IUE AND SKYLAB SPECTRA OF SOLAR-TYPE STARS AND OF SPATIALLY-RESOLVED SOLAR REGIONS

R. Pallavicini  M. Cerruti-Sola  C.C. Cheng
Osservatorio di Arcetri  Firenze, Italy  Naval Research Laboratory  Washington, D.C.

ABSTRACT

Short-wavelength IUE spectra of nearby solar-type stars are compared with high-resolution spatially resolved ultraviolet spectra of individual solar features (quiet region, plage, flare) obtained with the NRL Slit Spectrograph on board SKYLAB.

Keywords: Late-type stars, solar regions, IUE spectra, SKYLAB spectra

1. INTRODUCTION

Short-wavelength spectra of solar-type stars acquired with the IUE satellite show a broad range of different emission levels for stars of the same, or similar, spectral type. This is likely due to different levels of magnetic surface activity in stars, presumably related to differences in age and/or rotation rate. A similar wide range of emission levels exists in the Sun when comparing regions of different magnetic activity (quiet areas, active regions, flares). The chromospheric and transition region emission fluxes from many stars are far in excess to those observed on the average Sun, and are reminiscent of ultraviolet spectra of solar plages.

Although the stellar data have been frequently compared with ultraviolet spectra of the integrated solar disk (Refs. 1-2) no detailed comparison has yet been made with high resolution spatially resolved spectra of individual solar features. In this paper we report on the preliminary results of such a comparison using stellar data from the IUE archives and solar data obtained in 1973 during the SKYLAB mission. We show that the comparison provides valuable information on magnetic activity in solar-type stars as well as allowing a better estimate of the contribution of different lines to IUE blended features for different activity conditions.

2. SOLAR SPECTRA

A large number of high-resolution spatially resolved photographic spectra of solar features over the range 1175-1950 Å were obtained in 1973-74 by the Naval Research Laboratory Slit Spectrograph aboard SKYLAB. These spectra cover approximately the same spectral region as the IUE short-wavelength camera, while having a resolution a factor ≈ 100 higher (0.06 Å). The spectrograph slit had a size of 2" x 60" and was positioned across the solar disk to measure spectra of individual solar features (coronal holes, quiet undisturbed regions, on-disk and off-limb active regions, and flares). A few examples of these spectra have been published in atlas format (Ref. 3). However, rather than using the atlas, we have found it more convenient to retrace a few selected spectra at the microdensitometer and to convert the measured photographic densities into absolute flux units at the star surface using the appropriate calibration curve. The spectra then have been degraded to approximately the same resolution of IUE (= 5 Å). At this resolution only a few lines remain prominent. These include the chromospheric lines of O I at 1304 Å, C II at 1335 Å, C I at 1657 Å, Si II at 1808 and 1817 Å, as well as transition region lines of N V at 1241 Å, Si IV at 1396 and 1403 Å, and C IV at 1550 Å. Figures 1-3 show the smoothed spectra for a quiet Sun area, a bright plage region and a flare. Notice that all lines are strongly enhanced in plage and flaring regions, the degree of enhancement being larger for lines formed at higher temperatures. The He II line at 1641 Å, which is probably excited by coronal X-rays, becomes prominent only in the spectra of plages and flaring regions. Notice also in Figure 3 the strong Al III lines at 1855 and 1863 Å which are prominent only in flare spectra.

3. STELLAR SPECTRA

Low-resolution (= 5 Å) spatially-integrated ultraviolet spectra of many solar-type stars over the range 1150-2000 Å have been acquired with the short-wavelength camera (SWM) on IUE. At wavelengths shorter than 1800 Å the spectrum is dominated by a

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Figure 1. Degraded SKYLAB spectrum of a quiet solar region (in units of $10^6 \text{ erg cm}^{-2} \text{ s}^{-1} \text{ Å}^{-1}$).

Figure 2. Degraded SKYLAB spectrum of a solar active region (in units of $10^6 \text{ erg cm}^{-2} \text{ s}^{-1} \text{ Å}^{-1}$).

Figure 3. Degraded SKYLAB spectrum of the flare on September 5, 1973 (in units of $10^6 \text{ erg cm}^{-2} \text{ s}^{-1} \text{ Å}^{-1}$).

Figure 4. IUE spectrum of α Cen A (in erg cm$^{-2}$ s$^{-1}$ Å$^{-1}$).

Figure 5. IUE spectrum of χ¹ Ori (in erg cm$^{-2}$ s$^{-1}$ Å$^{-1}$).

Figure 6. IUE spectrum of 53 Aqr A+B (in erg cm$^{-2}$ s$^{-1}$ Å$^{-1}$).
few spectral features which are important diagnostics of stellar chromospheres and transition regions. These lines are readily apparent in spectra obtained using sufficiently long exposures. For wavelengths longer than $\lambda = 1800$ Å it becomes increasingly difficult to measure the line fluxes against the rapidly increasing continuum due to photospheric radiation and scattered light. Moreover, this longer portion of the spectrum is usually saturated in the long exposures used to improve the visibility of short wavelength lines.

SWP spectra of about 50 solar-type stars (spectral types F8 to G5, luminosity classes V and IV) have been analyzed by us using data from the IUE archive. Figures 4-6 show examples of these spectra. The observed fluxes have been converted into fluxes at the star surface (in erg cm$^{-2}$ s$^{-1}$ Å$^{-1}$) using the Barnes and Evans relationship. Lyman $\alpha$ should not be considered since it is contaminated by geocoronal radiation in IUE spectra. Comparison of different stars shows the extreme variety of emission fluxes observed for stars of different ages and/or rotation rates. Young, rapidly rotating stars show transition region and chromospheric lines strongly enhanced (up to a factor of $\simeq 10$) with respect to old, slowly rotating stars, and the spectra are qualitatively more similar to those of solar active regions and even flares.

4. DISCUSSION

Comparison of Figures 1-3 with Figures 4-6 shows a remarkable similarity between the range of emission fluxes observed in stars of various activity levels and the range of fluxes emitted by individual solar regions. Since the solar features we have considered differ mainly in the level of magnetic activity, it is likely that the same occurs for stars. The strong similarities between spectra of active stars and spectra of solar plages suggest that active regions cover a much larger fraction of the stellar surface in young rapidly rotating stars. An approximate estimate of the fractional area covered by active regions can be obtained by assuming a simplified two component model (plage regions + quiet areas) and assuming the solar values as typical for quiet and active regions, respectively. In this way we obtain fractional areas as high as $\simeq 60$-80% in very active stars. The corresponding figure for the Sun and a quiet star such as α Cen A is $\simeq 5\%$. Alternatively, smaller fractions of the surface of active stars may be covered by hotter and denser regions with surface brightness in excess to that of typical solar plages.

Another interesting application of our comparison is in the assessment of the relative contribution of different spectral lines to IUE blends under different activity conditions. To this aim we take advantage of the much higher spectral resolution of the solar data. The quantitative analysis of this effect - currently in progress - will eventually allow a better evaluation of radiative losses in various chromospheric and transition region lines, after appropriate correction for the contribution of nearby lines to IUE blends.

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REFERENCES