Suppression of Hydrogen Emission in a White-light Solar Flare


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Suppression of Hydrogen Emission in a White-light Solar Flare

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Abstract

We present an analysis of an X-class flare that occurred on 11 June 2014 in active region NOAA 12087 using a newly developed high cadence Image Selectors operated by Astronomical Institute in Ondřejov, Czech Republic. This instrument provides spectra in the 350 - 440 nm wavelength range, which covers the higher order Balmer lines as well as the Balmer jump at 364 nm. However, no detectable increase in these emissions were detected during the flare, and support observations from SDO/EVE MEGS-B also show that the Lyman line series and recombination continuum were also suppressed, particularly in comparison to an M-class flare that occurred on hour earlier, and two other X-class flares on the preceding day. The X-class flare under investigation also showed strong white light emission in SDO/HMI data, as well as an extremely hard electron spectrum (\(E \approx 5.6\)), and \(g\)-ray emission, from RHESSI data. This unique combination of datasets allows us to conclude that the white light emission from this flare corresponds to a black body heated by high-energy electrons (and/ or ions), as opposed to optical chromospheric emission from hydrogen.

Introduction

About 40 years ago Machado & Rust (1974) observed a white-light flare using a slit spectrograph working in waveband 350 - 430 nm and detected strong emission in higher order Balmer lines, calcium lines, and increased continuum of up to 12% around Balmer jump. Machado et al. (1986) then concluded that two types of white-light flares (WLF) are distinguished and each one can be a mixture of both types. Type I was described as flares with strong and broad Balmer lines caused by f-b transitions and originating in chromosphere at a temperature about \(10^5\) K, in contrast with type II with much weaker Balmer lines and flat wavelength dependence originating deeper in photosphere with density higher than \(10^{12}\) cm\(^{-3}\) and strong \(\chi^2\) contribution. An observation close to the limb was reported by Boyer et al. (1985). The measured contrast around Balmer jump reached up to 19% and emission in CaK, CaII H and K lines were detected. Authors concluded that Paschen or H\(\alpha\) continuum were unlikely responsible for the detected emission. Instead they proposed a presence of a slightly (\(\sim 150\) K) warmer layer in the photosphere while speculating about an existence of this phenomena in the absence of a flare just due to an evolution of magnetic structures with time. Kowalski et al. (2015) studied a response of SDO/EVE class stars’ atmosphere on high energy electron fluxes using SDO/EVE code and compared it with observations. They concluded that high flux (\(\sim 10^{-2}\) erg cm\(^{-2}\) s\(^{-1}\)) of non-thermal electrons produce a heated, high-density chromospheric condensation layer with a high hydrogen b-f and c-f opacity. In their simulations this atmosphere then produce black-body radiation with a temperature around \(10^5\) K and a relatively small Balmer jump ratio.

Main Findings

1. Absence of higher order Balmer and Lyman lines.
2. White-light emission.
3. Two sudden brightenings in Balmer continuum channel (351 - 365 nm).
4. Very hard particle beams, including ions.

Analysis

Spectroscopic observations

To explain an origin of white-light flares their spectrum is crucial to obtain. However due to a strong background radiation in visible range, contrast of the flare on the solar disk is too low to measure an irradiance from the whole disc.

Satellite data

SDO/HMI observations show WL emissions during all studied flares. M3 event shows several bright points, some of them lasting several dozens of minutes, X1 event produced a ribbon-like structure during the impulsive phase and a long lasting bright point in the decay phase. Yellow light curve in the bottom panel of Figure 5 shows a decay phase of a bright spot lasting about one hour, the green light curve shows gradual increase exceeding the investigated time range. These lifespans are significantly longer than that predicted by TRACE of the Solar Telescope. Brief analysis of RHESSI observation shows a presence of very hard particle beams. Spectral index during the impulsive phase probably reach \(\eta \approx 3\). The flare in Figure 4 does not match proposed scenario of type I nor type II WL flares, as both produce b-h hydrogen emission.

Observations

In this paper, we present the RHESSI observation of a strong X-class flare that occurred on 11 June 2014 in active region NOAA 12087. The device is operated by Astronomical Institute in Ondřejov, Czech Republic. This instrument provides spectra in the 350 - 440 nm wavelength range, which covers the higher order Balmer lines as well as the Balmer jump at 364 nm. However, no detectable increase in these emissions were detected during the flare, and support observations from SDO/EVE MEGS-B also show that the Lyman line series and recombination continuum were also suppressed, particularly in comparison to an M-class flare that occurred on hour earlier, and two other X-class flares on the preceding day. The X-class flare under investigation also showed strong white light emission in SDO/HMI data, as well as an extremely hard electron spectrum (\(E \approx 5.6\)), and \(g\)-ray emission, from RHESSI data. This unique combination of datasets allows us to conclude that the white light emission from this flare corresponds to a black body heated by high-energy electrons (and/ or ions), as opposed to optical chromospheric emission from hydrogen.

Conclusions

A suppression of hydrogen lines along with increased flux in wavelengths > 400 nm during a white-light emission might suggest that this emission is rather coming from a hot black-body component as proposed by Kowalski et al. (2015).

Forcoming Research

To explain the origin of WL flares shown in this poster, analysis of optical depth might be performed. HMI data are suitable for a technique proposed by Potts et al. (2010), who studied photospheric variations and their visibility through the ribbon. Also lots of theoretical work has to be done, such as hydrodynamics modeling using RADYN or RH code.

References


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