Mem. S.A.It. Suppl. Vol. 9, 436

Memorie della
Supplementi

The Atmospheric Dispersion Corrector Software for the VST

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Abstract. The effects of atmospheric differential refraction on astrophysical measurements are well known. In particular, as a ray of light passes through the atmosphere, its direction is altered by the effects of atmospheric refraction. The amount of this effect depends basically on the variation of the refractive index along the path of the ray. The real accuracy needed in the atmosphere model and in the calculation of the correction to be applied is of course, considerably worse, especially at large zenith angles. On the VLT Survey Telescope (VST) the use of an Atmospheric Dispersion Corrector (ADC) is foreseen at a wide zenith distance range. This paper describes the software design and implementation aspects regarding the analytical correction law discovered to correct the refraction effect during observations with VST.

Key words. Atmospheric Dispersion Corrector, control software, telescope

1. Introduction

The VST (VLT Survey Telescope) is a 2.61 m alt-az f/5.5 modified Ritchey-Chretien telescope. It is provided by one focus station in Cassegrain optical configuration, where there will be installed the 16Kx16K OmegaCAM imaging camera, committed to an international consortium in collaboration with ESO (European Southern Observatory). High image quality performance is guaranteed by an active control of the optics.

2. ADC optical architecture

The VST adapter is provided with two different correctors with refracting and dispersing elements. One corrector (here in after the "Two-Lens" corrector) is composed by two lenses and operates from U to I bands (0.320 $\div$ 1.014 μm) at 0° zenith angle; the other (here in after the "ADC" - Atmospheric Dispersion Corrector) is composed by two rotating double prisms and one different lens to observe from B to I bands (0.365 $\div$ 1.014 μm) at different angles until 52° from zenith. The telescope covers a very large field of view (1.47° diagonal), with a high resolution (0.21″/pixel) and a high image quality (80% of EE enclosed in two pixels). The light coming from celestial objects is continuously refracted by the effect of the refraction index variation of atmosphere which is present between object and observer. For an object with zenith angle z and at a specific wavelength range, the angular atmospheric dispersion is proportional to tan(z), HM Nautical Almanac (1995). For a telescope with focal

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length F, this dispersion produces a linear dispersion F at focus, that can be minimized by an optical system composed by thin prisms positioned at a distance D from telescope focus. The use of an Atmospheric Dispersion Corrector (ADC) determines an angular deviation F/D in the opposite direction of the atmosphere. With these considerations, by denoting with 1 and 2 the respective prism angles, and with n_1 and n_2 the respective prism glass refraction indexes at a fixed mean wavelength, it is obtained:

$$\left\{ \begin{array}{l} \alpha_1(n_{glass1}(\lambda)-1)+\alpha_2(n_{glass2}(\lambda)-1)=0 \\ \frac{F_{telescope}\delta}{D}=\alpha_1\Delta n_{glass1}(\lambda)-\alpha_2\Delta n_{glass2}(\lambda) \end{array} \right\}$$

where Δn_{glassi} is the refraction index variation of ith glass type, expressed in radiants (rad).

3. The VST ADC design

In the VST the angular ADC consists of two couples of prisms (in the following specified simply as two prisms), with a separation between them fixed at 10 millimeters (mm). For each couple, the two prisms are designed in such a way that their introduction in the light path does not cause any shift of the spot on image focal plane (zero-shift) Filippenko (1982). The correction mechanism is based on the counter-rotation of the two prisms by an angle around the optical axis.

3.1. Prism angle rotation calculation

As said above, the ADC angle rotation θ is calculated given specific parameters: air pressure and temperature, wavelength band, depending on the current filter type, and telescope zenith angle position. Some other parameters are constants: the prism orientation angle α_{prism} (equal for both prisms), the telescope focal length F_{ADC}. In the case of the VST angular ADC, the prism counter-rotation effect produces an angular rotation that can be derived, through simple geometrical considerations, by correlating α_{prism} with θ:

$$\alpha_{prism'} = arctg(H \cdot cos\theta) \quad (1)$$

Fig. 1. The VST ADC control software data/commands flow diagram.

The final formula for the ADC rotation angle is:

$$\theta = arccos\left[\frac{1}{H}\cdot tg\left(\frac{F_{VST}\delta}{D(\Delta n_{glass1}(\lambda)-\Delta n_{glass2}(\lambda))}\right)\right] \quad (2)$$

4. The adc control software

The ADC control software system is based on a distributed architecture following the common strategy applied over

4.1. Software control process

The VST ADC control SW (SoftWare) package is basically composed by a module, responsible of all calculations referred to atmospheric dispersion and prism angle rotation, Fig. 1. There are two kind of commands foreseen for the ADC:

1. indirect positioning: given the celestial object coordinates or the current telescope zenith angle, the next angular position for the prisms is calculated;
2. direct positioning: by specifying an absolute rotation angle to be reached by prisms.

5. The ADC test simulation model

As described above the VST atmospheric dispersion corrections are obtained by means of a rotation of the prisms taking into account both atmospheric and zenith angle parameters. In order to test and to optimize the correctness of this rotation, a matlab-based ADC model was designed, obtaining the angular rotation of prisms vs. the zenithal angle of the telescope. This theoretical rotation law has been compared with the ray tracing ADC model, designed by VST optical engineering staff to build the real ADC system, using Zemax software.

The comparison between Matlab and Zemax model is done at the zenith angle range between 0 and 52 degrees. The comparison shows that the angular rotation law can be considered very precise from 0 to 40 degrees. A little difference appears from 42 to 52 degrees. The reason is that the two simulations have been implemented considering two atmospheric models that, when the air mass starts to be predominant, reveal some difference. The Matlab atmospheric model has been basically derived by the VLT one, while the Zemax model is inherited in the ray tracing software and some of its theoretical details are not known. We decided to adopt the VLT atmospheric model to be implemented in the ADC software basically because the VST will be located at the same site. Another element that of course can affect the prism angular correction is the observing wavelength. The Fig. 2 shows an example of the VST focal plane spot behavior by applying ADC corrections at different wavelength ranges.

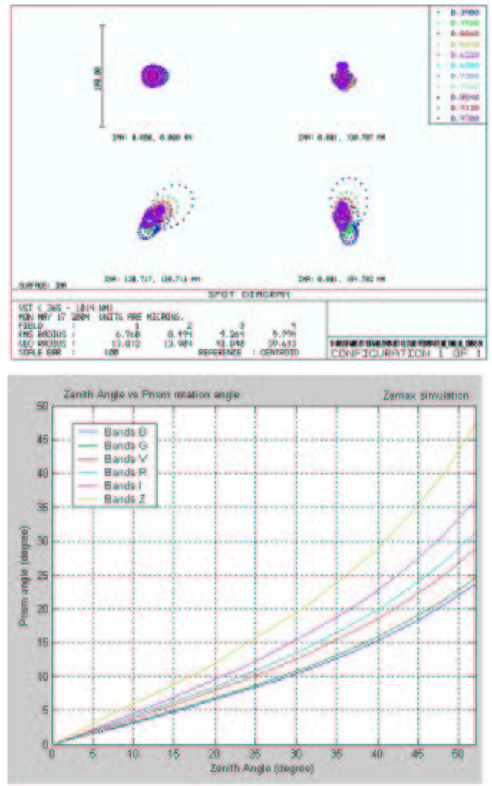

Fig. 2. The ADC ray tracing results at zenith (top) and the ADC correction law at different wavelength ranges.

6. Conclusions

The ADC opto-mechanical system is going to be installed at the telescope integration workshop. The ADC model and numerical simulations, performed crossing Matlab modeling and Zemax ray tracing procedures, show that the atmospheric dispersion corrector would be able to correct the light path position from atmospheric refraction in a wide zenith angle range, from 0° to 52°. Furthermore, the optimization of correction effect has been done by strongly correlating the telescope altitude zenith angle position with the particular wavelength range coming from the current optical filter present on the light path. Doing so, a more precise correction from refraction is applied during exposures. This careful approach has been required by the intrinsic features of the VST (short focal length together with a wide field of view). A more accurate prism rotation calculation will be fixed during test sessions ”on sky”, foreseen during the telescope commissioning period.

References

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