

Goldilocks Can't Stay Here: Habitable Zone Planets Around Gliese 581 are Stellar Activity Signals

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Context



- Earth-mass HZ planets have RV amplitudes of 1 m/s (M dwarfs) to ~10 cm/s (G dwarfs).
- New instruments (e.g. HPF, ESPRESSO) will reach these precision levels, but stellar magnetic activity will still prevent confident detections!
- Need new and improved techniques to both **measure** and **correct** activity-induced RV shifts.

About Gliese 581



- M3V dwarf at $d=6.3$ pc with a debris disk (Lestrade+ 2012).
- Four low-mass planets (b-e) discovered by ESO/HARPS (Bonfils+ 2005, Udry+ 2007, Mayor+ 2009), two more (f,g) with combined HARPS/HIRES RVs (Vogt+ 2010).
- Planets d, g potentially habitable (e.g. von Paris+ 2011).

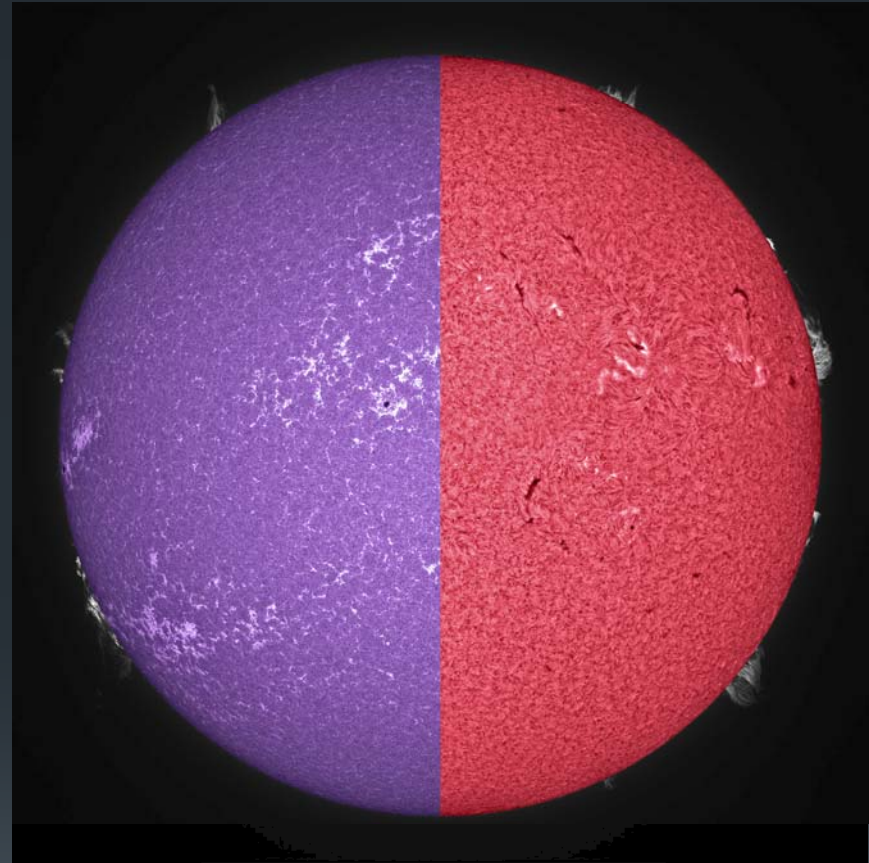
About Gliese 581



- Planets f & g questioned upon acquisition of additional data (Forveille+ 2011) and after Bayesian analysis (e.g. Gregory 2011, Tuomi 2011).
- Baluev (2013): Accounting for red noise reduces significance of planets d, g.

What about stellar activity?

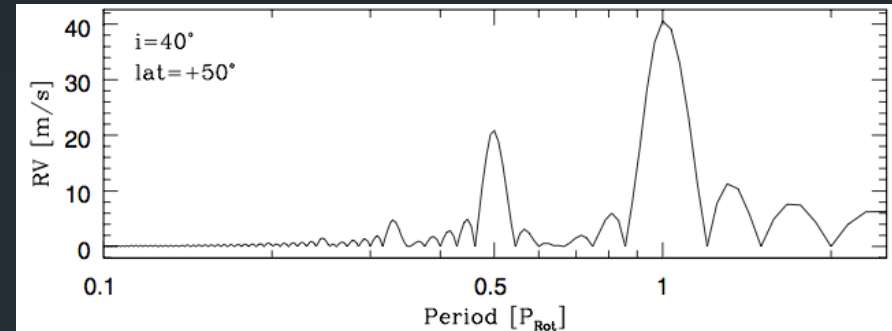
- Ca II H&K (Bonfils+ 2007), photometry (Vogt+ 2010) -> very low activity.
- Ca H&K has low S/N for mid-late M stars.
- Hatzes (2013), Robertson+ (2013) suggested activity, measured with H-alpha, might affect RVs of GJ 581.



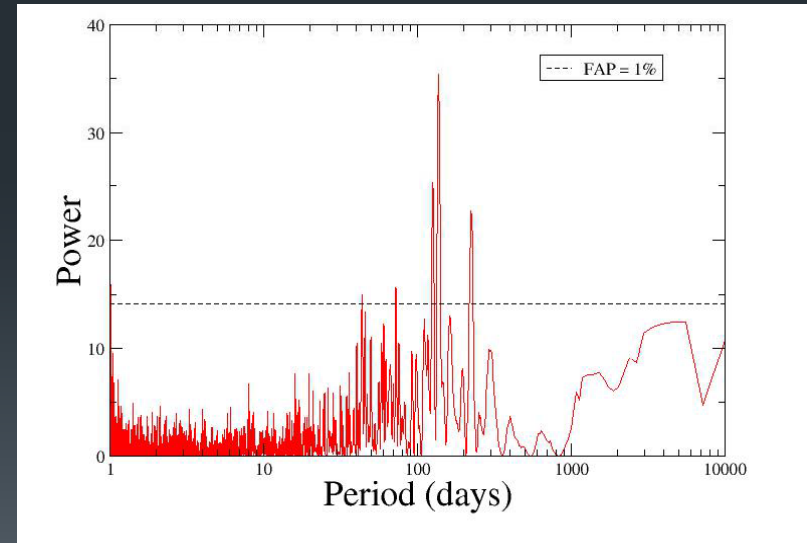
The Sun in Ca K (blue) and H-alpha (red)
Photo by Alan Friedman

Stellar Rotation and RV

- Boisse+ (2011): Rotating starspots create RV periodicity at rotation period and integer fractions ($P/2$, $P/3$,...)
- GJ 581: **Prot=130 days**, seen in H-alpha, Na I D lines
- Consistent with photometry? ASAS photometry shows weak confirmation of period, BUT, see Kurster+ (2003).



Simulated starspot-induced RV
(Boisse +, 2011, A&A, 528, A4)

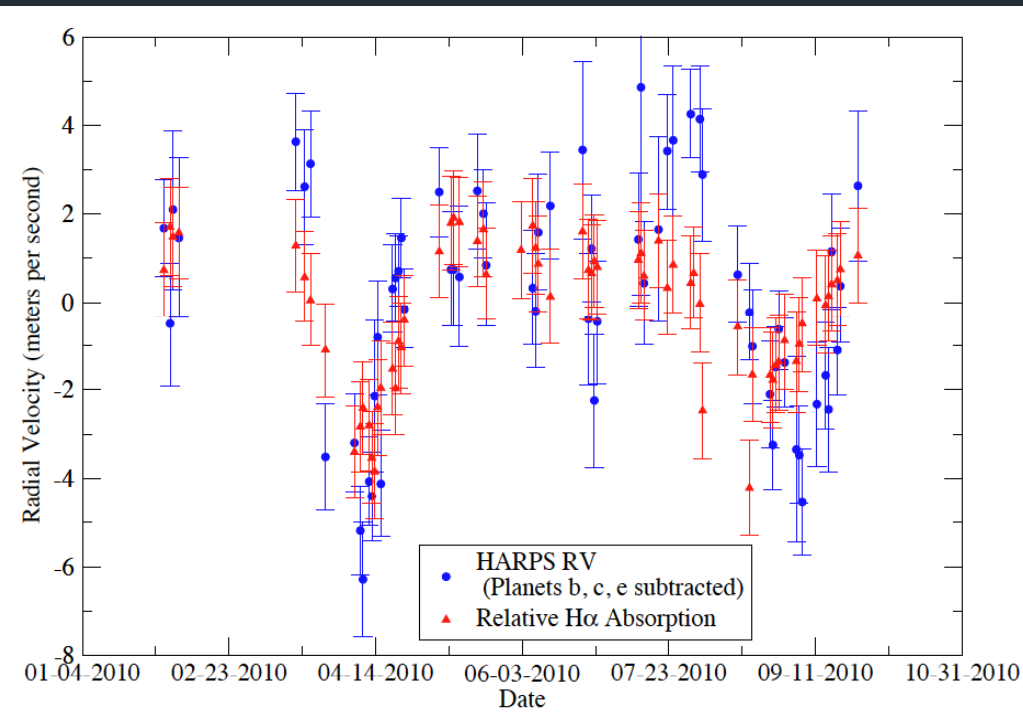


Gliese 581 H-alpha

Activity-RV Analysis

- Separate data into observing seasons (Hatzes, ApJ, 770, 133).
- Must remove planet b
- Model and remove RV-Ha correlations (if present)
- Re-analyze planet system

The bad news: no HZ planets for GJ 581

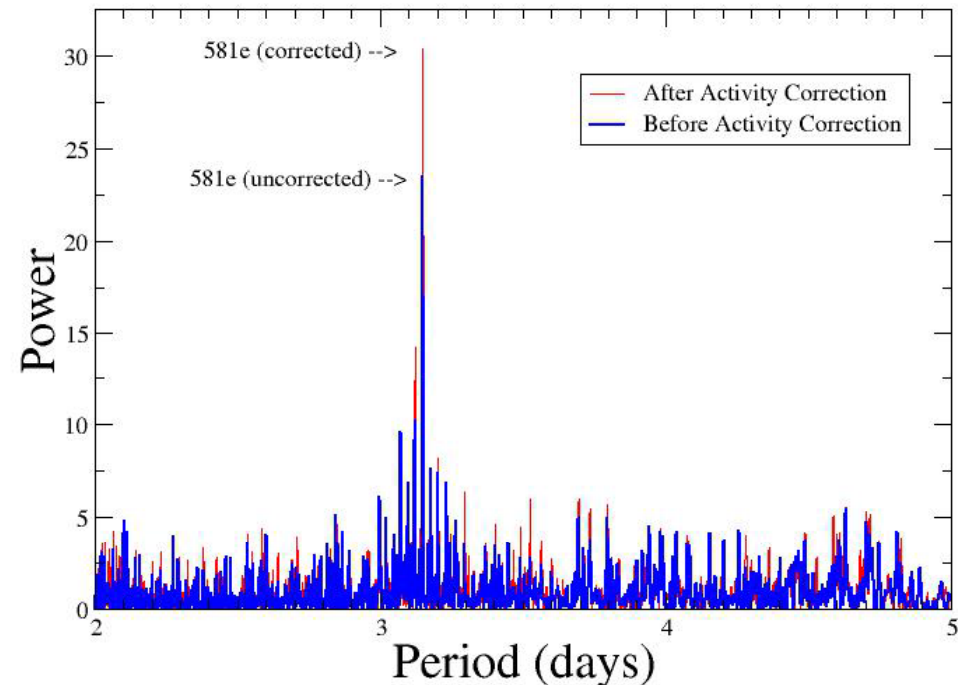


HARPS RVs of “planet d” (blue) and corresponding H-alpha (red)

- Period of “planet d” (66 days) is half the rotation period.
- “Planet g” is at $\text{Prot}/4$
- Circular Keplerian model of d \rightarrow incomplete “activity correction” \rightarrow false detection of g

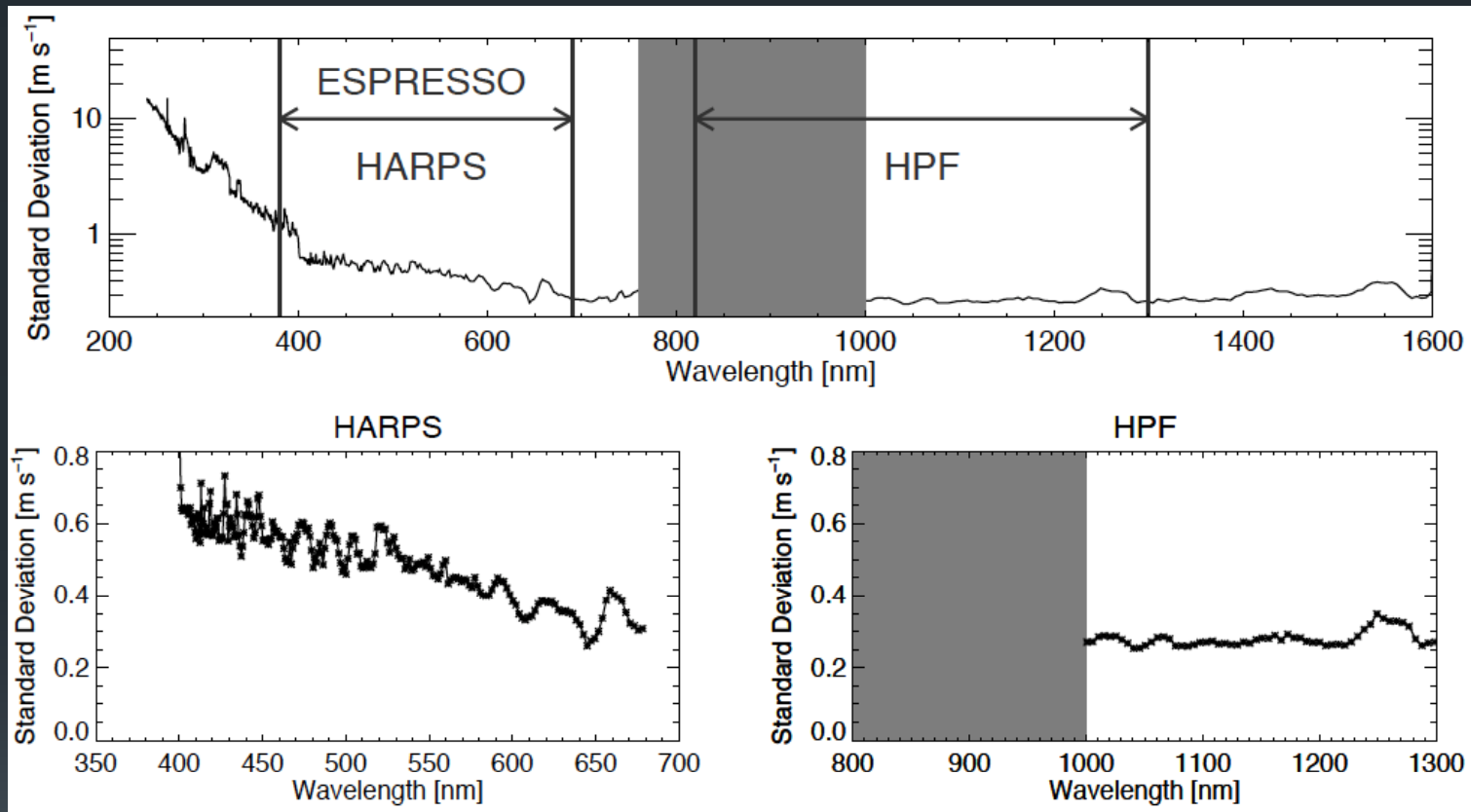
The good news: improved detection of low-mass planets!

- FAP of planet e—2nd-smallest RV planet to date—decreased by factor of ~800!
- Eccentricity of e disappears after activity correction.



L-S periodogram of planet e before (blue) and after (red) activity correction

Conclusions



Marchwinski+ (2014), ApJ, submitted, Poster 5.7

Conclusion 1: Let's go to the NIR and avoid the activity!

Conclusions



- Stellar activity has significant effects on RV signals at or below the m/s level, even for the very quietest stars!
- These effects can be corrected, leading to significantly improved detection efficiency for low-mass exoplanets.
- More work to be done in identifying and modeling activity-RV correlations.

Journal Ref: Robertson, Mahadevan, Endl, & Roy, 2014, *Science*,
345 440

See also: GJ 667C, Robertson & Mahadevan, 2014, *ApJL*, 793, 24