The Effect of Spot Temperature on Planet Detectability

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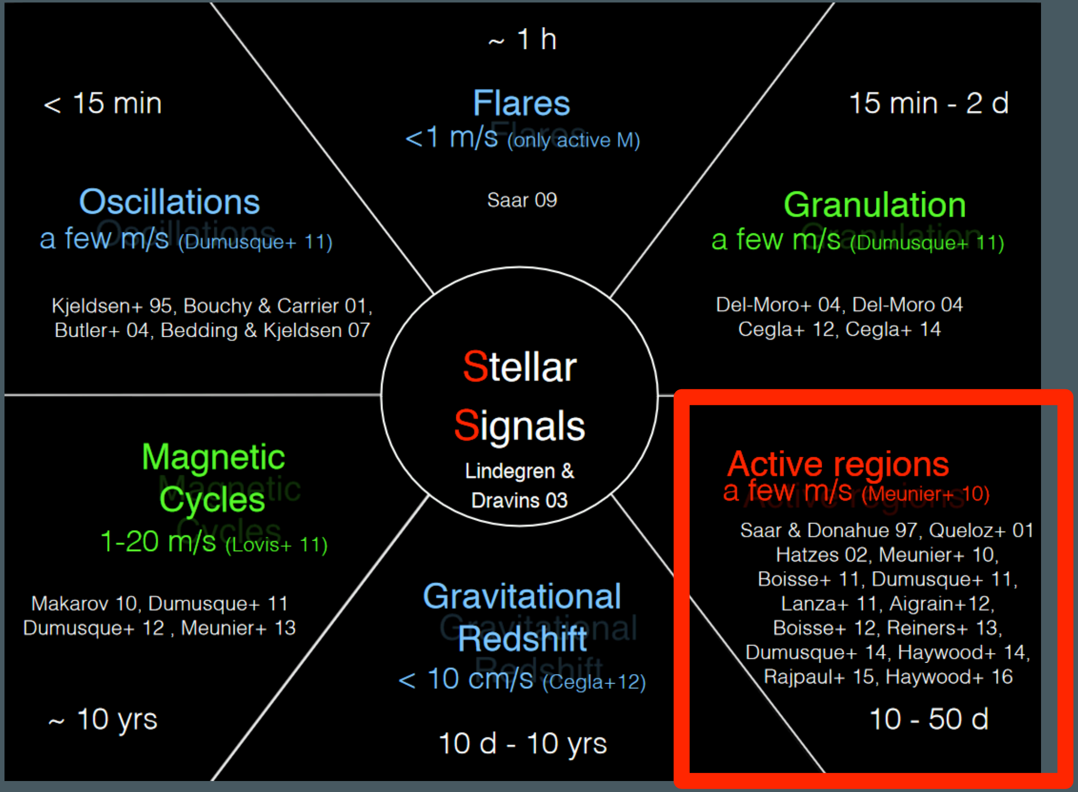
Stellar Spots limit planet detectability



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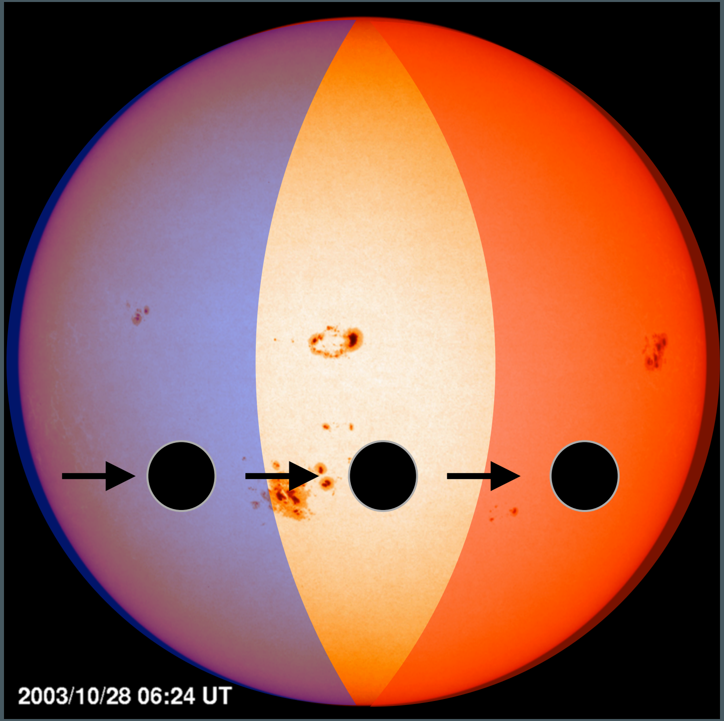
Stellar Spots create periodic RV signal due to...

Decreased Flux

Inhibited Convection



Credit: SOHO NASA

Hypothesis / Method

Question: How does planet detectability change with spot temperature?

Method:

1- vary the temperature of the spot and study the RV signal

2- inject a planetary signal and check whether the planet can be detected in the presence of spots and plage

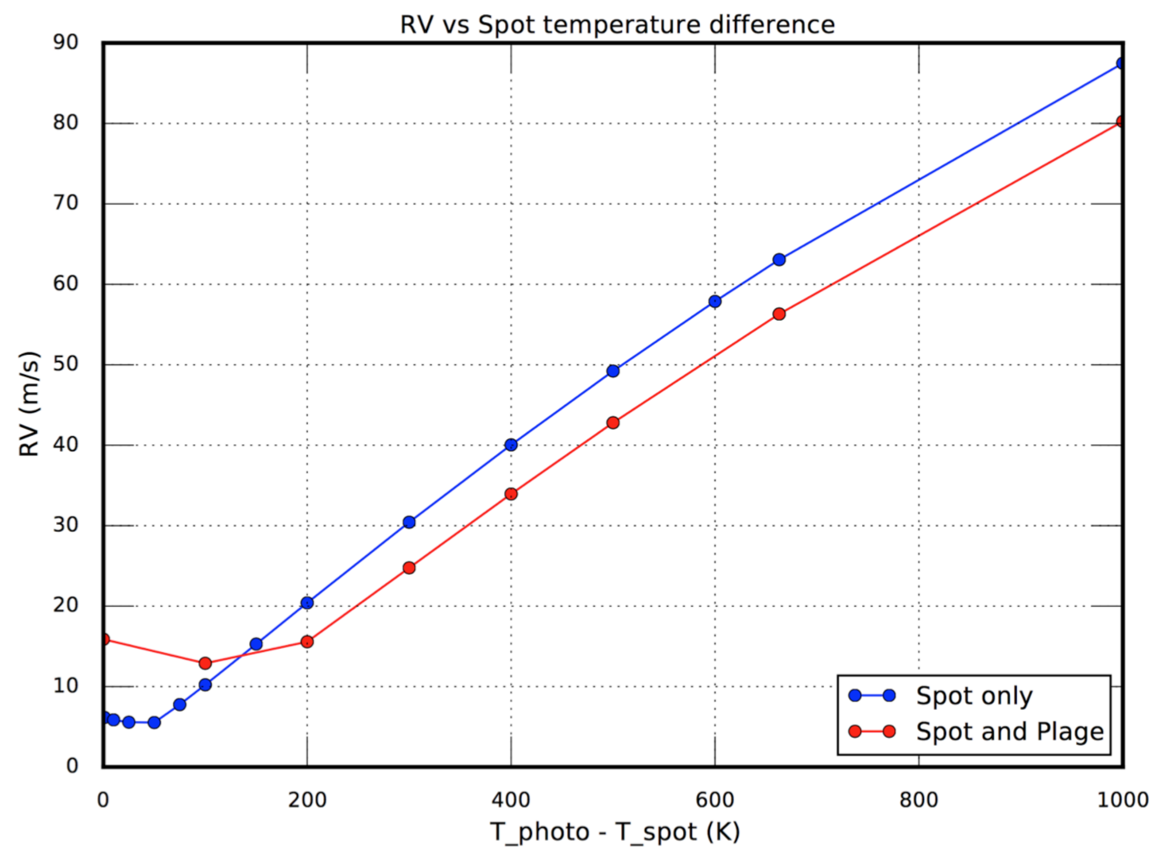
RV Effects of a Single Spot and Spot w/ Plage

Adjusted the temperature difference between a spot and the photosphere (SOAP 2.0)

Larger T_diff -> larger RVs from spots

RV = (max-min)/2

Addition of a plage decreases the effect from a spot



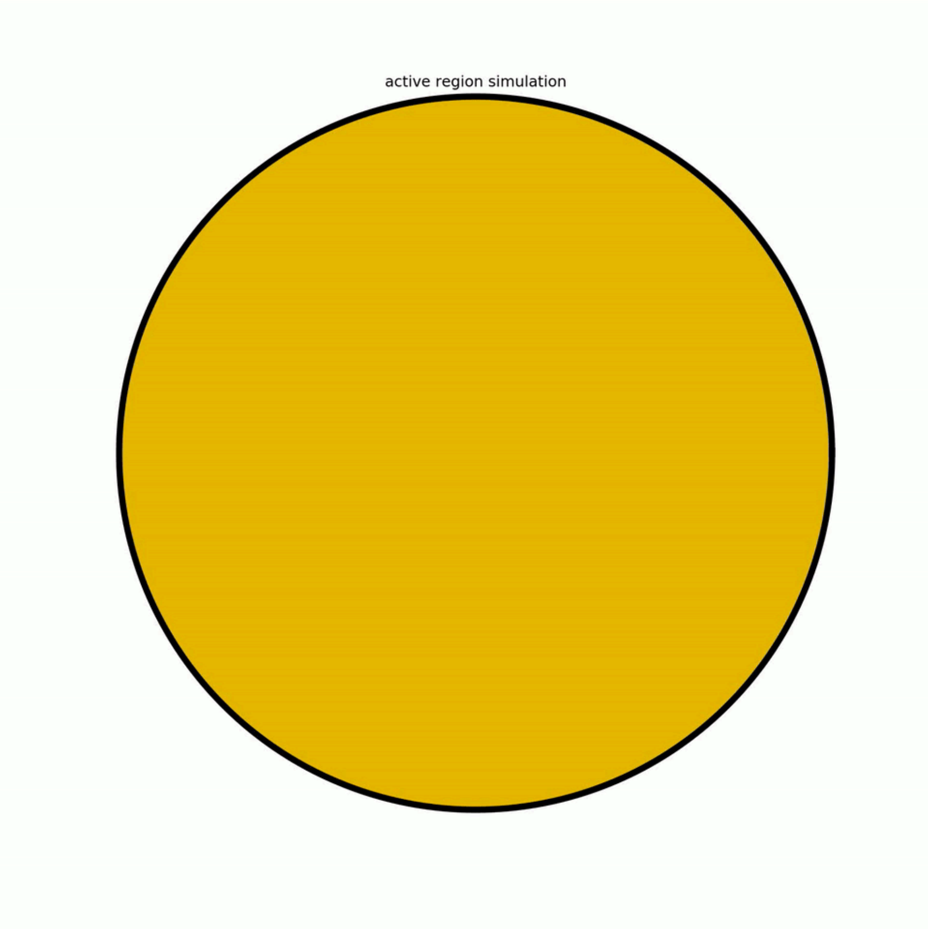
Modified solar model

Solar rotation period is set to 5 days

Plage surround the spots and are 10x larger

Features evolve, and they cluster at realistic longitudes and latitudes

Then inject planet with 13.3 day period

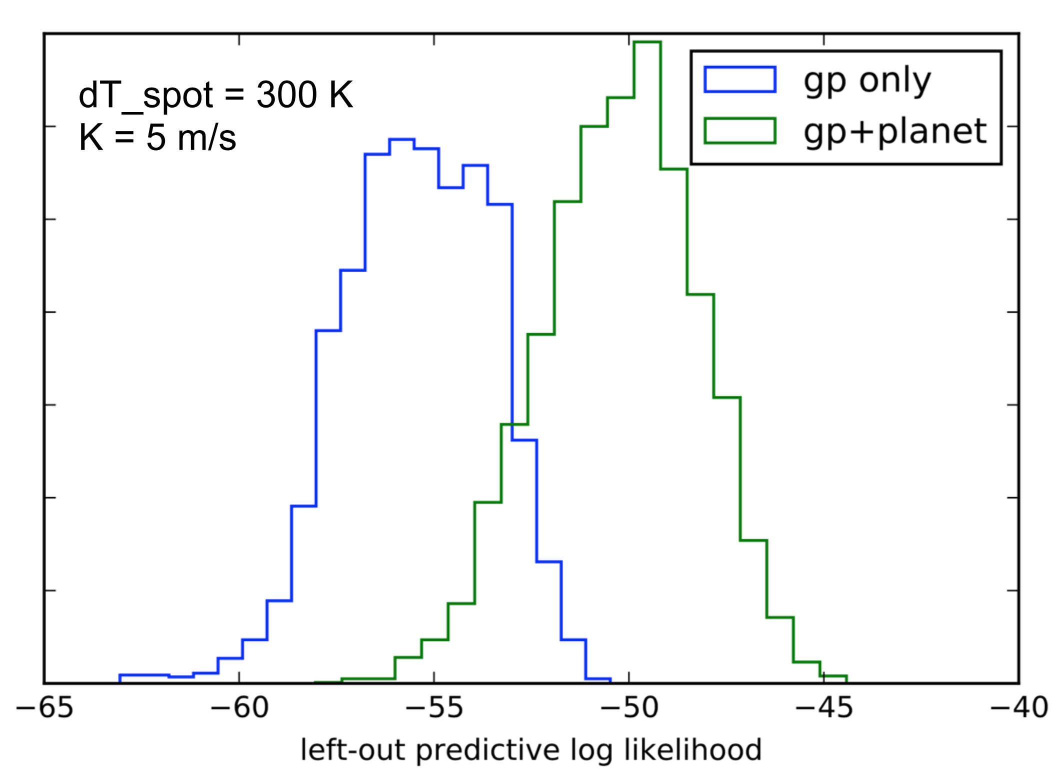


Left-out predictive log-likelihood

Predict last 20% of data based on model from first 80% of data

Compare the log-likelihood of the two models for the last 20%

Here, GP+planet model prefered by factor of exp(5.12) ≈ 167

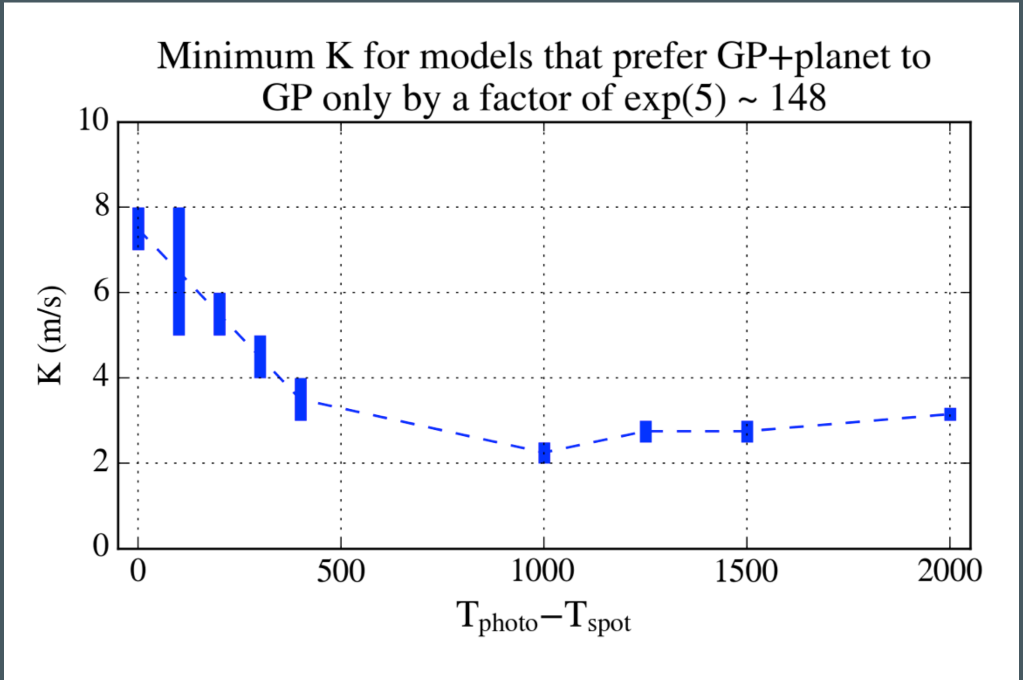


Minimum planet signal detectable

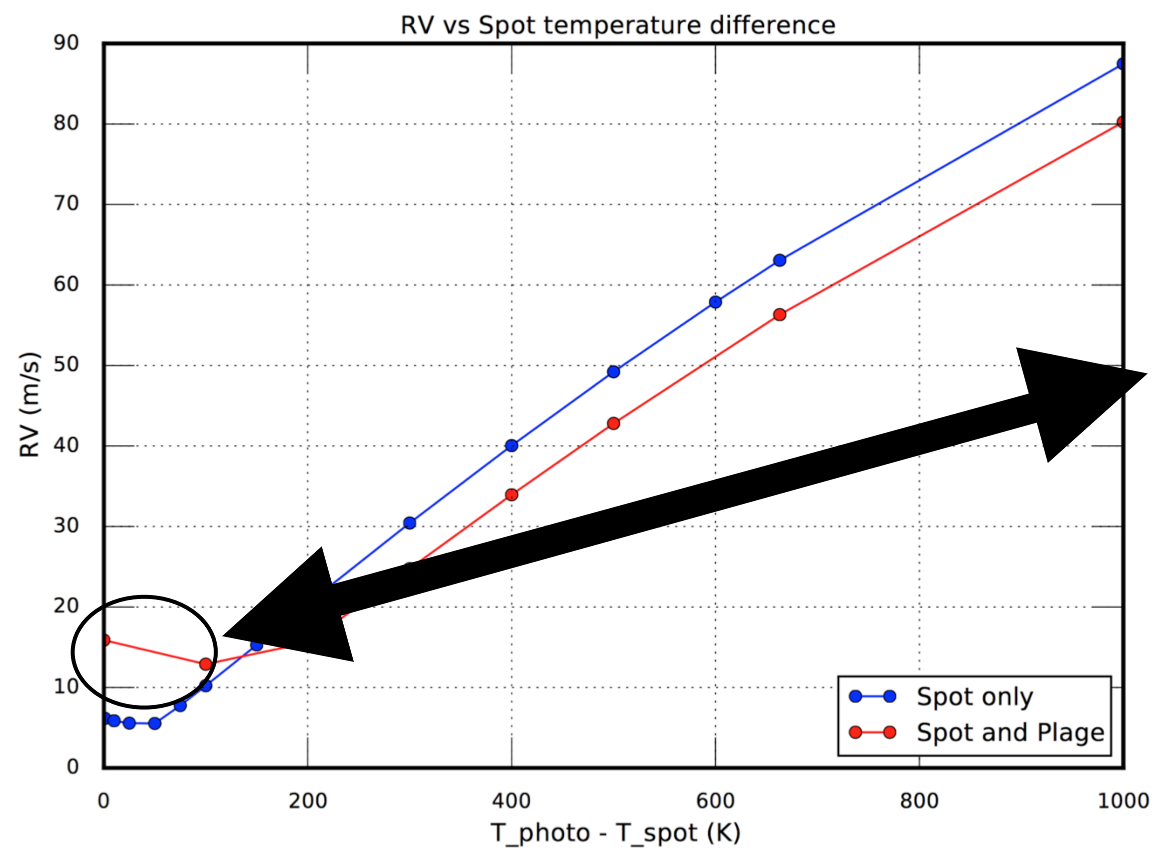
Set a threshold of preferring GP+planet model by factor of e^5

Search for minimum K; assume this factor varies monotonically with K

Surprising result!

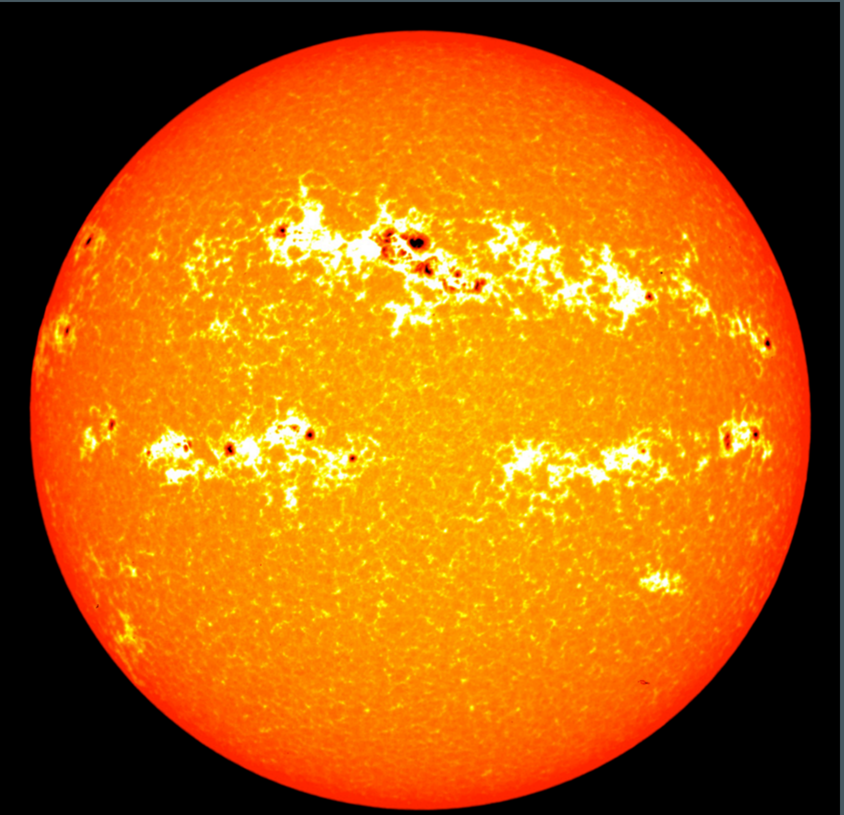


Conclusions



Our hypothesis that smaller spot temperature contrast will have a weaker RV signal is only correct when the spot flux effect is dominant. When the convective blueshift inhibition effect is dominant, higher temperature spots actually produce greater RV signals.

Conclusions


https://svs.gsfc.nasa.gov/vis/a000000/a002600/a002644/activity-02-high.jpg

In a more realistic model where the area fraction of faculae is 10x the area fraction of spots, the activity-induced RV signal is dominated by convective blueshift inhibition even for a star with a 5-day rotation period.

Thank You

to everyone who helped make the 2016 Sagan Exoplanet Summer Workshop and the hands-on session possible!!!

Data table

ΔT = 0 K	ΔT = 100 K	ΔT = 200 K	ΔT = 300 K	ΔT = 400 K	ΔT = 1000 K	T=1250	T=1500K	ΔT = 2000 K
K=5; E=1.5	K=5; E=4.54	K=5; E=4.94	K=4; E=4.44	K=5; E=6.62	K=4;E=10.2	K=2.5; E=4.90	K=5; E=9.64	K=5; E = 9.13
K=7; E=4.67	K=6; E=4.53 weird	K=6; E=5.37	K=30; E=26.8	K=3; E=3.77	K=2.5;E=5.76	K=3; E=6.90	K=3.5; E=7.97	K=3; E=4.54
K=8; E=6.41	K=8; E=5.34	K=10; E=7.8	K=5;E=5.12	K=4; 5.47	K=2;E=3.98	K=7;E=12	K=3; E=5.94	K=4; E=7.94
K=10; E=9.44	K=10; E=7.11						K=2.5; E=6.08	K=3.3; E=6.05
	K=50; E=33.65							