

# Solar Monitoring Program at Kanzelhöhe Observatory

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Kanzelhöhe Observatory has long time series of full disk solar observations in several spectral bands with high time cadence. Recent and planned instrument upgrades extend spectral and temporal capabilities; cooperation with Hvar observatory increases the spatial resolution of the data sets. Data are available through our on-line archives and might be useful for collaborative studies with other partners during the IHY-2007.

## Introduction

Kanzelhöhe Observatory (KSO) can be considered as the experimental executive of its hosting institution - Department of Geophysics, Astrophysics and Meteorology (IGAM), University of Graz. Therefore KSO is devoted to the observation and instrument development for Solar Physics and Environmental Research with emphasis on atmospheric physics. In the latter field KSO participates in the Austrian UV-B observing network [1], NASA's Aeronet [2] and operates a climate monitoring station as well as solar irradiance sensors. In Solar Physics, the branch which will be considered in this article, KSO has specialized to solar monitoring programs in order to track phenomena of solar activity as continuous operation all over the year yields about 300 days or 2000 hours of observations per year. Science objectives which were investigated by extensive use of Kanzelhöhe data are the physics of solar flares and related phenomena like, e. g., Moreton waves and CMEs [e. g. 3, 4], development and properties of sunspot evolution and proper motion as well as various aspects of the solar rotation [5] and solar cycle evolution [6, 7].

KSO supports also several data centers and international collaborations:

- Sunspot Numbers for the Solar Influences Data analysis Center (SIDC) in Brussels, see e.g. <http://sidc.be>;
- Flare patrol for the Solar Geophysical Data Center of NOAA, Boulder, Colorado, USA;
- Global H $\alpha$  Network, lead by Big Bear Solar Observatory, California, USA [8, 9];
- Debrecen Photoheliographic Data (DPD) [10];
- Ground Based Observations support for SOHO, RHESSI.

A milestone for availability and acceptance of data from KSO was the introduction of the online archive services which are discussed later in this article, practically all synoptic and recent observations are published on the WWW. Participation in AGRID, the Austrian grid computing initiative [11] will boost the capabilities of the archives in the International Heliophysical Year - 2007.

## Instrumentation and observing programs

For the investigation of solar activity phenomena which show a fast temporal evolution one needs time series of relatively high cadence of one or more images per minute in several spectral bands as different wavelengths reveal the related phenomena in the layers of the solar atmosphere. KSO has designed its instruments

to image the full solar disk; observations with high spatial resolution can be obtained e. g. by Hvar observatory which observes in the same bands using same techniques and will moreover publish their data in common archives in future.

The main patrol instrument at Kanzelhöhe consists of separate refractors for each observed band packed on a common equatorial mounting. The diurnal movement of the Sun is tracked basically time-controlled, but fine tuning is accomplished by deriving control vectors from the disk position in the field-of-view by analyzing the current image of a H $\alpha$  cam by the means of image processing.

### Sunspot drawings

Sunspot drawings are obtained by using a refractor ( $d/f = 110/1650$  mm) and a projection system with a zoom lens in order to enlarge the disk image to 25 cm diameter. The drawings are made on a daily base, weather permitting. In our archives we have a comprehensive series of more than 60 years, although there were technical changes in the instrument, this data set is well suited for long term studies and therefore still continued.

By use of the drawings we derive the daily sunspot relative numbers and provide an easy and quick impression what is going on the Sun as we scan and publish the data on the web. Therefore they are well suited for targeting high resolution instruments. An example of a drawing is shown as Fig. 1.

Several studies on differential solar rotation and distribution of active regions throughout the solar cycles were performed on the basis of these drawings [e. g. 12, 13, 14].

### Broad-Band Imaging

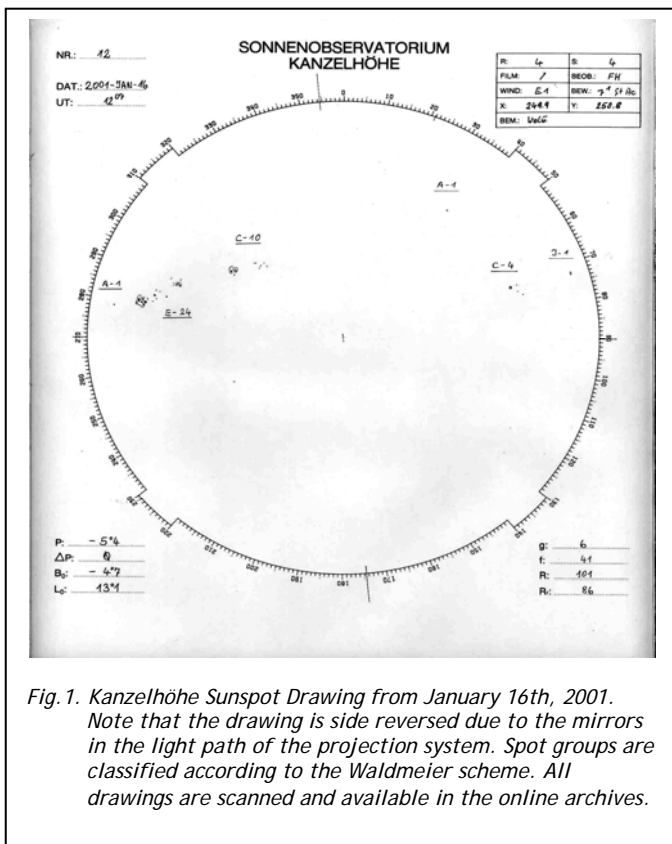
In 1990 an imaging system for the continuum in the 546 nm range (FWHM 10 nm) went into operation (nick-named Phoka for Photosphere Camera [15]). Special emphasis in the instrument design was put into low image distortion in order to achieve highly accurate sunspot areas and positions. Basic instrument parameters are: refractor  $d/f = 130/1950$  mm, primary focus image enlarged to 87 mm disk diameter which is recorded on a high resolution b/w film (13x16 cm plates). By default a set of 3 images per day is made for the DPD. The exposures are not yet scanned/digitized routinely for the archives but an online catalogue is in preparation.

Currently this instrument is under reconstruction as we will introduce a digital image acquisition system with a CCD camera and a frame grabber similar to the system which is already in use for the H $\alpha$  imaging. It will employ

a 2kx2k pixel camera with 10 bit and a frame rate of about 10 frames/sec which allows us to use frame selection techniques to benefit from moments of good seeing. The intended image recording rate will be about 1 image per minute or even faster to track photospheric changes during flares. We hope to come into operation by end of 2006 and support the IHY-2007.

### *H $\alpha$ Imaging*

Observation of the solar chromosphere has a long tradition at Kanzelhöhe. Since 1975 full disk observations in the spectral line H $\alpha$  were made by using the same telescope: a refractor with  $d/f = 100/2000$  mm and a Zeiss Lyot filter with 0.07 nm FWHM. Until end of 1999 the data were recorded on film with a cadence of 1 image per 4 minutes.



In 2000 we adapted the system for digital image acquisition and used a Pulnix TM-1001 1 Mega Pixel CCD camera with 8 bit. The feature of an electronic shutter enabled a short exposure time of about 2 msec at a frame rate of about 15 frames per sec which is used to benefit from moments of good seeing by applying frame selection. As a measure for the image quality we calculate pixel contrasts in a small image segment, this can be done very fast by the frame grabber logic. The exposure time is controlled by the image acquisition software to keep the image brightness fairly constant on changing solar disk intensity due to varying extinction in the atmosphere. In mid 2005 we could upgrade the system with 10 bit version of the cam (Pulnix TM-1010), a new frame grabber and new image acquisition software. An example of these observations is shown in Fig. 2.

The Zeiss Lyot filter can be tuned within limits by rotating the polarizers, therefore we can obtain optional observations in the line wings of the solar H $\alpha$  line. Line wing images show e. g. hot flare kernels much conspicuous due to the thermal line broadening or give the ability to construct a kind of Doppler images by combination of blue and red wing frames. The polarizers are rotated by a stepping motor which is software controlled and can be linked with the image grabbing application, so we can have a programmable set of image sequences at user defined acquisition rates. The upper limit of the cadence depends on the time needed for the filter tuning (5 sec.) and the time for writing onto the hard disk. A detailed description of the instrument is given in [16, 17, 18].

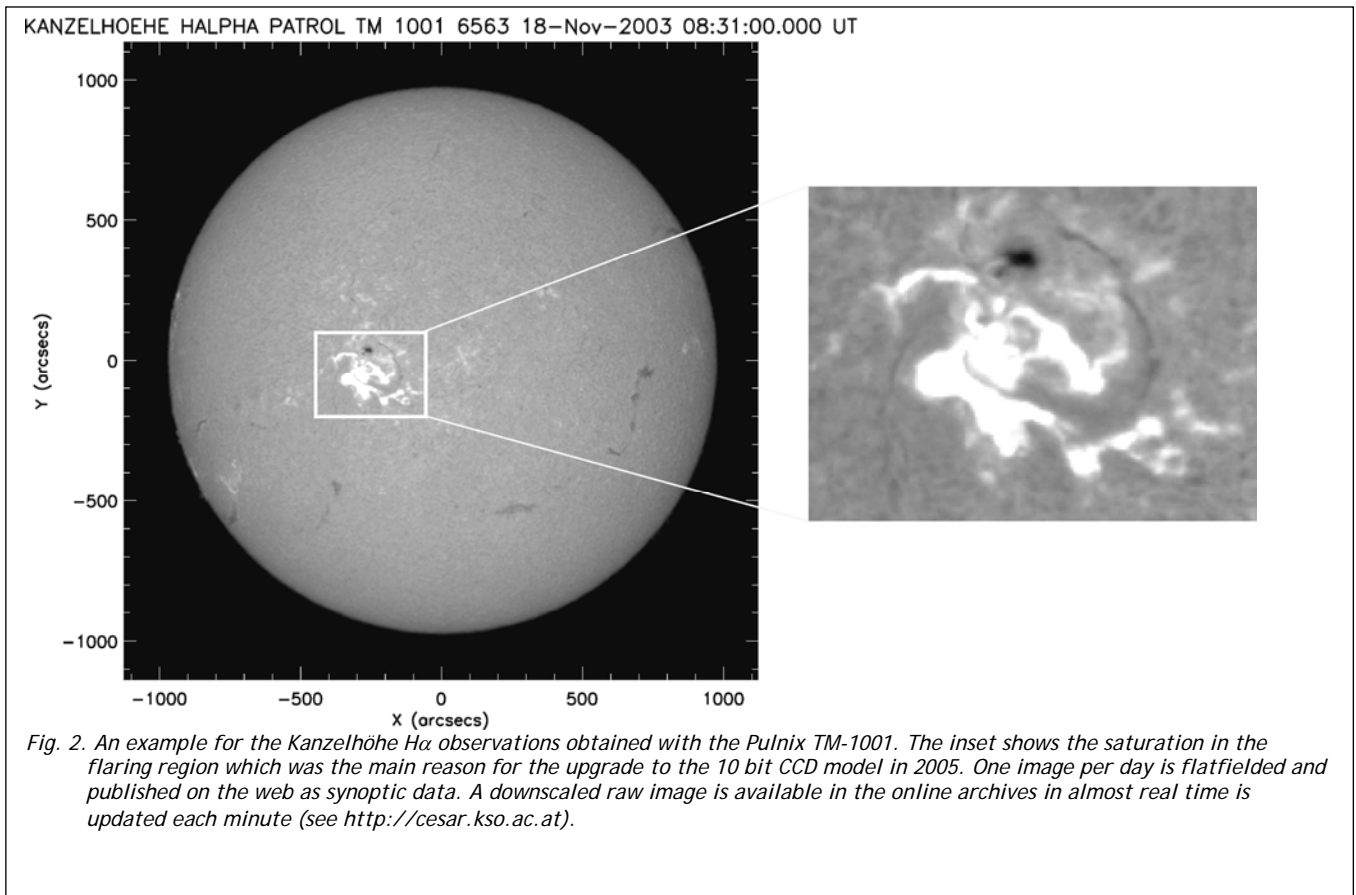
The standard observing mode is to save 1 image out of a frame set of 15 images (obtained in roughly 1 sec) each 5 seconds, after passing a quality control which checks for extreme under- or over-exposure and fragmentation of the disk due to passing clouds, we select and keep 1 image per minute by applying the optimum window method [19] during quiet solar periods and discard the rest after a while depending on the available hard disk capacity. For active periods we archive always the full set of images. The determination of active and quiet periods was made by evaluation of the GOES 1-min X-ray flux and the reported flare events from SEC. On special request or for certain research projects, as currently for the investigation of micro flares, we can keep the full temporal resolution for all observed periods.

Since 2000 KSO is one of the base stations of the Global H $\alpha$  Network (GHN), a world-wide collaboration of H $\alpha$  observing stations. In order to have comparable instrumentation at the different sites a 4 Mega Pixel 14 bit CCD camera (Apogee KX4) was attached to the H $\alpha$  telescope via a beam splitter. The high spatial resolution of this CCD camera is diminished by the disadvantages of the mechanical shutter and a slow read-out which prevents high frame rates. The cadence limit is about 1 image per 10 sec., the exposure time is preselectable by the observer (normally set to 30 msec) but not adapting. The standard observing mode for this camera system is thus set to 1 image per minute according to other member stations of the GHN and regardless to the actual solar activity level. Of course a quality checking procedure discards again heavily corrupted images.

### **Data management and archiving**

A data management and archiving system has two purposes, first it has to assist a potential data user in the data mining and retrieving process. Second, it should support the observer/operator to perform the observations and manage the data flow to the archives.

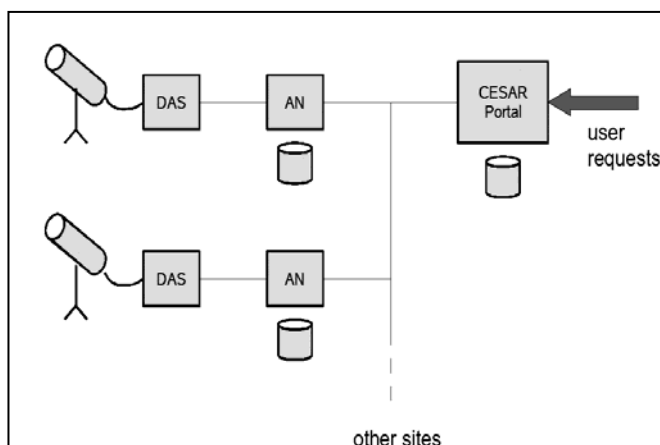
Soon after the reasonable availability of digital image acquisition systems and scanners we started with the introduction of the Kanzelhöhe Electronic Archives System (KEAS) to cope with the second challenge. It helps the observer by asking for data in webforms and logging instrument activities and data processing steps as well as managing the data standard processing,



transfer to the final archives and the building of a searchable data catalogue.

From the viewpoint of a data user the archives should answer the following questions:

- Are the desired data available, or which data are available and do they match my needs?
- Where are the data available and how?
- Get the data!
- How to use the data? Explanations and limitations of the data.



Of course, finding many data sources available in one single portal would reduce the efforts of data mining enormously.

As a first step we will include the observations from Hvar Observatory, Croatia, into our archives (as Central European Solar ARchives – CESAR). In order to implement such a one-stop-shop we derive daily synoptic data products from the observations and present observing logs of the instruments as well as a searchable data catalogue. The direct access to the data repository via web services is under construction. For security reasons the public web portal (<http://cesar.kso.ac.at>) is separated from main archives site and works on data base replications.

The archives system was implemented by using well established techniques, like NFS to build up the online data repository, a MySQL RDBMS for the data catalogues and repository for numerical data and an Apache web service for the user interface. Although we used high end quality hardware and RAID systems for the data storage it proved that this monolithic archives were vulnerable to hardware malfunctions as it contained several single point of failures.

As a solution we are splitting up the system into a grid of independent logical archives nodes (AN), one for each instrument (Fig. 3). The AN can handle the data standard processing, the transfer into the data repository which is locally on the AN and maintains the instrument's data catalogue including the specific observing log. So one instrument can observe independently from others or a working network environment. The common portal which handles the user queries has to know only about

the existence and the address of the participating AN. In case of a malfunction only one single instrument fails, or no user query can be processed during the problem. Another advantage is that participating AN can even be distributed over far distances as communication is only needed during queries. Application of grid technologies and web services enables working over unsafe or unreliable networks. Presently this system is under development and should be operational for participation in campaigns for the International Heliophysical Year - 2007.

### Data formats and description

Except raw data which exist in generic formats for technical reasons we archive all data in public formats. Although we have image data also in JPEG format (e.g. scanned analogue images, like our sunspot drawings) FITS is the standard for the basic archives. Generally we archive raw data and perform data reduction on request. A limited set which is called "synoptic data" (e.g. 1 image per day and instrument) is processed by default and published on our web service in several formats. The processing comprises dark current subtraction, flat fielding as well as contrast enhancement and center-to-limb variation compensation. A detailed description of the processing and the formats will be available soon in our online archives or can be found partly in [16, 17]. For the FITS keywords and the file naming syntax we follow generally the rules which were proposed for SOHO [20].

### Data policy

Free access is granted to the data which are available via our web service, we ask only for an acknowledgement in resulting publications. Other data for scientific use are provided on request.

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