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Statistical Properties of Soft X-ray Fluxes of Solar Flares† ⋆

ZHANG Ping[1,2,3]△ LIU Si-min[1,2]△

[1] *Purple Mountain Observatory, Chinese Academy of Sciences, Nanjing 210008*

[2] *Key Laboratory of Dark Matter and Space Astronomy, Chinese Academy of Sciences, Nanjing 210008*

[3] *University of Chinese Academy of Sciences, Beijing 100049*

Abstract In order to quantitatively study the statistical properties of the soft X-ray emission in solar flares, an algorithm has been developed to automatically detect flares in a given range of peak fluxes, and to analyze the flares observed by the GOESs (Geostationary Operational Environmental Satellites) from 1980 to 2013 in two soft X-ray bands. This study indicates that the statistical characteristics of the variation of flare soft X-ray flux near the peak time are independent to the magnitude of peak flux: on the average, the rising time of flare's soft X-ray flux is about half of the decay time, and the rising and decay times in the high-energy channel are shorter than the corresponding times in the low-energy channel, however, all these times will increase with the variation amplitude of flare's soft X-ray flux.

Key words The Sun: flares—The Sun: X-rays—Methods: statistical

1. INTRODUCTION

A major uncertainty in the studies of statistical properties of solar flares comes from the identification of flares, especially of small flares[1−5], meanwhile, considering that the effects of solar activities on the terrestrial environment are closely associated with the magnitudes of solar flares, the studies on the statistical properties of large flares have a greater practical

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△ zhangping@pmo.ac.cn, liusm@pmo.ac.cn

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importance. In the statistical studies of solar flares, the analysis on the light-variation features of solar flares, which are rather easy to be acquired, and the analysis on the relevant time scales have important significance. The time scales of light variations of solar flares are closely related to the dominant physical mechanisms during the solar eruptions, and they are also the basis for modeling the space weather prediction[6−8].

A series of environmental GOES satellites are operated in the geosynchronous orbits by the National Environmental Satellite, Data, and Information Service belonging to the National Oceanic and Atmospheric Administration of USA, and their onboard X-ray detectors provide the most complete data of soft X-ray fluxes of solar flares up to now. Since the first GOES satellite was launched in 1974, these X-ray detectors have collected the data almost continuously in nearly 40 years, with the time resolution of $2 \sim 3$ s in two soft X-ray wavebands of $1 \sim 8$ Å and $0.5 \sim 4$ Å. The flare classification based on the magnitude of flare peak flux at the $1 \sim 8$ Å band is the generally accepted standard for measuring the magnitudes of flares. And the previous studies on the statistical properties of soft X-ray fluxes of solar flares are mainly based on the flux data at the $1 \sim 8$ Å band.

Many parameters describing the flare features exhibit a power-law frequency distribution without a characteristic scale, this is quite similar to the phenomenon of self-organized criticality[7,9−11]. In this case, the larger and smaller events are completely similar to each other in their statistical properties, thus to ensure the power-law frequency distributions of relevant parameters. However, in the detailed multi-band observation and analysis of solar flares, it is found that the physical mechanism to produce large flares seems to be different from the production mechanism of small flares. For instance, the coronal mass ejections are commonly accompanied with large flares, and the two-ribbon flare loop systems also appear in many large flares. Moreover, according to the rising time of X-ray flux in the impulsive phase of flares, they are classified into two types: the gradual and impulsive flares. Further quantitative analysis is needed in order to make sure whether the statistical properties of the soft X-ray emissions in solar flares are related to the peak flux of soft X-ray emission.

In this paper, we have developed a group of programs for the flare identification in a given interval of peak fluxes. This method has avoided the traditional dependence of flare identification on the background flux, it can be used to analyze the variation characteristics of large flares (especially near the peak times). Using this algorithm, we have analyzed the flare data observed by the GOES satellites in several ten years at the two soft X-ray wavebands. We have not only reproduced the dependence of the eruption frequency of solar flares with different classes on the solar cycle, but also comparatively studied the behaviors of the solar flares with different classes near the peak times. In Section 2, we summarize the basic characteristics of GOES data, and discuss the algorithm for flare identification, the analyzed results are given in Section 3, and a brief discussion and summary are given in Section 4.