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The Solar-Stellar Connection (NAG5-6124: SOHO Guest Investigator Program)

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FINAL REPORT

SUMMARY.– SOHO Program: "THE SOLAR-STELLAR CONNECTION"—Objective was to conduct a variety of observing programs with the SUMER spectrometer on *SOHO*, in order to further the understanding of the solar-stellar connection.

The following is a final report on a *SOHO* Guest Investigator program to use the SUMER far-UV spectrometer to obtain imaging spectroscopy in support of the goals of the so-called "solar-stellar connection." In particular, a major emphasis is to utilize long-slit time-resolved maps of the solar surface in bright far-UV emission lines to deduce how particular aspects of the temporally and spatially averaged line profiles trace back to individual structural features of the magnetically disturbed outer atmosphere; to help interpret the unresolved line profiles from high quality *stellar* observations (say, with the Space Telescope Imaging Spectrograph). We (myself and collaborators A. Brown and G. Harper) served two tours of duty in the *SOHO* Operations Center as SUMER planners, during which time we conducted an extensive series of observing programs. These can be divided into three general categories: surface mapping, translimb spectroscopy, and active region diagnostics. We have analyzed some of the large volumes of data to the point where we have presented them in poster papers, and in invited papers at national and international meetings.

Listed below are the titles of the preliminary publications we have written, including brief abstracts to indicate the main results.

Chromospheric Structure and Dynamics—Observations

by Thomas R. Ayres

Published in: Synoptic Solar Physics – 18th NSO/Sacramento Peak Summer Workshop held at Sunspot, New Mexico 8-12 September 1997. ASP Conference Series; Vol. 140; 1998; ed. by K.S. Balasubramaniam; J. Harvey; and D. Rabin, p.209

Abstract. The chromosphere is a highly structured dynamic 'layer' of the solar outer atmosphere. Here, not only are the effects of mechanical heating first evident (moving upward in altitude from the deep photosphere), but also the amount of nonradiative energy deposited is far greater than in the albeit much hotter overlying transition region and corona. Further, the chromosphere is by far the thickest zone of the solar atmosphere with respect to the pressure scale height. A major goal of stellar astrophysics is to understand how the chromosphere is heated and why it adopts its peculiar structure.

A cursory examination of solar filtergrams and high-resolution movies demonstrates that much of the chromospheric "action" must be occurring on fine spatial scales and short times; particularly in the cell interior transient brightenings, but also in the longer-lived network fragments. That regime of investigation is far removed from what one usually associates with "synoptic" measurements. Nevertheless, synoptic observations of chromospheric indices, filtergrams, and globally-averaged profile parameters (e.g., for Ca II) not only can provide important insight concerning the crucial role of the cycle-variable part of the solar magnetic field; but they also can forge a key link with analogous measurements of the stars, where often the phenomena can be significantly exaggerated from the solar case, but high spatial resolution reconnaissance is not even a remote possiblity.

In addition to discussing the synoptic aspects of chromospheric structure and dynamics, I will summarize new insights into the general problem of the solar chromosphere that have been obtained recently with the SUMER far-ultraviolet spectrometer on SOHO.

CO and the Temperature Structure of the Solar Atmosphere

by Thomas R. Ayres

Published in: International Astronomical Union. Symposium No. 185. New Eyes to See Inside the Sun and Stars, ed. by F.-L. Deubner, J. Christensen-Dalsgaard, and D. Kurtz. Kyoto, Japan, 18-22 August, 1997, p. 403.

Abstract. The surface layers of the Sun provide a crucial boundary condition for many of the processes that occur in the deep interior. The stratification of the outer solar atmosphere once was thought to be well understood. However, studies of thermally sensitive molecular absorptions in the infrared revealed puzzling anomalies. Strong lines of the CO fundamental vibration-rotation bands near 5 microns showed very cool temperatures at the extreme limb, and remarkable off-limb emissions extending well into the supposedly hot chromosphere. The conflicting pictures of the photosphere/chromosphere interface, from the widely separated wavelength regimes, has raised suspicions that those "layers" of the atmosphere are much more inhomogeneous than previously suspected. One proposal is that the low chromosphere is dominated by cool gas—the "COmosphere," if you will—which is threaded by a network of persistent small-scale hot magnetic filaments and

occasionally disrupted by localized acoustic disturbances. The COmosphere is capped by the merged fields of the network elements in the chromospheric "canopy." I will describe the evidence in favor of that model, including recent work at the NSO McMath-Pierce telescope (including use of the new "Phoenix" spectrometer) and translimb far-UV spectroscopy by SOHO/SUMER.

Translimb Spectroscopy with SOHO/SUMER

by T.R. Ayres, P. Lemaire, U. Schühle, K. Wilhelm, I. Rüedi, and S. Solanki

Published in: American Astronomical Society, SPD meeting No. 29, paper No. 01.04 [1997]

Abstract. We have used SUMER to obtain deep exposures of the 1300–1400 Å spectrum, at the extreme limb and off-limb. Previous "translimb" studies in the thermal infrared had revealed remarkable extensions of cold material ($T \sim 3000$ K)—traced by carbon monoxide emission lines—into the heart of the hot chromosphere. A main objective of our program was to search for corresponding far-UV signatures of the "thermally-bifurcated" low chromosphere; for example, radiatively fluoresced emissions of the CO A–X 4th-positive system (collisional excitation would be negligible in cold gas). We conducted two separate observing programs with SUMER. Both made use of the 1″-diameter circular aperture, translated across the limb in the minimum motor step increments of 0.″375, along the central meridian in the Northern polar coronal hole. The first program executed for nine hours beginning 19UT 25 Oct 1996. The full wavelength range was 1340–1400 Å. It was recorded in two overlapping segments, placing key regions of the spectrum alternately on the KBr and bare parts of the detector, to help isolate 2nd-order features. Each segment was integrated for 500 s, and 32 pairs were obtained to span a 12″ swath centered on the optical limb. The second program was conducted 00–09UT 01 Dec 1996. It consisted of a single wavelength setting (1300–1340 Å) with exposure time 500 s, but twice the spatial coverage of the earlier series: 64 steps, for a total displacement of 24″. The strong chromospheric resonance lines of atomic oxygen (1302–1305 Å) and ionized carbon (1334–1335 Å) were observed on the bare part of the MCP camera.

We report our progress in cataloging the rich, diverse translimb emission spectrum; and our efforts to deduce fundamental properties of the thermally heterogeneous chromosphere.

We presently are preparing two publications for the Astrophysical Journal (one on chromospheric dynamics, the other on translimb spectroscopy), although unfortunately progress (due primarily to the complexity of the data sets) has been slow. The subsequent work will be supported by our NASA LTSA grant.