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Stellar activity or a planet? Revisiting dubious planetary signals in GJ581

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We reanalyzed the radial velocities and spectroscopic activity indicators of GJ581, an M-dwarf harboring questionable planetary signals. Our analysis challenges the periodic signals previously identified as likely artifacts of stellar activity rather than planetary influence, reinforcing the need for cautious interpretation.

Magnetic activity alters the shape of spectral lines, leading to apparent radial velocity (RV) variations which can be periodic or quasi-periodic and can mimic planetary RV signals. These signals often manifest at the star's rotational period and its harmonics (Boisse et al., 2011). GJ581, an M-dwarf hosting a multi-planetary system, has a reported stellar rotation period of 132.3 ± 6.3 days (Suárez Mascareño et al., 2015). Notably, it displays two periodic signals attributed to planets d ($P_{\rm orb}$: 66.8 [d]) and g ($P_{\rm orb}$: 36.5 [d]), both harmonics of the stellar rotation period. This raises questions about whether these signals originate from planets or are artifacts of stellar activity.

To confirm or refute these signals, we used publicly RV data from HARPS, HIRES and CARMENES instruments, giving a total of 718 RV datapoints. Furthermore, we included activity indicators such as the $S-$ index, Hα, Na ID.

By modeling Hα timeseries using Gaussian Process (GP) regression with a quasi-periodic (QP) kernel, we derived GJ581's stellar rotation period ($P_{\rm rot} = 132^{+1.82}_{-1.71}$ days), improving the accuracy compared to the literature value.

We computed the Generalized Lomb-Scargle (GLS) periodogram of the RVs, identifying periodic signals corresponding to planets: b ($P_{\rm orb}$: 5.37[d]), c ($P_{\rm orb}$: 12.9[d]), d ($P_{\rm orb}$: 66.3[d]), and e ($P_{\rm orb}$: 3.14[d]). For the other literature planets f and g, the periodogram does not show significant signals attributable to those planets.

We employed Keplerian models to the RVs for the period of planets b, c and e. The best Keplerian fit is presented in Table 1. Then we analyze the temporal stability of the residual signal from the (3-)Keplerian model using the stacked Bayesian GLS (sBGLS) periodogram (Mortier & Collier Cameron, 2017). The level of confidence in detecting a planetary signal should increase with additional data. However, Fig.1 shows that the probability around the 66-day signal attributed to planet d does not steadily rise with an increasing number of observations. Instead, it is

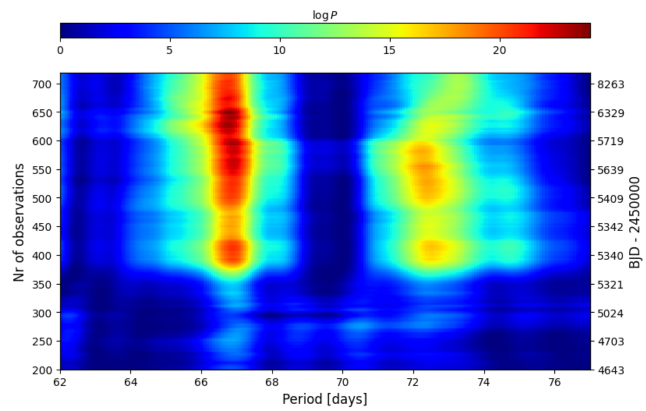

Figure 1. sBGLS periodogram of the RVs residual from the (3-planet)Keplerian model.

Planet	Period (days)	K(m/s)	$M_p(M_\oplus)$
b	5.36861±0.00002	12.39±0.07	15.5±0.6
c	12.9180±0.0004	3.49±0.07	5.9±0.2
e	3.14880±0.00004	1.56±0.08	1.6±0.1

Table 1. GJ581 orbital parameters derived from (3-) Keplerian model. K is the semi-amplitude of the signal and M_p is the mass of the planet in Earth masses.

alongside another signal around 72 days, with a pattern consistent of a stellar activity-induced signal.

Motivated by this, the next step is performing a simultaneous RV (Keplerian model) and activity indicators (GP+QP kernel) analysis to determine if the 66- day signal can be described by stellar activity.

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