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STELLA: Status Report

A. Hempelmann[1], J.H.M.M. Schmitt[1], H. Hagen[1],
K. Strassmeier[2], K. Arlt[2], T. Granzer[2], G. Hildebrandt[2], M. Weber[2],
M. Woche[2]

Abstract. STELLA is a joint project between the Hamburger Sternwarte and the Astrophysical Institute Potsdam for an automatically operating spectroscopic telescope. The scientific goals are observation and monitoring of stellar activity. By agreement with the Astrophysical Institute of the Canary Islands, STELLA will be installed at the Teide Observatory on the island of Tenerife. The actual progress in design and construction of the telescope, the instruments and the control software is presented in this report.

1. Project Overview

STELLA is a robotic telescope of 1.2m aperture with a spectrograph as primary and optionally a CCD-photometer as secondary instruments. It is a joint venture between the Hamburger Sternwarte and the Astrophysical Institute Potsdam (AIP). In collaboration with the Astrophysical Institute of the Canary Islands (IAC), STELLA will be installed at the Teide Observatory on the the island of Tenerife.

STELLA is a project for observation of stellar activity in the optical spectral range, i.e., observation of phenomena resulting from photospheric and chromospheric activity like, for example, spots and plages. The main scientific goals are determination of basic parameters like levels of activity derived from several spectral tracers, stellar age, stellar rotation, rotational axis inclination, surface rate of differential rotation, activity cycles as well as the study of surface spot patterns and their temporal evolution on different time-scales.

Time-series observations and monitoring of stars will be characteristic for STELLA. This kind of observations is ordinarily not possible at bigger telescopes of national or international institutions where the telescope time has to be divided between a number of applicants. This is only possible with telescopes which are dedicated to single projects. (A good example is the Mt. Wilson CaII H+K project.) To reduce the costs for such a project automatic telescope work is required. While this became normal for photometry an automatic spectroscopic work is an outstanding task and must be the next step. The requirements to the accuracy of pointing, tracking and guiding a spectroscopic telescope are

[1]Universität Hamburg, Hamburger Sternwarte

[2]Astrophysikalisches Institut Potsdam

extreme making automation much more difficult than in case of a photometric telescope.

The project was started in the late nineties with acquisition of funds (Hempelmann & Rüdiger 1995, Reimers et al. 1998). After funding by German governmental institutions telescope and building were ordered and modernization of the spectrograph TRAFICOS was started. In 2000 an agreement with the IAC on the installation of STELLA at the Teide Observatory (TO) on Tenerife was signed.

2. Telescope

The telescope was ordered from the German enterprise Halfmann Teleskoptechnik at the end of 1999. Halfmann contracted Carl Zeiss Jena for manufacturing the telescope optics. The mirror material is Schott ZERODUR.

The telescope is an f/8 Cassegrain-Nasmyth type with 1.2 m aperture and two focus positions. One focus position will be used mainly for spectroscopy with the fibre-linked Echelle spectrograph TRAFICOS, the other one optionally for CCD-photometry.

At the focus position for spectroscopy the telescope-instruments-adapter (see below) will be installed. This telescope adapter includes a further option for imaging in a 7 arcmin FOV.

The telescope has a fork alt/az mounting. The azimuth bearing is hydrostatic whereas in elevation spindle bearings tightened in O-arrangement are used. Direct final drives in both axes with absolute encoders will guarantee high precision tracking. By help of a pointing model a positioning accuracy of $< 5''$ will be reached. A fine positioning and guiding system which uses the target star itself as guiding star will guarantee final positioning and guiding the telescope with an accuracy much better than $1''$.

The lattice tube is of Serrurier type. It carries the primary mirror cell which is fixed adjustable on the central body of the tube and the secondary mirror cell which is fixed on the adjustment device of the front spider.

After finishing telescope manufacturing in spring 2002 the telescope shall be installed at Hamburg Observatory for testing the telescope and the telescope control software. After successful testing the telescope will be installed at TO.

3. Spectrograph

Main instrument of STELLA is the fibre-fed Echelle spectrograph TRAFICOS (Hildebrandt et al. 1997) which at present is under reconstruction to prepare it for automatic work and to enhance its efficiency.

Its spectral resolving power is up to 50 000 when a fibre of core diameter 50μ is used. The wavelength range is between 380 and 900 nm.

The old TRAFICOS had a few disadvantages which would have had its use for STELLA somewhat problematic. Its quantum efficiency below 400nm was spurious and, there was a stray light problem resulting from its special design. In the new TRAFICOS there are some significant changes:
i) collimator and camera are now separated from each other and off-axis parabolic

mirrors are used as collimator (FEROS design).
ii) The cross-disperser prism will be replaced by volume phase holographic gratings in the near future.
iii) The old fibres were replaced by fibres with much higher throughput in the UV and,
iv) the CCD-camera was replaced by a camera of high quantum efficiency over the whole spectral range required.

The reconstruction work is being done at the AIP workshop.

4. CCD-Camera

A new CCD-Camera for the spectrograph from Jobin-Yvong is now available. Its thinned, back-illuminated and UV enhanced SITe chip of Tectronics grade 0 has 2000x800 pixel of size 15μ. The chip is cooled with liquid nitrogen. At present the camera control system is being adapted to LINUX.

5. Fibres

The spectrograph is linked with the telescope by fibres of different core diameter 50, 100 and 200μ resulting in three eligible values of spectral resolving power 50 000, 26 000 and 13 000. A number of laboratory tests have yielded that the following fibres are suitable for STELLA: Polymicro FVP 200/220/240, FVP 100/120/140, CeramOptec 50/70/125 and Ceram/Optec 50/125/150. It is important to note that the test results for the 50μ fibres were not worse than for the other fibres.

The guidance of the fibres from the telescope to the spectrograph which is situated in a separate room guarantees minimal deflection and is nearly independent from the telescope position.

6. Telescope-Instruments-Adapter

The telescope-instruments-adapter is mounted at the flange of the Nasmyth derotator of the telescope. The adapter is the interface between the telescope, the spectrograph and the optional photometer. It contains the input fibre holder, the telescope fine positioning and guiding system, the 7' field of view corrector, a focal reducer and the calibration unit consisting of ThAr and flat field lamps.

The fibre holder is a glass block with six holes each holding a fibre. The front side of this block is formed as flat mirror where the flat normal is inclined to the optical axis. This mirror is viewed by a CCD-camera for positioning and possibly also guiding the target star on the fibre. The holder is computer-controlled adjustable to fix a chosen fibre in the telescope focus. A beam splitter before the holder reflects a few percent of light on a second CCD-camera serving as guider of the target star on the fibre during a spectrum exposure.

The adapter is being manufactured at the workshop of the Hamburg Observatory.

7. Building

The STELLA observatory has a roll-off roof instead of a conventional dome. The AIP plans the installation of a second telescope (STELLA 2) in this building. The building design has been finished under the responsibility of the AIP.

8. Weather Station

STELLA is controlled by its own weather station. It includes sensors for wind, temperature, humidity and rain/snow.Main instrument is a spatially resolving cloud monitor which can distinguish between clear and cloudy sky regions. The cloud monitor has been manufactured by the Hamburg Observatory workshop.

9. Site

STELLA will be installed at the Teide Observatory (island of Tenerife), in collaboration with the Astrophysical Institute of the Canary Islands. The IAC is supporting STELLA with several services.

10. STELLA Software

Software is a crucial component of the project which is at the development stage. In the following some basic principles of the STELLA software design are illustrated.

STELLA is a conglomerate of different, rather independent devices that communicate amongst each other by exchanging messages like commands, command-replies, or error messages. From the software side, the different devices and their data flow look like the network lined out in Fig.1.

As one can see from Fig.1, *commands* are exclusively sent from the central node, the *STELLA Control System* (SCS), to peripheral devices who confirm received command by sending back *replies*. *Errors* or *status-messages* can be sent anytime to the SCS who is responsible for proper reaction and error-recovery. *Data-messages* generated from weather sensors and mainly from the scientific CCD are sent directly to the data archive. The weather station additionally generates *weather events* to signal malevolent or benevolent observing conditions to the central node.

As command-messages and their reliable delivery are key ingredients to the functionality of the entire system, a command-acknowledge-done ratification cycle has been incorporated in the STELLA software design. This mechanism, outlined in Fig.2, follows closely the mechanism incorporated in the Liverpool Telescope (Steele & Carter 1997).

First, the SCS starts with sending a *command* to a (registered) listener. As soon as the command listener (or the command server) receives the command, it sends back an *acknowledge* message which carries a maximum completion time allowed for executing the command. The acknowledge listener, in this case again the SCS, waits at maximum for this time specified until it receives the final *done* message, or, for commands that require multiple sub-processes,

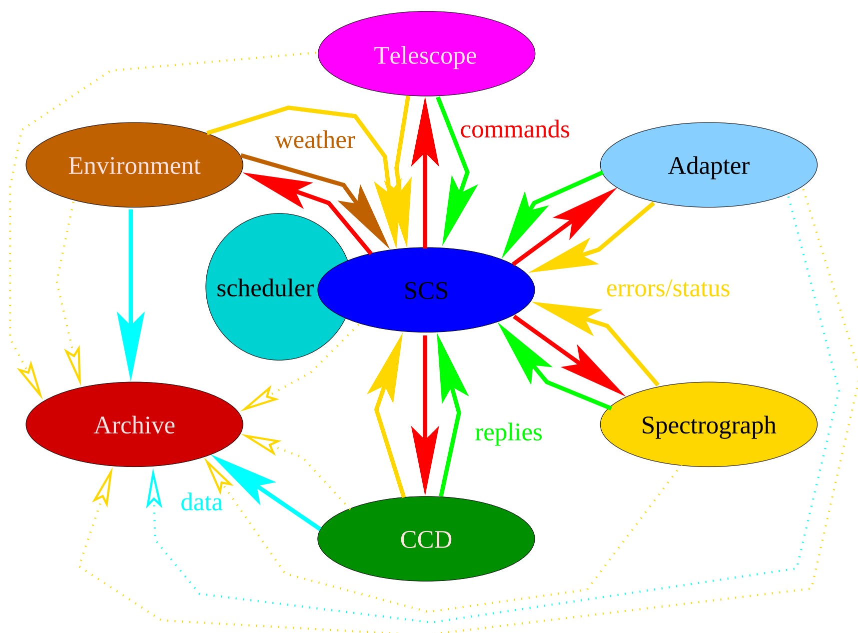

Figure 1. The different devices building up the internal software network of STELLA. Note that it is not necessary that each *software* device is represented by a *physical* device.

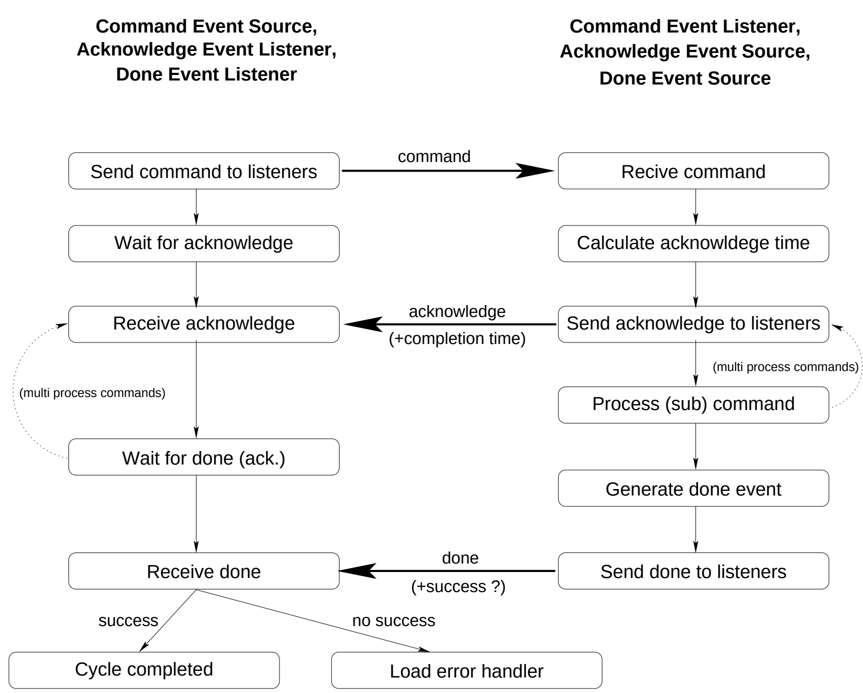

Figure 2. The principle steps involved in sending a command. Time runs from top to bottom. See text for explanation.

additional acknowledge messages. Meanwhile, the command listener executes the command. If the execution terminated regularly, the listener sends back the done message with the successful flag set. Note that *recognized* errors occurring during or after the command execution are sent back to an error listener (in most cases again the SCS). If occurring during a command sequence the error message is followed by a *successful* done message. Done messages with non-successful flags are *solely* reserved for *unexpected errors* within the command listener, like software exceptions/errors occurring at the listener during command execution. An unsuccessful done is considered a *severe* error, denoting a condition not expected during code development, and always result in a complete shutdown of the entire system.

In the object-oriented programming regime introduced by the extensive use of the JAVA programming language this concept can easily be realized as events passed from event-generating sources to (registered) event listeners. JAVA-RMI capabilities can be used to actually transport events from event sources to remote listeners *without* specifying a certain network protocol. Though some parts of the STELLA system programming are outsourced, it is agreed that command-passing is also possible using ASCII-representations of the command events sent over a regular TCP/IP-protocol based network.

For first light, no particularly complex scheduling algorithm is anticipated. The very few basic ingredients will include a priority of the target, a certain (jd) time span this target can be picked and an observing window denoted as an airmass or sidereal time bound.

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