Network for High Resolution Hα Full Disk Observations of the Sun

Proposal to the National Science Foundation

September 29, 1998

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A. Proposal Summary

Based on our successful experience at making high resolution full disk Hα observations at Big Bear Solar Observatory (BBSO), and the urgent needs to monitor the solar chromosphere continuously with the best data possible during approaching solar maximum, we propose to establish a network for Hα full disk observations utilizing existing facilities at the BBSO in California, the Kanzelhöhe Solar Observatory (KSO) in Austria, and the Yunnan Observatory (YO) in China. All these observatories have over 300 sunny days a year, good seeing conditions, adequate observing staffs and well-established Hα telescope systems. We only request funding to upgrade the detector systems at KSO and YO from film to 2k $\times$ 2k pixel digital systems, so that we can monitor solar chromospheric activity with 1 arc second pixel^{-1} resolution round-the-clock. We will also apply the same data calibration and analyzing techniques already developed at BBSO, which will significantly improve the data quality and provide a consistent and linked data set. We expect the network to be operational within six months after the funding is approved by NSF (approximately in the summer of 1999). This will ensure that we will begin continuous Hα monitoring before the peak phase of solar maximum No. 23, much earlier than the completion of the Improved Solar Optical Observing Network (ISOON). It is also much less expensive than the ISOON. The data will be readily available to the solar physics community around the world.

Continuous high resolution full disk data are especially useful in monitoring solar active regions, solar flares and filament/prominence eruptions. The scientific objectives will include:

1. Monitoring every new flux emergence and try to understand why some become super-active regions and other decay quickly.

2. Providing high quality data for solar activity forecasting.

3. Providing complete data for correlative studies with other ground-based and space observations.

4. Observing and classifying all the flares and filament/prominence eruptions obtained by the network.

B. Project Description

B.1. Results from the Prior NSF Support

This is a new project. However, the PI (Wang) and one of the Co-PIs (Goode) received the following NSF awards:

1. ATM-9714796, 01-01-1998 to 12-31-2000, $663,127, PI: Goode, Solar Activity and Atmosphere at Big Bear Solar Observatory

2. INT-9603534, 01-01-1997 to 12-31-1999, $39,900, PI: Wang, U.S.-China Collaboration in Solar Physics Research

3. ATM-9713359, 08-15-1997 to 07-31-2000, $73,135, PI: Wang, Space Weather: Automated Early Warning of Filament Eruptions

Parts of the research supported by above grants have some relevance to the proposed project. The results of the relevant part (Hα full disk observations and international collaboration) are described below:

BBSO has recorded full disk images from sunrise to sunset since 1969, forming a valuable data archive. Hα full disk images from BBSO recorded between 1991 and 1994 have been used in a statistical study of filament eruptions (Wang et al., 1998a). More than 10,000 Hα images covering the period from September 1991 to September 1994 have been digitized and archived (Wang et al., 1998a). In early 1995, BBSO started a new generation of Hα patrol observations utilizing a 2k $\times$ 2k pixel, 8-bit, Kodak Megaplus CCD camera to obtain Hα images with a one minute cadence. Since October 1997, we have provided daily, contrast enhanced full disk images taken in the line center of Hα, in which the limb darkening and non-uniformity are removed. First results on differential rotation and statistical properties of mini-filaments were reported in Johannesson et al. (1998). A detailed description of the synoptic Hα full disk observing program and its prospects is given by Denker et al. (1998).

Based on sequences of high-quality Hα images obtained at BBSO, an IDL program is being developed by a graduate student at NJIT to automatically recognize the structure of filaments. When a filament disappears, this news will be immediately sent via E-mail to researchers who are interested in the project and are on our BEARALERT (Zirin and Marquette, 1991) mailing list. The broadcasted information will include the time of the eruption, and the coordinates and size of the filament. Slight modifications to the program will lead to a similar automated early warning system to monitor the onset of solar flares. Substantial progress has been made for both the filament and the flare components in the program, and we plan to finish the project by December 1998 (Lin, 1998). The filament part of the program is further developed to detect mini-filaments, and to study their size and latitude distributions.

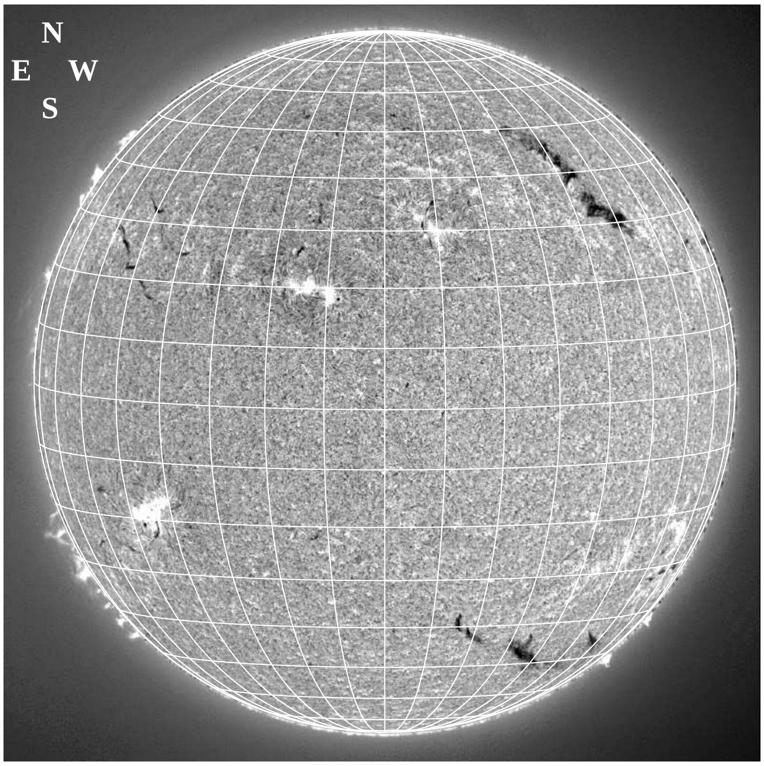

Figure 1: BBSO synoptic Hα full disk image observed on 29 October 1997. This image has been processed to remove limb darkening and to enhance contrast which allows the simultaneous display of disk features and limb prominences.

BBSO and Beijing Observatory in China pioneered coordinated round-the-clock magnetograph observations. Under the US-China collaborative research program, we just have had a very productive year with several projects. Dr. Wei Li from Beijing Observatory spent 6 months at BBSO, she finished a very comprehensive paper on the studies of flows, magnetic fields, electric currents and flares in the October 1991 super active region, jointly observed by BBSO and Beijing Observatory (Li et al., 1998). Dr. Jingxiu Wang, also from Beijing Observatory, visited BBSO for two months in 1998. He coordinated an observational study of mini-filament eruptions, by joint BBSO, Beijing Observatory and SOHO observations. He finished a first comprehensive statistical studies of mini-filaments and their magnetic field association (Wang et al., 1998c). The Hα full disk network idea was initially prompted during our discussion with Dr. J. Wang. Jingshan Wang, a graduate student has begun his thesis project in collaboration with Dr. Guoxiang Ai in Beijing Observatory. Jingshan Wang is taking the lead in the collaboration to build a narrow band filter for near infrared observations at 1.56 μm, which will be combined with a Fabry-Pérot filter to build a near infrared magnetograph system (Wang et al., 1998b).

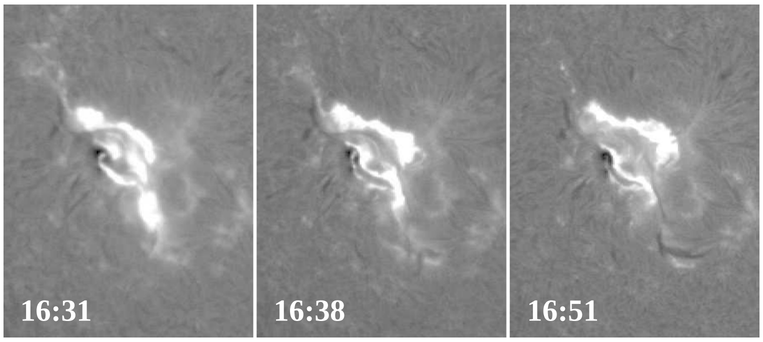

Figure 2: Temporal evolution of an M7 flare during its maximum phase in active region NOAA 8210 observed on 29 April 1998. The field of view of the individual frames amounts to $300'' \times 400''$. The images are γ-corrected to enhance the details in the background.

B.2. The Importance of High Resolution Network Full Disk Hα Observations

Combining with space and ground-based observations, Hα full disk observations of high temporal and spatial resolution have been proven to a key diagnostic for determining the magnetic field topology between the photosphere, chromosphere, transition region, and corona. BBSO started 2k $\times$ 2k pixels full disk Hα observations in 1995, and we have used these data extensively.

Figure 1 shows a Hα full disk image superimposed on a Stonyhurst grid. Several dark filaments and two active regions (NOAA 8099 and NOAA 8100) with bright Hα plages are visible in this contrast enhanced image. The image calibration and image processing procedures allow the simultaneous display of disk features, as well as prominences above the solar limb. The richness in detail of these limb features is at least comparable or even superior to observations made with complex instruments such as the Hα coronograph at the Observatoire du Pic du Midi in France (cf., Niot and Noëns, 1997). Studying prominences and corresponding filaments at the same time, which is only one of the advantages of our high contrast images, provides deeper insight into their temporal evolution and their supporting magnetic field configuration, especially in combination with simultaneous observations of sensitive magnetograms. We argue below that the round-the-clock network observations of this quality will significantly improve our understanding of solar activity in the chromosphere.

B.2.1. Flare Monitoring

Flares can occur anywhere and at any time on the solar disk. High resolution solar images with 24 hours high cadence coverage are essential to catch all the flares on the visible disk of the Sun. High spatial resolution and cadence will also allow a detailed picture of the evolution of flares as well as associated active regions. This is the core scientific objective of proposed Hα network.

Until now, Hα full disk images depicting solar flares were normally saturated because the exposure time was set to a constant value and optimized to yield high contrast images of the quiet Sun. The bright flaring regions were therefore over-exposed. Since the Hα intensity gives a minimum temperature for the flare region, it is important to obtain proper photometric data even when the full disk brightness is suddenly rising during a flare. While the BBSO Kodak 4.2 CCD camera has only an 8-bit dynamic range, an automatic software control has been implemented in the camera control software which permits an accurate evaluation of flare brightness. As an example, the temporal evolution of a M7 flare is shown in Figure 2 during its maximum phase from 16:31 to 16:51 UT on 29 April 1998, images were not saturated in the raw data. The proposed two new cameras for network are 14-bit cameras, it will further improve the photometric measurements.

B.2.2. Filament Eruption and Coronal Mass Ejections

The prominence, filament, and active region shown in Figure 3 give an impression of the fine structure visible in the Hα full disk images. Even faint threads are discernible in Figure 3(a) (cf., Niot and Noëns, 1997), and proper motions along individual barbs of a filament in Figure 3(b) are easily to trace in time lapse movies. One of the ongoing research projects at BBSO is to understand the correlation between filament/prominence disappearances and coronal mass ejections (CMEs) and to study their possible driving mechanisms. Round-the-clock high resolution full disk Hα movies have been extremely important for this study, as CMEs may occur any where at any time. Most previous observations failed to establish a systematic correlation among the onset of solar flares, filament/prominence eruptions, and CMEs (Harrison, 1995; McAllister et al., 1996). One of the difficulties in establishing a possible relationship between filament eruptions and CMEs is that CMEs are more likely to be detected if they are limb events, while filament eruptions are more easily visible as disk events. Any search for a correlation between filament eruptions and CMEs needs to be able to consider both disk and limb CMEs and the attendant phenomena.

B.2.3. Support of Space Observations

Space missions like SOHO and TRACE are designed to observe the Sun round-the-clock. So high resolution full disk images round-the-clock are extremely important to ensure continuous support of space observations. We give an example here: the observation of mini-filament eruptions. The purpose of this example is to show that round-the-clock high resolution Hα observations will be able to provide data with sufficient resolution and cadence to support the observing targets of space observations, anywhere on the face of

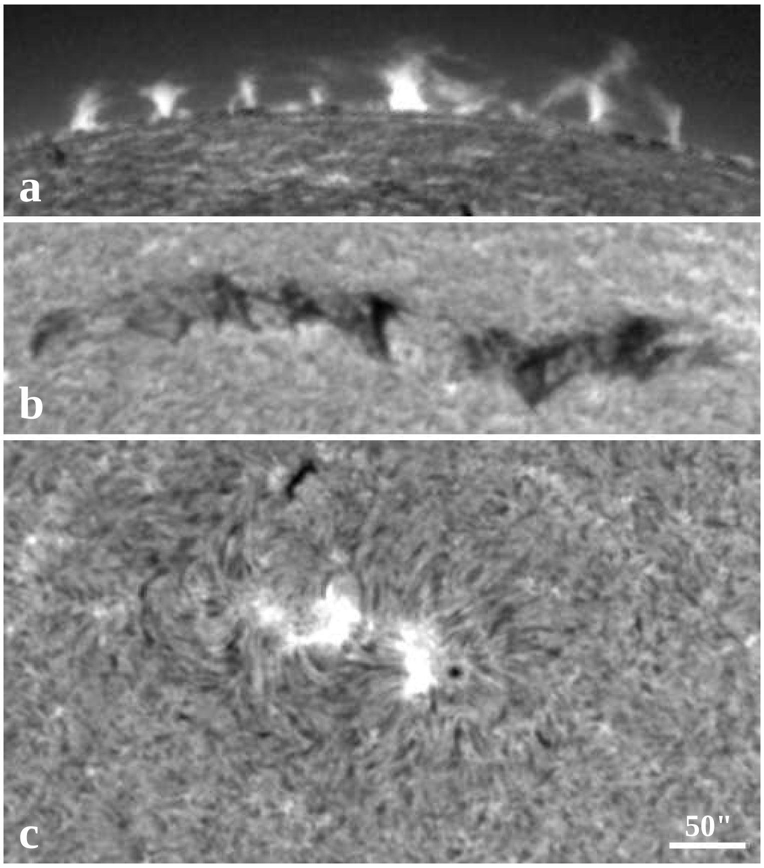

Figure 3: Detail study of (a) a prominence, (b) a filament, and (c) active region NOAA 8099.

the Sun and at any time.

The first detailed description of mini-filaments was given by Labonte (1979) who, however, subsumed them into the classification of macrospicules. Hermans and Martin (1986) pointed out that mini-filament eruptions are the small scale analog to large scale filament eruptions. Mini-filaments are a typical manifestation of magnetic activity on the quiet Sun. The energy release and mass ejection of erupting mini-filaments is of particular importance since both can contribute to coronal heating and solar wind acceleration due to the large number of these events. The advantage of daily high contrast Hα full disk images is obvious: the position of mini-filaments, and therefore their spatial distribution, is easy to measure. In addition, we can follow temporal variations of their surface density and spatial distribution so that we can address for example the question of whether their occurrence is correlated with coronal holes or not. With contrast enhanced full disk images in hand, detailed studies of individual erupting mini-filaments and their temporal evolution with time scales of a minute or less are possible as demonstrated in Figure 4.

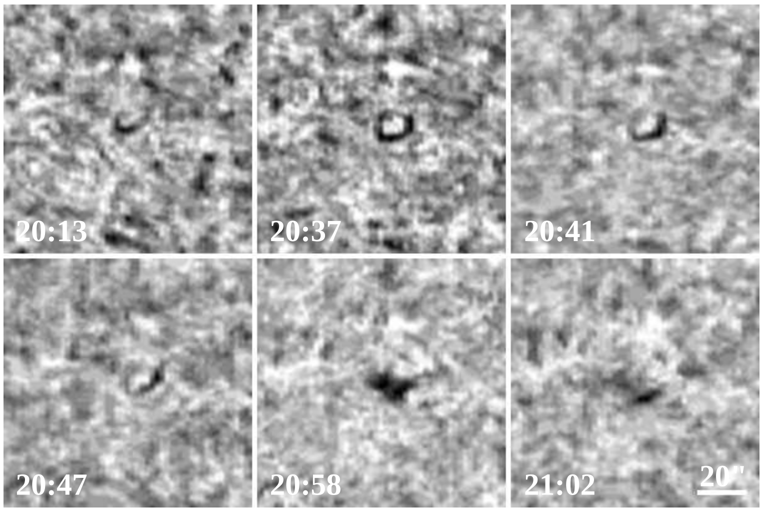

Figure 4: Temporal evolution of an erupting mini-filament observed at disk center on 29 October 1997 from 20:13 to 21:02 UT. The field of view for the individual images is $100'' \times 100''$.

B.2.4. Feature Identification and Feature Tracking

Figure 5 shows the average flow field near the south pole as derived using feature tracking software (developed by Dr. Strous at BBSO) on dark features in 3.3 hours of cropped full Hα disk images observed on 4 April 1998 when the Sun was near its maximum B angle. For display purposes, the flow field was reduced in resolution to a grid spacing of 50 arc seconds (from 5 arc seconds). The cross indicates the position of the south pole. Panel Figure 5(a) shows the measured flow field, smoothed using a Gaussian kernel (FWHM 250 arc seconds). Panel Figure 5(b) shows a least-squares solid-rotation model fit to the data, and also a heliocentric coordinate grid (using dashed curves). Parallels are shown at 10° intervals, and meridians at 30°. The solid-rotation model has a fitted synodical rotation period of 29 ± 6 days (formal standard error). This close to the pole, no other standard differential rotation model parameters can be reliably determined. Obviously, the night gaps in the single station observations severely affects the accuracy of the feature tracking, as Hα features can not be identified after more than 12 hours. Continuous network observations will ensure the tracking of features near the pole continuously. We estimate that if we have continuous high resolution Hα image obtained by a network, the accuracy of the rotation rate would increase by a factor of 3.

In summary, while single station high resolution full disk Hα observations can perform important research, for the following reasons, it is necessary to monitor the Sun round-the-clock:

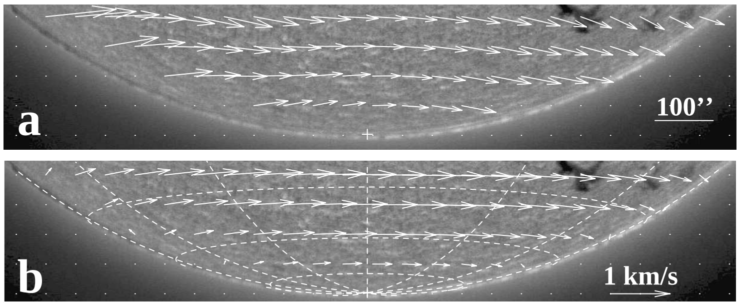

Figure 5: Rotation near the south pole measured with feature tracking techniques.

(a) The night gap is a severe problem for single station observations. Many important phenomena (flares and filament/prominence eruptions) could happen during the night gap.

(b) The continuous data set certainly would increase accuracy of measurement such as solar rotation by feature tracking, as described above.

(c) Round-the-clock observation can follow the evolution of active region which produce flares. Observations of many cases, and statistical analyses of events can enhance our knowledge of flare prediction.

(d) Uniformly processed continuous data certainly will be desirable by users around world for correlative studies with both ground-based and space observations.

Synoptic Hα full disk images are provided by many observatories around the world, e.g., Holloman Air Force Base in New Mexico, Kiepenheuer Institut für Sonnenphysik at the Observatorio del Teide/Tenerife in Spain, Learmonth Solar Observatory in Australia, National Solar Observatory at Sacramento Peak in New Mexico, Sonnenobservatorium Kanzelhöhe in Austria, and Hα spectroheliograms from Observatoire de Paris Meudon in France. In the past, high-resolution Hα imaging could only be carried out on limited areas of the Sun. Modern large format CCD cameras enable us to obtain detailed images of the whole Sun. To the best of our knowledge, the only other 2k $\times$ 2k pixels CCD camera used for Hα full disk observations is operated at the Hiraiso Solar Terrestrial Research Center in Japan (Akioka, 1996). Hα full disk observations were usually used to survey solar activity, to find interesting objects, and to monitor flares. However, there are only a few research projects based on Hα full disk observations alone but we believe that large format CCD cameras and advanced image processing techniques provide a unique opportunity for studies with full disk data.

The Airforce project ISOON is being carried out for the very same reason. It intends to replace the old SOON system. However, the projected ISOON completion date will

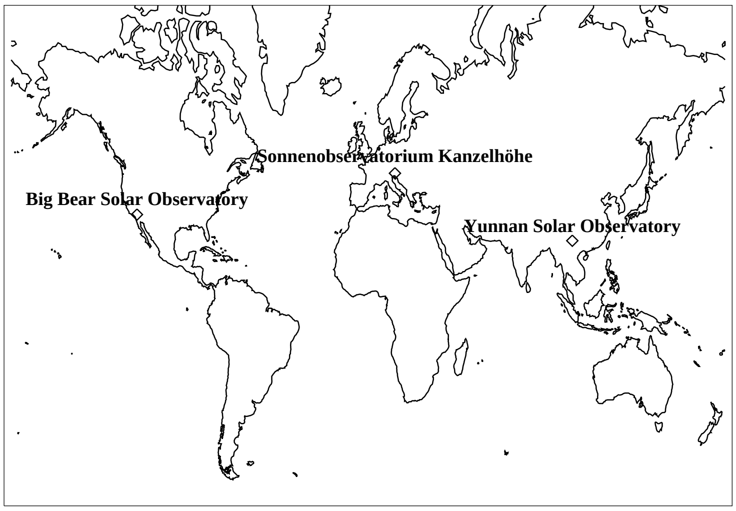

Figure 6: The Observing Stations of the Network.

be after the peak of next solar maximum. Our proposed network is based on existing facility, it is much cheaper and will be operational much sooner. After the ISOON is operational in the future, our stations can be coordinated with ISOON sites, and data analyses software developed by us can be used by ISOON.

B.3. The Observing Stations of the Network

We have chosen two other observatories to join BBSO to form our Hα full disk network: Yunnan Observatory in China and Kanzelhöhe Solar Observatory in Austria. Both observatories already have full disk Hα systems which include a telescope, a narrow band pass filter, and a 35-mm film camera. We emphasize that we can quickly and cheaply replace film cameras by 2k $\times$ 2k digital camera. Both stations are willing to provide operation and maintenance without charge to the grant. Those contributions would bear most of the financial burden of running a network. The geographic longitude distribution is basically acceptable. The following table gives an overview of basic status of the three observatories, and detailed description of each station will follow the table.

	Big Bear	**Kanzelhöhe**	**Yunnan**
Longitude	$-116°54.9'$	$+13°54.4'$	$+102°47.3'$
Latitude	$+34°15.2'$	$+46°40.7'$	$+25°1.5'$
Altitude	2067 m	1526 m	1940 m
Telescope Aperture	15 cm	??	18 cm
Bandpass Hα Filter	0.05 nm	0.07 nm	0.05 nm
Tunable Range of Filter	$\pm$0.10 nm	??	$\pm$0.06 nm

B.3.1. Big Bear Solar Observatory, U.S.A.

The Big Bear Solar Observatory exploits the excellent climatic conditions of Big Bear Lake to study the Sun. The observatory is located in the middle of Big Bear Lake to reduce the image distortion which usually occurs when the Sun heats the ground and produces convection in the air just above the ground. Turbulent motions in the air near the observatory are also reduced by the smooth flow of the wind across the lake instead of the turbulent flow that occurs over mountain peaks and forests. These conditions, combined with the usually cloudless skies over Big Bear Lake and the clarity of the air at 2,000 meters (6,750 feet) elevation, make the observatory a premier site for solar observations. The observatory was built by the California Institute of Technology in 1969, and was transferred to the New Jersey Institute of Technology on 1 July 1997.

Figure 7: Big Bear Solar Observatory and telescope cluster with the 15 cm Singer telescope in the foreground.

The observatory's telescopes are specially designed for solar observations. The top floor of the observatory contains a single fork mount supporting the three main telescopes: a 65 cm reflector, a 25 cm refractor, and a 15 cm refractor. The telescopes are equipped with various filters and cameras. The 25 cm and 65 cm telescopes observe partial fields of

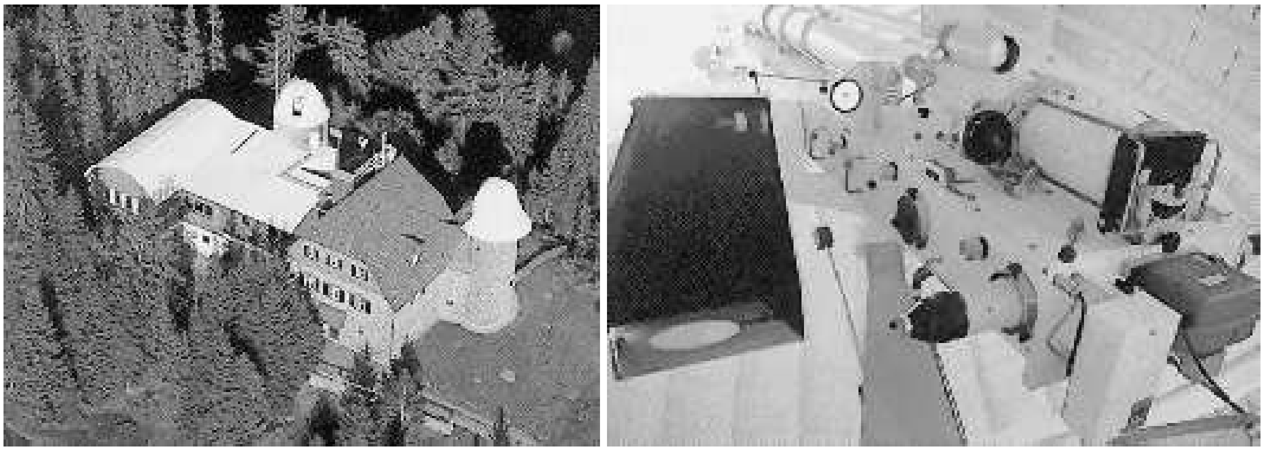

Figure 8: The Sonnenobservatorium Kanzelhöhe and the three refractors of monitoring instrument.

view of the Sun with high resolution. The 15 cm telescope monitors the whole Sun in Hα. The full disk images are obtained with a 2k $\times$ 2k pixels digital CCD and enhanced with modern image processing techniques. On every clear day the 15 cm full disk telescope observes the Sun from sunrise to sunset obtaining an image every 30 seconds. Attached to the underside of the 15 cm telescope is a 9 cm telescope that obtains daily full disk visible light images of the photosphere and CaK images originating in the chromosphere.

B.3.2. Kanzelhöhe Solar Observatory, Austria

The Kanzelhöhe Solar Observatory is the only one in Austria and belongs to the Institute of Astronomy of the Karl-Franzens-University Graz. Because of the favorable climate and the convenience of year-around access to the site via the cable railway Kanzelbahn the observatory was built at Kanzelhöhe near Villach (Carinthia) in 1943. The site consists of the main-building and two domes. The main-building holds all facilities. Additional financial support for the operation of the observatory is granted by the Land Kärnten (Province of Carinthia) and the Austrian Academy of Sciences.

At Kanzelhöhe Solar Observatory routine observations are taken with the Kanzelhöhe Vacuum-Telescope (KVT) and the three refractors of the monitoring-instrument (Überwachungsinstrument). About 2000 hours of sunshine each year allow to fulfill on nearly 300 days a year the routine tasks:

(a) Producing at least one drawing of the sunspot-groups at the 25 cm projection-image and derive the sunspot-number. The drawing are stored in the local archive and the sunspot numbers are reported monthly to the data center in Brussels (SIDC). The data set consists of continuous nearly 50 year time-series.

(b) Getting photoheliograms to derive the exact spot positions and to catalogue it. Copies of these exposures are sent to the Debrecen Solar Observatory (Hungary) to continue the over 100 year time-series of the Royal Greenwich Observatory.

(c) Continuous observation in the red spectral line of Hα for flare-monitoring. These results are sent to the world-data centers in Boulder, Paris and Moscow.

(d) Publishing of monthly solar-activity reports for users inside and outside Austria.

The Hα observations are performed with one of the three refractors of the monitoring-instrument. The bandpass of the temperature-controlled Lyot filter is 0.07 nm and the chromospheric images are currently recorded on 35 mm-film in intervals of seconds or minutes.

B.3.3. Yunnan Observatory, China

Yunnan Observatory is one of the five astronomical observatories in China, all operated by the Chinese Academy of Sciences. It is located in the suburban of Kunming City in the southern part of China. Although Yunnan Observatory carries out research in all areas of astronomy, solar physics is one of the most important project. It has the best weather condition of all the observatories in China, with about 300 clear days a year and excellent sky transparency.

The synoptic observations in Yunnan Observatory are carried out in a solar tower which hosts a twin telescope, both telescopes have 18 cm aperture. One of the telescope is used for white light observations, the other (relevant to our project) is the full disk Hα telescope. The Hα filter is a Lyot filter with a bandpass of 0.05 nm. The tunable range is $\pm$0.06 nm. the guiding system works properly. The current detector is a 35 mm film camera which takes image only occasionally. In addition to synoptical observations, Yunnan observatory also observes the Sun with high spatial resolution.

B.4. Setup and Operation

Immediately after the approval of the funding, two camera systems (KF-4200 sensor from Kodak, 2k $\times$ 2k pixels, 14-bit) will be purchased from Apogee, Inc. The price quote has been obtained already and is reflected in the budget. The camera will be controlled PC with LinuX as operating system. The software will be provided by ClearSkyInstiture, Inc., which requires no change to operate the camera. Such software has been tested in BBSO's Earthshine observations. Camera systems will be deployed to Kanzelhöhe and Yunnan in six months. The camera systems still belong to U.S. government, but on a long term loan to the two stations. To avoid the problem of an exporting license for a new camera system to China, we plan to ship the existing 8-bit system to China, and keep one of the new 14-bit system at BBSO.

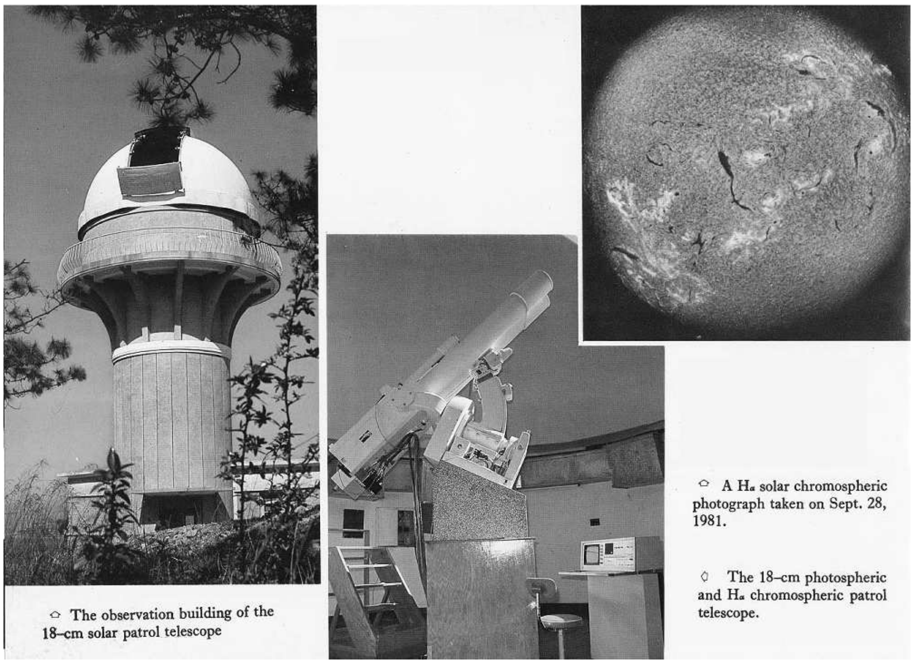

Figure 9: The observing building at Yunnan observatory, the 18 cm refractor, and a Hα full disk image observed on 28 September 1981.

The initial simple mode will just take one Hα center line image every minute. The data will in general in 8-bit JPEG format to save storage space, unless some special observing projects or flare sequences require 16-bit FITS data. Data will be archived on ExaByte tape and mailed to BBSO for processing. As both KSO and YO have similar instrumentation and seeing conditions to BBSO, we believe that new digital images from these two stations will be similar to that of BBSO, as shown in Figure 1.

The large time difference in the network in between BBSO and YO, about 9.5 hours. In the summer, each station can observe 12 hours in the clear days, therefore, normally, there is no night gap in the summer. In the winter, each station is expected to operate 8 hours; the BBSO/YO gap will be about 1.5 hours. Based on the weather record of three stations, we anticipate that the duty cycle is above 70% in summers, in 60% in winters.

A post-doc will be hired to oversee the operation and perform data analyses. Data reduction procedures would include dark and flat correction, image enhancement, and registration. The during the selection process of the post-doc, applicants from KSO and YO will be given higher priority, as they are already familiar with the instrumentation in their home institute. He or she will reside at BBSO. This arrangement will further enhance the collaboration of the three observatories. Creation of this position is necessary, because the data coordination and production of scientific results based on network data sets are heavy jobs, and they can not be covered by existing staff at BBSO. The deliverables of the network include:

1. Data accessible by all the researchers in the world: Limited number of processed images from all three stations (1 hour cadence) will be on line for a period of about one year at BBSO's home page `http://bbso.njit.edu`, which can be accessed by anybody. If data with higher cadence are required, data will be sent by ExaByte tapes or CD-ROMs.

2. Statistical studies of new flux emergence: Based on continuous movies, the post-doc will make list of all new flux emergence, as well as their size, complexity and latitude distribution.

3. Statistical studies of filament and prominence eruptions: Similar to (2), filament and prominence eruptions will be studied in detail, including size and latitude distributions. Our high quality data can provide images to study fine structure of filaments and prominences.

4. Provide improved knowledge for flare prediction: After study of the evolution of many flares by following regions continuously, we will be able to find new clues for flare detection. This will further improve the accuracy of our BEARALERT program.

B.4.1. Management and Budget Justification

Wang and Goode, the associate director and the director of BBSO, will oversee the overall operation of the network, as well as the daily operation of the BBSO station. Each foreign station has a local project leader who will insure the normal operation of each station: Prof. Arnold Hanslmeier, the director of KSO and Prof. Guoquan Luo, the director of YO. Their CVs are included in the proposal. The key persons in the project are the new Post-doc and Dr. Denker, who will setup instruments, compile, analyze and distribute data, and publish results. Data will be initially distributed to all three stations, although processing will be done at BBSO.

The requested funds are mainly for two cameras and the post-doc's salary. Some foreign travels, cost of tapes and supplies are included. In the second year, we include an IDL license for each station, so that some data processing can be done locally.

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Warren, H. P., Mariska, J. T., Lean, J., Marquette, W., Johannesson, A., 1996: *Modeling Solar Extreme Ultraviolet Irradiance Variability Using Emission Measure Distributions.* Geophysical Research Letters **23**, 2207-2210.

Zirin, H., Marquette, W., 1991: *Bearalert: A Successful Flare Prediction System.* Solar Physics **131**, 149-164.

D. Biographical Sketches

D.1. Haimin Wang

Curriculum Vitae

Education

B.S.: January 1982, Nanjing University, China.
Ph.D.: June 1988, California Institute of Technology.

Professional Experience

September 1997 – Associate Professor of Physics, NJIT.
September 1995 – Assistant Professor of Physics, NJIT.
October 1994 to September 1995 – Senior Research Fellow, Caltech.
October 1992 to September 1994, NASA Compton Research Fellow.
September 1990 to September 1992, Associate Scientist in Astronomy, Caltech.
July 1989 to September 1990, Assistant Scientist in Astronomy, Caltech.
July 1988 to July 1989, Post-Doctoral research fellow in Astronomy, Caltech.
September 1985 to June 1987, Teaching Assistant, California Institute of Technology.

Awards and Affiliations

CAREER Award, 1996, NSF
Compton Fellowship, 1992, NASA
Student ship Award, 1985 and 1987 Sol. Phys. Division of the American Astronomy Society
Special Institute Fellowship, 1983, Caltech
Student Award, 1981, Nanjing University, China
Member of the American Astronomy Society
Member of the International Astronomical Union

Book

Co-Editor of 'The Magnetic and Velocity Field of Solar Active Regions', Proceedings of IAU Colloquium No. 141.

Selected Publications

Chae, J., Wang, H., Lee, C. Y., Goode, P., Schühle, U., 1998: *Photospheric Magnetic Field Changes Associated with Transition Region Explosive Events.* The Astrophysical Journal Letters **497**, L109-L112.

Wang, H., Denker, C., Spirock, T., Goode, P. R., Yang, S., Marquette, W., Varsik, J., Fear, R. J., Nenow, J., Dingley, D. D., 1998: *New Digital Magnetograph System at Big Bear Solar Observatory.* Solar Physics, in press.

Wang, H., Johannesson, A., Stage, M., Lee, C. Y., Zirin, H., 1998: *Study of Hα Jets on the Quiet Sun.* Solar Physics **178**, 493-507.

Wang, H., Komenda, A., Tang, F., Zirin, H., 1998: *Filament Disappearances During the Period of 1991 to 1994.* Solar Physics **178**, 547-555.

Wang, H., Spirock, T., Goode, P., Lee, C. Y., Zirin, H., Kosonocky, W., 1998: *Facular Contrast at 1.6 μ.* The Astrophysical Journal **495**, 957-964.

Wang, H., 1997: *Analyses of Vector Magnetograms in Flare Productive Active Regions.* Solar Physics **174**, 163-173.

Wang, H., Gary, D., Zirin, H., Nitta, N., Schwartz, R. A., Sakao, T., Kosugi, T., Shibata, K., 1996: *Coordinated OVRO, BATSE, Yohkoh, and BBSO Observations of the 1992 June 25 M1.4 Flare.* The Astrophysical Journal **453**, 505-510.

Wang, H., Tang, F., Zirin, H., Wang, J., 1996: *The Velocities of Intranetwork and Network Magnetic Fields.* Solar Physics **165**, 223-235.

Wang, H., Gary, D., Zirin, H., Kosugi, T., Schwartz, R. A., Linford, G., 1995: *The Microwave and Hα Sources of the 1992 January 13 Flare.* The Astrophysical Journal Letters **444**, L115-L118.

Wang, H., Ewell, E., Zirin, H., Ai, G., 1994: *Vector Magnetic Field Changes Associated with X-class Flares.* The Astrophysical Journal **424**, 436-443.

D.2. Philip R. Goode

Curriculum Vitae

Education

Rutgers, The State University
New Brunswick, New Jersey
Ph.D. (Physics), February 1969
University of California
Berkeley, California
A.B. (Physics), June 1964

Positions

1997-present:	Director, Big Bear Solar Observatory
1997-present:	Director, Center for Solar Research
1994-present:	Distinguished Professor of Physics and Mathematics, New Jersey Institute of Technology
1984-present:	Professor of Physics, New Jersey Institute of Technology
1990-1991:	SERC Visiting Fellow, Institute of Astronomy, University of Cambridge
1984-1990:	Chairperson, Department of Physics, New Jersey Institute of Technology
1980-1984:	Associate Research Professor, University of Arizona
1977-1980:	Member of Technical Staff, Bell Telephone Laboratories
1971-1977:	Assistant Professor of Physics, Rutgers University
1969-1971:	Postdoctoral Research Associate, University of Rochester
1969:	Postdoctoral Research Associate, Rutgers University

Selected Publications

Dziembowski, W. A., Goode, P. R., Schou, J., Tomczyk, S., 1997: *Helioseismic Measure of Solar Activity-Meaning and Applications.* Astronomy and Astrophysics, in press.

Dziembowski, W. A., Goode, P. R., 1997: *Seismic Sounding of the Solar Core: Purging the Corruption from the Sun's Magnetic Activity.* Astronomy and Astrophysics **317**, 919-924.

Dziembowski, W. A., Goode, P. R., Pamyatnykh, A. A., Sienkiewicz, R., 1995: *Updated Seismic Solar Model.* The Astrophysical Journal **445**, 509-510.

Goode, P. R., Strous, L. H., Rimmele, T., R., Stebbins, Robin, T., 1998: *On the Origin of Solar Oscillations.* The Astrophysical Journal Letters **495**, L27.

Goode, P. R., Strous, L. H., 1996: *Observation of Excitation of Solar Oscillations.* Bulletin of the Astronomical Society of India **24**, 223.

Goode, P. R., 1995: *Internal Structure and Rotation of the Sun.* in: 4th SOHO Helioseismology Meeting, ESA, Noordwijk, SP-376, Vol. 1, 121.

Gough et al., 1996: *The Seismic Structure of the Sun.* Science **272**, 1296.

Rimmele, T. R., Goode, P. R., Harold, E., Stebbins, R. T., 1995: *Dark Lanes in Granulation and the Excitation of Solar Oscillations.* The Astrophysical Journal Letters **444**, L119-L122.

Rimmele, T. R., Goode, P. R., Strous, L. H., Stebbins, R. T., 1995: *Dark Lanes in Granulation and the Excitation of Solar Oscillations (Magnetic Effects).* in: 4th SOHO Helioseismology Meeting, ESA, Noordwijk, SP-376, Vol. 2, 329.

Wang, H., Spirock, T., Goode, P., Lee, C. Y., Zirin, H., Kosonocky, W., 1998: *Facular Contrast at 1.6 μ.* The Astrophysical Journal **495**, 957-964.

D.3. Carsten Denker

Curriculum Vitae

Birth date:	September 4th, 1965 Oldenburg, Germany
Marital Status:	not married

Education

1985-1996:	Georg-August Universität Göttingen, Germany
1991:	Awarded Diploma in Physics (equivalent to M.S.), Thesis title: The Magnetic Field of Penumbral Fine-Structures
1993:	Diploma in Social Science, Thesis title: The Enquete-Commission for 'Technology Assessment' of the German Parliament – On the Relation Between Politics, Science and Public Opinion
1996:	Awarded Dr. rer. nat. in Physics, Thesis title: The Investigation of Sunspot Fine-Structure by Means of Speckle Interferometry

Positions

1997-present:	Postdoctoral Research Associate at the Big Bear Solar Observatory/New Jersey Institute of Technology
1996-1997:	Postdoctoral Scholar in Solar Astrophysics at the California Institute of Technology
1994-1996:	Research Assistant at the Universitäts-Sternwarte Göttingen, Germany
1992:	Summer Research Assistant at the National Solar Observatory, Sacramento Peak, Sunspot, New Mexico
1989-1994:	Teaching Assistant at the Universitäts-Sternwarte Göttingen, Germany

Selected Publications

Al, N., Bendlin, C., de Boer, C. R., Denker, C., Kneer, F., Schmitt, D., Volkmer, R., Wilken, V., 1997: *Dynamics of Solar Fine Structure: Observations with High Spatial Resolution.* Proceedings of the 10th Cambridge Workshop on Cool Stars, Stellar Systems, and the Sun, Cambridge.

Denker, C., 1998: *Speckle Masking Imaging of Sunspots and Pores.* Solar Physics **180**, 81-108.

Denker, C., Wang, H., 1998: *High-Resolution Observations of a Small Delta-Spot.* The Astrophysical Journal **502**, 493-497.

Denker, C., Johannesson, A., Goode, P., Marquette, W., Wang, H., Zirin, H., 1998: *Synoptic Hα Full Disk Observations from the Big Bear Solar Observatory. I. Instrumentation, Image Processing, Data Products, and First Results.* Solar Physics, in press.

Denker, C., 1997: *Two-dimensional Speckle Spectroscopy of the Moustache Phenomenon on the Sun.* Astronomy & Astrophysics **323**, 599-605.

Denker, C., de Boer, C. R., Kneer, F., 1995: *Speckle Masking Imaging of Bright Points (Moustaches).* in: Strassmeier, K.G. (ed.), Poster Proceedings of the IAU Symposium No. 176 on 'Stellar Surface Structure', Vienna, 51-53.

Denker, C., de Boer, C. R., Volkmer, R., Kneer, F., 1995: *Speckle Masking Imaging of the Moustache Phenomenon.* Astronomy & Astrophysics **296**, 567-573.

Denker, C., Volkmer, R., de Boer, C. R., 1995: *Two-Dimensional Spectroscopy.* in: Saniga, M. (ed.), Annual Report of the Joint Organization for Solar Observations 1994, Polygrafia SAV, Bratislava, 78-80.

Wang, H., Denker, C., Spirock, T., Goode, P. R., Yang, S., Marquette, W., Varsik, J., Fear, R. J., Nenow, J., Dingley, D. D., 1998: *New Digital Magnetograph System at Big Bear Solar Observatory.* Solar Physics, in press.

Wilken, V., de Boer, C. R., Denker, C., Kneer, F., 1997: *Speckle Measurements of the Centre-to-Limb Variation of the Solar Granulation.* Astronomy & Astrophysics **325**, 819-824.

D.4. Arnold Hanslmeier

Curriculum Vitae

I was born in Feldbach, Austria on 10 February 1959. In 1979, I graduated from the senior high-school in Jennersdorf and began to study Astronomy and Physics at the Karl-Franzens-University Graz. In 1980, I got a part time position as a tutor at the Institute of Astronomy in Graz. The supervisor of my doctoral thesis 'Application of Lie Series to Celestial Mechanics' was Prof. Dvorak. I graduated in 1983 under the auspices of the Austrian President. In 1984, I got a full time position as research astronomer at the Institute of Astronomy in Graz.

Habilitation in 1991.

Since 1991, I have a tenure track position at the Institute of Astronomy Graz, and became provisional director in 1994. Since 1997, I am associate professor.

I am married since 1996 with Karoline Hanslmeier and we have three children.

Research Stays

1984:	Bureau de Longitudes, Paris (1 month)
1987:	Kiepenheuer Institute für Sonnenphysik(KIS), Germany, Freiburg. 6 months and in total 9 weeks during the period 1986-1992.
1992:	1 week at the Instituto de Astrofisica de Canarias (IAC), La Laguna, Tenerife, Spain.
1993:	6 weeks at the IAC
1994:	3 weeks at the IAC
1995:	in total 4 weeks at the IAC (guest professor)
1995:	Trieste Astronomical Observatory, Trieste (Italy), 1 week
1996:	Main astronomical observatory, Kiev (Ukraina) (1 week)
1997:	Ondrejevo (Czech Republic) (1 week)

Memberships

since 1980:	Astronomische Gesellschaft
since 1988:	International Astronomical Union (IAU)
since 1996:	Astronomical Society of the Pacific
since 1997:	New York Academy of Sciences

Selected Publications

Gadun, A. S., Hanslmeier, A., Pikalov, K. N., 1997: *Bisectors and Line Parameter Variations over Granular and Intergranular Regions in 2-D Artificial Granulation.* Astronomy and Astrophysics **320**, 1001-1012.

Grassmugg, M., Hanslmeier, A., Lavac, O., 1997: *A Solar Alpha-Omega Dynamo and its Transition to Chaos.* Solar Physics **174**, 437-441.

Hanslmeier, A., Nesis, A., 1994: *Non Linear Dynamics of the Solar Granulation: A First Approach.* Astronomy and Astrophysics **286**, 263.

Hanslmeier, A., Nesis, A., Mattig, W., 1993: *Dynamics of the Solar Granulation: Coherence of Line Parameters and their Variation with the Height.* Astronomy and Astrophysics **270**, 516.

Hanslmeier, A., Mattig, W., Nesis, A., 1991: *High Spatial Solar Photospheric Line Observations in Ca^{+} Active Regions.* Astronomy and Astrophysics **244**, 521.

Hirzberger, J., Vazquez, M., Bonet, J. A., Hanslmeier, A., Sobotka, M., 1997: *Time Series of Solar Granulation Images. I. Differences Between Small and Large Granules in Quiet Regions.* The Astrophysical Journal **480**, 406-419.

Nesis, A., Hammer, R., Hanslmeier, A., Schleicher, H., Sigwarth, M., Staiger, J., 1997: *Dynamics of the Solar Granulation. IV. Granular Shear Flow.* Astronomy and Astrophysics **326**, 851-859.

Nesis, A., Bogdan, T. J., Cattaneo, F., Hanslmeier, A., Knölker, M., Malagoli, A., 1992: *Evidence for Transsonic Flows in the Solar Granulation.* The Astrophysical Journal Letters **399**, L99.

Nesis, A., Hanslmeier, A., Hammer, R., Komm, R., Mattig, W., Staiger, J., 1992: *Dynamics of the Solar Granulation. I. A Phenomenological Approach.* Astronomy and Astrophysics **253**, 561

Sobotka, M., Bonet, J. A., Vazquez, M., Hanslmeier, A., 1995: *On the Dynamics of Bright Features in Sunspot Umbrae.* The Astrophysical Journal Letters **447**, L133.

D.5. Guoquan Luo

Curriculum Vitae

Education and Degrees

Department of Physics and Astronomy, St.Andrews University United Kingdom, Ph. D., 1991
Physics Department of Yunnan University, P. R. China B.S., 1986

Research Experience

1991-11 to 1996-03: Yunnan Observatory, research assistant
1996-03 to 1997-10: Beijing Astronomical Observatories, Postdoctor
1997-10 to now: Yunnan Observatory, Research Professor
1998-08 to now: Director of Yunnan Observatory

Publication

Luo, G. Q., 1997: *An Equation of State from hot Stellar Gases to Cool Dense Planetary Fluids for Mixed Elements.* The Astrophysical Journal **491**, 366.

Luo, G. Q., 1996: *Application of the Atomic Configuration Probability to the Equilibrium Calculation.* Astrophysics and Space Science **235**, 9-15.

Luo, G. Q., 1995: *An Equation of State with a Grand Canonical Approach.* PAPS Conference Series **78**, 99.

Luo, G. Q., 1995: *Nonideal Effects of Solar Interior Opacities.* PAPS Conference Series **78**, 93.

Luo, G. Q., 1995: *Uncertainties of Solar Interior Opacity for Solar Models.* Astrophysics Report **27**, 1.

Luo, G. Q., Huang, R. Q. 1995: *Astrophysical Application of the Equation of State with Nonideal Effects.* Astrophysics Report **25**, 17.

Luo, G. Q., 1994: *The Equation of State of a Grand Canonical Approach in the Chemical Picture. I. Theory.* Astronomy and Astrophysics **281**, 460-464.

Luo, G. Q., 1994: *The Equation of State of a Grand Canonical Approach in the Chemical Picture. II. Occupation Number of Molecules and Atoms.* Astronomy and Astrophysics **284**, 679-683.

Luo, G. Q., 1994: *The Equation of State of a Grand Canonical Approach in the Chemical Picture. III. Thermodynamic Functions and Nonideal Effects.* Astronomy and Astrophysics **284**, 684-688.

Luo, G. Q., 1994: *Influences of Nonideal Effects of Dense Plasmas on Solar Interior Opacities.* Astronomy and Astrophysics **281**, 561-564.