Toward a binary probability for every known exoplanet host star :

A statistical framework with Gaia

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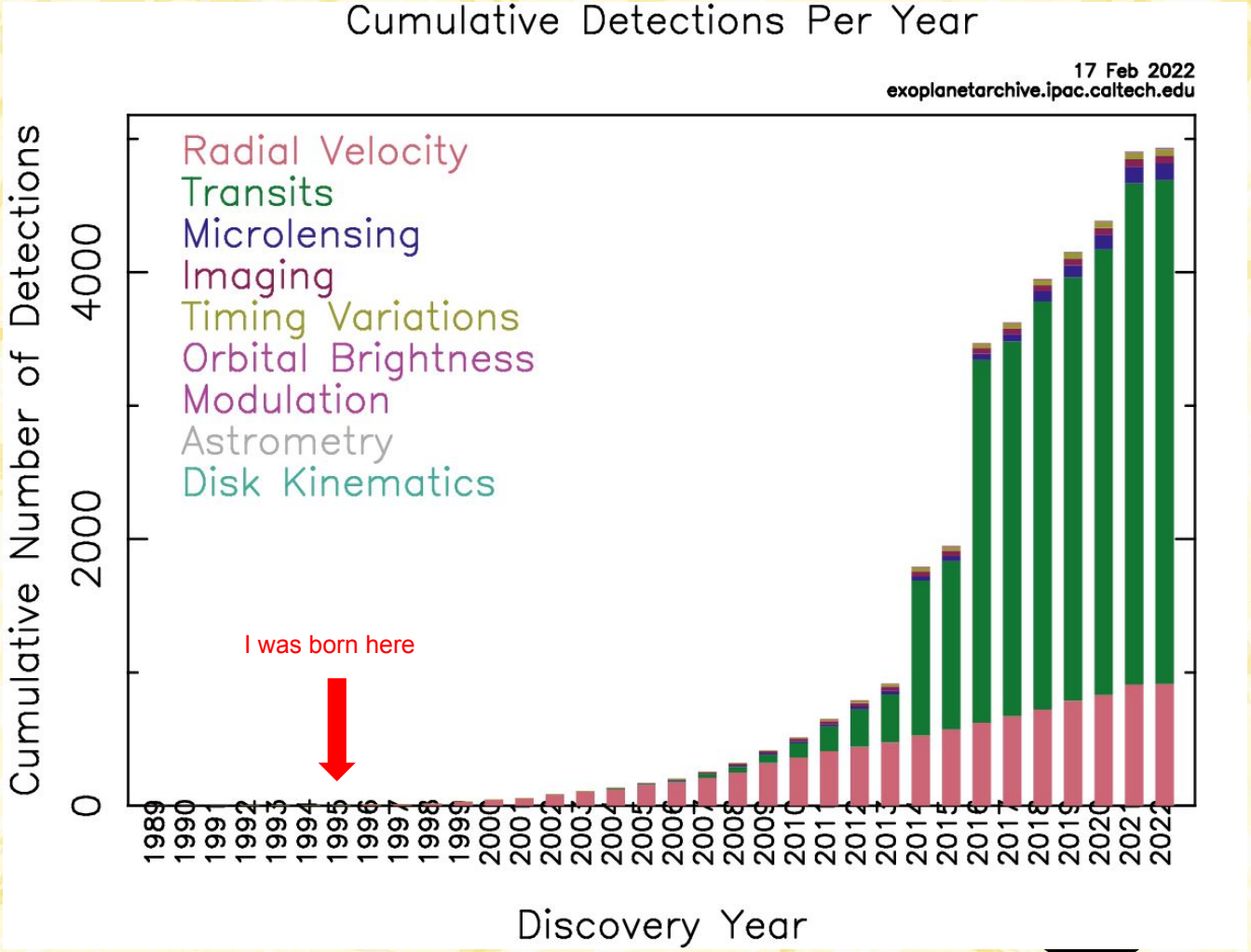
Cumulative Detections Per Year
17 Feb 2022
exoplanetarchive.ipac.caltech.edu
Radial Velocity
Transits
Microlensing
Imaging
Timing Variations
Orbital Brightness Modulation
Astrometry
Disk Kinematics
I was born here
Cumulative Number of Detections
0
2000
4000
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
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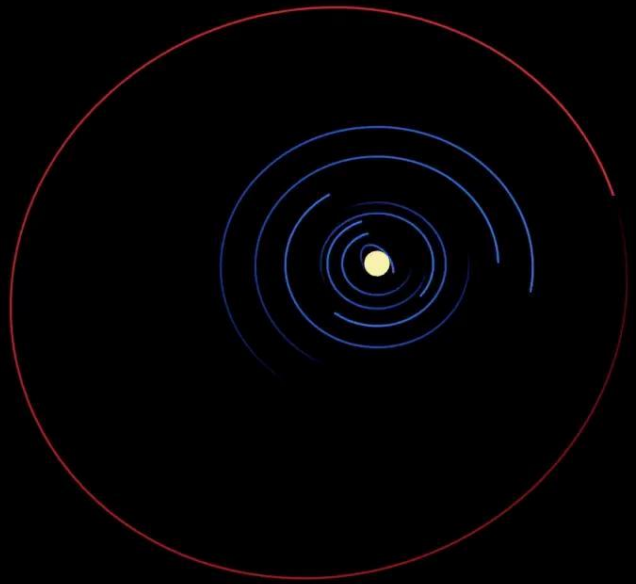
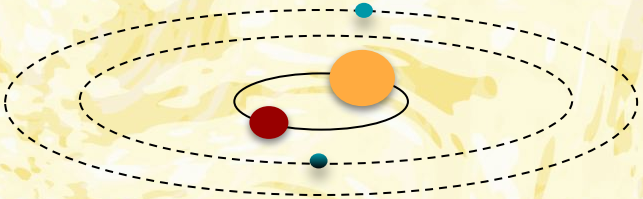
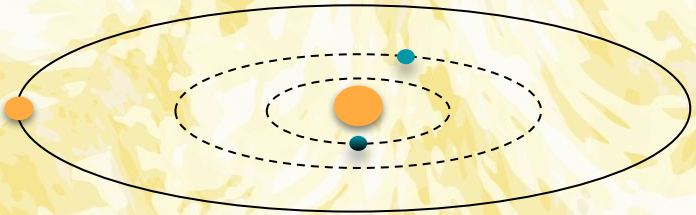
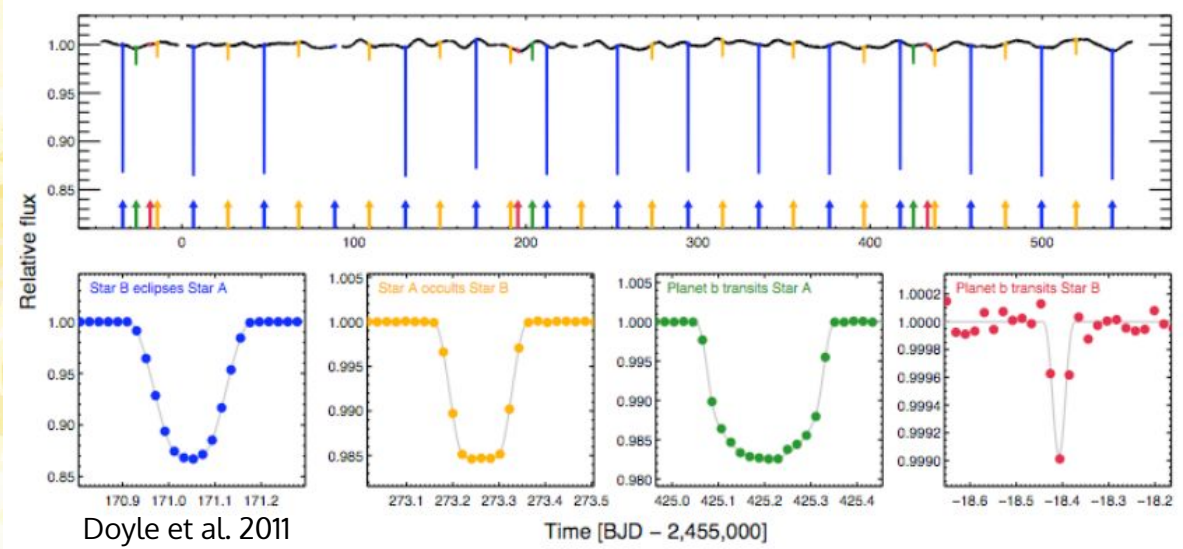
2015
2016
2017
2018
2019
2020
2021
2022
Discovery Year



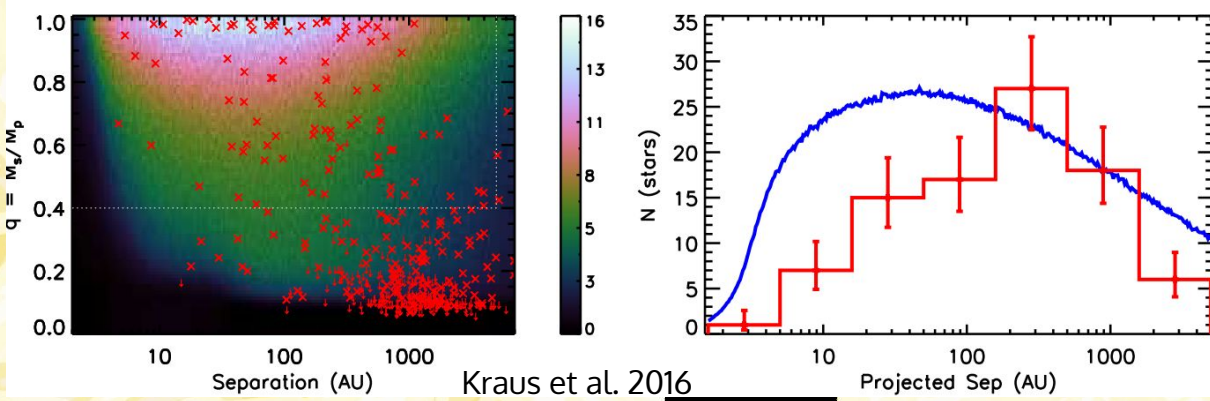
Introduction





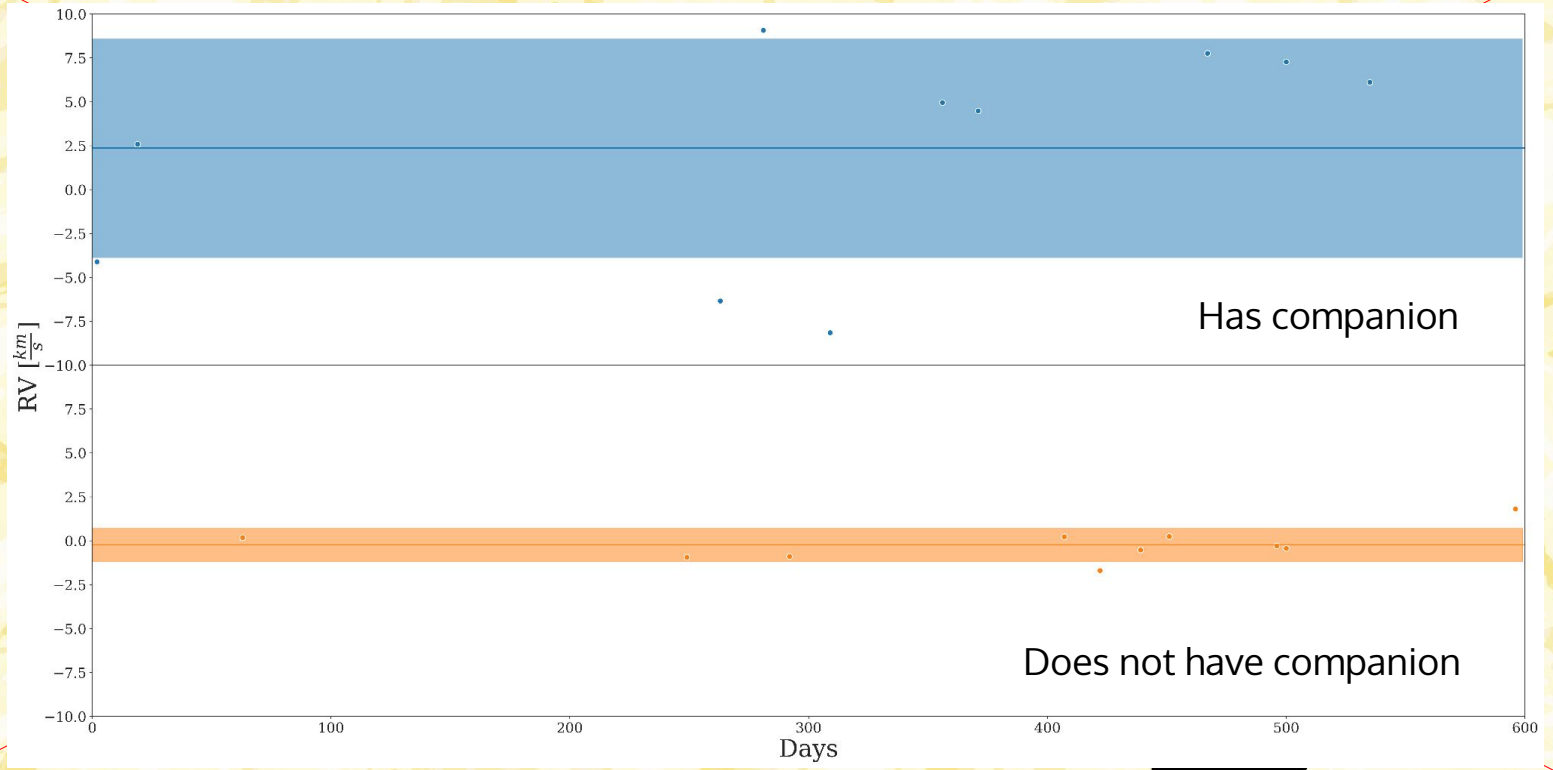


Doyle et al. 2011

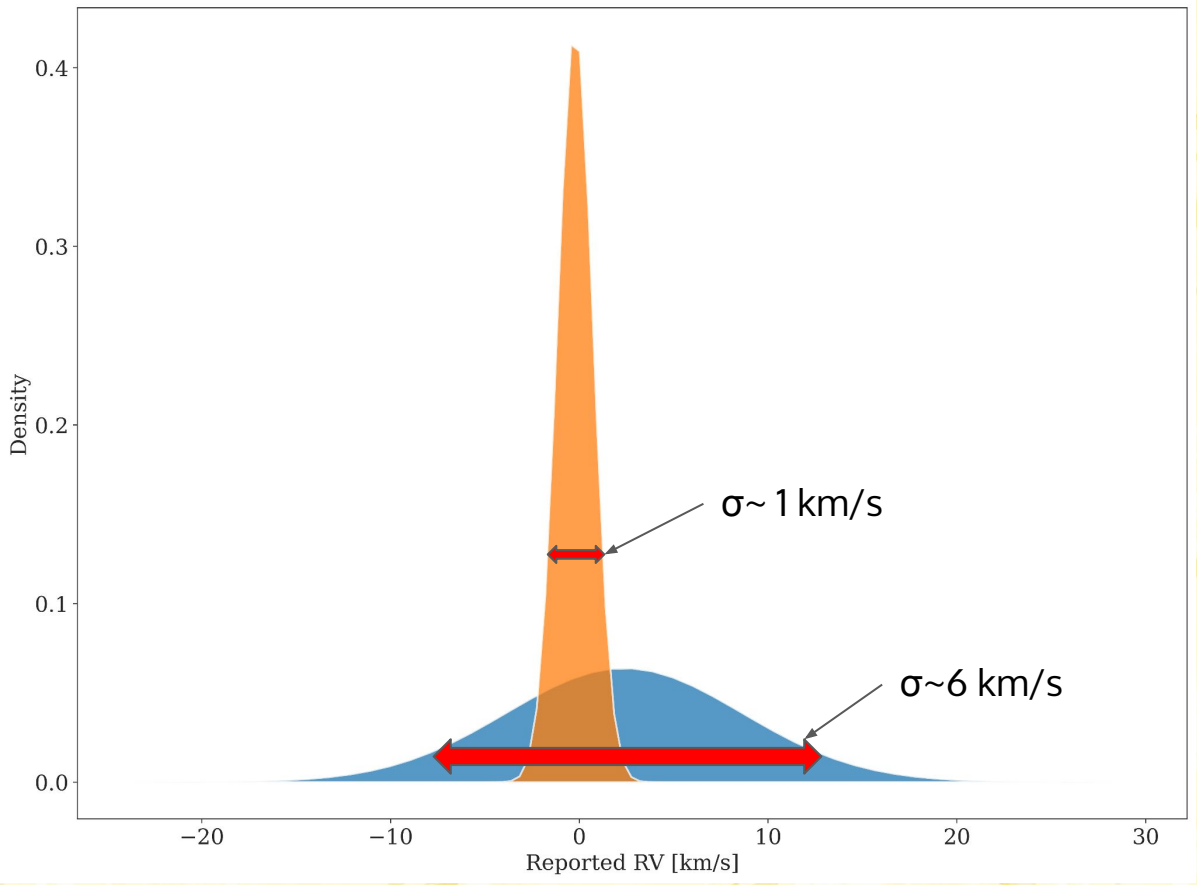


Kraus et al. 2016

How to find unresolved binaries with Gaia

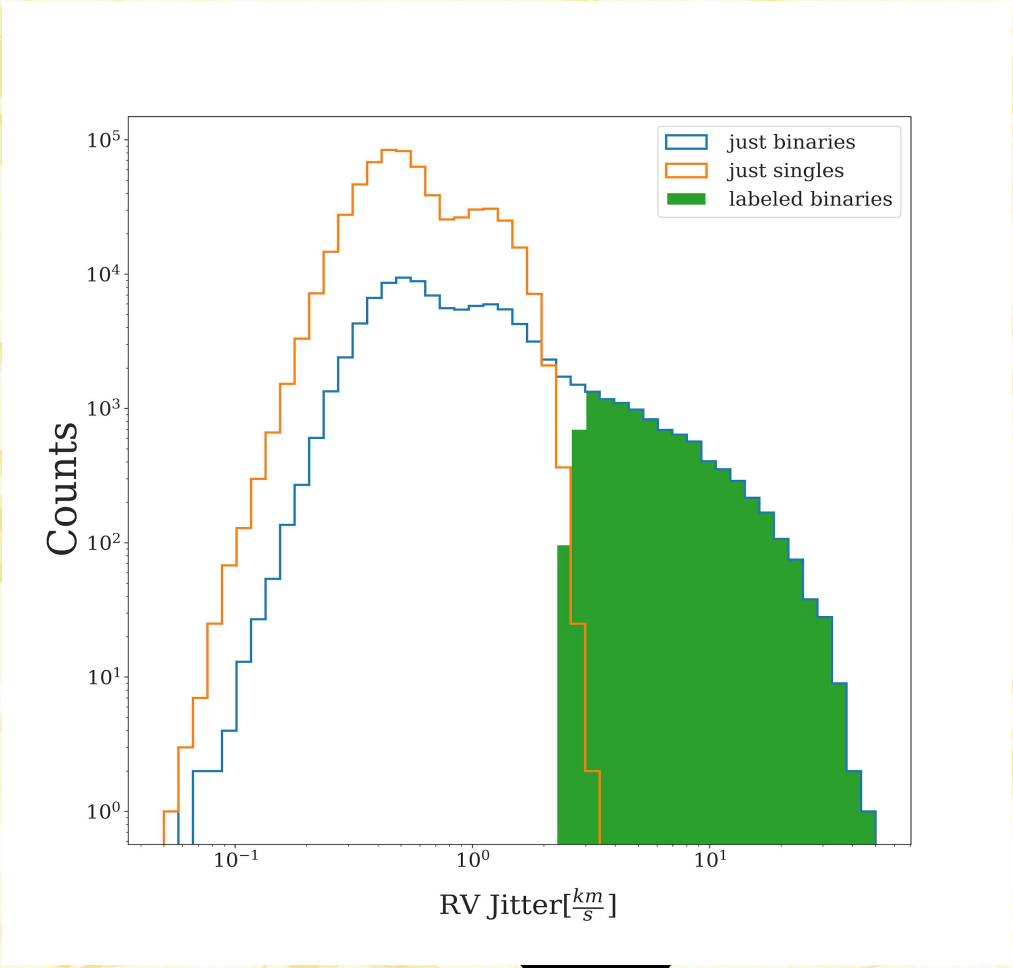


How to find unresolved binaries with Gaia

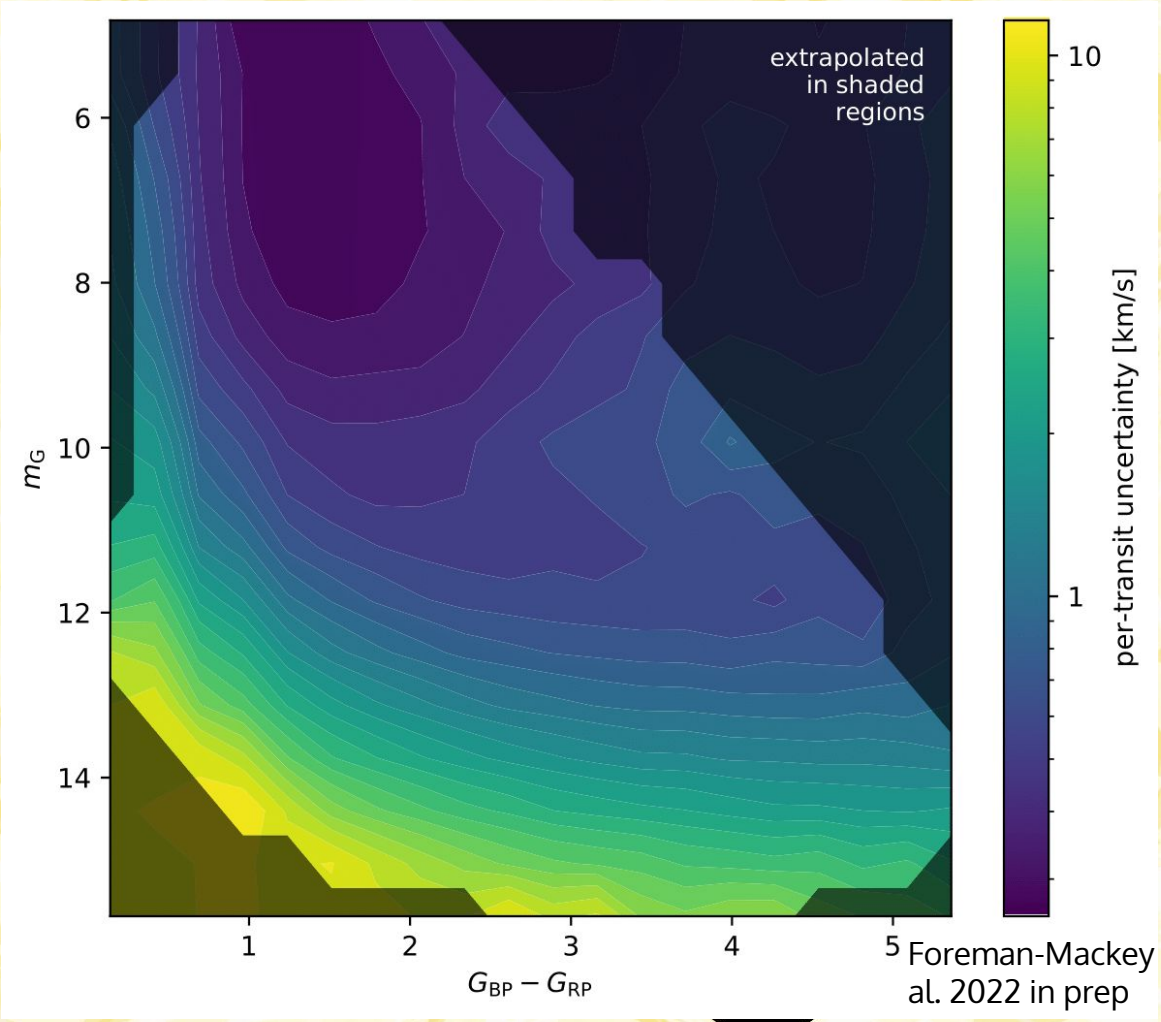


How to find unresolved binaries with Gaia

- There is some distribution of RV noise. Some of it is **intrinsic** to the star and some of it is created by **companions**
- We assume stars that are close in **color**, **magnitude,** and **sky position** have **similar** RV error bars; therefore have a similar classification model.
- We can **identify** stars that are in the long **tail** of the RV jitter distribution in each bin.



Does this model work?



Foreman-Mackey et al. 2022 in prep

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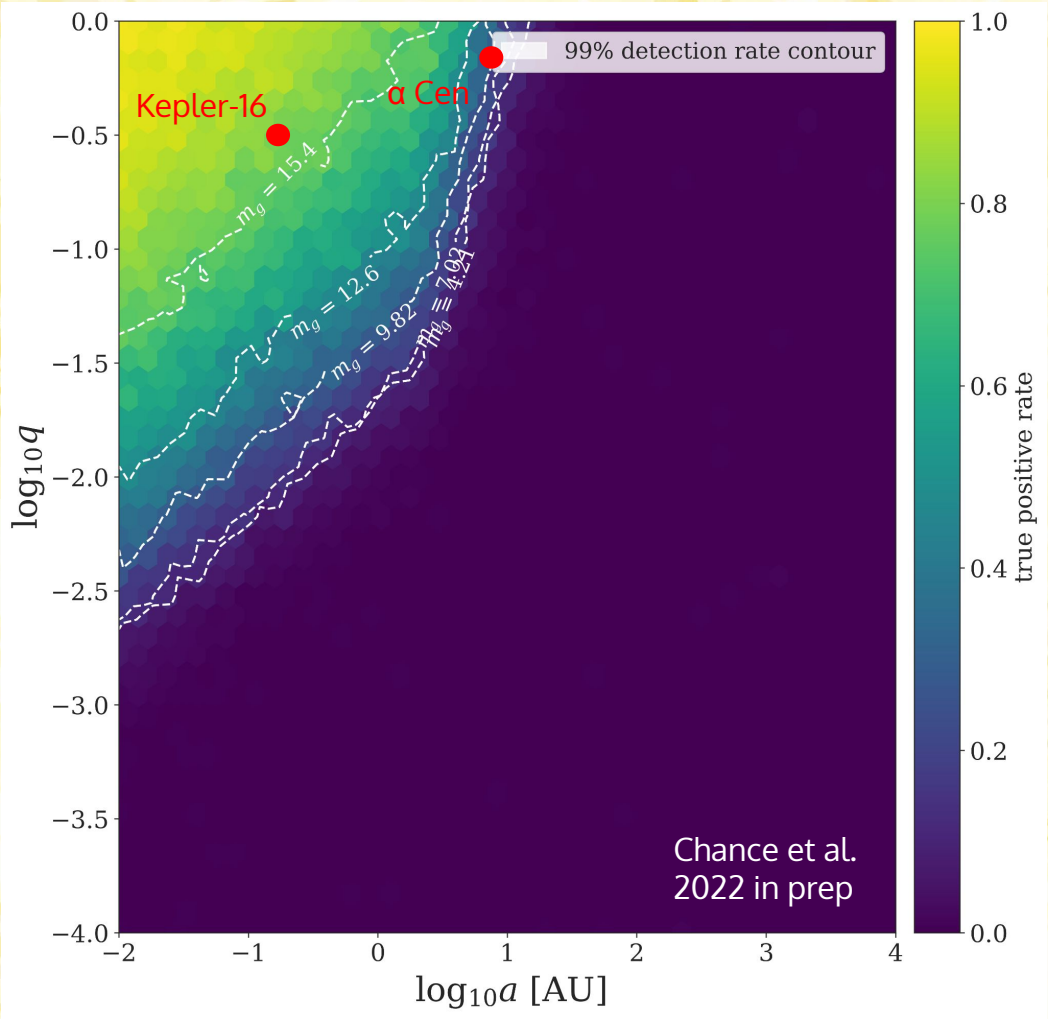

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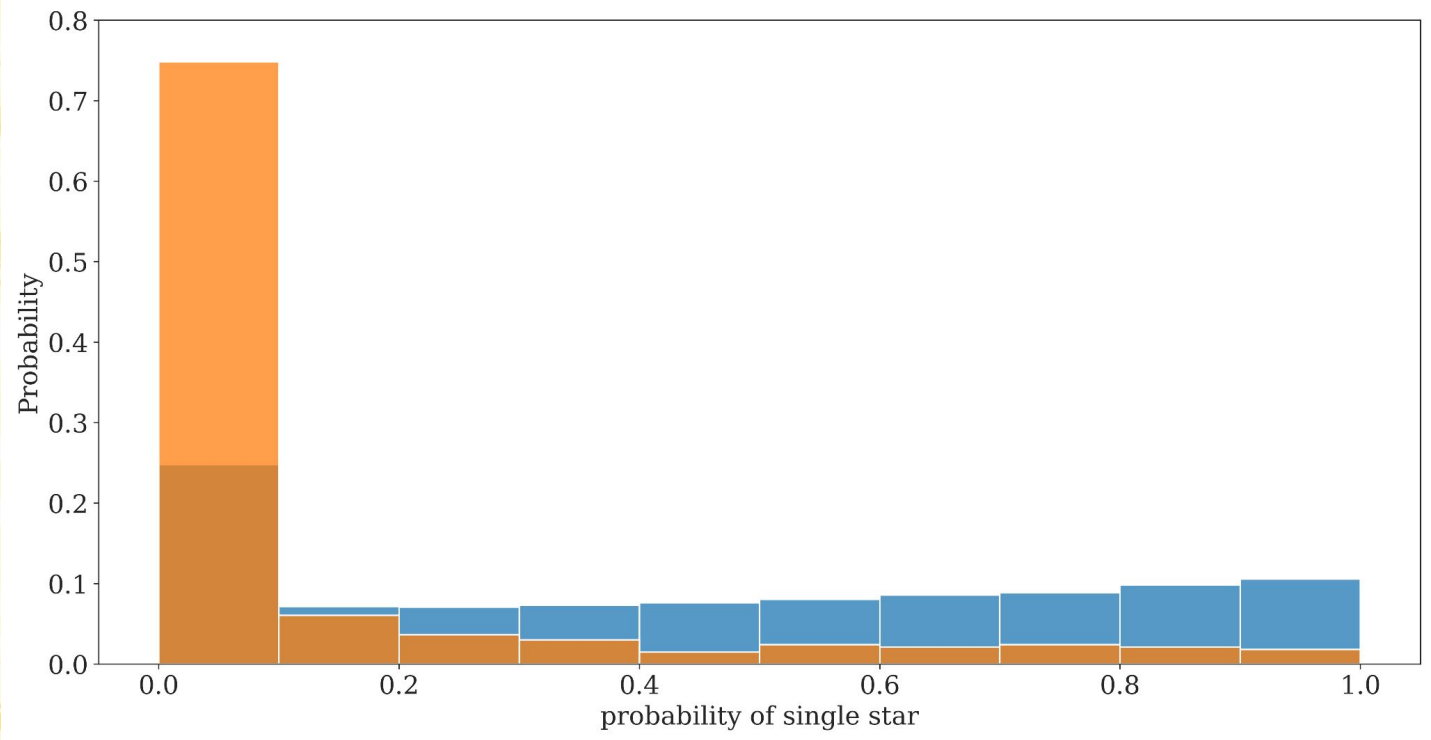

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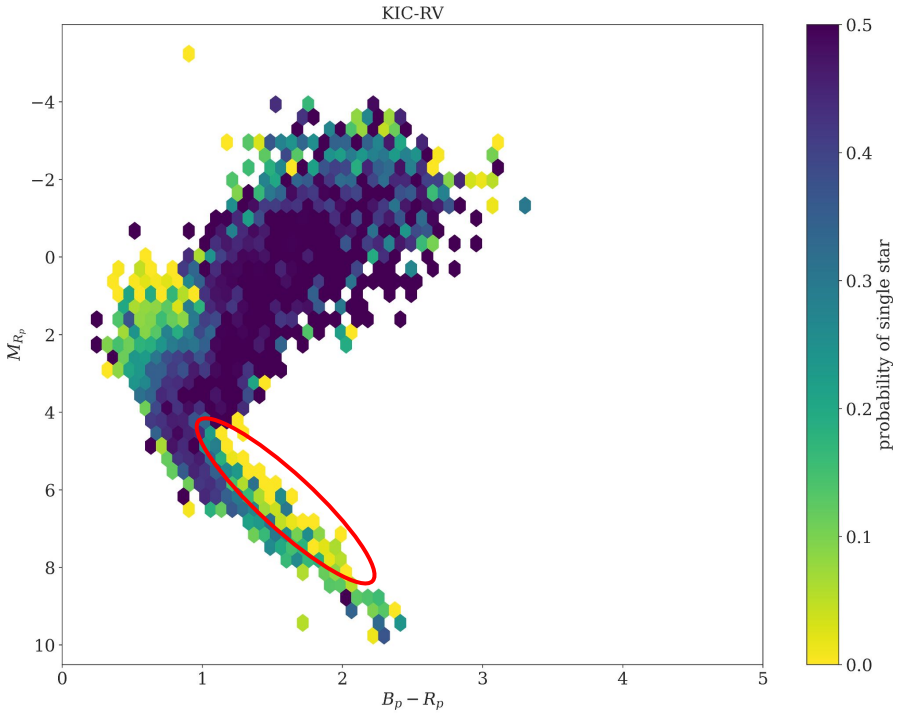
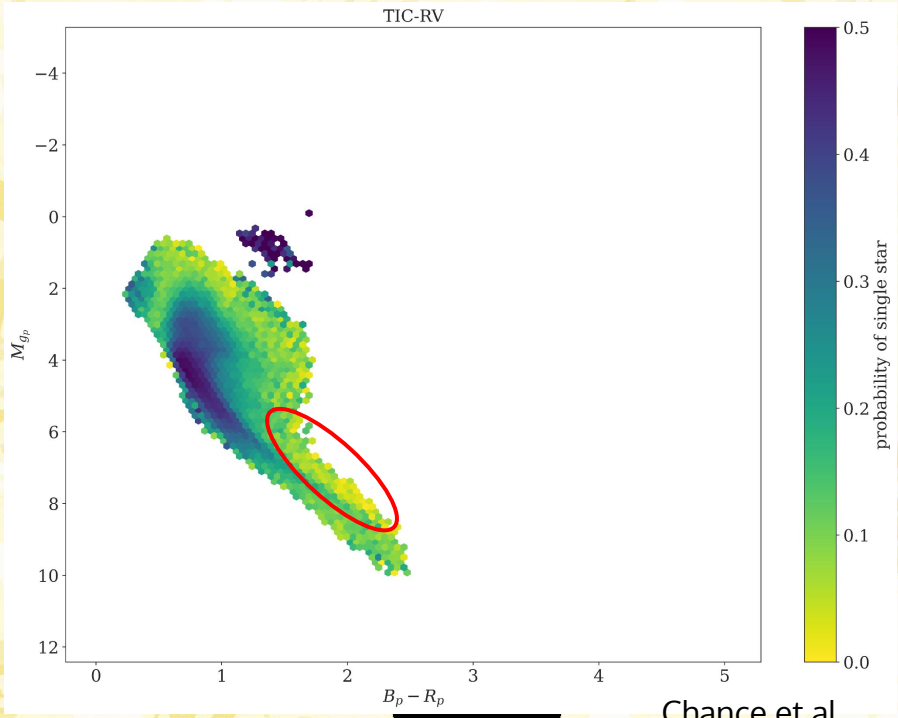
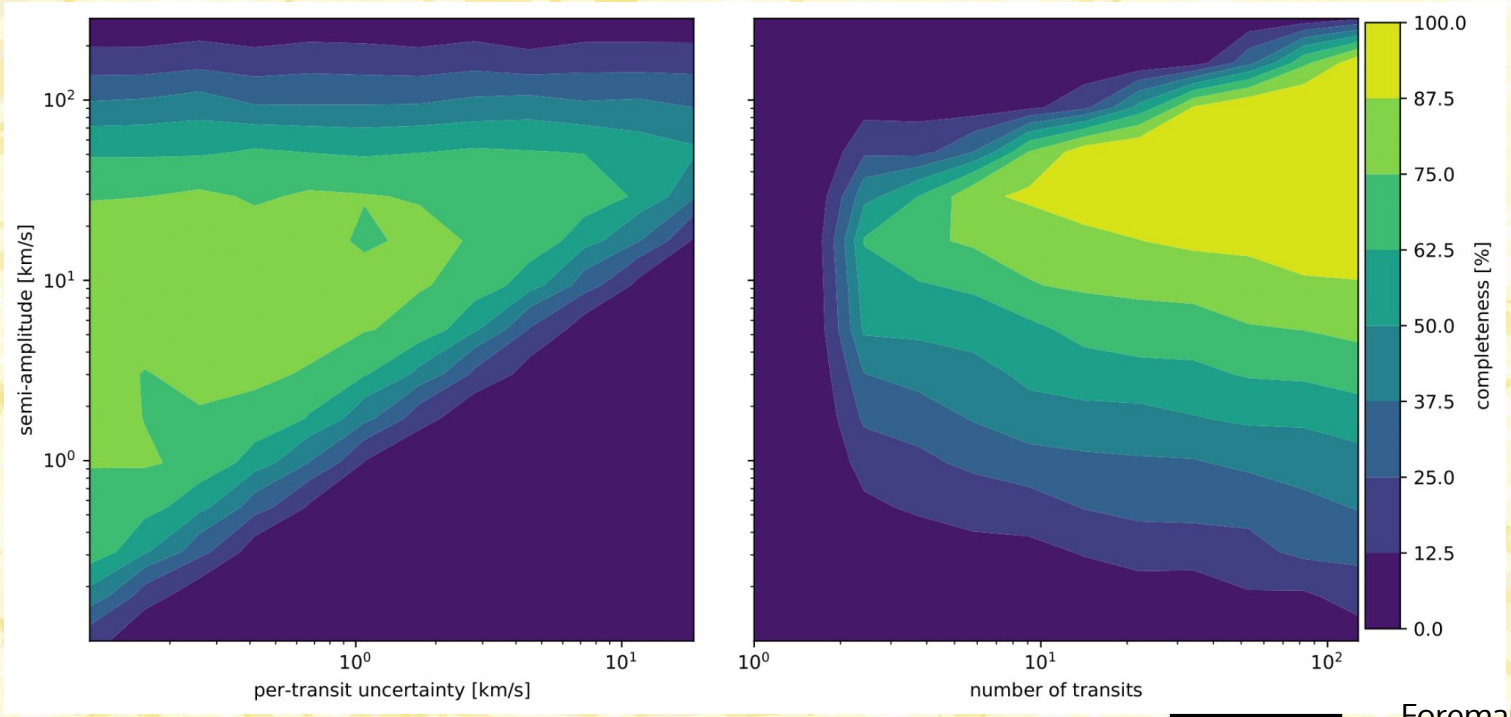




Chance et al. 2022 in prep

What else can we do?



Foreman-Mackey et al. 2022 in prep

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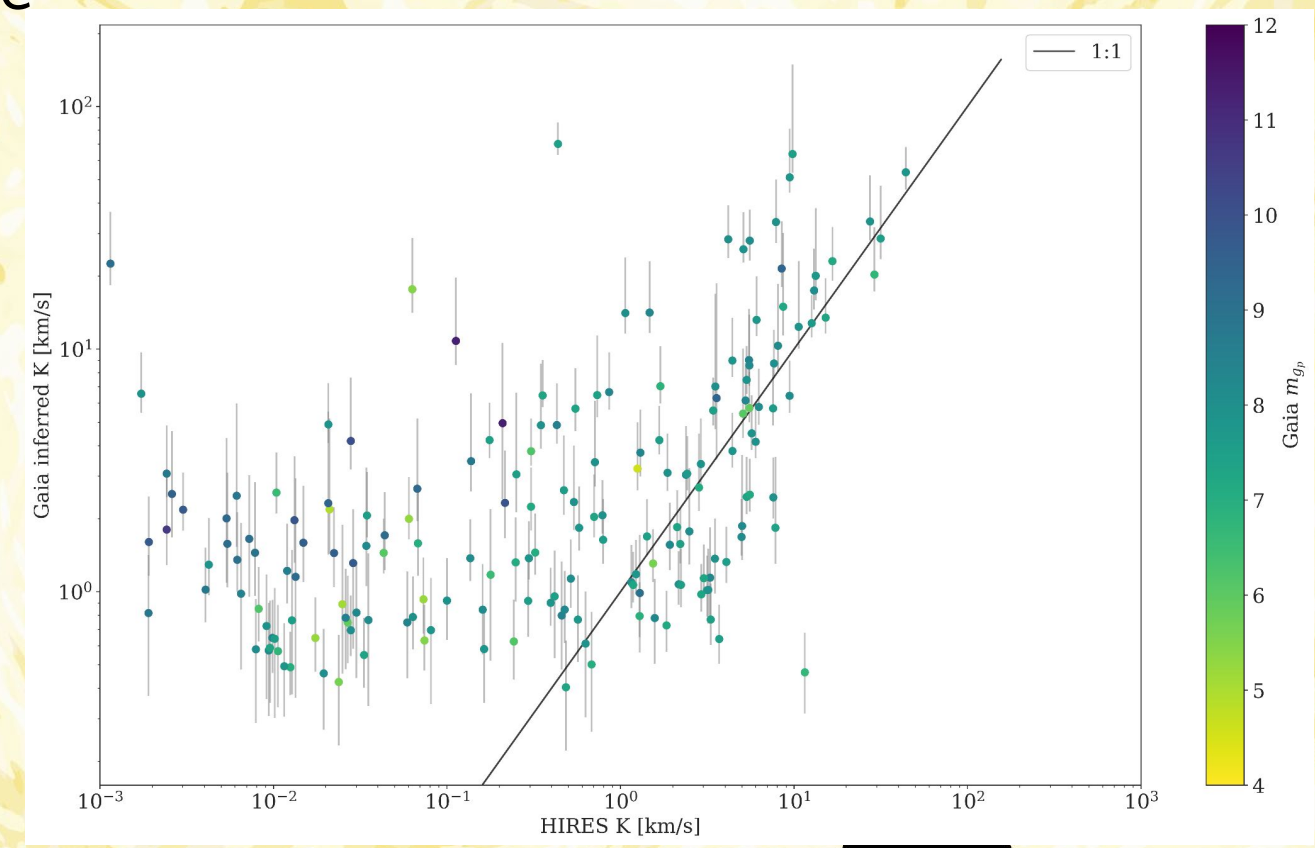
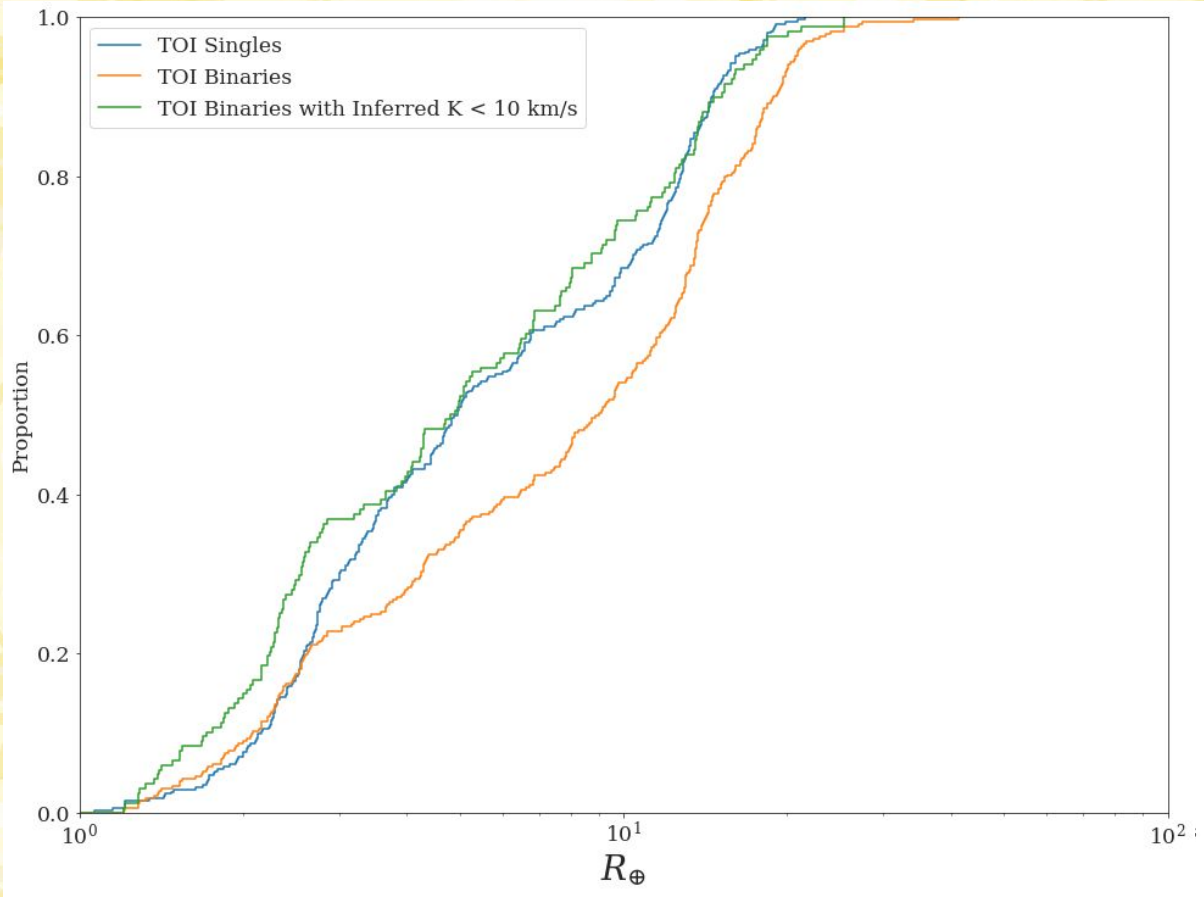


Chance et al. 2022 in prep

How can this be useful?

- False-positive identification
- Occurrence rates for planets in binaries
- Investigating outliers

What can we use this for?



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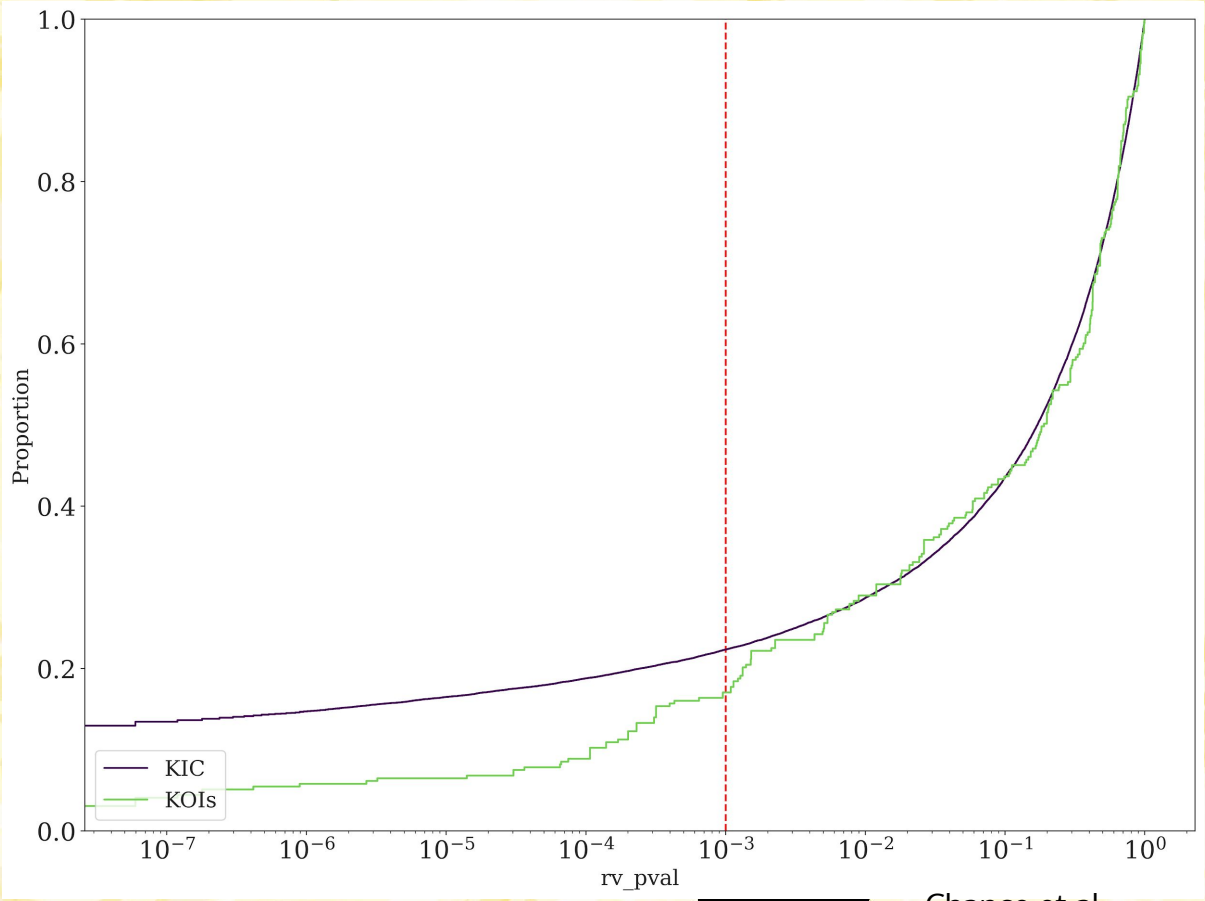

Chance et al. 2022 in prep

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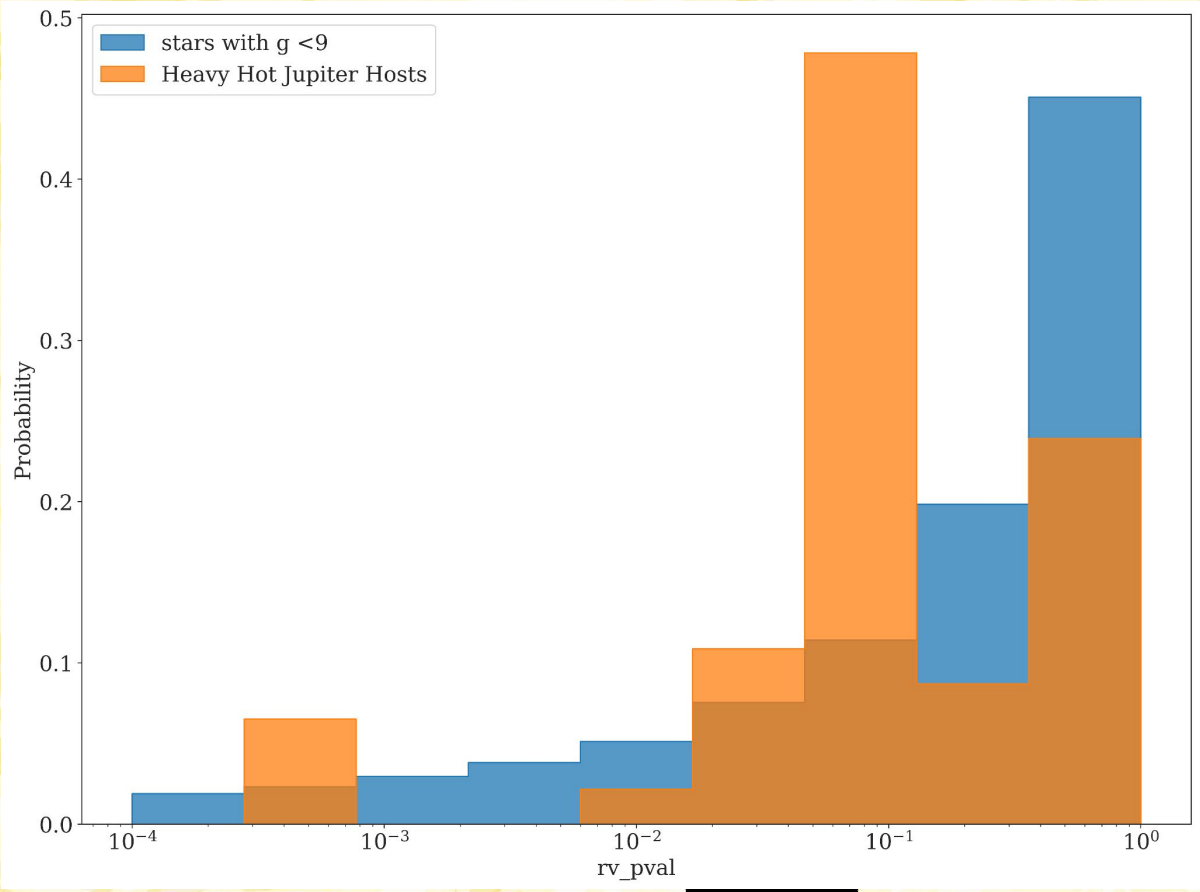
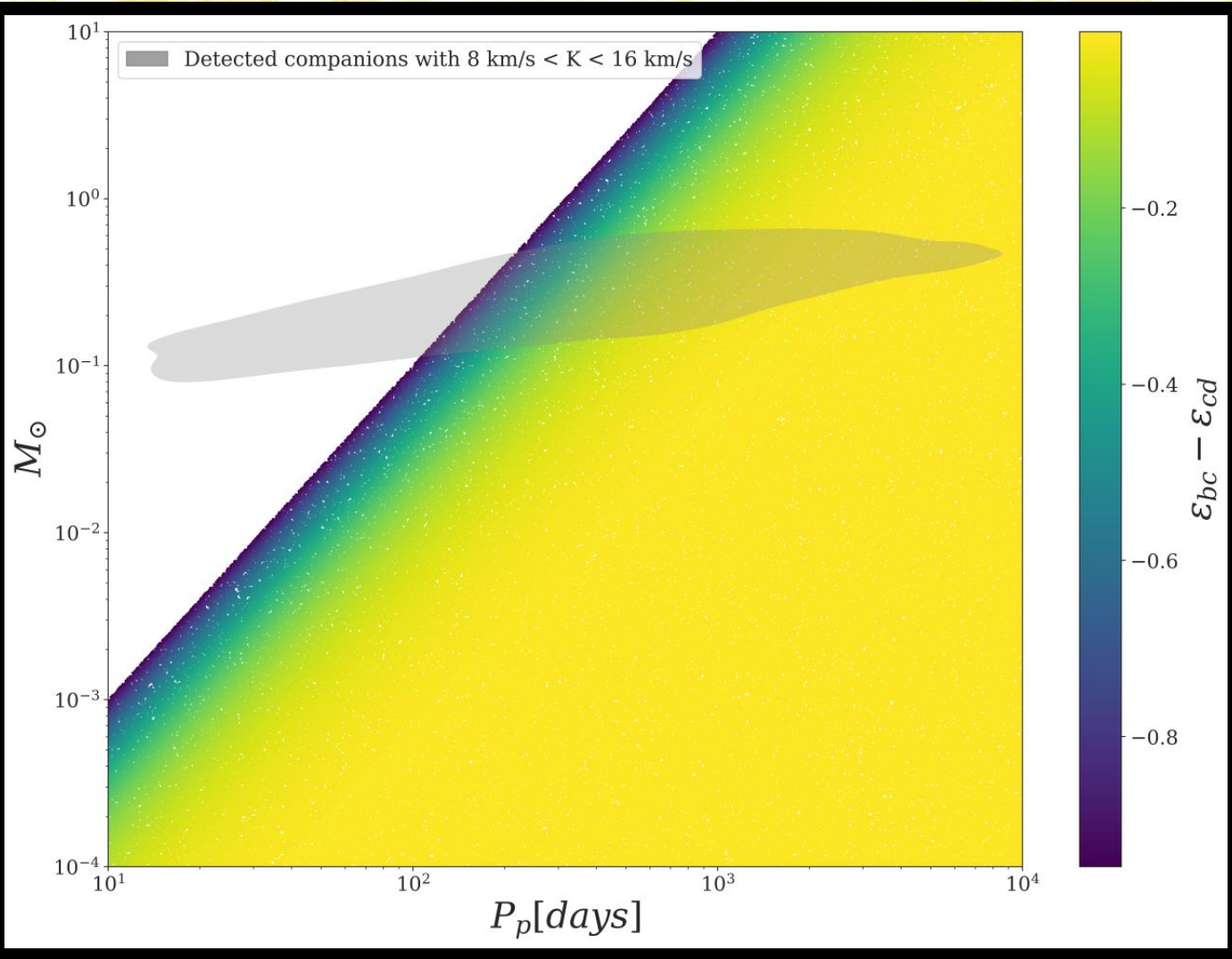


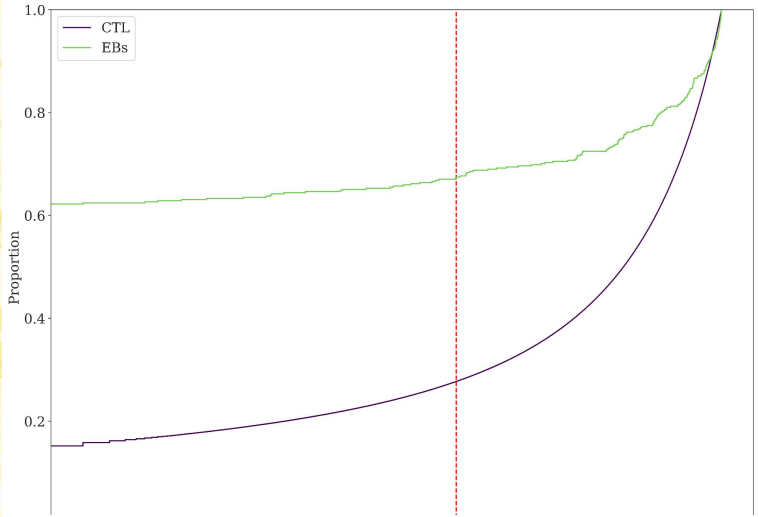

Detected companions with 8 km/s < K < 16 km/s
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
$M_{\odot}$
10^{1}
10^{2}
10^{3}
10^{4}
$P_p[days]$
−0.2
−0.4
−0.6
−0.8
$\varepsilon_{bc} - \varepsilon_{cd}$

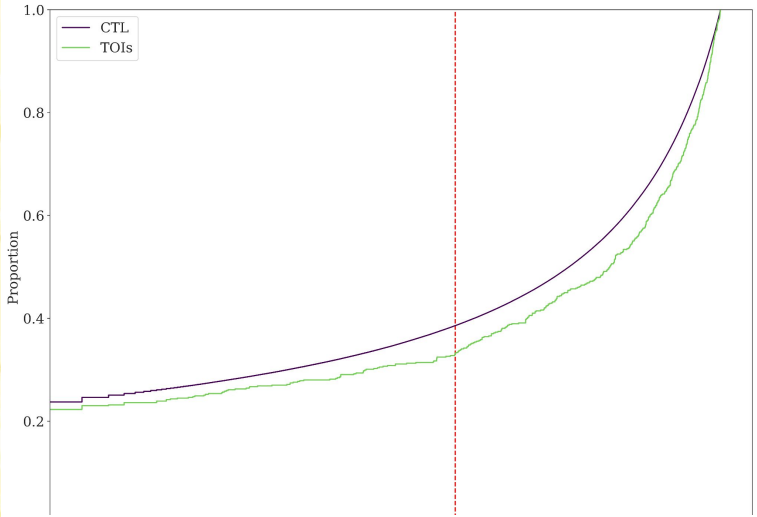
Takeaways

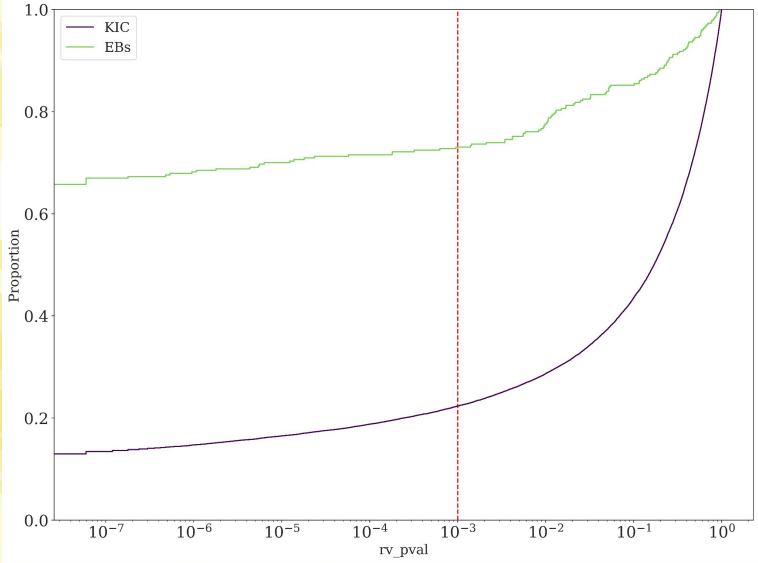
- Although the full RV curves are not available from Gaia, there is still plenty of **information** contained in the median and error that is reported
- This information is available for ~ **6.5 million** stars
- With this information, we are sensitive to **equal mass** binaries out to a few AU
- We also have some sensitivity to **sub-stellar** objects within ~1 AU

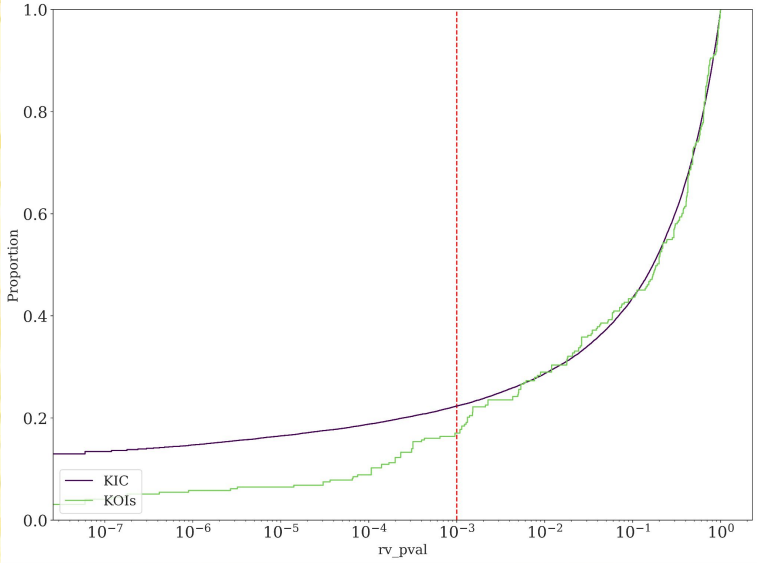
Questions?

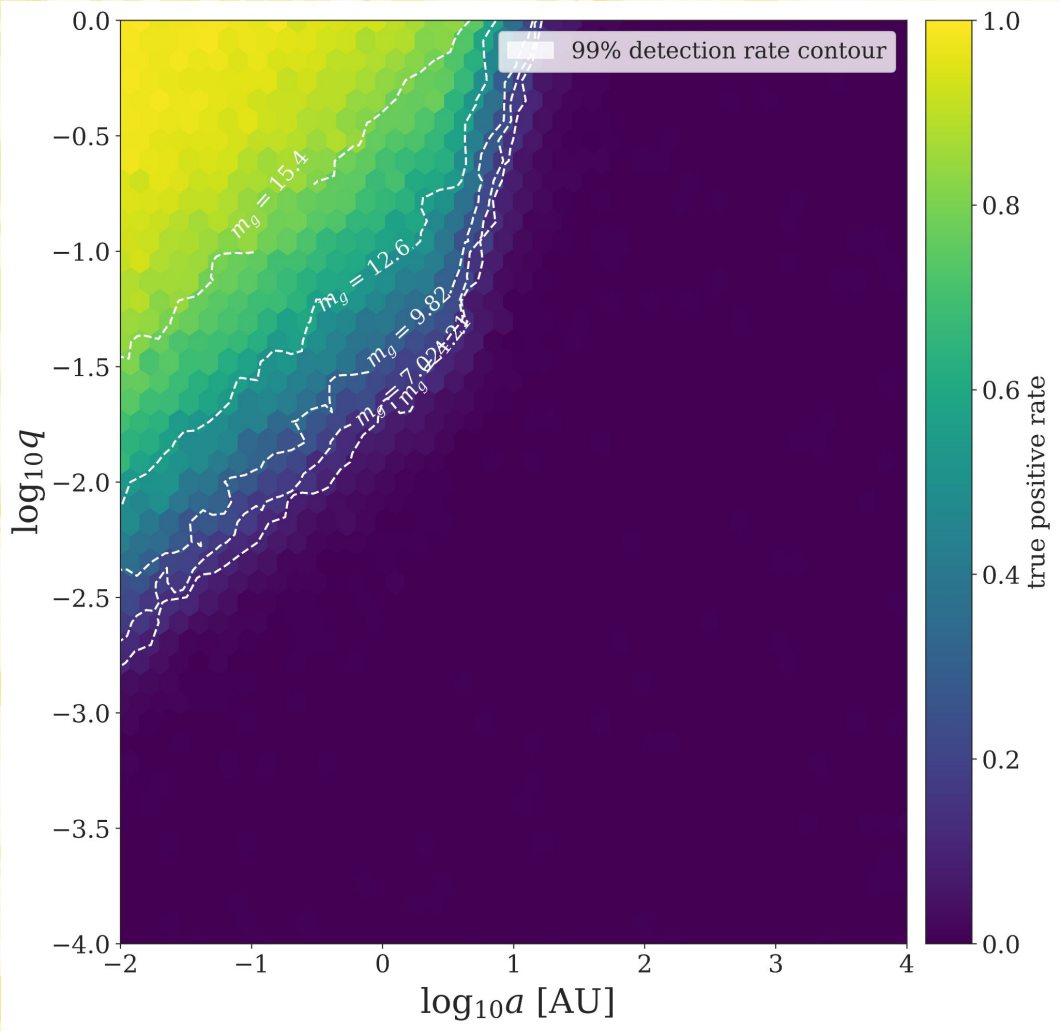
Email me at qchance@ufl.edu !

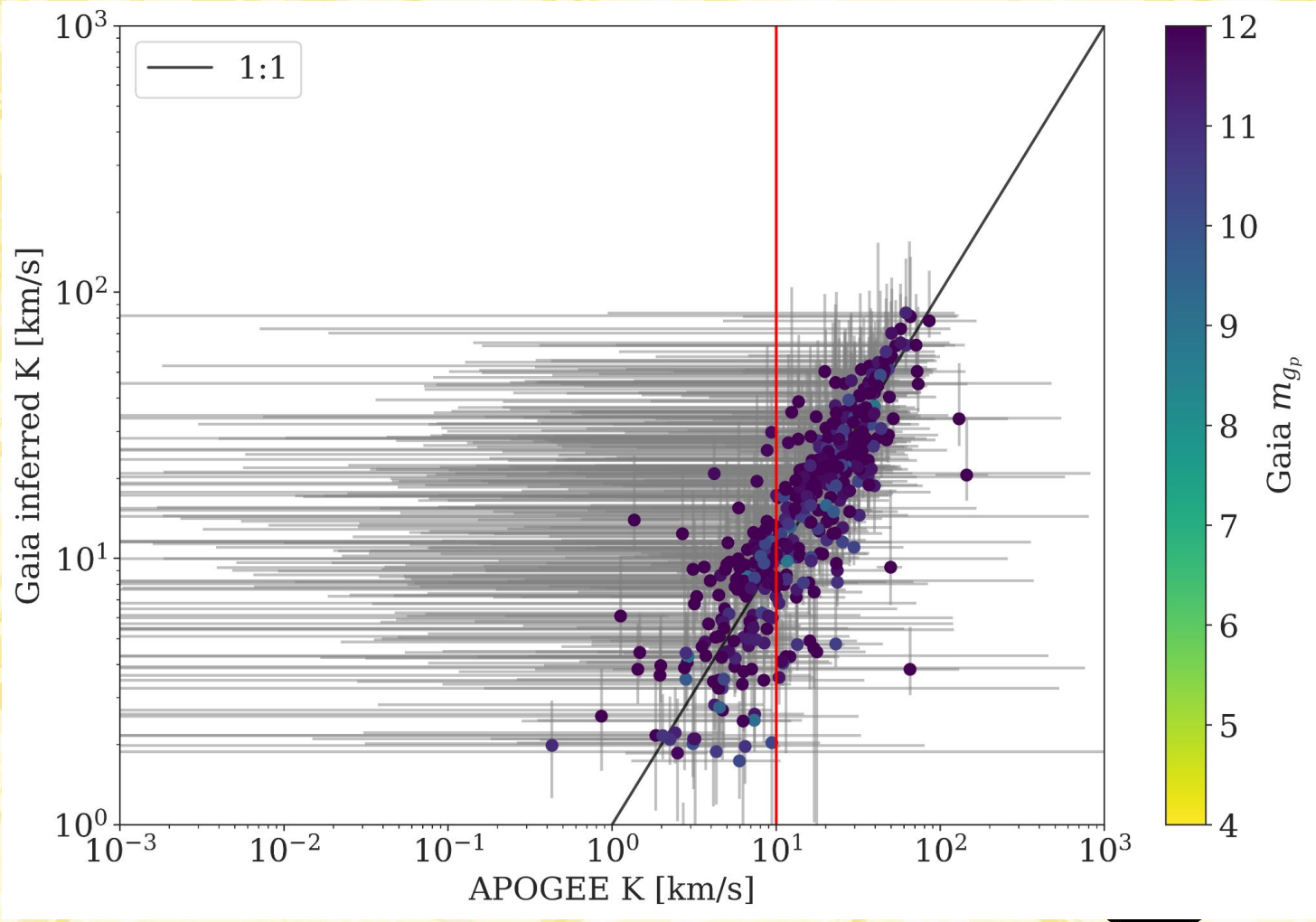

CTL
EBs
Proportion
1.0
0.8
0.6
0.4
0.2


CTL
TOIs
Proportion
1.0
0.8
0.6
0.4
0.2

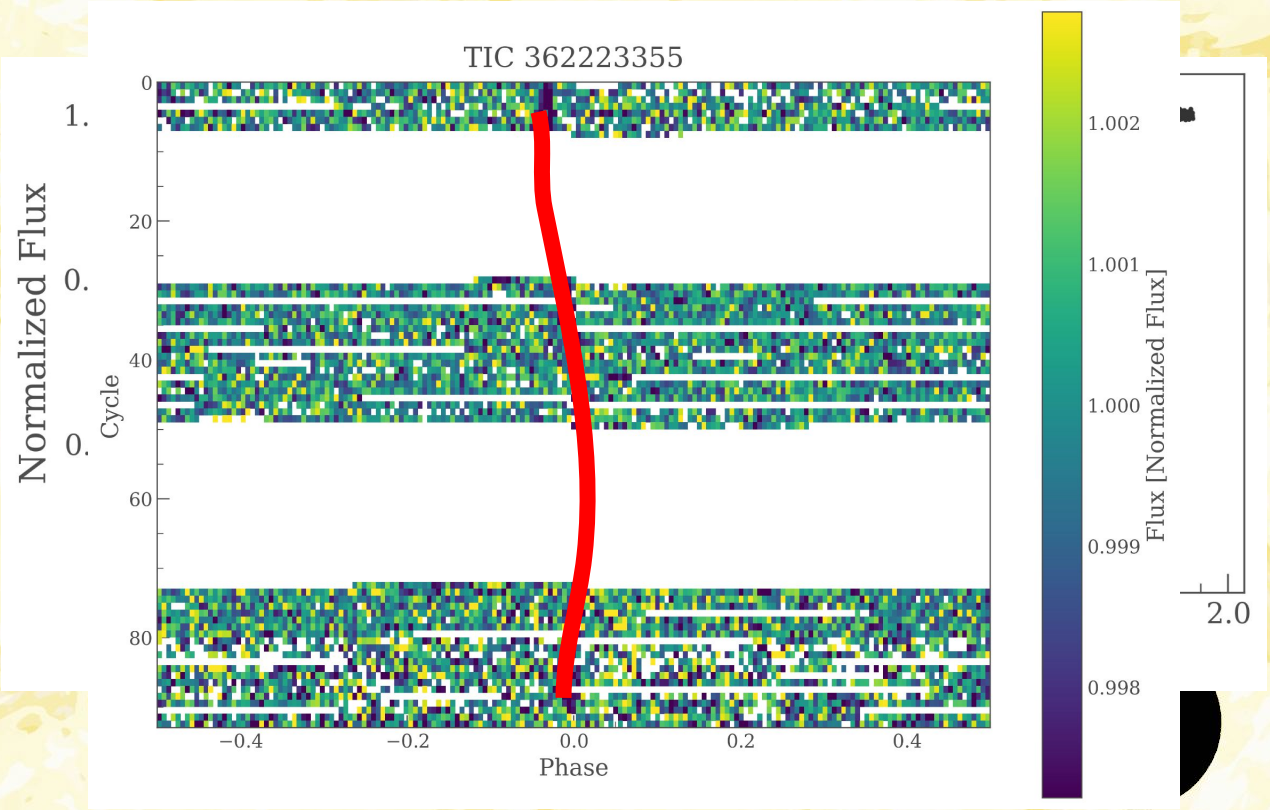

KIC
EBs
Proportion
1.0
0.8
0.6
0.4
0.2
0.0
10^{-7}
10^{-6}
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
10^{0}
rv_pval


KIC
KOIs
Proportion
1.0
0.8
0.6
0.4
0.2
0.0
10^{-7}
10^{-6}
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
10^{0}
rv_pval


99% detection rate contour
$m_g = 15.4$
$m_g = 12.6$
$m_g = 9.82$
$m_g = 7.02$
$\log_{10} q$
$\log_{10} a$ [AU]
true positive rate
0.0
−0.5
−1.0
−1.5
−2.0
−2.5
−3.0
−3.5
−4.0
−2
−1
0
1
2
3
4
1.0
0.8
0.6
0.4
0.2
0.0


1:1
Gaia inferred K [km/s]
APOGEE K [km/s]
Gaia m_{g_p}
10^0
10^1
10^2
10^3
10^{-3}
10^{-2}
10^{-1}
4
5
6
7
8
9
10
11
12

What can we use this for?



$$\epsilon = \left(\sqrt{\frac{\pi}{2N}}s\right)^2 + 0.11^2$$

$$s^2 = \frac{1}{N-1}\sum_{n=1}^{N}\left(\nu_n - \bar{\nu}\right)^2$$

$$\nu_n - \bar{\nu} \sim \mathcal{N}\left(\mu_n - \bar{\mu},\, \sigma^2\right)$$