VLF Detection of Ionospheric Disturbances Caused by Magnetar Flares

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It is well established that ordinary neutron stars possess magnetic fields of about 10^{12} Gauss. Recently, much attention has been drawn to exotic neutron stars called "magnetars". As the name implies, magnetars are considered to have extremely strong magnetic fields of about 10^15 G. Some of the magnetars emit short-duration (~0.1 s) gamma-ray bursts repeatedly in active phases, thereby they are named as "Soft Gamma-ray Repeaters (SGRs)". As rare events, SGRs emit exceptionally bright gamma-ray flares "giant flares", whose peak fluxes exceed those of X-class large solar flares by several order of magnitudes. So far, only four giant flares were observed: from SGR 0526+66 in 1979, SGR 1900+14 in 1998, SGR 1806-20 in 2004, and SGR 1550 in 2009.

Determination of gamma-ray energy spectrum of the giant flares are essential to reveal the flaring and emission mechanisms. However, it was difficult to measure because the huge flux saturates all the gamma-ray detectors on satellites, and hence alternative methods are needed. As a new approach, we have been recently interested in VLF data. Gamma-rays from the flares unusually ionized the lower ionosphere and caused ionospheric disturbances. These were detected as large and rapid amplitude and phase changes of VLF radio waves. In this presentation, we present recent results concerning how we deduce the energy spectrum from the VLF data.

Using Monte Carlo method, we modeled ionization of lower ionosphere, and obtained altitude profile of electron number density. We then utilized Finite-Difference Time Domain (FDTD) method to simulate VLF propagation. The altitude profile and simulated amplitude change differs depending on the energy spectrum. Therefore, by comparing simulation results with the observation, we can infer the source spectrum as an inverse problem. We present results concerning the SGR 1900+14 and 1806-20 giant flares in 1998 and 2004. We also show VLF data as well as initial results concerning the newest giant flare from SGR 1550-5418 on January, 2009.