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太陽風中で観測される波動スペクトルに対する位相速度と群速度の影響
Effects of phase and group velocities on wave spectra observed in the solar wind

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Waves propagating in a plasma medium which has a relative velocity to the observer are differently observed in the spectra from those in the plasma rest frame. As known in general, the observed frequency is Doppler shifted by the relative velocity between the medium and the observer, V_{rel}. The frequency shift is the result of the difference of the phase velocities of the waves in the medium rest frame and in the observer frame. When the wave vector has a finite angle with respect to V_{rel} and the component of V_{rel} parallel to the wave vector is considerable to the phase velocity, the difference of the phase velocities between the frames and the frequency shift become significant.

We note that the observed spectral density is also modified by V_{rel}. The modification of the spectral density is the result of the difference of the group velocities of the waves in the medium rest frame and in the observer frame. When the component of V_{rel} parallel to the group velocity vector is considerable to the group velocity, the difference of the group velocities between the frames and the modification of the spectral density become significant. In order to estimate the amount of the modification, we derive the analytical expression of the modified spectral density in the observer frame.

It is important to consider not only the frequency shift but also the modification of the spectral density of waves observed by spacecraft in a moving plasma, such as the solar wind. Indeed, the phase and group velocities of whistler-mode waves cause significant frequency shift and modification of the spectral density in the solar wind. By the modification of the spectral density, we can explain the characteristic properties of '1 Hz waves', which have been generally observed in the upstream regions of various bodies, and suggest that the broadband upstream whistlers are the same source waves. The understanding of the effects is necessary to reveal the true nature of waves propagating in a moving plasma and to discuss their generation processes.