© 2016 IJSRST | Volume 3 | Issue 3 | Print ISSN: 2395-6011 | Online ISSN: 2395-602X
Themed Section: Science and Technology

The Effects That Lead To the Degradation of the Images Obtained Using a Ground-Based Telescope

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ABSTRACT

Various methods of deconvolution have been developed for several decades, especially in astronomy. The extension of these techniques to the case of a spatially varying blur is currently an open problem. The objective of this article is to obtain an estimate of the different consistency parameters of wave fronts through a statistical analysis as the variance and covariance of the angles of arrival.

Keywords: Deconvolution, Covariance of the Angles of Arrival, Optics Atmospheric, Astronomical Image.

I. INTRODUCTION

Increasing the size of the telescopes over the centuries has led to a huge gain in the ability to collect light, and observe objects increasingly smaller. However, it was not really accompanied by a large increase in angular resolution of telescopes, that is to say their ability to observe details increasingly smaller. This lack of progress is due to the Earth's atmosphere which is constantly animated by the air mass movements that give rise to the so called atmospheric turbulence .The major consequence of this phenomenon is to divert constantly and randomly light rays coming from space. The flow of atmospheric air is almost always turbulent and characterized by changes in properties and by rapid changes in pressure, speed and temperature in space and time. Several theoretical and experimental models have been proposed to model the turbulence [1,2]: the first was introduced by LF Richardson in 1922 then developed by Kolmogorov in 1941, it later became the basis for the theory of the formation of astronomical images through the Earth's atmosphere, in the case of strong turbulence, our model considers the transfer of kinetic energy that takes place at all spatial scales (energy cascades) that can be summarized as follows: the turbulent flow process starts at a certain scale l_0 said the scale of turbulence, when the Reynolds number flow feature that measures the ratio the inertia forces and viscous forces (for air the Reynolds number is of the order of 10^6), the kinetic energy of turbulence is provided by the kinetic energy of the turbulence is provided by large-scale phenomena then transfer to movements of scales L_0 smaller and smaller until it is dissipated as heat, occurs at a so called scale internally, the area between the field and "inertia" where turbulence is assumed to be homogeneous L_0 and l_0 isotropic.[3,4].

In this article, we dedicate our work to the dynamic and optical properties of turbulence and the propagation of light waves through atmospheric turbulence [7, 8, 17]. Then we will define the parameters used to characterize the observation conditions and the effects of atmospheric turbulence on the wave front that are nothing but the angle of arrival fluctuations [6]. At the end we study the main effects that lead to the degradation of the images obtained using ground-based telescopes such as the effect of the optical system and the effect of turbulence. Using Matlab software, we will simulate temporal variation of atmospheric turbulence that will be modeled by approximating the turbulence frozen in several phase screens. The phase screen is the origin of the distortion of the wave front; this distortion is expressed mathematically by the spatial distribution of phase fluctuations whose Fourier transform is called the spectral density of the phase fluctuations.

II. STATISTICAL ANALYSIS OF ANGLE OF ARRIVAL FLUCTUATIONS

The angle of arrival (AA) of the wave front arrival the ground is the angle between the direction normal to the perturbed wave surface and the direction normal to the wave surface non disturbed to the point defined by $\vec{r}$.
The wave front arrival angle is proportional to the spatial drift of the φ phase in the x and y directions are given by [13]:

$$\alpha(x,y) = -\frac{\lambda}{2\pi}\ \frac{\delta}{\delta x}\ \varphi_0\ (x,y) \quad (1)$$

$$\beta(x,y) = -\frac{\lambda}{2\pi}\ \frac{\delta}{\delta y}\ \varphi_0\ (x,y) \quad (2)$$

If we held the diffraction on the pupil of the telescope's arrival angle of the wave front is given by [11]:

$$\alpha(x,y) = -\frac{4\lambda}{2\pi^2 D^2}\ G(x,y) * \frac{\delta}{\delta x}\ \varphi_0\ (x,y) \quad (3)$$

$$\beta(x,y) = -\frac{4\lambda}{2\pi^2 D^2}\ G(x,y) * \frac{\delta}{\delta y}\ \varphi_0\ (x,y) \quad (4)$$

Where G(x,y) is the pupil function and $\varphi_0(x,y)$is the fluctuation of the phase on the pupil. La spectral density of the angle of arrival of the two models Kolmogorov Von Karman [5]:

$$w_{AA}^{kol}(\vec{f}) = 0.3870 \int C_n^2\ (h)\delta h f^{\frac{-11}{3}}\ |\frac{2J_\Delta(\pi f D)}{\pi f D}|^2 \cos^2 \pi\lambda h f^2 \quad (5)$$

$$w_{AA}^{kol}(\vec{f}) = 0.3870 \int C_n^2\ (h)\delta h(\frac{1}{L_0} f^2)^{\frac{-11}{3}}\ |\frac{2J_\Delta(\pi f D)}{\pi f D}|^2 . \cos^2 \pi\lambda h f^2 \quad (6)$$

Variance fluctuations AA are related to the spectral density of the AA more particularly to the spectral density of phase by this relationship:

$$\sigma_{AA}^2 = \int_0^{+\infty} w_{AA}\ (\vec{f})\delta f \quad (7)$$

By replacing $w_{AA}\ (\vec{f})$ by its expression given by both Kolmogorov and Von Karman models respectively:

$$\sigma_{AA}^2 = 0.17\ \lambda^2\ r_0^{\frac{-3}{5}} \quad (8)$$

The covariance of the arrival angle fluctuations is related to the spectral density of the phase [13, 14, 15]:

$$C_{AA}(\theta) = \pi\ \lambda^2\ \int_0^{+\infty} dff^3\ w_{\varphi,0}(f)[J_0(2\pi f\theta h) + \cos\emptyset\ J_2(2\pi f\theta h)][\frac{2J_1(\pi Df)}{\pi Df}]^2 \quad (9)$$

In this paper we define the Analysis of fluctuations in arrival angles, this analysis is very important in the case of the study of the influence of atmospheric turbulence on the formation of astronomical images.

III. SIMULATION OF ATMOSPHERIC TURBULENCE

Images obtained using ground telescopes are blurred due to the action of two main effects, an instrumental effect and another atmospheric effect introducing filtering caused by atmospheric turbulence.

A. The Instrument Effects (the Response of a Telescope)

The response of the optical system shown in the images is the result of the finished opening of the instrument (pupil). It is not simple, but by analyzing the diffraction process (phenomenon in which light rays from a point source are deviated from their trajectory and based on the interference of light emitted), the diffraction pattern called an Airy task is a bright central disc surrounded by a number of rapidly diminishing concentric rings. This intensity distribution is described by the response of the optical system (telescope) imposed by diffraction aka Point spread Function (PSF). The radius of the pupil opening function R is given by [16], pupil of Simulation and PSF.

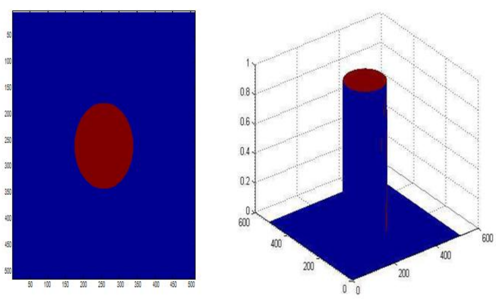

Figure 1: Telescope pupil left (2D) and right (3D) (512x512) pixel.

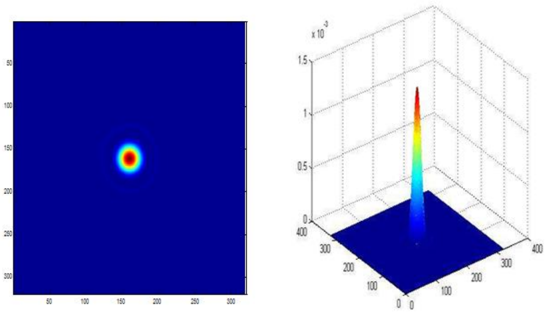

Figure 2: The response of a telescope (Airy disk) left to right 2D and 3D (320x320) pixel.

Atmospheric disturbances are largely responsible for the degradation of astronomical measurements (eg the sun); they degrade the wave front incident. This turbulence simulation generates atmospheric turbulence, and then the turbulence is generated as screen [9, 15]. It may be of Kolmogorov or Von karman. We then use the spectral method (method of Nakajima Thadashi) that is the ability to numerically find the spatial distribution of phase fluctuations using the inverse Fourier transformation of the spectral density phase [10]. The size of those screens is determined by simulation conditions like the sampling frequency $\Delta f_{max} = \frac{1}{2dx}$ where dx is the spatial sampling of the phase screen, and also these screens are generated according to the characteristics of turbulence parameter Fried r_0 and L_0 the external scale [11].

TABLE 1

THE INFLUENCE OF THE PARAMETERS R0, L0, H OF THE PHASE SCREEN

r_0 (cm)	2	2	2	8	2
L_0(m)	1	10	10	10	10
H(m)	1000	1000	10000	1000	1000
dx(cm)	0.2	0.2	0.2	0.2	0.8

B. Method

TABLE 2

METHOD OF CALCULATING THE SCREEN PHASE BY NAKAJIMA

Create a square matrix of size 2n x 2n for the spectral density of the fluctuations of the phase by a random draw	$W_{\varphi}(i,j)$
n switches to the sampling in the Fourier space which must satisfy the Shannon theorem, knowing that the frequency pitch Δf of the matrix corresponds to the spatial sampling step of the phase screen dx. According to Shannon this step is limited by a maximum value	$\Delta f_{max} = \frac{1}{2dx}$
Create two other matrixes	A (i , j) et $\emptyset(i,j)$
Draw real random numbers having a Gaussian distribution with variance 1 to A (i, j) and a uniform statistical distribution of real numbers for Ø (i, j).	Between -2π et 2π.
phase calculation	using the inverse FFT
Programming in C ++	In MATLAB.
obtains a phase screen	As show in figure (3,4):

C. The effect of atmospheric turbulence

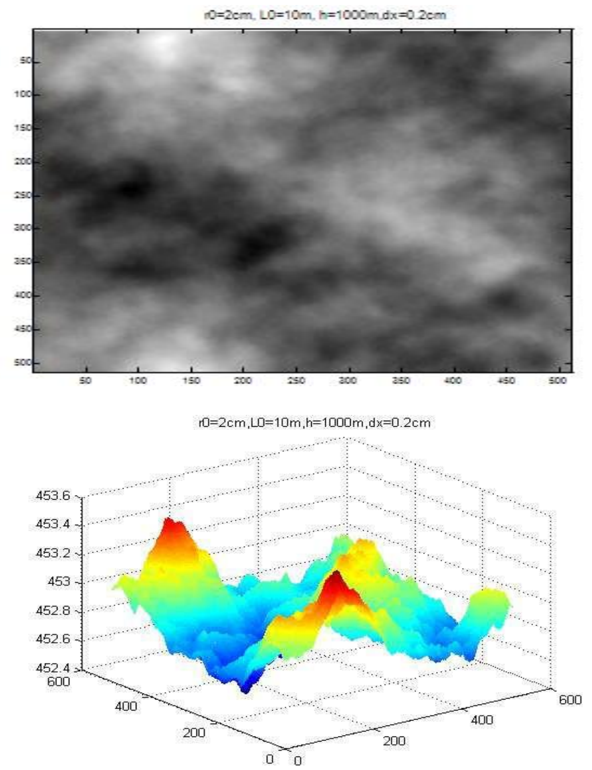

Figure 3: Size phase screen (512 512) pixels, 2D and 3D for different values of L_0

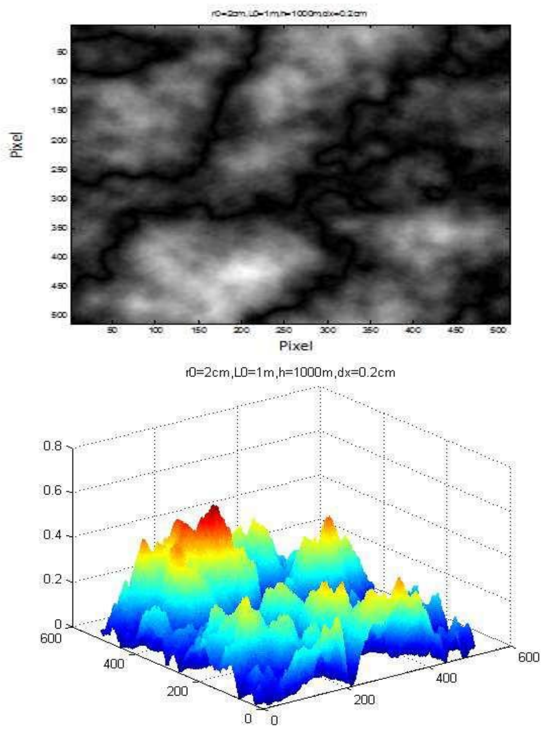

Figure 4: Size phase screen (512 512) pixels, 2D and 3D for different values of L_0

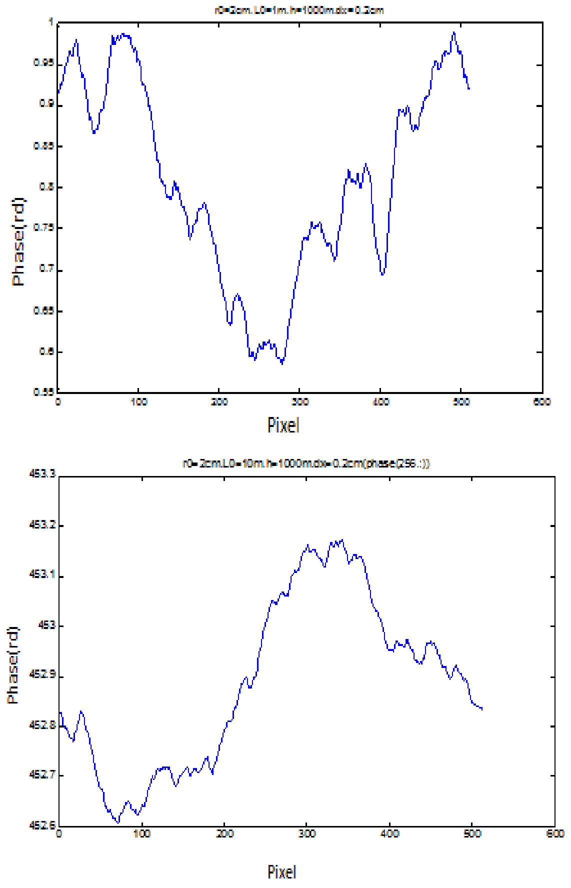

Figure 5: The influence of L_0 on the phase screen

IV. CONCLUSION

I presented the main effects that lead to the degradation of the images obtained using ground-based telescope such as the effect of the optical system and the effect of turbulence. I also presented the simulation of atmospheric turbulence where its temporal variation is modeled by approximating the frozen turbulence on several phase screens, knowing that a phase screen is at the origin of the distortion of the wave front, where this distortion function is the density spectral fluctuations of the phase, then I showed the method of Nakajima to simulate phase screens; this method is based on the procedure of the Fourier transform. The major result of this article focuses on Nakajima method; it is most often used to simulate the phase damage in a given direction to form isoplanar or anisoplanar images. So I simulated the influence of atmospheric turbulence parameters on phase screen, such as the Fried parameter and the external scale. It is known that the phase screen is subject to significant variation in the case where the parameter Fried increases, however if the external scale increases, the variation of the phase screen is very low.

V. REFERENCES

[1] M. Lemaitre, "Etude de la turbulence atmosphérique en vision horizontale lointaine et restauration de séqueances dégradées dans le visible et l'infrarouge" these doctorat(2007).

[2] P. Mège, "interférométrie avce des guides d'ondes optiques", Théorie et applications. These de doctorat (2002).

[3] J. Borgnino, "Estimation of the Spatial Coherence Outer Scale elevant to Long Baseline Interferometry and Imaging in Optical Astronomy," Applied Optics 29, 1863_1865, 1990.

[4] THIÉBAUT, Éric, DÉNIS, Loïc, SOULEZ, Ferréol, et al. Spatially variant PSF modeling and image deblurring. In: SPIE Astronomical Telescopes+ Instrumentation. International Society for Optics and Photonics, 2016. p. 99097N-99097N-10.

[5] J. Maire, "Modélisation des effets optiques de la turbulence atmosphérique pour les grands télescopes et les observations à Haute Résolution Angulaire," PhD Thesis, Université de Nice-Sophia Antipolis, 2007.

[6] [6] J. Borgnino, "Etude de la dégradation des images astronomiques diurnes par analyse statistique des fluctuations d'angles d'arrivée", thèse de doctorat (1978).

[7] T. Sadibekova,"contribution à l'etude des sites astronomique par modélisation et expérimentation in situ : Application aux sites de la silla et du dome C pour les telescopes geants du futur» Université de Nice-Sophia Antipolis, (2007).

[8] A.Ziad "estimation des échelles limites de cohérence spatiale des fronts d'onde et optimisation des observations à haute résolution angulaire en astronomie", thèse de doctorat (octobre 1993).

[9] F. Roddier, "Effects of Atmospheric Turbulence in Optical Astronomy," Progress in Optics 19, E. Wolf Ed, 281_376, 1981.

[10] C. Petit "Etude de la commande optimale en OA et OAMC, validation numérique et expérimentale",these de doctorat Paris(2006).

[11] W. Dali Ali, "Etude de la dégradation par la turbulence atmosphérique des images du bord

solaire : estimation du paramètre de Fried," Mémoire de Magister, USTHB, 2007.
[12] B. Le Roux, "commande optimale en optique adaptative classique et multiconjuguée", these de doctorat Nice (2003).
[13] J. Borgnino, "Estimation of the Spatial Coherence Outer Scale Relevant to Long Baseline Interferometry and Imaging in Optical Astronomy," Applied Optics 29, 1863_1865, 1990.
[14] J. Borgnino, F. Martin & A. Ziad, "E_ect of a Finite Spatial-Coherence Outer Scale on the Covariances of Angle-of-Arrival Fluctuations," Optics Communications 91, 267_269, 1992.
[15] R. Avila., A.Ziad., J.Borgnino., A.Agabi . and A.Tokovinin ”Theoretical spatiotemporal analysis of angle-of-arrival induced by atmospheric turbulence as observed with the grating scale monitor experiment “, J. Opt. Am. A / Vol. 14,N11, (1997).
[16] A. Berdja, "Effets de la Turbulence Atmosphérique lors de l’observation du soleil à Haute Résolution Angulaire", thèse de doctorat(2007).
[17] CHEN, Xiaoting, LU, Changhua, LIU, Wenqing, et al. A “New Algorithm for Calculating the Daytime Visibility Based on the Color Digital Camera”, IJCSI International Journal of Computer Science Issues, Vol. 10, Issue 1, No 1, January 2013.