Meeting Summary for the Live Professor Q&A on Time Series at the 2025 Astrostatistics Summer School (06/05/2025)

1 Quick recap

The meeting focused on discussing the complexities and challenges of analyzing time series data in exoplanetary astronomy, particularly around detecting weak periodic signals and calculating false alarm probabilities. Eric explained various statistical methods and techniques for time series analysis, including multi-tapering, block bootstrapping, and autoregressive models, while emphasizing the importance of checking residuals and model validation. The discussion concluded with recommendations for further reading and learning resources, including textbooks and statistical software, along with encouragement for attendees to seek additional guidance from instructors for their astronomical research.

2 Summary

2.1 Challenges in Time Series Analysis

Eric and Jessica discussed the complexities of analyzing time series data, particularly in the context of exoplanetary astronomy. Eric explained that detecting weak periodic signals is challenging, as there is no consensus on how to calculate false alarm probabilities. He noted that the best approach involves extreme value theory, a branch of statistics rarely used in astronomy. Eric also emphasized that regression on power spectra is statistically suspect due to the dependency of data points, violating fundamental statistical theorems.

2.2 Advancing Astronomical Time Series Analysis

Eric discussed the challenges of evaluating significance and characterizing data in astronomical time series analysis, highlighting the limitations of traditional Fourier analysis and the need for more advanced techniques like multi-tapering and block bootstrapping. He emphasized that while these methods improve signal-to-noise ratios and scientific inference, they still cannot provide definitive probabilities or models. Eric also addressed the issue of imputing missing data in time series, explaining the use of autoregressive

models and Gaussian processes for gap filling, while noting the difficulty in quantifying the uncertainty of these imputed values.

2.3 Understanding Residuals in Time Series

Eric explained to Sagnik the concept of residuals in time series analysis, which are the differences between observed data and model predictions. He described how to use the Autocorrelation Function (ACF) to analyze residuals, noting that Gaussian white noise residuals indicate a well-fitted model with no remaining structure. Eric emphasized that checking residuals is crucial for model validation in any type of regression or time series analysis.

2.4 Time Series Analysis in Astronomy

Eric discussed time series analysis in astronomy, recommending the textbook "Time Series Analysis" by Chatfield and Zing as a starting point for statisticians and astronomers working in the field. He explained the concept of tapering in time domain data, which helps reduce spectral leakage and edge effects in Fourier analysis by gradually reducing the influence of data at the beginning and end of a time series. Nancy inquired about multi-tapering, which Eric described as a technique involving multiple tapers applied to the data, though he admitted to not having personal experience with it.

2.5 Analyzing X-Ray Binary Time Series

Eric discussed the work of David Thompson, a mathematician and astronomer at the University of Toronto, and mentioned his involvement in statistical analysis with astronomers. He also talked about the complexity of harmonic analysis and Fourier analysis, referencing various textbooks and authors. Eric then explained how to analyze time series data, particularly for X-ray binaries, suggesting the use of both parametric and nonparametric approaches like ARIMA models and Fourier spectra. He recommended looking at papers by Jeff Scargle for insights on analyzing X-ray binaries and suggested that the accretion disk in X-ray binaries could be modeled as a "dripping rail."

2.6 Time-Domain Astronomy Analysis Techniques

Eric discussed the challenges and methodologies in time-domain astronomy, particularly focusing on the analysis of quasi-periodic behaviors in time series data. He emphasized

the importance of understanding the distinction between periodic phenomena and temporary autocorrelations, citing a Polish study by Tarno that modeled such behaviors as noise rather than periodic signals. Eric encouraged young scientists to explore various statistical tools and software, including R and Matlab, to enhance their analytical capabilities, and recommended reading foundational texts like Chatfield and Grisley for a comprehensive understanding of time series analysis.

2.7 Summer School Research Support Discussion

Eric discussed the Penn State Summer School and encouraged attendees to email instructors if they needed help with astronomical research methodology in the future. He mentioned that he and other instructors might be able to provide guidance or direct them to relevant resources like Wikipedia pages or textbooks. Eric also mentioned that he would check Slack for any additional questions from attendees after the session.