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Ratio of thermal to non-thermal energy in solar flares

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It has been a question in the particle acceleration problem in solar flares how much energy is to non-thermal. In non-thermal dominant cases, flares trend to generate high energy particles, such as electrons that is responsible to strong non-thermal emission in hard X-rays and in microwave as well as protons and alpha particles. Therefore, it is important not only for solar physics but also for space weather studies to understand what the conditions of intense non-thermal energy release are, and to quantify how much energy is. To estimate the ratio of thermal energies to non-thermal energies, we aim for the emissions from solar flares in thermal and non-thermal conditions. We treat other conditions such as duration of solar flares, and we think that the ratio of a flux of the thermal to the non-thermal emission gives a solution of the problem of the ratio of thermal to non-thermal energies.

An empirical raw, so-called the ”Neupert effect”, has a key to connect thermal and non-thermal energies. This suggests that the integration of flux of non-thermal emission (hard X ray, microwave) is consistent with the temporal behavior of thermal emission (soft X ray). However, the soft X-ray emission estimated from non-thermal emission is different from the observed soft X-ray flux and the error is about one order of magnitude. These problems can be thought that the ratio of the energies converted to the non-thermal energy in solar flare is not a constant.

We use the Neupert effect with microwave observation at the beginning of its theory, but now we use it mainly with the hard X rays observations. One of the reasons of this is the complexity of microwave emission mechanisms; microwave flux is depending on magnetic strength, energy of electron in flare loop, line of sight, pitch angle distribution of electrons, and so on. Microwave emission is observed from gyro-synchrotron radiation of electrons trapped in the flare loop, and same trapped electrons may emit microwave continuously. Therefore the flux of microwave is not always proportional to the number of the electrons. Another difference of hard X ray observation is that hard X ray observation watch emission from electrons of few keV to few hundred keV, on the other hand, microwave observation watch emission from electrons of few hundred keV to few MeV. Therefore, which energy gives Neupert effect, or chromospheric evaporation effectively is not revealed yet.

We compare soft X ray, hard X ray and microwave emissions, and evaluate the fraction of non-thermal energy in flares and the effectiveness of Neupert effect. We investigate soft X ray data taken by GOES and RHESSI, hard X ray data by RHESSI, and microwave by Nobeyama Radioheliograph (NoRH). We compare the time integration of non-thermal emissions to maximum flux of thermal emissions statistically. We discuss which energy band range (hard X ray or microwave) is effective for the Neupert effect using data of NoRH, RHESSI. We also investigate the morphology of flare loops and the energy release conditions using data of SOHO MDI/EIT, TRACE.

Keywords: solar flare, microwave, high energy, X-ray