COOLNEWS

A RESEARCH NEWSLETTER DEDICATED TO COOL STARS AND THE SUN

No. 74 — March 2002 Editor: Steve Skinner (coolnews@jila.colorado.edu)

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Stellar Abstracts

The 3 μm Spectrum of R Doradus Observed with the ISO-SWS

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We have modeled the 2.6–3.7 μm spectrum of the red semiregular variable R Doradus observed with the Short-Wavelength Spectrometer on board the Infrared Space Observatory. The wavelength resolution of the observations varies between R $\sim$ 2000–2500. We have calculated a synthetic spectrum using a hydrostatic model photosphere in spherical geometry. The agreement between the synthetic spectrum and the ISO observations is encouraging, especially in the wavelength region of 2.8–3.7 μm, suggesting that a hydrostatic model photosphere is adequate for the calculation of synthetic spectra in the near infrared for this moderately varying red giant star. However, an additional absorption component is needed at 2.6–2.8 μm and this discrepancy is discussed. The spectral signatures are dominated by water vapour in the stellar photosphere, but several photospheric OH, CO, and SiO features are also present. The effective temperature and surface gravity derived for R Dor, based on the 2.6–3.7 μm ISO spectrum and the modeling of it with a hydrostatic model photosphere, are 3000 ± 100 K and $\log g = 0 \pm 1$ (cgs), respectively. The spectral region observed is found to be temperature sensitive. The effective temperature given here is slightly higher than those reported in the literature. We also discuss possible reasons for this.

Accepted by A&A

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Detailed analysis of Balmer Lines in Cool Dwarf Stars

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An analysis of Hα and Hβ spectra in a sample of 30 cool dwarf and subgiant stars is presented using MARCS model atmospheres based on the most recent calculations of the line opacities. A detailed quantitative comparison of the solar flux spectra with model spectra shows that Balmer line profile shapes, and therefore the temperature structure in the line formation region, are best represented under the mixing length theory by any combination of a low mixing-length parameter α and a low convective structure parameter y. A slightly lower effective temperature is obtained for the sun than the accepted value, which we attribute to errors in models and line opacities. The programme stars span temperatures from 4800 to 7100 K and include a small number of population II stars. Effective temperatures have been derived using a quantitative fitting method with a detailed error analysis. Our temperatures find good agreement with those from the Infrared Flux Method (IRFM) near solar metallicity but show differences at low metallicity where the two available IRFM determinations themselves are in disagreement. Comparison with recent temperature determinations using Balmer lines by Fuhrmann (1998, 2000), who employed a different description of the wing absorption due to self-broadening, does not show the large differences predicted by Barklem et al. (2000). In fact, perhaps fortuitously, reasonable agreement is found near solar metallicity, while we find significantly cooler temperatures for low metallicity stars of around solar temperature.

Accepted by A&A

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For preprints via ftp or WWW: http://lanl.arXiv.org/abs/astro-ph/0201537

Beryllium Abundances in Stars Hosting Giant Planets

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We have derived beryllium abundances in a wide sample of stars hosting planets, with spectral types in the range F7V−K0V, aimed at studying in detail the effects of the presence of planets on the structure and evolution of the associated stars. Predictions from current models are compared with the derived abundances and suggestions are provided to explain the observed inconsistencies. We show that while still not clear, the results suggest that theoretical models may have to be revised for stars with $T_{\rm eff}$<5500 K. On the other hand, a comparison between planet host and non-planet host stars shows no clear difference between both populations. Although preliminary, this result favors a "primordial" origin for the metallicity "excess" observed for the planetary host stars. Under this assumption, i.e. that there would be no differences between stars with and without giant planets, the light element depletion pattern of our sample of stars may also be used to further investigate and constraint Li and Be depletion mechanisms.

Accepted by A&A

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Long-term Starspot Evolution, Activity Cycle and Orbital Period Variation of RT Lacertae

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A sequence of V-band light curves of the active close binary RT Lacertae (G5+G9 IV), extending from 1965 to 2000, is presented and analysed to derive the spot distribution and evolution on the component stars. In our modelling approach, the Roche geometry and Kurucz's atmospheric models were adopted. The resulting maps of the spot surface distribution were regularized by means of the Maximum Entropy and Tikhonov criteria to take full advantage of the increased geometrical resolution during eclipses. By comparing the maps obtained with these two criteria, it was possible to discriminate between surface features actually required by the data and artifacts introduced by the

regularization process. Satisfactory fits were obtained assuming spots on both components and the unspotted V-band luminosity ratio: $L_{G5}/L_{G9\,IV} = 0.65 \pm 0.05$. The more massive G5 primary appears to be the most active star in the system and its spotted areas are mainly responsible for the light curve distortions.

The yearly spot distributions on both components indicate that their spot patterns consist of two components, one uniformly and the other non-uniformly distributed in longitude, the latter suggesting the presence of preferential longitudes. In particular, spots are concentrated around the substellar points and their antipodes on both stars. The eclipse scanning reveals spots with diameters of $\sim 40°$, or possibly smaller, on the hemisphere of the primary star being occulted.

The primary shows clear evidence for a short-term activity cycle with a period of ~ 8.5 yr and a possible long-term cycle with a period of approximately 35 yr. The variation of the spot migration rate may be related with surface differential rotation, with a lower limit of $\Delta\Omega/\Omega \sim 3.2 \times 10^{-3}$. The G9IV secondary does not show evidence for an activity cycle, its spot coverage appearing rather constant at $\sim 15-20\%$ of its surface. The relative amplitude of its surface differential rotation, as indicated by the variation of the spot migration rate, is $\Delta\Omega/\Omega \sim 2.7 \times 10^{-3}$.

The variation of the orbital period shows a correlation with the activity level of the primary component. Specifically, the decreases of the orbital period appear to be associated with minimum spottedness and sizeable changes of the surface spot distribution which may be related with increases of the rotation rate of the spot pattern. Conversely, an episode of increase of the orbital period was related with an increase of the spotted area on the primary star. Such results give support to the recently proposed models that connect the perturbations of the orbital dynamics with the variation of the figure of equilibrium of the active components, due to the operation of non-linear hydromagnetic dynamos in their extended convective envelopes.

Accepted by A&A

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Solar Abstracts

Dynamic Hydrogen Ionization

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We investigate the ionization of hydrogen in a dynamic Solar atmosphere. The simulations include a detailed non-LTE treatment of hydrogen, calcium and helium but lack other important elements. Furthermore, the omission of magnetic fields and the one-dimensional approach make the modeling unrealistic in the upper chromosphere and higher. We discuss these limitations and show that the main results remain valid for any reasonable chromospheric conditions. As in the static case we find that the ionization of hydrogen in the chromosphere is dominated by collisional excitation in the Lyman-α transition followed by photoionization by Balmer continuum photons — the Lyman continuum does not play any significant role. In the transition region, collisional ionization from the ground state becomes the primary process. We show that the time scale for ionization/recombination can be estimated from the eigenvalues of a modified rate matrix where the optically thick Lyman transitions that are in detailed balance have been excluded. We find that the time scale for ionization/recombination is dominated by the slow collisional leakage from the ground state to the first excited state. Throughout the chromosphere the time scale is long (10^3-10^5 s), except in shocks where the increased temperature and density shorten the time scale for ionization/recombination, especially in the upper chromosphere. Because the relaxation time scale is much longer than dynamic time scales, hydrogen ionization does not have time to reach its equilibrium value and its fluctuations are much smaller than the variation of its statistical equilibrium value appropriate for the instantaneous conditions. Because the ionization and recombination rates increase with increasing temperature and density, ionization in shocks is more rapid than recombination behind them. Therefore, the ionization state tends to represent the higher temperature of the shocks, and the mean electron density is up to a factor of six higher than the electron density calculated in statistical equilibrium from the mean atmosphere. The simulations show that a static picture and a dynamic picture of the chromosphere are fundamentally different and that time variations are crucial for our understanding of the chromosphere itself and the spectral features formed there.

Accepted by ApJ

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Oscillations Above Sunspots

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The 3 minute oscillations in the sunspot atmosphere are discussed, based on joint observing with the Transition Region And Coronal Explorer - TRACE and the Solar and Heliospheric Observatory - SOHO. We find that the oscillation amplitude above the umbra increases with increasing temperature, reaches a maximum for emission lines formed close to 1 - 2 $\times$ 10^5 K, and decreases for higher temperatures. Oscillations observed with a high signal to noise ratio show deviations from pure linear oscillations. The results do not support the sunspot filter theory, based on the idea of a chromospheric resonator. Whereas the filter theory predicts several resonant peaks in the power spectra, equally spaced $\sim$1 mHz in frequency, the observed power spectra show one dominating peak, close to 6 mHz.

Spectral observations show that the transition region lines contribute less than 13 percent to the TRACE 171 Å channel intensity above the umbra. The 3 minute oscillations fill the sunspot umbra in the transition region. In the corona the oscillations are concentrated to smaller regions that appear to coincide with the endpoints of sunspot coronal loops, suggesting that wave propagation along the magnetic field makes it possible for the oscillations to reach the corona.

Accepted by Solar Phys.

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Change of Rotation Rates of Sunspot Groups During Their Lifetimes : Clues to the Sites of Origin of Different Flux Tubes

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From 103 years of data of non-recurrent sunspot groups and for the two sets (area $<$ 100 millionths of hemisphere and $>$ 100 millionths of hemisphere), irrespective of their life span, we compute rotation rates and rate of change of rotation rates during their lifetime. It is found that variation of rotation rates of sunspot groups with respect to their lifetime is approximately similar to the radial variation of internal rotation inferred by helioseismology and it is confirmed that all the spot groups decelerate as they evolve into later phases of their lifetime.

After classification according to different life spans, for the same two data sets, we compute initial rotation rates and rate of change of initial rotation rates of sunspot groups. For the two data sets, variation of initial rotation rates of sunspot groups with respect to their life spans is similar to the radial variation of internal rotation of solar plasma inferred from helioseismology. We also obtain the rate of change of initial rotation rates for two sets of spot groups and the results are as follows : (i) for the area $<$ 100, spot groups are accelerated for the life spans of 6-12 days and decelerated for the life spans of 3-6 days; (ii) for the area $>$ 100, acceleration for the life spans of 9-12 days and deceleration for the life spans of 3-9 days.

Interpreting these results, an attempt is made to locate the sites of origin of spot groups of different sizes and life spans in the convection zone.

Accepted by A&A

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Long-Period Chromospheric Oscillations in Network Bright Points

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The spatial variation of chromospheric oscillations in network bright points (NBPs) is studied using high-resolution observations in Ca II K_3. Lightcurves and hence power spectra were created by isolating distinct regions of the NBP via a simple intensity thresholding technique. Using this technique, it was possible to identify peaks in the power spectra with particular spatial positions within the NBPs. In particular, long-period waves with periods of 4–15 minutes (1–4 mHz) were found in the central portions of each NBP, indicating that these waves are certainly not acoustic, but possibly due to magneto-acoustic or magneto-gravity wave modes. We also show that spatially averaged or low spatial resolution power spectra can lead to an inability to detect such long-period waves.

ApJ (2002), 567, L165

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Flare Index Variability in the Ascending Branch of Solar Cycle 23

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A brief description and the results of the determination of the flare index as a measure of solar activity on the ascending branch of cycle 23 up to December 31, 2000, are presented. The patterns of similar activity indices that arise under different physical conditions during the rising activity phase are compared with the flare index. All studied solar indices rise more slowly in the current cycle than the last one, except the total solar irradiance. The intermediate-term periodicities in the daily flare index data were studied using the Fourier transform and it was found that the 35, 62, 116, 198 and 276-day periodicities are in operation during the ascending branch of cycle 23. Contrary the previous three cycles, 155, 73 or 51-day periodicities were not detected by the Fourier transform in this branch of the cycle. The wavelet transform results show that the occurrence of flare index power is highly intermittent in time and the most pronounced power peaks were found to be present at 35 days (the temporal locations at 1998.3, 1999.9 and 2000.5 years), 116 days (the temporal interval 1999.7-2000.4 years) and 276 days period (interval roughly from 1999.5 until the end of the flare index data). Comparison of the Fourier and wavelet transform results has clarified the importance of different periodicities, whether they are (62, 198 days) or are not (35, 116, 276 days) the harmonics of the basic ones, as well as the temporal location of their occurrence.

Accepted by J. Geophy. Res., Space Sci.

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Low-Mass and Substellar Abstracts

The CORALIE Survey for Southern Extra-solar Planets VII. Two Short-period Saturnian Companions to HD 108147 and HD 168746

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We present the discovery of two Saturn-mass companions to HD 108147 and HD 168746. Both belong to the lightest ever discovered planets. The minimum mass of the companion to HD 168746 is of only 0.77 the mass of Saturn and

its orbital period is 6.4 days. The companion to HD 108147 orbits its parent star in 10.9 days and its minimum mass is 1.37 that of Saturn. Its orbit is characterized by a high eccentricity, $e = 0.56$, indicating possibly the presence of a second companion.

The detection of Saturn-mass planets by means of the Doppler technique demands high radial-velocity measurement precision. The two new candidates were discovered by means of the CORALIE echelle spectrograph. The instrumental accuracy of CORALIE combined with the simultaneous ThAr-reference technique has reached a level better than 3 m/s. On many observed objects the precision is now limited by photon noise. We present in this paper the weighted cross-correlation technique, which leads to an improvement in the photon noise of the computed radial velocity. We discuss as well a modification of the numerical cross-correlation mask which reduces significantly the residual perturbation effects produced by telluric absorption lines.

Submitted to A&A

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The CORALIE Survey for Southern Extra-solar Planets VIII. The Very Low-mass Companions of HD 141937, HD 162020, HD 168443 and HD 202206: Brown Dwarfs or "Superplanets"?

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Doppler CORALIE measurements of the solar-type stars HD 141937, HD 162020, HD 168443 and HD 202206 show Keplerian radial-velocity variations revealing the presence of 4 new companions with minimum masses close to the planet/brown-dwarf transition, namely with $m_2 \sin i = 9.7$, 13.75, 16.9, and 15.95 $\mathrm{M_{Jup}}$, respectively. The orbits present fairly large eccentricities ($0.22 \leq e \leq 0.43$). Except for HD 162020, the parent stars are metal rich compared to the Sun, as most of the detected extra-solar planet hosts. Considerations on tidal dissipation in the short-period HD 162020 system points towards a brown-dwarf nature for the low-mass companion. HD 168443 is a multiple system with two low-mass companions being either brown dwarfs or formed simultaneously in the protoplanetary disks as *superplanets*. For HD 202206, the radial velocities show an additional drift unveiling a further outer companion the nature of which is still unknown. Finally, the stellar-host and orbital properties of massive planets are examined in comparison to lighter exoplanets. Observed trends include the need of metal-rich stars to form massive exoplanets and the lack of short periods for massive planets. If confirmed with improving statistics, these features may bring constraints for the migration scenario.

Submitted to A&A

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Discovery of a Methane Dwarf from the IfA-Deep Survey

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We present the discovery of a distant methane dwarf, the first from the Institute for Astronomy (IfA) Deep Survey. The object ("IfA 0230-Z1") was identified from deep optical I and z'-band imaging, being conducted as an IfA-wide collaboration using the prime-focus imager Suprime-Cam on the Subaru 8.2-m Telescope. IfA 0230-Z1 is extremely red in the $Iz'J$ (0.8–1.2 μm) bands but relatively blue in $J - H$; such colors are uniquely characteristic of T dwarfs. A near-IR spectrum taken with the Keck Telescope shows strong H_2O absorption and a continuum break indicative of CH_4, confirming the object has a very cool atmosphere. Comparison with nearby T dwarfs gives a spectral type of T3–T4 and a distance of ~45 pc. Simple estimates based on previous T dwarf discoveries suggest that the IfA survey will find a comparable number of T dwarfs as the 2MASS survey, albeit at a much larger average distance. We also discuss the survey's ability to probe the galactic scale height of ultracool (L and T) dwarfs.

Accepted by ApJL

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Ph.D. Thesis Abstracts

Coronal Activity in the First Phases of Stellar Evolution

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Ph.D degree awarded: February 2002

I have approached the problem of coronal activity in the first stages of stellar evolution, from the early PMS ($\sim$ 1 Myr.) to the ZAMS ($\sim$ 100 Myr.) from a mainly observational standpoint. I describe the analysis of X-ray observations of three young clusters. In order of age: the Orion Nebula Cluster (ONC, $\sim$1 Myr.), NGC 2264 ($\sim$3 Myr.) and NGC 2516 ($\sim$140 Myr.). The first and the last are observed with *Chandra*, NGC 2264 with *ROSAT*.

In the ONC I find no correlation between activity and stellar rotation. Instead I observe that median L_X correlates with mass, from the *brown dwarf* regime, ($M = 0.03 - 0.08 M_\odot$, $Log(L_X) \sim 10^{28}$ ergs s^{-1}) to about $3M_\odot$ ($Log(L_X) \gtrsim 10^{31}$) and then drops for stars that, according to models, do not have a convective region. The relation of L_X with mass can be also imputed to the fact that most stars have $Log(L_X/L_{bol})$ close, even though on average lower, to the *saturation* value (~ -3) and to the direct relation between L_{bol} and mass for stars of a given age. I observe that median $Log(L_X/L_{bol})$ also increases with mass by about 0.4 dex for $0.1 \lesssim M \lesssim 0.5 M_\odot$. A dependence of L_X and L_X/L_{bol} on circumstellar accretion and/or presence of circumstellar disks is apparent in the data, accreting stars showing significantly lower average levels respect to non accreting ones.

Low mass NGC 2264 members also display saturated emission levels, $Log(L_X/L_{bol}) \sim -3$. Investigating the X-ray variability of the sources detected in our HRI data, I find that Classical T Tauri Stars are significantly more variable than Weak Lined T Tauri Stars.

I derive activity levels for members of the young ZAMS NGC 2516 cluster and compare them with those of Pleiades stars, of roughly the same age, but with different metallicity. I find that G and K stars appear to be subluminous in NGC 2516 respect to the Pleiades. This result hints toward a role of metallicity in the determination of coronal activity.

Finally, by complementing the original observations with published data on two star forming regions, ρ Ophiuchi, and Chamaeleon I, and on the Pleiades cluster, all partially re-analyzed here in a consistent way, I try to derive a coherent description of activity evolution from the early PMS to the ZAMS. $Log(L_X/L_{bol})$, for stars of a given mass, is observed to increase in the first $3 - 5Myrs$ and to reach the saturation level, -3. This early evolution is slower for lower mass stars. Following this phase, low mass stars keep saturated activity levels up to the ZAMS, while more massive stars de-saturate at some point between the age of the Chamaeleon I region and that of the Pleiades. I find that the PMS data is compatible with the following picture: PMS stars have $Log(L_X/L_{bol}) \sim -3$, i.e. at the same level of small Rossby number MS stars, with the exception that accretion and/or the presence of disks acts to reduce their X-ray emission. Modern PMS evolutionary models and measured rotational periods indeed suggest that young stars *should*, have saturated emission according to the activity - Rossby number relation observed for main sequence stars. As the number of accreting/disked stars decreases with time, the fraction of saturated stars of a given mass increases and the mean activity level approaches the saturation level.

Thesis-related Publications: A&A, 345, 521; A&A, 355, 651; ApJ, 547, L141; A&A, 365, L259

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. Abstracts for conference proceedings articles are *not* posted in *COOLNEWS*. The subject matter should pertain directly to cool stars (spectral types F,G,K,M or L), substellar objects, or the sun. Both theoretical and observational abstracts are appropriate.

Abstracts dealing with cool pre-main-sequence (PMS) 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. If you wish to submit a cross-disciplinary abstract on PMS stars, then first submit it to the *Star Formation Newsletter*. After doing so, submit the abstract to *COOLNEWS* accompanied by a short e-mail stating that it has already been submitted to the *Star Formation Newsletter*, and summarizing why it will be of interest to the cool star/solar community at large.

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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