TWO FREQUENCY RANGES OF THE MAGNETIC FLUCTUATIONS IN THE SOLAR WIND DETECTED BY KAGUYA AROUND THE MOON. T. Nakagawa[1], F. Takahashi[2], H. Tsunakawa[2], H. Shibuya[3], H. Shimizu[4], M. Matsushima[2]. [1]Tohoku Institute of Technology, Miyagi 982-8577, Japan (nakagawa@tohtech.ac.jp), [2]Tokyo Institute of Technology, Tokyo 152-8550, Japan, [3]Kumamoto University, Kumamoto 860-8555, Japan, [4]Earthquake Research Institute, University of Tokyo, Tokyo 113-0032, Japan.

Abstract: Magnetic field measurement from the MAP-LMAG magnetometer [1-3] onboard Kaguya on its orbit encircling the moon revealed the predominance of magnetic fluctuations of two frequency ranges, 0.3-10 Hz and 0.008-0.01 Hz, when the moon was exposed to the solar wind.

Figure 1 shows an example of the dynamic spectrum for a 24-hour period on January 4, 2008, obtained by Kaguya/LMAG magnetometer at an altitude of 100 km on its orbit around the moon. Broadband magnetic fluctuations were observed repeatedly in the range from 0.03 Hz up to about 5 Hz, every 118 minutes of the spacecraft's rotation period of the orbital motion. In the lower frequency, rather narrow-band, intense magnetic fluctuations were recognized at around 0.008-0.01 Hz.

In some cases the two classes of waves were observed simultaneously, while either type was found with the absence of the others in other cases [4]. It is analogous to the waves upstream of the earth's bow shock which falls in two frequency ranges of 0.5-4 Hz and 0.01-0.05 Hz [5].

The non-monochromatic waves at 0.03-10 Hz were almost always observed on the solar side of the moon, with intensification above the magnetic anomalies. They were also detected just nightside of the terminator (SZA < 123 degree), but absent around the center of the wake. The level of the fluctuation enhanced over the wide range from 0.03 to 10 Hz, with no clear peak frequency. The fluctuations had the compressional component, and the polarization was not clear [4].

The large amplitude, monochromatic ultra low frequency waves had the dominant frequency of 0.008-0.01 Hz, corresponding to the periods of 120-100 s [6]. The amplitude was as large as 3 nT. The occurrence rate was high above the terminator and on the dayside surface. The direction of the propagation was not exactly parallel to the interplanetary magnetic field, but showed a preference to the direction of the magnetic field and the direction perpendicular to the surface of the moon just below the spacecraft. The sense of rotation of the magnetic field was left-handed with respect to the magnetic field in 53 percent of the events, while 47 percent showed right-handed polarization [6].

The possible generation mechanism of the waves of the two frequency ranges is thought to be the cyclotron resonance of the solar wind protons reflected by the moon [7, 8] with the whistler waves [4] and the magnetohydrodynamic waves [6]. Plotted onto a two-dimensional space of angular frequency versus wave number, the two classes of waves correspond to the two intersections of the resonance condition with the dispersion curve of the plasma waves in the solar wind. Generation of the two frequency bands is consistent with the previous theoretical and numerical works on the wave generation by the ion beam injected into the solar wind plasma [8].

As whistler waves can propagate against the solar wind flow, the generation site of the non-monochromatic waves can be either on the lunar side of the spacecraft, or upstream side in the solar wind flow. The non-monochromatic nature of the 0.3-10 Hz waves can be explained by the wide range of direction of the reflected protons.

On the other hand, the monochromatic ultra-low frequency wave can not propagate against the solar wind flow. They must be generated on the upstream side of the spacecraft, and then convected down by the flow. Nearly equal percentages of the lefthand and righthand polarizations of the low frequency waves are explained by the direction of proton reflection, which is not antiparallel to the incident solar wind flow.

References: [1] Shimizu et al. (2008), *Earth Planets Space, 60*, 353-363. [2] Takahashi et al. (2009), *Earth Planets Space, 61*, 1269-1274. [3] Tsunakawa et al. (2010), *Space Sci. Rev., 154,* 219-251, doi:10.1007/s11214-010-9652-0. [4] Nakagawa et al. (2011), *Earth Planets Space, 63,* 37-46. [5] Fairfield (1974), *J. Geophys. Res., 79,* 1368 -1378. [6] Nakagawa et al. (2011), submitted to *J. Geophys. Res.* [7] Saito et al. (2008), *Geophys. Res. Lett, 35,* L24205, doi:10.1029/ 2008GL036077. [8] Saito et al., *Space Sci. Rev., 154*, 265-303, doi:10.1007/ s11214-010-9647-x.[9] Gurgiolo et al. (1993), *Geophys. Res. Lett., 20,* 783-786.

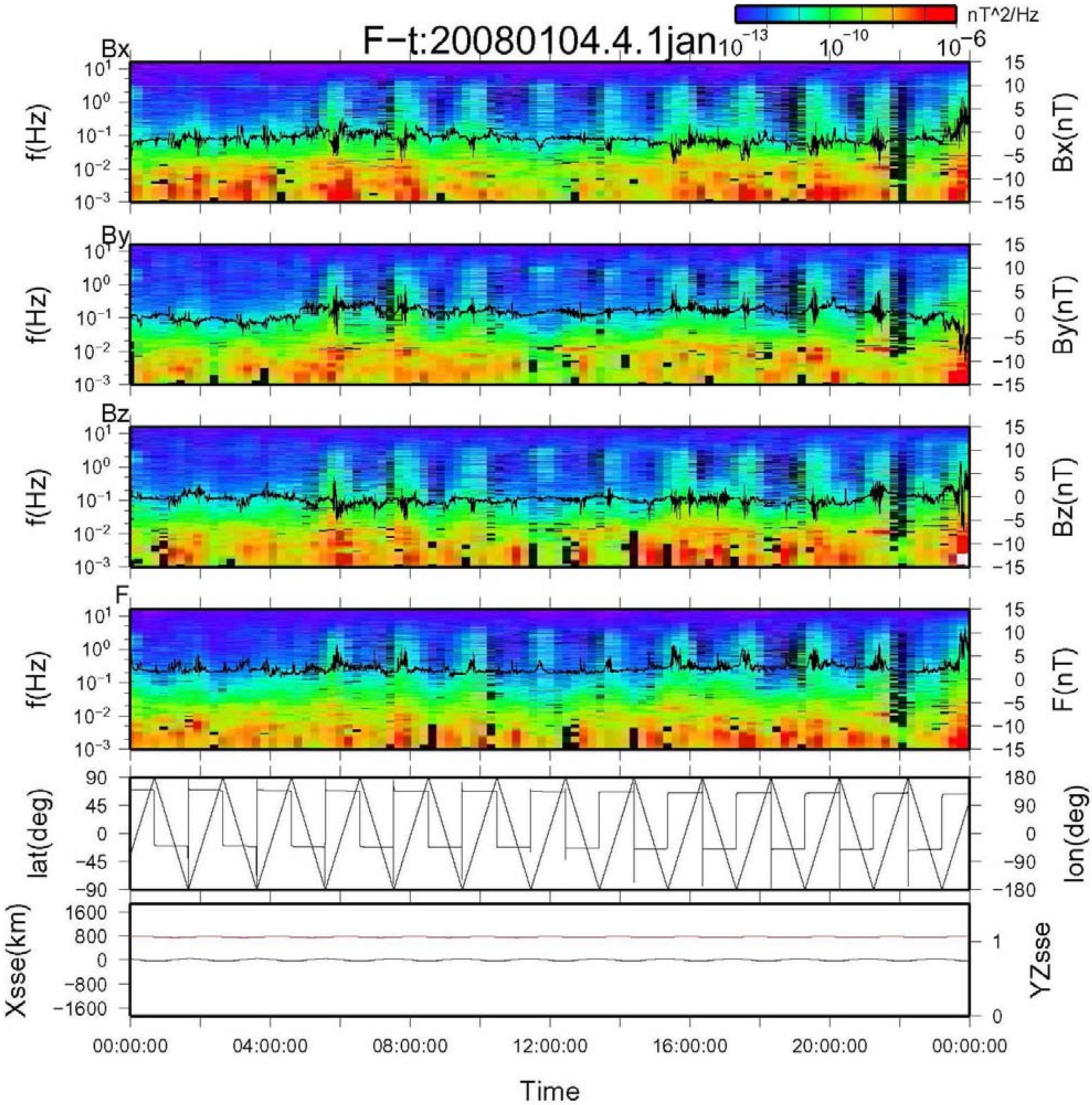

Fig. 1 The dynamic spectra of the magnetic field components Bx, By, Bz in SSE coordinates, and the magnitude |B| obtained by KAGUYA MAP-PACE on January 4, 2008. Overlaid are the magnetic field components and the magnitude. The magnetic field data sampled at 32 Hz were Fourier transformed every 1024 sec. The bottom two panels show the latitude and the longitude of Kaguya in the mean Earth/polar axis (ME) coordinate system, and the x-component of the position in selenocentric solar ecliptic (SSE) coordinates together with the distance Yzsse which is the square root of the sum of Ysse and Zsse squared, normalized by the lunar radius. YZsse>1 indicates that the spacecraft was not shadowed by the moon. The orbit of Kaguya was nearly along the terminator on this day [4].