COOLNEWS

A RESEARCH NEWSLETTER DEDICATED TO COOL STARS AND THE SUN

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Stellar Abstracts

The Evolution of the Lithium Abundances of Solar-Type Stars. VI. The End of Lithium in the Pleiades

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We have used the HiRes spectrograph on the Keck telescope to obtain echelle spectra of 15 late-K dwarfs in the Pleiades cluster. We derive lithium abundances, rotational velocities, and indices of chromospheric emission. There is less spread in the Li abundance for these cool stars than was seen for early-K dwarfs, and the correlation between rapid rotation and Li richness that was evident in more massive stars breaks down for the late-K dwarfs as well.

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Hα Emission Fluxes and Lithium Abundances of Low Mass Stars in the Young Open Cluster IC 4665

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As part of a long term effort to understand pre-main sequence Li burning, we have obtained high resolution spectroscopic observations of 14 late type stars (G0–M1) in the young open cluster IC 4665. Most of the stars have Hα filled-in and Li I absorption, as expected for their young age. From the equivalent widths of Hα emission excess (obtained using the spectral subtraction technique) and the Li I λ6708 feature, we have derived Hα emission fluxes and photospheric Li abundances. The mean Li abundance of IC 4665 solar-type stars is log N(Li)=3.1; the same as in other young clusters (α Per, Pleiades) and T Tauri stars. Our results support the conclusions from previous works that PMS Li depletion is very small for masses ~ 1 M$_\odot$. Among the IC 4665 late-G and early K-type stars, there is a spread in Li abundances of about one order of magnitude. The Li-poor IC 4665 members have low Hα excess

and vsin$i \leq 10$. Hence, the Li-activity-rotation connection which has been clearly established in the Pleiades also seems to hold in IC 4665. One M-type IC 4665 star that we have observed does not show Li, implying a very efficient Li depletion as observed in α Per stars of the same spectral type.

The level of chromospheric activity and Li depletion among the low mass stars of IC 4665 is similar to that in the Pleiades. In fact, we note that the Li abundance distributions in several young clusters (α Per, Pleiades, IC 2391, IC 4665) and in post T Tauri stars are strikingly similar. This result suggests that Hα emission and Li abundance not well correlated with age for low mass stars between 20 and 100 Myr old. We argue that a finer age indicator, the "LL-clock", would be the luminosity at which the transition between efficient Li depletion and preservation takes place for fully convective objects. The LL-clock could allow in the near future to derive the relative ages of young open clusters, and clarify the study of PMS evolution of cool stars.

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Formation of PAHs, Polynes, and Other Macro-molecules in the Photosphere of Carbon Stars

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Polycyclic Aromatic Hydrocarbons (PAH) have been suggested as a link in one of the possible routes from molecules to grains in carbon-rich stellar atmospheres. Carbon grains, except SiC, may form by conversion of C_2H_2 into PAHs. The most obvious site of this PAH production is the outer atmosphere of carbon stars. We present the first calculations of equilibrium partial pressures of PAHs and other complex carbon-bearing molecules in stellar photosphere models for carbon stars. We have included 38 atomic species and 338 molecules in chemical equilibrium. Our computed models have the following parameters: $T_{\rm eff}$=(2800K, 2600K, 2400K), Z=$Z_\odot$, log(g) ϵ $[-1,0.5]$, C/O ϵ [1.1,7.0]. The results of the hydrostatic model calculations show that for atmospheric regions with T>1000K the partial pressures of PAHs and other large molecules are negligibly small. This result is independent of the choice of fundamental stellar parameters.

For shallower depths than our hydrostatic photosphere models, however, a systematic chemical equilibrium exploration of the T-$P_{\rm gas}$ plane, Tϵ[750K,1000K], log$P_{\rm gas}$ ϵ[-5,3] ($P_{\rm gas}$ in dyn/cm^2), discloses PAHs as the species containing the largest fraction of carbon atoms not bound in CO for a range of temperatures around 850K. More carbon is contained in PAHs than in CO at these temperatures for C/O $\gtrsim$ 5.0.

Chemical equilibrium considered in a dynamical atmospheric structure confirms these results. The higher column density of PAHs is sufficient for the dynamic model to have an effect on the structure of the model (levitation) and on the emergent spectrum. However, some studies (Frenklach & Feigelson 1989) on kinetic PAH formation require a residence time at favourable T and $P_{\rm gas}$ which is longer than the time scales of realistic wind models. In the framework of our hydrostatic models we confirm that the conditions for PAH formation (T, $P_{\rm gas}$ or residence time) are not met, and we can point at the lower boundary condition needed for the wind models. Therefore either the observed dust grains form via other routes, or more complex stellar environments are required.

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EUV Line Emission From Cool Stars: Resonantly Scattered Or Not – That is the Question !

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A challenge to the classical assumption that the radiative losses from stellar coronae are optically thin has been raised by Schrijver, van den Oord & Mewe (1994), who argued that some of the stronger emission lines detected in the high-resolution spectra of cool stars observed with the *Extreme Ultraviolet Explorer* (EUVE) Satellite, are optically thick. If they assume all radiation optically thin, an explanation of the short wavelength (SW) part of the EUVE spectrum requires large amounts of emission measure at very high temperatures (T $\approx 10^8$ K), which is unlikely the case for rather inactive stars. We show that the soft X-ray pulse height spectrum obtained with the position sensitive proportional counter (PSPC) on board ROSAT is inconsistent with such high temperature emission and inconsistent with the assumption that the EUV line emission is optically thick. We further demonstrate via an analysis of fit residuals that the observed count fluctuations in the EUVE SW spectrum are inconsistent with the hypothesis that the bulk of the observed flux arises from a continuum. Therefore, resonance scattering does not appear to be required for the interpretation of the EUV and X-ray spectra of inactive cool stars.

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A Search for Variability in the Spectral Line Shapes of 51 Pegasi: Further Evidence for a Planet

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A search for variability in the spectral line shapes of 51 Pegasi is performed using high signal-to-noise ($S/N > 500$), high resolution (0.04 Å) data covering one "orbital" period. We find no evidence for variability in the velocity span of the spectral line bisectors greater than the error of the measurement ($\sigma \approx 20$ m s^{-1}). It is demonstrated that the lack of strong variations in the bisector velocity span can be used to exclude the presence of nonradial sectoral modes with $l \geq 4$. The expected change in the bisector velocity span from low order (l = 1-3) modes is about 10 m s^{-1}, or one-half the error measurement. Consequently, low-order nonradial pulsations can still account for the observed RV amplitude and the lack of observed line shape variability. There are also no apparent variations in the equivalent width of a low excitation V I line measured on three consecutive nights. These measurements place a limit of ΔT = 4 K for any disk-integrated temperature variations of the stellar surface. The projected rotational velocity was also measured using nine spectral lines, yielding a mean value of $v\sin i = 2.35 \pm 0.1$ km s^{-1}. This along with the published rotation period of 37 d yields a minimum stellar radius of 1.7 $R_\odot$. Although the planet hypothesis is still the most likely explanation for the radial velocity variations, this is still not definite. Precise photometric measurements and spectral observations at higher spectral resolution are needed to exclude with certainty the presence of low-order nonradial pulsations in 51 Pegasi.

Submitted to ApJ

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Mg II Emission from Hybrid-chromosphere Stars: 1.5 Decades of Chromospheric Variability Monitoring

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We present an analysis of the available long-wavelength, high-dispersion spectra of seven hybrid-chromosphere stars obtained with the *International Ultraviolet Explorer* between 1978 and 1993. Our investigation of the variability of the Mg II h and k resonance doublet demonstrates that the emission line fluxes are not rotationally modulated with

the periods previously suggested by Brosius, Mullan, & Stencel (1985). Furthermore, we find no evidence in the Mg II data to corroborate the multiple periodicities reported in the Ca II emissions of hybrid stars by Rao et al. (1992). Examination of 40 pairs of closely spaced Mg II observations failed to reveal the presence of any strong chromospheric flaring on the sample stars. Significant (20–40%) *non-periodic* Mg II flux variability on time scales of days to years, is observed in six of the seven stars. The flux variations occasionally are accompanied by dramatic changes in the morphology of the Mg II profiles, indicating variable stellar-wind absorption. We argue that the variability observed is consistent with stochastic changes associated with the slow growth and decay of chromospheric active regions and the gradual evolution of the physical conditions in the winds. It is our opinion that no compelling argument has yet been made for periodic variability in the chromospheric diagnostics of hybrid stars.

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EUV Emission from RS CVn Binaries

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We performed a study of 104 RS CVn systems in the extreme ultraviolet (EUV) using the all–sky survey data obtained by the Extreme Ultraviolet Explorer (EUVE). The present sample includes several new RS CVn detections; 11 more than in the published EUVE catalogs, and 8 more than in the ROSAT Wide Field Camera catalog. The ratio of detections to non–detections remained constant throughout the sky, implying that our detections are not limited by the exposure time but are most likely limited by absorption from the interstellar medium. A general trend of increasing Lex/B (50–180Å) flux with decreasing rotational period is clear. The dwarf systems exhibit a leveling-off for the faster rotators. In contrast, the evolved systems exhibit no such effect. For the RS CVn systems the losses in the EUV represent a smaller fraction of the coronal radiative losses, as compared to active late–type dwarfs.

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Properties of Sun-like Stars with Planets

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Radial velocity variations have revealed planets orbiting 51 Peg, 47 UMa, and 70 Vir, and a low-mass companion orbiting HD 114762. We analyze parallel records of photometric measurements in Strömgren b and y, and Johnson V, R, and I passbands, and Ca II H and K fluxes in those stars. In the case of 51 Peg, the high precision of the differential photometric measurements made by the 0.75m Automatic Photoelectric Telescope and the nonvariability of the star would allow the detection of a transit of a planet as small as Earth (corresponding to an amplitude of 0.0001 mag) if its orbit were nearly coplanar with our line of sight. No transits were observed.

For 51 Peg and 70 Vir, the upper limit of non-detection of photometric variability at their companion's orbital periods is $\Delta(b+y)/2 < 0.0002 \pm 0.0002$ mag. For HD 114762, it is $\Delta V < 0.0007 \pm 0.0004$ mag. Such small amplitudes of photometric variability seem to eliminate periodic velocity variations expected from p-mode oscillations.

All four stars are magnetically quiet; that is, they lack the typical Ca II and photometric variability due to rotation and activity cycles expected from surface magnetic activity in solar-type stars. Such quiescence produces an interesting observational bias that favors the detection of planets from low-amplitude radial velocity or photometric variations by minimizing the contribution from intrinsic stellar variability. We discuss the circumstances for which the probability of planet detections is improved by the reduced level of variability from surface magnetic activity in G and K stars.

Stars with low variability in surface activity should be the best candidates for planet searches using radial velocity and photometric techniques. Searches for planets around younger, more active stars will be impeded by variations in velocity or brightness caused by time-varying surface features.

The Ca II H and K fluxes indicate that all four stars are older than 5 Gyr. Ages were estimated from the average levels of Ca II H and K fluxes and an existing relationship of the decrease of Ca II fluxes with age on the lower main sequence, and drawn from previous results based on theoretical isochrone fitting. Values of the projected rotational velocity, $v \sin i$, are determined for 70 Vir and 47 UMa from high-resolution spectra.

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On Possible Multiplicity of Components of Some Low Mass Systems

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An attempt is made in this work to explain a shift of low mass components of binaries from their "normal" positions in the mass-luminosity plane. Assuming that "overmassive" stars are unresolved binaries (multiples), we calculate the most probable mass and luminosity values of hidden components. Some observational parameters are also estimated for the components.

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Environments of Active Close Binaries I: ER Vulpeculae

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High-resolution observations of the eclipsing active close binary system ER Vulpeculae have revealed excess emission in the Hα, the Ca II IRT and the Mg I b lines and excess absorption in the He I D_3 line. The emission appears to be from a global phenomenon with the secondary component the more active. Analysis has revealed that the emission arises in plage-like material covering perhaps half of the secondary's surface. This gives credence to X-ray and UV studies which have indicated that ER Vul is near the saturation limit for dynamo-induced activity. No firm spectroscopic evidence for the existence of extended material around ER Vul was found. A consistent velocity offset of $\sim$10 km s^{-1} was observed in the excess Hα emission from the secondary component which may be associated with active regions such as spicules. If so this represents the first observation of the equivalent of solar spicule emission in a stellar system other than the Sun.

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Limb Observations of He I 1083 nm

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Imaging spectroscopic data of the He I 1083 nm limb emission were taken on several dates in Oct and Nov 1995 with the NASA/NSO Spectromagnetograph at the NSO/Kitt Peak Vacuum Telescope and on 09 Dec 1993 with the Michigan Infrared Camera at the NSO/Sac Peak Vacuum Tower Telescope. Emission line profiles were observed in quiet Sun and coronal hole locations on the northern and southern solar poles and on the east solar limb. The height of the He I 1083 nm shell above the continuum limb at 1083 nm was measured to be 2.11$\pm$0.12 Mm with the Kitt Peak data, and 1.74$\pm$0.05 Mm with the Sac Peak data. The Kitt Peak data show (1) within the measurement error there is no significant difference in the height or thickness of the emission shell in coronal holes compared with the quiet Sun, (2) the 1083 nm emission intensity drops by 50% in coronal holes, (3) the line width decreases by about 2 km s^{-1} in coronal holes (suggesting less inclined spicules), (4) the line width of the He I 1083 nm line jumps significantly as the line-of-sight crosses the solar limb (consistent with a higher temperature upper shell), (5) a quiescent prominence shows a smaller spectral line width (consistent with a cooler temperature or less velocity broadening), and (6) the entire emission shell and the prominence show a He I spectral component ratio of about 8 (suggesting optically thin emission).

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Measurement of Hydrogen Velocity Distributions in the Extended Solar Corona

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H I Lyα spectral line profiles have been measured in polar regions of the solar corona at projected heliocentric heights of 1.8 to 3.5 $R_\odot$. Observations were made with the Ultraviolet Coronal Spectrometer on the Spartan 201 satellite from 16:52 UT to 04:04 UT on 11–12 April 1993 (south pole) and from 12:28 UT to 22:09 UT on 12 April 1993 (north pole). In general, the coronal profiles cannot be accurately curve-fit with a single gaussian function. The fits with two gaussians yield most probable velocities of 158 km s^{-1} and 322 km s^{-1} (south) and 98 km s^{-1} and 266 km s^{-1} (north). These parameters vary by less than 10% (1σ) over the observed heights.

The observations are consistent with a line of sight model that attributes the narrow component to background streamers and to sites within polar coronal holes or a surrounding diffuse corona and the broad component to the polar coronal holes and/or plumes. This interpretation suggests that there are regions within the observed coronal holes that have hydrogen and proton kinetic temperatures of $4-6\times10^6$K which is 4–10 times higher than the expected electron temperatures at the same heights. However, other models with, for example, local non-Maxwellian velocity distributions are also consistent with the observations.

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Abstract Guidelines

Abstracts for *COOLNEWS* are solicited for papers that have been recently accepted by or submitted to refereed journals, and for recent Ph.D. theses. The subject matter should pertain directly to cool stars (spectral types F,G,K, or M) or the sun. Both theoretical and observational abstracts are appropriate. Abstracts dealing with cool pre-main-sequence stars will generally not be included in *COOLNEWS*, since they are already covered by the *Star Formation Newsletter*. Exceptions to this rule will be considered if the subject matter is truly cross-disciplinary. A monthly call for abstracts will be issued and abstracts received by the last day of the month will usually appear in the following month's newsletter. Announcements of general interest to the cool star and solar communities may also be submitted for posting in the newsletter. These might include (but are not restricted to) the following: (i) *Job Openings* directed toward cool star or solar researchers, (ii) announcements of *Upcoming Meetings*, (iii) announcements of *Upcoming Observing Campaigns* for which participation is solicited from the community at large, (iv) reviews of *New Books*, and (v) *General Announcements* that provide or request research-related information. Please send all correspondence to the editor at coolnews@jila.colorado.edu. Abstract templates and back issues can be obtained from the COOLNEWS Web-page at

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