'Star light, star bright' as explained by math

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Model: A newly developed method mathematically describes periodic changes in the brightness of stars. The model can also be applied to similar variable phenomena such as climatology and solar irradiance. Credit: Morgan Bennett Smith

The evolving periodicity of the brightness of certain types of stars can now be described mathematically.

Not all stars shine brightly all the time. Some have a brightness that changes rhythmically due to cyclical phenomena like passing planets or the tug of other stars. Others show a slow change in this periodicity over time that can be difficult to discern or capture mathematically. KAUST's Soumya Das and Marc Genton have now developed a method to bring this evolving periodicity within the framework of mathematically "cyclostationary" processes.

"It can be difficult to explain the variations of the brightness of variable stars unless they follow a regular pattern over time," says Das. "In this study we created methods that can explain the evolution of the brightness of a variable star, even if it departs from strict periodicity or constant amplitude."

Classic cyclostationary processes have an easily definable variation over time, like the sweep of a lighthouse beam or the annual variation in solar irradiance at a given location. Here, "stationary" refers to the constant nature of the periodicity over time and describes highly predictable processes like a rotating shaft or a lighthouse beam. However, when the period or amplitude changes slowly over many cycles, the mathematics for cyclostationary processes fails.

"We call such a process an evolving period and amplitude cyclostationary, or EPACS, process," says Das. "Since EPACS processes are more flexible than cyclostationary processes, they can be used to model a wide variety of real-life scenarios."

Stars: The team applied their method to model the light emitted from the variable star R Hydrae, which exhibited a slowing of its period from 420 to 380 days between 1900 and 1950.© 2021 Morgan Bennett Smith

Das and Genton modeled the nonstationary period and amplitude by defining them as functions that vary over time. In doing this, they expanded the definition of a cyclostationary process to better describe the relationship among variables, such as the brightness and periodic cycle for a variable star. They then used an iterative approach to refine key parameters in order to fit the model to the observed process.

"We applied our method to model the light emitted from the variable star R Hydrae, which exhibited a slowing of its period from 420 to 380 days between 1900 and 1950," says Das. "Our approach showed that R Hydrae has an evolving period and amplitude correlation structure that was not captured in previous work."

Importantly, because this approach links EPACS processes back to classical cyclostationary theory, then fitting an EPACS process makes it possible to use existing methods for cyclostationary processes.

"Our method can also be applied to similar phenomena other than variable stars, such as climatology and environmetrics, and particularly for solar irradiance, which could be useful for predicting energy harvesting in Saudi Arabia," Das says.

More information: Soumya Das et al. Cyclostationary Processes With Evolving Periods and Amplitudes, *IEEE Transactions on Signal Processing* (2021). DOI: 10.1109/TSP.2021.3057268

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