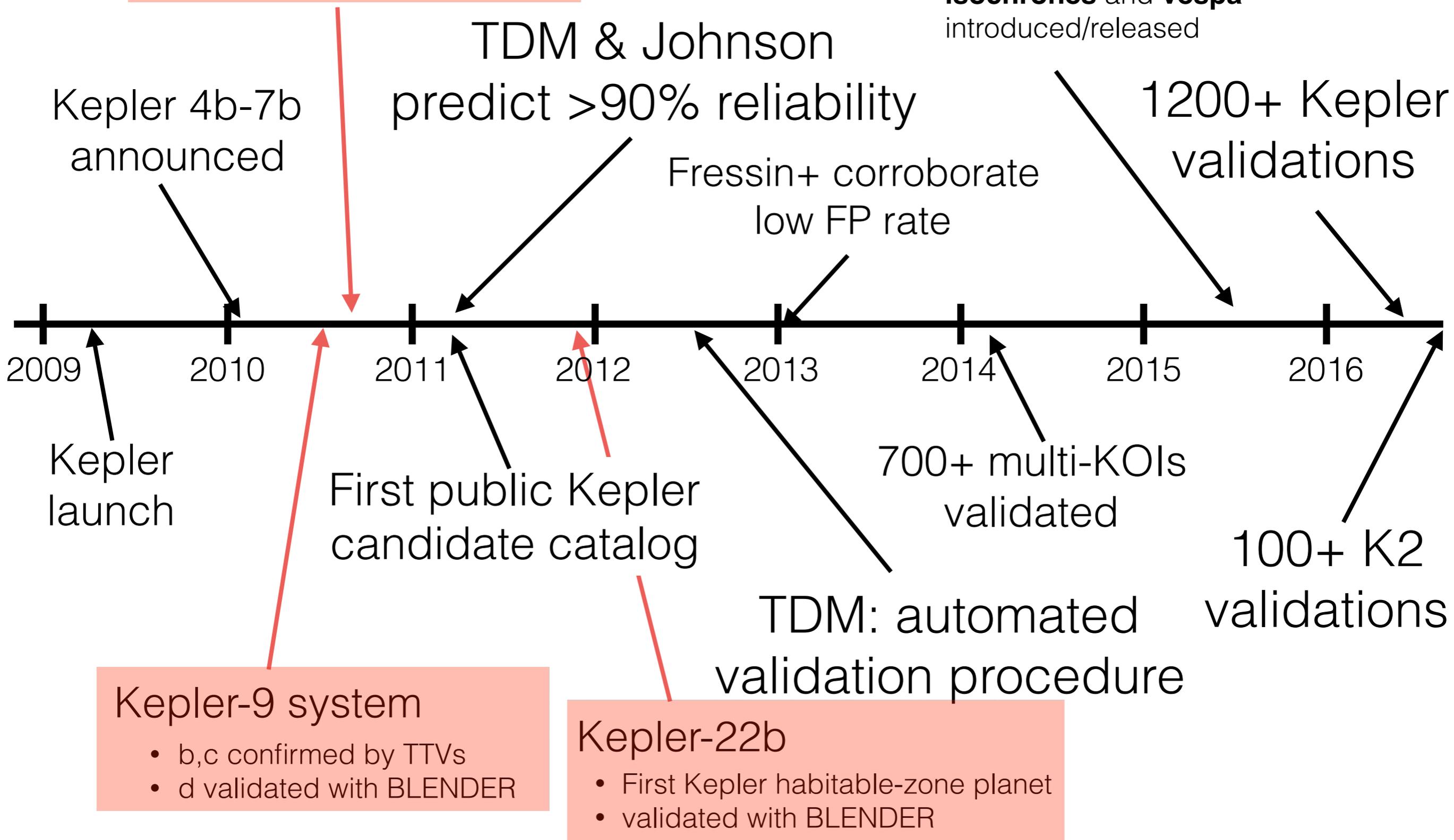
100+ K2
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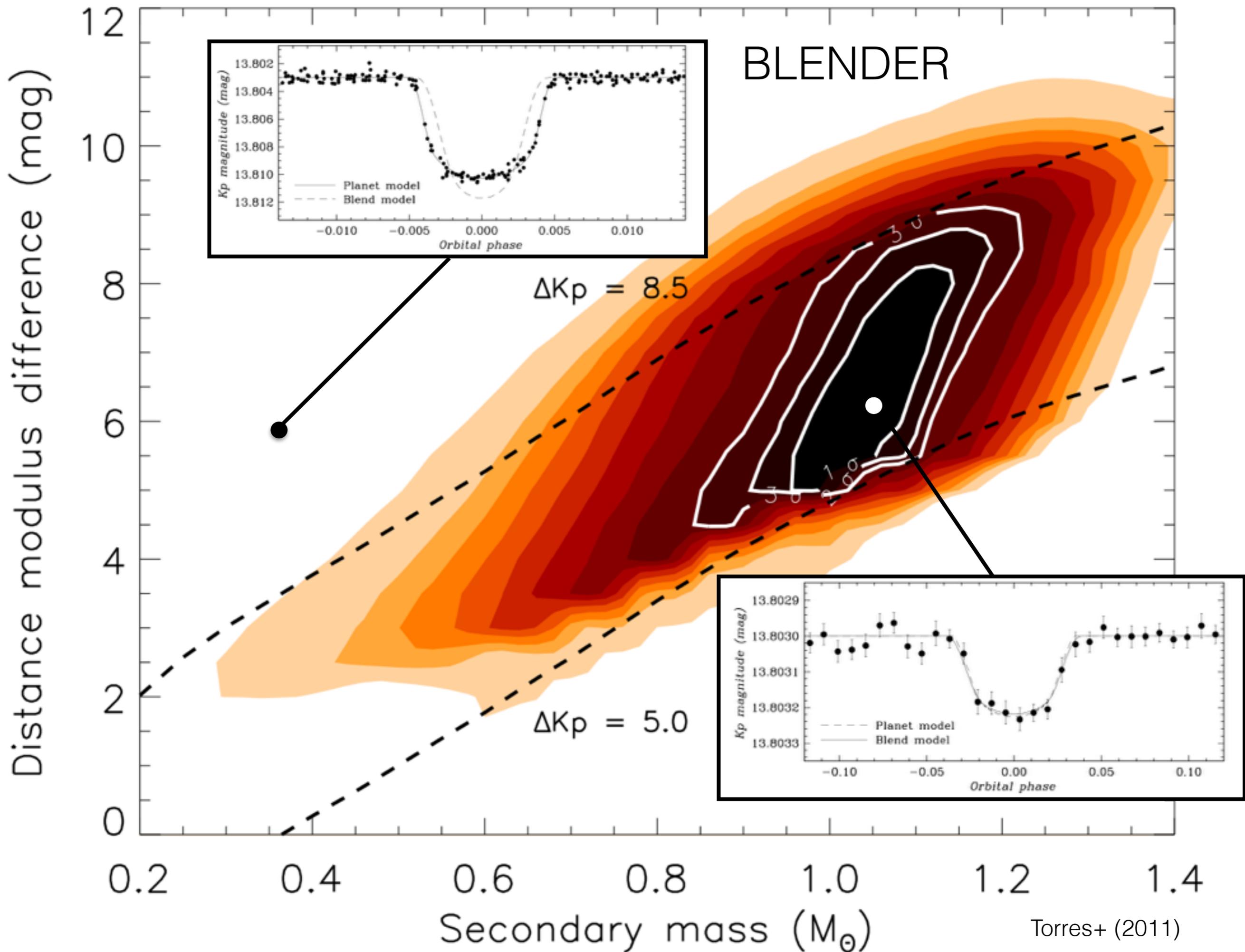
Kepler-9 system

- b,c confirmed by TTVs
- d validated with BLENDER

Kepler-22b

- First Kepler habitable-zone planet
- validated with BLENDER





Kepler-22b

Borucki et al. (2011):

- Imaging from 3 different facilities (seeing-limited, speckle, AO)
- Keck/HIRES spectroscopy at 17 epochs
- 17 hours of *Warm Spitzer* observation to measure transit color dependence
- BLENDER analysis



Kepler-10 system

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First K2 validations

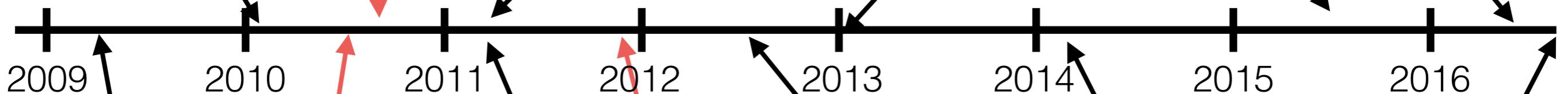
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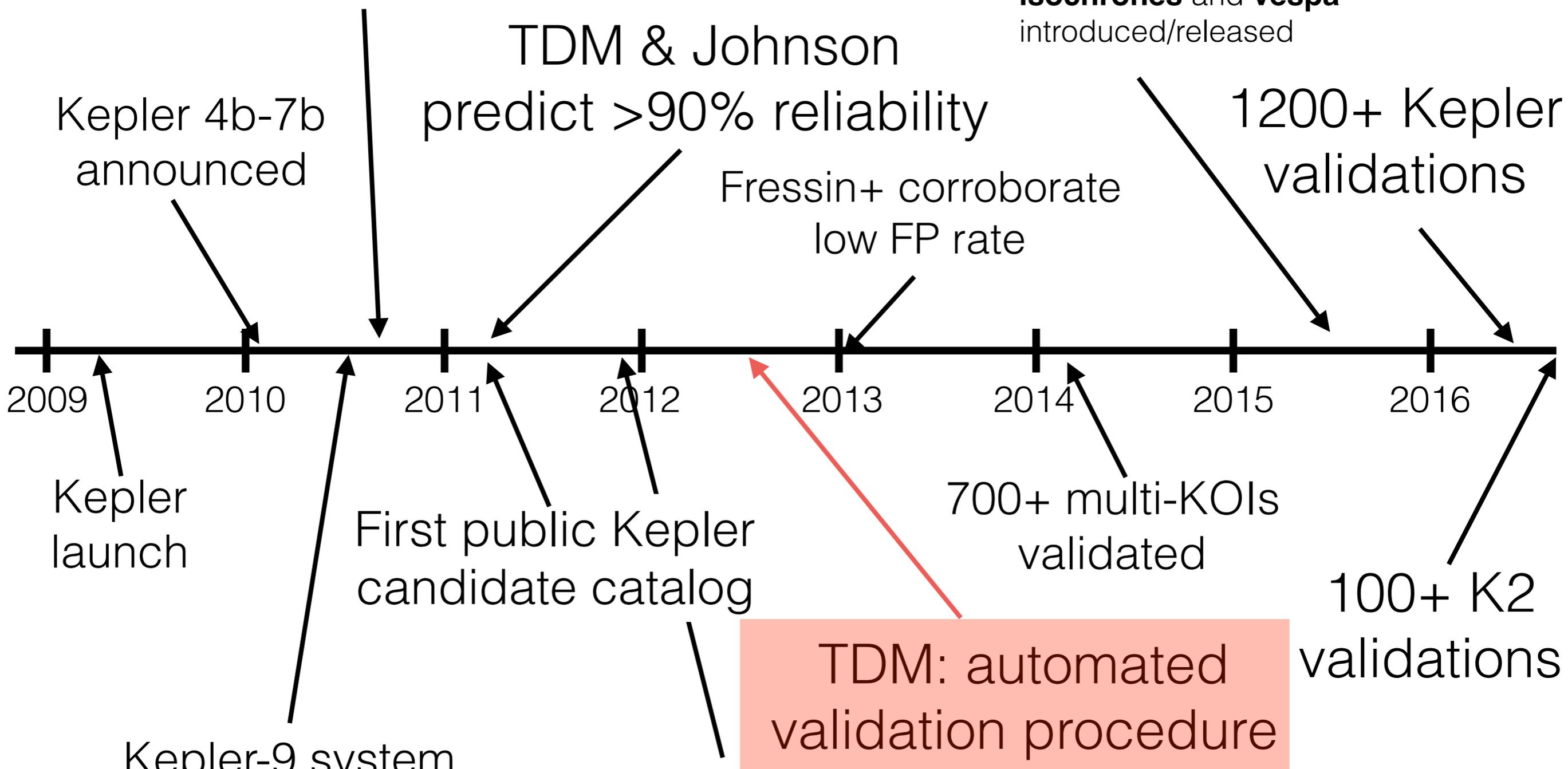
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Kepler 4b-7b
announced

2009

2010

2011

2012

2013

2014

2015

2016

Kepler
launch

First public Kepler
candidate catalog

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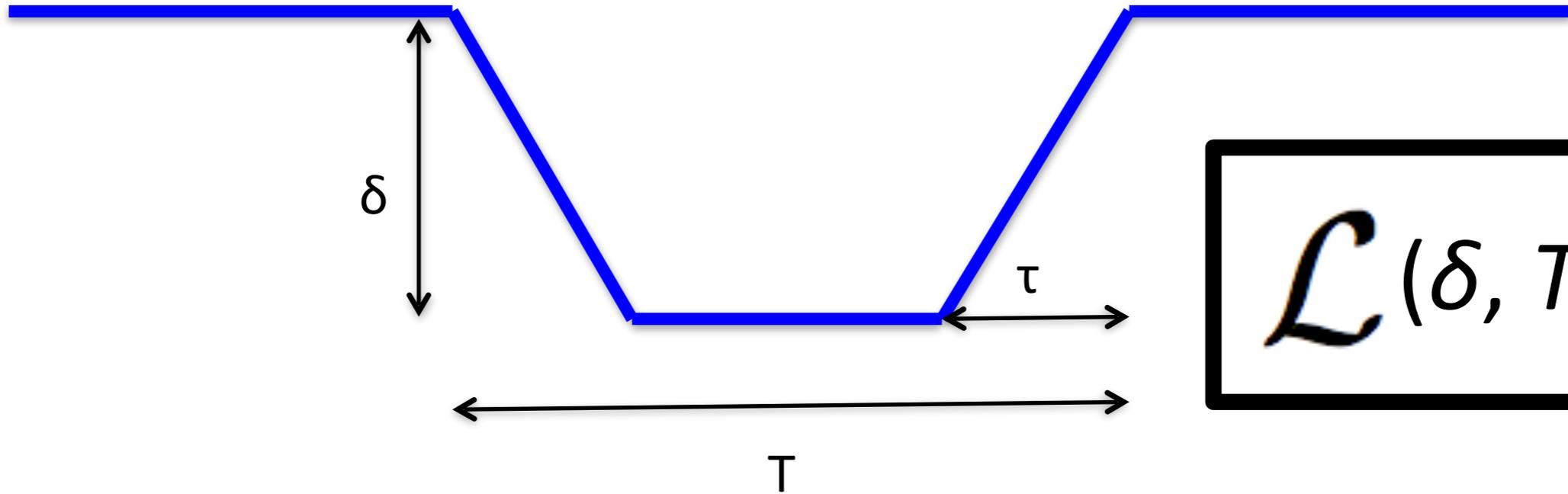
100+ K2
validations

light curve shape

Planet



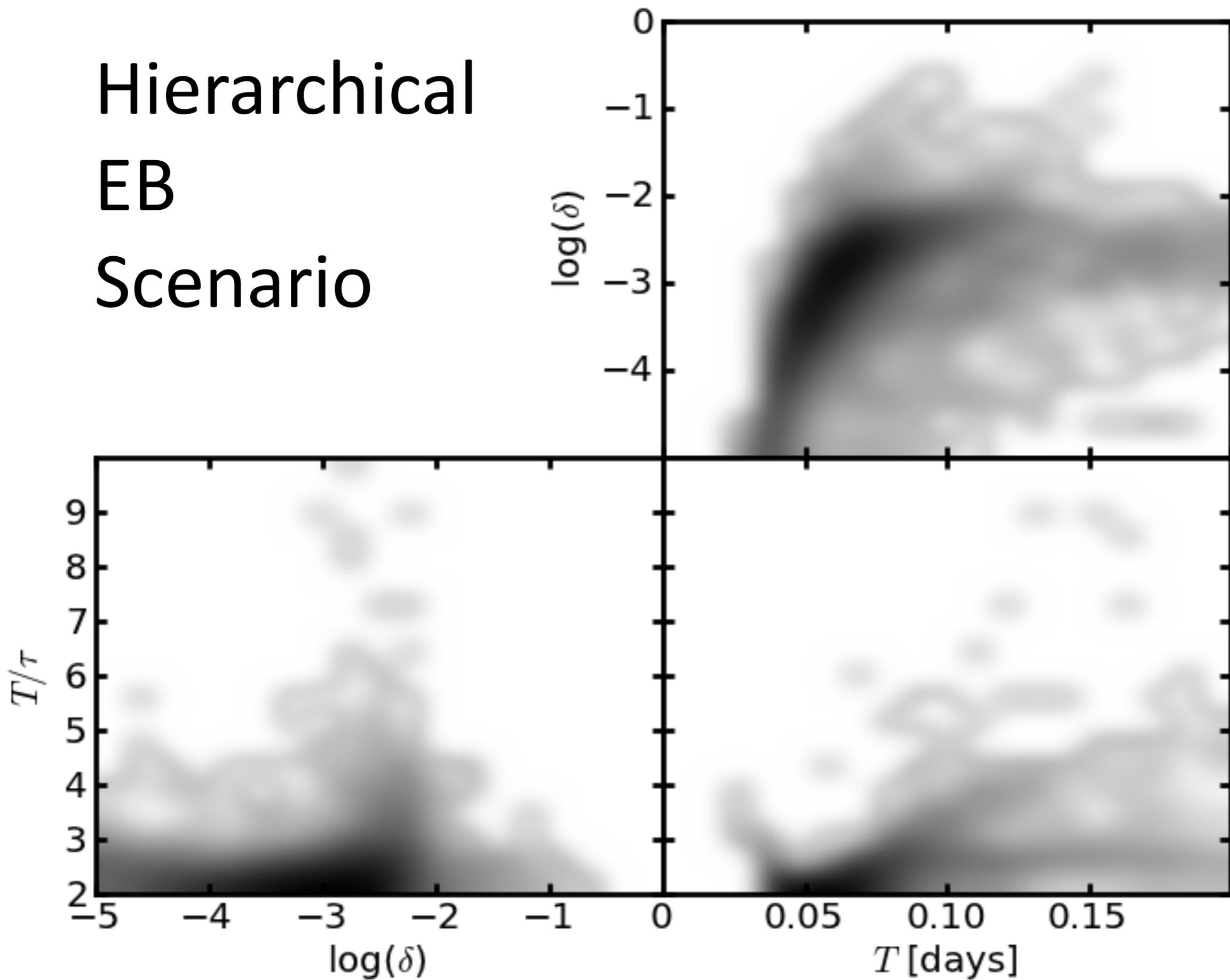
Stellar EB



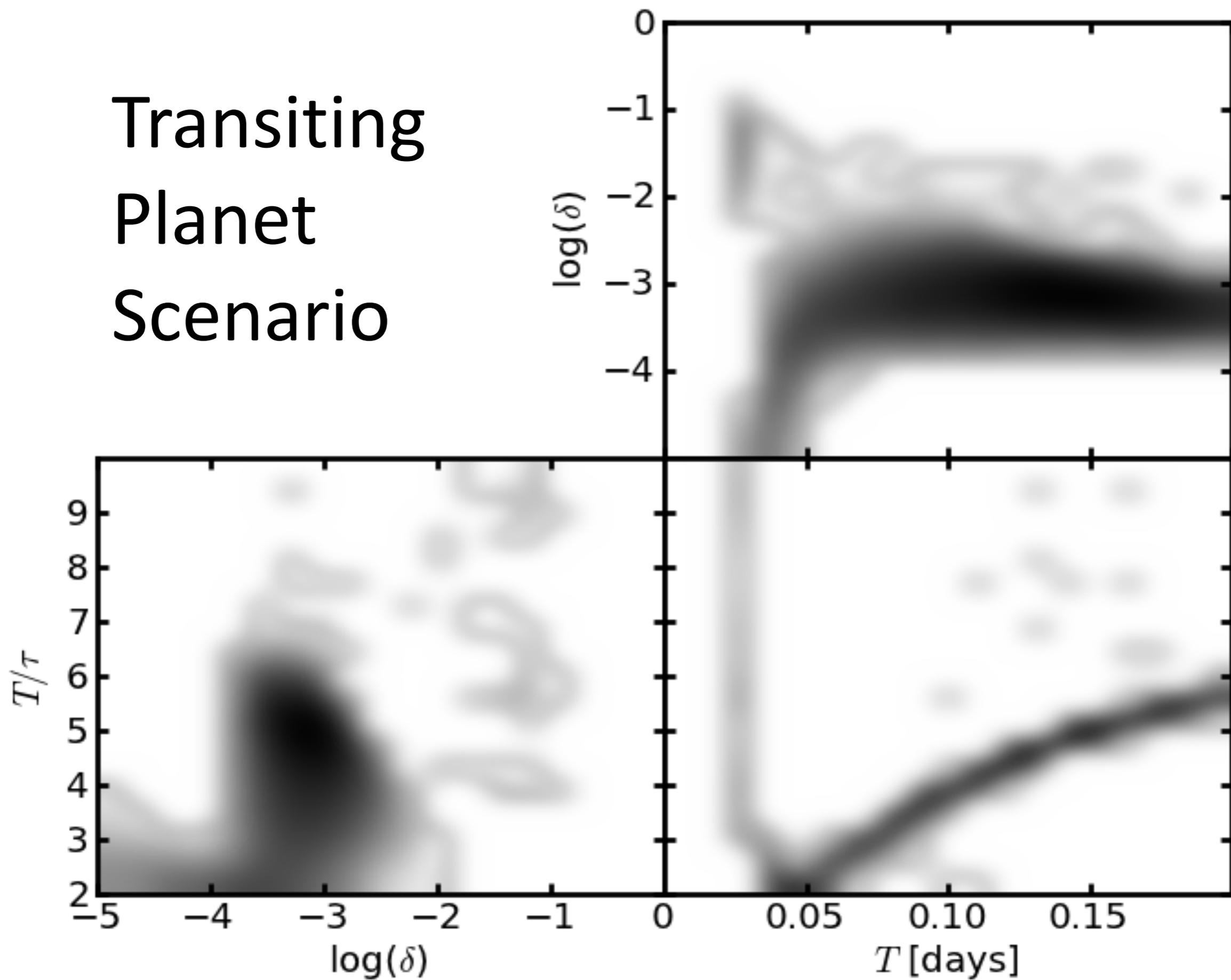
$$\mathcal{L}(\delta, T, T/\tau)$$

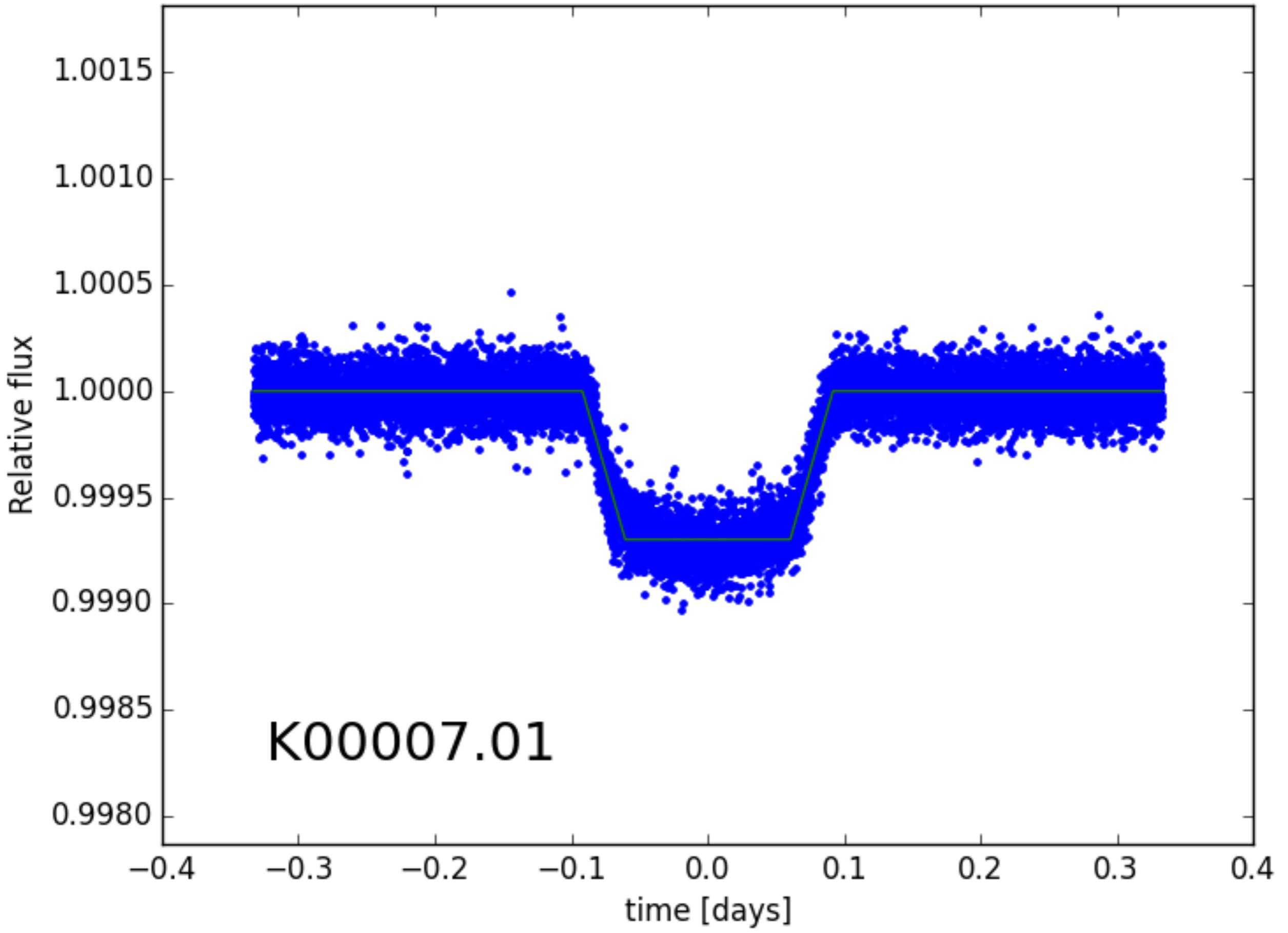
Simulate representative populations

Hierarchical EB Scenario

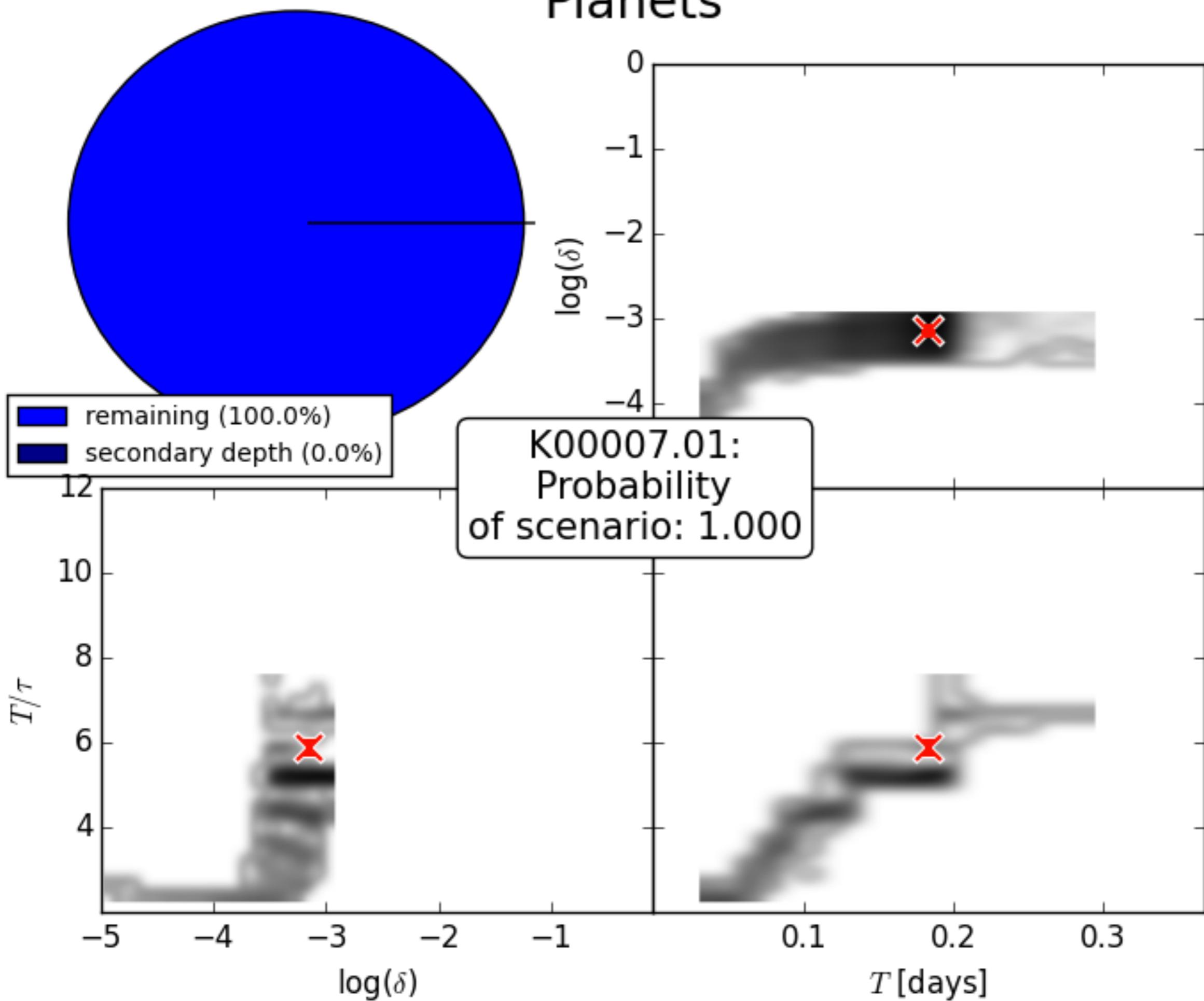


Transiting Planet Scenario

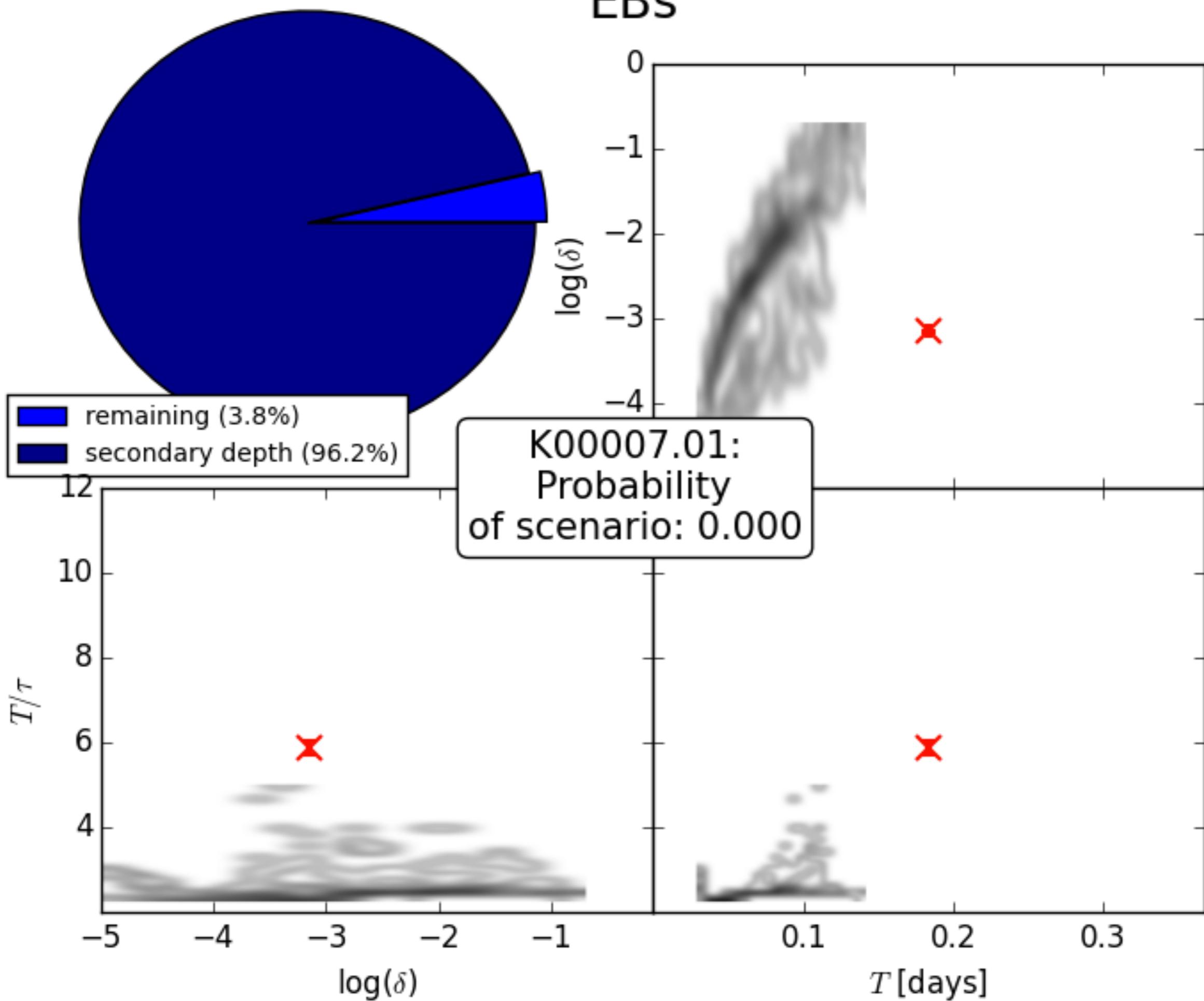




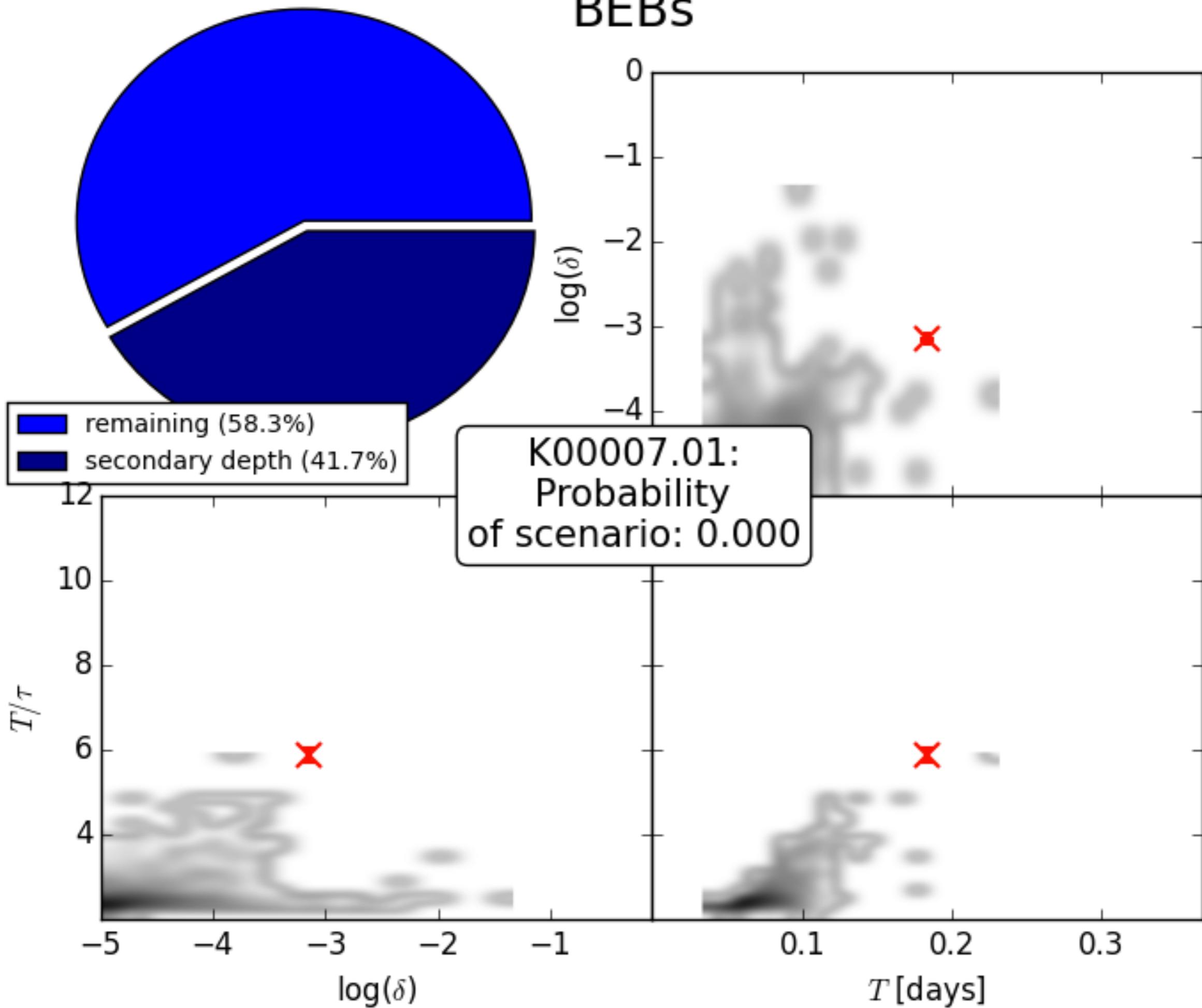
Planets



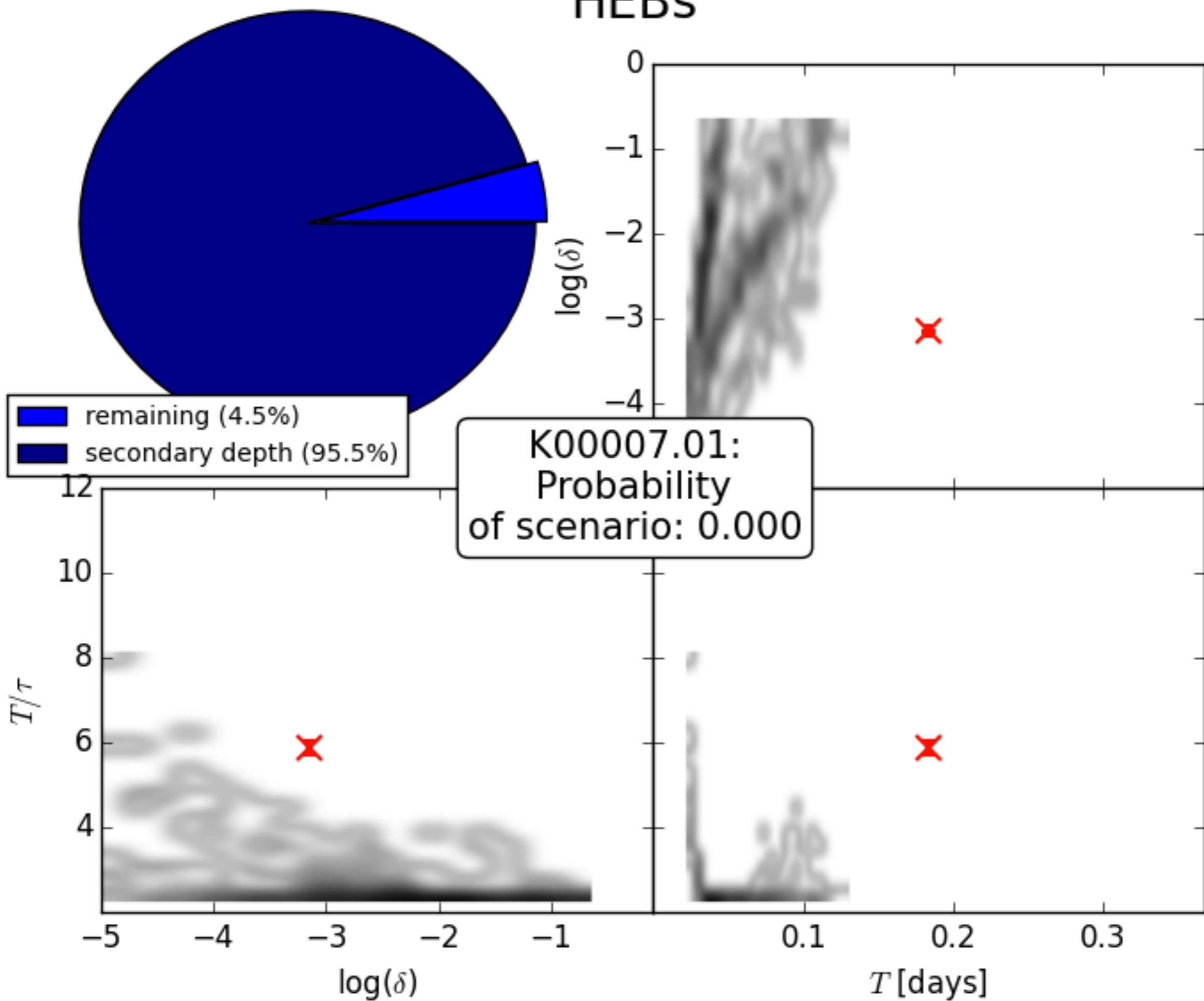
EBs



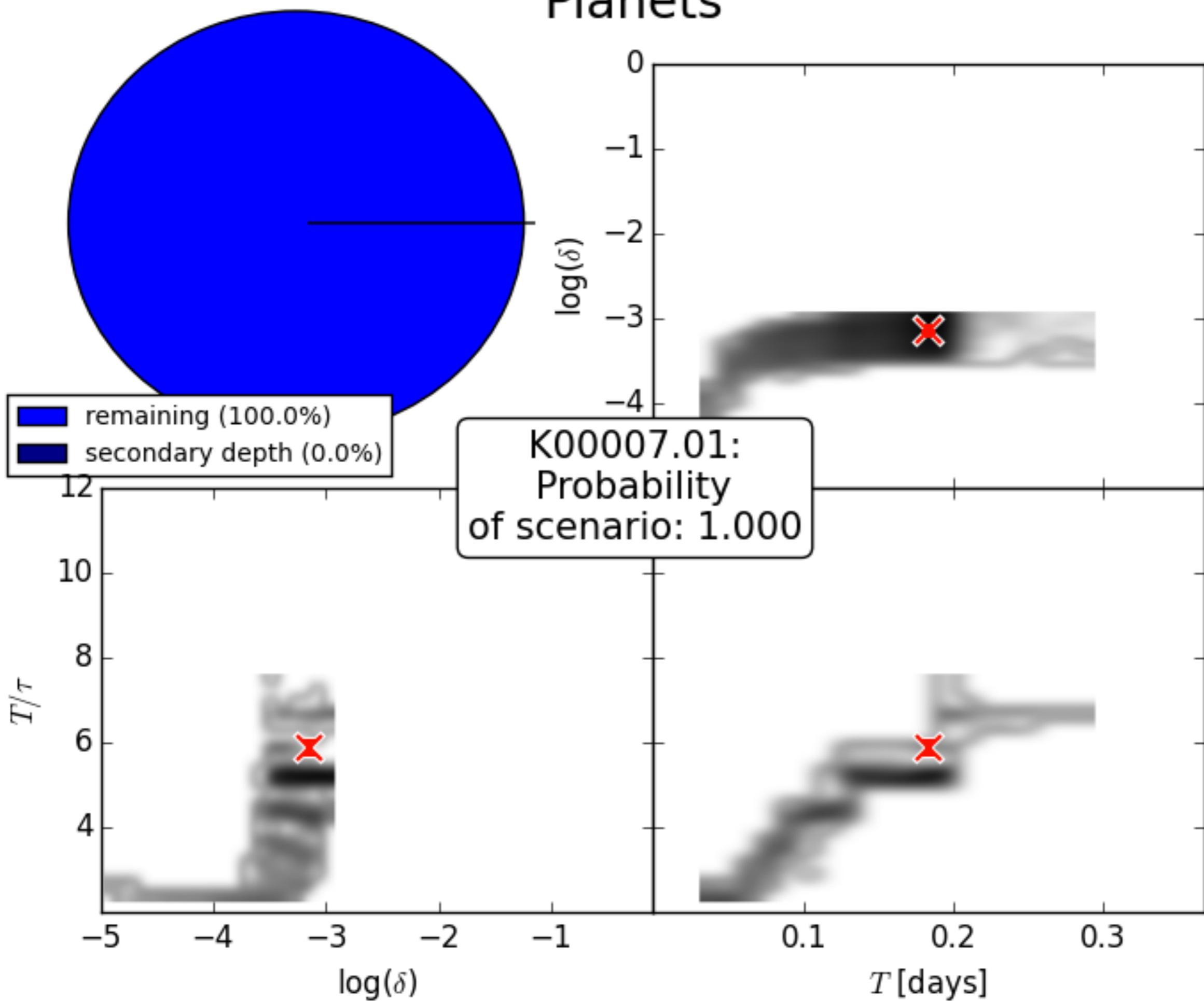
BEBs



HEBs

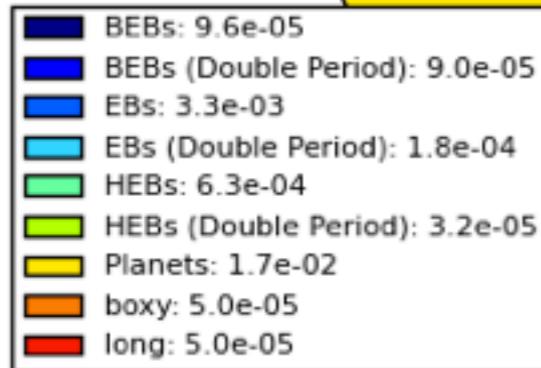
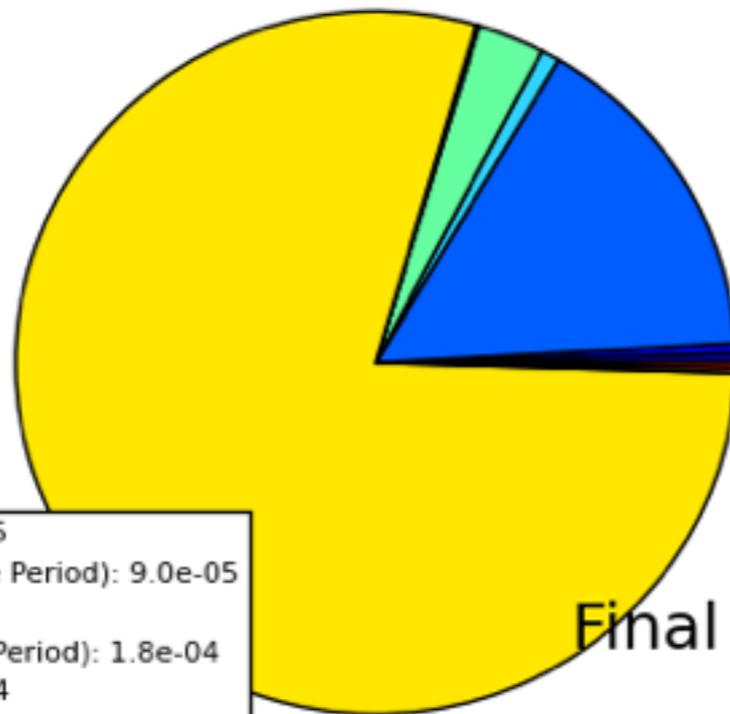


Planets

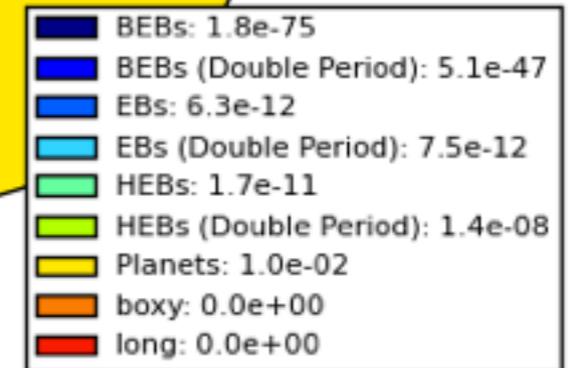
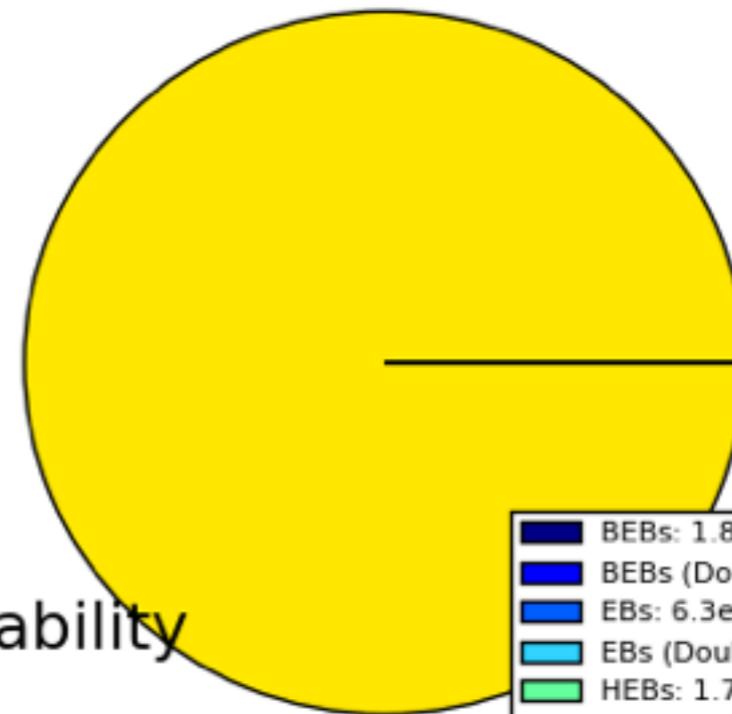


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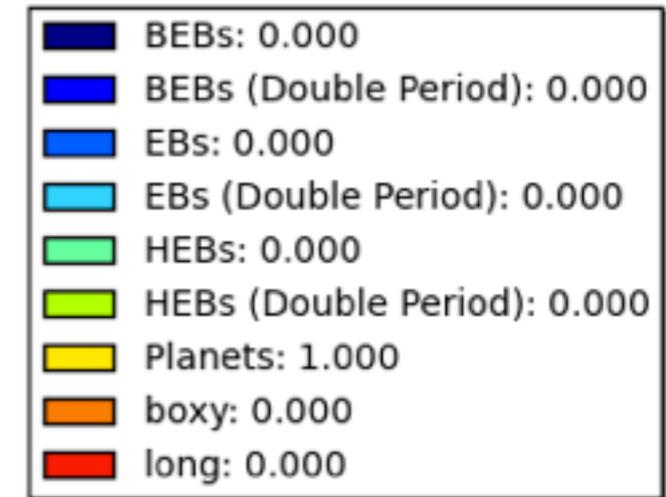
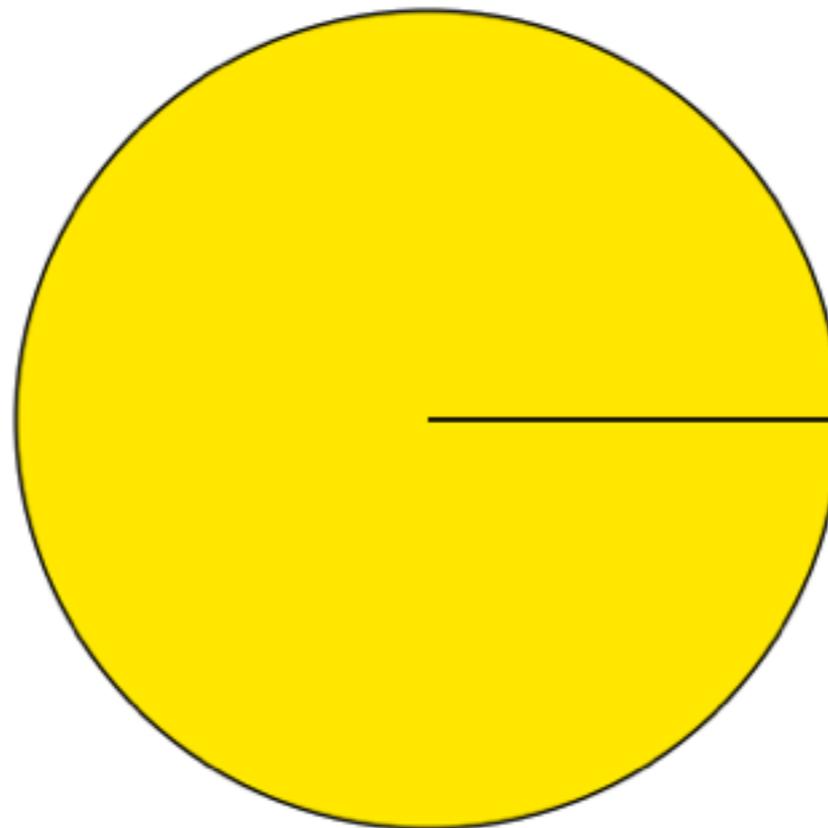
Priors



Likelihoods

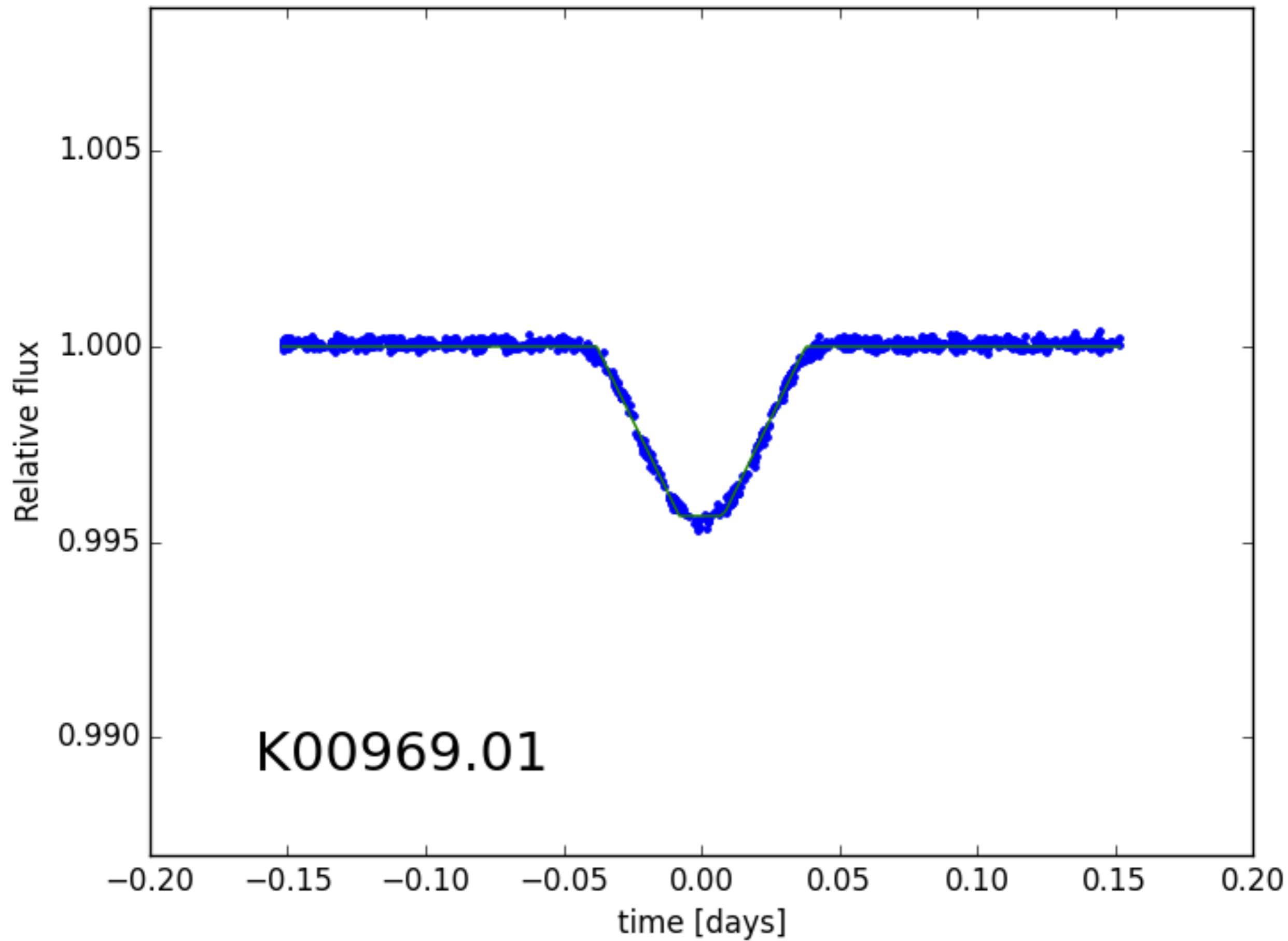


Final Probability

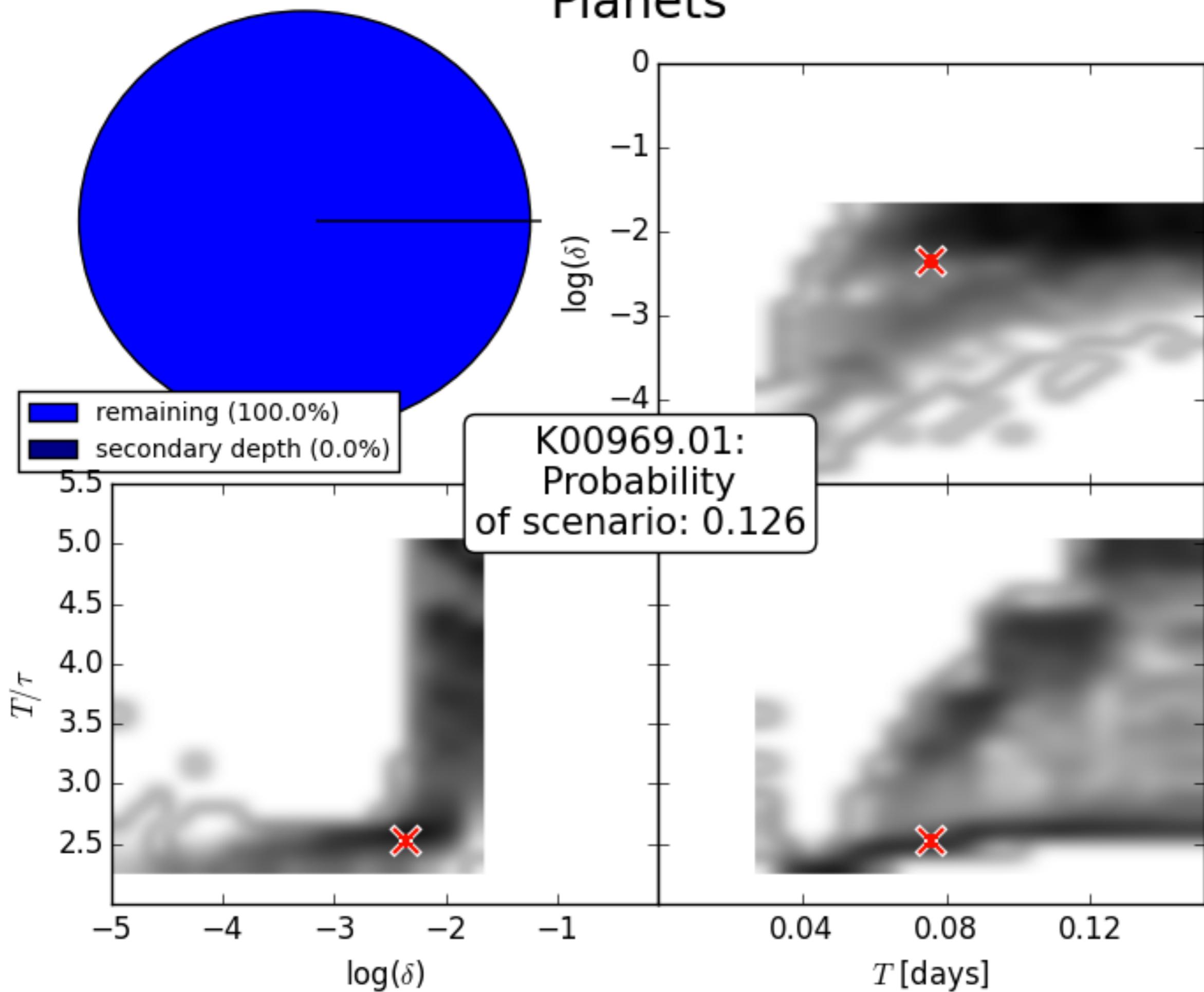


Constraints:
secondary depth < 1.24e-05
odd-even < 1.11e-05

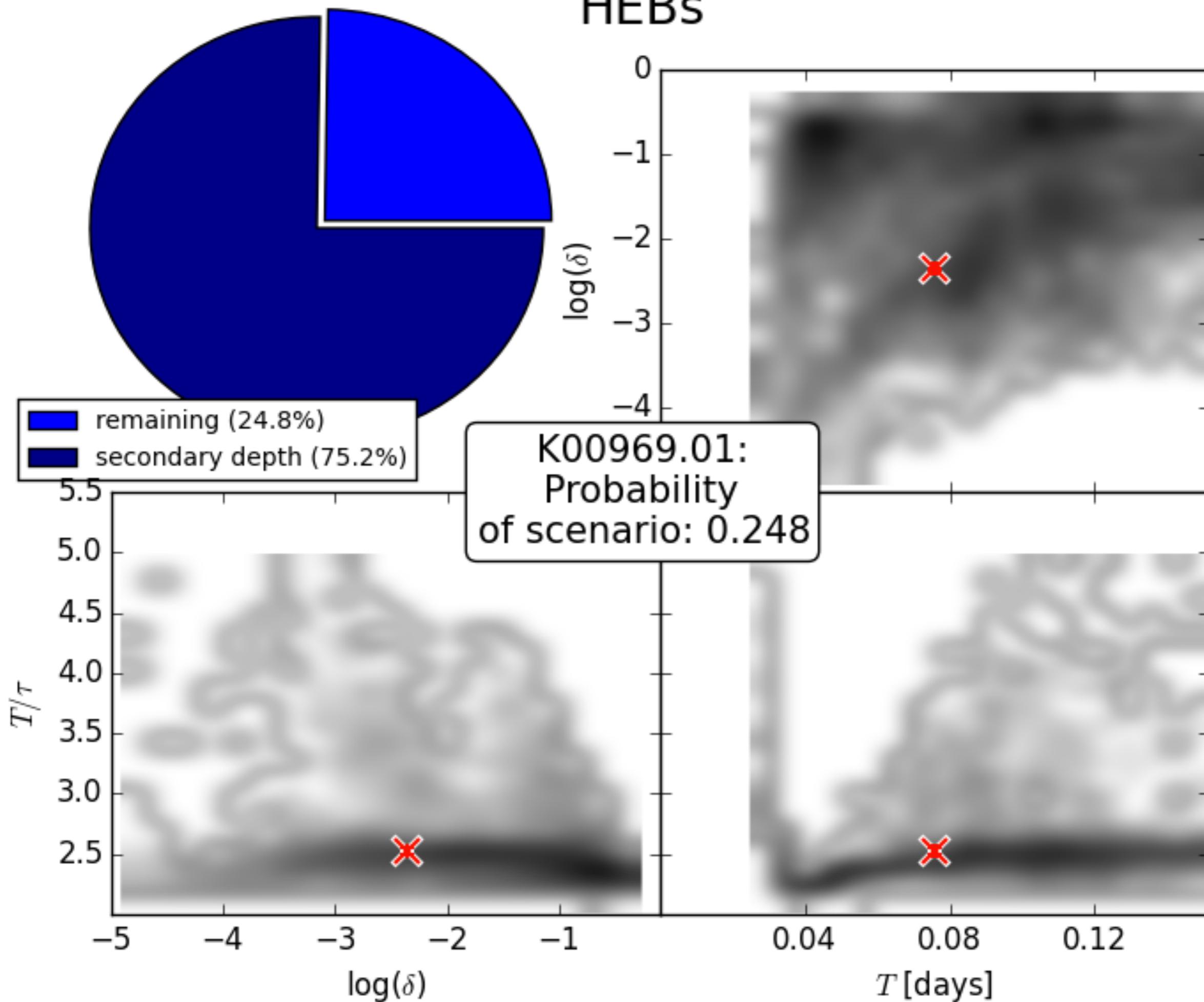
$f_{pl,V} = 0.000$
FPP: < 1 in 1e6



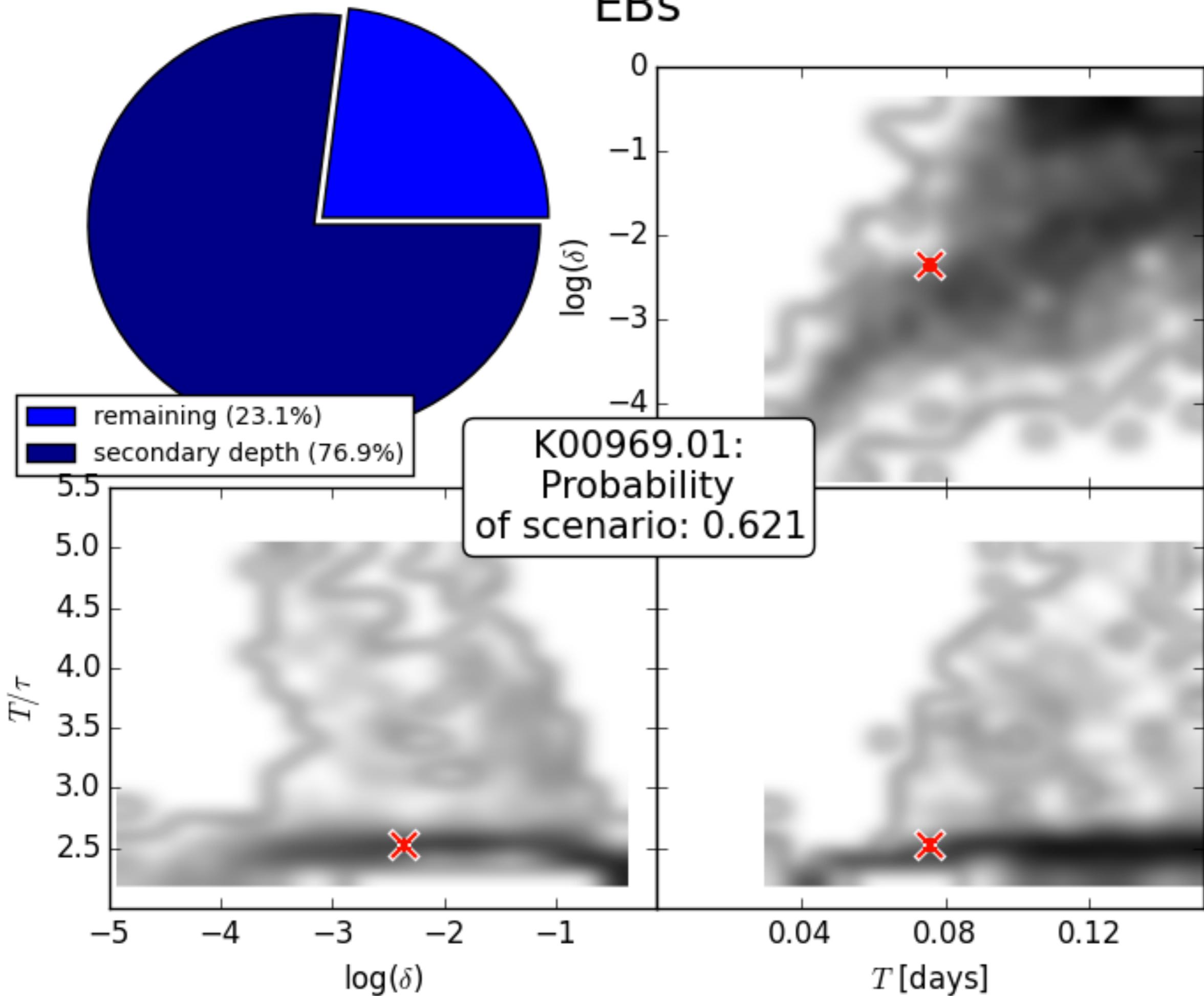
Planets



HEBs

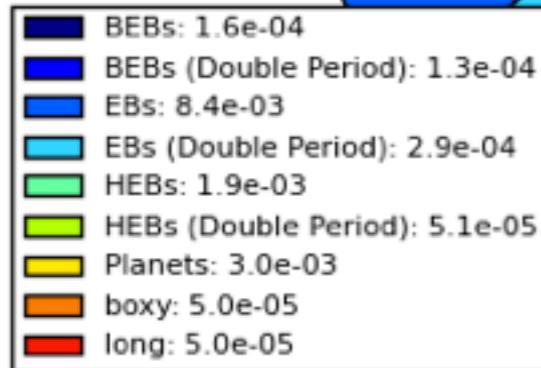
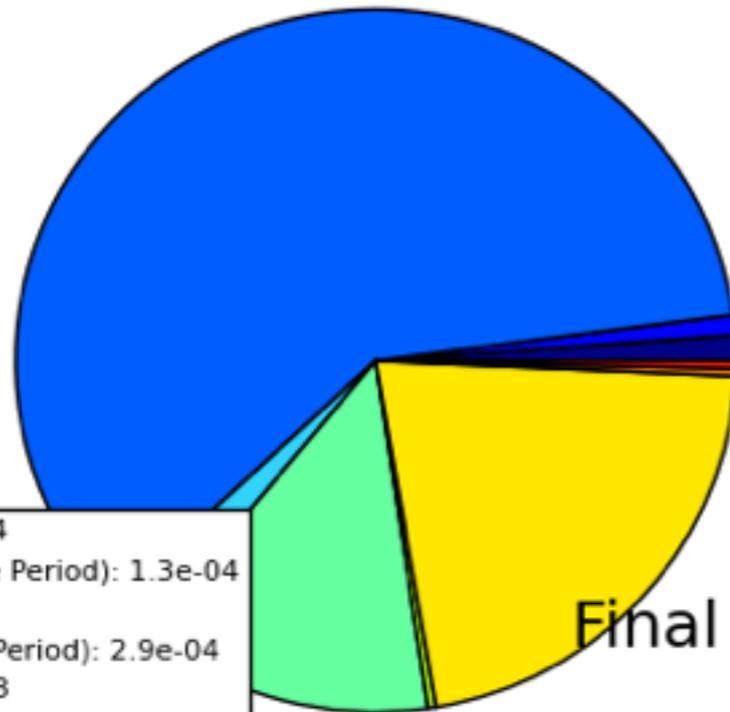


EBs

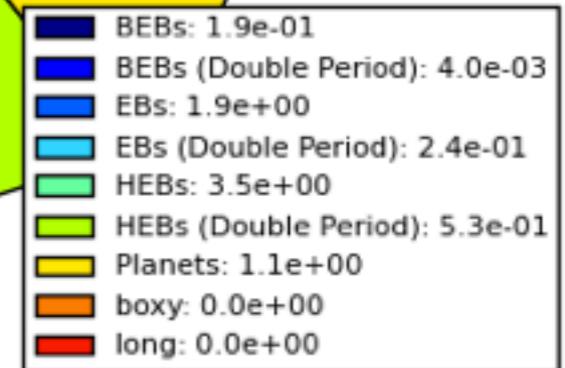
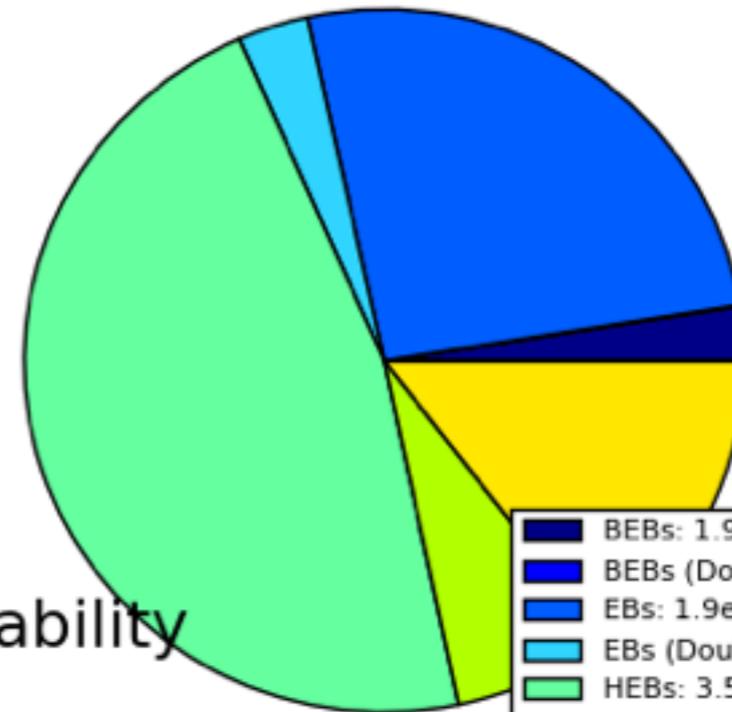


K00969.01

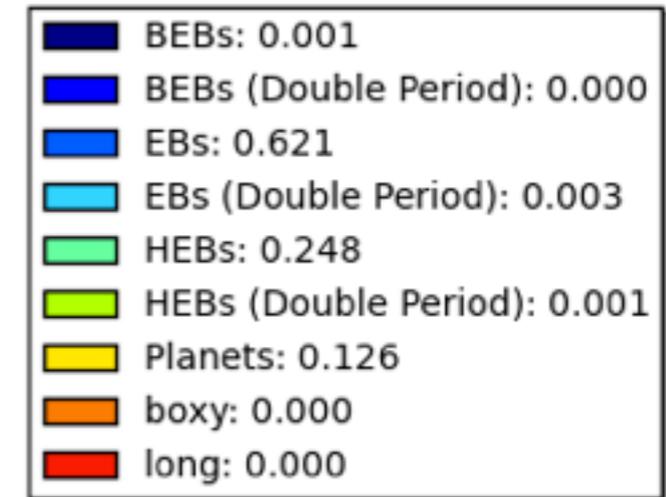
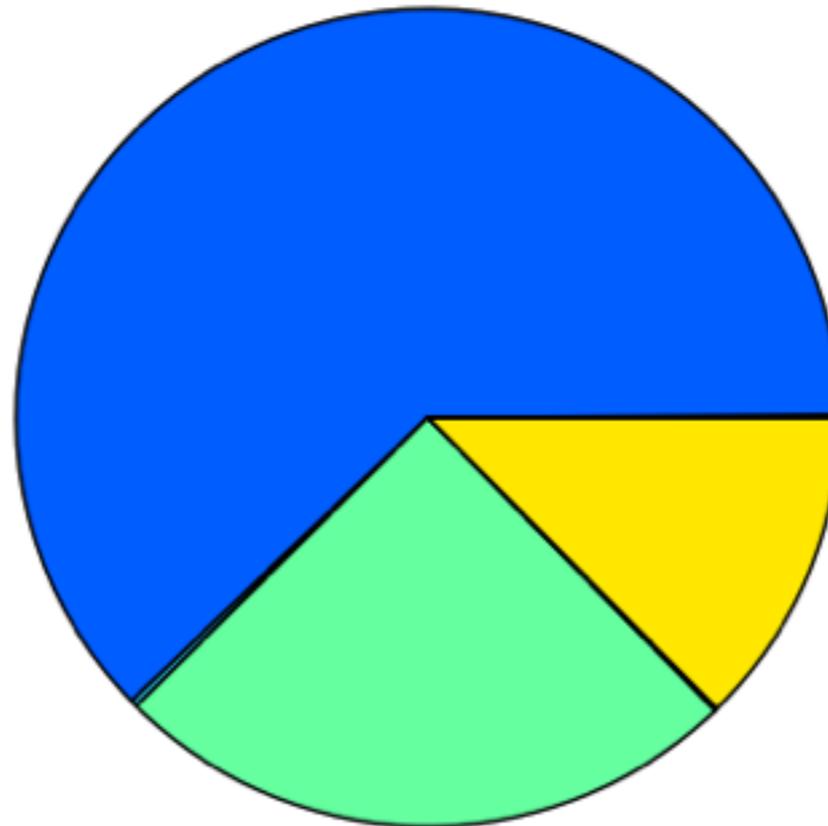
Priors



Likelihoods



Final Probability



Constraints:
secondary depth < 5.44e-05
odd-even < 0.000127

$f_{pl,V} = 48.681$
FPP: 1 in 1

Kepler-10 system

- b confirmed by RVs
- c validated with BLENDER

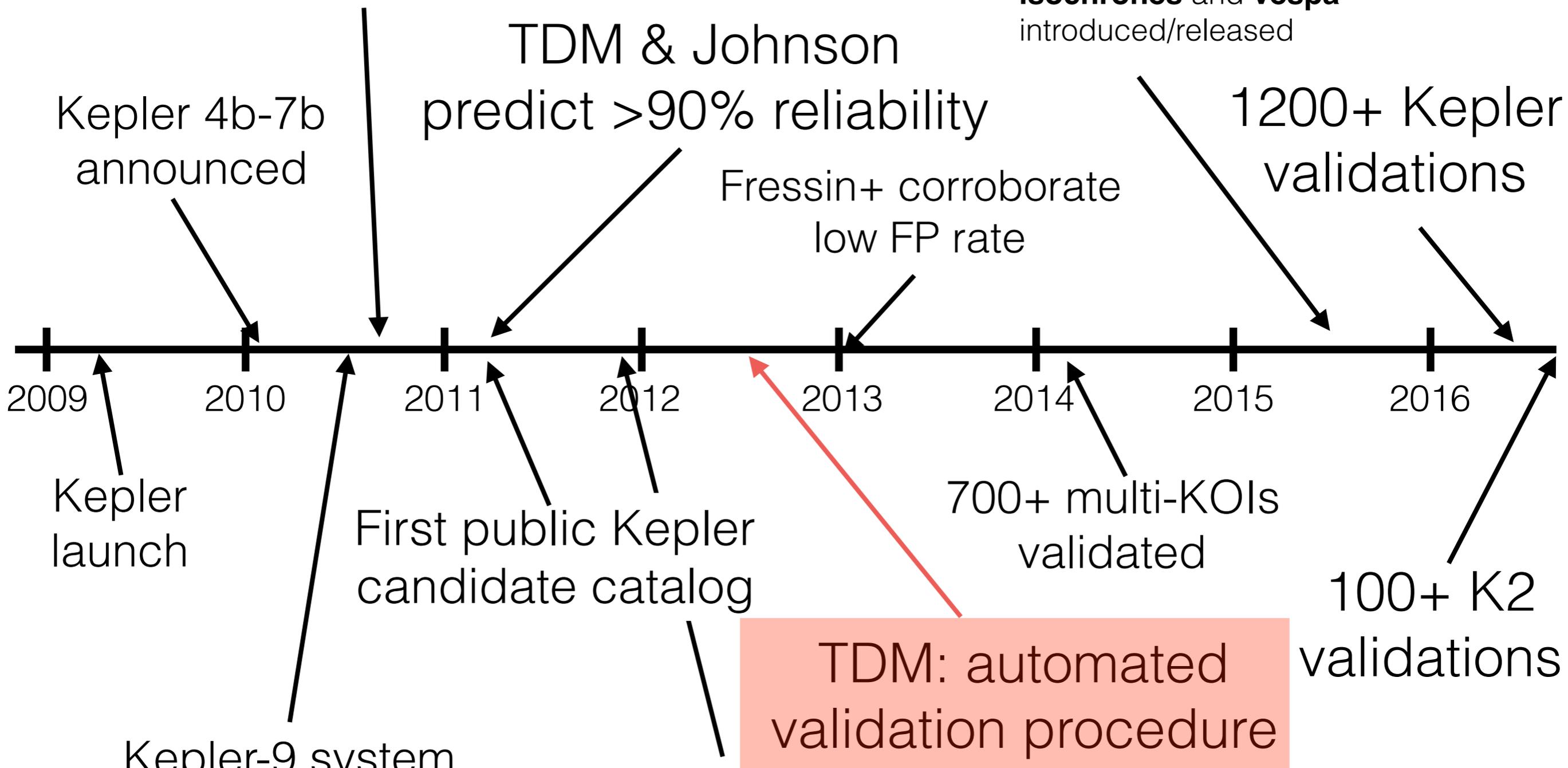
First K2 validations

- 17 planets
- **isochrones** and **vespa** introduced/released

TDM & Johnson
predict >90% reliability

Fressin+ corroborate
low FP rate

1200+ Kepler
validations



Kepler 4b-7b
announced

2009

2010

2011

2012

2013

2014

2015

2016

Kepler
launch

First public Kepler
candidate catalog

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TDM: automated
validation procedure

700+ multi-KOIs
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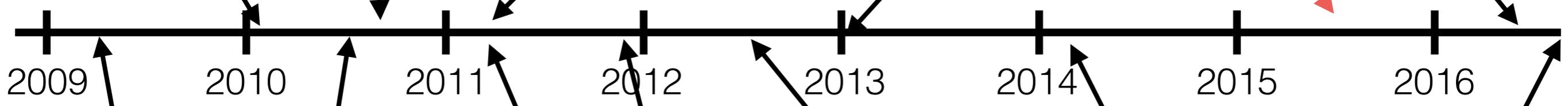
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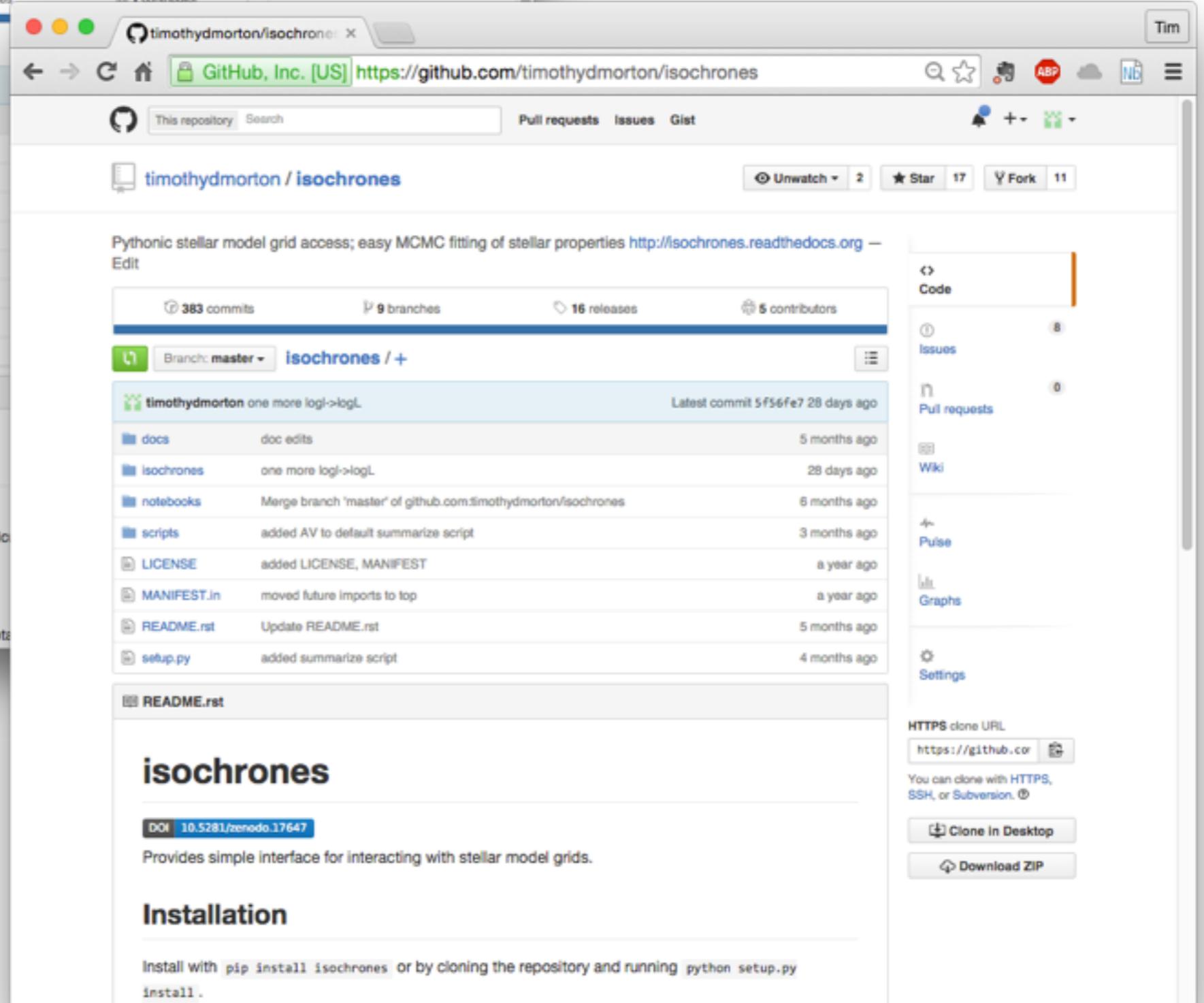
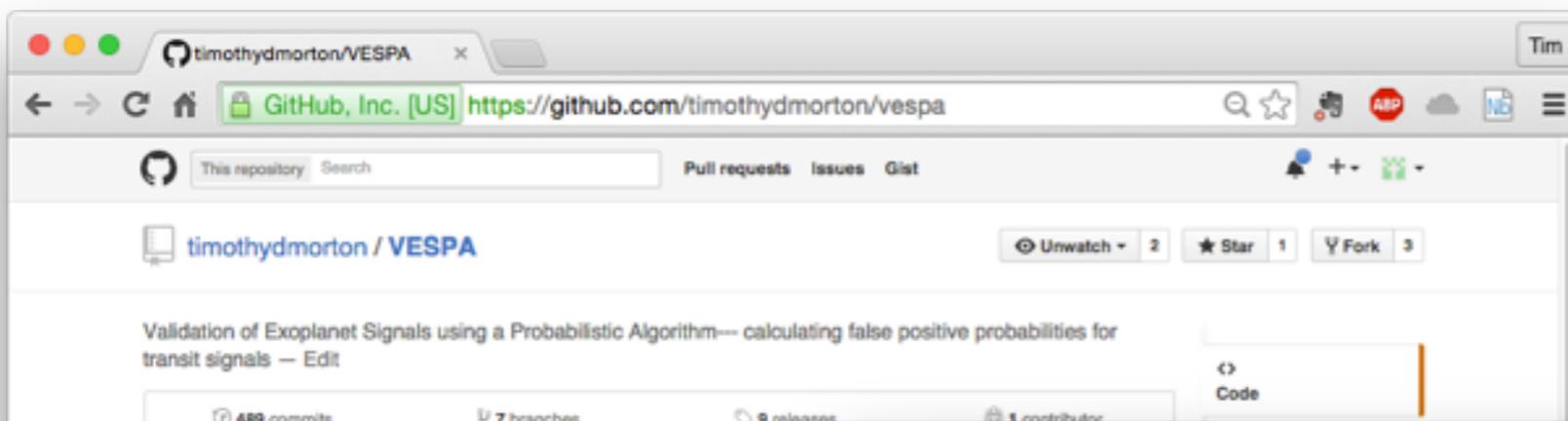
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github.com/timothydmorton

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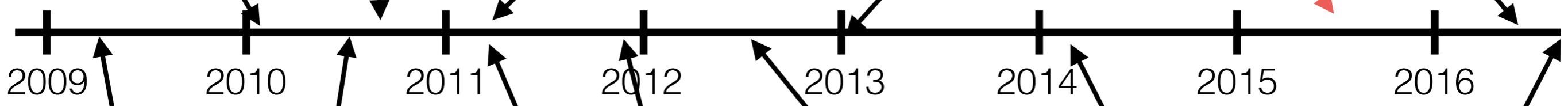
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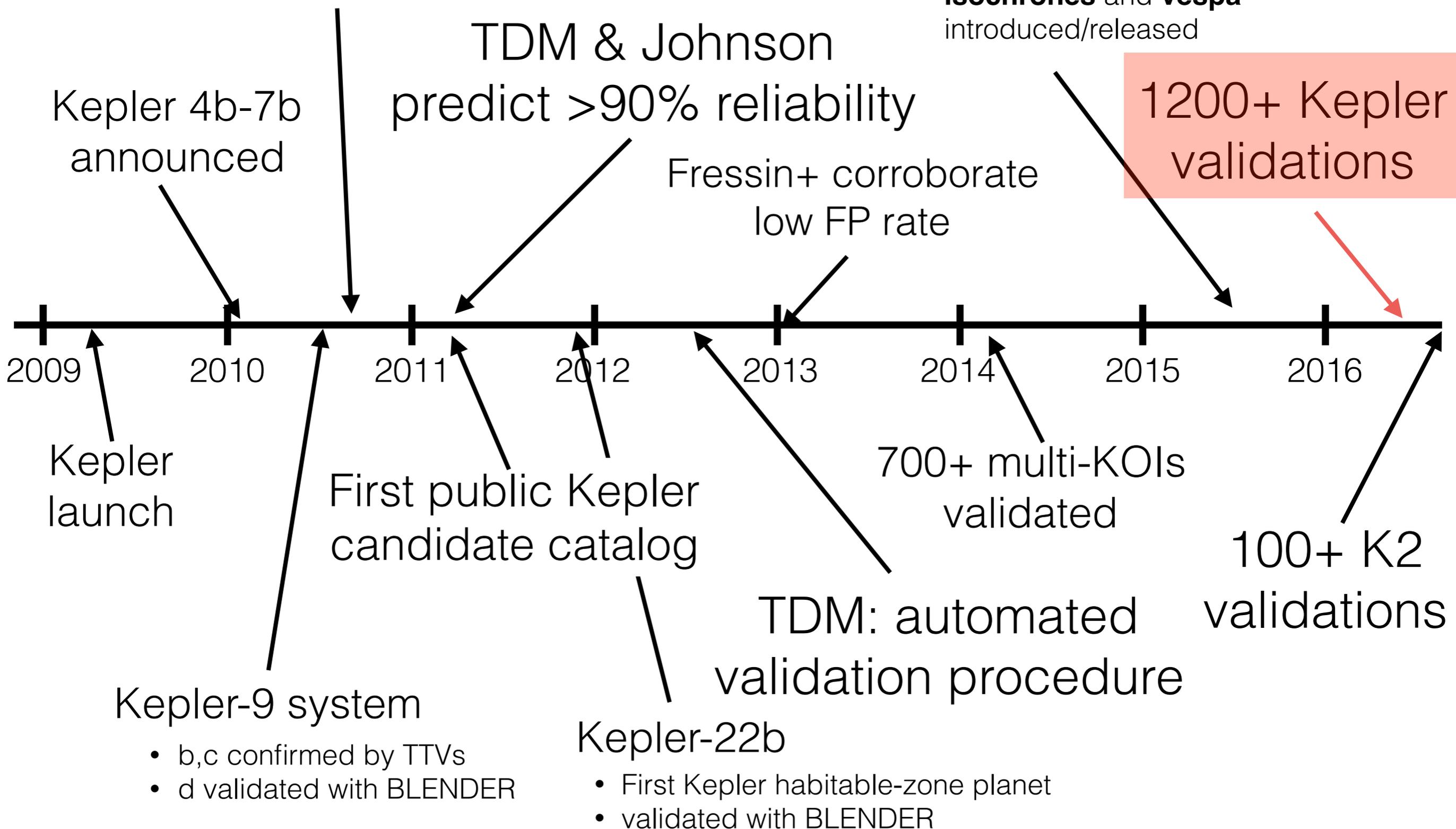
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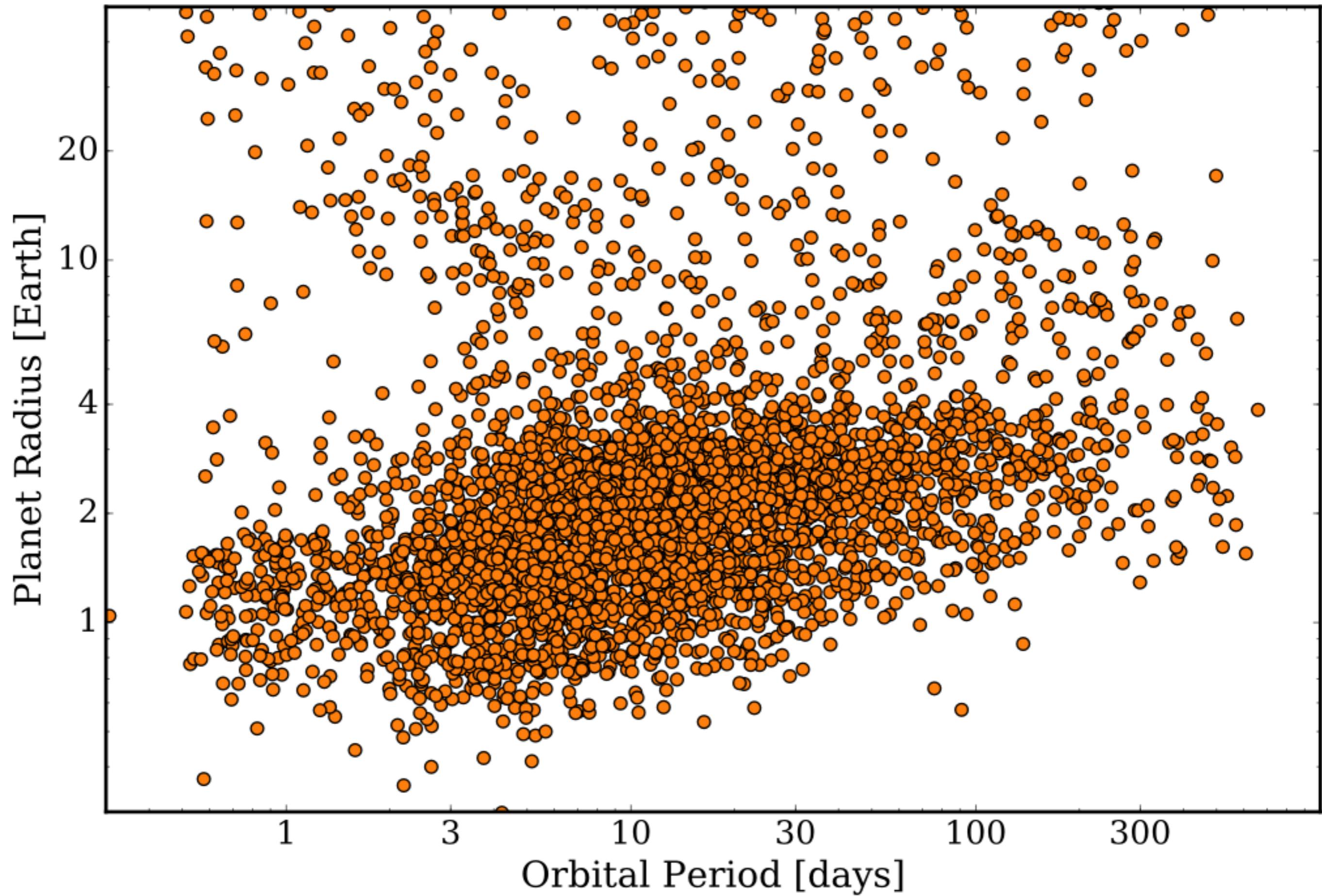
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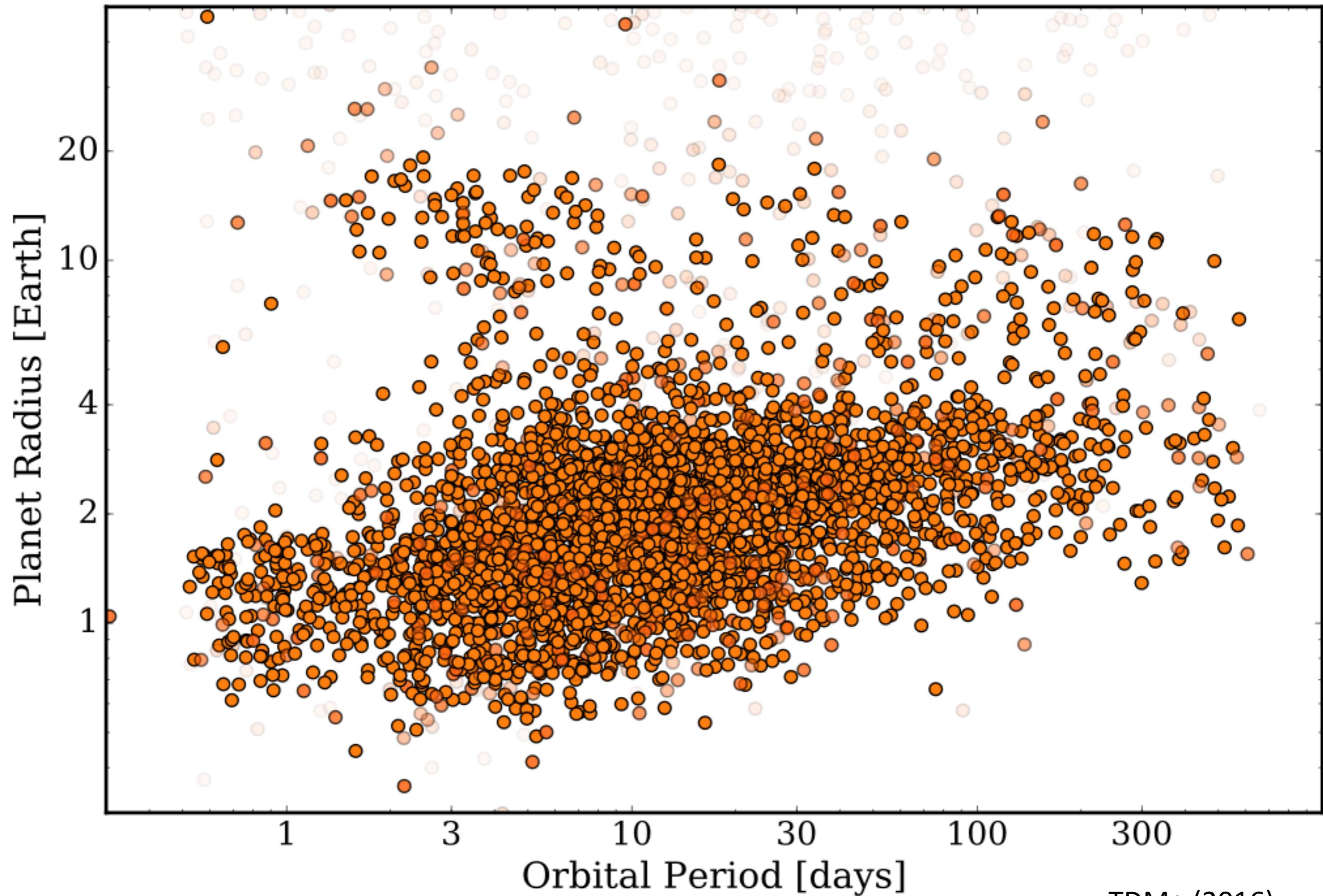
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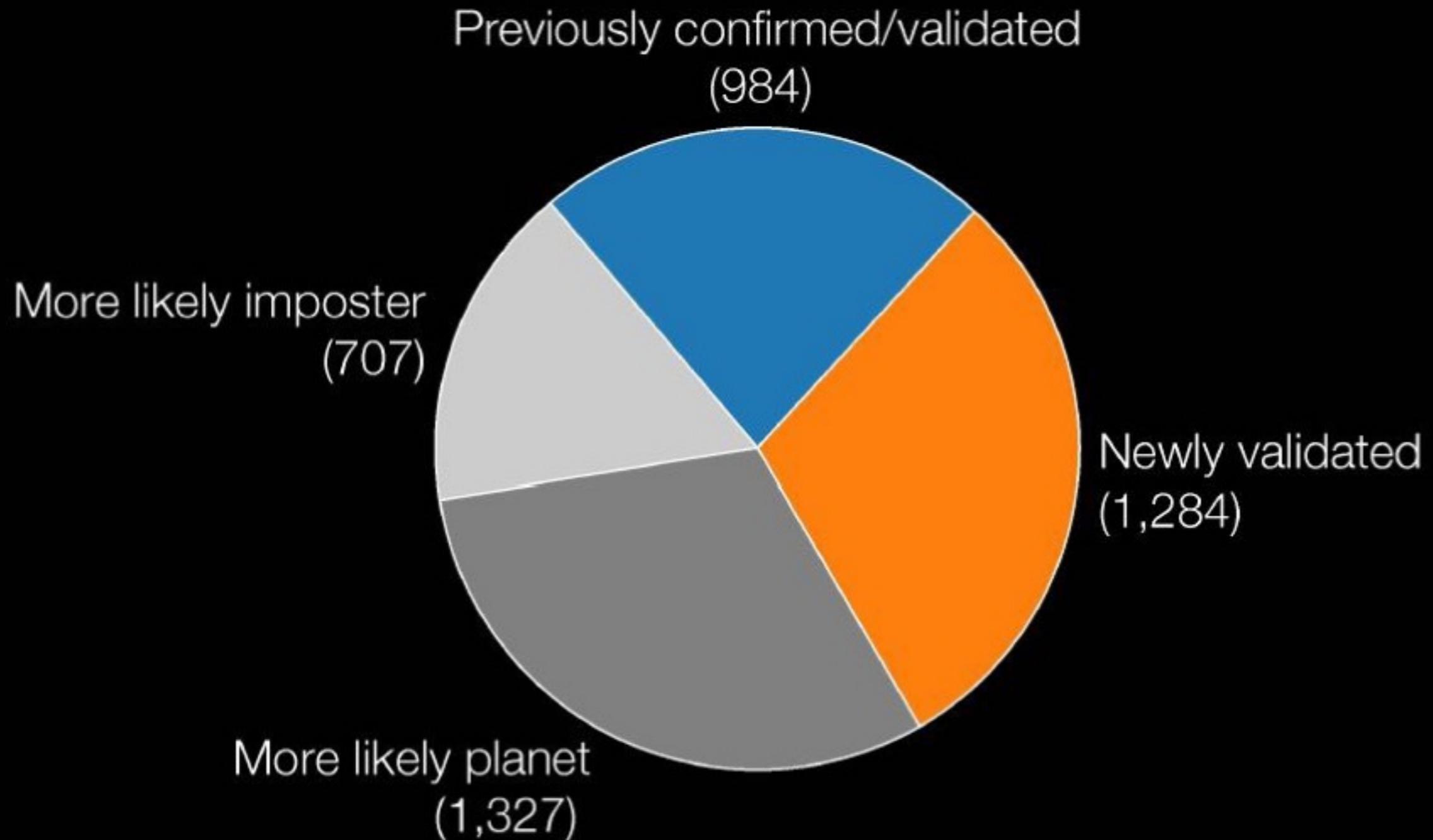






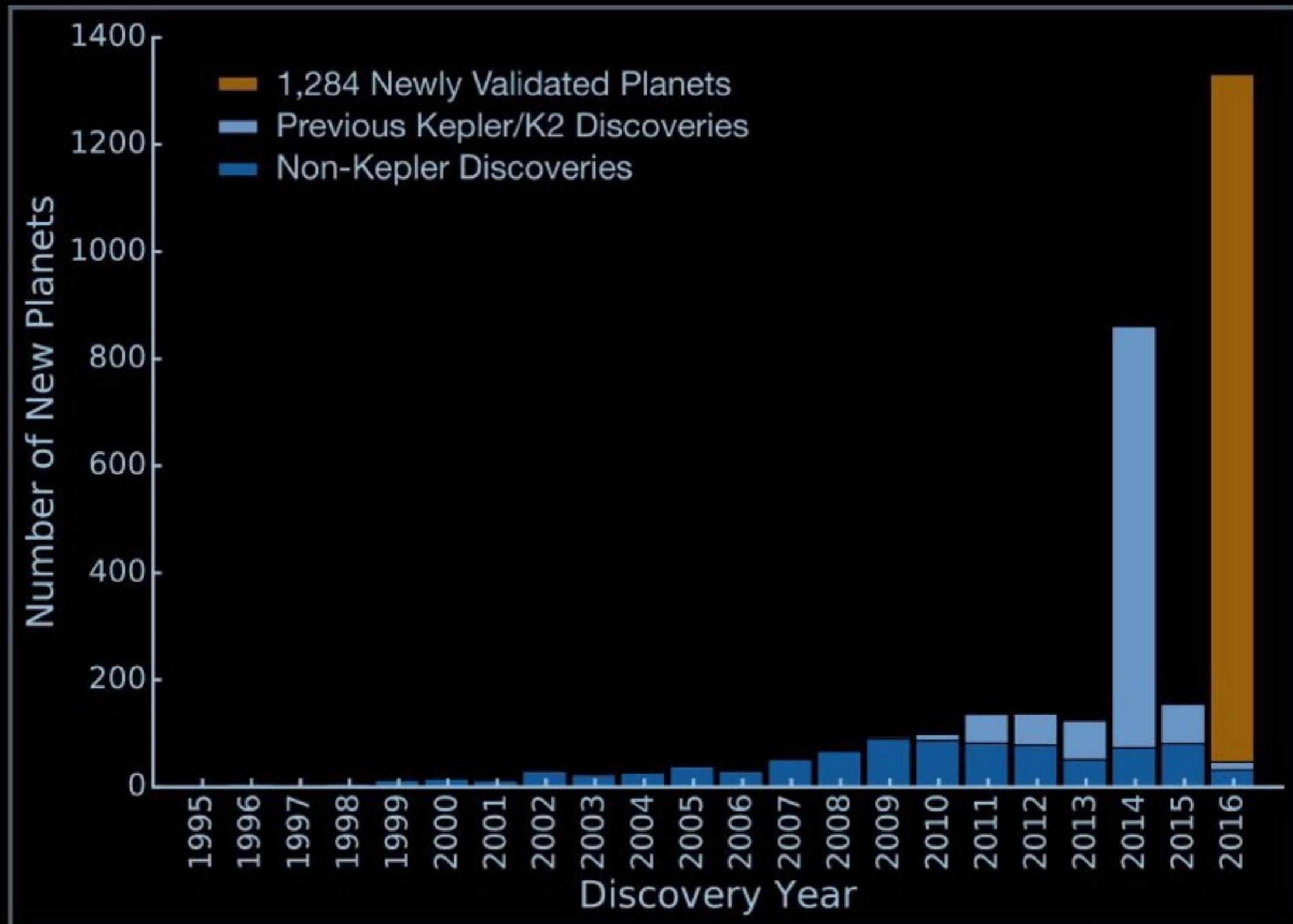
Kepler Candidates

From the DR24 Catalog (2015)



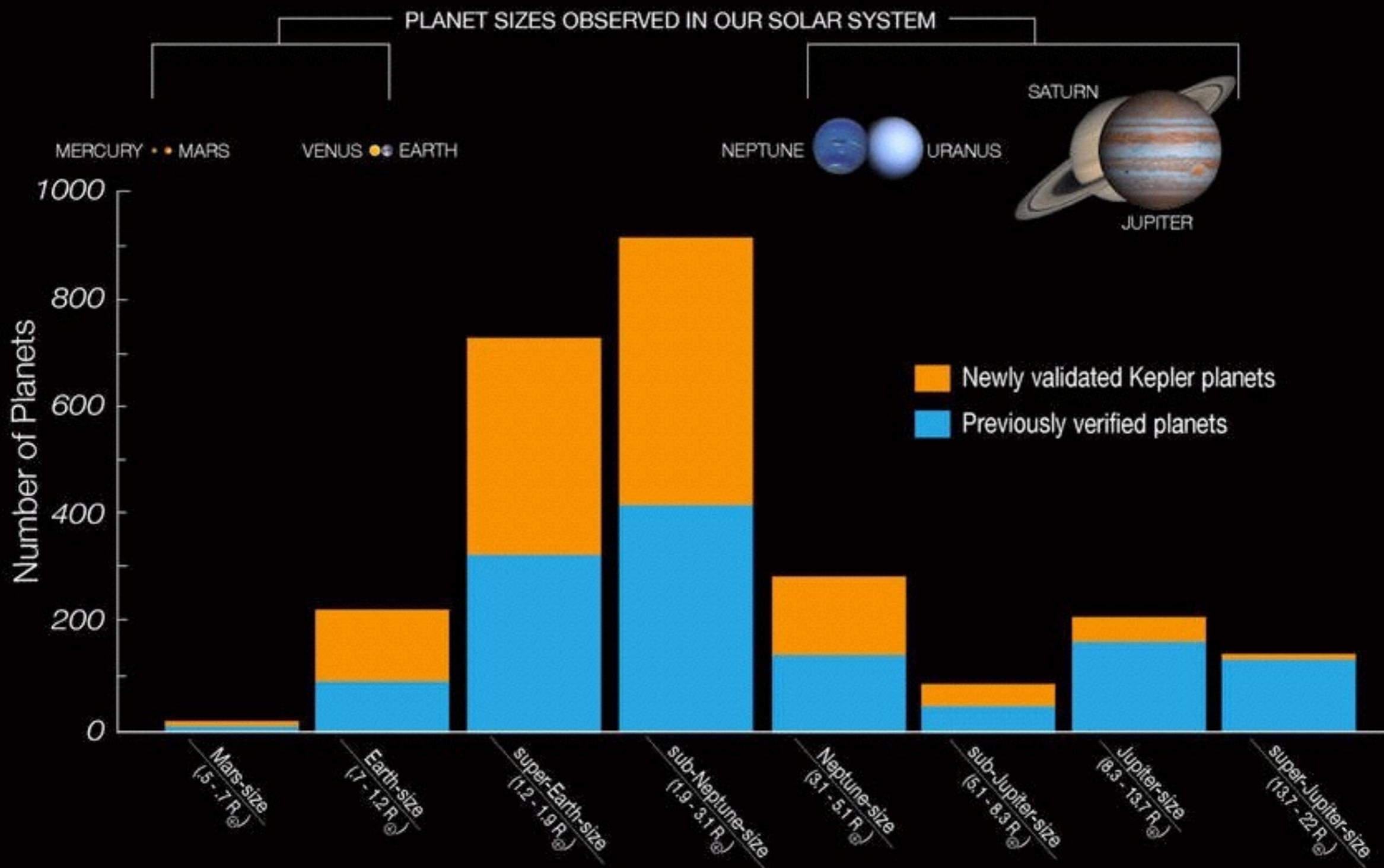
Exoplanet Discoveries Through the Years

As of May 10, 2016



Known Transiting Planets by Size

As of May 10, 2016



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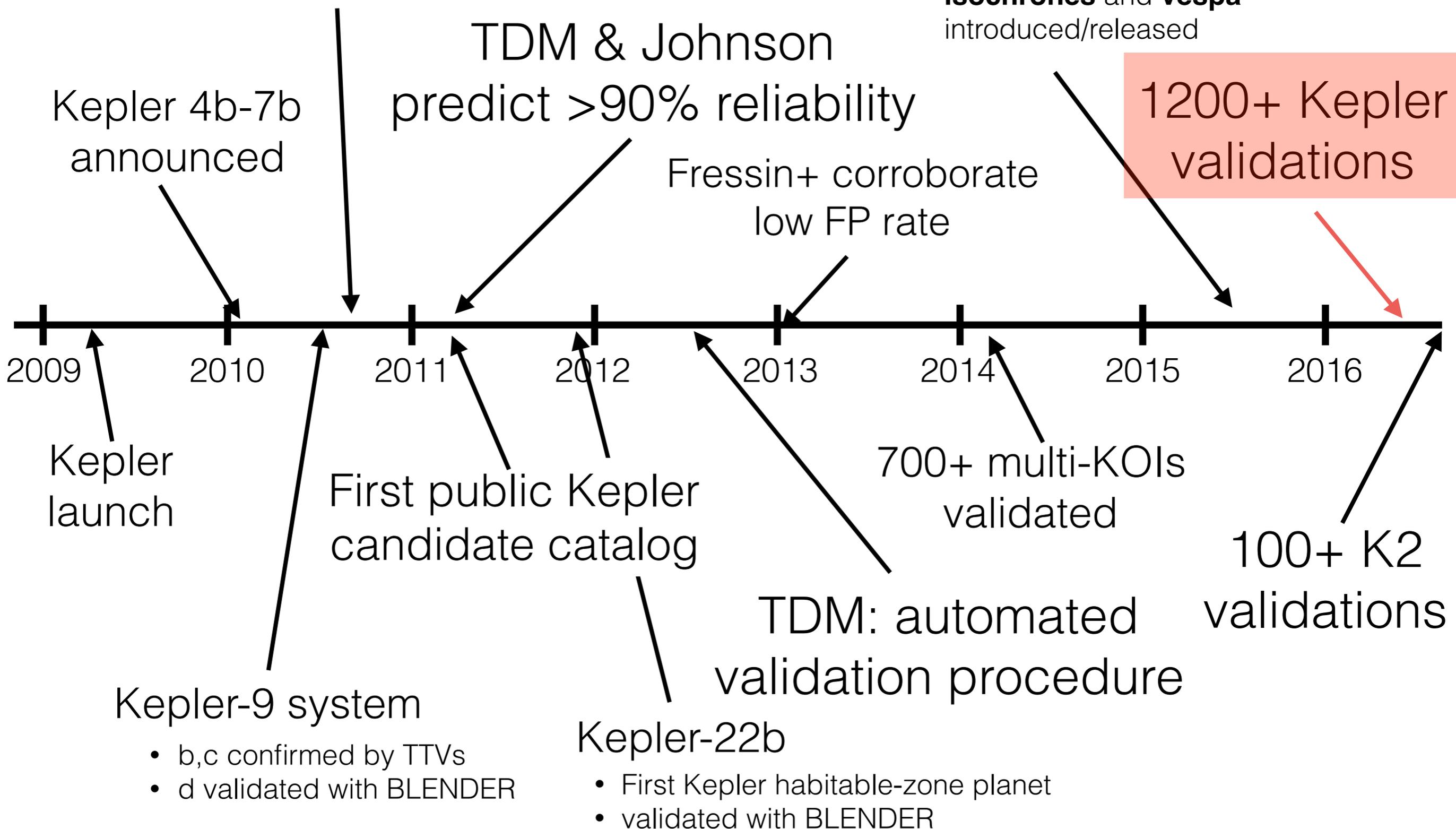
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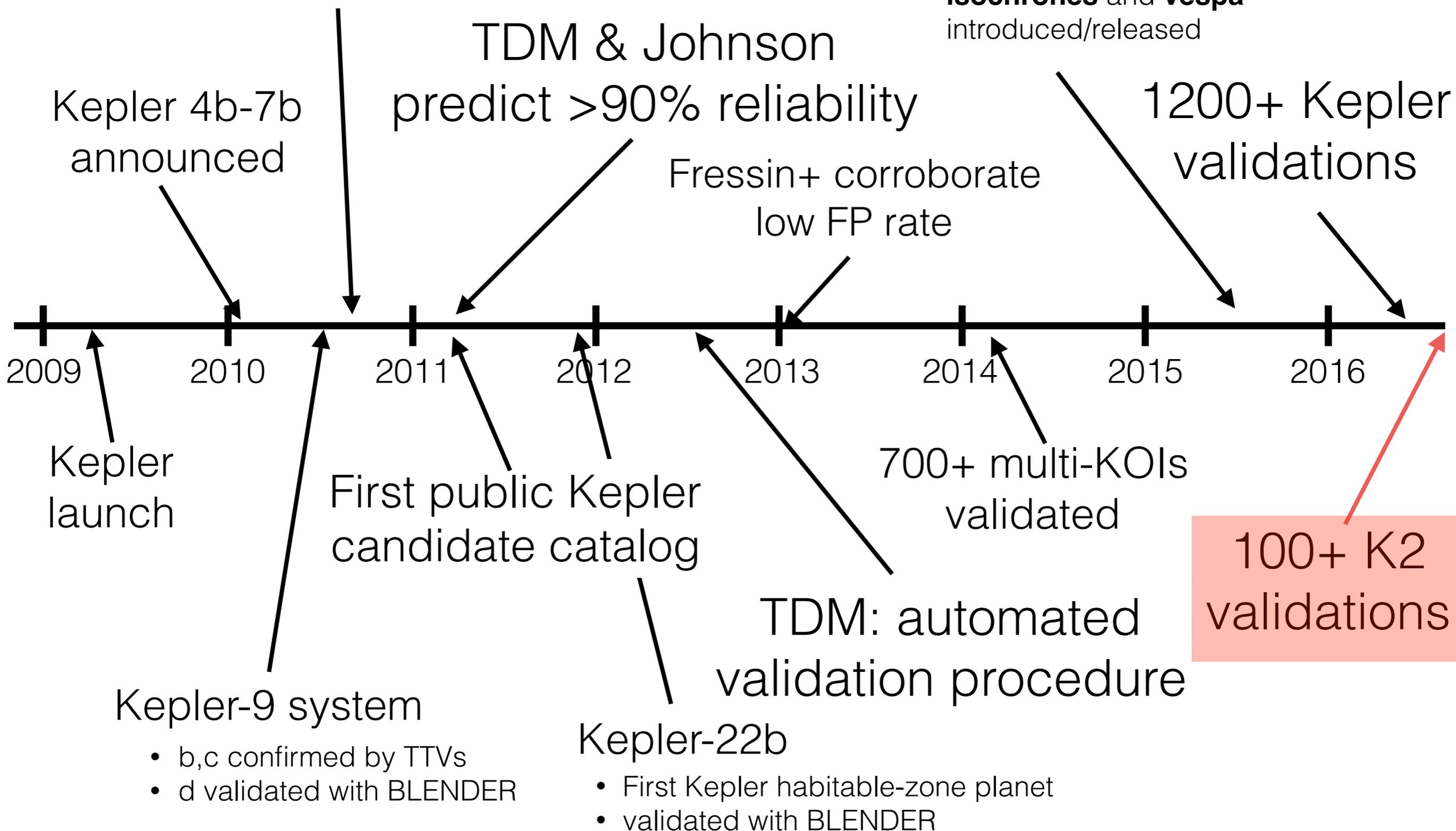
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