Title:	Characterizing and Imaging Supermassive Black Hole Accretion Flows with Red Noise Power Spectra
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Abstract:	This work explores novel applications of noise derived from a “red” power spectrum, i.e. a power spectrum which decreases smoothly from larger to smaller spatio-temporal scales, in the context of supermassive black hole accretion and imaging. We characterize the spatial power spectrum of density fluctuations in magnetohydrody- namic flows in various high-resolution, long-time span general relativistic magnetohydro- dynamic (GRMHD) simulations of supermassive black holes. Extracting the spatial power spectrum directly from GRMHD simulations is non-trivial, given the non-uniform coordinate grid of the outputs. Taylor’s frozen-in hypothesis derives a mapping between the temporal and spatial power spectrum of turbulence. We explore the utility of Taylor’s hypothesis to extract spatial power spectra of density from GRMHD simulations of black hole accretion and carefully test the validity of the assumptions under which the hypothesis holds true. Using outputs from the GRMHD code, KORAL, we explore models with strong and ordered magnetic fields (MAD, magnetically arrested disks) as well as weak and disordered magnetic fields (SANE, Standard and Normal Evolution). We also explore the effects of black hole spin on the power spectra and characterize their slopes as a function of distance from the black hole. We conclude that the number density power spectrum can be modeled using a red-noise power spectrum. We observe that the slope of the azimuthally and disk-averaged power spectrum of number density increases monotonically with the distance from the black hole. We also show that the slope is only weakly dependent on the black hole spin. Further, we demonstrate the use of an eigenbasis that is derived from principal component analysis (PCA) applied to an ensemble of random noise images that have a red-noise power spectrum. The pattern of the resulting eigenbasis allows for the reconstruction of images with a broad range of image morphologies. In particular, we show that this general eigenbasis can be used to efficiently reconstruct images that resemble possible astronomical sources for interferometric observations, even though the images in the original ensemble used to generate the PCA basis are significantly different from the astronomical images. This general- purpose algorithm provides a fundamentally new method for reconstructing images from very long baseline interferometers (VLBI) instruments like the Event Horizon Telescope (EHT).
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