White-Light Flares: A Proposed Improvement to Known Classic Reduction Methods

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Introduction: White-light Flares

In the last decades multi-wavelength observational studies have given different constraints to the energy transfer models during solar flares, in particular the so called white-light flares (WLF), where an enhancement of the continuum emission or white light (WL) is observed. These particular events have challenged the scientific community with different theoretical and observational issues, in particular in the physical processes behind their generation and their influence on the different layers of the solar atmosphere. In this work an observational method is introduced in order to identify WLF events and estimate, in a consistent way, the WL excess flux. A comparison with the classical reduction methods is performed based on synthetic and real observations, which allows the direct comparison of the advantages/drawbacks between these different observational treatments. We find that classical techniques are not capable to remove the intrinsic solar-noise and in some extreme cases unphysical and non-instrumental signals can be created, which could lead to an inaccurate estimation of the energy emitted during WLFs.

Methods

The second step includes a masking procedure which usually relies on geometrical and intensity threshold assumptions regarding the white light emission detected in the previous step. Common masking procedures are the following:

- **Geometries**
  1. Circles
  2. Ellipses
  3. Squares

- **Threshold**
  A. N-times the Quiet-Sun-Intensity
  B. Background Logarithm
  C. Instrumental number

Finally, the third step requires the estimation of the white light flare flux itself. This includes either the normal intensitygrams, their differences or, in our procedure, a simple integral reconstruction algorithm to remove the possible emerging artifacts in the final flux estimation. A flow diagram describing this numerical procedure is the following:

Analysis:

Nowadays several observational methods have been applied to measure the white-light excess from continuum images, giving as a result considerable differences in the estimated energy associated with the flaring event. These techniques are divided in three parts; in the first part differences between images are considered in order to localize the kernels of emission. In our notation, the discrete index (i) denotes a particular frame taken at a certain time which will be temporarily separated from the next frame by the cadence of the instrument. Three differentiation schemes are considered in this work:

- **Normal**
- **Average**
- **Integration**

Figures:

- **Fig 1.** Solar flare observed at the extreme ultraviolet by the Atmospheric Imaging Assembly (AIA) on board the Solar Dynamic Observatory (SDO).
- **Fig 2.** Normal differences (right) Average differences of the white-light flare SOL-2011-09-06 T22:00
- **Fig 3.** Integration differences + reconstructed signal + circle mask + N-times the Quiet-Sun-Intensity for the flaring event SOL-2011-09-06 T22:00
- **Fig 4.** Signal-reconstruction algorithm
- **Fig 5.** Geometrical configurations for the generated synthetic flares. These also include the information of the emission kernels in the field of view and changes itself frame-to-frame.
- **Fig 6.** Synthetic flare light curves. Considered shapes include three symmetrical triangular functions with different duration, a step-like and a Planck-like functions for the emission excess. All the profiles have been degraded to take into account the finite cadence of the instrument (HMI).
- **Fig 8.** White Light synthetic emission flux recovered using different combination of the reduction methods sample. Each colored line represents a procedure (lower trace). Upper-left plot shows the 5 best behaved procedures. Upper-right panels show the synthetic intensitygrams and their integrated differences.

Results & Discussion:

We have tested the reduction methods with 25 different types of synthetic white light flares (5 geometries x 5 light curves). For the white light excess estimation our comprehensive approach included 3 types of backgrounds (no spot, synthetic spot, observational spot), 5 differences methods, 5 types of masks and 3 different measurements performed over intensitygrams, their differences, and via the integral reconstruction algorithm (see Fig. 4). This means, that we have measured the synthetic white-light-excess over the 25 synthetic white light flares in 265 cases. A sample of the resulting measurements is present in Fig. 8, where the x-axis show the expected flux values for each flare (normalized to the brighter synthetic event) and the y-axis shows the measured value normalized by its corresponding expected value.

References: