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THE UNAM SCANNING FABRY-PEROT INTERFEROMETER (PUMA) FOR THE STUDY OF THE INTERSTELLAR MEDIUM

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RESUMEN

Se describen las características principales del Interferómetro de Fabry-Perot de Barrido de la UNAM (PUMA), para usarse en el estudio de la cinemática del medio interestelar en el Observatorio Astronómico Nacional en San Pedro Mártir, B.C. México (OAN-SPM). Este instrumento se está probando actualmente en el telescopio de 2.1-m de dicho observatorio. En el futuro, se podrá usar ya sea como un interferómetro de Fabry-Perot o como un espectrógrafo multi-rendija (del tipo FOSC).

ABSTRACT

We describe the main characteristics of the UNAM Scanning Fabry-Perot Interferometer (PUMA) applied to studies of the kinematics of interstellar medium at the Observatorio Astronómico Nacional at San Pedro Mártir, B.C. México (OAN-SPM). This instrument is being tested at the 2.1-m telescope of the OAN-SPM. Future work will allow the use of this instrument either as a Fabry-Perot interferometer or as a multi-slit spectrograph (FOSC-type).

Key words: **INSTRUMENTATION: INTERFEROMETERS — INSTRUMENTATION: SPECTROGRAPHS — ISM: KINEMATICS AND DYNAMICS — GALAXIES: KINEMATICS AND DYNAMICS**

1. GENERAL DESCRIPTION

The kinematics of interstellar matter in cosmic nebulae can be determined by observations at optical wavelengths with the use of a Scanning Fabry-Perot Interferometer (SFPI) with a bidimensional detector. This combination allows a wider field of view and higher spatial and spectral resolutions than those obtained with a classical high dispersion spectrograph. The system, called PUMA, is an instrument consisting of a focal reducer coupled to an SFPI, that has been developed for the Observatorio Astronómico Nacional at San Pedro Mártir, B.C., México. It has a series of interference filters and a calibration system. The SFPI can be moved out of the optical path in order to acquire direct images. It is now being tested at the 2.1-m telescope in its f/7.9 Ritchey-Chretien focus. The images produced by this instrument will be focused on an optoelectronic detector. The PUMA provides:

a) Direct imaging with interference or wide-band filters.

b) Interferograms at Hα, [N II] (λ6584), [O III] (λ5007), and [S II] (λ6717).

2. OPTICAL SYSTEM

The instrument covers a field of 10′ and provides a reducing factor of 2-in the telescope focal ratio (from f/7.9 to f/3.95). The plate scale will be 0.″67 per pixel for the 1024 × 1024 Thomson CCD in use at the observatory. The focal reducer consists of a collimator and a camera. The collimator consists of two different optical components: a doublet and a triplet. They were polished from PSK3 and FK54 optical glasses. The selection of materials was based on a design by the Marseille Observatory to achieve an apochromatic system, covering the desired wide spectral range, from the ultraviolet (3650 Å) to the near infrared (8650 Å).

Because this instrument is an "Integral Field Spectrometer" (Courtès 1995) it shares the advantages and limitations of this type of instrument. Indeed, an important characteristic of this system is that the collimated light bundle and the instrument configuration allow for the integration of optical elements such as multi-lens arrays, prisms or grisms. This is because the focal reducer acts as a "Courtès Toolbox" where several optical elements can be exchanged. This gives the instrument great versatility as a tool for other kinds of studies. These adaptations are in progress and as a first step we are now constructing a camera suitable for the wide spectral range covered by the collimator. This camera will replace the Leitz objective currently in use, which has a limited spectral range.

3. MECHANICAL SYSTEM

The mechanical system consists of an aluminum structure to attach the instrument to the telescope and optomechanical devices. It also includes movable parts such as field diaphragms, a carousel with three calibration lamps, a wheel with seven filters and a rail for moving the SFPI out of the optical path. Figure 1 illustrates the optomechanical design of the PUMA. Tolerances in the flexure of the mechanical structure are defined by half the size of the detector pixels. To have a stiff structure, we decided to include a flat mirror to deviate the optical path 60° from the optical axis of the telescope. This design reduces the length of the instrument and, consequently, the flexures. In addition, the structure was designed with aluminum tubes for greater stiffness with minimum weight.

4. THE INTERFEROMETER

The SFPI used is a 2-in diameter Queensgate, servo-stabilized by means of the CS100 system. The CS100 allows the adjustment of the servosystem parameters, the parallelism, and the separation between plates, with a response time of 0.5 s in steps of 0.5 nm. This interferometer has been used in the past, coupled to a Mepsicron detector (Carrasco 1983). Recent tests of the interferometer have allowed us to determine an effective "Finesse" of about 30 (new determinations of this important parameter will be obtained in the near future). The order of interference is 355, the free spectral range is 18.6 Å (equivalent to a velocity range of 847 km s^{-1}) and the sampling spectral resolution is 0.39 Å at Hα (equivalent to 17.6 km s^{-1}). Tests at the telescope have shown that the SFPI must be inside a dry nitrogen bath in order to avoid problems with the piezoelectric control due to moisture during the observations.

5. ELECTRONIC CONTROL

All the functions of the CS100 are achieved through a control bus that provides complete, computerized, remote control operation. Both the instrument and the étalon will be controlled with an Octagon microcomputer, model μPC 5080, based on an 8 bit 64180 processor (Z80 code compatible) running at 9.216 MHz. The software, CAMBASIC, is designed for control applications and consists of an operating system and a BASIC compiler. The entire system is supervised by a SPARC workstation as the host computer. The image series corresponding to different wavelengths will be stored on the workstation's hard disk.

6. ACQUISITION SOFTWARE

To acquire the FP data cubes, specialized software, similar to that used at the SURVEY Hα SFPI of the Marseille Observatory (Le Coarer et al. 1992) has been used. This software works under the Unix operating system and is quite friendly. There are several innovations in the new version: the ability to scan only a few steps in order to reduce the exposure time of small diameter objects with a single, narrow velocity component, the ability to bin the CCD's pixels, and automatized parallelization of the FP plates, etc. The data are automatically compressed to save storage space in the computer.

7. PARALLELISM ALIGNMENT OF THE FP PLATES

We have developed a computerized method to adjust the parallelism of the FP plates before observations. This innovative method uses four separate interference patterns obtained by placing an assembly of four low-

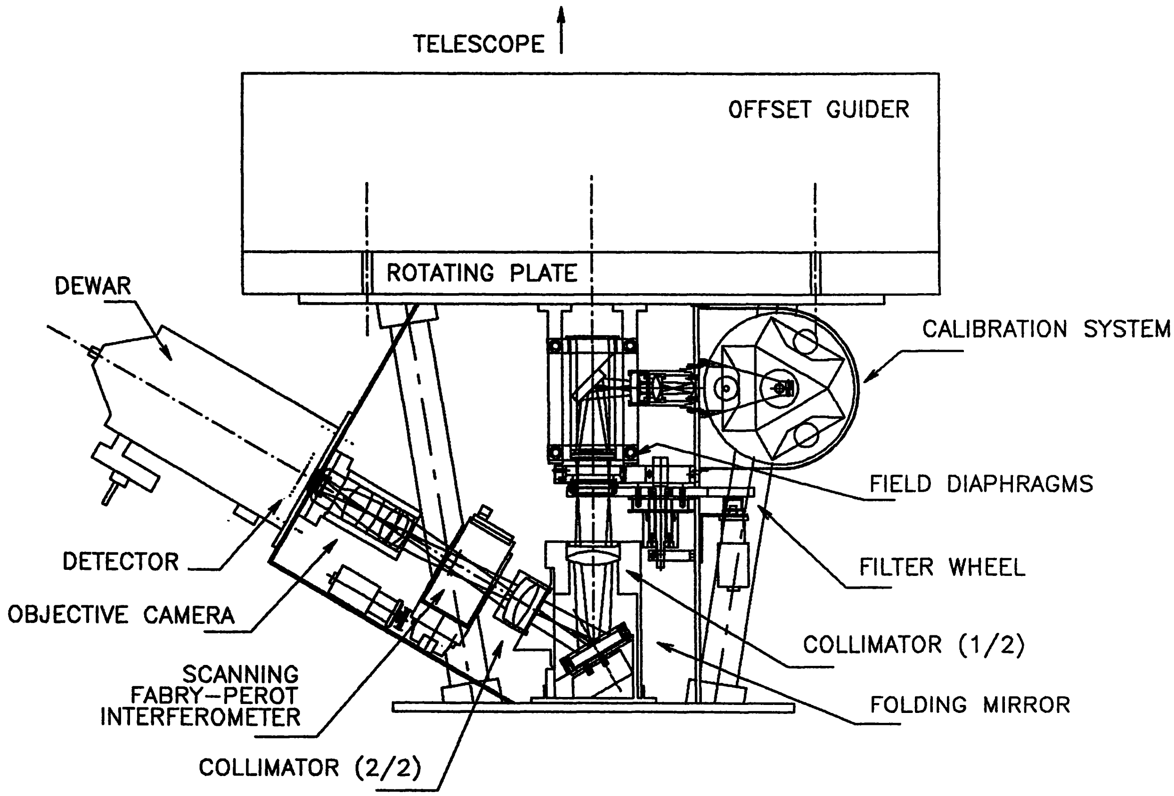

Fig. 1. Optomechanical design of the PUMA.

angle wedge prisms distributed symmetrically in a wheel placed between the FP and the camera. By measuring the diameters of the four interference rings, specialized software is able to correct the X and Y values of the plates (i.e., the tilt of the plates) to less than a CS100 step. This is a very easy method to obtain the starting parallelism of the FP plates. Once this is done, the prism assembly is removed and observations can be started.

8. IMAGE QUALITY AND WAVE-FRONT TESTS

We have obtained intra- and extra-focal images of an open star cluster in order to analyze the quality of the whole system: telescope plus instrument optics. We have applied Roddier's method to these images and compared the results with a similar analysis of the wave-front of the telescope alone. We have found that the main telescope aberrations do not suffer a significant change with the PUMA. They remain the same and, in fact, there is a large reduction of the "coma" aberration, perhaps because of better system alignment. In addition, we have found that 80% of the energy of the light beam is concentrated within a circle of $0\farcs28$ radius.

9. TESTS AT THE TELESCOPE

We have had two observational runs for testing this instrument in April and November 1994. Unfortunately the weather was quite bad during these runs. Consequently we could not determine the sensitivity limit from the data obtained. Nevertheless, we have obtained good kinematic data on the following objects: the Crab SNR, the planetary nebulae NGC 6337, NGC 3242 and NGC 2438, and the irregular galaxy IC 10. In the future we plan to observe more objects (some of them with well known kinematic data) to compare the performance of this instrument with that of similar instruments. Figure 2 (Plate 4) shows the λ–maps corresponding to the velocity channels of the planetary nebula NGC 3242 in [N II] (λ6584).

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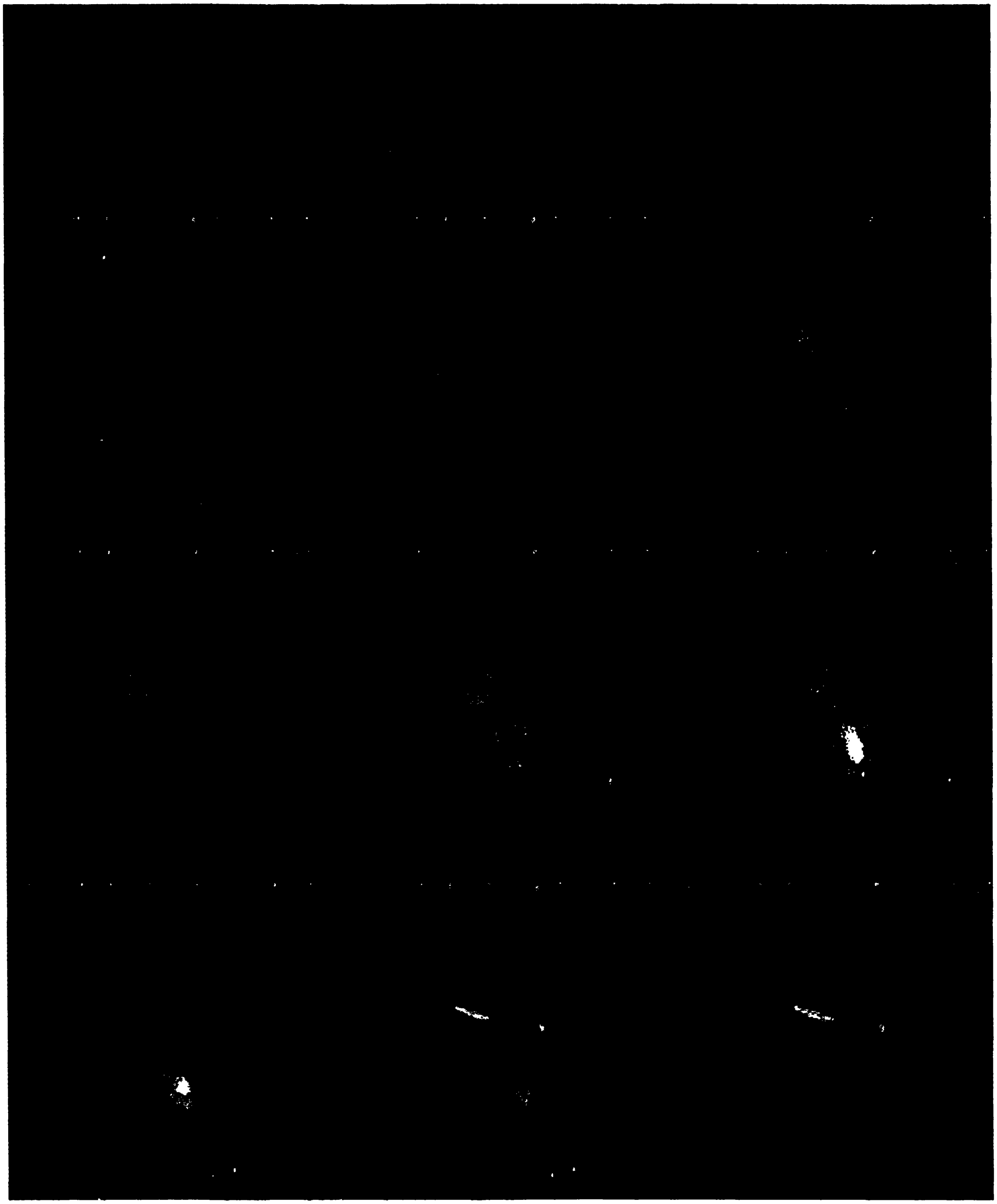

Fig. 2. Radial velocity channels of the planetary nebula NGC 3242 in the [N II](λ6584) line. The field covers only 200×200 pixels of the CCD chip, corresponding to 2'.2 at the angular resolution of 0''.67 per pixel. The velocity channel separation is 17.6 km s^{-1}.

ROSADO ET AL. (see page 263)