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Chinese Astronomy and Astrophysics 41 (2017) 588–600

CHINESE
ASTRONOMY
AND ASTROPHYSICS

A Study on the Application of Normalized Point Source Sensitivity in Wide Field Optical Spectrometer of the Thirty Meter Telescope† ⋆

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Abstract The image evaluation of an optical system is the core of optical design. Based on the analysis and comparison of the PSSN (Normalized Point Source Sensitivity) proposed in the image evaluation of the TMT (Thirty Meter Telescope) and the common image evaluation methods, the application of PSSN in the TMT WFOS (Wide Field Optical Spectrometer) is studied. It includes an approximate simulation of the atmospheric seeing, the effect of the displacement of M3 in the TMT on the PSSN of the system, the effect of the displacement of collimating mirror in the WFOS on the PSSN of the system, the relations between the PSSN and the zenith angle under different conditions of atmospheric turbulence, and the relation between the PSSN and the wavefront aberration. The results show that the PSSN is effective for the image evaluation of the TMT under a limited atmospheric seeing.

Key words telescopes—image evaluation—methods: numerical

1. INTRODUCTION

All the methods of image evaluation can be classified as the method based on geometrical optics and the method based on diffraction theory. The spot diagram is resulted by the

† Supported by National Natural Science Foundation (11273038) and Project of Strategically Guiding Science and Technology of Chinese Academy of Sciences (XDB09040104)

Received 2016–01–07; revised version 2016–03–05

⋆ A translation of *Acta Astron. Sin.* Vol. 57, No. 5, pp. 585–596, 2016

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doi:10.1016/j.chinastron.2017.11.009

aberration of an optical system when multiple light rays emerging from a point source are imaged by the optical system, because of the existence of aberration they are no longer concentrated in one point on the imaging plane, but exhibit a spread pattern. It is intuitive and easy to calculate, but when it is used for image evaluation, in many cases it is not consistent with the practice. The resolution of an optical system indicates the smallest distance between two objective points (or imaging points) that can be resolved by the optical system. It reflects the capability of the optical system to discriminate the object's fine structures. The resolution and the spot diagram method take account of mainly the effect of aberration on the image quality, they are suitable for a large-aberration system, but unsuitable for a small-aberration system[1].

The Rayleigh criterion says that when the maximum wavefront error between the practical wave surface and the reference spherical surface does not exceed $\lambda/4$, this wave surface is perfect. The Rayleigh criterion is a kind of relatively strict image evaluation method, convenient for practical applications, and suitable for small-aberration systems. But the Rayleigh criterion is not rigorous enough, it takes only the maximum value of wavefront aberration into consideration, does not take account of the proportion occupied by the defective part of the wave surface with respect to the whole area. SD indicates the ratio between the central brightness of the diffraction spot when the optical system has aberration and that when the optical system has no aberration. The Stoner rule stipulates that when SD ≥ 0.8, the image quality of the optical system is considered to be perfect. The Stoner rule is a criterion to evaluate the high-quality image, suitable for a small-aberration optical system, but because of its complicated calculation, it is rarely used for image evaluation[2].

When an object is imaged by an optical system, the transfer result is invariant for the spatial frequency of the object, but the frequency in the image space is shifted. The optical transfer function takes the spatial frequency as the variable, it is the function characterizing the relative variations of modulation factor and transverse phase shift in the imaging process. The optical transfer function suits both the large-aberration system and small-aberration system, but it takes account of only the ability to transfer the different frequency components, can not evaluate the overall performance of the imaging system[1].

The normalized point source sensitivity (PSSN) proposed especially for the seeing-limited TMT (Thirty Meter Telescope) reflects the scientific efficiency of the telescope, and describes the energy loss of the telescope during the observation[3]. The most important feature of PSSN is its multiplicativity, namely the PSSN of the system in which multiple errors coexist is equal to the product of the PSSNs when the every error exists individually in the system[4].