How the stellar flicker noise affects the characterization of planetary transits ?

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ABSTRACT

Stellar activity is known to limit exoplanet detection and characterization. Among this activity, stellar convection (``flicker'') evolves during the typical transit timescales (~ hours) and affects the inferred transit parameters.

We generated realistic simulations of transiting exoplanets based on solar HMI data. These simulations include planets from 1 to 10 Earth radii with different transit geometries. These simulations comprising hundreds of light curves are available to the community :

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We analyzed the data using standard MCMC methods assuming the noise is white and Gaussian (WGN), or a Gaussian Process (GP). We show that, in both cases, the resulting planet parameters can be affected by biases, which leads to biased planetary radius measurements. This demonstrates the need to develop robust stellar noise modeling to achieve PLATO's goal of characterizing exoplanets transiting solar-like stars.

Next steps of this study will be to investigate
i) how other noise sources (e.g., flares, spots and faculae) affect the inferred exoplanet parameters,
ii) which noise modeling allows to derive the most accurate transit parameters.

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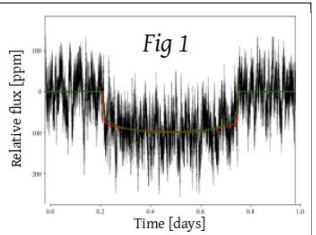
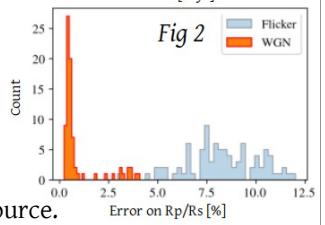
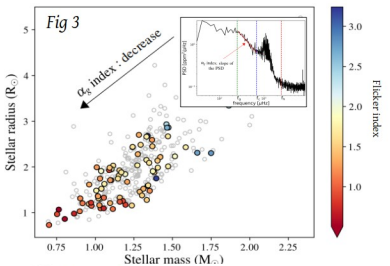
How flicker impacts the inferred planet radius ?

Stellar granulation (and oscillations) signals can reach several tens of ppm. When single transits are observed : this nuisance signal biases the transit parameters.
We have done simulations of synthetic exoplanet transits on quiet solar data (Fig.1) to quantify this bias.
Based on classical characterization MCMC algorithm (assuming the noise is a WGN), we found bias in the inferred planet radius that can reach 12% (blue histograms, Fig2). Simulating similar light curves, but with true WGN, led to error models << 3% (see red histogram).
Based on more complex flicker noise modeling (GP), the errorbars on the transit parameters are larger, but the unpredictable bias remains.
We need good indicators to characterize the statistical properties of this noise source.





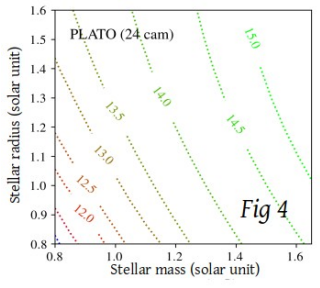
The flicker index : a new indicator to track the flicker noise



We developed a new indicator to track the granulation noise properties in photometric light curves: the flicker index. It is defined as the slope of the periodogram measured in the frequency range where granulation dominates (e.g., from 8 to 30 min for the Sun).

This indicator informs on the noise amplitude, characteristic frequency and correlation type. Based on hundred of Kepler light curves, we found it is correlated with the stellar parameters (Fig.3).

Predictions for PLATO



Based on the observed correlations, we predicted for which stars this noise source is expected to be significant enough to impact the characterization of Earth twin transits observed with PLATO (24 camera). For example, we expect the flicker noise to significantly impact the light curves of all solar-type stars with apparent magnitude <13 (dashed contour lines in Fig.4).