Remote Observing and Experience at ESO[1]

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1. History

Remote observing has been widely used in radio astronomy for the last decade. However, in the optical and infrared domain very few observatories have been successful in supporting it. One reason for this difference is that optical/infrared telescopes are more demanding in the sense of object acquisition and amount of science data produced. Another reason could be that optical astronomers have less trust in the performance of the telescope and instruments.

In the early 1980's a number of observatories started experimenting in remote observing (Raffi and Tarenghi, 1984, Longair et al., 1986, Raffi and Ziebell, 1986). Most of these early attempts failed, mainly because the technology was not yet matured. The communication links were not reliable and the data transmission rates were too low. It also became evident that it was very difficult to operate a telescope originally designed for local control in remote mode.

In the late eighties the situation became more favourable. First, there was a general improvement in communication infrastructure: cheaper, more reliable and faster, not to forget the development of Internet and, more recently, of the World-Wide Web. Second, a new generation of 3–4-m class telescopes were designed and went into operation. For some of these, remote observing had been foreseen already during the design phase (Loewenstein and York, 1986, Raffi et al., 1990).

Remote observing comes in many different modes, starting (or ending) at fully automatic telescopes. In 1992 a workshop dedicated to remote observing was held in Tucson (eds. Emerson and Clowes, 1993), where many of the available forms were extensively discussed. We will first summarise the terminology adopted at this conference for the various remote-observing modes, before describing the present situation at ESO.

2. Definitions

- *Robotic Telescopes* – A telescope and instrument which is programmed beforehand and needs little or no attention during the night. An entire nights observing programme may be downloaded during the day and the scientific data uploaded during the observation or later.
- *Remote Engineering* – A remote engineer performs engineering activities, e.g. installations, diagnostics, trouble-shooting, on local equipment. Although this is not an observing mode it should be included in the context, because if remote engineering is available, remote observing may come for free. Remote engineering can be very effective, especially since often engineers need to come to the telescope for relatively minor tasks and the travel distance can be significant.
- *Service Observing* – An astronomer fully specifies the objects to be observed and the instrument configuration beforehand, and the actual observation is carried out by the observatory staff. The astronomer is awarded observational data rather than telescope time.
- *Passive Remote Observing* – A remote observer monitors an observation carried out at a telescope by a collaborator or service observer. The remote observer has access to the data obtained and, optionally, observation parameters, and interacts with the local observer via voice, "talk", or e-mail. This is also called Eavesdropping. It is probably fairly common for the larger telescopes but observatories tend not to keep track of this.
- *Active Remote Observing* – A remote observer interactively controls an instrument and, optionally, a telescope at an observatory. In most cases a local telescope operator is required for safety reasons and sometimes to operate some telescope and auxiliary equipment. This is also called *Remote Control*.

Combinations of these observing modes are of course possible, and may in fact give additional advantages.

Robotic telescopes are by far the most popular of these options. They are typically small telescopes (50 cm). There are two important uses: the first is for long-term monitoring programmes (an example is the network of small telescopes looking for solar oscillations) and the second is for educational purposes. Some universities now have a small robotic telescope were astronomy students can send in requests electronically for short observations: this is especially useful for astronomy classes with many students in poor astronomical sites. One could also see automatic seeing monitors or small telescopes for measuring extinction coefficients as robotic telescopes.

At the other extreme, *active remote observing* is rare. The only large telescope for which this mode is the norm is the 3.5-m on Apache Point Observatory (APO), which is run by a consortium of US universities. This telescope is operated for 80% of the time available for scientific observations in remote control. Typically, a night will be split between several projects, and each astronomer can carry out the observations from his or her campus. ESO has two telescopes which can be operated in remote control: the 1.4-m CAT which is used for high-resolution spectroscopy mainly of bright stars, and the 3.5-m NTT.

3. Pros and Cons

The motivation for remote observing has been debated for some time in the literature, and a high level of agreement on the main arguments has been ob-

TABLE 1. WEIGHING THE PROS AND CONS OF REMOTE OBSERVING.

Proven Advantages	Likely Advantages	Likely Disadvantages	Proven Disadvantages
Flexibility	More than one participating astronomer	More difficult to concentrate on observing	Expensive - personnel - comms.
Shorter observing programs	May save costs in some cases	Not as efficient as classical	
Convenient for astronomer			

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tained (e.g. Emerson and Clowes, 1993). These arguments are summarised in Table 1 and briefly discussed below.

The main arguments in favour of remote observing are all related to the fact that the astronomer does not need to travel to the observatory. This is a strong argument if the observatory is in an inaccessible place, the most extreme example being the planned observatory on the Antarctic Plateau for which remote observing is envisaged (Burton, 1995). It also allows for the observing schedule to be made at short notice (e.g. the VLA). However, flexible and queue scheduling is not recommended in active remote control and/or eavesdropping: for the astronomer to be directly involved, the time of the observations needs to be known in advance. Instead it is possible to schedule shorter observing programmes, in units of hours instead of nights. Monitoring programmes also become easier to schedule without an astronomer at the observatory having to be involved. The elimination of long travel times and acclimatisation results in savings of astronomer's time – an important point for researchers at universities who may have teaching duties.

Remote observing very often allows more than one astronomer to take part in the observations. The impression at ESO is that, for the large telescopes, astronomers prefer to come with more than one person: while one person does the observing, the other concentrates on the on-line data analysis. For remote control, financial support for an extra observer is easier to arrange. The experience at ESO (NTT) is that in almost all cases, the home institute pays for a second observer in addition to the one paid for by ESO, in the case of remote control. This may increase the efficiency of the observations, but may also be of importance from an educational point of view. In addition, for the 1.4-m CAT telescope we also attract some Eastern European astronomers who could possibly not afford to travel to Chile. For them remote observing can save costs, but for the observatory this will in general not be true unless the required communication links are free, or very cheap, and little additional support is required.

Cost is the main argument against remote observing. In order not to degrade the scientific efficiency, the remote observer must get the same support as the local observer. This means that often the support personnel have to be duplicated. Sufficient bandwidth is also required in order not to have idle telescope time, and the cost of this bandwidth can very easily overtake the savings in travel cost. Table 2 shows typical cost estimates for the case of ESO[2], showing that remote observing only reduces total costs when it is used for a significant fraction of the observing proposals for at least two telescopes. A second argument against remote observing is, that, due to limitations in bandwidth, there is a time delay before the observer sees the data coming from the instrument. (This problem is not unique to remote observing but is experienced by everyone observing with CCDs.) The experience at ESO is that this becomes a problem whenever the extra delay is a significant fraction of the average integration time per exposure. Finally, if the observations are done from one's own office, the distractions due to the normal office activity may easily cause a loss of efficiency.

4. Requirements and Techniques

The main requirement for all modes of remote observing is a fast data transfer from the observatory to the remote site. Data files produced by modern instruments are large (a typical CCD frame is 2 to 8 Mbytes), and they should ideally be transferred in no more than a few minutes. To achieve this, a fairly high bandwidth is required, although modern data compression algorithms can improve the transfer rate. Compression based on the H-wavelet transform have been successfully applied at a number of observatories. In comparison, the data rates required to operate the telescope are tiny. However, for active remote observing, no delays in transmitting the requests can be tolerated. Both the availability and the reliability of the communication link need to be very high.

A second requirement is that the telescope and instrument must be reliable and stable. Solving technical problems is more difficult during remote observing. A good way to limit unforeseen problems is by keeping instrument change-overs to a minimum. Limiting the instrumentation is also a better way to ensure adequate know-how at the remote-observing site.

Internet is certainly the main carrier of remote-observing traffic. The tremendous advances in bandwidth and number of users, and more important, the fact that Internet is still "free", makes it the obvious first candidate to implement the communication link. The World-Wide Web gives a convenient interface which is already used for some robotic telescopes. Internet has proven reliability, and propagation delays are in most cases acceptable. A future commercialisation of Internet may make some of the advantages obsolete.

For observatories located in remote places it may be difficult to obtain a fast Internet access. As an alternative, dedicated links to more populated areas with Internet access can be acquired. Although dedicated links are more expensive, they also offer advantages like guaranteed bandwidth and propagation delays.

There are two different techniques for gaining remote access:

- *Remote Observing Centre* – A dedicated geographical site from where the observation is carried out. This is typically located in a major astronomical research institute and the remote observer has to travel to this site. The advantages are that expert knowledge, similar to a local observatory, can be built up in order to provide accurate support to the visiting astronomer.
- *Distributed Remote Observing* – Any site with a network connection, normally Internet, can perform remote observing. The obvious advantage is that no travel is required. However, it assumes that the remote observer has expert knowledge, in order to perform efficient observation.

5. ESO Experience

ESO currently supports *active remote observing* with two telescopes. The 1.4-m CAT has been operated routinely in active remote observing mode about 50% of the time for the last six years. The NTT was the first ESO telescope designed to accommodate remote observing. Remote ob-

[2]Assumptions:
Classical observing run (travel, accommodation, etc.) = kDM 4
Remote observing run (travel, accommodation, etc.) = kDM 0.8
Remote operator = kDM 10/month
Link cost (50%) = kDM 18/month
Same local support for classical and remote observing.

TABLE 2. COMPARING OPERATIONAL COST.

Monthly cost (kDM)	0% RO 0 r.ope	10% RO 1 r.ope	30% RO 2 r.ope	50%RO 2r.ope	100%RO 3 r.ope
1 tel. 5 runs/month	20	46	53	50	52
1 tel. 10 runs/month	40	61	68	62	56
1 tel. 20 runs/month	80	102	100	86	64
CAT/NTT 7+13 runs/m.	80	102	100	86	64
	0 r.ope	1 r.ope	3 r.ope	4 r.ope	6 r.ope
4 tel. 20 runs/month	320	322	291	250	142

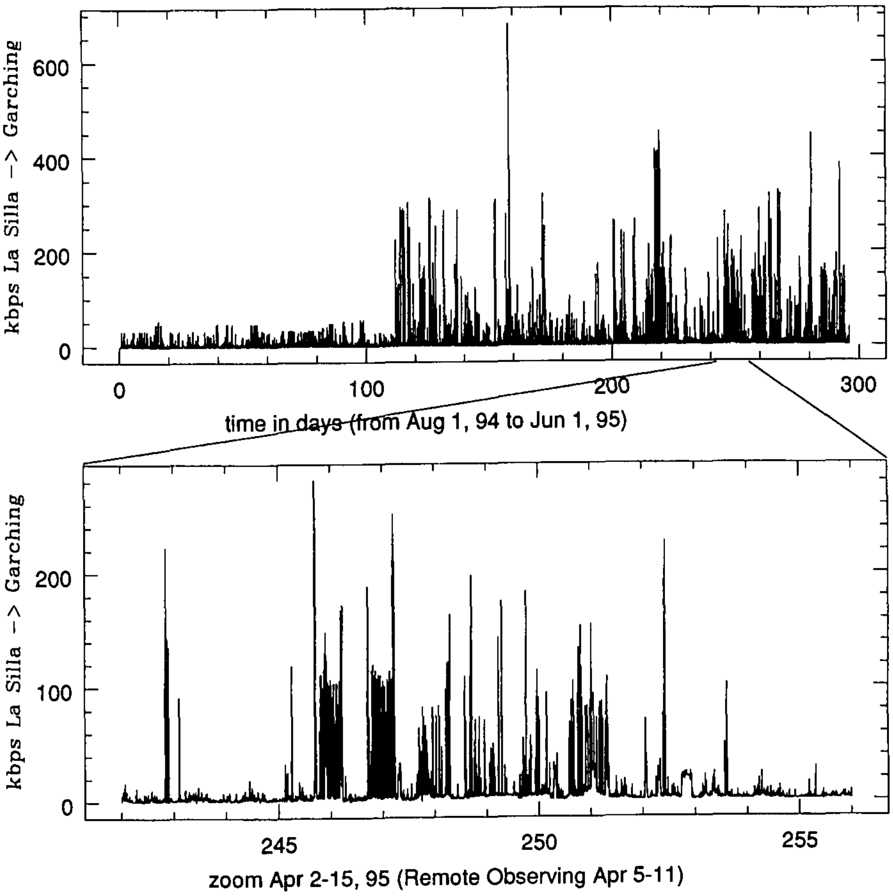

Figure 1: *Link Utilisation.*

serving was first offered to the user community in 1993, and since then about 15% (four to five nights per month) of the time is scheduled in active remote observing mode. Early experiences with the system are described in Balestra et al. (1992), Baade at al. (1993) and Wallander (1994).

The architecture of the NTT remote observing system was reported in detail in Tucson (Emerson and Clowes, 1993), and will not be repeated here. We only summarise the main parameters. At ESO Headquarters in Garching a *Remote Observing Centre* provides the interface for remote observers to the La Silla Observatory in Chile. Observing from other sites and institutes is not supported. A dedicated satellite link provides the bandwidth between the two sites. The system provides fully interactive *active remote observing* based on dedicated remote software executing at the remote site.

During the course of 1993 and 1994, the ESO executive identified the poor communication between ESO Headquarters and the Observatory as a main obstacle for success in the VLT era. In order to overcome this and to achieve a fully integrated environment between the two sites and different activities, it was decided, among other things, to invest in a high-bandwidth communication network. This upgrade was not driven by remote observing.

In November 1994 the 64 kbps (used by NTT) and the analogue (used by CAT) PTT-leased communication links were replaced with a 2 Mbps "roof-to-roof" satellite link. The complete system was obtained as a turn-key project from an external contractor. Although this involved a considerable capital investment, the actual operation costs did not increase. It turned out that by leasing the bandwidth directly from the satellite provider, instead of via national PTT's, a 26-fold increase in bandwidth could be acquired for a lower price. In addition, by mounting the antennas directly on the ESO premises and becoming independent of PTT's, the reliability of the link increased. During the period November 1994 to June 1995 the availability of the link has been over 99.8%. This should be compared to the record of the previous 64 kbps PTT leased line, which in the period 1991 to 1994 had an average availability of 95%.

Figure 1 shows the data transfer rate from La Silla to Garching, averaged every five minutes, over the last ten months. The saturation of the previous 64 kbps link, of which 32–48 kbps was allocated for data, is clearly visible. The zoom of the first two weeks of April shows that remote observing is a main, but not the only, user of the link.

Initially, the new link did not boost the data-transfer rate as expected, because the operating systems did not support the high value of the bandwidth–propagation-delay product. We obtained a patch from the supplier, which allowed us to increase the TCP window size from 8 to 32 kbytes. The next version of the operating system will allow us to increase this further. With the present patch, transferring a full 2k × 2k CCD image takes about 2 minutes, or less if one accepts lossy data compression. We find that this delay is acceptable: it is already much less than the read-out time of the CCD. It is still important to start a new exposure as soon as the old one is finished, rather than first wait for the image to appear on the remote system. Observers who use the latter approach have noticeably lower efficiency.

6. Observing Efficiency

We define the observing efficiency as the fraction of the time between nautical twilights that the shutter of the instrument is open. This number is derived from the computer-based operation log and we have routinely measured it for the NTT since November last year. We only used data from nights without any technical problems or time lost for weather, and where the instrument, EMMI or SUSI, was used in one of the standard modes (we have left out MOS which is not done remotely, and dichroic observations which can have efficiencies over 100%). The result is shown in Figure 2.

With the exception of one remote observing run (2 nights) the obtained efficiency for classical and remote observing is very similar. Performing some statistics on the data, we get the result shown in Table 3. The first night of a run is listed separately because of possible familiarisation effects ("first night syndrome"), which are indeed present.

The first number gives the efficiency expressed as a percentage, with the standard deviation. The number in braces gives the number of nights used in the

TABLE 3. COMPARING CLASSICAL AND REMOTE OBSERVING EFFICIENCY.

Classical observing		Remote observing	
First night	Later nights	First night	Later nights
64+/–11% (22)	71+/–10 (29)	60+/–18 (11)	67+/–18 (8)
		65+/–10 (10)	73+/–9 (7)

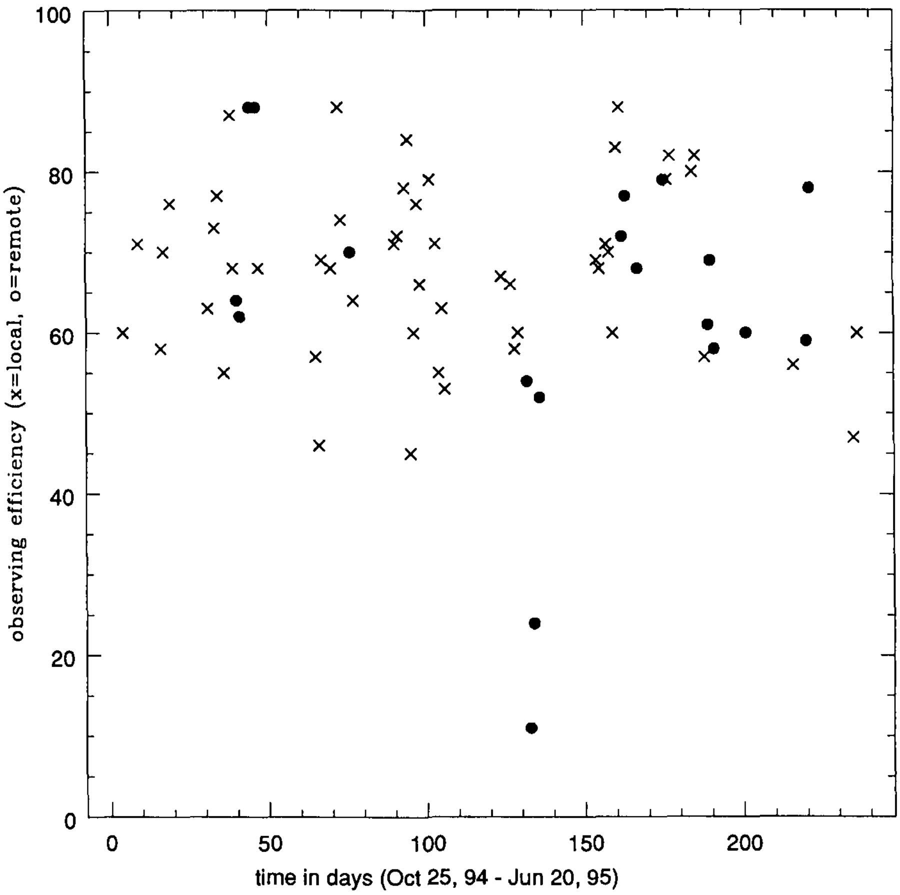

Figure 2: *Comparing classical and remote observing efficiency.*

calculation. Due to the still small number of nights, the difference between remote and local observing (a few per cent) can entirely be attributed to the one observing run which reached very low efficiency (which explains the larger standard deviation). Removing this run, we get identical figures. We have concluded from this that for normal observations remote observing is competitive. Based on the present data, we have concluded that a larger fraction of the proposals requesting the standard modes can be accepted for remote observing.

7. Observing Support

The support given to the remote observer requires special attention. Socially, there are more distractions making it more difficult to concentrate on observing. The time difference between La Silla and Garching is such that the second half of the night in Chile corresponds to the morning in Garching, when office life goes on as usual. Having a separate observing room is a necessity.

It is also more difficult to locate people with adequate technical knowledge of the system who can introduce the observer and help with preparing the observations. This is especially true if the remote observing system is only used occasionally. For the NTT, we now have a group of four post-doctoral fellows and students who give introductions in Garching. It should be noted that very few people have so much observing experience on EMMI that they don't need any introduction. In practice, most astronomers only use a particular telescope a few nights per year, and they will probably try to use a different mode from the one before. In order to allow the observer efficient use of the telescope, it is essential to arrange for good support.

During the observing night the astronomer is supported by a remote control operator in Garching, who controls the telescope, and a local night assistant present at the telescope.

One could describe the support problem as trying to build an observatory-environment away from the telescopes. People need to have the know-how and be aware of recent problems and changes (which requires good communication channels with the observatory). The introduction of a "telescope team" for the NTT, with staff both from Garching and La Silla, has helped significantly in improving communications. The effort put into the support structure is considerable, but is necessary if remote observing is to be more than a tool for highly experienced observers, which most astronomers are not.

8. Perceptions by Astronomers

Astronomers who have used the remote control system are often, but not always, satisfied. Often their feedback has resulted in improvements of the system or of the support. When applying for observing time with the NTT, the astronomer has to specify why the programme would not be suited for remote observing. We do not force people to use remote observing against their will, which would certainly backfire, but the remarks give a good impression of the perceived problems with remote observing.

Occasionally, the overheads are thought to be larger in remote observing. This may be true for complicated programmes, and is certainly true if the observer waits for the image to arrive before deciding what to do next, as some do. Part of this problem has been solved with the new, much faster link.

More commonly, the astronomer feels that the calibrations or the judgement whether the conditions are photometric, are more difficult in remote observing mode. It is not so clear whether this argument is correct. It is always difficult to judge how photometric conditions are when using CCDs, and taking a quick walk outside only really works with thick clouds or when the moon is present. The La Silla night assistant keeps an eye on the weather, but astronomers have been reluctant to accept his opinion. There have been cases where the observer wanted to continue while the moon was no longer visible. Data from the meteo-monitor, which displays seeing, wind speed, temperature, etc., are displayed on-line and this is one of the most popular things to watch in the control room.

Twilight flats are the most demanding part of the calibrations, because there is little time available and the observer cannot wait for the image to arrive before knowing what the count levels were in the previous flat. The solution here is to do fast statistics on the data on the La Silla workstation, where the original file arrives. This is perfectly possible, either by the observer working over the link or by the night assistant on La Silla who sees each image immediately after it has been read out. Good results have been obtained by using the Tyson sequences for twilight flats (Tyson and Gal, 1993). The programme to calculate these sequences is available on-line.

Some observers also express doubt about focusing. The instrument is generally focused by one or more exposures of a random field (preferably close to the target, of course). Here the image transfer can be very quick because it is not normally necessary to read out the full CCD. The image is normally analysed by the night assistant at La Silla, but it has been done remotely as well. This took 30 seconds longer and gave the same answer.

The most serious argument used by astronomers is that their object is very faint and that it is difficult to position it at the slit. If the object is not visible on the video screen, it is necessary to take acquisition images and to move the telescope such that the selected object falls in the slit. Sometimes two such exposures are needed. The additional overhead becomes larger if the science exposures are relatively short and there are many targets: if too many acquisition images need to be taken, the observer should go to La Silla.

Finally, multi-object spectroscopy is a special case: first the positioning of the telescope may be rather delicate (although here it helps that it is possible to take a direct image through the slit), but more important is the effort it takes to prepare the mask. This is generally done in the afternoon, but the software needed for this is so far only available at the telescope, and help by a technician with access to EMMI may be needed. We do not at the moment accept MOS runs for remote control.

9. Eavesdropping

So far we have not discussed *eavesdropping*. The system at the NTT allows for this as well (in fact it should be possible to implement this option for all telescopes on La Silla). If the true observer is at the telescope, and all the eavesdropper does is to help in analysing the data, there is little that can go wrong and the gain could be significant. We find that few observers have the time and energy to do a thorough analysis of their data while observing (which is a good reason why so many remote observers come in pairs). In view of this, surprisingly little use has been made of this facility at ESO, possibly because of a lack of awareness. It is also possible that the eavesdropper is the real observer, who instructs the person at the telescope what to do. In that case all of the above on remote observing applies, with the disadvantage that there is another delay when the eavesdropper communicates back to the person at the telescope, but with the advantage that he doesn't have to bother trying to find out how to operate the instrument. At ESO we have no experience with this.

10. Future

What is the future of remote observing? There is clearly a demand from the user community, seeing that a third of the optical NTT proposals request this mode. Part of this may be due to the fact that it is easier to come with more than one person in this mode. The recent experience has shown that, for many programmes, remote control is competitive with local observing, being as efficient in telescope usage while giving a saving of the astronomer's time. At the same time, there is a large group of people who prefer to travel to La Silla. We will for the time being continue to offer remote observing as a service to the community, but not force it upon people. (This last statement is true for the NTT: for the CAT we do prescribe it as the normal mode.) We will try to improve the system to alleviate the doubts as expressed above.

A major upgrade of the NTT control system is being undertaken as part of the NTT Upgrade Project. The aim of this activity is on the one hand to verify the concept and software to be used for the VLT, on the other hand to provide an identical interface on the NTT for higher level operational tools, procedures and methods to be used on VLT. Using the NTT as a testbed for VLT for all these aspects is considered essential in order to operate VLT in an efficient way. It is expected that the VLT technology and software architecture will give essential performance advantages also for remote observing. Faster computers, more efficient communication protocols, on-the-fly data compression and fast data forwarding will reduce the data-transfer rate. The limiting factor of a CCD display will become the read-out time, independent of where the display unit is located.

11. Conclusions

We have shown that the observing efficiency does not degrade when using *active remote observing* for the ESO NTT as compared to classical observing. This allows more flexibility in scheduling, shorter observing programmes, long-term monitoring programmes, and savings of astronomer's time.

However, *active remote observing* is nothing else than moving classical observing to another site. It does not address the "first night syndrome". To increase the scientific efficiency, service observing may be a more important observing mode than remote observing. The move to service observing may or may not make *active remote observing* obsolete. Assuming the service observer will be at the telescope, we would expect increased demands for *eavesdropping* capabilities. The requirements for this to be successful are a sufficiently fast link and adequate communication facilities, i.e. not much different from those of *active remote observing*. The main role of *active remote observing* may be found in the new generation of large telescopes, where the observing runs may be very short, and for astronomers in places where travel money is difficult to get.

12. Acknowledgement

Manfred Ziebell, with support from Joar Brynnel, has been responsible for the very successful installation and operation of the new satellite link. We thank Miguel Albrecht for providing the observing efficiency data. The successful operation of NTT remote observing would not have been possible without dedicated support from the whole operation crew, both at La Silla and in Garching.

References

Baade D., et al., 1993, *The Messenger*, **72**, 13.
Balestra A., et al., 1992, *The Messenger* **69**, 1.
Burton M., 1995, in ASP Conf. Series, **73**, p. 559–562.
Emerson D., Clowes R., 1993, Observing at a Distance, (World Scientific, Singapore).
Loewenstein R.F., York D.G., 1986, *SPIE* 627.
Longair M.S., Stewart J.M., Williams P.M., 1986, *Q. Jl R. Astr. Soc.* **27**,153.
Raffi G., Tarenghi M., 1984, *The Messenger* **37**, 1.
Raffi G., Ziebell M., 1986, *The Messenger* **44**, 26.
Raffi G. et al. 1990, *SPIE* 1235.
Tyson N.D., Gal R.R., 1993, *AJ*, **105**, 1206.
Wallander A., 1994, Nuclear Instruments and Methods in Physics Research Vol. A347.

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Library and Information Services in Astronomy II (LISA-II)

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Library and Information Services in Astronomy II (LISA-II), an IAU Technical Workshop, was held at the European Southern Observatory (ESO), Garching near Munich, Germany from May 10-12, 1995. LISA-I had been held in Washington D.C. in 1988. The aims of LISA-II were twofold: (1) to provide the opportunity for librarians of astronomical observatories