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Imaging with Hexagonal Segmented Mirror

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ABSTRACT
Different hexagons configuration aperture models of the optical telescope mirror is carefully considered in this study. The point spread function and the modulation transfer function of a reference star using different hexagons configuration are computed and the quantitative assessment for the results are described. It has been shown that the height of the point spread function decreases rapidly when the area of the circular aperture of the optical telescope is 18 times the area of the individual hexagon to be arrange to fill this aperture. No significant change has been noticed as the area of the this aperture exceeds 121 times the area of the individual hexagon.

التراتيب السداسية لمرآة التلسكوب البصري

الخلاصة
التراتيب السداسية المختلفة لمرآة التلسكوب البصري اخذت بعين الاعتبار في هذه الدراسة. ان دالة الانتشار النقطية ودالة التضمين لمصدر نقطي باستخدام تراتيب سداسية مختلفة قد حسبت وان التقييم الكمي لهذه النتائج تم عرضه.
اظهرت النتائج ان ارتفاع دالة الانتشار النقطية يقل بصورة سريعة جدا عندما تكون مساحة فتحة التلسكوب البصري اكبر بحوالي 11.3 مرة من مساحة الشكل السداسي الاحادي الذي سوف يشكل هذه الفتحة. لم تظهر النتائج اي تغيرات عندما تكون مساحة هذة الفتحة تتجاوز 85 مرة مساحة الشكل السداسي المراد ترتيبه في هذه الفتحة.

INTRODUCTION
The large aperture mirror array optical telescope is designed to observe a selected area of the night sky of the interest. This will enhance the sensitivity to about 1000 and the angular resolution to about 7.5 times the sensitivity and the angular resolution of the largest optical telescope available these days. The observations with this kind of promising optical telescope will able us to study the formation and evaluation of Galaxies at more than 98% of the age of the universe [1]. This large optical mirror needs to be designed in a certain configuration because the diffraction limited angular resolution is strongly depends of the type and the shape of this configuration. Hexagons are really the best shape

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that used heavily in the configuration because the gaps between hexagons in the configuration process would be the optimal one [2].

The hexagonal aperture is a modification of a circular aperture. It is desirable for multiple mirror system. The segmented mirror telescope (SMT) was built to develop the construction of optical space telescopes. The difficult task is to construct a large primary mirror of sufficient quality. The smaller segmented mirror could then be combined to form the large mirror. Many work have been done concerning large mirror segmentation and hexagons configurations [2-8]. The objective of this paper is to examine the effect of varying the number of hexagons that to be fill the telescope aperture on the quality of optical telescope.

METHEMATICAL FORMULATIONS

The wave front of a distant star that reaching the optical telescope is a plane wave in the abscense of atmospheric turbulence. Now if the telescope is ideal and free of any optical aberration, then the wave front at the exit pupil is a circular plane wave.

The optical transfer function of an incoherent optical system is given by [9]

$$T(u, v) = \frac{\int\int_{-\infty}^{+\infty} H(x,y)\, H^{\bullet}(x-\bar{\lambda}fu, y-\lambda fv)\, dxdy}{\int\int_{-\infty}^{+\infty} \left|H(x,y)\right|^2 dxdy} \qquad ..(1)$$

where $H(x, y)$ is the pupil function and f is the focal length of the lens, λ is a wavelength and u, v are spatial frequency variables. T(u,v) is a complex function defined in terms of the real and imaginary parts or amplitude and Fourier phase. The modulation transfer function (MTF) is defined as $|T(u,v)|$ and the point spread function (psf) could be defined as the absolute of the inverse Fourier transform of eq. (1). psf is always nonnegative and real.

The quality of the psf is strongly depends on the shape and the configuration of the optical telescope segmented mirror. The quality of psf and MTF are determined by the following equations:

$$I_{max} = \max \left[psf\ (x, y)\right] \qquad .. (2)$$

$$AF = \sum_{u=1}^{M} \sum_{v=1}^{N} \frac{MTF(u, v)}{MTF(0,0)} \qquad .. (3)$$

where $MTF(0,0)$ is the maximum value of MTF and it is located in the middle of an array.

COMPUTER SIMULATIONS

Two dimensional computer simulations are carried out to investigate the quality of imaging with segmented mirror. The size of the array is taken to be 256 by 256 pixels. The mirror is then segmented into different number of hexagons (N_h) that occupied a unit circle of diameter D=120 pixels. This value is taken to ensure that the diffraction limited cut off frequencies of the MTF to be approaching zeros inside this array. The results of these configurations are shown in Fig.(1). The psf and MTF corresponding to Fig.(1) are computed and the results are demonstrated in Fig.(2) and Fig(3) consequently. It is clear that as the number of hexagons increases, sharp spike will be built up on the surface of MTF and the central spike becomes larger. Fig.(4) show the normalized results of the maximum value of the psf and the average frequency components of MTF by implementing equations (2) and (3). The legend on Fig.(4) shows clearly that the maximum value of Imax is $9.96x10^7$ and the maximum value of AF is 0.1523. It should be pointed out here that Imax and AF values that obtained from using circular aperture of a unity magnitude with D=120 pixels are $1.2059x10^8$ and 0.1695 respectively. By comparing these values with the values that displayed in figure(4) , we pointed here that a trade off between the selection of the number of hexagons that used in the configuration and the values that shown in figure(4) is needed. Finally, MATLAB 2010a is used for computing the above equations and presenting the results of this paper.

CONCLUSIONS

The results of this work demonstrate the followings:

1-As N_h increases, the psf losing its fine details and spots become to be more pronounced (see Fig.2).

2-The height of the central spike that demonstrated on the 2-D surface plot of MTF (see Fig.3) is attributed to the spacing area between hexagons.

3- The height of the psf decreases rapidly up to the area of telescope aperture is approximately 18 times the area of the individual hexagon. The number of hexagons that fill the telescope aperture in this case is 13 hexagons while there is no significant change when the area of this aperture exceeds 121 times the area of the individual hexagon.

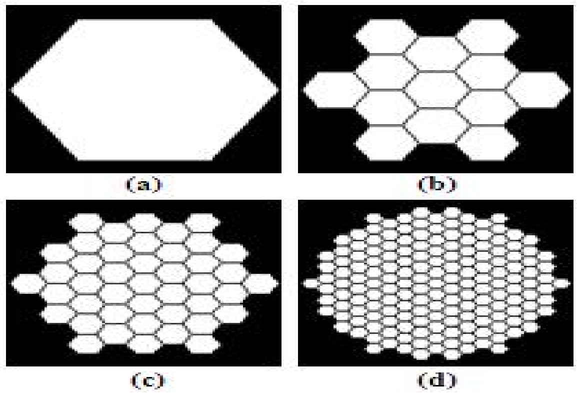


Figure (1) Segmented aperture: N_h= 1. b- N_h= 13. c- N_h= 43.d- N_h= 169.

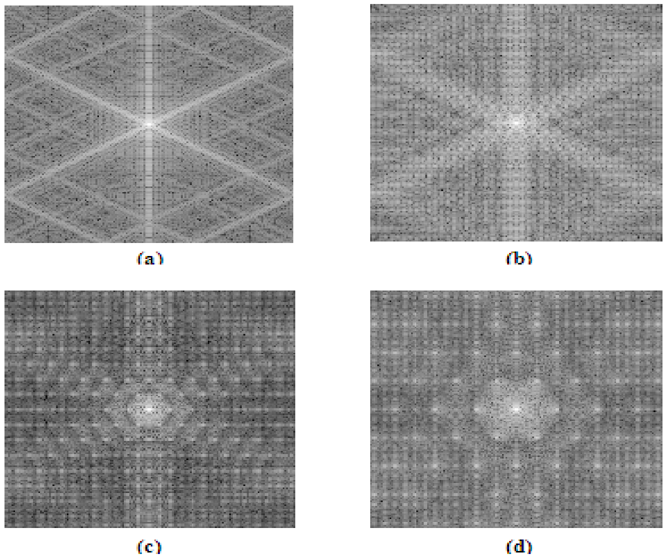
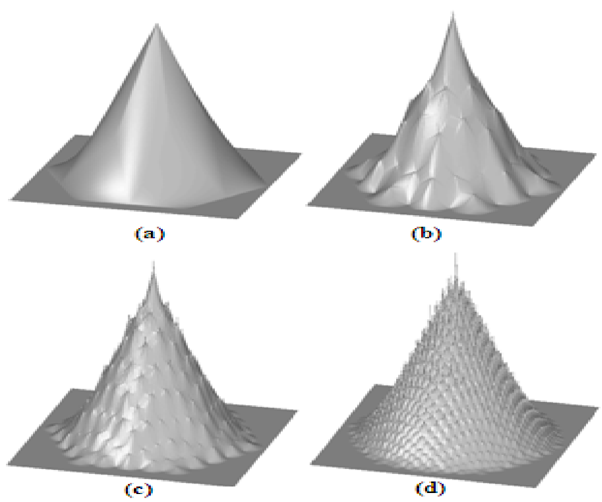


Figure (2) log(1+psf) corresponding to Figure (1) a- N_h= 1. b- N_h=13. c- N_h=43. d- N_h=169.



Figure(3) Surface plot of MTF corresponding to Figure (1): a- N_h= 1. b- N_h=13. c- N_h=43. d- N_h=169.

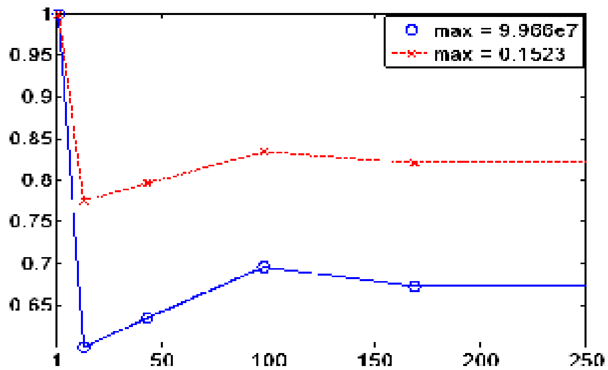


Figure (4) Normalized Imax (dotted line) and AF (solid line) as a function of number of hexagons.

REFERENCES

[1] Hickson, P. and K. Lanzatta2001."Large-Aperture mirror array", Internal report, Document LAMA-011210-1.

[2] Gardner, J. P. J. C. Mather, M. C. Renedoyon, M. A. Greenhouse, H. B. Hammel and others,2006."Future Instruments and Facilities". The James Webb space telescope, Space Science Reviews, **Vol. 123**, No. 4, pp. 485-606.

[3] Kuhn, J. R. G. Moretto, R. Racine, F. Roddier and R. Coulter,2001."Concepts for a large-perture, high dynamic range telescope". Astronomical society of the pacific, **Vol. 113,** ,pp. 1486-1510.

[4]Renaud Bastaits, 2010."Extremely large segmented mirror:Dynamics, control and scale effects". Ph.D thesis, Universite Libre de Bruxelles.

[5] Christopher, N. and F. Ralf, 2007 "Keck telescope wavefront errors: Implications for NGAO", Keck adaptive optics note 482, Keck Observatory.

[6] Canales,V., F. J. E. Oti, P. J. Valle, M. P. Cagigal, and N. Devaney, 2006 "Reduction of the diffraction pattern in segmented aperture, Optical Engineering", **Vol. 45**.

[7] Williams, E. C. B. Curtis, M. Terry, N. Jerry, P. Benjamin, R. J. Ponchione, P. Eric, S. Shahriav, S. Mark, S. Vince, S. Larry, and T. Alan, 2008 "Advancement of the segment support system for the thirty meter telescope primary mirror", SPIE Proceedings Marseille. [8]G. A. Chanan, and M. Troy, 1999 "Strehl ratio and modulation transfer function for segmented mirror telescopes as functions of segment phase error", Applied Optics **Vol. 38**, pp. 6642-6647,.

[9] Goodman, J. W. 2000 "Statistical optics", a Wiley-Interscience publication.