The University of Chicago

Department of Statistics

Ph.D. Seminar

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Point Process Models for Astronomy: Quasars, Coronal Mass Ejections, and Solar Flares

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ABSTRACT

This thesis presents a statistical analysis of two interesting astronomical applications that involve point process data.

The first chapter presents an application in solar physics that looks at two types of solar events: solar flares and coronal mass ejections (CMEs). The data are viewed as a marked point process in time, and the analysis seeks to determine whether there is a local temporal correlation between the two event types. A key statistical complication is that the two processes follow an inhomogeneous long term rate function that changes with the solar cycle. Our goal is to evaluate the local temporal correlation, adjusting for the fluctuation in intensity due to changes in the long term solar cycle. We present a novel approach that begins by aggregating the relative onset times for CME events relative to solar flare events in a small local window. Any local temporal correlation between the two processes would be represented by a dip or a bump in the histogram of those relative time points. We present two functional forms to model the distribution of the relative time points, and model parameters are estimated by the method of maximum likelihood. Statistical significance of the local temporal correlation was assessed via a bootstrap approach that attempts to mimic the long term trends in the data while removing any local dependence that exists. We find that there is indeed a statistically significant increase in the probability that a CME will occur in the minutes preceding the onset of a solar flare. A second bootstrap approach was implemented in order to construct confidence intervals for the fitted parameter estimates in order to provide a descriptive model for the nature of the local temporal correlation.

The second chapter presents a statistical analysis of the Quasar Luminosity Function. This application falls under the subfield of cosmology, and the thrust of the analysis is density estimation, model selection, and the detection of interaction effects in a two-dimensional point process. Following the work of Richards et al., this paper presents a flexible parametric model of quasars as a non-homogeneous Poisson process over the space of luminosity and redshift. Our contribution to this work is two-fold: first, to allow the introduction of higher-order terms as warranted by the data, and second, to extend the model in order to detect and describe any interaction effect between luminosity and redshift present in the data. Major complicating factors in this analysis are data truncation that occurs when quasars are too faint or too far away to be detected from Earth, and sampling bias due to the fact that quasars in the data set were not selected uniformly at random from the population of all quasars in the universe.

Information about building access for persons with disabilities may be obtained in advance by calling Karen Gonzalez (Department Administrator and Assistant to Chair) at 773.702.8335 or by email (karen@galton.uchicago.edu).