PEM25-01 Room:202 Time:May 25 09:00-09:15

Electron acceleration at high beta low Mach number collisionless shock

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Voyager spacecraft revealed that the solar wind termination shock is a rather weak shock since the upstream plasma beta is high and effective Mach number of the shock is low due to the presence of pickup ions. Nevertheless, the fluxes of non-thermal electrons and ions (the latter are called as termination shock particles) are enhanced when crossing the termination shock. Electron acceleration at a weak shock is also reported in terms of galaxy cluster merger shocks. In this study we perform two-dimensional full particle-in-cell simulation to discuss microstructure of the high beta and low Mach number shock and the associated electron acceleration. Unlike a one-dimensional simulation, electrons are not reflected at the shock when a shock angle is close to 90 deg. due to the effect of rippling. Nevertheless, some electrons are accelerated locally at the transition region. Wave-particle interactions appear to play a role.

Keywords: collisionless shock, numerical simulation, particle acceleration

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PEM25-02 Room:202 Time:May 25 09:15-09:30

Acceleration of pickup H^{+}, He^{+}, and O^{+} in the corotating interaction regions

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Pickup ions (PUIs), interstellar neutral particles ionized mainly by the charge exchange with solar wind plasmas, are considered to be the dominant source of anomalous cosmic rays (ACRs). Recent studies suggest that the heliospheric termination shock alone is not capable of accelerating primary PUIs up to the ACR energy range, an order of MeV. Among other mechanisms responsible for the PUI acceleration, we focus on the preacceleration process inside the heliosphere before the encounter with the termination shock. Corotating interaction regions (CIRs) are one of such a particle accelerator because their boundaries form the (forward and reverse) shocks. We perform two-dimensional hybrid simulations to investigate the PUI dynamics in association with CIRs. We have already shown that the hydrogen PUIs can gain energy over 250 keV. A periodic boundary in the present CIR model allows the successive CIRs, where the diffusive shock acceleration for PUIs can be attained between them. In the present study, we will pay additional attention to the behavior of other PUI species, helium and oxygen, which are also main ACR components. Detailed processes as well as efficiency of their acceleration are compared with those of hydrogen case. We will further unify the composite acceleration process during the CIR propagation.

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PEM25-03 Room:202 Time:May 25 09:30-09:45

Strahl formation in the solar wind electrons: Particle-in-cell simulation

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The present study puts forth a possible explanation for the outstanding problem of the *strahl* formation in the solar wind electrons. Making use of the fact that in the collisionless limit the electron core-halo relative drift exists in the direction away from the Sun in such a way that the halo usually flow faster than the core, the present study carries out one-dimensional particle-in-cell simulation of whistler instability, assuming anisotropic core and drifting isotropic halo. The enhanced whistler waves driven by anisotropic core lead to the pitch angle scattering of drifting halo in an asymmetric way since the number of the drifting halo participating in the resonant interaction is different between the halos moving the sunward and anti-sunward directions. In this way, pitch angle scattering of the anti-sunward moving halo by the whistler waves propagating sunward is more efficient in phase space and leads to the energy transfer from the drift energy to the thermal energy of halo. During the saturation phase of whistler wave-halo particle resonant interaction, the remaining part of the anti-sunward moving halo, which is out of resonance with the whistler waves propagating sunward, turns out to be a field-aligned *strahl* in the electron velocity distribution.

Keywords: non-thermal solar wind electron velocity distributions, the magnetic-field-aligend strahl, whistler instability

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PEM25-04 Room:202 Time:May 25 09:45-10:00

Forward cascade of whistler turbulence at ion scales

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Two-dimensional electromagnetic particle-in-cell simulations in magnetized, homogeneous, collisionless electron-ion plasma demonstrate the forward cascade of whistler turbulence at ion scales. Saito et al. (2015, submitted) emphasized that the modified two-stream instability could contribute the dissipation of kinetic turbulence at ion scales, by demonstrating rapid damping of a monochromatic ion-scale whistler wave in two-dimensional particle-in-cell simulation. The instability is driven by the electric current fluctuation perpendicular to the mean magnetic field. Through the development of the instability, electrons and ions are scattered in the directions parallel and perpendicular to the mean magnetic field, respectively. We expect that the forward cascade of whistler turbulence and the dissipation related to the modified two-stream instability contribute plasma heating and have key role of variability of power-law index of magnetic spectrum at ion scale in solar wind. Solar wind observations show that larger cascade rates of turbulence lead to steeper power-law magnetic spectra. The instability driven dissipation could explain property of the magnetic spectra at ion scales. Discussion will focus on properties of whistler turbulence, such as the power-law index, wavenumber anisotropy, electron and ion heating, through the forward cascade of decaying whistler turbulence.

Keywords: kinetic turbulence, plasma heating, wave-particle interaction

Japan Geoscience Union Meeting 2015
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PEM25-05 Room:202 Time:May 25 10:00-10:15

Turbulence analysis using Capon's method

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Multi-point measurements can separate temporal and spatial variations. In case of spacecraft experiments, the number of data points in the time domain can be large, but that in the spatial domain is simply the number of spacecraft, and is only a few at most. Since usual data analysis techniques, such as the Fourier decomposition, cannot be applied to such a dataset, more sophisticated techniques such as Capon's method or the maximum entropy method have been developed and successfully used in various applications.

On the other hand, magnetohydrodynamic (MHD) waves in space plasma often have very large amplitude and thus are subject to rapid nonlinear evolution. As a result, we often encounter MHD turbulence rather than a superposition of a few number of MHD waves in space plasma. The Capon's method cannot be applied to such situations, where the of waves exceeds the number of data points.

Recently, we have developed a method to analyze the turbulence data making use of the Capon's method, even though the number of waves is much larger than the number of data points. In the presentation, we will introduce the method and discuss how it can be applied to analyze the MHD turbulence in the solar wind.

Keywords: MHD turbulence, Capon's method

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PEM25-06 Room:202 Time:May 25 10:15-10:30

Kaguya observations of the lunar wake in the terrestrial foreshock

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There forms a tenuous region behind the Moon in the solar wind, as the lunar dayside surface adsorbs most of the incident solar wind plasma. Entry processes of solar wind plasma into this tenuous region, which is called the lunar wake, have been widely studied. In addition to gradual refilling of the wake by the ambient solar wind, it has been known that a portion of solar wind protons that are scattered at the dayside surface or deflected by crustal magnetic fields can enter the wake (i.e. type-2 entry). However, proton entry into the deepest lunar wake (i.e. anti-subsolar region at low altitude) by the type-2 process needs specific solar wind conditions. Here we report, using data from Kaguya spacecraft in orbit around the Moon, that solar wind ions reflected at the terrestrial bow shock easily access the deepest lunar wake, when the Moon is located in the foreshock. When the spacecraft location is magnetically connected to the lunar night-side surface, the kinetic energy of upward-going field-aligned electron beams decreases or electron beams disappear during the reflected-ion events, which shows that the intrusion of the shock-reflected ions and electrons into the wake changes the electrostatic potential of the lunar night-side surface.

Keywords: Solar wind-Moon interaction, Lunar wake, Plasma refilling, Shock-reflected ions, SELENE (Kaguya)

PEM25-07 Room:202 Time:May 25 10:30-10:45

Classification of ULF waves observed by ARTEMIS around the Moon in the solar wind

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Electromagnetic waves in the ULF band have been observed around the Moon in the solar wind by Explorer 35 [Ness, 1969], WIND [Farrell et al., 1996], Geotail [Nakagawa et al., 2003], Lunar Prospector [Halekas et al., 2006, 2008], Kaguya [Nakagawa et al., 2011, 2012; Tsugawa et al., 2011, 2012], and ARTEMIS [Halekas et al., 2013]. It has been suggested that these waves originate from the solar wind interaction with the Moon, e.g., particle reflections by the lunar magnetic anomalies or surface, temperature anisotropies through the surface absorption, or plasma instabilities at the lunar wake boundary. However, it has been difficult to establish the energy sources and the propagation processes of the waves by a single spacecraft observation. Their phase velocities comparable to or smaller than the solar wind velocity also make it difficult to identify the characteristics of the waves because of large Doppler-shift by the solar wind. We investigate the dataset of ARTEMIS which is a two-spacecraft (P1 and P2) complement in order to reveal natures of the ULF waves.

The two probes are orbiting around the Moon in the ecliptic plane at selenocentric distances$\sim$1.1-12 lunar radii since July 2011. We analyze the time series of the magnetic field vectors sampled in 4 Hz by the fluxgate magnetometer (FGM) in the fast survey mode. In consequence of comprehensive analyses, we identify four types of ULF waves: 1) broadband electromagnetic noise, 2) 1 Hz whistlers, 3) 30 s waves, and 4) wake front perturbation $<$0.01 Hz. The electromagnetic noise is caused by currents or drift driven instabilities in the dayside and wake boundary. 1 Hz whistlers also originate from the instabilities but propagate and group-standing in the Moon frame. 30 s waves of terrestrial ion foreshock are frequently observed around the Moon even 60 R_E upstream from the Earth when the interplanetary magnetic field (IMF) connects to the bow shock. 30 s waves are also occasionally generated by the ions reflected from the Moon when IMF is parallel to the solar wind. The wake front perturbation is observed with right-hand and left-hand polarizations at inbound and outbound the wake, respectively. These features suggest that they are phase-standing whistler perturbation outward the wake edge Doppler-shifted by the spacecraft velocity.

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PEM25-08 Room:202 Time:May 25 11:00-11:15

Long-term observation of the solar radio emission by the Nobeyama Radio Polarimeters

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Long-term monitoring observation of the Sun provides the basic data for investigating the variation of the solar activity. However, it is very difficult to consistently observe the solar activity, which has about 11 years cycle, because observational instruments and projects usually have limited durations. The Nobeyama Radio Polarimeters (NoRP) are radio telescopes to monitor the total flux of the Sun at the micrometer range. This frequency range is thought to be a good indicator of the solar activity at the upper chromosphere and corona. In this study, we summarize the 64 yeas of the NoRP observation and give a perspective of its future observation.

The NoRP was constructed at Toyokawa by Nagoya University on 1951 to observe at 3.75 GHz. Then, the observational frequency has been increased at Toyokawa and Nobeyama. The telescopes in Toyokawa were moved to Nobeyama on 1994. Then, the present 7 frequencies observation which contains 1.0, 2.0, 3.75, 9.4, 17, 35, and 80 GHz was started. The time resolution of this system is 0.1s. This high time resolution data are often used for flare studies. In addition, the calibration method has been kept consistently since the beginning of the observation. Hence, the continuous observation over about 6 solar cycles can also be an important data for the study of the solar activity. Daily operations of the NoRP are fully automated, which is suitable for the long-term monitoring observation. All parts used in the NoRP are listed and spare parts are stored for all parts as possible in order to minimizing the loss of the observation due to the mechanical troubles.

F10.7 index, which is a total radio flux of the Sun at 2.8 GHz (wavelength is 10.7cm), is widely used as an indicator of the solar activity. The observation bands of the NoRP cover around the 2.8GHz. The continuous observation of the NoRP will be a useful data to study the variation of the solar activity and its influence to the upper atmosphere of the Earth.

Keywords: Sun, Radio radiation, Long term variation

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PEM25-09 Room:202 Time:May 25 11:15-11:30

Average features of interplanetary shocks observed with the Global Muon Detector Network (GMDN)

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It has been well established that the short term decreases of galactic cosmic ray (GCR) isotropic intensity (or GCR density) at the Earth, called 'Forbush decreases' (Fds), are mostly caused by the interplanetary shocks passing the Earth. The GCR spatial distribution which reflects the magnetic structure and geometry of the shock causing Fd can be deduced from the observation of three dimensional GCR anisotropy associated with Fds, because the first order anisotropy arises from the diffusion and drift of GCRs which are proportional to the spatial gradient of GCR density in the Fd.

Deriving the dynamic variation of GCR anisotropy during the Fd observed with a single detector, however, has been difficult because the traditional analyses based on the diurnal variation of GCR intensity provide only the daily mean equatorial anisotropy. The present GMDN consisting of four multi-directional muon detectors in Nagoya (Japan), Hobart (Australia), São Martinho (Brazil) and Kuwait city (Kuwait) started operation in 2006 and successfully observed dynamic variations of GCR anisotropy associated with major Fd events (Okazaki *et al.*, 2008; Kuwabara *et al.*, 2009; Fushishita *et al.*, 2010; Rockenbach *et al.*, 2014).

In this presentation, we analyze the average features of GCR density gradient associated with interplanetary shocks identified by the Storm Sudden Commencement (SSC) onset recorded at the Earth between 2006 and 2014. About 100 SSC events classified into two groups arising from coronal hole and flare are analyzed. From the first order anisotropy corrected for the solar wind convection and Compton-Getting effect arising from Earth's orbital motion around the Sun, we deduce the three dimensional density gradient on hourly basis for each SSC event. We then derive the average temporal variation by superposing variations at the SSC onset timing. We find clear enhancements of radial and latitudinal density gradients after the SSC implying the geometry of low GCR density region in Fds behind the shock front. We also discuss the difference in average features in events caused by shocks arising from coronal holes and flares.

Y. Okazaki *et al.*, *Astrophys. J.*, **681**, 693-707, 2008.
T. Kuwabara *et al.*, *J. Geophys. Res.*, **114**, A05109-1~10, doi:10.1029/2008JA013717, 2009.
A. Fushishita *et al.*, *Advances in Geosciences*, eds. W. H. Ip and M. Duldig (World Scientific Publishing Co., USA), **21**, 199-210, 2010.
M. Rockenbach *et al.*, *Space Sci. Rev.*, **182**, 1-18, 2014.

Keywords: density gradient of galactic cosmic rays, Forbush decrease, solar modulation, interplanetary shock, solar flare, coronal hole

PEM25-10 Room:202 Time:May 25 11:30-11:45

The souce region of solar wind in the photosphere

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In this paper, we calculate coronal magneti field expanding to the interplanetary space by the Radial-Field model (devised by Hakamada) with synoptic maps of photospheric magnetic data observed by the NSO/Kitt Peak, USA. We project solar wind speed distribution on the source surface observed by the STE-Lab of Nagoya University to the photosphere along the line of force in the coronal magnetic field. We found the following results; (1) around the maximum pase of solar activity cycle, slow speed solar winds emanate from very narrow string like areas surrounding closed magnetic regions in the photosphere which have extreemely high magnetic expansion rate, (2) in the other phases, bisides the maximum, high speed winds emanate from high latitudes of less magnetic expansion rate, except near the poles, and slow speed winds emanate from narrow belts of large magnetic expansion rate in low to middle latitudes extending the solar equator.

Keywords: solar wind, photoshphere, source region, solar wind speed

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PEM25-11 Room:202 Time:May 25 11:45-12:00

Relationship between coronal hole area and solar wind speed

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We report the relationship between coronal hole areas and average solar wind speeds for Carrington rotations (CR) from 1893 to 2108. The coronal hole is known as a region with low X-ray emissivity, and a source of the high speed solar wind. Nolte et al. (1976) investigated the relationship between equatorial coronal holes, which are located within $\pm$ 10 degrees of the ecliptic plane, and the maximum solar wind speed using Skylab data. As the result, they reported a linear correlation between the coronal hole area and the maximum wind speed with a slope of 80 ± 2 km s^{-1} $(10^{10}$ $km^2)^{-1}$. In this study, we identify coronal holes using synoptic magnetic field data of Kitt-Peak National Solar Observatory (KP/NSO) and the potential field source surface (PFSS) model. The speeds of the solar wind from coronal holes are determined from interplanetary scintillation (IPS) observations of STEL which provide global information of the solar wind. Our analysis reveals a linear relationship between the coronal holes area and the average solar wind speed similarly to Nolte et al. (1976), but with a more gentle slope than the earlier study. We also discuss its dependence on the solar activity.

Keywords: solar wind, coronal hole

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PEM25-12 Room:202 Time:May 25 12:00-12:15

North-south asymmetry in global distribution of the solar wind speed during Cycles 22-24

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The north-south (N-S) asymmetry in the solar activity is important from viewpoint of the solar dynamo theory, since the axisymmetric magnetic field cannot be maintained by the dynamo action (Cowling, 1933). The N-S asymmetry in the solar activity has been studied from observations for various kinds of solar surface phenomena. However, the heliospheric consequence caused by the N-S asymmetric solar activity is poorly understood owing to shortage of global observations. The N-S asymmetry in the heliosphere is important information to study the propagation of cosmic rays and influence on the space weather. Therefore, we have studied the N-S asymmetry in global distribution of the solar wind speed using interplanetary scintillation (IPS) observations at the Solar-Terrestrial Environment Laboratory (STEL) of Nagoya University. IPS observations enable us to investigate global distribution of the solar wind speed on the source surface for a given Carrington rotation. The period analyzed here is between 1985 and 2013 (except for 2010), corresponding to between Cycles 22 and 24. We divided our IPS data into north and south data, and calculated the fractional areas of fast, slow and intermediate speed winds for those two groups. As result, we find that significant N-S difference in fast and slow wind distributions over the poles exist particularly at solar maxima. This asymmetry results from earlier occurrence of disappearance/reformation of fast winds at the north pole than that at the south pole, and it is closely linked with the time lag of the polarity reversal at both poles. Furthermore, enhanced N-S asymmetry of polar fast wind is also found between Cycle 23 declining phase and 24 maximum. We compared our IPS data with g20/g10, where g20 and g10 are quadrupole and dipole components of harmonic coefficients derived from the potential field analysis of magnetograph observations at Wilcox Solar Observatory. As result, a weak but significant correlation are found between those quantities, and this fact suggests that higher-order magnetic moments such as quadrupole make an important contribution to the N-S asymmetry in global distribution of the solar wind speed.

Keywords: solar wind, interplanetary scintillation, solar cycle, Sun's magnetic field, heliosphere, space weather