SONG - getting ready for the prototype

Grundahl, F.; Christensen-Dalsgaard, J.; Jørgensen, Uffe Gråe; Frandsen, S.; Kjeldsen, H.; Rasmussen, Per Kjærgaard

Published in:
Journal of Physics: Conference Series

DOI:
10.1088/1742-6596/271/1/012083

Publication date:
2011

Document version
Publisher's PDF, also known as Version of record

SONG – getting ready for the prototype

2011 J. Phys.: Conf. Ser. 271 012083

(http://iopscience.iop.org/1742-6596/271/1/012083)

Journal of Physics: Conference Series **271** (2011) 012083 doi:10.1088/1742-6596/271/1/012083

SONG – getting ready for the prototype

F Grundahl[1], J Christensen-Dalsgaard[1], U Gråe Jørgensen[2,3], S Frandsen[1], H Kjeldsen[1] and P Kjærgaard Rasmussen[2]

[1]Department of Physics and Astronomy, Aarhus University, Ny Munkegade, 8000 Aarhus C, DK

[2] Niels Bohr Institute, University of Copenhagen, Juliane Maries Vej 30, 2100 Copenhagen, DK

[3] Centre for Star and Planet Formation, University of Copenhagen, Geological Museum, Øster Voldgade 5-7, 1350 Copenhagen, DK

E-mail: fgj@phys.au.dk

Abstract. The Stellar Observations Network Group, SONG, is a project which aims at building a network of eight identical telescopes distributed geographically around the globe to allow long-term, high-duty-cycle observations of stellar oscillations and to search for exoplanets via the microlensing technique. At each of the network nodes a 1 m telescope with a high-resolution spectrograph and two lucky-imaging cameras is placed. The instruments and telescope, for the prototype node, are currently being built and installation at Observatorio del Teide, Tenerife, Spain is foreseen for early 2011.

1. Introduction

It is well known that observing solar-like oscillations from the ground is a very challenging task. Perhaps the most difficult aspect is organizing the access to observatories spread across the globe, which can provide the long, continuous, time coverage needed for such observations. The Stellar Observations Network Group – SONG – is an initiative to build a global network of 8 identical 1 m telescopes, dedicated to time-domain astronomy within the fields of asteroseismology and exoplanet studies. In order to do this we have obtained funding for designing and building the prototype node for such an observatory. Currently, autumn 2010, we are completing the instruments and the telescope and observatory site is being prepared for "first light" in the spring of 2011. Previous reports on SONG can be found in Grundahl et al. (2007, 2008, 2009).

The scientific goals of SONG are to: 1) study the interiors of stars using asteroseismology and 2) search for, and characterize, extra-solar planets via the radial-velocity and microlensing methods. These two goals put some clear requirements on the instruments needed for the network, and we optimize these such that the scientific goals can be met. Specifically we will study stellar oscillations using radial-velocity observations with a spectrograph designed with the goal of reaching 1 m/s precision for slowly rotating solar-like stars. The targets for asteroseismology will be among the brightest stars in the sky allowing us to use a relatively small telescope. Furthermore the bright stars are also well studied with other techniques, such that their basic parameters: distance, radius luminosity, effective temperature and surface composition are well known. Such detailed information is needed for confronting properly the stellar models with observed oscillation spectra. For the exoplanet observations, the main mode will be imaging observations of microlensing candidates towards the galactic bulge region. This requires high spatial resolution due to the high level of crowding in these regions, and to this end we use the lucky-imaging method (Baldwin et al. 2001). The radial-velocity measurements from the asteroseismic observations can naturally also be used to search for planets orbiting the stars under study.

In addition to these two primary science goals, it is our aim to observe the solar oscillations during daytime. This will be accomplished by installing a window in the dome which allows the telescope to be pointed towards the blue daytime sky and feeding the spectrograph with scattered sunlight, see e.g. Kjeldsen et al. (2008). The purpose of these observations is not only to study the "sun-as-a-star", but also to monitor the performance of the spectrograph, e.g., by comparing with results from ground-based solar networks and space-based observatories.

We note that, once the network is fully developed, it will be possible also to carry out time-critical observations such as photometry and spectroscopy of exoplanet transits, Doppler imaging of active stars, etc.

2. The nodes

We refer to the individual observatories in the network, as nodes. Our aim is to create a network with at least 8 nodes, four in each hemisphere, in order to have a good duty-cycle for any position in the sky. Each node should be placed at already existing observatory sites to avoid building extensive infrastructure.

For a network of 8 telescopes it is not feasible to carry out manned observations; therefore all functions of the observatory should be under computer control. An overall scheduling programme will take care of sending observing requests to the individual nodes which then carry out these when a number of constraints are fulfilled. The instruments must be capable of automatically acquire the desired object in the field of view or on the spectrograph slit, autoguide, and maintain an optimum focus.

Each node will carry two primary instruments: imaging camera(s) at the Nasmyth focus and a high-resolution spectrograph located at a Coudé focus. The Coudé focus is placed in an insulated shipping container next to the telescope pier. A weather station and cloud monitor is attached to the container.

The first node, for the prototype, is located at the Observatorio del Teide on Tenerife in collaboration with Instituto de Astrofísica de Canarias. It will be placed at the site where the STARE telescope (Charbonneau et al. 2000) was located.

2.1. Telescope

The telescope for SONG has an aperture of 1 m and a focal length of 36 m in order to provide an image scale adequate for lucky imaging (see below). It is located on an alt-az mount such that the same design can be used at all nodes. Two Nasmyth instrument ports are available; initially only one will house instruments, but the tertiary mirror is mounted on a rotating platform that allows switching between the two sides in 60 seconds.

The telescope will have a blind pointing of 5 arcseconds (rms), and is equipped with powerful direct-drive motors to allow rapid pointing. It is important to have a high image quality for lucky imaging, so the telescope has a built in Shack-Hartmann wavefront sensor which is used actively to control the thin (5cm) primary mirror.

The dome has a diameter of 5 m and is equipped with ventilation ports, which can be opened during night time, and a cooling unit which operates during the day to minimize heating of the telescope mirror and structure. To facilitate the daytime observations of the Sun, a window will be installed in the dome, such that the telescope can point to the blue sky.

2.2. Spectrograph

The main instrument for the asteroseismic observations is the spectrograph. In order to achieve the high-precision radial velocities needed, an iodine cell will be used as wavelength reference, and we have taken a number of steps in the design to allow us to reach a precision of 1 m/s for the brightest targets. The spectrograph is designed to cover wavelengths between 4800 Å and 6700 Å. Although this is a fairly limited range, it fully covers the region of the iodine absorption spectrum and, importantly, it allows us to use off-the-shelf optical components with very high efficiencies (99%), which helps to maintain a high throughput.

The spectrograph is equipped with 7 slits, allowing resolutions between 60.000 and 180.000 – these are mounted on a motorized stage to allow easy change. For obtaining precise velocities it is highly important that the slit illumination is stable. To this end, we have included a tip/tilt mirror for correcting the input to the slit. Our targets are bright so there is ample light available. Furthermore the Coudé path also includes a facility which continuously monitors the telescope pupil and feeds signals to a mirror on a piezo stage, to ensure a stable pupil location.

The spectrograph pre-slit table is equipped with flat-field and ThAr calibration lamps, as well as the iodine cell. It is important to note that these items can be inserted and removed from the beam as demanded by the application. Thus SONG will also be capable of observing without the iodine cell in a "normal" mode of operation.

The entire spectrograph is mounted on an optical table measuring 900 mm×1200 mm (Fig. 1), which is enclosed in an insulated box. For thermal control, we keep the entire container volume below a fixed temperature and then use heating elements in the insulating box to keep the spectrograph at a few degrees higher temperature. As our detector we use a 2K×2K CCD system from Andor which can read out in less than 5s with a readout noise below 8 electrons, as measured in our laboratory. For time-series applications it is obviously an advantage to be able to read so quickly with low noise. The size of the detector does not cover the full extent of the spectral orders at wavelengths longer than 5350 Å. The focusing camera has been designed to allow this if a larger CCD is used.

All spectra will be stored, flat-fielded and extracted on-site, and subsequently transferred to a central site for further processing (velocity extraction). We are using the REDUCE package by Piskunov & Valenti (2002) for the basic reductions and our own IDL-based code for the velocity measurement.

2.3. Imaging

For the microlensing observations SONG will employ two lucky-imaging (LI) cameras (Andor DU897 models) located at one of the two Nasmyth foci. Baldwin et al. (2001) has illustrated the use of LI. We decided to use two such cameras in order to increase the wavelength coverage, essentially doubling the number of measurements. The wavelength split between the two cameras, using a beamsplitter, is at 6500 Å. The lucky-imaging method should work extremely well on a 1 m telescope at a good site – there is already many reports showing very good results with 2-3 m class telescopes. The ratio between the telescope diameter and typical turbulence scale, D/r_0, is then correspondingly more favourable for the SONG telescope. This implies that a significant improvement in image quality can be obtained, for a large fraction of the available images. To accommodate this, the pixel sampling of the LI cameras is 0.09 arcsecond per pixel (for 2 pixel sampling of the diffraction limit). The field of view is 45 arseconds square – while quite small it is sufficient for our purposes. Since we may wish to observe targets at high zenith distances an atmospheric dispersion corrector is permanently installed in the beam.

In order to obtain the best performance for LI we must be able to focus the telescope very well – for this purpose a small fraction of the light at the Nasmyth focus is reflected to a small camera which will monitor the telescope focus during the observations, and automatically correct any observed drift.

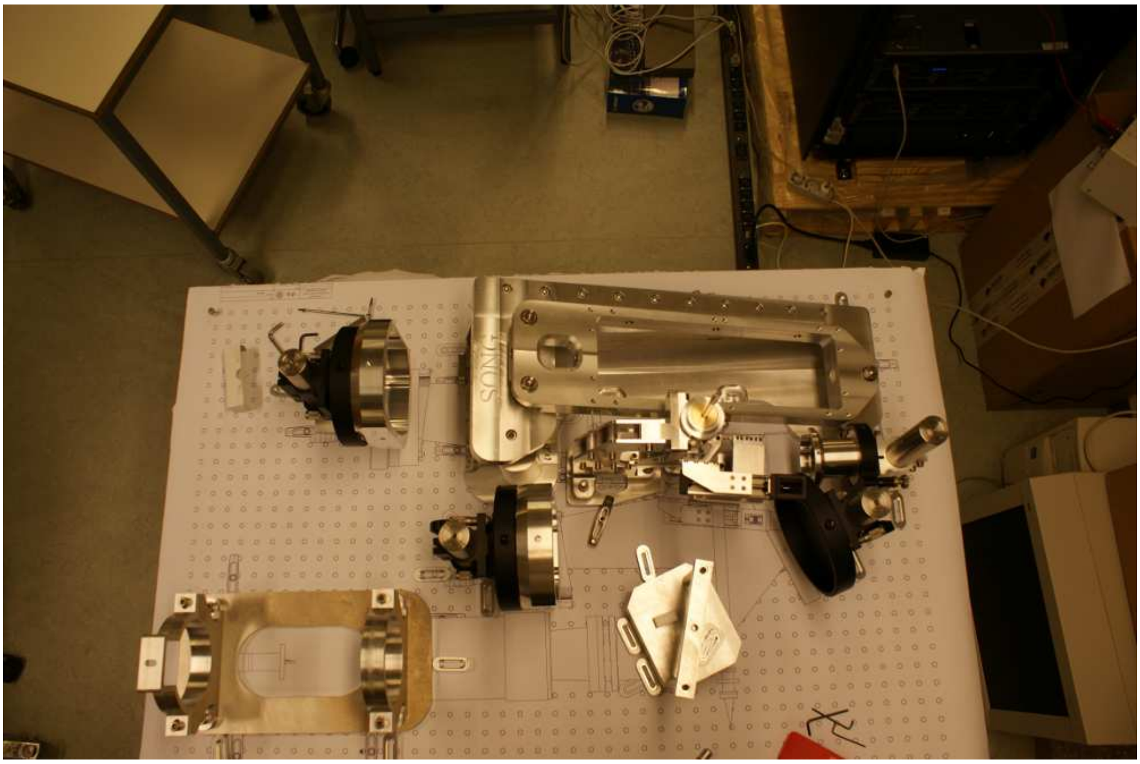

Figure 1. Test assembly of the spectrograph without optics and before anodizing. At the upper right hand corner the mount for the echelle grating can be seen. Mountings for the collimator mirrors, cross-disperser slit and spectroscopic are also present.

Each of the two LI cameras is equipped with a filter wheel with four positions. The two cameras can operate independently, having different frame-rates.

3. Status of the prototype development

There is currently (autumn 2010) a lot of activities ongoing at Aarhus and Copenhagen Universities. The mechanical parts for the instruments are nearly completed, with only minor components missing, and the assembly and integration of the spectrograph is starting. A test container is installed in Aarhus, where we will mount all items and do system integration and testing, before shipping instruments to Tenerife. The software for controlling the prototype, and ultimately the network is being developed, and the setup for automatic execution of observations and copying of data to archives and databases is ready. The site at Observatorio del Teide is being prepared, and installation of the dome support structure and container is scheduled for early 2011, followed by an extensive testing period lasting until the end of 2011.

A single node does not make a network, and we are actively seeking partners and collaborators for the funding and building of more nodes for the network. In China, a group led by Professor Licai Deng (National Astronomical Observatories, Chinese Academy of Sciences) has obtained funding to build a second node in China, to be ready by 2012. Several other groups has expressed strong interest in joining SONG and are actively seeking funds.

Acknowledgments

The authors gratefully acknowledge generous financial support for the SONG project from the Villum Fonden, Carlsbergfondet and The Danish Council for Independent Research | Natural

Journal of Physics: Conference Series **271** (2011) 012083 doi:10.1088/1742-6596/271/1/012083

Sciences

References

Baldwin J E, Tubbs R N, Cox G C, Mackay C D, Wilson R W and Andersen M I 2001 *A&A.* **368** L1-L4

Charbonneau D, Brown, T M, Latham, D W and Mayor M 2000, *ApJ* **529**, L45

Grundahl F, Christensen–Dalsgaard J, Arentoft T, Frandsen S, Kjeldsen H, Jørgensen U G and Kjaergaard P 2008 *Commumications in Asteroseismology.* **157** 273

Grundahl F, Christensen–Dalsgaard J, Kjeldsen H, Jørgensen U G, Arentoft T, Frandsen S and Kjærgaard P 2009 *Solar-Stellar Dynamos as Revealed by Helio- and Asteroseismology: GONG 2008/SOHO 21* 11–15 August 2008, Boulder, Colorado USA, (ASP Conf. Ser. vol 416) ed M Dikpati et al (San Francisco: ASP) p 579

Grundahl F, Kjeldsen H, Christensen–Dalsgaard J, Arentoft T and Frandsen S 2007 *Communications in Asteroseismology.* **150** 300

Kjeldsen H, Bedding T R, Arentoft T, Butler R P, Dall T H, Karoff C, Kiss L L, Tinney C G and Chaplin, W J 2008 *ApJ* **682** 1370

Piskunov N E, Valenti J A 2002 *A&A.* **385** 1095