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CAOS - the new high resolution spectrograph for the 0.91m telescope at Serra La Nave

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Abstract. We report on the status of the new high-resolution spectrograph CAOS under construction for the 0.91m telescope at Serra La Nave, Italy. Starting from defined scientific motivations, we derived the best instrumental requirements to meet observational goals within typical constraints like good performances and reduced overall cost. The new instrument will be able to enlarge present observational research activity at INAF-OACt, allowing spectropolarimetry at high S/N ratios.

Key words. Instrumentation: high-resolution spectroscopy – Instrumentation: spectropolarimetry

1. Introduction

Most of the observational research activity at the OACt is based on spectroscopic data collected at the Mario G. Fracastoro station (Mt. Etna) with the echelle spectrograph delivered by REOSC (France). This instrument, initially designed to work at the Cassegrain focus and to record the spectra on photographic plates, has been updated with a newer camera and a 1Kx1K CCD detector. During 2000, it has been equipped with a polarimetric module for the measurement of the four Stokes parameters.

The present observational activity at the OACt appears to be strongly limited by the relatively low performance of the spectrograph, expecially as it concerns the spectropolarimetry where high S/N ratios and resolutions are necessary. After the previous changing, the spectrograph cannot be further improved and the acquisition of a new high efficiency spectrograph cannot be delayed.

With the scientific activity carried out at the OACt, the importance of a higher resolution is related to the spectropolarimetry with particular interest to the measure of stellar magnetic fields (Leone & Kurtz 2003); Doppler Imaging of active stars and binary systems; measuring starspots temperature from line depth ratios (Catalano et al. 2002); radial velocities (Frasca & Lanza 2005), stellar atmosphere studies (i.e. determination of effective temperature, gravity, rotation velocity, micro macro-turbulence and abundances (Catanzaro et al. 2004); modeling of Balmer lines in presence of expanding envelopes (Markova et al. 2005). Moreover, it will be possible to carry out all those scientific programs that are usually based on R = 50 000 spectrographs.

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2. Design requirements

CAOS will have to be a high efficiency, high-resolution, fiber fed optical spectrograph with high stability and complete spectral coverage in one exposure. The main design requirements of the spectrograph are given below:

- Single object
- Integral light mode or polarimetric mode
- Fiber fed
- Spectral resolution: high resolution (R = 30 000 − 45 000 − 60 000) and low resolution (R = 3 000)
- Spectral region: 388–725 nm
- Full spectral coverage in one exposure
- Efficiency (integral light mode): > 20%
- High stability
- Low scattered light

Both integral light mode and polarimetric mode will feed two fibers for simultaneous measurements of source+sky or two independent polarimetric components, respectively.

3. Optical design

In order to meet design requirements we selected a bench-mounted, fiber fed, cross-dispersed echelle spectrograph (Spanò et al. 2004). As trade-off between resolution and cost, we selected a 10 cm collimated beam dispersed by a R4 echelle grating in *white-pupil* configuration (Dekker et al. 2000), focused with an optimized all-dioptric camera onto a 2K×2K, 13.5 μm pixels, CCD.

Unvignetted resolution defined by fiber projection is about 28000, while higher resolution modes will be available adding an entrance slit between preslit optics and spectrograph collimator. The maximum spectral resolution is R = 63000 with a 2 pixel sampling. Interorder separation allows us to accommodate two fibers for spectropolarimetric studies. The spectrograph will be installed onto an optical bench in a thermally and mechanically isolated environment inside a room below the the telescope level, allowing a stable spectrum position (figure 1).

3.1. Optical components

A paraboloidal mirror in Astrosital, with 400 mm clear area and a focal length of 1000 mm, has been polished by *Marcon* (Italy), cutted in two off-axis portions and then coated for high reflectivity (>97%) by *SILO* (Italy).

The echelle grating has been delivered in August 2004 by the Spectra-Physics. Made on a Zerodur substrate, is blazed at 76^o and has 41.59 gr/mm over a 102×408 mm ruled area. It works in Littrow configuration with a small 0.9° off-plane angle. Such a small angle introduce no evident line tilt, that remains below 0.2 pixel everywhere on the CCD focal plane.

A 140x160x160 mm SF1 prism with an apex angle of 53.1° has been realized by the *SILO* and delivered in February 2005. A/R coatings give an average efficiency better than 90%. The resulting echelle spectral format covers the 3881–7250Å spectral range in 56 orders without gaps and no overlapping for two fiber projections.

A lot of effort has been devoted to the optimization process of the optical design searching for a simple, efficient, low cost F/2.1 camera design. That has been manufactured by *SESO* (France). All surfaces are spherical or plane. Due to the fixed spectral format, axial chromatism has been corrected tilting the focal plane.

3.2. Observing modes and performances

At the Cassegrain focal plane, two fibers can accept light from the source and sky (integral light mode) or from the two output beams of the polarizer (polarimetric mode). Input microlenses reduce FDR losses (Avila 1998). At the spectrograph entrance, different resolutions can be achieved through an insertable slit mask.

A low resolution mode is obtained by inserting a small right angle prism near the slit position bending the light path directly to the second mirror, by-passing the echelle, and giving a resolution of R = 2 500.

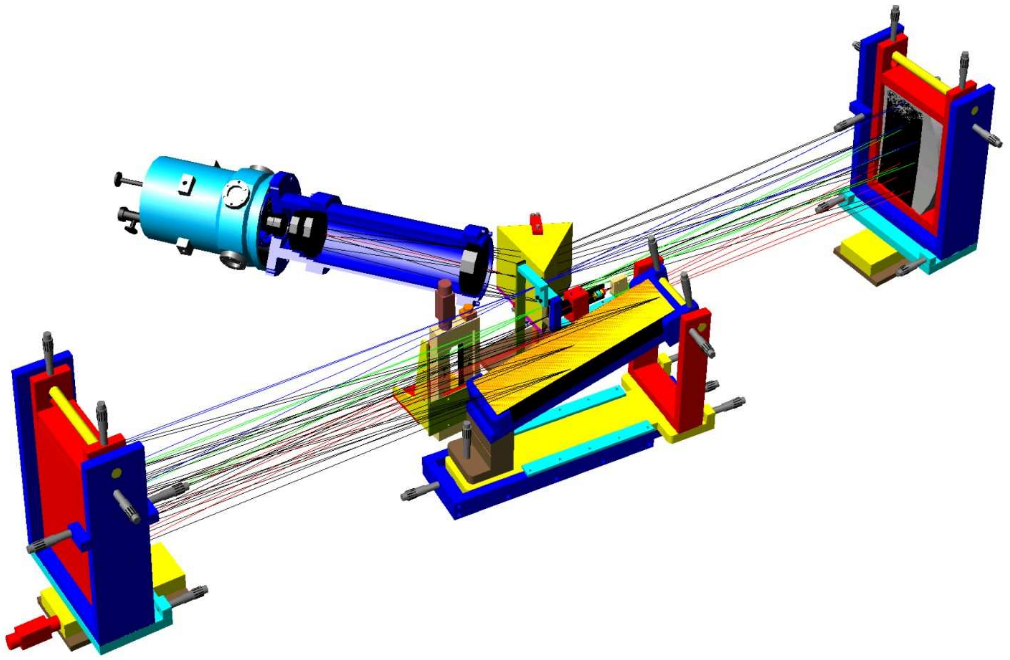

Fig. 1. Optomechanical layout of the spectrograph. Light enters from fibers through a preslit system into the spectrograph entrance slit.

Total throughput has been estimated between 25% and 32%, from the telescope focal plane to the detector, including fiber losses, and CCD QE. In standard observing conditions (seeing ≈ 2 arcsec, sky background V≈20), limiting magnitudes at R=28000 for 1 hr exposure are V≃12.5 and 16.5 at signal-to-noise ratio 100 and 10 per resolution element, respectively.

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