COOLNEWS

A RESEARCH NEWSLETTER DEDICATED TO COOL STARS AND THE SUN

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*** EARLY DEADLINE FOR JUNE ISSUE ***

Due to extended travel, I will be e-mailing out the June issue on May 29th. If you have a contribution for the June issue, please send it to me by May 28th. Thanks, Steve Skinner (ed.)

Stellar Abstracts

Abundances in the Metal-Poor Common Proper Motion Star BD+00 2058A

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Like two other metal-poor, late-type field stars showing odd abundance ratios suggestive of accreted origin, BD+00 2058A has a substantial apogalactocentric distance, reaches a large maximum height above the Galactic plane, and is a member of a common proper motion system. To examine whether whether such wide pairs might have a common origin in accreted subsystems, we present detailed abundances in BD+00 2058A derived from high S/N, high resolution optical spectroscopy. Using spectroscopically derived parameters, we find [Fe/H]= -1.16 ± 0.07, a factor of 2-4 larger than previous (but less direct) estimates. We find the α-element, iron-peak, and n-capture abundances to be unremarkable compared to other field stars of similar [Fe/H]. The derived Li abundance, log N(Li)=2.53, is large compared to otherwise similar stars; the normal n-capture abundances and upper limits to ^{6}Li/^{7}Li provide no evidence of Li enrichment from Li-rich AGB star material or spallation. Interestingly, the [C/Fe] and [Na/Fe] ratios appear to be $\sim$0.3 dex lower and higher, respectively, then otherwise similar stars. This might point to Li enrichment by contaminating material having undergone "cool bottom processing", but the lack of radial velocity variations provides no evidence of a close companion. Comparison with theoretical isochrones suggests a distance of 150 pc, which is in better agreement with two previous studies' estimates of the distance of the fainter wide companion; kinematic-based population classifications based on this distance are ambiguous. Finally, we draw attention to the importance of different, but reasonable, choices of Fe I gf values in our (and other) analyses.

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Are Stars with Planets Anomalous?

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The chemical-dynamical properties of stars with giant planets are compared to those of a nearby star sample within the framework of a stellar orbital diffusion model. The stars-with-planets sample includes recently discovered extrasolar planets and the Sun. We find that the planet-bearing stars, 14 Her, ρ^1 Cnc, and τ Boo are much more metal-rich than stars of similar age and cannot be easily explained by orbital diffusion. We also confirm previous claims that the Sun's motion relative to the LSR is very small compared to other G dwarfs of similar age and offer a possible explanation for this apparent anomaly.

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Multi-site Observations of Surface Structures on AB Doradus in 1994 November

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We present time-resolved optical spectroscopy and broad-band photometry of the rapidly-rotating southern K0 dwarf star AB Doradus, obtained during 1994 November. The data were obtained as part of a collaboration dedicated to MUlti-SIte COntinuous Spectroscopy (MUSICOS), and entailed coordinated observations on three continents to obtain the fullest phase coverage possible subject to limitations of local weather conditions. The Doppler images from the three consecutive nights of the run show excellent mutual agreement, with a dark polar cap and numerous intermediate- and low-latitude features. Simultaneous optical photometry showed numerous short-duration U-band flares, and two longer-duration optical flares with durations of order hours. The latter produced broad-band continuum enhancements throughout the optical spectrum. Where simultaneous spectroscopy was available, both types of flare were seen to have counterparts in Hα and the Ca II H line. Simultaneous time-resolved ultraviolet spectroscopy from the *Goddard High Resolution Spectrograph* aboard the *Hubble Space Telescope*, reported elsewhere, shows that at least one of the short-duration U-band flares was also observed in C IV with the *GHRS*. Time-series Hα spectra showed significant evolution of the circumstellar prominence system over five consecutive stellar rotations. One prominence underwent a dramatic increase in distance from the stellar rotation axis. We speculate that this event may have been associated with one of the long-duration flares.

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Heating and Cooling by Iron in Cool Star Winds

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The role of iron for the energy balance in the extended atmospheres and circumstellar envelopes of cool stars is explored. Based on large non-LTE model atoms for Fe I and Fe II, we study the influence of fine-structure, forbidden, permitted and bound-free transitions on the radiative heating and cooling of the gas under various temperature, density and radiation field conditions. The results are compared to those obtained in LTE and to those calculated when ignoring optical depth effects in the lines. The number of levels in the model atoms necessary to achieve convergence of the results is discussed.

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Orbital Elements and Physical Parameters of Ten Chromospherically Active Binary Stars

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Orbital elements have been determined for 10 chromospherically active binaries from a combination of new velocities and velocities in the literature. First orbits for three binaries, HD 33363, HD 152178, and HD 208472, are presented, as well as updated orbits for seven other binaries. Two of the latter systems, LN Peg and HD 106225 were discovered to be triple, and both short- and long-period orbits have been computed for each. Fundamental properties have been determined for the chromopherically active primary in each system.

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Rubidium in Metal-Deficient Disk and Halo Stars

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We report the first extensive study of stellar Rb abundances. High-resolution spectra have been used to determine, or set upper limits on, the abundances of this heavy element and the associated elements Y, Zr, and Ba in 44 dwarfs and giants with metallicities spanning the range $-2.0 <$ [Fe/H] < 0.0. In metal-deficient stars Rb is systematically overabundant relative to Fe; we find an average [Rb/Fe] of +0.21 for the 32 stars with [Fe/H] < -0.5 and measured Rb. This behavior contrasts with that of Y, Zr, and Ba, which, with the exception of three new CH stars (HD 23439A and B and BD $+5^{\circ}$ 3640), are consistently slightly deficient relative to Fe in the same stars; excluding the three CH stars, we find the stars with [Fe/H] < -0.5 have average [Y/Fe], [Zr/Fe], and [Ba/Fe] of –0.19 (24 stars), –0.12 (28 stars), and –0.06 (29 stars), respectively. The different behavior of Rb on the one hand and Y, Zr, and Ba on the other can be attributed in part to the fact that in the Sun and in these stars Rb has a large r-process component while Y, Zr, and Ba are mostly s-process elements with only small r-process components. In addition, the Rb s-process abundance is dependent on the neutron density at the s-processing site. Published observations of Rb in s-process enriched red giants indicate a higher neutron density in the metal-poor giants. These observations imply a higher s-process abundance for Rb in metal-poor stars. The calculated combination of the Rb r-process abundance, as estimated for the stellar Eu abundances, and the s-process abundance as estimated for red giants accounts satisfactorily for the observed run of [Rb/Fe] with [Fe/H].

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Beppo-SAX Observations of AR Lacertae

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We present the results of an X-ray observation of the binary system AR Lacertae (HD 210334) obtained with the Low and Medium Energy Concentrator Spectrometers (LECS & MECS) and with the Phoswich Detector System (PDS) on board the Beppo-SAX satellite.

Two flare episodes with comparable peak luminosities were detected, one in each of the two runs into which the observations were split. Several low amplitude flares appear to be superimposed on a rotational modulated light curve. A very tight and shallow primary eclipse was observed, which is different from primary eclipses observed at other epochs by other X-ray telescopes. No sign of secondary eclipse can be inferred from these data.

The PDS data show that the emission in the 15-300 keV range is generally not detectable, but there is convincing evidence of hard photons during the onset of a flare on Nov 4 and during the flare on Nov 11. There was no significant emission in the 15-300 keV range during the major flare on Nov 4.

The AR Lac spectrum between 0.1 and 9 keV is well fit by a two component optical-thin plasma model based on the MEKAL plasma emission code with subsolar metal abundances. We also performed spectral analyses of the two separate segments of data, and found that the plasma temperatures, abundances and emission measures did not significantly change between the two time intervals.

Hints of possible H I absorption in corona or in the circumstellar enviroment are also discussed.

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Activity Cycle and Surface Differential Rotation of the Single Pleiades Star HD 82443 (DX Leo)

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The results of a long-term photometric monitoring of the young Pleiades moving group member HD 82443 are presented. A sequence of fifteen optical light curves obtained from 1989 to 1998 confirms the presence of a rotational modulation with a mean period of 5.377 days attributable to cool photospheric spots. The Maximum Entropy and the Tikhonov regularization criteria have been applied to compute maps of the photospheric spot pattern. They show that the total spotted area is subject to cyclic changes as large as $\sim 10\%$ of the star's surface with a mean period of 3.89 yr.

The seasonal photometric period shows variations correlated with the phase of the activity cycle, which can be interpreted as the result of a migration of the starspots in latitude over a differentially rotating star. The dependence of the photometric period on the cycle phase is opposite that of the Sun and similar to those observed in HD 114710 and HD 10476. A lower limit for the amplitude of the differential rotation in latitude can be estimated to be $\frac{\Delta\Omega}{\Omega} \simeq 0.04$.

Nearly simultaneous UV observations obtained in 1991 show the presence of chromospheric and transition region plages which do not seem to be in close spatial association with the photospheric spots.

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Photospheric Magnetic Activity in a Proxy for the Young Sun: HD 134319

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We present the results of a long-term photometric monitoring of the young single main-sequence star HD134319. It shows short-term variability of the optical-band continuum flux with a period of 4.448 days. The variability is attributed to dark spots or spots groups unevenly distributed in longitude on the star's photosphere, whose visibility is modulated by the star's rotation. Maps of the photospheric spot pattern have been obtained with light curve inversion techniques based on the Maximum Entropy and the Tikhonov regularization criteria.

The overall spot pattern shows evidence for two long-lasting active longitudes located about 180° apart, with a total area of at least 16% of the stellar surface (assuming an inclination of the stellar rotation axis of 90° on the line of sight). The longitude distribution of the spot pattern and its total area do not show any clear evidence for a long-term variation along the five years of observations.

A comparison with recent mean field dynamo models is also addressed, suggesting a possible interpretation of such a behaviour.

Singularity, spectral type, youth and a high level of photospheric and chromospheric activity make HD134319 a suitable proxy for studying the magnetic activity of the young Sun not far after its arrival on the zero age main sequence.

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Probing the Na I D and K I λ7699 Resonance Lines Sensitivity to Background Opacity in Late-type Stars

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We have measured the equivalent width $W_{\rm K}$ of the K I resonance line at 7699Å for a large sample of low activity late-type stars observed with high spectral resolution and we have verified that the relation $W_{\rm K}$ vs. $T_{\rm eff}$ is monotonically decreasing, for both dwarf and giant stars. This behaviour is different from that of the Na I D lines for stars of the same type, which showed that the relation $W_{\rm Na}$ vs. $T_{\rm eff}$ has a maximum for $T_{\rm eff} \sim 4000$ K, which is better defined for giants than for dwarfs (Tripicchio et al. 1997).

The fit of the observed K I equivalent widths by means of a NLTE spectral line synthesis using conventional background opacity shows that, for dwarf stars, the adopted models overestimate the observed $W_{\rm K}$ for temperatures ≤ 4000 K. This result is similar to that discussed for the Na I D lines in our previous paper. On the other hand, for giant stars with $T_{\rm eff} \leq 3800$ K these models in general underestimate $W_{\rm K}$.

The discrepancies between observed and computed $W_{\rm K}$ and $W_{\rm Na}$ for cool stars are much stronger than the variations due to uncertainties in either atmospheric model or line parameters, like effective temperature and surface gravity, or Van der Waals broadening. For M dwarf stars, the most convincing explanation for the disagreement is the lack of atomic and molecular line opacity in the adopted models. In fact, a NLTE spectral synthesis including an additional background opacity reproduces with a good level of accuracy the equivalent widths, as well as the general shape of the profiles for both the Na I D and K I lines, in a subsample of early-M dwarfs.

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IUE Observations of the High-velocity Symbiotic Star AG Draconis. III A Compendium of 17 Years of UV Monitoring, and Comparison With Optical and X-ray Observations

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We present the first extensive analysis of the ultraviolet observations with the IUE mission of the high velocity symbiotic system AG Dra, covering the period June 1979–February 1996 which included three active phases of the system with six light maxima. The low resolution IUE line and continuum fluxes are compared with optical observations and with archival X-ray data. The analysis of the IUE observations near minimum (quiescence) led us to find that during the orbital motion the hot WD component is not eclipsed, in agreement with a not small inclination of the binary system orbit. The larger modulation of the N V, C IV, He II, and O I lines with respect to the intercombination lines indicates that the former are formed in a region near the line connecting the two stars, probably slightly receding, while the latter lines originate in an extended ionized nebula surrounding the white dwarf. Large orbit–to–orbit variation are probably associated with fluctuation of the K–star wind density. From the He II line we determine for the WD during quiescence a Zanstra temperature of 109600±5400°K, implying, at a distance of 2.5 kpc, a radius of 0.08±0.01 $R_{\odot}$, and a luminosity of 900±200 $L_{\odot}$.

During the different outbursts AG Dra displayed a variety of behaviours. According to the strength of the HeII/FUV continuum ratio we have identified *cool* and *hot* bursts. In fact, during the "minor" 1985–1986 outbursts the peak flux of the high ionization emission lines was comparable to those during the 1980–83 and 1994–95 major outbursts. The white dwarf temperature *decreased* to about 90000°K during the "cool" ourbursts, while it *increased* to 120000-130000°K during the 1985-86 "hot" outbursts. The behaviour during the major ("cool") outbursts is explained by expansion and cooling of the white dwarf atmosphere, which better explains the marked *anticorrelation* between optical/UV and X–ray fluxes. The minimum X–ray flux observed also during the minor ("hot") outbursts might attributed to the increased opacity of the WD envelope and wind to photons shorward the N^{+4} ionization limit. We also note that the beginning of the last activity phase of AG Dra was marked by the temporary appearance in July 1994 of strong P Cygni absorptions in the high ionization resonance lines with quite high terminal velocities of at least –700 km s^{-1}.

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Solar Abstracts

SOHO Observations of the Structure and Dynamics of Sunspot Region Atmospheres

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We present results from a study of the spatial distributions of line emission and relative line-of-sight velocity in the atmosphere above 17 sunspot regions, from the chromosphere, through the transition region and into the corona, based on simultaneous observations of ten EUV emission lines with the Coronal Diagnostic Spectrometer – CDS on SOHO. We find that the spatial distributions are non-uniform over the sunspot region and introduce the notation "sunspot loop" to describe an enhanced transition region emission feature that looks like a magnetic loop, extending from inside the sunspot to the surrounding regions. We find little evidence for the siphon flow. Attention is given to the time variations since we observe both a rapid variation with a characteristic time of a few to several minutes and a slow variation with a time constant of several hours to ≈ 1 day.

The most prominent features in the transition region intensity maps are the sunspot plumes. We introduce an updated criterion for the presence of plumes and find that 15 out of 17 sunspots contain a plume in the temperature range log

T ≈ 5.2 - 5.6. The relative line-of-sight velocity in sunspot plumes is high and directed into the Sun in the transition region. Almost all the sunspot regions contain one or a few prominent, strongly redshifted velocity channels, several of the channels extend from the sunspot plume to considerable distances from the sunspot. The flow appears to be maintained by plasmas at transition region temperatures, moving from regions located at a greater height outside the sunspots and towards the sunspot.

The spatial correlation is high to moderate between emission lines formed in the transition region lines, but low between the transition region lines and the coronal lines. From detailed comparisons of intensity and velocity maps we find transition region emission features without any sign of coronal emission in the vicinity. A possible explanation is that the emission originates in magnetic flux tubes that are too cold to emit coronal emission. The comparisons suggest that gas at transition region temperature occur in loops different from loops with coronal temperature. However, we cannot exclude the presence of transition region temperatures close to the footpoints of flux tubes emitting at coronal temperatures. Regions with enhanced transition region line emission tend to be redshifted, but the correlation between line emission and relative line-of-sight velocity is weak. We extend our conditional probability studies and confirm that there is a tendency for line profiles with large intensities and redshifts (blueshifts) above the average to constitute an increasing (decreasing) fraction of the profiles as the wavelength shift increases.

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The Anomalous Intensities of Helium Lines in the Quiet Solar Transition Region.

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Previous studies using observations made at low spatial and spectral resolution showed that the resonance lines of He I and He II are anomalously strong in the quiet Sun when compared with other transition region lines formed at similar temperatures. Here, the higher spatial and spectral resolution provided by the Coronal Diagnostic Spectrometer (CDS) instrument onboard the Solar and Heliospheric Observatory (*SOHO*) is used to re-examine the behaviour of the He I and He II lines and other transition region lines, in quiet regions near Sun centre. Supergranulation cell boundaries and cell interiors are examined separately. Near simultaneous observations with the SUMER instrument provide information on the lower transition region and the electron pressure. While the lines of He I and He II have a common behaviour, as do the other transition region lines, the behaviour of the helium lines relative to the other transition region lines is significantly different. The emission measure distributions that account for all transition region lines except those of helium, fail to produce sufficient emission in the He I and He II resonance lines by around an order of magnitude, in both supergranulation cell boundary and cell interior regions. The electron pressure appears to be higher in the cell interiors than in the average cell boundaries, although the uncertainties are large. While the VAL-D model gives a closer match to the He I 584.3-Å line, it does not successfully reproduce other transition region lines.

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Exploring the Dynamical Nature of the Lower Solar Chromosphere

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We examine spectral time-series of two lower-chromospheric lines (N I 1319 Å and C II 1335 Å) observed with the SUMER instrument on the SOHO spacecraft. We point out differences between (intensity and velocity) power spectra of network and internetwork regions and argue that the behaviour resembles that of Ca II power spectra. No significant phase differences are found between the intensities of both lines. However, when phase spectra are averaged along the slit there is some evidence that the C II intensity lags that of N I by 16 sec near 3 mHz. Intensity power spectra of C II are affected at higher frequencies by streams of emitting structures. Using contrast-enhanced time slices we show that 1) there exists a grain-like pattern which is found in both network and internetwork regions; 2) streams of

supersonically moving structures probably outline a wave interference pattern; 3) the sizes of structures observed in N I are smaller than when observed in C II. At various points our findings disagree with earlier results from SUMER. A cookbook formalism is presented to derive confidence levels for power, phase, gain and coherency spectra.

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Electron Densities Above a Polar Coronal Hole Based on Improved Si IX Density Diagnostics

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Using new close-coupling excitation rates for the C-like ion Si IX, density-diagnostic ratios based on Si IX lines have been re-evaluated and applied to a sequence of CDS observations taken above a polar coronal hole. The derived electron densities are in excellent agreement with previous values of N_e estimated from the N–like ion Si VIII for another coronal hole. The confirmed trend is for a fall-off of one order of magnitude within the first $0.3R_\odot$ above the limb. These densities are well fitted with an analytic formulae for the density profile out to at least $8R_\odot$, by which stage the electron density has fallen to $\sim 4\ 10^3$ cm^{-3}, from 1.5 10^8 cm^{-3} at $1.0R_\odot$.

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Transient Events In The EUV Transition Region and Chromosphere.

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Rapid time cadence observations of the quiet Sun extreme ultraviolet emission, observed by the CDS instrument on SOHO, are discussed. Numerous transient brightenings are observed in network features in both a transition region line (O V 629.73Å) and a chromospheric line (He I 584.33 Å), indicating a dynamic coupling between the chromospheric and transition region network. Their durations are between 80 and 200 s and dimensions 6 000–10 000 km. A wavelet analysis reveals a tendency for semi-periodic behaviour, with excess power at a frequency of about 4 mHz. The variations are much less evident in the internetwork or cell regions, although they are again semi-periodic. Relative line-of-sight velocities have also been derived from the data, the CDS spectral resolution allowing a precision of between 4.7 and 6 km s^{-1}. There is a clear association of brightenings in the network with downflows of $\sim$ 13 km s^{-1} at 250 000 K with some events having velocities of up to $\sim$ 20 km s^{-1}, these being measured relative to the average quiet Sun emission. Within the internetwork, we also find a weak correlation between events seen in the He I (584.33 Å) and the O V (629.73Å) lines. In this case, the events have a smaller size ($\leq$ 2 000 km), amplitude (both in terms of their intensity and velocity), and also show a higher frequency of about 6 mHz.

The apparent differing properties of network and internetwork events implies that both these regions are heated by two distinct mechanisms. In the case of the internetwork, these results further confirm that acoustic waves propagating up from the photosphere and forming shocks in the overlying atmosphere are the most likely heating mechanism. For the network, it is apparent that the heating required must be in excess of that supplied by acoustic shocks. Our view is that the network events are produced by nanoflare-like magnetic reconnections in the corona, or possibly excitation due to a spicule-type event in which there is a repeated rebound.

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Benchmarking the MEKAL Spectral Code with Solar X-ray Spectra

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With the likelihood that high-resolution soft X-ray spectra of non-solar astronomical sources will soon become available, it is desirable to examine the accuracy of spectral synthesis codes. In this paper, a benchmark study of the MEKAL code, extensively used in the past for spectra from *EUV*, *Chandra*, and other spacecraft, is presented using high-resolution solar flare X-ray spectra obtained with the Bragg Flat Crystal Spectrometer (FCS) on *Solar Maximum Mission* (*SMM*). Lines in the range 5–20 Å are used to adjust the wavelengths in the MEKAL code. Many of the lines are due to Fe ions, and arise from 3–2 transitions for spectra obtained during the decay phase of one of the flares, while others arise from higher-excitation (4–2, 5-2 etc.) transitions for spectra obtained near the peak of a second flare. Laboratory measurements of the wavelengths of these lines were also used to confirm the *SMM* values as well as published identifications from the HULLAC atomic code. The adjustments needed were up to 35 mÅ for line wavelengths above 13 Å but much less at shorter wavelengths. Some of these adjustments will be perceptible for spectra from the forthcoming *Chandra* spacecraft.

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Electron Density and Temperature of the Lower Solar Corona

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Off limb observations of the quiet Sun corona were made with the Coronal Diagnostic Spectrometer (CDS) on SOHO during the Whole Sun Month campaign in August 1996. Selected spectral lines in the Normal Incidence range were recorded up to 1.2 solar radii above the east and west limb and above the polar coronal holes. Intensities of the coronal lines covering the temperature range from 9×10^5 to 2×10^6 K have been measured and used to derive electron temperature and electron density as a function of the radial distance above the solar limb. Results from the east and west equatorial regions and polar coronal holes are compared. The temperature and density in the coronal holes is found to be lower than in the closed field regions. A density-sensitive line ratio of Si IX 350/342 Å is used to derive an average electron density which is found to decrease from 5×10^8 cm^{-3} near the limb to 1×10^8 cm^{-3} at $1.15 R_S$, in the equatorial region. Over the polar coronal holes, where polar plumes dominate the emission close to the limb, the density varies from 2×10^8 cm^{-3} at the limb to 6×10^7 cm^{-3} at $1.1 R_S$. The lowest density found inside the coronal hole on the disk is 9.9×10^7 cm^{-3}. An increase in the quiet Sun temperature with the radial distance is found from the Si XII/Mg X and Si XII/Mg IX line ratios, and an increase in the coronal hole temperature is seen from the Mg X/Mg IX ratio. The Si XII/Mg X temperature varies from 1.1×10^6 K at $r = R_S$ to 1.4×10^6 K at $r = 1.2 R_S$ in the equatorial regions. The EUV emission is compared with that of the soft X rays as measured by the Yohkoh SXT. The densities and temperatures determined from the SXT show a similar behavior to that determined from the CDS. Density and temperature, averaged over a position angle range of $20 - 54$ deg, show very little variation over a period of 20 days.

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EUV Observations Above Polar Coronal Holes

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We derive electron temperature and density as a function of height up to $0.2R_\odot$ above the limb in polar coronal holes, using five EUV datasets recorded by the SOHO Coronal Diagnostic Spectrometer between July 1997 and February 1998. Radial T_e and N_e distributions, averaged in a $2-10$ degree range of position angles, are the same above the North and South coronal holes. They do not show any time variability over a period of seven months. Polar plumes are found to have lower electron temperature and higher density than the interplume lanes. The electron density slope suggests that the proton temperatures are twice as high as the electron temperatures.

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