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San Fernando Observatory
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This report covers the period from 1997 through 1999.

1. FOREWORD

The San Fernando Observatory (SFO), operated for the Department of Physics and Astronomy, is located 9 miles from the CSUN campus at the north edge of the San Fernando Valley. The SFO is engaged in solar research and involves students in these programs. Financial support is obtained from federally funded grants and the University. Following the Northridge earthquake (January 17, 1994) the SFO received funds for repairs and upgrades from state and federal sources as well as from the Parsons Foundation. Repairs and most upgrades were completed by the spring of 1998. In this report, we review the main activities at the SFO during the period from 1997 through 1999.

2. PERSONNEL

The research staff of the SFO are also members of the faculty in the Department of Physics and Astronomy at CSUN. They are:

A.C. Cadavid, Professor; G.A. Chapman, Professor and SFO Director; J.J. Dobias, Associate Professor, part-time; J.K. Lawrence, Professor Emeritus; M.J. Penn, Assistant Professor; A.A. Ruzmaikin, Adjunct Professor; and S.R. Walton, Professor.

Supporting staff are:

A.M. Cookson, Research Assistant; D.G. Preminger, Research Assistant; P. Morariu, part-time Electronic Technician; and R. Rideout, Jr., on-site Technician.

Faculty associated with the San Fernando Observatory have been involved in the supervision of a number of graduate students, most of whom received a Master of Science degree in Physics. Several of these students have entered Ph.D. programs or have received their Ph.D.

2.1. SFO Faculty

- A. C. Cadavid, Professor (Ph.D. UCLA 1989) *Theoretical Plasma Physics*
- G. A. Chapman, Professor and SFO Director (Ph.D. U. of Arizona 1968) *Photometry and Magnetic Fields*
- J. J. Dobias, Associate Professor, part-time (Ph.D. UCLA 1987) *Solar Photometry*
- A. D. Herzog, Professor and Department Chair (Ph.D. New Mexico State University 1978) *Solar Photometry*
- J. K. Lawrence, Professor Emeritus (Ph.D. Northeastern University 1968) *Theory and Magnetic Fields*
- M. J. Penn, Assistant Professor (Ph.D. U. of Hawaii 1992) *Magnetic Fields and IR*
- A. A. Ruzmaikin, Adjunct Professor (Ph.D. Moscow State University 1972) *Theoretical Solar Physics*
- S. R. Walton, Professor (Ph.D. U. of Hawaii 1983) *Magnetic Fields and Photometry*

2.2. Students

Undergraduate and graduate students from CSUN participate in educational and research activities at the SFO. (Graduate programs at the CSU are limited to the Masters Degree by the California Master Plan.) Undergraduate students form the core of the diachronic solar photometry program. Undergraduate students since 1997 have been: Asma Al-Thakafi, John Catuna, Grant Coble, Steve Cooper, Joe Dotolo, Jessica Fritz, Luke Haley, Ludwig Hamo, Alicia Heckathorne, Andrea Hook, T.S. Jeong, Albert Lee, Taesong Lee, Kirsti Lewis, Rebecca Linck, Makan Mohageg, Ishtiak Murtaza, and Celia Smith. Graduate students since 1997 (and their advisors) have been Rick Hansell (G. Chapman), Demitri Muna (S. Walton), Bob Troy (A. Cadavid), and Alex Webster (A. Herzog).

3. SCIENCE PROGRAMS

3.1. Full-Disk Photometry

Precise, well-calibrated photometric images of the Sun are obtained on a daily basis at several wavelengths using two telescopes (CFDT1 and CFDT2; CFDT=Cartesian Full Disk Telescope). The smaller one (CFDT1) produces images having 512×512 pixels each of which is 5 arc-sec square. Images are obtained in red, blue and in the K-line. The K-line filter has a bandwidth of 9 Å thus responding mostly to the middle to upper photosphere. The larger telescope (CFDT2) produces images having 1024×1024 pixels each of which is 2.5 arc-sec square. In addition to images in the red, blue and K-line, CFDT2 also obtains images in the K-line with a 3 Å bandpass and in the IR.

These images are analyzed to obtain areas and irradiance variations of sunspots and faculae. Irradiance fluctuations determined from these images are highly correlated with total solar irradiance measured by spacecraft, particularly Nimbus-7 (Chapman, Cookson & Dobias, 1996) with coefficients of multiple determination, R^2, of over 0.8. The data are available on the home page of the Department of Physics and Astronomy (http://davinci.csun.edu/~astro) due to the efforts of S. Walton.

Improvements to the image processing software (Walton *et al.*, 1998) have allowed the detection of lower contrast faculae than before and have improved the accuracy of the photometry. Restoration of all useable CFDT1 images using the techniques described in Walton & Preminger (1999) is in progress. One of the outputs from the restoration process is the determination of the point spread function including stray light. The M.S. Thesis of Hansell showed that the long-range scattering coefficient from day-to-day images correlated well with the optical depth determined from an all-sky shadow band radiometer.

Ahern & Chapman (1999) studied the center-to-limb contrast of faculae in the red and blue using CFDT2 images from 110 days taken from the summers of 1993 through

1995. The location of continuum faculae were determined by registering a K-line image to the red and blue images for that day. This procedure allowed the unbiased detection of faint faculae in the red and blue images. The blue contrast was found to rise from near zero at disk center to about 12% at μ=0.2. The red contrast was found to rise from 0.13% at disk center to about 8% at μ=0.2.

3.2. Evolution of Active Regions

Active regions are studied using the 61/28 cm vacuum telescope and vacuum spectroheliograph in the Video Spectra-SpectroHelioGraph (VSSHG) mode (Walton & Chapman, 1996). The VSSHG produces a data cube in each of two opposite polarizations. The pixels are 0.5 arc sec spatially, using the 28 cm vacuum telescope (0.225 arc sec using the 61 cm vacuum telescope) and 9 mÅ spectrally. The sensitivity of the VSSHG to magnetic flux is $\pm$15 G per 0.5 arc-sec square pixel or about 2×10^{16} Mx for the 28 cm vacuum telescope using the 6302.5 Å line of Fe I. In a study of emerging flux regions, Chapman (1998) found little or no evidence of upward moving plasma near disk center but large areas of downward moving plasma. A broadly based study of active region evolution in conjunction with photometry continues and will hopefully lead to a better understanding of the energy fluctuations associated with the eruption and dissipation of magnetic flux in the photosphere.

3.2.1. Upgrades

A new CCD digital camera is being installed to replace an analog system for the recording of polarized spectral data cubes. A new reimaging system at the output of the spectrograph will permit the simultaneous recording of both 6301.5 and 6302.5 Å iron lines which will give improved Stokes information of active regions. The data will be buffered by a disk system and recorded onto a DLT. A state-of-the-art tilt plate system is in production to stabilize the image while the VSSHG is scanning an active region.

3.3. Magnetic Fields and Surface Flows

Drs. Cadavid, Lawrence and Ruzmaikin have studied the nature of solar surface flows and their interaction with magnetic fields. Both Fourier and wavelet-based spectral analyses of photospheric velocity and magnetic fields from SFO, KPNO and SoHO/MDI data found that, in addition to the characteristic granular and supergranular flow scales, a very much weaker mesogranular flow is clearly seen. Between the granular and supergranular scales the flows are dominated by a stochastic, self-similar (turbulent) structure (Cadavid *et al.* 1998; Lawrence, Cadavid & Ruzmaikin 1999). Random walks of small ~200 km G-band bright points in reconstructed SVST images also were studied. The walks exhibit stopping times on all scales up to ~20 min. implying a finite memory in the granular flow field (Cadavid, Lawrence & Ruzmaikin 1999). Temporal multiscaling of these walks indicates intermittent spatial steps, which show turbulent dynamics in intergranular lanes (Lawrence *et al.*, 2000 submitted).

3.4. Influence of Solar Variability on Climate

Attempts also have been made by Cadavid, Lawrence and Ruzmaikin to find mechanisms by which weak solar fluctuations, such as an 11-year irradiance cycle at the 0.1% level, or a slow secular drift from solar or anthropogenic sources, could have a detectable affect on the Earth's climate. One promising approach involves ''stochastic resonance,'' whereby the effect of a weak, periodic input, such as variable solar irradiance, to a noisy system like the Earth's climate (Lawrence & Ruzmaikin, 1998). More recently, a simple, nonlinear model of atmospheric circulation due to Lorenz was studied. It was found that inclusion of an annual cycle leads to extreme sensitivity to forcing parameters, such as North-South heating contrast, and that this can magnify a variable input (Lawrence, Cadavid & Ruzmaikin, 2000 submitted).

3.5. Observations of Chromospheric Spectral and Spatial Features in the Infrared

The SFO VSSHG camera was used on the SFO vacuum spectrograph, along with observations from the NSO/Kitt Peak Vacuum Telescope to make a new measurement of the ratio of chromospheric oxygen line emission at 7774 Å and 8446 Å (Penn, 1999). The observations showed a line ratio that agrees with theories of collisional excitation of these lines, rather than the photo-excitation by accidental resonance mechanism which was developed to explain previous photographic measurements. This conclusion will have implications on the interpretation of spectra from the NASA/ESA SOHO mission instruments, CDS and SUMER.

3.5.1. Upgrades

An infrared camera based on a InGaAs detector was borrowed from NSO/Sacramento Peak to take test observations at the SFO vacuum telescope and spectrograph. This camera was then used to obtain images of filaments in the He I 10830 Å line by scanning the SFO vacuum telescope. These images compared favorably with those obtained at NSO/KP on the same day. The camera was used to take sample spectra at 1.2 microns, and out to 1.5 microns too (the astronomy ''H'' band). A new IR camera has been proposed to observe at the SFO, aimed at making spectral observations of He I 10830 Å and the magnetically favorable g=3 Fe I lines at 15656 Å.

PUBLICATIONS

The publication list includes all papers published between 1997 and 1999 by SFO staff and students.

Ahern, Sean and Chapman, G.A., 1999, ''Facular Contrast Observations in the Red and Blue,'' Solar Phys. in press.

Cadavid, A.C., Lawrence, J.K. and Ruzmaikin, A.A., 1999, ''Anomalous Diffusion of Solar Magnetic Elements,'' Astrophys. J. 521, 844.

Cadavid, A.C., Lawrence, J.K., Ruzmaikin, A.A., Walton, S.R. and Tarbell, T.D., 1998, ''Spatio-temporal Correlations and Turbulent Photospheric Flows from SOHO/MDI Velocity Data,'' Astrophys. J. 509, 918.

Chapman, G.A., Cookson, A.M. and Dobias, J.J., 1996, ''Variations in Total Solar Irradiance during Solar Cycle 22,'' J. Geophys. Res. 101, 13541.

Chapman, G.A., Cookson, A.M. and Dobias, J.J., 1997, ''Solar Variability and the Relation of Facular to Sunspot Areas during Solar Cycle 22,'' Astrophys. J. 482, 541.

Chapman, G.A., 1998, ''Diachronic Photometric Full-Disk Solar Images,'' in Synoptic Solar Physics, K.S. Balasubramaniam, J.W. Harvey, and D.M. Rabin, eds., Astronomical Society of the Pacific Conference Series, 140, 237.

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Otte, K. and Chapman, G.A., 1999, ''The Energy Budget of Solar Active Regions,'' Solar Phys., submitted, in revision.

Penn, M.J. and Allen, C.L., 1997, ''He I 1083 nm Oscillations and Downflows near the North Solar Pole,'' Solar Phys. 174, 359.

Penn, M.J., 1999, ''New Measurements of the Solar Limb Emission in the OI 777.4 and 844.6 Nanometer Lines,'' Astrophys. J. (Lett.) 518, L131.

Walton, S.R. and Chapman, G.A., 1996, ''The San Fernando Observatory Video Spectra-Spectroheliograph,'' Solar Phys. 166, 267.

Walton, S.R., Chapman, G.A., Cookson, A.M., Dobias, J.J. and Preminger, D.G., 1998, ''Processing Photometric Full-Disk Solar Images,'' Solar Phys. 179, 31.

Walton, S.R. and Preminger, D.G., 1999, ''Restoration and Photometry of Full-Disk Solar Images,'' Astrophys. J. 514, 959.

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