Highlights on Spanish Astrophysics IX, Proceedings of the XII Scientific Meeting of the Spanish Astronomical Society held on July 18 – 22, 2016, in Bilbao, Spain. S. Arribas, A. Alonso-Herrero, F. Figueras, C. Hernández-Monteagudo, A. Sánchez-Lavega, S. Pérez-Hoyos (eds.)

Ultraviolet Echellé spectropolarimeter for the ARAGO mission.

Belén Perea Abarca, Ana I Gómez de Castro, and Pablo Marcos-Arenal

AEGORA, Fac. De CC. Matemticas, Universidad Complutense de Madrid, Spain.

Abstract

In this contribution, we describe an efficient instrument designed for mid resolution (25.000) spectropolarimetric observations in the ultraviolet wavelength range (119-320 nm). Spectropolarimetry in the ultraviolet range introduces challenging constraints in the image quality of the echellé design that are addressed via the introduction special optical elements.

1 Introduction

The ARAGO spectropolarimeter is designed to have a polarizer in the Cassegrain focus and a beam splitter after it that reflects the UV wavelengths (119 nm to 320 nm) into the UV spectrograph and transmits 320-888 nm wavelengths range into the visible spectropolarimeter. In the polarizer the light is split into 2 states of polarization. Simultaneous spectropolarimetry in the optical and ultraviolet (UV) range is the only tool to study the precise characteristics of stellars magnetic fields and their connection with atmospheric structures, outflows, envelopes [[3], [1]]. The new proposed design is based on the experience of the WSO-UV mission and spectrographs design [[5], [4]].

2 Scientific requirements

The scientic requirements of the UV spectropolarimeter are shown bellow [2]:

- Wavelength coverage: [119-320] nm.
- Resolution: minimum 25.000.
- SNR=100 in 30 minutes for V=7 OBA stars, SNR=100 in 60 minutes for V=7 FGK stars, and SNR=10 in 60 minutes for chromospheric lines of V=10 M stars.
- Length of the spectral orders: minimum 5 nm.

- Total throughput: > 3 %. It is necessary to minimise the number of surfaces, in order to achieve the required throughput. If this goal cannot be reached, the best design should be proposed and the science objectives will be reduced accordingly.
- The detector is planned to be a MCP+CMOS with a pixel size of 20 microns.
- Maximum beam separation (for the 2 states of polarisation): 300 microns. This implies a slit size of minimum 300 microns.
- A minimum of 4 pixels must be recorded between two polarisation states and two spectral orders.
- Polarimetry will be extracted only in the domain [123-320] nm.

3 Optical design

Arago's instrument is separated in two spectrographs (UV and VIS) both fed by light coming from a single polarimeter. In the design, it is assumed that the light beam gets into the UV spectrograph from the telescope after passing by the polarizer and the beam splitter. The polarizer spreads the beam linearly along 400 microns that contain the ordinary and the extraordinary beam. The beam splitter reflects UV wavelengths (119 nm to 320 nm) into the UV spectrograph. The view of the general optical layout is shown in Figure 1

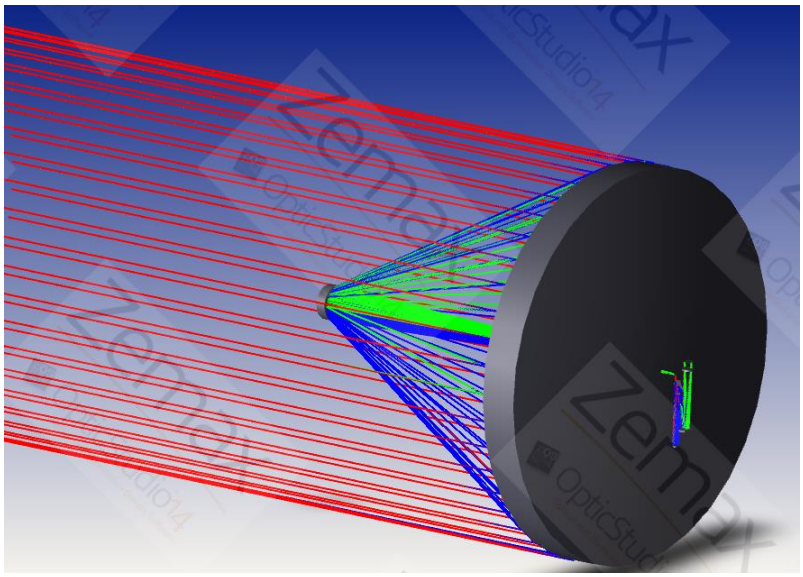

Figure 1: 3D view of optical path. The telescope primary has a diameter of 1.3 m.

The beam continues to the slit and an off-axis parabolic collimator (C) is placed in order to illuminate an Echelle-grating (E) with a collimated beam. The cross-dispersion (G) is made with a toroidal diffraction grating (see Figure 2). The main components of the optical design are shown in Table 1.

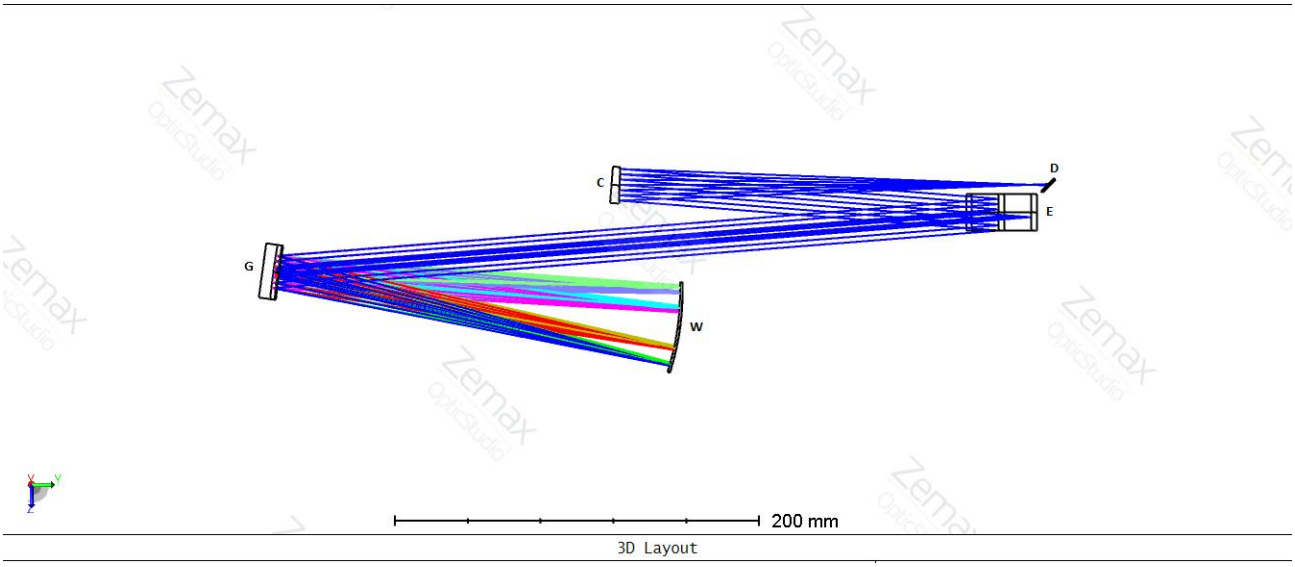

Figure 2: View of the UV optical design.

Table 1: Main components of the optical design.

Dichroic:
Reflects: 119-320 nm
Transmits: 355-888 nm
Collimator: off-axis parabolic mirror
Radius of curvature (mm): 450
Conic: -1
Echelle grating:
Grooves/mm: 270
Size (mm^2): 20x40
Number of spectral orders: 35
Absolute order number: m=21 m=55
Grating:
Curvature radius (mm): 445
Grooves/mm: 1000
Detector/Shape of the focal surface: toroidal
Size (mm^2): 50x50
Curvature radius (mm): 144
Pixel size (μm): 20

The spot diagrams are shown in Figures 3 and 4.

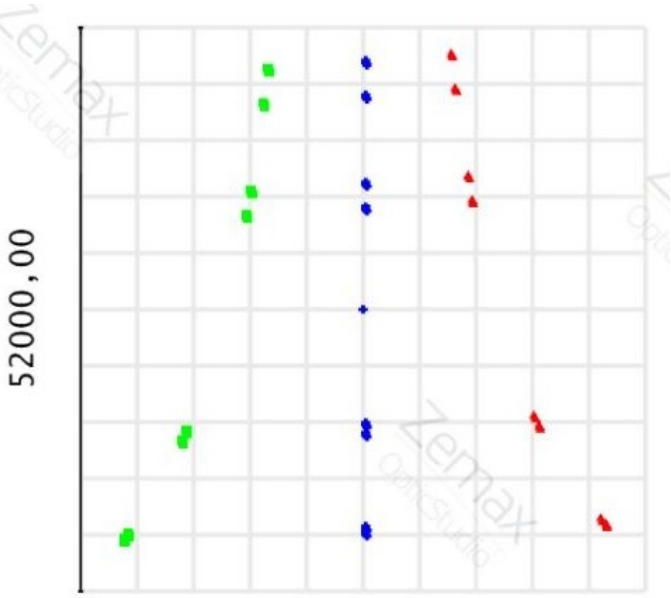

Figure 3: Matrix spot diagram.

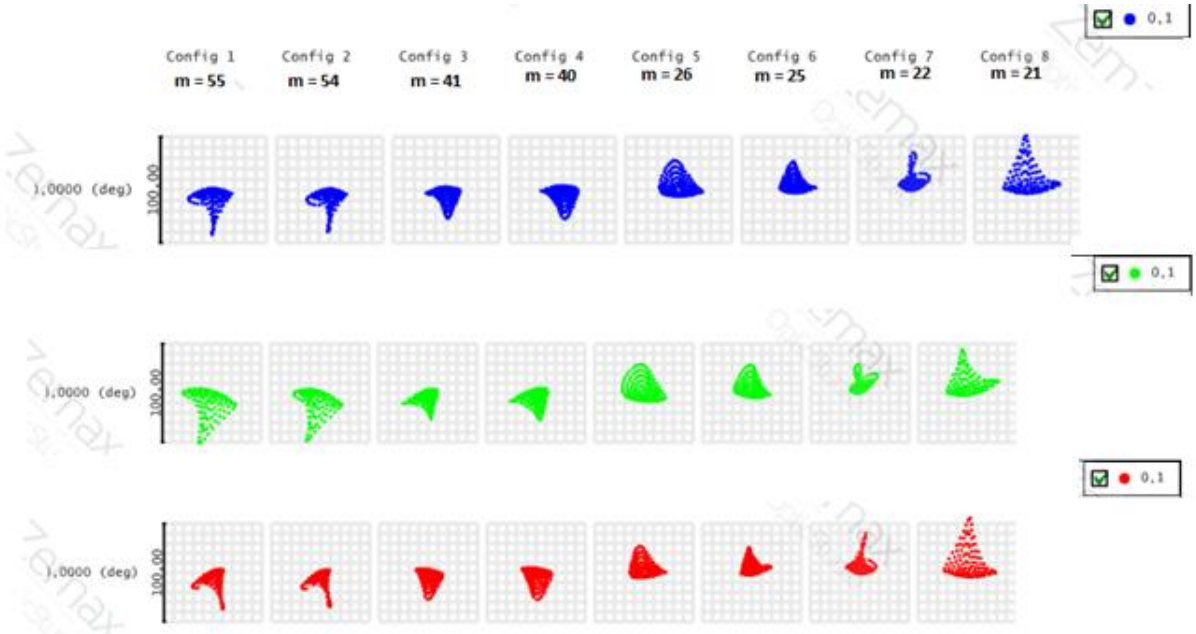

Figure 4: Configuration matrix spot diagram.

The encircled energy and RMS spot radius for m = 26 in the central wavelength is shown in Figure 5.

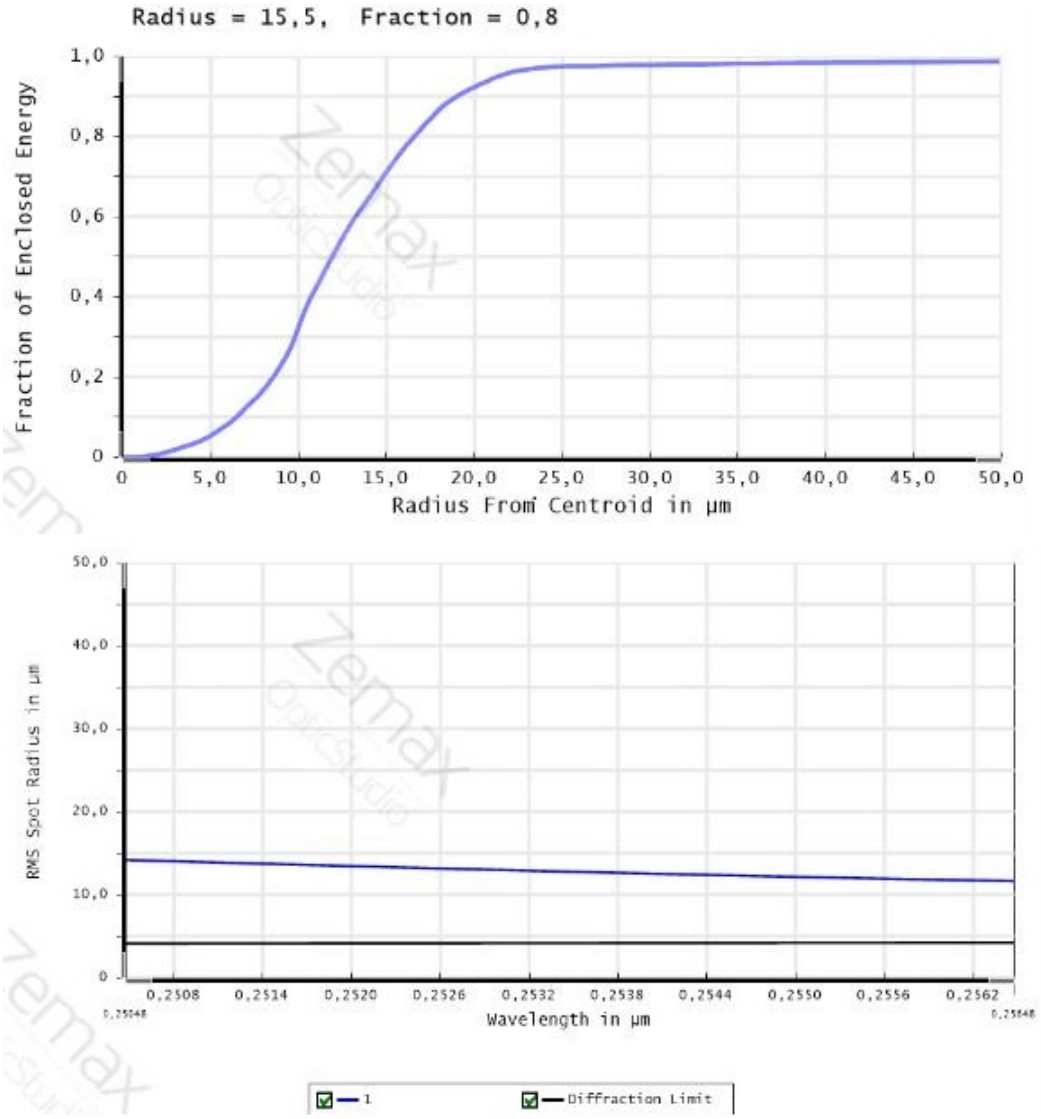

Figure 5: Encircled energy and RMS spot radius for m = 26 in 254 nm.

The Table 2. shows the current status of the scientific requirements with the proposed optical design. The radiometric requirements are not fullfilled in spite the UV spectropolarimer redesign with the smallest posible number of the optical surfaces. The image quality is aceptable being the RMS spot radious less than 1 pixel. The spectral resolution is about 23.000 in the central wavelengths for each order. The minimum value of the spectral resolution is 19.000 in FUV range of wavelengths.

Table 2: Current status of the scientific requirements with the proposed design.

Target	Optical design
Wavelength coverage: [119-320] nm	YES
Resolution: 25000	NO
Spectral coverage: 5 nm	YES
4 pixels recorded between two polarization states and two spectral orders	YES

Acknowledgments

We certainly acknowledge the Editors of Highlights of Spanish Astrophysics VII and VIII for their help while preparing this documentation.

References

[1] Arago consortium. ARAGO. The dynamic 3D environment of stars and planets: the life cycle of matter from the interstellar medium to the surface of stars, the edge of stellar systems, and back holes. ESA M4 proposal.

[2] Neiner C., 2015, Requirements for Arago's spectrograph for M5

[3] Pertenais, M., Neiner, C., Pars, L., Petit, P., Snik, F., van Harten, G., 2015, Proceedings IAU Symposium, 305

[4] Savanov, I., Sachkov, M., Shustov, B. and Shugarov, A., 2014, 40th COSPAR Scientific Assembly. Abstract E1.1111-14

[5] Shustov, B., Gmez de Castro, A.I., Sachkov, M., et al., 2014,ApDD, 354,155