Physical properties of the solar corona derived from radio scintillation observations with the Akatsuki spacecraft

*Shota Chiba[1], Takeshi Imamura[1], Munetoshi Tokumaru[2], Daikou Shiota[3], Takuma Matsumoto[4], Hiroki Ando[5], Hiroshi Takeuchi[6], Yasuhiro Murata[6], Atsushi Yamazaki[6], Bernd Häusler[7], Martin Pätzold[8], Kazumasa Iwai[2], Go Murakami[6], Yoshizumi Miyoshi[2]

1. Graduate School of Frontier Sciences, The University of Tokyo, 2. Institute for Space–Earth Environmental Research, Nagoya University, 3. National Institute of Information and Communications Technology, 4. National Astronomical Observatory of Japan, 5. Kyoto Sangyo University, 6. Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 7. Institut für Satellitentechnik und Weltraumnutzung, Universität der Bundeswehr München, 8. Rheinisches Institut für Umweltforschung an der Universität zu Köln

The solar wind is a supersonic plasma flow streamed from the solar corona. The solar wind is classified into the fast wind (typically ~750 km/s) and the slow wind (~300 km/s). The acceleration of the solar wind mainly occurs in the outer corona at heliocentric distances of about 5–20 R_S (= solar radii), where the coronal heating by magnetohydrodynamic waves and the wave-induced magnetic pressure are thought to play major roles in the acceleration. The mechanisms have not been fully confirmed by observations because the acceleration region is too close to the Sun to be observed by in-situ probes.

Recently, however, the inner heliosphere observation network is getting ready, such as NASA's Parker Solar Probe and ESA's Solar orbiter. The radio occultation observation covers the acceleration region fully and can obtain the large-scale process of the plasma complementary to in-situ observation. JAXA's Venus orbiter Akatsuki conducted the radio occultation observations on either side of the superior conjunction. The observations covered various solar cycle periods from solar maximum to solar minimum.

Key physical processes in the acceleration region can be observed with radio occultation. Coronal plasma traversing the ray path disturbs radio waves' amplitudes and frequency, from which we can derive physical parameters such as the flow speed and waves' amplitudes. We analyze data taken by radio occultation observations using Akatsuki's radio waves during the superior conjunction periods in 2011, 2016, 2018, and 2021.

The radial velocity and the turbulence characteristics (power-law exponent, axial ratio, and inner scale) were retrieved from the intensity scintillation time-series taken in 2016 by fitting a theoretical spectrum to the observed power spectra. In the radial distribution of the derived solar wind velocity, fast winds originating from regions near a coronal hole and slow winds from other regions were identified. We also found that the inner scale increases with the heliocentric distance and that the fast solar wind has larger inner scales than the slow solar wind. These tendencies are consistent with the inertial length model proposed by Coles and Harmon (1989).

We also applied wavelet analysis to the frequency time-series taken in 2011 to detect quasi-periodic fluctuations (QPC) that are thought to represent acoustic waves and quantify the amplitude, the period, and the coherence time of each wave event. The density amplitude and the wave energy flux were estimated following Miyamoto et al. (2014). We confirmed that the fractional density amplitude increases with distance up to ~6 R_S. The amplitude reaches tens of percent, suggesting a possibility of wave breaking. The energy fluxes increase with distance up to ~6 R_S, suggesting a local generation of waves. It is probable that these radial distributions indicate that the Alfvén waves propagating from the photosphere generate acoustic waves in the outer corona, and the generated acoustic waves dissipate to heat the corona, as suggested by numerical models. The wave energy fluxes in the fast solar wind were larger than those in the slow wind. The results suggest that the fast solar wind originating from the coronal hole is powered by a larger injection of wave energy than the slow wind originating from other regions. In this

presentation, we will also report results from the data taken by Akatsuki.

Keywords: Solar wind, Radio occultation, Akatsuki