

GONG Newsletter

Number 7

January 21, 1988

Happy New Year! The *GONG* is entering its fourth year, and good progress is being made on the instrument as well as the data reduction and analysis system, the site survey continues to get crucial data and is being expanded, and the Teams are beginning to make major contributions in several different areas. We are looking forward to significant progress on all of these fronts this year, and we hope that the information in these Newsletters will help you stay apprised of the state of the *GONG*, as well as encourage your participation in the Team's activities.

There is some recent good news on the people front. Deborah Haber received her Ph.D. — with a thesis entitled "Seismic Probing of Solar Flows using High-Degree Oscillations" — from the University of Colorado and is now at NSO/Sunspot. Pawan Kumar received his Ph.D. — with a thesis entitled "Excitation and Damping of Solar P-Modes" — from CalTech and is now at HAO.

Tom Duvall, Jack Harvey, Dave Jaksha, Stuart Jefferies, and Marty Pomerantz have returned from a successful observing run at the South Pole using the same spatial format as the *GONG* instrument. They got nearly 300 hours of useful data, with a two-thirds duty cycle and more than seventy hours of continuous coverage. In addition to its intrinsic helioseismic interest, the data will be very useful for our studies of scattered light and, along with the artificial data, will help in priming the data analysis and reduction pipeline.

In response to a number of suggestions, we have included an additional site at the Urumqi Astronomical Station in Xinjiang (Sinkiang) western China as part of the survey of potential locations. I was met at the Beijing airport by Li Kaifan who had traveled the 3000 km from Urumqi to assure that customs clearance of instruments went smoothly — it did — and Wang Jialong, from the Beijing Astronomical Observatory, who had encouraged us to consider Urumqi and very generously took the time to accompany me there. Teng Tingkan, vice-President of the Xinjiang Branch of the Chinese Academy of Sciences, officially invited and welcomed the *GONG*, and the installation went smoothly thanks to the support of Xu Jihong and Li Guoyin, and the Solar Division's Huang Zhen. My good friend Zhang Baocai seemed to take care of everything under the Sun, and the instrument is now in the capable hands of Xiao Shuming and Liu Changming. Xinjiang is a breathtakingly beautiful and exotic region with landscapes somewhat reminiscent of Death Valley, California and the Swiss Alps juxtaposed. The trip was made in conjunction with an invitation from Ye Binxun of Kunming, on behalf of the Chinese Academy of Sciences, to visit several observatories. Thank you all!

Don't forget, the Annual *GONG* Meeting will be held April 6 through 8 in Tucson. Information and attendance forms will be mailed out in a month. (*John Leibacher*)

Instrument Development

Substantial progress and several technical difficulties marked the last few months of work on the *GONG* breadboard and prototype projects. The breadboard system is intended to validate concepts while the prototype system is intended to demonstrate performance before making final hardware purchases. Both projects are proceeding in parallel with the emphasis in the breadboard project on the least certain instrumental aspects and in the prototype project on the most certain aspects.

Spectrum Line. During tests with the breadboard, we made measurements of modulation strength produced by the 6768\AA line. It was of interest to compare these with model calculations made by Tim Brown and Rob Hubbard based on line profiles computed by Harry Jones. These calculations indicate that we should expect a modulation of about 5% while measurements show somewhat smaller modulation. The cause of the discrepancy was identified as due to the 1\AA filter bandpass being greater than that used in the models.

Bill Livingston has recently been measuring the line profile of the 6768 line as part of his long term monitoring program at the McMath telescope. He discovered two, weak telluric lines in the far wings of the solar line under large airmass, moist conditions. These lines eluded our earlier screening for telluric interference and probably arise from water vapor. It is not likely that these lines will cause much trouble since they are weak, rather symmetrically located around the solar line and are spaced nearly an integer number of interferometer fringes apart.

Also at the McMath, Keith Pierce measured the center-to-limb variation of the wavelength of the 7525\AA Ni I line, one of the candidate *GONG* lines and a close proxy to the 6768 line. The limb redshift behaved normally for a line of that strength and the results will be incorporated in the simulations. Measurements of 6768\AA are underway.

Breadboard. The breadboard is used to test concepts and instrumental elements that are the most difficult to fabricate and most likely to introduce noise in a final instrument. The heliostat on the roof of the Tucson laboratory is not one of these elements but it unexpectedly started driving erratically in December. Examination of the instrument revealed that dirt from reroofing operations was the source of the trouble. This problem interrupted tests of the high-speed, tiltable, metal mirror that is intended to reduce noise caused by rapid image motion due to poor seeing. It also stopped other testing. The problem was fixed and full scale testing has again resumed.

Additions to the foreoptics are underway. Two lenses have been fabricated to interchange pupil and solar images in the optical system after the first focus. Tests of this calibration system show that it works as planned. An entrance window/filter has been ordered but not yet delivered.

Efforts by a commercial vendor to supply an ion-assisted interference filter did not produce a satisfactory product so we will rely on traditional hard-baked and well-sealed filters to isolate 5\AA around the solar line. Filter stability testing is planned for the near future now that a laser has become available in NOAO which emits light near the 6768 line. Measurements of

the filter that has been in use in the breadboard for several months have shown no detectable variation as yet.

Work on the fixed, 1\AA passband, birefringent filter has centered on improving temperature control. Stability is now at the 1 mK level and is being improved as time permits by tuning of feed-forward servo circuits, thermal and electronic time constants, *etc.* This level of stability is more than adequate given the athermal designs of the filter and interferometer. The filter design incorporates ADP crystals paired with calcite crystals so as to compensate each other's thermal coefficients. Fabrication of thin pieces of ADP is not easy but a commercial vendor has undertaken to do the job. At the same time, Frank Vaughan is producing the necessary pieces within NOAO just in case the vendor is overly optimistic.

The heart of the instrument, a Michelson interferometer, continues to be a source of difficulty. A second commercial vendor attempted to make the interferometer to our specifications. They produced excellent beamsplitter coatings that did not distort the figure of the prisms (the problem that plagued the first vendor) but are having difficulty adequately finishing the interferometer. A major effort by Frank Vaughan and Raleigh Drake produced an interferometer that has a wide angular field, is temperature compensated and has a modulation efficiency of 96% over the field that is used for observations. This interferometer was recently installed in the breadboard and is being tested. Assembly was a difficult problem and we are considering the use of one glued surface instead of an all optically contacted approach. We are also considering starting the development of our backup design which should be substantially easier to build and assemble but which is less efficient than the primary design.

The last major element in the optical system is the camera which detects the image. At present a Reticon™ 256 by 256 element camera is used at 75 frames per second. Initial tests produced a badly smeared image caused by charge transfer inefficiency. A new detector chip and other modifications improved this situation but the results are still not optimal. Thus, we have examined a Texas Instruments TC241 virtual phase CCD as a possible replacement and it looks promising. We are also attempting to test a Sony XC-77 CCD which uses an interline transfer design. Both of these options would unfortunately require adding a weak anamorphic element to the optical system since the pixels are not square.

The image cache, designed by Steve Colley and built at Sacramento Peak, has been integrated with the *GONG* lab workstation in Tucson and, after some debugging, has been serving its function of acquiring images for further analysis. A high-density, helical-scan, digital tape recorder was received some months ago but has proven hard to interface to our workstation. A second system, a completely integrated unit, is on order and is eagerly awaited.

An important auxiliary part of the optical system is the stable laser used as a wavelength reference. During the last quarter of the year we were able to measure the stability of the laser and found it to be within ± 50 kHz (one part in 10^{10}) over several days. For measurement of long term stability we require an iodine-stabilized laser and we have located a vendor who supplies a small portable unit.

Prototype. Negotiations with the University of Arizona have resulted in an excellent site for the prototype instrument on University land a few minutes from the NSO offices in Tucson. In the meantime, the shelter was delivered to our carpentry shop for interior fitting of utilities, insulation, painting, *etc.* Much of the support equipment was purchased for the prototype. For example, an uninterruptible power supply was delivered in October and has been under test since then. Additional equipment includes a small weather station, a radio receiver for Omega navigation signal reception (used to synchronize timing at all the *GONG* sites), electronic test equipment, *etc.*

At Sunspot, Lonnie Cole and his team have testing underway on the fully assembled, prototype tracking system. This unit involves a sealed assembly which contains two mirrors that send sunlight to the rest of the optical system. Open and closed loop tracking algorithms are under development and testing of the frequency response of the system is being done. Our hope is that the frequency response of the tracking system will be great enough to avoid having to rely on the fast mirror mentioned earlier. In the meantime, Dick Dunn has designed a "clam shell" housing which will close around the turret to protect it from inclement weather. Both the turret and its weather cover will be tested in the winter environment at Sac Peak over the next few months.

We are starting to evaluate potential vendors for construction of long lead time optical elements for the prototype. These include the calcite crystals for the birefringent filter, polarizing beamsplitter cubes and various half and quarter-wave plates. (*Jack Harvey*)

Management Report

The first phase of the *GONG* staff "ramp-up" is almost complete. The technical teams now total 14.5 FTE, including project staff and NOAO ETS and CCS people. This year's effort will be concluded shortly with the addition of another programmer to the data analysis group.

The Fall months saw a significant Project planning effort. The Instrument Group contingents at both Sac Peak and Tucson conducted a thorough review of the planned instrument's systems and subsystems. As a result, they produced an extensive systems description document and drawing tree organization which will be the basis for all further documentation. Configuration control received a great deal of attention in preparation for the emergence of a prototype from the breadboard.

The *GONG* staff held its semi-annual technical meeting in Tucson on November 4th and 5th. The systems document was discussed in great detail and responsibility for the continued development of the various systems was reviewed and assigned to specific working groups. The priority, scope, and extent of the development work for each of the systems during FY '88 was explored, with work schedules produced and coordinated. Teams involved in several of the major systems grouping held a number of topical meetings to discuss and resolve design and implementation issues.

On the financial management side, the close of the fiscal year demonstrated that an internal *GONG* budget tracking system worked extremely well. This system was implemented with a

spread-sheet program to provide daily tracking of fund balances during the last quarter of the year. This scheme allowed for close monitoring of the efficient disbursement of funds at year-end.

Although *GONG* still has no budget figure some 4 months into the fiscal year, with the specter of the Gramm–Rudman federal financing restrictions clouding the FY '88 budget prospects, considerable effort has been expended looking at alternative short- and long-range plans, based on different funding scenarios. A fair amount of the originally planned *GONG* budget for FY '88 was programmed for the purchase of long lead-time components for the six field instruments late in the year. As a consequence, the project could withstand a modest cut this year without significantly impacting the ongoing instrument and software development efforts. What would be affected by such an action would be the completion and deployment of the field instruments. Thus, budget circumstances may impose a delay in the first flow of data although the length of this delay is unclear. A return to normal funding in FY '89 should limit it to about one year, although some planning ideas are being explored that may be able to reduce this somewhat. (*Jim Kennedy*)

Site Survey Update

The site survey continues to roll along. There have been relatively few recent problems, with the battery charging system still occasionally proving to be the weakest link in the chain. We have also had a rash of wind-up cable breakages, suggesting that the lifetime of this component is about 2.5 years.

With this newsletter, we now have a full year of six site network data, from November 10 1986, to November 12, 1987. A preliminary analysis of the canonical anonymous network shows that a duty cycle of about 90% was achieved over the full year. This is somewhat lower than the 94% predicted by the model, and reflects the inaccuracy of the estimates of the fraction of clear time that can be obtained from sunshine maps. Seasonal variations are readily apparent, with a very high duty cycle of 95 to 99% being achieved in the Austral Summer, a drop into the 80 to 90% level during the Boreal Spring when it is rainy, a rise again to 94% in June, and another drop into the 80 to 90% range when the northern monsoons hit at several places in August and September and the Boreal Fall sets in. We have installed an additional instrument at Urumqi, Xinjiang in Western China, to provide alternative coverage during the Boreal summer months. This site should avoid the summer monsoons, and it has little precipitation year round.

The power spectrum of the observing time window function shows that the overall background noise, normalized to the central DC component, is at a level of 10^{-4} at frequencies of less than 10 μHz , decreasing to 10^{-5} at 60 μHz . The diurnal sidelobes are present at the level of 10^{-3} , an order of magnitude above the background, but still extremely attenuated. Thus, in an observed solar power spectrum, each oscillation singlet would be surrounded by a noise background with a signal-to-noise ratio of 10,000, and a signal-to-diurnal-sidelobe ratio of 1000. This, of course, is a measure of the observing window noise only.

Progress has been made on the analysis of the site survey database. Renate Kupke, a student from the University of Arizona, has been extremely helpful in developing programs and taking care of the regular chores in maintaining the data. She has corrected the data for clock errors, and the instrumental downtime has been explicitly flagged. She is about to run the entire data base through an improved atmospheric correcting program developed by Harry Jones. I am hard at work on modifying the analysis program to separate the instrumental downtime from the weather, and thus provide the best possible measurement of the fraction of clear time at each site. This information will then be incorporated in the modelling programs on a monthly basis, rather than the two seasonal numbers that have been used previously. Improved displays of the data and analysis are also being developed.

Roger Ulrich has provided us with strip chart recordings from the all-sky pyranometer at Mt. Wilson. The data covers the period of 14 April 1985 to 13 September 1987, and a coarsely time sampled window (morning and afternoon) has been entered into the computer by Lourdes Ramirez, a student assistant from the University of Arizona. Lourdes is currently entering a similar window using data obtained by the *GONG* instrument that was situated at Mt. Wilson from 2 October 1985 to 23 July 1986. A comparison of the windows from the two instruments will be made, and the weather statistics for the site will be estimated using the pyranometer data. (*Frank Hill*)

Data Management and Analysis

Ed Anderson, from the NOAO Central Computer Services, is taking charge of the development of *GRASP*, the interactive analysis package. Ed has considerable experience with *IRAF* which *GONG* will use as the software environment for *GRASP*. Since Ed was involved with the *GRASP* prototype demonstration for the 1987 *GONG* workshop, he is also familiar with the requirements for the *GONG* project.

Based on the results of the recent Garching Meeting, "Astronomy from Large Databases", the *GONG* project is not alone in hoping that (12-inch WORM) optical disk technology matures rapidly in the near future. Future astronomy projects and many existing projects could benefit substantially from a non-erasable removable media which provides comparable performance, greater reliability, and more storage per dollar than traditional half-inch magnetic tape. Optical disks certainly have the potential for being the removable media for future data storage facilities where high data transfer rates and media exchange with external sites are not required. The *GONG* ARCHIVE which will provide the data storage facility for *GRASP* will probably not require high data transfer rates. Non-erasability will also be a benefit to the ARCHIVE. However, the incompatibility among vendor products will discourage the use of optical disks for data shipments to external sites. For the data reduction PIPELINE optical disks are less attractive. The PIPELINE may require high data transfer rates and since reruns will be common, reusable media will be more desirable.

An evaluation of the arithmetic requirements for the *GONG* data reduction pipeline has begun. So far this has focused on the Spherical Harmonic Transform which may require 30M floating point operations per *GONG* image. It is possible that the arithmetic required for the

CORRECTIONS to the multiple site data prior to merge may exceed the arithmetic required for the Spherical Harmonic Transform. Six to nine images will be processed by CORRECTIONS for every one image processed by the Spherical Harmonic Transform. In the not too distant future, a *GONG* pipeline benchmark which models both the arithmetic and IO of the anticipated processing will need to be constructed and tested on various machines.

More Fat for the DEC vs SUN Fire: The above mentioned Spherical Harmonic Transform code was run on an 8600/VMS and a SUN 4. Results: it was a tie in the comparison of the CPU time to execute this very compute bound algorithm (counting floating point operations, both machines produced 1 MFLOPS); however, the UNIX f77 used 4 times more CPU than the VAX/VMS FORTRAN to compile the approximately 2000 lines of code.

Anonymous FTP: A storage facility has been established on the NOAO computer system which is accessible to members of the *GONG* community via existing computer networks. Our intent is to use this as an electronic library for *GONG* documents. It involves using the familiar *ARPANET* file transfer protocol (FTP) with a user name of "anonymous". FTP allows users to transfer files between machines, and is available on many *unix* and *VMS* systems.

To evaluate its effectiveness, the membership lists of the *GONG* science teams have been stored in the directory. If "Anonymous FTP" proves to be effective, other items will be added in the future. We need to know if this is a useful approach. We especially need to know if there are any *GONG* members who are unable for technical (network) reasons to access this storage facility.

Below is a "script" from an "Anonymous FTP" session, which illustrates how to use it; *i.e.*, user identification and directory structure.

```
% ftp noao.arizona.edu
Connected to noao.arizona.edu.
220 carina FTP server (Version 4.106 Tue Mar 24 16:10:02 MST 1987) ready.
Name (noao.arizona.edu:pintar): anonymous
331 Guest login ok, send ident as password.
Password:
230 Guest login ok, access restrictions apply.
ftp> dir
200 PORT command successful.
150 Opening data connection for /bin/ls (192.31.165.6,1145) (0 bytes).
total 4
dr-xr-xr-x2 root ftp          512 Jan 12 11:13 bin
dr-xr-xr-x2 root ftp          512 Jan 12 11:13 etc
drwxrwxrwx3 ftp ftp          512 Jan 12 11:30 gong
drwxrwxrwx2 ftp ftp          512 Jan 12 11:12 pub
226 Transfer complete.
246 bytes received in 0.79 seconds (0.3 Kbytes/s)
ftp> cd gong
250 CWD command successful.
ftp> dir
200 PORT command successful.
```

```
150 Opening data connection for /bin/ls (192.31.165.6,1146) (0 bytes).
total 1
drwxrwxrwx  2 ftp      ftp          512 Jan 13 07:33 science_teams
226 Transfer complete.
78 bytes received in 0.64 seconds (0.12 Kbytes/s)
ftp> cd science_teams
250 CWD command successful.
ftp> dir
200 PORT command successful.
150 Opening data connection for /bin/ls (192.31.165.6,1147) (0 bytes).
total 24
-rw-r--r--  1 ftp      ftp          4805 Jan 12 11:32 inversions
-rw-r--r--  1 ftp      ftp          2638 Jan 12 11:32 low_frequency
-rw-r--r--  1 ftp      ftp          2868 Jan 12 11:32 magnetic_effects
-rw-r--r--  1 ftp      ftp          2305 Jan 12 11:32 mode_physics
-rw-r--r--  1 ftp      ftp          6335 Jan 12 11:32 reduction_&_analysis
-rw-r--r--  1 ftp      ftp          2625 Jan 12 11:32 steady_flows
226 Transfer complete.
429 bytes received in 1.1 seconds (0.39 Kbytes/s)
ftp> get mode_physics
200 PORT command successful.
150 Opening data connection for mode_physics (192.31.165.6,1148) (2305 bytes).
226 Transfer complete.
local: mode_physics remote: mode_physics
2421 bytes received in 0.17 seconds (14 Kbytes/s)
ftp> !less mode_physics
```

mail.d listed at Mon Nov 16 19:43:44 1987

15 entries for select code: T3

Dr. Ashok Ambastha
Udaipur Solar Observatory
Vedhshala Udaipur Solar Observatory
11,Vidya Marg
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Dr. Shashkikumar M. Chitre
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Research
Homi Bhabha Road
Colaba, Bombay 400 005
INDIA
Telex # : 011-3009 TIFR IN, TELEGRAM = ZETESIS
Telephone no: (91) 22 219111

!rm mode_physics

```
rm: remove mode_physics? y
ftp> dir
200 PORT command successful.
150 Opening data connection for /bin/ls (192.31.165.6,1149) (0 bytes).
total 24
-rw-r--r--  1 ftp      ftp           4805 Jan 12 11:32 inversions
-rw-r--r--  1 ftp      ftp           2638 Jan 12 11:32 low_frequency
-rw-r--r--  1 ftp      ftp           2868 Jan 12 11:32 magnetic_effects
-rw-r--r--  1 ftp      ftp           2305 Jan 12 11:32 mode_physics
-rw-r--r--  1 ftp      ftp           6335 Jan 12 11:32 reduction_&_analysis
-rw-r--r--  1 ftp      ftp           2625 Jan 12 11:32 steady_flows
226 Transfer complete.
429 bytes received in 0.67 seconds (0.63 Kbytes/s)
ftp> cdup
250 CWD command successful.
ftp> dir
200 PORT command successful.
150 Opening data connection for /bin/ls (192.31.165.6,1150) (0 bytes).
total 1
drwxrwxrwx  2 ftp      ftp            512 Jan 13 07:33 science_teams
226 Transfer complete.
78 bytes received in 0.43 seconds (0.18 Kbytes/s)
ftp> bye
221 Goodbye.
( Jim Pintar )
```

Another Edition of the GONG Helioseismology Bibliography?

It has now been three years since the publication of *GONG Report Number 2: A Selected Bibliography on Helioseismology*, now out of print. During this time, two major and two smaller conferences have occurred and about three hundred additional papers have appeared. It thus seems appropriate that a new edition of the bibliography be produced, but since it does involve a fair amount of work, we would like to first estimate the demand for this project. To this end, a form has been provided at the end of this *Newsletter* for you to fill in over your coffee and return to us. Just fold the page into three, staple it, add a stamp and drop it in the mail (it's preaddressed). What could be simpler? (*Frank Hill*)

Team Communications

"Aliases" have been created at the Stanford solar group's electronic mail node to facilitate communication within the Teams, thanks to Phil Scherrer. So, for example, SolarMail to "GONGlow" (or "gonglow", since case is ignored) will be distributed to all members of the "Low Frequency" team. Each message will automatically be assigned a number, and a list of everyone getting the message will be appended. The message will also be forwarded to the Project in Tucson, and we will send good(?) old paper mail copies to those team members who do not yet have a reliable connection to one of the electronic mail networks that SolarMail is tied in to. To establish a path to SolarMail, if you do not already have one, please contact Rick Bogart or Phil Scherrer at Stanford. The aliases and team lists will be maintained by the *GONG*

project, so please contact us if you are misassigned or have suggestions for subgroups.

<i>Team / Group</i>	<i>Alias</i>
Data Reduction and Analysis	GONGdata
Artificial Data	GONGfake
Solar Models	GONGmodl
Inversions	GONGinv
Low Frequency	GONGlow
Magnetic Effects on Oscillations	GONGmag
Mode Physics	GONGphys
Nearly Steady Flows and Magnetic Fields	GONGflow
Scientific Advisory Committee	GONGsac
Team Leaders	GONGlead

(*John Leibacher*)

Fission of the Models and Inversions Team

It became clear early on that the Models and Inversions Team was too large and broad in its objectives to continue to function indefinitely as a single group. At the *GONG* Workshops held at Yale and the Harvard–Smithsonian Center for Astrophysics last Summer, the development of the coordinated objectives to prepare for the analysis of the *GONG* data led quite naturally to a separate Solar Models Team and an Inversions Team. Jørgen Christensen-Dalsgaard and Pierre Demarque have agreed to co-chair the Solar Models Team, and Douglas Gough and Juri Toomre have agreed to co-chair the Inversions Team. Frank Hill will provide liaison for both Teams.

The initial membership of the Solar Models Team is as follows: Hiroyasu Ando, Tim Brown, Jørgen Christensen-Dalsgaard, Werner Däppen, Philippe Delache, Pierre Demarque, Søren Frandsen, Ron Gilliland, Douglas Gough, David Guenther, Sylvain Korzennik, Dermot Mullan, Lucio Paterno, Clara Regulo, Ed Rhodes, Ian Roxburgh, Hiromoto Shibahashi, Bob Stein, Michael Stix, Juri Toomre, and Roger Ulrich. Other participants include H. M. Antia, Gabrielle Berthomieu, Arthur Cox, Woitek Dziembowski, Maurice Gabriel, Fernando Javier Perez Hernandez, Carlos Iglesias, Steve Kawaler, Yveline Lebreton, Forrest Rogers, Sabatino Sofia, Aad Van Ballegooijen, and Don Vandenberg.

The initial membership of the Inversions Team is: Rick Bogart, Tom Bogdan, Tim Brown, Jørgen Christensen-Dalsgaard, Werner Däppen, Bernard Durney, Phillip Goode, Douglas Gough, Jack Harvey, Frank Hill, John Jefferies, Bill Jeffrey, Sylvain Korzennik, Eugene Lively, Larry November, Bob Noyes, Bob Rosner, Takashi Sekii, Hiromoto Shibahashi, Juri Toomre, Roger Ulrich, and Martin Woodard. Other participants include Ira Bernstein, John Brown, Fernando Javier Perez Hernandez, Tom Jordan, Yveline Lebreton, Jeffrey Park, Michael Ritzwoller, Fumiko Tajima, Aad Van Ballegooijen, John Woodhouse, and Carl Wunsch.

If you have been incorrectly "assigned" to a Team, or would like to change, modify, or initiate your membership, please contact John Leibacher. The "Anonymous FTP" facility described above can provide relatively current Team Membership lists. (*John Leibacher*)

Magnetic Effects Team

The *GONG* Magnetic Team has been contacted about a possible meeting, most likely to be held in conjunction with the April meeting in Tucson or the September meeting in Tenerife. Possible problems of concern to the Magnetic Team are the calculation of magnetically induced mode frequency shifts in the reference model developed by the Models Team, modal decomposition appropriate to the study of active regions, possibly in collaboration with the Data Analysis and Reduction Team, and calculating the coefficients a_2 , a_4 on the expansion of frequency as a function of m . Preliminary measurements of these coefficients are available from Tim Brown. (*Ellen Zweibel*)

Low Frequency Team

Concerning our goals, I think we should begin to think in an organized way about certain topics that could influence the design of the *GONG* instrument or data analysis system.

I think an important topic that has yet to get a truly careful examination is the known sources of solar noise. The goal of course is to see if anything can be done to make it better. I suggest the following general topics as a starting point and hope to elicit some discussion:

1. examine noise
 - a) enumerate the low frequency noise sources,
 - b) estimate their power,
 - c) consider preventive or repair methods.
2. examine data merging questions
 - a) estimate spectral noise introduced by expected sky and image differences from different sites.
 - b) evaluate question of merging spherical harmonics *vs.* merging velocity maps.
3. consider observable components
 - a) develop analytical tools to extract g -mode peaks from noise with some but not too much help from models. Present methods are weak.
 - b) consider likely relative size of vertical and horizontal components *vs.* frequency of g -modes to help development of appropriate spatial filters.

If we could build a more detailed outline of topics that should be addressed by this team within the next 6 months, we would at least have a start. Comments? (*Phil Scherrer*)

Data Reduction and Analysis Team

Recent activities in the Data Reduction and Analysis Team (*DRAT*)^{*} have centered on the artificial data project. The aim of this project is to produce several kinds of artificial *GONG*

* Can we devise a team with the acronym "SHUCKS"?

data that can be used to (1) exercise and test the data reduction pipeline code, and (2) understand the limitations and ambiguities inherent in the data reduction process. We are also finding that simply thinking carefully about these problems has led to some suggestions about the instrument design and data-taking procedures. In a lightly attended (but highly successful) workshop held in Tucson in October[□] we arrived at several specific goals to be achieved by January 1988. Subsequent discussions have extended this list with other items that we hope to complete in time for the *GONG* meeting in April.

The first task we have undertaken is to produce two reasonably authentic-looking solar images, corresponding to *GONG* observations taken at the same time but from two different sites. For specificity's sake, we have chosen the time to be 17:00 UT on 1 August, 1985; the sites are Sacramento Peak and Haleakala. Making these images has involved several major steps. First, David Hathaway constructed velocity images corresponding to steady flows (including differential rotation, supergranulation, and limb red shift), and to oscillations (including modes with all l and m up to degree 300). These images have 256×256 pixel resolution; when summed, they provide a good approximation to solar velocity data at the *GONG* spatial resolution. Next, Frank Hill generated an intensity image to go with the summed velocity image, and applied synthetic atmospheric blurring and distortion to both of these images. Harry Jones calculated the center-to-limb variation of the 6768 \AA Nickel line profile, which is now incorporated in a pair of simple routines that give the limb darkening function and *GONG* instrument modulation amplitude as functions of μ . Finally, Tim Brown converted the velocity and intensity images, along with information about the *GONG* Fourier tachometer and the line profile, into three intensity images corresponding to the three different modulation phases of the *GONG* instrument.

In addition to the artificial data just described, three other significant data projects are in progress. Bo Andersen and Frank Hill are working on improved methods for simulating atmospheric seeing and scattering. These will be incorporated in later versions of the artificial solar images. David Hathaway is making another set of images containing only a few oscillation modes: $l = 2, 21, 50, 101, 200,$ and 301 , with $m = 0, l/2,$ and l for all degrees greater than 2. These images will be helpful in determining how well various analysis methods isolate individual spherical harmonics. Hathaway has also generated on a month-long time series for a single spherical harmonic (plus leakage from its neighbors). The mode chosen for this purpose is $l = 42, m = 21$. This series is now available for evaluating means of filling data gaps, for developing methods to measure mode amplitudes, frequencies, and phases, and for deriving optimal filters to remove the oscillations so that steady flows may be studied. Two data files containing time series and power spectra are available from David via the SPAN network. Send

[□] The complete proceedings of the Artificial Data Workshop, including contributions by Bo Andersen on scattered light, Tim Brown on the modeling of the Fourier tachometer, Dave Hathaway on the simulation of solar velocity fields and time series, Frank Hill on the effects of seeing and refraction, Harry Jones on the formation of the Ni I 6768 \AA line, and Roger Ulrich on lessons learned from the Mt. Wilson experiment, will be released as *GONG Report Number 5* in the near future. See the order form at the end of this Newsletter.

e-mail to him for details, if you wish to work on these data.

There are a few additional goals that we would like to address soon, but that are not yet under way. Between now and April we would like to have done the following:

- Completed all of the abovementioned projects.
- Identified criteria for image quality.
- Attempted to merge two images with different (but known) seeing and atmospheric distortion, and learned something thereby.
- Developed code to convert 3 intensity images into images of velocity, intensity, and modulation.
- Closed several short loops in the data creation and analysis process. For example, we would like to compare the velocities computed from the three modulation phases with those used as input to the routines that simulate the Fourier tachometer behavior. Likewise, we should compare the output of the spherical harmonic decomposition with the mode amplitudes that were input.
- Developed and tested quantitative measures to facilitate the comparisons described above.
- Determined how we may (within reasonable computer time constraints) include realistic line shape variations in our artificial data.

(*Tim Brown*)

Models Team

The plans for the *GONG* solar model project were described in detail in *GONG* Newsletter #6. The purpose is to compute solar models and oscillation frequencies with precisely defined physical assumptions, to allow careful testing and comparison of the computational procedures employed. The motivation for this is the substantial differences between the calculations carried out so far.

A first step in this project is to define and test the simplified physics to be used for the calculations. Fernando Perez Hernandez has obtained very simple approximations to the opacity, as well as to the energy generation and rate of change of the hydrogen abundance X . In addition two levels of approximation to the equation of state are foreseen: 1) assuming complete ionization everywhere; and 2) including partial ionization of H and He, while assuming that the heavy elements are completely ionized. In the latter case complete ionization in the solar interior is ensured by means of a prescription suggested by Eggleton *et al.* (*Astron. Astrophys.*, **23**, 325; 1973).

I have computed evolution sequences leading up to models of the present Sun at these two levels of approximation, and using the opacity and energy generation obtained by Perez Hernandez. At level 1 there are obviously very severe errors near the surface where H and He are essentially unionized in a realistic model. To compensate, modifications were required in the surface boundary conditions to obtain a model with the correct radius. In the interior of the model the errors are then modest. This is illustrated in the Figure, where temperature, pressure,

density and sound speed are compared in the models. In the convection zone pressure and density, and near the surface also temperature and sound speed, in the simplified model deviate strongly from the normal model. In the interior, however, the deviations are modest, and are caused predominantly by the assumed simplified opacity, with an additional small contribution from the simplified rate of change of X . Also shown in the figure are the results for the level 2 case. Here the contribution to the error from the equation of state is relatively modest, and the combined error in these quantities is everywhere less than about 15 per cent. Also, in agreement with the remarks just made, the errors beneath the convection zone are very similar to the level 1 case.

Figure Caption: A comparison between the simplified models of the present Sun and a normal model. Differences are taken at fixed fractional radius r/R . In *a*) are shown results for the level 1 case. The curves are

$$\begin{aligned} &: \log(T^{(2)}/T^{(1)}) \\ &: \log(p^{(2)}/p^{(1)}) \\ &: \log(\rho^{(2)}/\rho^{(1)}) \\ &: \log(c^{(2)}/c^{(1)}) \end{aligned}$$

Here superscripts "(1)" and "(2)" refer to the normal and the simplified model, respectively; "log" is the natural logarithm. Also T is temperature, p is pressure, ρ is density and c is sound speed. Notice that in most of the model the errors in c and T introduced by the simplified physics are only a few per cent. In *b*) are shown the similar results for the level 2 case; here the error in c and T is everywhere quite small. In the interior of the model the two approximations are essentially equivalent, and the differences are very similar in the two cases.

For the solar model comparison it is encouraging that the very simple physics results in models that are relatively close to realistic models. Thus it is meaningful to test the numerical accuracy of the calculation with even the level 1 physics, at least as far as the solar interior, and effects of evolution, are concerned. On the other hand the very small change in the sound speed

implies an equally small change in the computed frequencies of p -modes. This again emphasizes the great accuracy required in computation and observation of p -mode frequencies to allow information to be obtained about the physics of the solar interior.

Given these results, the next step is clearly to circulate the information required to the participants in the project. I have written a first draft of a manual on "Computational procedures for *GONG* solar model project", which is being checked and will be sent out shortly. Also under discussion is the most efficient way of organizing the comparison between the resulting models.

The response to the questionnaire in *GONG* Newsletter #6 has been encouraging, with 14 people indicating their intent to take part in the project. They are listed in the table below, with an indication of their initial level of involvement, as described in the table on page 13 of *GONG* Newsletter #6. A large majority intend to use the simplified physics (this is evidently a prerequisite for a detailed comparison between the computational methods), and an equally large majority intend to compute also oscillation frequencies. It should be noticed that, despite the deadline on the form, the project is still open for entry.

<i>Solar Model Project Participants</i>	<i>Level of entry</i>	<i>Compute frequencies?</i>
Gabrielle Berthomieu	1 - 3	yes
Jørgen Christensen-Dalsgaard	1 - 3	yes
Pierre Demarque	3	no
Maurice Gabriel	1 - 3	yes
Ronald L. Gilliland	1 - 3	yes
David Guenther	3	yes
Fernando Javier Perez Hernandez	1 - 3	yes
John Lattanzio	1 - 3	no
Yveline Lebreton	1 - 3	no
Lucio Paterno	2 - 3	yes
Ian W. Roxburgh	1 - 2	no
Hiroto Shibahashi	3	yes
Michael Stix	3	yes
Roger Ulrich	2 - 3	yes

In a parallel effort, Art Cox has agreed to oversee the comparison between different formulations for the equation of state. The precise format for this is under definition. Anyone wishing to take part is invited to get in touch directly with Cox, who will communicate with them and send them equation of state data in his format for their consideration. (*Jørgen Christensen-Dalsgaard*)

Models Team Report from Yale

We have been concentrating on several aspects of the physics of the solar interior:

- (1) the effects of uncertainties in the chemical abundances in the solar interior on radiative opacities, and how these opacities influence the calculated solar oscillation spectrum. Guenther has been working on a simplification and reformulation of the Los Alamos Opacity Library codes. Our first objective is to use this code to investigate the sensitivity of the oscillation spectrum on the choice of the chemical element mixture (*e.g.* Aller, Ross-Aller, Cameron, or Grevesse).
- (2) the formulation of the equation of state of degenerate electrons. Graduate student Jamie Howard is implementing the Eggleton formulation of the electron gas equation of state (used in particular by Jørgen Christensen-Dalsgaard) in our stellar evolution code. The aim is to estimate the effects on solar models of this approximation, when compared with the explicit calculation of the Fermi integrals.
- (3) the history of the angular momentum distribution in the Sun. Steven Kawaler has tested a model for the solar wind breaking on young solar stars. Graduate student Marc Pinsonneault has now implemented our new rotating evolution code. Using the forward approach are now able to provide a complete rotational history of the Sun and the corresponding p -mode splitting spectrum for a variety of input physics. Classification of these results will enable a strong physical interpretation of the observations to be made.

This work also includes the collaboration of David B. Guenther and Sabatino Sofia. (*Pierre Demarque*)

Inversions Team

The Team agreed to begin its work with a joint exercise to test a variety of inversion procedures applied to one of the simpler solar problems. The inversion problem is linear, and involves inferring the spherically symmetrical component of the sun's angular velocity from the rotational splitting, assuming that the hydrostatic structure is known. The exercise is of the hare-and-hounds variety, with Douglas Gough (the hare) providing artificial rotational splitting frequencies computed from a theoretical solar model with an imposed angular velocity $\Omega(r)$. Errors will have been added to the raw splitting frequencies, and for some data sets their statistical properties will be given. Douglas will provide splitting kernels for the modes under consideration, doing so to save duplication of effort, along with suitable instructions; no information is provided about the imposed angular velocity function. The inverters (the hounds), usually working independently, will infer $\Omega(r)$ by whatever means they choose. The results of the inversions will be compared in several stages, and it is hoped that preliminary results will be available to be discussed during the upcoming April *GONG* meeting.

The computation of the rotational splitting kernels for the first inversion experiment is nearly complete, though we are slightly behind the optimistic schedule announced at the CfA workshop in July. The kernels will be sent out to those intending to participate in this exercise as soon as they are ready, together with appropriate frequency splittings and instructions for use.

Frank Hill of NSO will coordinate their distribution, and verify with potential recipients the magnetic formatting that they can accommodate. Anyone wishing to participate in the experiment, but who either has not already indicated that they wish to do so, or cannot remember whether they have, please contact Douglas Gough or Juri Toomre preferably by e-mail [bitnet: dgough@susolar jtoomre@susolar] as soon as possible. The subgroup of the Inversion Team who we believe wishes to take part in this first experiment involves: J. C. Brown, Christensen-Dalsgaard, Durney, Gough, Hernandez, Hill, Jeffrey, Jordan, Korzennik, Lavelly, Lebreton, Noyes, Park, Rosner, Sekii, Shibahashi, Toomre, Ulrich, Woodard, and Woodhouse. Anyone else who is not on the Inversion Team, but wishes to join it and/or to partake in the first inversion experiment, should indicate such a preference, again preferably by e-mail.

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Symposium on Solar and Stellar Oscillations

Don't forget. The Symposium sponsored by the Instituto de Astrofisica de Canarias and the European Space Agency will be held at Tenerife, Canary Islands September 26 through 31. Contact Pere Pallé at the IAC for further information.