UV EMITTING SPICULES

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Abstract

Extreme ultraviolet observations of the chromospheric network in a coronal hole obtained in 1973 by the Harvard College Observatory experiment aboard Skylab are analyzed. Upper and lower limits to the actual emission measure in UV spicules have been obtained, and the consistency of the derived values with the hypothesis that UV spicules are Hα spicules falling back after being heated is discussed.

Introduction

EUV spectroheliograms from Skylab show evidence of a concentration of emission at the boundaries of the supergranular network, where it is well known that spicules originate. As their average cross-sections are well below the instrument spatial resolution, spicules cannot be individually resolved. However, evidence for the identification of the brightest network elements with spicules comes from the close spatial correspondence between dark Hα mottles and bright UV regions, as well as from their comparable time evolution (Feldman et al. 1976, Reeves et al. 1976). Significant UV emission from spicules is also required to match observed and theoretical limb-brightening curves, which result in a good agreement if the variation with height of the number of UV spicules is the same as for Hα spicules (Withbroe and Mariska, 1975; Kanno, 1978).

Even if their presence is well ascertained, the physical parameters of UV spicules are largely unknown. The purpose of this short note is to show how, from low-resolution data, upper and lower limits to the actual emission measures in UV spicules, could be derived, and how they compare with current ideas about their connection with Hα spicules.

The Method.

The data which are here analyzed were acquired by the EUV Harvard spectrometer on Skylab. Eight spectroheliograms obtained at different times on May 31, 1973 give the brightness distribution on a 5x5 arcmin coronal hole area located near the center of the Sun. Each spectro-

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heliogram has been produced at the seven wavelengths of the normal polychromatic setting, and consists of a number of picture elements, partially overlapping, with individual resolution of 5 x 5".

As spicules are concentrated in network areas, the network should be preliminarily identified. The network area percentage at increasing heights can be evaluated from the frequency vs. intensity distribution of chromospheric and transition region lines originating from ions formed in different temperature ranges. The histogram data have been interpreted as reproducing a symmetric distribution, representative of the cell plus an asymmetric distribution, obtained by subtraction from the total of the Gaussian-like distribution, representative of the network and spicule emission. The asymmetric distribution is found to occupy an area percentage between 35% (OIV) and 48% (CIII). In the following a constant value of 40% will be assumed for all of the ions, due to the order-of-magnitude character of the present considerations.

It is now necessary to derive the number of spicules a typical spectroheliogram is likely to contain. If, following Beckers (1968), the number of spicules per unit area, is assumed to be about 3×10^{-8} km^{-2}, a representative spectroheliogram will contain $\sim 1.5 \times 10^3$ spicules. Their distribution along the network can only be guessed, due to their unobservability, and two different hypotheses will presently be made: 1) the network itself consists of spicules evenly distributed along the supergranular boundaries, 2) spicules are clumped together and arranged so as to completely fill a fraction of the network picture elements.

In the first case all of the network elements will include a spicule (due to the already mentioned partial overlapping of picture elements), and the average intensities derived from the frequency vs. intensity distribution and usually ascribed to the network emission would rather be representative of the spicular emission. The spicule contribution to the global solar UV emission should therefore be identified with the "network" contribution.

In the latter case, average intensities in spicules could be derived, on the assumption that spicules are responsible for the brightest network elements, isolating a number of points, in the tail of the frequency vs. intensity distribution, equal to the ratio of the total spicule area to the network area. This allows us also to evaluate the spicule contribution to the global UV emission.

Differential emission measures $Q(T)$ for UV spicules can be easily derived once the spicule intensity is known, through the relationship (e.g. Withbroe, 1977):

$$I\ (\mathrm{erg/cm^2/sec/ster}) = 1.7\ 10^{-16}\ Af \int Q(T)\, gG(T)\, dT$$

where symbols have their usual meaning, and $Q(T)$ is defined by

$$\int Q(T)\, dT = \int Ne^2 dv$$

Taking into account that in case 1) the spicule intensity I is spread, due to the low instrument resolution, over a larger area, and therefore correcting it for this effect, it follows that the actual differential emission measures for spicules appear to be higher by a factor of ∿ 2 with respect to those usually ascribed to the network.

Discussion.

Assumption 1) and 2) should be considered as representative of extreme situations. Actual spicule behavior will somehow be an average between 1) and 2), where 1) is likely to give an upper limit to the actual Q(T) values, as spicules are known to frequently clump together, while 2) gives a lower limit, as no account has been taken of the intensity spreading caused by the instrument. As an order-of-magnitude estimate, it will be assumed that actual Q(T) spicular values are about 10 times greater than the usually reported network values.

Without further assumption, it is not possible to establish whether the Q(T) increase is due to a density increase or a temperature gradient decrease. However, since we know that in the brightest regions of the UV network strong redshifts are observed (Bonnet, 1978), we can admit that UV spicules are Hα spicules which fall back again after being heated to high temperatures. Moreover, since we know that only 1% of spicular material escapes in the solar wind, it follows, from mass conservation, that UV spicules should have about the same density as the Hα spicules (unless spicular material is able to traverse magnetic fieldlines).

To an increase of about a factor of 10 in the Q(T), it corresponds, if the temperature gradient does not change, an increase of about a factor of 3 in the densities. This will bring the average density in the $4.6 \lesssim \log T \lesssim 5.6$ interval close to a value of 2.10^{10} cm^{-3}, which favorably compares with the density in the upper part of cool spicules.

Therefore if UV spicules are to be interpreted as Hα spicules falling back after being heated, we are led to an average density of some $2\text{x}10^{10}$ cm^{-3}, and to a gradient comparable with that usually quoted as "network" gradient. Future high-resolution observations, allowing one to check these tentative values, will give a definite answer to the problem of the UV spicule nature and origin.

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