White-light Emission in the F-CHROMA Grid

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Basics

Introduction

Much of a solar flare's energy is thought to be released in the continuum. The optical continuum ("**white--light**") is of special interest due to the ability of observing it from the ground. Nonetheless, the mechanisms are still poorly understood, with two main branches of theories:

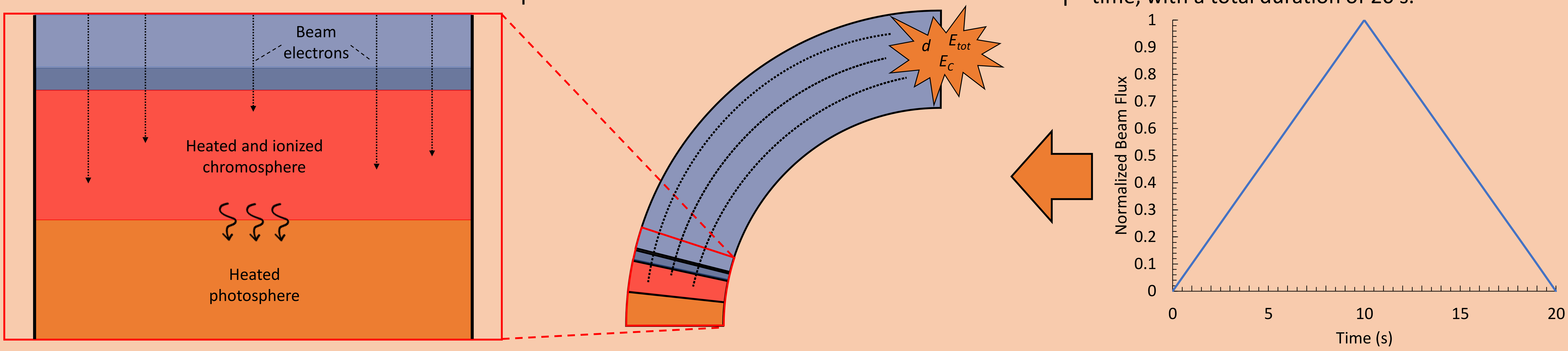
I. Optically thick radiation from the photosphere
II. Optically thin hydrogen-recombination radiation from the chromosphere

The RADYN Code

The 1D radiative hydrodynamics code **RADYN** can model the atmospheric response to an electron beam following either the description of Emslie or the Fokker-Planck formalism. The electrons in the beam are assumed to be non-thermal, having been accelerated in the corona, and to follow a power-law distribution. The characteristic properties of a given beam are the **spectral index** d, the **cutoff energy** E_C and the **total energy** per area E_{tot}.

The F-CHROMA Grid

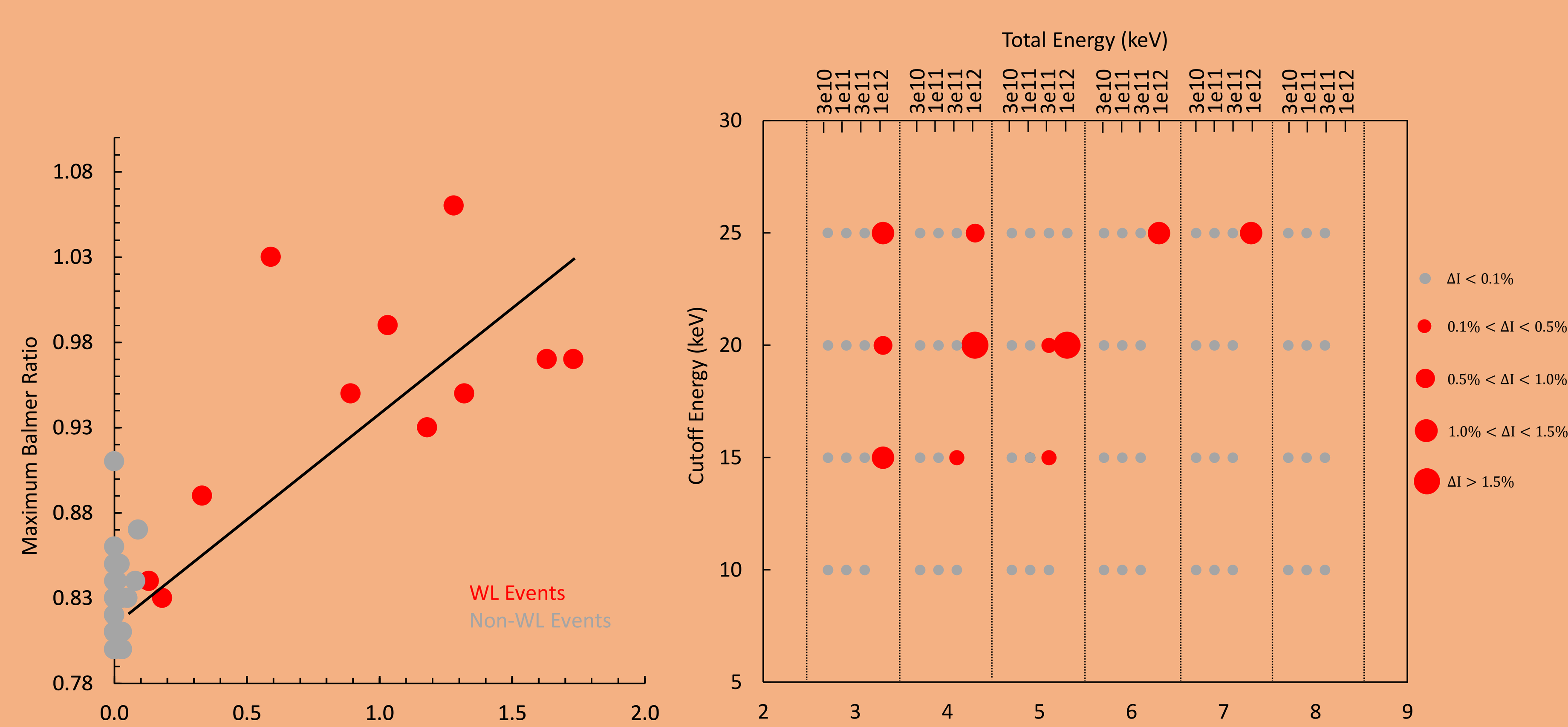
The F-CHROMA grid[3] is a grid of flare simulations which is **freely available**[4] and includes input files and a script to conduct the flare simulation. The atmosphere consists of a quarter-circle loop of half-length 10 Mm. The intersection of the loop with the bottom boundary (90 km below the $\tau = 1$ height) is assumed to be vertical. Both the lower and upper boundary are closed (i.e., reflective). The shape of the electron beam flux is triangular in time, with a total duration of 20 s.



Analysis

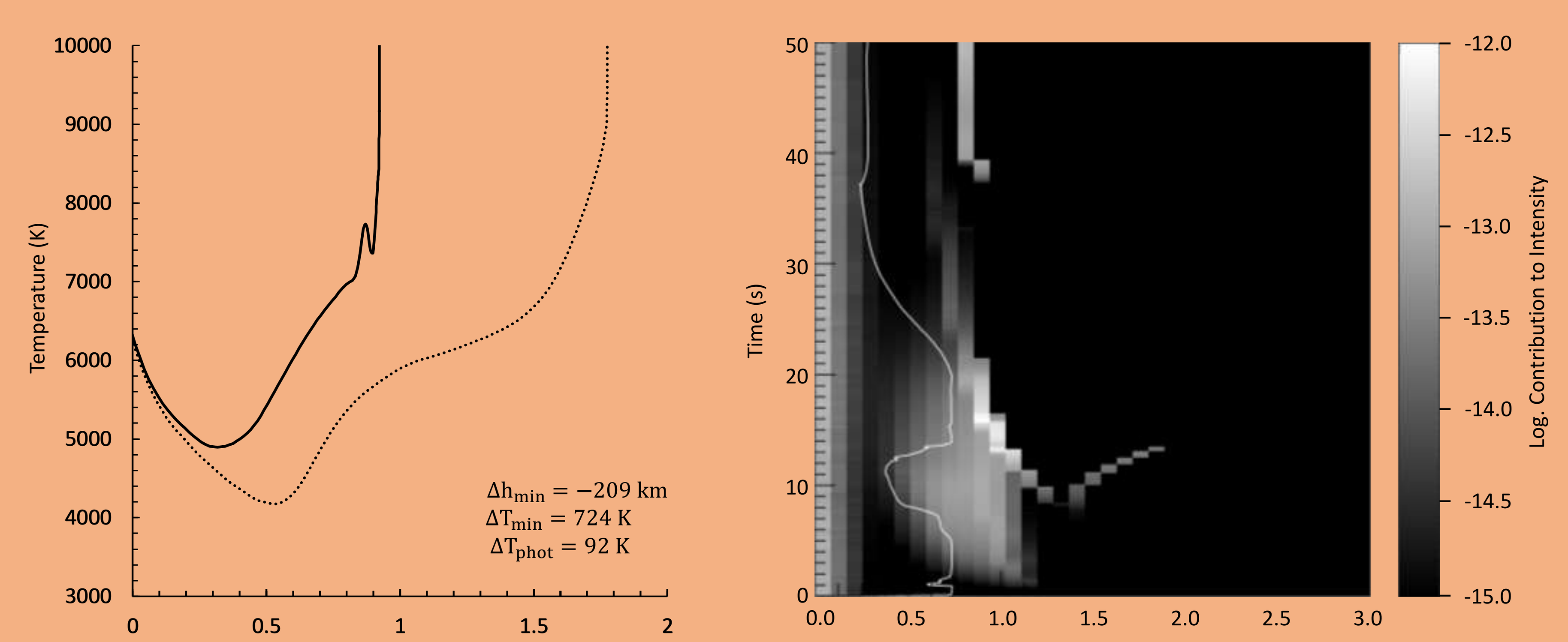
Statistical Results

12 of the 83 flares included in the F-CHROMA grid show white-light intensity enhancements relative to the pre-flare level that exceed 0.1%. Generally, a **higher total beam energy, higher cutoff energy and lower spectral index** are the preferential conditions for white-light intensity enhancements. Furthermore, there is a (linear) relationship between the Balmer/Paschen ratio and the relative continuum enhancement.



Case Study

Parameters: d = 4, $E_{tot} = 10^{12}$ keV, E_C = 20 keV. The bulk of the enhanced Balmer/Paschen continuum emissions is coming from an **optically thin region in the chromosphere**. However, there is also a temperature increase in the temperature minimum region and even down to the lower photosphere, which slightly enhances the intensity coming from those regions. There are two compact regions with very high contributions, which are characterized by a high (electron) density. These are part of a chromospheric condensation and a chromospheric blob travelling upward.



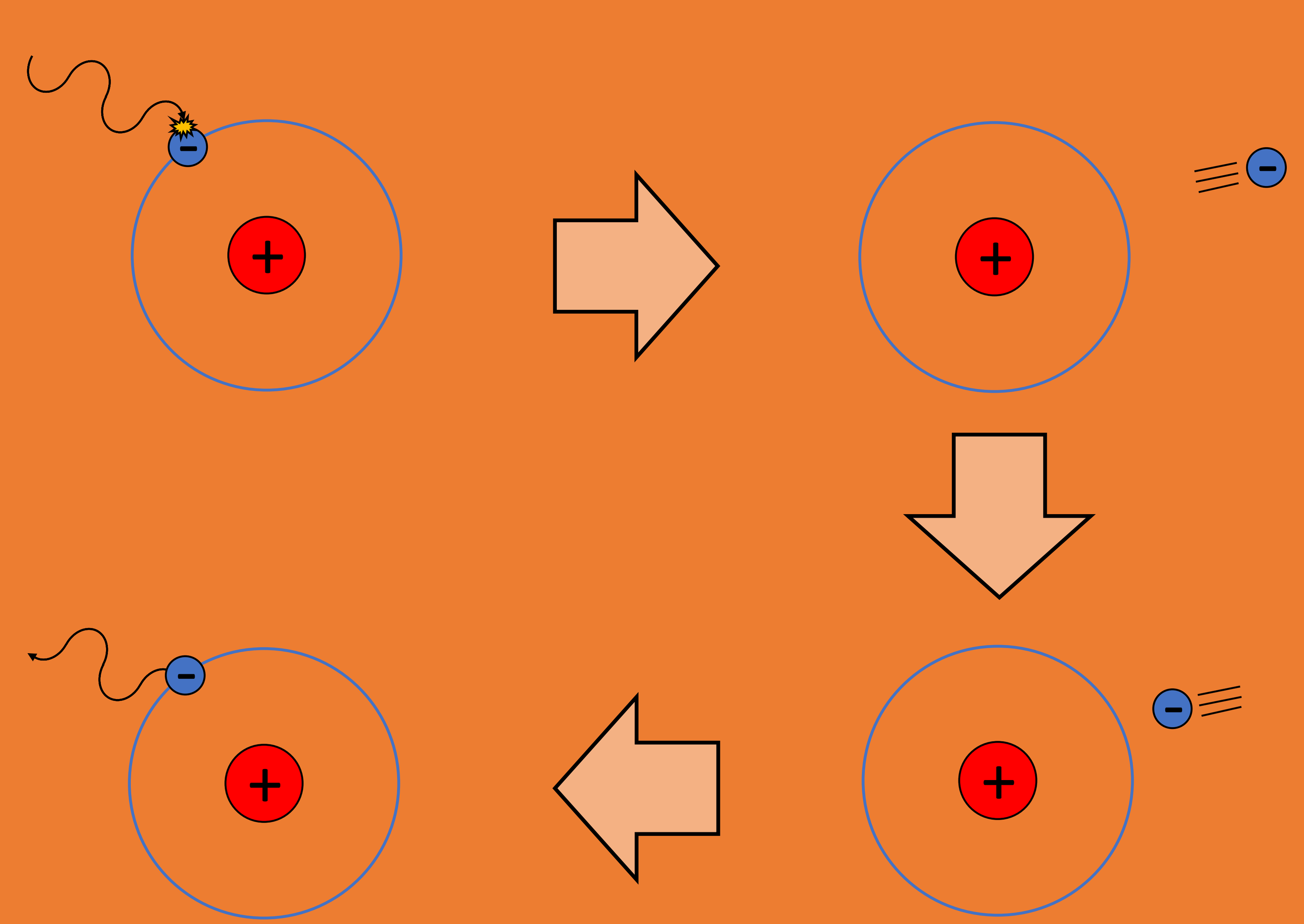
Discussion

The Statistics

The **total beam energy** (or maximum beam flux) seems to be the main factor for deciding whether white-light emissions will be detectable or not. The higher the spectral index in the F-CHROMA grid, the less likely white-light emission occurs. However, due to the enormous computational effort needed to simulate events with a high spectral index, high beam flux and small low-energy cutoff, there are only a limited number of events available at those ends of the parameter space, which may distort the distribution.

The Mechanism

H-ionization and subsequent recombination in the optically thin chromosphere is determined to be the most dominant mechanism for the enhanced Balmer/Paschen continuum emissions.



Links and Documents

[3] Carlsson, M., Fletcher, L., Allred, J., et al. 2023, A&A, 673, A150. doi.org/10.1051/0004-6361/202346087 (QR code on the left)

[4] Available at https://star.pst.qub.ac.uk/wiki/public/solarmodels/start.html (QR code on the right)