



# When Stars Misbehave: The Impact of Stellar Activity on Exoplanet Research and the Need for a Public Forecast

Lalitha Sairam

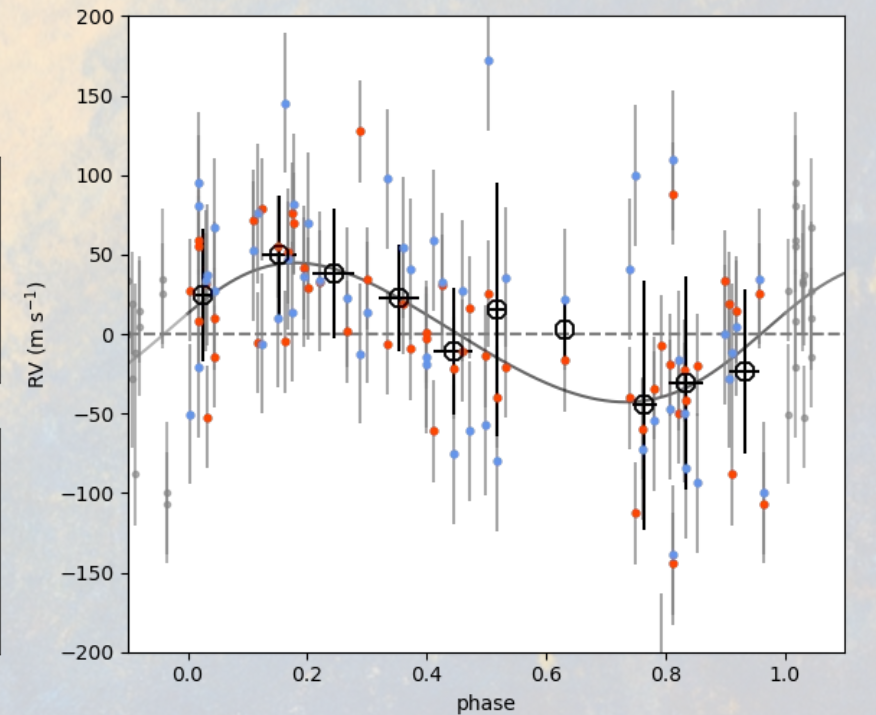
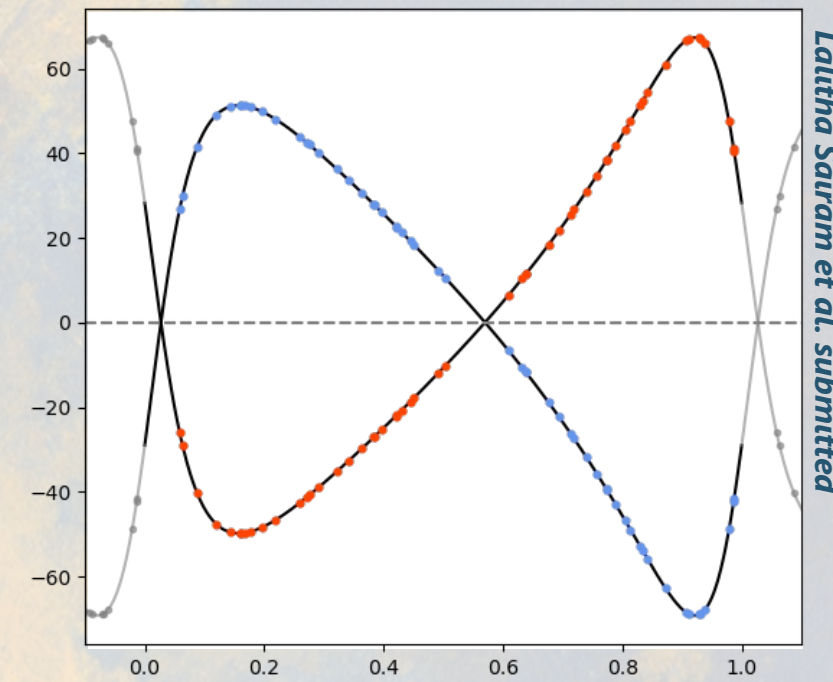
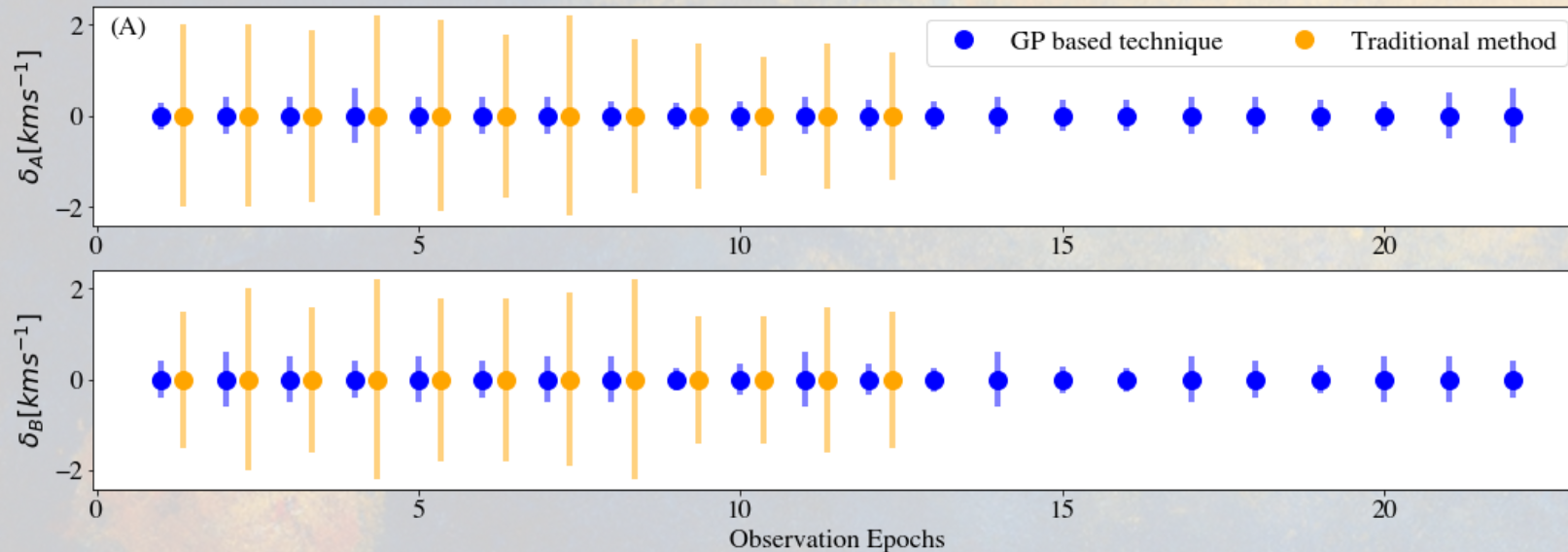
University of Birmingham → University of Cambridge

# CIRCUMBINARY PLANETS

Two decades after the first exoplanet discoveries, processes behind planet formation remain highly debated

Double-line binaries

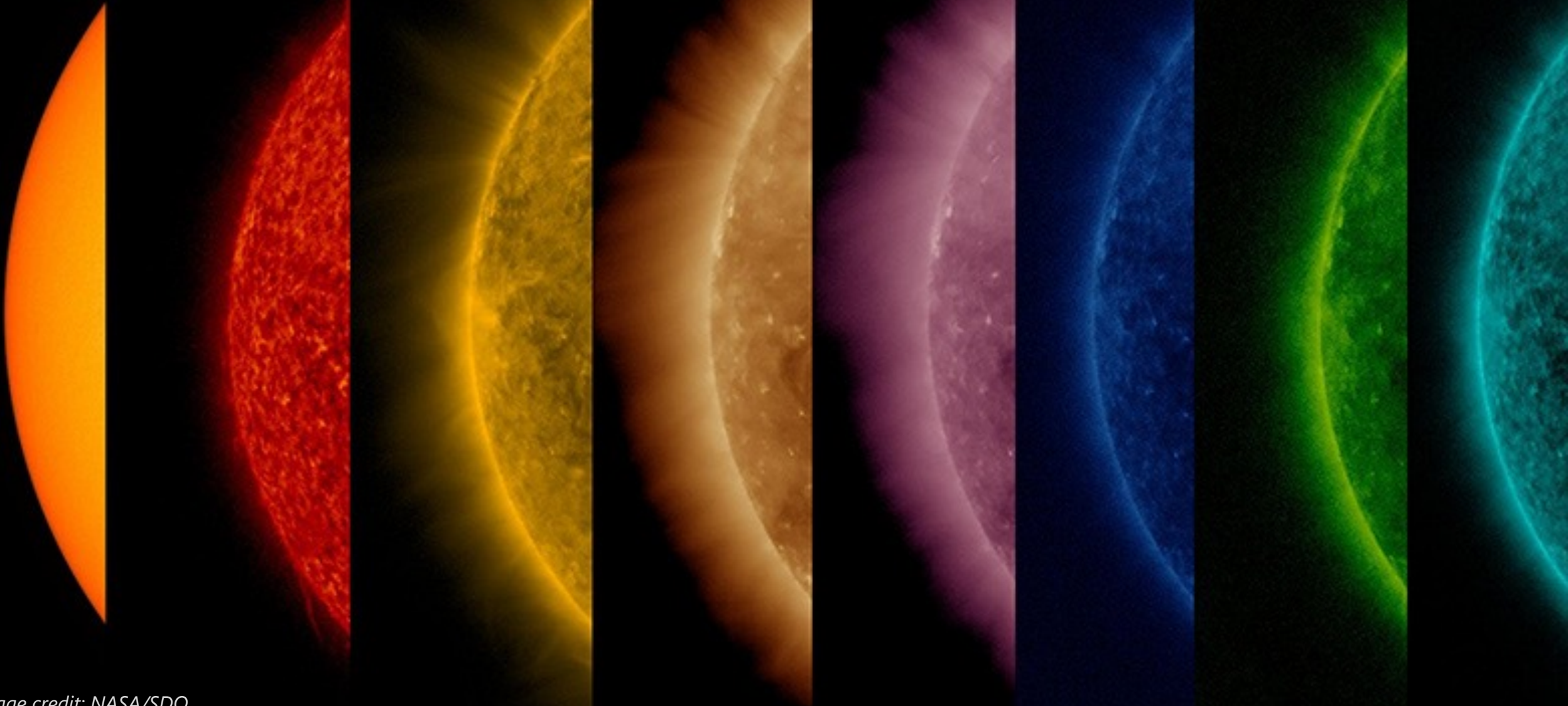
- Brighter, which eases planet detection
- Most common binaries in our neighbourhood (92%)
- But time-varying wiggles prevent planet detection
- Solving wiggles find planets that space missions struggle to detect
- Establish circumbinaries as an essential population





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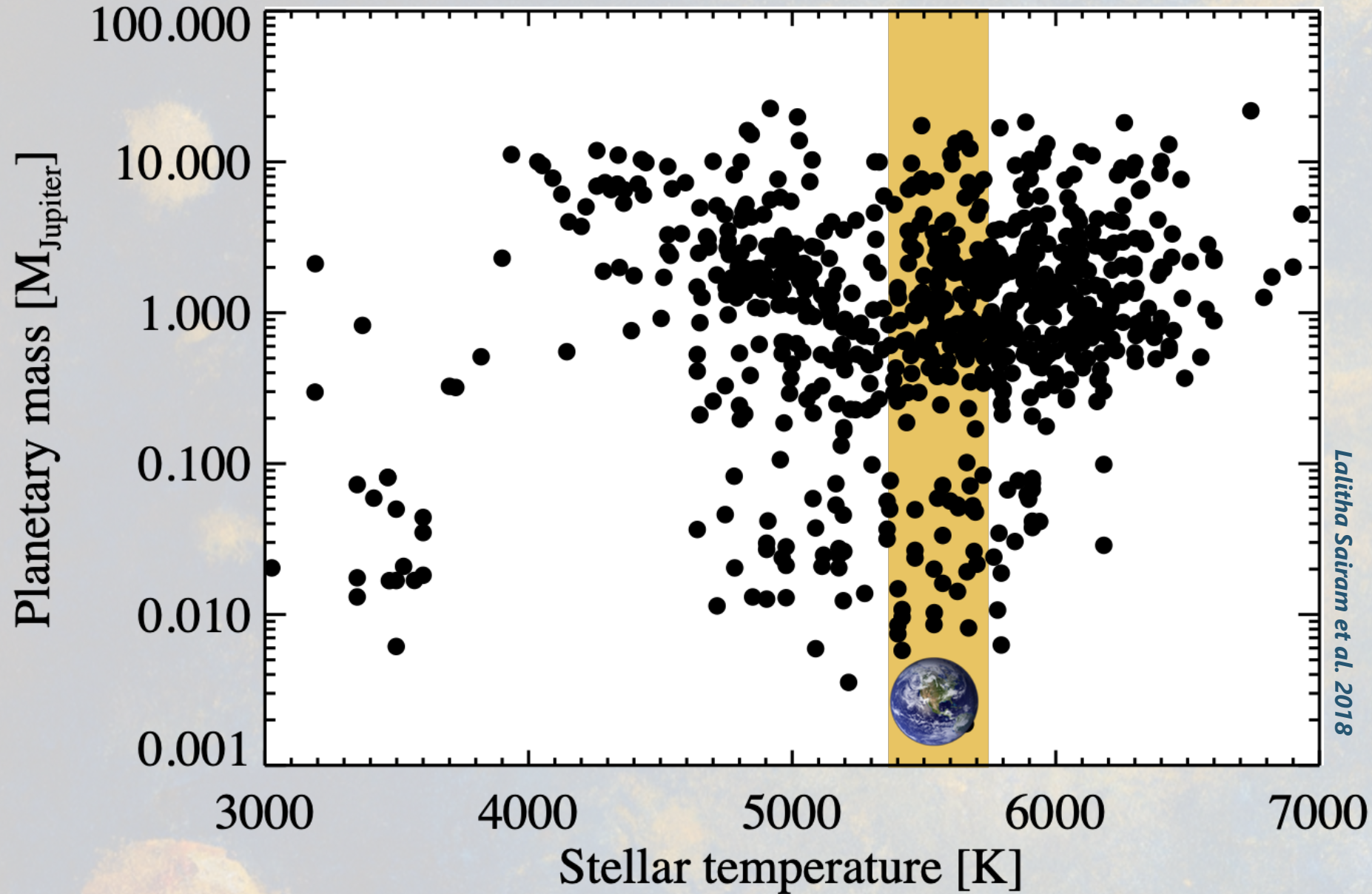
Lalitha Sairam



*Image credit: NASA/SDO*

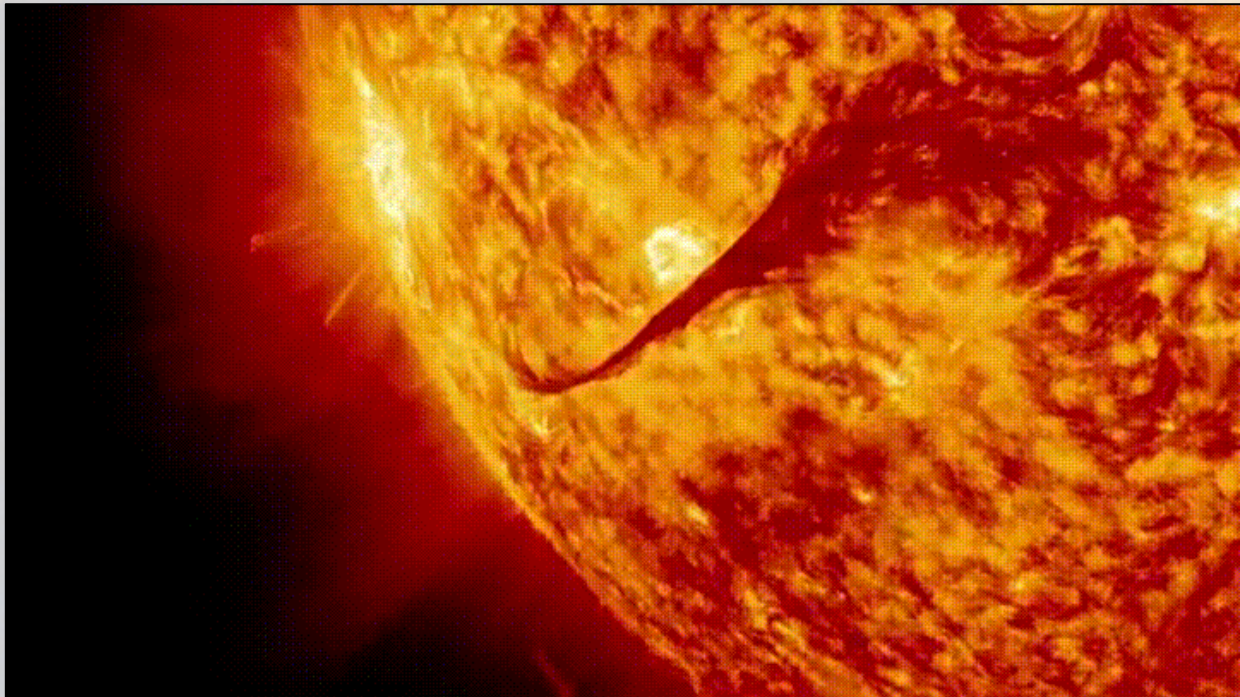
# STARS AS PLANET HOSTS

Knowing the host is  
increasingly necessary  
complement to improved  
instrument performance

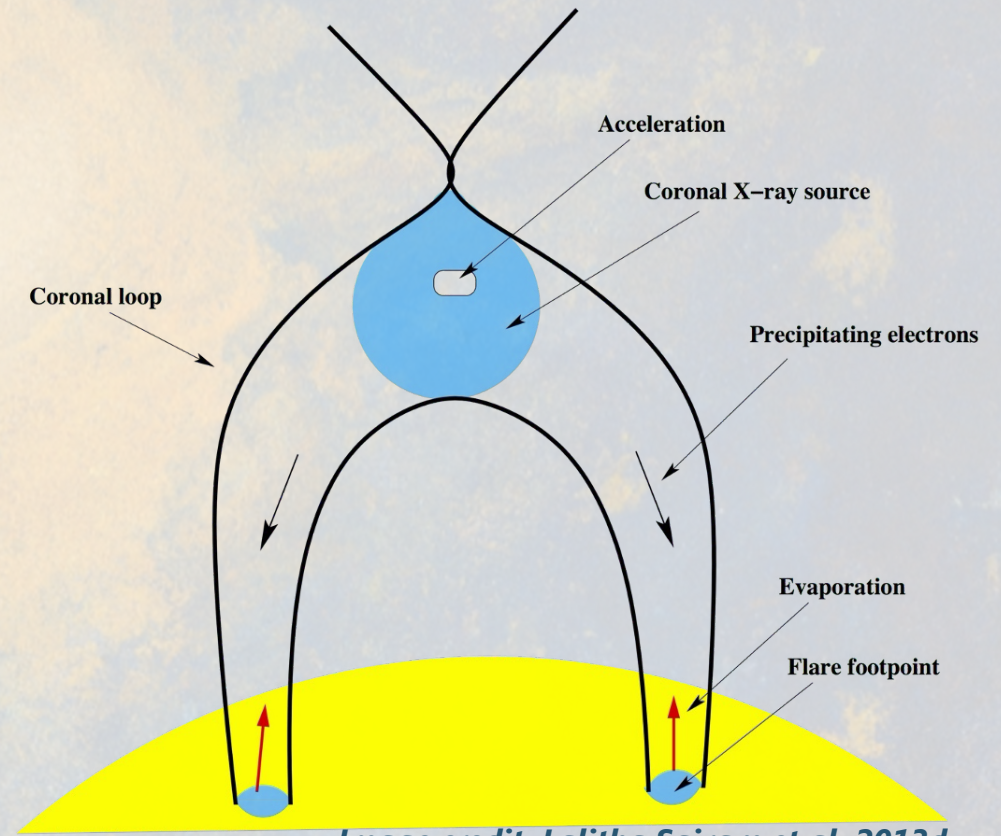


# STELLAR FLARES

magnetic structure -- ubiquitous -- loops anchored – photosphere into interplanetary space



*Image credit: NASA*



*Image credit: Lalitha Sairam et al. 2013d*

# INACTIVE STARS ARE DECEIVING

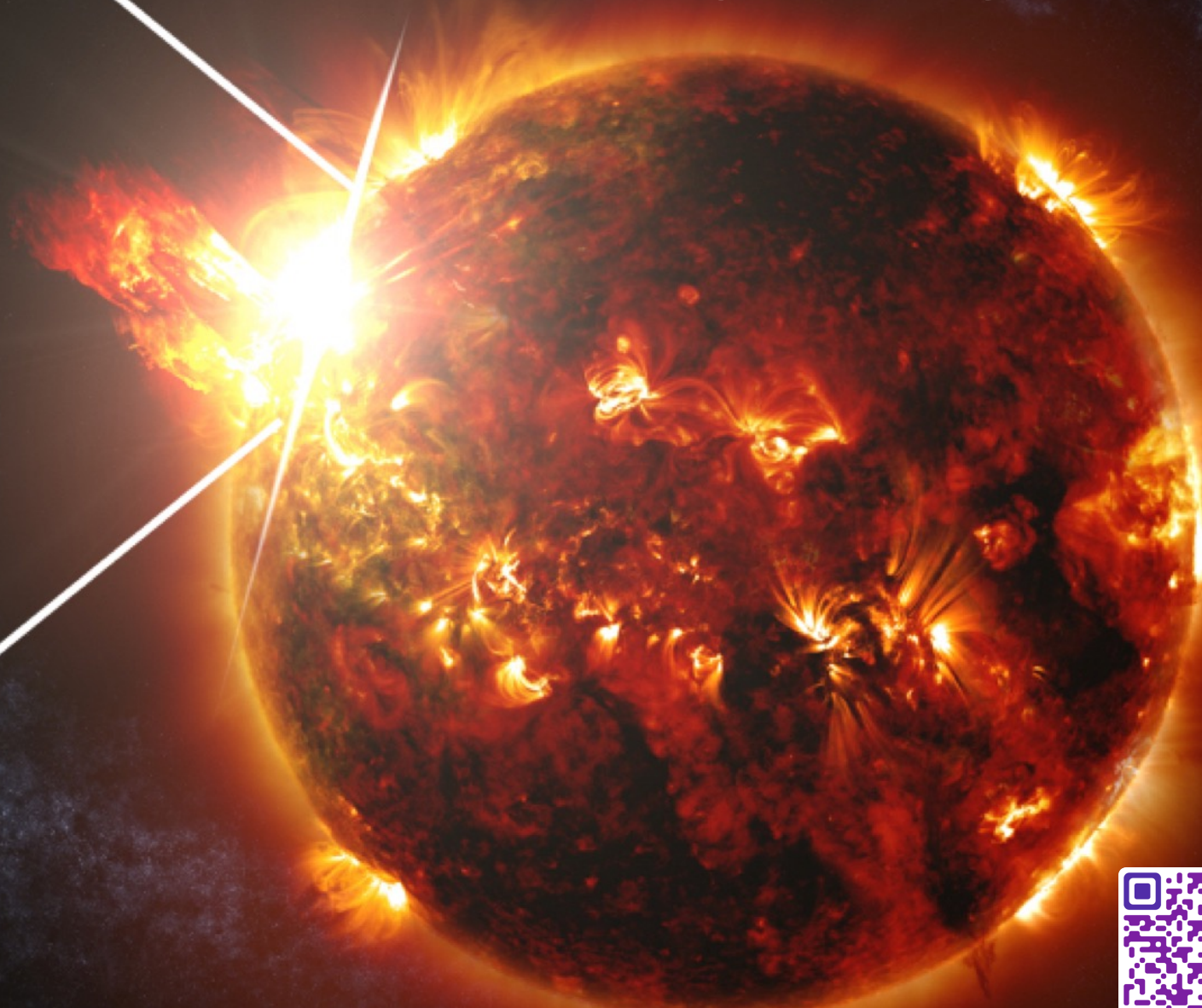
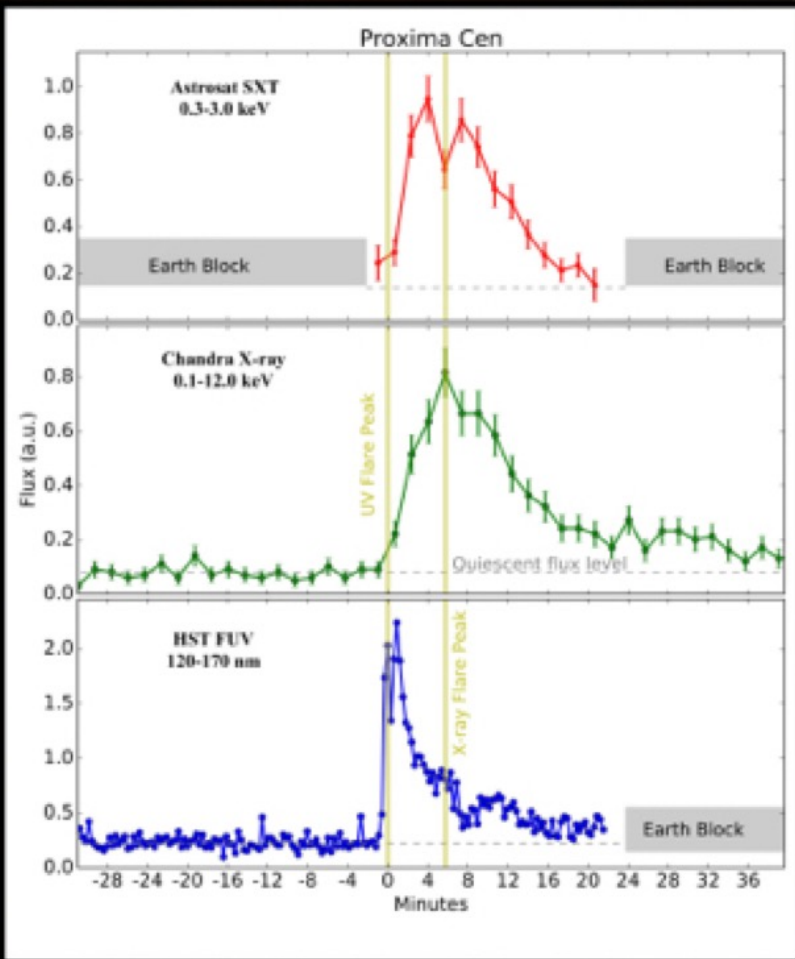
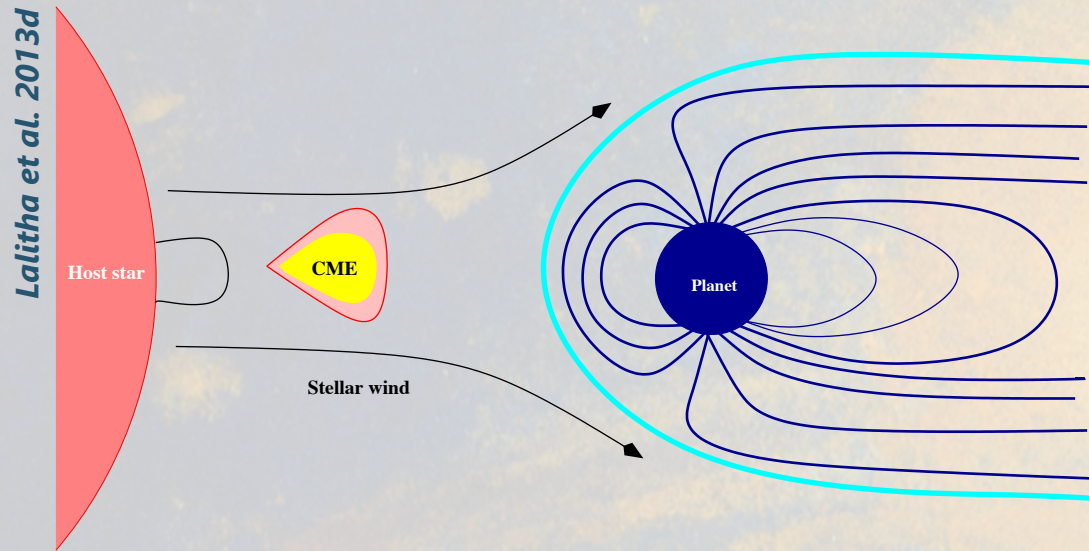


Image credit: Lalitha Sairam et al. 2017



# HAZARDOUS EXOPLANETARY ENVIRONMENT



*Image credit: NASA/ESA*

stellar high-energy radiation → exosphere heating → mass-loss





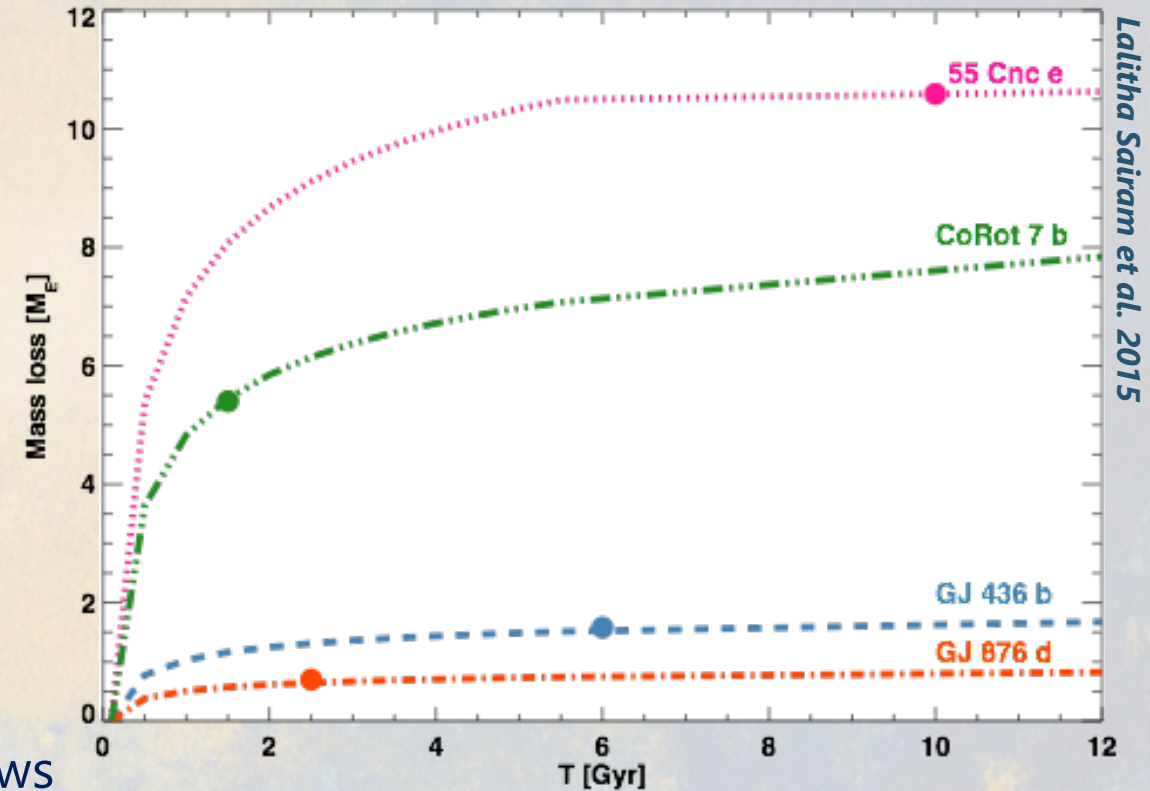
# IRRADIATION OF EXOPLANETS

The energy-limited hydrodynamical picture of planetary mass-loss

$$\dot{M} = \frac{3\pi\beta^2\epsilon F_{XUV}}{4GK\rho_p}$$

$$\left(\frac{\tau}{\tau_\star}\right)^{-1.23}$$

Stellar activity not constant over time — young stars shows higher X-ray luminosity than older stars.

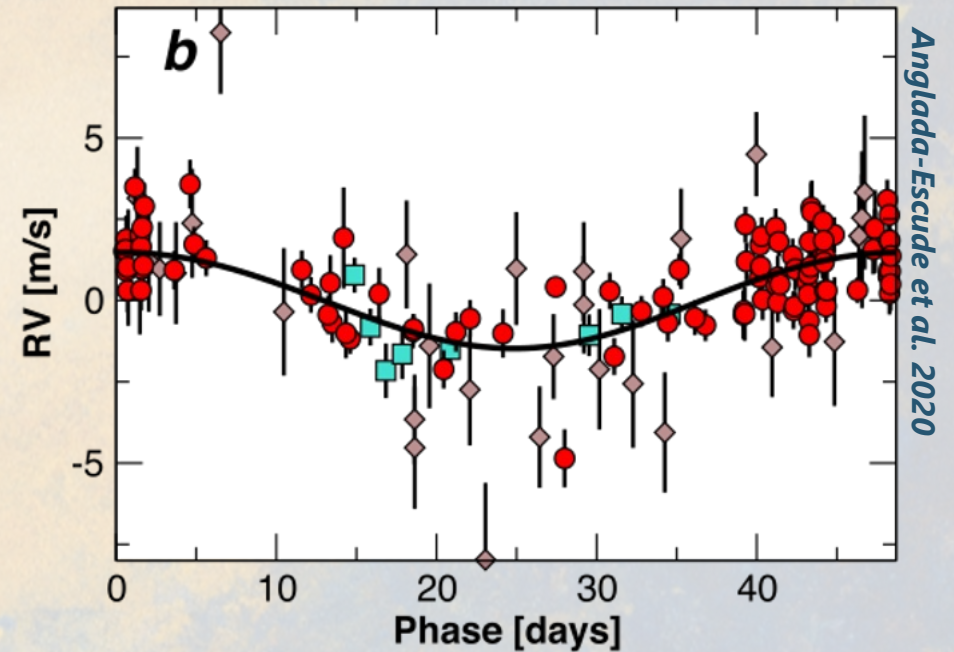
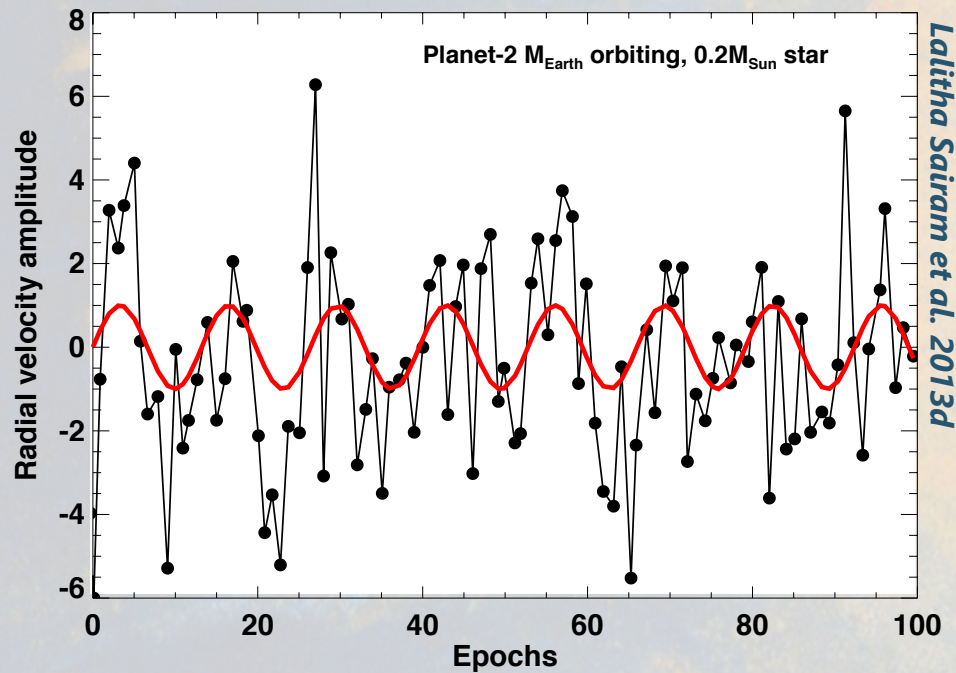


Lalitha Sairam et al. 2015



# RADIAL VELOCITY A POWERFUL TOOL FOR EXOPLANET DISCOVERY

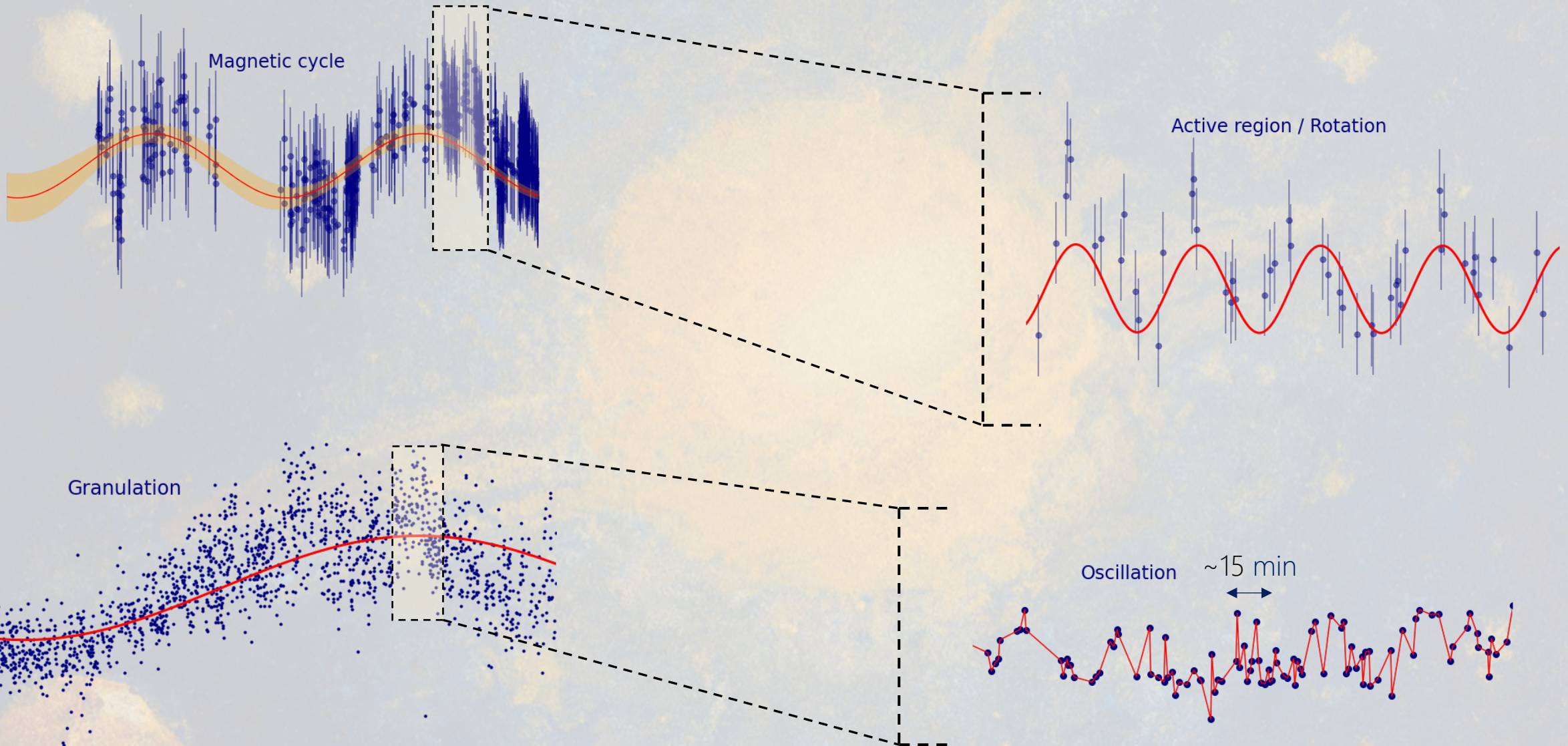
Shift/reflex motion due to orbiting companion or cool spot on the surface



Disentangle RV variation due to spot from the presence of planetary companion



# EFFECTS OF STELLAR ACTIVITY ON OBSERVATIONS



# CARMENES

Calar Alto high-Resolution search for M-dwarfs with Exo-earths with a Near-infrared Echelle Spectrograph

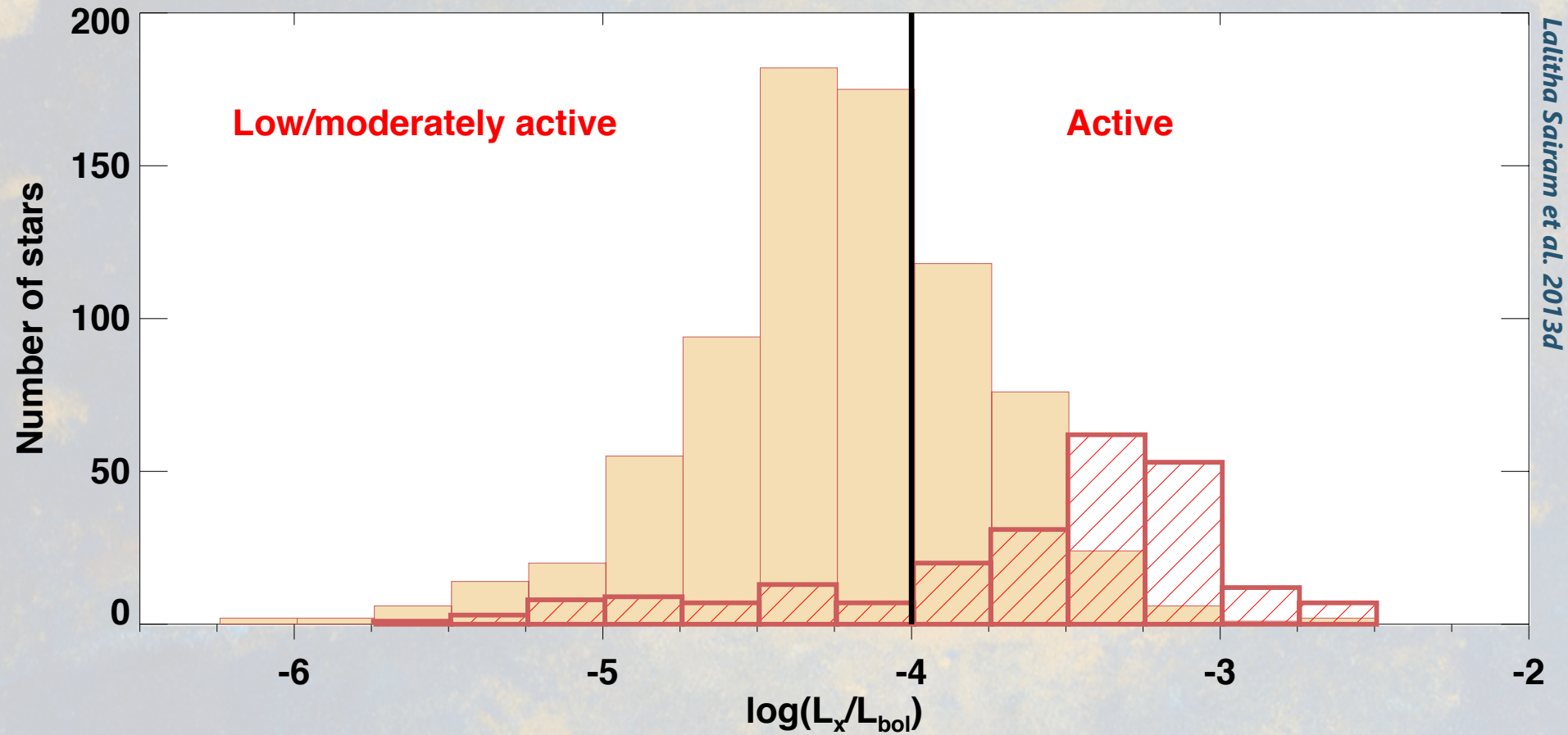
High-precision RV measurement  
Goal — Detect Earth-like planet in its  
habitable zone around M dwarfs

Visible - 0.53 - 1.05  $\mu\text{m}$   
NIR - 0.95 - 1.7 $\mu\text{m}$   
R  $\approx$  82000  
No. of targets  $\approx$  300 over 5 years



Image credit: Eike W. Guenther

# PRECISE SAMPLE SELECTION AT CARMENES

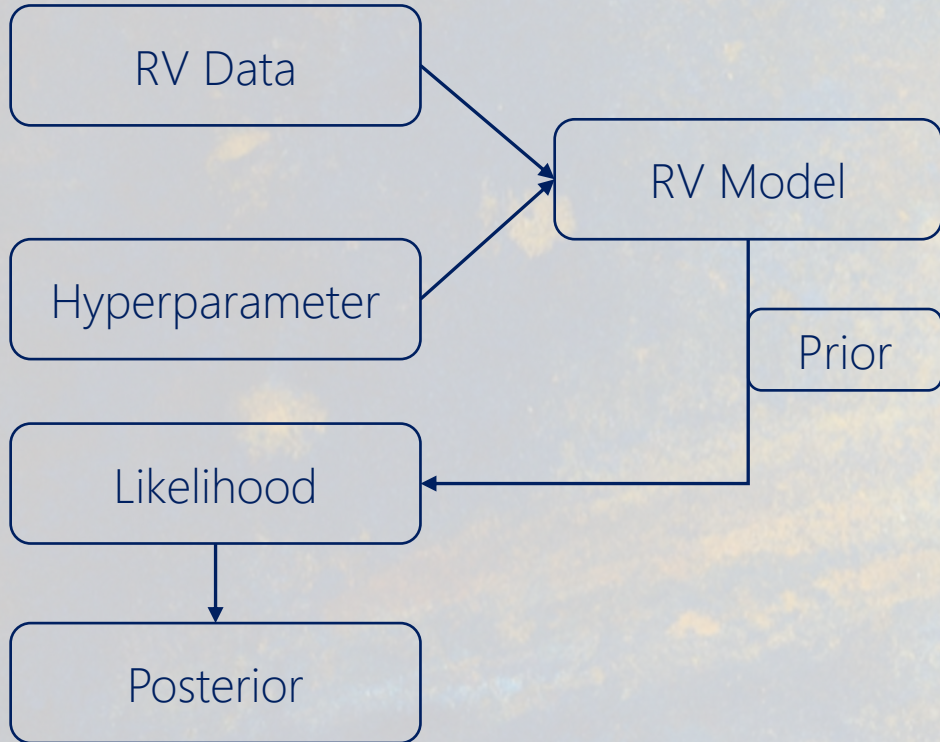


Lalitha Sairam et al. 2013d

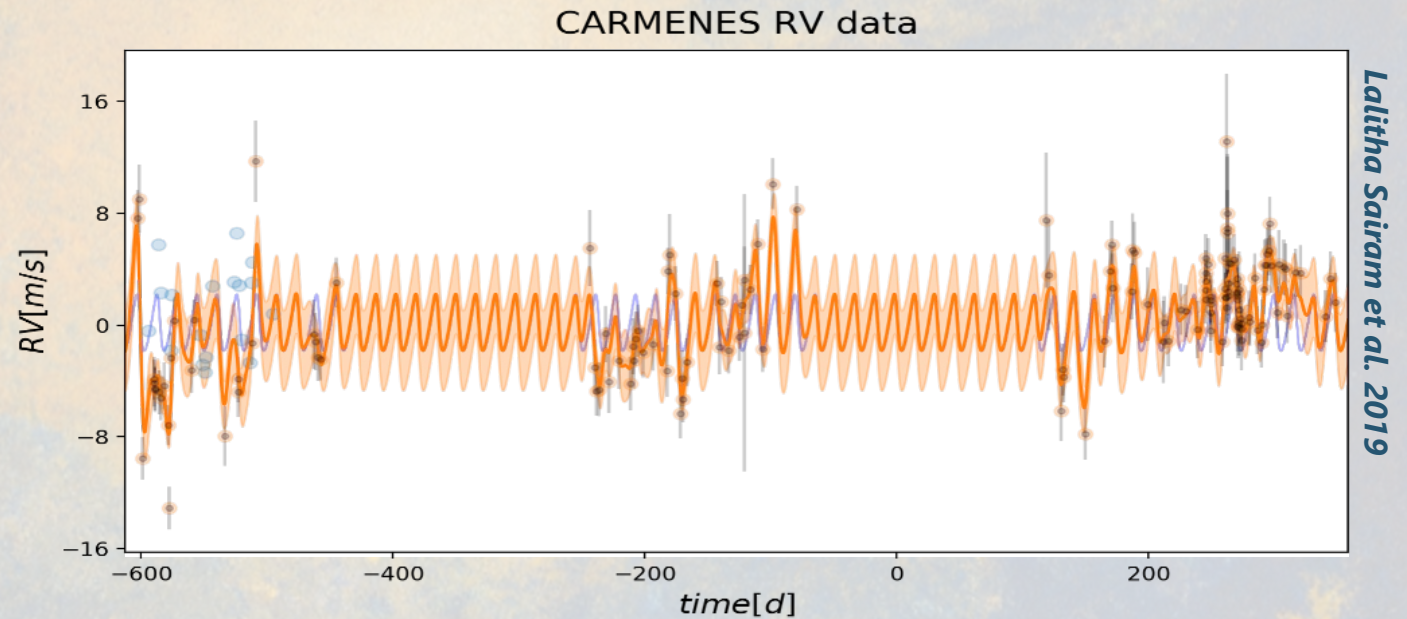
ROSAT all sky survey – complete and unbiased sample of X-ray sources



# NOISE MODELING CARMENES

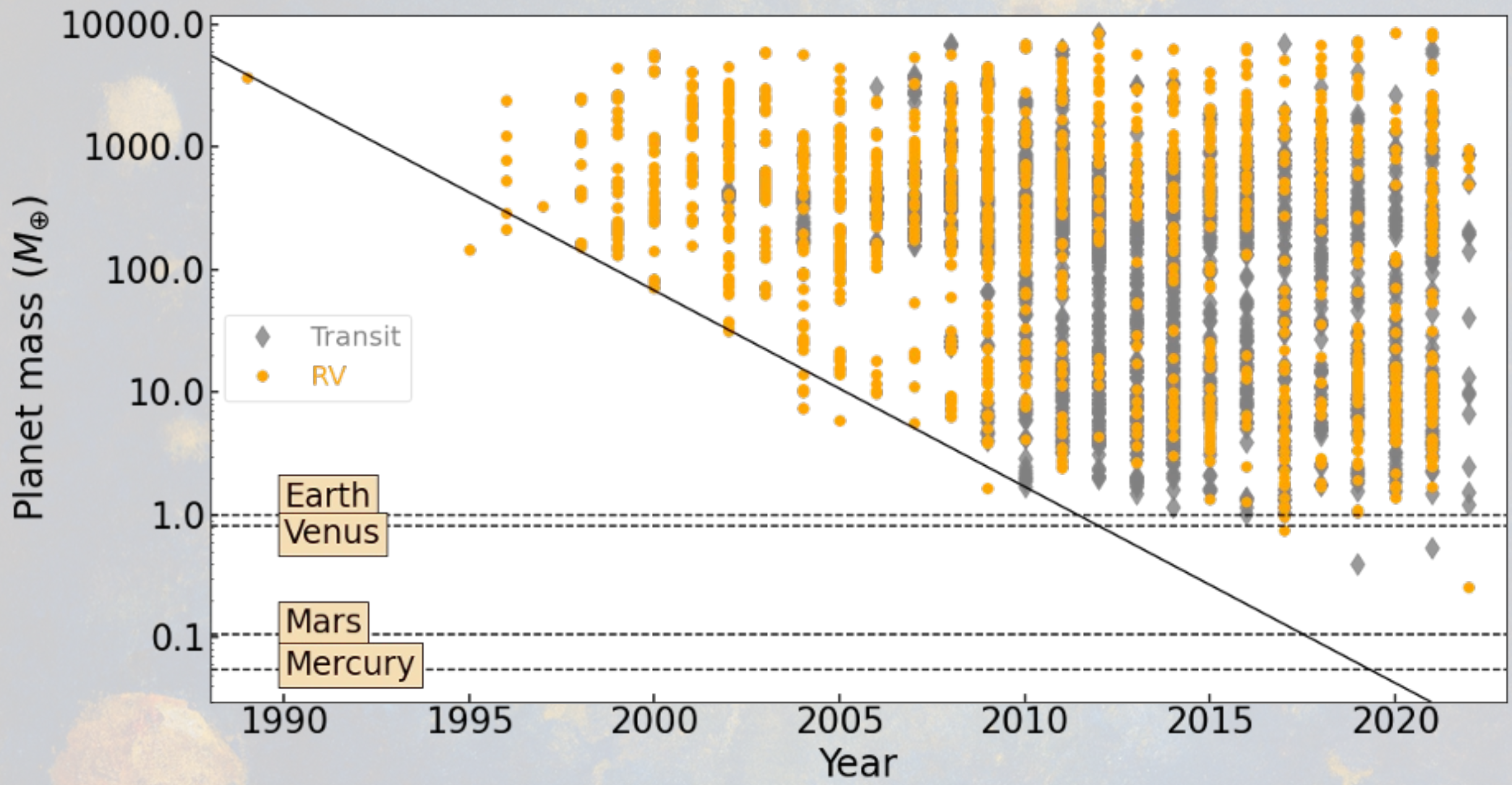


$$k(t, t') = \eta_1^2 \exp \left[ -\frac{(t - t')^2}{\eta_2^2} - \frac{\sin^2\left(\frac{\pi(t-t')}{\eta_3}\right)}{2\eta_4^2} \right]$$

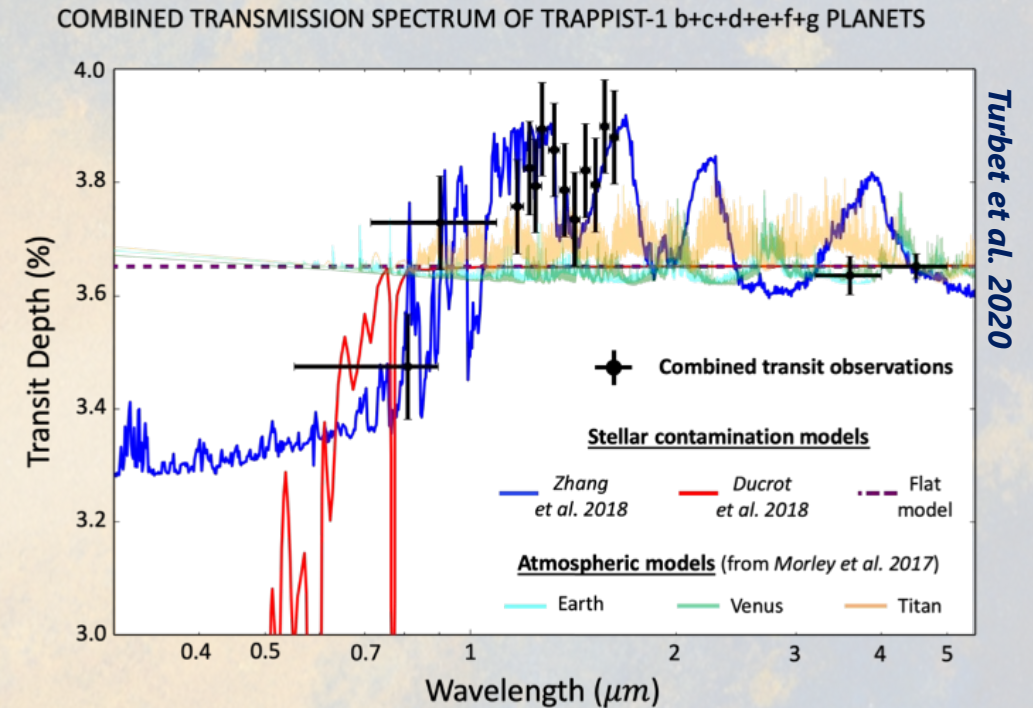
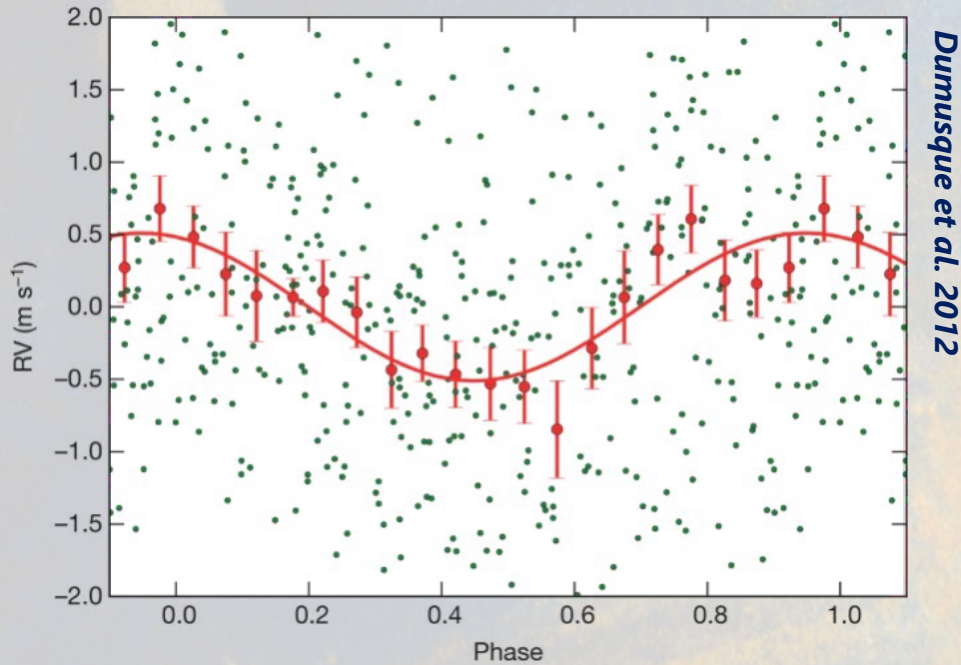


Non-parametric gaussian process – frequency shorter than stellar activity





# STELLAR ACTIVITY AS HINDRANCE TO OBSERVATION



✘ Mimic exoplanet and spurious atmospheric species

🔭 Observation bias -- inactive stars

☀️ Stellar activity affects 10-50% of observations

📊 Modelling inefficient and **erroneous** detections





# STELLAR ACTIVITY FORECAST FOR OPTIMAL OBSERVATIONS (STACCATO)



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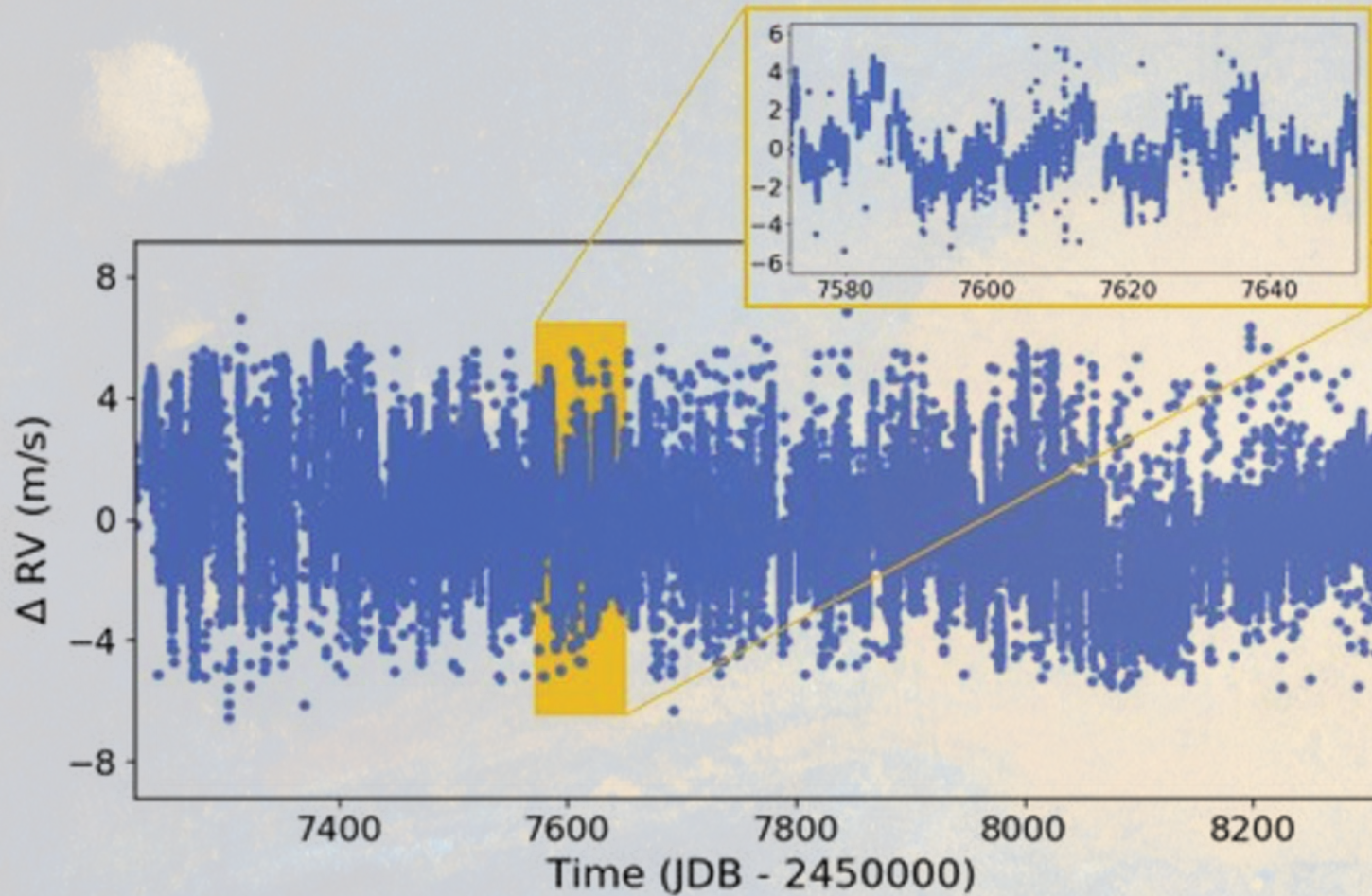
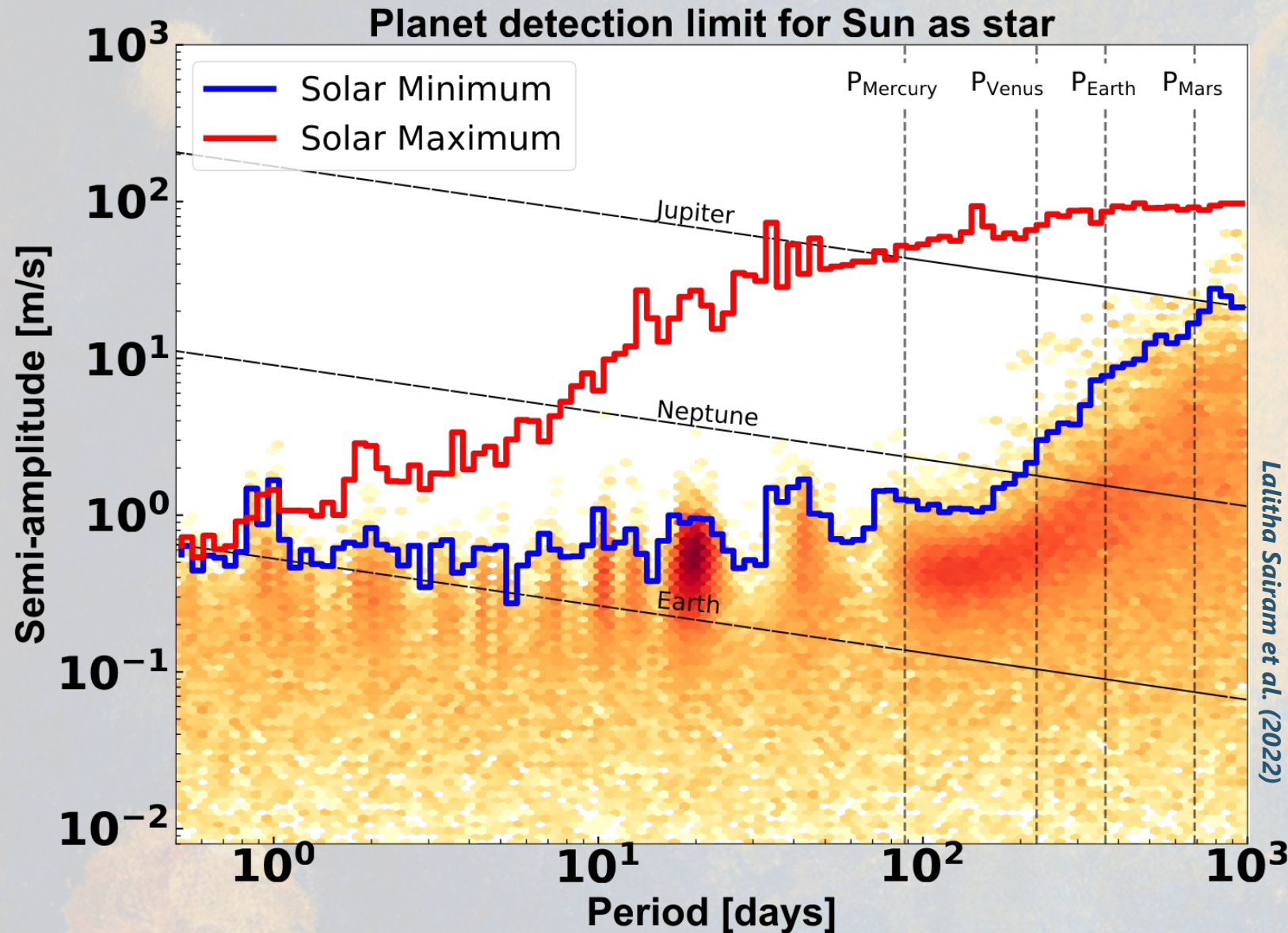


Image credit: D. Phillips and DACE

Solar minima -- sub m/s scatter in radial velocity  
Solar maxima -- 3m/s scatter in radial velocity



# STELLAR ACTIVITY FORECAST FOR OPTIMAL OBSERVATIONS (STACCATO)



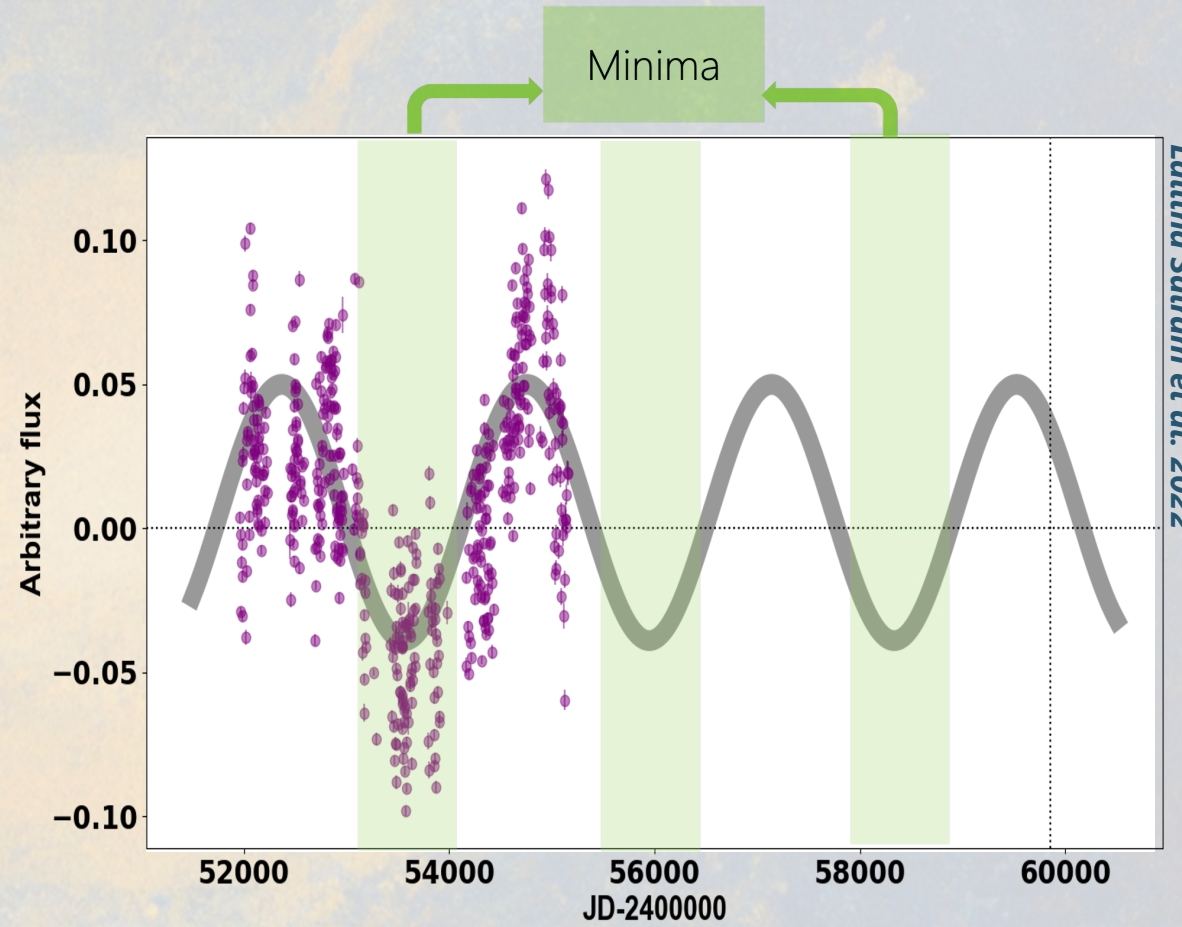
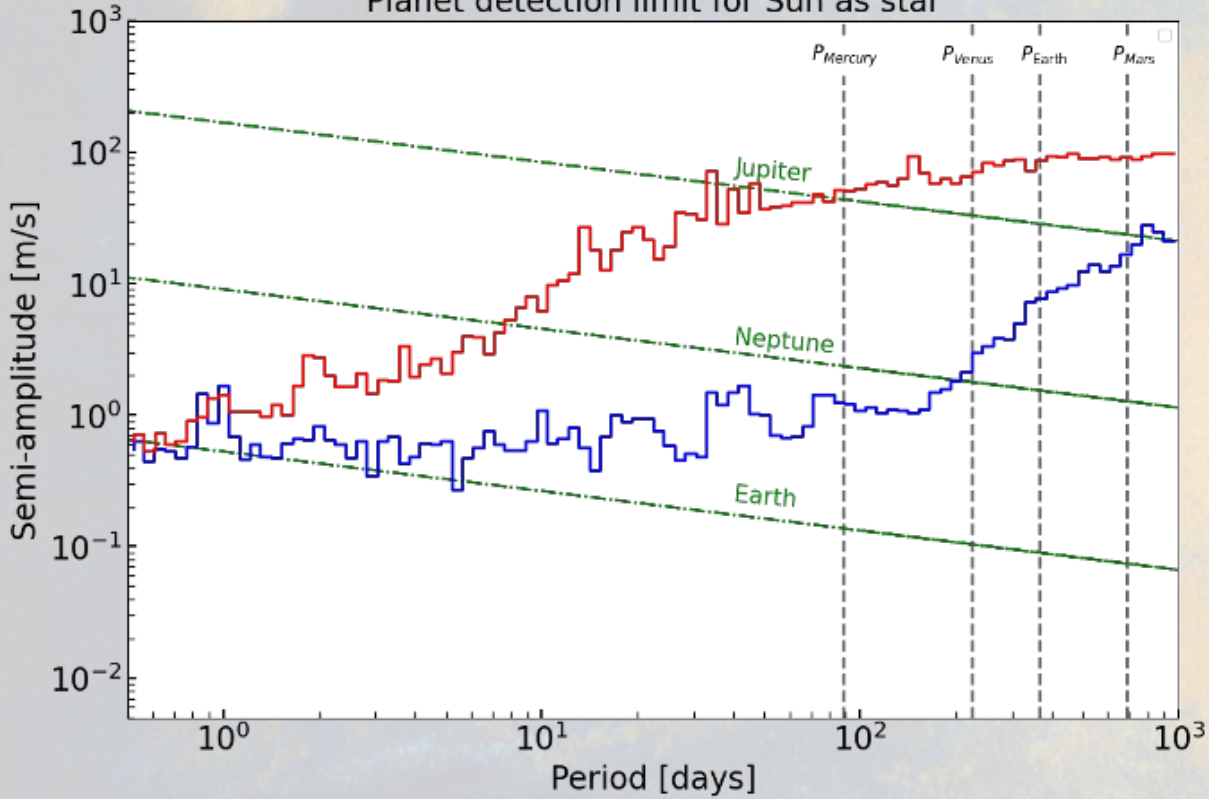
Solar maxima -- 3m/s scatter in radial velocity

Solar minima -- sub m/s scatter in radial velocity



# STELLAR ACTIVITY FORECAST FOR OPTIMAL OBSERVATIONS (STACCATO)

Planet detection limit for Sun as star



Lalitha Sairam et al. 2022



Stellar activity forecast using existing data



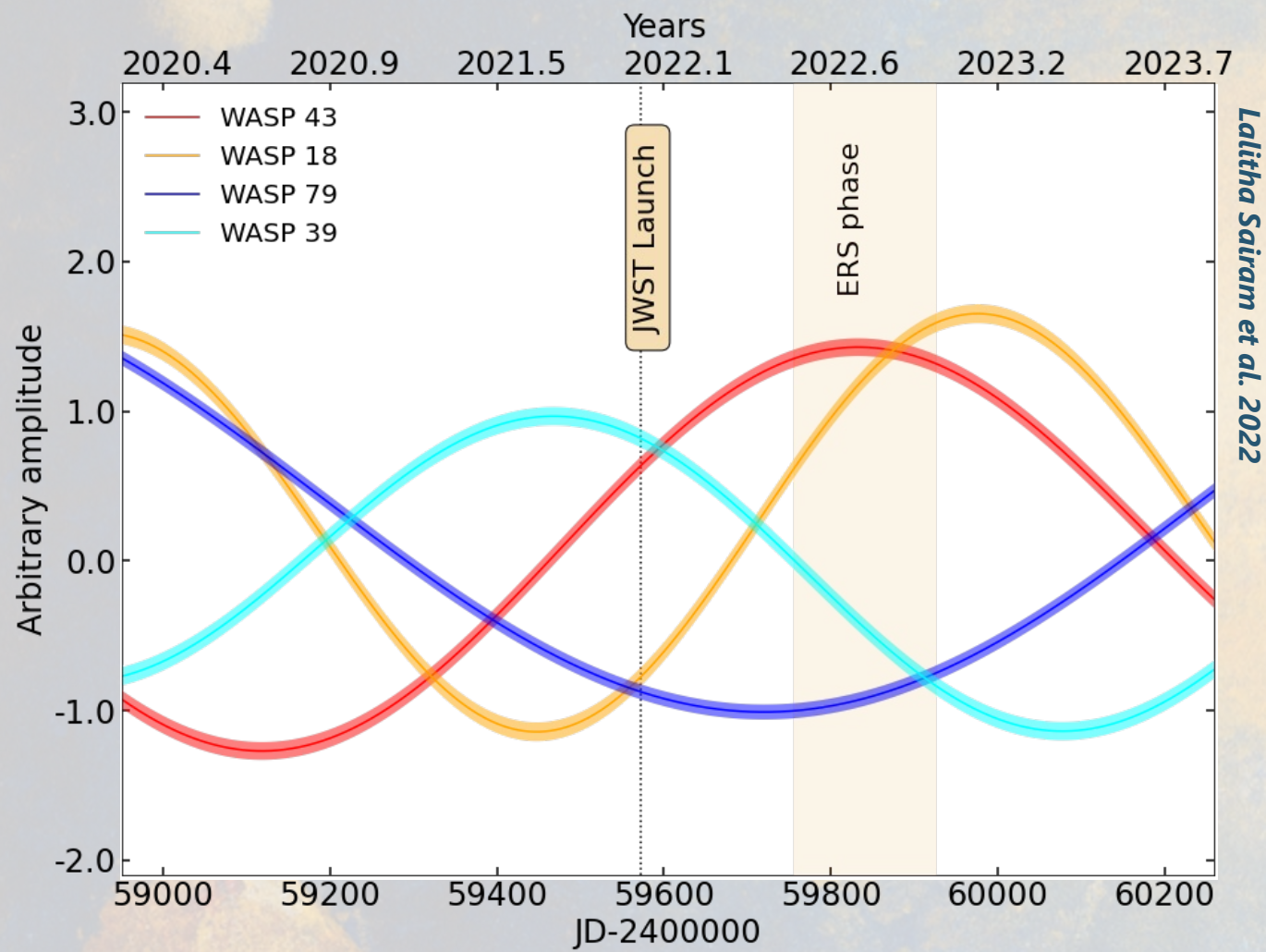
Predict activity cycle minima



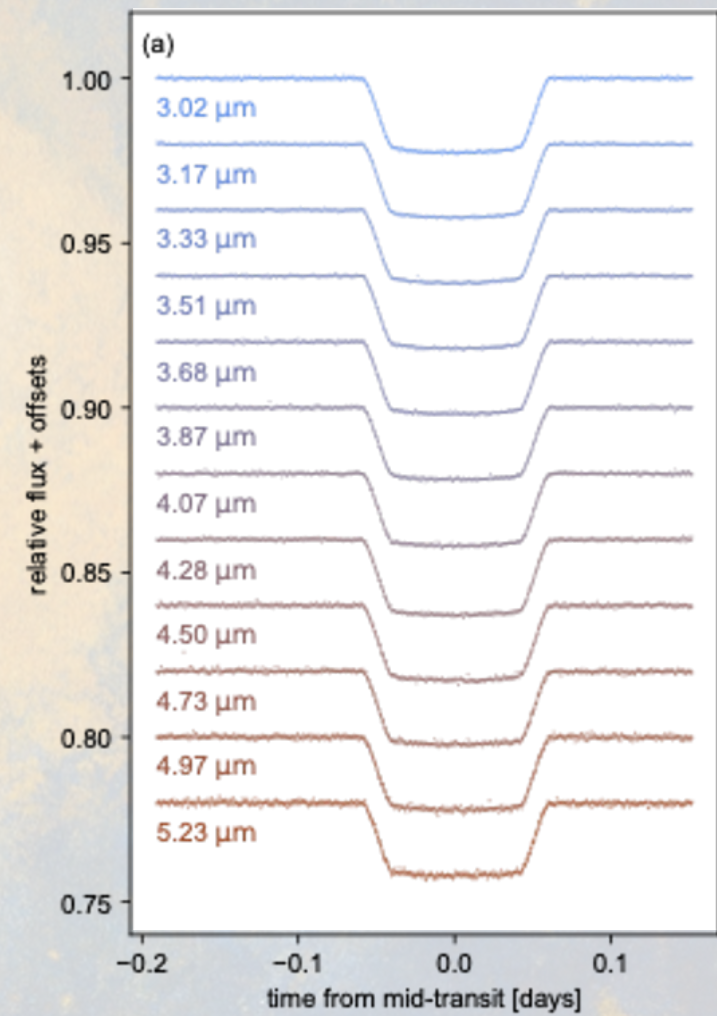
Optimal observing time for 5000+ stars



# JWST ERS



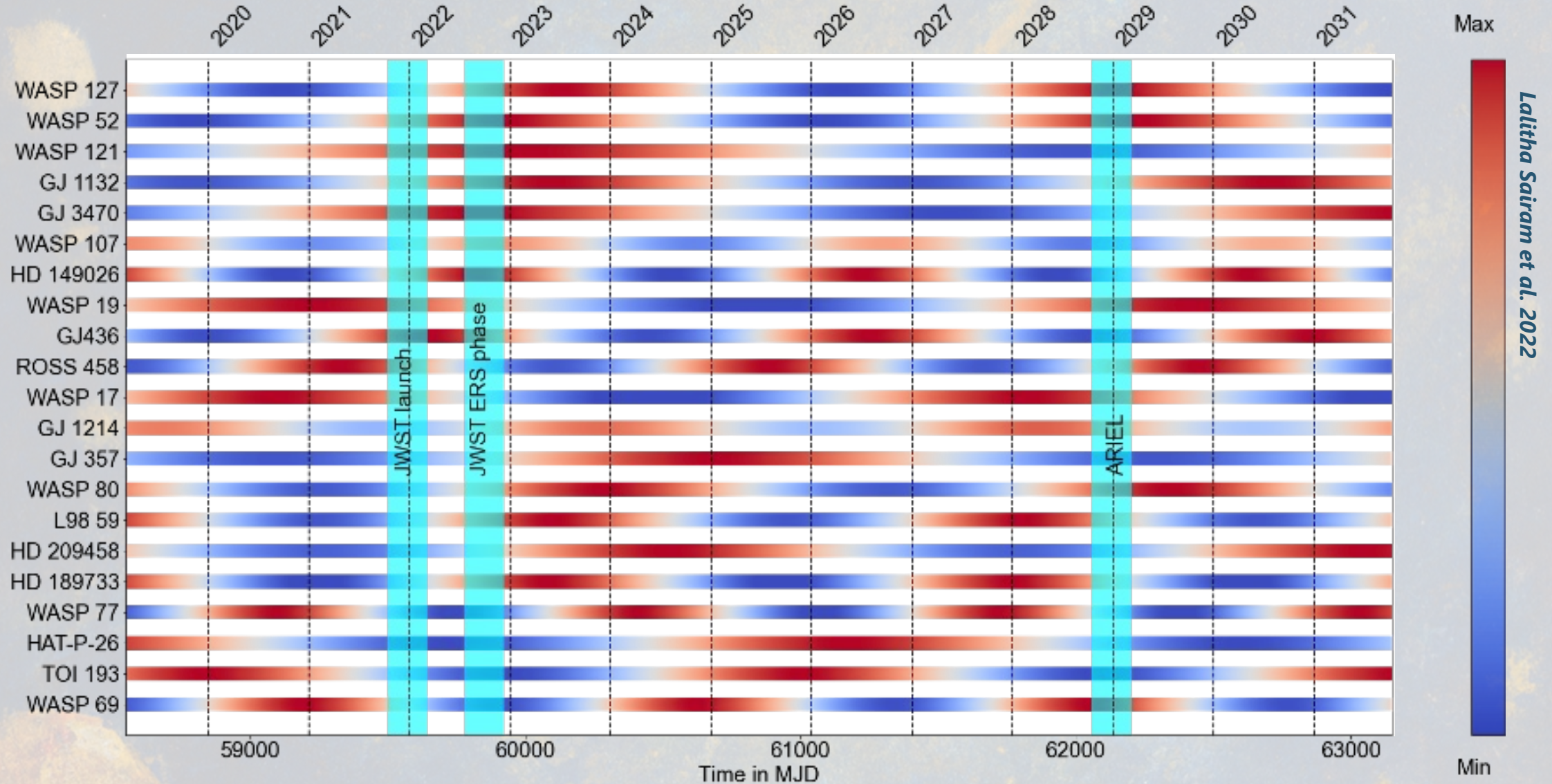
Lalitha Sairam et al. 2022



Ahner et al. 2022



# OBSERVING RIGHT STAR AT THE RIGHT TIME



# IMPACT OF STACCATO

## ATMOSPHERE

Enable deeper understanding of atmospheric species



## ACTIVITY CYCLES

Discovery of cycles for 5000+ stars



## CONNECTION

Establishing solar-stellar connection and seismic variability



## YOUNG PLANETS

Detect planets around active stars - consequence of planet formation

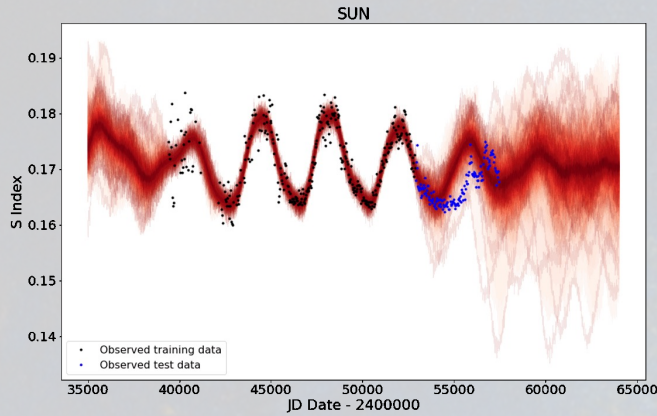


## EFFICIENCY

Increased observation efficiency on oversubscribed telescope

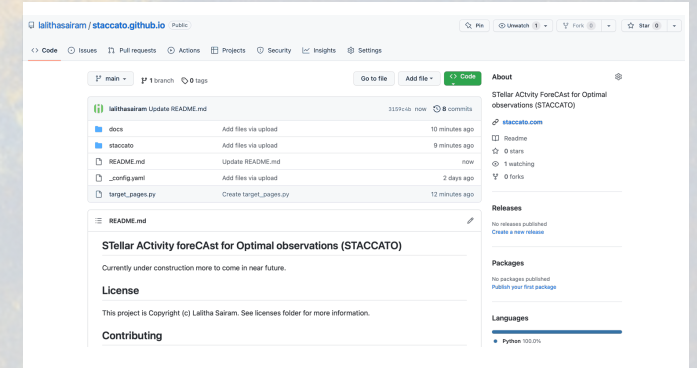


# Next steps for STACCATO

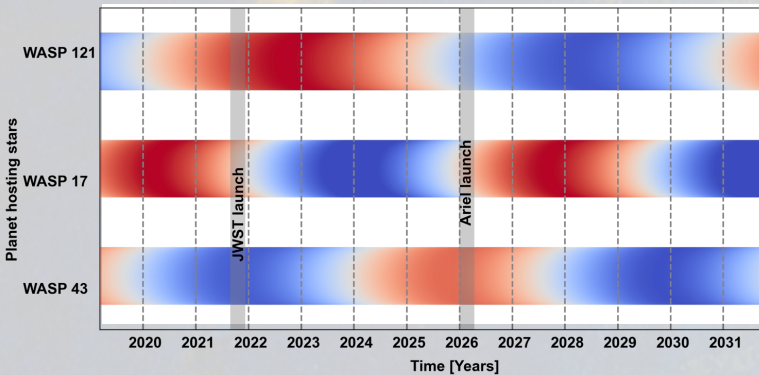


Credit: Saskia Hawkins

Enhanced forecast model



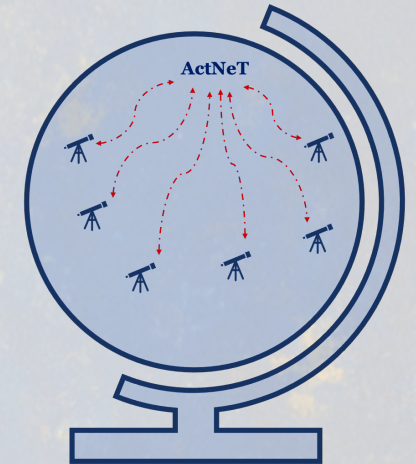
Open-source catalogue



STACCATO - live and upcoming projects



ActNeT





# ACTNET (ACTIVITY NETWORK TELESCOPE)






## Current status:

Expression of interest from **six potential partner** observatories

ActNeT webpage to be launched soon

## MoU with partners

Fast track commissioning

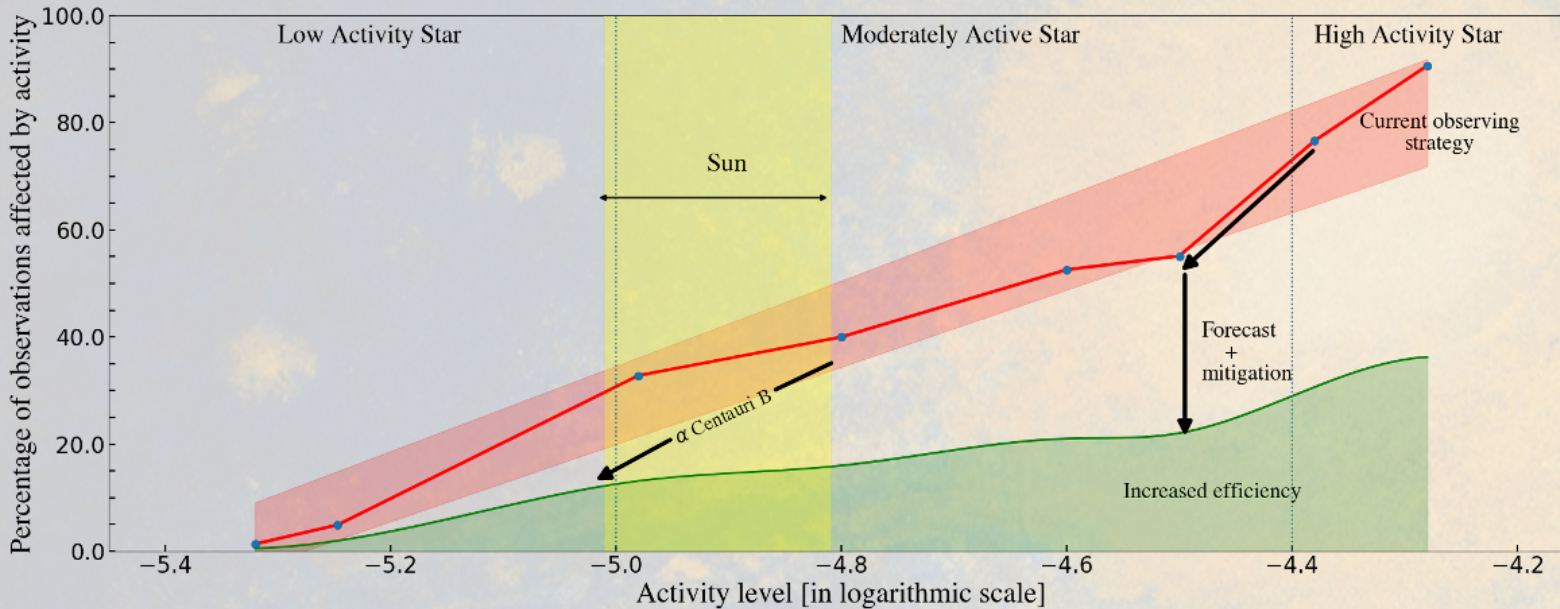
-  Multi-site, multi-national network of telescopes
-  Enhanced temporal coverage and validation of cycles
-  Platform to build largest survey of stellar activity

Email: [L.Sairam@bham.ac.uk](mailto:L.Sairam@bham.ac.uk)



# SUMMARY

- Nuisance-turned-necessity: Observations impacted by 10-50% depending on stellar activity level.



Modeling helps, but affects:

- ✓ Time
- ✓ Money
- ✓ Accuracy

- STACCATO - an observing strategy to reduce the stellar activity-induced signal
- STACCATO accelerates exoplanet detection and characterization alongside stellar physics

