Tools for Period Searching in AGN in the Era of "Big Data"

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A supermassive (millions to billions times the mass of our Sun) black hole resides at the center of each large galaxy. When gas and dust accrete onto the black hole and fall past the event horizon, it forms an Active Galactic Nucleus (AGN), which persistently releases large amounts of light across the electromagnetic spectrum as well as collimated jets of outflowing gas. Astronomers seek to understand the connections between the feeding and growth of supermassive black holes and their host galaxies' supply of gas and dust.

We also learn about the physics of black holes by studying Black Hole X-ray Binary (BHXRB) systems residing in our own Galaxy; they consist of a ~stellar-mass black hole fed by material from its stellar companion's wind. Both classes of black holes provide testing grounds for General Relativity via the dynamical accretion flows in the region of extreme gravity, just before matter crosses the event horizon. BHXRBs' X-ray emission routinely show evidence for periodic signals that may originate in various types of global oscillation modes in the accretion flow, and are likely an imprint of black hole mass and spin.

AGN are fainter and so the data quality is lower, but there have been some claims of strictly- and quasi-periodic signals in AGN light curves from across the electromagnetic spectrum, although the statistical significances of most of these claims are questionable. Nonetheless, claims of periodic signals in AGN are interpreted as, for instance, *binary* supermassive black hole systems, a potential source of gravitational wave emission. However, normal accretion activity and jet activity at all wavebands, and on timescales from minutes to decades, is "stochastic" and aperiodic. While this variability already gives us some clues about the physical mechanisms, it tends to overwhelm any possible periodic signal, preventing us from robustly confirming if periodic signals are present in AGN.

Astronomers use a variety of statistical methods to attempt to separate the stochastic signals from possible periodic signals, but some methods' accuracy may be hampered by limited data sampling (observations are too few or too irregular), and/or not knowing the proper form for the dominant stochastic signals. With this proposal, we will test four commonly-used statistical methods, and quantify how frequently purely aperiodic signals can "trick" each method into yielding a false-positive periodic signal. We will also provide guidance on how many cycles may be required for statistically robust detection of a periodic signal if one is present.

There is an urgency to complete these tasks due to ongoing automated large-area or all-sky survey monitoring programmes such as PanSTARRS and the Palomar Transient Factory. Such programmes each produce thousands to eventually millions of AGN light curves, enabling "bulk" searches for periods across vast numbers of AGN. Furthermore, in 2017, the Zwicky Transient Factory will come online, and the Large Synoptic Survey Telescope and the Square Kilometer Array will be online within the next decade. Because the era of "big data" is upon us, we will produce guidelines for the astronomical community regarding proper usage and interpretation of these statistical tools as they apply to period-searching across large numbers of AGN.

Our results will help the community to produce only robust, statistically-significant period claims in AGN — both for individual sources or for clusters of claims resulting from bulk searches of light curve databases — allowing us to finally determine if periodic signals exist in AGN. Our results can guide the paths that the astronomical community takes when forming estimates of the fraction of galaxies containing supermassive binary systems. Finally, our project will also yield insight into the similarities or differences between accretion processes occurring in supermassive black holes and those occurring in stellar-mass Black Hole X-ray Binary systems residing in our own Galaxy.