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THE OBSERVATÓRIO NACIONAL IMAGE PROCESSING SYSTEM

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ABSTRACT. In this paper we describe the image processing system developed at the Observatório Nacional (ON). The integrated hardware and software system is the result of an ongoing effort to provide adequate facilities for astronomical data analysis.

I. INTRODUCTION

Over the past few years the Department of Astronomy of the ON has been commited to the development of image processing facilities, to process the data available from our 1.6 m telescope, in operation since 1981. The primary concern has been to provide adequate facilities to measure photographic plates and computer installations for the ON astronomers to analyse the large volume of data generated by our microdensitometer and intensified photon-counting detector.

In spite of severe budget limitations, over the past three years we have been able to install several dedicated minicomputers for both instrument control and data analysis. This was only possible because of the major effort undertaken by our scientific and technical staff for in-house hardware and software development. The hardware configuration has evolved considerably over the years since our philosophy is to implement a basic interactive processing facility, to attend our most pressing needs, and upgrade its performance according to the available resources. Similarly, a prime consideration in the software development was to promote user participation in the implementation of application programs. In this fashion we were able to develop, in a short period of time, adequate software to satisfy the needs of a wide variety of applications.

A major drawback of our present system is that it can only attend a limited number of users and barely meets the ON staff demands for data analysis. Future progress will require the purchasing of more powerful computers to support interactive data analysis facilities in a multi-user environment. The expansion of our computer resources must preceed the implementation of modern imaging detectors, because their successful use will depend on the availability of adequate facilities to handle the large volumes of data produced by these detectors.

In section II we describe the configurations of the computer systems used for data acquisition and analysis. The different data analysis systems presently supported are described in section III. Finally, some of the current astronomical applications of our image processing system are presented in section IV.

II. HARDWARE

We measure photographic plates utilizing a PDS 1010A microdensitometer. This instrument is controlled by a dedicated DEC PDP-8/e minicomputer, which is also used for minor data processing and display. Figure 1 illustrates the configuration of our measuring system which includes a CRT used to enter control commands and to display the status of the system, a 1.6 Mby hard disk unit for temporary data storage, a 800 bpi magnetic tape unit for data transport, a strip-chart recorder, a serial line printer and a line scanned graphic terminal built at the ON. Normally, the data is stored directly on magnetic tape for later analysis. This is necessary for two reasons: i) the large volume of data generated in typical applications; ii) our PDS is the only available microdensitometer in the country and is used by visiting astronomers, who reduce their data in their home institutes. Finally, we should mention that small scans can also be temporarily stored on disk or alternatively sent directly to the data-analysis system through a serial link connecting the two machines.

For data reduction and analysis we use a dedicated MB 8000 minicomputer built by the brazilian manufacturer Sisco, which emulates the Data General Nova 3. The system includes several peripherals essential for the interactive data processing. These peripherals consist of a Tektronix 4010 graphics terminal and associated hard-copy unit, a medium-resolution graphics terminal built at the ON, a 80 Mby disk for mass storage, a dual-density magnetic tape unit, a parallel printer and a Versatec V80 printer/plotter for high quality hardcopy.

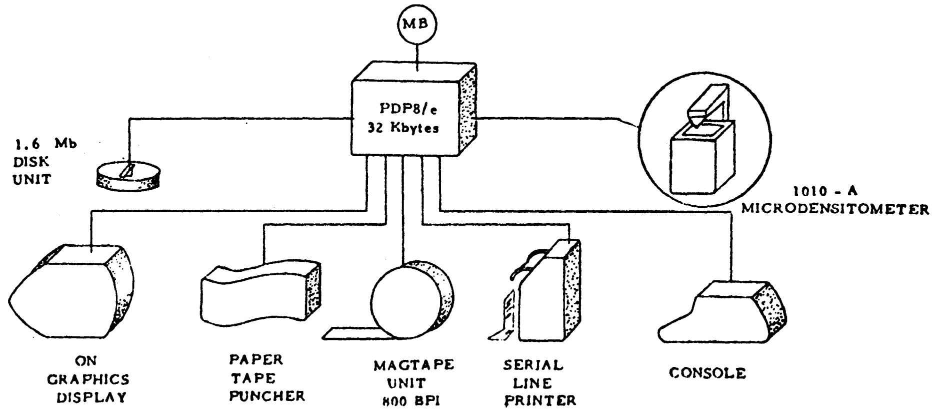

Fig. 1 ON measuring machine installation

Some applications, which require the reduction and analysis of very large scans, also utilize an IBM 370/158 machine located at the Laboratório de Computação Científica (LCC). One of the available remote terminals is located at the reduction room near the Tektronix graphics display, which is also connected to the IBM machine to provide interactive graphics capabilities.

The real-time operation of our photon-counting Reticon detector (da Costa et al. 1985) is based on a Data General Nova. The configuration at the mountain includes a Lexiscope 2000 alphanumeric terminal, a handheld terminal, a Lexiscope 4000 board for graphics display, a floating-point unit and a dual-floppy disk unit. A similar installation is available at the ON headquarters in Rio de Janeiro enhanced by a 10 Mby disk and sharing with the Sisco machine the access to the Tektronix terminal, the Versatec Printer/Plotter and the tape drive. The layout of the integrated hardware is given in figure 2. Note that the hardware configuration optimizes the use of the more expensive peripherals in order to reduce the installation costs.

III. SOFTWARE

Our major concern in the development of the driving software for the microdensitometer was to build a user-friendly system without compromising its capability. The data-acquisition system developed at the ON (ONSAD) is written in assembler language and consists of several modules for direct control of the PDS and to handle the data flow. It uses the program-chain facility available in the OS-8 DEC operating system to overcome the limited amount of main memory. The user interacts with the system by entering simple command words to execute a large variety of tasks, which allows the automatic control of all low level functions of the PDS and the creation and management of the data files.

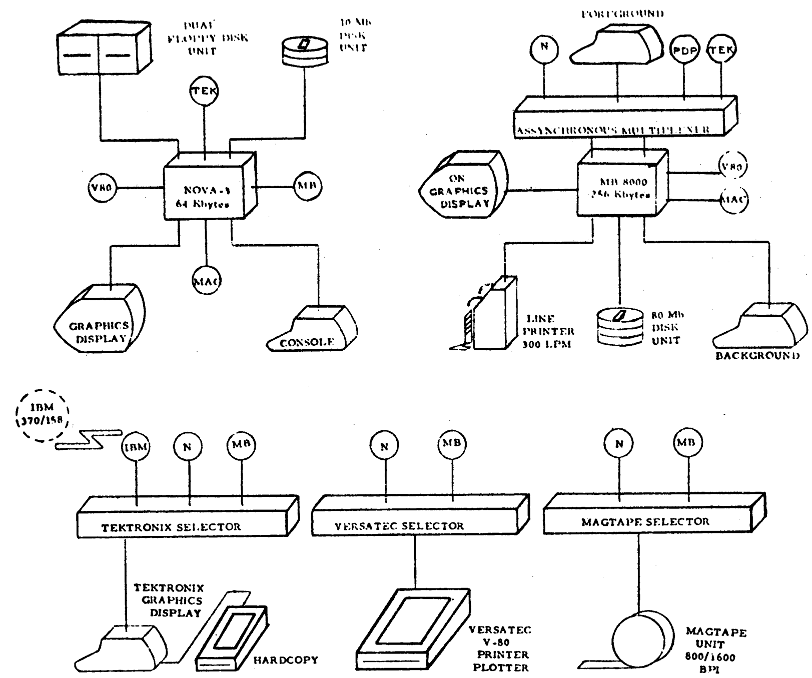

Fig. 2 Schematic diagram of the organization of the data-reduction systems

Another important feature of the ONSAD is the data file structure used, which allows the reduction programs to easily access all the necessary information for the data analysis. The structure of the raw data file consists of several fields where the identification of the scan, comments. plate and scan parameters and the density readings are stored separately.

A similar version of the ONSAD was implemented in the MB 8000 machine operating under RDOS, to read the tapes generated by the PDP-8 and to handle the communication between the computers. This system is also responsible for the creation of image files in an adequate format for the data-analysis system. The data-analysis system presently available in the MB 8000 consists of two distinct sets of routines: one used for one-dimensional spectral analysis and the other used for two-dimensional images.

The spectral analysis package includes routines for: determination of the characteristic curve as a function of the wavelength, determination of the dispersion curve, wavelength-dependent transformation of density into intensity, filtering, sampling of the spectra at different wavelenght intervals, determination of the continuum, profile fitting, measurement of equivalent widths and determination of radial velocities. The system is interactive and has been primarily used in Coude spectra analysis.

The surface photometry software was designed in a modular fashion and consists of over fifty programs, written in Fortran V, to attend a great variety of applications. It consists of several modules that can perform the following operations: determination of the characteristic curve of the plate and linearization of the data; sky background determination utilizing different techniques; filtering and cleaning of the data; profile analysis; graphical representation; statistical analysis; and mathematical operations on images and profiles. Most routines feature interactive graphics processing capabilities, greatly enhancing the efficiency and flexibility of the data reduction process.

We have also developed a system for image identification and automatic star/galaxy classification. It was implemented in the IBM 370/158 because most common applications require large amounts of memory and substantial processing time. The system consists of a sky determination routine, an algorithm to detect images and compute some characteristic parameters and several image classifiers based on moments of the light distribution.

Finally, the real-time and data analysis systems used with our intensified photon-counting Reticon detector is based on the forth operating system developed at the Harvard-Smithsonian Center for Astrophysics (CfA). The real-time system includes routines for direct control of the detector, graphic display and data analysis, thus allowing real-time data assessement. The data-analysis system is used to automatically convert raw data into reduced files containing the normalized sky-subtracted spectrum in the form of intensity-wavelength and to automatically carry out the radial-velocity and line-strength analysis. A detailed description of the procedure adopted in the redshift determination can be found in Tonry and Davis (1979).

IV. APPLICATIONS

At the present time there are several research programs routinely utilizing the facilities described above.

The spectral analysis system is used for a variety of stellar atmosphere studies. Current projects are: the search for line features which could indicate the existence of corona in late-type giant stars; the study of H and Fe II lines in the spectra of Be stars in order to understand their excitation mechanisms and the physical conditions in the envelopes of these stars (Pacheco et al. 1984).

One of the ongoing projects utilizing the image processing system is the photographic surface photometry program of SO galaxies (de Carvalho et al. 1985). The purpose of this study is to investigate the characteristics of the two-dimensional luminosity distributions of these galaxies (figure 3) and to derive their structural parameters from the decomposition of the light profiles into bulge and disk components, as illustrated in figure 4.

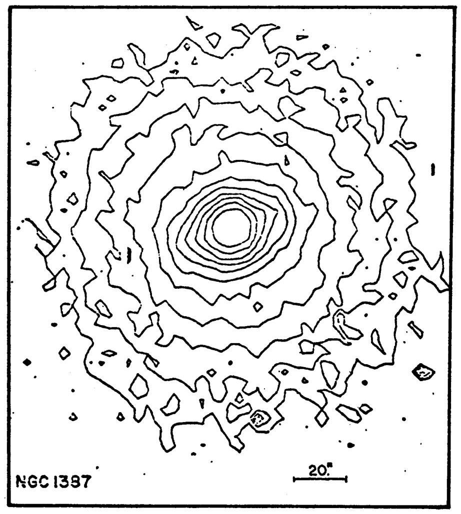

Fig. 3 Isophotal map for the face-on galaxy NGC 1387

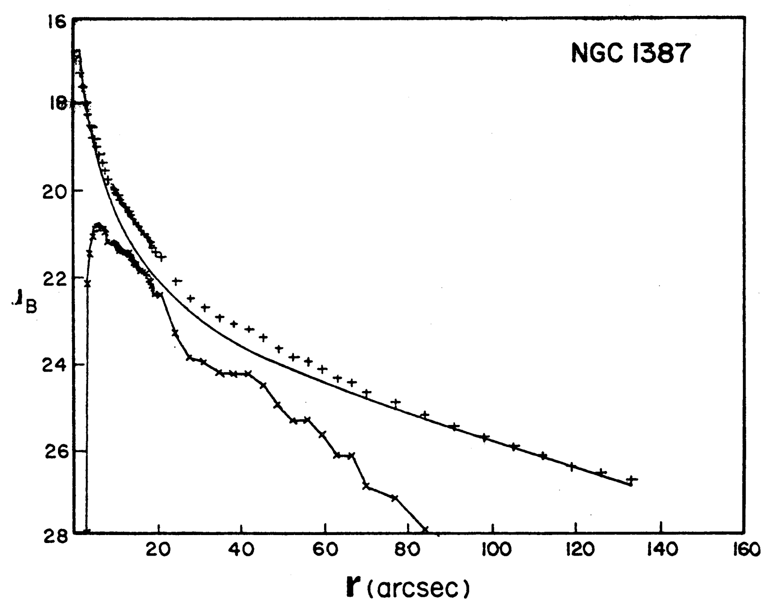

Fig. 4 Observed light profile of NGC 1387. The solid line represents the best fit of a bulge-disk model. Also shown is the residual light distribution after the subtraction of the bulge-disk model, which reveals the presence of underlying components.

Another recent application of the image processing system has been the position measurements of faint natural sattelites close to their parent planets. A particular example is presented in figure 5 showing the influence of Uranus on its sattelite Miranda. In order to determine the exact location of the sattelite, relative to the planet, it is necessary to model and remove the light distribution of the planet as discussed by Martins et al. (1984).

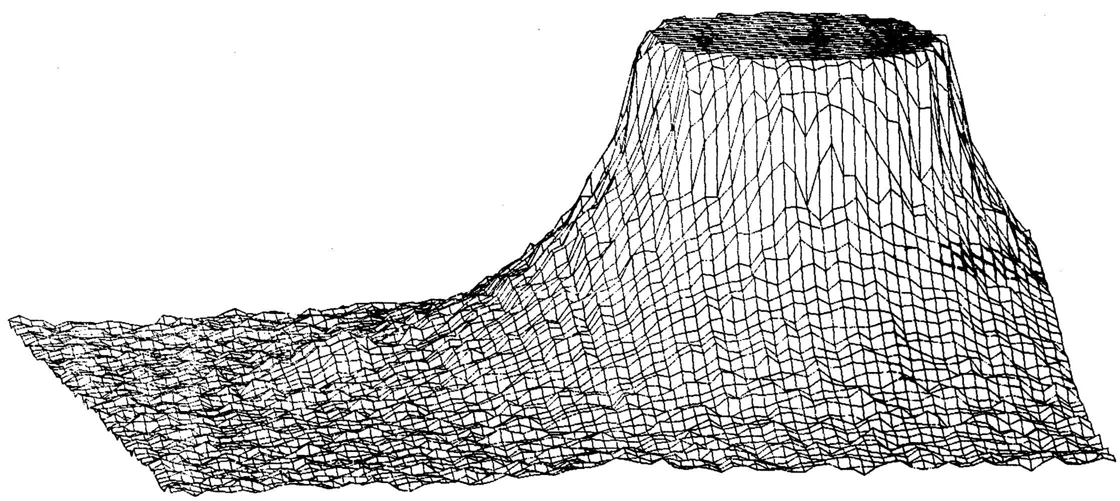

Fig. 5 3-D representation of the light distribution of the Uranus-Miranda system

The automated object detection and classification software has been used primarily to study the properties of moderately distant clusters of galaxies, utilizing on-film copies of the ESO and ESO/SRC Sky Atlas. A more detailed description of our algorithm and a preliminary discussion of the results are presented separately in this meeting (Chan et al. 1984).

A high-priority program presently being pursued is the ON-CfA Redshift Survey, whose ultimate goal is to measure radial velocities of all galaxies brighter than m_B=14.5, south of declination -30 degrees and below galactic latitude - 30 degrees. The present status of the survey, a joint effort between the ON and Harvard-Smithsonian Center for Astrophysics, is presented separately in this conference (da Costa et al. 1984).

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