Nonlinear reflection process of linearly-polarized, broadband Alfven waves in the fast solar wind

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Alfvén waves are frequently observed both in the solar atmosphere (DePontieu et al. 2007 Science, Okamoto et al. 2007 Science) and the solar wind (Belcher & Davis 1971 JGR), and widely believed to play a significant role in the coronal heating and the solar wind acceleration. Since the reflection of Alfvén waves triggers Alfvénic turbulence in the solar atmosphere and the solar wind (Matthaeus et al. 1999 ApJL, Dmitruk et al. 2002 ApJ), turbulent heating rate of the corona is sensitive to the reflection rate. Comparison of recent studies (Suzuki & Inutuska 2005 ApJL, Cranmer & van Ballegooijen 2005 ApJS) strongly suggest that the compressibility of plasma, in other words the nonlinearity of Alfvén waves, enhance the reflection rate up to 100-1000 times, whose mechanism is still unclear.
Using one-dimensional numerical simulations, we study the elementary process of Alfvén wave reflection in a uniform medium, including nonlinear effects. In the linear regime, Alfvén wave reflection is triggered only by the inhomogeneity of the medium, whereas in the nonlinear regime, it can occur via nonlinear wave-wave interactions. Such nonlinear reflection (backscattering) is typified by decay instability. In most studies of decay instabilities, the initial condition has been a circularly polarized Alfvén wave. In this study we consider a linearly polarized Alfvén wave, which drives density fluctuations by its magnetic pressure force. For generality, we also assume a broadband wave with a red-noise spectrum. In the data analysis, we decompose the fluctuations into characteristic variables using local eigenvectors, thus revealing the behaviors of the individual modes.
Different from circular-polarization case, we find that the wave steepening produces a new energy channel from the parent Alfvén wave to the backscattered one. Such nonlinear reflection explains the observed increasing energy ratio of the sunward to the anti-sunward Alfvénic fluctuations in the solar wind with distance (Bavassano et al. 2000 JGR) against the dynamical alignment effect (Dobrowolny et al. 1980 Phys.Rev.Lett.).

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