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GLObal Robotic telescopes Intelligent Array for e-Science

Report for standard methodology for online experimentation and the choice of the on-line experiments

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1. Introduction

This document discusses the detailed structure of the GLORIA system relevant to supporting **on-line experiments,** and contains the reference Software Requirements Specifications (SRS). As with the rest of the software in the GLORIA project, work is split between definitions, programing, deployment & testing and support to the community. Therefore the experiments software will be done in the following WP:

- **WP3 -> definitions work**. Even though UMA and UPM are the coordinator and deputy respectively of this WP, all partners of GLORIA participate. This document D3.10 is the report of this work.
- **WP8 -> programming work**. Performed mainly by UOXF & UWAR.
- **WP6 -> deployment & testing**. Performed mainly by UWAR & UOXF.
- **WP4 -> Support to the communit**y. Performed mainly by CSIC & FZU-CAS

2. How to observe

Online experiments are how the users access GLORIA's telescopes, and the obvious starting point is to ask what users actually want, and then to consider how to provide as much of that to as many users as possible, and to consider only solutions that scale to very large numbers of both users and telescopes. As currently understood, the entire range of astronomical work is covered by two multi-choice questions:

When will the experiment be run?
Fixed. At a time chosen by the *user.*
Scheduled. At a time chosen by the *system*.
Alert. When triggered by an *external event*.

How will the experiment be operated?
Interactive. Direct low-level remote control of the telescope functions.
Batch. The telescope receives a script, and executes it autonomously.

There are six combinations, for all of which there are valid uses:

Type	**Examples**
Interactive-Fixed	Classroom demonstration, maintenance & testing
Interactive-Scheduled	Smart monitoring of variable stars
Interactive-Alert	Supernova observation by a human or expert system
Batch-Fixed	Planetary transit
Batch-Scheduled	Deep image of a galaxy
Batch-Alert	Supernova or GRB obs, as a response by a predefined observing script

(On initial consideration, there appears to be a third question: "which?" (i.e. which telescope) which we are deliberately omitting. We expect that user requests will vary from "telescope X and none other" to "any telescope that meets criteria A, B and C" to "any telescope at all". The absence of discrete categories suggests a different solution is needed, which is considered below as the "Constraints" section of an Observing Plan)

As stated in Deliverable 7.5, we are developing an authoring tool to allow anybody to create and develop new on-line experiments. It is expected that some ideas for new experiments will require features not initially provided or considered, and that therefore the SRS (and this document) will be updated together with new versions of the corresponding code.

2.1. Fixed, Scheduled, or Alert

GLORIA has limited resources - it is appropriate to state the arguments in favour of implementation, in this case by stating the desirable activities that become difficult or impossible if the feature is removed.

Without Fixed:

- No classroom or system demonstrations
- No obvious way of doing online system tests at an owner-convenient time.
- No observations of eclipses, planetary transits, occultations, etc.

Without Scheduled:

- Astronomers have to manually determine good times/telescopes for their observation.
- No network benefits (ability to switch telescopes on-the-fly, etc.)
- No automatic rescheduling of failed observations

Without Alert:

- No ability to react to unexpected opportunities such as supernovae or GRBs. Although this is a single reason, GLORIA (being both global and made up of (mostly) physically agile telescopes) is potentially *the most capable scientific instrument in the world* in this realm.

Note: More than anything else, what professional astronomers want of a robotic telescope is the property that *successfully submitting* a job is *a guarantee of execution*. In most cases, observations are not time critical, but the astronomer cannot afford their own time to baby-sit the process. This may be decisive as regards expansion of the network: a network with this property is immensely attractive, a network without is (quite likely) not.

In analysing the software required to support these categories, it rapidly becomes clear that any solution for the Scheduled category can also handle Fixed and Alert categories as special cases. It may be preferable to provide distinct user interfaces, but the underlying engineering is common, and is of the form of an optimising scheduler with constraint-satisfaction (specific time and telescope constraints for Fixed, and higher priority for Alert).

2.2. Interactive vs. Batch

These two observing modes represent different ways of interacting with an individual robotic telescope. In that sense, they are control interfaces (and the associated network protocol) provided at the border between telescope and network whose capabilities define what outsiders are permitted to do.

Common properties of both Interactive and Batch operating modes

- All control connections to and from telescopes shall be encrypted.
- Where possible, connections shall be stateless, and state should be otherwise minimised.
- The protocol should be as simple as possible, with the goal of making third party implementations (both telescope and controller-side) easy to write.
- The protocol shall make the *absolutely bare minimum* assumptions with regard to link bandwidth and latency..

In **Interactive** mode, the telescope is under active remote-control, with semi-direct (mediated by the software on the telescope) access to individual devices such as cameras, filter wheels, etc., and prompt feedback on system state.

In **Batch** mode, the telescope receives an observing script at the beginning of a block of observing time, and executes it via a local interpreter without further interaction with the GLORIA system. In the event of a loss of the network connection, the script shall still complete.

For a telescope to participate in GLORIA, it must correctly implement at least one of these two modes.

Implementation Note #1: Any Interactive-only telescope can be given a Batch facility with a single additional piece of GLORIA tooling - a "loopback" interpreter that reads a Batch-mode script, and generates the corresponding commands, operating the telescope itself in Interactive mode. This could be written once, and run on any GLORIA telescope.

Implementation Note #2: Many existing telescopes do not implement an Interactive mode, (meaning that the universal loopback sequencer can't run), but do already have non-GLORIA batch mechanisms. In such a case, the simplest Batch implementation is probably a custom GLORIA-to-local-dialect translator. This is one reason for stressing the "minimal status updates" for Batch mode - in these cases the program carrying out the observation won't be GLORIA-aware at all. (Yes, some part of the translator needs to pick up the images produced by the local system, and post them back into the GLORIA universe, but otherwise feedback depends either on active polling or on how verbose the local system is....)

3. How to build a network scheduler

A variety of telescope schedulers already exist, mostly using genetic algorithms to find Pareto-optimal solutions (finding the single best solution is considered at least NP-hard). However, they are without exception *telescope* schedulers, not *network* schedulers. The entire "Intelligent" aspect of the GLORIA concept is based on taking the next step - providing a single scheduler that optimises the use of the network as a whole. There is no theoretical problem here, just the practical reality that schedulers are complex pieces of code.

GLORIA is not only a network of multiple telescopes, but a network of *heterogeneous* telescopes, which also puts the project into unexplored territory. The following outlines a solution based on four parts:

- An Observing Plan, a package containing everything the scheduler (and eventually a telescope) needs to know to carry out the observation.
- A telescope-neutral scripting language for defining the sequence of steps of an observation.
- A authoring tool to create, store, recall and modify such plans, as well as submit them to the scheduler
- The scheduler itself.

3.1. Observing plan

An *Observing Plan* represents:

- Everything the *scheduler* needs to know (called Constraints) and
- Everything the *telescope* needs to know (called Instructions).

Constraints:
Observing constraints are not a fixed and finite set, but will include:

- Specific time window
- Specific telescope (or selection from a set)
- Specific filters
- Height above horizon
- Moon separation
- Time after dusk/before dawn
- etc.

Instructions:
The instructions section is either:

- A sequence of instructions (in the scripting language described below), or
- A simple statement indicating that the observation will be run manually.

3.2. Scripting language

GLORIA already has a scripting language available to it: that which RTS2 relies on for its operation. This describes exposure times, filter settings, camera modes, repetitions, etc., and could be extended quite readily to include telescope pointing and constraints (such as distance above horizon, moon-distance, atmospheric seeing, etc.,). What it cannot do (nor can any other solution of which we are aware) is handle telescopes of varying capabilities. Until now, the power and abilities of the instrument were always learned *first*, and all observing plans were made in the light of that knowledge. Without knowing the power of the instrument, it is not possible to choose an exposure time that is neither under-exposed or saturated, but just right.

This can be solved, though not very neatly, by writing instructions in a telescope neutral fashion: specifically by writing exposure times in terms of depth (or signal/noise) rather than time, and to use an automatic exposure calculator to convert for the relevant telescope. (The calibration data required to drive such a calculator is hereby demanded as part of the GLORIA commissioning process....)

While this is not an attractive solution (because it is unfamiliar, because it means that the plan takes different lengths of time to execute on different telescopes), the only alternative is to keep the time fixed, but allow the science to vary (which is not acceptable - images that saturate and where the target is lost in the noise are complete wastes of time).

So what is proposed is a simple language with five verbs, explained individually below:

Verb	Meaning
Target	Astronomical target. The first Instruction must be this, but a plan may have more than one.
Camera	Windowing, binning, and other (possibly very specific) settings
Expose	Commands and exposure: defines timing, repetitions or duration, and filters
Label	No effect, but establishes a marker in for later reference
Repeat	Used after a block of instructions to indicate repetitions of the entire block.

Target: Identified by name (and rejected if unrecognised) or coordinates (both hour-min-second and decimal degrees notations accepted).

Camera: Some of the telescopes have cameras with multiple readout speeds, amplifier gain settings, etc., which (if the telescope owners allow access to them) may permit better science, although the resulting script is likely to be telescope specific. Technically this information belongs with expose, but this information is far more likely to be kept constant, and the expose command already has many parameters attached to it.

Expose: Take one or more identical exposures, defined by timing, repetitions, filters. Note that filters and camera settings (if used) constitute implicit constraints – not all telescopes have all filters, not all cameras possess the same features. Iteration is defined here for compactness and because some cameras can take sequences more efficiently than single frames, and this notation makes it easy to recognise the opportunity.

- Timing parameters
  - Fixed depth (specified by limiting magnitude)
  - Fixed depth, max. duration (as above, but subject to a maximum exposure time)
  - Fixed duration (the traditional version)

- Repetition parameters
  - Once (default)
  - Repeat N times
  - Repeat for T seconds

- Filters: Once filters are selected for any exposure, this creates a constraint that probably reduces the range of telescopes available. Subsequent filter drop-downs should only show those filters on the surviving telescopes.

Note: it doesn't matter if this is exactly correct, as long as it is extensible. The convert-for-that-telescope step happens in GLORIA, and can do minor expansions for telescopes with out-of-date batch handlers. The WWW functions perfectly well with HTTP 1.0 and 1.1 running in parallel, the highest common version is used.

(Proposal: That the authoring tool detects such things as filters used and converts these implicit constraints into explicit ones - adding the corresponding entry into the Constraints section.... unless the user has already done so. The idea here is that writing Constraints by hand is a quick way of checking which telescopes can do the job, but experienced astronomers can skip this, and bash out the script, leaving the software to write in the obvious.)

Label: Free-form text entry.

Repeat: Has a repetitions-or-duration field identical to the Exposure one, plus a drop down menu of Labels defined in already-encountered lines (i.e. not Labels that occur after the Repeat itself - forward references will not be allowed).

Batch Mode Example (please ignore the syntax, the logical structure is what matters!)

```
constraint duration 3600 seconds
constraint moon-distance minimum 60 degrees
constraint altitude target 0716+71 minimum 30 degrees
constraint seeing maximum 1.2 arcsec
constraint filters R,V,I
constraint time after 20120530T220000
constraint time before 20120607T070000
constraint exposure time maximum 10 seconds
target 0716+71
label loopstart
expose mag 17.5 but max 10 seconds x 2, filter V
expose mag 17.5 but max 10 seconds x 2, filter R
expose mag 17.5 but max 10 seconds x 2, filter I
repeat loopstart duration 3600 seconds
end
```

Interactive Mode Example

```
constraint duration 7200 seconds
constraint time exactly 20120530T220000
constraint filters R,I
constraint seeing maximum 1.2 arcsec
constraint altitude target Saturn minimum 30 degrees
target manual
access by token AA5697ZZHGIAGL790
```

3.3. Authoring tool

GLORIA web site will provide an Authoring Tool (see D7.5), which will integrate the different web components for the online and off-line experiments. This Authoring Tool will be used by users in order to easily design and create innovative experiments by using a user-friendly web interface.

The Authoring Tool will be mainly a palette of web components organized by categories. Figure 1 shows how the palette could be, divided by categories. As can be shown, there are two different categories for experiments, one for the web components for the on-line, and the other category for the off-line experiments. The web components will be added to any page of the platform through the drag-and-drop feature.

If someone would like to create a new web component in any category, the administrator will be the responsible for deploying it through the administrative panel, integrating it into the Authoring Tool.

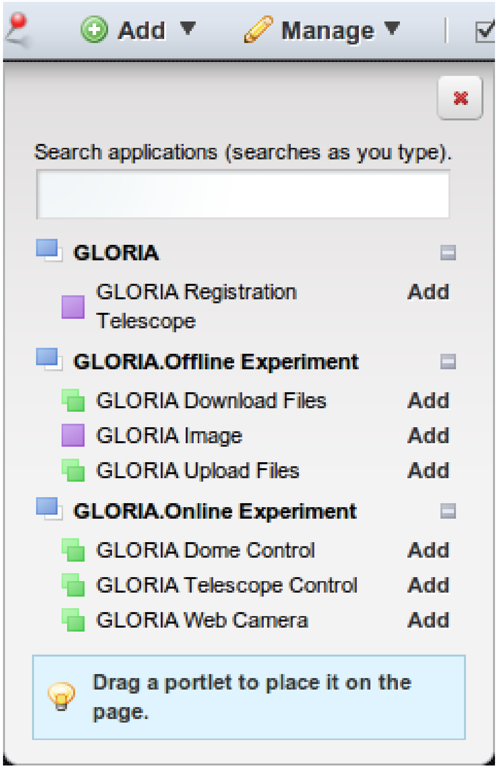

Figure 1: Palette of the web components, the Authoring Tool.

The authoring tool will use the contents of the Constraints, and the Instructions to maintain and update a (visible?) list of which telescopes in the network are capable of executing the script.... if the list is empty, the user is clearly doing something wrong!

Drop-down menus will be used where possible to avoid tedious typing and consequent errors, and to ensure that all relevant options (e.g. possible constraints) are made visible. Where such menus refer to the telescope or instrument capabilities, the options will not be hard-coded, but derived from the published capabilities of GLORIA connected telescopes. Lastly, the authoring tool can submit such Observing Plans to the scheduler, but will reject any scripts that are not executable (i.e. users can expect that a successful submission is a promise of execution).

Since observing constraints are not a fixed and finite set, and because only the scheduler needs a deep understanding of them, their individual specifications do not form part of the authoring tool and they will not be hard coded. However, in order to aid novice astronomers, and to avoid wasted karma/observation time due to a carelessly omitted constraint, the tool could insert certain constraints with reasonable default values into the constraints section of any newly created plan. These default constraints are decided by a configuration setting managed by GLORIA administrators.

3.4. Scheduler

To an astronomer, the sky is not uniformly dark or clear – among other factors, objects are seen more clearly when viewed directly overhead than near the horizon. Given a list of targets and knowledge of a telescope's position, observations can be arranged so that as much observing as possible is high into the sky – as well as meeting other constraints such as distance from the moon, whether the moon is over the horizon, sky brightness just after dusk and before dawn, etc. Generating the *best* schedule is not possible, but generating *good* schedules is an important part of determining what GLORIA will actually be able to achieve – not just the efficiency, but also the *predictability* of the network (and so how users perceive it, which affects the experiments they are interested in).

We do not intend to (attempt to) solve the heretofore insoluble by trying to write a true network scheduler. Instead, accepting certain losses of capability, we will implement something almost as good, far simpler, and more practicable.

Rather than a single, central super-scheduler that attempts to provide an optimal network schedule, we will assume that each telescope has a scheduler of its own (possibly with far more than GLORIA on its mind), and will implement a central "job board", from which observing tasks are advertised to all corresponding telescopes. Telescopes make execution proposals (or simply refuse the job), and the job board chooses the best offer (in terms of observing quality, telescope size, nearness in the future).

In this model, telescopes:

- receive job offers, and reply either with a proposal or a refusal.
- receive proposal acceptances
- send proposal cancellations (if they no longer intend to carry out the job)
- send execution confirmations (if the job has been completed)

The job board:

- receives new jobs from authoring tool
- advertises them and accepts the best proposal (if any).
- receives cancellations and re-advertises the affected job
- re-advertises old jobs that did not initially receive a proposal.

There are a variety of hidden problems in this - job starvation, handling telescopes with different planning horizons, etc. The most obvious objection is the possible "avalanche" problem: an attractive job is advertised, a telescope cancels an existing job to fit it in, causing another telescope to do likewise, and so on, until the entire network is cancelling and re-scheduling everything..... and this happens every time a user submits a job! In practice, this can be minimised (boost a job's priority as soon as a telescope accepts it - make it harder to unseat), and there will be occasions where it is absolutely desired (analogy: when an ambulance with blaring siren comes up to heavy traffic and red lights.... the road should clear, and the side-effects of clearing the way should not be allowed to be relevant).

3.4.1. Scheduler queues

It turns out to be a valuable (i.e. necessary!) feature to have multiple scheduler queues (equivalent to job categories). Both maintenance and alerts require the disruption of ordinary observation, but may themselves require the mechanisms of a scheduler. The obvious solution is that they *are* implemented as scheduler queues, but working at a different (higher than normal) priority. There are two basic approaches - a single scheduler with multiple queues vs. multiple schedulers with a single queue each, and a priority system at the telescope.

With a **multi-queue system** (a.k.a. "telescope-doesn't-know"), the central job board uses a priority boosting scheme to effectively force each telescope to observe all high-category jobs before considering any lower. Which telescopes are enrolled in certain optional GLORIA programs is maintained in a database table, and the scheduler uses this to determine which telescopes can be commandeered for an event. As far as the telescope is concerned, it's an abrupt change in the observation, but that's all it knows.

With **multiple single-queue schedulers** (a.k.a. "scheduler doesn't know"), a priority scheme is implemented at the telescope side, with one scheduler at each priority level. (Note: this discussion takes place in light of the fact that RTS2 already supports this feature). The telescope maintains conversations with multiple schedulers, and abruptly releases jobs that came from a low-ranked scheduler as soon as a higher-ranked task appears. Pre-empted schedulers do not know why the telescope suddenly did this. Which telescopes are in which programs is now stored in a simply priority list on the telescope itself.

In either case, maintenance mode is simply a high priority job via a mechanism that is available only to administrators and telescope owners

4. Online Experiments.

4.1. Interactive experiment

Most interactive experiments will be based on the free software Ciclope Astro, which provides a web interface for a single user to directly control the various devices of the robotic telescope such as mounts, cameras, domes, filter wheels, focusers, etc. It is expected that the most common use will be for maintenance and testing, or possibly during live demonstrations. Some teleoperation software, such as xobs, the CCD Commander interactive component has been tested teleoperating a telescope, shown in Figure 2.

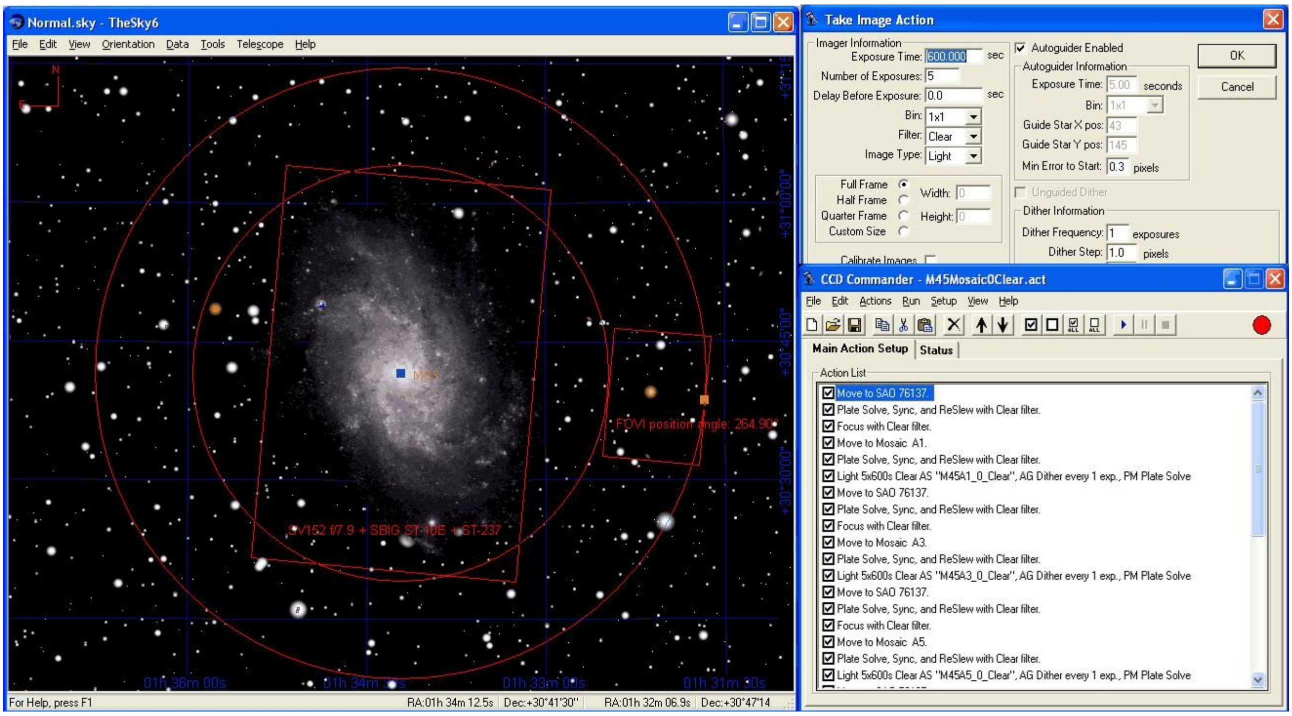

Figure 2: Xobs, CCD Commander component for interactive teleoperating a robotic telescope

However in GLORIA, there is a wide variety of hardware, plus the (internally discussed) need to create different control panels for different users – most users do not need (and therefore should not have) the ability to independently control individual devices such as filter wheels or focusers. Owners, however, do have such a need.

The requirement for different control panels for the same hardware strongly suggests a modular approach, with panels assembled from plug-together web components. Ciclope Astro meets this requirement, and is already in use. Figure 3 shows a caption of Ciclope Astro in Montegancedo Astronomical Observatory for observing the Sun in H-alpha frequency, oriented towards taking images of it. Figure 4 shows another web interface this time designed for educational purposes oriented towards the students of Topography in the UPM (Universidad Politécnica de Madrid).

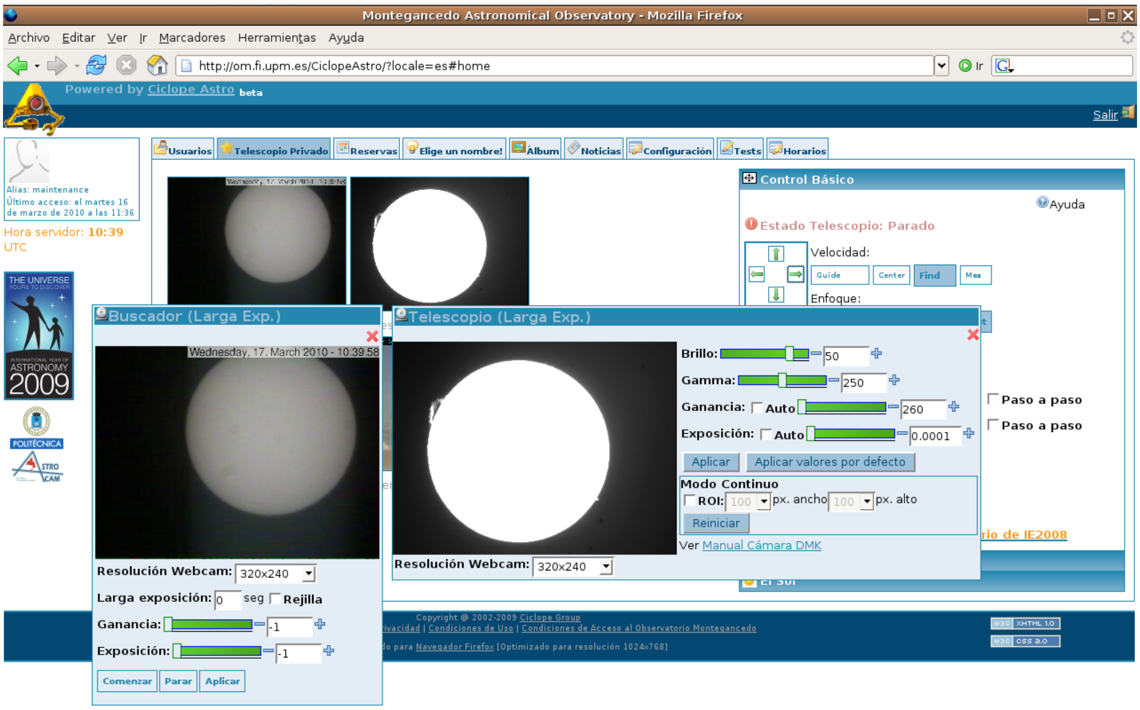

Figure 3: Ciclope Astro web interface in Montegancedo Astronomical Observatory. This interface is designed for observing the sun in H-alpha and adjusting the camera for taking images, which can be used, for example for counting and measuring the Sun spots.

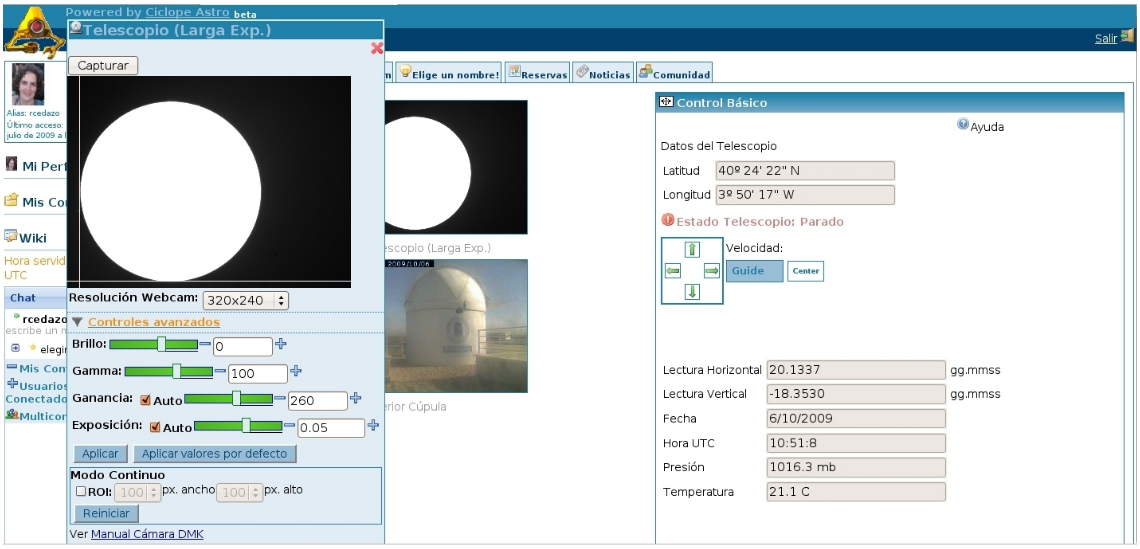

Figure 4: Ciclope Astro web interface in Montegancedo Astronomical Observatory. This interface is specially designed for the students of topography in UPM. By aligning the Sun with the vertical a horizontal lines and measuring the time and the telescope coordinates the students can calculate the geodesical position of the observatory.

4.2. Batch experiment

Batch experiments can be of many different types depending on their educational or research goal. However, in each experiment one can define 3 steps needed to define the batch operation. Depending on the experiment, these steps have to be reflected in the user interface.

1. The interface should allow for at least two modes of target selection:
   - Choice from predefined target list for example in educational level experiments list of interesting objects can be prepared; separate lists can be accessible for different types of experiments eg. lists of Cepheids or binary stars
   - defining arbitrary object by its coordinates (or specifying arbitrary field in the sky, which should be covered)

2. After selecting a target, observation mode has to be selected as well. For some of batch experiments it will be predefined (set by the designer of the experiment), in other cases it can be left for the users decision. Possible choices include:
   - Single observation (can include predefined time window)
   - Monitoring of the object (eg. of variable star) time intervals for subsequent observations should be defined
   - Multi-wavelength observations - when user requests eg. simultaneous observations in different filters

   The simplest type of batch experiment, and the first one to implement should be based on single scheduled observations. Other options, which are much more complicated as the observation scheduling is concerned, will follow after the scheduling system is well tested and understood.

3. The last step, after target and observation mode are defined, is to define observation parameters as exposure time or required sensitivity, telescope and camera configuration (eg. filter setting, image binning) and constraints (eg. selecting particular telescopes). Here again, for some of the experiments these requirements can result from the target selection (predefined for each target or calculated by the dedicated procedure), in some cases users will be able to select observation parameters by themselves.

   [One of the possible choices for on-line batch experiment is described in more details in TEC-00704.]

4.3. Alert experiment

A standard Alert programming interface will be designed for GLORIA schedulers. If single-queue schedulers are used, then only specific Alert schedulers will offer it. The message carrying news of the event will normally contain enough information to complete an initial Observing Plan OP (probably relying on some fill-in-the-coordinates type templates written by humans), and this is sent to one or more participating telescopes.

Note: there is deliberate ambiguity here as to where the OPs are generated - passed in with the alert, or generated by the scheduler itself. Given that Alerts are greedy for time, they don't share their scheduler with any other experiment, and for a single-experiment scheduler, it doesn't much matter on which side of the interface the work is done. The only reason to have an interface at all is to clarify how to write the message-handler part of an Alert scheduler.

In responding to Alerts, there are new forms of Observing Plan - the "broadcast" (where all telescopes get the same effective instructions, modified for their abilities) and "smart" (where different telescopes get different OPs specifically to target the object in multiple wavelengths and/or time sampling). There are also multi-step responses, where a first observation is done on a single instrument to determine better parameters for others (or even just to confirm that the event is real). Smart and Multi-step Alerts are *not* expected to be implemented under GLORIA, but the possibilities are there, and make it clear that Alert schedulers are likely to be strange and experimental animals long after the basic optimising scheduler is stable. The VOevent (http://en.wikipedia.org/wiki/VOEvent) is a possible type of alert that the system is going to manage.

5. The first generation on-line Experiment: Experiencing the solar activity

5.1. Objectives of the activity

The monitoring of solar activity through continued observation of the surface is an interesting project that will apply the scientific method. The objectives to be achieved are:

- Apply a methodology for calculating a parameter astrophysicist (Wolf index) from an observable (digital images) as a technique for teaching applications, documentaries and research. Apply knowledge of basic statistics and solar physics.
- Understand and apply basic analytical techniques of images (counting active sites, orientation, scale, ...).

5.2. Instrumentation

The on-line experiment will make use of the solar telescopes of the GLORIA network, currently the Solar TAD (Open Telescope Outreach, http://www.ot-tad.com), and Montegancedo Robotic Telescope (http://om.fi.upm.es).

5.3. Description of the Phenomenon

The Sun, for its proximity, is the star that can be studied in more detail and in which to test theories about the behavior and stellar evolution.

5.3.1. The Sun

The Sun is part of the 200,000 million stars in the Milky Way, but for us is the most important since it is only at an average distance of 150 million kilometers from Earth and is the main source of energy for our planet.

With a diameter of 1.392.000 km (to be compared with the Earth's one of 12.756 km at the Ecuator), it contains 98,6% of the entire mass of the solar system. The age of the Sun is estimated at about 4.500 to 5.000 million years. It is undergoing through the intermediate stage of their life in the so-called main sequence, thanks to a stable balance between the thermonuclear reactions that occur inside stars, which serve to transform hydrogen into helium, and gravity, which tends to crush them. The sun is expected to continue evolving and last for another 5,000 million years. The sun has several distinct layers, which can be divided into inner and outer relative to the surface or photosphere.

Inner part
It consists of layers that are not directly observable. The photosphere, a layer of about 300 km thick can be seen as the separation zone between the interior and the solar atmosphere.

The core
Is the central region of the Sun, with a temperature of about 15 million degrees. Here comes the star power, so that every second 564 million tons of hydrogen fuse, termonuclear, at 560 million tons of helium. Hydrogen nuclei (protons) become helium nuclei at a rate of four to one, but there is a mass difference that is released in the form of energy, since the four protons are slightly heavier than helium nucleus formed. This difference is due to four million tons per second that are surplus to transform hydrogen into helium.

The radiative zone
The first part of the transport of energy generated in the core is performed through a layer that surrounds it, by means of high energy radiation that is continuously absorbed and re-emitted.

The convective zone
The Sun has several layers above the radiative energy which is transferred to the surface or photosphere by convection phenomena. The result of these convection currents can be seen in the photosphere as granulation. All the photosphere is crossed in a similar cell pattern, by their geometry, like grains of rice. These cells are the top of each of the updraft column-hot-and-downward-cooler energy transport. The dimensions of this granulation is considerable: each "grain" is about 800 km in diameter.

The photosphere
It is the visible solar surface directly (with adequate protection), with an approximate temperature of 6.000 C. It may be phenomena like sunspots, which we discuss later, and by which it is possible to measure solar activity.

The Sun has a global magnetic field with an average intensity twice that of Earth. But in the vicinity of the spots the local magnetic field intensity is much more intense. It is generally believed that all phenomena of solar activity are determined by processes related to solar magnetic field.

Figure 5: Sunspots observed during the course of the transit of Venus.

Outer part
From the photosphere, photons can pass through these layers and disperse in space, so these areas are observable. The chromosphere it is a reddish layer enveloping the photosphere of about 10.000 km thick. It projects gas at very high temperatures and protrude protrusions, a kind of flares being thrown into space at enormous speeds and can reach several hundreds of thousands of kilometers in altitude.

Both the chromosphere and prominences can be seen directly in the moments of the totality of a total solar eclipse under normal conditions is necessary to use special devices or filtering provided for observation.

Corona

Above the chromosphere lies the corona, a sort of halo structure along the lines of force of the solar magnetic field. Comprises a gas temperature of more than 1 million degrees but with very low density, so that generates little heat and light. Its boundaries are imprecise, so much so that it can be seen that the earth is immersed in its outer regions where, in addition to the gases, dust particles are abundant. The solar corona is visible to the naked eye during the whole of a total solar eclipse .

5.3.2. Solar activity

Solar activity is manifested in the observable three layers of the Sun: the photosphere, the chromosphere and corona. This activity is propagated to Earth in the form of radiation and particles (so-called solar wind).

The photosphere is the visible layer is most easily observable. The most characteristic manifestation of solar activity are sunspots that appear on the surface of the sun. Although sunspots had been detected with the naked eye for several centuries before our era, they were not systematically known and registered as such until the invention of astronomical telescope (year 1610). Early observers soon perceived that they were not immutable, but had a duration and a variable size.

The German naturalist Heinrich Schwabe discovered in 1843 that the spots appeared to have a period of 10 years, which was confirmed in 1855 by Rudolph Wolf who found a periodicity of 11 years, known for Solar undecenal cycle.

In 1859 the Englishman Richard Carrington discovered that the Sun had a differential rotation, so it spins faster in Ecuador at the poles. Also found that the average latitude of the spots varies with time. At the beginning of the activity cycle spots appear near the latitudes of 30 ° for, as the cycle progresses, increasingly form close to Ecuador, being located at the maximum near 10 ° latitude. In fact the solar cycle is twice as long, some 22 years as every 11 years is a reversal of the solar magnetic poles and 22 years is the time it takes for the Sun returns to its original configuration. All cycles are not equal, but its duration and intensity vary. The shortest record for a single cycle was 7 years and the longest 17 years. It has also been exceptions to the cycle, as detected by EW Maunder in 1893, which showed that for 70 years, between 1645 and 1715 sunspots virtually disappeared (in his honor called "Maunder minimum"). Studies point to the existence of other similar to the Maunder minimum in earlier periods. Geological investigations show that millions of years ago and there was a period undecenal solar, so that in a long cycle time scale is a solar phenomenon undecenal permanent, although there are many indications that its intensity can vary widely.

The solar activity cycle are numbered from the maximum of 1761. Currently (2011) we are in the cycle No. 24, hoping to start its 24th period of solar maximum in mid 2013, according to the latest predictions (Fig. 5), so the proposed on-line experiment seems timely.

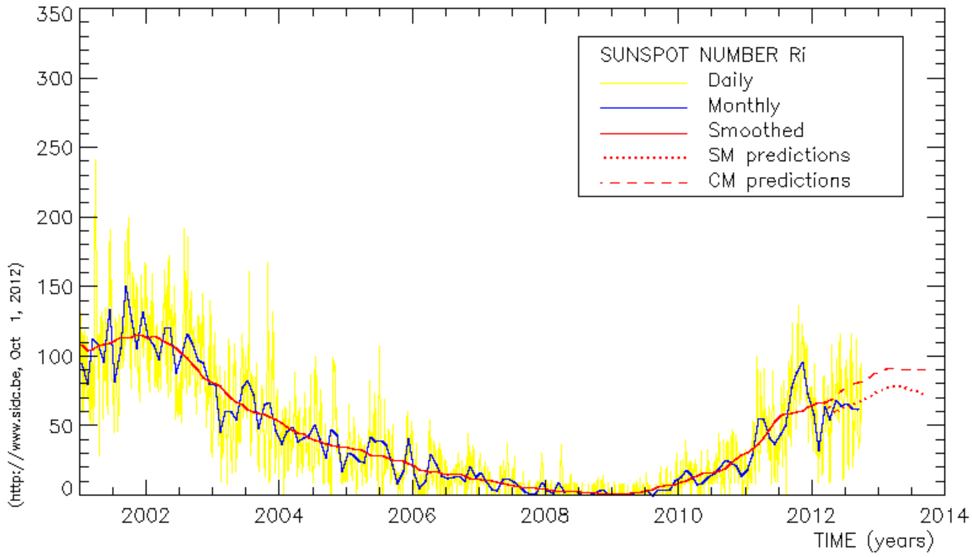

Figure 6: Solar activity plot (sunspot number against time). After the 2002 last solar maximum, predictions indicate that next maximum should occur around mid 2013.

5.4. Methodology

5.4.1. Systems - observation of the photosphere

Solar observation requires security measures to be tightened. Therefore we only indicate the safest methods of observation.

Sunscreens
Filters must be used to place in the aperture of the telescope specially designed for this purpose. The flexible sheet should be metallic, that can be adapted to different sizes or glass mount different diameters. In general it is the preferred method. The filters are placed directly in the eye should be disposed to be dangerous because of the risk of breakage by concentrated solar heat.

Projection
Preferably used with type refractor telescopes. It projects the solar image (no filter) on a white surface perpendicular to the optical axis of the telescope. Consider creating a dark environment around the projection screen to increase the image contrast and better visualization of the structures. This method allows the simultaneous observation of several people.

Helioscope (Herschel prism)
Recommended for refracting telescope. Consists of a prism placed in the eyepiece holder, diverting 95% of the incident light. It is also necessary to use an absorbent filter density (3).

Other methods
There are other alternatives such as using reflecting telescopes with primary mirror without aluminizar (or both mirrors, also the secondary). This requires a dense filter into the eyepiece holder, but without danger of breakage. This telescope will be unusable for other astronomical observations.

5.4.2. Training photospheric

Looking at the photosphere can capture a series of amenities and features formations.

Limb darkening
The center of the sun is brighter than the edges. This phenomenon is caused by absorption of part of the light by itself solar atmosphere.

Granulation
As mentioned, the photosphere is formed by a dither cells that make the solar surface appears rough. These "grains" are convective currents produced in lower layers with a duration of few minutes.

Stains
Areas are darker than the photosphere because of lower temperatures (2000 C lower) and are tracers of magnetic activity of the sun. Typically a sunspot consists of a dark central region called the umbra, surrounded by a lighter or twilight zone, consisting of light and dark filaments which start radially from the umbra. The average diameter of the penumbra is usually about two and a half times that of the shade, but in highly developed groups can represent up to 80% of the total area of the stain. If the stain is small and has no darkness in this case is called pore.

Faculae
Can be seen near the limb, such as areas brighter than the rest of the solar surface. They are associated with the spots and have a duration greater than these, often appearing before the stain and then disappear. They can be seen in both the maximum and minimum in the cycle and is a good indicator of electromagnetic activity and that often results in spots most of the time.

5.4.3. Register of sunspot activity

The spots come from the east of the sun disk and brought in the west. Appear confined between latitudes 5° and 40° (North or South). The lifetime of sunspots varies from several days to weeks. The apparent displacement of the spots by the disc is due to the rotation of the sun, although some may show small motions. A spot Ecuador never crosses the sun, always in one of the two hemispheres, north or south.

5.4.3.1. Heliographic coordinates

The solar rotation axis is tilted to the plane of the ecliptic (about 7 degrees), as well as the axis of rotation of the Earth (about 23 degrees). The combination of both inclinations causes, over the year, a deviation from the solar axis relative to the direction North-South and an inclination of Ecuator regarding the visual.

To determine the correct orientation of the solar disc three parameters must be known:

- The heliographic coordinates.
- P, the position angle of the north end of the axis of rotation measured from the northern point of the disc, positive and negative east to west. P varies between + / - 26.3 °.
- B0. The heliographic latitude of the center point of the solar disk. Is due to the inclination of the ecliptic to the equatorial plane solar. Ranges from + / - 7°.23.
- L0, the heliographic length of the central point of the disc. The length value is determined by a fixed length with a variation of 13.2° / day. The initial meridian is defined as the meridian that passed through the ascending node of the solar Ecuador June 1, 1854 at 12:00 UTC, being calculated to the date this sidereal assuming a uniform rotation of 25.38 days (the rotation period synodic Carrington rotation or 27.2753 days).

To calculate the coordinates of a spot or detail, measure its position on the apparent disk and then make the necessary corrections according to the heliographic coordinates of the moment of observación.2

5.4.3.2. The number of Wolf

Swiss astronomer Rudolf Wolf in 1848 introduced a method for registration of solar activity from counting the number of sunspots visible, known as index number or Wolf or Zurich (or worldwide as International Sunspot Number). Before calculating the solar activity by the number of Wolf definitions it is needed to take into account some corrections.

Sunspot groups: A group of spots (with penumbra) and pore, or individual pores, close together and evolve together. For its calculation will use the classification of Zürich (see section 4.3.3).
Spotlights: both are called foci spots as individual pores. For example, if within a spot there are 2 Umbrian they will consider to have 2 focus.
Unipolar group: A spot or stain a compact group with a maximum distance between the ends do not exceed 3° blueprints.
Bipolar group: Two spots or a group of several spots extending in an east-west a distance of 3° blueprints.

The Wolf number (W or R) is obtained from the following expression:

$$W = K\,(10\,G + f)$$

- With K is a statistical correction factor applied by the international center coordinates and reducing the observations, so that to obtain directly the value W is K = 1.
- With G represents the number of groups visible. A single pore counts as focus and as a group.
- With f is the total number of foci of all stains, as explained above.

The minimum activity or Wolf number is 0 (in case you are completely clean the solar surface), then going to 11 because one group on the solar disk with a single focus would be G = 1, f = 1, therefore, W = 11. From 11, you can follow the consecutive values of the natural numbers (12, 13, 14, ...). We can roughly calculate the number of individual spots on the solar surface if we divide the index or sunspot Wolf number by 15.

5.4.3.3. Classification of Zürich

Counting the number of groups to calculate the number of Wolf is based on the Zürich classification of sunspots.

The spots usually appear in groups. Ideally a group consists of two spots of opposite magnetic polarity, extended in the direction of the parallel multi-spots and pores in the intermediate part. Following the classification of Zürich, a spot well developed plays all types: A, B, C, D, E, F, G, H, J, ending finally in the A, but this happens only rarely. The type F is poor and usually evolve stains from type E to G. Many groups only get to develop to the D and most are in states A, B and C.

The duration of a group may be a few hours to a pore, to several months for the most evolved. The emergence and subsequent development can be very fast, from types A, B, C, D, E to F to get to in a week or 10 days, while the decline (types G, H and J) may be considerably longer. That's not unusual to see a stain persist H or J type for a couple of solar rotations.

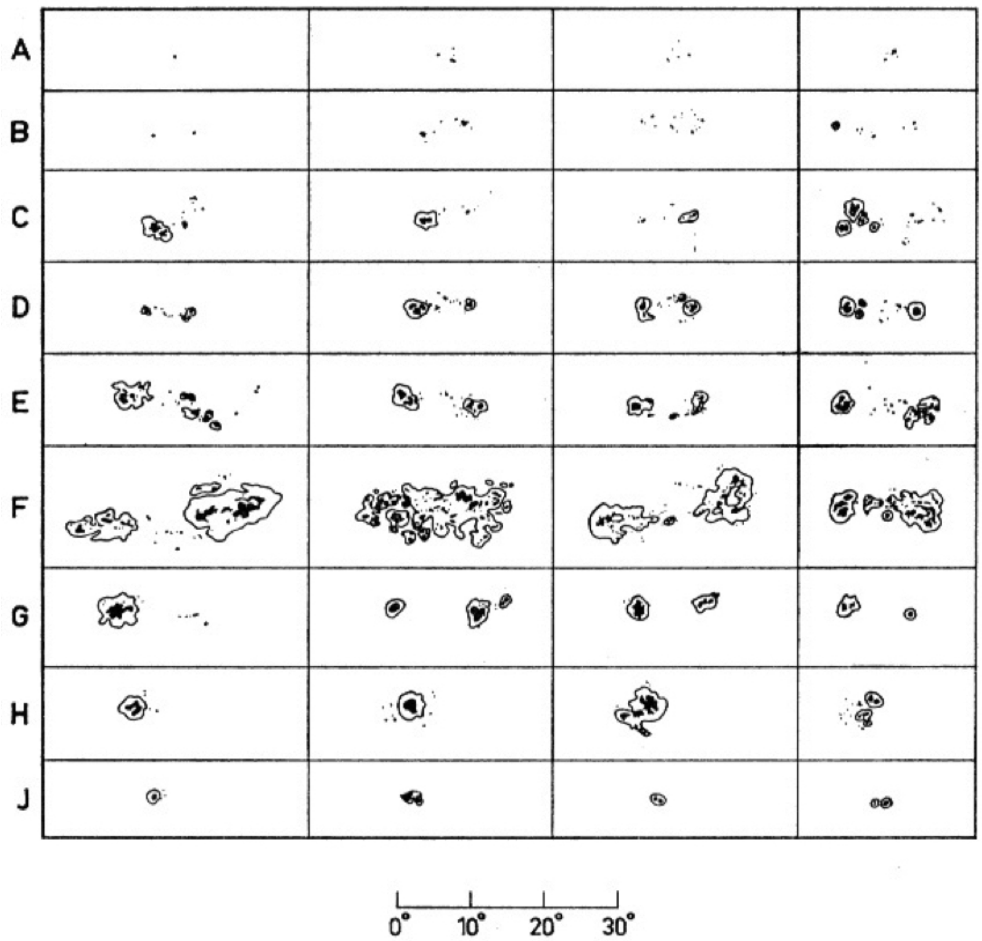

Figure 7: Zürich classification of sunspots. It shows four examples of each type and scale in heliographic longitude.

The Zürich classification is based on the magnetic polarity in the presence or absence of penumbra (in the latter case if present on one or both ends) and the extension of the group in longitude blueprinting. By imaging can determine the area and position of sunspots and calculate the index of solar activity. It is also recommended statistics on the number of spots in each solar hemisphere.

With images it can determine the area and position of sunspots and calculate the index of solar activity. It is also recommended statistics on the number of spots in each solar hemisphere.

Difficulties. It may be difficult to determine between two entirely different types of groups, for example, a type C and a type H. By observing the evolution of the group, it may possible to determine its classification, but this would not affect the calculation of the number of Wolf.
Sometimes the differences from one type to another (D and E, E and F, F and G, H and J) can only be established by the extension in length of the group. In this case, a template should be used, displaying the meridians and parallels of the Sun to determine the size of the groups which may be conflicting.
It can also be difficult to find out if a set of spots or spot corresponds to a single group or two. For being able to know exactly should be measured their magnetic polarities, both experience and observation on successive days will help the decision.

5.5. Internet Addresses

- Solar activity: http://sidc.oma.be/index.php3 and http://www.swpc.noaa.gov

- Solar Cycle Prediction: http://solarscience.msfc.nasa.gov/predict.shtml
- National Solar Observatory / Sacramento Peak (USA), images and daily data: http://nsosp.nso.edu/data/latest_solar_images.html
- Solar images (SOHO, ESA): http://sohowww.estec.esa.nl/data/realtime-images.html
- Solar Physics, Marshall Space Flight Center (USA): http://solarscience.msfc.nasa.gov

6. The second generation on-line experiments

A number of potential second generation on-line experiments have been also considered, which could be implemented in the near future. Amongst them: Earth movement, the Personal space (with Pi-of-the-Sky), confirmation of supernova candidates, etc.

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