To: Rick McGonegal

From: Mike Burns

Date: August 23,1993

Subject: SNR vs. Sample Rate for Tip-Tilt Using an Off-Axis Guide Star

Reference

[1] Burns, Mike "Restriction Imposed on Tip-tilt for an Off-Axis Guide Star" Technical Note Gemini 8-M Telescopes Project, August 1993.

Introduction

It is desired to use a bright guide star to attempt to decorrellate atmospheric noise in a faint science object. A larger field of view is more likely to have a brighter guide star which will in turn have a correspondingly better SNR (signal/noise ratio). Slower sampling will collect more photons, which will also improve SNR. This note shows the relationship between sampling rate and SNR for three different effective fields of view.

Summary

The SNR for a 3.5 arcminute field sampled at 200Hz is nearly 10.

Calculations

The science field is known to be 3.5 arcminutes in diameter and the guide field is 8.0 arcminutes in diameter. The area of the annulus obtained by removing the science field and leaving the guide field is equivalent to a circle of diameter 7.2 arcminutes (= sqrt(8.0^2 - 3.5^2)). From reference [1] it appears that the maximum diameter at which the atmospheric tip-tilt is reduced by a factor of two is 2.4 arcminutes. These three diameters are considered below and are marked on the attached figure.

Given a diameter D_90 in arcminutes, if it is desired that there be a 90% chance of finding a sufficiently bright star, then the number of stars required per square arcminute is:

$N = 2*(1.211/D_{90})^2$.
$N(2.4) = 0.52$
$N(3.5) = 0.24$
$N(7.2) = 0.057$

Empirically it is known that the number of stars per square arcminute near the North Galactic Pole is related to the visual magnitude V such that

V = (3.68 + log10(N)) / 0.158 ,
V(2.4) = 21.5
V(3.5) = 19.4
V(7.2) = 15.4

and flux (electrons/ sec) is
flux = 1.1e12 / (10 ^ (V/2.5)).
flux(2.4) = 2.8e3
flux(3.5) = 1.9e4
flux(7.2) = 7.6e5

So from a given diameter D_90, we can compute the flux as above.

SNR is related to flux and sampling rate (fs) by

SNR = sqrt (flux/ fs).
SNR(D_99=2.4, fs=200Hz) = 3.7
SNR(D_99=3.5, fs=200Hz) = 9.7
SNR(D_99=7.2, fs=200Hz) = 61.6

The sample rate of 200Hz is chosen arbitrarily to show the example SNR's above for the various diameters.

The attached figure shows SNR plotted vs. sampling rate for the three effective diameters, 2.4, 3.5 and 7.2 arcminutes, representing a minimum diameter, the science field, and the annulus surrounding the science field.