COOLNEWS

A RESEARCH NEWSLETTER DEDICATED TO COOL STARS AND THE SUN

No. 26 — December 1997 Editor: Steve Skinner (coolnews@jila.colorado.edu)

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Editor's Note

All contributors are reminded that abstracts on pre-main-sequence stars will generally not be posted in COOLNEWS unless they are of a cross-disciplinary nature (... as stated in the Abstract Guidelines at the end of each issue). If you would like to post a cross-disciplinary abstract on pre-main-sequence stars in COOLNEWS, then please first submit the abstract to the *Star Formation Newsletter* (SFN). After having done so, submit your abstract to COOLNEWS accompanied by a short e-mail stating that you have already submitted it to SFN and summarizing why it will be of interest to the cool star/solar community at large.

COOLNEWS will take a break for the year-end holidays, with **no issue planned for January**. Abstracts for the next issue, which will appear in early February, are due January 31. Many thanks to all of you who have supported the newsletter, and best wishes for the New Year.
Sincerely, Steve Skinner

First VLBI Images of a Main-sequence Star

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The binary system UV Cet A and B has been observed with the VLBA/VLA at 3.6 cm wavelength. Both dMe stars have been detected. The stronger, steady radio emitter of the two, UV Cet B, is resolved into at least two spatial components. Their relative intensities change during the 6.3 hours of observing time. One of the components is more stable and resolved, the other is possibly unresolved. The resolved component has a half-power diameter of 2.4×10^{10}cm, exceeding the size of the stellar photosphere. The separation of the two components of UV Cet B is $4.4(\pm 0.4) \times 10^{10}$cm or 4 - 5 stellar radii. The alignment of the two components is along the axis of the binary orbit and thus parallel and very likely close to the stellar rotation axis. The apparent trapping of the gyrosynchrotron emitting energetic electrons requires large coronal loops extending to several stellar radii. At the more variable source a magnetic field between 15 and 130 G is derived.

Accepted by A&A

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On the X-ray Emission from M-type Giants

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We have searched for X-ray emission from M-type giants and supergiants listed in the Bright Star Catalogue (BSC) in the data of the ROSAT all-sky survey (RASS). These stars lie to the far right of the X-ray dividing line and are thus not expected to be X-ray sources. Any X-ray detection would therefore violate the common paradigm of X-ray dark M-type giants beyond the X-ray dividing line. We found 11 BSC M-type giants and supergiants to coincide with RASS X-ray sources. While for 4 stars the X-ray emission is very likely related to their cataclysmic or symbiotic nature or can be attributed to a visual G-type companion, the other 7 stars are candidates for intrinsic X-ray emission. Of these objects, 3 have a rather large offset between optical and X-ray position, so their proper identification with late-type giants is at least questionable. For the remaining four stars, we obtained optical low-dispersion spectra in order to search for emission lines indicative of a possible symbiotic nature. None of these stars shows any bright emission lines, so they are probably quite normal M-type giants. We discuss possible origins of X-ray emission from these stars and derive their masses and evolutionary status by comparing their HR diagram positions (using *Hipparcos* parallaxes) with theoretical evolutionary tracks. We argue that the observed X-ray emission cannot easily be attributed to possible companions of these giants.

Accepted by A&A

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

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A sequence of AR Lac seasonal light curves covering the period 1967-1992 is analysed in the framework of the starspot hypothesis to derive the spot distribution and evolution on the component stars. The adopted approach makes use of the Maximum Entropy and Tikhonov principles to compute maps of the stellar photospheres exploiting also the eclipse scanning technique. Reliable results on the distribution of the spotted areas can be derived through a critical comparison of the maps obtained by the above quoted regularizing criteria. Satisfactory fits are computed assuming that spots are located on the photospheres of both components and that their unspotted luminosity ratio in the V band is: $\frac{L_1}{L_2} = 0.59 \pm 0.03$.
The derived yearly spot distributions are analysed to infer general activity characteristics. The spot patterns appear to consist of two components, one uniformly and the other non-uniformly distributed in longitude, the latter suggesting the presence of preferential longitudes. Starspots at latitudes higher than $\sim 50°$ are not needed to reproduce the photometric modulation. On the less luminous primary we find evidence for quite compact spotted areas ($\sim 30° - 40°$ in diameter) which are occulted during primary eclipses. On the more luminous and larger secondary, spots cluster preferentially around longitudes $\sim 60°$, $\sim 180°$ (i.e., around the substellar point) and $\sim 300°$ without showing evidence for a regular migration. The variation of the spotted area does not give a significant evidence for an activity cycle on the primary, whereas a possible modulation on a time scale of about 17 yr may be present on the secondary.
The spatial association among photospheric spots and chromospheric and coronal plages (as detected in the UV and X-ray spectral domains) is significant for the large active region around the substellar point on the secondary and is suggested also for the smaller starspots on the secondary and primary components.
A possible relationship between the orbital period modulation with a period of ~ 35 yr and an activity cycle on the secondary component is tentatively suggested and, if confirmed by future observations, can provide further support to recently proposed models for the connection between magnetic activity and orbital period variations.

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New Brown Dwarfs in the Pleiades Cluster

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We present optical intermediate and low resolution spectroscopy (650–915 nm) of new brown dwarfs ($I \leq 17.8$) in the young Pleiades open cluster with masses ranging from 0.08 down to 0.045 $M_{\odot}$. They were discovered in a CCD-based photometric survey covering an area of 1 deg^2 in the central region of the cluster. We compare their spectra to those of other reliable Pleiads like PPl 15, Teide 1 and Calar 3, and with several field very late-type dwarfs. All of our candidates clearly meet the spectroscopic and photometric criteria for being cluster members and therefore, brown dwarfs. In particular, we have discovered a substellar Pleiad, namely Roque 4, that is cooler and less massive than any other member previously known.

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Chromospherically Active Stars. XVII. The Double-Lined Binary 54 Camelopardalis = AE Lyncis

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New spectroscopic observations of the double-lined chromospherically active binary, 54 Camelopardalis = AE Lyncis have been obtained, resulting in improved orbital elements and the determination of the fundamental properties of the system. 54 Cam has a period of 11.06794 d, an eccentricity of 0.125, and a mass ratio of 0.9945. The spectral types are F8IV–V + G5 IV, positioning the components on opposite sides of the Hertzsprung gap. From a comparison with theoretical evolutionary tracks, the masses are estimated to be 1.60 and 1.59 solar masses for the G and F stars, respectively, while the radii are 3.7 and 3.2 solar radii. Only the G star is chromospherically active. 54 Cam is particularly interesting since the F star is the brighter star at blue and red wavelengths, but the G star is slightly more massive and evolved. Both stars appear to be pseudosynchronously rotating and the orbital and rotational inclinations are aligned. The lithium abundances of the two components are significantly different but consistent with standard theory, supporting the conclusion that both stars are more massive than the lithium-dip stars.

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Spot Activity and the Differential Rotation on HD 106225 Derived from Doppler Tomography

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Doppler images of the cool spot distribution on the RS CVn-type star HD 106225 are presented. These images, for Epoch 1995.14, were derived using four photospheric lines. The spot distribution is characterized by a large (radius = 20°) spot at latitude 45° and a weak polar spot with an appendage. The polar spot is considerably smaller than similar features found on other RS CVn stars. The rotation rate as a function of latitude was derived by comparing the Doppler images of this work to one found for Epoch 1991.3 by Strassmeier. This rotation law is consistent to the one found by Strassmeier in that the differential rotation on HD 106225 is in the opposite sense as on the Sun and at least a factor of 10 less extreme. A comparison of the differential rotation rates derived from Doppler imaging of other spotted stars yields a linear relationship with the logarithm of the stellar rotation period; the longer the rotation period the faster the polar regions are rotating with respect to the equatorial regions. The crossover point between polar acceleration and equatorial acceleration occurs at a rotation period of about 2 days.

The full Hα emission (after subtracting the absorption component of an inactive star) shows sinusoidal variations with an amplitude of about 10 km s^{-1}, significantly less than the rotation rate of 25 km s^{-1}. This modulation is interpreted as arising from plage located at high stellar latitude and adjacent to the polar appendage seen in the photospheric spot distribution.

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EUVE Right Angle Program Observations of Cool Stars

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The EUVE Right Angle Program (RAP) obtains photometric data in four bands centered at ~100 Å (Lexan/B), ~200 Å (Al/Ti/C), ~400 Å (Ti/Sb/Al), and ~550 Å (Sn/SiO) during pointed spectroscopic observations. RAP observations are up to 20 times more sensitive than the all-sky survey. We present RAP observations of two dozen late-type stars: BD+03 301, BD+05 300, HR 1262, BD+23 635, BD+22 669, Melotte 25 VA 334, Melotte 25 1366, Melotte 25 59, Melotte 25 65, θ^1 Tau, V834 Tau, GJ 2037, BD−21 1074, GJ 205, RE J0532−030, GJ 9287A, HT Vir, BD+46 1944, Proxima Cen, α Cen A/B, HR 6094, CPD−48 10901, and HR 8883. We derive surface fluxes from the Lexan/B and Al/Ti/C count rates and cataloged ROSAT PSPC data. The EUVE surface fluxes are reasonably correlated with surface fluxes calculated from PSPC measurements. The time variability of the sources has been examined. Most of the sources show no significant variability at the 99% confidence level. Flares were detected from the K7V star Melotte 25 Va 334, the K3V star V834 Tau (HD 29697) and the K3+K8 Hyades binary BD+22 669. The BD+22 669 count rate at the peak of the flare is a factor of 6 higher than the quiescent count rate with a peak Lexan/B luminosity of 7.9x10^{29} erg/s. The V834 Tau flare was detected in both Lexan/B and Al/Ti/C bands. The peak luminosity of the flare is 1.6x10^{29} erg/s and 8x10^{28} ergs/s for Lexan/B and Al/Ti/C, respectively.

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Self-Consistent and Time-Dependent MHD Chromosphere Models for Magnetically Active Stars

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We present self-consistent and time-dependent MHD heating models for chromospheres of magnetically active stars. We investigate the propagation and dissipation of longitudinal flux tube waves in K2 V stars with different rotation rates implying different photospheric and chromospheric magnetic filling factors. These filling factors are critical for determining the number of flux tubes on the stellar surface and the spreading of the tubes with height, which is relevant for the propagation and dissipation of the magnetic energy as well as the generated radiative emission losses. The filling factors used in this paper are estimated using a relationship between the photospheric values for $B_o f_o$ and $P_{\rm rot}$ in accord with very recent magnetic field measurements by Rüedi et al. (1997) [A&A 318, 429]. We also consider revised computations of magnetic energy fluxes by Ulmschneider & Musielak (1997) [A&A, submitted] generated by turbulent motions. Our models show increased shock strengths and energy dissipation rates in stars of faster rotation due to the narrower spreading of the tubes. This also leads to increased chromospheric emission particularly in Mg II in stars of faster rotation. We consider these results as a first step toward a theoretical derivation of chromospheric emission — stellar rotation relationships for stars of different masses and evolutionary status.

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High Velocity Flows in an Active Region Loop system Observed with the Coronal Diagnostic Spectrometer (CDS) on SOHO

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EUV spectra of coronal loops above an active region show clear evidence of strong dynamical activity. We present an example where the O V 629 Å line, formed at 240 000 K, is shifted from its reference position corresponding to line of sight velocities greater than 50 km s^{-1} with the shift extending over a large fraction of a loop. The observations were made with the Coronal Diagnostic Spectrometer (CDS) on the Solar and Heliospheric Observatory (SOHO), and are from active region NOAA 7981 on the east solar limb on 27 July 1996. An animation has been prepared showing the variation of the shift or flow velocity along the loop. This animation is to be found on the enclosed CD-ROM and gives a clear impression of the dynamical condition present in the loop. The appearance of the loop system in different lines formed over a range in temperature as well as the observed dynamics indicates that loops at different temperatures are not closely co-located. Finally, the results are discussed and related to mechanisms that may cause line shifts.

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Dopplershifts in the Quiet Sun Transition Region and Corona Observed with SUMER on SOHO

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New observations of systematic redshifts of transition region and coronal lines obtained with SUMER (Solar Ultraviolet Measurements of Emitted Radiation) on SOHO (the Solar and Heliospheric Observatory) are presented. With the extensive wavelength coverage of SUMER it is possible to extend the measurements of the redshifts to much higher temperatures compared to previous instruments. We find lines formed in the upper transition region (e.g. O V, S V, and S VI) to be redshifted similar to lower temperature lines ($T \leq 1.8 \times 10^5$ K). Even hotter lines such as O VI, Ne VIII and Mg X show systematic redshifts on the order of 5 km s^{-1} in the quiet Sun. This is a new and significant result since previous measurements of the redshifts were less well constrained.

The behavior of the redshifts above $T = 10^5$ K has been somewhat controversial. In some earlier investigations the magnitude of the redshift has been found to increase with temperature, reaching a maximum at $T = 10^5$ K and then to decrease toward higher temperatures. Thus, our results will put new constraints on theoretical models. The measured shifts are compared to recent observations of redshifted emission in stellar spectra obtained with the Hubble Space Telescope.

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Heading of the Corona and Acceleration of High Speed Solar Wind

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We present a parameter study of the corona–solar wind system. The corona is heated by an energy flux from the sun. This energy flux is lost as heat conductive flux into the transition region and as solar wind energy flux. We consider two-fluid models where most of the energy flux is deposited in the proton gas. Heating of the inner corona leads to a significant (electron) heat conductive flux into the transition region and a relatively high coronal electron density. This gives a relatively low coronal proton temperature, a large solar wind proton flux, and a relatively low asymptotic flow speed. In rapidly expanding flow geometries, where the thermal coupling between electrons and protons is weaker, heating of the protons in the inner corona may lead to a somewhat higher proton temperature, and higher asymptotic flow speed, but in order to drive high speed solar wind, a significant fraction of the energy flux from the sun must be deposited in the outer corona, where the protons are collisionless. In such a model only a small fraction of the energy flux is lost as inward heat flux, the transition region pressure is low, and the solar wind proton flux is quite small. The proton temperature in the outer corona is high, and a larger fraction of the energy flux deposited in the proton gas may be lost as solar wind kinetic energy flux.

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Optically Thin Irregularities in the Penumbrae of Sunspots

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Different estimates of the vertical gradient of magnetic field inclination in penumbrae disagree by two orders of magnitude. This disagreement may be resolved if measuring with typical angular resolutions implies averaging hundreds of independent fibrils whose residual variation, upon spatial averaging, give rise to the observed large-scale structures. The small-scale gradients show up in estimates based on the broad-band circular polarization, whereas significant bias affects other methods. From the comparison of these two types of measurements one can infer the typical sizes of the penumbral irregularities. They turn out to be between 1 and 15 km wide, depending on details of the calculation. This result supports the kind of highly irregular atmosphere that Sánchez Almeida et al. (1996, ApJ, 446, 537) proposed to represent the solar magnetic photosphere.

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Ph.D. Thesis Abstract

Angular Momentum Evolution of Low-Mass Stars in the Pleiades

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Ph.D degree awarded: December 1997

This dissertation presents a study of the angular momentum evolution in low-mass stars, concentrating on the Pleiades. I start with a theoretical study of the angular momentum evolution of 0.5-1.2 $M_\odot$ stars. Stellar models are constructed including the effects of internal angular momentum transport, angular momentum loss, and accretion disk lifetimes in the pre-main-sequence phase of evolution. I systematically and consistently explore the effects of varying these parameters. The angular momentum loss is prescribed to occur through a magnetic wind and to saturate at some value of the rotation. The resulting rotation rates are found to be a strong function of the value of this saturation threshold. I use rotation data from open clusters as constraints on the models. I find that a mass dependent saturation threshold is necessary to reproduce the distribution of rotation rates seen in open clusters. The inferred lifetime of the circumstellar accretion disk is found to depend on the assumptions made about core-envelope decoupling. The solid body models require longer disk lifetimes ($\sim$ 10-20 Myr) while the differential rotation models require shorter disk lifetimes ($\sim$ 3-10 Myr). This is consistent with the lifetime of the infra-red excess observed in pre-main-sequence stars, believed to be a signature of accretion disks.

I then present the results of a monitoring program to determine the photometric rotational periods of low mass stars in the Pleiades. I have determined rotation periods for 18 stars in the Pleiades, increasing the number of known rotation periods in the Pleiades to 51. I report the discovery of cool, slow rotators with high amplitudes of variation. This contradicts previous conclusions about the use of amplitudes as an alternate diagnostic of the saturation of angular momentum loss. I discuss the correlation between X-ray activity and rotation rates. I find that the X-ray data can be observational indicators of mass-dependent saturation in the angular momentum loss proposed on theoretical grounds. Finally, I discuss the correlation of surface Li abundances with rotation and activity. I find that there is a wide range in abundances with rotation. This disputes the strong correlation claimed between rotation and Li abundance.

Thesis-related Publications: 1997, ApJ, 480, 303; 1998, ApJ, 493 (in press)

Ph.D. Thesis Abstract

Angular Momentum Evolution of Young Low-mass Stars

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Ph.D degree awarded: October 1997

This thesis presents a study of the rotation of low-mass stars (from 0.5 to 1.2 $M_\odot$) during their pre-main sequence - from T Tauri ages, at a few million years old - and main sequence - to a few billion years old. We used both observations, to measure new rotational velocities of these objects, and models, to understand the physical processes involved in rotational evolution.

Observations were essentially aimed at measuring rotational periods and velocities in young clusters : IC 4665, α Perseus and the Pleiades. At the ages of these clusters, solar-type stars just arrive on the main sequence, and a large fraction have velocities lower than 10 km.s^{-1}. But, due to instrumental limitations, up to now, only upper limits have been derived. We observed all of the very slow rotators in α Perseus and the Pleiades with the instruments CORAVEL and ELODIE and resolved all the $v\sin i$ for masses between 0.6 and 1.1 $M_\odot$. Velocity distributions are computed for different masses in both clusters, and are compared to the models.

A model of angular momentum evolution has been developed in order to take into account pre-main sequence evolution, changes in internal structure, the effect of an accretion disk, angular momentum loss at the surface and angular momentum transfer between the core and the envelope. The new young clusters data provide strong constraints on the transfer of angular momentum in stellar interiors. It is found that for rapid rotators, a very efficient transfer leads to a nearly solid-body rotation during all the evolution, from T Tauri to solar ages. On the other hand, the existence of a large fraction of slow rotators requires a strong decoupling between the core and the envelope, with a characteristic time-scale of 100 million years. The evolution of the velocities of these slow rotators during the early ages of the pre-main sequence phase is also in good agreement with a long coupling time between the radiative core and the convective envelope.

Thesis-related Publications: A&A 1996, 305, 498; A&A 1996, 314, 173

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, or M) 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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