Annual Progress Report for Norris Foundation

September 8th, 1998

Summary. In this project, we proposed three specific upgrades in the instrumention at Big Bear Solar Observatory (BBSO): (1) a near infrared system to study the solar atmosphere below the solar surface both photometrically and spectroscopically, (2)a correlation tracker to stabilize images, and (3) a digital magnetograph system. We have made significant progress in the first year of this two-year project. We also have a solid plan for the second year to achieve the remaining objectives defined in the proposal.

1 Near Infrared System

With the aid of this award, we have purchased a 320×240 pixels InGaAs camera from Sensors Unlimited, Inc. This is the very first large format 12-bit InGaAs camera ever been built. In the original proposal, we proposed to buy a 640×480 pixels camera. Such a camera is not available and will not be available until three years from now, due in part to the untimely death of Walter Kosonocky, chief designer and NJIT professor. However, with our 320×240 pixel camera, we are confident that we can achieve most of our scientific objectives. The field of view of the near-infrared CCD camera is approximately $80'' \times 60''$ if we adapt the system to the diffraction limit of the vacuum reflector (our largest telescope with $D = 65$ cm) which is about $\lambda/D = 0.5''$. This field of view is sufficent to monitor large sunspots.

A complete system has been built, which is centered on this camera. The camera is interfaced with a Dipix board which is controlled by a 200 MHz Pentium computer. Other optical components for the system include a computer controlled liquid crystal, a 1/4 waveplate, polarizers, and narrow bandpass prefilters. The computer software is almost completed.

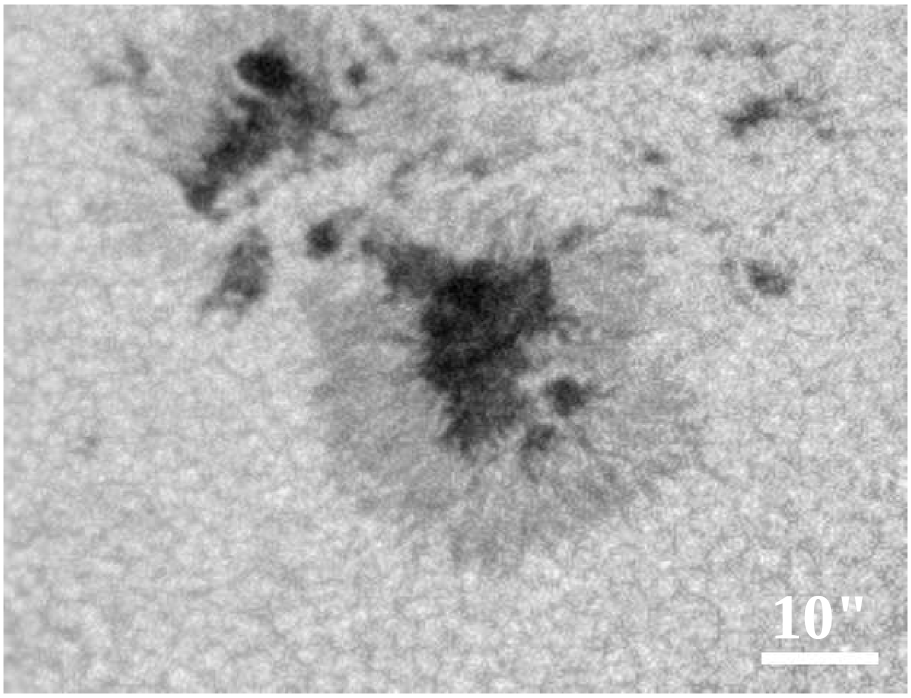

Figure 1: Sunspot observed in the infrared at 1.56 μm on August 8th, 1998.

We have carried out both photometric and polarimetric observations at the direct-through and spectrograph benches, respectively. Preliminary results demonstrate the excellent performance of the camera system. Figure 1 shows an example of granulation and sunspot fine-structure at 1.56 μm. Since the seeing (or atmospheric instability) is reduced according to a $\lambda^{6/5}$ power law, the seeing is roughly four times better in the infrared at 1.56 μm compared to visible light observations at 500 nm. Therefore, observations in the infrared, even at the 65 cm telescope, are almost always diffraction limited. The quality of the image in Figure 1 is unparalled in IR observations. Figure 2 shows the Stokes V images to measure the line-of-sight magnetic field in an active region with the Fe line pairs at 1.56 μm. This observation demonstrates the polarimetric capability of the system. Automation of the system is currently underway.

We have trained three NJIT graduate students in this project. Haifan Wang has been awarded a MS degree in computer science as the result of her software development. Tom Spirock, a Ph.D. candidate in ECE department, has been in charge of the electronic set-up and automation of the system. Jingshan Wang, a Ph.D. candidate in Applied Physics at NJIT, has been in charge of optical setup and data analyses of the system. He has also designed a narrow band infrared filter project for our new generation of an imaging infrared magnetograph system at BBSO.

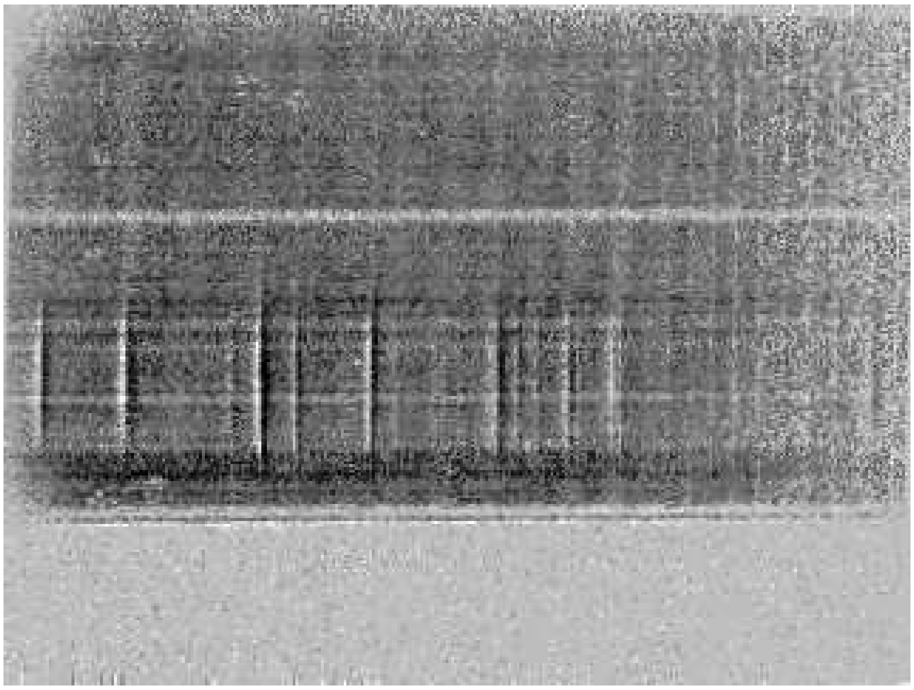

Figure 2: Stokes V image depicting the line-of-sight magnetic field in an active region with the Fe line pairs at 1.56 μm.

2 Correlation Tracker

As we stated in our original proposal, the objective of a correlation tracker is to stabilize images. We have purchased all the required hardware which include: a Dalsa 64 $\times$ 64 pixels, 12-bit camera, an Image Technology frame grabber, and a Sparc-UltraII 30 Sun workstation. The movable mirror of the existing BBSO spot tracker system will be used in the correlation tracker. We have assigned the task to Dr. John Varsik, assistant research professor, and Fred Yang, a Ph.D. candidate in the Applied Physics program. They have made two trips to the National Solar Observatory/Sunspot to work with Dr. Thomas Rimmele, one of the Co-Is of the proposal, to learn from the similar system at NSO. The software is currently under development. The camera can grab images, and an user interface has been built. The movable mirror has been tested at NSO. We anticipate that the system will be operational by next summer.

3 New Visible-Light Magnetograph System

Our motivation to build a new high speed magnetograph system is to improve the accuracy, sensitivity, and spatial resolution of the system. The first generation of our new digital system uses a 256×256 pixels, 12-bit Dalsa camera at a frame rate of 90 frames per second. Such a system is operational and producing scientific results (Denker and Wang, 1998, Wang et al., 1998). Figure 3 shows a four second integrated magnetogram in the quiet Sun, which detects intranetwork fields even in such a short integration, and a single pair subtracted magnetogram, which shows the majority of the network fields. This kind of observations were not possible with BBSO's videomagnetograph system. However, the Dalsa system is limited by its small field of view. We have purchased a Silicon Mountain Design camera to be used in the next generation digital magnetograph system. This 1024×1024 pixels, 12-bit camera has a frame rate of 15 frames per second in the full-frame mode, and 30 frames per second with a 2×2 pixels hardware binning. Figure 4 shows two sample solar images from the camera. It has substantially higher signal/noise ratio than the Dalsa camera. Prof. Haimin Wang, Dr. Carsten Denker (BBSO post-doc) and Hangjun Chen (a Ph.D. student) are in charge of the development of the system.

Since we saved some money in the IR camera system, we plan to go a step further to upgrade the filter system to a Fabry-Pérot system. This will allow us to tune across the spectral line and to measure the true strength of magnetic fields.

References

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

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

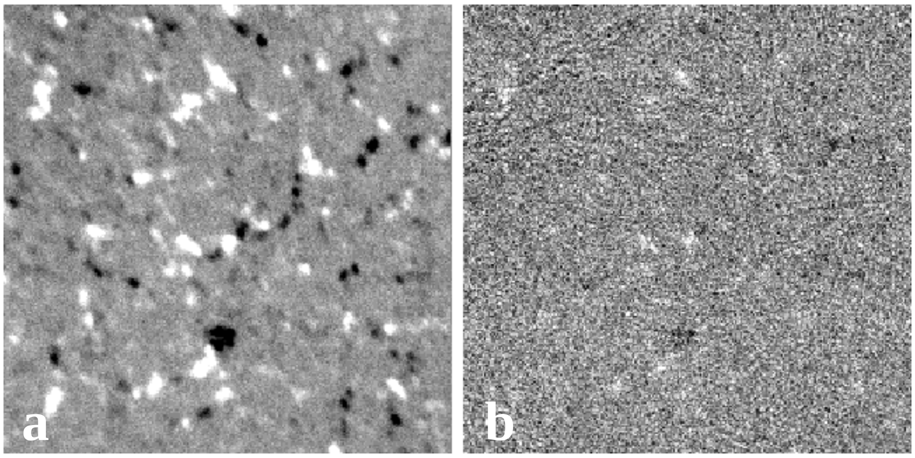

Figure 3: (a) Quiet sun magnetogram (400 integrations) of the solar disk center, obtained on March 17th, 1997. (b) Magnetogram resulting from a single pair subtraction to demonstrate noise and sensitivity. The field of view is to $256'' \times 256''$.

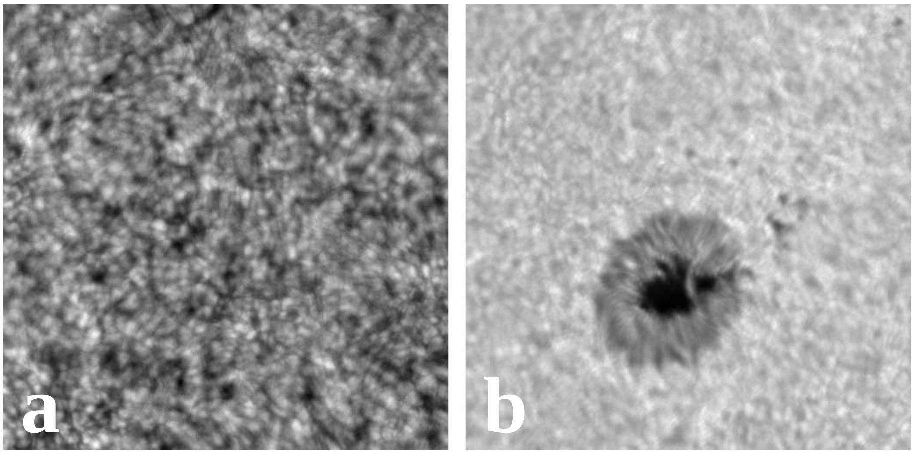

Figure 4: (a) Granulation observed at disk center and (b) a samll sunspot observed in the G-band at 430.6 nm with SMD CCD camera on September 11th, 1998. The field of view is approximately $90'' \times 90''$ and the exposure time is 8 ms.

Budget

Money Spent in the First Year

	Norris	NJIT Match
IR System		
IR Camera	16,000	16,000
IR Optics		5,000
IR Computer System		5,000
Correlation Tracker		
UltraII 30	5,300	5,300
Imaging Board	1,000	1,000
Camera	2,100	2,100
Magnetograph System		
SMD camera	7,000	7,000
computer system	2,600	2,600
Optics		5,000
Software		1,000
Synoptic System Built by Prof. Zirin		
Wintriss and Mac	16,000	
Total	**50,000**	**50,000**

Next Year

	Norris	NJIT Match
Fabry-Pérot	16,000	84,000
Synopic System (Zirin)	34,000	
Total	**50,000**	**84,000**