Application of Astrostatistical Methods in the Realm of Cosmological Experimentation

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Astrostatistics Abstract

With the development of increasingly complex astronomical theories and subsequent observational data, statistics has grown in importance as a necessity for confirming astrophysical truth, as well as predicting the development of the observable universe. Astrostatistics attempts to specifically target testable areas of theoretical astrophysics (as well as cosmology, in recent years), and develop efficient methods of analysis for the data being produced by such resources as telescope imaging systems, micro-level array imaging, and radiation detectors (the most famous being the Cosmic Background Explorer Satellite [COBE]).

Overview

In the papers explored in this short study, some common themes include particle and energy transport, galactic expansion and movement, and interference of cosmic imaging. Statistically, the methodology used in approaching these themes generally involve augmenting the data acquired into a regression centered at a specified parameter, or in more general cases constructing a three-dimensional model to describe overall trends (such as the vector-valued functions of angular momentum, magnetic flux, and light frequencies).

Astrostatistical Methodology

Data Acquisition

In astrostatistics, it can be easily inferred that the vast majority of data will be acquired using telescope technology. However, the algorithm with which the telescope acquires specific elements of data can vary greatly according to the experiment. For instance, the coronagraphic low-order wave-front sensor (CLOWFS), which explores the aberrations of astronomical data, implements an algorithm which involves the acquisition of a single frame from the detection array, computing the difference between the observed and reference frame (which is produced before the observations are made), decomposing the difference into a linear sum of modal responses (also calculated prior to the CLOWFS algorithmic loop), and using the coefficients of the sum to drive actuators, which adjust to reduce aberrations in the array (using the Monte Carlo technique). The entire loop takes about 25 seconds, only due to the insufficient hardware.

Computer Technologies and Programs

The algorithms used in the experiments vary according to the computer programs being used. The CLOWFS, as previously noted, utilizes a loop array that decomposes images into differential value summands that drive adjustment mechanisms. For the submillimeter array (SMA), which makes interferometric observations of the nuclear regions of galaxies, a MIR (micropower impulse radar) computer package is used (measuring the distance between galactic objects in proximity to each other). Finally, an experiment to measure the rate of the cosmic ray dynamo model uses a Zeus-3D MHD code to drive observations of magnetohydrodynamic (MHD) flux.

Parameters, Estimations, and Uncertainties

Dynamically, data can be adjusted to vary relative to only one parameter, allowing one to better identify statistical trends on a larger scale. However, when doing so, certain uncertainties must be considered in order to make accurate estimations. To better understand starbursts (specifically in Abell 851), data from the Spitzer space telescope can be constructed relative to the parameter of metallicity, the chemical proportions of a single-star population (with the exception of helium and hydrogen) that indicates the age of the formation. The flux density of the continuum emission of Arp 220 (the result of the collision of two major galaxies, that's still in the process of merging) plays an important role in the productivity of the submillimeter array's interferometric observations. As a result, such uncertainties as the emissivity index (the measurement of the absorbance of light at a specified wavelength) and the dust temperature must be taken into account when investigating Arp 220. In the CLOWFS experiment, the estimation of low-order aberrations can be premeasured via simulation (a priori), or in response to the observed measurement (posteriori). However, the latter would be increasingly robust, since it has already adapted to the new set of data (and thus increased its ability to withstand stress from variation). Finally, in the modeling of the cosmic ray driven dynamo, a numerical model (to be discussed in further detail in section [5]) can be used to construct radially-dependent parameter regressions. Examples of such parameters include, but are not restricted to, (1) the angular velocity of the galaxy (as a function of the galacto-centric radius), (2) the shearing parameter, i.e. the stress rate at which the substance observed deforms, (3) the gas column density, and (4) the supernova expansion rate (as a function of galacto-centric radius).

Regressions, Distributions, and Functions

Once astronomical data has been produced, such representations as regressions, distributions, and functions can be utilized to better explain observation. When studying the transport theories behind the scattering of high energy particles in the inner heliosphere (specifically, comparing the standard and dynamic quasi-linear theory [SQLT vs. DQLT]), scientists use partial differential equations (PDEs) and finite difference schemes to measure flux in energy transportation. In particular, the stochastic differential equations (SDEs) are constructed using Monte Carlo techniques. In the Spitzer telescope experiment, scientists construct point spread functions (PSFs) to describe the photometry of the starburst galaxy Abell 851 (PSFs describe the response of an imaging system to point sources, where the formulation process is linear). Using the spectral measurements from Spitzer, a X^2 function can be produced to describe the difference between the observed and predicted model (useful in the prediction of model robustness). The most relevant of these measurements is that of the metallicity of the single star population (as mentioned in [3]), where 11 different fits of the same observed data are compared, each by holding constant a particular parameter in the parameter space. The most robust (and subsequently, the most reliable) of these models can be deduced from their respective X^2 values. Finally, in the SMA measurements, a X^2 fitting is also used with respect to the flux density distributive data at various light frequencies.

Modeling and Mapping

In higher caliber experiments, in which numerous variables must be accounted for in the construction of a unified prototype, a multivariate three-dimensional (or higher) model or mapping might be the most effective. The best example of this is in our cosmic ray dynamo, in which a three-dimensional model is produced from a large, yet finite number of cubes emanating from the center of the galacto-centric measurements. As each cube gets smaller with higher resolution, the measurements converge to what is approximately the true model of the polarized emission of light from an observed edge-on galaxy (a galaxy which spins in space at an angle such that we may only observe its edge). Furthermore, the polarized emission measurements are mapped onto a contour model in the form of a circular vector field, representing the magnetic polarization of the galactic structure.

Future Work

Already, astrostatistics has displayed a prominent role in modern astronomical experimentation. The potential of applied (and even theoretical) statistics to this field becomes increasingly apparent as cosmology begins to envelope modern astrophysics, as theory overwhelms application. Modeling, in particular, appears to be the most fruitful and probable method of astrostatistical research, especially relative to high level cosmic movement (such as the expansion of galaxies, radiation propagation from newly formed supernovae, and the generation of coronal mass ejections (CMEs) within the heliosphere of our sun), allowing scientists a better understanding of astrophysical phenomena.

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