Noise Model for Imaging Simulator Software

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1 Introduction

The noise model consists of formulae for the variance of the squared visibility and bispectrum. These formulae are given in the memo "SNR squared visibility and closure phase: summary of equations in use" by Tatulli.

That memo should be read in conjunction with this note, which lists parameter values appropriate for MROI. These parameter values should be substituted into the expressions given by Tatulli.

1.1 Assumptions

The expressions given by Tatulli are not specific to any particular beam combiner design, but are based on the following assumptions:

- Photon and detector noise
- No background noise (e.g. from thermal radiation)
- No atmospheric noise
- The fringe signal is debiased *a posteriori*
- No calibration error (could add this, e.g. 2% in V^2)

2 Bispectrum noise

The memo by Tatulli gives the variance of the closure phase but not that of the triple (bispectrum) amplitude $T_{ijk} = |Q_{ijk}|$. Photon and detector noise give rise to a circular noise cloud in the complex plane, hence:

$$\sigma^2\{T_{ijk}\} = T_{ijk}^2 \sigma^2\{\phi_{ijk}\}, \tag{1}$$

with $\sigma^2\{\phi_{ijk}\}$ in radians.

3 Parameters

The expressions given by Tatulli are in terms of the overall squared visibility $|V^2|$ and number of photons detected per coherent integration $\overline{N}$. The squared visibility can be calculated as follows:

$$|V^2| = |\,(V_{\rm obj} V_{\rm inst})\,|^2, \tag{2}$$

where $V_{\rm obj}$ is the complex visibility calculated from the object model (pixellated image), and $V_{\rm inst}$ is the instrumental visibility degradation (see Table **??**).

The photon count per coherent integration is given by:

$$\overline{N} = F_0 10^{-0.4 m_\lambda} t_{\rm int} N_{\rm tel} \pi R^2 \Delta\lambda T S, \tag{3}$$

where m_λ is the apparent magnitude of the object at the observation wavelength, and the other symbols are defined in Table **??**.

Table 1: Parameter values to use.

Param	Units	Meaning	Value
N_{pix}		No. of pixels to sample fringes	128
N_{tel}		No. of telescopes combined	Max. 4
σ	e	Detector readout noise	5e
V_{inst}		Instrumental visibility	0.67
R	m	Telescope aperture radius	0.7m
T		Transmission (including detector QE)	0.23
F_0	photon m^{-2} s^{-1} μm^{-1}	Photon flux from 0-mag star	Table **??**
S		Strehl ratio	Table **??**
t_{int}	s	Coherent integration time	Table **??**

Table 2: Values of wavelength-dependent parameters. These may be assumed constant within each waveband.

Band name	Wavelength range	Flux / photon m^{-2} s^{-1} μm^{-1}	Typical Strehl S	Typical t_{int} / s
J	1.2–1.4	2.02×10^{10}	0.84	2.2×10^{-2}
H	1.5–1.8	9.56×10^{9}	0.95	2.9×10^{-2}
K	2.0–2.4	4.53×10^{9}	0.99	4.1×10^{-2}