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Linear Mode-Decomposition in Magnetohydrodynamics Revisited

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Small amplitude fluctuations in the magnetized solar wind are measured typically by a single spacecraft. In the magnetohydrodynamics (MHD) description, fluctuations are typically expressed in terms of the fundamental modes admitted by the system. An important question is how to resolve an observed set of fluctuations, typically plasma moments such as the density, velocity, pressure and magnetic field fluctuations, into their constituent fundamental MHD modal components. Despite its importance in understanding the basic elements of waves and turbulence in the solar wind, this problem has not yet been fully resolved. Here, we present a new method that identifies between wave modes and advected structures such as magnetic islands or entropy modes and computes the phase information associated with the eligible MHD modes. Our mode-decomposition method identifies the admissible modes in an MHD plasma from a set of plasma and magnetic field fluctuations measured by a single spacecraft at a specific frequency and an inferred wave number. We present data from a typical interval at 1 astronomical unit measured by the WIND spacecraft and another sub-Alfvenic interval measured by Parker Solar Probe, and show how the new method allows for the identification of both propagating (wave) and non-propagating (structures) modes, including entropy and magnetic island modes in super- and sub-Alfvenic flows. This allows us to identify and characterize the separate MHD modes in an observed plasma parcel and to derive wave number spectra of entropic density, fast and slow magnetosonic, Alfvenic, and magnetic island fluctuations for the first time. We discuss briefly how these results help in identifying the fundamental building blocks of turbulence in the magnetized solar wind.