A Terrestrial-mass Planet Orbiting GJ 1151: The Possible Source of Coherent Low-frequency Radio Emission from an Inactive Star

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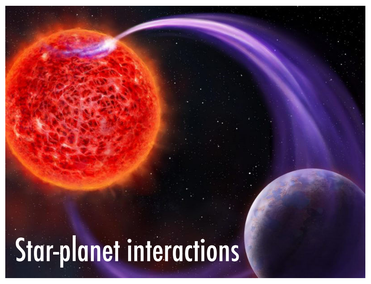
Star-planet interactions are capable of creating coherent emissions at radio wavelengths—a promising path to detecting and characterizing planets

Star-planet magnetic interactions (SPI) are capable of funneling charged particles (e.g., from the stellar corona) towards the host star, creating an auroral hot spot on the surface of the star. These interactions are further capable of creating coherent radio emission via electron cyclotron maser emission. Although a promising avenue to detect exoplanets, no exoplanets have been detected with this method to date.

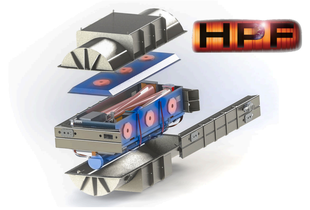


Recently, Vedantham et al. 2020 announced the detection of coherent radio emission from the inactive M4.5 dwarf star GJ 1151 using observations from the LOFAR (Low-Frequency ARray) radio array at 150MHz. The observations can be explained with SPI from a rocky planet in a short-period (1-5day) orbit. We have been observing GJ 1151 as part of the 5-year HPF survey to detect rocky planets around nearby mid-to-late M-dwarfs.

GJ 1151 Stellar Parameters	
Rotation Period	117days
Spt. Type	M4.5
Radius	0.202Rsun
Jmag	8.5
Distance	8pc

The Habitable-zone Planet Finder (HPF) is a near-infrared spectrograph on the 10m Hobby-Eberly Telescope at McDonald Observatory.

Wavelength range: 810-1280nm
Resolution: 55,000
Temp. stability: 1mK (Stefansson et al. 2016)
Calibrator: Laser-Frequency Comb (LFC)
RV Precision: ~1.5m/s (Metcalf et al. 2019)

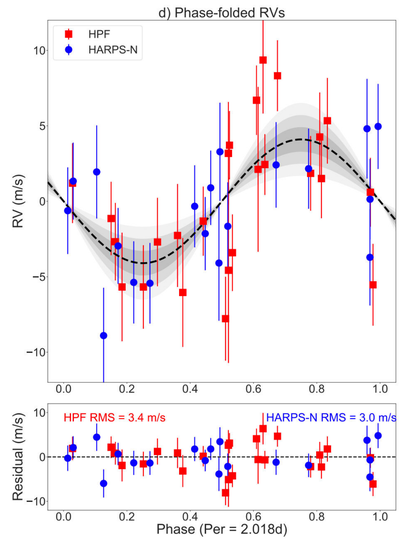


Precision RVs reveal a rocky planet orbiting GJ 1151bin a 2.02-day orbit

Using precision RVs from HPF and literature RVs from HARPS-N (Pope et al. 2020), we have detected a terrestrial planet orbiting GJ 1151 with a period of 2.02 days.

Planet Parameters	
P_{orb}	2.0180+-0.005days
K	4.1+-0.8m/s
Msini	2.5±0.5MEarth
a/R*	18.5+-0.9

Phased HPF and HARPS-N RVs

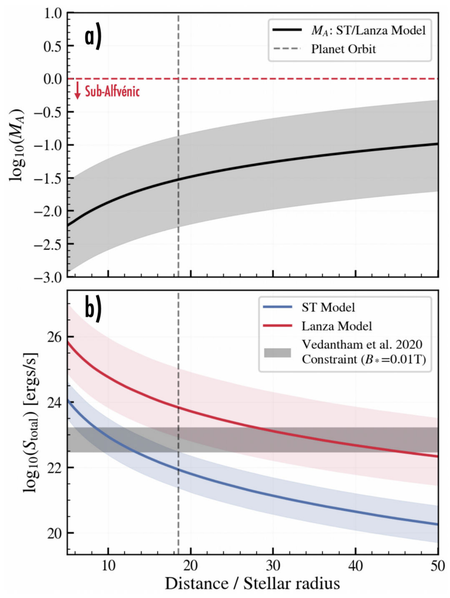


GJ 1151b is capable of star-planet interactions

The planet suffices the sub-alfvenic criterion and is capable of star-planet interactions.

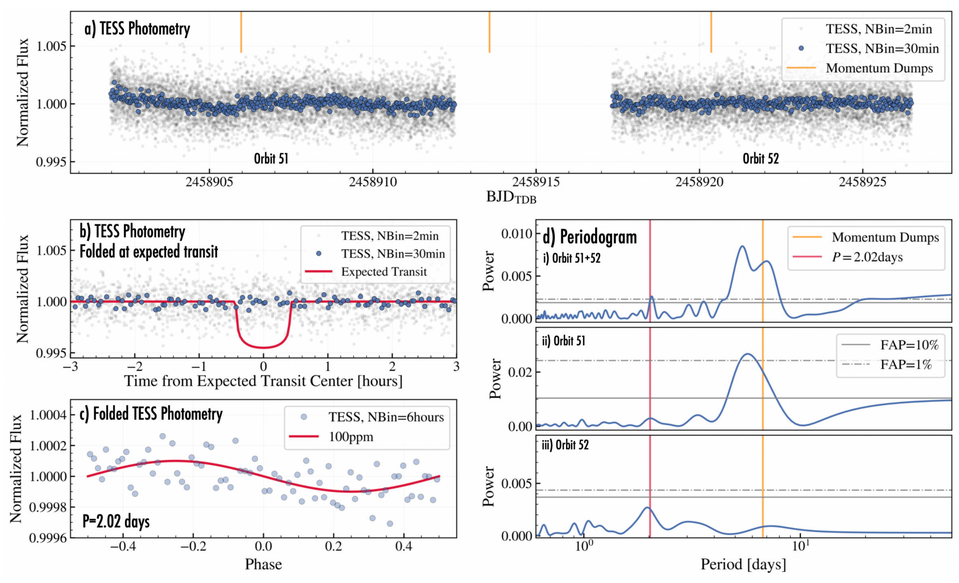
Plot a): Alfvén Mach number of the planet as a function of distance from the star. The planet (orbit at the dotted line) is confidently sub-alfvénic (log M_A < 0).

Plot b): We considered two different models describing the energetics of the sub-alfvénic star-planet interactions. The expected interactions are consistent with the radio observations in Vedantham et al. 2020 (grey shaded region).



TESS data rules out transits, but shows modulations at the planet period

Observations from TESS rule out a transiting configuration of the planet, but hint at a modulation seen at the planet period, which could be the optical counterpart of the stellar hot-spot created by the star-planet interaction.



Future Work: synergy between RVs and radio observations

We have detected a terrestrial planet in a short-period orbit around the inactive M-dwarf star GJ 1151. This planet could be interacting with its host star via sub-alfvénic magnetic interactions, explaining coherent radio emissions previously observed from the host star.

Further observations in the radio are needed to confirm that the radio observations originally detected from LOFAR are periodic. Now knowing the ephemeris and properties of the planet, this is easier to confirm with targeted radio observations.

We are excited to continue observing nearby M-dwarfs to find other planets that are interacting with their host stars. RV surveys in the near-infrared targeting nearby M-dwarfs—such as the ongoing 5-year HPF survey—are well matched to radio surveys observing such systems (e.g., with LOFAR, and in the future with the Square Kilometer Array) to detect and characterize systems showing evidence of star-planet interactions.

Cool Stars 20.5

References:
Mahadevan et al. 2012
Mahadevan et al. 2014
Metcalf et al. 2019
Pope et al. 2020
Stefansson et al. 2016
Stefansson et al. 2020a
Vedantham et al. 2020

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