

# The Effect of the Number of RV Observations on Planet Detectability

Carl Sagan Summer School 2016

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What happens to the *bayesian evidence* for detecting a planet as you vary the **number of observations** of a given target?

# M-Dwarf

Star

$T_{\text{start}} = 3000\text{K}$

$\text{Logg} = 4.5$

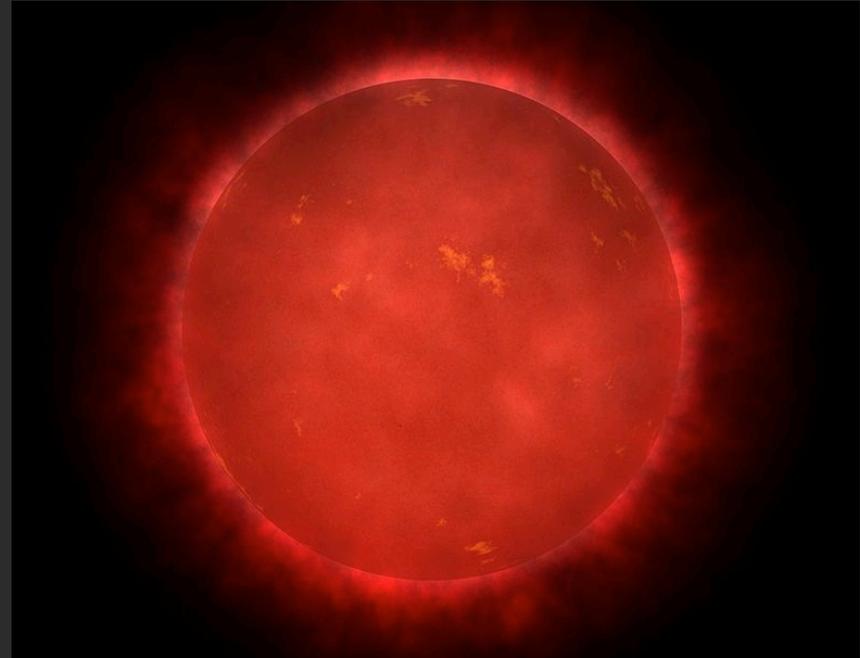
Rotation Period = 33 days

$R_{\text{star}} = 0.3 M_{\text{sun}}$

Limb 1 = 0.51    Limb 2 = 0.39

Inclination = 90 degrees

(Claret 2011)



# M-Dwarf with Simulated Spots

Spots from SOAP 2.0

$T_{\text{star}} = 3000\text{K}$

$T_{\text{spot}} = 2800\text{K}$

Initial spot # = 200

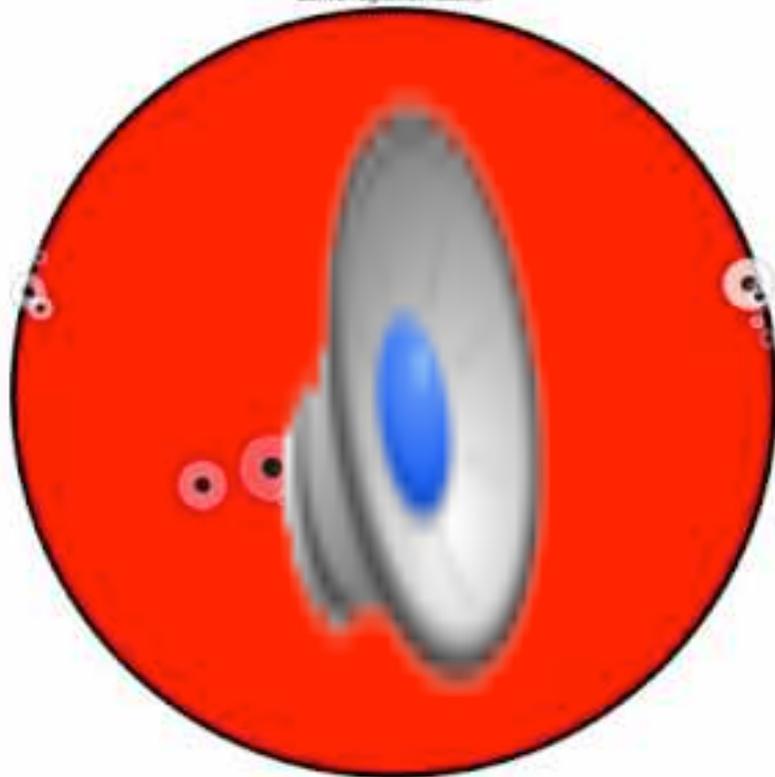
Spot Size =  $0.19 R_{\text{star}}$

50% of spot groups have lifetimes between 1.5h & 2.6d

40% of spot groups have lifetimes between 2.6d & 14.5d

10% of spot groups have lifetimes between 14.5d & 80d

active region simulation



# Data Set and Planet Parameters

Initial data set

4 years of data

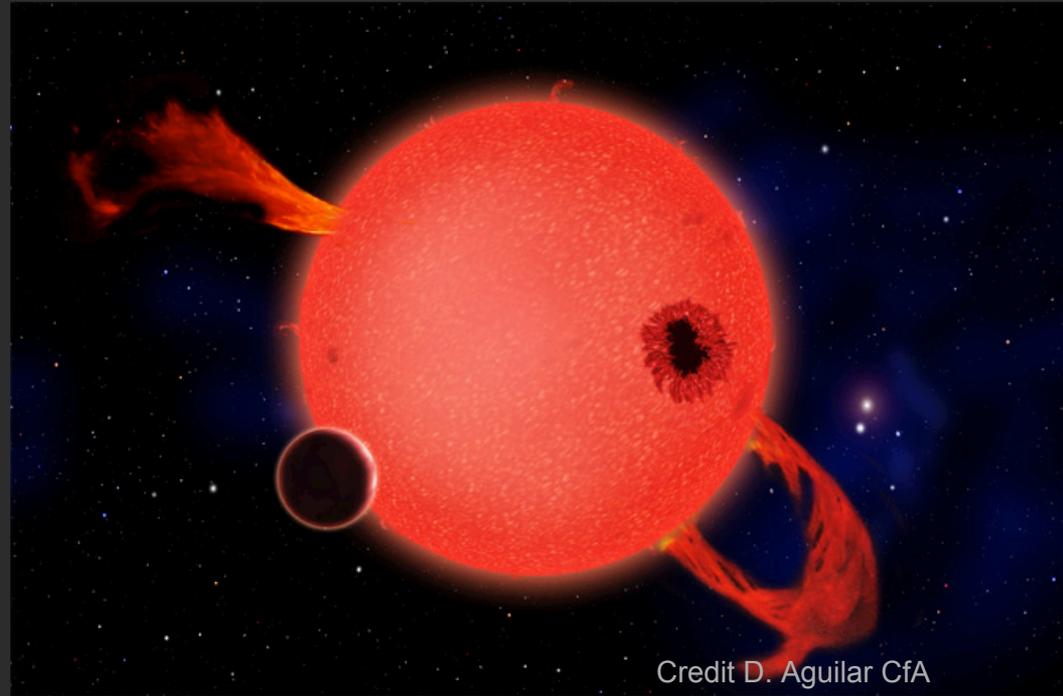
Observations every 6  
hours

5840 observations

Planet

$K = 3 \text{ m/s}$

Period = 13 days\*



\*Similar to Gliese 581b

# Optimistic observing from the ground

Initial data set

4 years of data every 6 hours

But GPs scale as  $O(n^3)$

Cut 2

Seasons

8 months of observing

4 months off

Cut 4

Instrumentation Issues

$N \sim (15,7)d$

One per season

# Optimistic observing from the ground



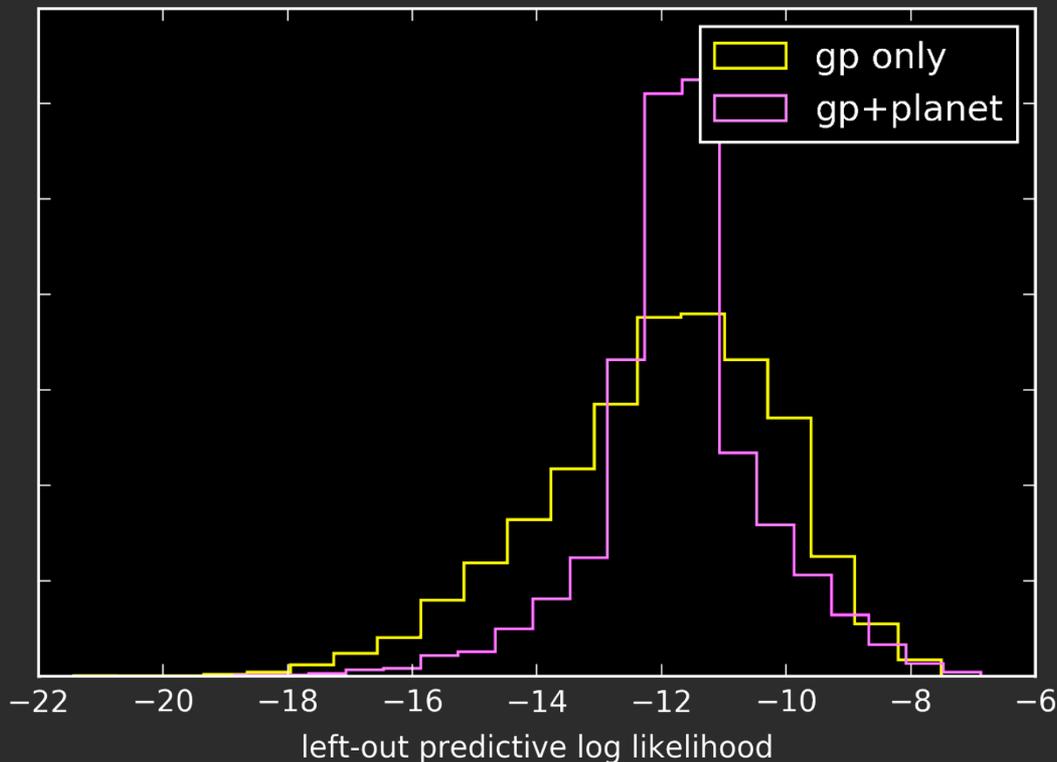
# Hypothesis and Methodology

Hypothesis: More data will yield better detection of planets.

1. Inject planet signal
2. Split into training/validation set
3. Fit RV curve only using a Gaussian Process (GP)
  - a. Compute initial guess
  - b. Explore parameter space using MCMC (Stellar variability amplitude, oscillation correlation length, amplitude of harmonics, period, RV, errors Initialise walkers in region about initial guess, Burn-In #1
    - i. Initialise walkers in new optimal guess, Burn-In #2
    - ii. Run production chain

# For Different Observing Lengths can We Recover the Planet?

Yellow =  
Gaussian  
Process  
to fit our  
data  
without a  
planet

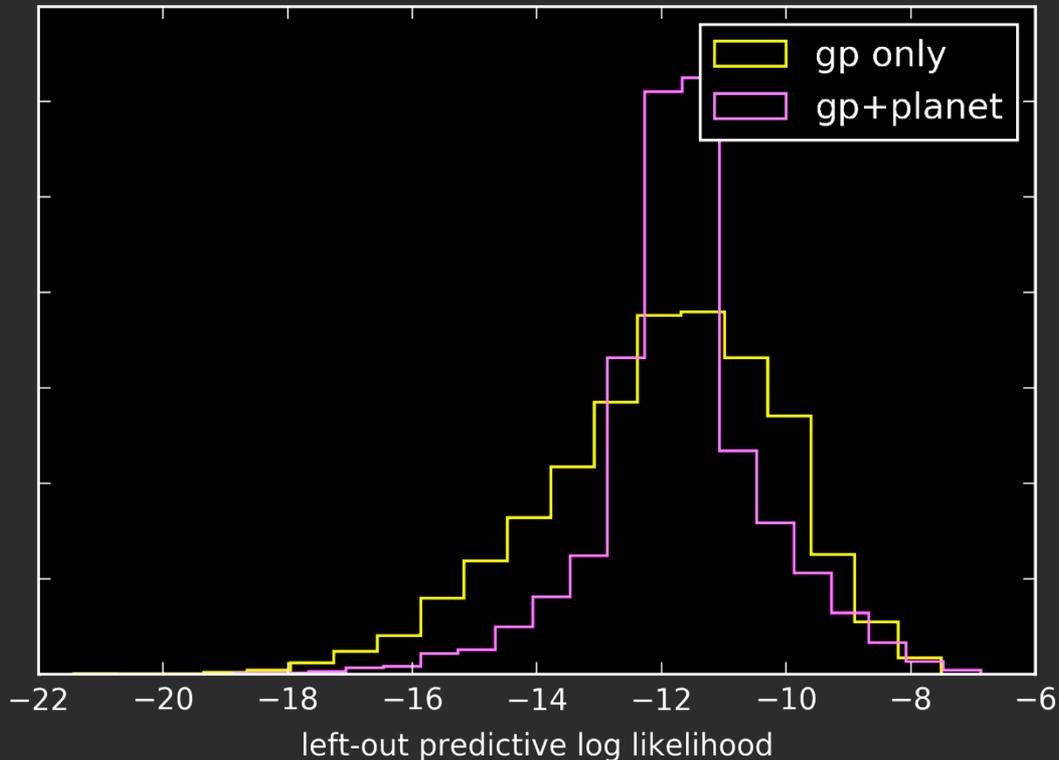


Purple =  
Gaussian  
Process  
to fit our  
data with  
a planet  
model

# One Month of Data

Bayesian Evidence = 1.42 ; no planet

Yellow =  
Gaussian  
Process  
to fit our  
data  
without a  
planet

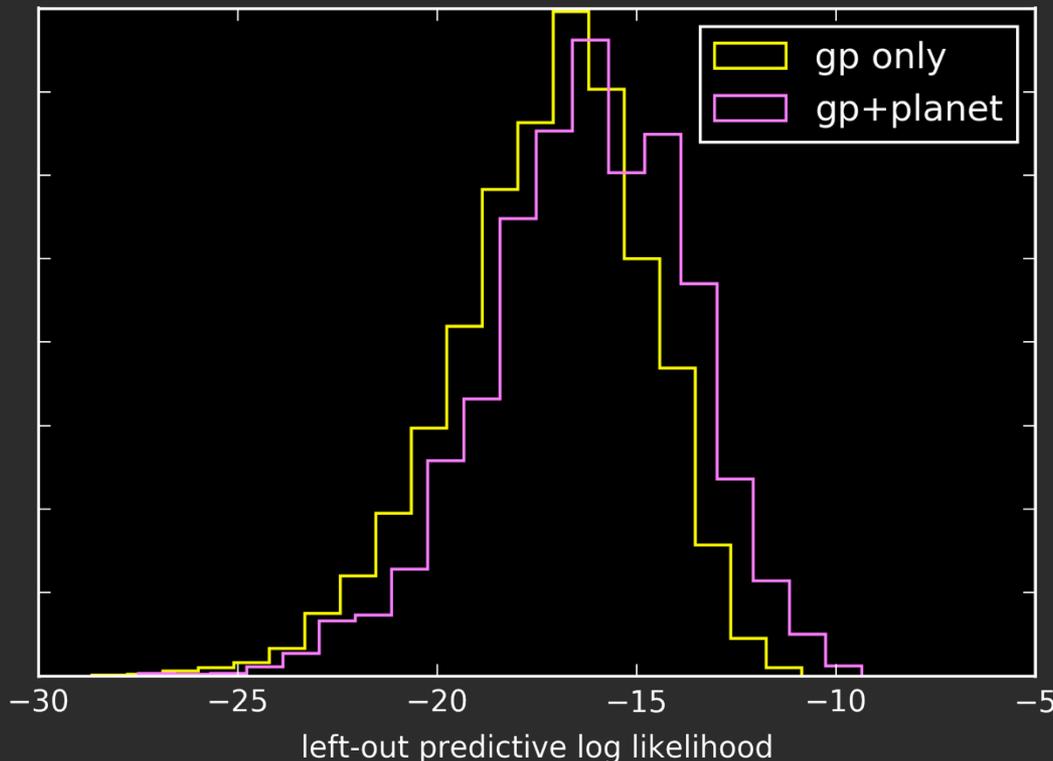


Purple =  
Gaussian  
Process  
to fit our  
data with  
a planet  
model

# Two Months of Data

Bayesian Evidence = 3.66 ; no planet

Yellow =  
Gaussian  
Process  
to fit our  
data  
without a  
planet

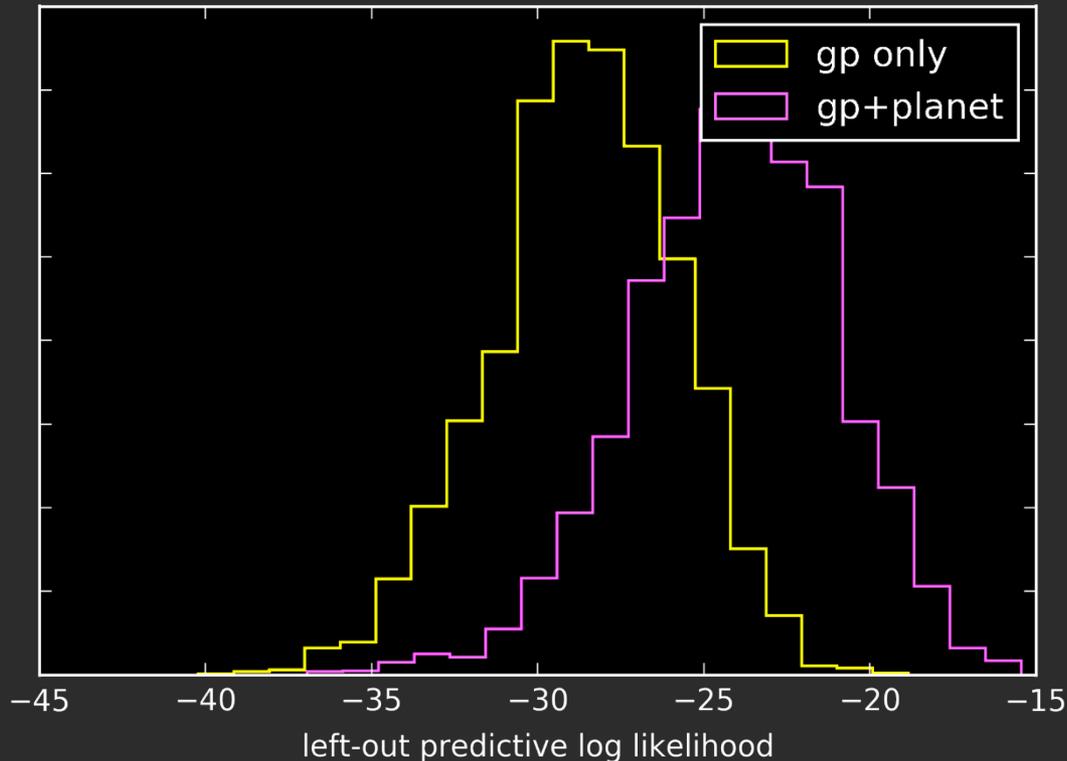


Purple =  
Gaussian  
Process  
to fit our  
data with  
a planet  
model

# Three Months of Data

Bayesian Evidence = 95.6 ; no planet

Yellow =  
Gaussian  
Process  
to fit our  
data  
without a  
planet

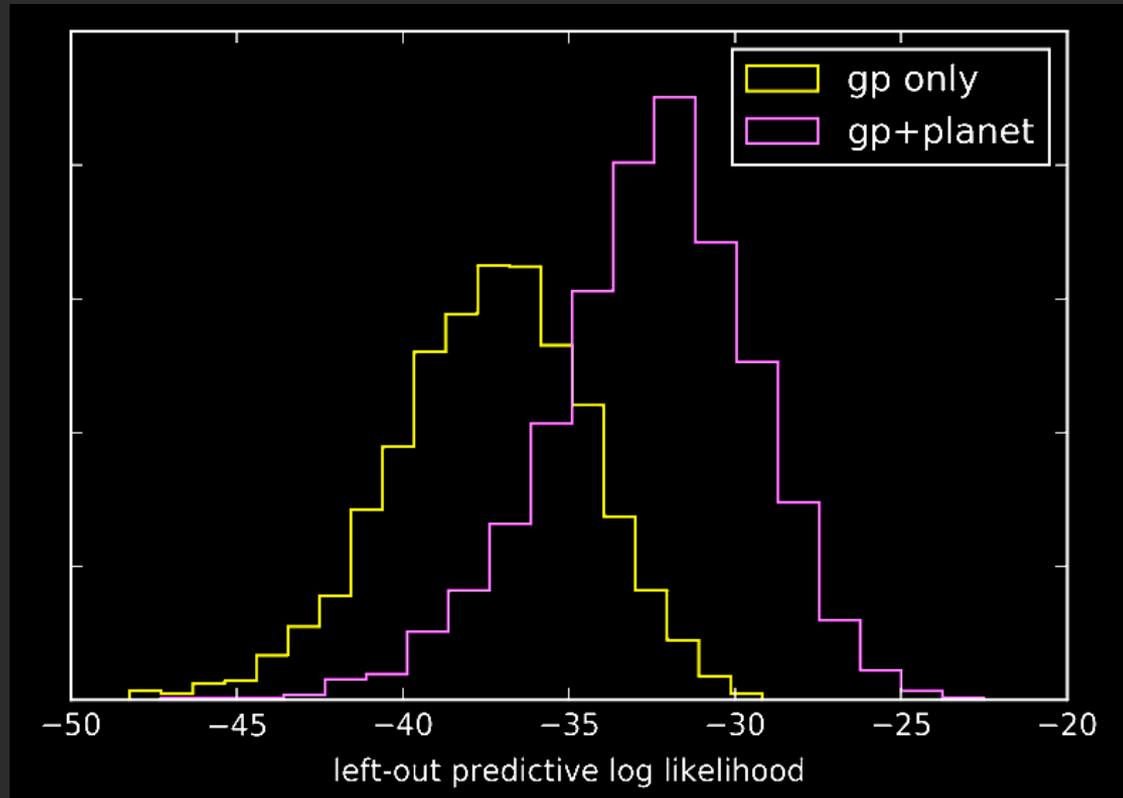


Purple =  
Gaussian  
Process  
to fit our  
data with  
a planet  
model

# Four Months of Data

Bayesian Evidence = 284; Possible Planet

Yellow =  
Gaussian  
Process  
to fit our  
data  
without a  
planet

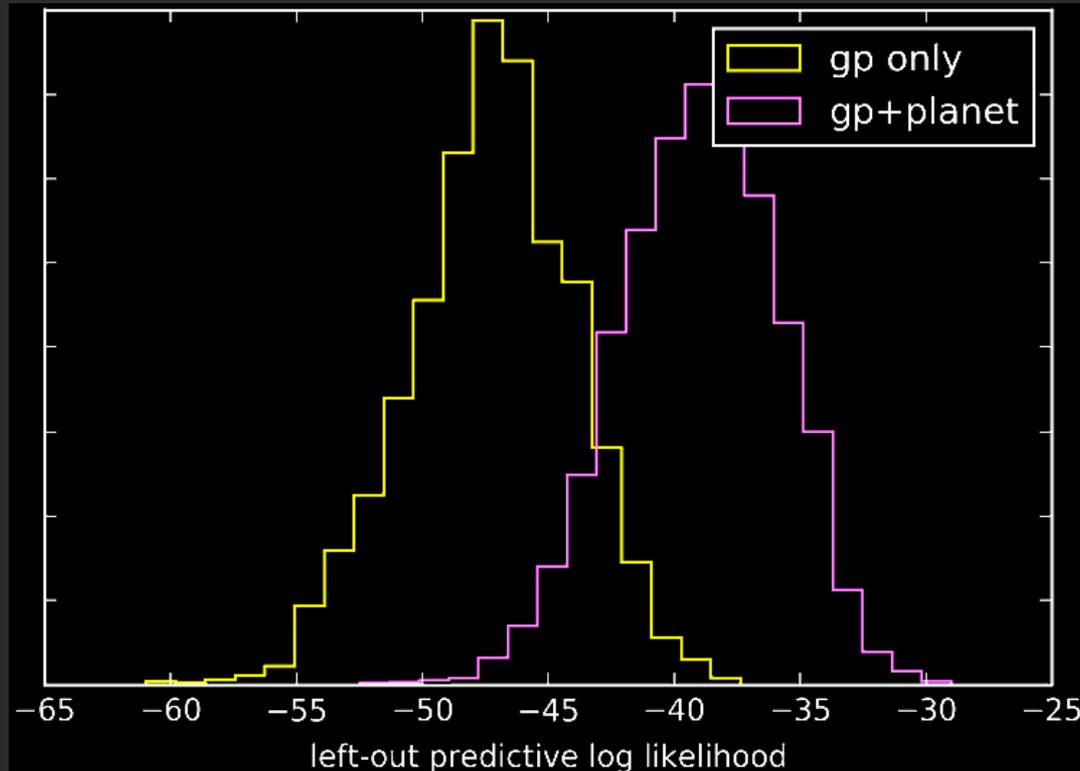


Purple =  
Gaussian  
Process  
to fit our  
data with  
a planet  
model

# Five Months of Data

Bayesian Evidence = 5884 ; PLANET :-)

Yellow =  
Gaussian  
Process  
to fit our  
data  
without a  
planet

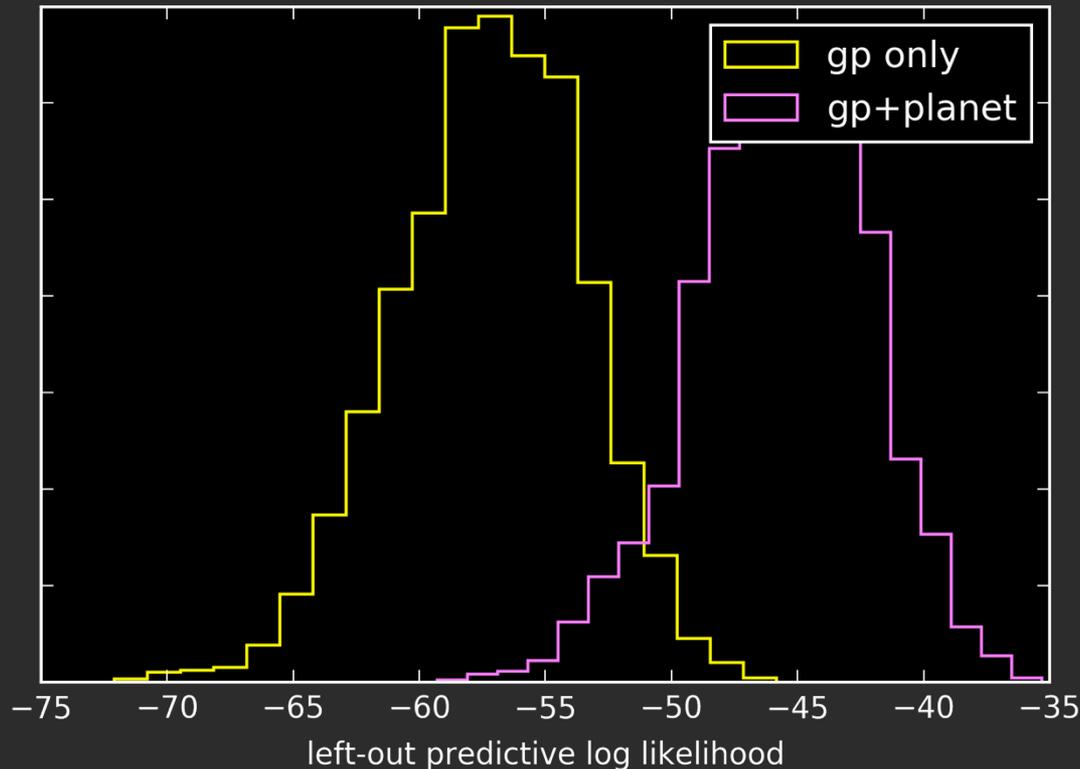


Purple =  
Gaussian  
Process  
to fit our  
data with  
a planet  
model

# Six Months of Data

Bayesian Evidence = 112420; PLANET

Yellow =  
Gaussian  
Process  
to fit our  
data  
without a  
planet

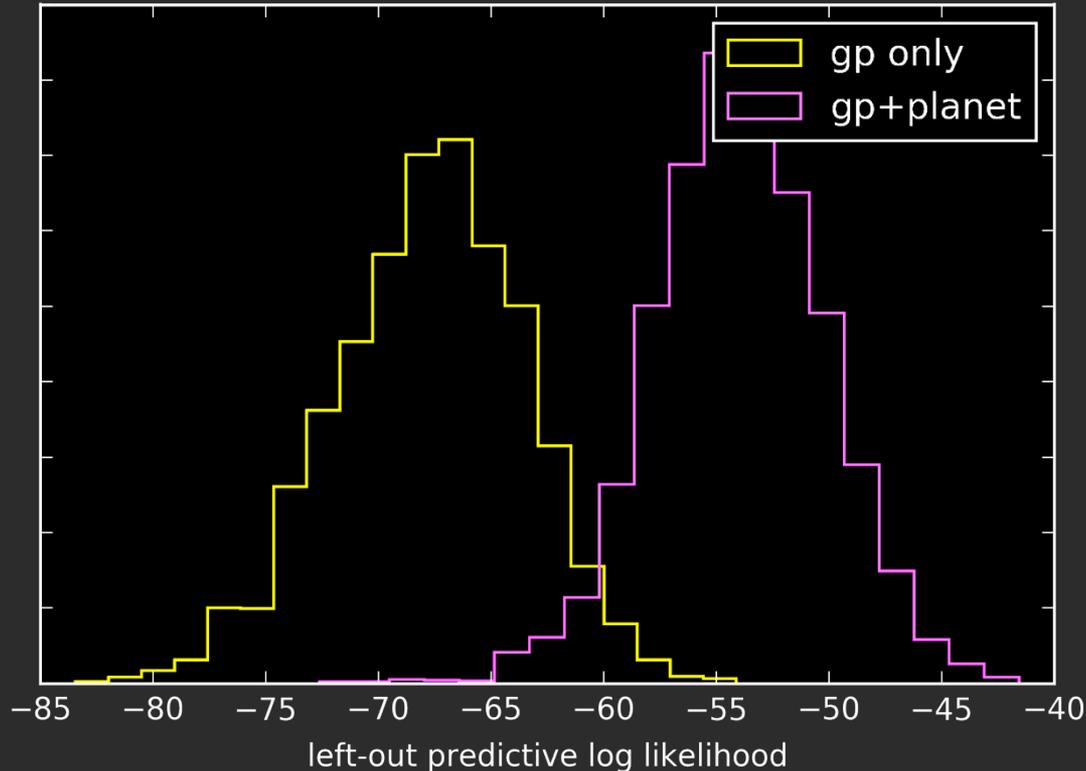


Purple =  
Gaussian  
Process  
to fit our  
data with  
a planet  
model

# Seven Months of Data

Bayesian Evidence = 707858; wasted Tele Time

Yellow =  
Gaussian  
Process  
to fit our  
data  
without a  
planet

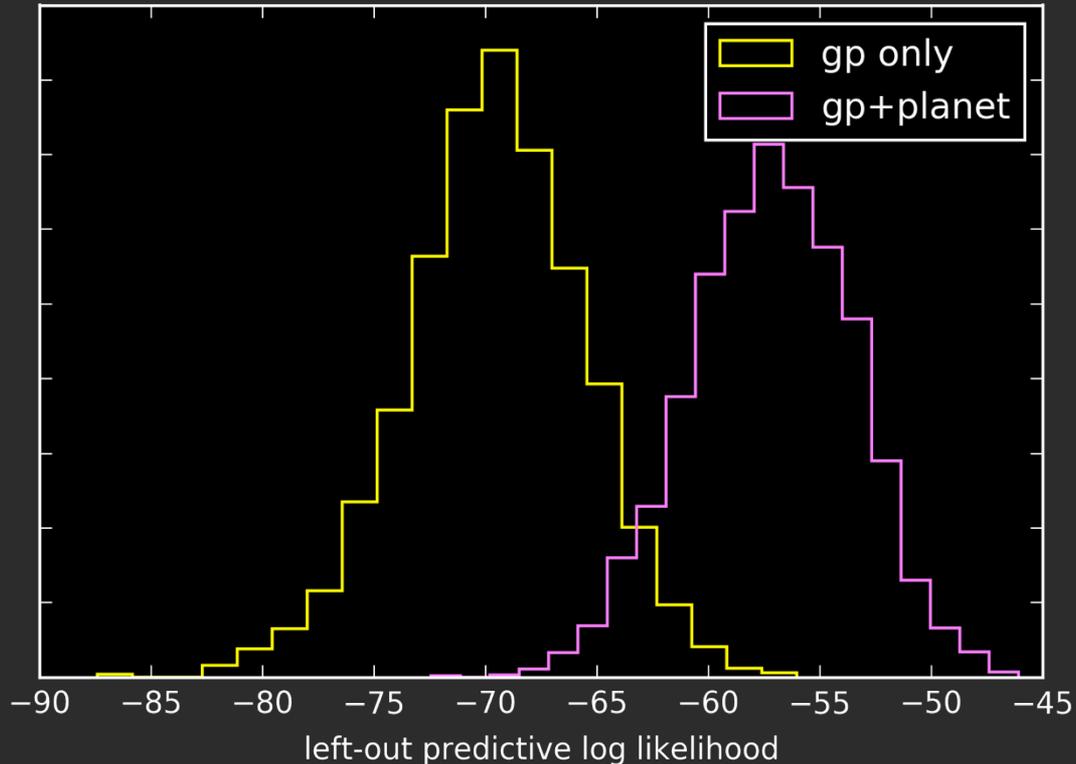


Purple =  
Gaussian  
Process  
to fit our  
data with  
a planet  
model

# Eight Months of Data

Bayesian Evidence = 235625; wasted Tele Time

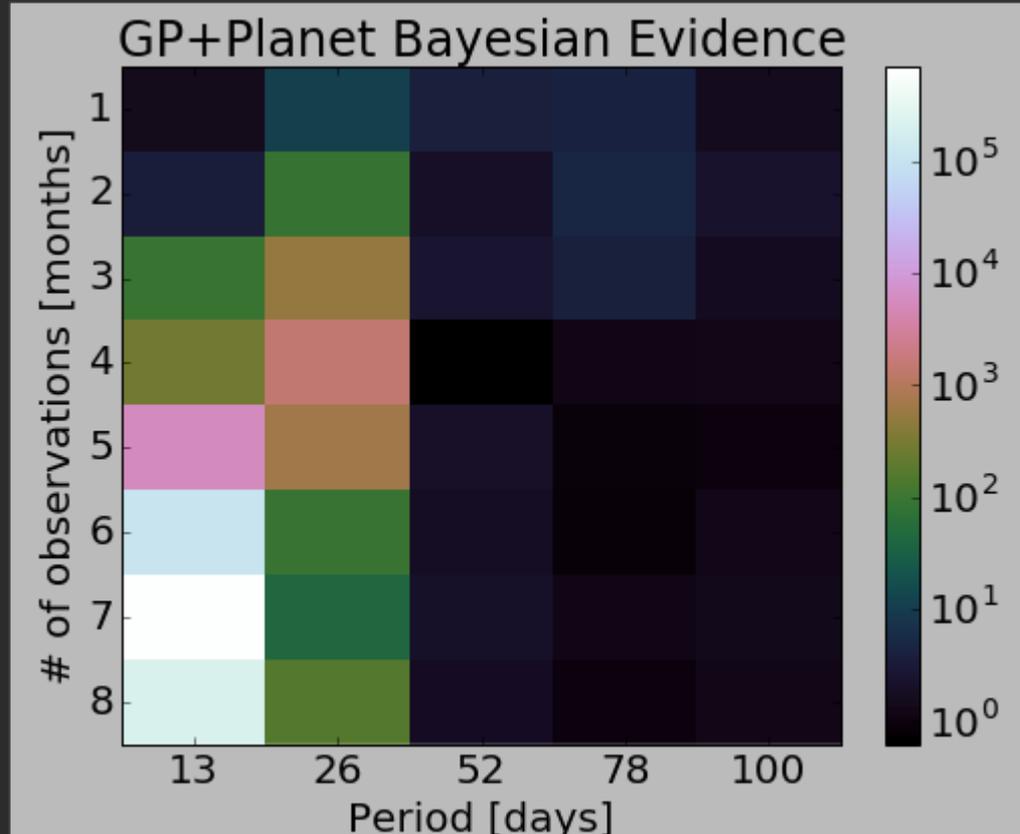
Yellow =  
Gaussian  
Process  
to fit our  
data  
without a  
planet



Purple =  
Gaussian  
Process  
to fit our  
data with  
a planet  
model

# 1-8 months of data with different periods

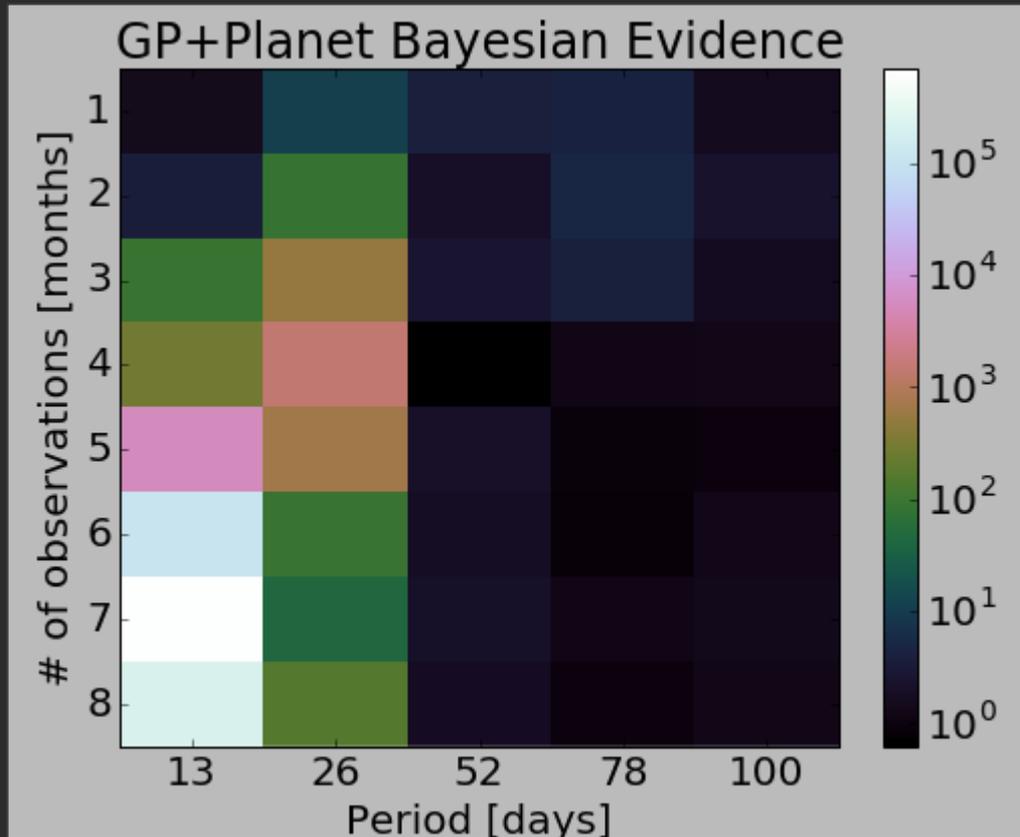
Planet  
found in  
white



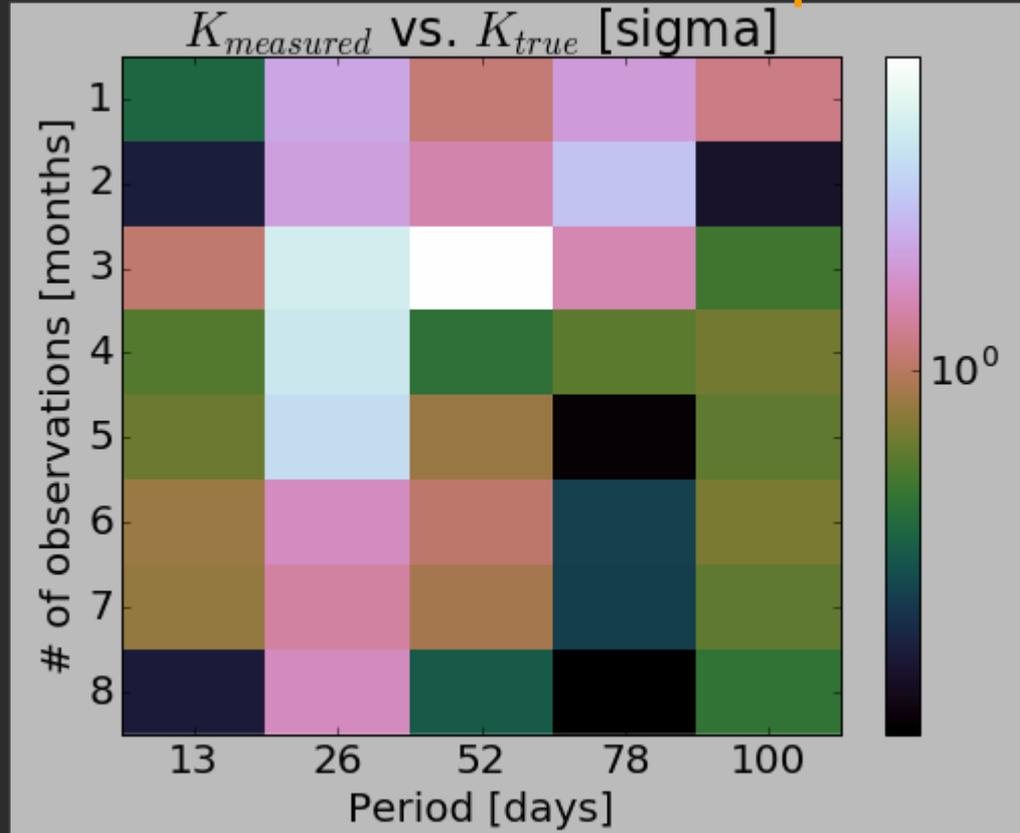
Planet  
not found  
in black

# Conclusions:

More data = better results



# Conclusions: extra K value heat map



# Conclusions: extra

## Period value heat map

