GONG
Teide Udaipur Learmonth Mauna Loa Big Bear Cerro Tololo

Newsletter

Number 27 April 1998

Greetings from Tucson! We have been having such a good time since GONG became operational, that it has been far too long since the last Newsletter rolled-off the press. We hope that you enjoy this new, slimmer format, which we will endeavor to get out at a minimum of twice per year. In keeping with the times, we will also be making the newsletter available on our WWW server. If you would like to be removed from the hardcopy distribution list, just send an e-mail to gong@noao.edu, and we will send you an e-mail notification as new issues become available. You will have a "pdf" - formatted version of the newsletter on the web that you can easily print yourself, saving the world a few trees and the Project a few dollars.

Operations have generally been proceeding more smoothly than we had any right to hope for, while the tape units are hanging up more frequently than we anticipated. But the folks at the sites have been extremely successful in recovering from these problems, and so far we have not had to send out a "crash team." That is not to say that the operations team in Tucson has been idle, checking in on each site daily, and traveling to each site on a six to nine month rotating schedule. The overall duty cycle of the merged time series is routinely reaching 87% and is very much in the range that we had been hoping for. More significantly, the small height of the daily sidelobes indicates the sensitive and stable nature of our network of instruments *(see the figure on page 2)*.

Data processing continues to keep up with its arrival, and we now have merged data through September 1997 (the last day of GONG month 24); that is, we have 23 36-day GONG months in hand. As we anticipated at the outset, once the bits started flowing into the pipeline we have learned a great deal more about the characteristics of the data. The processing has since been modified, and as a result of changes in the spatial region used in the remapping and advances in our ability to register images from the different sites, we are now reprocessing data backward from GONG month 16 through GONG month 12, and expect to have the reprocessed versions of months 10 and 11 by April of this year. In addition, we also have the merged time series and power spectra for intensity months 16 through 18 as the intensity oscillations have turned out to be much more interesting than we presumed. The baseline "peak bagging" has proven to be much more rapid than we had originally anticipated, but once again, now that we have real, high quality, low-noise data in hand, there have been many changes to the peak-bagging algorithm that continue to be implemented *(see Peakfinding on page 3)*. The DMAC Users' Committee has worked closely with the Project staff to devise quality checks on the frequencies being produced, and after a very lengthy process, the mode frequencies are once again being made routinely available via our web site. See the note on the following page describing the verification process.

On the personnel front, there have been many, significant changes in the project staff since the last Newsletter. Guillermo Montillo and Sang Nyguen have transferred over to NOAO's Engineering and Technical Services, and passed their responsibilities on to Bert Villegas and Jay Le Blanc. Jim Kennedy has joined the Gemini Project, and we have welcomed Pat Eliason to the Project Manager's hot seat. Rob Hubbard has left the fold to work with Tucson-based Breault Optical, with Ron Kroll stepping up to lead the operations group. Dan Bass has joined Wyko, another optics firm here in Tucson. Roy Tucker joined the Project to head up the development of the new 1024 × 1024 camera system, and Rachel Howe has joined the algorithm development team.

With the success of the first year's data from the merged velocity images and their spectra in hand, and the clear scientific significance of the solar-activity-caused frequency shifts and their implications for understanding the manifestations and the source of the magnetic activity cycle, we have successfully argued the scientific merits of continuing the GONG observations for a full eleven-year cycle. With the prospects for a substantial data acquisition run firmly established, we have turned our attention to remedying the deficiencies of the camera system: rectangular pixels giving 22% different spatial resolution in latitude and longitude, pixels too large to allow complete supression of aliasing of high spatial frequency power into the resonant *p*-mode region, and perhaps most significantly, a limitation to only the long-lived, globally resonant modes. With the higher-resolution camera, we will now include the running waves that sample the very important near-surface regions where convection is most super-adiabatic and where we have now learned that we can map out the flows with local helioseismology methods which were but a glimmer in our eyes when GONG began. The good news is that the existing optical-mechanical system will feed a 1024^2 camera, producing 2.5 arcsec pixel resolution, with little modification! We have the "proof of concept" camera in hand and should be collecting data by mid-Summer *(see "New Camera..." on page 2)*. The new systems *should* be deployed throughout the whole network within two years, just in time for the maximum of solar activity. Stay tuned!

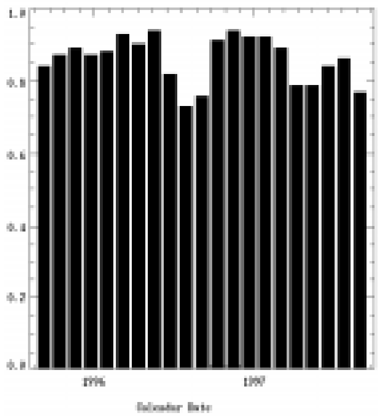
Finally, there is the science!! In addition to the structural and rotational inversions that were, and still are, the heart of the Project, all manner of novel applications of the new data are starting to emerge. Who would have thought that the GONG data would be used to place tighter limits on the variation of the gravitational constant or the solar diameter?! Who would have thought that the frequency spectra of intensity oscillations would be significantly different than those for velocity oscillations? As

Jack Harvey (right), and Roy Tucker, (left), performing initial laboratory tests to evaluate the performance of the new camera.

is the case for any vital, new field of research, while the initial promise is being very beautifully fulfilled, new and unforeseen questions are being posed more rapidly than the initial ones are being “closed out”. As we transition into the next phase of GONG, and the promise of enhanced, high-resolution instruments feeding the pipeline, we look forward to the challenges that lie ahead.

This year’s annual meeting will be held in Boston, June 1-4. The meeting will be held jointly with the SoHO helioseismology experiments and hosted by the Harvard-Smithsonian Center for Astrophysics. If you haven’t already registered, the URL for further information is *cfa-www.harvard.edu/GONG98.* We hope to see you there!

John Leibacher



The fraction of good data samples in the merged, network time series (after filling 2-point gaps, primarily from the magnetogram observations) for each of the 36-day GONG months since the beginning of full network operations in October 1995.

New Camera Development

Following recommendations from the scientific community, the GONG Instrument Group has been studying retrofitting a higher-resolution camera to the existing observing stations. When operated with a 1024^2 pixel array CCD, corresponding to 2.5 arcsec pixels and a factor of four increase in spatial resolution, the new square-pixel detector will eliminate spatial aliasing and problems associated with the current rectangular pixels and significantly enhance local helioseismology studies, enable studies closer to the visible surface of the Sun, *and* provide continuous magnetograms.

With the initial hardware review and evaluation behind us, the instrument modification and upgrade process is proceeding very well. Results from the initial laboratory tests using a Silicon Mountain Designs 1M60-20 camera have been good with regard to linearity, noise, image lag, modulation transfer function, and synchronization. In early March, the team moved the camera to the Tucson GONG shelter where it is being integrated into the Doppler imager optical system, and solar images are being acquired as a final verification of its suitability.

The data volume will increase thirty-two fold, and selection of a video data acquisition system will be the next milepost on the upgrade path, with a decision expected to be made in late April or early May. Pressing hard to stay on schedule, the “proof of concept”, high-resolution breadboard instrument should be in full operation by late Summer.

Roy Tucker

What Data can I get from GONG?

The GONG Project provides data freely to members. Becoming a member is simple—go to the GONG web page (the URL is on the back page) and click on the “Membership Forms” link. You can then fill out the form either electronically, or using a text file. After the form is submitted, we will establish an account for you on the GONG data server, and you can then search and order our available data.

Some of the currently available products for the helioseismologist are:

Power spectra of solar oscillations covering the range of $0 \leq \ell \leq 200$, $-\ell \leq m \leq +\ell$, *and* $0 \leq \nu \leq 8.33$ *mHz.*

Time series of complex spherical harmonic coefficients as a function of ℓ *and* m *in the range* $0 \leq \ell \leq 200$ *and* $0 \leq |m| \leq \ell$.

Estimated frequencies, amplitudes, and linewidths of solar oscillation modes, as a function of ℓ, m, *and* ν *covering the range* $0 \leq \ell \leq 150$, $-\ell \leq m \leq +\ell$, *and* $0.6 \leq \nu \leq 4.0$ *mHz.*

Both the time series and power spectra are available over temporal intervals of GONG months (GM), with 1 GM $\equiv$ 36 days. We also have these products available for $0 \leq \ell \leq 45$ over selected longer intervals up to 1 GONG Year (10 GM or 360 days). We are currently reprocessing the helioseismic data with a new spatial mask, and this has been completed for all data from 6 June 1996 to 16 September 1997. We are reprocessing the earlier data, and the starting point of available time series and power spectra will eventually be 7 May 1995. The ending point will naturally move forward in time. The frequency determination will be performed over three GM (108 day) temporal intervals, with a one-month (GM) sliding window. The average duty cycle of the helioseismic data is 0.87.

For the non-helioseismologist, we have the following products covering the period from 7 May 1995 to the present.

Minute-by-minute images of the solar surface Doppler velocity field.

Magnetograms every 20 minutes, plus derived synoptic maps.

Low-pass, temporally filtered, and geometrically registered images of the surface Doppler velocity with a cadence of 4 minutes and a filter width of 17 minutes, useful for studies of slowly evolving flows.

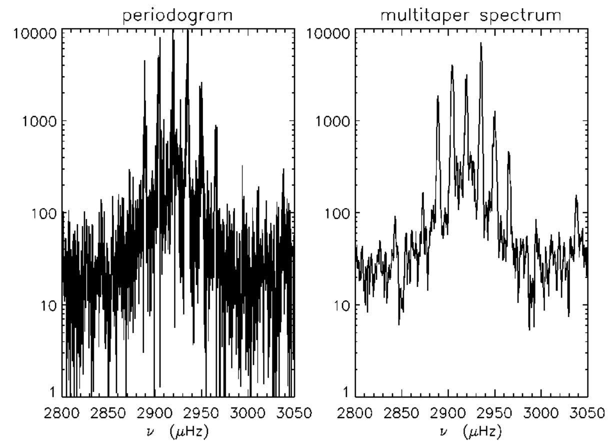
Frank Hill

Calibration Noise Reduction

The data reduction group has developed a simple and reliable method for reducing the noise that was, in the past, mapped into the oscillation images during calibration. The noise appears on a site-day ℓ–ν spectra as a diagonal band which appears at low ν and expands with increasing ℓ across the image, and intersects the lowest p-mode ridges at about $\ell = 200$. If the images from the daily calibration sequence, which contain the spurious modulation and interferometer field effects, are temporally averaged over many days before being applied to the oscillation images, the noise is greatly reduced. Along with the spurious modulation and field effects, these calibration images also contain the consequences of dirt and other optical flaws from the light feed assembly, the image of which is slightly out of focus when the calibration sequence is recorded and completely out of focus when the oscillation images are recorded. Since the light feed assembly rotates daily, relative to both the interferometer and the camera for the calibration images, and because the effects we want to remove (spurious modulation and field effects) change very slowly (at least between preventive maintenance visits), simple temporal averaging reduces the noise in both the calibration images and the calibrated oscillation images.

Jim Pintar & Roberta Toussaint

Multitaper Spectrum Estimation



The plots to the right show an example of a periodogram and a multitaper spectrum (using five generalized sine tapers) of a month-long GONG velocity time series ($\ell = 65$, $m = 0$). More modes can be fit in the multitaper spectrum than in the periodogram due to the reduced noise. The improvement depends on ℓ and other details of the time series and is typically between 20% and 60% for low to medium ℓ values.

The largest improvement occurs at low frequencies where the modes have a low signal-to-noise ratio. For the three-month time series covering GONG months 12, 13, and 14, the number of good fits increases by 10% on average for all modes from $\ell = 0$ to 150.

The multitaper technique does not introduce any detectable bias to mode frequency and amplitude when compared with the results of the periodogram. The mode width also shows no bias except for the narrowest modes at low frequency where multitaper spectra lead to slightly larger mode widths. A multitaper spectrum is an average over uncorrelated spectra derived from the same time series by applying a set of orthogonal tapers. Generalized sine tapers are orthogonal tapers taking the gap structure of the time series into account (Imola Fodor and Philip Stark, UCB). By increasing the number of tapers a multitaper spectrum can be made as smooth as desired, but as a trade-off the narrowest modes are then eliminated. The useful number of tapers is on the order of five.

Rudi Komm

Peakfinding

Recent work on PEAKFIND has focused on testing an asymmetric profile. The profile used for this testing is the Osaki model with the source inside the cavity. The background appears as a source term which more accurately describes the 5-minute oscillation envelope.

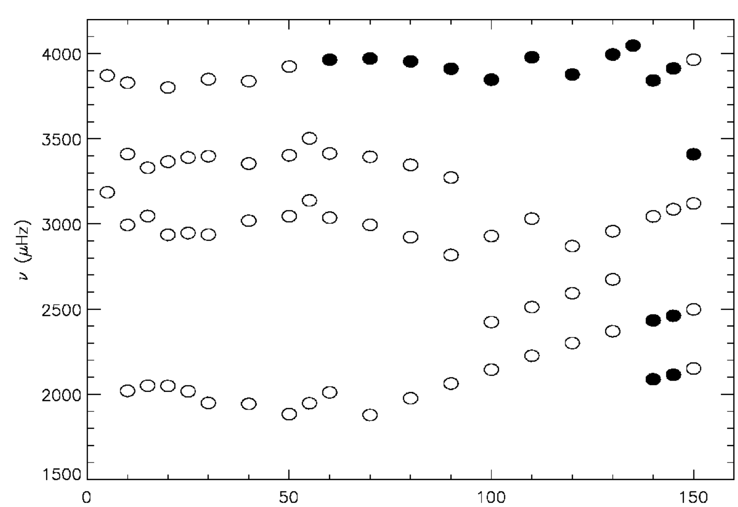
Initial testing used artificial data (1000 realizations), which was generated using a Lorentzian profile with no asymmetry and a flat background. We immediately found that there was significant "cross-talk" between several of the profile parameters (amplitude, contrast, and reflectivity) and introduced a normalization which successfully isolated the amplitude. However, subsequent testing showed that there was still a large amount of questionable interaction between the asymmetry and background parameters, so we replaced the source term of the profile with a linear, additive background as is done for the Lorentz profile.

Tests using the artificial data (where we would expect that the mode frequencies and background terms of both profiles to be the same, and the asymmetry term to be 0) still yield results that indicate considerable ambiguous and unwanted coupling between the background and the asymmetry terms. The asymmetry of the profile is primarily determined far from the line center, which is the same area that contributes to the background. We are therefore considering a two-part (perhaps iterative approach) which will first fit the background and then hold it fixed during the line profile fitting.

We are also creating an artificial data generator for the Osaki profile to help refine the testing.

Ed Anderson

The figure on the right summarizes the final results of a random-restart test of the GONG peak-fitting algorithm. In this test, a new set of starting guesses for the fitting of a mode is created by adding a random perturbation to the initial fit results and the peak is then refitted starting from the new first guess. The added random component is uniformly distributed between ± twice the formal error of the fit. If the model of the peak is correct, and if the fit converges to the global minimum in the likelihood surface, then the rms variation in the ensemble of "random-restart" fits should be a small fraction (2%) of the formal error estimate.



The open symbols in the ℓ - ν plot show where this is the case for a test carried out on a limited set of modes, while the filled circles indicate where the 2% criterion is not satisfied. For all points, the ratio of the rms variation in the new fits to the formal error estimate has been averaged over m. The solid circles are outside a boundary within which $d\nu/d\ell$ > twice the line width. It is in this region that spatial leaks are blended with the target, and an underlying model assumption of resolved leaks is not satisfied. We have installed this boundary criterion in the GONG peak-fitting algorithm to reject these cases. We have also incorporated a number of new quality flags that proved to be effective in rejecting fits that fail the random-restart test. These new quality criteria are: strict numerical convergence in the minimization of the likelihood function, a fitted width that is within a factor of 2 of the first guess width, and a test to ensure that the fit has not locked onto the first guess. While the application of all of these new criteria has reduced the proportion of good fits from 85% to 45%, it has greatly improved the reliability of the estimated mode parameters.

Frank Hill

Site Focus ... Big Bear Solar Observatory

We thought that we would highlight one of the GONG sites in each issue of the Newsletter, and as there have been significant changes at Big Bear recently, we'll start there.

The Big Bear Solar Observatory (BBSO) is located on a small island near the north shore of Big Bear Lake in the San Bernardino Mountains in southern California, 120 km East-Northeast of Los Angeles. Flying west into Los Angeles, one can frequently see the bright white observatory glistening in the forest-surrounded lake. The observatory is located in the lake to reduce image distortion which occurs when the Sun heats the ground, producing convection currents. The reduction of local convection currents along with the usually cloudless skies of southern California and the clarity of the air at the 2,000 meter elevation of Big Bear Lake, make BBSO one of the best sites in the world for solar observations. The GONG site is alongside the causeway near the high water level of the lake.

BBSO, and a dedicated array of solar radio telescopes at Owens Valley Radio Observatory in Owens Valley California, are managed by the Center for Solar Research at the New Jersey Institute of Technology located in Newark, New Jersey. Management of BBSO and the Solar Array at Owens Valley was transferred from the California Institute of Technology to the New Jersey Institute of Technology on July 1, 1997.

BBSO specializes in high resolution, high frame rate observations of the Sun in both the visible and near-infrared light. BBSO is well-known for its observations and research of solar magnetic fields, flares, solar oscillations, and ***as one of the GONG network sites***.

Bill Marquette

GONG's web site *www.gong.noao.edu* is up-to-date with Project status, scientific investigations and publications, access to data products, and links to other activities within the field of helioseismology.

The FTP archives for GONG can be found at the anonymous FTP address: *helios.tuc.noao.edu.*

The *GONG Newsletter* is also available on GONG's web site as a WWW document and an easily printable PDF document. We encourage you to avail yourself of this service.

You can be removed from the hardcopy mailing list, and added to the e-mail notification list, by simply sending an e-mail message to *gong@noao.edu*.

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