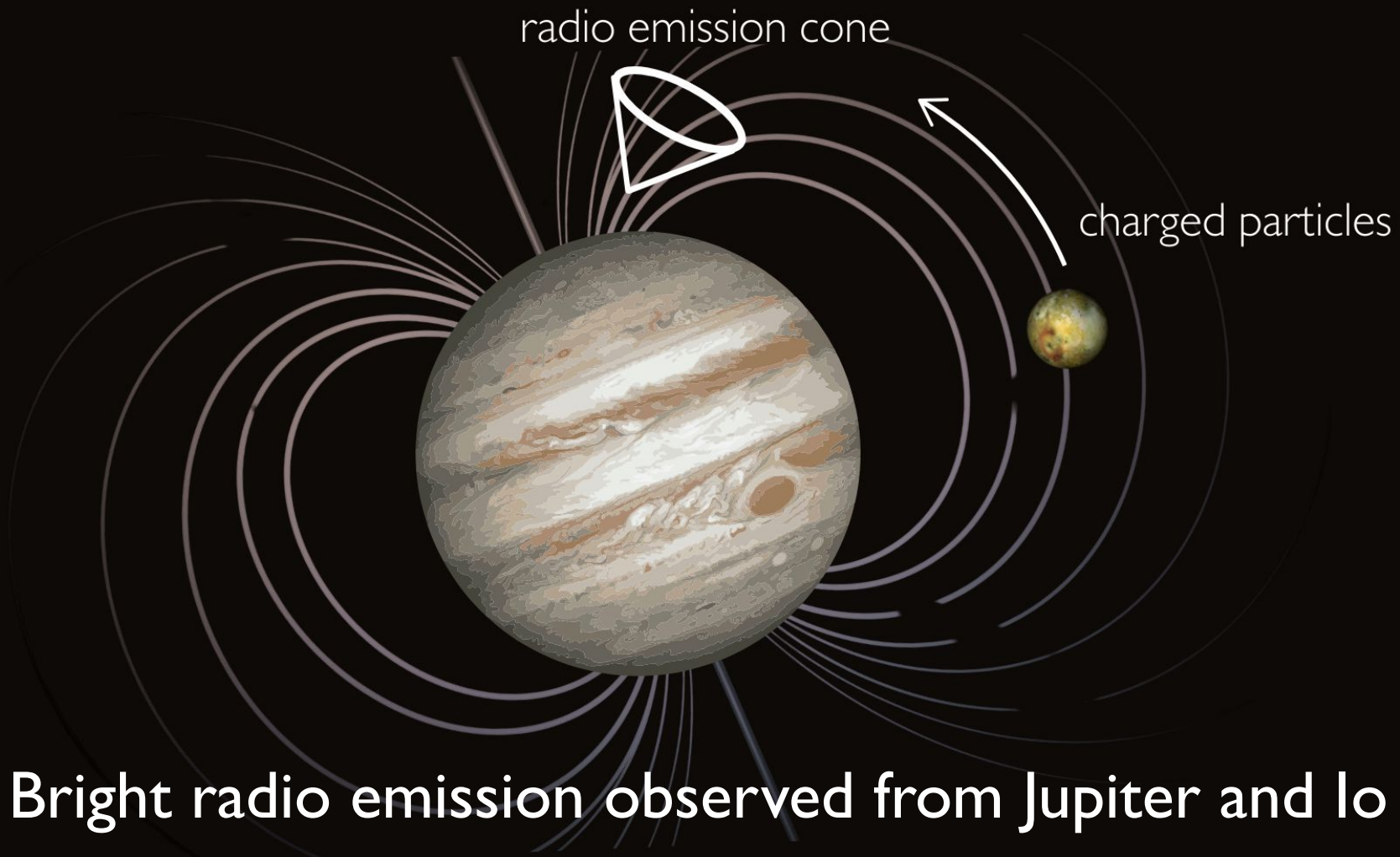


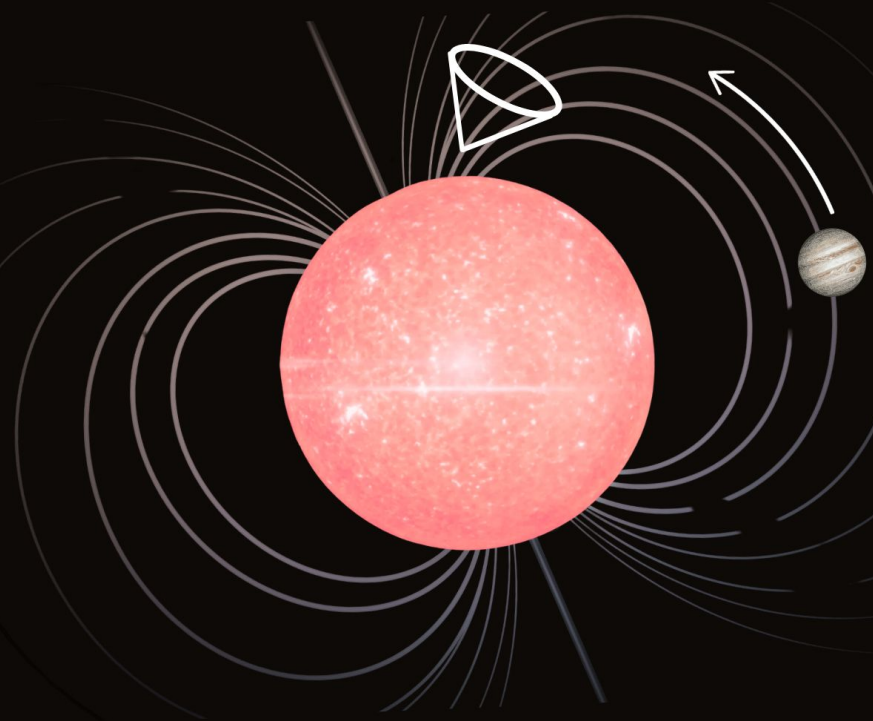
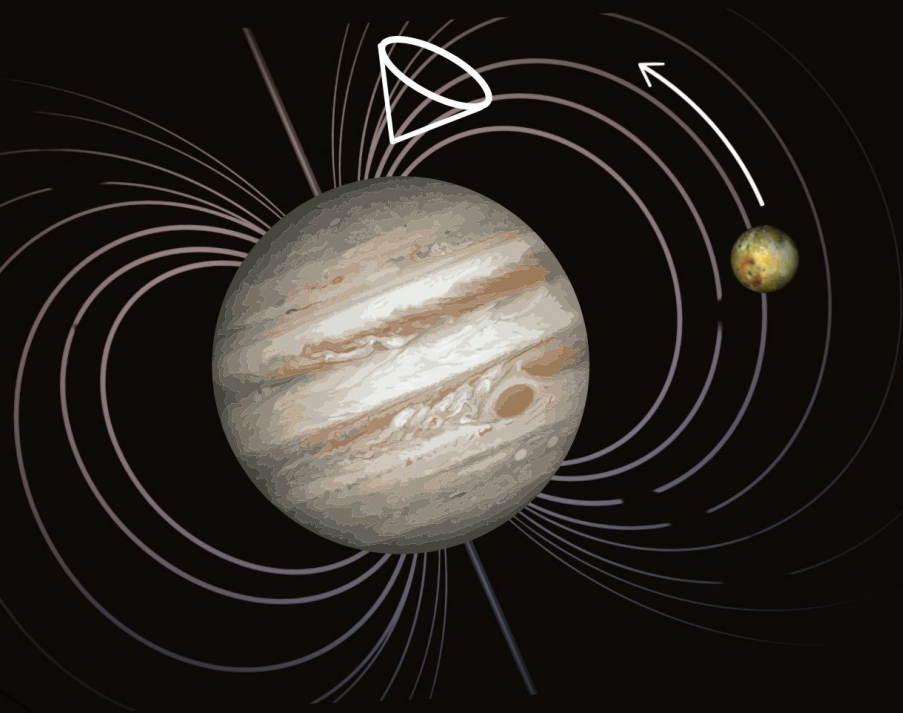


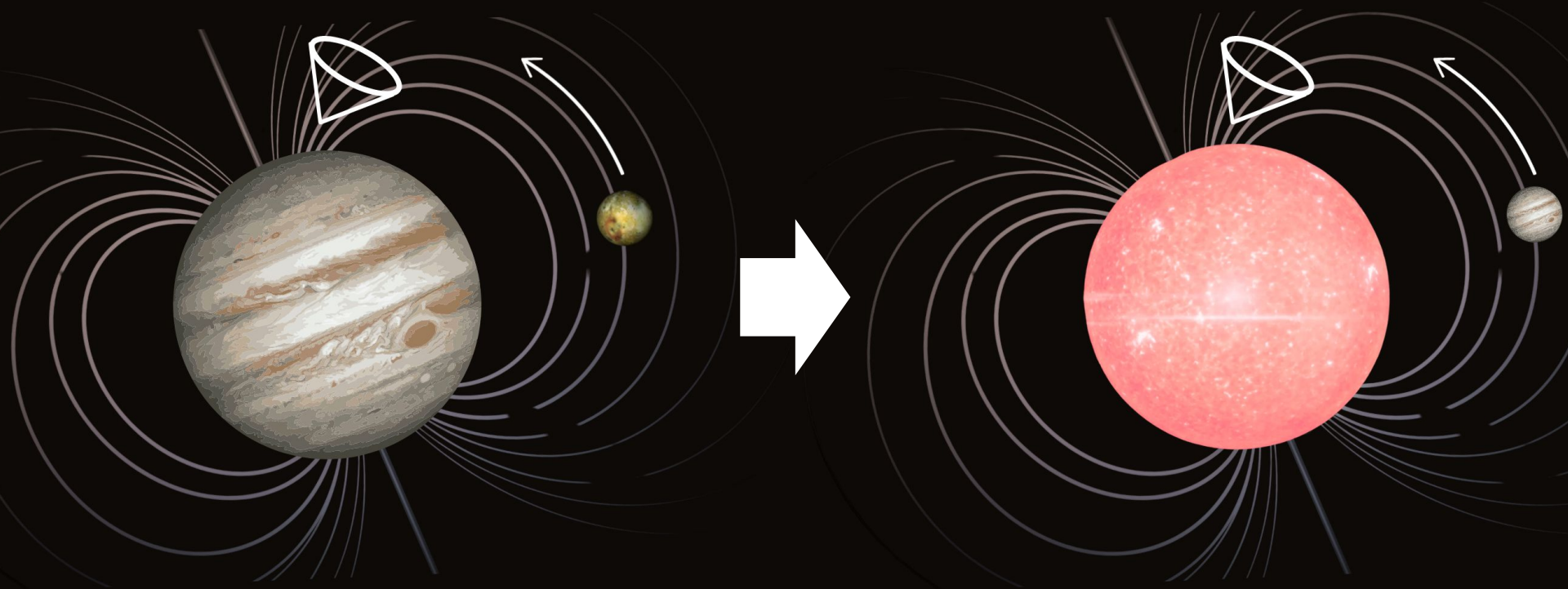
Know Thy Radio-Emitting M star

Spectroscopic Insights into Star-Planet Interaction Candidates

Elise Koo, G. Stefansson, M. Delamer, S. Mahadevan, P. Robertson, J. Callingham, H. Vedantham, R. Kavanagh
PhD candidate at the University of Amsterdam

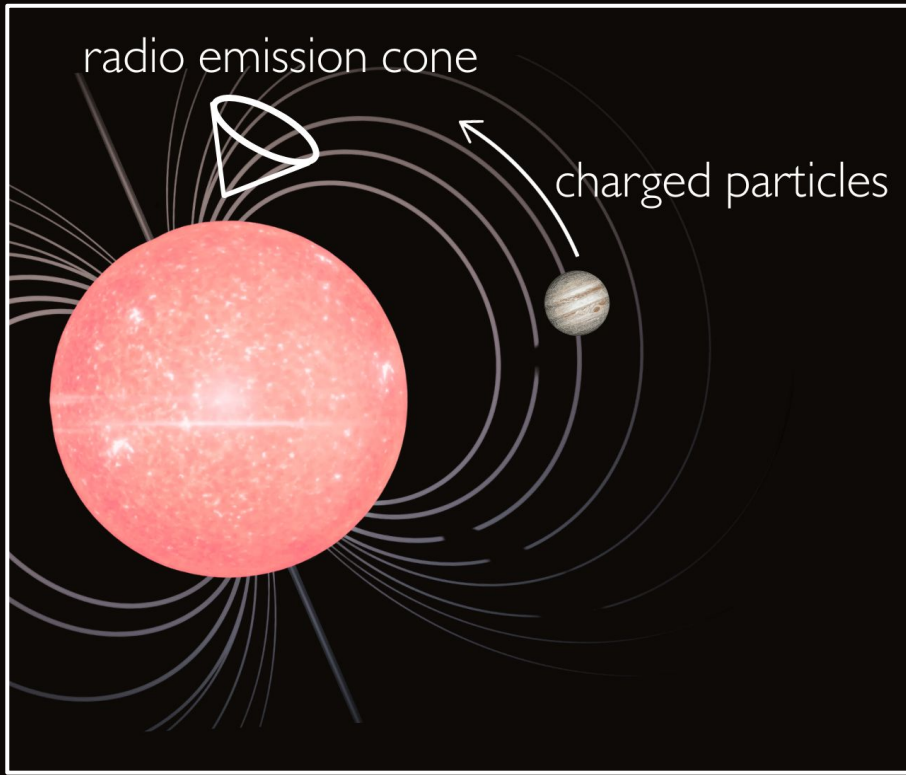






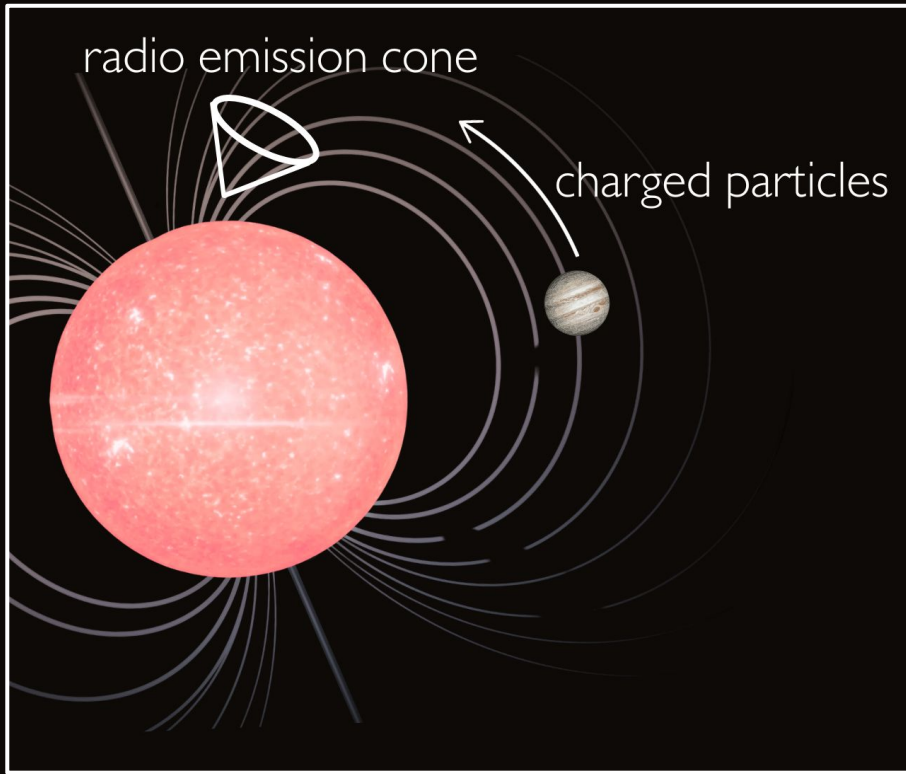
Bright radio emission also expected from
star-planet systems

Two mechanisms to produce radio emission

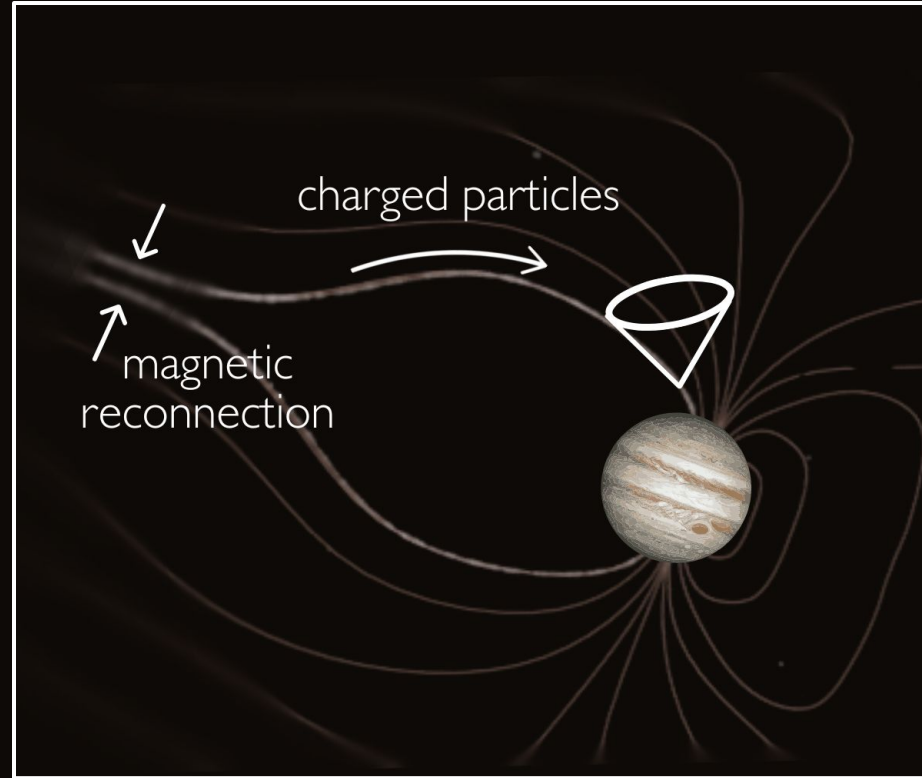


Star-Planet Interactions (SPI)

Two mechanisms to produce radio emission

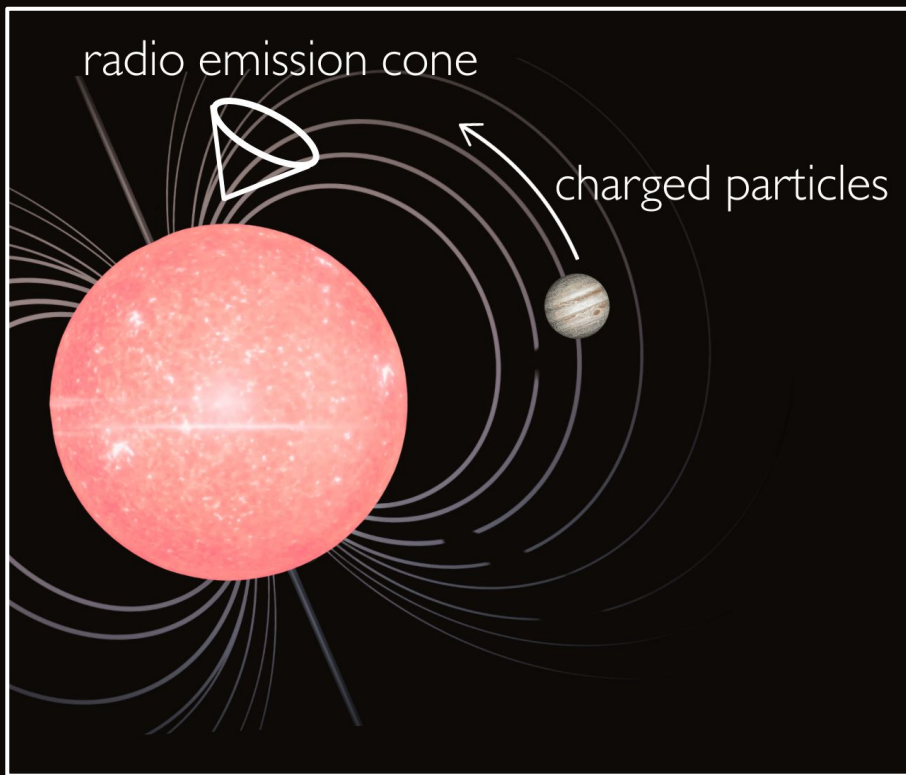


Star-Planet Interactions (SPI)



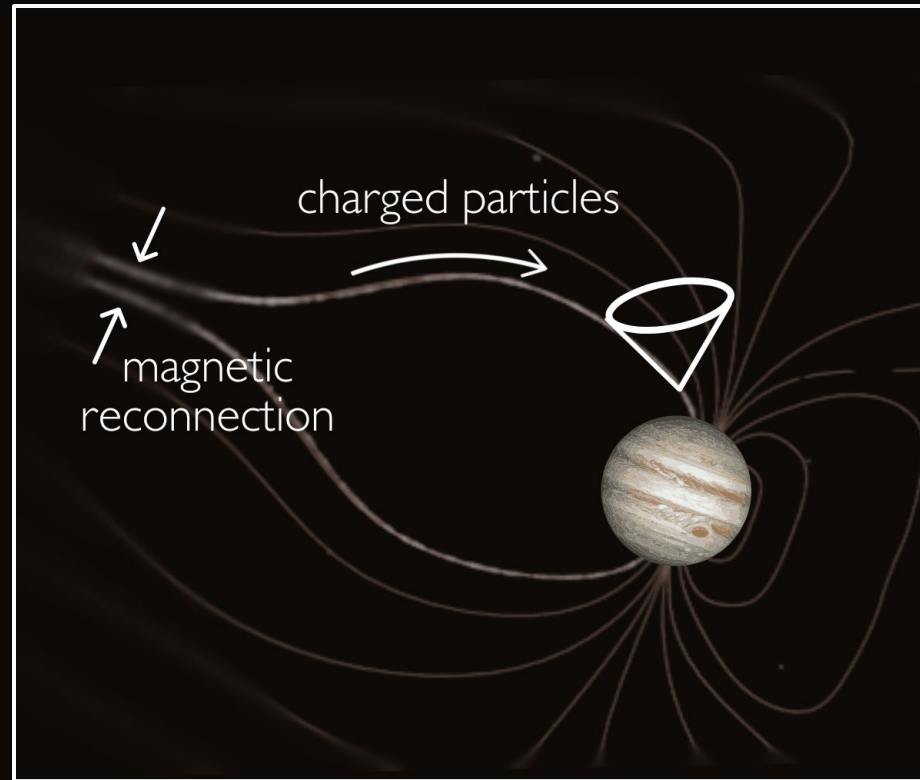
Magnetospheric Interactions

Two mechanisms to produce radio emission



Star-Planet Interactions (SPI)

Close-in planets



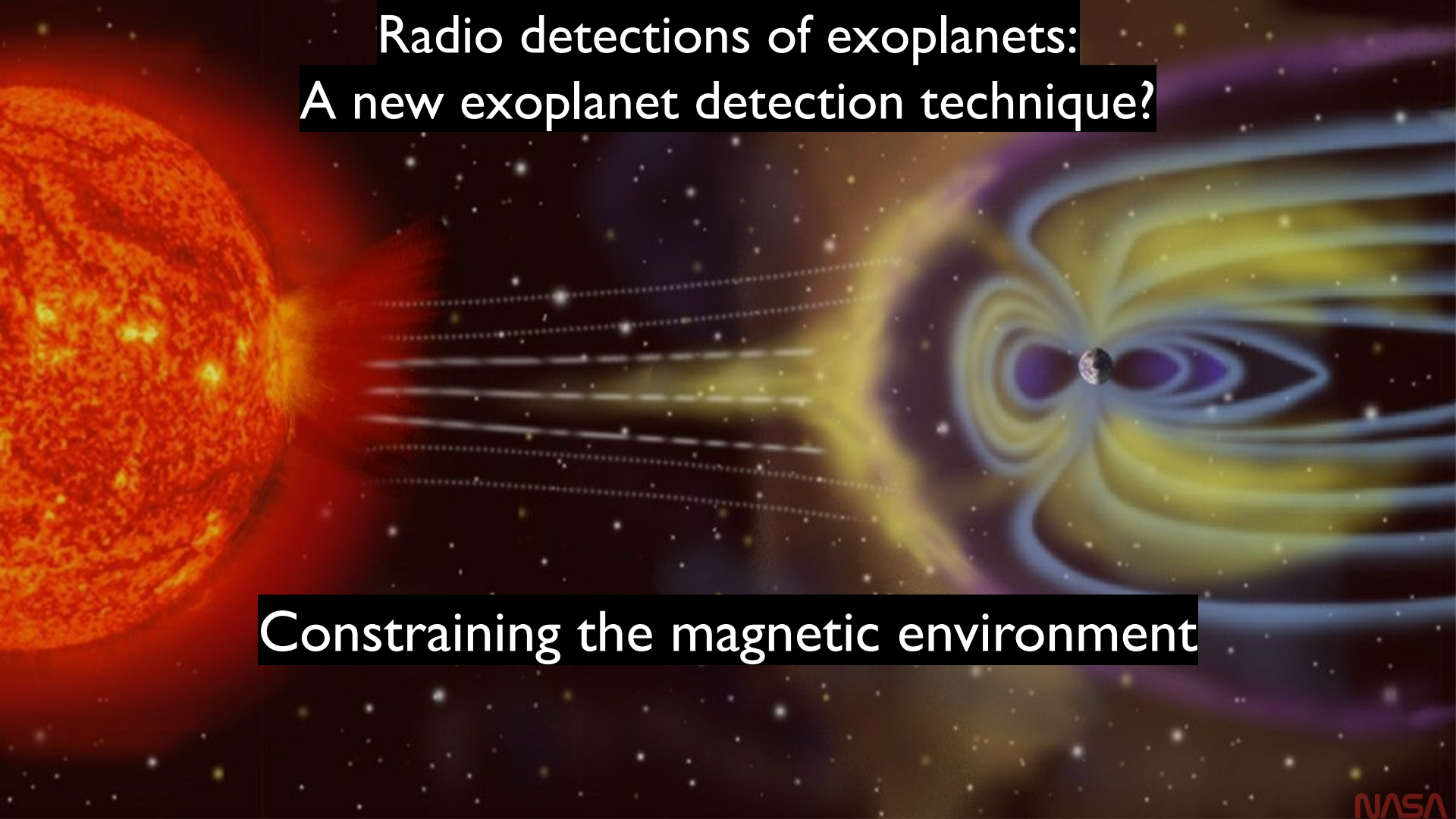
Magnetospheric Interactions

Massive, far-out planets

Radio detections of exoplanets:
A new exoplanet detection technique?

Radio detections of exoplanets: A new exoplanet detection technique?

Constraining the magnetic environment



Radio detections of exoplanets: A new exoplanet detection technique?

Constraining the magnetic environment

Currently no robust detections of magnetic SPI

Challenge in observing SPI: Low Frequency Radio Emission



LOW Frequency ARray (LOFAR) is for the first time reaching frequencies sensitive to SPI



10 to 240 MHz

LOW Frequency ARray (LOFAR) is for the first time reaching frequencies sensitive to SPI



10 to 240 MHz

19 radio-emitting M stars uncovered (*Callingham+2021*)

LOW Frequency ARray (LOFAR) is for the first time reaching frequencies sensitive to SPI



**What is causing the radio emission?
Is it SPI?**

10 to 240 MHz

19 radio-emitting M stars uncovered (*Callingham+2021*)

The 'smoking gun evidence' for SPI:
repeated radio emission

The 'smoking gun evidence' for SPI: repeated radio emission



Continued monitoring with
LOFAR

The 'smoking gun evidence' for SPI: repeated radio emission



Continued monitoring with
LOFAR



RV observations to confirm planets
compatible with SPI

The 'smoking gun evidence' for SPI: repeated radio emission



Continued monitoring with
LOFAR



RV observations to confirm planets
compatible with SPI

Two arrows point from the text above to the main sentence below.

The Radio EXoplanet (T-REX) survey is following up the radio-emitting M stars

We obtained high-precision RVs with the Habitable-zone Planet Finder (HPF) on the 10m Hobby Eberly Telescope



Wavelength range:

810-1280 nm

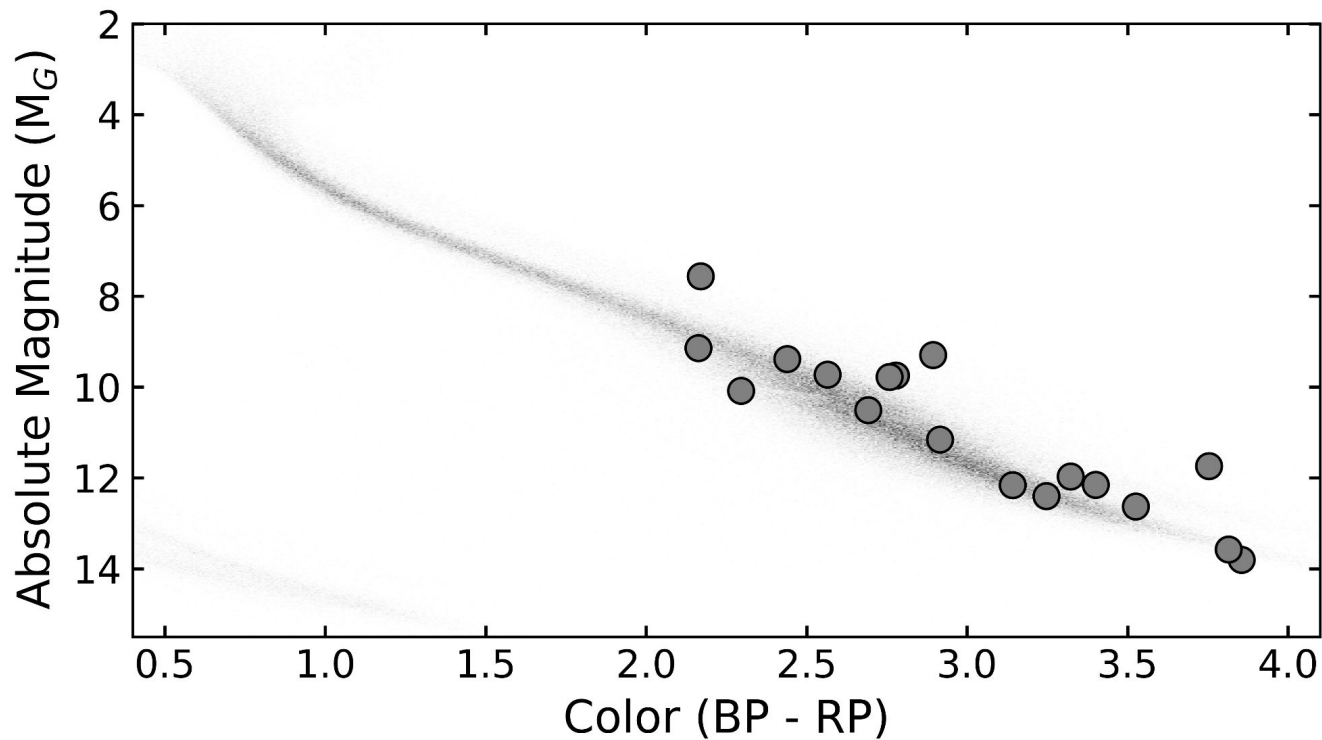
Resolution:

55,000

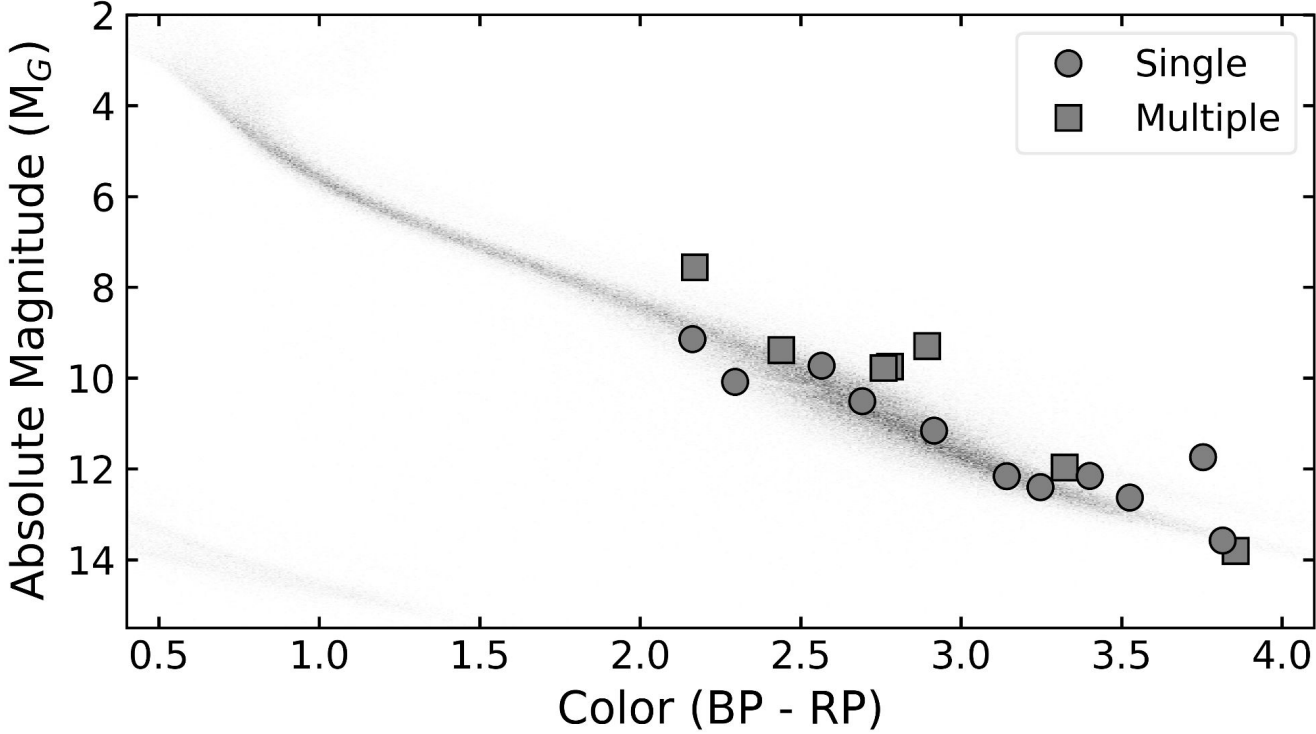
RV precision:

~1 m/s

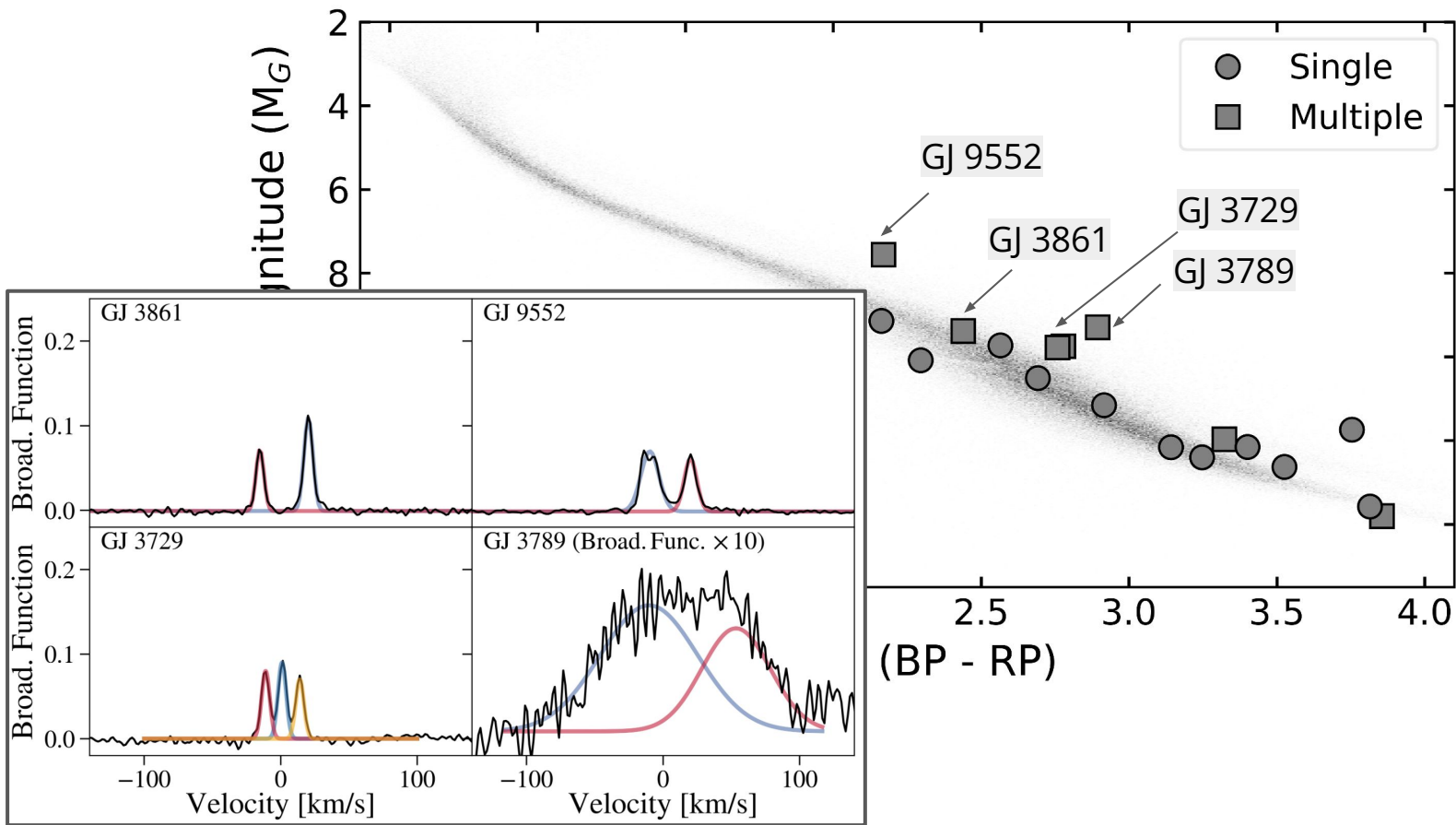
HPF observations show the sample varies in multiplicity and activity



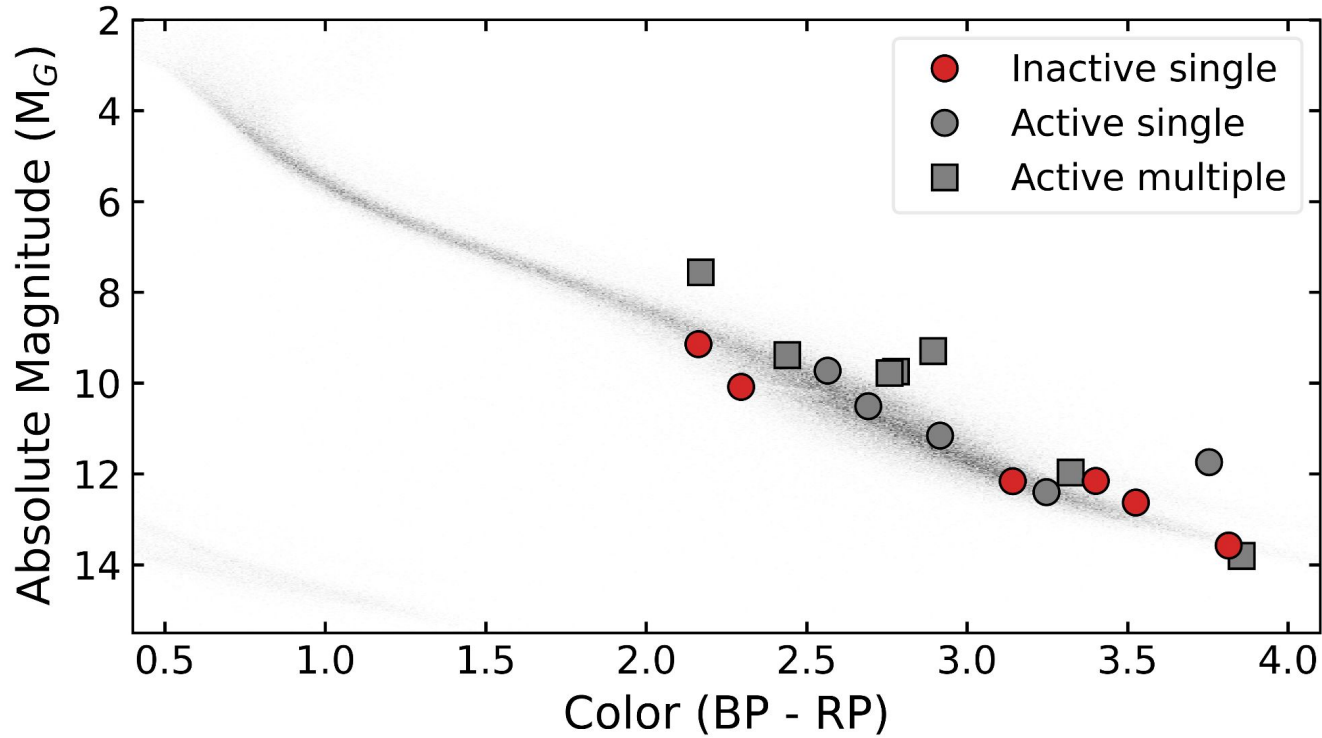
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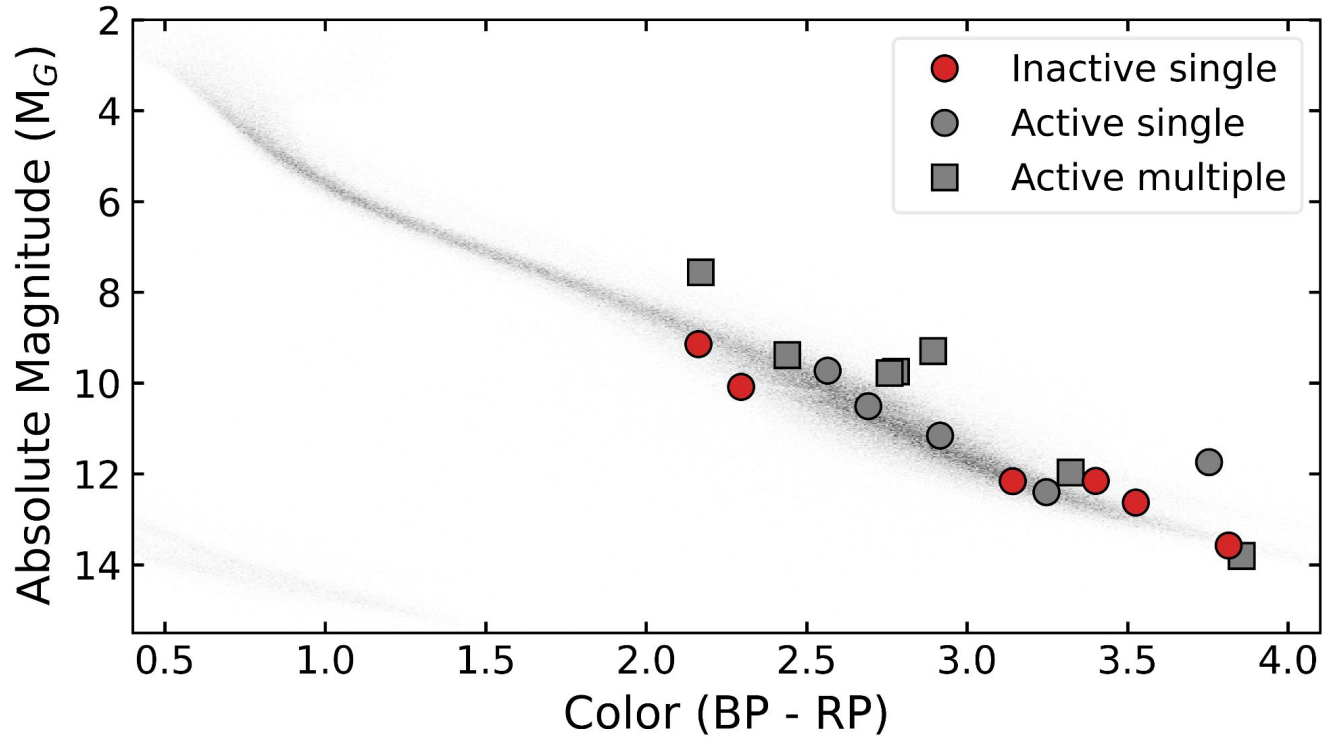
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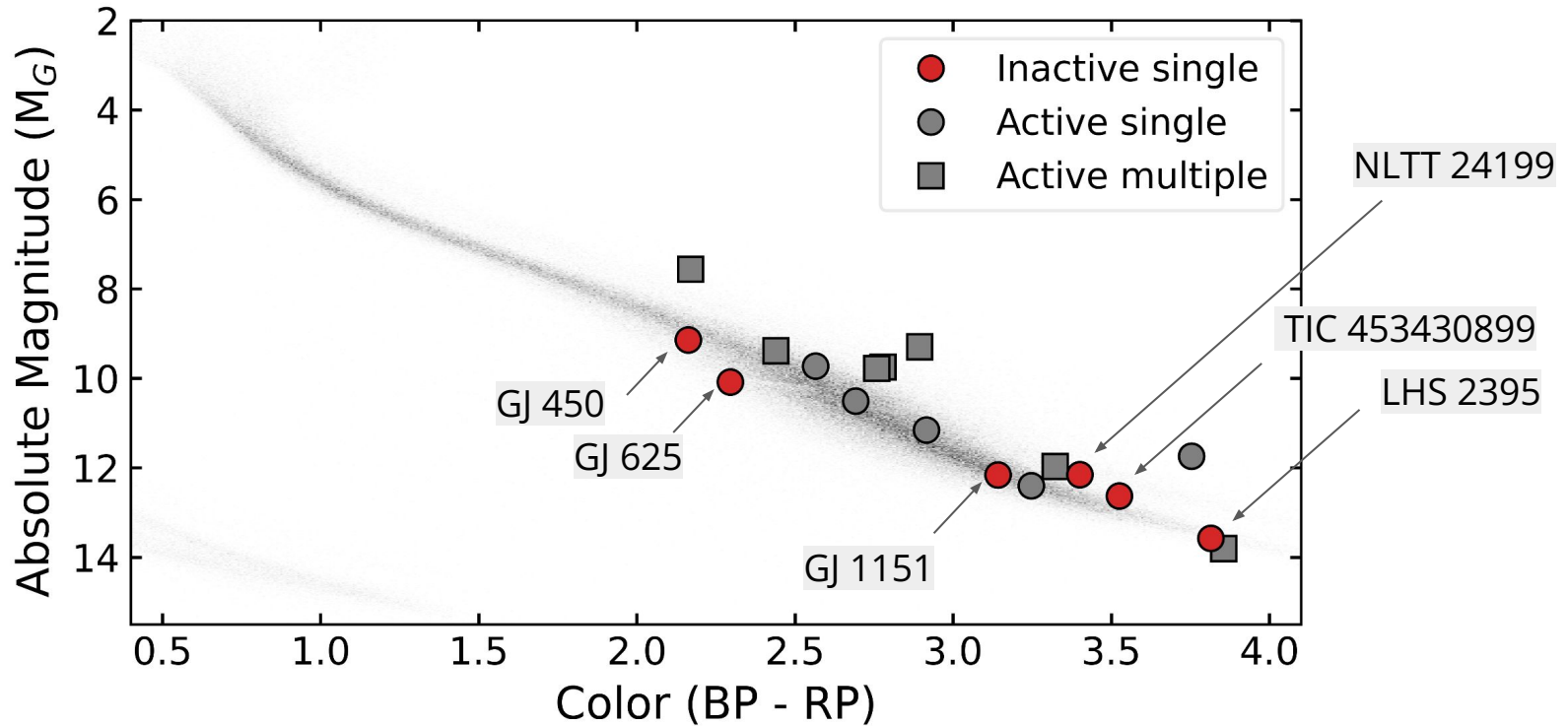


HPF observations show the sample varies in multiplicity and activity



The **inactive, slowly rotating stars** are prime targets for SPI

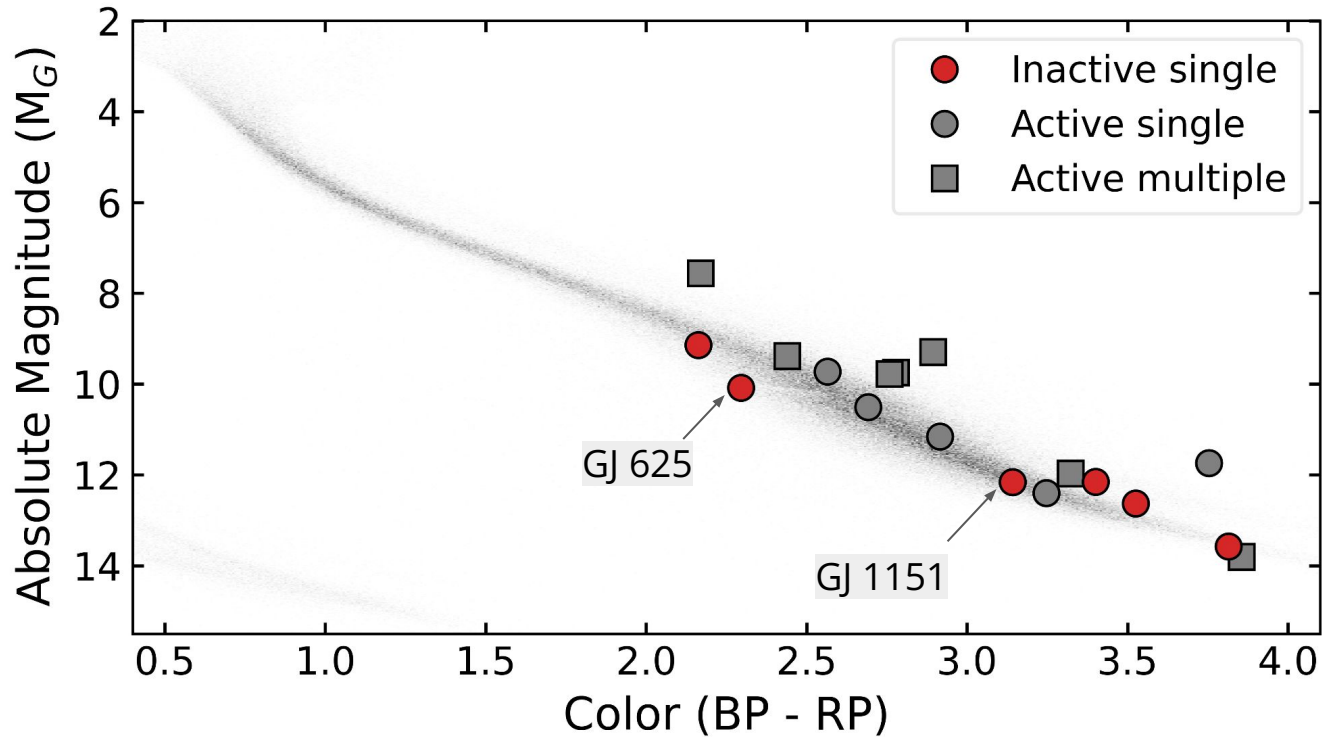
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The **inactive, slowly rotating stars** are prime targets for SPI

Ongoing **search for planetary companions** around these SPI candidates

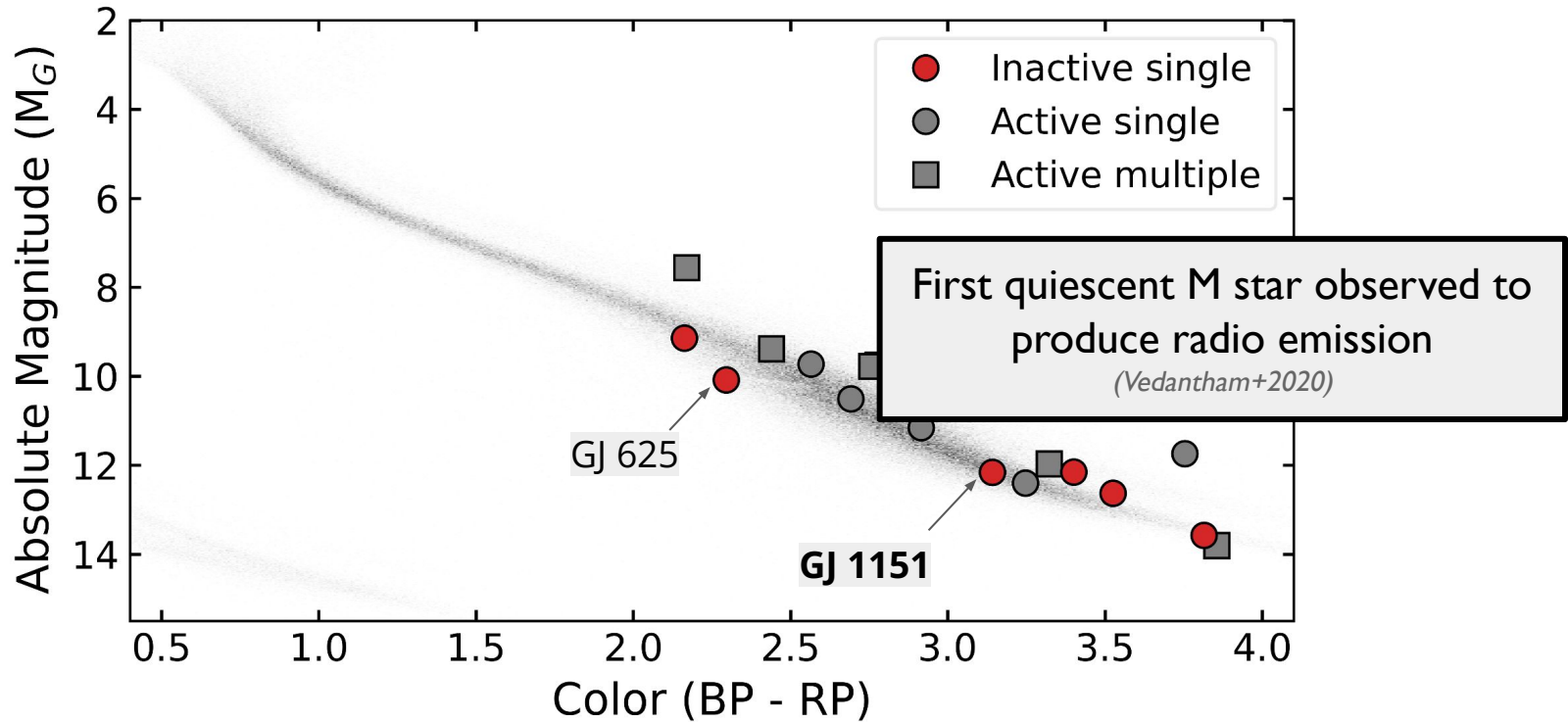
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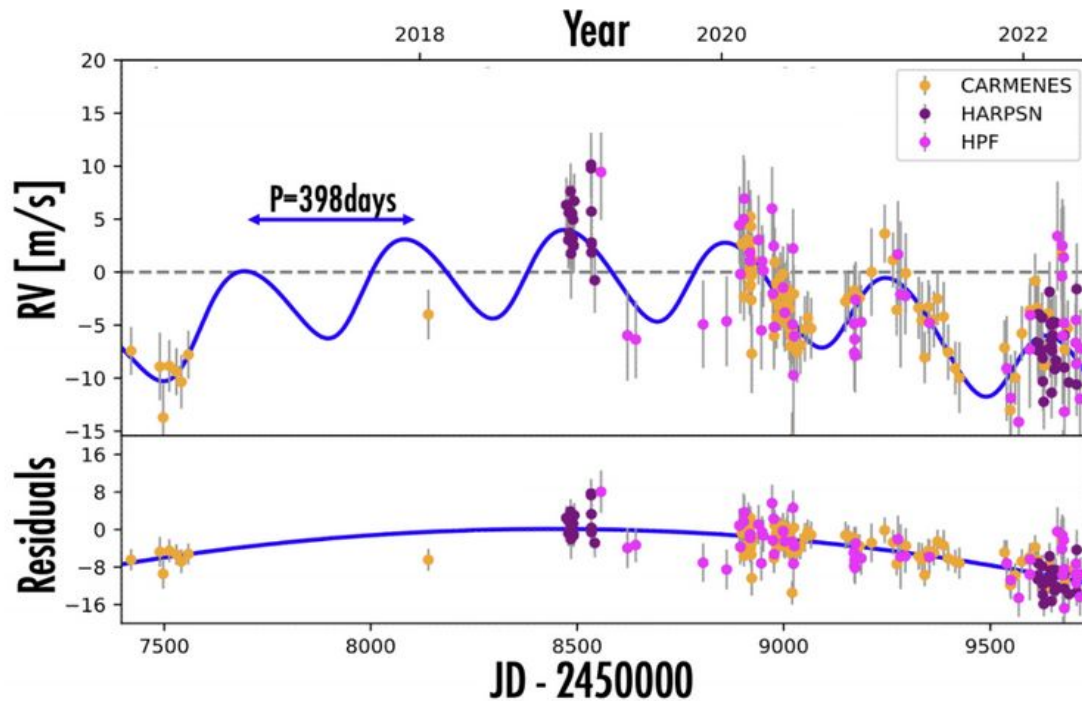
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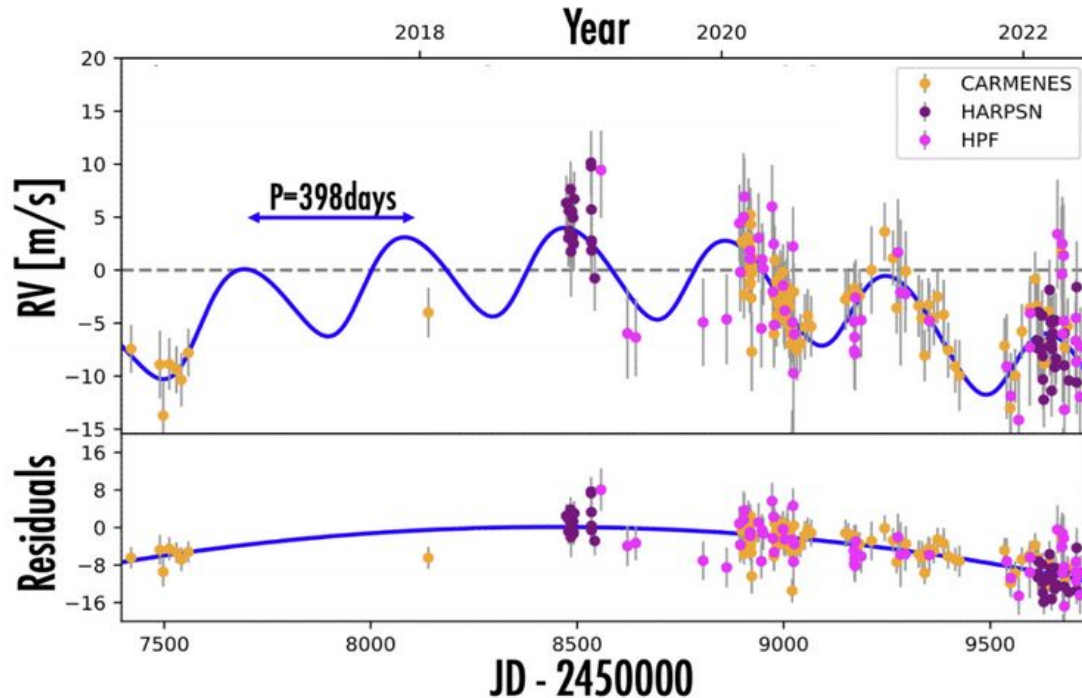
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GJ 1151 RVs reveal a 398d sub-Neptune and a long-term RV curvature

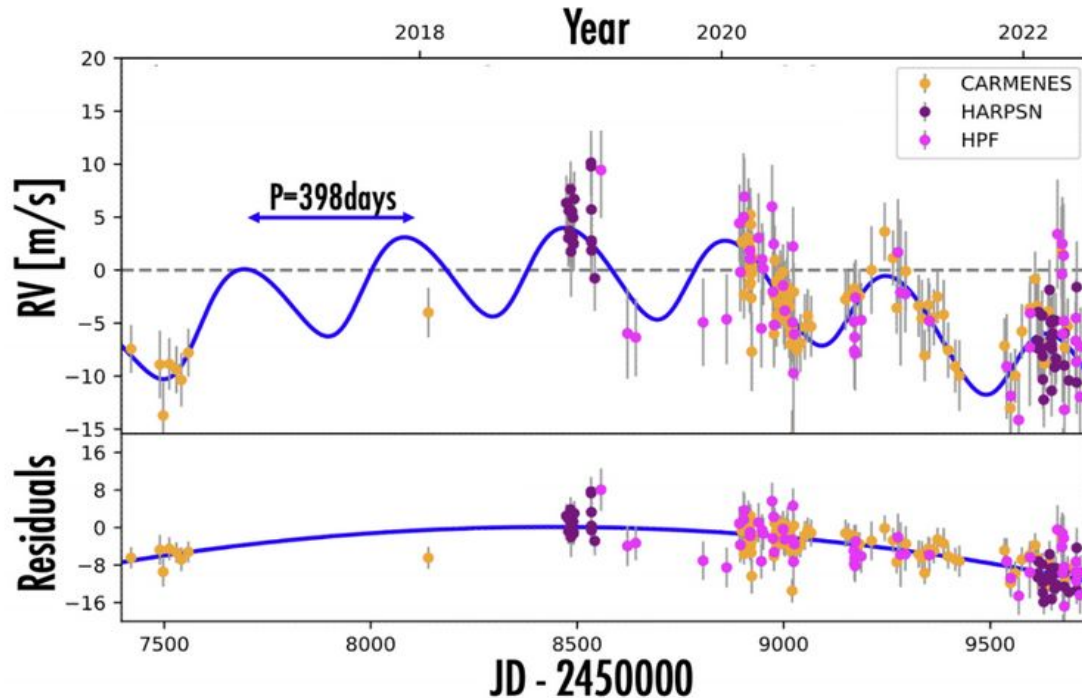


GJ 1151 RVs reveal a 398d sub-Neptune and a long-term RV curvature



The **sub-Neptune** is not consistent with SPI.

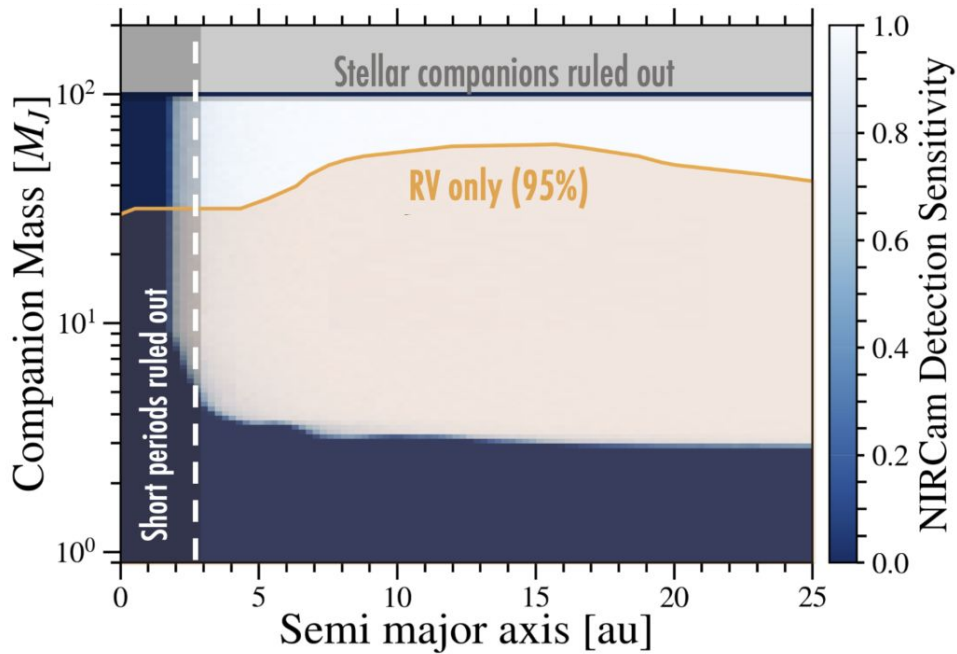
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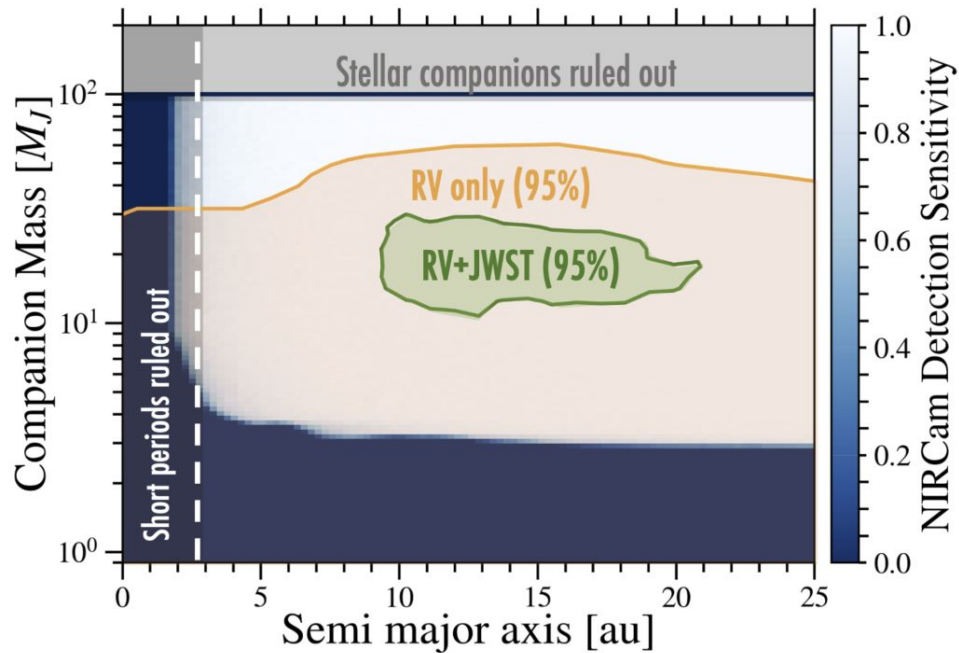
The **sub-Neptune** is not consistent with SPI.

Is the **outer massive companion** the source of radio emission?

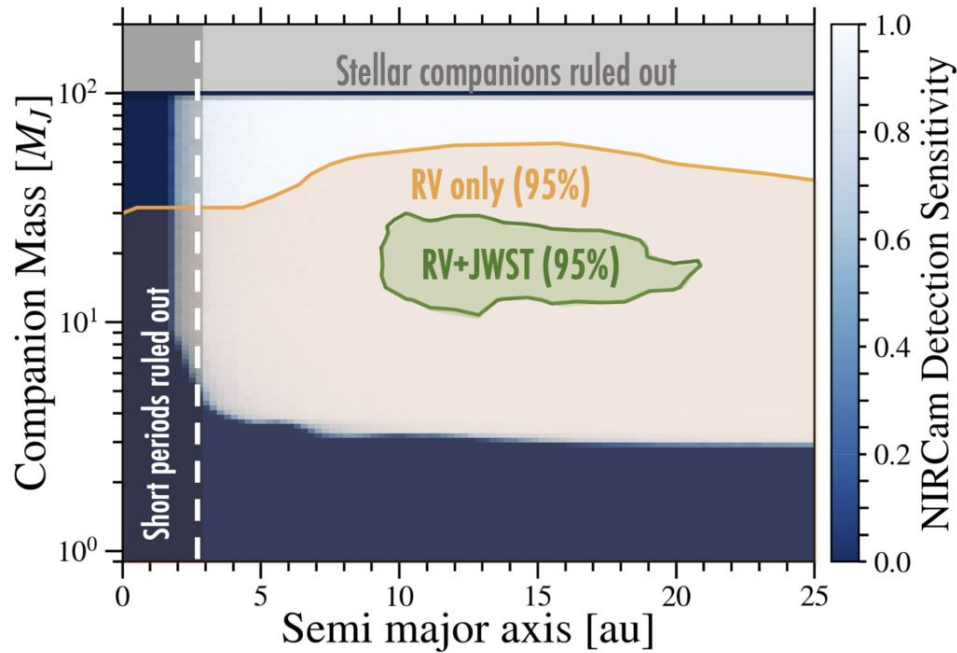
We will observe GJ 1151 with JWST/NIRCAM to further characterize the distant companion



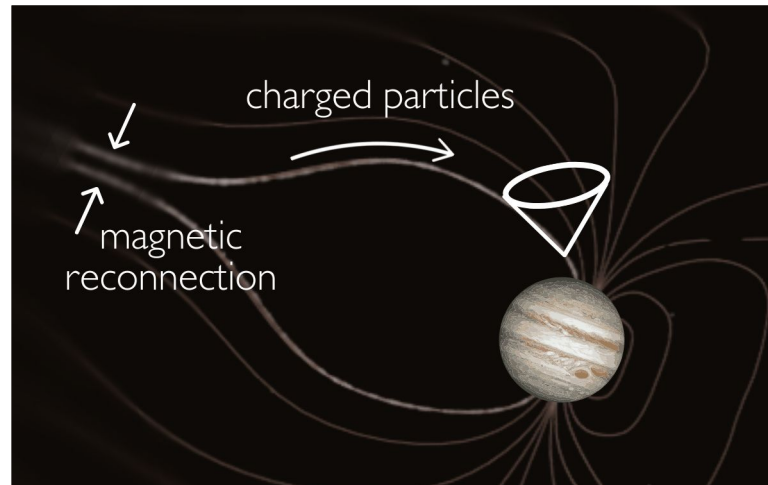
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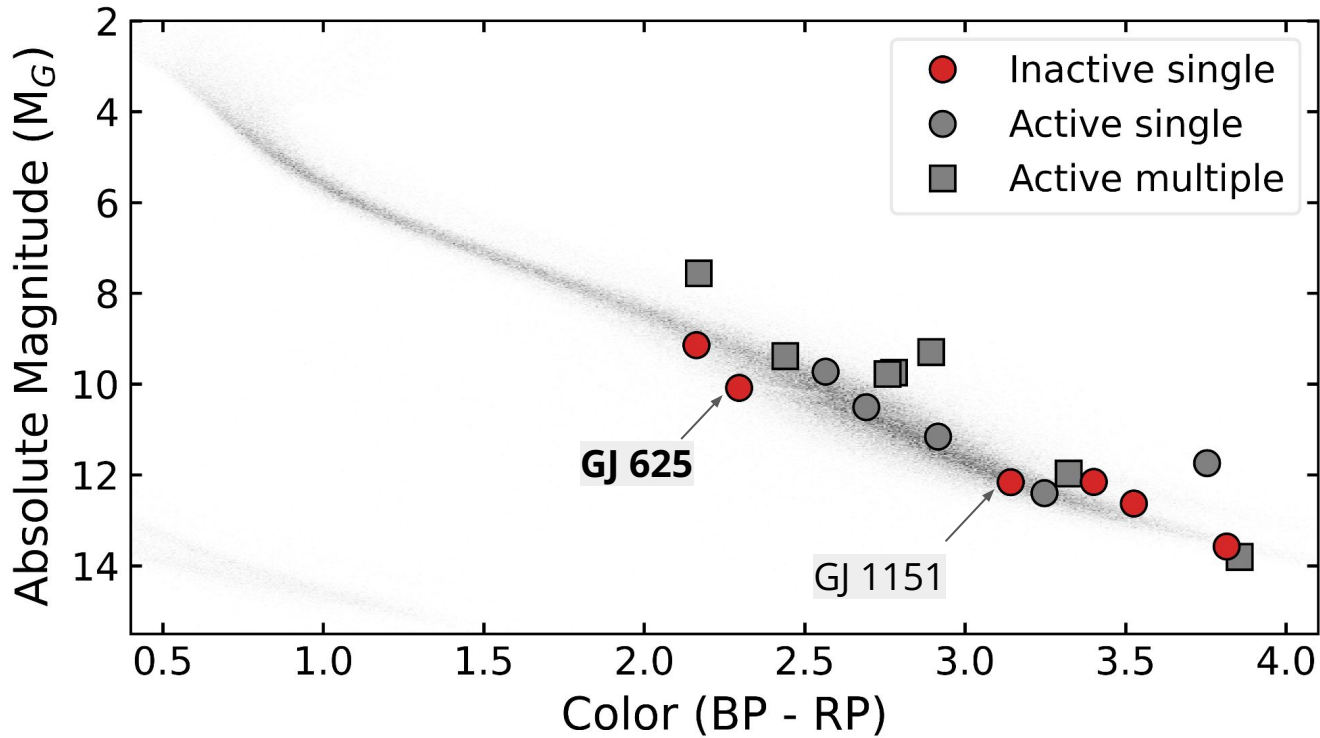
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If this is a brown dwarf or giant planet:

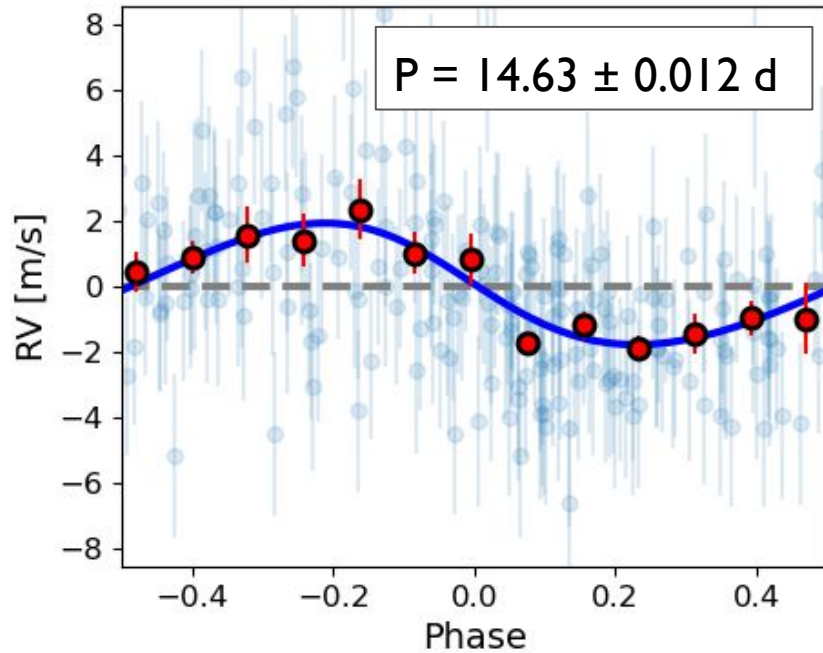


Consistent with
magnetospheric interaction

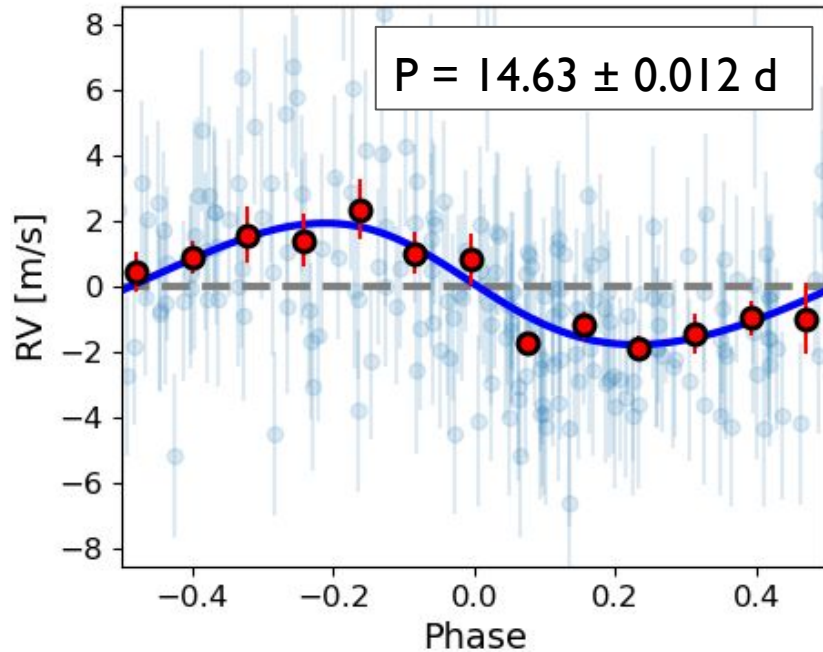


Ongoing **search for planetary companions** around SPI candidates

HARPSN RVs have revealed an **orbiting planet** around GJ 625 (Suárez-Mascaresño+ 2017)

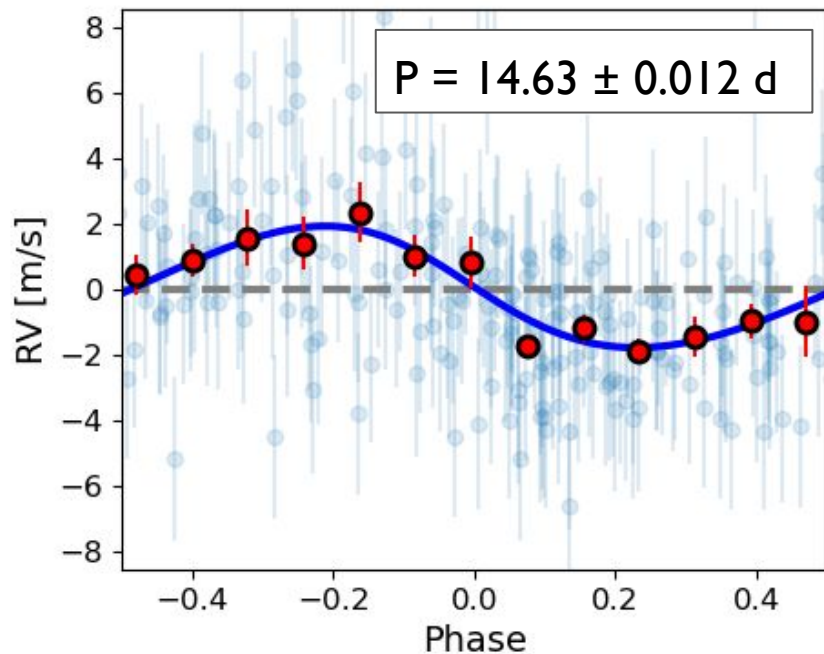


HARPSN RVs have revealed an **orbiting planet** around GJ 625 (Suárez-Mascaresño+ 2017)



Is this planet compatible with SPI?

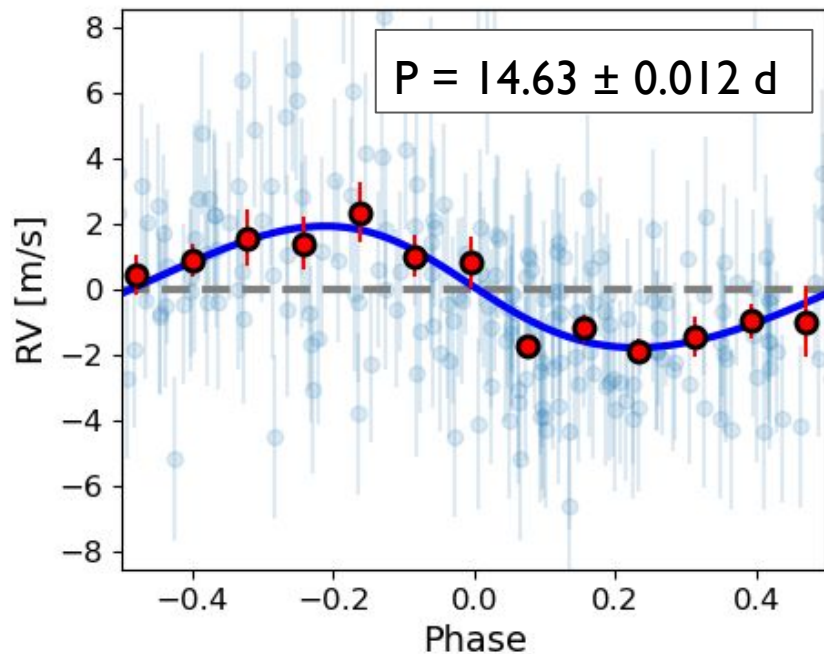
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Example: magnetic SPI can occur around AU Mic at an orbital period of 18.9 d
(Kavanagh+2021)

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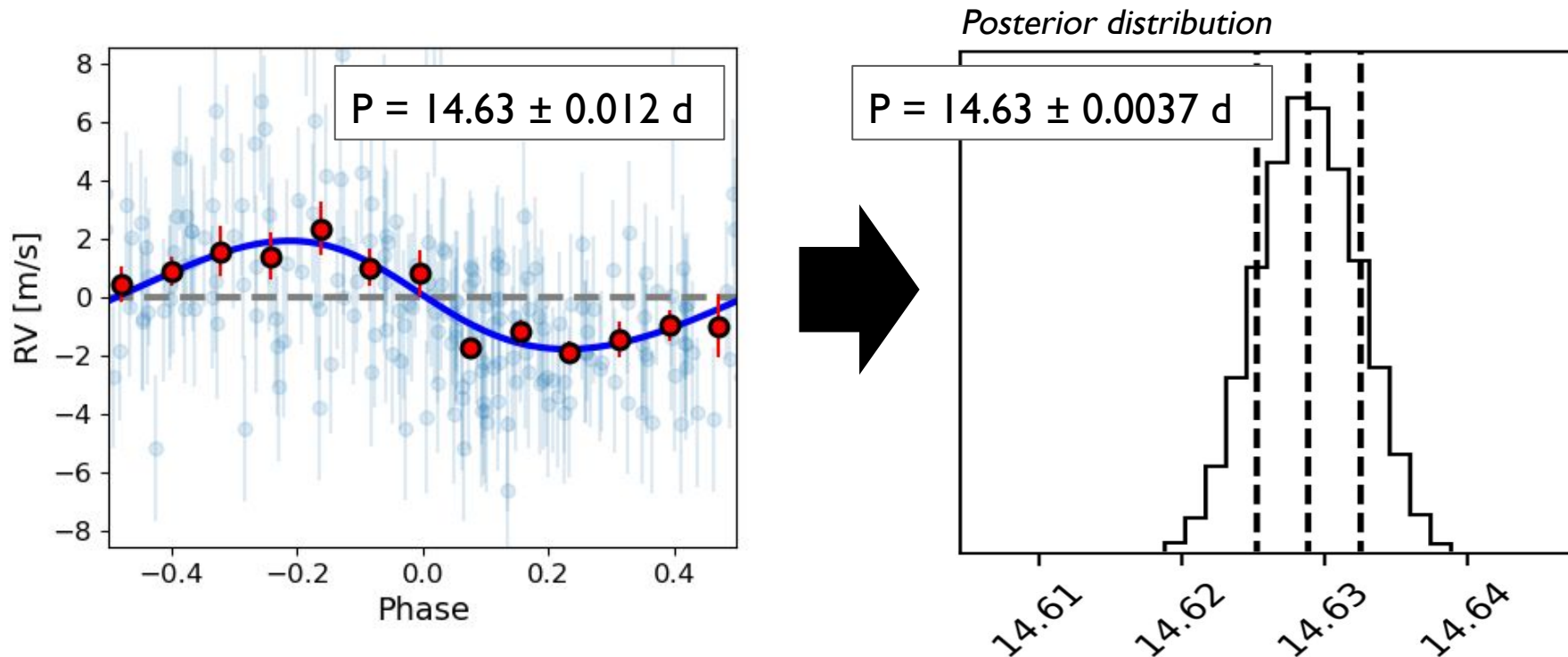


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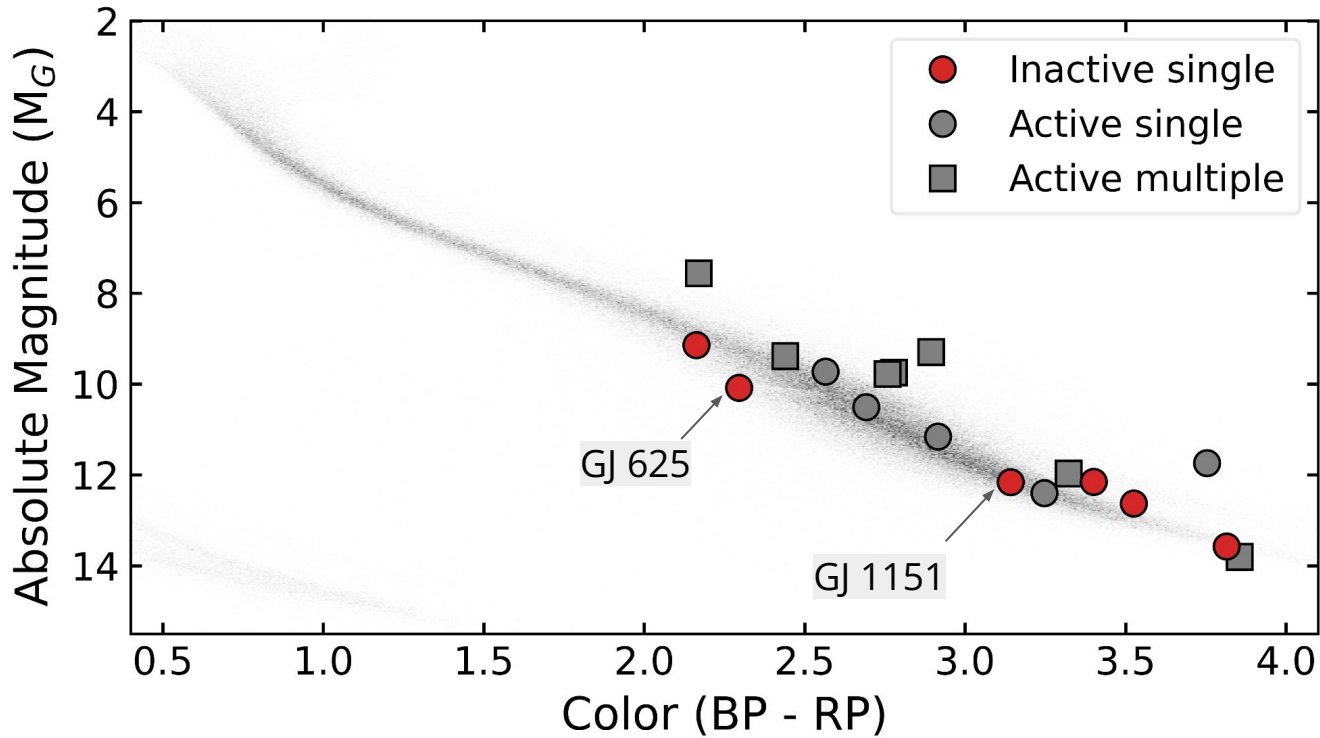
Example: magnetic SPI can occur around AU Mic at an orbital period of 18.9 d
(Kavanagh+2021)

Difficult to assess further without large-scale **stellar magnetic field** measurements

HARPSN RVs have revealed an **orbiting planet** around GJ 625 (Suárez-Mascañeño+ 2017)

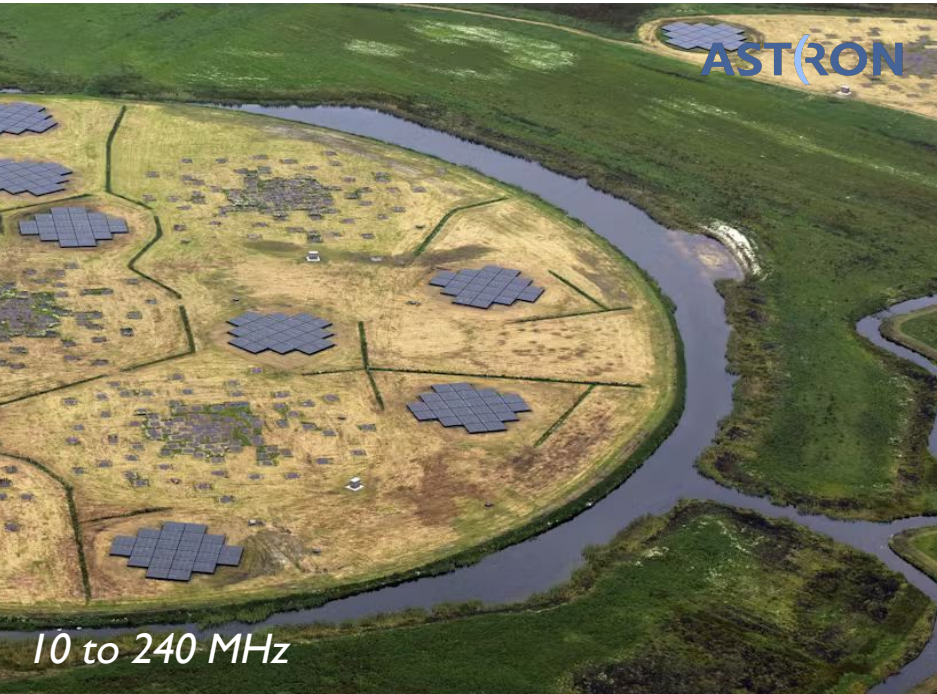


New RVs from HIRES, CARMENES, HPF and NEID have **improved ephemerides** by $\sim 3x$

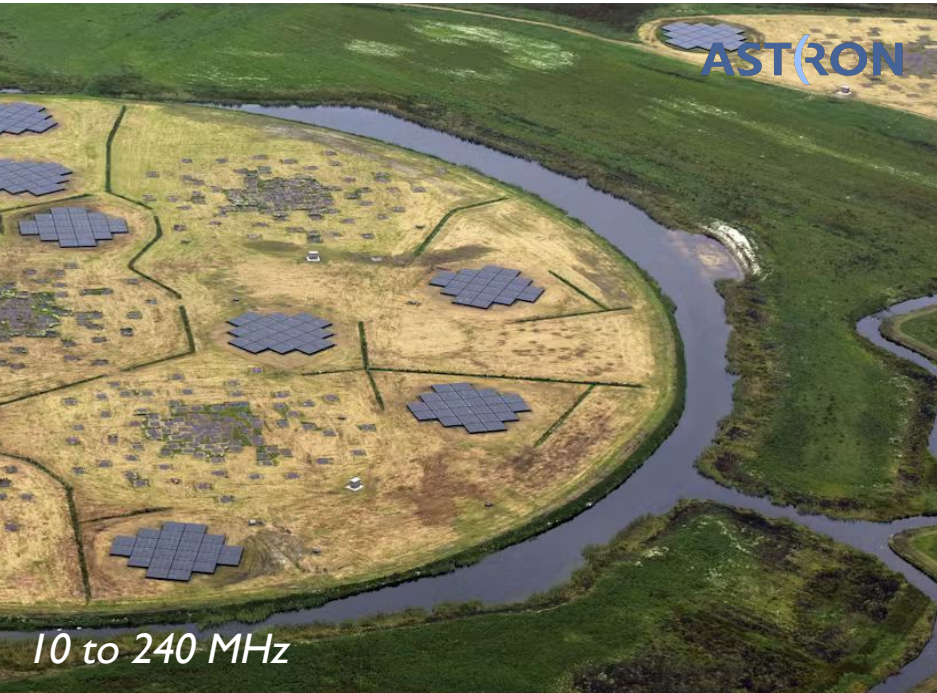


Ongoing **search for planetary companions** around SPI candidates

This LOFAR sample drawn from 20% of the northern sky

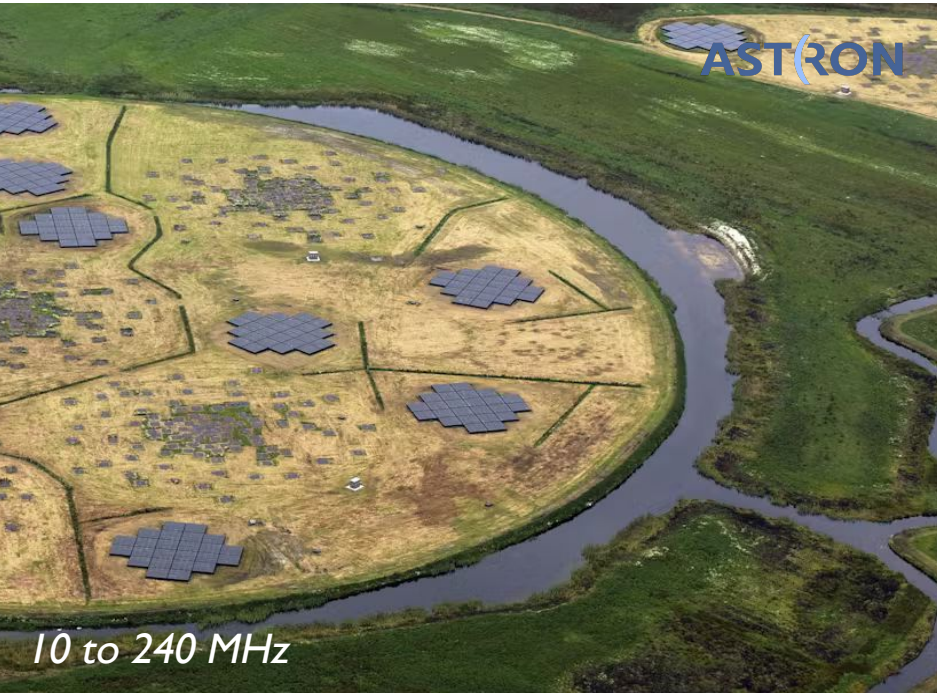


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~60-80 more radio-emitting
targets expected from LOFAR

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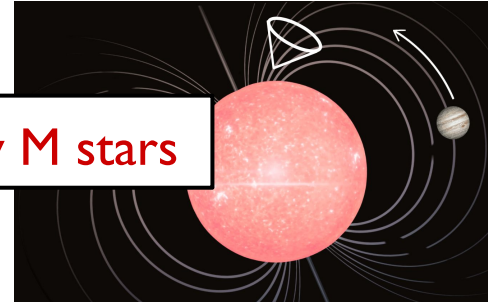
~60-80 more radio-emitting targets expected from LOFAR



Many more targets expected from the Square Kilometer Array

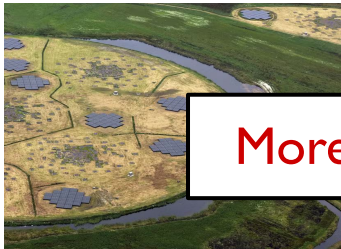
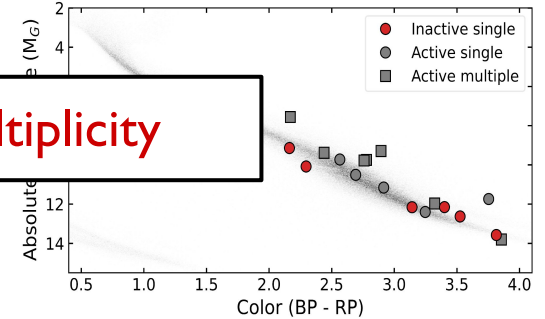
Summary

Radio telescopes have uncovered **radio emission** from **nearby M stars**



T-REX is probing for planets compatible with SPI around this sample

Radio emitting M stars **vary in stellar activity levels and multiplicity**



More radio detections expected in the near future with LOFAR and SKA