Publications of the Astronomical Society of the Pacific, **113**:397–400, 2001 March

Using Adaptive Optics Systems on Large Telescopes: A Study of the Fraction of Observing Time Really Spent for Science

O. Marco, N. Ageorges, and M. Sterzik
European Southern Observatory, La Silla, 3.6 m Telescope Team; omarco@eso.org, nageorge@eso.org, msterzik@eso.org

Received 2000 October 16; accepted 2000 December 5

ABSTRACT. All large telescopes in the world are now equipped with adaptive optics systems. These systems are usually used for near-infrared imaging, spectroscopy, and/or coronography. Their efficiency in terms of spatial resolution improvement is now globally accepted. But no study has been made so far about the (in)efficiency of such systems in terms of telescope observing time, i.e., effective integration times used for scientific observations (shutter time). This is the aim of this paper.

For the very first time, adaptive optics observations, over 3 years, are studied in detail: the relative scientific shutter efficiency is found to be between 10% and 35%, significantly below the average for other infrared instrumentation, i.e., between 50% and 80%.

This study also shows that the use of adaptive optics observation preparation tools together with smart observing templates will dramatically increase the average shutter efficiency for many adaptive optics programs.

The observational experience of the users also influences the (in)efficiency: users with more experience in the operation of the system are in general more efficient in using the allocated observing time. Scheduling of service-mode observation programs should be preferred in the future.

1. INTRODUCTION

ADONIS (Beuzit et al. 1997), the ESO ADaptive Optics Near Infrared System, has been—in its current configuration—offered as common-user instrument on the 3.6 m telescope in La Silla (Chile) since 1997. A description of the instrument, the detector, and the observing modes as well as links to scientific results can be found on the Web at the ESO ADONIS instrument site.[1]

In order to understand the efficiency of adaptive optics (AO) observations in general, and of ADONIS in particular, we have analyzed the nights on which ADONIS was offered for regular programs approved by the ESO Observing Programmes Committee. For almost 90% of all nights we were able to retrieve backup data tapes and extract the output produced automatically from the ADOCAM (ADOnis CAMera) acquisition system, which logs continuously the status of the camera and the instrument/bench configuration (Lacombe et al. 1998). Our analysis comprises six ESO observing periods, i.e., from 1997 September until now (ESO periods 60–65), or 141 individual nights.

2. METHODOLOGY

Scientific shutter times (i.e., effective integration times used for scientific observations) are extracted from these log files by removing the times spent for calibration like flat fields and dark frames (sky frames have been considered as part of the science program). The number of individual readouts also are extracted in order to estimate the total detector readout time per night (taking into account the different readout times for the two infrared cameras SHARP and COMIC; ESO Adaptive Optics Group & Lacombe et al. 1995). The information from the nightly log files is then combined with reports by the astronomer using the REMEDY database. In this way we are able to take into account the time lost because of bad weather and/or technical problems. For each night, we relate these quantities to the available astronomical dark time (defined as the time between astronomical twilight), which sets the theoretical maximum efficiency for observations. Thus, the mean overhead is then defined as the residual time, which cannot be attributed to integration, readout, or downtime. This overhead, or idle time, typically consists of periods when no scientific data are recorded and stored to disk.

3. EFFICIENCY OF ADONIS

Table 1 summarizes our results for the entire data set and also for each ESO period. The sum of the relative values for the average shutter times, detector readout times, bad weather downtime, technical downtime, and mean overhead sometimes does not necessarily match 100%, as the bad weather and technical downtime hours are based on the subjective estimates of

---

[1] See the ESO ADONIS instrument site at http://www.ls.eso.org/lasilla/Telescopes/360cat/adonis.

TABLE 1

Results for the Entire Data Set and Each ESO Period

Parameter	All Data	Period 60	61	62	63	64	65
Total time (hr)	1260	151	167	222	265	216	239
Fraction of time:							
Shutter (%)	23	27	10	35	13	34	20
Readout (%)	5	3	7	4	5	4	8
Weather (%)	31	42	65	1	48	17	23
Technical (%)	4	12	3	3	3	2	2
Overhead (%)	41	27	24	57	34	46	48

Note.—The table presents, for each ESO period, total hours available and fraction of time corresponding to shutter, readout, bad weather, technical problem, and overhead.

TABLE 2

Complementary Information to Table 1

Parameter	All Data	Period 60	61	62	63	64	65
Mean length (hr)	8.9	7.5	9.8	7.7	10.6	7.7	10.8
Shutter (hr)	2.1	2.0	1.0	2.7	1.4	2.7	2.2
$\sigma_{\rm shut}$ (hr)	1.8	2.3	1.2	1.5	1.9	1.7	1.9
Overhead (hr)	3.6	2.2	2.4	4.4	3.6	3.5	5.2
$\sigma_{\rm over}$ (hr)	2.7	2.0	2.9	1.6	3.4	2.1	3.0
Acquisitions $\rm hr^{-1}$	7.3	5.8	4.5	8.9	3.2	7.6	12.8
Overhead $\rm acquisition^{-1}$ (minutes)	3.3	2.7	3.2	3.8	6.5	3.6	2.2

Note.—The table presents absolute values for the mean length per night, mean total shutter (=integration) time per night and its standard deviation, mean total overhead per night and its standard deviation, average number of acquired images per hour, and mean overhead per acquisition.

the visiting astronomers and only approximate the true losses per night.

Whereas the values for observing time lost because of bad weather and technical problems are consistent with the general trend at the 3.6 m telescope over the past years, the relative scientific shutter efficiency of ADONIS between 10% and 35% is significantly below the average overhead. This is in contrast to other La Silla instrumentation where relative shutter efficiencies between 50% and 80% are normal (e.g., with EFOSC2 and CES operated at the 3.6 m telescope, or SUSI, EMMI, and SOFI operated at the New Technology Telescope). A seasonal modulation of the ADONIS efficiency is noted in the sense that winter periods tend to further decrease the shutter efficiency, whereas summer periods help to increase it.

4. ADONIS OVERHEADS: WHAT ARE THEY?

The detector readout times alone constitute an average fraction of about 5% of the total observing time. To minimize the readout noise, the ADONIS/SHARP camera uses the standard readout speed of NICMOS3 detectors, which is 800 ms per image. It is clear that short exposures decrease the efficiency. Figure 1 shows the normalized, cumulative distribution of the mean detector integration time (DIT) in seconds: over the periods studied, 60% of the observations had a DIT shorter than 5 s, increasing to 99% for a DIT shorter than 1 minute. Obviously, almost exclusively bright targets have been observed, a natural consequence of the limited sensitivity of the wavefront sensor ($m_v < 13.5$). The derived average value of 5% for the readout time can be reduced only by longer integrations—i.e., deeper imaging of faint objects—or spectroscopy.

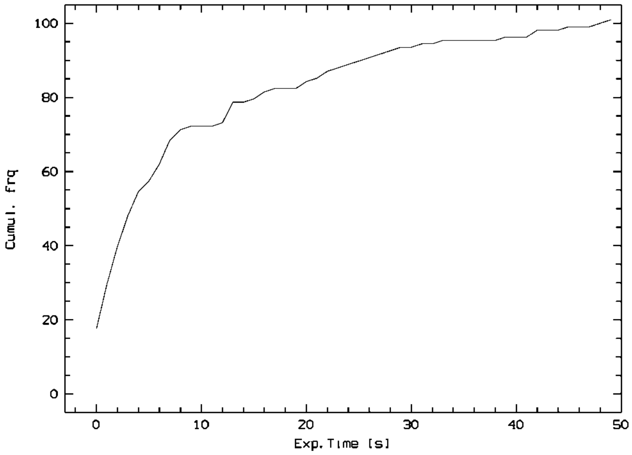

Fig. 1.—Cumulative distribution of mean DIT per night over ESO periods 60–65.

Complementary information can be extracted from Table 2, where we give absolute values for the mean length per night, the mean total shutter (=integration) time per night and its standard deviation, and the mean total overhead per night and its standard deviation. We have also calculated the average number of acquired images per hour and the mean overhead per acquisition. Beside the seasonal effect, we notice a remarkable spread in the nightly integration times which is of the same order as the integration time itself.

The overhead time has been calculated as the time not used for science integrations per observing night, i.e., the total number of hours offered per night minus all other times known (shutter, readout time, bad weather, and technical downtime). It also includes times for target acquisition (telescope positioning, guide star search, and, if applicable, target positioning behind a coronographic mask). In the specific case of AO observations, additional idle time results from image optimization or the difficulty in closing the AO loop.

Concerning the point-spread function (PSF) determination, we could not estimate the time used specifically for observations of PSF stars. Instead, the exposure time spent on PSF stars has been considered as "shutter time," but the time necessary to move the telescope, close the AO loop, etc., has been included is the overhead time. Indeed, the exposure time on PSF stars is usually very short because the user tries to choose bright stars (in the infrared).

In Figure 2 we plot the distribution of the overhead time (in

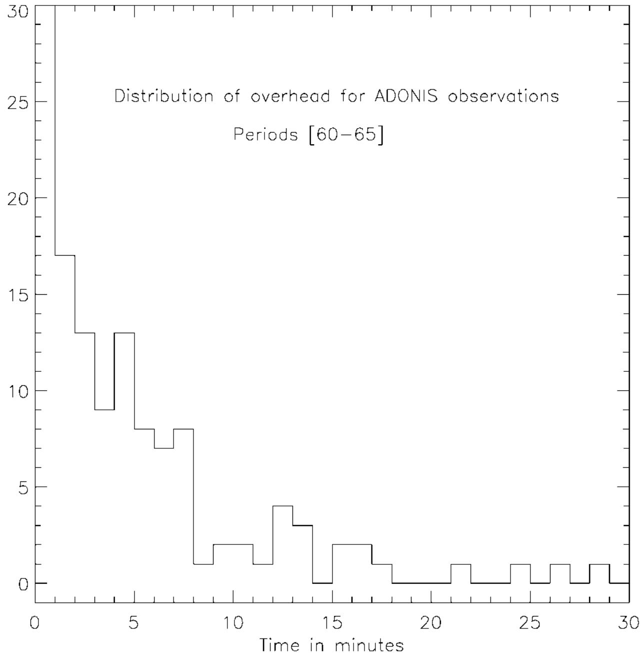

Fig. 2.—Distribution of the mean overhead per image acquisition in minutes for ESO periods 60–65.

minutes) per image acquisition for all our data. The distribution exhibits a narrow peak around 1 minute, corresponding most probably to the time to perform a new acquisition within the same instrumental configuration. Camera configuration changes, such as the filter, pixel scale, integration time, and sky mirror position (“on/off”), are typically done in the so-called pick-up (or real-time) mode, which lasts between 1 and 5 minutes. This then has to be followed by the editing of the FITS header of the acquisition file before data can be recorded (to input some key parameters such as the target name, the number of images to record). Typical AO overheads are present in the longer tail of the distribution. After pointing the telescope to a new target, it is necessary to center the target, or a nearby bright object, in the wave-front sensor field (6″) and to close the AO loop. The dispersion depends on whether or not a new AO optimization has been requested by the astronomer. The time required for the optimization varies as a function of different parameters, the most important being the atmospheric conditions and the brightness of the source. In fact, a good optimization on a faint source under poor weather conditions often requires more than one attempt. The typical timescale to perform an AO optimization is around 5 minutes. Some rather long periods of overhead can be explained when an ongoing integration was aborted. This happens, e.g., when the loop opens in the middle of an observing sequence. The acquisition files are lost and, from a statistical point of view, the shutter efficiency decreases. The use of the coronograph further slows down the acquisition process, as the centering of the mask on the source can take considerable time for nontrained astronomers.

In summary, we attribute the large spread in shutter and overhead times to the following facts:

1. The observing modes offered by ADONIS are vastly different, ranging from shutter mode and direct imaging observations with very short integration times (implying many target acquisitions and optimizations) to narrowband filter imaging, or even spectroscopic observations, which can be performed with high efficiency in long integrations.
2. We estimate an overhead of about 50%, i.e., typically 1–2 minutes for each scientific acquisition due to the fact that the ADONIS system and the ADOCAM control software are not integrated in the telescope control system (TCS) environment. The missing communication to the TCS causes overhead for: target positioning on the camera, tip-tilt adjustments, target centering behind a coronographic mask, and manual editing of FITS header information.
3. The observational experience of ADONIS users varies from beginners to expert level. The graphical user interface to control ADONIS and its associated cameras is complex, multilayered, and error prone. No standardized observing block preparation tools are available. Our experience as support astronomers at the ESO La Silla 3.6 m Telescope allows us to say that users with more experience in the operation of the ADONIS system are in general more efficient in using the allocated observing time. Expert-level users also prepare semiautomatic observing batches, which further decreases system overhead.
4. The observers often make the decision to actually start recording scientific integrations “on line” depending on the appearance of quick-look data in the real-time display. If the results in pick-up mode do not look promising, a new observation is started without saving the previous observation.

5. SUMMARY

In this contribution we have analyzed for the first time the efficiencies of ADONIS, a common-user AO instrument offered by ESO to the scientific community. ADONIS will be decommissioned in the foreseeable future, and our analysis based on 3 years’ statistics of scientific program will help to benchmark the shutter performance of the upcoming NAOS at the VLT. We strongly believe that the compulsory use of AO observation preparation tools such as Phase II Proposal Preparation (P2PP) together with smart observing templates will dramatically increase the average shutter efficiency for many AO programs. Scheduling of service-mode observation programs should be preferred in the future.

REFERENCES

Beuzit J. L., et al. 1997, Exp. Astron., 7, 285

ESO Adaptive Optics Group & Lacombe, F., Marco, O., Eisenhauer, F., & Hofmann, R. 1995, Messenger, 82, 16

Lacombe F., et al. 1998, PASP, 110, 1087