SIMULATED DISPERSED FRINGES OF AN ASTROMETRIC SPACE INTERFEROMETRY MISSION

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ABSTRACT

Several astrometric space interferometry mission projects (e.g. GAIA, FAME, DIVA) for scanning the sky in a similar fashion as Hipparcos are currently being discussed. Their raw detector signals will be dispersed interferometer fringes. This new type of signal will be directly recorded by CCD mosaics in drift-scan mode in the focal plane of Fizeau interferometers. The astrometric measurement, i.e. the determination of the one-dimensional relative position of the fringe pattern, perpendicular to the fringes (i.e. in the direction of the sky scan), and the extraction of the spectro-photometric information contained in the direction of the dispersion of the fringes (i.e. perpendicular to the sky scan) need a complex reduction technique.

We report on the simulation of polychromatic dispersed fringe patterns of stars with different spectra taken from spectrophotometric libraries using the presently envisaged parameters of the DIVA instrument. The stellar signal was combined with expected dark current and sky background and then transformed according to Poisson distribution. The assumed read-out noise of the CCD was added. The resulting images will be used for the development of algorithms for the combined astrometric and spectrophotometric reduction.

Key words: space astrometry; interferometry; GAIA; DIVA; FAME.

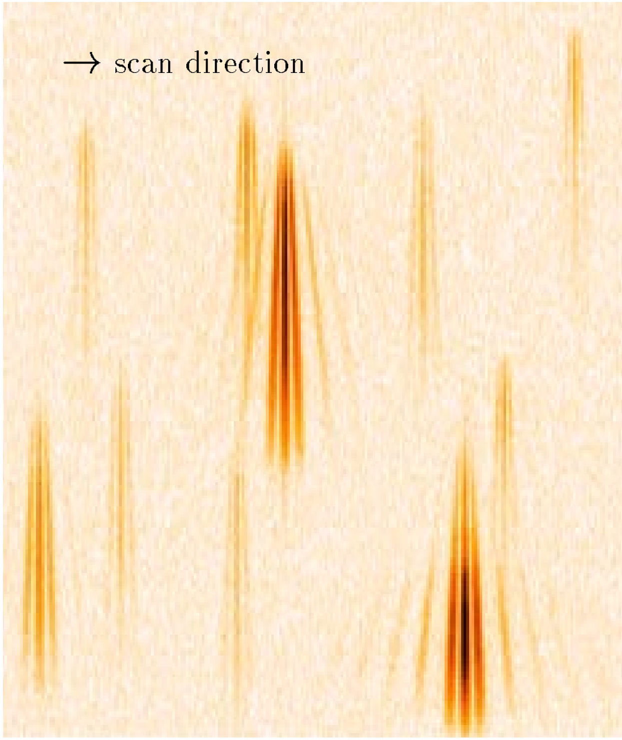

Figure 1. Part of DIVA observation field (85 × 100 arcsec^2) in a dense sky region with 10 stars of different spectral type simulated: a G5 star (V = 7.5 mag) in the centre, three stars with V = 10 and 6 stars with V = 11. The lower right bright star is a very red M5 star with V = 10. The V magnitude corresponds to a region in the upper half of each spectrum.

1. INTRODUCTION

The use of dispersed fringes and direct fringe detection was already discussed at the RGO-ESA workshop (ESA 1995) as an alternative to the detection of the interferometric fringe pattern by modulating grids as proposed for the original design of GAIA by Lindegren & Perryman (1996). The advantages of the dispersed fringes are described by Høg et al. (1997), who presented a new optical design for GAIA, called GAIA95. This design served as the basis for the DIVA proposal of a small interferometric satellite for astrometry and spectrophotometry (Bastian et al. 1996, Röser et al. 1997). There is a further space interferometry mission project - FAME (Seidelmann et al. 1995) using dispersed fringes and their detection by CCDs in drift-scan mode.

We have carried out simulations of dispersed fringes for a better estimate of this new type of signal and its reduction. The simulations can be applied to all three mission concepts (GAIA95, DIVA, FAME) by changing the corresponding input parameters.

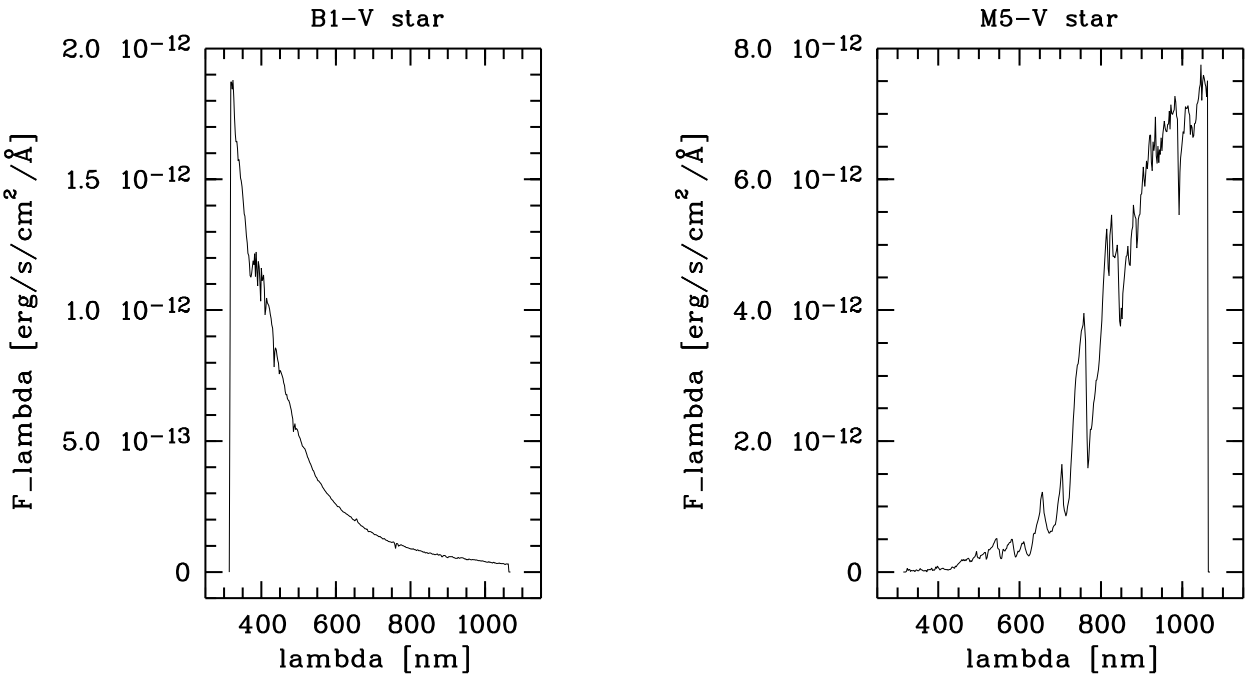

Figure 2. Stellar spectra normalized to $V = 10$ for a blue B1-star and a red M5-star with many absorption lines, taken from the stellar spectrophotometric atlas of Gunn & Stryker (1983).

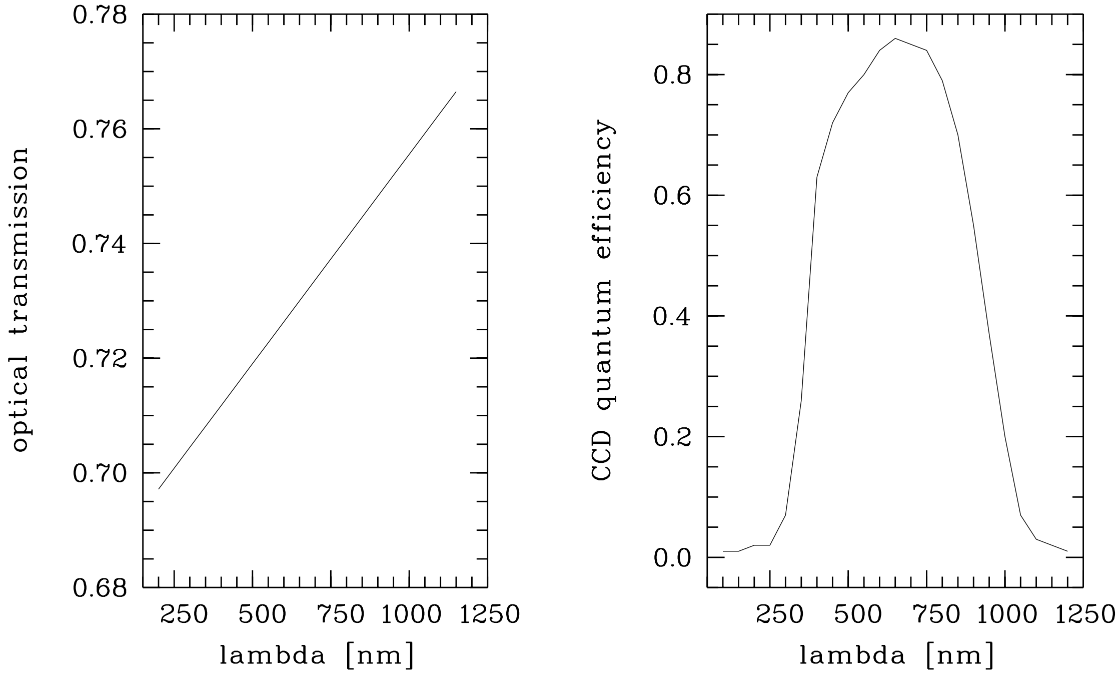

Figure 3. Assumed transmission of the optical system (left) and CCD quantum efficiency (right).

2. INPUT PARAMETERS FOR SIMULATIONS

The following input parameters were used for the simulation of the polychromatic fringe patterns shown in Figure 1 and Figure 6.

- stellar spectra from Gunn & Stryker (1983) (from 313 to 1080 nm, see Figure 2)
- transmission of the optical system as a function of wavelength (from 70 to 77 per cent, see Figure 3)
- quantum efficiency of the CCD as a function of wavelength (maximum 85 per cent, see Figure 3)

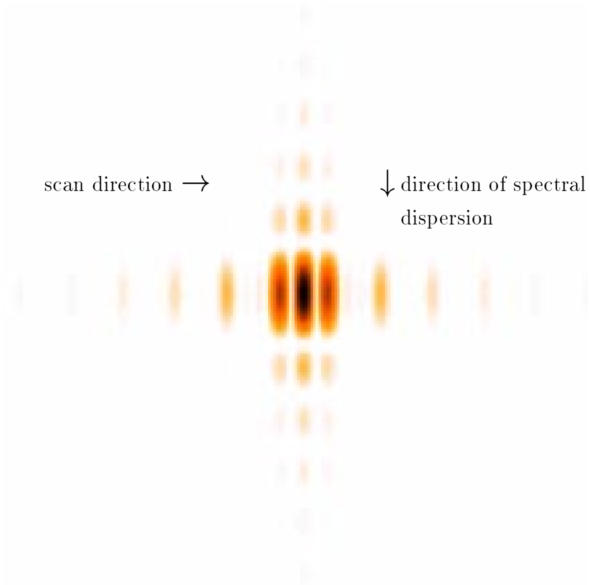

Figure 4. Monochromatic fringe pattern of the DIVA interferometer in a logarithmic intensity scale. The central fringe dimension is 1×4 arcsec^2. The 0th and 1st order fringes in horizontal direction contain 90 per cent of the light, second and other even-order fringes are suppressed due to the optical design of the DIVA-interferometer.

- two interferometer apertures (2×25cm^2), 1 s of exp. time
- monochromatic diffraction pattern of the interferometer (see Figure 4)
- dispersion curve of the prism (see Figure 5)
- dark current and sky background (1.4 e$^-$/pix/s and 0.1 e$^-$/pix/s)
- on-chip-binning → effective pixel size 13.5μm $\times$ 81μm = 0.17 arcsec $\times$ 1.02 arcsec for DIVA
- read-out noise of CCD ($\sigma = 2.1$ e$^-$/eff.pix/s)

Figure 5 shows the dispersion curve of the currently discussed DIVA prism (1 pixel = 13.5μm = 170 mas). The dispersion is essentially constant with λ. The wavelength interval from 400 to 1000 nm gives a spectrum of $\sim$ 3 mm in the focal plane.

3. RESULTS OF SIMULATIONS

Figure 6 contains the polychromatic fringe patterns with noise contributions for the blue B1- and the red M5-star (cf. Figure 2 and Figure 7) with two different magnitudes. Each of the four images contains 116×50 effective pixels. The effective pixel size of 13.5μm $\times$ 81μm was achieved after on-chip-binning over 6 pixels in vertical direction, corresponding to the DIVA concept.

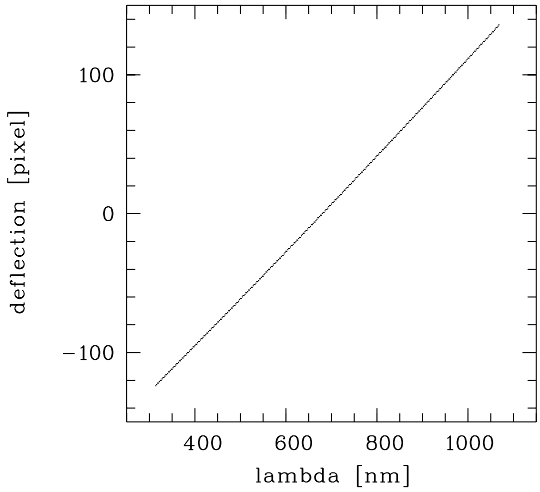

Figure 5. Dispersion law of the DIVA prism.

Figure 7 gives the resulting spectra of the two stars shown in Figure 2 with $V = 10$ after taking into acount the optical transmission, CCD quantum efficiency, monochromatic fringe pattern and the dispersion law of the prism. No noise has ben added on this stage and the on-chip-binning has not yet been carried out in order to show the smearing of the spectra due to the dispersion of the prism only.

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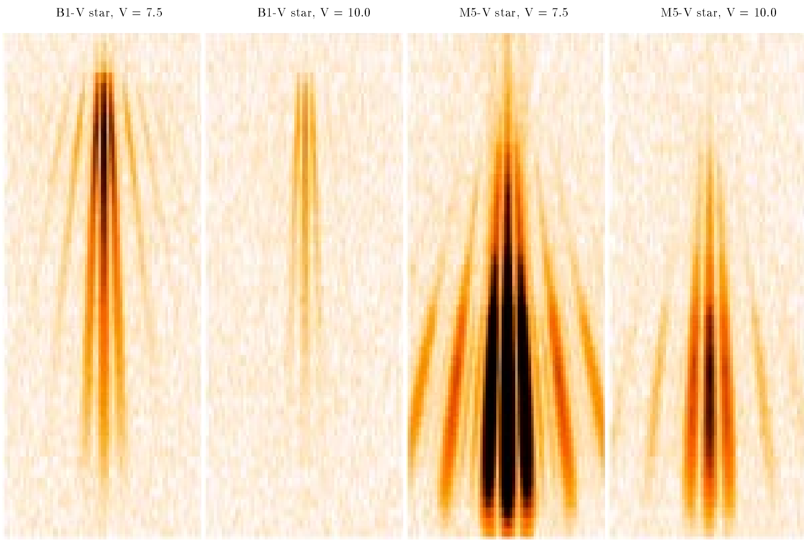

Figure 6. Simulated dispersed fringes with on-chip-binning and noise. The polychromatic fringe pattern was computed by co-adding 378 monochromatic images with 2nm steps. The length of the spectra from about 300 nm (top) to about 1100 nm (bottom) is limited mainly by the CCD quantum efficiency.

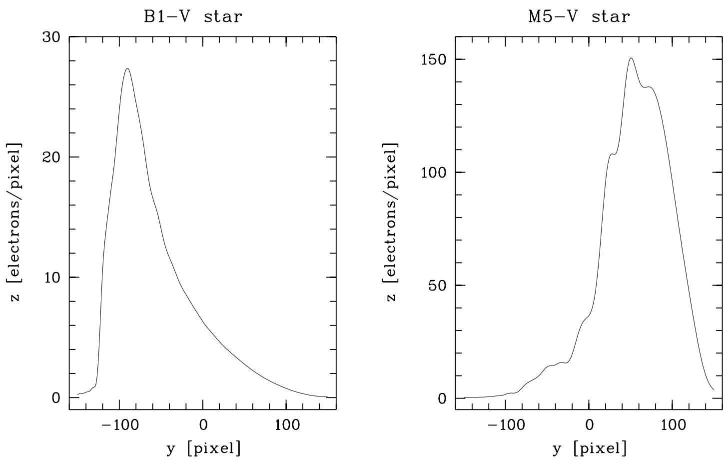

Figure 7. The pixel values of one CCD column in vertical direction demonstrating the spectral light distribution within the central fringe. The spectra are shown here without noise and before the on-chip-binning.