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NEEDS FOR HIGH RESOLUTION SPECTROSCOPY IN ULTRAVIOLET SOLAR PHYSICS

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Résumé : L'étude des couches extérieures de l'atmosphère solaire (de 5000 °K à quelques 10^6 °K) s'effectue à l'aide des raies ultraviolettes émises par des éléments plusieurs fois ionisés. La résolution des structures fines solaires a été faite avec une bonne résolution spectrale par quelques expériences (OSO 8, SMM, HRTS) au dessus de 100 nm. L'établissement du bilan global et détaillé de l'atmosphère est nécessaire pour essayer de comprendre les processus de chauffage, la génération du vent solaire et ses mécanismes d'accélération. Les nouveaux spectromètres ultraviolets proposés sur le satellite SOHO doivent permettre de combiner les résolutions angulaires, spectrales et temporelles suffisantes pour répondre à ce besoin.

Abstract : The study of the solar atmosphere (from 5000 °K to few millions °K) is made through ultraviolet lines emitted by ionized elements. Some experiments (OSO 8, SMM, HRTS), observing above 100 nm have resolved the fine solar structure with a good spectral resolution. The understanding of the heating processes, the solar wind generation and its acceleration mechanisms require a global and detailed mass and energy budget of the atmosphere. The new ultraviolet spectrometers proposed on SOHO satellite are able to combine enough angular, spectral and temporal resolutions to establish this budget.

1. Introduction

The solar atmosphere is highly structured with flux tubes (photosphere and low chromosphere) and loops (upper chromosphere and corona) embedded in a wide background atmosphere. From the ultraviolet and extreme ultraviolet observations (below 200 nm down to 10 nm) a lot of lines emitted by several times ionized species give access to atmospheric parameters in the 5000 °K. With such lines the chromosphere to corona characteristics can be defined. The importance of high resolution observations in this spectral range has been already emphasized by Brueckner [1].

2. A Structure Solar Atmosphere

Although the structuration of the Solar atmosphere has been known from the ground (eclipse observations) and from space (from rocket flights and OSO series) the ATM/SKYLAB observations, by their quality and the large community involved in their acquisition, reduction and interpretation have produced a significant progress in our knowledge. From these data we know that the upper solar atmosphere is build by loops (cool or hot) whose lengths range from 10^4 km up to $7 \cdot 10^5$ km (30 arcseconds up to 16 arcmin) and diameters varie from about 1000 km (1.5 arcsec) to 10000 km (15 arcsec) and some cool loops ($\approx 10^5$ °K) may be overlying hot loops ($\approx 10^6$ °K). High resolution HILy pictures obtained during rocket flights (Bonnet et al., [2]) show that at the one arcsecond resolution there is a fibril structure of that will appear homogeneous with low resolution observation, and, probably there is still unresolved features.

High Resolution Telescope and Spectrograph rocket flights (HRTS, [3], [4]) have determined some line profile characteristics above 117 nm. The doppler shift of lines in small area (down to one arcsecond) varies from few kilometers per second to more than 400 kms^{-1} in ejecta events with about 60 seconds lifetime.

Figure 1a Performances of previous in-orbit experiments and proposed new instrumentations
The resolving power $\lambda/\Delta\lambda$ is given as a function of the wavelength

OSO 7/GSFC (1974 ; [6])
HCO/ATM (SO55, 1973-74 ; [7])
NRL/ATM (SO82B, 1973-74 ; [8])
OST/SALYUT 4 (1975 ; [9])
LPSP/OSO 8 (1975-78 ; [10])
UVS/OSO 8 (1975-78 ; [11])
UVSP/SMM (1980-87 ; [12])
HRTS/SPACELAB 2 (1985 ; [13])
CHASE/SPACELAB 2 (1985 ; [14])
CDS/SOHO (Patchett B., 1987, Private communication)
SUMER/SOHO (Wilhelm K., 1987, Private communication)

3. Resolution Required to Obtain Improved Diagnostics

It is clearly evident that to improve densities and temperatures values deduced from line ratio techniques or from emission measures (such as derived by Doyle et al. [5]) an angular resolution better than the 25 arcsec² obtained by HCO/ATM experiment in the 30-130 nm wavelength range is needed to separate the contribution of several loops or different parts of the loop. An improved throughput is gained by a simultaneous collecting of several angular pixels along the entrance slit of a stigmatic spectrometer.

Identification of line shape to deduce line profile deformations and shifts is required to measure flow velocities, turbulence or impulsive events. Line shape may be detected with few pixels in the profiles and the line center position with good statistic may be estimate to about one tenth of the spectral resolution element. A detection of 1 km/sec doppler shift may be performed with a 3.10^4 resolving power.

Two new instrumentations, CDS and SUMER, have been proposed for the SOHO (Solar and Heliospheric Observatory-ESA) payload. The first one is mainly dedicated to line pair ratios and emission measure techniques in short wavelength domain (15-80 nm) and the second one is optimized to line profile measurements in the 50-160 nm wavelength range. These two complementary instruments use stigmatic spectrometers with two dimensional detector arrays. The performances are given in

figure 1a and b. They represent a real gap above those obtained by previous satellite experiments (Spacelab 2 experiments had only a week of observations in the cargo bay of the Space Shuttle).

Figure 1b Performances of previous in-orbit experiments and proposed new instrumentations
The angular resolution is given by the entrance slot pixel (squared arcsecond, left ordinate) as a function of wavelength and angular pixel number (right ordinate). Experiments are identified as in Figure 1a. For OSO 8 and SMM instrumentations the resolution corresponds to the most used entrance slits. Instrumentations listed on the right column have simultaneous angular pixels, all other space experiments have only one entrance angular pixel at a time.

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