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SIMULATION OF THE ANISOPLANATIC ANGLE-OF-ARRIVAL FLUCTUATIONS MEASURED ON THE SOLAR EDGE IMAGES

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Abstract. Anisoplanatism in adaptive optics or differential astrometry as in ground-based solar diameter measurement needs the knowledge of atmospheric turbulence profiles. MISOLFA is a monitor dedicated to statistically estimate daytime turbulence profiles $C_n^2[h]$ from solar limb agitation measurements. In order to understand the statistics of the system performance, an accurate numerical simulation of multi-layer anisoplanatic angle-of-arrival fluctuations simultaneously measured over different lines of sight is performed. A comparison between simulation and theory leads to valid the method and its efficiency. The method of the simulation will be presented.

1 Introduction

MISOLFA (*Moniteur d'Images SOLaires Franco-Algérien*) is a solar monitor developed for probing atmospheric turbulence. It is based on anisoplanatic measurements of the solar limb motion induced by Angles-of-Arrival (AA) fluctuations integrated all over the instrument pupil (Irbah *et al.* 2001). Recorded solar images lead to compute the AA angular structure function $D_\alpha[\Theta]$. The optical turbulence profiles $C_n^2[h]$ are deduced from $D_\alpha[\Theta]$ using appropriate inversion techniques. A numerical simulation of the expected AA fluctuations is however needed to improve the inversion methods.

2 Random phase (or AA) screen simulations by Fourier transform

Simulations in optical turbulence (Phase screen or AA simulations) are often based on inverse Fourier transforms of a random complex quantity which variance is given by the 2d-spatial power spectral density (PSD) of the targeted simulated quantity. They require however an optimal sampling of the theoretical PSD. In fact, regular sampling of the space frequency domain in FFT-based methods provide only a part of the spectral information and a large part of low-frequency spectrum is lost.

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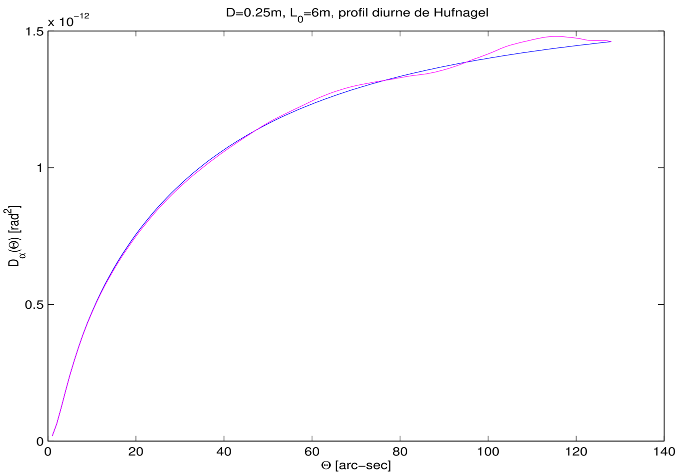

Fig. 1. Simulated and theoretical AA structure functions.

3 Semi-regular sampling of the 2d-space frequency domain

Our Fourier transform simulation is based on a semi-regular sampling of the PSD. This method is summarized by the following equation :

$$\alpha[\overrightarrow{\Theta}] \simeq 1.7497 \sum_{f_x, f_y > 0} df\,(f_x + f_{a_x})\left((\overrightarrow{f} + \overrightarrow{f_a})^2 + \frac{1}{L_0^2[h]}\right)^{-\frac{11}{12}} \left| \frac{2J_1(\pi D|\overrightarrow{f}+\overrightarrow{f_a}|)}{\pi D|\overrightarrow{f}+\overrightarrow{f_a}|} \right| \sum_{h=0}^{h_{max}} dh R_1[\overrightarrow{f}, h]$$

$$\sqrt{C_n^2[h]}\,|\cos(\pi\lambda h(\overrightarrow{f}+\overrightarrow{f_a})^2)| \left| \frac{\sin(\pi T_m(\overrightarrow{f}+\overrightarrow{f_a})\overrightarrow{v[h]})}{\pi T_m(\overrightarrow{f}+\overrightarrow{f_a})\overrightarrow{v[h]}} \right| \cos(2\pi h\overrightarrow{\Theta}(\overrightarrow{f}+\overrightarrow{f_a}) + R_2[\overrightarrow{f}, h])$$

$L_0[h]$ and $\overrightarrow{v[h]}$ are respectively the wave-front outer-scale and wind velocity profiles. D is the diameter of the MISolFA entrance pupil and T_m is its exposure time. A given angular distribution $\alpha[\overrightarrow{\Theta}]$ of the AA fluctuations is the summation of contributions at different frequency values $\overrightarrow{f} + \overrightarrow{f_a}$ where $\overrightarrow{f}[f_x, f_y]$ are equally spaced by df in both f_x and f_y directions. $\overrightarrow{f_a}[f_{a_x}, f_{a_y}]$ is a random quantity such as $0 < f_{a_x} < df$ and $0 < f_{a_y} < df$ which statistically allows to cover space frequency values not attempted by the regular sampling $\overrightarrow{f}$ alone. $R_1[\overrightarrow{f}, h]$ and $R_2[\overrightarrow{f}, h]$ are respectively a normal random quantity with unitary variance and an uniformly random quantity with $-2\pi < R_2 \leq 2\pi$.
Figure 1 shows the good agreement observed between the structure functions obtained from the simulation and with the theoretical one.

References

Irbah, A. *et al.* 2001, SF2A 2001-Lyon, EDPS Conference Series in Astronomy and Astrophysics.