Real-time System for Solar Spectrophotometry

G. A. DE BIASE AND G. DE GREGORIO
Osservatorio Astronomico di Roma

SUMMARY

A system is being developed at the Rome Astronomical Observatory for real-time detection of solar spectral information. The scheme and the philosophy of the system are here described. Finally, the first program to which it will be applied is presented.

INTRODUCTION

The availability of new techniques either for the acquisition of information or for its elaboration, and the possibility to get numerical control of the observational apparatus, allow us to build up complex systems with the purpose of increasing the efficiency of traditional methods and of improving their flexibility with high time-resolution.

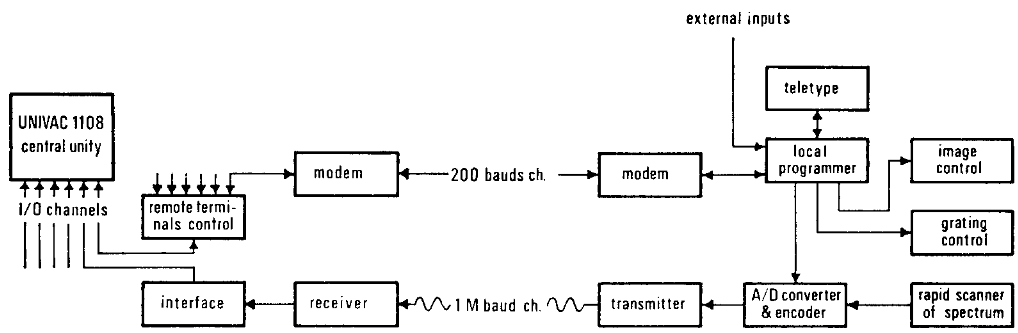

Fig. 1
Block diagram of the system for the solar spectrophotometry in real-time.

A real-time system is a system able to collect and to process information at the same time as it is being generated, and capable of operating on the instruments depending on the information collected, in a time short with regard to the observational requirements of the phenomena.

When such a system has to be used for solar spectrophotometry, it must satisfy the following requirements:

(*a*) it must be able to control the solar image position according to preset coordinates;

(*b*) it must acquire the desired spectral information as quickly as possible.

A system which satisfies these requirements suits either the study of more or less quickly time-variable phenomena, or the acquisition of that spectral information, of which the spatial distribution over the solar disc is desired.

REALIZATION OF THE SYSTEM

A system able to work in real-time with the features (*a*) and (*b*) of the previous section is being built up at the Rome Astronomical Observatory. The solar optical image and its spectrum are obtained at the Observatory Solar Tower with a 18 m focal length spectrograph.

In Figure 1 the block diagram of the whole system is shown. The displacement of the solar image and the grating position are controlled either by a local programmer, when it is not necessary to get feedback due to information, or by a UNIVAC 1108 computer (with real-time capability), when one desires to get information feedback.

The acquisition of the spectra is executed by a rapid scanning system with a capability of up to 10^3 scans per sec. The instruments are connected to the computer through two transmission channels; the first one is a telephonic channel with transmission rate of 200 bauds, for service communications

https://doi.org/10.1017/S0252921100032310 Published online by Cambridge University Press

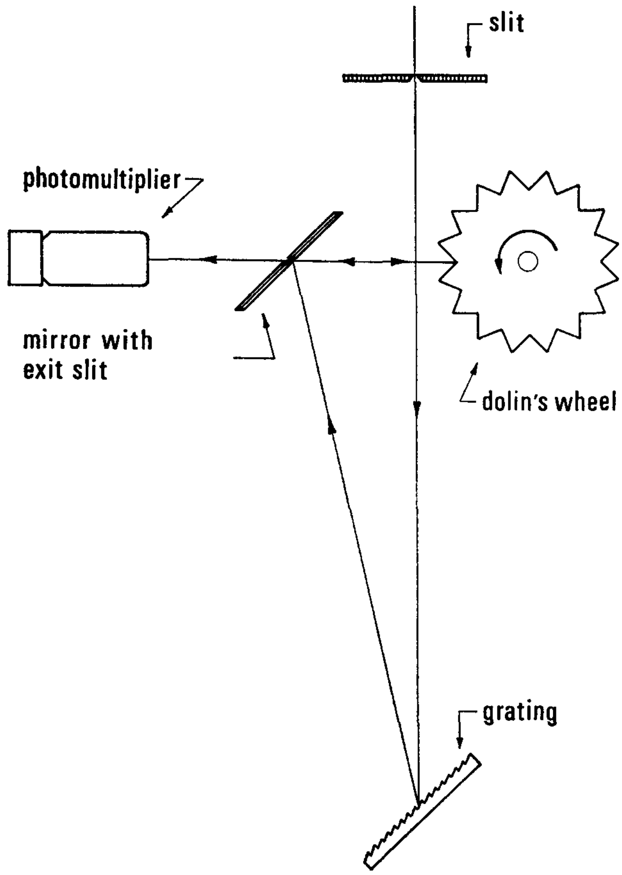

Fig. 2
Scheme of the system for the rapid scanning of the spectral line profiles.

and for setting the solar image and grating positions; the second one is an optical 1 Mbaud channel used only for spectral information transmission.[1]

THE SPECTRAL SCANNER

Some authors have studied the problem of rapid scanning of spectral information, and for this purpose many of them have utilized different configurations of rotating mirrors.[2, 3, 4, 5] In Figure 2 there is a schematic view of the experimental configuration using Dolin's wheel[4] in our system,[6] and in Figure 3 the working principle is shown.

The electrical information is obtained in analog form by photomultiplier; it is then converted into a numerical form, encoded and sent to the computer through the rapid channel. A slow scan has not been taken into consideration, because even in the case of very small signals and consequently of high noise, the average or the autocorrelation of many rapid scans has some advantages over one slow scan.[7, 8]

Recently, "COHERENT OPTICS INC." has developed a piezoelectric device which can be usefully utilized for a rapid scanning of light intensity distributions and which seems to have some advantages over the rotating mirror system.

THE SOLAR IMAGE AND GRATING CONTROL

The Solar Tower generates a 28 cm diameter solar disc image with 0.3 arcsec resolving power. The displacement of the image is controlled by numerical position detectors allowing for a precision of about 2 arcsec. Similar numerical detectors are placed on the spectrograph grating; they determine the spectral range to be examined within 10^{-1}Å; the rapid scan system covers a 4Å range with resolving power of about 10^{-2}Å, using the greatest dispersion and light efficiency. When working in lower grating orders, the resolution and the dispersion can become smaller.

https://doi.org/10.1017/S0252921100032310 Published online by Cambridge University Press

The time for setting the coordinates is 10^{-1} sec for adjacent coordinates ($\Delta x = 2$ arcsec), or about 1 arcmin s^{-1} for distant points. Concerning the grating, the rate of change of the range is about 10^{-1} sec for adjacent ranges, ($\Delta r = 2$Å), or 100Å/sec for distant ranges. These rates are due to the time constants caused by the mechanical moving parts. Figure 4 is a photograph of a numerical detector for the solar image position.

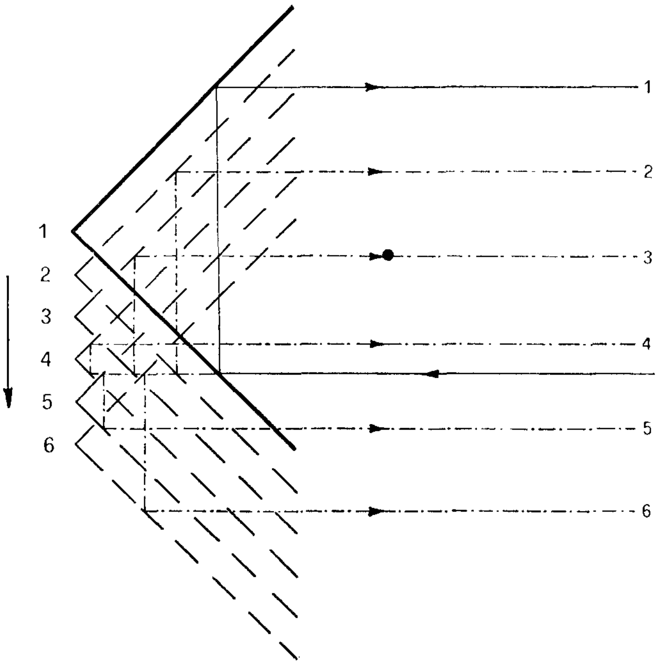

Fig. 3

Working principle of the corner mirror scanning. The scan 1–6 on the right corresponds to the displacement 1–6 on the left.

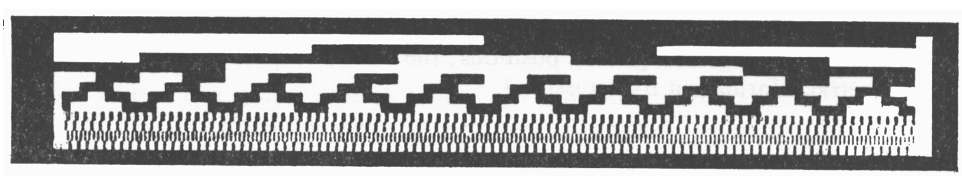

Fig. 4

Numerical 1000 positions detector. The code is BCD Gray modified.

THE LOCAL PROGRAMMING SYSTEM

The local programming system, shown in Figure 1, allows for the following operations:

1. setting of the solar image in a preset position;
2. scanning of the solar image with changeable scan rate and over a given range;
3. setting of the grating over a range of prefixed wavelengths;
4. setting of the grating in sequence over a certain number of prefixed ranges;
5. predetermination of the number of rapid scans necessary in each case.

In these working conditions the spectral information is sent to the computer without manual intervention, however, the partial results being immediately processed and visible on the teletype can advise the observer about some operations required. The system is also able to operate under external commands.

THE TRANSMISSION CHANNELS

When feedback is desired between the information and the development of the observational program, the instrument will be directly driven by the computer through the telephonic 200 bauds channel.

https://doi.org/10.1017/S0252921100032310 Published online by Cambridge University Press

In this case, all commands provided by the local control are transferred to the computer and depend, through a suitable program, on the processing of the spectral information acquired by means of the rapid channel.

The format of the word necessary to obtain a command on the slow channel is constituted by five standard code (ASCII) characters: the first character indicates the command word (to distinguish it from other informations sent to the teletype from the computer); the second character selects the command; and finally the last three characters indicate the numerical value of the request. The system is able to communicate 5 commands per second. In case of error, on this channel an error signal is given, and the information is re-transmitted.

The optical channel for transmission of information on the spectral line profiles has not the capability of re-transmission; therefore, the word is sent by a very redundant code, in order to minimize the probability of transmission error (more than two bit errors, synchronization error, absence of the information, etc.). In this second case, an error signal is given, and a fictitious word is communicated to the computer.[1, 9] The word format is 18 bits without any subdivision into characters.

Because of the statistical character of the spectral information, the re-transmission can be removed after having made the error probability as small as possible.

This channel can work at 1 Mbaud and utilizes a 6328Å laser beam as carrier.[9] Because of the high transmission speed, an interface able to be connected directly to a central unity channel of the computer has been built up.[1]

PHILOSOPHY OF THE SYSTEM

As previously seen, the system has the capability of working in two ways:

(*a*) locally controlled;

(*b*) controlled by the computer.

In both cases, the spectral information is directly sent to the computer.

When this system is working according to method (*b*), it has the capability to take some decisions about the execution of the program, for instance:

(*a*) capability of controlling the number of fast scans until a fixed signal noise is reached;

(*b*) capability of collecting information only in preset seeing conditions (obviously, detected by suitable instruments);

(*c*) capability of changing the spatial range of the solar image in function of the spectral distribution features;

(*d*) capability of passing, in preset times or at preset conditions, to other types of working programs.

The association of the rapid scanning of spectra with the automatic control system allows in any case for an extremely high efficiency; this efficiency can be increased by means of an automatic insertion of suitable polarizers, filters, etc., before the spectrograph slit.

Finally, the system is capable of optimizing at each instant the observation conditions.

AN EXAMPLE OF APPLICATION

A first application of the whole system is being developed. It consists in the scanning of the profiles of Hα line and of the other Balmer series lines in solar flare regions.[10] For this purpose, a flare monitor operates, which is able to indicate the start time and the coordinates of the phenomenon. It is inserted in the system as shown in Figure 5, and consists of an optical system with Hα filter and of a telecamera, the electrical signals of which are analysed by a discriminator; when they are higher than the background, a flare notification is given, and the coordinates of the phenomenon area are detected. These coordinates are sent to the computer with a suitable start signal for the observation program.

The flare monitor presents some similarities with the Tallant videometer.[11] but its purpose is only to provide the start time and coordinate information for the flare.

By means of such a system there is the capability of opportunely intervening at the occurrence of the phenomenon, and of executing the observation program with a very high time resolution.

The profiles of the lines examined are connected with a point on the solar image having the spatial resolution seen previously. The system is able to follow the evolution of the phenomenon area and therefore is able to give spatial and time information about the line profile variations.

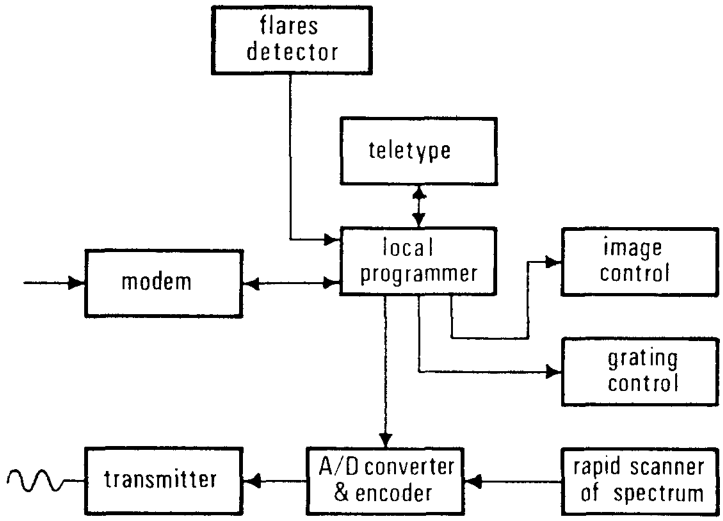

Fig. 5
Block diagram of the Fig. 1 system with the flare detector in addition.

CONCLUSIONS

The above system for solar spectrophotometry is extremely flexible and efficient either for specific or for routine work. The fact that the instruments are connected to a large computer allows for operating in real time even with very complicated processing of information. For this reason and for the large memory capacity of UNIVAC 1108, the configuration here described has been chosen instead of the utilization of a small local computer.

REFERENCES

1. Ferrari Toniolo, M., 1969. Thesis in Physics, University of Rome.
2. Liberman, I., Church, C. H. and Asars, J. A., 1967. *Appl. Opt.* **6,** 279.
3. Croce, V. and De Biase, G. A., 1967. *Appl. Opt.* **6,** 1433.
4. Dolin, S. A., Kruegle, H. A. and Pensias, G. J., 1967. *Appl. Opt.* **6,** 267.
5. Livingston, W. C., 1968. *Appl. Opt.* **7,** 425.
6. Croce, V. and De Biase, G. A., 1967. Atti XI Congr. SAI.
7. Livingston, W. C., 1965. *Publ. Astr. Soc. Pacific,* **77,** 133.
8. Lynds, C. R. and Aikens, R. S., 1965. *Publ. Astr. Soc. Pacific,* **77,** 347.
9. Croce, V , De Biase, G A. and Ferrari Toniolo, M., 1968. Atti II Congr. Naz. AICA, (in press).
10. Smith, H. J. and Smith, E. V., 1963. *Solar Flares,* pp. 119, 141. New York: The Macmillan Co.
11. Tallant, P. E., 1970. *Solar Phys.* **11,** 263.

DISCUSSION

R. F. NIELSEN: What is your reason for using an optical channel, rather than a purely electrical one, for the fast data transmission? What kind of photodetector do you use in the data transmission channel?

G. DE GREGORIO: We use laser optical transmission because of the fast response required over the transmission path of 6 km. The detector is a photomultiplier.

https://doi.org/10.1017/S0252921100032310 Published online by Cambridge University Press