Estimating Observing Time for Speckle Programs

The speckle imaging observing protocol is to observe science targets in one or more image sets. Adjacent in time and location to each science target, we take an observation of a bright, single star to serve as a point source standard to quantify the effects of focus, differential refraction and seeing. The point sources are observed with one image set in each filter used for the science target.

To prepare an observing proposal, you need to estimate the time to carry out your observations. This will depend on:

T^{acq}, the time to acquire each target,
N_{targ}, the number of science targets,
N_{fpairs}, the number of filter pairs observed per target,
N_{sets}, the number of image sets observed per target/filter pair and
N_{ps}, the number of point source standard observations.

Note that a filter pair consists of a choice of one blue and one red filter. With NESSI, you have a choice between the 467nm or 562nm filter to pair alongside the 716nm or 832nm filter. If you want observations of an object in both the 467nm and 562nm filters, it will require 2 filter pairs (so at least 2 exposures).

The time required to slew to and acquire an object depends on its angular separation from the previous observation. To acquire and start data-taking on a new target with a long slew takes 5 minutes. For closely-spaced objects this is 3 minutes. Taking an image set requires 1 minute. The number of point source standard observations needed depends on how widely separated your science targets are. For that reason, there are two scenarios to consider when estimating your total observing time:

If you have a group of 4 or more science targets closely spaced on the sky (within $\sim$ 15 degrees in e.g., a star cluster or K2 or Kepler field), your targets may share a common point source observation, which should be re-visited for every half hour you spend observing science targets.
Time (in minutes) spent on science targets is the sum of time spent in acquisition and integration,

$$T_{sci} = T_{sci}^{acq} + T_{sci}^{int}.$$

Allow 5 minutes to acquire the first science target and 3 minutes to acquire the additional science targets nearby:

$$T_{sci}^{acq} = 5 + 3 \times (N_{targ} - 1).$$

To find the time spent in science target integration, allow 1 minute per image set per filter pair for each target:

$$T_{sci}^{int} = N_{targ} \times N_{sets} \times N_{fpairs}.$$

(note that T_{sci}^{int} could be calculated separately for different targets if they require different N_{sets}, etc.)

To determine the number of point source observations needed, N_{ps}, plan on one point source visit for every half hour of science time:

$$N_{ps} = 1 + int(T_{sci}/30) \text{ (ie. integer math).}$$

Time (in minutes) spent on point sources is the time to acquire them and time spent integrating on them,

$$T_{ps} = T_{ps}^{acq} + T_{ps}^{int},$$

where the nearby point source takes 3 minutes to acquire,

$$T_{ps}^{acq} = 3 \times N_{ps},$$

and you must observe one image set for each filter pair:

$T_{ps}^{int} = N_{ps} \times N_{fpairs}$.

Your total observing time will be the sum of time on science targets and point sources:

$T_{total} = T_{sci} + T_{ps}$.

Example: Suppose you have 10 science stars in one cluster and you want to observe each one through the 4 speckle filters (ie. 2 filter pairs). You plan to observe the 3 brightest stars using 3 image sets in each filter and 7 fainter stars using 6 image sets in each filter.

$T_{sci}^{acq} = 5 + 3 \times 9 = 32\ minutes$

$T_{sci}^{int} = T_{sci}^{int}(3\ brightest\ stars) + T_{sci}^{int}(7\ fainter\ stars)$

$= (3 \times 3 \times 2) + (7 \times 6 \times 2) = 102\ minutes$

$T_{sci} = 32 + 102 = 134\ minutes$

$N_{ps} = 1 + int(134/30) = 5$

$T_{ps}^{acq} = 3 \times 5 = 15\ minutes$

$T_{ps}^{int} = 5 \times 2 = 10\ minutes$

$T_{ps} = 15 + 10 = 25\ minutes$

$T_{total} = T_{sci} + T_{ps} = 134 + 25 = 159\ minutes$

If you have fewer than 4 science targets or your targets are widely separated on the sky, plan on a point source observation for each of them. Then you have an equal number of science targets and point sources:

$$N_{ps} = N_{targ}$$

and total time spent acquiring all targets (science and point sources) depends on the number of science targets (8 min. for each):

$$T^{acq} = N_{targ} \times 5 + N_{ps} \times 3 = N_{targ} \times 8 \ minutes.$$

The time integrating on all the science targets is

$$T^{int}_{sci} = N_{targ} \times N_{sets} \times N_{fpairs}$$

and time spent integrating on point sources is

$$T^{int}_{ps} = N_{ps} \times N_{fpairs} = N_{targ} \times N_{fpairs}.$$

Your total observing time can then be written:

$$T_{total} = T^{acq} + T^{int}_{sci} + T^{int}_{ps} = N_{targ} \times (8 + (N_{sets} + 1) \times N_{fpairs})$$

(note that T^{int}_{sci} could be calculated separately for different targets if they require different N_{sets}, etc.)

Example: Suppose you have 10 science stars around the sky and you want to observe each through the 4 speckle filters (ie. 2 filter pairs). You plan to observe the 3 brightest stars using 3 image sets in each filter and 7 fainter stars using 6 image sets in each filter.

$$T_{total} = (3 \times (8 + (3+1) \times 2)) + (7 \times (8 + (6+1) \times 2)) = 48 + 154 = 202 \ minutes$$