A Different Star Every Day: How Stellar Activity Impacts Exoplanet Science

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Stars are not constant in time





Exoplanets exist around active stars



Reed/NA as



What are all the ways stellar activity can ruin the exoplanet party?

Timescales & Amplitudes to Consider

- Main sequence stars are variable on many timescales
 - Incl. Minutes/Hours, Days/Months, Years (and beyond...)
- Also a wide range of amplitudes
- Both these depend on stellar properties (esp. mass & age)

Timescales & Amplitudes to Consider*



Timescale

*an incomplete census



Combining Data



Time from mid-transit [hours]

WASP-39b (Carter+2024)



Combining Data



Time from mid-transit [hours]

WASP-39b (Carter+2024)





Timescales & Amplitudes to Consider*



*an incomplete census





GJ 1243 (Kepler)





GJ 1243 (Kepler)











Davenport, Tovar Mendoza, & Hawley (2020)





Flare Morphology A common profile



Relative Time

Tovar Mendoza et al. (2022)



Every flare is "complex"





TESS 2-min vs. 20-sec

Howard & MacGregor (2022)





Flares + Transits

AU Mic b E. Gilbert+2022

- Flares can have comparable timescales & amplitudes as transits
- Stochastic events, complex structure
- Headache esp. for TTV work! \bullet



Flares in the Optical & IR



Tofflemire et al. (2012)



K2 (Luger+2017)

Flares in the Optical & IR

Trappist-1



Spitzer

Flares in the Optical & IR Trappist-1



JWST finds lots of IR flares!



Barycentric Julian Date – 2,457,700 [day]

K2 (Luger+2017)



Spitzer



Flares in the Optical & IR

- Flare temperatures a "hot" area of research
- ~10,000K blackbody is not a good model
- Infrared dominated by a cool component
- UV & blue optical very important for correct energies



Howard+2023





Morris et al. (2019)

Year

Activity Cycles: the Sun



See also e.g. Veronig et al. (2002)





M3 dwarf

Decade Timescale Variation?



Wainer+2024

- No strong long-term flare change
- Modeling FFD variation as function of observing baseline
 - More Sectors = Better!
 - Sector 41 is a 2.7σ outlier

Decade Timescale Variation!



- Activity "cycles"?
- Star-planet interactions?
- Subtle binary star behavior?



Gaia DR4 will be transformative, esp. in concert with TESS!

- Assume you're observing a different star every day!
- Observe star in blue optical along with infrared
- Use high time cadence (under 1-min if possible)
- Get stellar calibration for every transit (and lots of out-of-transit baseline!)
- Single transit: can assume the star is same (though inhomogeneous)
- Many transits: possibly marginalize over stellar variability



Know Thy Star I (2017)



Flares *may* be bad for habitability!





Know Thy Star 3 Predictions

- The year: ~2032 (extrapolating from 2017)
- JWST just reached 10-year milestone
- CMEs/Flares impacting exoplanets will be detected
- Know Thy Planet -> Know Thy Star will be major focus
- Long (decade) timescale behavior will be major focus

J.R.A. Davenport (Feb 5, 2025)



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