Recent Classifications of Solar Flares

Jia – Long Wang

Beijing Astronomical observatory, Beijing 100080 *P. R. China*

Abstract

A review on solar flare classifications proposed recently is given firstly in the first part of this paper. Then a new classification of solar flares, based on optical, radio and X-ray observations of flares, is proposed in the second part. The classification tries to reflect temporal process and spacial structure of a flare with the optical, radio and X-ray observational data obtained at different phases of a solar flare. The first one of the three letters used in the classification is decided by the spacial relation of the hard X-ray source with the H_α source in the early phase of the flare classified. The second letter is decided by the temperature of the X-ray source around the peak phase of the flare and the third letter of the classification is decided by the configuration of the relevant magnetic field in the late phase of the flare.

1. Introduction

Great progresses of solar flare observations and studies have been made since 70s of this century, in particular of the spatial observation of flares. These progresses have greatly changed our traditionary conception of a solar flare which was established mainly based on optical observation, and have given us a completely new idea of what a solar flare should be according to ground-based and space - based observations in multi-energy-bands. Now, we know that a flare is a time process with a three dimensional spatial structure radiating various emissions in a certain temporal order, although we do not quite know the mechanism of a flare in detail, yet. A number of classifications of solar flares (e. g. Pallavicini et al. 1977; Ohki et al. , 1983; and Tanaka, 1983) have been proposed recently along with these progresses. The proposed classifications, in principle, well reflect the progresses of solar flare study made in various periods of time, on one hand. On the other hand, it is obvious that we should have a multi-energy-bands classification of flares instead of a single-band or a simple classification of flares, by which we may appropriately describe the time process and the spatial structure of a flare. In the first part of this paper a brief review of the recently proposed classifications of flares is given. Then in the second part, a new classification based on multi-bands observations is proposed. Finally we simply discuss the flare classifications in the third part of this paper.

2. Review of the Recently Proposed Flare Classifications.

Švestka (1976) divided solar flares into two kinds in his book, Solar Flares, published in 1976. One kind of flares is called low temperature flares, the other one is called high temperature flares. Actually, his high temperature flares mainly are the high temperature sources emitting radio, X-ray and other energetic emissions while low temperature flares mainly are the low temperature sources of the flares emitting optical emissions. Based on soft X-ray imaging observations of 43 limb flares by satellite Skylab Pallavicini et al. (1977) grouped flares as compact flares, bright point-like flares and large and extended flares firstly. Then they simplified their three groups of flares into two groups, low and compact flares and high, extended and low density flares. Thus, the density of flares is the critical parameter in Pallavicini's classification.

In 1980s, hard X-ray imaging of solar flares was successfully carried out by satellites such as SMM and Hinotori. This supplied a good condition to the study of energetic part of flares. Using the hard X-ray images of flares obtained by satellite Hinotori, Ohki et al. (1983)classified hard X-ray bursts as two types: (a) flares with impulsive time profiles and low positions. and (b) flares with gradual time profiles and high positions. That flares are grouped as impulsive and gradual is of considerable significance but it is found that some flares have a moving source from low position at early phase to a high position at late phase (Wang et al. , 1987).

A widely quoted classification (types A, B and C) of flares was proposed by Tanaka (1983) and discussed by Tsuneta (1984), which was mainly based on the different characteristics of flares in hard X-ray images, spectra and flux variabilities. Some radio properties of flares of different classes of this classification were mentioned when Tanaka (1987) reviewed the impact of X-ray observations from Hinotori satellite on solar flare research. In this classification, hot thermal flares especially with Fe XXVI line emissions are defined as type A, impulsive flares emitting from the extended low corona including the footpoints and with softening spectra are defined as type B, and gradual-hard flares especially with a high source and hardening spectra are defined as type C flares. No doubt, this classification is a good summary of the very successful Hinotori observation, but it is faced the ununiqueness problem as pointed out by de Jager and Svestka (1985) and Nitta et al. (1989). Meanwhile, Takakura et al. (1984). analyzed Hintori data and argued that a burst might be a combination of some among the components including impulsive component, gradual component, thermal component, quasi-thermal component and hot thermal component. This idea is obviously more physics. However, it seems to be not convenient to use in realistic and morphological applications.

In a discussion of physical aspects of the prediction of solar flares with solar activity forecasters. Sturrock (1984) divided flares into 7 types considering mainly filament activities and magnetic configurations before a flare. These 7 types of flares are $\overline{\mathrm{F}}\mathrm{N}$, $\overline{\mathrm{F}}\mathrm{C}$, $\overline{\mathrm{F}}\mathrm{O}$, $\mathrm{F}\overline{\mathrm{E}}\mathrm{C}$, $\mathrm{F}\overline{\mathrm{E}}\mathrm{O}$, FEC, and FEO respectively, where F means no filament, F~filament, E~filament eruption but no ejection, E~filament ejection, N~no current sheet, C~closed current sheet and O~open current sheet. Surely this is a more theoretical classification of flares. Actually, till now we can not directly measure the feature of a current sheet on the sun just before a flare. Since the complicacy of classifying flares and every classification of flares has its own weak points, Švestka (1986) persisted his suggestion that flares should be simply divided into two categories, dynamic flares and confined flares. This classification appears to be too simple to use in applied aspects and subclassifications have to be developed. In 1989, Bai and Sturrock (1989) reviewed solar flare classifications with an emphasis on energetic flares, and proposed a new classification of flares. Flares are classified as thermal hard X-ray flares, non-thermal hard X-ray flares, impulsive gamma-ray/interplanetary proton flares, gradual gamma-ray/interplanetary proton flares and quiet filament eruption flares. A possible problem for the practical use of this classification might be the serious dependence of the interplanetary proton measurement on the interplanetary condition.

3. A New Multi-Energy-Bands Classification of Flares.

Observational base of the classification: optical (H_α) radio (dynamic spectrum) and hard and soft X-ray observations.

Purpose of the classification: trying to reflect the recently ground-based and space-based observational results of flares and give physical differences of different types of flares.

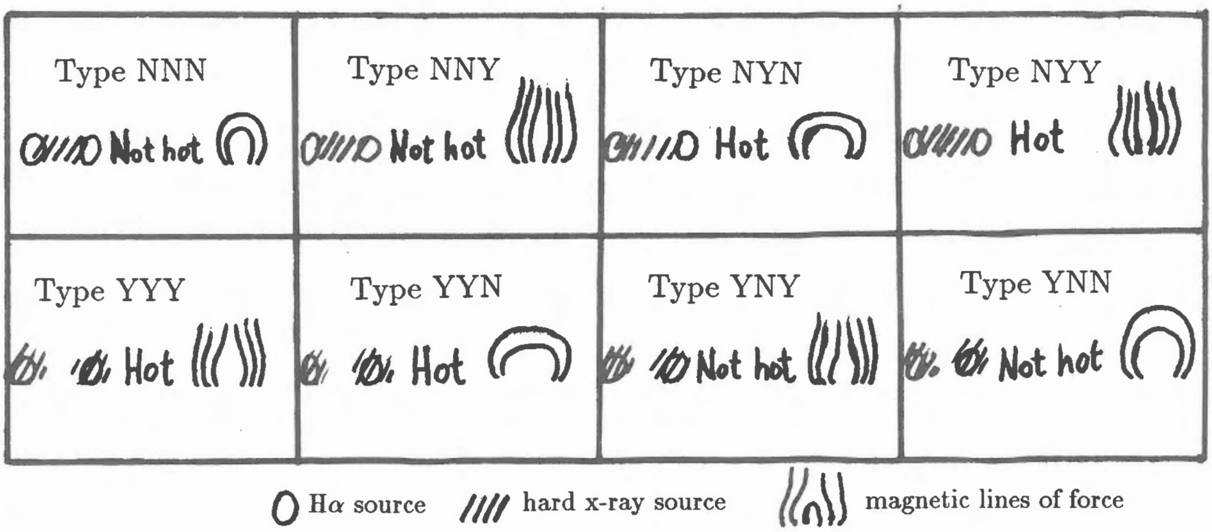

Fig. 1 Illustration of the multi-bands classification of solar flares.

Method of the classification: We use a group of three letters to classify flares. We use the first letter of the letter group to reflect the spatial structure of the flare in the early phase. If the hard X-ray source of the flare is low near the chromosphere or the normal projection of the main hard X-ray source is coincident with the H_α patch of the flare in the early phase, we take Y as the first letter. Otherwise, put N as the first letter. The second letter is used to reflect the thermal status of the plasma of the flare in its peak phase. If Fe XXVI line emissions are observed from the flare around the peak phase, we take Y as the second letter. Otherwise N should be the second letter. The third letter is used to reflect the magnetic configuration of the flare in its late phase. It has been known for a long time that proton flares have a close relation with an open magnetic field and a type VI radio burst. So we put Y as the third letter if the flare is accompanied by a radio type VI burst in it late phase. Otherwise the third letter is taken as N.

Thus, all of flares is classified into eight types as illustrated in Figure 1. Obviously, every certain flare would belong to a certain type and flare such as the flare on 1980 May 21 which is thought to have simultaneously properties of type B and C (de Jager and Svestak, 1985) and the flare on 1982 February 3 which is thought to have simultaneously properties of type A, B, and C, (Nitla et al., 1989) can easily be classified in our classification.

4. Discussion

From what we reviewed above we can see that the progress of flare classifications goes along with the progress of solar flare observation and study and that any parameter or a combination of parameters of flares can be used as a criterion of a classification but only a multi-bands classification might be able to reflect the complicated process of a flare and to show the physical differences between flares.

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