Improving the Wendelstein Observatory for a 2 m class telescope

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ABSTRACT

The Ludwig-Maximilians-Universität München operates an observatory on the summit of Mt. Wendelstein in the Bavarian alps which will be equipped with a modern 2 m-class, robotic telescope. We did extensive site evaluations and started various monitoring programs on transmission, extinction, and seeing. Implementation and results of these monitorings are reported. We further present our strategy to prepare the observatory for this major upgrade, including hardware installations (besides the telescope), network and software infrastructure upgrades, as well as improvements in the observatory operations. We aim at most efficient observations in a "low-person-power" situation on a site which allows only partial robotic operations. The basic telescope design and the strategy for its first generation of instruments are briefly discussed.

Keywords: Observatory operations, telescope operations and improvement

1. INTRODUCTION

Small optical observatories can play a major role in astronomical research and education besides the major, ground-based facilities with their 8 m class telescopes and besides satellite observatories. Due to their different operational approach and different ownership, they can devote major time fraction to either educate student for proper use of the large facilities or science projects where large amount of observing time is essential for a scientific success. These kinds of projects are either surveys, monitoring projects, feasibility studies for new methods or instruments or a combination of the three. The student training can be done very effectively in the course of larger programs and instrument building.

The observatory (USM) of the University of Munich (LMU) operates a small observing site on Mt. Wendelstein (1836 m) (Fig. 1) which served since decades for student training as well as monitoring projects like WeCAPP.[1] Its meanwhile aged 1 m class telescope will be replaced in ≈ 2010 by a 2 m class, semi-robotic telescope to be built by the company *Kayser-Threde GmbH*, Munich. In chapter 2, we briefly describe the history and astronomical quality of the site. Chapter 3 reports on the activities for up-grading the observatory in its operation and technical periphery while chapter 4 summarizes all steps towards an improved image quality. Short descriptions of the observatory operating model and the concepts for the 2 m telescope, including its first generation of instruments, are given in chapter 5 and 6. Some aspects of the instrumentation are discussed by Grupp et al.[2] and Fabricius et al.[3] in their contributions to this SPIE meeting.

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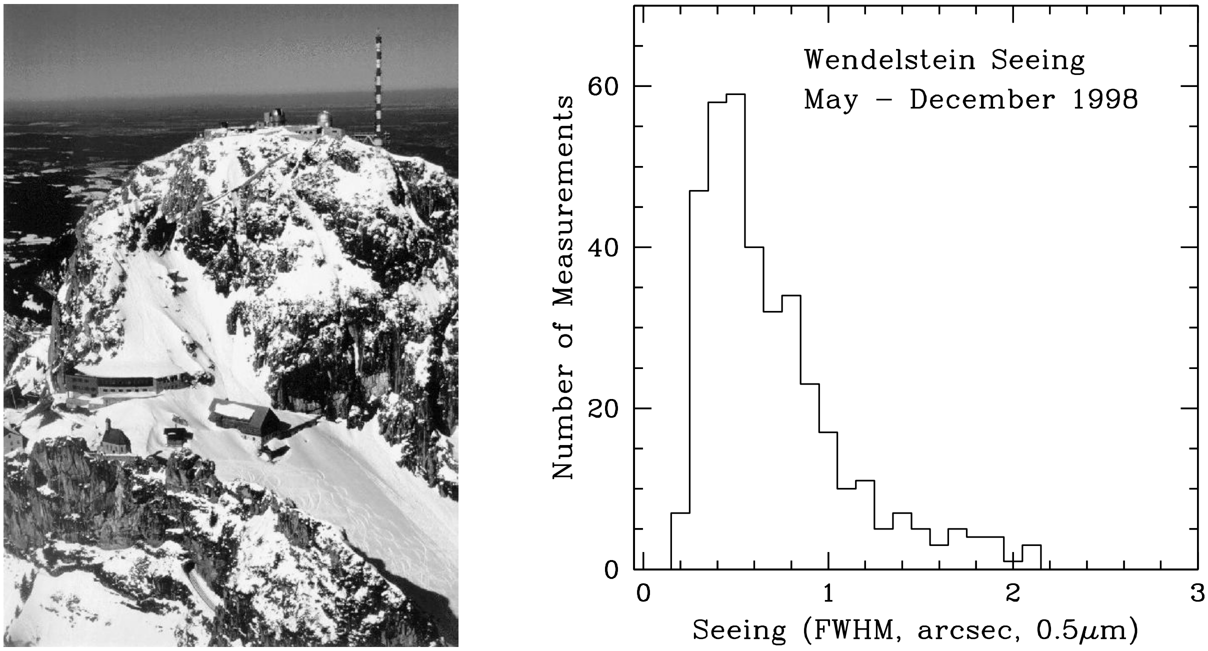

Figure 1. Left: View from south to Mt. Wendelstein with the observatory (middle), the radio broadcasting station (right), and the weather station (left) on its summit. The existing 80 cm telescope is placed in the open dome. Dome and telescope will be replaced with the new 2 m telescope and its housing. Right: Seeing of the free atmosphere above Mt. Wendelstein as measured within 9 months from May to December 1998 by an ESO DIM.

2. HISTORY AND SITE CHARACTERISTICS

The astronomical observatory on Mt. Wendelstein was originally established as a solar activity monitoring station in the early-1940s. The observatory is installed on the summit of a very steep mountain which rises over the surrounding terrain by several 100 meters. This has consequences for its astronomical site properties (see below) as well as for its operation. The steep sloped mountain prevents road access and therefore personal and equipment have to be transported by cable car or by rack-railway. For the last 104 m up to the summit an elevator is used to transport small equipment and personnel. Heavy or bulky equipment (e.g. a dome) can only by delivered by helicopter (Fig. 1, 3).

The observatory is within 1.5 hour travel distance from the home university in Munich which allows student training on all levels starting with observational exercises already during the Bachelor education.

Until the mid-1980’s, the Wendelstein observatory participated in the world-wide solar activity surveys.[4] Then, the station has been refurbished for night-time observations focusing on stellar astronomy. In 1987, an 0.8 m $f/12.5$ fork-mounted Ritchey-Chrétien telescope ($f' = 9.9\,\mathrm{m}$, $A = 0.59\,\mathrm{m}^2$, un-vignetted field-of-view diameter ø $= 125\,\mathrm{mm} \approx 0.72^\circ$; plate scale of $20.8\,''/\mathrm{mm}$) built by *DFM Engineering* was installed at the observatory within a 5.6 m dome. The telescope was first equipped with multi-channel, fast, classical photometers with rather large entrance apertures.[5] Since the mid-1990s a CCD camera (MONICA, MOnochromatic Imaging CAmera[6]) became the major observing instrument. MONICA features a Tektronix 1k × 1k CCD with $24 \times 24\,\mu\mathrm{m}^2$ pixels delivering a pixel scale of $0.5''$/pixel. The camera was used almost exclusively for broadband imaging (B, R, and I), especially within variable object monitoring projects.[1,7] MONICA was de-commissioned in March 2008 and replaced by a two-channel camera.[8]

After the installation of MONICA, the need to improve the telescope focal plane image quality (IQ) became obvious. Besides improvements to operation and hardware (see chapter 3), we started to investigate the origins of the IQ (see chapter 4) and the other astronomical observing parameters of the site. This was especially needed to decide whether the installation of a bigger telescope at this site is worthwhile.

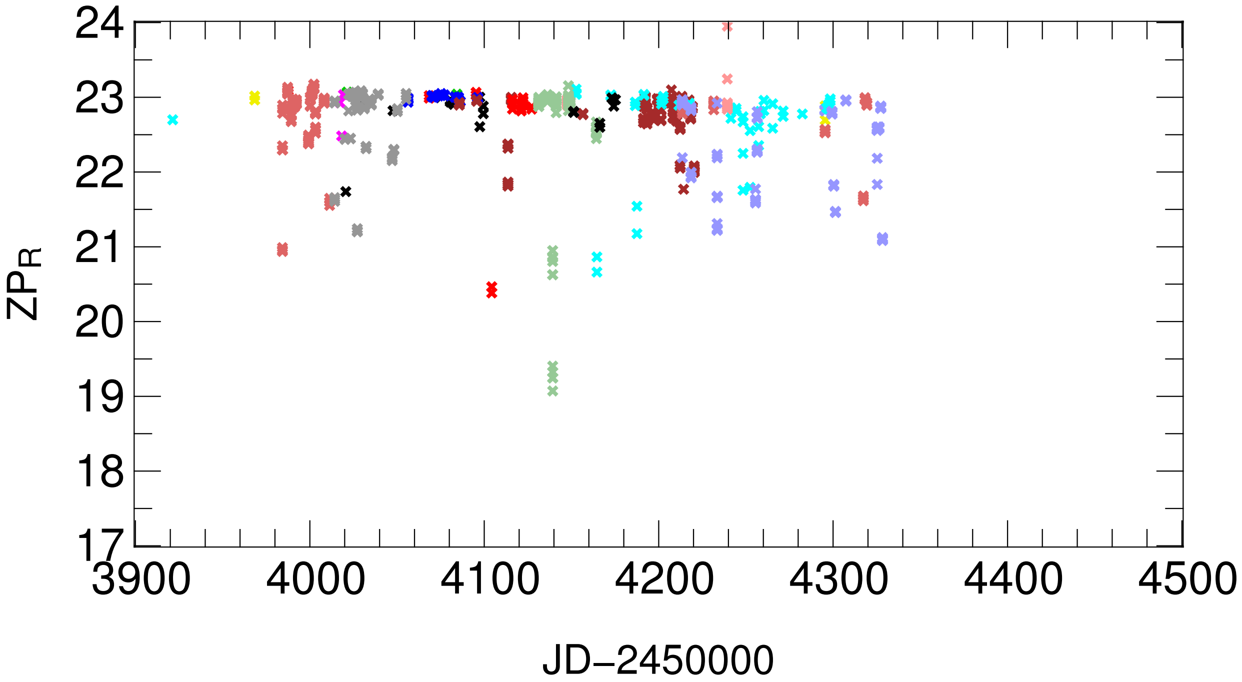

Figure 2. *R*-band example for the zero-point monitoring done at Mt. Wendelstein. Each clear night, standard stars[10] are observed at least twice. The measured flux is translated into zero-points. Scatter below the optimal line indicates non-photometric observing conditions while a trend of the line give hints to system degradations. Observations are immediately reduced by the observing staff using automated scripts allowing a quasi on-line night transparency quality determination.

An ESO-built differential image motion monitor (DIMM), on loan from the European Southern Observatory, was operated for a total of nine months in 1998. As shown in figure 1, an outstanding seeing quality was recorded during this survey; the observed site quality approaches those of the Chilean desert sites. From all other environmental measures available, we have no indication that the conditions during the DIMM monitoring campaign were special in any respect and therefore assume that this seeing statistics is typical for the free atmosphere above the site.

The CCD monitoring programs which extended over the last nine years using the identical equipment also allowed to measure the night sky brightness. The light pollution by nearby towns like Munich and Rosenheim as well as by surrounding winter sport resorts result in $\leq 30\%$ brightening of the night sky (*R*-band) in those nights which are clear at the observatory as well as in its surroundings. During a good fraction of the clear nights, the peak of Mt. Wendelstein reaches above the clouds covering the surroundings. In those nights the site is as dark as at more remote observatory locations.[9]

The fraction of clear nights has been derived from records of the on-site DWD weather station (1976-1982) and from our observational logs of the last decade. A total of about 1100 clear hours is available, a large fraction of these hours occurs in the 120 nights with continuous clear hours of six hours or more. About half of the nights has photometric or near photometric conditions (Fig. 2)

3. IMPROVING AND UPGRADING THE INFRASTRUCTURE

Many individual projects were realized to achieve the improved, present day operational conditions of the existing equipment and also to test schemes for the future operation of a bigger telescope. These included hardware projects as well as changes in the operation and upgrades to operating and data processing software.

- A 0.4 m telescope from *Astelco GmbH* was installed to monitor atmospheric extinction and for educational purposes. This $f/8$ Cassegrain system on a German mounting is hosted in an 3.2 m *Baader* dome (Fig. 3),

Figure 3. Left: 0.4 m Cassegrain telescope from *Astelco GmbH* for extinction monitoring and student lab, installed within a recently erected 3.2 m Baader dome. Right: Due to its size, this new dome had to be delivered by helicopter which likewise will be done with all major parts of the new 2 m telescope making the logistics the most challenging task of the total project.

Figure 4. Examples of night-sky images of the all-sky camera (middle panel). The left image indicates the sensitivity of the system under clear conditions (below 6 mag) while the right one outlines how easily approaching thin cirrus and clouds can be identified. At the right edge of the images, the 5.6 m dome of the old 0.8 m telescope is visible, the new 2 m telescope and its slightly larger dome will be installed at the same place. The left edge shows the antenna of the radio broadcasting system.

and equipped with a *SBIG ST10* CCD imager with an image scale of $0.44''$ per $6.8\,\mu$m pixel.[11] The installed filter-set matches SDSS g', r', and i' filters which will be in use by the CCD cameras at the future 2 m telescope.

- To facilitate easy checking of cloudiness we installed a webcam based all-sky cloud monitor consisting of a Mintron MTV-12V1 with a Sony HAD interline-CCD system behind a 6mm lens protected by a small (transparent and heated) perspex box (Fig. 4). The data of the allsky camera are archived to allow offline atmospheric transmission checks during the science data reduction.
- An EM-shielded electronics laboratory was newly installed which allows on-site maintenance of electronics despite the strong emission of the nearby radio broadcasting station ($\approx 20\,$V/m in the UHF and VHF bands altogether) and therefore minimizes down time.
- A new emergency power generator can overcome 3 days of power outage. All instruments including computer hardware are locally protected by uninterruptible power supplies coupled with insulating transformers.
- We installed a high performance Internet connection which now allows immediate access to astronomical Web tools as well as to big storage archiving facilities. This network enables off-site personal to offer service at short notice and is essential for remote observations. A modern Firewall protects the observatory LAN. All network cabling is done with fibres minimizing damages caused by relatively frequent lightning.
- The operating personnel (either remote or locally from the observers room) can supervise the building, the telescopes, and the night-sky trough a set of webcams installed inside and outside the domes. Temperature and humidity sensors (with network interfaces) have been installed inside the dome while a fully automatic weather station for the ambient conditions will be installed in 2008.
- A DCF-77 receiver as well as a GPS-based clock system were installed in early 2008 as high quality clock systems.
- The telescope observing software has been expanded and complemented by client / server-architecture applications which use a *Beck IPC Microcontroller* as a relay between the observatory LAN and the telescope's serial interface and most of the telescope's hardware switches and now allows full remote access to the telescope.[12]
- A new camera controlling program was developed[13] supporting menu and simple scripting control of all camera features. Observation logs are automatically generated and the data are stored in FITS-format[14] including telescope settings. The telescope software expansions enabled observing scripts to include an autofocus function, automated twilight flatfield acquisition and an improved guiding software with an autodithering mode.[7] All improvements together enabled to reduce the operational overhead from about 50% of the observations having more than 40% overhead in 1998 to more than 90% having less than 40% overhead now (Fig. 5).

Large efforts went into documentation of all the individual projects which also offers online help for troubleshooting and guides for the operations personnel, including some simple tutorials for the student lab observations.

Additionally, we developed a dedicated reduction pipeline which accounts for standard reduction (bias removal, flatfield calibration, cosmics rejection, stacking) including error propagation as the first part of our projects relying on difference image analysis.[15, 16]

Originally, the final goal was a full robotic mode of the existing equipment as a study case for a larger telescope. A remote mode with full acquisition of environmental conditions and optional pipeline reduction could indeed be achieved. However, a fully robotic mode turned out to be too ambitious and potentially hazardous with the aged telescope and dome control sensors (i.e. pointing).

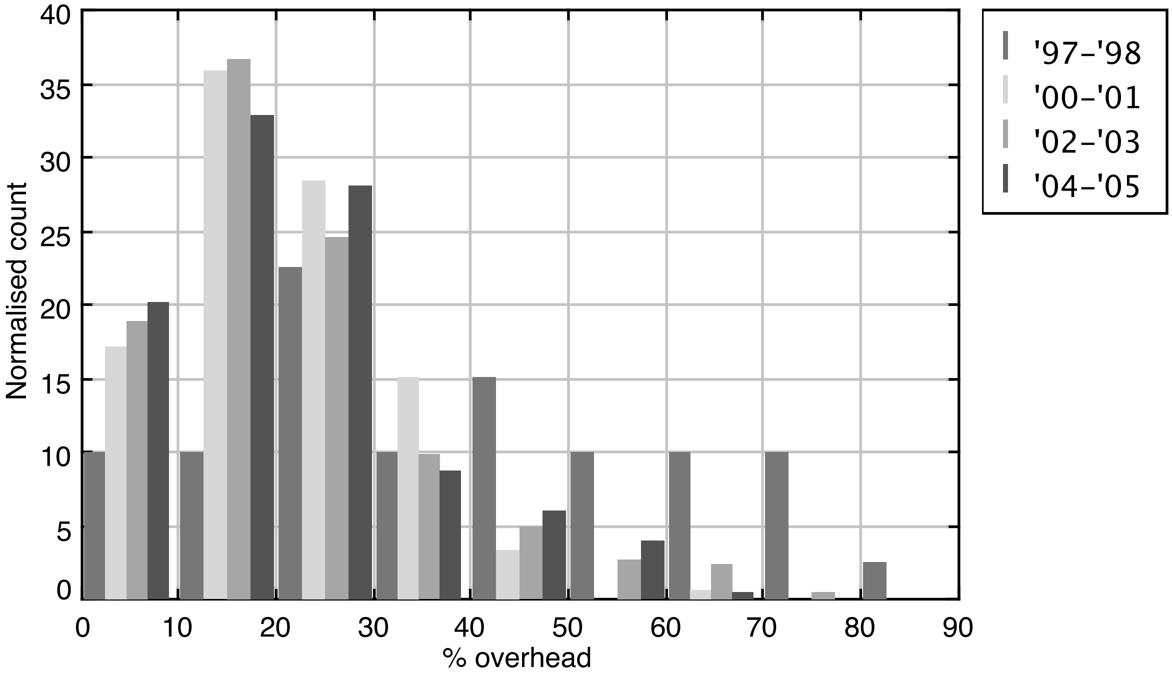

Figure 5. Overhead of CCD imaging observations with the 0.8 m telescope (excluding pure camera overhead as CCD wipe or CCD readout): The overhead is the percentage of "idle" time of the camera in the span between the first and the last science night sky image of each night. Observations performance was greatly improved until 2001 and remained on that high level since. In '97/'98 about 50% of the observations had less than 40% overhead whereas more than 90% of the observations did so since 2000.

4. IMPROVING IMAGE QUALITY

Two major sources impacting the IQ of the 0.8 m telescope were identified: The experimental primary support system of the telescope was not able to stabilize the figure of the installed thin mirror. Therefore, the thin mirror was kindly replaced by DFM by a thicker one which improved the IQ considerably. Still, the available support system forces very frequent focus calibrations introducing a severe amount of overhead for every observation. A major step forward to the nowadays available IQ were observing scripts which include frequent focus checks. The other major source was 'dome seeing'. The original observers room was placed directly below the telescope level and acted as a major heating source for the dome. Further, the simple metal dome had no insulation and the air inside the dome heated up by more than 10 degrees during sunny days. Several steps were taken to improve the situation from the late 1990s until today:

- A second door was installed to enable passive ventilation and thermal equilibrium to outside conditions during twilight and night. While this helped somewhat it was not sufficient.
- The dome and its supporting structure were foamed with $\approx 100\,\mathrm{mm}$ of Polyurethan reducing the day-time heating of its interior. Again, some success was achieved but no major breakthrough.
- An air-conditioning system was installed and operated such that the expected next night outside air temperature was kept in the dome. This was the single most important step towards good IQ. Occasional technical break-down of the air conditioning always showed a strong degradation of the IQ.
- The telescope peer and the roof of the "old" observers room were insulated with styrofoam plates. In a second step, the observers room was moved from below the telescope into the adjacent building. This last action was mostly motivated in further reducing the heat load of the dome, but also as a first attempt to prepare for a larger telescope and allow for remote observations.

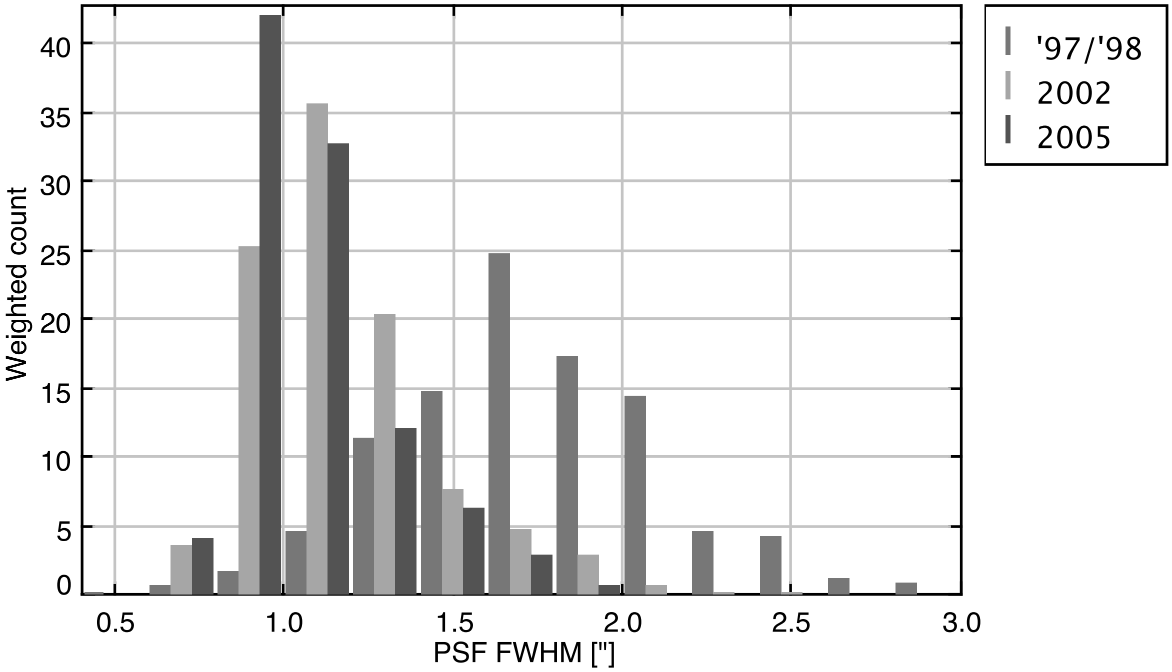

Figure 6. Distribution of MONICA / 0.8 m WST imaging point spread function (PSF) full width half maximum (FWHM) measurements (in the R-band for 1997/1998, 2002, and 2005, Bin size is $0.2''$).[7] The data are all normalized to unity airmass and 100 measurements. In 2005 almost half of the observations had PSF FWHM below $1''$ and about 75% were below $1.2''$ whereas merely two third were below $1.8''$ in the winter of 1997/1998. Note that the Nyquist[17] rate of MONICA at the Wendelstein 0.8 m telescope is $\approx 1''$.

Substantial IQ improvements were achieved: Fig. 6 compares the situation for winter 1997/1998 season, when we started the CCD monitoring campaigns,[1] with 2002, and 2005.[7] The PSF statistics mode improved from about $1.7''$ in 1997/1998 to about $1.1''$ in 2002, and even below $1.0''$ in 2005. Since 2005, the IQ is stable for the CCD images regularly obtained in normal operation mode.

To minimize scattered light illumination effects we floored the dome buildings in black. For the same reason, the inner side of the dome slit of the 0.8 m telescope was painted in black. (In case of the newly installed 0.4 m telescope (see above), the complete interior of its dome is black.) This somewhat unfriendly looking painting improves mostly on twilight flat field calibration and "bright time" images when bright light tends to scatter within the dome and open telescope structure eventually finding its way onto the CCD.

Finally, we started regular performance measurements of the system including at least bi-nightly observations of Landolt stars[10] for overall quantum efficiency control (Fig. 2), simple IQ recording from the regular focus settings, and monthly monitoring of the mirror alignment by so-called pupil tests[18] for which scripts for execution and quasi-on-line analysis were developed.[11] Thus, we tried to minimize the well-known problem with RC systems, i.e. decenter coma.

5. OPERATING MODEL

The above described improvements have been achieved in a low budget and low person-power (FTE) situation. Parts of the activities have been carried out within student graduation work (34 diploma and 9 PhD theses). The staff nowadays include three astronomers (all part-time, operation, software, instruments, management), one engineer for electronics and local hardware maintenance, one instrument builder, two night-time staff (operation), and one mechanical technician. Resources from the home institute (e.g. system manager, support with ZEMAX calculations, administration and further lab FTEs from the electronic and mechanic labs) have been available occasionally. Gaps in the night-time operation have been closed with astronomers carrying out their own program, especially with PhD students. Since the first light of the 0.8 m telescope a total of 34 refereed science papers, several technical papers and many short communications have been published.

6. THE 2M TELESCOPE PROJECT

The 2 m telescope was contracted to *Kayser-Threde GmbH (KT)*, Munich and its sub-contractor *Astelco GmbH*, Martinsried. Its principle restriction results from the available space on the mountain summit which leads to a dome diameter of no more than 8 m. The telescope should be able to support several instruments almost parallel in two ports and should be operational locally, in remote-mode (e.g. from Munich), or semi-robotic. The science drivers are the wish for a large field CCD imager and the possibility of a fast switch to the other port hosting up to three instruments. The switch may be due to external astronomical triggers (e.g. a Gamma ray burst observing request) or changing observing conditions which favor other programs than the one in execution. For this second focal station, a three-channel system with two optical CCDs and a NIR-camera,[2] and a medium-resolution field spectrograph linked with a fiber-coupled integral field unit[3, 19] are under design while the third instrument will be an upgraded high-resolution echelle spectrograph (FOCES[20]) which is currently in operation at the Calar Alto Observatory.

A $f/7.8$ RC system with classical thickness-diameter ratios of the mirrors is designed and will be installed into a modern alt-azimuth mounting. The specifications for optical aberration and mounting performances are driven by the site IQ and the wide-field mode. The telescope is now in its advanced design phase, first light anticipated for late 2010. A thorough description of the telescope project will follow elsewhere after finalizing the design.

7. CONCLUSIONS

Smaller observing facilities in close neighborhood to their home institute can strongly support the students eduction and carry the major load of long term monitoring projects. We have shown that modern equipment and operation concepts can improve the observing quality and the efficiency of such a small observatory even in a low budget and low person-power situation and prepare the place and its equipement for competitive research projects which complement the research activities at major national and international facilities.

Acknowledgements

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